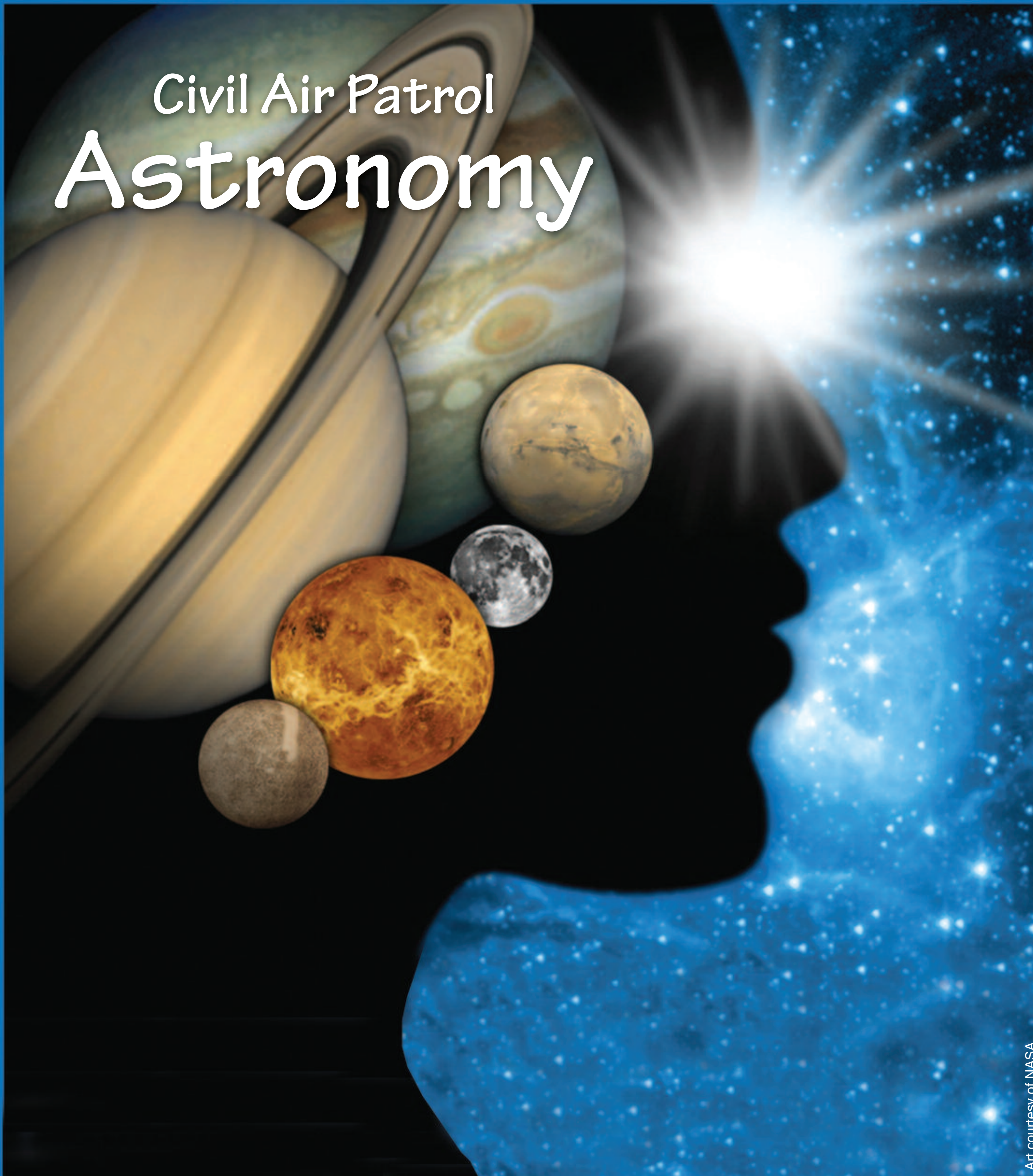
Civil Air Patrol

Astronomy



Art courtesy of NASA

Aerospace Education Excellence (AEX) Module

ASTRONOMY

Aerospace Education EXcellence Module

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INTRODUCTION

This module was developed to provide increased knowledge of and excitement about astronomy. Included is information about telescopes and their use to observe objects in our universe. Introductory activities are found at the end of each chapter. The module is designed to be taught in sequential order, as one lesson gives foundational knowledge for the following lessons. A full astronomy activity book accompanies this module and can be obtained by contacting ae@capnhq.gov.

If participating in CAP's no cost Aerospace Education Excellence (AEX) program, this module and accompanying activity book are excellent resources to use.

Not familiar with the AEX program? Any member of CAP can register for AEX online in CAP's eService's program. Participants are asked to complete any six aerospace/STEM activities plus one two-hour event. Using this module, a "Star Gazing" evening would be a perfect two-hour event. Upon program completion and reporting, participants receive nice certificates for the program. For more information, go to **www.capmembers.com/aex**.

Contacting your area Astronomical Society will enhance the star gazing event *and* bring a wealth of knowledge and experience to your astronomy program.

NATIONAL ACADEMIC STANDARD ALIGNMENT

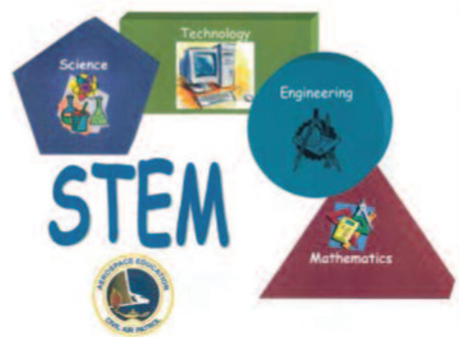
The **Science** Standards used in this publication came from the Next Generation Science Standards. These standards are based on the *Framework for K-12 Science Education* developed by the National Research Council. The *Framework* outlines the three dimensions that are needed to provide students a high quality science education. The integration of these three dimensions provides students with a context for the content of science, how science knowledge is acquired and understood, and how the sciences are connected through concepts that have universal meaning across the disciplines. The *Framework's* three dimensions are: Practices, Crosscutting Concepts, and Disciplinary Core Ideas. **Engineering** relationships are part of the Practices found in these standards. Following are the selections from each of the three dimensions of the *Framework* that apply to this publication:

Practices:

- Asking questions and defining problems
- Developing and using models
- Analyzing and interpreting data
- Obtaining, evaluating, and communicating information

Crosscutting Concepts:

- Patterns
- Systems and system models
- Structure and function



Disciplinary Core Ideas

- ESS1.A – The universe and its stars
- ESS1.B – Earth and the solar system
- PS4.A – Wave properties
- PS4.B – Electromagnetic radiation
- PS4.C – Information technologies and instrumentation

To find out more about the NGSS, go to http://www.nextgenscience.org/.

Common Core Standards for **Mathematics** (using the 6th grade standards)
http://www.corestandards.org/assets/CCSSI_Math%20Standards.pdf

- Ratios and Proportional Relationships 6.RP
- The Number System 6.NS
- Geometry 6.G

Technology Standards are from the International Society for Technology Education, known as NETS. The National Educational Technology Standards (NETS) are the standards for learning, teaching, and leading in the digital age and are widely recognized and adopted worldwide. (http://www.iste.org/standards/nets-for-students) These standards are composed of:

- Creativity & Innovation
- Technology Operations
- Digital Citizenship
- Critical Thinking
- Research & Information
- Communication & Collaboration

Astronomy Careers

Engineering Careers and Astronomy
Engineering is an important part of astronomy. Behind every piece of machinery or computer program astronomers use to make fantastic discoveries, there is an engineer or computer programmer that helped make it happen. NASA and other research institutes are always looking for talented engineers and computer programmers to help keep their machinery and programs running smoothly.

Teachers
Teaching about astronomy is one of the best jobs available. There are opportunities for teaching astronomy in high schools as well as undergraduate and graduate courses in universities and colleges. To become an astronomy teacher, you should first develop your own love for astronomy. The teaching opportunities can occur in a classroom, in a planetarium or science museum, or online. A good foundation in science and math is essential as is a college degree.

Industry and Business
Hundreds of astronomers are employed by private industry (many with PhDs). These contractors typically design and manufacture everything from telescopes to space probes, write software, and do many tasks in support of NASA labs and space missions, ground-based observatories, and data processing / management offices. Writing software is an especially fast-growing field for astronomers in private industry.

Public Relations and Journalism
Astronomers with a talent for explaining complex ideas to the general public play a big role in keeping the taxpayers informed and interested in government funded research. Every NASA mission has public relations, education, and outreach staff with astronomy expertise. Organizations like the National Academy of Sciences and the American Association for the Advancement of Science hire people with astronomy backgrounds. Companies that manufacture telescopes and space probes need knowledgeable public relations people. Also, science journalism is a growing field.

Astrophysicist
Astrophysicists study objects in the universe, including galaxies and stars, to understand what they are made of, their surface features, their histories, and how they were formed. Astrophysicists spend most of their time in laboratories and offices looking at a lot of information gathered by instruments such as telescopes, sensors, and probes. They decide what the information means and write papers and reports about what they find to advance mankind's quest for astrophysical phenomenon.

Education/Training Needed
For most careers involving astronomy, the education requirements range from at least two years of specialized training in science or science-related technology to a PhD in an astronomy-related or engineering field. An interest in solving physics and math problems, formal writing skills, and the ability to work in a team, as well as independent environment, is also important.

For more information on astronomy careers, to include geologists and mathematicians, visit http://www.sciencebuddies.org/science-fair-projects/science-engineering-careers/Astro_astronomer_c001.shtml#whatdotheydo or the American Astronomical Society website at http://aas.org/learn/careers-astronomy. The American Astronomical Society can provide mentors, demonstrations, and assorted assistance in building varied interest in astronomy careers. Find chapters near you for assistance!

AAS AMERICAN ASTRONOMICAL SOCIETY
ADVOCATES FOR SCIENCE SINCE 1899

1 TELESCOPES

Learning Outcomes

– Describe how telescopes work.
– Define the function of an eyepiece.
– Explain magnification.
– Explain field of view.
– Describe the components of both a refracting and reflecting telescope.

Important Terms

Alignment – the process of adjusting all optical elements of a telescope so that they line up along the main optical axis

Chromatic Aberration – the distortion of light when a lens fails to bring all colors to the same focal point

Convex Lens – thicker in the middle than the edges; light passing through is bent bringing the light to a central point

Concave Lens – at least one surface curves inward; the lens spreads out light rays that have been refracted through it

Field of View – the area visible through an eyepiece

Eyepiece – an assembly of lenses that magnify the image created by the main objective

Focal Length – the distance behind a lens or in front of a mirror where an image forms

Focal Plane – the plane, perpendicular to the axis of a lens, in which images are focused

Focal Point – the place at which all collected light is concentrated

Focuser – the mechanism that allows the eyepiece to be adjusted so that the image is in focus (sharp) for any given observer

Lens – an optical device that "bends" light as it goes through it; all the light is brought to the focal point at some distance behind the lens

Magnification – to magnify something in appearance, not in physical size

Main Objective – the primary optical component of a telescope

Mirror Cell – a mechanical device for holding a primary mirror in place and allowing for adjustments (alignment)

Mount – mechanical device for holding a telescope and accurately pointing it

Power – the amount of magnification; the number represents how many times an object is enlarged compared to its size when viewed with the unaided eye

Parabola – a geometric shape in the form of an open curve; when used as the shape ground into a telescope mirror, it reflects all light falling on it to the focal point at some distance in front of the mirror

Primary Mirror – the mirror that collects the light from an object in a reflecting telescope

Secondary Mirror – the mirror that directs the focused light from an object toward the focuser and eyepiece

Spider – a mechanical device for holding a secondary mirror in place and providing for adjustments

Reflection – the process of redirecting a light back to its source

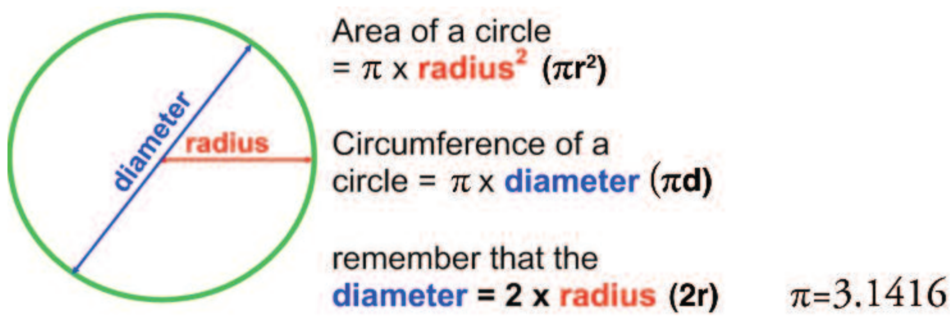
Refraction – the bending or redirection of light as it passes through a lens

MANIPULATING LIGHT

The night sky has always been a source of wonder to man. The invention of the telescope and its use to observe the heavens opened up a realm of new knowledge and the desire to understand the cosmos. Galileo Galilei (1564-1642) made improvements to the rudimentary telescopes of his time and was one of the first to use these instruments for the study of the heavens. Then, years later, Sir Isaac Newton (1642-1727) invented a different type of telescope to solve some problems inherent in the ones being used.

Telescopes allow us to view distant objects and make them appear closer. Telescopes use mirrors and lenses to gather light and create a higher magnification and resolution than the human eye. Telescopes come in all shapes, sizes and costs. Telescopes range from toy telescopes up to NASA multi-million dollar telescopes that are orbiting around us in space.

The function of the telescope is to gather as much light as possible. That is, the bigger the area of the main optical element (***Main Objective***) the more light that can be gathered. For example, a mirror 6 inches in diameter has an area of 28.3 square inches, while a 12-inch mirror has an area of 113.1 square inches, or almost four times that of a 6-inch mirror. This is why astronomers strive to construct bigger and bigger telescopes as technological advances make it possible.



As the main objective gathers light, it brings it to a point **(focal point)** where a very small image of the object being observed is formed. The eyepiece then enlarges this image. We will cover these functions in more detail later.

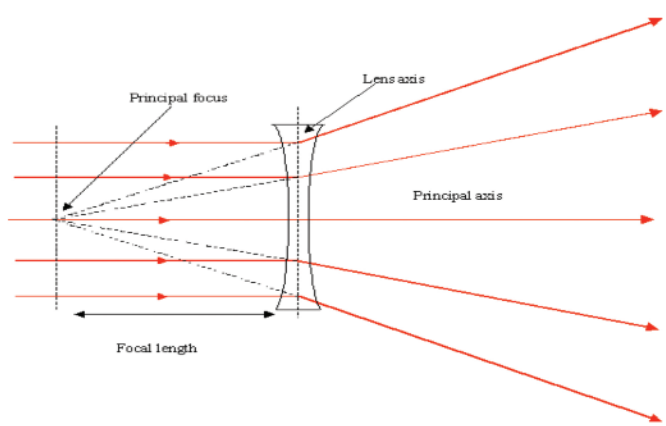
There are two basic lens shapes in telescopes: ***concave lens*** and ***convex lens***. These lenses control how the gathered light is transferred (focused) to form an image the telescope viewer observes.

LENS

Concave lenses known as diverging lenses, are wider on the edges than in the middle. At least one side of a concave lens must curve inwards.

Concave lenses reflect light outwards. This spreads the light rays outward, which will create an image upright and smaller than the actual object. The image created by a concave lens will appear farther away than it is. A diverging lens refracts any light ray parallel to its axis as if it came from a focal point.

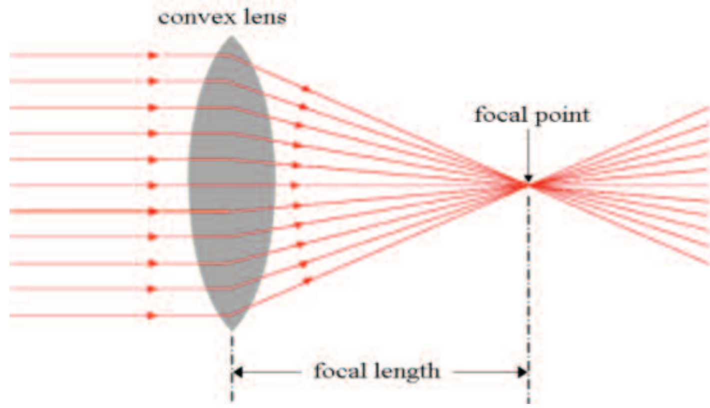
Parallel rays of light pass through the concave lens and the refracted rays move away to make it appear to come from the principal focus.



Credit: Antonine Education Website

CONCAVE LENS

Convex lenses, known as converging lenses, are wider in the middle than the edges. A converging lens takes the beam of light passing through it and brings it to a point of focus. The light rays passing through a convex lens are parallel to its principal axis. Two or more light rays passing through a convex lens are bent, bringing the light toward a central point. Thicker lenses bend light more and are more powerful. The more powerful the lens the shorter the focal point. Convex lenses make things bigger and bigger as you move it away. While the image will get bigger and bigger, it will also be blurrier.



Credit: Dirac Delta Science and Engineering

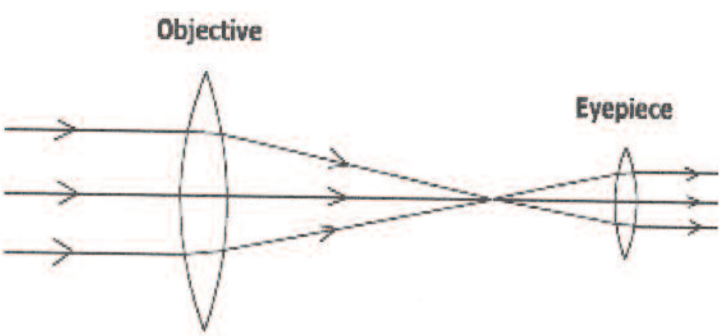
CONVEX LENS

There are two basic types of telescopes: ***refractors*** and ***reflectors***. The part of the telescope that gathers light determines whether it is a refracting or reflecting telescope.

REFRACTING TELESCOPE

Refracting telescopes use a lens to bend and redirect the light to a single point (called the ***focal point***) at a distance behind the lens called the ***focal length***. At the focal point, a very small image of the object being observed is formed. This image is bright because all the incoming light has been concentrated to form it. An ***eyepiece*** is focused at this point to enlarge (magnify) the small image so that details can easily be seen.

A refracting telescope has two basic components; a convex lens and an eyepiece lens. The telescope refracts (or bends) light at the large end and bends the light again at the eyepiece. The bent light creates parallel light rays that unite at a focal point and the unparalleled rays gather on the ***focal plane***. This allows distant objects to appear larger and more visible. A refracting telescope works the same as binoculars. The largest refracting telescope is at Yerkes Observatory, in Williams Bay, Wisconsin; a facility of the University of Chicago.



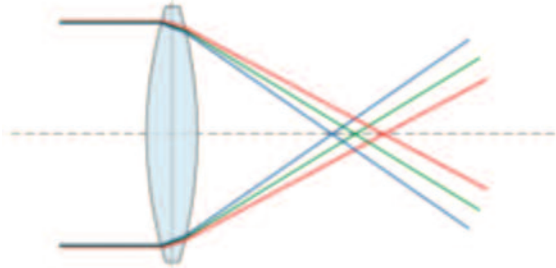
Credit: Las Cumbres Observatory

REFRACTING TELESCOPES USE TWO OR MORE LENSES TO GATHER AND FOCUS LIGHT

Credit: DLC Science

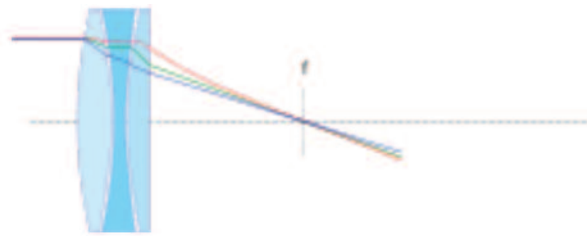
REFRACTING TELESCOPE

Chromatic aberration is a common optical problem that can make images blurred or cause colors around the edges of objects. Chromatic aberration is also known as "color fringing" or "purple fringing." As the light goes through the glass and is bent, the different colors making up the white light are bent at different angles. Therefore, they do not all come together at the focal point. This makes the image have a rainbow-like halo around the edges just as a prism takes a beam of white light and creates a rainbow of colors. To correct for chromatic aberration, opticians developed the apochromatic lens. These lenses are made up of two types of glass, (crown and flint), with optical qualities that cancel each other's aberration resulting in an image free of color separation. The glass elements are either cemented together or mounted with an extremely small space between them.



Credit: Vision Engineering

CHROMATIC ABERRATION



Credit: Vision Engineering

APOCHROMATIC DOUBLET

REFLECTING TELESCOPE

As the name implies, reflecting telescopes use a ***primary mirror*** to reflect the light to a single point in front of it. The shape ground on the mirror's surface is that of a ***parabola***. We find parabolas in use all around us. Have you looked closely at the dish used to receive satellite TV signals? The dish's shape is a parabola so that all the incoming signals are concentrated in a receiver held in an arm in front of it. What about the headlights on a car or a flashlight? You guessed it; that shiny reflector behind and around the bulb is in the shape of a parabola.

The reflecting telescope requires a second mirror appropriately called the ***secondary mirror***. This flat mirror will direct the light coming from the main objective towards the side and out of the telescope through a hole cut on the side of the tube.

Look at the mirror in your bathroom's medicine cabinet. The reflective coating on the back of the mirror protects it from oxidation and damage. This is not possible on telescope mirrors. The back of the mirror is flat and the reflective coating (most of the time aluminum) must be in the front surface so that it has the required parabolic shape. In addition, if the light went through the glass it would be distorted producing chromatic aberration.

Alignment of the optics is extremely important. All optical components must be centered and aligned with the main optical axis of the telescope. Any deviation will yield a very poor, out of focus image or, in the worst of cases, no image at all.

Refracting telescope components are usually mounted in finely machined housings that are strongly attached to the telescope tube. Reflectors, on the other hand, have more components making the alignment complex and requiring ways to make adjustments. The primary mirror is mounted on a ***mirror cell*** that is attached to the bottom of the tube. Ideally, the mirror "floats" in the cell to prevent any pressure points that would cause the mirror to become distorted. The secondary mirror is mounted on a holder called a ***spider***, which is attached toward the front end of the tube. Both the cell and spider have adjustment screws to allow for alignment.

Credit: North Instrument Technology Industries Group

NEWTONIAN EQUATORIAL REFLECTING TELESCOPE

FOCUSER

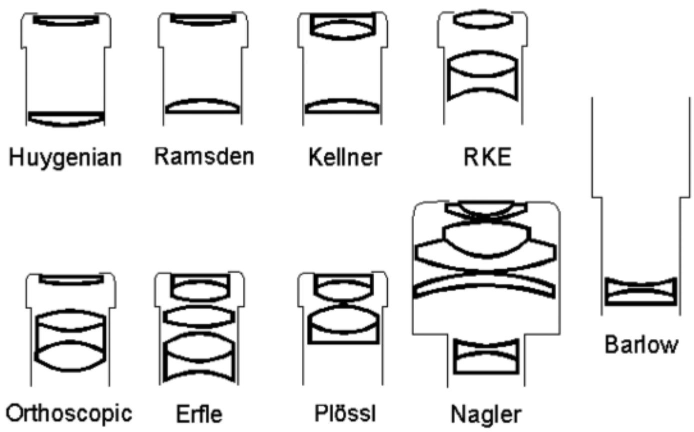
The ***focuser*** is a mechanical device, which holds the eyepiece and allows the user to adjust the telescope to bring the image to a sharp focus. There are various mechanical designs, even some electrically operated, but the result is the same; to provide a sharp image for the user.

Credit: Orion Electric

FOCUSER

EYEPIECE

The ***eyepiece*** is a magnifier similar to the hand-held magnifiers found in many households. Most eyepieces have complex optical designs to achieve certain desired effects. Today's modern eyepieces achieve images undreamed of by early astronomers but their price can exceed the cost of the entire telescope. Eyepieces are named either after the opticians who designed them or by the manufacturer.



Credit: Universe Today

EYEPIECES

Credit: Wikipedia

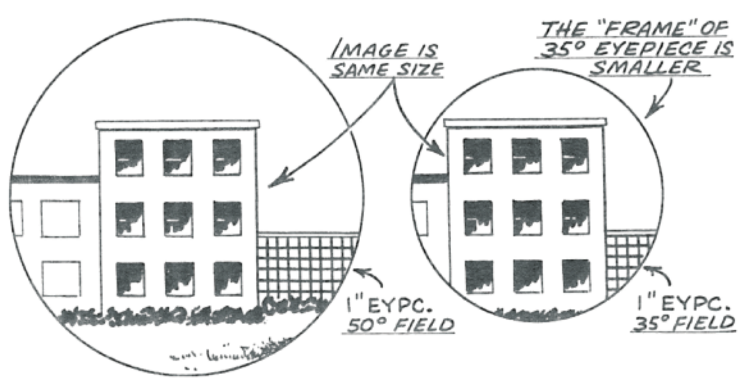
EYEPIECES

Besides their name, eyepieces are described by their focal length, usually given in millimeters (mm). The ***power*** (magnification) yielded by using an eyepiece with a specific telescope can be obtained with a simple formula:

POWER = FOCAL LENGTH OF TELESCOPE ÷ FOCAL LENGTH OF EYEPIECE

For example, if we use a telescope with a focal length (f.l.) of 100 inches (2500 mm) with an eyepiece of 25 mm f.l. we get 100X power (power is indicated by the letter "X") and we will see the object 100 times bigger than with the unaided eye.

Eyepieces with the same focal length can have different ***fields of view*** depending on their optical design. Take a close look at the drawings to right:



Credit: "How to Use Your Telescope" published by Edmund Scientific Co.

FIELD OF VIEW

Notice that both views are through eyepieces with one-inch focal length. The size of the building is also the same, but the left-hand diagram shows more of the buildings on either side. The right-hand view shows mostly the building. Also, notice that the left side is labeled "50° (degrees) field" while the right is labeled "35° field." The larger the field of view of an eyepiece the greater the area you will see. Astronomers will choose wide or narrow field of view eyepieces depending on what they wish to observe. For example, when viewing a star close to the Moon, an astronomer will choose a narrow field eyepiece to keep as much of the bright moonlight out of the way.

MOUNT

The way a telescope is mounted and supported is as important as the optics and other components. The ***mount*** gives an extremely stable platform to support the optical tube and allows the instrument to be carefully pointed to any celestial body.

Most mounts allow the telescope to move in two axes that are 90 degrees opposite from each other. The two most common mount designs are the equatorial and the altazimuth.

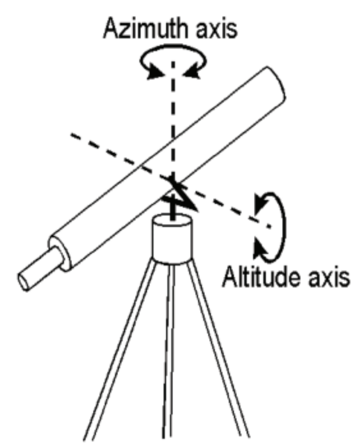
The equatorial mount is adjusted to an observer's latitude and the polar axis is pointed north towards Polaris, the North Star. This axis is often driven by an electric motor that is geared to compensate for the rotation of the Earth. This allows the instrument to track celestial objects for long periods. The second axis, 90 degrees opposite the polar axis, allows the telescope to be pointed toward any object in the sky.

Credit: Derby and District Astronomical Society

TELESCOPE ON EQUATORIAL MOUNT

The altazimuth telescope mount's name is made up of the words "altitude" and "azimuth." The altitude axis allows the telescope to be moved up and down while the azimuth axis moves the telescope around. The instrument can then be pointed towards any object in the sky by moving it along these two axes.

John Dobson, an amateur astronomer, popularized the altazimuth telescope mount because it allowed anyone with basic woodworking skills and tools to build large reflecting telescopes. These scopes are called Dobsonian telescopes.



Credit: Morehead Planetarium and Science Center

ALTAZIMUTH TELESCOPE MOUNT

Today's telescope mounts have many auxiliary and variable-speed slow motion controls to make it easier to point the instrument. Built-in microprocessors hold information on thousands of objects and help the user find these objects in the sky.

The introduction of GPS receivers has taken the work out of adjusting the mount to the proper altitude and northward alignment. All the user has to do is to turn on the power to the mount and wait as the GPS determines its location and, along with the built-in computer and drive motors, perfectly aligns the instrument so that it can find and track any object the astronomer wants to observe. These telescopes are referred to as GoTo telescopes.

1 Identify telescopes and components

EXERCISE ONE

WARNING !!! – NEVER LOOK AT THE SUN OR OTHER EXTREMELY BRIGHT OBJECTS THROUGH ANY OPTICAL DEVICE

You will need:

Ask the cadets in your squadron or students in your class if they have telescopes, spy glasses, etc. Request that they bring them for this activity.

Procedure:

1. Carefully examine each optical device and try to identify its components. Check for:
   - Type of telescope
   - Main objective (lens or mirror)
   - Secondary mirror
   - Lens or mirror cell
   - Spider
   - Focuser
   - Eyepiece (identify the eyepiece focal length and field of view if so labeled)
   - Mount

2. Look for poor designs or mechanical problems such as:
   - Wobbliness of mount
   - Excessive play in focuser mechanism
   - Poor fit of eyepieces in focuser
   - Sloppy slow motion controls
   - Difficulty in making any adjustments

You will find that inexpensive telescopes often have many of the mechanical problems listed above. In addition, the optical elements are of low quality and yield poor images.

1

Determining focal length of magnifying mirrors and lenses

EXERCISE TWO

WARNING !!! – DO NOT USE SUNLIGHT TO PERFORM THE FOLLOWING EXPERIMENTS

You will need:

Magnifying mirrors; handheld magnifiers; a strong light source, such as a table lamp with the shade removed; a piece of white paper or cardboard to act as a screen

Procedure:

1. Hold the mirror at least five to ten feet from the light source (to ensure light rays are fairly parallel to the mirror surface).
2. Place the screen to the side and forward of the lamp.
3. Hold the mirror at a slight angle to the lamp so that the image is formed to the side on the screen.
4. Move the screen back and forth until you get a sharp image of the bulb.
5. Have someone else measure the distance from the mirror to the screen while you hold everything steady. This distance is the focal length of the mirror.
6. Repeat the experiment with the handheld magnifier.
   - Place a magnifier between the lamp and the screen.
   - Move the screen back and forth until you get a sharp image of the bulb.
   - Have someone else measure the distance from the bulb to the screen while you hold everything steady. This distance is the focal length of the magnifier.

QUESTION: Why is the projected image upside down?

ANSWER: The magnifying glass is a lens. All the light coming from one spot on one side of the lens is bent so that it is concentrated (focused) through a single point on the other side.

2 THE EARTH AND THE NIGHT SKY

Learning Outcomes

– Define mean solar time and sidereal time.
– Define Universal Time (UT) or Greenwich Mean Time (GMT).
– Define declination and right ascension.
– Describe the celestial equator.
– Identify a constellation.
– Define an asterism.

Important Terms

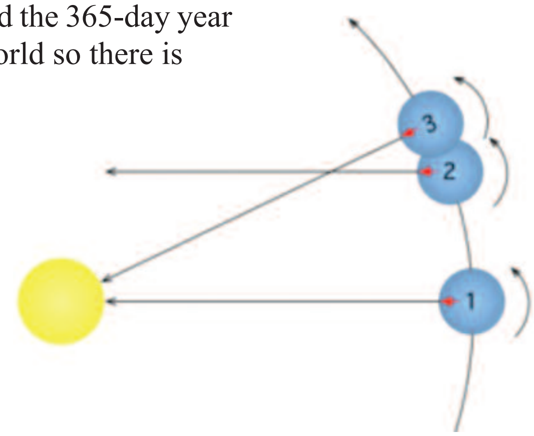
Apparition – a period of time that a planet can be seen
Asterism – a group of stars easily recognizable; the stars may be part of one or more constellations
Celestial Equator – Earth's equator extended infinitely into space
Constellation – a group of stars that, to ancient observers, represented a figure in the sky; most constellations are associated with a mythological person, an animal, or an object
Daylight Saving Time – resetting clocks one hour ahead on the second Sunday of March and reset back one hour on the first Sunday in November
Declination – angular distance measured north or south of the celestial equator
Equator – divides Earth into the northern and southern hemispheres; located at zero degrees latitude
Ecliptic – the apparent path of the Sun across the sky as seen from Earth's center
First Point of Aries – meeting point of the vernal equinox and the ecliptic over two thousand years ago; used to mark the first hour of right ascension
Fixed Stars – any star that does not seem to move in relation to the other stars in the sky
Greenwich Mean Time (GMT) – an absolute time reference and does not change with the seasons; also called the UTC (Coordinated Universal Time)
Latitude – the angular distance, in degrees, minutes, and seconds, of a point north and south of the equator
Longitude – the angular distance, in degrees, minutes, and seconds, of a point east and west of the prime meridian
Mean Solar Time – average time used by clocks around the world based on Earth's rotation relative to the Sun
Meteor – a bright light that appears when a meteorite enters Earth's atmosphere
Planisphere – a star chart that can be set to show the visible constellations for any given day and time
Precession – the slow and continuous changes in the rotational axis or orbital path of celestial bodies; Earth's axis takes close to 26,000 years to complete one revolution
Prime Meridian – the geographical zero degree of longitude located at the Greenwich Observatory, a suburb of London, England
Right Ascension – like longitude, it locates where a star is along the celestial equator
Sidereal Time – time scale based on Earth's rate of rotation relative to the fixed stars
Time Zone – area, from the North to the South Poles, 15 degrees in longitude, which keep the same time
Universal Time – time measured from the prime meridian at the Greenwich Observatory; also referred to as Greenwich Mean Time (GMT)
Vernal and Autumnal Equinoxes – the two points at which the celestial equator and the ecliptic meet
Summer and Winter Solstices – the two points on the celestial sphere where the Sun has a maximum separation from the celestial equator; in summer, it is above the celestial equator and, in winter, it is below

AROUND AND AROUND WE GO

Anyone who has spent an evening looking at the stars has noticed that they seem to rise in the east, travel across the sky and then set in the western horizon. In reality, the effect is due to the rotation of Earth on its axis from west to east. We don't feel Earth moving (about 1,040 mph at the equator) but it is and we, as passengers on "Spaceship Earth," go along for the ride.

If you concentrate on a particular star (pick a bright one), watch it for consecutive evenings, and keep track of the time when it rises above a given point on the eastern horizon, you will notice that it comes up about 4 minutes earlier from evening to evening. Why would that be? Earth turns on its axis once in 24 hours or one day…doesn't it? Well, almost. We use a 24-hour cycle to describe a day because it is convenient. Actually, Earth's rotation on its axis is 23 hours, 56 minutes, and 4.99 seconds, and this is the reason why stars rise about four minutes earlier each day. This is called ***sidereal time*** or star time. The 24-hour day is called a solar mean day because it is an average that is based on Earth's orbital speeds that vary throughout the year. Additionally, we use 365 days when we talk about Earth's revolution around the Sun, but it actually takes 365.242199 days. These additional hours explain why we have a leap year every four years. Using 365 days as the standard year is actually referred to as ***mean solar time***. So, the 24-hour day and the 365-day year are really averages used by the world so there is a standard clock time.

SIDEREAL TIME



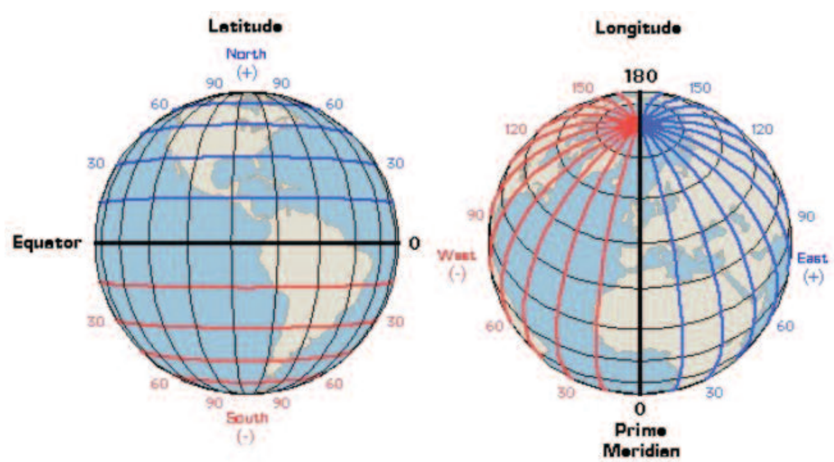
1. A given star and the Sun are overhead at the same time.
2. The star is overhead (sidereal day, about 23 hrs, 56 min) but not the Sun.
3. Sun is overhead again (mean solar time, 24 hours).

Credit: principles.ou.edu

FINDING OUR WAY AROUND

To find our way on Earth we use a system of coordinates called ***latitude*** and ***longitude***. To review, latitude is measured in degrees, minutes and seconds going either north or south (or parallel) of Earth's equator. The equator is located at zero degrees latitude. Longitude is measured eastward or westward (or perpendicular to the equator) from the ***prime meridian*** (zero degree) located at the Royal Observatory in Greenwich, a district in southeastern London, England. Longitude is also measured in degrees, minutes and seconds. Today's Geographical Positioning System (GPS) receivers can provide your exact geographical location very quickly.

Originally developed for the military, GPS is used today in commercial and sport aviation as well as in automobiles, handheld units and cellular telephones.



LATITUDE AND LONGITUDE

Credit: Wilderness Navigation

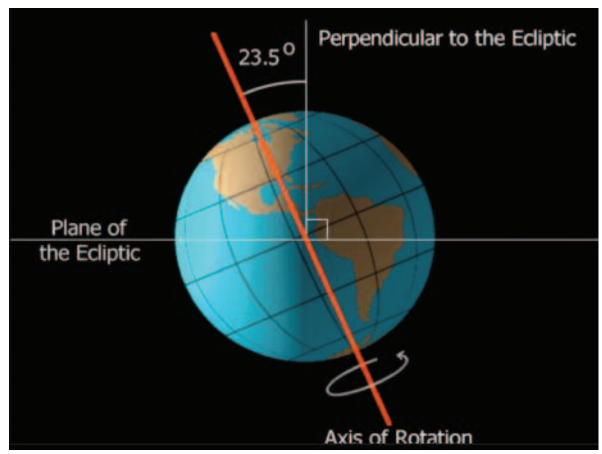
Credit: Wikipedia Commons

GREENWICH, ENGLAND

Credit: Wikipedia Commons

GREENWICH OBSERVATORY
Brass bar imbedded in ground to show location of prime meridian

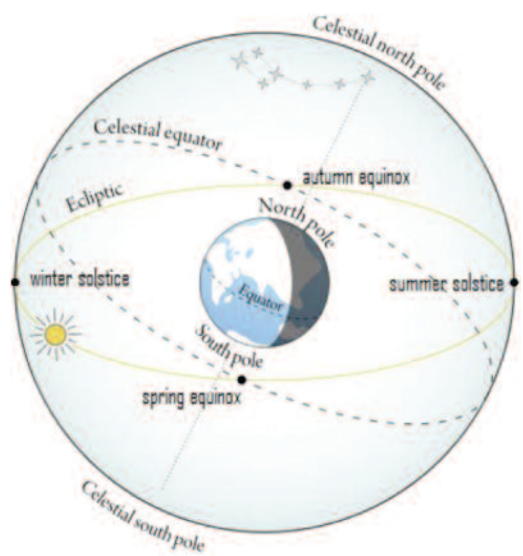
Astronomers also use a similar system to locate objects in the night sky. Our night sky is part of the celestial sphere, which is an imaginary sphere projected from Earth out into our universe, including all of the celestial bodies. This system uses ***declination*** (similar to latitude) and ***right ascension*** (similar to longitude) to assign coordinates. Declination is expressed as an angular distance projected on to the celestial sphere and measured in degrees, minutes and seconds.



Credit: Science Blogs

TILT OF THE EARTH

There are 24 hours of right ascension and each hour is the same as 15 degrees of longitude (24 hours x 15 degrees = 360 degrees). The first hour starts at the intersection of the celestial equator and the ecliptic called the ***vernal equinox***. When the equinox was first observed thousands of years ago, it actually laid in the constellation Aries (the Ram) so it was called "***the first point of Aries***." Due to an effect called ***precession***, the slow and continuous changes of the rotational axis or orbital path of a celestial object, the vernal equinox is not a fixed point in space. Earth's axis rotates slowly westward along the poles of the ***ecliptic***. It takes about 26,000 years to complete one trip. The ecliptic is the point where astronomers start to locate every star, nebula, and galaxy. It is the plane of Earth's orbit around the Sun that moves along the ecliptic at a rate of approximately one degree every seventy-two years. Today, this point is in the constellation Pisces (the Fishes).



Credit: Earth Sky

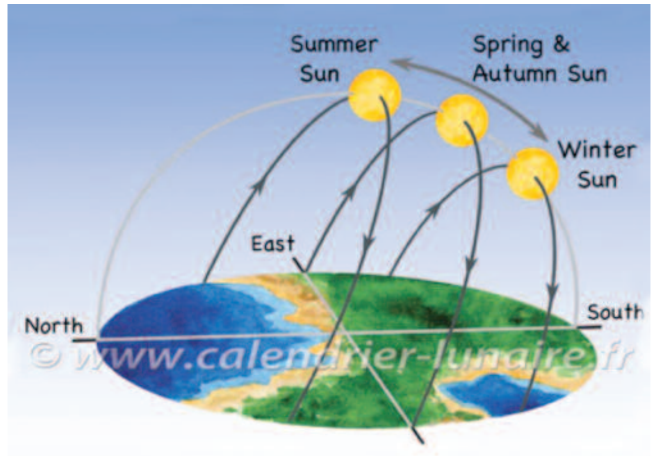
VERNAL EQUINOX

The celestial equator is an imaginary line that runs along the same plane as Earth's equator. It is always 90 degrees from the poles.

It is considered positive (+) if north of the celestial equator and negative (-) if south of the celestial equator.

THE SEASONS

If you pay attention to sunrises and sunsets, you will notice that the Sun appears and disappears at different locations and at different times. This is due to the tilt of Earth's axis in relationship to the plane of its orbit around the Sun. The tilt is 23.5 degrees from the perpendicular to the orbital plane. The tilt of Earth's axis causes the hemispheres to receive different amounts of the Sun's energy. This tilt causes our seasons.



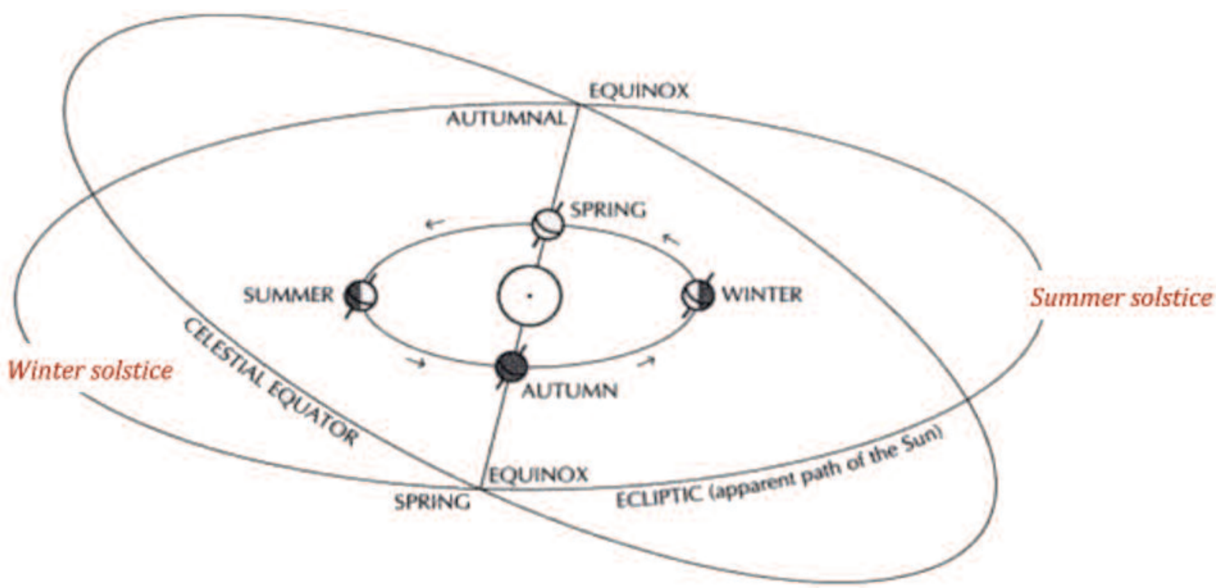
Credit: Calendrier Lunaire Diffusion

The Sun reaches its highest point in the summer months

For all practical purposes, over the life of a person or even during several generations, the direction to which the axis points hardly changes.

There are four points on Earth's orbit around the Sun that are of particular importance; the equinoxes and the solstices.

Before going any further let us answer why the date of these events varies. We learned that Earth revolves or orbits the Sun in 365 days. Well, in reality it takes 365.242199 days. That means that for every 365-day year that passes the Earth falls roughly one quarter of a day or 6 hours behind. To make up for this "lost" time we add one day to every fourth year. A year with this extra day is called a leap year. The extra day is added to the month of February so that it has 29 days rather than the regular 28. In addition, precession of the Earth's axis and gravitational pull of other planets affect the Earth's orbit and its arrival at the points of equinoxes and solstices.



Credit: thesociety.org

EQUINOXES AND SOLSTICES

Vernal or ***spring equinox*** is said to mark the beginning of spring. This doesn't mean that on that particular day (March 20 or 21) the flowers and trees will bloom. It does mean that the Sun's center is at the intersection of the ecliptic and the celestial equator. On this day, the Sun rises directly due east and sets directly due west. On the equinoxes, we experience days with equal number of daylight and nighttime hours. The same happens six months later when Earth is on the opposite side of its orbit and the ***autumnal*** or ***fall equinox*** takes place (September 22 or 23).

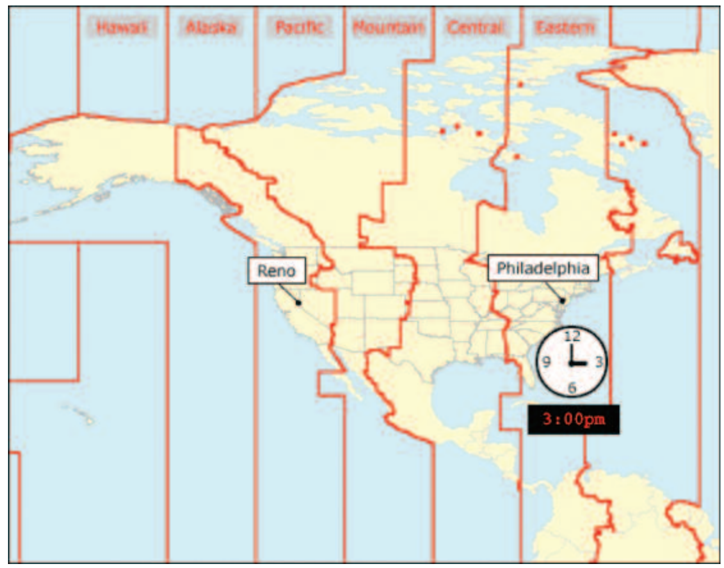
The ***summer solstice*** marks another special position. On this day (June 20 or 21), the axis of Earth is tilted towards the Sun on the northern hemisphere. We experience the earliest sunrise and latest sunset of the year. The Sun is high above the southern horizon at local noon. This day has the longest period of daylight of the year. Six months later, we experience the ***winter solstice*** (December 21 or 22). Now, the axis of Earth is tilted away from the Sun on the northern hemisphere. We experience the latest sunrise and earliest sunset of the year. The Sun is at its lowest on the southern horizon at local noon. This is the day with the shortest period of daylight of the year.

TIME

We use 24 hours to measure one day of time and we assign 15 degrees of longitude to each hour. We call these time segments ***Time Zones*** (360 ÷ 15 = 24). There are four time zones across the contiguous United States. From East to West they are; Eastern, Central, Mountain, and Pacific. The non-contiguous states' time zones are Alaska Standard and Hawaii-Aleutian.

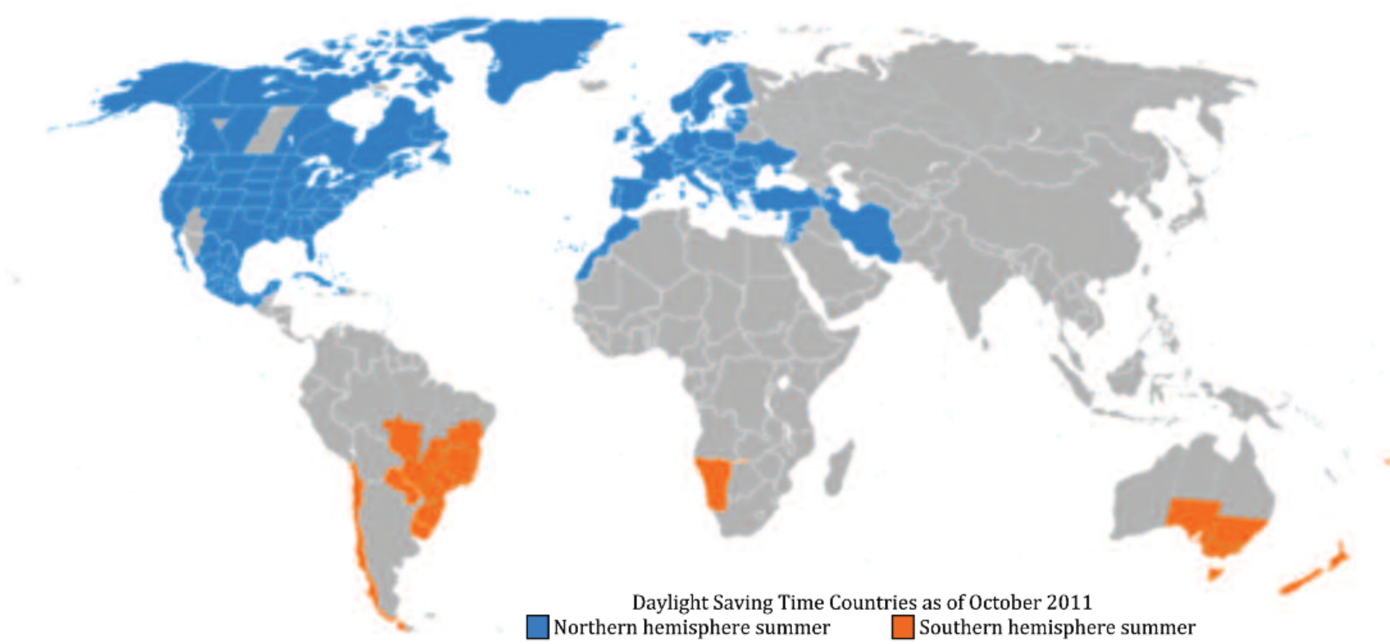
The prime meridian is the starting point for time-keeping. As we go west from the prime meridian, we are at earlier times. For example, when it is 1:00 a.m. on a Monday in Greenwich, England, it is 8:00 p.m. on Sunday in New York.

Daylight Saving Time is the practice of advancing clocks so that evenings have more daylight and mornings have less. Typically, clocks are adjusted forward one hour near the start of spring and are set back one hour in autumn. Benjamin Franklin mentioned the idea in 1784 but it was not implemented until World War I. This helped reduce the demand for electricity used to illuminate factories and homes.



Credit: Exploring Earth

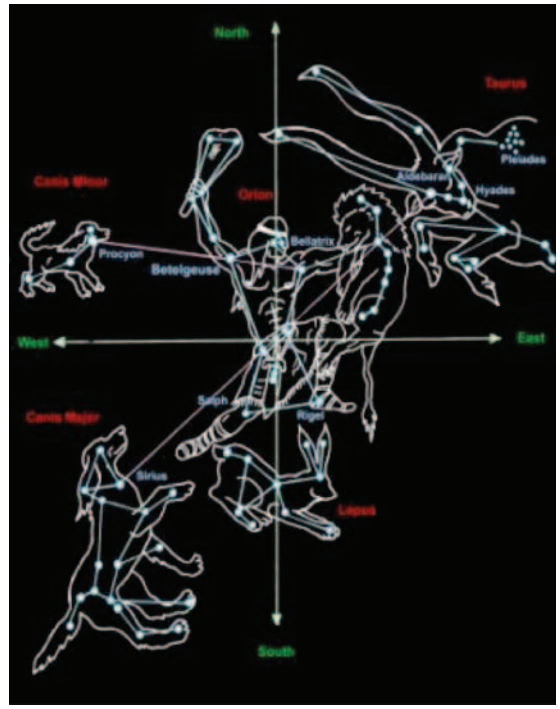
TIME ZONES IN THE UNITED STATES



Credit: Wikipedia

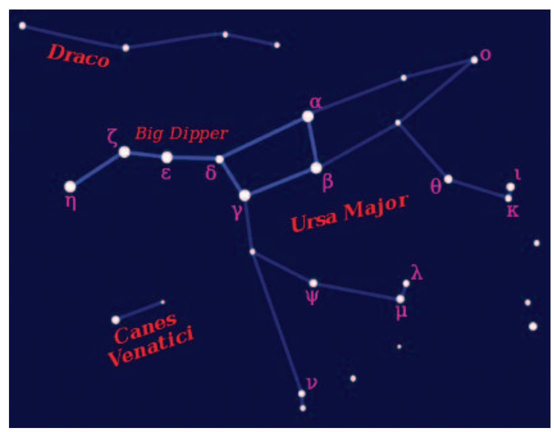
CARINA (KEEL OF A SHIP) CONSTELLATION

Credit: deorbit.com



ORION- THE HUNTER

Credit: Bramwell International



BIG DIPPER

Credit: Wikipedia

MYTHOLOGY AND CONSTELLATIONS

Ancient civilizations took the characters of their legends and myths and envisioned them in the night sky. They would look for a group of bright stars and, drawing imaginary lines, connect them to form stick figures representing the images called constellations. The stars in any given constellation have nothing in common. They can be thousands of light years away from each other, but as seen from our viewpoint they form these patterns.

These manmade patterns would look very different if they could be observed from outside our solar system, such as the center of our home galaxy, the Milky Way. All the stars you can see with your unaided eye are part of the Milky Way. We cannot see stars in other galaxies without the aid of a telescope.

Some constellations have come and gone as the civilizations that created them rose and fell. Today, there are 88 official constellations. In 1922, the International Astronomical Union**,** a worldwide organization of astronomers, recognized the 88 constellations and established boundaries for each one.

Astronomers use the name of constellations, as well as the stars within them, as a quick reference to a given part of the sky. For example, if an astronomer refers to the star α Orionis (α = Greek letter "a," called "alpha"), he is referring to the brightest star in the constellation Orion (the Hunter). It is not unusual for the brightest stars in constellations to have names. The name of α Orionis is Betelgeuse, and it indicates the location of the hunter's right shoulder. Betelgeuse means *Yad al-Jauzā'* meaning "the Hand of *al-Jauzā.*" Many individual star names, like Betelgeuse, are Arabic in nature. The Arabs were students of astronomy and mathematics.

Before we go any further, let us correct a common misunderstanding. The group of seven stars we call "The Big Dipper" is not a constellation. The Big Dipper is called an ***asterism***. An asterism is a group of stars that, due to brightness and/or configuration, is easy to recognize. The Big Dipper is made up of the brightest seven stars in the constellation Ursa Majoris or the Big Bear. The same holds true for "The Little Dipper" which is made up of stars in the constellation Ursa Minoris or the Little Bear.

ASTEROIDS, COMETS, METEOROIDS, METEORS, AND METEORITES

Asteroids, meteors and meteorites are terms that are often confused and misused. Asteroids have no atmosphere, are too small to be a planet, and they range from a few feet to several miles across. Ceres is the largest know asteroid at 590 miles wide. Asteroids orbit the Sun and are made of rock, carbon or metal. Some asteroids have moons, and some form a binary system, in which two same sized asteroids orbit each other. There is an asteroid belt between the orbits of Mars and Jupiter. This is different from the asteroid belt called Kuiper, where the dwarf planet Pluto is one of the objects in the belt.

A comet is composed of dirt and ices, and can grow a tail as it travels toward the Sun. Comets originate in the outer solar system but some can be pulled into the inner solar system. When they are far away from the Sun, it is hard to tell the difference between a comet and an asteroid.

A meteoroid is a small particle from an asteroid or a comet. It is bigger than a grain of salt but smaller than an asteroid. There is a fine line in distinguishing between an asteroid and a meteoroid.

A ***meteor*** is an asteroid or other object that burns and vaporizes upon entry into Earth's atmosphere. Meteors are commonly referred to as "shooting stars." Small meteors light up the sky for only a brief period. The larger the meteor, the longer time it is visible. It can appear brighter as it burns up. Brighter meteors can be seen during the day, but are best viewed at night. Several times during the year, there are large numbers of meteors that can be seen in a short period. This is called a meteor shower. Earth Sky, www.earthsky.org, has a monthly meteor shower guide. Other websites and phone apps can also tell you when these meteor showers will occur, and when is the best time to view them.

An unusually large or bright meteor is called a fireball. For a meteor to be a fireball, the meteor must be as bright as Venus. A meteor this bright is probably a couple meters in diameter when it enters Earth's atmosphere. Fireballs sometimes emit a sound and can create a sonic boom. They can be visible for several minutes.

If the meteor survives the trip through the fiery atmosphere and lands on the surface of Earth, it is known as a meteorite.

SIRIUS

Sirius is one of the easiest stars to find in the sky. Sirius is the brightest star in the night sky, and most people in the northern hemisphere will spot Sirius in the south, southeast or southwest from winter to mid-spring. Although white to blue-white in color, Sirius might be called a *rainbow star*, as it often flickers with many colors. This is because the bright light of Sirius shines through our atmosphere. The changes in density and temperature of the air affect the light and cause the twinkling and the colors we see in Sirius. This also happens to other stars, but since Sirius is so bright we can see the changes more prominently. Sirius will rise in the southeast and set in the southwest. You can also find Sirius by locating Orion's belt and following a straight line from his belt down to the left. The distance will be roughly eight times as far as the belt is wide.

STAR CHARTS

Remember that astronomers use the system of coordinates (right ascension and declination) to map the night sky. Recall the information learned earlier about the celestial equator and the ecliptic. We will now turn our attention to the maps or charts of the firmament, or the field of the sky. There are many versions of the night sky but they all show the same constellations, stars, etc., just like there are different types of terrestrial maps that show the same area of Earth's surface.

Maps for beginner stargazers usually show only the brighter stars and have lines connecting the stars that make up constellations for easy identification. Regardless of the level of familiarity with the sky, an observer tends to match his star map to the observing conditions where he lives. Today, this is easy to do because star maps can be customized, downloaded and printed from the Internet. The website **www.fourmilab.ch/yoursky** is one of many. You can indicate your location by typing in your latitude and longitude (they don't have to be exact). You may also choose the date and time, magnitude (brightness of the stars you want shown), etc., for your map.

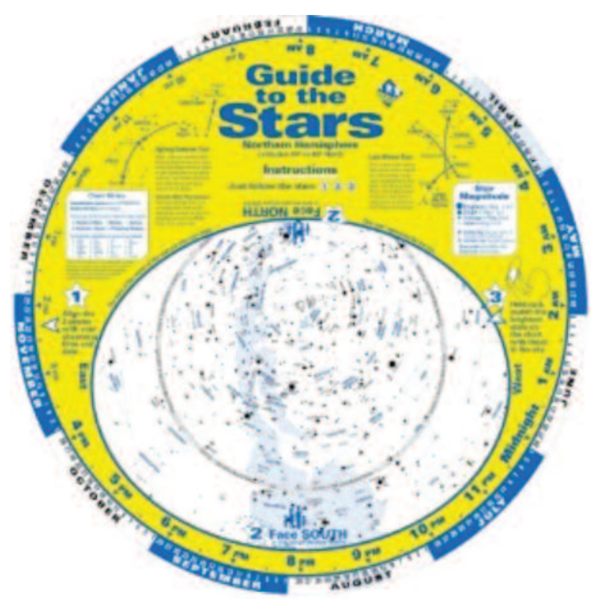
There are many websites and apps that provide star maps, teaching aids, etc. Use your favorite search engine to look for these and others:
www.science-teachers.com/constellation_flashcards.htm
www.skymaps.com/downloads.html
www.midnightkite.com/starcharts.html

PLANISPHERES

A ***planisphere*** is a perpetual star chart. It can be adjusted to show the visible night sky for any date and time. It consists of a circular star map showing all the stars in the sky. The months and days are shown on a scale on the outer edge of the chart. The chart is inside a holder with a window through which you can see some of the stars. The holder has a scale that shows the time in hours. All you do is turn the star chart to align the date and time of your choice. The stars that show through the window are the ones you can see in the sky.

Credit: Philips' Planisphere

PHILIPS' PLANISPHERE



Credit: Skie's Unlimited

GUIDE TO THE STARS

Make a model of Earth and the Sun and demonstrate the position of the equinoxes and solstices

2

EXERCISE ONE

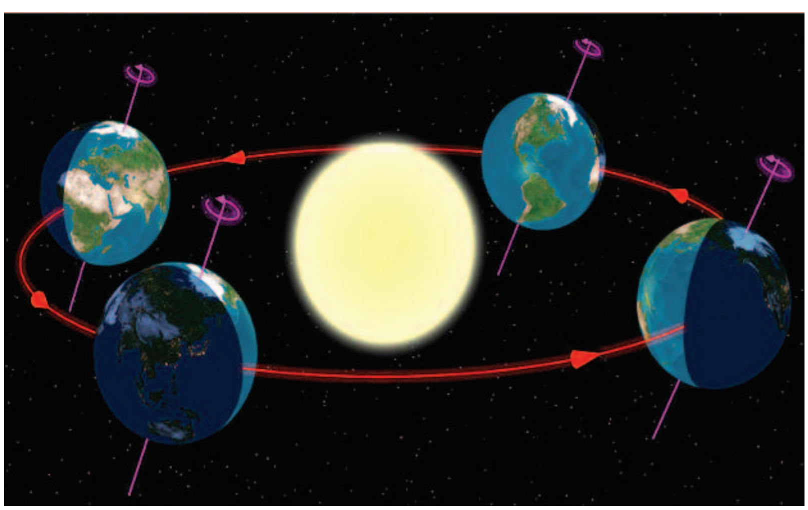
You will need:

- Any sphere, such as a Styrofoam ball, an orange, etc., that can be pierced; to represent Earth
- Bamboo skewer, small diameter dowel, pencil, knitting needle or other shaft to act as the axis of rotation of Earth
- Floor lamp or table lamp with the shade removed to represent the Sun

Procedure:

1. Place the lamp (the Sun) in center of room and turn it on.
2. Pierce your sphere (Earth) with the shaft so that it runs through the center. This is the axis.
3. Hold "Earth" in your hand and tilt it so that the axis is approximately a 23.5 degree angle from the perpendicular to the floor.
4. Pick a point in the room and hold "Earth" so that the axis points to it.
5. Walk around the lamp (the Sun) in a circular pattern keeping the axis aiming at the point you picked. Notice the "daylight" and "night" portion of Earth and the position of the axis.

When the northern end of the axis is at its farthest tilt towards the Sun, you have the summer solstice. When the northern end of the axis is at its farthest tilt away from the Sun, you have the winter solstice. At ninety degrees from the solstices you have the equinoxes.



Credit: Tau'olunga

EARTH'S TILT ACCOUNTS FOR A SEASONAL CHANGE

Time the rising of a given star above the eastern horizon

2

EXERCISE TWO

You will need:

- Clear nights
- A clear view of the eastern horizon
- Unusual landmark, such as a radio or cellular telephone tower; a power or telephone pole will also work
- A watch
- Pen and paper to keep a star-rise time log (note the 24-hour clock time used on the sample time log below)

Procedure:

1. Observe the night sky from your location and look for a very bright star low in the eastern horizon.
2. Carefully examine other stars around it so that you become familiar with the location of the bright star and can find it from one night to another.
3. Pick an easy to find landmark.
4. Pick a place to stand or sit from which you can align the star with the landmark you have chosen. Mark this location so you can return to it night after night.
5. Once you are satisfied you have a good location and landmark, observe and record the time when your star touches the landmark.
6. Repeat step four as many nights as you want. Remember that the star should rise about four minutes earlier from day to day. (You are bound to run into cloudy nights so just keep track of the days between observations.)

DATE	TIME
3-Jun	20:30
4-Jun	20:26
5-Jun	Cloudy
6-Jun	20:18
7-Jun	20:14

EXAMPLE OF A STAR-RISE TIME LOG

3 MANMADE OBJECTS IN NEAR EARTH ORBITS

Learning Outcomes

– Identify an artificial satellite
– Describe the different types of orbits for artificial satellites.
– Describe the *Hubble Space Telescope* (HST).
– Describe the *International Space Station* (ISS).

Important Terms

Ariane Rocket – European-made civilian expendable rockets used for space launches

Artificial Satellite – man-made spacecraft that orbits around Earth, the Moon and other planets in our solar system

Envisat – European Space Agency's Earth-observing satellite

***Explorer* I** – first artificial satellite by the U.S., which launched on January 31, 1958

***Genesis* I and II** – spacecrafts built and launched to test inflatable habitats for use in space

Geocentric Orbit – orbit of an object going around another object; for example, a satellite going around Earth

Geosynchronous Orbit – a satellite that orbits at the same orbital period as Earth's sidereal rotation period

Hubble Space Telescope – orbits above Earth's atmosphere allowing us to see deeper and further into our universe

International Space Station (ISS) – habitable artificial satellite in a low-Earth orbit; built by five space agencies representing fifteen countries

Iridium Satellite – communications satellites that provide voice and data coverage to satellite phones, pagers, and integrated transceivers

Low Earth Orbit – generally an artificial satellite that orbits below an altitude of 1,200 miles

Polar Orbit – orbit in which a satellite passes over both poles of the body it is orbiting

Sun-synchronous orbit – satellite passes over the same part of Earth at approximately the same time every day

***Vanguard* 1** – second artificial satellite launched by the U.S.

MANMADE OBJECTS IN ORBIT AROUND THE EARTH

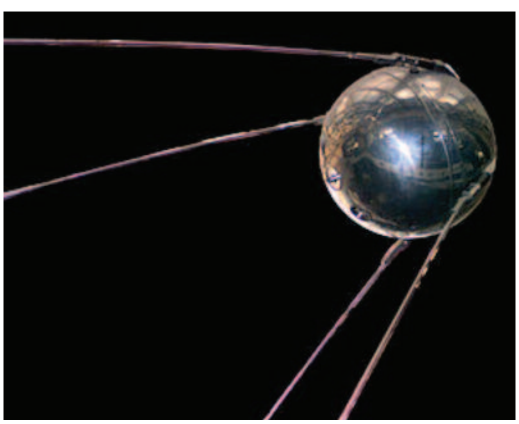
An ***artificial satellite*** is a man-made spacecraft placed in an orbit around Earth or other celestial object. Artificial satellites provide worldwide communications and navigation (GPS); weather surveillance and tracking; monitoring of environmental changes in the landmasses and oceans; gathering of military intelligence, etc.

The first artificial satellite, *Sputnik,* was launched by the Russians. *Sputnik* was placed in an elliptical, low-Earth orbit on October 4, 1957. *Sputnik* had a diameter of about 22 inches (56 cm) and weighed close to 184 pounds (83 kg). It took about 98 minutes to orbit Earth.

Its successful launch and placement in orbit around Earth precipitated the American Space Age and triggered the Space Race between the United States and Russia. The launch of *Sputnik* caught the United States off guard. There was fear that this capability allowed the Russians to launch nuclear weapons.

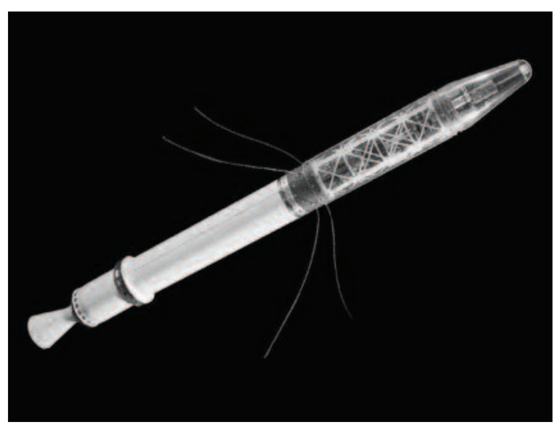
Russia put another artificial satellite up in orbit, *Sputnik* II. *Sputnik* II was launched on November 3, 1957, carrying a larger payload, including the first animal to orbit Earth, a dog named Liaka. Other payload onboard included spectrophotometers that measured solar radiation and cosmic rays. Mission control monitored Laika's vital signs and captured her movements via a camera mounted in the capsule. Thermal problems, causing the capsule to overheat, probably led to Laika's death after only two days in orbit. This was the first data collected on behavior of a living organism in a space environment. The information gathered from *Sputnik* II enabled Russia and the United States to launch the first men in space. *Sputnik* II reentered Earth's atmosphere after 162 days in orbit.

The United States launched and successfully orbited ***Explorer* I** on January 31, 1958. *Explorer* I was the first satellite to detect the Van Allen radiation belts. *Explorer* 1 remained in orbit until 1970. On March 17, 1958, the second U.S. satellite, ***Vanguard* 1**, was placed in orbit. *Vanguard* 1 is the oldest artificial satellite still in space, but it is no longer operational.



Credit: NASA

SPUTNIK



Credit: NASA

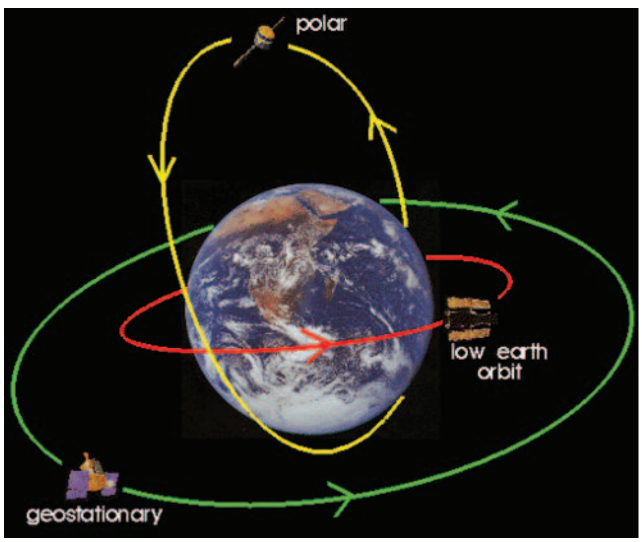
EXPLORER I

TYPES OF SATELLITE ORBITS

Satellites can be placed in various orbits depending on their intended use. The most common are polar orbit and geosynchronous orbit.

Polar Obit – The correct term should be "Near Polar Orbit" because their inclination is near but not exactly 90 degrees to Earth's equator. At this gradient, the satellite virtually passes over all parts of the globe. The satellite does not stay over the same place on Earth's surface; it can pass over every point on Earth. That is, Earth spins on its axis underneath the satellite while the satellite orbits around Earth. This orbit is especially ideal for any type of surveillance or data collection such as weather, ecology, intelligence, etc. The data acquired can be continuously sent to various receiving stations around the world, or stored until the satellite flies over its dedicated receiver.

Geosynchronous Orbit – Also known as Geostationary Orbits, these orbits allow the satellites to orbit Earth at the same rate as Earth spins on its axis. Therefore, they stay over the same place on Earth's surface. You may remember that Earth spins on its axis in 23 hours, 56 minutes and 4 seconds. In order for the satellite to stay geostationary, it must be at an altitude of about 22,238 miles (35,790 km). Geostationary satellites are placed in orbit around the equator because the force of gravity is constant from all directions. Geosynchronous orbits allow the satellite to cover most of a hemisphere. They are useful to observe large-scale phenomena like hurricanes and cyclones. They are also used for communication such as landline and cellular telephone, TV, etc. There is no need for multiple ground stations because the satellite can stay above just one station all the time.



Credit: 1001 Messages

COMMON ORBITS OF SATELLITES

OBSERVING MANMADE CRAFTS IN NEAR EARTH ORBIT

If you look at the sky on a clear, moonless night, you have a very good opportunity to see a few of the many satellites orbiting Earth. We can see these satellites because they reflect sunlight. These crafts can be very bright, dim, or seem to flash or blink depending on their shapes and the reflectivity of their surfaces.

The following spacecraft discussed in this section are from the most bright and easiest to see, to those requiring more careful search and patience. Regardless of which you observe, satellite observing is exciting and rewarding. It is fun to check predictions for the date and time when a particular satellite will be visible from where you live, and then go out and find it.

An excellent website for obtaining predictions is **www.heavens-above.com.** You can either use the map on the site to find your location or, better yet, subscribe for free so that you can obtain predictions customized to your location. You can also get apps for your phone and iPad, including the NASA app, which will allow you to track satellites.

INTERNATIONAL SPACE STATION (ISS)

The ***International Space Station*** (ISS) is, by far, the most easily observed man-made, low Earth orbit satellite. Its first component, *Zarya*, was launched in 1998 aboard the space shuttle *Endeavour*. Credited as being one of the *Greatest International Space Programs of All Time,* the ISS was completed in 2010 with the help of five participating space agencies: NASA, the Russian Federal Space Agency (Roscosmos), the Japanese Aerospace Exploration Agency (JAXA), the European Space Agency (ESA) and the Canadian Space Agency (CSA). People have been continuously living and working on the ISS since 2000.

The ISS is almost as big as a football field. With a length of 357 feet (109 meters) and solar rays spanning 240 feet (73 meters), the station weighs just less than one million pounds. Fifty-two computers control the systems on the ISS and guide it at an altitude of about 200 miles (386 km) over Earth. The ISS orbits Earth approximately every 90 minutes. The astronauts onboard experience 15 sunrises and 15 sunsets a day. The last major component of the ISS, *Tranquility*, was launched on *Endeavour*, in May 2010. The *Tranquility* Module allows the ISS crew a 360-degree view of space and of Earth, and it also stores the equipment that converts urine into drinkable water, a bathroom and a treadmill. The ISS can support crews of six.

Credit: NASA

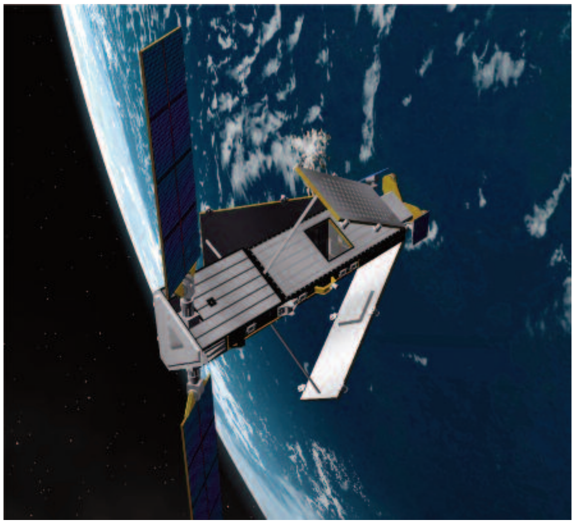
INTERNATIONAL SPACE STATION

Astronauts are continuously doing experiments while on the ISS. Crewmembers conduct experiments in biology, human biology, physics, astronomy, meteorology, and other fields. You can learn more about NASA spinoffs by going to the NASA website, **www.spinoff.nasa.gov**. The Human Research Facility and the Microgravity Science Glovebox are the two main research facilities onboard. The Human Research Facility allows astronauts and scientists on Earth to study how the human body reacts to living in space. The Microgravity Glovebox allows astronauts to handle dangerous fluids and provide a sealed location for conducting experiments. Astronauts perform experiments in space because things act differently in microgravity. Crews on the *International Space Station* learn about how people, plants, and animals are able to grow and survive in space and other places like the Moon or Mars. Since astronauts live continuously in space, they are able to keep these experiments going for a long time.

The ISS is a science lab in space where many technologies have been developed to make our lives safer and more convenient. Some of these technologies, called NASA spinoffs, include: programmable ovens (allows you to start dinner from the web); air purifiers (eliminates pathogens and preserves food); and robotics (designed to repair complex repairs on the ISS), which are now being used in surgical procedures here on Earth.

IRIDIUM SATELLITES

There are close to 100 Iridium Satellites in Earth's orbit. Iridium satellites use a geostationary orbit. These satellites provide voice and data coverage to satellite phones and pagers. The Iridium communications satellites have an unusual shape with three polished door-sized antennas (Main Mission Antennas or MMAs), 120 degrees apart and at 40 degrees angles from the main body. The forward antenna faces the direction the satellite is traveling. Occasionally, an antenna reflects sunlight directly down at Earth, creating a predictable and quickly moving illuminated spot on the surface below about 10 kilometers in diameter. An observer will see a bright flash, or flare in the sky.



Credit: Chimes

IRIDIUM COMMUNICATIONS SATELLITE

Credit: Space Archive

IRIDIUM SATELLITE FLARE

The flares can last anywhere from 5 to 20 seconds before the satellite once again becomes almost invisible to the naked eye. Some flares can be observed during the daylight hours. Knowing where to look to observe these flares during the daylight hours is essential. There are websites and apps that will help you track and locate any Iridium flares occurring over your location.

GENESIS I

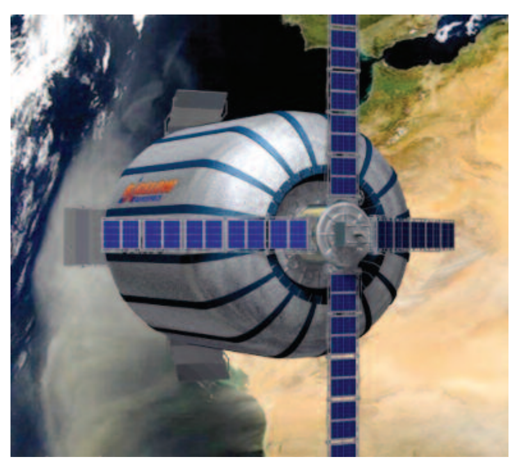
***Genesis* I** is an operational spacecraft developed by Bigelow Aerospace, and launched on July 12, 2006, at the ISC Kosmotras Space and Missile Complex near Yasny, Russia. This was the first commercial launch to take place at this complex. *Genesis* I launched in a contracted state with dimensions of 14.4 feet (4.4 meters) in length and 5.2 feet (1.6 meters) in diameter. Once it was orbiting in space, *Genesis* I expanded to 14.4 feet (4.4 meters) in length and 8.3 feet (2.54 meters) in diameter. It will have 406 cubic feet (11.5 cubic meters) of usable space. The *Genesis* I has been instrumental in demonstrating microgravity pressurization and the deployment process of an expandable craft, proving that an expandable habitat can endure vibration and loads of the launch environment. The cost of launch and spacecraft production for *Genesis* I was probably the lowest in the history of aerospace.

GENESIS II

***Genesis* II** is the second experimental habitat designed by Bigelow Aerospace. Launched on June 28, 2007, *Genesis* II looks similar to *Genesis* I, but carries more cargo, including upgrades in sensors, additional cameras and a Biobox. Twenty-two cameras are abroad *Genesis* II, which is nine more than its predecessor. As of February 2013, *Genesis* I and II continue to transmit a wealth of photos and data to Bigelow's Mission Control, in Las Vegas, Nevada.

Credit: Bigelow Aerospace

***GENESIS* I**



Credit: Bigelow Aerospace

***GENESIS* II**

ENVISAT

Launched on March 1, 2002, for a five-year mission, the European Space Agency satellite is the size of a school bus and is the world's largest imaging satellite for civilian use. ***Envisat*** was designed to take high-resolution images of Earth. It has a ***polar Sun-synchronous orbit*** with an altitude of 790 km (490 miles). Communications with *Envisat* were lost on April 8, 2012, and the mission was officially cancelled on May 9, 2012. *Envisat* continues to orbit Earth.

Credit: Earth snapshot

ENVISAT

HUBBLE SPACE TELESCOPE

The ***Hubble Space Telescope***, named for astronomer Edwin Hubble, was launched into low Earth orbit by the space shuttle ***Discovery*** (STS-31) in 1990. The primary mirror of the telescope is 7.9 feet (2.4-meters) in diameter. Hubble's six science instruments work together to bring us images from deep in space. The first instrument is the Wide Field Camera 3, which helps observe how galaxies evolve over time.[1] The Cosmic Origins Spectrograph breaks ultraviolet radiation down so they can be viewed in more detail and used to examine the formation of planets. It breaks light down in colors and measures the strength of each color. Advanced Camera for Surveys studies ultraviolet emissions from stars and is used to find planets of neighboring stars.[2] The Space Telescope Imaging Spectrograph studies black holes, the composition of galaxies and the atmospheres of planets around other starts. The Fine Guidance Sensors provide information to help guide the telescope.

The Hubble telescope had problems soon after it arrived in orbit. One of the main issues was that the images were blurry. Hubble's primary mirror had a fault called spherical aberration. This is an optical problem that occurs when all the incoming light rays focus at different points on the other end of the spherical surface. This will cause the image to appear hazy or blurred. The telescope could be repaired by adding a series of small mirrors to intercept the light reflecting off the mirror and bouncing the light to the telescope's science instruments. Hubble repair mission STS-6 launched in December, 1993. Soon after, the first new images from Hubble's fixed optics were released in January, 1994. The last Hubble repair mission in 2009, was the culminating service mission that extended the life of the telescope until its final descent back to Earth.

[1] In 2009, the Wide Field Camera 3 replaced the Wide Field and Planetary Camera 2, which took most of the famous Hubble pictures.

[2] This camera replaced the Faint Object Camera, which performed as a telephoto lens that recorded high-resolution images in a small field of view, in 2002.

HUBBLE SPACE TELESCOPE

STS-61 HUBBLE REPAIR

Scientists had thought that our universe continued to expand, but at a decreasing speed. Hubble's clear images, showing brilliant stellar explosions (supernovae), were used to find distance galaxies and measure the expansion of the universe. Hubble's observations showed that the expansion of the universe was not slowing down but speeding up and expanding faster and faster.

NASA is working on a new space telescope, the *James Webb Space Telescope*, named after James Webb. Mr. Webb was a staunch supporter of space science and was an integral part of the *Apollo* program. The target launch date is 2018. Its primary mirror will be 21.3 feet (6.5 meters) in diameter with a sunshield the size of a tennis court. The telescope's orbit will be about 1 million miles (1.5 million kilometers) from Earth. It will take pictures further and deeper in space than ever before.

http://www.youtube.com/user/NASAWebbTelescope
http://www.youtube.com/watch?v=k2wtBWYjdRk

3

Observing satellites with your unaided eye

EXERCISE ONE

You will need:

A location where you can see the sky on a moonless night shortly after sunset

Procedure:

1. Go out on any clear and moonless night shortly after sunset
2. Place a piece of plastic on the ground, cover it with a warm blanket and lie down
3. Look at the sky and see if you can see what appears like a star moving slowly across the sky.
4. Make sure you don't mistake it for a high-flying aircraft. (Look for a white and/or a flashing red light, or, look for the green and red navigational lights on the wing tips. This will help you identify your object as an aircraft.)
5. Remember that the satellite could get brighter and dimmer as different parts of it are illuminated by sunlight. Also, don't be surprised if the satellite starts getting fainter and then disappears. This happens when the satellite enters the shadow of the Earth and sunlight is no longer reflecting from its surfaces.
6. Observe the general direction of travel and from it make an educated guess as to the purpose of the satellite. Review the section dealing with satellite orbits for clues.
7. See if you can track the satellite using binoculars. Is it easy?

Hold a contest with several cadets/students to see who can spot the most satellites!

3 Obtaining predictions and looking for bright manmade objects in orbit around Earth

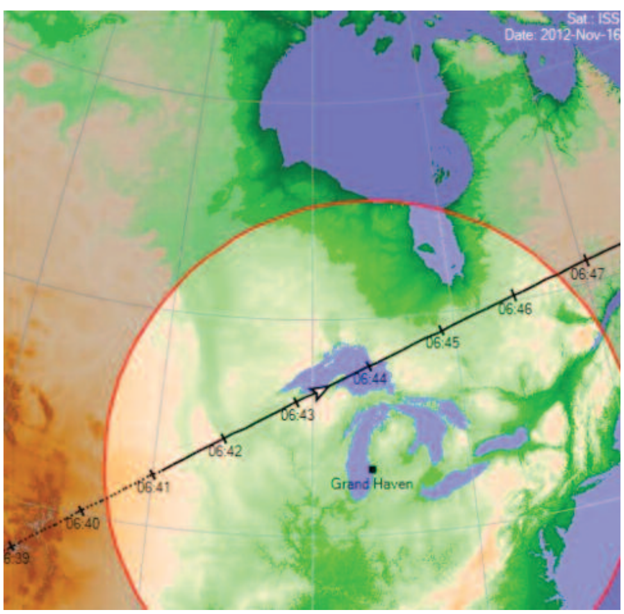
EXERCISE TWO

You will need:

• A computer and internet access

Procedure:

1. Go to the website **www.heavens-above.com** and review all the different satellites for which you can get predictions.
2. Start with getting predictions for the *International Space Station* for the location where you live.
3. Remember, the time given for the predictions is the local time for the location you request. Also, it will be in a 24-hour format. This means that 1 p.m. will show as 1300 hours, etc.
4. Try getting predictions and locating fainter satellites as your skills improve. Iridium flares are exciting to observe but require patience and concentration.



Credit: Heavens-Above

Credit: Heavens-Above

Samples of information given for *International Space Station* passage predictions from website www.heavens-above.com

4 EARTH'S MOON

Learning Outcomes

– Explain the different phases of the Moon.
– Describe the shape of the Moon's orbit around Earth.
– Define Earthshine.
– Define a blue moon.

Important Terms

Apollo – NASA program that Americans landed on the moon six times between July 16, 1969 and December 7, 1972

Blue Moon – the second full Moon in any given month

Complex Crater – a Moon crater with a central mountain or another unusual feature

Earthshine – illumination of the dark portions of the Moon's surface by sunlight reflected from Earth's atmosphere

Ejecta – the material thrown out of the crater area during impact

Elliptical Orbit – an oval-shaped path of a celestial body

Lunar Eclipse – when the Moon moves in Earth's shadow

Lunar Terminator – boundary between illuminated and dark lunar hemispheres

Natural Satellite – a celestial body that orbits a planet or other body larger than itself that is not man-made

Sidereal Month – the time it takes the Moon to do one revolution around Earth as measured from a given position among the stars

Synodic Month – the time between two full moons (29 days, 12 hours, 44 minutes); longer than the sidereal month; also called lunar month

THE DANCE OF EARTH AND MOON

Our planet has one natural body revolving around it, the Moon. It is often referred to as our ***natural satellite***. The orbit of the Moon around Earth is in the shape of an ellipse.

The Moon's ***elliptical orbit*** brings it as close as 225,291 miles (perigee) to Earth and as far away as 251,910 miles (apogee). A ***sidereal month*** is the time it takes the Moon to return to the same place in the sky in relation to the stars (27.321661 days). The Moon takes exactly 29.5305882 days to complete a cycle of phases as seen from Earth. This is called a ***synodic month***. The Moon takes longer to go through the lunar phases because while the Moon is orbiting the Earth, the Earth is orbiting around the Sun. Once the Moon has completed a sidereal month, it has to move a little further to reach the position on Earth.

The lunar phases change regularly as the Moon orbits Earth, according to the changing relative positions of Earth, the Moon, and the Sun. The half of the lunar surface facing the Sun is always lit and reflects the Sun's light, while the other half is not lit and is not visible to us. The portion of the illuminated hemisphere that is visible to an observer on Earth can vary from about 100% (called full Moon) to 0% (called new Moon).

There are 8 Moon phases; new Moon, waxing crescent, first quarter, waxing gibbous, full Moon, waning gibbous, last quarter and waning crescent.

During a new Moon, the Moon and the Sun are on the same side as Earth and the illuminated side of the Moon is away from Earth, so we only see the shadowed side. The unlit side of the Moon is somewhat perceptible due to sunlight reflecting from Earth's atmosphere and illuminating the dark portion of the Moon's surface. This is called ***Earthshine***. Solar eclipses can be experienced during this time of the new Moon. The new Moon will rise at dawn and set at sunset.

The next phase, the waxing crescent phase, is when we see the first sliver of the Moon. The northern hemisphere will see the illuminated edge on the right and the southern hemisphere will see the illuminated edge on the left. The waxing crescent rises in the east a little after sunrise, but it is too close to the Sun to see. However, you can see it soon after sunset low in the west.

The name of the next phase is a little misleading because we actually see half of the Moon during the first quarter phase. It is called the first quarter because the Moon is a quarter of the way through its orbit. The lit side is on the right, if viewed in the northern hemisphere. The first quarter Moon will rise in the east around noon and set in the west around midnight. You can spot the first quarter Moon high above the southern horizon at sunset.

When the Moon is illuminated more than half, but not quite a full Moon, it is in the waxing gibbous phase. The Moon will rise between noon and sunset, and set in the early morning hours after midnight. Waxing means the illuminated parts of the Moon are increasing day to day.

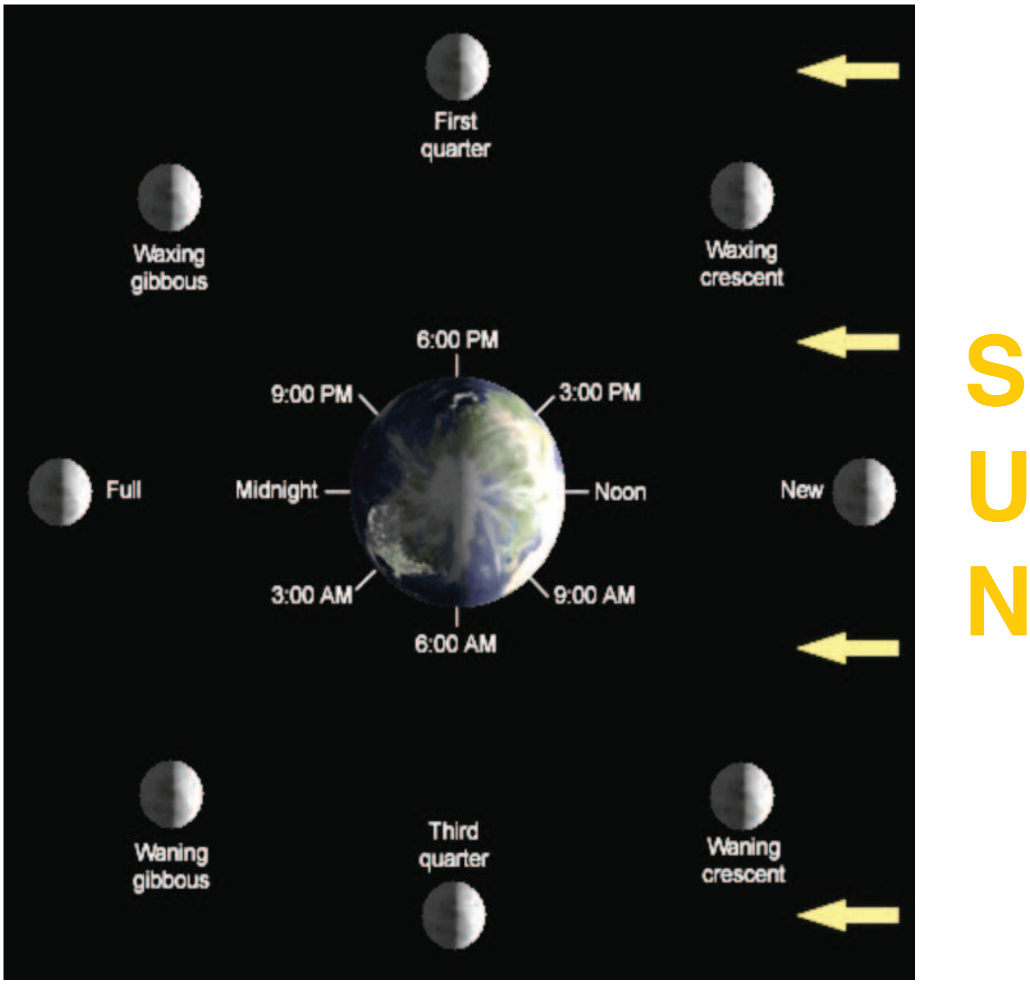
The full Moon appears about two weeks after the new Moon, when the Moon is brightest in the sky. A full Moon rises at sunset and sets at sunrise so it is visible all night long. Lunar eclipses can occur during this time. Total lunar eclipses occur when the Earth, the Moon and the Sun are perfectly aligned. During a portion of a total eclipse, the Moon may appear red as some light from the Sun passes through Earth's atmosphere towards the Moon.

The waning gibbous Moon appears a few days after a full Moon. It appears in the hours between sunset and midnight, and sets in the early dawn hours. The Moon will appear less than full. Now the northern hemisphere sees the left side of the Moon illuminated and the right side is in darkness. After the Moon has become a full Moon, but has not reached the last quarter, the Moon is waning, or the illuminated parts are decreasing.

The third quarter or last quarter the Moon is half illuminated. This Moon is sometimes referred to as a half moon. The last quarter Moon rises around midnight and sets in the mid-morning. The northern hemisphere sees the left side of the Moon illuminate and the right side is in darkness.

We only see a small fraction of the Moon's dayside during a waning crescent Moon. The waning crescent Moon is almost in line with Earth and the Sun. Sometimes called an old Moon, it is seen best in the east before dawn. The waning crescent Moon will rise a couple hours before the sunrises, but is barely visible during the day. This will be the final fraction of the Moon phase before the Moon goes into darkness again.

Credit: Universe Today



PHASES OF THE MOON

THE MOON AT ITS BEST

Credit: M. Taha Ghouch Kanlu

MOON SLIVER

The best time to look at the Moon is from a few days after the ***new Moon,*** until a couple of days before the ***full Moon*** (about 10 days). Early on in this period, the sunlight is coming at a steep angle (the angle increases from day to day). The shadows cast by the mountains and crater rims are long on the Moon's surface. The long shadows give the observer a good feel for the height of mountains and the depth of craters.

As the full Moon phase approaches, the light intensifies to the point that it is uncomfortable to stare at the Moon for any length of time. Also, as the sunlight shines almost straight down on the surface, the shadows get shorter and shorter and all dimensional effects disappear. By the full Moon, most shadows are gone and many features become hard to see.

Viewing the Moon with your naked eye will allow you to be able to see many details, such as seeing different shades of gray and noticing the southern half has large bright areas while the northern half is darker and grayer.

It is recommended that you download or buy a map of the Moon to help you locate the Moon's many features. Mirror-reversed maps are used with refractor and Cassegrain telescopes. These maps reverse the Moon's image from left to right. Viewing through the telescope, you will be able to see more detail in the mountains, valleys, plains and craters. The Moon is lit by full sunlight and allows you to take pictures of the Moon by just holding the camera up to the telescope's eyepiece.

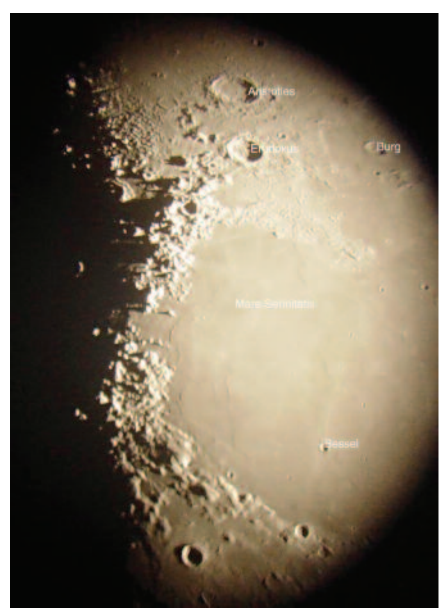
Many astronomers use a neutral-density filter at this point to cut down the amount of light (just like sunglasses). If no filters are available, some observers place a mask in front of the telescope tube opening. This mask can be simply a piece of cardboard with a hole cut in it. The hole is of a smaller diameter than the telescope's mirror or lens (objective or primary optical element). This mask cuts down the amount of light entering the instrument. The downside of this procedure is that with less light entering the telescope, the sharpness and contrast of the image decrease.

TERMINATOR LINE

The Lunar ***Terminator*** is the line between daylight and nighttime on the Moon. Because the Moon doesn't have an atmosphere there is no dawn or dusk effect like here on Earth. The line, or Terminator, is well defined. You will see stark contrasts of radiant white and coal black along the terminator line.

Notice in the picture how some of the high mountains that are in the night side have their peaks illuminated by the approaching sunlight.

Spend an evening watching the terminator line. By just watching the line for a few minutes, the shadows will change as the sun rises. Use a Moon map and try to locate the craters up and down the terminator line. Note the different sizes and other topographic features. As it gets closer to the full Moon, the terminator line is closer to the edge of the Moon, and that makes it harder to see detail.



Credit: World Press

TERMINATOR LINE

LUNAR CRATERS AND RAY SYSTEMS

Craters that have mountains or peaks in or near their centers are called ***Complex Craters***. When light conditions are right, an observer can see the tip of the central peak, as well as parts of the crater's rim illuminated, while the floor and some of the sidewalls are in darkness. This allows the observer to estimate the height of the central peak from the crater floor, the height of the rim above the surrounding area and the steepness of the crater walls. A simple crater is a simple bowl shaped. One of the most well-known simple craters on Earth is Barringer, a.k.a. Meteor Crater, located 20 miles west of Winslow, Arizona. Meteor Crater is close to a mile across and more than 550 feet deep.

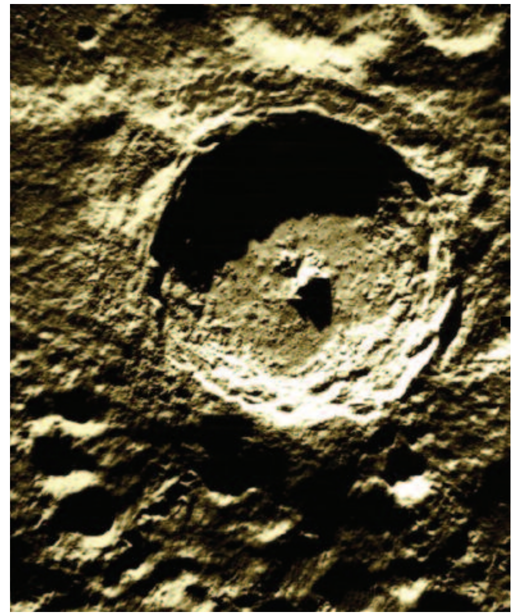
How these peaks formed had early astronomers puzzled until experiments were conducted. A spherical, heavy object was dropped from some height onto a bed of sand. The sphere would hit the surface, make a dent (crater), and then bounce up pulling some material up with it. Thus forming the central peak.

Another outstanding feature to look for on the Moon's surface are ***rays***. The rays are formed when a large body hits the Moon and huge debris or ***ejecta*** is thrown out during the formation of an impact crater. These fine lines of lighter material look like spokes emanating from the center of the crater. Some of the surface area impacted by the large body will form the crater's rim, and other material is scattered across the surface forming the rays of the crater. Rays are usually brighter because they are younger than the surface they were cast on.

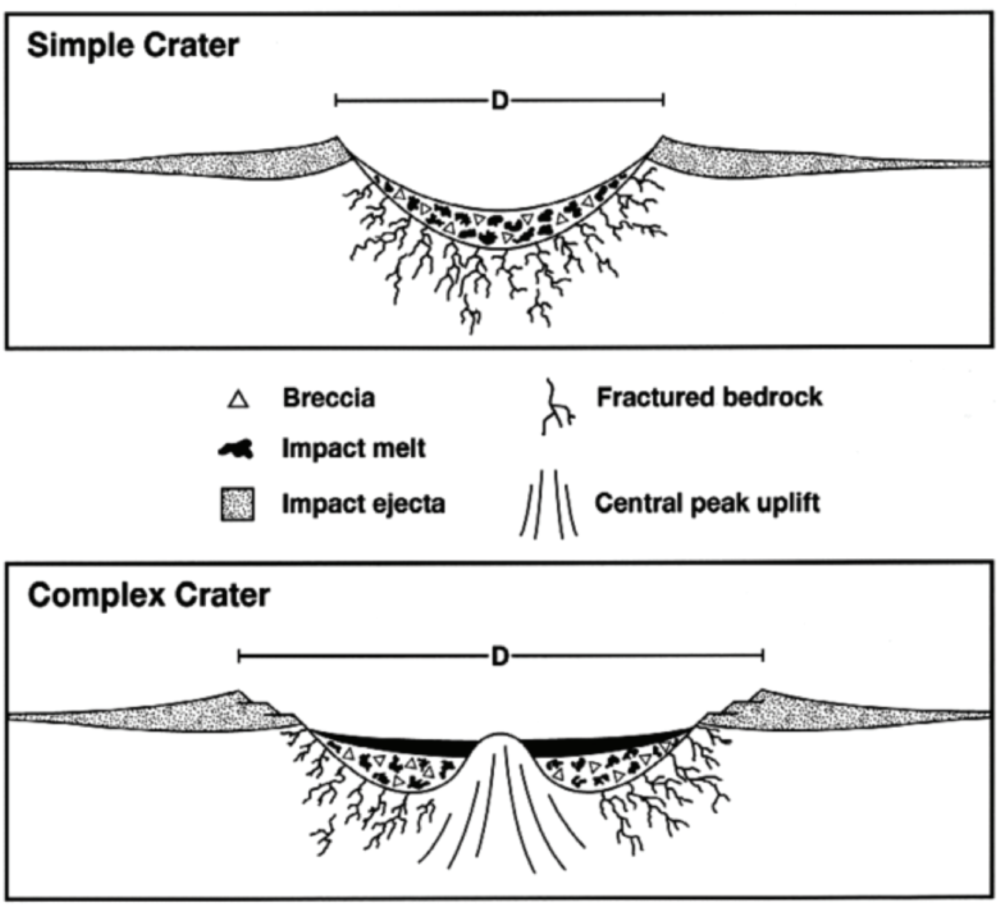
The rays' length can be several times the diameter of their originating crater. Along them, you can often find small secondary craters formed by larger chunks of ejecta.

Credit: Frank Barrett

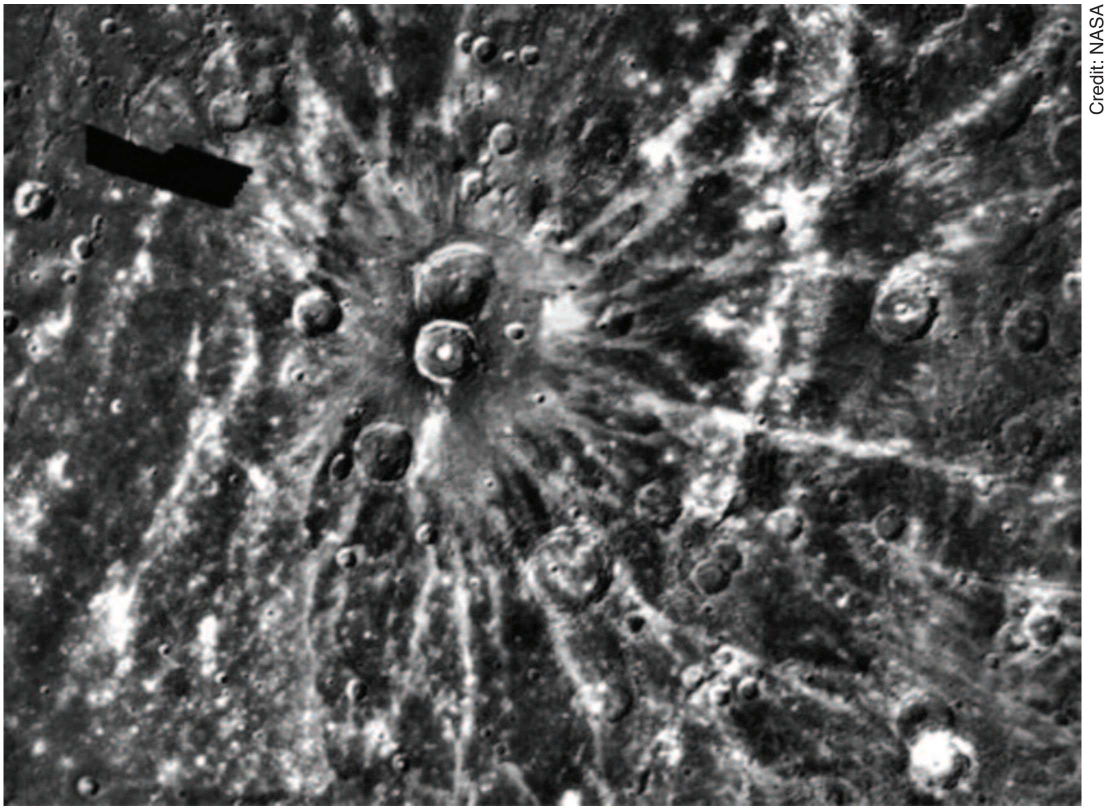
TYCHO'S LOCATION


Credit: NASA

CRATER TYCHO



Credit: Melosh (1989) H.J.



CRATER NEAR APOLLO 16 LANDING SITE

Early astronomers thought they could tell the age of a crater based on the relative brightness of its rays. Recent studies suggest that the composition of the material making up the ray must be taken into consideration when trying to determine a crater's age.

The above unnamed crater, close to the Apollo 16 landing site (April 1972), is a very good example of a crater with a complex ray system. Notice that the ejecta forming the rays covers portions of the larger nearby craters. This shows that this crater is younger than its neighbors.

Spotting craters on the Moon can be easy and fun. Remember, viewing the Moon on either side of the first quarter will provide you with the best viewing of the Moon's features. The first thing you want to do is familiarize yourself with some of the prominent craters visible on the Moon's surface. Make sure you recognize the features and know the general location of the crater. That will help you locate the crater faster when you are using your telescope.

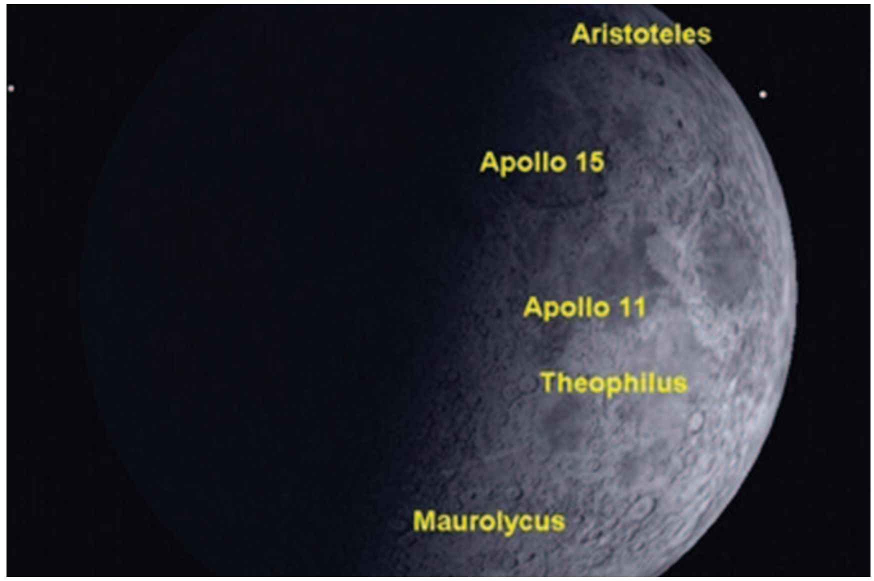
Three larger craters (Aristotelis, Theophilus, and Maurolycus), are prominent craters that can be located easily. The first crater, Aristoteles, is a complex crater. Aristoteles is 54 miles across and has terraced walls. Aristoteles is located near the Moon's north pole.

Theophilus is located near the center of the Moon and is slightly bigger than Aristoteles. Theophilus is 62 miles wide, with walls 3,940 feet high. Another distinguishing feature is that it has a large central peak.

Located below Theophilus is a crater named Maurolycus. This crater is 71 miles wide and 15,500 feet deep. Maurolycus also has a large central peak, and it looks like Maurolycus is located right on top of an older crater.

Credit: Luc Viatour

MOON



Credit: Starry Night Softwave

MOON CRATERS AND LANDINGS

APOLLO LANDING SITES

Once you have located those three craters, it will make locating Apollo 11 and 15 landing sites a lot easier. You will not be able to see any hardware left behind at these sites.

Just north of Theophilus is Mare Tranquillitatis, where Apollo 11 landed on July 20, 1969. Mare Tranquillitatis is a relatively flat area, and the site was chosen to allow for an easy landing. There are three small craters located north of the landing site. The craters are named for Neil Armstrong, Buzz Aldrin and Mike Collins. These craters range from 1.5 to 2.9 miles across. You will not be able to view these craters with an amateur telescope.

North of the Apollo 11 landing is an area that is more mountainous, and where Apollo 15 landed on July 26, 1971. This landing spot was located between the Mare Serenitatis and the Mare Imbrium. A valley called Rima Hadley, which has a long, narrow grove that stretches across the valley, was studied and explored by the Apollo astronauts. You can view this surface feature using a large telescope (8 inches aperture) and correct lighting.

4 Observing the Moon with the unaided eye

EXERCISE ONE

You will need:

A moon map; can be found at **www.virtual-moon-atlas.en.softonic.com**

Procedure:

1. Go out on any clear night when the Moon is a few days old.
2. Look at the Moon and see if you can observe the earthshine illuminating the dark side of the Moon.
3. Using a Moon map as a reference, see if you can estimate the whereabouts of the Terminator. The website **www.virtual-moon-atlas.en.softonic.com** lets you download a free Moon atlas program. With it you can find any lunar feature, Apollo landing sites, pictures, and other useful information about the Moon.

Whenever man has looked at the night sky, he has allowed his imagination to find familiar objects, animals, etc. among the stars and on the Moon's surface. See if you can spot the following images on the face of the full Moon:

THE MAN IN THE MOON

THE WOMAN IN THE MOON

THE COW JUMPED OVER THE MOON

THE RABBIT IN THE MOON

4 Demonstrating the different phases of the Moon

EXERCISE TWO

You will need:

A table lamp with the shade removed and a calendar that shows the four major phases of the moon

Procedure:

1. Place a lamp with the shade removed in center of a room and turn it on. This will be the Sun.
2. Hold a hand in the "thumbs up" position at arms length. Your thumbnail will be the Moon. You will be Earth.
3. Start with the hand facing the lamp. It is hard to see it because of the bright light from the lamp. This is a new Moon, when the Moon is between the Sun and Earth and the illuminated side of the Moon is facing away from Earth.
4. Turn, in place, 90 degrees counterclockwise. Half of your thumbnail is illuminated. This is the first quarter phase.
5. Turn another 90 degrees counterclockwise. Hold your hand high enough so that your head doesn't block the light from the lamp. Your whole thumbnail is illuminated. This is the full Moon phase.
6. Turn another 90 degrees counterclockwise. Now the opposite half of your thumbnail is illuminated. This is the third quarter phase.
7. Finally, turn another 90 degrees counterclockwise. You are now back at the new Moon phase and your thumbnail is not illuminated.
8. Consult a calendar that shows the four major phases of the Moon (new, first quarter, full and third quarter). Go out every night that it is clear and compare the predictions from the calendar with what you see in the sky.

To get a better effect, take a small Styrofoam ball and stick a pencil or piece of dowel into it to make a handle. Use this prop instead of your hand and thumbnail to represent the Moon.

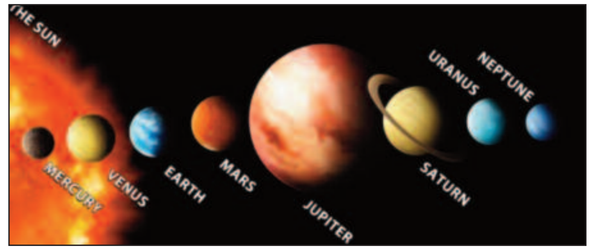
As you slowly turn counterclockwise, in place, hold the ball at arm's length. Notice how the light illuminates more and more of the ball's surface as you go from the new Moon to the full Moon position, and then decreases as you continue from full Moon back to new Moon.

Notice how the trailing edge of the ball faces the light as you go towards full Moon. The opposite happens; the leading edge of the ball is illuminated as you move through full Moon back to new Moon.

One counterclockwise turn represents one revolution of the Moon around Earth.

KEEP LOOKING UP!

5 VIEWING THE PLANETS



Learning Outcomes

– Define albedo.
– Describe the rotation of a planet in our solar system.
– Describe the revolution of a planet in our solar system.
– Describe optical filters.

Important Terms

Albedo – amount of sunlight reflected by a planet or other surfaces as a percentage of all the light falling on it

Band-pass Filter – filters designed to only allow the desired wavelengths to go through

Conjunction – an apparent close approach between two or more objects as seen in the sky

Frederic Wratten – British inventor who developed a numbering system for labeling color filters; founded the first company that manufactured optical filters

Gas Giants – term used for large planets made up of frozen, liquid or gaseous elements

Inferior Conjunction – as seen from Earth, the alignment with another planet and the Sun in which Earth and the observed planet are on the same side of the Sun

Jovian Planets – term used to describe Jupiter-like planets

Nanometer – a billionth of a meter

Neutral Density Filter – filters that reduce the amount of light going through them without changing the color balance

Opposition – Earth and a celestial body are in the same direction as seen from the Sun

Orbit – path followed by a planet as it rotates around the Sun

Polarizing Filter – filters that block all light traveling on a given plane; when they are piggybacked, one can be rotated in front of the other to control the total amount of light

Resolution – the ability to separate two very close point sources into two images

Revolution – movement of a planet around the Sun

Rotation – circular movement of a planet around its axis

Superior Conjunction – as seen from Earth, the alignment with another planet and the Sun in which the planet being observed is on the opposite side of the Sun

Wavelength – the distance between two equal points (crest to crest, etc.) in one oscillation of an electromagnetic wave

PLANETS AND THEIR ORBITS

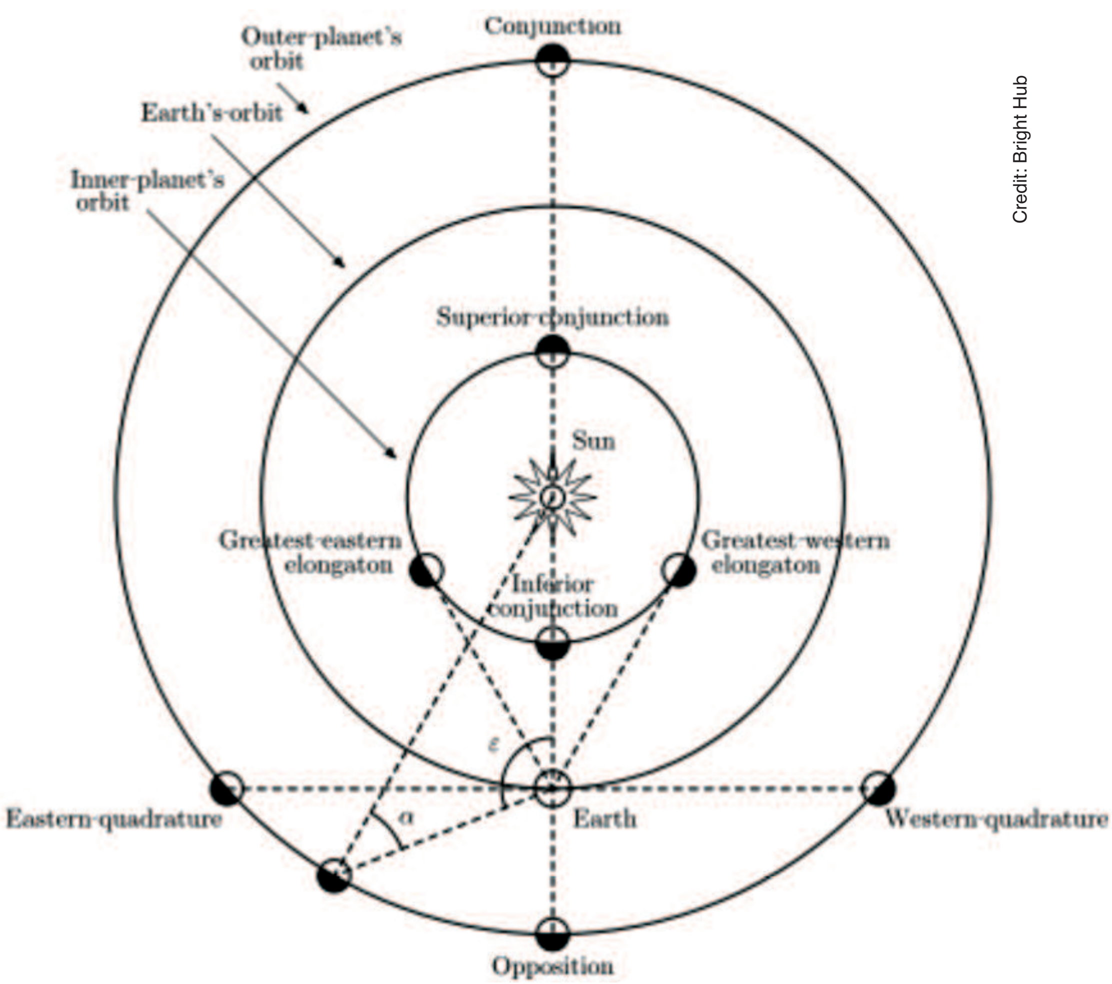
The planets in our solar system are not visible all the time. The reason is the different length of time each takes to go around the Sun. Earth takes 365.25 days to orbit the Sun, but what about Mars? Mars takes about 687 days to orbit the Sun. This means that, at times, Mars is opposite the Sun compared to Earth. Mars would be in our daytime sky and impossible to see due to the bright sunlight during this time.

The same is also true for all the other planets. They appear in our nighttime sky for different periods of time depending on their period of ***revolution***. Each planet's revolution is different depending on how long it takes to complete it's path around the Sun.

The two inner planets, Mercury and Venus, also pose interesting viewing placements. Because they are closer to the Sun than Earth, we can only see them when they rise ahead of sunrise or set shortly after sunset.

Venus is easier to see because it is very bright. On the other hand, Mercury is smaller, not very bright and stays close to the horizon.

NAME OF PLANETARY POSITIONS IN RESPECT TO ORBIT



Credit: Bright Hub

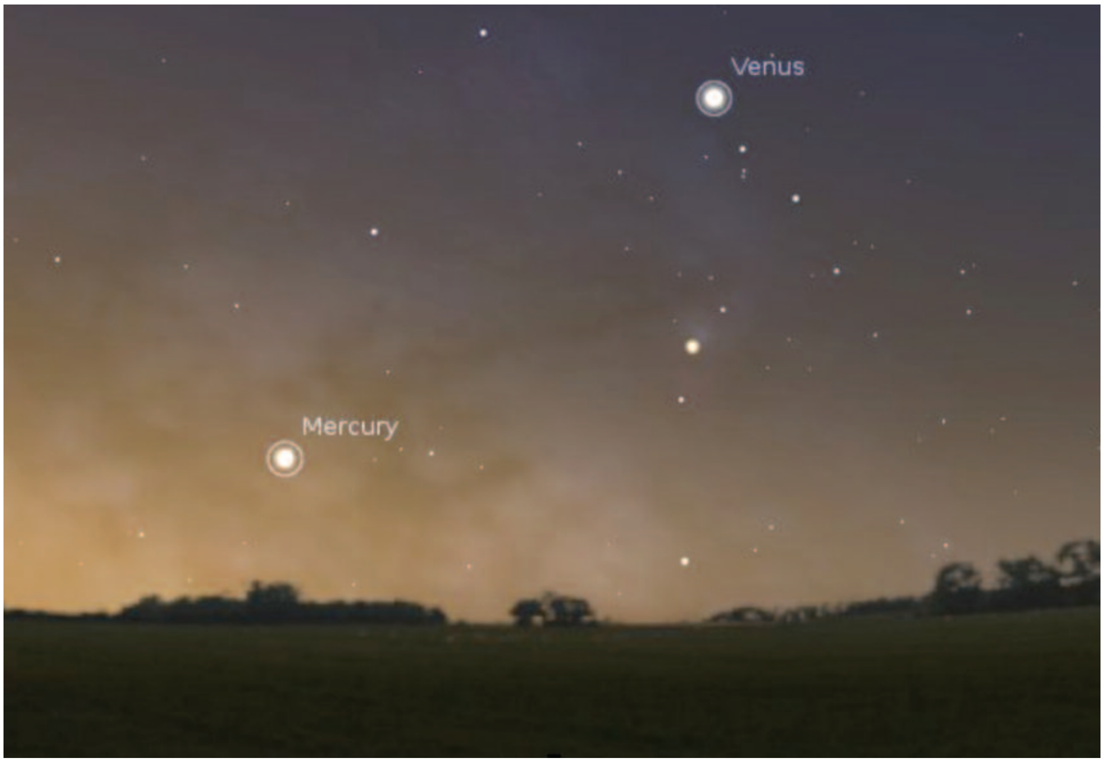
POSITION OF PLANETS AS SEEN FROM THE EARTH

The diagram above does a great job in displaying various terms used to describe the position of planets as seen from the Earth. These terms are mentioned on the next page.

A ***conjunction*** is the apparent closeness of two or more planets as seen from Earth. In reality, they can be very far away from each other, but from our viewpoint, they seem close to each other.

A ***superior conjunction*** occurs when a planet is on the other side of the Sun as seen from the Earth, while an ***inferior conjunction*** happens when the planet is on the same side of the Sun as the Earth.

A planet is at ***opposition*** when the Earth is between it and the Sun.



Credit: Bob Moler's Ephemeris Blog

VENUS AND MERCURY RISING IN THE EAST
DAWN, MID JANUARY 2011

REFLECTION OF SUNLIGHT

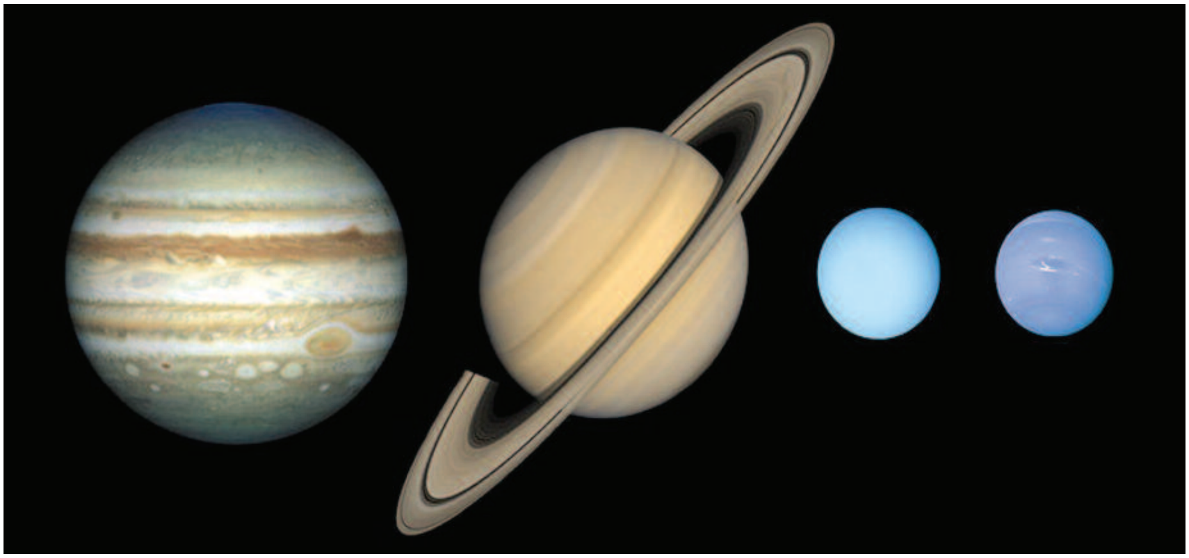
Planets do not produce their own light the way stars do. Planets reflect the light produced by the Sun. The amount of light reflected is called ***albedo,*** and it is expressed as a percentage of the total amount of light that illuminates the planet. The higher the number the more reflective the planet surface. A low albedo says the planets absorb most of the light that hits it. Earth has an albedo of about 30 to 35%. This is mostly due to the amount of clouds in Earth's atmosphere which reflect much of the sunlight. The percentage can vary widely across Earth's surface depending on the geological and environmental features.

Mercury is the closest planet to the Sun, but it lacks an atmosphere, and its surface is rocky and dark, so its albedo is only about 10%.

Venus, on the other hand, is larger and totally covered with light-colored clouds. Its albedo is a whopping 75%!

Mars is the other terrestrial-type planet. Mars is almost half the size as Earth. It has a very thin atmosphere with hardly any moisture so it doesn't have cloud formations. The surface is reddish because of the high iron content of the soil. All these factors attribute to its 15% albedo.

The other planets in our solar system are considered ***gas giants***, also called ***Jovian planets,*** because they are very large and Jupiter-like. The Jovian planets consist of the outer planets: Jupiter, Saturn, Uranus, and Neptune. Their small cores are made mostly of rock, silicates, and iron surrounded by a layer of frozen gas, such as hydrogen or methane. Above that, we find the same gasses in liquid form that change to a gaseous state as they get further from the nucleus. The gas giants do not have solid surfaces like the rocky planets, therefore, there is no definite separation between the "surface" and the atmosphere. The gases become less dense as they get further from the core.



Credit: NASA

THE GAS GIANTS: JUPITER, SATURN, URANUS, AND NEPTUNE

The albedo of the gas giants are:

Jupiter =34% Saturn = 34% Uranus = 30% Neptune = 29%

Their albedo is fairly similar regardless of their size and distance from the Sun. Why? Remember, albedo is the percentage of light reflected to the amount of light received. The gas planets are cloudy and clouds increase the overall albedo, reflecting much of the sunlight.

TELESCOPE FILTERS (OPTICAL FILTERS)

Filters can greatly improve the quality of an image seen through a telescope. With the proper filter one can:

- Eliminate glare
- Penetrate the atmosphere
- Increase contrast
- Resolve finer details
- Improve the dark sky effect
- Improve resolution

You wear sunglasses on a bright sunny day to reduce light and see things more clearly. Adding a filter is like adding a pair of sunglasses to your telescope so you can see things better. The filter enhances the light that reaches your eye but does not enhance the image. This same thing happens with a telescope. You can see things more clearly when you wear colored sunglasses or polarized sunglasses.

Color filters can enhance telescopic images. They are particularly helpful in observing details in the planets.

Different colors will bring out atmospheric and surface features that are hard to perceive under full light.

The following list gives the ***Wratten*** numbers and labels colors for specific use:

- #12 Yellow - Deepens blues and brings out reds and yellows on Jupiter and Saturn, and improves surface detail on Mars. Best on medium to large scopes.
- #21 Orange - Increases differences between light and dark areas and detects dust storms on Mars. It can sharpen the contrasts of Jupiter and bring out the Great Red Spot. Can be used with smaller scopes.
- #25A Red - Fantastic filter for increased contrast on Jupiter. It really makes the belts “pop out.” Very nice on Mars and brings out the surface detail on Saturn. Only recommended for larger scopes.
- #58 Green - Improves contrast and detail to the cloud belt structure on Jupiter and Saturn. Also useful on the Martian polar caps. Best performance on larger scopes.
- #80A Blue - This filter can really pull the detail out on Jupiter’s cloud belt and Great Red Spot. Also useful for enhancing Saturn’s contrast.

The quality of all the optical elements in a telescope is as important as the seeing conditions. This applies to the main objective (primary light gathering element), whether a lens or mirror, and the eyepieces. Filters are no different. Those made of good quality optical glass are superior to cellophane or gel.

HAND-HELD COLOR FILTERS

COLORED FILTERS THAT CAN BE ATTACHED TO EYEPIECES

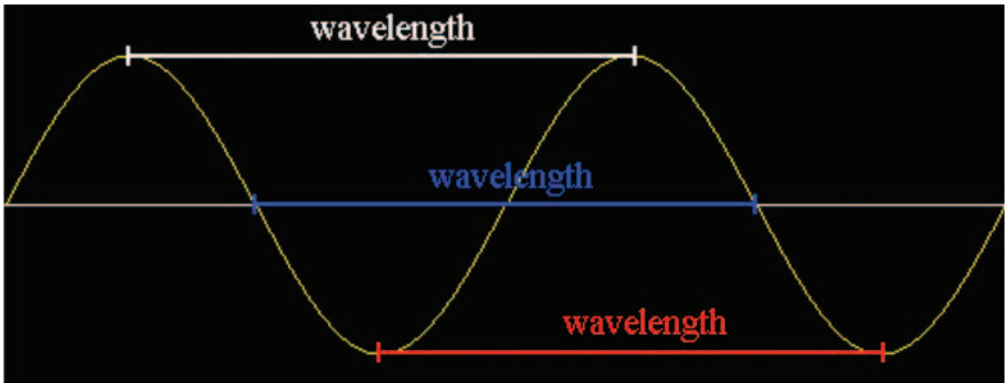
Remember when we look at astronomical objects, we do it from the bottom of our thick atmosphere. The steadiness of the air (what astronomers call “seeing”) will greatly affect the quality of your image.

If the seeing is bad, wait a half hour or so to see if it improves. The main reason why winter observing yields better images is because, often, there is little temperature fluctuation between daytime and nighttime. This translates to fewer air masses at different temperatures rising or sinking. The atmosphere is steady (the seeing is very good) and our images will be sharp and steady.

Color filters for telescopes equates to high cost. Don’t be afraid to experiment and try different transparent color materials found around your home. Just make sure they are very flat and that the color is even throughout.

Our human eye can only recognize certain wavelengths of light between the ultraviolet and infrared ends of the visual spectrum. An optical filter will eliminate or enhance certain wavelengths of light that allows us to see objects more clearly. Some filters will cut down on glare and bring out better detail, and some work to eliminate certain colors in the visible spectrum of light.

We now know that visible light is part of the radiation known as the electromagnetic spectrum. The difference between various colors is their ***wavelength.*** A wavelength is the distance between two consecutive points in one oscillation, from any point on one cycle to the same point on the following cycle.



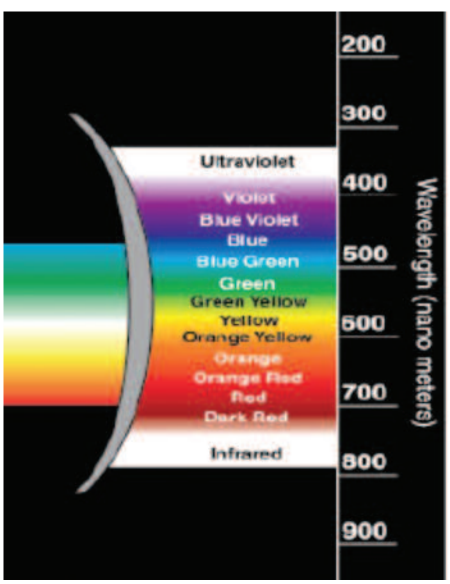
Credit: Zona Land Education

WAVELENGTH

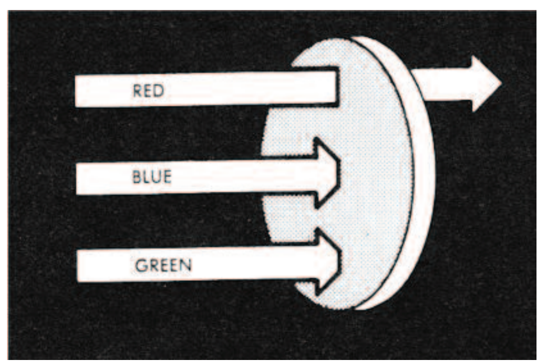
For example, the average wavelength of green light is around 510 ***nanometers*** (nm), while yellow light is around 570 nm.

The image below shows the "visible light" colors on the electromagnetic spectrum. We see these colors with our human eye. There are wavelengths in the electromagnetic spectrum that our human eyes cannot see. Energy with too short wavelengths are called "Ultraviolet" light, and wavelengths too long to see, "redder than red," are called "Infrared" light.

PHOTO COURTESY OF NASA



WAVELENGTHS



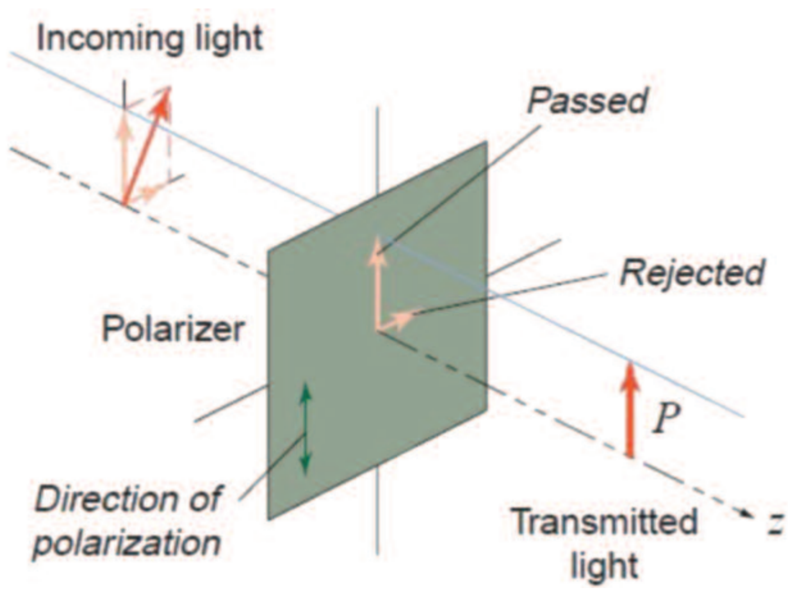
Credit: The Optica b/c Company

The red band-pass filter at left allows red light through and blocks the blue and green light

Different filters have different uses. For instance, a ***band-pass filter*** allows the passage of only the wavelength/s associated with its design and blocks all others.

Color filters can be used to reduce the intensity of the light reaching the eye of the telescope user, but when the balance of the different colors needs to be equally maintained, ***neutral density filters*** are the right choice.

Polarizing filters block only the light going through them in a specific direction. All other light passes through unopposed.



Credit: Best Innovative Source

POLARIZING FILTER

There are a lot of good apps and websites that tell you the best time to view the planets from your location. Some of the apps are free and some will charge you a small fee. Two free apps are listed, but there are many more.

- ***Google Sky Map* app**
- ***Planets* app**

5 Locating the planets

EXERCISE ONE

You will need:

A star chart and planet information. Many websites will give you information about the location of the planets on any given night. Some of these sites are: **http://www.skymaps.com**, **http://www.skyandtelescope.com**, and **http://www.astronomy.com**. Visit these and other sites to download the star chart and planet information you like best.

Procedure:

1. Go out on a clear night, preferably when there is no Moon.
2. Using the chart and directions, locate the planets that are visible. Planets like Jupiter and Saturn will be the easiest to spot because of their size and brightness. Venus is also bright, but is usually only visible just after sunset or before sunrise; most often it is low on the horizon.
3. Get familiar with the bright stars nearby to make it easier to spot the planet in subsequent nights. Over a period of months, you should notice that the planets move in relationship to the stars.
4. Observe a planet with binoculars and then with a telescope. Notice the difference in image size and visible detail.

In the above websites, you will also find predictions for the location of Jupiter's Galilean Moons, which are the largest four moons first observed by Galileo. You can watch as the moons cross in front of the planet and cast their shadows on the surface. They also get eclipsed by the planet when they go behind it or when the planet's shadow falls on them.

Predictions are also available for Saturn's moons. These are a little harder to observe due to the distance and orbital times. Can you determine which moons you see?

5 Using color filters

EXERCISE TWO

You will need:

If you have access to filters (either the kind that screw into the bottom of eyepieces or hand-held filters), use them for the following observations. If not, look around your home and see if you have different color cellophane paper or other transparent color materials. Remember, whatever you use must be flat and free of wrinkles, since wrinkles will deteriorate your image quality.

Procedure:

1. Pick an easy target like the Moon and observe a large feature such as a big crater.
2. Use filters of different colors to look at the same feature. Does one color bring out details better than others?
3. If you have polarizing sunglasses, put them on and observe the same area. Does it make a difference? If so, why?
4. If Jupiter or Saturn are visible try steps 2 and 3 on them.
5. Use the color guide in this chapter to observe specific features on the planets. Does the recommended color/filter help in bringing out details or improve contrast?

Take your time and observe the same features on different days. You will be surprised how the cloud bands of Jupiter change. Can you locate the elusive Red Spot? On Saturn, can you see how the shadow of the ring system blocks out the cloud cover on the planet?

As the saying goes, “the sky is the limit.” Take your time and enjoy the journey!

6 BEYOND THE SOLAR SYSTEM

Learning Outcomes

– Explain arc of minutes.
– Define eclipsing binary stars.
– Describe a primary and companion/secondary star.
– Identify a globular cluster.
– Define a galaxy.

Important Terms

Asterism – a recognizable pattern of stars within a constellation; usually made up of the brightest stars. They have names such as The Big Dipper, The Northern Cross, etc.

Binary Star System – a pair of stars in mutual orbit that are gravitationally bound to each other

Double Star – a pair of stars that appear close to each other in the sky, as seen from Earth, when viewed through an optical telescope

Eclipsing Binary Stars – a binary star system in which the orbital plane of the two stars lie in an individual's line of sight so that the stars undergo mutual eclipses; the brightest star is called the primary and the second is called the companion star, or secondary

Globular Star Cluster – tight group of hundreds of thousands of very old stars that are gravitationally bound

Milky Way – the galaxy that contains our solar system; composed of hundreds of billions of stars

Minute of Arc – the angular measurement of the separation between two binary stars; angular measurement equal to one sixtieth of a degree, or 60 seconds

Nebula – interstellar cloud of dust, hydrogen, helium and ionized gases; original term used for any fuzzy object observed through a telescope

Non-Visual Binary Stars – stars whose binary status was deduced through occultations, spectroscopy, but not visually (developments in telescopes can make what was a non-visual binary into a visual binary)

Star – glowing balls of gas composed of mostly hydrogen and helium; our Sun is a star

Star Cluster – a group of stars that are gravitationally bound

Visual Binary Stars – gravitationally-bound stars, which are separately visible with a telescope

Zenith – the point in the sky directly over the observer's head

MEASURING ASTRONOMICAL DISTANCES

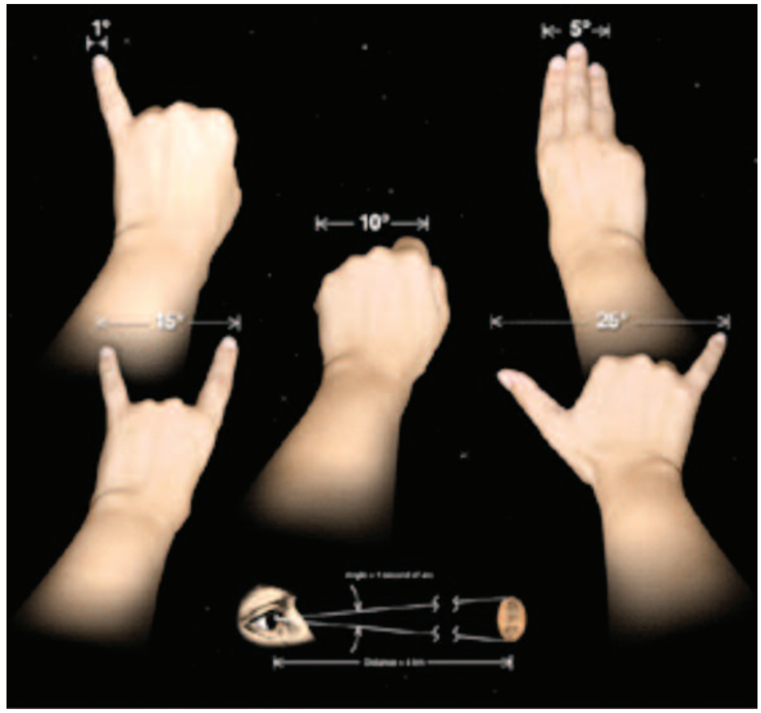


Photo Credit: NASA/CXC/M.Weiss

COMMON SKY MEASUREMENTS

Astronomers use a system of angular measurement that is based on a circle. The circle is divided into 60 ***minutes of arc***, or arc of minutes, and each minute is divided into 60 arc seconds. There are 60 arc-minutes in one degree. This system of measurement is how astronomers measure size and distance between objects in the sky. If you reach once around the sky, it will make a 360º circle. The sky rotates about 15º each hour, which equals 360º in a 24-hour period. If you are standing under the night sky and look straight overhead, which is about 90º from the horizon, this is called ***zenith***. Halfway between zenith and the horizon is a point 45º from the horizon. Going around another 45º brings you to the horizon only if facing north. In astronomy, we need to use smaller units of measure than degrees, to get better accuracy. A simple way to measure degrees is to use your hand as a measuring tool. The following measurements should be used when your hand is held at arm's length. Use the width of your little finger to represent one degree. Holding your hand in a fist and going across the top of your four finger knuckles is about ten degrees. Holding your pointer, middle, and ring fingers up equals five degrees. The distance between your pointer and little finger is about fifteen degrees, and the distance between your thumb and little finger is about twenty-five degrees.

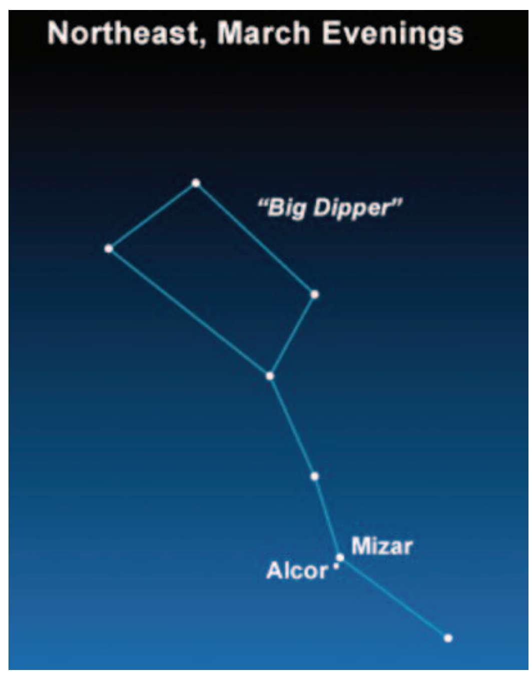
DOUBLE STARS

At least half of the stars in the universe (possibly up to 85%) are not just single stars but, instead, are part of a ***double star*** systems.

Have you taken a close look at the second star from the end of the handle of the Big Dipper? Notice anything unusual? This star, named Mizar, has an apparent magnitude of 2.23. Most people with normal eyesight can make out a faint companion, named Alcor, which has a magnitude of 3.99. It is believed that Native Americans called these stars the "horse and rider" and used them as a test of visual acuity.

As of 2007, the best estimate of Mizar and Alcor's respective distances places them 1.1 light years and 4 minutes of arc apart. Their proper motions show they move together (they are both members of the Ursa Major Group), and it has long been believed that they do not form a true ***binary star system***, but simply a double star.

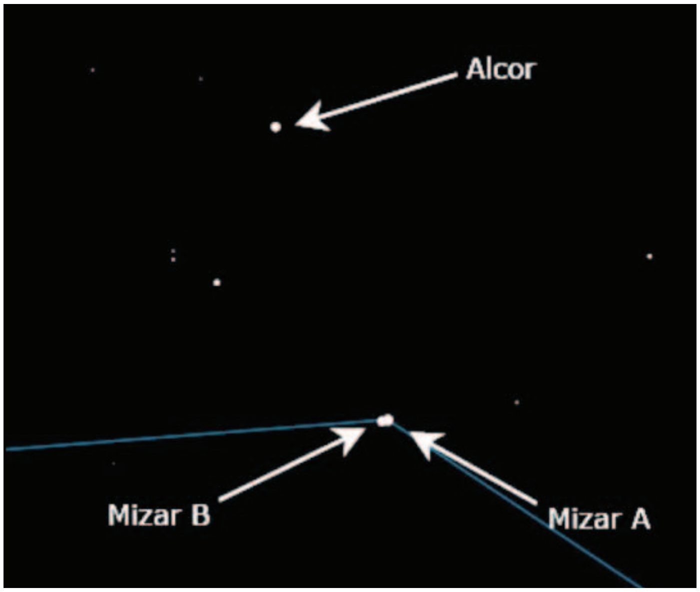
A view with binoculars easily reveals the separation between Mizar and Alcor.



Credit: EarthSky

THE BIG DIPPER WITH ALCOR & MIZAR

Credit: Cosmo Quest Forums

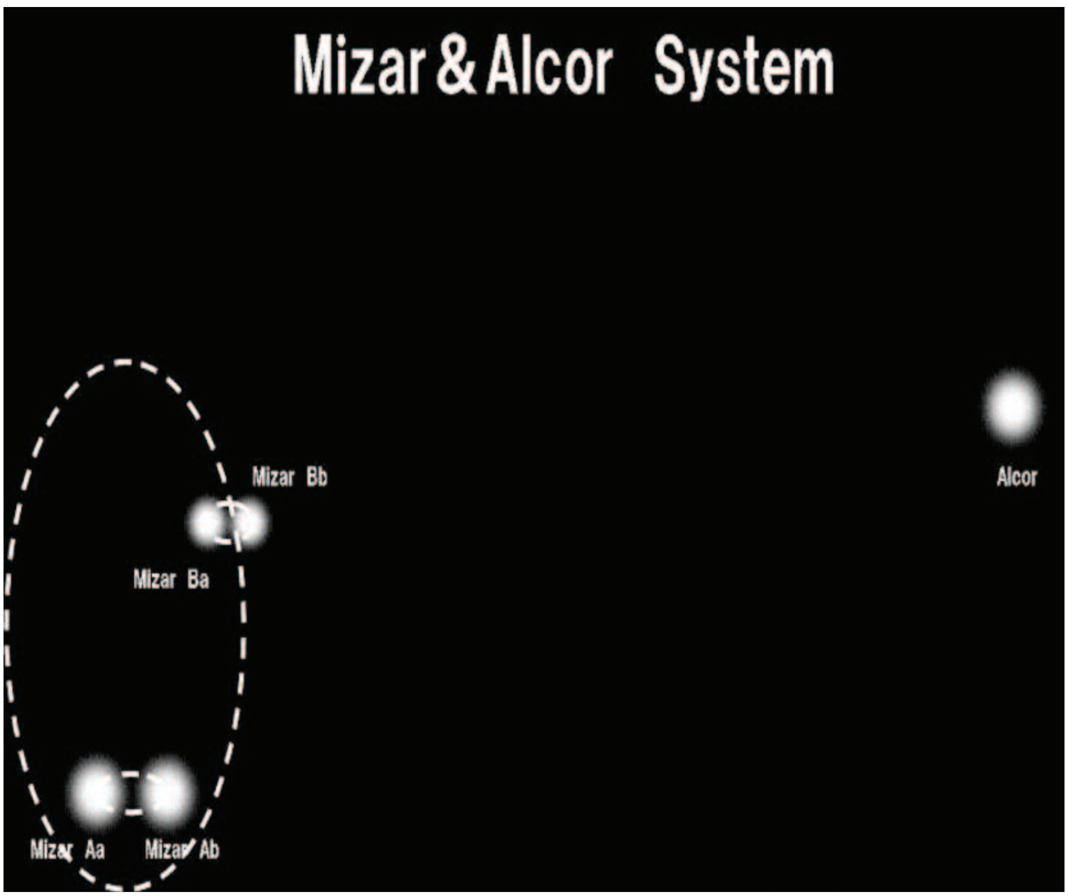


FURTHER MAGNIFICATION OF MIZAR

Further magnification with a modest size telescope will show that Mizar is a double star made up of Mizar A and Mizar B.

Research by astronomers have reported that Mizar A and Mizar B are each a binary star system. The one system is made up of Mizar Aa and Mizar Ab and the second system comprises of Mizar Ba and Mizar Bb. It also turns out that Alcor is orbited by a faint red companion star and is, therefore a binary star system. This brings the total number to six stars in this very complex system. Do not expect to see all six stars; average telescopes only yield Alcor, Mizar A and Mizar B.

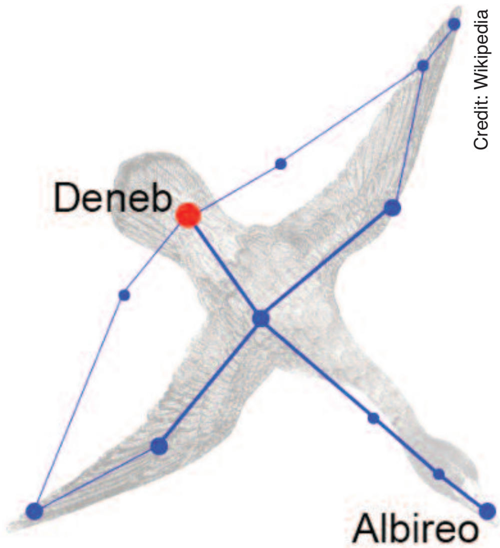
Credit: Astronomy.lolipop



THE ABOVE DIAGRAM DOES NOT SHOW ALCOR'S COMPANION

The constellation Cygnus, the Swan, lies along the ***Milky Way***. The four brightest stars in the constellation form a cross giving this ***asterism*** the name of The Northern Cross. Its second brightest star is called Albireo and it marks the head of the swan.

Albireo is a binary star system. The primary star is a yellow-orange giant star (visual magnitude 3.1) and the secondary star is a blue-green hued star (visual magnitude 5.1). The contrast of their colors makes Albireo a favorite target for amateur astronomers with small telescopes.



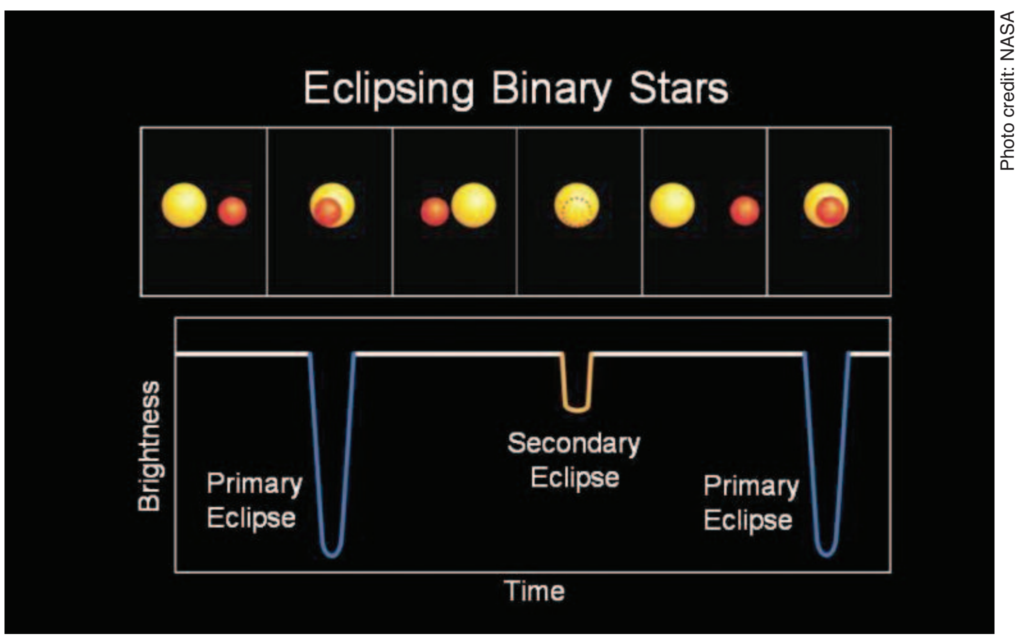
THE SWAN CONTAINS NORTHERN CROSS ALBIREO

ALBIREO AND BETA CYGNI CYGNUS

ECLIPSING BINARY STARS

Eclipsing binary stars' orbits are oriented so that one star passes in front of the other as we view the system. The brightest star is called the primary and the other is called a companion star or secondary.

The picture to the right depicts the light curve of binary star Kepler-16. When the smaller star partially blocks the larger star, a primary eclipse occurs. A secondary eclipse occurs when the smaller star is occulted, or completely blocked, by the larger star.



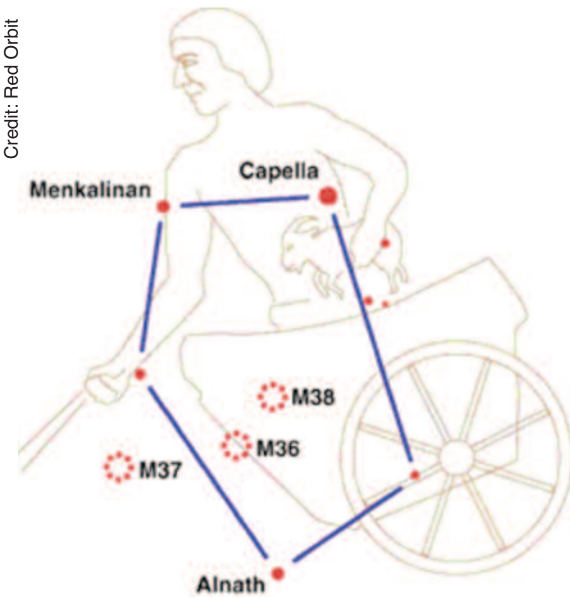
BINARY STAR LIGHT CURVE

Eclipsing binary stars are too far away from our view on Earth, but by astronomical standards they are too close together to allow us to see them as two separate stars. Instead, we observe the variations in the total light output as the stars eclipse each other.

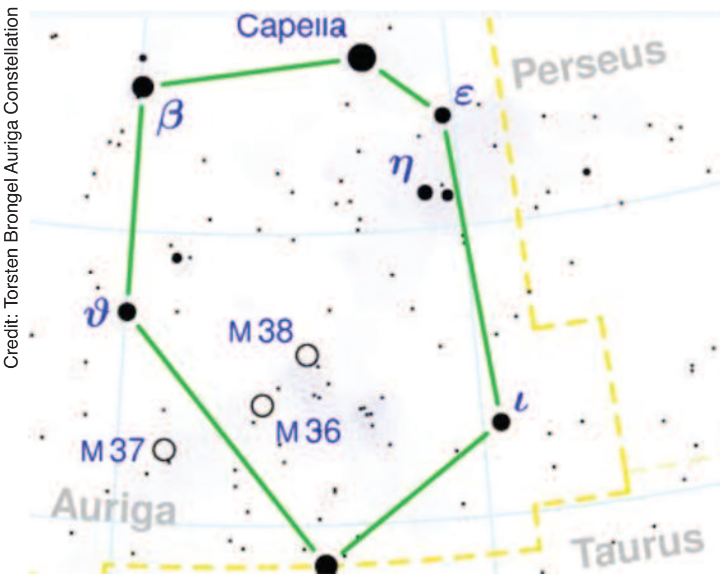
These observations allow astronomers to calculate the period of the orbits and to determine their mass, luminosity, radius, and density.

The American Association of Variable Stars Observers (AAVSO) is a non-profit worldwide scientific and educational organization of amateur and professional astronomers who are interested in variable stars. Its members observe and analyze variable stars; collect and archive observations for worldwide access; promote collaborations between amateur and professional astronomers, and support public outreach. One of the AAVSO programs is called citizen scientists. It is geared toward volunteers with no prior scientific training who desire to work with trained researchers.

The star Almaaz, in the constellation Auriga (the Charioteer) has baffled scientists since 1821. The secondary of this eclipsing binary system has been subject to much debate because it does not emit as much light as is expected for an object its size. As of 2008, the most commonly accepted model is a binary star system surrounded by a massive, opaque disk of dust. Become a citizen scientist and help solve this puzzle, while learning under the tutelage of a professional researcher.



AURIGA CONSTELLATION



AURIGA CONSTELLATION

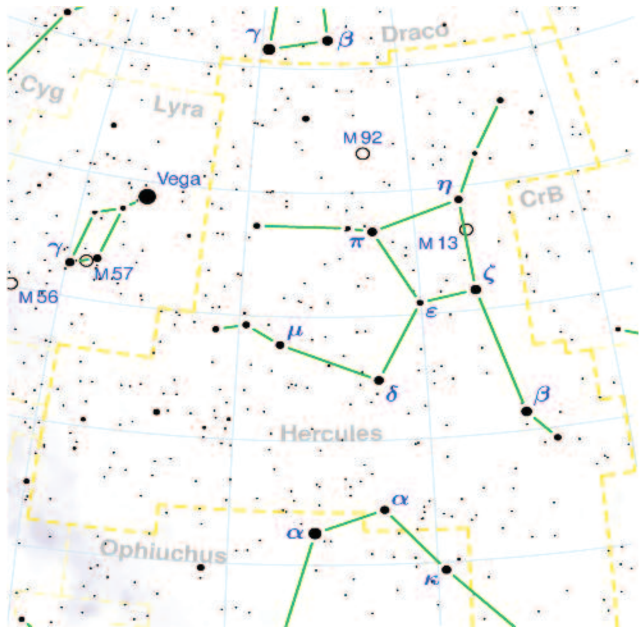
GLOBULAR STAR CLUSTERS

A ***globular star cluster*** is a group of stars that orbit (satellite-like) the cores of galaxies. Clusters are very tightly bound by gravity, hence their spherical shape, and have a higher density of stars toward their centers. The name “globular” comes from the Latin word “globulus,” which means a small sphere.

There are about 150 currently known globular clusters in orbit around our home galaxy, the Milky Way. There could still be another 20 or so yet to be discovered. Larger galaxies, like the Andromeda Galaxy, can have as many as 500 globular clusters.

M-13 GLOBULAR CLUSTER

One of the better-known globular clusters is in the constellation Hercules, the famous mythological strongman. The cluster is located on his left side and a little below his left armpit. It was given the designation M13 by Charles Messier (1730-1817), a French astronomer and comet hunter. When comets are first observed, they resemble a globular cluster or just faint fuzzy objects. It was not uncommon in Messier's day for comet hunters to confuse clusters (permanently placed objects) with the transient and visually diffused comets. Messier decided to catalog all known clusters, galaxies, etc., to prevent further confusion. His catalog gave the designation "M" plus a number to each of these objects. The first version of his catalog contained 45 objects and was published in 1774. The final version, published in 1781, listed 103 objects. To this day, many amateur astronomers pursue the observation and recording of all 103 objects.



Credit: Torsten Bronger

CONSTELLATION HERCULES

The Astronomical League, a nation-wide organization of amateur astronomy societies, has an award called the "Messier Program Certificate," which is given to members who have observed most or all of the Messier objects.

Early astronomers, observing without the aid of telescopes, saw some fuzzy objects in the heavens. They knew they were not stars. Due to their appearance, they called them ***nebulas***, Latin for cloud. Today we still use this designation, but we know that they are not clouds like the ones in our atmosphere, instead they are the remains of stars that completely or partially exploded at the end of their life. The term was used for galaxies or gigantic clouds of interstellar gases before research and modern telescopes showed them what they really are.

A galaxy is a gravitationally-bound grouping of stars, stellar remnants and interstellar gas and dust. They can be as small as 10 million stars (dwarf galaxies) or as large as trillions of stars (the Andromeda Galaxy).

The only galaxy visible with the unaided eye is the Andromeda Galaxy, in the constellation Andromeda. Messier definitely saw this one because he labeled it M31. At one time, it was estimated that M31 was much bigger than our own Milky Way, but recent studies suggest that although Andromeda is larger, the two galaxies are about equal in mass.

It is interesting that both Andromeda and the Milky Way have satellite galaxies orbiting them. In this picture, you can see the Andromeda galaxy and both of its satellite galaxies. One is in the forefront and the other behind.

Credit: NASA

ANDROMEDA GALAXY AND ITS SATELLITE GALAXIES

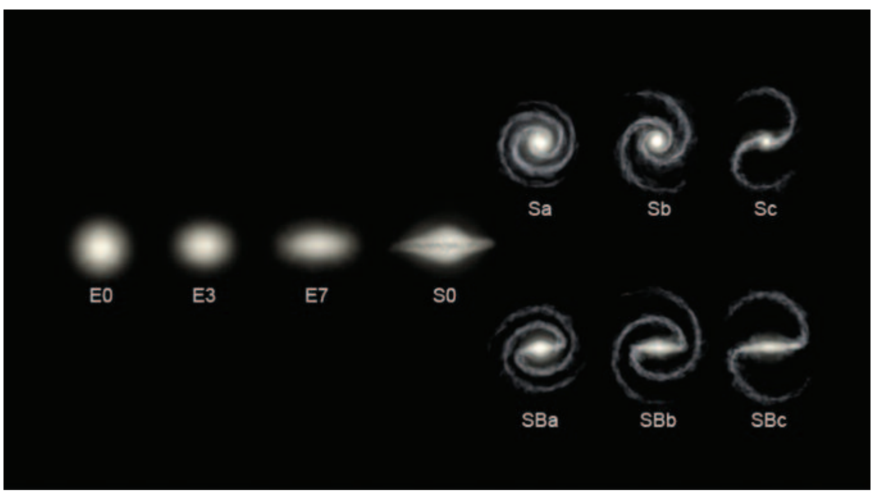
The Milky Way's satellite galaxies are called the Magellanic Clouds and are visible only from the southern hemisphere. They were named after Ferdinand Magellan (1480-1521), a Portuguese explorer who circumnavigated the world between 1519 and 1522. The clouds are identified as the Large Magellanic Cloud (LMC) and the Small Magellanic Cloud (SMC).

Credit: European Southern Observatory

SMALL (SMC) AND LARGE MAGELLANIC (LMC) CLOUDS

Edwin Powell Hubble (1889-1953), an American astronomer, developed a system to classify galaxies. The two major classes are elliptical and spiral and are further organized into other subgroups.

Credit: Wikipedia



HUBBLE'S GALAXY CLASSIFICATION

Showing some of the designations for various shapes of ellipticals & spirals and spiral

6 Locating Mizar and Alcor

EXERCISE ONE

You will need:

– Low power and higher magnification binoculars

– Chart or instruction to locate the Big Dipper. Most people can locate the Big Dipper in the northern sky. If you are unable to locate the Big Dipper, check your local public library for astronomy books with instructions and charts geared for the beginning observer. The internet is also a good source. Some good sites are: **http://www.skymaps.com**, **http://www.skyandtelescope.com** and **http://www.astronomy.com**

Procedure:

1. Go out on a clear night, preferably when there is no Moon.
2. Using a chart and directions, locate the Big Dipper.
3. Using your unaided eye locate Mizar, the second star from the end of the Big Dipper handle. Next, see if you spot Alcor. It will be very faint and close to Mizar. Don't worry if you can't see it. Low power binoculars should enable you to see the two stars.
4. Higher magnification binoculars or a small telescope will allow you to resolve Mizar as two stars. (This is the limit for most amateur telescopes. It would take a very large professional telescope and special instrumentation to resolve Mizar further into two binary star systems.)
5. Next, use your charts to find the constellation Cygnus. Be aware that it is only visible in late spring and all summer.
6. Look at the star that represents the head of the swan. It should look like a single star.
7. Using your binoculars, can you see the two stars close to each other? Can you detect that they are two different colors? (The larger or primary star is a golden-orange color while the companion or secondary is bluish.)
8. Research the location of other double stars and try to find them. You will soon realize that the quality of your telescope along with magnification will determine which double star you can resolve.

Locating the Andromeda Galaxy

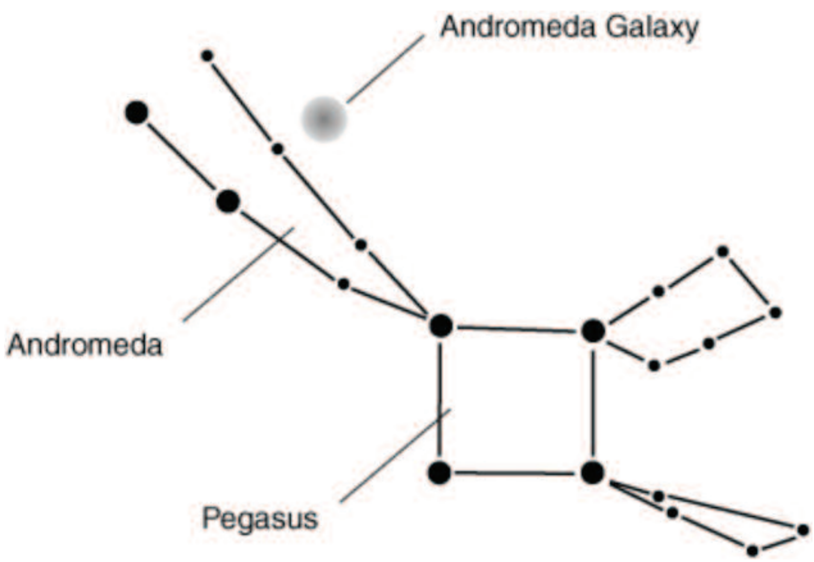
EXERCISE TWO

You will need:

Binoculars and a telescope. The best time of the year to look for the constellation Andromeda is mid fall to early winter. It will be located well above the eastern horizon.

Andromeda is not the easiest constellation to find but the constellation Pegasus (the Flying Horse) can be used as a guide. Four bright stars form a square. Astronomers call it “The Great Square of Pegasus.”

Credit: Education.com



From the diagram on the left, you can see that the constellation Andromeda shares a star with the constellation Pegasus. This star, called Sirrah, forms the bottom of an elongated letter “V.” Follow the bottom arm of the V moving away from Sirrah and stop at the second star called Mirach.

Procedure:

Draw an imaginary line from Mirach to the star above it. This star doesn’t have a name but is designated as η, the Greek letter “mu” or “m.” Continue your line about the same distance as between Mirach and mu and you will come across the Andromeda Galaxy.

1. Can you see it without any optical aid?
2. Can you see the spiral shape using binoculars?
3. Can you detect the spiral arms using a telescope?

Remember, the more you magnify the galaxy, the smaller area you will be able to see. Make sure you search around and look for the two satellite galaxies.

There are billions of galaxies in the universe. How many do you think you can find?

7 LIGHT POLLUTION

Objectives

– Describe an observatory.
– Define light pollution ordinance.
– Identify a skyglow.
– Define acid rain.

Important Terms

Acid Rain – material from the atmosphere that contains higher than normal amounts of nitric and sulfuric acids

Dark Sky Park – a park or other public land recognized for excellent stewardship of the night sky; designation is based on stringent outdoor lighting standards and innovative community outreach

Light Pollution – also known as photopollution or luminous pollution; it is the excessive and obtrusive use of artificial light

Light Pollution Ordinance – guidelines created by communities to control the location and design of exterior lighting; to prevent electrical power waste; light trespass and light pollution

Light Trespass – light that falls outside of the area intended to be lit

Observatory – a place using scientific equipment to observe an astronomical phenomenon

Particulates – tiny particles of fly ash and dust that are expelled from coal-burning power plants

Skyglow – the illumination of the night sky by artificial lights

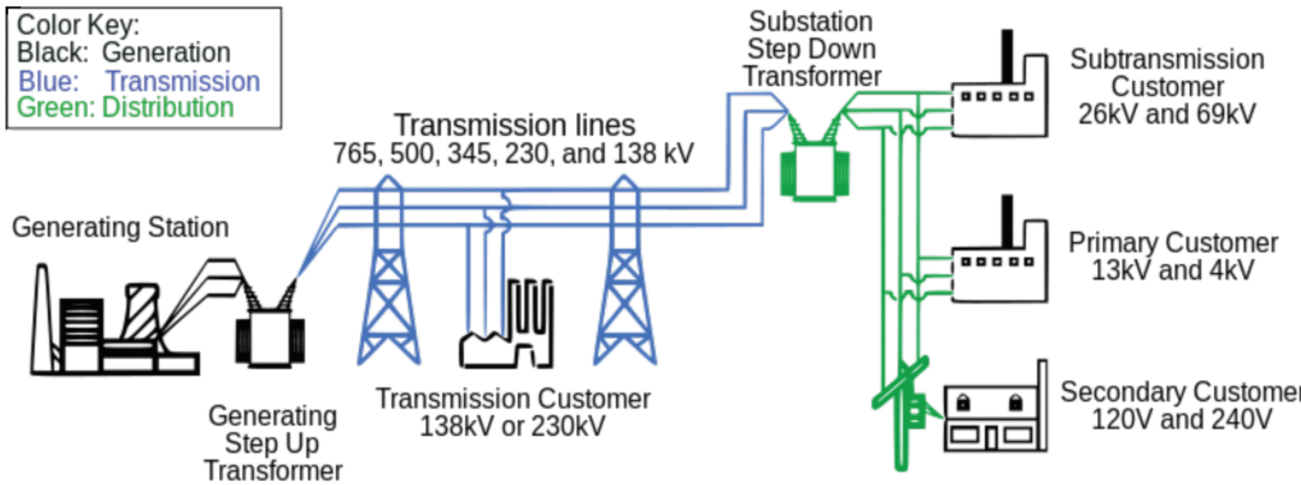
Sulfur Dioxide – a pollutant gas; produced when coal is burned, the sulfur gas given off combines with oxygen in the air

ELECTRICITY

No one can deny that the development of electricity generation and distribution was one of the major triumphs of the late 19th century. Electricity brought about better illumination of homes and businesses while removing the dangers associated with candles, gas jets, etc.

Electricity also brought advancement in manufacturing by introducing electric motors to replace waterpower and steam engines. Goods were produced faster and cheaper. The world was on its way to a new utopia.

Credit: New Jersey Clean Energy Program



ELECTRIC TRANSMISSION AND DISTRIBUTION SYSTEM

New technology can have a dark side. People who accidentally come in contact with power lines are often electrocuted. Many power plants generating electricity burn coal, which produces ***sulfur dioxide.*** This is a pollutant gas that contributes to the production of ***acid rain*** and causes significant health problems, particularly through its role in forming ***particulates***. Acid rain causes acidification of lakes and streams, and it contributes to the damage of trees at high elevations and in many sensitive forest soils. In addition, acid rain accelerates the decay of building materials and paints, including irreplaceable buildings, statues, and sculptures that are part of our nation's cultural heritage. Prior to falling to the earth, sulfur dioxide and nitrogen oxide gases contribute to visibility degradation and harm public health.

To both amateur and professional astronomers, artificial lighting has brought devastating effects in the form of ***light pollution***. Many places have ***light pollution ordinances*** to limit light pollution from streetlights and other fixtures. These ordinances are designed to conserve energy, reduce glare that creates traffic hazards, and to allow amateur and professional astronomers better views of the night sky. Light from your neighbor's house that keeps you awake and interferes with you observing the sky is called ***light trespass***. Lights at a shopping center or baseball field that are aimed incorrectly can also be light trespass.

An ***observatory*** allows professional and amateur sky watchers to study and practice astronomy, and helps schools and universities to further their educational astronomy outreach. Observatories are built at a high altitude and in an area of very low light population and growth potential. This environment provides dark clear skies in which to conduct observations and research.

OBSERVATORIES

The Yerkes Observatory, a University of Chicago, Department of Astronomy and Astrophysics facility, was built on the shores of Lake Geneva, Wisconsin. Why didn't they build the observatory in Chicago? By the 1890s, Chicago already suffered from polluted skies due to artificial lighting, the burning of fossil fuels, etc. On the other hand, Lake Geneva in Wisconsin provided a rural setting with clear, dark skies and was easily accessible via railway. The observatory houses the largest refracting telescope in the world. The refracting telescope is 63 feet long, has a 40-inch wide lens and weighs 20 tons. It is housed in a 90-foot diameter dome. There are also two smaller domes on the east end of the observatory. The telescope sits on a 75-foot diameter movable floor so astronomers can be raised up to the telescope eyepiece. The telescope is moved from one position to another by an electric motor, and is so well balanced you can move it with your hand. The observatory was the first to be built for the purpose of research and not just observational astronomy. It was the first observatory to house physics and chemistry labs. Yerkes Observatory claims to be the birthplace of modern astrophysics. Edwin Hubble worked as a graduate student at Yerkes and Albert Einstein worked at Yerkes to prove his theory of relativity.

Unfortunately, growth caught up with Lake Geneva. The railroad that made it easy for Chicago astronomers to reach the observatory also made the area a popular summer retreat for the barons of wealth in lumber, cattle, oil, steel, cement, manufacturing, and durable goods. As years went by, the population of the area grew. With the growth came outdoor lighting and the degradation of the dark sky conditions.

By March 2005, the University of Chicago had discontinued astronomical research at the observatory so they announced plans to sell it and one purchaser wanted to develop luxury homes on the site. The Geneva Lake Conservancy, a regional conservation and land trust organization, took the position that it was critical to save the historic Yerkes Observatory structures and telescopes for education and research. The plans for the sale of the property were terminated when the Village of Williams Bay refused to change the zoning of the facility from educational to residential. Today the facility is used for educational programs, public tours and amateur observation sessions.

Credit: Okrent Associates

YERKES OBSERVATORY

The Kitt Peak National Observatory, part of the National Optical Astronomy, is located 56 miles southwest of Tucson, Arizona, high above the Sonoran Desert. The facility supports the most diverse collection of astronomical observatories on Earth for nighttime optical and infrared astronomy, as well as daytime study of the Sun. There are three major nighttime telescopes plus a consortium of organizations that operate 24 optical telescopes and two radio telescopes. Kitt Peak houses the world's largest collection of optical telescopes and the largest, most diverse assembly of astronomical instruments in the world. The National Solar Observatory at Kitt Peak is the largest in the world.

As with most observatories, the site was chosen in 1958 because of its altitude of 6,875 feet above sea level, flat mountain top, good weather and proximity to both the University of Arizona and an international airport. At the time, the population of Tucson was about 50,000. Unfortunately, by 1970 research astronomers were beginning to notice changes in the quality of the night sky. As the city of Tucson grew in population, so did light pollution and skyglow. Skyglow can be produced by both natural and man-made sources. Examples of naturally produced skyglow would be sunlight reflected off the Moon, Earth, interplanetary dust, starlight in the atmosphere, and light from unresolved celestial objects. This glow and man-made skyglow emits light pollution, which creates an enormous glow that can be seen miles away and high in the sky.

Credit: Kitt Peak Observatory

KITT PEAK OBSERVATORY

INTERNATIONAL DARK SKY ASSOCIATION

The International Dark Sky Association (IDA), a non-profit organization, was founded in 1988. Dr. David L. Crawford and colleague Dr. Tim Hunter founded the organization to address the growing problem of light pollution.

Over the past twenty years, IDA has grown from two members and volunteers to a membership of over 11,000 and a full time staff. In leading the fight against light pollution, IDA has published a number of articles, helpful guides, and a quarterly newsletter highlighting the leading topics in dark sky preservation. It also holds public meetings and events, and has developed a number of programs and features such as the Fixture Seal of Approval Program (FSA) and the International Dark Sky Communities (IDSC), Parks (IDSP), and Reserves (IDSR) Programs.

The leadership of IDA recognizes that merely preserving the night sky for astronomers will not motivate individuals and municipalities to get involved in fighting light pollution. Fortunately, many studies on the effects of artificial light and its misuse have shown that there can be:

- Energy savings resulting in economic benefits
- Increased visibility, safety, and security at night by reducing glare
- Conservation of nocturnal wildlife and ecosystems
- Safeguarding scientific and educational opportunities, such as astronomy
- Protection of human health

IDA promotes responsible legislation, public policy, research, and standards in a professional and scientifically sound manner. IDA seeks specific solutions that mitigate light pollution by both time-proven methods, as well as promotes new technologies.

Dark Sky Parks are established to protect areas for natural night skies and recognize these parks's commitment to the preservation of darkness. The IDA designates a Dark Sky Park by its nighttime beauty, dark skies and preservation of the nighttime environment. The parks are given a rank of bronze, silver or gold. To earn a gold rating, the park must have near natural conditions, allowing the observer to view the total night sky phenomena including: aurora, airglow, Milky Way, zodiacal light, and faint meteors. As of this writing, the IDA has designated eight parks in the United States as Dark Sky Parks. To find out where these parks are located you can visit the International Dark-Sky Association website: **http://www.darksky.org**.

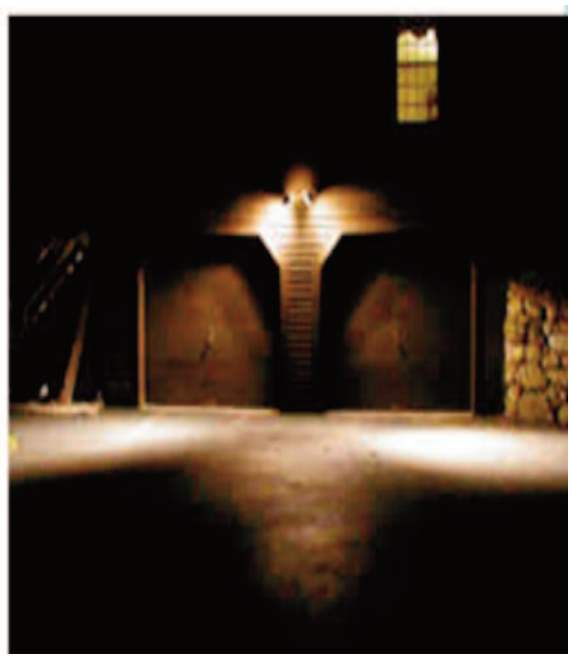
GOOD VS BAD LIGHTING FIXTURES

In many cases, light pollution can be easily resolved. Below are two pictures of the same house with the same outdoor light fixtures between the two garage doors. The picture on the left shows the fixtures without any light shield to direct the light. Notice how much glare is thrown upwards towards the upstairs window and on to the sky. Someone driving up to the house would be blinded and unable to safely see ahead. The picture on the right shows the same light fixtures with shields installed. The shields are nothing more than simple cone-shaped metal shades. The shields allow light to be placed on the desired areas and prevent glare and upward illumination. With proper shielding, the size of the electric bulb (wattage) can be reduced, which results in lower electrical cost. In addition, proper lighting improves night visibility.

Credit: greenaction.org

THE LIGHT SHIELD IS A METAL SHADE THAT DIRECTS THE LIGHT TO THE DESIRED AREA

LIGHTS ON THE GARGAE TRAVELING UPWARD CAUSING SKY GLOW



Credit: Green Action

GARAGE LIGHT WITH A SIMPLE SHIELD TO REDUCE GLARE.

STREETLIGHTS PRODUCE A LOT OF GLARE AND UNWANTED UPWARD LIGHTING

Credit: 2.bp.blogspot

THESE ROAD LIGHTS ILLUMINATE ONLY THE ROADWAY AS NEEDED

7 Check your home and neighborhood for light pollution

EXERCISE ONE

You will need:

A home with outdoor lights

Procedure:

1. Go outside on a dark night (no Moon) and see if the light/s from your home illuminates the home and yard of your neighbors. Do you think that a properly designed light fixture would help place the light in the area you want to illuminate without affecting others?
2. Look at your neighbors' homes. Do they have outdoor lights? Do these lights produce glare? Does the light trespass on the homes around it?
3. Does your home or your neighbor's home use motion detection lights? These lights only come on when the sensor detects motion by a person, vehicle, etc.
4. Are there street lights in your neighborhood?
    - Do they properly light up the roadway and sidewalks?
    - Does the light illuminate upwards toward the sky?
    - Can the glare from the fixture prevent drivers from seeing pedestrians or bicycles on the road?
    - Do the lamps put out more light than necessary?

7 Your home town and outdoor lighting controls

EXERCISE TWO

You will need:

A computer with internet access

Procedure:

Do you know if your town or city has an ordinance to regulate outdoor lighting? You usually can check by visiting your town's website and looking around for the area where ordinances are listed. Some cities list them under "Online Resources" or "Information." Sometimes ordinances may not be easy to find but there is usually an area on the website where you can do a search. Type "ordinances" in the search area and you should be directed to the correct location.

1. Study the ordinance and see if it lists guidelines and specifications for outdoor lights. Are they listed as requirements or simply as recommendations? Requirements will usually list some type of fine or other penalty if the mandate is not followed.
2. Are there specific businesses addressed in the ordinance? For instance, are new or used car lots mentioned and are there specific rules, such as how many light posts they are allowed to have, or at what time of the night the lights must be turned off?
3. What about sport fields such as baseball/softball, football, tennis, etc.?
4. If your town doesn't have any ordinances or guidelines for outdoor lighting do you think it should?
5. Are there any other civic and social groups in your town that feel there should be such ordinances?

Civil Air Patrol
www.capmembers.com/ae

Air Force Association
www.afa.org

AIR FORCE
STEM

Outreach Coordinator Office
afsoco.afcivilian careers.com

Partners in Aerospace and STEM Education