Part I
Telescopes in general

Chapter 1
Welcome to amateur astronomy!

Welcome to amateur astronomy! If you are new to this field, and especially if you have never owned a telescope before, this chapter is for you. Otherwise, feel free to skip ahead. I've tried to write a book that I'll actually use while observing. Parts of it are quite specialized; take what suits you and save the rest for later.

Amateur astronomy, like other hobbies, is something you can go for a little or a lot. Computerized telescopes make casual stargazing easier than ever before, since you don't have to gather up star maps and look up planet positions before going out under the sky. At the other end of the spectrum, the advanced amateur with a busy, semi-professional observing program will find that a computerized telescope is a real time-saver. Both approaches to amateur astronomy are respectable, and so is everything in between.

The key to enjoyment is to have realistic expectations and continue building your knowledge and skill. Looking through a telescope is a very different experience from looking at photographs in books, and it may take some getting used to. If you don't already have a telescope, get some experience looking through other people's telescopes before buying one of your own. Contact a local astronomy club if possible.

1.1 Using a telescope

Newcomers are sometimes surprised to find that spectacular objects such as the Horsehead Nebula are not normally visible in telescopes at all – the eye cannot accumulate light the way the camera does. But other nebulae, such as M42, are far more spectacular visually than on film because the eye can see the faint outer regions without overexposing the center. Likewise, the three-dimensional ball shape of a globular star cluster is more impressive "live" than in pictures because the eye covers a greater brightness range. And the ever-changing phenomena of Jupiter, Saturn, sunspots, and variable stars provide a constant supply of new sights – though the real colors of the planets are much more subtle than the bright colors of computer-processed pictures.

One important tactic is to use low power. Unlike microscopes, telescopes do not perform well at their highest powers; this is true of *all* telescopes because of the wave properties of light and the turbulence of the Earth's atmosphere. Most astronomy is done at 20× to 100×, with 15- to 40-mm eyepieces. Use whatever eyepiece gives the most comfortable view – usually the lowest-power one – and switch to high power only when actually necessary.

1.2 Learning the sky

A computerized telescope will help you learn the sky; it won't eliminate the need to do so. Every time you set up your telescope, you will need to identify at least two bright stars. Although the telescope will try to find the stars for you, things go much more smoothly if you learn to recognize them on your own.

Don't try to memorize a star map; that would be tiresome. Instead, find something in the sky that catches your eye, then use a map to identify it. (My personal career began with the Belt of Orion.) Some constellations, such as Ursa Major and Cassiopeia, jump right out at you; others are obscure, and you will never need to learn them. Not one astronomer in a hundred can sketch Camelopardalis from memory.

You'll also need to build your awareness of how the sky moves, how the moon goes through its phases, and so forth. That's what Chapter 2 is about, but a couple of hours of *watching*, repeated every week, will make the sky come alive in a way that no diagram can do.

Above all, though, don't let imperfect conditions, imperfect equipment, or a lack of technical mastery keep you from looking at the sky. On the first night with a new telescope, just take it outside and *look!* Start by viewing distant treetops and the Moon; then examine anything that looks interesting – bright stars, star clusters, the Milky Way, or whatever you can see, whether or not you can identify it. You've just begun a lifelong adventure.

1.3 Is a computerized telescope right for you?

Computerized telescopes are not ideal for everyone. There are three situations in which I do not recommend purchasing one.

First, if you are completely unfamiliar with the sky, you are probably not ready for any telescope, not even a computerized one. Instead, get some star maps and perhaps a pair of binoculars, and spend several evenings looking at the stars, learning some constellations, and becoming aware of how the sky moves. Until you can identify at least a few constellations, you will not be able to set up a computerized telescope reliably, nor will you know whether it's working correctly once you get it going.

Second, if you need maximum optical performance at minimum cost, you will probably not want to spend the extra money for a computerized mount. Instead, go for a **Dobsonian** telescope (a Newtonian on a low-cost altazimuth mount that looks like a cannon). Finding objects with a Dobsonian takes considerable skill and extensive use of star maps, but the views are rewarding, especially under a dark country sky. A given amount of money will buy a much larger Dobsonian than any other kind of telescope. Dobsonians can be outfitted with computerized motor drives later.

Third, if you want to do astrophotography on a limited budget, you need smooth drive motors, which the cheapest computerized telescopes do not have. Save up for a high-end computerized telescope that is specifically designed for astrophotography, or stick with conventional AC motors.

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 Does this book cover your telescope?

All computerized telescopes work on the same basic principles. Chapters 10–12 give detailed instructions for the Meade LX200, Celestron NexStar and Meade Autostar (ETX and LX90), based on my experience with three specific telescopes purchased in 2000 and 2001.

By the time you read this, none of these telescopes will be the current model. As manufacturers continue to update their software and expand their product lines, the information in those chapters will inevitably become out of date. But plenty of older telescopes remain in use, and in general, the oldest versions of the software are the most in need of explanation. Newer versions have better documentation, and the older versions are always a good starting point for comparison.

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Chapter 2
How the sky moves

2.1 Daily motion

The universe is a mass of swirling motions, but most of the time, you can ignore all but one of them. That one is **daily motion** (**diurnal motion**), caused by the rotation of the Earth. You will see it immediately if you aim a 100× telescope at a star with the drive motor turned off.

As you know, celestial objects rise in the east, move across the sky, and set in the west. But as Figures 2.1 and 2.2 show, that is not the whole story. The motion is not directly from east to west; instead the whole sky rotates like a globe with Polaris at its north pole.

In the southern sky, each object rises somewhere on the eastern horizon (not necessarily due east!), passes across the sky, and sets somewhere in the west. Its path may be long or short. In the far southern sky, objects rise just east of south, climb only a short distance above the horizon, and set again a short time later, just west of south.

> *Hint:* Maps of the sky have north at the top, east at the *left* (not right as on a terrestrial map), in order to match the view that you see when facing south and looking up. Get used to facing south to get your bearings when looking at the sky.

The most northerly celestial objects are **circumpolar**; that is, they do not rise or set at all. Instead, they twirl around the north celestial pole, which is conveniently marked by the star **Polaris**. Each revolution takes one day (24 hours).

Opposite the circumpolar region, there is a region in the far south containing stars that never rise. That is why Alpha Centauri, for instance, is not visible from the continental United States.

The diagrams show the sky as seen from New York. Farther north, everything in the south is lower, everything in the north is higher, and the circumpolar region is larger. Within the Arctic Circle, the Sun can become circumpolar; that's how

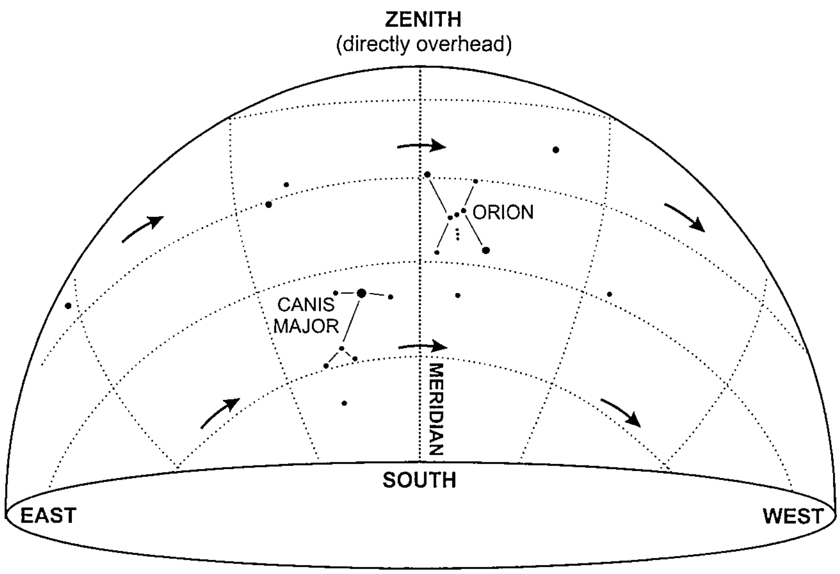

Figure 2.1. The southern sky at the latitude of New York (40° N) at 8 p.m. on February 21.

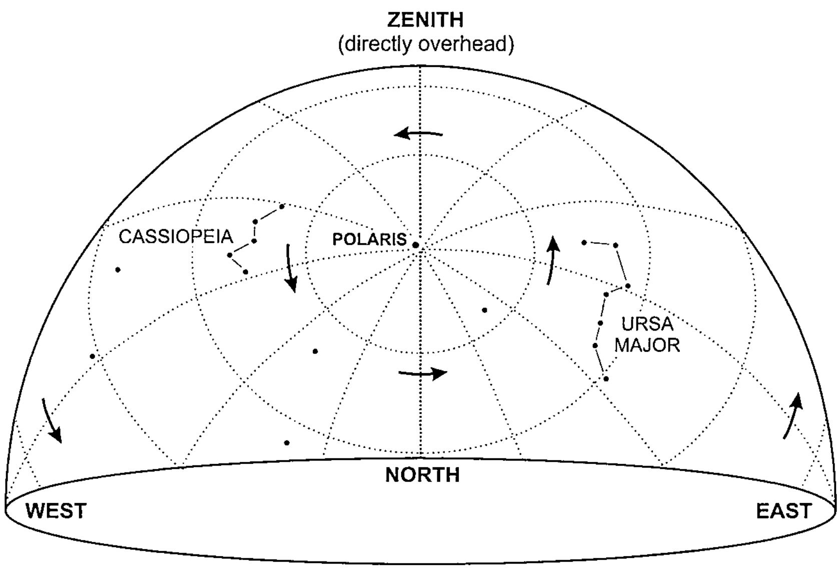

Figure 2.2. The same, but looking north. Celestial objects twirl around Polaris once every 24 hours.

they get the Midnight Sun. Even in England, the Sun is so nearly circumpolar in mid-June that the sky does not get completely dark.

At more southerly latitudes, the opposite is the case. From Florida, you can see the star Canopus, which is due south of Sirius and below the New York horizon.

Seen from the equator, Polaris lies on the northern horizon, and nothing is circumpolar, but nothing is hidden from view in the south; you can see the entire sky. From the southern hemisphere (Australia, for instance), Polaris is below the horizon but the south celestial pole is high in the sky; from there, you can see all of the southern sky but not all of the north.

2.2 Coordinates

2.2.1 Right ascension and declination

The alert reader will notice that Figures 2.1 and 2.2 are crisscrossed by lines that look like latitude and longitude on a globe.

That's exactly what they are, but the globe to which they refer is the **celestial sphere** (Figure 2.3). This is an imaginary sphere, infinitely large, surrounding the Earth, on which the stars have fixed positions. Since the sphere is imaginary, its motion can be imaginary too, so astronomers pretend that the Earth holds still (with the observer's location right on top, of course) and the sphere rotates around it. Its rotation is that of the Earth, but in the opposite direction.

Coordinates on the celestial sphere are called **declination** (abbreviated **Dec.** or δ) and **right ascension** (**R.A.**, **AR**, or α). Together, right ascension and declination are known as **equatorial coordinates** because they are based on a sphere whose equator and poles correspond to those of the Earth.

Declination is like latitude and is measured in degrees, negative if south of the equator. Right ascension is like longitude but is measured in hours (0 to 24). Since the sphere rotates once per day, it makes sense to measure longitude in time units.

Figure 2.4 shows the whole sky (as seen at the same time and place as Figures 2.1 and 2.2) with lines of R.A. and declination labeled.

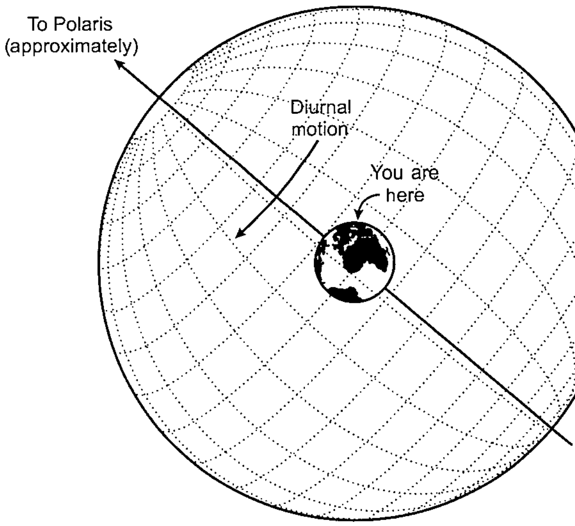

Figure 2.3. Right ascension and declination are measured on an imaginary sphere that surrounds the Earth, on which the stars have fixed positions.

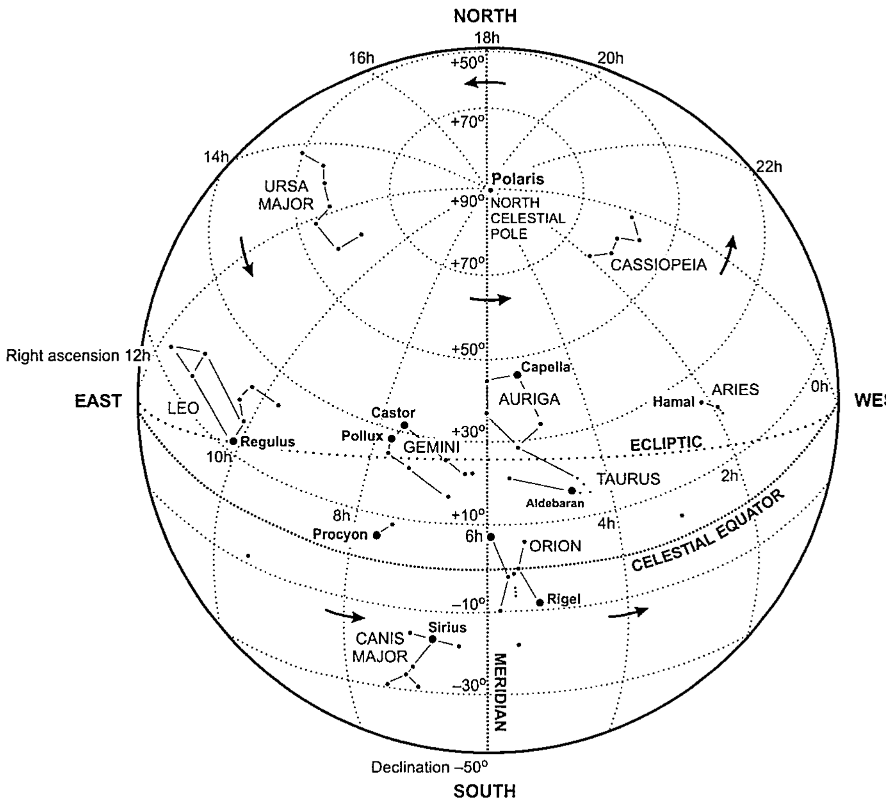

Figure 2.4. The whole sky as seen in Figures 2.1 and 2.2. Based on a chart created with *Starry Night Pro* astronomy software (http://www.starrynight.com), reproduced by permission.

> *Hint:* In astronomy, the directions *north*, *south*, *east*, and *west* always refer to the celestial sphere unless otherwise indicated. To move north in the sky means to move toward the north celestial pole.

The right ascensions and declinations of the stars are, for all practical purposes, constant. The Sun, Moon, and planets move around on the celestial sphere, so their right ascensions and declinations vary.

The term *right ascension* sounds as if it refers to something ascending or rising at a right angle, and indeed it does. Seen from the Earth's equator, all celestial objects rise and set at right angles to the horizon, at times that depend directly on their right ascensions. *Declination* is from the Latin word for "bending", an appropriate name for an angle.

2.2.2 Declination and latitude

The altitude of the celestial pole above the horizon equals the observer's latitude. Thus, at New York (latitude +40°), the pole is 40° above the horizon.

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The declination of a star directly overhead also equals the observer's latitude. Thus, ϵ Persei (declination +40°) can pass directly overhead at New York, but the Sun (which is never north of +23.4°) cannot.

Letting L stand for the observer's latitude, a star is circumpolar if its declination is north of $90° - L$, and never rises if it is south of $L - 90°$. Thus, at New York, stars north of declination +50° are circumpolar, and those south of −50° never rise.

2.2.3 Some terminology

As shown in Figures 2.1–2.2, the **zenith** is the point directly overhead, and the **meridian** is the line that runs directly north and south through the zenith.

Altitude is height above the horizon, measured as an angle. The horizon is at altitude 0°; the zenith is at 90°.

Azimuth is direction measured *rightward from north* (0°) through east (90°), south (180°), west (270°), and back to north (360°).

However, Meade LX200 telescopes follow an older tradition and reckon azimuth rightward from south through west, giving values that are 180° away from ordinary azimuths.

Together, altitude and azimuth are known as **horizontal coordinates** since they use the horizon as their equator. Computerized telescopes compute the altitude and azimuth of celestial objects automatically from the right ascension and declination.

Right ascension can be measured in degrees ($1^h = 15°$; $1° = 4$ minutes of R.A.). When measured this way, it is often called **sidereal hour angle (SHA)**.

The **local hour angle** (or just **hour angle**, abbreviated **HA**) of a star is the difference between its right ascension and that of the meridian. For example, in Figure 2.4, the hour angle of Rigel is almost 1 hour west, or +15°.

Telescope instructions often say to aim the telescope at **hour angle zero** during setup. That means to aim it at the meridian, i.e., due south.

2.2.4 Other coordinate systems

Besides right ascension and declination, two other systems of fixed coordinates are used in the sky.

The **ecliptic**, marked on Figure 2.4, is a line that indicates the plane of the Earth's orbit. The Sun is always on the ecliptic, and the Moon and planets are always close to it. **Ecliptic latitude** and **ecliptic longitude**, often called just **latitude** and **longitude**, use the ecliptic in place of the celestial equator. Ecliptic coordinates are used in calculating planetary orbits but not, nowadays, for much else, though in ancient times they were the basis of star catalogues and maps. Like right ascension, ecliptic longitude starts at 0° at the point where the Sun crosses the celestial equator in the spring.

Galactic latitude and **galactic longitude** are measured relative to the plane of our galaxy, with longitude 0° defined as the galactic center in Sagittarius. These coordinates are not used for finding objects, but they are important to astrophysicists because they provide a quick way to tell what part of our galaxy we are looking at (or through) when we view an object.

The Greek letters beta (β) and lambda (λ) stand for latitude and longitude, respectively, in these and other systems.

2.2.5 Degrees, minutes, and seconds

Because the celestial sphere appears to be infinitely large, distances on it can only be measured as angles. For example, the apparent width of the Moon is half a degree, which means that two opposite edges of the Moon make a 0.5° angle with its vertex at the observer's eye (Figure 2.5). In similar terms, we can talk about two stars being ten degrees apart or the true field of a telescope being a quarter of a degree.

There are 360 **degrees** (360°) in a full circle. Each degree is divided into 60 **arc-minutes** or simply **minutes** (60′), and each minute is divided into 60 **arc-seconds** or simply **seconds** (60″). Thus $1' = 1/60°$ and $1'' = 1/3600°$.

Some calculators have a built-in function to convert degrees, minutes, and seconds into decimal degrees and vice versa. If yours doesn't, the following examples will show how the conversion is done.

To convert 33°45′18″ into decimal degrees, simply add up its component parts:

$$33°45'18'' = 33 + \frac{45}{60} + \frac{18}{3600} = 33 + 0.75 + 0.005 = 33.755°$$

If the angle is negative, the minutes and seconds are included within the negation:

$$-33°45'18'' = -\left(33 + \frac{45}{60} + \frac{18}{3600}\right) = -(33 + 0.75 + 0.005) = -33.755°$$

It is probably easiest to ignore the minus sign until after the conversion.

Converting the other way is more complicated. First split the integer part from the fractional part:

$$33.755° = 33° + 0.755°$$

Now convert the fractional part into minutes:

$$0.755° = (0.755 \times 60)' = 45.3'$$

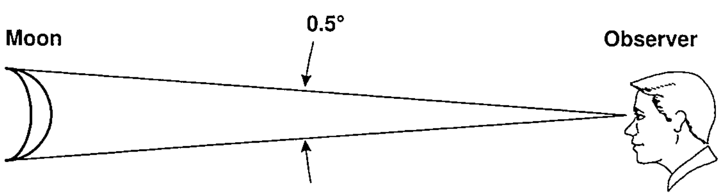

Figure 2.5. The apparent width of the Moon is half a degree. (From *Astrophotography for the Amateur*, Cambridge, 1999.)