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The 100 Best Targets for Astrophotography

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To my parents, Pearl and Ralph, in celebration of their 60th wedding anniversary:

For the nights when you would fall asleep in the car waiting for me at the local observatory, to your support and encouragement of my education, and your enthusiasm about my astrophotography, I am eternally grateful.

To my children, Melanie and Shelley, through whose eyes I have rediscovered the marvels of the cosmos; may you never abandon your sense of wonder at the miracles of nature.

And to my wife, Stephanie, who by her example has motivated me to become a better citizen, physician, teacher, parent, and spouse.

Preface

A picture tells a thousand words. Some of astronomy's best communications and teaching tools are its rich legacy of images. Astroimaging began in 1840 when American astronomer John W. Draper took a 20-minute exposure of the Moon through a 5-inch. Newtonian reflecting telescope. Since then, professional and amateur astronomers, nature photographers, and ordinary people with cameras have created millions of celestial images. Some of these photos have led to important discoveries.

In 1888, a photograph of the Andromeda Galaxy (M31) revealed its spiral structure. In 1919, a picture taken during a total solar eclipse confirmed Einstein's theory that massive objects bend starlight. In 1930, American astronomer Clyde Tombaugh discovered Pluto on a photograph of a starry region in Gemini. And in 2004, the Hubble Space Telescope took a million-second-long exposure of a seemingly empty region of space in the constellation Fornax and revealed thousands of distant galaxies.

Likewise, amateur astronomers have made important contributions. Some of their images have shown previously unknown comets, asteroids, and supernovae. Most amateurs, however, image celestial objects for the sheer joy of it. They produce impressive results using techniques unknown to astronomy only a decade ago.

Like a telescope, astroimaging encompasses two aspects. Most people picture a telescope as a long tube through which you view celestial objects. But the optical tube assembly is just half of a high-quality telescope. Without the accompanying mount, the tube would be of little value.

So it is with astroimaging. If all it took to be an astroimager was to sit for long hours at a telescope, many amateur astronomers would be great at it. But there is another facet to producing excellent images – postprocessing. This includes everything that happens after you acquire the raw data, which, in many instances, does not look all that appealing.

Astroimagers spend years developing and refining their techniques. A high-quality image will show intricate detail, have a wide dynamic range, and exhibit the correct color rendition.

As Photo Editor of the world's best-selling astronomy magazine, I receive thousands of images each year. Of those, we publish perhaps 100. Ruben Kier's images are well represented every year.

By following his instructions, you, too, can produce equally beautiful astroimages. When you do, be sure and send them to me for the magazine. Send your very best work. Remember, you will be competing with Ruben.

Senior Editor/Photo Editor, *Astronomy* magazine Michael E. Bakich

Acknowledgements

I would like to thank my editors at Springer, Maury Solomon and John Watson, for supporting my interest in producing this book. Their advice and guidance have been invaluable in bringing this project to fruition.

This book is a compilation of many influences. I first became interested in CCD imaging after hearing Robert Gendler speak at the Connecticut Star Party in 2001. Since then, his lectures on luminance layering and hybrid imaging have influenced my processing routines, and the images in his book, *A Year in the Life of the Universe*, have been an example of what I aspire to create with more humble equipment. Ron Wodaski's book, *The New CCD Astronomy*, served for several years as my basic text for CCD techniques. Mike Rice, at the New Mexico Skies Guest Observatory, provided me with invaluable hands-on training. Neil Fleming has helped me to streamline my focusing routines. Scott Ireland's textbook and Jerry Lodriguss' CD on Photoshop techniques have improved my processing skills. Stephen O'Meara's observing guides have helped me understand more about my celestial targets, and his *Hidden Treasures* have helped me select some of the more obscure targets in my book. Robert Burnham's *Celestial Handbook* has provided valuable background detail on many of the Best Targets. Most of the object data was compiled either from Robert Strong's *Sky Atlas 2000 Companion* or from CCDSoft's program *TheSkySix*. Jay Pasachoff and Alex Filippenko's college textbook, *The Cosmos*, has been a resource for clarifying many of the more difficult concepts in astronomy. Ray Gralak has kindly provided data on the periodic error of several mounts. Finally, I thank Michael Bakich, Photo Editor for *Astronomy* magazine, for selecting many of my favorite images for the Reader Gallery over the past several years. Each inclusion reinforces my interest and enjoyment of this exciting hobby.

Contents

Introduction

How This Book Differs from Observing Lists

Over 200 years ago, many of the celestial treasures on the following pages were cataloged by Charles Messier and William Hershel using telescopes primitive by today's standards. These catalogs have formed the basis of most amateur astronomers' targets for observing. The most famous is Messier's Catalog of 109 objects. Despite their popularity with visual astronomers, Charles Messier's choices were neither the brightest nor the most beautiful through the eyepiece. His list was compiled to define objects that might be confused with comets by other comet hunters – in other words, a list of potential mistakes. Entire regions of the sky, which fell outside of the area where comets might be found, were excluded from his list. This may explain how several bright deep sky objects such as the Double Cluster in Perseus were excluded.

In this century, the growth in quality and accessibility of amateur telescopes has driven an explosion of observing lists. The Herschel 400 list, compiled more than 30 years ago by the Ancient City Astronomy Club of Florida, includes objects selected from Herschel's General Catalog that would "challenge" observers with telescopes 6 in. or larger. In 1995, Patrick Moore published the Caldwell list (his legal last name is

Caldwell-Moore) of 109 objects, which includes both bright and dim objects excluded by Messier. His selection includes some small and challenging targets, not just the crowd pleasers. Most recently, in 2007, Stephen O'Meara published a list of 109 "hidden treasures" that seeks to fill in the gap left by the Messier and Caldwell lists. Like the Caldwell list, O'Meara's list dips deep into the southern hemisphere.

These famous lists are excellent for visual astronomy but can be disappointing for the astrophotographer. For example, a sparse open star cluster sparkles at the eyepiece but can be uninspiring as an image. A small planetary nebula may be striking visually but may be too small to show interesting detail in a photograph. On the other hand, many nebulae that are faint to the eye can have striking texture and hue on long exposures. Spiral galaxies blossom into a rich diversity of shapes and colors.

How the Targets Were Chosen

This book showcases the 100 best targets available to backyard astrophotographers in the Northern Hemisphere. These selections include 48 Messier, 28 Caldwell, and 13 O'Meara objects, plus several others cited in catalogs by Arp, Hickson, Sharpless, and Barnard. Almost a third of the targets can be framed to include multiple objects. The criteria for inclusion were simple:

- Does the image inspire the viewer?
- Is the object bright enough to image with a backyard amateur telescope, an average CCD camera, and 2–3 h of exposure?
- Is it large enough to show detail, usually 5 arcmin or more?
- Can it be photographed successfully from northern latitudes? (This usually requires a declination above –25°.)

Other features favoring inclusion are:

- Among similar objects, is it the easiest to image because of declination, size, color, or brightness?
- Can the object be framed with a second object to create a more dynamic image?

The images on the following pages represent what an average amateur can expect to accomplish with some practice and effort. In some cases, with modest equipment, you can expect to approach the efforts of the best imagers who use large format cameras through sophisticated astrographs on monolithic mounts. In other cases, a more humble image can be quite satisfying. In every case, you will be capturing views of celestial objects matching or surpassing the photographs taken only decades ago from the finest observatories such as Palomar, Lick, Mt. Wilson, and Lowell.

Our goal is to walk you through the steps of choosing an object, acquiring the image, and then processing the data until you say, "Wow!" The date at the top of each entry indicates the day when the target is on the meridian at 9 p.m. standard time (10 p.m. daylight savings time) for observers in the center of their time zone. Accompanying each illustration, the first paragraph gives a brief background about the object and its significance. A second paragraph advises on how to acquire the image, including suggestions on framing, exposures, binning, guiding, and filters. A third paragraph provides specific suggestions for processing the object.

The second section of this book is a brief introduction to digital astrophotography, with an emphasis on CCD imaging with moderately priced equipment. For beginners, we have tried to keep explanations straightforward. For more advanced imagers, we have included some pointers gained from experience (i.e., mistakes!).

What Are We Looking at?

At the beginning of time, the Big Bang spread mostly hydrogen and some helium into the early inflating universe. These gases condensed into the giant luminous stars that populated young, unstructured galaxies, barren of planets, burning brightly yet briefly, and then dying violently in the cataclysm of supernova explosions. These blasts created the heavy elements, which produced the wide expanses of interstellar dust that drift among the Milky Way's spiral arms. Other gravitational interactions collapsed this dust and gas into new generations of stars. These descendants have evolved into the spectacular diversity of clusters, nebulae, and galaxies that entice the astronomer in all of us.

The following 100 targets include 21 images dominated by emission nebulae, often in combination with an open cluster. Clouds of gas and dust abound in our galaxy. In interstellar space, far from any star, the gas is cold and dark. In some cases, a portion of the gas cloud collapses under its own gravity to generate young bright O and B type stars, which form an associated open star cluster. The ultraviolet light from these new stars ionizes the surrounding gas, stripping off electrons. When the electrons recombine with ions, they release photons of discrete energy (and thus discrete wavelengths) as the electrons cascade back down to a lower energy level. One of these wavelengths is termed the hydrogen alpha band, which contributes to the red glow of emission nebula and allows us to image these nebulae with H-alpha filters.

These pages also include six images dominated by reflection nebulae. In these cases, interstellar dust contributes up to 2% of the mass in a gas cloud. These microscopic particles of dust collectively reflect the blue light of nearby stars, both because they are usually associated with young hot stars that shine blue-white, and because dust is more effective in reflecting blue light than red light. For much the same reason, the dust in Earth's atmosphere reflects sunlight to make our sky blue. However, as the dust becomes denser, or collects farther from any stars, it may actually block the light of stars or the glow of hydrogen emission, giving rise to a dark nebula. Depending on the distribution of gas and dust, many of these images contain mixtures of emission, reflection, and dark nebulosity.

With time, the solar winds of these young stars disperse surrounding clouds of dust and gas. They leave the open star clusters shining alone, as illustrated in nine images. The younger clusters will appear to shine blue-white in our images, not because their stars are all the same color but because the red and yellow stars are much dimmer than the blue and white stars. As star clusters age, the short-lived blue stars expire, and the remaining white and yellow stars begin to dominate our images.

An extreme example of stellar evolution is seen in the seven images of globular clusters. These ancient dense clusters of hundreds of thousands of stars are at least 12 billion years old. White and yellow stars comprise most of the stars in the cluster, appearing as countless tiny points of light that appear to merge in the core of the globular cluster. Scattered red giants, swollen to luminosity a hundred times greater at the end of their lifespan, become the largest and brightest individual stars within the image.

Eighteen images show stars at the end of their stellar evolution, either as planetary nebulae (11 images), Wolf–Rayet stars (3 images), and supernova remnants (4 images). Planetary nebulae are created by dying stars that blow off their outer layers once their central supply of fuel is exhausted. The remnant central star is a dense "white dwarf" that can no longer support nuclear reactions, yet provides the ultraviolet torch that illuminates the outer shells of gas. Whereas the lifespan of the star is measured in billions of years, the stunning colors of the planetary nebula last a mere thousand years. Thus, upon their deaths, these stars impart to the universe a brief but memorable gift of beauty.

Thirty-nine images emphasize galaxies. Most are variations of spiral galaxies, including face-on pinwheels, edge-on cylinders, and several peculiar galaxies. Elliptical galaxies are only shown as companions to spirals. Ellipticals are relatively inert, composed largely of older stars, and lacking sufficient interstellar gas or dust to undergo much new star formation. Therefore, elliptical galaxies also lack the red glowing hydrogen-alpha regions, the blue-white clusters of newly formed stars, and the dark dust lanes that enrich images of spiral galaxies.

Thirteen of these galaxy images show groups of two or more galaxies. We imagine galaxies drifting in the endless sea of space, like isolated universes, stable and timeless. Yet most galaxies are associated into clusters and superclusters, constantly interacting, occasionally disrupting each other, and sometimes even merging, with each appearing unique in shape, size, and structure.

As you image these wonders, remember to contemplate their role in the evolution of our universe.

The excitement of any hobby is based on discovery and creativity. Many routes can be followed to the final image, which merges art with science. Adapt these techniques to your equipment, environment, and inclination, and experiment after taking the advice of others. Allow your images to become a unique interpretation of each cluster, nebula, and galaxy.

SECTION ONE

Best 100 Astrophotography Targets

CHAPTER ONE

January: Mostly Nebulae

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January 1: Spiral Galaxy IC 342

Designation	IC 342
Other names	Caldwell 5
Right ascension	03 h 46.8 min
Declination	+68° 06′
Magnitude	9.2
Size	18 × 17 arcmin
Constellation	Camelopardalis

Spiral Galaxy IC 342 closely resembles our own Milky Way Galaxy. At a distance of between 10 and 14 million light-years, a galaxy of this size would be expected to be one of the brightest in the sky. However, because it lies only 10° above the disk plane of the Milky Way, its light is dimmed tenfold by dust within our own galaxy, and therefore was not discovered until 1895. Several prominent hydrogen clouds, termed H2 regions, populate its spiral arms.

Imaging. Frame this galaxy with a field of view of at least 25 arcmin to define the full extent of its spiral arms, although a field up to 40 arcmin can yield pleasing details. Imaging IC 342 can be a challenge despite its large size and relatively bright magnitude of 9.2. Because it is large, this magnitude is spread out, yielding a low surface brightness. Choose a night of excellent transparency, without the distraction of the Moon. A dark sky is especially helpful. If you must image from suburban skies, consider a light pollution filter such as the IDAS. Gather as much luminance data as possible, perhaps over more than one night. For this image, a high-resolution luminance was obtained with a large telescope and lower resolution color channels with a medium-sized telescope. Single-shot color cameras would require very long exposures to capture IC 342.

Processing. Begin processing your exposures of IC 342 with routine calibration, alignment, and combination of images. After balancing color, gently enhance your color intensity. Do not be surprised if the color remains bland or "muddy" within IC 342. You are imaging through galactic dust, which both scatters the blue light of young star clusters and dulls the red of emission nebulae. Sharpen the brighter regions of the galaxy but smooth its outer arms (Fig. 1.1).

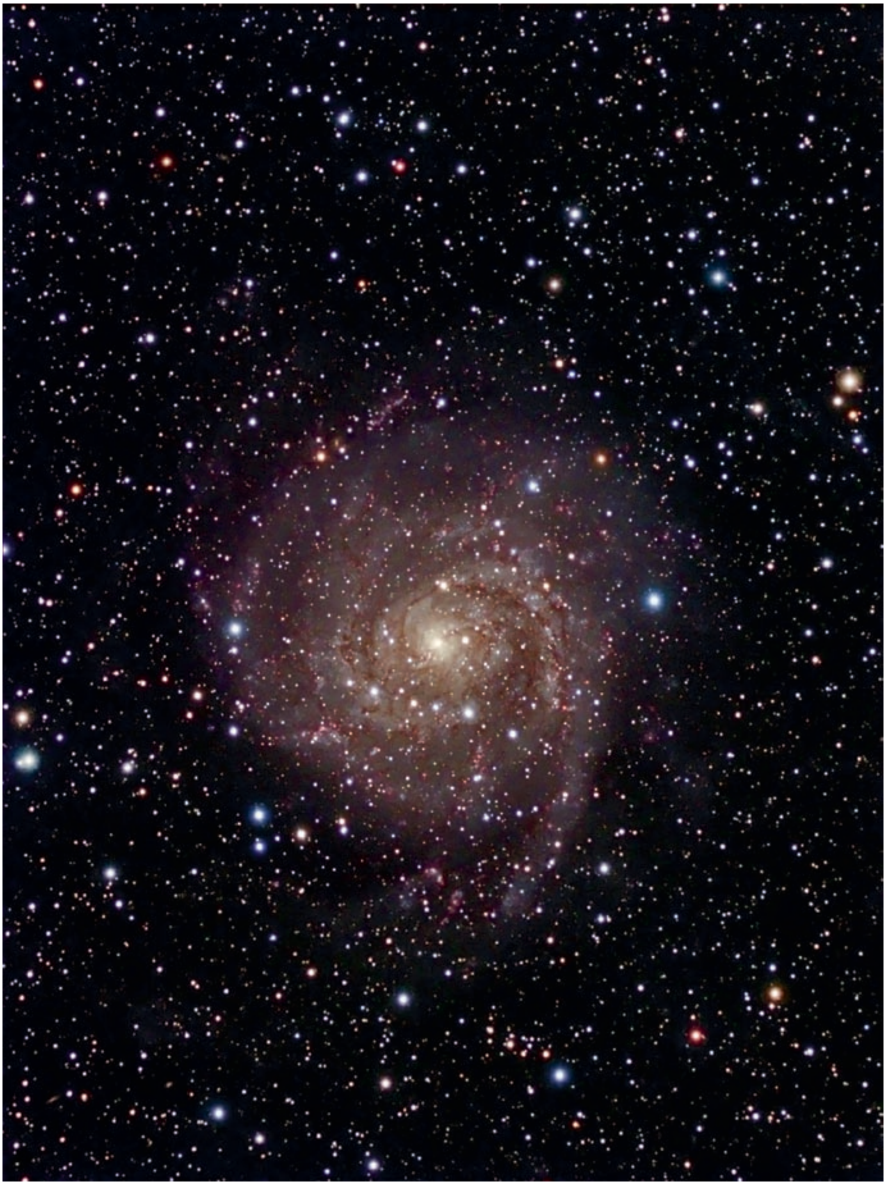

Fig. 1.1. Spiral Galaxy IC 342. East–northeast is up.

Cameras	ST10XME (luminance), ST2000XM (color)
Telescopes	12-in. Meade LX200R at f/7 (luminance) 5.5-in. TEC refractor at f/7 (color)
Field of view	41×31 arcmin
Exposures	Luminance 21×5 min, unbinned R 6×10 min, G 3×10 min, B 4×10 min, unbinned
Scale	1.6 arcsec/pixel
Limiting magnitude	6.0

January 2: Pleiades Open Cluster

Designation	Messier 45
Other names	Pleiades
Right ascension	03 h 47.5 min
Declination	+24° 07′
Magnitude	1.2
Size	110 arcmin
Constellation	Taurus

The M45 Pleiades Cluster contains 500 stars spread across a sphere 14 light-years wide at a distance of 400 light-years. Termed the "Seven Sisters" in mythology, at least seven of the stars can be seen with the naked eye, making a small dipper shape. A telescope can show faint nebulosity of interstellar dust that blossoms in CCD images. The cluster is moving with a radial velocity different from the nebulosity, suggesting that its stars are crossing the path of dust in a molecular cloud (Fig. 1.2).

Imaging. The Pleiades is a challenge because the stars are bright compared to the surrounding nebula. Routine RGB methods or single-shot color is suggested. A separate luminance channel is neither necessary nor desirable. Antiblooming cameras help suppress the excess light of the bright stars from spilling into adjacent pixels in the camera. Even with antiblooming protection, short exposures are required to keep the brighter stars in M45 from overwhelming the image. Consider exposures of 2 min or less if using an antiblooming camera or of 1 min or less if using a non-antiblooming camera. To capture the nebulosity, try to obtain a dozen or more exposures with each filter. Either a short focal length telescope or camera lens that yields a wide field of view is best for framing M45. Because camera lenses and semiapochromatic refractors will focus differently with each filter, make sure to refocus with each filter change.

Processing. When aligning images from different filters, be careful about slight differences in scale. If your focus varied much between filters, the scale will be altered. Some astronomical processing programs will rescale images during alignment, and others will not. If your program does not rescale the images, then wait to combine your color channels in Photoshop and rescale there. The halos around the brighter

Fig. 1.2. Pleiades Star Cluster M45. East is up.

stars are unavoidable, and are caused by internal reflections between the camera and the overlying filters. These can be toned down in Photoshop and other programs by selecting the halos and dimming them (see section "Final Cleanup" in Chap. 15).

Camera	ST2000XM
Telescope	3.5-in. Takahashi refractor at *f*/4.5
Field of view	100 × 75 arcmin
Exposures	R and G each 25 × 2 min, B 45 × 2 min, unbinned
Scale	3.8 arcsec/pixel
Limiting magnitude	6.0

January 6: California Nebula

Designation	NGC 1499
Other names	Sharpless 2-220
Right ascension	04 h 00.7 min
Declination	+36° 37′
Magnitude	–
Size	145 × 40 arcmin
Constellation	Perseus

The California Nebula derives its name from its characteristic shape on long exposure photographs. This gas cloud is located 2,000 light-years away with a total mass of 240 suns and is illuminated by the bright star to its right in this photo. Visually, this emission nebula is hard to observe even with large telescopes, because its dim light is spread over an area four times the size of the Moon (Fig. 1.3).

Imaging. The California Nebula requires a large field of view. Unless you have a giant imaging chip, or are willing to devote the effort to create a mosaic image, your best bet may be to use a camera lens. An old manual 300-mm ED lens purchased on EBay for a fraction of the cost of a new lens was used here. If you use a camera lens, remember to refocus between filters. This image was acquired in the light-polluted skies of Connecticut, using a Hydrogen-alpha narrow band filter for the luminance. Narrow band filters allow high-quality imaging from suburban areas by excluding most light pollution. If you do not have an H-alpha filter, you can still get excellent results with a red filter for luminance. You can bin the images to gather light faster, but you can acquire higher resolution images unbinned. Tracking is not very demanding with the short focal length.

Processing. Because the California Nebula is a purely emission nebula, you would not lose any detail by keeping the H-alpha or red exposures for luminance. A HaRGB- or RRGB-layered luminance works well. A pure H-alpha luminance may create dark halos around small stars. To prevent this, you can match the star sizes of H-alpha luminance to the RGB channels either by blending the H-alpha image with the red channel, using pixel math to combine red with H-alpha, or using the lighten or screen mode in Photoshop to superimpose red on H-alpha.

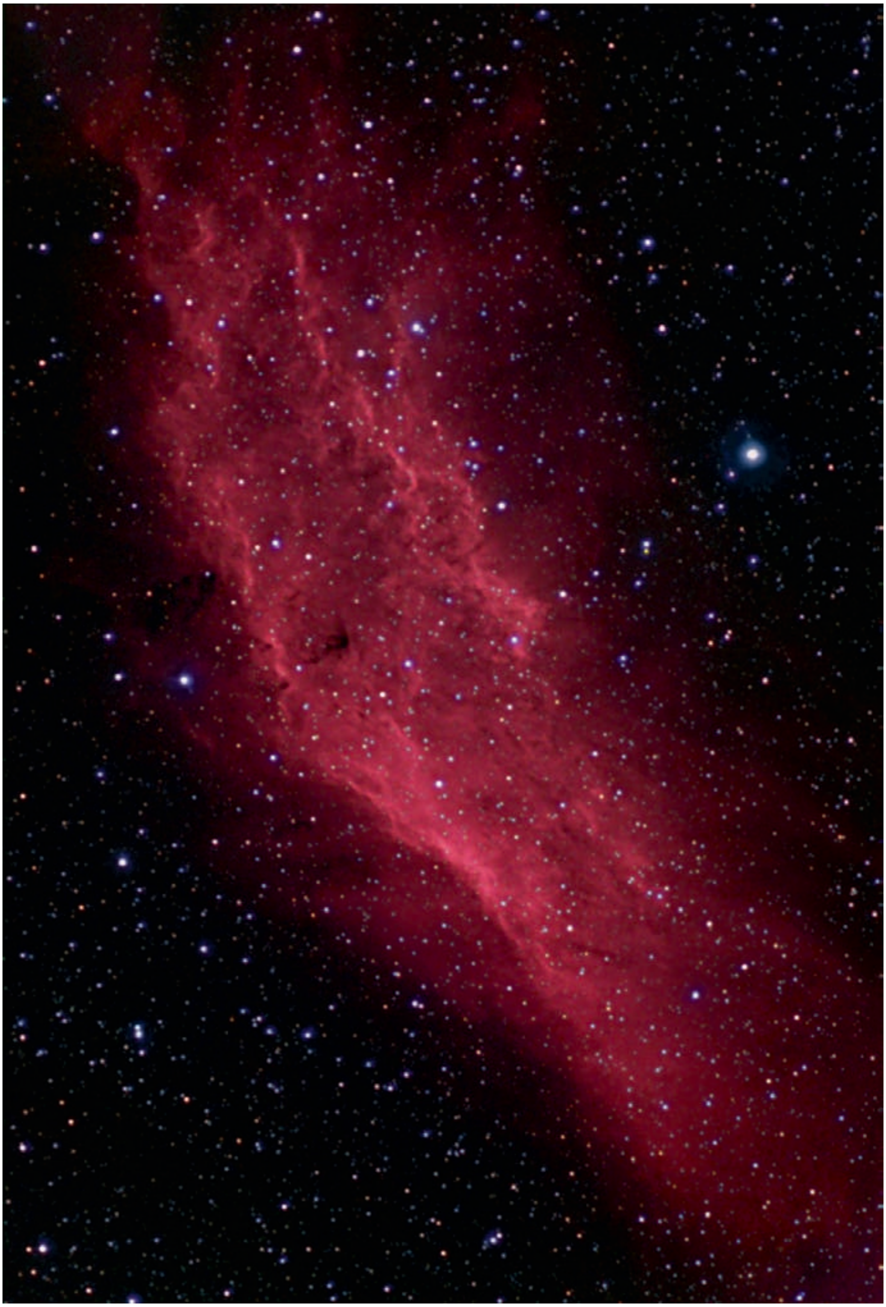

Fig. 1.3. California Nebula NGC 1499. West is up.

Camera	ST10XME
Telescope	300-mm Nikon camera lens at *f*/4.5 lens
Field of view	167×112 arcmin
Exposures	Luminance H-alpha, 24×5 binned 2×2 R 3×5 min, G 4×5 min, B 3×7 min, binned 2×2
Scale	9.2 arcsec/pixel
Limiting magnitude	3.5

January 21: Witch Head Nebula

Designation	IC 2118
Other names	Witch Head
Right ascension	05 h 06.9 min
Declination	–07° 13′
Magnitude	–
Size	180×60 arcmin
Constellation	Eridanus

The faint Witch Head Nebula, 1,000 light-years distant, is composed of small dust grains reflecting blue light from the nearby brilliant star Rigel, which is just beyond the field of this image on the right. Can you make out the large chin, round open mouth, and pointed nose of the wicked witch? Like children lying back on the grass on a summer day, astronomers also gaze at the sky, imagining shapes in ethereal wisps of dust and gas. Human nature tries to create order from chaos (Fig. 1.4).

Imaging. The Witch Head requires a large field of view. This image spans an area 2×1.5°, which barely covers the object. You may prefer to use a camera lens with a shorter focal length to better frame the object. Any light pollution will obscure the nebula. Furthermore, light pollution will introduce background gradients that are exaggerated by the large field of view and (from northern latitudes) by the low altitude of the object. Minimize these effects by trying to image close to the meridian when the Witch Head is highest. A single-shot color camera will require multiple long exposures under a dark sky to capture the dim nebulosity. Tracking is not very demanding with the large field of view.

Processing. After routine calibration, alignment, and combination of exposures, use either digital development (DDP) or multiple applications of curves/levels to bring out the dim nebulosity without bloating the stars. Gently sharpen just the nebulosity with a selection or a layer mask to enhance the detail; avoid sharpening in dim areas and in the background to prevent annoying noise. Finally, after carefully balancing the color, boost the color saturation to display the rich blue and violet nebulosity. Very long exposures from a dark sky may reveal faint red and blue nebulosity in the background, so be careful when correcting background gradients.