Part I
Amateur astronomy

Chapter 1
Using this book effectively

1.1 Amateur astronomy for a new generation

This is a handbook for the modern amateur astronomer. As far as possible, I've tried to write the book that I'd like to have in my own hands while at the telescope – along with a star atlas and the *Handbook of the B.A.A.*, of course.

Amateur astronomy isn't what it used to be. A generation ago, most serious amateurs observed from their homes with large Newtonians; one star atlas and two or three reference books were the amateur's complete guide to the sky; the latest news, arriving by magazine, was two months old; and most of the stars visible in the telescope were absent from even the largest catalogues and atlases.

Those days are gone, thank goodness. Telescopes have changed – they are nearly all portable, and compact designs such as the Schmidt–Cassegrain are popular. As often as not, the telescope is computer-controlled.

More importantly, computers have brought high-quality data sources within the amateur's reach. Alongside star atlases, we use software that plots the star positions measured by the Hipparcos satellite. We can compute the positions of comets, asteroids, and artificial satellites at the touch of a button. We can even track clouds by satellite to see if we're going to have clear weather.

Accordingly, a major theme of this book is the effective use of astronomical data, especially the Internet. Web addresses are given throughout, as well as detailed information about classic and modern catalogues of celestial objects. The book's web site, http://www.covingtoninnovations.com, will give ongoing updates.

1.2 The maps are backward!

On a more mundane level, the bulk of amateur telescopes now have star diagonals or flip mirrors, so that they present an image that is right-side-up but flipped left to right (Figure 1.1, bottom).

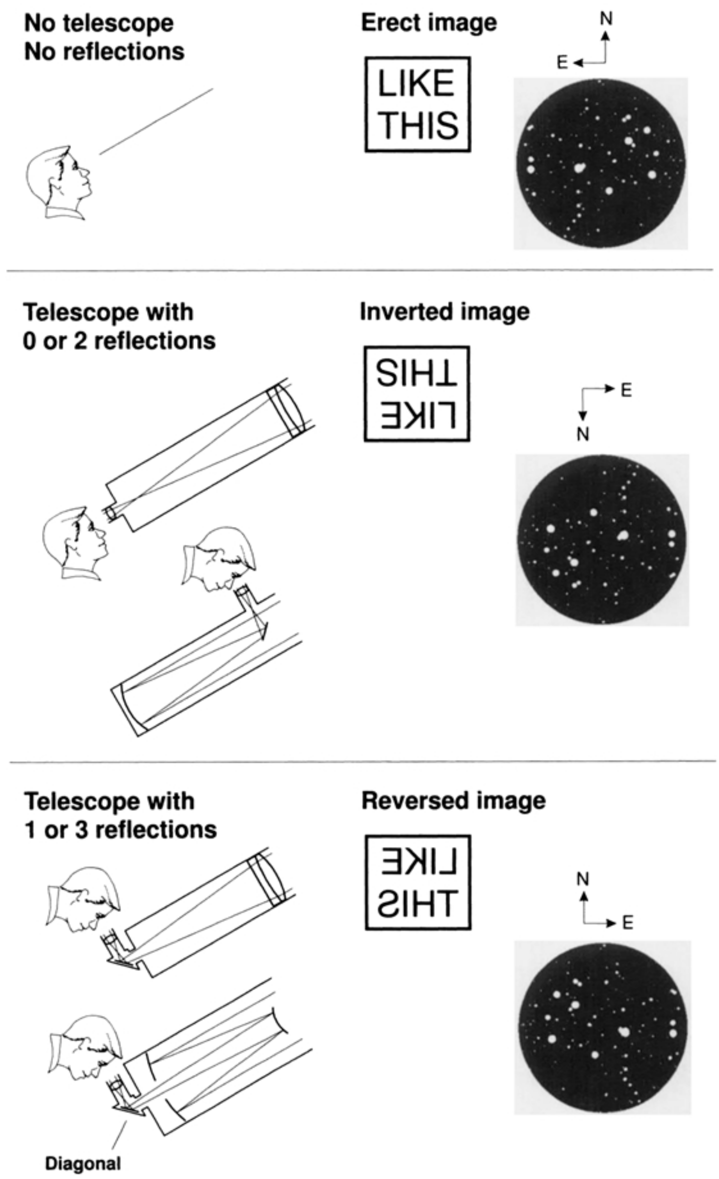

Figure 1.1. Image in telescope may be upside down or reversed left to right. Most of the maps in this book show the view through a telescope with one or three reflections (bottom).

Accordingly, my maps of the Moon (p. 25), Mars (p. 50), Jupiter (p. 53), and most telescopic star fields show the image with north up but flipped east to west, to match the view in the telescope. Users of Newtonians, and anyone who still uses a refractor without a diagonal, will have no trouble using numerous maps available elsewhere. On the art of matching up a flipped image with a non-flipped map, see p. 95.

1.3 Old books

Like many amateur astronomers, I enjoy comparing my observations to those of Admiral Smyth, T. W. Webb, Sir John Herschel, and other nineteenth-century observers who used telescopes about the same size as mine. To facilitate this, I have included information on obsolete constellation names (p. 86), precession of coordinates (p. 249), and old magnitude scales (p. 114), as well as information on classic observing guides, some of which are readily available in reprint (pp. 161–164).

1.4 Material you can skip

Smaller type, like this, indicates technical material that you can skip until you need it. By printing it in smaller type, I avoided having to take it out of its logical place in the text.

1.5 Pronouncing foreign names

One thing that frustrated me, when I was new to astronomy, was the vast number of foreign names I didn't know how to pronounce. Indeed, that may have been one of the things that led me to take up linguistics instead of astronomy as a career!

To keep you from being equally frustrated, in this book I indicate the pronunciation of every name likely to give difficulty. I even consulted native speakers of Danish and Czech, respectively, to placate years of curiosity about how to pronounce *Tycho Brahe* (p. 102) and *Antonín Bečvář* (p. 94).

Latin presents special problems. The ancient Roman pronunciation (with *v* pronounced as *w*, etc.) was reconstructed around 1900 but is rarely used by scientists. Arguably, it is not appropriate for names that originated after Roman times.

For familiar historical and mythological names, including those of the constellations, planets, and satellites, I follow the "English method." That is how Latin was pronounced in England in the 1800s, and it remains the traditional way to pronounce Latin names in English context.

For less familiar Latin names, such as lunar and planetary features, I use a "Continental" (late medieval) pronunciation that is similar to that of the Romans but pronounces *c*, *g*, and *v* as in English and *ae* and *oe* like Latin *e*. This pronunciation would have sounded natural to Copernicus and Kepler and is still widely used in Europe.

For full Latin pronunciation rules, ancient and modern, see William T. Stearn, *Botanical Latin* (David & Charles, 1995).

Though modern astronomers need not learn Latin, one piece of classical erudition that you still can't do without is the Greek alphabet (p. 91). Memorize it right away or be puzzled by every star chart.

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Chapter 2
Observing sites and conditions

2.1 Darkness and night vision

2.1.1 Dark adaptation

The human eye takes time to adapt to dim light. Although the pupil opens up almost immediately, that's not the whole story. Dark adaptation involves the release of the light-sensitive chemical **rhodopsin** (visual purple) in the retina. For astronomy, useful dark adaptation takes about ten minutes, and substantial improvement continues for half an hour or more.

The central part of the retina does not function in dim light; faint objects disappear if you look straight at them. Experienced observers use **averted vision,** which means that they view the faintest stars, nebulae, and galaxies by looking slightly to one side of the object rather than directly at it.

Visual perception of faint objects is not continuous. A star near the limit of vision may be evident only a third of the time; it will seem to pop into and out of view. As long as you keep seeing it in the same place, you can be sure that it's real even though you can't see it continuously.

Even a small amount of bright light prevents complete dark adaptation; that's why a distant streetlight or even an illuminated doorbell button can be so annoying. Red light does not do this as much as other colors, which is why astronomers use red flashlights. The light must be *red* (or orange), not just *reddish;* what matters is the absence of blue wavelengths, not the red color.

Red photographic safelights are ideal, as are red light-emitting diodes, but anything that looks pink or purplish is inadequate, and red lights should not be too bright. Red filters for flashlights can be made from Rubylith, a masking material sold at art supply stores.

Night vision is impaired by too much bright sunlight during the day, especially during the hours immediately before observing. Sunglasses can be a wise investment. During brief trips indoors while observing, or to start dark-adapting before you go outside, you can wear red goggles.

2.1.2 Twilight and moonlight

The sky is not completely dark when the Sun is less than 18° below the horizon. This period of semidarkness is called **astronomical twilight** and its exact duration can be computed with software or looked up in the *Astronomical Almanac.* The following rough guide is good enough for most purposes:

- At latitude +30° (Florida, Texas), astronomical twilight lasts about $1\frac{1}{2}$ hours year-round.
- At latitude +40° (New York), astronomical twilight lasts $1\frac{1}{2}$ hours most of the year, but 2 hours from May to August.
- At latitude +50° (Vancouver and southern England), astronomical twilight lasts about 2 hours most of the year, $2\frac{1}{2}$ hours in May and August, and never ends in June or July because the Sun is never 18° below the horizon, even at midnight.

The 18° limit is not hard and fast. Good astronomical photographs have been taken when the Sun was 15° or even 12° below the horizon. Particularly at suburban sites, there is no point in waiting for perfect darkness that will never come.

Complete darkness also requires the Moon to be absent; see p. 24 for more about its movements.

2.1.3 Light pollution

Because of city lights, many of us have to go out into the country to see the stars. Even the most avid astronomers don't want cities to be dark; artificial light makes driving safer and prevents burglary and vandalism. But much of the light sent into the sky by city lights is completely unnecessary. This wasted energy is called **light pollution**. Far too much light is directed into people's eyes or into the sky rather than onto the objects that were meant to be illuminated.

Most non-astronomers don't care whether lights block the view of the sky, but there are other ways to motivate them to oppose light pollution. Most importantly, unshielded outdoor lights don't do their job. When you look down a street, you should not see streetlights – you should see the street! We have lampshades indoors; why not outdoors?

What's more, waste is waste. Light that goes up into the sky is wasted energy, and somebody is paying for it, both in money and in pollution from power plants. Properly shielded lighting provides better visibility at lower cost.

Campaigns against light pollution are conducted by the International Dark-Sky Association (3225 N. First Ave., Tucson, AZ 85719, U.S.A., http://www.darksky.org) and the British Astronomical Association (see p. 30). These organizations can also advise you about shields that can be added to streetlights to direct more of their light toward the ground.

The best way to deal with a bothersome streetlight near your site is to contact the local authorities and offer to pay for such a shield. Some amateur astronomers turn streetlights off by directing a laser pointer at the photocell, but this should only be done on private property with the full consent of everyone affected. In 2001, a Maryland amateur was fined $450 for tampering with county property when a neighbor innocently reported that a streetlight was out, and the repair crew saw his laser beam. If the absence of light had been blamed for a crime or accident, he might have faced a costly lawsuit.

Light pollution does not interfere with lunar and planetary observing, though there is some benefit from going out into the country to get away from hot pavement, rooftops, air conditioners, and the resulting unsteady air.

Nor does light pollution prevent you from using large telescopes. A big telescope is better than a small one at the same site, no matter where that site may be. Note however that one of the main uses of really large amateur telescopes – 16 inches (40 cm) and larger – is to view faint galaxies. That can't be done in the city because the surface brightness of the sky greatly exceeds that of the galaxies, regardless of the telescope.

2.1.4 Naked-eye limiting magnitude

The clarity of the air varies dramatically from night to night. Factor-of-two variations between seemingly clear nights often go unnoticed.

One way to measure transparency, as well as quality of the observing site, is to find the magnitude of the faintest stars that can be seen by dark-adapted eyes without a telescope. This is called the naked-eye limiting magnitude (NELM) and ranges from about 4 in the city to 5.5 at a good small-town site, 6.2 in the country, and 6.5 to 7 in the desert. (For explanation of the magnitude system, see p. 112.)

Figures 2.1–2.4 show the magnitudes of stars in selected regions of the sky. You can use them to determine your NELM. Deep-sky observers always want the NELM to be as faint as possible, but in practice, 5.0 to 5.5 is good enough for serious observing.

Remember that an *intermittently* visible star should be counted; a star at the limit of visibility will seem to flicker in and out of view. A more practiced observer will get a fainter NELM than a less experienced observer at the same site.

2.1.5 The Bortle dark-sky scale

Taking the idea of NELM further, John Bortle has defined a quality scale for rating dark-sky observing sites (*Sky & Telescope*, February, 2001, pp. 126–129). Table 2.1 on p. 11 sums it up. Remember that the top two classes are rarely seen, and most amateur observing is done in skies of Classes 4 to 6. Kitt Peak National Observatory is somewhere around Class 2 or 3.

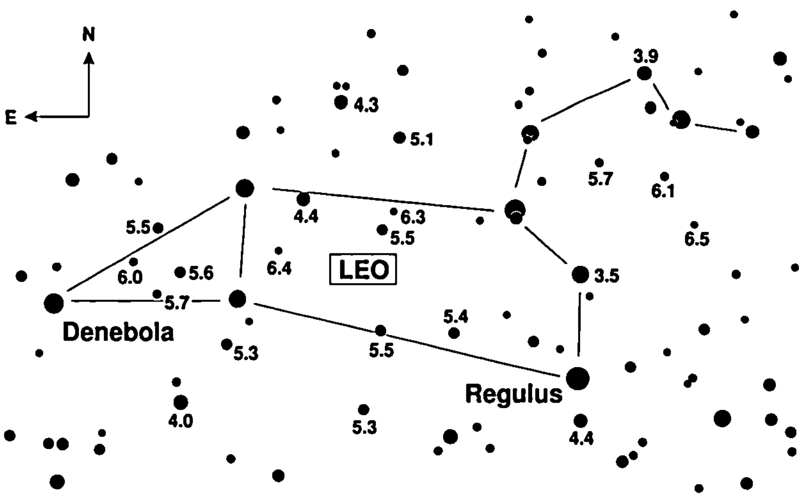

Figure 2.1. Naked-eye limiting-magnitude map of Leo, high in the spring evening sky. Adapted from a chart generated with *TheSky* software, copyright 2001 Software Bisque, Inc., used by permission.

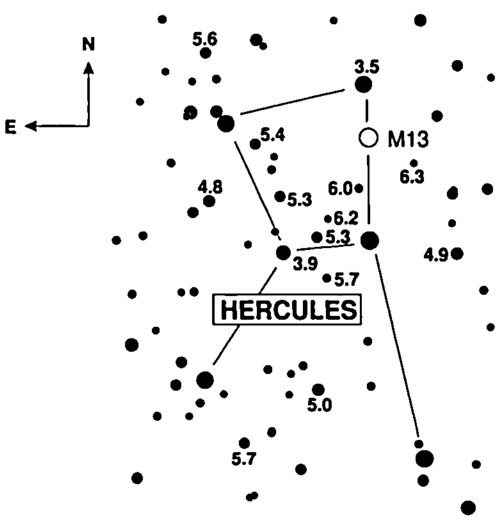

Figure 2.2. Naked-eye limiting-magnitude map of Hercules, high in the summer evening sky. Adapted from a chart generated with *TheSky* software, copyright 2001 Software Bisque, Inc., used by permission.

Notice that there is a sharp transition around NELM 5.0. Going from 5.0 to 5.5 is a big improvement; going from 5.5 to 6.0 or even 6.5 is not so dramatic. The reason is that 5.0 is the approximate limiting magnitude of an experienced observer *without dark adaptation*, or at least without much dark adaptation. Thus, 5th-magnitude stars are visible, or almost visible, even under poor conditions, but it takes a much darker sky to get to 5.5 or 6.

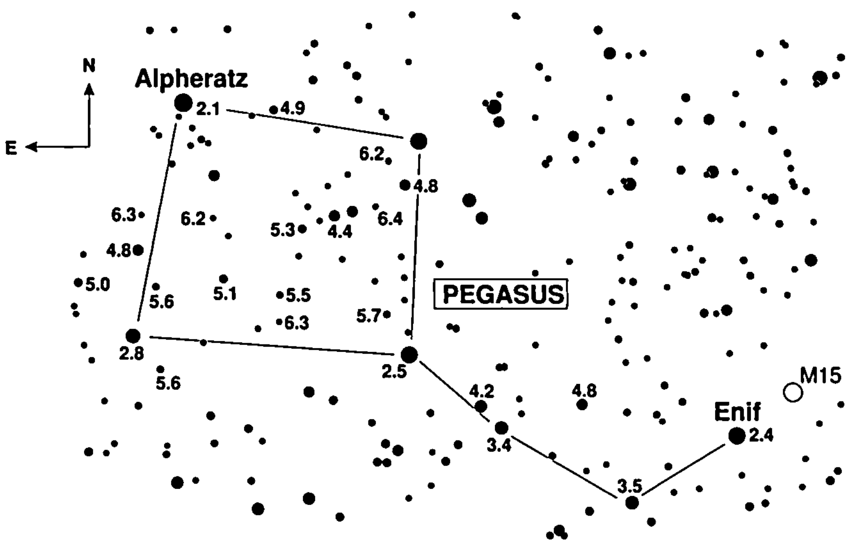

Figure 2.3. Naked-eye limiting-magnitude map of Pegasus, high in the autumn evening sky. Adapted from a chart generated with *TheSky* software, copyright 2001 Software Bisque, Inc., used by permission.

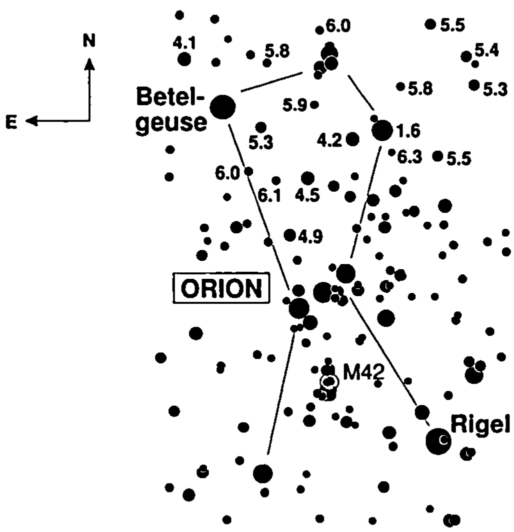

Figure 2.4. Naked-eye limiting-magnitude map of Orion, high in the winter evening sky. Adapted from a chart generated with *TheSky* software, copyright 2001 Software Bisque, Inc., used by permission.

Many of Bortle's tests involve the visibility of the **zodiacal light,** a cloud of interplanetary dust that looks a bit like twilight, extending upward along the ecliptic (the plane of the solar system) after true twilight is over. The zodiacal light is about half as bright as the Milky Way, and under extremely dark, clear skies, extends to form a **zodiacal band** all along the ecliptic, with a bright spot,

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Table 2.1. *The Bortle dark-sky scale*

Class	NELM	Description
1 (Excellent)	>7.6	Rarely seen. Milky Way spectacular; zodiacal band (along ecliptic) plainly visible; no light on ground (cars, telescopes invisible).
2 (Truly dark)	7.1–7.5	Remote western deserts. Milky Way elaborately structured; zodiacal light prominent along ecliptic in the west after end of twilight; M33 and many other Messier objects seen without telescope.
3 (Rural)	6.6–7.0	Some light pollution on horizon, none overhead. Milky Way prominent; zodiacal light easily seen. Good country skies in the eastern U.S. and Britain.
4 (Rural–suburban)	6.1–6.5	Definite domes of light pollution on horizon. Milky Way clearly visible; brightest part (in summer) shows considerable structure. Telescopes and cars are visible from across the field.
5 (Suburban)	5.6–6.0	Milky Way visible but only brightest parts are prominent. Obvious sources of light pollution in several directions. Still good enough for serious observing and astrophotography.
6 (Bright suburban)	≈5.5	Milky Way somewhat hard to see. M31, M44 visible to naked eye but not prominent. Clouds, when present, are bright, illuminated from below. All Messier objects are visible in a 5-inch (12.5-cm) telescope, but more serious deep-sky observing and photography are not feasible.
7 (Suburban–urban)	≈5.0	Entire sky grayish, not black. Milky Way invisible or very hard to see. M31, M44 barely visible without a telescope. Deep-sky enthusiasts should concentrate on multiple stars, clusters, and planetary nebulae.
8 (City)	≈4.5	Gray or orangish sky. Objects on the ground are very clearly visible by reflected skylight. Many constellations unrecognizable because so many stars are hidden.
9 (Inner city)	≤4.0	Only the brightest stars are visible. Planets, Orion, and Ursa Major may still be picked out. Fainter objects can only be found with the help of a computerized telescope.