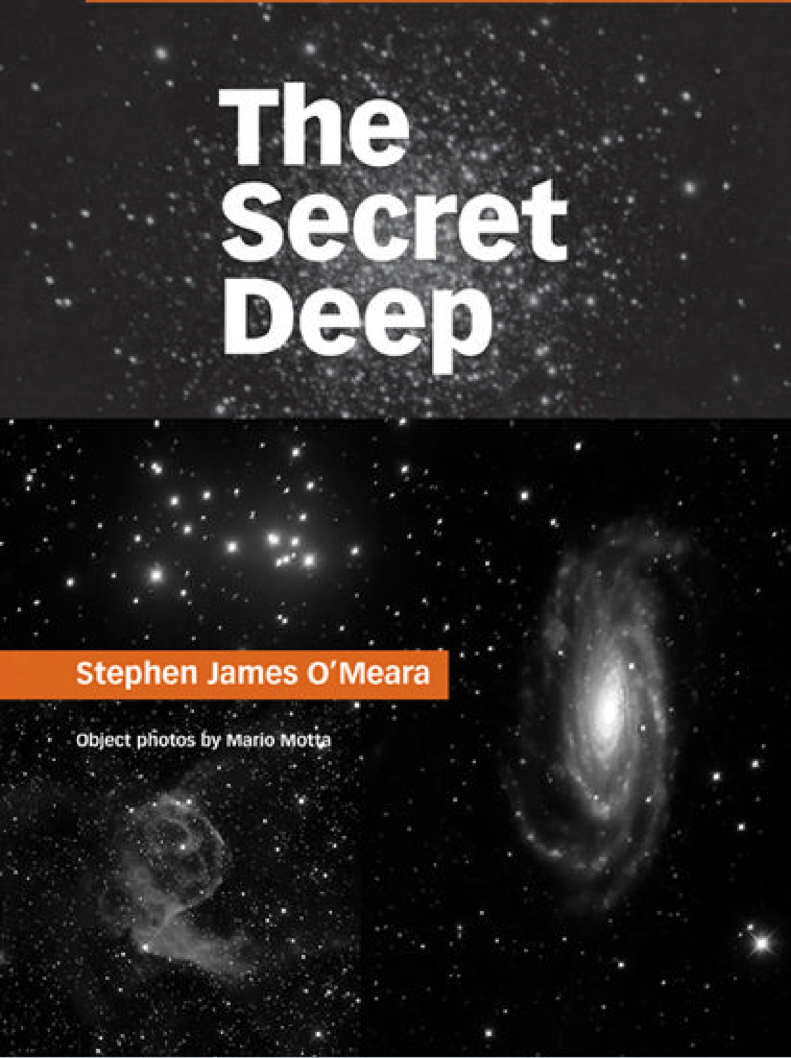
DEEP-SKY COMPANIONS

The Secret Deep

Stephen James O'Meara

Object photos by Mario Motta



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The Secret Deep

In this fresh list, Stephen James O'Meara presents 109 new objects for stargazers to observe. *The Secret Deep* list contains many exceptional objects, a piece of the only supernova remnant known visible to the unaided eye; the flattest galaxy known; the largest edge-on galaxy in the heavens; the brightest quasar; and the companion star to one of the first black hole candidates ever discovered. Each object is accompanied by beautiful photographs and sketches, original finder charts, visual histories, and up-to-date astrophysical information to enrich the observing experience. Featuring galaxies, clusters, and nebulae not covered in other Deep-Sky Companions books, this is a wonderful addition to the series and an essential guide for any deep-sky observer.

Author of several highly acclaimed books, including others in the celebrated Deep-Sky Companions series, Stephen James O'Meara is well known among the astronomical community for his engaging and informative writing style, and for his remarkable skills as a visual observer. O'Meara spent much of his early career on the editorial staff of *Sky & Telescope*, before joining *Astronomy* magazine as its Secret Sky columnist and a contributing editor. An award-winning visual observer, he was the first person to sight Halley's Comet on its return in 1985, and the first to determine visually the rotation period of Uranus. One of his most distinguished feats was the visual detection of the mysterious spokes in Saturn's B-ring before spacecraft imaged them. Amongst his achievements, O'Meara has received the prestigious Lone Stargazer Award, the Omega Centauri Award, and the Caroline Herschel Award. Asteroid 3637 was named O'Meara in his honor by the International Astronomical Union. In his spare time, O'Meara travels the world with his wife, Donna, to document volcanic eruptions. He is a contract videographer for National Geographic Digital Motion, and a contract photographer for National Geographic Image Collection.

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STEPHEN JAMES O'MEARA

with object photos by

Mario Motta

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore,
São Paulo, Delhi, Dubai, Tokyo, Mexico City

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521198769

First published 2011

Printed in the United Kingdom at the University Press, Cambridge

A catalog record for this publication is available from the British Library

Library of Congress Cataloging-in-Publication Data

O'Meara, Stephen James, 1956–
Deep-sky companions : the secret deep / Stephen James O'Meara ; with object photos by Mario Motta.
p. cm.
ISBN 978-0-521-19876-9 (Hardback)
1. Galaxies–Observers' manuals. 2. Astronomy–Observers' manuals. I. Title.
QB63.O638 2011
523–dc22

2010038356

ISBN 978-0-521-19876-9 Hardback

To Donna,
My love for you is fathomless.

To Daisy Duke, such a joy,
My secret writing companion.

And in memory of Milky Way, Miranda-Pyewacket, and Pele,
My spirits in the sky.

Contents

Preface

The Secret Deep is the fourth title in my Deep-Sky Companions series – the other three books are *Deep-Sky Companions: The Messier Objects*, *Deep-Sky Companions: The Caldwell Objects*, and *Deep-Sky Companions: Hidden Treasures*. Like the third companion, *The Secret Deep* is an important work because it brings to light a new list of 109 deep-sky objects visible in small telescopes under a dark sky. None of the objects in the Secret Deep list appear in the Messier, Caldwell, or Hidden Treasures catalogues; I've included an additional 20 objects in Appendix B. Owners of this series, then, have at their fingertips more than 450 deep-sky objects to explore.

All the Secret Deep objects are visible from mid-northern latitudes, though five or fewer are best seen from more southerly locations in the Northern Hemisphere or further south. Still, the most southerly object in the Secret Deep list – globular cluster NGC 2298 in Puppis – lies at a declination of –36° exactly, so it is only 1¼° further south than open cluster M7 in Scorpius, the most southerly Messier object. From the latitude of New York City, NGC 2298 will be 9° above the southern horizon when highest.

I have taken great care to select objects visible through my new 5-inch Tele Vue f/5 refractor (see Chapter 1) under a clear, dark sky. As with some objects in the Hidden Treasures list, several of the Secret Deep objects are surprisingly bright – including some open star clusters visible in binoculars and to the unaided eyes, a few galaxies more apparent than the dimmest Messier ones, and a couple of planetary nebulae with central stars you can spy through large binoculars. Take, for instance, 10.7-magnitude IC 4593 – the White-Eyed Pea planetary nebula in Hercules. A 2½-inch refractor can easily sweep up this object, but many fail to see it because they are fooled by its starlike form at low and moderate powers. But this striking planetary, consisting of a complex system of asymmetrical shells, is a glorious little gem at high magnifications; I've viewed it with magnifications up to 100× per inch of aperture! Then there's NGC 5846 in Virgo; this fantastic elliptical galaxy not only flanks the celestial equator, but its size and brightness rivals many Messier galaxies in the Coma–Virgo Cluster.

Again (and I never get tired of repeating this), despite popular belief, the famous Messier catalogue is not a list of the "brightest and best" deep-sky objects for small telescopes. It is a catalogue of objects *compiled* by the eighteenth-century French comet hunter Charles Messier (he did not discover many of these objects), who believed they could be confused with comets "just beginning to shine." Like *Hidden Treasures*, the Secret Deep list is an extension of the Messier catalogue – a deep-sky list for the twenty-first-century observer. In fact, two Secret Deep objects could very well be considered true Messier objects: Messier mentions NGC 5195 (Secret Deep 67) in his description of M51 but does not give it an individual listing. And there's an argument that NGC 3953 (Secret Deep 48) is actually M109.

HOW THE 109 SECRET DEEP OBJECTS WERE SELECTED

The purpose of this book is simple. It's designed to help you continue to explore the infinite wonders that populate the starry heavens and enrich your observing experience. As with my Hidden Treasures list, it would be wrong to call any of the Secret Deep objects "the best," because what's "best" is highly subjective. (What one person claims is "the best" others might not agree.) It would be fair to say that the 109 selections in the Secret Deep are all deep-sky splendors worthy of your attention.

The Secret Deep list is actually an extension of the Hidden Treasures list. Both were created, in part, by the collective "you." While researching *Hidden Treasures*, I came up with more than enough objects to fill the table. The "remainder" then became the foundation of a new list of 109 objects that I decided to call "The Secret Deep." That new list expanded after I completed my *Herschel 400 Observing Guide* (Cambridge University Press, 2007), which alerted me to some fascinating deep-sky objects I hadn't previously encountered. Once I received my new telescope, I began to re-observe all these objects with a fresh eye.

With that telescope, I also resurveyed the night sky, constellation by constellation, for other bright or interesting objects that would be visible to amateurs living in the Northern Hemisphere – ones not already listed in the Messier, Caldwell, and Hidden Treasures catalogues. When the list grew to more than 200 objects, I decided to whittle it down. I did so, in part, by comparing my findings against those in the popular deep-sky object lists published by the following astronomical societies:

- "Herschel 400": Ancient City Astronomy Club (St. Augustine, Florida)
- "Additional Objects": Hawaiian Astronomical Society
- "Best Objects in the New General Catalog": A. J. Crayon and Steve Coe, Saguaro Astronomy Club (Phoenix, Arizona)
- "Finest N.G.C. Objects": Alan Dyer, Royal Astronomical Society of Canada
- "TAAS 200": The Albuquerque Astronomical Society (New Mexico)

As you can see in Appendix C, 51 percent of the Secret Deep objects appear in these other lists: this is remarkable given that, unlike the Secret Deep list, many of these lists include objects only in the NGC; they also include objects in the Messier, Caldwell, and Hidden Treasures catalogues! The Secret Deep list contains 97 NGC objects, and fully 75 percent of these appear in the other lists.

The final 109 Secret Deep objects comprise 38 galaxies, 23 open star clusters, 18 planetary nebulae, 15 bright nebulae (some with clusters embedded in them), 11 globular star clusters, 1 supernova remnant, 1 asterism, 1 quasar, and 1 black hole (the visible companion star). The table compares the number and types of deep-sky objects covered in all four catalogues.

Owners of all four titles in the Deep-Sky Companions series will have the most up-to-date astrophysical and visual information on 436 deep-sky objects, with ancillary data on many more. And since the astrophysical, visual, and tabular data in *The Secret Deep* have been gleaned from many of the same sources in the other three volumes, you can compare the data with confidence. No other series of books to my knowledge offers observers such consistent data.

Object comparison table

Object type	Messier Catalogue	Caldwell Catalogue	Hidden Treasures Catalogue	Secret Deep Catalogue
Open star clusters	27	28	38	23
Galaxies	39	35	35	38
Globular star clusters	28	18	8	11
Bright nebulae	7	12	8	15
Planetary nebulae	4	13	14	18
Dark nebulae	0	1	1	0
Supernova remnants	1	2 segments of 1	0	1
Star clouds	1	0	0	0
High-proper-motion stars	0	0	1	0
Double stars	1	0	0	0
Asterisms	1	0	4	1
Quasars	0	0	0	1
Black holes	0	0	0	1

The Secret Deep list has many superlative and fascinating objects. These include a planetary nebula whose last thermal pulse has produced a circumstellar shell similar to the one expected in the final days of our Sun's life, a piece of the only supernova remnant known that's visible to the unaided eye, the flattest galaxy known, the largest edge-on galaxy in the heavens, the brightest quasar, and the companion star to one of the first black hole candidates ever discovered.

And there's much more. Several of the open clusters are not only double but also possible binary clusters, being physically related. Some of the nebulae (vast swaths of dust and vapor) form fanciful shapes (a flying fox, cosmic rosebud, and fossil footprint, for instance). Many of these clouds of nascent matter harbor new stars and those still in the process of formation. There's also an abundance of globular star clusters. These ancient stellar "cities," which populate the outskirts of our Galactic disk and halo, contain tens to hundreds of thousands of suns. Held together by the fantastic bond of gravity, these stellar congregations may be as old as the universe itself.

You'll also find many starburst galaxies (extragalactic systems that can manufacture suns at the phenomenal rate of hundreds of millions per year), cannibalistic galaxies (those consuming their dwarf neighbors), interacting pairs of galaxies, and grand-design spiral systems with supermassive black holes at the center of their active galactic nuclei.

In Chapter 1, "About this book," I discuss the telescopes I used to observe the Secret

Deep objects, my observing site and methods, helpful observing hints, and more. Since the history, astrophysics, and visual descriptions of many of these objects have never been described at length in any other popular work, this chapter also explains my approach to presenting the information.

I detail the 109 Secret Deep objects in Chapter 2. In many cases the essays describe recent observations from the Hubble Space Telescope, the world's largest ground-based telescopes, and a fleet of spacecraft that now peer (or have peered) into the universe with X-ray and infrared-sensitive "eyes." The essays are also flush with historical anecdotes and some have a dash of mystery (such as whether NGC 3953 is the real M109, and whether NGC 5195 should become the mysterious M102). Those interested in the history of astronomy will not be disappointed. The Secret Deep list includes objects discovered by many great astronomers from the eighteenth, nineteenth, and twentieth centuries, including William and John Herschel, but also Per Collinder, James Dunlop, Williamina Paton Fleming, Beverly T. Lynds, Albert Marth, Lord Rosse, Édouard Jean-Marie Stephan, Jürgen Stock, Wilhelm Tempel, and others.

Since some of the objects will present a visual challenge, especially to novice observers, I try to help as much as possible in the related essays by offering tips on how best to succeed in your search. It's also important to note that some of the nebulae in the list may appear quite small to visual observers, but they transform into magnificent cloudscapes in CCD images. In fact, this is the first book in the Deep-Sky Companions series that considers the astro-imager, whose efforts in the field I appreciate just as much as I do those employing the eye alone. Just take a moment to scan the gorgeous images of each Deep Sky object as captured by Mario Motta, whose work is featured in the book (see also Chapter 1). The details are stunning, the framing, exquisite.

Several appendices complete the work. Appendix A tabulates each Secret Deep object's position, constellation, type, apparent magnitude, and angular size. Appendix B does the same for the 20 additional Secret Deep objects. Appendix C is a table that lists each Secret Deep object and shows which astronomical societies considered it be one of the finest in the night sky. Appendix D is a list of photo credits, and at the end of the book is a Secret Deep checklist – a place for you to make personal notations on each object you find; it includes spaces for you to write down important information, such as the date observed, your location, the telescope and magnification used, atmospheric seeing and transparency, and any other special notes you want to record. It is a personal log that you can return to weeks, months, or years, later to see how you are progressing as an observer.

Deep-Sky Companions: The Secret Deep is not only a valuable resource or companion volume; it is *your* companion to take with you under the stars. I want the words to speak to you as you search, as if I were there to help guide you. It's difficult in our hobby sometimes to be alone under the stars. I want you to know that you are not; I am there with you in spirit. We all share a common bond – a love for the night. Not only do I want to encourage you to observe, to push yourself to new limits, but to enjoy a shared camaraderie. As I often tell my wife, Donna, when we are apart traveling, "No matter how many miles separate us, we can still share the sky."

I've written each essay so that you can not only enjoy your time with it under the stars, but also in the daytime, or on those cloudy nights. I hope you enjoy reading the histories and science of these glorious objects. We have come so far in our knowledge of the night and the things we seek out with our "star ships." I want to share with you that realized wonder.

I would like to thank Vince Higgs, Lindsay Barnes, Caroline Brown, and the editorial staff at Cambridge University Press for their encouragement, help, and support in this book and the Deep-Sky Companions series. I applaud Al and David Nagler of Tele Vue Optics in Chester, New York, for making such superb refracting telescopes that help me to dive deep into the visible universe.

I give special thanks to my longtime friend Mario Motta for taking the time to create the wonderful images of the Secret Deep objects he imaged with his 32-inch reflector – a part of his home! I thank Harvard astronomer and historian Owen Gingerich for looking over the interesting histories of some of the deep-sky objects whose discoveries have ties to Harvard College Observatory.

I thank my friend and colleague Larry Mitchell of Houston, Texas, for supplying me with William Herschel's original notes, which he drew from his original catalogues as they appeared in the *Philosophical Transactions of the Royal Society of London*; your kindness has been invaluable. Thank you to Terry Moseley, John M. Farland, and Wolfgang Steinicke for their help with Lord Rosse's discovery of NGC 3165. And a big bow goes out to the large pool of professional astronomers (many of whom are listed as the authors or principal investigators of professional papers on the objects being discussed) who took the time to look over the science presented in this book; you've enriched the text so much with your words and wisdom. Of course, if any errors have crept their way into this book, I'm responsible.

Finally, I would like to express my love for my beautiful wife, Donna, and Daisy Duke, our loving papillon, for standing beside me on this long journey; I thank you for your love, support, and understanding.

Well, it's time for you to go forth under the stars, pick away at the Secret Deep, and savor each galactic and extragalactic treat. Good luck.

CHAPTER 1
About this book

Beauty is a manifestation of secret natural laws, which otherwise would have been hidden from us forever. Johann Wolfgang von Goethe (1749–1832)

I HAVE BEEN STARGAZING FOR NEARLY half a century. But I have yet to see all the sky's bright telescopic wonders. I don't mind. I'm in no rush. Unlike time and tide, the deep-sky objects we seek seem to hang around and wait for us to care. I suspect we all care. But I also understand that the task of seeking out these wonders without some guidance can be overwhelming. I felt that way recently when I forgot my star atlas on one very clear night. The stars shined down in magnificent splendor, the Milky Way appeared rich and pure, a marvel to behold. But I also felt a sense of loss, in that, without an atlas in hand, I didn't know where to point my telescope to find new wonders. The fact is, when it comes to taking any journey, guidance helps.

That's why I write these books. By sharing with you lists of celestial objects that have inspired me over the years, I hope to chart a course for you through the stars, to help you see its deep-sky splendors and enrich your time under the night sky. Besides, half the fun of any journey is sharing what we've learned along the way. This book is my latest message to you about yet another "romp" through the heavens and the wonders I have seen.

As silent as the sky may appear, it has a voice. It's the inner voice we listen to each time we look through our telescopes. It cheers us on during the excitement of the search, and celebrates with us each time we find a new target. It influences our thoughts and inspires emotion. It adds significance to our nights and makes us

yearn for more. If anything, in the Deep-Sky Companions series, I've tried to use my inner voice, to inspire you to find your own teller of secrets, so that you too can share the joy of astronomy with others. It's how we grow both personally and spiritually.

The Secret Deep objects are a rich assortment of visual and photographic gems that can add depth to your observing experience. They're all relatively bright, some more obvious than others, with a sprinkling of visual challenges. Admittedly, beyond the bright and obvious Messier objects, we have to search for fainter and less conspicuous wonders, but wonders nevertheless. Besides, I'd argue that many of the faint fuzzy objects we like to seek require half eyesight and half imagination to "see." I'm not talking about the "bad" imagination – the one that leads us to see things that don't exist – but the good imagination that fires up that special background knowledge of what we're actually looking at.

That's why the CCD images that Mario Motta took of these objects are so special. They help add a visual perspective not attainable in that type of detail with the eyes alone. It's like being in an art gallery looking at Van Gogh's *Starry Night* and trying to see beyond the canvas, into the creator's mind. In our quest, we satisfy our visual appetites by not only looking at CCD images, but also reading about the history and physics of each object. Indeed, many of these objects have been studied with large ground-based and space telescopes in all wavelengths of light. So we have a lot to ponder as we look through our telescopes. It's an exciting time to be an amateur astronomer. We have at our fingertips greater insight into the nature of the universe than ever before. This book, like its companions, will help you to see how astronomers have peeled back the onion layers of understanding over the years to give you the best and present knowledge of each wonder.

THE TELESCOPE AND SITE

There has been a change. The Tele Vue 4-inch f/5 Genesis refractor I used to observe all the objects in the three preceding Deep-Sky Companions series of books, as well as my *Herschel 400 Observing Guide*, is no longer in my possession. I loved (and still do love) that scope. It had been my observing partner for 13 years. But in 2007, Tele Vue founder Al Nagler and I had one of those eerie, simultaneous light-bulb moments. I felt it was time for me to graduate to a slightly larger telescope; at the same time, I wanted to somehow pass on my observing "torch" (the Genesis) to another observer. When we talked, Al not only understood, but he had already thought of the solution.

It turned out that he was considering donating his prototype of the 13-mm Nagler ultrawide eyepiece to the Springfield Telescope Makers, the amateur astronomy and telescope-making club that sponsors the annual Stellafane convention on Breezy Hill, Vermont. Al suggested we unite the Genesis refractor (with an autographed tube, and the accessories I used including three eyepieces (22-mm Panoptic eyepiece, and 7- and 4.8-mm Nagler eyepieces), 2-inch star-diagonal (with a 1¼-inch adapter), 1.8× Barlow, Tele Vue Qwik-Point finder, and original carrying case) and his prototype 13-mm Nagler, and jointly auction them off on eBay. The proceeds from the sale, he said, would be donated to the Stellafane convention to help defray the cost of Stellafane's recently completed Flanders Pavilion.

Al's thinking was most appropriate: The Stellafane convention, whose roots date to the 1920s, inspired a revolution in amateur telescope making; Al's 13-mm Nagler inspired a renaissance in deep-sky observing that began in the 1980s and continues to this day; and Tele Vue's Genesis refractor has been referred to as "*the* catalyst for todays growing popular 4-inch APO market." The auction closed on August 17, the Genesis refractor and Al's historic eyepiece have found a new home, and the money earned was donated to Stellafane.

on occasion (again with small and bright planetary nebulae), I've gone as high as 990×.

As a finder I use a Tele Vue Starbeam (it's like a laser pointer). The NP-127 offers me a field of view near 2.4° wide when I use the 20-mm Nagler. The telescope sits in the cradle of a sturdy Gibraltar mount, and the entire setup can be broken down in a couple of minutes in case I need to be mobile.

What I now have in my possession is a beautiful Tele Vue NP-127 Nagler-Petzval 5-inch (660-mm) f/5.2 apochromatic refractor with a redesigned four-element optical system that offers me not only crisp wide-fields of view with 2-inch eyepieces, but also high-power capability with 1¼-inch eyepieces. And by high power, I mean, at times, I have pushed the instrument to its extreme: 100× per inch of aperture, especially with planetary nebulae. Note that, throughout Chapter 2, I generally refer to this telescope simply as "the 5-inch."

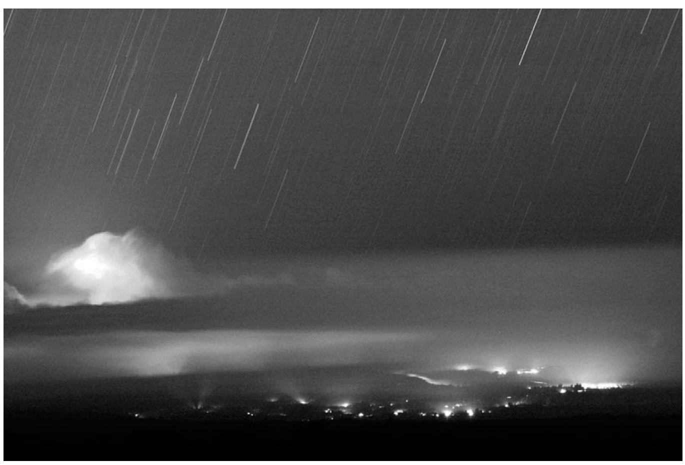
My arsenal of eyepieces consists of four workhorses: a Tele Vue 20-mm Nagler type 5 (33×), Nagler 11-mm type 6 (60×), Nagler 7-mm type 6 (94×), and Nagler 2–4-mm zoom (330×–165×). I also have a Tele Vue 3× Barlow, which offers me more magnification options up to 990×; as a rule, I generally go no higher than 495×, but I must admit that,

All the observations for this book were from my front yard in Volcano, Hawaii, which is at an altitude of 3,500 feet (1,100 m). I used to observe near the summit of Kilauea volcano in Hawaii's Volcanoes National Park, but something dramatic changed the environment and the landscape: On March 19, 2008, after I had finished my observations for the *Hidden Treasures* and *Herschel 400 Observing Guide*, Kilauea had its first summit explosion since 1924.

Since then, large swaths of the volcanic caldera have been off-limits, and dust and ash remain a problem there to this day; the summit eruption continues to enlargen a new vent inside Halemaumau crater, which also contains a glowing lava lake. So, while viewing the volcano is an awesome sight at night, it can also be less than ideal for looking at the stars on some "bad air" days (see the photo at the opening of this chapter).

Once I began observing at home, I actually found the "journey" very peaceful. I didn't have to drive anywhere, contend with car headlights in the Park, or the issues of volcanic smog (vog) and particle fallout – though now our home sits between two erupting vents and the vog conditions can be a problem here when the winds shift. The photo below shows vog over the town of Volcano at night from the "second" erupting vent, called P'u O'o.

Another benefit of observing from home was that I no longer had to "migrate" to avoid the ins and outs of the island's whimsical clouds or of curious passersby. No. If the clouds rolled in, all I had to do now was sit back in a chair, take a sip of hot chocolate, look up at the sky in the comfort of my home, and wait. Besides, although the telescope I have today is only 1 inch wider in aperture than my Genesis, it's a little bit heavier (perhaps Al thought I needed more exercise). But seriously, the night sky as seen from my house is no different than that up on the volcano's summit, which is just a few miles away. I can see the zodiacal light and band, as well as the gegenschein, from my home. I also get to run inside whenever something wonderful is out, so I can share it with Donna. It's been a wonderful and calming experience, working on this book, and I appreciate the sky I have.



In addition to the Tele Vue 5-inch, I also used 10×50 Meade binoculars, and, on occasion, a nineteenth-century brass telescope made by Ross of London, which I simply refer to as "the antique telescope" in Chapter 2. It's the same antique telescope I used to observe some of the Hidden Treasures. The tube measures $17\frac{1}{8}$ inches when open, and $7\frac{1}{4}$ inches when closed. The $1\frac{3}{4}$-inch objective is in excellent condition.

HOW TO USE THIS BOOK

To find a Secret Deep object, first locate its position on the wide-field finder chart that opens each entry. The chart not only gives you a wide-field view of the constellation it's in, but marks the location of the object relative to bright nearby stars (those with Greek letters or Flamsteed numbers). Next, locate those stars on the detailed finder chart that accompanies the object's photograph and text. Both the wide-field finder charts and the detailed finder charts are oriented with north up and east to the left. Finally, find the part of the text that describes how to locate the object and simply follow the directions.

After the full-page wide-field finder chart, each object's entry in Chapter 2 opens with an image of the object (oriented with north up and east to the left, unless otherwise noted) and a table of essential data: Secret Deep number; common name(s), if any; object type; constellation; equinox 2000.0 coordinates; apparent magnitude; angular size or dimensions; surface brightness in magnitudes per square arcminute (for most objects) and a personal rating of the object's ease of visibility from 1 (difficult) to 5 (easy); distance; and the object's discoverer and discovery date.

Note that you don't have to use the charts in this book. Since I provide the object's equinox 2000.0 coordinates, you can instead employ your favorite detailed sky atlas (such as Wil Tirion's *Sky Atlas 2000.0*) to locate the object. The choice is yours. The charts I created have a simple design. I've tried not to clutter them up with unnecessary details. They are designed to help you make the simplest and fastest sweep to each object, based on my personal experience. You might think otherwise, and I encourage you to pursue whatever venue you find suitable to your needs. Otherwise, my charts should be easy to read and simple to use.

Below the table you'll find William Herschel's original published description of the object, or, if William did not observe the object, his son John's. If neither observer discovered or observed the object, that section is blank. Larry Mitchell, a member of the Houston Astronomical Society, supplied me with William's original notes, which he drew from his original catalogues as they appeared in the *Philosophical Transactions of the Royal Society of London*.

Most of the John Herschel quotations have been gleaned from those given by the "Deepsky Observer's Companion" (www.fortunecity.com/roswell/borley/49/), which was created by the Astronomical Society of South Africa to promote its Deepsky Observing section. The quotes are from John Herschel's original observations, published in 1847 as "results of Astronomical Observations made during the years 1834, 5, 6, 7 [and] 8, at the Cape of Good Hope; Being the completion of a telescopic survey of the whole surface of the visible heavens, commenced in 1825." During his stay in South Africa, John Herschel often made several observations of each object. The quotes used in this book's tables, however, refer only to his first observation; a date is given only if the junior Herschel discovered the object. At the end of each Herschel description is a code contained in parentheses ("H VIII-88," for instance, or "h 2327"). These codes date to a classification system created and used by the Herschels. "H" stands for the elder Herschel and "h" for his son.

The Roman numeral in William Herschel's system identifies the class into which the elder Herschel placed each object:

I. Bright nebulae
II. Faint nebulae
III. Very faint nebulae
IV. Planetary nebulae: Stars with burs, with milky chevelure, with short rays, remarkable shapes, etc.
V. Very large nebulae
VI. Very compressed and rich clusters of stars
VII. Pretty much compressed clusters of large or small stars
VIII. Coarsely scattered clusters of stars

The Arabic numeral that follows is simply the order in which that object appears in that class. So H I-156 is the 156th object in Herschel Class I (bright nebulae).

The original 1888 *New General Catalogue* (NGC) description, or a description from the supplemental *Index Catalogues* (IC), follows each Herschel entry (if any). If the object is not from one or the other of these catalogues, it is left blank.

The Herschel and NGC/IC catalogue descriptions are followed by the running text, which may not only enhance the historical entries mentioned above but also bring to light any recent research findings. I then begin to describe the object's appearance in the sky, starting with its location and how best to find it. The directions are followed by my visual impressions as seen through the 5-inch at various magnifications. At times, I record its naked-eye or binocular appearance, or the view through my antique telescope; ocasionally I include descriptions by other observers using larger instruments. There may also be a visual challenge or two, as well as a brief visual impression of any other interesting objects nearby.

A drawing of the object as seen through the 5-inch at various magnifications also accompanies the text, so you can compare your view of any Secret Deep object with my own. The views may be very dissimilar, but that's okay; we all see things differently.

SOURCES OF DATA AND INFORMATION

The data and information in this book were drawn from a variety of modern sources.

Many of these sources were used in *Deep-Sky Companions: The Messier Objects*, *Deep-Sky Companions: The Caldwell Objects*, and *Deep-Sky Companions: Hidden Treasures*, so you can compare the properties of these objects with confidence. Generally speaking, I gleaned recent research findings on the physical nature of each object from the *Astronomical Journal* or the *Astrophysical Journal*, and citations are given. From each object's apparent diameter and distance I calculated its physical dimensions using the formulas that appear on page 35 of *Deep-Sky Companions: The Messier Objects*. Other information, such as constellation lore; properties of stars; and objects' positions, apparent magnitudes, angular sizes, and surface brightnesses, come from the following excellent sources (primary sources are listed first).

Star names, constellations, and mythology

Allen, Richard Hinckley. *Star Names: Their Lore and Meaning*. New York: Dover Publications, 1963.

Ridpath, Ian. *Star Tales*. New York: Universe Books, 1988. See also www.ianridpath.com/startales/contents.htm.

Staal, Julius D. W. *The New Patterns in the Sky: Myths and Legends of the Stars*. Blacksburg, VA: McDonald and Woodward, 1988.

Stellar magnitudes and spectra

Stars, http://stars.astro.illinois.edu/sow/sowlist.html.

Hirshfeld, Alan, Roger W. Sinnott, and Francois Ochsenbein, eds. *Sky Catalogue 2000.0*, Vol. 1, 2nd edn. Cambridge, UK: Cambridge University Press, and Cambridge, MA, USA: Sky Publishing Corp., 1991.

Stellar data

Stars, http://stars.astro.illinois.edu/sow/sowlist.html.

ESA. *The Hipparcos and Tycho Catalogues*. Noordwijk, the Netherlands: European Space Agency, 1997.

Double stars

Luginbuhl, Christian B., and Brian A. Skiff. *Observing Handbook and Catalogue of Deep-Sky Objects*. Cambridge, UK: Cambridge University Press, 1989.

USNO. *The Washington Double Star Catalog*. Washington, DC: Astrometry Department, U.S. Naval Observatory. http://ad.usno.navy.mil/ad/wds/wds.html.

Variable stars

American Association of Variable Star Observers, www.aavso.org.

Open star clusters

Archinal, Brent A., and Steven J. Hynes. *Star Clusters*. Richmond, VA: Willmann-Bell, Inc., 2000.

Open star cluster distances generally were gleaned from the professional literature.

Globular star clusters

Harris, William E. *Catalog of Parameters for Milky Way Globular Clusters*. Hamilton, ON: McMaster University. www.physics.mcmaster.ca/~harris/mwgc.dat.

Skiff, Brian A. "Observational Data for Galactic Globular Clusters." Webb Society *Quarterly Journal* **99**:7 (1995), updated May 2, 1999.

Globular star cluster distances generally were gleaned from the professional literature.

Planetary nebulae

Skiff, Brian A. "Precise Positions for the NGC/IC Planetary Nebulae." Webb Society *Quarterly Journal* **105**:15 (1996). (Positions.)

Luginbuhl, Christian B., and Brian A. Skiff. *Observing Handbook and Catalogue of Deep-Sky Objects*. (Dimensions and central star magnitudes.)

Cragin, Murray, James Lucyk, and Barry Rappaport. *The Deep-Sky Field Guide to Uranometria 2000.0*, 1st edn. Richmond, VA: Willmann-Bell, Inc., 1993.

Planetary-nebula distances generally were gleaned from the professional literature or from the World Wide Web page of the Space Telescope Science Institute (www.stsci.edu).

Diffuse nebulae

Cragin, Murray, James Lucyk, and Barry Rappaport. *The Deep-Sky Field Guide to Uranometria 2000.0*, 1st edn.

Diffuse nebula distances were gleaned from the professional literature.

Galaxies

The Deep-Sky Field Guide to Uranometria 2000.0, 1st edn. (Positions, angular size, apparent magnitude, and surface brightness.)

NASA. *The Extragalactic Database*. Pasadena, CA: Infrared Processing and Analysis Center. http://nedwww.ipac.caltech.edu/. (Types, mean distance, radial velocity, and all detailed descriptions of galaxy structures as seen in photographs have been gleaned from the accompanying notes.)

Tully, R., Brent. *Nearby Galaxies Catalog*. Cambridge, UK: Cambridge University Press, 1988. (Inclination, total mass, and total luminosity.)

Extragalactic supernovae

List of Supernovae. Cambridge, MA: Central Bureau for Astronomical Telegrams. http://cfa-www.harvard.edu/iau/lists/Supernovae.html.

Other details of discovery were gleaned from individual IAU *Circulars*.

Historical objects

Smyth, Captain William Henry. *A Cycle of Celestial Objects*. Richmond, VA: Willmann-Bell, Inc., 1986.

Glyn Jones, Kenneth. *The Search for the Nebulae*. Chalfont St Giles, UK: Alpha Academic, 1975.

Other historical anecdotes in this book were gleaned from various individual and professional papers from the nineteenth and early twentieth centuries.

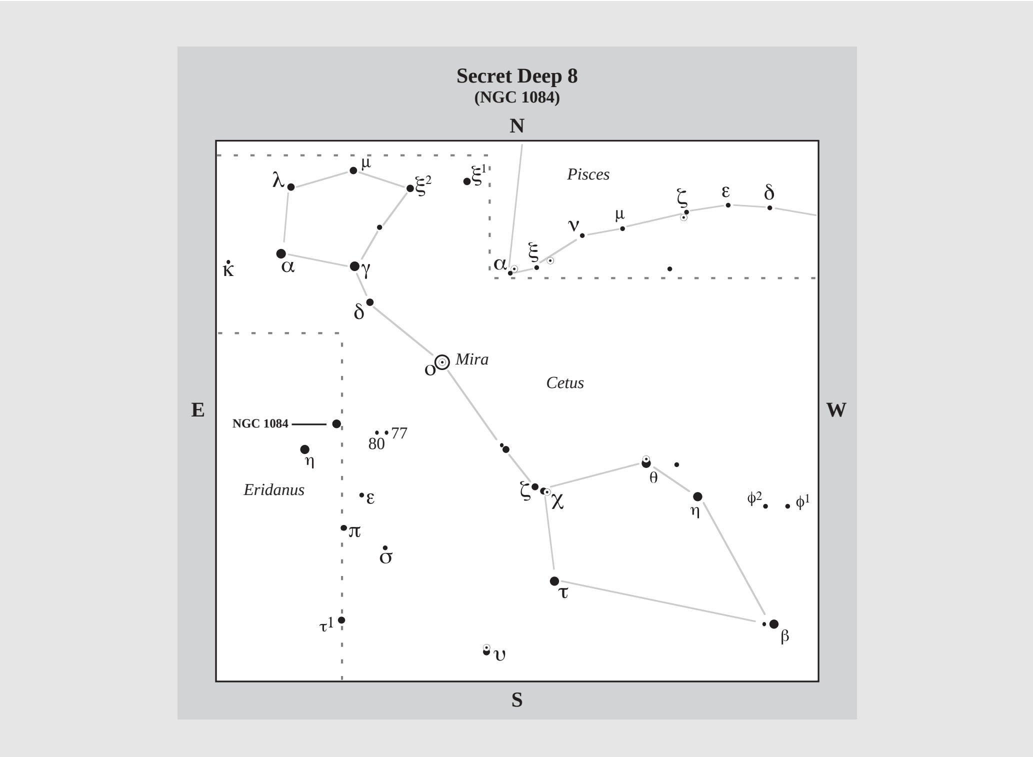
General notes

Note that the World Wide Web Uniform Reference Locators, or URLs, are subject to change. The dimensions, magnitudes, and positions of all other additional deep-sky objects in this book were taken from *The Deep-Sky Field Guide to Uranometria 2000.0*.

As in the other books in the Deep-Sky Companions series, the data in this book differ from those appearing in older but popular references. This book contains the most up-to-date astronomical data and accurate historical and observational information about each object in the Secret Deep catalogue that you'll find in any book in the popular literature.

THE FINDER CHARTS

As I previously mentioned, the wide-field and detailed star charts in Chapter 2 are of my own design. The Secret Deep number



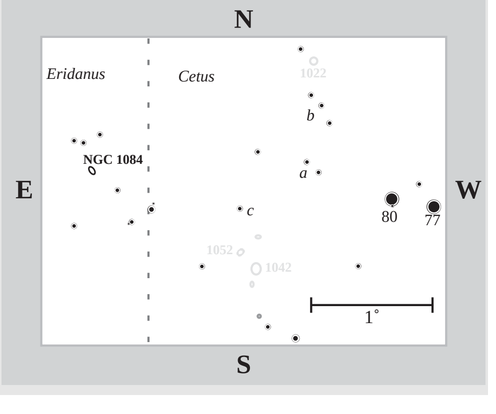
and proper name of each object appears at the top of the chart. The maps appear with north up and east to the left.

The purpose of the wide-field finder charts is simply to show you the brightest constellations or star fields around the Secret Deep object. Each shows stars roughly to magnitude 4 or 5, and sometimes 6 (but generally only in the region near the Secret Deep object, and only if I feel they will help in the naked-eye or binocular search. Faint stars are more prevalent if the constellation is dim, like Sculptor.

In creating these charts my philosophy was to simplify the view, to help you focus on your target by removing peripheral noise. The purpose of these charts is to help you hone in on one object and one object only, and I've done the field work to help you get there in the fastest and most efficient way possible. Why clutter the view, I reasoned, with lots of dim stars and other objects when all you want to do is see the target you're after. As the old saying goes, "Obstacles are what you see when you take your eye from the goal."

To help you in your search, I've traced out the "stick figure" form of the main constellations in the view. I've also labeled them and their brightest stars, using the traditional Bayer (Greek) letters or Flamsteed numbers. Sometimes I've included a popular star name, such as Mira, the well-known winking star in Cetus the Whale. But in special cases, you may find a non-traditional, italicized, lower-case letter, such as an *a* or *b*; these are additional unnamed or numbered guide stars, which you'll find in the text described as Star *a* or Star *b*, etc. One symbol, a circle, is used to mark the location of each Secret Deep object on these wide charts.

The detailed finder charts have the same orientation as the wide-field charts, but they show a much smaller area of sky in more detail. The constellation name is given as are any boundary lines. A scale bar appears at the bottom of each chart. Stars are shown to magnitude 11 near the target; sometimes, fainter stars are shown, if I feel they'll help you to identify it. In the detailed charts, I've labeled each Secret Deep target with its full proper name (such as NGC 1084) in black. A faint gray symbol is used to mark the location of other interesting deep-sky objects nearby, which are labeled (also in gray) with the NGC prefix omited. Note too that, in these charts, the italicized letters may also refer to an asterism (a triangle, arc, pair of stars, or line), as described in the text.

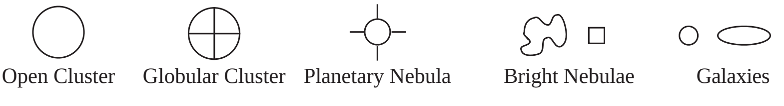


I use the traditional symbols below to represent the different classes of deep-sky objects. In the case of galaxies, I also show their apparent orientations.

Thus, to find a Secret Deep object, first locate the object's position on the wide-field finder chart. Next, note the brightest star near the object and locate it on the detailed finder chart. Now, read the accompanying text on how to locate the object and simply follow the directions.

THE IMAGES

All the object images in this book are reproduced in black and white, with north up and east to the left. Unless otherwise noted, all were taken by my longtime friend and colleague Mario Motta with an STL 1001E SBIG camera on his homemade 32-inch telescope. It has a field measuring 17′ × 17′. Photos of objects larger than 17 arcminutes were taken with Motta's 6-inch F/9 Ritchey–Chrétien astrograph, which has a 1° field. (Detailed credits for these and additional photos appear in Appendix D.) I took some of the wider shots, such as Orion's Belt and other large deep-sky objects. I've also reproduced images from the Hubble Space Telescope and other large telescopes. These images were used for the sole purpose of inspiring you to use your imagination. You certainly will not see anything like these images when you look through your telescope, but how else can you fully appreciate what it is you are seeing? So do not be discouraged, be enlightened.



Mario Motta and his 32-inch dreamscope

Astrophotographer and longtime amateur astronomer Mario Motta wears many hats. By day, he's a renowned cardiologist in Salem, Massachusetts. He served as the President of the Massachusetts Medical Society from 2009 to 2010, is a member of the American Medical Association's New England Delegation, serves as an AMA delegate from Massachusetts, was elected to serve on the AMA Council of Science and Public Health, and holds an academic appointment as Associate Professor of Medicine at Tufts Medical School, among other things. By night he's an extraordinary amateur astronomer and dark-sky advocate.

An advanced amateur astronomer, Mario has built several observatories and telescopes. His Wingaersheek Observatory – which sits atop his study in his home in Gloucester, Massachusetts – houses his homemade 32-inch reflector under a 20-foot dome that overlooks Ipswich Bay to the north and a large salt-water marsh to the south. These calm bodies of water help to produce great local atmospheric seeing conditions; they also help to keep his skies reasonably dark. A member of the International Dark Sky Association and the local New England Light Pollution Group, Mario has been, and continues to be, an avid promoter/protector of dark skies: Thinking globally and acting locally, Mario spearheaded a successful lighting ordinance to further protect the night sky over his town.

Mario is quick to tell you, however, that it was his charming wife, Joyce Motta, a lawyer by profession and an artist/photographer by avocation, who was responsible for finding this astronomer's paradise, which also doubles as a quiet reserve for Joyce's artistic and photographic endeavors.

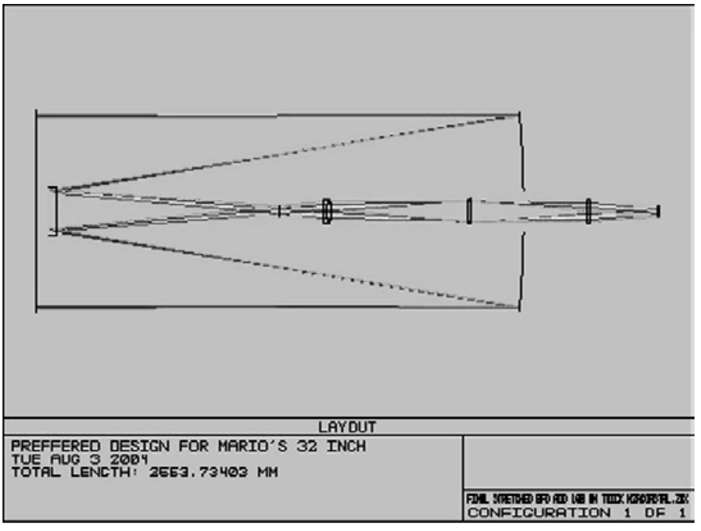
One of the largest telescopes in New England, Mario's Monster (as I congenially call it) is a state-of-the-art, robotic telescope that weighs 1,200 pounds and sports a special optical system of the relay design. It was the brainchild of Mario, his optical-designer friend Scott Milligan, and other members of the Amateur Telescope Makers of Boston (ATMOB), of which Mario has been a longtime member and past president. It is this same telescope that Mario used to take the images in this book.

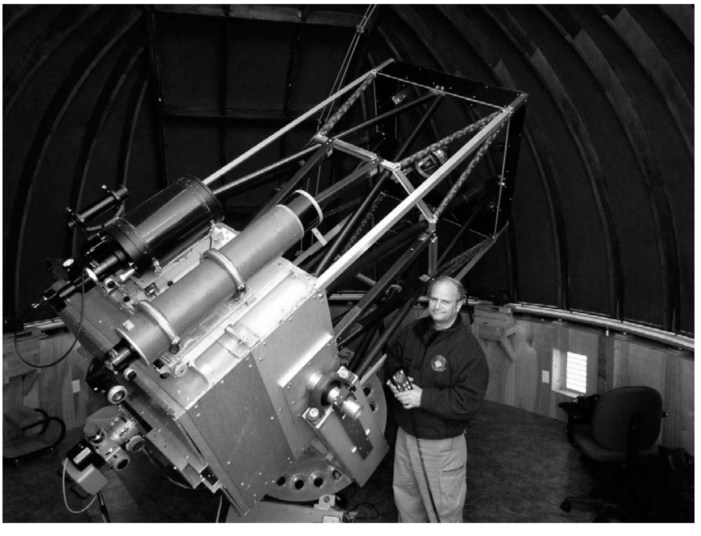
Mario's telescope is an all-spherical, multi-element, relay design – an improved optical system of the one pioneered by Donald Dilworth a quarter century ago and displayed at the annual Stellafane telescope-makers convention in Vermont. This new system (which ameliorates chromatic

aberration effects and extends the sharp imagery in the telescope's off-axis performance), provides "significant advantages," Mario says, over a conventional Newtonian, Cassegrain, or Dall–Kirkham telescope.

The new design incorporates a 32-inch f/3 spherical primary mirror, a 7.8-inch Mangin spherical secondary mirror (with a flat back end), and 3.8-inch spherical corrector lenses. The main advantage of the scope is the smooth, highly accurate, fully coated, spherical optical surfaces. The double pass through the front surface removes the spherical aberration of the primary mirror.

"The converging beam then comes to a focus back down the central axis," Mario explains, "allowing for a natural field stop for much greater contrast and enhancement than that in conventional telescopes." This converged beam is then passed through an all-spherical doublet, then two separate spherical lenses. "These lenses both collimate the beam for refocusing back behind the primary," he says, "and also remove the color aberrations of the system." The light finally passes through a central 5-inch perforation in the primary mirror, and comes to a focus 11 inches behind it, offering sharp, high-contrast images.





When I first met Mario, I was a 14-year-old "apparition" haunting the halls of Harvard College Observatory, in Cambridge, Massachusetts, where I had been given permission to use the Observatory's 9- and 15-inch refractors to study the stars and planets. Mario was there because the ATMOB held its monthly meetings at the Observatory's Phillips Auditorium, and its members used the 9-inch refractor on clear nights after the meetings. It didn't take long before Mario and other friendly faces invited me to join them. They also persuaded me to give a talk to the club about deep-sky observing – specifically on how to find Messier objects with my own 4½-inch reflector from the city.

Since I had never given a public talk before, I didn't know what to say or how to say it. So I rehearsed for weeks, trying to memorize a half-hour worth of words. When the big night arrived, I thought I was ready. But as soon as I faced the audience, my body seized up. My throat tightened, my eyes widened. I began to sweat profusely. My heart thumped uncontrollably in my chest (Mario was probably ready to get his portable heart paddles). Everything I had planned to say was wrapped in a mental fog. I couldn't breath. When my mouth broke free, and my lips moved, nothing audible came out.

An eternity passed. I heard people in the room shuffling in their seats, some cleared their throats. Their eyes bored into mine. Then Mario asked me a simple question about a Messier object. After a moment of thought, calmness magically returned. I wasn't speaking to an audience anymore (at least not in my mind), I was speaking to Mario, and that made all the difference. I answered his question, then another, and another. The night didn't turn out so bad in the end.

After that, Mario and other ATMOB members took this "kid" under their wings. Their meetings were like being with family. We enjoyed not only nights at Harvard, but, over the years, many crisp nights under the stars at the club's dark-sky site and clubhouse. After I moved to Hawaii, Mario and I kept in touch. Occasionally he makes it out to the Rock, and occasionally I get to visit him on the East Coast. In fact, on a memorable Halloween night in 2009, I was a guest of Mario and Joyce. Mario and I stayed up almost until the dawn, visually observing deep-sky objects through his impressive 32-inch telescope. In fact, the first object we looked at was van den Berg 1 – the first object in the Secret Deep catalogue.

As former president of the ATMOB, Mario initiated a collaboration between public schools and the ATMOB, who now give over 50 star parties a year in the greater Boston area for school kids, and partner an amateur with a school district. Mario's interests have been in galactic evolution, gamma-ray bursters, supernovae, as well as variable stars. He also gives many talks on light pollution issues. In 2003 Mario received the Las Cumbres Award from the Astronomical Society of the Pacific for astronomical outreach, and in 2005 he received the Walter Scott Houston Award from the Astronomical League. I am honored to share with you the results of his latest passion: deep-sky imaging. Mario also wanted to share the following words with you.

> I have enjoyed astronomy for as long as I can remember, starting as a young child. For a time, I strongly considered making astrophysics my career choice, but eventually ended up in medicine as a cardiologist. My love of astronomy, however, has never waned. I built my first telescope, an 8-inch Newtonian, as a teenager at age 14. I enjoyed that telescope, but always yearned for larger optics. As my appetite for large telescopes

always exceeded my budget, I, through the years, continued to build larger and larger telescopes, always completely homemade. I bought an old lathe and milling machine and learned to make all the mechanical parts as well. I consider grinding the optics and manufacturing all of the mechanical parts not only a challenge and scientific pursuit, but also an art form.

I have built three home observatories through the years. My latest telescope and observatory, which was completed in 2006, is what I consider my ultimate dream telescope. A 32-inch f/6 relay telescope, it has the power to allow me to gaze deep into the universe, and the precision and accuracy to give me stunning views when I image. All of the images attributed to me in this book were taken from my home observatory with this telescope. It is an unusual design, an all-spherical optical design with 11 optical surfaces.

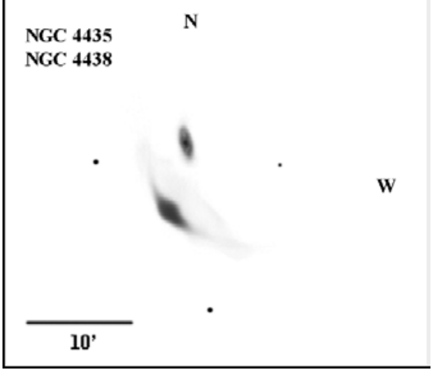
The primary mirror is 32 inches. It has 584 mechanical parts, all personally hand made. The final result is an instrument of beauty to behold and to use. I have the very good fortune of being married to a wonderful woman who allows part of her house to be an observatory. This house was built from the initial design to have an observatory as an integral part of the house, with a pier extending through two floors to reach the observatory. This allows me to observe the heavens any clear evening with little effort, the telescope always ready.

When my good friend and author of this book asked if I would be interested in obtaining the images I jumped at the chance. Steve O'Meara and I have a long-term friendship going back over many years, and what has always cemented our friendship is a mutual and deep love of observing the universe. This has created a deep bond that binds us despite the fact that we now live thousands of miles apart. Steve's books are always well written and highly informative, and thus it was an honor to be associated with this project. I hope all of the amateur astronomers who track down the objects in this book will get as much pleasure from observing or photographing them as I did.

THE DRAWINGS

All the sketches in Chapter 2 are composites of field drawings I made at various magnifications. They are shown with north up and east to the left. The orientation matches that of the corresponding photograph. Each Secret Deep object in the drawing is labeled with its proper name in the upper left corner, two field orientation labels (N for north and W for west), and a scale bar to help you size up each object in your own telescope.

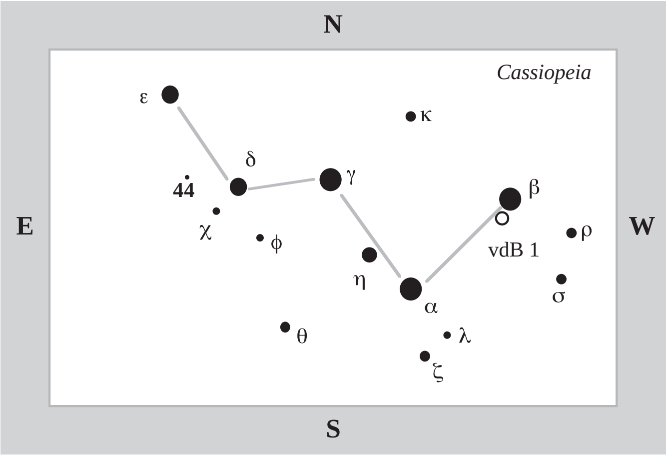
The composites show details visible at low, medium, and high power. This is a technique I've employed for decades and enables me to share with you the overall grandeur of the object in one portrait. It's important to note, however, that I've boosted the contrast greatly for two reasons: (1) to hold the detail for reproduction, and (2) to enhance the beauty of the subtle



view. If I were to try and reproduce the delicate details of some deep-sky objects, you probably wouldn't recognize them, or see them for that matter, in the drawings, they would be too faint. In the text, I do break down what details I could see (and could not see) at different magnifications, so use the verbal description as your explanatory guide.

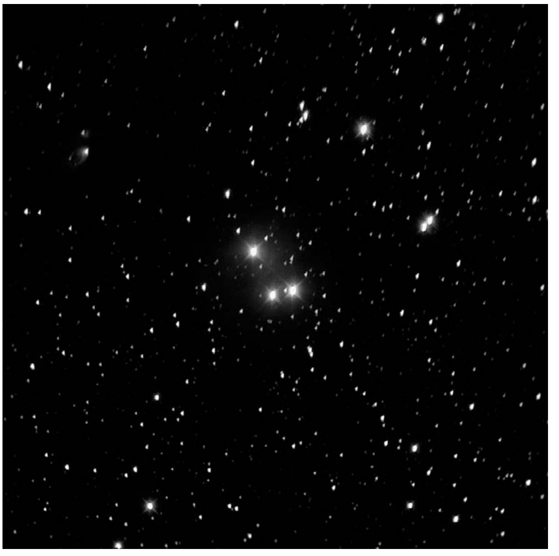
It's time now to go out and explore and give thought to the splendor of the universe.

Secret Deep 1
(van den Bergh 1)



1

van den Bergh 1 = LBN 578
Type: Reflection Nebula
Con: Cassiopeia



RA: 00^h 11.0^m
Dec: +58° 46′
Mag: –
SB: 13.5 (Rating: 3)
Dim: 5′ × 5′
Dist: ~1,900 l.y.
Disc: Beverly T. Lynds (listed in her 1965 Catalogue of Bright Nebulae)

W. HERSCHEL: None.

NGC: None.

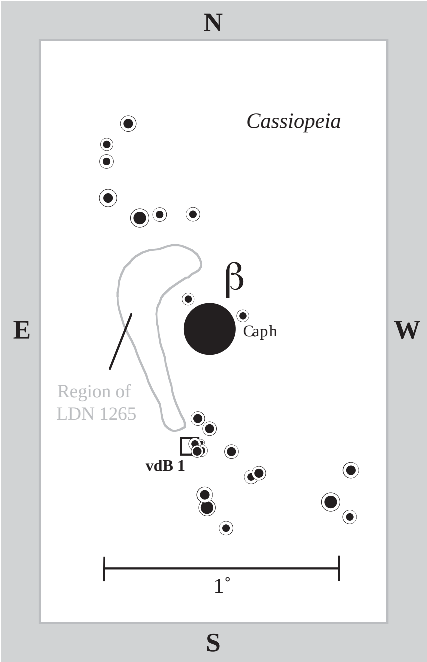
VDB 1 IS A LITTLE-KNOWN REFLECTION nebula only about 30′ south-southeast of Beta (β) Cassiopeiae (Caph). It is also a dim reminder not only that little treasures can hide in the glare of brighter companions, but also that not all objects accessible to small- to moderate-sized backyard telescopes have associated with them a Messier, New General Catalogue (NGC), or Index Catalogue (IC) designation. In fact, this first object in the Secret Deep catalogue is also the first object in Sidney van den Bergh's catalogue of reflection nebulae, which was originally published in a 1966 *Astronomical Journal* (vol. 71, p. 990).

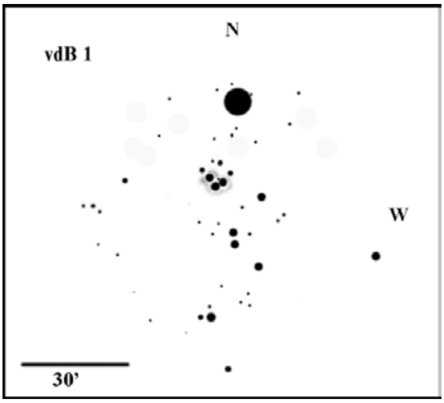
In his study, van den Bergh scanned Palomar Sky Survey prints in an attempt to identify reflection nebulosity associated with all Bonner Dürchmusterung (BD) and Cordoba Dürchmusterung (CD) stars – two of the most complete pre-photographic star catalogues covering the northern and southern celestial hemispheres, respectively. Of the 100,000 or so stars investigated to a declination of −33°, he identified reflection nebulosity associated with about 500 of them.

In his catalogue, van den Bergh also included nebulae already found in similar surveys; vdB 1 was one such inclusion; it appears in Beverly T. Lynds Catalogue of Bright Nebulae (University of Arizona), first published in a 1965 *Astrophysical Journal Supplement* (vol. 12, p. 163). Like van den Bergh, Lynds encountered it in her scans of Palomar Sky Survey prints and listed it as the 578th object in her catalogue. Thus, vdB 1 is also known as Lynds' Bright Nebula 578 (LBN 578).[1]

In his emulsions, van den Bergh noted that the nebula is both "very bright" and "very blue." In modern color shots, it's a

[1] In their 2003 book *Star Clusters* (Willmann-Bell, Inc., Richmond, VA), Brent Archinal and Stephen Hynes caution that this nebula should not be mistaken for the open star cluster vdB 1, with which it has no connection; the latter being apparently known as the "CV Monocerotis Cluster."





5′-long wash of cerulean light surrounding bright illuminating stars; the hue rivals the azure sheen of the Merope Nebula in the Pleiades star cluster (M45) in Taurus, though vdB 1's glow is set against a dusty carpet of multicolored stellar jewels in the Cassiopeia Milky Way.

Detecting vdB 1 is by no means difficult in a 5-inch refractor under a dark sky. The small, foggy glow is primarily illuminated by three roughly 9th-magnitude stars, which burn through the nebula like lights seen through a fog. I find the nebula about as challenging to see as some of the small patches of nebulosity in the Pleiades. The night must be very transparent, because the slightest haze will cause all the stars in the region to appear nebulous.

But that's the key to identifying the nebula. You simply have to use low power and averted vision to compare the triad of 9th-magnitude stars embedded in the nebula with stars of similar magnitude nearby. I found that once I carefully performed this exercise, vdB 1 appeared evermore prominent with time.

The nebula takes magnification surprisingly well. At 60×, for instance, the glow appears as a fuzzy wrap of uniform light with a slight teardrop shape toward the southwest, but this is an illusion, I'm sure, owing to the fact that that's where the pair of 9th-magnitude suns resides.

At 94×, the nebula is most apparent around the solitary 9th-magnitude sun at the northeast end of the triad. The triad also is joined by a roughly 11th-magnitude sun further to the northeast, making the asterism appear like a little Sagitta. To the northwest is an equally bright arc of three suns, the end stars of which are near equal double stars. The longer I look at this amazing little path of light, the more extended it appears, especially to the northwest and southeast of the solitary northern star in the triad.

Return to low power. If you can get a field of 2°, all the better. Now, let your eye relax and view the entire field from Beta Cassiopeiae to vdB 1. Do you see anything curious? I can't recall how many times I have viewed this field at low power without ever having noticed the fact that vdB 1 lies on an island of stars surrounded by a large loop of dark nebulosity, LDN 1265, like the murky waters of a dark moat.

I didn't notice the dark nebula until December 11, 2009 – a night of unexpected clarity and transparency. That night, the low-power, wide-field view of vdB 1 looked, in my mind's eye, like an aerial view of city lights on a mist-laden island at night. The darkest part of LDN 1265 takes the shape of an upside down J; it begins near Beta Cassiopeiae and curls around vdB 1 to the southwest. It's been a while since I've been taken by surprise. The dark J is very bleak. Even at 60× or 94×, I could not detect any starlight within it. It's worth a visual sail along those "dark waters."

The field is even more amazing in wide-field images I've seen, which show the multifaceted nature of this nebulous region (both bright and dark) in remarkable detail. The large swath of LDN 1265 appears as a fat dusty crescent that seems to caress Caph at its northeastern tip – interesting, since Caph is from *Kaff-al-Khadib*, meaning "the stained hand." Here's another interesting aside: this dark nebula is not shown on most popular atlases today. But I was happy to find it plotted (though not labeled) on Antonon Becvar's 1950 *Atlas of the Heavens* (also known as the *Atlas Coeli*).

In October 2009, I viewed vdB 1 from a dark-sky site just beyond Edmonton, Alberta, Canada. Larry Wood, of Edmonton, and Rick Huziak, of Saskatoon, offered me glimpses of this beautiful nebula through 12-inch f/6 and 10-inch f/5 reflectors, respectively. In both scopes, the nebula was an unmistakable glaze of white light surrounding the bright triad of 9th-magnitude stars. But unlike the view in my 5-inch, faint tendrils of light could be seen along the edges of the main nebulosity, giving the object the appearance of a wind-tattered flag. Both Larry and Rick agreed that this object would be perfect for the Secret Deep catalogue, especially since it's not difficult and would otherwise remain a deep-sky obscurity.

AN IMAGING CHALLENGE

If you look carefully at Mario Motta's beautiful image of vdB 1, you can see to the northeast an interesting loop structure associated with a nebulous star, as well as another nebulous star just 37″ to the north: These stars (V633 Cassiopeiae (also known as LkHα 198) and V376 Cassiopeiae, respectively) are Herbig Ae/Be stars associated with extended reflection nebulosity. They lie some 1,900 light-years distant, about as close as the North America Nebula in Cygnus; the distance to vdB 1 in the table on page 18 assumes the Herbig–Haro object and it belong to the same molecular cloud complex, and thus have a similar distance.

Herbig Ae/Be stars are intermediate-mass, pre-main sequence stars that share numerous spectroscopic and photometric properties with T Tauri stars – very young (<10 million years) stars found in reflection nebulae that are still undergoing gravitational contraction and often have large vestige accretion disks. But the exact nature of the Herbig Ae/Be circumstellar environment is quite complicated and uncertain. Many such intermediate-mass young stellar objects may be surrounded by large quantities of circumstellar material in a circumstellar disk, which may be still accreting onto the central star.

In high-resolution imaging, V633 Cassiopeiae appears to be a single star with an extended "loop-like" reflection nebula oriented northwest–southeast. The "loop" traces the redshifted lobe of a CO outflow, the driving force of which may be an infrared source 6″ to the north (V633 Cassiopeiae B (LkHα 198-B)). The loop also contains two Herbig–Haro objects: HH 161 and HH 161-B.

These objects – named after George Herbig (University of California, Berkeley) and Mexican astronomer Guillermo Haro, who discovered the first three such objects in 1946–7 in images of the nebula NGC 1999 in Orion (Hidden Treasure 33) – are small-scale shock regions intimately associated with star-forming regions. They're created when fast-moving jets of material ejected from very young stars collide with the interstellar medium. As the ejected flow plows into the surrounding gas, it generates strong shock waves, which move at speeds topping 100,000 miles per hour, exciting atoms along the way and causing the nebula to glow. All known Herbig–Haro objects have been found within the boundaries of dark clouds and are strong sources of infrared.

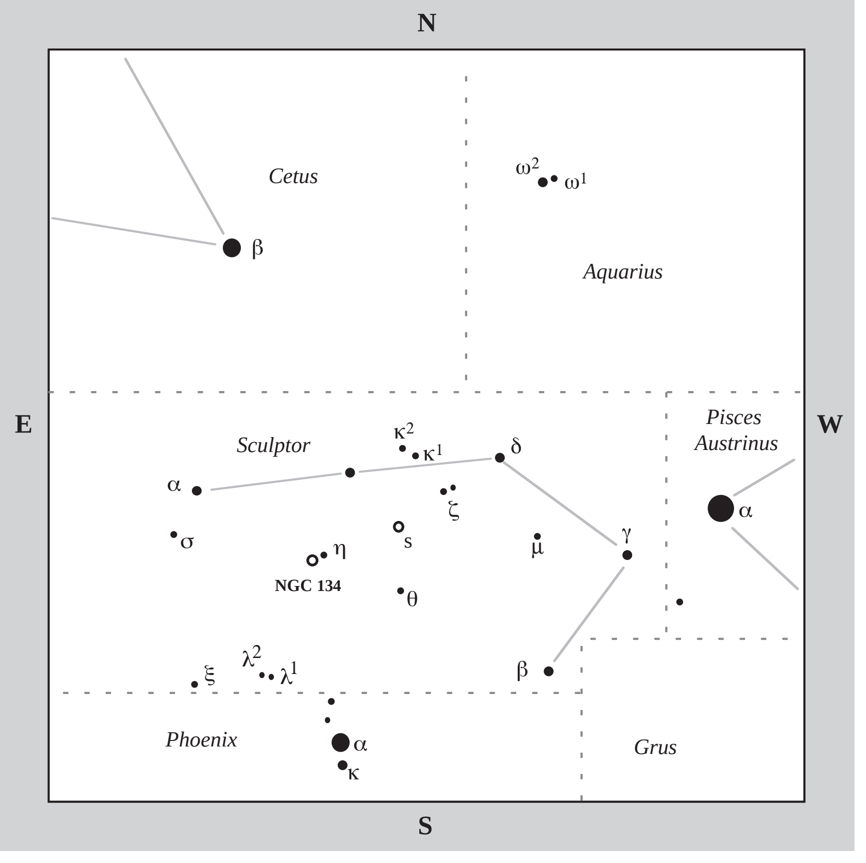
V 376 Cassiopeiae is equally intriguing. In a 1996 *Astrophysical Journal* (vol. 472, p. 349) Canadian astronomer Louis Asselin (Observatoire du Mont Megantic and Department of Physique, Montreal) announced that on the basis of seeing-limited images taken at the Canada–France–Hawaii Telescope atop Hawaii's Mauna Kea, V376 Cassiopeiae is seen close to edge-on with a possible circumstellar disk.

Kester W. Smith (Max-Planck-Institute for Radio Astronomy, Bonn) and his colleagues support that claim. In a 2004 *Astronomy & Astrophysics*, the astronomers report that speckle observations of V376 Cassiopeiae partially reveal that the inner regions of the system are in fact obscured by a flaring circumstellar disk or torus seen close to edge-on. A Hubble Space Telescope image also lends support. However, it suggests a nearly edge-on disk at a position angle of about 140°; the near-side of a bipolar outflow lobe can also be seen extending to the west. The observed light probably arises mostly from scattering from the inner edge of the outflow cavity or from the surface of a flared disk or circumstellar torus.

In October of 2008, Mario Motta and I viewed vdB 1 visually through Mario's 32-inch reflector. The 9th-magnitude stars dominated the view and the nebula nearly filled the field of view; it looked as if a cirrus cloud had moved in and destroyed the night's viewing. Unfortunately, we did not know at the time about the two nearby Herbig Ae/Be stars. It wasn't until Mario later imaged the field that he noted the mysterious loop of nebulosity nearby. That sent me on a search of the literature. Now I wonder how large an aperture is required to see the loop visually. Go out and give it a try!

2

Secret Deep 2
(NGC 134)



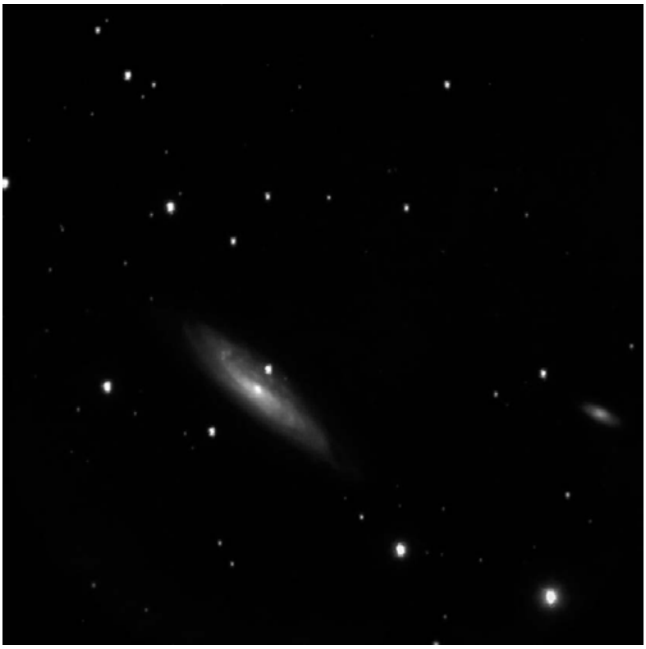
2

Giant Squid
NGC 134
Type: Mixed Spiral Galaxy (SABbc)
Con: Sculptor

RA: 00^h 30.4^m
Dec: −33° 15′
Mag: 10.4
SB: 13.3 (Rating: 3.5)
Dim: 8.5′ × 1.9′
Dist: ~62 million l.y.
Disc: John Herschel; James Dunlop possibly included it as the 590th object in his catalogue of 1828

J. HERSCHEL: BRIGHT; large; very much elongated; pretty suddenly a little bright in the middle; 4″ long; 1″ broad; position angle 227°; the following of two. (h 2327)

NGC: Very bright, large, very much extended toward position angle 47°, pretty suddenly bright in the middle, following of two, 10th-magnitude star north preceding 45″.



NGC 134 IS AN EXTRAORDINARY, nearly edge-on spiral galaxy in Sculptor, just 30′ east-southeast of 5th-magnitude Eta (η) Sculptoris, or nearly 10° (about a fist held at arm's length) south-southwest of NGC 253 (Caldwell 65), the more popular Silver Coin galaxy. In fact, in a sweeping view of the region, NGC 134 just happens to be surrounded by, and somewhat lost among, a cast of extragalactic prima donnas – including NGC 253, NGC 300 (Caldwell 70), and NGC 55 (Caldwell 72) – all of which are savagely beautiful when seen through small telescopes.

Nevertheless, NGC 134 is a treasure that's relatively easy to acquire. At a declination of −33° 15′, the object is only 1° farther south than M7 in Scorpius. Of course, the galaxy's faintness makes it a challenge to find from mid-northern latitudes. But it's a stunning object when seen from the southern USA.

NGC 134's discovery is often attributed to John Herschel, but Herschel did note that it may be the 590th object listed by James Dunlop in his 1828 catalogue, which was published six years before Herschel arrived at the Cape of Good Hope and began surveying the southern heavens with his 18-inch f/13 speculum reflector. Of the new object Dunlop wrote: "A faint round nebula, about 2′ diameter." Of course, while his position places the object near NGC 134, his description of it does not sound at all like this elliptical wonder, which is even apparent in the smallest of telescopes.

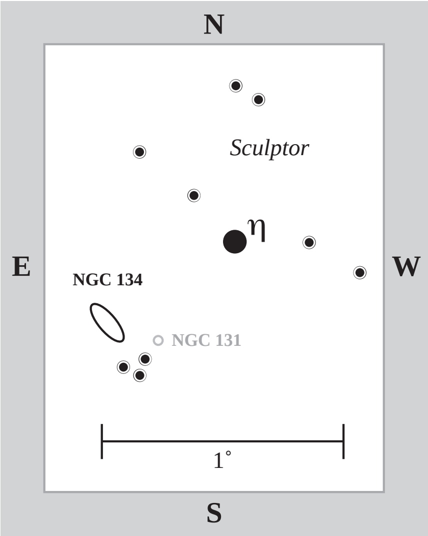
Herschel also sketched the galaxy, clearly showing its spindle-shape with tapering edges. He classified NGC 134 as an elliptical nebula "normal" in its character, meaning "as the condensation increases towards the middle, the ellipticity of the strata diminishes, or in which the interior and denser portions are obviously more nearly spherical than the exterior and rarer." Of its nature, Herschel suggested that the "time is clearly arrived for attempting to form some conception at least of the possibility of such a system being either held in a state of permanent equilibrium, or of progressing through a series of regular and normal changes, resulting either in periodical restorations of a former state, or in some final consummation."

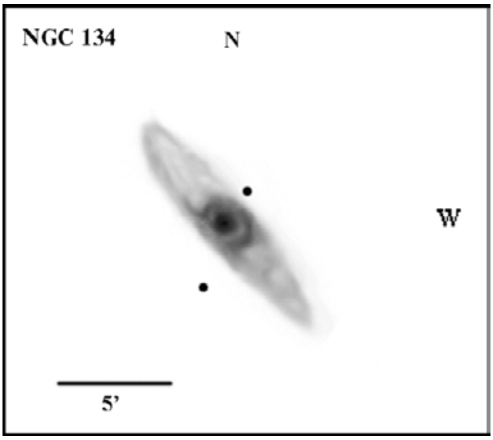
Seen through small telescopes, wafer-thin NGC 134 appears to be a near twin of the spectacular edge-on galaxy NGC 4565 (Caldwell 38) in Coma Berenices.

Photographs, however, reveal the two galaxies to be worlds apart in appearance. NGC 4565 is a classic example of a nearly edge-on spiral galaxy with an oval hub surrounded by a large symmetrical disk of dust and starlight. Although NGC 134 is similarly oriented (~14° from edge on), it is a different class of spiral. The innermost part of the disk is smooth out to about 50″. Multiple dust lanes that outline the arm fragments then begin at the rim of this smooth disk. Its bright, very small nucleus is partly hidden by a series of dark, feathery dust lanes that delineate the galaxy's clumpy, spiral arms (rich in star-forming HII regions) that loosely wrap around a bright, bar-shaped central region. Dust-lane asymmetry between the near and far sides is particularly strong.

Deep exposures have also revealed plumes streaming off the galaxy's major axis in both directions – like the flagella of some extraterrestrial euglena. Indeed, as Mario's image on page 23 shows, the galaxy's disk appears warped, resembling a bent vinyl LP left out too long in the burning sun. Such warps are not unusual; our Milky Way, for instance, has a small one, and they are found on many other galaxies that have an interacting companion. It's possible that a smaller galaxy has gravitationally stretched matter from NGC 134, forming the plumes (and the warp). One likely candidate would seem to be 13th-magnitude NGC 131, which lies only 5′ west of NGC 134, but this galaxy does not seem to be involved; a still fainter galaxy, ESO 350-G21, may be the disturbing culprit. It's also possible that a smaller galaxy collided with NGC 134 in the past, causing the visible disruption. The answer still eludes astronomers.

From our perspective, NGC 134 lies in a haystack of galaxies, centered on the impressive Sculptor Group, which lies at a distance of 10 million light-years, and is the nearest gathering to our own Local Group. But NGC 134 is not a true member of the Sculptor Group. R. Brent Tully (University of Hawaii) places it 62 million light-years from Earth in the Telescopium–Grus Cloud of galaxies. NGC 134 is a massive system





with a diameter of about 150,000 light-years, making it as large as NGC 4565.

To find this southern wonder, use the chart on page 22 to locate 4th-magnitude Alpha (α) Sculptoris, which is some 12° south-southeast of Deneb Kaitos, or Beta (β) Ceti. Next, use binoculars to locate 5th-magnitude Eta (η) Sculptoris about 7½° southwest of Alpha Sculptoris. Now center your telescope on Eta Sculptoris and use the chart on this page to locate NGC 134, which will look like a 10th-magnitude needle of pale light 30′ to the east-southeast of that star.

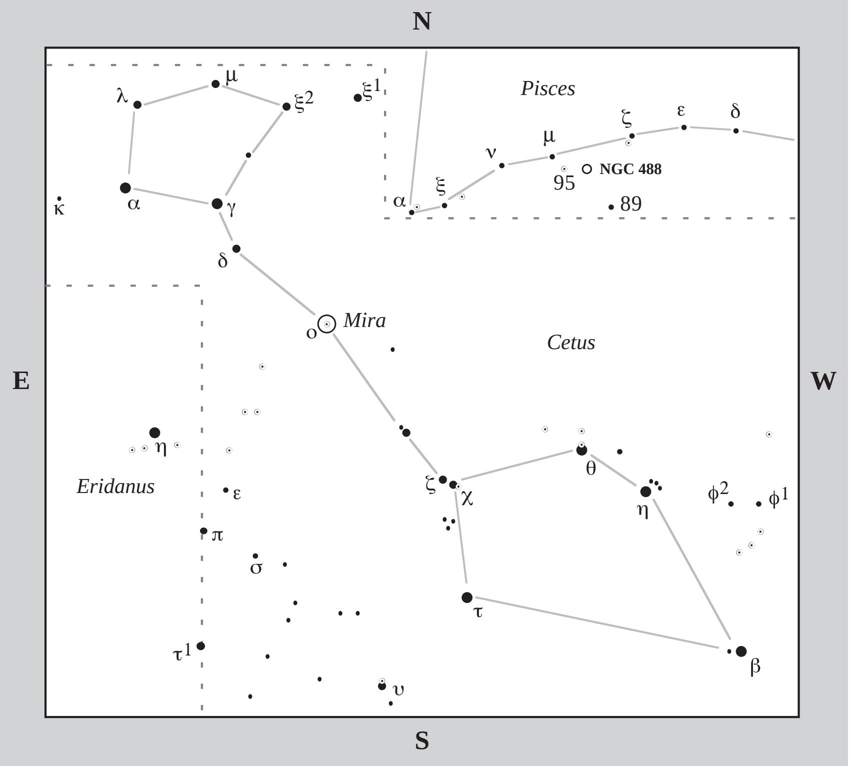
The galaxy is visible from Hawaiian skies in 7 × 50 binoculars and in my antique telescope. At 33× the galaxy sits atop a trapezoid of suns southeast of Eta. The galaxy is immediately noticeable as a white scratch between the trapezoid and other field stars that pen the galaxy in. Since the galaxy is nearly edge-on, its thin arms are less noticeable than the core, which requires averted vision to see at this magnification. With time, the galaxy's bright core swells in layers.

At 60×, the galaxy is a fine sight and seems to awaken the senses. The trapezoid is more of a square with a dim star within. The arms appear to favor each side of the nucleus along the major axis. The north side also seems to have a break near the faint star on its western side. At 94×, the galaxy looks more milky and feathery. The core is mottled, and the arms look like moist breath on string. The southern half of the galaxy is definitely brighter than the northern half. The southern arm is also knotted in a most delicate manner.

A 13th-magnitude star can be seen north-northwest of the galaxy's nuclear region and could easily be mistaken for a supernova. A supernova was discovered in the galaxy in 2009: Stuart Parker, who lives in the small village of Oxford in New Zealand's South Island, discovered Supernova 2009gj on June 20, 2009, shining at magnitude 15.9 in his images of the galaxy, which he had taken through his Celestron 14 telescope.

Note that since NGC 134 is located about 60 million light-years away, the light we see from its disk through our telescopes left the galaxy around the time of the Cretaceous–Tertiary mass extinction of the dinosaurs on Earth.

Secret Deep 3
(NGC 488)



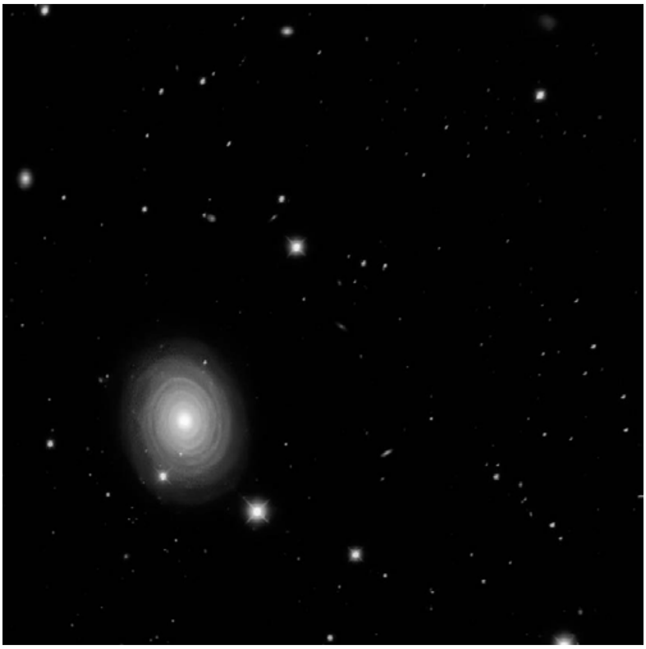
3

Whirligig Galaxy
NGC 488
Type: Spiral Galaxy (SA(r)b)
Con: Pisces

RA: 01^{h} 21.8^{m}
Dec: $+05°$ $15'$
Mag: 10.3
SB: 13.5 (Rating: 4)
Dim: $5.5' \times 4.0'$
Dist: ~95 million l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed December 13, 1784] Very faint, pretty large, irregularly round, little brighter in the middle. (H III-252)

NGC: Pretty bright, large, round, suddenly very bright in the middle, 8th-magnitude star following 10′.



NGC 488 IS A SMALL BUT BEAUTIFUL spiral galaxy in the mysterious cord of Pisces – about 10° west-northwest of Alpha (α) Piscium, the knot in the line that joins the two Fishes. I say mysterious because no one is quite sure why this cord exists, why the fishes have been united in this way. It may refer to the Roman myth in which Venus and Cupid (the goddess of love and her boy) startled the monster-dragon Typhon, who thrives in fire but fears water. To escape the beast's wrath, the pair tied themselves together with a long cord (so they would not be separated), then dove into the dark waters of the Euphrates, where they turned themselves into fishes. Today we see the successful escape commemorated in the sky as Pisces.

I first encountered NGC 488 in Burnham's *Celestial Handbook* (Dover Publications, New York, 1978), which spotlights the compact spiral simply in a photo. Still, the galaxy's fine weave of spiral arms, dappled with extragalactic filigree, was enough to entice wonder. Not until I moved to Hawaii in 1994, though, did I try to hunt it down. When I did, the view didn't disappoint me. But more on that later.

For now, just look at Mario Motta's marvelous image that opens this page. The disk has nearly perfect spiral structure, which we see 46° from face-on. Astronomers refer to NGC 488 as the prototype multiple-armed spiral galaxy (more-evolved galaxies have thicker, more-open arms).[1] NGC 488's tightly wound spiral pattern reminds me of a Fourth-of-July whirligig, surrounded by bursts of foreground starlight and little extragalactic sparklers. Despite its small apparent size (5.5′ × 4.0′) the galaxy is a true astrophysical wonder, measuring 150,000 light-years across in true physical extent. It appears so small in the sky because we see its light 95 million light-years distant in the Cetus–Aries Cloud of galaxies. NGC 488's form consists of a large and smooth central bulge surrounded by a uniform arrangement of thin, stringy fragments. The tight spiral pattern can be traced across the entire face of the disk, though no fragments can be followed for more than about half a revolution. Each filament appears clumpy, though without prominent star-forming knots.

As German astronomer Burkhard Fuchs (University of Heidelberg) discusses in a 1997 *Astronomy & Astrophysics* (vol. 328, p. 43), the young galaxy has a prominent central bulge and an inner counter-rotating disk, both of which suggest that the bulge formed – not during the collapse of the protogalaxy or by secular evolution of the galactic disk – but by cannibalizing satellite galaxies. NGC 488's counter-rotating disk, for instance, can be interpreted as the debris of satellite galaxies that disintegrated while they merged with NGC 488.

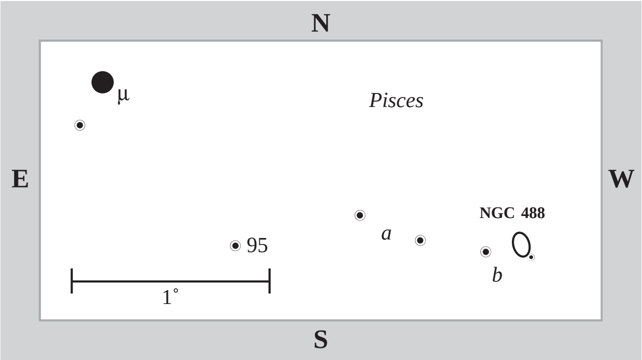
Kinematic studies have been made of the stars in NGC 488's disk out to a radius of 65,000 light-years from the galaxy's bulge, at which point the stars travel at a velocity of 363 km/second – an astonishing rate given that our Sun orbits the Milky Way at a speed that's about 1.5 times slower! NGC 488 has, in fact, the largest rotational velocity known for any normal spiral galaxy.

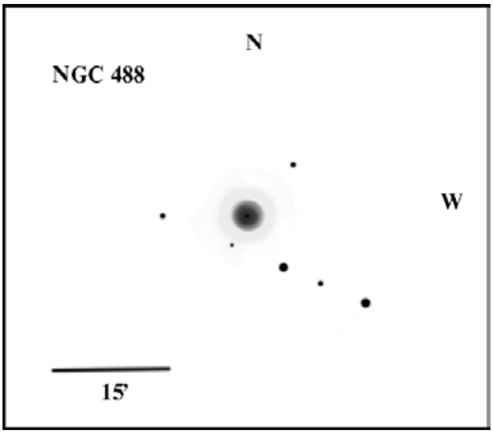
These studies have also furthered the contention that the spiral appearance of galaxies represents areas of enhanced density (density waves). Compression waves rotate more slowly than the galaxy's stars and gas – like cars in a traffic jam. As gas enters a density wave, it gets squeezed and triggers star formation, which illuminates the arms, creating the visible spiral structure.

NGC 488 is a good target for small telescopes, even from suburban locations; I've seen it in telescopes as small as a 4-inch refractor with direct vision under the light of a first-quarter Moon. To find it, use the chart on page 26 to locate 3.5-magnitude Alpha (α) Piscium, which is 10° due west of 4th-magnitude Gamma (γ) Ceti. Now use your unaided eyes or binoculars to find Mu (μ) Piscium about 8° further to the northwest in the Fishes' cord. Center Mu Piscium in your telescope at low power, then switch to the chart on page 29. From Mu Piscium, move 1° south-southwest to 7th-magnitude 95 Piscium. Now move about 50′ west to a wide pair of 8.5-magnitude stars (*a*) oriented east-northeast to west-southwest and separated by about 20′. Next move about 35′ west-southwest to 7.5-magnitude Star *b*. NGC 488 is only about 10′ west of Star *b*.

At 33× in the 5-inch, NGC 488 can be seen as a small but bright and highly condensed glow just northeast of a roughly 12th-magnitude star. At a glance the light

[1] The Deep-Sky Companions series contains several other galaxies with similar structure: NGC 1398 in Fornax (Hidden Treasure 19), NGC 2775 in Cancer (Caldwell 48), NGC 2841 in Ursa Major (Hidden Treasure 49), NGC 3521 in Leo (Hidden Treasure 56), and NGC 7793 in Sculptor (Hidden Treasure 109).



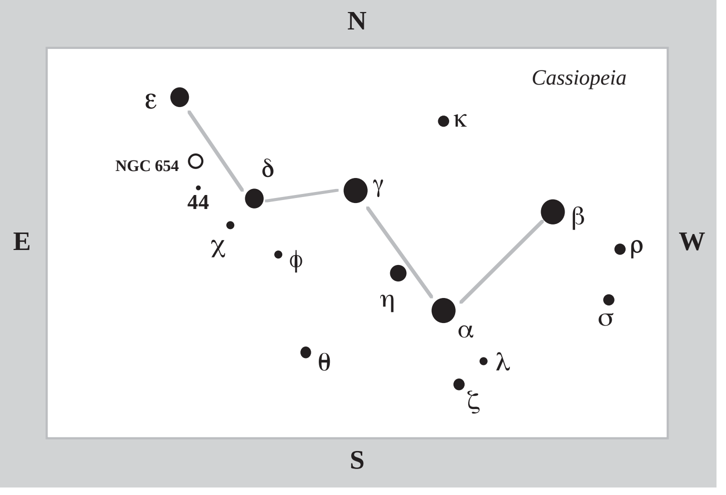


from the galaxy and star seem to meld, making the galaxy appear larger than it is. Once you realize that a star is contributing to the overall view, the galaxy suddenly shrinks in the mind's eye. It's a fabulous illusion. Because, the galaxy is so condensed, it takes magnification well.

For this study, I immediately went to 94× to start. At this power, the galaxy is quite a subtle beauty, displaying a conspicuous starlike nucleus in a soft nest of light 1′ across, surrounded by an even softer halo at least twice that extent, which is best seen with averted vision. The proximity of the ~12th-magnitude star is somewhat of an irritant, but it helps to keep the eye focused on the target. The view at 165× is equally enticing, though I cannot see any further details. Those using larger telescopes should be able to make out some of the thin spiral patterns.

On October 21 and 23, 1976, a 15th-magnitude Type I supernova was discovered photographically 2″ west and 111″ south of NGC 488's nucleus. Designated SN 1976G, it was discovered about 30 to 40 days after maximum light. Keep watch on this galaxy for future eruptions.

Secret Deep 4
(NGC 654)



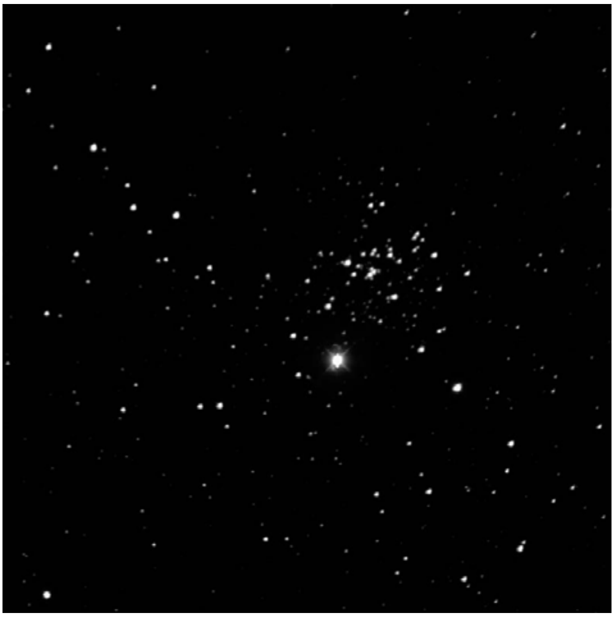
4

Fuzzy Butterfly
NGC 654
Type: Open Cluster
Con: Cassiopeia

RA: 01^{h} 44.0^{m}
Dec: $+61°$ $53'$
Mag: 6.5
SB: 10.4 (Rating: 4)
Diam: 6.0′
Dist: ~7,800 l.y.
Disc: William Herschel, 1787

W. HERSCHEL: [Observed November 3, 1787] A small cluster of pretty [bright] stars, considerably rich. (H VII-46)

NGC: Cluster, irregular figure, rich, one magnitude 6.7 star, stars from 11 to 14 magnitude.



NEXT TO THE BIG DIPPER, THE W OF Cassiopeia is arguably the most sought after star pattern in the northern heavens. They're both conspicuous and neither sets as seen from mid-northern latitudes. But unlike the Big Dipper (and its parent constellation Ursa Major), which is rich in galaxies, Cassiopeia lies on the Galactic equator and hosts a wealth of other deep-sky spectacles, including include two Messier objects (M52 and M103); six Caldwell objects (NGC 147, NGC 185, NGC 457, NGC 559, NGC 663, and NGC 7635); five Hidden Treasures (NGC 189, NGC 225, NGC 281, NGC 659, and NGC 7789), and four Secret Deep objects (NGC 654, NGC 7790, Stock 2, and vdB 1).

One of the richest deep-sky regions in the celestial W lies only 2½° east-northeast of 3rd-magnitude Delta (δ) Cassiopeiae. That's where you'll find five open clusters. They are, in order of brightness, NGC 654 (6.5), NGC 663 (7.1), M103 (7.4), NGC 659 (7.9), and Trumpler 1 (8.1). Note that our target, NGC 654, is the brightest of them all. Yet it's easy to overlook because the cluster "hides" in the glare of a yellowish 7th-magnitude sun, which initially overpowers the view. But, as I will soon describe, this yellow star is actually a member of the cluster.

Nevertheless, NGC 654 can be spied by a keen observer using 7 × 35 binoculars under dark skies. Telescopically, it's a tiny and tight grouping of little gems. The cluster's 80 measured members (7th-magnitude and fainter) appear in little clumps scattered across a mere 6′ of sky, or 14 light-years. G. Lynga classified it as Trumpler II2r – a rich, detached cluster with little central concentration whose stars have a moderate range in brightness. It's a young cluster, with an age of about 14 million years, or about the same age as the Double Cluster in Perseus.

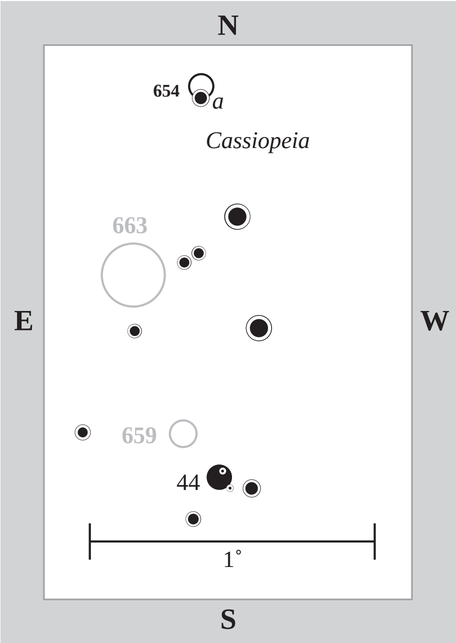
Astronomers have taken keen interest in NGC 654 because it displays nonuniform extinction across its face, with stars reddened by about 1 magnitude on average. As early as 1975, W. B. Samson (Royal Observatory, Edinburgh, UK) proposed that a dust shell of interstellar matter – swaddling matter left over from the period of cluster star formation – is responsible for the nonuniform extinction across the cluster region. But Sidney W. McCuskey (Warner and Swasey Observatory, Cleveland, Ohio) and his colleagues countered that local dust clouds lying in the cluster direction can explain the observed extinction, which is very patchy. Besides, the researchers failed to find evidence that the extinction varies with distance from the cluster center as might be expected with a dust-shell model.

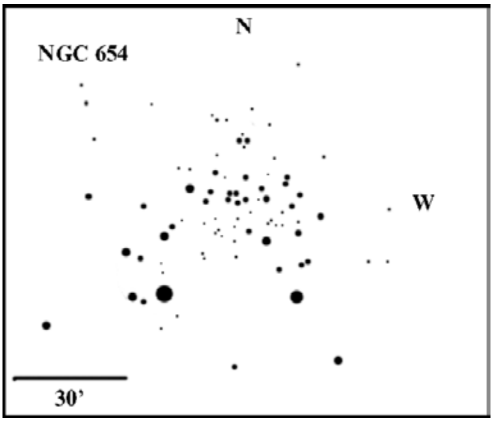
Some of the cluster's stars also display a large color excess – the difference between the observed color of a star compared to its spectral type. Color excess indicates the amount of interstellar reddening suffered by the light from the star when it passes through dust in space. In some clusters, this extinction is caused by the presence of hot and ionized dust circumstellar envelopes around stars.

But this does not appear to be so in the case of NGC 654. In a 2008 *Monthly Notices of the Royal Astronomical Society* (vol. 388, p. 105) Indian astronomer Biman J. Medhi (Aryabhatta Research Institute of Observational Sciences, Manora Peak, Nainital) and colleagues published their polarimetric observations for 61 stars in the NGC 654 region. The data show evidence for the presence of at least two layers of dust along the line of sight to the cluster, which lies at a distance of about 7,800 light-years. They estimate the distances to the two dust layers to be about 652 and 3,300 light-years, placing the clouds much closer to the Sun than the cluster. The dust forms a ring with the central hole coinciding with the center of the cluster. The foreground dust grains, then, appear to be responsible for the nonuniform extinction towards the cluster, whose least reddened stars lie close to the cluster center.

Photoelectric observations and proper motion studies of NGC 654 have helped astronomers determine which stars belong to the cluster. These studies have identified the 7th-magnitude yellow supergiant star HD 10494 as a likely member with a recessional velocity of about 31 km/sec.

To find this hidden treasure you can star and cluster hop. Start by using the chart on page 30 to locate Delta Cassiopeiae, then 5th-magnitude Chi (χ) Cassiopeiae nearly 1½° to the southeast. The 6th-magnitude star 44 Cassiopeiae forms the northeast apex of a near-equilateral triangle with Delta and Chi. Center that star in your telescope then see the chart on page 33. Open cluster NGC 659 is only about 10′ north-northeast of Chi, and open cluster NGC 663 is only 35′ northeast of it. Our target is only 40′ north-northwest of NGC 663. It sits just north and slightly west of a 7th-magnitude sun (Star *a*) that shines with a rich golden hue; this is the yellow supergiant HD 10494. Note that the magnitude 9.5 star a few arcminutes to the west is not a cluster member, but it adds to the cluster's apparent beauty.





Using direct vision through the 5-inch at 33× the cluster appears as a breath of circular light hugging a bright topaz-yellow sun. This nebulous knot transforms into a beautiful fuzzy butterfly with averted vision; thus my nickname for the cluster. The butterfly's upward-flapping wings open toward the 7th-magnitude star like a reverse letter "C". With averted vision and 33×, the cluster resolves into little patches of stardust with an obvious congregation at the northwest end, making it appear quite irregular.

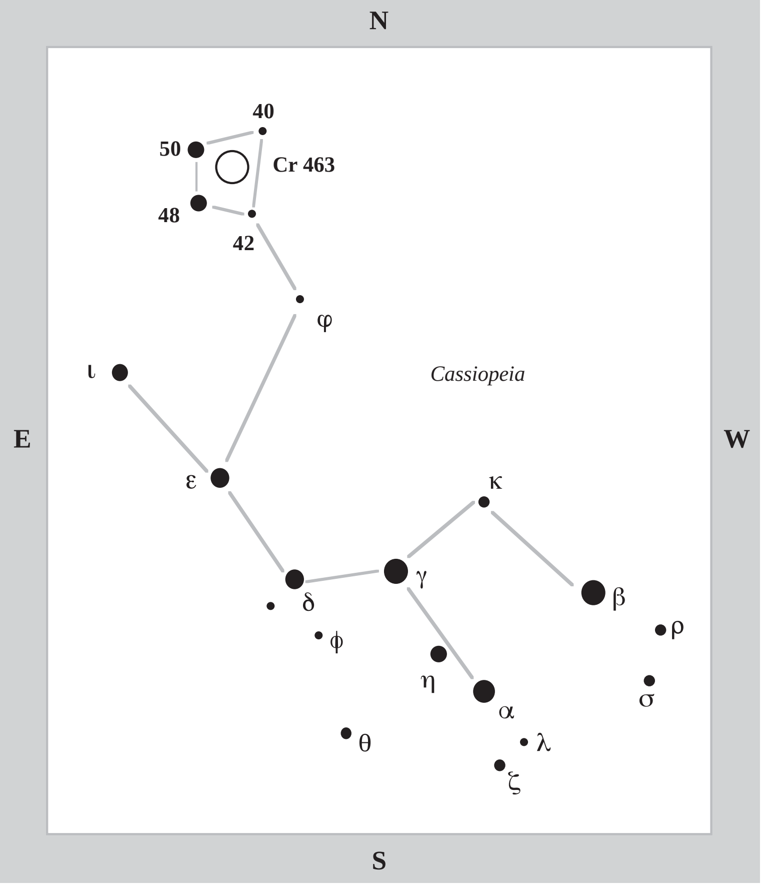
At 60×, the cluster's vast majority of 11th- and 12th-magnitude suns form a 6′-long ellipse of irregularly bright stars, oriented east–west and flanked to the south by milky starlight. At 94×, the greatest congregation of some two-dozen suns looks like two superimposed clusters: one shaped like a tadpole (oriented roughly east–west) and an inverted V of stars (oriented north–south).

The cluster is small enough, and bright enough, to handle high magnifications. In the 5-inch, the most comfortable power is 180×, which shows the shapes just described burning against a fainter scrim of dim suns. If you look closely at the 7th-magnitude sun, you will see an obvious 11th-magnitude sun about 1.5′ north of it, and another 11th-magnitude sun about 1′ north-northeast of it. That latter star is another nonmember.

By the way, if you can get a 2° field of view at low power, all three clusters – NGC 654, NGC 663, and NGC 659 – will fit comfortably in the field with 44 Cassiopeiae. In physical space, NGC 654 (~7,800 light-years distant) lies between the other two: NGC 663 (The Horseshoe Cluster) is a bit closer at ~7,200 light-years; NGC 659 is a tad farther away at ~8,200 light-years.

5

Secret Deep 5
(Collinder 463)



5

Loch Ness Monster Cluster, The Queen's Reflection
Collinder 463
Type: Open Cluster
Con: Cassiopeia

RA: $01^h\ 45.7^m$
Dec: $+71°\ 49'$
Mag: 5.7
SB: 14.5 (Rating: 4)
Diam: 57′
Dist: ~2,280 l.y.
Disc: Per Collinder, listed in his 1931 paper "On structural properties of open galactic clusters and their spatial distribution."

W. HERSCHEL: None.

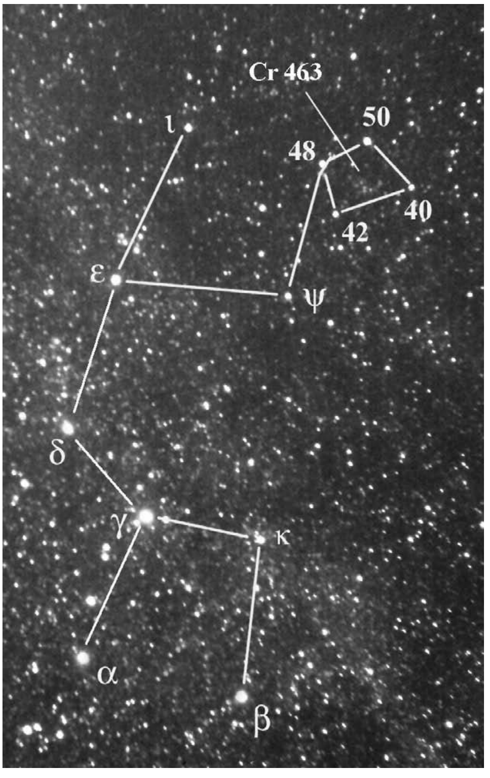
NGC: None.

MOST BACKYARD ASTRONOMERS ARE aware of Collinder 399, the pretty Coathanger asterism in Vulpecula (Hidden Treasure 97). In my *Deep-Sky Companions: Hidden Treasures*, I also spotlight two other Collinder clusters: Collinder 69 (the Lambda Orionis Cluster (Hidden Treasure 29)) and Collinder 72 (the Lost Jewel of Orion (Hidden Treasure 31)). Now I take you to the forgotten high northern reaches of Cassiopeia, to Collinder 463, a large and beautiful cluster "reflected" in the vain Queen's mirror – a 2°-wide trapezoid of 4th- and 5th-magnitude suns (50, 48, 40, and 42 Cassiopeiae).

This mirror is of my own invention. I think it's easier to see the Queen of Ethiopia sitting in her chair or throne, if you envision the chair as depicted on page 36: with Epsilon (ε) and Delta (δ) as the raised back, Gamma (γ) and Kappa (κ) as the seat, and Alpha (α) and Beta (β) as two legs. I first saw the throne depicted this way in Lou Williams' 1950 book *A Dipper of Stars* (Follett Publishing Company, Chicago). As a child, I found it easier to imagine the Queen seated in this celestial throne than the way she's positioned in classical star charts. If you adopt my nonclassical version of the Queen, look for her in profile: Iota (ι) Cassiopeiae is the Queen's head; the mirror is being held in her bent arm with Phi (ψ) Cassiopeiae at the elbow.

You'll find the Queen's mirror roughly two-thirds of the way along an imaginary line between 3rd-magnitude Epsilon (ε) Cassiopeia, the easternmost star in the Celestial W, and the North Star (see the chart on page 34). The mirror marks a little spur in the eastern reaches of the Milky

5



Way that sweeps past 3.5-magnitude Gamma (γ) Cephei, just a little more than 10° from the North Celestial Pole. Collinder 463 lies in the middle of the mirror, midway between 40 and 48 Cassiopeiae. It is, in fact, the largest star cluster in the constellation.

The Swedish astronomy graduate student Per Arne Collinder (1890–1975) discovered the cluster, which he listed in his 1931 doctoral dissertation "On structural properties of open galactic clusters and their spatial distribution." Collinder was a surveyor by profession, spending much of his career on the seas around Sweden and in the Arctic. He devoted his life to the history of astronomy in his retirement, when he became historian of the development of astronomy in his homeland. His records are kept at the Uppsala Astronomical Observatory in Sweden.[1]

Collinder 463 is a large and loose Galactic cluster close to the Sun near the edge of the Orion arm – the same one that carries our Sun. At the cluster's given distance, it spans 38 light-years of space.[2] It's also relatively young, being only 150 million years old. That makes Collinder 463 the same age as M35 in Gemini. But Collinder 463 is nearly two times larger than M35 in true physical extent. Since Collinder 463 is only about 220 light-years closer, we see it almost twice as large as M35 in the night sky.

In apparent size and magnitude, Collinder 463 is more akin to NGC 752, a magnitude 5.7 open cluster in Andromeda that spans a whopping 75′ of sky. NGC 752, however, lies nearly twice as close. With an age of 2 billion years, NGC 752 is also one of the oldest open clusters known. Still, isn't it interesting that Collinder 463, which is visible to the unaided eye under a dark sky (just like NGC 752), went unnoticed by so many great observers. NGC 752, on the other hand, which is just as bright and about 25 percent larger than Collinder 463, was at least nabbed by the keen gaze of Caroline Herschel in 1783. Perhaps Collinder 463's position so close to the north celestial pole caused it to be ignored for so long. Collinder 463 stands just far enough

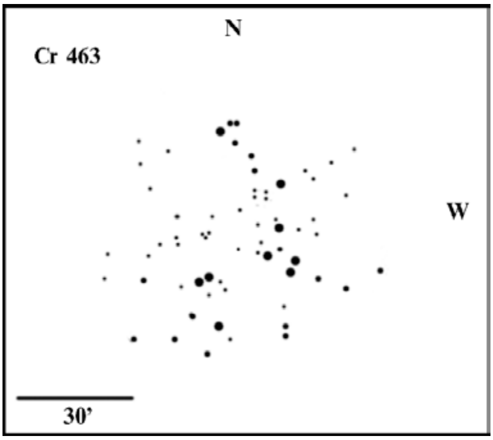
[1] Collinder's paper "Swedish astronomers 1477–1900" appears in the 1970 *Acta Universitatis Upsaliensis*. His "Astronomical works and papers printed in Sweden between 1881 and 1898" appears in the 1966 *Arkiv for Astronomi* (vol. iv).

[2] "Proper motions of open clusters within 1 kpc based on the TYCHO 2 catalogue," W. S. Dias., J. R. D. Lépine, B. S. Alessi, 2001, *Astronomy & Astrophysics* (vol. 376, p. 441).

away from the central madness of the Cassiopeia Milky Way to be easily overlooked.

To see Collinder 463 with the unaided eye, you'll need to be under a dark and transparent sky. I find that if I orient my head so that Collinder 463 appears to the upper left of 50 Cassiopeiae, then stare at 50 Cas with direct vision, NGC 463 pops into view with averted vision. It's an intriguing sight in 10 × 50 binoculars, appearing as wide splash of about a dozen suns 8.5-magnitude and fainter.

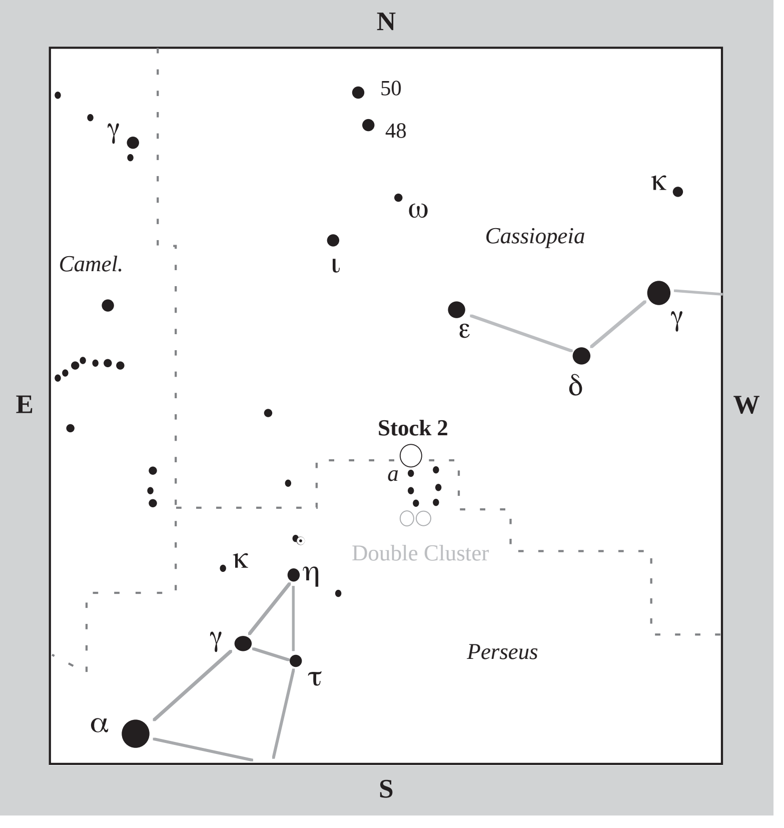
The cluster is an eye-grabber in rich-field telescopes, which are best for showing such a large celestial treasure. In the 5-inch at 33×, my eye was immediately attracted to a pretty neck of stars in the southeast quadrant of the cluster that connects to a roughly 10′-wide trapezoid of relatively bright stars at the cluster's core. In fact, when the cluster's central 30′ of stars are seen with south up, they remind me of a plesiosaurus – the large marine dinosaur that swam in the Jurassic seas; or, better yet, how about "Nessie," Scotland's legendary Loch Ness Monster? An acute triangle of suns in the north forms the dinosaur's head; lines of stars extending to the north-northwest, southwest, and northeast look like the beast's flippers. And a "wagging" tail reaches to the east, before making a sharp jog southward.



Of course, a loose cluster of this size is a virtual celestial Rorschach test; just turn your head and all manner of forms can be created. Although the cluster has only 40 confirmed members (three of them confirmed giants), the field is surprisingly rich. I counted at least 80 stars in a roughly 1° sphere without straining, and there's probably a hundred. And while the cluster loses its luster at higher powers and smaller fields of view, I found lots of interesting stellar pairings and other attractive gatherings of stars at 60×. So go out and enjoy this "monster" of a cluster. The good news is that it's circumpolar from mid-northern latitudes. Even when lowest, it stands about 20° above the horizon, so it's always accessible.

6

Secret Deep 6
(Stock 2)



6

9 (Stitchpunks)
Stock 2
Type: Open Cluster
Con: Cassiopeia

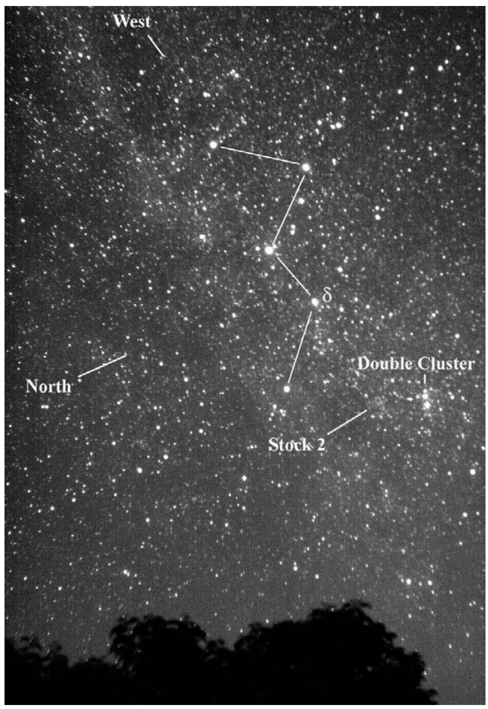
RA: 02^h 14.7^m
Dec: +59° 29′
Mag: 4.4
SB: 13.3 (Rating: 4)
Diam: 60′
Dist: ~1,100 l.y.
Disc: Jürgen Stock, 1956

W. HERSCHEL: None.

NGC: None.

STOCK 2 IS A SURPRISINGLY BRIGHT and large open cluster about 2° north-northwest of the great Double Cluster in Perseus. Like the latter wonder, it lies near the Galactic equator in the stellar tapestry of the winter Milky Way. And while Stock 2 is just as bright as the Double Cluster, it lacks a strong central condensation (the Double Cluster has two!), which makes it less obvious; imagine seeing two concentrated flashlight beams against a distant background versus that of a single diffuse beam. Indeed, the irregularly bright suns of Stock 2 are coarsely scattered across two Moon diameters of sky in a rich band of Milky Way, causing it to almost blend with the background. Yet, once detected, Stock 2 springs to life, becoming quite obvious, especially in binoculars and wide-field telescopes.

What's visually intriguing is that while the Double Cluster lies some 7,300 light-years distant in the Perseus Arm of the



Milky Way (the one opposite the Galactic center from the spiral arm containing our

Sun), Stock 2 is a foreground object 1,100 light-years distant (lying almost in front of the Double Cluster) in the Orion spiral arm – the same spiral arm in which our Sun and the stars of Orion reside.

If the Double Cluster were at the distance of Stock 2, each member would span three Moon diameters and shine more than 100 times brighter than it does now in the sky. Conversely, if Stock 2 were at the distance of the Double Cluster, it would appear as a roughly 10th-magnitude cluster about 8′ in apparent diameter. As it stands, despite Stock 2's closeness to us, we see it strongly obscured by dense and patchy interstellar dust clouds along this line of sight.

Jürgen Stock at Warner and Swasey Observatory found Stock 2 while searching blue objective prism plates along the Galactic equator. He found the new cluster based on the spectral class and approximate magnitudes of its stars. He catalogued it as a cluster in 1956.

Interestingly, Stock 2 is a Trumpler class I2m, meaning it's a detached and moderately rich cluster with a strong central concentration and a medium range in the brightness of the stars (though the visual appearance through a small telescope is of a loose aggregation of suns hardly concentrated at all!). In their wonderful book *Star Clusters*, Archinal and Hynes list Stock 2 as having 166 members 8th-magnitude and fainter. But recent studies have increased that number dramatically. In a 2000 *Astronomy & Astrophysics* (vol. 143. p. 409), D. C. Foster and his colleagues used the cluster's proper motion to separate members from background and foreground stars. The team found 634 stars with a membership probability equal to, or greater than, about 50 percent to a limiting blue magnitude of about 20, corresponding to late-M dwarfs at the distance of Stock 2.

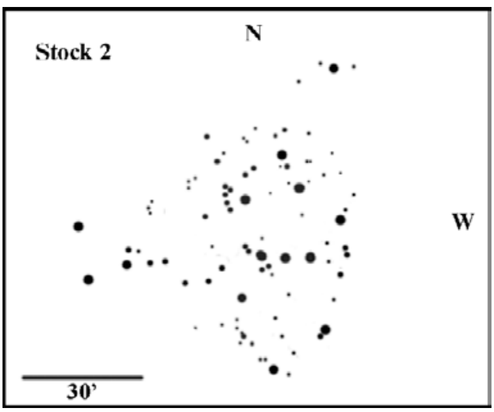
Stock 2 has long been classified as a young cluster, with an age ranging anywhere from 100 million to 170 million years. But these values are not consistent with results obtained by Salvatore Sciortino (Astronomical Observatory of Palermo, Italy) and colleagues, who used the ROSAT satellite data to assess the X-ray luminosity level of 112 high-probability cluster members. As reported in a 2000 *Astronomy & Astrophysics* (vol. 357, pp. 460–470), their measurements of the cluster's X-ray emission revealed that it more closely resembles that of a much older cluster, having an age intermediate between the Hyades (~700 million years) and the Pleiades (~100 million years).

Determining the lithium abundance of Stock 2's members may help to refine the cluster's age. Lithium (the third element in the periodic table) formed together with hydrogen and helium in the immediate aftermath of the Big Bang. All stars contain lithium. But those massive enough to start burning hydrogen into helium also destroy lithium in the process – in part through slow mixing as the star rotates; in part through diffusion, whereby a star's constantly churning surface pulls lithium from the surface and drags it into the star's hydrogen-burning core where it is destroyed.

Our Sun, a middle-aged star, has only about 1 percent of its original lithium. In contrast, brown dwarfs – the dimmest and least massive kind of star – never get hot enough to burn hydrogen, so they retain most of their lithium. The highest-mass brown dwarfs, however, will eventually burn the element. Thus, determining the highest mass of brown dwarfs still containing lithium in the cluster can give astronomers an idea of its age. Sciortino *et al.* believe that future high-resolution lithium observations will settle the age debate that their X-ray survey has opened.

To find Stock 2, use the chart on page 38 to find the Double Cluster, which is about 7½° east-southeast of 2.7-magnitude Delta (δ) Cassiopeiae (Ruchbah). The Double Cluster appears to the unaided eye as a 4th-magnitude fuzzy knot in the gentle folds of the Milky Way. It is a beautiful and unmistakable peppering of suns forming two mounds of highly condensed starlight spread across 25′ of sky.

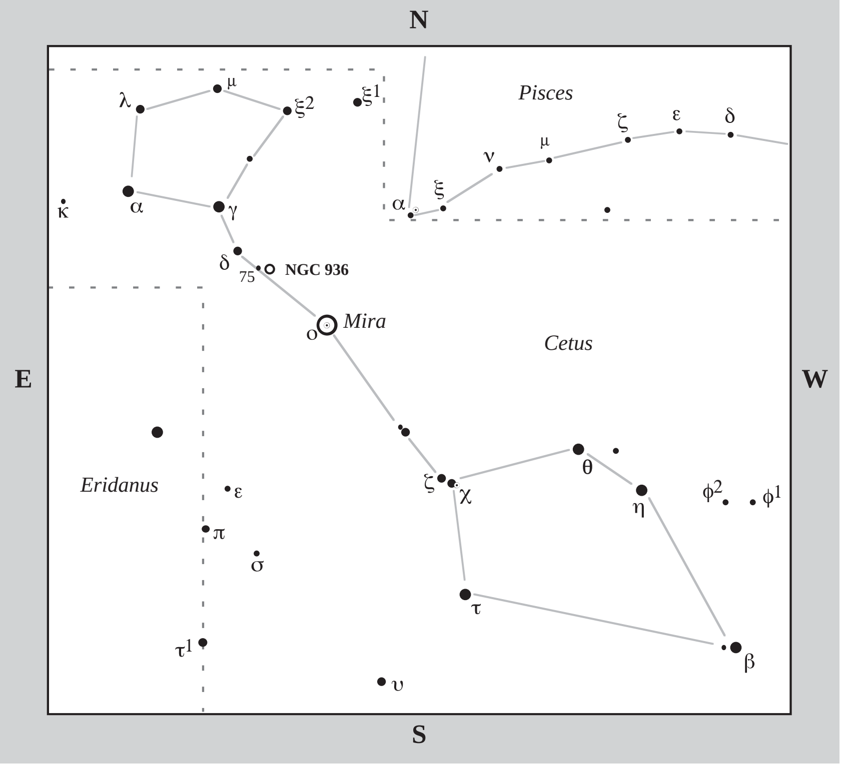
Visible just north of the cluster's westernmost member (NGC 869), you'll find a 1½° long ellipse of about a half-dozen 6th-magnitude suns; the two most obvious of which are 7 and 8 Persei, just north of NGC 869. The center of Stock 2 is 1° due north of the northernmost star (*a*) in the ellipse.



In binoculars, Stock 2 appears as 1° -wide scintillating flurry of irregularly bright suns. It's simply a low-power object. For me, 33× in the 5-inch is the ideal power to appreciate this diffusion of stellar gems. I spotted some 80 irregularly bright members arranged in a multitude of patches across 1° of sky. The cluster's western side is arranged in two overlapping loops, each 20′ wide, and oriented north–south. A zipper of stars juts to the east, where it ends in "two little feet." That's why I call the cluster "9" – because the overall shape of its brightest stars reminds me of the lead character in Tim Burton and Timur Bekmambetov's animated fantasy of the same name. Known as "Stichpunks" to fans of the film, 9 is a courageous little mechanical humanoid (part soul of his creator) with huge binocular-like eyes and a burlap body dominated by a zipper that runs up his torso.

I don't recognize a cluster core, though two tiny Y-shaped strings of stars, each just a few arcminutes long with some nice stellar pairings can be found here. The cluster's most prominent pair (8th- and 10th-magnitude suns separated by ~2′) lies on its southwest edge and is oriented southeast–northwest. The brighter of the two has an interesting ruddy hue. Use powers between 60× and 100× to investigate the cluster's multitude of fainter pairs and interesting groupings, which include stars arranged in letters, such as "P," "Y," "L," "O", "J," etc. Relax your mind and have fun with the view.

Secret Deep 7
(NGC 936)



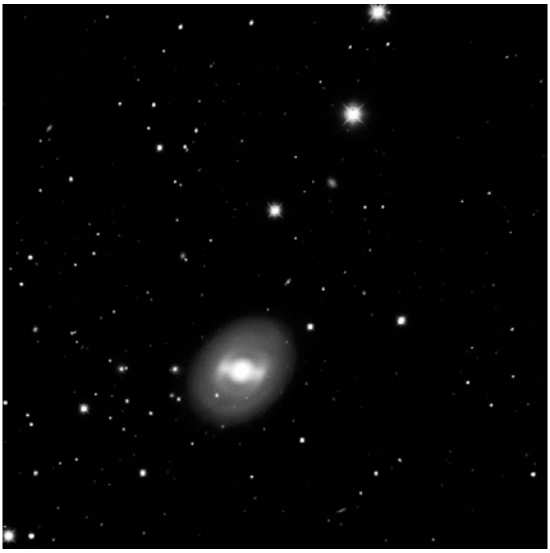
7

Darth Vader's Starfighter
NGC 936
Type: Barred Spiral Galaxy (SB0 (rs))
Con: Cetus

RA: 02^h 27.6^m
Dec: −01° 09′
Mag: 10.2
SB: 13.5 (Rating: 4)
Dim: 5.7′ × 4.6′
Dist: ~54 million l.y.
Disc: William Herschel, 1785

W. HERSCHEL: [Observed January 6, 1785] Considerably bright, a very bright nebula with a chevelure of 3 or 4′ diameter. (H IV-23)

NGC: Very bright, very large, round, much brighter in the middle to a nucleus, preceding of 2.



NGC 936 IS A SMALL BUT BEAUTIFUL barred-spiral galaxy in the middle of Cetus the Whale's neck, almost midway between mid-4th magnitude Delta (δ) Ceti[1] and the celebrated "winking" variable star Mira. It's also about 1¼° west, and a tad south, of 5.5-magnitude 75 Ceti. In a way the galaxy's position places it just beyond notice, given that most attention in the area is either given to Mira or the bright Seyfert galaxy M77, which lies only about 1° southeast of Delta. Interestingly, NGC 936's core is extremely condensed and bright, so it's a great object for suburban observers.

Note that Herschel classified it as a planetary nebula (his Class IV object) owing to its round shape. This classification may have caused the great nineteenth-century observer Admiral William Henry Smyth (1788–1865) to see it not only as round, like a planetary, but also "bluish white, and pale, but very distinct, and brightening toward the centre." The color he saw was probably the result of mental suggestion, given that many bright planetary nebulae shine with a green or aqua hue.

But as modern images clearly show, NGC 936 is a prototypical barred spiral galaxy, seen inclined 40° from face-on. It belongs to the Cetus–Aries Cloud of galaxies and is receding from us at 1,430 km/sec. The galaxy is quite large. If we accept a mean distance estimate of 54 million

[1] For those interested in astronomical trivia, owing to Earth's 26,000-year precessional cycle (one complete top-like wobble of Earth's axis), Delta Ceti transitioned from being a Southern Hemisphere star to a northern late in the year 1923.

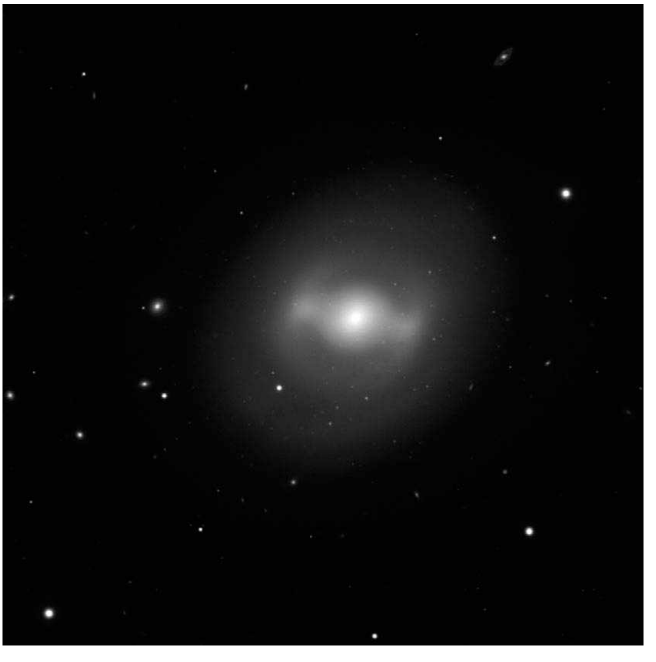
light-years, the galaxy measures more than 90,000 light-years in linear extent.

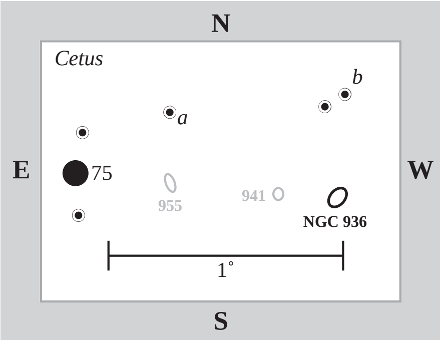
Our target actually is joined by (though not interacting with) the much fainter barred spiral galaxy NGC 941 (magnitude 12.4) 12.6′ to the east, the edge-on spiral NGC 955 (magnitude 12.0) 44′ to the east, and several other dimmer anonymous companions. In true linear projection, NGC 941 lies nearly 400,000 light-years from NGC 936, while NGC 955 is about 1.3 million light-years distant from it. This loose group is about half the size of the Local Group; so large telescope users should have fun trying to imagine this as they peer into this region of space.

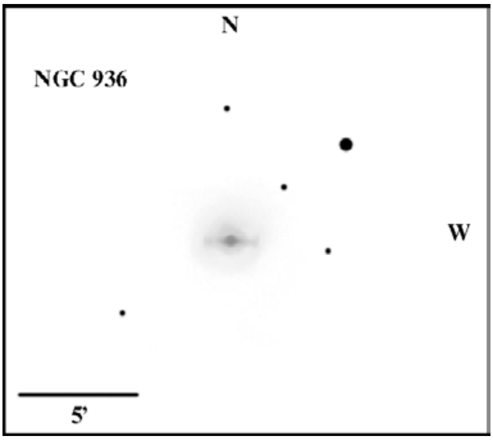
Deep images of NGC 936 reveal it to be of the earliest barred spiral class, showing a nearly smooth, extended disk with an abnormally prominent bar that ends well inside the edge of the disk (out to a distance of 20,000 light-years), which has a luminosity of nearly 6 billion Suns. A diffuse, massive, ill-defined but definite spiral pattern exists outside the end points of the bar, where we see a parallel pair of arcuate arms with fainter extensions that form a complete ring around the nuclear region, which consists of a very bright and diffuse nucleus or inner lens (0.6′ × 0.4′). This oblate bulge also has a luminosity of nearly 6 billion Suns.

The spiral features that thread through the disk of NGC 936 are generally diffuse and ill-defined. The arms, though massive, are smooth, and indefinite – similar to the pattern seen in the early mixed spiral galaxy NGC 2655 (Hidden Treasure 48) in Camelopardalis.

A 2010 European Southern Observatory (ESO) press release noted that the appearance of the galaxy (as imaged by the 8.2-meter telescopes of ESO's Very Large Telescope on top of Cerro Paranal, Chile; see below) bears a striking resemblance to "the Twin Ion Engine (TIE) starfighters used by the evil Dark Lord Darth Vader and his crew in the epic motion picture *Star Wars*. The galaxy's shiny bulge and a bar-like structure crossing it bring to mind the central engine and cockpit of the spacecraft; while a ring of stars surrounding the galactic core completes the parallel, corresponding to the wings of the TIE fighters that are equipped with solar panels." As with other early-stage barred spirals, NGC 936 comprises exclusively old stars and shows no sign of any recent







star formation. And, as with most other galaxies, no one knows if it is dominated by a large amount of dark matter.

To find this unusual treasure, use the chart on page 42 to locate 75 Ceti, which is about 2¼° southwest of Delta (δ) Ceti. Center that star in your telescope at low power, then switch to the chart on this page. From 75 Ceti, move a little less than 30′ northwest to 9th-magnitude Star *a*. Now move about 45′ west-northwest to 7th-magnitude Star *b*, which has a 9th-magnitude companion about 6′ to the south-southeast. NGC 936 is about 25′ south of that star pair.

At 33× in the 5-inch, NGC 936 is a bright, small (3′), and highly condensed, round glow of mostly uniform brightness but with a definite central concentration; the view begs for more power. At 60×, the galaxy's nucleus burns with a fiery intensity, like a hypnotizing eye. It truly does look like a bright planetary nebula with a punchy central star. The intense nucleus lies in a soft nest of circular light, which itself is surrounded by an equally soft and circular collar of dim emission.

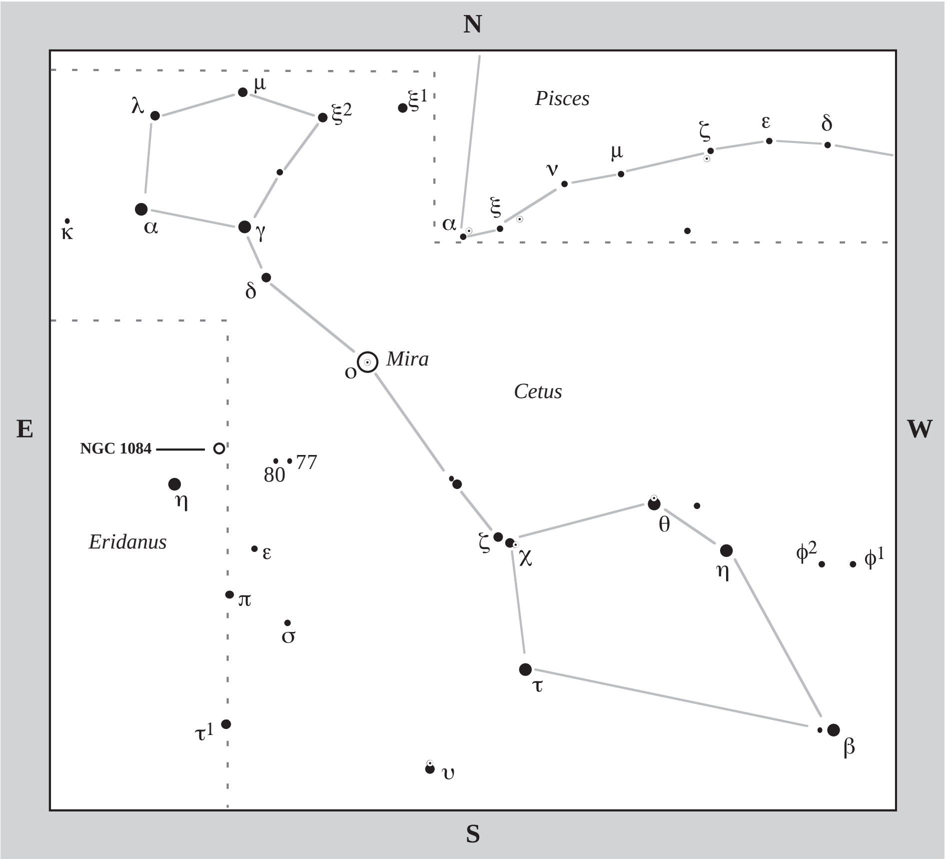
Every now and then I saw with averted vision NGC 941 popping in and out of view, as if vying for attention (it appears as a large dim glow just above the sky background). NGC 936's outer halo definitely needs averted vision; it vanishes with a direct gaze; even then, like NGC 941, it is flirtatious, flitting in and out of view appearing slightly out of round, oriented slightly northwest–southeast.

NGC 936's nuclear region takes magnification well, so crank it up! I studied the inner lens at 330× with little problem. At that magnification I could see its prominent bar with weak concentrations on either end of it. I could not justify seeing bright arcs, just a ring of light around that lens, though I'm certain larger telescopes can eek out such minute detail.

As reported on International Astronomical Union *Circular* number 8171, on July 29, 2003 UT, the great Australian supernova discoverer Robert Evans of Hazelbrook, New South Wales, discovered a magnitude 13.8 supernova in NGC 936 through his 12-inch reflector. He found it about 20″ southeast of the nucleus, noting that he detected nothing to magnitude 15 on July 3 UT. Designated Supernova 2003gs, the new object had a peculiar spectrum roughly consistent with a Type Ia supernova perhaps one week after maximum light.

In one popular model, a Type Ia supernova results from the violent explosion of a white dwarf star that may be in a close binary system with a red giant star from which it accretes matter. The white dwarf feeds on its companion's outer layers until it essentially overdoses and erupts as a supernova. This occurs when the mass of the white dwarf reaches 1.4 solar masses (40 percent more mass than that of our Sun); a runaway nuclear chain reaction occurs, causing the white dwarf to destroy itself by exploding. For white dwarfs in such systems, gluttony can be sinfully bad news!

Secret Deep 8
(NGC 1084)



8

NGC 1084
Type: Spiral Galaxy (SA (s)c)
Con: Eridanus

RA: $02^h\ 46.0^m$
Dec: −07° 35′
Mag: 10.7
SB: 12.5 (Rating: 4)
Dim: 3.2′ × 1.9′
Dist: ~60 million l.y.
Disc: William Herschel, 1785

W. HERSCHEL: [Observed January 10, 1785] Very bright, pretty large, little extended, much brighter in the middle. (H I–64)

NGC: Very bright, pretty large, elongated, gradually pretty much brighter in the middle.

DO NOT BE FOOLED BY NGC 1084's magnitude. It is a small but obvious galaxy about 3° northwest of 4th-magnitude Eta (η) Eridani (Azha), just east of the Cetus border, or about 2½° east-northeast of the close pair of 6th-magnitude suns 77 and 80 Ceti. It's very visible in a small telescope, being highly condensed, making it an excellent target for suburban observers. Its declination places it just a little lower than that of the southernmost portion of Orion's Sword.

NGC 1084 is actually the brightest and easternmost of a half-dozen galaxies near 80 and 77 Ceti with the others being as follows: NGC 991 (magnitude 11.7) about 30′ to the north; NGC 1022 (11.3) about 1¼° to the northeast; and NGC 1035 (12.2), NGC 1052 (10.5; see page 50), and NGC 1042 (11.0) making a pretty 30′-wide triangle about 1° to the southeast. All belong to the Cetus–Aries Cloud of galaxies and lie about 60 million light-years distant.

Despite its somewhat ungainly appearance in some images (which tend to burn out the core), NGC 1084 is, at a glance, a typical, late-type spiral galaxy, receding from us at about 1,500 km/sec. Like other Sc galaxies, NGC 1084 has a small central nucleus compared to its main massive spiral arms, two of which form a regular grand-design S-shaped spiral pattern with much irregular structure, bright knots and emission objects. But while NGC 1084's northwestern arm is well defined (being lined on its inside edge with a dust lane), the spiral pattern on the eastern side of the galaxy (the one nearest to us) is not so easy to trace; here, two arms start as thin, luminous threads that overlap after unwinding by half a turn – beyond that the spiral pattern is confused, being a mishmash of dust lanes and feathery spiral segments.

The galaxy's disk is moderately sized, spanning some 56,000 light-years in its longest extent, and mildly inclined at 63° from face-on. It has a total mass of some 50 billion Suns. The galaxy's weak nuclear bulge is elongated along the disk's major axis and shows no sign of a bar. In a 2000 *Astronomy & Astrophysics* (vol. 363, pp. 843–850), Russian astronomer Alexei V. Moiseev (Special Astrophysical Observatory) found giant star-formation regions in a 11,500 light-years-long "spur" in the northeast part of the galaxy that "avoids the bright HII regions."

The most intriguing feature, he says, was not the spur itself, but the strong unusual gas motions around it (up to ±150 km/sec!). To explain this curiosity, he suggests either (1) an infall of high-latitude gas clouds (intergalactic clouds or clouds expelled from the disk earlier) onto the galactic disk, which could trigger star formation, or (2) an interaction with a gas-rich dwarf galaxy accompanied by tidal disruptive merging.

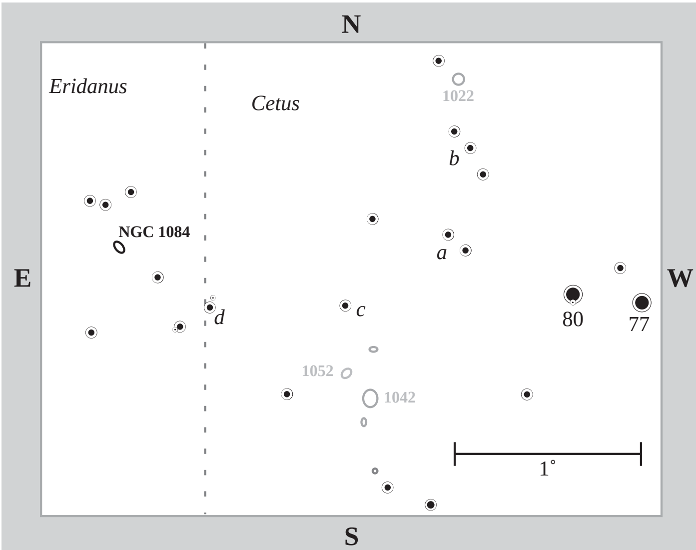
As for the latter theory, Moiseev notes that a small "island" of H-alpha emission does exist there, which may be associated with a radio tail that begins there and extends to another radio source 3.5′ from the galaxy. "As no HI map at 21 cm is available for NGC 1084," Moiseev says, "one cannot confirm whether this radio tail contains some expelled gas. But the configuration resembles a tidal tail as usually developing on the opposite side of a galaxy colliding with another one. Therefore, the gas flow twisted in the northern half of NGC 1084 might be accretion."

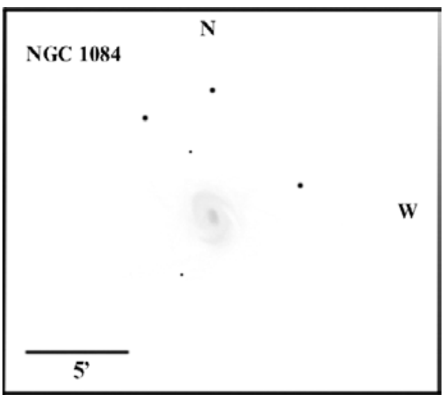
In a 2007 *Monthly Notices of the Royal Astronomical Society* (vol. 381, pp. 511–524), S. Ramya (Indian Institute of Astrophysics, Bangalore) and colleagues discuss their study of star formation in NGC 1084, which supports Moiseev's second theory. They found star-formation rates for a few of the complexes to be as high as 0.5 million solar masses per year, with the complexes themselves lying in the age range 3 to 6.5 million years. "The star formation in NGC 1084 has taken place in a series of short bursts over the last 40 million years or so," they say. "It is proposed that the likely trigger for enhanced star formation is merger with a gas-rich dwarf galaxy."

Indeed, Moiseev says that in a 2010 University of Strasburg preprint (http://cdsads.u-strasbg.fr/abs/2010arXiv1003.4860M) Martinez-Delgado and colleagues say they have obtained ultra-deep images of this galaxy. "They detected several external plumes or tidal tails around NGC 1084," Moiseev says. "Now the fact of merging with one (or several) dwarf companions is directly confirmed."

To find this possible extragalactic cannibal, use the chart on page 47, to first locate 2nd-magnitude Alpha (α) Ceti (Menkar). Now look for Eta (η) Eridani a little more than 10° (a fist held at arm's length) to the south and ever so slightly west.

Now use your unaided eyes or binoculars to find 80 Ceti, which is 5° to the west-northwest. You'll know when you have this star because similarly bright 77 Ceti lies only about 20′ to its west. Center 80 Ceti in your telescope at low power and switch to the chart on page 50. From 80 Ceti, move 40′ northeast to a pair of 8.5-magnitude stars (*a*), which are oriented northeast to



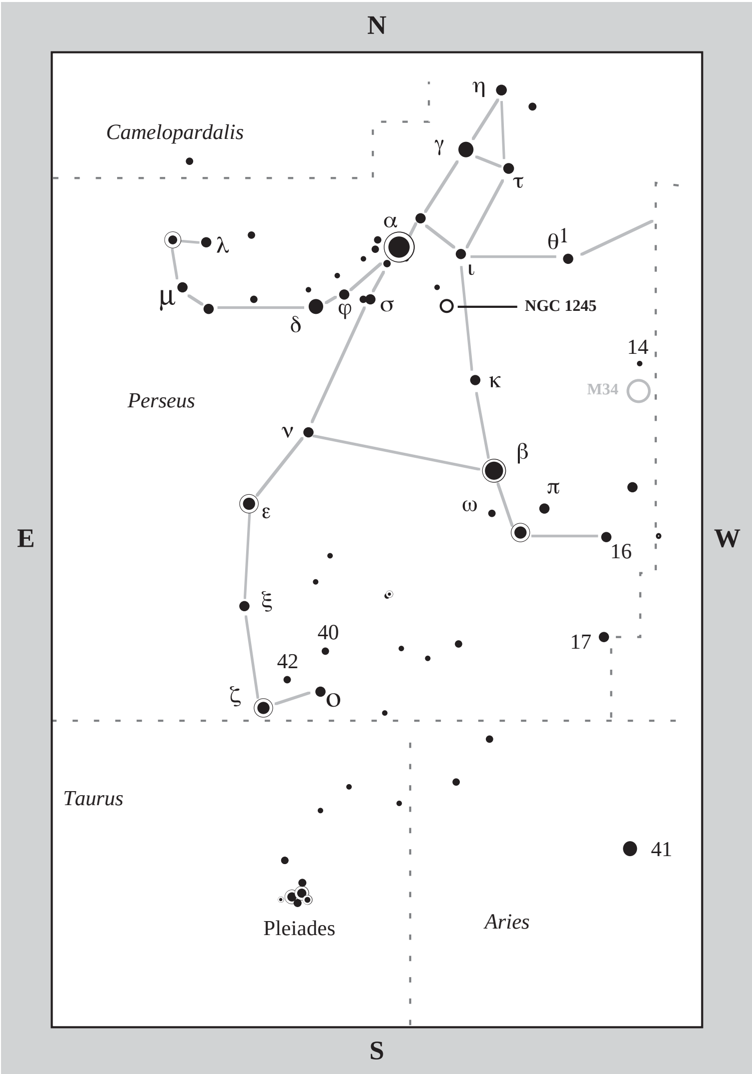


southwest and separated by about 5′. Now make a careful sweep about 45′ southeast to 8.5-magnitude Star *c*, which has an 11th-magnitude companion about 4′ to the east-southeast. Finally, move about 50′ east to 7th-magnitude Star *d*. NGC 1084 is about 35′ northeast of Star *d*.

At 33× in the 5-inch, NGC 1084 is easily seen with direct vision as a little bead of light. With averted vision it's still a small but very condensed ellipse measuring about 2′ in diameter and oriented northeast to southwest. At 60×, the galaxy is a very conspicuous egg of largely uniform light with few other defining characteristics. Increasing the magnification to 94× brings out some feathery details to the egg's rim. The galaxy started to reveal itself at 164×, when I saw two arcs: a long one at the position of the bright northwestern arm (it starts at the northeast side of the galaxy (the spur?) and winds around to the west, where it gradually fades); and a short and stubby arm beginning at the southwestern end of the egg. Averted vision at this power also shows the core to be slightly brighter and elongated.

CCD imagers take note: NGC 1084 is a great galaxy to watch for supernovae, with four known to date having occurred over the last half century. They are: SN 1963P, SN 1996an, SN 1998dl, and SN 2009H. Happy hunting!

Secret Deep 9
(NGC 1245)



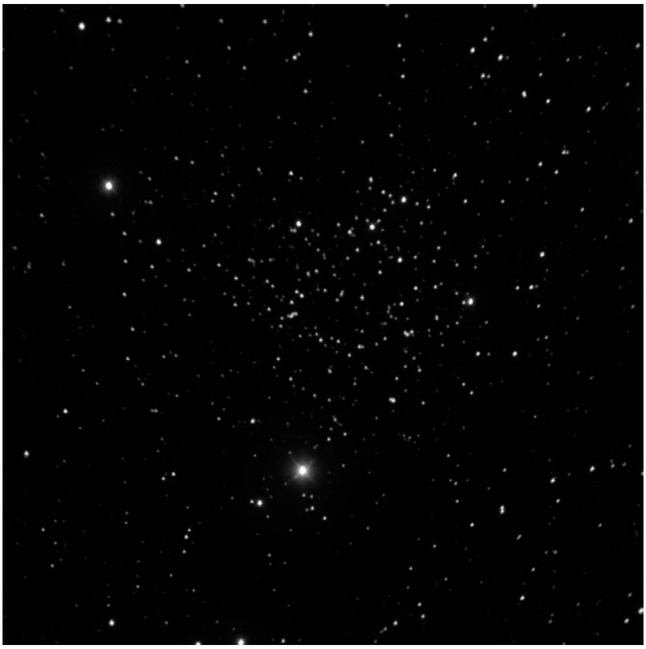
9

Patrick Starfish Cluster
NGC 1245
Type: Open Cluster
Con: Perseus

RA: $03^h\ 14.7^m$
Dec: +47° 14′
Mag: 8.4
SB: 13.4 (Rating: 3.5)
Diam: 10′
Dist: ~9,100 l.y.
Disc: William Herschel, 1786

W. HERSCHEL: [Observed December 11, 1786] A beautiful, compressed and rich cluster of [faint] and [bright] stars 7 or 8′ diameter, the bright stars arranged in lines like interwoven letters. (H VI-25)

NGC: Cluster, pretty large, rich, compressed, irregularly round, stars from magnitude 12 to 15.



NGC 1245 IS A RELATIVELY SMALL, dim, but rich open cluster a little more than 3° southwest of 2nd-magnitude Alpha (α) Persei, roughly midway between Alpha and 4th-magnitude Kappa (κ) Persei. It's another one of those small and compressed wonders that's greatly overshadowed by larger, brighter, and more visually accessible clusters, such as the Alpha Persei Moving Cluster (Hidden Treasure 14) and M34, about 7° to the southwest. But despite NGC 1245's seemingly diminutive nature, it is a surprisingly rich cluster and quite the spectacle under a dark sky.

In 1930, Trumpler classified NGC 1245 as a rich, detached cluster with little concentration. As open clusters orbit the Galaxy and age, they gradually "evaporate," losing their less massive stars first. NGC 1245 is, in fact, one of the senior members of the open cluster family, being about 1 billion years old. It's an irregular and loose aggregation spread across 27 light-years of space in the antigalactic direction. It lies close to the Perseus arm, nearly 1,500 light-years below the plane of the Galaxy. While most of the cluster's brighter stars are slightly blue main-sequence (hydrogen burning) stars, the cluster also contains a large population of evolved orange (hydrogen-shell burning) stars, indicating that it might belong to the Galaxy's old disk population.

In a 2003 *Bulletin of the Astronomical Society of India*, Annapurni Subramaniam

(Indian Institute of Astrophysics) confirmed the cluster's age and the fact that it appears to have a small deficiency of bright stars near the center of the cluster, which matches the visual impression through backyard telescopes; the brightest stars form several looping hollows that take on a starfish pattern.

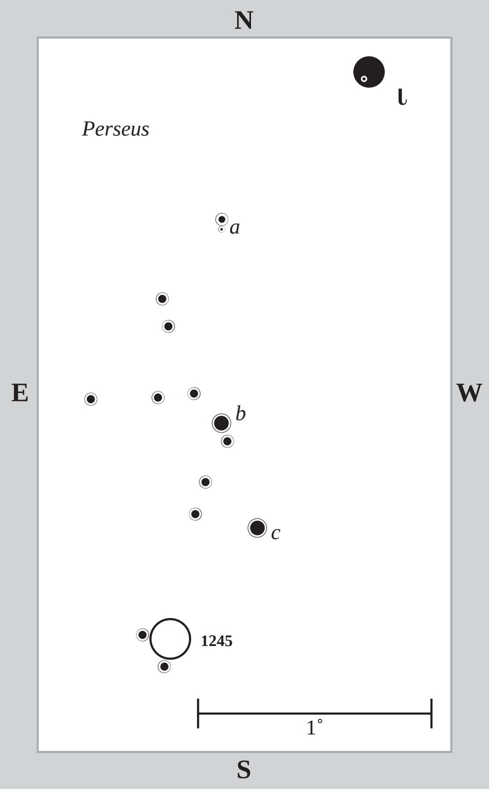
As I mentioned earlier, all star clusters experience the tidal force of the Galaxy, which can result in the cluster losing low-mass stars to the Galactic field. And this appears to be the case with NGC 1245 as we see it today. NGC 1245 is highly relaxed, and its stellar population is strongly segregated by mass. Its outer periphery is indeed enriched with low-mass members while devoid of high-mass members out to its tidal radius of 54 light-years. "The lost stars could be present in the corona of the cluster," Subramaniam says, noting that as recently as 2002 it has been discovered that clusters in general have large coronae, which contain a large fraction of cluster stars.

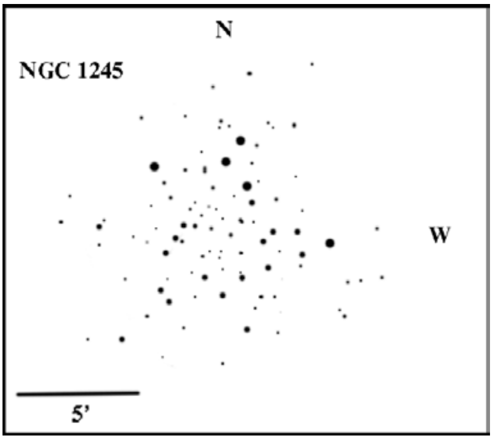
In a 2004 *Astronomical Journal* (vol. 127, pp. 2382–2397) Christopher J. Burke (Ohio State University) and his colleagues derived a total cluster mass of about 1,300 Suns, a distance of 9,100 light-years, and found it to have a slightly subsolar metallicity. Burke *et al.* have also conducted searches for transiting extrasolar planets to assess the frequency of close-in extrasolar planets around main-sequence stars in several open clusters. They began by surveying stars in NGC 1245 and expected to see two transits. Their preliminary search of the data, published in 2003, revealed a transit candidate with a depth of 4 percent. They observed the transit on two separate nights. "Unfortunately," the researchers lament, "the transit is unlikely to be a planetary transit, since the [light curve] is indicative of a grazing binary eclipse. [Those of] planetary transits tend to be boxier in shape with more rapid ingress and egress durations and flat-bottom eclipses."

Burke and Joshua Pepper (Ohio State University) also determined the variable-star content of the cluster. Out of 6,787 stars observed to a visual magnitude of 22, they found 14 stars with clear intrinsic variability that are also potential cluster members and 29 clear variables that are not cluster members. None of these variables had been previously identified. Four stars at the main-sequence turnoff of the cluster have light curves consistent with Gamma (γ) Doradus variability. If these Gamma Doradus candidates are confirmed, they represent the oldest and coolest members of this class of variable discovered to date.

To find this fascinating cluster use the chart on page 51 to locate Alpha Persei. Now look about 2½° west for 4th-magnitude Iota (ι) Persei. Center Iota Persei in your telescope at low power, then switch to the chart on page 54. From Iota, make a slow sweep 50′ southeast to 8th-magnitude Star *a*. Now make another sweep 50′ south to 6th-magnitude Star *b*, then slide about 30′ south-southwest to 6.5-magnitude Star *c*. NGC 1245 is about 35′ southeast of Star *c*.

In the 5-inch at 33× under a dark sky, NGC 1245 is quite impressive, being a tiny packet of bright and faint suns in a starfish pattern. This brighter form is sprinkled over with dim suns that look like droplets of dew on a flower. The cluster's core is exceptionally granular at low power. At 60×, some 40 to 50 prominent cluster members are loosely scattered across





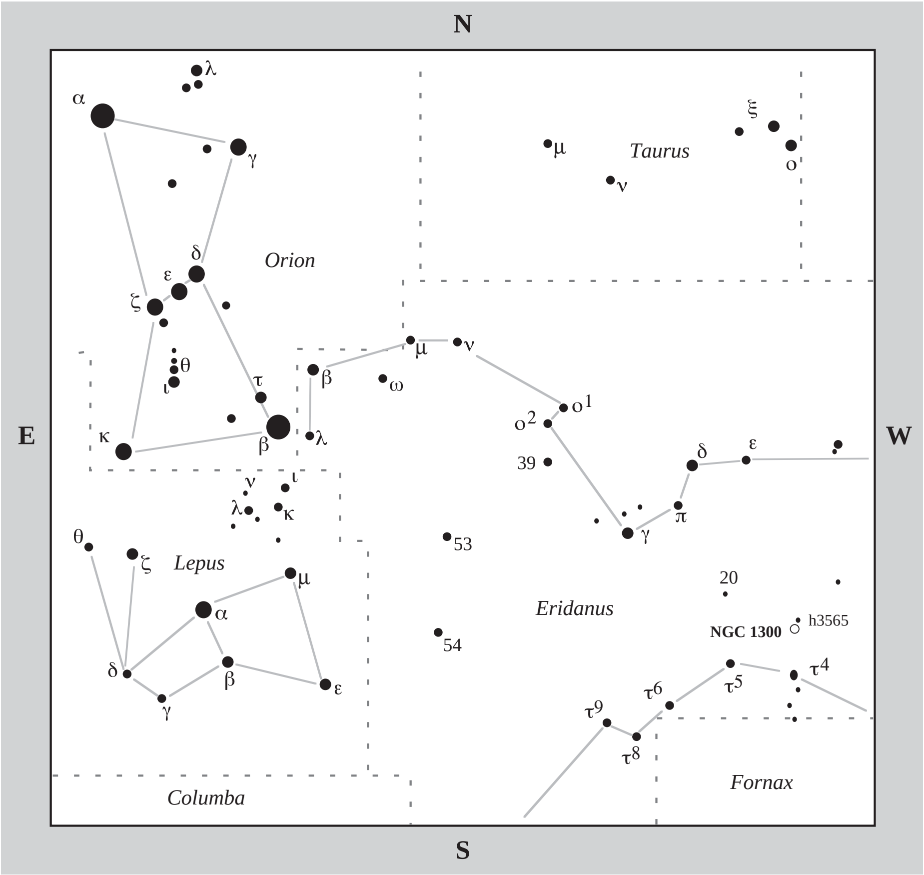
10′ of sky, forming a series of seemingly overlapping ovals, especially in the east–west direction near the "core." The core at first has a snaking river of about eight similarly bright stars at its northern border running west to northeast. The granular texture is between the two brightest stars to the south and east of this river.

In photographs, the cluster looks like a lily to me, but I cannot fully appreciate this impression in the 5-inch. There really are no spectacular double stars, though a careful survey will show the occasional odd pairing of a bright sun with a dimmer companion. No, the simple beauty of this cluster lies in its elegant richness at low power. I just cannot escape seeing the starfish form of bright suns, sprinkled over with celestial "sea salt" (a granular texture composed of countless dim suns). For this reason I call NGC 1245 the "Patrick Starfish" cluster. It's a special imaginary creation for young Alison Nagler, daughter of Tele Vue Optics' president David Nagler, who's a fan of the animated kids' TV show "SpongeBob Squarepants"; Patrick, a pink starfish, is SpongeBob's best friend and neighbor.

At higher powers, you may find the main concentration of the cluster's most prominent suns mixing with other stellar gatherings to create more fanciful shapes. I've found letters – such as A, Y, L, G, and U – floating in the darkness like letters in an alphabet soup. (I must admit that I made this observation before I had learned from Larry Mitchell of Houston, Texas, that William Herschel observed a similar pattern, writing, "the bright stars arranged in lines like interwoven letters.")

Perhaps with the age of this cluster in mind, I can see it as a cluster in the process of "falling apart," especially where the arms appear "separated" from the central framework, as if the cluster's being dismantled. Have fun with your own imaginings.

Secret Deep 10
(NGC 1300)



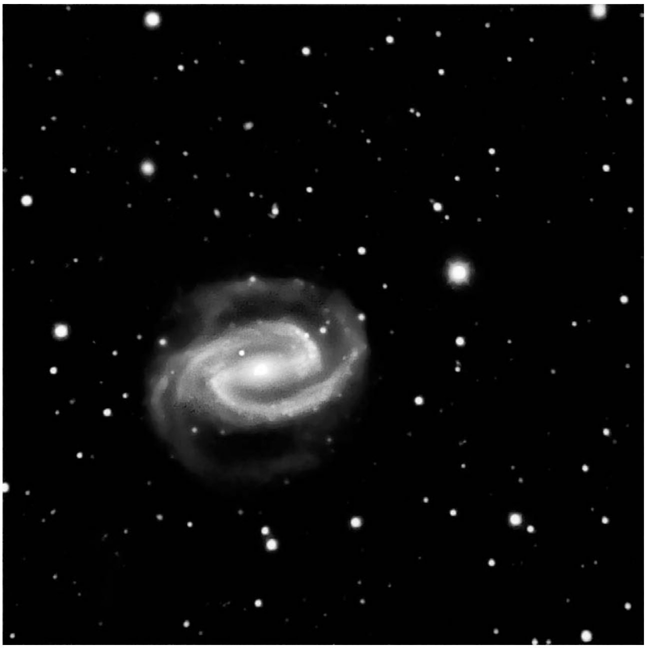
10

NGC 1300
Type: Barred Spiral (SB (s)bc)
Con: Eridanus

RA: 03^h 19.7^m
Dec: −19° 25′
Mag: 10.4
SB: 13.3 (Rating: 3.5)
Dim: 5.5′ × 2.9′
Dist: ~70 million l.y.
Disc: John Herschel

W. HERSCHEL: None.
(h 2522)

NGC: Considerably bright, very large, very much elongated, pretty suddenly very much brighter in the middle.



WE'VE NOW COME TO ONE OF THE most perfect examples of a grand-design barred spiral galaxy in the heavens: NGC 1300, a cosmological wonder of elegance, grace, and style. This southern galaxy is much sought after from northern locals, though it may prove difficult from some suburban locations with poor horizons. It's best to pursue it under a dark sky with few or no obstructions.

The galaxy is only 0.3 magnitude fainter than M98 and M91 in Coma Berenices, and it has about the same surface brightness as them as well. The difficulty is not so much its declination – which places it a little bit higher in the sky than M 41 in Canis Major – but its relative isolation in the weak star fields of Eridanus. But many northern observers have spied it in 4-inch and smaller telescopes. For instance, the late, great deep-sky observer Walter Scott Houston (1912–1993) of Connecticut observed it in a 3½-inch Questar.

If you see this wonder, you're looking at a giant extragalactic system more than 150,000 light-years across and some 70 million light-years distant in the Fornax Cluster and Eridanus Cloud of galaxies. The light we see emanating from it today first escaped that galaxy during Earth's Cenozoic period around the time of the extinction of the dinosaurs. We see the galaxy's disk inclined 43° from face-on, and it has a total mass of 150 billion suns. In deep images, like the one on page 57 taken by the Hubble Space telescope, NGC 1084 is a fantastic tapestry of starlight and glowing gas mixed with slithering wisps of dark obscuring interstellar dust.

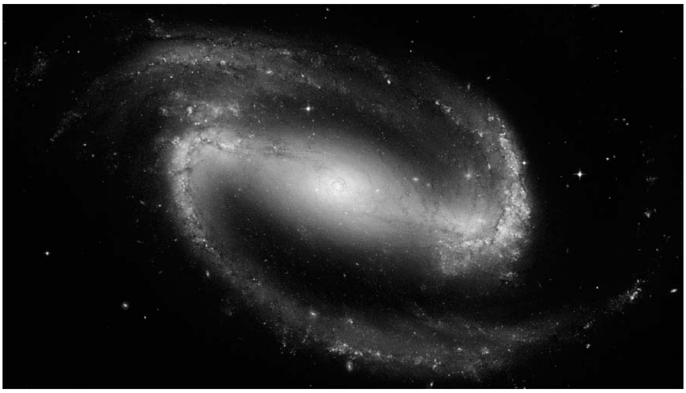
Most alluring is the way the galaxy's brilliant spiral arms fly off of the ends of the galaxy's bar and bulge, looking like water jetting from a reciprocating lawn sprinkler. Most galaxies of this spiral-arm subclass (s) have dominant, massive arms rather than a weak, filamentary pattern where the arms fray like feathers from an almost-complete ring. There is a concentration of HII regions where the arms join the bar, and mainly so on the western side. The western arm also contains several very luminous HII regions, while the eastern arm shows some less luminous enhancements.

In the HST image, note how the bar blends with the smooth, and equally majestic, elliptical bulge, which measures some 150,000 light-years across. Two straight dust lanes line the opposite sides of the nucleus and can be traced to the ends of the bar, where they turn sharply and follow the insides of the spiral arms. The tightly wound arms extend roughly 180 degrees before fading. The far ends of the arms straighten out, rather than curving back into a pseudo-ring.

At HST's resolution, a myriad of fine details, some of which have never before been observed, is seen throughout the galaxy's arms, disk, bulge, and the very small and extremely bright nucleus. Supergiant stars, star clusters, and star-forming regions are well resolved across the spiral's thin, knotty arms. Smooth dust lanes trace out fine structures in the disk and bar. Numerous more distant galaxies are visible in the background, and are seen even through the densest regions of NGC 1300.

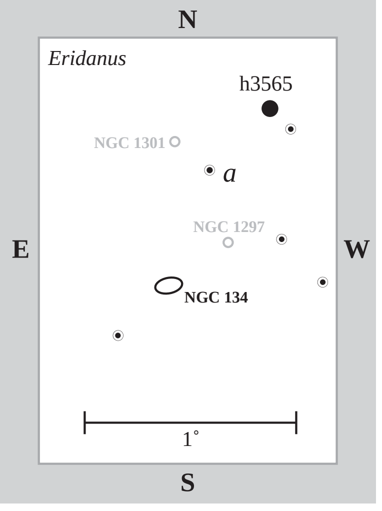
These features are not unique to NGC 1300. Most barred spirals with "grand-design" structure – meaning a small but distinct nuclear spiral centered on the larger spiral pattern formed by the galaxy's arms (a spiral within a spiral) – share several distinctive features: a large-scale prominent bar; two straight and symmetrical dust lanes, each on the outside of the otherwise smooth bar; and recent and robust star formation in the arms near the ends of the bar, which occurs in a number of discrete clumps.

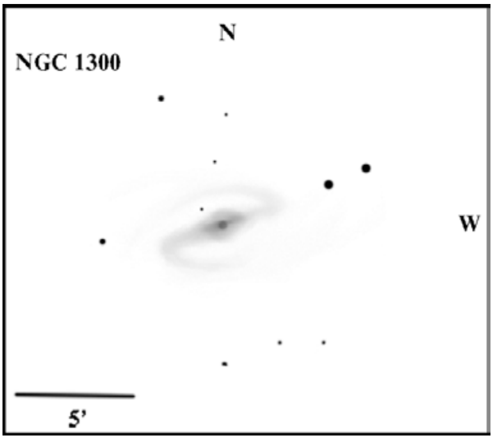
The core spiral of NGC 1300 spans about 3,300 light-years, and the HST image resolves it into a series of tightly wound armlets, outlined in dust and stellar populations. This core also is a site of considerable star formation. Models suggest that the gas in a bar can be funneled inwards, and then spiral into the center through the grand-design disk, where it can potentially fuel a massive central black hole. But, unlike other spiral galaxies, including our own Milky Way, NGC 1300 doesn't appear to harbor one. NGC 1300 is not known to have an active nucleus, indicating, again, either that there is no black hole, or that it is not accreting matter.



To find this "perfect" barred spiral, use the chart on page 55 to locate 3rd-magnitude Gamma (γ)

10





Eridani, which is nearly 20° west-southwest of brilliant Beta (β) Orionis (Rigel). Now look about 12° (a little more than a fist held at arm's length) for 4th-magnitude T^4 Eridani. About 3° north of it is the 6th-magnitude double star h3565 (magnitudes 5.9 and 8.2 separated by 8″). Now use the chart on this page to find NGC 1300 only 55′ south-southeast of h3565, or about 35′ south-southeast of 7th-magnitude Star *a*.

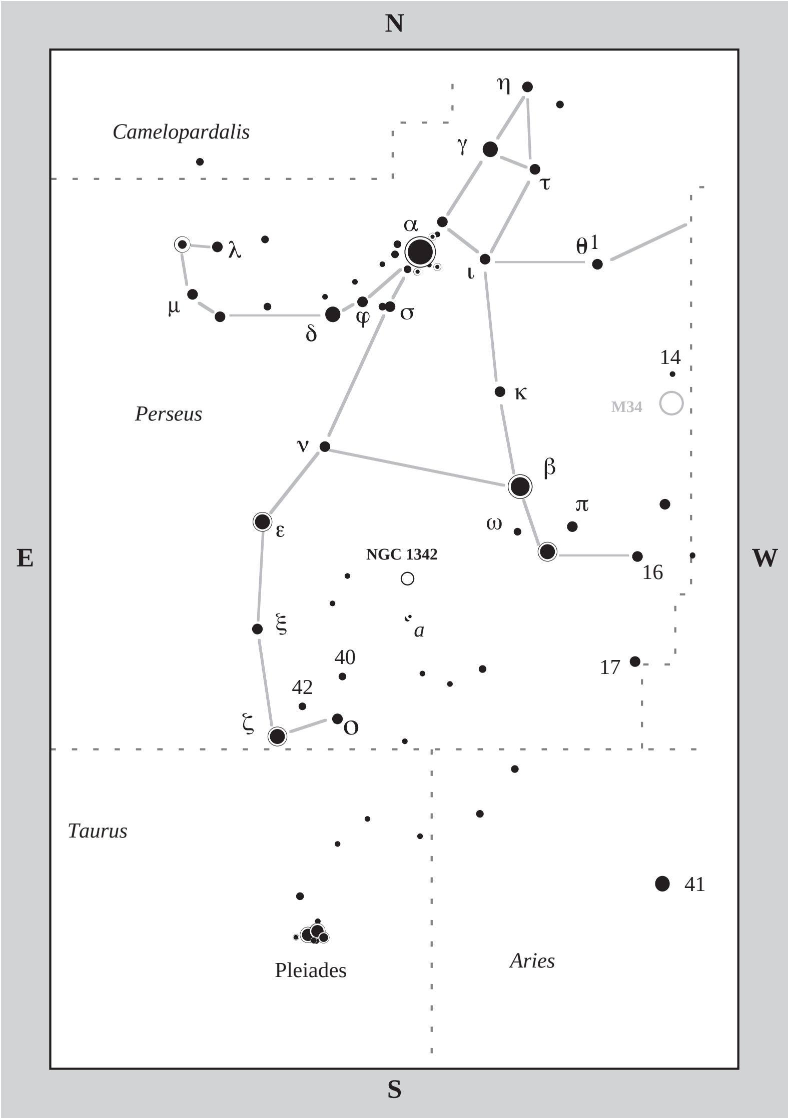
Through the 5-inch at 33×, NGC 1300 appears as a large diffuse oval patch that I feel may be difficult to detect for those under conditions with moderate amounts of light pollution. It's a low-surface-brightness glow. Still, under a dark sky and with my modest-sized telescope, I can definitely see it well with averted vision, trapped in a delicate line of three moderately bright stars. With time, the glow transforms into a diffuse elliptical lens of light with a small and diffuse nucleus surrounded itself by a small oval glow with fuzzy edges.

At 60×, I immediately suspected seeing the galaxy's barred spiral structure. The outer arms appeared very tattered. These twin arms on opposite sides of the galaxy mirror one another as they sweep away from the bar.

The galaxy comes to life at powers between 94× and 165×. But, to see the most detail, you might have to battle between low-power views (which condense the light, making faint structures easier to see) and high-power views (which help to resolve these faint structures, though they are not as immediately visible).

With time and concentration, I could make out a tiny starlike nucleus embedded in the central lens from which juts the bar. One arm shoots off from the west end of the bar to the north. The other arm curves from the east to the south. A dim star is trapped between the northwestern arm and the inner lens. Can you see it?

Secret Deep 11
(NGC 1342)



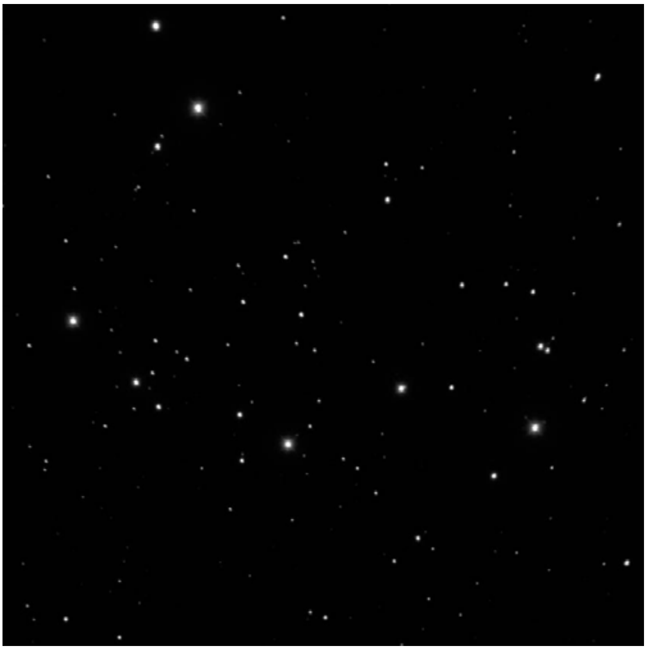
11

Stingray, Sea Robin
NGC 1342
Type: Open Cluster
Con: Perseus

RA: 03^h 31.7^m
Dec: +37° 22.5′
Mag: 6.7
SB: 12.9 (Rating: 4)
Diam: 17′
Dist: ~1,700 l.y.
Disc: William Herschel, 1799

W. HERSCHEL: [Observed December 28,1799] A cluster of coarsely scattered [bright] stars about 15′ diameter. (H VIII-88)

NGC: Cluster, very large, about 60 stars.

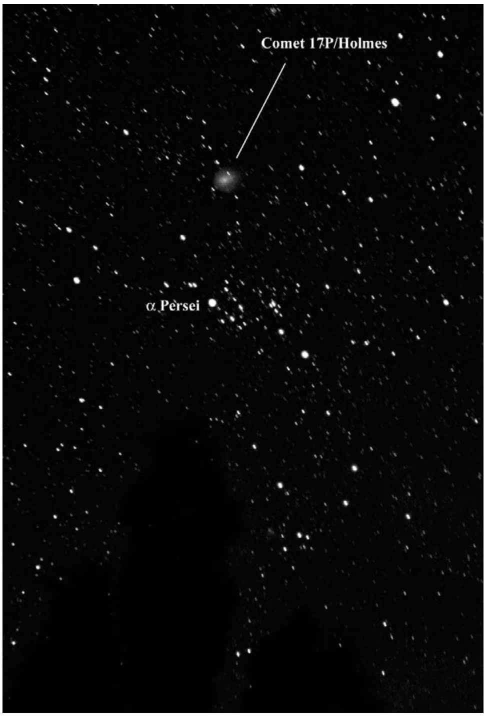


LIKE NGC 1245 (SECRET DEEP 9), open cluster NGC 1342 is another overlooked deep-sky object in Perseus. It lies in a fist-sized celestial chasm, almost midway between the eastern foot of the Hero (3rd-magnitude Zeta (ζ) Persei) and the head of the snake-haired gorgon Medusa (the 2nd-magnitude eclipsing binary star Beta (β) Persei (Algol)), or about about 5½° west-southwest of 3.5-magnitude Epsilon (ε) Persei.

Many observers were first introduced to NGC 1342 in December 2007, when Comet 17P/Holmes (see next page) passed near the cluster. It was just the latest in a long string of close encounters the comet had with other interesting objects in Perseus. In fact, amateur astronomers used the comet as a sort of celestial tour guide, alerting the public whenever the comet was to pass near a target of interest in the constellation. And it worked.

Many observers got to see Comet Holmes soon after its magnificent outburst on October 23–24, 2007. The comet erupted like a nova, emerging from telescopic obscurity (16th-magnitude) to naked-eye prominence (3rd-magnitude) in just two days, flaring nearly half a million times in brightness (the largest known outburst of a comet in that period of time). The excitement surrounding the sudden flaring of Comet Holmes was tangible.

By the time Comet 17P/Holmes neared NGC 1342, however, it was a telescopic object. Still, seeing these two objects in the same field of view was dramatic – an opportunity to appreciate the three-dimensional aspect of the sky, with the comet being a Solar-System object



millions of miles distant and the cluster being 1,700 light-years distant.

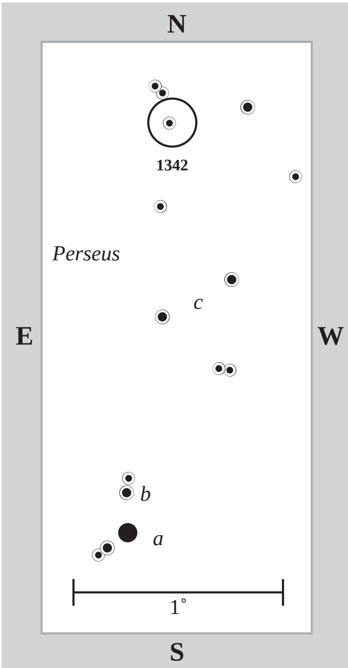
That a comet could draw attention to an obscure deep-sky object is not new. Consider the first object in Charles Messier's catalogue (M1, the Crab Nebula), which the great French astronomer independently discovered in 1758 while observing the Comet of 1758. Likewise, French astronomer Jean-Dominique Maraldi (1709–1788) discovered the globular clusters M2 and M15 in 1746 while following the movements of De Cheseaux's Comet of 1746.

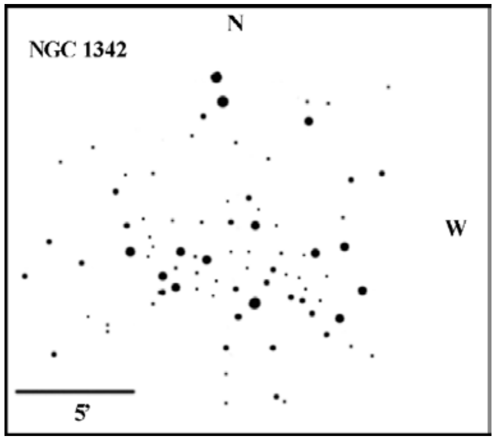
Yet, and I find this surprising, NGC 1342, a magnitude 6.7 open cluster 17′ across, went unnoticed until William Herschel detected it on December 28, 1799. Today, you can spy it under dark skies in binoculars. How did something so bright and obvious avoid detection? I don't have the answer.

In 1930, Trumpler classed it as IImr, a moderately rich and detached cluster whose moderately bright members are more-or-less uniformly scattered with little concentration. In a 1994 *Journal of Mexican Astronomy and Astrophysics* (vol. 28, pp. 7–16), J. H. Peña (Universidad Nacional Autónoma de México) and colleagues report how their photometric studies of NGC 1342 confirm that the cluster seems to have a relatively large number of young stars. Temperatures determined of the hottest stars along with their luminosities have yielded an age estimate of 400 million years – about as old as the Coma Berenices Star Cluster (about the time when the first winged insects appeared on Earth), and about four times older than M34, which is about as far away northwest of Algol as NGC 1342 is to the southeast in apparent angular distance.

To find this pretty object, locate Epsilon (ε) Persei and Xi (ξ) Per 4° to the south. NGC 1342 marks the western apex of an equilateral triangle with those stars. Just raise your binoculars to that location and look for what appears to be a diffuse, 7th-magnitude "comet" immediately south-southwest of an 8.5-magnitude star. Otherwise, from Xi Per, look 5° west for 6th-magnitude Star *a*, which in binoculars should be a nice triple. Center Star *a* in your telescope at low power, then switch to the chart on page 62. From Star *a*, hop about 10′ north to 7.5-magnitude Star *b*. Next, move about 55′ northwest to a wide pair of 8th-magnitude stars (*c*), oriented west-northwest to east-southeast and separated by about 20′. NGC 1342 is 50′ due north of the southeastern 8th-magnitude star in Pair *c*.

Although it is just below naked-eye visibility, the cluster is visible in 10 × 50



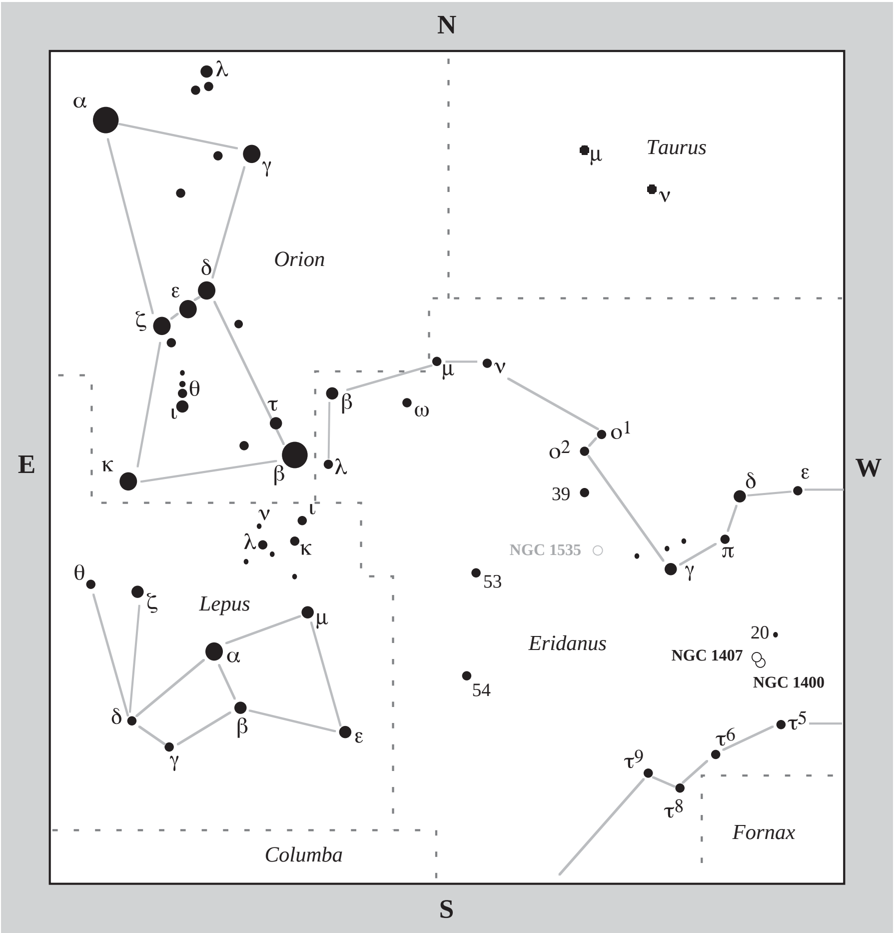


binoculars. At 33× in the 5-inch I can immediately see about a dozen stars, including a jagged, 10′-long flat ellipse of some half-dozen suns of mixed magnitudes (oriented east-northeast to west-southwest). The ellipse glitters with tiny flecks of dim stars that seem to scintillate with averted vision.

When I relax my gaze at 60×, I can envision a sea robin swimming south. Its wing-like fins extend to the east and west from the southern part of the cluster, and its tail reaches to the north where it ends at a pretty double star. In their 1998 *Observing Handbook and Catalogue of Deep-Sky Objects* (Cambridge University Press), Christian Luginbuhl and Brian Skiff see a stingray swimming to the west in these stars.

With averted vision, the cluster's brightest stars lie against a gauzy backdrop of fainter suns. The cluster contains nearly 100 members 8th magnitude and fainter, though only about 50 or so are prominent in the 5-inch.

Secret Deep 12 & 13
(NGC 1400 & 1407)



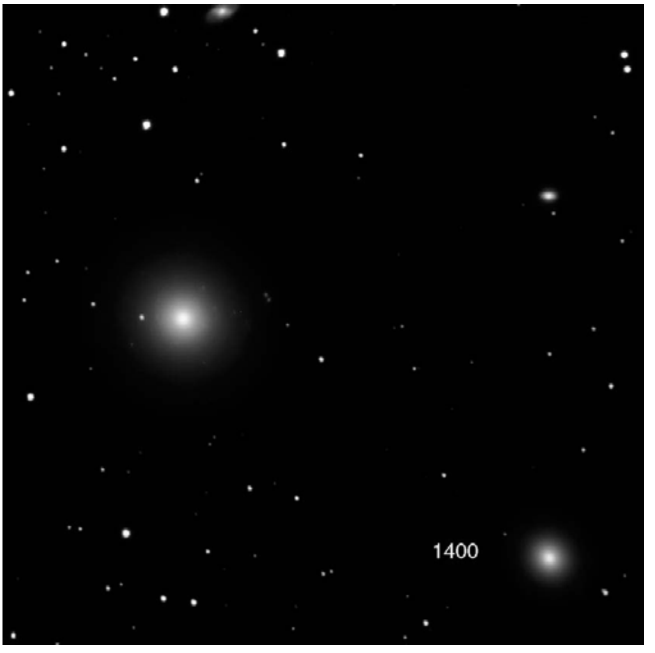
12

NGC 1400
Type: Lenticular Galaxy (SA0)
Con: Eridanus

RA: $03^h\ 39.5^m$
Dec: −18° 41′
Mag: 11.0
SB: 13.0 (Rating: 3.5)
Dim: 2.8′ × 2.5′
Dist: ~53 million l.y.
Disc: William Herschel, 1786

W. HERSCHEL: [Observed September 20, 1786] Pretty bright, pretty small, round, resembling [NGC 1407] but is smaller. (H II-593)

NGC: Considerably bright, pretty small, round, pretty suddenly much brighter in the middle.



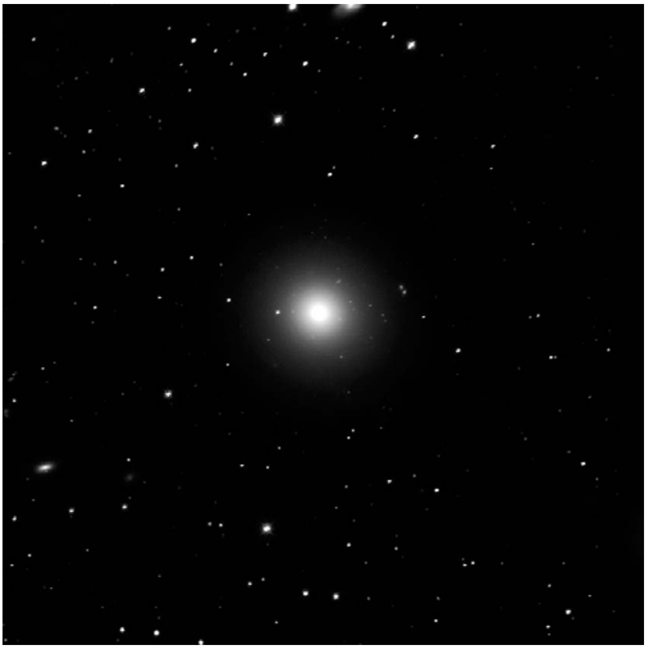
13

NGC 1407
Type: Elliptical Galaxy (E0)
Con: Eridanus

RA: $03^h\ 40.2^m$
Dec: −18° 35′
Mag: 9.7
SB: 13.4 (Rating: 4)
Dim: 6.0′ × 5.8′
Dist: ~53 million l.y.
Disc: William Herschel, 1785

W. HERSCHEL: [Observed October 6, 1785] Very bright, round, bright nucleus in the middle. 1′ ½ diameter. (H I-107)

NGC: very bright, large, round, suddenly very bright in the middle to a nucleus.



NGC 1400 AND NGC 1407 ARE THE TWO brightest, and most central, galaxies in the Eridanus A group of galaxies – the largest clump of island universes in the very patchy Eridanus Cluster of galaxies. Lying about 53 million light-years distant, the Eridanus A subcluster includes roughly 50 galaxies (mostly dwarf ellipticals and dwarf lenticulars) within a 1½° circle of sky centered at $3^h\ 40^m$, −19°. And while Eridanus can easily conjure up visions of deep southern splendors, our two targets, when culminating, are about 2° higher in the sky than open cluster M41 in Canis Major.

The pairing of NGC 1400 and NGC 1407 in the sky presents an astrophysical puzzle. Although these two early-type galaxies lie only 12′ in apparent distance apart, they are not interacting. In fact, their recessional velocities differ dramatically. NGC 1407 is receding from us at a velocity of 1,776 km/sec (typical of other galaxies in the group), while NGC 1400 is moving at a relative snail's pace: only 549 km/sec – about one-third the velocity of NGC 1407. Thus, in some early studies of the galaxies, some astronomers suspected that NGC 1400 is a foreground object.

The answer to the puzzle is important. As Andrew Gould (Institute for Advanced Study, Princeton, New Jersey) and his colleagues explain in a 1993 *Astrophysical Journal* (vol. 403, pp. 37–44), since the Eridanus A group contains only two bright galaxies (NGC 1400 and NGC 1407), its mass depends on whether NGC 1400 is a member. NGC 1400's membership also affects what's known as the group's mass-to-light ratio, which determines how much dark matter the cluster harbors.

Using five different methods to determine galaxy distance – including whether it appears coarse and grainy (indicative of a nearby galaxy) or smooth (indicative of a distant galaxy)[1] – researchers found that not only is NGC 1400 at the same distance of NGC 1407 (~53 million light-years), but also that these two galaxies supply two-thirds of the cluster's light.

Based on available data, NGC 1400's high velocity is not indicative of a rogue galaxy passing through the subcluster but of the subcluster's enormous mass, namely 90 times that of the Milky Way. But the total light output of the Eridanus A group is only twice that of the Milky Way. Thus, the researchers say, the subcluster is awash in dark matter; indeed, Eridanus A is the darkest galaxy group known. Its mass-to-light (mass–luminosity) ratio could be as high as 2,500, though conservative estimates place it around 600. By comparison, the dark-matter rich Coma Cluster of galaxies has a mass–luminosity ratio of only about 200!

If the mass–luminosity of the Eridanus subcluster holds true, and if dark galaxy groups such as Eridanus A are common, they could account for much of the universe's mass and perhaps halt its expansion; but if the universe's critical mass–luminosity ratio is less than 1,600, it will continue to expand forever.

NGC 1407 is 1.3 magnitudes brighter than NGC 1400. It is also much larger.

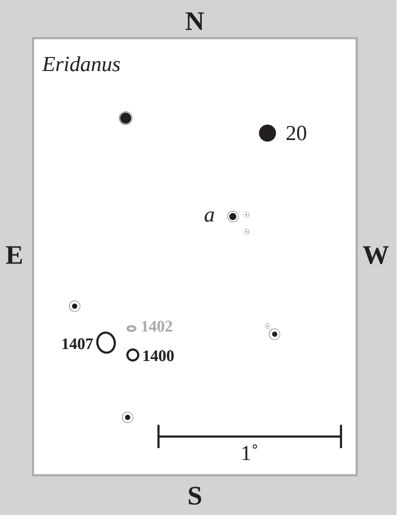
[1] If you look at an impressionist painting up close, you can see the multitude of minute brush strokes of unmixed colors that the artist used to create the overall image, which appears smooth and seamless when viewed at a distance. It's argued that the same principle applies to the images of galaxies seen in space.

NGC 1407 measures 87,000 light-years across in true physical extent, while NGC 1400 is about seven times smaller. In physical appearance, both of these early-type galaxies are quite simple. Both have a small, bright, and diffuse nucleus with what appears to be a dust ring. In the case of NGC 1400, that inner ring is seen nearly pole on; the galaxy is also surrounded by an extended outer envelope. It's possible that both NGC 1400 and 1407 formed more than half of their mass in a single short-lived burst of star formation (>100 solar masses/year).

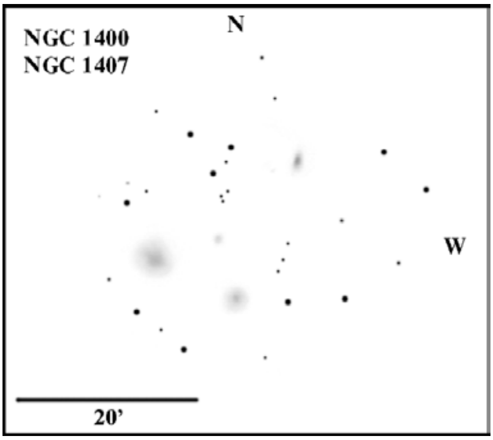
As reported in a 2008 *Monthly Notices of the Royal Astronomical Society* (vol. 385, pp. 667–674), Max Spolaor (Swinburne University, Hawthorn, Australia) and his colleagues used spectroscopic and other data from the ESO 3.6-meter, Subaru 8-meter, and Hubble Space telescopes to determine that the burst most likely involved supernova-driven galactic winds, supporting a monolithic collapse model for galaxy formation and evolution: As a large gas cloud collapses, it triggers a massive burst of star formation; the newly formed stars orbit the core with eccentric orbits, creating what we see as an elliptical galaxy; disk stars form later.

The researchers also speculate that, since their formation, the galaxies have evolved quiescently, and that we are witnessing the first infall of NGC 1400 in the group. They also confirmed that NGC 1400 and NGC 1407 are not interacting, and that NGC 1407 harbors a 1 billion solar mass supermassive black hole at its core.

To find these fascinating extragalactic simpletons, use the chart on page 63 to locate 5.5-magnitude 20 Eridani. Start with Brilliant Beta (β) Orionis (Rigel). Nearly 20° (two fists held at arm's length) to the west-southwest is 3rd-magnitude star Gamma (γ) Eridani (Zaurak), the brightest star in the region; it's also the same guide star you use to find the famous planetary nebula NGC 1535 (Hidden Treasure 24), Cleopatra's Eye. But you're going to now use your unaided eyes or binoculars to look 6° to the southwest to find 20 Eridani. Center that star in your telescope at low power, then switch to the chart on this page. From 20 Eridani, move a little less than 30′ south-southeast to 8th-magnitude Star *a*. NGC 1407 is 1° to the southeast.



As seen at all powers through the 5-inch, the galaxy is a fine, yet simple, ellipse of light, oriented north-north-east to south-southwest, about 1′ in extent. Its core is bright and starlike. The surrounding disk is magnificently uniform and swells to nearly 2′ with averted vision. Under a dark

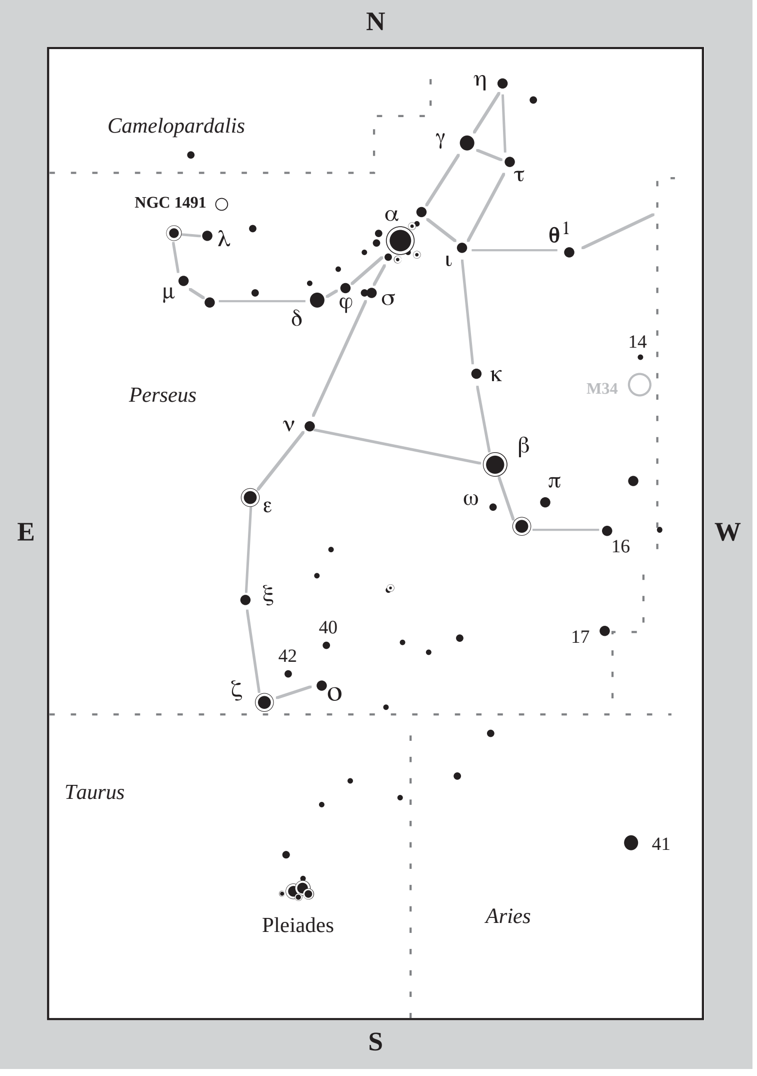


sky, I find that whenever I use averted vision to view NGC 1400, fainter NGC 1407 suddenly wafts into view like some luminous vapor rising from the depths of space.

Being so near to NGC 1407, and mysterious, NGC 1400 has the capability of stealing one's attention. When I investigate it at moderate to high powers, I can't help but notice that NGC 1400's core is smaller than NGC 1400's; it's a starlike bead surrounded by a little elliptical lens of light that suddenly turns into a larger and more diffuse halo.

When I use 33× and relax my gaze, I find the area to have other hidden treasures. Most noticeable is 12th-magnitude NGC 1393 about 20′ northwest of NGC 1407. With moderate to high powers, I can also see 12.6-magnitude NGC 1402 about 10′ west-northwest of NGC 1407.

Secret Deep 14
(NGC 1491)



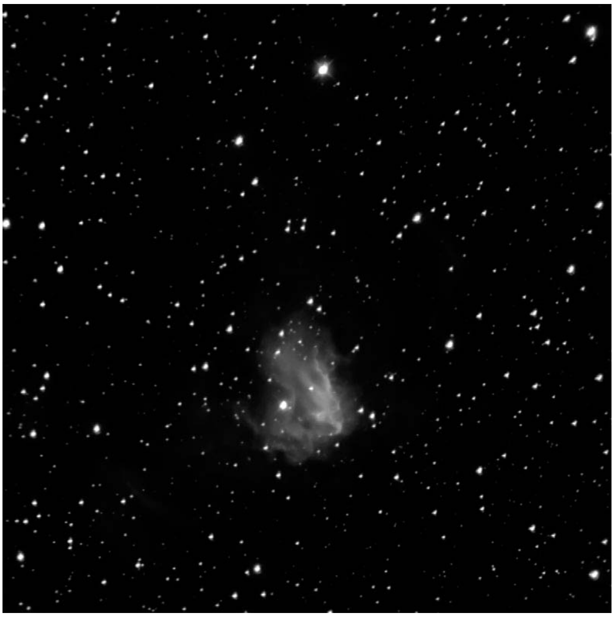
14

Fossil Footprint Nebula
NGC 1491
Type: Emission Nebula
Con: Perseus

RA: $04^h\ 03.4^m$
Dec: $+51°\ 19'$
Mag: –(Rating: 3)
Dim: $25' \times 35'$ (red light); ~4′ (blue light)
Dist: ~12,000 l.y.
Disc: William Herschel, 1790

W. HERSCHEL: [Observed December 28, 1790] Very bright, irregularly faint, resolvable (mottled, *not* resolved), brighter in the middle, 5′ long, 4′ wide, a pretty [bright] star in it towards the following side, but unconnected. (H I-258)

NGC: Very bright, small, irregular figure, bright in the middle, round, star involved.



NGC 1491 IS A VISUALLY SMALL, AND photographically large, emission nebula just a little more than 1° north-northwest of 4.5-magnitude Lambda (λ) Persei, the last star in the curved Segment of Perseus. The Segment is a prominent spine of bright stars between the W of Cassiopeia the Queen and the Pentagram of Auriga the Charioteer. It's a graceful arc of moderately bright suns projected against a dynamic section of Milky Way including the Alpha Persei Moving Cluster (Hidden Treasure 14). The Segment's brightest section measures about 10° in length (a fist held at arm's length) and consists of the stars Eta (η), Gamma (γ), Alpha (α), Sigma (σ), Phi (π), and Delta (δ) Persei. The Segment then curves to the northeast and includes the stars Mu (μ), and Lambda (λ) Persei. So the overall shape of the Segment is a J or fishhook.

Many of the stars in the Segment lie at distances ranging from about 530 light-years in the Alpha Persei Association to 900 light-years for Mu Persei. At a distance of 1,200 light-years, NGC 1491 lies a little bit further away in this section of the Perseus arm of the Milky Way – between open cluster M34 (1,400 light-years) and the little reflection nebula NGC 1333 (Hidden Treasure 15; 1,100 light-years).

Again, in wide-field images, NGC 1491 is an evolved HII region (a complex expanse of ionized interstellar hydrogen) that extends at least to 35′ in red light, with weak diffuse emission out to at least 1°.

If we accept the nebula's distance as 1,200 light-years, this glowing cloud spans an impressive 21 light-years of space, about half the linear extent of the Great Orion Nebula. In the widest images I've seen, the nebula complex has a bright 3′-wide "pad" of intensely glowing nebulosity with at least three dimmer "toes" of gas reaching out to the east. Overall, the nebula complex looks like the fossil footprint of one of those flesh-eating Jurassic terrors, such as *T-Rex*, *Allosaurus*, or *Velociraptor* – thus my moniker for the nebula.

In both radio and optical wavelengths, NGC 1491's structure is very inhomogenous. Indeed, the nebula's 11th-magnitude type O5 exciting star (BD+50°886) is located about 1′ east of the the brightest region – with rippling "curtain folds" oriented roughly north-northeast–south-southwest. Two parallel folds appear in this region northwest of the exciting star. The western and southern extensions, however, are more sinuous. All these folds have the appearance of an ionization front with steep edges. A dark "elephant trunk" in the western fold (the sideways finger of darkness outlined by bright emission) points very clearly towards the exciting star.

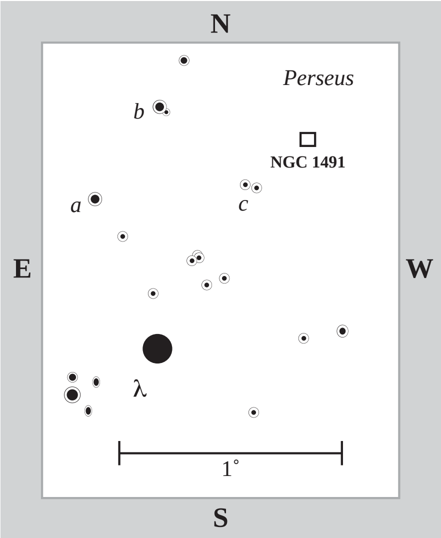
The exciting star also lies at the center of a "half-ring" of nebulosity, which can be seen faintly immediately to the star's west (no emission has been detected along the ring's eastern half). In a 1976 *Astronomy & Astrophysics* (vol. 48, pp. 63–73), Lise Deharveng (Marseille Observatory) and colleagues note that while the nebula's most outstanding feature (the wrinkled bright emission described above) is very probably from an ionization front, the half-ring of nebulosity immediately west of the exciting star is not; more likely, the half-ring is a shock front reminiscent of the one in NGC 7635, the Bubble Nebula in Cassiopeia (Caldwell 11). This rim, then, would mark the edge of a rapidly expanding shock wave that's washing onto the nebula's shore like a tidal wave intercepting a coastal plain. In a private 2010 communication, Deharveng notes that this structure probably shows a shock between two flows of material in opposite directions, one of material ejected by the central star (present and not past activity), the other of material receding from the high density ionization front.

In the researchers' model of NGC 1491, the nebula is open (mass limited) to the east where we see a vast expanse of diffuse emission. At present, they see the exciting star outside the boundaries of the neutral cloud and suggest that the star may have come into existence at the edge of the cloud. Currently, the exciting star is ionizing the nearest part of the neutral cloud ahead of the elephant trunk and in the northwest extension.

The ionization front is advancing in a direction roughly perpendicular to the line of sight, where it is "slowly eating its way" into the dense neutral medium with a velocity on the order of 0.03 km/sec. From the ionization front, ionizing matter is streaming away with a velocity on the order of a few tenths of a kilometer per second, becoming slower the farther it is away from the front. At present the star does not appear to be loosing mass at a high rate, but the shock front may indicate a stronger activity in the past. Deharveng now thinks that the star must be presently ejecting material if we want to see the shock. But observations are needed to be certain.

The absence of any strong infrared sources (which would indicate star formation in opaque dust clouds) and other data suggest that stars are not being born in or near NGC 1491. But Deharveng cautions that there are no recent infrared observations of this region, telling us things about star formation. "A look at the 2MASS images (JHK nearIR bands)," she says, "shows several red stars in the direction of the nebula, but it is difficult to say if it is due to extinction or to an infrared excess (link to an envelope or a disk). Mid IR observations are needed to say more about star formation."

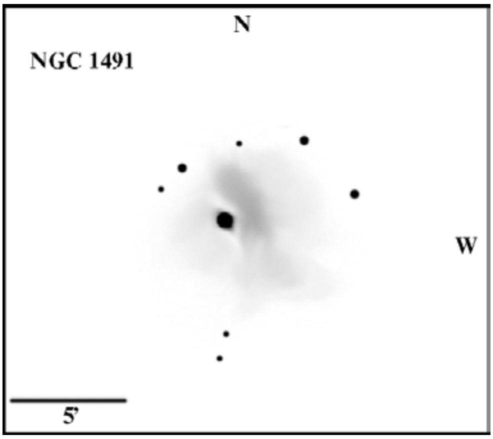
To find this little wonder, use the chart on page 68 to find Lambda (λ) Persei, then switch to the chart on this page. From Lambda, move your telescope 40′ north-northeast to roughly 7th-magnitude Star *a*, then 30′ north-northwest to 7.5-magnitude Star *b*. NGC 1491 is only 40′ west-southwest of Star *b* and 20′ northwest of a pair of 9.5-magnitude stars (*c*).



I could see the 11th-magnitude exciting star and its brightest emission to the west immediately at 33× in the 5-inch under a dark sky. The bright horns northwest of the exciting star appear as a highly condensed elliptical patch, while the western and southern extensions appeared less definite (though still obvious), looking like a wider and less-condensed skirt of light; so it looked like an uneven mustache.

These two bright patches (~3′ in length) are surrounded by a very faint and highly elusive haze that extended to about 6′ on a side. I couldn't detect any of the much fainter nebulosity sweeping far away to the east as some photos show. Still, seeing this fainter 6′-wide envelope in the 5-inch gave me hope that larger instruments with wider fields of view might be able to take in more of this very expansive nebula.

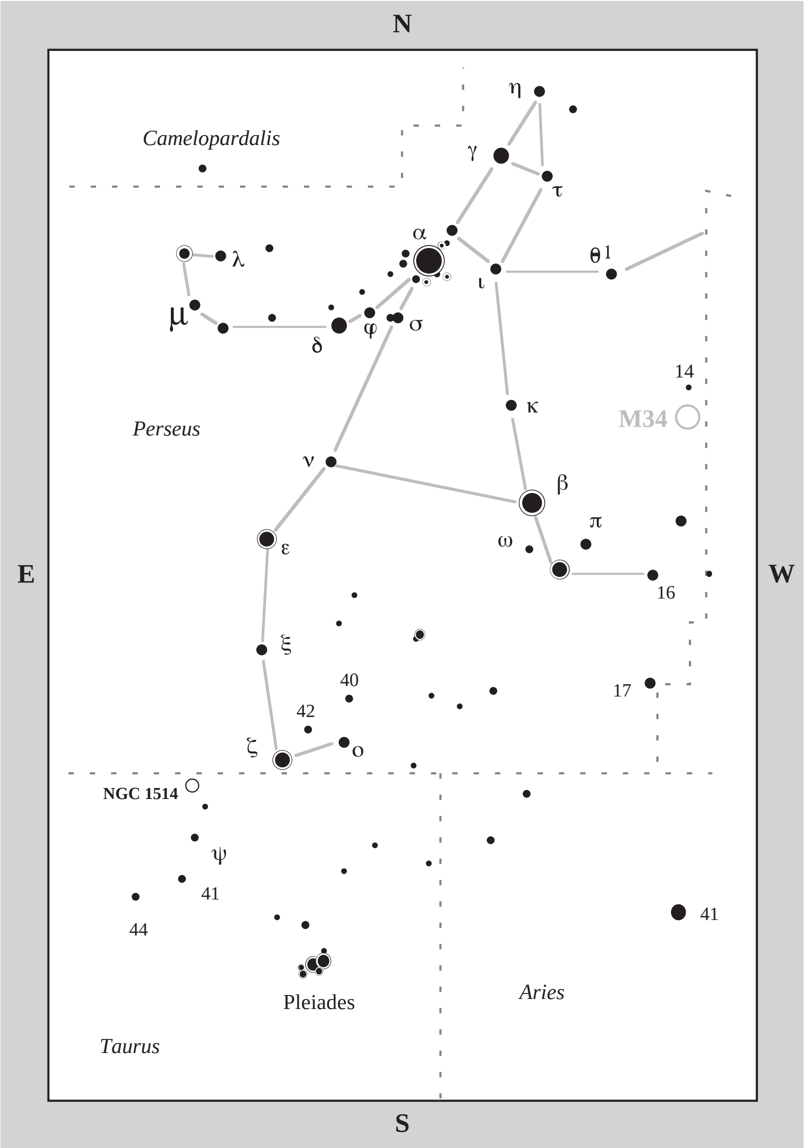
Yet when I looked at NGC 1491 through Larry Wood's 12-inch reflector at the George Moore Astronomy Workshop near Edmonton, Alberta, I was surprised to see more or less the same detail that I picked up in my 5-inch – only much more pronounced. Also, the shape of the nebulosity was more clearly defined, with the northwestern horns



being more enhanced, while the southern extension seemed separated from the northwestern emission by a dark lane. This rift of darkness was in the place of the “elephant trunk,” though I couldn’t see any bright rim.

Through the 5-inch, the nebula takes power moderately well, and I found that 94× was near the maximum useful magnification. The views at 60× and 94× did not bring out any finer features in the nebula (just enhanced the view) but the increase in magnification did bring out some fainter stars in and around the nebula. So take your time with this celestial cloudscape, and see if you can visually dig up some of its more intricate details.

Secret Deep 15
(NGC 1514)



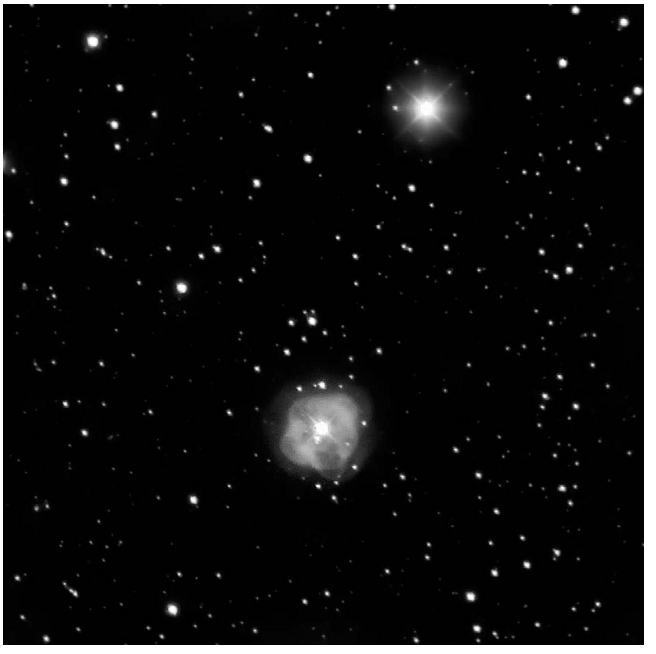
15

Crystal Ball Nebula
NGC 1514
Type: Planetary Nebula
Con: Taurus

RA: 04^h 09.6^m
Dec: $+30°$ 46.5′
Mag: 10.9 (nebula) (Rating: 3.5)
Mag: 9.4 (star)
Diam: 2.3′ × 2.0′
Dist: ~2,000 l.y.
Disc: William Herschel, 1790

W. HERSCHEL: [Observed November 13, 1790] A most singular phenomenon; a star of 8th magnitude with a faint luminous atmosphere of a circular form, about 3′ in diameter. The star is perfectly in the centre, and the atmosphere is so diluted, faint, and equal throughout, that there can be no surmise of its consisting of stars, nor can there be a doubt of the evident connection between the atmosphere and the star. Another star not much less in brightness, and in the same field with the above, was perfectly free from any such appearance. (H IV-69)

NGC: Star of 9th-magnitude in a nebula 3′ in diameter.



NGC 1514 IS A SUBTLE BUT FASCINATING planetary nebula in the northernmost reaches of Taurus the Bull, about 3½° east-southeast of 3rd-magnitude Zeta (ζ) Persei in the Hero's eastern foot. This 9th-magnitude star surrounded by a dim halo of nebulosity has long been considered a visually troublesome object. The late deep-sky expert Walter Scott Houston once noted that some observers considered it a difficult object for an 8-inch.

While the planetary's central star can be spied with a 2-inch telescope, seeing the 2′-wide nebulosity is a different story. I know I've had my problems with it. I don't recall ever having successfully seen it through the 9-inch f/12 Alvan Clark refractor at Harvard College Observatory in light-polluted Cambridge, Massachusetts. And I've had some unconvincing views through my 4-inch Tele Vue refractor under dark Hawaiian skies: I thought I could see a dim collar of light around the central star, but I couldn't convince myself it wasn't starlight shining through moisture in Earth's atmosphere. My first definite views of NGC 1514's nebulosity came in November 2009, when I decided to try once again, this time with the 5-inch. I was amazed at what a difference 1 inch of aperture made in bringing out the nebula with distinct clarity.

Not surprisingly, NGC 1514 went unnoticed until November 30, 1790, when the great German-born English astronomer William Herschel encountered it during one of his slow and meticulous sweeps of the heavens with his speculum reflector. One can only imagine the great surprise Herschel received when he saw this mysterious object: a bright star "with a faint luminous atmosphere of circular form, about 3′ in diameter." Herschel had never seen anything like it before.

Prior to this discovery, Herschel and his contemporaries believed nebulae were simply clouds of unresolved suns, like the naked-eye appearance of the Milky Way. But Herschel saw NGC 1514 as a "most singular phenomenon! . . . The star is perfectly in the centre, and the atmosphere is so diluted, faint, and equal throughout, that there can be no surmise of its consisting of stars; nor can there be a doubt of the evident connection between the atmosphere and the star."

NGC 1514 convinced Herschel that the nebulous matter surrounding stars in his planetary class (IV) were not unresolved clusters. If the cloud and the star are connected, Herschel reasoned, the nebulosity could not consist of very remote and unresolvable suns because the central star is visible. In other words, Herschel found it inconceivable that the central star would burn so brightly as to outshine all the other suns comprising the nebula. Herschel surmized that either the luminous central object is not a star, or that the nebula is not of a "starry nature."

He accepted the latter sentiment, postulating that the nebula consists of a "shining fluid of a nature totally unknown to us . . . since the probability is certain not for the existence of so enormous a body as would be required to shine like a star of the 8th magnitude at a distance sufficiently great to cause a vast system of stars to put on the appearance of a very diluted milky nebulosity."

In 1864, English amateur astronomer William Huggins (1824–1910) found the first clue to the true nature of planetary nebulae in the spectrum of NGC 6543 (Caldwell 6), which was that of a luminous gas and not that of a haze of unresolved suns. So when we look at NGC 1514 we are seeing the object that led our astronomical ancestors down a new path of thinking – one that began in the late eighteenth century with William Herschel.

Today we know much more about the physical nature of planetary nebulae, and NGC 1514. In a 2003 *Astronomical Journal* (vol. 126, pp. 2963–2970), C. Muthu and B. G. Anandaro (Physical Research Laboratory, Ahmedabad, India) discuss the results of their spectroscopic studies, which helped them to determine a three-dimensional model of NGC 1514. The nebula has three basic structures: a faint outer shell, an inner ellipsoidal shell titled with respect to the observer, and nearly symmetric bright blobs embedded inside along the polar axis (in the northwest and southeast directions), which is nearly on the sky plane.

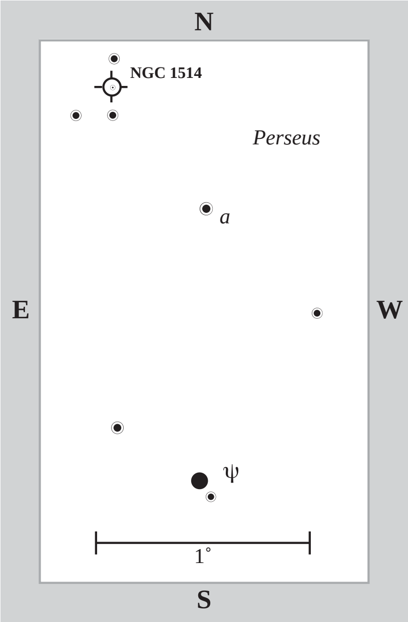
The authors note, however, that the blobs do not conform to bipolar morphology. "The large velocity dispersion across each blob shows that the blobs are not collimated," the authors say. In order to form a bipolar planetary nebula, an equatorial disk is essential to collimate the subsequent ejections toward the polar directions, and NGC 1514 lacks one. Instead, the researchers argue that the nebula is a descendant of a common envelope binary system. In such a system, it's possible that polar blobs or jets can form by the companion's mass transfer to the progenitor at the end of the common envelope phase. "These blobs can be poorly collimated as a result of the possible large size or even the absence of an equatorial disk" the researchers say, adding that NGC 1514's polar blobs could have formed in a similar way.

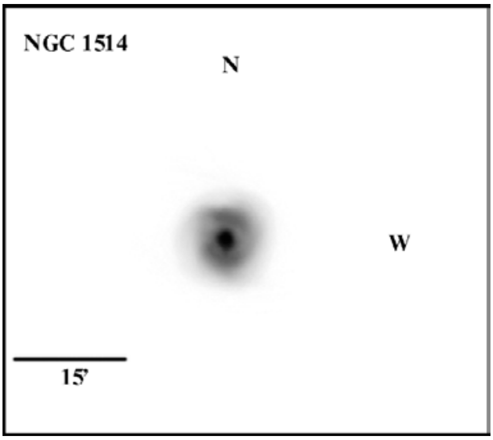
NGC 1514's central star has long been an object of intense study. It differs greatly from other planetary nebulae nuclei in that it is very bright (9.3 magnitude) and, as mentioned, is suspected of being a binary system with an orbital period of about 10 days, and a progenitor mass of 4.5 Suns. In a 1997 *Publications of the Astronomical Society of the Pacific*, Walter Feibelman (NASA-Goddard Space Flight Center) shared that International Ultraviolet Explorer satellite spectra of the star reveal that it consists of a bright type A star (BD+30°623) and a very hot O subdwarf companion. The system is enigmatic, having unexplained variations in brightness and a weak P Cygni profile – a combination of spectral features that indicates an outflow of material in the form of either an expanding shell of gas or a powerful stellar wind.

A rotating central binary system would also help to explain the mirrored symmetry of the planetary's two tilted shells. Interestingly, in a 2010 *Monthly Notices of the Royal Astronomical Society* (vol. 402, pp. 1307–1312), Binil Aryal (Tribhuvan University, Nepal, and Innsbruck University, Austria) and colleagues report their discovery in Infrared Astronomical Satellite (IRAS) data of a huge (8.5 light-year) dust emission region around NGC 1514 as well as two giant (7 and 3 light-year) bipolar dust emissions structures centered on the visible nebula and star. The researchers suspect that each of these regions is physically connected to the planetary nebula, noting that the bipolar structures are slightly tilted with respect to each other, possibly due to precession.

These structures could be associated with the proto-planetary nebula – the transition phase between a spherically symmetric asymptotic giant branch star and an aspherical planetary nebula. The total mass (dust and gas) of all the newly found structures is about 2.2 Suns. "We argue that NGC 1514 and its dusty surroundings represent one of the very few known cases where the preserved history of all main mass-loss phases of a star of intermediate initial mass can be seen," they say.

To find this intriguing nebula and bright central star – one of the few that can be seen in a decent pair of 10 × 50 or larger binoculars under a dark sky – use the chart on page 73 to find Zeta (ζ) Persei, then 5.5-magnitude Psi (ψ) Tauri, 4° to the southeast. Depending on your sky and eyesight, you may need binoculars to confirm this latter star; note how it is the northernmost





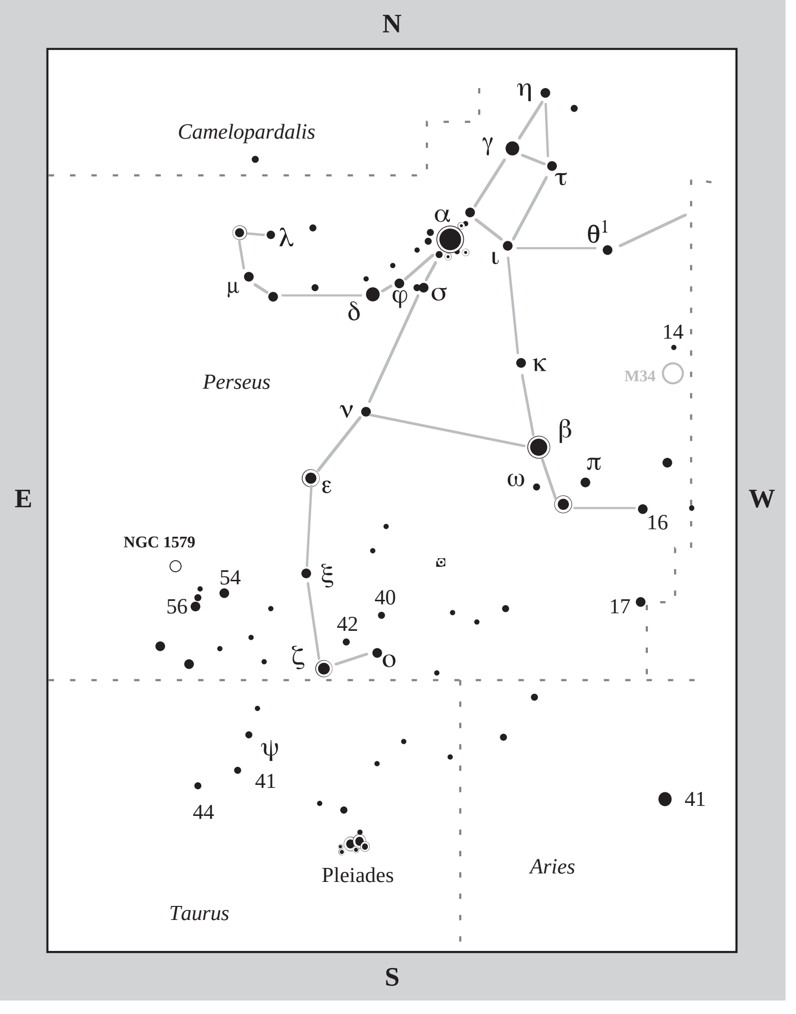
member of a roughly 3° curve of three similarly bright stars oriented north–south. Once you confirm Psi Tauri, center it in your telescope and switch to the chart on this page. From Psi Tauri make a slow 1¼° sweep due north to the solitary 8th-magnitude Star *a*. Now look 40′ to the northeast for a roughly 20′-wide right triangle of 8.5-magnitude suns. The western side of that triangle should have a 9.4-magnitude sun between the northern and southern points. This is NGC 1514. In other words, NGC 1514 lies midway between two 8.5-magnitude stars, about 20′ apart and oriented north-northwest–south-southeast.

At 33× in the 5-inch, NGC 1514 appears as a subtle amorphous haze tightly wrapped around an easily seen central star. The nebula is quite discernible with averted vision, especially if you compare NGC 1514's appearance to those of the two flanking 8th-magnitude suns, which don't show any glow. The nebula intensifies at 60×, showing a well-defined circular form out to at least 2′ all around, and perhaps even a bit further out. The nebula is bright enough to be viewed at 180× but I find the best and most comfortable view in the 5-inch at 94×.

At this power, the inner shell is most prominent, appearing obviously mottled. With time and averted vision, I can clearly see two prominent arcs of light along the outer edge of the inner shell ~1′ out to the northwest and southeast; the south-eastern arc is the brighter of the two. Perpendicular to these arcs are fainter elliptical lobes. These features are surrounded by a circular collar of dim light. By the way, an OIII filter really helps to bring out the arcs and other subtle details in the inner shell.

Enjoy!

Secret Deep 16
(NGC 1579)



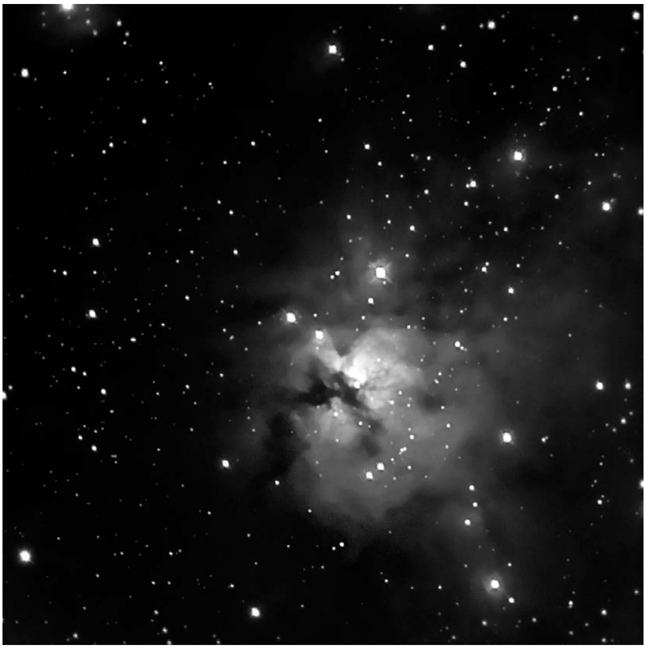
16

Northern Trifid
NGC 1579
Type: Emission/Reflection Nebula
Con: Perseus

RA: 04^h 30.2^m
Dec: +35° 16′
Mag: – (Rating: 3.5)
Dim: 12′ × 8′
Dist: ~2,000 l.y.
Disc: William Herschel, 1788

W. HERSCHEL: [Observed December 27, 1788] Considerably bright, considerably large, much brighter in the middle. Stands nearly in the centre of a trapezium. (H I-217)

NGC: Pretty bright, very large, irregularly round, much brighter in the middle, 8th-magnitude star at position angle 350° 2′.



PERSEUS IS HOME TO SEVERAL BRIGHT and delightful open star clusters: M34, NGC 869 and 884 (the Double Cluster), and Melotte 20 (the Alpha Persei Moving Group). Its boundaries also harbor some fainter, though equally marvelous deep-sky wonders, such as planetary nebula M76, lenticular galaxy NGC 1023, and the tiny reflection nebula NGC 1333 (Hidden Treasure 15).

Like NGC 1333, our target NGC 1579 is an irregularly mottled reflection nebula lying in a dark lane relatively near 3rd-magnitude Zeta (ζ) Persei (Atik) in the eastern foot of the Hero. NGC 1333 lies about 5¼° east-southeast of that star, while NGC 1579 is about 8° to the east-northeast of it. In physical space, however, the two nebulae are "miles apart": NGC 1333 lies about 1,100 light-years away, while NGC 1579 is nearly twice as distant.

In 1917, Francis G. Pease used the 60-inch f/5 reflector atop Mount Wilson in Southern California to image this little visual dynamo, which was one of several objects he selected whose "real nature was unknown or those which possessed curious or questionable characteristics." His photographs of the bright central region of NGC 1579 revealed the nebula's curious dark lanes which, he said, "call to mind the Trifid nebula" – thus the object's modern moniker, the Northern Trifid. The nebula's more expansive and dimmer outer regions, though, reminded Pease of the Orion Nebula, namely it being a large bulbous swath of mottled light marred by dark webs of dust.

Interestingly, direct photographs do not show any nearby bright stars that could be the illuminating source of the nebula. Pease did note that directly south of a broad and prominent arrowhead of dark material – one adjoining the principal dark lane on the north and pointing due east – is a very faint star. In 1956, George Herbig, using a spectrograph on the 36-inch Crossley reflector at Lick Observatory, found Pease's star (magnitude 16) to be very red, having a remarkably high hydrogen-alpha emission and an unusual emission-line spectrum. Subsequent observations showed that the spectra of the star (designated LkHα 101) and the nebula are identical; thus LkHα 101 is responsible for the illumination of NGC 1579.

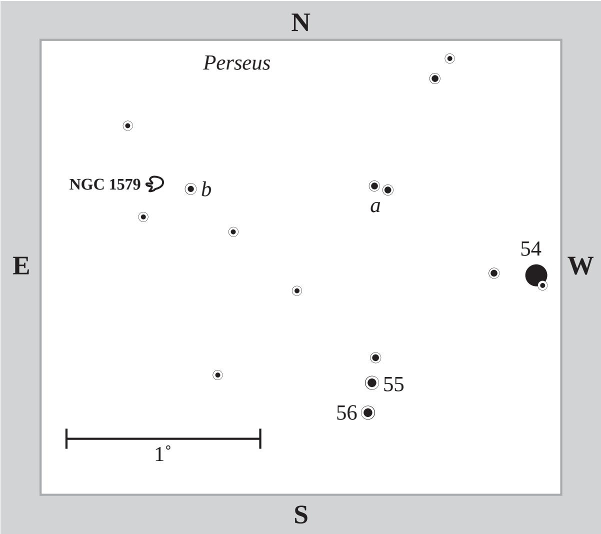
Although Sharpless (1959) catalogued the nebula as an HII region (S-222), it has no characteristic HII emission lines in its spectrum. Sharpless was obviously misled by the fact that the nebula's image appears so much brighter on the red Palomar plates than it does in the blue. A visual inspection of modern wide-field color images of NGC 1579 can be equally deceiving. They show the nebula as a colorful menagerie of beautiful shades of gunsmoke blue, peach, melon, orange, and rust. But these warmer hues are not due to the excitation of hydrogen gas by ultraviolet radiation streaming from nearby hot stars, but owe their redness to interstellar extinction and to the nature of its illuminating source. The extinction is caused by a vast cloud of dust (L1482) belonging to the Taurus–Auriga Cloud complex – a line of sight that also passes through the more distant Perseus OB2 Association.

Today we know the nebula to be a dusty star-forming region. In a 2004 *Astronomical Journal* (vol. 128, p. 1233), Herbig and his colleagues note that infrared and radio observations of LkHα 101 suggest that it is a hot star about 8,000 times more luminous and 15 times more massive than the Sun surrounded by a small HII region, both inside an optically thick dust shell. The star appears to be in an interesting phase of its early evolution, being a transition object – one between an optically inaccessible massive star forming deep within its dark and dusty natal cloud and a zero-age, main-sequence star (one that just evolved onto the main sequence) whose radiation and winds have cleared out the dusty neighborhood making it dimly accessible at optical wavelengths.

Although LkHα 101 is heavily obscured by dust (by about 10 magnitudes), it's still the brightest member of a young cluster of stars that contains 35 much fainter hydrogen-alpha emitters (all still embedded in the dusty cloud) with a median age of about 0.5 million years. The cluster also contains at least five bright B-type stars, presumably of about the same age.

To find this intriguing object, first use the chart on page 78 to locate Zeta (ζ) Persei, then look about 6° northeast for 5th-magnitude 54 Persei and center it in your telescope at low power. Now, using the chart on page 81 as a guide, move 1° northeast to a pair of roughly 7.5-magnitude stars (*a*), then make another 1° sweep due east to a solitary 7.5-magnitude sun (*b*). NGC 1579 is a little more than 10′ due east of Star *b*.

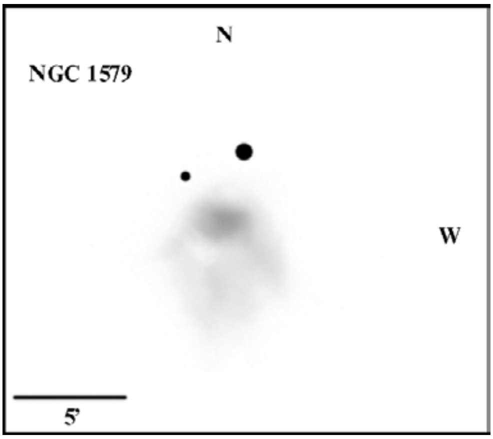
In the 5-inch at 33× the object is a dim sight – a milky smudge barely visible with



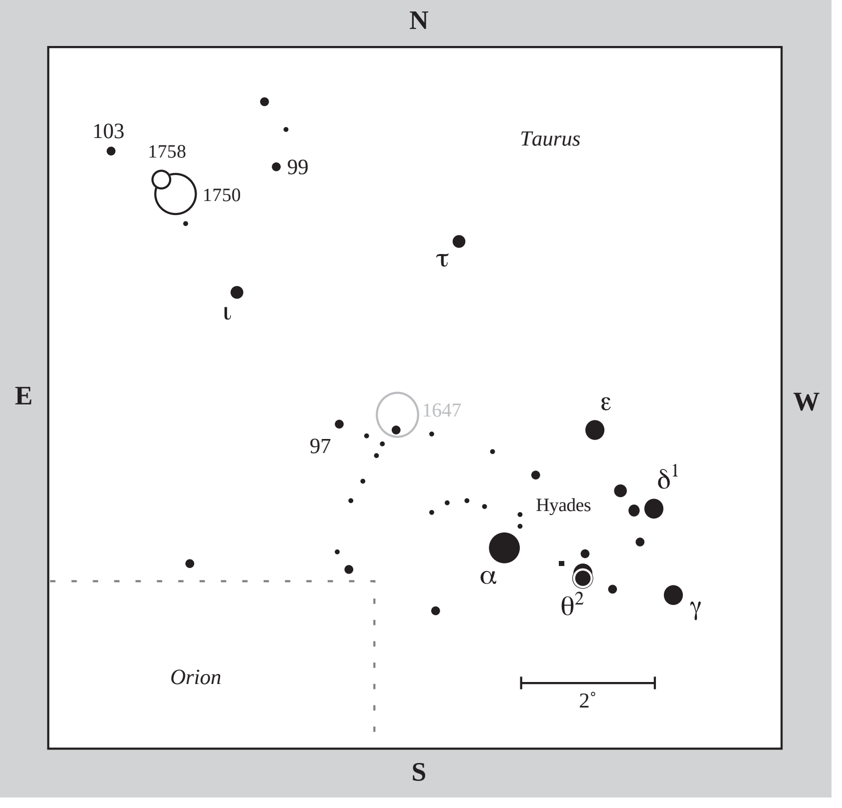
averted vision, spanning about 6′ in its longest extent to the north. (But don't despair, Christen Luginbuhl and Brian Skiff say that they saw NGC 1579 "easily at low power" through a 6-inch telescope!) Indeed, I found that with time and averted vision, the nebula becomes more and more apparent, especially since a nearby magnitude-12 star to the north helps to focus attention. The nebula has a somewhat delta-wing shape with three irregular extensions to the south (with the middle one being the longest). I also spied what might be the central dark rift, the one that contains LkHα 101 (though it is too dim to see).

At 60×, I saw a roughly 13th-magnitude star pop into view east-southeast of the 12th-magnitude star. The central mass of nebulosity becomes almost rigidly round with a dim snowy beard of fainter nebulosity extending to the southeast toward a roughly 12.5-magnitude star. The nebula did not appear any more dramatic at higher powers, so I found 60× the best view in my small scope. With time and averted vision, the core can be seen as a bright nebulous concentration, though the dark lane disappears at this power. Interestingly, I did not see much more detail when I viewed the nebula through Larry Wood's 12-inch reflector at the George Moore Astronomy Workshop near Edmonton, Alberta. The glow was much brighter, and very obvious, but it had a round and distinct cometary form, with a strong central concentration surrounded by a circular diffuse halo.

Indeed, in a 1974 *Publications of the Astronomical Society of the Pacific* (vol. 86, p. 813), Martin Cohen (University of California, Berkeley) notes that NGC 1579 and LkHα 101 may represent a more-massive and more-luminous example of a typically smaller cometary nebula (see Secret Deep 32 (NGC 2316)).



Secret Deep 17 & 18
(NGC 1750 & 1758)



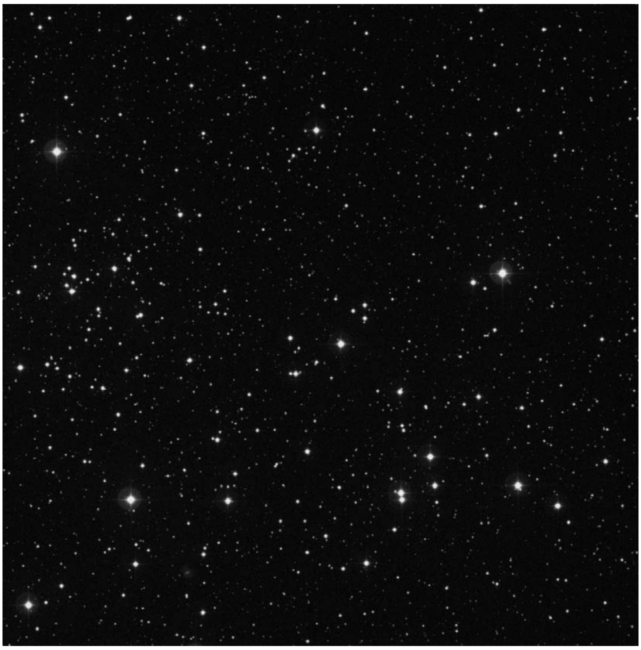
17

NGC 1750 = NGC 1746
Type: Open Cluster
Con: Taurus

RA: 05^h 04.3^m
Dec: +23° 44′
Mag: ~6 (O'Meara)
SB: – (Rating: 4)
Diam: 30′
Mean Dist: ~2,050 l.y.
Disc: William Herschel, 1785

W. HERSCHEL: [Observed December 26, 1785] A cluster of very coarsely scattered [bright] stars that join to [NGC 1758]. (H VIII-43)

NGC: Cluster, stars large, very considerably scattered.



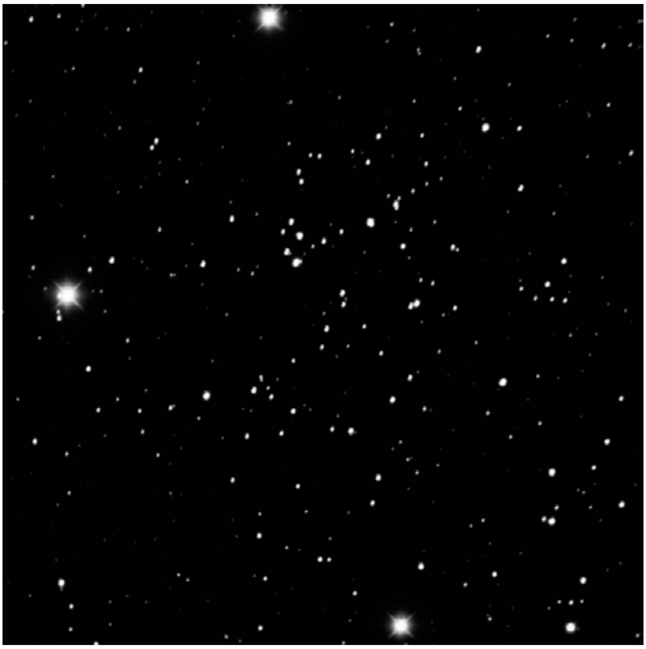
18

NGC 1758
Type: Open Cluster
Con: Taurus

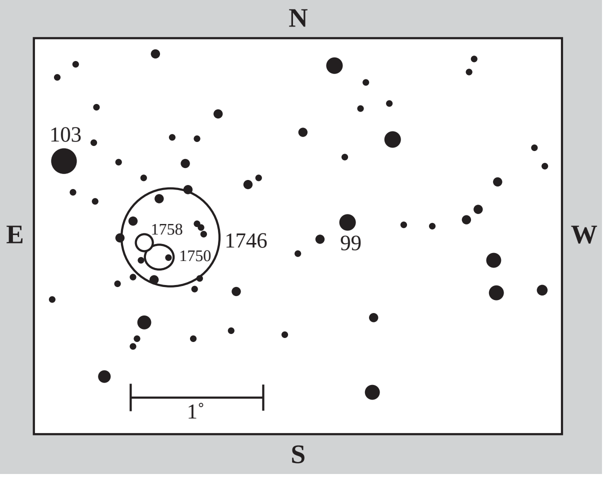
RA: 05^h 04.7^m
Dec: +23° 48′
Mag: ~7.5 (O'Meara)
SB: – (Rating: 3.5)
Diam: 10′
Mean Dist: ~2,480 l.y.
Disc: William Herschel, 1785

W. HERSCHEL: [Observed December 26, 1785] A cluster of pretty compressed stars with many extremely [faint] stars mixed with them. (H VII-21)

NGC: Cluster, pretty compressed, stars [bright] and [faint].



17 & 18



If you sweep your binoculars across the length of Taurus the Bull under a clear dark sky, you'll encounter a number of star clusters: the famous Pleiades (M45), Hyades (Caldwell 41), NGC 1647 (Hidden Treasure 27), and NGC 1807 and 1817 (Secret Deep 15 and 16). Let's, for the moment, also include the large 45′-wide NGC 1746, a highly neglected object about 10° northeast of Alpha (α) Tauri (Aldebaran) and 1° southwest of 6th-magnitude 103 Tauri.

All these young objects lie very close to the point directly opposite the Galactic center, in the direction of the Taurus dark clouds – a 4-million-year-young complex with a mass of some 6,500 Suns. It is a beautiful region of solar-mass star formation riddled with stunning dark nebulae, Herbig–Haro objects, and other enigmatic young stars. At a distance of some 570 light-years, the Taurus dark cloud complex is one of the nearest to the Sun, placing the Hyades in the foreground and the Pleiades partially immersed into the cloud's front edge.

The other clusters mentioned are all highly reddened background objects, with the amount of dimming dependent on the density of the obscuring clouds. Of them, NGC 1746 is especially intriguing, since it is not only an historical curiosity (as well as a highly neglected visual target), but also an object that is fast attracting the attention of modern astrophysicists. But let's first look at NGC 1746's history.

On the evening of November 9, 1863, German astronomer Heinrich Louis d'Arrest (1822–1875) was using the 11-inch f/17.5 Merz refractor at Copenhagen Observatory to observe H VIII-43 (GC 970 = NGC 1750), which William Herschel had discovered on December 26, 1785. After d'Arrest observed this "poor cluster," he determined its position, placing it about 10′ north of Herschel's, but he still referred to it as H VIII-43.

In his 1888 *General Catalogue*, however, John Louis Emil Dreyer mistook d'Arrest's new position for a new object, listing it as GC 5349 (NGC 1746). Interestingly, on the same night Herschel discovered H VIII-43, he swept up another new cluster in the same region, H VII-21, which Dreyer listed as GC 977 = NGC 1758. As plotted above, you can see how the three open clusters overlap, with NGC 1758 abutting NGC 1750 immediately to the northeast, while both NGC 1750 and NGC 1758 are superimposed on larger (45′) NGC 1746.

In time, the reality of some of these clusters was questioned. Indeed, Harvard astronomer James Cuffey had mentioned only NGC 1746 in a 1937 Harvard College Observatory tercentenary paper on Galactic clusters (*Annals of Harvard College Observatory*, vol. 105, no. 21). Since then, and until recently, NGC 1750 and NGC 1758 have remained largely historical footnotes;

in fact, I am not aware of any modern star chart showing these two clusters.

But the tides have turned. In a 2003 *Baltic Astronomy* (vol. 12, pp. 323–351), Vitautus Straizys (Vilnius University, Vilnius, Lithuania) and colleagues explain how their photometry, on 420 stars down to visual magnitude 16 in the region, found NGC 1750 and NGC 1758 to be two separate and real clusters at the same mean distance of about 2,500 light-years. These findings support their earlier study in 1992 that had similar results.

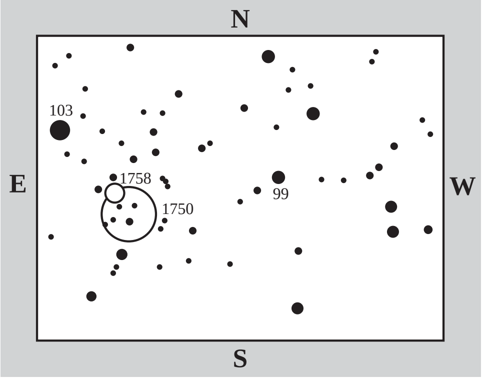
Furthermore, Spanish astronomer David Galadí-Enríquez (University of Barcelona) and his colleagues concur. In a 1998 *Astronomy & Astrophysics* (vol. 337, p. 125), the researchers conclude that the mutual separation, relative velocity (they found the presence of two stellar populations in the region with somewhat different directions of motion), and age difference of NGC 1750 (200 million years) and NGC 1758 (400 million years) led them to agree that these are two physically independent clusters. The distances to the clusters, they found, are 2,050 light-years for NGC 1750 and 2,480 light-years for NGC 1758. The researchers also provided the more accurate cluster coordinates given in the table above.

As for NGC 1746 – a small clump of stars that d'Arrest positioned 10′ north of NGC 1750, none of the modern research supports the existence of a real object in the area. One can only imagine that d'Arrest either made an error in his declination measurement, or that he mistook this rogue clump of milky starlight for Herschel's VIII-43. Remember, it was Cuffy in 1937 who abolished NGC 1750 and NGC 1758 from the records and reassigned NGC 1746 to an erroneously large cluster in the area: the one that exists on most (or all) modern star charts. In fact, in a private 2010 communication, Galadí-Enríquez said, "I think that the research by Straizys *et al.* and by our group definitively clarify the structure of this area in Taurus, and NGC 1746 should be taken out from the list of galactic open clusters."

The modern resolution to the NGC 1746 field mystery also solves another age-old conundrum that the late deep-sky expert Walter Scott Houston loved to ask: What is the apparent diameter of NGC 1746? Houston noted that estimates ranged from 25′ to 1°. Now we know the answer.

The fact is, a true cluster exists at Herschel's positions for both H VIII-43 (NGC 1750) and H VII-21 (NGC 1758). Thus, of the three objects – NGC 1746, NGC 1750, and NGC 1758 – only NGC 1746 has been erroneously assigned (meaning, it doesn't correspond to a true cluster)! The modern portrait of the region (see the illustration below based on Straizys *et al.*'s 1992 work), then, shows the presence of two overlapping open star clusters, possibly seen in the act of penetrating one another. NGC 1750 is the more massive of the two, equaling some 10,000 Suns.

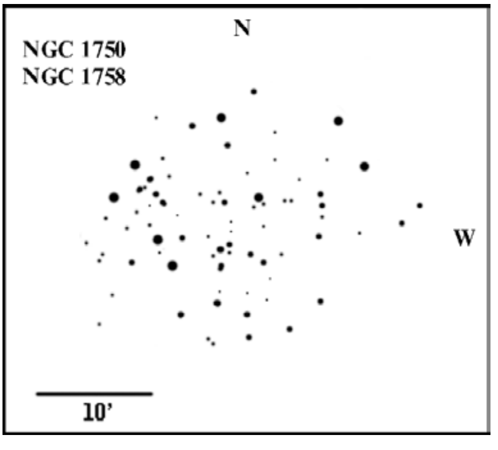
To find these twin delights, I suggest first hunting down the region with binoculars.



Look about 10° northeast of Aldebaran, in a line with Beta (β) Tauri (Alnath), the tip of the Bull's southeastern horn. In 10 × 50 binoculars under a dark sky, the region including NGC 1750 and NGC 1758 appears as a 50′-wide patch of milky starlight, like an isolated star cloud with bright and faint stars that shines around 5th magnitude. (It can also be seen with averted vision and the unaided eyes.)

This region hugs a 20′-long Y-shaped asterism of roughly 8th-magnitude suns (oriented northeast–southwest) about 1° southwest of 6th-magnitude 103 Tauri. With averted vision, NGC 1750 becomes apparent as a smaller, isolated patch of starlight, 30′-wide, just west of the Y's stem. It has a more delicate luster than its brighter neighbor NGC 1647 some 6° closer to Aldebaran. NGC 1758 on the other hand appears only as a small suggestion of hazy light tucked into the open end of the Y; you need extremely dark skies to "sense" it in handheld binoculars.

In the 5-inch at 33× and a nearly 2° field of view, the two clusters appear as a warped peanut of irregularly bright suns, with a major axis oriented roughly northeast–southwest. The stars seem to bloom out of the Y-shaped asterism like two polyps of starlight; these are a mixture of true cluster members and field stars, but don't worry about that, just enjoy the view. Look for a prominent gathering of about a dozen stars in NGC 1750, which form a roughly 8′ irregular circle of starlight, whose center lies about 6′ northwest of the Y's stem.

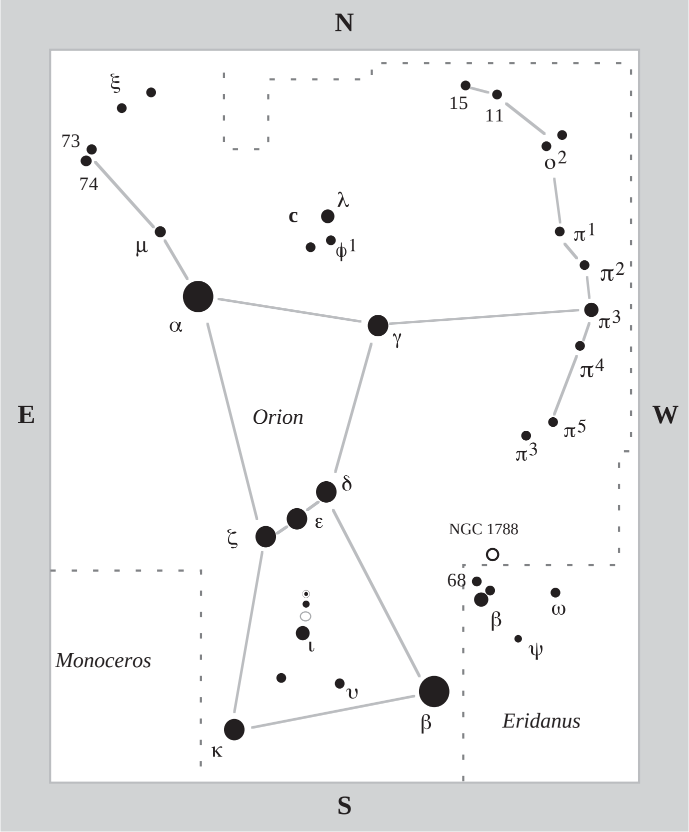


Two wide pairs of roughly 10th-magnitude suns jut beyond this stellar ring: one pair to the west-northwest (oriented west-northwest to east-southeast), and the other pair to the west-southwest (oriented northeast to southwest); these pairs define the true western boundary of NGC 1750. The stars in the direction of NGC 1758 appear more congested and compact and congregate just southwest of the two stars at the open end of the Y. Most apparent is a fine pair of suns toward the northeast end of the cluster.

Long spidery filaments of field stars extend the true cluster boundaries in all directions in this rich Milky Way region. The clusters truly do, however, look best at low power. But they will also stand scrutiny at higher magnifications. I especially enjoyed looking at NGC 1758 at 94×, which brought out some fanciful arrangement of dim suns that seemed to loop and curl in haphazard directions, depending on how I mentally "attached" the suns. The clusters also have a fair share of tight pairs and tiny triangular arrangements of stars.

With time, these loose clusters become quite distinct, and it's not hard to imagine one interacting with the other. So take your time and enjoy this view of two clusters literally passing through one another.

Secret Deep 19
(NGC 1788)



19

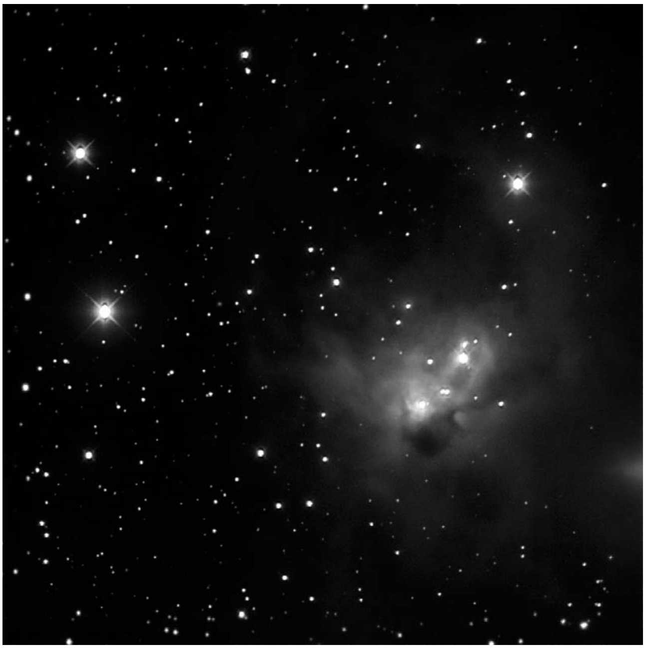
19

Cosmic Bat, Foxface Nebula
NGC 1788
Type: Reflection Nebula
Con: Orion

RA: $05^h\ 06.9^m$
Dec: −03° 21′
Mag: – (Rating: 3.5)
Dim: 5′ × 3′
Dist: ~1,600 l.y.
Disc: William Herschel, 1786

W. HERSCHEL: [Observed February 1, 1786] Considerably bright, very large, much diffused and vanishing, near and south following a bright star. (H V-32)

NGC: Bright, considerably large, round, bright in the middle with three stars of 15 magnitude, star of 10th magnitude, 1½° away at position angle 318°, involved in the nebulosity.



ORION IS CHOCK-FULL OF DEEP-SKY wonders. Every veteran observer has tackled the constellation's "big three" nebulae: M42 (the Great Orion Nebula with its famous Trapezium of stars), M43, and M78. My Hidden Treasures list added eight more visual delights in Orion: open star clusters Collinder 69 and 72 and NGC 2169; the nebulae NGC 1977, 1981, 1999, 2024, and 2163, and several other "celestial hors d'oeuvres" near the Belt star Zeta (ζ) Orionis.

Although the small but obvious reflection nebula NGC 1788 didn't make it to the final Hidden Treasures list, I did consider it. This isolated patch of glowing gas and dust lies nearly 7° west-northwest of M42 and the young, hot stars that make up the heart of the Orion OB1 Association. You'll find it just above the northeastern border of Eridanus, only about 1½° north-northwest of 3rd-magnitude Beta (β) Eridani.

In the standard scenario of triggered, or induced, star formation, ultraviolet radiation streaming out from hot, young OB stars, or shock waves expanding out from supernovae explosions, compress the cold material in giant molecular clouds. Consequently, dense cores form and collapse in the cloud due to self-gravity, forming embryonic protostars in the process. As each new

core accretes more and more material, internal pressure builds until it ignites a core reaction that starts burning hydrogen into helium.

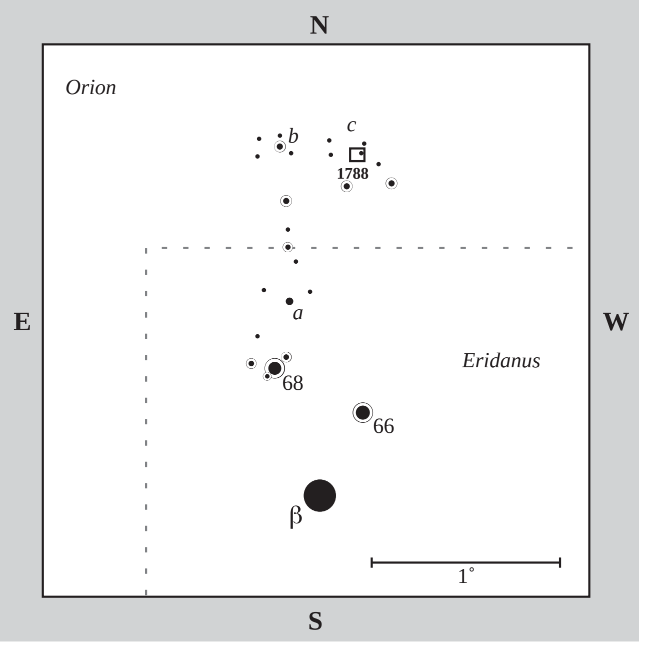
As Juan Alcalá (Osservatorio Astronomico di Capodimonte, Naples, Italy) *et al.* explain in a 2004 *Astronomy & Astrophysics* (vol. 516, p. 677), this model successfully describes the onset of star formation in large conglomerations of stars such as those in the Orion Nebula. But the spatial distribution of stars in the universe cannot be fully explained if stars only form in large clusters. “Thus,” they say, “effective star formation in isolated molecular clouds, far from the massive complexes but most likely still induced by them, offers an explanation for the observed distribution of stars.” The region around NGC 1788 is one such isolated cloud. “Although this ghostly cloud is rather isolated from Orion’s bright stars,” they explain, “the latter’s powerful winds and light have had a strong impact on the nebula, forging its shape and making it home to a multitude of infant suns.”

Energy streaming from the bright, massive stars belonging to the vast stellar groupings in Orion has also caused hydrogen gas in the region to glow, creating a long wing of matter east of the main reflection nebula – the part we see most prominently through our telescopes, which is mottled with “furry-looking” dust (Lynds 1616). Seen together with a short vertical segment of reflection nebulosity northwest of the main nebula, NGC 1788 looks like a fantastic bat in flight, darting on the feed (see the European Southern Observatory image above).

A 2010 ESO press release notes that all of the stars in the NGC 1788 region have an average age of only a million years. These “preschool” stars fall naturally into three well-separated classes: (1) the more senior stars lie east of the long wing; (2) moderately young ones make up the small cluster enclosed in the main nebula which they illuminate; and (3) the youngest suns, still embedded in their natal, dusty cocoons (those visible only at infrared and millimeter wavelengths), lie further to the west. The segregation of stellar groups suggests that a wave of star formation, generated around the hot and massive stars in Orion, propagated throughout NGC 1788 and beyond.

Telescopically, NGC 1788 is a small but pleasing reflection nebula that appears more extensive at lower power than at high power. To find it use the chart on page 87 to locate 0-magnitude Beta (β) Orionis (Rigel), the left knee of Orion, then 3rd-magnitude Beta Eridani 3½° further to the northwest. Beta Eridani marks the southern apex of a 40′-wide isosceles triangle with the 5th-magnitude stars 66

19

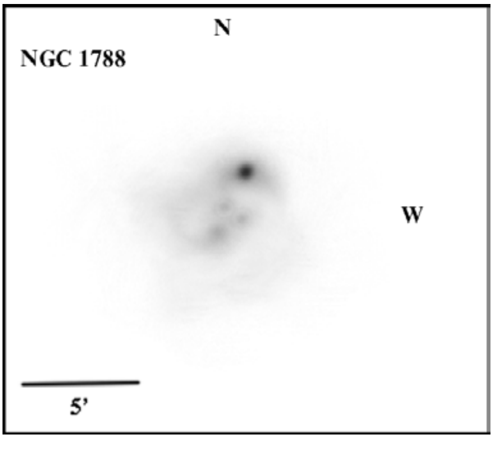


and 68 Eridani. Center 68 Eridani in your telescope at low power, then switch to the chart on this page. Now follow the roughly 1°-long line of 7th- to 9th-magnitude stars that flows northward from 68 Eridani. Begin the search along this line by moving 20′ north-northwest to 9th-magnitude Star *a* and stop when you get to 8th-magnitude Star *b*. NGC 1788 lies only about 25′ to the west-southwest of Star *b*.

The brightest part of the nebula lies southeast of a 10th-magnitude star (HD 293815) that marks the southwest corner of a 10′-wide Trapezoid of similarly bright suns (*c*). HD 293815 is actually the brightest member of a dim cluster of suns in NGC 1788; the cluster aspect, however, is lost to the eye when seen through small backyard telescopes, though it is often revealed glamorously in images.

With direct vision at 33× in the 5-inch, NGC 1788 appears as a fuzzy stellar-like object that swells with averted vision. The brightest parts actually form an ellipse of light oriented northwest–southeast – with the 10th-magnitude star at the northwestern focus and the fuzzy knot of light at the southeastern focus. At times I suspected two dimmer stars between them. The averted view showed the brightest part of the nebula soft and elegant, like sheer silk. The more I gazed, and tapped the tube gently with a forefinger, the more I convinced myself of seeing a much larger halo of light stretching toward another 10th-magnitude star 5′ northwest of HD 293815, so the outer halo looks off-center.

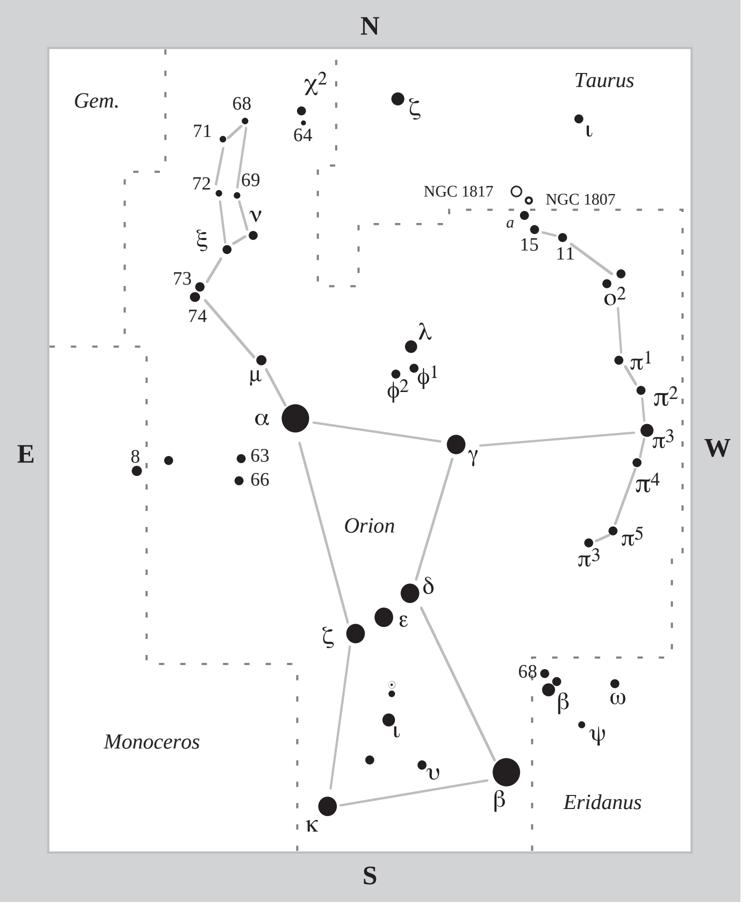
At 60×, dark dust (Lynds 1616) near HD 293815, which streams through the southwestern part of the nebula, caused my eye to see variations in the reflection nebula's brightness, but I couldn't perceive any definite structures – just ghostly shadows that wafted in and out of view. Small nebulous



knots of dim stars also appeared superimposed on the cloud, though these too were difficult to define. The nebula is much more difficult to see in my modest scope at 94×, though it does show HD 293815 as a clear, blazing star, and a dim 11.5-magnitude sun embedded in the southeastern nebulous knot.

20 & 21

Secret Deep 20 & 21
(NGC 1807 & 1817)



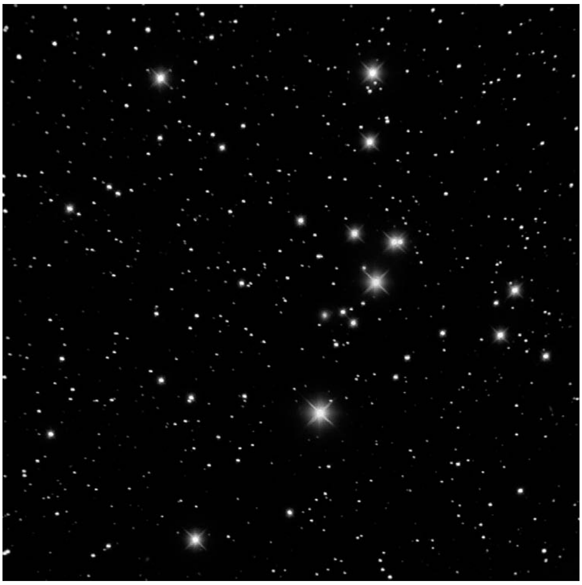
20

Poor Man's Double Cluster
NGC 1807
Type: Open Cluster
Con: Taurus

RA: 05^{h} 10.8^{m}
Dec: +16° 31′
Mag: 7.0 (Rating: 4)
Diam: 12′
Dist: ~5,900 l.y.
Disc: John Herschel

W. HERSCHEL: None.
(h 348)

NGC: Cluster, pretty rich, stars [bright] and [faint].



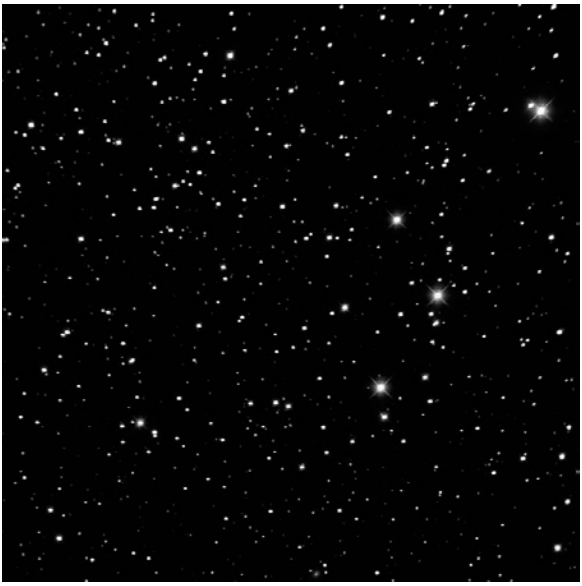
21

Poor Man's Double Cluster
NGC 1817
Type: Open Cluster
Con: Taurus

RA: 05^{h} 12.4^{m}
Dec: +16° 41′
Mag: 7.7 (Rating: 4)
Diam: 20′
Dist: ~5,900 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed February 19, 1784] A cluster of pretty [bright] and pretty compressed stars, considerably rich, 20 or 25′ in diameter, irregularly round. (H VII-4)

NGC: Cluster, large, rich, little compressed, stars of magnitude 11 to 14.



20 & 21

NGC 1807 AND 1817 ARE TWO INTRIguing patches of starlight in Taurus that form a visual double cluster at the northern tip of Orion's Shield. William Herschel discovered the larger and fainter cluster (NGC 1817) in February 1784. What he apparently did not notice is the brighter and slightly smaller gathering of suns (NGC 1807) 25′ to the southwest; his son John catalogued that object. Interestingly, while, NGC 1807 is 0.7 magnitude brighter than NGC 1817, it is the less visually obtrusive, containing only 37 members in an area 12′ across. NGC 1817, on the other hand, contains more than 280 members (most being fainter than 12th magnitude) spread across 20′ of sky.

Then again, the "double" aspect of the cluster may just be an illusion. In a 2004 *Astronomy & Astrophysics* (vol. 426, p. 819), Spanish astronomer L. Balaguer-Núñez (Barcelona University) and colleagues calculated proper motions for, and re-evaluated the membership probabilities of, 810 stars in the area of NGC 1817 and NGC 1807. Of those, the researchers found 169 probable members in what appears to be only one very extended physical cluster: NGC 1817. Thus, John Herschel's paltry NGC 1807 may just be part of a larger and very extended cluster.

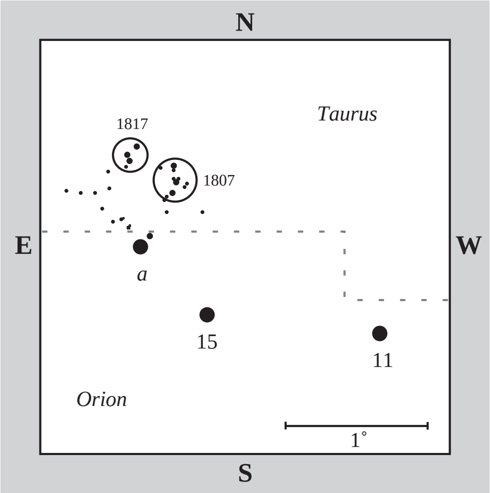
Indeed, in a 2003 *Astronomy & Astrophysics* (vol. 399, pp. 105–112) J.-C. Mermilliod and colleagues confirmed members out to a distance of 27′ from NGC 1817's core, doubling its previous radius. NGC 1807/1817, then, can be viewed as a single cluster nearly 1° across in the sky, perhaps with dual cores. Seen this way, NGC 1807/1817 has the same apparent diameter (and separation between the two cores) as the Double Cluster in Perseus.

But at an estimated distance of 5,900 light-years, NGC 1807/1817 is 1,400 light-years closer, giving it a true physical extent of about 100 light-years, or about 30 light-years smaller than the Double Cluster in Perseus. NGC 1807/1817 is an intermediate-aged cluster and probably formed between 0.5 and 1 billion years ago from the same cloud of dust and gas in the Galaxy's outer Perseus arm, directly opposite the Galactic bulge. NGC 1807/1817 then is in the same age group as the neighboring Hyades (650 million years): The Perseus Double Cluster, by comparison, is a mere 13 million years young.

In a 2009 *Astronomical Journal* (vol. 137, pp. 4753–4765), Heather R. Jacobson and her colleagues found NGC 1817 to have about the same amount of iron (per unit of hydrogen) as does the Sun. But she says that follow-up spectroscopy of 30 confirmed cluster members has revealed a lower metal abundance: about two-thirds the amount found in the Sun. Other studies found that its color–magnitude diagram also shows a well-defined main-sequence turnoff region, and a populous red-giant clump (one about 0.15 magnitude bluer than the Hyades giants, suggesting that NGC 1817 may have a slightly lower heavy-element abundance).

The cluster also has a lot of variable stars (27). Most interesting are the 17-odd δ Scuti stars, which Danish astronomers M. F. Anderson and T. Arentoft (Aarhus University) and their colleagues say makes NGC 1817 the most abundant cluster in this type of stars. Delta Scuti stars are of spectral type A to F and have masses ranging from 1.5 to 2.5 Suns. They lie at the bottom of the classical Cepheid instability strip (narrow, vertical region in the Hertzsprung–Russell diagram, between the high end of the main sequence occupied by stars more massive than the Sun and the giant branch). Delta Scuti Stars, then, are pulsating stars in a post-main-sequence stage of stellar evolution. They show multi-periodic signals with periods on the order of 0.25 to 5 hours, and display light variations of less than 1 magnitude. For NGC 1817 the turnoff from the main sequence, due to exhaustion of hydrogen in the core of stars, is located inside the instability strip.

To "fish" up this interesting solo/duet, John Herschel suggested "carrying a line from the foremost star in Orion's belt, Mintaka, though Bellatrix, and there intersecting it by another from Aldebaran, due east towards gamma Geminorum." Otherwise, use the chart on page 92 to follow Orion's Shield northward to the 5th-magnitude stars 11 and 15 Orionis; you'll also find them about 7½° east and a bit south of Alpha (α) Tauri (Aldebaran) in the Hyades. Now use the chart on this page to locate 5th-magnitude Star *a*, about 40′ northeast of 15 Ori. Under dark skies, I can see NGC 1817 in 10 × 50 binoculars as a

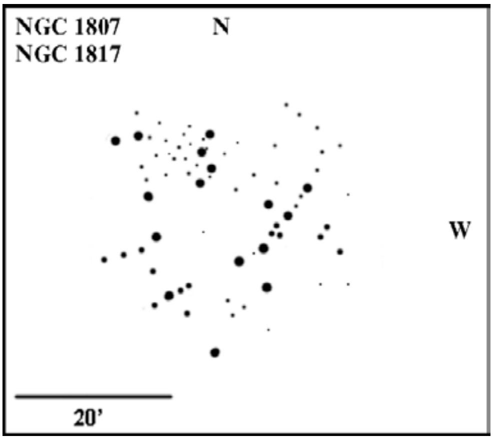


distinct fuzzy glow 40′ northeast of Star *a*. NGC 1807 pops into view with a bit more concentration.

Together, the clusters will be difficult to appreciate in small telescopes under bright skies. Admiral William Henry Smyth called NGC 1817 "A very delicate double star preceding a tolerably condensed cluster." He saw a yellow primary and a blue secondary. The pair, he said, is an "outlier of a rich gathering of [faint] stars, which more than fills the field, under an estimation of 20′ or 25′ of diameter, but he did not notice the pair here measured. However, Sir John Herschel thus describes it, No. 349: "large rich cluster; stars 12 to 15 magnitude; fills field. Place that of a double star. The most compressed part is 42.5 seconds following the double star, and 3′ south of it."

At a glance at 33× in the 5-inch, NGC 1817 and 1807 appear as two separate lines of stars. But in averted vision, NGC 1817 suddenly swells as a wide wash of stars that flows off that line to the northeast. With time, fainter stars also pop into view to the west-southwest of NGC 1807. Both clusters have long tails of starlight that seem to attach the clusters to Star *a*, like strings to balloons. If you slightly defocus the view, the region separating the two clusters looks like a 20′-wide V-shaped black lagoon – as if some divine power had driven a wedge into the cluster in an attempt to rip it apart.

At 60× and 94×, NGC 1807 is a sparse aggregation of more than two-dozen suns that make up a doll-like stick figure: a prominent line of stars oriented northwest-southeast forms the doll's spine, a wide pair of stars at the southeast end form the legs, and a solitary star at the

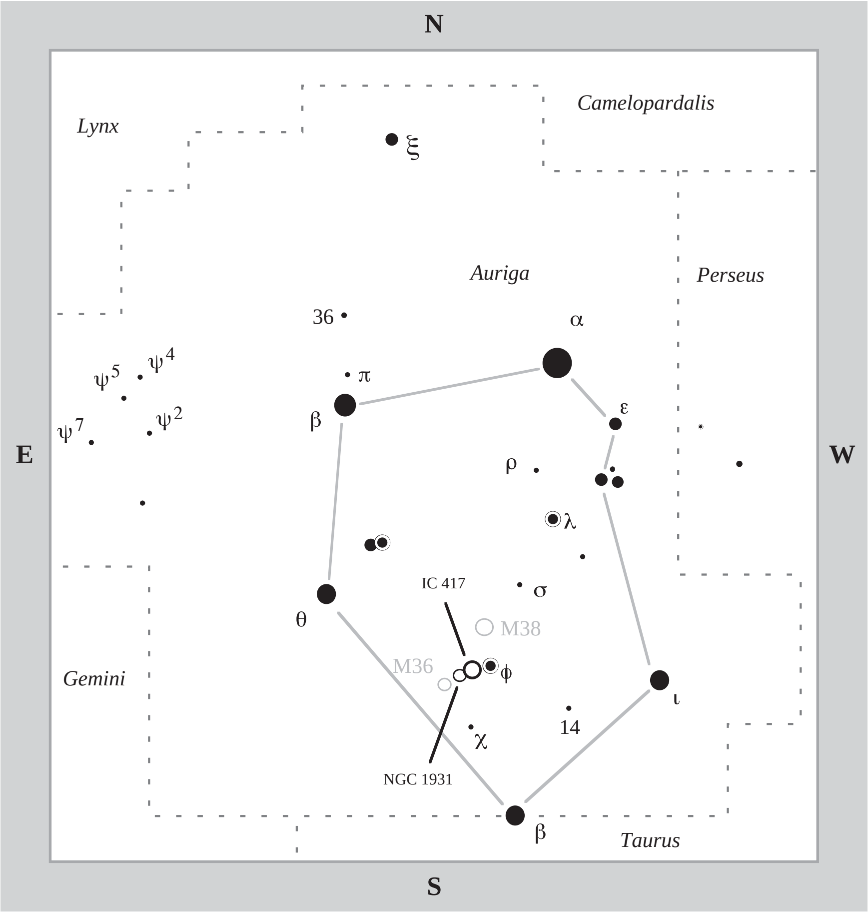


north end marks the head. The arms cross the spine from the northeast to the southwest. Note too the pretty triad of stars at the midpoint of the doll's spine.

At these same powers, NGC 1817 is a more dynamic grouping of irregularly bright suns spread across 20′ of sky. It contains four bright stars that shine between 9th- and 10th-magnitude and form a short lightning-bolt pattern oriented northwest–southeast. With averted vision, the east-northeast side of NGC 1817's lightning bolt swells into a ball of noisy starlight. Some two-dozen suns cram into a roughly 10′-wide ellipse of fuzzy starlight.

Now return to low power and relax your mind. Do you see the long and looping arms that seem to stream away from each cluster fragment, visually extending their boundaries across nearly 1° of sky? Remember, many of the stars you see here in this region actually belong a single cluster; the double aspect is most likely only an illusion. Still, expert deep-sky observer Steve Coe of Arizona likes to call the two cluster fragments the Poor Man's Double Cluster.

Secret Deep 22 & 23
(NGC IC 417 & NGC 1931)



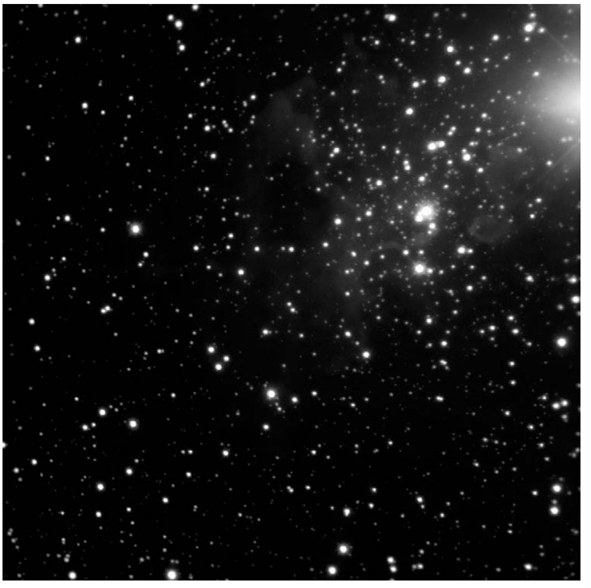
22

The Spider
IC 417/Stock 8
Type: Emission Nebula and Cluster
Con: Auriga

RA: 05^h 28.1^m
Dec: +34° 26′
Mag: ~8 (cluster)
SB: –9.0 (Rating: 4)
Diam (Cluster): 15′
Dim (Nebula): 13′ × 10′
Dist: ~8,150 l.y.
Disc (Cluster): Jurgen Stock, 1954
Disc (Nebula): Max Wolf, 1892

W. HERSCHEL: None.

IC: Very large, diffuse, magnitude 6 star involved.



23

The Fly
NGC 1931
Type: Emission/Reflection Nebula and Cluster
Con: Auriga

RA: 05^h 31.4^m
Dec: +34° 15′
Mag (Cluster): 10.1
SB: 14.0 (Rating: 4)
Dim (Nebula): 4′ × 4′
Diam (Cluster): 6′
Dist (Cluster): ~7,000 l.y.
Disc: William Herschel, 1793

W. HERSCHEL: [Observed February 4, 1793] Very bright, irregularly round, very gradually brighter in the middle, 5′ in diameter. Seems to have 1 or 2 stars in the middle, or an irregular nebula; the chevelure diminishes very gradually. (H I-261)

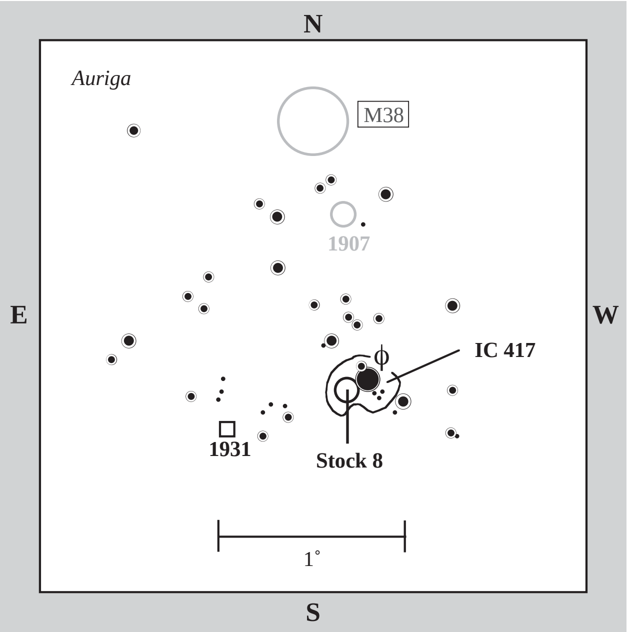
NGC: Very bright, large, round, bright triple star in the middle.

Take the time to study a wide-field photograph of, or turn your binoculars to, the rich Milky Way region around the bright open star clusters M36 and M38 in Auriga the Charioteer. Two curious threads of starlight seem to connect M36 to M38, and M38 to 5th-magnitude Phi (ϕ) Aurigae, an orange K-class giant flanked some 10′ on a side by two 6th-magnitude attendants. As a whole, this star-and-cluster stream forms an open V, like the fleshy flower of a calla lily.

As seen through binoculars, New York City skywatcher Ben Cacace refers to the latter star stream as the Cheshire Cat asterism – referring to the lingering smile that belongs to the fictitious cat in Lewis Carroll's 1923 children's classic *Alice's Adventures in Wonderland*. The smile begins just 30′ south-southeast of M38, at the 7th-magnitude variable star LY Aurigae, then arcs 1° south-southwest to Phi Aurigae, and ends 30′ further to the south-west at another 7th-magnitude sun with an 8.5-magnitude companion. The cat's eyes are two 6.5-magnitude stars: one 30′ southwest of M38, and the other about 42′ south-southwest of it.

More impressive is the same 2° region seen at low power in a rich-field telescope. When I first observed it through the 5-inch at 33×, Phi Aurigae immediately captured my attention. That crisp golden star has numerous fainter stars sprinkled across it linearly from the northeast to the southwest. Equally appealing, however, is a small collection of crisp jewels, 9th-magnitude and fainter, in a 5′-wide region just hugging Phi to the southeast, surrounding three roughly 9th-magnitude suns in a small arc. With averted vision, the region looks like a patch of Milky Way shaped like an inverted V (seen with north up). Unlike other nearby swaths of Milky Way, the region just southeast of Phi also has an added glaze, a frosting of nebulosity that made it appear as if I had accidentally breathed on the eyepiece (but I didn't).

I knew that light from the emission nebula IC 417 washed through this region; I also I knew that it appeared most intense in the region where I suspected seeing it. But I wasn't prepared to spy that small aggregation of suns sparkling between it and Phi Aurigae. None of my star charts showed a cluster in this position, though the *Millennium Star Atlas* did have one object (Stock 8) plotted about 5′ to the west. Since I didn't see any cluster in that latter



position, I suspected that Stock 8 must have been misplotted in the *Millennium*, and it was.

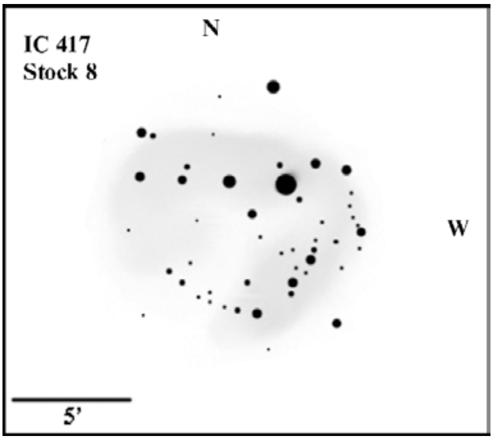
These observations later caused me to reflect on a mysterious historical discovery: one made by Caroline Herschel (William Herschel's sister and observing assistant) on the evening of October 13, 1782. That night, Caroline spied a "nebula below Phi Aurigae." It has been proposed that Caroline must have observed one of the bright Messier objects in the region. But M38 is nearly 1½° to the north-northeast. M36 is nearly 2° to the east-southeast. And M37 is even further away, some 5° to the east-southeast. The fact is, a nebula and cluster do exist south of Phi Aurigae. Even if Caroline did not see the nebulosity, she could have easily seen Stock 8 as an unresolved glow. Given Caroline's great eye for dim nebulae and comets, why wouldn't she have noticed such a bright and obvious hazy collection of suns?

No matter, Jürgen Stock at Warner and Swasey Observatory found the cluster while searching blue objective prism plates along the Galactic equator and catalogued it in 1954; it was the eighth of 21 possible new clusters he found based on the spectral class and approximate magnitudes of their stars. He then published the list in a 1954 *Astronomical Journal* (vol. 59, p. 332).

The nebula around the cluster was discovered by Max Wolf in 1892. Wolf's plates show the immediate region of Phi Aurigae and Stock 8 covered with the glow. On the evening of March 6, 1902, Wolf also discovered the "Great V" – a larger swath of nebulosity that seems to connect the nebulae IC 417, IC 410, and IC 405, the star clusters M38 and NGC 1907, and the stars 16, 19, and 36 Aurigae. He discovered this "Great Nebula in Auriga" after scanning a five-hour-long exposure he made of the field surrounding Nova Aurigae. The photo, he said, supported the theory that nearly all these stars, clusters, and nebulosity are at the same order of distance from our Earth as in similar cases in Cygnus and Orion.

As for Stock 8, it is indeed embedded in its nascent nebula IC 417. But it's not the youngest object in the region. In a 2008 *Monthly Notices of the Royal Astronomical Society* (vol. 384, pp. 1675–1700), Indian astronomer Jessy Jose (Aryabhatta Research Institute of Observational Sciences, Nainital) and colleagues found that Stock 8 is a youthful cluster about 8,150 light-years distant. It spans some 23 light-years across and intervening dust dims it by at least 0.5 magnitude. But Two Micron All Sky Survey near-infrared and spectroscopic data have also identified a population of young stellar objects – stars that have evolved past the protostar stage but have not yet reached the main sequence – in the area with ages between 1 and 5 million years; the other cluster stars are around 2 million years.

Many of the young stellar objects lie along a nebulous stream belonging to IC 417 towards the east side of Stock 8. A small cluster was also found embedded in that feature. Both the young stellar objects in the nebulous stream and in the embedded cluster, the researchers explain, are younger than the stars in Stock 8. Thus, it appears that star formation activity in the nebulous stream and embedded cluster may be independent from that of Stock 8. Apparently shocks created by the ionizing sources in (and west of) Stock 8 have not yet reached the nebulous stream.



Note that the dimensions of IC 417 given in the table on page 98 reflect only its brightest section southeast of Phi Aurigae. In long-exposure photographs, however, IC 417 is a vast cloud of glowing hydrogen gas with long spindly legs that stretch across 1½° of sky. This larger form of IC 417 was glamorized by Boston amateur astronomer Steve Cannistra, who, after looking over one of his marvelous wide-field photos of the region, nicknamed IC 417 "The Spider" and our next target – the tiny (4′) emission/reflection nebula NGC 1931 (about 50′ to the east-southeast) – "The Fly."

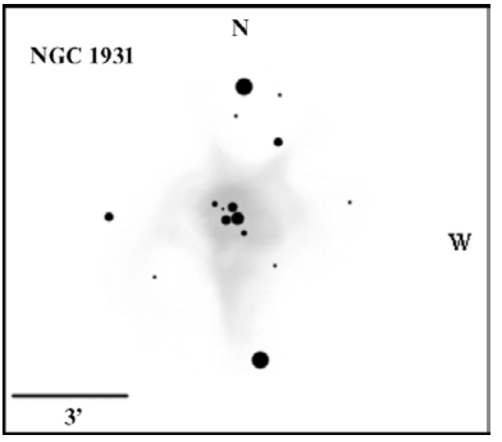
NGC 1931 is a beautiful little nebula harboring a tiny cluster that's easily seen in small telescopes. William Herschel discovered this gem in 1793, cataloguing it as a bright nebula (H I-261). In his *Cycle of Celestial Objects*, Admiral William Henry Smyth calls it a "resolvable nebula" – no doubt in deference to William's Herschel's belief that most nebulae, under sufficient magnification, will resolve into a multitude of suns, just as the naked-eye Milky Way does under even the lowest of powers.

Indeed, Smyth says that William Herschel resolved "one or two stars in the middle, or an irregular nucleus," while his son John saw a triple star within the nebula which surrounds them like an atmosphere. "With these premonitions," Smyth continues, "I attacked it under most favorable circumstances. The nebula is situated in a rich field of minute stars, with five of the 10th-magnitude, disposed in an equatorial line above, or to the south, of it, and preceded by a bright yellow 7½ magnitude star in the same direction. After intently gazing, under moderate power, the triangle rises distinctly from the star-dust, and presents a singular subject for speculation."

NGC 1931 is a young and low-mass open star cluster in an extension of the Milky Way's Perseus Arm. The cluster appears surrounded by emission and reflection nebulosity (Sharpless 2-237 = NGC 1931), though in a 1986 study of interstellar reddening across the region, astronomers at Uttar Pradesh State Observatory in Naini Tal, India, found that the nebula is a background object on which the cluster is superimposed. NGC 1931 is 7,000 light-years distant and about 10 million years young, placing it in an age group with NGC 2362 (Caldwell 64), the Tau Canis Majoris Cluster.

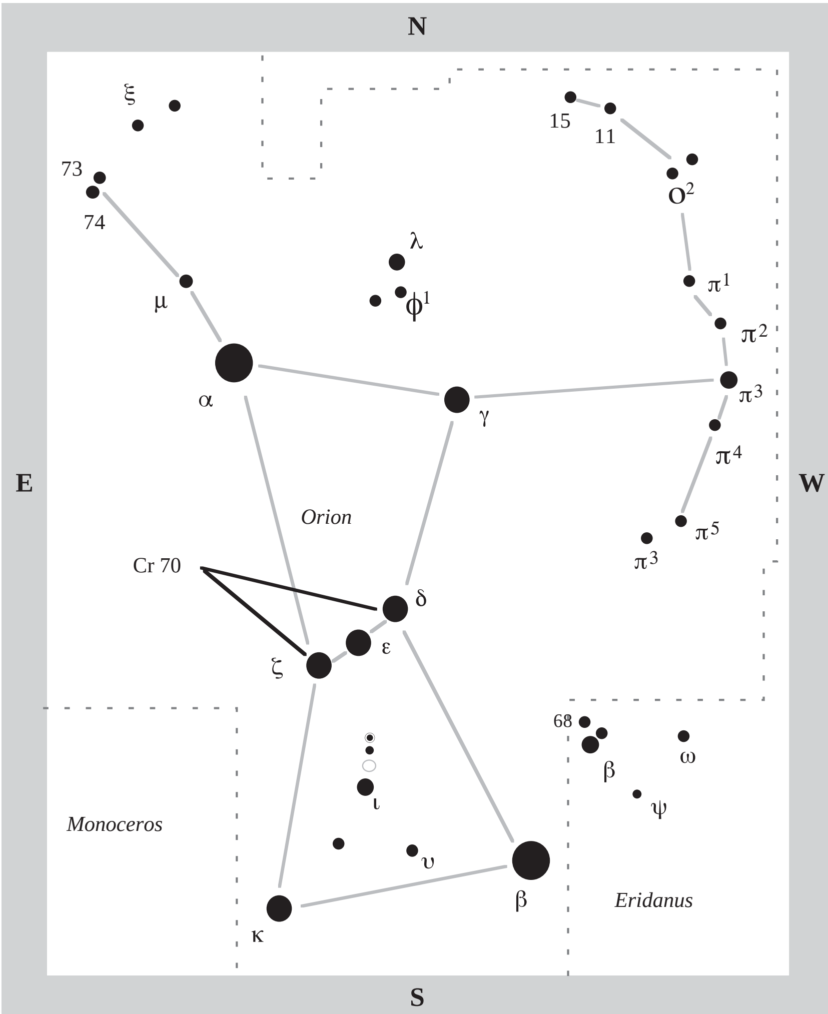
In a 2009 *Monthly Notices of the Royal Astronomical Society* (vol. 397, p. 1915B), Brazilian astronomer C. Bonatto (Universidade Federal do Rio Grande) used Two Micron All Sky Survey photometry data to confirm the age estimate for NGC 1931, adding that the cluster doesn't appear to be in dynamical equilibrium, and either may be evolving into an OB association or is doomed to dissolve into the Milky Way in a few tens of millions of years.

In the 5-inch at 33×, NGC 1931 is the easternmost "star" in a 20′-long, upward curving arc of three 7.5-magnitude suns, oriented east to west. It appears stellar with a direct glance, but swells into a distinct nebulous knot with averted vision. Doubling the power doesn't change much; the nebula continues to appear small (~2′) and round but with a starlike object at the core. A row of five conspicuous stars (oriented north–south) lies a few arcminutes west-northwest of NGC 1931, which is bracketed by two roughly 10th-magnitude suns oriented in the same direction, so there appear to be two parallel (but offset) rows of stars here, side by side. Increasing the power to 94×, I could see thin rays of nebulosity, but they might also have been faint star streams.



The glow is extremely condensed and takes magnification well. I especially enjoyed viewing the nebula and cluster at powers ranging from 165× to 330×. At 165×, the nebula is most intense and obvious and has a smooth milky sheen that gradually, then rapidly, fades as I look outward from the bright core. At the higher end of the power scale, the roughly 12th-magnitude central star becomes a stunning triad of suns attended by three other fainter jewels that swim in and out of view as I move my eye around using averted vision. Seen together, these stars form a marquee diamond. The southern end of the nebula is more condensed than the northern end. I also suspected a graceful sweep of reflection nebulosity stretching southward from the main nebula, but this may be an illusion owing to a nearby star that tends to pull the light in that direction. See what you think.

Secret Deep 24
(Collnder 70 — Orion's Belt)



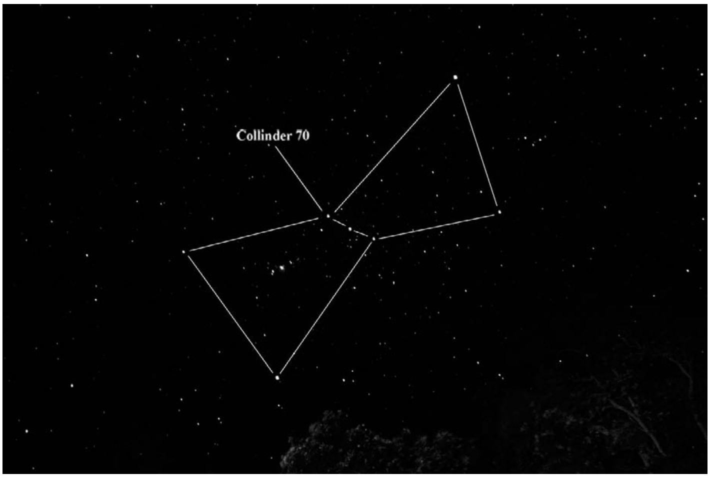
24

Orion's Belt, Serpentine Column
Collinder 70
Type: Open Cluster
Con: Orion

RA: 05^{h} 35.6^{m}
Dec: −01° 05′
Mag: 0.6
SB: 11.3 (Rating: 5)
Diam: 140′
Dist: ~1,260 l.y. (Tycho)
Disc: Per Collinder, listed in his 1931 paper "On structural properties of open galactic clusters and their spatial distribution."

W. HERSCHEL: None.

NGC: None.



Like those three stars of the airy Giants' zone,
That glitter burnished by the frosty dark;
And as the fiery Sirius alters hue,
And bickers into red and emerald, shone
The Princess, *Alfred, Lord Tennyson, 1847*

WHEN I WAS A CHILD GROWING UP IN Cambridge, Massachusetts, it was customary to attend midnight mass on Christmas Eve. On one of those memorable evenings, my friends and I walked the quarter mile or so to Sacred Heart Church in Watertown under a star-filled sky – boots crunching in the snow, cold nipping our cheeks, comets flying from our mouths into the crisp winter air. Naked oaks lined the streets, and their long and skeletal branches formed a complex web through which I could see the brilliant stars of Orion the Hunter flashing in and out of view as we walked. Orion followed us, its giant form stomping across the neighborhood rooftops keeping pace. Suddenly, the Hunter's hourglass body stood boldly before us in a clearing, his narrow waist adorned by three sparkling gems in a row, and we paused. The Belt had captured my friends' attention. Although it was just a moment as fleeting as a shooting star, we each in our own way paid homage to these stars in silent wonder before continuing on.

There isn't a time-honored stargazer who hasn't looked up on crisp winter evenings and marveled at Orion's Belt. This splendid row of three 2nd-magnitude stars, stretching 3° across the velvet night like a string of pearls, culminates in late January (meaning it stands highest above the southern horizon after sunset) and forms the most significant asterism in the winter night sky next to the Big Dipper.

Actually, the Arabic name for the Belt's middle star, Alnilam (1.7-magnitude Epsilon (ε) Orionis), means "the String of Pearls." The Belt's western star, Mintaka (2.2-magnitude Delta (δ) Orionis) is Arabic for "the Belt" and the first to rise above the eastern horizon; early astrologers saw Mintaka's arrival as important, for it portended good fortune. The Belt's easternmost star, Alnitak (1.8-magnitude Zeta (ζ) Orionis), is Arabic for "the Girdle."

Orion's Belt is a celestial magnet, one that draws attention to itself and inspires the imagination. Different cultures throughout time have pondered these three celestial wonders and attributed significance to them. Robert Bauval and Adrian Gilbert gave great cosmic importance to the Belt stars in their 1995 book *The Orion Mystery* (Three Rivers Press, New York), claiming that the Pyramids of Giza are an earthly representation of the three stars as they appeared in the sky around 10,400 BCE. Alas, as Griffith Observatory director Edwin C. Krupp wrote in the February 1997 issue of *Sky & Telescope*, the orientation of the Belt stars and those of the pyramids simply do not match. Still, it's agreed that the stars of Orion were important to the ancient Egyptians who saw in them their great god Osiris, who not only presided over the life and death of his people, but also the fertile flooding of the Nile. This fact also explains the proximity of Orion (Osiris) to Eridanus (the Nile).

To the Chinese of old, the Belt was a weighing beam. Early Hindus saw its stars as the three-jointed arrow that the hunter Lubddhaka (Sirius) shot into Prajapati (Alpha, Gamma, and Lambda Orionis), the father of beautiful Rohini (Aldebaran). Prajapati had lusted after his own daughter, who cavorted around disguised as an antelope. To win her, Prajapati changed himself into a deer. Realizing this trick, Lubddhaka shot Prajapati with an arrow (the Belt), riveting him to the sky between him and Rohini. To this day, amateurs still find Aldebaran and Sirius by extending Orion's Belt equidistant to the northwest and southeast, respectively.

In Hawaii, the Belt stars were *Na kao*, meaning "the darts," (these darts were long poles thrown with both hands); their station on the celestial equator made them a crucial navigation tool during their great Pacific voyages. Hawaiians also believed that when these stars ascended, stormy winds would blow:

> Pierced by the three stars of Orion
> Are the clouds,
> of rain as they drift on
> The Rain!

In the April 2001 issue of *Natural History*, renowned archaeoastronomer Anthony F. Aveni (Colgate University) tells us the significance of Orion's Belt to the Aztecs, who saw in the heavens the sustainers of life – "the gods they sought to repay, with the blood of sacrifice, for bringing favorable rains, for keeping the earth from quaking, for spurring them on in battle." Among the gods was Black Tezcatlipoca ("smoking mirror"), god of the night, which he ruled from the north. We see him in the sky – in the stars of what we call the Great Bear – hopping around the North Star on his one foot.

On Earth, Tezcatlipoca was a sorcerer and liked to prowl the roads after sunset to surprise tardy travelers. He could appear as a shrouded corpse or a headless man with his chest and stomach slit open; anyone brave enough to rip out his heart could demand a reward for returning it. But Tezcatlipoca wasn't always bad. He later used fire sticks (Orion's Belt) to bring warmth to the central hearth, whose fire ensured the continuation of life. The lighting of the sticks may also be a metaphor for the sexual energy needed to procreate, thus sustaining life on Earth.

Interestingly, in Mayan mythology, Orion's Belt is the center of creation. It's where the paddler gods transported the maize gods in a huge canoe that corresponded to the Milky Way until they arrived at Orion's Belt, which they envisioned as a huge cosmic turtle. Using a lightning stone, the god Chak cracked open the back of the cosmic turtle, from which the maize gods grew. We can see the cracked turtle shell in the ballcourts of the Yucatan, which are long lines like Orion's Belt. In Pre-Columbian times, the ballcourts substituted for observatories that the Maya used to watch the passage of time. Indeed, when Orion's Belt appeared through a designated hole, or the Sun shone directly on a specific spot, it meant spring (the moment of creation/life) was near.

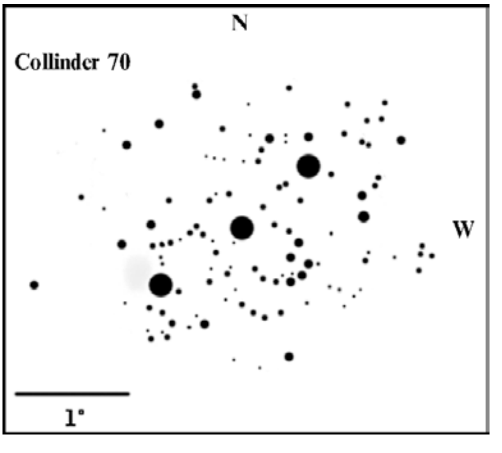
Australian aborigines also, in a way, envisioned the Belt stars as stars of fertility. They saw the three stars as young men dancing to attract the attention of the maidens (the Pleiades). In South Africa they were the three kings or sisters. While in Upper Germany they were seen, among other things, as the Magi – the three wise men who followed the Star of Bethlehem to Christ's birthplace (another fertility symbol).

The Belt of Orion even appears in the Bible (Job 38:31): After a lengthy debate with Job and his friends, God emphasizes his sovereignty in creating and maintaining the world, asking Job if he has ever had God's experience or authority:

> Canst thou bind the cluster of the Pleiades, Or loose the bands of Orion?

In a different vein, to the Chimu Indians of Peru, Epsilon, the central Belt star, was a criminal being held by the arms by two celestial guards (Delta and Zeta Orionis). There they await the Moon goddess to punish the criminal by tossing his body to the four vultures (Alpha, Beta, Gamma, and Kappa Orionis) who will devour him: these stars served as a perpetual reminder to all of the penalty awaiting anyone who follows a life of crime.

Imagine all this attention to the Belt stars, yet no one realized that they belong to an open star cluster until Swedish graduate student Per Arne Collinder listed it as the 70th such object in his 1931 doctoral dissertation "On structural properties of open galactic clusters and their spatial distribution." Collinder 70 contains



100 members that thread across, or loop around, the three Belt star like a giant serpent. The view is most pronounced in binoculars, which shows some 70 stars at a glance.

I liken the binocular view to the historic Serpentine Column – an ancient bronze column at the Hippodrome of Constantinople (now Istanbul, Turkey). In his *History of the Decline and Fall of the Roman Empire*, Edward Gibbon describes the column as "the bodies of three serpents twisted into one pillar of brass. Their triple heads had once supported the golden tripod which, after the defeat of Xerxes, was consecrated in the temple of Apollo at Delphi, by the victorious Greeks."

In true physical extent, this stellar column spans 50 light-years of space. Now lower your binoculars and look at Rigel. All the cluster members lie in the same region of space as this blue supergiant (860 light-years distant). In fact, the three bright Belt stars are all hot giant stars. All are destined to die in a fiery supernova explosion at some unknown date in the future. Let's look at the three Belt stars now in more detail.

Mintaka (915 light-years) is a B-type giant 90,000 times more luminous than the Sun and 20 times more massive; it's also a spectroscopic double, having an O-type companion of similar luminosity and mass. The stars orbit one another every 5.73 days and share a common center of gravity. As the stars orbit, they slightly eclipse each other, causing the "single" star we see with our eyes to vary in brightness by a mere 0.2 magnitude. But if you look at the star with even the smallest of telescopes, you'll see the pale white primary has a bluish 7th-magnitude visual companion only about 1′ due north.

In 1904, German astronomer Johannes Hartmann (1855–1936) at Potsdam Observatory found stationary calcium absorption lines in the star's spectrum. Since these lines did not share in the periodic displacements of other spectral lines caused by Mintaka's orbital motion, Hartmann deduced that the calcium line belonged to an intervening absorbing cloud. This discovery helped prove the existence of interstellar matter – the thin but pervasive veil of interstellar gas and dust out of which new stars are born; when stars die, they recycle some of their material back into the interstellar medium. What I find most fitting in Hartmann's discovery is that it involves a star central to the Mayan creation myth.

Alnilam (1,374 light-years) is a B-type supergiant 40 times more massive than our Sun. The star produces mighty winds that flow at speeds up to 2,000 km/sec, while radiating prodigious amounts of ultraviolet light (375,000 solar luminosities) from its 25,000 kelvin surface. The circumstellar environment is so hot that it illuminates a dim and diffuse swath of interstellar gas (reflection nebula NGC 1990, discovered by William Herschel in 1786). This gas is but an enhancement of a much larger cloud of gas and dust that surrounds the entire constellation.

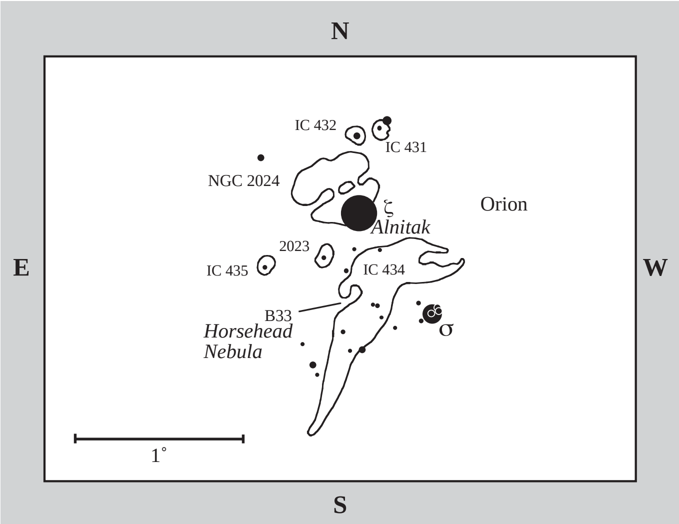
You can spend some time looking for NGC 1990, but beware, while some images show the nebula, many skilled observers using sizable telescopes have been frustrated in their attempts to nab it. Thus, some have doubts as to whether the nebula can be seen at all. Some have argued that Herschel and others (like his son John who even measured it, suggesting that it extends at least 12 arcminutes north and south of Epsilon Orionis) must have been fooled into believing they had seen something there (even though, coincidentally, it exists). The problem is that the nebula lies within the "glare" of the star, which can be enhanced with the slightest amount of moisture or dew on the telescope objective (a moist breath on the eyepiece), or dust or other pollutants in the atmosphere. I've tried with the 5-inch without success, but that's just me. Others have claimed success. Perhaps it comes down to what Hal Corwin, director of the NGC/IC Project (www.ngcic.org) wrote in November 2006: "I think that we need to get out with big reflectors similar to the Herschels' telescopes and really examine these stars in dark skies. I'd be interested in seeing what the extended star images look like under these conditions, and especially why some stars misled the 19th century guys while most did not."

Alnitak (800 light-years) is another hot O-type blue supergiant – the brightest O-type star in the sky. To the eye, Alnitak is 20 times more massive, and 10,000 times more luminous, than the Sun; to a bee, who can see in the ultraviolet region of the spectrum, the star's light would appear 100,000 times solar. As University of Illinois astronomer James Kaler touts, "A planet like the Earth would have to be 300 times farther from Alnitak than Earth is from the Sun (8 times Pluto's distance) for life like ours to survive." And though Alnitak may be about about 6 million years "young" (as opposed to the Sun's 4.6 billion year age), it has already begun to die. Its fate will be to swell into a red giant like Betelgeuse in the shoulder of Orion, and suffer a cataclysmic explosion as a supernova.

Alnitak travels through space with a hot, B-type 5th-magnitude companion 2.6″ to the southeast; few seem to agree on the companion's color. William Henry Smyth saw it as "light purple." William Tyler Olcott said it is "blue." But in 1836, F. G. Willhelm Struve invented a lovely name for it: *olivacea subrubicunda*, meaning "slightly reddish olive." Another "companion," though most likely not a true physical member, is a 9.5-magnitude star 57″ to the northeast.

The region around Alnitak is remarkable as well, containing several dusty clouds of interstellar gas, including the famed "Horsehead Nebula" to the south, and NGC 2024 (Hidden Treasure 34) just 15′ to the northeast. If you are under a dark sky, look at Alnitak with keen averted vision (cover the star with the edge of a distant object, like a roof or tree limb, if necessary). Can you see the nebula without optical aid? In binoculars? In 10 × 50 binoculars, it's a pale, sepulchral glow (the ghost of Alnitak) that could easily be mistaken for an optical reflection. NGC 2024 is an HII region some 1,300 light-years distant. It is part of one of the closest sites of recent and massive star formation. Energetic photons from young stars strip the surrounding hydrogen atoms of their electrons, causing the gas in the visible nebula to glow. And though you cannot see it, NGC 2024 contains an embedded cluster of stars 300,000 years young.

By the way, the low-power field surrounding Alnitak has several other smaller reflection and emission nebulosities: IC 432, IC 431, NGC 2023, IC 435, and IC 434 (which includes the dark Horsehead Nebula). They are plotted on page 109, but described in detail in my *Deep-Sky*



All are part of the Orion OB1 Association, which includes many of the stars in Orion.

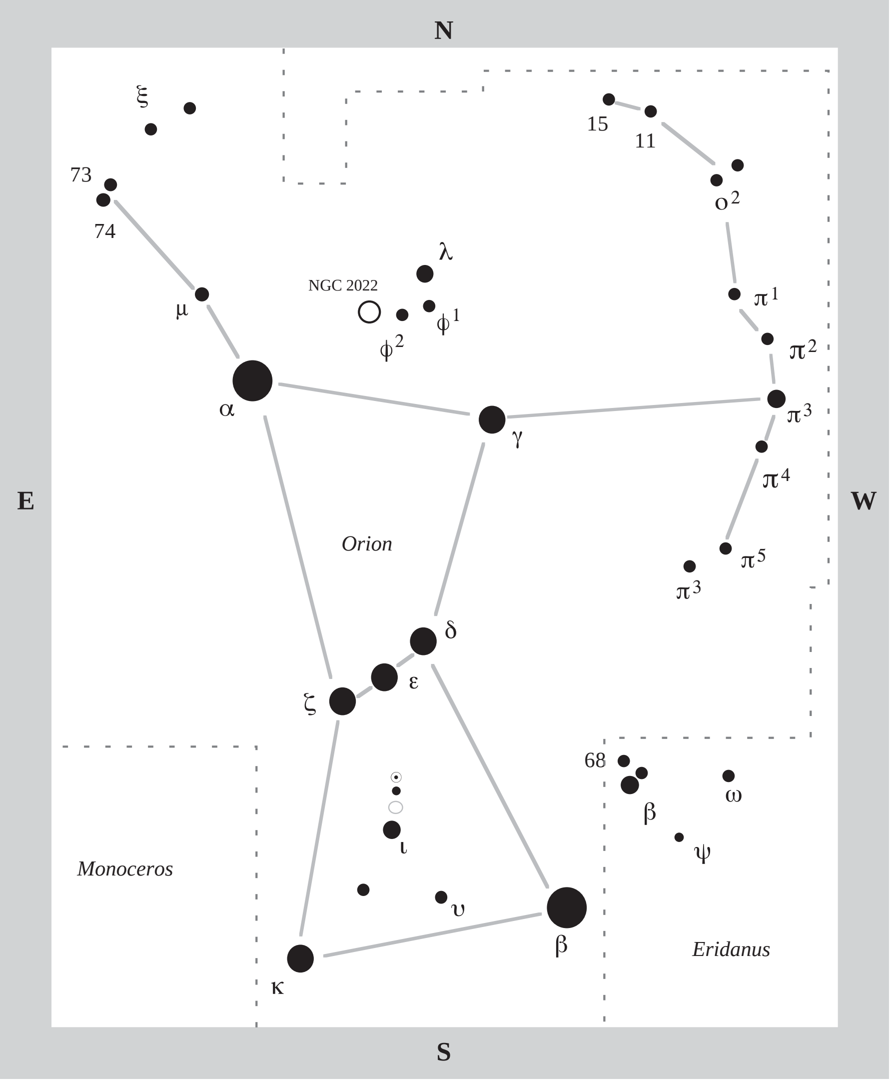
Finally, how can I not at least mention the fact that from Collinder 70 hangs the illustrious Sword of Orion, which contains a wealth of deep-sky treasures, including M42, the Great Orion Nebula – an enormous cloud of fluorescent gas 40 light-years in diameter and some 1,500 light-years distant.

Companions: Hidden Treasures book (Cambridge University Press, 2007). Also, what about Sigma Orionis about 50′ southwest of Alnitak. It's a stunning multiple star system even in a small telescope, but it's not a part of Collinder 70. In fact, it's a star cluster of its own – the Sigma Orionis cluster, 1,150 light-years distant. It's composed of four members (a tight quartet), which are responsible for illuminating the nebula surrounding the Horsehead.

As I write in my *Observing the Night Sky with Binoculars* (Cambridge University Press, 2008): "Few sights in the night sky excite beginners more than being able to detect this, the most glorious of all nebulae, without optical aid. Its beauty and glory is justly magnified in binoculars and telescopes, which also reveal its little companion nebula, M43, kissing it to the north and the famous Trapezium star cluster at its core." Enjoy!

25

Secret Deep 25
(NGC 2022)



25

Kissing Crescents Nebula
NGC 2022
Type: Planetary Nebula
Con: Orion

RA: $05^h\ 42.1^m$
Dec: $+9°\ 05'$
Mag: 11.9 (Rating: 3.5)
Dim: $22'' \times 17''$
Dist: ~7,600 l.y.
Disc: William Herschel, 1785

W. HERSCHEL: [Observed December 28, 1785] Considerably bright, nearly round, like a star with a large diameter, like an ill-defined planetary nebula. (H IV-34)

NGC: Planetary, pretty bright, very small, very little extended.

SOMETIME IN THE MID TO LATE 1970s, the famous visual nova hunter Peter Collins introduced me to NGC 2022. Although I can't recall the exact date, I do recall that winter experience. We were using the 9-inch f/12 Clark refractor at Harvard College Observatory in Cambridge, Massachusetts. At the time, I had been concentrating most of my time to studying the planets, though I had a keen interest in many aspects of visual astronomy, including the deep-sky.

On this night, Peter had come to the dome excited to show me this planetary nebula, which shone dimly in the nape of Orion's neck. Sometimes seeing planetary nebulae from a city can present a challenge to observers. But NGC 2022 was, to my surprise, quite obvious. Its tiny annulus shined forth like a moist and narrow loop of light.

NGC 2022's true shape is a prolate spheroid (like an American football) surrounded by an almost spherical, fainter shell of matter. Like NGC 1535 (Hidden Treasure 24) in Eridanus, NGC 2022 is a planetary nebula in a rather early evolutionary phase, so it has a high surface brightness. We see two main structures: The most obvious is an inner annulus tilted about 45° to our line of sight toward positional angle 30° in the sky; the other is a fainter, almost spherical shell of matter expanding at a lower rate than the inner ring. The nebula's mean ionized mass (whose emission lines are dominated by neutral hydrogen) equals 0.2 Sun, and its magnitude 14.8 pre-white-dwarf central star has a surface temperature of 100,000 K.

The nebula formed from an asymptotic giant branch star that loses mass at quite a strong rate (10^{-5} to 10^{-6} solar masses per year) and at a low velocity (5–10 km/sec). When the star begins its fast evolution toward the left of the HR diagram, it ejects a mass of gas of 0.1 to 0.5 Sun with a range of velocity from zero up to 50 km/sec. The outer parts of this gas interact with the former ejected wind. The gas glows as ultraviolet light from the hot central star excites it.

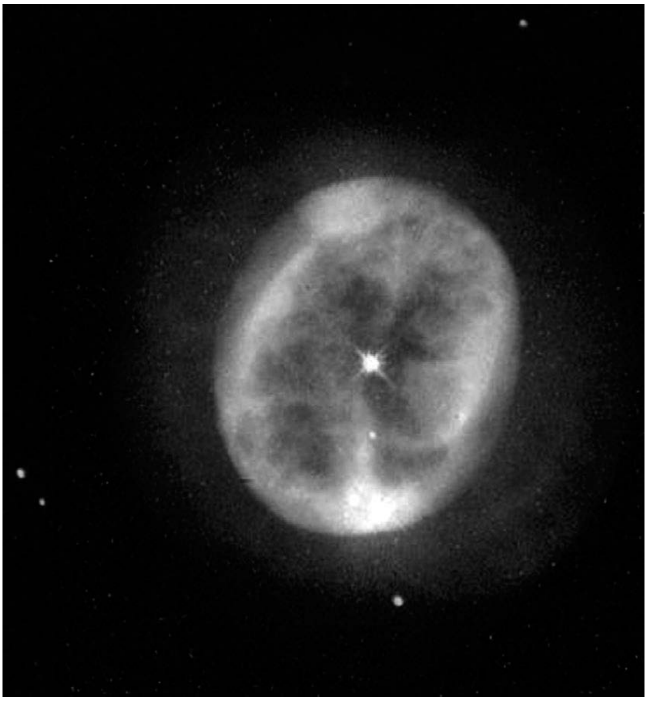
In the early evolutionary phases, the nebula has a high surface brightness and the interaction region is external to the ionized part of the nebula, and this is the stage in which we see NGC 2022. In time, NGC 2022's density will decrease and the radius of its ionized region will extend outward toward the dusty shell surrounding it, causing the nebula to shine with a lower surface brightness.

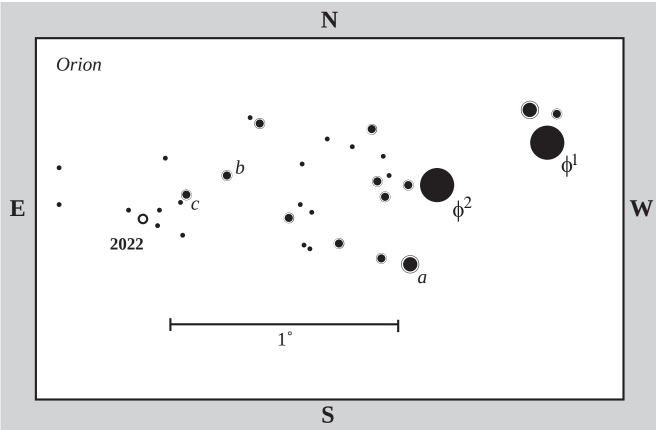
NGC 2002's inner annulus, the one most obvious in backyard telescopes, measures 22″ × 17″; at an approximate distance of 7,600 light-years; the ring's true physical extent, then, is 0.8 × 0.6 light-year. The dim outer shell measures about 28″ across or 1 light-year. If you look carefully at the HST image at right, you'll see that the inner ring's brightest sections appear at the ansae of the major axis.

HST principle investigator Howard Bond (Space Telescope Science Institute) notes that such bright rims have the expected sheet-like attributes of a bubble-driven snowplow, meaning that as fast wind from the central star expands, it sweeps up the cooler gas like a snowplow.

Planetary nebula expert Sun Kwok (then at the University of Calgary) says that these "'interacting-winds' have become the standard model of planetary nebulae formation, and have led to a new understanding of the dynamical evolution of planetary nebulae as well as the origin of their different morphologies." Bond adds that the HST image of NGC 2022 shows that the snowplowed sheets are rather thick and have easily resolved rims with a sharp leading edge.

To find NGC 2022, use the chart on page 110 to locate 3rd-magnitude Lambda (λ) Orionis and its two 4th-magnitude attendants – Phi^1 (ϕ^1) and Phi^2 (ϕ^2) Orionis. Center Phi^2 in your telescope, then switch to the chart on page 113. From





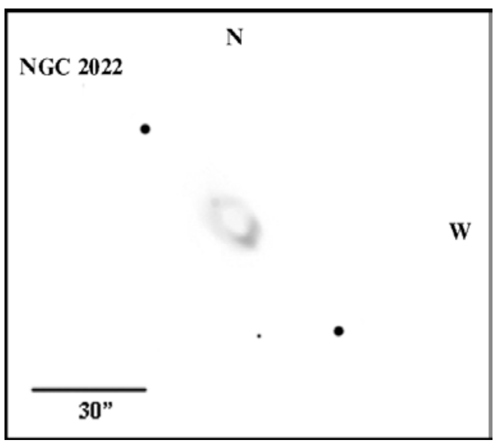
against the sky background. The nebula displays a bright disk that remains highly condensed. With concentration, I believe I can start to detect definition – namely a brighter core with fuzzy edges. I find that all powers just tease the eye until I get to about 282×, when the annulus pops clearly into view with averted vision. I see two crescents with sharp inner edges joining to create the ring, thus my nickname for the planetary: the Kissing Crescents Nebula.

Phi², move 20′ south-southeast to 6th-magnitude Star *a*. Now, head northeast and follow the roughly 50′-long chain of 8th- to 9th-magnitude stars that ends at Star *b*. Just 10′ southeast of Star *b* you'll find a nice pair of stars: 7.5-magnitude Star *c* and a 9th-magnitude companion to the southeast. NGC 2022 lies about 10′ further to the southeast.

At 33× in the 5-inch, NGC 2022 is virtually stellar, even with averted vision. It shines as a solitary 12th-magnitude sun in a line of 12th- and 13th-magnitude stars; it blends in with its surroundings well and can easily be passed over. So don't be fooled. Use the chart here to pinpoint its exact location. Once you're certain of its position, see if you can't see it swell just ever so slightly. Remember to use averted vision, and give it time. I really enjoy trying to detect planetaries at low power; it's like trying to coax your eyes to see a white rabbit in the snow. At 60×, the nebula is a very small, pale gray, and highly noticeable disk, nicely condensed; it truly looks like a distant gas-giant planet.

Increasing the magnification to 94× causes the nebula to stand out boldly

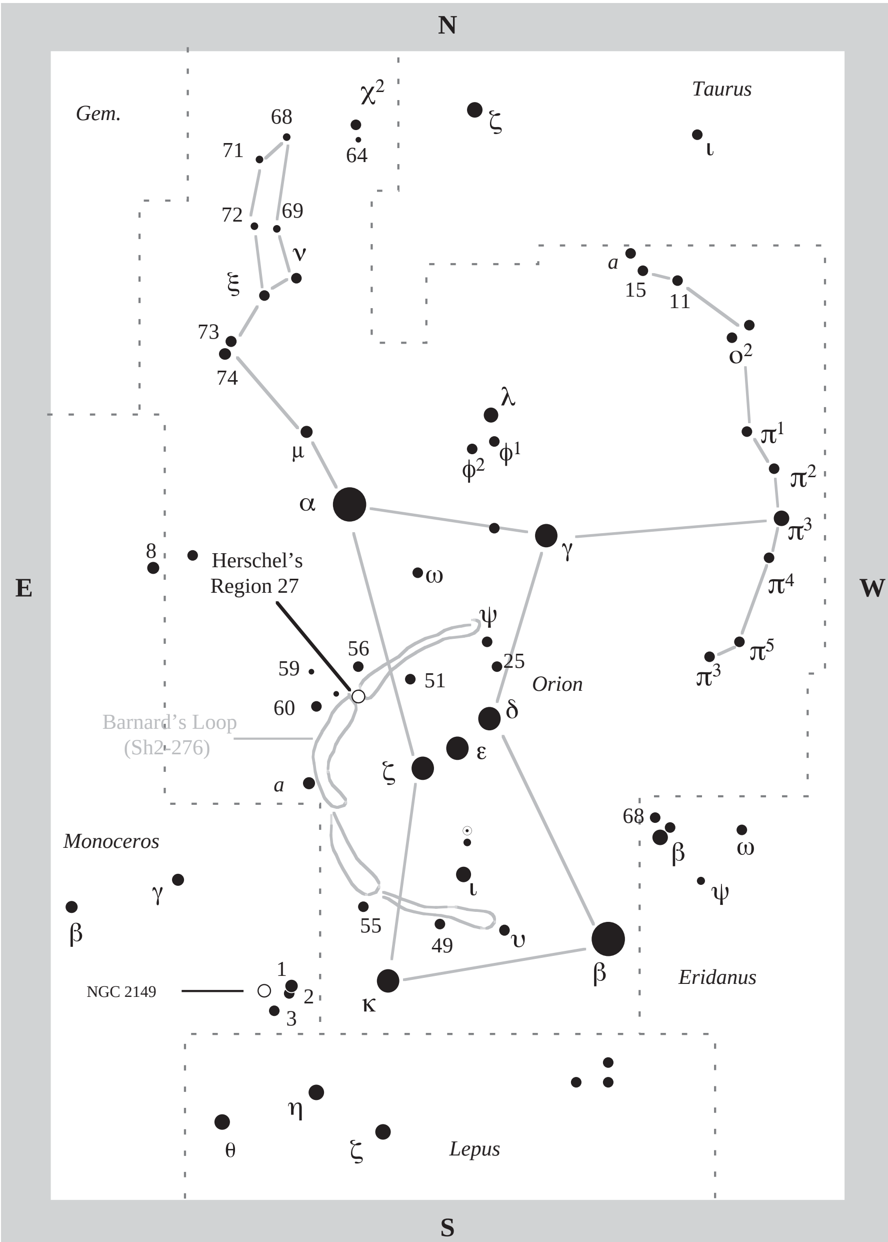
Just as HST and other images show, the nebula certainly is brighter around the ansae of the major axis (oriented northeast–southwest). This causes the minor axis, oriented northwest–southeast, to appear dimmer. The southwestern end is particularly brighter than the northeastern end and has a beaded appearance. John Herschel (1792–1871) also noted a beaded texture, describing the nebula as "rather oval, and perhaps a mottled light." On that note, Admiral William Henry Smyth said



that John's "power of vision [was] beyond what my means afforded." Smyth employed a 6-inch refractor to observe the nebula, which he found "small and pale, but very distinct." Perhaps he wasn't using enough magnification.

Smyth did, however, see NGC 2022's disk tinted bluish white – a color also noted by Rev. Thomas W. Webb in his *Celestial Objects for Common Telescopes* (Dover Publications, Inc., New York, 1962). Planetary nebulae often appear greenish (sometimes bluish) because of an abundance of ionized oxygen [OIII], which radiates in the green part of the visible spectrum. What do you see?

Secret Deep 26a
(Herschel's Region 27)



26

Part of Barnard's Loop
Sh2-276 (brightest segment) =
Herschel's Region 27
Type: Supernova Remnant
Con: Orion

RA: 05^h 52.5^m
Dec: $+00°$ $45'$
Mag: –
Dim: $90' \times 30'$
Dist: ~1,600 l.y.
Disc: William Herschel, 1786

W. HERSCHEL: [Observed February 22, 1786]. I am pretty sure the following space is affected with milky nebulosity.

NGC: None.

WHEN I BEGAN TAKING COLOR photographs of the constellations in the 1970s, a weakly glowing stream of red light, arcing nearly 15° along the eastern side of Orion's Belt and Sword, caught my eye. At first I thought it was caused by a film defect or a light leak in my camera. Later I learned its identity: the emission nebula Sharpless 2-276, more commonly known as Barnard's Loop.

In wide-field photographs, especially in long exposures taken in red light, the Loop looks like the wing of a celestial snow angel made with Orion's right arm and leg. Actually, it's a giant ($600' \times 300'$) swath of ionized gas with a mass of about 100,000 Suns. It was probably produced by the explosion(s) of one or more supernovae some 5 to 6 million years ago – the only such remnant visible to the unaided eye. The nebula's expansion (10 to 25 km/sec) is also being driven by strong stellar winds from the Orion I OB Association, of which the famous Orion Nebula (M42) is a major part; M42 also lies at the heart of the Loop.

In a 1992 *Journal of Soviet Astronomy* (vol. 36, p. 246A), E. A. Abramenkov and V. V. Krymkin (Radio Astronomy Institute, Ukrainian Academy of Sciences) explain that various opinions have been advanced about the mechanism that excites the emission of Sharpless 2-276. In early papers, the Loop's ionization was explained by either the collision with interstellar gas or cosmic and X-ray bombardment. But modern observations disagree. It's now believed that excitation by hot stars in the OB association causes Sh2-276's thermal emission, whose radiation is scattered by the dust component and emitted intensely by the nebula in the ultraviolet. The nebula's non-thermal component, on the other hand, is typical of those from supernova remnants, which may be due to a compression of the region's interstellar magnetic field induced by the explosion's shock wave.

The Loop's visibility to the unaided eye was, for a long time, a matter of interesting debate, and I will discuss this later. But the Secret Deep object you're after is the brightest telescopic region of the Loop, known as Herschel Region 27.

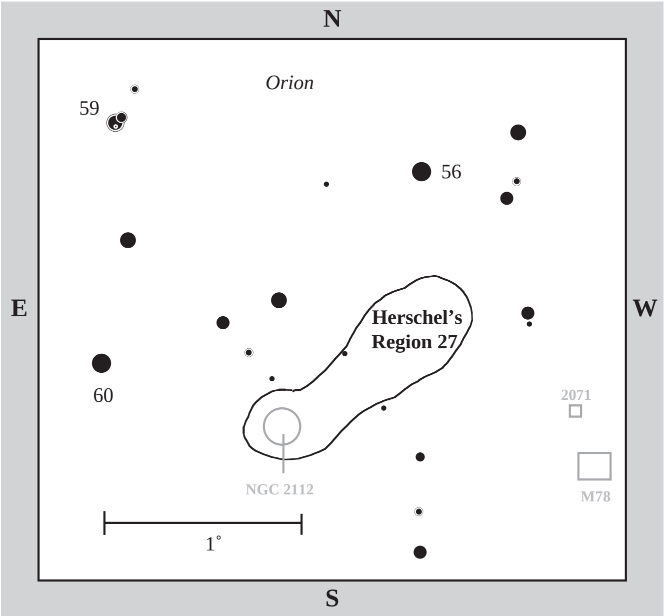
Despite the Loop's popular name (Barnard's Loop), the legendary visual observer and photographic genius Edward Emerson Barnard (1857–1923) was not the first to discover it. The nebula's history is, in fact, shrouded in "ignorance" – not in a derogatory sense, but in the sense of "not knowing." The story is one best told backwards, beginning with Barnard.

In his 1995 book, *The Immortal Fire Within: The Life and Work of Edward Emerson Barnard* (Cambridge University Press), William Sheehan describes how, in October 1894, Barnard used a very small magic lantern lens (1.5 inches in diameter and 3.5 inches focus) attached to the Crocker Telescope mounting at Lick Observatory in Southern California to make wide-field exposures that took in nearly the entire constellation of Orion. On those images, he noticed a "great nebula extending in a curved form over the entire body of Orion."

At the time, Barnard was unaware that Harvard astronomer William Henry Pickering had already imaged it five years earlier from nearby Mount Wilson, using a Voigtlander portrait lens of 2.6 inches aperture and 8.6 inches focus.

Barnard acknowledges this in a 1903 *Astrophysical Journal* article (vol. 17, p. 77) titled "Diffused nebulosities in the heavens." He also reveals that on one of his photographs, "Most of the great curved nebula is clearly shown, especially [region 27] described by Herschel."

"Region 27" is one of several areas of the sky that the great *visual* astronomer William Herschel listed as being "affected with milky nebulosity." The table on page 116 gives the region's central position, which lies about 30′ south of the midpoint between the 5th-magnitude stars 56 and 51 Orionis. So while the Loop may be rightly called either Pickering's or Barnard's Loop, Herschel definitely was the first human known to spy a segment of it



visually. Barnard extolled the wonder of Herschel's region 27 as seen in his photographs, touting it as "really the brightest portion of one of the most extraordinary nebulae in the sky."

But not all astronomers were convinced. The renowned English photographer Isaac Roberts, for instance, tried to image Herschel's milky nebulosity in region 27 (as well as 51 other nebulous regions described by Herschel) with a 20-inch reflector and 5-inch Cooke Portrait lens. His 90-minute exposures failed to show any trace of these supposed glows in all but four regions – region 27 not being among them.

In his 1903 paper, Barnard immediately addressed this issue: "Dr. Roberts' negative results are so sweeping in character that it is highly important that anything tending to prove the existence of any of these questioned regions of nebulosity should be brought forward at once."

Barnard went on to argue that Roberts' exposures were too short (imagine that, considering how modern-day astronomers can achieve success with CCD cameras in a matter of seconds), adding, "It is a little unreasonable to suppose that Herschel, who made so few blunders compared with the wonderful and varied work that he accomplished, should be so palpably mistaken in forty-eight out of fifty-two observations of this kind."

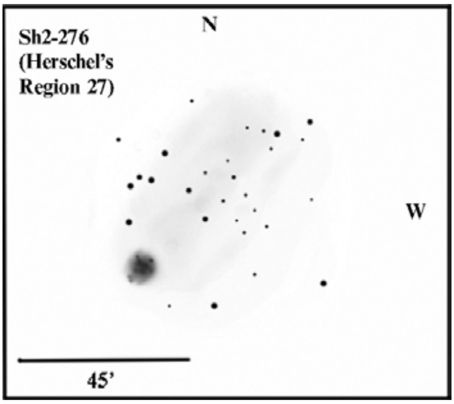
Indeed, Barnard notes that his images show the nebula in region 27, exactly where Herschel had recorded it. In a final verbal thrust, Barnard notes, "Dr. Roberts failed to get any traces of the exterior nebulosities of the *Pleiades*, which have been shown by four observers with four different instruments not only to exist, but to be not at all difficult objects."

This debate mirrored many similar arguments in the coming years as to what any given observer could, or could not, see through a telescope, using photography as the sole judge and jury. Some astronomers apparently had so much faith in photography (especially during its infancy) that they were blinded by its imperfections, putting absolute trust in what we now know was an inherently fallible medium – one limited by the technology of the day, especially the insensitivity of old photographic emulsions to faint, diffuse light.

Curiously, Barnard, the greatest visual observer of his day, someone who had discovered the large and dim California Nebula in Perseus, among other awesome visual feats, did not try to detect visually the nebula in Herschel's region 27. Had the great observer sold his soul to the new promise of astrophotography, while retaining a healthy respect for the power of the eye?

In *The Immortal Fire Within*, Sheehan argues that Barnard largely gave up his visual observations of nebulae after he started making wide-angle photographs with the Willard lens at Lick Observatory in 1889. The lens gave a 20° field of view and had tremendous potential for celestial photography. "I think he realized," Sheehan explains, "that photography was so much more discerning as a medium for making out these objects. I suppose that the dry-plate photography had about the same impact on nebular studies as CCD imaging has had on planetary studies today – to the point where very few observers bother to make visual observations any longer."

Today, sighting the nebula in Herschel's region 27 is not tremendously difficult – if



you have access to a dark sky, and especially if you employ an ultra-high-contrast filter. Again, I'm asking you to see the brightest part of this Great Curved Nebula (the name that Barnard bestowed upon it), which was discovered visually, not photographically. It runs from a point about 1¼° due east of 5th-magnitude 60 Orionis, near the 9th-magnitude open star cluster NGC 2112, to a point about 1¾° southwest of 56 Orionis. So its long axis is oriented northwest to southeast, with a midpoint about 30′ northwest of open cluster NGC 2112, which is 18′ in greatest extent and has about 50 stars 10th-magnitude and fainter.

The nebula's glow is quite substantial, measuring 1½° in length and about 30′ wide (the exact dimensions of what you see will vary on the night, your instument's aperture, and the magnification used). The greater the aperture and the lower the power, the more you will see, again, especially with a UHC filter. The dimensions are larger than those of the Veil supernovae remnants in Cygnus and a bit smaller than those of the California Nebula in Perseus, all of which are large visual wonders.

I know of many successful attempts to see the brightest section of the nebula in Herschel's region 27. I was most impressed with its appearance in my Tele Vue 4-inch f/5 Genesis refractor at 23×, the view of which was more enhanced than that through my 5-inch at 33×. That increase of 10× in the 5-inch was enough to spread the nebula's dim light across a greater area, making it a bit more difficult to detect.

It's a subtle glow that is best seen with a slow and generous sweep – much in the way that Herschel discovered it. As Robert L. Gregory informs us in his 1966 book *Eye and Brain: The Psychology of Seeing* (McGraw-Hill Book Co., New York, Toronto), part of the function of eye movement is to sweep the image over the receptors, "to signal to the brain the presence of the image." Herschel, like other observers of his day, employed this technique. "I used every means of ascertaining [these nebulae]," Herschel says, "by motion of the telescope."

Start your search by sweeping slowly from 60 Orionis toward M78. As you move the tube toward the nebulosity, align your eye so that the incoming light sweeps across the long axis of the eye. As you approach the nebula, the background sky should become a little bit brighter (the presence of the nebula), then fade again as you move away from it. It's a sensation very similar to crossing a highway lit by starlight surrounded by dark grasslands.

In fact, the method you use to see Herschel's nebula through a telescope is very similar to the method experienced observers use to detect the dim zodiacal band with the unaided eye, namely by sweeping the head back and forth across the target region, all the while looking for a dim band of light. You can also try gently tapping the telescope tube; which sets the field in a rocking motion, thus sweeping the nebula back and forth across the retina. (Remember to align your eye with the axis of motion.)

Seeing this large and ghostly veil against stars on the outskirts of the galactic plane is an acquired skill. It takes time and patience, and repeated efforts on dark nights of varying transparencies. Once you see the glow, though, its form becomes more and more apparent with time as your eye–brain system becomes more and more familiar with the view. You're looking for something large and diffuse – a ghostly corridor of elusive vapors some four times as long as, and just as wide as, the apparent diameter of the full Moon.

With the passage of time, I thought I could see actual ribbons of nebulosity. In other words, the view was not that of a large and dim glow but of a frayed fabric. See if you can justify seeing these details in your own eye and mind. I could also detect faint traces of nebulosity in the more northwestern regions of Herschel's region 27, but the number of bright stars in this region is greater, and tracing out the glow is more difficult because of the stellar distractions. It is still substantial, however, in photographs and CCD images.

THE NAKED-EYE LOOP

Although it's not part of the Secret Deep list, seeing the entire Barnard's Loop without optical aid has long been a fun and exciting challenge, testing the visual mettle of even the most skilled observers. Admittedly, sightings of it (or at least parts of it) through UHC and H-beta filters have become commonplace to downright simple; it's one of the advantages of living in a world filled with technological wonders.

Dave Riddle of northern Florida explains how the north part of the Loop is a well-known naked-eye H-beta object. "My previous attempts to follow the nebula southward with an H-beta filter revealed nothing and I had pretty much written off the object as 'photographic only,'" he says. "When I spotted a large bright glow *without* the filter in the position of the Southern Loop, I initially was puzzled by what I was seeing and thought it must be one of the weakly illuminated dark nebulae that mottle this area of Orion." But a follow-up observation revealed to him that he had indeed sighted the Loop's southern extension. "I could trace the entire nebula that curves westward near 53 Orionis (Kappa)," he says, "and ends just eastward of Rigel." He also found the "curve" west of Kappa particularly well defined in his Tele Vue Pronto telescope at 16× with a UHC filter.

I've found the eastern and southern segments of the Loop not that difficult to see without optical aid under dark skies, especially at altitudes 4,000 feet and higher. Beware, however, of Orion's False Loop – a 10°-wide semicircle of light that follows a coincidental curve of nine 4.5- to 5th-magnitude suns. Its northern segment begins at Psi (ψ) Orionis, which is about 4° north of Delta (δ) Orionis (Mintaka), the westernmost star in Orion's Belt. It then arcs northeastward through Omega (ω) Orionis, then southeastward through 56 and 60 Orionis, before dipping almost 3½° south to Star *a*. The far southern extension travels through 49 and Upsilon (υ) Orionis just south of the Sword.

With averted vision, these stars appear as a fuzzy beaded necklace owing to the "etcetera principle": Under low light level situations such as stargazing, our eye–brain system not only likes to play "connect the dots" (in an attempt to create familiar patterns), but also fill in the blanks; in this case, causing us to see a fuzzy loop.

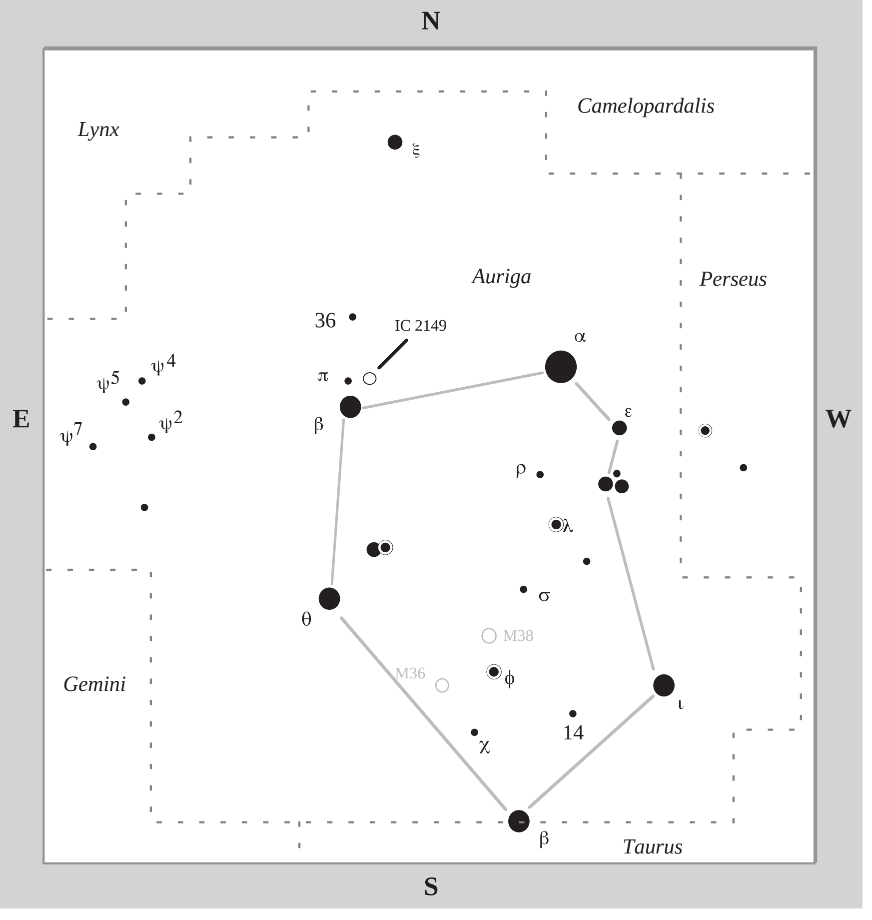
To see the true nebulosity, try tackling it bit by bit. Start with Herschel's region 27 (about 1° south of 56 Orionis) and its south-southeastern extension (which ends about ½° west of Star *a*). If you have trouble seeing it, try this averted vision trick: Look at Omega Orionis but focus your attention on the region of sky between 56 and 51 Orionis. You can also try directing your attention at the point halfway between Psi and 56 Orionis, or, better yet, alternate between the two views. If you suspect something, sweep your direct gaze from 51 Orionis to 2nd-magnitude Zeta (ζ) Orionis (Alnitak), while using your averted vision to seek out the region of the Loop extending toward Star *a*. Now focus on a point above Orion's Sword but concentrate on the region between Star *a* and 55 Orionis.

The Loop's most difficult region in the south lies midway between 2nd-magnitude Kappa (κ) Orionis (Saiph) and 0-magnitude Beta (β) Orionis (Rigel). Seeing this thin wisp of light requires not only patience and rhythmic breathing, but also perhaps the advantage of altitude; it also helps to extend your fingers to block these two bright stars.

As Riddle said, the northern segment of the arc is an H-beta object. I have never convinced myself that I've seen the glow between Omega and Psi Orionis without a filter. The biggest problem is that the nebula unfortunately follows a string of dim suns between them, and it's hard to tell if the etcetera principle is not at work.

By the way, amateurs have spied sections of the western part of the supernova remnant, more formerly known as the Eridanus Bubble – a 25° area of interlocking arcs of H-alpha-emitting filaments, driven by stellar winds and supernovae. The brightest segment is NGC 1909. Once believed to be a nonexistent object, it is is now known to be coincident with IC 2118, the Witch Head Nebula in Eridanus. Riddle has spied it through apertures as small as 70-mm.

Secret Deep 27
(IC 2149)



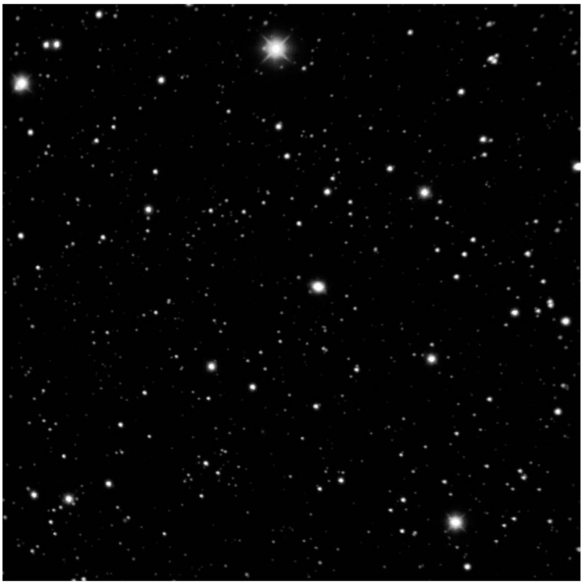
27

IC 2149
Type: Planetary Nebula
Con: Auriga

RA: 05^h 56.4^m
Dec: +46° 06′
Mag: 10.7 (Rating: 4)
Dim: 8.5″
Dist: ~3,600 l.y.
Disc: Williamina Paton Fleming, 1906

HERSCHEL: [None]

IC: Planetary, stellar.



IC 2149 IS A PECULIAR LITTLE GEM IN northeastern Auriga, near 2nd-magnitude Beta (β) Aurigae (Menkalinan) – the shoulder of the Rein-holder. This important planetary nebula was discovered in 1906 by Williamina Paton Fleming (1857–1911) – one of Harvard College Observatory's best-known woman astronomers in the world. Fleming permanently joined the observatory staff in 1881 and observatory director Edward C. Pickering soon entrusted her (and other stellar women assistants) with the monumental and fatiguing task of examining, indexing, and caring for the photographic plates in Harvard's growing collection.

While visually scanning the plates, Fleming and her coworkers not only measured the positions of thousands of stars (and compared their results against those in known catalogues), but also searched eagerly for new objects by means of their spectra. "Many departments of astronomy have been revolutionized by the application of photographic methods," touts Pickering in a 1908 *Annals of the Harvard College Observatory*, "Among them may be included the discovery of nebulae by means of their spectra."

Indeed, Fleming's discovery of IC 2149 came as she inspected plates taken with Harvard College Observatory's 8-inch f/5.5 Bache refractor, which was equipped with an objective prism to record spectra. It was during one of these scans that she noted a star in Auriga whose spectrum displayed peculiar bright lines; this object – one of 43 objects she ultimately added to the *Index Catalogue* – she listed as a "gaseous nebula," a phrase commonly used back then to describe planetary nebulae.

At the time of Fleming's discovery, the Bache refractor was no longer at Cambridge, but at Harvard's southern station in Arequipa, Peru. Interestingly, had not circumstances changed there by 1898, the discovery of IC 2149 (and many others) might not have gone to Fleming. In 1897, the hunt for variable stars and other new objects had become increasingly competitive.

As Bessie Zaban Jones and Lyle Gifford Boyd explain in their 1971 book, *The Harvard College Observatory: The First Four Directorships, 1839–1919* (Belknap Press, Cambridge, MA), Harvard astronomer Solon Bailey, who took charge of the Arequipa station in 1893, began to encourage his Peruvian assistants to scan the photographic plates before boxing and shipping them off to Cambridge. If they found a new variable or other interesting object, Bailey told them to mark it.

This practice displeased Fleming, who felt she was being deprived not only of the joy of discovery but of original discovery credit. In a letter to Bailey, Pickering raised Fleming's concern, noting that her work was now being duplicated by Bailey's assistants. "She feels that in these cases the credit goes to the Peruvian observers," Pickering said, "while a large amount of work falls upon her." But Bailey defended the practice, saying that the person who took the plate (and inspected the result) shouldn't be forbidden to note the appearance of new objects.

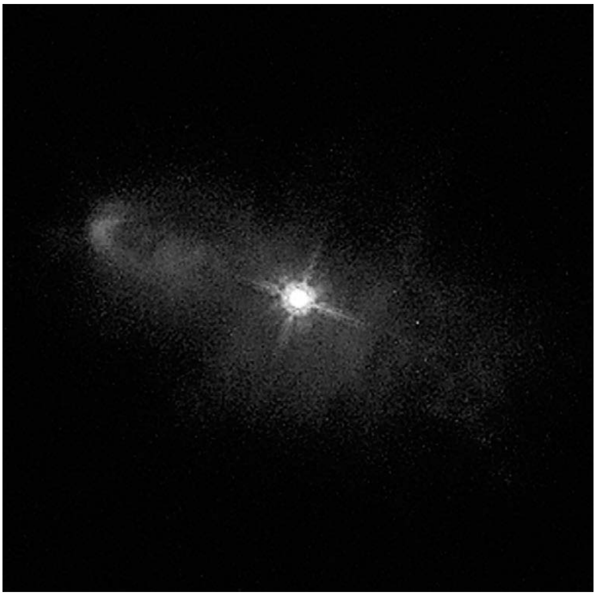
Pickering was sympathetic: "Personally, I think that the ability to make first class plates is greater than that required in the mere picking up of new objects by the assistants there… But the latter has been publicly recognized and the former seldom or never, it is perhaps not strange that an ambitious assistant should desire to try also the latter … Mrs Fleming is not the only one who has felt vexed at times."

The matter seemed to end when Bailey turned his post over to William F. Clymer in December 1897 and headed back to America; though in a letter to Clymer, Pickering made a preemptive strike: "Evidently it is for the mutual interest to avoid duplication [in the efforts of all] and there surely should be some way by which justice should be done to all." For instance, Pickering suggested to recognize in print "the assistant by whom each photograph is taken." If anyone had a problem with this, Pickering said, they could take it up with him.

In 1899 Pickering made Fleming Curator of Astronomical Photographs – the first such corporation appointment of a woman at Harvard. And in 1906, the year she discovered IC 2149, the Royal Astronomical Society elected her as an honorary member.

IC 2149 has long been an enigma among planetary nebulae, eluding clear classification until 2002. In optical images, the compact (8.5″) nebula displays a bright elongated central structure surrounded by a faint envelope. It is dominated, however, by the light of its 11.3-magnitude central star. Of spectral type O7.5, this low-mass star (~0.5 Sun) has an effective temperature of about 30,000 kelvin and a stellar wind (~1,000 km/sec) indicating a mass-loss rate of around 10^{-8} solar masses per year. The metal-poor central star (whose progenitor was about the mass of our Sun) appears to be slowly evolving and is only about 7,000 years young; this would also explain the small, highly ionized nebula around it.

Hubble Space Telescope images, as well as Earth-based imaging and spectra, have revealed important structures within the low-mass nebula (~0.03 Sun). As Mexican astronomer Roberto Vázquez (Instituto de Astronomía, UNAM, Ensenada) and his



colleagues describe in a 2002 *Astronomical Journal* (vol. 576, pp. 860–869), the nebula's bright inner ellipse is an inhomogeneous ring seen almost edge-on. Assuming that the ring is circular, it would be inclined 86° with respect to the line of sight (with the southeast half of the ring angled toward us). At an assumed distance of ~3,600 light-years, the ring's width spans some 0.2 light-year and is expanding at 24 km/sec.

Earth-based observations indicate that an elliptical (oblate ellipsoidal) shell surrounds the ring. In addition, arclike structures at the ring's ansae suggest the possible presence of faint bipolar lobes. Thus, the authors conclude, IC 2149 can be suitably classified as a bipolar planetary nebula (diabolo or hourglass type) with the main (bipolar) axis at position angle −23°.

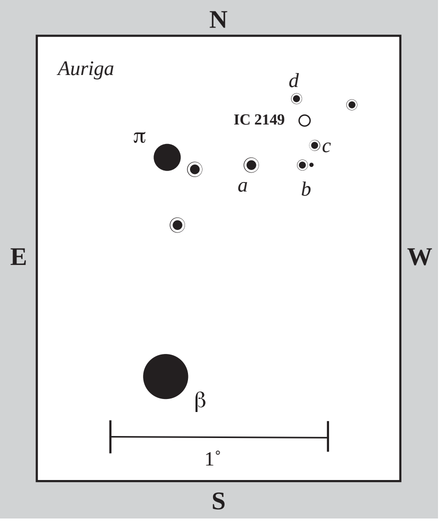
The presence of an ellipsoidal shell suggests that the nebula may still be in the process of forming and that complete bipolar lobes could develop in the future.

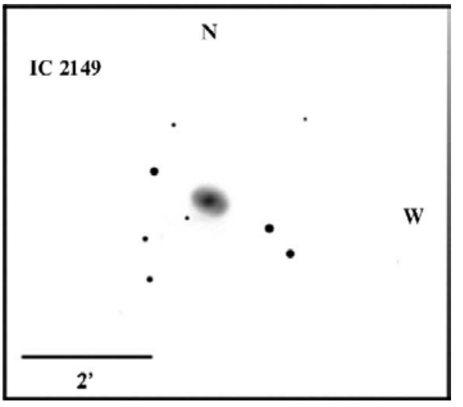
In a 2008 *Astronomy & Astrophysics* (vol. 481, p. 107), Vázquez and his colleagues note similarities between IC 2149 and NGC 6309 (see Secret Deep 77) in Ophiuchus, and also NGC 4361 (Hidden Treasure 61) in Corvus.

As for NGC 4361, both it and IC 2149 are compact and deficient in heavy elements. They also have an inner ring and bipolar lobes, though IC 2149's ring is more prominent than its lobes, while the opposite is true for NGC 4361. The central star of NGC 4361 is also considerably hotter than the central star of IC 2149. Thus these two planetaries apparently show us different stages in the final evolution of low-mass central stars, with NGC 4361 being the more evolved.

To find this tiny wonder, simply use the chart on page 123 to locate Beta (β) Aurigae and 4th-magnitude Pi (π) Aurigae, just 1° to the north. Center Pi in your telescope at low power and use the chart on page 126 to find IC 2149 only about 40′ to the west-northwest. Pi marks the eastern end of a roughly 25′ arc of three stars; you want to center the westernmost star (labeled *a*). Now look about 12′ further west for a dim pair of stars (*b*), whose components shine between magnitudes 10 and 11. About 6′ northwest is a solitary 10th-magnitude star (*c*). IC 2149 is almost 10′ to the northeast, about midway between Star *c* and another 10th-magnitude star (*d*).

At low power, you probably won't see the nebula hugging the star . . . just the star. So center that star, and get ready to use high powers. Once you're sure you've located the star, though, try to see if you





can't make the star "swell" with averted vision. I convinced myself I could at 33×. Again, since the nebula is so small (8.5″), you'll want to crank up the power. Use as much as you, and the night, can handle. The nebula is of high surface brightness, so go to the highest extreme. I found the view of the nebula (just as a glow) "comfortable" at magnifications between 165× and 180×. Double those powers and you may start to see tiny structures.

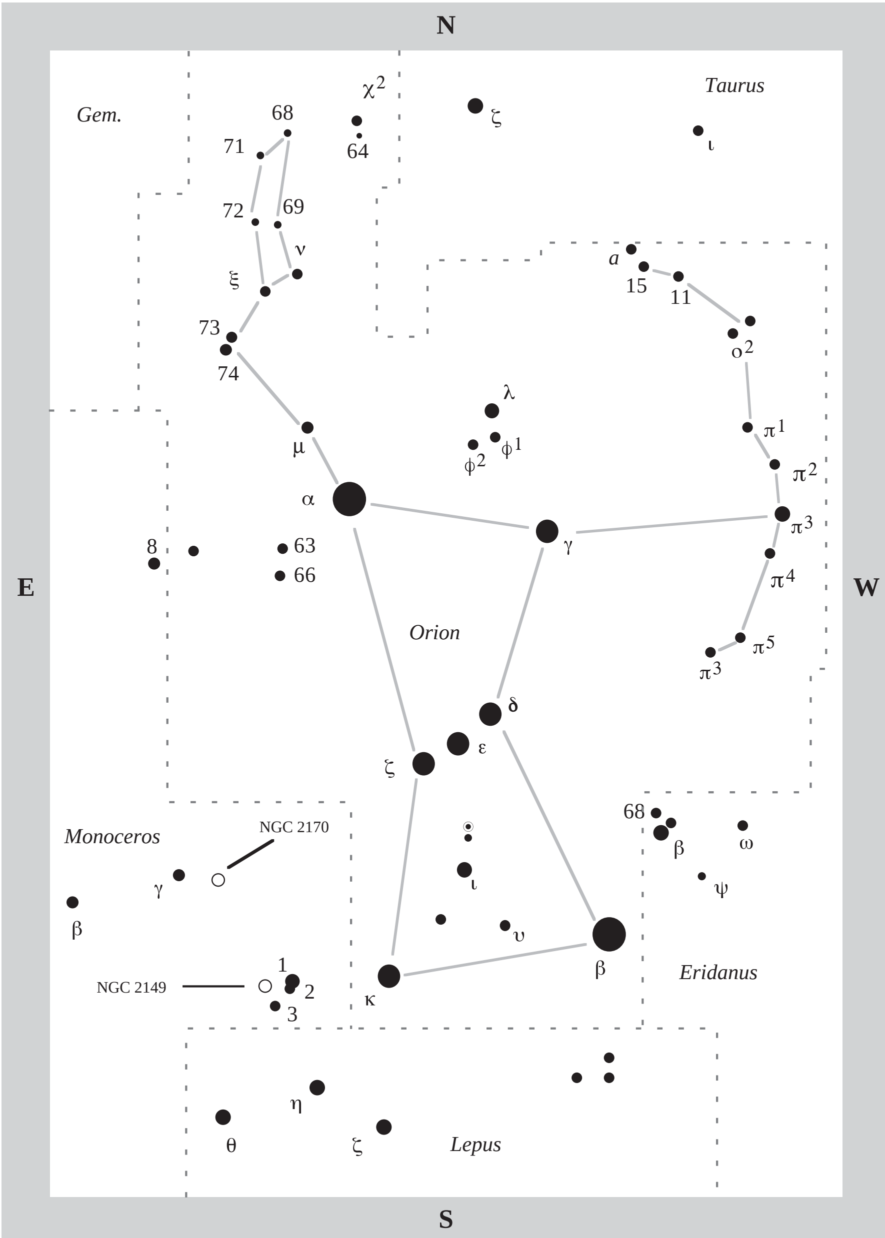
By alternating between averted and direct vision, the nebula expands and contracts (albeit minutely), respectively. An OIII filter creates a bizarre effect.

As you peer at this seemingly insignificant 11th-magnitude star surrounded by an annoyingly small and trivial bit of fuzz (perhaps even wondering why I would include such a visually lame object), consider this: In a 2008 *Monthly Notices of the Royal Astronomical Society* (vol. 386, p. 155), Klaus-Peter Schröder and Robert C. Smith compare the current appearance of IC 2149 with that of the expected final stage in the life of our Sun.

While our Sun will become a 0.3 solar mass red giant 7.6 billion years from now, the authors say, its luminosity will come short of driving a final, dust-driven superwind. No regular solar planetary nebula will form, they argue. Instead, a last thermal pulse may produce a circumstellar shell similar to, but rather smaller than, that of IC 2149. At that point, the Earth will be engulfed by the Sun's cool giant photosphere!

Does the thought of that event annoy you? How lame and insignificant do you think that moment in our Sun's life will appear to future backyard astronomers – those living on an Earth-like planet orbiting a type G2 star some 3,600 light-years distant? Would they think it a waste of time to search for such a visual trifle? In the grand scheme of things, just how significant are we? The answer may lie in your perception of IC 2149.

Secret Deep 28 & 29a
(NGC 2149 & 2170)



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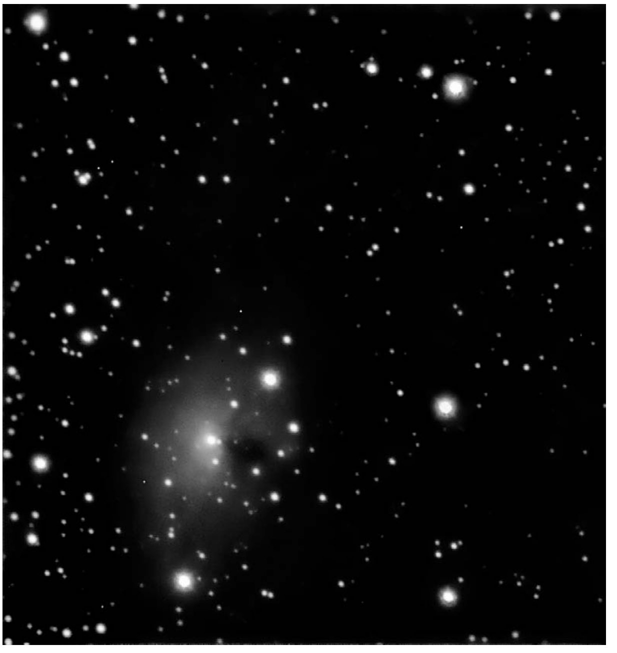


NGC 2149
Type: Reflection Nebula
Con: Monoceros

RA: $6^h\ 03.5^m$
Dec: −09° 44′
Mag: –
(Rating: 3)
Diam: 3′ × 2′
Dist: ~1,300 l.y.
Disc: Édouard Jean-Marie Stephan, 1877

HERSCHEL: NONE.

NGC: Faint, 12th-magnitude star involved.

29

NGC 2170
Type: Reflection Nebula
Con: Monoceros

RA: $6^h\ 07.5^m$
Dec: −06° 24′
Mag: – (Rating: 3)
Diam: 2′ × 2′
Dist: ~2,600 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed October 16, 1784]. A star of the 9th magnitude, with much chevelure, irregularly elliptical. (H IV-19)

NGC: Magnitude 9 star in a very faint, pretty large nebula, extended 170°.

M42, THE GREAT NEBULA IN ORION, IS the most stunning nebula visible from mid-Northern latitudes and the most popular Messier attraction. Peering into this vast and brilliant cloudscape of dust and gas, a fanciful tapestry of delicate loops and folds draped across 20 light-years of space, is a favorite pastime of many amateur astronomers on cold winter nights. But what is sometimes overlooked is that M42 lies at the heart of the much larger Orion–Monoceros complex of molecular clouds – one of the most important and best studied regions of star formation. Our next two Secret Deep targets, NGC 2149 and NGC 2170 in Monoceros, are tiny parts of that enormous structure, but have special features that may share in M42's history.

William Herschel discovered NGC 2170 in 1784, but equally bright (and I would argue more obvious) NGC 2149 somehow escaped his gaze and that of his son John. The renowned French astronomer Édouard Jean-Marie Stephan (1837–1923) first detected NGC 2149 through the 31.5-inch silvered glass reflector at Marseille Observatory, where he was director. The discovery was part of a program to seek out new nebulae, which began in vigor in 1869 and lasted until 1884 (see Secret Deep 102 (NGC 7048) for more information about Stephan's search). NGC 2149 was one of 420 nebulae he catalogued and sent to John Louis Emile Dreyer, who was collecting data for the 1888 *New General Catalogue* (NGC).

Before we look more closely at NGC 2149 and NGC 2170, it's important to "break down" the Orion–Monoceros complex into its smaller components. The Orion–Monoceros complex lies 15° below the Galactic plane toward the outer Galaxy. It serves as an excellent laboratory for studying the interaction between massive stars and the interstellar medium. Over the course of the last 12 million years the molecular clouds in the region have been shaped, compressed, and disrupted by the powerful ionizing radiation, stellar winds, and supernova explosions of the young massive stars in the Orion OB association.

The complex contains three giant (100,000 solar masses) molecular clouds (Orion A, Orion B, and Mon R2 (to which NGC 2170 belongs)), two long filaments, which extend approximately 10° from the cloud complex to the Galactic plane, and numerous smaller molecular clouds (of which NGC 2149 is an example).

In a 2009 *Astrophysical Journal* (vol. 694, p. 1423), Hsu-Tai Lee and W. P. Chen (National Central University, Taiwan) say that most of the molecular clouds in the complex are located on the border of the Orion–Eridanus Superbubble. This large cavity in the interstellar medium was created by at least six or seven supernova explosions that have occurred in the past 5 to 10 million years, the combined energy of which has blown the bubble out to a diameter of about 1,000 light-years. The Superbubble is still expanding at about 20 km/sec (13 miles per second), comparable to the speed of an expanding shock wave from a powerful nuclear blast.

The supernovae responsible belong to the same OB association – in this case the Orion OB1 association, which includes young, hot stars in several famous objects: M42, M43, M78, NGC 2024 (Hidden Treasure 34), and Barnard's Loop, to name a few. The researchers note that star formation in the Orion OB1 association progresses from the oldest subgroup, Orion OB1a (the area around the Belt (see Secret Deep 24)), to 1b (which lies northwest of the Belt stars), to 1c (the region containing Orion's Sword), and 1d (a special class that separates out M42 and M43; the youngest stars of the Orion OB1 Association).

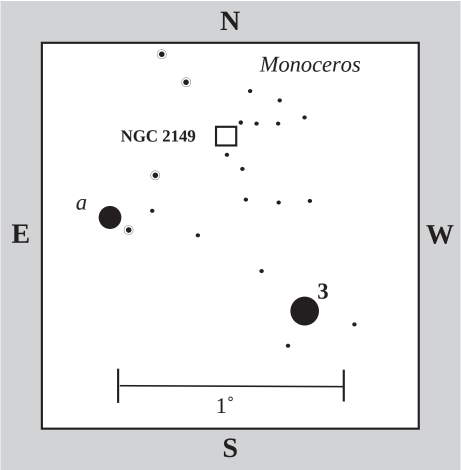
But the Superbubble, they say, also compresses and initiates starbirth in clouds such as NGC 2149 in the deep southwestern recesses of Monoceros, which is located more than 330 light-years away from the center of the Superbubble. "A superbubble appears to have potentially a long-range influence in triggering next-generation star formation in an OB association," they say, adding that they traced its effects out to 650 light-years from its core.

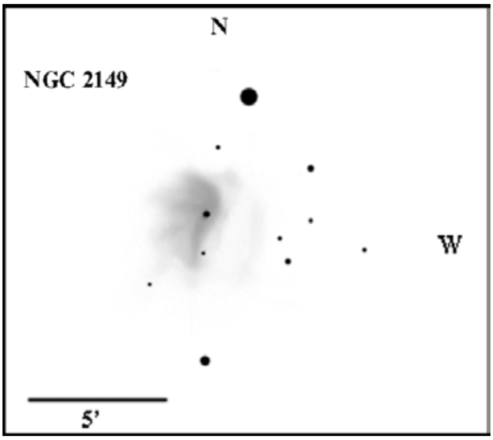
Reflection nebula NGC 2149 itself appears to be a giant expanding ring between the high longitude end of the Orion A Cloud and the Mon R2 Cloud. In most projections, these clouds appear to be unconnected. However, in a 2008 *Astronomy & Astrophysics*, B. A. Wilson (University of Bristol), Thomas M. Dame (Harvard-Smithsonian Center for Astrophysics), and colleagues say that their three-dimensional display (with velocity as the third dimension) indicates that the clouds in this region may be connected to form a ring. If NGC 2149's distance is 1,300 light-years, they note, the diameter of the ring is about 260 light-years, which corresponds to an expansion age of about 9 million years and may be the result of a supernova.

NGC 2170 on the other hand is part of the Mon R2 giant molecular cloud. Although this region is about 1,000 light-years more distant than the Orion OB1 Association, it's of similar size and mass. It's also located at the same distance below the Galactic plane and has a similar velocity gradient. "[W]hen confronted by the numerous similarities between Orion A and Mon R2," the researchers conclude, "it is difficult to avoid speculating that these clouds, and by extension all the clouds in the region, share a common origin."

Indeed Carl Heiles (University of California, Berkeley) proposed that the formation of Orion–Monoceros was associated with the expansion of the Vela Supershell, which may have originated from the open cluster Collinder 121 in Canis Major and at a distance of about 1,800 light-years. The Vela Supershell encloses an enormous irregular bubble in the region where it has blown out of the Galactic plane. John Bally (University of Colorado) proposed that the Vela Supershell first collided with a fossil remnant of the Lindblad Ring – a 30- to 60-million-year-old fossil supershell driven into the local interstellar medium by a massive OB association whose remnants are recognized as the Cas–Tau group – which then may have played a role in triggering the formation of the proto Orion–Monoceros complex.

NGC 2170 is the brightest and westernmost of several reflection and emission nebulae in the Mon R2 region about 3½° northeast of NGC 2149. In photographs, the NGC 2170 region is a visual playground – a 1°-long ghostly corridor (oriented east-northeast–west-southwest) lined with cobweb-like blue (reflection) and red (emission) glows and dark dusty threads illuminated by burning blue suns. The photo-ionizing energy and rushing winds from massive stars formed in this stellar nursery are believed to have





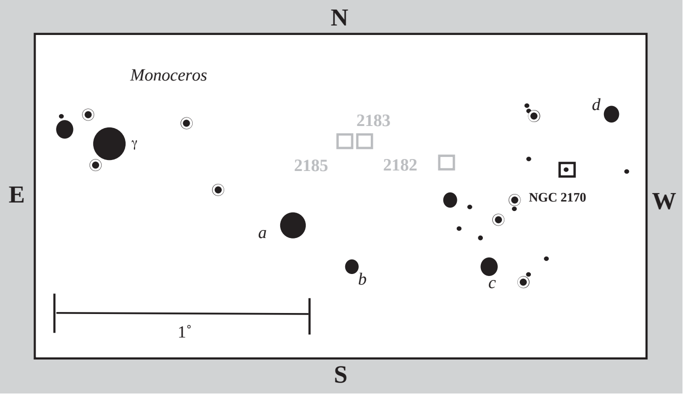
scoured and shaped the surrounding natal clouds, creating a tapestry of light and color that, though on a smaller scale, rivals the beauty of Orion Nebula.

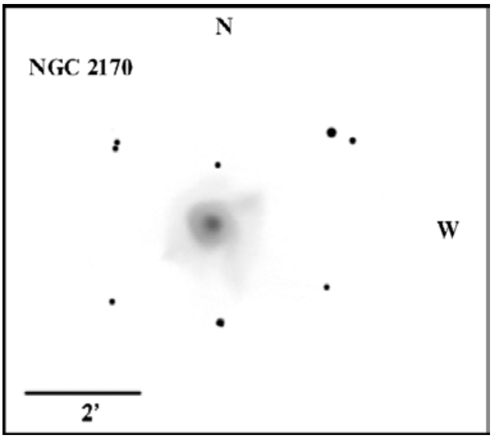
To find these intriguing wonders, begin with NGC 2149. Use the chart on page 128 to locate 2nd-magnitude Kappa (κ) Orionis (Saiph), then the roughly 5th-magnitude sun 3 Monocerotis about 3½° to the east-southeast. Now use the chart on this page to locate 6th-magnitude Star *a* about 1° east-northeast. NGC 2149 is about 40′ northwest of Star *a*.

At 33× in the 5-inch, NGC 2149 is a faint fan of light trapped between two roughly 11th-magnitude suns, oriented north-northwest–south-southeast and separated by about 5′; the nebula is a bit closer to the northern star in the pair and a tad east of the line joining them. The field is quite rich, making it a pleasing view. I find the nebula swells nicely with averted vision. At this low power, the nebula appears larger than it should owing to the richness of the field.

The view at 60× is quite different, revealing a dim central star (perhaps magnitude 12.5) in a 4′-wide glow. The star is surrounded by a patchy inner shell that's brightest to the east. This eastern side also has a fainter shell that creates the illusion of fanning; I say illusion, because, as you can see in Mario Motta's revealing photograph on page 128, the nebula sports a dark cloud on its western side, making it appear lopsided. At 94×, a dimmer sun (perhaps 13th-magnitude) lies immediately to the southwest of the central star. The eastern side of the nebula is quite pronounced and seems spiked at the northern and southern ends. The western side appears to have an arc of light surrounding the dark void. So, even though I could not distinctly see the dark cloud, it is nonetheless apparent in my drawing. When I returned to 33× and used averted vision, I suspected an even wider, fainter glow surrounding the main nebula. See what you think.

To find NGC 2170, look about 4½° to the northeast for 4.5-magnitude Gamma (γ) Monocerotis, then use the chart on page 132 to find 5th-magnitude Star *a* nearly 50′ to the west-southwest, which is paired with 6th-magnitude Star *b*, about





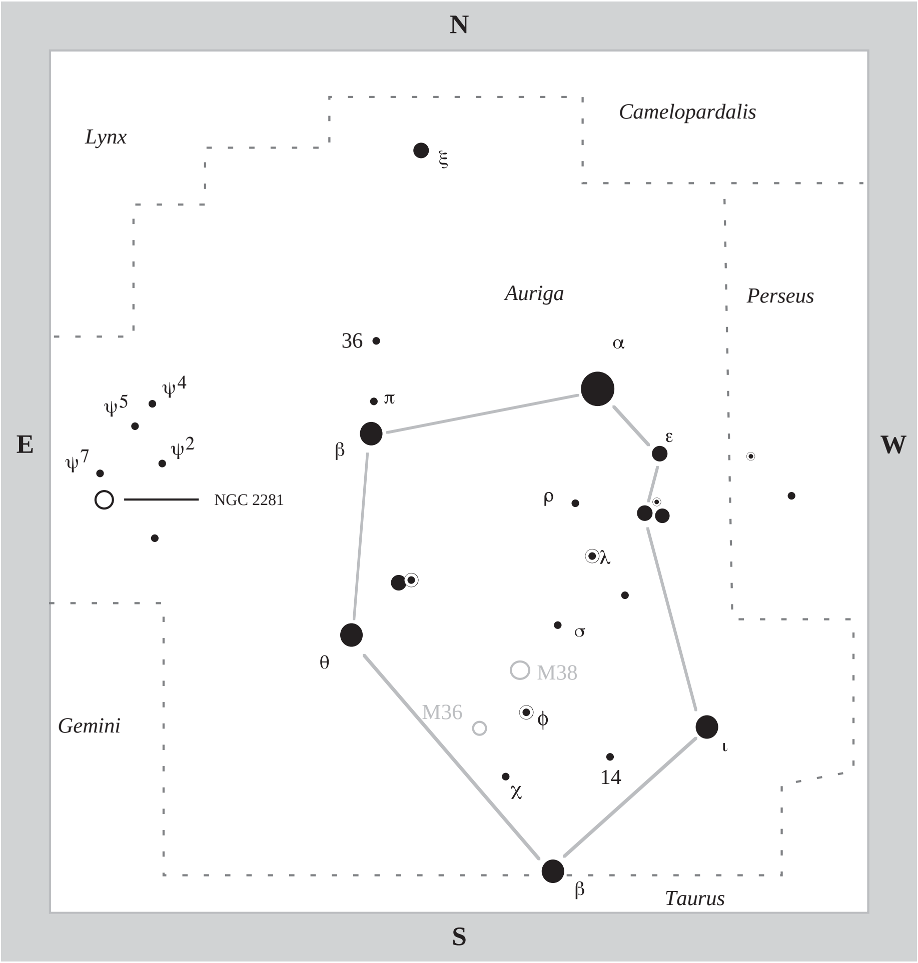
20′ to the southwest. From Star *b*, move a little more than 30′ west to 6.5-magnitude Star *c*. NGC 2170 lies a little more than 30′ to the northwest, about 12′ southeast of 6.5-magnitude Star *d*.

At 33×, NGC 2170 appears as a roughly 9th-magnitude double star, oriented northeast–southwest, with the 2′-wide circular nebulosity centered on the northeastern member. With averted vision, the nebula fades away from that star and touches (tickles) the southwestern companion, so it appears slightly elongated in that direction. At 94×, I can see a much dimmer star to the north, and wings of nebulosity stretching to the northwest and southeast. Otherwise, this nebula is one of the simplest in the heavens, and it's simply beautiful just for that.

If you feel adventurous you could look for NGC 2182, a dim reflection nebula 30′ to the east-northeast; and the fainter pair of nebulae, NGC 2183 and NGC 2185. Interestingly, while Herschel discovered NGC 2182 and NGC 2185; Heinrich d'Arrest found NGC 2183, which is only about 5′ to its west.

By the way, at a 1999 American Astronomical Society meeting in Chicago, Heiles, who discovered the Orion–Eridanus Superbubble in 1970, and a University of Wisconsin team headed by Ron Reynolds, explained how they combined infrared, optical, and X-ray observations to create the most complete picture to date of the Superbubble, which shows both its near and far walls. In one area, however, they could see no rear wall, which, in X-rays, shows gas leaking out. "This hole is like a champagne bottle just uncorked," Heiles revealed in a University of California, Berkeley, press release, "The high pressure gas inside pops out the hole with explosive force."

Secret Deep 30
(NGC 2281)



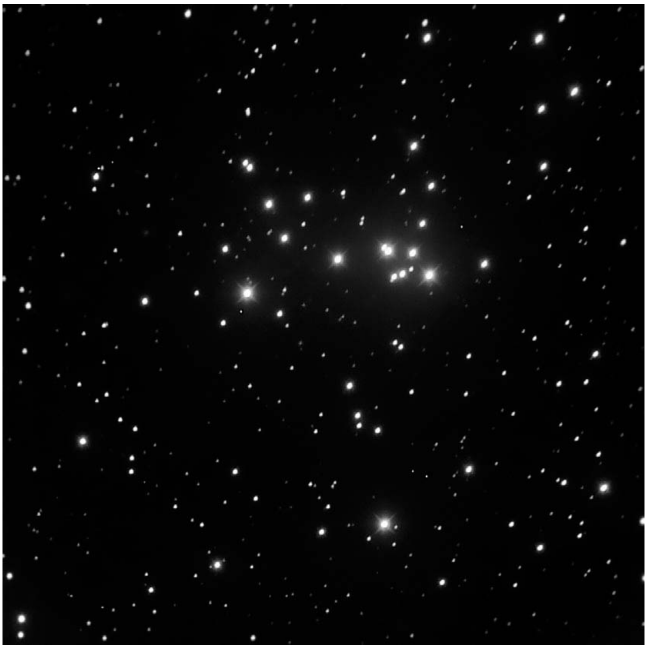
30

Broken Heart Cluster
NGC 2281
Type: Open Cluster
Con: Auriga

RA: 06^h 48.3^m
Dec: +41° 05′
Mag: 5.4
SB: 12.4 (Rating: 4)
Diam: 25′
Dist: ~1,800 l.y.
Disc: William Herschel, 1788

W. HERSCHEL: [Observed March 4, 1788] A cluster of coarsely scattered pretty [bright] stars, pretty rich, the place is that of a double star of the 3rd class [the double star is AH.II.71]. (H VIII-71)

NGC: Cluster, pretty rich, very little compressed, stars pretty [bright].



NGC 2281 IS A VERY PRETTY AND bright open star cluster in the obscure eastern reaches of Auriga the Charioteer. The late deep-sky veteran Walter Scott Houston of Connecticut noted that it is seldom observed, perhaps because of its "sideline" nature – it lies well outside the beautiful Pentagram of Auriga, which contains three stunning Messier open clusters (M36, M37, and M38). The Victorian poet Alfred, Lord Tennyson saw the Pentagram as a funerary wreath. In his dusky 1855 poem *Maud*, in which a man hopelessly tries to contact the dead, Tennyson likens Auriga at winter's end to a "glorious crown" hanging "Over Orion's grave low down in the west."

But NGC 2281, in fact, resides in one of the seven lashes of the Charioteer – a curious but ignored part of the constellation consisting of ten 5th-magnitude stars (Psi^1 (ψ^1) through Psi^{10} (ψ^{10})); I call this region Psi-clone Alley. It lies about 3/4° southwest of Psi^7. It also lies beneath the southwest quadrant of the now obsolete constellation Telescopium Herschelii (Herschel's Telescope), which celestial cartographer Johann Bode created to honor the the telescope William Herschel had used to discover the planet Uranus, as depicted in Bode's 1801 *Uranographia* atlas. As Ian Ridpath shares in his wonderful 1989 book *Star Tales*, "Bode, having bought telescopes from Herschel, knew what they looked like and he realistically depicted the 7-ft telescope with which Herschel actually made the discovery of Uranus."

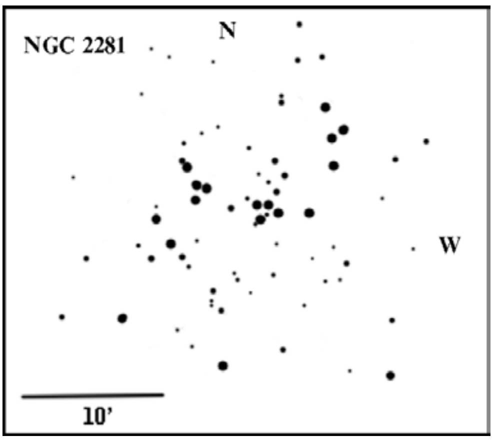
Under a dark sky, I could spy NGC 2281 in 7 × 50 binoculars, appearing as a large diffuse glow nestled between two 7th- and 8th-magnitude stars. Can you see it with the unaided eyes? What's more, both of these stars have dramatic golden hues, adding to the glory of the scene. Here is a dazzling pendant of suns hanging from an imaginary necklace anchored by two golden clasps. Trumpler listed it as a type I3m, meaning that it's a detached and moderately rich cluster with a strong concentration of bright and faint suns 8th-magnitude and fainter. In a 2004 *Astronomische Nachrichten*, Ukranian astronomer N. V. Kharchenko (Main Astronomical Observatory) lists the distance to NGC 2281 as 1,800 light-years; if we accept that value, NGC 2281 spans only 13 light-years of space. And because this interarm cluster lies on the fringe of the visible Milky Way, its stars are reddened by only 0.1 magnitude.

NGC 2281 is some 300 million years old, making it younger than the ~625 million-year-old Hyades (Caldwell 41) and older than the ~100 million-year-young Pleiades (M45). At a declination of +41° it is well placed for observations in the Northern Hemisphere, culminating after sunset in late winter.

In a 1975 *Publications of the Astronomical Society of the Pacific*, Masanori Yoshizawa (University of Kyoto, Japan) says that his photometric study of the cluster shows it to have a rather short main sequence, owing to the fact that 25 percent or more of its bright members are binary systems. The binaries in NGC 2281 are of both low and high mass and concentrate toward the cluster center more intensely than single stars. It is believed that binary stars formed at the same time as single stars in open clusters.

As with other clusters, the heaviest single stars and binary systems tend to concentrate at the core while the lighter stars tend to populate the outer periphery. Over time, stellar encounters eject individual stars, reducing their mass in the process and causing the cluster to contract. The more tightly bound binaries become at the core, the more energy they add to impart to other stars, inhibiting further contraction and offering stability to the cluster system.

To find this neglected treasure, use the chart on page 133 to locate 2nd-magnitude Beta (β) Aurigae and 2.6-magnitude Theta (θ) Aurigae. NGC 2281 forms a near-equilateral triangle with these stars to the east. You'll find the cluster about 45′ south-southwest of 5th-magnitude Psi^7 (ψ^7) Aur, which is part of a pretty, 3°-wide, Y-shaped asterism of similarly bright stars – the others being Psi^2 (ψ^2), Psi^4 (ψ^4), and Psi^5 (ψ^5) Aurigae. Confirm these stars in your binoculars, then center Psi^7 (the



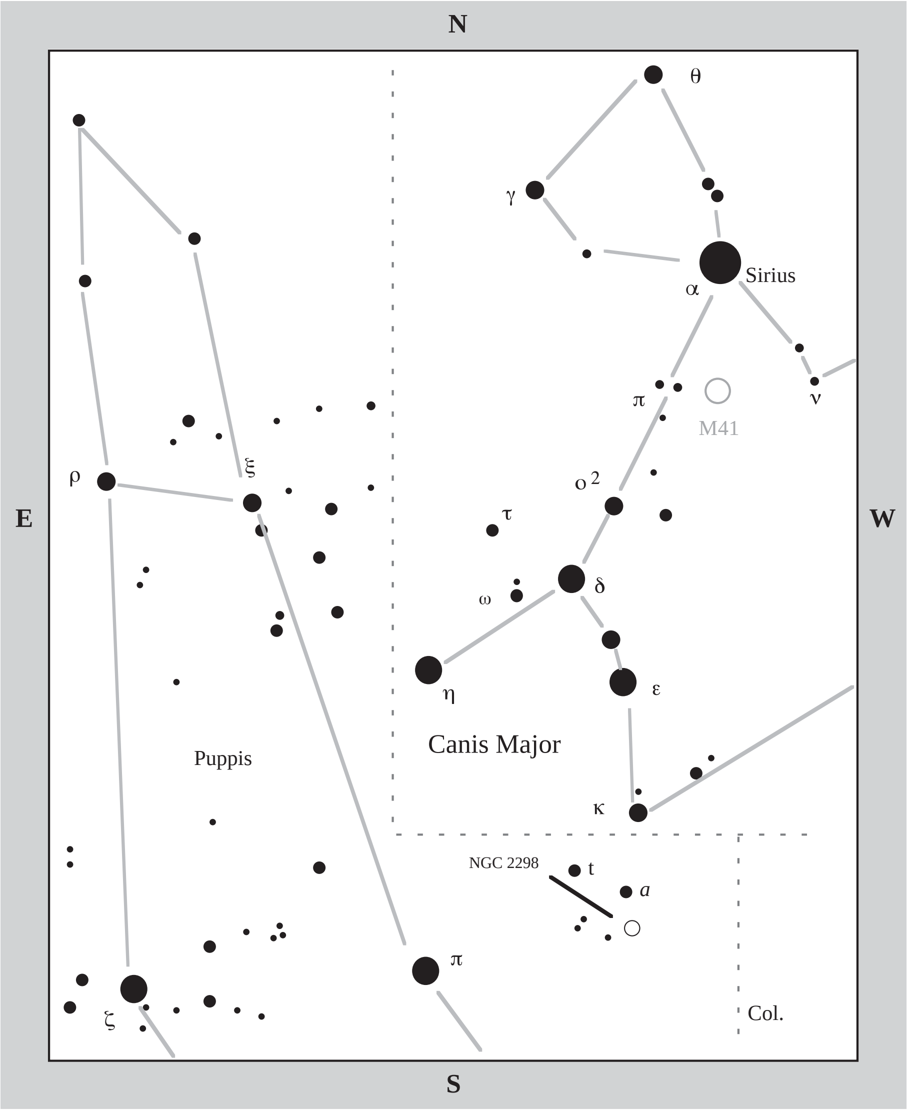
southernmost one) in your telescope at low power. Again, NGC 2281 should be easily identified some 45′ to the south-southwest.

At 33× in the 4-inch, NGC 2281 is a beautiful cluster with some three dozen irregularly bright suns radiating out from a tight, diamond-shaped asterism at the cluster's core; a tail of four stars extends to the east, before making a sharp jog to the north. These are some of the brightest stars in the cluster and together they look like a diamond-headed snake. The cluster also has loose arms extending to the south, east (beyond the snake), and north; the northern arm loops broadly to the west and south.

Overall, the cluster looks like a tortured stellar system, one that's been "stretched on the rack," in all four directions, creating gumby-like arms in the process. The surrounding Milky Way makes it difficult to judge the cluster's true extent, but don't let that stop your wandering eye from enjoying the view. NGC 2281 has about 120 members 8th-magnitude and fainter, with many of the fainter stars hovering around 13th magnitude. Again, add the golden companions nearby, and the overall view is quite stunning and bright.

The cluster is best admired at 60× and 94×, which show about 50-odd suns at a casual glance. At 60×, the stars of the central diamond stand out boldly, since they are all of near-equal magnitude. Look especially at the southeastern and northeastern members, since they're close doubles; in photographs, the southeastern star is a triple with companions getting progressively fainter to the west-northwest. The diamond is surrounded by a loose and coarse gathering of mixed suns that form various geometrical patterns. The rest is up to you to decipher, since imagination is a personal matter of opinion. The Albuquerque Astronomical Society list refers to this cluster as the Broken Heart.

Secret Deep 31
(NGC 2298)



31

NGC 2298
Globular Cluster
Con: Puppis

RA: $06^h\ 49.0^m$
Dec: −36° 00′
Mag: 9.3
SB: 12.8 (Rating: 4)
Diam: 5′
Dist: ~35,000 l.y.
Disc: James Dunlop, included in his 1828 catalogue

J. HERSCHEL: Bright, round, gradually pretty much brighter in the middle, all resolved into stars of 14th magnitude. In the centre is a star of 13th magnitude. (h 3065)

NGC: Globular cluster, bright, pretty large, irregularly round, gradually brighter toward the middle, partially resolved, some stars seen.

NGC 2298 IS A SURPRISINGLY CONdensed and obvious globular cluster tucked into the far northwestern reaches of Puppis, near the Canis Major and Columba borders. It's easily located 3° south of 3rd-magnitude Kappa (κ) Canis Majoris, the star marking a bend in the Greater Dog's most southerly leg. With a declination of −36°, it is only about 1° further south than open cluster M7 in Scorpius, the most southerly Messier object. Observers at mid-northern latitudes can best spy it at culmination, when it sits about 10° above the southern horizon.

Of course, dark skies and a southern horizon with few or no obstructions will help immensely. At more southerly latitudes across the continental United States and beyond, NGC 2298 is a gleaming little treasure among the rich star fields along the western fringes of the Milky Way, where there is little interference with dust. So our view of it is relatively clean and clear.

James Dunlop (1793–1848) discovered the little gem while surveying the southern night sky from Australia with a 9-inch f/12 reflector. He listed it as the 578th object in his 1828 *A Catalogue of Nebulae and Clusters of Stars in the Southern Hemisphere, Observed at Paramatta in New South Wales.* Of it he wrote: "A pretty bright round nebula, 3′ or 4′ diameter, moderately condensed to the centre. This is resolvable into stars."

John Herschel observed the cluster four times during his survey of the southern skies from the Cape of Good Hope, which began in 1834. A summary of these observations reveals NGC 2298 to be a small globular cluster (2.5′), irregularly round and gradually brighter toward the middle. He resolved it into stars of 14th- to 16th-magnitude "with stragglers and some large stars near."

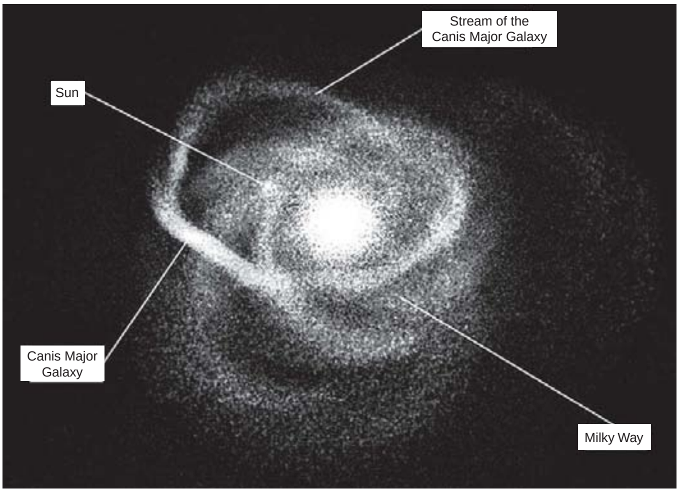
Today's astronomers recognize the importance of this tiny cluster. Of the 150-odd Galactic globular clusters known, NGC 2298 is one of the smallest, measuring only about 50 light-years across – about one-third the true linear extent of M13 in Hercules, and one-fourth the size of 47 Tucanae. The cluster resides in the inner halo at a distance of 51,000 light-years from the Galactic center. Although NGC 2298 lies almost twice as far from the Galactic center as other, better studied clusters, astronomers have obtained high-precision photometry of NGC 2298's upper main sequence. They have also used the Hubble Space Telescope to perform accurate photometry of cluster members deep in the cluster's core.

Studies of globular clusters are one of the main tools for understanding whether our Galaxy formed by merging with small satellite galaxies or after a rapid halo collapse. While the two models may not be exclusive, recent support for the mergers came from the discovery of very young clusters in the Milky Way's halo (which appear to have formed differently from the vast majority of Milky Way globulars), and also by the discovery in 1994 of the Sagittarius dwarf galaxy, which the Milky Way is swallowing. In fact, globular cluster M54 may be the Sagittarius dwarf's nucleus. Thus, not only may our Galaxy grow by cannibalizing smaller systems, but its globular cluster system may be, in part, composed of extragalactic immigrants from neighboring dwarf galaxies and proto-galactic fragments that our Milky Way accreted.

In 2003, an international team of astronomers used Two Micron All Sky Survey (2MASS) infrared data to find the dismembered corpse of yet another previously unknown galaxy being cannibalized by our Milky Way. Known as the Canis Major dwarf, its nucleus is surrounded by several Milky Way globular clusters, including NGC 2298, which belongs to the dwarf's globular cluster system. The other associated globulars may be M79 in Lepus, NGC 1851 (Caldwell 73) in Columba, and NGC 2808 in Carina.

The researchers also found long streams of stars that have apparently been gravitationally ripped away from the dwarf's main dismembered corpse during the merger. Computer simulations show that the Milky Way has been taking stars from the Canis Major dwarf and adding them to its own disk, and will continue to do so. In a 2MASS press release, Michele Bellazzini (Bologna Observatory) says, "This small galaxy is unlikely to hold together much longer. It is being pushed and pulled by the colossal gravity of our Milky Way, which has been progressively stealing its stars and pulling it apart." The illustration on page 140 shows the location of the newly discovered galaxy and its associated tidal streams in relation to our Milky Way Galaxy.

In a 2004 *Astronomical Journal* (vol. 127, pp. 3394–3398), Australian astronomer Duncan A. Forbes (Swinburne University, Hawthorn, Victoria) and his colleagues

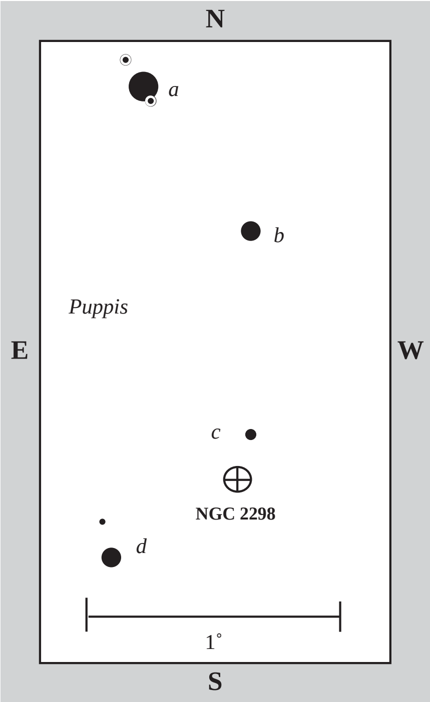


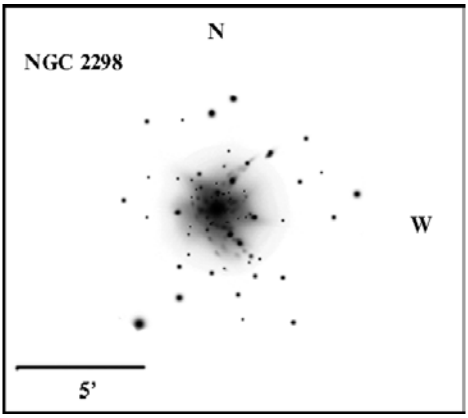
summarize their study of the Canis Major dwarf's globular cluster system, including NGC 2298. The 12.9-billion-year-old cluster is moderately metal poor, and its stars contain, on average, about 1/70 as much iron (per unit hydrogen) as does our Sun. The fact that NGC 2298 and the other Canis Major dwarf clusters are all metal poor argues against the belief that the Canis Major dwarf is a major building block of the Milky Way's thick disk – a flattened, highly rotating system in the Galactic plane with a relatively high metallicity. Instead, they are more typical of halo globular clusters.

Forbes *et al.* conclude that even when satellite accretions add globular clusters to the Milky Way's system, such additions are unlikely to contribute significantly to a thick disk or the bulge population of globular clusters. Based on studies of halo stars, it appears that only about three to seven dwarf accretions may have occurred over the Milky Way's lifetime, contributing only about 10 percent to the mass of its halo. If the Milky Way's young, metal-poor globular clusters have been accreted from as yet unidentified galaxies, then, the researchers conclude, accretion was not a major factor in building the thick stellar disk or bulge. Instead, the Galaxy and most of its globular clusters formed *in situ* after a very rapid halo collapse. But, as Forbes informed me, in 2010, "this is a fast moving field, and estimates of accreted vs. *in situ* fractions are changing all the time."

To find this fantastic treasure, use the chart on page 137 to locate Alpha (α) Canis Majoris (Sirius), then 1.5-magnitude Epsilon (ε) Canis Majoris (Adhara) in the lower leg of Canis Major, the Great Dog. Now look for 3rd-magnitude Kappa (κ) Canis Majoris about 4° to the south. Kappa forms the northwestern apex of a 2°-wide triangle with two 5.5-magnitude suns, the eastern one of which is τ Puppis. You want to center the western star in that triangle (*a*) in your telescope then switch to the chart on page 141. From Star *a*, move 40′ southwest to 7th-magnitude Star *b*. Then drop 50′ south to 8th-magnitude Star *c*. NGC 2298 is only about 12′ south-southeast of Star *c* and 35′ northwest of 6th-magnitude Star *d*.

In the 5-inch at 33×, NGC 2298 is a moderately condensed glow measuring a few arcminutes across. It lies in a hook of stars, which is part of a rich and pretty Milky Way field. The cluster just seems to burn steadily like a trusted beam of light. I could see it without difficulty with direct vision and notice structure with averted vision, namely sparkling clumps in the outer halo. At 60×, the clumps in the tight



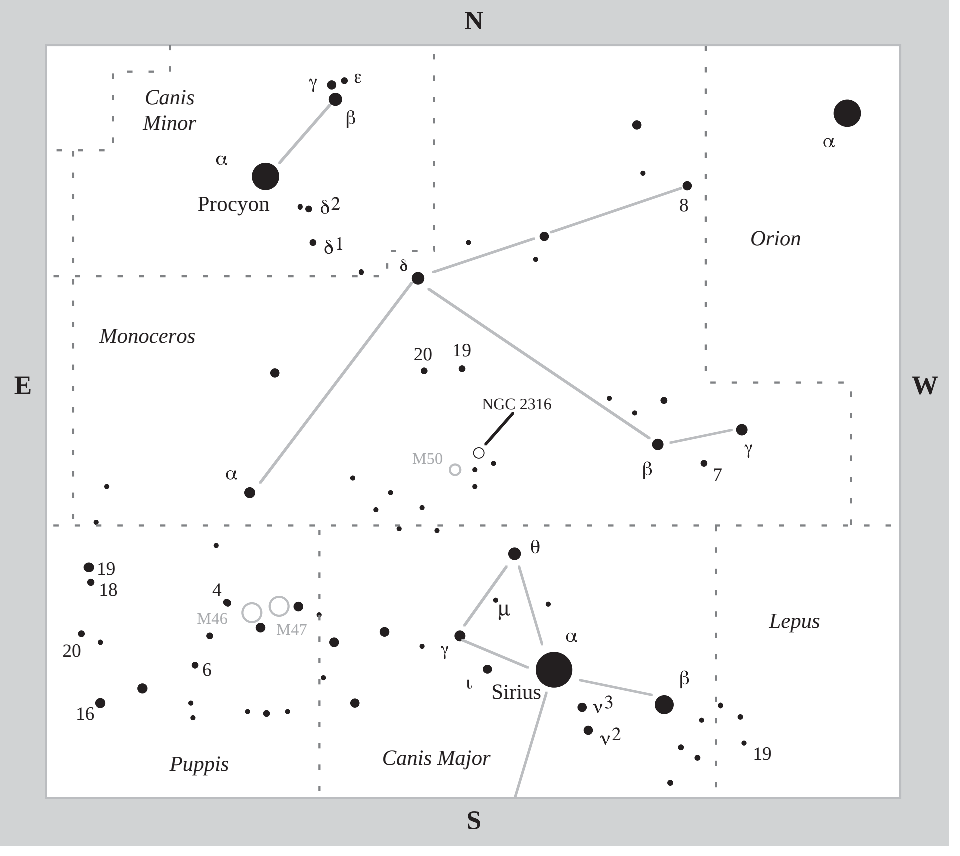


outer halo appear more prevalent, while the core itself breaks up into fine mottled patches.

At 94×, individual stars pop in and out of view in the halo, which looks irregularly round with long wispy extensions flowing to the northwest, west, and southwest; some shorter wisps also extend outward from the cluster's eastern side. Increasing the power to 165×, then to 330×, reveals two layers of starlight: a scrim of about a half-dozen obvious suns, mostly flowing to the southwest and northwest, and a fainter orb of dim suns at the threshold of visibility. Certainly observers with larger apertures should be able to resolve this cluster well; its brightest stars shine around 13th magnitude, with a horizontal branch magnitude of around 16th magnitude.

By the way, since the nucleus of the Canis Major dwarf lies only about 25,000 light-years away from the Solar System and 42,000 light-years from the Milky Way's center – or about three-quarters of the distance to the Sagittarius dwarf and a quarter of the distance to the Large Magellanic Cloud – it is now recognized as the closest known galaxy to the Milky Way. So add that fact to your astronomical trivia. And remember, when you're spying NGC 2298, you're viewing part of an extragalactic system being swallowed by the Milky Way. If you can resolve the stars of NGC 2298 through your telescope, you're resolving stars that belong to another galaxy!

Secret Deep 32
(NGC 2316)



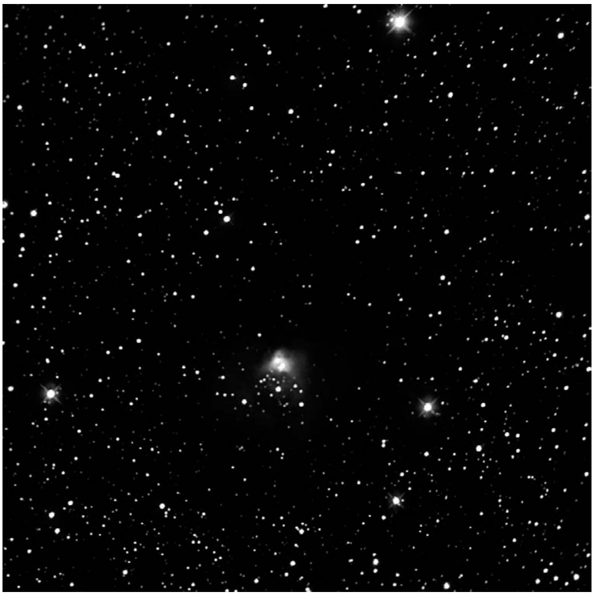
32

NGC 2316
Type: Emission/Reflection Nebula
Con: Monoceros

RA: $06^h\ 59.7^m$
Dec: $-07^\circ\ 46'$
Mag: – (Rating: 3.5)
Dim: $4' \times 3'$
Dist: ~3,300 l.y.
Disc: William Herschel, 1785

W. HERSCHEL: [Observed March 4, 1785] Some [faint] stars with pretty bright nebulosity. (H II-304)

NGC: Pretty faint, small, round, resolved, [faint] star involved.



MOST VETERAN OBSERVERS ARE WELL aware of the most observed cometary nebula in the heavens: NGC 2261 (Caldwell 46), more popularly known as Hubble's Variable Nebula, or what I call Herschel's Forgotten Fan, in Monoceros. But what some are unaware of is that Monoceros has another cometary nebula: our target, NGC 2316 (Parsamyan 18). What's more, it's only 1° northwest of M50, the brightest binocular open cluster in Monoceros just 7° north of 4th-magnitude Gamma (γ) Canis Majoris.

Although William Herschel discovered it in 1785, the Third Earl of Rosse (1800–1867) in Ireland rediscovered it in 1851, thinking, however, that it was a new object. John Louis Emil Dreyer (1852–1926) gave it a separate NGC number (2317) and positioned it about 1′ west of Herschel's nebula, noting that it makes "a close double nebula with [NGC 2316])." It's commonly believed, however, that Rosse's object is only a part of Herschel's NGC 2316.

The term "cometary nebula" is essentially an "historic relic" that describes the photographic and visual appearance of a distinctive group of nebulae: small clouds of dust and gas that resemble a comet with a stubby tail. Today, cometary nebulae are those little nebulae that not only look like a comet but are connected with a star of the T Tauri or related variable variety – very young, lightweight stars, less than 10 million years old and under three solar masses that are still embedded in their natal clouds and undergoing gravitational contraction; they represent an intermediate stage between protostars and low-mass main-sequence stars like our Sun. Some cometary nebulae display variability over time and appear bright at long-infrared wavelengths.

32

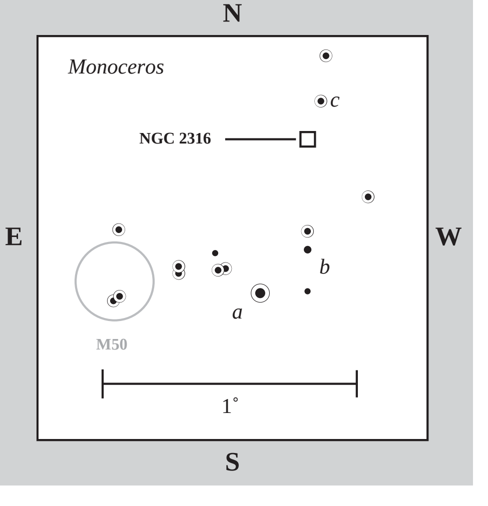
In 1965 Elma S. Parsamyan examined Palomar Sky Survey prints in a quest to discover new or little-known cometary nebulae. Of the 23 objects she identified, NGC 2316 was the 18th on her list. In a study of 19 of these, Martin Cohen (University of California, Berkeley) found only five objects that displayed significant long-wavelength radiation of at least 10 micrometers, with NGC 2316 being the reddest. Consequently, in a 1974 *Publication of the Astronomical Society of the Pacific* (vol. 86, p. 813), Cohen redefined this group of objects, placing them into four morphological subsets: (1) arcuate structures, like the incomplete ring near T Tauri; (2) conical or fan nebulae, like NGC 2261; (3) nebulous appendages, like commas (Z Canis Majoris); and (4) bicones or hourglasses.

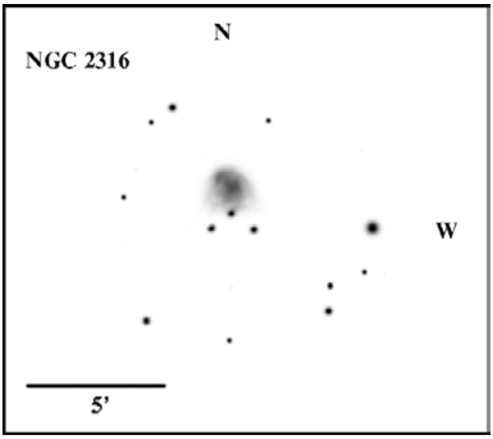
Cohen also noted that the nebulae are almost invariably associated with stars or starlike condensations, which lie in a position of geometrical significance, such as in the waist of an hourglass, or near the apex of a fan. The nebulae also have small apparent diameters, usually 2′ or less, and the definition of the visible structures is crisp and well-defined, very rarely being associated with larger swaths of surrounding nebulosity.

NGC 2316, he found, is a bright conical nebula very reminiscent of NGC 2261 near R Monocerotis. The nebulosity contains two small (~10″) condensations, the brighter one being located near the apex of the cone; this condensation has a very high infrared luminosity – between 11.3 and 18 micrometers, making it the reddest observed of any object then known to Cohen, with a color temperature close to 100 K. The nebula also envelops a small cluster of faint red stars.

In a 2008 *Astronomical Journal* (vol. 136, pp. 602–613) T. Velusamy (Jet Propulsion Laboratory) and William Langer (JPL/Caltech) describe how they used infrared data from NASA's Spitzer Space Telescope to resolve that young star cluster, which spans 4 light-years across. They found more than 200 cluster members with an age of about 2.5 million years. They identified a B3 zero-age main-sequence star as the main power source; that star is still embedded in a nearly spherical HII region (dimming it by about 4.5 magnitudes), which is being shaped and chemically altered by ultraviolet radiation emitted by this young star.

To find this little nebula, use the chart on page 142 to locate brilliant Sirius, the Alpha star of Canis Major, then look 5° east-northeast for Gamma (γ) Canis Majoris. The 6th-magnitude open cluster M50 will be 7° north of Gamma. Center that cluster in your telescope at low power, then switch to the chart on this page. From M30 move only 35′ west to 6th-magnitude Star *a*. About 10′ west of it, you'll see

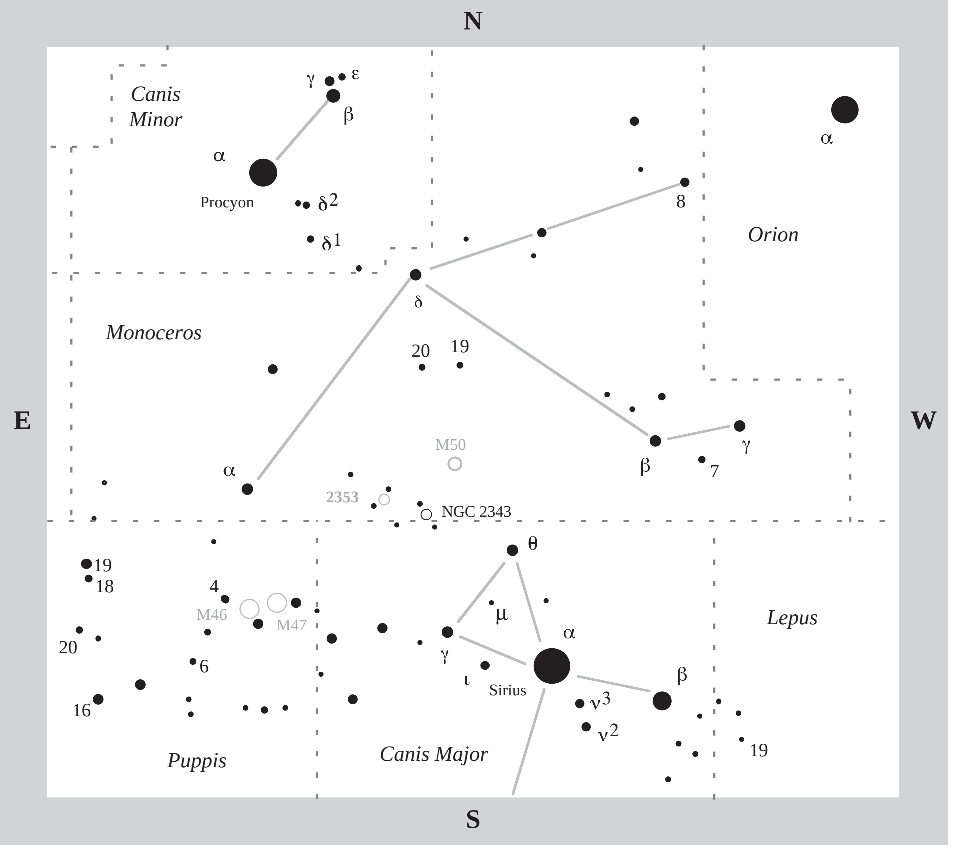




a roughly 15′-long line of three 8th- to 9th-magnitude stars (*b*). NGC 2316 is just a little more than 20′ due north of the northernmost star in that line, about 10′ south-southeast of 9th-magnitude Star *c*.

I spied the nebula at 33× in the 5-inch with averted vision. It lies within 2′ north of a little arc of three roughly 12th-magnitude stars. At this power, the arc of stars and the nebula seem to glow as one object. It takes magnification to separate them well. At all powers up to 94×, the nebula appears much the same: a highly condensed, irregularly round glow with a fainter fan of nebulosity stretching toward the arc of stars. In my scope, though, it's hard to make any definition out in the fan. Those using larger telescope should look for a delicate "bubble" of glowing gas surrounding, and centered on, the middle star in the arc – the one closest to the nebula. Those with large light buckets should strain their eyes for the dimmer arcs of nebulosity surrounding all three stars. Good luck!

Secret Deep 33
(NGC 2343)



33

Doublemint Cluster
NGC 2343
Type: Open Cluster
Con: Monoceros

RA: 07^h 08.1^m
Dec: $-10°$ 37′
Mag: 6.7
SB: 10.6 (Rating: 4)
Diam: 6.0′
Dist: ~3,400 l.y.
Disc: John Herschel

W. HERSCHEL: None.
(h 3100)

NGC: Cluster, considerably large, poor, little compressed.

NGC 2343 IS A COARSE AND FAIRLY bright open cluster about 8° northeast of dazzling Alpha (α) Canis Majoris (Sirius), the famous Dog Star. I first encountered it in November 2002, while trying to locate one of Caroline Herschel's lost deep-sky objects (NGC 2349) near the northern border of Canis Majoris and the southern border of Monoceros with my 4-inch refractor. It was one of five open clusters that grabbed my attention in the 3° field. I made the brightest and most alluring of these clusters (NGC 2353) the 40th object in my Hidden Treasures list and included it in *Deep-Sky Companions: Hidden Treasures*. But as I noted in that book, "I could have made any one of the objects a Hidden Treasure."

I encountered NGC 2343 once again as I worked on the Herschel 400 list. Now it's time for this peppery little cluster – the second brightest and most alluring cluster in the NGC 2353 area – to be further recognized. NGC 2343 lies about 1½° west-southwest of NGC 2353 and can be seen in 7 × 50 binoculars from a dark-sky site. It's also the most conspicuous of four clusters in a 1° area of sky: Collinder 465, a roughly 10th-magnitude asterism of dim suns 15′ west of NGC 2343; Collinder 466, a tiny 11th-magnitude cluster of 25 stars a little more than 10′ south-southeast of Collinder 465; and NGC 2335, another rich, 7th-magnitude cluster with 57 suns nearly 1¾° north-northwest of NGC 2343.

NGC 2343 and its four companions (but not NGC 2353) are aligned with the long curving emission nebula IC 2177, most commonly known as the Seagull Nebula, for its appearance in photographs. The

Seagull Nebula actually comprises two main parts: the Seagull's head (Robert's Nebula), and its wings (Wolf's Nebula)." (For a more detailed discussion of the Seagull Nebula and its parts see *Deep-Sky Companions: Hidden Treasures*, pp. 200–201.)

The nineteenth-century British astronomer Admiral William Henry Smyth called NGC 2343 a "double star in a loose cluster, under the Unicorn's chest. . . This is a scattered group of brightish stars, in an irregular lozenge form, and consists chiefly of three vertical rows, having four individuals each; several are of the 9th magnitude, and reddish."

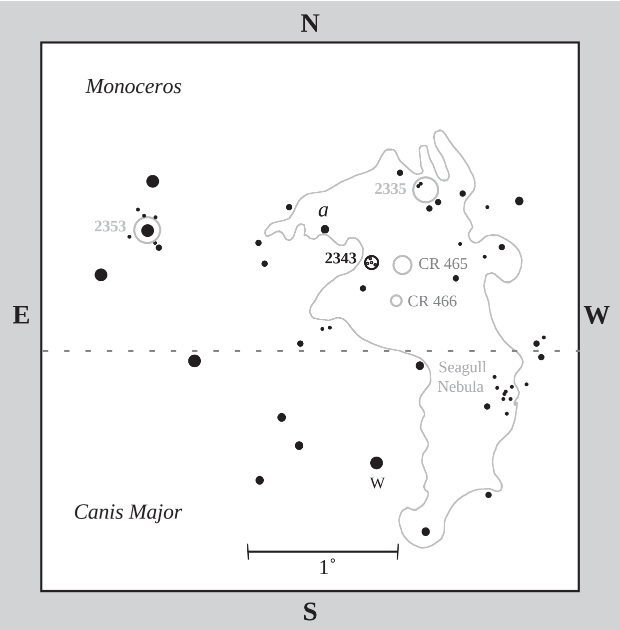
In 1930, Trumpler classified it as IIpn, meaning it's a detached and poor cluster of stars with little central concentration associated with nebulosity. The 104-million-year old cluster lies 3,400 light-years from the Sun and 65 light-years below the Galactic plane. At that distance, the cluster has a true linear extent of only 6 light-years. The cluster is poor, having some 50 members, of which one star (HD 54387) is a very possible giant member.

NGC 2343 is located in the direction of the Canis Major OB1 association – a region in the plane of the Milky Way where dust and gas are being compressed into new and massive stars. Astronomers believe the Canis Major OB1 association formed in the aftermath of a supernova explosion about 1 million years ago. This event occurred at the edge of a dense cloud of gas and dust that measured about three light-years wide and had a mass of about 1,000 Suns. Then, about 100,000 years ago, the propagating blast wave from that explosion slammed into another cloud of dust and gas, triggering star formation that continues to this day in a region known as Canis Major R1 – a lean and extremely youthful star-forming region 100 light-years in extent.

Canis Major R1 appears to follow the Seagull Nebula, which itself is part of a larger ring nebula (Sharpless 296) that includes the Seagull Nebula (the curved western portion of the ring) and the nebula LBN 1036 near NGC 2353 along the ring's eastern boundary. And though it's uncertain, this large ring of emission nebulosity may be a relatively old supernova remnant; however, it could also be an old HII region blown out by stellar wind.

In a 1986 *Soviet Astronomy* (vol. 30, p. 648) the late Tamara Borisovna Pyatunina (Institute of Applied Astronomy, St. Petersburg) and Yu M. Taraskin (Special Astrophysical Observatory, Pulkovo) note, "in all likelihood four generations of stars coexist in [the Canis Major OB1 and R1 associations]" with NGC 2343 and NGC 2335 being the oldest generation, followed by NGC 2353, then the Canis Major OB1 association, and, finally, the youngest Canis Major R1 association. "All these different stellar generations probably are not just occupying the same region but are physically related to one another, constituting separate phases of a sequential star-forming process, operating within a single complex of dust and gas."

Indeed, Pyatunina and Taraskin say that radio observations confirm that the field contains a massive molecular cloud of intricate structure. NGC 2343 also matches an extended radio feature, which they find interesting. While it could be a coincidence, the researchers argue, "while a massive young cluster containing OB stars that ionize and heat the gas would tend to

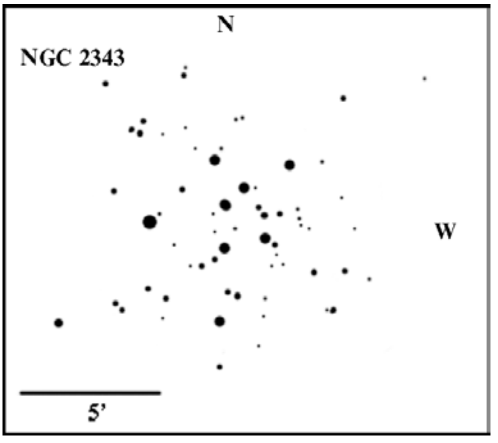


destroy the surrounding 'parent' cloud, an old cluster whose OB stars have gone through their evolution would cease to heat the ambient gas but would serve as a 'gravitational well' for it – a cell of recurrent condensation." Thus, they conclude, the ionizing gas near NGC 2343 is being drawn there from outside sources in the Canis Major OB1 association.

To find this interesting cluster, it's best to first find NGC 2353. First locate Sirius on the chart on page 146, then the two 4th-magnitude stars marking the top of the Dog's head: Gamma (γ) and Theta (θ) Canis Majoris. Fifth-magnitude Mu (μ) Canis Majoris lies midway between, and a little southwest of, those two stars. Using your binoculars, draw an imaginary line from Sirius though Mu, then extend that line about 6° to the northeast; you should encounter three 6th-magnitude stars in an arc only ¾° long and oriented north-northwest–south-southwest. The middle of these three suns is NGC 2353. Look for a 6th-magnitude star caught in a web of nebulosity – in this case, the "nebulosity" is that of unresolved starlight. Now use the chart on this page to locate NGC 2343 about 1½° to the west-southwest just 35′ southwest of 6.5-magnitude Star *a*.

At 33× in the 5-inch, NGC 2343 at first glance appears as a sparkling pyramid of starlight that consists of about a half-dozen irregularly bright suns, with a few outliers. The pyramid's brightest star is yellow 8.5-magnitude ADS 5817, which marks the pyramid's southeast corner. With averted vision, a dim, roughly 10th-magnitude sun can be seen mirroring the pyramid's apex to the south, transforming it into a diamond or a cross, with the 11th-magnitude sun being the foot of the cross.

At 60×, the cross asterism stands out prominently (more prominently than you might see in photographs). A meandering, north–south oriented, stream of faint starlight flows through the pyramid, joining the top of the cross to its foot and forming the cross's vertical beam. The star marking the cross section of the two beams is a fine wide double. A wider pair lies just to its north inside the northwest quadrant of the pyramid. A number of dim suns pop into view with averted vision to the west of that latter pair. And three dim suns form a long and graceful arc over the top of the cross, from east to west, transforming the cross and the arc into a celestial hieroglyph.



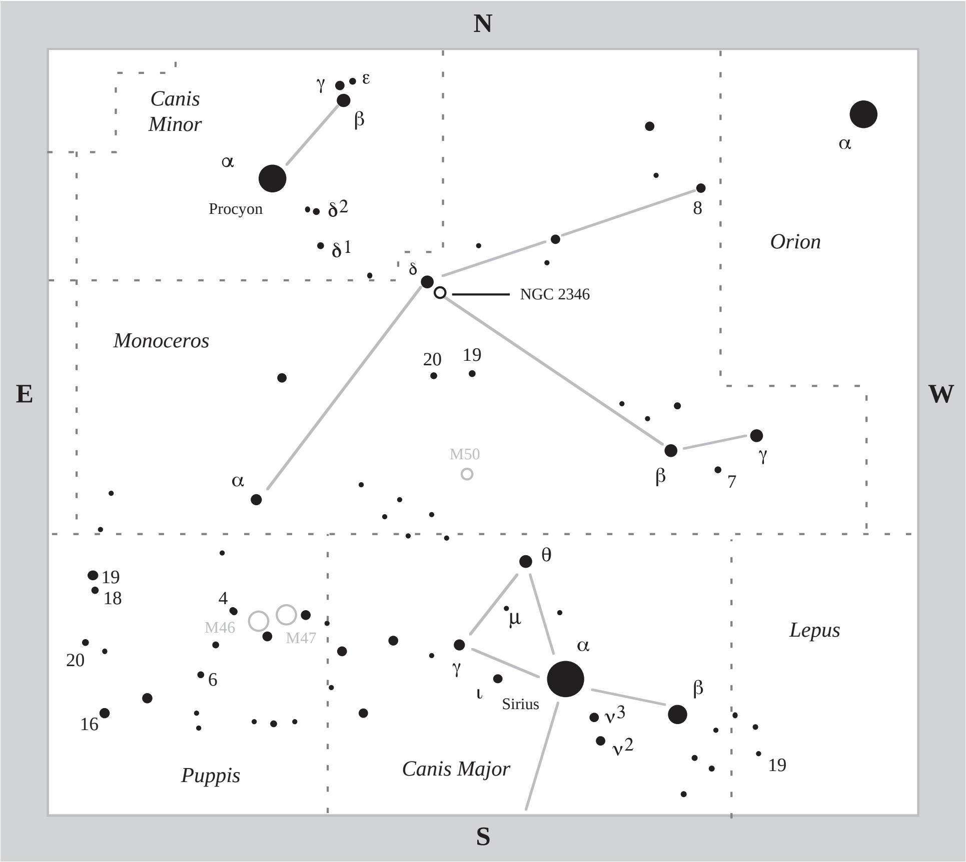
The view is glorious at 94×, when many of the single suns can now be seen as double or multiple pairs. For instance, the double star at the intersection of the cross's beams has a faint companion to the southeast. And the double star north of it has a fainter double star to its southwest with another pair of stars to its west-northwest. The longer I look the more pairs I see. (All this is magnified even more dramatically at 165×.) Most beautiful is the 11th-magnitude companion to ADS 5817, just 11′ to the northeast. Like me, Admiral Smyth saw the primary as yellow, and the secondary as "dusky."

In fact, each corner star of the pyramid is a multiple; the star at the pyramid's southwest corner has a close pair of suns to its west-southwest and, if you look carefully, another pair continues in a stream to the southwest of those stars. And the top of the cross has a wide and faint companion to the north of it. The middle star in the lower part of the cross's vertical beam is double, as is the middle star in the northern arc over the cross! Owing to the cluster's wealth of double and multiple stars, I call it the Doublemint Cluster – in deference to the "refreshing taste of Doublemint™ gum," which, at least when I was a kid in the 1960s, was advertised to double your pleasure.

All in all, NGC 2343 contains about 30 obvious stars 8th-magnitude and fainter in an area only 6′ across. Larger scopes will have a better view of the dimmer companions and will pick up twice as many members. By the way, if you can mentally lose the pyramid image in your mind and look at the cluster with north up, you'll see, just as Admiral Smyth describes, that the cluster does indeed comprise three major rows of stars, all roughly oriented north-northwest–south-southeast. See if you can make them out.

While in the area, be sure to admire the Seagull Nebula, which is unmistakable in the 5-inch at 33×. The glow hardly needs any effort to see. It just "is." I'm always amazed at the clarity of this ghostly visage – such a graceful and luminous arc of nebulosity.

Secret Deep 34
(NGC 2346)



34

Crimson Butterfly
NGC 2346
Type: Planetary Nebula
Con: Monoceros

RA: 07^h 09.4^m
Dec: $-00°$ $48'$
Mag: 11.8
Diam: >50″
Dist: ~2,253 l.y.
Disc: William Herschel, 1790

W. HERSCHEL: [Observed March 5, 1790] A pretty considerable star, 9th or 10th magnitude, visibly affected with very faint nebulosity, of very little extent all around. A power of 300 sh[o]wed the same, but gave a little more extent to the nebulosity. The 22nd Monocerotis was quite free from nebulosity. (H IV-65)

NGC: 10th-magnitude star associated with small, very faint, nebula.

NGC 2346 IS AN INTERESTING BIPOLAR planetary nebula riding the Celestial Equator in Monoceros, just 40′ west-southwest of 4.5-magnitude Delta (δ) Monocerotis. It's one of the few planetaries with a central star that is visually more prominent than its surrounding nebula (when the star, which varies in brightness, is at maximum light), at least as seen through backyard telescopes.

Larry Mitchell of Houston, Texas, notes that there was some uncertainty as to whether the polar declination Herschel recorded in his original notes was 90° or 91°. The 6.5-magnitude star following the nebula was supposed to be 22 Monocerotis, but the observed polar declination of this star must be 1° wrong, as the "P.D. piece" was immediately afterwards set from 88° 50′ to 89° 48′, "supposing it to have been set upon the wrong degree or changed by some accident."

While William Herschel first noted the nebulosity surrounding the star in 1785, it wasn't until 1946 that Rudolph Minkowski at Mount Wilson Observatory classified it as a planetary nebula in the modern sense; he determined the nebula's true identity on the basis of its appearance on direct photographs obtained at the

Newtonian focus of the 60-inch or 100-inch telescope.

In 1973, Lubos Kohoutek and G. Senkbeil found that the nebula's bright central star is spectral type A, and therefore not hot enough to excite the surrounding nebula, which requires an ionizing radiation of at least 45,000 K. Thus, the team proposed that the central star is a binary system, comprising an A0 III main component and a blue (O) subdwarf (the actual planetary nucleus). They also commented on the remarkable similarity of NGC 2346's nucleus to that of NGC 1514 (Secret Deep 15).

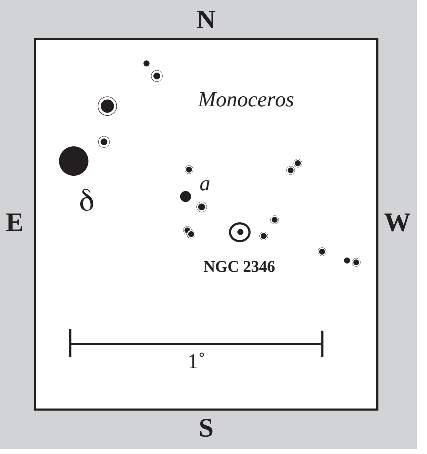
Today, astronomers accept that theory, advancing that the subdwarf has a sufficient temperature (100,000 K) to have ionized the nebula. The two stars closely orbit one another with a period of about 16 days. This is so close that even the Hubble Space Telescope could not resolve the pair. The Type-A component is also a variable known as V651 Monocerotis; it was not noticed to be variable until deep eclipses began at the end of 1981. These continued with a period of 16 days (the orbital period of the central pair). The variability, however, remained a mystery because the hot dwarf was thought to be too small to cause the large drops in brightness (the star can vary from magnitude 11.2 to 13.5 or fainter). This was eventually explained as a cloud of material moving across our line of sight. But after 1986, the eclipses stopped occurring until a dramatic series began 10 years later. The eclipses were still occurring in 1997 when the Hubble Space Telescope imaged the nebula, when the central star was barely visible (see the HST image above right).

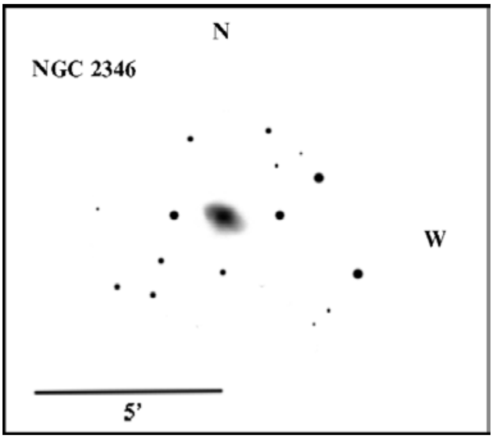
Astronomers now believe that millions of years ago one of the two stars (the more massive one at the time) expanded to become a red giant, swallowing its less-massive companion, causing it to spiral ever closer in toward the more massive star, where it orbited inside its swollen envelope. In the process, rings of gas were expelled from the red giant. Most of the outer layers were ejected into a narrow but dense central waist (oriented east–west) surrounding the central star (see the Hubble image). As the hot core of the red giant was gradually uncovered, powerful stellar winds inflated two huge bubbles of gas that expanded perpendicular to the torus, producing the nebula's classic butterfly shape, whose major axis is inclined about 23° to the line of sight.

In a 2001 *Astronomical Journal* (vol. 122, p. 3293), Lorena Arias and Margarita Rosado (Astronomical Institute, Mexico City) found that this dense disk, or torus, is expanding at a velocity of 16 km/sec. The total diameter of the nebula is about one-third of a light-year, or 2 trillion miles, and its age is estimated to be only about 2,200 years young – about the time when the Greek mathematician and astronomer Apollonius passed away.

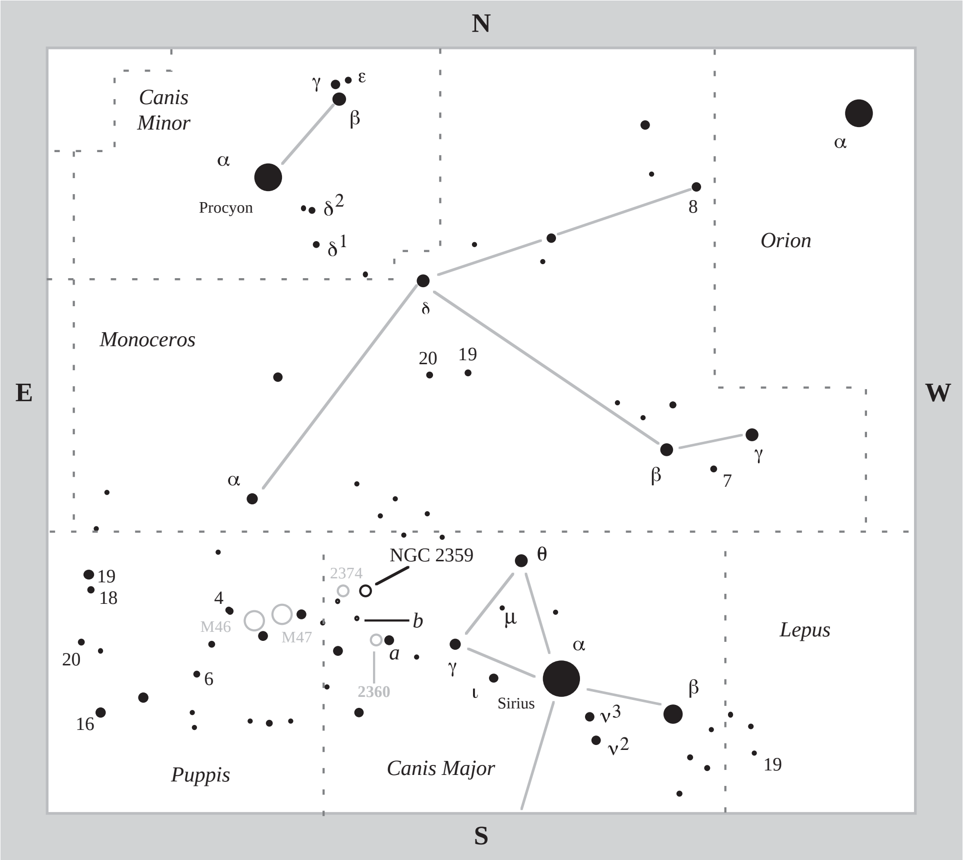
To find this little treasure, use the chart on page 151 to locate Delta Monocerotis, then switch to the chart on this page. From Delta, move about 30′ southwest to a pair of 8.5- and 9.5-magnitude stars (*a*), oriented northeast–southwest, and separated by about 5′. NGC 2346 is only 10′ further to the southwest. Again, note that the visibility of the central star depends on how, and when, it is being obscured by orbiting clouds of obscuring matter. When faintest, the star may not be visible in your scope. When brightest, it will appear as a near twin to a field star only about 5′ to the west.

At 33× in the 5-inch, NGC 2346 is visible with averted vision. It seems larger than expected because its light blends with three other nearby stars. It takes concentration to separate them. But increasing magnification will resolve the problem. I'd use as much magnification as your telescope can handle. The central star is visible, being surrounded by a tight torus, which, under severe scutiny, I can see it at 165×, the torus being elongated northeast–southwest. This becomes even more apparent at higher powers. Larger telescopes may show the nebula's short perpendicular lobes stretching to the northwest and southeast, but I could not dect them at any magnification through my small aperture.





Secret Deep 35
(NGC 2359)



35

Flying Eye, Thor's Helmet, Duck Head Nebula
NGC 2359
Type: Emission/Reflection Nebula
Con: Canis Major

RA: 07^h 18.6^m
Dec: $-13°$ $12'$
Mag: – (Rating: 3.5)
Dim: $9' \times 6'$
Dist: ~1,600 l.y.
Disc: William Herschel, 1785

W. HERSCHEL: [Observed January 31, 1785] A broad extended nebulosity, forms a parallelogram with a ray southwards; the parallelogram is 8′ long, 6′ wide, very faint. (H V-21)

NGC: *Remarkable*, very faint, *very* large, very irregularly faint.

THE REGION OF SKY 10° NORTHEAST of Alpha (α) Canis Majoris (Sirius), the brightest star in the heavens, contains a rich stream of telescopic nebulae and clusters that can keep visual observers and CCD imagers occupied for nights on end. This region is one of my favorite winter haunts, and its wonders continually amaze me. NGC 2359 is one of the more remarkable nebulae in that region. I don't know how this beauty escaped my attention prior to the creation of the Secret Deep list. Nevertheless, this fantastic wash of nebulosity has numerous subtle structures visible to the eye, which blossom into a wonderland of delight when imaged through a CCD.

For some odd reason, I always thought this nebula was a deep southern object, but NGC 2359, in fact, lies a bit farther north than open clusters M46 and M47 in neighboring Puppis. In his book *Astronomical Objects for Southern Telescopes*, Ernst J. Hartung notes that 51 years after his father's discovery of the object, John Herschel compared it to "the profile of a bust (head, neck and shoulders)." Indeed, as you can see from the table above, the nebula has all manner of fanciful names; I like the "Flying Eye" moniker the best, since it spotlights the beautiful bubble of gas (the eye) nestled within wide wings of associated nebulosity. It's quite a remarkable sight in color CCD images, and one of the more exotic-looking nebulae in the sky.

NGC 2359 is an emission/reflection nebula excited by the powerful wind (about 2,000 km/sec) and chemically enriched radiation of the 11.4-magnitude Wolf–Rayet Star HD 56925 (WR7). Wolf–Rayet stars represent a rare evolutionary phase in the lives of massive stars during which they undergo heavy mass loss, typically on the order of 10^{-5} solar mass per year. Due to the chemically enriched radiation, they display an extraordinary spectrum dominated by emission lines of highly ionized elements.

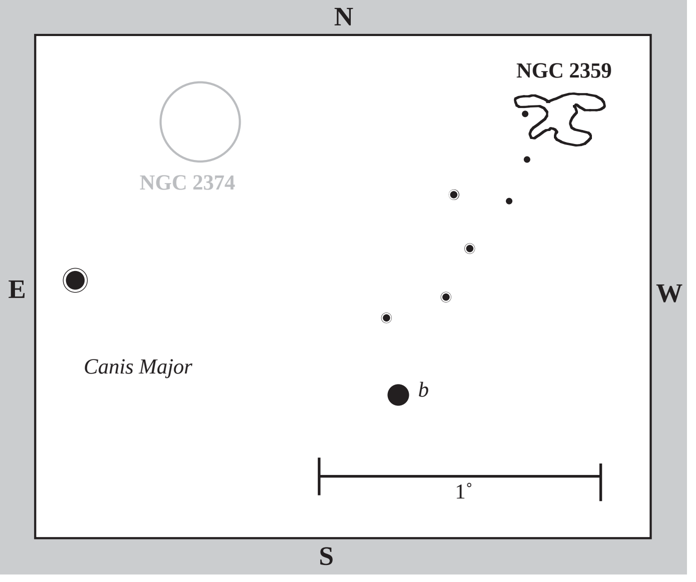
During its main-sequence phase, the 25 solar mass HD 56925 carved a huge bubble into a rather dense warm molecular cloud (Sharpless 298) that partially bounds it. The 2.3-million-year-old ring-like nebula is centered on HD 56925 and has a mass between 700 and 2,400 Suns. At an accepted distance of 1,600 light-years, the filamentary bubble has a true linear extent of about 230 × 120 light-years. Strong winds streaming from the extremely hot (up to ~50,000 K) Type O central star are driving the bubble's expansion at about 12 km/sec.

At a 2001 IAU meeting, C. E. Cappa (Argentinean Institute of Radio Astronomy, Villa Elisa) and colleagues described their radio observations of neutral and ionized gas in NGC 2359. NGC 2359 appears to be associated with three molecular clouds. The mass of neutral gas associated with NGC 2359 is about 320 Suns, while the ionized, neutral, and molecular material in the surrounding region amounts to about 2,200 Suns. They found that the amount of ionized gas in the molecular cloud associated with the filamentary bubble indicates that it mostly consists of swept-up interstellar gas.

Two other molecular structures also appear closely related to the bubble: One includes an arc-like feature that closely surrounds the northern part of a streamer of diffuse gas pointing to the northwest, the eastern region of the filamentary bubble, and a southern bar with an associated filament (all these features mark the location of the ionization front); the other structure consists of clumps that surround a major part of the shell and the southern bar of NGC 2359.

In a 2003 *Astronomy & Astrophysics* (vol. 411, pp. 465–475), Jose Ricardo Rizzo (European Space Astronomy Centre) and colleagues detected three different velocity components to the gas in the NGC 2359 region. The researchers found that its kinematics, morphology, mass, and density are clearly stratified (like an onion) with respect to HD 56925. These multiple bubbles, they believe, tell us something about the recent evolutionary history of HD 56925; namely, that they're related to several different energetic events that have acted upon the surrounding circumstellar medium. From the analysis of the mass-loss history of HD 56925, they suggest that the multiple layers of shocked molecular gas are likely to be produced during the earlier luminous blue variable phase and/or the actual Wolf–Rayet stage of HD 56925.

To find this delightful bubble of gas and its associated optical structures, use the chart on page 155 to first locate Sirius, then 4th-magnitude Gamma (γ) Canis Majoris, the easternmost star in the Great Dog's head. Now use your naked eye or binoculars to locate the 5.5-magnitude Star *a*, 3° to the east, next to which is open star cluster NGC 2360 (Caldwell 58). Then look about 1½° to the northeast for similarly bright Star *b*. Now use the chart on this



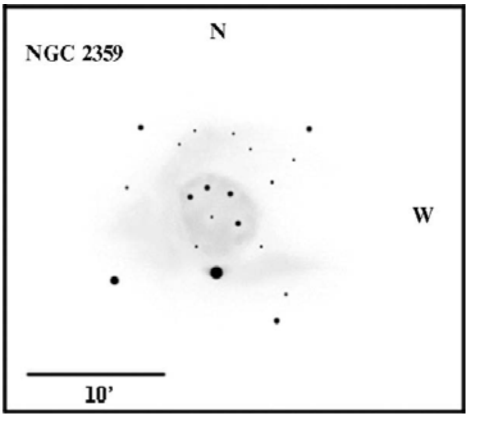
with a faint extension to the northeast, though following it or defining it in any way was extremely difficult. Averted vision just shows an amorphous diaphanous glow of ill-defined light. The bubble is well defined, appearing as a filled-in ring of light with slightly sharper edges. It's somewhat detached from the southern bar but connected nevertheless by patches of faint light. I could not detect any of the fainter emission filaments like the one extending to the northwest from the north side of the bubble, nor could I see the filament extending to the west of the southern bar. The 11.4-magnitude Wolf–Rayet star is visible within the shell, along with a fainter "companion." An arc of three similarly bright suns follows the northern curve of the bubble.

Of course, CCD images bring out all manner of detail. The Eye is filled with wispy filaments, the brightest emission

page to look for NGC 2359 about 1¼° north-northwest of Star *b*, about 1¼° west of the 8th-magnitude open cluster NGC 2374.

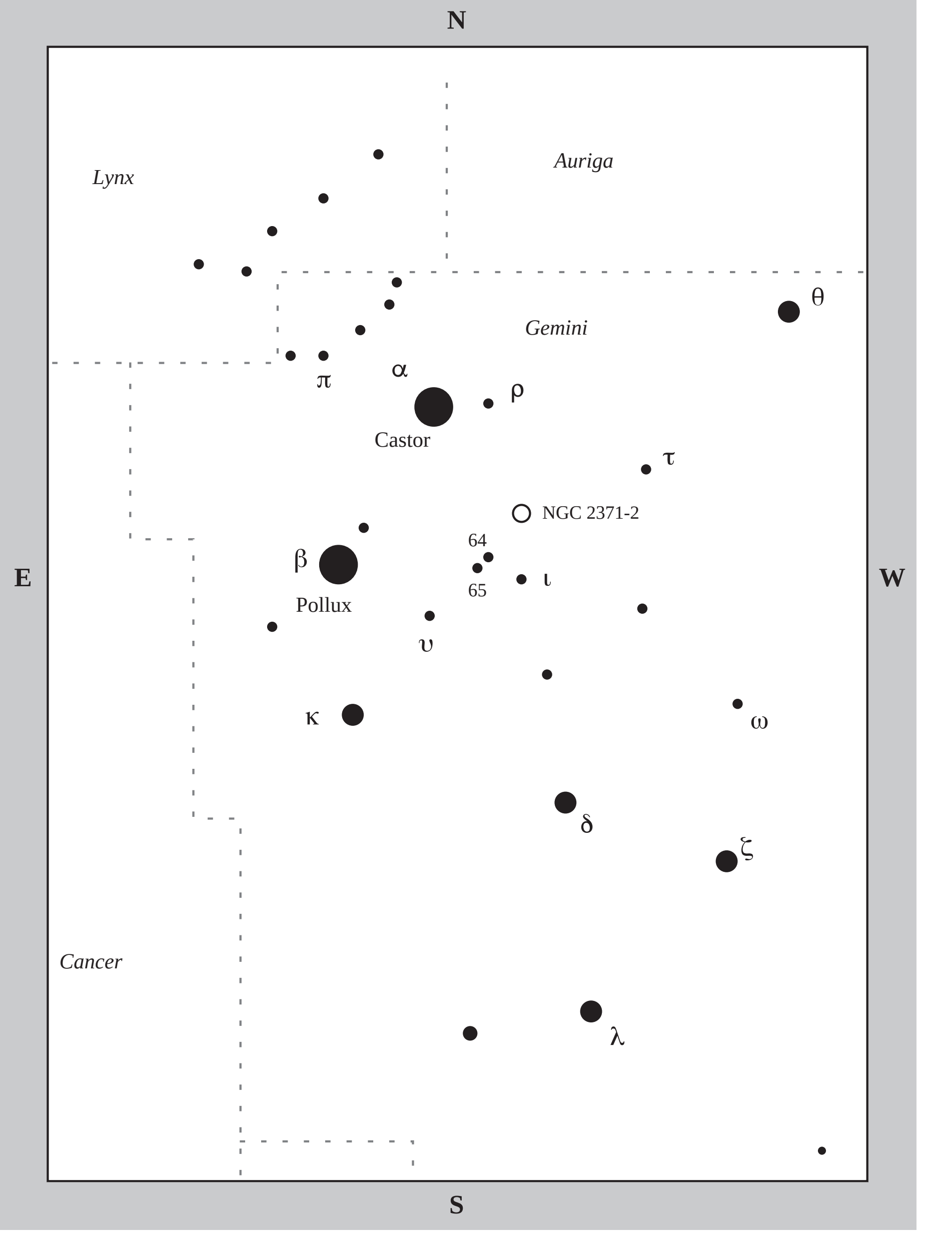
At 33× in the 5-inch the nebula is very obvious, with the first impression of it being a large, ~10′-long elliptical patch, oriented roughly east-northeast–south-southwest, punctuated on the eastern end by a roughly 11.5-magnitude star. A pretty 5′-long chain of four 9.5- to 10.5-magnitude suns lies to east-northeast of this bar of light and parallels it. With time and averted vision, I detected the nebula's "eye" – rising above the eastern section of the southern bar to the northwest – like one of the cauliflower heads of a cumulus cloud. Averted vision also showed several dim stars swimming in and around the northern section of the bubble.

The nebula has a low surface brightness, so I found that, at least in the 5-inch, it doesn't take magnification well. I found the best view to be at 60×. At this magnification the southern bar is most distinct,



comes from the southern bar, which has a crab-leg-like bend that narrows to the west. Fainter filaments of gas can be seen to the east and northwest of the Eye, while vast washes of emission lie well to the northeast and southwest, among other structures both delicate and clumpy. Have fun exploring!

Secret Deep 36
(NGC 2371-2)



36

Double Bubble Nebula
NGC 2371-2
Type: Planetary Nebula
Con: Gemini

RA: $07^h\ 25.5^m$
Dec: +29° 29′
Mag: 11.3 (Rating: 3)
Dim: 58″
Dist: ~4,300 l.y.
Disc: William Herschel, 1785

W. HERSCHEL: [Observed March 12, 1785] Two, south preceding north following, separated by 1′, chevelure mix, both faint and small equal nuclei. (H II-316)

NGC (2371): Bright, small, round, brighter in the middle to a nucleus, part of a double nebula.

NGC (2372): Pretty bright, small, round, brighter in the middle to a nucleus, part of a double nebula (H II-317).

NGC 2371-2 IS A DIM, LOW-SURFACE brightness planetary nebula 1½° north of 4th-magnitude Iota (ι) Geminorum. As with planetary nebula M76 (NGC 650–1), Herschel resolved this object into two parts (thus the double NGC number). The southwestern lobe is NGC 2371, the northeastern one is NGC 2372. Unknown to Herschel, these parts belong to a single nebula, one he did not recognize as a planetary because, simply put, when seen together the entire form resembles a dumbbell or butterfly more than a circular planet like Uranus.

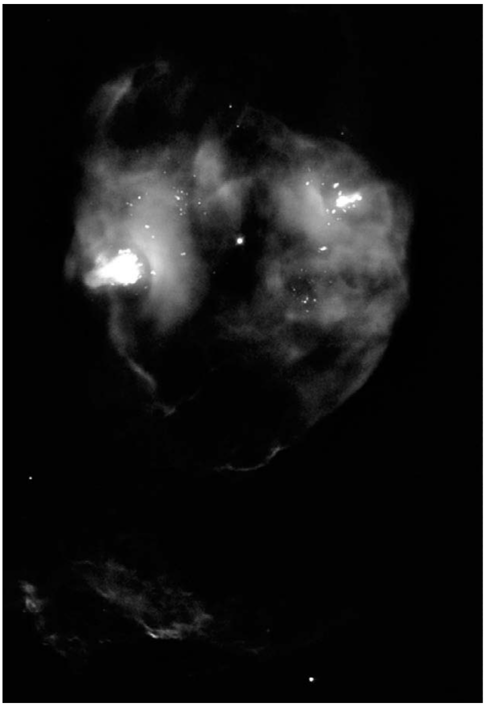
Heber Doust Curtis (1872–1942) first recognized NGC 2371-2 as a planetary nebulae (*Publications of the Lick Observatory*, vol. 13, part III, 1918). He based his opinion on the object's characteristic appearance, which included the nebula's symmetry around a central star, on plates taken with Lick Observatory's Crossley reflector. His image of NGC 2371-2 shows two central lobes forming an irregular and patchy oval and two faint wings of exterior matter.

These outer wings are quite extensive, measuring about 2′ in apparent diameter, which, at an estimated distance of 4,300 light-years, means that the nebula's true physical extent is 3 light-years across – three-fourths the distance between the Sun and Alpha (α) Centauri. The inner lobes are one-third that size. Indeed, NGC 2371-2 is one of the largest planetary nebulae known.

The nebula's central star is rather faint (14.8), though not beyond the realm of moderate-sized backyard telescopes, and its spectrum shows strong emission lines that belong to the OVI class – very hot stars located toward the blue end of the post-asymptotic giant branch in the Hertzsprung–Russell diagram. NGC 2371's white dwarf central star has a seething surface temperature of 130,000 °C with a luminosity ranging between 700 and 1,400 Suns.

OVI central stars are also nonradial pulsators – only 16 of which are currently known. These rare planetary nebulae nuclei have distinct spectral lines with OVI emission at 3811 and 3824 angstroms. These lines can be either narrow and resolved or broad and blended. But only the central star of NGC 2371-2 shows both kinds of lines simultaneously, narrow features set atop a strong broad blend. NGC 2371-2's central star also displays slight magnitude variations with a period of about 17 minutes.

In November 2007, as part of the Hubble Heritage program, the Hubble Space Telescope took a strikingly detailed image of NGC 2371-2 (shown above right), with north to the lower right and east to the lower left). The image, which shows an area equal to 1.6 light-years, shows the nebula's bright inner lobes and one of the exterior "wings," part of a huge halo of gas, which may be excited by ultraviolet radiation streaming out from the hot central star via a dark lane.

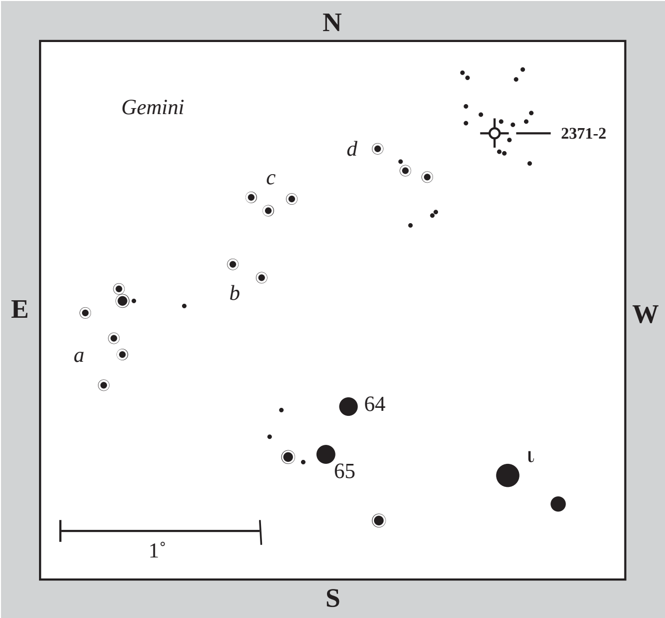


Most remarkable, however, are the prominent bright clouds and spots (which appear pink in the color image) in the two central lobes. These are relatively cool and dense knots of gas and may be jets of material ejected from the star along its rotation axis. Space Telescope Science Institute astronomers note, however, that the jet's direction has changed with time over the past few thousand years.

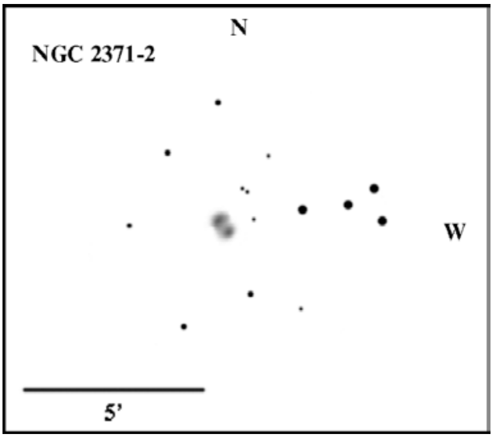
While the reason for this behavior is not well understood, it might be related to the possible presence of a second star orbiting the visible central star, causing the system's rotational axis to shift, affecting changes in the nebula's morphology.

In a 2008 *Bulletin of the American Astronomical Society* (vol. 40, p. 206), Douglas N. Arion and coworkers (Carthage College) note how their deep [OIII] images of NGC

2371-2 with the Steward Observatory 61-inch Kuiper telescope also show a broad range of filamentary structures permeating the entire nebula.



To find NGC 2371-2, use the chart on page 160 to locate Iota (ι) Geminorum, which forms the southwestern apex of an isosceles triangle with the 1st-magnitude stars Alpha (α) and Beta (β) Gem. Less than 1° northeast of Iota Geminorum are the 5th-magnitude stars 64 and 65 Geminorum. Center 64 Geminorum in your telescope at low power then switch to the chart on this page. From 64 Geminorum, make a generous 1° sweep east-northeast to a crooked Y-shaped asterism of five 6th- and 7th-magnitude stars (*a*). Now move 50′ northwest to a pair of roughly 8.5-magnitude stars (*b*). A 25′ hop to the north-northwest will bring you to an arc of three 7.5- to 8.5-magnitude stars (*c*). Now move 30′ northwest to 7.5-magnitude Star *d*, which lies at the northeast end of a 15′-long crooked line of slightly fainter suns. NGC 2371-2 lies only 35′ west and slightly north of Star *d*. Use the stars in Mario's image on page 161 to identify the field of faint stars that lie around the little planetary nebula.



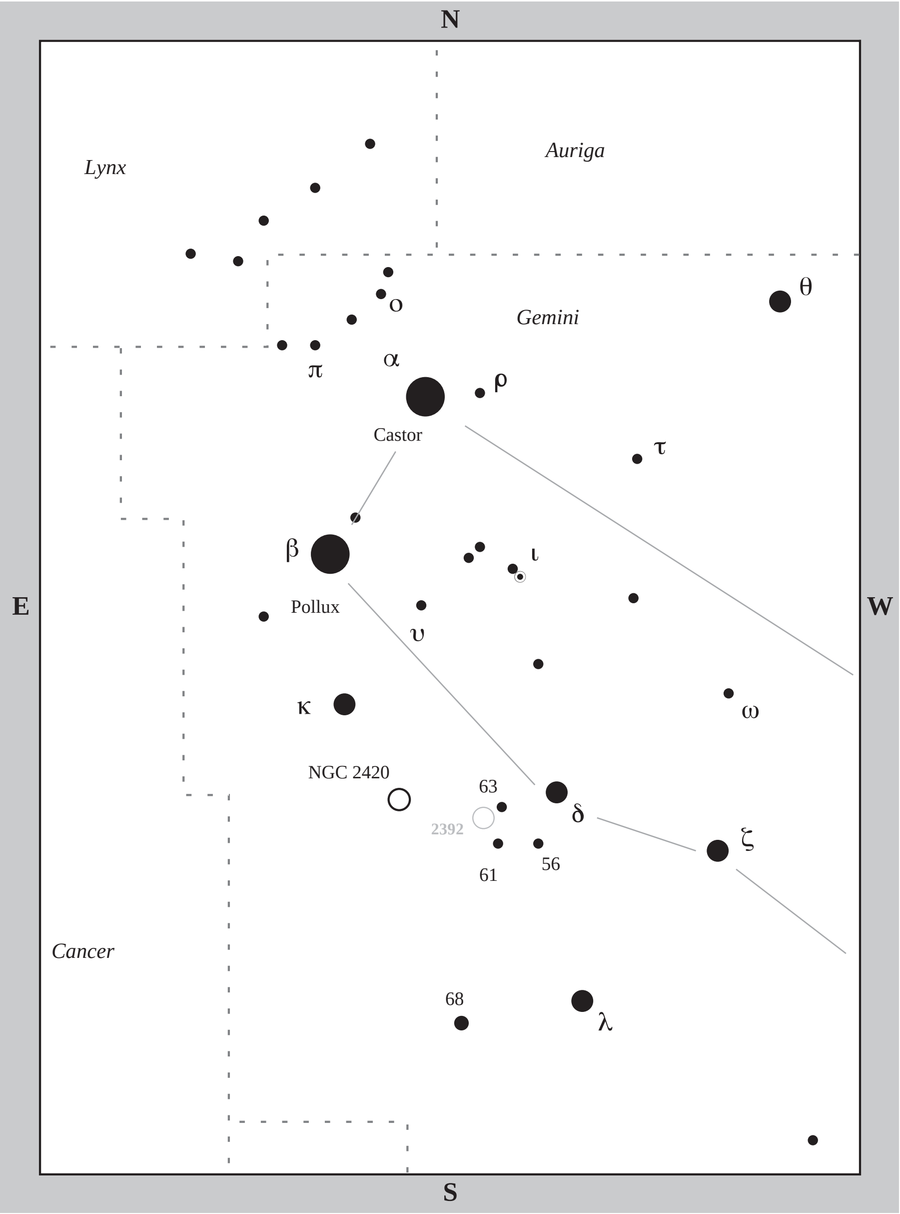
Remember, to claim this prize, you must resolve the nebula into two bright patches. The key to success for small-telescope users is to be under a dark sky, know *exactly* where to look, and use *high* power with averted vision. If you still have trouble, try gently tapping the tube. Plan to spend some time with this object. If you're patient, chances are you'll succeed.

At 33× in the 5-inch (and once I knew where to look) I could glimpse the nebula with averted vision as a tiny bit of fuzz 1′-wide. Increasing the magnification to

60× reveals the nebula's elongated nature, being oriented northeast–southwest. NGC 2371-2's binary nature is quite apparent at 94×, appearing as two distinct orbs divided by a clean dark lane, oriented northwest–southeast. If you have a large amateur instrument, try looking for the nebula's fainter exterior "wings" to the northwest and southeast. I could not see them in the 5-inch. I find the view at 180× very comfortable.

I have not yet detected the planetary's central star, but I encourage you to try, especially if you have a larger instrument that can handle power well. In their *Observing Handbook and Catalogue of Deep-Sky Objects* (Cambridge University Press, 1998), Christian B. Luginbuhl and Brian A. Skiff note its presence at 225× in a 12-inch telescope. They also note that NGC 2371 (the southwest lobe) is slightly brighter than NGC 2372, having what appears to be stellar nucleus. Could this be the "jet"?

By the way, at 58″ in apparent diameter, the bright inner lobes measure 1 light-year. So this would be a great object to show friends and guests at star parties who want to "see" a light-year.


N
E
W
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Lynx
Auriga
Gemini
Cancer
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Castor
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Pollux
υ
κ
ω
NGC 2420
63
δ
2392
ζ
61
56
68
λ

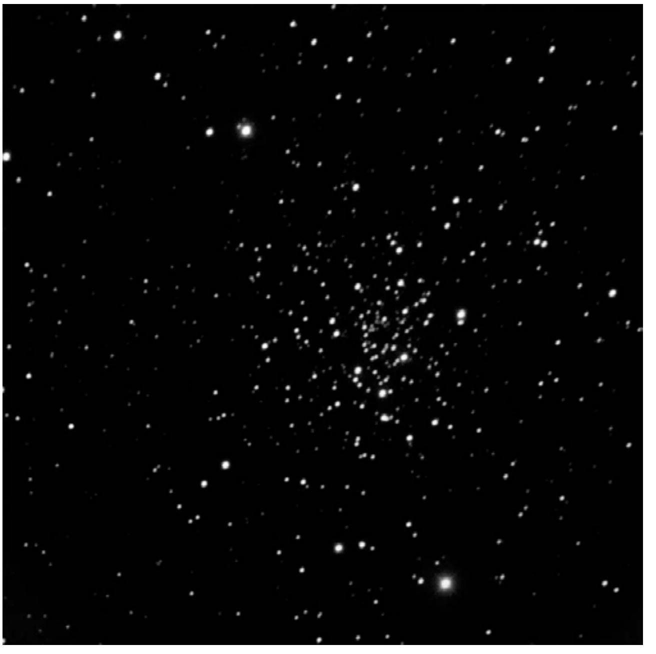
37

Twinkling "Comet" Cluster
NGC 2420
Type: Open Cluster
Con: Gemini

RA: 07^h 38.4^m
Dec: +21° 34′
Mag: 8.3
SB: 12.2 (Rating: 3)
Diam: 6′
Dist: ~8,800 l.y.
Disc: William Herschel, 1783

W. HERSCHEL: [Observed November 19, 1783] A beautiful cluster of many [bright] and [faint] stars about 12′ in diameter. (H VI-1)

NGC: Cluster, considerably large, rich, compressed, stars from magnitude 11 to 18.



NGC 2420 IS A SOMEWHAT DIM BUT very beautiful, rich, and finely spun open cluster about 6½° south-southwest of 1.5-magnitude Beta (β) Geminorum (Pollux), the southeastern Twin star. It's also a little more than 2¼° east-northeast of NGC 2392, the Eskimo planetary nebula (Caldwell 39) in Gemini.

I'll never forget my first encounter with it many years ago during a sweep of the heavens with the 9-inch f/12 Clark refractor at Harvard College Observatory in Cambridge, Massachusetts. I was comet hunting. Although the skies were a bit light polluted at the time (I could still see the Milky Way dimly on the best nights), I was certain I could nab a new comet shining brighter than 10th-magnitude, with an 8th-magnitude object being quite the comfortable sight in a sweep. One night while moving the great refractor slowly eastward beyond the southern arm of the Twins, I saw a round cometary form (about 8th magnitude) enter the field. My heart stopped; the diffuse object looked so stunning against the mottled starlight in the field – like a little fuzzy snowball. (The late Harvard astronomer Fred Whipple had, in 1950, referred to comets as "dirty snowballs," so my imagining seemed appropriate.)

But on closer inspection, I saw the "comet's vapors" twinkling with averted vision. When I increased the magnification, the "vapor" shattered into a myriad of tiny scintillating gems. A look at a star atlas confirmed that I had found open cluster NGC 2420. Nevertheless, I have since became truly fond of this "twinkling comet."

NGC 2420 is another astrophysically interesting open cluster. Trumpler classified it as type I1r, meaning it's a moderately rich, detached cluster with little central concentration whose stars exhibit a medium range in brightness. It's also an old cluster with an age of about 2 billion years. Only a handful of open clusters in our Milky Way are known to be more than 1 billion years old. So NGC 2420 joins an elite group of senior Galactic cluster residents, including NGC 752 (Caldwell 28) in Andromeda (~1.7 billion years), M67 in Cancer (~4 billion years), and NGC 188 (Caldwell 1) in Cepheus (~5 billion years).

Unlike many open clusters, which lie in the plane of the Milky Way, NGC 2420, which is about 35 percent farther from the Galactic center than our Sun, lies about 3,000 light-years above the main disk. What's more, while NGC 2420's age is about one-third that of our Sun, the cluster's average composition seems to be very similar to the Sun's.

In a 2002 press release from Kitt Peak National Observatory, Emily Freeland (Indiana University) – who, with her colleagues made new observations of NGC 2420 with the refurbished WIYN 0.9-meter telescope at Kitt Peak National Observatory, as part of a long-term project called the WIYN Open Cluster Study – says, "It is unclear how a cluster that is as rich in chemical elements as the Sun is can have such a location and motion around the Galaxy. Such clusters usually lie right in the Galactic disk."

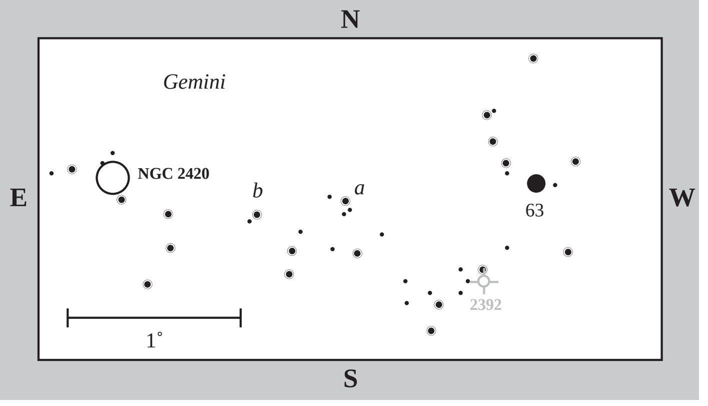
The researchers remain puzzled. It's possible, they say, that NGC 2420 formed in the disk but got ejected to its present location by a close encounter with a massive object (such as a giant molecular cloud), but it's not readily apparent how such an encounter could toss the cluster to such a high Galactic latitude. Another possibility is that NGC 2420 didn't originate in the Milky Way but in a dwarf galaxy that the Milky Way cannibalized.

"One problem with this idea," notes Constantine Deliyannis, a WIYN Open Cluster Study team member from Indiana University and Freeland's research advisor, "is that small galaxies of this type are generally believed to be less rich in the chemical elements than the Sun. How could this little galaxy generate such a high abundance of heavy elements?"

The research team determined that the cluster contains 1,000 members out to 30 light-years. (Most catalogues attribute only about 300 members out to 15 light-years.) They also found a very clear main sequence (stars like our Sun that convert hydrogen into helium in their core), subgiant and giant branches (stars that have exhausted their core hydrogen), a red clump (giant stars converting helium into carbon in their cores), and blue stragglers (stars that appear younger than they should and may be the product of two suns merging into a single star).

NGC 2420 also contains a significant population of binary stars, with a surprisingly large fraction of these binaries being "twins" of roughly equal mass. "Other star clusters don't seem to have nearly as many twins," Deliyannis says. "This interesting result, together with studies of the general distribution of binary mass fractions, will teach us about the environments in which stars and star clusters form." Indeed, the researchers believe that NGC 2420 may contain a multitude of clues about the history and evolution of the Milky Way.

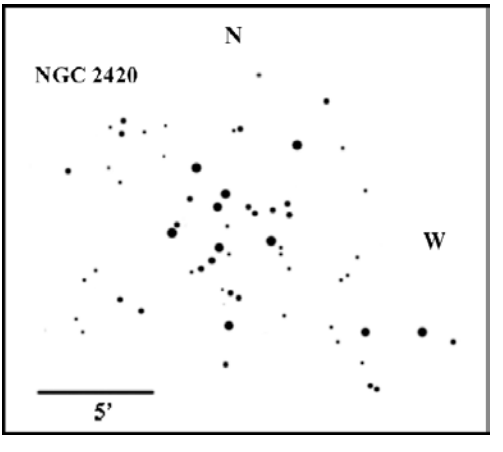
37



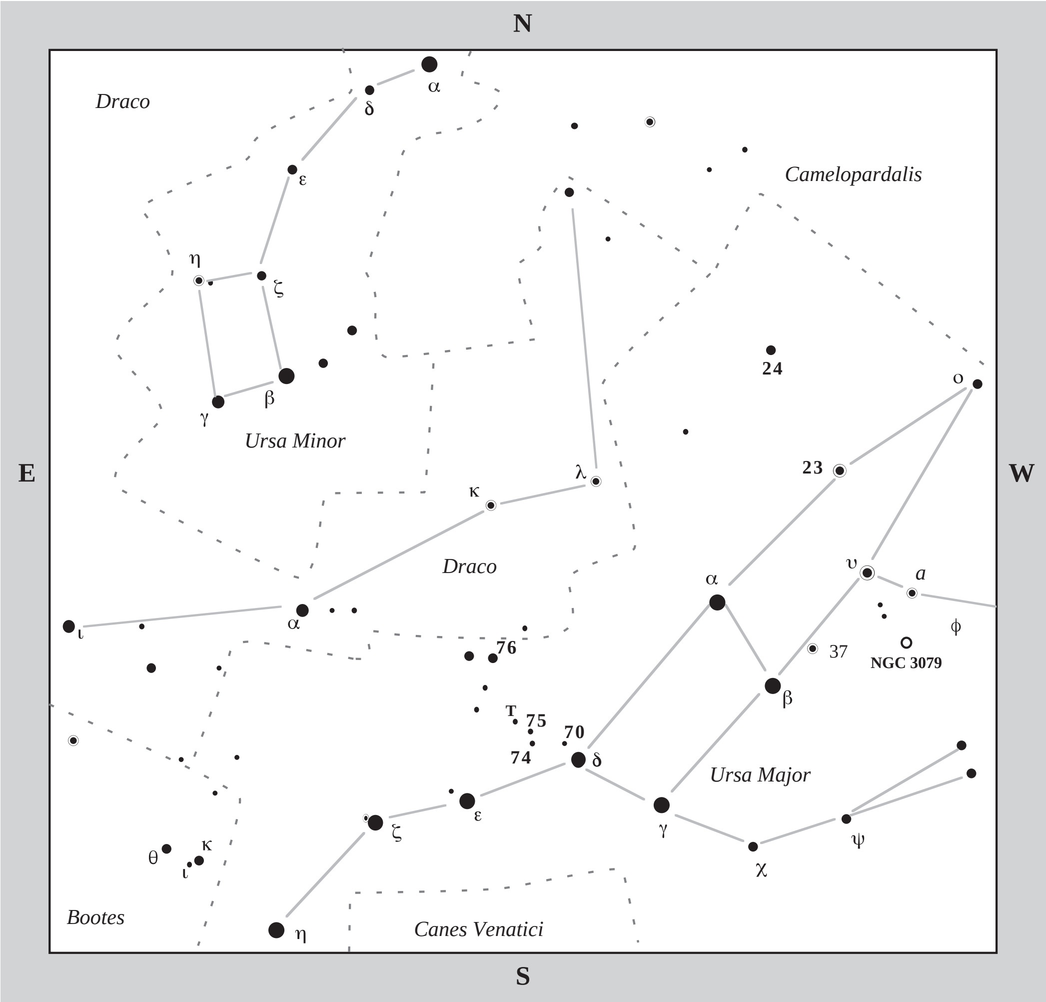
transforms into an irregularly round blaze of tiny glittering gems, about a dozen or more of which seem to shine between 11th and 12th magnitude. It's hard to tell exactly, there is so much starlight that tiny bits seem to blend into more prominent ones, though this could be a trick of averted vision. At 60×, the core looks like a wet tulip glinting flecks of moonlight. The tulip is narrow on the southern end and fans out to the north; it is surrounded by a filamentary background of dimmer suns, as if diamond dust has been blown away from the cluster's core in all directions. At 94×, the wet tulip has a smaller sideways Y-shaped asterism of suns, oriented east–west; this smaller Y opens to the west. Again, the intriguing core is surrounded by a faint noisy background of cluster outliers; they seem to flit about in a halo that appears to extend beyond the cluster's 6′ diameter.

To find NGC 2420, I like to first find NGC 2392, Eskimo Nebula. Use the chart on page 165 to locate Delta (δ) Geminorum (Wasat). Note that Delta Geminorum is the bright star at the northwest end of a 2½°-wide kite-shaped asterism with the 5th-magnitude stars 56, 61, and 63 Geminorum. Use binoculars to verify this appearance. Now center 63 Geminorum at low power in your telescope, then switch to the chart on this page. NGC 2392 lies just 40′ southeast of 63 Geminorum and 1.6′ due south of an 8th-magnitude star. Now, after you enjoy this delightful planetary nebula, make a slow and careful sweep about 55′ northeast to 7th-magnitude Star *a*. Now look about 35′ east and slightly south of Star *a* for 9th-magnitude Star *b* with a roughly 10th-magnitude companion. NGC 2420 is about 50′ east-northeast of Star *b*.

At 33× in the 5-inch NGC 2420 is at a glance a round ghostly apparition of largely uniform light, like a tailless comet that gets gradually brighter in the middle. The glowing cluster is neatly framed inside a crooked Y of 9th- to 10th-magnitude stars. With averted vision, the glow



Secret Deep 38
(NGC 3079)



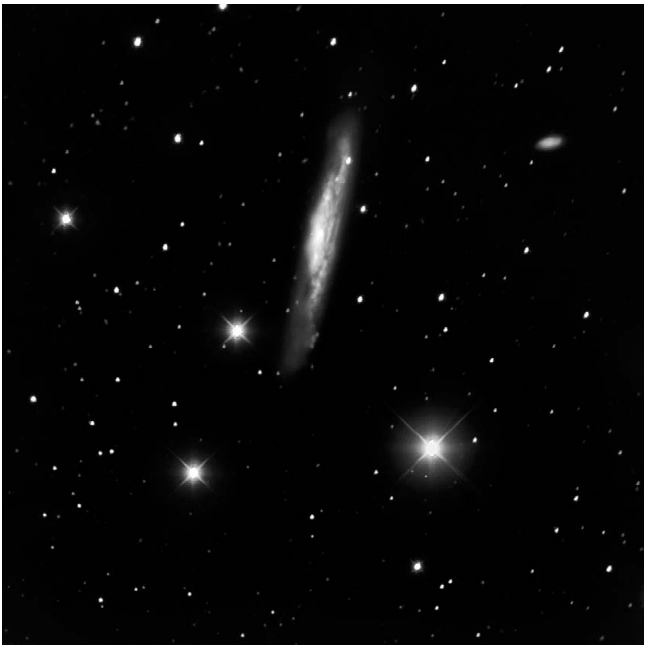
38

Phantom Frisbee Galaxy
NGC 3079
Type: Barred Spiral Galaxy (SB(s)c)
Con: Ursa Major

RA: 10^h 02.0^m
Dec: +55° 41′
Mag: 10.9
SB: 13.4 (Rating: 3)
Dim: 8.0′ × 1.5′
Dist: ~64 million l.y.
Disc: William Herschel, 1790

W. HERSCHEL: [Observed April 1, 1790] Very bright, much extended, north preceding south following, very gradually much brighter in the middle, 8′ long, 2′ wide. (H V-47)

NGC: Very bright, large, much extended toward position angle 135°.



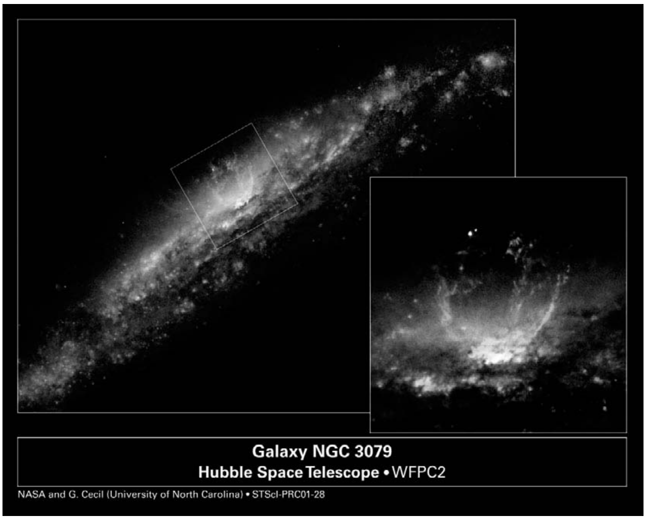
NGC 3079 IS A SPECTACULAR, EDGE-on galaxy 64 million light-years distant in the Ursa Major Southern Spur of galaxies. It lies about about 3½° south-southeast of 3.8-magnitude Upsilon (υ) Ursae Majoris, in the Great Bear's foreknee. As seen from mid-northern latitudes, the galaxy never sets, though it's highest in the sky after sunset during the spring.

In high-resolution images taken with large telescopes, the galaxy is an awesome sight, displaying a bright nucleus in a lens-shaped maelstrom of galactic vapors – a sight that brings to mind the "phrensied convulsion" described by Edgar Allan Poe in his *A Descent into the Maelstrom*:

> Here the vast bed of the waters, seamed and scarred into a thousand conflicting channels... gyrating in gigantic and innumerable vortices, and all whirling and plunging on the eastward with a rapidity which water never elsewhere assumes except in precipitous descents.

The galaxy's central lens is surrounded by a seemingly warped disk, which, in the whole, makes NGC 3079 look like a phantom frisbee. The warp is largely an illusion created by dark dust irregularly distributed throughout the galaxy. The outer portions of its disk, however, have been distorted by tidal interactions with its two dwarf companions: 13th-magnitude NGC 3073, 10′ to the west, and a fainter anonymous companion nearly 6.5′ to the northwest.

Although we view NGC 3079's disk only 2° from edge on, we can still see its central, peanut-shaped bar and two principal arms, the latter of which show partial resolution. One arm is longer than the other and forms an outer loop. NGC 3079 may be similar in size and structure to the 9th-magnitude edge-on barred spiral galaxy NGC 4361 (Caldwell 32) in Canes Venatici. Thus, if we could turn 3079 face on, we'd probably see a magnificent, late-type barred spiral, 150,000 light-years in extent, with very clumpy and loosely wound arms.



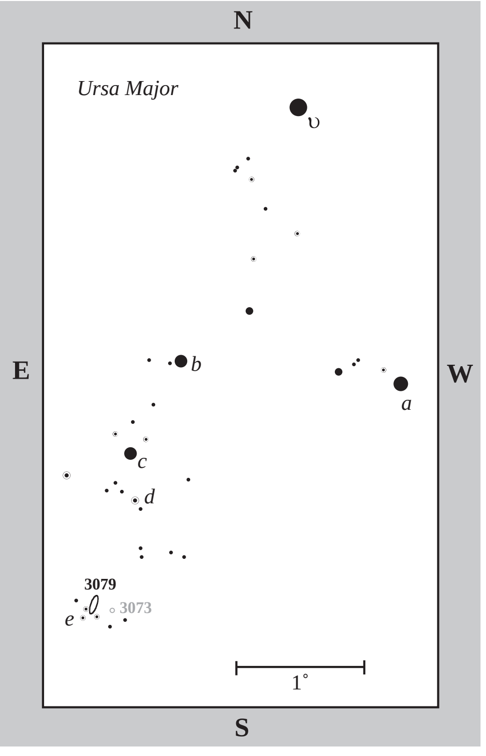
NGC 3079 is also one of the nearest and brightest Type 2 Seyfert galaxies known. Consequently, its nucleus burns with starlike intensity. As typical of Type 2 Seyferts, spectra of NGC 3079's nucleus are dominated by narrow-line emission. It has been argued, however, that all Type 2 Seyferts are intrinsically Type 1 Seyferts whose broad-line-emission component cannot be seen from our vantage point in space. Regardless, the spectra of all Seyferts indicate the presence of very hot, fast-moving gas close to that starlike active galactic nucleus (AGN) – most likely surrounding a massive black hole, which accretes gas from its surrounding environment.

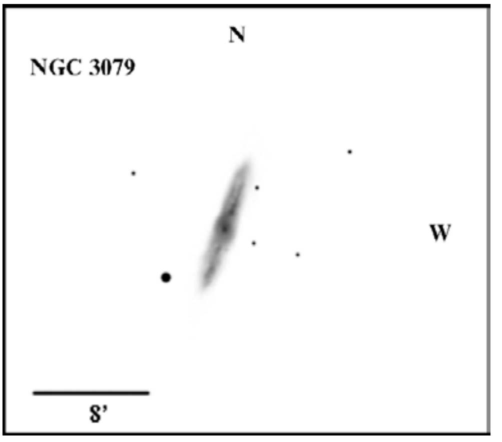
Judith A. Irwin of Queen's University and D. J. Saika of the National Centre for Radio Astrophysics note that NGC 3079 is also unique among spiral galaxies, because it shows well-defined radio lobes extending from its AGN. It may be the closest analog of an extragalactic radio source (EGRS), providing a laboratory for understanding the relationship between starburst activity (such as that in M81) and the AGN in galaxies.

Indeed, in 2001, NASA released dramatic Hubble Space Telescope images of a lumpy bubble of hot gas, some 3,000 light-years wide, rising above the galaxy's disk from a cauldron of glowing matter within NGC 3079's core. The feature looks remarkably like a bursting lava bubble – a product of rapidly expanding gases within the melt. Indeed, it's theorized that NGC 3079's bubble formed about a million years ago when streams of particles rushing away from hot stars at the galaxy's core mixed with small bubbles of very hot gas expelled during supernova explosions, resulting in a burst of star formation.

Radio observations reveal that gaseous filaments at the top of the bubble are still whirling around in a vortex and being expelled into space. Eventually, this gas will rain down upon the galaxy's disk where it may collide with gas clouds, compress them, and form a new generation of stars. These bubble bursts may be episodic, occurring about every 10 million years – until the hot stars expend their energy, depleting the bubble's energy source.

38





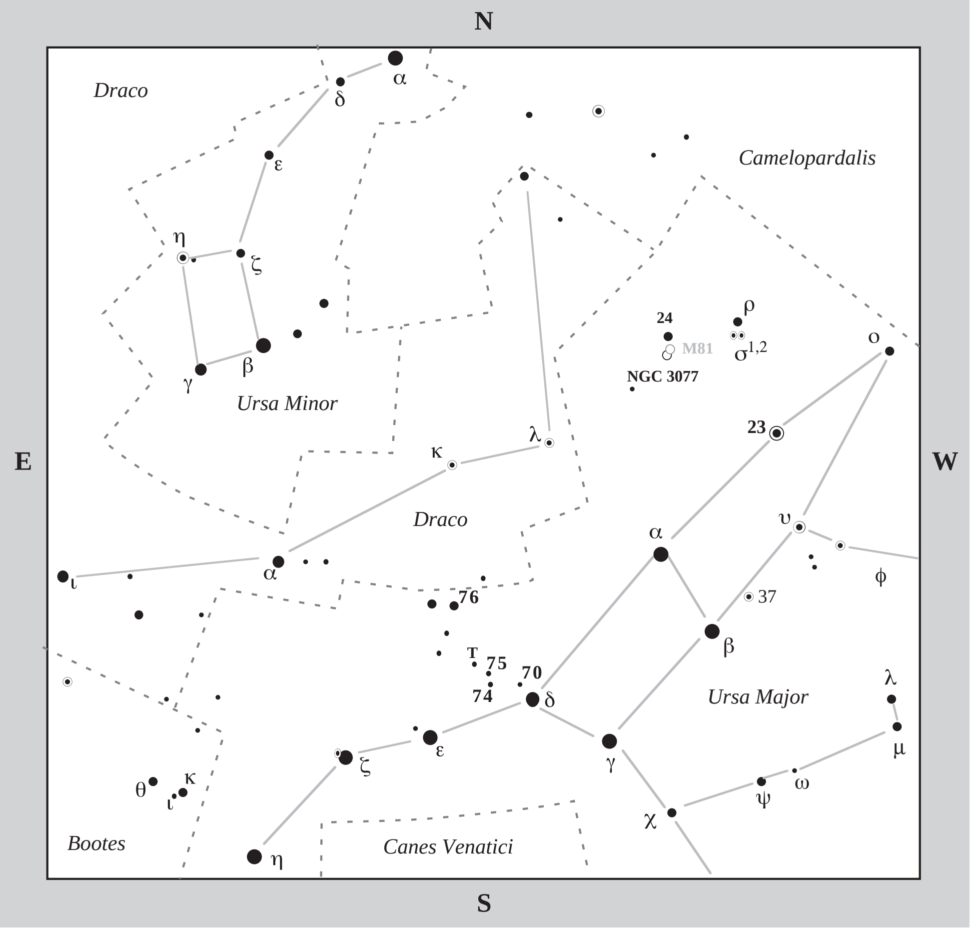
It may take some time to find this extragalactic wonder, because it requires some star hopping. First, use the chart on page 169 to locate the Big Dipper's Pointer Stars: Alpha (α) and Beta (β) Ursae Majoris, Dubhe and Merak, respectively. Now look about 10° to the west for Upsilon (υ) Ursae Majoris, which forms the apex of a near-equilateral triangle with Dubhe and Merak. Now use the chart on this page to find NGC 3079, which lies about 3½° southeast of Upsilon. Begin by looking 2° south-southwest of Upsilon, where you'll find 5th-magnitude Star *a*. Next, move 1½° east-northeast to 6th-magnitude Star *b*, which marks the southeastern corner of a nearly equilateral triangle with Upsilon and Star *a*. Now hop 40′ southeast to similarly bright Star *c*. From Star *c*, move 20′ south-southwest to magnitude 7.5 Star *d*. NGC 3079 is a little more than 50′ southeast of Star *d*, just 6′ northwest of a triangle of roughly 8.5- to 9.5-magnitude stars (*e*).

Years ago, in my 4-inch Tele Vue refractor, NGC 3079 was a somewhat difficult galaxy to see at 23×, appearing as a long and narrow streak of fairly faint light. But in the 5-inch at 33×, it was a fine sliver of light – 5′ long and oriented roughly north to south (with a slight tilt westward) – penetrating a tiny triangle of suns (Triangle *e* on the chart). With concentration and averted vision, the galaxy's bright Seyfert nucleus pops into view surrounded by a central lens with a delicately mottled texture. The longer you look at it with averted vision (though be sure not to stare too long; it'll "drain" your eyesight) at this power, the more magnificent the galaxy appears.

At 60×, the inner lens stands out well, as does its Seyfert nucleus, while the galaxy's length appears scarred with light: two sharp, needle-like protrusions – one on either side of the central lens. With concentration, these needles appear isolated in the disk, surrounded by patches of dust. Indeed, at 94×, these arms give the galaxy's preceding side a sharp edge, while the entire disk (especially the nuclear region) is a maelstrom of faintly dappled light. As you gaze at this waver of extragalactic vapors, try imagining it receding from you at a speed of 1,116 km/sec (693 miles/sec).

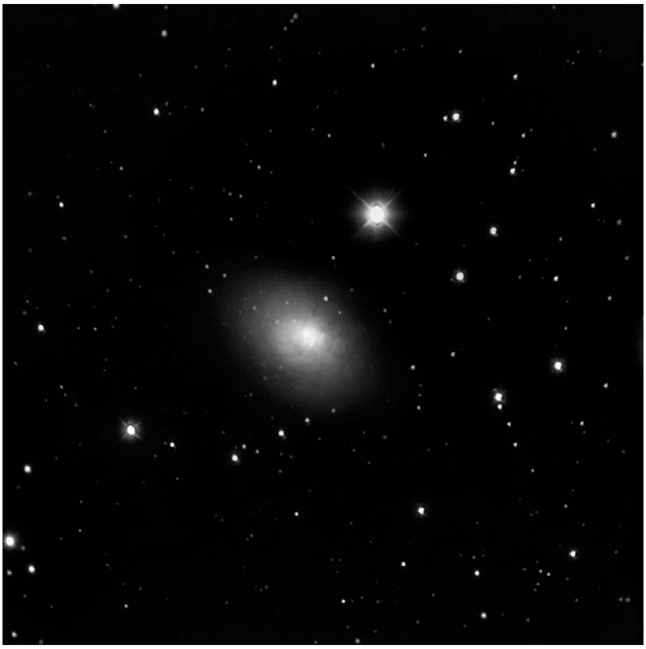
39

Secret Deep 39
(NGC 3077)



39

NGC 3077
Type: Peculiar Irregular Galaxy (I0 peculiar)
Con: Ursa Major



RA: $10^h\ 03.3^m$
Dec: +68° 44′
Mag: 9.8
SB: 13.1 (Rating: 4)
Dim: 5.5′ × 4.1′
Dist: ~12.5 million l.y.
Disc: William Herschel, 1798

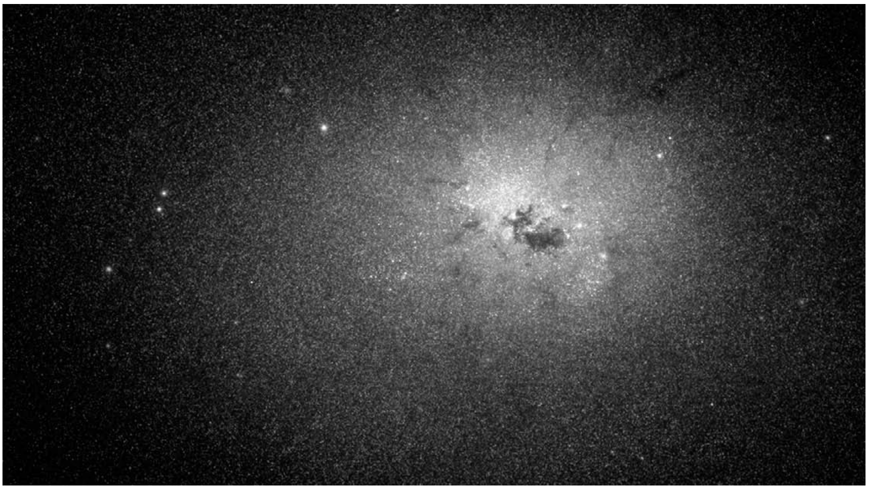
W. HERSCHEL: [Observed November 8, 1798] Very bright, considerably large, round, very gradually brighter in the middle. On the north-following side there is a faint ray interrupting the roundness. (H I-286)

NGC: Considerably bright, considerably large, much brighter in the middle, round with ray.

NGC 3077 IS A SMALL BUT BRIGHT peculiar galaxy about 45′ east-southeast of the magnificent spiral galaxy M81 in Ursa Major, which has an equally dynamic companion, M82. NGC 3077 is a member of the M81 group, making it a well-known triplet of galaxies for small telescope users. Despite its apparent obscurity, NGC 3077 is just as bright and large as M89 (a much sought after elliptical galaxy in Virgo). This only helps prove the point that many non-Messier deep-sky objects are greatly neglected because they suffer the fate of being close to more visually overpowering sights, such as the powerful attraction of such a grand duet as M81 and M82. Yet our target is only a slight tap of the tube away from M81.

In the mid-nineteenth century, NGC 3077 was thought to be either an irregular lenticular (I0) galaxy or a peculiar mixed spiral lenticular galaxy (SAB0p). In plates, it appeared as a little elongated, smooth nebulosity marked by irregular patches of dark matter; two of them emerging on both sides near the minor axis simulate a nascent spiral pattern. The texture of the dust patches silhouetted against the galaxy's diffuse luminous glow is similar to that of M82 and NGC 5195 (Secret Deep 67).

Later images showed the irregular array of dusty filaments to have a roughly radial



pattern centered on the nuclear region. Other images also revealed some "knots" near the core, which were interpreted as either individual stars or star clusters, but their spectral luminosities were more like that of super star clusters.

Like its larger companion M82, the most unusual feature in NGC 3077 is that it's not well resolved into stars despite the small distance (10.4 million light-years). Astronomers postulated that if NGC 3077 is a starburst galaxy like M82, the activity, then, must be hidden (as in M82) presumably by dust.

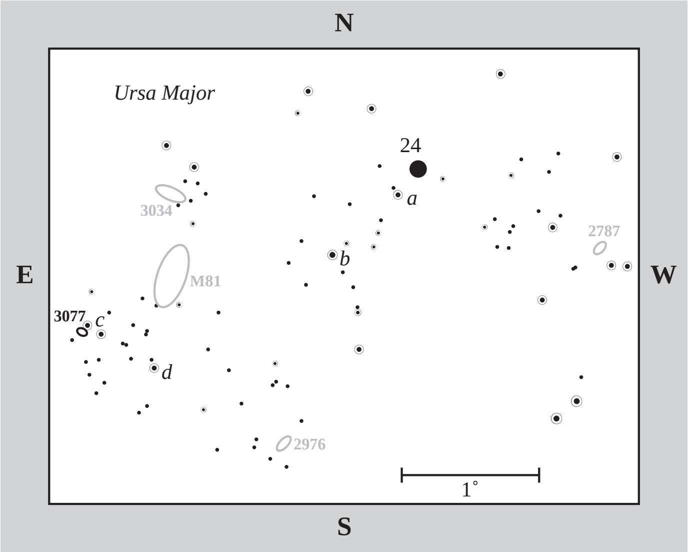
Today we know NGC 3077 is a nearby dwarf starburst galaxy with a true linear extent of 20,000 light-years, a total mass of about 1.5 billion Suns, and a total luminosity of some 450 million Suns. In 2008, NASA released an incredible image that proved, the press release said, that "galaxies are like people. They're only normal until you get to know them." NGC 3077 was part of a detailed survey, called the ACS Nearby Galaxy Survey Treasury (ANGST) program, in which astronomers used HST to observe roughly 14 million stars in 69 galaxies. The survey explored a region called the "Local Volume," which spanned distances ranging from 6.5 million light-years to 13 million light-years from Earth. The image reveals in stunning detail (see above) not only a young massive star cluster with a mass of 200,000 Suns but also that the dark clumps of material scattered around the bright nucleus of NGC 3077 are pieces of wreckage from the galaxy's interactions with its larger neighbors.

Indeed, radio observations dating to 1978 have shown a bridge of neutral hydrogen gas extending northward from a large concentration in the southeast of the galaxy (seen inclined by 38° from face on) toward the outer spiral arm structure of M81. But, as Walter Fabian (National Radio Astronomy Observatory, New Mexico) reported in 2002, the extended tidal arm of neutral gas near NGC 3077 is "one of the most dramatic features of its kind seen in the local universe." It was created by an interaction with M 81 some 300 million years ago. It is one of the few tidal systems where atomic (HI) and molecular (CO) gas as well as low-level star formation (H-α) is detected over an area of several thousand square light-years. "This tidal complex," Fabian says, "is believed to be in the process of forming a tidal dwarf galaxy."

In 2003, deep Chandra X-ray observations of NGC 3007 resolved emissions from several supershells. About 85 percent of the X-ray luminosity in NGC 3077 comes from hot interstellar gas that stretches to the north but not to the south; the remainder comes from six X-ray point sources. Two years later, in a *Monthly Notices of the Royal Astronomical Society*, Mexican astronomer Daniel Rosa-Gonzalez made subarcsecond radio observations of the galaxy and found that one of the Chandra X-ray sources is associated with a supernova remnant (SNR) some 760 years old – between the average age of SNRs detected in M82 and those detected in the Milky Way and the Large Magellanic Cloud. The other X-ray source may be from an X-ray binary in the young, massive star cluster detected by HST.

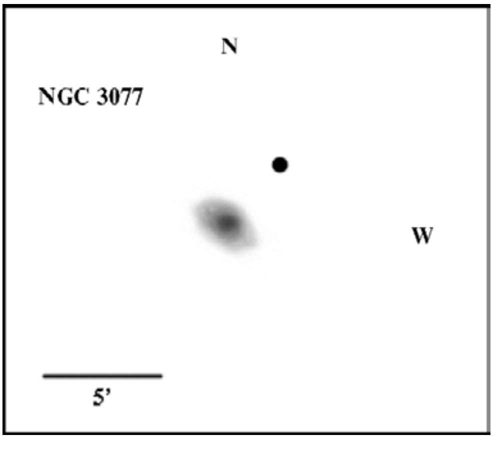
At a 2009 American Astronomical Society meeting, Zhong Wang (Harvard-Smithsonian Center for Astrophysics) explained that a recent study of the star-forming regions in the tidal arms of NGC 3077, by him and his colleagues, revealed a gigantic shell-like structure that suggests an earlier starburst occurring on scales comparable to the galaxy itself. They also detected more than 30 HII regions previously identified in the immediate vicinity of this structure showing a common origin of shock disturbance. They proposed that gravitational interactions within the triplet (M81, M82, and NGC 3077) have not only torn away large amounts of HI gas from NGC 3077's mass center, but also induced large-scale star formation over a time scale longer than a typical bursting event.

To find this peculiar dwarf galaxy, use the chart on page 174 to locate 2nd-magnitude Alpha (α) Ursae Majoris. Now look 12° to the northwest for 4.5-magnitude 24 Ursae Majoris. If you live under light-polluted skies, you may need to confirm the star with binoculars; notice that it forms the northeastern apex of a roughly 3°-wide acute triangle with the similarly bright stars Rho (ρ) and Sigma (σ) Ursae Majoris – actually this star marks the position of Sigma^1 and Sigma^2 Ursae Majoris.



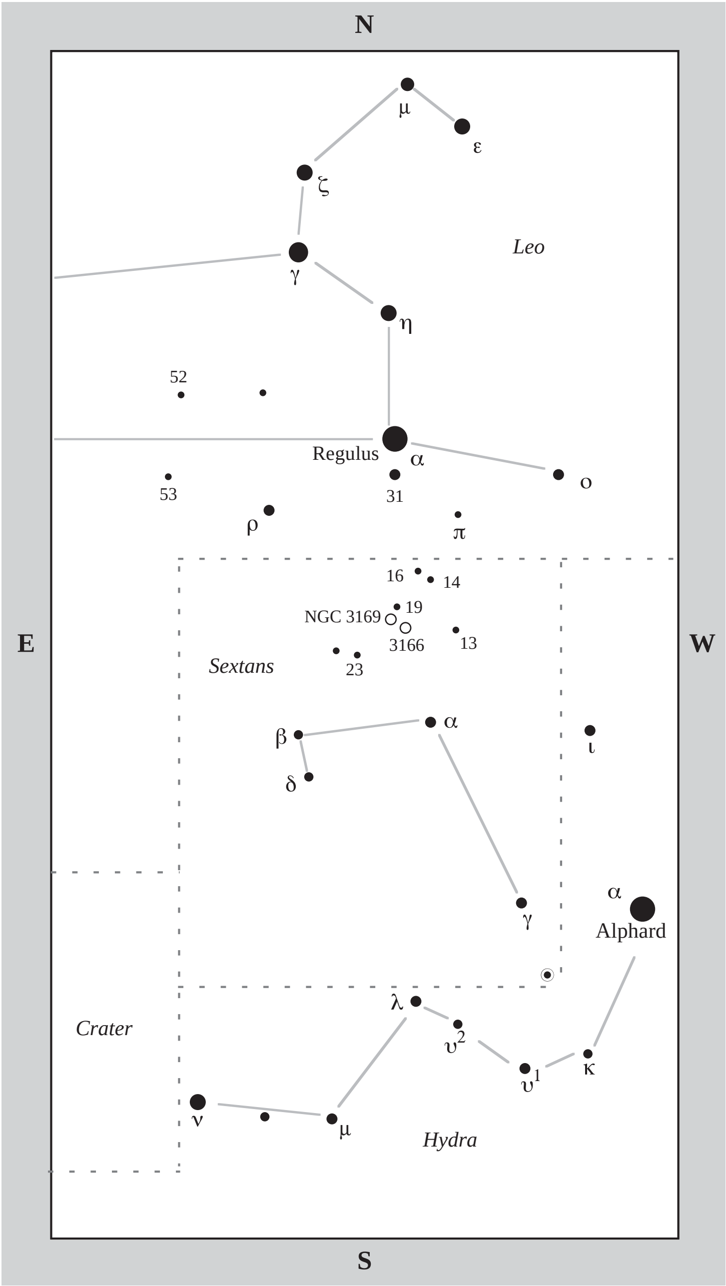
Center 24 Ursae Majoris in your telescope at low power, then switch to the chart on page 177. From 24 Ursae Majoris, move 25′ southeast to 7.5-magnitude Star *a*. Next, move about 35′ further to the southeast to 6th-magnitude Star *b*. Bright M81 lies about 1¼° east-southeast of Star *b*. Now look for the pair of 8th-magnitude stars (*c*) 40′ to the south-southeast of M81. NGC 3077 is immediately southeast of the northeastern star in Pair *c*. It is best seen with magnification and looks like a small tailless comet. So be prepared to find the field then zoom in on your target.

At 33× in the 5-inch, I could fit the triplet of galaxies in the same field of view. NGC 3077 was a bright but small (5′-wide) uniform glow kissing an 8th-magnitude star. Its form is very circular and tight, looking like a concentrated puff of diffuse light like a cotton swab. With averted vision, I could see a distinct starlike core and detect an out-of-round shape. At 60×, the galaxy takes on a more clearly elliptical form, and displays a very dense central core that gradually gets brighter toward the middle. The galaxy has a slightly mottled texture when seen with averted vision, with the northwestern side appearing slightly brighter, though this may be an illusion owing to the fact that the galaxy's southeastern side is closest to the 8th-magnitude star.



When you're done viewing NGC 3077, you may want to turn your attention to another forgotten wonder: NGC 2976, another member of the M81 group of galaxies, though it appears in a small telescope as only a dim ellipse of light. It's best viewed under a dark sky at low power. You'll need to take your time when searching for it, because the surrounding field has no bright stars. It lies about 1½° southwest of the core of M81, less than 10′ northwest of a 15′-long line of three 11th-magnitude stars (oriented northeast to southwest). I observed NGC 2976 in my smaller 4-inch Tele Vue refractor years ago, recording it at 33× as a faint ellipse of diffuse light that almost vanishes with increased magnification. Larger scopes will reveal a mottled texture to the galaxy, which has no distinct central condensation. Yet the late deep-sky observing veteran Walter Scott Houston says he spied this 10th-magnitude galaxy in a 2.4-inch Unitron refractor, noticing it had a slight diamond shape. See what you think.

Secret Deep 40 & 41
(NGC 3166 & 3169)



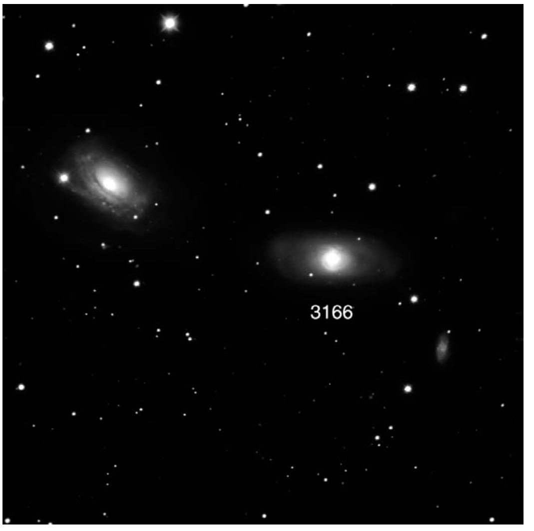
40

NGC 3166
Type: Mixed Spiral Galaxy (SAB(rs)0)
Con: Sextans

RA: 10^h 13.8^m
Dec: $+03°$ $26'$
Mag: 10.4
SB: 12.9 (Rating 4)
Dim: $4.6' \times 2.6'$
Dist: ~72 million l.y.
Disc: William Herschel, 1783

W. HERSCHEL: [Observed December 19, 1783] Considerably bright, pretty large, compressed, much brighter in the middle. (H I-3)

NGC: Bright, pretty small, round, pretty suddenly much brighter in the middle, 2nd of 3.



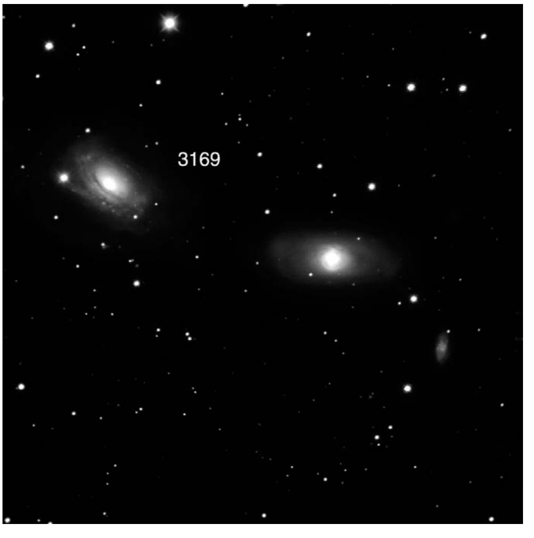
41

NGC 3169
Type: Peculiar Spiral Galaxy (SA(s)a Peculiar)
Con: Sextans

RA: 10^h 14.2^m
Dec: $+03°$ $28'$
Mag: 10.2
SB: 12.9 (Rating 3)
Dim: $5.0' \times 2.8'$
Dist: ~64 million l.y.
Disc: William Herschel, 1783

W. HERSCHEL: [Observed December 19, 1783] Considerably bright, pretty large, compressed, much brighter in the middle. (H I-4)

NGC: Bright, pretty large, very little extended, pretty gradually much brighter in the middle, star of magnitude 11.78, 80″, 3rd of 3.



NGC 3166 AND 3169 ARE TWO SMALL, yet pretty, interacting galaxies less than 2° south of 1st-magnitude Alpha (α) Leonis (Regulus). Although the pair lies about 3° north of the Celestial Equator – so they stand halfway up the sky when highest in the south, as seen from mid-northern latitudes – they suffer from lack of attention owing to their lonely location in one of the classic voids of the night sky: Sextans, the Sextant.

Actually, Johannes Hevelius (1611–1687) – who formed the constellation in 1687 from 12 unclaimed stars between Leo and Hydra (to honor the huge instrument he used in Danzig [now Gdansk] to make stellar measurements) – called it "Sextans Uraniae." Hevelius placed the instrument between Leo and Hydra because, in the vernacular of astrologers, these beasts were fiery in nature. As Richard Hinckley Allen explains in his book *Star Names: Their Lore and Meaning* (Dover Publications, New York, 1963), William Henry Smyth said its placement "formed a sort of commemoration of the destruction of [Hevelius's] instruments when his house at Dantzic was burnt in September, 1679; or, as [Hevelius] expresses it, when Vulcan overcame Urania."

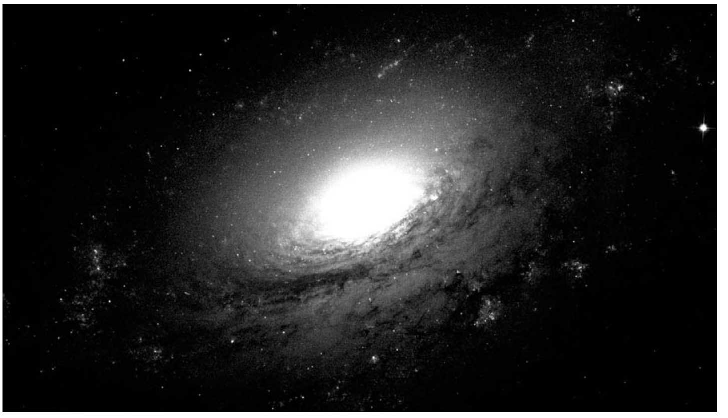
The stars of Sextans are further doomed to obscurity by having no names associated with them, only Greek letters; even its Alpha star shines at a meek magnitude 4.5, faint enough to succumb to suburban light pollution. In his book *Star Tales* (University Books, New York, 1988), Ian Ridpath suggests, "it was perhaps to demonstrate the keenness of his eyes that [Hevelius] formed Sextans out of such faint stars."

When William Herschel discovered NGC 3169 in 1783, he went on to make three additional observations of it before noticing that it had a companion (NGC 3166) only ~8′ away; how this other object, nearly equal in brightness, had escaped Herschel's attention for so long is a mystery, given the observer's acute ability to ferret out new nebulae – especially one so close to another.

William and his son John also failed to notice NGC 3165 only 4.5′ southwest of NGC 3166. But this isn't surprising; NGC 3165 shines at magnitude 14 and is only 1.5′ in apparent length. Still, as Brian Skiff and Christian Luginbuhl note in their *Observing Handbook and Catalogue of Deep-Sky Objects* (Cambridge University Press, 1998), NGC 3165 is "clearly visible" with averted vision as a "faint, difficult object" at medium powers in a 10-inch reflector.

Nevertheless, it took the visual prowess of R. J. Mitchel working under William Parsons (Third Earl of Rosse) to pick out this tiny little object on January 30, 1856, with the 72-inch Leviathan at Birr Castle. Lord Rosse and his assistants excelled at discovering new nebulae near brighter known nebulae. NGC 3165 was but one of 233 nebulous objects they discovered between 1848 and 1865 with the 36-inch and 72-inch reflectors at Birr Castle.[1]

[1] Lord Rosse's 72-inch Leviathan left an impression on science-fiction novelist Jules Verne, who mentions it in his 1905 fictional classic *From the Earth to the Moon*: "The distance which had then separated the projectile from the satellite was estimated at about two hundred leagues. Under these conditions, as regards the visibility of the details of the disc, the travelers were farther from the moon than are the inhabitants of earth with their powerful telescopes. Indeed, we know that the instrument mounted by Lord Rosse at Parsonstown, which magnifies 6,500 times, brings the moon to within an apparent distance of sixteen leagues."



Dreyer listed NGC 3165 as GC 2037 in his supplement to the *General Catalogue*; French astronomer Édouard Jean-Marie Stephan at Marseille Observatory independently discovered it on March 18, 1884, with the 31½-inch reflector at Marseille. Stephan was obviously not aware that Lord Rosse's son, Lawrence Parsons (Fourth Earl of Rosse), had published the discoveries made at Birr Castle in an 1878 *Scientific Transactions of the Royal Dublin Society*.

All three objects (NGC 3166, NGC 3169, and NGC 3165) belong to the Leo Cloud of galaxies some 72 million light-years distant. NGC 3166 and NGC 3169, your targets, are receding from us at speeds of 1,345 and 1,238 km/sec, respectively. They have similar inclinations (58° and 59°, respectively) and true physical extents (97,000 and 93,000 light-years, respectively). They also share a common envelope of neutral hydrogen, suggesting tidal interaction. So the two are tugging twin systems.

NGC 3166 is the brighter of the two galaxies by a mere 0.2 magnitude in visual light (it is fainter than NGC 3169 in blue light), has a very small, very bright nucleus extending into a short smooth bar whose major axis is perpendicular to the major axis of the disk, which is oriented nearly east–west. The bar gives way to a disk of dust-lane fragments with no evidence for spiral features or star-forming knots. The disk resides in a lens surrounded by a weak extended envelope.

NGC 3169, on the other hand, has a very bright, flattened nucleus that extends some 3,000 light-years almost perpendicular to the plane of the galaxy. Paul B. Eskridge and his colleagues (2002) note that it may also have a weak bar (seen in the near-infrared) embedded in a large elliptical bulge, whose outer regions appear sightly boxy. As the Hubble Space Telescope image above shows, the galaxy's weak disk has a complex and varied dust morphology, from nuclear spiral lanes to chaotic feathery spiral features, all seen dramatically in silhouette against the galaxy's bulge. The disk also contains more than 60 HII regions, with some of them arranged in a shell-like structure that doesn't form a clear spiral pattern.

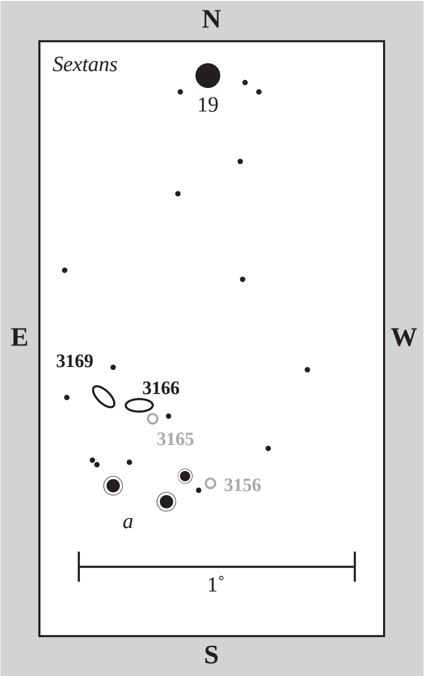
NGC 3169's most curious feature, however, is a highly distorted southeast spiral arm, suggesting that a tidal encounter has occurred between it and NGC 3166; NGC 3166's disk also shows peculiar tidal effects. The two galaxies reside some 100,000 light-years apart and are surrounded by an extended HI cloud more than 300,000 light-years across.

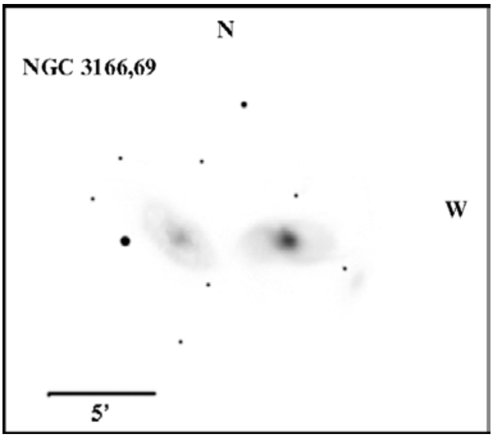
The envelope, which is centered on NGC 3169, surrounds not only NGC 3166 and

3169, but also NGC 3165. Indeed, in a 2006 *Astronomy Letters* (vol. 32, pp. 534–544), Russian astronomers Olga K. Sil'chenko (Sternberg Astronomical Institute, Moscow) and her colleagues note that they found the mean age of the stellar populations in the centers of all three galaxies to be approximately the same, about 1 billion years young. Since the galaxies are early-type ones, and since NGC 3166 and NGC 3156 show no global star formation, the astronomers suggest we are witnessing a synchronous star-formation burst in the centers of all three galaxies.

To find the celestial twins, use the chart on page 179 to locate 1st-magnitude Alpha (α) Leonis. About 25′ south of it is 4th-magnitude 31 Leonis. Now look about 35′ southwest for 5th-magnitude Pi (π) Leonis. Now use your unaided eyes or binoculars to locate 14, 16, and 19 Leonis, which form a 25′-wide isosceles triangle about 45′ southeast of Pi Leonis. Center 19 Leonis, the southernmost star in that triangle, in your telescope at low power, then switch to the chart on this page. From 19 Leonis, make a generous, but slow and careful 1½° sweep south and slightly east to an 18′-wide triangle of 7.5- to 8.0-magnitude stars (*a*). NGC 3166 is less than 20′ north-northwest of the easternmost star in Triangle *a*. NGC 3169 is immediately to its north-northeast.

At 33× in the 5-inch, the galaxies lie in a beautiful field, one rich in stellar pairs and groups. You'll find the pair about 25′ northeast of a 6′-wide triangle of magnitude 7.5 to 8.5 stars, and about 15′ north of a 6′ line of magnitude 8 to 10 stars. While NGC 3166 is the brighter of the two, my eye is drawn first to NGC 3169 because it abuts an 11th-magnitude sun to the east, causing the eye to see an illusory larger object





in that position. (This is probably why Herschel also noticed NGC 3169 first before he realized NGC 3166 was nearby.) Once I realized that there was a star next to the galaxy, NGC 3169 immediately shrank in splendor. It really is a tiny object, being only about 1′ in extent visually in my small telescope. So remember that you're looking for a little lens of light. Its disk is elongated northeast to southwest and has a small bead of light at its core. The galaxy's larger swooping and warped arms are much too faint for my 5-inch.

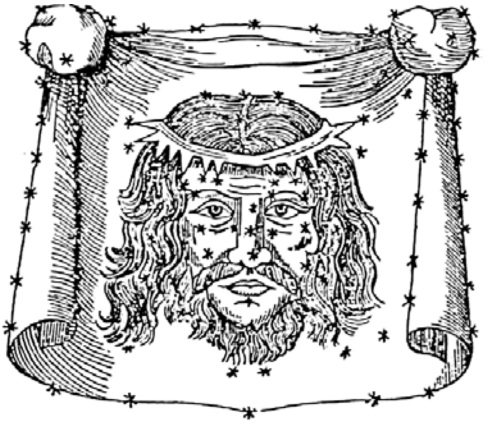
As I stare at NGC 3169, I cannot help but notice NGC 3166 to the southwest, which suddenly swells to prominence with averted vision. It's also hard to observe one, without comparing it to the other. The differences are quite striking considering the galaxies are "twins" in other respects. As I compared the two, it became immediately obvious that NGC 3166 is the slightly larger and brighter one. It also has a bright circular core that suddenly increases in brightness toward the middle where there shines a bright and stellar nucleus. At 94×, NGC 3166's elliptical disk is faintly apparent compared to NGC 3169's, which is more intense, a result of the galaxy's large central bulge. With averted vision, NGC 3169's central disk is a chaotic brew of light – various shades that swim in and out of view at the limit of visibility, leading to the impression of a misshapen and tortured nest of galactic vapors.

NGC 3169 has been the site of two known supernovae eruptions. The first (SN 1984E) was discovered visually on March 29, 1984, by Australian supernova hunter Robert Evans. It was learned, however, that three days earlier, Nataliya Metlova, of the Sternberg Crimean Station, had seen the supernova, as had Kiyomi Okazaki of Japan. The supernova was discovered near maximum light, which occurred on April Fool's Day. This Type IIL supernova (one that displays a linear decrease in its light curve) displayed the largest hydrogen luminosity ever seen from a single star; its light output was comparable to the luminosity of a spiral galaxy.

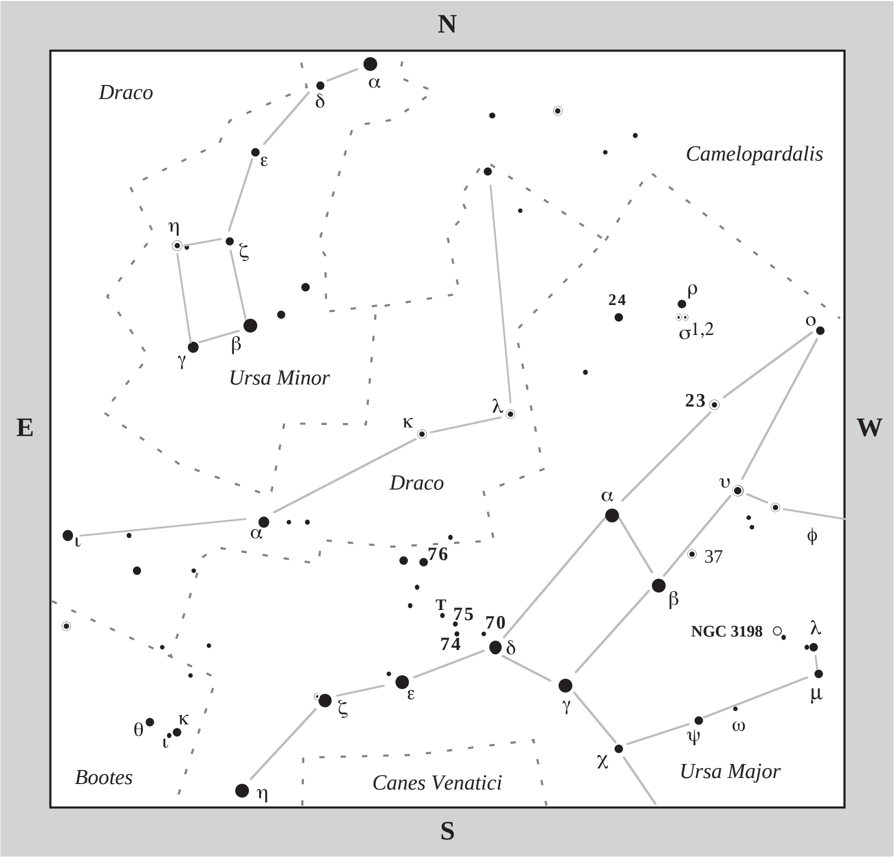
In 2003, amateur astronomers Koichi Itagaki of Japan, and Ron Arbour of the UK, independently discovered a 14.5-magnitude Type Ia supernova (one that lacks hydrogen and presents a singly ionized silicon line near peak light) 14″ east and 5″ north of the nucleus of NGC 3169. They discovered SN 2003cg near maximum light. Itagaki made his photographic discovery on March 21.51 UT; Arbour made his photographic discovery on March 22.835 UT.

By the way, in his *Cycle of Celestial Objects*, Admiral William Henry Smyth notes that NGC 3166 and 3169 are "on or near the spot where the Capuchin, De Rheita, fancied he saw the napkin of S. Veronica, in 1643, with an improved telescope which he had just constructed."

He adds, "It would be much easier to ascribe this strange discovery to a heated imagination, than to deliberate falsehood; but it happens unfortunately that there is no staring cluster or nebula near." He ends his discussion of this interesting observation by quoting Sir John Herschel: "Many strange things were seen among the stars before the use of powerful telescopes became common." Can you find the napkin?



Secret Deep 42
(NGC 3198)



42

NGC 3198
Type: Spiral Galaxy (S(rs)c)
Con: Ursa Major

RA: 10^h 19.9m
Dec: +45° 33′
Mag: 10.3
SB: 13.9 (Rating: 3.5)
Dim: 9.2′ × 3.5′
Dist: ~47 million l.y.
Disc: William Herschel, 1788

W. HERSCHEL: [Observed January 14, 1788] Considerably bright, much extended south-preceding north-following, very gradually brighter in the middle, 5′ length or 3′ wide. (H I-199)

NGC: Pretty bright, very large, much extended toward position angle 45°, very gradually brighter in the middle.

NGC 3198 IS A SOMEWHAT "SOFT" AND extended spiral galaxy about 2½° north-northeast of 3rd-magnitude Lambda (λ) Ursae Majoris (Tania Borealis) in the Great Bear's left-hind foot, close to the northern border of Leo Minor. In fact, the galaxy belongs to the Leo Spur of galaxies. The great Irish astronomer Lord Rosse included NGC 3198 as one of his 14 "spiral or curvilinear nebulae" discovered prior to 1850; Lord Rosse initially described as "spiral" any object exhibiting "a curvilinear arrangement not consisting of regular re-entering curves."

In early plates, it was classified as a barred spiral galaxy, and many sources to this day refer to it as such. The early images of the galaxy revealed a small, very bright nucleus in what appeared to be a bar, partially obscured on one side. The galaxy also displayed what appears to be a pseudo-ring in the intermediate part of the galaxy's disk, and several knotty, partially resolved branching arms with numerous HII regions. The arms in NGC 3198 appear moderately thin and fairly well defined. However, the inclination angle of this 125,000 light-year-long system is so high (19° from edge on) that the pattern is not easily traced.

In a 1991 *Astronomy & Astrophysics* (vol. 244, pp. 27–36) R. L. M. Corradi (University of Padua, Italy) and colleagues say that modern CCD images of the galaxy, however, have failed to reveal the presence of a bar. "Despite the RC2 classification," they say, "there is no strong evidence that NGC 3198 is a barred spiral." Their images show a "quite normal bulge" and an incomplete ring-like structure in the central region, noting that the spiral pattern appears complex because of the patchiness and the high inclination of the galaxy to the line of sight.

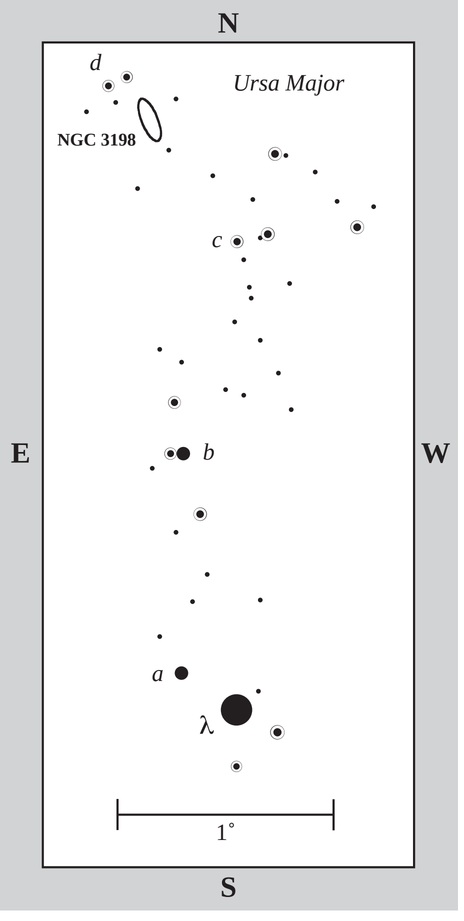
Given a more perfect viewing angle, we would probably see NGC 3198 as a two-armed spiral with a secondary third arm. The two principal S-type arms would start at the center, then wind around for about half a revolution before each arm branched to form the multiple pattern we see in the outer regions. In a private 2010 communication, Bruce Rout explained that, through a geometric projection on each of the pixels in the image, the galaxy can be seen as if looking at it from directly above. "In this case we can see the galaxy as being a perfect Archimedean Spiral," he shared.

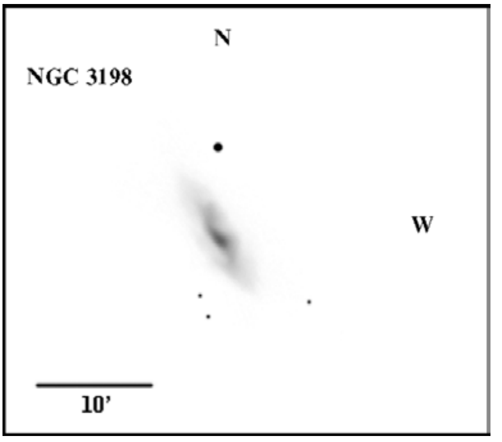
The researchers, however, did not totally discount the possibility that deep infrared images might reveal a bar, which could be responsible for an observed "twisting" at the galaxy's core. Indeed, in an email, Rout informed me that "upon further research into the structure of galaxies, and from noting the 'flat' velocity of rotation being 151 km/s, we can determine a small bar at the center of NGC 3198 having a radius of 12,500 ly. This is almost unnoticeable compared to the expanse of the entire galaxy which stretches for at least 300,000 light-years in diameter."

Rout adds that NGC 3198 is quite a normal galaxy that orbits about its center of mass in a single plane of orbit, and its stars all orbit with a constant rotational velocity. He describes the arms of NGC 3198 as a "linear star cloud of near-uniform density which appears, from our local reference frame, as a non-uniform disc due to its rotation. The apparent non-uniform radial distribution of stars is described by delayed gravitational interactions over great distances in an accelerating reference frame whereby a uniform distribution of stars appears to occupy an increasing circumference." He stresses that from "overwhelming evidence" in the observations of our own galaxy, "there is no requirement for exotic material [such as dark matter] in the linear mass distribution," Rout says, as has been postulated by other astronomers. "Any material, exotic or otherwise, having a geometry other than that given by a linear mass distribution would invalidate a constant rotational velocity profile of material making up the galaxy. We therefore conclude there is no 'dark matter' in NGC 3198."

In the Hubble Space Telescope's key project, the Cepheid distance of NGC 3198 was determined to 47 million light-years. The team identified 78 Cepheid candidates in the period range from 8 to more than 50 days, of which 52 were selected for establishing the galaxy's distance. At that accepted distance, the galaxy has a true linear extent of about 40,000 light-years, a total luminosity of about 10 billion Suns, and a total mass of 60 billion Suns.

To find this object, users of small telescopes under somewhat light-polluted skies might want to first star-hop to the field, then use moderate magnifications to sight it. Light pollution will certainly impair the view, so try for it under the darkest skies available. Start by using the chart on page 185 to locate Lambda Ursae Majoris, center it in your telescope at low power, then switch to the chart on page 188. From



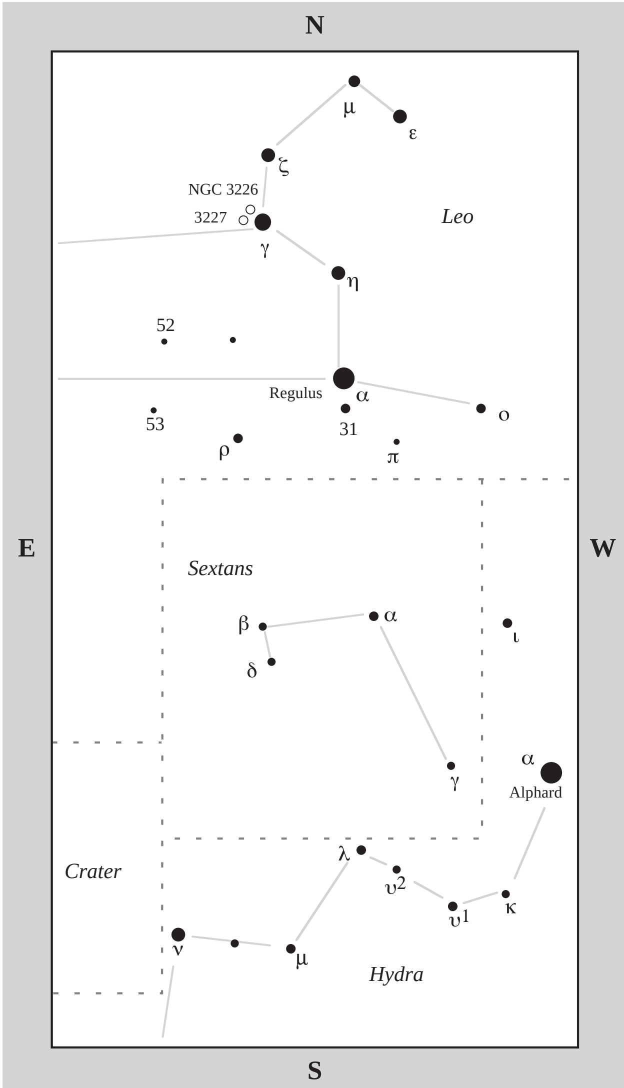


Lambda, move 18′ northeast to 6.5-magnitude Star *a*. Exactly 1° due north of Star *a* is 6.5-magnitude Star *b*, which has a 9.5-magnitude companion immediately to its east. Now make a slow and careful sweep 1° north-northwest to a pair of 7.5 and 8.0-magnitude stars (*c*). Another 1° sweep, this time to the northeast, will bring you to a tighter pair of 9th-magnitude suns (*d*). NGC 3198 is about 15′ southwest of Pair *m*.

Under a dark sky at 33× in the 5-inch, NGC 3198 is a big (nearly 10′) diffuse elliptical glow with a very nice diffuse concentration at the core but no starlike center. With time and attention I could make out traces (or hints/suggestions) of the galaxy's high-surface brightness inner S-shaped arms. At 60×, NGC 3198 is a beautiful phantom of elongated light with the inner S-shaped arms more defined, emanating from a diffuse elliptical core with no further definition. At 94×, the core does sharpen in the middle to a brighter concentration of light, but even that is a diffuse speck of light. The arms are best defined at this power, and I could see enhancements at the bends in the S. Larger telescopes, however, will reveal the galaxy's sharp core and mottling throughout the disk.

Also, be on the lookout for supernovae. As of this writing, the last one (SN 1999bw) was discovered at 18th magnitude by the Lick Observatory Supernova Search on April 20, 1999 UT. Spitzer images of the object on May 1 revealed that the shell's size is consistent with ejecta expanding at 1000 km/sec in the five years since core collapse, suggesting the reported emission may be from dust that condensed within the ejecta. NGC 3198 was the site of another supernova (SN 1966J), a prototype-Ib supernova, that had a peak blue magnitude of 11.2.

Secret Deep 43 & 44
(NGC 3226 & 3227)



43 & 44

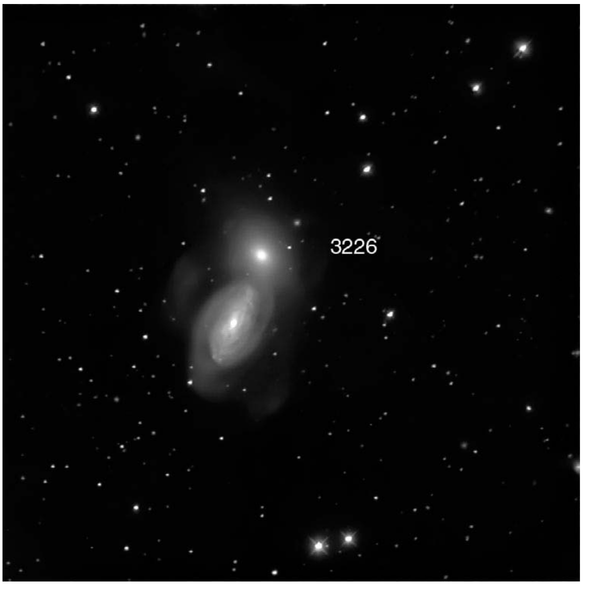
43

NGC 3226
Type: Elliptical Galaxy (E2 peculiar)
Con: Leo

RA: $10^h\ 23.4^m$
Dec: +19° 54′
Mag: 11.4
SB: 13.1 (Rating: 3.5)
Dim: 2.5′ × 2.2′
Dist: ~66 million l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed February 15, 1784] Two, about 2′ asunder. Both faint, considerably large, round. (H II-28)

NGC: Pretty bright, considerably large, round, double [with 3227], toward position angle 159°, 138″.



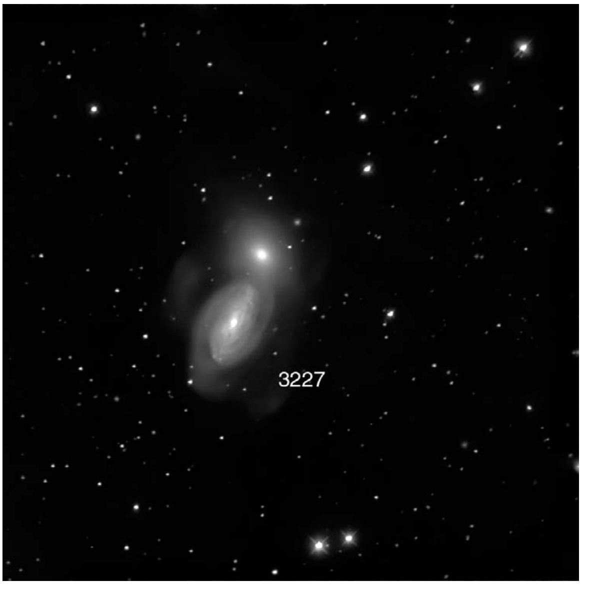
44

NGC 3227
Type: Spiral Galaxy (SAB(s) peculiar)
Con: Leo

RA: $10^h\ 23.5^m$
Dec: +19° 52′
Mag: 10.3
SB: 14.1 (Rating: 4)
Dim: 6.9′ × 5.4′
Dist: ~66 million l.y.
Disc: W. Herschel, 1784

W. HERSCHEL: [Observed February 15, 1784] Two, about 2′ asunder. Both faint, considerably large, round. (H II-29)

NGC: Pretty bright, considerably large, round, double nebula [with 3226] toward position angle 159°, 138″.



43 & 44

The interacting galaxy pair NGC 3226–7 was "invisible" when I was a youth. They were too faint to appear on my *Norton's Star Atlas*, so widely used by backyard astronomers during my generation. Not until I began using the library at the Harvard College Observatory in the early 1970s did I learn of the true wealth of galaxies and other deep-sky objects populating the heavens beyond the bright Messier objects and some equally apparent Herschel ones. My main resource was Antonin Becvar's 1962 *Atlas of the Heavens*. But even on it, NGC 3226 and NGC 3227 eluded attention; they, like many other galaxies in the *Atlas*, were "anonymous," appearing as red ellipses of varying sizes without descriptive labels: Becvar identified only those galaxies brighter than 12th magnitude.

At the time, searching for little galaxies fainter than 12th magnitude with a 9-inch f/12 refractor from a city seemed next to ludicrous. But how times, telescopes, eyepieces, and attitudes have changed. Our knowledge of the deep sky and approach to visual observing have also changed... for the better; we're becoming more brazen in our attempts to push the limits of our telescopes and our vision.

More importantly, the magnitudes of many "faint" galaxies found in older sources have been modified – though it's still not uncommon for some to have their brightnesses underestimated by one or more magnitudes, or to find different values in different sources! For instance, in a 1985 *Astrophysical Journal* article, the authors state that NGC 3227 has an apparent visual magnitude of 12.2; Burnham's *Celestial Handbook* has it as magnitude 11.6; the Nasa Extragalactic Database lists it as magnitude 11.1; and *The Deep Sky Field Guide* says magnitude 10.3 – only 0.2 magnitude fainter than the galaxies M91 or M98 in Coma Berenices!

As you will discover in your own searches, an object's visibility is determined by more factors than magnitude alone. For instance, NGC 3226 shines about a magnitude fainter than its companion; but its small apparent size ($2.5' \times 2.2'$) and higher surface brightness (13.1 compared to 14.1) make it stand out against the sky background almost as well as NGC 3227. Also, NGC 3226's close proximity to larger NGC 3227 ($5.4' \times 3.6'$) helps the eye to enhance 3226's visibility. In fact, Skiff and Luginbuhl found NGC 3226–7 "easily detectable" in a 6-inch telescope. I have since seen these galaxies in telescopes as small as 4-inches under a dark sky. And I wouldn't be surprised if a keen-eyed observer under similar conditions could detect at least the brighter member in a good 2-inch scope, with patience.

William Herschel discovered the pair in 1784 and considered them a "double nebula." Today we know NGC 3227 is a peculiar mixed-spiral galaxy (an intermediate case between a spiral and a barred spiral), 130,000 light-years in linear extent and inclined 42° from face on. It is strongly interacting with NGC 3226, a peculiar elliptical companion less than half its size and inclined 59° from face on. The pair is linked by a long tidal tail – one reminiscent of that between M51 and its irregular companion NGC 5195 (see Secret Deep 67).

NGC 3226–7 has been the object of much professional study. The most detailed images of NGC 3227 show a bright active nucleus at the galaxy's core, which is surrounded by a faint spiral structure dappled with HII regions. Its outer north-western arm appears to be the bridge between it and NGC 3226.

Halton Arp included NGC 3226–7 in his 1966 *Atlas of Peculiar Galaxies*. Known as Arp 94, the tidal pair has two neutral hydrogen (HI) plumes: one extending 7′ north of the system, the other 16′ south; there's also an unusual HI feature at the base of the north plume – at the projected intersection of two faint stellar tidal streams wrapped around the interacting pair of galaxies; this feature, dubbed J1023+1952, appears to be a star-forming, tidal dwarf galaxy candidate. Writing in a 2008 *Astrophysical Journal*, Ute Lisenfeld (University of Grenada, Spain) and colleagues report that data from the IRAM 30-meter telescope show that the galaxy candidate is made from metal-enriched gas. Thus, the Lisenfeld team argues, it did not pre-exist but most likely formed from recycled, metal-enriched gas expelled from NGC 3227 or NGC 3226 in a previous phase of the interaction.

NGC 3227 is classified as a Type 1 Seyfert galaxy. A Seyfert galaxy has a small but intensely bright nucleus that behaves like a low-energy quasar, exploding matter episodically into space. A massive black hole, accreting gas from its surrounding environment, is thought to power this active galactic nucleus (AGN).

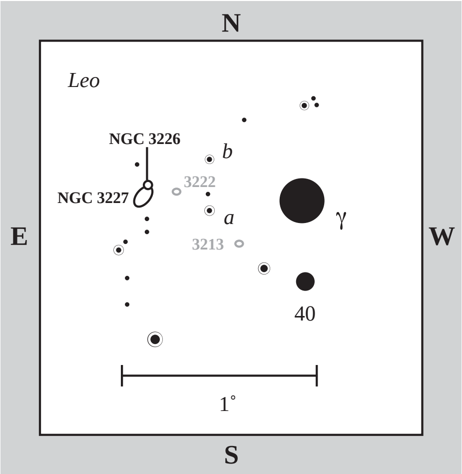
X-ray observations of NGC 3227's AGN reveal it to be highly variable (in time scales of months or less). The variability may be caused by clouds of gas and dust of varying sizes and densities orbiting the AGN and absorbing X-ray emission. A substantial amount of the X-ray absorbing gas may lie within 1.3 light-years of the nucleus.

Phil Uttely and Ian McHardy (University of Southampton, UK) used data from the Rossi X-Ray Timing Explorer (RXTE) spacecraft to observe a three-month-long dimming event that they suspect was due to a cold cloud of dust and gas eclipsing the central source of NGC 3227's AGN, temporarily obscuring it from our line-of-sight. As discussed in a 2003 *Astronomical Society of the Pacific Conference Series* paper, the researchers determined that the observed cloud had a diameter of around a light-day and was located 10–100 light-days from the X-ray emitting source. Likewise, in the 2001 *ASP Conference Series*, Stefanie Komossa (Max-Planck Institute for Extraterrestrial Physics, Germany) and her colleagues report how Chandra X-Ray Observatory data also favor the theory that variable obscuration by cold clouds passing our line of sight occurs frequently in this galaxy.

Based on observations at the European Southern Observatory Very Large Telescope, Richard I. Davies (Max-Planck Institute for Extraterrestrial Physics, Germany) and his colleagues report in a 2006 *Astrophysical Journal* that within a few light-years of the AGN there has been an intense starburst, the most recent episode of which began about 40 million years ago but has now ceased. They found the current luminosity of stars within 100 light-years of the AGN to be about 3 billion Suns, which is comparable to that of the AGN. Thus, star formation must be occurring in the obscuring material surrounding the central black hole, for which Davies *et al.* have derived a mass range of 7 million to 20 million Suns.

NGC 3226 is a Seyfert galaxy, but one with a low-ionization nuclear emission-line region (LINER) nucleus. In other words, its AGN is perhaps in its lowest state of activity, a trait commonly found in many bright galaxies. An AGN, then, can be likened to a powerful volcano, one that can lay dormant for tens, hundreds, or many thousands of years, before exploding onto the scene; after expending its energy, the volcanic powerhouse returns to sleep, though ready to awaken once again some time in the distant future.

Aaron J. Barth (California Institute of Technology) and his colleagues note in a 2004 *Astrophysical Journal* that while there is no question that NGC 3226 hosts a genuine AGN, it is too massive and too large to be classified as a true dwarf elliptical galaxy. Instead, he says, it appears to be a small but ordinary elliptical, probably with a fairly massive black hole with a mass on the order of 100 million solar masses. But this, Barth says in a private 2010 communication, was "just a rough estimate based on the galaxy's stellar velocity dispersion, not a real measurement of the black hole mass."



To find this interesting interacting pair, simply find 2.4-magnitude Gamma (γ) Leonis (Algieba) in the Sickle of Leo (or the Lion's mane) and center it in your telescope at low power. NGC 3226–7 lies only 50′ east of that star; in many backyard telescopes the galaxy pair will share the same low-power field of view with Gamma.

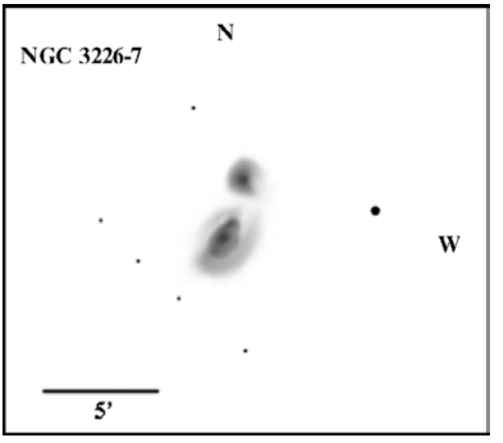
But before you sweep up that extragalactic pair, look at Gamma Leonis with a magnification of 100× or more. The star is one of the most magnificent doubles in the northern skies. William Herschel discovered it in 1782, though it is more commonly known as W. Struve (STF) 1424AB. The pair consists of a magnitude 2.4 golden primary (K0III) and a green 3.6-magnitude secondary (G7III) separated by 4.4″, so they are resolvable under steady skies in a 2-inch scope. Under steady seeing, the primary has a lemon yellow sheen tinged with red (giving it its overall golden hue); the secondary burns a paler yellow with a touch of pistachio. In his *Cycle of Celestial Objects*, Admiral William Henry Smyth saw the primary as bright orange and the secondary as greenish yellow. Try comparing the light of these stars with those of the slightly fainter but popular double Beta (β) Cygni (Albireo), which, to some observers, have similar complimentary colors.

When you have finished admiring this gorgeous double, return to your lowest power then gently move your scope 50′ to the east, where you'll find NGC 3226–7. Otherwise, you could first search about 30′ east-northeast of Gamma for the two roughly 9th-magnitude stars labeled *a* and *b* on the chart on this page. The galaxies form the eastern apex of a near-equilateral triangle with them. Look for a delicate elliptical glow (the combined light of the two galaxies), some 2′ across, oriented north-northwest to south-southeast.

At 33× in the 5-inch, that single glow immediately splits in two. With averted vision, NGC 3227, the more southerly of the two, swells in size and intensity to become the larger and brighter one. Still, at 60×, NGC 3226's core is quite remarkable and extremely prominent, like a swollen star; it's surrounded by a faint circular disk that gradually fades away from the nucleus. With averted vision its southern edge seems to touch NGC 3227, where the two gently kiss.

At this power, NGC 3227 appears as an amorphous elliptical glow with an intense starlike nucleus nested in a wider (2′) lens of light. With time and patience, I saw the outer edge of that lens as horseshoe-shaped on the southeastern side, the western arm of which extended fully to NGC 3226, apparently linking them in what appears to be the first step in a gravitational embrace. The cores of both galaxies hold up well at 94× and higher magnifications, which tend to enhance NGC 3227's horseshoe-shaped appearance.

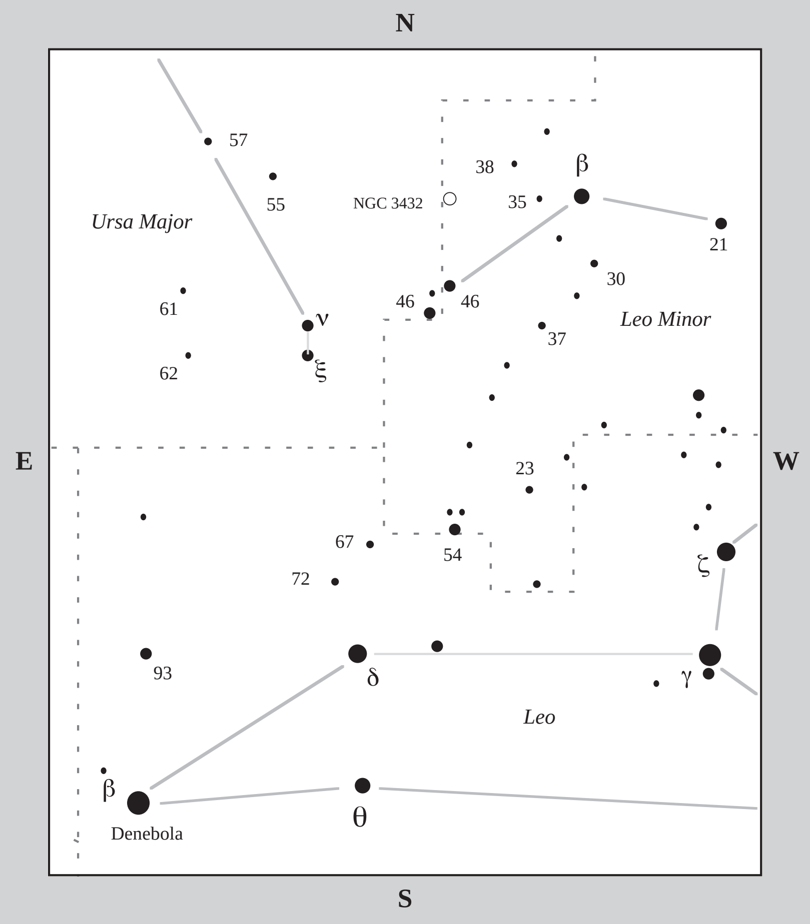
I don't know why NGC 3227's northwestern side is not as apparent as its southeastern side; it should be. I can only suspect that in my small telescope, at these



modest powers, the proximity of NGC 3226 to NGC 3227's northwestern side steals the eye's attention, making NGC 3227's disk appear to fade in that direction. In other words, NGC 3227's asymmetry is likely an illusion.

Be on the lookout for supernovae in NGC 3227. On December 21, 1976, Arnold Richard Klemola (Lick Observatory) discovered on photographic plates a supernova, of blue magnitude 17, 27″ east and 22″ north of NGC 3226's nucleus – but SN 1976K is most likely associated with NGC 3227. Another supernova appeared in NGC 3227 in 1983 along a faint extension of a spiral arm, near (but not in) the dust lanes.

Secret Deep 45
(NGC 3432)



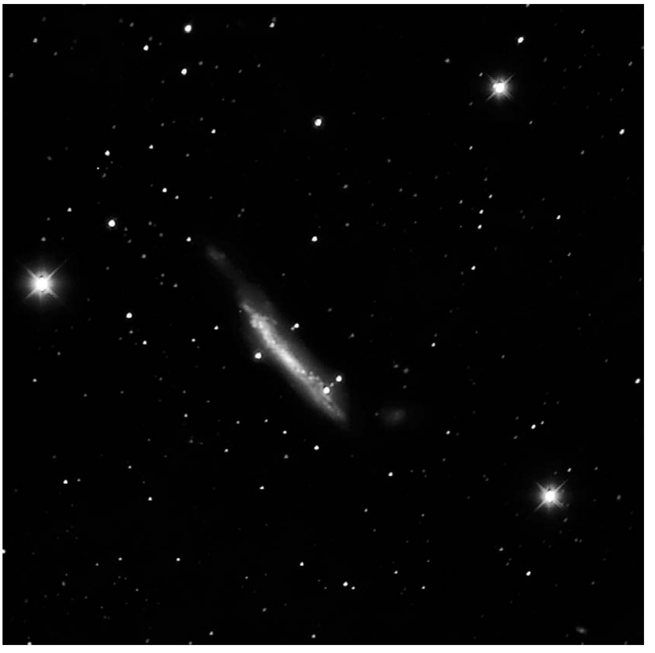
45

Knitting Needle Galaxy
NGC 3432
Type: Dwarf Barred Spiral Galaxy (SB(s)m)
Con: Leo Minor

RA: 10^h 52.5^m
Dec: +36° 37′
Mag: 11.2
SB: 13.9 (Rating: 4)
Dim: 6.9′ × 1.9′
Dist: ~42 million l.y.
Disc: William Herschel, 1786

W. HERSCHEL: [Observed March 17, 1786] Considerably bright, extended south preceding north following, few stars in preceding, 1 in north, unconnected. (H I-172)

NGC: Pretty bright, pretty large, very much extended toward position angle 40°, double star close south preceding.



NGC 3432 IS A VERY NICE EDGE-ON, barred spiral galaxy, inclined 84° from our line of sight. It lies about 3° southeast of 38 Leonis Minoris, an isolated 4th-magnitude star in the back of the Lesser Lion, the sky's 64th largest constellation in area.

Polish astronomer Johannes Hevelius formed Leo Minor in 1687, using 18 "left over" stars between the back of Leo the Lion and the rear feet of Ursa Major, the Great Bear. The constellation contains only 22 square degrees of sky. It is also dim, having only one star brighter than fourth magnitude – though only by a whisker.

The constellation's three brightest stars – 46, Beta (β), and 21 Leonis Minoris, respectively – form a long, flat triangle. Curiously, Leo Minor has no Alpha (α) star, making it the only northern constellation without one. Hevelius is not to blame. As Ian Ridpath informs us in his delightful book *Star Tales* it was an oversight by the nineteenth-century English astronomer Francis Baily, who labeled and numbered the new constellation's stars 150 years after Hevelius's death. "In his *British Association Catalogue* of 1845," Ridpath explains, "Baily assigned the letter Beta to the second-brightest star in Leo Minor, but left the brightest star (46 Leonis Minoris) unlettered by mistake."

Although Hevelius did not number or letter the stars in Leo Minor, he apparently did bestow a name to 46 Leonis Minoris, calling it *Praecipua*, meaning "the Excellent One" or "the Chief" – quite amazing considering the star shines at only magnitude 3.8. And while Hevelius first imagined a lion cub in this region, one mimicking the posture of its grander relative (Leo), he was not the first to arrange stars in this region as an imagined figure. Ancient Chinese stargazers saw them as *Noui-p'ing*, the Administrator of the Interior – either a magistrate who equalized punishments or the officer in charge of the imperial harem; it's uncertain, so you decide.

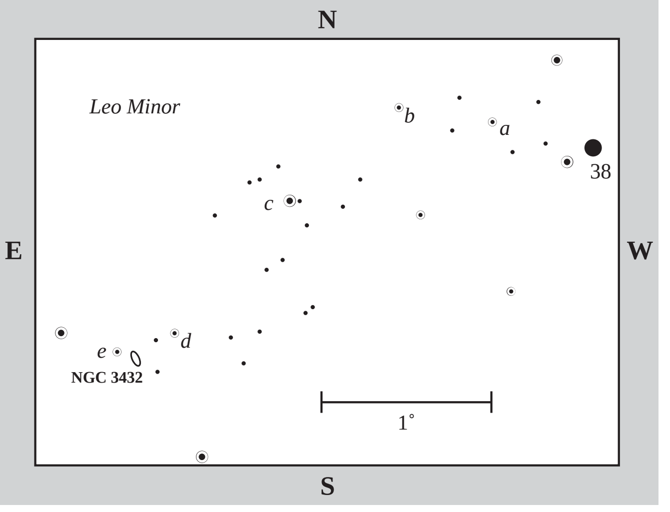
Leo Minor has a few deep-sky objects of interest. Take, for instance, the face-on spiral galaxy NGC 3486. Although it is brighter than NGC 3432 by 0.7 magnitude, its lower surface brightness (14.1) makes this galaxy more difficult to detect, especially under skies of less-than-perfect quality. No matter, I find NGC 3432 fascinating, not only because it's a slender edge-on wonder (wonderfully wedged between three moderately bright stars as seen through backyard telescopes), but also because it's an astrophysical curiosity.

NGC 3432 is a member of the Leo Spur of galaxies and is moving away from us at a velocity of 616 km/sec. The galaxy, recognized as a dwarf, is also known as Arp 206 and UGC 5986. NGC 3432 is interacting with UGC 5983, a dim dwarf galaxy 3′ to the west-southwest. Its disk is very complex, showing considerable distortion and a bright central bar – riddled with bright knots and chaotically distributed across its length – and a curious condensation (MAC 1052+3640) at the galaxy's northeast end. Two distinct tidal tails are also visible in HI images, as Eric M. Wilcots, Catherine Lehmen, and Bryan Miller describe in a 1996 *Astronomical Journal* (vol. 111, p. 1575).

In a 1996 *Astronomical Journal*, Canadian astronomers Jayanne English and Judith Irwin (Queen's University, Kingston, Ontario) note that their Very Large Array observations show a radio halo extending up to 17,300 light-years above the galaxy's plane as well as radio "spurs." These latter features, they say, do not generally align with regions of star formation in the disk nor with discrete ionized features, such as supernovae remnants or emission nebulae.

The galaxy also does not have an enhanced giant (e.g. 30 Doradus-sized) HII region formation rate at this stage in the interaction. "Nor is it forming massive stars at a high rate," English says. "The reason this is important is that the wind from massive stars and their supernova explosions create blowouts – chimney-like holes in the gas – that allow cosmic rays to escape above the disk to form the halo which is detected in radio continuum observations; radio continuum observations detect electrons (cosmic rays) accelerating in a magnetic field. This is consistent with radio observations of hydrogen gas which show the galaxy has two distinct tidal tails."

In May 2000, the Lick Observatory Supernova Search encountered a curious 17.4-magnitude variable star about 123″ east and 180″ north of the the galaxy's diffuse nucleus, superimposed on an HII region or a spiral arm. At first, the star appeared to be an extragalactic nova, but it was later reclassified as a Type IIn supernova and given the designation SN 2000ch. But analysis of the star's complex light curve, spectrum, and luminosity



suggested that the star is a "supernova impostor."

Indeed, the object is now believed to be a very massive, luminous blue variable star analogous to Eta Carinae; thus, the star's observed variations are due to repeated mass-ejection events. At a 2001 American Astronomical society meeting, R. Mark Wagner (LBT Observatory) and his colleagues noted that the star's brightest apparent magnitude implies an absolute magnitude of about –12.7 at the distance of NGC 3432 – a value comparable to Eta Carinae during its grand outburst in the mid-nineteenth century. At the 2006 IAU meeting in Prague, Schulyer D. Van Dyk argued that NGC 3432 is but one of several recent luminous events that have been identified initially as supernovae but are probably not genuine. Instead, he says, these highly luminous events represent an interesting pre-supernova evolutionary phase for very massive stars.

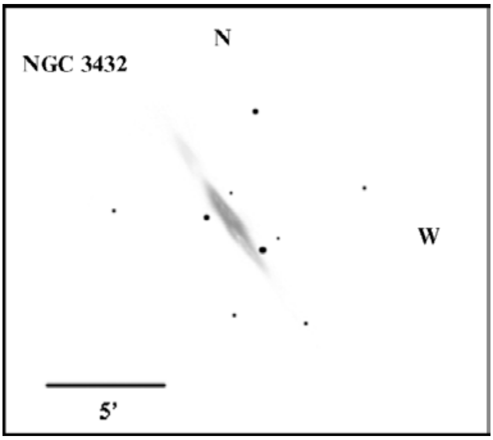
Finding this interesting galaxy requires a careful star-hop. Seeing it also takes a bit of patience, so be prepared and take your time. Using the chart on page 195, start by looking about 10° (a fist width) above 3rd-magnitude Delta (δ) Leonis (Zosma) in the Lion's hindquarters for the pair of roughly 3rd-magnitude stars marking the right hind foot of the Great Bear: Nu (ν) and X; (ξ) Ursae Majoris. About 5° west of Nu is a ~1°-wide arc of three suns, oriented north-northwest to south-southeast; the brightest star in the arc is 3.8-magnitude 46 Leonis Minoris (Praecipua); the second brightest is 5th-magnitude 46 Ursae Majoris, so don't confuse the two. NGC 3432 is about 2¼° almost due north of Praecipua.

Unfortunately, the region of sky between Praecipua and NGC 3432 is fairly devoid of good guide stars to make a star hop. You can try sweeping, though, if you have a moderately large-aperture telescope. But I suggest continuing your naked-eye search from Praecipua to look 5½° west-northwest for 4.2-magnitude Beta (β) Leonis Minoris. Now use your binoculars or naked eye to find 6th-magnitude 38 Leonis Minoris about 2½° to the northeast. You'll know if you have found it, because the star has an 8th-magnitude companion about 10′ east-southeast.

Using low power, center 38 Leonis Minoris, then move about 40′ east-northeast to 9th-magnitude Star *a*. Now move 30′ east-northeast to similarly bright Star *b*. Next make a 50′ swing southeast, to 7.5-magnitude Star *c*. A careful 1° sweep further to the southeast will bring you to

9th-magnitude Star *d*. NGC 3432 lies about 15′ southeast of Star *d* and 5′ west-southwest of 9th-magnitude Star *e*.

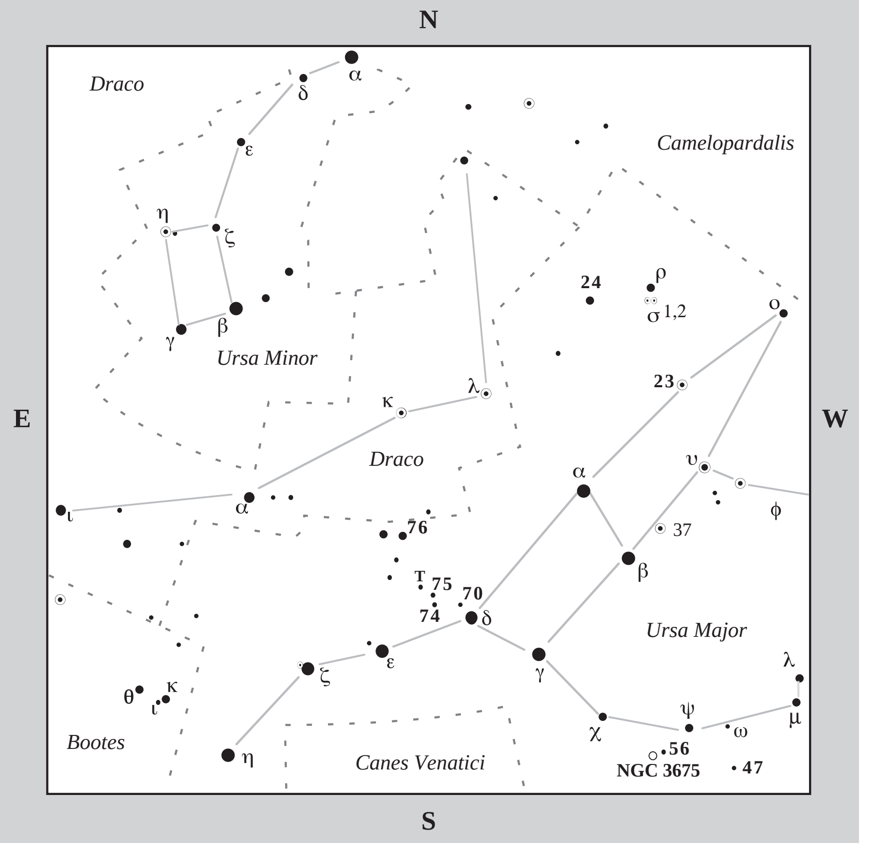
At 33× in the 5-inch, NGC 3432 is a truly mesmerizing sight, appearing as a slender 5′-long streak of light, oriented northeast to southwest, with a bright and sharp central glow that seems to stab three tightly knit field stars: a nice pair to the southwest and an equally bright sun to the east. It looks as if the galaxy were a needle being pushed gently into black sequined fabric. The stars help guide the eye to the galaxy's bright core. At 60× and averted vision, the "needle's" light tapers unevenly away from the center, being brightest on the southwest end. At 94×, the galaxy holds up well. The 2′-long core seems faintly mottled, with a knot just north of the star bordering the core to the east. From this knot, the galaxy fades away toward the northeast,



though, once again, unevenly, with the northeast tip being brighter than the section closest to the core. That brightening at the northeast tip coincides with the position of MAC 1052+3640, though it is not visible at all as a distinct feature in a 5-inch telescope, just an extremely small enhancement of faint light.

46

Secret Deep 46
(NGC 3675)



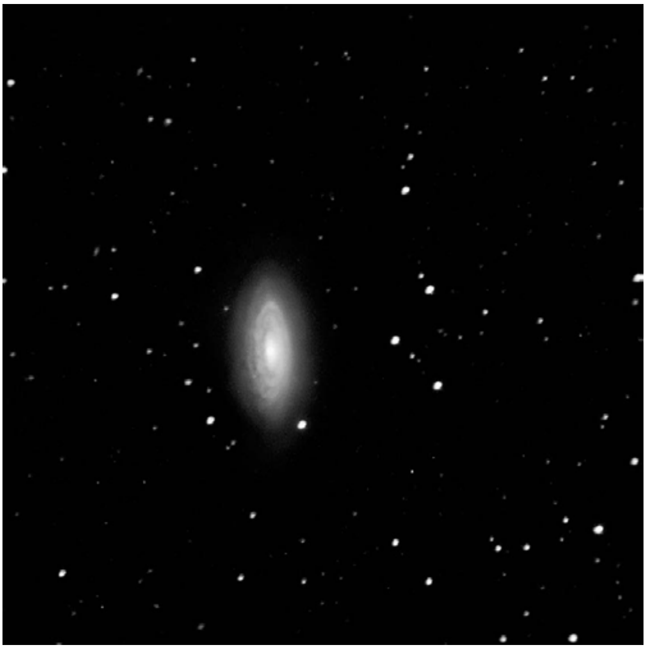
46

NGC 3675
Type: Spiral Galaxy (SA(s)b)
Con: Ursa Major

RA: 11^h 26.1^m
Dec: +43° 35′
Mag: 10.2
SB: 13.3 (Rating: 4)
Dim: 6.2′ × 3.2′
Dist: ~42 million l.y.
Disc: William Herschel, 1788

W. HERSCHEL: [Observed January 14, 1788] Very bright, considerably large, much extended, mer., bright nucleus, 6′ long, 2′ wide chevelure. (H I-194)

NGC: Very bright, considerably large, very much extended toward about position angle 0°, very suddenly much brighter in the middle to a nucleus, many stars preceding.



NGC 3675 IS A FAIRLY BRIGHT SPIRAL galaxy about 3° east-southeast of 3.5-magnitude Psi (ψ) Ursae Majoris, the Great Bear's right hind knee. As Herschel noticed, the object's core is very bright, making it a good object for small-telescope users to hunt down – especially since it shares the same low-power field with 5th-magnitude 56 Ursae Majoris. In the nineteenth century, Admiral William Henry Smyth had an interesting description of this "pale, white" glow whose "axis of extension is preceded by stardust," no doubt a reference to the "many stars" that Herschel saw preceding it. Smyth also said the "ill defined surface . . . has the appearance of a flat stratum seen obliquely."

Today we know this spiral system, which is receding from us at 770 km/sec, is about as large as our Milky Way; it spans 100,000 light-years of space and has a total mass of some 110 billion Suns. The galaxy belongs to the nearby Leo Spur, which also includes the flocculent spiral galaxy NGC 2841 (Hidden Treasure 49) in Ursa Major. We see NGC 3675 tilted nearly 30° from edge on, so the galaxy's remarkably high dust content (which can be seen well in silhouette against the near side of the disk) has caused some confusion over the years as to the galaxy's type.

Grand design spiral galaxies display at least two well-defined and magnificent arms. But early images of NGC 3675 showed it to be an exception, sporting only one. In a 2002 *Astrophysical Journal Supplement* (vol. 143, p. 73), Paul B. Eskridge (Ohio State University) and his colleagues found that later images showed not only the galaxy's bright nucleus embedded in an elliptical bulge but also a low-contrast bar and multiple arms in a clear interarm disk. Deeper images also showed the galaxy's narrow, tightly wound spirals forming an inner pseudo-ring, which has been followed for another full winding outside the ring. Beyond that, the galaxy's outer arms are very patchy and filamentary.

Hubble Space Telescope optical images (V and R bands) and ground-based optical images (B, V, and R bands) have now revealed these features sans bar in even more intricate detail. In the HST image, for instance, the spiral pattern appears unlike a grand-design spiral and more like the flocculent arms in NGC 2841 or NGC 488 (Secret Deep 3), consisting of a large number of individual spiral fragments in close concert with rich segments of spiral dust lanes out to large distances. The central bulge in NGC 3675, however, is smaller than those in NGC 488 or in NGC 2841.

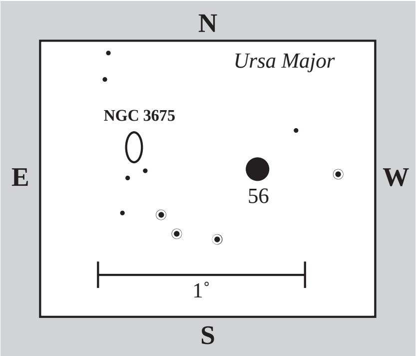
The very few knots in the arms of NGC 3675 are presumed to be HII regions, though they are poorly resolved. The poor resolution into HII regions and stars shows that the current rate of star formation is low. And while the HST and ground-based optical images showed a bulge component with the same position angle as the disk, they revealed no signature of a bar.

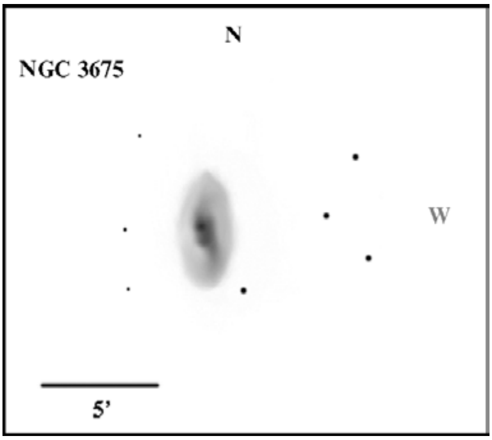
In a 2000 *Astronomical Journal* paper (vol. 119, p. 536), however, Eskridge and his colleagues argue that while optical images of galaxies might show no bar, they can be identified in the near-infrared (J, H, and K bands) – and NGC 3675 displays a strong bar in the near-infrared. Galaxies with optically hidden bars, they explain, are most often systems with relatively short, high-contrast, infrared bars that are "hidden in the optical by patchy foreground extinction and complex inner arm structure." They note that it's also notoriously difficult to detect bars in edge-on galaxies based on imaging data alone, "thus we are not troubled by the disagreement for these galaxies." Although NGC 3675 is not edge on, it is highly inclined.

"Another issue with identifying bars in optical vs. near-infrared light," Eskridge explains, "is that bars are mainly composed of old stars. B-band images are really good at showing the distribution of young stars and dust. H-band images are much better at showing the distribution of the older stars."

The authors disagree, however, with claims found in the recent literature that all or nearly all bright spirals are barred in the near-infrared. They do find that nearly 50 percent of galaxies classified as unbarred in the 1994 *Carnegie Atlas of Galaxies* are strongly barred in the near-infrared, with late-type spirals (Sc-Sm) having essentially the same bar fraction as early-type spirals (Sa-Sb). Thus, while deep optical images show NGC 3675 as a normal SA(s)b-type spiral, in the near infrared, it's an SB(r)a barred spiral.

Finding NGC 3675 is a cinch. Just use the chart on page 200 to locate Psi (ψ) Ursae Majoris, which is a little more than 7° southwest of Chi (χ) Ursae Majoris. From Psi, use your unaided eyes or binoculars to find 5th-magnitude 56 Ursae Majoris. NGC 3675 is only 35′ east-northeast of 56 Ursae



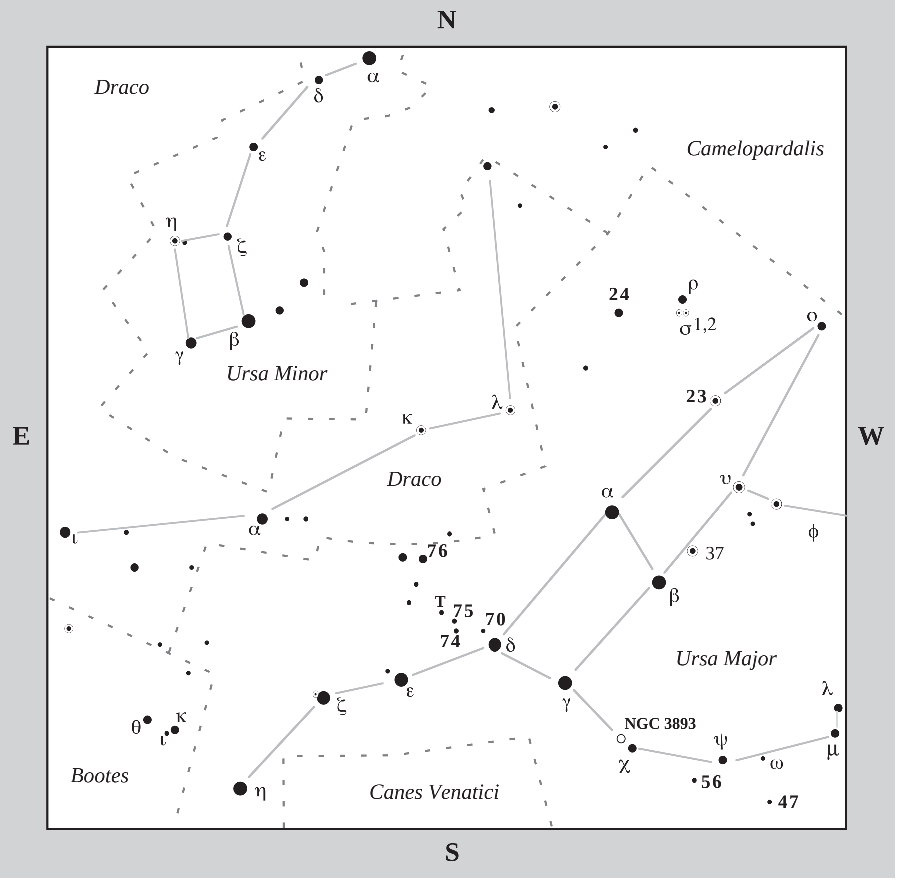


Majoris. Use the chart on this page to identify the galaxy's exact location.

At 33× NGC 3675 was a big, bright, and quite obvious 4′-long ellipse, oriented north–south, which swells with averted vision. The galaxy is so bright that Brian Skiff and Christian Luginbuhl saw it as a "faint patch" through a 2.5-inch telescope. At 60× the nuclear region is very bright and extremely starlike in a tiny central lens. The disk is a large and uniform elliptical glow with a dim sun punctuating its southwestern flank. With time, I could also suspect some enhancements in the disk along the major axis, and a possible knot about 2′ north of the nuclear region. At 94×, the core remains very stellar, and I traced out what appeared to be an S-shaped spiral structure to the disk, which is otherwise faintly mottled.

As reported in IAU *Circular* No. 4021, on December 2, 1984, UT, Japanese amateur Kaoru Ikeya of Shizuoka visually discovered a possible 13th-magnitude supernova in NGC 3675 during one of his extragalactic supernova patrols. Ikeya made further observations on December 3 and 8, which again showed the object shining at 13th magnitude. The position of the possible supernova (SN 1984R) was measured by H. Shibasaki on an exposure on December 4 UT with the 0.5-m Schmidt at the Dodaira station. Unfortunately, following Ikeya's discovery no spectra were ever made of this star, so its type remains unknown.

Secret Deep 47
(NGC 3893)



47

NGC 3893
Type: Mixed Spiral Galaxy (SAB(rs)c)
Con: Ursa Major

RA: $11^h\ 48.6^m$
Dec: $+48°\ 43'$
Mag: 10.5
SB: 12.8 (Rating: 4)
Dim: $4.2' \times 2.3'$
Dist: ~51 million l.y.
Disc: William Herschel, 1788

W. HERSCHEL: [Observed February 9, 1788] Pretty bright, pretty large, round, much brighter in the middle. (H II-738)

NGC: Bright, pretty large, round, much brighter in the middle.

NGC 3893 IS A SOMEWHAT BRIGHT and obvious spiral galaxy about 1° north-northeast of Chi (χ) Ursae Majoris, a beautiful reddish star in the rear of the right hindquarter of the Great Bear. It belongs to the Ursa Major Cluster of galaxies – a large spur of spiral systems in the Ursa Major Cloud of galaxies, which is as near as, and on one side of, the Virgo Cluster, stretching across nearly 6 million light-years.

It's moderately large, extending about 60,000 light-years. The size is slightly smaller than the largest galaxies in the Virgo Cluster such as NGC 4321 and NGC 4303. NGC 3893's stars shine with a total luminosity of 20 billion Suns and the entire system has a mass of about 50 billion Suns. It's receding from us at nearly 1,000 km/sec.

In images, the galaxy is a stunning barred spiral system seen 30° from edge on. Old plates showed it as a small (4′) object, sporting a bright nucleus in a short bar inside a small pseudo-ring. But the spiral pattern of NGC 3893 is magnificent, one of the grand-design type, formed by two main, knotty, filamentary spirals – both of high surface brightness – that wind around the core for at least half a turn from their place of origin near the center. Both arms sport numerous, large HII regions, though the southernmost one appears stronger than the northern one.

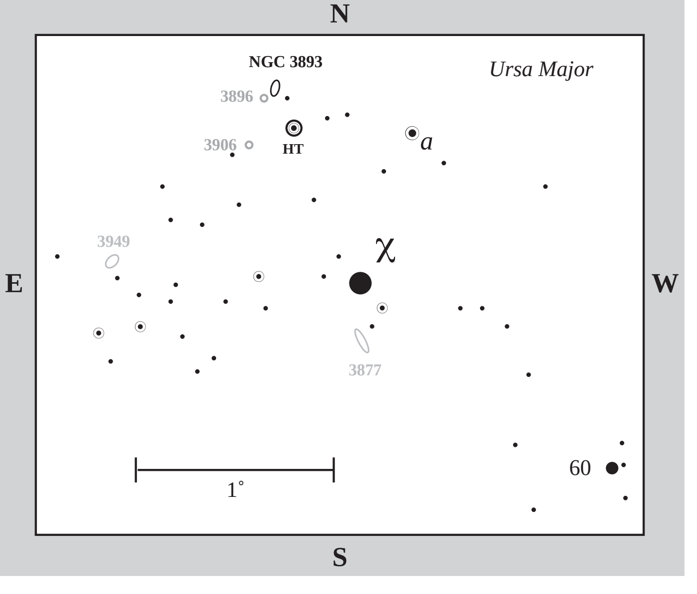
In 2001, Mexican astronomers Hector M. Hernandez-Toledo and Ivanio Puerari announced that, while their multi-color broad-band images of the galaxy show a beautiful spiral structure with knotty blue features all along the arms, they could not identify signs of a barred structure, thus classifying it as an Sc-type spiral. But in a 2002 *Astronomy & Astrophysics* (vol. 387, p. 821), a year later, O. Garrido (Observatoire Astronomique Marseille-Provence) and colleagues announced that their Hα image of this late-type spiral did display a small central bar. They also found a strong warp to the disk, probably due to the interaction with its 13th-magnitude companion NGC 3896, a peculiar barred dwarf lenticular 4′ to the southeast.

The bar in NGC 3893 was also detected in the 2002 Ohio State University (OSU) Bright Spiral Galaxy Survey, a near-infrared imaging survey of a well-defined sample of 205 bright, nearby spiral galaxies. The near-infrared image of the galaxy shows a centrally condensed, slightly elliptical bulge, from which emerges a grand-design two-armed spiral pattern. The inner arms are high-contrast, rich with star-forming knots, and have obvious inner dust lanes. After winding for ~250°, they become broad, low-surface-brightness outer arms that can be traced for another ~100° before fading into the sky.

In a 2008 *Astronomy & Astrophysics* (vol. 466, pp. 847–854), Isaura Fuentes-Carrera (at the time at the Universidade de São Paulo, Brazil) and colleagues compare the kinematics and dynamics of NGC 3893 and NGC 3896 to those of M 51 and NGC 5193 (Secret Deep 67). Such pairs are formed of a large spiral galaxy and a less massive companion, with some sign of interaction. The arm of NGC 3896 that stretches towards NGC 3893 is apparently bifurcated, forming an external arc/shell-like feature. Radio images show extended HI emission encompassing both galaxies; the envelope is elongated from southeast to northwest, parallel to the line that joins the nuclei of both galaxies. This long radio tail, or broad arm, appears to connect the two galaxies. The team also detected non-circular rotation in both galaxies. "These motions," they say, "can be associated to perturbations due to the encounter and, in the case of the main galaxy, to the presence of a structure such as spiral arms."

To find NGC 3893, use the chart on page 204 to locate Chi Ursae Majoris. Now move about 45′ north-northwest to 7th-magnitude Star *a*. NGC 3893 is a little more than 40′ northeast of Star *a* and about 10′ north-northeast of the variable star HT Ursae Majoris.

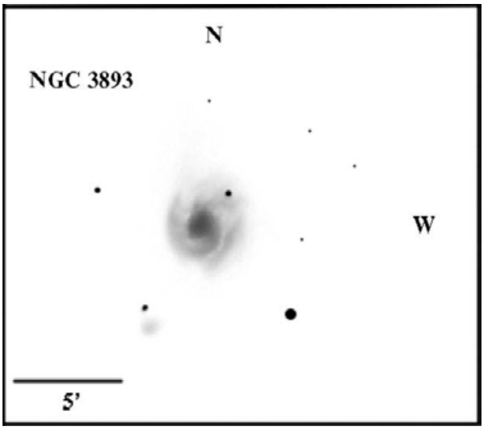
At 33× in the 5-inch, NGC 3893 is a largely uniform oval glow about 2′ in extent with a small, but highly condensed circular



core just 3′ northeast of an 11th-magnitude star. The core stands out first, appearing extremely starlike (so think "small"). The galaxy's disk suddenly blossoms with averted vision.

The view at 60× remains much the same, though the disk is much more obvious, appearing as a 4′ × 2′ spindle with a soft oval core and fainter arc-like extensions. Supernova hunters take note: a magnitude 12.5 star appears projected against the galaxy's northwestern flank.

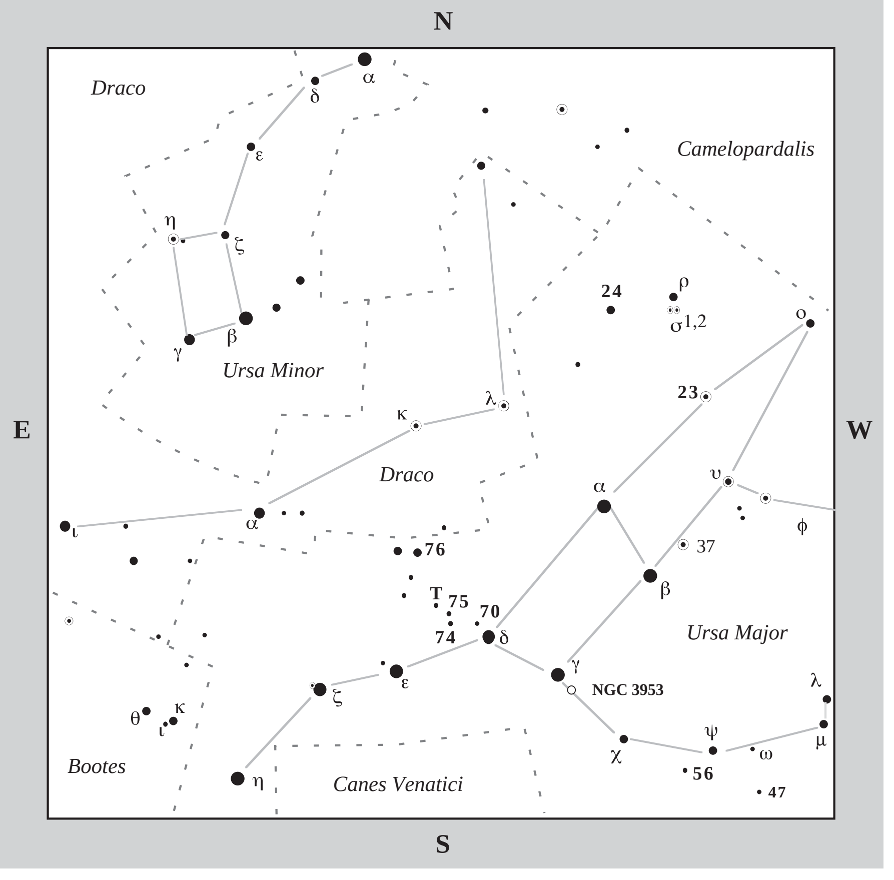
At 94×, the core shrinks to a tiny starlight point in a soft oval lens. Although I found the view difficult (the intensity of the disk appears "fainter"), I could with time make out the two major spiral arms wrapping tightly around the core. A very elegant and impressive sight. That I can see the arms in a 5-inch should not be surprising, given their high surface brightness. Although I could not make out any HII regions, or other mottling (the arms to me just appear smooth), the southern one is more intense than the northern one, as



images show. Also, visually, the northern arm seems to suddenly end at the 12.5-magnitude star.

Finally, I surprised myself by seeing, quite impressively, the galaxy's 13th-magnitude companion. But this is obviously a mistake in the object's brightness, since it appears more like 11th magnitude. I could resolve its bright nucleus and slightly oval disk. Herschel also discovered NGC 3892, cataloging it as H II-739.

Secret Deep 48
(NGC 3953)



48

NGC 3953 = M109?
Type: Barred Spiral Galaxy (SB(r)bc)
Con: Ursa Major

RA: 11^h 53.8^m
Dec: +52° 20′
Mag: 10.1
SB: 13.1 (Rating: 4)
Dim: 6.0′ × 3.2′
Dist: ~51 million l.y.
Disc: William Herschel, 1789

W. HERSCHEL: [Observed April 12, 1789] Considerably bright, irregularly faint, extended, milky, easily resolvable, large, bright nucleus with faint branches 7 or 8′ long, 5 or 6′ wide. (H V-45)

NGC: Considerably bright, large, extended toward position angle about 0°, very suddenly brighter in the middle to a large mottled nucleus.

NGC 3953 IS A PRETTY, BARRED-spiral galaxy nearly 1.5° south of 2nd-magnitude Gamma (γ) Ursae Majoris (Phad) and a little more than 1° south-southwest of the more famous 10th-magnitude M109 (NGC 3992). Its position near both Gamma Ursae Majoris and M109 has made it an object of controversy.

As is well known, the final catalogue of nebulae and star clusters compiled by the French astronomer Charles Messier (1730–1817) contained only 103 objects. The remaining seven objects (one a duplication) were later additions. Beginning in 1921, French astronomy popularizer Camille Flamarrion added NGC 4594 as M104, on evidence he found in a manuscript addition to Messier's own copy of the *Connaissance des Temps* for 1784. It wasn't until 1953, however, that the famous Harvard astronomical historian Owen Gingerich added NGC 3992 as M109, based on a note he found that Messier made to M97 (the Owl Nebula); without knowledge of this observation, William Herschel rediscovered this object on April 12, 1789, cataloging it as H IV-61.

But is NGC 3992 M109? Henk Bril, an active member of the Royal Dutch Association for Meteorology and Astronomy and 2005 recipient of its prestigious Dr. J. van der

Bilt Award, does not think so. Proof, he says, can be found in J. Fortin's 1795 *Atlas Céleste*, which was edited by Joseph Jérome le Français de Lalande and Pierre Méchain, who discovered the nebula attributed to M109. Bril notes that on Plate 6 of the atlas and also on Plate 7, "a nebula is drawn exactly on the position of NGC 3953," our Secret Deep target!

Bril notes that although NGC 3953 is only 0.3-magnitude fainter than M109, it is also about 1.5′ smaller, so it has a slightly higher surface brightness, making it an easier target through small telescopes.

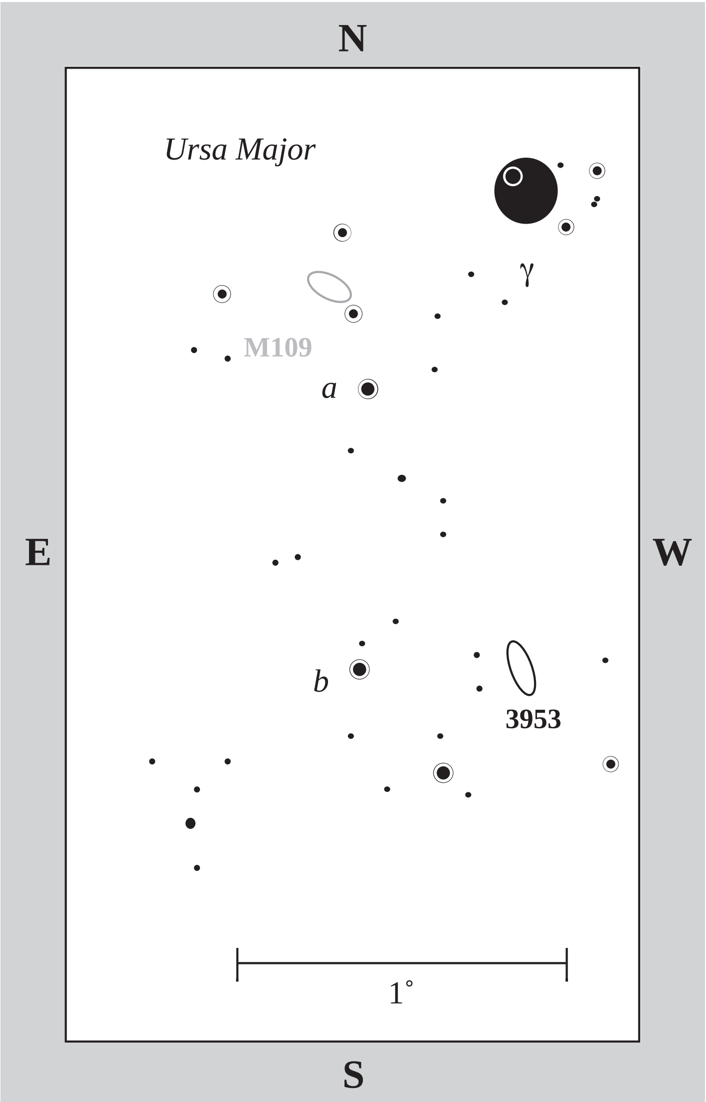
"There is another scenario possible." Bril explains: "Méchain made his discovery on March 12, 1781. Messier observed it on March 24, 1781. But did he actually? Maybe Messier did observe (and as a matter of fact discover) NGC 3992, but mixed it up with Méchain's observation twelve nights earlier."

Bril's more detailed account appears in the March 2007 issue of the Dutch astronomy magazine *Zenit*, and the July/August 2007 issue of the French *Astronomie Magazine*.

Whether NGC 3953 is the real M109, it is a "companion" to M109; both belong to the Ursa Major Cluster of galaxies, some 50 million light-years distant. The cluster is not to be confused with the Ursa Major Cloud of galaxies, to which the cluster belongs. In a 1996 *Astronomical Journal*, R. Brent Tully (University of Hawaii) and his colleagues explain the difference between the two in more detail. In brief, the cluster has been hard to define because it lacks a concentrated core. It lies in a particularly confusing part of the sky because it is in the plane of the Local Supercluster at the junction of filamentary structures. In particular, the researchers say, the cluster lies behind the long axis of the filament of galaxies we live in, the so-called Coma–Sculptor Cloud.

NGC 3953 is inclined 29° from edge on, so we see it more obliquely than M109. It's a fairly large system measuring about 90,000 light-years in true linear extent with a total mass of 14 billion Suns. If we could see its form more face-on, it might have the appearance of our own Milky Way. NGC 3953 is receding from view at 1,052 km/sec. In short exposures, the galaxy shows a small, very bright nucleus in a bright inner lens (more of an oval than a bar). The galaxy's sharply angled disk comprises several filamentary, knotty arms near the limit of resolution. Deeper images show two characteristic thin (shock-induced) dust lanes may be present in the central disk, which harbors a low-luminosity active galactic nucleus (AGN).

To find this wonder, use the chart on page 208 to locate Gamma (γ) Ursae Majoris in the Big Dipper's Bowl, then switch to the chart on this page. From Gamma, try locating M109 first, which is a moderately bright and compact glow only 40′ east-southeast of Gamma. From M109, you can either try making a slow and careful sweep 1¼° southwest to NGC 3953 (which will appear similar to NGC 3992 in brightness and size), or you can make smaller star-hops. From M109, move about 18′ south-southwest to 9th-magnitude Star *a*. Next, make a slow 50′ sweep due south to similarly bright Star *b*. NGC 3953 is about 30′ west of Star *b*.



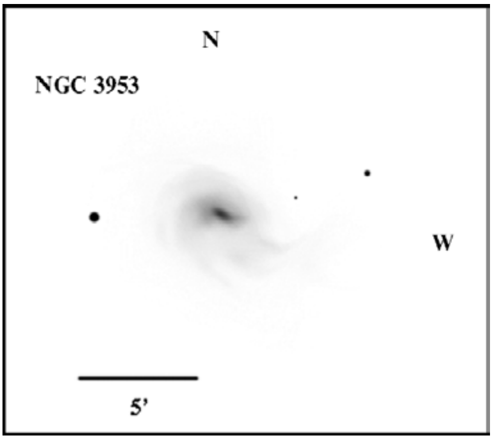
irregularities. But that only means it needs more power.

At 60×, the galaxy is quite detailed. The nucleus appears as a crisp stellar point framed by a fractured inner lens from which spiral arms appear to hook. The fracturing is caused by the bar and the bright spiral arcs emanating from it. The galaxy is flanked to the east by three equally bright suns in a line, and a 3rd-magnitude star shines just west of the nucleus.

At 94× the galaxy's bar and central arcs are well defined with faint spiral wisps in the disk wavering in and out of view. The disk appears lopsided, being brighter on the eastern side, with the southeastern part of the disk showing the most spiral features. But again, these fine filaments waft in and out of view.

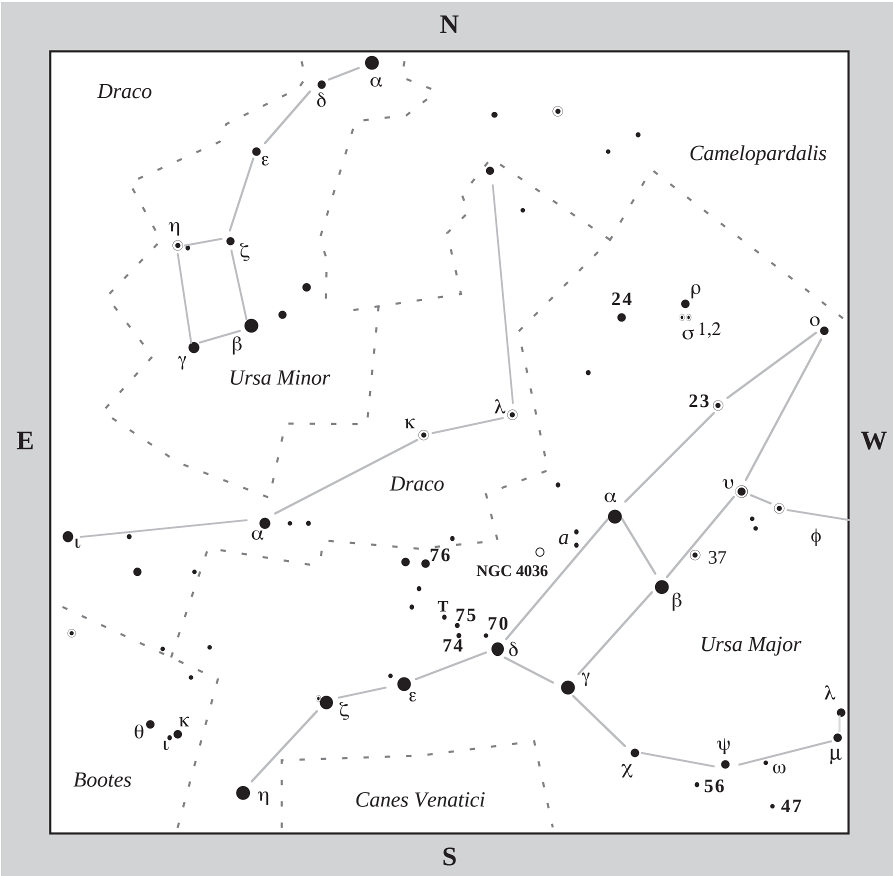
At 33× in the 5-inch, I can fit Gamma Ursae Majoris, M109, and NGC 3953 in the same field of view. The two are truly a matched pair visually. NGC 3953 immediately has a bright circular core with a star-like point in an oblong disk 5′ × 2′ in extent. The core really packs a punch, while the disk has some frustrating

NGC 3953 was host to two known supernovae: According to IAU *Circular* 7683, supernova 2001dp was discovered at magnitude 14.5 on August 12–13 UT, by M. Migliardi and E. Dal Farra, of Haute-Provence, France. The object was 24″ west and 81″ north of the galaxy's nucleus. Spectra of SN 2001dp resemble



that of the Type Ia SN 1994D, one month after maximum. The other supernova, 2006bp, was discovered at magnitude 16.7 by Koichi Itagaki in Yamagata, Japan, around April 9 UT. This one was a Type II found very young and was 62″ east and 93″ north of the center of NGC 3953.

Secret Deep 49
(NGC 4036)



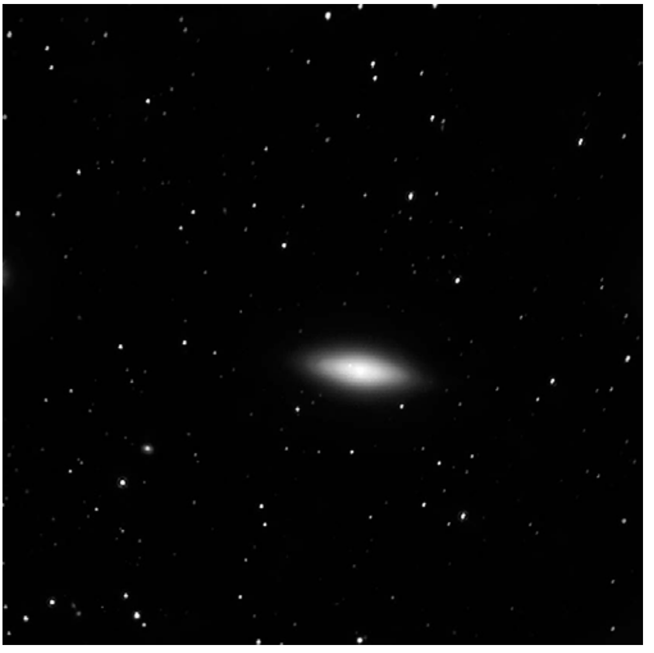
49

NGC 4036
Type: Mixed Lenticular/Spiral Galaxy (S0a/Sa)
Con: Ursa Major

RA: $12^h\ 01.4^m$
Dec: $+61°\ 54'$
Mag: 10.7
SB: 12.7 (Rating: 3.5)
Dim: $3.8' \times 1.9'$
Dist: ~80 million l.y.
Disc: William Herschel, 1790

W. HERSCHEL: [Observed March 19, 1790] Very bright, very little extended. (H I-253)

NGC: Very bright, very large, extended.



NGC 4036 IS A VERY CONDENSED AND obvious lenticular galaxy a little north of the midpoint between the 2nd-magnitude stars Alpha (α) Ursae Majoris and Delta (δ) Ursae Majoris in the Big Dipper's Bowl. It's only about 1 magnitude fainter than the famous lenticular galaxy NGC 5866 in Draco and forms a noninteracting pair with the small (2′), 11th-magnitude face-on spiral galaxy NGC 4041 just 15′ to the north-northeast. At the mean redshift distance of 80 million light-years, the projected linear separation of the pair is about 400,000 light-years.

This disk-dominated lenticular belongs to the Ursa Major Cloud of galaxies, whose hundreds of members are glued together by the bond of gravity and whizzing away from us at 1,445 km/sec. It's a nearly edge-on system (18° inclination) that has a true linear extent of 90,000 light-years and a total luminosity of 26 billion Suns. Thus, it's the same size as NGC 5866. But since NGC 5688 is 30 million light-years closer, we see that galaxy shining more prominently in the sky.

NGC 4036 was first classified as a clean, early type (S0) lenticular – a lens-shaped galaxy with a central bulge and disk but no spiral arms and interstellar material. But later images revealed intensity irregularities in the disk, so it was not a typically smooth S0 galaxy. These "irregularities" turned out to form a tightly wound spiral pattern. Indeed, deep images also revealed three clearly defined dust lanes threading through the disk in an embryonic spiral pattern and a low-contrast nuclear ring. The galaxy also shows an asymmetry, owing to the dust pattern, so that the south side seems dimmer (redder) than the north. The dust lanes are not as regular as those in a pure lenticular type, indicating that NGC 4036 is a mixed lenticular/spiral (S0/Sa) form. In a 2001 *Astronomy Letters* (vol. 27, pp. 15–24), Olga Sil'chenko and V. V. Vlasyuk report that they found evidence for a tilted circumnuclear stellar disk with a radius of about 1,600 light-years.

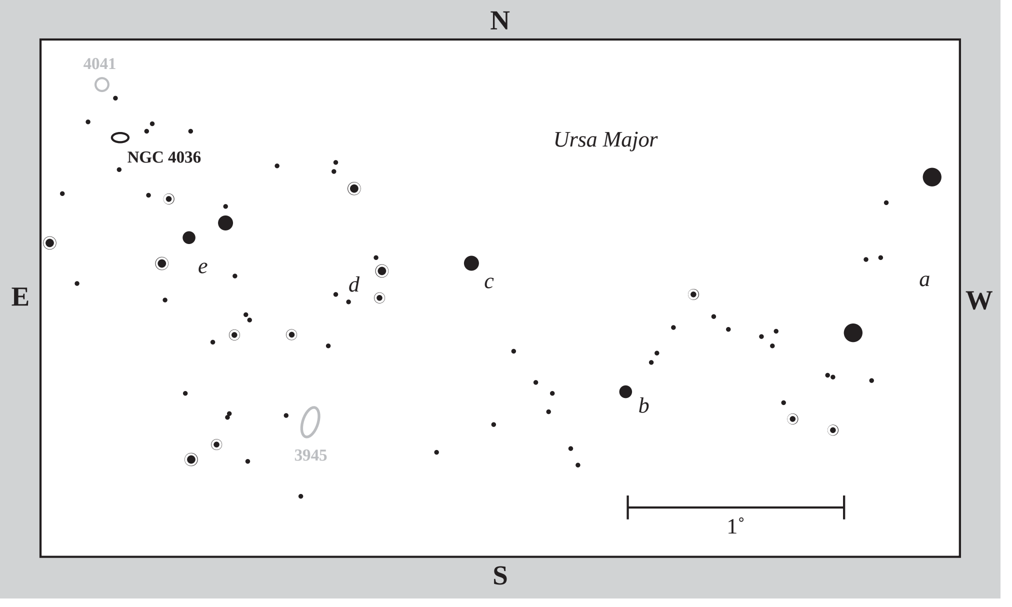
NGC 4036 has also been classified as harboring a low-ionization nuclear emission-line region (LINER) – a type of gaseous region common in the centers of galaxies that have been shown to be a low-energy type of active galactic nuclei (AGN) – like that of a Seyfert at its lowest level of activity. A Seyfert galaxy is one with a small and bright nucleus that behaves like a low-energy quasar, jetting matter episodically into space. The production of the energy feeding the jet probably comes from a supermassive black hole at the galaxy's heart.

While LINER emission exists in the nuclei of a large fraction of luminous galaxies, their connection with AGN has remained elusive. In a 2000 *Astrophysical Journal* (vol. 532, pp. 323–339) Richard W. Pogge (Ohio State University) and colleagues presented Hubble Space Telescope narrowband emission-line images of the central regions of NGC 4036 and 13 other galaxies with LINER nuclei. NGC 4036's nucleus proper resembles an ellipse with a major axis of 0.6″ along a position angle of 45°.

One of HST's unsharp-masked images reveals wisps of dust in a disk-like configuration surrounding the nucleus on all scales probed. The core also has a complex filamentary and clumpy structure, with several "tentacles" extending up to 4″ northeast of the nucleus along a position angle of 70°; this could be a possible ionization cone of the kind often seen in Seyfert galaxies. "This is one of the few LINERs in our sample," the researchers say, "whose emission-line morphology can possibly be termed 'linear' in some sense, but it seems that this morphology is in the plane of the inclined dusty disk, rather than perpendicular to it."

To find this interesting galaxy, use the chart on page 213 to locate Alpha (α) Ursae Majoris. Then use your unaided eyes or binoculars to find Pair *a* – two 6th-magnitude stars a little more than 3° east-northeast of Alpha. Center the southernmost star in Pair *a* in your telescope at low power, then switch to the chart on page 216. Now make a slow 1° sweep east-southeast to 7th-magnitude Star *b*. Next, swing 55′ northeast to 6.5-magnitude Star *c*. Just 25′ east-southeast is a pair of 8th- and 9th-magnitude stars (*d*). Now move another 55′ east-northeast to a 20′-wide arc of three 6.5- to 7.5-magnitude suns (*e*); the stars in Arc *e* get progressively fainter to the southeast. NGC 4036 is about 35′ northeast of the center star in Arc *e*.

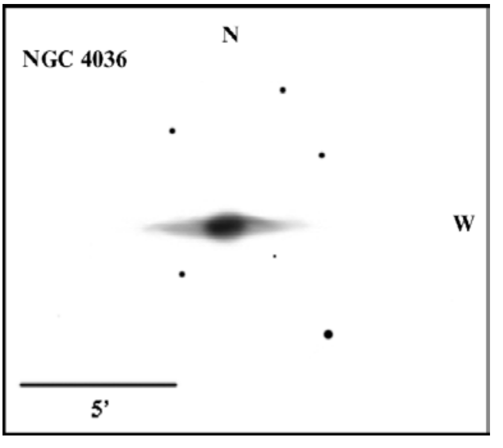
At 33× in the 5-inch, NGC 4036's very small but bright core pops immediately into view. Once spotted, the galaxy's 4′-long lens (oriented east–west) appears to burn forth about 10′ east of two roughly 11th-magnitude stars. Be sure to employ averted vision, which will make the galaxy's disk more obvious. The galaxy is very obvious at 60×, displaying a bright core surrounded by a smooth spindle of light. But with averted vision, I suspected enhancements at the ansae of the lens.



At 94×, the galaxy's nucleus snaps into view as an extremely sharp stellar point immersed in a circular nebulous haze within a faint spindle. It may have been an illusion, but on one night the galaxy's north side did indeed seem brighter than the south side, though I have to wonder. See what you think.

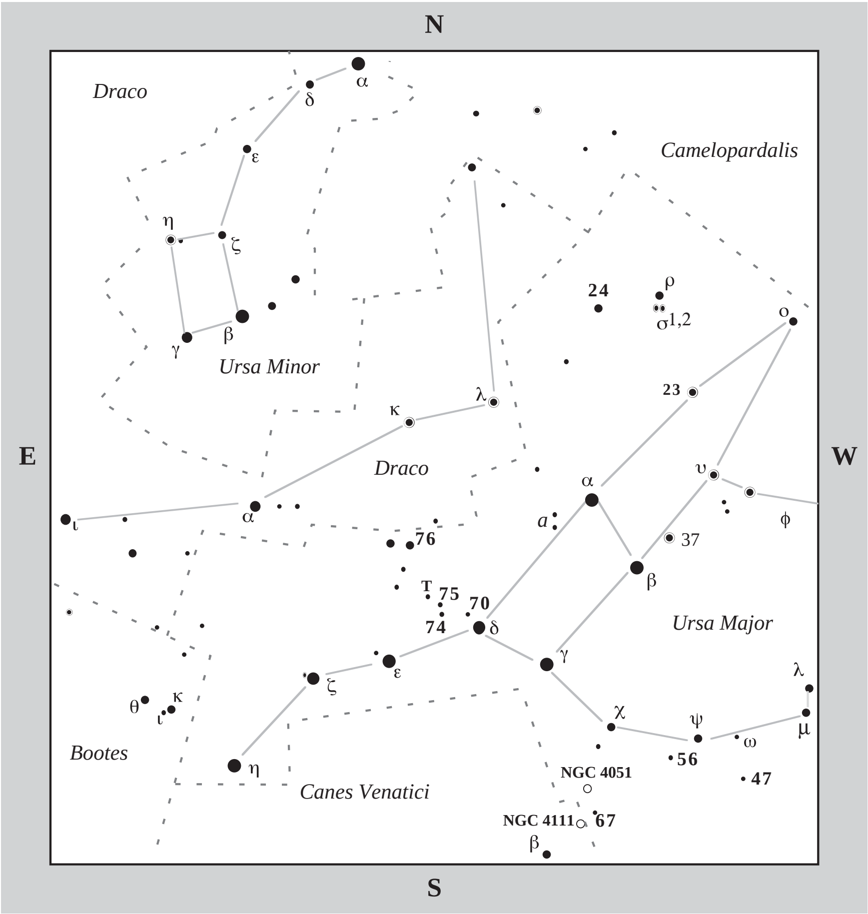
By the way, despite its early type, NGC 4036 has produced at least one known supernova. IAU *Circular* 1017 reports that K. Itagaki (Teppo-cho, Yamagata, Japan, 0.60-m f/5.7 reflector) discovered a 16th-magnitude supernova (SN 2007gi) on multiple unfiltered 15-second CCD frames taken around July 31.49 UT. The new object was located about 23″ west and 11″ south of the nucleus.

When you're finished observing NGC 4036, be sure to move 15′ north-northeast



to NGC 4041. Small-telescope users may need to use moderate magnification to see this little spiral, which appears as a small (3′) and dim cometary glow with a starlike core.

Secret Deep 50 & 51
(NGC 4051 & 4111)



50 & 51

50

NGC 4051
Type: Mixed Spiral Galaxy (SAB(rs)bc)
Con: Ursa Major

RA: 12^h 03.2^m
Dec: +44° 32′
Mag: 10.2
SB: 13.5 (Rating: 3.5)
Dim: 5.5′ × 4.6′
Dist: ~48 million l.y.
Disc: William Herschel, 1786

W. HERSCHEL: [Observed February 6, 1786] Considerably bright, irregularly round, considerably bright nucleus in the middle, with extensive chevelure, 5′ in diameter. (H IV-56)

NGC: Bright, very large, extended, very gradually, then very suddenly, much brighter in the middle to an 11th-magnitude star.

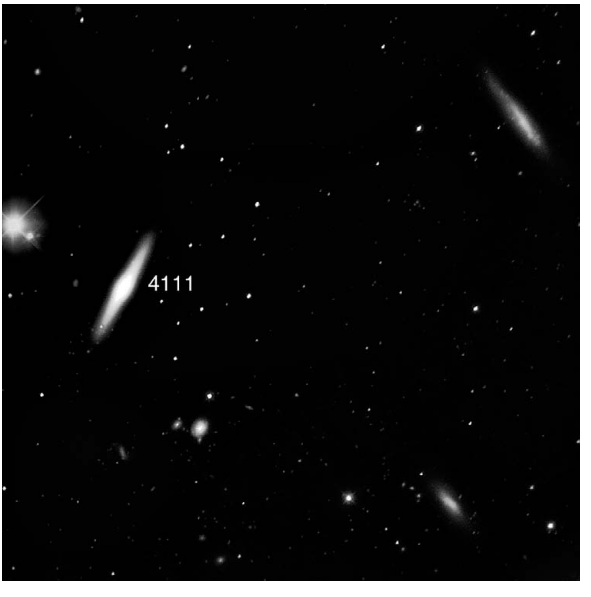
51

NGC 4111
Type: Lenticular Galaxy (SA0(r))
Con: Canes Venatici

RA: 12^h 07.1^m
Dec: +43° 04′
Mag: 10.7
SB: 12.1 (Rating: 3.5)
Dim: 4.4′ × 0.9′
Dist: ~52 million l.y.
Disc: William Herschel, 1788

W. HERSCHEL: [Observed January 14, 1788] Extended, very bright nucleus and faint branches. (H I-195)

NGC: Very bright, pretty small, much extended toward position angle 151°.



NGC 4051 AND NGC 4111 ARE TWO pretty galaxies near 5.5-magnitude double star 67 Ursae Majoris, which is about 5½° southeast of 4th-magnitude Chi (χ) Ursae Majoris in the Hind Leg of the Great Bear – in the far southeastern portion of that constellation near Canes Venatici. Both belong to the Ursa Major Cluster of galaxies and are receding from us at 700 and 807 km/sec, respectively. Let's start with bright and obvious mixed spiral NGC 4051, the brightest galaxy within 2° of 67 Ursae Majoris, beating out NGC 4111 by 0.5 magnitude.

NGC 4051

Like the more famous spiral galaxy M77 in Cetus, NGC 4051 is a classical Seyfert, one of the original six galaxies listed in a 1943 paper by their namesake Carl K. Seyfert (1911–1960). In that paper, Seyfert discussed Mount Wilson spectra and direct plates of a class of galaxies (mostly spirals and barred spirals) known – initially to Edward Faith at Lick Observatory in 1908 and Vesto Slipher at Lowell Observatory in 1917 – to have "stellar or starlike" (unresolved) nuclei and stronger and broader emission lines in their spectra than those in normal galaxies. Although Seyfert was not the first to notice the peculiar nature of these extragalactic nuclei, his systematic work on them made this galaxy class a popular object of study in the mid-twentieth century and beyond.

Actually, it was American astronomer Edwin P. Hubble (1899–1953) – most noted for his observations that proved that galaxies are "island universes" beyond our Milky Way and for his discovery of the linear relationship between a galaxy's distance and its velocity (Hubble's law) – who first to noticed NGC 4051's peculiar nucleus, reporting in 1926 that it showed a "planetary nebula type" emission-line spectrum.

At the time when Hubble was examining plates, NGC 4051 appeared as a "nebula" with a very small, extremely bright nucleus or star in a lens-shaped bulge, from which two main arms branched. It was not known at the time, nor was it in Seyfert's day, that the galaxy's peculiar nucleus was the site of a rapidly flickering active galactic nucleus (AGN) – one that was drawing energy from a tiny volume of space and releasing more energy than can be accounted for by the number of stars present in the region.

The beginning of the modern work on Seyfert galaxies and related AGN objects (quasars are, for instance, maxi-Seyferts) was made in a seminal paper by Lodewijk Woltjer in 1959, and research on AGN on many wavelength fronts has expanded exponentially ever since. NGC 4051 is one of the lowest luminosity Seyferts known, with conspicuously narrow emission lines in its spectrum. But before we look more closely at NGC 4501's well-studied nucleus, let's now zoom in on its overall morphology.

The galaxy is moderately large, extending 80,000 light-years in true physical extent and has a total mass of nearly 120 billion Suns. We see it at an inclination of about 40°, shining with a total luminosity of about 20 billion Suns. Short exposures at large telescopes reveal an intense starlike (unresolved) nucleus, which has been interpreted as a mini-quasar at the center of the galaxy. Deeper images show the nucleus embedded in an elliptical bulge threaded by a prominent bar aligned with the galaxy's major axis. Two dominant arms emerge from the ends of the bar. There are also two fainter arms. One emerges from the west end of the bulge. The other appears to form via the bifurcation of the southern main arm.

The outer spiral structure is nearly of the grand-design type, having only several major arms rather than a series of fragments. Many HII (star-forming) regions dapple NGC 4051's spiral arms, the largest of which can be decently resolved. Deep imaging has also revealed compact HII regions within 15″ of the nucleus. Detailed optical emission-line and continuum contour maps of the inner few arcseconds surrounding the nucleus suggest that the Seyfert activity may have been triggered tidally through interactions with NGC 4013, an 11th-magnitude galaxy about 1° to the southwest, which is separated from NGC 4051 by ~800,000 light-years in physical space.

Infrared observations show a cold and a very intense warm component to the disk. The cold component is most likely emission by dust heated by young OB stars in star-forming regions. The warm component is probably due to dust in the form of small grains heated either directly by the nucleus or by very massive stars in circumnuclear starbursts. Indeed, the Kuiper Airborne Observatory detected extended far-infrared emission, which suggests that NGC 4051 has a modest outgoing starburst.

The radio structure of the nuclear region is known to be quite complex, having three clearly distinct components: fine nuclear emission, extranuclear (diffuse emission associated with the spiral arms of the galaxy), and a large-scale radio emission associated with the entire galaxy disk.

At the highest available resolution, the central core splits into a small-scale double separated by 0.4″ roughly in the east–west direction. There is also a jet-like emission extending toward the southwest. In 2001, Luis C. Ho (The Observatories of the Carnegie Institution of Washington, Pasadena, CA) and James S. Ulvestad (National Radio Astronomy Observatory) also detected a fainter, oppositely directed component to the northeast. The total linear extent of this "jet" is about 4,000 light-years, and it lies along position angle 41° perpendicular to the galaxy's major axis. Radio observations also show that the southwest side of the galaxy is the nearer side, so that the jet is projected against the side of the galaxy farthest from us.

This galaxy's nuclear region (5″–10″) has also been observed with all the major X-ray satellites, which have detected variability of NGC 4051's AGN on a number of different time scales: from those as short as a few hundred seconds to tens of minutes. The variations are most likely due to central (nuclear) activity plus an extended starburst component.

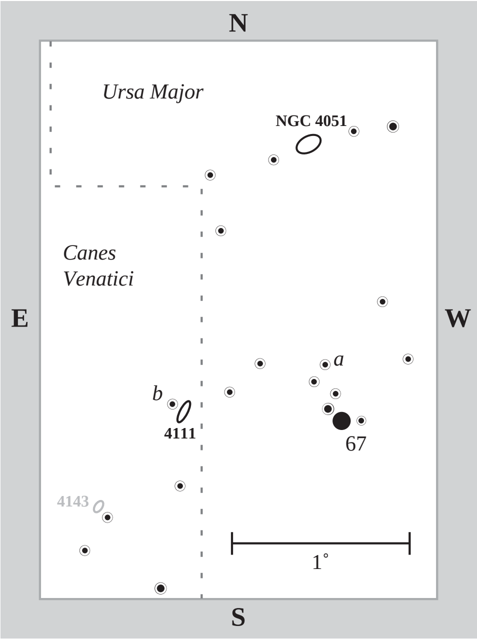
It's long been suspected that the central engine of an AGN is a supermassive black hole. The one at the core of NGC 4051 is estimated to have an emission region of about 2 light-days across and a black hole mass of about 1.7 million Suns. A 2007 Harvard-Smithsonian Center for Astrophysics (CFA) press release announced yet another astounding finding: The black hole at the center of the NGC 4051 galaxy emits a hot wind of chemical elements, including elements such as carbon and oxygen that are critical for life. The hot wind originates very close to a black hole, at a distance about five times the size of Neptune's orbit – closer than previously thought.

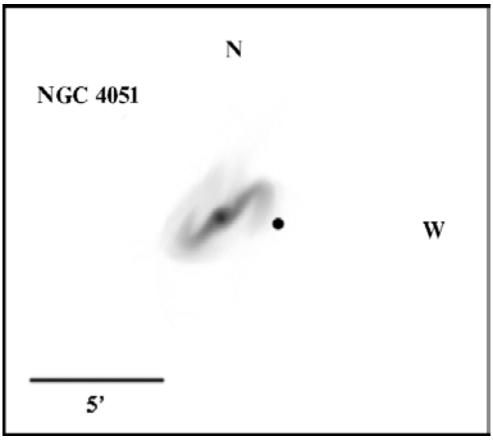
Winds from black holes have been clocked at speeds of up to 4 million miles per hour. Although speedy, the wind from NGC 4051's black hole is weaker than expected and ejects only 2 to 5 percent of accreting material. Over thousands of years, however, the chemical elements such as carbon and oxygen in those winds can travel immense distances, eventually becoming incorporated into the cosmic clouds of gas and dust, called nebulae, that will form new stars and planets.

"One of the big questions in cosmology is how much influence massive black holes exert on their surroundings," said Martin Elvis of CfA, who co-led the team of astronomers studying the black hole. "This research helps answer that question." Thus, the press release explained, "black holes are not the ultimate destroyers that are often portrayed in popular culture. Instead, warm gas escaping from the clutches of enormous black holes could be one source of the chemical elements that make life possible."

To find this extragalactic wonder, use the chart on page 217 to locate 67 Ursae Majoris and center it in your telescope at low power, then switch to the chart on this page. First, note that 67 Ursae Majoris is the brightest star in a 25′-wide W-shaped asterism, oriented northeast to southwest. Now center the northernmost star in the W-shaped asterism, 9.5-magnitude Star *a*. NGC 4051 is 1¼° north and slightly east of that star.

At 33× in the 5-inch, NGC 4051 appears as a very bright and obvious glow (3′) immediately northwest of an 11th-magnitude star.





With averted vision, the galaxy sports a very stellar core in a small, circular inner lens surrounded by a nonuniform outer ellipse oriented northwest to southeast.

At 60× the galaxy's form is much enhanced (enlarging to 5′), and its outer disk has mottling or irregularities. With time, however, and much visual coaxing, I could make out quite distinctly an arc of a spiral arm to the southwest – the more dominant one as seen in photographs. The northeastern arm (or a fragment of it) could also be suspected.

At 94×, the galaxy's outer disk fades, but the arms become more enhanced. I could not only clearly see the galaxy's two major spiral arms but also that the southwestern side of the disk is more prominent. With averted vision and time, once again, I believe I could also differentiate the spiral branches on the southwest side. Larger scopes will show this mottled texture to be HI regions and dust lanes in the galaxy's S-shaped inner spiral arms.

NGC 4111

NGC 4111 is a small but fascinating edge-on lenticular galaxy in Canes Venatici, about 5° west-northwest of Beta (β) Canum Venaticorum (Chara) and only 55′ due east of 67 Ursae Majoris. Through backyard telescopes, it's the brightest of four galaxies in a 12′-area of sky. Its other companions are 14th-magnitude NGC 4109 about 5′ to the southwest and NGC 4117–8 (magnitudes 13 and 14.6, respectively) about 7′ to the east-northeast. Actually, NGC 4111 has at least five more (much fainter) companions, none of which appear to have had any tidal effects on NGC 4111 itself.

NGC 4111 is classified as a normal lenticular galaxy seen only 3° from edge on, so it cuts a fine line against the night sky. In deep images, the galaxy's nucleus, lens, and outer envelope are all easily visible. The central region appears to be composed of a very small, very bright nucleus in a peanut-shaped bulge. The edge-on disk is smooth and sliced cleanly through by a dust lane.

Early spectroscopy of the galaxy's stars revealed them to be old. Those in the reddish nuclear disk are consistent with those in the main galaxy, so it's possible that both the core and disk formed at the same time. However, in a 1997 *Astrophysical Journal* (vol. 113, p. 950), David Fisher (Kapteyn Astronomical Institute, the Netherlands) notes that it's also possible that the stellar disk is a more recent addition to NGC 4111.

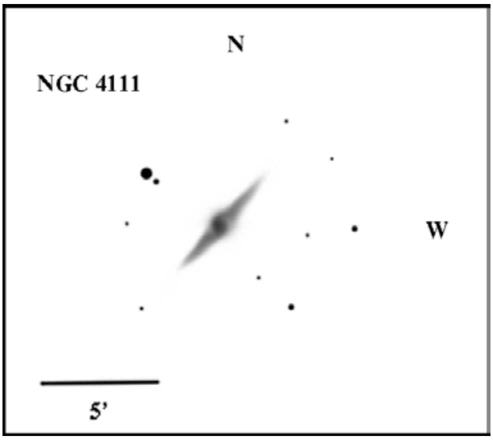
Surrounding the bright, compact nucleus is a dust lane oriented perpendicular to the galaxy's plane, causing a dramatic decrease in luminosity between the edge of the bulge and the beginning of the disk; its morphology is suggestive of a polar ring having a radius of 3″, which is also responsible for the galaxy's "peanut-shaped" bulge.

In a 2000 *Astronomy & Astrophysics Supplement Series* (vol. 141, pp. 1–22) R. Michard (Observatoire de la Côte d'Azur, Nice, France) presented his study of the color distribution of 12 lenticular galaxies, including NGC 4111. Of that galaxy he detected not only the "peanut-shaped" bulge, but also an inner disk. "There is a small but high contrast central dust pattern," he says, "elongated along both galaxian axes." This suggests that the peanut bulge may result from extinction by the pattern of the overlying dust. He also found the galaxy to be surprisingly blue compared to other galaxies in his sample, especially in the disk, away from the central dusty bulge. "Its stellar population is probably younger than average," Michard concludes.

NGC 4111's central dust disk has been classified as a LINER (low-ionization nuclear emission-line region). If so, the AGN may be on the boundary between a low-luminosity AGN – one that emits more energy than can be explained purely in terms of its star content – and that of a normal galaxy. AGNs are believed to contain material heated to several million degrees in an accretion disk before tumbling into a central black hole, or being shot away in twin jets along the central engine's spin axis. NGC 4111 also has a very high rotational velocity: The velocity difference between the galaxy's central lens and outer disk is 400 km/sec, making NGC 4111 one of the fastest rotators known.

To find this galaxy, return to 67 Ursae Majoris and center it in your telescope at low power, then switch to the chart on page 221. NGC 4111 is 55′ due east of 67 Ursae Majoris, about 4′ southwest of 8.5-magnitude Star *b*. NGC 4111 and 67 Ursae Majoris will fit in the same field of view with most telescopes at low power.

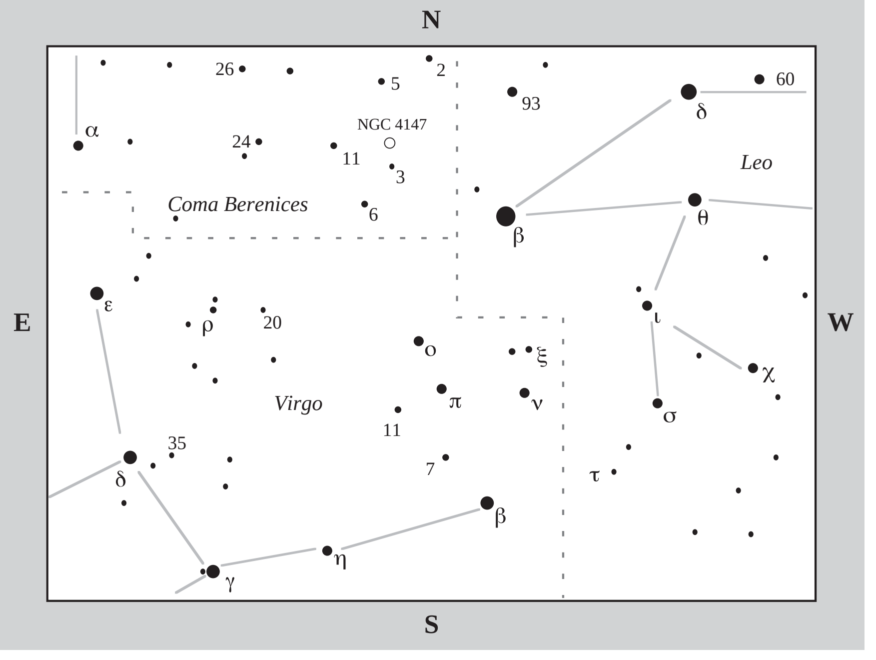
In the 5-inch at 33×, NGC 4111 looks like a small fuzzy star. What I'm seeing with direct vision is the galaxy's very small (~1′) and very bright (like a star) core. With averted vision the galaxy swells to 2′, appearing as a star in a tiny lens. But with time, and breathing, the lens tapers on each end into an extremely fine thread of light. At 60× the galaxy has a very intense, quasi-stellar nucleus surrounded by a very bright and condensed inner core of light.



Under a very dark sky with averted vision, the galaxy's tapered disk can be seen very faintly, being oriented northwest to southeast. As I have found with other edge-on galaxies at low to moderate magnifications, the length of the system appears exaggerated. Our eyes like to extend lines and this is what happens when a needle of light is perceived against the starry darkness. The illusion breaks down at 94×, when the galaxy's extent seems to shrink (a disappointment of sorts). But study the inner lens carefully. I could see the patchy fragments of light and shadow that make up part of the peanut (not visible). At high power the galaxy is a fantastic sight. A brilliant bead of light burns at the core. It resides in an eye-shaped bulge with bright knots at the ansae, out of which extend the hyperfine needle-like extensions of the galaxy's edge-on disk. A beautiful sight to behold and one that tickles the imagination.

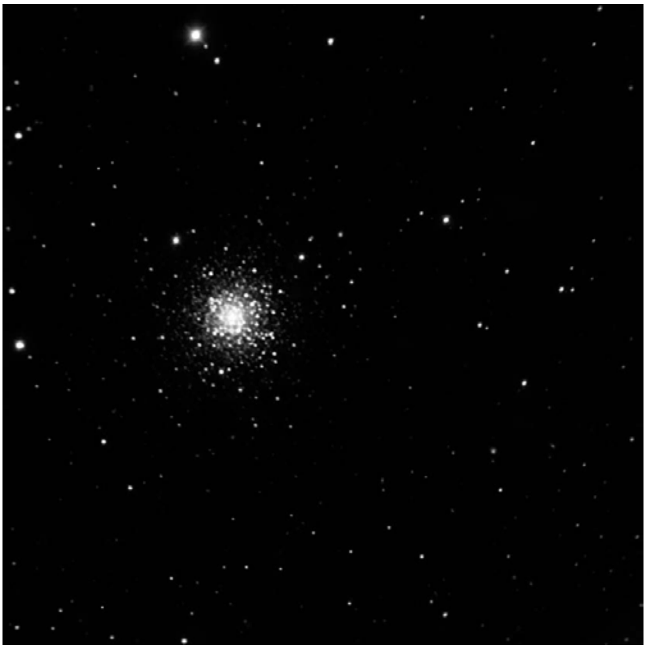
52

Secret Deep 52
(NGC 4147)



52

Kick the Can Cluster
NGC 4147
Type: Globular Cluster
Con: Coma Berenices



RA: $12^h\ 10.1^m$
Dec: $+18°\ 32.5'$
Mag: 10.3
SB: 13.6 (Rating: 3)
Dim: 4′
Dist: ~63,000 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed March 14, 1784] Very bright, pretty large, gradually brighter in the middle. (H I-19)

NGC: Globular cluster, very bright, pretty large, round, gradually brighter in the middle, well resolved, clearly consisting of stars.

NGC 4147 IS A SMALL, TIGHT, AND FAINT globular cluster in a rather bland parcel of celestial real estate between Beta (β) Leonis (Denebola), the Lion's tail, and Melotte 111, the Coma Berenices Cluster (Hidden Treasure 62), just a little more than 2° south-southwest of 5 Comae Berenices – a magnitude 5.5 star midway between Denebola and the Coma Berenices Cluster; it's also about 2½° west-northwest of 4.5-magnitude 11 Comae Berenices. You can use these stars to visually triangulate to the region. But be prepared to make a slow and careful search, since the area immediately surrounding the cluster is largely devoid of conspicuous stars.

Coma Berenices is also the constellation that harbors the North Galactic Pole: the location on the north celestial sphere that marks the imaginary location of a point 90° above the Milky Way's plane as viewed from Earth. NGC 4147 lies only about 13° from that point. Indeed, the globular cluster is a small and compact object some 61,000 light-years above the Galactic plane, 70,000 light-years from the Galactic center, and 63,000 light-years from Earth, plunging it deep into the Galaxy's halo.

Early studies of it were problematical because they suggested the cluster was missing significant giant branch stars. At the time, this threw a monkey wrench into models of stellar evolution in globular clusters, which have a well-populated giant branch and a horizontal branch as a main feature. The most prominent stars in globular clusters should be the luminous cool supergiants at the tip of the red giant branch. Instead, studies by Walter Baade (1930) and Nicholas Mayall (1946) showed RR Lyrae variables at maximum brightness as the most prominent members. RR Lyrae stars are evolved old, low-mass stars (on average only 40–50 times as luminous as our Sun), while red giants may release 1,000–10,000 times the Sun's luminosity.

But in a 1987 *Publications of the Astronomical Society of the Pacific*, University of Hawaii astronomer Eileen D. Friel and her colleagues abolished that claim with results obtained at the 3.6-meter Canda–France–Hawaii Telescope atop Mauna Kea. Their photometry of the roughly 14-billion-year old cluster, which reached to magnitude 22 (several magnitudes below the main-sequence turnoff), found a normal color–magnitude diagram that resembled that of a cluster with intermediate metallically – one only slightly more metal-poor than M13, the Great Hercules Cluster; each of NGC 4147's members has about 1/68 as much iron (per unit hydrogen) as does the Sun.

The researchers also found the cluster's core out to 20″ was bluer than light from the outer regions. In a 1991 *Astrophysical Journal* (vol. 372, p. 41), S. George Djorgovski (Palomar Observatory) notes that some clusters show color gradients in the sense of being bluer at smaller radii (the "core" is not a distinguishing characteristic), and that this seems to be caused by a relative deficit of red giants in the central regions. However, subsequent studies have shown that the situation is really complex, and that there are probably several competing effects involved. These seemingly youthful stars at the core of ancient clusters are called blue stragglers, and they have indeed been detected in NGC 4147. This situation of rejuvenated youth amongst the senior members of the cluster reminds me of a 1962 episode of TV's *The Twilight Zone*, called "Kick The Can."

This moving production takes us to the Sunnyvale Rest Home for the Aged, where the main character, Charlie, tries to inspire youth into his languishing companions by playing kick the can. "All kids play that game," he says. "And the minute they stop, they begin to grow old. It's almost as though playing kick the can keeps them young."

In the end, Bernie and his friends play kick the can and turn into youths (all except for one, who refused to join the fun). In a way, we can see the blue stragglers of globular clusters as the reward for playing "kick the can" – a celestial youth-restoring venture. Perhaps the collapsed cores of globular star clusters are, as Twilight Zone creator Rod Serling reminds us at the end of "Kick the Can", that the Sunnyvale Rest Home is a "dying place for those who have forgotten that childhood, maturity, and old age are curiously intertwined and not separate."

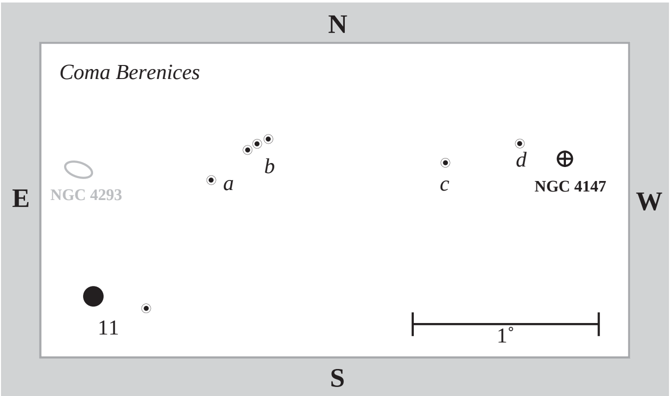
Blue stragglers also tend to be more massive than average stars in the cluster. As such, each tends to "sink" to the cluster's center, like a ship taking on water before it plunges into the murky deep. As these stars approach "bottom," they can rebound back out until they reach a point where they remain in a globular cluster twilight zone. NGC 4147, in fact, appears to be a post-core-collapse cluster, where heating binaries have stabilized the collapse, which is expected to undergo oscillations even in the absence of binaries.

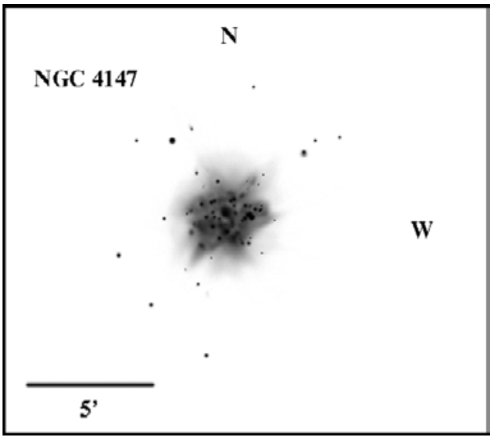
It has also been suggested that NGC 4147 is associated with the Sagittarius tidal stream, and thus assumed to be a previous member of the Sagittarius dwarf spheroidal galaxy – of which globular cluster M54 in Sagittarius is suspected of being its nucleus, and NGC 4147, one of its captured globulars. In a 2003 *Astronomy & Astrophysics* (vol. 405, pp. 577–583), Michelle Bellazzini (Astronomical Observatory of Bologna, Italy) and her colleagues used infrared color–magnitude diagrams from the Two Micron All Sky Survey (2MASS) to search for stars belonging to that tidal stream around selected Galactic globular clusters, finding a statistically significant detection around NGC 4147, strongly supporting the idea that this cluster is associated with the stream and that they were previous members of the Sagittarius dwarf spheroidal galaxy.

Interestingly, in a 2009 *Bulletin of the American Astronomical Society* (vol. 41, p. 205), Inese I. Evans (Princeton University/Carnegie Observatory) shares her chemical analysis of four red giants in NGC 4147 made with the 10-meter Keck Telescope atop Mauna Kea, Hawaii. She found their metal abundances all similar to that of Milky Way field stars, with none of the unusual abundances observed in the Sagittarius dwarf field or globular cluster stars of higher metallicities. If NGC 4147 is part of the stellar population of the Sagittarius dwarf spheroidal, it shared a similar formation history with the Milky Way. Now the Sagittarius dwarf spheroidal galaxy is being tidally destroyed by the interaction with our Galaxy, losing its stellar content along a huge stream clearly detectable in the Galactic halo. The stellar content and internal dynamics of it, however, are marginally known due to its large dimensions (~20° × 10° in the sky).

To find this probable captured extragalactic globular, use the chart on page 224 to find 5 and 11 Comae Berenices. Then use the chart on this page. From 11 Comae move a little more than 50′ northwest to 8th-magnitude Star *a*. Next move about 20′ further to the northwest to a roughly 8′-long line of three 11th-magnitude stars (*b*), oriented northwest to southeast. Now make a slow and careful 1° sweep west, and ever-so-slightly south, to 9th-magnitude Star *c*. A short 25′ hop to the west-northwest will bring you to 8th-magnitude Star *d*. NGC 4147 is a little less than 15′ southwest of Star *d*.

In the 5-inch at 33×, it is a condensed circular glow, almost starlike; it swells slightly with averted vision, with which I can see a dim 2′-wide halo brighten gradually to a smaller core. The more time I spend looking at the cluster at low power, the more intense it appears. If you take

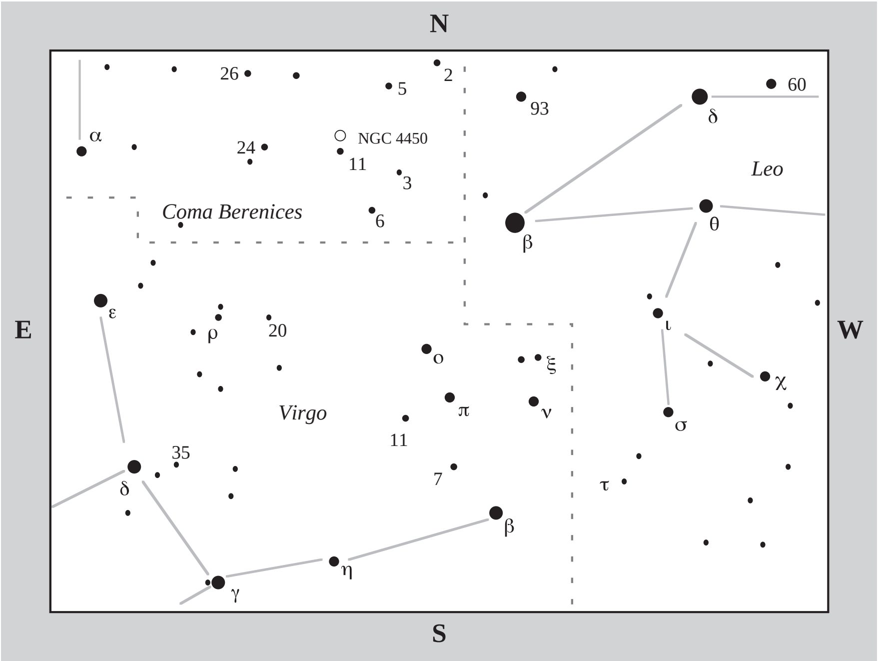




short breaks and breathe rhythmically, you may be able to see some dim suns, or groupings of stars, sparkling across the little globular's face. At 60×, the cluster's core is a very pronounced and rather intense bead of light surrounded by a cauliflower halo with a curious patch or enhancement of light to the east-northeast.

At 94×, the cluster's starlike core is surrounded by a fragmented inner core and a ragged and spiked halo, like the flaring of light caused by astigmatism in the eye. But these "flares" are short stubby arms extending about 2′ from the core; in order of intensity, these arms are to the west-northwest, south-southwest, east and southeast. With averted vision, I can see dark veins separating the cluster fragments, which are made up of highly concentrated aggregations of dim, unresolved stars. The cluster's core takes magnification well. But 180× seems to be the maximum power for a somewhat comfortable high-power view in the 5-inch. At this power, the core appears as a ghostly hexagon of light superimposed on which are about a half-dozen suns surrounding a dim central glow, which, with concentration, seems to fragment. The brightest stars in the cluster shine at a reasonable 14.5 magnitude; the RR Lyrae stars hover around 17th (too dim for this scope).

Secret Deep 53
(NGC 4293)



53

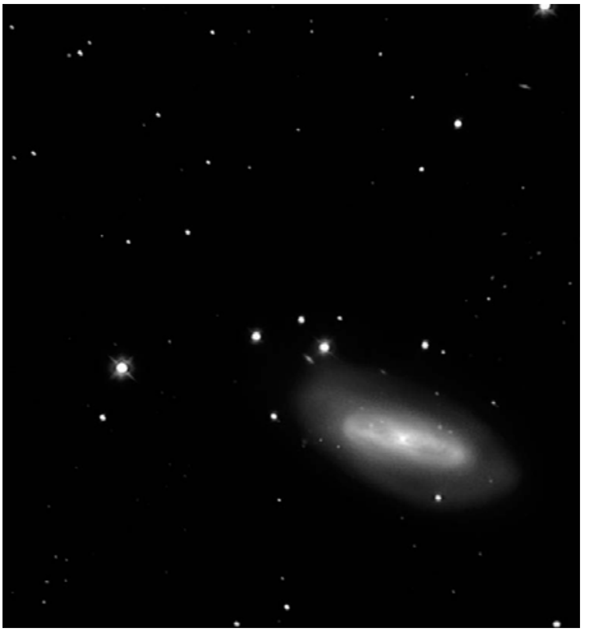
53

NGC 4293
Type: Barred Spiral Galaxy (SBab)
Con: Coma Berenices

RA: $12^h\ 21.2^m$
Dec: $+18°\ 23'$
Mag: 10.4
SB: 13.2 (Rating: 4)
Dim: $5.3' \times 3.1'$
Dist: ~55 million l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed March 14, 1784] Large, extended, resolvable, 6 or 7′ long. (H V-5)

NGC: Faint, very large, extended, little brighter in the middle, resolvable (mottled, *not* resolved).



NGC 4293 IS A REASONABLY BRIGHT and elongated galaxy just north-northeast of 4.5-magnitude 11 Comae Berenices. It is fairly condensed and should be a nice sight even in small telescopes, especially at moderate magnification. It belongs to the Virgo Cluster and southern extension of galaxies and we see it inclined only 24° from edge on.

In photographs, the 85,000 light-year-wide galaxy is quite a perplexing brew of light and dark textures and features. In the 1960s, astronomers believed that NGC 4293 might belong to the second major subdivision (Sa) of spiral systems – those with predominantly small nuclei and somewhat regular, thin, internal dust lanes lining thin S-shaped (s) spiral arms. Later images revealed NGC 4293 not only to have heavy dust lanes spread throughout its lens (0), but also one strong dark lane in a bar (SB) that partially hides the galaxy's very small but bright nucleus, as well as a very faint pseudo outer ring (R) composed of soft, non-symmetrical arms making massive spiral sweeps. So to this day we still see it classified as the complicated type of (R)SB(s)0/a.

But some astronomers argued that the spiral pattern of the dust in NGC 4293 precludes an S0 classification. The lack of resolved stars also precludes an Sb classification. It does have a weak, short, broad bar that threads the bulge along a diagonal. And spiral arms made of dust alone are known in other Sa galaxies. So, it's more common today to see the galaxy classified simply as an SBab system seen nearly edge on.

In a 2002 *Astrophysical Journal* (vol. 143, p. 73) Paul B. Eskridge and colleagues announced the initial release of data from the Ohio State University Bright Spiral Galaxy Survey – a near-infrared imaging survey of a well-defined sample of 205 bright, nearby spiral galaxies. Their images of NGC 4293 reveal two very open, stubby, broad spiral arms emerging from the ends of the galaxy's central bar. The arms can only be followed for 45° before terminating abruptly at a discontinuous decline in disk surface brightness. The arms are defined by a series of bright blobs. The outer low-surface-brightness disk has a position angle skewed about 45° from that of the boxy inner disk/bulge with traces of spiral structure.

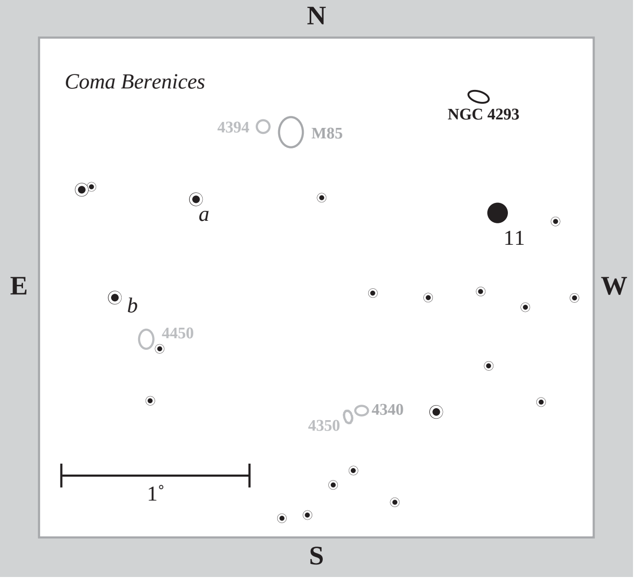
The roiling cores of many active galaxies are difficult to see in detail because of surrounding gas and interstellar dust. This is especially true for highly inclined systems, such as NGC 4293, where the line of sight cuts through such a long slant path in the galaxy. But in a January 2006 press release, astronomers at the Harvard–Smithsonian Center for Astrophysics (CFA) announced a new way to better trace the structure of these unusual regions – namely, by measuring millimeter and submillimeter wavelengths of extragalactic water maser emission in the core of active galactic nuclei (AGN). "Detections of water masers at these wavelengths will provide a unique new means of determining the physical conditions near the center of active galactic nuclei, where supermassive black holes are believed to lie," said Elizabeth M. L. Humphreys.

Humphreys and her CfA colleagues had their first success with NGC 3079 – a galaxy 50 million light-years distant in Ursa Major. Over millions of years, an immense hourglass-like bubble of hot gas has emerged from the core of NGC 3079, in a process, they believe, that directly relates to the many-million solar-mass black hole at the neck of the hourglass. Then, in a 2006 *Astrophysical Journal* (vol. 638, pp. 100–105), Paul T. Kondratko (a student at the time at CfA) and colleagues announced the successful detection of water maser emission from the core of NGC 4293 with the 70-meter NASA Deep Space Network (DSN) antenna at Tidbinbilla, Australia. The position of the maser emission, measured with the Very Large Array (VLA) of the National Radio Astronomy Observatory, matched the optical position of the galaxy's AGN, confirming its association with the accretion disk at the galaxy's core.

Lincoln Greenhill at CFA notes that though water masers (much weaker ones) are also known to arise in regions of star formation, the VLA measurements make association with the disk much more certain.

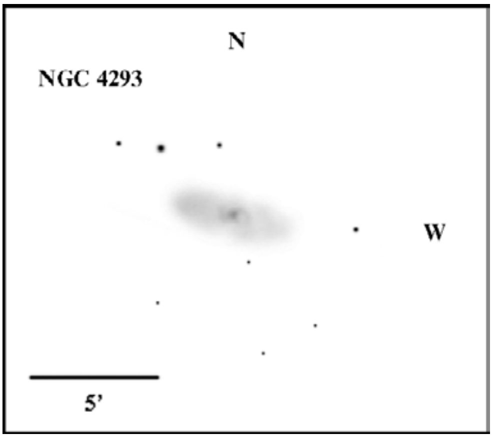
NGC 4293 was also one of the objects studied in a high-resolution radio census of 70 nearby LINERs (low-ionization nuclear emission-line regions) and composite LINER/HII galaxies. As M. E. Filho (Centro de Astrofísica da Universidade do Porto, Portugal) and colleagues report in a 2006 *Astronomy & Astrophysics* (vol. 451, pp. 71–83) the work, carried out with the Jodrell Bank Multi-Element Radio-Linked Interferometer Network (MERLIN), found a rotating compact source in NGC 4293's core, which they believe is thermal radiation flowing from an accretion disk that's feeding the supermassive black hole at the heart of the galaxy.

To find this intriguing galaxy, use the chart on page 229 to find 11 Comae Berenices, which is nearly 10° (a fist held at

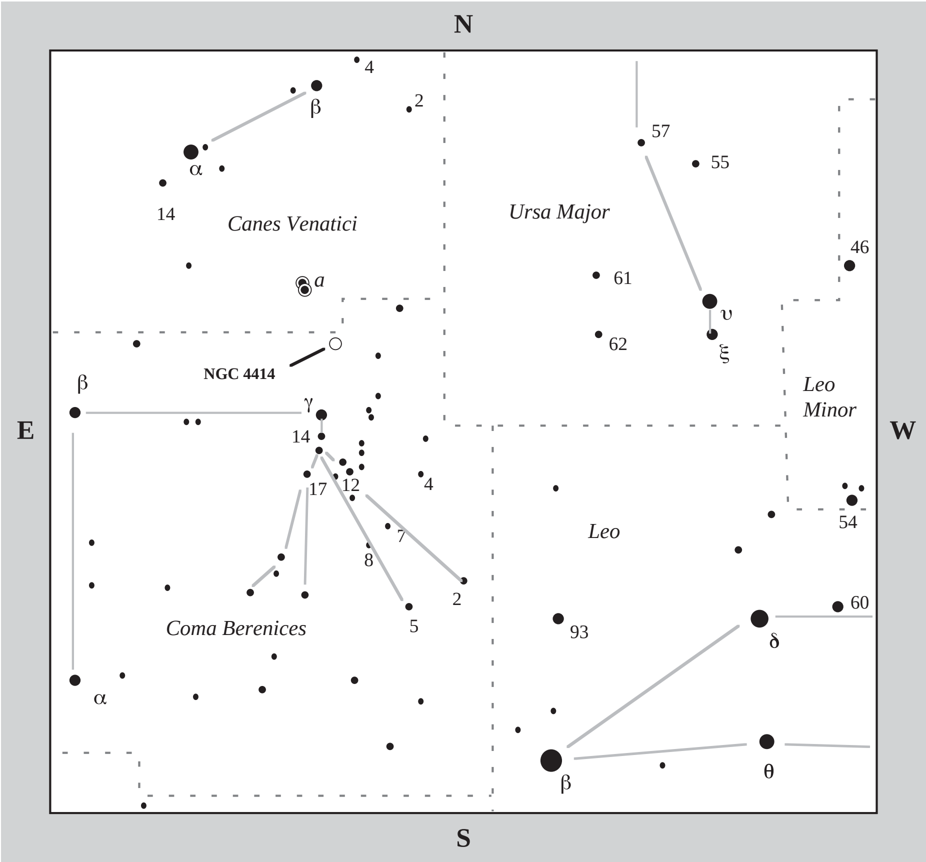


arm's length) northwest of Rho (ρ) Virginis. It also forms the northwest apex of a 5°-wide isosceles triangle with the similarly bright stars 24 and 6 Comae Berenices. Center 11 Comae in your telescope at low power then switch to the chart on page 232. NGC 4293 is only 35′ north and slightly east of 11 Comae.

At 33× in the 5-inch, NGC 4293 is a beautiful phantom ellipse (about 3′-long) at the end of a pretty star chain. It is oriented east-northeast to west-southwest and shines with a uniform brightness. At 60× the galaxy is a most intriguing sight. The galaxy's core is a diffuse lens bracketed on either side of the major axis by two diffuse arcs of light, separated from the nucleus by dark matter. The view is much the same at 94×, though the core suddenly becomes much brighter to the middle to a tiny nucleus. With time and averted vision, I could see hints of the galaxy's dim and fuzzy outer halo, making the glow swell to 5′ in length. That outer disk appears warped or unevenly bright with dim and uneven enhancements near the ansae.



Secret Deep 54
(NGC 4414)



54

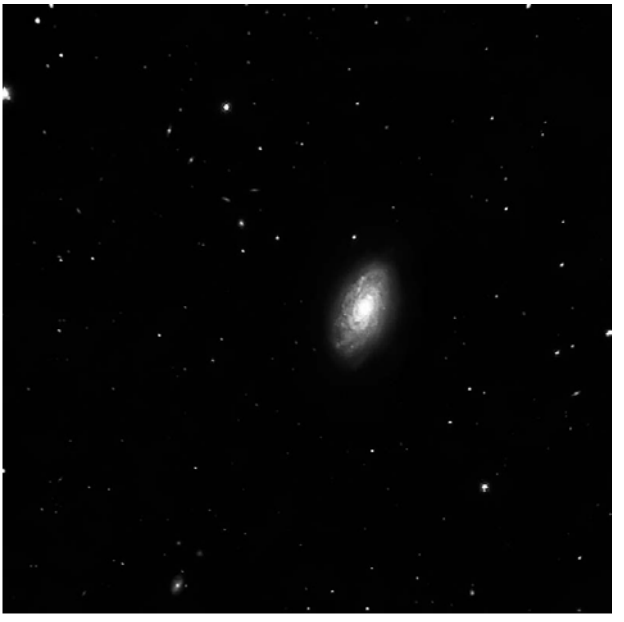
54

NGC 4414
Type: Spiral Galaxy (SA(rs)c?)
Con: Coma Berenices

RA: $12^h\ 26.4^m$
Dec: $+31°\ 13'$
Mag: 10.1
SB: 12.8 (Rating: 4)
Dim: $4.4' \times 3.0'$
Dist: ~62 million l.y.
Disc: William Herschel, 1785

W. HERSCHEL: [Observed March 13, 1785] Very bright, large, broadly extended, bright in the middle. (H I-77)

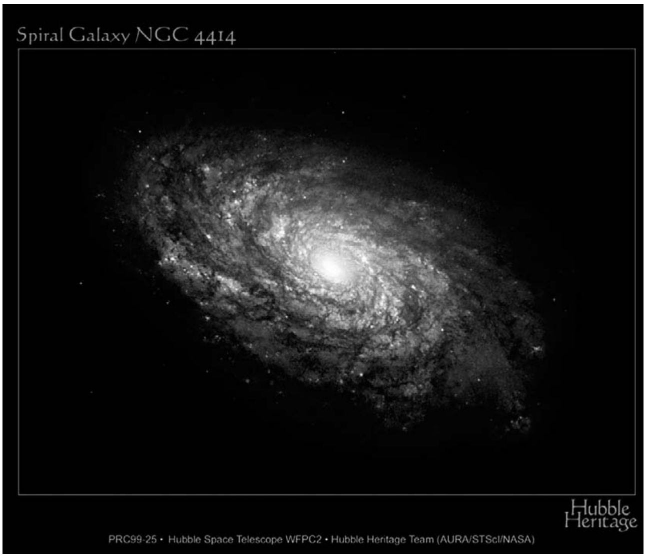
NGC: Very bright, large, extended, gradually, very suddenly much brighter in the middle to a star.



NGC 4414 IS A MODERATELY SMALL but very conspicuous lens-shaped spiral galaxy about 3° north and very slightly west of Gamma (γ) Comae Berenices – just at the southwestern-most corner of Canes Venatici. The galaxy has a relatively high surface brightness and should be a good target for small-telescope users, even under suburban skies. Those using equatorial mounts can simply place Gamma in their scope at low power and move the scope 3° north to strike it.

Gamma is the bright northern star in the λ-shaped asterism of the Coma Berenices star cluster (Melotte 111 (Hidden Treasure 62)), which lies only about 5° west of the North Galactic Pole – the imaginary point in the sky that marks where the rotational axis of our Milky Way Galaxy intersects the north celestial sphere. Although the region is just about as far away as you can get from the stellar and dusty madness of the Milky Way's plane, it is an area rich in extragalactic wonders. NGC 4414 lies on the western skirt of the great Coma Berenices Cluster of galaxies, a turbulent array of more than 3,000 galaxies (mostly ellipticals and lenticulars), some 300 million light-years distant. It is the nearest massive cluster of galaxies and is scattered across 20 million light-years of space.

But NGC 4414 is only 62 million-light-years distant, receding from us at about 700 km/sec. It belongs to the Coma–Sculptor Cloud (or wall) of galaxies, which includes the Local Group (home to our Milky Way). The Coma–Sculptor wall may actually be part of a long filament of galaxies that extends from the distant Coma Cluster, runs through the Virgo Cluster,



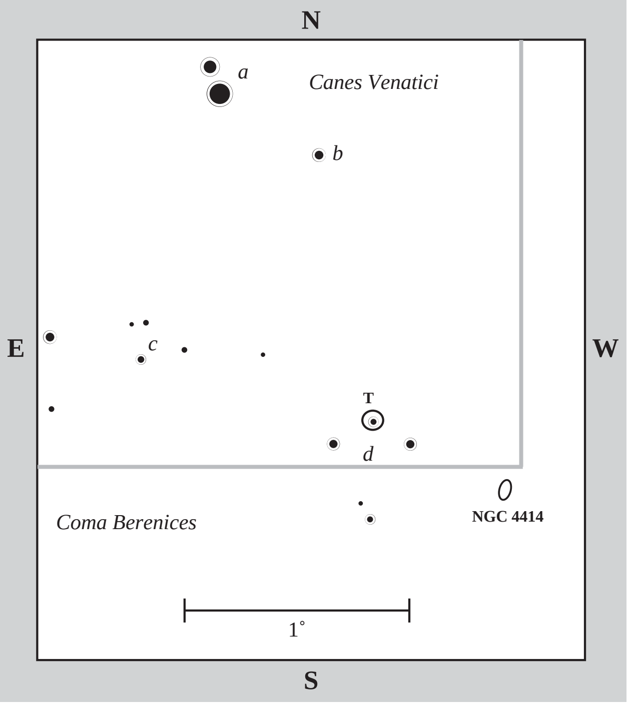
and tickles the Local Group. At the given distance, NGC 4414 has a true linear extent of 80,000 light-years and a total mass of 80 billion Suns.

Typical astrophotos show NGC 4414 to have a bright diffuse nucleus in a bright bulge. But unlike the magnificent arms in the disk of grand-design spirals, those of NGC 4414's are filamentary (flocculent); in white light, they appear as a complex array of luminous, knotty fragments that remain only partially resolved (though well developed). Dark lanes accompany many of the feathery branches, which appear well silhouetted against the near side of the underlying disk. But near-infrared images have revealed active star-forming regions spread over the disk. Notably, bright regions northwest and southeast of the nucleus seem to form an apparent ring/arm structure with a radius of 20″ (~6,500 light-years). Outer "arm" segments to the north and south extend to a radius of about 40″ and are continuous over 60° in azimuth, but they do not appear to form a regular two-arm spiral pattern.

In 1995, the Hubble Space Telescope imaged NGC 4414 as part of the its Key Project on the Extragalactic Distance Scale. An international team of astronomers, led by Wendy Freedman of the Observatories of the Carnegie Institution of Washington, observed parts of the galaxy on 13 different occasions over the course of two months. Based on their discovery and careful brightness measurements of nine Cepheid variable stars in NGC 4414, the Key Project astronomers determined that the galaxy lies about 62 million light-years away.

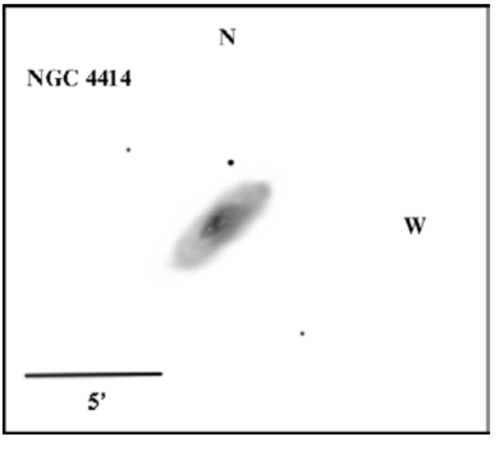
HST imaged the rest of the galaxy in 1999 as part of the Hubble Heritage Project (see image above). The end result of the two observations is a stunning look at the entire dusty spiral galaxy. In the color image (not shown here) the galaxy's central region is typical of most spirals, containing primarily warm-hued older stars; the outer spiral arms, however, appear considerably bluer and younger due to ongoing star formation. The brightest of the young stars can be seen individually at the high resolution provided by the Hubble camera. The arms are also very rich in clouds of interstellar dust, seen as dark patches and streaks silhouetted against the starlight.

Although NGC 4414 is as bright as M91 in Coma Berenices, few go after it because it is somewhat of a "bear" to find. It lies in a relatively star-poor region, one especially devoid of bright ones. Nevertheless, use the chart on page 233 to locate 4.5-magnitude Gamma Comae Berenices. Then look about



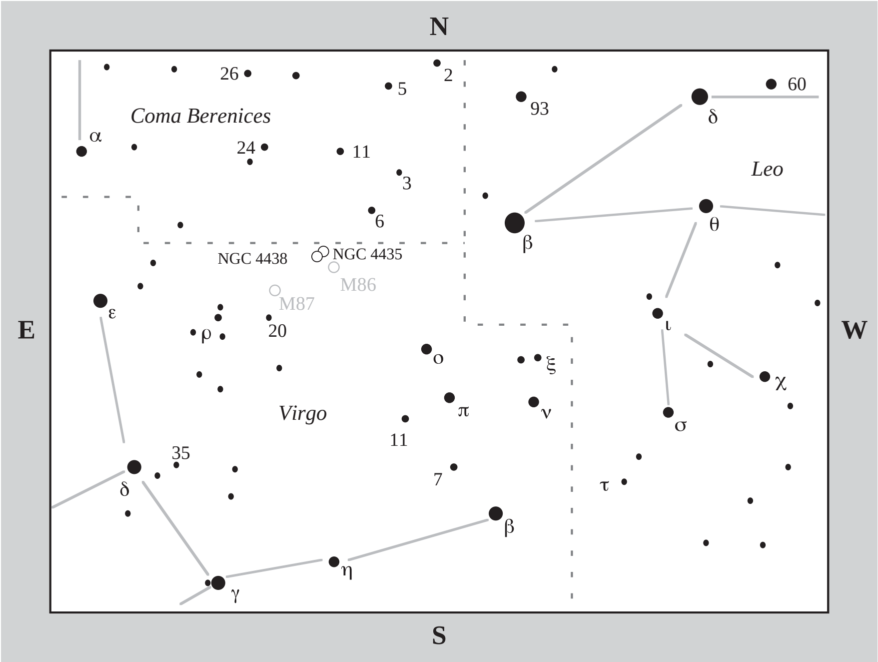
halfway between it and 3rd-magnitude Alpha (α) Canum Venaticorum for a tight binocular pair of roughly magnitude 5.5 stars (*a*), oriented north-northeast–south-southwest and separated by about 10′. Once you locate this pretty pair, center it in your telescope then switch to the chart on this page. From the southern star in the pair, move 30′ west-southwest to 7.5-magnitude Star *b*. Then make a careful 1° sweep southeast to Triangle *c* comprising three roughly 9th-magnitude stars about 12′ wide. Now make another 1° hop, this time to the southwest, where you'll find a pair of stars (*d*) that shine between 7th and 8th magnitude, are separated by about 25′, and are oriented east–west. Beware, another star (the long-period variable T Canum Venaticorum) lies a bit north and midway between these stars; it varies between magnitudes 7.6 and 12.6 and back every 290 days. NGC 4414 is about 35′ west-southwest of the westernmost star in Pair *d*.

At 33× NGC 4414 is moderately large (4′) and surprisingly bright. Most prominent (even with direct vision) is a bright starlike core surrounded by a fuzzy elliptical core embedded in a larger diffuse lens that's oriented northwest to southeast. At 60× the galaxy is very beautiful, appearing as a large tapered lens with a very prominent nucleus. The inner lens appears mottled along the major axis and the outer lens has hints of knotty enhancements along what appears to be a spiral pattern, though nothing is connected.



At 94×, the galaxy smoothes out and less detail is seen. The core is extremely sharp and the major axis of the galaxy seems enhanced, as if light were glinting off it at an angle. As of this writing, SN 1974g was the only known supernova to appear in this galaxy.

Secret Deep 55 & 56
(NGC 4435 & 4438)



55 & 56

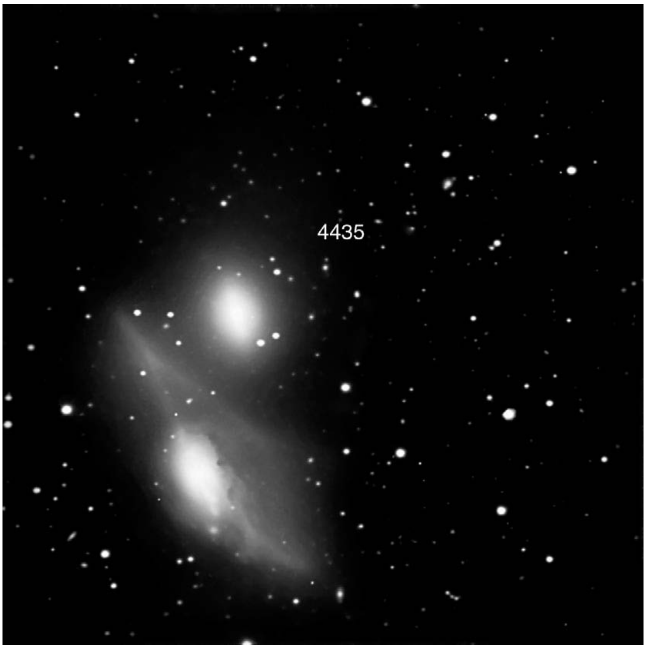
55

The Eyes
NGC 4435
Type: Barred Lenticular Galaxy SB(s)0
Con: Virgo

RA: 12^h 27.7^m
Dec: $+13°$ $05'$
Mag: 10.8
SB: 12.7 (Rating: 3.5)
Dim: $3.2' \times 2.0'$
Dist: ~55 million l.y.
Disc: William Herschel. 1784

W. HERSCHEL: [Observed April 8, 1784] One of two, separated by 4 or 5′, bright, considerably large. (H I-28,1)

NGC: Very bright, considerably large, round, north preceding of 2.



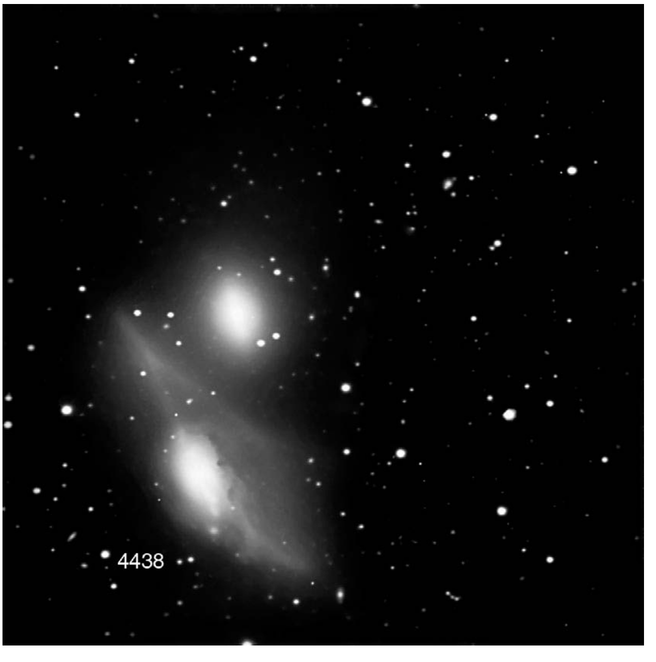
56

The Eyes
NGC 4438
Type: Lenticular Galaxy SA(s)0/a peculiar
Con: Virgo

RA: 12^h 27.8^m
Dec: $+13°$ $01'$
Mag: 10.2
SB: 13.8 (Rating: 4)
Dim: $8.9' \times 3.6'$
Distance: ~55 million l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed April 8, 1784] One of two, separated by 4 or 5′, bright, considerably large. (H I-28,2)

NGC: Bright, extremely large, very little extended, round, south following of 2.



55 & 56

NGC 4438 IS A RATHER BRIGHT AND obvious galaxy roughly 20′ east and slightly north of the magnificent elliptical galaxy M86 in Virgo; it is paired with smaller and dimmer NGC 4435 immediately to the northwest. M86, NGC 4438, and NGC 4435 make up part of Markarian's Chain – an intriguing arc of galaxies at the heart of the vast Virgo Cluster of galaxies. Viewed together, NGC 4438 and 4435 are known as The Eyes, a moniker bestowed upon them by Leland Copeland in a 1955 *Sky & Telescope* article, for their appearance through a telescope. For some reason, The Eyes have morphed into the Little Eyes in some popular circles.

Of all the galaxies in Virgo, NGC 4438 is arguably the most fascinating, at least its appearance in high-resolution images immediately captures the attention. Here is a large and peculiar nonbarred lenticular galaxy whose outer disk is fantastically warped and ripped into shreds. Halton Arp, the P. T. Barnum of modern astronomy, listed NGC 4438 as the 120th object in his 1966 *Atlas of Peculiar Galaxies* – a photographic sideshow starring 338 extragalactic "freaks," namely wildly deformed galaxies that pique our curiosities.

NGC 4438 is certainly an attraction, being a perturbed spiral, 140 million light-years across, seen nearly edge-on. It's also the most disturbed large spiral galaxy in the Virgo Cluster. Its stars are clearly disturbed, indicating a strong gravitational encounter with another galaxy. But its gas is even more disturbed than that in most gravitationally interacting systems. "Something has pushed most of the gas west of the stars in the galaxy and heated it up," says Yale astronomer Jeffrey Kenney. "There are two mysteries: who did NGC 4438 collide with? And why is its gas so disturbed?

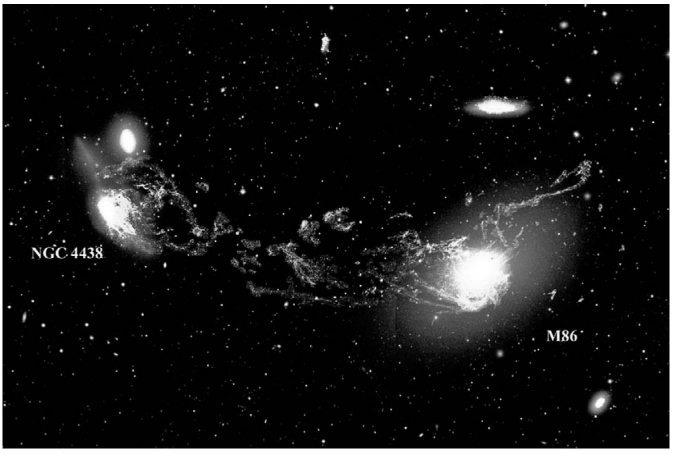
Kenney sees two options for the collision (NGC 4435 or M86) and three options for the gas distuption: The intrastellar medium of NGC 4438 collided with (1) the intracluster medium of the Virgo Cluster; (2) the intrastellar medium of NGC 4435; or (3) the intrastellar medium of M86.

The most obvious candidate for the gravitational encounter, Kenney says, is NGC 4435. But problems exist with this idea: (1) While NGC 4438 is madly distorted, NGC 4435 shows no evidence of tidal effects; so the do-unto-others-as-they-would-do-unto-you gravitational model doesn't seem to apply here. (2) The two galaxies have different redshifts; NGC 4435 is receding from us at 753 km/sec, while NGC 4438's recessional velocity is 115 km/sec, showing that the encounter is one of exceptionally high velocity.

In 2008 Kenney and his colleagues used the 4-meter NOAO telescope in Arizona to find "monumental tendrils" of ionized hydrogen gas 400,000 light-years long (four Milky Way galaxies in length) connecting M86 and NGC 4438!

"This discovery provides some of the clearest evidence yet for high-speed collisions between large galaxies," Kenney says. Spectroscopic observations of selected regions along the filament, obtained with the WIYN 3.5-meter telescope on Kitt Peak, show a fairly smooth velocity gradient between the galaxies, further supporting the collision scenario.

As in most elliptical galaxies, most of the gas within M86 is extremely hot, and therefore radiates X-rays. While galaxy



heat up so much that it cannot easily cool and form stars. Further studies may help astronomers learn about the role of gravity in the heating of galaxy gas, which appears to be quite significant.

NGC 4438 also has a cool outflow bubble, probably driven by its active galactic nucleus/nuclear black hole.

In June 2000, the Space Telescope Science Institute released Hubble Space Telescope images of the galaxy's central region, which revealed evidence for a supermassive central black hole – one that's belching huge bubbles of hot gas into space. The images clearly show one bubble rising from a dark band of dust. Another bubble, emanating from below the dust band, is barely visible, appearing as dim blobs in the close-up view in the image below.

As the supermassive black hole feeds on the dust and gas spinning around it in what's known as an accretion disk (the white blob below the bubble seen in the close-up image above), some of the material rapidly spews away from it in opposite directions as long jets. As the jets rush forward at speeds greater than 223,000 miles per hour (360,000 kilometers per hour), they collide with slower moving matter, causing it to not only swell and expand like a bubble but also glow. The hot bubble is much more obvious on one side of the nucleus because that's where one jet smashed into a denser amount of gas; it measures 800 light-years across. While these outflow shells share similarities with those in some other

gas stripping from motion through the intracluster gas may also be occuring, the X-ray distribution in M86 is irregular and sports a long plume, which had previously been interpreted as a tail of gas that is being stripped by ram pressure as M86 falls into the intracluster medium of the Virgo cluster. The new H-alpha image from Kitt Peak suggests that most of the disturbances to the interstellar medium in M86 are instead due to the collision with NGC 4438.

Interestingly, unlike with many tidal tails seen between galaxies, here there are no obvious stars in the filaments. It's long been a mystery as to why large galaxies, especially ellipticals like M86, stop forming stars. It now appears that high-velocity collisions (which happen naturally between large galaxies, since their large gravity pulls mass inward much faster), is a leading mechanism.

Kenney explains that the consequences of such collisions are a plausible alternative to black holes in trying to explain the mystery of what process turns off star formation in the biggest galaxies. The kinetic energy of the collision can cause the gas to

starburst or Seyfert galaxies, these in NGC 4438 are notable because NGC 4438 harbors neither a luminous starburst nor a luminous active galactic nucleus.

NGC 4435 is another early-type galaxy inclined 45° from face on. Its dominant central bulge contains a very bright nucleus in a bright bar, centered on a dusty circumnuclear disk that's surrounded by a spherical envelope.

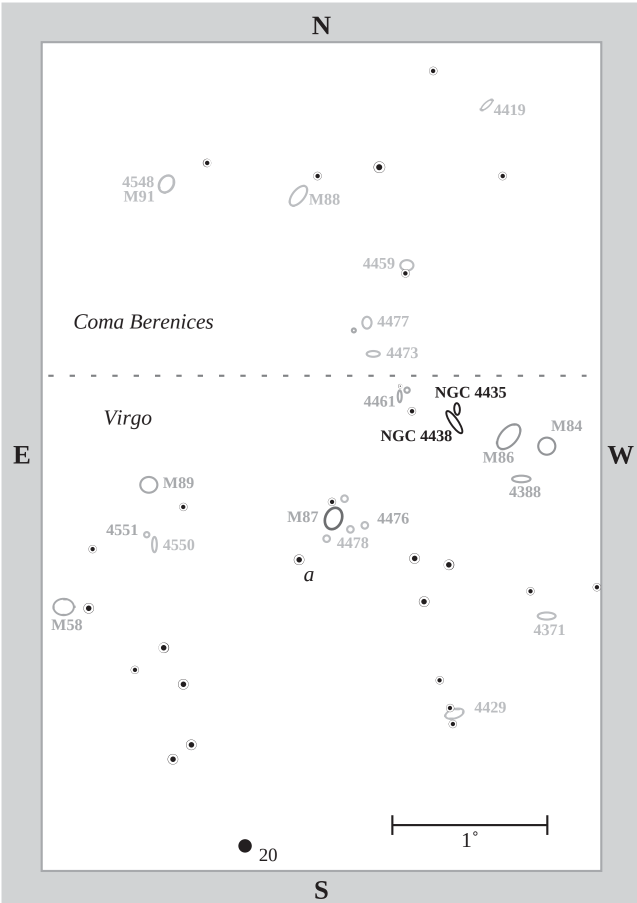
Pasquale Panuzzo (Astronomical Observatory of Padua, Italy) and his colleagues combined new spectroscopic observations obtained with the Spitzer Space Telescope and existing infrared and broadband data to find evidence for starburst activity in the galaxy. As reported in a 2007 *Astrophysical Journal* (vol. 656, pp. 206–216), the estimated age of the burst is found to be around 190 million years, which is fully consistent with the notion that the star-formation process was triggered by the interaction with NGC 4438.

And in a 2006 *Monthly Notices of the Royal Astronomical Society* (vol. 366, pp. 1050–1066) Lodovico Coccato (Kapteyn Astronomical Institute, the Netherlands) and his colleagues note that spectra obtained with the Hubble Space Telescope reveal that the galaxy's circumnuclear disk also appears to be rotating around a supermassive black hole with a mass of some 75 million Suns.

To find this wonderful pair of interacting galaxies, it's best to first locate 9th-magnitude M86. Start by using the chart on page 237 to locate 5th-magnitude Rho (ρ) Virginis, which is easy to identify, since it is the central bright star in a 30′-wide upside-down Y of stars (oriented north–south). About 2° to the west you'll find 6.5-magnitude 20 Virginis. Center 20 Virginis in your telescope at low power, then switch to the chart on this page. From 20 Virginis, make a careful sweep 2° north and a tad west until you hit 8.5-magnitude M87, just 20′ northwest of 8th-magnitude Star *a*. If you're careful, you shouldn't miss M87, since it will be the first bright galaxy to enter the field in your sweep; in other words, there simply are no other objects to confuse it with in the sweep. M86 is the next brightest object you'll encounter by moving your scope 1¼° to the northwest. It will be paired with similarly bright M84 to its west-southwest. The Eyes (NGC 4435 and 4438) lie only 20′ east and a tad north of M86. It's that simple.

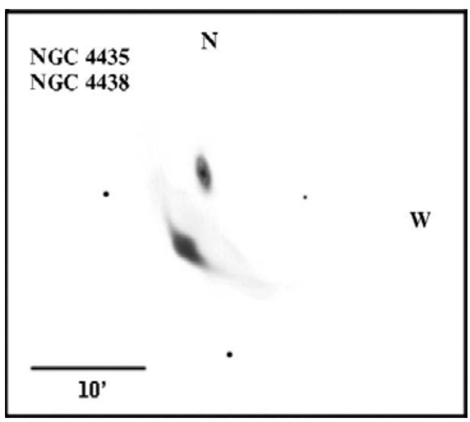
At 33× NGC 4435 appears as a sharp star surrounded by a 1′ circular halo of light. NGC 4438 is a larger, fuzzier oval (2′) with a fainter central bead. With averted vision, the two make quite a lovely low-power pair in the 5-inch; with imagination, they do look like eyes, one of which (NGC 4438) is winking. The view at 60× is quite interesting as both objects double in apparent size.

55 & 56

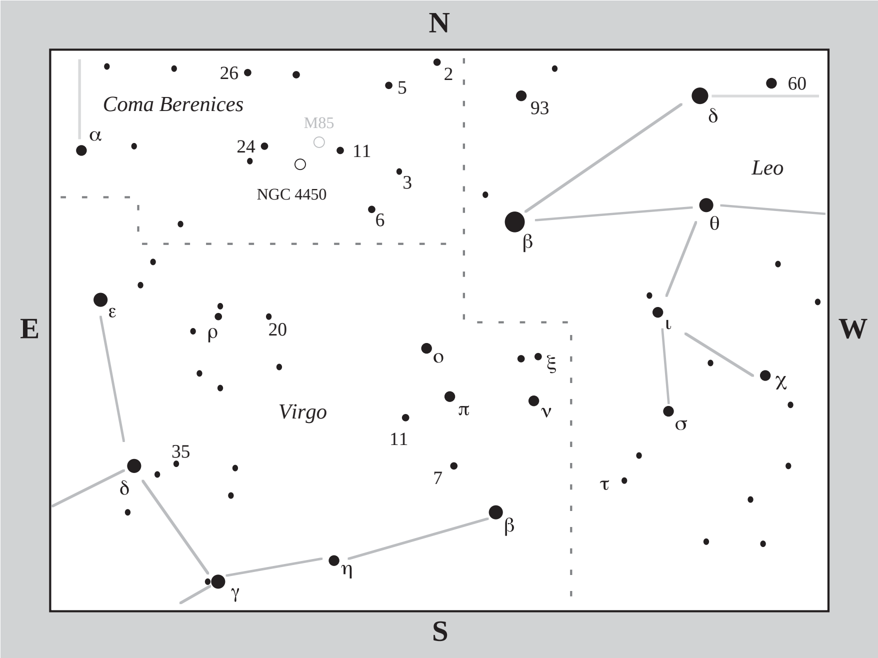


NGC 4435's nucleus remains sharp. Its central region is round, but with averted vision it extends into an ellipse that gets gradually fainter away from the nucleus. But what's most interesting is the visual *tug* of NGC 4438 because its dim arms appear warped (something I've seen in a 4-inch refractor). The arms curve bow-like toward NGC 4435 and the region between the two galaxies is filled with playful light, like breath that comes and goes on a cold window pane.

The galaxies take high power well, but I feel most comfortable viewing them at 94×. At this magnification, NGC 4438's warped arms are most apparent with averted vision, and its northwestward distortion fills the void between the galaxies, the northwestern edge of which is like the string being pulled away from the bow to form a broadly sloping arc. NGC 4435's nucleus continues to look amazingly starlike and its central bulge dominates the view as a bright lens of light, like a small spindle. With imagination, I can see NGC 4438 as a glowing flying saucer and NGC 4435 as a smaller "scouting vessel" preparing to dock. What do you see?



Secret Deep 57
(NGC 4450)



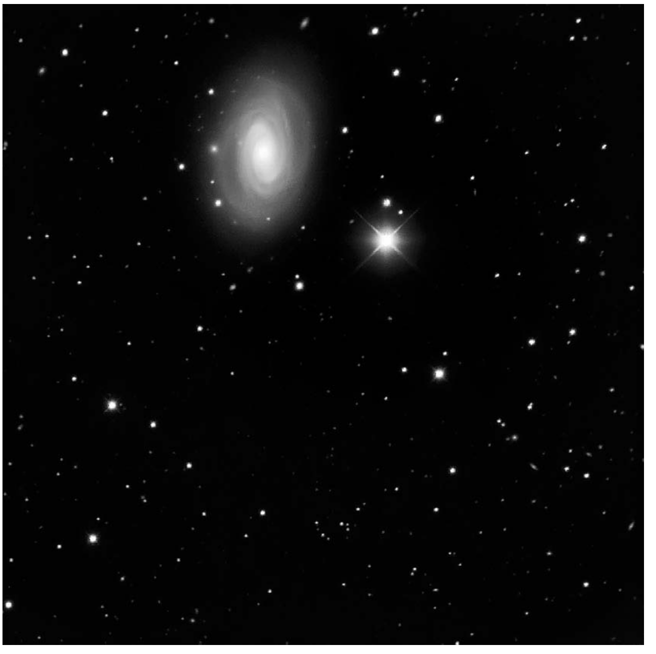
57

NGC 4450
Type: Spiral Galaxy (SA(s)ab)
Con: Coma Berenices

RA: 12^h 28.5^m
Dec: +17° 05′
Mag: 10.1
SB: 13.0 (Rating: 4)
Dim: 5.0′ × 3.4′
Dist: ~55 million l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed March 14, 1784] Pretty large, irregularly round, bright in the middle, 2 or 3′ in diameter. (H II-56)

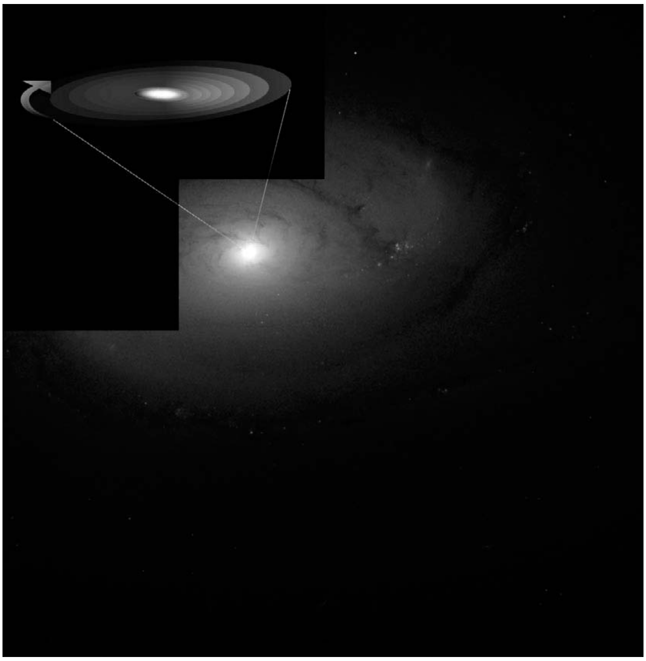
NGC: Bright, large, round, gradually very much brighter in the middle to a star, resolvable (mottled, *not* resolved), bright star south-preceding.



NGC 4450 IS A SMALL BUT FAIRLY bright spiral galaxy a little less than 1½° southeast of M85. It is nicely compact, making it a good target for small-telescope users. In fact, our target is only 1 magnitude fainter than M85 and has the same brightness as the more popular barred spiral galaxy M91, also in Coma Berenices; NGC 4450 even has a slightly higher surface brightness than M91. Yet who looks at NGC 4450?

I found it interesting that, in 1961, Edwin Hubble reported imaging NGC 4450 with the 100-inch reflector atop Mount Wilson in California, but complained about the effects of light pollution on it. "The plate was taken with the 100-inch after the war, when the city lights from Los Angeles were bright," he said. "The faint outer detail is lost because of the bright background sky." Still, Hubble could see that the galaxy has the same soft, "massive" arms as M64 (The Black-Eye Galaxy) and M90 in Coma Berenices, and M58 in Virgo. "The internal dust lanes are quite regular," Hubble continued, "The most conspicuous lane does not start in the nuclear region but begins abruptly some distance from the center – an unusual feature in galaxies."

Later, more detailed images began to reveal a small, very bright, diffuse nucleus in a smooth bulge with strong, regular dark lanes. The milky smooth arms also revealed a few condensations. In 2002, Debra Meloy Elmegreen (Vassar College, New York) and her colleagues report in an *Astrophysical Journal* (vol. 564, pp. 234–243) how they used archival HST Planetary Camera and other images to investigate the nuclear dust in NGC 4450. In general, nuclear dust spirals have several characteristics that differ from

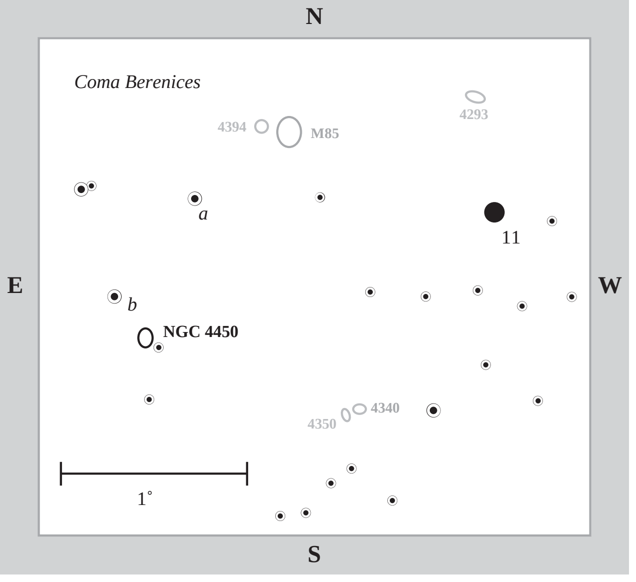


spiral arms and dust clouds in main galaxy disks: (1) They have no associated star formation, (2) are very irregular with both trailing and leading components that often cross, (3) become darker as they approach the center, (4) fill the inner disk completely with structure (main galaxy disks often have a small number of arms that get farther apart with radius), and (5) decrease in number with increasing arm width.

The detailed images of NGC 4450 they surveyed show two long dust spirals in the main disk, along with some flocculent structure; the stellar spiral arms are smooth. In contrast, the nuclear region has no stellar arms and at least seven prominent dust arms, some with pitch angles as high as 45° and some crossing each other. The eastern side of the nuclear region shows more dust than the western side because of the galaxy's inclination. Some small dust feathers extend nearly radially from the center toward the south, reminiscent of jets. While the researchers found no *direct* evidence for the dust spirals feeding a central accretion disk, they do note that the galaxy's increase in dust opacity toward the nucleus is what they'd expect to see if the spirals were driving nuclear accretion.

Indeed, in a 2000 *Astrophysical Journal* (vol. 541, p. 120), Luis C. Ho (Observatories of the Carnegie Institution of Washington, Pasadena, California) and colleagues reported that HST spectral observations revealed high-velocity "wings," which are characteristic of accretion disk activity observed in low-power Seyfert galaxies known as LINERs (low-ionization nuclear emission-line regions), of which NGC 4450 is one. They believe the wildly rotating accretion disk, which is inclined by 27° along the line of sight, is feeding a supermassive black hole (see the illustration above).

In a 2000 NASA/ESA press release of that observation, Dutch astronomer Roeland van der Marel (Space Telescope Science Institute), who is collaborating with another international group of black hole astronomers, elaborates: "It has long been hypothesized that black holes act as the engines that power the centers of active galaxies, but conclusive measurements have remained elusive. Thanks to Hubble and other telescopes this has changed and little room is now left for doubts that black holes do exist in galaxy centers." Team leader Hans-Walter Rix (Max-Planck-Institut fur Astronomie, Heidelberg), adds that it is



“quite clear that the nearby Universe is full of black holes in galaxies. Using Hubble we now routinely find black holes in perfectly typical, normal, boring galaxy centers. Indeed it seems likely, that Nature can’t make a big galaxy without a black hole at the center.”

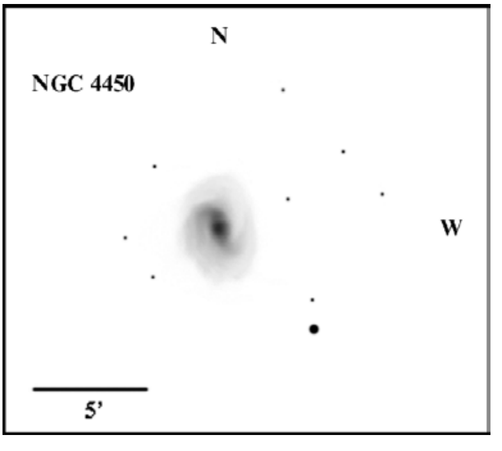
NGC 4450 belongs to the Virgo cluster of galaxies and is receding from us at 1,954 km/sec. In true physical extent, it spans 80,000 light-years of space, has a total mass of 70 billion Suns, and shines with a total luminosity of some 20 billion Suns.

To find this extragalactic dynamo, use the chart on page 243 to locate M85, which is a little more than 1° east-northeast of the 4.5-magnitude star 11 Comae Berenices, which is about 8° northeast of 2nd-magnitude Beta (β) Leonis (Denebola). M85 is a bright 9th-magnitude lenticular galaxy and should appear as a powerfully glowing oval mass. Center M85 in your telescope at low power, then switch to the chart on this page; note that little NGC 4394 lies only about 8′ to the east-northeast. From M85, move about 35′ southeast to 7.5-magnitude Star *a*. Now move 40′ southeast to equally bright Star *b*. NGC 4450 is about 20′ southwest of Star *b*, and 4′ north-east of a 9.5-magnitude star.

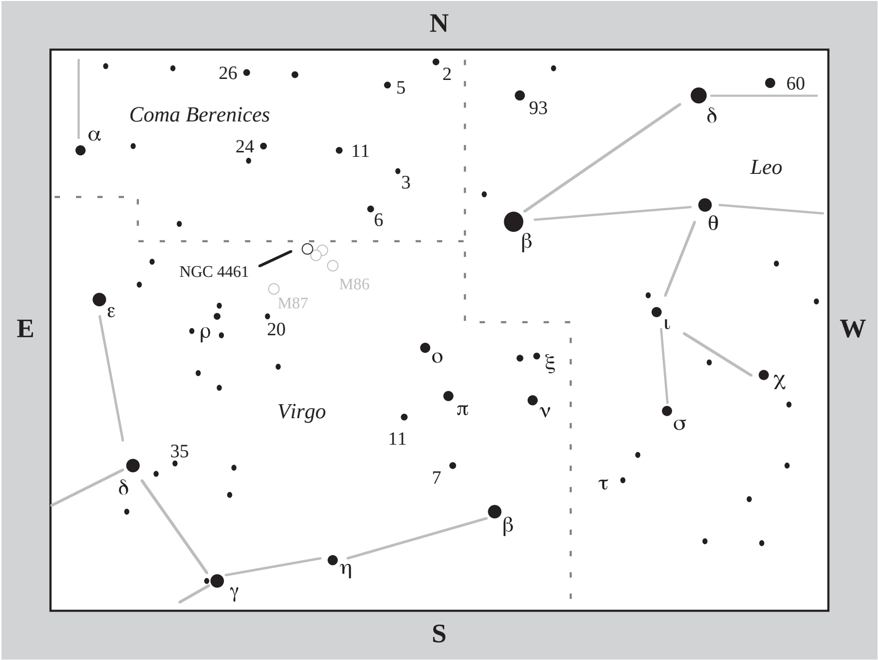
At 33× in the 5-inch, NGC 4450 is a bright and moderately condensed oval glow about 3′ in extent. Its major axis is oriented north to south, and it gradually, then suddenly, gets brighter toward the middle but not to a starlike core. It looks very much like a comet with a DC (degree of concentration) of 5 (on a scale of 0 to 9).

At 60×, the galaxy is very apparent. It has a bright circular core that now appears a little more concentrated toward the center to a fuzzy “star.” The core is surrounded by an oval of light with a soft, milky texture.

At 94×, the core is surrounded by an eye-shaped inner lens (a pseudo-ring) and a diffuse outer halo. The galaxy has a satiny sheen with hints of thin wisps of arms, but nothing definite. Larger telescopes may show the galaxy’s spiral structure.



Secret Deep 58
(NGC 4461)



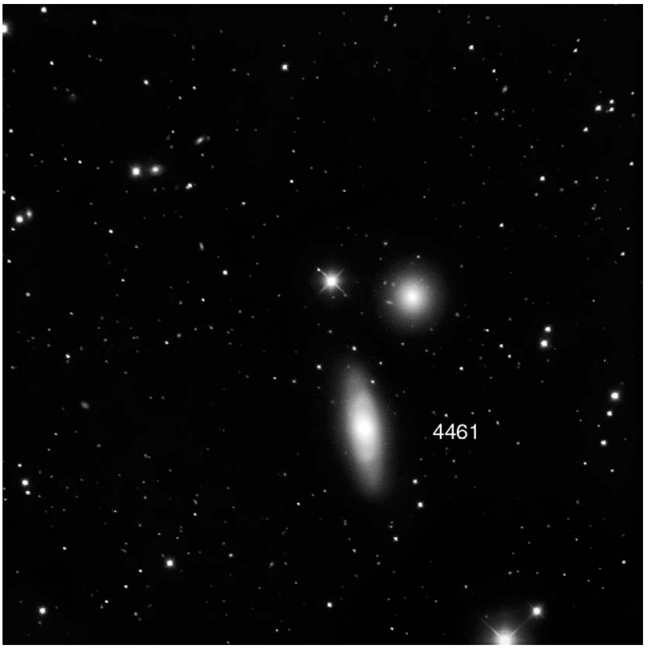
58

NGC 4461 = NGC 4443?
Type: Lenticular Galaxy (Sa0)
Con: Virgo

RA: 12^h 29.0^m
Dec: +13° 11′
Mag: 11.2
SB: 13.9 (Rating: 3.5)
Dim: 3.7′ × 1.4′
Dist: ~55 million l.y.
Disc: William Herschel, 1786

W. HERSCHEL: [Observed March 17, 1786] Considerably bright, extended south preceding north following, few stars in preceding, 1 in north, unconnected. (H II-122)

NGC: Pretty faint, small, round, bright in the middle, following of 2.



NGC 4461 IS THE SOUTHERNMOST OF two galaxies a little northeast of The Eyes NGC 4435 and 4438 (Secret Deep 55 and 56, respectively) – in Markarian's Chain, a great string of galaxies at the heart of the vast Virgo Cluster that arcs away from the extragalactic dynamic duo, M84 and M86; the other members of the Chain include Virgo galaxies NGC 4458, and NGC 4473 and 4477 (Secret Deep 60 and 61, respectively) just over the border in Coma Berenices.

Our target, NGC 4461, is one of those little wonders that possess a seemingly dim magnitude (11.2) – one that could turn people away from it – but is, in fact, owing to the galaxy's compactness, a reasonable target for small-telescope users under decent skies. And though its noninteracting companion NGC 4458 lies only 3.7′ to the north-northwest, I did not include that object in the Secret Deep list; I thought it might be just a little too faint (12.1) and a bit too small (1.5′) for anyone using a small telescope under any kind of light pollution, though I do encourage you to try to see, or image, it, but more on that later.

It's not surprising that NGC 4461 would be involved in a historical mystery, given the richness of galaxies around it. It turns out that NGC 4461 is probably the missing galaxy NGC 4443, of which there is nothing at the NGC position aside from a 19th or 20th magnitude object. Hal Corwin of the NGC/IC project proposed the link between NGC 4461 and 4443. The only evidence we have for this, Corwin says, comes from one observation in 1849, when Lord Rosse sketched 11 nebulae, the last of which is

NGC 4443. "The sketch is fairly crude and the distances between the objects do not correspond well to what we see on the sky," Corwin admits. Indeed, of the drawing, Lord Rosse himself says, "Found the objects as in sketch, positions being put down very rudely."

Nevertheless, Corwin was able to identify all the objects Rosse sketched with known NGC galaxies, except for the one Dreyer lists as NGC 4443. (The other galaxies in the sketch (listed from east to west across the center of the Virgo Cluster) are NGC 4305, 4306, 4374 (M84), 4387, 4388, 4406, 4402, 4425, 4435, and 4438.) Corwin notes, however, that, while there is nothing in the exact position of NGC 4443, NGC 4461 is not too far away. "It is certainly not a big stretch to this galaxy," Corwin says, and its description is a relative fit to the other galaxies. "Given the hurried nature of the observations, though," Corwin explains, "it may be that Lord Rosse thought NGC 4458 to be a star. It is considerably smaller and fainter than its companion, so this is a possibility. So, I'm going to take NGC 4443 to be a duplicate discovery of NGC 4461, but with some uncertainty."

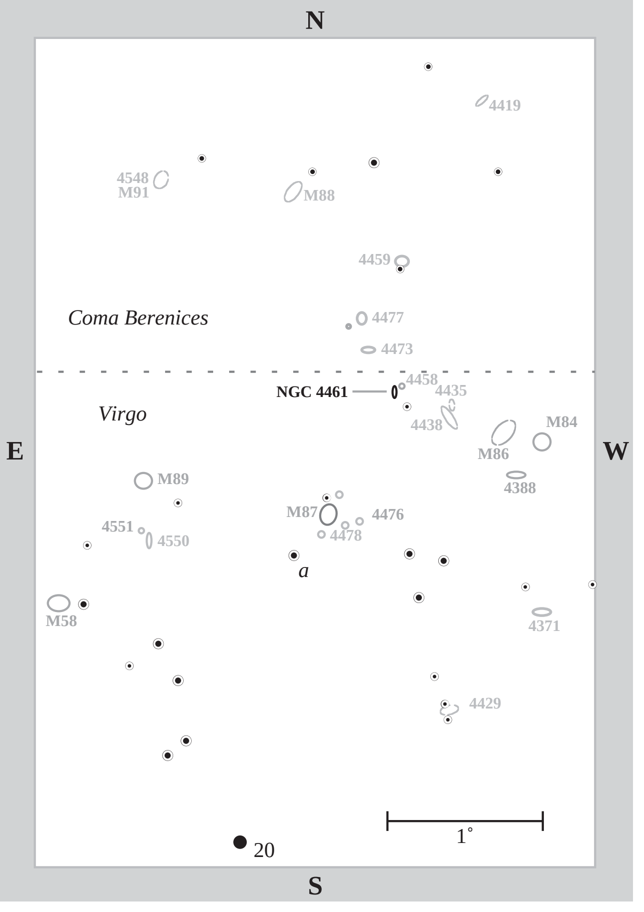
In support of Corwin's suggestion, I'd like to add that Lord Rosse also failed to record NGC 4413, a small (2.2′) 12th-magnitude galaxy, near NGC 4425 and 4388, which is of similar size and brightness to NGC 4458.

In images, NGC 4461 displays a very small, very bright, diffuse nucleus. There's a slight brightening at the edge of the lens and early thoughts had this classified as a barred lenticular galaxy. But now it is believed to be a lenticular galaxy with spiral structure that can be traced counterclockwise from the outside inward for each of the arms emerging from the bulge at about 1 o'clock and 7 o'clock positions.

In true physical extent, this Virgo Cluster member is about 60,000 light-years across, seen 20° from edge on, and shines with a total luminosity of about 8 billion Suns. In 2005, J. Christopher Mihos (Case Western Reserve University, Ohio) and colleagues presented deep optical imaging of the inner ~1.5° × 1.5° of the Virgo cluster to search for diffuse intracluster light (ICL). They found an intricate web of it with several long (>300,000 light-year) tidal streamers, as well as a myriad of smaller-scale tidal tails and bridges between the galaxies in the region – including one that stretches to NGC 4461 and NGC 4458. The researchers traced the very irregular, diffuse halo of M87 out to nearly 650,000 light-years. They also detected significant diffuse light around the M84/M86 pair. Several galaxies in the core are embedded in common envelopes, suggesting they are true physical subgroups.

Two long streamers can be seen extending to the northwest from M87: One projects through our target (NGC 4461) and NGC 4458 and extends beyond, toward a group of galaxies to the north. From the point at which it emerges from M87's stellar halo to where it fades into the background, the streamer has total length of 580,000 light-years and a characteristic width of 52,000 light-years. "Because NGC 4458 and NGC 4461 have a very high velocity relative to one another (Δv = 1,296 km/s)," the researchers say, "it is unlikely the streamer comes from any strong interaction between the pair; instead, stripping from one of the galaxies individually is more likely."

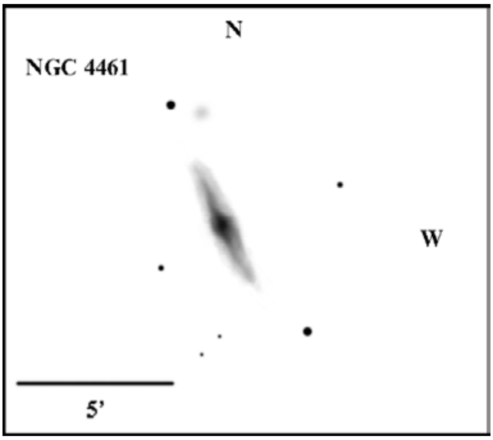
The ICL is not radially symmetric around M87, the nominal central galaxy of Virgo; much of the diffuse light is centered upon the M84/M86 complex. “Rather than the ICL growing simply via smooth accretion around a central galaxy,” the researchers conclude, “its distribution reflects the substructure inherent in the cluster.”



To find NGC 4461, it’s best to first locate 9th-magnitude M86. Start by using the chart on page 247 to locate 5th-magnitude Rho (ρ) Virginis, which is easy to identify, since it is the central bright star in a 30′-wide upside-down Y of stars (oriented north–south). About 2° to the west you’ll find 6.5-magnitude 20 Virginis. Now use the chart on this page to make a careful sweep 2° north and a tad west until you hit 8.5-magnitude M87, just 20′ northwest of an 8th-magnitude sun (*a*). If you’re careful, you shouldn’t miss M87, since it will be the first bright galaxy to enter the field in your sweep; in other words, there simply are no other objects to confuse it with in the sweep. M86 is the next brightest object you’ll encounter by moving your scope 1¼° to the northwest. The Eyes (NGC 4435 and 4438) lie only 20′ east, a tad north of M86. And NGC 4461 is only about 20′ northeast of NGC 4438.

At 33× in the 5-inch, NGC 4461 snaps into view (even with direct vision) as a 12th-magnitude “star” surrounded by a 2′-wide soft circular glow. With averted vision, the disk elongates, extending north–northeast-south-southwest. I could not see NGC 4458 at this power. Indeed, Luginbuhl and Skiff say that while NGC 4461 is “easily visible” in a 6-inch telescope, NGC 4458 is “difficult to view,” being “much fainter and smaller.”

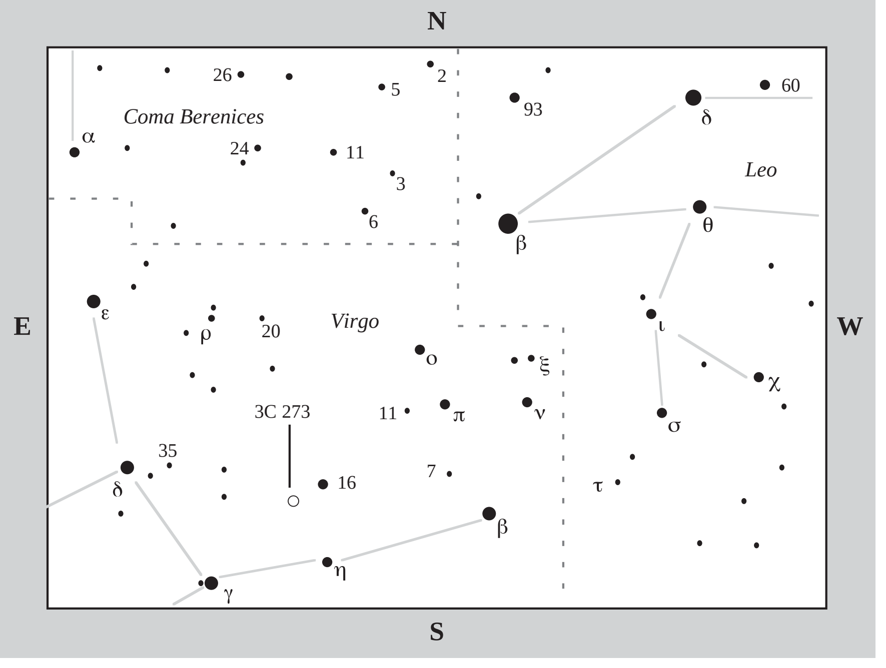
At 60× in the 50-inch, NGC 4461 is a very pretty “spindle,” showing a bright central glow with a stellar core and two elliptical extensions on either side of the major axis, looking like the ghost image of Saturn seen at low power when the rings are nearing



edge on. With care and patience, NGC 4458 did materialize as a very *tiny* puff of pale light. NGC 4461 is best at 94×, though, when the galaxy looks like a beautiful, though gently glowing lens of light with a smooth elliptical center. Curiously, the "starlike" core disappears at this magnification. NGC 4458 is also much easier to see at this power; its circular form becomes gradually brighter in the middle to a small round core.

59

Secret Deep 59
(3C 273)



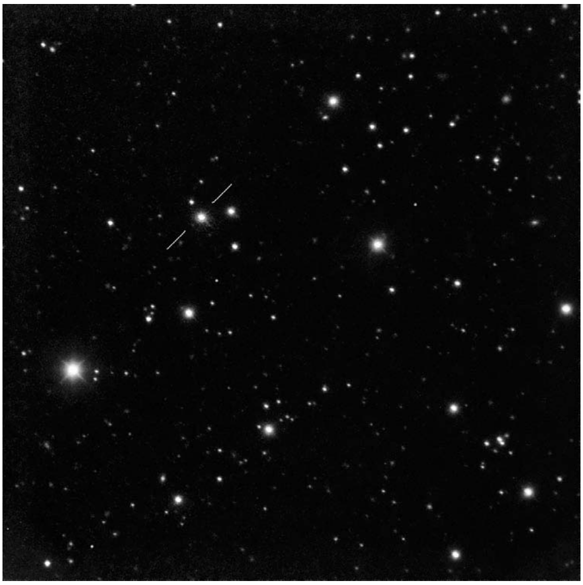
59

3C 273
Type: Quasi-Stellar Object (Quasar)
Con: Virgo

RA: 12^h 29.1^m
Dec: +02° 03.1′
Mag: 11.7–13.2
(Rating: 3.5–3.0)
Dim: –
Dist: ~2 billion l.y.
Disc: Listed as the 273rd object in the *Third Cambridge Catalogue of Radio Sources*, published in 1959

W. HERSCHEL: None.

NGC: None.



When you look through your telescope, have you ever wondered how far your eyes can penetrate space? In prior *Deep-Sky Companions* volumes, I've taken you as far as 300 million light-years distant, to the elliptical galaxy NGC 4889 in Coma Berenices (Caldwell 35). But you can see much further than that, even with a relatively small telescope. Our next Secret Deep target, 3C 273, is a quasar some 2 billion light-years distant.

Quasars are the highly energetic cores of remote active galaxies and the most luminous objects known in the universe. 3C 273 is the nearest and brightest of them. Most quasars lie much farther away (some 10 billion light-years distant). They're also relatively tiny objects (many are smaller than the size of our own Solar System), but they burn with a radiance that's brighter than hundreds of galaxies combined. So finding 3C 273 is a special treat; it's like bringing a slice of the early universe into our backyards.

It wasn't until the 1950s, when radio astronomy was first developed, that astronomers realized some extragalactic objects emit massive amounts of radio energy. These early discoveries were being made with military surplus radio equipment left over from the Second World War but converted to suit astronomical applications. To match any optical counterparts, radio astronomers used occultations of radio sources by the Moon to pinpoint their exact locations. Some were identified as galaxies, but others were point sources whose radio intensities varied and twinkled like stars, so they became known as radio stars.

One source, 3C 48 – the 48th object in the *Third Cambridge Catalogue of Radio Sources*, published in 1959 – was the first discovered to have a small radio diameter.

59

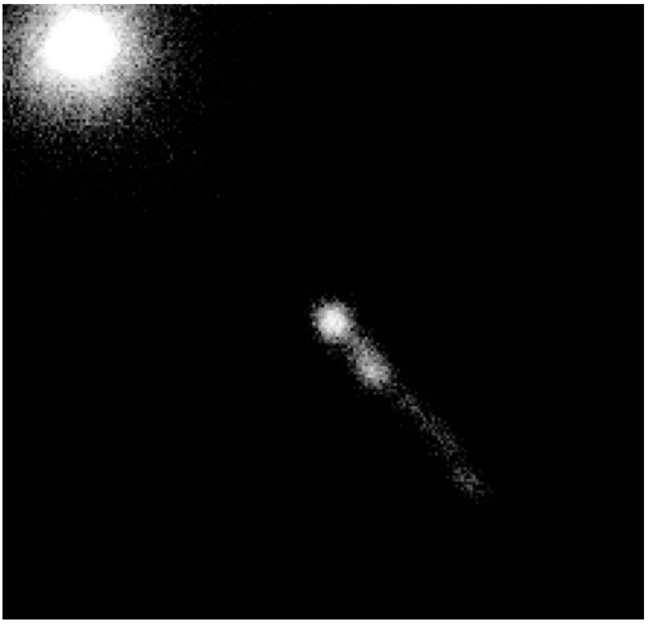
When Alan Sandage observed 3C 48 with the Palomar 200-inch telescope, he expected to see a dim extragalactic disk but instead found a peculiar, blue, point-like object that not only varied in brightness but had "the weirdest spectrum I'd ever seen," with emission lines unlike those from any known substance.

In late 1962, Maarten Schmidt (Caltech) noticed that 3C 273 – the 273rd object in the *Third Cambridge Catalogue of Radio Sources*[1] – showed a similar peculiar spectrum. By 1963, quasi-stellar radio sources were a hot topic of research. That year Schmidt realized that what made 3C 273's spectrum so peculiar is that its lines were redshifted by an amazing 16 percent. "I was stunned by this development," he said. "Stars of magnitude 13 are not supposed to show such large redshifts!" Schmidt immediately informed his colleague Jesse Greenstein of his findings. When Greenstein, who had been inspecting the spectrum of 3C 48, looked for this shift, he was amazed to find known lines redshifted by an even more amazing 37 percent, implying that this object was more than 3 billion light-years distant.

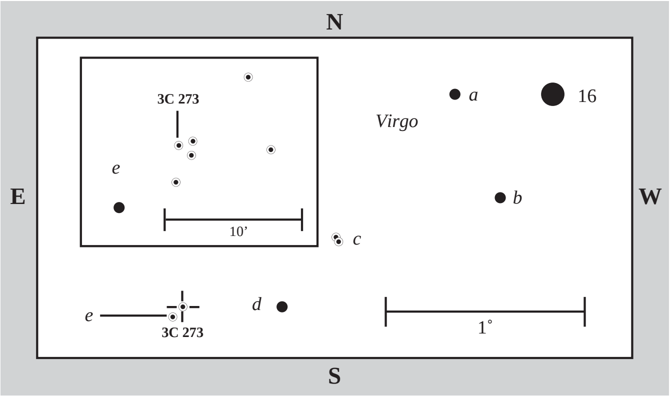
3C 273, then, became the first known *quasi-stellar radio source* – a name later shortened to *quasar*, though astrophysicists today more appropriately refer to them as QSOs, or quasi-stellar objects. But at least two decades passed before astronomers had observational evidence that they reside in galaxies.

Today we know that 3C 273 is at least about 2 billion light-years away, zipping away from us at one-tenth the speed of light, or about 48,000 km/sec. That we can see it blazing so brightly in our backyard telescopes is a direct result of this energetic object, with a mass of about 100 million Suns, radiating with a luminosity of about about 2 trillion Suns.

3C 273 was also one of the first extragalactic X-ray sources discovered in 1970. Large ground-based and space-based images have revealed a 200,000 light-year-long jet of charged particles moving at relativistic speeds emanating from 3C 273's active nucleus. Most optical, radio, and early X-ray observations revealed this powerful jet to consist of inconsistent,



1 The catalogue listed objects in order of right ascension, so, despite its high number, 3C 273 was among the first quasars to be identified.



"lumpy" clouds of gas. But a Chandra image released in 2000 reveals for the first time the presence of faint X-ray emitting material connecting the core of the quasar to the jet, which may reveal why matter is violently ejected from the quasar's core, then appears to suddenly slow down.

The energy emitted from the jet in 3C 273 probably comes from gas that falls toward a supermassive black hole at the center of the quasar, but is redirected by strong electromagnetic fields into a collimated jet. While the black hole itself is not observed directly, scientists can discern properties of the black hole by studying the jet. The formation of the jet from the matter that falls into the black hole is a process that remains poorly understood.

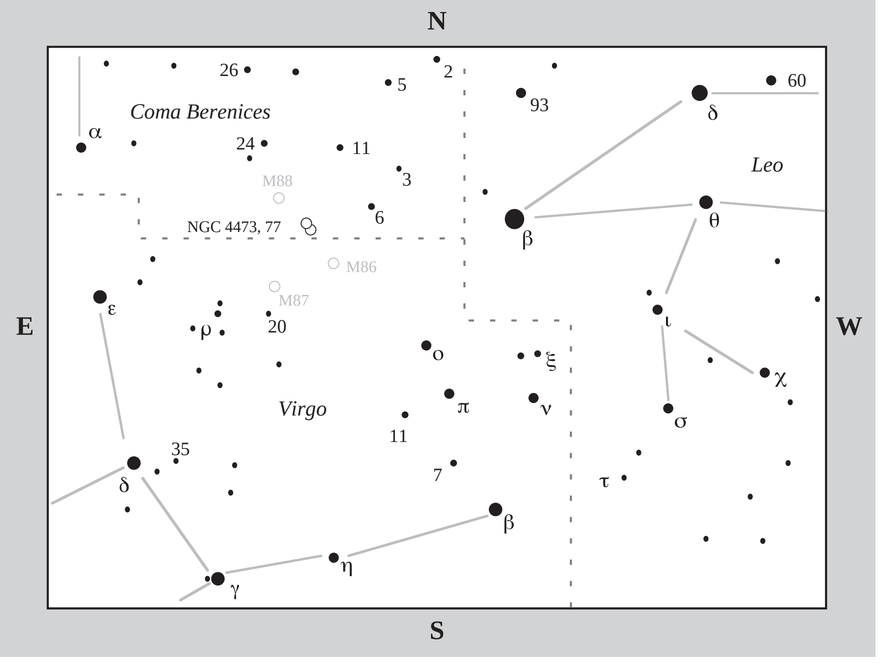
In 2003, Hubble Space Telescope images provided the clearest view yet in visible light of the nearby quasar 3C 273. Using the new camera's coronagraph to block the light from the brilliant central quasar, astronomers discovered that the quasar's host galaxy is significantly more complex than had been suggested in previous observations. Features in the surrounding galaxy that are normally drowned out by the quasar's glow now show up clearly. The image reveals a spiral plume wound around the quasar and a red dust lane. Material in the form of a clump and a blue arc are shown in the path of a jet that was blasted from the quasar.

To find this distant denizen of our universe, use the chart on page 252 to find 2.5-magnitude Gamma (γ) Virginis (Porrima), then 4th-magnitude Eta (η) Virginis about 1¼° to its west-northwest, and finally 5th-magnitude 16 Virginis 4° to its north. Center 16 Virginis in your telescope at low power, then switch to the chart on this page. From 16 Virginis, make a little 30′ hop east to 8th-magnitude Star *a*, then make a 35′ hop to south-southwest to magnitude 8.5 Star *b*. Now move nearly 55′ to the east-southeast to the tight 9th-magnitude double Star *c*, 30′ away from which, to the south-southeast, is the more obvious 7.5-magnitude Star *d*.

Now use the chart inset to pinpoint the exact location of 3C 273, which is about 55′ due east of Star *d*, and some 6′ northwest of 10th-magnitude Star *e*; 3C 273 forms the eastern apex of a near-equilateral triangle with two stars of near-equal magnitude. The quasar is easily identifiable because it has a close stellar neighbor immediately to its west-northwest. But beware. Don't expect 3C 273 to always be obvious. Although its peak magnitude is a reasonable 11.7, this quasi-stellar object can fade to magnitude 13.2, making it about 0.5 magnitude brighter than Pluto when it's brightest. Good luck.

60 & 61

Secret Deep 60 & 61
(NGC 4473 & 4477)



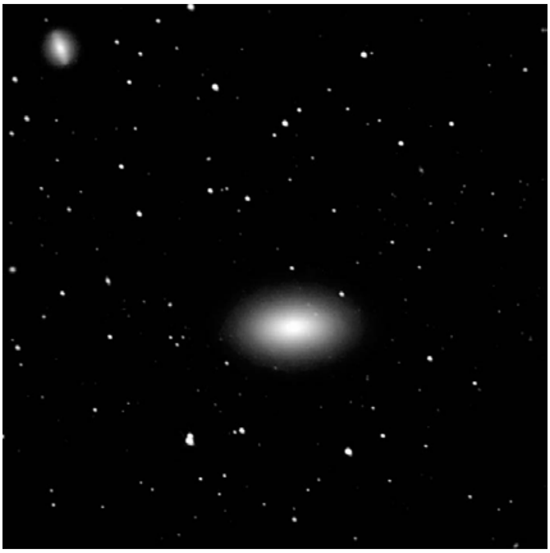
60

NGC 4473
Type: Elliptical Galaxy (E5)
Con: Coma Berenices

RA: 12^h 29.8^m
Dec: $+13°$ $26'$
Mag: 10.2
Dim: $3.7' \times 2.4'$
SB: 12.4 (Rating: 4)
Dist: ~52 million l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed April 8, 1784] Faint, round. (H II-114)

NGC: Pretty bright.



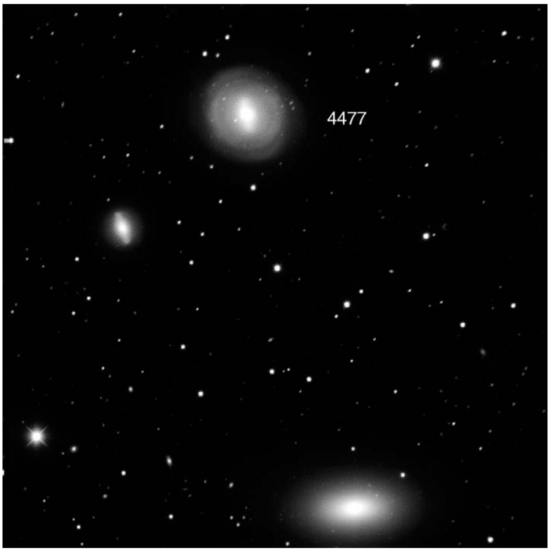
61

NGC 4477
Type: Barred Spiral Galaxy (SB(s)0)
Con: Coma Berenices

RA: 12^h 30.0^m
Dec: $+13°$ $38'$
Mag: 10.4
Dim: $3.9' \times 3.6'$
SB: 13.1 (Rating: 4)
Dist: ~55 million l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed April 8, 1784] Combined with H II-116 (NGC 4479). Two, both round.

NGC: Pretty bright, considerably large.



NGC 4473 AND 4477 ARE A BEAUTIFUL galaxy pair in Coma Berenices, just a whisper away from the Virgo Border. NGC 4473 is only 0.1 magnitude fainter than the more celebrated galaxies M91 and M98 in Coma Berenices, while NGC 4473 is only 0.3 magnitude dimmer. They mark the northeastern end of a great chain of galaxies (the Markarian Chain) that arcs away from the extragalactic dynamic duo, M84 and M86 in Virgo; the other members of the chain include Secret Deep members NGC 4435 and 4438 (numbers 55 and 56, respectively) and the dimmer duet: NGC 4458 (12.1 magnitude) and NGC 4461 (Secret Deep 58; 11.2 magnitude).

One has to wonder how Messier and Méchain could have overlooked NGC 4473 and 4477. Clearly, the "nebulous nature" of these objects must have been near the threshold of visibility in their modest instruments, especially during a sweep of the sky. Indeed, in Messier's description of M91 (magnitude 10.1; surface brightness of 13.3), he says it is one of 13 objects in the Virgo region that "can be seen only under extremely good skies, and close to meridian passage." It's possible Messier or Méchain might have seen the bright cores of NGC 4473 and 4477 but mistook them for stars. Then again, it's also possible that the greater brilliance of M84, M86, and M87 may have set a subconscious precedent for the intensity of objects in that specific region, thus drawing attention away from any fainter curiosities.

Though not physically related (they're not interacting), NGC 4473 and 4477 belong to the Virgo Cluster of galaxies – the nearest of the large galaxy clusters and the gravitational hub of the Local Supercluster, to which our own Milky Way Galaxy and Local Group belong. The Virgo Cluster is centered about 50 million light-years distant and contains some 2,500 galaxies, around 150 of which are large.

NGC 4477 is the larger of the two, being some 62,000 light-years in extent compared to NGC 4473's 56,000, thus, even though NGC 4473 is 3 million miles closer, it still appears a tad smaller than its extragalactic neighbor from our viewpoint. A giant elliptical, NGC 4473 is the more luminous of the two, shining with a brilliance of 19 billion Suns compared to 14 billion for NGC 4477; thus the slight brightness difference in favor of NGC 4473.

NGC 4473 is also unusual in that it has been slightly flattened into a disk, which we see inclined 56° from face on. In a 2003 *Astrophysical Journal*, Jason Pinkney (University of Michigan) and his colleagues explain how their high-resolution Hubble Space Telescope (HST) observations suggest that NGC 4473 is indeed a peculiarity, probably originating from a merger of two galactic nuclei with black holes that coalesced.

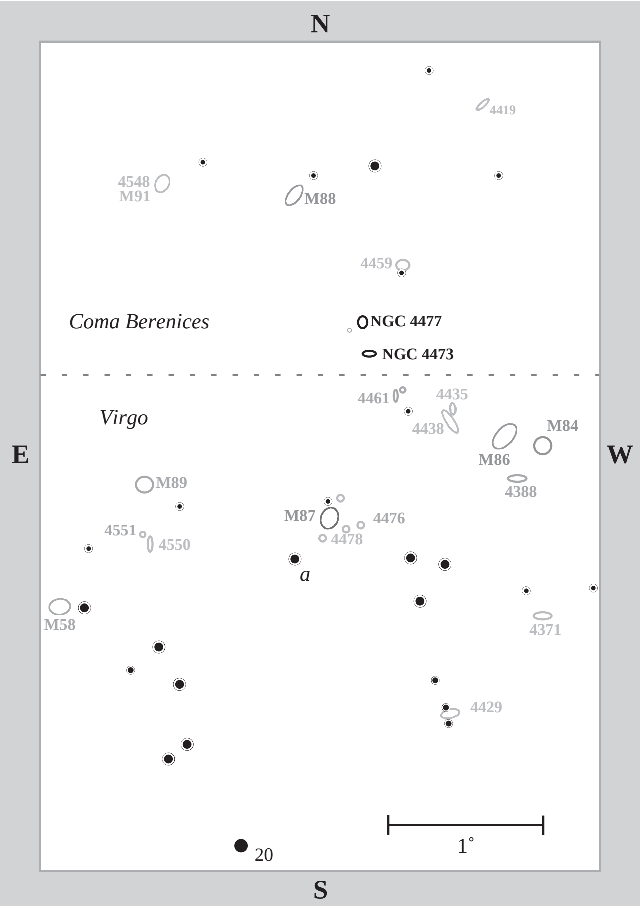
Although the HST observations found no obvious evidence for a recent merger – no counter-rotating stellar or gas system, no erratic dust, and no multiple nuclei – the authors still believe it's a good candidate to explain the galaxy's artificially flattened core and account for its peculiar surface-brightness profile. A merger, they say, could deposit dust that could mask the central nuclei from view. The resulting inflow of gas could also form a stellar disk or torus that, in turn, makes detection of the nuclei more difficult. HST found some evidence for each of these scenarios.

Furthermore, by using HST and ground-based spectroscopic data to measure the orbital motions of stars near NGC 4473's core, Douglas Richstone (University of Michigan) and his colleagues concluded that the stars orbit a supermassive black hole of roughly 50 million to 100 million solar masses. Since radiation and high-energy particles released by the formation and growth of black holes are the dominant sources of heat and kinetic energy for star-forming gas in protogalaxies, such as NGC 4473, it's possible that they are linked to the formation and evolution of galaxies.

As evidence, Richstone notes that all, or nearly all, galaxies with spheroidal distributions of stars (including bulges in spirals) appear to have massive black holes. And the mass of these objects seems to correlate with the mass of the central part of the host galaxy. But the connection between the massive black hole and the galaxy also poses the "chicken-and-egg" dilemma of which came first. If the supermassive black hole at the heart of NGC 4473 formed first, it could have acted as a gravitational "seed" to attract the gas and dust that give birth to a galaxy's stars. Richstone says we may already see evidence of this – in a more universal sense – in quasars, which are believed to develop well before most star formation in galaxies. "The massive black holes now seen in centers of galaxies are relics of these quasars," Richstone explained in a 2000 University of Michigan press release, "so these black holes must have been present at the height of the quasar epoch when the universe was about one billion years old."

NGC 4477's structure is equally interesting, being an early-type lenticular galaxy with a smooth oval disk (inclined 26° from face-on) and bright starlike nucleus nestled inside a well-defined bar that terminates well inside the disk. The surrounding lens has a sharp edge (reminiscent of a ring structure) bracketed by two external spiral arms. High-resolution images also reveal weak and ill-defined spiral structure threading the disk. In this way, NGC 4477 resembles the mixed lenticular galaxy NGC 2655 (Hidden Treasure 48) in Camelopardalis.

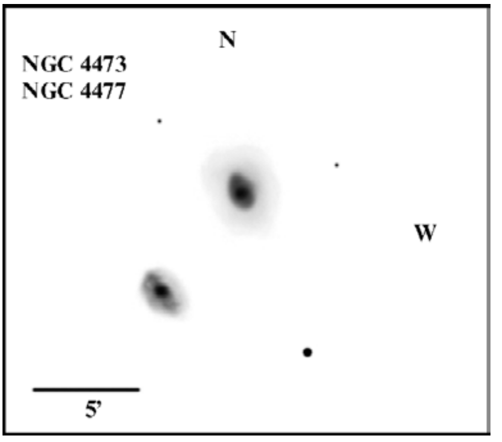
To find the pair, start by using the star chart on page 256 to find 5th-magnitude Rho (ρ) Virginis, which is easy to identify,



since it is the central bright star in a 30′-wide upside-down Y of stars (oriented north–south). About 2° to the west you'll find 6.5-magnitude 20 Virginis. Now make a careful sweep 2° north and a tad west until you hit 8.5-magnitude M87, just 20′ northwest of an 8th-magnitude sun. If you're careful, you shouldn't miss M87, since it will be the first bright galaxy to enter the field in your sweep; in other words, there simply are no other objects to confuse it with in the sweep. M86 is the next brightest object you'll encounter by moving your scope 1¼° to the northwest. M86 is partnered to the west by slightly fainter M84. NGC 4435 and NGC 4438 (Secret Deep 55 and 56, respectively) lie only about 20′ east-northeast of M86. NGC 4473 is 40′ northeast of NGC 4438 and just 10′ west-southwest of a 10th-magnitude star. NGC 4477 is only about 12′ north and slightly east of NGC 4473.

At 33× in the 5-inch, both NGC 4473 and 4477 appear as two circular hazes of unequal size; NGC 4473 is about 1′ across and NGC 4477 is about twice as large. Both disks are uniformly bright and have tack-sharp stellar cores. Comparing the two with time and averted vision, though, NGC 4473 becomes more lens shaped.

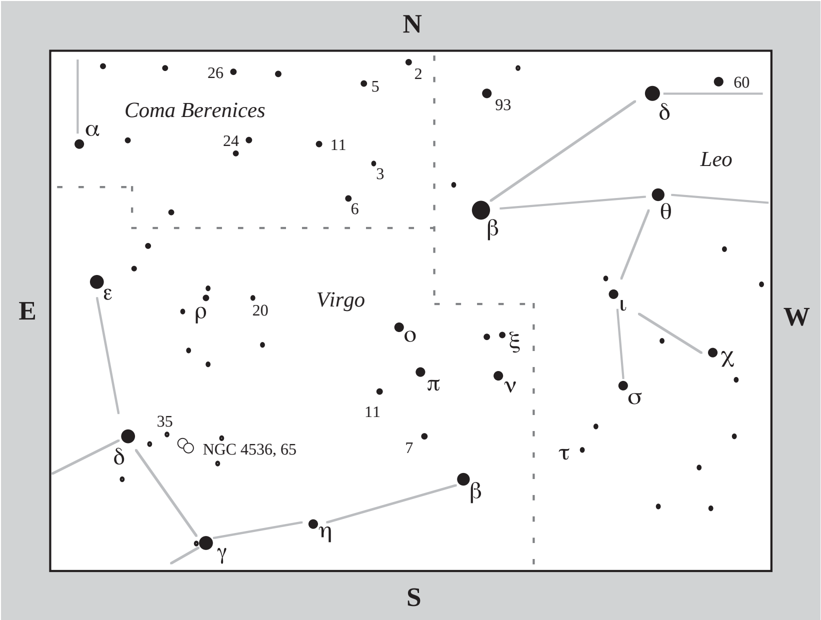
At 60×, NGC 4473's core appears round with a tiny stellar nucleus. This round core is surrounded by a slightly less intense lens



of light that seems to taper along its major axis. These features are embedded in a larger ellipse of light that appears layered at 94×.

NGC 4477, on the other hand, appears more textured at 60× than NGC 4473. With averted vision, the galaxy has a bright nucleus in an oval core, which is surrounded by a mottled and slightly irregular envelope. With averted vision and 94×, the rim of NGC 4477's halo forms a weak ring that's slightly out of round. The ring's perimeter is dappled with dim light, while the interior halo seems layered like an onion, though this is just a visual suggestion. Looking at these galaxies is like looking into a fog and trying to make sense of the ethereal vapors.

Secret Deep 62 & 63
(NGC 4636 & 4665)



62 & 63

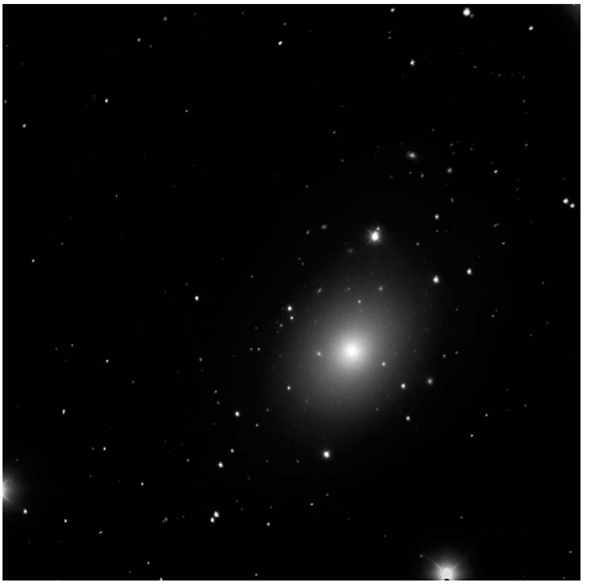
62

NGC 4636
Type: Elliptical Galaxy (E0-1)
Con: Virgo

RA: $12^h\ 42.8^m$
Dec: $+02°\ 41'$
Mag: 9.5
SB: 13.3 (Rating: 4)
Dim: $7.1' \times 5.2'$
Dist: ~52 million l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed February 23, 1784] Pretty bright, pretty large, irregularly faint, resolvable. (H II-38)

NGC: Bright, large, irregularly round, very gradually very much brighter in the middle, resolvable (mottled, *not* resolved).



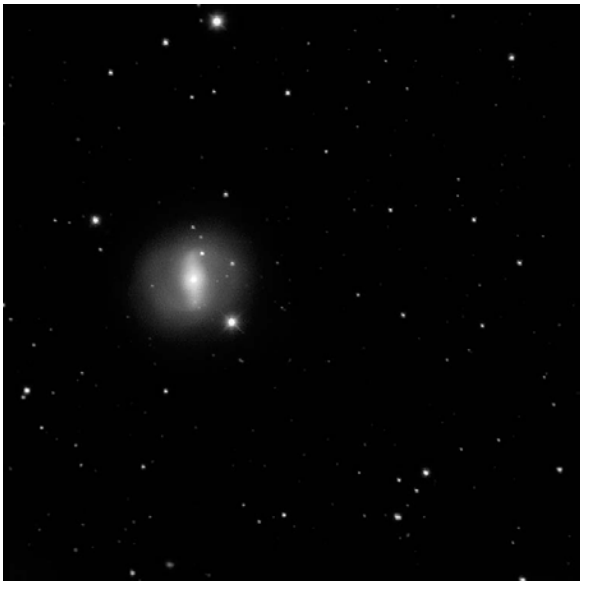
63

NGC 4665 = NGC 4664 = [NGC 4624 = NGC 4636]
Type: Barred Lenticular Galaxy (SB(s)0/a)
Con: Virgo

RA: $12^h\ 45.1^m$
Dec: $+03°\ 03'$
Mag: 10.5
SB: 13.4 (Rating: 3.5)
Dim: $4.1' \times 4.1'$
Dist: ~58 million l.y.
Disc: William Herschel, 1786

W. HERSCHEL: [Observed April 30, 1786] Considerably bright, pretty large, irregularly round, gradually much brighter in the middle. (H I-142)

NGC: Bright, pretty large, irregularly round, much brighter in the middle, magnitude 10 star south preceding.



62 & 63

NGC 4636 AND NGC 4665 ARE A VERY interesting, though wide (40′ separation) pair of galaxies roughly 3° west-southwest of 3rd-magnitude Delta (δ) Virginis – one of the heaven's "golden" stars. Not only is Delta the very navel of Virgo the Maiden, but its golden color seems coincidentally appropriate since Virgo is sometimes identified with Ceres – goddess of the fields and agricultural activities, and nurturer of crops.

Our targets, NGC 4636 and NGC 4665, are connected with an historical mystery concerning the identities of NGC 4664 and NGC 4624, both of which do not exist. Hal Corwin at the NGC/IC Project (http://www.ngcicproject.org) notes that NGC 4664 is one of William Herschel's early discoveries with a large error in the position. "There is nothing at William Herschel's given position," Corwin says, noting that it appears to be a simple digit error (10′ error in declination) in his recording or reduction. "Dreyer correctly convinced himself that it explains the missing NGC 4664 as a prediscovery observation of NGC 4665. The star 4.8 seconds preceding (mentioned in both of William Herschel's observations, according to Dreyer) is the clincher here."

As for the missing NGC 4624, which Herschel's son John discovered, Corwin suggests that owing to an error in right ascension, it is also most likely NGC 4665, which John Herschel described as "bright and pretty large," in two other sweeps. "This," Corwin says, "and the appearance of the bright bar of the galaxy, matches his terse description for NGC 4624, 'bright, extended.' In addition, his declination is correct for all three observations."

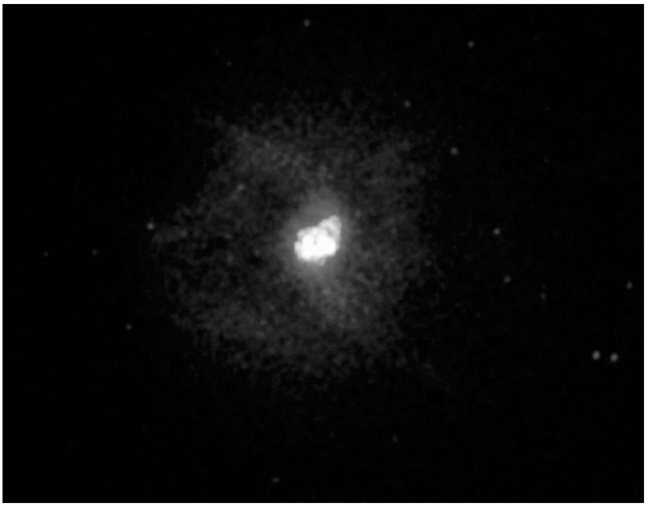
How does NGC 4636 come into play? Well, Corwin says that during the same sweep John Herschel made for NGC 4624, he made a 1° error in the polar distance for NGC 4636, "an error that he himself suggested, and that Dreyer finally rectified for the NGC. Thus, NGC 4624 cannot be NGC 4636 as suggested by Reinmuth[1] and adopted by RNGC." So, NGC 4624 is the same object as NGC 4665 but is not NGC 4636.

Any low-power eyepiece should fit the two galaxies in the same field of view. But each deserves individual attention. Let's start with NGC 4636, the brighter of the two galaxies by a full magnitude and also the one studied more copiously by astrophysicists.

NGC 4636 is a nearby, gas-rich elliptical galaxy 52 million light-years distant in the outskirts of the Virgo Cluster. The galaxy is 100,000 light-years in extent, and shines with a luminosity of 30 billion Suns. It's receding from us at 938 km/sec. In short exposures, the galaxy appears circular, but deep images show its faint elliptical envelope at a position angle of 330°. The galaxy not only also has an unusual gaseous ring extending asymmetrically around the galaxy's nucleus, but also irregular dust lanes, a large and luminous X-ray halo with a central hole, numerous globular star clusters, and a radio jet along the galaxy's minor axis with a strong ridge of emission lying on either side of the nucleus; the ridge shows an S-shaped bend about 16 light-years from the nucleus.

In 2009, NASA released an amazing Chandra X-ray image of NGC 4636

[1] His and Dorothy Carlson's work at Mount Wilson Observatory in 1940 led to major corrections of NGC/IC. See www.klima-luft.de/steinicke/Deep-Sky/deep-sky_e.htm.



showing extraordinary detail in the galaxy, including spectacular symmetric arm-like arcs of hot gas extending 25,000 light-years into a huge cloud of multimillion-degree-Celsius gas that envelops the galaxy. At a temperature of 10 million degrees, the arms are 30 percent hotter than the surrounding gas cloud. Each of these features defines the rim of an ellipsoidal bubble. Another bubble-like feature was found south of the northeastern arc. The temperature jump together with the symmetry and scale of the arms indicate that the arms are the leading edge of a galaxy-sized shock wave that is racing outward from the center of the galaxy at 700 km/sec. An explosion with an energy equivalent to several hundred thousand supernovas would be required to produce this effect.

It's believed that the bubbles were produced by shocks, probably driven by energy deposited off-center by jets. Indeed, the, radio jets extend toward the bubbles from a weak X-ray and radio source, which are most likely the signs of active galactic nuclei activity that was more intense in the past. Indeed, this eruption could be the latest episode in a feedback cycle of violence that keeps the galaxy in a state of turmoil. The cycle starts when a hot gas cloud that envelops the stars in the galaxy cools and falls inward toward a central, massive black hole. The feeding of the black hole by the infalling gas leads to an explosion that heats the hot gaseous envelope, which then cools over a period of several million years to begin the cycle anew.

Although NGC 4665 is dimmer than NGC 4636 by a full magnitude, it's remarkably obvious, because it packs a lot of its light into a small area of sky (~4′). The galaxy's bar is its most redeeming and interesting quality – at least in photographs. If we accept its distance of 58 million light-years, this barred lenticular system spans some 70,000 light-years of space and shines with a luminosity of 9 billion Suns. (Both NGC 4636 and NGC 4665 lie in the southern extension of the great Virgo Cloud of galaxies, where we see them receding from us at 938 and 785 km/sec, respectively.)

In deep images, NGC 4665 displays a right round nucleus embedded in a luminous, slightly elliptical bulge, threaded by a prominent high-surface-brightness bar. Two faint, diffuse spiral arms emerge from the ends of the bar and form a complete pseudo-ring. There are also clear interarm features. The faint outermost regions of the disk are clearly elliptical, at a position angle ~45° away from that of the bar.

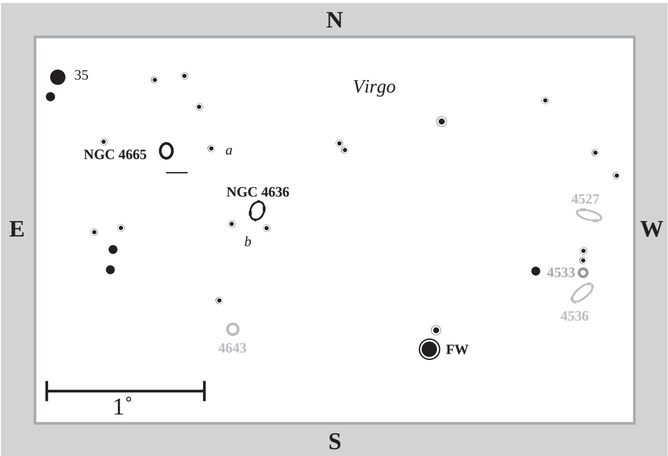
In a 2007 paper, Xiaolei Zhang (formerly of the U.S. Naval Research Laboratory) and

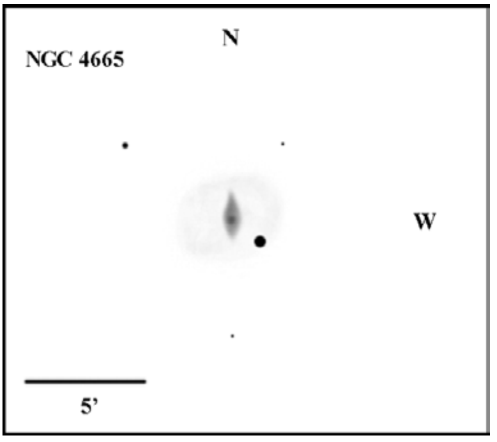
Ron Buta (University of Alabama) used infrared light to infer characteristics of the gravitational field in NGC 4665, and concluded that NGC 4665's well-defined bar pattern may extend beyond its own corotation radius (where the bar density wave pattern and the underlying differentially rotating disk matter rotate at the same angular speed), a phenomenon which challenges the conventional view that stellar orbits in galaxies cannot support a bar outside their corotation. "Since it is by now well-established that a spiral pattern can extend beyond its co-rotation radius," the researchers say, "and since bars are density wave patterns just like the spirals apart from the fact that they appear at the central regions of galaxies, one naturally suspects that a bar might be able to extend beyond its own corotation radius as well."

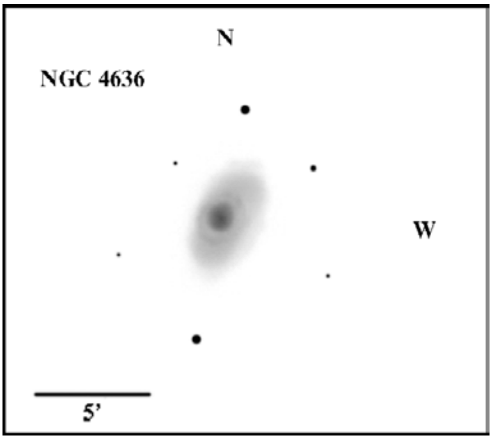
Nevertheless, in a private 2010 communication, Buta stresses that the issue of bars extending beyond their corotations is very contentious. "The argument in the case of NGC 4665 is that there must be some wave material outside the bar's corotation to receive the emitted energy and angular momentum from inside corotation. Thus, some part of the bar itself could lie outside corotation to serve this purpose, since there is very little other structure outside the bar ends, only a very weak spiral."

To find these galaxies, use the chart on page 261 to locate Delta Virginis, which is about 6° northeast of Gamma Virginis. But be sure to take some time to appreciate Delta – one of the sky's few naked-eye M-class red giants. Seen at a distance of 202 light-years, golden Delta has a pretty, reddish, 11th-magnitude K-type dwarf companion 80′ distant. The nineteenth-century Italian astronomer Angelo Secchi called Delta Virginis *bellissima*, owing to its "most beautiful" banded spectrum. When spied through a telescope, Delta has a rich golden yellow hue, which, when seen together with its more ruddy companion, could take on a slight shade of green (the complementary color). Stellar astronomer James Kaler tells us, if the K-type dwarf is a true companion to Delta (and that's uncertain since it lies about 5,000 times the distance from the Earth to the Sun from Delta), it would take more than 200,000 years to complete an orbit. If you were transported to a planet orbiting Delta, Kaler notes, its companion would shine twice as brightly as Venus does in our skies and appear four times brighter than our full Moon.

From Delta, use binoculars to find 6.5-magnitude 35 Virginis, a little less than 2° to the west and slightly north. Center 35 in your telescope at low power, then switch to the chart on this page. NGC 4665 is about







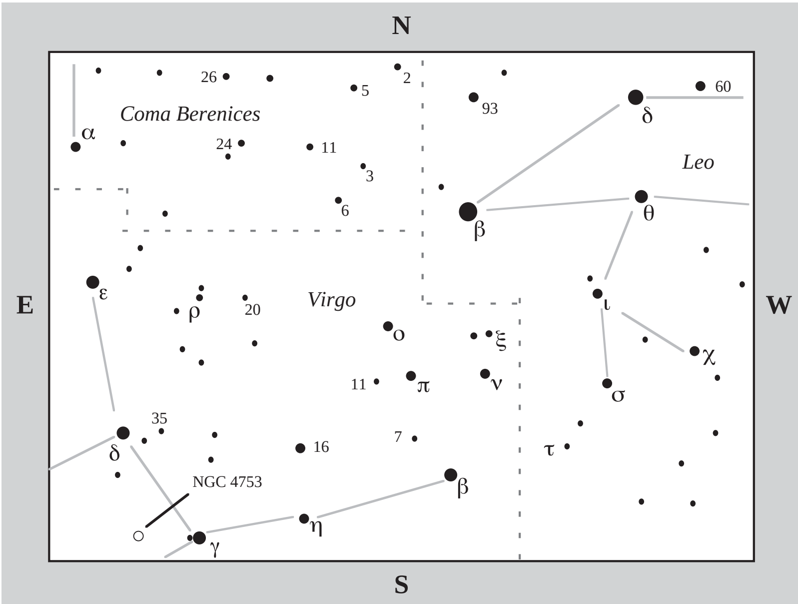
50′ southwest of 35 Virginis, about 18′ east of 9th-magnitude Star *a* and 1.5′ northeast of an 11th-magnitude star.

When you look for NGC 4665, think "small" and "fuzzy pair" (like M40), in your search – that'll be the galaxy and the 11th-magnitude star nearly kissing, which together will look like a larger extended object oriented northeast to southwest. At 33×, NGC 4665 can be a complicated view. Depending on how dark your sky is, the galaxy may at first appear simply as a well-condensed, 2′-wide circular glow. But with averted vision and time, I saw one bright north–south oriented lens nested in an equally long, though *much* fainter (extremely hyperfine, almost imaginary), east–west extended halo; the true halo in deep images is actually oriented northwest–southeast, but what I saw could be hints of the pseudo-ring formed by the arms looping out from the (unseen) bar.

At 60×, the galaxy displays a tight core that seems oddly warped toward the companion star (yet another clearly fascinating illusion; the star just seems to suck the light of the galaxy toward it!). With time I could resolve a diffuse starlike knot at the center of the north–south trending lens of light, appearing as a very bright patch with an intense core that intensifies inward to a starlike center. The fainter halo diminishes with higher powers and is best seen in my scope at 33×. The galaxy definitely appears as a spindle in the north–south direction, though I could not resolve the bars from the core. Larger scopes may be able to do so. Good luck.

NGC 4636 lies 40′ further to the southwest. At 33×, it's a big amorphous glow, like a comet just beginning to shine. It gradually brightens toward a dim circular core with no nucleus. With averted vision, the 2′-wide disk appears quite elongated, oriented northwest–southeast, like an egg. At 60×, a tiny drop of light appears at the core with averted vision, even then it's somewhat difficult to detect. The galaxy takes power well and at 94× all the features thus described become more apparent: a drop of light at the nuclear region nested in a circular core that elongates slightly with averted vision, surrounded by a larger ellipse of light. The galaxy is nicely framed inside a triangle of roughly equal dim stars.

Secret Deep 64
(NGC 4753)



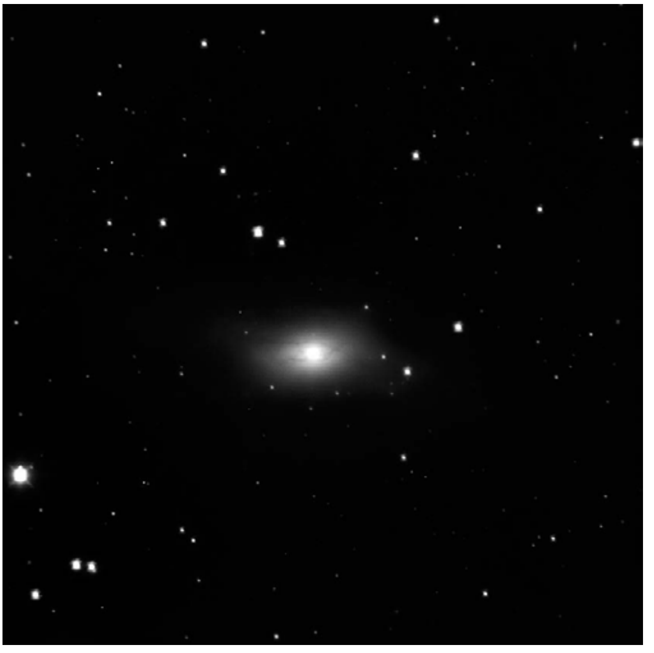
64

Dust Devil
NGC 4753
Type: Irregular/Lenticular Galaxy (I/S0 peculiar)
Con: Virgo

RA: 12^h 52.4^m
Dec: $-01°$ 12′
Mag: 9.9
SB: 12.2 (Rating: 4)
Dim: 4.1′ × 2.3′
Dist: ~64 million l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed February 22, 1784] Considerably bright, very large, irregularly faint, very gradually brighter in the middle. (H I-16)

NGC: Considerably bright, large, very little extended, very gradually a little brighter in the middle.



NGC 4753 IS A REASONABLY BRIGHT and obvious, though peculiar, galaxy 2¾° east-northeast of Gamma (γ) Virginis – in the southern boundary of the Virgo cluster. The galaxy is peculiar because its classification is a matter of great curiosity. Early plates revealed its nuclear region crossed by complex dark lanes, which appear to be on the near side below the nucleus, and on the far side above it. One interpretation of this form was that of the near end-on view along the bar and lens of an armless barred lenticular galaxy (like NGC 5195 (Secret Deep 67)), though it could also be an irregular system – one with poorly defined structure, which falls outside the categories of disk or elliptical galaxies. It may, in fact, be similar to the way in which American astronomer Edwin Hubble (1889–1953), whose observations proved that galaxies are "island universes," classified NGC 4753 as a barless peculiar lenticular (S0 pec) because, if the many irregular filamentary dark lanes that partly hide the galaxy's small but extremely bright nucleus were removed, the galaxy would resemble an S01-type.

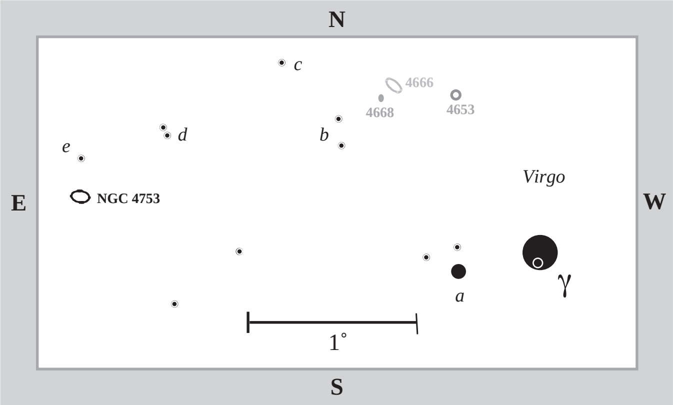
A decade later Gerard de Vaucouleurs classified it as an I0 galaxy, but the consensus today is that NGC 4753 is probably outside the classification sequence. In *The Carnegie Atlas of Galaxies* (Carnegie Institution of Washington, vol. 1, 1994) Alan Sandage and J. Bedke say, "If we force it into the classification we do so on the same basis used by Hubble. If the absorption lanes were removed, the underlying luminosity distribution would approximate an S0 form."

Modern images show the galaxy, which spans nearly 80,000 light-years across in true physical extent, in much finer detail. The disk, which is strongly twisted, has complex dust lanes that are very thin, delicate, and continuous over traceable long arcs. Although, at a glance, they appear to show no rotational symmetry (as is common to dust lanes in the disks of spirals), Thomas Y. Steiman-Cameron (NASA/Ames Research Center, California) and colleagues argue that the twisted dust can be explained by an accretion event. As described in a 1992 *Astronomical Journal* (vol. 104, p. 1339), they find the galaxy's twisted disk inclined by 15° relative to NGC 4753's equatorial plane.

The twisted disk, they propose, is a product of an accretion event and the dust from the merger has been wrapped several times around NGC 4753's center. "This demystifies what previously looked like a complicated galaxy," the researchers say, "and shows that yet another apparently peculiar object can be understood as an otherwise normal galaxy which has experienced an accretion event."

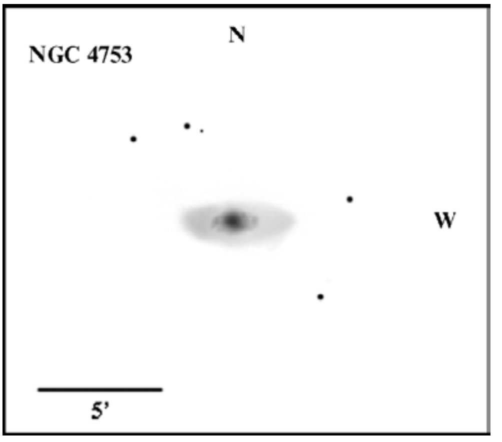
In a 1999 issue of the *Astronomical Journal* (vol. 118, p. 785), Gulab Chand Dewangan (Tata Institute of Fundamental Research, Mumbai, India) and colleagues say that optical observations made with the Vainu Bappu Telescope and far-infrared observations with the Infrared Astronomical Satellite (IRAS) suggest a dust mass of 150,000–350,000 Suns, respectively. Since the mass loss from red giants in this roughly 1- to 10-billion-year-old galaxy is expected to be about 1800 Suns (with a factor of 2 to 3 uncertainty), the researchers argue that the origin of NGC 4753's interstellar dust could be due to either galaxy–galaxy interaction (or a merger) or an internal process. A substantial amount of dust within NGC 4753, they add, exists in the form of cirrus, which are sufficiently dense so that they are not destroyed by ionizing radiation or by supernova-driven blast waves.

To find this dusty wonder, which is whizzing away from us at 1,239 km/sec, use the chart on page 267 to to locate Gamma (γ) Virginis. Center the star in your telescope at low power, then switch to the chart on this page. From Gamma Virginis, move 30′ east-southeast to 6th-magnitude Star *a*. Next, make a gentle 1° sweep to the northeast, to a pair of 8th-magnitude stars (*b*). Now move 30′ northeast to 8th-magnitude Star *c*, then drop 45′ southeast to 8.5-magnitude Star *d*, which has a 10.5-magnitude companion about 4′ to the northeast. A short hop 25′ further to the southeast will bring you to 7.5-magnitude Star *e*. NGC 4753 is only about 15′ south-southeast of Star *e*.

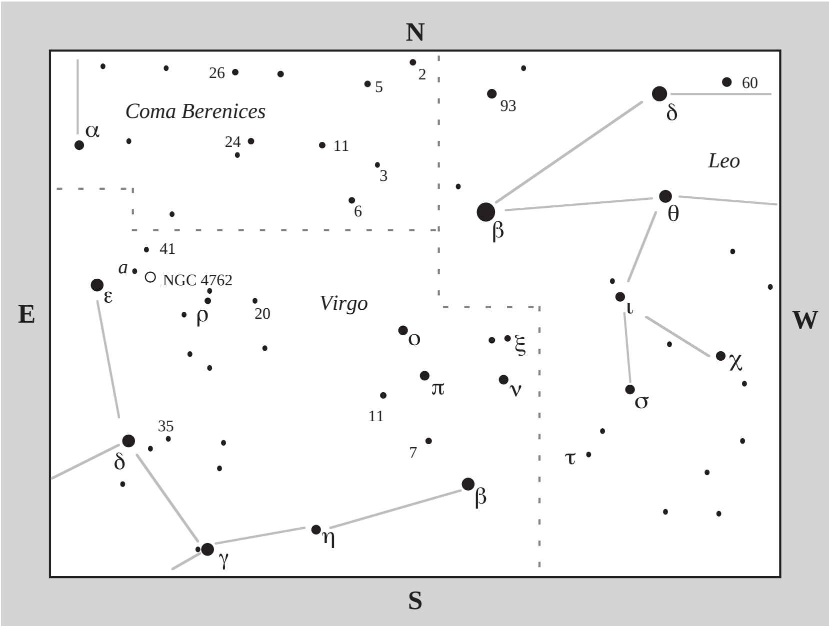


At 23× in the 4-inch, NGC 4753 is a bright, multi-layered oval glow about 3′ wide. With averted vision the nuclear region pops into view, appearing extremely bright – a small starlike bead nestled in a faint lens. With a glance, the galaxy looks circular, but averted vision quickly rectifies that view, revealing it as a nice ellipse with a circular core. The galaxy simply becomes suddenly much brighter in the middle. At 60×, NGC 4753 displays what appears to be a sharply defined nuclear region, consisting of a starlike nucleus in a ring of light with a bright outer boundary. The disk beyond is a dappled tapestry of milky light, with bright patches midway along the major axis aligned east–west The ansae seem somewhat ill-defined.

The galaxy is more simple at 94×: A tiny circle of light surrounds a starlike nucleus that's nested in a small lens of light and collared by a larger dappled elliptical disk. Although I could not trace the dust veins that appear in images of the galaxy, I "felt" their presence in the mysterious dappled tapestry before me. The galaxy has been host to two supernovae: SN 1965i and SN1983g.



Secret Deep 65
(NGC 4762)



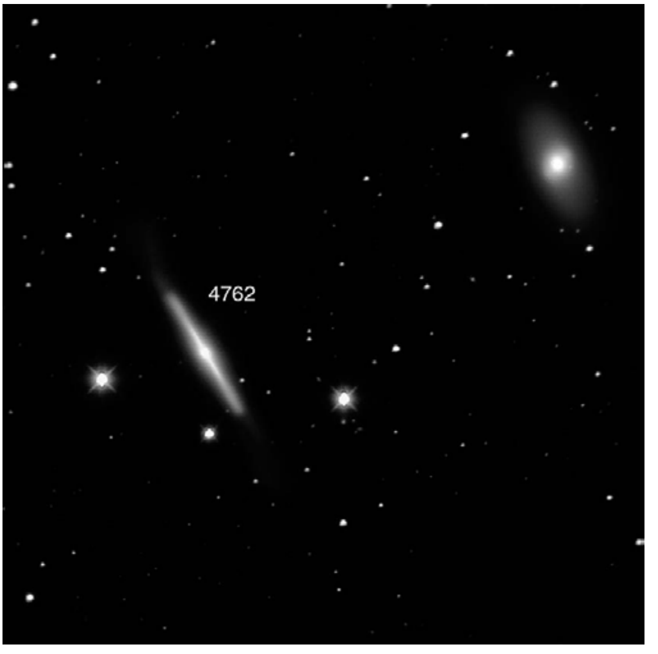
65

Paper-Kite Galaxy
NGC 4762
Type: Lenticular Galaxy (S0 special)
Con: Virgo

RA: 12^h 52.9^m
Dec: $+11°$ 04′
Mag: 10.3
SB: 13.4 (Rating: 3.5)
Dim: 9.1′ × 2.2′
Dist: ~65 million l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed March 15, 1784; combined with H II-74 (NGC 4754)] Two, nearby and parallel, the preceding pretty bright, nearly round. The following [NGC 4762] pretty bright, very much extended, 8 or 10′ in diameter. (H II-75)

NGC: Pretty bright, very much extended in position angle 31°, 3 bright stars south, following of two.



NGC 4762 IS A SMALL, STUNNINGLY thin, yet reasonably bright, edge-on galaxy about 2° west and slightly north of 3rd-magnitude Epsilon (ε) Virginis. It forms a noninteracting pair with less-exciting (and dimmer) NGC 4754, though the two can be quite stunning in large telescopes, especially from a dark sky. But our target is a special one. It is, in fact, the flattest galaxy known in the heavens.

We see NGC 4762 perfectly edge on. And interestingly, despite its intense needle-like appearance in images, Admiral William Henry Smyth saw more to it than that. “This is a fine object,” he says, “trending south preceding and north following, nearly in the vertical, but from its superior brightness in the south, or upper end, it rises while gazing from the dumpy egg-shape to that of a paper kite: over it is an arch formed by three telescopic stars the symmetry of which is so peculiar as to add to that appearance.”

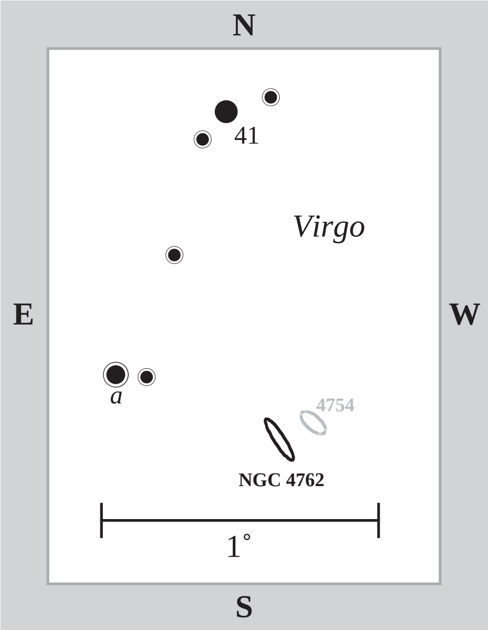
Although it’s hard to tell how much of what Smyth saw was indeed mental suggestion, deep images of the galaxy today do show long warped extensions to the main disk – but they appear of near-equal brightness and do not favor a brighter southern portion. Yet, I like Smyth’s description, so I have decided to honor him by calling this galaxy the Paper-Kite, because, who knows, you might experience a similar view.

NGC 4762 belongs to the Virgo Cluster of galaxies and is receding from us at 984 km/sec. If we accept its distance of 65 million light-years, the galaxy spans 170,000 light-years across and shines with a luminosity of nearly 1.5 billion Suns. Most peculiar is that images fail to reveal any dust along the galaxy's razor-sharp edge. This aspect led astronomers early on to classify it as an armless edge-on lenticular (S01) – one consisting of a very small, very bright nucleus in a narrow, high-surface-brightness, flat central disk (1.7′ × 0.1′) with faint, twisted (S-shaped), brush-like extensions. These details are surrounded by a quite asymmetric thick disk (lens) of gas.

Some astronomers suspected that the galaxy may hide a bar in its perfectly flat inner disk. Indeed, some sources classify NGC 4762 as the prototype SB0 galaxy of the flat-bar variety. But in a 1995 *Astronomy Letters and Communications* (vol. 31, pp. 165–167), Herve Wozniak (Geneva Observatory, Switzerland, and Marseille Observatory, France) argues that such a system should have a "thick bar," while NGC 4762 has only a thin central structure. He also notes that the galaxy's very luminous bulge is too small for a galaxy classified as an "early type." And why, Wozniak asks, is the galaxy's outer lens "bluer" than the central "bar"? (Observations of lenses around stellar bars in early-type galaxies show that their colors are the same.) What's more, in face-on galaxies, bars and lenses have almost the same major axis length, but NGC 4762's bar is almost 50 percent the length of the lens!

To explain these anomalies, the author suggests that NGC 4762 has cannibalized a small satellite galaxy with 10 percent of the host galaxy's mass; the companion, then, could have could settled inside the host's disk – distributing its stars partly in the galaxy's thin central disk and partly in the thick disk (which formed by thermal heating during the merging). NGC 4762 consuming a small companion would also explain the mysterious warping seen in the disk's extensions. A merger would also explain the blue color of NGC 4762's lens, as the interaction may have triggered star formation there. "NGC 4762 is thus not a galaxy with a flat edge-on bar," Wozniak concludes.

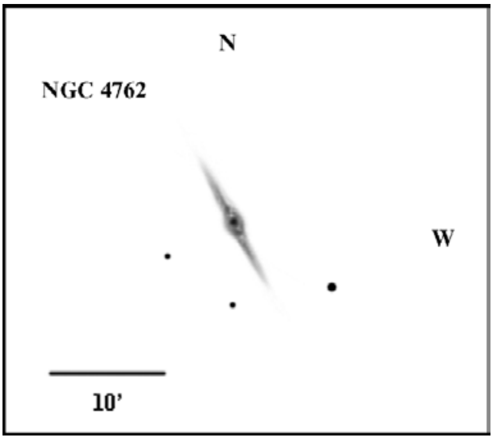
To find this perfect edge-on system, use the chart of page 271 to locate Epsilon Virginis. Now use binoculars to find 6.5-magnitude 41 Virginis 2½° to the northwest. Center this star in your telescope, then switch to the chart on this page. From 41 Virginis, make a careful sweep 1° southeast to 7th-magnitude Star *a*. NGC 4762



is 40′ southwest of Star *a*, between two 9.5-magnitude stars.

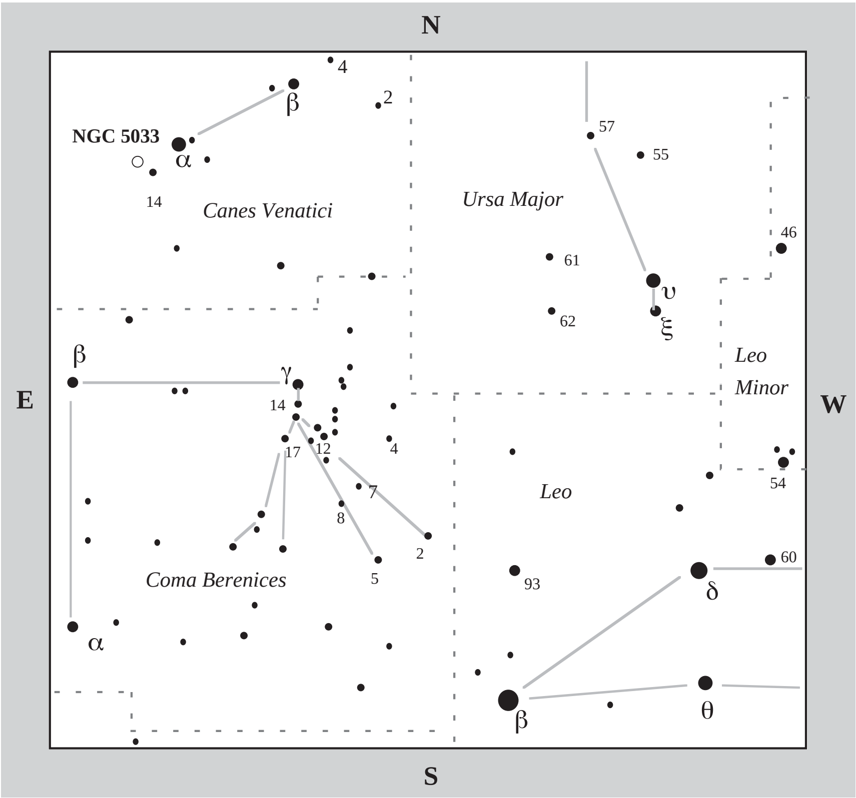
At 33× in the 5-inch, NGC 4762 is a tiny little wisp of light, a sharp needle 4′ long, oriented northeast to southwest, jutting into a pretty cap of three suns. At this power, the galaxy is best seen with averted vision, as it is inconceivably thin. The galaxy becomes much more obvious at 60×, though it still appears as a waif of light, but with an obvious brightening at the core – a hyperfine bead of gently glowing light that looks somewhat like a milkweed seed with opposing threads. Averted vision brings out some "girth" to the "threads."

I found 94× to provide the best comfortable view in my small scope. At this power, the core appears slightly lens shaped with a faint circular, "starlike" core. An elongated bead flanks the core on either side along the major axis, which gives way to a hyperfine extension of light that gradually fades away from the center.



I could not see any difference in brightness along the needle-like extension as Smyth did. But Luginbuhl and Skiff found the galaxy to shine with a silvery light in a 10-inch telescope. In a 12-inch, they traced the spindle to a length of 7.5′ and found the ends to taper to "sharp points."

Secret Deep 66
(NGC 5033)



66

Waterbug Galaxy
NGC 5033
Type: Spiral Galaxy (SA(s)c)
Con: Canes Venatici

RA: 13^{h} 13.4^{m}
Dec: +36° 36′
Mag: 10.2
SB: 14.4 (Rating: 3.5)
Dim: 10.5′ × 5.1′
Dist: ~60 million l.y.
Disc: William Herschel, 1785

W. HERSCHEL: [Observed May 1, 1785] Very bright, pretty large, extended, nearly milky, easily resolvable, much brighter in the middle. (H I-97)

NGC: Very bright, pretty large, extended toward position angle 167°, suddenly much brighter in the middle to a very bright nucleus.

NGC 5033 IS A MODERATELY LARGE and bright galaxy about 3° east-southeast of the fine 3rd-magnitude double star Alpha (α) Canum Venaticorum (Cor Coroli) – the brightest star in the celestial Hunting Dogs between Boötes and Ursa Major, which lies only 110 light-years distant. Sometimes called the Puppies, the constellation is usually depicted as two Greyhounds held by a leash in the hands of Boötes, the Herdsman, ready to chase the Great Bear around the North Celestial Pole – a depiction that resurrects Hevelius' original idea that Boötes was a hunter. Cor Caroli marks the southern hound's collar, but was later set apart in 1725 by Astronomer Royal Edmond Halley. As Richard Hinkley Allen explains in his 1963 book *Star Names: Their Lore and Meaning* (Dover, New York), the suggestion came from the court's physician, Sir Charles Scarborough, who said that the star had shone with special brilliancy on the eve of the King's return to London on May 29, 1660. Thus, in some old star charts, the star is rendered as a heart-shaped figure surmounted by a crown.

Our target, NGC 5033 is but a fuzzy flea on the hound's back. But in true physical extent it's a whopping 180,000 light-years in length. NGC 5033 is just ½° southeast of its telescopic "twin," NGC 5005 (Caldwell 29). Both galaxies are relatively close, residing in the Canes Venatici Spur of galaxies, and are Seyfert galaxies, receding from us at nearly 900 km/sec.

In deep images, NGC 5033 displays a small, but very bright, diffuse nucleus in a bright bulge. They also reveal a spiral pattern of intricate, thin dark lanes, which are seen best in silhouette against the evident near side of the bulge. These lanes help define several partially resolved, filamentary arms with branches. (One observer likened the sprawling "pincers" to thick insect-like arms, and I agree, though I liken them to those of a water strider, one of those graceful water bugs that skate, skimmer, and scoot across the surface of ponds and slow-running streams.) Although many small HII regions exist in the arms, the star-formation rate in the arms is moderate. Giant star-formation regions, however, clearly trace the spiral arms out to at least 4′ radius.

We see NGC 5033's disk inclined by 68° from face on at position angle 352°, but due to warping, these figures fall to 64° and 342°, respectively, for the galaxy's outermost reaches. As A. H. C. Thean (University of Manchester, UK), and colleagues note in a 1997 *Monthly Notices of the Royal Astronomical Society* (vol. 290, pp. 15–24), they have found some evidence for a previous tidal encounter. Although the galactic disk is perturbed, it's also well-ordered, suggesting that any interaction has been relatively weak.

This Seyfert galaxy's nuclear region is extremely luminous. It's conspicuously brighter in the near-infrared than at visible wavelengths, suggesting that dust significantly obscures the nuclear region. Like its extragalactic neighbor, NGC 5005 (Caldwell 29), NGC 5033 is a LINER (low-ionization nuclear emission-line region), meaning that it is not as energetic as other active galactic nuclei (AGN); still, LINERs emit X-rays and vary in brightness. About half of all galaxies studies are of this type.

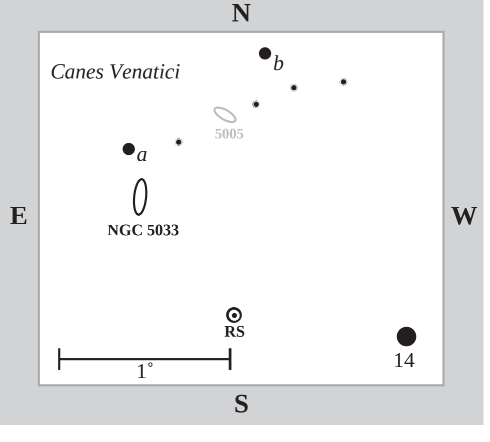
Interestingly, Thean *et al.* did not find any evidence for a central bar or noncircular motions in NGC 5033's central region. These observations counter the theory that links large-scale bars to Seyfert fueling mechanisms. Also surprising, the Seyfert nucleus appears to have no effect on the molecular hydrogen within a few thousand light-years from the galaxy's nucleus.

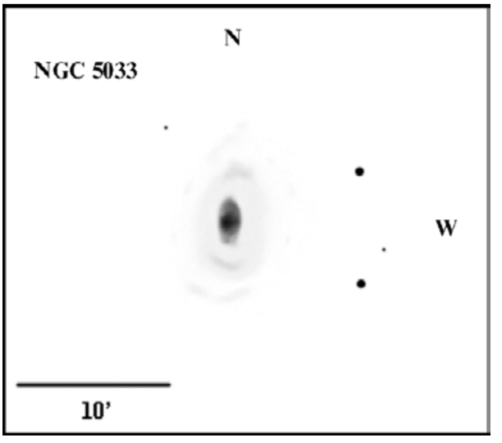
But in a 2003 *Publications of the Astronomical Society of Japan* (vol. 55, p. 103), Kotaro Kohno (University of Tokyo) and colleagues tell how their near-infrared observations of the galaxy's near-nuclear region "clearly suggests the presence of a small (the semi-major axis of about 12″–15″ or 1.1–1.4 kpc) nuclear bar (or oval structure) in the center of the 'non-barred' galaxy."

Many Seyfert galaxies do display many qualities of quasars and almost certainly produce the bulk of their energy output in the same way – through the gravitational influence of a supermassive black hole at the heart of the AGN. Radio observations by M. A. Pérez-Torres (Instituto de Astrofísica de Andalucía, Granada, Spain) and colleagues, and presented in a 2007 *Monthly Notices of the Royal Astronomical Society* (vol. 379, pp. 275–281), revealed a core-jet structure.

The researchers also note that radio and far-infrared emission from NGC 5033 are dominated by a starburst that during the last 10 million years produced stars at a rate of 2.8 million solar masses per year, yielding about one supernova event every 22 years. They also found evidence for a radio spur in NGC 5033, which, they say, "could have been due to a hot superbubble formed as a consequence of sequential supernova explosions occurring during the lifetime of a giant molecular cloud." NGC 5033 has been an active supernova producer, with events occurring in 1950 (SN 1950C), 1985 (SN 1985L), and 2001 (SN 2001gd).

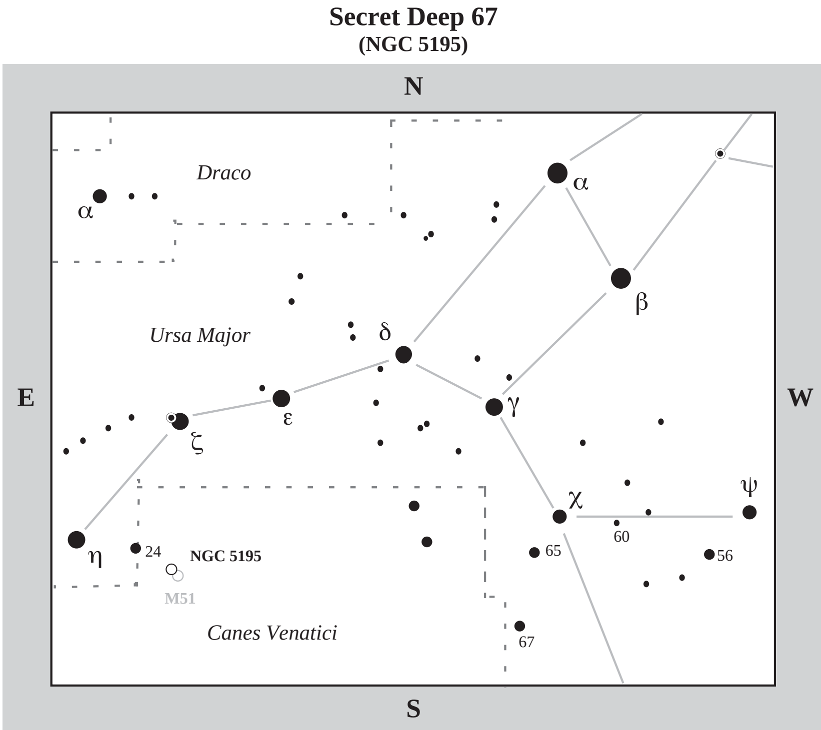
To find this Seyfert galaxy, use the chart on page 275 to locate Alpha Canum Venaticorum, which is a little less than 15° southwest of Eta (η) Ursae Majoris, the easternmost star in the Big Dipper's Handle. Now use your unaided eyes or binoculars to locate 5th-magnitude 14 Canes Venaticorum about 3° to the southeast. Center 14 Canes Venaticorum in your telescope at low power, then switch to the chart on this page. From 14 CVn, make a slow and careful sweep 1° east-northeast to the 8th-magnitude eclipsing binary star RS CVn. (The star varies between 8th- and 9th-magnitude every 4.8 days.) NGC 5033 is about 50′ northeast of RS CVn, and a little less than 20′ south of 6.5-magnitude Star *a*. Take care, though, when identifying





NGC 5033, because it lies just ½° southeast of its telescopic "twin," NGC 5005.

Through telescopes of all sizes, it has a bright core. Under a dark sky the core can be seen in 7 × 50 binoculars with averted vision. At 33×, NGC 5033, though larger, appears less conspicuous than NGC 5005, but its bright core (which can be seen with direct vision) helps it to stand out in the field. With averted vision, the galaxy swells magnificently to a moderately large (5′) elliptical haze with a bright round core that lies in a diffuse lens. The bright nucleus forms the northeastern apex of an isosceles triangle with two roughly 11th-magnitude suns. At 60×, the galaxy is a fine lens-shaped object that becomes increasingly more condensed and round toward the center. With time, I spotted what appeared to be two enhancements along the galaxy's major axis, which transformed into two arcs of diffuseness at 94×. These appear to be two HII-rich enhancements in the galaxy's inner arms. The galaxy's outer diffuse elliptical halo also appears fractured with an S-shape, though I cannot make out any distinct arms.


Secret Deep 67
(NGC 5195)
N
E
W
S
Draco
Ursa Major
Canes Venatici
α
α
β
γ
δ
ε
ζ
η
χ
ψ
24
NGC 5195
M51
65
60
56
67

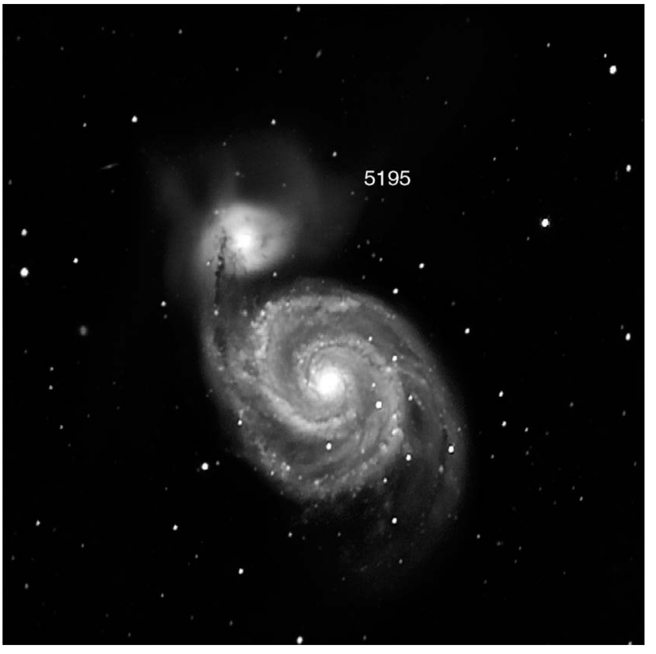
67

A Justifiable Replacement for M102
NGC 5195
Type: Peculiar Barred Spiral (SB0? Pec)
Con: Canes Venatici

RA: $13^h\ 30.0^m$
Dec: $+47°\ 16'$
Mag: 9.6
SB: 13.1 (Rating: 4)
Dim: $6.4' \times 4.6'$
Dist: ~30 million l.y.
Disc: William Herschel, 1787

W. HERSCHEL: [Observed May 12, 1787] Considerably bright, pretty large, round or little extended, very gradually brighter in the middle, 3′ north preceding the 51st of the *Connaissance des Temps* [M51]. (H I-186)

NGC: Bright, pretty small, little extended, very gradually brighter in the middle, involved in M51.



ASTRONOMY IS FULL OF HISTORICAL quirks and curiosities. One of the most famous is the case of M102 – the "mysterious" non-Messier object. First, as a reminder, Charles Messier did not discover all of the objects in his now famous catalogue of 110 nebulae and clusters.[1] His was a compilation of previously known objects, objects he discovered, and objects discovered by his contemporaries, most notably Pierre Méchain (1744–1805).

Messier also did not include the last seven objects we recognize in many of today's popular versions of his catalogue. These were added posthumously in the twentieth century; inclusion was based on the discovery of notes and letters by Méchain and Messier, as well as annotations found penned by Messier in his original printed catalogue and on an engraving.

Of the original 103 objects, four were, until modern times, considered missing: M47 in Puppis, M48 in Hydra, M91 in Coma Berenices, and M102 in Ursa Major. All have been reasonably identified except for, some say, M102. But this is not true.

[1] *Deep Sky Companions: The Messier Objects*, Stephen James O'Meara (Cambridge, UK, Cambridge University Press; Cambridge, MA, USA, Sky Publishing, 2000).

As I describe in *Deep-Sky Companions: Hidden Treasures*, the story of M102 can be briefly told: Méchain communicates to Messier a list of new objects. Messier confirms all but three of them before he submits his work for publication. In haste, Messier appends the three unconfirmed objects to his work and introduces an error. Méchain notices the mistake and immediately publishes a letter of correction. In that letter Méchain explains, "This is nothing but an error. The nebula is the same as the preceding No. 101. In the list of my nebulous stars communicated to him M. Messier was confused due to an error in the sky-chart."

With that mystery solved – at least to those willing to accept the preponderance of evidence over speculation[2] – the Messier catalogue truly does contain an unsung (unlabeled/numbered) discovery that could justifiably fill the M102 gap. The story is one of how history, in its annotated form, can hide some interesting and enlightening facts about discovery. I'm referring specifically to Messier's discovery of M51, the Whirlpool Galaxy in Canes Venatici, and the subsequent and unsung discovery of its companion, NGC 5195. Messier discovered M51 on October 13, 1773, "when observing the comet that appeared in that year." After making a refined observation of it on January 11, 1774, he described the object in his expanded catalog, which appeared in the French almanac *Connaissance des Temps* for 1783 (published in 1780). He called it a "Very faint nebula without stars," noting that it could be seen "only with difficulty with a simple three-and-a-half-foot refractor. Nearby there is an eighth-magnitude star." Messier makes no mention of any other "nebula" in the field, and a 7th-magnitude star does lie roughly 20′ to the east.

Harvard historian Owen Gingerich notes, however, that in the 1784 *Connaissance des Temps*, Messier appended his original catalogue description of M51 to include these words: "It [M51] is double: both parts have bright centers, and they are 4′ 35″ apart. The two atmospheres are in contact; one is much fainter than the other. Observed several times."

Despite what may be falsely implied, Messier didn't discover M51's companion; Méchain did – a fact unearthed by French astronomy popularizer Camille Flammarion (1842–1925), who owned an original copy of Messier's 1784 manuscript of his catalogue. In it, Flammarion found a margin note – in Messier's handwriting (accompanied with "a little sketch") – stating that "M. Méchain" saw M51 as "double." He then transcribed Méchain's original notes: "March 20th, 1781, saw this nebula; effectively it is double. The center of each is brilliant and clear; distinct and the light of each touches each other."

After receiving Méchain's discovery notes, Messier must have gone out and measured the separation of the two objects, thus explaining the noted separation and his comment that he observed them "several times." Some might argue that, like most astronomers of his day, Messier believed that nebulae were clouds of matter from which stars were born – so

[2] Today, some still dispute Méchain's claim, believing instead that Méchain discovered NGC 5866, a bright lenticular galaxy in Draco, discovered by William Herschel in 1788. See *Deep-Sky Companions: Hidden Treasures*, Stephen James O'Meara (Cambridge, UK, Cambridge University Press; Cambridge, MA, USA, Sky Publishing, 2007).

it would be not surprising that, like M78 in Orion, he would treat M51 and its companion as a single object.

But Messier didn't see M78 as a "double" nebula. He and Méchain (who discovered the object) described it as a cluster of stars involved with nebulosity, which had two bright nuclei – a very different description than what was penned for M51 and its companion. *Each* of these objects, Méchain said, has a "distinct" center. In other words, he did not see two nuclei embedded in a single nebulosity but two objects, clearly identifiable, yet touching.

When William Herschel encountered M51's companion during a sweep of the heavens on May 12, 1787, he might not have been aware of its existence (especially if he was using the 1783 *Connaissance des Temps*), which would explain why he felt justified in giving the companion an independent catalog number: H I-186 (now NGC 5195).

Gingerich concludes, "While it's safe to assume that Herschel believed he had discovered a new object, Méchain is NGC 5195's rightful discoverer, and Messier was the first to include it in a catalog."

Thus, it seems totally reasonable that anyone who wants to flesh out the Messier catalogue – so that it includes 110 objects rather than 109 (the 110 objects of modern times minus M102), can replace M102 with NGC 5195: It's an object mentioned in Messier's original catalogue; it was discovered by Pierre Méchain, whom Messier erroneously credited with the discovery of M102 (a nonexistent object); it's a distinct object (a peculiar barred spiral galaxy, well worth one's attention); and no one can argue the credibility of its discovery or of its existence. So, go ahead, be bold, be brave, and tick off NGC 5195 as an unsung Méchain missive. (Important note: Remember, I'm *not* suggesting that NGC 5195 *is* M102; I'm suggesting it can be used to *replace* a nonexistent M102.)

The importance of giving some spotlight to NGC 5195 is evidenced by the many careful visual observations of it. In images taken with large telescopes, the galaxy is a marvel unto itself, especially as it is interacting with M51 (Arp 85) – one of the grandest examples of a spiral galaxy in the sky.

NGC 5195 most likely passed closest to M51 some 70 million years ago and is now on the far side of M 51, receding from us with a radial velocity of 465 km/sec. Indeed, high-resolution images reveal a vast swath of dust in M51's northeast arm slicing across the eastern face of NGC 5195, lending visual proof of the pair's relative placement with respect to us.

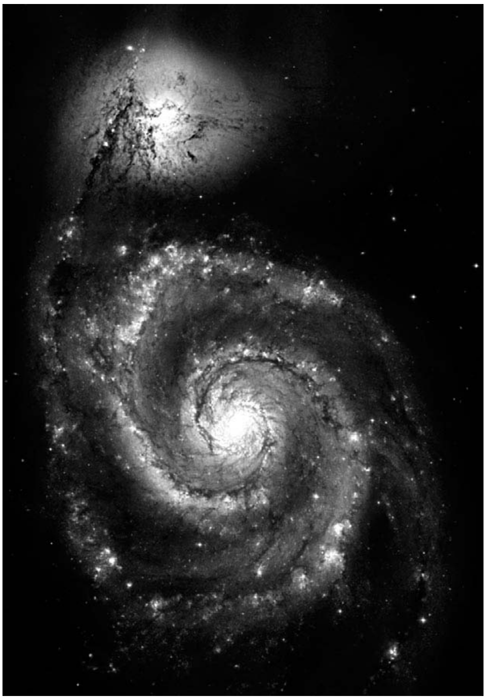
Otherwise, NGC 5195 appears as a diffuse disk galaxy, inclined 46° from face on, with numerous internal dust lanes that appear on the galaxy's west side. The galaxy is small, measuring only about 55,000 light-years in extent. If you could take a broom and sweep away that dust, we might see NGC 5195 as an SB0 type galaxy, with peculiarities induced by tidal interactions with M51. But no one is certain of the true classification of the system (thus the question mark in the table above); for now it's all guess work. The description in the *Hubble Atlas* suggests that the morphology has similarities to the Amorphous class, including M82.

While M82 is a starburst galaxy, NGC 5195 appears to be a post-starburst galaxy, as evidenced by its warm thermal emission deduced from IRAS measurements.

Curiously, no star-formation regions have yet been found. In a 1996 *Astronomy & Astrophysics* article, Olivier Boulade (CEA/DSM/DAPNIA/Service d'Astrophysique, Saclay, France) and his colleagues suggest the infrared emission most likely results from dust heated by the evolved starburst population. "It is clear that NGC 5195 has undergone a starburst," the Boulade team argues, "that this starburst has ceased." The team also notes that very few stars younger than B5 exist in NGC 5195, thus leading them to believe that the thermal emission comes from the evolved stellar population.

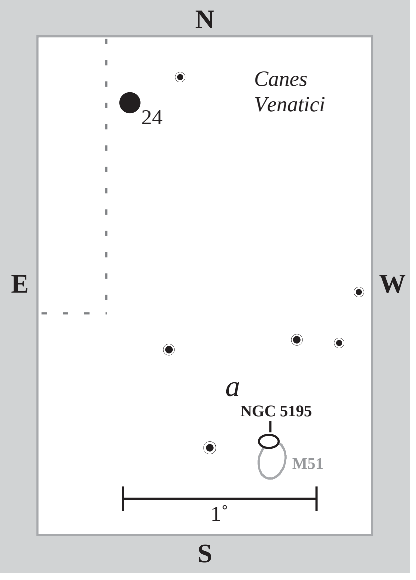
In 2006, Korean astronomers Narae Hwang and Myung Gyoon Lee (Seoul National University) announced how they had used mosaic images taken by the Hubble Space Telescope to discover about 50 faint, fuzzy, star clusters around NGC 5195 with effective diameters of about 46 light-years, which is more than ~4–5 times larger than typical globular star clusters. The clusters are about 100,000 times more massive than our Sun and older than 1 billion years. Most of these new clusters are scattered in an elongated region almost perpendicular to the northern spiral arm of M51, slightly north of NGC 5195's nucleus. In contrast, NGC 5195's normal compact red clusters are located around the bright optical body of the host galaxy. Hwang and Lee suggest that at least some faint fuzzy clusters are experiencing tidal interactions with the companion galaxy M51 and must be associated with the tidal debris in the western halo of NGC 5195.

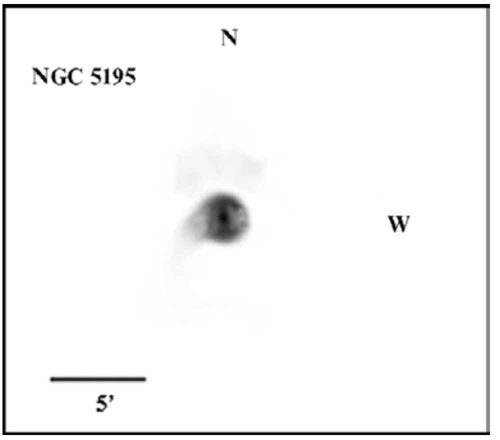
To find this little marvel, you, of course, want to first locate M51. Use the chart on page 279 to locate 2nd-magnitude Eta (η) Ursae Majoris, the easternmost star in the



Big Dipper's Handle. Now use your unaided eyes or binoculars to find 5th-magnitude 24 Canum Venaticorum, which is 2¼° west-southwest of Eta Ursae Majoris. After centering 24 Canum Venaticorum in your telescope at low power, use the more detailed chart on page 284 to make a slow and careful 1½° sweep southwest to a 40′-wide equilateral triangle (*a*) of 7th-magnitude suns. NGC 5195 is 20′ west of the southernmost star in Triangle *a*, a little less than 5′ north of M51's nucleus.

At 33× in the 4-inch, NGC 5195 is a brilliant 3′-wide circular glow, with an intense core that's brighter than M51's! It shines like a 9th-magnitude comet (sans tail) with a bright nucleus, intense inner coma and a diffuse outer coma. It all but joins M51; with averted vision and a careful gaze, I can see a thread of darkness





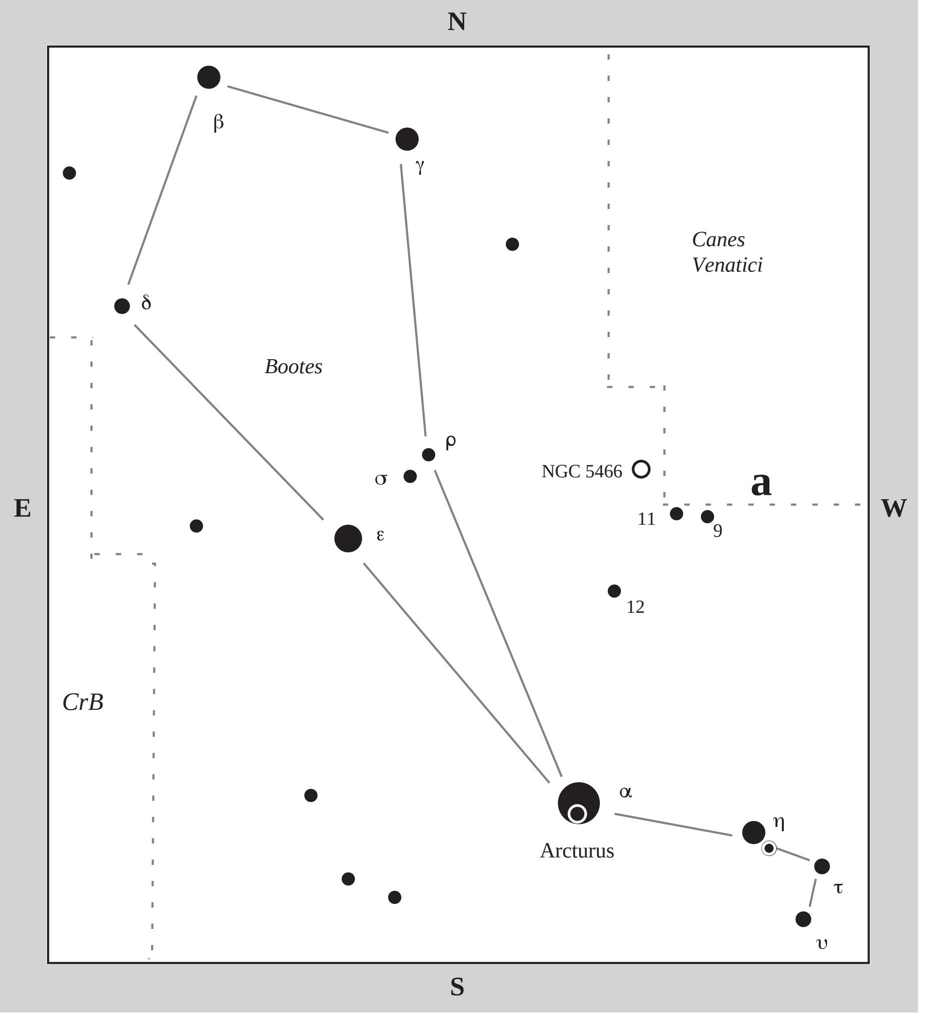
between them. At 60×, the two galaxies are a marvel. The gulf separating the two can be clearly seen, except on the eastern side, where M51's arm lances NGC 5195. This protruding arm is a subtle revelation, however, even in the 5-inch under dark skies; and it requires a bit of gentle tube tapping or making tiny, slow sweeps back and forth (from east-to-west), so the galaxies drift across the field of view, causing light to continuously sweep over the eye's many rod cells (those sensitive to dim light), stimulating awareness.

As I describe in *Deep-Sky Companions: The Messier Objects*, this sweeping of the telescope is akin to an old trick employed by the nineteenth-century astronomer George Phillips Bond (1825–1865) at Harvard College Observatory in Cambridge, Massachusetts. When using the great 15-inch Merz and Mahler refractor to observe diffuse objects, he would, at times, place the object out of the field of view; then, with the clock drive off, he waited patiently for the object to drift back into the field of view – all the while waiting with averted vision, until he saw the faintest breath of light enter the field. Thus, he would record the object's dim outer extensions.

With averted vision, the view at 60× shows NGC 5195 appearing more oval shaped, oriented east to west. A bright nebulous "star" shines at the galaxy's core, which is surrounded by a circular collar of snowy white light, which is, in turn, nestled in a diffuse and slightly elliptical outer halo. At 94×, the galaxy's core looks irregular with faint extensions bleeding off to the west from the galaxy's northern and southern tips; the core (like a stubby bar oriented north–south) also appears to bulge in that direction, as if it were impregnated with matter. The core's overall appearance is that of a capital sigma (Σ). With time, much attention, and averted vision (almost to the point of straining), I can see some diffuse material just north of NGC 5195, appearing as a dim patch of feeble light separate from NGC 5195. The views were consistent enough for me to put faith in the fact that this was light from the tidal plumes so apparent in larger telescopes.

Indeed, it's hard to say just how beautiful M51 appeared when I observed it from the the Texas Star Party one year through Larry Mitchell's 36-inch reflector. Seeing it so high in the sky required standing in peril high atop a 20-foot-tall ladder near the top rungs and holding on to the telescope's truss supports as a precaution against demonic wind gusts that continually threatened my existence. Feet braced, hands clutching, heart-pounding, I brought my eye to the eyepiece and saw M51's spiral wonder with one long arm embracing NGC 5195. Defaced with dust, "arms" contorted into wide-sweeping nebulous arcs on the galaxy's northern and southern edges, NGC 5195 burned forth with imperial light. And without much need for averted vision, I saw wide plumes of gaseous matter "sweeping off" the galaxy to the north and spreading into a glorious wash of wispy tendrils that seemed to flow away like ash blown by a gust of wind – the beauty that is the hobby of astronomy captured in a single view.

Secret Deep 68
(NGC 5466)



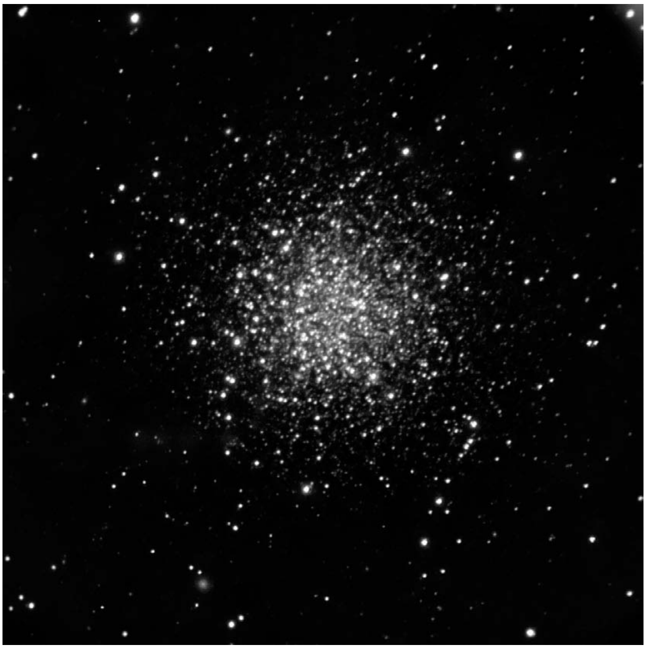
68

Snowglobe, Ghost Globular
NGC 5466
Type: Globular Cluster
Con: Boötes

RA: 14^h 05.4^m
Dec: +28° 32′
Mag: 9.0
SB: 14.0 (Rating: 3)
Diam: 9′
Dist: ~52,000 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed May 17, 1784] A cluster of extremely [faint] and compressed stars 6 or 7′ in diameter, many of the stars visible, they are so [faint] as to appear nebulous. (H VI-9)

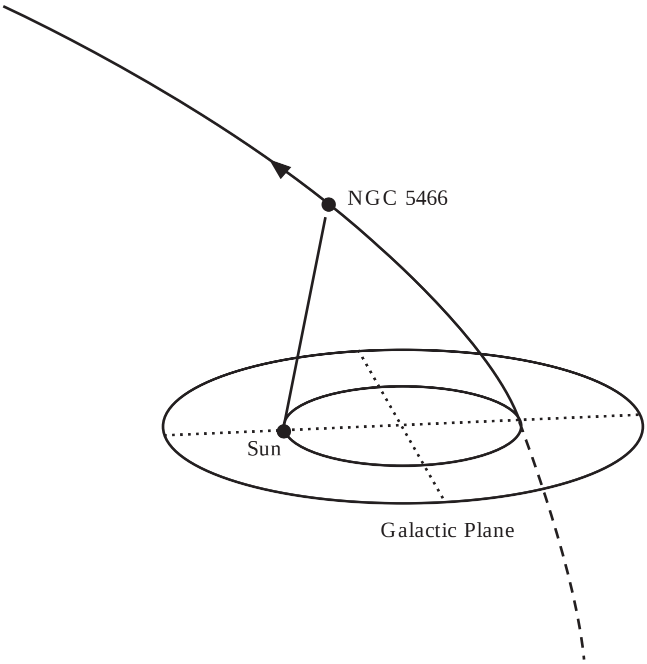
NGC: Cluster, large, very rich, very much compressed, stars 11th-magnitude and fainter.



NGC 5466 IS A BEAUTIFUL GLOBULAR cluster almost 10° north-northwest of 0-magnitude Alpha (α) Boötis (Arcturus). It's in one of those inconspicuous regions of sky that, save for globular star cluster M3 in Canes Venatici some 5° to the west, is largely devoid of any notably bright deep-sky objects for 20° or so on a side. But the globular is very much worthy of your attention.

NGC 5466 is one of the Galaxy's metal-poor globulars; its stars have, on average, only about 1/166 as much iron (per unit of hydrogen) as does the Sun. It's also one of the less luminous, having a mass of about 50,000 Suns spread across nearly 140 light-years of space. Its core is also large, spanning 20 light-years. In a 2004 *Astronomical Society of the Pacific Conference Series* (vol. 327, p. 284), Michael Odenkirchen and Eva K. Grebel (Max Planck Institute for Astronomy, Heidelberg, Germany) noted that the cluster's internal properties, then, are very similar to those of the low-mass halo cluster Palomar 5, which was recently found to have long tails of tidal debris.

Interestingly, in 2007 Michael Fellhauer (Universidad de Concepción, Chile) and his colleagues discovered that NGC 5466 also has a tidal tail – currently the longest on record for a globular cluster in the Milky Way. Unlike with Palomar 5, the researchers suggest that NGC 5466 may

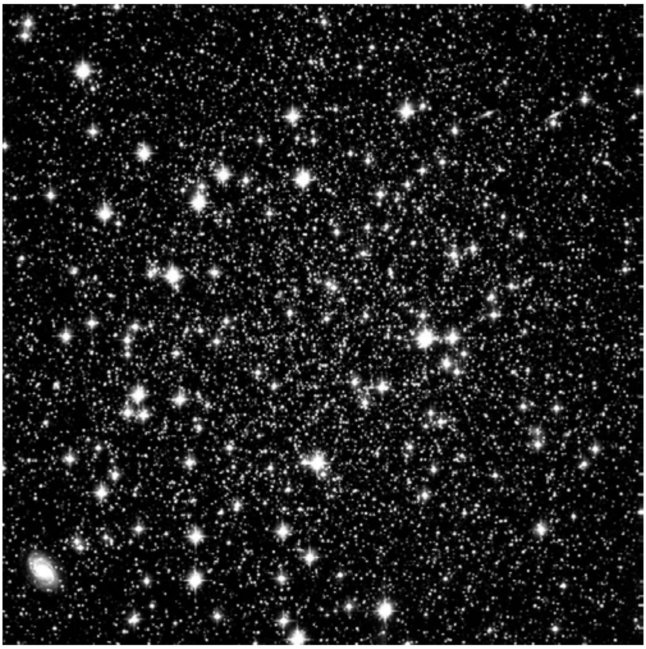


be the remnant core of a now dispersed dwarf spheroidal galaxy cannibalized by the Milky Way. Fellhauer *et al.* note that Sloan Digital Sky Survey data show this roughly 1½°-wide stream extending across 45° of sky – from Boötes to Ursa Major. The tail, they presume, is the result of tidal forces ripping the cluster apart as it passed the closest point to the Galactic center as it crossed the Milky Way's disk. The effect was a slow dissolution of NGC 5466, accounting for about 60 percent of its mass to be lost over the course of its evolution.

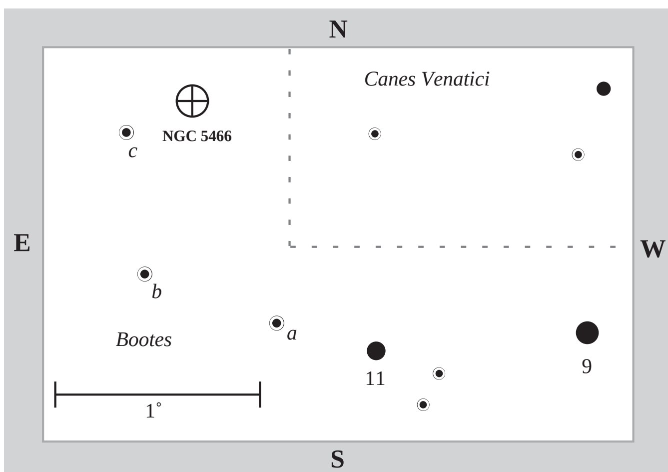
Today, NGC 5466 lies about as distant from the Sun as it does from the Galactic center, as it is now above the plane of the Galaxy (~52,000 light-years). But as Odenkirchen and Grebel demonstrate, the cluster lies on a highly eccentric orbit that brings it as far away as about 130,500 light-years from the Galactic center. (We see it approaching in its high arc at a velocity of about 120 km/sec.) But about 50 million years ago, the cluster was passing through the Milky Way's disk at a distance of only about 26,000 light-years from the Galactic center. Thus, the researchers say, the cluster probably received a tidal shock, which, due to the low mass and low concentration of the cluster, might have led to a significant loss of stars.

In deep images, NGC 5466's halo appears elongated towards the southwest and northeast, so the stars are seen preferentially near the directions towards the Galactic center. Odenkirchen and Grebel argue that since the position angle of the cluster's halo is about +30° and the direction position angle of the Galactic center–anticenter is +43°, this "provides first evidence for a possible tidal perturbation of the cluster and eventual mass loss because the Galactic tidal field will drag stars away from the cluster along the Center–Anticenter line." Thus, each time the cluster passes through the Galaxy's disk, it robs low-mass stars from the cluster (because they tend to lie at the cluster's periphery) while stretching out the cluster like a comet's tail.

While it's known that globular star clusters contain some of the oldest stars known, some cluster cores are found to have stars that are bluer and brighter than other cluster members – as if, somehow, they were born more recently than their



siblings. These “blue stragglers” remained a mystery for about half a century. Now astronomers believe they’re formed either when the stars in a binary system slowly merge or when two unrelated stars collide. Hugh C. Harris and his colleagues found nine blue-straggler variable stars in NGC 5466: six are dwarf Cepheids and three are eclipsing binaries, the latter being the hottest blue stragglers known. The researchers postulate that all the blue stragglers in this cluster have undergone mass transfer in close binary systems.

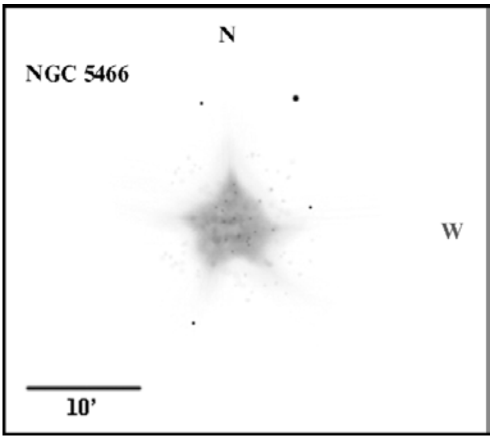


To find this delicate and mysterious object, use the chart on page 286 to locate Alpha Boötis. Next, use your unaided eyes or binoculars to find 5th-magnitude 12 Boötis (about 6° to the north-northwest). Now look 4° northwest for 5th-magnitude 9 Boötis. Center 9 Boötis in your telescope at low power, then switch to the chart on this page. From 9 Boötis, make a gentle 1° sweep east-southeast to 6.5-magnitude 11 Boötis. Next, move 30′ east-northeast to 7th-magnitude Star *a*. A 40′ sweep to the east-northeast will bring you to 8th-magnitude Star *b*. And a roughly 45′ swing to the north-northeast takes you to 7th-magnitude Star *c*. NGC 5466 is only 20′ northwest of Star *c*.

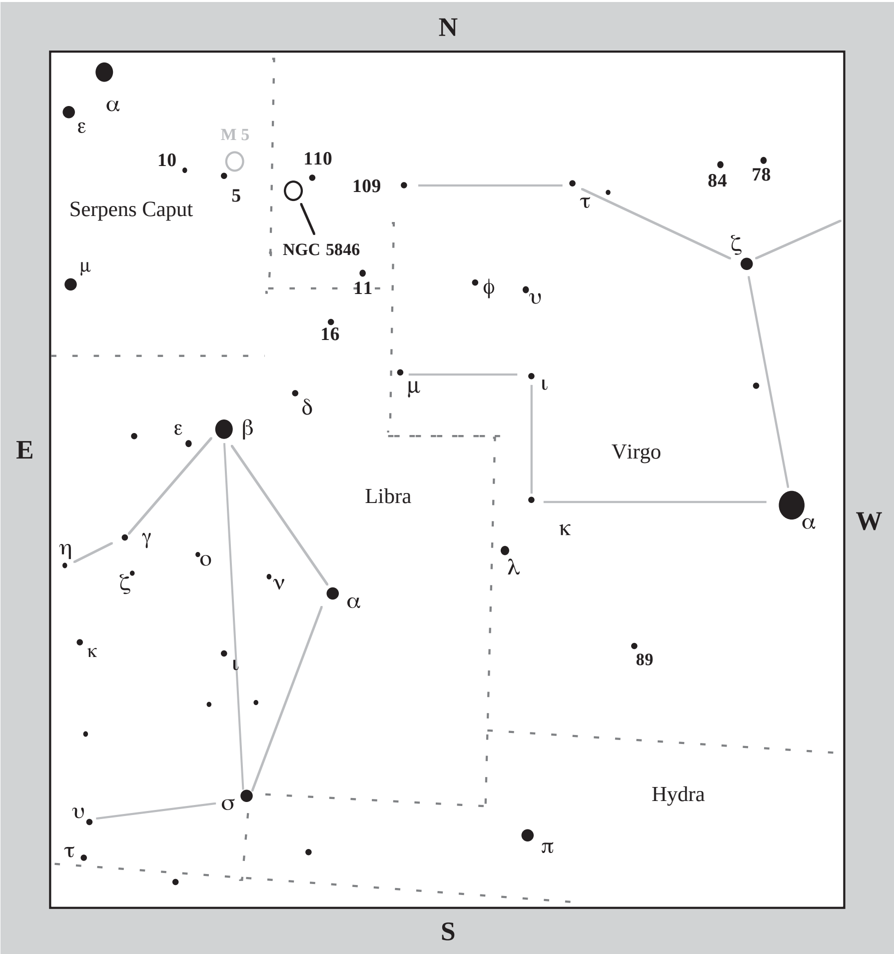
In a small telescope under a dark sky NGC 5466 will look like the diffuse head of a 9th-magnitude comet with little central concentration. But any light pollution will ruin the view. In the 5-inch at 33× under a dark sky, it’s a roughly 8′-wide glow, round and uniform, like a tailless comet with no central condensation. With averted vision, the globular's fringe looks irregular and somewhat frazzled. When I spend time looking at the cluster with low power and averted vision, faint stars pop in and out of view; it reminds me of an old snowglobe (minus the model landscape) that's been vigorously shaken.

At 60×, the cluster remains a large and uniform, low-surface-brightness glow that transforms into a fractured spread of very dim stars, like a fog suddenly shattered by the wind. With time and concentration, I can see some stubby starfish-like arms that extend from a ring of stellar clustering at the core.

At 94× (the most magnification this low-contrast cluster will take comfortably) with the 5-inch, the globular breaks up into dim mottled patches with some irregularities. Most apparent are two parallel rows of stars at the core (the brightest framework of the central ring seen at 60×) oriented north–south and extending perhaps 4′. The cluster's brightest stars, which hover around 14th magnitude are but ephemeral waifs of light that sparkle briefly in and out of view, mainly throughout the core, whose horizontal branch magnitude is a dim 16.5.



Secret Deep 69
(NGC 5033)



69

69

NGC 5846
Type: Elliptical Lenticular Galaxy (E1/S01?)
Con: Virgo

RA: $15^h\ 06.4^m$
Dec: $+01°\ 36'$
Mag: 10.0
SB: 12.3 (Rating: 4)
Dim: $3.0' \times 3.0'$
Dist: ~130 million l.y.
Disc: William Herschel, 1786

W. HERSCHEL: [Observed February 24, 1786] (H I-128)

NGC: Very bright, pretty large, round, pretty suddenly brighter in the middle to a nucleus, faint star involved south, partially resolved, some stars seen.

NGC 5846 IS A SMALL BUT RELATIVELY conspicuous elliptical lenticular galaxy near 4th-magnitude 110 Virginis in the far eastern reaches of the Maiden near the western border of Serpens Caput. It's also only about 3° west-southwest of the great globular star cluster M5.

The galaxy appears charted in my 1966 *Norton's Star Atlas* (Sky Publishing Corp., Cambridge) but I had never hunted it down until I tackled the Herschel 400 list, of which it is a member. Even through my 4-inch Tele Vue Genesis refractor, the galaxy was a 2′-wide and relatively obvious fuzzy patch, yet I rated it only as a "3," meaning it's only moderately impressive. But this fact changed when I serendipitously turned my 5-inch Tele Vue refractor on it in May 2010. Upon seeing its obvious form at low power, I immediately altered my Secret Deep list to accommodate this wonderfully bright elliptical – one nearly 0.5 magnitude brighter than the faintest Messier galaxies.

The galaxy belongs to the Virgo–Libra cloud of galaxies and is receding from us at 1,714 km/sec. We see the galaxy tilted 31° from face on, 130 million light-years distant, making it span 110,000 light-years of space and shine with a total luminosity of 62 billion Suns. NGC 5846 is also the brightest member in the NGC 5846 group, which includes other nearby splendors such as 12.7-magnitude NGC 5839 (about 28′ west-northwest), 12.5-magnitude NGC 5845 (about 8′ west-northwest), magnitude 10.8 NGC 5850 (about 10′ southeast), and 12.8-magnitude NGC 5846A only 35″ south, with which it forms a noninteracting pair. The NGC 5846 group is the third most massive aggregate of early-type galaxies after the Virgo and Fornax clusters in the local universe. As of 2005, altogether, 324 candidate members have been identified, and 83 have been confirmed spectroscopically.

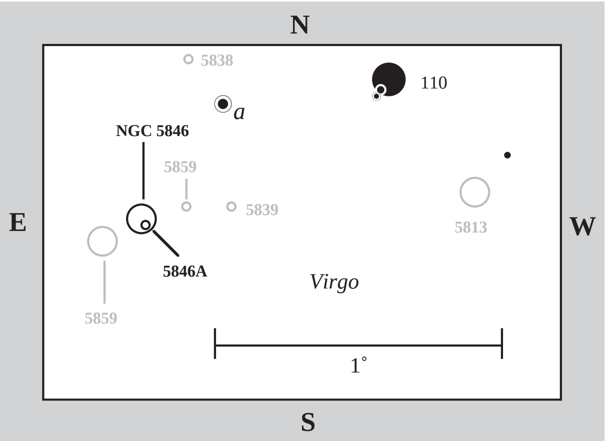
NGC 5846 was initially classified as a giant elliptical (E1) galaxy, but modern studies argue that claim. The galaxy's classification as an elliptical was largely based on early white-light photos of NGC 5846, which showed it to possess a bright diffuse nucleus surrounded by a smooth lens of little definition – typical of an elliptical system.

But NGC 5846 is a fascinating X-ray galaxy with a complex, filamentary morphology – one that extends over more than 3′, almost to the limits of the optical galaxy. X-ray images reveal two "spiral arms," directed to the southeast and southwest and a weak hard X-ray nucleus coincident with a radio source detected by the Very Large Array. Some astronomers argue that the galaxy's extended envelope and lens is not characteristic of an elliptical system, but is prototypical of a lenticular S01 type. Others say that NGC 5846 is an example of a giant elliptical with a very low (but present) rotation and a high central dispersion.

In a 1998 *Astronomy & Astrophysics* (vol. 330, pp. 123–135) Paul Goudfrooij (Space Telescope Science Institute) and Ginevra Trinchieri (Brera Astronomical Observatory, Milan, Italy) presented new optical imagery and ROSAT X-ray imagery of NGC 5846, which revealed a filamentary dust lane with a dust mass of about 7,000 Suns in the few central thousand light-years of the galaxy. The astronomers say that while the feature could have condensed out of a cooling gas flow, or from mass loss of late-type stars within the galaxy, they argue that the dust and optical nebulosity seen in the galaxy are materials donated during a recent interaction with a small, gas-rich, neighboring galaxy, probably of the Magellanic type.

As for NGC 5846's non-interacting companion (NGC 5846A), it has a redshift difference of 554 km/sec which, although large, is not uniquely so for close pairs. If the pair is a binary at the given distance, the projected linear separation would be only about 23,000 light-years, supportive of the large velocity difference. However, there is no evidence for a physical bridge between the galaxies.

As reported in a 2006 *Astronomy & Astrophysics* (vol. 455, p. 453), Brazilian astronomer A. L. Chies-Santos and colleagues used archival Hubble Space Telescope images to survey the galaxy's well-studied globular-cluster system. The team detected two dozen previously unknown candidates in the central regions. Their typical effective radii are in the range 10–16 light-years. They also found seven compact X-ray

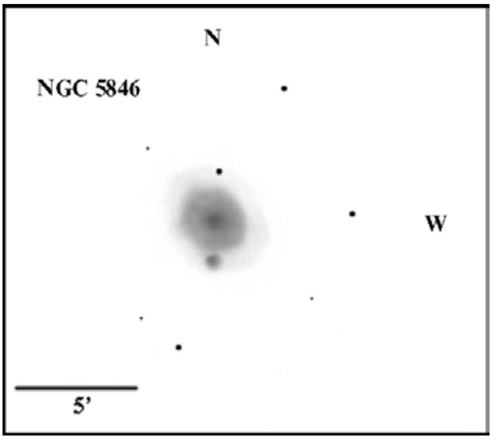


counterparts to globular clusters, most of them in the central region. These are among the most luminous X-ray sources in NGC 5846.

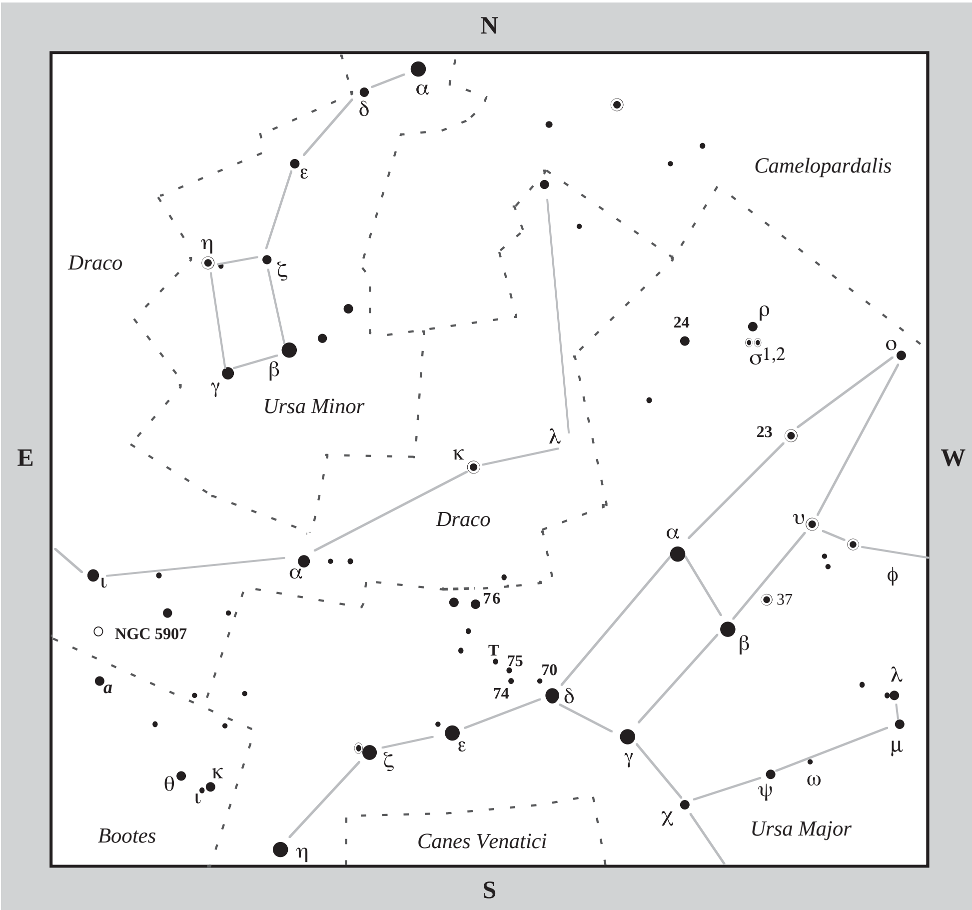
To find NGC 5846, use the chart on page 291 to locate 110 Virginis, which is 4° east-northeast of 109 Virginis. Center 110 Virginis in your telescope at low power, then switch to the chart on page 293. From 110 Virginis, move about 35′ east-southeast to 8th-magnitude Star *a*. NGC 5846 is just 30′ southeast of Star *a*.

Under a dark sky in the 5-inch at 33×, NGC 5846 is a 2′-wide and immediately obvious diffuse circular glow, very condensed, that brightens to a core. With averted vision, it appears trapped between two stars. I feel the galaxy is obvious enough to be readily visible with a small telescope from a suburban location.

At 60×, my eye was immediately caught by the obvious dual nature of the core, which at times even seemed triple along a north–south line, making the galaxy appear elongated in that direction. But the southern part of the "core" was the nearly 13th-magnitude companion NGC 5846A! I was startled at that little galaxy's obvious appearance. The northern component was a faint star projected on the galaxy's outer halo. Although condensed, the main galaxy's sole nucleus is somewhat diffuse, not star-like. The view is much clearer at 94×, when all these features are well resolved. I was still especially taken by the prominence of NGC 5846A and how compact and steadfast it appeared. The 11th-magnitude galaxy NGC 5850 can also be seen 10′ to the southeast as a larger and fainter ghostly glow, but in CCD images, like Mario Motta's that opens the section, it's a much more remarkable sight than NGC 5846!



Secret Deep 70
(NGC 5907)



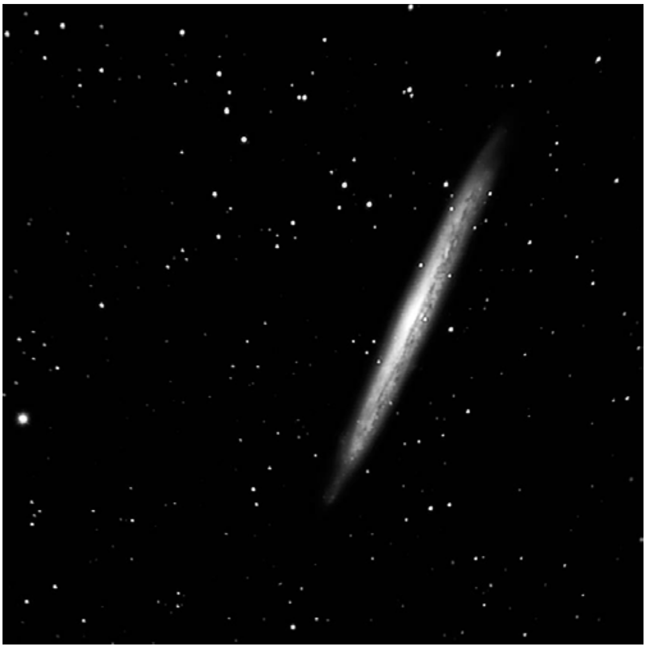
70

Splinter, Knife-Edge, Cat Scratch Galaxy
NGC 5907
Type: Spiral Galaxy (SA(s)c)
Con: Draco

RA: $15^h\ 15.9^m$
Dec: +56° 20′
Mag: 10.3
SB: 13.4 (Rating: 3)
Dim: 11.5′ × 1.7′
Dist: ~36 million l.y.
Disc: William Herschel, 1788

W. HERSCHEL [Observed May 5, 1788]: Pretty bright, faint near the middle, 8 or 10′ long, 1.2′ wide. (H II-759)

NGC: Considerably bright, very large, very much extended toward position angle 155°, very gradually, then pretty suddenly brighter in the middle to a nucleus.



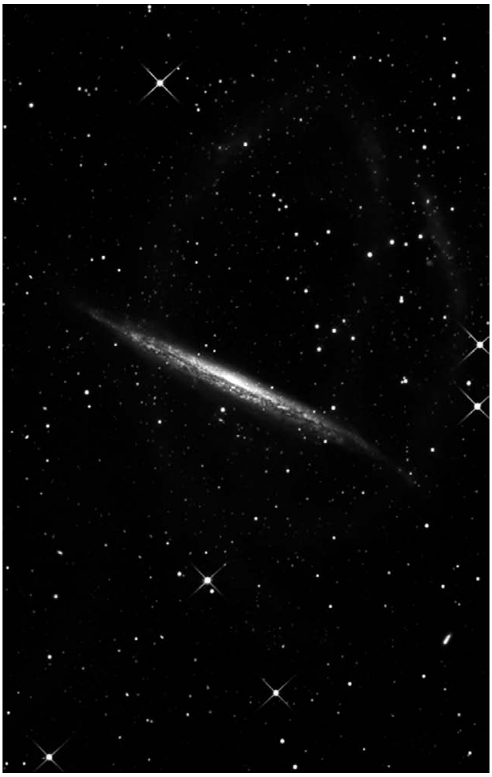
NGC 5907 IS A MODERATELY LARGE and extremely thin edge-on galaxy in Draco only about 1½° northeast of the more famous edge-on lenticular galaxy NGC 5866, which some like to think may be M102 (see also Secret Deep 67). Commonly called the Splinter or Knife-Edge Galaxy (I call it the Cat Scratch Galaxy), NGC 5907 will be a challenge for small-telescope users who are not under a dark sky. But I've glimpsed the galaxy in a 4-inch from Hawaii, and it's an impressive sight in larger instruments.

A relatively close neighbor, the early spiral galaxy resides in the Draco Cloud of galaxies, where we see it inclined only about 2° from edge on. Consequently, strong, opaque dust lanes all but hide its tiny nuclear bulge. In the late nineteenth century, the Third Earl of Rosse detected and drew a "ray, very much extend, parallel to [NGC 5907], and close preceding it." Although Dreyer gave it a separate NGC number (5906), the "ray" is nothing more than the side of NGC 5907 just to the west of the dust lane.

In true physical size, NGC 5907 is a splendid system: Spanning about 120,000 light-years in length and having a mass of 230 billion Suns, the galaxy is one of the largest edge-on systems visible on the sky. Its outermost spiral arms can be seen at either end of the spindle, with the northern one opening toward the observer and the southern one going away. Spectroscopic observations show that the south end of the spindle is approaching, indicating that the galaxy's arms are trailing. Radio observations indicate that the rotation velocity of the galaxy increases steeply in the central ~10″ (~1,600 light-years). After that, the rotation curve is almost flat until 65,000 light-years, beyond which it gradually declines. The galaxy as a whole is receding from us at a velocity of 780 km/sec.

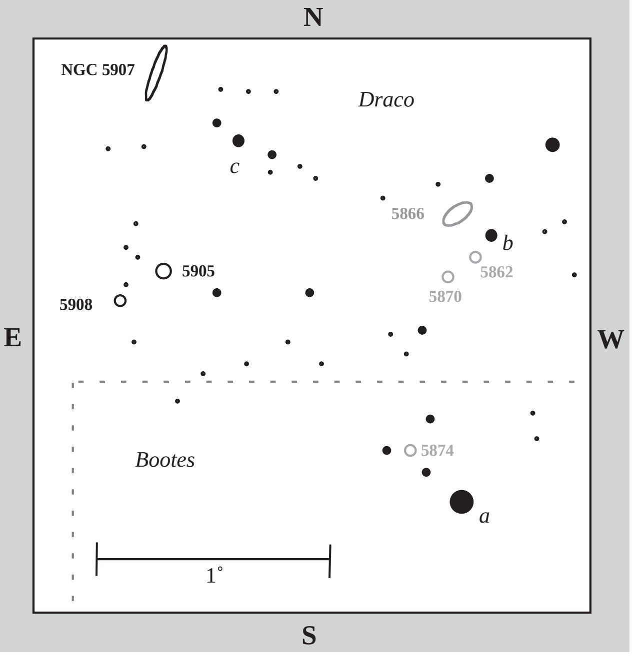
Unlike many large spiral galaxies that have equal populations of giant and dwarf stars in their halos, that of NGC 5907 appears to be delinquent in giant stars. As reported in a 1999 University of California, Berkeley, press release, astronomers using the Hubble Space Telescope to image the extended halo of NGC 5907 found it highly deficient in giant stars. They expected to see more than 100 giants, but instead only turned up one candidate; the halo dwarfs outshine the giants by a factor of 20. While it's been proposed that just such a population of dwarfs could be a constituent of the dark matter making up galaxy halos, a group of French astronomers suggested the giant depletion was the result of a long-ago collision with a companion elliptical galaxy, which eventually merged with NGC 5907. HI observations have shown a large disk of interstellar gas, which is warping in the outermost regions of the galaxy, which could be a sign of a previous merger.

New evidence came in a 2008 *Astrophysical Journal* (vol. 689, pp. 184–193), where David Martínez-Delgado (Instituto de Astrofísica de Canarias, Tenerife, Spain) and colleagues present evidence for an extended stellar tidal stream wrapping



around NGC 5907. Their deep images, from a small robotic observatory in New Mexico, reveal for the first time a large-scale complex of arcing loops, which they say is an "excellent example of how low-mass satellite accretion can produce an interwoven, rosette-like structure of debris dispersed in the halo of its host galaxy."

The arcing structures, which form tenuous loops extending more than 150,000 light-years from the galaxy, probably represent the ghostly debris trail of a dwarf galaxy that once orbited NGC 5907 but was gradually ripped apart. Over the course of some 4 billion years, the scattered remains ultimately merged with NGC 5907, leaving behind only faint traces (the ghostly loops) of the cannibalistic



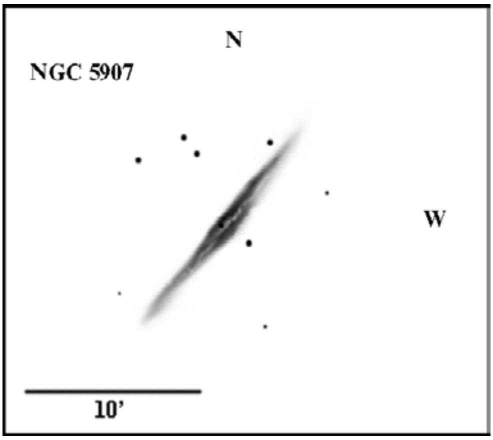
event. “The findings confirm that halos of spiral galaxies in the local universe may still contain a significant number of galactic fossils from their hierarchical formation,” the researchers say. Indeed, the finding supports the theory suggesting that large spiral galaxies such as NGC 5907 and our own Milky Way formed by cannibalizing and accreting smaller neighbors.

Their model of the tidal disruption demonstrates that most of the tidal features observed in NGC 5907 can be explained by a single accretion event. The findings are interesting because NGC 5907 has long been considered a prototypical example of a warped spiral galaxy in relative isolation. “The presence of an extended tidal stream,” the researchers argue, “challenges this picture and suggests that the gravitational perturbations induced by the stream progenitor must be considered as a possible cause for the warp.”

To find this beautiful galaxy, I suggest first finding NGC 5866 – a moderately sized and highly condensed lenticular galaxy about 4° southwest of 3rd-magnitude Iota (ι) Draconis. Use the chart on page 295 to first find Iota Draconis, then look for 5th-magnitude Star *a* just about 5° southwest. Use binoculars if you have to, but Star *a* should be easy to identify, since it is the brightest star in the region. Center Star *a* in your telescope at low power, then switch to the chart on this page. NGC 5866 is just a little more than 1° north of Star *a*, and 10′ northeast of 7.5-magnitude Star *b*. From NGC 5866, move 55′ east-northeast to 7.5-magnitude Star *c*. NGC 5907 is 30′ further to the northeast.

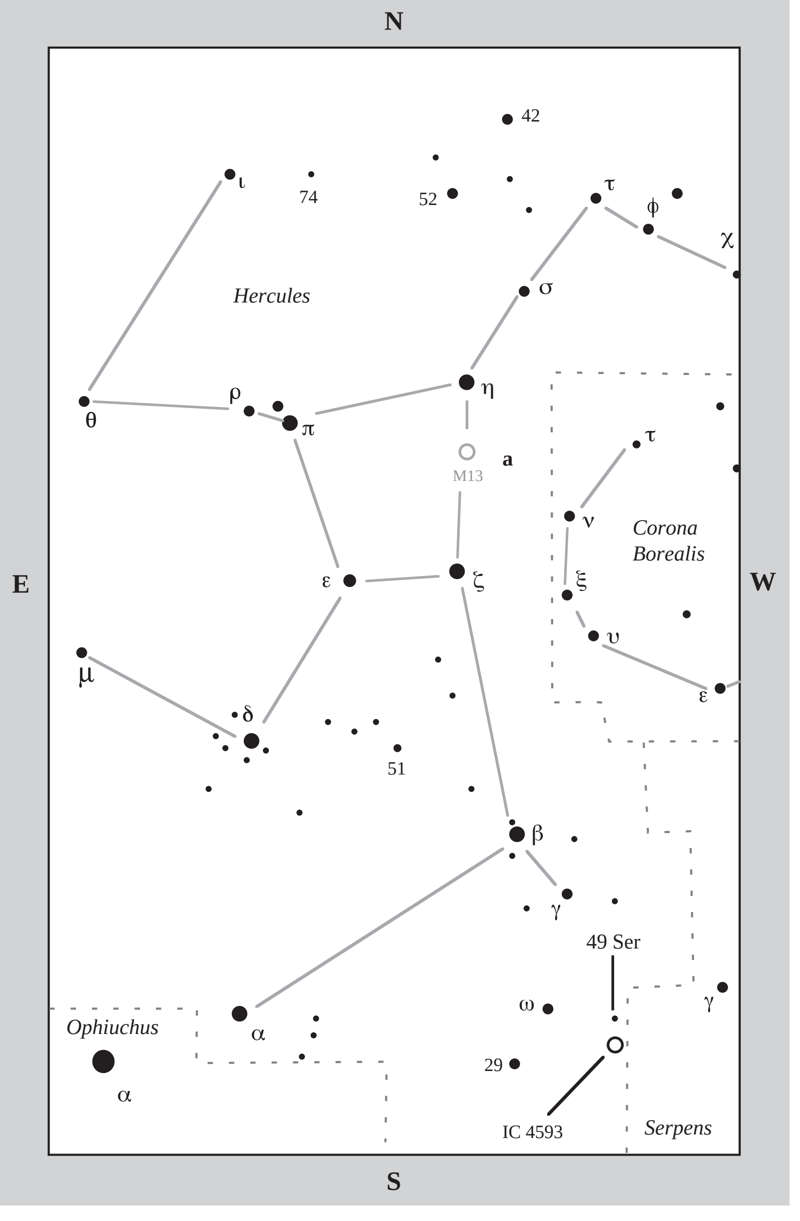
I tried to spy it in binoculars but failed. I wasn’t certain either if I spied it in my antique telescope; if it was, it certainly was at the limit. But at 33× in the 5-inch under a dark sky, NGC 5907 is a 10′-long phantom sliver of light (oriented north-northwest to south-southeast). With time and averted vision this magnificent needle looks like a tiny tear in the fabric of space. (That’s why I call it the Cat Scratch Galaxy.)

At 60×, the needle seems to swell insignificantly in the middle, while the arms appear slightly uneven in brightness. The northwest side of the galaxy appears sharper and brighter than the southeast side. I believe the former feature may be Lord Rosse’s mysterious “ray.”



At 94×, the bulge stands out more prominently as a flattened oval that gradually gets brighter toward the center to a starlike nucleus, which appears extremely sharp with averted vision. When I run my eyes along the razor-sharp edge of the disk, I can see hyperfine wisps of dust lining it. The faintly glowing disk stretches out on either side of the dust, and appears fractured in places, particularly near the ansae, which is where the furthest spiral arms open. The sight is quite mesmerizing and I'm certain its ghostly visage will impress you.

Secret Deep 71
(IC 4593)



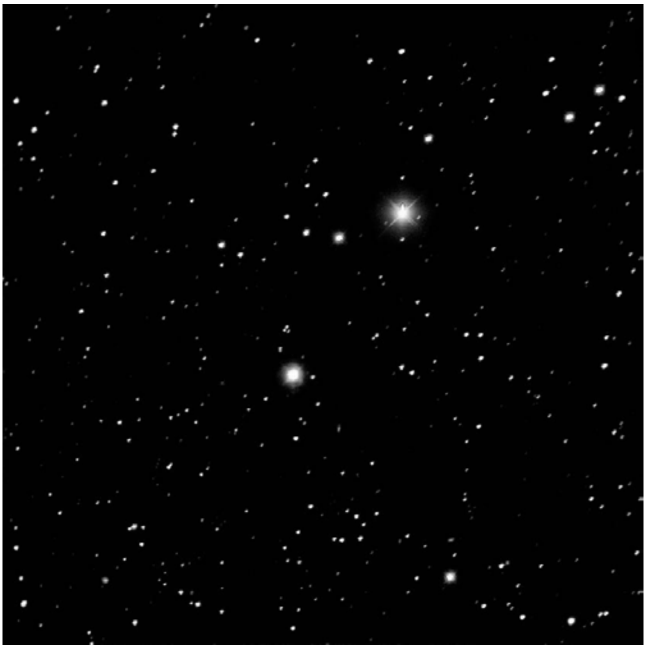
71

White-Eyed Pea
IC 4593
Type: Planetary Nebula
Con: Hercules

RA: 16^h 11.7^m
Dec: +12° 04′
Mag: 10.7 (Rating: 4)
Dim: >12″
Dist: ~3,400 l.y.
Disc: Williamina Paton Fleming, 1907

W. HERSCHEL: None

IC: Planetary, stellar



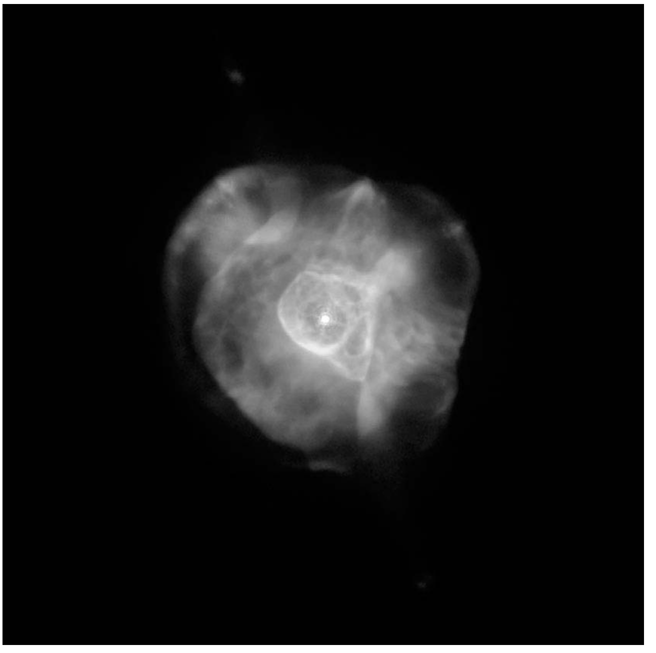
IC 4593 IS A LITTLE STELLAR PLANETARY nebula in southwestern Hercules, about 9° northeast of 3rd-magnitude Alpha (α) Serpentis (Unukalhai) – the neck of the Snake (Serpent) and possibly the *lucidus Anguis* (bright Serpent) in Virgil's *Georgics*: I. 204–7:

> Furthermore we farmers should pay as much attention to Arcturus, the times of the Kids and the bright Serpent as do those who, sailing homewards over stormy seas, attempt the Pontus and the straits of oyster-bearing Abydos.

Thus we see yet another reference to our astronomical ancestors' reliance on the stars to predict the weather. In Roman times, for instance, the Hyades (Caldwell 41) were known as *Sidus Hyantis*, the Rain-Bringing Stars, and in his *Natural History*, Pliny the Elder (AD 23–79) devotes a section to "The weather and the effect of heavenly bodies on natural phenomena."

But IC 4593 lies just over the northeastern border of Serpens, in a stellar desert of Hercules – a neglected and obscure stretch of space, just beyond the hazy splendor of the Milky Way. Yet this little gem has an 11th-magnitude central star visible in large binoculars, and even the smallest of telescopes will show the tiny nebula's pale greenish pallor – if your eyes are sensitive to color.

Our target is another discovery overlooked by all the great observers until Williamina Paton Fleming found it in 1907 while surveying glass plates taken with Harvard College Observatory's 8-inch f/5.5 Bache refractor, which was equipped with an objective prism to record spectra. In her scans, she had noticed that this object in Hercules displayed the peculiar



bright lines of a "gaseous nebula," a phrase commonly used back then to describe planetary nebulae.

Harvard College Observatory director Edward Charles Pickering announced her discovery in the observatory's 1908 *Annals* (vol. 60, pp. 147–194). Subsequently, John Louis Emil Dreyer included it in his 1908 *Second Index Catalogue of Nebulae and Clusters of Stars,* which contained objects found in the years 1895 to 1907. IC 4593 was one of 43 objects Fleming ultimately added to the Index Catalogue. (For a more descriptive write-up of Fleming's work, see Secret Deep 27 (IC 2149).)

In his 1918 summary of 762 nebulae and clusters photographed with the 36-inch Crossley reflector at Lick Observatory (*Publications of Lick Observatory,* vol. 13, pp. 9–42), Heber D. Curtis described IC 4593 as a "Central star ... surrounded by a disk of bright matter ... fading out a little toward the edges ... bright wing at north ... and a smaller and fainter projection opposite this."

Modern images of IC 4593 (including the Hubble Space Telescope image above right) reveal it to be a striking asymmetrical planetary nebula, consisting of a complex system of shells with clearly defined ansae and condensations that extend to in excess of 1′ (1 light-year) from the roughly 11th-magnitude variable central star. (Note that the diameter listed in the table above is only for the bright inner shells.) The origin of IC 4593's different morphological structures is difficult to interpret. Some of the work that has been done on the nebula is described below.

Seen in color, the HST image shows the nebula glowing with a greenish hue, making it look like some form of ectoplasmic wonder from the movie *Ghost Busters.*

The nebula's most pronounced features are two inner shells out to 10″, the outermost one of which is clearly elliptical. In a 1996 *Mexican Journal of Astronomy and Astrophysics,* J. Bohigas and L. Olguin (Universidad Nacional Autonoma de Mexico) argue that the morphology of IC 4593 may be due to different forms of mass loss from the central star and not caused by supersonic motion into the interstellar medium, which had been earlier proposed.

The inner shell has a high-density inner rim 2.5″ from the central star. This appears to be the result of the interaction between the nebula and a fast (1,600 km/sec) hot wind from the central star. While the two shells themselves are perhaps related to different episodes of mass ejections from the central star; similar structures are seen in NGC 6543 (Caldwell 6) in Draco and IC 418 (Hidden Treasure 28) in Lepus.

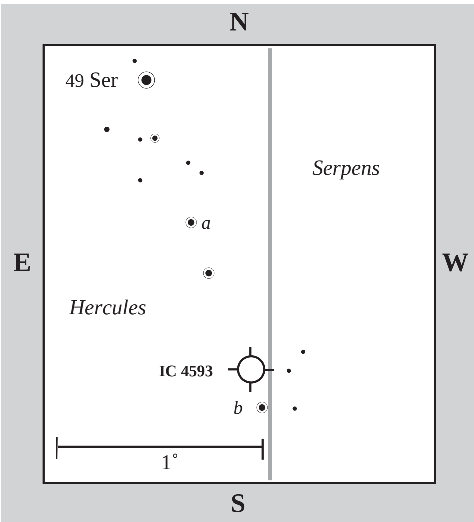
The inner shell also has a highly asymmetrical system of low-ionization bright knots to the southwest, which resemble outward-facing bow-shocks. These are located at different position angles and lie at different distances from the central star. In a 1997 *New Astronomy* (vol. 2, p. 461), Romano L. M. Corradi (IAC, La Laguna, Tenerife, Spain) and his colleagues note that these features also have low radial velocity tails pointing to the central star, as well as enigmatic extensions in the outer regions of the nebula. It's possible, the astronomers argue, that the observed features are the result of multiple collimated outflows propagating from the central star.

The inner shell is bounded by an outer inner shell that is strongly brightened to the northwest, forming an intriguing arc-like feature with a noticeable bulge. This appears to be associated with opposing, collimated outflows, culminating at about 12″ (0.2 light-year) from the central star with bright knots at each ansa. The ansae are reminiscent of those in NGC 7009 (Caldwell 55), the Saturn Nebula in Aquarius.

The two inner shells are nested within a nearly spherical and highly excited halo, which is most likely entirely dominated by photo-ionization from the central star. Indeed, the nebula's 11th-magnitude type O central star is still heating the nebula with a current relatively low temperature of 40,000 K. It should also be noted that the distance to the nebula is vague, with determinations ranging from 3,000 to 10,000 light-years, with the best estimate being around 3,400 light-years.

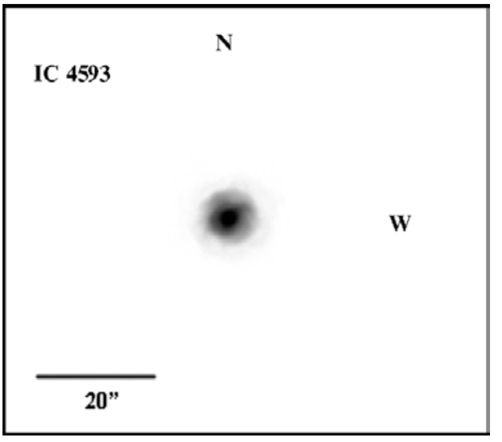
To find this lovely emerald nebula, use the chart on page 300 to locate 4.5-magnitude Omega (ω) Herculis. You'll want to use your binoculars to now locate 6.5-magnitude 49 Serpentis 3° to the west-southwest; 49 Sepentis (now in Hercules) marks the northern tip of a nearly 20′-wide triangle with two roughly magnitude 8.5 suns. Once you confirm it, switch to the chart on this page, center 49 Sepentis in your telescope, then look about 45′ south-southwest for 7th-magnitude Star *a*, which has an 8th-magnitude companion about 12′ to the south-southwest. IC 4593 is about 45′ further to the south-southwest, about 10′ north-northeast of 8.5-magnitude Star *b* – actually a tight double star Struve 2016 with a 10th-magnitude companion 7″ distant.

Before searching for this object, I was astutely aware that many amateurs have had trouble locating it. This seems surprising, since an 11th-magnitude "star" can be seen in a telescope as small as a 2.5-inch

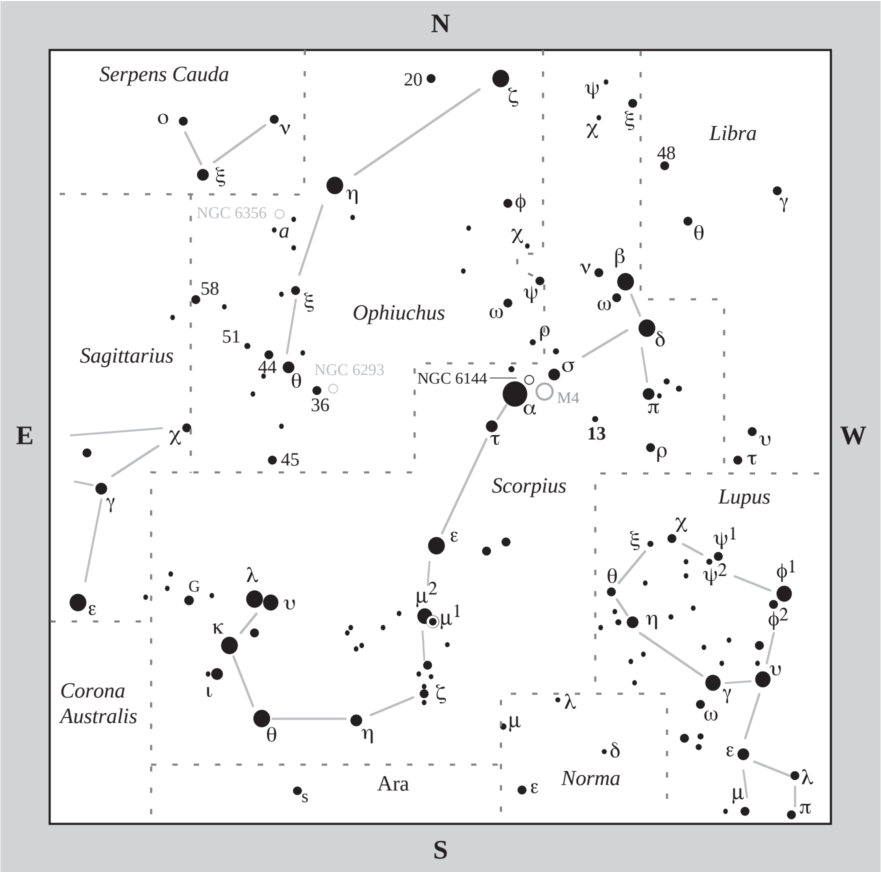


refractor. The problem appears to be that it is so bright that it's hard to believe that the "star" one is seeing at its position can actually be a planetary nebula. What's worse is that even through my 5-inch telescope (and I know others with much larger telescopes have all had the same experience) the nebula remains starlike until you reach magnifications of at least 70× and depending on the seeing conditions perhaps even 100×.

One night when I went out to study it, I found it virtually starlike at a power of 94×. What you're seeing, of course, is the nebula's 11th-magnitude central star! Higher magnification is required to resolve the tiny ~10″ nebulous disk from the star. But this is doable. The nebula has an extremely high surface brightness, so it can handle all manner of power. I found that the nebula just starts to show well at 180×. A power of 282× shows the bright stellar core surrounded by a very fine, though tight, halo of bright light. My most astounding view came at 495× – that's a magnification of virtually 100× per inch of aperture! At that grand magnification, the star and halo were clearly defined. I could make out a cross-shaped inner ring surrounded by a more diffuse and irregularly round halo. The details wafted in and out view, and it was a challenge to keep tracking the nebula with my driveless scope in such a small field of view, but the effort was worth the detail seen. Give it a try. And remember, in the corrupted vernacular of TV's U.S.S. Starship *Enterprise* engineer Scotty, "You've got to give it more power!"



Secret Deep 72
(NGC 6144)



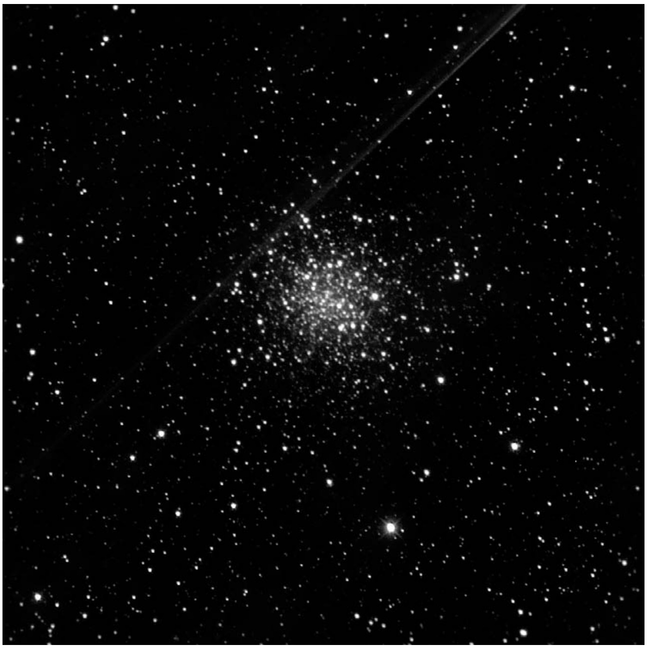
72

NGC 6144
Type: Globular Cluster
Con: Scorpius

RA: $16^h\ 27.2^m$
Dec: −26° 01′
Mag: 9.0
SB: 13.3 (Rating: 3.5)
Diam: 9′
Dist: ~27,700 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed May 22, 1784] A very compressed and considerably large cluster of the [faintest] stars imaginable, all of a dusky red colour. The next step to an easily resolvable nebula. (H VI-10)

NGC: Cluster, considerably large, much compressed, gradually brighter in the middle, well resolved, clearly consisting of stars.



NGC 6144 IS A PRETTY SECRET globular cluster about 40′ northwest of the ruby heart of the celestial Scorpion – 1st-magnitude Alpha (α) Scorpii (Antares) – and about 1° northeast of the much more famous and dazzling globular star cluster M4 (the Cat's Eye Cluster). All three are a sight to see in a rich-field telescope that gives a comfortable 2° field of view. But so brilliant is Antares, and so magnificent and large is M4 (rivaling a full Moon's apparent size), that they upstage lowly NGC 6144, thrusting it into the shadowy backdrop of this dark and dusty realm of the Milky Way.

Dusty indeed! This cluster lies on the other side of the bleak Rho (ρ) Ophiuchi dust cloud. At a distance of only 450 light-years, it's one of the nearest star-forming regions to the Sun. In photographs, the cloud is a complex web of wonder, a vast scrim of colorful reflection and emission nebulae, washed through and through with dark, serpentine forms of cold molecular matter. Here is arguably one of the most magnificent celestial landscapes in the heavens.

To those keen enough, and who have fields wide enough, the region can also inspire a sense of visual dread, as if one is visually crossing a desert at night. "For many years this part of the sky troubled me every time I swept over it in my comet seeking," Edward Emerson Barnard revealed in a letter to George Ellery Hale dated January 29, 1895; "though there seemed to be scarcely any stars here, there yet appeared a dullness of the field as if the sky were covered with a thin veiling of dust, that took away the rich blackness peculiar to many vacant regions of the heavens."

This very region was one of William Herschel's "holes in the heavens," a "*Loch im Himmel*," an unfathomable vacancy "though which we seem to gaze into an uninterrupted infinity." Herschel went so far as to suppose that, since these voids appeared near the richest star clusters, they would "almost authorize a suspicion that the stars of which it is composed, were collected from that place, and had left the vacancy."

William Sheehan in his must-read autobiography of Barnard, *The Immortal Fire Within* (Cambridge University Press, 1995), adds how, when Barnard photographed the region for the first time in March 23, 1895, he found "a vast and magnificent nebula, intricate in form and apparently connected with many of the bright stars of that region including Antares and Sigma Scorpii [one that] has scarcely an equal for interest in the entire heavens."

And it is here, between Antares and Sigma Scorpii that our target lies, in a remote corner of that well of darkness, looking as if NGC 6144 had constructed itself from whatever scraps of stars M4 could not grasp from the region. Of course, the idea is just fancy. When you look at the distances of these objects, the true three-dimensional expanse becomes awesomely apparent. Antares lies only 150 light-years behind the Rho Ophiuchi veil of dust; M4, the closest globular cluster to the Sun, is 6,650 light-years farther away. But NGC 6144 is a dizzying 21,000 light-years deeper again – so far behind the cloud that it lies a mere 8,500 light-years from the Galactic center. Note how Herschel, who must have been peering at this object so low in the sky, perceived the reddening of local extinction, describing its stars (the faintest imaginable) "all of a dusky red colour."

The dust in the region dims the cluster by nearly half a magnitude. Without it, NGC 6144 would shine at 8.5-magnitude and be just as bright as globular cluster M80 in Sagitta, or M56 in Lyra. As it stands, at 9th-magnitude, NGC 6144 is still 0.2-magnitude brighter than the dimmest Messier globular cluster, M72 in Aquarius. Proof, perhaps, that Antares' glare hid the cluster from view of Charles Messier or his contemporary Pierre Méchain (and others), who would have arguably snatched it up before William Herschel.

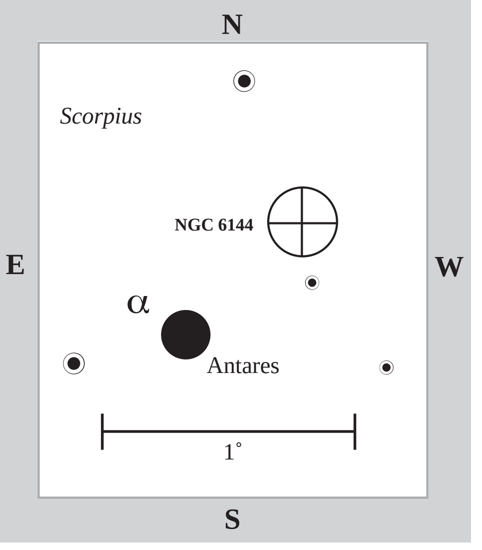
In true physical extent, NGC 6144 is relatively small, about 70 light-years across, making it somewhat similar in size to NGC 6712 in Scutum (Hidden Treasure 95), which is 0.8-magnitude fainter and about 5,000 light-years closer, and is moving 190 km/sec in approach. It's of a low-to-intermediate metal abundance, with its members containing, on average, about 1/56 as much iron (per unit of hydrogen) as does the Sun – a value matching that of the nearby Messier globular cluster M80 in Scorpius. If NGC 6144 has an age similar to that of other moderately metal-poor clusters, it may be around 10 billion years old – near the minimum age for the oldest Galactic globular clusters; the maximum age for globulars lies somewhere between 13 and 13.7 billion years.

Chandra X-ray Observatory and Hubble Space Telescope observations found six

X-ray sources within NGC 6144, four of which appear to be background sources. At least one, and perhaps two, of the sources are likely to be cataclysmic variables. These stars are most likely binary systems consisting of a white-dwarf primary and a red or orange main-sequence giant secondary that shows a sudden and dramatic increase in brightness. The outbursts are believed to occur when gases stripped from a red giant star by a closely orbiting and massive white-dwarf star, accrete into a disk (emitting X-rays in the process) that eventually "overloads" and explodes in a thermonuclear reaction, which we see as a flaring of the star. Unlike with a supernova event, however, which can totally destroy a star, a cataclysmic variable remains untouched, giving it a chance to repeat the process. The Chandra and HST observations did, in fact, confirm that one source in NGC 6144 is an active binary, based on both its X-ray and optical properties.

Again, locating NGC 6144 is easy. Simply use the chart on page 305 to locate brilliant Alpha Scorpii. Center that star in your telescope at low power, then switch to the chart on this page to ferret out the dim glow about 40′ to the northwest.

But first, take the time to enjoy reddish Antares, popularly known as the Rival of Mars. The name Antares is, in fact, derived from the Greek *ant- Ares*, meaning "like Mars." Through a telescope, though, the star's reddish hue to the unaided eye appears more sunburst orange. Keen skywatchers of ancient times noticed that Antares is only the rival of Mars when the planet appears most red to the unaided eye – which happens either early on, or late, in its *apparition* (defined by the period of time when the planet first



becomes visible before sunrise in the east to the time it departs the sky after sunset in the west); when Mars is closest to Earth, its color shifts to a cooler yellow.

Antares is indeed cool, being an M-type red supergiant star with a surface temperature of only 3,600 K. (Ever hear the saying, "Red giants aren't so hot!") But the star is nevertheless magnificent, 10,000 times more luminous than the Sun in visible wavelengths, and 60,000 times brighter than the Sun in the infrared. It's also extremely large. The star, which is 15 times more massive than the Sun, has an equatorial diameter of nearly 400 million miles, its body would stretch from our Sun out to the orbit of Jupiter; a hypothetical planet at Earth's distance would be consumed by the star's tenuous outer atmosphere. Antares is a semi-regular variable that varies in brightness by several tenths of magnitude over a period of years. As is the fate of all red supergiants, Antares is now nearing the end of its life and is expected to go supernova sometime in the dim future.

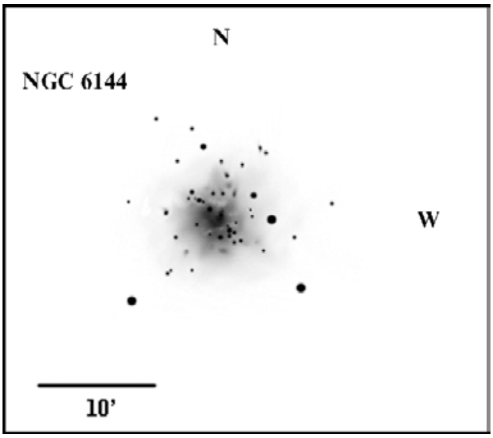
As I write this sentence, Antares is forging iron in its core. Unable to create any further heavier elements, the star will stop releasing energy, forcing the star's core to collapse. In a matter of a few precious seconds, the massive giant's surface will shrink to a sphere 6 miles across (the size of Manhattan Island); the rest of the star will violently collide into that core before rebounding a quarter second later as a cataclysmic supernova explosion, spewing matter across space at speeds of several thousand kilometers per second. Those watching from Earth will see the star shine with the light of a billion Suns – though, thankfully, seen from a distance of 600 light-years.

As the ejected matter flees into space, it will collide with interstellar material, heating it up and causing it to glow. The collisions will also seed the interstellar material with gold, silver, and other heavy metals. Indeed, your mother's wedding band, and the silverware you use to eat, are made of elements forged in a supernova explosion – the one that gave birth to our Solar System!

There's something else you should try to detect with your telescope. Antares has a little "green" companion – a result of simultaneous contrast, but fantastic to see nevertheless. You'll find the magnitude 5.5, type B companion star only 3″ to the west. The two orbit one another once every 2,500 years or so, so don't expect to see it move. A very steady atmosphere is required to see it in small telescopes, and I suggest looking in the twilight.

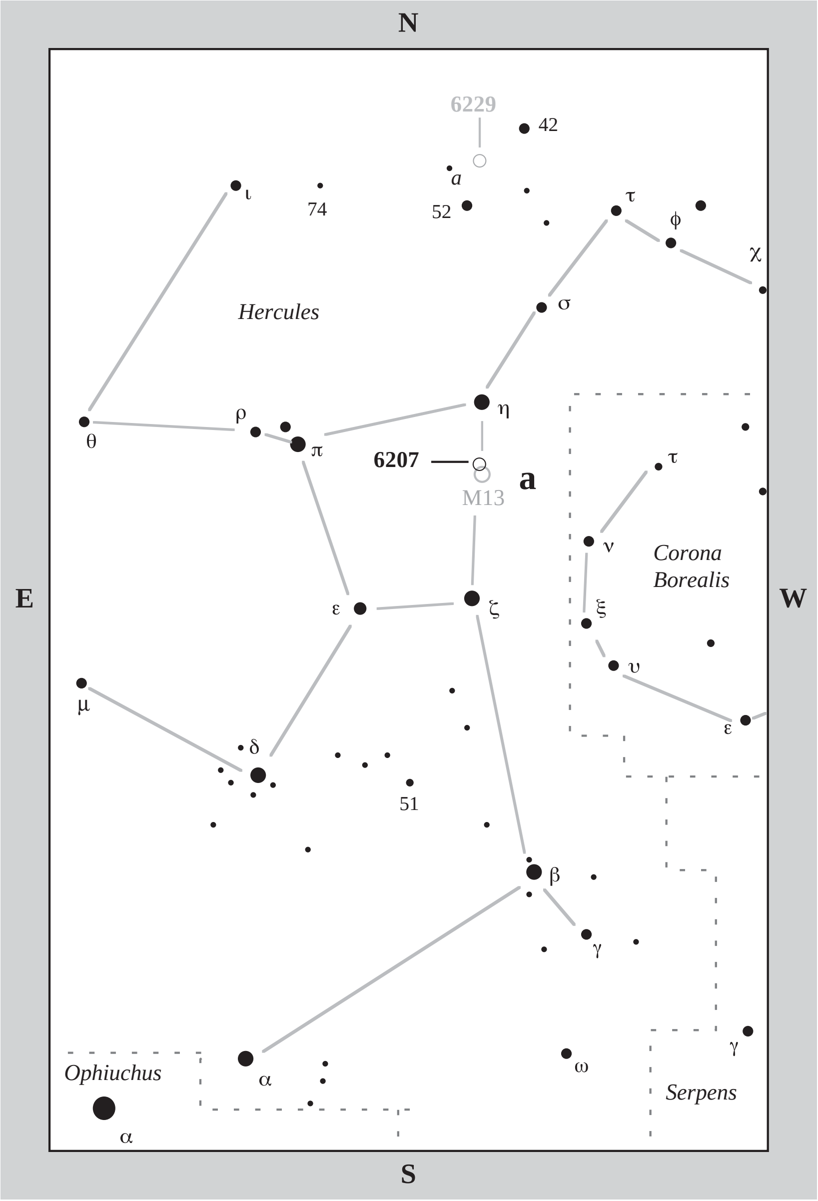
Once you're done admiring Antares, start your search for NGC 6144. As I said, NGC 6144 is one of the most overshadowed and overlooked globular clusters in the heavens, and can be easily mistaken for a ghost image of a star. As the late deep-sky expert Walter Scott Houston appropriately noted, "In the open sky this would be a most easy object, but Antares must be out of the field of view if any success is to be expected."

Actually, in the 5-inch at 33×, I found NGC 6144 quite visible with Antares in the field, appearing as a pretty little uniform glow, the brightest part of which measures about about 5′ across. With averted vision I could sense an irregularity to its form and a mottling across its face, but these glimpses are corrupted by the light of Antares, which continually tries to steal attention. At 60×, the globular is weakly resolved into little patches of faint light. A 12th-magnitude star bursts forth on its western side looking like a nova. At 94×, the globular shows a slightly brighter core, about 3′ in diameter, surrounded by an irregular halo peppered with dim suns (or bunches of them). A star of about magnitude 13 joins the 12th-magnitude star to the southwest.



At 180×, the cluster shatters into various ill-defined clumps of stars that seem to scintillate with dimmer suns. Averted vision shows its brighter core sliced by a row of stars oriented northeast–southwest, and another dimmer band jutting more or less to the north. The pair of stars to the west seem to cut off the cluster's fainter light, making it seem slightly out of round and extended more to the northwest. All this detail rests on a dim glow of unresolved suns.

Secret Deep 73
(NGC 6207)



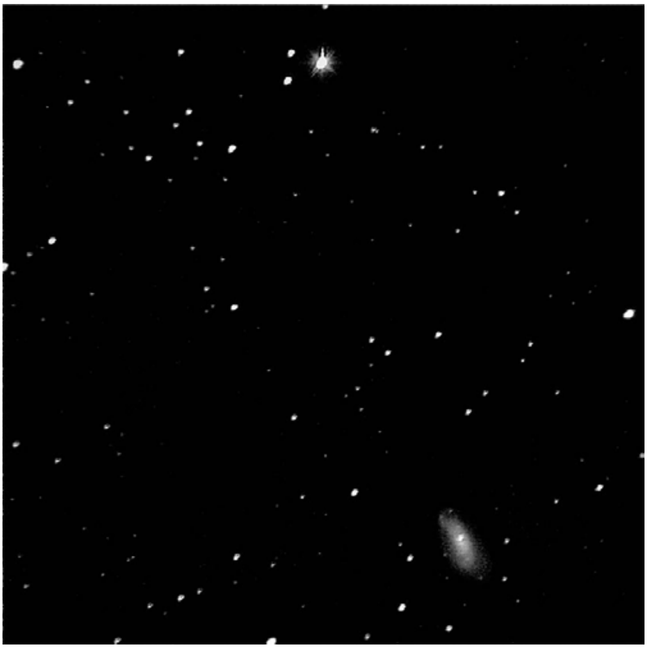
73

NGC 6207
Type: Spiral Galaxy (SA(s)c)
Con: Hercules

RA: 16^h 43.1^m
Dec: $+36°$ $50'$
Mag: 11.6
SB: 12.8 (Rating: 3.5)
Dim: $3.0' \times 1.1'$
Dist: ~69 million l.y.
Disc: William Herschel, 1787

W. HERSCHEL: [Observed May 16, 1787] Pretty bright, pretty small, extended south preceding north following, very gradually much brighter in the middle. (H II-701)

NGC: Pretty bright, pretty large, extended roughly toward position angle 45°, very gradually much brighter in the middle.



NGC 6207 IS A TINY SPIRAL WONDER hiding in the "shadow" of M13, the great globular cluster in the Keystone of Hercules, which is why I include it in the Secret Deep catalogue. In the summer of 2002, I was a guest at Starfest (Canada's largest annual star party) enjoying a striking view of M13 through a large Dobsonian telescope. But the owner wasn't aware that in the same field of view, just 30′ from the cluster's core, was a small extragalactic lens of light nearly 70 million light-years beyond the farthest reach of the great globular's arms. So I showed it to him. His reaction of delight inspired me to spotlight the galaxy in this book.

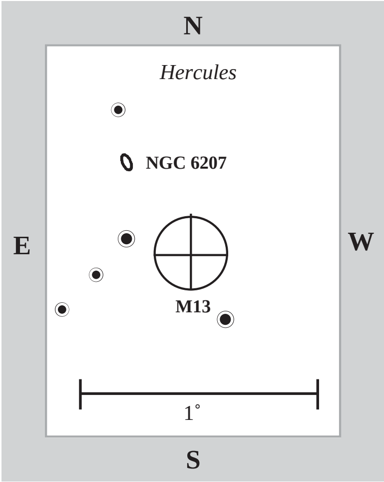
I don't blame the owner for not being aware of NGC 6207, which is one of the most understated spirals in the heavens. Yet I know many observers who say they've enjoyed seeking out NGC 6207, which really is a surprising little gem, especially since it is paired with such a grand spectacle as M13. These pleasant reactions confirm my belief that we not only enjoy seeing deep-sky objects paired but also less obtrusive ones that go unnoticed owing to the unfortunate circumstance of being so near a celestial celebrity; everyone likes an underdog to shine! I know how I felt when I first saw this gem through the 9-inch refractor at Harvard College Observatory, because my observing partner Peter Collins had done to me what I had done to the Canadian observer mentioned above; and my reaction was much the same: delightfully surprised.

Professional studies of NGC 6207 are particularly anemic. The S-shaped spiral belongs to the Draco Cloud of galaxies and is receding from us at a speed of 62 km/sec. If we accept the distance of 69 million miles, it has a diameter of 60,000 light-years and a luminosity of 10 billion Suns. The lens-shaped disk, which we see inclined 18° from edge on, has three obvious (albeit small), crinkled arms rich in HII regions. Two of the arms sweep out to the southwest, the other is more open on the opposing side.

The character of NGC 6207's spiral arms and the high surface brightness of its central lens is similar to that of the 7th-magnitude, mixed spiral galaxy NGC 2403 (Caldwell 7), which lies only 14 million light-years distant in the direction of Camelopardalis. Indeed, as I describe in *Deep-Sky Companions: The Caldwell Objects*, NGC 2403's face "explodes" with clumps of starlight, one of which is larger than any HII region known in our Milky Way.

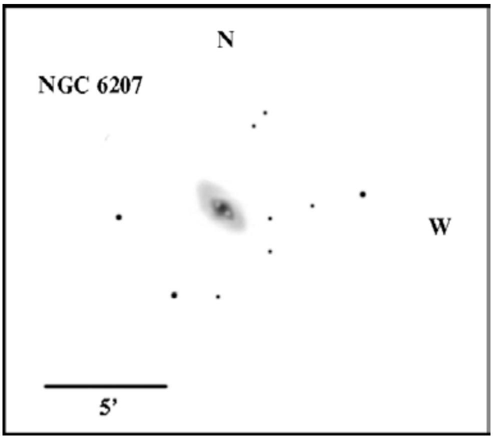
NGC 6207's nuclear region may seem of special interest because it appears strikingly starlike, but as Daniel W. Weedman (Dyer Observatory) and Robert F. Carswell (Steward Observatory) report in a 1974 *Astrophysical Journal*, that apparent nucleus is a foreground object in our own galaxy with a spectrum of an early F star.

On January 9, 2004, Koichi Itagaki of Yamagata, Japan, discovered on CCD frames taken with an 11-inch f/10 reflector a magnitude 15.7 supernova 22″ west and 17″ north of NGC 6207's center. Known as Supernova 2004A, it is probably a Type II event, which is due to the core collapse of a massive star leading to a powerful explosion of the star; the blast from Supernova 2004A is believed to have expanded into space with a velocity of 12,000 km/sec, scattering heavy elements, like iron, into the surrounding interstellar medium.



To find the little jewel, use the chart on page 311 to locate M13, which is about 2½° south of 3.5-magnitude Eta (η) Herculis; under a dark sky, M13 can be seen as a fuzzy, 5th-magnitude star with the unaided eye. Center M13 in your telescope at low power, then use the chart on this page to star hop to NGC 6207, which is only about 30′ northeast of M13's core.

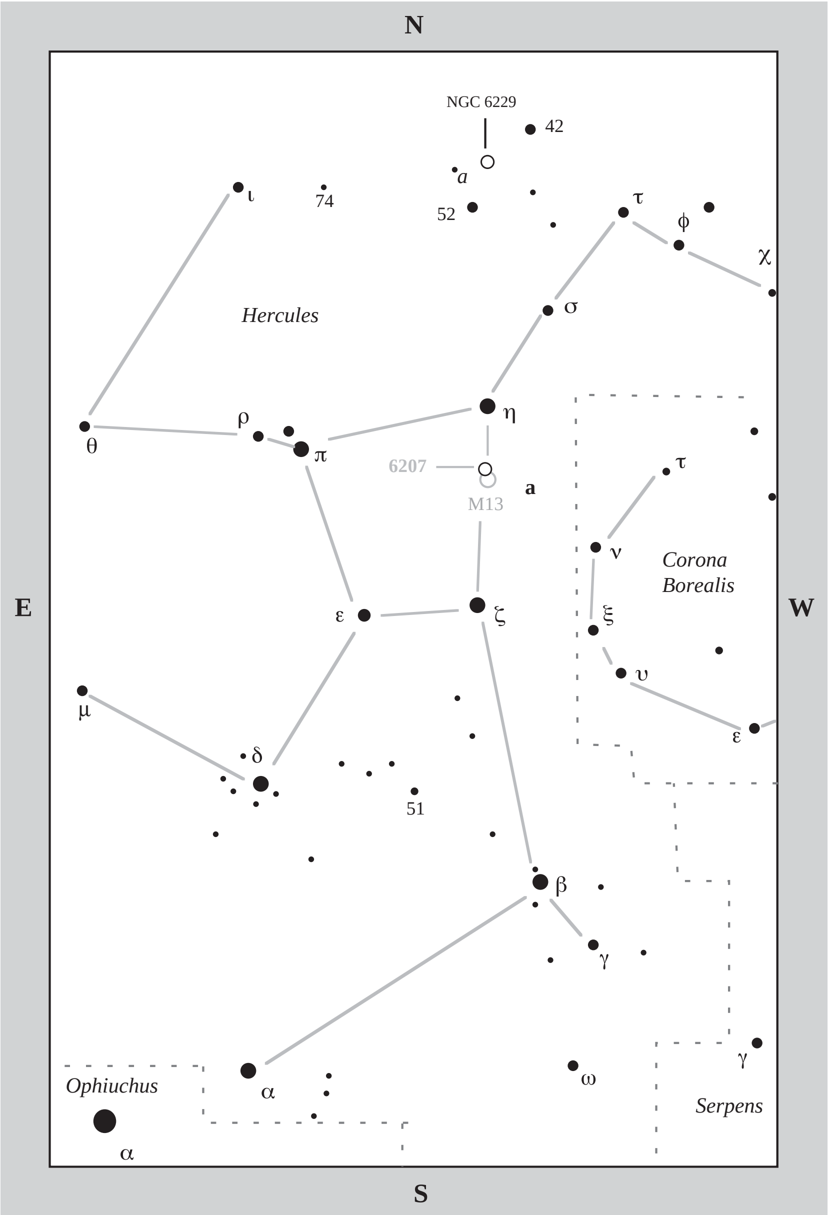
Remember, the galaxy is small, so I recommend using moderate magnifications to find it, which may still require use of averted vision. Once you find it, you can always change to low power to see if you can detect it, which may require advance knowledge of its appearance at moderate magnification and knowing exactly where to look. Under dark skies, I have seen NGC 6207 in a 4-inch telescope; at 74×, it appeared as a weak 2′-long ellipse that popped into view with averted vision. Under the same



skies through the 5-inch, the galaxy's core is visible at 33× as a dim puff of light only about 1′ in extent – awesome nevertheless considering M13 is in the same field of view as a bright and brash spectacle of glittering starlight.

At 60×, the galaxy is quite apparent, appearing as a little foggy ellipse 3′ long (oriented northeast to southwest) with a fuzzy central lens; it's that simple. The galaxy's core is quite concentrated, though, so it holds up well with magnification. At 94×, the star at the heart of the central lens stands out well, as do two arcs of light, like ears, framing the northeast and southwest edges of that lens. The remaining disk is just a structureless elliptical wash of light, all beautiful in its simplicity, like freshly fallen snow.

Secret Deep 74
(NGC 6229)



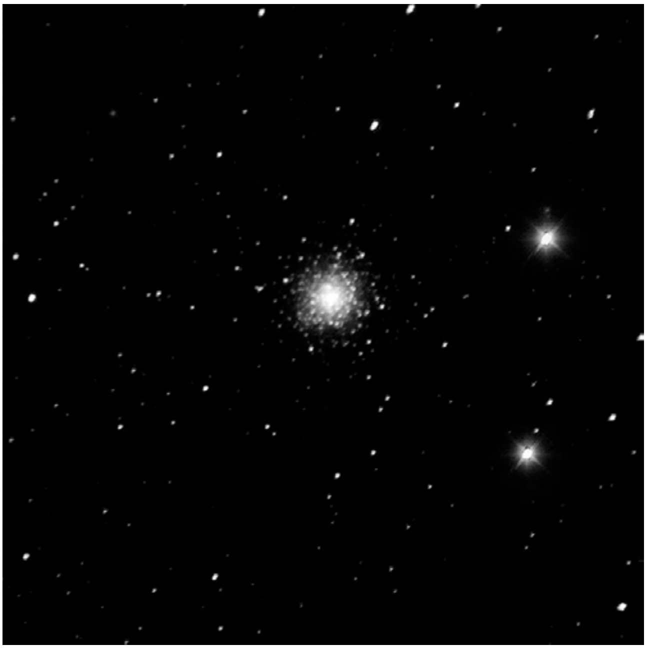
74

"Prize Comet" Globular
NGC 6229
Type: Globular Cluster
Con: Hercules

RA: 16^h 46.9^m
Dec: +47° 32′
Mag: 9.4
SB: 12.7 (Rating: 3.5)
Diam: 4.5′
Dist: ~100,000 l.y.
Disc: William Herschel, 1787

W. HERSCHEL: [Observed May 12, 1787] Very bright, round, 4′ in diameter, almost equally bright with a faint round margin. (H IV-50)

NGC: Globular cluster, very bright, large, round, disc and faint border, resolved.



NGC 6229 IS A SMALL BUT VERY conspicuous globular cluster about 1½° north-northwest of 5.5-magnitude 52 Herculis, between the left heel and the right knee of the celestial Strongman. When William Herschel discovered it in 1787, he classified it as a planetary nebula, owing to the object's fantastically round structure. What's more, the nineteenth-century British observer Admiral William Henry Smyth said it was not only round but that it also shined with a "lucid pale-blue hue." One has to wonder if this was merely a visual suggestion brought on by the knowledge that many planetary nebulae shine with blue-green shades. If true, it is evidence that the mind has a "say" in what we see. Then again, the blue color might be a color-contrast illusion, due to the fact that an orange star lies very close to it to the southwest.

Smyth also elaborates on the cometary nature of this object, inferring that the great comet hunter Jean-Louis Pons (1761–1831) mistook it for one in 1819, which he offered as a "prize comet" to his patron, her Majesty Maria Louisa of Bourbon. In that year, Maria Louisa had appointed Pons director of the new observatory at the Villa Reale di Marlia near the city of Lucca in Tuscany. As "her Majesty's *astroscoper*," Pons was to receive 100 dollars from the royal purse for every new comet he discovered. "But the establishment, though commenced under considerable pomp and circumstance, only lingered about four years, and was then formally abolished," Smyth says.

NGC 6229's nature began to unravel in 1856, when Heinrich Louis d'Arrest identified it as a "very crowded cluster." A decade later, William Huggins noted, in an 1866 *Philosophical Transactions* paper titled "Further Observations on the Spectra of some of the Nebulae," that the object's spectrum was unlike that of a gaseous nebula, but continuous, like that of a star cluster. The object's identity was still uncertain in 1908, when, in an *Annals of Harvard College Observatory* (vol. 60, p. 199), Solon Irving Bailey included NGC 6229 in his "Catalogue of Bright Clusters and Nebulae," identifying it as a questionable globular cluster. He also noted that was "extremely condensed" and "not resolved" on a 10-minute exposure made with the observatory's 24-inch Bruce telescope.

In 1912, Heber D. Curtis at Lick Observatory identified NGC 6229 only as a "small, greatly condensed cluster," based on its appearance on plates taken with the 36-inch Crossley reflector. The cluster's identity remained uncertain until 1917, when Harlow Shapley, in his "Descriptive Notes to Nine Clusters," published in a *Publications of the Astronomical Society of the Pacific* (vol. 29, p. 185), says that NGC 6229, "whose type is recorded as uncertain," is a "globular cluster, very much condensed." The identity was made possible by examining a 69-minute exposure of NGC 6229 taken with the 60-inch at Mount Wilson, on which he and Francis Pease counted 1,540 stars in the cluster out to an "extreme diameter" of 5′; the cluster's mildly concentrated core was measured to be only 1.5′. The counts, Shapley says, "show a trace of ellipticity, notwithstanding the small number of stars involved." That same year, Helen Davis used 60-inch-telescope plates of the cluster to discover its first variable star – the second brightest star in the cluster when at maximum magnitude.

NGC 6229's nature was a bear to label because it's one of the most remote globular clusters known in our Galaxy, lying about 100,000 light-years from the Sun and the Galactic center. Studies of it are important, then, as they can help astronomers better determine the halo's property and history. Several studies have shown NGC 6229 to have a mildly poor metallicity, with about 1/15 as much metal (per unit hydrogen) as does our Sun.

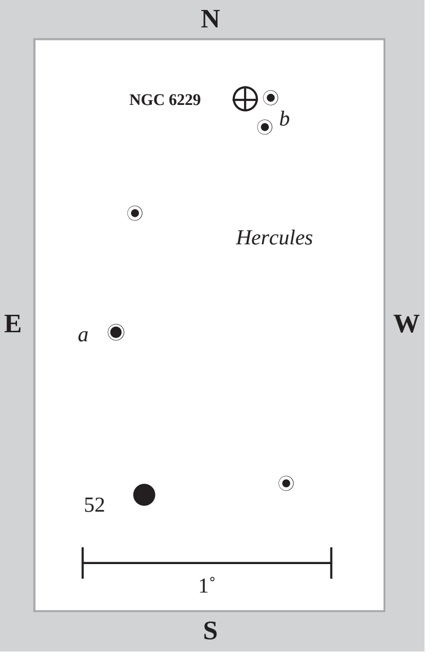
In a 1999 *Astronomy & Astrophysics* (vol. 343, pp. 813–824) Jura Borissova (University of Valparaíso, Chile) and colleagues found that NGC 6229, whose integrated spectral type is F7, has about the same metal content as M5, a typical halo cluster 26,000 light-years distant; though M5 has a very eccentric orbit that takes it far from the Galactic plane. They also found the two clusters to have nearly identical ages, roughly 13 billion years, give or take 1 billion.

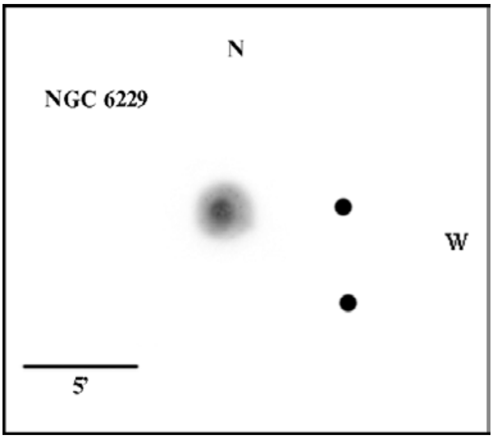
Their color–magnitude diagram of the cluster's crowded core shows an entire giant branch in addition to its relatively blue horizontal branch. The horizontal branch is also peculiar in that it is bimodal. Oleg Y. Gnedin (University of Michigan) and colleagues note that globular cluster systems in most large galaxies display bimodal color and metallicity distributions, which are frequently interpreted as indicating two distinct modes of cluster formation. In an invited talk at a 2009 IAU Symposium in Rio de Janeiro, Gnedin's team argued that if all globular clusters form only during mergers of massive gas-rich protogalactic disks, their metallicity distribution could be statistically consistent with that of the Galactic globulars. They therefore suggest that bimodality arises naturally as the result of a small number of late massive merger events.

All globular clusters are dominated by aged red-giant stars. Those not particularly metal rich usually contain RR Lyrae stars. Thus, Borissova and colleagues also made an extensive CCD survey (the first of its kind on this cluster), in which they obtained periods for 36 previously known/suspected variable stars and 12 newly discovered variables – including 15 RR Lyrae pulsators and one eclipsing binary (Algol-type). In fact, NGC 6229's confirmed variable-star population is mostly composed of RR Lyrae stars. The cluster may also contain two Population II Cepheids of the W Virginis type.

Mixed in with the cluster's old stars are some "youngsters" known as blue stragglers. Borissova's team identified 22 blue-straggler candidates in the cluster, the fraction of which is similar to that of M13, the Great Cluster in Hercules.

To find this distant wonder, use the chart on page 315 to find 52 Herculis, which is about 7° north-northeast of 3.5-magnitude Eta (η) Herculis. It also forms the northeastern apex of a near-equilateral triangle with the 4th-magnitude stars Sigma (σ) and Tau (τ) Herculis. Center 52 Her in your telescope at low power, then switch to the chart on this page. From 52 Herculis, move 40′ north-northeast to 7th-magnitude Star *a*. Now make a slow sweep 1° northwest to a pair of 8th-magnitude stars (*b*), oriented north-northwest to south-southeast and separated by 5′. NGC 6229 is only 5′ east-northeast of Pair *b*.

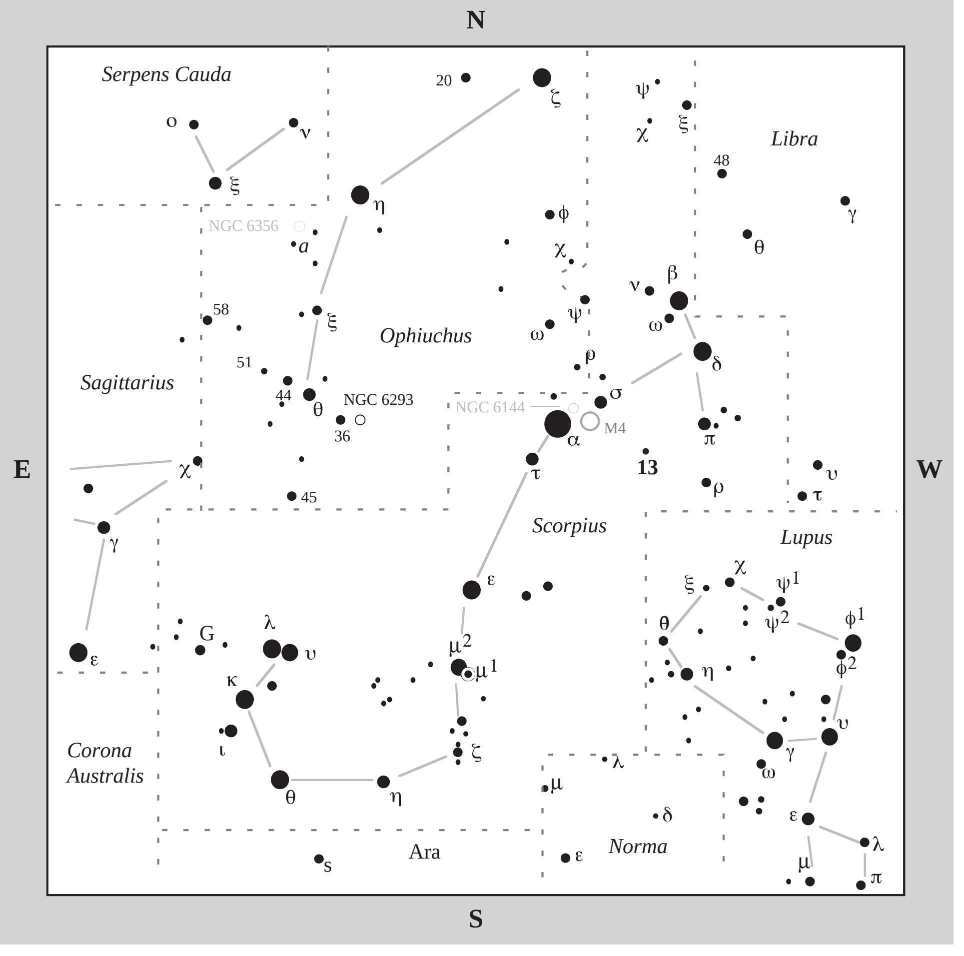




At 33×, NGC 6229 is a very bright and relatively condensed (~1′) glow that I find beautiful in its purity of light. As Pons believed, the cluster looks like a comet flaring into view. Making the view all the more dramatic is that the cluster forms the eastern vertex of a 5′-wide right triangle with two 8th-magnitude suns, the southwestern of which shines with a lovely orange hue. The cluster is bright enough and condensed enough to be seen with a direct gaze, which only shows the core. The object swells to twice the core's extent with averted vision, the extension being fainter but equally round.

At 60× and 94×, the cluster takes on a mottled appearance, but I find it hard to pinpoint the exact location of these features, which cause the eye to jump randomly about. At powers ranging between 180× and 282×, the cluster's core is definitely mottled with a prominent clump to the northwest. Otherwise, the object is a circular globe comprising a tight core and faint outer halo of unresolved starlight.

Secret Deep 75
(NGC 6293)



75

NGC 6293
Type: Globular Cluster
Con: Ophiuchus

RA: 17^h 10.2^m
Dec: $-26°$ 35′
Mag: 8.2
SB: 12.9 (Rating: 4)
Diam: 7.9′
Dist: ~27,400 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed May 24, 1784] Another miniature cluster like the preceding [NGC 6284] but rather coarser. (H VI-12).

NGC: Globular cluster, very bright, large, round, pretty suddenly brighter in the middle, well resolved, clearly consisting of stars, stars of magnitude 16 and fainter.

NGC 6293 IS A SMALL BUT NICELY condensed globular star cluster less than 1¼° west of 4th-magnitude 36 Ophiuchi – nearly midway between it and the brighter (magnitude 6.8) and much more popular globular cluster M19 between the Scorpion's back and the Serpent Bearer's left foot. This is in the region that the nineteenth-century British observer Admiral William Henry Smyth says affords "a grand conception of the grandeur and richness even of the exterior creation; and indicate[s] the beauteous gradation and variety of the heaven of heavens. Truly has it been said, 'Stars teach as well as shine.'"

He also noted that this region is near the large opening or hole, about 4° broad, in the Scorpion's body that William Herschel found almost destitute of stars. The implication was, as Herschel had speculated in his famous 1785 paper, "On the Construction of the Heavens," that when globular and open clusters formed, they robbed the nearby heavens of stars, leaving behind "great cavities or vacancies by the retreat of the stars toward the various centers which attract them..."

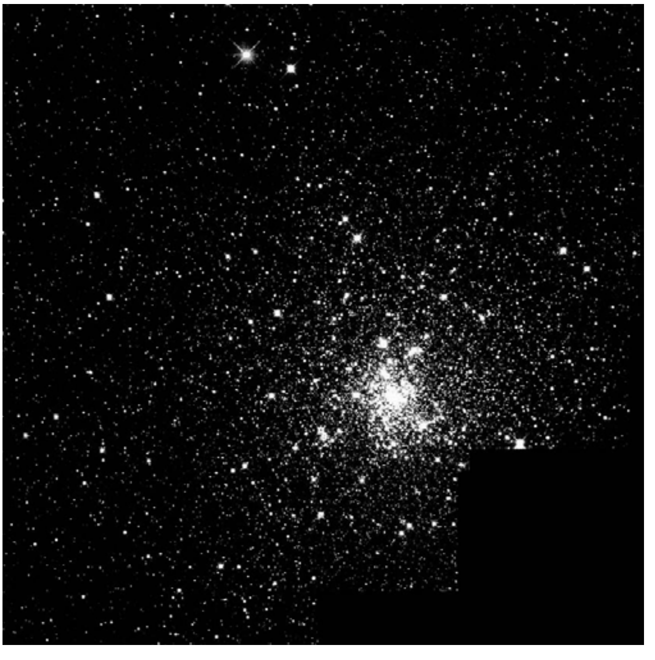
Although we now know that Herschel's theory doesn't hold starlight, globular cluster studies have evolved into an important area of research that's helping astronomers figure out the construction of our Galaxy. Although much progress has been made, questions associated especially with the formation and early evolution of our Galaxy remain unanswered.

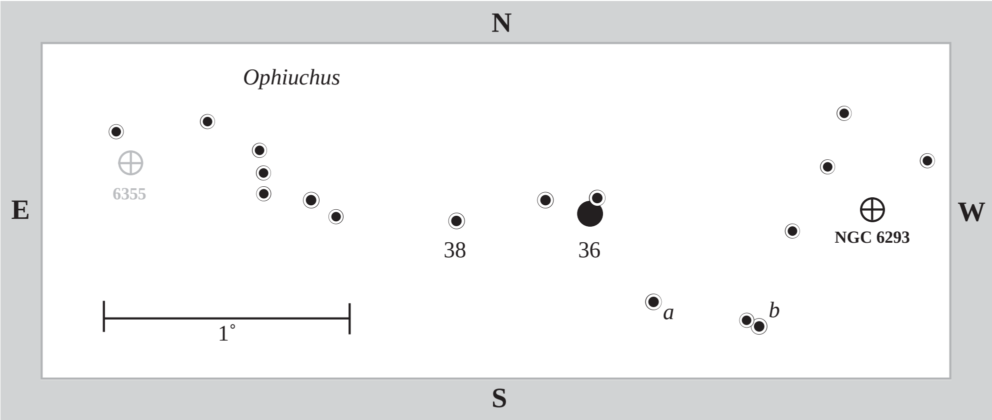
In 1993, Robert Zinn argued that the bulk of the old halo globular clusters formed during a monolithic dissipative collapse, while the young halo globular clusters formed independently of the Galaxy and later accreted into our Galaxy. But the most accepted scenario (the inside-out theory) today is that the Galaxy formed as a result of small density perturbations in the early universe that cooled, condensed, and grew by gravitational attraction into a larger system over time. Whether the Galaxy formed from a single collapsing and fragmenting gas cloud, or was built up from smaller clouds that coalesced, astronomers agree that the most metal-poor stars in a region should be the oldest. Thus, as Richard Larson (Yale Astronomy Department, New Haven, Connecticut) says, globular clusters are "almost certainly fossil remnants of the early star-forming subsystems from which galaxies were built."

To find out how rapidly star formation began throughout the Galaxy and its then more numerous proto-Galactic fragments, Young-Wook Lee (Yonsei University, Seoul, South Korea) and Bruce W. Carney (University of North Carolina, Chapel Hill) used the Hubble Space Telescope to explore the relative ages of NGC 6293 – the second most metal-poor globular cluster within 10,000 light-years from the Galactic center; it lies 3,900 light-years from that point – and NGC 6541 (Caldwell 78) in Corona Australis, another old inner halo globular cluster.

The researchers report, in a 2006 *Astronomical Journal* (vol. 132, pp. 2171–2186), that the most notable result of their study is that both NGC 6293 and NGC 6541 are about 14 billion years old, or about the same age as M92 (which lies 31,000 light-years from the Galactic center); the relative age difference between the two clusters is less than 0.5–1 billion years. This finding suggests that globular cluster formation must have started everywhere at about the same time in our Galaxy. But with a sample of two, Carney says, it's hard for them, or anyone, to conclude firmly that star formation began rapidly everywhere. "It is *consistent* with such a model," Carney says, noting that the research is an important contribution.

Lee and Carney also found NGC 6293 to have a well-developed blue horizontal branch, particularly in the central part of the cluster. Indeed, this type F3 globular is a post-core-collapse cluster with blue stragglers in its central region (2.5′), which



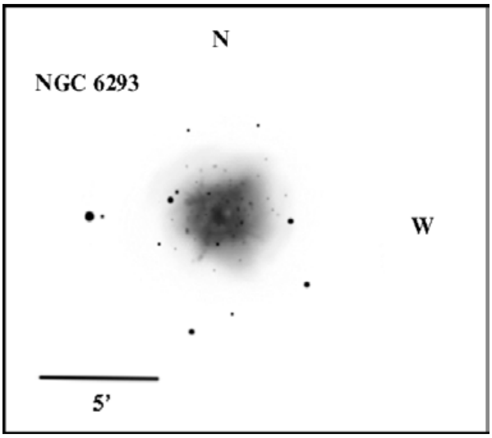


is reddened by varying degrees – from 0.2 to about 0.4 magnitude. This reflects its metal-poor status, having only 1/98 as much iron (per unit hydrogen) as does our Sun.

The researchers found quite a few blue-straggler candidates in the HST data. Discovered more than half a century ago, blue stragglers – stars that appear mysteriously younger than their cluster comrades (as if they were somehow born later than most of the cluster's stars) – are now thought to be formed when the stars in a double system slowly merge or when two unrelated stars collide in the compact confines of these core-collapse clusters, as shown in the HST image on page 322.

To find this interesting cluster, use the chart on page 320 to locate 36 Ophiuchi, which is about 2° southwest of 3rd-magnitude Theta (θ) Ophiuchi. Center 36 Ophiuchi in your telescope, then switch to the chart on this page. You can either make a direct sweep 1¼° west to nab the cluster, or you can make a series of short hops. From 36 Ophiuchi, move a little more than 25′ southwest to 7th-magnitude Star *a*. Now make a roughly 30′ hop west-southwest to similarly bright Star *b*. NGC 6293 lies a little less than 40′ northwest of Star *b*.

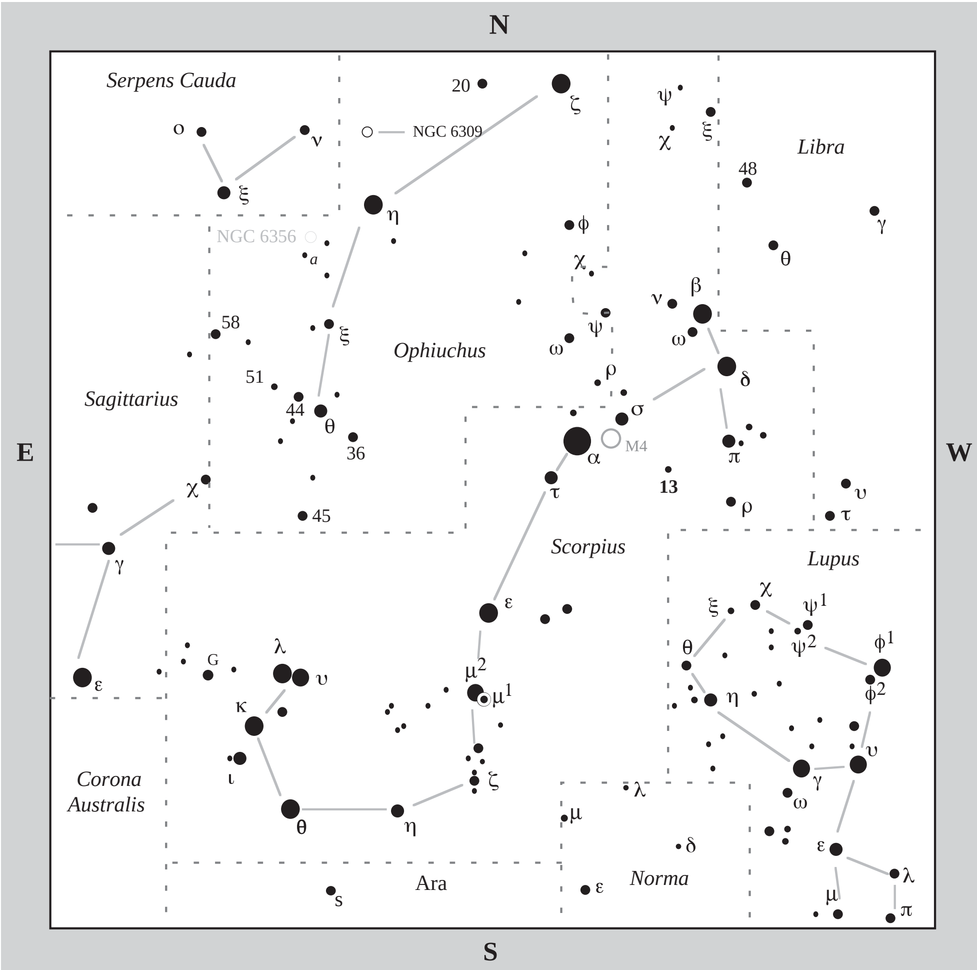
At 33× in the 5-inch, NGC 6293 is an easy sight – a nicely condensed globe of light, about 4′ in diameter, with a bright core surrounded by a mottled halo. With averted vision, the core looks very irregular, like lumpy mashed potatoes, while the halo appears softly dappled. Since the cluster's core is so well defined, I bumped up the power to 94×, which revealed a three-tiered structure: an intense disk of light at the core surrounded by a diamond-shaped



inner halo of fractured starlight within an irregularly round outer halo that sizzled with packs of suns on the verge of resolution.

The cluster's brightest stars shine at magnitude 14.3, so they are within reach of modest-sized telescopes, though its horizontal (RR Lyrae) branch magnitude is 16.5. A moderately dim star lies off its east-northeastern flank. At 180×, the core remains fantastically compact; the inner halo becomes elongated (like a warped bar) stretching from the north-northwest to south-southeast; it also bulges prominently to the east toward the dim sun. The cluster's outer halo continues to simmer with little suns, which blossom into flower-petal shapes.

Secret Deep 76
(NGC 6309)



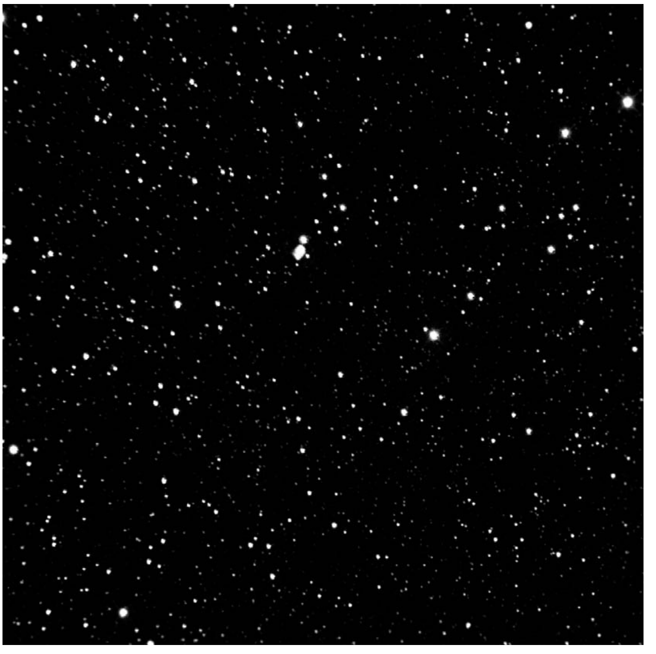
76

Box Nebula, Exclamation Mark
NGC 6309
Type: Planetary Nebula
Con: Ophiuchus

RA: $17^h\ 14.1^m$
Dec: $-12°\ 55'$
Mag: 11.5 (Rating: 3)
Dim: $>16''$
Dist: ~7,700 l.y.
Disc: Wilhelm Tempel, announced in 1878

W. TEMPEL: [*Astronomische Nachrichten*, vol. 178, no. 2122] A bright little nebula; stands midway between two very close stars in a line, but can be recognized easily in the middle as a nebulous star. Position very uncertain. (GC 5851)

NGC: Bright, small, between 2 stars very near.



ALTHOUGH SMALL, NGC 6309 IS another rewarding planetary nebula that encourages the judicious use of high power. The tiny nebula escaped notice until the late nineteenth century, when Wilhelm Tempel (1821–1889) discovered it visually with the 11-inch Amici refractor at Arcetri Observatory in Florence. The German-born astronomer included the object in a list of 56 new nebulae he discovered, which was published in an 1878 *Astronomische Nachrichten* (vol. 178, no. 2122). John Luis Emil Dreyer of Armagh Observatory included it in his 1878 *A Supplement to Sir John Herschel's General Catalogue of Nebulae and Clusters of Stars*, bestowing upon it the GC designation 5851.

Tempel was an astute and prolific observer. He would ultimately be credited with the discovery of 123 true nebulae, including Tempel's Nebula (NGC 1435) in the Pleiades. He also discovered or codiscovered 21 comets (including 55P/Tempel–Tuttle, the parent body of the Leonid meteor shower, and 9P/Tempel, into which NASA smashed its Deep-Impact probe in 2005).

Four years after Tempel discovered NGC 6309, Harvard College Observatory director Edward C. Pickering determined its true nature. In an 1882 *Astronomische Nachrichten* (no. 2454, p. 95), Pickering announced that Tempel's object is a planetary nebula, "detected by means of its spectra as seen through a direct vision prism." Curiously, Pickering noted that Tempel's description of the nebula being "between two stars" did not seem applicable. Instead, he said, the nebula is "oblong" with a "small star just below." Actually, both Tempel and Pickering are correct. NGC 6309 does lie between two stars in a row, and there is another star "beneath" it. Perhaps, since that latter star is the second brightest in the field, and is not in a line with the nebula and the brighter star above it, Pickering thought Tempel's description inappropriate.

Today we know NGC 6309 as a little wonder 19,000 light-years from the Galactic center and 2,000 light-years from the Galactic plane. Ground-based and HST imaging reveal it to be a high excitation nebula with an ionized mass of 0.07 Sun. HST images show the nebula's rich internal structure to be a deformed torus that is expanding at about 25 km/sec. The ring is tilted 70° with respect to the plane of the sky and (assuming it's a circle) 72° with respect to our line of sight. Accepting a distance of 7,700 light-years, the ring spans only 0.75 light-years across.

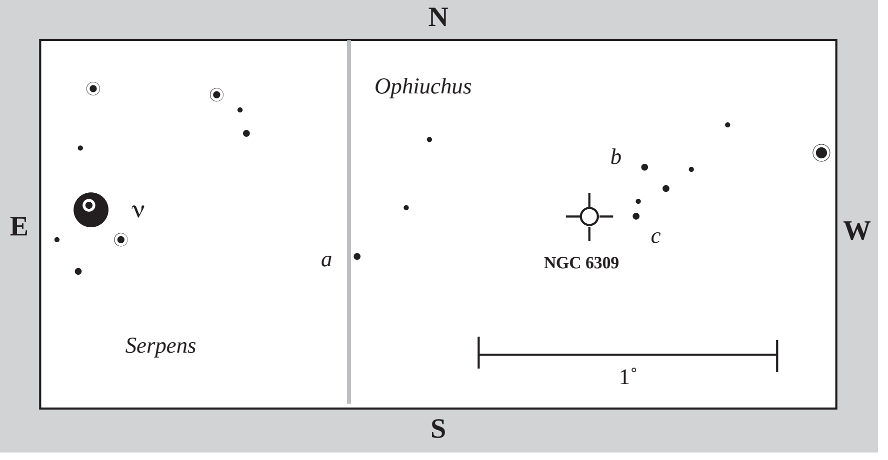
The ring is surrounded by a mass of amorphous detail. Most interesting are two, faint, S-shaped arms, which "spiral" away from the ring in a perpendicular direction. Such "point-symmetric" morphology is usually believed to result from the consequence of the episodic ejection of material in a two-sided jet that "wobbles" or rotates. But in a 2008 *Astronomy & Astrophysics* (vol. 481, pp. 107–116), Roberto Vázquez (Instituto de Astronomía, UNAM, Ensenada, Mexico) and his colleagues say that this appears not to be the case.

The point-symmetric structures, the authors say, do not emit in [NII] as would be expected from jet-like ejecta. Instead, NGC 6309 appears to be a quadrupolar nebula with two pairs of bipolar lobes whose axes are oriented at position angles 40° and 76°. The knotty lobes or cavities seem to protrude from the extremes of the internal ring instead of the nucleus – in 1918, Heber Curtis at Lick Observatory assigned magnitude 13 to the central star, but in 1974, S. J. Czyzak and Lawrence H. Aller reported that the central star is much fainter than that. HST imaging revealed the central star to be a binary with a main-sequence companion less than 1″ away.

The lobes are expanding at velocities of ~40 km/sec, which is typical of those found in other bipolar planetary nebulae. The authors also found evidence for the presence of a faint halo, possibly related to the envelope of the asymptotic giant branch (AGB) star progenitor. These jets carved the bipolar lobes in the previous AGB wind; their remnants are now observed as the point-symmetric knots tracing the edges of the lobes.

The authors conclude that NGC 6309 was formed by a set of well-collimated bipolar outflows (jets), which were ejected in the initial stages of its formation as a planetary nebula some 3,700 to 4,000 years ago. Thus NGC 6309 is of a similar age and stage of evolution as IC 2149 (see Secret Deep 23).

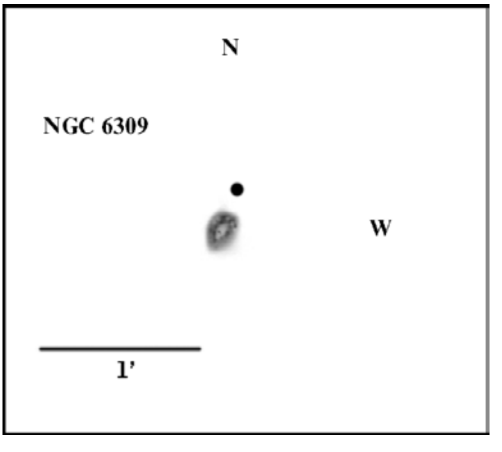
To find this tiny beauty, use the chart on page 325, and set your sights on 2nd-magnitude Eta (η) Ophiuchi (Sabik), part of the Serpent Bearer's skirt. Next locate 3rd-magnitude Nu (ν) Serpentis nearly 4° to the northeast. Center Nu in your telescope at low power, then use the chart on page 328 to find NGC 6309 about 1½° west,



and slightly south of Nu. From Nu, hop about 55′ west-southwest to 8th-magnitude Star *a*. NGC 6309 is about 45′ further to the west-northwest, just ~18′ southeast of another 8th-magnitude sun (*b*), and 10′ due east of a magnitude 9.5 Star *c*.

In the 5-inch at 33×, the nebula is immediately apparent as a fuzzy double star in a rich field of stars. Actually, the fuzzy double is the combined light of NGC 6309 and an 11.5-magnitude sun ~25″ to its north. Close and faint double stars (such as M40 in Ursa Major) have a tendency to trick the eye into believing that the stars are surrounded by nebulosity, and the same applies here. Thus the glow I saw at 33× was half illusory. At 60×, the nebula stands out well from its northern neighbor. Consequently, in the mind's eye, the nebula appears to shrink dramatically – since the illusory "glow" around the nearby star disappears. The nebula now stands alone as a small and softly glowing orb. The view doesn't change much at 94×.

The best views I had were between 282× and 495×. At the lower range, the nebula appears as a well-defined gray oval ~20″ across, with a clear central cavity filled with gauze-like light. The ellipse is angled north-northwest–south-southeast and is nonuniformly illuminated. With averted vision and 282× the rim's northwestern end looks broken into three nebulous knots. A fainter bead lies midway along the eastern rim, though, at times, I wondered if this were not the central star. In images, the central star does hug the eastern inner lip of the ring, which we see at an angle. At 495× and averted vision, the



details remain the same, though the inner lip of the torus runs along the nebula like a fine thread. The ring's dimmer, southern extremity seems to flare to the south.

At no point did I detect the fainter stars that Tempel and Pickering noticed, though I did not try for them. In other words, they aren't readily visible in a 5-inch at a glance. It's amazing, though, what one can miss seeing when one's concentration is fully focused on a particular object or detail.

As reported online at www.visualdeepsky.org, in June 2003, Massachusetts amateur Lew Gramer observed NGC 6309 with a 25-inch f/3.5 Dobsonian set up at The Amateur Telescope Makers of Boston's Britton Clubhouse and Milon Observing Field in Westford, Massachusetts. The nebula, he said, was barely noticeable as a blue-green "blip" in the telescope's 80-mm finder. He then went on to study it using powers ranging from 110× to 460× (as well as, at times, with ultra-high-contrast and OIII filters).

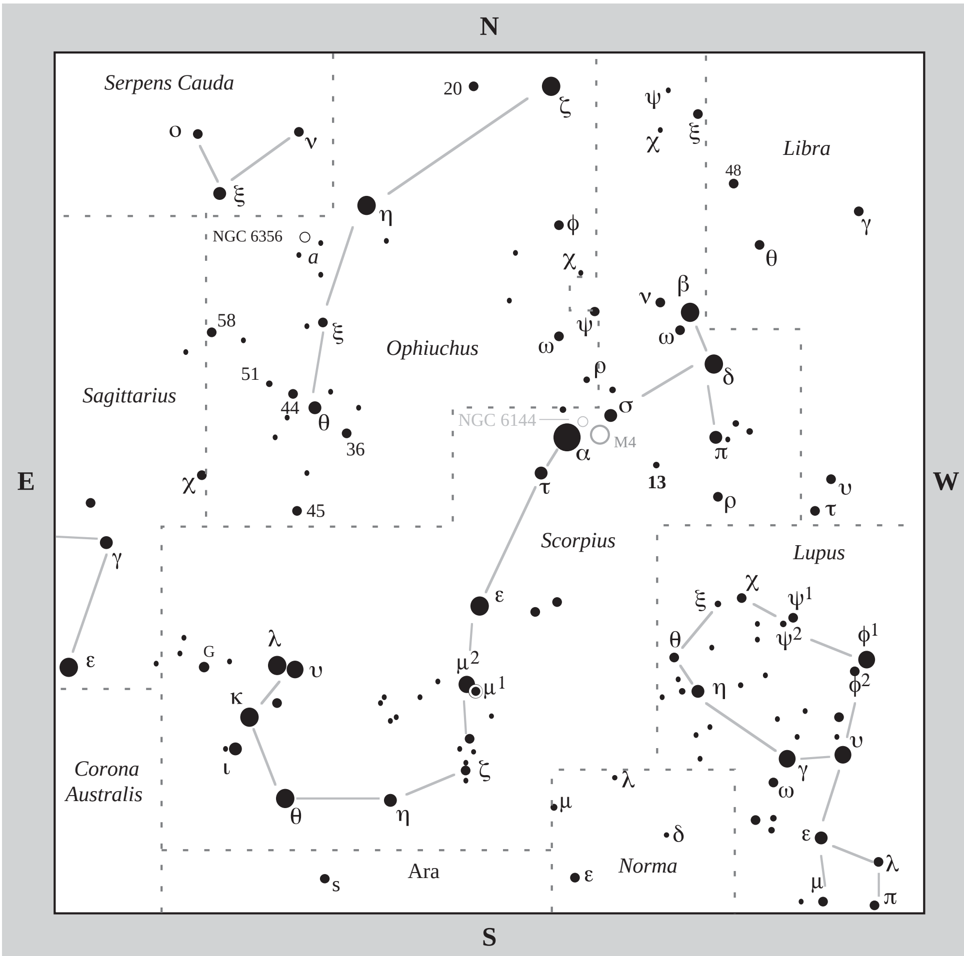
As seen at low power, the nebula lived up admirably to its local name: the Exclamation Mark, "appearing at first glance very much like a highly elongated rectangle aimed NW toward the magnitude [11.5] star that is the 'dot.'" But at 245× with the UHC-filter, "the bizarre shape of this planetary started to become conspicuous." Gramer got a strong impression that the northwest half of the nebula was clearly somewhat brighter and larger than it was to the southeast. While at 460×, Gramer had this to say:

> The Exclamation Mark suddenly presented a whole new wealth of detail! What had looked like a very thin rectangle, now resolved in to successive lobes or 'pulses' of nebulosity, *three* of them in fact! ... Even more intriguing, fainter wisps of nebulosity could be seen stretching out from the northwest lobe of the planetary nebula, arcing southward to a point maybe 5″ due west of the midpoint of the main nebula.

May your own views of this southern marvel be just as glorious!

77

Secret Deep 77
(NGC 6356)



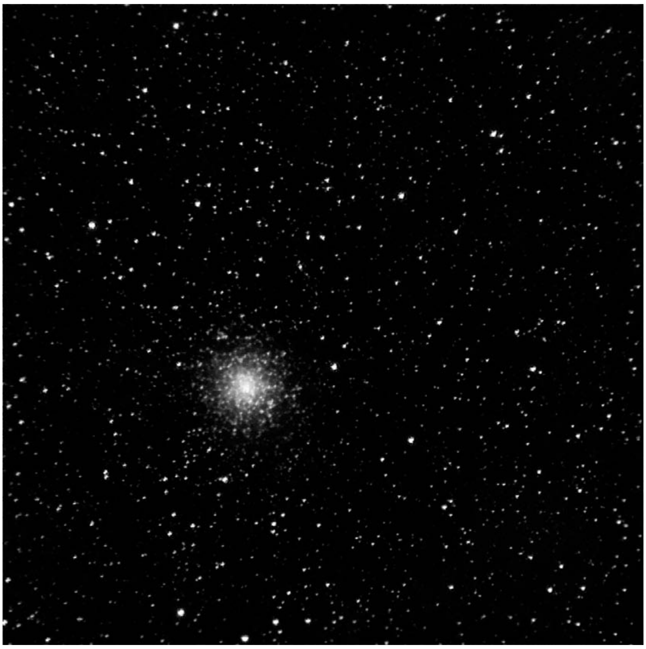
77

NGC 6356
Type: Globular Cluster
Con: Ophiuchus

RA: 17^h 23.6^m
Dec: $-17°$ $49'$
Mag: 8.2
SB: 13.2 (Rating: 4)
Diam: 10′
Dist: ~49,600 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed June 17, 1784] Bright, large, round, gradually brighter in the middle, easily resolvable. (H I-48).

NGC: Globular cluster, very bright, considerably large, very gradually very much brighter in the middle, well resolved, clearly consisting of stars, stars of 20th magnitude and fainter.



NGC 6356 IS A NICELY CONDENSED and reasonably bright globular cluster about 4° southeast of 2nd-magnitude Eta (η) Ophiuchi. It's also about 1½° northeast of the more popular, magnitude 7.8 globular cluster M9, which robs it of attention – mainly because of its inclusion in the Messier catalogue, though it is nearly 0.5-magnitude brighter than NGC 6356. Still, I have to wonder how Charles Messier and his contemporary Pierre Méchain missed this one.

In 1969 and 1974, the late Jack Bennett of South Africa (discoverer of C/1969 Y1 (Comet Bennett), the Great Comet of 1970) created his own lists of deep-sky objects, which, like Messier, could easily be confused with comets. NGC 6356 is the 93rd object in his combined list of 152 objects, which he referred to as "shades of Messier."

NGC 6356 is a very metal-rich globular cluster, having about half as much metal (per unit hydrogen) as does the Sun, making it intermediate between 47 Tucanae (1/6) and NGC 6528 (Secret Deep 80). Our target, then, is among the most metal-rich Galactic globular clusters visible from the Northern Hemisphere.

It's a distant system, twice as far from us as M9 (remember this when you compare the two) and nearly three times farther away than 47 Tucanae. In fact, one novelty of observing this cluster is that you're looking at an object on the other side of the Galaxy, projected against the dusty Galactic bulge 25,000 light-years from the Galactic center and nearly 10,000 light-years out from the Galactic plane, making it not only part of the metal-rich disk system of globular clusters but also one of the farthest from the Galactic plane.

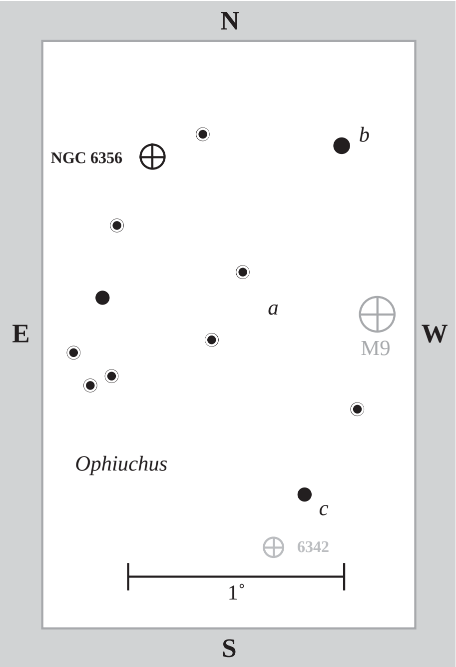
Owing to its great distance (49,600 light-years) and dusty line-of-sight placement, the cluster is reddened by about 0.2 magnitude. And though it will appear small through your telescope, the cluster is quite large, measuring some 145 light-years across in true linear extent, which is twice as large as M9!

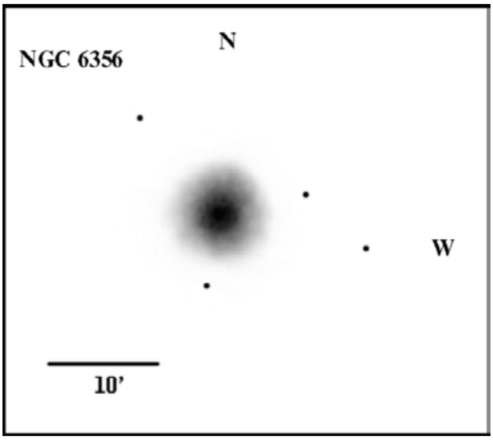
While it's not actually known, a guestimate based on the height of NGC 6356 above the Galactic plane shows that the cluster may have last crossed the Galactic plane 500 million years ago. In a 1998 *Monthly Notices of the Royal Astronomical Society* (vol. 301, pp. L30-L32) Madelaine Hopwood and Nye Evans (Keele University, UK) and colleagues note that this is sufficient time in which the globular cluster stars are able to produce and eject circumstellar material into the intra-cluster medium. When a globular cluster passes through the plane of the Galaxy, the researchers say, any interstellar material it contains will be removed tidally and by ram pressure. Subsequently, the interstellar medium of the globular cluster will be replenished with material since a large fraction of the stars within the cluster will have progressed to a post-main-sequence evolutionary stage and therefore ejected matter into the intracluster medium.

If each evolved star loses a mass of about 0.3 Sun, the researchers say, then they would expect to detect some 100 to 1,000 solar masses of gas and some 0.1 to 1 solar mass of dust in the cluster. In their search for intracluster dust grains in the core of NGC 6356 with the James Clerk Maxwell Telescope atop Mauna Kea, Hawaii, they found a dust mass of about 0.004 to 0.017 Sun – values well below those expected. To explain the deficiency, the researchers propose that some fraction of the dust has been destroyed or ejected from the cluster environment after formation, or alternatively, that its formation is somewhat inhibited. Regardless, their findings support previous conclusions that globular clusters are seriously lacking in intracluster dust grains.

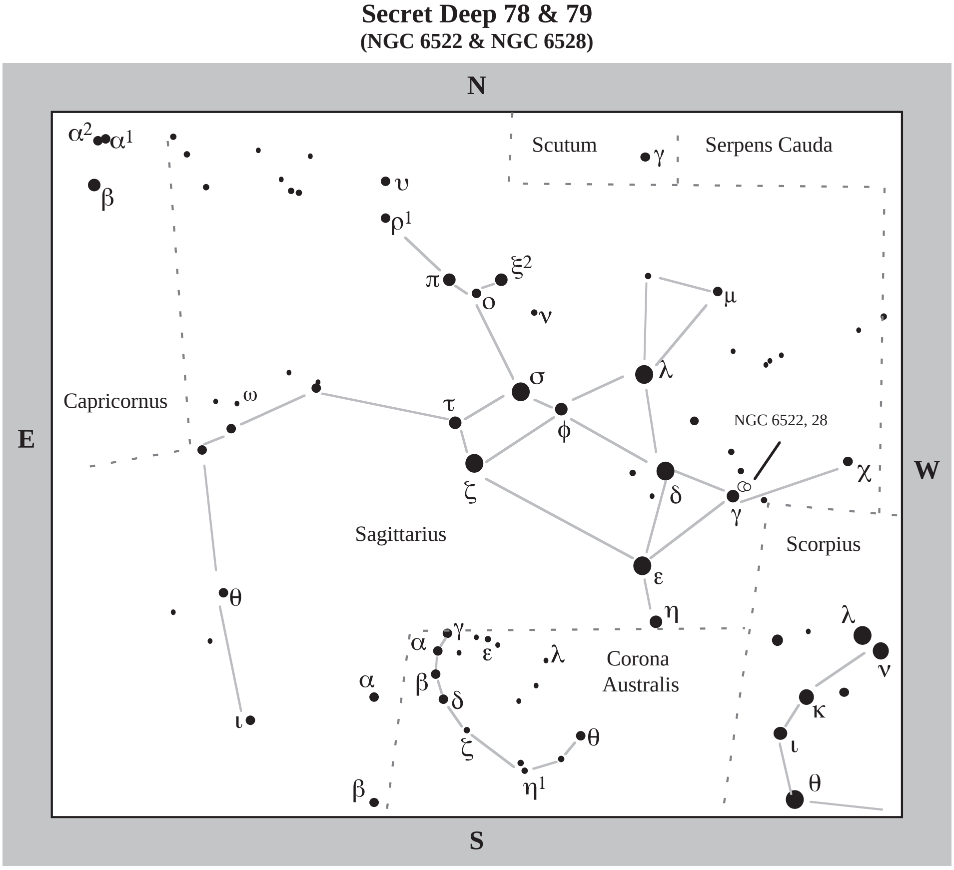
This moderately condensed cluster has an integrated spectrum of G3/4, and its color–magnitude diagram shows a stubby red horizontal branch and a giant branch with an extremely low slope. While no RR Lyrae stars have been observed in NGC 6356 (nor would any be expected in such a highly metal-rich cluster), it does harbor five Mira-type stars and one irregular variable. If these variables prove to be cluster members, then NGC 6356 contains more than one-third of the Mira stars with known periods that belong to globular clusters in our Galaxy.

To find this distant marvel, use the chart on page 330 to find Eta Ophiuchi. Now use your unaided eyes or binoculars to find 1½°-wide Triangle *a*, about 4° to the southeast; it is composed of three roughly 6.5-magnitude suns. Now switch to the chart on page 333. You want to center the northernmost star (*b*) in the Triangle *a*, in your telescope at low power. NGC 6356 is a little more than 50′ east and slightly south of Star *b*. Note that similarly bright M9 lies about the same distance to the south-southwest of Star *b*.





At 33× in the 5-inch, NGC 6356 is a very bright and highly condensed (about 3′ across) knot of light, appearing almost as prominent as M9 when seen with averted vision. At 60×, the cluster displays a very intense and starlike core surrounded by a diaphanous circular glow of unresolved starlight; with averted vision and time, this outer region seems mottled. At 94×, which gives the best and most comfortable view in my telescope, the cluster's core is less intense, like a soft wad of cotton or a comet that has lost its nucleus and is beginning to fade. Averted vision shows the outer region breaking up into foggy patches, while the core becomes a blizzard of stellar snowflakes. These are, no doubt, star clumps and some of the cluster's brightest members, which shine around 15th magnitude. The brightest stars in the cluster shine at 15th magnitude. But clumps of them condense to form a mottled haze.


Secret Deep 78 & 79
(NGC 6522 & NGC 6528)
N
S
E
W
Scutum
Serpens Cauda
Capricornus
Sagittarius
Scorpius
Corona
Australis
NGC 6522, 28

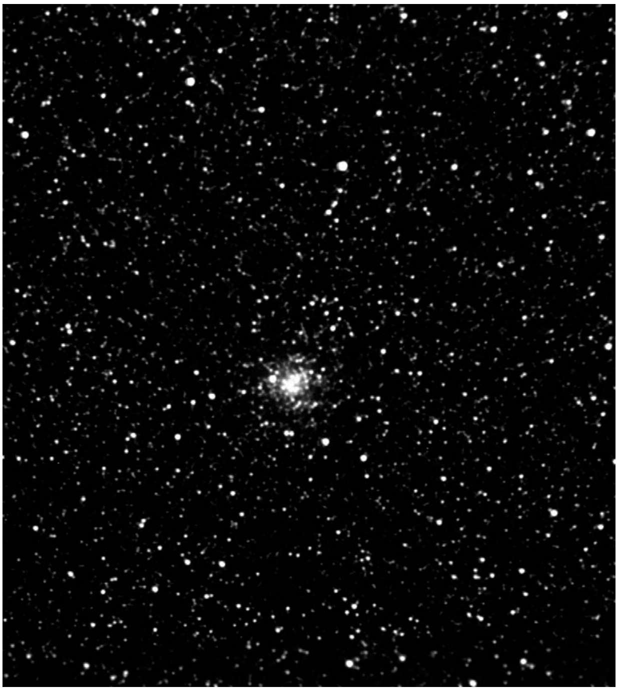
78

NGC 6522
Type: Globular Cluster
Con: Sagittarius

RA: $18^h\ 03.6^m$
Dec: $-30°\ 02'$
Mag: 8.3 (Rating 3.5)
Diam: 9.4′
Dist: ~20,000 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed June 24, 1784] Bright, pretty large, bright in the middle, resolvable (mottled, not resolved). (H I-49)

NGC: Globular cluster, bright, pretty large, round, gradually very much brighter in the middle, well resolved, clearly consisting of stars, stars from 16th magnitude downwards.



79

NGC 6528
Type: Globular Cluster
Con: Sagittarius

RA: $18^h\ 04.8^m$
Dec: $-30°\ 03'$
Mag: 9.6 (Rating 3.5)
Diam: 3.7′
Dist: ~25,800 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed, June 24, 1784] Faint, pretty small, resolvable (mottled, not resolved), unequally bright. (H II-200)

NGC: Globular cluster, pretty faint, considerably small, round, gradually brighter in the middle, well resolved, clearly consisting of stars, stars from 16th magnitude downwards.

78 & 79

NGC 6522 IS A MODERATELY LARGE and surprisingly obvious globular cluster near 3rd-magnitude Gamma (γ) Sagittarii in the Large Sagittarius Cloud. The fainter globular star cluster NGC 6528 joins it only about 20′ to the east. In small- to modest-sized backyard telescopes, just about any low-power eyepiece will show the two in the same field of view. For that reason, I like to call them the M81 and M82 of globular star clusters.

On June 24, 1784, William Herschel discovered both clusters, cataloging NGC 6522 as a "bright nebula" (a class I object) and NGC 6528 as a "faint nebula" (a class II object). His actions are understandable, since both clusters contain dim stars seen projected against the Milky Way.

The view of them at low power in a rich-field telescope is a sight to behold, especially since they lie only about 4° south of the Galactic center, trapped between two 3rd-magnitude stars (Gamma and W Sagittarii) where myriad suns congregate to form a dynamic stellar backdrop against which loom long rivers and tiny islands of dark dust. One might expect the clusters to be highly reddened, but they're not; both clusters lie in what's known as a "Baade Window" – a region of sky in the direction of the Galactic bulge with relatively low amounts of interstellar dust.

Baade Windows allow astronomers to study stars deep within the Milky Way's heart. Indeed, the German born American astronomer Walter Baade (1893–1960), for whom these "Windows" are named, used one to observe RR Lyrae stars in the bulge region near NGC 6522. These yellow or white giant pulsating variable stars (often found in globular star clusters or elsewhere in the Galactic halo) obey a period–luminosity relation that allows astronomers to use them as reliable distance indicators. Using these stars, Baade estimated 27,000 light-years as the distance to the Galaxy's center – a value comparable to one recently published in 2006 by Ming Shen and Zi Zhu (Nanjing University, China) based on proper motion studies of NGC 6522's stars.

NGC 6522 and 6528 are not only seen against the Galactic bulge, but both lie within it. Studies of globular clusters in the Galaxy's bulge are difficult, because their stars mingle with bulge stars of similar magnitudes, blurring member identification and making color–magnitude diagrams – which say much about the age and evolution of the cluster's stars – formidable to analyze. As early as 1964, Sir Richard Woolley (Royal Greenwich Observatory), in discussing the region of NGC 6522 at an IAU Symposium in Canberra, said, "It requires the eye of faith to see at all the familiar [Hertzsprung–Russell] pattern of a globular cluster showing amongst the field stars."

But today's astronomers don't need faith, just superior optics and instrumentation. In 2004, for instance, Swedish astronomer Sofia Feltzing (Lund Observatory) and Rachel Johnson (Cambridge, UK, and ESO, Chile) used HST to image NGC 6528 and obtain proper motions for all the stars in the field. The data were then used to separate the bulge stars from the cluster stars. Thus, for the first time, they created a color–magnitude diagram of NGC 6528 free from background stars. Based on their findings, the researchers estimate NGC 6528 is probably 11 billion years old.

If we accept the distances in the table above, NGC 6528 spans 28 light-years, while NGC 6522 is twice as large in true physical extent. NGC 6528 has an integrated spectral type of G3 and has often been compared to the G4 cluster 47 Tucanae (Caldwell 106). But Feltzig and Johnson's study also revealed that the stars in NGC 6528 are much more metal rich than those in 47 Tucanae, having about as much iron in each star as there is in our Sun. Beatriz Barbuy (Universidade de São Paulo, Brazil) says that NGC 6528 appears to be the most metal-rich cluster known; by comparing the red-giant branch of the most metal-rich clusters, Barbuy and her colleagues found NGC 6528 to be the reddest, which, they believe, is due to the cluster's high metallicity.

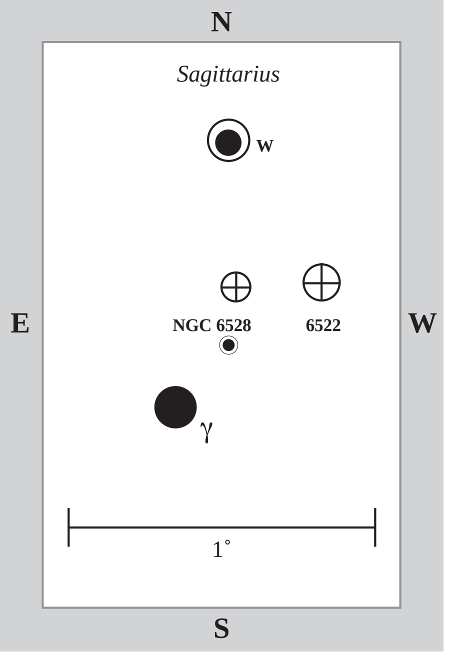
In contrast, Barbuy and colleagues (2009) found that NGC 6522 is metal-poor, having only about 1/10 as much metals in each of its stars as in our Sun. Indeed, NGC 6522 was the first metal-poor globular cluster identified in the bulge by Baade. At nearly 14 billion years old, it is, Barbuy *et al.* note, among the oldest globular clusters in the Galaxy – perhaps a relic dating to the formation of the Galactic nucleus, which we see now as a relatively metal-poor globular star cluster. Bulge metal-poor clusters, such as NGC 6522, may be important tracers of the early chemical enrichment of the Galaxy.

In a 2009 *Astronomy & Astrophysics*, Barbuy and her colleagues position NGC 6522 at a distance of some 20,00 light-years from the Sun and some 6,500 light-years from the Galactic center, placing it slightly in the foreground to the majority of metal-rich stars found in the Galactic bulge, yet still within the bulge. The sharp difference in the visual view of the two clusters – with NGC 6522 appearing more distinct and of greater brightness – is most likely due to the fact that NGC 6522 is probably a very massive cluster, which is remarkable considering that since its formation it has probably lost a lot of its stars.

Indeed, NGC 6522 is one of the most compact globular clusters known. Clusters that pass within a few hundred parsecs of the Galactic center are likely to be "shocked" by strong gravitational tugs between the bulge and inner disk. As evidence, NGC 6522 is one of the Galaxy's 20 or so core-collapse clusters, meaning that its brightness increases steadily and dramatically straight to the core; M15 in Pegasus and M30 in Capricornus are other examples of core-collapse clusters. During such intense tidal interactions, not only would stars have been stripped away from NGC 6522's outer halo, but stars at the core would have experienced a tidal compression, speeding up a core collapse that forces heavier stars at the cluster's center to interact with less massive companions further out, drawing them in.

As part of an ongoing program studying the stellar content of globular cluster cores, M. M. Shara and colleagues used the Hubble Space Telescope (HST) Planetary Camera to study NGC 6522. As the authors explain in a 1998 *Astrophysical Journal*, they found strong evidence that the cluster's core has a dearth of red giants but an interesting population of suprahorizontal-branch (SHB) stars. The SHB stars may be evolved blue horizontal-branch stars, the tidally stripped cores of red giants, or evolved blue stragglers – all products of core collapse.

To find these interesting objects, use the chart on page 334 to locate Gamma (γ) Sagittarii (Alnal) – the tip of the Archer's arrow. Center that star in your telescope at

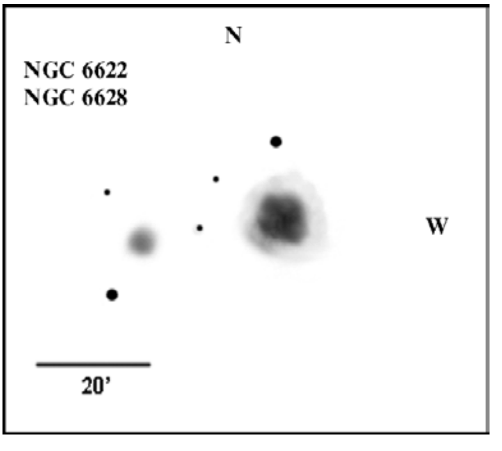


low power, then switch to the chart on this page. Before moving on, take some time to admire Gamma, an orange class K0 giant 96 light-years distant with a marigold sheen. NGC 6528 is about 25′ north-northwest of Gamma, while NGC 6522 is a little less than 20′ west, and a little north, of NGC 6528.

Through the 5-inch, the view is glorious at 33×. The two globulars seem to bob in a flood of Milky Way that rushes between Gamma and W Sagittarii. Under a dark sky, dark rivulets of obscuring matter trickle through the flood forming three diverging branches, like crow's feet; the dustiest region flows around Gamma. The globulars themselves avoid one dense patch of darkness, appearing just to the north of it. Indeed, a bleak black spot (Barnard 298) lies only about 12′ southeast of NGC 6528 – dimmer of the two clusters by more than a magnitude; it also appears much smaller than NGC 6522. In a more romantic sense, the two clusters seen projected against the rich background of Milky Way look like beads on a snow-covered sweater.

At 60×, NGC 6522 is a fine object, appearing as a fuzzy knot of light roughly 3′ across with a tight 1′ bead of light at the cluster's core. The cluster's halo appears neatly circular with direct vision and a bit tattered with averted vision. A roughly 12th-magnitude sun kisses the halo toward the northeast, and a similarly bright sun lies a tad farther away to the south-southwest. At 94×, the core appears slightly elongated (northwest to southeast) and mottled. Indeed, the cluster's brightest stars are not 16th and fainter, as noted in the NGC description, but rather 14th and fainter. So do not be afraid to use higher powers and averted vision to see the dappled face of the cluster – though, as the professional astronomers have noted, it's difficult to judge which stars belong to the Milky Way and which stars to the cluster.

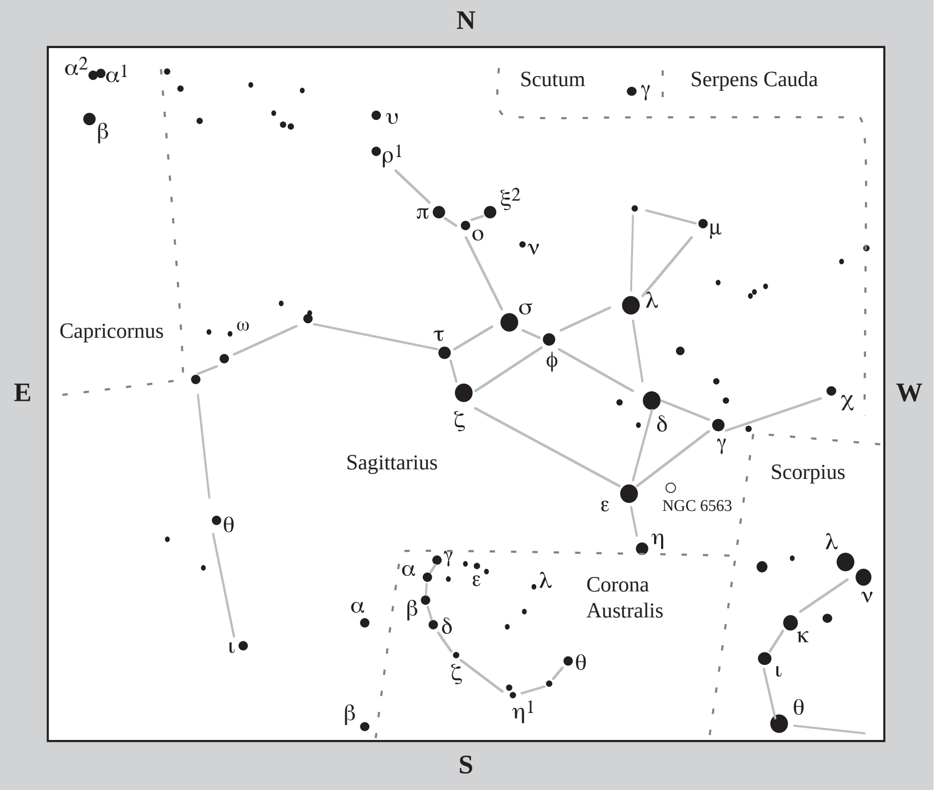
At 33×, NGC 6528 is a dim patch of light (a tiny, isolated glow only about 1′ in



extent) appearing as a fuzzy star with an almost insignificant halo that quickly fades into the rich Milky Way background. I find that NGC 6528's halo swells to greater significance if I look at NGC 6522 but direct my averted vision to NGC 6528. At 60× and 94×, the view of NGC 6528 does not improve much. But its core does seem bifurcated, while the entire halo seems to scintillate nervously with erratic flashes of dim light. This is most likely a visual illusion owing to the multitude of stars seen projected against its face, since the cluster's brightest stars shine at only magnitude 15.5.

By the way, W Sagittarii is a Cepheid variable star that fluctuates between magnitudes 4.3 and 5.1 every 7.59 days.

Secret Deep 80
(NGC 6563)



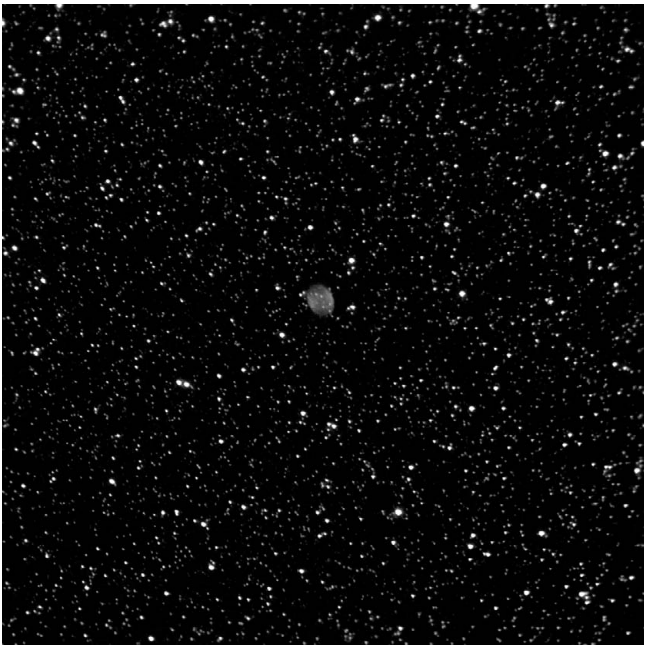
80

Southern Ring
NGC 6563
Type: Planetary Nebula
Con: Sagittarius

RA: $18^h\ 12.1^m$
Dec: −33° 52′
Mag: 11.0 (Rating 4)
Dim: 50″ × 38″
Dist: ~7,600 l.y.
Disc: James Dunlop, included in his 1828 catalogue

J. HERSCHEL: Planetary nebula, little elliptic, hazy at borders, seen as last night. (h 3734)

NGC: Planetary nebula, faint, large, considerably extended, hazy border.



NGC 6563 IS A BEAUTIFUL PLANETARY nebula about 2½° east-northeast of 2nd-magnitude Epsilon (ε) Sagittarii (Kaus Australis) – a beautiful A-type blue giant, 145 light-years distant, which marks the southern part of the Archer's bow (or the lower right star in the famous Teapot asterism). Ironically, Epsilon, not Alpha, is the brightest star in the Archer; evidence that Johann Bayer (1572–1625) did not always stick to any specific ruling (such as ordering stars according to brightness) when he alphabetized a constellation's stars.

Sagittarius is more than an Archer; he is a Centaur, a "monster" with the torso of a man (from head to loins) and the legs and body of a horse. But not all people saw the stars in this region in that way. In India, for instance, Epsilon was part of a smaller constellation depicting an elephant: Delta (δ) Sagittarii is the elephant's head; Gamma (γ) Sagittarii marks its lowered trunk; Epsilon is the mammal's rear flank; while Eta (η) Sagittarii is its tail. NGC 6563, then, would be a digested peanut in the elephant's stomach.

James Dunlop discovered the nebula during his sweeps of the southern heavens from his home in Paramatta, New South Wales, Australia. It is the 606th object listed in his 1828 *A Catalogue of Nebulae and Clusters of Stars*. Of its appearance through a 9-inch reflector (with a focal length of 9 feet) he wrote: "A faint nebula, about 1¼′ long and 30″ or 40″ broad, with a considerable brightness near each end, and faint in the middle, resembling two small nebulae joined." John Herschel concurred; in his second observation of it, he described it as a "large, faint, oval, planetary nebula, about 1′ long, 50 arcseconds broad, or 55 arcseconds; considerably hazy, or rather indistinctly terminated at the borders, but not brighter in the middle; a magnitude 6–7 star precedes it, just 1 diameter of the field and nearly in the parallel."

The object is clearly a hidden treasure; had I encountered it earlier, I certainly would have included it in my *Deep-Sky Companions: Hidden Treasures*. Alas, little is mentioned about it. Fortunately, in August 2009, I was cruising around Sagittarius with my telescope, checking objects that appear on Wil Tirion's *Sky Atlas 2000.0*, when I noticed NGC 6563's tiny symbol near Epsilon and decided to "check it out." I'm glad I did; the view delighted me so much that I immediately enlisted it as a member of the Secret Deep.

In optical images, NGC 6563 (also known as PK 358–7.1) is a pretty standard elliptical planetary nebula with, as Dunlop noted, brightening at the ends of the minor axis. We see it oriented in the sky east-northeast to west-southwest. In three-dimensional space, its major axis is inclined 75° to our line of sight.

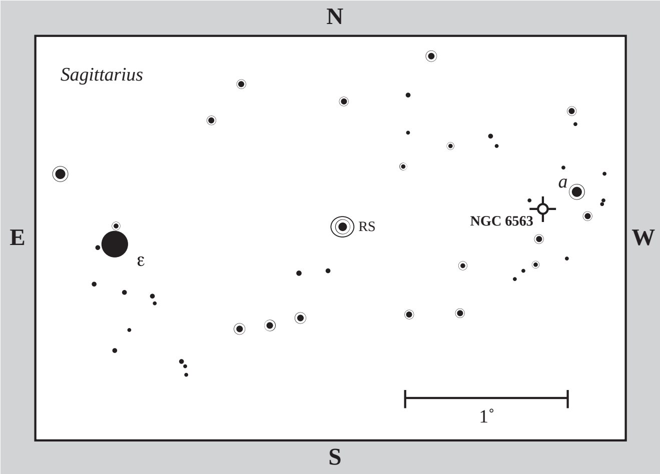
P. Cox (Marseille Observatory, France) and colleagues, in a 1991 *Astronomy & Astrophysics*, note that their observations of NGC 6563 with the 1.5-meter Swedish European Submillimeter Telescope at La Sille, Chile, show that it has intense and extended molecular emission.

It's now believed that molecular gas represents a substantial part of the total mass of planetary nebulae. These molecules must have been formed within, and were ejected by, the star. Mapping carbon monoxide (CO) emission is particularly valuable since it can be used to trace the more highly excited gas produced in the poorly understood transition from the star's red giant phase to a planetary nebula. Cox *et al.* found that NGC 6563's CO emission forms a fairly complete ring around the nebula's minor axis, or waist, while the structure is much more open along the major axis. NGC 6563, then, appears very similar in form to M51, the Ring Nebula in Lyra, which has a main ring-like structure with a pair of coaxial bipolar cones.

The researchers also note that the ring appears fragmented, with the CO emission coming from discrete, though unresolved, clumps within it. This may be indicative of asymmetrical mass-loss processes starting early at the asymptotic giant branch phase. Planetary nebula are believed to form from the remnants of circumstellar envelopes of AGB stars, which represent the very last phase of normal stellar evolution. The clumps could have formed as energetic winds rushed out from the dying star causing shocks within the circumstellar shells.

NGC 6563 is highest in the sky during mid-August around 9 p.m., the perfect time for summer stargazers at mid-northern latitudes to turn their telescopes to the south. The planetary's declination of −33° 52′ places it almost 1° further north than open cluster M7 in Scorpius, the most southerly Messier object. To find it, start by using the star chart on page 340 to find Epsilon (ε) Sagittarii. Center that star at low power in your telescope, then use the chart on page 343 to star hop to your target.

First make a careful and rough 1½° sweep west-northwest to the 6th-magnitude variable star RS Sagittarii – an eclipsing binary that fluctuates between magnitude 6.0 and 6.5 every 2.4 days. Another rough 1½° sweep to the west-northwest will bring you

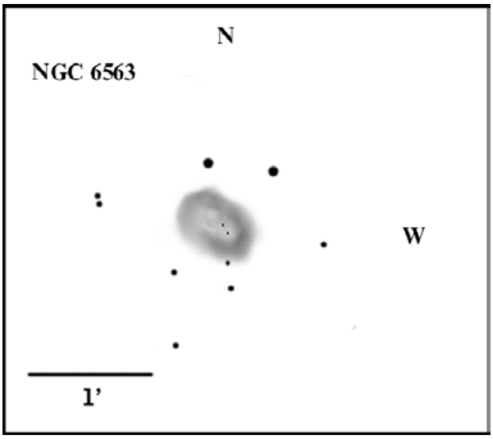


At powers of 165× and 330×, the ring is a beautiful sight – a clear annulus lying inside a warped pentagon of uneven starlight. A dim star can also be seen nudging the southwestern flank of the ring (though in high-resolution photographs, this "star" is actually two stars; I was obviously seeing their combined light).

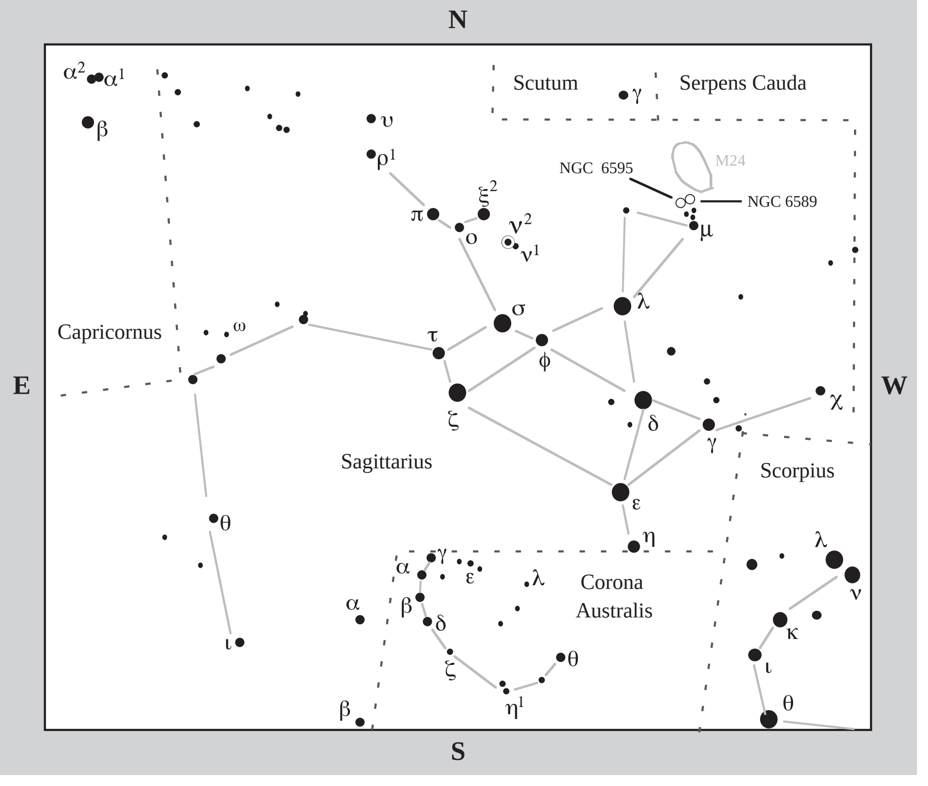
The center of the nebula is not dark but filled with misty light less intense than that of the surrounding ring. At this power it is also clear that the central star I detected at lower power was an illusion created by the combined glow of two dim stars within the ring; the true central star shines at a dim magnitude 18.3, making it well beyond the grasp of small- to moderate-sized telescopes. The ring also appears slightly brighter at the northwest and southwest edges. Overall, it's quite a noble sight!

to 6th-magnitude Star *a*, which is the northernmost member of a 20′-long triangle with two 7th-magnitude stars. NGC 6563 is about 15′ east-southeast of Star *a*, almost due north of the southernmost star in the triangle.

At 33× in the 5-inch, the nebula is just barely visible as a tiny (<1′) round haze next to Star *a*; the entire field is beautiful, being rich in milky starlight. At 60×, the nebula stands out well as a condensed circular glow of uniform light with what appears to be a hint of a central star. The nebula is so small and condensed that it takes power well, so don't be afraid to crank up the magnification. At 94×, I can start to see the ring structure framed by three bright field stars to the north, northwest, and west-northwest. The annulus also appears brighter on the southwest end of the ellipse, which is oriented east-northeast–west-southwest.



Secret Deep 81 & 82
(NGC 6589 & 6595)



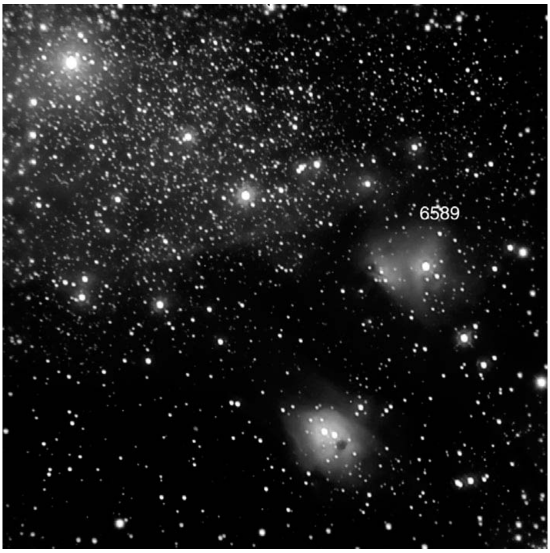
81

NGC 6589
Type: Reflection Nebula
Con: Sagittarius

RA: 18^h 16.9^m
Dec: $-19°$ $47'$
Mag: – (Rating 3.5)
Dim: $5' \times 3'$
Dist: ~5,540 l.y.
Disc: Lewis Swift, 1885

L. SWIFT: Another double star in center of an extremely faint, pretty large nebulosity; north preceding of 2. Except the inequality of the stars and the excessive faintness of the nebula, it would resemble the preceding [see NGC 6590 below]. (No. 63 Swift's Cat. II)

NGC: Double star in centre of extremely faint, pretty large nebulosity.



82

NGC 6595 = NGC 6590
Type: Reflection Nebula
Con: Sagittarius

RA: 18h 17.1m
Dec: –19° 52′
Mag: – (Rating 3.5)
Dim: 4′ × 3′
Dist: ~5,540 million l.y.
Disc: John Herschel, 1830

J. HERSCHEL: Faint; pretty large; considerably extended; double star involved. (h 2002)

L. SWIFT: [Observed in 1885] A nebulous double star; pretty faint; south following of 2. A double star in center of a pretty faint, pretty large circular atmosphere each star of the 8.5 magnitude and about 20″ distant. A wonderful object, not difficult. (No. 62 Swift's Cat. II)

NGC 6590: Double star in centre of pretty faint, pretty large, round nebulosity.

NGC 6595: Faint, pretty large, clearly elongated, double star involved.

NGC 6589 AND 6595[1] ARE TWO SMALL but reasonably bright reflection nebulae in the maddening crowd of stars, dust, and gas that populate the Galactic plane in Sagittarius, just off the southeastern lip of the Small Sagittarius Star Cloud (M24). They're perfect examples of how little things of interest can be overlooked because larger celestial wonders nearby steal our attention.

Actually the two nebulae lie immediately southwest of a larger HII region: IC 1284 (or Sharpless 2–37), discovered photographically by Edward Emerson Barnard on May 31, 1892; though he later found it on an image he took of the region in 1889. Barnard describes the discovery in an 1892 *Astronomische Nachrichten* (vol. 130, p. 77), writing that he tried to see this 15′-wide

[1] NGC 6589 and 6595 are also known as the reflection nebulae van den Bergh 118 and 119 (vdB 118 and 119), respectively, so, by sighting them, you can add two more van den Bergh objects to your growing list of obscure nebulae, Secret Deep 1 (van den Bergh 1) being the first.

nebula through the Lick Observatory's 12-inch refractor but he "could not be certain of seeing the nebulosity" on account of the brightness of a magnitude 7.6 star embedded in it.

Further investigation of the plate also led Barnard to notice a discrepancy in Dreyer's NGC catalogue. Aside from the nebula he just discovered, he expected to see three other nebulae in the region: NGC 6589, 6590, and 6595. But his investigation of the plate, coupled with visual observations through the Lick 12-inch telescope, showed that Swift's positions of NGC 6589 and NGC 6590 were off in right ascension by about 45 seconds of time; he also noted that NGC 6590 and NGC 6595 were the same nebula. "The nebula 6590 is therefore to be stricken out," he extolled, "as the position of NGC 6595 is essentially the correct one."

But the story doesn't end there. In his write-up, Barnard erroneously attributes the discovery of NGC 6595 to Lewis Swift. Actually, indefatigable John Herschel discovered that nebula while observing at Slough in 1830, cataloging it as h2002. Of it Herschel wrote: "Faint; pretty large; considerably extended; double star involved." Swift rediscovered the nebula in 1885 but published an incorrect position for it. Dreyer's catalogue also erroneously lists NGC 6595 as a cluster, but no cluster exists, only the nebula's central double star.

Furthermore, as Hal Corwin writes on his NGC/IC website, NGC 6589 may also be IC 4690. Swift's position for NGC 6589, Corwin explains, is about 36 seconds of time off, a mistake corrected by Barnard, and included in the 1908 *Second Index Catalogue's* Notes. "Ironically," Corwin continues, "Barnard is also responsible for a mistake of his own which makes the identity with IC 4690 probable."

In a private 2010 communication Corwin adds that NGC 6590/95 is probably also IC 4700. Barnard, he says, turned this up on a later plate at Yerkes. In a 1908 *Astronomische Nachrichten* (vol. 177, p. 232), he wrote, "The two stars BD –19 4881 and –19 4946 are closely and densely nebulous. The nebulosity about –19 4881 is somewhat extended [north following] and [south preceding]."

Corwin notes that Barnard's first reference to BD –19 4881 must actually be to BD –19 4940 (as I have suggested above). He also believes that Barnard must also have been mistaken when he made BD –19 4881 extended, adding, "This description fits –19 4946 very well. Given all that, the IC 4690 and IC 4700 numbers are clearly redundant." In summary, Corwin says, "Yep, this Sagittarius field is enough to give one brain warp if we try to keep everything in mind and sorted out all at once. Ouch!"

To add fuel to the fire, modern star charts reflect some of the confusion: Tirion's *Star Atlas 2000.0*, for instance, labels IC 1284 as IC 1283,84 – though IC 1283 is a minute nebula around a star in IC 1284 discovered photographically by Barnard; it also shows NGC 6995 to be both a nebula and a star cluster, erroneously labeling them as NGC 6590,95. The *Uranometria 2000.0* (Vol. II), repeats the IC 1283, 84 label listed above, as well showing NGC 6595 as a nebula and cluster; but it also mislabels NGC 6589 as NGC 6589, 90. *The Millennium Star Atlas* also uses the IC 1283/84 label and clearly misidentifies NGC 6595 as an open star cluster, with the nebula NGC 6590 superimposed on it. And while NGC 6589 is labeled correctly in the *Millennium*, the nebula is misplotted, showing it about 8′ west, and slightly south, of its true position. The chart on this page shows the correct and current thinking: your Secret Deep targets NGC 6589 and NGC 6595, and the large emission and reflection nebula IC 1284 to their northeast.

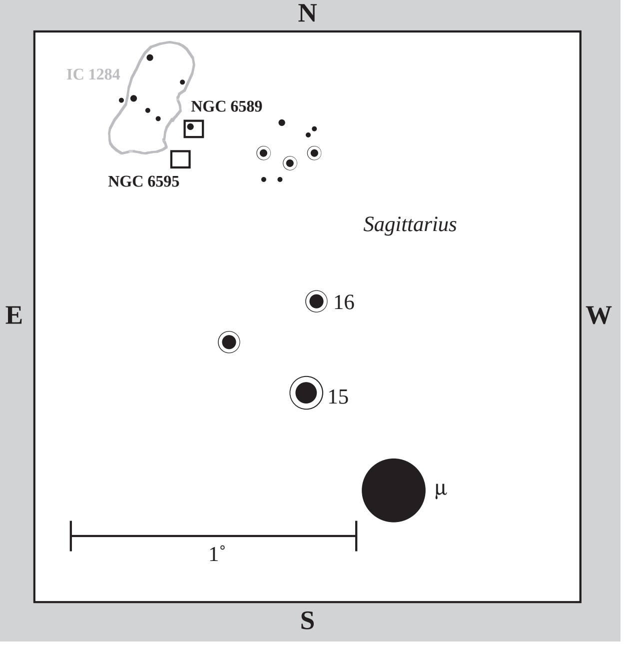
In his article "Star formation in Sagittarius: The Lynds 291 Cloud," which appears in the 2008 *Handbook of Star Forming Regions* (Vol. II), published by the Astronomical Society of the Pacific, University of Hawaii astronomer Bo Reipurth and his colleagues summarize the history and astrophysics of this region.

NGC 6589 and 6595, together with IC 1284 and a number of other interesting smaller nebulous features are part of the Lynds 291 (L291) Cloud – a major molecular cloud complex in Sagittarius that stretches across four square degrees of sky. In true physical extent, the complex spans some 260 × 65 light-years and has a mass exceeding 100,000 Suns; although its distance is not accurately known, 5,500 light-years is commonly used in the literature.

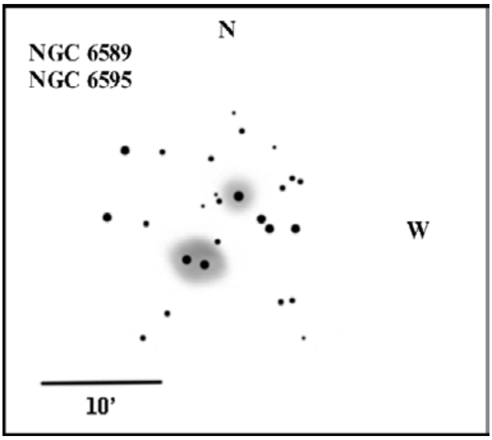
The entire L291 cloud is embedded in a larger ionized region known as Gum 78, which may be excited by the Sgr OB1 Association – a very active region of star formation. The northwest corner of L291 abuts the side of the Small Sagittarius Star Cloud (M24), near which IC 1284, NGC 6589, and 6595 lie. The latter three objects reside in an enormous hole in the molecular cloud.

In color photographs IC 1284 appears red – the color being due to the glow of hydrogen gas, which has been ionized by its central 7th-magnitude double star HD 167815 (both of spectral type B). NGC 6589 and 6595 have rich bluish shades, the result of light reflecting off interstellar dust. The B2 star HD 167638 illuminates NGC 6589, while the B5 binary HD 313094 + HD 313095 lights up NGC 6595.

To find these intriguing nebulae, start by locating 4th-magnitude Mu (μ) Sagittarii; M24 is about 2½° north, but I suggest centering Mu in your telescope at low power. Now switch to the chart on this page and move 30′ northeast to 5th-magnitude 15 Sagittarii, then 20′ northward to 6th-magnitude 16 Sagittarii. NGC 6589 lies nearly 45′ north-northeast of it; NGC 6595 is 6′ south-southeast of NGC 6589.



At 33× in the 5-inch, the two nebulae attract attention because they at first look like a pair of fuzz-collared stars 6′ apart in a dark river that separates two milky looking star clouds. IC 1284 to the northeast and Sharpless 2–35 to the southeast. Seen together, the little glowing clouds set against a dark veil of bleak gas draped across the rich star fields of this molecular complex are a sight to behold and worthy of some time alone to take in the grandeur. In extreme wide-field images, it's apparent that IC 1284 and NGC 6589 and 6595 are visible through an enormous hole in the surrounding giant molecular cloud.



In time, I find my eye is immediately drawn to NGC 6595, because its central star is actually a pair of 10th-magnitude suns, oriented east-northeast–west-southwest, separated by only 20″. The reflection nebula around the stars is bright and quite uniform, even at 66×. The higher the magnification, though, the less grand the view. The roughly 3′ nebula loses its luster and the overall scene becomes less dynamic. Photographs show NGC 6595 as a double tiered nebula: a bright ellipse of light hugging the double star surrounded by a fainter, irregularly oval halo of light; I cannot detect this effect visually, because the light from the central stars overpowers my eye; besides, close pairs of stars easily trick the eye into thinking they're *fuzzy* (like M40 in Ursa Major). As Mario Motta's beautiful photograph shows, NGC 6595 also has an interesting dark hole punched just south-southwest of the central double star.

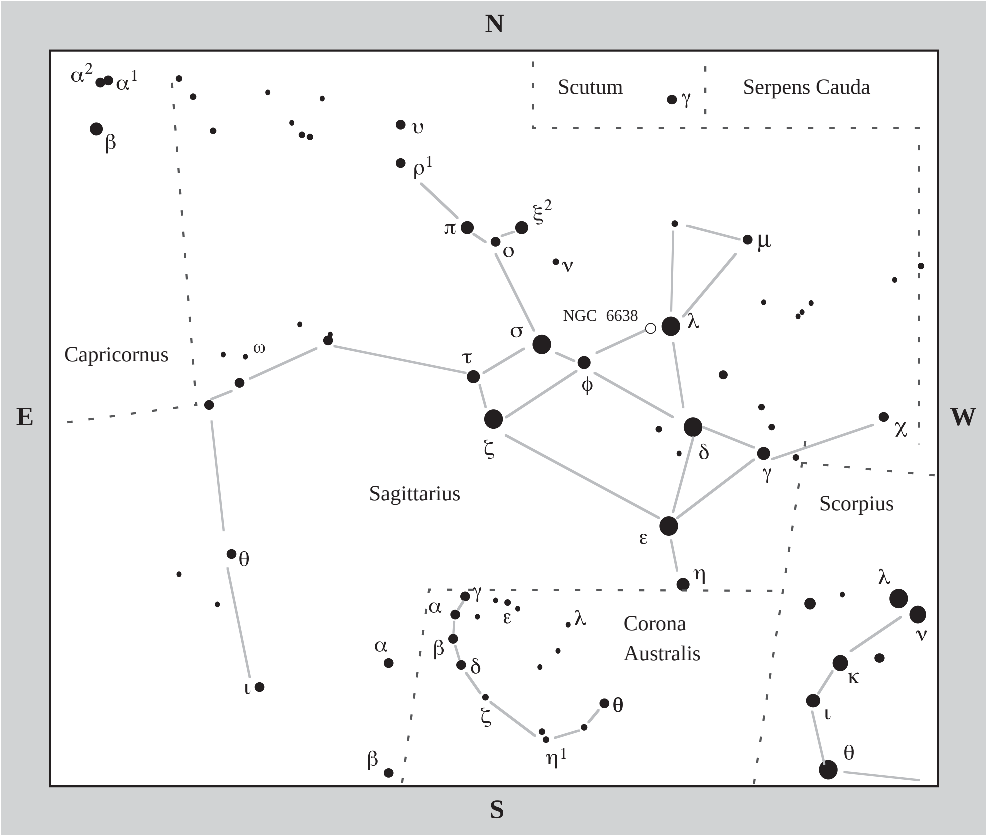
By comparison, at 33×, NGC 6589 is a less brilliant haze of light, one best seen with averted vision. Its "central star" shines at magnitude 9.5 and has a diminutive companion about 1′ away. I put central star in quotes because visually, at least in the 5-inch, I can see a small 1′ collar of light surrounding the magnitude-9.5 star but not its eastern extension, which shows so magnificently in images. Again Mario's image reveals NGC 6589 as a cloud equally as large as NGC 6595, but one not centered on the 9.5-magnitude star. Instead the nebula appears bifurcated by dim dark nebulosity, with one part centered on the magnitude-9.5 star and another part centered on a dim pair of stars to the east.

In 1998, Jenni Kay, a Fellow of the Royal Astronomical Society and a member of Australia's Canberra Astronomical Society, observed NGC 6589 in more detail using a 12.5-inch f/5 Newtonian from Lobethal, South Australia: "[NGC 6589 is] a rather faint, relatively large, round hazy glow with a double star of uneven brightness… Not seen at the lower power, however, is a second, faint round glow, east-southeast of the first. The two round glows may be bridged by a narrow strip of nebulosity, or they are barely detached. Both hazy glows are similar in size and brightness. The first may have been more easily detected having the prominent double star involved. This second glow has a faint 14 mag star at the centre, and could easily be overlooked if not given care and attention. Both round, hazy glows are 1.5′ in diameter. N6589, being made up of both nebulous patches, has an overall size of 4.0′ × 2.0′."

Kay also spied IC 1284, saying it required averted vision and describing it as being "faint, very large, about 15′ in diameter, with a very irregular overall shape. There are about twenty stars ranging from 7.5–12 mag which are scattered across the nebula. The brightest 7.5 mag star, which lies near the centre of the nebula, seems to be wrapped in a soft, nebulous halo."

Through my 5-inch at 33×, IC 1284 is merely suspect. In other words, I do not know if the "glow" I'm seeing is from the nebula or whether it's the "milkiness" of unresolved starlight. See what you think.

Secret Deep 83
(NGC 6638)



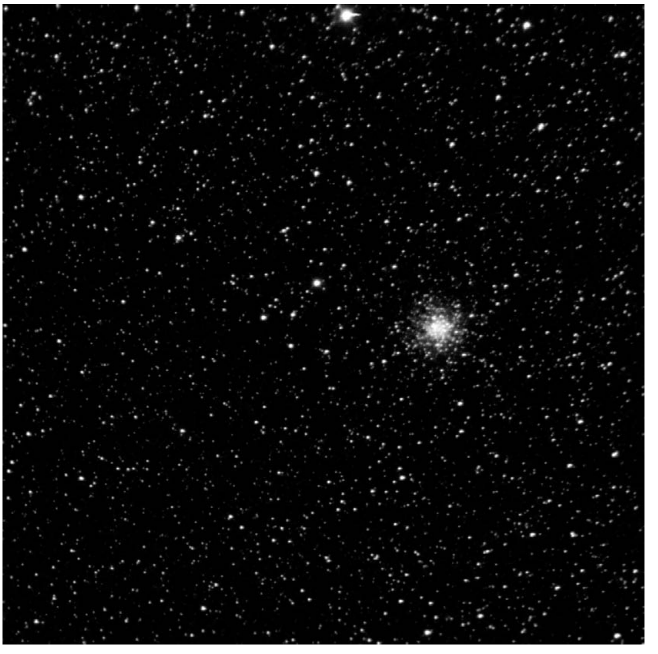
83

NGC 6638
Type: Globular Cluster
Con: Sagittarius

RA: $18^h\ 30.9^m$
Dec: $-25°\ 30'$
Mag: 9.2
SB: 13.5 (Rating: 3.5)
Diam: 7.3′
Dist: ~31,100 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed July 12, 1784] Considerably large, round, very bright in the middle, easily resolvable. (H I-51).

NGC: Globular cluster, bright, small, round, well resolved, clearly consisting of stars.



NGC 6638 IS A VERY SMALL BUT highly condensed globular star cluster near 3rd-magnitude Lambda (λ) Sagittarii, the tip of the celestial Teapot. This hidden gem suffers the unfortunate distinction of being in the company of two of the greatest globular clusters hunted down by amateur astronomers: M22, about 2° to the northeast; and M28, about 1½° to the west-northwest.

William Herschel, the cluster's discoverer, must have been impressed with the view, classifying it as a nebula (one easily resolved into stars). Herschel had a varying belief that all nebulae were resolvable into stars, given sufficient aperture. But he later thought of nebulae as star systems in various states of evolution. "When round nebulae have a nucleus," he imagined, "it is an indication that they have already undergone a high degree of condensation. . . . These clusters of stars are more condensed and brighter in the middle and the central brightness must be the result of central powers. [A] Nebula that [is] composed of a thousand stars must arrive at the perfection of its form sooner than another which takes in a range of a million years." In 1814, he wrote of the new object as being a miniature of M53 in Coma Berenices and M69 in Sagittarius. Curiously, when his son John observed the object, he saw it as "barely resolved, a very delicate object, doubtless a globular."

But NGC 6638 is a globular cluster with an integrated spectral type of G0. It's a moderately metal-rich bulge cluster (see also Secret Deep 85 (NGC 6717)) 7,500 light years from the Galactic center and 31,100 light years from our Sun – making it 66 light-years across in true physical extent. In a 2005 *Monthly Notices of the Royal Astronomical Society* (vol. 361, pp. 272–282) E. Valenti (University of Bologna, Italy) and colleagues found that the cluster has about 1/10 as much iron (per unit hydrogen) as does our Sun and is reddened by nearly 0.5 magnitude.

NGC 6638 is relatively rich in RR Lyrae variables, which is not surprising, since more than 90 percent of variable stars found in globular star clusters are of this variety. RR Lyrae stars are evolved, low-mass (~0.8 Sun) pulsating stars, burning helium in their cores and hydrogen in their shells. Because RR Lyrae stars are unstable (their evolutionary course depends on each star's mass and chemical composition, among other things) they are not plotted on the Hertzsprung–Russell (HR) diagram, leaving at their position a "gap," known as the RR Lyrae gap.

What is surprising about NGC 6638's RR Lyrae stars, however, is that of the 15 variables identified as members, 14 of them are c-type RR Lyrae stars, the other one is an ab-type RR Lyrae. This is odd because most RR Lyrae stars (91 percent) are of the ab-variety. The difference between the two classes is based on the shape of their light curves: ab-type RR Lyrae stars have light curves with a steep rise in brightness; the c-type RR Lyrae stars (9 percent) have shorter periods and show a more sinusoidal variation. The differences are related to the interior mechanisms driving gas outflow and the stellar pulsations.

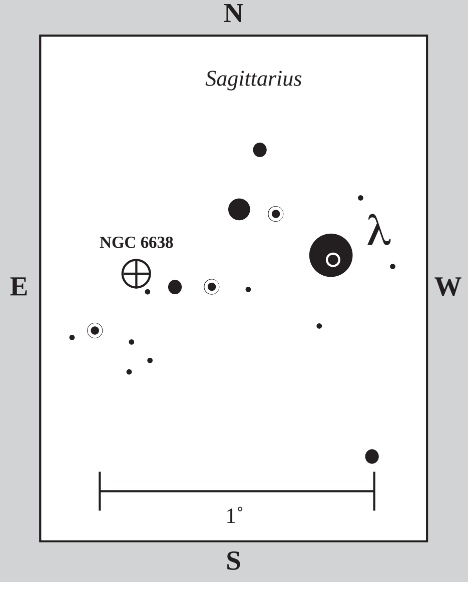
In a 1986 *Publications of the Astronomical Society of the Pacific* (vol. 98, pp. 453–456), Horace A. Smith (Michigan State University) and his colleagues say that such a preponderance of c-type variables is unique, in that NGC 6638 has twice as many known c-types variables as ab-types. Generally, there is a scarcity of c-type variables in globular clusters with similar metallicities to NGC 6638.

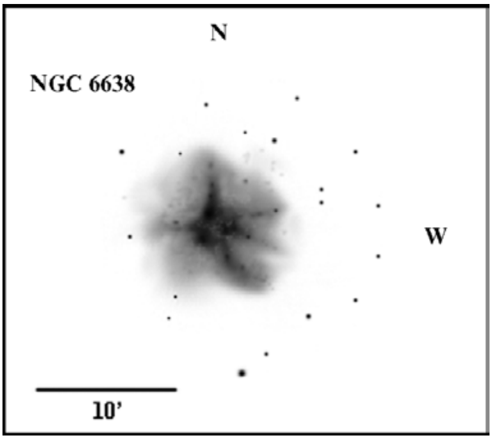
The researchers say that the abundance of c-type variables in NGC 6638 can probably be attributed to an unusual distribution of stars on its horizontal branch – the part of the HR diagram of a typical globular cluster that shows the stage in a star's life when it is fusing helium in its core and burning hydrogen in a shell around the core – which has a broad gap dividing it into red and blue sections. "The blue component extends into the RR Lyrae gap," they say, "far enough to produce c-type RR Lyrae stars, whereas the part of the instability strip [a nearly vertical region in the HR diagram occupied by pulsating variable stars] in which stars would pulsate as ab-type RR Lyrae stars must be particularly devoid of stars."

Smith also suggests that the cluster is ripe for a new variable star search, especially with modern CCD methods. "Some modern CCD searches are finding significant numbers of previously unknown globular cluster variables," Smith says, "although usually it is the low amplitude RRc stars that are preferentially among the undiscovered. A new variable star search might be able to confirm whether there really are very few RRab variables or whether they for some reason escaped discovery in the previous search. If they really do not exist, then the hypothesis that the excess of c-type variables is owing to the peculiar distribution of stars on the horizontal branch would be strengthened. The HST color–magnitude diagram of NGC 6638 by Piotto *et al.* (*Astronomy & Astrophysics*, vol. 391, p. 945, 2002) does make me wonder a bit whether there might be more RRab variables for some reason undiscovered so far."

To find this hidden gem, use the chart on page 351 to locate Lambda Sagittarii. Center that star in your telescope at low power, then switch to the chart on this page. NGC 6638 is only about 40′ east and slightly south of Lambda. At 33× in the 5-inch, the globular is a tiny (2′) fleck of fuzzy light that swells with averted vision, making it appear like a very condensed 9th-magnitude comet. You'll find it as the easternmost "star" in a 15′-long chain including two 8th-magnitude suns to the west. The cluster almost disappears with a direct gaze. With attention and averted vision, I can see a tiny core inside an irregular halo.

At 60×, the cluster is a pleasing sight, appearing as a round and highly con-



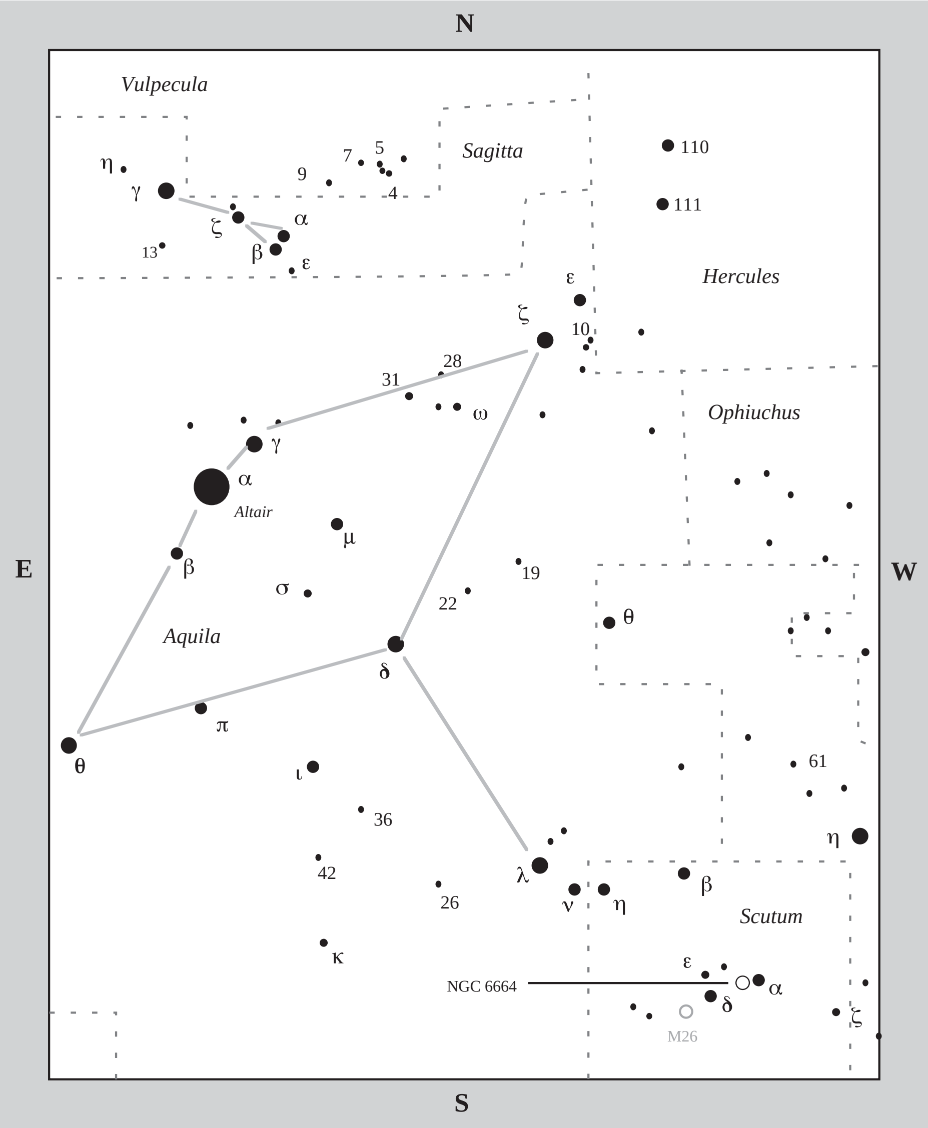


densed glow with a bright starlike knot at the center, which I can see distinctly with direct vision. At 94×, with averted vision, the core stands out prominently surrounded by a tight and dense collar of mottled light nested in a larger outer halo that scintillates.

The most fantastic shapes and forms appear at 180×, including looping fountains of knotty starlight to the east, northeast, west, and south. These arms seem almost flamboyant, as if bursting forth through the cluster's dense core and escaping with wild abandon into the freedom of outer space. The core fans out to the south, forming a wedge bordered by a trine of "stars" – more likely clumps of stars.

The cluster's brightest stars shine at 14th magnitude, and these can be seen swimming around the halo at high magnification and averted vision. Sweeping my vision across the outer halo brought views of faint arms extending radially away from the core like fractured ripples. Quite an interesting sight and one worthy of attention for such a small object.

Secret Deep 84
(NGC 6664)



84

Santa's Sleigh, Teacup Cluster
NGC 6664
Type: Open Cluster
Con: Scutum

RA: 18^h 36.5^m
Dec: -08° 11′
Mag: 7.8
SB: 13.2 (Rating: 4)
Diam: 12′
Dist: ~4,900 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed June 16, 1784] A cluster of very coarse, scattered stars. (H VIII-12)

NGC: Cluster, large, pretty rich, very little concentrated.

I HAVE TO ADMIT THAT NGC 6664 escaped my attention for several decades – until I swept it up in 2003 with my 4-inch refractor. I called it a "true hidden treasure," penning, "I cannot believe how many times I must have passed over the cluster, not knowing it existed." I was especially surprised to see it under dark skies through 7 × 50 binoculars (once I knew where to look), because the cluster lies in one of my favorite nova-hunting regions in Scutum, yet I never noticed it.

This shows the important role an intensely focused mind plays when we seek out specific objects of astronomical interest (a nova would appear as a star, not as a dim and diffuse object). But there's more to it than that. NGC 6664 lies only 20′ east of 4th-magnitude Alpha (α) Scuti, whose light overpowers the cluster, stealing attention away from it. Finally, the cluster is large and scattered, appearing as a dim and diffuse haze in binoculars, which would have been easily washed out from the city and suburban environments from which I nova hunted.

Actually, despite its bashful appearance, NGC 6664 is the second brightest open star cluster in Scutum; its two magnitudes fainter than similar sized M11 and a mere 0.2 magnitude brighter than slightly smaller M26, which is only about 2¼° away to the east-southeast. At first I wondered why Messier and Méchain, as well as other keen-eyed contemporary observers prior to the cluster's discovery by William Herschel in 1784, missed seeing it (because they were looking for diffuse cometary forms), but I think most of the reasons I cited above are sufficient to explain the cluster's elusiveness.

If you have the opportunity to look at the positions of M11, M26, and NGC 6664 in a wide-field photograph, you'll see that they frame the Scutum Star Cloud – a plump 5°-wide, pork-chop-shaped star cloud with dark nebulae biting into it along the north, west, and southern sides. "This, the gem of the Milky Way," writes the pioneering astrophotographer Edward Emerson Barnard, "is the finest of the star clouds. … In looking at this great cloud one cannot imagine that it is anything but a real cloud in form, with a depth comparable to its width … its serrations are probably due to dark obscuring matter." Barnard's is a justifiable opinion. A sweep of this rich stretch of Milky Way through a wide-field telescope or large binoculars brings unfathomable starscapes into view.

When we look in the direction of Scutum, we are along the Carina–Sagittarius spiral arms, between us and the Galactic center. If we accept the outer-edge boundaries of that arm adopted by Tatya P. Gerasimenko (Astronomical Observatory of the Ural State University) in 1993, NGC 6664 lies in the interarm gap just beyond the point where the arm curves inward. In other words, we're looking tangentially at the arm's curve and seeing the cluster near its edge. (The same also goes for M11 and M26, which are at similar distances and Galactic longitudes.) Of course, the structure of our Galaxy's arms is not fully understood. We do not know for sure if they are flocculent (feathery) or not. As the researchers note, "We can say nothing definite about the edges of the arm in Sagittarius at longitudes $l = 10°–30°$ [NGC 6664 ($l = 23.95$)]."

In 1958, Halton Arp (Mount Wilson and Palomar Observatories, California) found that in red light NGC 6664 is difficult to distinguish from its surroundings. On blue plates, however, the cluster is quite obvious. He also found the cluster's color–magnitude diagram shows a clear main sequence and a few red giants. In a 1982 *Astronomical Journal* (vol. 87, p. 1197), Edward G. Schmidt (University of Nebraska) found the cluster's distance to be 4,900 light-years and the foreground reddening to vary from 0.5 to 0.6 magnitude across the cluster, which includes the bright Cepheid variable star EV Scuti with a period of 3.09 days, during which time it dips from 10th magnitude to 10.3 magnitude and back. EV Scuti's radial velocity indicates that it is likely a cluster member.

In a 2003 *Astronomy & Astrophysics* (vol. 401, p. 661), Ukrainian astronomers Valery V. Kovtyukh, Sergey M. Andrievsky (Odessa State University) and colleagues report that EV Scuti is most likely not a spectroscopic binary as had been previously suggested but a non-radial pulsator.

NGC 6664 is around 46 million years old, making it younger than the Pleiades. The cluster harbors three blue stragglers – hot, bright stars that appear to be younger than their siblings; these mystery stars are much more common in globular clusters, where stars at the tightly packed core can collide. Since open clusters are much more loosely accumulated, the blue stragglers must result from dynamical interactions in binary systems, which causes them to coalesce into a single hot and deceptively youthful appearing star.

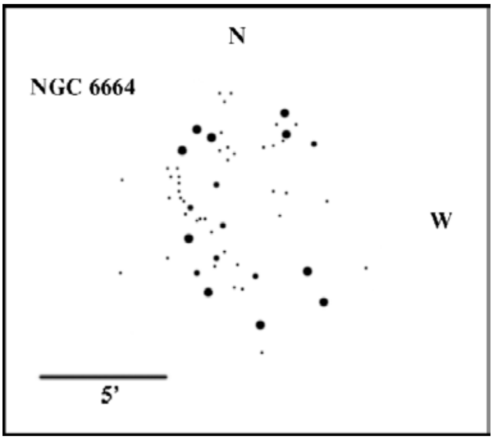
To find this obscure and neglected cluster, use the chart on page 355 to locate Alpha Scuti. Again, NGC 6664 is just 20′ east of that star. In the 5-inch at 33×, the cluster is a very pretty, yet subtle, attraction, quite large and scattered across

12′ of sky. At a distance of 4,900 light-years, the cluster's 60 or so members, which are quite easily resolved, span a true linear extent of 17 light-years. Trumpler classified it as a type III2m – meaning it's a detached cluster with no discernible concentration, in which the moderately bright stars are more-or-less thinly but uniformly scattered.

About 20 stars are readily apparent at a glance, and they seem to stand out against a fainter backdrop of dimmer suns with a bold L shape. Together the brightest members and the dimmer suns appear unevenly spread across the field, aligned north-northeast to south-southwest, in the shape of a semicolon. The "semicolon" appears to be linked to Alpha Scuti by a chain of three roughly 10.5-magnitude suns. Alpha Scuti itself adds a rich golden hue to the scene.

The cluster contains about 60 stars 9th magnitude and fainter, and the possible double Cepheid EV Scuti (marked in the photograph) is among the brightest.

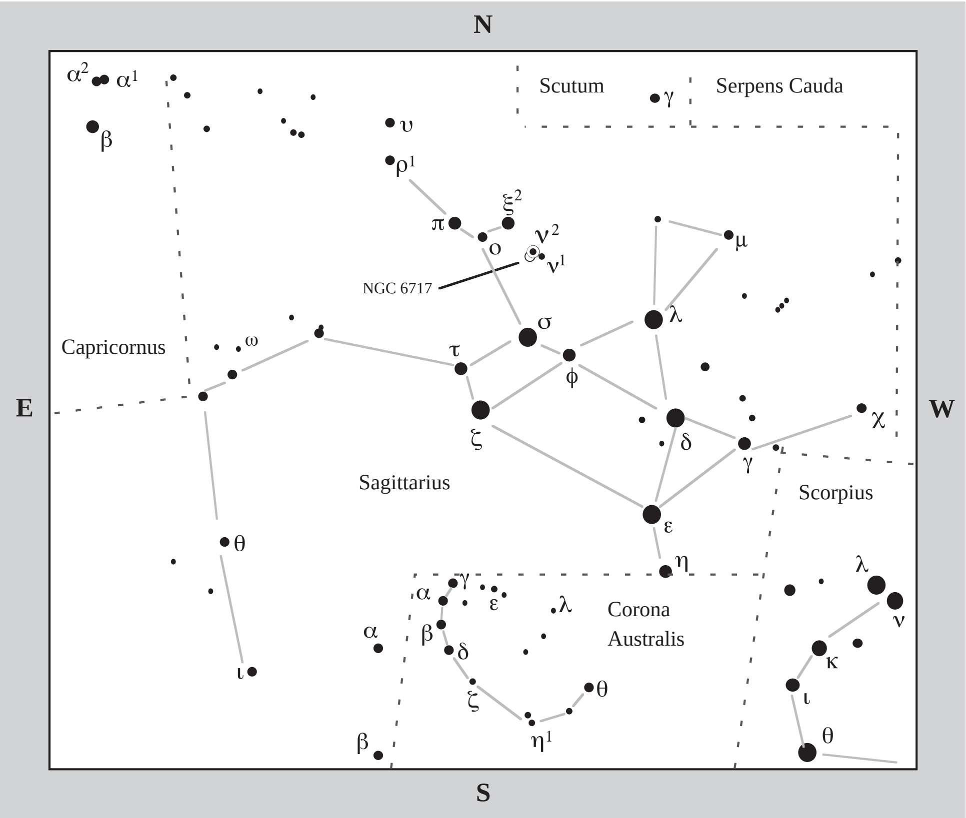
For me, the view is best at 60×. And though the cluster does not have a clear central concentration of stars, look for a small knot of starlight near the northwestern end. With imagination, the stars can be seen, with west up, as a one-horse open sleigh, Santa's sleigh, or a swan boat. On



his his website Wayne Schmidt (www.waynesthisandthat.com/stellarasterisms.htm) calls NGC 6664 "a 12-minute tall teacup with a little tea still in it," as viewed through his 8-inch reflecting binoculars.

Through his 11× tripod-mounted 3-inch binoculars in 1992, Auke Slotegraaf of Stellenbosch, South Africa, saw a "beautiful soft glow, round, upon a murky field. A delicate object, surprisingly large, like percolated starlight, a slightly condensed milky-way star-patch, or a low surface-brightness globular cluster." He also reminds us to nudge the field 2° to the west, where we'll find a massive lightless void, over 3° degrees long." See what you see . . . or don't see!

Secret Deep 85
(NGC 6717)



85

IC 4802 = Palomar 9
NGC 6717
Type: Globular Cluster
Con: Sagittarius

RA: 18^{h} 55.1^{m}
Dec: $-22°$ 42′
Mag: 8.4
SB: 12.1 (Rating: 3)
Diam: 5.4′
Dist: ~23,100 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed August 7, 1784] Three very small stars with suspected nebulosity. (H III-143)

NGC: Faint, small, very round, cluster and nebula.

NGC 6717 IS A SOFTLY GLOWING globular cluster, in a beautiful field between the Spoon and Teapot asterisms in the celestial Archer punctuated by two golden gems: Nu^1 (ν^1) and Nu^2 (ν^2) Sagittarii; NGC 6717, in fact, lies all but hidden in the glow of Nu^2. This inconspicuous gem, one well worth the hunt, also has a curious history.

When William Herschel discovered it in 1784, he catalogued it as a faint nebula – seeing through his scope three dim stars in "suspected nebulosity." No doubt, Herschel was partially resolving the tiny "clump" of stars on NGC 6718's northeastern flank, which stands out against the glow of the remaining cluster, which appears nebulous. Herschel's son, John, reiterated his fathers words when he later surveyed the object from England and South Africa, calling it "a very small clustering knot, with perhaps nebula. A doubtful object. I see 3 or 4 of the stars, but there is also a nebulous appearance."

Around 1900, French astronomer Camille Guillaume Bigourdan (1851–1932) complicated matters by giving the clump of stars its own designation (Big 434), which Dreyer listed as IC 4802 in his 1908 *Second Index Catalogue*, describing it as a "[n]ebula with a 13th-magnitude star, 15″ north following [H III-143 (NGC 6717)]." But as Brent Archinal and Steven J. Hynes explain in their book *Star Clusters*, Brian Skiff (Lowell Observatory) suspected that Bigourdan's object was the same as Herschel's, and Hal Corwin at the NGC/IC Project (www.ngcicproject.org) concurred, saying IC 4802 "bears the same relationship to NGC 6717 as NGC 3189 does to NGC 3190, or NGC 5906 to NGC 5907: it's part of the larger object."

Corwin also suspected that the proximity to 35 Sagittarii probably provided some field glare that contributed to the "nebulosity" that the Herschels and Bigourdan saw. While that's certainly possible, I believe it's simple enough to say that these observers saw the clump within the unresolved cluster as their "stars and nebulosity." Nevertheless, it wasn't until 1931 that Per Collinder recognized NGC 6717 for what it truly is: a globular star cluster.

Interestingly, NGC 6717 is also known as Palomar 9. In his 1955 *Publications of the Astronomical Society of the Pacific* paper, "Globular Clusters and Planetary Nebulae discovered on the National Geographic Society–Palomar Observatory Sky Survey," George O. Abell obviously failed to notice Collinder's identification of NGC 6717, listing it as the 9th of 13 star clusters "found on the survey photographs which appear to be globular." It was one of seven clusters at low galactic latitudes that "suffer considerable obscuration. They appear to be globular on the survey plates, but confirmation is not yet available."

Modern studies of NGC 6717 are sparse. We know it is a bulge globular, 23,100 light-years distant (making its true linear extent 36 light-years across) with a possible post-core-collapse structure.

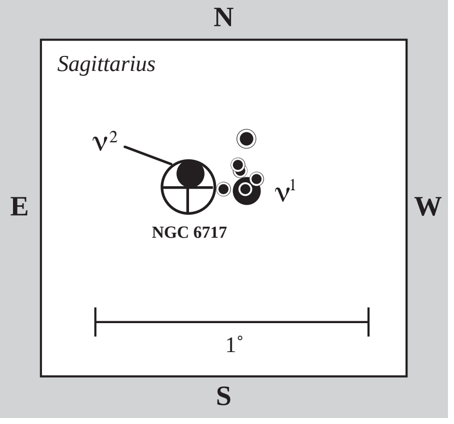
The cluster presents a blue horizontal branch and is reddened by 0.2 magnitude. Like other bulge globulars, NGC 6717 is of high metallicity, having nearly 1/20 as much iron (per unit of hydrogen) as does our Sun. Indeed, in a 2001 *Astrophysical Journal* (vol. 556, L83) Duncan Forbes (Swinburne University, Hawthorn, Australia) and his colleagues note that there is now "strong evidence that the metal-rich globular clusters near the center of our Galaxy are associated with the Galactic bulge rather than the disk as previously thought."

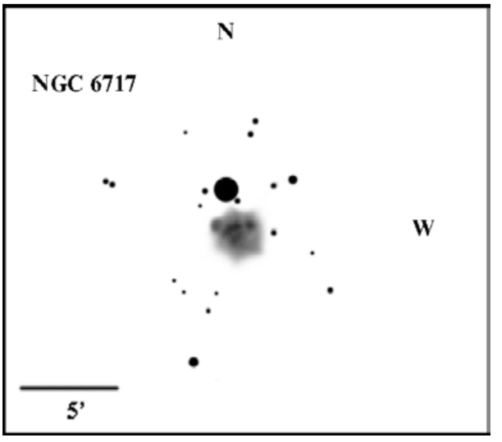
Globular clusters in our Galaxy, they say, had been broadly divided into two classes on the basis of their metallicity and/or kinematics: a metal-poor, nonrotating subpopulation (long associated with the Galaxy halo), and a metal-rich system with significant rotation (historically associated with the disk). But Forbes *et al.* say that a view is now emerging that metal-rich globular clusters within about 16,000 light-years of the Milky Way Galactic center are associated with the bulge rather than the disk. NGC 6717 is only about 8,500 light-years from that point.

The researchers say that globular cluster systems share a similarity with elliptical galaxies and spiral bulges. "By extension," they say, "this would suggest that bulges and elliptical galaxies formed by a similar mechanism." In the case of the Milky Way's bulge, it appears to have formed by a rapid but clumpy collapse, though it could also have been formed by mergers, "We still don't know for sure," Forbes says.

NGC 6717 has an integrated spectral type of F6 and a blue horizontal branch magnitude of 15.6. Its brightest stars shine around 14th magnitude, making it a good target for modest amateur telescopes, which can achieve at least partial resolution.

Again, finding this globular cluster is easy. Just use the chart on page 359 to locate 5th-magnitude Nu^2 Sagittarii, then use the chart on page 362 to pinpoint the



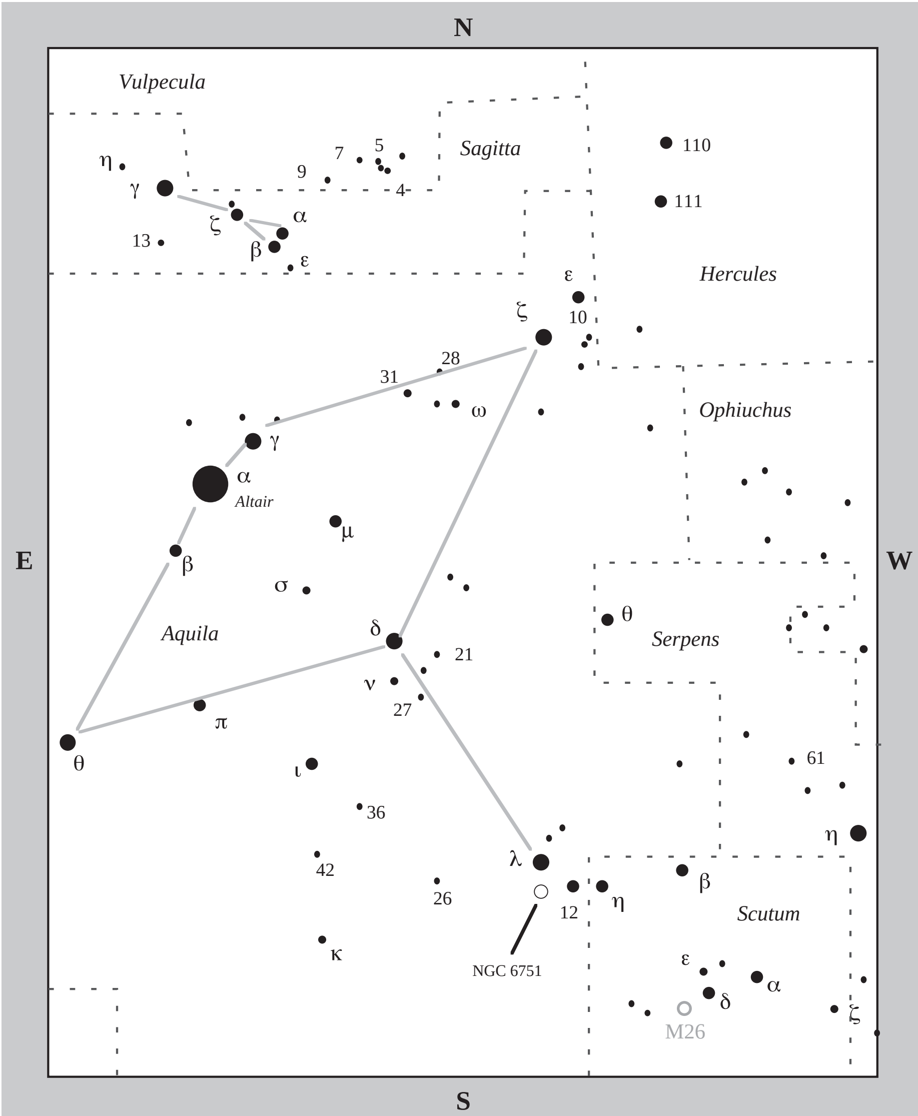


cluster only 2′ to the south. At 33× in the 5-inch, the cluster lies in a beautiful field punctuated by the twin Nu stars, which shine forth like topaz gems among a scattering of other dimmer suns, including a fine open pair. NGC 6717 itself is but a breath of light abutting Nu^2; I couldn't detect the cluster with direct vision, but it was most apparent with averted vision, appearing as a shy little ghost hiding in Nu^2's glare.

Increasing the magnification to 60× shows the globular a bit better, but it still shines like an afterthought of light. The cluster now appears a little less "shy," having "stepped away" from Nu^2 a bit. With averted vision, I can make out a tiny heart to the cluster, which is surrounded by a soft collar of light.

The cluster can just be seen with direct vision at 94×. With averted vision, the core is more distinct and appears broken. The surrounding halo of light is angular, but this may be an illusion owing to its proximity to Nu^2. The cluster holds magnification well, so I took the time to study it in varying degrees, from 165× to 282×. The clearest and most comfortable views, though, are around 200×. The cluster's core is definitely fragmented into tiny mottled beads with a distinct one, or a large clump of little beads, to the northeast (IC 4802) and another to the northwest. The faint outer halo of unresolved starlight fades away rapidly with each increase in power – at least through my modest scope.

Secret Deep 86
(NGC 6751)



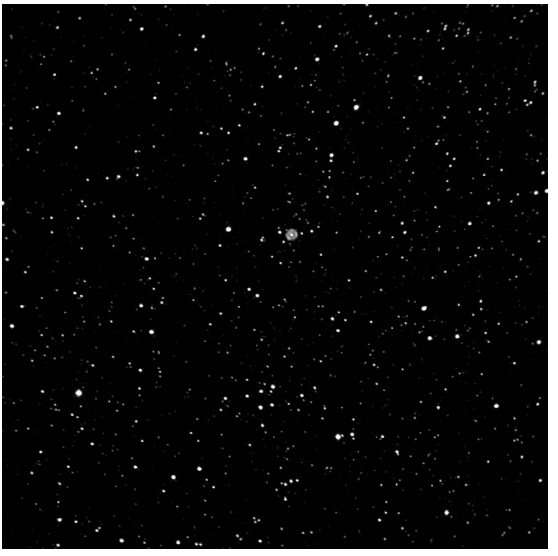
86

Glowing Eye Nebula, Dandelion Puff Ball
NGC 6751
Type: Planetary Nebula
Con: Aquila

RA: 19^h 05.9^m
Dec: $-05°$ 59.5′
Mag: 11.9 (Rating: 3.5)
Dim: 24″
Dist: ~7,000 l.y.
Disc: Albert Marth, 1863

HERSCHEL: [None].

NGC: Pretty bright, small.



NGC 6751 IS A NEGLECTED GEM DEEP in southwestern Aquilae. It lies a little more than 1° south of Lambda (λ) Aquilae, the 3rd-magnitude star marking the tail of Aquila, the Eagle, as depicted by H. A. Rey in his delightful 1952 book *The Stars: A New Way to See Them* (Houghton Mifflin Co., Boston). In Rey's depiction, the constellation's Alpha (α) star Altair and its two fainter attendants (Beta (β) and Gamma (γ) Aquilae) form the bird's head. Delta (δ), Eta (η), Theta (θ) and Zeta (ζ), mark its wings, and Lambda its tail.

It's surprising to me that William Herschel and his son John missed this little marvel, especially since it lies only about 6° south of the Celestial Equator – the imaginary great circle on the Celestial Sphere that divides the northern and southern hemispheres and reflects Earth's equatorial plane projected into space. Instead, the discovery honor goes to Albert Marth (1828–1897) a German-born astronomer who, from 1863 to 1865, worked in the Mediterranean isle of Malta as an assistant to William Lassell (1799–1880) of Liverpool.

In 1858, Lassell had erected at Starfield (near his hometown) his greatest telescope-making achievement: a 48-inch f/9 speculum-metal Newtonian reflector. Two years later, he had the monster scope dismounted and shipped to Malta, where he used it to survey the heavens. Marth joined him two years later. Through the 48-inch, Marth found 601 new deep-sky objects (580 being credited to him), including NGC 6751, which he discovered on July 20, 1863. Most of these had avoided detection by other observers. Marth listed our target as the 397th object in his catalogue of objects found by him. He also determined the positions of these objects with a great degree of accuracy – a remarkable feat considering the unwieldy instrument he had to use. John Louis Emil Dreyer gave the new object the general catalogue number GC 5940.

Edouard Jean-Marie Stephan included it in his 1883 list of objects discovered and observed at Marseille, calling the nebula “bright; small; round; with a central condensation.” Thirty-five years later, Heber Curtis identified NGC 6751 as a true planetary based on its impression on plates taken with the 36-inch Crossley reflector at Lick Observatory. He described the “rather faint” nebula as “Nearly round [with] indistinct evidence of a very irregular ring formation.”

Note the distinct 14th-magnitude central star. Its spectrum is dominated by strong emission lines typical of a Wolf–Rayet star. These stars are extremely luminous and hot and shed mass at enormously high rates, in many cases after passing through a supergiant stage. NGC 6751’s central star has a searing surface temperature of over 100,000 degrees Celsius and shines with a luminosity of 9,200 Suns. The star appears to be in its heating phase after losing its entire hydrogen envelope in a mass ejection.

In a 1991 *Astrophysical Journal* (vol. 476, pp. 150–160) Y.-H. Chu and colleagues note that NGC 6751’s nebula did not attract much professional attention until 1986, when spectroscopic data revealed a bipolar mass outflow and a faint envelope outside the bright main nebula with faint filaments extending out to a radius of greater than 100″. Some of the outer filaments belong to a halo of NGC 6751, while others are interstellar material ionized by NGC 6751’s hot central star.

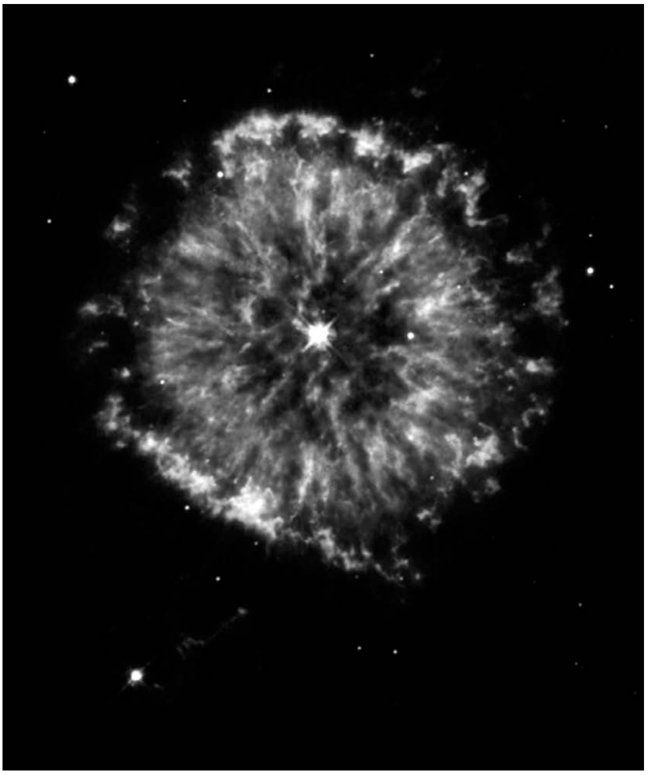
This can be dramatically seen in the Gemini South telescope image at above right. The image is the result of the winning entry in the 2009 Gemini Student Imaging Contest, submitted by high school student Daniel Tran of PAL College (high school),

Cabramatta, New South Wales, Australia. The contest, sponsored by the Australian Gemini Office, solicited high school students from across Australia to submit a target and explain why it would make a good image. As reported in a Gemini press release, when Daniel saw this planetary online at the WorldWide Telescope (WWT, a project of *Microsoft*®) he found, “its unique colour and structure made me want to know more about it, and the name itself caught my attention and started to reel me in.” The image, a result of his one hour’s observing time for multi-band optical imaging with the Gemini South Multi-Object Spectograph, shows in stunning detail the approximately 3,000-year-old Glowing Eye Nebula and the other wisps of gas in the interstellar medium (upper-left-hand corner of the image) being ionized by the nebula’s central star.

NGC 6751 appears to be a rare (only seven are known) triple shell nebula moving through a dense interstellar HII region. Indeed, the radial velocity of this region is different from that of the planetary nebula by 55 km/sec, and the helium to hydrogen ratio is lower in the HII region. The medium also appears to be slowing the expansion of the nebula's halo. Chu *et al.* add that the shell structure of NGC 6751 gives clear evidence that the progenitor of the planetary nebula's nucleus must have gone through mass loss in a complex way.

In 1998, a team of astronomers led by Arsen Hajian of the U.S. Naval Observatory in Washington, D.C., used the Hubble Space Telescope (HST) to image NGC 6751's main nebula in great detail (see image below, with north to the lower right, and east to the upper right). The Hubble Heritage Project released this picture in 2000 to commemorate the Hubble telescope's 10th anniversary.

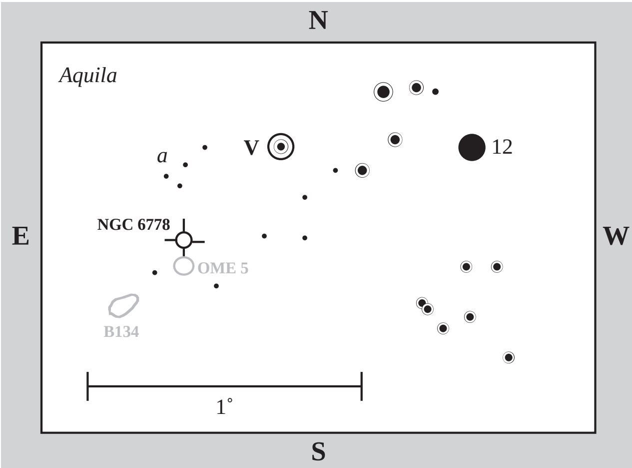
In the HST image, the main hot shell looks like a frayed ring at the outer edge of the nebula. This region was probably ejected about 3,000 years ago from the central star. Inside the ring, cool gases (bright filaments in this black and white image) lie in long streamers pointing away from the central star. The origin of these cooler clouds within the nebula is still uncertain, though they appear to have been created by intense winds expanding at a velocity of about 42 km/sec and radiation pressure from the intensely hot central star.



University of Washington astronomer Bruce Balick likens the nebula's filamentary appearance to that of the puff ball of a dandelion, adding that the HST image "gives the impression of an explosion rather than an organized ejection, as for the other nebulae." The nebula's most popularly used moniker, however, is the Glowing Eye. If we accept NGC 6751's distance as 6,500 light-years, the main shell's true physical extent is about 0.8 light-year across, or about 600 times the size of our Solar System.

Finding this Glowing Eye is not difficult. Again, it's only a little more than 1° south of Lambda Aquilae, which places the two in the same low-power field in most telescopes. Use

86

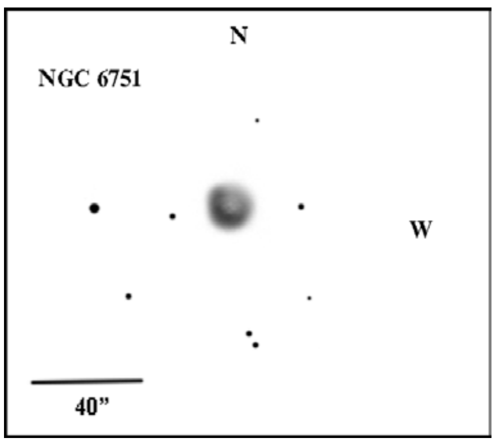


the chart on page 363 to pinpoint Lambda, then 4th-magnitude 12 Aquilae almost 1.5° to the southwest and center it in your telescope at low power. From 12 Aquilae, move 40′ east to V Aquilae – a semiregular variable star that changes brightness from 6.6 magnitude to 8.4 magnitude and back, about every 353 days. Now move 25′ to the east-southeast, where you'll find a roughly 12′-long Sagitta-like asterism of four 10.5-magnitude stars (*a*) oriented northwest–southeast. NGC 6751 appears as a 12th-magnitude star just 10′ due south of the southern tip of asterism *a*.

When I first looked for the nebula, I was confused by the appearance of another significant asterism of dim suns that forms a 3′-wide cluster-like glow about 5′ to the south. This asterism (OME 5 (O'Meara 5)) is at right ascension 19^{h} 06^{m}, declination –06° 04.5′, and shines more brightly than the planetary, so it tends to capture the eye first, especially since the planetary is very stellar at 33×. I suggest that once you find the field, switch to a medium magnification to spot the planetary. At 60×, its disk just starts to emerge as a slightly bloated 12th-magnitude star with averted vision. There are plenty of field stars around to compare with the planetary's image, helping you to see its disk.

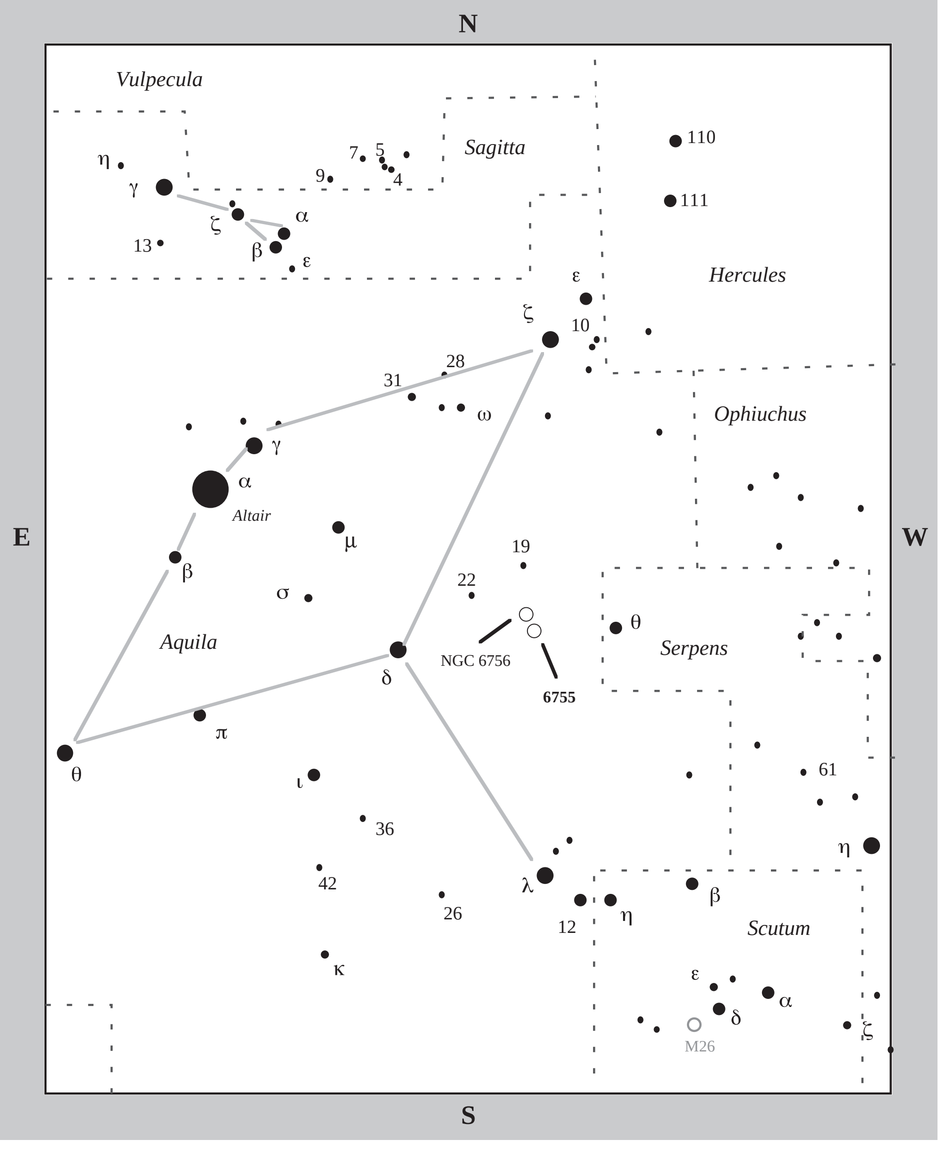
At 94×, the now more prominent shell just begins to show signs of a ring. The nebula takes magnification fairly well. At 180×, for instance, the nebula appears as a snowy collar wrapped around a moderately dark hole. I could not see any trace of the 13.5-magnitude central star. Nor could I make out any filamentary detail.

I must admit that whenever I viewed this object, the seeing was poor. I've yet to get it on a really crisp night. Brian Skiff and Christian Luginbuhl, however, note that they've spied the central star "just barely" in a 6-inch telescope. The central star, they say, is clearly visible in a 10-inch; and in a 12-inch, "two dark spots can be seen on the [south] side of the broad core."



87 & 88

Secret Deep 87 & 88
(NGC 6755 & 6756)



87

Part of Possible Binary Cluster
NGC 6755
Type: Possible Binary Open Cluster
Con: Aquila

RA: 19^h 07.8^m
Dec: +04° 16′
Mag: 7.5
SB: 13.4 (Rating: 3.5)
Diam: 15′
Dist: ~5,500 l.y.
Disc: William Herschel, 1785

W. HERSCHEL: [Observed July 17, 1785] A pretty compressed cluster of pretty scattered stars of various sizes, magnitudes, and colours, irregularly faint, and unequally compressed, 12 or 15′ in diameter. (H VII-19)

NGC: Cluster, very large, very rich, pretty compressed, stars from magnitude 12 to 14.

88

Part of Possible Binary Cluster
NGC 6756
Type: Possible Binary Open Cluster
Con: Aquila

RA: 19^h 08.7^m
Dec: $+04°$ $42'$
Mag: 10.6 (9th, O'Meara)
SB: 13.6 (Rating: 3.0)
Diam: $4'$
Dist: ~4,900 l.y.
Disc: William Herschel, 1793

W. HERSCHEL: [Observed August 21, 1793] A small, pretty compressed cluster of stars not very rich. (H VII-62)

NGC: Cluster, small, rich, little compressed, stars from magnitude 11 to 12.

NGC 6755 AND NGC 6756 ARE A PAIR of interarm open clusters in the far western reaches of Aquila the Eagle – almost 4¼° west-northwest of 3.5-magnitude Delta (δ) Aquilae, or about 3° east of 4.5-magnitude Theta (θ) Serpentis (Alya) – the terminal star in the Serpent in one of the bleak branches of the Great Rift, a series of overlapping dust clouds that divides the Milky Way. The clusters lie just beyond that murkiness, on the western shores of the Milky Way, which brushes through Aquila like a gentle stroke of the hand.

Owing to intervening dust clouds, we see both NGC 6755 and NGC 6756 greatly dimmed, by about 3 and 4 magnitudes, respectively. If they weren't so greatly obscured, NGC 6755 would be visible to the unaided eye as a diffuse magnitude 4.5 glow one-fourth the apparent size of the full Moon, and NGC 6756 would be a magnitude 6.6 object, appearing as a tight knot of 9th-magnitude suns $30'$ to its northeast. Together, they would have been an admirable binocular pair, or a telescopic showpiece, with both clusters vying for attention in the same wide field of view. Indeed, it's possible that NGC 6755/56 may be a rare binary open star cluster.

Of the more than 1,600 open clusters known in our Galaxy, astronomers recognize only one as a well-ascertained binary: h and χ Persei (NGC 869 and NGC 884), the famous Double Cluster (Caldwell 12). NGC 6755/56, however, is one of 18 probable binary open star clusters now under study. (See also Secret Deep 20 and 21 (NGC 1807 and 1817).) A binary open star cluster is an object consisting of two open clusters that form together from the same giant molecular cloud – a vast, cold, and dense interstellar cloud, rich in gas and dust, out of which stars grow. The components must have a center-to-center separation of less than 65 light-years and an age difference less than 10 million years; or their ages must agree well within the uncertainties of their age determination. Do NGC 6755 and NGC 6756 meet these criteria?

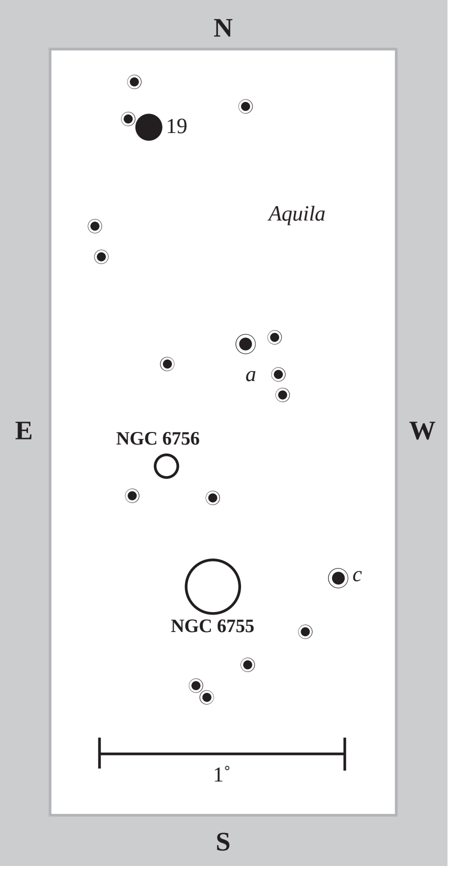
As we can see in the tables above, the clusters appear to lie about 500 light-years apart. If these distances are correct, then the clusters are too far apart to be considered a binary pair. The distances to these poorly studied clusters, however, are uncertain. The cluster pair also appears to have another strike against them. In a 2007 *Bulgarian Journal of Physics* (vol. 34, pp. 236–239), Valentin Kopchev (Bulgarian Academy of Sciences, Sofia) and colleagues describe their attempt to photometrically confirm or disprove the binarity of NGC 6755/56. Their age determinations – ~155 million years for NGC 6755 and ~224 million years for NGC 6756 – imply that these young clusters are not related. "[W]e can not confirm their binarity based on age determination," the authors say, noting that further photometry needs to be done to see if a tidal link exists between them. So the verdict is still out on this possible binary couple.

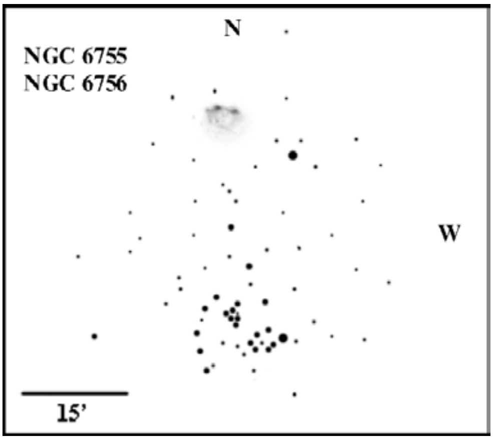
NGC 6755 (Trumpler class II2r) is a rich, magnitude-7.5 cluster in an area of intermediate apparent star density, so it appears detached from the Milky Way background. Its stars are moderately bright (11th-magnitude and fainter) and show little central concentration. The cluster's nearly 160 members span 15′ of sky; if we accept the cluster's distance of 5,500 light-years, its true linear diameter is 24 light-years.

NGC 6756 (Trumpler class I1m) lies only 30′ (the apparent diameter of the full Moon) northeast of NGC 6755. It's a moderately rich magnitude-10.6 cluster that lies in a somewhat less densely populated section of Milky Way, so it too appears detached from the stellar background. But NGC 6756's 40-odd members, which are roughly of the same magnitude (around 13th), are highly concentrated in an area only 4′ across. If we accept the cluster's distance of 5,000 light-years, its true linear extent is only 6 light-years – four times smaller than its visual neighbor.

The two cluster make a very pretty target under dark skies in moderate-sized apertures. They're also a bit of a visual enigma. But first, to find the pair, use the chart on page 368 to locate Theta Serpentis. If you're daring and have an equatorially mounted telescope, you can simply center Theta, then move the scope 3° to the east where you'll encounter NGC 6755, then NGC 6756 30′ further to the northeast. Otherwise, you could first find Theta Serpentis, then use binoculars or your naked eyes to find 5.5-magnitude 19 Aquilae 3¾° to the east-northeast. It's easy to identify 19 Aquilae, because it has an 8th-magnitude companion about 6′ east-northeast of it.

Center 19 Aquilae in your telescope at low power, then use the chart on page 372 to find a 30′-long, Y-shaped asterism *a* (oriented north–south) 1¼° to the south-southwest. The brightest star in the asterism shines at magnitude 7.5 and marks the northeastern arm of the Y. An 8.5-magnitude double star marks the position of the other arm. NGC 6755 is about





1° south-southeast of that 7.5-magnitude star; fainter NGC 6756 is about 40′ southeast of it.

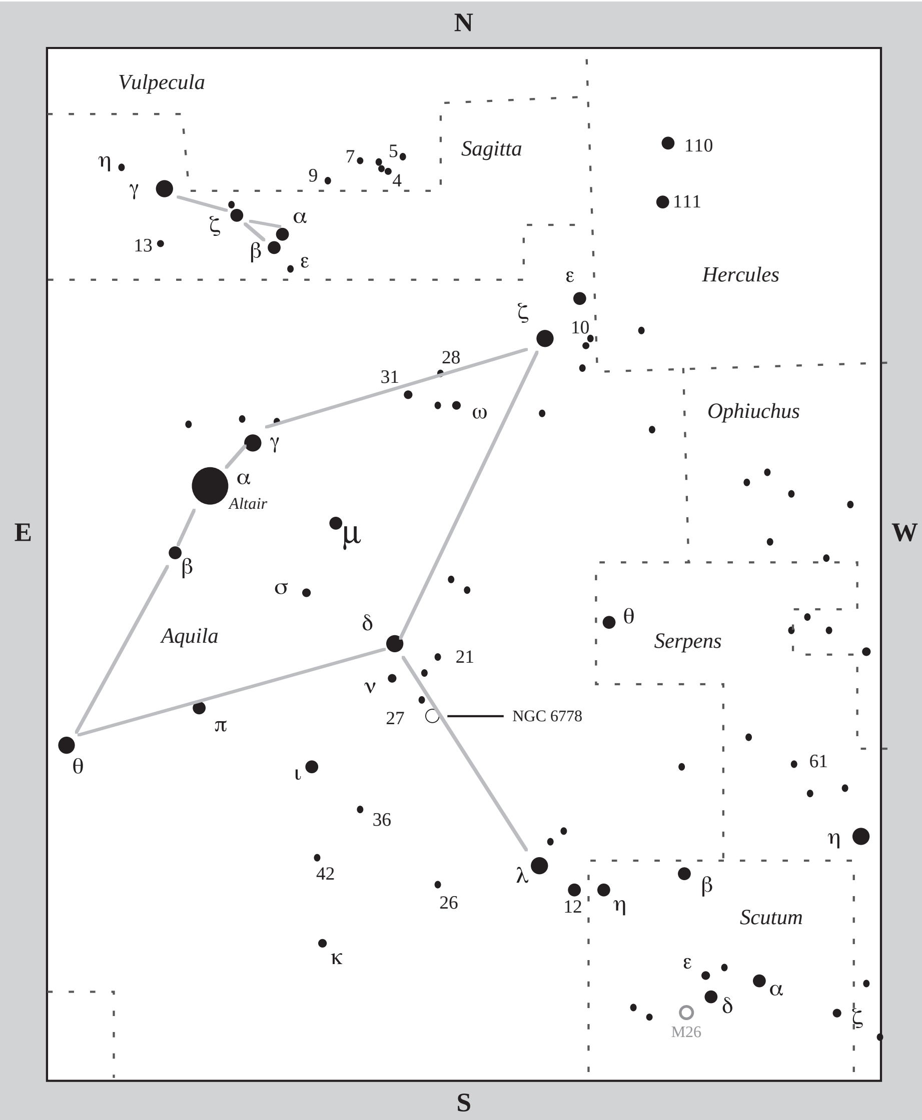
Remember, NGC 6755 is the larger and brighter cluster; NGC 6756 is small and somewhat dim. Interestingly, because NGC 6755 is large and scattered, under a bright sky, highly compressed NGC 6756 might stand out from the sky background more easily. (Don't let NGC 6756's listed magnitude of 10.6 frighten you. I didn't believe it, so I made my own estimate at 33× in the 5-inch and got roughly around 9th magnitude.)

In the 5-inch at 33× under a dark sky, NGC 6755 is a very large and diffuse ball of nervous starlight. With south up, I see the cluster's brightest stars forming a cat-like figure with an upright tail (oriented northwest–south-southeast) to the east, an upside-down U of stars forming its front legs to the west, and a straight back of stars running between them, oriented roughly northeast–southwest. Otherwise the dimmer stars are generally and uniformly scattered across the cluster's 15′ width. Some 50 to 60 stars materialize at 60× and these are randomly scattered into fractured arrangements, with a compact "core" of about a dozen stars in the cat's back. It looks like a cluster within a cluster, like a nested Russian doll.

The more I look at NGC 6755 with averted vision, the more NGC 6756 tries to steal my attention, because its tiny compact form is like a visual mosquito – making enough "noise" to distract. At 33×, it's but a 4′ puff of light in the Milky Way, shining like a lost comet without a tail. It lies almost midway between, and slightly north of, two 9th-magnitude stars separated by 20′ and oriented east to west. At 60×, the cluster has an intriguing compact core of stars, slightly east of the center of a roughly 4′-wide, irregular halo of unresolved starlight – with a dim, fuzzy apron to the south, a fainter cap of light to the north. (In photos, these fuzzy extensions are stunning arcs and strings of 14th-magnitude suns.)

At 94×, NGC 6756's core fractures into a bright triangular wedge and other patchy fragments. But time and averted vision is necessary to bring out these features. The wedge itself is resolved into mottled bits of cramped stars. It's all somewhat frustrating (and mesmerizing), because try as I might, I cannot make a star count – the patch of condensed light is less than an arcminute across and it seems to be teaming with tiny twinklers.

Secret Deep 89
(NGC 6778)



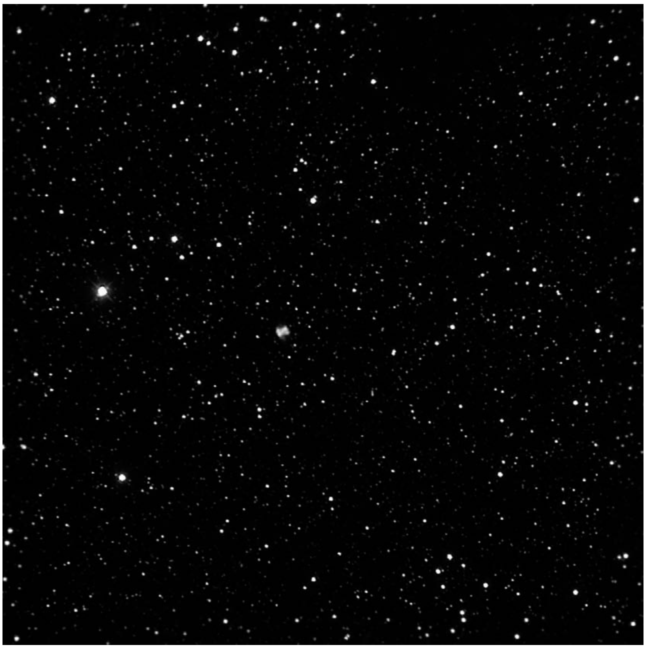
89

Son of M76
NGC 6778 = NGC 6785?
Type: Planetary Nebula
Con: Aquila

RA: $19^h\ 18.4^m$
Dec: $-01°\ 36'$
Mag: 11.9 (Rating: 3)
Dim: $20'' \times 40''$
Dist: ~9,800 l.y.
Disc: John Herschel, independently discovered by Albert Marth between 1863 and 1865.

W. HERSCHEL: None.

NGC: Small, elongated, ill-defined disk.



NGC 6778 IS A SMALL BUT DECEIVINGLY conspicuous planetary nebula 5° south-southwest of 3.5-magnitude Delta (δ) Aquila, in the majestic bird's tail, as depicted by H. A. Rey in his 1952 book *The Stars: A New Way to See Them* (Houghton Mifflin, Co., Boston), which shows the Eagle flying toward the Swan. In wide-field photographs NGC 6778 appears 20′ southeast of the dark nebula Barnard 139, which Edward Emerson Barnard described as a "narrow black spot" with a 10th-magnitude star on the southeast edge." Actually, Barnard 139 is a 20′-long dollop of darkness at the southeastern tip of Barnard 138, a "great curved, semi-vacant lane over 3 degrees in length."

In his 1888 *New General Catalogue*, John Louis Emil Dreyer credits Albert Marth with the discovery of NGC 6778. A German-born astronomer, Marth worked from 1863 to 1865 as an assistant to William Lassell of Liverpool on the Mediterranean isle of Malta. There, Marth made 580 original discoveries of deep-sky objects with Lassell's 48-inch f/9 speculum-metal Newtonian reflector. He also found an additional 21 deep-sky objects that other observers had seen first or were identical to objects found earlier by other observers. NGC 6778 may belong to the latter group.

Hal Corwin, who directs the on-line NGC/IC Project (www.ngcicproject.org), presents a good argument for John Herschel being the discoverer of NGC 6778. In the *NGC*, Dreyer credits Herschel with the discovery of NGC 6785 and Marth with the discovery of NGC 6778. But nothing exists in the published position of NGC 6785. So Corwin considered Herschel's description of that object, which reads, "An extremely small stellar nebula equal to a magnitude

15 star; it is 2/3 of a diameter of field (10′) from a double star which it follows, to south position from the star equals about 240°. The right ascension is excessively loose."

Corwin says that Herschel's description fits NGC 6778 if the phrase "which it follows" is changed to "which follows it." The position angle agrees as well, he says. "This means, however, that not only is the right ascension 'excessively loose,' but that there is 30 arcminutes error in John Herschel's declination as well." (John Herschel's position published in the *NGC* is 19^h 13^m 23^s −01° 21.4′ (epoch 1860.0).) Corwin adds that a published correction to the object's right ascension appeared in the second Index Catalogue, but it places the object "to a random clump of stars at John Herschel's (incorrect) declination. These [stars] are clearly not NGC 6785." Astronomy is full of such fun historical mysteries.

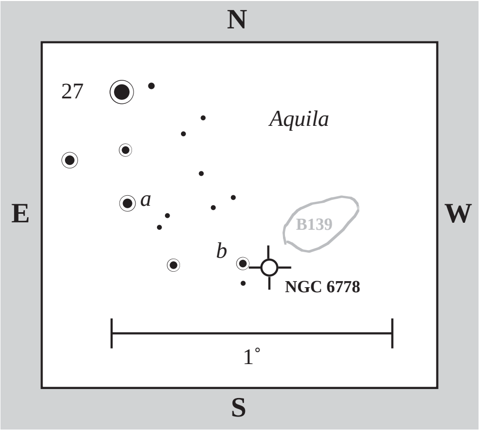
Today we know NGC 6778 as a bipolar, filamentary planetary nebula with a very prominent equatorial dust disk. Two opposing lobes of matter balloon through this dense torus, creating a butterfly-shape. The nebula's distance is uncertain, ranging between 3,300 light-years and 12,000 light-years with an average value of 9,800 light-years.

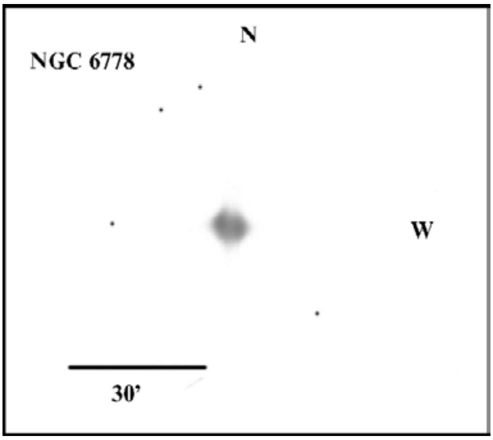
In a 2004 *Astronomical Society of the Pacific Conference Series* (vol. 313, p. 127) Martin Guerro (University of Illinois, Urbana) and colleagues say that their observations show a nebula 20″ × 40″ (1 light-year × 2 light-years) in size with the nebula's major axis tilted about 15° with respect to the plane of the sky. This main nebula lies inside a faint elliptical shell with a size of about 50″ × 60″ (about 2.5 light-years × 2 light-years). The equatorial region is bright and knotty.

The two jet-like lobes differ from one another: one lobe is linear and oriented along the bipolar axis (~PA 15°); the other presents an S-shape with changing orientations – between PA ~15° and ~50°. Both lobes can be traced to 35″ from the high excitation central star, which has an effective temperature between 45,000 K and 75,000 K. The researchers believe these are collimated outflows whose velocities increase linearly with the distance to the central star: the velocity of the lobe that's aligned with the bipolar axis varies from 20 km/sec up to 60 km/sec; the S-shaped lobe has a maximum observed radial velocity of 100 km/sec.

"It is interesting to note that the collimated outflows seen to originate from bright knots at the tips of the bipolar shell," the researchers say, "as it has already been observed in NGC 6891 [(Secret Deep 95) in Delphinus]. The likely connection between the collimated outflows and nebular features suggests either that the shell has contributed to the collimation of the outflows or that the outflows have interacted and shocked material in the nebular shell."

To find this little wonder, first use the chart on page 368 to locate Delta Aquilae and 5th-magnitude Nu (ν) Aquilae, which is 2¾° to the south-southeast. Now use your unaided eyes or binoculars to find 6th-magnitude 27 Aquilae nearly 2° southwest of Nu Aquilae. You can easily identify 27 Aquilae because it's the most northern and brightest star in a tight 25′-long triangle of binocular stars. Now use the chart on page 377 to locate NGC 6778 only about 55′ southwest of 27 Aquilae. You can also star hop further to it. From



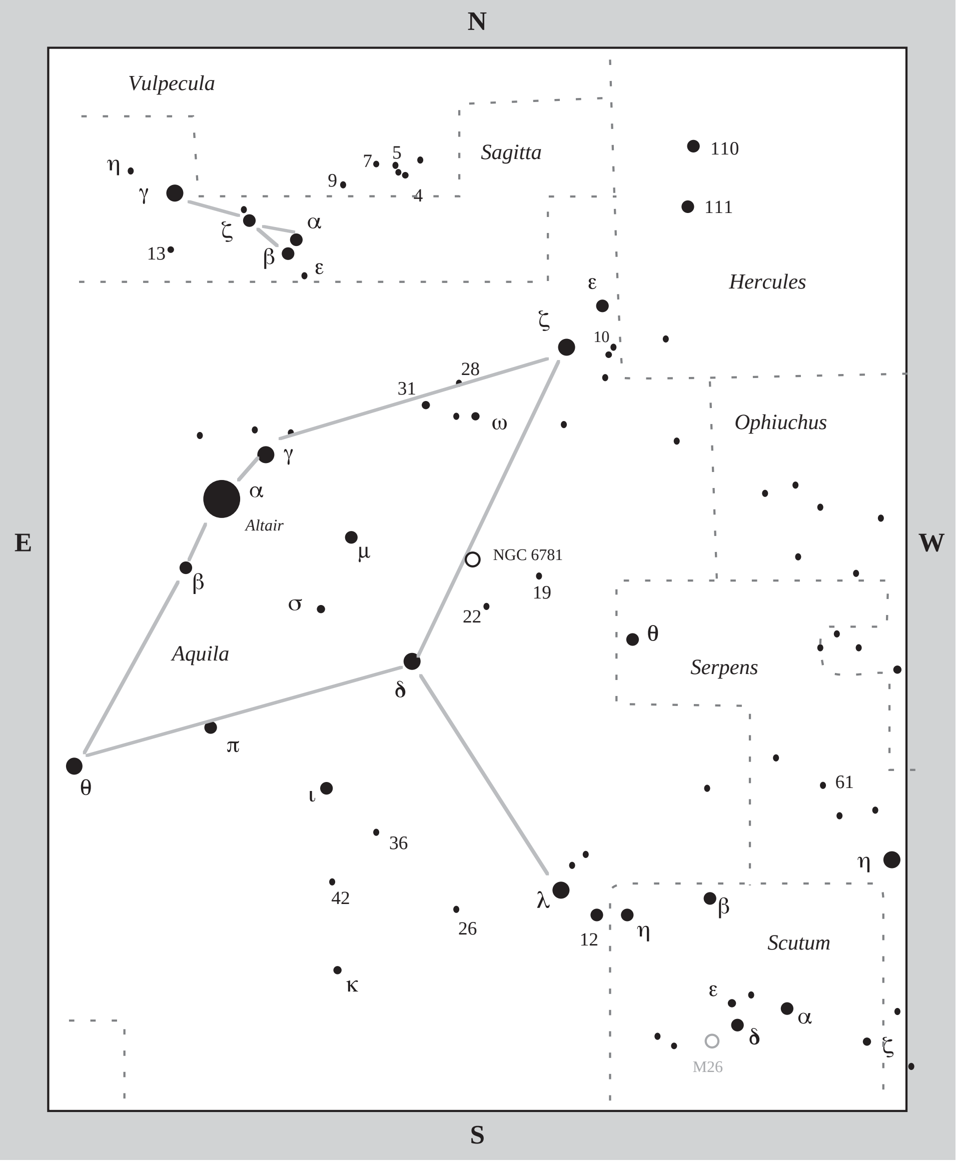


27 Aquilae drop 25′ south to 6.5-magnitude Star *a*. Then look 30′ southwest for 8.5-magnitude Star *b*. NGC 6778 is only about 5′ west-southwest of that star.

At 33× in the 5-inch, the nebula was barely visible with averted vision. It responded well, however to an OIII filter, becoming definite with averted vision. At 60×, I could see the nebula clearly without the filter, appearing as a small fuzzy knot of light, definitely more swollen than any field stars. At 94×, I could detect little diffuse wings extending from a bright core that does not appear stellar. The wings are oriented east–west and extend about 20″. And this is how the nebula more or less stays at magnifications ranging from 94× to 165×. But powers up to 282× show the nebula's two bright lobes, which appear as slightly tilted twin knots in a cross-shaped halo, though this could have been a trick of the eye working at the limit. I could not detect the 15th-magnitude central star, though Luginbuhl and Skiff say they've occasionally glimpsed it in a 10-inch scope at 200×. They also saw the nebula with a hairy edge in a 12-inch scope.

In October 2004, Armin Hermann at Sangkhlaburi, Thailand, used a 15-inch f/4.5 Obsession reflector at 342× to see this "colorless" nebula as an elongated glow (12″ × 15″) with two connected lobes that made NGC 6778 "look very much like a tiny copy of M76!" He saw no central star. And in 1998 Scott Hogsten at McConnelsville, Ohio, who used a 12.5-inch f/5 Dobsonian reflector at 150× and no filter, found it very faint, small, and round. "It did not require averted vision to see," he says. "I honestly did not expect to find this. … I question the printed magnitudes on this planetary." See what you think.

Secret Deep 90
(NGC 6781)



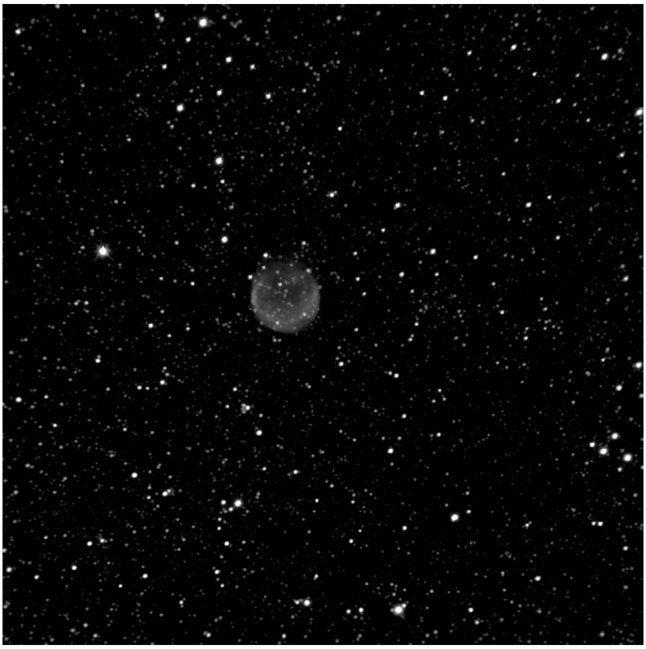
90

Ghost of the Moon
NGC 6781
Type: Planetary Nebula
Con: Aquila

RA: 19^h 18.5^m
Dec: +06° 32′
Mag: 11.4 (Rating: 3.5)
Dim: 2′
Dist: ~3,100 l.y.
Disc: William Herschel, 1788

W. HERSCHEL: [Observed July 30, 1788] Considerably faint, irregularly round, round 3 or 4′ in diameter. (H III-743)

NGC: Planetary nebula, faint, large, round, very suddenly brighter in the middle to a disk, [faint] star north following.



NGC 6781 IS A LARGE RING PLANETARY nebula about 3¾° north-northwest of 3.5-magnitude Delta (δ) Aquilae in the Eagle's body. Its discoverer, William Herschel, catalogued it as a very faint nebula. In detailed images, NGC 6781 shows a 2′-wide, nearly circular bright shell, double in parts, with fainter lobes emanating at the north–south ends where the ring is double and fainter. The ring is also brighter in the east–west directions.

The nebula's ring is a deception, of sorts, since it is now catalogued as a bipolar butterfly planetary nebula seen nearly along its polar axis, which is tilted only about 25° with respect to our line of sight. As with M57, the Ring Nebula in Lyra, NGC 6781's morphology appears to be that of a thin hollow cylinder whose axis is tilted with respect to the line of sight. The ring we see is the nebula's equatorial waist formed from a high-density slow wind from the evolving star. Fast, low-density gas is flowing through the torus and expanding perpendicularly with a velocity proportional to the distance to the central star. Thus the lobe geometry may be a bipolar, open-ended cylinder with an hourglass shape.

In a 2006 *Astrophysical Journal* (vol. 648, pp. 430–434), the late Hugo E. Schwarz (Cerro Tololo Inter-American Observatory, Chile) and his colleagues found that the central star's luminosity is 385 Suns with a mass of about 0.6 Sun, and a mass of the progenitor star of about 1.5 Suns. Stars in this mass range cannot explode catastrophically, like supernovae. Instead,

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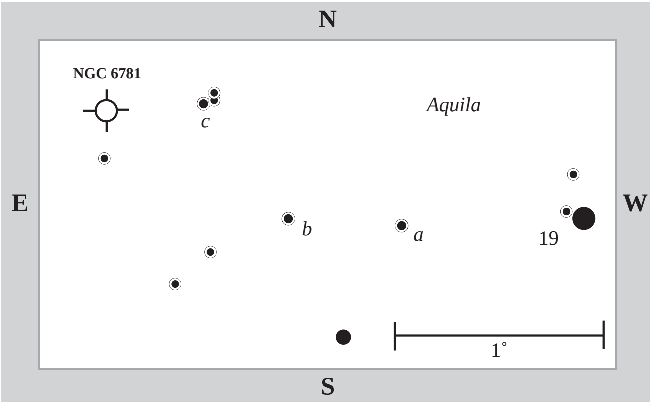


as the star nears the end of its life, it begins to eject clouds of gas, which trudge outward from the star into the interstellar medium. The loss of the outer layers of the star into space exposes the hot stellar core, whose strong and fast ionizing winds can interact with these more slowly moving previously ejected shells, causing them to fluoresce as a planetary nebula.

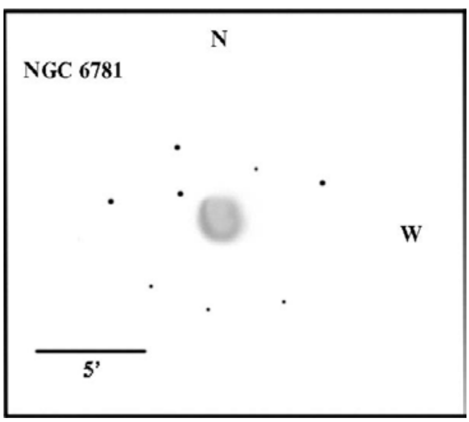
In a 2005 *Astronomy & Astrophysics*, D. Hiriart (Instituto de Astronomía, UNAM, Ensenada, México) says that the structure of NGC 6781 was formed from the "ionization and destruction of an ellipsoidal molecular envelope that began with the destruction and ionization of the least dense polar caps and will continue until the densest molecular material at nebular waist is fully ionized."

In deep images, the hourglass extensions can faintly be seen extending beyond the ring, and they are decomposing owing to interactions with energetic UV photons from nearby bright stars. If we accept the nebula's distance to be 3,100 light-years, the nebula's true physical extent is some 2 light-years, or about 1 light-year for each arcminute.

To find this delicate beauty, use the chart on page 378 to find Delta Aquilae, then 6th-magnitude 19 Aquilae about 5° to the northwest. Now use the chart on this page to find 7th-magnitude Star *a*, almost 45′ to the east. Next hop about 35′ east-northeast to 7th-magnitude Star *b*, then about 35′ northeast to equally bright Star *c*, which has a tight pair of unequal 10th-magnitude suns just to its west-northwest. NGC 6781 is almost 30′ due east and a tad south of Star *c*.

At 33× in the 5-inch the nebula is a large (1.5′), pale specter in a rich Milky Way field. It immediately appears as an irregularly bright annulus with a dimmer, but uniformly bright interior. The northern rim is conspicuously fainter than the southern rim. It's quite a pleasing view at low power, because of its ample size, and the concentration of light.

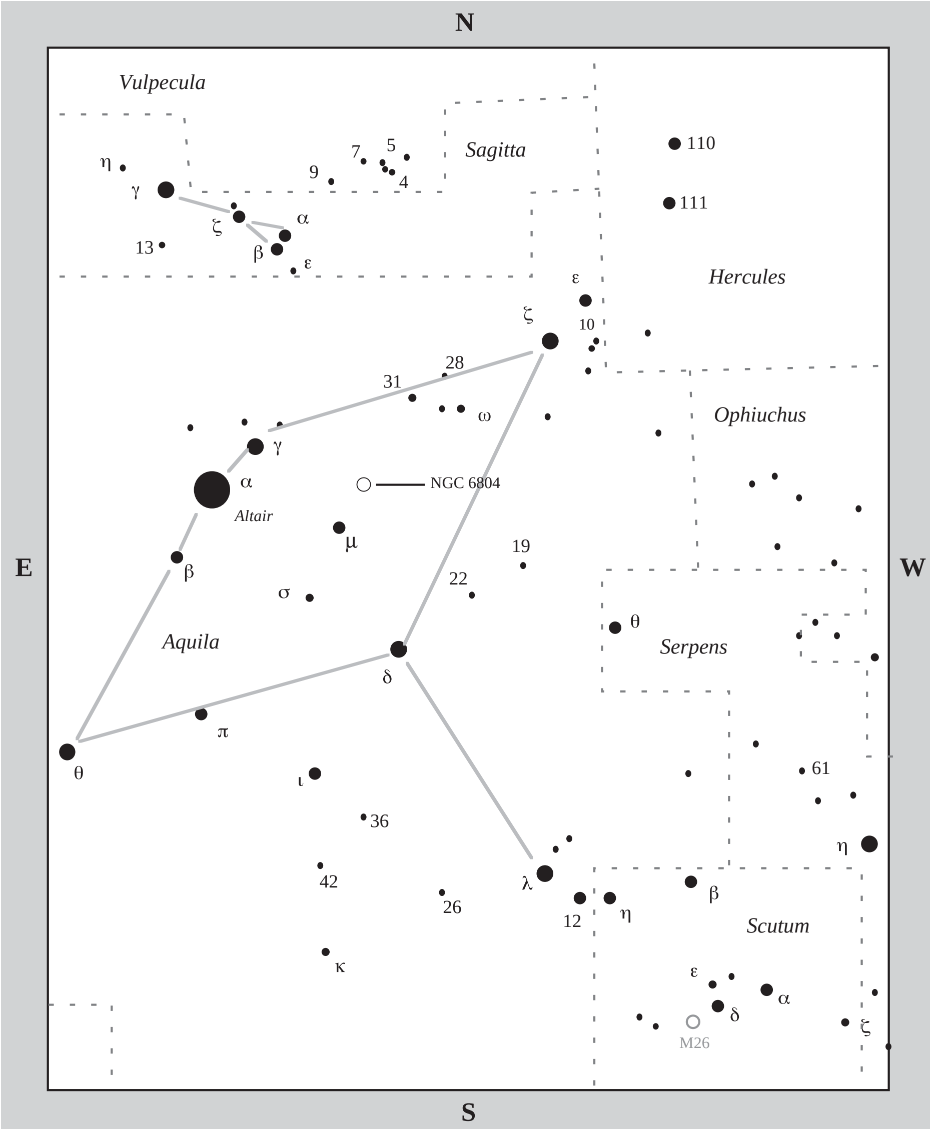
At 60×, the nebula has a fantastic shell, mostly filled in with pale light, making it appear like a ghost image of the naked-eye



Moon, thus its moniker. The interior of the ring remains filled with faint light, though it now doesn't appear to have a uniform luster.

At 94×, the annulus is very obvious, looking like the letter C with east up. Dim stars surround the phantom shell, with a 12.5-magnitude one skirting its northeast flank. The hole is more obvious at 180×, but the overall view is best at 94× in my modest telescope. The magnitude-16.2 central star was too dim for me to see. But be careful, because a roughly 14th-magnitude star lies just north-northeast of the nebula's true core.

Secret Deep 91
(NGC 6804)



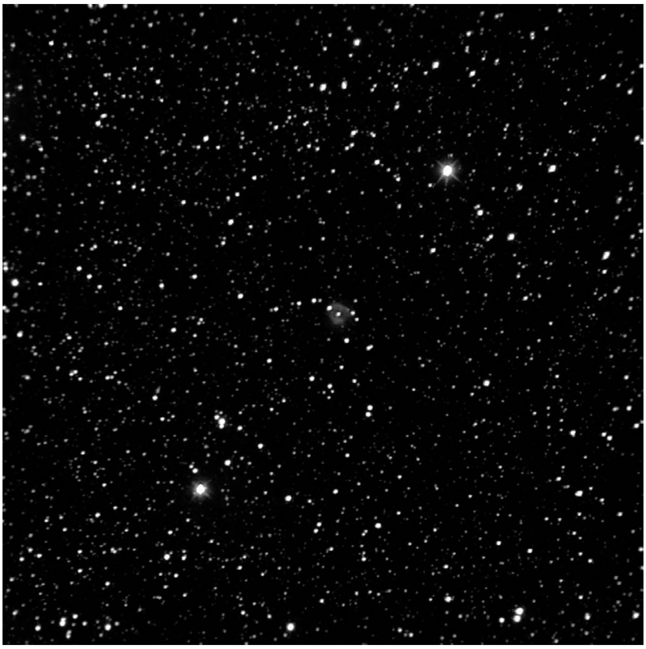
91

Incredible Shrinking Nebula, Snowball Nebula
NGC 6804
Type: Planetary Nebula
Con: Aquila

RA: 19^h 31.6^m
Dec: $+09°$ $13'$
Mag: 12.2 (Rating: 3)
Dim: ~50″ (~8″ inner shell)
Dist: ~4,200 l.y.
Disc: William Herschel, 1793

W. HERSCHEL: [Observed August 25, 1793] Considerably bright, small, irregularly faint, easily resolvable, some of the stars are visible. (H VI-38)

NGC: Considerably bright, small, irregularly round, well resolved, clearly consisting of stars.



NGC 6804 IS A FASCINATING LITTLE planetary nebula in Aquila, nearly 5° west and a bit north of 1st-magnitude Alpha (α) Aquilae (Altair). Despite its magnitude, the nebula is quite condensed, making it appear stellar at low power under a dark sky. But, unlike many of the smaller "stellar" planetary nebulae, this one morphs into an annulus under high power. Under a dark sky NGC 6804 should not be much of a challenge to those using 5-inch-class telescopes, though it's important to pinpoint the nebula's exact location.

Note how William Herschel believed this planetary resolved into stars. Herschel initially believed that nebulae were clouds of unresolved suns beyond the nearby landscape of stars (those that could be resolved into single suns) to which belonged our Sun. (He later proposed that nebulae were composed of unknown matter in various stages of development.)

The nineteenth-century observer Admiral William Henry Smyth seemed particularly impressed by this nebula, which Herschel discovered with his 20-foot reflector. "[Herschel] saw it considerably bright and easily resolvable," Smyth says, "estimating its profundity as of the 900th order, indicating a distance altogether overwhelming to the mind." William's son John also resolved the nebula, calling it a "curious object."

None of these great observers are to be faulted. The nebula lies in a rich Milky Way field and several stars are superimposed on the nebula, as can be well seen in Mario Motta's fine image that opens this section. Nevertheless, the nebula wasn't truly recognized as a planetary nebula until years later. In 1886, Sir William Huggins found that the nebula had a curious bright-line spectrum. The nature was truly revealed in 1917, when Francis G. Pease began a program to photograph, with the 60-inch f/5 Mount Wilson reflector, faint nebulae whose "nature was unknown or those which possessed curious or questionable characteristics."

On the 60-inch plates, Pease found NGC 6804 to be "a faint annulus with an irregularly shaped ring 5″ to 10″ in width and about 32″ × 25″, $p = 60°$. It has the typical central star and another of about the same magnitude lying directly upon the ring at the W end of the major axis. As in many planetaries, the nebulosity is stronger near the ends of the minor axis than near the ends of the major axis."

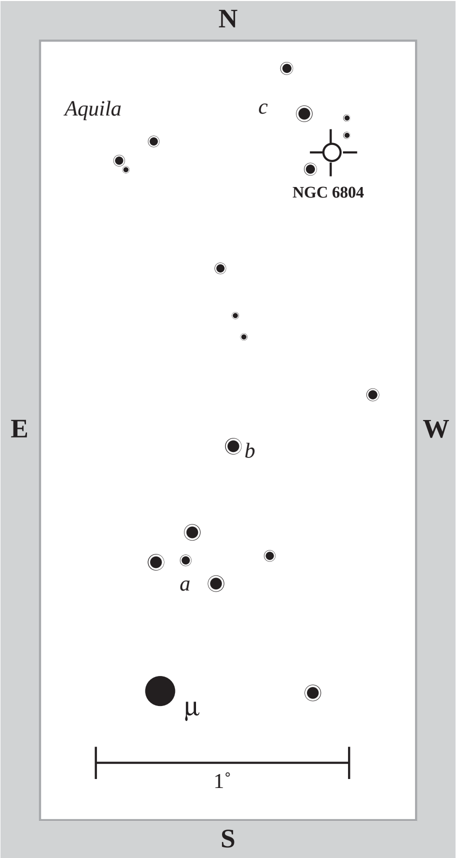
The fact is, NGC 6804 continues to be a curious planetary, with fascinating structures. The nebula lies 22,100 light-years from the Galactic center, 6,100 light-years from the Sun, and 480 light-years from the Galactic plane. Unlike many planetaries that have two shells, or, on rare occasions, three shells, NGC 6804 may have four different shells: A bright inner shell 8″ (0.16 light-year) in size, a second shell about 11″ (0.22 light-year), an asymmetrical third shell 30″ (0.6 light-year) to the southwest and 22″ (0.45 light-year) to the northeast, and a faint fourth shell measuring about 50″ (1 light-year).

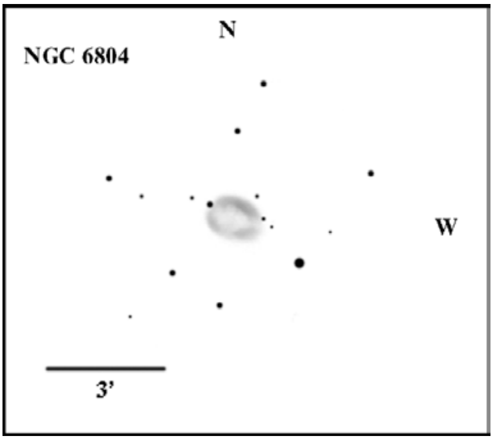
In a 1998 *Astrophysical Journal* (vol. 507, pp. 889–908), M. A. Guerrero (Instituto de Astrofísica de Canarias, Tenerife, Spain) and colleagues interpret the pattern of motions of the outer shells as the expansion of symmetric bubbles. The second shell expands faster (21 km/sec) than the inner shell (14 km/sec), whose expansion velocity is similar to that of the third shell (13 km/sec).

NGC 6804's bright central annulus (the part most recognized through amateur telescopes) is a tilted elliptical nebula, The second shell symmetrically surrounds it. Guerrero *et al.* found two kinds of ansae protruding from the major axis of the inner ellipse, extending 50″ to the northeast and 35″ southwest; these seem to make up the fourth shell. They also note that the size of each shell is always lower in the southwest than in the northeast direction. At the same time, the radial velocity of the shells decreases from the inner to the outermost shells.

"All these data confirm the interaction of the [planetary nebula] with the [interstellar medium]," they say, "which would be slowing down the nebula in the southwest direction. In fact, the appearance of the halo around the main nebula, which does not show limb brightening toward the northeast, and their different expansion velocities, 1 km[/sec] faster in the northeast part, support this interpretation."

To find this alluring nebula, use the chart on page 382 to find Altair. Now look about 4° west-southwest for 4.5-magnitude Mu (μ) Aquilae. Center Mu in your telescope at low power, then switch to the chart on page 385. From Mu Aquila, move 30′ north-northwest to a roughly 12′-wide sideways Y-shaped asterism (*a*) of four 7th- to 8th-magnitude suns. Next move about 25′ northwest to 7.5-magnitude Star *b*. Now make a slow and careful 1¼° sweep further to the north-northwest to 7th-magnitude Star *c*, NGC 6804 is about





10′ southwest of Star *c* and about 6′ northwest of a 9th-magnitude star.

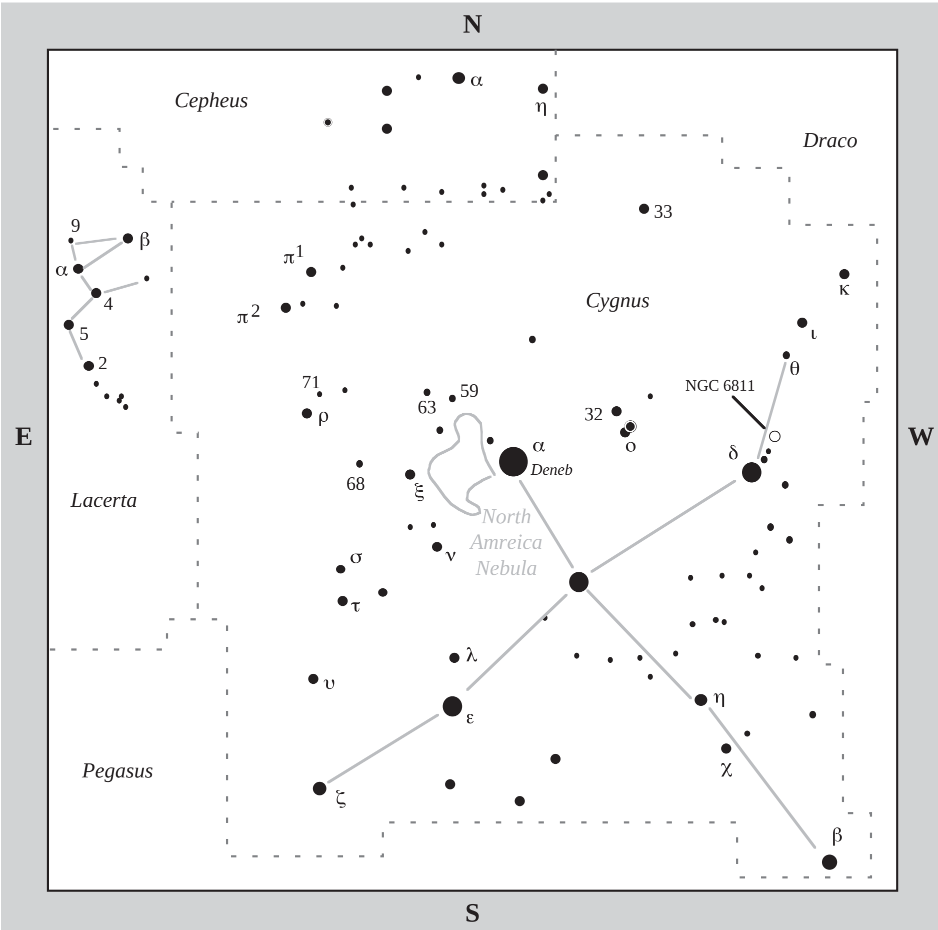
In the 5-inch at 33×, the nebula appears tiny, like a 12th-magnitude star that swells slightly with averted vision. So think "small" when you're searching. Don't expect to see a big diffuse halo. Again you're searching for the tiny inner ellipse of light whose longest extent is only 8″. The longer I look at it with averted vision, the more definite the nebula appears. (By the way, Admiral Smyth also called it a "stellar planetary.")

At 60×, the nebula is very fine and unmistakable, thanks to the high contrast of its inner shell. The glow is quite condensed and obvious. At times I detected what appeared to be a stellar core. The nebula's central star, however, shines at about 14th-magnitude, and this is too faint to be seen through nebulosity at this power in this telescope. What I had spied was a 12.5-magnitude star at the northeast edge of the bright inner shell. This becomes obvious at 94×, when that star blazes forth prominently. Resolving this star at this power also makes the nebula appear to shrink. Now it's a ball of mottled light that appears to brighten suddenly toward the center.

The annulus suddenly became noticeable at powers ranging from 165× to 330×. The inner ring takes power well, so don't be afraid to crank it up. Note that, at the high end, I was using a magnification of nearly 70× per inch of aperture. At these higher powers, the annulus is framed between two pairs of stars: the 12.5-magnitude sun to the northeast and a roughly 13.5-magnitude sun a bit further to the northeast; and a pair of roughly 13.5-magnitude suns to the west-southwest. The nebula once again seems to shrink between them, appearing as two arcs of light, like lipstick marks on a mirror. The reason the nebula continues to shrink is because the stars framing it add to the nebula's length when insufficient magnification is used. That's why I like to call it the Incredible Shrinking Nebula, because instead of growing in size as you increase the magnification, it seems to shrink instead.

With careful averted vision I could make out another roughly 13.5-magnitude sun to the northwest and, at times, I sensed an enhancement toward the center, which could have been the central star. I saw no traces of the nebula's outer shells. And this was also the case when I saw the nebula through Larry Wood's 12-inch reflector at the George Moore Astronomy Workshop near Edmonton, Alberta. The inner annulus was a brilliant ellipse, and really looked like lips ready to be kissed; but alas, I detected no hints of fainter structures. I wonder what size scope is needed to reveal these intriguing outer shells?

Secret Deep 92
(NGC 6811)



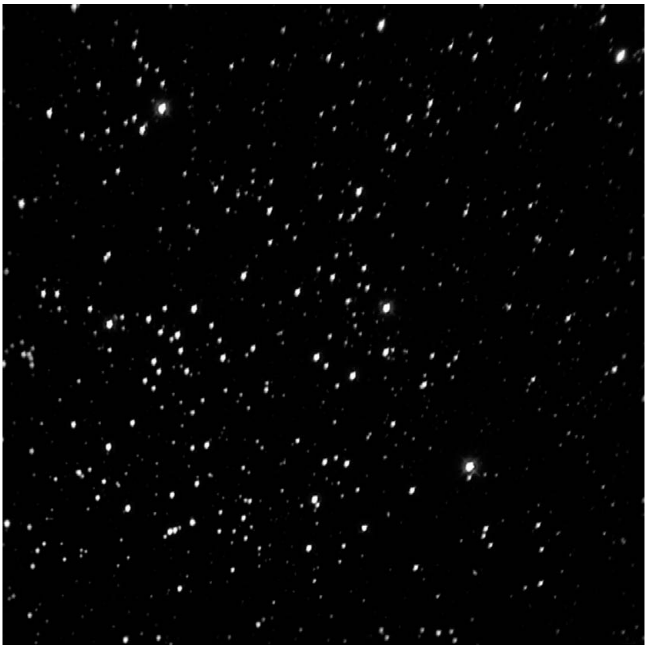
92

Smoke Ring, Hole in a Cluster, the Reliquary
NGC 6811
Type: Open Cluster
Con: Cygnus

RA: $19^h\ 37.2^m$
Dec: +46° 22.5′
Mag: 6.8 (Rating: 4)
Diam: 15′
Dist: ~3,100 l.y.
Disc: John Herschel

W. HERSCHEL: None
(h 2044)

NGC: Cluster, large, pretty rich, little compressed, stars of magnitude 11 to 14.



OF ALL THE MAJOR STARS IN CYGNUS the Swan, 3rd-magnitude Delta (δ) Cygni, which marks the western wing of the celestial bird or the western arm of the Northern Cross asterism, is the one least spotlighted in astronomical texts: Alpha (α) Cygni (Deneb), at the head of the Cross, is a magnificent blue-giant star and a visual guidepost to the great North America Nebula (Caldwell 20); Beta (β) Cygni (Albireo), at the foot of the Cross, is one of the sky's most celebrated colorful telescopic double stars; Gamma (γ) Cygni (Gienah), at the intersection of the vertical and transverse beams, marks the headwaters of the Great Rift in the Milky Way; and Epsilon (ε) Cygni, the east end of the transverse beam, leads the way to the stunning Veil supernova remnant. So Delta Cygni usually lies in the backwater of our attention.

Befitting of a sideliner, Delta is the only major star in Cygnus with no official proper name. But the star does help to point the way to one intriguing deep-sky object: NGC 6811, the little-known Hole in the Cluster.

This moderately bright, but unassuming, open star cluster lies almost 2° northwest of Delta. When the late deep-sky expert Walter Scott Houston first spied NGC 6811 in his youth, he found it "unimpressive." But in the mid-1980s, Scotty (as his friends knew him) received a letter from Danish amateur astronomer Tommy Christensen, who used a 3½-inch refractor to view the cluster and thought it was one of the most beautiful he'd ever seen, likening it to a "smoke ring" of stars.

Inspired, Scotty asked readers of his September 1985 Deep-Sky Wonders column, in *Sky & Telescope* magazine, if anyone had seen anything "unusual" in the cluster. Reports flowed in with numerous and highly imaginative descriptions: a clover of stars, a frog, a butterfly, and Nefertiti's headpiece. But others reported the cluster's dark center. Somewhere down the line, Christensen's "smoke ring" was forgotten, and people started to name NGC 6811 "Walter Scott Houston's Hole in a Cluster," though credit should clearly go to Christensen.

The question is, does the cluster have a "hole"?

NGC 6811 is a Trumpler type III 1r cluster. In 1930, Robert J. Trumpler (1886–1956) developed a time-tested classification system for open star clusters, which identifies them by three criteria independent of distance: (1) the degree of central concentration (from I (very strong) to IV (very loose)); (2) the brightness range of its members (from 1 (nearly equal in brightness) to 3 (both bright and faint)); and (3) the number of members (from p (poor, less than 50), to m (moderately rich, 50 to 100 stars), to r (rich, more than 100 stars)). NGC 6811, then, is a rich cluster of equally bright stars with no noticeable central concentration.

Indeed, the cluster has about 250 members scattered across 15′ of sky (half the apparent diameter of the full Moon), which corresponds to a true linear extent of nearly 14 light-years. The cluster lies relatively far from the Galactic plane (725 light-years), as is typical of fairly old clusters. In a 1978 issue of *Soviet Astronomy* (vol. 55, pp. 56–61), Klavdiia Aleksandrovna Barkhatova (Astronomical Observatory, Swerdlovsk) and her colleagues found a large deficiency of faint stars, "perhaps," they argue, "because of the dynamical evolution of the cluster." Star formation, they suspect, began 800 million years ago and ended 700 million year ago.

In a 2009 American Physical Society abstract, however, Brad Trees (Ohio Wesleyan University) and his colleagues say their spectral analysis of NGC 6811 gives a mean cluster age of about 1 billion years and a distance of 3,100 light-years. NGC 6811, then, is of similar age to the Hyades, M44, and M23. Professional studies of NGC 6811 have also revealed a distinct central region 10′ across in the cluster; it also appears to have an unusual distribution of stars, including a dense corona of brighter stars, which might explain the visual "hole."

To find this visual enigma, use the chart on page 387 to find Delta Cygni, then center it in your telescope at low power. Now, using the chart on page 390 as a guide, move about 50′ northwest to the roughly 5th-magnitude Star *a*, then 30′ north-northwest to a tight little gathering of three suns, the brightest of which is 7th-magnitude Star *b*. NGC 6811 is about 40′ to the north-northwest.

Under a dark sky, and with a sweep at 33×, NGC enters the field of view as a large (15′) amorphous glow of uniform light with no central concentration – a ghostly cometary form reminiscent of NGC 2129 in Gemini, only much larger. With averted vision, I can see a host of dim twinklers, superimposed on which is centered a pretty oval of a half-dozen or so brighter stars, looking like a jeweled mask a woman might wear to a masquerade ball.

At 60×, NGC 6811 really is a blowhole of stellar delight. The oval mask becomes more apparent and forms the smoky ring that Christensen so beautifully

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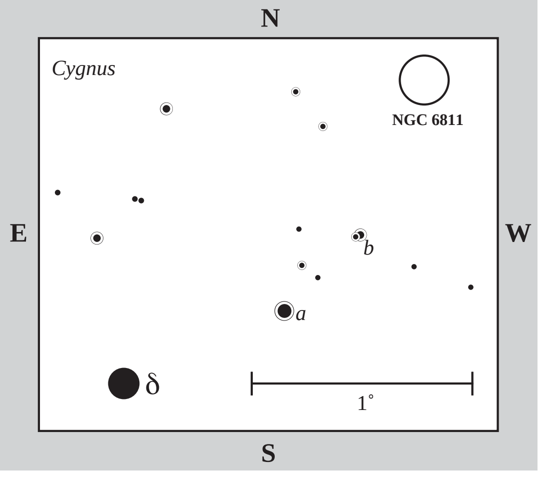
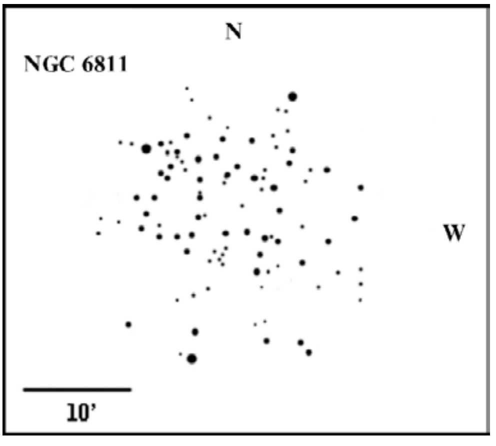




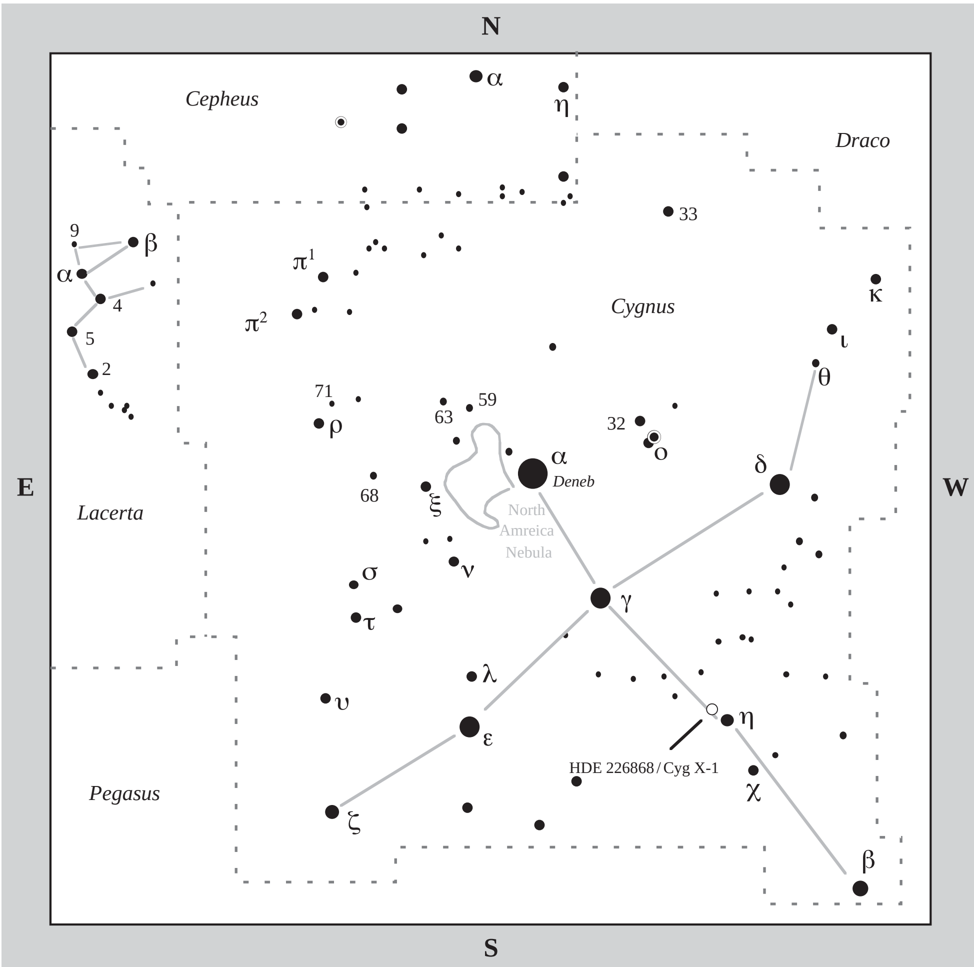
described; I find it reminiscent of the scintillating knots in M57, the Ring Nebula, so Christensen's description really is appropriate. Of course, this ring frames the "hole" in the cluster, which is just a contrast illusion.

The cluster is neighbored by several prominent stars that appear to play with the cluster's shape. There's a tail of similarly bright suns that flows to the southwest with another to the northwest, which seems to contain the cluster like a reliquary – such as the one displayed annually at Duomo di Napoli (Naples Cathedral) in Italy; a sealed glass flask in a silver reliquary that is believed to contain the scattered traces of clotted blood of San Gennaro (Saint Januarius (The Patron Saint of Naples)); apparently the blood liquifies each year on the feast of San Gennaro (September 19), as well as on other key dates in the year.

At 94×, the cluster's ring is foremost present and appears fragmented into a number of geometrical patterns with distinct clumps of starlight, which can easily be imagined as the scattered drops of San Gennaro's blood contained in the glass flask (the stellar ring). So the Hole in this cluster is not devoid of starlight. Not by any means. The longer you look with averted vision, and the more you concentrate on the Hole (and not the ring) the more faint scintillating suns you should see. In my 5-inch, these stars pop in and out of view like sparklers. So it's a very visually intriguing cluster, one that can keep you entertained for the night. In color images I've seen, many of the brighter outlying stars have a warm hue. Can you see that in your telescope?

By the way, Delta Cygni is one of the bright stars that will one day become Earth's "North Star," a result of the Earth's 26,000-year precession cycle, which causes the poles to wobble like a top. But don't wait around to see that event; Delta Cygni will be the North Star for a period of about 400 years around AD 11,250.

Secret Deep 93
(Cygnus X-1)



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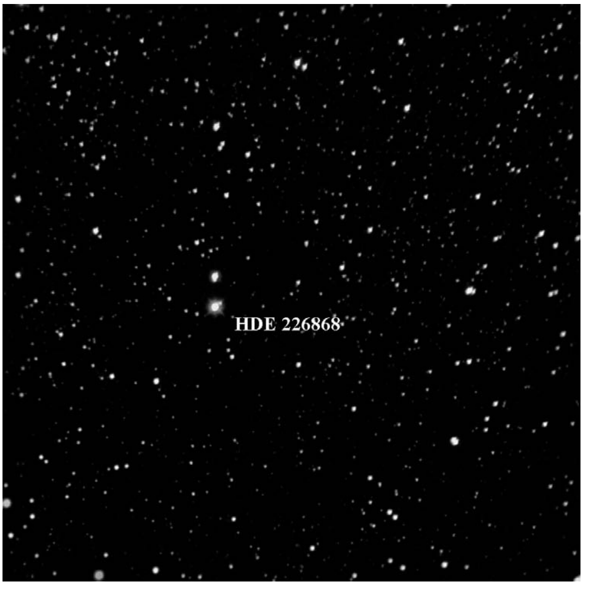
HDE 226868
Cygnus X-1
Type: Star associated with a Black Hole
Con: Cygnus

RA: 19^h 58.4^m
Dec: +35° 12′
Mag: 8.8 (Star; Rating: 4)
Diam: –
Dist: ~8,000 l.y.
Disc: S. Bowyer and colleagues (of X-ray source), 1964

HERSCHEL: None

NGC: None



ALTHOUGH WE CAN'T SEE A BLACK hole through our telescopes, we can see its bright visible-light companion (if it has one) and use our imaginations to "see" the rest. And Cygnus X-1 is among the best and most well-known black-hole candidates, and its 9th-magnitude companion is a cinch to see in even the smallest of telescopes, making it a fun target, one that can inspire deep thought when the area is shown to the public at star parties or to family and friends.

The discovery of Cygnus X-1 (the brightest X-ray source detected in Cygnus) was announced at a 1965 IAU symposium in Leige, Belgium. A paper by S. Bowyer and colleagues titled "Observational results of X-ray astronomy," described how the team detected 10 discrete X-ray sources from observations made with Geiger counters aboard unstabilized Aerobee rockets in 1964. X-ray astronomy was still in its infancy, beginning only in 1962 with the detection of a strong signal from the direction of the Galactic center. Thus, the discovery of Cygnus X-1 was among the first sources detected in this burgeoning field.

Bowyer and his team did not find any known optical or radio object at the position of the X-ray source. Adding to the puzzle, by 1971, UHURU satellite observations had shown the source varied strongly on the order of milliseconds, leading astronomers to speculate that the source of X-ray emission was coming from an extremely small, gravitationally collapsed object. But the apparent absence of radio emission at the time ruled out the possibility of it being a pulsar – like the one at the heart of the Crab supernova remnant, which displays both radio and X-ray emission.

Eerily enough, radio emissions at the position of Cygnus X-1 suddenly "turned on" in 1971 (in concert with X-ray emissions decreasing by a factor of three), leading two teams of astronomers from Leiden Observatory and the National Radio Astronomy Observatory to link the X-ray source to the 9th-magnitude type O9 blue supergiant with the cumbersome Henry Draper Extension (HDE) catalogue name HDE 226868 – a weak variable radio source.

Since blue supergiants do not radiate significant X-rays unless they are in binary systems, searches for a companion ensued. Before the close of 1971, B. Louise Webster and Paul Murdin (Royal Greenwich Observatory) announced that HDE 226868 indeed has a massive spectroscopic companion. Charles Thomas Bolton (David Dunlap Observatory) verified their discovery in 1972, making Cygnus X-1 now a high-mass X-ray binary.

From the orbital elements, it was determined that the blue supergiant has a mass of 30 Suns and a luminosity of about 400,000 Suns, while the unseen companion is about 10, if not possibly 15 to 20 Suns – making it much too massive to be a neutron star (by more than a factor of at least three), and well above the limit at which a collapsed object must become a black hole.

In a 1973 *Astrophysical Journal* (vol. 179, p. 125) H. E. Smith and colleagues proposed that the X-ray emission originates in a gas stream falling from the supergiant toward the unseen secondary, providing observational evidence that the X-ray source is powered by accretion – that little unseen mystery object is stripping matter away from HDE 226868, which flows toward the mystery spot and forms an orbiting disk that heats up to millions of degrees, emitting X-rays in the process.

By the end of 1973, the mounting evidence (including more precise measurements of the X-ray source's single millisecond variability, which led astronomers to suspect that the mystery object had diameter less than 100 miles!) pointed to it being a black-hole candidate. Debates over this interpretation continued for the next quarter century, until further observations revealed that the two companions (in a very close orbit of just 5.6 days) display the telltale sign of a black hole at work: flickering X-ray bursts on the order of one-third of a second, which is the expected time frame of accreted matter descending toward the dark star.

But it's important to remember that a black hole has never been observed directly; it's a theoretical object predicted by Albert Einstein's General Theory of Relativity. It's formed in the final stage of a massive star's death, when it undergoes gravitational collapse. When a star of at least 3 solar masses dies, its material does not explode into space (as in a supernova) but rather quietly collapses under the force of gravity (like Alice in Wonderland, it gets smaller, and smaller, and smaller), until the infalling matter compresses into a space that's infinitely dense – a point called a *singularity*.

The result is infinite space-time curvature around the singularity's *event horizon* – the point's surrounding border at which the escape velocity is greater than the speed of light; in other words, the gravitational force is so great at the event horizon that nothing, not even light, can escape from it. Like the rock group The Eagles' song, "Hotel California," a black hole is a place where "you can check in, but never leave." By the way, the black hole got its name from Anne Ewing in a letter to the AAAS in 1964; though it was John Wheeler's use

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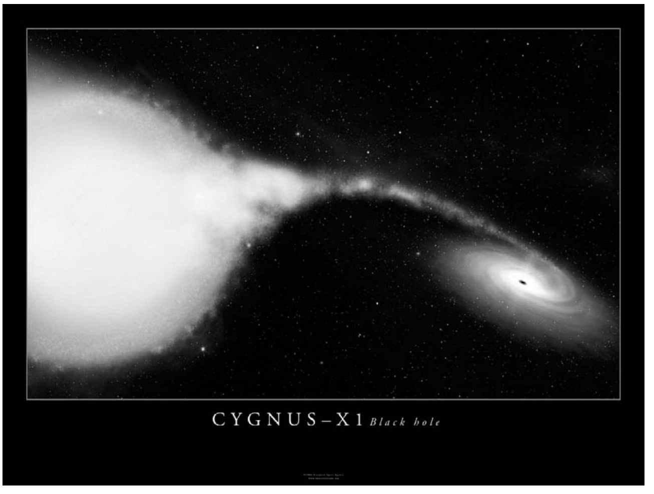
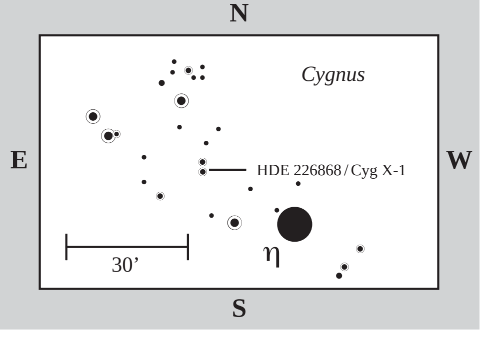


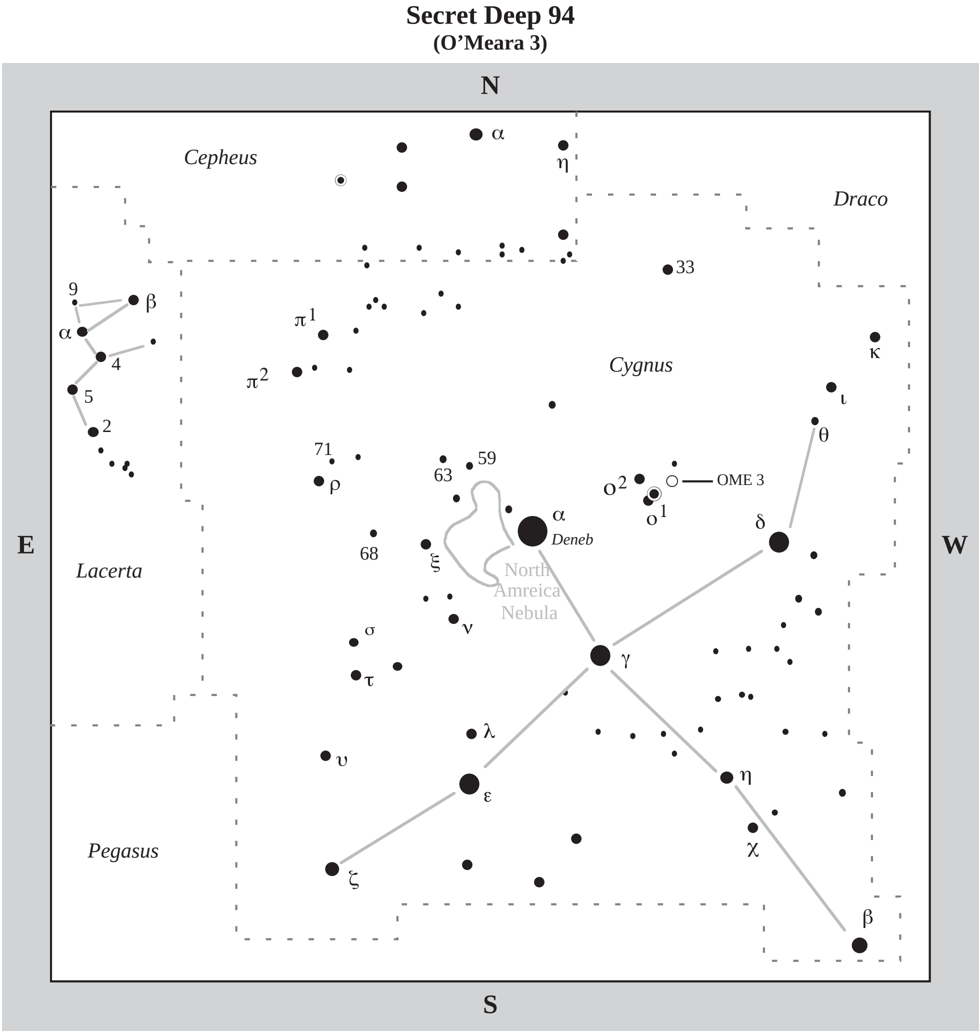


of it in a lecture three years later that brought the term into general usage.

In an April 2003 issue of *Science* (vol. 300 pp. 1119–1120), I. Félix Mirabel and Irapuan Rodrigues show that the black-hole candidate Cygnus X-1 had an initial mass greater than 40 Suns. "During the collapse to form the 10-solar mass black hole of Cygnus X-1," they say, "the upper limit for the mass that could have been suddenly ejected is 1 solar mass, much less than the mass ejected in a supernova." Their observations suggest that the black hole was formed *in situ* and did not receive an energetic trigger from a nearby supernova. They also suggest that high-mass stellar black holes "may form promptly, when massive stars disappear silently."

The Cygnus X-1 system lies in the Orion Spur – the same Galactic feature that harbors our Sun – at a point near the Sagittarius arm. Some sources place Cygnus X-1 in that latter arm, but we still do not have a full understanding of the Milky Way's structure, so its exact location is somewhat uncertain. The Cygnus X-1 system appears to also be associated with the Cygnus OB3 association – a loose gathering of hot Type O and B stars that typically stretches over hundreds of light-years.

To find this invisible marvel's companion, use the chart on page 391 to find 3rd-magnitude Eta (η) Cygni, then switch to the chart on this page to pinpoint 9th-magnitude HDE 226868 only about 25′ to the northeast; it's the southern star in a tight pair of suns with its companion being a little bit fainter. To see Cygnus X-1, you'll need to open the floodgates of your imagination. Have fun!



Secret Deep 94
(O'Meara 3)
N
S
E
W
Cepheus
Draco
Cygnus
Lacerta
Pegasus
α
η
33
9
β
α
4
5
2
π1
π2
κ
ι
θ
71
59
63
ρ
o2
OME 3
o1
α
Deneb
δ
68
ξ
North
Amreica
Nebula
σ
ν
γ
τ
λ
υ
ε
η
χ
ζ
β

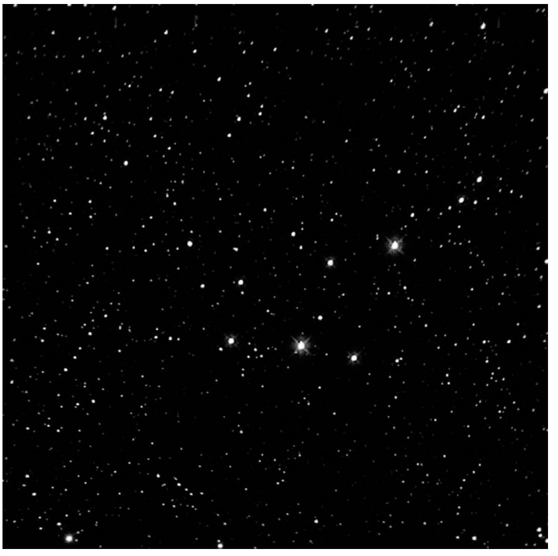
94

O'Meara 3 = Alessi J20053+4732
Type: Asterism
Con: Cygnus

RA: 20^h 05.3^m
Dec: $+47°$ $32'$
Mag: – (Rating: 5)
Diam: $12'$
Dist: –
Disc: Bruno Alessi, 1997–98; independently by Stephen James O'Meara, 2009

W. HERSCHEL: None.

NGC: None.

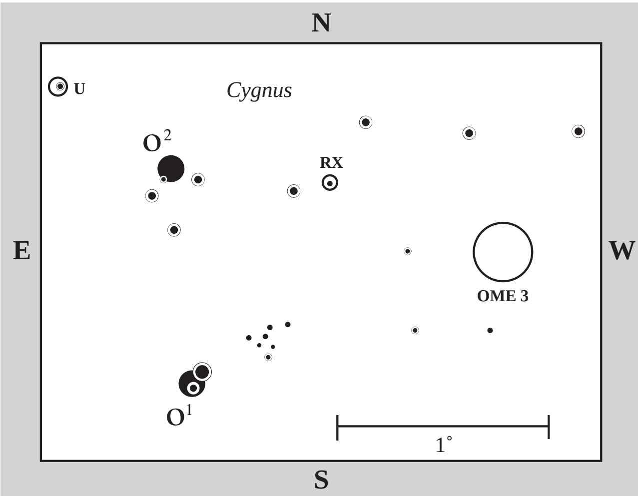


ON THE NIGHT OF SEPTEMBER 10, 2009, I was investigating objects to include in this book, specifically a few open star clusters in Cassiopeia and Cygnus. I was about to go after NGC 6811 (Secret Deep 92), when some patchy clouds moved in. To kill time, I decided to view the beautiful field of Omicron^1 and Omicron^2 Cygni at 33× in the 5-inch. If you haven't turned your telescope to this field ... you must!

First, with a quick look to the unaided eye Omicron^1 and Omicron^2 Cygni appear as a wide pairing of 4th-magnitude suns 1° apart. The stars are oriented north-northeast–south-southwest, with Omicron^1 at the southwestern end. Look carefully at Omicron1 with averted vision and you may split it into two stars: 4th-magnitude Omicron^1 and 5th-magnitude 30 Cygni about 6′ to the northeast. Telescopically, a 6th-magnitude sun lies half that distance to Omicron^1's south-southeast. Omicron^2 has its own bevy of telescopic companions, while the red carbon star U Cygni lies a little more than 40′ to its east-northeast.

While none of these stars are physically related, Omicron^1 and Omicron^2 not only share a similar brightness, but they both appear golden (each being a K-type giant) and are Epsilon Aurigae-type stars in which a hot B-type dwarf partially eclipses its larger and cooler giant companion. Omicron^1 varies in brightness by only 1/10 magnitude every 10.36 years, with the eclipse lasting 63 days. Every 3.143 years, Omicron^2's light dips a mere 6 percent during a grazing eclipse.

The entire field is dappled with rich Milky Way, so a sweep around these stars is worth the effort. And that's what I did on the evening of September 10th. Just a short brush to the west at low power revealed a curious gathering of irregularly bright suns about 1.5° west and a little north of the midpoint between the two Omicrons. At 33×, I saw about two dozen stars shining between 9th and 11th magnitude in an



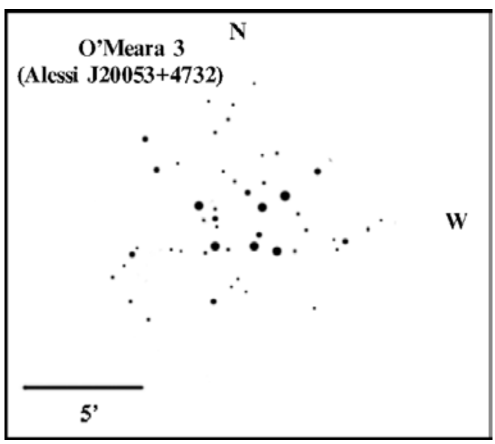
area no larger than 10′. The view was better than some dim star clusters I had recently hunted down, so I immediately made a sketch of the brightest stars, grabbed my *Millennium Star Atlas*, and began searching for the "cluster."

To my surprise, not only did I find that the group was not a cluster (at least it wasn't labeled as one), but also that I had already circled the group on the atlas, penciling in the letters "OME" next to it! I had already encountered the group some time ago (the exact date I don't know, since I didn't write it down), but obviously failed to follow it up. Only now did I rediscover this little visual marvel. When I returned my eyes to the sky, however, clouds had completely moved in (this happens frequently where I live).

I did not return to the group until three nights later, when I studied it in more detail. Meanwhile, I had discovered that, once again, the astute amateur astronomer Bruno Alessi of San Paulo, Brazil, had already alerted star-cluster expert Brent Archinal to the existence of this group of stars; it being one of 41 possible star clusters he had discovered between 1997 and 1998, while looking at plots for clumps of galactic star clusters or by examining Digitized Sky Survey images. To my knowledge, this group is an asterism, not a star cluster. Indeed, in their book *Star Clusters* (Willmann-Bell, Inc., Richmond, VA), Archinal and Steven J. Hynes list the object (designated Alessi J20053+4732) as an asterism.

I list the group here as O'Meara 3, because it is the third such group I independently discovered in my visual sweeps of the heavens. The first is O'Meara 1 in Pisces (the 107th object in my *Deep-Sky Companions: Hidden Treasures* book), which equals Alessi J23407+0757; I call it the Little Ladle in Pisces. The other is O'Meara 2 in Aquila (published in my book *Observing the Night Sky with Binoculars*) which equals Alessi J20046–1030, and may actually be a new star cluster.

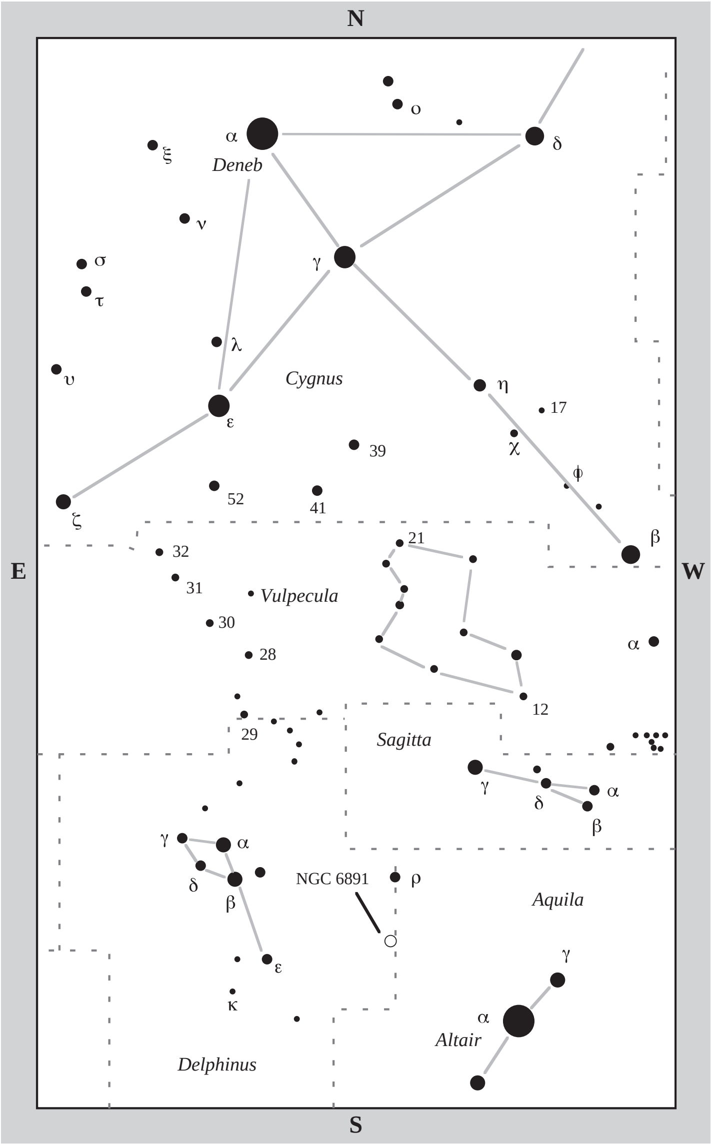
With a careful look at 33×, I can see more than a dozen suns suspended in a bright little asterism that at first looks



like a pot with a long handle. At 66×, I tally more than 40 stars between 9th and 12th magnitude in an area 12′ across. With concentration, the pot becomes a square with wings. One bright wing extends northwest from the northwest corner of the square, the first star in this wing shines at 9th magnitude and has a lovely golden hue. A fainter wing extends to the northeast from the northeast corner of the square. So it looked like Pegasus, the Winged Horse flying directly at me. Actually, the base of the square is a straight line of three roughly 9th-magnitude Suns. While the wings are more-or-less straight, two curved arms flow from the base of the square, giving it a spiral look.

Encountering little gems like this is a lot of fun and exciting, especially when you don't know if you've come across something new – something you'll want to share, which is my only intent. Enjoy!

Secret Deep 95
(NGC 6891)



95

NGC 6891
Type: Planetary Nebula
Con: Delphinus

RA: $20^h\ 15.2^m$
Dec: $+12°\ 42'$
Mag: 10.5 (Rating: 4)
Diam: $>18''$
Dist: ~12,400 l.y.
Disc: Ralph Copeland, 1884

HERSCHEL: None.

NGC: Planetary nebula, stellar, equal to the brightness of a magnitude 9.5 star.

NGC 6891 IS A VERY BRIGHT PLANETARY nebula in far western Delphinus, about 2½° south, and a tad east, of 5.5-magnitude Rho (ρ) Aquilae, which is right on the border between Aquila and Delphinus. English-born astronomer Ralph Copeland (1837–1905) discovered it on September 22, 1884, with a visual spectrograph (a Secchi prism) attached to the front objective of the 6-inch Simms Equatorial refractor at the Earl of Crawford's private observatory at Dun Echt, near Aberdeen, Scotland.

Prior to his taking charge of Lord Crawford's Observatory, Copeland was an assistant at Dunsink Observatory near Dublin, the oldest scientific institution in Ireland. He had also spent three years under the employ of Lord Rosse (from 1871 to 1874), where he used the 72-inch reflector at Birr Castle to make his most memorable discovery: Copeland's Septet (Hickson 57) – a gaggle of seven galaxies in Leo: NGC 3745, 3746, 3748, 3750, 3751, 3753, and 3754.

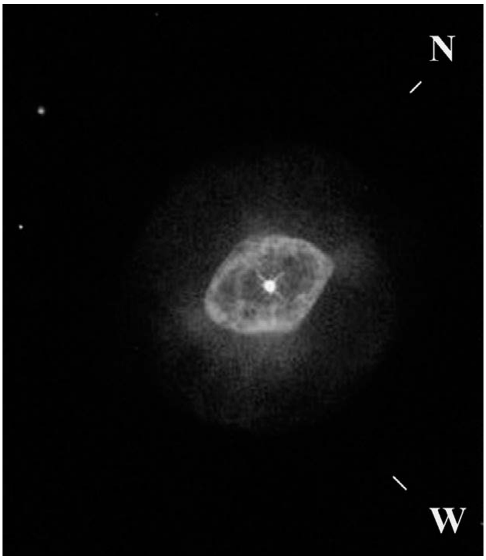
In 1876, Copeland arrived at Dun Echt, and permanently moved to Scotland, where he became Astronomer Royal in 1889. Interestingly, Danish astronomer John Louis Emil Dreyer (who would originate the NGC catalogue) almost followed in Copeland's footsteps – replacing Copeland at Birr Castle, before moving on to Dunsink Observatory, then finally to Armagh Observatory in 1882. The two astronomers enjoyed a long friendship, and both served as editors of *Copernicus*, an international journal of astronomy printed in Dublin between 1881 and 1884.

Throughout Copeland's distinguished career, he discovered 35 NGC objects. That of NGC 6891 came during one of his routine sweeps of the heavens, the purpose of which was to search for small nebulae and other objects with remarkable spectra (see also Secret Deep 27 (IC 2149)). NGC 6891 was one of four noteworthy objects Copeland found in late September 1884 and reported in an 1884 *Monthly*

Notices of the Royal Astronomical Society (vol. 45, p. 90). Of the new nebula he writes, "This seems to be identical with the 9.5 mag. star D. M., +12°, 4266. It is in reality a planetary nebula about 4″ in diameter with a nearly monochromatic spectrum."

Today we know NGC 6891 belongs to the group of very exclusive triple-shell planetary nebulae. The nebula consists of a bright inner shell (9″ × 6″) surrounded by a circular intermediate shell (18″) and a nearly symmetrical outer halo (80″). At an accepted distance of 12,400 light-years, the nebula's three shells have the following true linear extents: 0.5 × 0.4 light-year, 1 light-year, and 5 light-years, respectively.

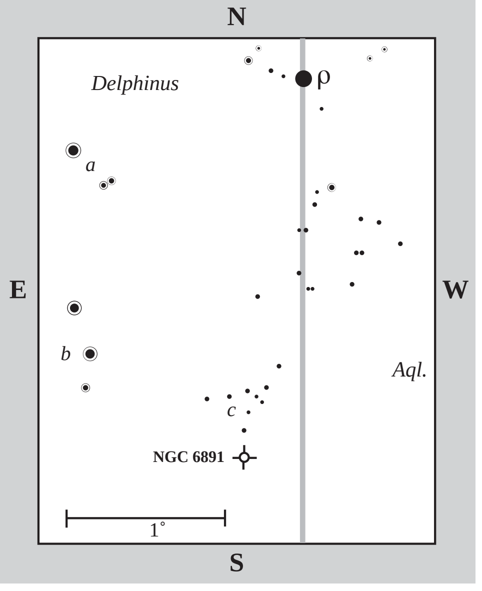
As you can see in the Hubble Space Telescope image below, the inner shell (the bright main nebula) is elliptical. Its major axis is tilted 80° from the line of sight and oriented at position angle 135°; it's centered on the nebula's magnitude 12.4 central star, which has an effective temperature of 50,000 K and a mass of 0.75 Sun. The nearly round intermediate shell is expanding faster into the outer halo. It is tilted 50° from the line of sight and oriented at position angle 160°; so the inner and intermediate shells are not aligned.

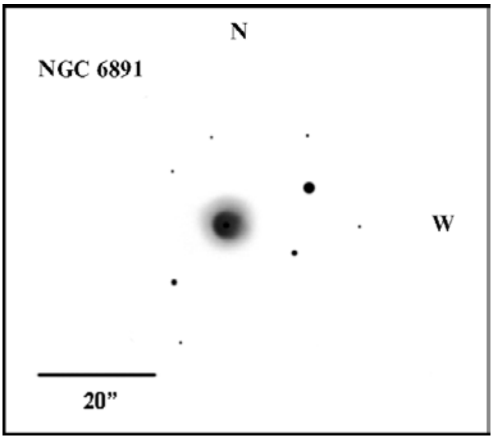


In hydrogen-alpha images, two faint knots can be seen at the ansae of narrow, streamlike structures, which connect the major axis of the inner shell to the knots. The outer shell is also nearly circular, but it bulges to the south where it appears to break and form a spearheaded outer structure.

In a 2000 *Monthly Notices of the Royal Astronomical Society*, Martin A. Guerrero (Astrophysical Institute of the Canaries, Tenerife) and his colleagues explain how NGC 6891's nebular structures reflect the different mass-loss episodes experienced by its progenitor star. The halo formed first, about 28,000 years ago – a product of the progenitor star losing mass during its episodic pulsations during the late asymptotic giant branch phase (the last phase of normal stellar evolution prior to becoming a planetary nebula). Some 4,800 years ago, the progenitor star ejected most of its remaining envelope, and the inner and intermediate shells arose.

The researchers found NGC 6891's inner ellipsoidal shell expanding with a velocity of 10 km/sec at its equator and 17 km/sec at its tips. The intermediate shell is expanding faster (45 km/sec and 28 km/sec) into the outer halo. The streamlike features may be collimated outflows (45 km/sec), which they interpret as FLIERs – fast low-ionization emission regions. The outflows run from the tips of the major axis of the inner shell to the outer edge of the intermediate shell, where they are deflected, causing the outer boundary of the intermediate shell at that location to bulge. The formation



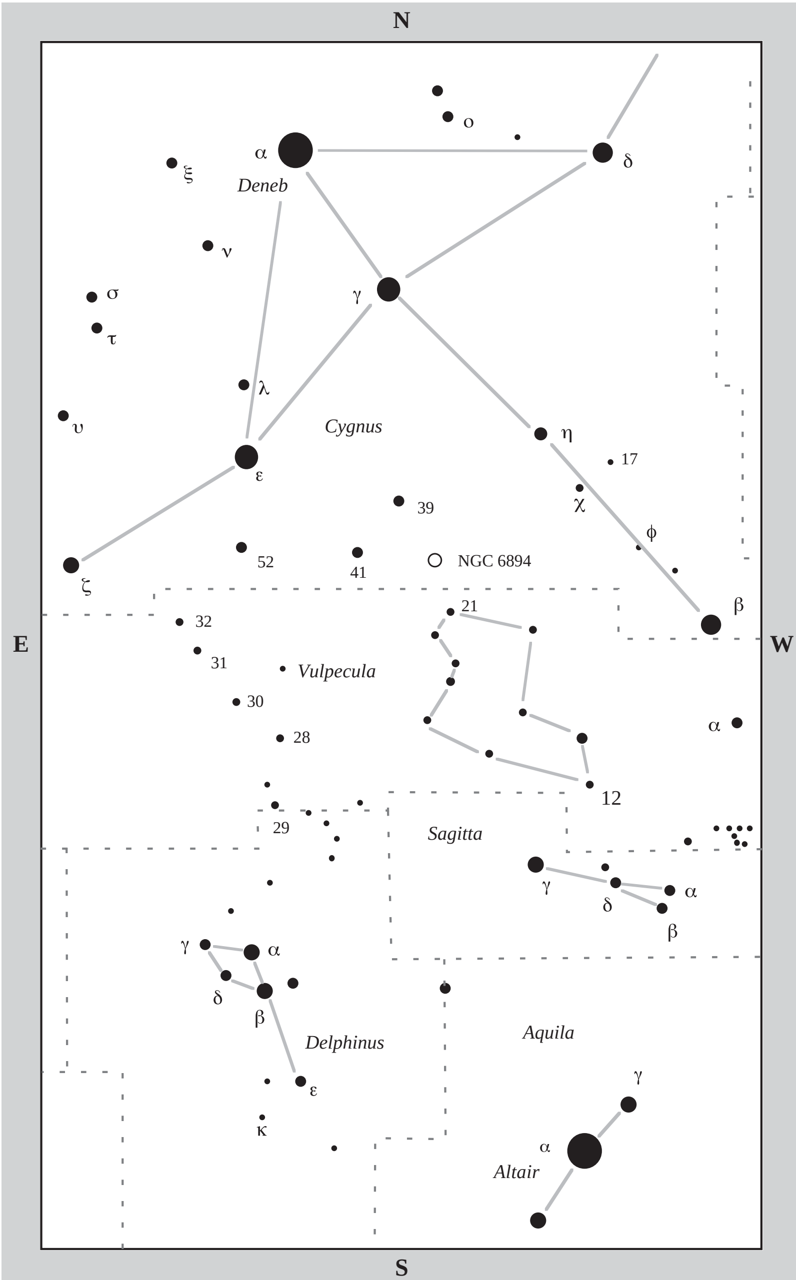


mechanisms of these features are still unknown.

To find this bright but tiny planetary, use the chart on page 399 to locate Rho (ρ) Aquilae, which is about 6½° west of the Diamond asterism of Delphinus, on the Aquila–Delphinus border. Now use the chart on this page to make a slow and careful sweep a little more than 1½° southeast to a 20′-wide trio of 6th- and 7th-magnitude suns (*a*); the southwestern two stars make a nice pair. Now look for a 30′-wide trio of 6th- and 7th-magnitude suns (*b*) 1¼° to the south; these stars are roughly oriented north–south. From the southernmost star in that trio, make a 1° sweep due west and look for an upsidedown and tilted V of suns, roughly 20′-wide (ranging in magnitudes from 8th to 10th). NGC 6891 lies less than 10′ due south of the southernmost star in the V.

At 33× in the 5-inch the planetary shines like a magnitude –10.5 star. When I pinpointed the object and used averted vision, I could sense that something was odd about it. When I compared its visage with those of similarly bright stars in the neighboring V asterism, NGC 6891 simply appeared to bloat. At 60×, the nebula swelled enough with averted vision for me to to confirm its identity. The nebula took high magnification well, though I found powers of 165× to 282× quite comfortable. All high powers show the same structures: a bright central star surrounded by a smooth (somewhat creamy) disk centered on a very slightly larger collar of light that fades quickly away from the inner disk. I couldn't resolve the inner shell into an ellipse. But see if you can.

Secret Deep 96
(NGC 6894)



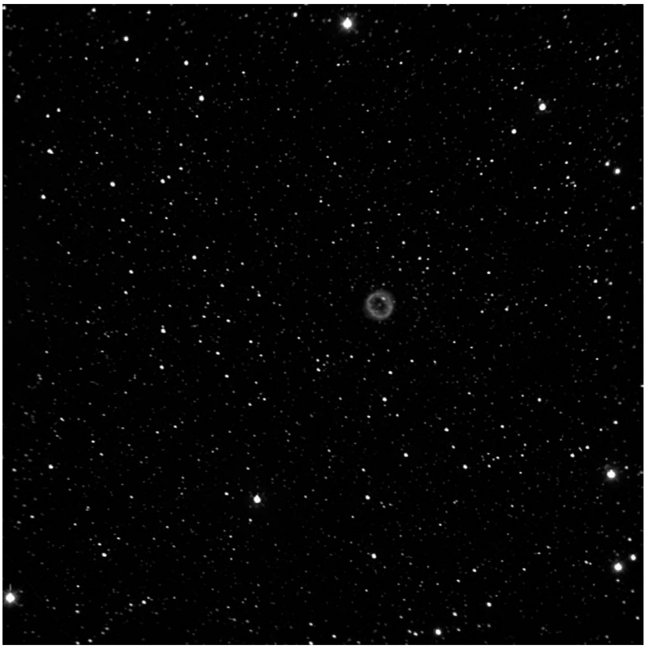
96

Diamond Ring Nebula
NGC 6894
Type: Planetary Nebula
Con: Cygnus

RA: 20^h 16.4^m
Dec: +30° 34′
Mag: 12.3 (Rating: x)
Diam: >42″
Dist ~5,000 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed July 17, 1784] Pretty faint, exactly round of equal light, the edges preceding well defined, 1′ in diameter. (H IV-13)

NGC: *Remarkable*, annular or ring nebula, faint, small in angular size, *very* little extended.



NGC 6894 IS A SIZABLE BUT DIM planetary nebula (at least for a 5-inch) in Cygnus, about 7° west-southwest of 2.5-magnitude Epsilon (ε) Cygni, or about 2° north-northeast of 5th-magnitude 21 Cygni. The late deep-sky expert Walter Scott Houston considered it a decent target for amateurs. Note too the *New General Catalogue* description above, which refers to it as a *remarkable* ring nebula. Still, I didn't plan on including it in this list, believing it would be too faint to enjoy in a 5-inch. Then I surprised myself one night by spying it at high power and became mesmerized by the phantom glow. Later, I found other sightings made through 8-inch-class scopes with an OIII filter. So I changed my mind. I still consider it a challenge to anyone who owns a 5-inch telescope. (But what's life without a challenge!) Regardless, it's a very interesting sight in moderate to large scopes and a beautiful object to CCD image.

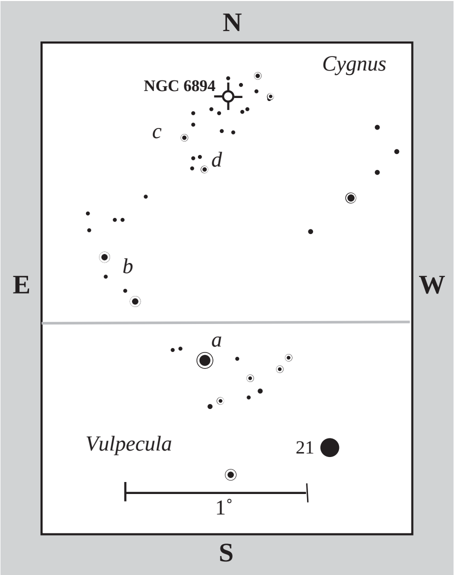
The nebula is also a fascinating object of astrophysical interest. It comprises two attached shells, the outer one of which is peculiar. Planetaries fall into three broad morphological categories: round, elliptical, and butterfly. They are further described by the relative proximity of the bright inner rims to the central planetary nucleus. Bruce Balick (University of Washington, Seattle) classifies NGC 6894 as middle round.

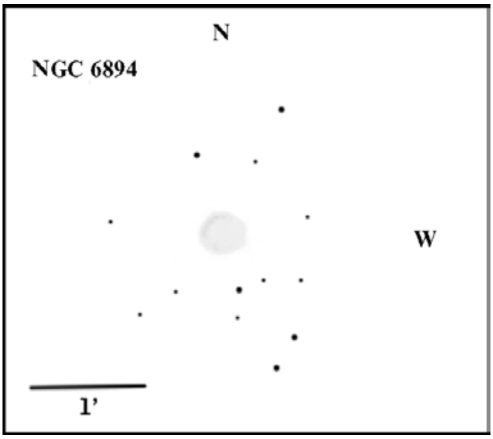
At an estimated distance of 5,000 light-years from the Sun, NGC 6894's shell extends 1 light-year across space. The planetary also lies 230 light-years below the Galactic plane, where the Galactic magnetic field is parallel to the Galactic plane. And that's what makes this planetary very interesting.

In a 1997 *Monthly Notices of the Royal Astronomical Society* (vol. 289, pp. 665–670), Noam Soker (University of Haifa at Oranim, Israel) and Daniel B. Zucker (University of Washington, Seattle) discuss their observations of faint, parallel nebulous stripes northwest, and partly tangential to, NGC 6894's outer halo. The stripes, which run from the northeast to the southwest may have been stripped away from NGC 6894's halo as the nebula moved through the interstellar medium to the southeast at a velocity of about 23 km/sec. The magnitude 17.6 central star, Noam and Zucker argue, ionized the material in the stripes, which the Galactic magnetic field had shaped.

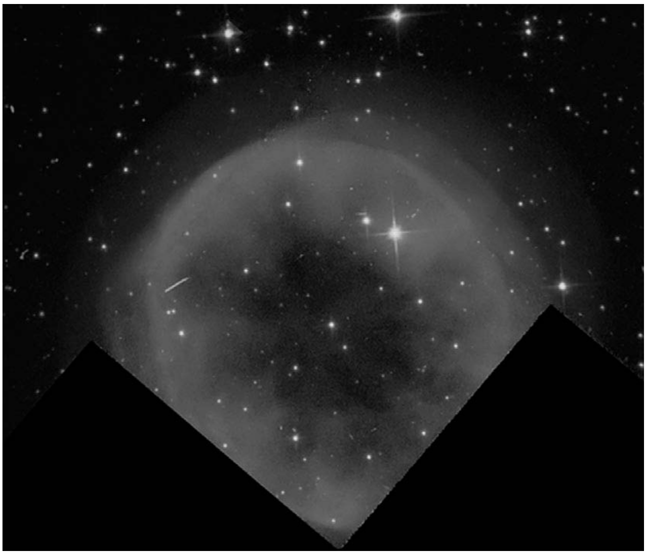
The four major stripes typically measure about 11.5″ (0.25 light-year) wide and 250″ (6 light-years) long. Noam and Zucker estimate that the total mass of the material ranges from about 0.3 Sun to about 2 Suns, which is the expected mass range for extended haloes of planetary nebulae. The stripes are also parallel to the Galactic plane, which, they say, is a result of magnetic-field shaping. The researchers assume that NGC 6894's halo had a temperature of about 100 K before it was stripped and then re-ionized by the central star. The expansion age of the halo's rim is about 3,500 years, which is about when the ionization of the nebula started.

To find this interesting object, use the chart on page 403 to locate Epsilon Cygni, then the 4th-magnitude stars 39 and 41 Cygni 5° to the southwest. Now look nearly the same distance further to the southwest for the 5th-magnitude star 21 Vulpeculae.





Center 21 Vulpeculae in your telescope at low power, then switch to the chart on this page. From 21 Vulpeculae, move about 50′ northeast to 6.5-magnitude Star *a*, then about 35′ further to the northeast to the pair of roughly 7th-magnitude suns (*b*). Next look a little more than 45′ to the north-northwest for 8th-magnitude Star *c*, which is about 12′ northeast of a 6′-wide trapezoid of 8.5- and 9.5-magnitude suns



adorns the northwest side of the nebulous ring, shining like a precious jewel. By the way, in color images, the ring is very red. I've also heard NGC 6894 called the Engagement Ring, but since this name is already associated with an asterism of stars near Polaris, the North Star, I prefer the Diamond Ring moniker. You can also see the "diamond" in the Hubble Space Telescope image at left.

(*d*). Return to star *c*, then look 20′ to the northwest for NGC 6894. Use the stars on the chart to carefully pinpoint the nebula's exact location, this is key to success. This is a very rich Milky Way field.

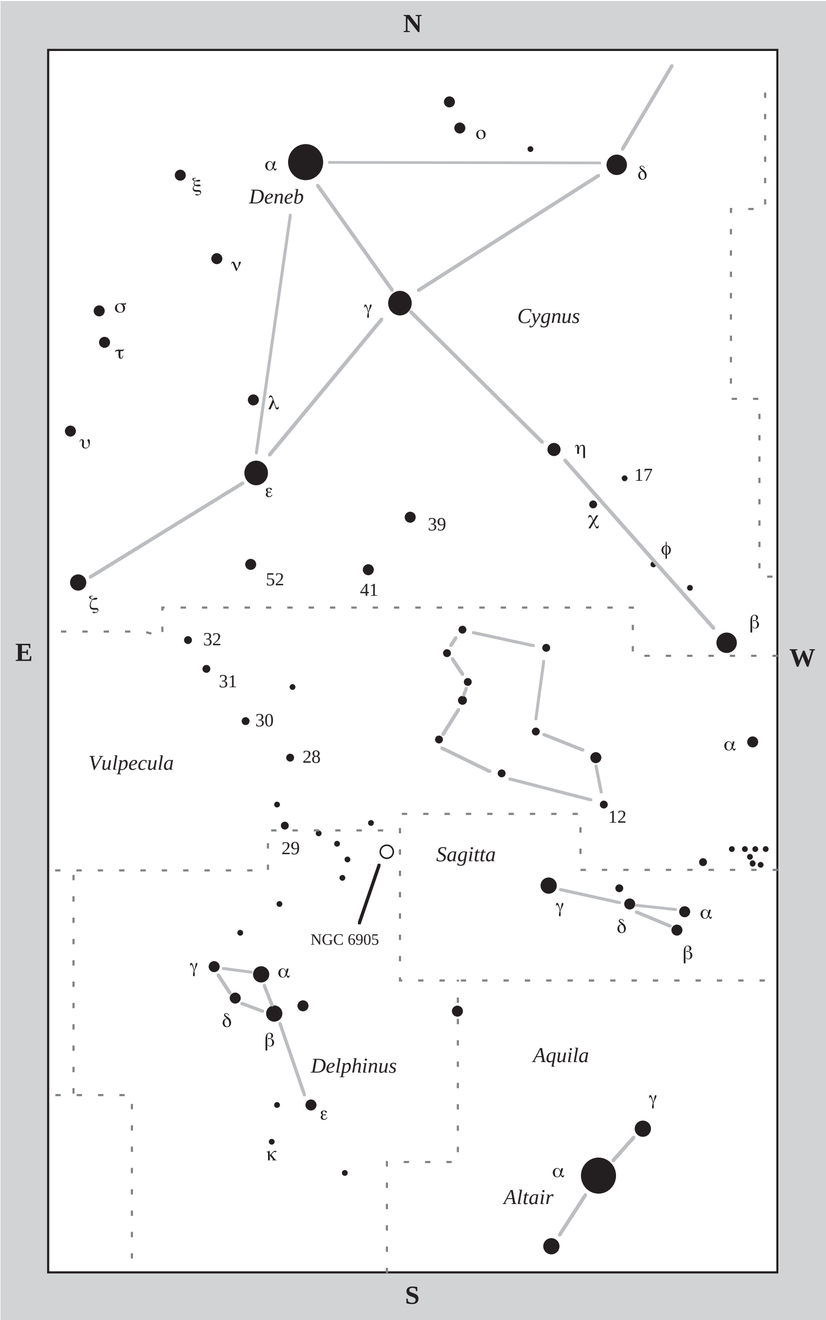
Again I could not see the nebula at 33× or 64×. When I located the precise position, I did see it at 165×. The nebula was at the limit in the 5-inch under a very dark sky. But it was quite unmistakable with averted vision. I could also see its annular form at 282× and then at 165× with much concentration. The nebula is relatively large, having the same apparent size as Jupiter, so one could rightly conceive of it as a less conspicuous relative to NGC 3242 in Hydra, the Ghost of Jupiter Nebula.

But NGC 6894's popular nickname is the Diamond Ring Nebula, which comes from its appearance in photographs and CCD images, in which a 14th-magnitude star

In an on-line search, I thought the following observation by Kim Gowney of Wales in the United Kingdom extremely helpful. Using an 8-inch f/5 equatorial telescope under excellent seeing conditions, Gowney found NGC 6894 an "easy and large object," that showed well with an OIII filter and powers of 50× and 100×. The planetary had "an obvious disk but no discernible detail, it was easiest at 50× with the OIII." And in the *Observing Handbook and Catalogue of Deep-Sky Objects* (Cambridge University Press, 1989) Christian Luginbuhl and Brian Skiff say that in a 10-inch scope, the nebula appears as a "round, well-defined disk". At 250× it has a gray color and indefinite annularity.

At high power, I was impressed at the exceeding richness of stars near the nebula, especially a clustering of roughly 12th- and 13th-magnitude suns immediately to the south and southeast of the nebula.

Secret Deep 98
(NGC 6905)



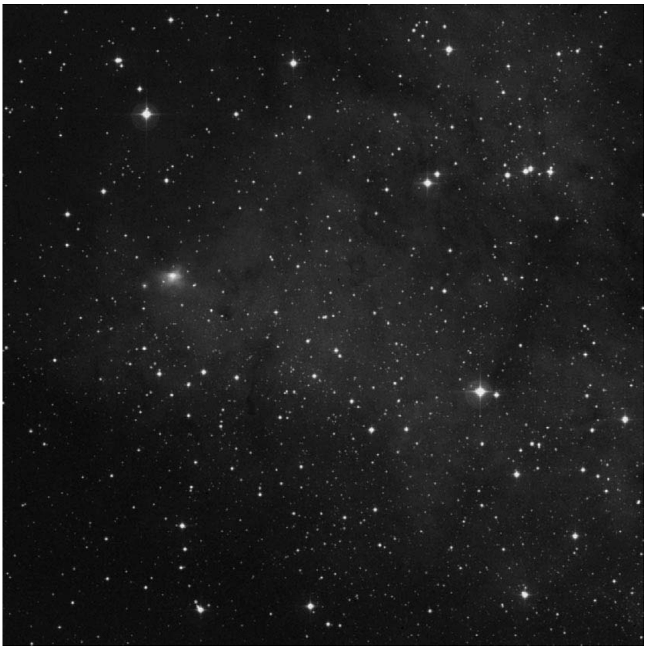
97

Part of the Gamma Cygni Nebula
IC 1318(a)
Type: Emission Nebula
Con: Cygnus

RA: $20^h\ 16.6^m$
Dec: $+41°\ 49'$
Mag: –
SB: 12.4 (Rating: 3)
Diam: $45' \times 20'$
Dist: ~5,000 l.y.
Disc: Edward Emerson Barnard, found during a photograph survey of the Milky Way at Lick Observatory between the years 1892 and 1895.

W. HERSCHEL: None.

IC: Gamma Cygni, surrounded by large patches of faint nebulosity.



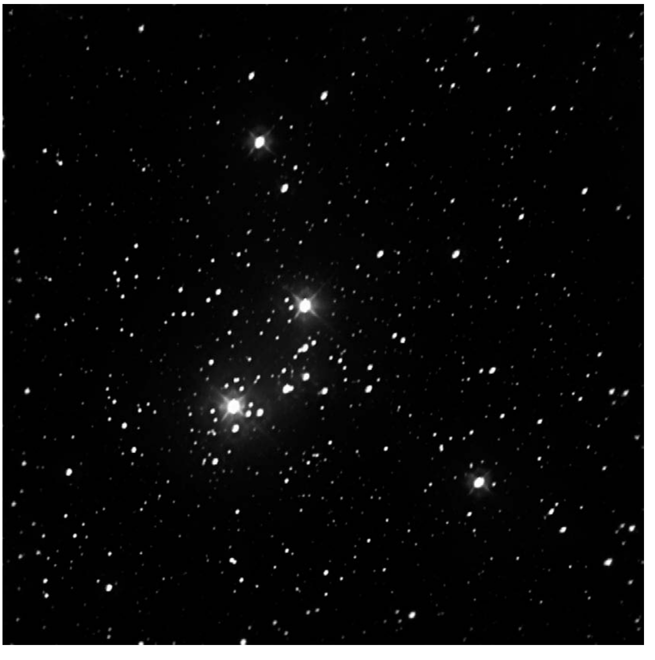
99

Inchworm Cluster
NGC 6910
Type: Open Cluster
Con: Cygnus

RA: $20^h\ 23.2^m$
Dec: $+40°\ 47'$
Mag: 6.6
SB: 12.4 (Rating: 4)
Diam: $10'$
Dist: ~5,000 l.y.
Disc: William Herschel, 1786

W. HERSCHEL: [Observed October 17, 1786] A small cluster of coarsely scattered stars of various sizes, Extended like a forming one. (H VIII-56)

NGC: Cluster, pretty bright, pretty small, poor, pretty compressed, stars from 10th to 12th magnitude.



Open cluster NGC 6910 and emission nebula IC 1318(a) are visual companions to 2nd-magnitude Gamma (γ) Cygni (Sadr), the middle star in the crossbeam of the Northern Cross. Gamma marks the headwaters of the Great Rift – a colossal river of darkness that splits the stream of the galaxy lengthwise through Cygnus. Sadr also marks the northeastern end of the great Cygnus Star Cloud, which lies between it and Beta (β) Cygni (Albireo). Our attention, however, will be focused on the region surrounding Gamma, which is one of the most dramatic in the Northern Milky Way.

William Herschel visually detected NGC 6910 in 1786. Edward Emerson Barnard discovered IC 1318(a) photographically while conducting a photograph survey of the Milky Way at Lick Observatory between the years 1892 and 1895. Since John Louis Emile Dreyer had already published his 1888 *New General Catalogue of Nebulae and Clusters of Stars* (NGC), which contains the places and descriptions of all the nebulae known at the end of the year 1887, he included Barnard's new discovery in his 1895 *Index Catalogue* (IC) of nebulae found in the years 1888 to 1894.

Barnard had long been fascinated with the Milky Way. As he writes in his *A Photographic Atlas of Selected Regions of the Milky Way*, "The Milky Way has always been of the deepest interest to me. My attention was first especially attracted to its peculiar features during the period of my early comet-seeking. To [the searcher] the Milky Way reveals all its wonderful structure, which is so magnificent in photographs made with the portrait lens. The observer with the more powerful telescopes, and necessarily more restricted field of view, has many things to compensate him for his small field, but he loses essentially all the wonders of the Milky Way. It was these views of … the Milky Way that inspired me with the desire to photograph these extraordinary features, and one of the greatest pleasures of my life was when this was successfully done at the Lick Observatory in the summer of 1889."

Despite his wondrous achievements during his pioneering efforts in Milky Way photography, Barnard had no way of realizing the true splendor of the Gamma Cygni region, arguably the most fascinating expanse of celestial real estate in the Northern Milky Way. Gamma is projected against the area of the Cygnus X complex – a large radio-emitting region, which is also the place of intensive star formation. It harbors at least five OB associations, including the Cygnus OB2 association (one of the richest in the local Galaxy), and the Cygnus OB9 association, of which NGC 6910 forms its nucleus.

NGC 6910 is also surrounded by many dark and bright nebulae, including IC 1318 (a), which itself is a part of the fractured IC 1318 nebular complex. In soft X-rays the region out to 10° is dominated by an extended source known as the Cygnus Superbubble – a ring-like structure associated with atomic and molecular gas, dust, and objects related to recent star forming activity. The Superbubble is 10 times larger than the large supernova remnants, occupies 1,000 times more volume, and contains 20 times more energy. The Superbubble appears to be an arrangement of unrelated objects including discrete sources, coronal gas created by stellar winds and, possibly, supernova explosions in individual associations.

Despite its prominent position, Gamma is not related to this drama. At an uncertain distance of 1,500 light-years, it's a foreground object. NGC 6910 and IC 1318(a) lie 5,000 light-years distant, placing them behind the Great Rift, within the Local (Orion) spiral arm of the Galaxy. Consequently, the two objects suffer light extinction by intervening dust. NGC 6910 is dimmed variably across its face by as much as 1.3 magnitudes. If the cluster wasn't affected by extinction, it would be one of the brightest in the sky, rivaling the Trapezium in the Orion Nebula, or M44 (the Beehive) in Cancer.

NGC 6910 is a very young (5–10 million years) OB star cluster with 66 stars shining 10th magnitude and fainter. Its 10 brightest stars have spectral types from O9 to B2; the brightest of which is a blue supergiant. In a 1991 *Astronomicheskii Zhurnal* (vol. 68, p. 466–486), V. S. Shevchenko (Uzbek Academy of Sciences) and colleagues note that the star-forming region to which NGC 6910 belongs (also known as SFR 2 Cyg) contains 61 early-type stars. The region is fairly extensive, having a diameter of more than 160 light-years, and contains a very large amount of gas and stars. The mass of its molecular clouds equals 500,000 Suns and the mass of stars in the region is 10,000 Suns. The researchers determined the cluster's distance at 3,200 light-years. But in a 1992 *Baltic Astronomy* (vol. 1, pp. 91–96), V. Vansevicius (Institute of Physics, Lithuania) found NGC 6910 to be 5,000 light-years and its age 7 million years. If we accept that distance, NGC 6910 spans 15 light-years across.

IC 1318 is one of the brightest emission nebula complexes in the Cygnus X area. It consists of three main optical components (a, b, and c). Of them IC 1318(a) is the most prominent and quite easily seen under a dark sky in a small scope and low power; it measures 50′ across, which at a distance of 5,000 light-years equals some 70 light-years in true physical extent. Despite its fractured appearance, the IC 1318 nebular complex as a whole is considered to be a completely spherical shell (32 light-years across) expanding at about 20 km/sec. Indeed, the nebulae surround NGC 6910 like Barnard's Loop around the Trapezium in Orion. The nebula complex shines by light radiating from hot OB stars within, though it emits light in the red part of the visual spectral range, making it somewhat of a challenge to see with the human eye.

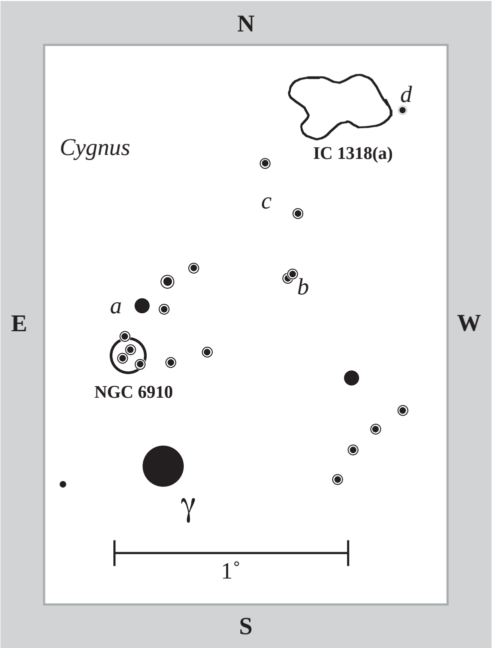
To find these objects, begin by using the chart on page 407 to locate Gamma Cygni in the Northern Cross. Center that star in your telescope at low power, then switch to the chart on page 411. Target NGC 6910 first, which is just 30′ north-northeast of Gamma Cygni, about 18′ south-southeast of a 6th-magnitude star (*a*).

At 33× in the 5-inch, NGC 6910 looks like a crisp, 4′-long crescent of stars (oriented northwest–southeast) between two roughly 7th-magnitude golden gems. Two slightly dimmer stars projecting to the east from the middle of the crescent give the crescent a "hump," making it appear like the raised back of an inchworm on the move. Surrounding the "worm" is a coarse and scattered aggregation of another half-dozen or so stars.

At 60×, the crescent becomes part of a larger "stream" of stars that flows past the 7th-magnitude stars on either end before forking. With time, tiny fragments of stellar gatherings can be seen radially around the "worm," like a tiny 1′-long triangle of dim suns to the northeast, and loose strings of stars to the southeast. At 94×, the main concentration of suns appears to be around the southeastern 7th-magnitude sun and the worm's "hump." Again, there are 66 stars here 9.6 magnitude and fainter, so take some time to see if you can ferret them out. With a casual gaze, I could count about 30 suns out to 10′.

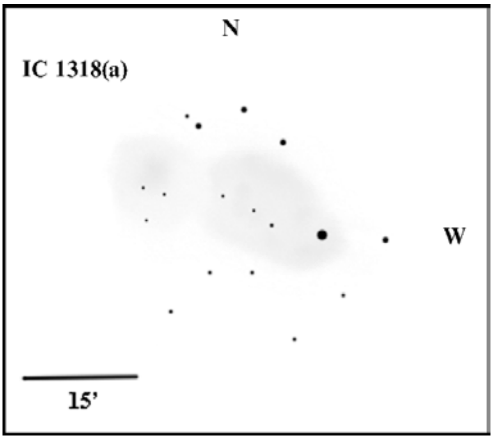
The field of IC 1318(a) lies nearly 2° north-northwest of Gamma. I find it best to take a long and leisurely star hop to it from NGC 6910. Using a wide field of view and the chart on this page, return to Star *a*, which has a near equal companion 10′ to the northwest. Now slide 25′ west of that latter star to a tight double Star (*b*) comprising an 8th-magnitude primary and a roughly 10th-magnitude secondary to the northwest. Now move 20′ north-northwest to another pair of 8th-magnitude stars (*c*) separated by about 12′ and oriented northeast–southwest. Your final sweep, 25′ northwest of the northern most star in Pair *c*, will bring you to a solitary 8th-magnitude star (*d*) which marks the western side of the brightest 30′-long segment of IC 1318(a).

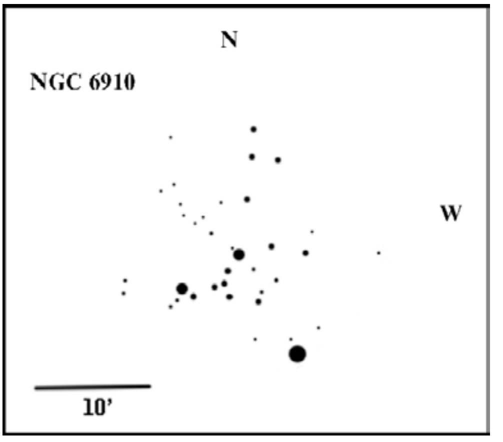
In the 5-inch at 33×, I found the nebula "very obvious" under dark skies, which shocked me, since, I expected most IC objects to be exceedingly faint. But there obviously are exceptions. Indeed, in their *Observing Handbook and Catalogue of Deep-Sky Objects* (Cambridge University Press, 1998), Brian Skiff and Christian Luginbuhl found the nebula visible in a 2½-inch telescope! The key to success is to have a wide field of view, low power, and a dark sky. I find slowly sweeping the scope back and forth across the area helps to bring it out, as moving the scope in such a gentle way sweeps the faint light of the



nebulosity continuously across your eye's night-sensitive rod cells, keeping them stimulated and alert.

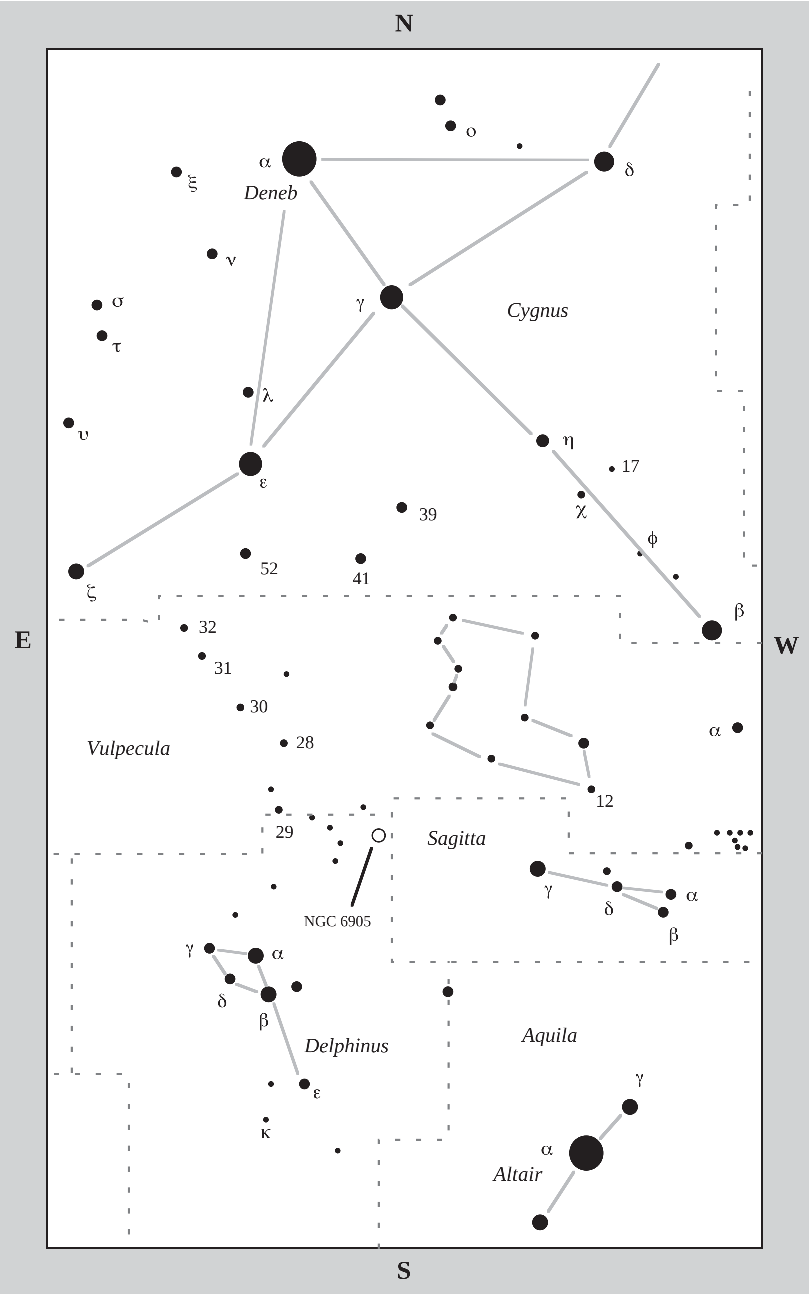
The nebula stands out prominently enough that it cannot be confused with simply a rich Milky Way star field, of which Cygnus has many. And, admittedly, teams of dim stars sparkle within the nebula. To me, the shock of seeing IC 1318(a) is the visual equivalent of running into a cobweb at night. With scrutiny, I find the brightest 30′-long segment fractured in two: a roughly 15′-long, irregular oval nebula that expands to the northeast from Star *d* to a close group of three suns; and a roughly 10′-wide irregular nebulosity about 5′ east of the northeastern tip of the previous glow. There's not much detail to detect, the prize is simply capturing this faint light in your telescope. Of course, the real beauty of this region comes out in photographs and CCD imaging.





When you're finished enjoying the region around Gamma Cygni, do take the time to admire this bright foreground star. University of Illinois astronomer James Kaler refers to Sadr as a "fairly unusual" F-type supergiant. "Most of these brilliant stars are either fairly hot or quite cool and reddish," Kaler says. "Few, like Sadr, are yellow-white and in the mid-temperature range near 6500 degrees Kelvin, not much hotter than the Sun." In his *Celestial Objects for Common Telescopes* (Dover Publications, New York, 1962), Rev. Thomas W. Webb notes that Sadr has a reddish 10th-magnitude companion 141″ to the south-west, though it might not be physically related. The companion also has a companion of equal brightness 2″ to the north-northwest.

Secret Deep 98
(NGC 6905)



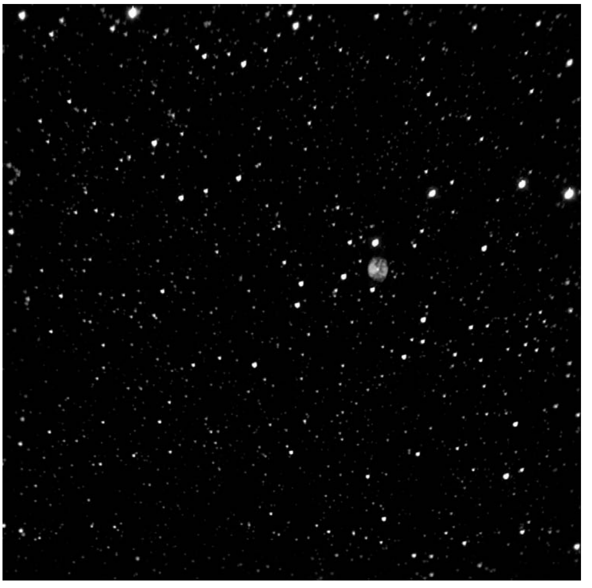
98

Blue Flash Nebula, Caged Spirit Nebula
NGC 6905
Type: Planetary Nebula
Con: Delphinus

RA: 20^h 22.4^m
Dec: $+20°$ $06'$
Mag: 11.1 (Rating: 3)
Dim: $42'' \times 35''$
Dist: ~5,870 l.y.
Disc: William Herschel, 1784

W. HERSCHEL: [Observed September 16, 1784] Pretty bright, perfectly round, pretty well defined, 3/4′ in diameter, resolvable (mottled, *not* resolved). (H IV-16)

NGC: Very remarkable, planetary nebula, bright, pretty small, round, 4 [faint] stars nearby.



NGC 6905 IS A BEAUTIFUL PLANETARY in the Delphinus Milky Way, near the borders of Vulpecula and Sagitta. At low powers, it looks like a hint of lint in a carpet of stars; at high powers, it's a fascinating furball of dappled light in a tight trapezium of equally bright suns that continually plays with, and confuses, the eye. The nineteenth-century British observer Rev. T. W. Webb referred to the nebula as "misty" and "ill-defined," noting the proximity of several faint stars.

After William Herschel discovered this ball of gas (which has about the same apparent size as the planet Jupiter), his son John wondered if the nebula was somehow connected to the surrounding stars (perhaps like jovian moons): "The enormous magnitude of these bodies," he says, "and consequent probable mass (if they not be hollow shells), may give them a gravitating energy, which, however rare we may conceive them to be, may yet be capable of retaining in orbits, three or four times their own diameter, and in periods of great length, small bodies of a stellar character." Such thinking demonstrates how difficult it was to interpret a two-dimensional sky in the pioneering days of visual telescopic astronomy.

While NGC 6905 has no formal connection with the surrounding line-of-sight field stars, the nebula is a curiosity. Modern studies reveal NGC 6905 to be an unusual high-excitation nebula with conical outflow lobes (100″ across) superimposed on a spheroidal inner shell ($47'' \times 34''$). Each lobe extension terminates at a nebulous knot.

Planetary nebulae are believed to originate from the remnants of circumstellar envelopes of asymptotic giant branch

(AGB) stars – those that represent the very last phase of normal stellar evolution. Since these remnant shells are spherical (except for a few), the origin of aspherical nebulae, such as NGC 6905, presents a problem for astronomers studying planetary nebula formation and evolution. What physical process (or processes) can explain the shape(s) of aspherical planetaries?

In a 1993 *Astronomy & Astrophysics* (vol. 267, pp. 199–212) Luis Cuesta (Instituto Nacional de Técnica Aeroespacial, Madrid, Spain), James Phillips (Harvard-Smithsonian Center for Astrophysics) and their colleagues report how their broad range of spectroscopic images with the 2.5-meter Isaac Newton Telescope on La Palma may help to model the appearance of NGC 6905 – namely, how conical outflow lobes can appear superimposed upon a spheroidal inner shell.

In their model, the nebula's principal axis has a position angle of 163°, while the core ellipsoid appears inclined at ~60° to our line of sight. The inner shell, they believe, has symmetrically inclined holes, which funnel stellar winds into the outer shell. As these winds rush out with velocities of about 430 km/sec, they plow into the more slowly expanding exterior halo, creating shocks that formed the lobes' distinct hourglass configurations. The knots at each ansa may mark the focal point of material plowed ahead as the winds pushed forward. These observed structures would require the central star to be losing mass at the rate of about 10^{-7} solar masses per year, which is typical for planetary nebulae.

"Such a mechanism," the researchers claim, "would not only account for the morphology of the lobes, and the broad variations in surface brightness and excitation, but also match the observed shell kinematics, and goes some way to explaining the location and characteristics of the associated ansae." On the other hand, there's also a possibility that the entire nebula is a consequence of shock interaction, with the internal nebulosity constrained by a higher density disk.

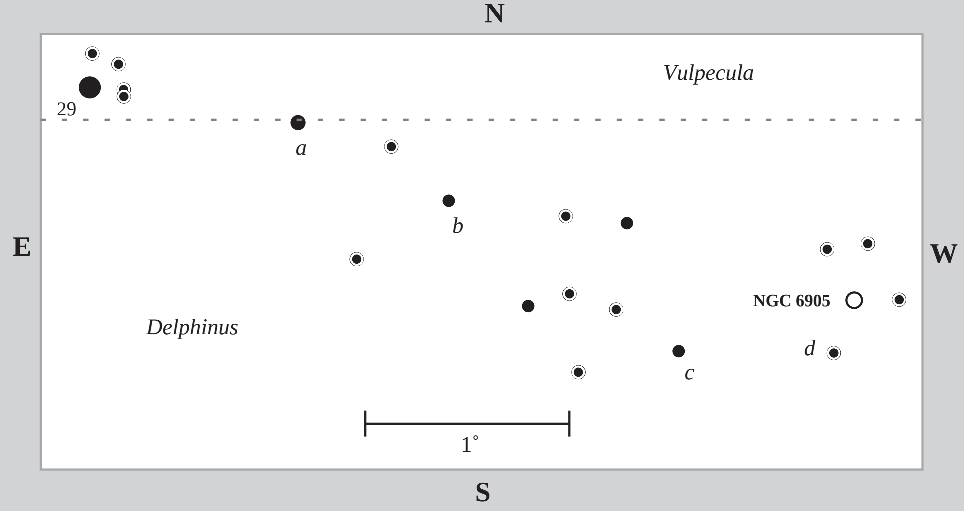
NGC 6905 has long been known as a variable planetary. In a 1961 *Soviet Astronomy* (vol. 5, p. 186) B. A. Vorontsov-Vel'Yaminov of the Sternberg Astronomical Institute, details how spectra of NGC 6905 taken from 1945 to 1959 revealed that the nebula's HeII to H-beta ratio increased (approximately from 0.5 to 1.3) over the course of 15 years, leading to the belief that the temperature of NGC 6905's nucleus must have risen by 30 percent – a rise of about 2 percent per year.

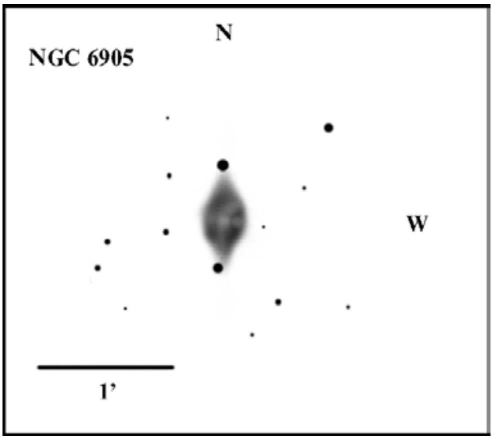
The late Walter A. Feibelman (NASA-Goddard Space Flight Center), offered support for the variable nature of the nebula. In a 1996 *Astrophysical Journal* (vol. 472, p. 294), he explained that International Ultraviolet Explorer's spectroscopic observations of NGC 6905's nucleus – a single Wolf–Rayet star with a temperature of 104,000 K (making it one of the hottest known objects in the Hertzsprung–Russell diagram) – shows a P Cygni variable-star profile in the ultraviolet, which points to an outflow of material in the form of either an expanding shell of gas or a powerful stellar wind, thus raising the probability that the observed visible variability in NGC 6905 is caused by intermittent activity in the nucleus.

To find this interesting celestial sapphire (at least photographically it's a blue gem), be prepared to make a very slow and careful search. Star-hopping to NGC 6905 takes time, and identifying it may require some effort because it lies in a fabulously dense field of stars and its little disk may not stick out at low power in the stellar confusion. Rather than searching for a faint fuzzy, first be sure to locate the correct star field, then zoom in for the capture.

Using the chart on page 413, look about one-third of the way from Epsilon (ε) Cygni, the southern wing tip of the Swan, and Gamma (γ) Delphini, the eastern star in the Diamond. There you'll find a 5½°-long chain of four 5th-magnitude stars: 32, 31, 30, and 28 Vulpeculae (from northeast to southwest, respectively). About 3° south of 28 Vul is the 5th-magnitude star 29 Vul. Center it in your telescope at low power, then switch to the chart on this page. From 29 Vul, move 1° west to 6th-magnitude Star *a*, right on the border between Vulpecula and Delphinus. A 50′ hop southwest will bring you to another 6th-magnitude Star (*b*), in Delphinus; it marks the northeast end of a 1¼°-long diamond of similarly bright suns. Center Star *c* at the southwest tip of the diamond, then move about 50′ due west to 7th-magnitude Star *d*; it lies at the northeastern end of a bent Sagitta-like asterism of four similarly bright stars. NGC 6905 lies a little more than 15′ to the north-northwest of Star *d*.

You really can't mistake the location of NGC 6905, because the eye is immediately drawn to the nebula, which is caged in a tiny triangle of 11th- to 12th-magnitude suns, which, at 33×, appears to the eye as a single and little milky patch of concentrated starlight – a *very tiny* globe of fuzzy stardust, one quite distinct from the otherwise rich stellar background. In fact, it looks very much like a small and dim star cluster, which is why, no doubt, John Herschel was so taken by the nebula's proximity to the stars. At 60× the nebula is more clearly seen set midway between the triangle's two western stars. The triangle's third star lies to the east, while a fainter star northeast of the nebula makes the triangle a trapezoid.





These low-power views still leave the impression that the nebula's trapped in a maze of starlight, so don't be afraid to power up! The more magnification, the better. I find through my 5-inch (using a combination of 11- and 7-mm eyepieces with a 3× Barlow) I get the most comfortable views of the nebula (where it is seen as a distinct object separated from the stars) at 180× and 282×. Portions of the nebula swell in and out of view depending on where I position my eye and how I use averted vision.

I find it best to alternate between direct and averted vision, especially since the eye cannot help but jump from star to star in the triangle near the nebula, before leaping back to the nebula, which suddenly flashes into view – thus the reason for NGC 6905's most popular name, the Blue Flash Nebula (though I cannot see the disk as blue, but a pale gray; it does have a pale blue sheen in larger telescopes). According to Steve Gotlieb, the late John Mallas gave the nebula its name for just the reason I described above. For partly the same reason, I call NGC 6905 the Caged Spirit Nebula. It's also referred to as a copycat M97 (Owl Nebula), owing to the view in large backyard telescopes, which show dark "eye hollows" in the nebula's central region.

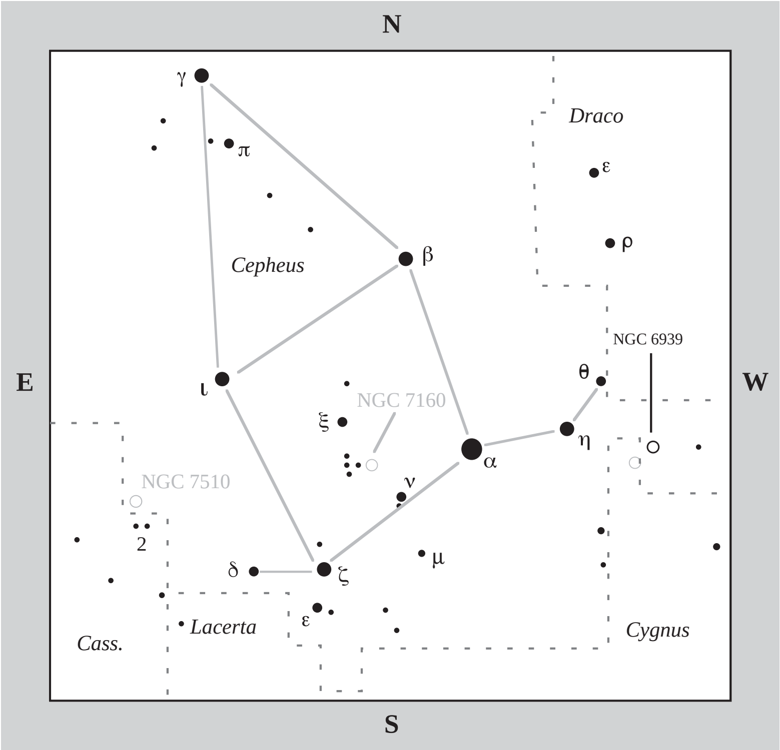
It is certainly hypnotic to try and separate the nebula from the stars. As the eye swims around, the planetary wafts in and out of view like vapors from a moist mouth on a cold day. The overall impression I get is that there is a weak ring or bright-edged shell whose interior is filled with faint, mottled nebulosity. The "ring" or bright rim is not of uniform brightness. Curiously, I find it difficult to nail down which sections appear most intense in the 5-inch. At one moment, I'll see see two arcs of light – one to the north and one to the south – but with a tilt of the head, I'll see two new arcs – one to the west and one to the east. Perhaps this is all illusory.

In the various CCD images I have seen, the nebula's east and west edges appear as scalloped arcs, with wispy tendrils of nebulosity wafting across the entire shell. So this object really can be a celestial Rorschach test. I've also seen suggestions of the elongated outer shell stretching to the northwest and southeast – but only at low powers, which concentrates faint light. Then again, I believe these could also be illusory: the eye tends to extend nebulous objects linearly toward nearby stars.

In larger scopes, amateurs have had success seeing rich hues, as well as the central star. In October 2009, *Astronomy* magazine contributing editor Alister Ling and I observed NGC 6905 through Larry Wood's (Edmonton, Alberta) 12-inch f/6 Newtonian reflector at the George Moore Astronomy Workshop at Pigeon Lake outside of Edmonton, Alberta. The nebula appeared as a well-defined blue-gray ellipse whose dense shell had a bright outer edge then gradually, then suddenly got less defined toward the center, where we saw the nebula's central star. Although the transparency was excellent, the atmospheric seeing was poor, so detecting fine details in the shell seemed out of the question, as they most likely blurred together.

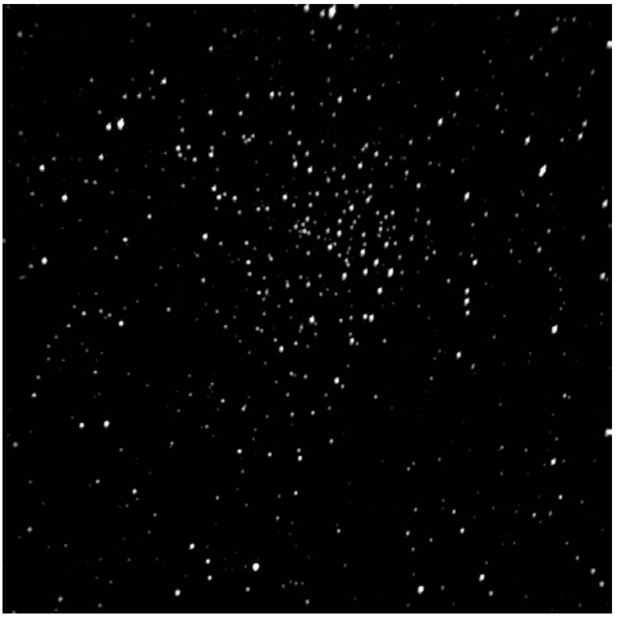
By the way, one night, my wife Donna and I were camping under the stars, on the slopes of Kilauea. I had brought my telescope and we observed NGC 6905 at gradually higher powers. Donna commented that viewing this object with different powers gave her a feeling of depth perception. It seemed to her the more power we used, the deeper she was peering into space. So why not try taking a similar visual plunge.

Secret Deep 100
(NGC 6939)



100

Flying Geese Cluster, Silk Fan Cluster
NGC 6939
Type: Open Cluster
Con: Cepheus



RA: 20^h 31.5^m
Dec: $+60°$ $40'$
Mag: 7.8
SB: 12.8 (Rating: 4)
Dim: $10'$
Dist: ~5,700 l.y.
Disc: William Herschel, 1798

W. HERSCHEL: [Observed September 9, 1798] A beautiful compressed cluster of [faint] stars extremely rich, of an irregular form, the preceding part of it is round, and branching out on the following side, both towards the north and towards the south, 8 or 9′ in diameter. (H VI-42)

NGC: Cluster, pretty large, extremely rich, pretty concentrated in the middle, stars from 11th to 16th magnitude.

OWNERS OF MY DEEP-SKY COMPANIONS: *The Caldwell Objects* (Cambridge University Press, 2004) may already be familiar with our next target, open star cluster NGC 6939. In that book, I briefly describe the cluster under the entry for the mixed-spiral galaxy NGC 6946 (Caldwell 12), near which it lies, just over the border in Cygnus. The fact is, NGC 6939 is the brighter and more visually impressive of the two objects in a small telescope. Yet it was not recognized as a Caldwell object.

It's time now for us to focus our attention on NGC 6939, a wonderfully large and rich cluster. As the nineteenth-century British observer Admiral William Henry Smyth says of it: "the whole exhibits a grand but distant collocation of suns, which are evidently bound together by mutual relations, under the energy of a force, which, though reason asserts its existence, imagination fails in conceiving."

In 1933, Robert J. Trumpler classified NGC 6939 as a type II1r, meaning it's a detached but rich open cluster with little central concentration and stars of near equal magnitude. Although the intermediate-age cluster has been an object of study since the 1920s, its parameters are in disagreement in the literature. Recent studies, however, seem to be converging on an age of about 1 billion years and a distance of 5,700 light-years. At that distance, the 300 cluster members would span 17 light-years of space.

In a 2007 *Astronomische Nachrichten* (vol. 329, pp. 387–391), Polish astronomer G. Maciejewski (Uniwersytet Mikoaja Kopernika) and colleagues describe how their photometric survey of NGC 6939 detected 22 variable stars (four previously known), including four eclipsing binaries (three detached and one contact binary). The researchers' analysis of the brightness of the contact binary (V20) strongly supports a distance estimate of 5,700 light-years to the cluster, which lies 32,000 light-years from the galactic center.

The discovery of contact binaries in open clusters is turning out to be a useful tool in helping astronomers to determine the age of the cluster. But it's not that simple a task. In a 1993 *Astronomical Society of the Pacific Conference Series* (vol. 53, p. 164), J. Kaluzny (Warsaw University Observatory, Poland) and S. M. Rucinski (Institute for Space and Terrestrial Science, Toronto, Canada) note that the number of contact binaries in open clusters may be dependent on cluster richness: more populous clusters seen to have fewer contact systems. They write, "Possibly, the dependence of the contact system frequency on the cluster richness may relate to the dynamical evolution of clusters and 'evaporation' of lighter single stars."

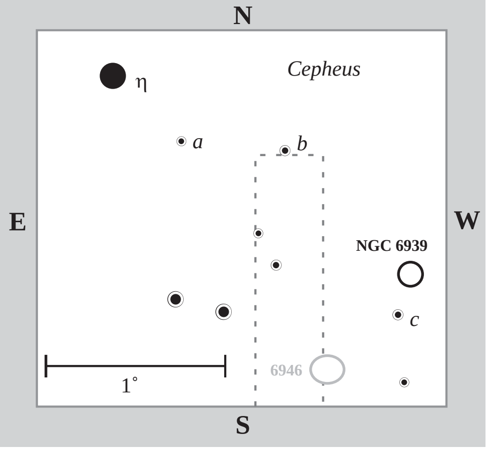
By comparing contact binaries in clusters of varying ages, astronomers can determine the minimum time it takes for contact systems to form from more widely separated stars. It's believed that the lifetime of the contact phase in these binary systems (the most common type of which is a W Ursae Majoris-type variable) is on the order of 500 million years. But it's possible that as star clusters age they could have a second burst of star formation, or more bursts for much older clusters, increasing the number of contact binaries we see in the cluster.

Only a few open clusters are known to be around a billion years old. And most of them have only one known contact system. The oldest open clusters known in our Galaxy are around 8 billion years old, such as NGC 188 in Cepheus (Caldwell 1) and NGC 6791 in Lyra, and they have up to eight contact binary systems.

Thus, the single contact binary in NGC 6939 appears to confirm the cluster's intermediate age.

In a 2004 *Monthly Notices of the Royal Astronomical Society*, Gloria Andreuzzi (Astronomical Observatory of Rome, Italy) and her colleagues found the cluster's color–magnitude diagram to show a very clear main sequence extending down to about magnitude 24 and a prominent red-giant clump, including 40 stars.

Andreuzzi *et al.* also found a very well-defined white-dwarf cooling sequence down to a similar magnitude. Stellar evolution predicts that all single stars having a main-sequence mass lower than about 8 Suns live as white dwarfs. Since white dwarfs cool at a well-known rate, the color–magnitude diagram's cooling sequence could be used to estimate a cluster's age. But the researchers did not have a large enough sample of these stars (among other things) to apply this model. For more information about the use of the white dwarf cooling sequence as a device for estimating the age of a cluster see Andreuzzi's paper in the 2002 *Astronomy & Astrophysics*, vol. 390, p. 961.



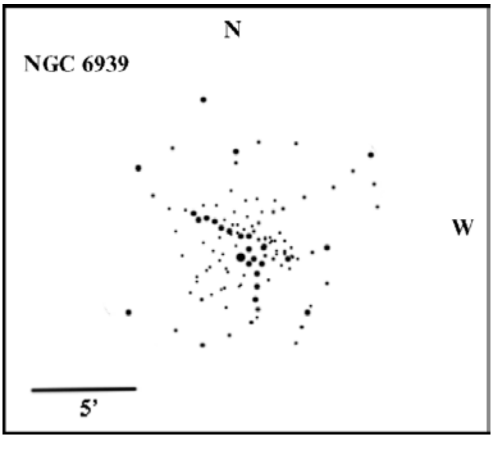
To find this large and reasonably bright open cluster, use the chart on page 419 to find 4th-magnitude Eta (η) Cephei, the left elbow of the celestial King. Center that star in your telescope at low power, then switch to the chart on this page. From Eta Cephei, move 30′ southwest to 8.5-magnitude Star *a*. Next, move about 35′ west to 7.5-magnitude Star *b*. NGC 6939 is 1° southwest of Star *b*, and just about 12′ north-northwest of 7th-magnitude Star *c* and only ⅔° away from NGC 6946. So the two objects are quite the dramatic pairing.

In the 5-inch at 33×, NGC 6939 is a very pretty orb of "noisy" starlight. With direct vision, the cluster appears somewhat cometary in form with little central concentration. But with averted vision, a striking sideways V of roughly 12th- to 13th-magnitude suns can be seen cleanly projected against the dimmer stellar madness, which spans one-third of the full-Moon's apparent diameter.

The V is composed of one sharp row of stars slicing across the cluster's face from the east-northeast to the west-southwest. Another row of stars extends nearly equidistant to the south. So the two rows can be easily imagined as a flock of geese flying to the west. (Note too, how William Herschel noted the formation, seeing the stars "branching out on the following side, both towards the north and towards the south." Now relax your gaze. Do you see the dark lane paralleling the first mentioned row of stars to the southeast?

If you defocus the view ever-so-slightly, the darkness may stand out more prominently. I also find it helps to prepare your mind for the search by concentrating on seeing the darkness rather than the stars. Your mind's a flexible tool, so bend it. (While you're at it, try envisioning the vast difference in distance between NGC 6939 (5,700 light-years) and NGC 6946 (18 million light-years)).

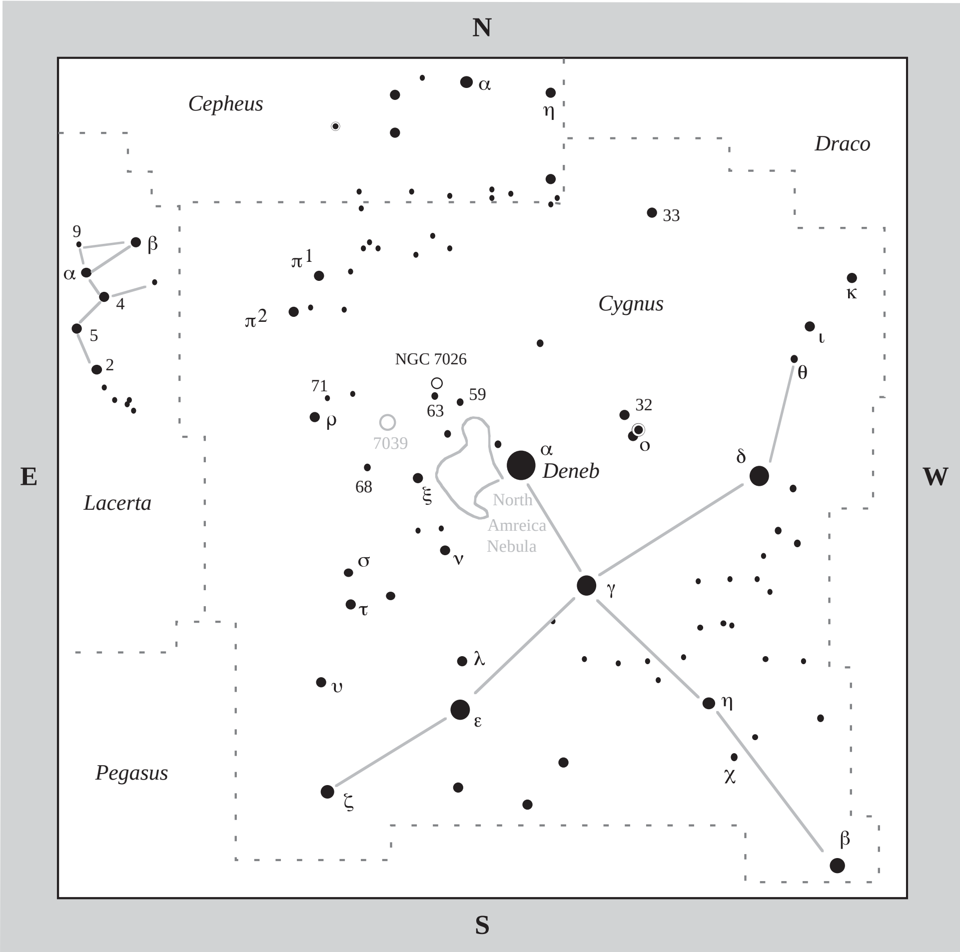
At 60×, the V stands out quite prominently and looks remarkably angular – a clean right angle! What's more, the cluster appears oddly off balance, being much more full to the southeast and northwest and essentially devoid of stars to the west and southwest. When I increased the magnification to 94×, much of the fainter outer parts of the



cluster vanished leaving a broad fan (the V filled to the brim with stars to the east), like a delicate oriental silk fan. Indeed, this impression was also recorded by Admiral Smyth: “The preceding portion of the most gathering part of the cluster is formed by a regular angle, or fan-shape figure.”

Now return to low power, and, once again, relax your gaze. This time concentrate on the neighboring starfields. First, the cluster appears capped by three 10th-magnitude suns to the north. But do you also see the capricious arms of starlight extending from, and spiraling around, the cluster’s fan like a spinning pinwheel?

Secret Deep 101
(NGC 7026)



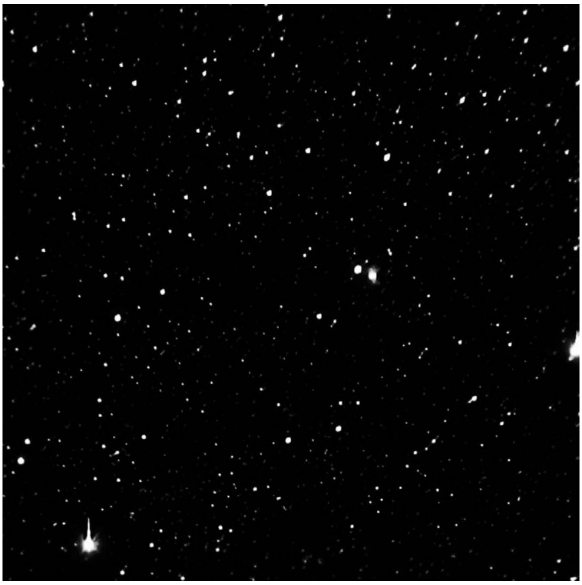
101

Cheeseburger Nebula, Burnham's Nebula
NGC 7026
Type: Planetary Nebula
Con: Cygnus

RA: 21^h 06.3^m
Dec: +47° 51′
Mag: 10.9 (Rating: 4)
Dim: 21″
Dist: ~6,500 l.y.
Disc: Sherbourne Wesley Burnham, 1873

HERSCHEL: None.

NGC: Pretty bright, binuclear, annular or ring nebula.



NGC 7026 IS ANOTHER NEBULOUS marvel tucked away in a rich expanse of Milky Way only 12′ north-northwest of 4.5-magnitude 63 Cygni. Perhaps the nebula's closeness to 63 Cygni caused many great observers with large telescopes to miss it in their sweeps of the sky at low power. It took the sharp eye of American astronomer Sherbourne Wesley Burnham (1838–1921) to spy the new nebula on July 6, 1873. He accomplished this feat with his own 6-inch refractor, which he used in his backyard.

Burnham is an icon in the annals of stellar astronomy. He was especially renowned for his double star research and discoveries. His visual prowess led to him to a very successful career in astronomy, which culminated at Yerkes Observatory, where he was senior astronomer from its opening in 1897. Burnham did, nonetheless, discover 6 NGC and 21 IC-objects with various telescopes over his long career. All of these objects are galaxies, except NGC 7026, a planetary, which became popularly known as Burnham's nebula.

What makes the discovery all the more inspiring is that Burnham was a "self-made man," having had no formal studies in astronomy or mathematics. He acquired his astronomical knowledge through books and literature that he borrowed from Chicago libraries. After the Civil War (during which he served as a government reporter in New Orleans with the Union army and subsequently as a reporter at several Constitutional Conventions in the southern states), he returned to hometown Chicago, where he spent 20 years as a court reporter. At night, however, his passion was for astronomy and the night sky.

Burnham's interest in the stars blossomed in 1870 after he purchased an exceptional 6-inch refractor from Alvan Clark & Sons in Cambridge, Massachusetts, and turned it to the sky at night. (Dearborn Observatory in Chicago later purchased that scope.)

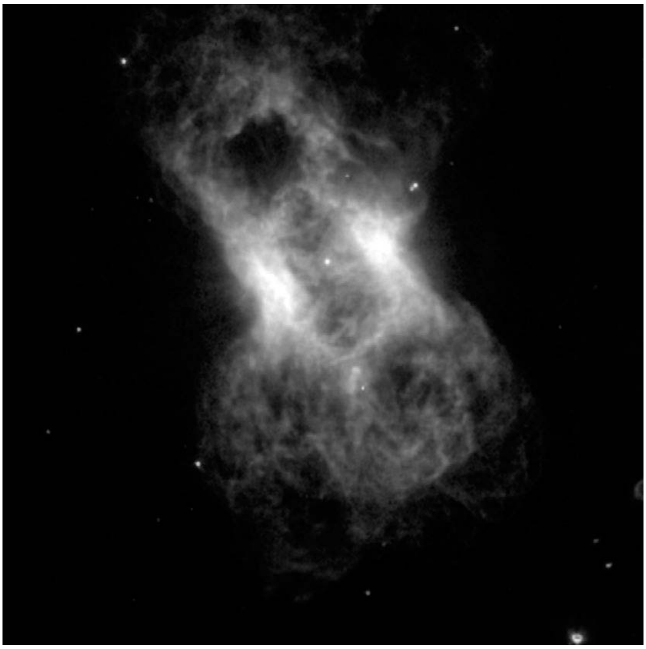
Rev. Thomas W. Webb's *Celestial Objects for Common Telescopes* helped Burnham into his pursuit for double stars.[1] In letters, Webb encouraged Burnham in this endeavor, for which Burnham had an unusually sharp eye. With the 6-inch alone, Burnham went on to discover 451 new doubles, many of which were so close that observers with larger instruments had difficulty detecting them. Thus, in a way, it's fitting that this iconic observer of double stars would discover a binuclear nebula just three years into his new endeavor. As Edwin B. Frost recalled in his 1921 biography of the man, "His symbol β [associated with double stars] is recognized throughout the astronomical world as the synonym of scientific precision and of remarkable visual discrimination."

Edward Holden at Lick Observatory described NGC 7026 as resembling "two sheaves of wheat placed side by side." Indeed, the late Lawrence Aller (University of California, Los Angeles) called NGC 7026 one of the most remarkable bipolar (butterfly) planetary nebulae in the northern sky. This peculiar "beast" exhibits two intensely bright and elongated inner lobes, separated by about 7″ and symmetrically placed with respect to the nebula's magnitude 14.2 central star. The nebula also has two other exterior lobes extending over a 25″ × 43″ area. This fits Sun Kwok's (University of Calgary) definition of a planetary in the butterfly class, which he defines as those exhibiting a pair of lobes with a perfect axis of symmetry, like butterfly wings, the lobes are wide at the ends with a narrow center.

NGC 7026's hot central star (80,000 K) has a distinct Wolf–Rayet spectrum, the spectral lines of which exhibit a double "bowed" appearance, both components of which consist of several condensations of smaller extent. In a 2004 *Astrophysical Journal* (vol. 614, pp. 745–756), Siek Hyung (Chungbuk National University, South Korea) and Walter A. Feibelman (NASA Goddard Space Flight Center), found that the star's carbon, nitrogen, oxygen, neon, sulfur, and argon abundances are highly enhanced, whereas other rare elements – potassium, silicon, and probably chlorine, appear to be depleted – resulting in a relatively low gas temperature. The star's mass is about 0.56 Sun and has a luminosity of about 2,400 Suns. With an estimated age of 5,000 years, the star appears to have evolved from an asymptotic giant branch (AGB) progenitor that must have been slightly less massive than our Sun during its main-sequence phase of evolution.

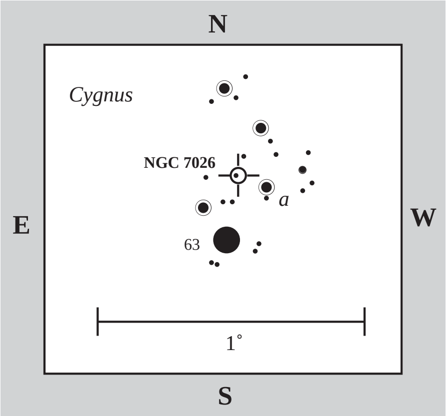
The researchers conclude, "If NGC 7026 is evolved from a low-mass single star, this low-mass progenitor star indicates its relatively long age, borne relatively earlier in the Galactic history. Meanwhile, the chemical abundance enhancement indicates that the star was borne from chemically already enriched gas, probably, in the Galactic plane. The other possibility is that the CSPN of NGC 7026 is evolved from a massive progenitor in a binary system, of which a large mass fraction was already transferred into the other (unobservable) companion."

[1] First published in 1859, this book became the classic amateur astronomer's handbook for many years and its 1962 Dover reprint is still popular today.

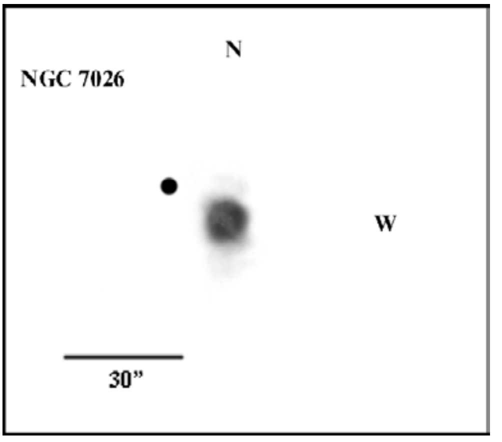


The HST image at right shows a central ring structure (inclined 75° with respect to the line-of-sight) with bipolar lobes on each side. Velocity measurements of the gases within the nebula suggest a nonspherical expansion of an elongated thin shell structure – an ovoidal or "bipolar" nebula consisting of an equatorial toroid expanding with a velocity of 54 km/sec, as well as two blobs moving at higher velocities outwards along the polar axis. Several filaments protrude from the equatorial regions to the poles, perhaps as a result of shock interaction. The bipolar structure of NGC 7026 might be caused by an equatorial concentration of the circum-stellar material lost during the late phase by the progenitor AGB star.

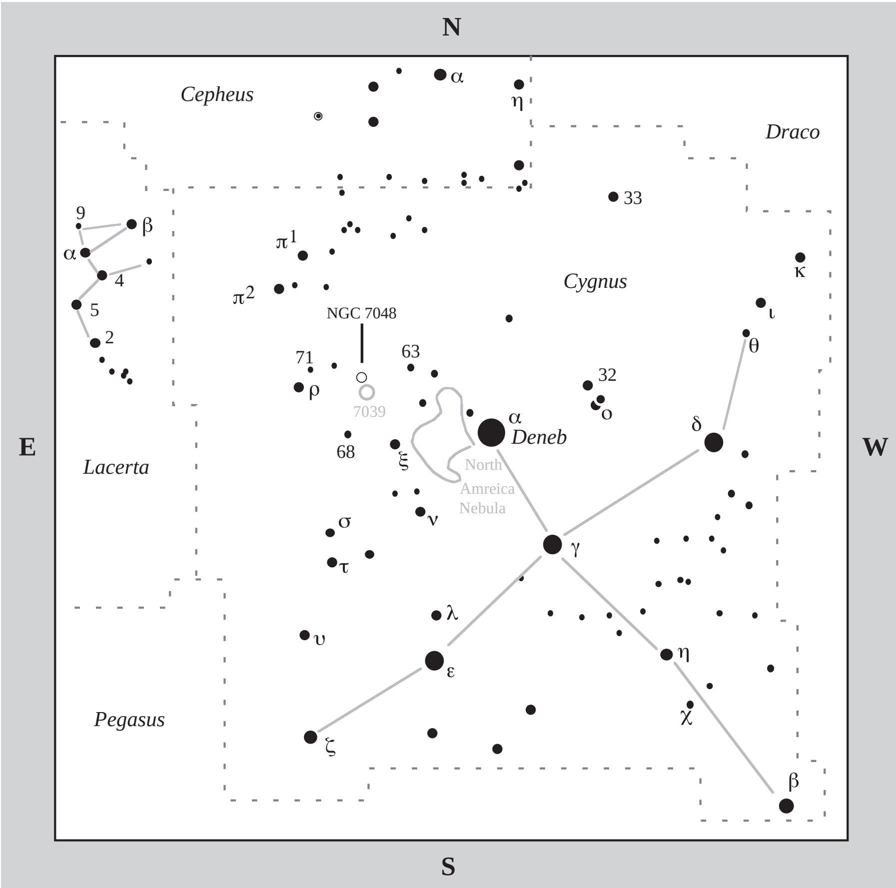
Finding NGC 7026 is easy. Simply use the Chart on page 424 to find 63 Cygni, just 5° northeast of Alpha (α) Cygni (Deneb). Then use the chart on page 427 to pinpoint it only 12′ north-northwest of that star. It also lies 6′ east-northeast of 7.5-magnitude Star *a*, and a mere 25″ west-southwest of a 10th-magnitude star. The brightest part of the nebula is tiny, only about 10″, but is still very apparent at 33× in the 5-inch; together the 10th-magnitude star and NGC 7026 at 33× look like a dim double star, which might have been the reason Burnham became attracted to it.



The nebula remains distinct but small at 60×. It's much the same at 94×, but now, when I use averted vision, the disk swells by a factor of two. Still, it's quite a distinct and pleasant sight. At 180×, the nebula's butterfly shape begins to become apparent oriented roughly north–south. With keen averted vision, the nebula's inner core looks mottled. But it wasn't until I employed powers of 330× and 495× that I was able to behold Holden's "sheaves of wheat." At the higher powers, the bright core is what shows best; the fainter butterfly wings almost vanish. You can see these features better at more moderate magnifications. So don't be afraid to push the limits of your scope with this object, which takes magnification well. By the way, deep-sky expert Tom Polakis likes to call NGC 7026 the "Cheeseburger Nebula."



Secret Deep 102
(NGC 7048)



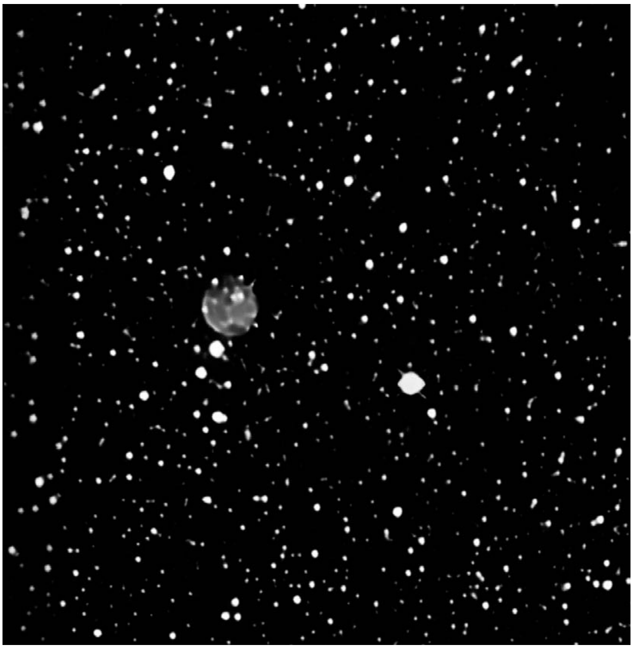
102

Peek-a-Boo Nebula
NGC 7048
Type: Planetary Nebula
Con: Cygnus

RA: 21^h 14.2^m
Dec: +46° 17′
Mag: 12.1 (Rating: 2)
Diam: 61″
Dist: ~4,600 l.y.
Disc: Édouard Jean-Marie Stephan, sometime between 1869 and 1884.

W. HERSCHEL: None.

NGC: Pretty faint, pretty large, diffused, irregularly round, very little brighter in the middle.



OF ALL THE OBJECTS IN THE SECRET Deep list, the most challenging for small telescope users may just be NGC 7048. Seeing it in an instrument comparable to my 5-inch refractor will be a testament to your skill as a deep-sky observer. It simply takes a dark sky, good star-hopping skills, and some patience. But the reward is worth it. I find the field absolutely mesmerizing and the nebula somewhat haunting.

This faint fuzzy escaped the gaze of the great Herschels – William, John, and Caroline – as well as a host of others. It was not detected until October 1878, when the renowned French astronomer Édouard Jean-Marie Stephan detected it through the 31.5-inch silvered glass reflector at Marseille Observatory, where he was director. The discovery was part of a program to seek out new nebulae, which began in vigor in 1869 and lasted until 1884.

To find the nebula, Stephan pointed the telescope to the meridian and made sweeps of the sky from north to south, taking advantage of their maximum placement in the sky, where the atmosphere would be the most transparent in the object's arc across the sky. This approach, Stephan noted, was key to his success, because most of the objects were very faint and had previously escaped attention. He also admitted that it was not fool-proof, realizing that he might have missed some nebula given the amount of time he took to read the setting circles when he encountered new objects, the state of the sky, or eye fatigue. Still, he made redundant sweeps of some regions.

In a summary of his research, which he published in an 1884 *Bulletin Astronomique* (vol. 1, pp. 286–290), he says it would be "no exaggeration to say that [he] observed more than 6,000 nebulae. We know that the nebulae are not uniformly distributed over the heavens and many of them are united in groups of more or less numerous and more or less close… Of the 420 nebulae published, 171 belong to 65 groups…" Of course, Stephan is perhaps most famous for his discovery in 1877 of Stephan's Quintet: a cluster of five visually challenging galaxies near NGC 7331 (Caldwell 30) in Pegasus, the first compact galaxy group ever discovered. In 1887 Stephan sent his final list of new nebulae and precise positions to John Louis Emile Dreyer, who was collecting data for the *New General Catalogue* (NGC), which was to be published the following year.

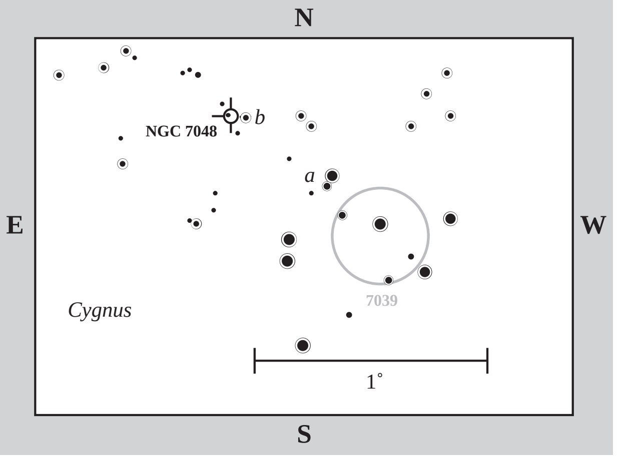
The true nature of NGC 7048, however, was not revealed until 1919, when Heber D. Curtis identified it as a planetary. During the summer of 1919, Curtis used the 36-inch Crossley reflector to study some nebulae in the NGC very close to the plane of the Milky Way. Based on their published descriptions, he suspected that some might be faint star clusters or even "spirals." As he writes in a letter to the Astronomical Society of the Pacific dated September 1919, "Most of these nebulae have proved to be of the diffuse type; one or two are faint star clusters. Three nebulae, from the evidence of their form, are undoubtedly planetary nebulae." NGC 7048 was one of the three (the others being NGC 1295 and NGC 6842).

Based on his observations, Curtis described NGC 7048 as a "rather faint oval, with slight traces of ring structure. It is about 60″ × 50″ in [~] p. a. 20°. The brightest portions are at the east end of the minor axis. There is a very faint central star." This identification of a central star is testament to the observer's skill, since it shines at a lowly 18th magnitude! Curtis also examined visually the spectrum of NGC 7048 through Lick's 36-inch refractor, finding it to be "gaseous," verifying the nebula's planetary classification.

In time, astronomers began to group the wide range of complex structures of planetaries into various subtypes: stellar, disk, ring, irregular, helical, bipolar, quadrupolar, and other anomalous types. NGC 7048 fell into a mixed category: a disk with ring-like structure. Today, however, more and more astronomers are converging on a simpler classification scheme: round, elliptical, and bipolar. The fact is, there's literally more to a planetary nebula than meets the eye. Virtually every planetary takes on different shapes when seen under different light.

Take, for instance, the infrared view of NGC 7048. In a 1996 *Astrophysical Journal* (vol. 462, pp. 777–785), Joel H. Kastner (then of the MIT Center for Space Research and now of the Rochester Institute of Technology's Center for Imaging Science) and his colleagues reveal that NGC 7048 displays a somewhat ragged but generally ring-like appearance with a diffuse halo extending roughly perpendicular to the ring's major axis (p. a. ~100°). In fact, their infrared imaging survey, which included about 60 planetary nebulae, reinforced the burgeoning argument that many ring-like planetary nebulae are bipolar in structure. "Thus, it seems reasonable to conclude," the researchers say, "that these two classes of objects in fact represent a single class."

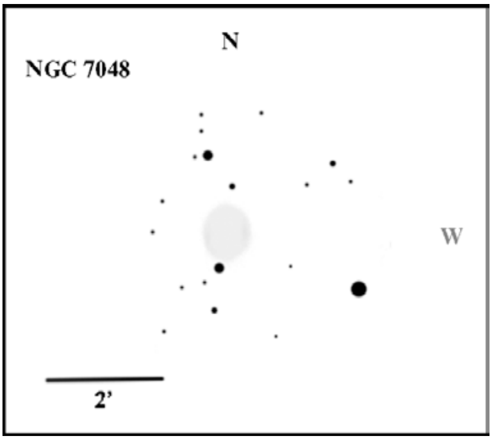
Indeed, in his delightful book, *Cosmic Butterflies: The Colorful Mysteries of Planetary Nebulae* (Cambridge University



Press, 2001), Sun Kwok writes, "Maybe the different morphologies that we see in planetary nebulae are an illusion. They all may have the same intrinsic structure after all. Astronomers have long been puzzled by the variety of shapes seen in planetary nebulae. It is tempting to believe that such diverse morphologies are just different manifestations of a single, unified, basic three-dimensional structure ... projected at different orientations on the sky."

Look down the axis of symmetry, and a butterfly nebula will appear as a ring surrounded by diffuse haloes (this is exactly what we see when we look at tM 57, the famous Ring Nebula in Lyra). Turn it 90° to our line of sight and we'll see a stunning bipolar nebula (two opposing lobes of gas emerging symmetrically from a thin waist of dust (an edgewise torus) like butterfly wings. Turn it 45°, and we'll see one lobe appearing larger and more defined than the other, which is being partially eclipsed by the central torus. But Kastner cautions that while it's true that the "contemporary explanation of the wide variety of shapes is that planetary nebulae indeed have a fairly broad range of intrinsic structures – from spherical (rare) to elliptical (common) to pinch-waist bipolar (also common but not as common as ellipticals – and are viewed at a range of viewing angles. The thinking these days is also that the shaping is ultimately due to the effects of binary companions to the mass-losing central stars that generate planetary nebulae, with the range of intrinsic shapes likely reflecting the range of planetary nebulae progenitor binary star mass ratios and separations." An excellent paper by Orsolla De Marco explains this hypothesis in detail (De Marco, *PASP*, vol. 121, p. 316).

To find this challenging object, use the chart on page 429 to locate Alpha (α) Cygni (Deneb), then 3rd-magnitude Xi (ξ) Cygni near the North America Nebula. Now use your scope or binoculars to locate the neglected 7.5-magnitude open cluster NGC 7039, about 2° to the northeast. The 15′-wide cluster resides in a 40′-wide butterfly asterism of about a half-dozen 7th- to 8th-magnitude suns oriented east–west. Using the chart on this page start your careful search for NGC 7048, which lies only about 45′ northeast of the 7th-magnitude star at the heart of NGC 7039. Start by moving from that star 18′ northeast to a pair of roughly 8th-magnitude stars (*a*). Now move about 30′ further to the northeast to 9th-magnitude Star *b*. NGC 7048 is immediately east of that star. Note that a 10.5-magnitude star lies only 3.5′ to the south-southwest, and a roughly 11th-magnitude star is immediately to the

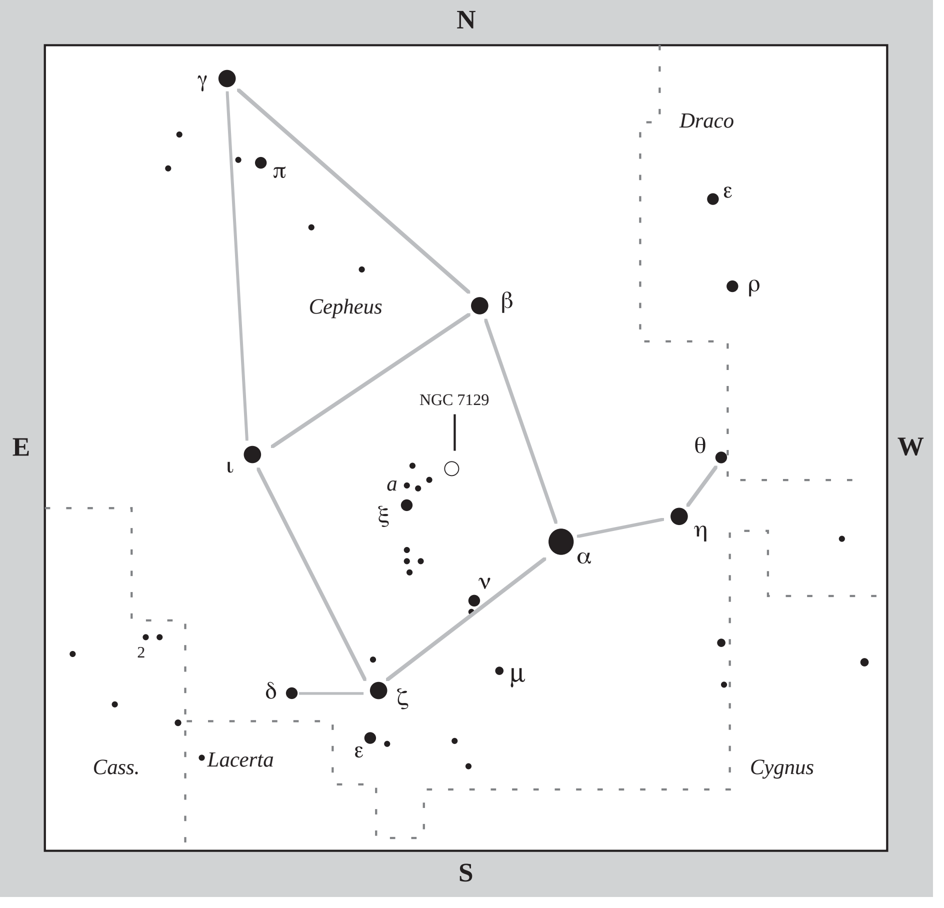


north-northeast. Another sun further to the northeast helps to create a distinct Y-shaped asterism; be careful not to mistake this grouping for the nebula at low power.

I could not see NGC 7048 at 33× in the 5-inch, even when I knew exactly where to look, after I had spied it at higher magnifications. It's that sensitive even under a dark sky, though, admittedly, my view might have been compromised by some thin high cloud. So give it a try, nevertheless. At 60×, the nebula flitted in and out of view, until I could pinpoint its exact location with averted vision, then I captured it! And once I saw it surface among the faint stars in this rich Milky Way field, I thought of it as a ghost in the machinery of the heavens, something nagging to be noticed among the wheeling firmament until it received recognition.

At 94×, the nebula remains an amorphous circular glow of mostly uniform light with averted vision, though, at times, I could sense a slight enhancement around its limb. But this was just so fleeting. The nebula vanishes instantly with direct vision and I found its nature very coquettish, slipping in and out of view with direct and indirect vision, so that it was like playing peek-a-boo with a child. The maximum power I used to get a comfortable view was 180×. Higher powers in the 5-inch just dimmed the apparent contrast. At 180×, the nebula stood out more boldly, appearing ever-so-slightly elongated north–south, with a thin ring-like enhancement more pronounced to the east and west. Other observers have reported success at seeing it (and similar details) with similar magnifications and an OIII filter. So give that a try as well, and good luck!

Secret Deep 103
(NGC 7129)



103

Cosmic Rosebud
NGC 7129
Type: Reflection Nebula and Cluster
Con: Cepheus

RA: 21^h 42.8^m
Dec: $+66°$ $06'$
Mag: –
SB: – (Rating: 3)
Dim: $7' \times 7'$
Dist: ~3,300 l.y.
Disc: William Herschel, 1794

W. HERSCHEL: [Observed October 18, 1794] Three stars about 9th magnitude involved in nebulosity. The whole takes up a space of about 1½′ in diameter. Other stars of the same [brightness] are free from nebulosity. (H IV-75)

NGC: Remarkable, considerably faint, pretty large, gradually brighter in the middle to a triple star.

NGC 7129 IS A PRETTY LITTLE reflection nebula 4¼° northeast of 2.5-magnitude Alpha (α) Cephei (Alderamin), or 2¾° northwest of 4.5-magnitude Xi (ξ) Cephei (Kurhah), the heart of the celestial King. It's also an astrophysical wonder and a participant in an historical mystery.

William Herschel discovered the nebula in 1794, cataloging it as a planetary (because of its round form) involved with three roughly 9th-magnitude stars. William's son John concurred, describing NGC 7129 as a "very coarse triple star involved in a nebulous atmosphere; a curious object. The nebula is extremely faint and graduates away."

That three bright stars huddled at the nebula's core would not have been surprising to William, since he believed that all diffuse nebulae would collect into smaller concentrated clouds, which then condensed into scattered suns; very prescient on his part.

In 1884, French astronomer Camille Guillaume Bigourdan began using a micrometer attached to the 12-inch west equatorial refractor at Paris Observatory to measure nearly every nebula in the NGC and IC catalogues visible from that location. His noble and principal intent was to to discover whether nebulae had measurable proper motions. After devoting more than a quarter century to this task, the untiring observer had accumulated some 20,000 measurements of more than 6,600 nebulae and clusters. In the course of his work, Bigourdan also discovered 100 nebulae, the list of which he communicated to Dreyer in 1887. One of these objects was to be labeled NGC 7133. Bigourdan positioned it about 3′ northeast of NGC 7129 and described it as a "Pretty extended area, perhaps 2 arcminutes across, in which I suspect some extremely faint nebulosity, at the extreme limit of visibility."

THE MYSTERY

While researching objects for this book in August 2009, I found these two nebulae overlapping in Wil Tirion's *Sky Atlas 2000.0*. As would be expected, NGC 7133 was to the northeast of NGC 7129. Thinking that these nebulae might make an interesting pair to include in this book (if I could see them), I went out one night with my 5-inch refractor and gave them a try. As I swept the sky to their position, I first encountered, to my surprise, an interesting 9th-magnitude open star cluster (NGC 7142) only about 30′ southwest of the two nebulae; this cluster is not plotted in the Tirion atlas but I did find it in the *Millennium Star Atlas*.

As I continued on to NGC 7129 and 7133, I encountered another surprise: Although I did see a twin glow in the area of the nebulae, the two glows I saw were oriented northwest–southeast, not northeast–southwest as they appear in the Tirion. Furthermore, when I reviewed the area in the *Millennium Star Atlas*, I discovered that NGC 7129 was plotted only as a cluster (not a nebula) about 8′ west-southwest of where I saw the twin glows. What's more, the *Millennium Star Atlas* plotted NGC 7133 as a nebula 20′ east-northeast of the "cluster" NGC 7129!

That night I gave up the ghost and let matters lie until the next morning. After a bit of research, I discovered I wasn't the only one who's been confused. In an insightful article in a 2000 *Journal of the Royal Astronomical Society of Canada* (vol. 94, p. 194), Mark Bratton unveils some "Mysteries in Cepheus," in which he describes an experience similar to mine in the NGC 7142, 7129, 7133 field.

The problem is that Bigourdan was a meticulous observer. As Hal Corwin explains in his NGC/IC Project (www.ngcicproject.org/), "The really valuable part of the observations are the details of the micrometric observations, presented not only in their raw form of position angles and distances from the comparison stars, but also as RA and Dec offsets. This means that the exact location which Bigourdan measured can be pinpointed on the sky today. … Assuming that the proper motions of the comparison stars are small, modern positions for them (from the GSC, or if they are brighter, from Hipparcos/Tycho or any other modern catalogue) will allow positions accurate to about two arcseconds for the nebulae to be found from Bigourdan's observations, at least for the brighter nebulae which he could see well."

And therein lies the rub. As I shared earlier, NGC 7133 was a nebulosity at the extreme limit of Bigourdin's vision. Certainly this fact negates any suspicion that he mistook NGC 7129 for a new nebula. Perhaps as Sven Cederblad noted in his 1946 catalogue of nebulae, one could argue that NGC 7133 is simply a part of NGC 7129, perhaps some faint stretch of nebulosity. But Corwin isn't so sure: "There is nothing near his single micrometrically measured position but a few faint stars. My guess is that this is another of what he would call his 'fausses images.'"

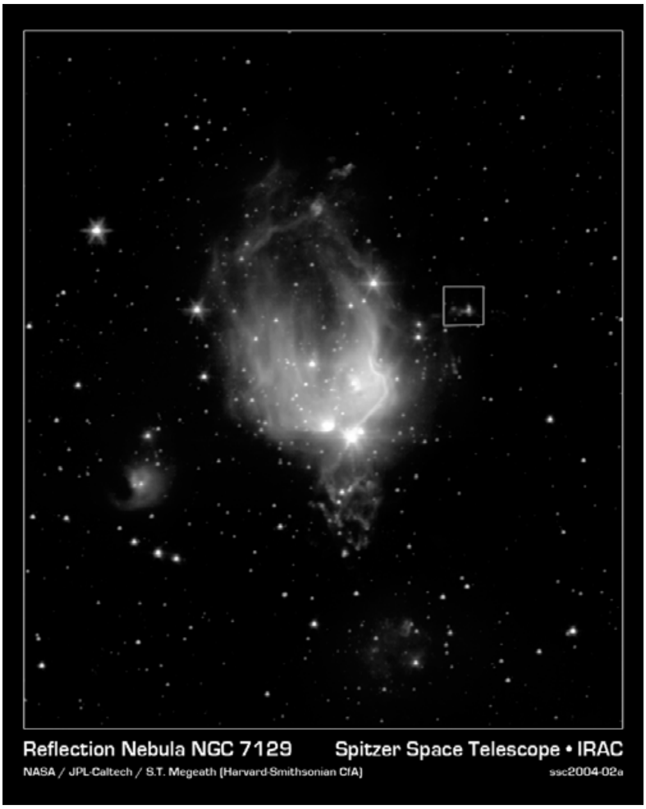
If we accept Corwin's verdict, the mystery is solved, NGC 7133 does not exist. NGC 7129 is a nebula and cluster whose position is listed in the table above (and plotted correctly in the chart on page 438), and NGC 7142 is a pretty (though dim) cluster of stars nearby.

Note how close NGC 7129 is to the young open cluster NGC 7160 (Secret Deep 104). NGC 7160 belongs to the Cepheus OB2 Association, one of the nearest regions of high-mass star formation. But the Milky Way in Cepheus contains several star-forming regions. In fact, the molecular gas here consists of different clouds partly projected against each other. Indeed, NGC 7129 belongs to a complex molecular cloud some 3,300 light-years distant, placing it farther away than the Cepheus OB2 association.

NGC 7129's molecular cloud skirts the upper regions of the Cepheus Bubble – a giant dust ring with a diameter of about 10° (nearly 400 light-years across) – of which NGC 7160 lies at the heart. In a 1998 *Astrophysical Journal* (vol. 507, pp. 241–253), Nimesh A. Patel (Smithsonian Astrophysical Observatory) and his colleagues, however, bring up the possibility that NGC 7129 may not belong to it.

NGC 7129's nebula, though, is itself a little bubble of hot gas created by the three B stars surrounded by colder, dense clouds (the molecular cloud). NGC 7129 lies within that cavity. In color images, the nebula shines predominantly blue because its gases either scatter or reflect light from the hot young stars embedded in it. And the cluster is indeed very young, with the optical stars being only about 3 million years young. Our Sun, by comparison, is 5 billion years old. The stars of NGC 7129, then, are only slightly older than those inside the Great Orion Nebula (~1 million years). The cluster's three brightest members (LkHα 234, BD +65° 1638, and BD +65° 1637) shine around 10th magnitude and are all B-type stars that help illuminate the cloud. Wind streaming from LkHα 234 is the most likely cause of the cavity.

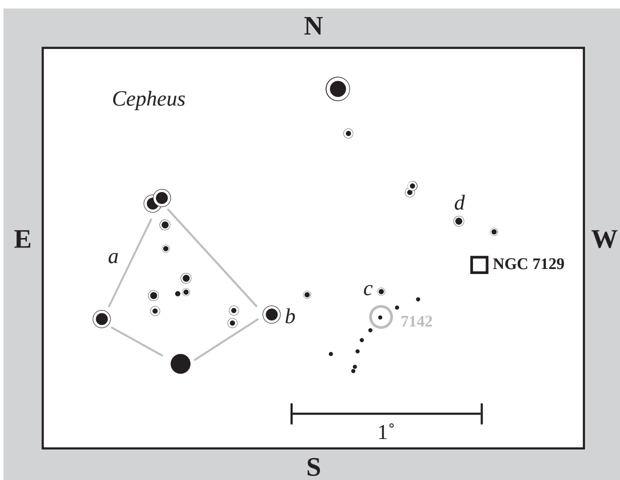
The nebula also contains several embedded infrared sources. In fact, images taken by NASA's Spitzer Space Telescope (formerly known as the Space Infrared Telescope Facility) revealed a "rosebud" of hot dust particles and gases cradling stars less than 1 million years old (see the image below). In a 2004 press release of the image, Thomas Megeath (then of the Harvard Smithsonian Center for Astrophysics, now at the University of Toledo, Ohio) explains how that formation is the result of adolescent stars blowing away blankets of hot dust, while the tapered "stem" of gas holds newborn stars whose jets torched surrounding gases. The image also shows for the first time young, infrared, protostars (stars in the process of forming) and visible light Herbig–Haro objects (shocks generated by jets from the protostars) outside of the primary nebula. "We can now see a few stars beyond the nebula that

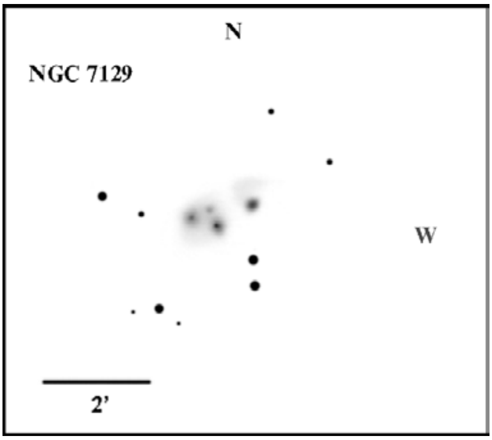


were previously hidden in the dark cloud," Megeath says. Megeath's colleague Rob Gutermuth (University of Rochester, New York) found that roughly half of the stars observed harbor disks.

Another surprise came in 2009 when spectra of one of these embryonic regions (the boxed area in the Spitzer Space Telescope image above) taken with the Herschel satellite revealed various strong fingerprints of water. Here, a forming star slightly more luminous than our Sun is heating up its surroundings. As a result, water molecules frozen on the icy dust grains sublimate into a gas, like ice on a comet heated by the Sun. Only this embryonic steam cloud contains enough water to fill at least a million oceans!

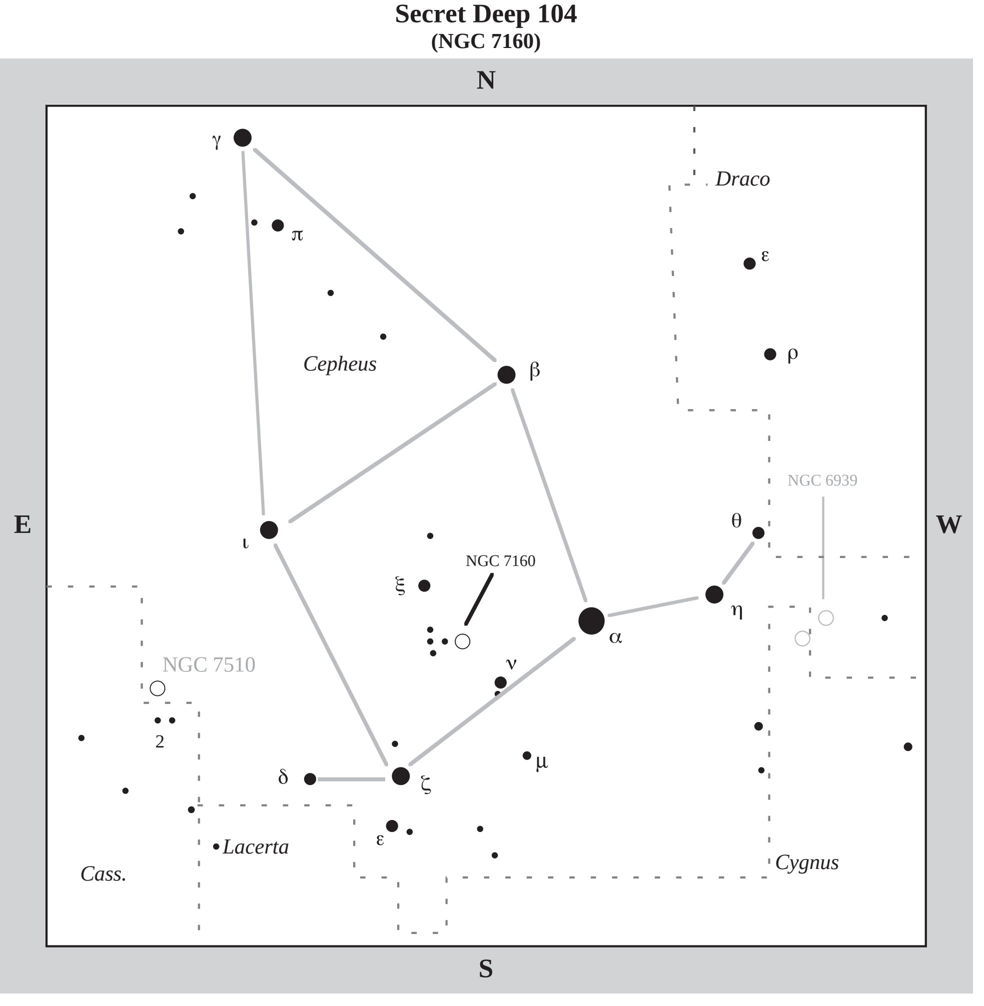
To find NGC 7129, use the chart on page 434 to locate Xi Cephei. Now use your naked-eyes or binoculars to locate the Trapezoid *a* comprising four roughly 6th-magnitude stars. Center the Trapezoid in your telescope at low power then switch to the chart on this page. Once you confirm the Trapezoid, center its westernmost star (*b*). Now move about 35′ west-northwest to 8.5-magnitude Star *c*. Open cluster NGC 7142 is immediately south of that star. NGC 7129 is about 30′ west-northwest of that star and about 18′ southwest of 8th-magnitude Star *d* – so you can easily fit the cluster and the nebula in the same field of a low-power eyepiece.





I say the nebula's field because, at least in the 5-inch at 33×, the nebula didn't "jump out" at me. Instead what I saw were two tight pairs of double stars forming an upside-down (and mirror-reversed) greek letter Lambda (λ), as seen with north up. With averted vision the northerly pair (oriented northwest–southeast) appeared somewhat fuzzy, though the brightness of the four bright stars tends to overwhelm the view. So look for the four stars first, then crank up the power. In the 5-inch, the brightest parts of this 7′-wide nebula extend to only about half that length.

I found the view comfortable at 94× when the most intense parts of the nebula – two bright knots about 1′ northeast of the northeastern-most star in the Lambda – stand out most dramatically. Tempting as it might sound (that these knots are northeast of the nebula surrounding the bright aforementioned stars), they cannot be Bigourdan's NGC 7133; again, because they are so bright and what he saw was exceedingly faint. The easternmost knot is also the brightest and has structure, namely a bright starlike core surrounded by a nebulous corona. The western knot is just an amorphous, irregularly round glow. The northwestern-most star is also flanked to the northwest by a dim wash of light. Try as I might, I could see no other hints of nebulosity, though I'm limited by my telescope's small aperture. The nebula will be a delight to all astrophotographers and I urge owners of large telescopes to visually explore the fainter expanse of this subtle celestial landscape.


Secret Deep 104
(NGC 7160)
N
E
W
S
γ
π
Cepheus
β
Draco
ε
ρ
NGC 6939
θ
ι
NGC 7160
ξ
η
α
ν
NGC 7510
2
μ
δ
ζ
ε
Lacerta
Cass.
Cygnus

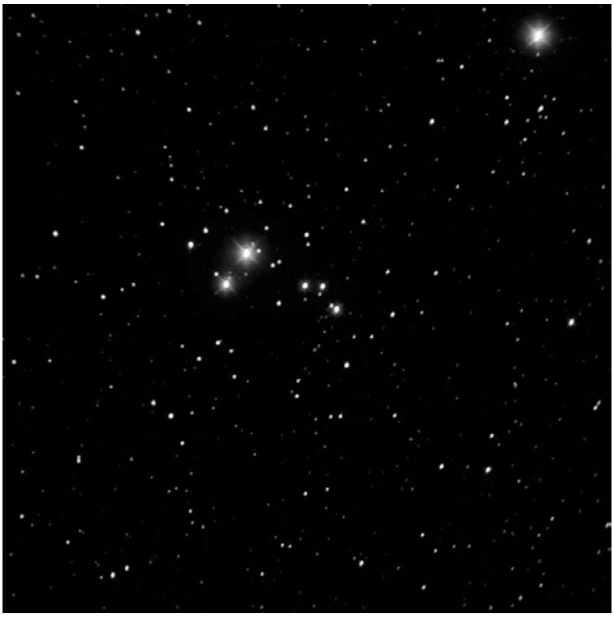
104

Swimming Alligator, Bruce Lee Cluster
NGC 7160
Type: Open Cluster
Con: Cepheus

RA: 21^h 53.7^m
Dec: +62° 36′
Mag: 6.1
SB: 9.6 (Rating: 4)
Dim: 5′
Dist: ~2,500 l.y.
Disc: William Herschel, 1787

W. HERSCHEL: [Observed November 9, 1787] A cluster of coarsely scattered [bright] and [faint] stars, 7′ in diameter, like a forming one. (H VIII-67)

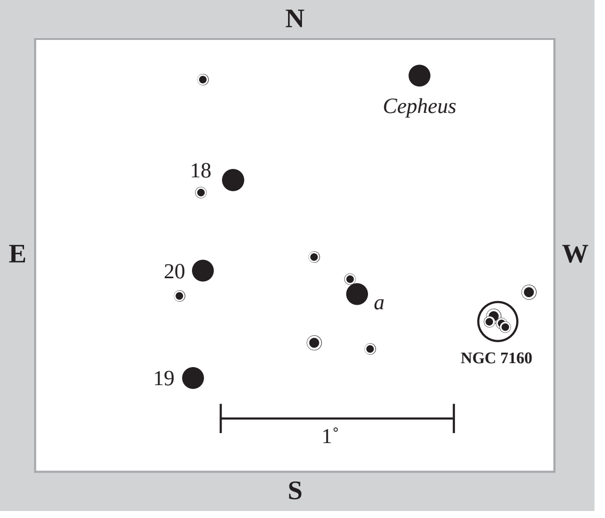
NGC: Cluster, pretty, very little compressed.



NGC 7160 BELONGS TO THE CEPHEUS OB2 association, one of the nearest regions of high mass star formation – an extended HII region situated near the galactic plane rich in bright-rimmed clouds distributed over an area of 3°. The Cepheus OB2 association has two main nuclei: the 3-million-year-young Trumpler 37 (Hidden Treasure 105), which contains 480 stars populating 46 light-years of space), and NGC 7160, a much smaller aggregation of about 60 hot suns spread across 3 light-years of space. The region also contains about 40 O-type stars, some 100 stars with masses greater than 9 Suns, and more than 200 faint type F-G stars with masses below 3 Suns, all of which are in their pre-main sequence stage.

While Trumpler 37 (one of the youngest clusters in our Galaxy, being around 6 million years young) is the most prominent part of the association, NGC 7160 is a delightful sight, a little less than 4° east of Alpha (α) Cephei, 4° north-northeast of Mu (μ) Cephei (Herschel's Garnet Star), and about 2¼° south-southwest of 4.5-magnitude Xi (ξ) Cep. It is visible as a tiny knot of starlight in binoculars and is very distinctive in telescopes of all sizes.

NGC 7160 is itself a very young cluster, being between 10 and 30 million years old. It's comparable in age to NGC 2244 (Caldwell 50), the cluster at the core of the Rosette Nebula in Monoceros; NGC 2264 (Hidden Treasure 38), the Christmas Tree Cluster in Monoceros; and NGC 6530, a cluster inside M8, the Lagoon Nebula. Our target lies near the center of the Cepheus Bubble, an expanding ring of dust and gas with a diameter of about 10° (nearly 400 light-years across) discovered in 1987 on Infrared Astronomical Satellite



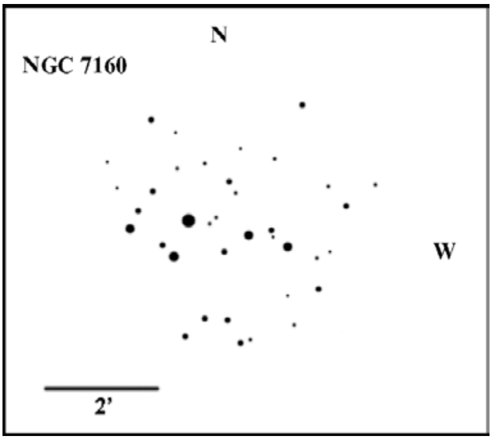
(IRAS) maps. At a distance of about 2,500 light-years, NGC 7160 lies behind the Great Cygnus Rift and suffers nearly half a magnitude of extinction by intervening dust.

In a 2003 *Astronomy & Astrophysics* (vol. 405, pp. 1087–1093), K. Yakut (University of Ege, Izmir, Turkey) and colleagues note that their studies of the physical parameters of V497 Cephei (BD+61° 2213), a very close ellipsoidal or eclipsing binary and confirmed member of NGC 7160, allowed them to determine the distance to the cluster at about 2,500 light-years, which agrees well with other available estimates. The binary itself comprises two 9th-magnitude suns (8.9; 9.1). Both are little-evolved, pre-main sequence stars with ages between 11 and 28 million years; the primary appears slightly more evolved than the secondary. The researchers note that this agrees well with the evolutionary age estimates of the cluster. The star varies with a period of $1^{d}.2028251$.

To find NGC 7160 use the chart on page 440 to locate Alpha (α) Cephei, then Xi (ξ) Cephei to the east-northeast. Now use your unaided eyes or binoculars to look for a roughly 45′-wide, sideways pyramid of starlight 2° to the south. Center that pyramid in your telescope at low power and confirm the field with the chart on this page. The pyramid's eastern base comprises three 5.5-magnitude suns: 18, 20, and 19 Cephei (from north to south) respectively. Now center the Pyramid's western apex, Star *a*, and move 35′ west and slightly south to NGC 7160.

My first impression of the cluster at 33× through the 5-inch is that it reminds me of a larger version of the Y-shaped asterism M73 in Aquarius: Two bright 7th-magnitude suns punctuate the Y on the eastern end, and a tight arc of three 9th-magnitude stars forms the long axis on the western end. A dusting of dimmer suns surrounds these stars, the most notable of which is a star to the northeast that forms a triangle with the 7th-magnitude suns on the eastern end. Seen together, the triangle looks like the head of an alligator in the water, while the arc of stars to the west looks like scutes on the beast's inflated back. (Anyone who's been to Florida's Everglades will appreciate the view.)

At 60×, the gator's eyes (the two 7th-magnitude suns) have a warm hue to them, just as a gator's eyes appear at night when a flashlight is reflected into them. The best view of this tiny sprinkle of some 60 gems spread across 5′ of sky is at 94×, when the brightest two dozen or so stars form a series of arcs and loops around the



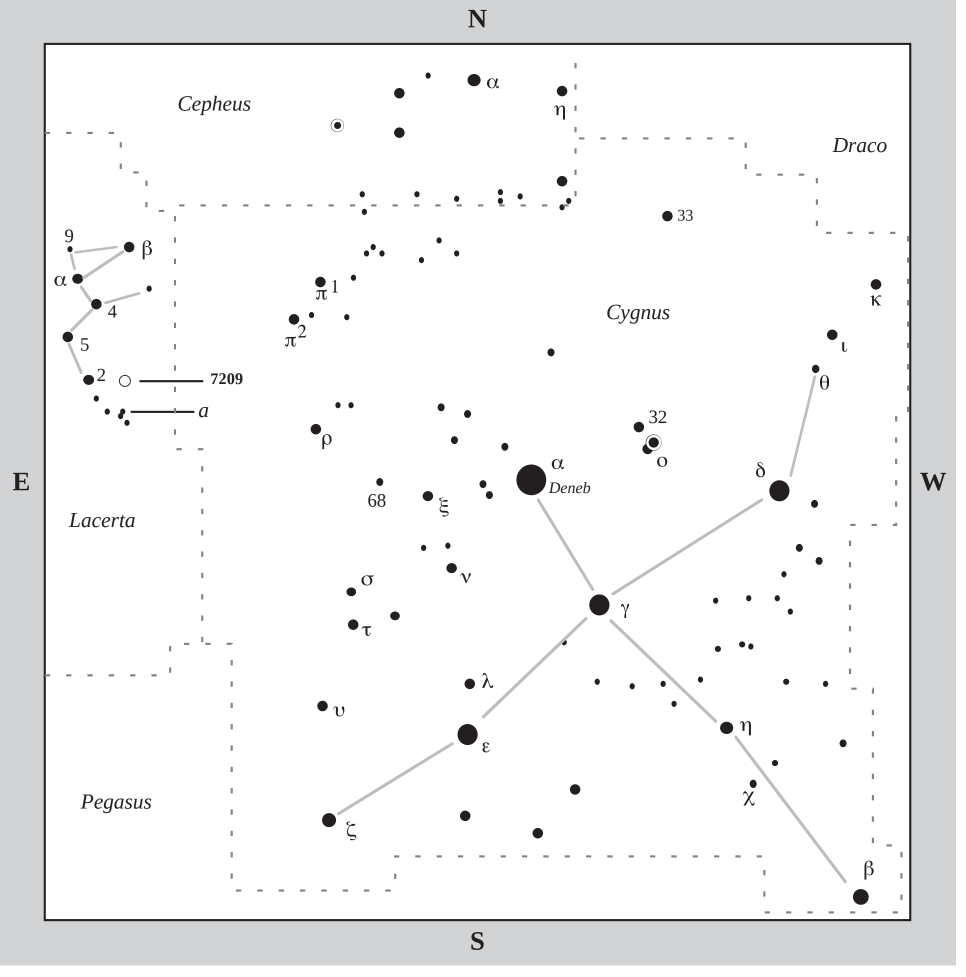
main body of the Y. The farther away you look from the Y-shaped core, the more stars that can be added to coarse clumping of young suns, though many of these may be field stars.

Some amateurs have said that the cluster at low power reminds them a lot of NGC 457 (Caldwell 13), the famous E. T. Cluster in Cassiopeia. And I have to agree. But at moderate magnifications, the cluster has also been likened to the late martial artist Bruce Lee "doing Jeet Kune Do." See what you think.

When you're done enjoying NGC 7160, move about 1¼° north-northeast to VV Cephei, a 5th-magnitude eclipsing binary star that James Kaler (University of Illinois) calls one of the most magnificent and largest stars in the sky, adding that if it weren't for intervening dust it would have shined at third magnitude and undoubtedly would have been part of the main naked-eye constellation. It's actually one of two blood-red suns in the Cepheus Milky Way – the other being 4th-magnitude Mu Cephei, Herschel's Garnet Star. Through a telescope I find VV just as alluring as Mu, and, because of its more diminutive light output, much redder.

VV Cephei is an enormous and vastly distended M-class supergiant with a diameter that might exceed the Sun's by 3,300 times. VV shares its orbit with a dim, O-type dwarf, which not only tidally distorts its larger companion (causing it to appear teardrop-shaped), but siphons off some of its outer envelope, which then forms a torus around the smaller and much hotter, companion. The two orbit one another with a period of 20.4 years. Unlike Mu Cephei, however, VV Cephei, like NGC 6170, may be part of the Cepheus OB2 association, though the verdict is still out on that claim. One day, Kaler tells us, VV Cephei will explode as a supernova, perhaps shoving off its tiny companion into space, where it will live out its days as an inconspicuous drifter with a memorable past.

Secret Deep 105
(NGC 7209)



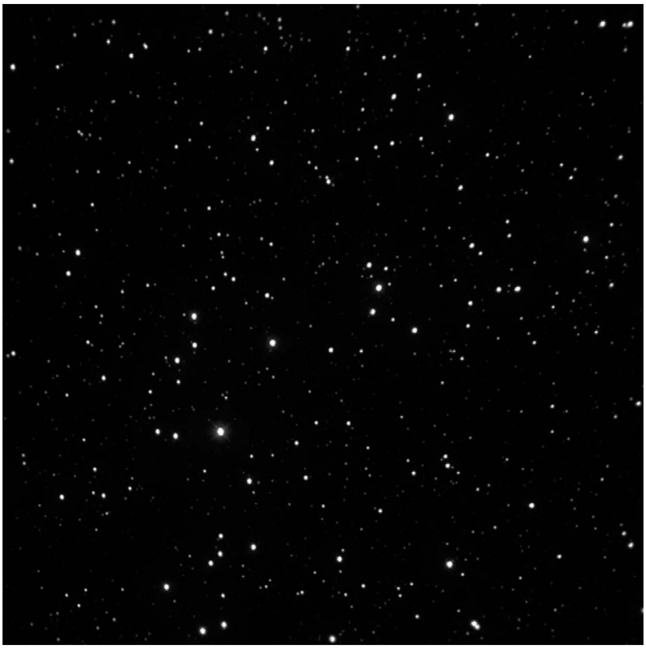
105

Star Lizard
NGC 7209
Type: Open Cluster
Con: Lacerta

RA: $22^h\ 05.8^m$
Dec: +46° 29′
Mag: 7.7
SB: 13.6 (Rating: 4)
Diam: 15′
Dist: ~3,350 l.y.
Disc: William Herschel, 1787

W. HERSCHEL: [Observed October 19, 1787] A little cluster of pretty compressed, considerably [bright] stars, above 15′ in diameter, considerably rich. (H VII-53)

NGC: Cluster, large, considerably rich, pretty compressed, stars from 9th to 12th magnitude.



NGC 7209 IS A LARGE AND LOOSE open cluster about 5½° south-southwest of 4th-magnitude Alpha (α) Lacertae, the brightest star in Lacerta, the Lizard. Johann Hevelius created the constellation in 1687 using unclaimed stars between the borders of Cygnus and Andromeda. The constellation appears on his *Firmentun Sobiescianum*, a star atlas published in 1690. Its stars form a long and narrow body that slinks northward from Pegasus toward Cepheus.

Hevelius actually labeled the fanciful creature *Stellio*, referring to the common star lizard (newt) found along the Mediterranean coast. As the seventh-century scientist Isidore of Seville writes in his book *Etymologies*, "The newt (stellio) takes its name from its color, because its back is painted with shining spots like stars. It is the enemy of scorpions and its appearance causes them fear and numbness." Perhaps Hevelius also had in mind Stellio, the crafty rogue in ancient Greek and Roman mythology, who Ceres (Demeter) changed into a lizard for mocking her.

Today, Hevelius's playful name has been banished to the hinterlands of celestial lore; the constellation is now known simply by its generic term: the Lizard. Interestingly, early Chinese stargazers used the same stars that Hevelius had selected, along with those in the eastern portion of Cygnus, to create the constellation *Tengshe*, the Flying Serpent.

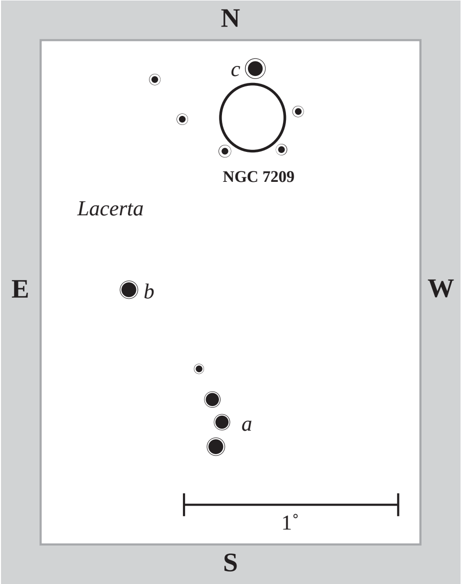
With imagination, and a pair of binoculars, NGC 7209 could be imagined as one of the Lizard's "spots." Actually, this "spot' comprises about 150 stars to magnitude 15 spread across 15′ of sky. At a distance of about 3,350 light-years, the cluster's true linear extent is about 15 light-years, or 1 light-year for every arcminute. In a 1994 *Mexican Journal of Astronomy & Astrophysics* (vol. 28, pp. 139–152), Jose Peña and Rosario Peniche (Institute of Astronomy, UNAM, Mexico) proposed that, based on photometry of 54 stars in the cluster direction, NGC 7209 might be a projection of two clusters at distances of 2,500 and 3,800 light-years, with the reddening of the more distant cluster being greater.

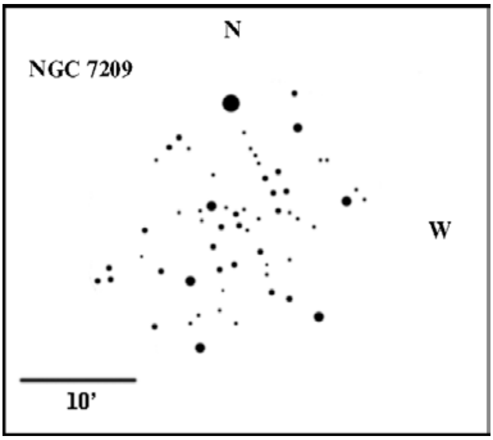
But V. Vansevicius (Institute of Physics, Vilnius, Lithuania) and colleagues disagree. In a 1997 *Monthly Notices of the Royal Astronomical Society* (vol. 285, pp. 871–878), they found that NGC 7209, a rather poorly populated cluster of intermediate age (0.45 billion years), is a single cluster with a solar metallicity that contains at least six photometrically suspected binaries, though the true number might be higher. The reddening across the cluster shows a slight trend along the north–south direction, with a mean extinction of about 0.5 magnitude.

One of the cluster's most interesting stars is SS Lacertae, a 10th-magnitude eclipsing binary of 14.4 days. But sometime in the middle of the twentieth century, the eclipses stopped completely. The end of the eclipsing phase has been set around 1940 by L. V. Mossakovskyaya (1993) and around 1960 by Lehmann (1991). It was initially suggested that the eclipses ceased after the two members, which were dancing around a common center of gravity, collided with another cluster member and merged. Another suggestion was that a third star in the system disrupted the perceived orbital inclination. As Robert P. Stefanik (Harvard–Smithsonian Center for Astrophysics) explains in a 2010 private communication, "the system remains but the star's gravitational perturbations change the orientation of the inner binary orbit relative to the line of sight."

In a 2000 *Astronomical Journal* (vol. 119, pp. 1914–1929), Guillermo Torres and Stefanik present results of their spectroscopic observations of SS Lacertae, which show clearly a distant third star in the system; it lies in a slightly eccentric orbit with a period of about 679 days. They show how the plane of the binary's orbit is changing relative to the line of sight in response to perturbations from this third object. Indeed, Torres adds that a recent analysis of all photometric material available for the system, including a remeasurement of original Harvard plates, has confirmed earlier reports of changes in the depth of the eclipses as a function of time, which are due to the third star. Torres notes that the nodal cycle is found to be about 600 years, within which two eclipse "seasons" occur, each lasting about 100 years. The noneclipsing status of the system is expected to continue until the beginning of the twenty-third century. (See also Torres, *Astronomical Journal* (vol. 121, p. 2227, 2001)).

To find this wonderful cluster, use the chart on page 444 to find 4th-magnitude Alpha (α) Lacertae, then 5th-magnitude 2 Lacertae about 4° to the south-southwest. Now use your binoculars to look for Star *a* – which is really three beautiful stars close together forming a small arc – less than 3° further to the southwest. Center this triple in your telescope at low power. Now, using the chart on page 447 as a guide, sweep





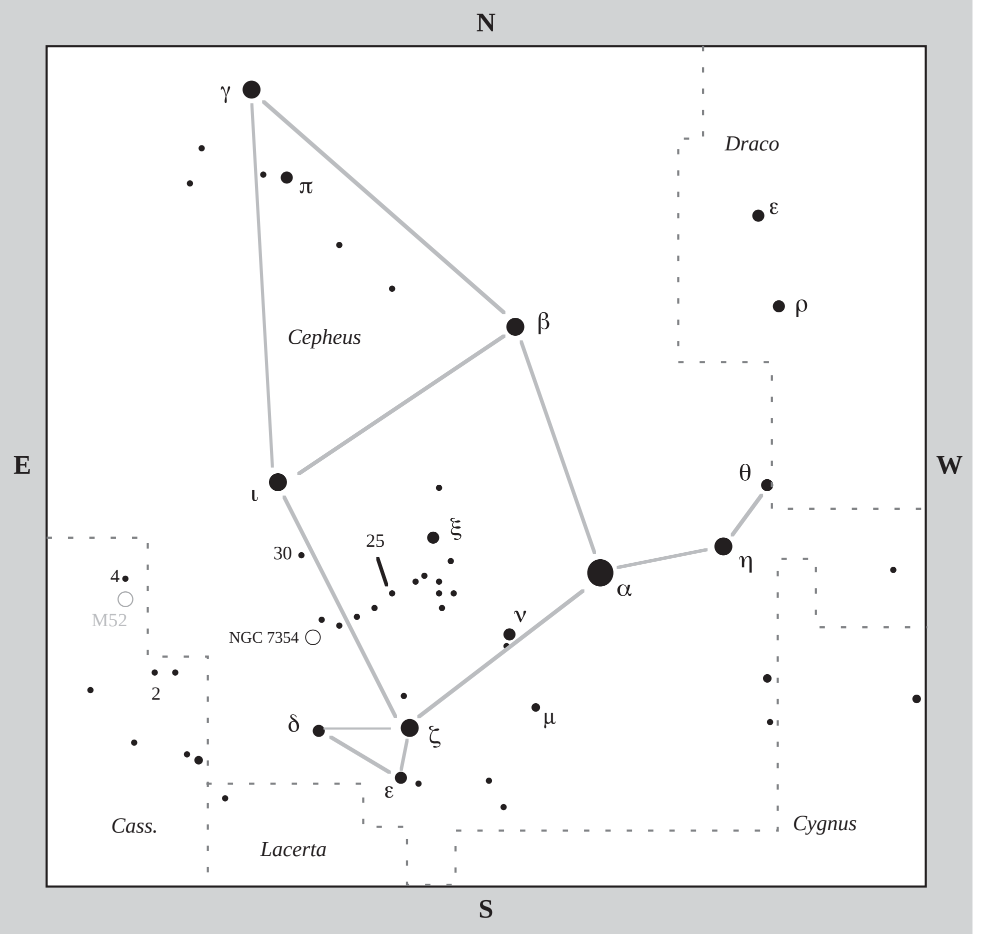
about 45′ northeast to 6th-magnitude Star *b*. NGC 7209 is a little less than 1° northwest of Star *b*, just south of 7th-magnitude Star *c*. The cluster is visible in binoculars under a dark sky, and it is a very attractive sight in telescopes of all sizes.

In the 5-inch at 33×, NGC 7209 is a very beautiful and conspicuous cluster with no central concentration. Rather it's a beautiful hook-shaped cluster with a few dozen resolved suns spread across 15′ of sky. The field is extremely rich in starlight but not all the stars are cluster members, so the cluster actually looks almost twice as large as it really is. Still, there are nearly 100 cluster members here 7.7-magnitude and fainter. The entire scene looks like a large and isolated patch of Milky Way.

The cluster is truly best at low power, so take your time with it. I see many skeletal and spidery forms (maybe this would be a good cluster to show family and friends on Halloween) with lots of dim stars forming a milky backdrop. At 60× the cluster loses its luster, but tight groupings of suns are better seen, including those in a C-shaped "core."

At 94× the cluster reveals a lazy, zigzagging line of stars running north to south through the cluster's center, which with attendant appendages of stars looks like a star lizard on the run. Use your imagination, connect the dots, and have fun.

Secret Deep 106
(NGC 7354)



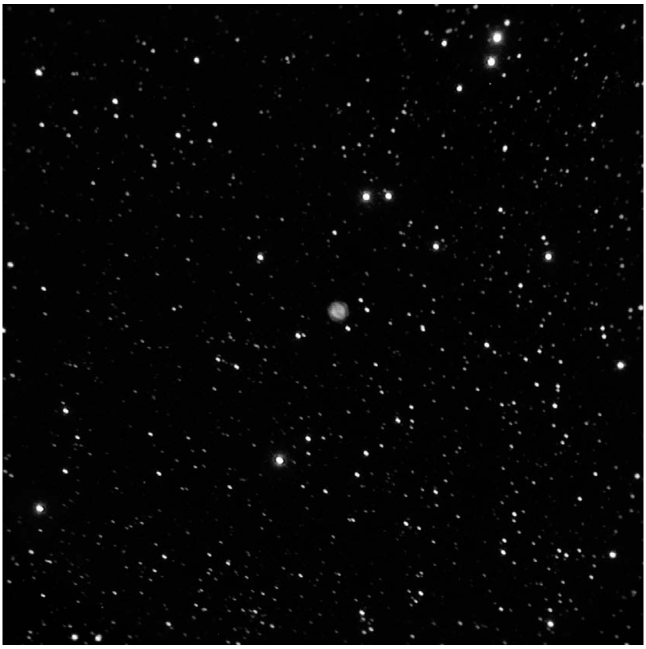
106

NGC 7354
Type: Planetary Nebula
Con: Cepheus

RA: 22^h 40.3^m
Dec: +61° 17′
Mag: 12.2 (Rating: 3)
Diam: 22″ × 18″
Dist: ~4,200 l.y.
Disc: William Herschel, 1787

W. HERSCHEL: [Observed November 3, 1787] Pretty bright, small, irregularly round, Er, almost equally bright. (H II-705)

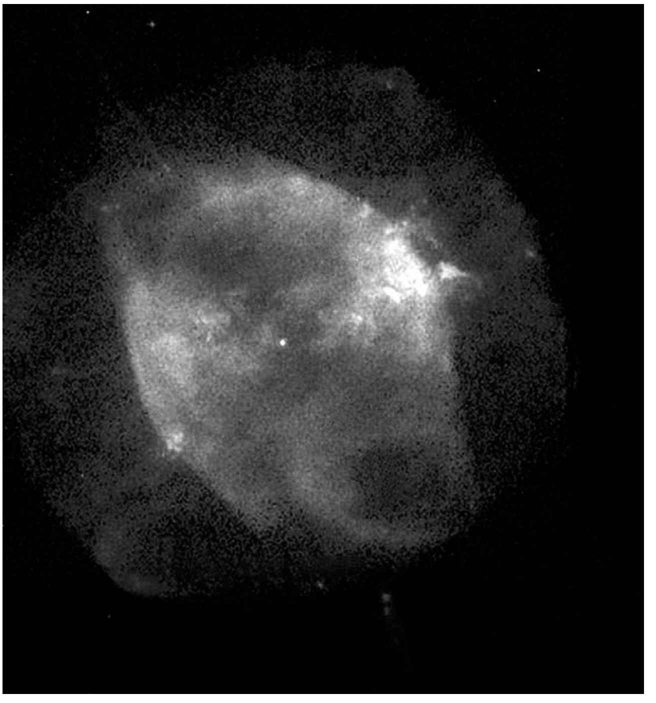
NGC: Planetary nebula, bright, small, round, pretty gradually very little brighter in the middle.



NGC 7354 IS A NEGLECTED PLANETARY nebula in a rather inconspicuous part of Cepheus the King. It lies about 3¼° north-northeast of Delta (δ) Cephei, one of the most famous variable stars in the heavens, and a bit east of the "box" in the House asterism. This region also contains two other neglected gems in this book: open cluster NGC 7510 (Secret Deep 107) and diffuse nebula NGC 7538 (Secret Deep 108), both of which lie about 4 to the east. You'll also find Hidden Treasure 106 (NGC 7380) – a nebulous cluster that, to me, looks like Harry Potter on his Firebolt broomstick, playing Quidditch and trying to grab the Golden Snitch – about 3¼° to the south-southeast of NGC 7354. As you can see, despite the region's obscurity, it's rich in little wonders.

William Herschel discovered NGC 7354 on November 3, 1787, and classified it as a faint nebula. The object wasn't identified as a planetary – meaning that it looked small and round, like the planet Uranus – until 1862, when Lord Rosse at Birr Castle in Ireland saw it as such through his great 72-inch Newtonian reflector – the Leviathan of Parsonstown. Rosse and his contemporaries, however, were not aware of the nebula's true nature, namely luminous shells of matter spewed forth by Sun-like stars as they near the end of their lives. Like Herschel, Rosse believed that all nebulae could be resolved into individual stars given sufficient aperture and magnification.

The first clue to the true nature of planetary nebulae came two years later, on August 29, 1864, when English amateur astronomer William Huggins turned a spectroscope to NGC 6543 (the Cat's Eye Nebula in Draco): "The reader may now be



able to picture to himself to some extent the feeling of excited suspense, mingled with a degree of awe, with which, after a few moments of hesitation, I put my eye to the spectroscope," Huggins wrote in his 1864 discovery paper, "Was I not about to look into a secret place of creation? I looked into the spectroscope. No spectrum such as I expected! A single bright line only!" He later resolved that bright line into two emission lines. Huggins recognized that the nebula's spectrum was that of a luminous gas, not a haze of unresolved suns. In time, spectroscopy was used to ferret out more of these peculiar objects and separate them from emission and reflection nebulae.

Modern images of NGC 7354, like HST's above right, better reveal NGC 7354's complex nature. The nebula consists of a bright and clumpy inner, and slightly irregular, oval ring (or torus) measuring 22″ × 18″ across in positional angle 27°. It's inclined about 45° to our line of sight. The oval fades out at each end. A smooth spherical disk of much fainter matter (~32″ in extent) surrounds the inner ring. Thus, NGC 7354 appears to be a prolate spheroid (like a symmetrical egg or American football) or a three axes ellipsoid with a central, bright ring or torus. If we accept the nebula's distance as 4,200 light-years, the nebula's true physical extent is 0.6 light-year across.

The HST image also shows two linear, jet-like features emerging from the spherical halo, which were imaged as "streaks" by Heber Curtis in 1918. But in 2000, J. Patrick Harrington (University of Maryland, College Park) argued that the jets in NGC 7354 are not true jets, which he defines as narrow, continuous, high-velocity flows. These, he says, are rare among planetaries. Instead, the "jets" in NGC 7354 are what he refers to as "cometary structures," first seen in the Helix more than four decades ago.

Cometary structures have a bright "head" at the end nearest the star, from which a low-ionization tail, often sinuous, extends outward. HST images have shown that the heads are neutral globules, which are photo-evaporating. The globules are drifting outward more slowly than the surrounding ionized gas; the tails presumably result as evaporated material is dragged back by the flow. These sinuous tails, which, as in the case of NGC 7354, can be quite long, could indicate a subsonic flow past the globules.

For the first time, astronomers have also detected the presence of a halo and ring system in NGC 7354. J. P. Phillips (Institute of Astronomy and Meteorology Guadalajara, México) and colleagues describe the discovery in a 2009 *Monthly Notices of the Royal Astronomical Society* (vol. 399, pp. 1126–1144). Their mid-infrared observations of NGC 7534 with the Spitzer Space Telescope suggest that some of the rings may be associated with higher densities of dust particles. They also note that there are many ways such rings can be formed, including spiral density shock waves and variations in the stellar magnetic field. It is still unclear, however, which of these mechanisms is the most important.

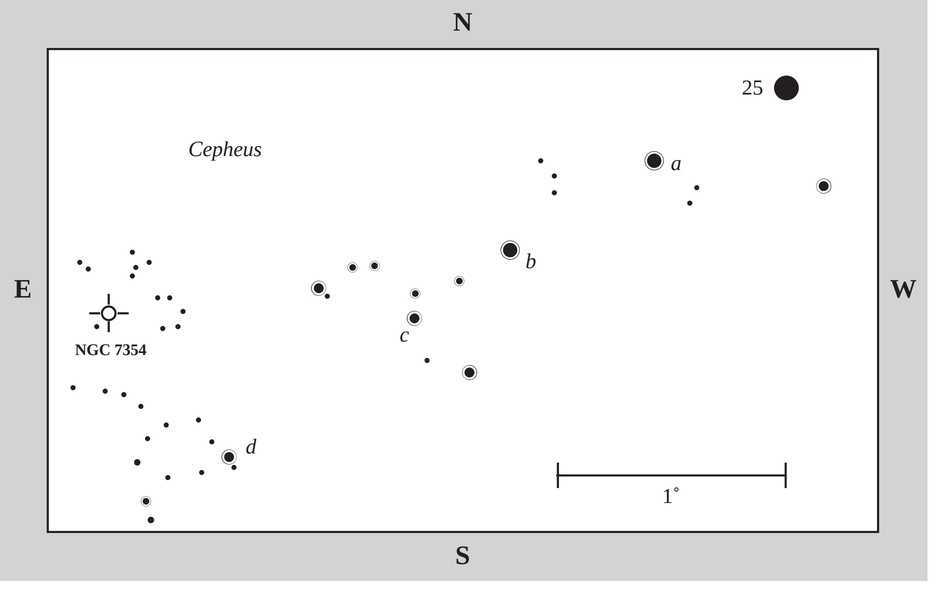
To find this little wonder, start with Delta (δ) Cephei, the classical example of the Cepheid variable. Delta Cephei pulsates with extreme regularity, varying in brightness from 3.5 to 4.3 and back every 5 days 8 hours 47 minutes and 32 seconds. Its precise pulsations beat out the passage of time like a heart. The star's "heartbeat" was discovered in 1784 by the Dutch-born English amateur astronomer John Goodriche who was both mute and deaf. Delta Cephei is a true supergiant star, 40 times as large as our Sun and about 2,000 times more luminous.

At Harvard in 1912, Henrietta Leavitt discovered that a Cepheid's luminosity is directly related to its period. The longer a Cepheid's pulsation period, the more luminous the star by a constant factor. "A straight line," Leavitt said, "can be readily drawn among each of the two series of points corresponding to maxima and minima, thus showing that there is a simple relation between the brightness of the variable and their periods." Because of this precise relationship, astronomers can use Cepheid variables as distance indicators. Delta Cephei itself lies about 1,000 light-years distant. But we've detected Cepheid variables in other galaxies, helping them to determine their distances.

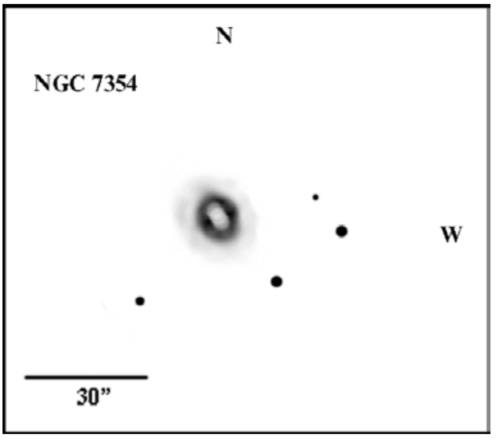
The star's pulsations are also accompanied by a color shift, changing from an F-type star to a cooler G-type star. Delta's also an overlooked double star. The yellow primary has a magnitude 6.3 aqua companion 41″ away. With imagination, the pair looks like the view some incoming extraterrestrial might see of the Earth orbiting its Sun.

From Delta, use your naked eyes or binoculars to locate 6th-magnitude 25 Cephei about 4½° to the north-northwest. This star is part of a nearly 3°-long chain of similarly bright suns just southeast of Xi (ξ) Cephei. Now use the chart on page 452 to find 6.5-magnitude Star *a* about 40′ to the southeast. Now move another 40′ to the southeast, where you'll find 7th-magnitude Star *b*. Next, look for a 40′-long gentle arc (*c*) of three similarly bright suns (oriented northeast–southwest) about 30′ further to the southeast. Now search about 1° to the south-southeast for 7.5-magnitude Star *d*, which has a 9th-magnitude companion immediately to the south-southwest. NGC 7354 lies a little less than 50′ to the northeast of Star *d*, and about 5′ north-northwest of a 10.5-magnitude star.

When you spy NGC 7354, you're looking at an object that lies 28,000 light-years from the Galactic center and about 170 light-years above the Galactic plane in the Cepheus Milky Way. At 33× in the 5-inch, I found the 12th-magnitude nebula readily visible with averted vision even under the

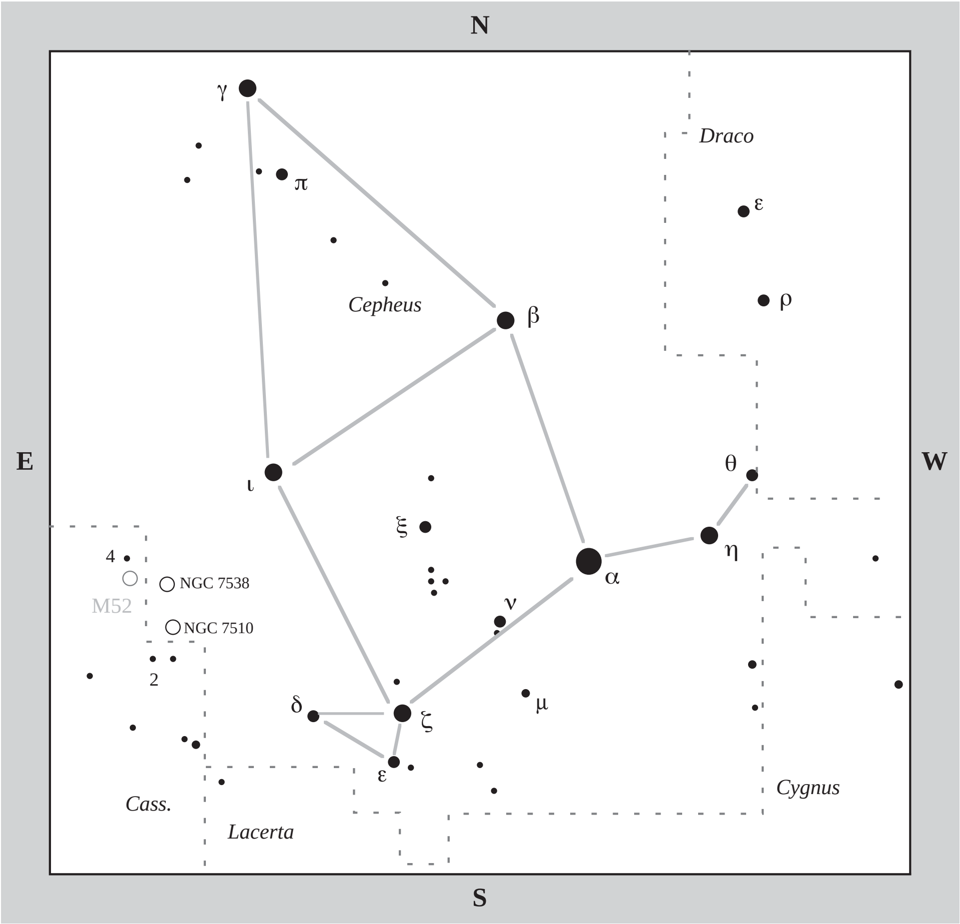


light of a waxing crescent Moon, looking like a tiny fluff of light, almost starlike, but clearly "different" than the surrounding stars. It's easy to identify, because of its proximity to Star *c*, both of which are part of a clean line of stars. The nebula is very apparent at 60× as a tight and diffuse glow with a bright core with a small outer halo. The outer halo appears somewhat elongated northeast–southwest at 94×, and I can suspect a mottled inner ring. Resolving the ring requires powers of around 180×.



All views from 180× to 330× show the outer nebula as an egg-shaped glow with a beaded inner ring. These "beads" are simply enhancements of gases in the ring and lie to the east-northeast and west-southwest. Through the 5-inch, I cannot confirm the inner oval ring, which is oriented northeast–southwest. As far as I could tell the two enhancements lie on the inner ring's minor axis, making it appear to be elongated in the wrong direction. Note that a roughly magnitude 13.5-star is very close to nebula's south-west edge and can be mistaken for a detail if insufficient magnification is used. I could also see a roughly 14th-magnitude star to the west. Photographs show a slighter fainter companion northeast of it. I could not see the 15th-magnitude central star.

Secret Deep 107 & 108
(NGC 7510 & 7538)



107 & 108

107

Dormouse Cluster
NGC 7510
Type: Open Cluster
Con: Cepheus

RA: 23^{h} 11.1^{m}
Dec: +60° 34′
Mag: 7.9
SB: 12.1 (Rating: 3.5)
Diam: 7.0′
Dist: ~9,800 l.y.
Disc: William Herschel, 1787

W. HERSCHEL: [Observed November 3, 1787] A cluster of pretty compressed, pretty [bright] stars, considerably rich. The stars arranged chiefly in lines from south preceding to north following. (H VII-44)

NGC: Cluster, pretty rich, pretty condensed, fan-shaped, stars pretty bright.

108

Northern Lagoon Nebula, Brain Nebula
NGC 7538
Type: Emission/Reflection Nebula
Con: Cepheus

RA: 23^{h} 13.5^{m}
Dec: +61° 31′
Mag: – (Rating: 3.5)
Dim: 9.0′ × 6.0′
Dist: ~9,100 l.y.
Disc: William Herschel, 1787

W. HERSCHEL: [Observed November 3, 1787] Pretty bright in the middle, 2 stars involved in nebulosity, 2′ long, 1′ ½ wide. (H II-706)

NGC: Very faint, large, 2 pretty bright stars involved.

Open star cluster NGC 7510 and emission/reflection nebula NGC 7538 in Cepheus are great examples of how interesting deep-sky objects can be overlooked when they lie in the vicinity of a more glamorous attraction – in this case the 7th-magnitude open cluster M52 in Cassiopeia. Despite their associations with two different (yet arbitrary) constellations, all three objects are celestial neighbors, lying within an apparent area the size of a thumbnail held at arm's length.

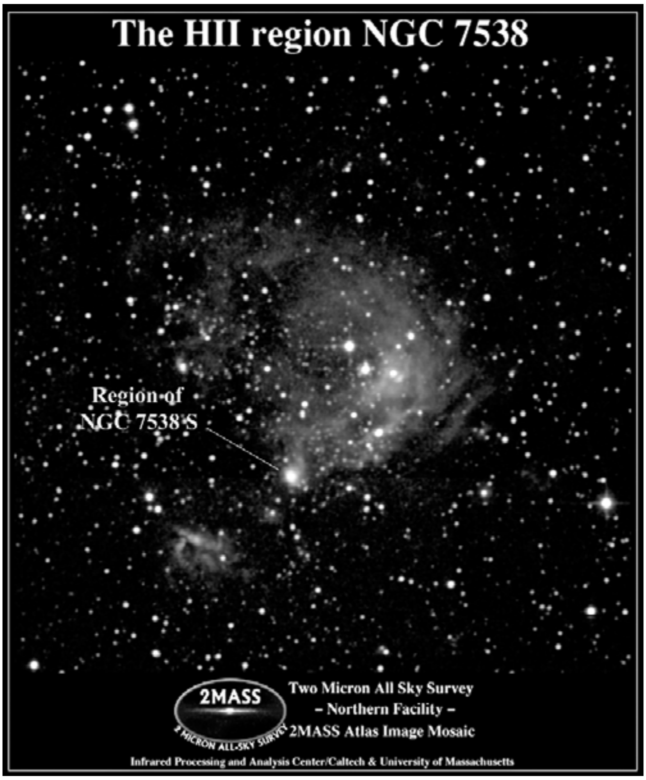
NGC 7538 is only about 1¼° west and slightly south of M52, while NGC 7510 is 1° south-southwest of NGC 7538. These objects also frame NGC 7635, the swath of nebulosity that contains the dim and elusive Bubble Nebula (Caldwell 11); interestingly, some sources misidentify NGC 7538 (the Northern Lagoon Nebula, named for its photographic appearance) with the Bubble Nebula. Actually, if you're interested in astro-imaging, this region is nothing short of a wellspring of galactic wonders. It's in the Perseus arm of our Milky Way, in a region called the Cassiopeia OB2 association, which is rich in HII regions, dark clouds, young clusters, and reflection nebulae.

Values for the distance to the Cassiopeia OB2 association vary from 8,100 to 11,400 light-years, but an estimate of 8,600 light-years for the entire region seems reasonable. NGC 7538, also known as Sharpless 2-158, though, is an HII region embedded in a 595 thousand solar mass molecular cloud surrounded by the much larger diffuse nebula Sharpless 2-161B, which lies at a distance of about 7,800 light-years. This very active star-formation region contains at least 11 high-luminosity infrared sources – the brightest of which is an O-type star that's likely the principle ionizing source for the HII region.

NGC 7538 has a shell structure that appears to be a cavity at the edge of the surrounding molecular cloud. The cavity is well defined in most directions, except towards the north; in the south and west the researchers have found several ionization fronts. NGC 7538, then, may be a region where successive generations of stars have been formed as a result of shocking from ionized gas expanding from its central primeval, yet massive O-type star. The optical nebula we enjoy in our backyard telescopes is the most evolved section. Probing the cloud deeper in the infrared, we find, toward the south, successively younger objects, which themselves may have been successfully generated.

As revealed in the Two Micron All Sky Survey (2MASS) image on page 456, several infrared bright (hot) stars at the nebula's center contribute to the ionization of the cloud. The image also shows the nebula to be quite dusty and reflecting starlight (the bright region at top, coincident with the optical nebula, surrounding the central stars). What is unseen optically, but most visible in the 2MASS image, is the embedded star formation in the molecular cloud to the southeast.

As reported in 2003, a team of Berkeley astronomers led by Göran Sandell (a senior scientist at the Universities Space Research Association) found in this bright infrared region the youngest high-mass star ever observed. The roughly 30-solar-mass protostar star (NGC 7538 S) is surrounded by a huge rotating disk of gas more than 100 times the mass of our Sun and embedded inside a compact dense cloud core of more than 1,000 solar masses. The protostellar



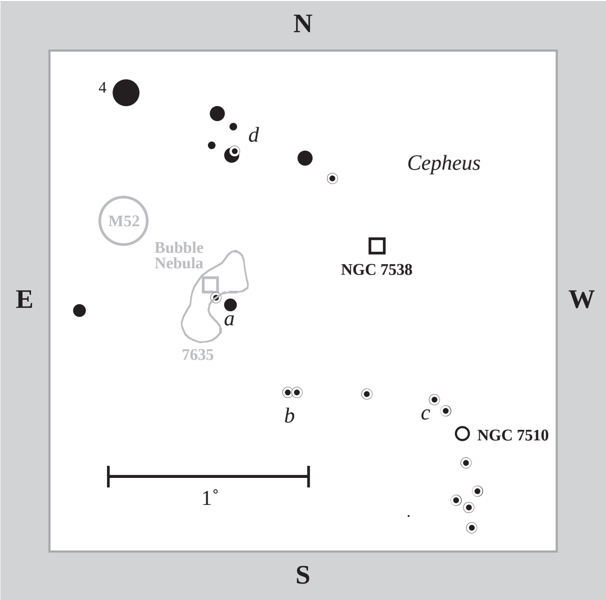
disk – seen nearly edge on with a diameter more than 1,000 times that of our Solar System – drives a jet-like outflow which may be as young as only 2,000 years.

The molecular cloud also contains many other similar objects. But what's unique about NGC 7538 S is its dense cloud core. As Sandell reports, "Most young high mass stars or protostars are found in the immediate vicinity of compact ionized regions and near or in so-called hot cores. Here we find what appears to be a massive protostar, but which apparently has not yet had time to heat up the surrounding cloud, i.e., it is the first high mass star forming in this massive cloud core."

In a 1996 *Astronomy & Astrophysics Supplement*, Roberto Barbon (Asiago Astrophysical Observatory, Italy) and Egyptian astronomer Samia M. Hassan (National Research Institute of Astronomy and Geophysics, Cairo) note that distance estimates to NGC 7510 range from about 7,200 light-years to 16,400 light-years. But in their three-color photometry studies of the bright end of the 10-million-year-young cluster, the researchers achieved a rough distance estimate of 10,000 light-years. If true, the fact that the cluster lies on the galactic plane is interesting, because it places the external boundary of the Perseus arm up to 9,800 light-years from the Sun.

But more studies need to be done to refine the distance estimates to both NGC 7538 and 7510. For instance, in a 2007 *Astronomy & Astrophysics*, Delphine Russeil (Laboratoire d'Astrophysique de Marseille, France) and her colleagues estimate NGC 7538 to lie 7,400 light-years distant, and in a 2005 *Astronomy & Astrophysics*, Nina V. Kharchenko (Astrophysical Institute of Potsdam, Germany) and her colleagues find the distance to NGC 7510 as only 6,800 light-years. These newer distances place both objects in front of the Cassiopeia OB2 association.

NGC 7510 is in the same age group as NGC 2362 (Caldwell 64), the Tau Canis Majoris Cluster, which itself is part of a bubble of gas some 5° across; like the gas cloud that surrounds NGC 7510, it too appears to be the remains of the cluster's



have a large telescope, don't expect these nebulae to jump out at you, so just focus on Star *a*). Now make a slow and careful 35′ sweep southwest to a little arc of three 8.5- to 9th-magnitude suns (*b*), followed by a 40′ sweep west to a pair of 9th-magnitude suns (*c*) separated by 5′ and oriented northeast–southwest. NGC 7510 will immediately pull your attention 10′ further to the southwest.

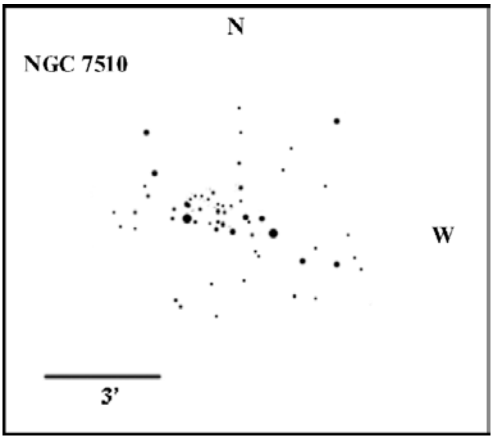
There's no mistaking this tiny (7′-wide) spearhead of stars, even from urban locations. At 33× its core is a tiny squashed ellipse of about a half-dozen stars of near similar brightness, about 5′ in length and oriented east-northeast to west-southwest. With averted vision, the cluster swells to nearly twice that size to include a smattering of surrounding suns. Interestingly, despite this obvious "core," Trumpler classed it as a rich cluster with little concentration with a medium range in the brightness of its stars. The fact is, the visual core mentioned here really is the main component of the cluster; it has no obvious central concentration of stars.

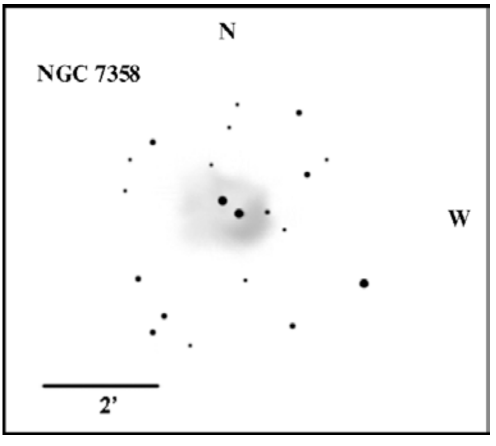
At 60×, the spearhead (now something like a squashed ellipse) appears to rest on a faint background of simmering suns that seems to enjoy playing with one's averted vision. I've used magnifications as high as 282× to study this little gem, which contains about two dozen suns ranging in brightness from about magnitude 10 to 13. With imagination, these stars look like a sleepy mouse (like the Dormouse in Lewis Carroll's 1923 children's classic *Alice's Adventures in Wonderland*), pressing itself against the

natal cocoon, which has been blown away by the cluster's hot, young stars.

To find our two objects, start by using the chart on page 453 to locate 3rd-magnitude Iota (ι) Cephei), then 5th-magnitude 4 Cassiopeiae 5½° to the southeast. Take a minute, however, to enjoy the bloody appearance of 4 Cassiopeiae, which is an M-type red giant 770 light-years distant. It's also the coarse quadruple star H VI 24 (discovered by Sir William Herschel), with a yellowish 8th-magnitude companion about 1.5′ to the southwest; an 8.6-magnitude star lies another 2′ to the southwest, and a 9.6-magnitude companion is only about 10″ to the north-northeast of the primary.

M52 lies only about 45′ to the south. Center the cluster in your telescope at low power, then switch to the chart on this page. From M52, move 40′ southwest to 7th-magnitude Star *a*, just west of NGC 7635 and the Bubble Nebula (unless you





floor with its thin tail curled up on its back. The cluster must be a glorious sight in larger telescopes, which can illuminate twice as many stars to fainter magnitudes.

NGC 7538 lies 1° north-northeast of NGC 7510. You can try to pick up its tiny form in a low-power sweep. Otherwise, return to 4 Cassiopeia, and move about 45′ west-southwest, to a 30′-wide triangle of roughly 7th-magnitude suns (*d*). NGC 7538 is only about 35′ southwest of the westernmost star in Triangle *d*. Actually, in my 5-inch at 33×, I can just fit all three objects (M52, NGC 7510, and NGC 7538) in the same low-power field, which gives me a field of view slightly larger than 2°.

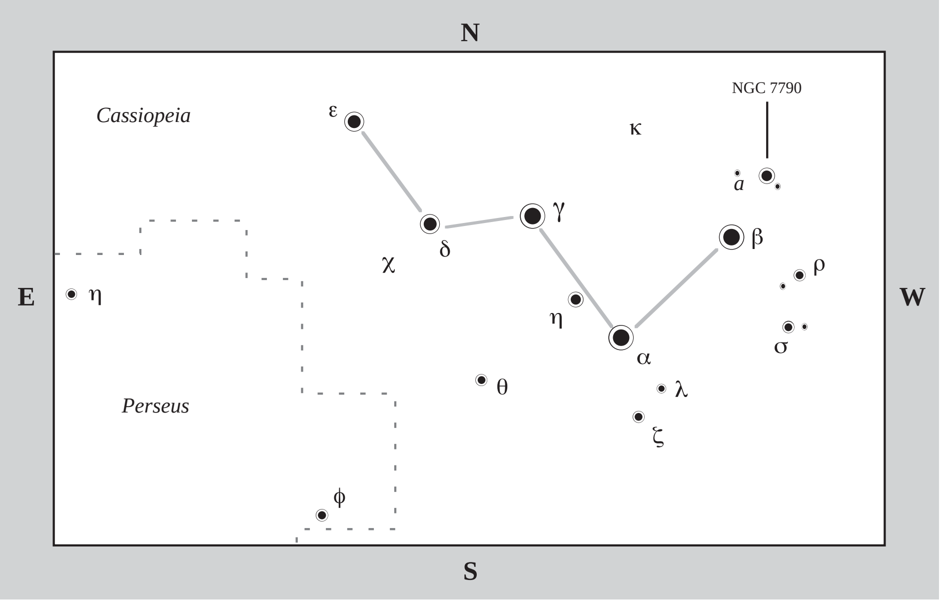
Seen in this way, M52 dominates the view, with NGC 7510 appearing as a little tangle of suns on the opposite side of the field; NGC 7538 is a tiny fuzz of light best seen with averted vision. It's also easy to imagine M52 being almost twice as close as the other two objects, though if we accept the distances in the tables above, NGC 7510, which appears more prominent than NGC 7538, is the more distant of the two. So looking at these three objects can truly play with your mind in more ways than one.

I can just see NGC 7538 with direct vision, but averted vision really brings it out. Look for a tight pair of 11th-magnitude stars, separated by a mere 35″, swimming in a little pool of nebulosity ~2′ in length (the greater apparent diameter is for the photographic image). Seen under a dark sky, the nebula is not difficult at all; it simply pops into view – hardly a challenge. At 60× and 94×, the glow appears irregularly round, hugging the two central stars, though with averted vision the nebula looks heavy on the southwestern side and seems to sag with that added weight; this is more an illusion, because the nebula is just more concentrated and brighter at this region. Although I cannot detect any of the nebula's finer structures in my 5-inch, I wonder if anyone can see the nebula's lagoons – the dark bays of dust separating loops of nebulous matter stretching to the northeast. Though much smaller in angular extent, the photographic image of NGC 7538 is definitely reminiscent of M8, the Lagoon Nebula, in structure. Aside from NGC 7538's more familiar moniker, the Northern Lagoon Nebula, Kevin Jardine (creator of the Galaxy Map website:

http://galaxymap.org/drupal/node/23), has appropriately dubbed it the Brain Nebula.

By the way, if we could remove NGC 7510 and NGC 7538 from their distant location in the Perseus Arm of our Milky Way, and place them at a convenient distance of 400 light-years, both objects would appear 400 times brighter and 20 times larger, making NGC 7510 outshine the Pleiades by roughly a magnitude and appear 1.5 times as large in angular extent! NGC 7538 would be of similar extent, and its two central stars would rival the brightest in the Pleiades, but I'd suspect that the naked-eye view of the Pleiades cluster would still flutter more poets' hearts.

Secret Deep 109
(NGC 7790)



109

Widow's Web Cluster
NGC 7790
Type: Open Cluster
Con: Cassiopeia

RA: 23^h 58.4^m
Dec: $+61°$ $12.5'$
Mag: 8.5
SB: 12.0 (Rating: 3)
Diam: 5′
Dist: ~10,600 l.y.
Disc: William Herschel, 1788

W. HERSCHEL: [Observed December 16, 1788] A pretty compressed cluster of [faint] stars of several sizes, considerably rich, extended nearly parallel, 5 or 6′ long. (H VII-56)

NGC: Cluster, pretty rich, pretty compressed.

NGC 7790 IS A PRETTY LITTLE CLUSTER in Cassiopeia, about 2½° northwest of Beta (β) Cassiopeiae. Don't let the seemingly dim magnitude fool you. When William Herschel discovered the object in 1788, he classified it as a pretty compressed cluster of bright and faint stars. Likewise, in 1931, Trumpler listed it as a moderately rich and isolated cluster with a slight concentration and a medium brightness range of stars. I find it aesthetically pleasing in my 5-inch; it's compact enough (5′), rich enough (more than two dozen suns at high power), and its stars are bright enough (magnitude 10 and fainter) to make it a pleasing visual attraction.

NGC 7790 is an important star cluster because it contains three classical Cepheid variables: QX, CEab, and CF Cassiopeiae. CEab Cassiopeiae is of very special interest because it is the first known binary system consisting of *twin* Cepheid variable stars with slightly different periods (5.14 days for star *a* and 4.47 days for star *b*). The stars are separated by 8,000 astronomical units and appear to form a physical pair.

Cepheids – yellow giant or supergiant pulsating variables – are of great importance because their periods of variability are directly related to their luminosities – the longer the period, the greater the mean intrinsic brightness. Thus, as Jaymie M. Matthews (University of British Columbia, Canada) and colleagues expound in a 1995 *Astronomical Journal* (vol. 110, p. 2280): "NGC 7790 has the potential to be a Rosetta Stone for refining the zero point of the extragalactic distance scale."

Their surface brightness analysis of the Cepheid CF Cassiopeiae (P?4.88 days), which is widely believed to be a member of the cluster, led to a determined distance of about 10,100 light years. In a 2000 *Astronomy & Astrophysics Supplement Series*, Indian astronomer Alok C. Gupta (University of Gorakhpur, India) and colleagues determined its distance to be about 10,600 light years. They also found its age to be about 120 million years, though other researchers have found the age to range between 100 million years and 500 million years, depending on the model used; Gupta's value, however, seems to be more in agreement with the ages obtained by applying the period–age relations to the three Cepheids in it, which range between 100 million and 200 million years.

If true, NGC 7790 is an intermediate-aged cluster, about the same age as NGC 2451 (Hidden Treasure 42). NGC 7790 lies in the Galactic disk near the Perseus arm and is only slightly reddened (~0.05 magnitude). Since the age distribution of open clusters overlaps that of globular clusters, studies of open clusters can also help astronomers understand how stars in the Galaxy's disk evolve compared to those in globular cluster in the Galaxy's halo. NGC 7790, then, is also valuable to the study of the evolution of intermediate mass stars. The current thinking is that the disk started to form before the halo stopped assembling.

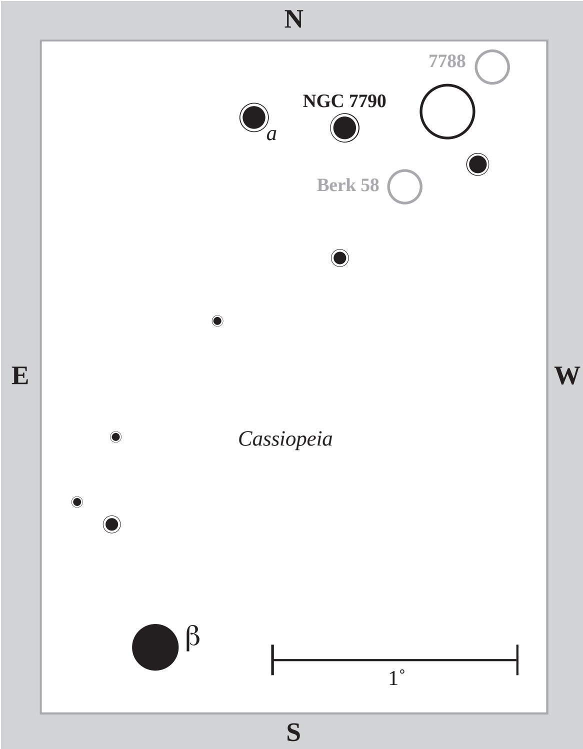
At a distance of 10,600 light years, NGC 7790 spans 15 light-years of space in true physical extent. If we could see NGC 7790 at the same distance as the Pleiades (or 25 times closer), the cluster would shine roughly at 5th-magnitude and span 2° of sky, or the same apparent size as the Pleiades. Still, its brightest members would be about 2 magnitudes fainter than those in the Pleiades, which would still dominate the minds and eyes of star-struck humans. Still, what a wondrous sight NGC 7790 would be to behold in binoculars.

Even at its current distance, NGC 7790 is a binocular wonder. As Canadian amateur Stéphane Meloche of Coaticook reports online, when viewed through Vixen 9 × 63 binoculars, the cluster is "Very beautiful... [with] 4–5 very weak individual stars, forming a 'Y' figure, accompanied by a weak [nebulous] background, made up of unsolved stars."

To find this visual curiosity, use the chart on page 460 to locate Beta (β) Cassiopeiae. Then use the chart on page 463 to guide you to a pair of 6th-magnitude stars (*a*) a little more than 2° to the north-northwest. Center the westernmost star in the pair in your telescope at low power. NGC 7790 is only about 25′ due west of that star and about 15′ northeast of a magnitude 6.5 star (*b*).

At 33× in the 5-inch, NGC 7790 is a small but very nice sight – a highly concentrated east–west-trending ellipse of stars against a rich backdrop of Milky Way. Two 11th-magnitude members punctuate the cluster's west end (the northern of which is the Cepheid variable CEab Cas), and a little knot of stars lies at the east end; the Cepheid variable QX Cas lies about 2′ southeast of that eastern knot, and CF Cas lies is about 1.5′ northeast of CE Cas and appears slightly fainter.

At 60×, I see dim cluster members flowing westward from the eastern knot like a comet tail that seems to tickle the two 11th-magnitude stars. Seen with west up, the cluster does indeed form a prominent Y-shaped grouping, with about a

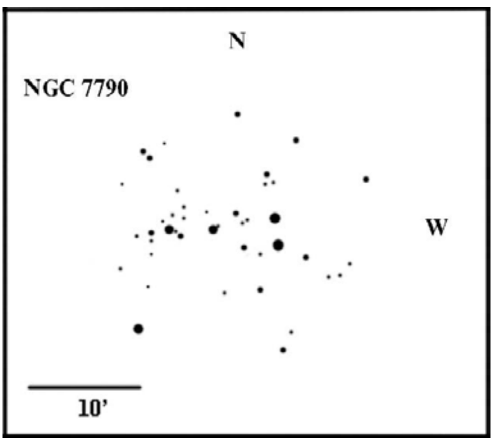


about 20′ to the southeast. These three make an interesting wide-field photographic subject. In photos, NGC 7790 and 7788 look like twins – a lovely double cluster. Alas, they are not physically related. Although it is visually fainter, NGC 7788 lies nearly 5,000 light years closer to us than our target NGC 7790.

I call NGC 7790 the Widow's Web Cluster because its appearance reminds me of a black-widow spider's web I once saw in southwest Texas, near the Mexican border. The spider had positioned the web so that it crossed part of a narrow opening between two wooden crossbeams in an old fort. The web successfully trapped a bat that had used that opening to roost. The captured body caused the silken threads to sag earthward, forming a creepy Y-shaped web.

dozen irregularly bright suns splashed across the cluster's face. At higher powers, the cluster breaks down into a western trapezoid of 11th- and 12th-magnitude stars and a tiny eastern grouping dominated by a tight arc of 12th- to 13th-magnitude suns with one double star centrally located in the cluster, which I resolved at 180×. At 94×, though, a wash of two dozen faint cluster members flit in and out of view with averted vision.

Note that two fainter clusters lie nearby: 9.4-magnitude NGC 7788, about 15′ to the northwest, and 9.7-magnitude Berkeley 58



APPENDIX A
The Secret Deep: basic data

SD[a]	NGC/Other[b]	RA[c]	Dec[d]	Con.[e]	Type[f]	Mag.[g]	Size (′)[h]	Notes
1	vdB 1	00^h 11.0^m	+58° 46′	Cas	BN	–	5 × 5	
2	134	00^h 30.4^m	−33° 15′	Scl	GX	10.4	8.5 × 1.9	Giant Squid
3	488	01^h 21.8^m	+05° 15′	Pis	GX	10.3	5.5 × 4.0	Whirligig
4	654	01^h 44.0^m	+61° 53′	Cas	OC	6.5	6	Fuzzy Butterfly
5	Cr 463	01^h 45.7^m	+71° 49′	Cas	OC	5.7	57	Loch Ness Monster
6	St 2	02^h 14.7^m	+59° 29′	Cas	OC	4.4	60	9 (Stitchpunks)
7	936	02^h 27.6^m	−01° 09′	Cet	GX	10.2	5.7 × 4.6	Darth Vader's *fighter
8	1084	02^h 46.0^m	−07° 35′	Eri	GX	10.7	3.2 × 1.9	
9	1245	03^h 14.7^m	+47° 14′	Per	OC	8.4	10	Patrick Starfish
10	1300	03^h 19.7^m	−19° 25′	Eri	GX	10.4	5.5 × 2.9	
11	1342	03^h 31.7^m	+37° 22.5′	Per	OC	6.7	17	Stingray
12	1400	03^h 39.5^m	−18° 41′	Eri	GX	11.0	2.8 × 2.5	
13	1407	03^h 40.2^m	−18° 35′	Eri	GX	9.7	6.0 × 5.8	
14	1491	04^h 03.4^m	+51° 19′	Per	BN	–	4 (blue)	Fossil Footprint
15	1514	04^h 09.6^m	+30° 46.5′	Tau	PN	10.9	2.3 × 2.0	Crystal Ball
16	1579	04^h 30.2^m	+35° 16′	Per	BN	–	12 × 8	Northern Trifid
17	1750	05^h 04.3^m	+23° 44′	Tau	OC	~6th	30	= NGC 1746
18	1758	05^h 04.7^m	+23° 48′	Tau	OC	~7.5	10	
19	1788	05^h 06.9^m	−03° 21′	Ori	BN	–	5 × 3	Cosmic Bat
20	1807	05^h 10.8^m	+16° 31′	Tau	OC	7.0	12	Poor Man's Double
21	1817	05^h 12.4^m	+16° 41′	Tau	OC	7.7	20	Poor Man's Double
22	IC 417/St 8	05^h 28.1^m	+34° 26′	Aur	BN/OC	–	13 × 10	The Spider
23	1931	05^h 31.4^m	+34° 15′	Aur	BN/OC	–	4	The Fly
24	Cr 70	05^h 35.6^m	−01° 05′	Ori	OC	0.6	140	Orion's Belt
25	2022	05^h 42.1^m	+09° 05′	Ori	PN	11.9	22° × 17″	Kissing Crescents
26	Sh2–276	05^h 52.5^m	+00° 45′	Ori	SNR	–	90 × 30	Part of Barnard's Loop
27	IC 2149	05^h 56.4^m	+46° 06′	Aur	PN	10.7	8.5	
28	2149	06^h 03.5^m	−09° 44′	Mon	BN	–	3 × 2	
29	2170	06^h 07.5^m	−06° 24′	Mon	BN	–	2 × 2	
30	2281	06^h 48.3^m	+41° 05′	Aur	OC	5.4	25	Broken Heart
31	2298	06^h 49.0^m	−36° 00′	Pup	GC	9.3	5	
32	2316	06^h 59.7^m	−07° 46′	Mon	BN	–	4 × 3	
33	2343	07^h 08.1^m	−10° 37′	Mon	OC	6.7	6	Double Mint
34	2346	07^h 09.4^m	−00° 48′	Mon	PN	11.8	>50″	Crimson Butterfly
35	2359	07^h 18.6^m	−13° 12′	CMa	BN	–	9 × 6	Flying Eye
36	2371–2	07^h 25.5^m	+29° 29′	Gem	PN	11.3	58″	Double Bubble
37	2420	07^h 38.4^m	+21° 34′	Gem	OC	8.3	6	Twinkling "Comet"
38	3079	10^h 02.0^m	+55° 41′	UMa	GX	10.9	8.0 × 1.5	Pantom Frisbee
39	3077	10^h 03.3^m	+68° 44′	UMa	GX	9.8	5.5 × 4.1	
40	3166	10^h 13.8^m	+03° 26′	Sex	GX	10.4	4.6 × 2.6	Part of Pair
41	3169	10^h 14.2^m	+03° 28′	Sex	GX	10.2	5.0 × 2.8	Part of Pair
42	3198	10^h 19.9^m	+45° 33′	UMa	GX	10.3	9.2 × 3.5	
43	3226	10^h 23.4^m	+19° 54′	Leo	GX	11.4	2.5 × 2.2	Part of Pair

SD[a]	NGC/Other[b]	RA[c]	Dec[d]	Con.[e]	Type[f]	Mag.[g]	Size (′)[h]	Notes
44	3227	$10^{h}\,23.5^{m}$	+19° 52′	Leo	GX	10.3	6.9 × 5.4	Part of Pair
45	3432	$10^{h}\,52.5^{m}$	+36° 37′	LMi	GX	11.2	6.9 × 1.9	Knitting Needle
46	3675	$11^{h}\,26.1^{m}$	+43° 35′	UMa	GX	10.2	6.2 × 3.2	
47	3893	$11^{h}\,48.6^{m}$	+48° 43′	UMa	GX	10.5	4.2 × 2.3	
48	3953	$11^{h}\,53.8^{m}$	+52° 20′	UMa	GX	10.1	6.0 × 3.2	M109?
49	4036	$12^{h}\,01.4^{m}$	+61° 54′	UMa	GX	10.7	3.8 × 1.9	
50	4051	$12^{h}\,03.2^{m}$	+44° 32′	UMa	GX	10.2	5.5 × 4.6	
51	4111	$12^{h}\,07.1^{m}$	+43° 04′	CVn	GX	10.7	4.4 × 0.9	
52	4147	$12^{h}\,10.1^{m}$	+18° 32.5′	Com	GC	10.3	4	Kick the Can
53	4293	$12^{h}\,21.2^{m}$	+18° 23′	Com	GX	10.4	5.3 × 3.1	
54	4414	$12^{h}\,26.4^{m}$	+31° 13′	Com	GX	10.1	4.4 × 3.0	
55	4435	$12^{h}\,27.7^{m}$	+13° 05′	Vir	GX	10.8	3.2 × 2.0	Part of The Eyes
56	4438	$12^{h}\,27.8^{m}$	+13° 01′	Vir	GX	10.2	8.9 × 3.6	Part of The Eyes
57	4450	$12^{h}\,28.5^{m}$	+17° 05′	Com	GX	10.1	5.0 × 3.4	
58	4461	$12^{h}\,29.0^{m}$	+13° 11′	Vir	GX	11.2	3.7 × 1.4	
59	3C 273	$12^{h}\,29.1^{m}$	+02° 03′	Vir	QSR	11.7–13.2	–	Quasar
60	4473	$12^{h}\,29.8^{m}$	+13° 26′	Com	GX	10.2	3.7 × 2.4	Part of Pair
61	4477	$12^{h}\,30.0^{m}$	+13° 38′	Com	GX	10.4	3.9 × 3.6	Part of Pair
62	4636	$12^{h}\,42.8^{m}$	+02° 41′	Vir	GX	9.5	7.1 × 5.2	
63	4665	$12^{h}\,45.1^{m}$	+03° 03′	Vir	GX	10.5	4.1 × 4.1	
64	4753	$12^{h}\,52.4^{m}$	−01° 12′	Vir	GX	9.9	4.1 × 2.3	Dust Devil
65	4762	$12^{h}\,52.9^{m}$	+11° 04′	Vir	GX	10.3	9.1 × 2.2	Paper-Kite
66	5033	$13^{h}\,13.4^{m}$	+36° 36′	CVn	GX	10.2	10.5 × 5.1	Waterbug
67	5195	$13^{h}\,30.0^{m}$	+47° 16′	CVn	GX	9.6	6.4 × 4.6	
68	5466	$14^{h}\,05.4^{m}$	+28° 32′	Boo	GC	9.0	9	Snowglobe
69	5846	$15^{h}\,06.4^{m}$	+01° 36′	Vir	GX	10.0	3.0 × 3.0	
70	5907	$15^{h}\,15.9^{m}$	+56° 20′	Dra	GX	10.3	11.5 × 1.7	Splinter
71	IC 4593	$16^{h}\,11.7^{m}$	+12° 04′	Her	PN	10.7	>12″	White-Eyed Pea
72	6144	$16^{h}\,27.2^{m}$	−26° 01′	Sco	GC	9.0	9	
73	6207	$16^{h}\,43.1^{m}$	+36° 50′	Her	GX	11.6	3.0 × 1.1	
74	6229	$16^{h}\,46.9^{m}$	+47° 32′	Her	GC	9.4	4.5	"Prize Comet"
75	6293	$17^{h}\,10.2^{m}$	−26° 35′	Oph	GC	8.2	7.9	
76	6309	$17^{h}\,14.1^{m}$	−12° 55′	Oph	PN	11.5	>16″	Box
77	6356	$17^{h}\,23.6^{m}$	−17° 49′	Oph	GC	8.2	10	
78	6522	$18^{h}\,03.6^{m}$	−30° 02′	Sgr	GC	8.3	9.4	
79	6528	$18^{h}\,04.8^{m}$	−30° 03′	Sgr	GC	9.6	3.7	
80	6563	$18^{h}\,12.1^{m}$	−33° 52′	Sgr	PN	11.0	50″ × 38″	Southern Ring
81	6589	$18^{h}\,16.9^{m}$	−19° 47′	Sgr	BN	–	5 × 3	
82	6595	$18^{h}\,17.1^{m}$	−19° 52′	Sgr	BN	–	4 × 3	= NGC 6590
83	6638	$18^{h}\,30.9^{m}$	−25° 30′	Sgr	GC	9.2	7.3	
84	6664	$18^{h}\,36.5^{m}$	−08° 11′	Sct	OC	7.8	12	Santa's Sleigh
85	6717	$18^{h}\,55.1^{m}$	−22° 42′	Sgr	GC	8.4	5.4	Palomar 9
86	6751	$19^{h}\,05.9^{m}$	−05° 59.5′	Aql	PN	11.9	24″	Glowing Eye

SD[a]	NGC/Other[b]	RA[c]	Dec[d]	Con.[e]	Type[f]	Mag.[g]	Size (′)[h]	Notes
87	6755	$19^{h}\ 07.8^{m}$	+04° 16′	Aql	OC	7.5	15	Part of Binary Cluster?
88	6756	$19^{h}\ 08.7^{m}$	+04° 42′	Aql	OC	10.6	4	Part of Binary Cluster?
89	6778	$19^{h}\ 18.4^{m}$	−01° 36′	Aql	PN	11.9	20″ × 40″	Son of M76
90	6781	$19^{h}\ 18.5^{m}$	+06° 32′	Aql	PN	11.4	2	Ghost of the Moon
91	6804	$19^{h}\ 31.6^{m}$	+09° 13′	Aql	PN	12.2	~50″	Incredible Shrinking
92	6811	$19^{h}\ 37.2^{m}$	+46° 22.5′	Cyg	OC	6.8	15	Smoke Ring
93	Cyg X-1	$19^{h}\ 58.4^{m}$	+35° 12′	Cyg	BH (star)	8.8 (star)	–	HDE 226868
94	OME 3	$20^{h}\ 05.3^{m}$	+47° 32′	Cyg	AST	–	12	Alessi J20053+4732
95	6891	$20^{h}\ 15.2^{m}$	+12° 42′	Del	PN	10.5	>18″	
96	6894	$20^{h}\ 16.4^{m}$	+30° 34′	Cyg	PN	12.3	>42″	Diamond Ring
97	IC 1318(a)	$20^{h}\ 16.6^{m}$	+41° 49′	Cyg	BN	–	45 × 20	Near Gamma Cygni
98	6905	$20^{h}\ 22.4^{m}$	+20° 06′	Del	PN	11.1	42″ × 35″	Blue Flash
99	6910	$20^{h}\ 23.2^{m}$	+40° 47′	Cyg	OC	6.6	10	Inchworm
100	6939	$20^{h}\ 31.5^{m}$	+60° 40′	Cep	OC	7.8	10	Flying Geese
101	7026	$21^{h}\ 06.3^{m}$	+47° 51′	Cyg	PN	10.9	21″	Cheeseburger
102	7048	$21^{h}\ 14.2^{m}$	+46° 17′	Cyg	PN	12.1	61″	Peek-a-Boo
103	7129	$21^{h}\ 42.8^{m}$	+66° 06′	Cep	BN	–	7 × 7	Cosmic Rosebud
104	7160	$21^{h}\ 53.7^{m}$	+62° 36′	Cep	OC	6.1	5	Bruce Lee
105	7209	$22^{h}\ 05.8^{m}$	+46° 29′	Lac	OC	7.7	15	Star Lizard
106	7354	$22^{h}\ 40.3^{m}$	+61° 17′	Cep	PN	12.2	22″ × 18″	
107	7510	$23^{h}\ 11.1^{m}$	+60° 34′	Cep	OC	7.9	7	Dormouse
108	7538	$23^{h}\ 13.5^{m}$	+61° 31′	Cep	BN	–	9′ × 6′	Northern Lagoon
109	7790	$23^{h}\ 58.4^{m}$	+61° 12.5′	Cas	OC	8.5	5	Widow's Web

[a] SD, Secret Deep.

[b] NGC/Other, NGC, *New General Catalogue*; Cr, Collinder; IC, *Index Catalogue*; OME, Omeara; Sh, Sharpless; St, Stock; vdB, van den Berg.

[c] RA, right ascension (equinox 2000.0).

[d] Dec., declination.

[e] Con., constellation.

[f] Type, AST, asterism; BH, black hole; BN, bright nebula; GC, globular cluster; GX, galaxy; OC, open cluster; PN, planetary nebula; QSR, quasar; SNR, supernova remnant.

[g] Mag., magnitude.

[h] Size (′), in arc minutes.

APPENDIX B
Twenty additional Secret Deep objects

SD[a]	NGC/Other[b]	RA[c]	Dec[d]	Con.[e]	Type[f]	Mag.[g]	Size (′)[h]	Notes
1	129	$00^h\ 29.9^m$	+60° 13′	Cas	OC	6.5	12	
2	436	$01^h\ 15.9^m$	+58° 49′	Cas	OC	8.8	5	
3	IC 1747	$01^h\ 57.6^m$	+63° 20′	Cas	PN	12.1	13″	Holepunch
4	1499	$04^h\ 00.7^m$	+36° 37′	Per	BN	–	160 × 40	California
5	IC 2165	$06^h\ 21.7^m$	−12° 59′	CMa	PN	10.6	4″	
6	2232	$06^h\ 27.2^m$	−04° 45′	Mon	OC	4.2	53	
7	2439	$07^h\ 40.8^m$	−31° 41.5′	Pup	OC	6.9	9	
8	2489	$07^h\ 56.2^m$	−30° 04′	Pup	OC	7.9	5	
9	2527	$08^h\ 04.9^m$	−28° 08′	Pup	OC	6.5	10	
10	UGC 5470	$10^h\ 08.4^m$	+12° 18′	Leo	GX	10.2	12.0 × 9.3	Leo I Dwarf
11	3607	$11^h\ 16.9^m$	+18° 03′	Leo	GX	9.9	4.6 × 4.1	Pair
12	3608	$11^h\ 17.0^m$	+18° 09′	Leo	GX	10.8	2.7 × 2.3	Pair
13	3640	$11^h\ 21.1^m$	+03° 14′	Leo	GX	10.4	4.6 × 4.1	
14	3938	$11^h\ 52.8^m$	+44° 07′	UMa	GX	10.4	4.9 × 4.7	
15	4698	$12^h\ 48.4^m$	+08° 29′	Vir	GX	10.6	3.2 × 1.7	
16	5084	$13^h\ 20.3^m$	−21° 50′	Vir	GX	10.4	11.0 × 2.5	
17	5634	$14^h\ 29.6^m$	−05° 59′	Vir	GC	9.5	5.5	
18	5824	$15^h\ 04.0^m$	−33° 04′	Lup	GC	7.8	6	
19	IC 4603	$16^h\ 25.6^m$	−24° 28′	Oph	BN	–	35 × 20	
20	6603	$18^h\ 18.5^m$	−18° 24′	Sag	OC	11.1	4	
21	IC 1295	$18^h\ 54.6^m$	−08° 50′	Scu	PN	12.5	>86″	

[a] SD, Secret Deep.
[b] NGC/Other, NGC, *New General Catalogue*; IC, *Index Catalogue*; UGC, *Uppsala General Catalogue*.
[c] RA, right ascension (equinox 2000.0).
[d] Dec., declination.
[e] Con., constellation.
[f] Type, BN, bright nebula; GC, globular cluster; GX, galaxy; OC, open cluster; PN, planetary nebula.
[g] Mag., magnitude.
[h] Size (′), in arc minutes.

APPENDIX C

Deep-sky lists: comparison table[a]

SD	NGC/Other	OME	H400	HAS	RASC	SAC	TAAS
1	vdB 1	*					
2	134	*		*			
3	488		*				
4	654		*	*		*	
5	Cr 463	*		*			
6	St 2	*		*			
7	936	*	*			*	
8	1084	*	*				
9	1245	*	*				*
10	1300	*					*
11	1342	*	*				
12	1400	*					
13	1407		*				
14	1491	*				*	
15	1514	*		*	*		
16	1579	*					
17	1750	*					
18	1758	*					
19	1788	*	*		*	*	
20	1807	*	*				
21	1817	*	*				
22	IC 417/St 8	*					
23	1931	*	*		*	*	
24	Cr 70	*					
25	2022	*	*		*	*	
26	sh2-276	*					
27	IC 2149	*					
28	2149	*					
29	2170	*					
30	2281		*	*			*
31	2298	*					
32	2316	*					
33	2343		*				
34	2346	*					
35	2359	*			*	*	*
36	2371-2	*	*		*		
37	2420		*				*
38	3079	*	*		*	*	*
39	3077	*	*		*	*	*
40	3166		*				
41	3169			*			
42	3198	*	*				*

SD	NGC/Other	OME	H400	HAS	RASC	SAC	TAAS
43	3226		*				
44	3227		*				
45	3432		*		*	*	*
46	3675	*	*		*		
47	3893		*	*			
48	3953	*	*				*
49	4036	*	*				
50	4051		*				
51	4111	*	*		*	*	*
52	4147	*	*				
53	4293	*	*				*
54	4414	*	*	*	*		
55	4435		*		*		
56	4438		*		*	*	
57	4450	*	*				
58	4461	*		*			
59	3C 273	*					
60	4473		*	*			
61	4477	*					
62	4636	*	*				
63	4665		*				
64	4753	*	*				
65	4762	*	*		*	*	*
66	5033	*	*		*	*	*
67	5195	*	*				
68	5466	*	*		*		
69	5846		*				
70	5907	*	*		*	*	*
71	IC 4593	*					
72	6144	*		*			
73	6207	*	*			*	
74	6229	*	*				
75	6293	*	*				
76	6309	*					
77	6356	*	*				*
78	6522	*	*				*
79	6528	*	*				
80	6563	*					
81	6589	*					
82	6595	*					
83	6638	*	*				

(cont.)

SD	NGC/Other	OME	H400	HAS	RASC	SAC	TAAS
84	6664	*	*				
85	6717	*					
86	6751	*					
87	6755	*	*				
88	6756	*	*				
89	6778	*					
90	6781	*	*		*	*	*
91	6804	*					
92	6811	*					
93	Cyg X-1	*					
94	OME 3	*					
95	6891	*					
96	6894	*					
97	IC 1318(a)	*					
98	6905	*	*				
99	6910	*	*	*			
100	6939	*	*		*	*	*
101	7026	*					
102	7048	*					
103	7129	*			*	*	*
104	7160		*	*			
105	7209	*	*			*	*
106	7354	*					
107	7510	*	*			*	
108	7538	*					
109	7790	*	*				

[a] Selected comparison lists: OME, O'Meara (Hawaii); H400; Herschel 400; HAS, Hawaii Astronomical Society; RASC, Royal Astronomical Society of Canada; SAC, Saguaro Astronomy Club (Arizona); TAAS, The Albuquerque Astronomical Society (New Mexico).

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The Secret Deep checklist

SD	NGC/ Other	Date observed	Location (altitude)	Telescope & magnification	Seeing & transparency	Notes
1	vdB 1					
2	134					
3	488					
4	654					
5	Cr 463					
6	St 2					
7	936					
8	1084					
9	1245					
10	1300					
11	1342					
12	1400					
13	1407					
14	1491					
15	1514					
16	1579					
17	1750					
18	1758					
19	1788					
20	1807					
21	1817					
22	IC 417/St 8					
23	1931					
24	Cr 70					
25	2022					
26	Sh2–276					
27	IC 2149					

(cont.)

SD	NGC/ Other	Date observed	Location (altitude)	Telescope & magnification	Seeing & transparency	Notes
28	2149					
29	2170					
30	2281					
31	2298					
32	2316					
33	2343					
34	2346					
35	2359					
36	2371–2					
37	2420					
38	3079					
39	3077					
40	3166					
41	3169					
42	3198					
43	3226					
44	3227					
45	3432					
46	3675					
47	3893					
48	3953					
49	4036					
50	4051					
51	4111					
52	4147					
53	4293					
54	4414					
55	4435					

SD	NGC/ Other	Date observed	Location (altitude)	Telescope & magnification	Seeing & transparency	Notes
56	4438					
57	4450					
58	4461					
59	3C 273					
60	4473					
61	4477					
62	4636					
63	4665					
64	4753					
65	4762					
66	5033					
67	5195					
68	5466					
69	5846					
70	5907					
71	IC 4593					
72	6144					
73	6207					
74	6229					
75	6293					
76	6309					
77	6356					
78	6522					
79	6528					
80	6563					
81	6589					
82	6595					

(cont.)

SD	NGC/ Other	Date observed	Location (altitude)	Telescope & magnification	Seeing & transparency	Notes
83	6638					
84	6664					
85	6717					
86	6751					
87	6755					
88	6756					
89	6778					
90	6781					
91	6804					
92	6811					
93	Cyg X-1					
94	OME 3					
95	6891					
96	6894					
97	IC1318(a)					
98	6905					
99	6910					
100	6939					
101	7026					
102	7048					
103	7129					
104	7160					
105	7209					
106	7354					
107	7510					
108	7538					
109	7790					

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