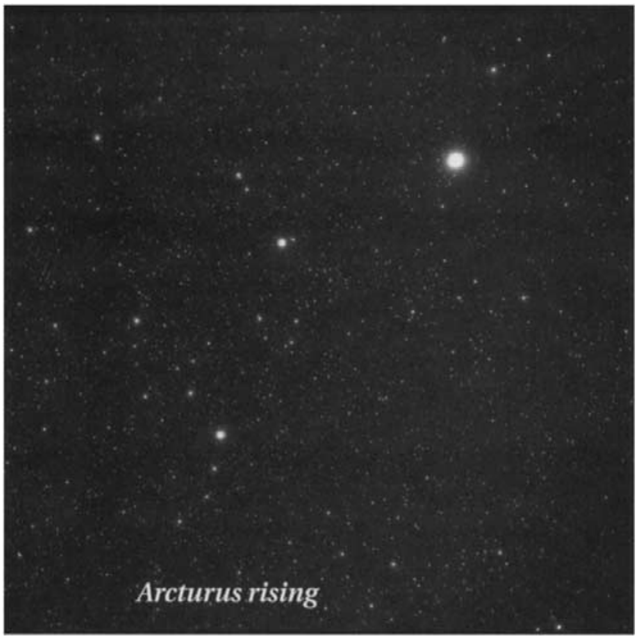
CHAPTER 1
About This Book

On one spring evening in the 1980s I was working late at *Sky & Telescope*, which is produced in three old yellow houses in Cambridge, Massachusetts. My office was on the second floor of one of those buildings, and my desk faced a window that looked out to the south. Everyone else had gone home, the Sun had set, and the stars were just beginning to shine. I love the subtle tones of twilight and soon found myself gazing out the window, transfixed. That's when the phone rang. Usually I wouldn't take a call after hours, but this time I did. On the other end of the line the faint, slightly strained voice of an elderly man asked, "Could you tell me the name of the yellow star shining outside my window?" At first I thought the call might be a prank, but the tone of the man's voice told me otherwise; it had an almost dire quality to it, like that of a sick child asking for comfort. "I remember seeing the star when I was a child," he explained, "but I never bothered to learn its name." He paused a moment to catch his breath. "You see, I'm dying."


Arcturus rising

An electric shock raced up my spine. For a moment I didn't know how to react. I wanted to say something sympathetic; instead, I asked him where he was looking. The star was low in the east, he replied. Without looking, I knew his star. Still, I had to be certain. He deserved that much. I asked the man to hold on, then ran downstairs and dashed outside. The air was cool and still, and it smelled sweet. Looking to the east I saw a stand of trees bursting with fresh spring leaves. How ironic, I thought, as I spied his star above them. And for the first time I really saw that star and realized its significance. I returned to the phone and, with a voice that was both excited and solemn, said, "It's Arcturus." I paused, then added, "or Hoku-lea, the Hawaiian star of gladness, the star that leads great voyagers home." I heard a sniff on the other end of the line, followed by a whispered "Thank you." The phone clicked. I never learned the man's name.

I'll never forget that call. It made me realize how important the stars are to humanity, how comforting they can be in times of distress. But why, I wondered, had this man never bothered to learn that star's name or to pursue his interest in the night sky? There's so much in the heavens to delight our eyes and warm our hearts. By nature we are an inquisitive species. When we smell a rose, the fragrance makes us giddy, and immediately we ask, "What kind of rose is that?" And we learn its name — say, a Lady X. The same happens when we see a flash of red feathers in our yard. "What bird is that?" we wonder. "That's a cardinal," we're told. Pick up a pure green gem, and our mind queries, "Emerald?" And we seek the answer. But how many millions of people look to the sky at night

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and simply say "Wow," leaving it at that? To many the sky is overwhelming, mind-boggling, too metaphysically deep.

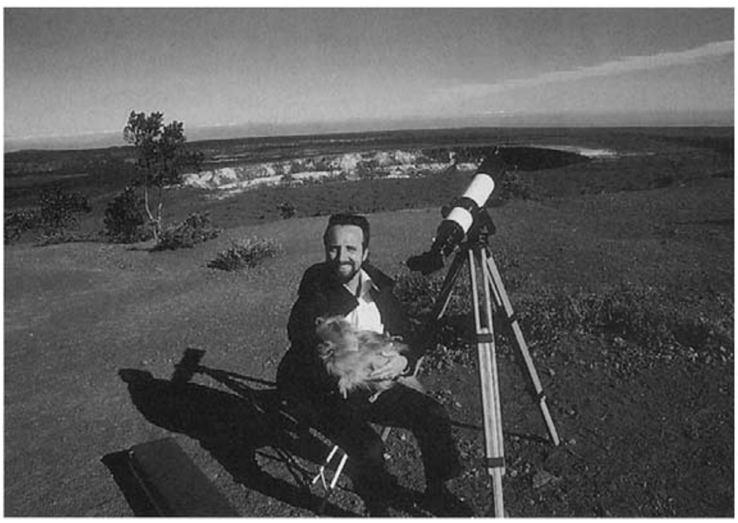
That's why if you're interested in learning the night sky, chances are you'll be alone in your pursuit. You'll be one of many "backyard" astronomers, isolated lovers united under one sky. But we are not really alone. We have friends, we have companions, and they are the ever-loyal stars — and even more, entire clusters and galaxies of them. (What's a cluster anyway, but a family of stars traveling through space?) We have above us a cityscape of starlight. We have within our grasp all the natural wonders in the heavens. And each has a story to tell. To "hear" those stories all we have to do is look, "listen," and read. That's why I've created the *Deep-Sky Companions* series — to help introduce you to some new companions beyond the friendly veneer of stars. It's also why I use a conversational tone in the text. I want you to feel my presence as I describe what it is you're seeing. I want to make your nights less lonely, more complete. The late Leslie C. Peltier opens the sixth chapter of his endearing book *Starlight Nights* with a drawing of a child out under the stars. That child — Peltier himself — holds open before him a book, Martha Evans Martin's classic, *The Friendly Stars*, and you can sense his enamored skyward gaze. When I look at that drawing I can almost hear the book speaking to him, helping him become, as Robert Frost said, "acquainted with the night." Similarly, I try to describe and guide you to each Caldwell object in a friendly and fun manner.

If you're a beginner and have not used *Deep-Sky Companions: The Messier Objects*, I encourage you to do so, because it is . . . well, a companion to this work, the first in what promises to become a family of titles. More important, its second chapter is designed to help newcomers get started in astronomy. That section is not repeated in this work. But do not despair. This book can stand on its own. Its charts and text will enable you to locate each Caldwell object with ease. But they do not eliminate the need for newcomers to learn how to navigate the sky or to become familiar with astronomical terms. If you live in the Southern Hemisphere, please note that the book is written with a definite Northern Hemisphere bias. For instance, when I refer to the object's location above the horizon, it's generally as seen through the eyes of someone living north of the equator. But the star charts, photographs, sketches, and descriptive essays can be used by anyone, anywhere.

FIELD WORK

I live on the Big Island of Hawaii, the same island that supports the fleet of monster telescopes atop the nearly 14,000-foot-high summit of Mauna Kea. My house, however, is in a little town called Volcano at an altitude of 3,600 feet on the burning back of Kilauea volcano. I generally observe from Kilauea's 4,200-foot-summit in the Hawaii Volcanoes National Park. There I get unobstructed views of declinations (celestial "latitudes") as far south as –70°. That means only four Caldwell objects are below my horizon, though that number increases to seven if I want to get a decent view a few degrees above the horizon.

In the photograph on the next page you can see one problem I sometimes have when observing near the horizon of my unique observing site. The dark band skirting the distant horizon is vog, or volcanic smog, from a cone erupting on Kilauea's southeastern flank. When this photograph was taken the vog was concentrated to the east, toward the erupting vent; on other days the vog can drift farther to the south. It's not always a menace, but sometimes vog can back up and cause a smelly whiteout in Volcano. On average, Kilauea releases anywhere from 350 to 1,850 tons of sulfur dioxide per day; about 90 to 260 tons of that is released at the summit, where I observe. When sulfur dioxide is released at the summit it reacts chemically with moist air to form sulfuric acid or, with water vapor, acid rain. With a pH as low as 2.0, this acidic precipitation keeps the landscape around the crater nearly devoid of vegetation, which is why my horizons are free of obstructions.



I'm not trying to give you a geochemistry lesson. I just thought you might like to know that after I completed the observations for *Deep-Sky Companions: The Messier Objects*, I discovered a problem. Four years of exposure to the acidic Kilauea environment had all but obliterated the coatings on the objective lens of my 4-inch Tele Vue Genesis refractor. The glass elements also had some strange semitransparent blemishes, like alien bacteria magnified a million times over, and hairy growths had taken hold around the objective's elements, on the telescope's diagonal mirror, and . . . well, all over. Some of those abstract creations might have been mold nurtured by the tropical downpours of La Niña. I suppose I could have sacrificed the scope to the volcano and then gone out to buy a new one. But I'm a sentimental observer. Not only do I love my Genesis, I love my old, beat-up, sulfur-eaten Genesis. I wanted to observe all the Caldwell objects with it. So I called Tele Vue Optics founder Al Nagler, a true friend to the amateur community, and asked if his company could clean up an old friend. "Of course," Al said. So the telescope went on a 6,000-mile journey to New York. A week later, Al called. "Stephen!" he cried (not really), "what did you do to this telescope?" After I told him, I think I heard him faint and hit the floor.

Anyway, I got my Genesis back with a card from the optician, who said Al was still recuperating. I unpacked the telescope and looked at the lens — perfect. I had back my old 4-inch f/5 (500-mm) Genesis refractor. (Actually, Al recently looked up this telescope's original "specs" and told me that it has a focal length of 504.8 millimeters.) And with this new lease on life, my Genesis turned its tiny 4-inch eye out over the volcanic landscape and began hunting down, one by one, the 102 Caldwell objects I planned on observing from Hawaii. To my surprise I was also able to use my restored Genesis to make an additional, dramatic sighting: I spotted NGC 4833 (Caldwell 105) just 13′ above the southern horizon, making it the most southerly Caldwell object visible from the United States.

For this five-year-long study I used three eyepieces (also made by Tele Vue): a 22-mm

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Panoptic, a 7-mm Nagler, and a 4.8-mm Nagler. On the Genesis these eyepieces provide magnifications of 23×, 72×, and 105×, respectively. A 1.8× Barlow lens gave me additional magnifications of 41×, 130×, and 189×, while a 3× Barlow gave me high powers of 216× and 315×. On the Genesis 216× is equal to a textbook 54× per inch of aperture, while 315× gives nearly 80× per inch of aperture — perfect for those nights when the atmosphere is extremely steady, or for high-power observations of planetary nebulae. Occasionally I would pop in some of my old Fecker eyepieces, which I used for planetary observing a quarter century ago with the 9-inch and 15-inch refractors at Harvard College Observatory. These eyepieces aren't manufactured anymore, though they are superb two-element eyepieces (albeit with little eye relief). Observing with them is sort of like looking through the eye of a sewing needle, but the star images are tack-sharp. It is with these eyepieces that I made pre-Voyager 1 observations of the spokes in Saturn's rings and determined the rotation period of Uranus's cloud tops (pre-Voyager 2) among other things. Unfortunately, because of their minimal eye relief, only a handful of today's observers would feel comfortable using these eyepieces. On this project I employed these veterans only when I needed to search for, say, a planetary nebula's central star, or to try to resolve a troubling knot in a galaxy's arm. As a "finderscope" I now use a Tele Vue Qwik Point (it's like a laser pointer). The Genesis offers me a field of view nearly 3° wide when I use the 22-mm Panoptic, and I can't remember a time when I had trouble locating an object with that eyepiece and the Qwik Point.

The weather, as anywhere, can be weird in Volcano. Clouds can suddenly appear out of nowhere and force me to move my telescope. But that's another reason why I like the Genesis and its sturdy Gibraltar mount; in two minutes I can pack it up and move on. (I hope Al never sees the mount, though, because one leg is being held together by duct tape, and it has all manner of love taps and bruises.)

In the five years it took to make the observations in this book, I watched my night sky brighten, not from light pollution but from airglow. When I made the observations for *Deep-Sky Companions: The Messier Objects* in the mid-1990s, the sky over Hawaii was the darkest it had been in 10 years, with sunspot minimum occurring in 1995. But when I began observing the Caldwell objects in 1996, solar activity had begun to rise, and sunspot data indicate that solar maximum occurred in May 2000, just as I was wrapping up. The increase in natural sky brightness over the years was subtle yet remarkable. For instance, in June 2000, shortly after astronomical twilight, the base of the zodiacal light stretched across the northern horizon, where I saw an extremely pale green glow at a height of about 10°. This latter luminescence was not artificial light pollution but airglow, a sort of permanent aurora that intensifies during heightened solar activity. Overhead, the effect dims starlight, perhaps by a magnitude. It's an incredible phenomenon.

By emphasizing natural, not manmade, light pollution, I do not want to give you the impression that everything is rosy in Volcano. In the seven years that I've lived here I have seen unnatural changes in the night sky as well. I had been traveling to the island of Hawaii for 15 years before I moved here in 1994. Now, for the first time in about 20 years, I can see skyglow emanating from Hilo, 25 miles to the northeast, and from some closer subdivisions. It's not much compared to what others have to contend with at dark sites on the U.S. mainland, and the artificial glow only appears when there is moisture in the air. But it's there. I've also seen our village grow and more streetlights go up. An armed-forces recreational facility in the national park was recently renovated, and this has added light to the summit environment. The saddest experience I've had, though, occurred one night as I traveled to the summit of Mauna Kea and noticed a strange dim reflection on the west side of the Keck Observatory domes. Light from Kona, 14,000 feet below the observatory, was defiling these temples to the stars. The eastern horizon had an unhealthy pallor caused by Hilo's sodium-vapor lamps, whose brightness seemed to have intensified. And lights from the neighboring island of Maui, which I had never noticed before, burned through low clouds to the northwest. "But there are lighting ordinances and low-pressure sodium-vapor lamps on the island, aren't there?" you ask. Well, yes. That's true. But take a drive around the island. Most of the lights are unshielded, and extended-tube lighting is becoming more widespread. Many of the new lamps are overpoweringly strong, so much so that the roads are difficult to see in a rainstorm. And so it's happening: one of the last untouched astronomical frontiers is being peeled away in strips. I suppose that as long as the major observatories have their filters, they're all set, unlucky as we may be down below. But I have not sat idle. I have met with senators, local entrepreneurs, and park officials. I've given lectures on light pollution and voiced my concerns at meetings. Some village businesses such as the Kilauea Lodge and the Steam Vent Cafe took immediate action to shield or remove troublesome lights. So light pollution can be mitigated. It just takes a little time and faith in the human condition.

My first Hawaii observation for *Deep-Sky Companions: The Caldwell Objects* took place in August 1996, and my last in August 2001. Between those dates I made two trips to New Zealand (one successful, one dampened by clouds), and one to South Africa, to observe the southernmost Caldwell objects. In August 1997 I was a guest at the Auckland Observatory (in Auckland), at Carter Observatory (in Wellington), and of amateurs Rob and Lesley Hall in Wellington. Auckland Observatory has a fantastic 20-inch f/13.5 Zeiss reflector with a 4½-inch refractor as a finderscope. Despite the temptation to use only the 20-inch, I primarily observed the globular star clusters Caldwell 105 (the one I saw 13′ above my Hawaii horizon), Caldwell 107, and Caldwell 108 with the 4½-inch finder, whose aperture was comparable to that of the Genesis — though I did spy the objects through the main scope as well. In fact, my drawings of these objects are composites based on these views. While the main structures and shapes represent what was seen through the 4½-inch at 19×, 75×, and 150×, I added stars seen through the 20-inch. I did this because I was observing under the light of a bright gibbous Moon; my moonlit views through the 4½-inch alone were not representative of what patient observers could hope to see under darker skies with a small telescope. And though I also observed Caldwell 109 (a planetary nebula) with the 4½-inch, my drawing of it is based solely on my view through the 20-inch. This planetary is easily visible in any small telescope, but small apertures reveal only its swollen disk.

My observations of Caldwell 103, 104, and 106 (and Caldwell 107, again) were made with a Celestron 8-inch Schmidt-Cassegrain in the Halls' Wellington backyard. As I explained in *Deep-Sky Companions: The Messier Objects*, the 4-inch Genesis under a dark sky shows as much detail in an object as an 8-inch Schmidt-Cassegrain does from a suburban sky. Therefore I did not stray from my mission.

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Why didn't I bring the Genesis to New Zealand? That's simple. I would have had to check it as luggage, and the airline was unwilling to reimburse me if the telescope were lost en route. Why New Zealand? It's beautiful and I have friends there — and that's half the observing experience.

I have been traveling to the Southern Hemisphere since 1982, and over the years I have accumulated impressions of some of the more prominent Caldwell objects through a variety of instruments. I observed some of them through Carter Observatory's impressive 9-inch refractor in 1982. Four years later I observed some from the Australian outback. I've spied a few during visits to Central America; and I've seen others from the altiplano in Bolivia and game reserves in South Africa. But for this book, I've focused on how 96 percent of these objects look through the same 4-inch telescope from my home in Hawaii.

HOW TO USE THIS BOOK

To locate a Caldwell object, first look up its celestial coordinates (right ascension and declination) in its section of Chapter 2, or in the table in Appendix A. Next, flip to the all-sky maps located on the endpapers and use the coordinate grid to find the object in the sky. Take note of the brightest stars (those with Greek letters or Flamsteed numbers) that lie within a few degrees of your Caldwell pick. Next, locate those stars on the detailed finder chart that accompanies the object's photograph and text in Chapter 2. (The detailed finder charts in Chapter 2 are oriented with north up and west to the right.) Finally, find the part of the text that describes how to locate the object and simply follow the directions.

Each object's entry in Chapter 2 opens with a photograph (oriented with north up and west to the right, unless otherwise noted) and a list of essential data: Caldwell number; common name(s), if any; NGC, IC, or other catalog number, if any; object type; constellation; equinox 2000.0 coordinates; apparent magnitude; angular size or dimensions; surface brightness in magnitudes per square arcminute (for galaxies); distance; and the object's discoverer and discovery date. The text includes a history of the object's discovery; recent research findings; naked-eye or binocular impressions; the object's appearance through the 4-inch Genesis refractor at various magnifications; descriptions by other observers using larger instruments; a visual challenge or two; and brief notes on any interesting objects in the same patch of sky.

A drawing also accompanies the text, so you can compare your view of any Caldwell object with my own. The views may be very dissimilar, but that's okay; seeing things differently is a human condition.

You'll find William Herschel's original published description of the object or, if William did not observe the object, his son John's. Deep-sky aficionado Barbara Wilson (like Larry Mitchell, a member of the Houston Astronomical Society, and a modern incarnation of William Herschel) supplied me with William's original notes, which she drew from his original catalogs as they appeared in the *Philosophical Transactions* of the Royal Society of England.

John Herschel's quotations have been gleaned from a variety of secondary sources. For objects in the northern skies I relied on *Burnham's Celestial Handbook* and Walter Scott Houston's "Deep-Sky Wonders." For the southern objects I used Herschel quotes as 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

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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." John Herschel resided in South Africa from 1834 to 1838, during which time he cataloged more than 1,700 clusters and nebulae. During his stay 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.

Incidentally, when Barbara and I began to compare William's notes with the descriptions in the 1864 *General Catalogue of Nebulae* (or "*GC*," as it is commonly called), we noted that the *GC*'s descriptions of a given object do not always match William Herschel's. For example, compare William Herschel's description of NGC 7023 (Caldwell 4), a reflection nebula in Cepheus, with that in the *GC*:

W. HERSCHEL: [Observed 18 October 1794] A star of 7th magnitude. Very much affected with nebulosity, which more than fills the field. It seems to extend to at least a degree all around; fainter stars, such as 9 or 10 magnitude, of which there are many, are perfectly free from this appearance. (H IV-74)

GC: Extremely faint, star of 7th magnitude in nebula (?).

John Herschel compiled the data for the *GC*, and he based the object descriptions largely on his observations and his father's. Thus I have included *GC* descriptions for Caldwell objects, when available. The *GC* descriptions that don't match William's original notes probably reflect observations made by John Herschel and not by his father.

An *NGC* description (whenever available) follows each Caldwell object's *GC* description. In 1888 Johann Louis Emil Dreyer published a modified version of the *General Catalogue*; he merged the *GC* and all prior catalogs, as well as any new discoveries available to him, into a new catalog: the *New General Catalogue*, or *NGC*. The *NGC* repeated most of the original *GC* object descriptions unaltered. But every now and again we find slight, and sometimes major, variations. Compare the following *NGC* description of NGC 7023 with Herschel's original description and that from the *GC*, given above:

NGC: A star of 7th magnitude in an extremely faint, extremely large, nebulosity.

The Caldwell Catalog also includes descriptions from the *Index Catalogues*, supplements to the *NGC*. Caldwell 5, for instance, is the 342nd object in the Index Catalogues, and thus goes by the name IC 342. And Caldwell 9's moniker, Sh2-155, identifies that nebula as the 155th object in Stewart Sharpless's *Catalogue of H II Regions*, which appeared in the December 1959 *Astrophysical Journal Supplement*.

At the end of each Herschel description is a code contained in parentheses ("H IV-74," for instance, or "h 34"). This code dates to a classification system created and used by the Herschels. "H" stands for the elder Herschel and "h" for his son.

Nothing is ever simple when dealing with historical observations, so I'll make this point brief. William Herschel had his own numbering system for his objects. So did John. When John Herschel combined his observations with his father's to create the *General Catalogue*, he created an entirely new numbering system. Of course, when Dreyer modified the *GC* to create the *NGC*, he did away with the *GC* numbering system and assigned to the objects the *NGC* numbers we use today. Here's an example of the possible confusion: Caldwell 2, a planetary nebula in Cepheus, is also H IV-58, h 8, GC 20, and NGC 40.

Now to explain the Roman numerals and numbers in William Herschel's system. The Roman numeral identifies the class into which 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 IV-58 is the 58th object in Herschel's Class IV (planetary nebulae).

Herschel and *GC* designations no longer see much use. But I give them here for two reasons. William Herschel's designations tell us something about the 18th-century perception of these objects' very natures. Remember that Herschel did not know about galaxies as we think of them today, and he believed that planetary nebulae were solar systems in formation. In fact, Herschel believed that *all* nebulae could be resolved into stars provided the observer used a telescope of sufficient aperture and magnification. Indeed, some of his "clusters" are actually galaxies peppered with foreground stars, while many of his "nebulae" are in fact galaxies — island universes like our Milky Way, endowed with billions or trillions of stars.

These classical descriptions have also helped me, and other astronomers, solve some historical mysteries attending several of the Caldwell objects. The histories of many of these objects have never been published in any detail in the popular literature, and this book required extensive research. In doing the research, I have found some perplexing puzzles. Two of the most dramatic examples of this kind of historical detective work are provided by the open cluster NGC 6885 (Caldwell 37) in Vulpecula and the nebula-and-cluster complex that was listed as IC 2944 (Caldwell 100) in the original Caldwell Catalog. The findings are too complex to discuss here, but I encourage you to read the fascinating accounts given in Chapter 2.

As these accounts make clear, I did not solve the puzzles alone. Barbara Wilson and Brent Archinal (U.S. Naval Observatory) were my main archive companions, and in some cases we had to call upon the assistance of other sleuths, all of whom are credited in the essays in the next chapter. The historical mysteries were rather vast. Roughly half of the objects in the Caldwell Catalog were subjects of some historical intrigue. For instance, are you aware that many observers (including professional astronomers) do not know which star in the Kappa Crucis Cluster (Caldwell 94) is Kappa Crucis? Do you know the proper designation of the Cocoon Nebula (Caldwell 19)? (According to Archinal, the "Caldwell Catalog has it right and everyone else has it wrong.") And did you know that Eta Carinae (in Caldwell 92) may have pulsed in and out of view since the dawn of humanity? These are but a few of the many findings that follow in the individual Caldwell accounts.

MAGNITUDES THEN AND NOW

One important, albeit technical, point of historical contention involves the apparent magnitudes of stars and deep-sky objects. In *Deep-Sky Companions: The Messier Objects* I thoroughly discuss limiting magnitudes and the origins of the magnitude formula we use today. But what about the magnitudes we see in the historical records? How do they compare to those that

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we use today and to one another? I was always fascinated by the following entry in the log of the 19th-century Harvard astronomers William Cranch Bond and his son, George. On October 11, 1847, these men used the Harvard College Observatory's 15-inch refractor to probe the depths of the Trapezium star cluster in the Orion Nebula. While doing so they found that "a star of the *fifteenth* magnitude is seen with this Telescope within, or less than, twenty minutes of sunrise, and this without any particular effort, a good evidence of its tenacious grasp of light" (emphasis mine). How could this be, I long wondered — seeing a star more than a full magnitude fainter than Pluto in bright twilight?

Now consider the brightness of the central star in NGC 40 (Caldwell 2), a planetary nebula in Cepheus. William Herschel estimated the star to be of magnitude 9, the *GC* records it as magnitude 10, and the *NGC* (as well as many modern references) lists it as 12th magnitude. Has the star faded over the years? It's certainly possible. Many central stars of planetary nebulae vary in brightness. Does this string of historical data prove that this particular star did so? Not necessarily.

In the *Monthly Notices* of the Royal Astronomical Society (Vol. XVII, 1857), Rev. Norman R. Pogson, the father of our modern magnitude formula, points out that, though many "great catalogue-makers" adopted his brightness ratio of 2.512 between stars that were one magnitude apart (so a difference of five magnitudes would correspond exactly to a brightness ratio of 100 to 1), some great observers of his day adopted *different* ratios — among them the Struves, William Dawes, the Bonds, John Herschel, and Adm. William Henry Smyth. The implications are extraordinary.

Pogson explained that the Struves had 6 magnitudes spanning the entire range between the limit of naked-eye vision (namely, 6th magnitude) and the visual limit of his 15-inch refractor (namely, 12th magnitude). This implied that each successive step on the apparent-magnitude scale corresponded to a brightness ratio of 4. By contrast, Pogson's ratio suggests that the visual limit for that telescope was magnitude 15.1, more than 9 magnitudes fainter than the dimmest stars visible to the naked eye. Dawes adopted Struve's ratio. The Bonds, on the other hand, chose to designate the visual limits of 1-inch and 15-inch telescopes as magnitudes of 9 and 20, respectively, while Herschel divided such stars between magnitudes of 6 and 18. And Smyth "took 16th magnitude as the limit for [an instrument with an] aperture of 5.9 inches" while Pogson's formula suggests a limiting magnitude of 13 for a telescope of that size.

Pogson's table, reproduced on the next page, allows us to get a feeling for the visual limiting magnitudes that Struve, Bond, Herschel, and Smyth would have attributed to instruments of various apertures. It gives, in the first column, a "standard" magnitude, with each step corresponding to a decrease in stellar brightness by a factor of 2.512 (Pogson's ratio). The second column gives the "apertures required by an *average sight* to reduce such stars to a limit of vision" (emphasis mine) — in other words, the aperture required to make such stars visible at the eyepiece (assuming that the fully dark-adapted eye has a limiting magnitude of 6.0 and a pupil diameter of 0.23 inch, or 5.8 mm). And the remaining columns show the corresponding limiting magnitudes of Struve, Bond, Herschel, and Smyth.

The table's bottom line tells the story by itself. Through a 14.4-inch telescope Pogson's "average" observer would see stars as faint as 15th magnitude, while Struve would deem the limit 12th magnitude; Bond, 20th magnitude;

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STANDARD MAGNITUDES	APERTURES IN INCHES	CORRESPONDING MAGNITUDES OF			
		STRUVE	BOND	HERSCHEL	SMYTH
6	0.229	6.0	6.0	6.0	6.0
7	0.363	6.6	7.0	7.3	7.0
8	0.575	7.3	8.0	8.6	8.0
9	0.912	8.0	9.0	10.0	9.6
10	1.44	8.6	10.0	11.3	11.2
11	2.29	9.3	11.6	12.6	12.8
12	3.63	10.0	12.9	13.9	14.4
13	5.75	10.6	15.2	15.2	16.0
14	9.12	11.3	17.5	16.6	—
15	14.4	11.9	19.8	17.9	—

and Herschel, 18th magnitude. So it's clear we have to take into account the magnitude scale used by each observer before saying anything definitive about an object's apparent brightness — much less any brightness changes — on the basis of their logs. A discussion of *your* telescope's visual limits can be found in *Deep-Sky Companions: The Messier Objects*.

DATA SOURCES

The data in this book were drawn from a variety of modern sources. Many of these sources were used in *Deep-Sky Companions: The Messier Objects*, so you can compare the properties of the respective catalogs' objects with confidence. Generally speaking, recent research findings on the physical nature of these objects were gleaned from the *Astronomical Journal* or the *Astrophysical Journal;* citations are frequently 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.

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

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Stellar Magnitudes and Spectra

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