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Cambridge University Press
978-0-521-85893-9 - Steve O'Meara's Herschel 400 Observing Guide
Steve O'Meara
Excerpt
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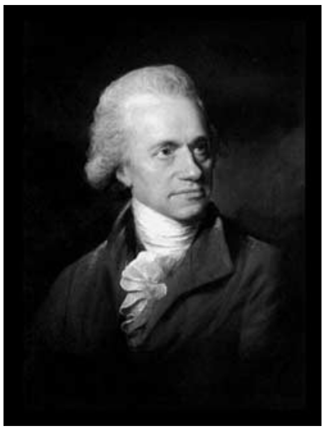
Introduction

Before you set off to observe the Herschel 400 objects, you should know a little about the man who discovered the vast majority of them, and his equally remarkable sister.

Friedrich Wilhelm (later William) Herschel (1738–1822) was the pre-eminent astronomer of his time. Born on November 15, 1738, in Hanover, Germany, Herschel began his career as a musician and composer. In the fall of 1757, the 18-year-young man moved to England. After 10 years of a weathery existence, he settled down in Bath, where he made a comfortable living as an organist, teacher, and concert director. In 1772, Herschel's beloved sister, Caroline (1750–1848), joined him in Bath, where she helped keep her brother's house while enjoying a brief career as a vocalist. She also arrived in Bath at a most auspicious time: when William's passion for music was being eclipsed by his passion for making telescopes and observing the night sky.



William's career changed dramatically after March 13, 1781, when he discovered a new planet (Uranus) with a 6.2-inch reflector set up in his backyard. The following year, King George III offered him the position of court astronomer with an annual salary (of £200) for life; the reward allowed Herschel to give up music and make astronomy his career. The King subsequently made an allowance of £50 a year to Caroline as her brother's assistant, making her the first professional female astronomer. In 1772, William and Caroline moved to Dachet near Windsor Castle, where William began making increasingly larger reflecting telescopes. By the fall of 1783, he was sweeping the heavens with his large 20-foot reflecting telescope, which had an aperture of 18.7 inches. Mainly he used this telescope to survey double stars; little was known about the nature of these stars and their motions, and Herschel's examination of them – he often observed 400 a night – was the first systematic survey.

Meanwhile, Caroline's astronomical career was also blossoming. In August 1783, William surprised her with a gift of a homemade telescope, which she used to sweep the heavens for new comets; her success in this new venture led to her own fame and glory. While sweeping the heavens, she also discovered several deep-sky objects not on Messier's list. Her success impressed William, who suddenly became curious about the abundance of these new, unseen wonders. As Barbara Wilson notes in her biography of Caroline,* it was Caroline's "rash of deep-sky discoveries that prompted William to turn his attention away from double-star observing and to start his greatest endeavor – a systematic search for nebulae with his large 20-foot telescope, which began shortly after Caroline made her twelfth deep-sky discovery on October 30, 1783."

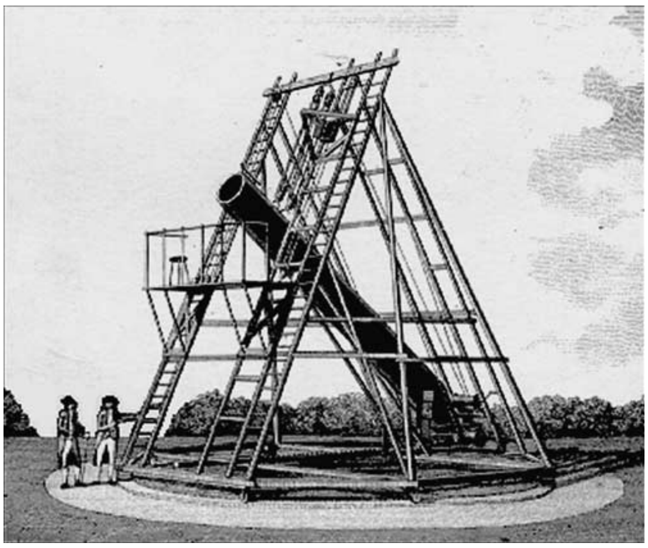
After some experimental attempts, William began a new systematic survey of the heavens with his large 20-foot reflector. After 20 years of review, William had discovered and cataloged (with the help of his sister) no fewer than 2,508 new "nebulae" and "clusters." His first official series of sweeps commenced on December 19, 1783, and the fruits of his labors led to the creation of his first *Catalogue of One Thousand New Nebulae and Clusters of Stars*, which was published on April 27, 1786. He published his *Catalogue of a Second Thousand of New Nebulae and Clusters of Stars* on June 11, 1789, and a final *Catalogue of 500 New Nebulae, Nebulous Stars, Planetary Nebulae, and Clusters of Stars*, was published on July 1, 1802.

I say "nebulae" and "clusters" because in Herschel's day no one knew the true nature of these objects. As William peered into the eyepiece of his large telescope, he could only imagine what wonders were before him. Yet the man displayed remarkable aptitude and deductive reasoning as he contemplated their natures. As Larry Mitchell explains, in his biography of William,** "Herschel carefully analyzed everything he saw in the night sky, and he tried to understand what all astronomical objects were composed of, and how and why they acquired their diverse forms."

To make better sense of the varied objects he was seeing, Herschel created a system to classify them. The code he created is the letter H, followed by a Roman numeral and an Arabic number – H I-11, for instance. The H stands for

* "Caroline Herschel: no ordinary eighteenth-century woman." Barbara Wilson, in *Deep-Sky Companions: Hidden Treasures*, Stephen James O'Meara (Cambridge: Cambridge University Press, 2007).

** "William Herschel: the greatest visual observer of all time." Larry Mitchell, in *Deep-Sky Companions: The Caldwell Objects*, Stephen James O'Meara (Cambridge, MA: Sky Publishing and Cambridge: Cambridge University Press, 2002).



William Herschel, the Roman numeral identifies the class into which Herschel placed each object:

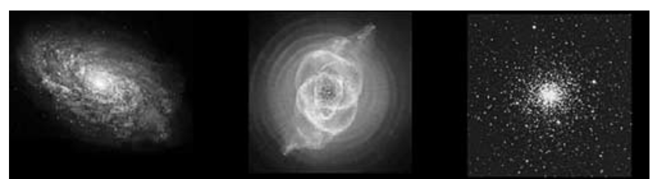
- I (bright nebulae)
- II (faint nebulae)
- III (very faint nebulae)
- IV (planetary nebulae: stars with burs, with milky chevelure, with short rays, remarkable shapes, etc.)
- V (very large nebulae)
- VI (very compressed and rich clusters of stars)
- VII (pretty much compressed clusters of large or 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 I-11 is the 11th object in Herschel Class I (bright nebulae).

With this and other data before him, Herschel tried to fathom the construction of the universe. At first, he believed that all nebulae could be resolved into stars, given sufficient aperture. But by the turn of the nineteenth century, he had changed his mind, believing that some nebulae were indeed composed of some form of luminous matter. In William's new cosmology, the universe was in a state of flux.

As Mitchell explains, Herschel believed that "[n]ebulae and star systems slowly developed over time under the constant action of gravity, and the source of their luminosity was unknown. A nebula that was a little brighter in the middle than along its periphery had not undergone much central attraction and therefore was not very advanced. A nebula 'gradually brighter in the middle' was in a more advanced evolutionary state, while one that appeared 'gradually much brighter in the middle' was even more evolved." To Herschel, planetary nebulae were highly evolved nebulae, and globular star clusters (which he found lying near dark vacancies in the heavens) were objects that had somehow congealed to form these dark voids.

Had William and Caroline been alive today, they would have marveled at the images of their discoveries taken with our great telescopes. Today, we now know that many of the Herschel nebulae are actually galaxies – vast citadels of stars, dust, and gas, held together by gravity; these island universes range from tiny dwarfs measuring a few hundred light-years across and containing a few million stars, to spectacular systems spanning over hundreds of thousands of light-years and containing several trillion stars (below, left). Some of the nebulae are planetary nebulae – luminous shells of matter spewed forth by sun-like stars as they near the end of their lives (below, middle). Still other nebulae turned out to be very distant globular clusters, orbs of ancient starlight, some 10 to 14 billion years old that reside in the Milky Way's halo tens of thousands of light-years distant (below right).



H I-77 (NGC 4414) H IV-37 (NGC 6543) H VI-40 (NGC 6171)

How lucky we are today. When we look through our telescopes at the faint, fuzzy glows that Herschel tried so desperately to understand, we see them with the added dimension of knowledge. So no matter how dim and faint a Herschel 400 object appears in your telescope, be thankful that, at least, as the poet Robert Frost had penned, we are, "Acquainted with the Night". Besides, to quote Frost again, "Do we know any better where we are[?]"

My observing site and telescope

The observations for this book were made from Volcano, Hawaii, where I live. Volcano is on the island of Hawaii – the youngest, largest, and most southerly of the Hawaiian islands. Also called the Big Island, Hawaii comprises five coalescing shield volcanoes of various ages. The tallest, Mauna Kea, is nearly 14,000-feet high and is occasionally snowcapped. It is also home to many of the world's largest and most technologically advanced telescopes, including the twin 10-meter Keck telescopes, the 8.2-meter Subaru telescope, and the 8-meter Gemini North telescope.

I'm often asked why I don't observe from the summit of Mauna Kea. While viewing the heavens from this lofty peak is an experience almost beyond imagining, conditions at the summit can be severe. (Remember, any professional astronomer observing atop Mauna Kea does so inside an enclosed and heated structure and is most likely monitoring a computer

screen, not standing outside with a telescope enduring the elements.) Outside the mighty observatories, the air is crisp and dry, with temperatures that typically hover near, or fall below, freezing. Winds can be strong; during severe conditions, winds can whip up to over 100 miles per hour. Also, the atmospheric pressure at the summit is 40 percent less than at sea level, so less oxygen is available to the lungs, and acute mountain sickness is common (though I have yet to suffer such conditions). But what concerns me, a visual observer, the most is that less oxygen is available to my eyes and mind, putting me at a disadvantage fully to appreciate and see the wonders above, unless I'm sucking on bottled oxygen.

Besides, there's no need for me to travel to Mauna Kea, because my home and its surroundings have world-class skies. I live at an altitude of 3600 feet, just a few miles from the 4200-foot-high summit of Kilauea, a gently sloping shield volcano that has been in near-continuous eruption since January 1983. Most of the observations for this book were made in the summit area of Kilauea Volcano (shown below). The large circular depression near the middle of this frame is the volcano's caldera, which measures about 2.5 miles long and 2 miles wide. The smaller pit is Halemaumau crater, which spans about 1000 feet (305 meters). Some of the observations were made from my front yard (see above right).

I observed all of the Herschel 400 objects with an old Tele Vue 4-inch f/5 Genesis refractor. I generally used only three eyepieces (also made by Tele Vue): a 22-mm Panoptic, a 7-mm Nagler, and a 4.8-mm Nagler, which provided magnifications of 23×, 72×, and 105×, respectively. Some of the planetary nebulae, especially, required higher magnifications to see well. In these cases, I employed either a 1.8× or a 3× Barlow lens in combination with the eyepieces listed above. As a finder I use a Tele Vue Qwik Point (it's like a laser pointer). The telescope sits in the cradle of a sturdy Gibraltar altazimuth mount; the entire set-up can be broken down in two minutes in case I need to be mobile.

It may surprise some that all 400 Herschel objects can be seen in a 4-inch telescope. But there's no need to be surprised. As I mentioned in the Preface, the members of the Ancient City Astronomy Club created the Herschel 400 list to challenge observers using *6-inch* or larger telescopes under skies that were affected somewhat by *light pollution*. Tests with the 4-inch Genesis under dark Hawaiian skies at altitude prove that it can perform as well as an 8- to 10-inch Schmidt-Cassegrain telescope from a suburban site.

Now consider that although William's 18.7-inch telescope was large by the standards of his day, the mirror in

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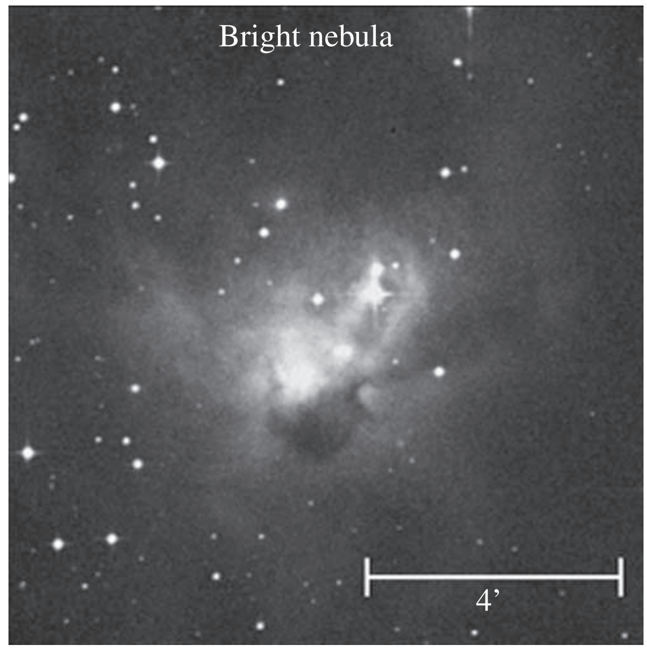
that telescope was of inferior quality by the standards of today. Herschel's mirrors (see photo below) were not finely polished silvered glass. They were made of low-reflectivity speculum metal – a copper–tin alloy containing 45 percent tin. A speculum-metal mirror tarnishes quickly and loses reflectivity. Experiments have shown that reflectivity of speculum-metal mirrors varies from 63 percent at 4500 Angstroms to 75 percent at 6500 Å. In a study published in a 1947 *Journal of Scientific Instruments*, Tolansky and Donaldson (University of Manchester) reported that after keeping speculum mirrors for six months in a damp environment, their reflectivity decreased by 10 percent in the red region and by 2 percent in the blue region. So Herschel had, in essence, *discovered* the faintest objects in the Herschel 400 list with a telescope equivalent to a modern 10-inch reflector with excellent coatings.

How to use this book

To find a Herschel object, first turn to the season and month you want to begin and review the table of essential data for the first target of the first night. The table includes the following data: NGC number, object type; constellation; equinox 2000.0 coordinates; apparent magnitude; angular size or dimensions; and object rating.

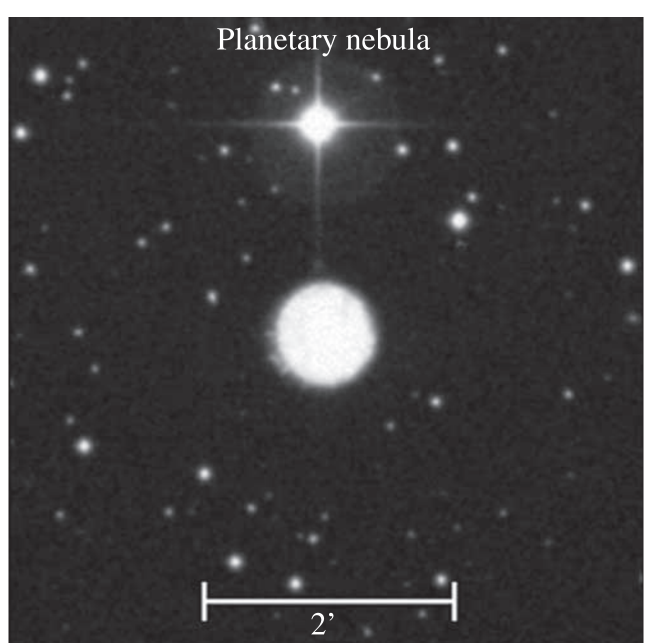
The **NGC** refers to the object's *New General Catalogue* (*NGC*) number, published in 1888 by Johann Louis Emil Dreyer. The NGC is an enlarged version of the *General Catalogue of Nebulae and Clusters* (*GC*) published in 1864 by William Herschel's son, John. All of the "nebulae" and clusters discovered by William, then, can be identified either by William's original code, its *GC* number, or an *NGC* number. Today, deep-sky objects are widely identified only by their NGC numbers; for instance, H VIII-8 is commonly referred to today as NGC 1647, an open star cluster in Taurus.

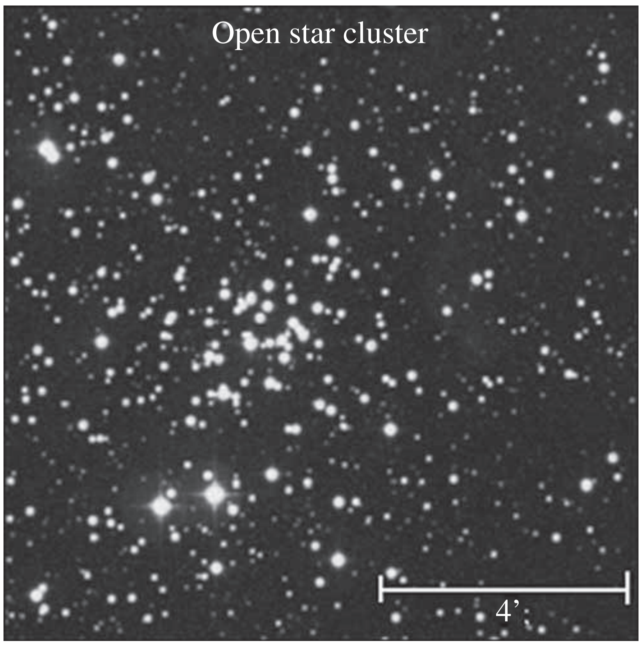
Object **type** identifies the object's class: a *bright nebula* is a luminous, interstellar cloud of dust and gas that either gives

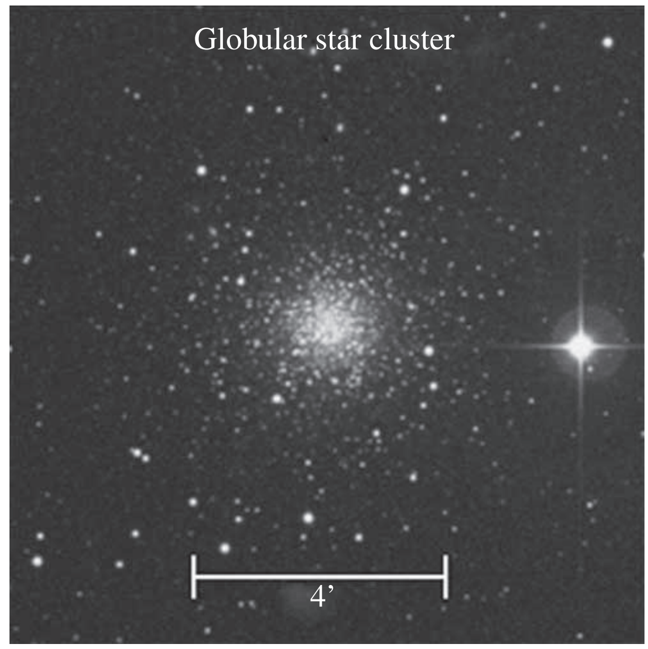


off its own light (emission) or shines by reflecting the light of nearby stars (reflection).

A *planetary nebula* is a luminous shell of gas cast off and caused to fluoresce by an evolved star of less than about four solar masses. William Herschel coined the term "planetary nebula" because, through his telescope, these objects appeared round in form and resembled the green, gas-giant planet Uranus, which he discovered. Note that not all planetary nebulae listed by Herschel are, in fact, true planetary nebulae in the modern sense; again, Herschel's







classification refers to the object's visual appearance through a telescope, not to its astrophysical nature.

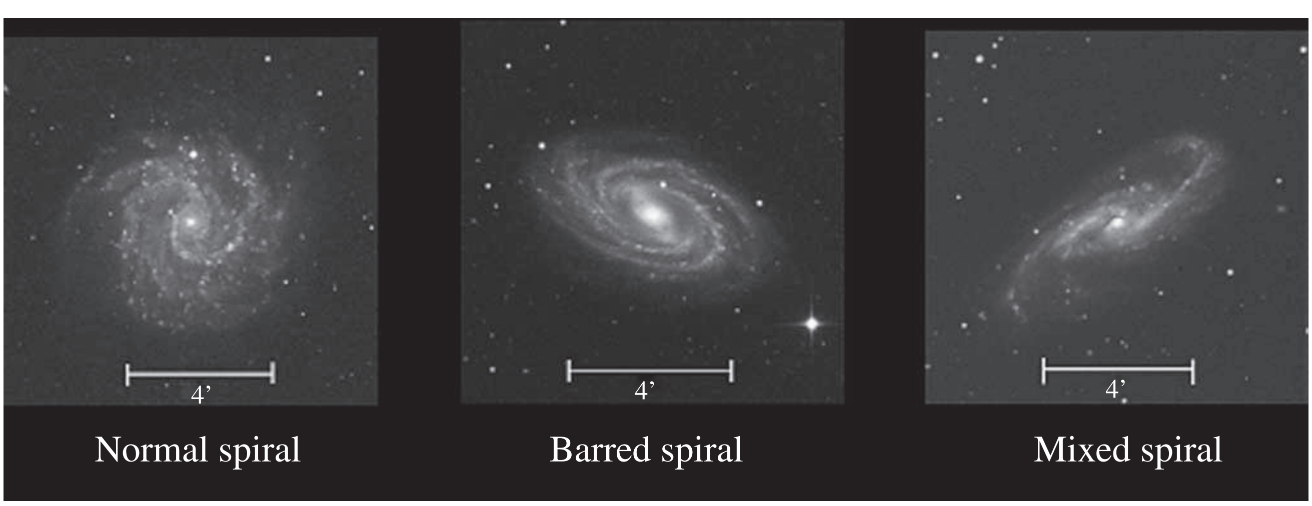
Open star clusters are loose and irregularly shaped collections of dozens or hundreds of young stars that travel in the thin disk of stars, dust, and gas comprising the plane of our galaxy. They occupy a volume of space typically less than 50 light-years across, are loosely held together by gravity, and are fated to disperse over a period of several hundred million years.

Globular star clusters are spherically symmetric collections of old stars that share a common origin. They lie far above or below the plane of our galaxy (in its halo), contain from tens of thousands to millions of stars, and measure from 100 to 300 light-years across.

Galaxies, also called island universes, are giant assemblies of stars, gas, and dust into which most of the visible matter of the universe is concentrated. They range in size from the smallest dwarf galaxies only a few hundred light-years across with just a few million suns, through normal galaxies like our own Milky Way, with a few hundred billion stars, to giant ellipticals spanning over hundreds of thousands of light-years and containing several trillion stars. Galaxies are of three basic types: spirals (normal, barred, or mixed), ellipticals, and irregular. Lenticular galaxies are those midway in form between a spiral and an elliptical. We see the various types of galaxies in a variety of orientations – from face-on to edge-on, to, in the case of some ellipticals, end-on.

Constellation refers to the grouping of stars within a region of sky that has been divided by international agreement. There are 88 official constellations.

The object's **coordinates** are given in *right ascension* (RA) and *declination* (Dec). Think of these latter terms as celestial longitude and latitude. Note: if you plan to star-hop to the



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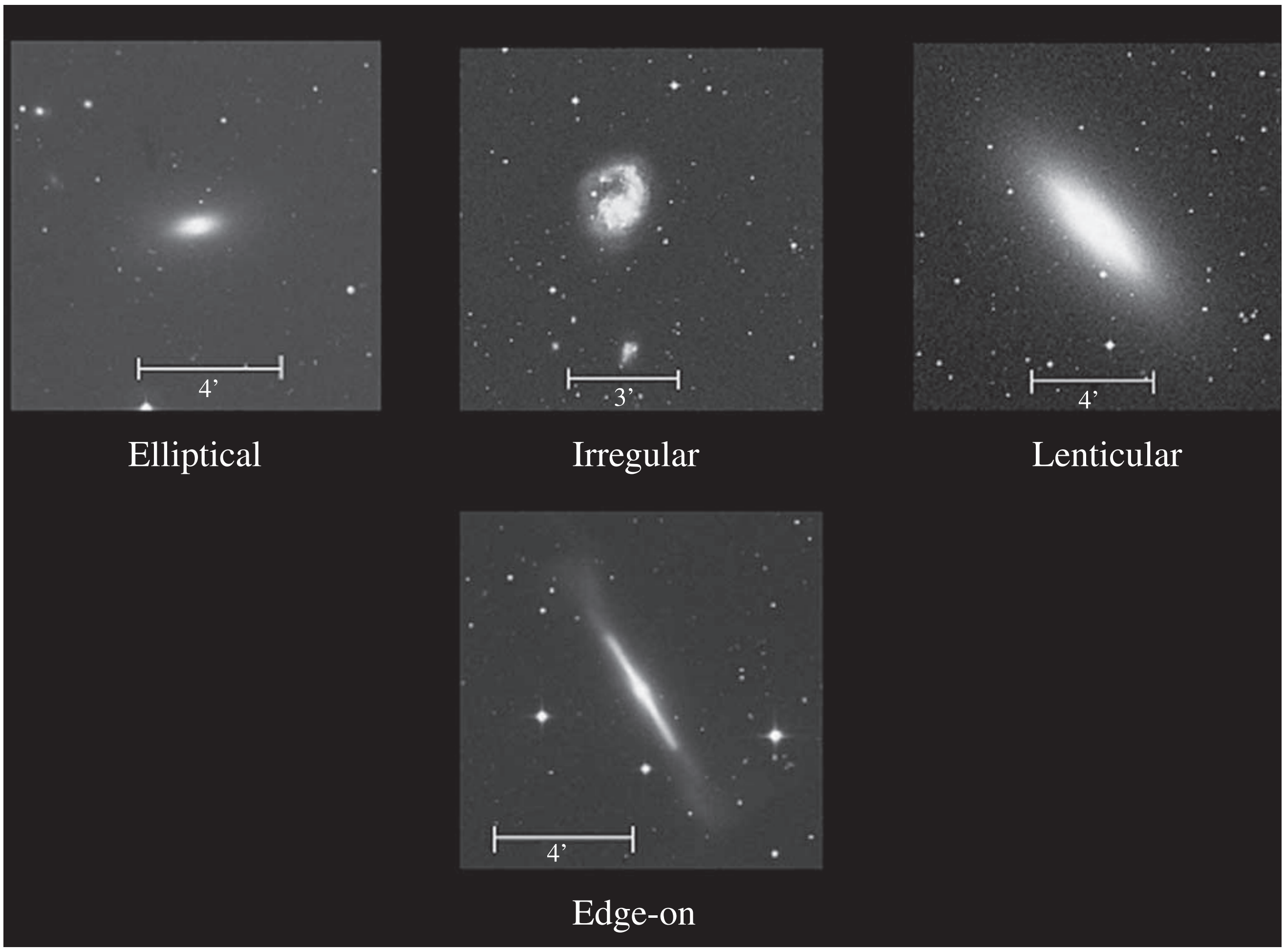

Abbrev.	*Constellation*	*Latin genitive*	*Abbrev.*	*Constellation*	*Latin genitive*
And	Andromeda	Andromedae	CMa	Canis Major	Canis Majoris
Ant	Antlia	Antliae	CMi	Canis Minor	Canis Minoris
Aps	Apus	Apodis	Cap	Capricornus	Capricorni
Aqr	Aquarius	Aquarii	Car	Carina	Carinae
Aql	Aquila	Aquilae	Cas	Cassiopeia	Cassiopeiae
Ara	Ara	Arae	Cen	Centaurus	Centauri
Ari	Aries	Arietis	Cep	Cepheus	Cephei
Aur	Auriga	Aurigae	Cet	Cetus	Ceti
Boo	Bootes	Bootis	Cha	Chamaeleon	Chamaeleontis
Cae	Caelum	Caeli	Cir	Circinus	Circini
Cam	Camelopardalis	Camelopardalis	Col	Columba	Columbae
Cnc	Cancer	Cancri	Com	Coma Berenices	Comae Berenices
CVn	Canes Venatici	Canum Venaticorum	CrA	Corona Australis	Coronae Australis

Abbrev.	*Constellation*	*Latin genitive*	*Abbrev.*	*Constellation*	*Latin genitive*
CrB	Corona Borealis	Coronae Borealis	Oct	Octans	Octantis
Crv	Corvus	Corvi	Oph	Ophiuchus	Ophiuchi
Crt	Crater	Crateris	Ori	Orion	Orionis
Cru	Crux	Crucis	Pav	Pavo	Pavonis
Cyg	Cygnus	Cygni	Peg	Pegasus	Pegasi
Del	Delphinus	Delphini	Per	Perseus	Persei
Dor	Dorado	Doradus	Phe	Phoenix	Phoenicis
Dra	Draco	Draconis	Pic	Pictor	Pictoris
Equ	Equuleus	Equulei	Psc	Pisces	Piscium
Eri	Eridanus	Eridani	PsA	Pisces Austrinus	Piscis Austrini
For	Fornax	Fornacis	Pup	Puppis	Puppis
Gem	Gemini	Geminorum	Pyx	Pyxis	Pyxidis
Gru	Grus	Gruis	Ret	Reticulum	Reticuli
Her	Hercules	Herculis	Sge	Sagitta	Sagittae
Hor	Horologium	Horologii	Sgr	Sagittarius	Sagittarii
Hya	Hydra	Hydrae	Sco	Scorpius	Scorpii
Hyi	Hydrus	Hydri	Scl	Sculptor	Sculptoris
Ind	Indus	Indi	Sct	Scutum	Scuti
Lac	Lacerta	Lacertae	Ser	Serpens	Serpentis
Leo	Leo	Leonis	Sex	Sextans	Sextantis
LMi	Leo Minor	Leo Minoris	Tau	Taurus	Tauri
Lep	Lepus	Leporis	Tel	Telescopium	Telescopii
Lib	Libra	Librae	Tri	Triangulum	Trianguli
Lup	Lupus	Lupi	TrA	Triangulum Australe	Triangulum Australis
Lyn	Lynx	Lyncis	Tuc	Tucana	Tucanae
Lyr	Lyra	Lyrae	UMa	Ursa Major	Ursae Majoris
Men	Mensa	Mensae	UMi	Ursa Minor	Ursae Minoris
Mic	Microscopium	Microscopii	Vel	Vela	Velorum
Mon	Monoceros	Monocerotis	Vir	Virgo	Virginis
Mus	Musca	Muscae	Vol	Volans	Volantis
Nor	Norma	Normae	Vul	Vulpecula	Vulpeculae

object using the method in this book, you do not need to use these coordinates. They are here for the benefit of those who will be using Go To telescopes, or for those who want to find an object on their own star atlases or charts that have right ascension and declination grids (the star charts in this book do not have these grids). The coordinates are precise for "equinox 2000.0". The coordinate system is in constant change. Gravitational tugs by the Sun, Moon, and planets, cause the Earth's axis to wobble like a top. It takes about 26,000 years for the axis to complete a wobble. Although this is a long time, the gradual shift adds up, so every 50 years or so star charts are revised to incorporate this shift, or precession, of the coordinate system against the backdrop of stars. For this book, the coordinates given correspond exactly to the year 2000, hence equinox 2000.0.

Magnitude refers to an object's apparent brightness. The brighter an object appears, the smaller the numerical value of its apparent magnitude. On the brighter side of the magnitude scale, the values soar into the negative numbers. Sirius, the brightest star in the night sky, for instance, shines at magnitude −1.6. As a general rule, the faintest stars visible at a glance to the unaided eye hover at around 6th magnitude. Mathematically, a 1st-magnitude star is 2.512 times brighter than a 2nd-magnitude star, which is 2.512 times brighter than a 3rd-magnitude star, and so on. The math works out nicely so that a star of 1st magnitude is exactly 100 times brighter than a star of 6th magnitude. The faintest star visible *at a glance* in 7×50 binoculars is of about 9th magnitude, and 12th magnitude is the faintest star visible in a 4-inch telescope without effort. But these numbers are *very* conservative; the limit you see will vary wildly depending on your location, the clarity of the atmosphere, the degree of light pollution, your visual acuity, the time you spend looking behind the eyepiece, and your expertise.

When it comes to observing deep-sky objects, "magnitude" is also deceiving. In most cases, the Herschel 400 objects do not appear as point sources – although the nuclei of some galaxies, and the view of some planetary nebulae at low power, do appear starlike (which is important to keep in mind). For the most part, the light of these deep-sky objects is spread across a specific area of sky. A 10th-magnitude galaxy, then, will *appear* dimmer than a 10th-magnitude star, because the light is no longer concentrated but diffused over a greater area of sky. Imagine how the concentration of light differs when you use the different settings of a flashlight with an adjustable beam. The wider the beam, the less intense the beam appears. This dimming effect is intensified under less-than-perfect sky conditions. It is easier to see the flashlight beam in a lighted room, for instance, when the beam is concentrated. For the same reason, that's why you can see a 4th-magnitude star in the daytime through your telescope but not a 4th-magnitude nebula.

You can get a sense of how difficult the object will be to see by comparing its magnitude with the object's apparent **size** – given in the table as its diameter (Diam) or dimensions (Dim). The apparent size of a deep-sky object is an angular measure of its dimensions against the celestial sphere. The units of angular measure are degrees (°), arc minutes (′), and arc seconds (″): 1° is 1/360 of a circle; 1′ is 1/60 of a degree; and 1″ is 1/60 of an arc minute. The larger a diffuse object appears against the night sky, the more difficult it will be to pick out from the sky background, and vice versa.

The tabular data listed above were drawn from a variety of modern sources: three primary sources were the books in my *Deep-Sky Companions* series: *Deep-Sky Companions: The Messier Objects*, *Deep-Sky Companions: The Caldwell Objects*, and *Deep-Sky Companions: Hidden Treasures*. Otherwise, the data came from the following sources:

Stellar magnitudes	Alan Hirshfeld, Roger W. Sinnott, and Francois Ochsenbein, eds. *Sky Catalogue* 2000.0, 2nd edn., vol. 1 (Cambridge: Cambridge University Press and Cambridge, MA: Sky Publishing, 1991).
Open star clusters	Brent A. Archinal, and Steven J. Hynes. *Star Clusters* (Richmond, VA: Willmann-Bell, Inc, 2003).
Globular star clusters	Brent A. Archinal, and Steven J. Hynes. *Star Clusters* (Richmond, VA: Willmann-Bell, Inc, 2003.
Planetary nebulae	Brian A. Skiff, "Precise positions for the NGC/IC planetary nebulae." Webb Society *Quarterly Journal* 105:15, 1996. (Position.) Christian B. Luginbuhl and Brian A. Skiff. *Observing Handbook and Catalogue of Deep-Sky Objects* (Cambridge: Cambridge University Press, 1998). (Dimensions and central star magnitudes.) Murray Cragin, James Lucyk, and Barry Rappaport. *The Deep-Sky Field Guide to Uranometria* 2000.0, 1st edn (Richmond, VA: Willmann-Bell, Inc., 1993).
Diffuse nebulae	*The Deep-Sky Field Guide to Uranometria* 2000.0, 1st edn. Alan Hirshfield and Roger Sinnott, *Sky Catalogue* 2000.0, vol. 2 (Cambridge: Cambridge University Press and Cambridge, MA: Sky Publishing, 1993).
Galaxies	*The Deep-Sky Field Guide to Uranometria* 2000.0, 1st edn. Alan Hirshfield and Roger Sinnott, *Sky Catalogue* 2000.0, vol. 2 (Cambridge: Cambridge University Press and Cambridge, MA: Sky Publishing, 1993).

The table ends with an object **rating**, which is a five-point scale I created for this book. The number reflects how easy or difficult an object is to see through a 4-inch telescope under dark skies (or an 8- to 10-inch telescope under slightly light-polluted skies). A rating of 1 means that the object is very difficult to see; a rating of 5 means the object is easy to see. Some objects have an intermediate rating: 1.5, or 2.5, for instance.

	H400 Rating scale
1	Very difficult
2	Difficult
3	Somewhat difficult
4	Fairly easy
5	Easy

A black-and-white photograph of the Herschel object being reviewed accompanies each data table. The photograph shows the object in rich detail with north up and west to the right. All the images are reproduced digitized photographs taken by enormous Schmidt telescopes in both hemispheres. These photos have been made available to astronomers and scientists worldwide by the visionary architects of the Digitized Sky Survey (DSS), which can be perused on the World Wide Web at http://archive. stsci.edu/dss/. (The copyright for the DSS photos of objects used in this book rests with the Anglo-Australian Observatory Board, the United Kingdom Particle Physics and Astronomy Research Council, the California Institute of Technology, and the Associated Universities for Research in Astronomy; they are used here with permission.) Detailed credits appear in Appendix C.

Why use a photograph instead of a drawing? I used a 4-inch telescope to observe the Herschel objects, which is considered small by today's standards. Most observers will be using larger (much larger?) telescopes that will show more detail. So a drawing of a 12th-magnitude galaxy as seen through a 4-inch (essentially a ghost mote of light) does little to help someone using, say, a decent 12-inch reflector under a dark sky, which might show the galaxy as a beautiful little spiral system (arms and all!). The photograph, on the other hand, demonstrates a more "perfect" view; it shows you the true glory of the object. How much detail you see in that object will depend, again, on a number of variables. I must also stress again that the principal purpose of this book is to help you *find* each Herschel object.

To help give you an idea of what the Herschel 400 objects looked like through my 4-inch refractor after some study, I include on the next few pages some drawings I made of various Herschel objects in various classes at different ratings. I suggest you tab these drawings and refer to them if you ever have trouble seeing an object, because they should help you get an idea of what to look for or expect to see.

Each drawing has a rating above it, and its NGC number below it. A scale bar also accompanies each drawing. As you review these drawings, think, "variations on a theme." As you start to observe some open star clusters, for instance, you'll discover that the vast majority of the brightest ones are well-resolved splashes of stars of mixed magnitudes; what will differ is their shape, size, and degree of concentration. Note too how a globular star cluster with a rating of 1.5 can look like an oblique or face-on galaxy with a rating of 2. (This also demonstrates how difficult it was for Herschel to fathom what it was he was seeing.) I've broken down the galaxy drawings into three general subcategories: the top row shows three edge-on systems at different ratings, the middle row shows three oblique galaxies at different ratings, and the last row shows three face-on galaxies at different ratings. So, if you are searching for an edge-on lenticular galaxy in Virgo that has a rating of 2, it might look something like NGC 4419.

Once you have reviewed an object's data table and photograph, read the **General description** that follows. It tells you what the object is, where it can be found in the sky, what's the brightest star near it, and, if it is visible to the naked eye or binoculars, what it looks like. It also prepares you for the telescopic view.

The next section, **Directions**, tells you, step by step, how to go about finding the Herschel 400 object using the star charts that open each night's observing plan. Use these charts in concert with your own detalied star charts. To find a given Herschel object, I will direct you to a specific wide-field star chart. The purpose of this chart is to show brightest stars in a constellation near the Herschel objects of interest. Each wide-field chart shows stars roughly to 6th magnitude, but generally only in the region around the Herschel objects. The brightest stars in each constellation have been labeled with either a Bayer (Greek) letter or a Flamsteed number. The Greek letters belong to a nomenclature system introduced in 1603 by the Bavarian astronomer Johann Bayer, who labeled stars in each constellation according to their brightness. The most prominent star was given the letter alpha (α); the faintest became omega (ω). The brightest star near NGC 1647, for example, is Alpha Tauri; note that the Greek letter is followed by the Latin genitive of the constellation. There are exceptions, however, such as with the stars in the Big Dipper, which are labeled in order of right ascension, from west to east, not by brightness.

The Greek alphabet (lower case)					
α	Alpha	ι	Iota	ρ	Rho
β	Beta	κ	Kappa	σ	Sigma
γ	Gamma	λ	Lambda	τ	Tau
δ	Delta	μ	Mu	υ	Upsilon
ε	Epsilon	ν	Nu	ϕ	Phi
ζ	Zeta	ξ	Xi	χ	Chi
η	Eta	o	Omicron	ψ	Psi
θ	Theta	π	Pi	ω	Omega