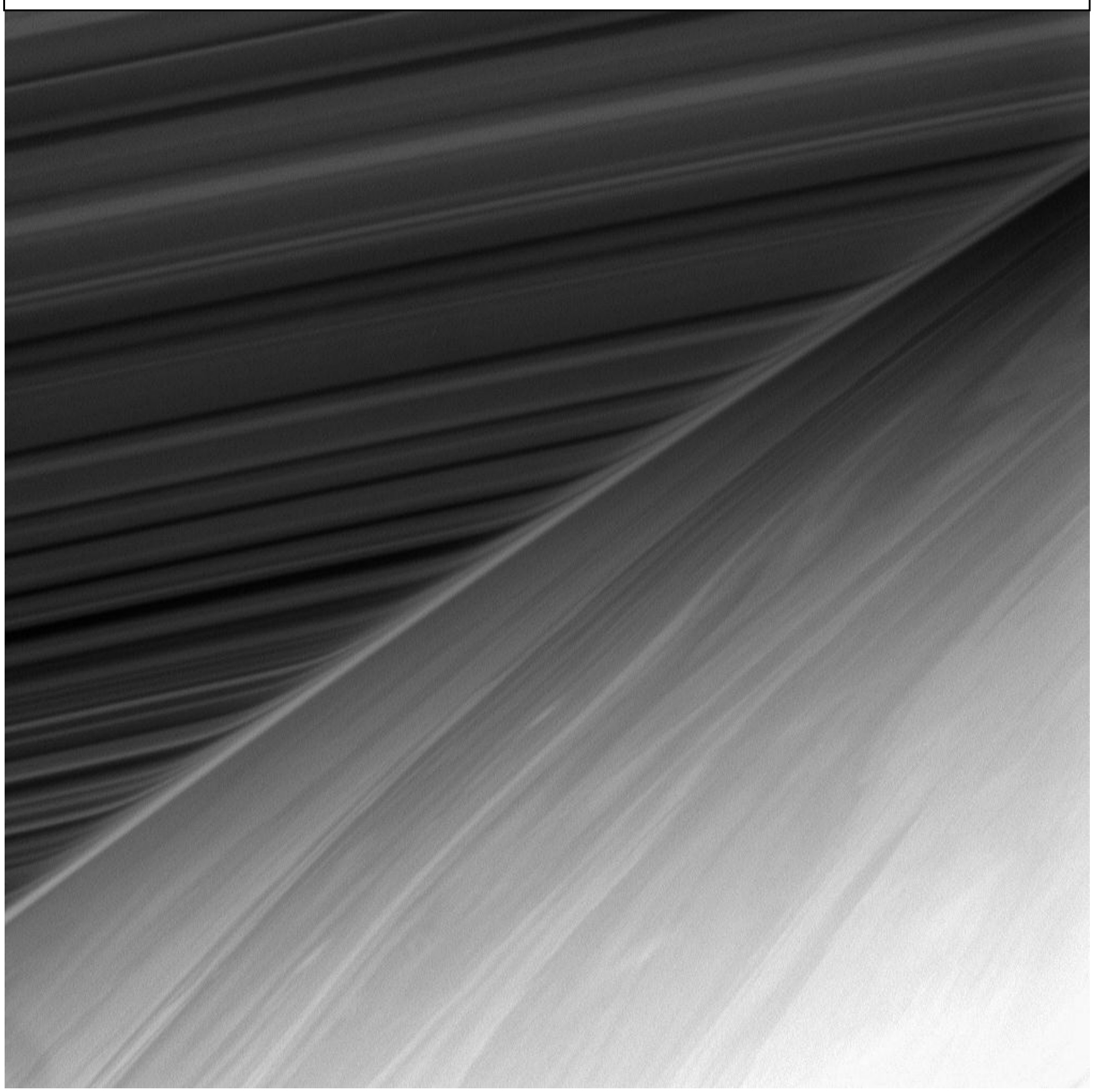
The Art & Science of Visual Astronomical Observations



The Art and Science of Visual Astronomical Observations, 1E

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Table of Contents

NOTE: Cover photo of Saturn's rings and refracting atmosphere courtesy of NASA

Introduction: Book Overview and Purpose

Purpose

The purpose of this book is to provide the visual astronomer, especially the beginner, a greater sense of appreciation of each object he or she observes. In addition, I want to instill a greater sense of wonder for the universe as a whole, to discover for oneself one's place in the universe and the privilege to be able to contemplate these ideas. Most of the chapters in this book will be divided into two parts, the "art" (named "appreciation") section and the "science" (or "application") section. You may say, "Sure it may be just a 'white dot', but consider what is hidden in that 'white dot'…"; I want to help with the second by discussing the physical nature of the "white dot", I hope to stimulate observers' interests to keep looking. This is the "art/appreciation" portion of the book, which also seeks to share my own passion for these things. The "science/application" part of the book outlines how amateurs who either cannot afford the sophisticated equipment becoming more widely available, or just prefer to use their own eyes to view celestial objects, can make a contribution to astronomy as a science. This portion includes a collection of references to projects and guidelines on how to get started, all of which are geared toward the visual astronomer. The references come primarily from such organizations as ALPO, IOTA, AAVSO, IMO, and others (read on to find out what these mean if you do not know already).

One of the unique features of this book is what I have peppered throughout: for select objects I have included some information that would be useful if you like to consider what it might be like to "be there". In other words, if you were to pretend that you were looking through the port hole of a spaceship rather than the eyepiece of a telescope, how far from the object in question would you physically need to be in order to match the view you get in the eyepiece. Of course one important difference is that we are looking thru air, dealing with "seeing" whereas in space, the object would look sharp and crisp through the port hole, with fine details rock steady. But we can always imagine! Try to mentally note "the equivalent distance" (what I call this calculation) next time you observe the particular object. This also answers a question I get from time to time of "how much closer does the object look when you are looking at it through the scope?"

On the practical side in general, the focus of the "Applications" sections of each chapter is on scientifically useful observations. Key pieces of information will be obtained from online and offline professional-amateur collaborative sources such as the IOTA manual, ALPO online guides, the AAVSO handbook excerpts, IMO notes and others. Links to each of these organizations and resources may include one or more of the following:

- Profile and focus of each
- Organization information
- Contact information and resource list
- How professionals use the data submitted to each

Many of these organizations accept both visual and electronic data-I will focus exclusively on the former in this book. In most cases I will provide the important points, enough to get started and make some beneficial contributions, but I will leave the finer details, as well as specific contact details (as these change from time to time) to these featured organizations and websites. I will also provide my own experience in each area and end the book with a list of more resources to get more information.

Introduction

My Own Journey through the Cosmos (June 18, 2012)

I will also present, from time to time, some anecdotes throughout the book to show my fascination in the natural order of things in the Earth and the Cosmos. And now a little about my own cosmic journey (some of you may have been at this longer or more intently than I, while others may just be starting out)…

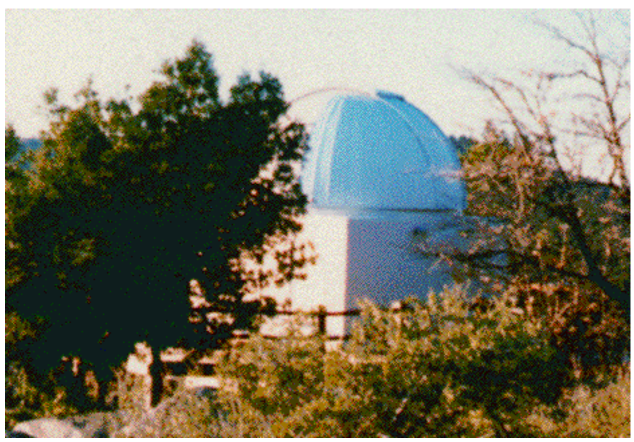
I had been interested in astronomy since my early childhood in the 1970's. From tracking the movement of the sun, moon, and stars using the shadows cast by (or imagined to be cast by in the case of the stars, since I could not see them directly) each object as guideposts, to peering deep into the cosmos through a 36 inch monster Dobsonian, my journey through the Cosmos has been a fascinating and fulfilling one. I am fortunate to be alive in an age where machines are being sent to other worlds in our own solar system, and other "solar systems" are being discovered on an almost daily basis. I remember with fascination the pictures returned from Voyager at Jupiter in March 1979 and the Saturn encounters of 1980 and 1981. I was a big fan of *Cosmos* in 1980 and that motivated me to pursue a deeper knowledge in the subject.

With the imminent return of Halley's comet beginning in the Fall of 1985, I began to look for a larger telescope than the 2.4-inch (60 mm) refractor I had been using, off and on (mostly off) for several years (1982-1984), and I found the 4.5-inch (114 mm) reflector that I currently still use for sunspot counts. With this telescope, and some encouragement from mentors and the Chagrin Valley Astronomical Society (Northeast Ohio, USA) I began backyard observing in earnest during the summer of 1985. I bagged my second comet, Giacobini-Zinner in July of that year (my first was IRAS-Araki-Alcock, which I easily spotted with 7x35 binoculars in May 1983) and was starting to "get warmed up" for Halley's Comet which was only months away from being accessible with my own instruments.

Over twenty five years ago (November 8, 1985) I made my first observation of Comet Halley, and this would be the first of 50 observations over a seven-month period which would make this comet one of the more memorable comets that I have seen. I remember pristine views from Indian Hill Observatory south of Chardon, Ohio, in zero-degree weather in March 1986. The comet emerged into view as the waxing gibbous Moon set, leaving the sky dark for an hour or so before the start of twilight. Halley looked great through binoculars and the telescope, and was just glimpsed naked-eye. Another view came from New Mexico, under the darkest skies that I have ever experienced near the New Mexico / Arizona border. By then the tail of Halley was mostly behind the head as seen from Earth, and that gave the comet the appearance of being a large gray fuzzy snowball.

I continued to explore comets, planets, and the deep sky for the next several years from the backyard until 1990. Prior to that time, I had collected many observations of comets, all the major planets except Pluto, and many deep-sky objects including most of the Messier objects and many NGC's. I have also witnessed five aurora (northern lights) displays.

From 1990 to 1995, my observing took place in Northern Arizona as I pursued a bachelor's degree in Astronomy. Not only was I into the visual dimension of astronomy, I was also gaining professional experience in the science as well. This involved many a night at the Northern Arizona University (NAU) Campus Observatory, pictured left, using its (24-inch (0.6-m) Cassegrain and 6-inch (15-cm) refractor to enjoy some of the best views of the stars and planets to date (these have since been replaced in a recent upgrade). I also have enjoyed the dark skies of Northern Arizona from Camp Verde (about 45 minutes' drive south of Flagstaff on Interstate-17) and Anderson Mesa (just southeast of Flagstaff).



From 1995 to 1998, I lived in San Diego where I had access to the telescopes on Mount Laguna Observatory (MLO, about 50 minutes' drive from eastern San Diego) while pursuing a Master's degree in Astronomy at San Diego State University (SDSU). My thesis topic was the comet Hale-Bopp, inspired by the appearance of Hyakutake in spring 1996, the first truly great comet since 1976 and the best comet that I have seen since Halley's ten years earlier. The picture that remains is this: laying on the deck of the 21-inch (53-cm) Buller observatory / visitor's telescope (right) and looking overhead at a long-comet shaped apparition, with its head in the northern skies and tail stretched more than 60 degrees in length overhead and into the southern skies. I watched thru the 21-inch scope at the nuclear region of the comet as it made its 9.9-million mile (15.8-km) flyby of Earth, moving visibly in only a few seconds.

In addition to the comet work, I also have maintained a regular watch on the planets and deep sky objects, with the best views of the latter being realized at MLO. The combination of dark skies and large instrumentation regularly available resulted in these views, which I documented in the form of drawings and notes. In the Spring of 1997, comet Hale-Bopp (which I first saw in July 1995, four days after its discovery from the NAU observatory during my last night at that facility) made its closest approach to the Sun and Earth and put on the best showing of any comet in almost 30 years.

My wife of 17 years (Susan) and I currently reside in Houston, Texas, from 1998 (after graduating with an M.S. degree in astronomy from SDSU) until the present time (2012). For the first three years of our Texas residence I worked with the Prairie View Solar Observatory, making solar observations by day, and doing amateur observing (apart from work) by night. During most of my time in Houston, I used the Dark Site Observatory of the Houston Astronomical Society, where I made one of the most memorable observations of my life: the first scientifically confirmed lunar meteoroid impact observation during the 1999 Leonid meteor storms. This was thru a 14-inch Cassegrain in the HAS observatory (right, the orange one). This has literally sparked my interest in lunar impact phenomena to include activities such as assuming the role as coordinator of the Lunar Meteoritic Impact Search section of the Association of Lunar and Planetary Observers, writing a book “Lunar Meteoroid Impacts and How to Observe Them”, and publishing several journal articles on the subject.

Also since 1999 I have enjoyed many a memorable night at the “dark site”, just west of Columbus, Texas; and have participated in several runs to even darker sites for specific astronomical events. These runs included the Texas Star Party in 2003, Fort Griffin State Historical Site (a.k.a. “Bunkleyville”) in 2002 (Perseid Meteors), 2005 (included the impact of the Deep Impact projectile into the nucleus of Comet Tempel 2), 2008, and 2010; the El Dorado Star Party in 2007; and a run to SW Louisiana for the best meteor shower I have ever witnessed, the Leonids of 2001 (with 440 meteors observed in a single hour). I have worked through enough Astronomical League Observing clubs to earn a Master Observer’s certificate, and have enjoyed crisp views of Mars, Jupiter, Io, Europa, Ganymede, Callisto, Saturn, Titan, Uranus, and Neptune (each of these seen as disks, most of which displayed detail of some sort at its best).

I am confident that there are many who have seen more, farther, deeper, and in more detail than I have seen of this great Cosmos of ours, but at the same time I have seen more than many. Over the last 33 years of exploring the universe, I have seen one total solar eclipse, three annular solar eclipses, many lunar eclipses of all kinds, and much, much more. Since the early 1990’s I have regularly monitored variable stars for the AAVSO (I am up to nearly 20,000 observations submitted to this organization). Since the late 1990’s my focus in amateur astronomy has been to make observations in a way as to maximize the scientific use of the observation. I am a visual person at heart and most enjoy the intimate connection with the object I am studying, and this is obtained, I feel, through the eyepiece looking directly at the object.

This book is my small contribution to the amateur astronomy community at large and I want to use it as a vehicle (a spaceship?) to share my passion for the science and hobby of astronomy. I want to share the knowledge and experience that I have accumulated over the years along with practical guidelines to help the visual observer make the most of his or her observing experience. These are themes that are frequently revisited throughout this work.

Natural Beauty at all Levels—My Perspective (June 4, 2009)

(In many ways, on many days, the natural beauty of the Earth inspires my appreciation for the heavens. I have been to places that really inspire. The following was written from a trip I took on the date listed in the heading as a way of showing my appreciation for the beauty of the Far North…by the way, the image of Southeast Alaska was taken by Alaska Mountain Guides, not me, and posted on the website for Haines, Alaska, http://www.haines.ak.us/)

For the past several days, including today, I had been treated to much natural beauty throughout Southeast Alaska, British Columbia and the Yukon, Canada. At this time of year and at these latitudes (58 to 60 degrees north) the days are quite long and it does not get very dark (only somewhat fainter than the end of civil twilight around 1 to 2 am local time only the brightest stars came out (magnitude brighter than 2), and it is too bright for auroras or other forms of nighttime astronomy.

Yet natural beauty is in all this, in the long days, warm weather, the mountains and valleys the vegetation and the animals. Dramatic, towering mountains are seen; many capped with or covered with snow and ice. Closer in, the varieties in vegetation are amazing as well as the animals that inhabit these locations. Wonder comes in all shapes and sizes-from tiny, colorful, geometric flowers, to birds, eagles, trees, to black and brown bears, to land and water and terrain, to the blue sky, sunshine, the waxing gibbous Moon, and beyond. Natural beauty and wonder, a feast for the senses, awaits those ready and willing to explore.

All of this natural beauty occurs on one place-the Earth. It is interesting to note how the sun takes dramatically different paths at different latitude: steep and almost overhead with 14 hours of daylight and 30 degrees north, yet shallow and lingering, with 19 hours of daylight at 60 degrees north. Twilight proceeds rather swiftly, only about 50 minutes from sunset to end of nautical twilight at 30 degrees north; but very gradual at 60 degrees north, with it barely getting dimmer than civil twilight at its darkest. Twilight itself is a thing of majesty, with its gradual parade of colors that start prior to sunset and continue until full nightfall. Twilight is caused by the reflection of sunlight in the upper atmosphere to regions just within the shadow of the Earth; as the planet rotates, the fraction of reflected sunlight gets less and less, making the twilight fainter and fainter. It was said that the planet Earth has the most colorful displays of twilight in the solar system. Any planet with an atmosphere displays twilight, but the details of that display (as would be seen by astronauts exploring these worlds) depends on many factors…

Venus is cloud covered so what is seen is merely an orange version of that experienced by an overcast location on Earth-a gradual dimming of environment over the span of an hour or two on Earth (but lasting several Earth days on Venus due to its much slower rotation). Mars has a thin atmosphere that provides a paler version of twilight display lasting more than twice that of an Earthly display at a given latitude (due to the deeper atmosphere as a result of the weaker gravity pull). But Mars behaves much like the Earth in terms of latitude variations of the Sun’s path- 24 hour rotation period, 24 degree tilt, both resulting in similar variations in the duration of daylight as seen from the Earth.

Jupiter and Saturn have deep, hazy atmospheres which display blue skies by day (assuming one is just above the cloud decks) but bland displays of twilight due to the haze in the atmosphere. But a certain Cassini image (and Galileo images) shows the rising / setting sun on Jupiter and Saturn is orange-just like our home planet.

And the Northern lights or Aurora Borealis (those seen from the Northern Hemisphere) – called the southern lights or aurora australis, can be a spectacular sight to see at specific locations and under specific times of the year. Unfortunately, June is not a good month for viewing aurora in Alaska and Canada, but during other times of the year, especially in March, residents and visitors alike get treated to spectacular displays. Aurorae are caused by the interactions of solar particles dumped into the upper atmosphere (the Ionosphere) via the Earth’s magnetic field. These interactions cause the molecules and ions in the Ionosphere to glow (the color depends on the element excited). Aurorae are not limited to the Earth but also occur on other planets as well. The displays on Jupiter and Saturn dwarf Earth’s in size and intensity (a display has also been imaged on Io). It is not clear weather Mars, Venus, Uranus, and Neptune display aurorae as well.

So what we enjoy on Earth can be seen, to some extent, on many of the planets of the solar system. Many have mountains and valleys, wind and clouds, blue skies and sunshine, twilight and aurorae. In addition, the same star patterns, constellations, and bright stars that we see from Earth are also visible from the night sides of the planets. So as we look at other worlds, either with the naked eye or with optical aid, it is fascinating to remember that these are real places, not just some distant heavenly ornaments to gaze upon. They are as real as Juneau or Denver or Seattle but as distinct and mostly untouched by civilization. One key difference between our home planet and these others is that Earth has abundant life with all its beauty-the other worlds have not.

Some other parallels between Earth and other planets include:

- Weather and clouds, winds and storms
- Water and other liquids
- Mountain formations, landforms and rocks
- Ice and snow
- Rotation, length of day, seasons
- Natural satellites (Moons)

As you are viewing these worlds through your telescope, remember that they are real places, not just vague points in the nighttime sky. They have their own shares of phenomena that make them, in many ways, as interesting as planet Earth. But remember also that Earth is unique in that it is the only planet in the solar system with conscious, intelligent life.

Chapter 1 –the Art and Science of Visual Astronomy

Waiting for Nightfall…(May 24, 2009)

We (the late Don Pearce and I) are on a scenic overlook looking toward the western horizon about 45 minutes prior to sundown. This is just outside of La Grange, Texas, which is north of our usual Houston Astronomical Society (H.A.S.) dark sky observing location near Columbus, Texas. Skies are mostly clear with clouds mainly to the North, South, Northwest, and we anticipate spying a very young Moon prior to some dark sky observing…

- Beautiful deep blue skies to the East
- A golden Sun descends toward the west-northwestern horizon
- A few towering ivory cumulonimbus to the north-northeast
- The moon was not seen but many interesting sunset phenomena was seen

As darkness falls, Sirius is easily visible, a blue pinpoint against deeper blue twilight low in the west. Shortly afterward, more of the nocturnal lights appear.

Back at Columbus later that evening (after a delicious late dinner at a Mexican restaurant within LaGrange) at the H.A.S. dark site, it is always a treat when the predicted “mostly cloudy” forecast turns out to be clear – and that is what happened – Don and I returned from our New Moon / Dinner expedition by 11:15pm local time by when it had become partly cloudy. These clouds later cleared completely, revealing the starry night sky.

We looked at variable stars, Saturn, the globular cluster ω Centauri, the galaxies M81 and M82, the open star cluster NGC 6231 in the lower part of Scorpius, the galaxies M95 and M96, open clusters M6 and M7, emission nebulae M8 and M20 (with the UHC filter), and many dark nebula through binoculars. We looked at Antares and v Scorpii thru Don’s 6-inch refractor. We also found M4 and M80, M22, M24, M25, and five clusters for the AL cluster project.

Why do we do these things?

Different people have different reasons why they persist in the (mostly) nocturnal activity of astronomy. In my own experience, and in the experiences of others that I have crossed paths with over the years, here are some of the reasons why we make it a regular activity to get out under the nighttime skies. We have a desire to look beyond earthly things, a passion and a purpose. This includes the inner desire to explore new things. Others may wish to systematically explore as many members of the various classes of celestial objects as possible (e.g. to earn award pins from the many observing clubs of the Astronomical League). Some strive to collect a photo album of celestial sights. In some cases, astronomy can serve as an escape, to get our minds off the troubles of the world. Astronomy provides a challenge to “push the envelope” to go beyond the norm to see dimmer, farther, etc.

In my own case, I have many reasons why I have pursued (and continue to do so) astronomy for 35 years (to the point of earning the Master of Science degree in the subject) and they include much of what I already mentioned. I wish to explore-to see as much of the cosmos as possible, to regularly visit the brighter objects and contemplate their physical nature (I regularly ask myself, "What would it be like to go there and explore?"). I enjoy watching other worlds beyond our own, to monitor large scale changes, to see something new. I desire to contribute something scientifically useful with the minimal equipment while retaining the physical connection with the object (photon to retina). I want to get out under the night sky (and out during the late afternoon hours and watch the process of nightfall) and to connect with the Creator God. Finally I enjoy the challenge of bagging that occultation, getting as many variable star observations and comets as possible, completing the various AL projects and observing lists (the thrill of the hunt).

In addition to all this, many people dedicate their time under the night sky showing the universe off to others (public, classes, etc.). In most cases, we do these things to embrace something bigger than ourselves, bigger than life, broader than our imaginations, something otherworldly.

Looking at several of these more closely we learn what drives us amateur astronomers to persist in our hobby / activity. First and foremost we do this to connect with the Cosmos. We stand in awe of the numberless stars above us, the many unseen worlds in unseen solar systems that are just now being discovered. At no other time in history have we known so much about the world we live on and the universe we inhabit than we do at this present age. Our eyes literally connect with the universe as the photons meet our retinas.

When we "do astronomy", some of us are admiring the beauty of God's creation. It is easy to see and appreciate the beauty of a sunset or a total lunar eclipse, and other objects easily display beauty as seen through a telescope's eyepiece (e.g. Saturn). The vast majority of telescopic objects, however, have a subtle beauty all their own. One of the purposes of this book is to reveal that subtle beauty and to instill an appreciation for the true nature of the fuzzy smudge that fails to impress most.

Finally, with all that is going on in the world these days (and much of it is not good), astronomy provides something to lift our focus off the troubles of this world. When times are hard, the nighttime sky provides a refuge to go to. After you have a bad day, enjoy the silent beauty and majesty of a celestial scene. The stars provide an avenue of escape, as well as time of quiet fellowship with God (for those of us who have religious beliefs).

There are those that do astronomy to contribute to the growing body of knowledge about the Universe. Today's amateurs are well-equipped to do science comparable to professional astronomers just a few short years ago. Even in the age of electronics and technology, there is still a place for the purely visual astronomer to contribute something to the science of astronomy, from counting sunspots by day to estimating the magnitude of variable stars by night. This book will describe some useful projects that the visual astronomer can do to contribute to this celestial science.

Why it is an Art and how we can be Scientifically Useful

Many of the descriptions that I shared above apply to the artistic side of visual astronomy. There is indescribable beauty, sort of an artwork that each planet, each nebulae, each star cluster, displays, from texture to shape to amorphous features No two objects are exactly alike and this is true for: planets, moons, asteroids, comets, stars, star clusters, nebulae and galaxies. Such beauty and variety is displayed throughout the universe

Since the laws of physics are the same everywhere in the universe, there is a certain consistency in the underlying source and dynamics of all of this. And yet the size scale is truly immense. As astronomers, we long to understand all the hidden features / activity in the objects we view:

- Planets-landscapes, weather, storms, rocks, sunsets, day/night, seasons
- Stars-hidden planets / planet systems with many of the above features, including life
- The dynamics of the stars themselves, like the Sun, complex nuclear generators putting out immense amounts of energy each second
- Nebulae-like a hike in a canyon or mountain on Earth reveals hidden things in the landscape, there are many hidden nooks and crannies to explore: clumps, clouds, protostars, solar systems in the making…
- Galaxies, each has its own collection of stars, planets, nebulae, and the possibilities are endless for variety
- Galaxies, in many cases, show a symmetric or quasi-symmetric geometry.

Again we strive to appreciate the beauty of the celestial object, to marvel at the variety that exists in celestial objects, and to use the time at the eyepiece to make a contribution to science. A carefully drawn sketch, a carefully timed event, a carefully estimated magnitude can have true scientific value, and there is even that chance at a discovery.

Granted, the best images of the above objects come from large ground-based or space-based telescopes, most notably the Hubble Space Telescope. Or these come from the detectors on spacecraft in orbit around these worlds, such as the Cassini spacecraft that is currently exploring the Saturnian system (and will continue to do so until at least 2017). I encourage the readers to enjoy the spectacular vistas offered by the data returned from these probes, and to appreciate the sheer scale, magnitude and majesty of the objects studied. I also encourage everyone to have a look for themselves through the eyepiece of a telescope, each of the objects (at least the ones they have access to) and think about all that is going on at the location of the object being looked upon, all the hidden nooks and crannies, and the physical processes that take place to shape and govern the behavior of the object seen through the eyepiece.

The Science

While gazing at all this heavenly spender is all well and good, we can also make purposeful use (that is, scientifically beneficial use) of our time at the eyepiece. There exist today a number of organizations that promote the scientific use of astronomical observations of all kinds and taken in all manners, some examples of which are listed below:

- AAVSO-the American Association of Variable Star Observers, which collects observations on variable stars and sunspots
- IOTA-the International Occultation Timing Association, which works with lunar, planetary, and asteroid occultations
- ALPO-Association of Lunar and Planetary Observers, which accepts data on lunar and planetary phenomena
- IMO-(International Meteor Organization) / NAMN-(North American Meteor Network) accepts data and observations on terrestrial meteors

The Appendix of this book provides a list of resources that one can use to select material suited to their needs and desires-these include:

- Information about each of the above organizations
- Books and websites on how to get started in visual astronomy
- Books about astronomical techniques,
- Books on how to use the telescope
- Books on making scientifically useful observations—both visual and electronic

This book focuses on good-old-fashioned visual astronomy, which still has a place in the scientific dimensions of astronomy (more about this is discussed in the next section). For example, visual variable star observations are needed to provide historical continuity between pre-photographic observations and today; in other words, it extends the coverage of stars considerably, stretching it from the present to pre-photographic times and earlier. Planetary observations are needed to provide objective estimates of the intensities of surface / atmospheric features, central meridian passing timings of features, satellite eclipse timings, crossing of lunar features by Earth's shadow during lunar eclipses, and more.

The Scope of this Book

The scope of focus for this book is the amateur astronomer who wishes to get the most out of astronomy. In sharing about the wonders of the universe I include my own passion for the material discussed herein. This book is also intended to serve as a central resource for the visual astronomer who not only wants to more fully appreciate astronomy but who also wants to contribute to the science.

There is much satisfaction in making an observation that outlasts you and becomes a permanent record, is used by professionals to aid in their research, provides continuity with visual observations past and context for digital data, helps to contribute to a growing body of knowledge about the universe, and represents a potential discovery.

Some examples of scientifically useful observations -when done carefully and according to guidelines-can be quite useful (these observations, listed next, are discussed in more detail throughout the book).

- Drawings of major planets
- Drawings of lunar features
- Sunspot counts
- Variable star magnitude estimates
- Careful timings of lunar, asteroid, and planetary occultations
- Visual magnitude estimates and physical characteristics of comets
- Supernova and comet searches/discoveries
- Binary star p.a. / separation measurements
- Lunar meteor phenomena
- Terrestrial meteor counts and identification
- Lunar / solar eclipse timings and observations
- Central meridian timings of giant planet features
- Magnitude estimates of remote planets

I have selected a number of projects that I describe in some detail throughout the book, and in so doing, I wanted to share with the world my own passion for astronomy-particularly visual observations. I wanted to provide a resource that enables people to get a deeper sense of appreciation for what it is they are looking at (thru naked eye, binoculars, or a scope), and move away from the flippant response of “it’s just a faint fuzzy thing”. This book reaffirms the statement that in the 21st century, visual astronomy is not dead, but is still serving a purpose which is described in more detail in this book.

Finally in this book my intention is to consolidate key information (and links to more information) from a variety of sources on how to make and submit observations that are scientifically useful and in demand, to serve as a resource for those who want to go beyond visual and go digital—where to find these resources, and to increase the activity of individuals doing science.

Ch. 2 - Visual versus Electronic

Visual versus Photographic (or Electronic) Appearance

One question that commonly arises is this: "Why is it that what we see through the eyepiece does not look like the beautiful images published in magazines?" The human eye-once dark-adapted, is still limited as to how much light it can take in which limits the appearance of the faint object that we perceive. We use telescopes to alleviate this some. We are seeing the image in real time. However, in the case of electronic/analog imaging-The CCD chip or film can collect photons over a long stretch of time and allow these to accumulate building up the beautiful, colorful images we see in magazines. The eye cannot do this. For really deep images, in the case of the eye, really big scopes and really transparent skies are needed. For digital/analog a lot of time (at least a few hours) and precise tracking are needed (one bump of the scope or flash of white light, and that's it!).

There are some advantages to the human eye versus video or imaging. With the eye, you get to see things in real time; the electronic imaging-takes a considerable amount of time and processing (and much patience!) to get the image after the fact. Integration, the digital chip or film can collect photons over time while the eye cannot, but the eye has a greater dynamic range, meaning it can see both relatively bright and relatively faint objects adjacent to each other and not lose one or the other. Digital imaging (or film imaging) is crucial to create colorful, detailed images with a limited supply of light. For the really deep images, it is crucial to allow lots and lots of time for photons to fall on and "accumulate" on the CCD chip or film

Pros and cons of visual versus electronic

Again, there are pros and cons to everything; capturing an astronomical image is no different. These are summarized in the following (not a complete list, but enough to convey the idea).

Visual pros:

- an immediate record of what is observed / real time results
- Provides a check / serves as a benchmark or reference to check / confirm a video recorded event
- direct connection to the cosmos, more of a "romantic" feel
- latitude of brightness that electronics don't have (although with improvements in technologies and techniques, this is no longer as much an advantage)

Visual cons:

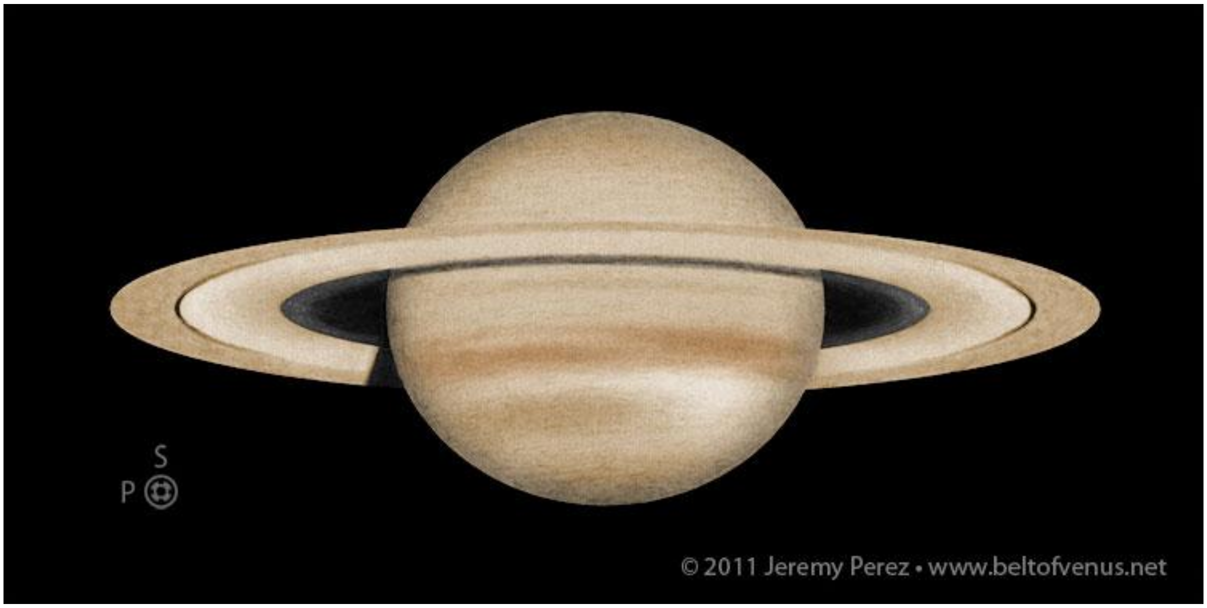
- manually drawing cannot recreate a planet image with high precision
- misses finer detail
- cannot see much color at night
- subject to lapses in concentration and focus and fatigue, one can miss something with a blink of the eye or inattentiveness
- imprecise photometric results

The bottom line is this: the trick is to capitalize on the strengths while minimizing the drawbacks of astronomical visual observations, which still have an important role to play in the science of astronomy. Those who image regularly and have become very good at it provide the rest of us with views that are impossible to get by eye and telescope alone. We are definitely fortunate to have many skilled imagers in our community and their work continues to advance the science of astronomy.

One useful area of visual astronomy involves variable stars which I actively observe. Granted there is equipment out there that enables one to measure, quite precisely, the magnitude of a variable star, and cover far more variables in a given night than visual observers can. However, this equipment has been around for a relatively short period of time, and some variable stars have been observed for up to several centuries visually. Modern visual magnitude estimates of variable stars of all sorts provides a connection and a calibration to stars observed in pre-electronic times, and that extends the record significantly and enables a longer-term picture of the star's behavior and evolution to emerge.

Planetary drawings offer another avenue where visual astronomy is useful. Prior to electronic and film equipment, planets were drawn, and that's how their changing appearance is recorded. By comparing modern drawings to images, one can have a means to calibrate historic drawings to derive as much scientific data out of these drawings as possible, and this extends the historic record of planetary behavior back to nearly the dawn of the age of the telescope.

Figures 2-1 (left) and 2-2 (top of next page). These are drawings made by astronomer Jeremy Perez of Arizona showing some of the detail that one can see visually through a modest sized scope. Mr. Perez takes his drawings one step further: after making the drawing itself (he indicates on his website what he uses for each) he digitizes the artwork and adds color to the image (the example of a colored image is the Saturn drawing on the next page).



Book Focus-the Visual Astronomer: Connecting Directly with Extraterrestrial Wonders

As has been stated already, this book's primary focus is the visual astronomer, which includes those who cannot afford the fancy equipment that is becoming more commonplace and those who chose to remain visual and who prefer simplicity and to retain the ability to see something live and direct (as opposed to an "artificial reproduction"). I aim to introduce some fascinating pieces of knowledge along with the guidelines for amateur visual astronomy, with the light travel / look-back time being one example. Consider the following--the light-travel-time delay-as one looks at more and more distant objects, one actually looks back in time:

- Moon = 1.25 seconds ago
- Sun = 8 minutes 20 seconds ago
- Mars = 4 to 20 minutes ago (depending on where it is in its orbit)
- Sirius = 8.7 years ago
- Vega = 25 years ago
- Antares = 600 years ago
- Shaula (in Scorpius) = 2,000 years ago
- M31, the Andromeda Galaxy = 2,500,000 years ago
- M87 = 65,000,000 years ago
- 3C 273 (quasar) = 2 billion years ago
- Ursa Major Double Quasar = 7 billion years ago

This shows how looking up in the sky is actually looking back in time. When we look at the sun in the daytime, we are seeing it as it looked some 8.3 minutes ago. If an explosion (a.k.a. solar flare) were to occur for an instant in time, we would not see it until over 8 minutes later; the light produced by the flare leaves the sun's "surface" and takes the 8 minute journey across interplanetary space until it reaches Earth's orbit (assuming it happens on the side of the sun that faces Earth).

If we look at and identify the planets in the night sky, we are seeing the planets as they looked from 4 minutes to 80 minutes ago, depending on the planet and its distance from Earth. It took light reflected from the Sun this span of time to reach our waiting eyes on Earth. Consider the brightest stars in the nighttime sky. We are seeing them as they looked, years, decades, and even centuries ago, as it has taken light that long (in the case of Antares, 600 years) to reach the Earth from these stars.

Galaxies are even more extreme. The Andromeda Galaxy, faintly visible with the naked eye from a rural location, is some 2,500,000 light years away, so we are seeing the galaxy as it appeared 2.5 million years ago. Other galaxies, typically observed with binoculars or telescopes, are more distant. The quasar 3C 273, one of the most distant objects accessible to relatively modest equipment, is over 2 billion light years away. For those who have observed the Ursa Major Double Quasar through their large scopes, they are observing this object as it looked before the local Solar System was thought to have been formed.

In Conclusion

Electronic astronomy has its advantages and there are plenty of astronomers who prefer to operate in this manner. I have a low light CCD video camera that I use for asteroid occultations and lunar meteor studies, and I enjoy the benefits of this technology in these studies. As of this writing my most recent confirmed lunar meteor observation was a video of a Geminid meteor impact in December 2010. I have also recorded the winking out of a star being blocked by an asteroid (occultation) early in 2011 and have been able to use this, not only to extract times to the nearest 15 ms, but also to show friends and family what an asteroid occultation looks like.

There are plenty of guides for both visual and electronic astronomy in the market today, and I have links to some of the more popular ones listed in the Appendix. I do provide some general guidelines in the next chapter. I will not go into detail on the basic techniques for visual astronomy, but rather save these for other books and references. I will be focusing mainly on the nature of celestial objects and providing practical and easy means to enhance your appreciation for what you are looking at. The techniques that I will provide will be primarily for the purpose of increasing the scientific value of your visual observations. Even with this, I will provide listings of references and books that will provide further guidance in maximizing the science of your astronomical experience.

Let the journey begin…

Figure 2-3: NGC 1999, courtesy of Hubblesite.org

Ch 3 – Some General Guidelines

Overview

We start by describing some general “who, what, where, when, how, and why” of amateur visual observing. Each subsequent chapter which presents a particular family or type of object, will outline techniques and information specific to that object or object type. There will be many representative examples of such kinds of objects that include the most popular targets of amateur astronomers (e.g. the Hercules globular cluster, the Ring Nebula, the Andromeda Galaxy, etc.). I will draw upon my own experience as well as that of others in assembling this material.

Appendix A contains a short list of books and resources showing how one can get started in amateur visual astronomy. These resources include suggestions for the beginner in terms of techniques, instrumentations, projects to pursue, and sources of assistance. I will defer the detailed discussion of these areas to these resources and focus on one item: “How to make scientifically useful visual astronomical observations.”

Some (More) Reasons to go Visual

Why would one want to make visual observations to contribute to the science of astronomy in a world were astronomical technology and electronics abound, and many astronomers are making ample observations in these areas? Why would one want to put that extra time and effort to making a visual sketch when an image far surpasses the sketch in detail and accuracy? Why would one spend an entire night estimating the magnitudes of variable stars, one-by-one, when there are observatories that are actively measuring thousands simultaneously and with superior accuracy?

The answers to the above questions lie in a number of areas that complement each other’s. First, the cost to the observer of purchasing electronic equipment for such pursuits may be beyond the observer’s financial capabilities. Even if he or she were able to purchase said equipment, the time it takes to collect the components, assemble them, trouble shoot the system, and spend considerable time afterwards reducing and processing the image may be beyond what they can afford time-wise. For me it is a combination of both. I enjoy the feel and intimacy of actually looking at an object through the eyepiece and not thru the monitor or after the fact in an image. I enjoy the quick setup and teardown, the instant results, and not having to troubleshoot on a regular basis. But don’t get me wrong, I also enjoy when a video system for asteroid occultations or lunar meteor studies is up and running and producing results, but sometimes troubles may arise that compromise a session or otherwise make an observation impossible.

I also am limited in budget so I am unable to purchase (aside from the system I had mentioned above) very many electronic gadgets for astronomical work. There are large numbers of astronomers in a similar situation that would like to pursue the instrumented side of astronomy but cannot afford the instruments. They could check their local astronomy club for loaner programs for telescopes, and perhaps a friend may have an extra camera to spare. But if one wants to make a scientific contribution via visual means, there is a way, and a host of organizations, that make this possible.

Over the remaining chapters of this book, different types of celestial objects are discussed. Each chapter comes in two parts: the appreciation part (what to look for, how to appreciate what you see, the “art” part), and the application part (how to make observations that maximize their scientific usefulness, to whom to report these observations, the “science” part). The application, again, is specific to the object in question and includes the contact information about the organization(s) which you can connect with to get more information about the object of interest as well as the finer points of observations, observing forms that help to standardize your observations (making them more scientifically useful), and the ability to network with other astronomers to increase the effectiveness of your collective observations.

There are several things to keep in mind when making scientifically useful visual observations. Make sure your instrument is in the best condition it could be in (to include, especially, the optics and eyepieces), and that you are thoroughly familiar with its workings. Make sure you have a plan of observation that will enable you to maximize the time used in making the observation, and that all (or at least as many as possible) objects on your list get covered.

I will provide enough information to get you started, including (in many cases) some basic techniques, what to observe and record, and were to find more information. As part of the listing of resources, I will also feature organizations who promote such work, and who have a wealth of resources to help you become a successful observer. In many cases you can visit their websites and get in contact with people who would be willing to serve as mentors and guides to help you along. The organizations who promote professional / amateur astronomer collaboration include those organizations listed earlier, as well as professional astronomers themselves; from Lowell Observatory in Flagstaff, Arizona, to the American Astronomical Society (AAS) who has had a pro-am section (I have not been able to find any recent information about this section, however).

Some Help for the Frustrated Deep Sky Observer

(Courtesy of Steve Fast and Steve Goldberg, Houston Astronomical Society)

Here are some useful hints for those who are struggling with deep sky visual astronomy. These came from a recent discussion between members of the Houston Astronomical Society (H.A.S.) and I thought it appropriate to insert these here.

> 1. Go to social astronomical events (H.A.S. has Urban Observing Nights and to the dark site at Columbus). One can learn lots from being around good observers, and almost all of them are willing to help you.

2. Do constellation tours as twilight is fading but before you can really observe. If there is an experienced person around, ask him if he'll do a constellation tour. If not, get a star chart and go through the constellations one by one yourself.

3. Get Harvard Pennington's book *The Year-Round Messier Marathon Field Guide*. It has simple but effective charts to find every Messier object, and all the charts are linked, so you never wonder what you should look for next. Start with the Messier objects because they are the easiest to find and the most impressive visually.

4. Start with a few easy open and globular clusters in constellations near the zenith. Most of them are easier to find than most galaxies and nebulae.

5. An observing buddy is key. It can get very frustrating when you search and search for something and can't find it, so you need encouragement. Ask someone with a GOTO if he can show you the object you are searching for. Look at it through his telescope so that you know what you are supposed to see. At the beginning, I could have the object in the eyepiece, but I couldn't see it. Then when I looked at it another scope and knew what it should look like, it would pop into view in mine! (Note that it doesn't count for the Astronomical League Messier pin if you yourself use a GOTO to find the object.)

6. If your buddy has a Telrad, you can also see exactly where you should point your scope. I've gotten turned around in the sky and been hopping the wrong direction from the initial star (and star patterns tend to replicate themselves nicely just enough to throw you off!).

7. Pick some galaxies and nebulae to hunt down. Most of these are tougher, but once you figure out what they look like, they are obvious too.

8. Keep a log and write down descriptions of what you see. This will train your eyes and brain to become better observing tools. Plus you need the log for the Astronomical League observing award pin. Make sure you are recording all the information required for the pin.

There is much to be said about point #5, the observing buddy. It is easy to get frustrated at times, so having an observing buddy to help check a field you are looking at to confirm that it is the right field, or to check on the presence of an object within that field (especially if you have your doubts as far as your ability to see that object). If you do not have such a buddy, you can find your own, either within a local astronomy club, or at one or more of their activities and venues.

It is also possible to have 2 “virtual” observing buddies, computer s/w SkyTools and MegaStar. These both show what the object should look like in your telescope and eyepiece, since both packages allow you to set up what telescope and eyepieces you have. So they can simulate what you are supposed to see and can help to confirm the star pattern in the eyepiece to know you are in the right field.

There are three more hints that Steve Goldberg has shared:

1. To help train your eye to see details, stare at the shell of a raw egg. It's just not white but many shades of white. Look at the flowing lines as they go throughout the egg.

2. When writing a description of the object, think about how you would explain it to a blind person. Example of things NOT to use: fuzzy; more fuzzy than the last object; see description for object <blah>

3. As twilight starts and the bright objects start to appear (i.e. a planet or the moon) align your finder with your main optics. Don't say "I'll do that later" because then you will be wasting time after it gets dark when you should be USING your finder, not aligning it. Having a misaligned finder / telrad is one of the leading causes of not finding objects and tops the list for causing frustration.

Good luck and don't give up!

Ch. 4 – Daytime and Nighttime Atmospheric Phenomena

Overview

There is a wealth of phenomena that happen on a daily basis that sometimes we take for granted. Lots of time we are so eager for the night to come that we miss things during the day that are also enjoyable. There are lots of wonderful things that happen above our heads during the day and continue to occur as the day turns to night and night to day. Such phenomena include sunrise / sunset events, twilight, optical phenomena, and cloud appreciation. They occur under a wide variety of atmospheric conditions, and can have a wealth of information to the trained observer.

This chapter will go into the atmospheric phenomena, from clouds to meteors, and how each of these occurs, and how they become visible to those watching from the ground. The images (starting with fig. 4-1) provided in this chapter (and elsewhere) were graciously made available by Jeremy Perez in and near Flagstaff, Arizona, a place very near and dear to my heart, where I attended college at Northern Arizona University and had the privilege of experiencing the beauty of terrestrial nature by day and a very dark, clear starry sky by night.

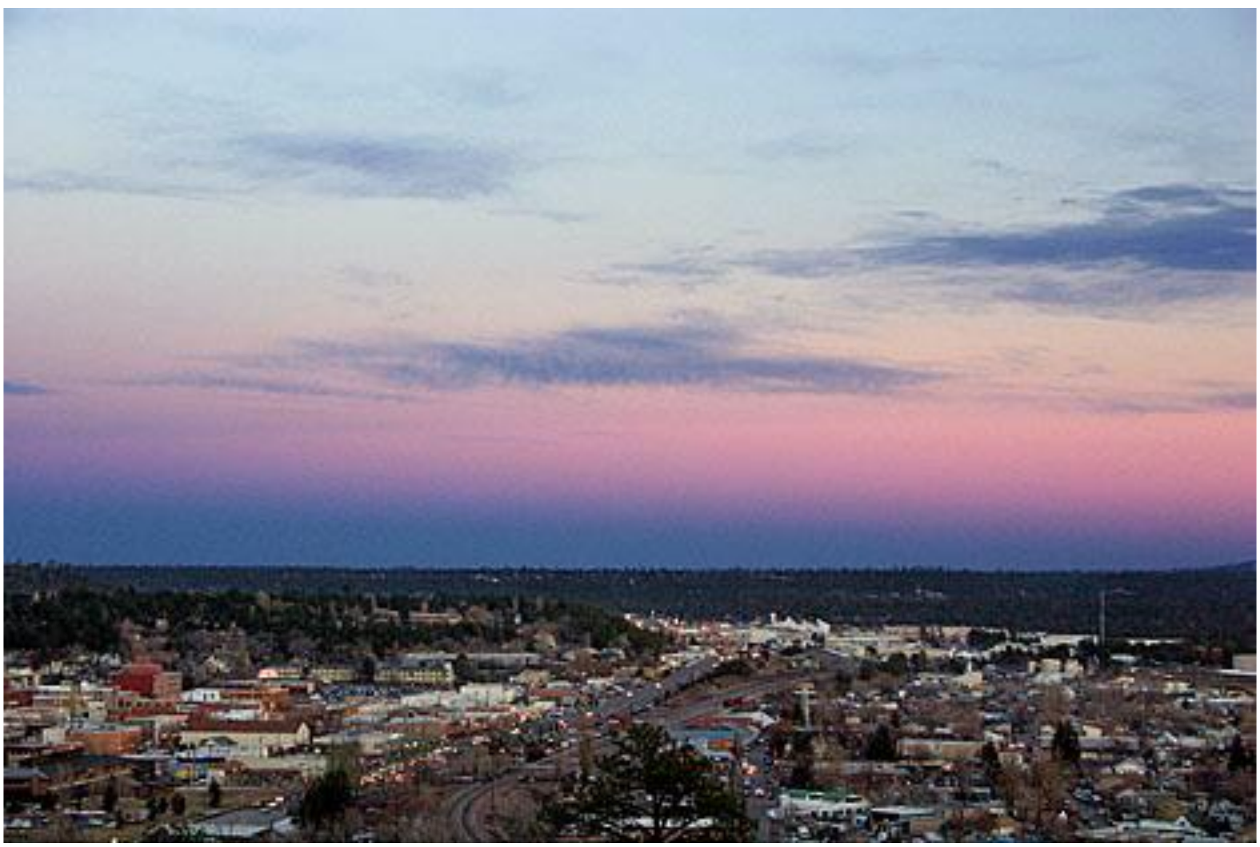


Figure 4-1. Twilight and the Belt of Venus over Flagstaff, Arizona. Images in this chapter courtesy of Jeremy Perez, http://www.perezmedia.net/beltofvenus/, unless otherwise indicated.

The Day-Night Cycle

Starting with a new day, and following the phenomena that one encounters on a daily basis, there is a rich variety of sights to see, objects to contemplate, and cycles to witness. From the dawn's earliest light to the last glimmer of dusk, there are lots to look for before setting up the telescope.

As the Earth rotates, objects are seen to appear in the east, cross the sky from left to right (if you are in the northern hemisphere facing south) or right to left (if you are in the southern hemisphere facing north) then set in the west. This is due to the 24 hour rotation of the Earth that brings land areas into the sunlight, then into the shadow, and back again. We also live at the bottom of an "ocean" of air, and the optical properties of the air make possible the daily phenomena (as well as our being alive…) that we experience. When the first glow of twilight appears in the east, what we are seeing is the glow of air molecules in the upper atmosphere in the distance catching the first rays of sunlight. As the Earth continues to rotate, bringing one's location closer and closer to the day-night boundary, this glow brightens and goes from a gray to a bluish color. Soon the entire sky begins to faintly glow with reflected twilight, and the faintest stars fade from view.

Figure 4-2, the dawning of a new day.

As the dawn progresses, warmer colors become visible in the eastern sky, the rising sun beginning to illuminate the lower atmosphere in the distance. This expands and brightens, while the rest of the sky takes on a steel-blue glow and all the brighter stars and planets remain visible in this brightening glow. One also begins to notice a wide, diffuse, dark band along the western horizon extending a third of the way from horizon to zenith. This is the part of the atmosphere still in the Earth's shadow (and this includes the observer's location as well).

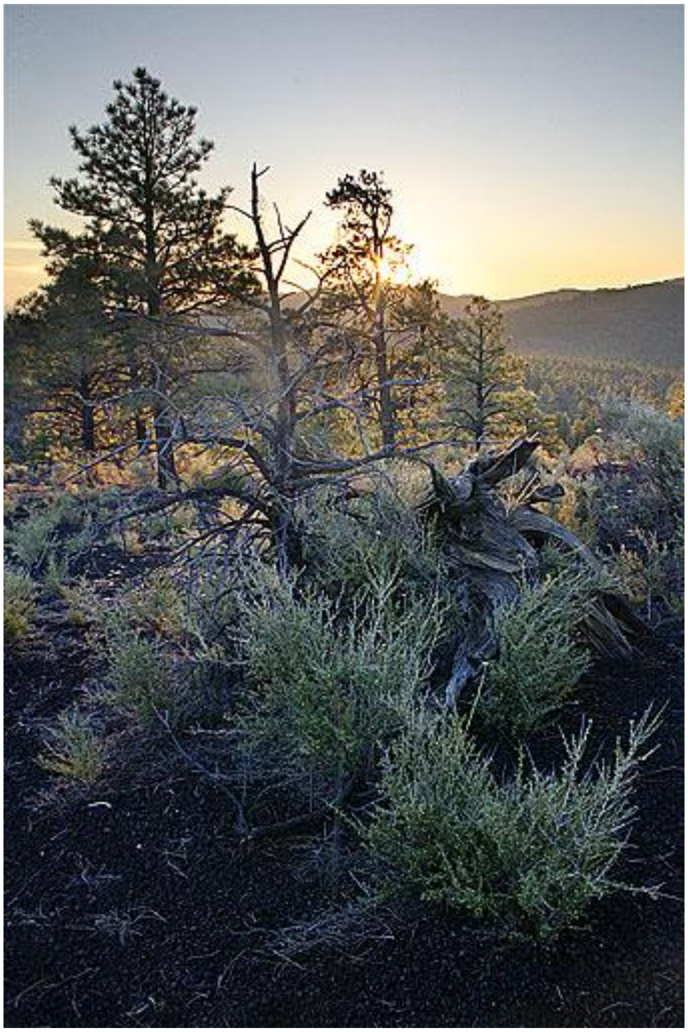


Figure 4-3 (above) a crepuscular anti-ray (dark shaft) is the shadow of a cloud projected on the sky, in this scene just before local sunrise. The sun has risen in Figure 4-4 (left) bathing the scene in its golden early-morning glow.

If there are high cirrus clouds, they are the next to catch the light of a rising sun. Cirrus in the East begin to "light up" brightening from a gray silhouette to an orange-pink feathery glow. This progression of color works its way from east to west, with the clouds low in the east changing color from pink to red-orange to brilliant orange and orange-yellow; those in the west are more orange and pink in color. If clear, the "band of night" lowers in the western sky and develops a rosy border, transitioning to a dark blue band. This is sometimes called the "belt of Venus". As sunrise approaches, this belt continues to lower in the western sky as the Earth's shadow, projected on the atmosphere, continues to recede with the Earth's rotation. Finally, the glow immediately around the rising sun brightens in the East, then the sun itself begins to peek over the horizon. Meanwhile, all that is left of the Belt of Venus (Fig. 4-5) is a rosy glow along the immediate western horizon.

Figure 4-5. the Belt of Venus at Anderson Mesa near Flagstaff, Arizona

The Sun is orange as it rises because of the atmosphere: air molecules scatter the blues, and greens away from the observer, leaving the yellows, oranges, and reds to penetrate through. This scattering is most pronounced near the horizon where the sunlight has to penetrate a thick column of air. As the sun climbs higher and higher, the column gets thinner and thinner; as a result the sun goes from orange, to yellow, to yellow-white. The blue in the sky results from the same scattering of blue and violet light, scattered in all directions, so we see blue in all directions. The blue is slightly darker overhead because we are seeing the blackness of space starting to show through; along the horizon we are looking through much thicker air, so the blue is much paler.

The artist in me appreciates the mood created by the varying lighting throughout the day. There is a certain quality of the early morning with the long shadows, the midday with the short shadows and the most intense sunlight. There is a certain mood seeing the sun come up as far north as possible for a given latitude, and conversely as far south. There is the scene set by the summer solstice sun shining from overhead, and another of the winter solstice sun hanging low in the south (or north if you are in the southern hemisphere…).

Clouds and Optical Phenomena

Clouds usually act as the enemy of the astronomer, as they tend to block or at the very least reduce the quality of an observing session. But there are times where clouds can be a thing of beauty, particularly around sunset and sunrise when one does not have any observing plans especially. As noted above, with the rising and setting sun, clouds at different levels get illuminated with sunlight that progresses at different rates and times in its changing of colors. If one has a partly cloudy sky near sunset, for example, and there are scattered low (cumulus) and high (cirrus) clouds, the high clouds, in thinner air, are catching sunlight that has not passed through nearly as much air as sunlight nearer the ground. Hence, the lower cumulus clouds appear more golden or orange while the high cirrus may appear white or yellow-white. As the sunset progresses, the cumulus clouds quickly gray as they are moved into shadow while the high clouds put on a brilliant display of golden yellow, then orange, then pink before becoming gray themselves some 15 to 20 minutes after local sunset.

Figure 4-6 (left) upper tangential glow.

Cirrus clouds, particularly the fibrous ones, can be nice to look at against the blue daylight sky. They remind me of supernova remnants like the Veil Nebula, and no two of them are exactly alike. They can take on many different shapes and forms, depending on the prevailing atmospheric conditions of the day. Many times the clouds are of the "fair weather variety". When a warm or cold frontal system approaches, many times, the system is led by high clouds which gradually lower as the system approaches. One useful exercise is to note the change in the sky appearance starting with the first high clouds and watching as they thicken and lower, transitioning to a dark gray. In the early stages, optical phenomena like haloes and parhelia may be visible. It was particularly interesting to watch how the skies changed at the approach of hurricane Ike in 2008. The sky started to be covered with high clouds which gradually thickened, turning the sky from blue to white, then to gray. When the lower clouds moved in, they were moving relatively quickly from northeast to southwest. Some of the cloud structures were impressive as the storm got closer and closer, and a sunset in the west, which still had a strip of clear, illuminated all of this structure dramatically.

After the storm passed, the low clouds were moving from west to east at a high rate of speed, and the skies gradually cleared. It was fascinating to see the change in direction of cloud motion as the storm passes. Clouds can move in different direction at different elevations, as I have seen many times thru the eyepiece doing sunspot counts. High clouds were drifting over the sun from west to east, while scattered lower cloud fragments raced from south to north across the sun's disk. I also noticed the texture of the clouds as they were silhouetted against the solar disk. More information as well as a gallery of images of clouds can be seen at http://cloudappreciationsociety.org/.

Figure 4-7a (above) and 4-7b (below). Rainbow Pictures courtesy of Wikipedia: The double rainbow (above) source: German wikipedia, original upload 28 Nov 2002 by de:Benutzer:Ben-Zin; the supernumerary rainbow image (below), taken by Andrew Dunn, has been enhanced by dramatically increasing the contrast from the original and by cropping to emphasise the strongest portion of the supernumerary arcs. The supernumerary bows are the repeated green and purple bands just inside the primary bow.

Sometime, when conditions are favorable, bright spots appear 23 degrees to the left and / or right, and these sometimes display reds and oranges facing the Sun, and white and blue away from the sun. Sometimes these parhelia or "sun dogs" as they are commonly known, have long bluish tails that point directly away from the sun like a comet's. These phenomena are caused by sunlight refracted by (bent as it passes through) plate-like crystals falling in the atmosphere. Sometimes these sun dogs appear on the inside edge of a ring around the sun, the 22 degree halo, that looks like a pale rainbow. This halo is produced by sunlight that passes through hexagonal ice crystals from the side of the crystal. At the top of this halo may appear an inverted rainbow whose colors are more distinct—this is the upper tangential arc. An image of the arc appears over Grand Forks, ND on 31 January 2007 (The perspective with the sun shows the high angle the circumzenithal arc is found in the sky) and is made available courtesy of Wikipedia.

Rainbows are the most well-known and spectacular optical phenomenon. These are caused by a combination of reflection and refraction of sunlight by raindrops. The sunlight is refracted as it enters the drop, reflects off the back edge of the drop, and bends again as it leaves the drop. Each component color of white sunlight (red, orange, yellow, green, blue, indigo, violet) is bent to a slightly different degree which results in the colorful appearance of the rainbow. Oftentimes, conditions are favorable for a secondary rainbow to appear outside the main or primary rainbow: the secondary rainbow is fainter and shows the colors reversed, and is caused by a double reflection (versus a single reflection) off the back of water droplets as the sunlight travels through the droplet.

On occasion, the inside of the primary rainbow has a rippled effect that makes it look like several mini-rainbows stacked on one another. These are known as the supernumerary rainbow and are made up of several faint rainbows of green and pink coloration, caused by the interference of rays of sunlight. Some of the rays of sunlight interfere constructively, making a resultant ray with greater wavelength than each of the two original and result in a brighter band. Other waves are up to one half wavelength out of phase and experience destructive interference, where the two partially (or totally) cancel each other out.

On Other Worlds

Planets with atmospheres also experience cloud and optical phenomena. It has been suggested that Saturn's Moon Titan, with its wet surface and liquid droplets in its atmosphere, also experiences rainbows. The difference is that the rainbow on Titan has a diameter of 49 degrees, rather than 42 degrees for primary terrestrial rainbows, due to the nature of the liquid involved. Also it is more likely that the rainbow would be visible in the infrared since visible wavelengths are absorbed after short distances by the hazy atmosphere of Titan.

Mars and the gas giant planets, with ice crystals of various molecules, would likely display optical phenomena different from what is experienced on Earth. The shape of the crystal determines what sort of display would be produced. Mars's high clouds are made primarily of carbon dioxide ice crystals; Jupiter and Saturn's clouds contain ammonia and water ice crystals, and Uranus's and Neptune's clouds house crystals of methane ice. Even the tenuous atmospheres of Pluto and Triton, with crystals of methane ice and oxygen, would produce displays of bright spots, haloes and other phenomena. A more detailed discussion, along with pictures, can be seen at this website http://www.atoptics.co.uk/halo/oworld.htm or by googling “atmospheric optics on other planets”.

A nice overview of the skies of other worlds is printed at http://en.wikipedia.org/wiki/Extraterrestrial_skies or one can google “skies of other planets”. I also write a bit more about this in Chapter 6 “The Planets”. I will have more information about meteors in Chapter 8 “Minor Components of the Solar System”.

Ch. 5 – The Moon

Figure 5-1: An Almost Full moon, image courtesy of Prem Saganti

Appreciation

In General

On most clear nights, the Moon can be seen in the terrestrial sky, a slate-gray sphere "floating" in the distance some quarter million miles. This lifeless world is in some respects, similar to the Earth since it is thought, by most astronomers, to be a piece of the Earth that was blasted off by a huge impact. With the naked eye, the moon appears as a smooth, two-toned sphere of rock with no relief or texture whatsoever. But as seen through most any pair of binoculars, the texture changes from smooth to rough as bumps and pock-mark craters become visible.

Like the Earth, the moon has mountains, valleys, rocks, and other features, but unlike the Earth, it has no air, water, or life: it is literally an example of vast "magnificent desolation". Also like the Earth, the moon has a day-night cycle, but unlike Earth, the moon's "day" lasts 29 Earth days. Unlike the Earth, the moon has great temperature swings from day to night: noontime temperatures can be as high as 250 degrees Fahrenheit, but at night they can dip as low as -250 degrees.

Unlike the Earth, the daytime lunar sky is completely black. As soon as the long sunset is ended, full darkness sets in, leaving the large conical Zodiacal glow plainly visible (and a bright area marked by the sun's outermost corona at the location where it just set), and a sky full of more stars than can be seen anywhere on Earth. Also like the moon as seen from Earth, the Earth seen from the moon goes through phases but the Earth phases are a complement of the moon's phases as seen from Earth. In other words, when a thin waxing crescent is visible from Earth, a nearly full, but waning, Earth is visible from the Moon. When the moon appears three-quarters lit, the Earth appears one-quarter lit.

Figure 5-2: MoonKAM view of Earthrise over the far side of the moon (Image #PIA15514), courtesy of NASA/Caltech-JPL/MIT/SRS

Unlike the moon, which rises and sets regularly as seen from the Earth, the Earth is only visible from one lunar hemisphere, and for that hemisphere the Earth hangs motionless in the black Lunar sky, slowly going through its phases while it sits there. The full Earth is some four times wider and eighty times brighter than the full moon. During a full Earth period, if you could stand on the Moon's surface and block out the Earth with your hand, the sky would appear very dark and very full of stars. Since the moon has no atmosphere, the light scattered from the full Earth is non-existent, unlike the situation on the Earth's surface with the full moon.

Through the Eyepiece

In many aspects, looking at the Moon through a telescope at high magnifications is like looking down on the Earth from orbit. In many ways, it is like a terrestrial landscape which changes its character throughout the day as the sun angle and illumination changes; the lunar face (as seen from the Earth) changes with different features coming into view and changing appearance with the changing sun-angle. At the same time, the moon is very different from the Earth, as there are no seas, rivers, lakes, plants, clouds, and air on the moon, giving the moon the appearance of "magnificent desolation".

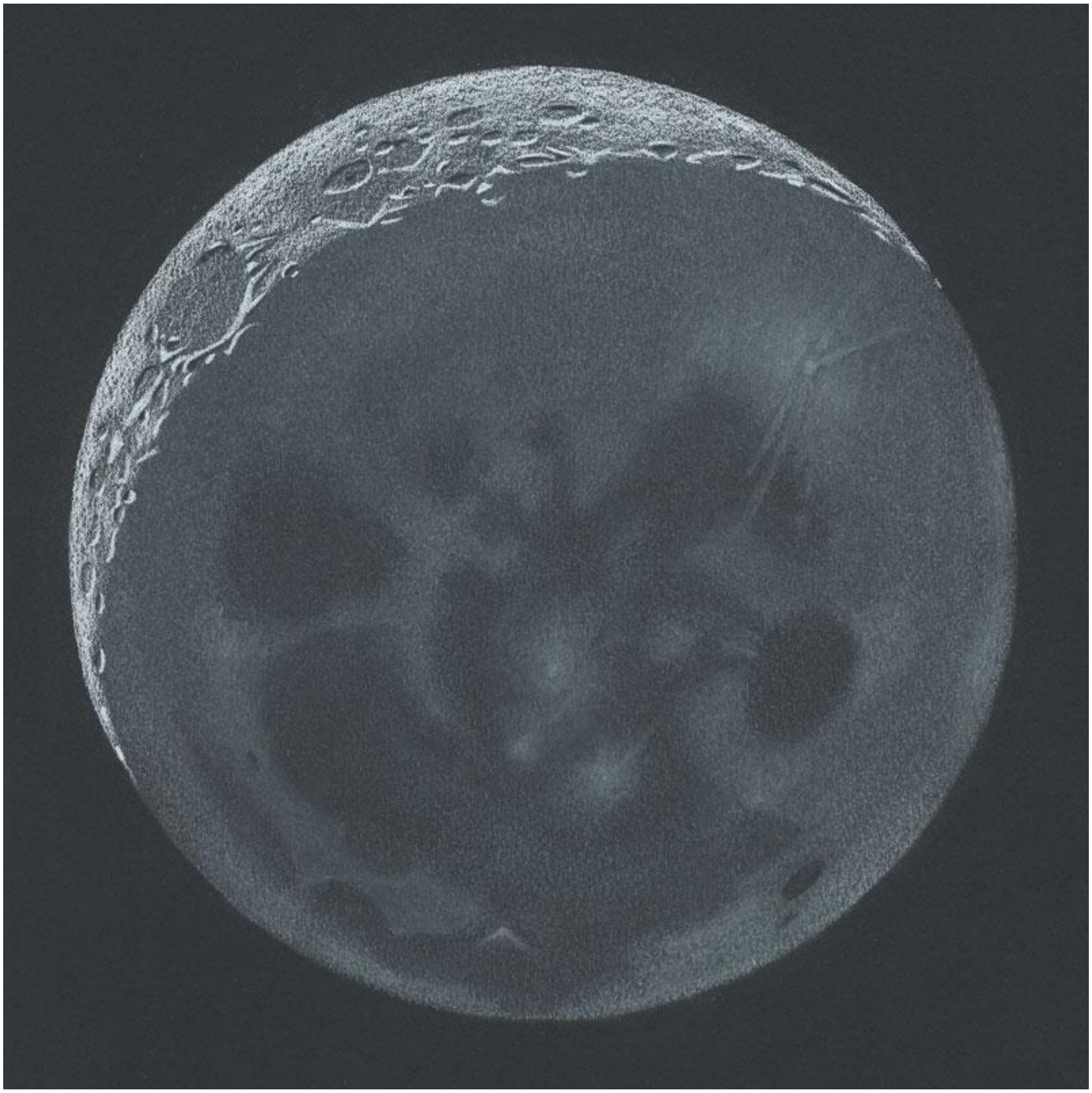


Figure 5-3: Sketch of waxing crescent Moon showing Earthshine, courtesy of Jeremy Perez, http://www.perezmedia.net/beltofvenus/

The moon goes through its monthly cycle of phases as it circles the Earth. The cause of these phases is the change in position of the moon with respect to the sun, resulting in different fractions of the Earth-facing hemisphere being illuminated by sunlight. The phase cycle is often defined as starting at new moon, where the moon is completely invisible to ground-based observers due to its close proximity to the Sun and little to none of its sunlit hemisphere visible from Earth. As the moon continues in its orbit, it first becomes visible as a thin crescent low in the evening twilight. On subsequent evenings, this crescent gets higher in the sky and also thickens: by the third day after new moon, the crescent is high enough in a dark sky to show “earthshine” or “the old moon in the new moon’s arms” (Figure 5-2 shows this nicely). The earthshine glow is caused by earthlight reflected back to earth by the moon. From the Earth-facing lunar surface, the Earth appears nearly full and bright—bright enough to illuminate the lunar landscape to levels making it easily visible from a quarter million miles away.

As the days pass, the moon becomes a thicker and thicker crescent, rising and setting later and later in the day. The earthshine fades, necessitating a telescope to see it by first quarter, which occurs approximately one week after new moon. By then, the moon rises around local noon, is in the south at sunset, and sets around local midnight. Half of the moon’s Earth-facing hemisphere is now visible from the ground. The moon continues to get “bigger” and brighter as it passes into the waxing gibbous phase. It appears later and later in the afternoon and sets later and later at night, and illuminates the sky more and more. The Earthshine may be faintly seen thru larger telescopes up to the tenth or eleventh day before becoming too faint (and being overwhelmed by the bright part of the moon) to be visible. Finally some two weeks after new phase, the moon becomes full, appearing as a full circle in the nighttime sky. The full moon rises near the time of local sunset, crosses the meridian due south near local midnight, and sets near local sunrise. Its light renders the Milky Way and fainter stars invisible (and even gives the sky a familiar blue color as seen through long-exposure, wide field nighttime images).

While looking at the moon thru a telescope we are seeing the moon as it would appear to the naked eye from a spacecraft a certain distance away. Like anything, the apparent size of an object of a given size gets bigger the smaller the distance is between the observer and the object. For example, consider the following. Under ideal seeing conditions at a magnification of 125x, we can resolve features as small as 2 arc seconds. This goes done to 1 arc second at 250x and, if the seeing is exceptional, ½ arc second at 500x. Rarely does the atmosphere allow resolution better than 1 arc second, but there were times in my observing career that I have been able to see things less than ½ arc second across (such as Vesta’s disk). If we assume that the average person with 20/20 vision under average conditions can see with a resolution of 2 arc minutes with their unaided eyes, then we can use trigonometry to compute the distance that person would be from the moon to get a naked eye view comparable to the view he/she gets at a magnification of 125x. The information follows:

Here is how the data shape up (perigee = 221,000 miles; apogee = 252,000 miles)

	2 arc seconds (125x)	1 arc second (250x)	0.5 arc second (500x)
Linear resolution at perigee	2.14 mi	1.07 mi	0.54 mi
Equivalent distance	3,700 mi	1,850 mi	920 mi
Linear resolution at apogee	2.43 mi	1.22 mi	0.61 mi
Equivalent distance	4,200 mi	2,100 mi	1,050 mi

In other words, for the best case scenario (500x with 0.5 arc second seeing) the view you get thru the eyepiece would enable you to see features as small as 0.54 miles (or 2,800 feet) across, which gives a view equivalent to being in a spacecraft situated a little over 1,000 miles above the lunar surface. So you can get a sense of what the Apollo astronauts saw as they approached the moon, but this is not nearly close enough to see the flag! Of course, the real life spacecraft view would not be softened at all by the atmosphere (since we would be looking thru no atmosphere) but would appear crisp, sharp, and rock steady.

Of course your telescope has to be of large enough aperture so that 500x is not just empty magnification. In other words, for small instruments, one can pump up the power this high, but due to limited aperture, detail would not be added. The image would merely get bigger, fainter, and lose contrast (in other words, get "washed out"). I have included a table that shows what the upper limit of magnification would be for instruments of various sizes. If your instrument is not listed, you can interpolate. Anything larger than the value given for a particular scope size would be useless magnification.

Maximum useful magnification by telescope aperture (50x aperture in inches or 2x aperture in millimeters)

Aperture	Magnification		Aperture	Magnification
2.4 in	120x		14 in	700x
4.5 in	225x		18 in	900x
6.0 in	300x		20 in	1000x
8.0 in	400x		25 in	1250x
10 in	500x		36 in	1800x
12 in	600x		48 in	2400x

For telescopes larger than about 12 inches, higher magnifications become a moot point, beyond about 600x one is merely magnifying the seeing unless one has truly exceptional seeing. To get the full benefit of higher magnifications, one would need adaptive optics or be outside the atmosphere, but this is still an interesting exercise to do.

Celestial Alignments Involving the Moon--Eclipses

One of the most spectacular sights in the nighttime sky is that of a total lunar eclipse. The most recent eclipse that I have been able to enjoy was that which occurred on 21 December 2010. This event was nearly clouded out from my backyard location, but I was able to get some nice binocular views of the moon at various stages of eclipse through fairly frequent holes in the clouds. The multicolored moon at totality had an appearance of a frosted, translucent globe being illuminated from within, with several shades of yellow and orange. This appearance changed subtly over the course of totality and it maintained this appearance during the deep partial phases of the event.

Lunar eclipses are fascinating to watch, from the slightest event (a penumbral eclipse) to the longest total eclipse (145 minutes, which is the length of totality of the July 5, 1982 total eclipse). The Earth's shadow is decidedly curved and one can track its movement across the moon's face in real time at the eyepiece. The shadow is not completely dark but is illuminated within by sunlight bending around the Earth's edge through its atmosphere, filling the shadow with the light of the world's sunrises and sunsets. No two eclipses are exactly alike, which adds to the experience.

Figure 5-4: Total Lunar Eclipse of June 2011 taken by Muhammad Mahdi Karim and is courtesy of Mr. Karim and Wikipedia.

Watching a total lunar eclipse from a dark sky location offers the experience of not only watching the moon change in appearance, but watching the surroundings and sky change their appearance: the event starts with a bright, moonlit night, with the sky aglow with moonlight and only the brighter stars visible. As the eclipse progresses, the moonlight fades and fainter stars come out, until the start of totality when the skies become fully dark, complete with Milky Way, and the moon a translucent, ruddy "planetary nebula" suspended among the stars.

Solar eclipses offer their own brand of excitement. Total solar eclipses are rarer due to the confined nature of their paths: one has to be located in the right location and time (and with the right weather!) to be able to witness a total solar eclipse. I have had the privilege to witness one (there are those out there that have seen many…), the July 11, 1991 Total Solar Eclipse observed from the lower end of the Baja Penninsula, in La Paz, Mexico. I have also witnessed two annular (ring) eclipses, one of which happened at sunset, and half-dozen partial-only solar eclipses.

Celestial Alignments Involving the Moon--Occultations

Lunar occultations are another example of celestial alignment, this time between stars or planets, the moon, and the Earth. I have on many occasions watched visually or videotaped the moon as it approaches a star, then suddenly blocks the star's light in an event known as a lunar occultation. I also have watched the moon glide across open star clusters such as the Pleiades, an event I last videotaped on August 14, 2009. I have even, in June 2007, witnessed a grazing occultation where the star winks off and on as it passes behind multiple peeks of lunar mountains (this one saw 21 events, one of the most ever witnessed in a single graze).

Since the moon remains within 5.5 degrees of the Ecliptic, there is a limited number of stars and planets (and other objects) that the Moon “has access to” occult. All of the major planets, as well as many bright stars and several deep sky objects lie in the moon’s path. I have seen the moon occult Venus, Mars, Jupiter and Saturn as well as bright stars and star clusters. Occultations of these objects nicely show the moon in motion and these give a dynamic dimension to the sky as things do change (slowly). Watch as the moon slowly creeps up to the star, then the star seems to “hang” on the edge (especially if that edge is earthlit, as is the case with most of the occultations I have seen), then suddenly pop out of view. Double stars are especially interesting, in the case of Antares, the bright orange-yellow primary winks out first, leaving the bluish secondary visible for several seconds before it winks out suddenly. If the star has a large angular diameter (on the order of tens of milli-arcseconds), it may appear to fade rather than quickly wink out of view. If the star is a close binary, the disappearance may occur in steps.

Lunar Occultations, while they offer little in the way of additional science for the physical nature of the moon itself (given the spacecraft sent there regularly), provide an opportunity for research and discovery. High speed video has the potential to discover new binary star systems. Such systems have been discovered even with regular speed video (see http://www.poyntsource.com/New/Gallery.htm for several examples of “step events” and other astronomical videos of interest).

From time to time, the Moon passes in front of planets, and this offers another spectacular opportunity to watch “the sky in motion”. A recent example of one such event that I enjoyed was the grazing occultation of a crescent Venus by a crescent moon on the morning of April 21, 2009. The first thing one notices is the difference in distances (and albedo) as apparent by the large faint crescent moon and the small bright crescent Venus (the event was observed visually with a 4.5-inch f/8 reflector). I watched as the moon approached Venus, then the planet began to slowly disappear as the unlit (and invisible because of the blue early-morning sky) part of the moon progressively covered the planet. After several minutes the planet was completely covered, but just barely as this was a quasi-grazing occultation: before one knew it, the planet began to re-emerge slowly, breaking free of the moon’s hiding after many minutes of emerging (the entire event lasted less than 15 minutes from first contact to last contact).

Many websites and astronomical magazines and books have information on the upcoming occultations of bright stars and planets by the moon and you are encouraged to seek these out to look for events that are coming up in the near future. Plan to spend time to observe these events, telescopically and (if the occulted object is bright enough) with binoculars and the naked eye. I also watched the above Venus event with unaided eyes and Venus was easily seen when it was uncovered or mostly uncovered.

Application

Special Lunar Features and LTP

Earth's nearest large planetary neighbor offers a wealth of observing projects to work on. The Bright Rays Project is an activity coordinated by ALPO to study the finer details of lunar rays. These details include the distribution, the ray structure, the appearance of rays, and the interaction of rays with the local features. The following website: www.zone-vx.com/alpo-rays.html contains a list of 260 features needing closer visual examination. Resources can be downloaded from and observations can be reported to the contact listed on the website.

Several programs exist to closely monitor Lunar Transient Phenomena (LTP). This includes a systematic approach to watch features that have a history of LTP reports to qualify the authenticity of the event. This activity promotes a network of observers that work together to achieve the common goal of validating LTP and learning more about it. ALPO maintains a list of features monitored on a regular basis for LTP. The object is to repeatedly observe these under almost identical illumination conditions to determine the truthfulness of the LTP report. Among other outcomes, the group seeks to find statistical patterns in LTP occurrence, and to utilize narrowband filters to look for subtle color changes on the moon.

In addition to the LTP section, the ALPO maintains two sections for monitoring LTP: the Lunar Meteoritic Impact Search section which specifically looks for meteoroid impacts and their manifestations; and the Lunar Topographic Studies which has a list of surface features which are monitored closely. The list, as well as instruction on what to look for and how to proceed, can be found at http://www.zone-vx.com/topo-study.pdf. Also, monitoring changes in appearance due to changes in illumination angle over the long term (this for specifically designated or "selected" areas), and banded craters (to study craters with dark and light radial bands within their walls) are activities that are being carried out. For the latter project, the outcome is to look for trends and patterns in banding related to crater type and size.

Lunar Occultations and Eclipses

For more information, refer to the IOTA manual to get the overviews to be included. You can access this manual from here:

http://www.poyntsource.com/IOTAmanual/Preview.htm

Solar eclipses are fascinating events to watch, and come in three forms: partial, which is by far the most common; annular, which happens in the case of the moon being too small to cover up the entire sun, leaving a ring or "annulus" of bright sunlight; and total, where the moon completely covers up the Sun, allowing the corona to be seen.

The book *Observe Eclipses!* By Dr. Michael D. Reynolds and Richard A. Sweetsir outlines several projects one can participate in while watching a solar eclipse. These are outlined below, with the book providing much more information:

- Contact timings for the 2nd and 3rd contacts with voice recorder and time signal (done similarly as visual asteroid occultation events where an observer calls out the contact as it happens with WWV playing in the background) or with an accurate wristwatch
- Contact timing of sunspots to include how long it takes for the spot or group to be covered by the moon
- Lunar limb profile irregularities can be noted-record the appearance time and duration of any irregularities and the compass p.a. with respect to nearby sunspots
- Environmental changes such as changes in ambient light level, changing sky / cloud / landscape colors and any asymmetries in these going into versus coming out of totality.
- Wildlife and meteorology during totality (and the several minutes leading up to and following totality)
- Shadow bands
- Lunar shadow appearance and motion, locations of visible stars and limiting magnitude
- Bailey's Beads, Chromosphere and Prominence observations, p.a. of each
- Morphology of corona: overall shape and size, length of streamers, number of streamers and p.a. of each, anomalous features within the corona, etc.

Lunar eclipses, for a given location, occur more frequently and present more opportunities for study. These come in three types: the penumbral eclipse (where the dusky outermost part of the shadow is crossed by the moon), the partial eclipse (where part of the moon is covered by the dark central part of the Earth's shadow), and the total eclipse (where the entire moon is in the umbral shadow). There are a number of projects that observers can participate in such as the following (again more details can be found in the Reynolds and Sweetsir book) -

- Penumbral portion of eclipse→ timings of first and last visibility, tape record the time of when the visibility was first suspected, then definitive (with WWV or other time source playing in the background)
    - How soon can you detect the very first hint of penumbra? Can filters enhance its appearance? I noticed that the blue/violet filter may make it more easily visible.
    - Try to change the focus slightly and use different filters (color and neutral density) to find out how penumbral visibility changes.
    - Separation between the edge of the umbra and limit of detectible shadow (penumbral) and changes throughout the eclipse.

- Partial eclipse → Contact timings with the lunar limb, record verbal description against time signal
    - Contact timings of craters, time when the edge of the shadow crosses the center of a feature (or time both ends of the umbral crossing of a large feature)-there are 25 craters / features to choose from.

- Umbral characteristics: sharpness and changes of sharpness of edge, color and brightness of umbra (0 being darkest, 5 being the brightest, calibrated with several lunar features inside the umbra).
- Magnitude and Danjon estimates of the eclipsed moon—details of this can be found with the ALPO Eclipse section and the book referenced above.
- Look for LTP-changes in the appearance of a feature before, during, and after the passage of the shadow. Physical changes during eclipse may trigger actual changes so monitor areas suspected of exhibiting LTP.
- Look for meteor impacts in the shadowed region (partials with umbral coverage of greater than 50%; total eclipse).

- Total Eclipse → Time the 2nd and 3rd contacts, note the general color and uniformity (or lack of) across the moon.
  - Look for the variations in the appearances of lunar features, especially those near the limit of resolution.
  - Determine the moon's luminosity using the Danjon Scale (do an estimate just after totality starts, near mid-totality, and just before totality ends.
  - Look for LTP, stellar total and grazing occultations, and lunar meteoroid impacts.
  - Notice how the sky brightness changes during the event (if observing away from city lights), to include estimates of sky limiting magnitude throughout the entire eclipse.

- Drawing of surface features at all illuminations—accuracy is key.
- Shadow measurements done several times and averaged for accuracy.

As we have seen, our nearest neighbor in space, the moon, has a wealth of interesting things to offer and can be enjoyed, rather than distained, when it is present on a given night. Oftentimes, amateur astronomers view the moon with contempt (if at all) because of it lighting up the night sky, but it is only present for a short time each month, and it offers a wealth of detail to explore.

Ch. 6 - The Planets

Appreciation

Beyond the moon are other worlds, each as real and as unique as the Earth. They are (in order of their closest approach to Earth, which is somewhat different than what you may be used to): Venus, Mars, Mercury, Jupiter, Saturn, Uranus, and Neptune. Each became more than simply wandering points of light with the invention of the telescope and its use by Galileo to explore the night sky in 1609. As the design and quality of the telescope improved, the planets became clearer and clearer (with new ones being found) over the centuries. They truly become real places during the advent of space exploration, starting in 1959. Since the dawn of the space age, we have enjoyed up close images of all major planets and most major satellites, views from the surfaces of Moon, Mars, Venus, Titan; and views close enough to resolve individual rocks on Phobos, Deimos, Itokawa, Eros, the Galilean moons, Enceladus, Phoebe. We have taken pictures of several asteroids: Ceres, Vesta, Annefrank, Eros, Mathilde, Ida, Dactyl, and Gaspra. And thanks to our up close and personal way of studying planets, we know now of many fascinating and spectacular geologic features and landscapes on many planets and moons- many, many cool places to go hiking if we have the technology to get there.

The View from the Air

I have been on many airline flights and the Earth looks different from 7 to 8 miles up (the highest I have been was 8.1 miles) than it does from the surface. For those willing to look out the window, especially if they have window seats, each flight presents a different “skyscape” consisting of cloud layers and structures, landforms, and a deep blue sky. On a clear day above 7 miles, one can just make out the curvature of the Earth using the tops of the row of aircraft windows as a reference marker. The horizon, some 200 miles distant at altitude, is noticeably lower than horizontal (or eye level) by about 3 degrees. Things begin to take on the general appearance that one gets from low Earth orbit.

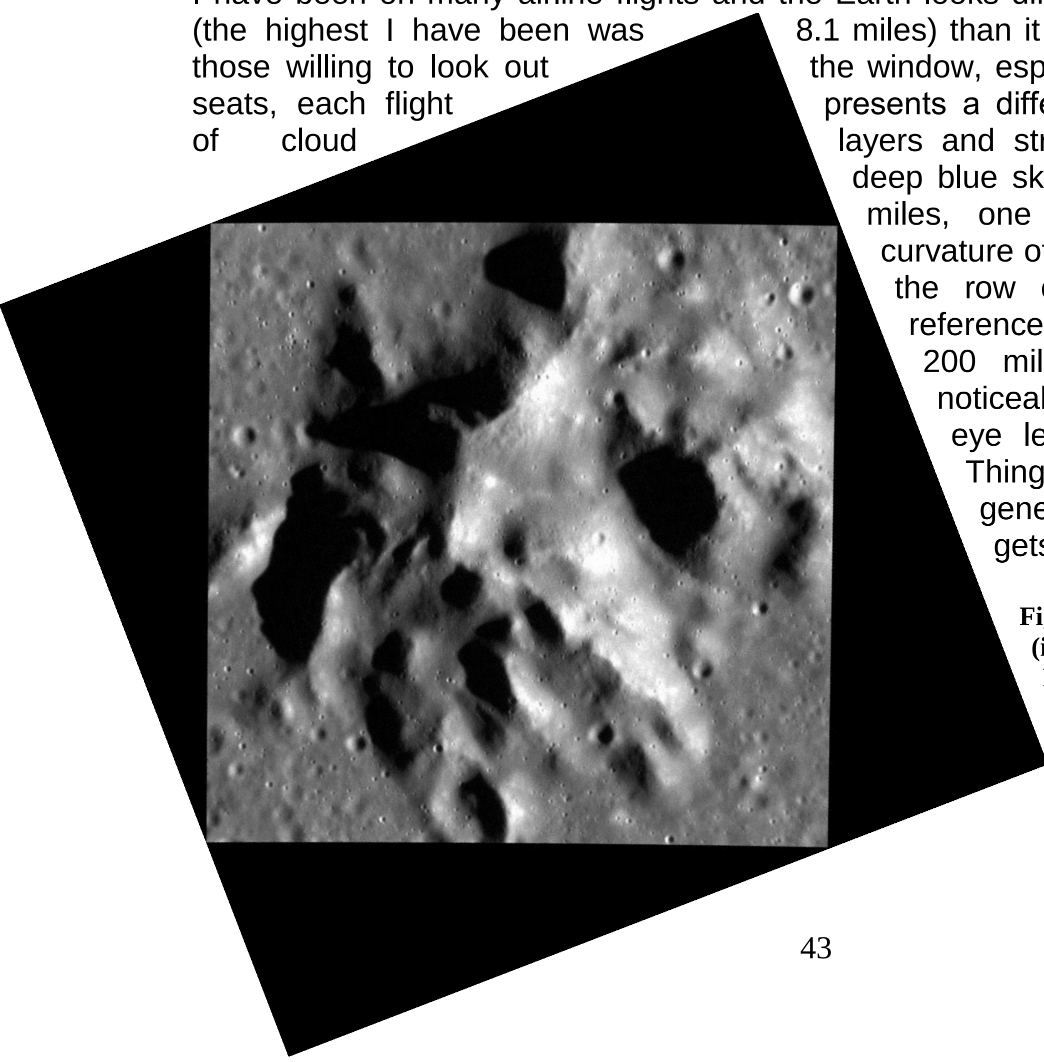
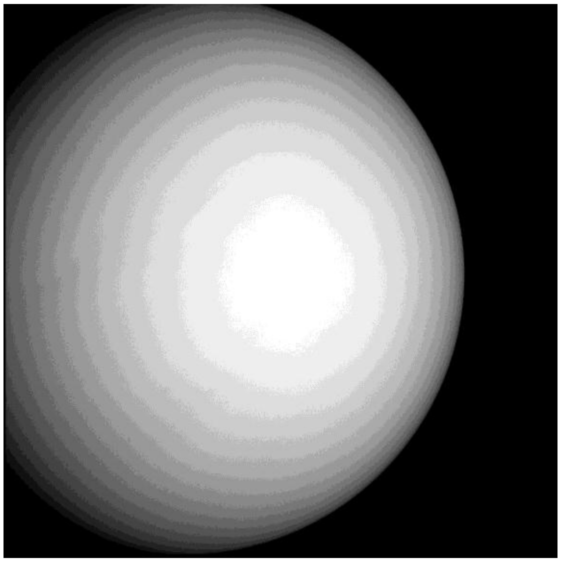


Figure 6-1. Mountains of Mercury (image courtesy of NASA, image # PIA 15760)

Also, whenever I fly I often wonder what it would be like to take a flight on Mars, Venus, Jupiter, or Neptune. On Mars, from 5 to 7 miles up, the landscape, dominated by reds and browns, would look similar to that of the desert southwest on a clear day-the sky would be pink or brownish instead of deep blue, and there would be few, if any, clouds. On Mars we can see mountains and river channels, craters of various sizes, canyons, and even some orographic (mountain-lifted) hazy clouds.



Flying on Venus the cloud deck is still some 30 miles up, so the sky would be overcast orange. The landscape below would clearly be seen, and would feature a varied array of mountains, crevices, cracks, rocks, boulders, etc. Everything would have an orange cast to it.

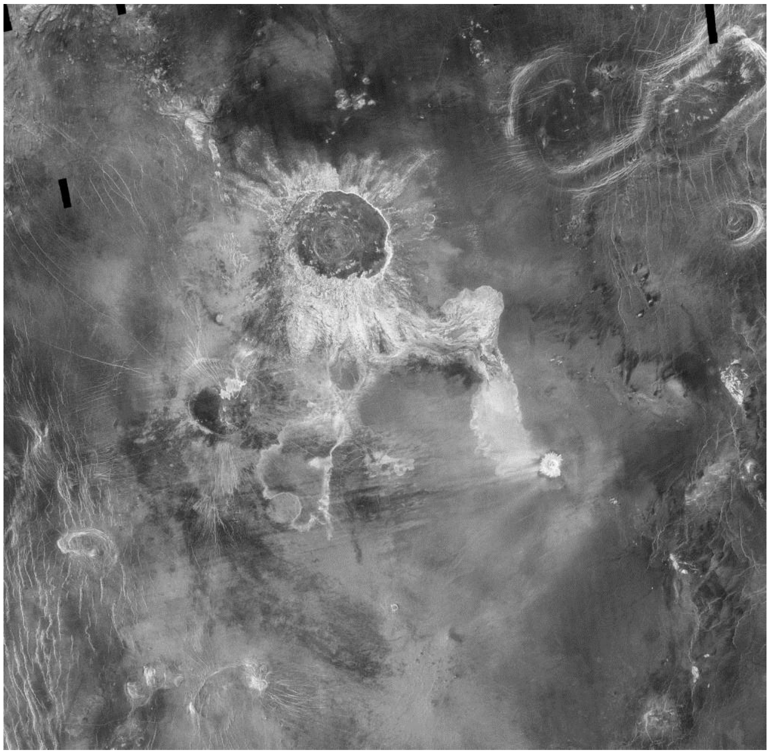
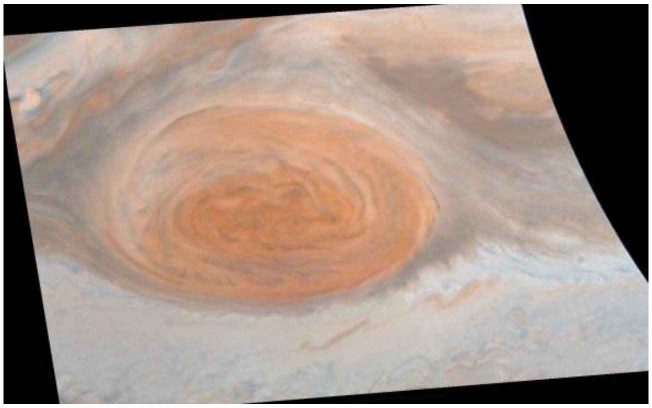


Figure 6-2 (above): Venus from space, as it would appear to the eye, image courtesy of NASA (#PIA 10124). Figure 6-3 (left): radar view of Isabella Crater on Venus; NASA image PIA 00480

If we were able to visit Jupiter, the skyscape there would be more varied and extreme than anything on Earth. The horizon is thousands, not hundreds, of miles away but there is no solid surface underneath; looking down one would see deeper cloud layers or a dark gray haze. All we see are clouds for hundreds of miles. However, like Earth, there are desert like regions, and cloudy regions, haze layers and thunderstorms. Looking up, the clear sky would be blue but the Sun would be a shrunken disk only 1/5 as big and 1/25 as bright as seen from Earth, and haze may obscure the distant horizon and the sunset.



There seems to be a sense of artificiality to what I see out an airplane window since this is not the view I am accustomed to on a daily basis and that would probably be even truer if we were able to fly on other planets. Many artists over the years have attempted to depict what it would be like to visit other worlds with varying degrees of accuracy. Many of today's artwork (such as that found in *The Grand Tour*) are based on scientific results sent back from various spacecraft and attempt to depict things as accurately as possible.

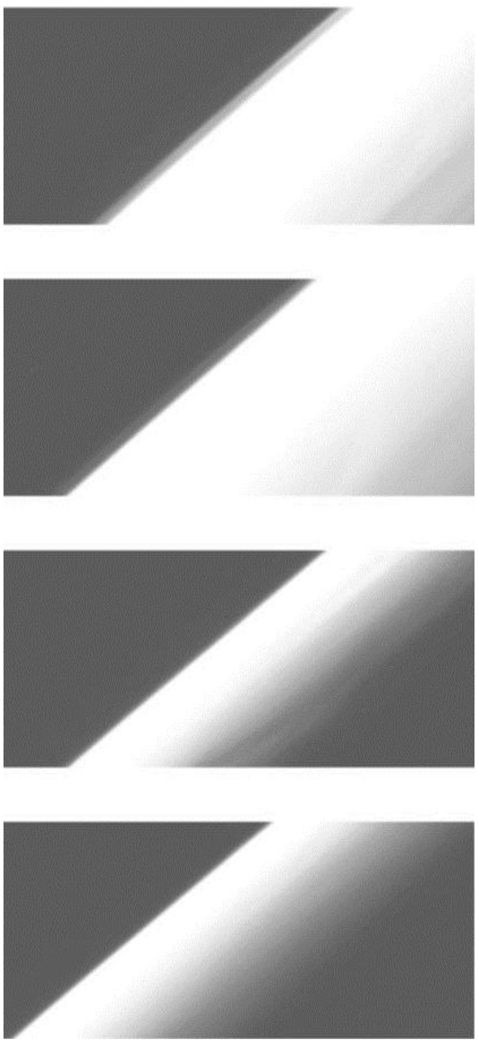


Figure 6-4 (upper left on this page): The Great Red Spot in true color. Image courtesy of NASA (#PIA00708). Figure 6-5 (lower left): the limb of Jupiter in various colors showing detached haze layer. Image courtesy of NASA (#PIA01197).

Cassini has shown that Saturn also has blue skies- when they are free from haze. The atmosphere appears more deep and murky than Jupiter's. Some of the deeper cloud features are lost in the haze. Like Jupiter, Saturn has no solid surface to land on. We see clouds of many types, including cumulus and cirrus and stratus, and we have seen 3D texture to them. Storms do happen on Saturn as evidenced by radio frequency "crackles" picked up by Cassini.

Neptune also shows signs of blues skies. The planet itself has blue coloration due to methane. Voyager 2 images show high cirrus-like clouds above what looks like a blue, stratiform cloud deck. One particular image shows these high clouds casting shadows on the deck below, and the shadows are dark blue, not black, indicating the presence of scattered light from the atmosphere itself (blue skies).

What we can see: We can ponder all of the above as we look at each world through the eyepiece. Consider each is a real place, like Earth, with its own array of features, weather, landscapes, action all going unseen by human eyes and only glimpsed as a snapshot by spacecraft.

The Physical Nature of Each Planet (in Brief)

Spacecraft have visited all of the planets in the solar system except Pluto and have sent back spectacular images over the past 50 years or more. They show vistas never before seen in the history of humankind, from the rocky surfaces of Mars and Venus, to the high, pearly-white clouds of Neptune (driven by winds of up to 1,000 mph or 1,600 km/h). The NASA photojournal website (photojournal.jpl.nasa.gov) has a searchable, clickable menu hosting thousands of images of most major objects in the solar system. The images in this and other chapters come courtesy of NASA and each image caption includes the image identifier ("PIA" number) so that the reader can visit the website and search for the image. With the image, there is text that provides much more about that image or the subject covered by that image.

Figure 6-6: Mars at noon from the site of the Sojourner rover (July 1997), image courtesy of NASA (PIA01546)

The planet we can relate most to is Mars. Not only does it have a 24 hour day and an axial tilt comparable to Earth's but it also has a solid surface and features that are not unlike what we see on Earth. The images on this and the next pages illustrate the appearance of the Martian surface by day, and the colors of a Martian sunset and color of twilight by evening. Twilight on Mars lasts almost twice as long as that from Earth on average due to the greater height of the Martian atmosphere compared with Earth's and due to the dust that is suspended in the atmosphere which catches the sun and reflects that sunlight to the surface well after the local setting of the sun.

What Mars is missing is the cloudy, rainy weather. Clouds do occur on Mars but they are few and far between. Like Earth, morning fogs and hazes happen on Mars, but they are not as widespread. There is evidence for an ocean covering up to 40% of the surface area of the planet in its distant past. This evidence includes markers made by wave action, sediments, and minerals normally present in moist conditions. The planet also displays numerous examples of dried river channels and features that seem to show a flash flooding event that took place at some point in the past.

Unlike Earth, Mars experiences global dust storms which can render the surface dimly lit at midday (and the stars invisible by night). This phenomenon usually happens once per Martian year (687 Earth days) and may take weeks to subside.

Figure 6-7 (top): the hills of Mars as seen by the Opportunity Rover, image courtesy of NASA (PIA 14508); Figure 6-8 (below): as seen from these same hills, the view looking over the adjacent plains as seen by Opportunity. Image courtesy of NASA (PIA 15281)

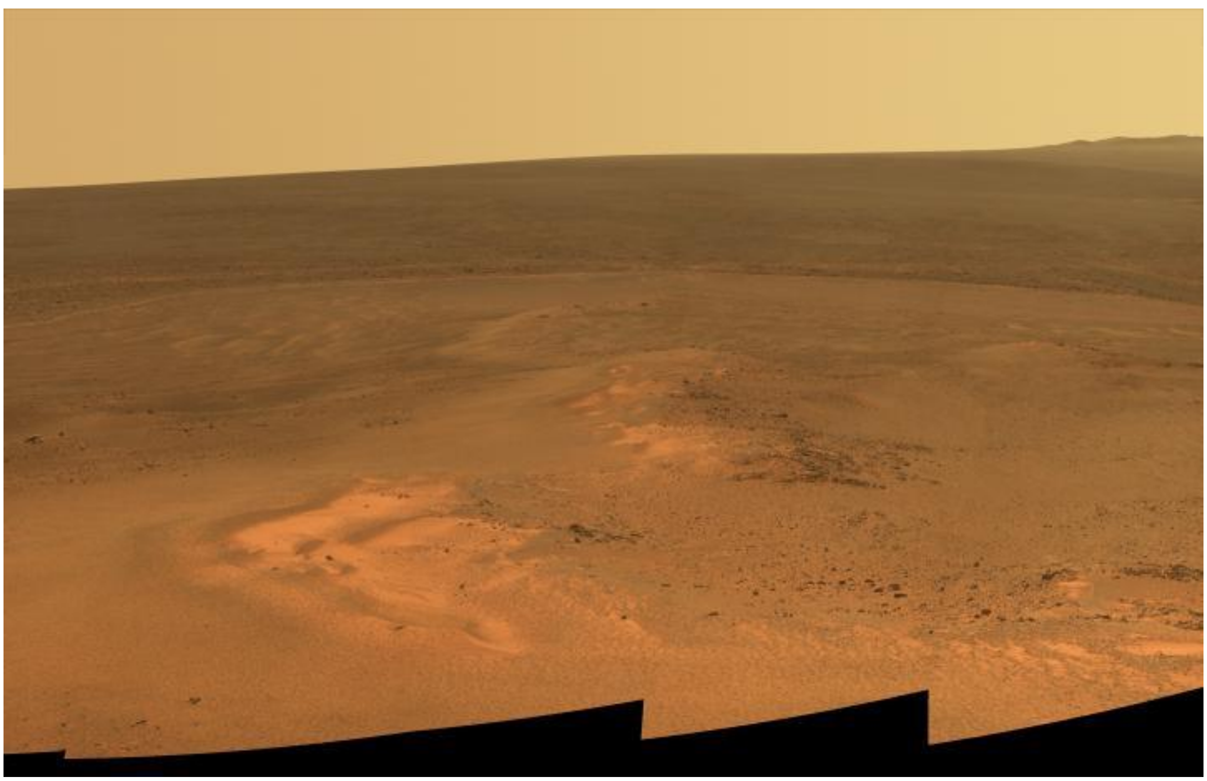


Figure 6-9 (above): sunset as seen from Sojourner's site (image courtesy of NASA, image # PIA01547). Figure 6-10 (below): sunset seen by Spirit rover (image courtesy of NASA, PIA00920). Figure 6-11 (right): twilight on Mars some 45 minutes after local sunset.

Jupiter does have lots of clouds but no solid surface, and is physically much bigger than Earth or Mars. Not only that, but the planet rotates much faster, once every 10 hours versus 24. The planet shows lots of dynamic weather, including the Great Red Spot (Figure 6-4) and limb hazes (Figure 6-5), and winds up to 330 mph; the planet also shows thunderstorms (Figure 6-12, next page, shows lightning from moon lit clouds-lit by the moon Io) and aurora borealis (Figure 6-13, next page). It is fascinating to really consider how these phenomena would look if viewed from up close, within the planet's atmosphere (Figure 6-14 shows a close-up).

Saturn displays similar, yet muted features, and its own auroral rings (Figures 6-15, 16, and 17). Like Jupiter, Saturn is a fast rotator and does not have a solid surface, but it does feature vast stretches of clouds, a fascinating polar helix formation, and winds in excess of 1,000 mph in spots. Lightning has also been seen and imaged on Saturn (Figure 6-18).

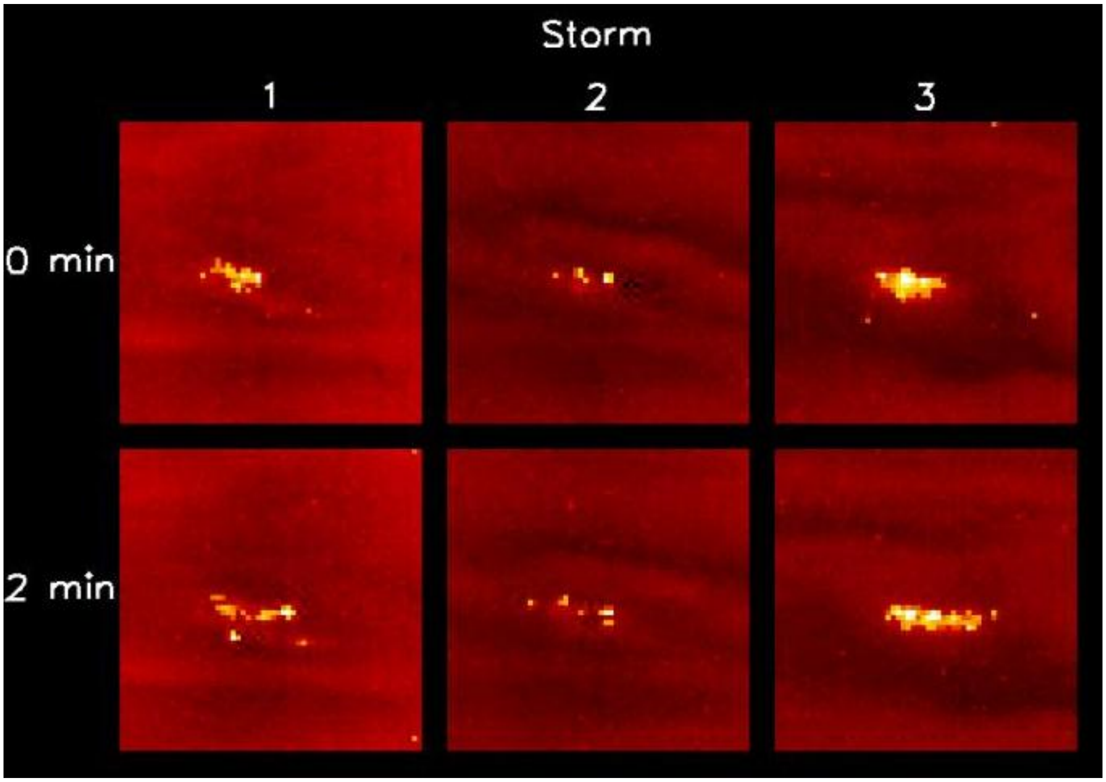


Figure 6-12 (above). Lightning flashes from three storm complexes in the Jovian atmosphere, with the surroundings illuminated by the ruddy light of the moon Io (Courtesy of NASA photojournal, image PIA01636). Figure 6-13 (below). Aurora ring as it changes over a 45 minute period (note also the changing perspective as the spacecraft has moved with respect to the planet; image courtesy of NASA, PIA 01603.

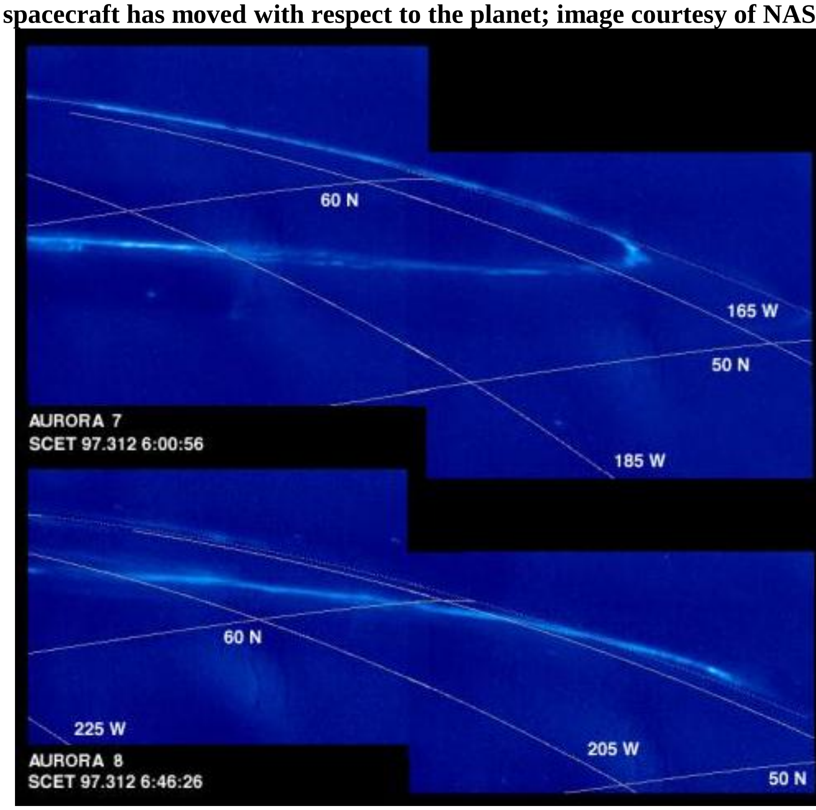


Figure 6-14: close-up of the boundary between one of the equatorial belts and the equatorial zone. Clouds of various types at various levels and even a bit of haze (lower part of picture) can be seen in this image, which is courtesy of NASA (photojournal image #PIA00574).

How Close Can You Get?

Depending on the planet and the time of year, the viewing circumstances vary, and this will determine “how close you can get”. There are (at least) two ways to answer this question: by linear resolution (the size of the smallest features you can see on a planet), and by what I call the “equivalent distance” (which I have described already). Venus approaches the closest of any major planet, and the others are progressively further away. There are two “inferior planets”, Mercury and Venus, which are always closer to the Sun (owing to their smaller orbits) and only appear in the evening or morning skies of Earth. Mars, Jupiter, Saturn, Uranus, and Neptune are “superior planets”, which have orbits larger than Earth’s and can appear at any possible time, from morning or evening to midnight. Each planet has something unique to offer by way of features and appearance on a given night, and changes over many nights (or many months).

For Mercury and Venus, they come closest to Earth when they pass between the Earth and Sun, a configuration called “inferior conjunction”. But they are invisible to Earth (unless they pass in front of, or “transit” the Sun, such as what Venus did in June 2012) at that time. They show phases (as seen through the eyepiece) like the Moon depending on where they are at in their orbit. When the planets are closer to Earth, they look like larger crescents; when farther away they appear half-lit to gibbous.

For Mars, Jupiter and the rest, they appear best at opposition, where they rise at sunset, cross the meridian due south at local midnight, and set at sunrise. This is also the time that the planets are at their closest to the Earth, and show the best detail. Mars, Jupiter, and Saturn show the most detail out of all the superior planets, but their opposition distance varies from opposition to opposition depending on where they are at in their own orbits. For Mars, this is the most noticeable; its closest (or perihelic) opposition makes it appear almost twice as large (25.0”) as the farthest (or aphelic) opposition (13.7”). Jupiter also varies in opposition size (45” to 50”) but not as dramatically; Saturn varies in size also (though less than Jupiter), but Saturn has the brilliant rings which vary in how wide (o to 27 degrees) they open.

	INFERIOR CONJUNCTION OR OPPOSITION-Linear resolution in miles			**EQUIVALENT DISTANCES** (given in miles; to get km simply multiply by 1.609)		
OBJECT	2" resolution	1" resolution	1/2" res.	2" res.	1" res.	1/2" res.
Moon*	2.14	1.07	0.536	3680	1840	920
Venus	250	126	63	434,000	217,000	108,500
Mars	450	225	113	775,000	387,500	193,800
Mercury	550	275	138	946,000	473,000	236,000
Jupiter	3790	1895	945	6,510,000	3,260,000	1,630,000
Saturn	7660	3830	1915	13,200,000	6,590,000	3,290,000
Uranus	16,400	8205	4100	28,200,000	14,100,000	7,050,000
Neptune	26,200	13,100	6560	45,100,000	22,500,000	11,300,000

*Moon: this corresponds to perigee

	GREATEST ELONGATION OR QUADRATURE- Linear resolution, miles			**EQUIVALENT DISTANCES** (miles)		
OBJECT	2" resolution	1" resolution	1/2" res.	2" resolution	1" res.	1/2" res.
Venus	1100	555	277	1,910,000	955,000	477490.6
Mars	1630	813	406	2,790,000	1,400,000	698575.6
Mercury	965	482	241	1,660,000	829,000	414534.5
Jupiter	4775	2390	1190	8,200,000	4,100,000	2,050,000
Saturn	8610	4310	2150	14,800,000	7403177	3,700,000
Uranus	17,400	8670	4330	29,800,000	14900169	7,450,000
Neptune	27,200	13,600	6790	46,700,000	23340370	11,700,00

Since the distances vary over the course of a planet’s apparition, I provide linear resolutions and equivalent distances for each planet in sets of three. The distances are listed by planet, are to the nearest 100 miles, and assume 2, 1, and ½ arc second resolution, which corresponds to 125x 250x and 500x respectively. The magnification to be used will depend on the seeing conditions, the instrument used, and the preference of the observer.

	SUPERIOR CONJUNCTION – Linear resolution in miles			**EQUIVALENT DISTANCES** (miles)		
OBJECT	2" res.	1" res.	1/2" res.	2" resolution	1" resolution	1/2" res.
Moon**	2.43	1.22	0.608	4,180	2,090	1,045
Venus	1550	775	388	2,670,000	1,330,000	667,000
Mars	2250	1130	564	3,880,000	1,940,000	969,000
Mercury	1250	627	313	2,150,000	1,080,000	539,000
Jupiter	5590	2790	1400	9,610,000	4,810,000	2,400,000
Saturn	9470	4730	2370	16,300,000	8,140,000	4,070,000
Uranus	18,200	9100	4550	31,300,000	15,700,000	7,830,000
Neptune	28,000	14,000	7010	48,200,000	24,100,000	12,000,000

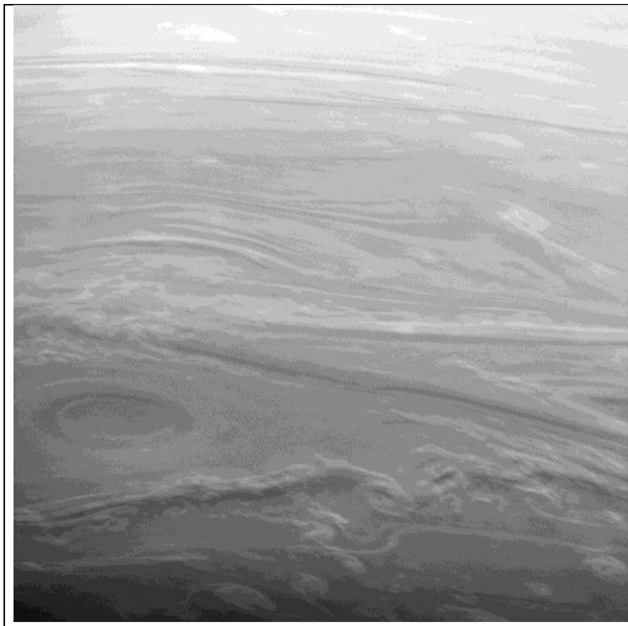
** Moon: this corresponds to apogee

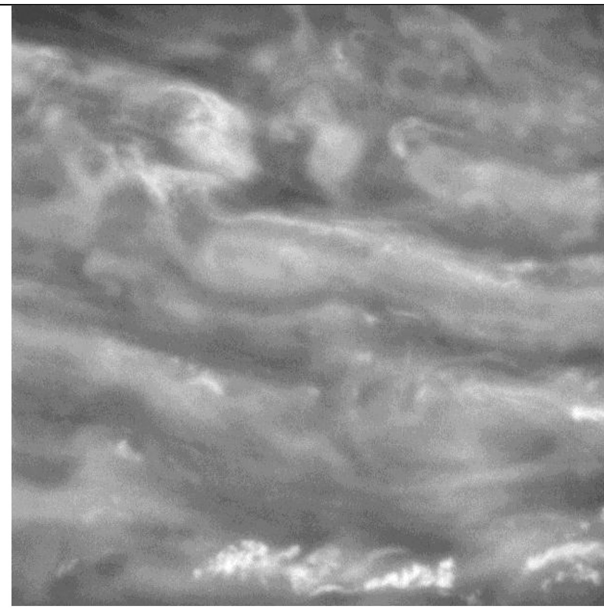
If you want to get the most out of this, note the values for resolution and equivalent distance for the next night you plan to observe planets. You can do a rough interpolation as needed, but jot down the figures as needed and keep them close by. That way, when you are contemplating the wonders of Saturn at 250X or thinking about the rovers on Mars as you spy the planet at 500X you can have a rough idea how small of features you can see on each (you DEFINITELY cannot see the rovers!) and how close an incoming spacecraft would have to be to match the view (naked eye) with the view you now see through the eyepiece. This is something different to add some “flavor” to your observing session.

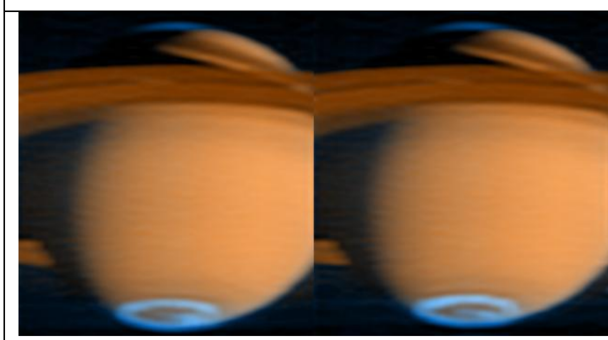
Application

Here are some (more) general guidelines when observing the planets. Visual observations can be a rewarding experience, especially if one takes the time (which will take at least several observing sessions to complete) to allow one’s eye-brain system to perfect the subtle skill of perceiving the not-so-obvious details visually. With this ability, and a night of excellent seeing, not only can you enjoy observing and contemplating the nature and makeup of another world, you can also watch as changes unfold on another world over the course of a terrestrial evening. For instance, planets rotate and depending how fast they rotate, the change can be seen in minutes to an hour. This is most easily seen with Mars and Jupiter. The effect is much more subtle or unnoticeable for Saturn (unless it has a once-in-a-30-Earth-year white spot you can easily see), due to its muted atmosphere. It is interesting to watch features appear over the hazy Jovian horizon, drift across the disk, then disappear on the opposite end several hours later. This opens the door for a useful visual observation: central meridian transit timings. For a fluid planet like Jupiter, this is an ongoing useful exercise to undertake.

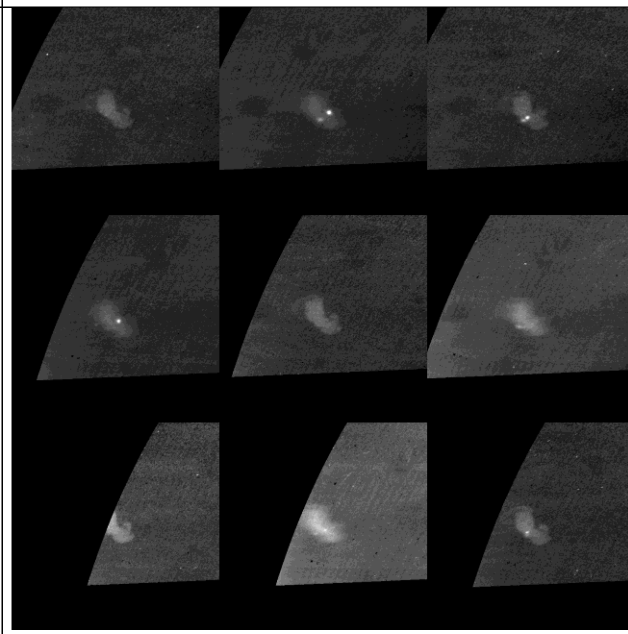
In addition to the atmospheric or surface features being carried along by rotation, there is another feature of a planet that changes in a short period of time. If the planet has several bright moons, like Jupiter and Saturn, the configuration of these moons changes over a relatively short period of time as these moons "slowly" dance around the planet resulting in an ever-changing pattern centered on the planet.







Figures 6-15a to d (clockwise starting from upper left): clouds casting shadows in Saturn's high latitudes (PIA08821), a close up of the clouds on Saturn (PIA10444), sequence showing lightning flashes within a thunderstorm (PIA12576), and the auroral ring in the southern polar regions (PIA06436). Images courtesy of NASA/JPL and the Cassini team.



Here are some general suggestions to help you see even more detail (and yes, filters, practice, and patience help out a lot!)…

- General tips – reference to "How to" books given in Appendix A, check these sources out for lots more detailed information; you can also go to the website http://www.alpo-astronomy.org for lots of information and advice (and links to even more resources to help you out).

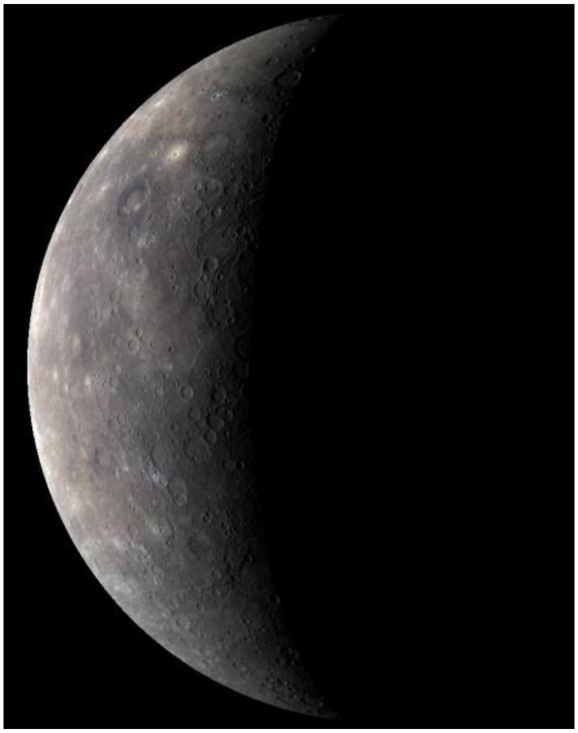
- Use 50X of power for every inch of telescope aperture.
- Do most planet-watching on nights of steady seeing (that is, when the air is still and offers the sharpest viewing, usually on summer evenings, but not restricted to this season).
- Use filters to help enhance contrast, and what filter(s) you use will depend on which planet you are looking at and what you are looking for.
- Spend time at the eyepiece: don't be in a hurry to check this off of your to-do list. In order to get the finest detail, an observer needs to train the eye-brain system (over time and through repeated sessions at the telescope) to see such detail.
- Practice and patience: keep a log or notebook of what you see; as you sketch something, you encourage the eye to look for finer and finer detail.
- Look for changes on various worlds (changes do happen "up there", or "out there", depending on your perspective…); here are some of these changes to look for (and they happen over all time spans, from moments to years):
    - Phases of Mercury and Venus,
    - Surface markings and how these change as the planet rotates-Mars,
    - Appearance and changes in the polar ice caps of Mars,
    - Atmospheric features and how these change as the planet rotates, and changes in the appearance and structures of belts and zones-Jupiter,
    - Galilean moons changing their configuration, eclipses, transits, occultations, mutual events-look for their disks, and
    - On multiyear scales, changes in the orientation of the rings of Saturn and how that changes the overall shape of the planet.

Venus

The Association of Lunar and Planetary Observers (ALPO) is leading a comprehensive research program to conduct systematic studies of the planet Venus with teams of observers. They provide observing forms and guidelines to follow to maximize the scientific value of the observations. ALPO offers 7 visual observing projects for Venus, and interested observers can go to www.alpo-astronomy.org and look for the Venus section, click on the link, and get the contact information of the section coordinator(s).

The planet displays, in addition to the phase cycle, "polar caps" and other subtle atmospheric shading that changes over time. The atmosphere circulates around the planet every four Earth days, and very subtle features may (or may not) vary over that time scale. Filters mentioned next may help to bring out some features. One interesting exercise would be to have several observers make simultaneous observations of the planet to gauge the intensity of atmospheric features on the planet. Different people have slightly different abilities to see into the ultraviolet and this has an effect on one's ability to see details in Venus's atmosphere.

Filters useful for observing Venus include the W (Wrätten) 38A (blue) and W47 (violet) filters. I have used the latter to help make out the subtle cloud details often seen on the planet when viewed at high power under the best seeing conditions. I have also used the W80A (light blue) filter to help bring out the "polar caps" of the near-half-lit (and often crescent) Venus. Other filters that observers have found useful include the red filters (W23A and W25), the yellow filters (W12 and W15), and the green filters (W57 and W58).



Mercury

Observations should be made according to the standard methods outlined by the planetary observational societies ALPO and BAA (British Astronomical Association). As part of the process, using society-issued observing forms, one makes estimates of disk feature intensities at the eyepiece, then completes the drawing and submits it to the section coordinator. One is urged to make any planetary sketch at the eyepiece or immediately afterwards so as to not distort the recorded information. For Mercury, a deep red or orange filter helps to bring out the contrast; the filters useful in this color range include the W 21, 23A, and 25. Observations should be done every three days at a minimum.

Figure 6-16 (above): Mercury in color as seen by the approaching MESSENGER spacecraft in early 2012. Image courtesy of NASA (Photojournal image #PIA12365). Figure 6-17 (below): Mars as seen near opposition with the Hubble Space Telescope. Image courtesy of NASA/ESA/STScI (Image PIA01592).

Mars

International Mars Watch projects are provided on the Mars Watch website http://elvis.rowan.edu/marswatch/, and these include visual projects. One suggestion provided here involves the use of color filters to enhance features, increase contrast and reduce glare. An eyepiece micrometer may be used to measure the sizes of polar caps and other features. Good optics, excellent collimation, clean eyepieces are all essential to get the most out of the observing experience.

The ALPO website http://www.alpo-astronomy.org/jbeish/Observing_Mars.html provides more information to maximize the value of your Mars observations. They suggest making detailed documentation of what you see, including drawings made on forms provided at the ALPO website. Also, look for the “violet clearing” using Wrätten 47 filters. One can use the W80A filter to look for clouds and hazes, and the W21, W23A, and W25 filters to enhance the albedo features.

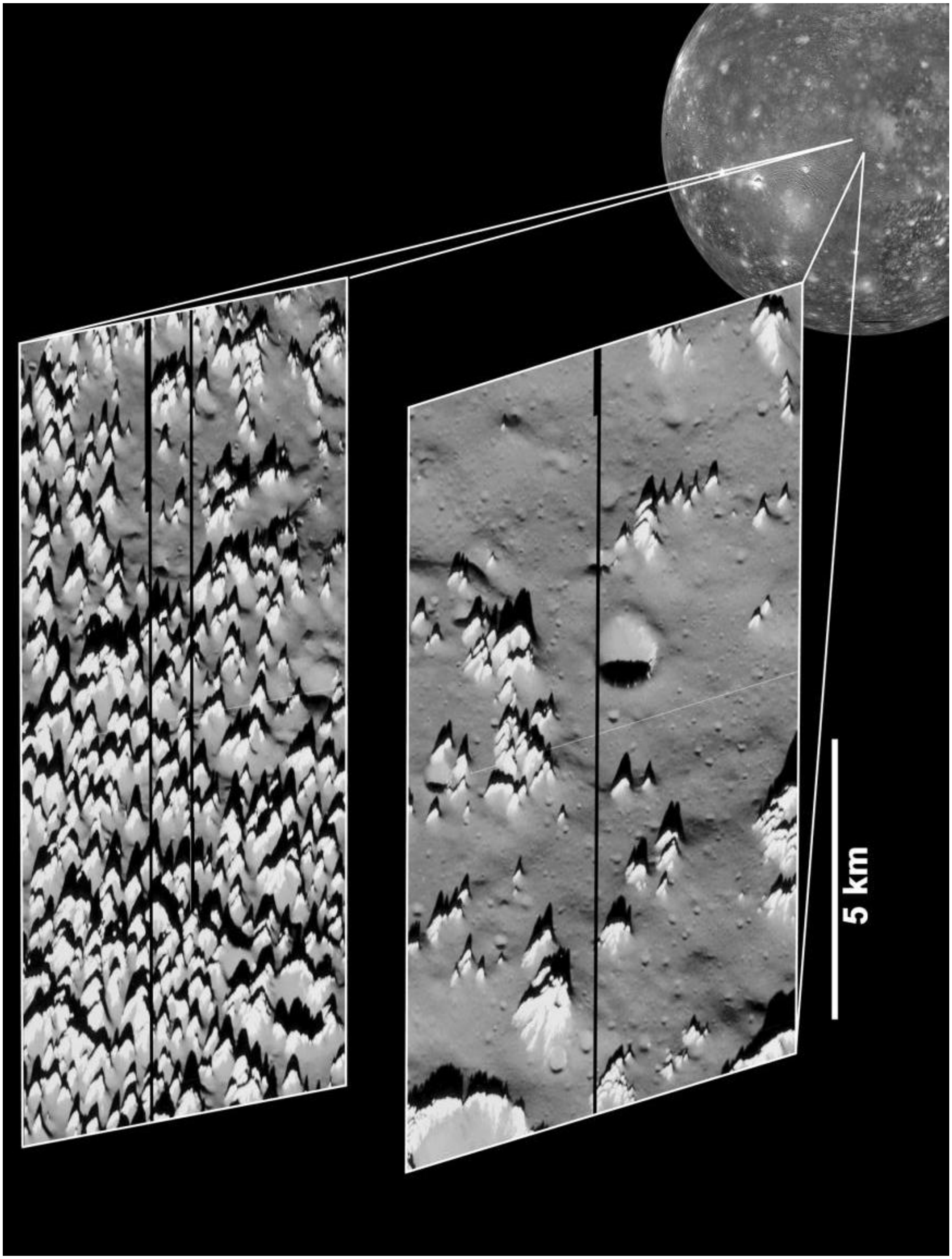


Figure 6-18: Closeup of another moon, the moon Callisto which orbits Jupiter, courtesy of NASA. Go to the NASA photojournal pages, http://photojournal.jpl.nasa.gov/ for more images of the moons of Jupiter, Saturn, and many other worlds, along with detailed descriptions of each image.

Jupiter

Jupiter provides a wealth of detail, second only to the Earth's moon (perhaps third after the active Sun), to an astronomer with a larger instrument and excellent seeing conditions. Visual projects that are described in more detail at the afore-mentioned ALPO website include the following:

- Cloud features, cloud morphologies, and changes with filter color
- Intensity estimates of atmospheric features (usually done unfiltered)
- Central Meridian crossing times of features
- Timings of eclipses of Galilean satellites
    - These are made to 1 second precision
    - Time the instant that the last "speck" vanishes for a disappearance or when the first "speck" appears for a reappearance
    - Note that published predictions are made for the time midway between first/last contact and total immersion
- Meteoroid impact sites during and after the initial fireball event

Jupiter has been the scene for fascinating large-scale atmospheric changes over the years, to include the complete disappearance of one of the two prominent equatorial belts. The belt does come back eventually and it follows a sequence of events as it does so. Other things to keep watch include the width and darkness of each of the major and minor belts of the planet, the size and prominence of the Great Red Spot, comparing the north and south polar regions to each other to determine which appears darker, and (if you have a large enough aperture) note the colors of different regions and features as seen with the unfiltered eye at moderate powers.

Additional useful observations of Jupiter or any other planet can be made when the planet is very low in the dawn at the beginning of one apparition, as well as very low in the dusk at the end of the apparition. When the planet is this low, astro-imagers typically shy away from imaging due to the bad seeing encountered and the challenge of shooting a target that is quite low on the horizon. By watching the planet for as long as possible, one can extend the arc of apparition to a greater extent and obtain extended coverage and information about the planet.

Saturn

Visual numerical relative intensity estimates of belts, zones, and ring components are some of the primary observations that visual astronomers can make. These are included with drawings of global and ring phenomena. Central meridian crossing timings are made of any feature that appears, such as the storms that appear from time to time (one such storm appeared in 2011, another in the fall of 1990, both of these were visible through modest sized ground-based instruments). Color estimates of ring and globe features are accepted, as well as ring features, intensity minima, and any bi-colored aspects of the rings.

Other applications include stellar occultations of stars by Saturn's rings, and visual observations / magnitude estimates of the satellites of Saturn. When the rings become edge-on every 15 years, special observations during and near the ring-plane crossing are usually requested. More information about the many useful observations that can be made is found on the ALPO Saturn section webpage.

Remote Planets

Some applications for the remote planets include magnitude and color estimates and any atmospheric features / satellites that may be visible on / at Uranus or Neptune. Visual magnitude estimates are also welcome; to be able to do these, one should contact ALPO and the remote planets coordinator to get a copy of the annual remote planets newsletter which provides the information needed to find the planets and the comparison stars with which one can make magnitude estimates.

The rare stellar occultation by the planet or one of its satellites is also worthy of pursuit but these usually necessitate large apertures and/or dark skies. Uranus and Neptune offer most of the opportunities, whereas Pluto is much more limiting, being little more than a faint starlike object in the largest instruments.

The figures below show the planets Uranus and Neptune from various vantage points, and in true and false colors. Particularly interesting are the various cloud formations at Neptune and a crescent Uranus (something we never get to see from Earth). One of the views of Uranus and one of Neptune are printed so that the colors are what our eyes would see if we were riding along with the space craft.

Figure 6-19. Uranus from Voyager 2 in 1986, as it would appear to the eye of an observer riding along with the spacecraft. This is half of image PIA00032 courtesy of NASA/Photojournal

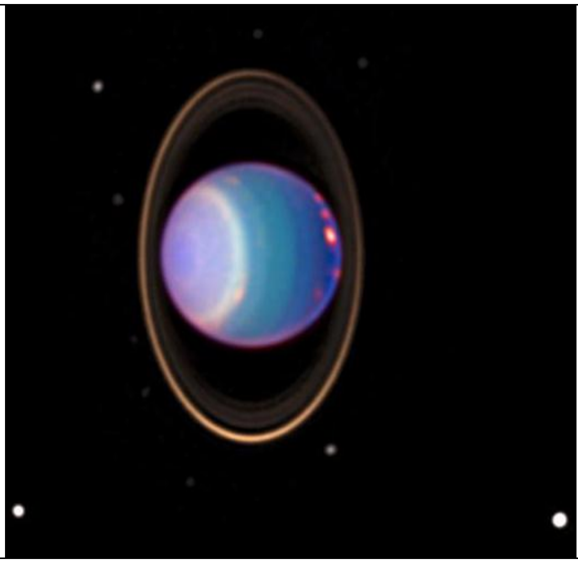
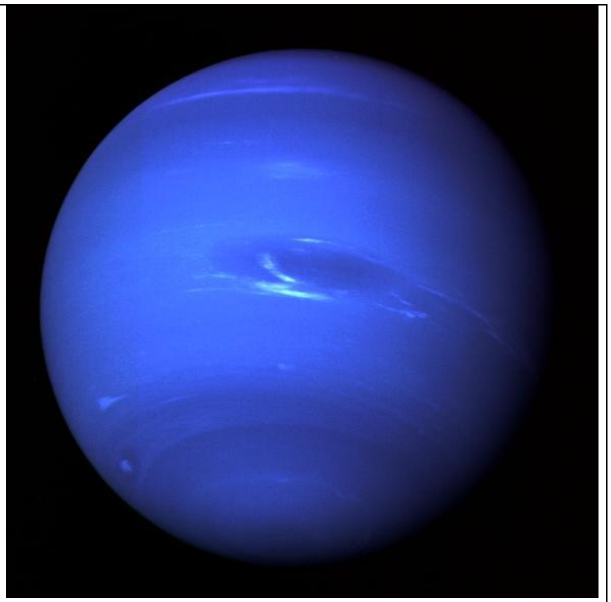
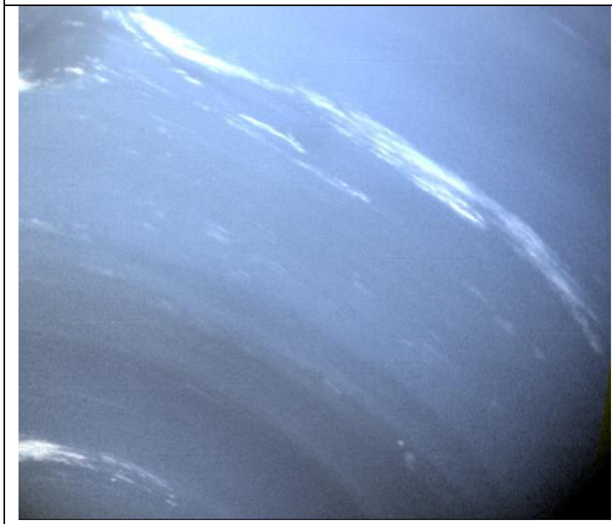
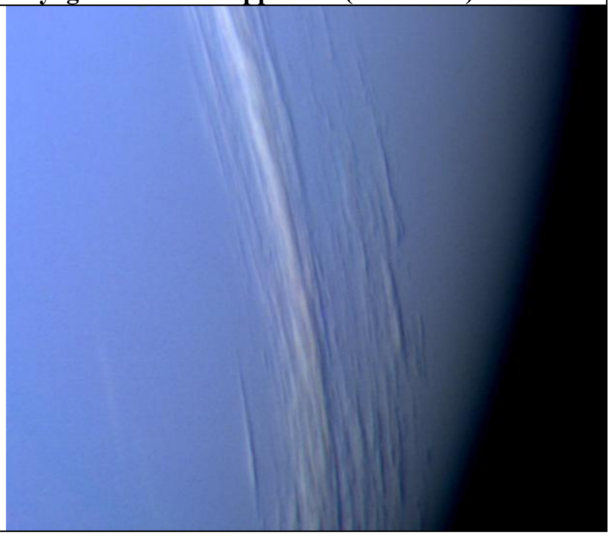


Figure 6-20. False color, multi-wavelength composite showing Uranus, its rings, and major satellites, taken with HST on August 8, 1998 (Courtesy of NASA/JPL/STScI, Image # PIA02963)



Each of these images comes courtesy of NASA and the Photojournal pages. Figure 6-21 (upper left): Crescent Uranus from a departing Voyager 2 (PIA00143). Figure 6-22 (immediately above): full-disk Neptune from Voyager 2 (PIA01492). Figure 6-23 (lower left): true color view of Neptune's clouds (PIA00063). Figure 6-24 (immediately below): close-up view of cirrus-like clouds in Neptune's atmosphere seen two hours before Voyager 2's closest approach (PIA00058).





Chapter 7 – the Sun

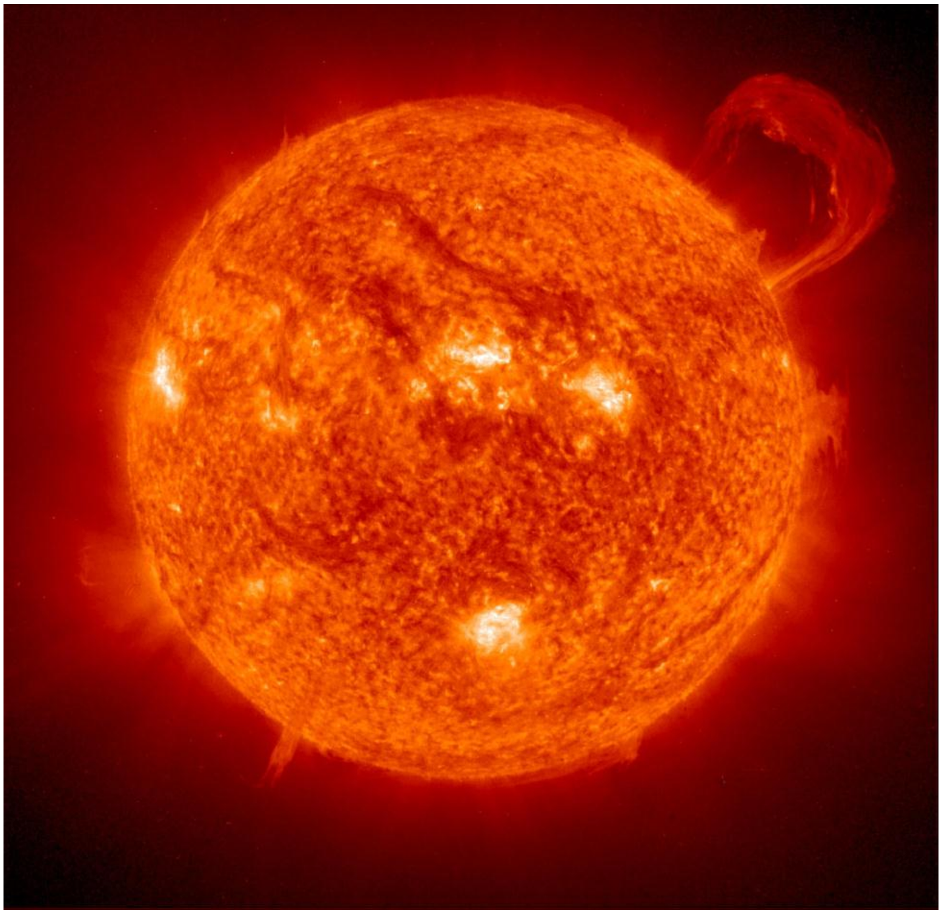


Figure 7-1: the Sun (Courtesy NASA Photojournal #PIA03149)

Appreciation

The only star within the Solar System, the Sun (Figure 7-1, taken in the extreme ultraviolet but colored orange to make it look familiar) makes up nearly all of the mass of the local planetary family and serves as its gravitational anchoring point. It gives light and warmth by day and shields the Earth by night (and by day…) from deadly cosmic rays. It can provide a wealth of detail to the protected telescope (depending on where in its sunspot/activity cycle it is).

The Sun is a star by definition meaning that it gets its power to shine by fusing hydrogen nuclei into helium nuclei in its core, a process called fusion which releases lots of energy. This energy, initially in the form of neutrinos and gamma rays, works its way from the core to the “surface” (the neutrinos are nearly massless particles that hardly interact with matter so they escape the Sun quickly) and is radiated into space in all directions. This is the manner by which all true stars are thought to shine. The main difference between the Sun and true stars is that the sun is much closer than even the nearest star. To get a sense as to how much closer the sun is, consider this: light travel time (already mentioned). Light takes only 8.3 minutes, at 186,283 miles per second (or almost 300,000 km per second) to travel interplanetary space to Earth's orbit. Light traveling at the same velocity takes 4.3 years to get from the nearest star (proxima Centauri) to Earth. So consider how long (or how short) 8 minutes is compared to 4 years, and you get a sense as to how much farther away the stars are than the Sun. And the stars seen in the night sky are all tens, hundreds, even thousands of light years away.

We are fortunate enough to orbit a very stable star, one that does not vary so drastically in light and heat output. This makes life possible on planet Earth. There are stars in the galaxy that vary by factors of millions (variable stars), and other stars that seem to be just like the Sun, but they explode forth powerful, atmosphere stripping "super flares". The Sun does vary in terms of its activity, which is most easily seen in the numbers of dark spots visible on its disk. These are the most obvious features that are seen through a properly filtered telescope.

Sunspots are fascinating creatures. These are "works of magnetic art on a canvas of fire" and come in a variety of shapes and sizes. One of the most common and widely accepted schemes used to classify sunspots is the Macintosh scheme which makes use of the old Zurich scheme and adds to this. There are seven broad categories of spots:

- A: Unipolar group without penumbra which marks the star or end of a spot group's life
- B: Bipolar group with penumbra on at least one of the member spots
- C: Bipolar group with penumbra on one end of the group; this usually surrounds the largest of the leader umbrae.
- D: Bipolar group with penumbrae on spots at both ends of group, the length (longitudinal extent) is less than 10 arc seconds (120,000 km or 72,000 miles)
- E: Bipolar group with penumbrae on spots at both ends of group, the length (in the longitude dimension) now extends between 10 and 15 arc seconds (120,000 and 180,000 km or 72,000 and 108,000 miles)
- F: Bipolar group with penumbrae on spots at both ends of group, the length exceeds 15 arc seconds (180,000 km or 108,000 miles)
- H: Unipolar group with penumbra. Principal spot is usually the remnant leader spot of pre-existing bipolar groups

Source: http://logic.mimuw.edu.pl/publikacje/iis04_son.pdf

Sunspots are concentrations of powerful magnetic fields. A magnetic field is a field of influence exerted by a magnetic substance whether it is a solid metal magnet (like what is on your refrigerator) or plasma (very hot gas) with an electric charge moving around. The Sun is like a huge magnet with a very complicated field, and this field changes polarity (the location of the north and south magnetic poles). Some of this field makes its way through the solar "surface" (the level of the solar atmosphere that becomes opaque to deeper layers) and emerges, and in so doing it interferes with some of the convection and causes a net cooling. A cooler surface gives off less light and heat, hence the spots give off less light and heat so they appear darker in contrast to the surrounding surface.

Although a good 93 million miles distant, the Sun appears as a round disk in the sky. The Sun is so large (109x across as the Earth) that the entire Earth / Moon system can fit inside with room to spare. Visually it has a slightly yellow appearance when it is high in the sky, but appears white in color from space. Its light is a mixture of all the colors of the rainbow, and as the light enters the Earth's atmosphere, some of it gets redirected or scattered, which leads to the blue color of the sky.

Application

Safety First!

Of all the celestial objects the Sun is the most dangerous to observe but it does not need to be so. Here are some useful tips on how to safely observe the Sun and enjoy its beautiful details:

- Projection – using a pinhole device, a pair of binoculars (with one side capped) or a telescope.
- Welder's glass of at least number 14, but number 17 is recommended
- Over the aperture filters approved and designed for that purpose
- Specially designed solar telescopes such as the Coronado Personal Solar Telescope

Once a safe setup for solar viewing is secured, one can not only enjoy the ever-changing face of the Sun but also contribute to the science of solar physics. The primary contribution one can make to the study of solar physics is that of sunspot counts. From over 100 observers (amateur and professional) on six continents, the American Relative Sunspot Number (R_A) is computed. More information about this process, and how you can get involved (including observing tutorials), is posted at www.aavso.org/observing/programs/solar/.

Resources to Get More Involved

Some sources for more guidelines for solar observing:
Guidelines for the Observation of Monochromatic Solar Phenomena, edited by Jamey Jenkens, originally compiled by Randy Tatum. This serves as a handbook of the Association of Lunar and Planetary Observers solar section. This work, among other things, suggests using refracting telescopes for monochromatic work, and shielding your eye from outside stray light.

Guidelines for the Observation of White Light Solar Phenomena by Jamey Jenkins, originally compiled by Rik Hill lists a number of projects that can be performed including the following:

- Sunspot Numbers
- Sunspot group Classification (using the Zurich Classification Scheme)

- White Light Solar Flare Patrol
- Active Region / Sunspot group drawing
- Whole disk drawing

From the above sources, what follows is information on general solar observing. First, use a safe solar filter, an over-the-aperture kind that will block all the harmful rays while letting in the visual light, reduced to a comfortable level. Note well that they make filters for photographic use which may not necessarily be safe for visual use. Also, never use the type of filter that screws into the eyepiece (except to place it over the eye-WHILE YOU LOOK DOWN-then move your head and shielded eye up to meet the sun, for naked eye use only) as these can crack during use, letting intense, harmful radiation through.

Be sure to protect your equipment from too much sun exposure. Cap your finderscopes (or remove them). If projection techniques are used, set the focus of the image well outside direct visual range, then bring it back to focus. Use an aperture between 50mm and 80mm; if your scope is larger than this, stop down the aperture to this range. Observe the sun at several magnifications, go to higher power if the seeing allows. Observe the Sun each day at the same time and be familiar with its layout and diurnal motions, so as to maximize the benefit of your observation.

Learn the Zurich and MacIntosh classification schemes-use the evolution of the groups to achieve an accurate sunspot estimate. Look closely at the solar limb (as spots are more difficult to see here) and then make several passages at counting groups and spots to take advantage of sudden improvements in seeing. Finally, send your observations to the AAVSO Solar Division in a timely manner.

Use a variety of magnifications and, if possible, instruments to get a view of the Sun from different perspectives. Start with a full disk view and bump up the power in steps; if the seeing is favorable you can go to very high magnifications and look for the finer details in spots. If you choose to do sunspot counts for the AAVSO, be sure to, as far as it is possible; make your observations at the same magnification near the same time each day. I prefer morning because the seeing is generally better and the observation is secured before I get too involved in the business of the day (which could lead to my forgetting to make the daily observation, something I have done on a few occasions).

Happy Sunspotting!

Chapter 8 – Minor Components of the Solar System

Introduction and Census

As I write this part, on 14 June 2012, an asteroid is about to make a "close approach" to the Earth. Dubbed 2012LZ1, this newly discovered asteroid, about the size of a city block, or estimated to be about 500 meters (1,500 feet) across, is to make its closest approach at 23:10UT (less than four hours from now…) at a "safe" distance of 14 times the Earth-Moon Distance (3.3 million miles or 0.036AU). Because of its size and distance, it has been added to the list of 1,320 potentially hazardous asteroids (the number is effective 3 July 2012).

As of now, we have the following orbiting the Sun (that we know of…) –

- 8 major planets, 4 ring systems (made up of billions of particles each)
- 173 planetary satellites (as of May 2012) distributed as follows: Earth 1, Mars 2, Jupiter 67, Saturn 62, Uranus 27, Neptune 13. Among the dwarf planets, Pluto has 5, Eris 1, and Haumea 2. (NOTE: the locations of 11 Jovian and 7 Saturnian moonlets are known so poorly that they are basically lost)
- 5 dwarf planets
- Minor components of the solar system: inner/mid solar system asteroids
    - 17 Atiras (their entire orbits are within Earth's, subclass of Atens)
    - 700 Atens (near Earth asteroids with semi-major axes less than one)
    - 4266 Apollos (semi-major axis > 1AU, perihelion >1.017AU)
    - 3495 Amors (approach Earth from behind but do not cross its orbit)
    - 11,215 Hungarias (orbit between 1.78 and 2.00AU)
    - 8,452 Mars-Crossers (Cross Mars's orbit but with perihelion > 1.30AU) There are two Mars Trojans in this batch.
    - 559,354 Main-Belt Asteroids (located roughly between orbits of Mars and Jupiter)
    - There are a total of 587,482 asteroids in the inner and mid solar system, but there could exist between 1.2 and 1.9 million objects larger than 0.6 miles (1.0 km).
- Minor components of the solar system: mid/outer solar system objects
    - 3,760 Hildas (dynamic group in a 3:2 orbit resonance with Jupiter)
    - 5,416 Jupiter Trojans (Co-orbit with Jupiter, hanging out at 60^0 ahead and behind the planet in its orbit)
    - 431 Centaurs/scattered disk (objects that are a mix of ice and rock in unstable orbits in the outer solar system; could be as many as 44,000 that are 1km or larger)
    - 243 Plutinos (Trans-Neptunian object in a 2:3 orbit resonance with Neptune)
    - 892 Classical Trans-Neptunian Objects (Orbit beyond Neptune and is not controlled by any orbital resonances with Neptune)
    - 36 Other Trans-Neptunian Objects
- Source: http://www.minorplanetcenter.net/, they list 609 comets

- 262 numbered periodic comets, 259 unnumbered are listed on Wikipedia's comet pages; 42 non-periodic comets after 1910, 41 from 1106 to 1910 (including one from 44 BC), total of 604 comets.
- There could be up to 10 million asteroids and billions of comets in the local solar system, not to mention the pebbles, stones, and dust that occupy interplanetary space.

Solar system objects present their own challenges for observers of faint objects. The vast majority of the components of the solar system are invisible to all but those that have the largest scopes, most detailed star charts, and best orbital predictions. But these do provide that level of satisfaction of, like deep sky faint fuzzies, having seen an object that not very many people have laid eyes upon. We start by describing, briefly, the physical nature of these objects and where they fit in the grand scheme of faint objects.

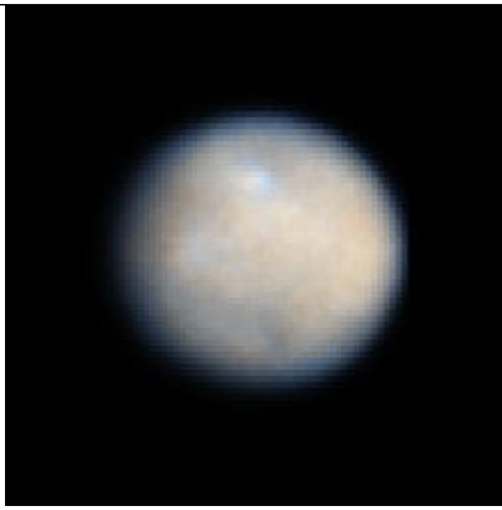
The material presented herein is only a broad overview of the types of objects considered; more information about these can be found in other works that are written specifically about these objects (e.g. "Asteroids and How to Observe Them"). This is generally true for all of the object types presented in this book: the purpose is to "whet the appetite" of the budding observer and motivate him/her to look deeper into the hobby and science of astronomy, to include making use of some of the resources that I provide throughout the book and in the appendices at the end.

Asteroids

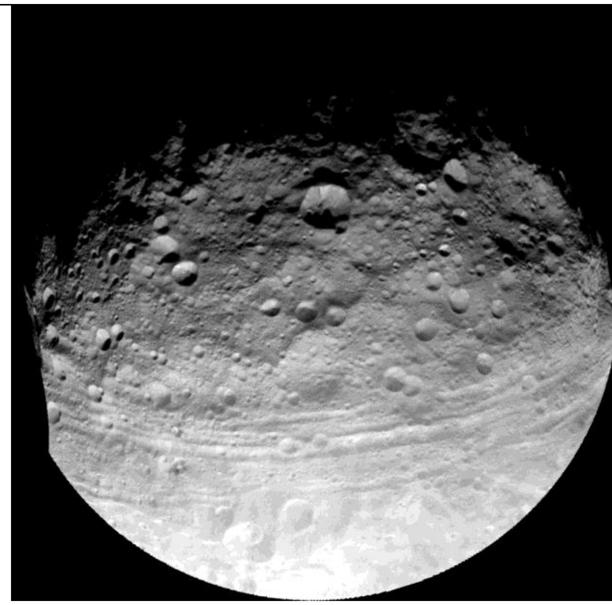
Appreciation

Between the orbits of Mars and Jupiter lie the asteroids. The main asteroid belt is home to over a million known asteroids. The largest of these is the former asteroid, now dwarf planet Ceres, easily visible to those with small telescopes and finder charts. At least a couple dozen of the largest and brightest asteroids are routinely visible through backyard telescopes, including Pallas, Vesta, Juno, and Astraea, which round out the first five discovered asteroids. These objects are as individual and as unique as the major planets, and two of them (Ceres and Vesta) are due to receive visitors in the form of the DAWN spacecraft, on course to rendezvous with Ceres in the summer of 2015. Ceres is thought to have ice deposits on its cratered surface, and Vesta (Figures 8-1) shows signs of volcanic activity in its past, something totally unexpected for an object its size.

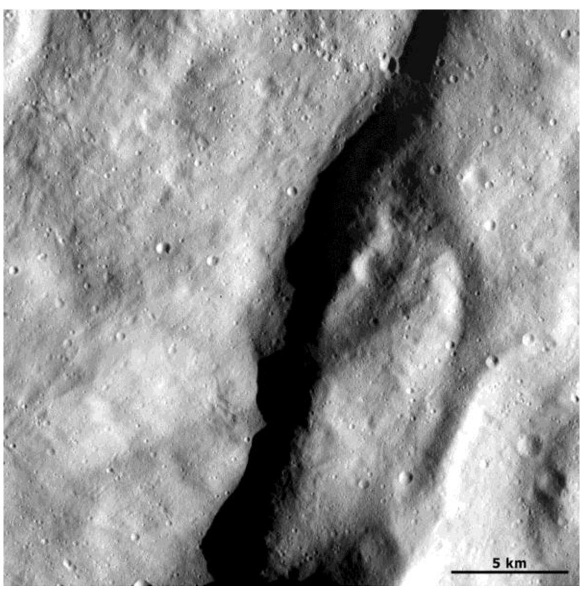
There are a number of interesting asteroids in the asteroid belt (examples are shown Figures 8-2 through 8-7), ten of which have been visited by spacecraft and imaged up close. The ones visited by spacecraft show heavily cratered, Moon-like surfaces, complete with boulders, mountains, and other interesting geological features. 25143 Itokawa, the asteroid visited by the Japanese Hayabusa spacecraft, shows a crater-free surface covered in boulders. It is likely this is a recent "chip-off-the-old-block" type asteroid which was produced as a piece of debris from a collision during the recent past. Collisions are common in the Asteroid Belt and are thought to be the origins of most of the meteorites recovered on the Earth's surface.

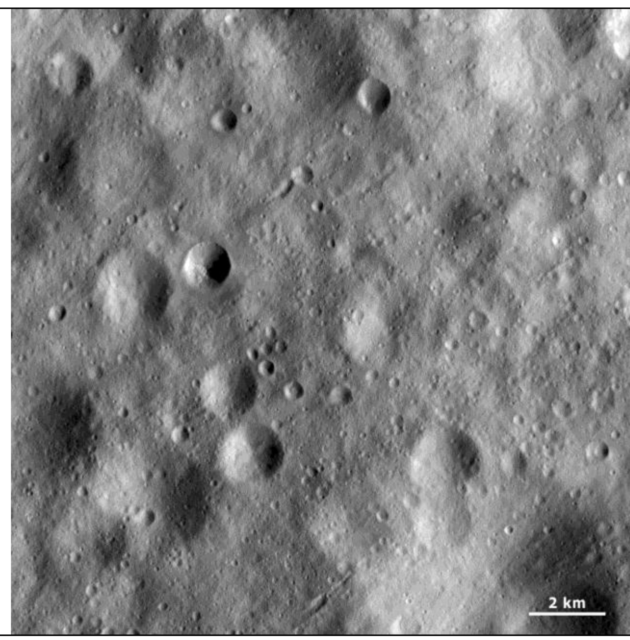


Figures 8-1a,b,c,d: Vesta from different distances, (a, above) a distant, color image (PIA10235) obtained by HST; (b, right top) fulldisk Vesta as imaged by DAWN (PIA14894); (c and d, left and right below) close-up of Vesta's surface showing a variety of features.



Each of these four images is courtesy of NASA Photojournal.





Asteroids are not always so well-behaved, as many stray from the main belt and cross the planets' orbits. Asteroids that cross Mars's orbit but not the Earth's are known as the Amors. Asteroids that cross the Earth's orbit are known as Apollos, and those that cross Venus's orbit are the Atens. Trojan asteroids share the orbit of Jupiter, with a group centered 60 degrees ahead of Jupiter in its orbit and a smaller group centered 60 degrees behind Jupiter's position in its orbit. Trojan-like asteroids are found accompanying Mars (5261 Eureka, 1998 VF31, 1999 UJ7, and 2007 NS2), and

Neptune (seven known). The physical makeup of asteroids (e.g. stony, stony-iron, metallic, carbonaceous, etc.) provides another classification scheme.

Asteroids range in size from 975 km diameter down to tens of meters across. The three largest are 1 Ceres, 2 Pallas, and 4 Vesta, all of which are larger than 500 km. There are a total of 5 known main belt asteroids larger than 300km, and 30 larger than 200km across.

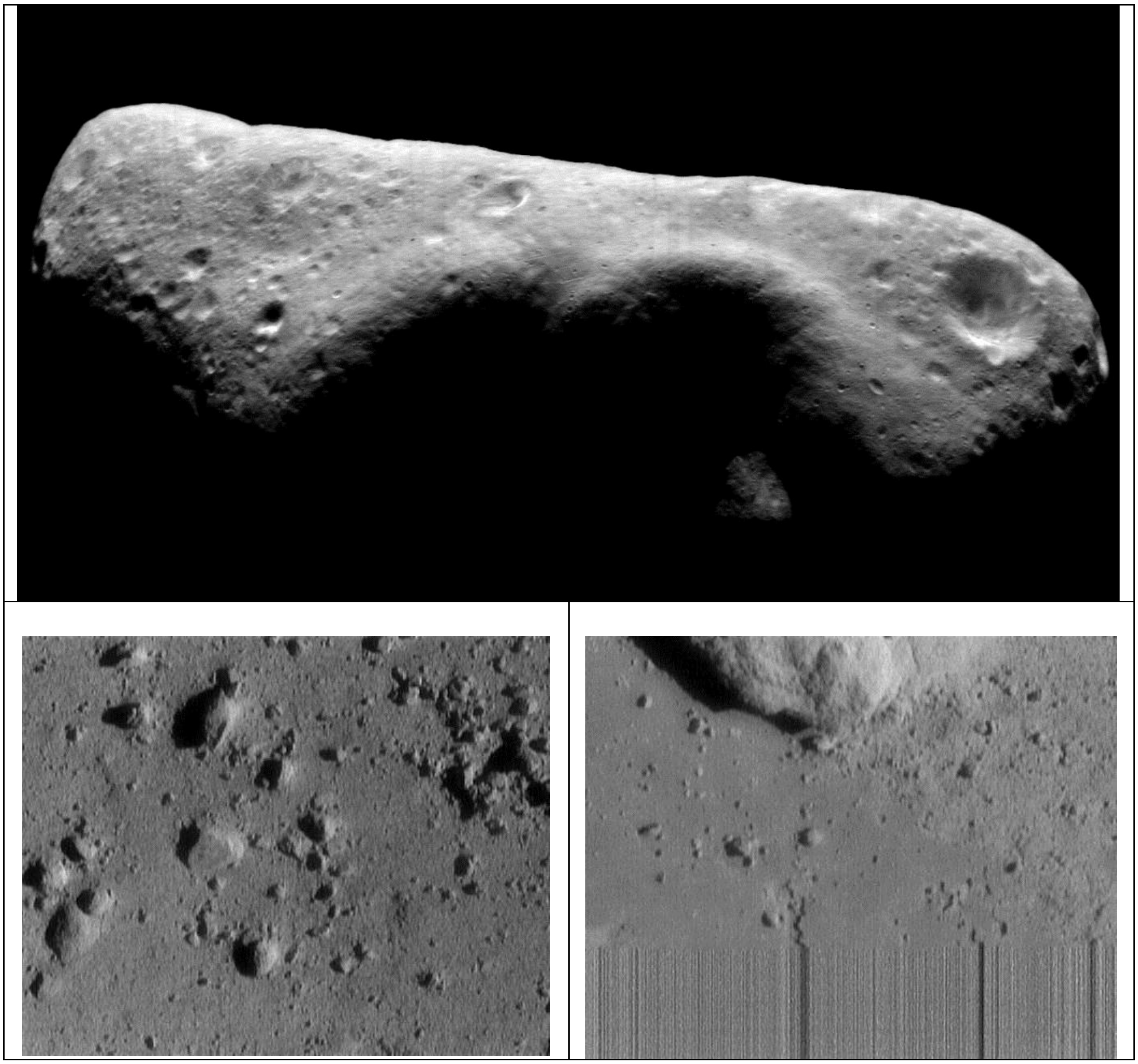


Figure 8-2a – c: Images of the asteroid Eros from the NEAR/Shoemaker satellite. The top image (PIA03141) shows the entire spacecraft facing side of the asteroid. The images immediately above are two shots of the surface from the descending spacecraft (Images PIA03147 and PIA03148). Images courtesy of NASA/JHUAPL.

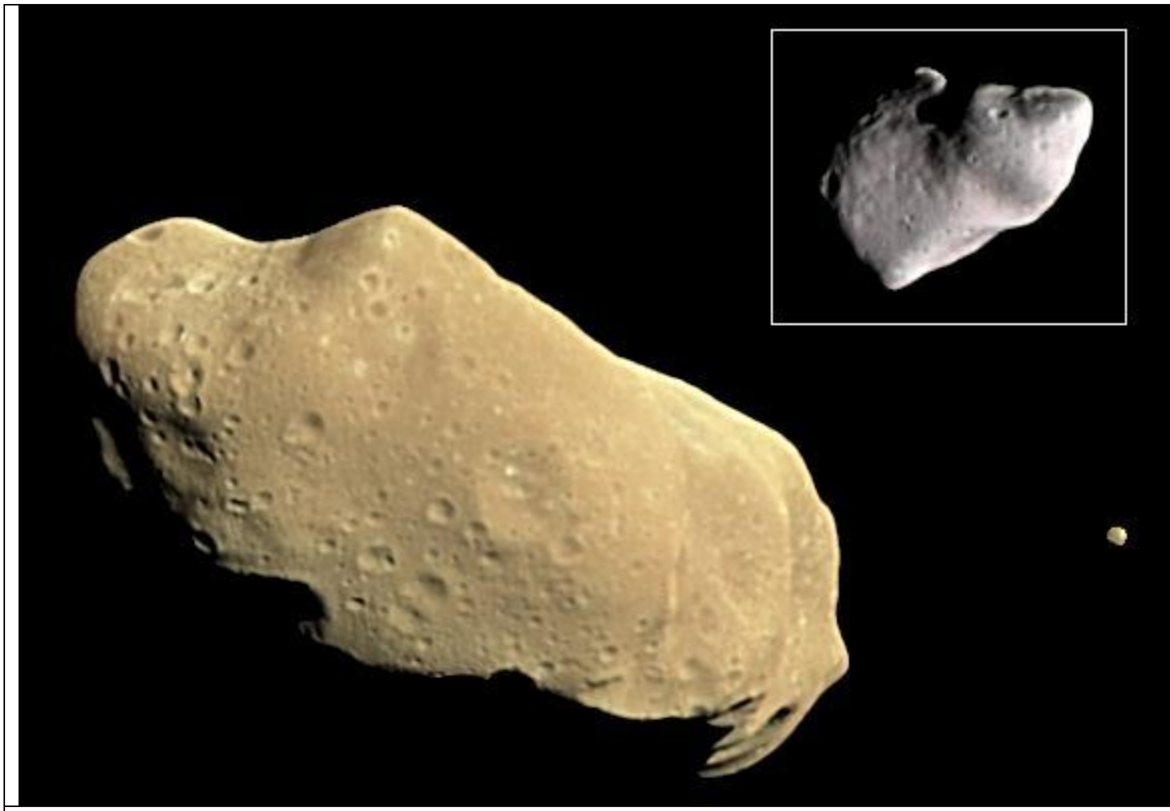


Figure 8-3 (above): Ida (large object) and Dactyl (small object near right edge) along with Gaspra (inset) printed at the same scale. Image (PIA00333) courtesy of NASA/JPL/USGS. Figure 8-4 (below): Near Earth asteroid 2005 YU55 as imaged by radar (PIA15019); image courtesy of NASA/JPL-Caltech.

As we have seen with spacecraft images, asteroids are not all alike. Each is a world in its own right, complete with craters, rocks, interesting geological feature, etc.; no two are exactly alike. When we look at main belt asteroids up close (e.g. Vesta, Eros), they seem to have a similar surface texture and appearance (up close) as the Earth's Moon. So far we have directly imaged, at high resolution, the asteroids Gaspra, Ida / Dactyl, Mathilda, Eros, Itakawa, and Vesta; at low resolution we have seen: Ceres, Pallas, Steins, Annefrank.

Application

We have several things that you can do to observe asteroids in a meaningful way. Magazines such as Sky and Telescope and Astronomy typically feature one or two each month, complete with the object's track against the more distant stars. There are other sources of information online, including the Minor Planet Center that provides ephemerides (tables listing the celestial coordinates and other parameters of objects).

One of my favorite things to do with asteroids are occultations, which mean one object covering up another for a short time. This is the supreme master alignment in the Universe: your telescope / eyeball or camera, the asteroid itself, and the distant star it blocks (which can be tens of thousands of light years away). I have seen many positive events where the star seems to vanish abruptly, then reappear seconds later. For that to happen, the alignment must be perfect. Most events happen to stars that are too dim to be seen naked eye, so a telescope and a finder chart and at least some knowledge of star hopping and GOTO technology is needed to successfully get the field.

The website www.asteroidoccultation.com (from the International Occultation Timing Association or IOTA) has a wealth of resources to get you started including a link to their manual on how to do observations successfully. They also provide information on upcoming events and links to download some free software to help you not only plan your own observations but coordinate your plans with others for maximum impact.

Occultations are not limited to asteroids. The moon regularly covers up stars and IOTA seeks observations of these as well. Of particular interest are the grazing observations. I had the privilege of witnessing a dozen disappearances and reappearances of a star in Aries by the waning crescent Moon from near Hockley Texas in June 2007. This happened when the moon grazed the star, allowing Earth-bound observers in a narrow track to witness the repeated blocking of the star's light by several lunar mountains.

Other types of occultations include: planets covering stars; satellites going behind host planets; the Moon covering up planets; and mutual satellite events for Jupiter, Saturn, Uranus—this happens when one satellite ducks behind another (and this can include eclipses and occultations). Mutual satellite events occur whenever the Earth passes through the equatorial plane of the outer planet, which happens every six years for Jupiter, every fifteen years for Saturn and every 42 years for Uranus.

Near Earth Objects: see 'em move in real time (e.g. 2002 NY40), and these come along every few years or so. Go to www.spaceweather.com regularly to stay informed of such close passages of the Earth by these small space rocks. On a more leisurely note, one can also see a main belt asteroid move and confirm its existence by watching the field containing the asteroid on 3 consecutive nights, looking for the object that moved. It may not be in "real time" but at least it will provide a positive identification of the objects.

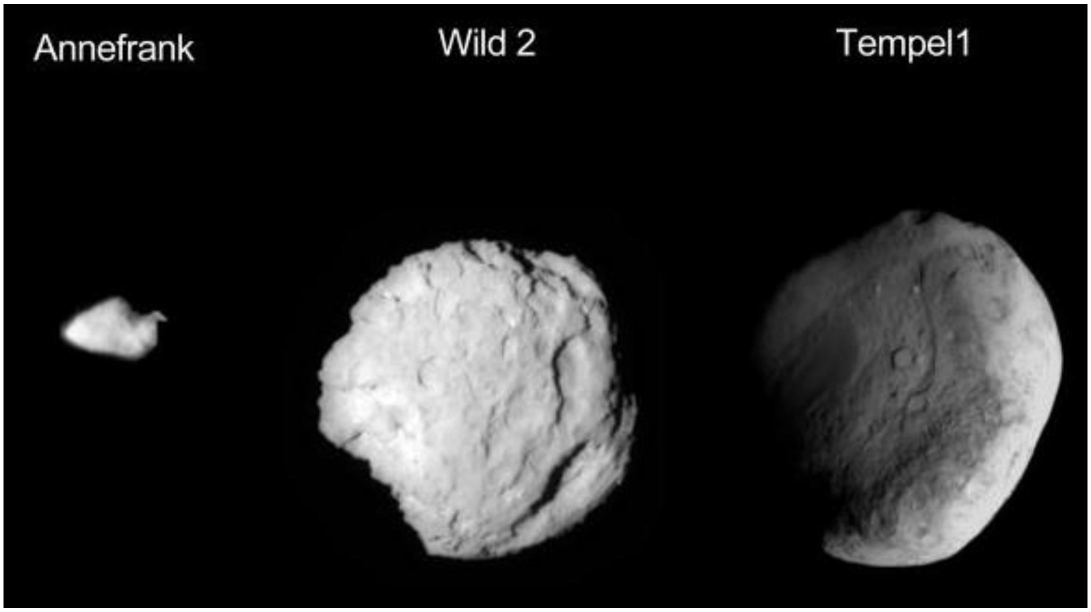


Figure 8-4. Three objects drawn to scale to compare their sizes: the asteroid Annefrank, and the nuclei of Comets Wild 2 and Tempel 1. Image (PIA13943) courtesy of NASA/JPL-Caltech/University of Maryland/Cornell.

Comets

Appreciation

Comets are truly amazing. The typical comet looks like a small, faint fuzz patch through a telescope, but consider what is going on at the location of the comet as you watch. What you see is a cloud of vaporized gases and dust that come from a small solid component called the nucleus. This nucleus is made up of a mixture of rocks, dust, and ices. Sunlight heats this nucleus and causes the gas to vaporize, carrying any dust present along with it. The solid part is small, only hundreds of meters (feet) to a few km (miles) across, but the cloud of material can be larger than the planet Jupiter. The material making up the cloud, or coma, tends to congregate closer to the nucleus, forming what is observed as the central condensation, which thins as you go outward.

Occasionally, a comet becomes bright enough to be seen with binoculars or even the naked eye, although most need a telescope (usually a large one) and dark skies to be seen. No two comets are exactly the same: on a certain dark night, I surveyed a half-dozen comets at the Dark Site Observatory near Columbus, Texas, and found that each looked different. The following are descriptors of the comets I saw through the 14-inch Cassegrain:

- Small and brighter
- Small and fainter
- Large and faint
- Large, faint, and condensed
- Moderately bright and “spheroidal”
- Moderately faint and featureless

It is best to view a comet (with the possible exception of the brightest ones) with a large aperture under dark skies. To see the tails of bright comets, a low power, wide field view under a dark sky is essential for a pleasing view. Your view of a given comet may not match what is seen on the images, but it is special to ponder what is going on at the comet as you watch it unfold.

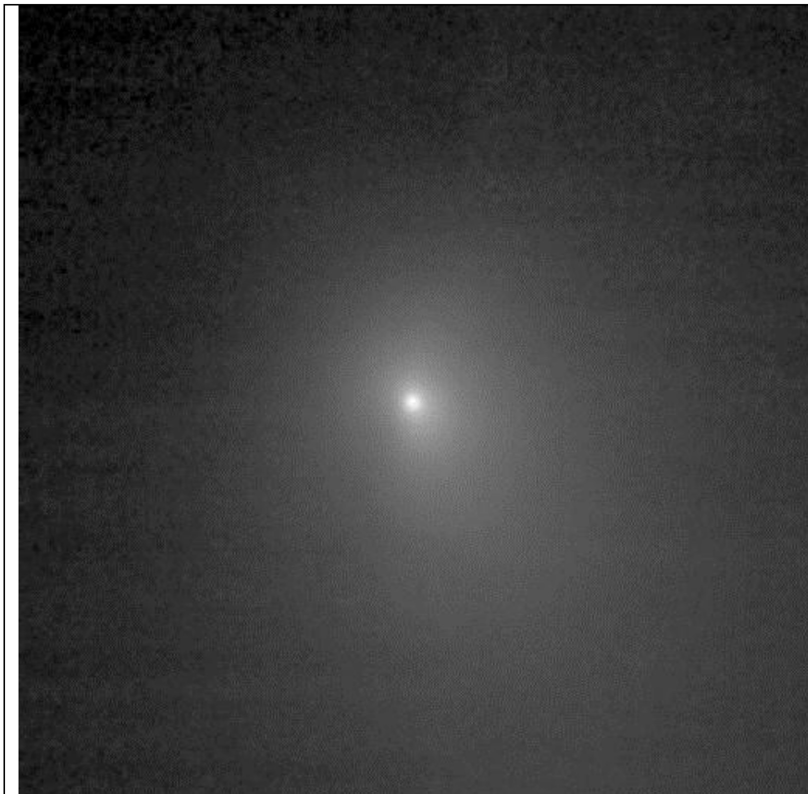


Figure 8-5: This images looks much like a bright comet as seen through a ground-based telescope, but in reality it is comet Tempel 1 just days before the Deep Impact encounter. One can notice subtle hints of jets pointing toward the 12:30 position and near the 6:00 position. This image (PIA02101) comes courtesy of NASA/JPL-Caltech/UMD.

Figure 8-6: Hidden deep within the bright central condensation is the nucleus (also seen in its entirety in Figure 8-4) which is a solid body, a world of its own complete with craters, crevices, mountains, rocks, etc. This view was taken by Deep Impact moments before impacting the surface shown here. Image (PIA02129) is credited to NASA/JPL-Caltech/UMD.

A comet making a relatively close approach to Earth is a most interesting sight to behold. First of all, to watch it over time as it “grows” and brightens, passes near, then recedes back into the depths of space gives a nice sequence or “story” on this comet’s behavior. The best views are usually near closest approach at which time (especially if it is an especially close one) we are getting a rare, close-up look that reveals detail not seen at more “average” distances. An especially notable case was C/1996 B1 Hyakutake where one was able to see its motion in seconds (my experience described here…). This produces a distant glimpse of what a spacecraft “sees” as it begins to approach a comet.

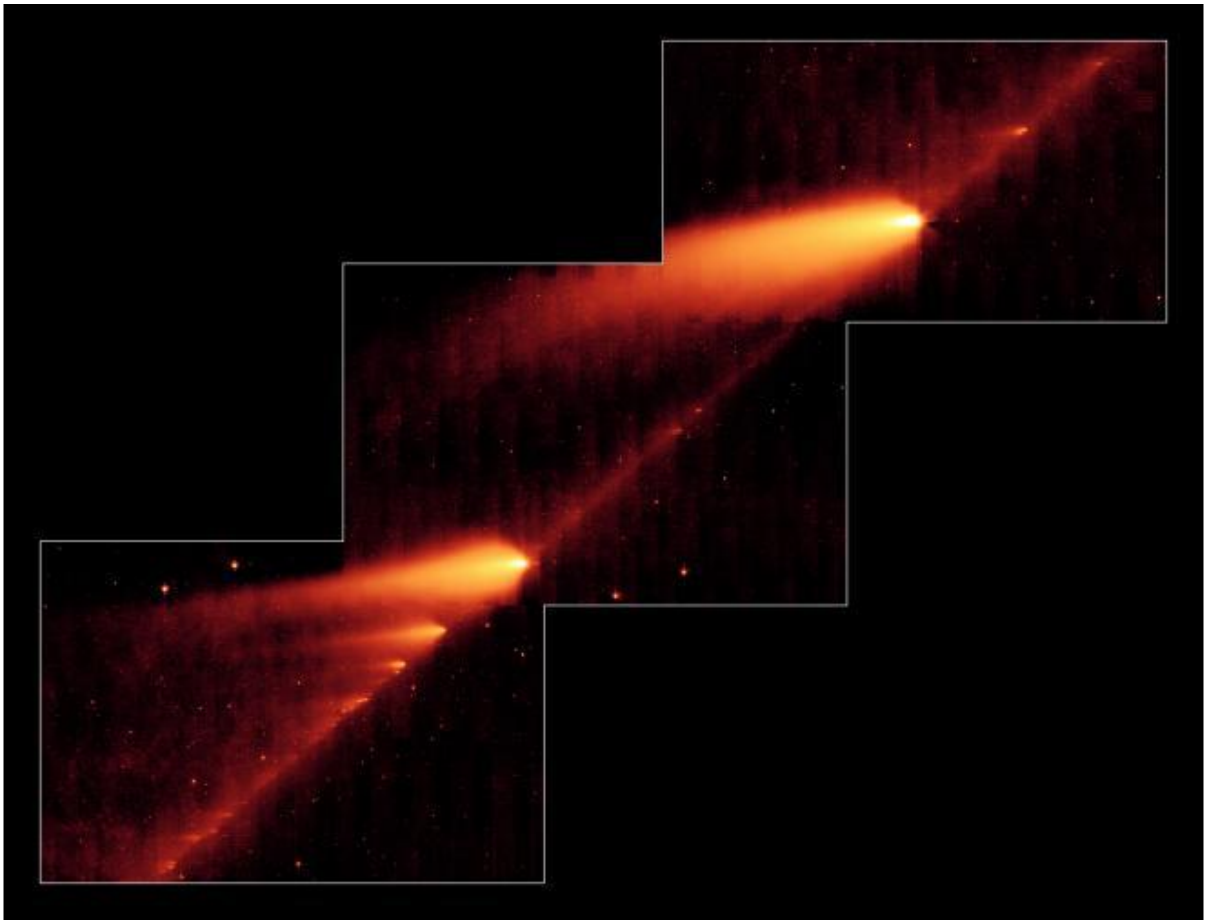


Figure 8-7: This image from Spitzer Space Telescope (image PIA 08452 from the NASA/JPL photojournal) shows the trail of fragments, dust, and comets that make up the unusual object 73P/ Schwassman-Wachmann 3, a comet which began to break up in 1995 and shows to be well along in the process by May 2006. The image credit goes to NASA/JPL-Caltech.

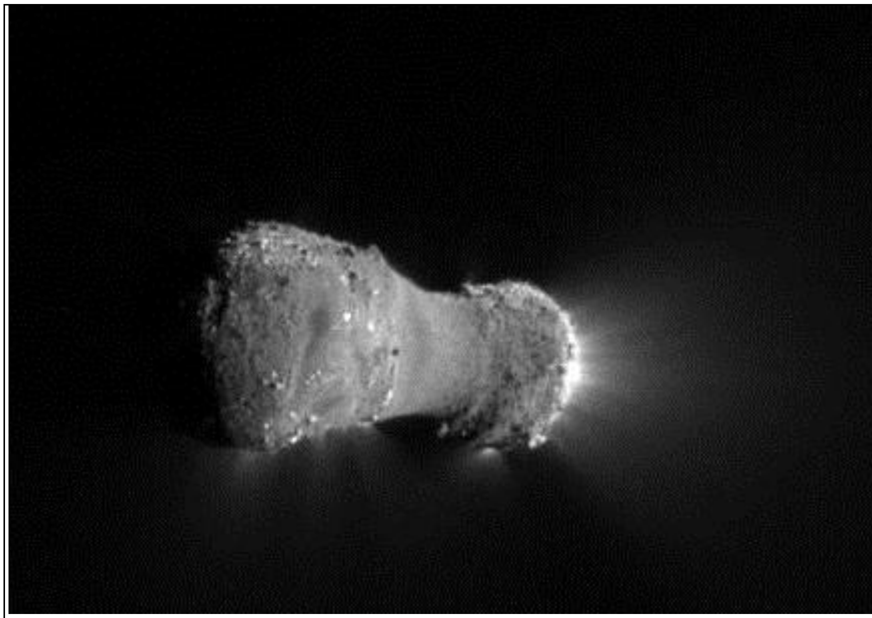


Figure 8-8a (left) and b (below): Comet Hartley 2 as seen from the NASA EPOXI spacecraft. The left image (PIA13579) was obtained from a distance of 507 miles (816 km) and shows the entire nucleus, with jets streaming out on the right side. The comet's nucleus is approximately 1.2 miles (2 km) long and 0.25 miles (0.4 km) at the "neck," or most narrow portion. The close up below (image PIA13622) was obtained near closest approach. Both images courtesy of NASA/JPL-Caltech/UMD.

A bright comet from a dark sky is truly a sight to behold-there is something unique to see at all magnifications, from naked eye to high power. Some recent examples of “great comets” include Hyakutake, Hale-Bopp, and McNaught. It is indeed fascinating to watch over time as the brightness increases, tails grow and change, day by day, then the entire comet declines, fades, and ultimately recedes into the depth of space, and I had the privilege of seeing this very process for comets Halley, Hyakutake, and Hale-Bopp. Of the half-dozen or so “bright” comets (those brighter than about the second magnitude) no two of these were exactly alike in their appearance (and this is true for most of the fainter comets as well). Not only is the overall appearance something to behold, but it can also be fascinating to peer into the heart (nucleus) of these brighter beasts at high power-it shows color and considerable details.

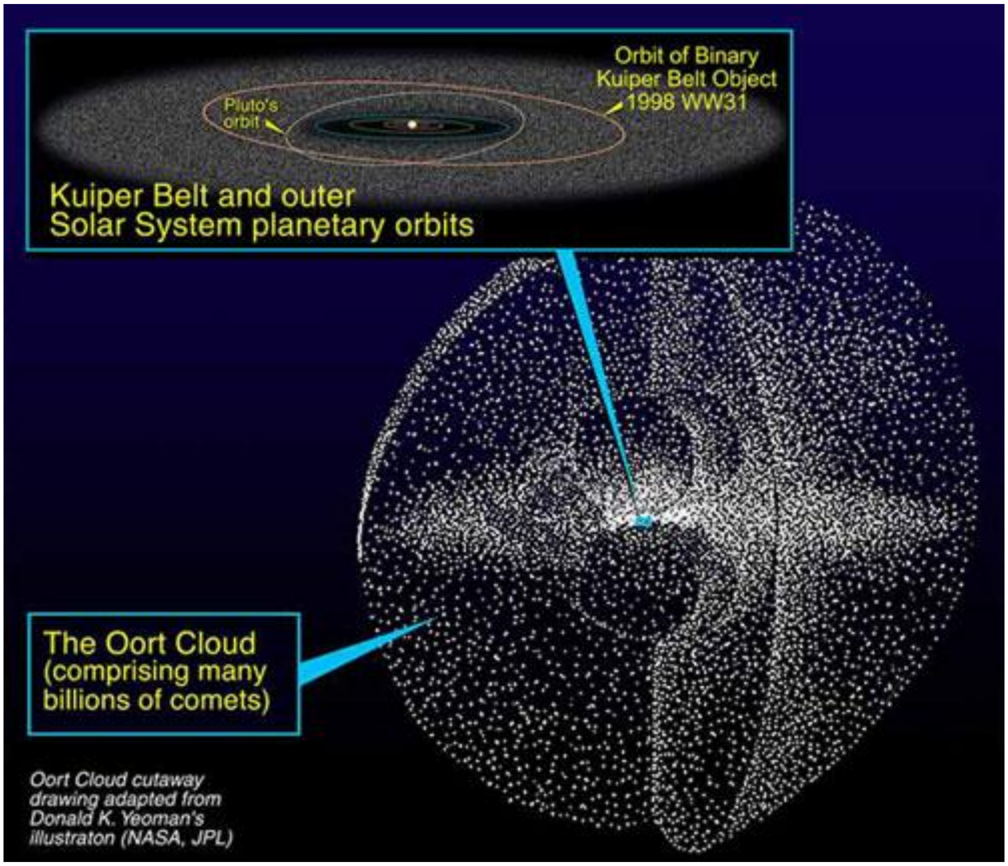


Figure 8-9. Visualizations of the Kuiper Belt and Oort cloud, dots exaggerated in size for clarity. Image courtesy of NASA.

Think about the source and nature of comets: Short-period comets are local and regional, from within the realms of the planets, while long-period comets come from beyond the orbit of Pluto, from the deep-dark distant reaches of the Solar System. These objects have their genesis in the deepest, darkest parts of the Solar System and those that come close enough to be seen from Earth travel tens of billions of miles to the inner solar system. Comets are the fossils of the solar system, presenting the original, unchanged composition of the early system, and the vast majority of them have their origins in the Kuiper Belt or Oort Cloud. The Kuiper belt is like another asteroid belt beyond the orbit of Neptune where icy objects like Pluto lurk. Beyond that is the Oort cloud, a vast cloud of billions of comets that extend from well beyond the Kuiper belt to nearly half way to the nearest star.

Application

Comets offer many opportunities for the amateur astronomer to make contributions to solar system science. Comets are relics of the ancient solar system, and the more we find out about them, the more we find out about the earliest years of the solar system. Basic visual observations are useful in gauging the overall activity level of comets.

Careful observations include making estimates of the apparent magnitude (which include two parts, the overall magnitude or m_1, and the nuclear magnitude or m_2), the coma diameter and degree of concentration (DC), the length of the tail(s) and the position angle(s), and any anomalies in the above parameters.

Two ways of measuring the diameter of a comet involve using the drift time to measure the diameter in the RA direction and using the known separations of pairs of stars as a "ruler" to measure the size of the coma. The former uses the following formula to measure the diameter of the comet:

$$diam = 15t\cos\delta$$

with "t" being the transit or drift time in seconds and "δ" being the declination in degrees (and decimal degrees).

If you want to take on the challenge of comet hunting you are up for a real challenge given the abundance of automated surveys that are currently scanning the sky and finding new comets regularly. But amateur astronomers are still able to discover comets as we have seen in the examples of Comet Lovejoy which recently (December 2011) survived a close brush with the Sun and put on a rather fine display for the southern hemisphere in the northern hemisphere winter / southern hemisphere summer 2012. I have little to offer by way of how to hunt comets, but there are plenty of sources of information out there, including comet mailing lists and books. Also, if you believe you discovered a new comet or even recovered a periodic comet…http://www.cbat.eps.harvard.edu/CometDiscovery.html is the website to visit to find out what you need to do next.

Resource: *Advanced Amateur Astronomy*, Gerald North; the above formula and information tidbits in this section were derived from this book, which has a lot more information about various projects the intermediate to advanced amateur can take on.

Interplanetary dust

When comets, over time, visit the inner solar system, they leave behind trails of dust. These trails spread out and ultimately fill the space between the planets. The dust can also come from asteroid collisions-also they can be left over from the formation of the solar system. We can see this dust best from dark sites, in March and April in the evening after twilight fades; and in the predawn sky in September and October. The glow appears as an ill-defined tall cone of light that extends from the WNW upward along the ecliptic. From truly dark locations, especially spring and fall (when it is not overwhelmed by the MW) the Gegenschein is seen: it is the opposition brightening of solar system dust, about 15 degrees wide, 5 tall, a diffuse patch of very faint light.

Meteors

A "shooting star" is an amazing sight to see: it is one of the most widely seen dynamic phenomena. There is the drama of something surprising you with its appearance, brightening, and fading, and can often be a colorful event. A "shooting star" or "falling star" is actually a meteor, which happens when a piece of dust or pebble collides with the atmosphere and it lights up for several seconds, as the compression and heating of the atmosphere by friction with the moving object causes the object to glow brightly. Meteors last from a fraction of a second to several seconds, depending on the object's cosmic velocity.

There are several annual showers throughout the year that occur when the Earth passes thru the trail of debris from periodic comets. The best of these are the Perseids and Geminids which each can produce up to 100 meteors (or more) per hour from a dark, moonless, clear, Northern Hemisphere location. Good annual showers include the eta Aquarids, Orionids, Leonids, Lyrids, and Quadrantids.

Outside of the major and good annual showers are the minor showers and the sporadic background of meteoroids (the objects in interplanetary space) from various sources: comet dust, meteoroid dust and stones from asteroid collisions, and miscellaneous interplanetary debris. On a given clear moonless night in the country, people can see up to 10 sporadics per hour. Occasionally these can be very bright, briefly lighting up the sky and the ground before burning out and (sometimes) leaving a trail of glowing particles. These are called fireballs and can happen anytime, but sometimes occur during regular showers.

Applications

Asteroids

Magnitude estimates – the magnitude alert project for ALPO, go to www.alpo-astronomy.org/minor/mapmission.html to find out more and how to get involved. Another very active area of contribution to the science is asteroid occultation, where stars are covered by asteroids for several seconds. Here you can get answers to frequently asked questions and links to more information, at http://www.asteroidoccultations.com/asteroid_help.htm. The IOTA observer's manual, also available online, contains lots more information.

My main activity with asteroids is observing occultations. This is an activity best done in groups and IOTA (the International Occultation Timing Association) is one of the premier groups in North America for such observations. I do both visual and video observations, depending on observing circumstances, the magnitude of the target star, etc. For the visual activity, I have in hand a radio that broadcasts WWV (Shortwave radio, one can get this from Radio Shack in America) and a digital voice recorder. I start observing two minutes prior to the target time, call out "off" and "on" for any disappearance and reappearance, respectively, and continue observing for two minutes after the event. Most of my events, visual or video, are misses, which are useful also, as they help constrain the size of the object.

If you get a hit, there are a few things to keep in mind. Be sure to gauge your reaction time and include that in your report (you can find the report form at the above-mentioned website along with information on how to fill it in, how to get your precise coordinates, etc.). To get your reaction time, go to http://www.topendsports.com/testing/reaction-timer.htm and follow the instructions to get your reaction time. Repeat the process twenty times or so and take the average to get your typical reaction time, with which you can correct your occultation times. You can also get lots more information on how to reduce your visual observations at this website-

http://www.poyntsource.com/IOTAmanual/IOTA_Observers_Manual_all_pages.pdf

Meteors

Three organizations seek meteor observations: ALPO (Association of Lunar & Planetary Observers), IMO (International Meteor Organization) and NAMN (North American Meteor Network). The observations come in (at least) two flavors: visual observations of shower and sporadic meteors, and observations of fireballs.

For the observations of shower and sporadic meteors, notes recorded on audiotape or paper to include the estimated magnitude and shower membership are two of the basic properties one can capture. I use the following method to record what I can without taking my eyes off the sky. After getting the meteor observing chair set up and myself in place, I have a clipboard with a blank sheet of paper, a pen or pencil, and a radio broadcasting WWV. I also have a code sequence set up so that I jot down a few characters describing the meteor. I stay aware of the time so that when a meteor appears, I can jot down the minutes part of the time (I watch for one hour intervals), as part of the following example: 07P-1yw20tr, which means: "Perseid meteor seen 7 minutes after the hour, estimated magnitude -1, yellow-white color, 20 degree long track with train." After the hour is up, I can add details such as time interval, radiant altitude, weather, limiting magnitude, etc. Later, inside, I can tally up my observations for the hour and submit the results, in their preferred format, to one of the above organizations. One drawback of this is that I am "writing blind", that is, jotting down this on a random location on the paper without looking down, which can lead to several of these character strings overlapping. Most of the time, however, I have been able to disentangle my notes to produce a useful observation.

For major showers, simply counting meteors in a given time interval (usually over the course of one hour or more frequently for more active bursts) is useful information to collect. For less active showers, plotting the path of the meteor on an all-sky star chart is best; this enables the accurate determination of the radiant(s) of the shower. If a stream has more than 20 meteors per hour, counting should be the procedure followed, while plotting only minor shower members. For high activity, record the number of meteors in short (~15 minute) intervals. Minor showers and sporadics need more data. Include the following: Path, maximum magnitude, angular velocity or estimated path length (can get that from the plot), speed, trains and their length of persistence, and color.

For fireballs (those as bright as the planet Venus or brighter), there are a number of things to record: Date and time of occurrence, location of observations, apparent magnitude at peak brightness (and changes in brightness), path coordinates of first and last sighting, duration, color and changes in this, train and its persistence, fragmentation details, the apparent velocity and any sounds perceived.

In summary, here are some useful tips for making useful meteor observations-

- Patience: a long time may pass between meteors, depending on the shower you are watching.
- Set up a reclining lawn chair (I usually face toward the radiant, so that if the radiant is high in the northeast, I face northeast, and focus my gaze as close to the zenith as I can, but I keep my eyes moving around the sky to keep them awake) and just watch
- Dress warmly as you will be still for a while
- Bug repellent in the summer
- Check out more on the websites provided to get details on technique, when the showers happen, etc.

Let the fireworks begin!

Chapter 10 – Beyond the Solar System to the Nearest Stars

Introduction—Leaving the Solar System

So far we looked at stuff within the local solar system but there is a whole universe of objects to be checked out. Moving out beyond the local solar system, going past Neptune, here is what we find: lots and lots of empty space and the most distant man-made objects are Voyager 1 at 122AU (as of June 22, 2012) and Voyager 2 at 99AU.

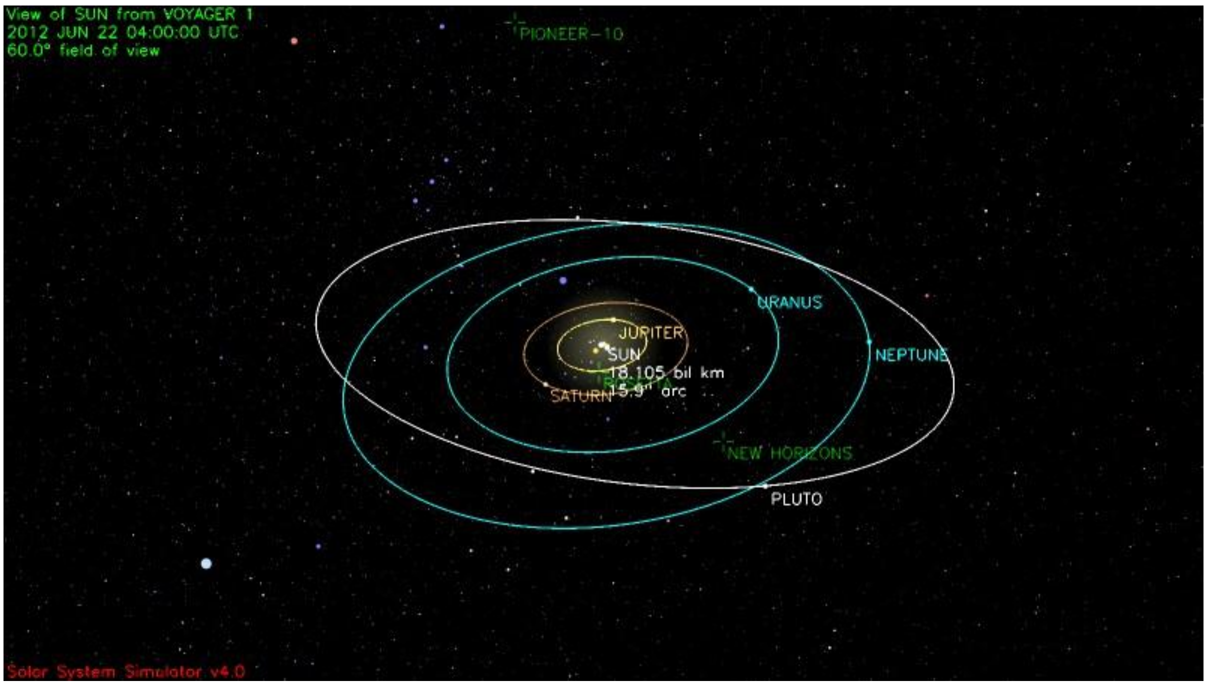


Figure 10-1, courtesy of NASA

Have you thought about what the surroundings of one of these lonely machines look like? The Sun appears stellar, but bright (15.3 arc seconds across) from Voyager 1 (Figure 10-1); as the spacecraft continues outward the sun will be as bright as the full moon when it passes 630AU distance in another 130 years or so. Aside from the brilliant sun, situated in the northernmost part of Lepus, the sky above and below is filled with stars. There is no solid surface that the spacecraft rests upon, the spacecraft is all there is at its location, its own little isolated world bathed in sunlight that is 14,900 times weaker than what we receive at Earth.

Some Stellar Basics

Apparent vs. absolute magnitude; the magnitude system

When we talk about the brightness of stars we use the term "magnitude" to describe this natural property. The magnitude system has its origins with the ancient Greeks and, with a few modifications, continues to this day. It starts with the premise that the brightest stars be rendered of the 1st magnitude, the faintest ones 6th, and the 2nd, 3rd, etc. be assigned to stars of decreasing brightness. Since the invention of the telescope and the ability to see stars fainter than what the unaided eye can see, the magnitude system underwent some modifications to include these fainter stars. It also was made more precise, being defined in such a way as to render 5th magnitude stars 100 times fainter than 1st magnitude stars. The 0th magnitude and negative magnitudes were added to enable a more accurate description of the brightness of planets, the Sun and the Moon.

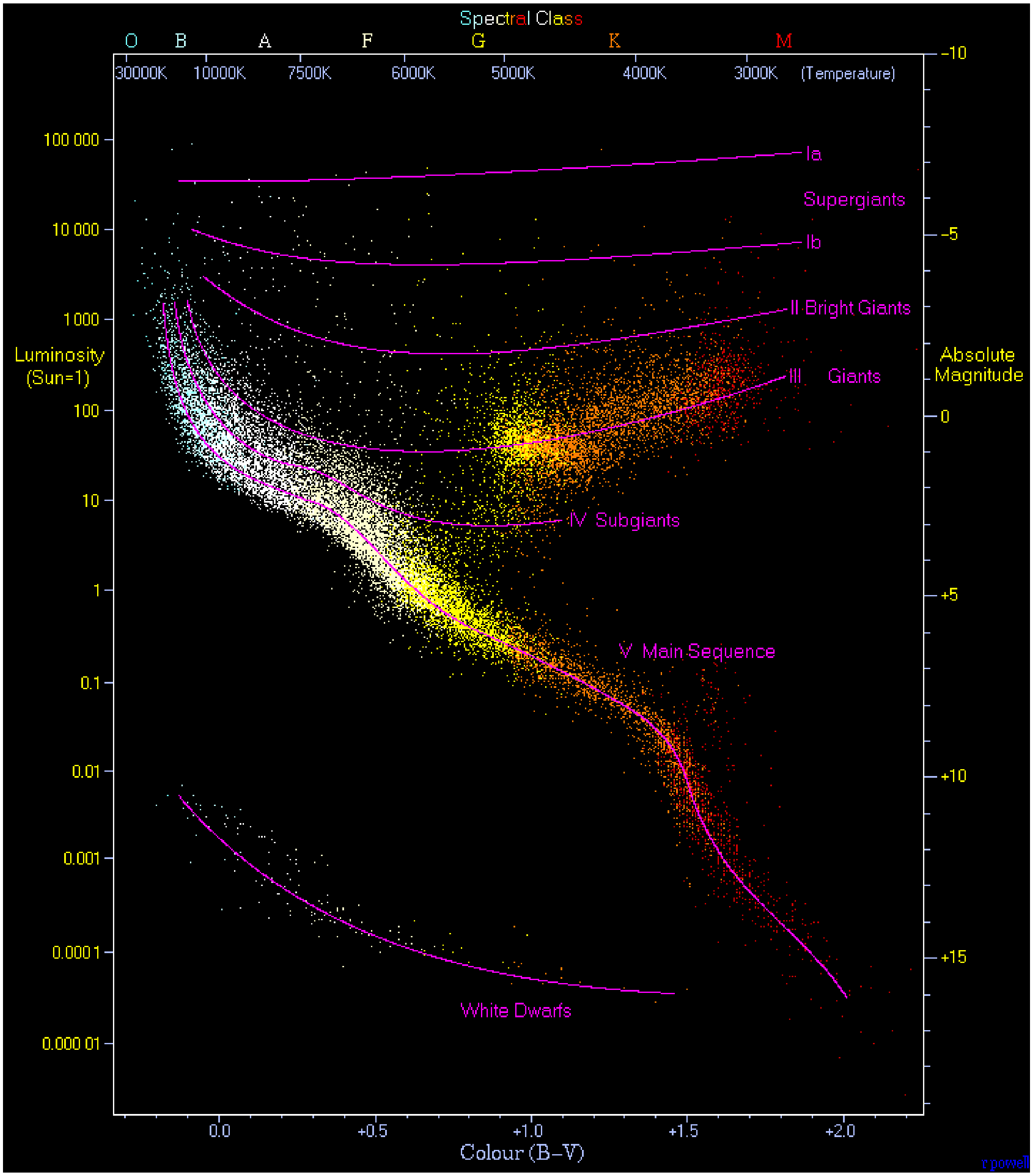


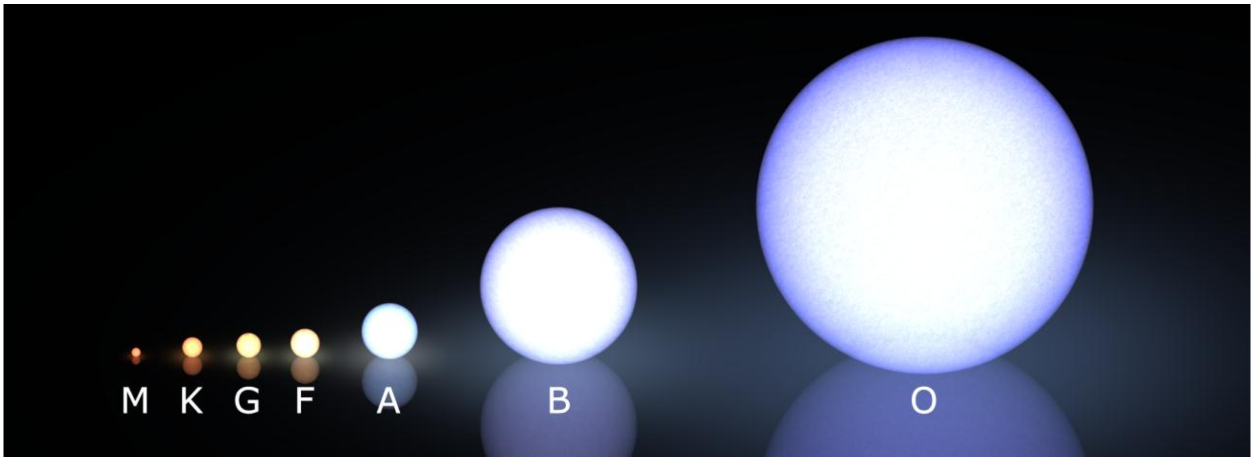
Figure 10-2: H-R Diagram, courtesy of Wikipedia Commons / Richard Powell

Look up at the nighttime sky, there is a handful of bright stars (1st magnitude and brighter); there are many more medium bright stars (2nd to 4th magnitude); and there are many, many more faint stars (5th magnitude and fainter). One can see that as stars get fainter, they get more numerous. From the city you only may be able to see the bright and medium-bright stars-and be able to pick out the constellations (which are not the focus of this book…if you want to learn more about constellations, look for a book that has more constellation details, or go to www.stellarium.org to download a free planetarium program that shows where the constellations are and provide details about these stellar arrangements). The brightness of the stars as we see them define what is termed "apparent magnitude"; then "absolute magnitude" refers to how bright a star would appear if it were placed at 10 parsecs (33 light years) from us. This is more indicative of the true luminosity of stars and puts all of them "on equal footing" so-to speak. This gives an idea on how much brighter or fainter one star is compared to another, or compared with the sun.

Stellar Taxonomy—the H-R Diagram

Figure 10-2 on the previous page shows an H-R (Hertzsprung-Russell) diagram, which is the astronomer's way of classifying stars. The diagram is a graph or plot of stellar luminosity versus temperature (or a variation of the themes) and it shows some patterns when actual stellar data is plotted. What is shown in Figure 10-2 is a plot of actual data from the Hipparcos catalog: 22,000 stars plus 1,000 low-luminosity (red- and white-dwarf stars). The Sun, for comparison with the stars on this plot, has a spectral type of G2 and an absolute magnitude of +4.83.

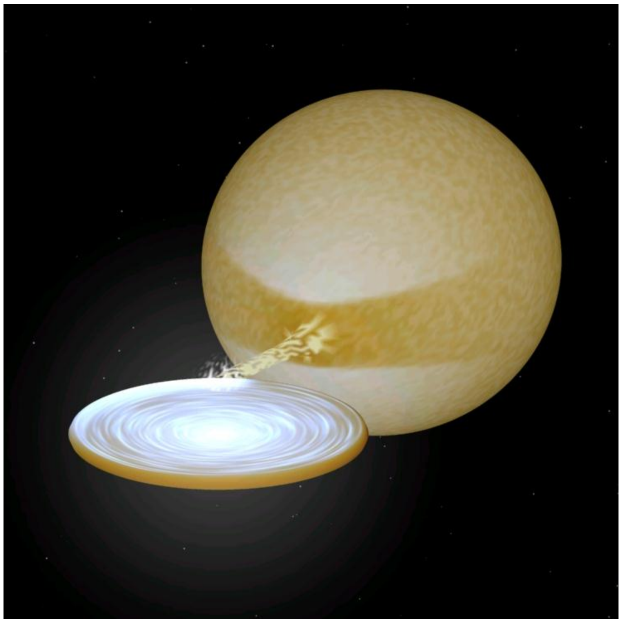
We can see from the graph that there are huge stars, and there are tiny stars. There are very hot stars, and there are very "cool" (less hot but still much hotter than fire in the fireplace) stars. The Sun is right in the middle of the stellar possibilities. It is interesting to note that the majority of stars in the immediate solar neighborhood are smaller and fainter than the Sun. We need telescopes to see most of these, even though they are the closest stars in the universe. The stars we can actually see easily with the naked eye are further away than these, for the most part. This means that the brightest stars in the terrestrial skies are bright for real, anywhere from several times to several thousand times (or more) brighter than the Sun.



The true nature of stars

The figure on the previous page shows what is termed the Morgan-Keenan spectral classification of main sequence stars (Figure 10-3). At first glance, aside from the fact that some are bright and some are faint, all stars seem to look alike: colorless pinpoints of light in a dark sky. However, if you look more closely, some subtle differences do come out, namely the color of the star. Some appear bluish, some yellowish, some orange or reddish, but most look white. Color is apparent in only the brightest stars; our eyes are not sensitive enough to pick up color from the fainter stars. But if you look with binoculars or a telescope, the colors of stars become easier to see. As it turns out, the color of the star is a direct relation to its surface temperature and contrary to what you may be used to, red represents relatively "cool" stars while blue means very hot.

All true stars, the Sun included, shine by way of very powerful nuclear reactions at their cores. The stars are huge balls of plasma (superheated gas) that are powered by energy generated by these reactions. Their surface temperatures can range from 2,000 K (Kelvin, a unit of temperature measure or $3,100^0$ F) to 45,000 K ($81,500^0$ F) or higher. The Sun, for comparison, has a surface temperature of 5780 K or $9,940^0$ F.



Binary Stars and Variable Stars

Binaries

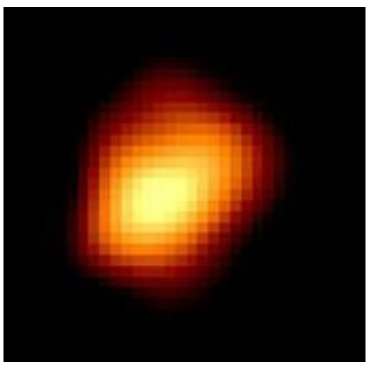
Stars tend to pair up. In fact between two-thirds and three-quarters of the stars in the galaxy are thought to be members of binary or multiple star systems. These systems are often beautiful to see through the telescope as many offer contrasting colors that make them visually appealing. Star pairs come in a variety of configurations, from closely paired, equally bright components to widely spaced, very dissimilar components. More on some of the practical side of binary star observations is written in the following sections.

(Figure 10-4 X-ray low-mass binary star artist image credit = Vdsluys) If one wishes to hunt down multiple star systems there are many resources out there to help one along. There are lists of doubles of all types that are accessible visually. The vast majority of these take so long to go around each other that each stays the same, in terms of separation and angle of position, for an entire human lifetime. But there is a handful of double stars (e.g. Vindemiatrix) change over the years and are interesting to watch long term. Some vary in separation as well as position angle, which is a measure of the angle (from due north) of a line segment running from the primary to the secondary. There are still available special eyepieces that one can use to visually measure the position of the secondary star with regards to the primary, and this is one thing the practical astronomer can do. For a long-term project, one can select fast binaries and measure these over time, piecing together a picture of this system's orbit.

There are three main types of binary stars; the first already has been introduced. The second kind is the spectroscopic binary, where the stars appear as a single pinpoint, even when viewed through a large telescope, but the components reveal themselves by their spectra which exhibit the Doppler Effect (the apparent shift in wavelength due to motion). Of these spectroscopic binaries, a handful makes up the third type of binary star, the eclipsing binary. The most famous example of these is Algol-which is also a type of variable star

Variable Stars

Eclipsing variable stars appear as single points of light through a telescope which stays constant in brightness until one of the components passes in front of the other. When this happens the combined light of the system drops for a time, then rises again. This happens a second time during the cycle as the first star that passed in front of the second now passes behind the star. If the two stars are of equal size and brightness, the two drops in light level are equal. But more often than not, one component is much brighter than the other (the first contributes most of the system's light) so when the brighter component is blocked, the light drop is significant, the primary minimum. When the bright component blocks the faint component, only a little light drop is observed (the secondary minimum).



The eclipsing binary stars are what are known as "extrinsic" variables, meaning their variation is due to one object blocking another. Most variables, however, are "intrinsic" variables, meaning they change brightness because they themselves change. There are many types of intrinsic variables, the most famous of these are the long period or Mira type variables (Figure 10-5 immediately above is a Hubble Space Telescope image of Mira, taken in 1997, courtesy of NASA and the STScI). http://www.aavso.org/types-variables has an excellent overview of the different types of variables that are out there, including their typical light curve behaviors.

It is interesting to watch one over time to see how a variable star dramatically changes brightness. For example, one may first see it being brighter than a bright 8th magnitude comparison star, and then several weeks later that same star is as faint as the faintest stars visible through the same eyepiece on the same telescope at the same observing location. Some stars show color, from spark-red to golden flame yellow (one of "my" variables, T Lyrae, is a carbon star with a nice ruddy hue). Others are more dramatic: dwarf novae like SS Cygni and RX Andromedae spend most of their lives faint but periodically brighten many magnitudes. Here is what is going on with these systems: In both cases the system is binary, with two components in close proximity to each other. One is drawing material off of another into a disk surrounding it, or the material may be collecting on its surface, but in either case, the material builds up until a tipping point is reached. At this point, runaway nuclear reactions take place at the surface, causing the system to brighten dramatically. When the excess material is "burned off" the system returns to normal brightness.

Consult the AAVSO (www.aavso.org) for more information on anything dealing with variable stars. They have excellent resources, tutorials, and charts to help you get started. I have had much experience watching these objects and have derived great satisfaction making and reporting close to 20,000 magnitude estimates for some 200 unique variables (there are literally millions to billions of these changeable stars in our galaxy alone, each with its own unique "personality").

In my own case, variable stars provide the main amateur astronomy activity that I am involved in. I focus on what the AAVSO used to call "Stars in Need of More Data", which I designated as "NMD" stars. These are stars that have historically been covered only sparsely and are thus in need of more observations. The organization dropped that designation in 2011 with a new format to their annual bulletin that provides predictions of maxima and minima, and instead provides the number of observations AAVSO received of a given star during the previous calendar year.

I kept most of the "NMD" stars that I had been following in years' past, and if a particular "NMD" star on my list was dropped from the predictions list, I dropped it from my own list. I also looked for stars that have less than 30 observations during the previous year and included these in my list of stars to monitor. I currently watch some 130 stars at a given time, with 60 or so of these observable from my light polluted backyard and the remainder observable from the local "dark site" observatory. By keeping a regular watch on these stars, over the long term, I am able to contribute useful data to the database of observations of these stars.

Variable stars…magnitude estimates, "NMD" stars, novae, hunting for supernovae: these are some of the areas that visual amateurs can make a significant contribution as many of the stars on their list of stars are in need of visual observations to provide continuity between historical and modern data.

Other Planetary Systems

One of the more fascinating aspects, to me, of astronomy beyond the solar system is the presence of planets orbiting other stars. To date (07/05/2012) 778 planets in 571 "solar systems" have been found. It is interesting to visually observe these stars to see another "solar system" from a distance. The planets themselves are not visible but to know the star you are viewing has planets, each one unique and beautiful like our own solar system's planets, is an amazing fact to ponder. Astronomers have several tools and methods at their disposal to find planets around other stars, the most productive of which (at this time) is the radial velocity or Doppler method (similar to the spectroscopic binary situation mentioned earlier.

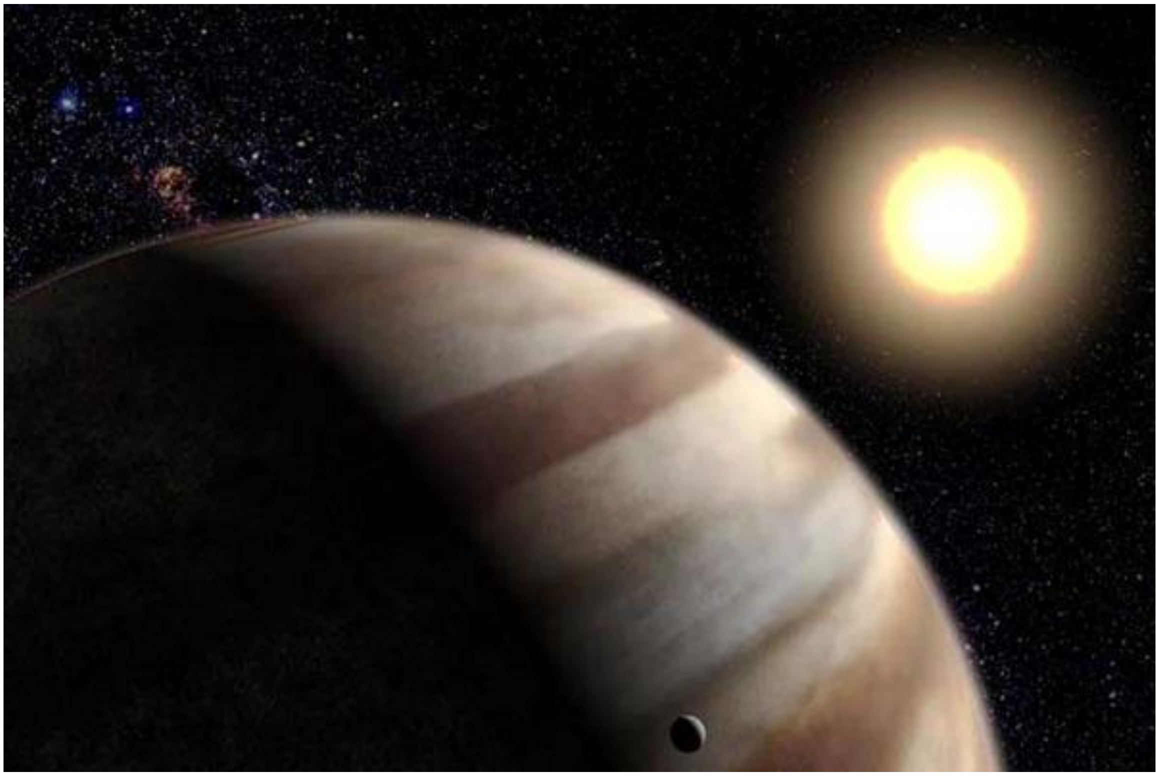


Fig 10-6 Tau Bootis b and a hypothetical satellite with tau Boo in the distance. Image courtesy of NASA.

In most cases, what is actually seen may represent the largest or closest large object in a whole family of objects that orbit the star. Considering that our own solar system has many varied and unique worlds, it is likely that every single one of the orbiting objects in a given planetary system is unique. And then there are the interrelationship between dusty disks and planet systems…disks are unobservable, as are usually the planets, but it is likely that the disks are made up of dust, asteroids, comets, or all three (there are 221 such systems as catalogued by a query made at http://www.roe.ac.uk/ukatc/research/ddd/query3.php; some of these are included in a list of 160 resolved circumstellar disks listed on the website http://circumstellardisks.org/, which is updated from time to time. Some specific examples of the more interesting multi-planet systems (there are 101 known).

There are many cases of worlds not like anything we see in our own Solar system (such as Hot Jupiters, Jupiters in elliptical orbits, super-Earths, etc.). These planets probably have their own set of features, dynamics, storms, seasons, satellites, blue skies, seasons, day/night cycles, and possibly life. The possibilities are limitless but are constrained by the laws of physics which are the same everywhere in the universe. A list of the stars with planets (that can be observed with backyard telescopes) can be obtained from http://www.exoplanet.eu/catalog-all.php?mdAff=output#tc (check, uncheck what you want to keep, not keep and download it). A couple of extrasolar planets have had their spectra sampled, diameter, mass, and temperature measured. The website extrasolar,net ("Extrasolar Visions) has some excellent visualization artwork showing what it may be like to visit these worlds (and worlds in our own solar system).


Figure 10-7 upsilon Andromeda moons, artwork courtesy of Lucianomendez

One fun exercise I have done in the past when there were far fewer known extrasolar planets was to collect a list of host stars and try to observe them with your scope. In most cases they look like indistinguishable points from other points of light, but consider the point that you are gazing upon hides a host of “strange new worlds”. You may want to try to observe each of the hundreds of observable stars with planets, or perhaps pick the most interesting 50 and hunt these down. This makes for an interesting observing project.

Ch. 11-Deep Space Objects

Introduction

Beyond the immediate solar neighborhood is a vast galaxy to explore. When I go observing at a dark sky location, one of the things I enjoy doing is scanning the Milky Way Galaxy with binoculars, going from horizon to horizon. Here are some of the things I look for when I do this activity:

- Open star clusters that appear as distinct groupings of stars or small clumps of brightening, streaming along the plane of the galaxy
- Star clouds, especially those in Sagittarius, Scorpius, Scutum, and Cygnus; it is interesting to notice how grainy these appear, some appear quite grainy and starry, while others appear more smooth
- Nebulae of the emission and large planetary type (try an 1-1/4-inch OIII filter set between one eye and the eyepiece of the binocular, or a 2-inch held in binocular aperture, or tape them, being careful not to let the tape or your fingers touch the filter part itself, in place)
- Dark nebulae
- Bright stars—This gives a sort of three-dimensional aspect to the scenery as these seem to be in the foreground and the fainter stars and star clouds reside in the background; if you know the distance to some of these objects, you can imagine the three dimensional aspect of the placement of these (which is really cool)

This and the next chapter I want to continue the theme of appreciation. Aside from observing changes in brightness for certain nebulae, looking for undiscovered novae and supernovae, I am not aware of much in the way of application the visual astronomer can do with deep space (more commonly called "deep sky objects" but I prefer the term "deep space" since that is where they really are…) objects aside from enjoy them and consider their physical nature. I will suggest some "cloudy night activities" to do in conjunction with deep space observing to (hopefully) enhance your appreciation of these faint fuzzies.

Open Clusters & Stellar Associations

Many stars come in groups that are bound by gravity (open clusters) or not bound by gravity (associations). The latter are groups of stars that had been created / were born together but are moving fast enough to escape the mutual gravitational grip. The Sun is thought to have been part of such a group but has since left to wander the galaxy on its own. Open clusters and associations are gems to behold either through the city light haze or under dark, pristine, rural skies. No two of these objects is exactly alike—the astronomer Trumpler created a classification scheme, utilized by the AL (Astronomical League) in their clusters club, to make sense of these objects. You can read more of the particulars on their website www.astroleague.org.

Some star clusters barely stand out against the Milky Way starry background. Some only have a few stars, while others have many. Some clusters are richly endowed with stars, others are sparse. Some have members that are mostly the same brightness, while others have a mixture of bright and dim stars. Some clusters are surrounded by nebulae, some occupy a hole in the nebula, and others shine among the clouds of the nebula. Most are beautiful and unique, some have multi-colored stars, others have stars of the same or similar color. Remember that each member is a sun, just like our daytime star, complete with its own display of activity and complexity. Several bright O-B associations are sights to behold in binoculars, like the Perseus association surrounding the bright star Mirfak, or the Scorpius-Centaurus association of stars. These, and many like these, are made up of mostly blue-hot stars that have that nice icy hue.

Some nice examples of open clusters appear in images below. Each of these images are courtesy of Ken Miller, www.raftermranch.com.

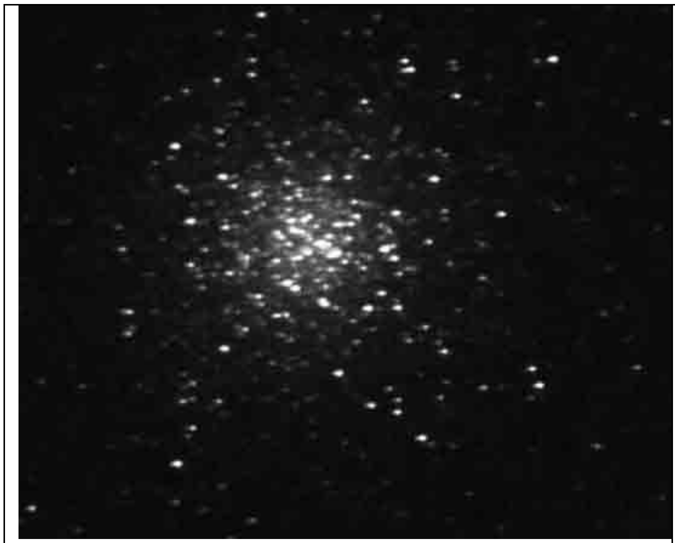


Figure 11-1 (left) the Wild Duck Cluster, M11. Figure 11-2 (above) M16 the Eagle Nebula with the associated star cluster. Open star clusters often appear together with nebulae, other examples of these include M8, the Lagoon Nebula; and NGC 2244, the open cluster inside the Rosette Nebula.

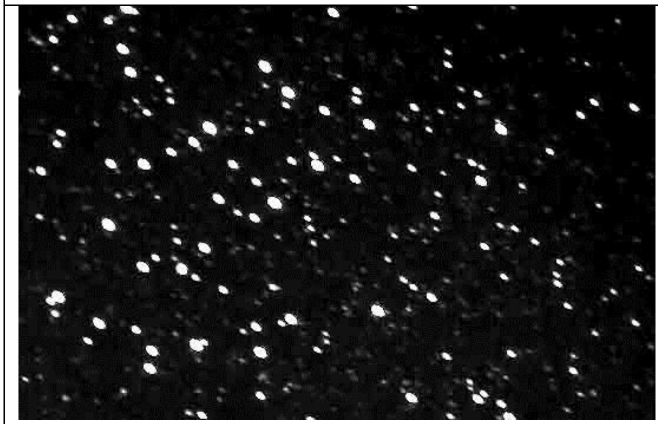
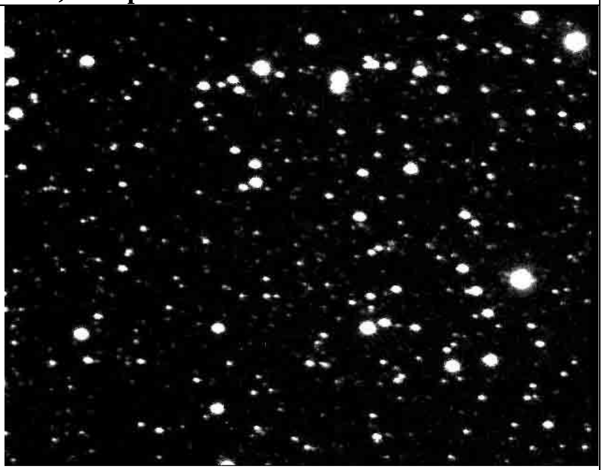


Figure 11-3 (above) the open cluster M23. Figure 11-4 (right) the open cluster M25. Both are rich open clusters found in the summer sky among the rich star clouds of Sagittarius.



Globular Clusters

At first glance, these appear as spheroidal balls of fuzz, but upon closer inspection (with larger instruments and dark skies) they resolve into countless stars. These look spectacular thru a modest-sized (8-12 inch) instruments. Some 160 of these are known in the Milky Way Galaxy, and one can see most of these from Earth. Upon even closer inspection as one observes different objects, some appear big and rich, others have central brightness concentrations, others are more uniform in their brightness distributions, still others appear quite weak (or faint and featureless). Some are distant and cannot be resolved. One can also spot OC's and GC's in nearby galaxies, particularly Andromeda and M33 (G1 is brightest).

Some nice examples of globular clusters appear in images below. Each of these images is courtesy of Loyd Overcash, http://www.skyshooter.net/.

Figure 11-5 (above) M5; Figure 11-6 (top right) M10; Figure 11-7 (below) M13; and Figure 11-8 (bottom right) omega Centauri.

Emission Nebulae

The Milky Way contains its host of star clusters, emission nebulae, planetary nebulae, super nova remnants, dark nebulae, variable stars, double stars, reflection nebulae, and planetary systems. As for emission and reflection nebulae we can see the brighter representatives of these (such as the Messiers and some of the NGC's) through a backyard scope in a dark site. Nebulae are especially fun to look at – just like stars and planets, no two nebulae are exactly alike. They come in several different types: emission, reflection, dark, planetary, and supernova remnants.

Emission or bright nebulae ("Bright Nebulae" can refer to reflection nebulae also) may not have the detailed, multi-colored appearance as seen in photos; in fact, they all look grayish or blue-gray→even so there is something about seeing a luminous celestial cloud thru the eyepiece. Telescopic visual appearances range from more diffuse gray patches to detailed textured areas (like M8 and M42); nebula filters really help to bring out the contrast and the details. Consider for a few moments what is causing the light that we pick up with our instruments…bombardment of stellar UV light causing component atoms to fluoresce or glow. In some cases, we see the same stars in the form of a nearby or embedded open star cluster.

Figure 11-9 NGC 1499, the California nebula taken through a hydrogen-alpha filter, showing intricate structure and dark nebulae silhouetted in front of the bright emission nebula. Image courtesy of Don Taylor, http://theatomiccafe.com/

Nebulae are very complex and dynamic places where star formation is taking place. They can be several tens to hundreds of light years across but we are literally seeing the "tip of the iceberg" thru the eyepiece: hidden from view is a lot of fascinating processes that shape the nebulae that form stars and possibly planetary systems. The next cloudy night, go to hubblesite.org and check some of these out: you will see wonderlands with gaseous spires light years tall, clumps of dark material and brighter material, shockwaves, bow shocks, stars hidden and visible, and even planetary systems in the process of being born.

Reflection nebulae simply reflect the light of nearby stars, like sunlight reflected off of a cloud on Earth. They tend to appear simpler than their emissive cousins but can also be complex regions. They are more localized, as the light from stars reflected and scattered by the gas and dust in these objects is what reveals them to us. Emission and Reflection nebulae that are seen thru the eyepiece may be the bright complexes of a larger, more complex region known as a Giant Molecular Cloud complex; one example being the Great Orion Nebulae with the Horsehead nebulae and related objects.

Figure 11-10. The North America and Pelican Nebulae in Cygnus, in broad band and color. Image courtesy of Don Taylor.

The galaxy M33 and other nearby galaxies display emission nebulae, some of which dwarf the Orion nebulae and most nebulae in the Milky Way.

Dark Nebulae

Barnard catalogued a number of dark nebulae. In the case of a certain object in Sagittarius (a cluster/dark nebula complex) we can see one or more stars shine thru the nebula and appear noticeably red, just like our Sun as seen thru smoke or haze. Many dark nebulae are scattered along the Summer MW (winter MW from southern hemisphere). These consist of clouds of gas and dust that block light from the more distant stars.

Planetary Nebulae

Planetary nebulae are truly wonderful objects to look at and are among one of my favorites. The name comes from their telescopic appearance-one similar to that of planets, complete with disk and (in at least one case), rings. They come in a wide variety of shapes and sizes: some appear as face-on disks, some as rings, most are grayish, but some have a strong blue, blue-green, or green color. The central star appears easily in some, but faint or invisible in others. Some appear to be bipolar in shape, elongated or entirely different. Many can be seen from a bright, urban site. OIII filters can help boost contrast and differentiate stellar looking PN from background stars: as one passes the OIII filter between one's observing eye and eyepiece, the field stars appear to fade while the planetary remains at full brightness, making it stand out easily.

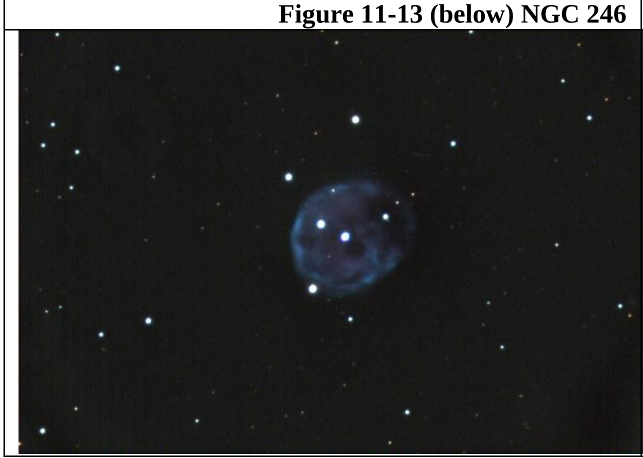
The Milky Way has an estimated 3,000 planetaries, mostly located near the plane of the galaxy and concentrated more densely toward the center. Planetary nebulae can also be seen in the nearby large galaxy Andromeda (M31). Some nice examples of planetary nebulae appear in images below. Each of these images is courtesy of Paul and Liz Downing http://www.paulandliz.org/Latest_Images/Default.htm.

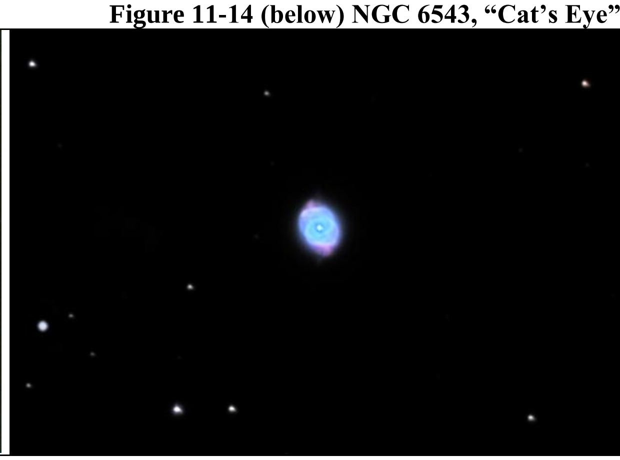
Figure 11-11 (above) M27, the "Dumbbell".

Figure 11-12 (above) NGC 6781

Figure 11-13 (below) NGC 246

Figure 11-14 (below) NGC 6543, "Cat's Eye"





All of the glowing starstuff of a PN are remnants of solar-type stars now irradiated by very hot stellar cores or WD's. These objects are often bright enough and large enough to display color and fine detail to observers using larger instruments. I have recently spied a number of bright objects at 558.8x with the C-14 that I use at the dark site observatory and was able to see some really impressive detail in many of these, such as the "Ghost of Jupiter" nebula or the "Saturn" nebula. Color tends to show up most easily at low powers in larger apertures and I have seen Planetaries display shades of green and blue.

Supernova Remnants

Supernova remnants (SNR) are the leftovers of massive stars that exploded at some point in the past. The brightest example in Earth's skies is Messier 1, the Crab Nebula, which is the leftovers of a supernova event that exploded in 1054 AD. Other examples of remnants include the Veil Nebula complex (NGC 6992/95, and NGC 6960) originated from a SN that happened between 5,000 and 8,000 years ago and has a spectacular lacy appearance with a 14-inch scope equipped with a nebular filter and viewed on a clear, dark night. Lots of detail is seen under these circumstances, giving the nebula an appearance similar to terrestrial cirrus clouds.

Figure 11-15, the Western Veil nebula, broad band image, courtesy of Don Taylor

Most SNR visible thru scopes appear as little more than diffuse gray patches of hazy light. They are leftovers of suns thousands, tens of thousands, even hundreds of thousands times more brilliant than the noonday sun; these distant stars exploded a long time ago, leaving behind the material we see with the aid of telescopes.

As we look at images of these objects we see that no two of them look exactly alike. Circumstances behind the supernova event in each case determine what sort of object we end up with. Simeis 147 (below) is an interesting case of a large, complex SNR, but visually this object is quite hard to see, with only the brightest filaments and sections faintly seen through medium sized instruments from dark skies.

Figure 11-16:Sharpless 240 (Sh 2-240) – Simeis 147 in Taurus, Narrowband Image courtesy of Don Taylor.

Chapter 12—Beyond the Galaxy

Appreciation

The Milky Way is but one of hundreds of billions of galaxies in the known universe. They range in size from the dwarves, barely larger than a globular cluster, to giants several times larger than the Milky Way. Each galaxy contains its own collection of clusters, nebulae, stars, etc. (in other words, all the types of objects that we can see in our own section of the Milky Way galaxy) but the finer details (numbers of each object, amount of gas and dust, the makeup of the interstellar medium, etc.) vary from galaxy to galaxy.

Each galaxy may also have its collection of planetary systems, with each system containing a unique host of varied worlds, some Jupiter like, some Neptune-like, some possibly Earth and Mars-like, perhaps with life; some may be quite different than anything we have seen to date. Consider the following next time you look at a galaxy through the eyepiece: the haze you see is the combined light of billions of stars. Hidden in that haze are countless objects as mentioned above…within the galaxy its own countless collections of hidden corners, places, spots, etc.; places as real as the site you are observing from the space between the stars in that galaxy is as vast as the space between stars in the Milky Way (distant galaxies each contain its own Interstellar Medium). These are the main types of galaxies, which are classified by shape:

- Spiral – spiral shaped arms coming from a bright center
- Barred Spiral – spiral shaped arms coming from a straight bar-like structure that goes through the center
- Elliptical – round to flattened, oval shaped fuzzies with a bright center and little to no structure
- Lenticular – lens-shaped with bright centers and no arms
- Irregular – anything that does not fit into the above categories
- Active – galaxies that fit one of the above types but display an elevated amount of radiation coming from the nucleus, these include quasars

Observers with small telescopes set up under dark skies can pick up many galaxies with only a few showing appreciable detail. A 14-inch or larger scope, with dark, transparent skies, can pick up spiral structures in many spiral galaxies. In a handful of the brightest galaxies, especially M31; larger star clouds are visible. In other galaxies (including M31), dust lanes can be seen. In a few cases, other deep space objects (open clusters, planetary and emission nebulae, and stellar associations) can be seen.

Like anything else in the universe, no two galaxies are exactly alike. This is especially true when you look at images of galaxies. In many cases, and as seen through moderate-sized to large telescopes with experience, the visual appearances of galaxies can vary subtly from one galaxy to another. Try to notice as many differences as you can when looking at two or more galaxies in an observing session and the effort you put forth doing so will help build your skills as a visual observer. As we look around the immediate neighborhood of the Milky Way we see that most of what we call the "local group" of galaxies are small, hard-to-see dwarf galaxies with three dominant spirals: the Milky Way, Andromeda, and M33. We have to go beyond the Local Group to find more large galaxies. The Andromeda galaxy is the most distant object that one can see with the naked eye, at 2.5 million light years. A number of others can be seen with binoculars under a dark sky.

Figure 12-1 The galaxy M101, image courtesy of Loyd Overcash.

When I am out observing from a dark site, I generally look at brighter as well as fainter objects. For brighter galaxies I try to spy as many features as the seeing and the scope allow. Many of the brighter galaxies show star clouds, bright knots, and (in some cases) HII regions (emission nebulae). The nebulae can be picked up by blinking the galaxy and spying which spots remain at constant brightness and which ones become fainter. What one is seeing when one looks at galaxies is the combined light of a minority of stars, the brightest minority which puts out the most light. Stars like the Sun and fainter have their feeble glows overwhelmed by the brightest members. However, the majority of stars that make up a galaxy, in terms of the numbers, are objects smaller and fainter than the Sun.

The images shown on these pages are three of the brighter galaxies visible in our nighttime skies and show nicely the color differences between the various parts of the galaxy. The yellowish centers are made up primarily of older, redder, giant stars. The bright, nearly starlike centers are homes to supermassive black holes, thought to inhabit nearly all of the major galaxies of the universe. The blue in the spiral arms come from the light of blue giant stars that are young, short lived, and form along density waves that travel through the galaxies' disks triggering star formation. Pink spots are emission nebulae or HII regions and dark spots are obscuring dust silhouetted against the starry background.

Figure 12-2 The "Silver Dollar" galaxy, NGC 253, one of a handful that shows features quite nicely through a small scope under dark skies. Image credit = Loyd Overcash

All of the stars visible in each image are stars that belong to our own galaxy, and are in the foreground, with the vast external galaxy in the background. If you look carefully, you can see more fuzzy objects which are whole other galaxies in the distance. There are various objects and groups of objects at various distances. The Virgo supercluster is the nearest supercluster, centered at about 65 million light years. Dozens of cluster members are easily seen through small telescopes. There are dozens of other, more distant galaxy clusters, including the Coma supercluster of galaxies, which need larger instruments to see (although the two dominant ellipticals, NGC 4874 and NGC 4889, can be seen through smaller instruments). This is some five times further away from us than the Virgo cluster (the former is centered some 321 million light years distant).

Looking at more distant objects, we find the quasar 3C 273 in Virgo which is 2.44 billion light years away and is one of only a handful of such objects that can be seen with amateur equipment. Quasars are the active nuclei of normal galaxies, which are invisible to amateur telescopes visually. For large telescopes, perhaps the most distant (or one of the most distant) object directly observable visually is the Ursa Major double quasar. It glows at magnitude 16.7 and is 7.8 billion light years distant. It appears double because of gravitational lensing by a closer, unseen massive object.

Figure 12-3. M106 and more distant objects, image courtesy of Loyd Overcash

Application

So how far can you see? That may be an interesting project to pursue. On a cloudy night, make a list of some of the more distant objects that can be seen by backyard telescopes, then the next time you are out in a dark sky, try to find out what the most distant object is that you can see. When you spot that object, take a few moments to enjoy the view of the most distant thing that you have ever seen (to this point) and consider how long and how far the object's light has traveled to get to your scope and eyepiece. Also, the distance you can see depends on the object type itself: the brighter the class of object, the more distant you can see that type of object. Galaxies can be seen at much greater distances than asteroids, for example.

Finally one can, if one is patient, observe change in the distant universe in the form of supernovae that go off from time to time. One can observe and monitor supernovae that have been discovered in nearby galaxies, and/or one can conduct systematic searches for supernovae. To do the latter, it is important to have finder charts of targets to monitor, charts that go at least as deep as what you can observe through your telescope. Then whenever you are out, check on the set of galaxies that you determine to watch for supernova explosions and keep watch until one appears, and even after.

The next (and last) table is a selection of some of the best deep sky objects visible in backyard telescopes, along with distance and equivalent distance information. The equivalent distance, which corresponds to the naked eye view of the same object at that distance, is given for magnifications of 50x, 200x, and 500x. The last one is generally used for close-up studies of planetary nebulae, which I have done and have seen some finer details of several objects. So while you are viewing these objects, consider not only the physical nature of what you are viewing, but what it may take to travel the distance to get that same view naked eye. (1 LY = 63,241 au)

Table 12-1. Limiting Resolutions of various objects at various magnifications in linear units

		Distance	**Resolutions**		
OBJECT	**Mag.**	**Light Years**	**50x**	**200x**	**500x**
M45 the Pleiades	1.6	420	515 au	193 au	64 au
M35 Open Cluster	5.3	2800	3400 au	1290 au	429 au
NGC 7293 the Helix Nebula	7.6	695	852 au	319 au	106 au
M81 and M82	6.94 & 8.41	11,500,000	223 LY	83.6 LY	27.9 LY
M42 the Great Orion Nebula	4	1344	1650 au	620 au	205 au
M1 the Crab Nebula	8.4	6500	7970 au	2990 au	995 au
M31 the Andromeda Galaxy	3.44	2,540,000	49 LY	18.5 LY	6.15 LY
M65 and M66	10.25 & 8.9	36,000,000	698 LY	262 LY	87.2 LY
NGC 3242 The Ghost of Jupiter	8.6	1400	1720 au	640 au	215 au
M104 the Sombrero galaxy	8.96	29,300,000	568 LY	213 LY	71.0 LY
M8 the Lagoon Nebula	6	4000	4900 au	1800 au	610 au
M17 the Swan Nebula	6	5500	6700 au	2500 au	840 au
M11 the Wild Duck Cluster	6.3	6200	7600 au	2850 au	950 au
M57 the Ring Nebula	8.8	2300	2820 au	1060 au	350 au
M27 the Dumbbell Nebula	7.5	1360	1670 au	625 au	208 au
The Veil Nebula complex	7	1470	1800 au	675 au	225 au
M51 Whirlpool galaxy	8.4	23,000,000	446 LY	167 LY	55.7 LY
NGC 253 galaxy	8.4	11400000	221 LY	82.9 LY	27.6 LY
NGC 7662 "The Blue Snowball"	8.6	5600	6870 au	2580 au	860 au
M87 (dominant Virgo Cluster member)	9.59	53500000	1037 LY	389 LY	130 LY

Table 12-2. Equivalent Distances to the favorite objects at various magnifications. That is, the distance one has to be to get a naked eye view of the object comparable to what one sees through the eyepiece.

		Distance	**Equivalent Distances- Light Years**		
OBJECT	**Mag.**	**Light Years**	**50x**	**200x**	**500x**
M45 the Pleiades	1.6	420	14.0	5.25	1.75
M35 Open Cluster	5.3	2800	93.3	35.0	11.7
NGC 7293 the Helix Nebula	7.6	695	23.2	8.69	2.90
M81 and M82	6.94 & 8.41	11,500,000	383,000	143,800	47,900
M42 the Great Orion Nebula	4	1344	44.8	16.8	5.60
M1 the Crab Nebula	8.4	6500	217	81.3	27.1
M31 the Andromeda Galaxy	3.44	2,540,000	85,000	31,750	10,580
M65 and M66	10.25 & 8.9	3,600,0000	1,200,000	450,000	150,000
NGC 3242 The Ghost of Jupiter	8.6	1400	46.7	17.5	5.83

M104 the Sombrero galaxy	8.96	29,300,000	976,000	366,000	122,000
M8 the Lagoon Nebula	6	4000	133	50	16.7
M17 the Swan Nebula	6	5500	183	68.7	22.9
M11 the Wild Duck Cluster	6.3	6200	207	77.5	25.8
M57 the Ring Nebula	8.8	2300	76.7	28.7	9.58
M27 the Dumbbell Nebula	7.5	1360	45.3	17.0	5.67
The Veil Nebula complex	7	1470	49.0	18.3	6.13
M51 Whirlpool galaxy	8.4	23,000,000	767,000	287,500	95,800
NGC 253 galaxy	8.4	11,400,000	380,000	142,500	47,500
NGC 7662 "The Blue Snowball"	8.6	5600	187	70	23
M87 (dominant Virgo Cluster member)	9.59	53,500,000	1,780,000	669,000	223,000

In some cases the resolution is given in astronomical units (au) rather than light years (1 LY = 63,241 au) since the values for light years are quite small. One au is equal to the mean Earth-Sun distance of 93,000,000 miles or 149,000,000 km. If you consider that at high power (500 x), as you observe M57 the Ring Nebula, the smallest resolvable feature is 350 au. When you have this in mind you have an appreciation just how vastly huge this object is compared to the solar system (diameter of Neptune's orbit is ~60 au). And yet M57 is quite small compared to some of the other objects on the list.

There's a whole universe of objects to explore, so let's get busy!

Appendix: Resources to get started or to go deeper

Books and Reference Materials

Springer publishing has a useful set of observing guides that provide not only the information behind the physical nature of an object type, but also tools and techniques on how to observe that object type. The titles are listed below and more information on these observing guides can be found at: http://www.springer.com/series/5338. Prices quoted are as of mid-2012 and could change without notice.

Cudnik, Brian - *Faint Objects and How to Observe Them*
2013, ISBN 978-1-4419-6756-5, Softcover, Not yet published. Available: August 2013 (approx. $39.95)

Lashley, Jeff - *The Radio Sky and How to Observe It*
2010, ISBN 978-1-4419-0882-7, Softcover, $34.95

Cudnik, Brian - *Lunar Meteoroid Impacts and How to Observe Them*
2009, ISBN 978-1-4419-0323-5, Softcover, $34.95

Dymock, Roger - *Asteroids and Dwarf Planets and How to Observe Them*
2010, ISBN 978-1-4419-6438-0, Softcover, $39.95

Schmude, Richard - *Comets and How to Observe Them*
2010, ISBN 978-1-4419-5789-4, Softcover, $34.95

Mobberley, Martin - *The Caldwell Objects and How to Observe Them*
2009, ISBN 978-1-4419-0325-9, Softcover, $34.95

Jenkins, Jamey L. - *The Sun and How to Observe It*
2009, ISBN 978-0-387-09497-7, Softcover, $34.95

Lunsford, Robert - *Meteors and How to Observe Them*
2009, ISBN 978-0-387-09460-1, Softcover, $34.95

Mobberley, Martin - *Cataclysmic Cosmic Events and How to Observe Them*
2009, ISBN 978-0-387-79945-2, Softcover, $34.95

Schmude, Richard - *Uranus, Neptune, and Pluto and How to Observe Them*
2008, ISBN 978-0-387-76601-0, Softcover, $34.95

Grego, Peter - *Venus and Mercury, and How to Observe Them*
2008, ISBN 978-0-387-74285-4, Softcover, $34.95

McAnally, John W. - *Jupiter and How to Observe It*
2008, ISBN 978-1-85233-750-6, Softcover, $39.95

Mobberley, Martin - *Total Solar Eclipses and How to Observe Them*
2007, ISBN 978-0-387-69827-4, Softcover, $29.95

Mullaney, James - *The Herschel Objects and How to Observe Them*
2007, ISBN 978-0-387-68124-5, Softcover, $32.95

Mobberley, Martin - *Supernovae and How to Observe Them*
2007, ISBN 978-0-387-35257-2, Softcover, $32.95

Coe, Steven - *Nebulae and How to Observe Them*
2007, ISBN 978-1-84628-482-3, Softcover, $32.95

Steinicke, Wolfgang; Jakiel, Richard - *Galaxies and How to Observe Them*
2007, ISBN 978-1-85233-752-0, Softcover, $32.95

Allison, Mark - *Star Clusters and How to Observe Them*
2006, ISBN 978-1-84628-190-7, Softcover, $39.95

Benton, Julius - *Saturn and How to Observe It*
2005, ISBN 978-1-85233-887-9, Softcover, $39.95

Grego, Peter - *The Moon and How to Observe It*
2005, ISBN 978-1-85233-748-3, Softcover

Mullaney, James - *Double & Multiple Stars, and How to Observe Them*
2005, ISBN 978-1-85233-751-3, Softcover

Some potentially useful websites
http://www.wikihow.com/Get-Started-in-Amateur-Astronomy is a useful quick-reference on how to get started in astronomy

http://www.skyandtelescope.com/howto/basics/How_to_Start_Right_in_Astronomy.html with the magazine *Sky and Telescope*. This magazine contains a wealth of resources on getting started, what to observe, how to purchase your first telescope, and more.

A selection of books that come recommended by amazon.com are listed here…
http://www.amazon.com/Getting-Started-In-Amateur-Astronomy/lm/R1WJL3BVEONQAK

Resources Online, Including Pro-Am Collaboration Information

http://www.perezmedia.net/beltofvenus/ lots of useful tidbits for making astronomical sketches.

The Lowell Amateur Research Initiative (LARI) is looking for amateurs that are willing to collaborate on a number of projects. This initiative targets those equipped with electronic observing capability so if you are ready to take that next step and want to share your results, here is one place to consider. More information on this initiative can be found at: http://www.lowell.edu/LARI_welcome.php.

- AAVSO-the American Association of Variable Star Observers, collects observations on variable stars and sunspots and makes this information available to the professional community. Website = www.aavso.org
- IOTA-the International Occultation Timing Association, coordinates lunar, planetary, and asteroid occultation observations, collects data from these events and makes these data available to the professional community. Website = http://www.lunar-occultations.com/iota/iotandx.htm
- ALPO-Association of Lunar and Planetary Observers, which accepts data on lunar and planetary phenomena and makes that data available to the professional community. Website = www.alpo-astronomy.org
- IMO-(International Meteor Organization) / NAMN-(North American Meteor Network) accepts data and observations on terrestrial meteors. Their websites are www.imo.net and http://www.namnmeteors.org/

Some (More) Potentially Useful Websites
The following are some websites with suggestions on how to make your observations scientifically valuable…

http://www.astro-tom.com/messier/messier_files/observing_tips.htm

Book → http://www.amazon.com/Observers-Guide-Astronomy-Practical-Handbooks/dp/0521379458

A journal article from a professional astronomer on how professionals can make use of amateur astronomy data … http://adsabs.harvard.edu/abs/2008epsc.conf..960K has the abstract, then you can click on the link that says “Full Printable Article (PDF/Postscript)” to get the article itself.

Another book → Schmude, Jr., Richard - *Artificial Satellites and How to Observe Them* (Springer) Series: Astronomers' Observing Guides, 2012, 2012, XIII, 181 p. 157 illus., 20 in color, ISBN 978-1-4614-3914-1, Due: July 31, 2012, $34.95

And here is a suggested observing form format for you to use … http://www.wwu.edu/depts/skywise/pdf/observingdatasheet.pdf

For cloudy nights …

- Hubblesite.org – lots of wonderful Hubble Space Telescope images
- Photojournal.nasa.jpl.gov – lots of images from lots of places in the solar system
- Space.nasa.gov – solar system simulator, to gauge the view from another world
- www.spaceweather.com – the latest news in the space and earth environment
- www.cleardarksky.org – to find out if your next outing will be a dud or not

Not to mention the various links that are peppered throughout this book—I encourage you to take advantages of these resources to make the most of every opportunity you have under clear dark skies. And you can use this opportunity to make scientifically valuable observations that will be around long after you are gone.

And finally…this is an evolving work; in other words, as people submit suggestions, point out corrections, new techniques emerge, etc. this will likely undergo some changes and upgrades. If you have any suggestions on how to improve this book, drop me a few lines at cudnik@sbcglobal.net. Thanks!