Chapter 11

Solar System Observing

Solar System Targets

In this chapter we review various aspects of observing objects within our Solar System using telescopes and binoculars—both for pleasure and also for making useful observations. So vast is this field that numerous entire books have been written about each and every one of the various objects discussed. The coverage given here, of necessity due to space limitations, provides only an overview of this subject. References for further study and contact information for various organizations in this field are also given.

Sun

We begin with our dazzlingly bright *daytime star*, the Sun, which lies at an average distance from us of 93,000,000 miles (or 8 light-minutes). Now here's one celestial object that supplies far too much light rather than not enough (which is the usual complaint of stargazers!)—so much so that it's actually a very dangerous object to observe without proper precautions. Serious eye damage or even permanent blindness can result from attempting to look at our star directly, or from using inadequate filtering techniques. While solar filters were briefly discussed in Chap. 7, it needs to be emphasized here that the *finders* of telescopes must also be capped whenever viewing the Sun, as they too can do damage to the eye, hair, skin (and even clothing!) of the observer. And binoculars, of course, must have proper solar filters

J. Mullaney, *A Buyer's and User's Guide to Astronomical Telescopes and Binoculars*,
The Patrick Moore Practical Astronomy Series, DOI 10.1007/978-1-4614-8733-3_11,

Fig. 11.1 A full-aperture optical glass solar filter mounted over the objective of an 80 mm refractor. (Note the capped finder—a very vital precaution!) While more expensive than Mylar solar filters, these provide better image contrast and a more natural looking yellowish-orange Sun rather than a blue one. Securely mounted, such full-aperture devices are completely safe for viewing our Daytime Star—in contrast to the highly dangerous practice of placing a filter over the eyepiece itself. Courtesy of Orion Telescopes & Binoculars

secured over both of their objective lenses (again, as with telescopes, *not* over their eyepieces!) for safe viewing (Fig. 11.1).

The most obvious visual features of the Sun even in a 2- or 3-in. glass at 25× to 30× are the *sunspots*, with their dark inner *umbra* and lighter outer *penumbra*. (A few of the very largest ones are visible to the unaided eye on occasion and many are visible in binoculars.) Not only are they constantly changing in size and shape, but they continually parade across the face of the Sun from day-to-day as it rotates. Near the limb, they become obviously foreshortened and some even show an apparent depression in the *photosphere* (the visible surface) at their centers. As is well known, sunspots come and go in a period that averages 11-years—the so-called *sunspot cycle*. Near maximum (most recently 2013), the Sun's face may be littered with them, often in large groups, while at minimum it may be difficult to find any at all! (Fig. 11.2)

On rare occasions, a brilliant *white-light flare* will suddenly make its appearance within a sunspot, cutting across it in minutes as it rises up into the Sun's outer atmosphere. Other things to look for are the *limb darkening* towards the edge of the Sun, giving it a very striking three-dimensional shape and looking like the vast sphere it actually is. There are also the minute *granulations*—tiny thermal convective cells in the photosphere that are constantly churning, appearing and disappearing, that are most conspicuous in the areas of limb darkening. A 4- or 5-in. glass at

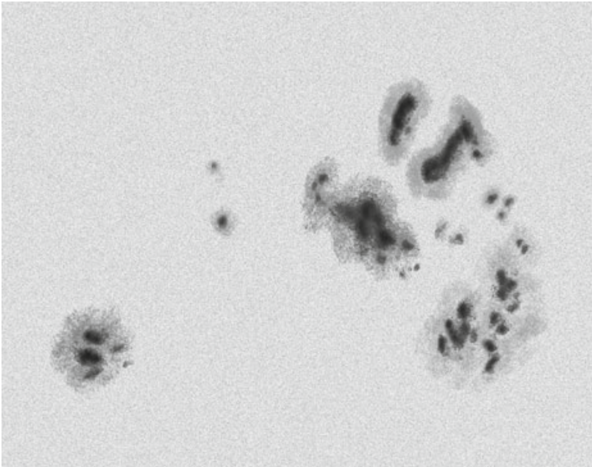

Fig. 11.2 A highly-detailed, stylized sunspot sketch based on a famous classical observation by Samuel Pierpont Langley in 1870 using a 13-in. refractor at very high magnification under superb seeing conditions. Note the dark inner umbra, the lighter wispy outer penumbra and two "light-bridges" crossing the spot. The "freckles" surrounding the sunspot itself represent solar granulation, which are convective cells in the Sun's photosphere (or visible surface)

50× or more will readily show them when seeing conditions are good. Somewhat similar are the *faculae*, which are hotter and therefore brighter patches in the photosphere that are typically seen near sunspots and, as with granulation, are most obvious near the darkened limb.

All of the above are features of the Sun as seen in visible or white-light. With the advent of affordable hydrogen-alpha filters (and even designated solar telescopes with such filters built into them—see Chap. 4), it's become possible for amateur astronomers to look deeper into our star's seething layers and also to view its huge arching *prominences*. The latter can not only be seen rising majestically off of the edge of the Sun, but also across its face as giant snake-like dark ribbons. If you're looking for a celestial object that "does something" while you watch it, there's none more dynamic or spectacular than the Sun viewed in hydrogen-alpha light! (Figs. 11.3 and 11.4)

On rare occasions, *transits* of the Sun by the inner planets Mercury and Venus can be seen. Of the two, those of Mercury are the more common; the last ones having been on May 7, 2003, and November 8, 2006. At such times, the tiny planet appears as a black dot about 10 seconds of arc in size (requiring high-powered binoculars or a small telescope to be seen) slowly moving across the Sun over a period of several hours. Transits of Venus are incredibly rare, and when they do happen they take place in pairs 8 years apart. The previous set occurred in 1874 and 1882, while the most recent one was widely observed on June 8, 2004 and June 5, 2012. At those times, Venus looked like a huge round black sunspot and was easily visible even in binoculars. It should also be mentioned here that transists of dark

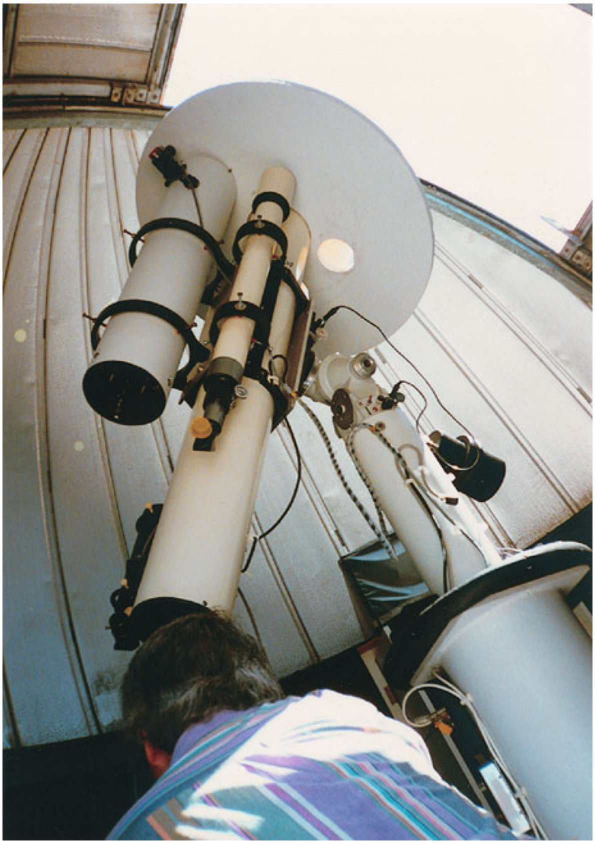

Fig. 11.3 The author at the working end of a 6-in. refractor equipped with a hydrogen-alpha solar filter. Note the circular disk at the top of the tube (through which the filtered objective end of the telescope itself protrudes) covering both the finder and an auxillary short-focus reflector (a very important precaution!). This also serves to block direct sunlight from falling on the observer. Photo by Sharon Mullaney

objects other than Mercury and Venus themselves across the face of the Sun have been reported ever since the invention of the telescope (and there are even some pre-telescopic naked-eye accounts). Although more than 600 have appeared in the astronomical literature over the past three centuries, their nature is still a mystery. So observers should always be on the lookout for such anomalous sightings. Note here that balloons and artificial satellites drift quickly over the face of the Sun while the dark objects that have been seen move slowly, much like the planets themselves. And here again, of course, a proper solar filter is required when observing transits whatever their source!

One last area of interest concerning the Sun is that of *solar eclipses*, in which the Earth passes through the Moon's narrow shadow cone. These may be partial,

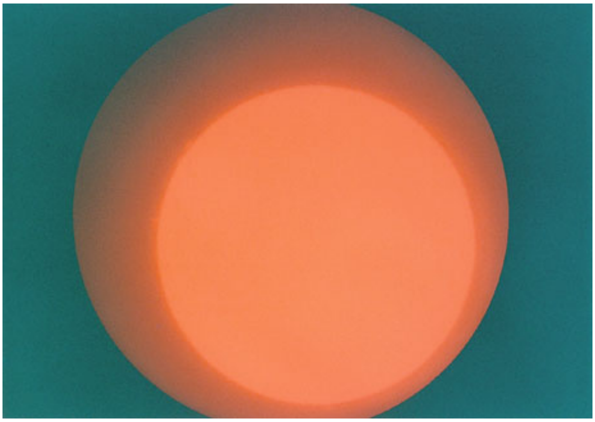

Fig. 11.4 A view of the Sun made by simply pointing a camera through the eyepiece of the telescope in Fig. 11.3. Careful inspection of the Sun's off-center image reveals several tiny prominences along the limb, especially in the 9- to 10-o'clock position. Visually they are much more prominent than shown here, and their graceful movement can actually be seen by patient watching. Photo by Sharon Mullaney

total or annular (with a ring of light still surrounding the Moon at "totality") in nature. It's the total solar eclipse itself that's without question nature's grandest spectacle, and which brings with it so many exciting events all happening within a precious few minutes of totality. These include the sudden visibility of the Sun's delicate but magnificent *corona*, scarlet prominences dancing along its limb, and the well-known "diamond-ring" effect. There's also the dramatic turning of day-light into darkness, the planets and brighter stars making their appearance, and a sudden drop in air temperature as the Sun's light is extinguished. Except within the narrow interval of totality itself, solar filters are absolutely essential for safely viewing an eclipse—whether with the unaided eye, binoculars (which typically provide the best view) or through a telescope itself.

Moon

At an average distance from us of 239,000 miles, our lovely satellite is the nearest of all celestial bodies (with the exception of "Earth-grazing" asteroids!). And as such, it offers so many and varied, fantastic things to see—even in a pair of binoculars. Aside from the obvious dark lunar "seas" (or maria) and bright lunar highland areas, there are majestic mountain ranges, vast walled plains, craters, craterlets, pits, domes, rilles, clefts, faults and rays. As the Moon advances through its monthly *phases*, the interplay of light and shadow across this alien landscape is ever-changing, not only from hour-to-hour but from minute-to-minute! Many observers assume that when a given phase, such as first-quarter (or half-full), repeats itself each month that its features will look exactly the same. Yet, due to the subtleties of orbital dynamics, the Moon does not present the exact same appearance for 7 years! With the exception of the bright lunar rays which are most prominent when the Moon is full, surface features are best seen along the ever-advancing *terminator*—the dividing line between night and day. Here, sunlight coming in at a very low glancing angle casts long dramatic shadows across the landscape, greatly exaggerating vertical relief. The Moon is perhaps most striking when around first-quarter (or half full) (Fig. 11.5).

One of the most fascinating—and controversial—aspects of viewing the Moon is the subject of *transient lunar phenomena* or TLPs. Ever since the invention of the telescope, both amateur and professional astronomers have reported seeing flashes, obscurations, colorations—and even moving lights on its surface! These have been attributed to everything from an over-active imagination to atmospheric refraction, outgassing of sub-surface water, volcanic activity and meteorite impacts. A classic example (which the author himself has witnessed) involving the crater Plato is the slow disappearance of cratelets from one end of its dark floor across to the other side, and then their equally slow reappearance in reverse order—all over a period of just a few hours. Another apparently active area is the crater Aristarchus, where reddish glows have frequently been seen—by everyone from Sir William Herschel to orbiting Apollo astronauts. The key word here is “watchfulness” whenever you’re observing the Moon!

As our satellite moves continuously eastward around the sky in its orbit (by roughly its own diameter each hour), it occasionally passes in front of planets, asteroids, stars and various deep-sky objects such as star clusters resulting in an *occultation*. The disappearance and reappearance of these objects can be quite dramatic—especially for the planets, where the rings of Saturn or the satellites of Jupiter can be seen being gobbled up and swallowed by this huge orb. In the case of stars, they instantly snap off and then later back on, like someone flipping a light switch! (For some close double stars, this will happen in steps, with one star being first occulted and then the other.) One of the most spectacular sights here is the Moon passing in front of a bright star cluster like the Pleiades or Hyades, at which times you can not only watch it ponderously moving through space (especially when its dark part is faintly illuminated by “earthshine”), but also see it seemingly suspended three-dimensionally against a backdrop of more distant stars!

Precise timing of occultations provides valuable information on such topics as the profile of the lunar limb, the Moon’s orbital position and motions and, in the case of asteroids, their sizes and shapes. Especially dramatic are *grazing occultations*, where objects are seen going in and out of valleys and behind mountains at the edge of the Moon. Adding to the fun is a slow “rocking” or “nodding” of the Moon in both longitude and latitude known as *libration* (which allows us to actually see some of its back side, or a total of 59 % of the entire Moon). As a result, features on its edge are constantly changing their aspect to us. Among others, the US-based International Occultation Timing Association (IOTA) collects and analyses observations of lunar occultations. It can be reached at www.occultations.org/. Among other important organizations that collect observations of the Moon of all

Fig. 11.5 The Moon seen near its half phase imaged through an 11-in. Schmidt-Cassegrain catadioptric. A few days on either side of the quarters is the best time to view surface features such as craters, mountains and valleys. It's then that sunlight comes in at a glancing angle, casting long dramatic shadows which exaggerate vertical relief (especially along the terminator, or dividing line between day and night on the Moon). Here's a fascinating alien world right up-close to explore with binoculars and telescopes of all sizes! Courtesy of Dennis di Cicco

types (as well as those of the planets and other Solar System objects) by amateur astronomers are the historic British Astronomical Association (BAA) and the US-based Association of Lunar and Planetary Observers (ALPO). They can be contacted at www.britastro.org/ (or) E-mail at *office@britastro.com*) and www.lpl.arizona.edu/alpo/, respectively.

Two other areas of lunar observing need mention, neither of which has scientific but rather aesthetic value. One is that of *lunar eclipses*, in which the Moon passes through the inner and/or outer parts of the Earth's long cone-shaped shadow—turning pink, copper, orange, rose or even dull- or blood-red due to light being refracted by the Earth's atmosphere into the shadow. Here again, the slow continuous motion of the Moon eastward through the shadow is strikingly obvious even in binoculars. Note also that the shadow of the Earth projected onto the Moon is curved during all phases of the eclipse—vivid proof (known even to the ancients) that our planet is round! The other area is that of *conjunctions*—or the close coming together in the sky—of the Moon with the brighter stars and, especially, brilliant planets like Venus or Jupiter. A typical sight is the lovely crescent Moon hovering over the western horizon at dusk (or over the eastern horizon at dawn), its dark portion beautifully illuminated by *earthshine* and accompanied by one or more brilliant planets and/or stars. Such gatherings are very striking, especially viewed in binoculars and rich-field telescopes (or RFTs). On occasion, both the Moon itself and a planet or bright star can be encompassed within the same low-power eyepiece field of standard telescopes, offering a stunning contrast between different kinds of celestial objects.

There's no greater pleasure than embarking on a nightly telescopic "sightseeing tour" of the Moon's surface features through a small telescope, using a good lunar map to guide you. Wide-angle, low-power views make our satellite seem suspended in space, while high-power ones give the strong impression of hanging in lunar orbit! Being an extended object and so bright, the Moon takes high magnification well, given good seeing conditions. Dividing the distance of the Moon by the power used will tell how far away it appears in the eyepiece. Thus, a magnification of 240× will seemingly bring it to within 1,000 miles at its average distance from us. The lunar detail visible in a good 6-in. aperture telescope (of any type) at this power is simply staggering! Sky Publishing offers several excellent lunar maps that are ideal for such a sightseeing tour. Note here that if using a star diagonal (which is nearly always the case) on a refractor, Cassegrain-style reflector or catadioptric telescope, a traditional inverted lunar map will be all but impossible to compare with the real Moon due to the mirror-image produced by the diagonal. Sky Publishing also offers lunar maps that compensate for this. On-line and hard-copies of their latest catalog (which contains many other valuable observing guides and references) can be obtained at www.skyandtelescope.com. Two other excellent lunar works are *Atlas of the Moon* by Antonin Rukl and *The Modern Moon*: *A Personal View* by Charles Wood. The latter author is also originator of the popular *Lunar 100 Card*, which lists the top lunar sights in order of increasing difficulty on one side and has an identifying map of the Moon on the other. All three of these observing aides are by Sky Publishing, 2004.

Planets

We begin with the elusive planet *Mercury*, closest of them all to the Sun. This tiny orb goes through *phases* like the Moon, never appearing larger than about 7-arcseconds in apparent size when best placed for viewing. This occurs at its greatest *elongations*

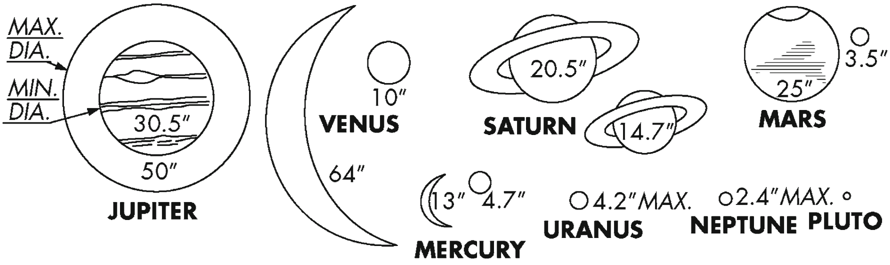

Fig. 11.6 The maximum and minimum relative sizes of the planets in arcseconds to the same scale. Note that Venus is at its apparent largest in the crescent phase, which is why it's then at its brightest rather than when full—as you would expect! Also, remote Pluto remains totally star-like in backyard (and most observatory-class) telescopes no matter how large they may be

east (in the evening sky) or west (in the morning sky) of the Sun, at which time it appears half-illuminated. A 3-in. scope at 100× will show the phases and its tiny pinkish disk, while 200× or more in 6-in. and larger apertures reveals hints of subtle surface markings. Unfortunately Mercury never strays far from the Sun and so is always fairly low above the horizon, where its image is often degraded by the atmospheric turbulence and haze typically found there. For this reason, it is best observed in broad daylight when its much higher in the sky. But finding it then can present something of a problem without the use of precision setting circles—especially with the dazzling Sun so dangerously close by. Go-To or GPS-equipped scopes that have been previously aligned on stars at night and not moved should be able to readily and safely find it using their databases (Fig. 11.6).

Next in order of distance from the Sun is *Venus*, the radiant "Evening/Morning Star" and brightest of all the planets—and indeed of all celestial objects aside from the Sun and Moon. Like Mercury, it goes through *phases*, from full when on the opposite side of the Sun from us to a big crescent when passing between it and us. At such times, its minimum distance from us is some 25,000,000 miles—significantly closer than Mars or any other planet ever approaches. Its crescent then spans over 60-arcseconds in apparent size and can be seen in 10×50 binoculars. Atmospheric extensions of the *cusps* of the crescent into the nighttime side can also sometimes be seen around this time. At its greatest *elongations* east and west of the Sun when half illuminated, it averages 24-arcseconds across. Although perpetually shrouded in dense clouds, subtle *shadings* (including an elusive atmospheric radial "*spoke system*" that's sometimes glimpsed) and *terminator irregularities* can be seen on occasion in telescopes as small as a 4-in. glass. Especially fascinating are the *ashen light* and the *phase anomaly*. The former is an occasional apparent illumination of the dark side seen when Venus is in the crescent phase that has been attributed to possible intense auroral activity. The latter is the strange fact that when Venus reaches its predicted half-full phase (or dichotomy) as seen from Earth, the terminator is not straight as it should be. Instead, this occurs several weeks earlier than predicted for evening elongations and several weeks later for morning ones.

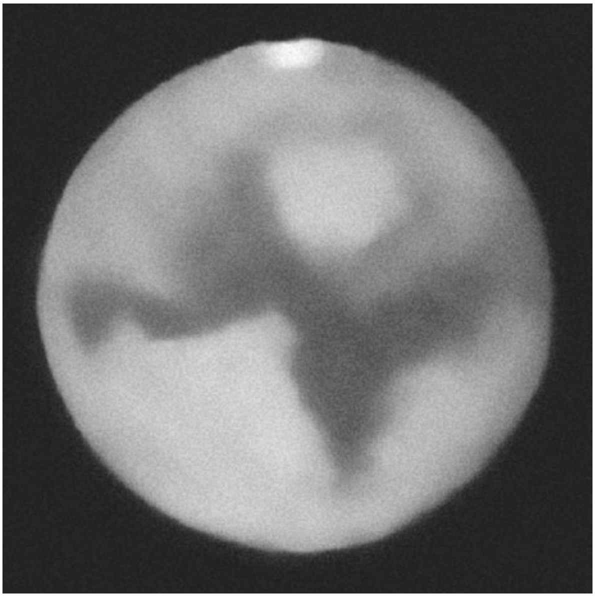

Fig. 11.7 A stylized drawing of Mars as typically seen in large backyard telescopes at high power during its close approaches to us every 26 months when at opposition. Shown here are its dark surface features, lighter deserts and one of its white polar caps. Note also the *streaky linear markings*—the famed "canals" reported by Percival Lowell and other observers, both past and present. South is up, as viewed in an inverting telescope

Sometimes referred to as the "Schroter effect" after its discoverer, its exact cause is unknown. As with Mercury, observations are best made in daylight when the planet is not only higher above the horizon, but also when the sky background reduces the intense glare of the planet as normally seen at night. Another useful technique here is to observe Venus in the evening or morning twilight, when contrast with the illuminated sky also helps reduce glare and improve image quality.

Continuing to move outward from the Sun we find the famed "Red Planet" (it's actually orange!) *Mars*, of mythology, fiction and science, once believed to be an abode of intelligent life. At its *oppositions* every 26 months, it can come as close to us as 34,000,000 miles and appear as large as 25 seconds of arc in apparent size. At such times, a magnification of about 75× makes it look as big in telescopes as does the Moon to the unaided eye! Outside of opposition the planet can be a disappointing sight, as it shrinks to well under 10-arcseconds in size. But during its close approaches, many fascinating features can be seen—especially in 8-in. and larger telescopes (Fig. 11.7).

These include the white *polar ice caps*, the *dark melt band* around each one as they alternately melt with the onset of summer and the accompanying "*wave of darkening*" equatorward, the expansive *orange deserts*, large *dark markings* (which turn from grey in the winter to bluish-green in summer but are not vegetation

Fig. 11.8 Mars as imaged through an 11-in. Schmidt-Cassegrain catadioptric. Compare the surface features seen in this picture with those shown on the drawing in the previous figure (the planet having rotated significantly to the left here). Courtesy of Dennis di Cicco

growing as once believed), vast yellowish *dust storms* which occasionally cover much of the planet, bluish-white *clouds*, streaky "*canals*" and the rotation of the planet every 24 and 1/2 h. Of special interest are the occasional *flares* or flashes that have seen around the time of opposition, now believed to be sunlight reflecting from ice deposits on the surface. However, this doesn't explain those seen projecting off the limb of the planet itself. There's also the mysterious "*blue clearing*" in which the normally opaque atmosphere as seen through blue filters becomes transparent, revealing surface features. Mars has two well-known but very tiny *satellites*, Phobos and Deimos. Shining dimly at about 11th-magnitude and rapidly orbiting close to the planet, they require a 10-in. telescope to be seen, in addition to excellent seeing *and* transparency, due to the glare from Mars itself (Some observers actually place the planet behind an occulting bar to hide it while looking for the moons.) (Fig. 11.8).

The "Giant Planet" *Jupiter* is the most dynamic and exciting object in the Solar System for most observers. At its favorable oppositions, it comes to within 365,000,000 miles of us and its disk grows to as large as 50-arcseconds in size, making the planet obviously non-stellar even in 7× or 10× binoculars. Among the features to be seen here with just a 3-in. telescope at 75× to 100× are its *polar flattening* or elliptical shape (due to its rapid *rotation* of less than 10 hours, which is obvious at the eyepiece as features transit the planet's central meridian), colorful dark belts or *bands* and bright *zones*, the *limb and polar darkening*, snake-like *festoons* and cell-like *ovals*, the famed *Great Red Spot* (which currently looks

Fig. 11.9 A dynamic but moonless Jupiter photographed through an 8-in. Newtonian reflector, showing its two prominent equatorial belts. This was one of those rare occasions when *none* of its satellites was visible—all four moons being either in eclipse, transit or occultation! The rapid rotation of the planet (less than 10 h!) is evident within just minutes of careful watching and results in Jupiter being noticeably flattened through its poles. As for planets in general, much more detail can be seen visually than captured on film. (However, modern high speed electronic imaging can now largely capture what the eye sees.) Courtesy of Steve Peters

salmon-pink), and the thrilling phenomena of its four bright *Galilean satellites*, Io, Europa, Ganymede and Callisto, discovered by Galileo (Figs. 11.9 and 11.10).

These jewel-like moons are visible in steadily-held binoculars (there are even a number of naked-eye sightings in the literature!) and can be seen changing position from night-to-night as they dance about the planet. Even a 4-in. telescope at 100× on nights of steady seeing will show that the moons are "non-stellar" in appearance, having tiny disks (on which marking have been glimpsed with large amateur scopes). And here we truly have a "three-ring circus"—or actually a four-ring, since there are four satellites! Perhaps most spectacular are the *eclipse* disappearances and reappearances, as the orbiting moons move into or leave Jupiter's huge invisible shadow. Io, being the innermost and fastest moving of them requires only a minute or so to fade and then brighten again an hour or two later, while the slower moving outermost two moons take a good 5 min to do so. It's an indescribable thrill to see one of these satellites disappear or reappear right at the time predicted! There are also the *occultation* disappearances and reappearances, as the moons pass behind and then exit the planet's disk. Another set of phenomena are the *transits* of both the moons themselves across the face of Jupiter and of their ink-black shadows cast on the cloudtops. And as if that's not enough action, every 6 years as the Earth

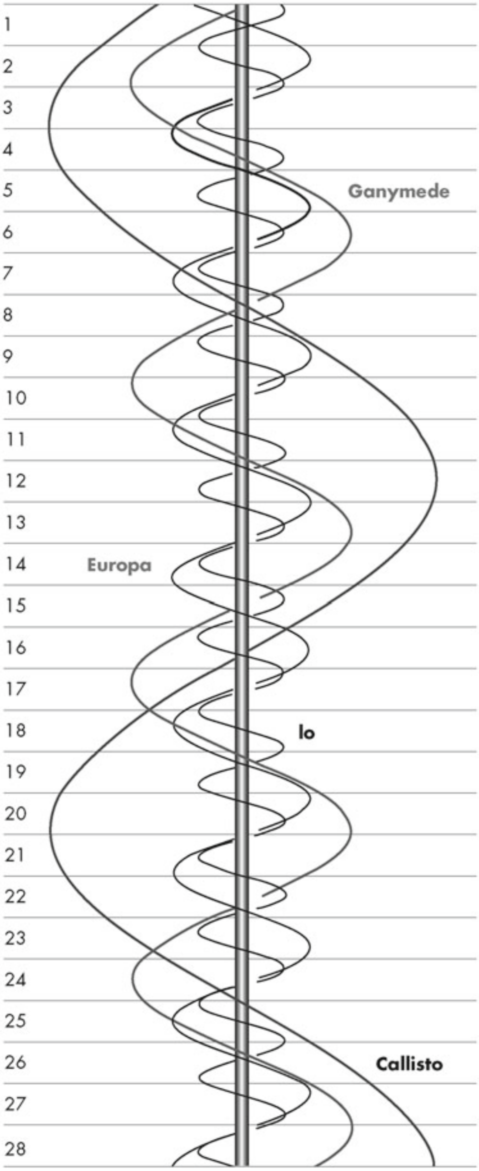

Fig. 11.10 The majestic dance of Jupiter's four bright Galilean satellites about the planet over a 4-week period. (The *double line* down the *center* of the diagram represents the disk of Jupiter itself.) The ever-changing positions of the moons makes this the most fascinating of all the planets for many observers. Visible in steadily-held binoculars, they're a thrilling sight in even the smallest of telescopes

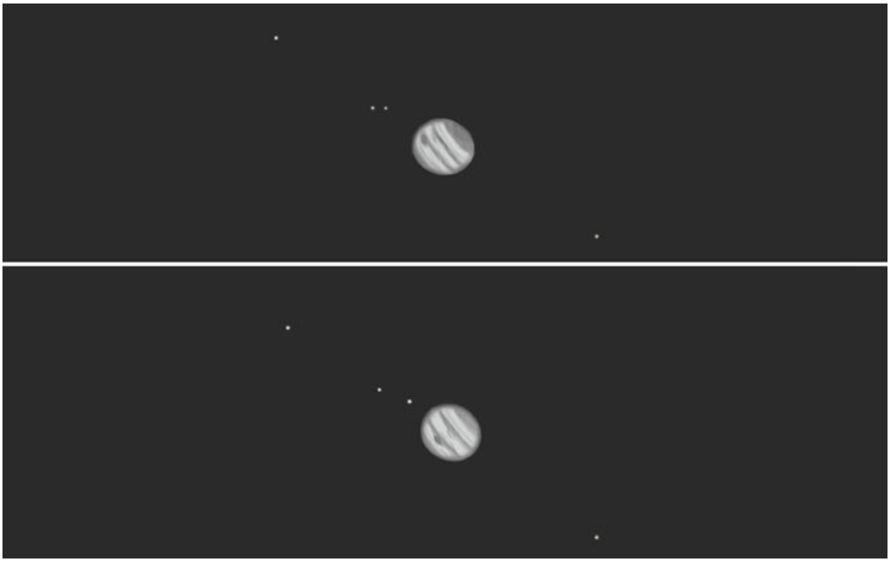

Fig. 11.11 Two eyepiece sketches through a 6-in. reflector showing the change in relative positions of Jupiter's four bright satellites about the planet over a period of 3 h. When one of the inner moons (which move the most rapidly) is near the edge of Jupiter itself or going into its shadow, its orbital motion can be detected in just a matter of minutes!

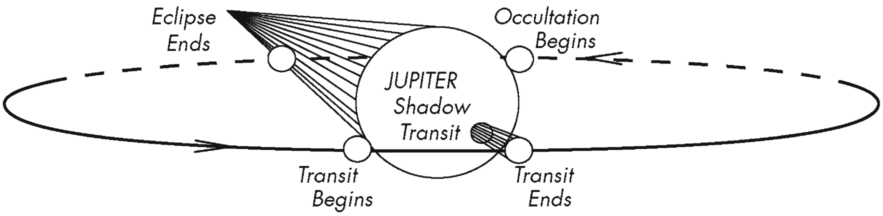

Fig. 11.12 This diagram shows the aspects of the eclipses, occultations and transists of Jupiter's four bright moons, as well the transists of their shadows on the planet's cloud tops. These ongoing events make this giant world ever-fascinating to watch

passes through the plane of Jupiter's orbit, the moons themselves can eclipse and occult each other in a thrilling series of *mutual satellite phenomena*! Times for all of the foregoing events are given monthly in *Sky* & *Telescope* magazine and also on its web site. (Incidentally, even though Jupiter is known to have more than 63 moons at the time of writing, none of the others can be seen visually except in the largest of observatory telescopes.) (Figs. 11.11 and 11.12).

For most people (whether stargazers or not), the "Ringed Planet" *Saturn* is without question the most beautiful and ethereal of all celestial wonders! At its

Fig. 11.13 Magnificent Saturn with its awesome ice-rings imaged through an 11-in. Schmidt-Cassegrain catadioptric. Even at low power in a small glass, the planet looks some exquisite piece of cosmic jewelry. As telescope aperture and magnification increase, it becomes a source of ever-increasing wonder! Here the rings are seen moderately wide open. Note the *thin dark* Cassini Division encircling the rings, and also the shadow of the planet on the rings behind and just to the *left* of the ball. Courtesy of Steve Peters

oppositions, this stunning object passes to within about 750,000,000 miles of us and subtends an apparent size across the rings of some 50-arcseconds (about the same apparent size of Jupiter at opposition), while the ball of the planet appears about 20-arcseconds in size. Just 25× on a 2-in. glass shows them, looking like some exquisite piece of cosmic jewelry, while the view in 12- and 14-in. apertures at 200× or more leaves one gasping for breath in astonishment! (The planet looks egg-shaped in 10×50 and larger binoculars.) These razor-sharp *rings* are made up of billions of chunks of ice and rock orbiting Saturn. There are actually multiple rings, the most obvious being the broad middle B ring and—separated from it by the black *Cassini Division*—the narrower outer A ring. There's also the dusky inner C ring, most obvious as a shading where it crosses the ball of the planet. The rings cast their *shadows* on the planet's cloudtops and the planet casts its shadow on the rings behind it (Figs. 11.13 and 11.14).

Other features to note are the *polar* and *limb darkening* and the obvious *polar flattening* of the planet due to its rapid *rotation* of just over 10 hours at the equator. Transient *white spots* are occasionally seen in the atmosphere. On rare occasions occultations of stars by the rings and planet have been observed, one of the most spectacular of recent times being that of 5th-magnitude 28 Sagittarii in July of 1989.

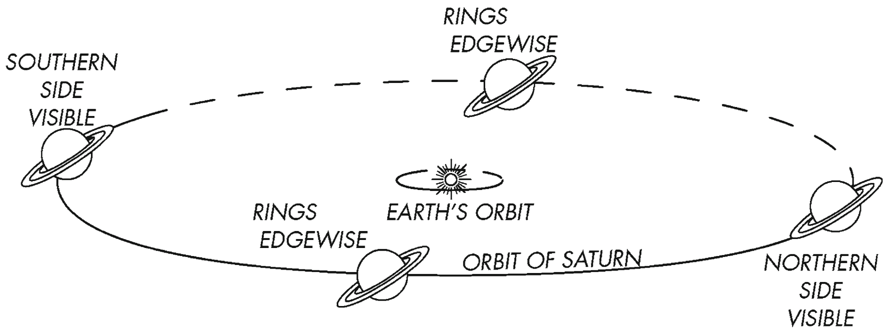

Fig. 11.14 The ever-changing aspect of Saturn's rings as seen from Earth resulting from its 27° axial tilt. After having slowing closed up for several years, the last edge-on ring-plane crossing occurred in September of 2009. At that time they disappeared from sight in all but the largest telescopes and the ringed-planet briefly appeared ringless!

At the time of writing, Saturn is known to have some 60 *satellites*, at least four or five of which can be seen in a 6-in. glass. Titan, the largest, is actually visible in large binoculars and several others can be glimpsed in a 4-in. From one year to another, Saturn's rings noticeably change their inclination or tilt towards us. Every 15 years, the Earth passes across the ring plane, at which time the rings actually disappear from our view for several weeks in amateur scopes—and for several hours in observatory instruments, including the Hubble Space Telescope. (The rings are estimated to be less than 100 *feet* thick!) For a year or so before and after these edgewise events (the last of which occurred in September of 2009), the moons can be seen "threading the rings" like beads on a string! It's also near these times of ring crossings that Saturn's moons go through phenomena similar to those of the satellites of Jupiter, as discussed above.

Uranus was the first of the major planets to be discovered (by Sir William Herschel in 1781 using a 6.2-in. homemade metal-mirrored reflector). Reaching magnitude 5.5 when at opposition, it's just visible to the unaided eye and is an easy object to see in binoculars and to follow its slow orbital motion among the stars. Its tiny greenish disk (only 4-arcseconds in size) is obvious in a 4- or 5-in. glass at 100× on a steady night but is virtually featureless in amateur telescopes. Its retinue of more than 20 dim moons (including its two largest ones, Titania and Oberon) requires large telescopes to glimpse visually, although several of the brighter ones have been imaged in apertures as small as 8-in. Uranus' extremely faint and narrow ring system has only been imaged by spacecraft.

Neptune at 8th-magnitude is visible in binoculars as a star-like object, while 5-in. and larger telescopes at 150× will show its tiny bluish disk just 2.4-arcseconds in apparent size. Its largest moon Triton has been glimpsed visually in large amateur instruments, but the remaining dozen or so currently known, as well as its ultra-faint ring system, all lie beyond backyard telescopes.

Pluto, the former outermost planet, appears star-like and never gets brighter than magnitude 14.5. It requires at least a 10-in. telescope, a dark transparent night, and a detailed chart of its position among the starry background to glimpse at all. As most readers are surely aware by now, the International Astronomical Union has demoted Pluto to being a minor planet or “planetoid” due to its minuscule size—smaller than our Moon! Its large satellite Charon (half as big as Pluto itself) lies less than an arcsecond from the planet and has never been seen visually in any telescope. So too four other smaller moons that have been discovered. The real thrill in observing Uranus, Neptune and Pluto with your telescope is simply being able to look upon these remote and mysterious worlds lurking in the outer Solar System from across *billions* of miles of interplanetary space!

Comets

Another traditional field of observational astronomy in which amateurs have done outstanding work in the past is searching for and monitoring *comets*—using everything from the unaided eye and binoculars to large backyard telescopes. The real lure here, of course, is the chance to achieve astronomical fame by discovering a new comet and having your name attached to it!

There are noted observers like Leslie Peltier, David Levy and William Bradford who have discovered *dozens* of them, while others have found only one—but one so spectacular that it and its discoverer became world-famous. These typically have been the result of purposeful and methodical sweeping of the sky with binoculars and wide-field telescopes. But there have also been totally accidental discoveries, as well as multiple ones by the same observer within a night or two of each other! Today, however, sophisticated professional, wide-angle survey telescopes equipped with CCD “eyes” (designed for patrolling the sky for Near Earth Asteroids—see below) are making most of the finds as a byproduct of their main program. Even so, it’s believed that many comets are still missed as they enter the inner Solar System, so opportunities do present themselves for their visual discovery by amateurs. Should you believe you may have found a new comet, you must do the following (Fig. 11.15).

First, using a detailed star atlas (see Chap. 13) carefully check the starfield it lies in for any deep-sky objects posing as comets. Second, make sure that it’s not an already known new or returning comet using the *Sky & Telescope* web site. Third, wait at least 15–30 min to make sure that the object is actually moving—something comets must do! If your suspected comet passes these tests, note its position on the atlas, the direction it’s moving and its apparent brightness (using surrounding stars of known magnitude defocused to match its appearance). Then immediately report your discovery to the International Astronomical Union’s Central Bureau for Astronomical Telegrams, located in the Harvard-Smithsonian Center for Astrophysics at 60 Garden Street, Cambridge, Massachusetts 02138. Most discoveries of comets and other transient astronomical objects/events today are usually communicated by e-mail at cbat@cfa.harvard.edu rather than by telegram.

Fig. 11.15 Comet Hale-Bopp photographed with a 50 mm camera, showing both its *blue* gas tail and more prominent *pinkish-white* dust tail in addition to its bright coma or head. This is how it actually appeared to the unaided eye and through binoculars at its peak during the spring of 1997. Comet tails always point away from the Sun (due to radiation pressure)—which means that when inward-bound they trail the head, but after rounding the Sun and heading back out into the Solar System they go tail-first! Courtesy of Steve Peters

(The IAU itself is actually headquartered in Paris; its official web site can be found at www.iau.org/.) A good primer for would-be comet hunters, as well as a comprehensive text covering all aspects of comets (including photographic and electronic imaging, photometry, spectroscopy, and even orbit calculation using computers) is *Observing Comets* by Gerald North and Nick James (Springer, 2003).

Asteroids

It's estimated that there may be more than million minor planets or *asteroids* larger than a mile across orbiting the Sun between Mars and Jupiter. Ceres, Pallas, Juno and Vesta were the first four to be discovered (which was done visually with telescopes). Of these, only Vesta becomes bright enough (magnitude 5.5) to be visible with the unaided eye. But hundreds can be seen in binoculars and literally thousands in backyard telescopes. Following their slow movement across the background starfield from night-to-night constitutes their chief attraction to casual observers. However, most are not round and change in brightness as they spin, so their rotational periods can be determined by making continuous magnitude estimates (or measurements if done electronically). And as mentioned above under occultations by the Moon, an indication of their actual shapes can also be obtained by recording the precise times of their disappearances and reappearances from the edge of our satellite. There are even some amateurs who have joined the search by professional planetary astronomers for threatening Near Earth Asteroids (or NEAs), more than a thousand of which are known to cross the Earth's orbit. This includes several that have actually passed *between* the Earth and the Moon in near misses! The clearinghouse for asteroid discoveries and observations is the IAU's Minor Planet Center, also located at the Harvard-Smithsonian Center for Astrophysics.

Meteors

"Shooting Stars" may not seem to be a class of object that would come under the topic of using telescopes and binoculars. But, in fact, *meteors* are often seen unexpectedly flashing through the eyepiece fields of such glasses—typically sending a rush of surprise and excitement (especially in the case of bright ones!) through the unsuspecting observer. Traditionally, naked-eye studies of meteors have focused on counting "hourly rates" and this applies equally to those seen through optical instruments. Keeping track of their numbers over a given interval of time is normally a very casual program that can be done while conducting other observations. But during one of the major annual showers like the Perseids or the Geminids, the eyepiece field may be flooded with faint streaks of light—especially in large-aperture, wide-field telescopes like Dobsonian reflectors. Most of these typically lie near the limit of vision, but on occasion a bright naked-eye meteor (and its train) may actually pass across your view. Talk about being surprised and thrilled! There are two main organizations collecting meteor observations by amateur astronomers. One is the American Meteor Society (AMS), whose web site address is www.amsmeteors.org/. The other is the International Meteor Organization (IMO), which can be reached at www.imo.net/.

Before moving on, it should be mentioned here that one of the standard classic references to observing all of the various objects discussed above is *Observational*

Astronomy for Amateurs by J.B. Sidgwick. Together with his companion volume, the *Amateur Astronomer's Handbook*, they provide an authoritative and comprehensive guide to visual Solar System (as well as stellar) astronomy for serious amateurs that, while somewhat dated, remains very valuable. Both were reprinted by Dover Publications in 1980 from the 1971 Faber & Faber third edition. And while they have been updated and reissued several times since under revised titles, the original editions of Sir Patrick Moore's two classics, *Guide to the Moon* and *Guide to the Planets* from the early 1950s, provide charming and nostalgic overviews of their subjects. Dating from a time when the Moon and planets were still magical and mysterious places for amateur astronomers to explore in their telescopic spaceships, they are simply "must reading" for cloudy nights—if only you can manage to find copies!

Artificial Satellites

Just as meteors seem unlikely telescopic targets, so too do *artificial satellites*. The wide fields of view and rapid pointing capability of binoculars have long been used to follow satellites across the sky. Their frequent variation in brightness due to spinning (especially in the case of the solar panels on the Iridium satellites catching the sunlight and causing them to flash brighter than Venus for a few seconds!) and their slow fading as they pass into the Earth's shadow cone are things to watch for using both binoculars and the unaided eye itself. But there's rarely a night that at least several satellites don't also pass through the eyepiece field of a telescope during an observing session (sometimes several in rapid succession!) no matter where it's pointed in the sky, so many of these objects are there. Undoubtedly the most spectacular of them all is the International Space Station (or ISS). If it happen to pass through the eyepiece, its characteristic shape is quite obvious even though the view only lasts a second or so. The ISS has even been seen silhouetted against the Moon (and the Sun)! And it has also been imaged by amateurs using telescopes on special tracking mountings designed to follow their rapid orbital motions. The author is continually amazed at how often a satellite will pass *directly over* prominent deep-sky objects like the Ring Nebula, the Hercules Cluster or the Andromeda Galaxy. While such passes are definitely an unwelcome annoyance to astroimagers, they are thrilling sights to visual observers. The National Aeronautics and Space Administration (NASA) offers a number of Internet sites that provide satellite predictions for those interested in viewing these hurtling manmade moons. Probably the best of these is the one known as "J-Pass," which can be accessed by placing the following address in your web browser: www.J-Pass.com or http://science.nasa.gov/Realtime/JPass/PassGenerator/. By simply entering your e-mail address in the appropriate box on the site's home page to subscribe, J-Pass will provide times and look-angles for passages over your location of up to ten satellites, including the ISS. Two other useful sites are Real Time Satellite Tracking at http://www.n2yo.com/ and Heavens Above at http://www.heavens-above.com/.