Special Supplement:

Observing The Moon and Planets With Binoculars

A Publication of

One-Minute Astronomer

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The Moon

The Phases of the Moon

The Moon is our nearest neighbor in space — bright, barren, and bleak, and just a quarter million miles away, roughly 100 times closer than our next nearest neighbor, Venus.

While small in size—just ¼ the diameter of the Earth, the Moon's proximity makes it appear large, about 0.5 degrees across when full, and brighter than any other sight in the sky except for the Sun. It has hundreds of interesting features to see in a telescope. And even a modest pair of binoculars reveals dozens of craters, mountains, and smooth seas, or *maria*.

Figure 1 - The phases of the Moon.

The Moon revolves around the Earth each month, and as it does so, we see it go through *phases* (see Figure 1). When the Moon lies between the Earth and the Sun, it's in the "new Moon" phase and is not visible to us. Over the next few days, the Moon grows (or "waxes") to a crescent, then to first quarter, when it appears half-lit, roughly one week after the new Moon. Then its face becomes ever more lit by the sun and enters the gibbous phase until about two weeks after the new Moon, when it lies directly opposite the Sun in the sky and appears fully lit. Then the Moon's phases move in reverse, when they "wane" back through gibbous, last-quarter, and crescent phases, and back to new Moon again some four weeks after it was last new. During the waxing phases, the Moon is visible mostly in the evening. As it wanes, it's best seen in daylight hours.

When you see the Moon partially illuminated by the Sun, the line between bright and dark is called the "terminator". Along this line, the craters, mountains and valleys stand out in stark relief caused by the long shadows cast by the Sun at lunar sunset and sunrise. Away from the terminator, the surface appears smoother, because the Sun casts shallower shadows.

The Landscape of the Moon

The Moon's largest and most visible features are its large, flat, gray patches called *maria* (MAH-ree-a), the Latin plural of mare (MAH-ray), or "sea." You can see the *maria* with the unaided eye. To some, these dark patches appear to form the outline of a face, or "man in the moon".

Of course, these *maria* are really not really seas or oceans. But early telescopic observers did not know this. The Italian astronomer Giambattista Riccioli gave them fanciful names such as *Mare Tranquillitatis* ("Sea of Tranquillity") and *Oceanus Procellarum* ("Ocean of Storms"), generally for the imagined astrological influences of the Moon's phases on the weather. Although astronomers soon realized the Moon has no water, the names of these surface features remained. Observation with telescopes and space probes revealed the "seas" are ancient lava flows that flooded most of the Moon's lowlands between 3.0 and 3.8 billion years ago.

The major *maria* are shown on Figure 2. Even the smallest binoculars will clearly show them. Learn their positions a little at time each night, and you will be on your way to understanding the geography of another world.

Because the *maria* are so smooth, they were selected as landing site for the manned Apollo lunar missions of 1969-1972. Figure 3 shows the position of each landing of Apollo 11 through 17; Apollo 13 did not land because of damage to its service module on the way to the Moon. You will not, of course, see any evidence of spacecraft landing or remnants through binoculars or even with the most powerful backyard telescope.

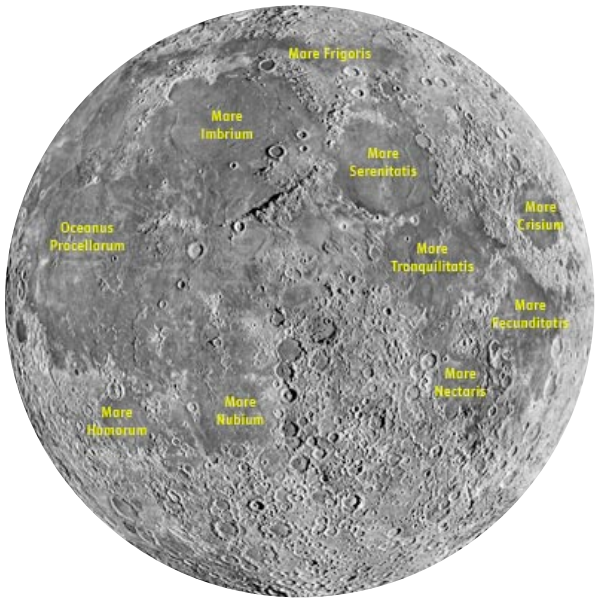

*Figure 2 - The dark seas or "*maria*" on the Moon's surface.*

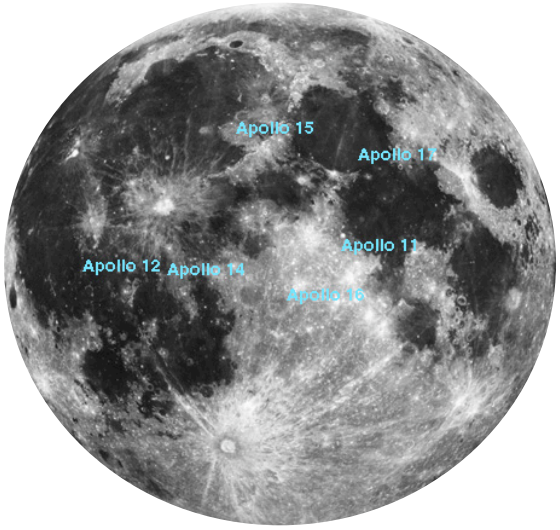

Figure 3 - Landing sites of six manned Apollo missions

The side of the Moon seen in Maps 1 and 2 are the only sides we ever see from Earth. That's because the Moon rotates about its axis in the same period it takes to go around the Earth. This situation arose because of tidal effects by the Earth and Moon on each other. This "tidal locking" is seen on many moons throughout the solar system

The "far side" of the Moon was first imaged in the late 1950's by satellites. As Figure 4 shows, this side of the Moon appears quite different, with few *maria* and many more craters. The far side should not be confused with the dark side of the Moon; the far side essentially get just as much sunlight as the side of the Moon facing Earth.

Craters

The Moon is covered with thousands of craters, scars left by the impact of asteroids and comets over the past 4 billion years. While the Moon is too far away for us to see any craters with our unaided eye, even a small pair of binoculars reveals dozens of craters worthy of examination. A telescope reveals hundreds, if not thousands, more.

Most craters were formed during an era of "heavy bombardment" about 3.9 billion years ago by comets and asteroids left over from the formation of the solar system. Because the Moon has no air or water to erode the surface features, we see the craters fairly unchanged from the early days

of the Moon. The Earth, too, was peppered with craters at the same time as the Moon, but those craters have eroded away over the eons. The moons *maria* have relatively few craters, which means these dark lava plains formed after the era of heavy bombardment.

The large bright areas of the Moon— the lunar highlands — are the Moon's oldest terrain and are crusted with craters of every size, from dozens of miles wide down to tiny craterlets as small as a couple of hundred feet or less. In a telescope, you can even see craters within craters, or craters that overlap because a meteoroid smashed into an existing crater.

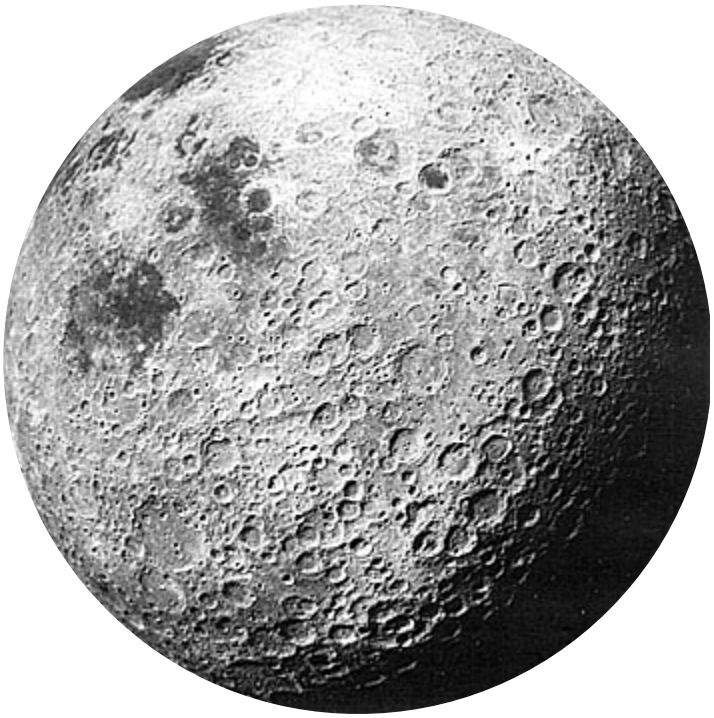

Figure 4 - The far side of the Moon.

A telescope reveals that some large craters have a peak at their center caused by a rebound of the Moon's surface after a large impact. Other large craters look less like holes and more like walled plains, with dark, flat bottoms that flooded with lava after impact.

Young craters are surrounded by bright rays that extend radially across the surrounding landscape. Rays are great splashes of molten rock ejected by the impacts. Unlike craters and mountains, rays are best seen when illuminated more directly by the sun, away from the terminator. In binoculars, at full Moon, bright rays are visible extending from the large, young crater Tycho, which is only about 110 million years old.

The Moon also has a number of mountain ranges and individual peaks. Canyon-like cracks, or rilles, are sometimes visible, especially around the edges of *maria*.

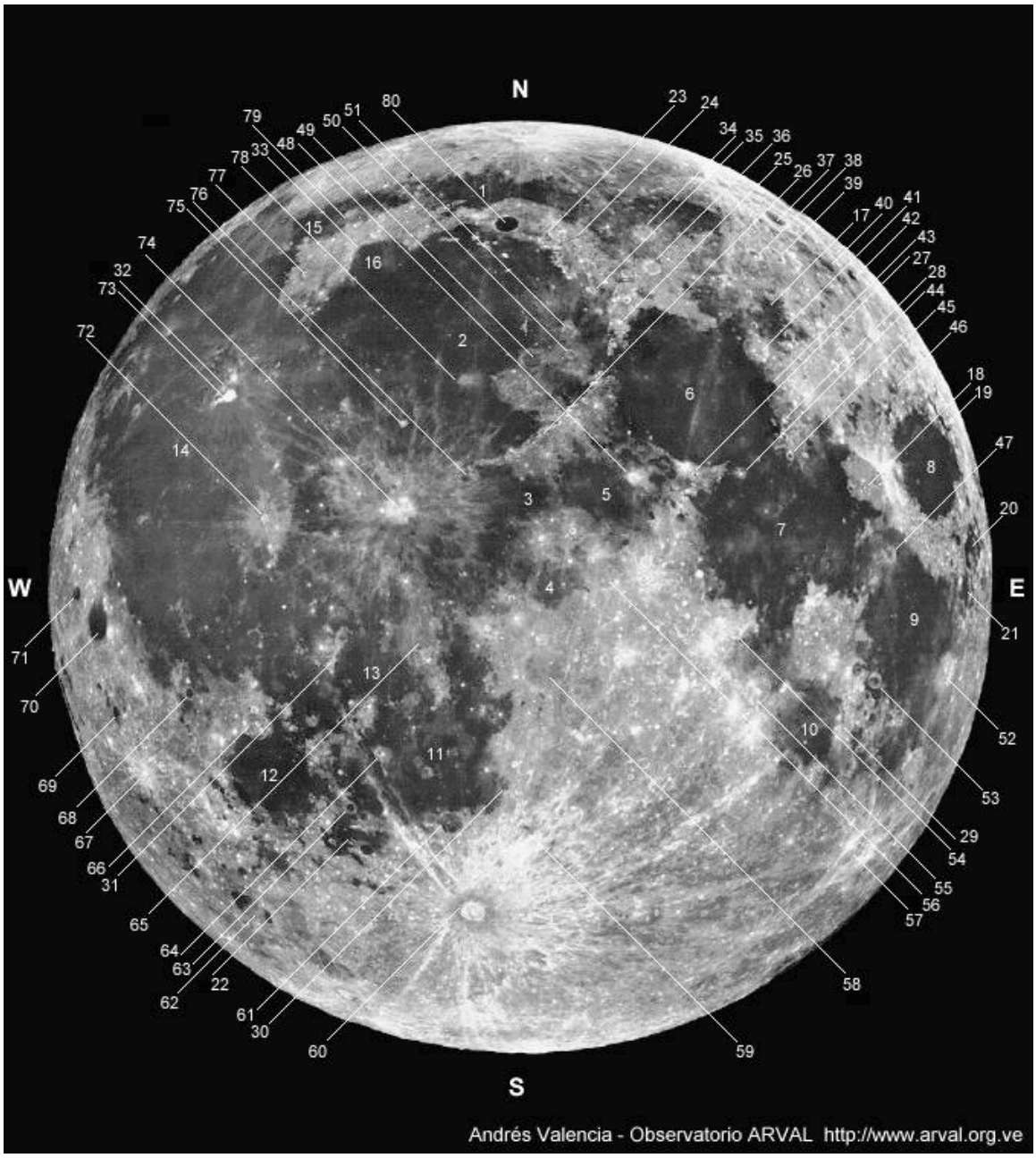

Figure 5- A detailed map of the Moon. All numbered features are found in the Appendix; select features visible in binoculars as discussed in the text.

Touring the Moon's Seas

Now that you know a little about the Moon's surface, let's embark on a descriptive tour of the major features visible through binoculars of magnification of 7-10x. At a magnification of 10x, the

Moon appears just 25,000 miles away, similar to what an Apollo astronaut saw just hours before entering lunar orbit.

We will tour the moon's "seas" from east to west on the Moon, in order of appearance as the Moon waxes from new to full.

The apparently oval form of the *Mare Crisium* (Sea of Crises) (#8) is the first of the "seas" to come into sight after new moon. It makes a very striking sight for viewing at the waxing crescent phase. It measures about two hundred and eighty by three hundred and fifty-five miles in extent and is surrounded by mountains, which can be readily seen when the sun strikes a few days after new moon. A spacecraft, Luna 24, landed in this region in 1976 and returned a soil sample to Earth.

West of *Crisium*, you can see the triangular region *Palus Somnii* (Marsh of Sleep) (#18); south of this region lies *Mare Fecunditatis* (the "Sea of Fertility or Fecundity") (#9). Unlike the smooth-edged *Crisum*, this sea is remarkable for its irregularly-shaped surface edges and the long crooked "bays" into which its southern extremity is divided.

The broad, dark-gray expanse of the *Mare Tranquillitatis* (Sea of Tranquility) (#7) is easily recognized. It looks mottled in some regions as a result of ridges and elevations. Apollo 11 landed in the extreme southwest of this sea on July 20, 1969, when astronauts Neil Armstrong and Buzz Aldrin became the first humans to walk on the Moon.

Mare Nectaris (Sea of Nectar) (#10) is connected with the Sea of Tranquility by a broad strait, while between it and the Sea of Fertility runs the lunar Pyrenees Mountains (#29), which are some twelve thousand feet high.

Mare Serenitatis (Sea of Serenity) (#6) lies northeast of the Sea of Tranquility. It's about four hundred and twenty miles across by four hundred and thirty miles long, being very nearly of the same area as the Caspian Sea on Earth. Serenity is deeper than the Sea of Tranquility, and is deepest toward the middle. Three-quarters of its "shore-line" are bordered by high mountains, and many isolated elevations and peaks are scattered over its surface. The last manned mission to the Moon, Apollo 17, landed at the eastern end of this sea. The Sea of Serenity is divided nearly through the center by a narrow, bright streak, apparently starting from the crater Tycho far in the south. This curious streak can be readily detected in binoculars.

Along the southern shore of the Sea of Serenity extends the high range of the Haemus Mountains (#27). South and southeast are the *Mare Vaporum* (Sea of Vapors) (#5), *Sinus Medii* (Bay of the Center) (#4), and *Sinus Aestuum* (Bay of Seething) (#3). At full moon, you may see three or four dark spots in the region occupied by these flat expanses. On the north and northwest of the Sea of Serenity is *Lacus Somniorum* (Lake of Sleep) (#17).

Mare Imbrium (Sea of Rains) (#2) is a fascinating region, not only in itself, but on account of its surroundings. Its level is very much broken by low, winding ridges, and it's variegated by numerous light-colored streaks. On its northeast border is the *Sinus Iridum* (Bay of Rainbows) (#16), upon which moon gazers have exhausted the adjectives of admiration. The bay is semicircular in form, one hundred and thirty-five miles long and eighty-four miles broad. Its surface is dark and level. At either end a splendid cape extends into the Sea of Rain, the eastern one being called Cape Heraclides, and the western Cape Laplace. They are both crowned by high peaks. Along the whole shore of the bay runs a chain of gigantic mountains, forming the southern border of a wild and lofty plateau, called the *Sinus Iridum* Highlands. Of course, a telescope is required to see the details of this magnificent lunar landscape, and yet much can be seen with binoculars. You may glimpse the capes at the ends of the bay projecting boldly into the dark, level expanse surrounding them, and the highlights of the bordering mountains sharply contrast with the dusky semicircle below. Two or three days after first quarter, the shadows of the peaks about the Bay of Rainbows may be seen. *Sinus Roris* (Bay of Dew) (#15) above the Bay of Rainbows, and the *Mare Frigoris* (Sea of Cold) (#1), are the northernmost of the dark seas visible from Earth.

Extending along the eastern side of the disk is the great *Oceanus Procellarum* (Ocean of Storms) (#14) southeast of which lie *Mare Nubium* (Sea of Clouds) (#11), *Mare Humorum* (Sea of Moisture) (#12) and *Mare Cognitum* (Known Sea) (#13). These regions are irregular in outline, and broken by ridges and mountains. To the naked eye, even the relatively small Sea of Moisture is easily seen as a dark oval patch.

Craters and Mountains

Now, to lunar mountains and craters. The dark oval called Grimaldi (#70) can be detected on the western limb of the Moon by the unaided eye, although it requires a sharp vision and perhaps filter to reduce the glare of the moon. Grimaldi is simply a plain, a basin with worn down walls containing some fourteen thousand square miles. It's remarkable for its dark color. Grimaldi is also know to exhibit "transient lunar phenonmena" such as flashes of light and patches of color and haze. The reason for such activity is unknown and is an area of active research among dedicated amateur astronomers.

The basin called Schickhard (#62) is similar to Grimaldi, nearly as large, but it does not possess the same dark tint in the interior. The huge mountains around Schickhard make it a fine sight when the sun is rising upon them shortly before full moon.

Other than the *maria*, the feature of the full Moon's surface that instantly attracts attention is the remarkable brightness of the southern part of the disk, and the brilliant streaks radiating from a bright point near the lower edge. Of this region, many observers remark the Moon looks like a

peeled orange. The bright point, which is the great crater Tycho, looks exactly like the pip of the orange, and the light streaks radiating from it in all directions bear an striking resemblance to the streaks that one sees upon an orange after the outer rind has been removed.

Tycho (#60) is the most famous of the Moon's crater, though it's not the largest. It's about fifty-five miles across and three miles deep. In its center is a peak five or six thousand feet high. Tycho is the radial point of the great rays that are caused by ejected molten rock thrown out by the impact of a comet or asteroid. Unlike many details on the Moon's surface, the rays are best seen at full Moon; they cannot be seen at all until the sun has risen to a certain elevation above them. The rays pass straight over the most rugged regions of the moon for some 2,000 kilometers, retaining their brilliance as far away as the Sea of Serenity. Some of the rays can be seen on parts of the Moon illuminated only by the reflected light from the Earth.

The double chain of great crater-plains reaching halfway across the center of the moon contains some of the grandest configurations of mountain, plain, and crater. The names of the principal ones can be learned from the map, and you will find it interesting to watch them come into sight about first quarter, and pass out of sight about third quarter. With binoculars, some of them look like enormous round holes in the inner edge of the illuminated half of the moon. Theophilus (#55), and nearby Cyrillus and Catharina are three of the finest walled plains on the Moon.

The Caucasus Mountains (#25) are a mass of highlands and peaks which introduce you to a series of formations resembling those of the mountainous regions of the earth. The highest peak in this range is about nineteen thousand feet high. Between the Caucasus and the Apennines (#26) lies a level pass, or strait, connecting the Sea of Serenity with the Sea of Rains. The Apennines are the greatest of the lunar mountains. They extend some four hundred and sixty miles in length, and contain one peak twenty-one thousand feet high; many others vary from twelve thousand to nearly twenty thousand feet, much higher than the Apennines of the earth. As this range runs at a considerable angle to the line of sunrise, its high peaks can be seen tipped with sunlight for a long distance beyond the generally illuminated edge about the time of first quarter. Even with the naked eye the sun-touched summits of the lunar Apennines may at that time be detected as a tongue of light projecting into the dark side of the moon. The Alps (#23) are another mountain range of great elevation, whose highest peak is a good match for the Mont Blanc of Earth, after which it has been named.

Plato (#80) is a celebrated dark and level plain, surrounded by a mountain ring, and presenting in its interior occasional changeable phenomena which have caused much speculation, but which, of course, lie far beyond the reach of binoculars.

The great crater Copernicus (#74) bears a general resemblance to Tycho, and is slightly greater in diameter but is not quite so deep. It has a cluster of peaks in the center, whose tops may be seen

with binoculars as a speck of light when the rays of the morning sun, slanting across the valley, illuminate them while the floor of the crater lies in darkness. Copernicus is the center of a system of rays that resemble those of Tycho, but are very much shorter.

The Planets

When attempting to view the planets with binoculars, don't expect too much. The features of the surfaces and cloud-tops of the planets are far beyond the capabilities of even powerful binoculars. But the difference between the appearance of a large planet and that of the stars will certainly be obvious.

Unlike the stars, planets move about in the sky from week to week and month to month as they and the Earth revolve around the sun. In fact, planets take their name from the ancient Greek term, "wanderer". To find where each planet lies in the sky, you can check online resources such as *Sky and Telescope*, or printed yearly guides of the position of the Moon and planets, such as that published by the Royal Astronomical Society of Canada.

Mercury

Mercury, the closest planet to the sun, rapidly changes its place in the sky from week to week, even from day to day. Not many people ever see Mercury; even the great Nicholas Copernicus was said to never have seen the planet in his lifetime. A powerful backyard telescope shows no surface detail on Mercury... it's too far away and lies to close to the sun. But compared to viewing with the unaided eye, the beauty of the planet is greatly increased when viewed with binoculars. Mercury is brilliant enough to be readily distinguishable, even at twilight. When it's far enough from the sun in the sky for viewing, you may have fine views of this tiny baked world, glittering like a globule of shining metal through the fading curtain of a sunset or the onset of a sunrise.

Venus

Venus is, under favorable circumstances, much more interesting for binocular observations. Because they lie closer to the sun than the Earth, Venus, like Mercury, goes through phases much like the Moon. The crescent phase, where the angular span of the planet is largest, can be glimpsed with a powerful glass when the planet is nearest the Earth and sun (a position called inferior conjunction). Even when the form of the planet cannot be seen, its brilliance makes it an attractive sight. Venus is embedded in a dense blanket of permanent cloud cover that adds to the reflectivity of the planet, but which means you'll see no surface features. Just watching the dance of Venus across the sky as it moves cyclically from evening "star" to morning "star" and back again

is a delight in itself. Aside from the sun and the Moon, Venus is the brightest object in the night sky.

Mars

Mars is smaller and more distant than Venus, and it's too far away to display surface detail in binoculars. Yet when it's at or near opposition, that is, opposite the sun in our sky and closest to Earth, it is a superb object even for a binoculars because of the contrast its deep reddish-yellow color presents with most stars. It can often be seen close to the moon and stars, and the beauty of this proximity is in some cases greatly enhanced in binoculars.

Jupiter

Jupiter, although much more distant than Mars, is a far more conspicuous object in the sky because of its immense size. Binoculars offer too little magnification to show the banded clouds and features such as the famed "Red Spot", which is an immense hurricane-like storm that has persisted for hundreds of years. But even a modest glass will show Jupiter's four moons, which, as they revolve around the giant planet, present a miniature of the solar system.

If you can't spot all four of Jupiter's largest moons, chances are one or more of them lies either between you and the planet, or behind the planet, or buried in the planet's shadow, or else so close to the planet as to be concealed by its brilliance. The positions of the moons, named Io, Europa, Ganymede, and Callisto, can be found in the print or online edition of Sky and Telescope and other almanacs.

Figure 6 - Jupiter and its four largest moons

Of course, since the motions of Jupiter's satellites, particularly of the inner ones, are very rapid, their positions are continually changing, and their configurations are different each night, and indeed, from hour to hour. If you have any doubt about which moon is which, or think they may be little stars, you have only to carefully note their position and then look at them again the next evening. You may even notice their motion in the course of a single evening, if you begin early and follow them for three or four hours. It is impossible to describe the peculiar attractions of the scene

presented by the great planet and his four little moons on a serene evening to an observer armed with good binoculars. Probably much of the impressiveness of the spectacle comes from the knowledge that those little points of light, shining in a row are, at every instant, under the gravitational influence of Jupiter, and that as we look upon them, obediently making their revolutions, never venturing beyond a certain distance away, we behold the forces to which our own planet is subject as it revolves around the sun, to whose control even Jupiter in his turn submits.

Saturn

The beautiful planet Saturn requires for the observation of its rings magnifying powers far beyond those of binoculars. It would be well, however, for you to trace its slow motion among the stars with the aid of an almanac. You may be able to see, under favorable circumstances, the largest of its eight moons, Titan, which has a brightness of magnitude 8.5: faint, but still within the range of most binoculars.

The Outer Planets

It may appear somewhat presumptuous to place Uranus, a planet which required the telescope and the eye of William Herschel to discover, in a list of objects for binoculars. But Uranus was likely seen many times before Herschel's discovery, being simply mistaken, on account of the slowness of its motion, for a fixed star. When near opposition from the sun, Uranus looks as bright as a sixth-magnitude star, and can be easily detected with the naked eye when its position is known. With binoculars, this distant planet can be watched as it moves deliberately onward in its gigantic orbit. Its passage by neighboring stars is an exceedingly interesting sight; it's in this way that you may most easily find the planet. Armed with binoculars, a star map, and positional information from an almanac or periodical such as *Sky and Telescope*, you can discern the location of Uranus and assure yourself of the existence of the planet by watching its motion against the background stars from night to night.

Neptune, alas, is beyond the reach of all but the most diligent binocular observer. It can be found in the same way as Uranus, but at magnitude 8 it shines more than 6x fainter than Uranus, so a careful eye is required to spot this distant world at all. Pluto, whether you consider it a planet or not, if far beyond the reach of binocular observers, and indeed most backyard telescopes.

Appendix - A Detailed Map of the Moon

Here is a list of the detailed features in the map of Figure 5. Most of the *maria* are visible in binoculars, but a telescope is required to see all the craters, mountains, and other features listed here.

North:

1- Mare Frigoris (Sea of Cold)
2- Mare Imbrium (Sea of Rains)
3- Sinus Aestuum (Bay of Seething)

Northeast:

4- Sinus Medii (Bay of the Center)
5- Mare Vaporum (Sea of Vapors)
6- Mare Serenitatis (Sea of Serenity)
7- Mare Tranquillitatis (Sea of Tranquillity)
8- Mare Crisium (Sea of Crises)
17- Lacus Somniorum (Lake of Sleep)
18- Palus Somnii (Marsh of Sleep)
19- Mare Anguis (Sea of Snakes)
20- Mare Undarum (Sea of Waves)

Southeast:

9- Mare Fecunditatis (Sea of Fecundity)
10- Mare Nectaris (Sea of Nectar)
21- Mare Spumans (Sea of Foam)

Southwest:

11- Mare Nubium (Sea of Clouds)
12- Mare Humorum (Sea of Moisture)
13- Mare Cognitum (Known Sea)
22- Palus Epidemiarum (Marsh of Diseases)

West:

14- Oceanus Procellarum (Ocean of Storms)

Northwest:

15- Sinus Roris (Bay of Dew)
16- Sinus Iridum (Bay of Rainbows)

Mountains

Northeast:

23- Montes Alpes
24- Vallis Alpes (Alpine Valley)
25- Montes Caucasus
26- Montes Apenninus
27- Montes Haemus
28- Montes Taurus

Southeast:

29- Montes Pyrenaeus

Southwest:

30- Rupes Recta (Straight Wall) [Geological Fault]
31- Montes Riphaeus

Northwest:

32- Vallis Schröteri (Schröter's Valley) [Northwest of Crater Aristarchus, 73, and North of Crater Herodotus]
33- Montes Jura

Craters

Northeast:

34- Crater Aristotle [on the East part of Mare Frigoris, 1]
35- Crater Cassini
36- Crater Eudoxus
37- Crater Endymion
38- Crater Hercules
39- Crater Atlas
40- Crater Mercurius
41- Crater Posidonius
42- Crater Zeno
43- Crater Le Monnier
44- Crater Plinius

45- Crater Vitruvius
46- Cráter Cleomedes
47- Crater Taruntius
48- Crater Manilius
49- Crater Archimedes
50- Crater Autolycus
51- Crater Aristillus

Southeast:

52- Crater Langrenus
53- Crater Goclenius
54- Crater Hypatia
55- Crater Theophilus
56- Crater Rhaeticus [Crater Hipparchus is directly South of Crater Rhaeticus]
57- Crater Stevinus
58- Crater Ptolemaeus
59- Crater Walter

Southwest:

60- Crater Tycho
61- Crater Pitatus
62- Crater Schickard
63- Crater Campanus
64- Crater Bulliadus
65- Crater Fra Mauro
66- Crater Gassendi
67- Crater Byrgius
68- Crater Billy [Mons Hansteen is to the North of Crater Billy]
69- Crater Crüger
70- Crater Grimaldi
71- Crater Riccioli

Northwest:

72- Crater Kepler
73- Crater Aristarchus [Crater Herodotus is West of Crater Aristarchus]
74- Crater Copernicus
75- Crater Pytheas
76- Crater Eratosthenes [near the Southwestern extreme of Montes Apenninus, 26]
77- Crater Mairan

78- Crater Timocharis

79- Crater Harpalus [Crater Pythagoras is North of Crater Harpalus]

80- Crater Plato