Seeing the Solar System

Telescopic Projects, Activities & Explorations in Astronomy

Fred Schaaf

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FRED SCHAAF

with illustrations by Doug Myers

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Preface

This book is complete in itself. But it is also the second in what will be at least a trilogy. The first volume, published in 1990, is *Seeing the Sky*—a selection of astronomical activities for naked-eye observers. The book you now hold in your hands offers projects concerning the Sun, Moon, planets, and other bodies of our solar system for telescopic observers. The next book will also feature telescopic projects, but ones involving celestial objects beyond our solar system—stars of all kinds, star clusters, nebulas, galaxies, and quasars.

All three of these books are intended to be suitable for use by everyone from the beginning to the quite advanced observer, by the bright junior high school student as well as the adult amateur astronomer. A fairly small telescope will suffice for most of activities in the telescopic books. The present book does contain some projects that are devoted largely to elementary facts and basic observations, but in most cases I think these projects are presented in a manner that even the veteran skywatcher will benefit from reviewing.

In the previous book, *Seeing the Sky,* I was anxious to present projects that were outstandingly original. That was easier to do with naked-eye observations because they have been neglected so much in recent years. After the completion of that book, however, I realized that organizing *all* the important telescopic observations that can be made of various celestial objects in the format of projects like those of the first book would itself be original. I am not aware of anyone who has attempted this with anything like comprehensiveness or for adult amateur astronomers (though not only for adult amateur astronomers).

PREFACE

This book covers so much territory, with hundreds of individual inquiries for the observer to pursue, that it scarcely needs (and would be unwise to try including) the whole vast additional realm of possibilities opened by advanced astrophotography or the use of other instruments with the telescope. But there are other reasons for this book to concentrate on projects requiring the telescope only. Not everyone—not even all high schools or colleges, let alone all individuals beginning the study of astronomy—can immediately afford much equipment beyond the basic telescope. In this book, I have made comment on the use of various filters for planetary observation because they can be so helpful and are not prohibitively expensive. Otherwise, the book assumes only a basic telescope—and not necessarily a large one—is in the reader's possession. And, as for the proper use and care of a telescope or the advantages and drawbacks of different kinds of telescope, these are certainly matters that require a lot of explanation, but they certainly fall outside the province and aim of this book. See the "Sources of Information" section for ideas about where to turn for this advice.

In conclusion, I wish to encourage readers to write to me with any comments or suggestions, and especially with any observational results elicited by the reading of this book. You can write to me in care of Wiley Science Editions, John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158.

My sincerest hope about this book is that it will be used. Make acquaintance with the fellow worlds of our solar system—not just on the page but in your telescope. I do not think you will find it easy to get over the polar ice caps of Mars, to forget the rings of Saturn, or to let go of the lunar crater Copernicus—not once you have looked upon these things with some depth of knowledge and with a purpose.

Fred Schaaf

Note on Telescopes, Transparency and "Seeing," and Light Pollution

Telescopes. In the preface, I explained that this book is not a guide to telescope selection, use, or care. The reader is directed to the "Sources of Information" section for suggested reading on the topic. But a few elementary points on telescopes may be mentioned here.

The three most important types of telescopes are the *reflector*, the *refractor*, and the *catadioptric*. The reflector uses mirrors and the refractor uses lenses, while the catadioptric employs both reflective and refractive elements. The most popular type of reflector is the Newtonian; the most popular catadioptric is the Schmidt–Cassegrain. For the lunar and planetary observing with which most of this book is concerned, the large focal ratios (ratio of mirror or lens focal length to its width) of refractors and of some reflectors are most desirable. A good Schmidt–Cassegrain will be sufficient for such observations, however. And four of the activities concern comets—objects for which the lower magnifications and wider fields of a "faster" (smaller focal ratio) telescope are most needed. A comet observer will often be using a small Newtonian RFT (rich-field telescope) or refractor.

The two most important types of telescope mountings are the *equatorial* and the *altazimuth*. A special form of the latter, the Dobsonian mounting, has become popular in the past decade for "deep-sky" observing. But for observing fine details on the Moon and planets, a clock drive to compensate for Earth's rotation becomes more important—and such a drive must be used with an equatorial mount. (Adapting an altazimuth for a clock drive is possible but requires considerable modifications.)

The quality of the eyepieces, or *oculars*, used with a telescope can make a great difference in what you see. Also very important is the proper alignment, or *collimation*, of the optical elements. The finest telescope will not perform very well with poor eyepieces and may be positively wasted if it is not kept at least fairly well collimated.

Transparency and "Seeing." There is more to good observing conditions than a cloud-free sky. The atmosphere's degree of freedom from moisture and dust is called *transparency*. The atmosphere's degree of freedom from turbulence is called "seeing."

Some kinds of astronomical observations demand good transparency; others, good seeing. Any observation that requires glimpsing faint objects is best tried when the transparency is good, for the light from celestial objects is scattered away by moisture and dust in the air. Any observation that requires sharp images is best tried when the seeing is good, for the steadier the atmosphere is (the less turbulent) the sharper your view should be. Most lunar and planetary viewing does not require excellent transparency because we are dealing with bright objects. In fact, in some cases they are so bright against the night sky that twilight or daytime observation or use of filters may be in order. On the other hand, the fine detail and subtle contrasts of features on the surface or in the atmosphere of these distant worlds demand good seeing.

Light Pollution. Some of the planets are so bright that telescopic observation of them is not really hindered by brilliant moonlight or city lights. The other planets, the planetary satellites, the asteroids, the meteors, and, most especially, the comets are a different story, however. Nowadays, anyone who wants to view them faces the same critical problem that confronts almost all observations, naked-eye or telescopic, of anything beyond our solar system—the problem of *light pollution*.

Light pollution is usually defined as excessive or misdirected artificial outdoor lighting. It results from inferior lighting fixtures and practices that do more than rob us of our view of the universe. Light pollution costs all of us money (several billion dollars a year in the United States alone) and wastes energy, forcing millions of extra tons of coal and barrels of oil to be burned each year—a significant contribution to air pollution, acid rain, and greenhouse warming. The glare from poor lighting fixtures greatly reduces traffic safety and certainly does not help provide greater security against crime.

Since light pollution hurts all of us, there is real hope that the movement to reduce it will eventually succeed. I urge every reader of this book to help restore our generation's view of the heavens, and to save the next generation's, by learning more about the problem and its solutions and by sharing that information with others. The essential way to begin is to consult the central clearinghouse for light pollution information and advice, the International Dark-sky Association (IDA). For information, write to:

IDA
3545 North Stewart
Tucson, AZ 85716

Note on the Measurement of Time, Position, Angular Distance, and Brightness in Astronomy

The following concepts are not necessary to know for most activities in this book; for a few activities, however, they are very important.

Time. Universal Time (UT) is 24-hour time, essentially the same as Greenwich Mean Time (GMT). The day in UT begins at midnight in the time zone of England's Greenwich meridian. In the United States, Local Standard Time is 5 (Eastern Standard Time [EST]), 6 (Central Standard Time [CST]), 7 (Mountain Standard Time [MST]), and 8 (Pacific Standard Time [PST]) hours behind UT. Thus, 10h UT on January 18 would be 5:00 A.M. EST, and 4h UT on January 18 would be 11:00 P.M. EST on January 17.

Position. A system of celestial coordinates sometimes referred to in this book is that of right ascension (RA) and declination. On the celestial sphere of the heavens, with its equator and poles directly over those of Earth, RA and declination are similar to longitude and latitude, respectively, on Earth. RA is not measured in degrees west or east of the Greenwich meridian, however, but in 24 "hours" (containing "minutes" and "seconds" of angular measure), which run east from the 0^h line of RA. That line goes through the vernal equinox point in the sky (where the Sun is located in the heavens as spring begins). Declination is measured in degrees, minutes, and seconds, like latitude, but declinations north of the celestial equator are preceded by a plus sign (+) and those south of the celestial equator by a minus sign (−).

NOTE ON MEASUREMENT

Angular Distance. From horizon to zenith is 90 degrees (out of the 360 degrees around the entire heavens above and below the horizon). The Moon and Sun appear about 0.5 degree wide. Your fist at arm's length is about 10 degrees wide.

Brightness. In astronomy, brightness is measured by *magnitude*. Originally, all naked-eye stars were categorized in six classes of brightness, from first magnitude (brightest) to sixth magnitude (faintest). In modern times, the scale has been extended to zero and to negative magnitudes for very bright objects and to much higher numbers for objects so faint that they require optical aid to see. Decimals are used between two magnitudes: A star midway in brightness between magnitudes 1.0 and 2.0 is 1.5 (the magnitude 1.5 star is dimmer than magnitude 1.0—the lower the magnitude, the brighter the object). A difference of 1 magnitude means one object is about 2.512 times brighter than another. This is because it was considered useful to set a 5-magnitude difference equal to 100 times—2.512 (actually 2.5118. . .) multiplied by itself 5 times is 100.

Metric Conversions. This book uses both miles and kilometers. To convert from kilometers to miles, multiply the figure by 0.6214. To convert from miles to kilometers, multiply the figure by 1.609.

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MOON, SUN, AND ECLIPSES

1.

General Observations of the Moon

Compare the visibility of topographic lunar features near the terminator to that of features far from it. Observe the first appearance and then increasing prominence of rays from lunar craters as the Moon waxes and their decreasing prominence as it wanes. Study the foreshortening of lunar craters and other features near the limb. Note the changes in the amount of foreshortening caused by libration over the course of many nights.

Everyone who owns a telescope knows the awe of that first look at the Moon. Perhaps no sight in all of nature presents us with a greater impression of brightness, hugeness, and glorious complexity.

The only problem is that for beginning lunar observers the complexity can also be bewildering. Since a 6-inch telescope can reveal craters down to about a mile across and linear formations much thinner, something like a million features are visible with such an instrument. Far more confusing than mere numbers is the changing appearance of the features caused by the fairly rapidly changing angle of sunlight on the Moon due to the Moon's orbiting and the slower waggings of the Moon's face (both side-to-side and up-and-down) called *libration.*

What, then, is the best way to start the seemingly monumental task (and truly monumental adventure) of learning the features on the Moon? Our first activity in this book does not even call for learning individual features. It calls for studying how libration and the progress of the lunar day change the appearance of all lunar features.

After your initial marvel at the brilliance and hugeness of the Moon and the mind-boggling number of craters and other features on its face, you may next notice that the general visibility of these features varies according to two factors. One is how far the feature is from the line separating light and dark (day and night) on the Moon. The other factor is how far the feature is from the edge of the earthward-pointing side of the Moon, the edge of the disk of Moon we observe.

The line separating day and night on the Moon (or on any world) is the *terminator.* At any phase except Full Moon and New Moon, you can view the terminator with a telescope and see in a moment that the topographic features near the terminator all appear much sharper and more

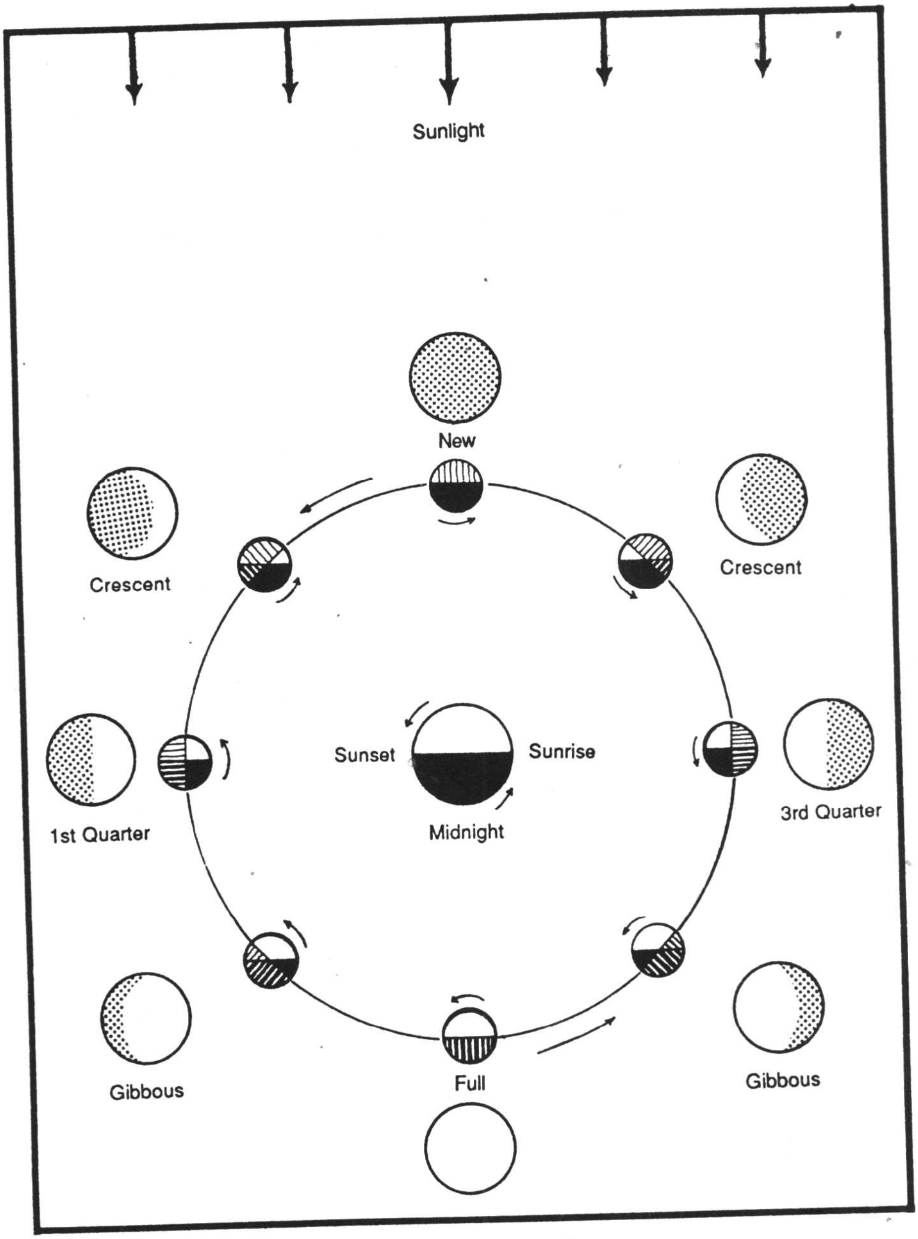

Figure 1 Phases of the Moon.