The Art of Sky Interpretation

TCAA Guide #4

Carl J. Wenning

TWIN CITY AMATEUR ASTRONOMERS

ESTABLISHED 1960

THE ART OF SKY INTERPRETATION

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ABOUT THIS GUIDE:

This *Membership and Benefits* guide – the third of several such TCAA guides – was created after several years of thinking about the question of why it is people who join astronomy clubs often don't make the transition to become lifelong members. Many, perhaps most, pay their dues with the intention of becoming involved, but then something happens and before long they are no longer members. Why this happens remains a mystery for most astronomy clubs, but especially for the TCAA where we have good members, a stable organization, outstanding resources, a good observing site, a solid web presence, a fine newsletter, membership brochures, regular publicity, member education, and regular public outreach. Despite these facts, membership in the TCAA has been roughly stable at around 40-50 members since the start of the club in 1960.

Why should the failure to transition from novice to advanced observer be so common in astronomy clubs in general and the TCAA in particular? There appears to be two contributing causes: (1) people in today's frenetic and wired society no longer understand the concept of a hobby, and (2) many people feel out of place when it comes to seeking and finding the necessary help to make the transition. This guide has been created in response to the latter impediment.

This guide is an introduction to TCAA membership and benefits. Anyone who belongs to a service or social group should have an understanding of its history and practices. Members should also understand what benefits membership confers and how to access or obtain them. Without such information, it is more difficult to become part of the group. A guide can be most helpful in doing so. Herein you will find information about the club's history, activities, resources, and communications. It concludes with some sage advice from a person who has been an active club member since 1978.

The author gratefully acknowledges the assistance of the following TCAA members who either provided guidance or conducted an editorial review: Tim Stone, Bob Finnigan, Duane Yockey, Tom Weiland, Vivian Hoette, Mark Heiniger, and Tony Cellini, Jim Gibbs, and Sunil Chebolu.

ABOUT THE AUTHOR:

Dr. Carl J. Wenning is a well-known Central Illinois astronomy educator. He started off viewing the heavens with the aid of his grandfather in the summer of 1957. Since that time he continued viewing the night sky for nearly six decades. He holds a B.S. degree in Astronomy from The Ohio State University, an M.A.T. degree in Planetarium Education from Michigan State University, and an Ed.D. degree in Curriculum & Instruction with a specialization in physics teaching from Illinois State University.

Dr. Wenning was planetarium director at Illinois State University from 1978 to 2001. From 1994-2008 he worked as a physics teacher educator. Retiring in 2008, he continued to teach physics and physics education courses for an additional seven years. He also taught astronomy and physics lab science almost continuously at Illinois Wesleyan University from 1982 to 2001. He fully retired from Illinois State University in 2014 after nearly 40 years of university-level teaching.

Carl became associated with the TCAA in September 1978 – shortly after he was hired to work at Illinois State University. Today he is an Astronomical League Master Observer (having completed 14 observing programs to date) and received the 2007 NCRAL Region Award for his contributions to amateur astronomy. He is a lifelong honorary member of the TCAA and is a member of its G. Weldon Schuette Society of Outstanding Amateur Astronomers.

SKY INTERPRETATION

Guide goal and objectives: The goal of this chapter is to heighten awareness of the heavens and important Earth-sky relationships. Master naturalists will learn techniques used for sky interpretation. At the conclusion of this chapter, sky interpreters should be able to accurately and clearly describe the following:

- reasons for interpreting the sky
- motions of the sun including its relationship to seasons and time keeping
- motions and appearances of the moon including phases, eclipses, and the moon illusion
- planets and minor denizens of the solar system such as dwarf planets, asteroids, and comets
- key constellations and motions of three groups of stars: north circumpolar, equatorial, and south circumpolar
- Milky Way and first magnitude stars including names, constellations, distances, sizes, and luminosities
- Earth-space interactions as they relate to the sun, moon, comets, meteors, and asteroids
- basic use of sky maps, binoculars, and telescopes
- essential atmospheric phenomena with celestial underpinnings such as meteor showers and auroras
- common approaches to and best practices of sky interpretation

Sky Interpretation is the art and process of coupling direct observation with skilled communication for the purpose of informing people about the sky, its objects, and phenomena, with special emphasis on relationships of these to Earth and its occupants.

Von Del Chamberlain

Why Interpret the Sky?

Famed sky interpreter John Dobson once asked a ranger about setting up a telescope in a park to show people the heavens only to be told, “The sky is not a part of the park.” to which Dobson replied, “No, but the park is part of the sky.” What Dobson said was true. Without any doubt whatsoever, we know that the sky is just as much a part of the natural scene as are animals, plants, rocks, and humans. Astronomer Carl Sagan once noted, “We are star dust….” Because the very elements that make up our bodies were forged in the hearts of exploding stars billions of years ago, the sky is just as much a part of us as we are of the sky. This is just one reason to interpret the sky. There are many other reasons.

- *People are curious about their entire environment.* Humans are curious about their place in the universe, not just the animals, plants, and rocks that surround them. Unfortunately, the vast majority of people today live in towns and cities surrounded by a landscape that physically blocks the sky from view. At night, cities have a constant glow that also blocks the sky from view. Many of us have isolated ourselves from the environment for matters of convenience. We hide away in our houses. If it is too hot, we turn on the air conditioner; if it is too cold, we turn on the heat; if it is too dark, we turn on the lights. For the vast majority, our lives seemingly are disconnected from the natural world.
- *The contrast between city sky and country sky at night is profound.* Because the vast majority of America’s population today lives in urban settings, it is only when they travel to parks in dark-sky locations that they actually can see the stars of night. It is an unfortunate fact that by the year 2025 some 90% of the American people who live in cities will never see the night sky in all its glory according to the National Park Service. If they don’t see the sky in today’s rural parks, when and where will they?
- *People are amazed when they see a dark night sky.* It is not uncommon to hear people who have returned from a camping trip under a dark sky to tell with awe “the stars seemed much nearer the earth”. As a result of this cosmic wonder, astronomy programs have proven to be wildly popular in state and national parks. For some a dark night experience leads to a lifelong memory. It’s easy to see why, considering the amazing beauty of the universe that surrounds us.
- *People appreciate looking through a telescope.* One look at the craters of the moon, the rings of Saturn, a sparkling star cluster, a wispy nebula, a distant galaxy, and it’s all oohs and aahs. No one unfamiliar with the wonders of the cosmos can walk away not being impressed. This is the beginning of both a heightened awareness and a new respect for the world around us.
- *People enhance their understanding our unique and precious place in the universe.* Perspectives change when people come to realize that humans – over 7 billion strong – occupy a tiny blue marble orbiting in the “Goldilocks zone” – not too hot and not too cold – around just an ordinary star in the vast hostile place we call space. We seem to have a primal need to understand, and this understanding has implications.
- *People preserve what they experience and appreciate, they protect what they know about, and they defend what they understand.* Earth is a spaceship orbiting a star – one of hundreds of billions that make up the Milky Way galaxy; the remainder of the universe – consisting of hundreds of billions of galaxies each with billions and billions of stars – makes up the remaining 99.9999999999 ad infinitum percent of the universe. It is incumbent upon nature interpreters to point out and explain the relationships between Earth and the rest of the cosmos, and help humans understand their place in it.

Sky Interpretation in General

In order to be good interpreters of the sky, we must become, as it were, living field guides to the heavens. This means that we should know and be able to do many things. We should understand and be able to accurately and concisely explain the observable and provide necessary details about interactions between the Earth and sky. We need not know about all the latest things in astronomy, about wimps, the Higgs boson, string theory, dark matter, dark energy, and so on and so forth. That’s where astronomy clubs and other experts can come to our aid. Until such time, we should be able to interpret the more common aspects of the sky in an interesting, informative, and accurate manner.

What We Need to Know

This chapter is at best a primer to observational astronomy. Reading astronomy textbooks, studying field guides, and working with experienced amateur astronomers can provide a much fuller knowledge of the sky. Still, the fundamentals – what we need to know and be able to do for park visitors at the most basic levels – are pretty clear in the mind of experienced sky interpreters. Consider the following things about which many who live in this supposed space age are grossly unfamiliar:

The Sun's Motions

The sun rises daily along the eastern horizon and sets daily along the western horizon. Despite the misleading nature of the terms "rises" and "sets", the sun's daily or diurnal motion is only apparent. It is caused by Earth's rotation – spinning upon its axis.

The sunrise and sunset points change throughout the course of a year. The sun rises due east and sets due west at the times of the equinoxes – the beginning of spring in March and the beginning of autumn in September. During the first days of summer in June, the sun rises to the northeast and sets to the northwest. During the first days of winter in December, the sun rises to the southeast and sets to the southwest.

Contrary to the popular belief, the sun does not pass directly overhead at noon each day as seen from Illinois. (Our home location – when it matters – is assumed to be 40° north latitude or central Illinois.) In fact, in the temperate zone in which we live, the sun never passes overhead at midday on any day throughout the year – that only occurs in the tropics. On the first day of summer for us, the sun will reach a maximum midday elevation of 73.5° above the southern horizon. On the first day of winter, it will reach a maximum midday elevation of only 26.5° above the southern horizon. On the equinoxes, the sun appears 50° above the southern horizon at midday.

Objects always reach their highest positions in the sky when they cross from east to west over the meridian – an imaginary north-south line in the sky that passes through the overhead point, the zenith. As objects pass from east to west over the meridian, they move from AM (ante meridiem) to PM (post meridiem) – hence the origins of these terms.

The Seasons

The sun's annual north-south migration along the horizon and changing midday elevation along the meridian is caused by Earth's axis of rotation being inclined 23.5° to its orbital plane. This "tilt" of Earth's axis is fundamentally responsible for the seasons – not the changing Earth-Sun distance that is a commonly thought. (Earth is closest to the sun in early January when we are experiencing winter and farthest from the sun in early July when we are experiencing summer. It is good to note, too, that the seasons are always opposite in the northern and southern hemispheres.)

The seasons result from both the changing hours of sunlight and the changing elevation of the midday sun. On the first day of summer in the northern hemisphere, around June 21st each year when Earth's north polar axis points toward the sun (see Figure 1), the sun is in the sky for just over 15 hours; on the first day of winter, around December 21st each year when Earth's north polar axis points away from the sun, the sun is in the sky for only about 9¼ hours.

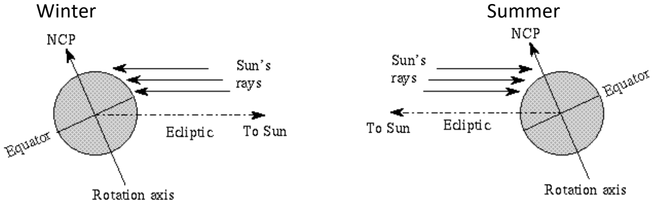

Figure 1. *Seasons result from irregular heating of Earth's surface.*

The sun beats down more intensely when it is high in the sky. (Imagine anyone going out to get a suntan around the times of sunrise or sunset. No, they won't do this. They go out at midday when the sun is highest in the sky.) On the first day of summer, the sun's path across the sky is highest and it's in the sky for greatest period of time thereby producing the greatest amount of heating. On the first day of winter, the sun's path across the sky is lowest and it's in the sky for the shortest period of time thereby producing the least amount of heating. These two phenomena combine to give us the cycle of the seasons.

Over the cycle of the seasons, the sun's path across the sky changes daily because the sun is changing its apparent position among the background of stars (known as the constellations of the zodiac). As Earth revolves around the sun, the sun appears to shift its position among the stars. The precise path of the sun's center among the stars over the course of a year is known as the ecliptic. The ecliptic is inclined 23.5° from Earth's orbital plane, causing the sun to migrate north and south in the sky on an annual basis. The ecliptic is, in essence, defined as the place where Earth's orbital plane appears to intersect the sky.

The Sun's Irregular Motions

The sun's apparent motion along the ecliptic is slightly irregular due to the fact that Earth orbits the sun in a slightly flattened circle – an ellipse. As Earth approaches the sun, it speeds up in its orbit causing the sun to move more rapidly along the ecliptic. As Earth pulls away from the sun, it slows down in its orbit causing the sun to move more slowly along the ecliptic. This irregular motion (tied into the inclination of the ecliptic to Earth's orbital plane) causes the sun to move irregularly in the sky. This requires us to make a correction to sundial readings known as the equation of time. The true sun's position in the sky can deviate from the fictitious mean sun's position in the sky. (It is upon this fictitious mean sun that we base civil time keeping.) The difference can cause sundials to be off as much as plus or minus 14 to 16 minutes at various times of year (to say nothing of the required longitude correction for different locations within the Central Time Zone).

The Moon's Motions and Phases

The moon's motion is a bit more complicated than that of the sun, or so it seems. The moon moves from east to west across the sky daily due to Earth's rotation. At the same time, the moon moves from west to east among the background of stars – just like the sun – but this time due to the moon's monthly revolution about Earth. As a result of these combined motions, the moon moves across the sky going from east to west on a daily basis, but does not move as quickly as the background stars. Those move from east to west at a rate of about 15° per hour (360°/24 hours). The moon drifts eastward among the background of stars at a rate of just over 13° per day. As a result, each evening the moon starts its westward trek across the sky some 13° farther to the east among the stars. This causes a day-to-day delay in the moon's rising (and setting) that averages about 50 minutes over the course of a year.

During the moon's westward motion across the sky and eastward motion among the stars, the moon continually shifts its position in the sky with respect to the sun. Once every 29½ days, the moon passes the sun as seen from Earth and this results in new moon phase. About 7⅓ days later, the moon reaches first-quarter phase. In another 7⅓ days, the moon reaches full phase, then similarly third-quarter phase, and finally new phase once again.

As the moon orbits Earth (see Figure 2), we see more and then less of its sunlit surface. When the moon is located roughly in the same direction of the sun, the moon's night side faces us and we "see" a new moon phase. About a week later, the moon is now one-quarter of its way around Earth in its orbit and we see the side facing the sun being brightly lit and the side opposite the sun in darkness. About a week later still, and we see the moon roughly opposite the sun in the sky. It now appears fully illuminated and the side opposite Earth is in darkness. A week further along and the moon it is three quarters of the way around Earth in its orbit and we see it lit half way once again. So, the phases of the moon are caused by seeing sometimes more and sometimes less of the moon's day and night sides; they have nothing whatsoever to do with the shadow of Earth.

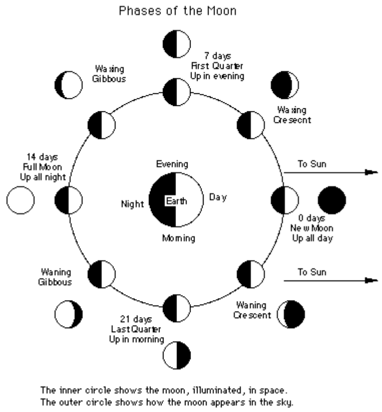

Figure 2. *The moon's phases result from seeing more and then less of the moon's sunlit surface.*

The moon's phases are variously described, but the best terms to use include waxing, waning, crescent, and gibbous. When the side facing us becomes increasingly lighted (moving from new to first quarter to full), the phase is said to be waxing; when the moon becomes increasingly darkened (moving from full to third quarter to new), the phase is said to be waning. The phases before and after new are known as crescent when the moon is less than half full; the phases before and after full are known as gibbous when the moon is more than half full. The monthly cycle of the moon's phases go as follows: new, waxing crescent, first quarter (sometimes called evening half moon), waxing gibbous, full, waning gibbous, third quarter (sometimes called the morning half moon), waning crescent, and new. The cycle then repeats.

Eclipses

Moon phases have absolutely nothing to do with Earth's shadow falling on the moon. The only time this occurs is during a lunar eclipse (from the Greek word *ékleipsis* meaning "abandonment") when the moon fades from the sky as it passes through Earth's dark shadow. This occurs only at full moon phase.

At the time of new moon, the moon usually passes above or below the sun in the sky as seen from Earth. A similar situation occurs at the time of full moon when the moon passes above or below Earth's shadow. The moon's orbital plane is inclined just over 5° to the ecliptic. As a result, of this misalignment, eclipses of the sun and moon do not occur during most new and full moon phases. Solar eclipses (or abandonments) occur only at new moon phase when the moon crosses over the face of the sun as seen by earthlings. Lunar eclipses occur only at full moon phase when the moon passes through Earth's shadow. (See Figure 3.)

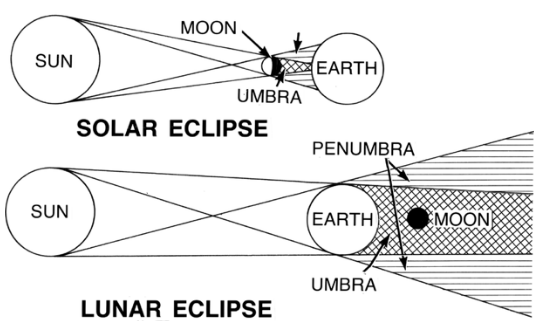

Figure 3. *The shadows of Earth and Moon; no the umbra and penumbra.*

There will be from 4 to 7 lunar eclipses visible from Earth each year. There are between two and five solar eclipses each year, with between zero and two of them being total eclipses. There are between zero to three lunar eclipses per year where the Moon passes through at least a portion of the Earth's dark central or umbral shadow (where the sun cannot be seen from the perspective of the moon thereby producing a partial to total umbral eclipse. Earth's penumbral shadow surrounds the umbral shadow. Within the penumbra Earth blocks only part of the sun from the perspective of the moon.

Though lunar eclipses are less common than solar eclipses, people more commonly observe lunar eclipses. This is because lunar eclipses are much more widely visible from Earth (more than half the planet at a time over the course of the hours-long event) when compared to solar eclipses that are visible only from restricted regions of Earth's surface at any one time.

Solar eclipses come in three types – partial, total, and annular. The latter occurs where the sun appears as a ring of light in the sky because the moon is located too far from the Earth to totally block the sun from view. (Total solar eclipses occur only when the moon is near Earth; annual solar eclipses occur only when the moon is far from Earth. These variations show that the moon follow an elliptical orbit around Earth.) The dark umbral eclipses of the moon come in two types, partial and total. (Penumbral eclipses are barely noticeable to the casual observer.)

During a lunar eclipse, the moon will take on an array of colors appearing anywhere from a dull white, to orange, to red, to brown. These colors originate in Earth's atmosphere as light passing through the atmosphere at the day-night boundary loses primarily blue light by filtering, allowing primarily red light to be refracted into the dark umbral shadow behind Earth. This is the same phenomenon that causes red sunrises and sunsets on Earth. During a lunar eclipse, the moon is viewed with the light of all sunrises and sunsets all around the world. Table 1 is a listing of all lunar eclipses visible from Illinois through 2025.

Date of Eclipse	***Type of Eclipse***
January 20, 2019	Total
November 19, 2021	Partial
November 8, 2022	Total
September 18, 2024	Partial

Table 1. *Lunar eclipses by type visible from Illinois through 2025.*

The conditions of solar eclipses will vary dramatically during a single eclipse due to the location of the observer and the Earth-Moon distance. Total eclipses of the sun can be seen as such along a long, narrow ground track only about 300 miles or less wide. Either side of that ground track, observers will see a partial eclipse. Under certain circumstances, the moon will be located too far from Earth during a solar eclipse to entirely cover the sun. This leaves a ring of light in the sky in what is known as an annular (from Latin for "ring") eclipse. The last such event to occur in Illinois was May 10, 1994. Table 2 is a listing of all solar eclipses visible from Illinois through 2025. Southern Illinois will experience two total solar eclipses during this time interval. Most locations on Earth experience this rare dual event approximately once every 300 years.

Date of Eclipse	***Type of Eclipse***
August 21, 2017	Total/Partial
June 10, 2021	Partial
April 8, 2024	Total/Partial

Table 2. *Solar eclipses by type visible from Illinois through 2025.*

Earthshine

When the moon is close to the sun in the sky (during waxing and waning crescent phases) the moon's dark night side can been faintly illuminated. This illumination comes from Earth. Light reflects from Earth to the moon and back again. This faint illumination is known as Earthshine – not moonshine – for a very obvious reason!

Lunar Topography

The presence of dark basaltic lavas filling numerous craters on the moon's near side – as opposed to the basalt free lunar mountains that are made up mostly of a lighter anorthosite – gives the moon a unique topology – patterns of light and dark. The dark regions tend to be round and smooth – so smooth in fact that early astronomers observing through rather poor quality telescopes called these areas walled seas or "maria". The light regions tend to be rugged and are today referred to as highlands.

The mixture of darker maria and lighter highlands gives rise to several images when the imagination is put to use. (See Figure 4.) Some see a man in the moon, others a matronly woman's face looking upward to the left, still others see a woman reading a book. The Swedes always claimed that Jack and Jill went "up the hill" to fetch a pail of water. The hill actually turns out to be the moon. Anyone who looks carefully at the time of full moon can see the two standing side by side on the surface of the moon with the pail between them and there, on the ground between them, a splash of water.

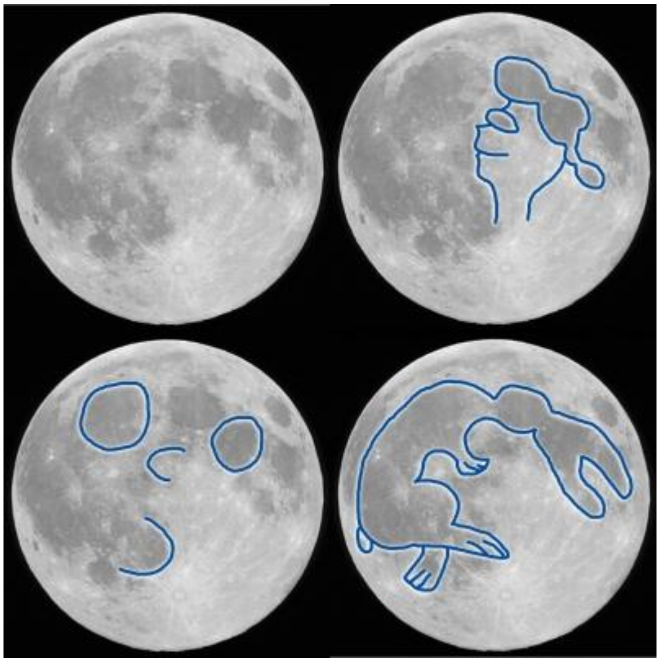

Figure 4. *Images visible on the moon to those with an active imagination.*

Tidal Locking

Observant moon watchers will note that the moon always keeps the same side facing Earth. This is due to tidal locking that keeps the moon's rotation pretty much in lockstep with its revolution. As a result of tidal locking, the moon rotates once on its axis for each time it revolves around Earth – one rotation per revolution. Tidal locking results from Earth's gravity "holding on to" dense mass concentrations (dark basaltic lavas) that appear on the near side of the moon as "seas" (and not much at all on the far side). This coupling is not entirely synchronous and – in combination with the moon's inclined and ellipsoidal orbit as well as the changing position of the observer – results in libration. As a result of the combination of these effects the moon librates or wobbles back and forth and tips up and down over the course of a month. This allows humans to see some 59% of the moon's surface over time.

The Moon Illusion

The full moon upon rising and setting appears much larger than when viewed higher up in the sky. The fact of the matter is the moon is actually larger when higher in the sky because the distance between the observer and the moon is smaller – if only by a tiny amount. This large apparent difference in size is known as the moon illusion. This illusion is also seen when the sun and star patterns such as Orion or the Summer Triangle are near the horizon. When measured with scientific instruments, the difference is actual angular size is almost imperceptible. What causes this illusory change in size?

The simplest explanation is that we are viewing the railroad track (or Ponzo) illusion inverted. (See Figure 5.) We probably all have seen two blocks of identical size resting as it were on parallel railroad tracks that converge in the distance. One block looks nearer and the other block looks farther. The more distant block appears larger than the nearer block despite the fact they are of identical size. The background in some way influences the apparent sizes of the blocks.

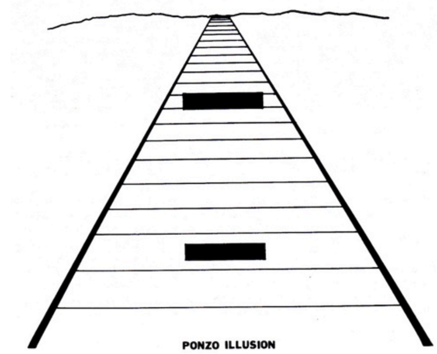

Figure 5. *The Ponzo Illusion*

The sky overhead by day seems much closer than the sky near the horizon as shown in Figure 6. Clouds overhead might be two or three miles up whereas the same cloud near the horizon will be many more miles distant. This gives the impression the higher means nearer and lower means farther. This impression is somehow carried over into the night sky. When viewing the actual moon at different elevations above the horizon, the same moon appears larger when viewed against the distant horizon and smaller when viewed higher up in the sky. It is as if the railroad track illusion has been turned upside down. The lower block now appears larger than then higher block. So it is with the moon illusion. What you see is not real. That's why it's known as an illusion.

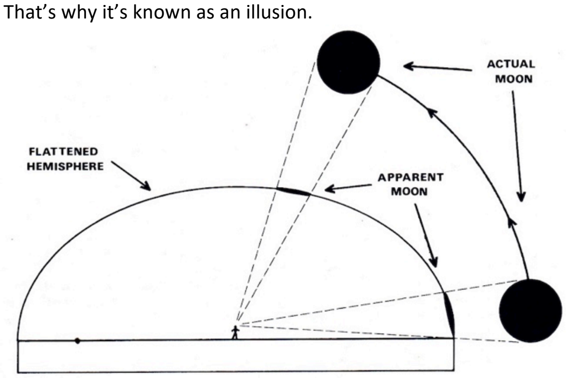

Figure 6. *The hemispherical appearing sky causes the moon illusion.*

Calendar Keeping

The motions of both sun and moon are used for the keeping of calendars – civil and religious. For instance, the year is roughly equal to the period of time required for Earth to orbit the sun once. (Technically, this is known as a sidereal year – the time required to move precisely 360° around the sun measured with respect to the stars. It has a length of 365.256363 days. The year of 365.242199 days, the period of time upon which the civil calendar is based, is known as the tropical year. The two differ in length by only 20.4 minutes. The difference is due to Earth's precession or wobbling on its axis.)

The period of the month is based upon the moon's synodic period, 29.5 days, which is the period from full to full or new to new phase. It is also the period of time it takes the moon to go through a complete orbital motion *with respect to the sun* that – like the moon – is moving eastward along the ecliptic. The time required for the moon to orbit 360° with respect to the stars is known as the sidereal month. It consists of some 27.3 days.

It is interesting to note that the names of weekdays are based on the sky as well. Such can be seen in the worlds "Saturday" (Saturn day), "Sunday" (sun day), and "Monday" (moon day). In Nordic the names of the planetary gods also can be found: Tiu's day (Tuesday), Woden's day (Wednesday), Thor's day (Thursday), and Freya's Day (Friday). And in Spanish we have lunes (Moon's day or Monday), martes (Mars' day or

Tuesday), miércules (Mercury's day or Wednesday), jueves (Jupiter's day or Thursday), and viernes (Venus' day or Friday).

Today's civil calendar is based primarily upon the motion of the sun. Religious calendars historically have been based on the motions of the moon. In Christianity, Judaism, and Islam, events such as Easter, Passover, and Ramadan are based on the phases of the moon. For instance, Easter falls on the first Sunday after the first full moon of spring. A similar rule applies to Passover. The Jews add an "intercalary" month about every three years to bring the civil and lunar calendars back into alignment so that Passover remains a spring event. Moslems do not introduce this extra month into their lunar calendar and, as a result, the month of Ramadan – which lists one synodic month – can start during any season of the year. During 2014 Ramadan began on June 28th and ended on July 28th. During 2015 Ramadan began on June 18th and ended on July 17th – 11 days earlier. This earlier start each year is due to the difference between 12 lunar months (354.37 days) and the length of the civil year of 365.25 years. This amounts to approximately 11 days (365.25 days – 354.37 days = 10.88 days).

Space-Atmosphere Interactions

Pronounced space-atmosphere interactions are readily visible. During daytime we can experience rainbows, sun pillars, coronas, halos, arcs, and sundogs (also known as parhelia or mock suns). These phenomena are meteorological in effect and, therefore, they will not be described further in this chapter with but two exceptions – twinkling and lunar/solar colors upon rising and setting.

At night we can see twinkling in stars. It is yet another common misconception that the stars themselves that are twinkling. This is just not so! Stars appear to twinkle (change color and brightness) due to Earth's atmosphere. Stars closer to the horizon commonly twinkle, but all stars will twinkle after the passage of a warm or cold front when atmospheric turbulence causes starlight to be broken down into its component colors (ROY G. BIV – red, orange, yellow, green, blue, indigo, and violet). Each color takes its own path to the observer. These varying paths give the impression that the star is changing color and jumping about – a purely atmospheric phenomenon. Because planets are not "point sources" like stars, the atmosphere has to be really turbulent before twinkling is observed in them.

At times of sunset and sunrise we can often see the sun arrayed with different colors. Sometimes the sun (which appears white – not yellow – when high in the sky) will take on a yellow, orange, or red cast upon rising or setting. This coloration is due to white light passing through Earth's atmosphere. The air molecules preferentially scatter out the blue rays. (That's why we have a blue daytime sky.) When the sun and moon appear lower in the sky, more scattering of blue light occurs. As scattering increases, the white sun changes appearance to yellow, orange, and red. This also has the effect of dimming the sun and moon. The greater the amount of dust in Earth's atmosphere, the greater the amount of scattering occurs at the blue end of the spectrum. This in turn causes the sun or moon to appear redder at a given distance above the horizon.

Of considerably greater astronomical interest are meteors and auroras. Meteors are streaks of light in the night sky (sometimes visible by day in an event known as a fireball or bolide) caused by the collision of a meteoroid – a small chunk of rock, metal, or rock and metal left over from the formation of the solar system – with the atmosphere. Meteors can originate as ejecta from the asteroid belt between Mars and Jupiter due to collisions or gravitational perturbations. These meteors occur only sporadically. The bright light seen is the sky is the air glowing as it is heated by friction associated with the meteoroid moving at speeds ranging between 25,000 to 100,000 miles per hour!

At certain times of the year we have meteor showers (see Table 3). At such times, meteors can be seen streaking outward from a point in the sky known as the radiant. The location of the radiant gives its name to the meteor shower. For example, the Perseids radiate from the constellation Perseus and the Geminids radiate from the constellation Gemini. Meteor showers originate from the debris left behind by the passage of decaying comets. Comets are best thought of as ice-packed sand banks that slowly fall apart as the ices that hold them together are vaporized by the sun. When Earth's orbital motion carries it through these debris streams, we encounter swarms of meteoroids and end up with meteor showers. No meteorite has ever been associated with a meteor shower because tiny grains of sand burn up as they pass through Earth's atmosphere. The meteorites we do have on Earth originated from "sporadic" meteors; no meteorite is known to be associated with any meteor shower.

Meteor Shower	Peak Night	Active Dates	Hourly Rates
Quadrantids	January 2-3	January 1 to 10	25
Lyrids	April 21-22	April 16 to 25	10
Eta Aquariids	May 5-6	April 19 to May 26	10
Delta Aquariids	July 27-28	July 21 to August 23	10
Perseids	July 28-29	July 13 to August 26	50
Orionids	August 11-12	October 4 to November 14	15
Leonids	November 12-13	November 5 to 30	10
Geminids	November 17-18	December 4 to 16	75

Table 3. *Meteor showers and average hourly rates for moonless rural sky.*

Dangerous Earth-Space Interactions

Who will forget the meteoric explosion over Chelyabinsk, Russia, that occurred on February 15, 2013? This is not the only time Earth has experienced an aerial burst such as this. An even greater explosion occurred over Tunguska, Siberia, on June 30, 1908. Earth is today scarred with the remains of nearly 200 impacts of meteors and comets. Perhaps the most famous of these is Meteor Crater near Winslow, Arizona. The crater is nearly a mile wide and almost 600 feet deep. The rim of the crater rises 150 feet above the surrounding landscape. Fortunately, this blast occurred around 50,000 years ago in a region where there were few if any witnesses.

There might well have been hundreds of thousands of such impact craters on Earth, but the effects of weathering have wiped away all but the most recent. The history of the solar system is replete with evidence of such impacts as even a cursory telescopic examination of the moon will show. Dark lunar maria provide evidence of these impacts. Lunar craters are reminders of the precarious lives we live on the surface of this planet. As of mid 2014 astronomers knew of about 1500 potentially hazardous asteroids whose orbits bring them alarmingly close to Earth. It's only a matter of time before one of these hits Earth (one we probably don't even know about yet) with devastating consequences.

Comets, too, wander the solar system and not all have long flowing tails that make them obvious. Indeed, the 1908 Tunguska meteoric explosion might well have been the aerial burst of a tailless comet that no one even saw coming. Like asteroids, comets are abundant and it's possible that one of these will again someday strike Earth bringing about cataclysmic events for all earthbound living creatures. The 1994 series of impacts with Jupiter by Comet Shoemaker-Levy 9 will live in the memories of all those who saw it.

Other dangers also exist within our solar system. The sun has a violently active surface that erupts with a frequency tied closely to the sunspot cycle. Over the course of roughly 11 years, the number of sunspots rises and falls and rises again. At the same time, the frequency and violence of coronal mass ejections (CMEs) rises and falls and rises again. In a CME, millions of tons of hot charge plasma are ejected from the sun at millions of miles per hour. Within two to three days these blobs can hit Earth. Today, Earth's magnetic field intercepts these CMEs and their energy is harmlessly dissipated in Polar Regions as beautiful glowing aurorae in the highest layers of our atmosphere. Unfortunately, Earth's magnetic field is weakening, perhaps in preparation for a flip of the magnetic poles. Recent evidence shows Earth's magnetic field has weakened 15% over the past two hundred years. If the field collapses and Earth is hit by a significant CME in the future, nearly all of our electrical devices will be destroyed and we will be cast into a literal "dark age" that could last many, many years.

The Friendly Stars

The most awe inspiring celestial phenomenon that visitors to a dark sky site will see are the stars and Milky Way. Depending upon local conditions, observers might see hundreds to thousands of stars, and the

Milky Way might or might not be visible depending upon the time of night and year. To the uninitiated, the stars appear randomly distributed like diamonds scattered against the velvety black background of night. Despite this random distribution of stars, the human mind looks for and sees patterns. These patterns are called either constellations or asterisms, but they are not the same thing.

A constellation is one of 88 official star patterns recognized by the International Astronomical Union. Each constellation has official boundaries that are used to break the night sky into easily recognized regions. Asterisms on the other hand are unofficial and have no formal boundaries. Asterism might be part of one constellation (such as the Big Dipper which is part of the constellation Ursa Major the Great Bear, and the Little Dipper which is part of Ursa Minor the Little Bear) or parts of several constellations (such as the Summer Triangle that is composed of the bright stars Vega in Lyra the Harp, Altair in Aquila the Eagle, and Deneb in Cygnus the Swan).

Star Patterns Have Their Uses

One might question why we have constellations and asterisms at all. They and their stories have been handed down from antiquity, but few today know their true worth. The best way to understand star patterns, perhaps, is to think of the heavens as a giant cathedral with a huge amount of stained glass (as in Gothic cathedrals), mosaics (as in Romanesque and Byzantine cathedrals), or icons (as in Orthodox cathedrals) in or on the interior walls. These architectures have one thing in common – the images built into these structures were once used as instructional media. Gone are the days when priests would draw the attention of the congregation to these works of art and use them to illustrate a biblical story. Rather than building huge edifices of worship, simpler civilizations merely used the starry canopy of night to illustrate their stories. This approach to the night sky leads to the concept of the "cathedral of the heavens".

Even today, people love stories. How is it that television – today's premiere story telling device – is really any different from a campfire? We gather around to watch and hear stories. Long ago, the ancients sat around campfires to hear stories. The story telling of old served a much more important purpose than entertainment however. The elders of the tribe told stories to pass on traditions, teach religious beliefs, provide examples of appropriate behavior, as well as to entertain. The heavens also would have been used to teach direction finding (the Big Dipper and North Star come to mind), and tell the seasons (the Big Dipper is low in the north scooping up snow during the autumn, pouring it out during winter when it begins to turn over, and releasing the melted snow as rain during the summer when it is overhead). More sophisticated observers of not so long ago knew that the North Star could be used to find one's latitude north of the equator as well, its angular distance above the horizon being roughly equal to one's northern latitude.

Constellation Stories

A sky interpretation event wouldn't be complete without constellation stories. Nearly all 88 officially recognized constellations – and even some of the asterisms – have one or more mythological stories associated with them. Major constellations commonly have both Greek and Roman stories associated with them. Zeus, Callisto, Arcas, Cassiopeia, Cepheus, Andromeda, Perseus, Pegasus, and Cetus all have share in a single story. Orion and his dogs Canis Major and Canis Minor are there in the sky to do battle with Taurus the Bull. The constellations of the zodiac – Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpius, Sagittarius, Capricornus, Aquarius, and Pisces – each has its own story. Cultures around the world have their own stories as well as different names for the star patterns we see at night. For instance, the so-called Big Dipper was known as the bear with three hunters to American Indians, as the drinking gourd to runaway slaves prior to the Civil War, as the cart or plow to the English, and as the crocodile to the Egyptians.

Because relating star stories here would take so much space than is available, sky interpreters are encouraged to seek out any of the dozens of field guides to the sky – both old and new – that are commonly available online and in book stores. Searches of the library and Internet undoubtedly will provide many stories at no cost at all.

Star Names

Every sky interpreter should be familiar with the names and constellations of all first magnitude and brighter stars visible by night from Illinois: Sirius, Arcturus, Vega, Capella, Rigel, Procyon, Betelgeuse, Altair, Aldebaran, Antares, Spica, Fomalhaut, Pollux, and Deneb. In addition, sky interpreters should know one dimmer star – Eta Cassiopeiae – located below the third segment of the W that marks Cassiopeia the Queen. (See Figure 7.) While Eta is actually a double star, its fainter stellar component is not readily visible to the unaided eye.

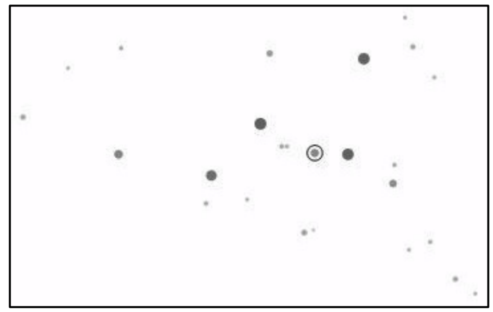

Figure 7. *The location of Eta Cassiopiae among the stars of the Queen.*

Many of these star names seem unfamiliar to the uninitiated, but every well-attuned sky interpreter will know them. Many of these names have Arabic origins. For instance, Altair in Aquila the Eagle means "the beak", Betelgeuse in Orion the Hunter might mean "the arm pit of the mighty one" (though this seems to be hotly contested), Capella in Auriga the Charioteer means "the mother goat", and Deneb in Cygnus the Swan means "the tail". It would behoove sky interpreters to know something about each of these stars – size, distance, color, stage of evolution, and so forth. Also not to be forgotten is Eta Cassiopeia that also known by the proper name Achird. This is a third magnitude sun-like star located about 19.4 light-years from the solar system – the closest sun-like star in the night sky. While it's a double star, it can be pointed out to show that even this relatively nearby star appears quite dim to us.

Motions of the Stars

Unbeknownst to some people, the stars move over the course of the night. This apparent motion occurs as a result of Earth's rotation. The motion of the stars is most curious to the uninitiated. Looking east we see stars rise, moving to the upper right as they do so. Looking to the west we see stars set, moving to the lower right as they do so. Looking to the south, we see stars making long gentle arcs running from roughly east to west. Looking to the north, we see stars moving in a counterclockwise direction around Polaris the North Star.

Of all the stars in the heavens, only the North Star stands still (essentially; it makes a tiny circle in the sky less than ½ degree away from the north celestial pole – the point directly over Earth's north geographic pole). This star is famous NOT because it is bright (it's the 49^{th} brightest star in the sky), but because it stands almost directly overhead Earth's North Pole. It is therefore the one star that stands still as the night progresses, and all the other stars appear to circle it. Once a person has found the North Star, a line dropped straight down to the horizon indicates the direction north. For this reason alone, the North Star Polaris is perhaps the most famous star in the night sky.

There are three distinct groups of stars in the sky with which interpreters should be familiar. To the north are the circumpolar stars. Circumpolar literally means "around the pole". These stars never rise or set because they are located close enough to the North Star that their entire circle of motion can be seen. At their lowest point they are still located above the northern horizon.

The other stars in the sky are called equatorial. These are the stars that appear to rise and set because they go around the North Star with such large circles the lowest parts of their paths extend below the horizon.

Believe it or not, there are stars that we cannot see from here in Illinois. They are located around the dim "south star," Sigma Octantis, that appears just as far below the southern horizon as our North Star does above our northern horizon. These stars represent the opposite poles of a large sphere that appears to encompass the Earth – with stars at indeterminate distances. Stars in the proximity of Sigma Octantis circle the so-called “south star” with a clockwise motion but are so far below our southern horizon that they never appear in our sky. We know these hidden luminaries as south circumpolar stars. Stars can be seen as either circumpolar or equatorial depending on the observer’s latitude.

Star Colors

At night it is almost as though the color has drained out of everything we see by day. There is a reason for this and it has to do with the human eye. During the daytime or when things are otherwise brightly illuminated, the active light-sensing cells working in the back of the eye are the cones. Cones consist of distinct red, green, and blue color detectors (each with a significant amount of overlap – that’s why we can still see yellow for instance). In order to “fire” the color detectors, the light must be reasonably intense. During the night the intensity of the light is too low to “fire” the cones, and black & white sensing rods take over. Rods are very sensitive to gradations of light, but not color. As a result, the things we see at night take on shades of grey. When the amount of light increases, the color is restored.

While you might not have noticed it, stars have colors ranging from blue-white to white to yellow to orange to red. If you have not noticed, it is probably because you have never closely examined the brightest stars that do show their colors. The stars of first magnitude and brighter all exhibit some sort of “color”, even if it’s white. The colors of stars can be more readily seen with the use of telescopes that gather up much more light than can the human eye. When seen through telescopes, all but the faintest stars exhibit some sort of color.

It is interesting to note that there are no green stars. Red stars appear red because they give off mostly red light. Blue stars appear blue because they give off mostly blue light. When stars give off mostly green light, they appear white! Humans see the composite of all the colors of the spectrum as white. That most plants on Earth appear green is due to the fact that they reflect green light as a way of protecting themselves from the sun’s most intense color of radiation.

Stars are different colors merely because they are of different temperatures. Star color has nothing to do whatsoever with the chemical composition of stars. Hotter stars are bluer stars; cooler stars are redder stars. It is a common misconception that red stars are hot (like fire) and that cool stars are blue (like ice). The fact of the matter is that it’s just the exact opposite. For example, a high temperature welding torch appears blue to blue-white whereas the low temperature fire in a barbeque is orange to red.

How Far are Stars?

The answer in short is, “Very far – farther than you can imagine.” The moon is a mere 238,000 miles distant on average. The sun is 93 million miles distant on average. The next nearest star in space to the solar system is Proxima Centauri. It is part of the Alpha Centauri system located among the south circumpolar stars not visible from Illinois. This star is a mere 24.94 trillion miles away from us. This distance is so vast as to be incomprehensible. If we express this distance in light years – the distance that light travels in one year at a speed of 186,282 miles per second or 5.879 trillion miles per year – Proxima Centauri’s distance can be expressed as a more manageable 4.243 light years. That is, it is so far distant from us that it takes light 4.243 years to reach us. So, when you see this star (if ever you do), know that you are not looking at it that way it appears today, but the way it looked when the light left its surface 4.243 years earlier. When looking at distant celestial objects, we are literally looking back in time!

Sky interpreters should keep in mind that almost every star in the night sky we see with the unaided eye is bigger and brighter than our sun. Of the nearly 9,000 stars visible to the unaided eye across the entire heavens seen from Earth, only a very few of the faintest stars are the same size and brightness of our sun (e.g. Eta Cassiopiae). The rest are all larger and intrinsically more luminous than our sun – many by a large percentage. While stars smaller and dimmer than our sun are far more abundant, they cannot be seen with the unaided sky despite the fact that they are much closer than many of the bright stars we see at night.

Deneb in Cygnus is one of the most distant stars we can see with our unaided eyes due to its intrinsic brightness. While it is only the 19th brightest star in the sky, it is so luminous that we can see it despite the fact that it is about 12,000,000,000,000,000 miles away. That’s 12 quadrillion miles, some 2,000 light years! Deneb – a blue-white supergiant star – shines with the light of about 100,000 suns. The star is prominent in the evening skies of summer being part of the asterism known as the Summer Triangle. The light that we see coming from the star started coursing its way to Earth around the time of the Roman Empire.

How Big Are Stars?

Stars are enormous and have a dramatic range of size. The sun is 109 times the diameter of Earth and has a mass 330,000 times that of Earth. Regardless, our sun is a dwarf in comparison to the largest stars of the cosmos. The largest star known, UY Scuti, is some 1,700 times the diameter of the sun. Stars are so distant from Earth, however, that they have no visible surface seen from our perspective.

How do we know how big stars are if they are so far away as to be mere points of light? Recall that star color is an indication of surface temperature. The luminosity of a star (the total outpouring of light in comparison to the sun) is a function of – among other things – radius and temperature. The absolute brightness of a star can be worked out from knowledge of its apparent brightness (more distant means dimmer) and its distance using the distance modulus formula. The process of determining a star’s size is highly mathematical. Okay, so math might not be your strong suite. Suffice it to say that some “white dwarf” stars are the size of Earth while others are many millions of miles across (giants) and even billions of miles across (supergiants).

Seasonal Constellations

As was noted previously, the sun appears to move eastward among the stars of the zodiac at a rate of just under 1° per day (360° in 365.25 days) due to Earth’s annual motion around the sun. This slight apparent shift in location accumulates over time to give us changing seasonal constellations.

While all stars appear to rise, cross the meridian, and set daily due to Earth’s rotation, they do so precisely every 23 hours, 56 minutes, and 4.1 seconds. This interval of time is known as the sidereal (or starry) day. The 24 hours we keep on our clocks and watches is the average time it takes for the sun to cross the meridian twice; this internal is known as the mean solar day. This 3 minute, 55.9 second difference between the mean solar day and the sidereal day is the amount of additional time it takes Earth to turn the additional 0.9856° (360°/365.25) that the sun moves eastward along the ecliptic each day (on average) as a result of Earths’ revolution to bring it back to the same place in the sky.

Because Earth orbits the sun, at one point a given constellation like Aries the Ram might appear opposite the sun at midnight, but six months later it is located behind the sun at midday. As a result of the sun’s apparent motion through the constellations of the zodiac, different constellations can be seen opposite the sun in the night sky as a function of season. As a result, different constellations are visible at night over the course of the seasons – the stars having risen some 4 minutes earlier each evening. Over the course of the year all equatorial constellations are visible from Illinois during evening hours.

Using Sky Maps

It can be a daunting task to get to know all the constellations visible from Illinois. The author of this chapter didn’t get to know the faintest constellations of the zodiac (Capricornus, Aquarius, and Pisces) until early adulthood. Some constellations are just harder to find and remember than others. Not to worry though; sky maps are available to help with our learning.

A sky map (or star map) is a representation of the starry night sky marked on the surface of a flat piece of paper. As a result of this projection from a hemisphere to a plane, the images on a star map will always be somewhat distorted in comparison to what is seen in the sky. This is so primarily with star patterns seen near the edge of the star map. They tend to be stretched more and more horizontally the nearer they are to the edge of the sky map. (Try flattening a hemispheric orange peel without any folds and you will see that the out edge stretches then rips as it is flattened.) Despite this limitation, sky maps can be immensely useful in getting to know the constellations and asterisms of the starry night.

One excellent source of free evening sky maps for each month of the year can be found at www.skymaps.com. These sky maps show the constellations on the front (along with a calendar of events) and observing tips on the back (along with a glossary of astronomical terms and lists of naked-eye, binocular, and telescopic objects marked on the sky map). It should be noted that sky maps are useful from year to year as the same sky presents itself to Earth at the same time of night and season year after year.

A careful examination of the circular disk of the celestial map shows the edge of the circle to represent the horizon and the middle of the circle the zenith or overhead point. Along the horizon one can find the cardinal points or directions. If south is placed at the bottom, north appears at the top. To the left is east and the right is west – just the exact opposite seen on terrestrial maps. East and west are opposite to what is found on terrestrial maps because celestial maps represent the sky. Once a star map is held up against the sky, the directions resolve themselves.

Stars on these sky maps are black and white; so, star colors cannot be determined from them. However, stellar brightness can be. The larger the dot representing a star on a sky map, the brighter the star in the sky. Some dots are linked together with thin lines denoting constellations or asterisms in stick-figure form. The dashed line cutting across the sky is the ecliptic – the path of the sun among the constellations over the course of half a year. (Recall that the map represents only half of the stars in the sky at any one time; the other half is below the horizon.) It is near to or on this ecliptic where planets can sometimes be found. Be certain to note, too, that the sky map is drawn for a specific time of night both early and late in the month represented. This is due to the fact that we have changing seasonal constellations and each month's stars will be slightly different from other months' due to the sun's apparent *eastward* motion along the ecliptic. Be certain to use the sky map within about an hour of the time indicated for the given date.

The Milky Way is also visible on these maps as a shaded region. Note its irregular boundary and dark regions here and there. Recall, too, that when the Big Dipper is overhead, the Milky Way will appear close to the horizon and might not be visible due to the dimming and obscuring aspects of our atmosphere.

Scattered among the stars of night are tiny images representing celestial objects such as variable and double stars, star clusters, nebulas, and galaxies. Some of the more prominent are easily viewed with the unaided eye. Others, however, are best viewed with a pair of binoculars or a telescope.

Using a sky map is simple. First, view the sky from a dark setting with a horizon relatively free of obstructions. When facing north, merely rotate the sky map until NORTH is located at the bottom and hold the sky map up to the northern sky. Objects located half way between the northern horizon and the overhead point on the sky map will be half way up in the sky and vice versa. The same is true with the other directions as well.

Because dark adaption is necessary for viewing the fainter stars and Milky Way, be certain to use a dim, red-filtered flashlight to view the sky map at night. This will allow you to move quickly between map and sky without having to readapt. If you use a bright white flashlight, your dark adaption will be destroyed and you'll have a hard time seeing the constellations depicted on the sky map.

Observing Planets

Binoculars and telescopes are not needed to view the planets. They have been viewed since ancient times with nothing more than the unaided eye. The planets constantly mystified the ancients, but not only because of their brighter appearances. The name "planet" comes from the Greek word "planetes" meaning "wanderer".

The planets appear to wander among the background of stars with time and it is this motion that sets them apart from the fixed stars of the constellations. Planets are generally brighter than stars. They are also much closer, but their surfaces show no discernable detail to the unaided eye.

Without telescopes, the ancients just didn't know what to make of the planets. To some peoples these were godlike creatures. Indeed, all are named after gods from Roman tradition. The reason peoples of the past were intrigued by the planets is because they move relative to the background of fixed stars. With the passage of time, planets move toward the east along the ecliptic. They periodically stop this eastward or prograde motion, and move backward toward the west in retrograde motion. Today we know that these curious motions have nothing to do with a godlike nature. It is merely a reflection of the fact that these planets are worlds in orbit around the sun just like Earth, and that – when viewed from Earth's moving platform – some planets (Mars, Jupiter, and Saturn among the naked-eye planets) move backward because of Earth's more rapid motion. Other planets (Mercury and Venus) move backward at times because they orbit the sun more rapidly than does Earth.

Mercury and Venus are known as inferior planets. They orbit the sun inside Earth's orbit and never appear far from the sun. This explains why these planets are only seen in the west after sunset or in the east before sunrise. Mars, Jupiter, and Saturn are known as the superior planets. They orbit the sun outside Earth's orbit and will at times appear opposite the sun in the sky, rising at sunset and setting at sunrise. When this occurs, they are said to be at opposition to the sun (some 180° away from or opposite the sun in the sky). At opposition, superior planets are at their nearest to planet Earth and at their brightest in the sky. When in conjunction with the sun, they appear behind the sun and rise and set with it. They are not then visible at night.

As the planets orbit the sun, they also change rapidly in brightness. Superior planets are brightest at the time of opposition because they are then closest to Earth. Inferior planets, because they exhibit a set of phases just like the moon, are a bit more complex. Venus for instance is brightest approximately 33 days before and 33 day after passing roughly between Earth and the sun.

Venus, Mars, Jupiter, and Saturn are familiar planets to most of us. Because Mercury orbits so closely to the sun, it is very difficult to observe. Only during spring evenings and autumn mornings can Mercury be seen to advantage. The ecliptic is then steeply inclined to the horizon during twilight. While superior planets can appear opposite the sun in the sky (elongations of 180°), Mercury has greatest elongations between 18° and 28° degrees from the sun. Venus – because of its larger orbit – has greatest elongations between 45° and 47° from the sun. As a result, it is much easier to see Venus than Mercury. The greater brilliance of Venus also helps with visibility.

When planets are in the sky at sunset they are known as "evening stars." When in the sky at sunrise, they are known as "morning stars". They are not really stars at all. The naming convention comes from the fact that the ancients considered all bright points of light in the sky stars. They were not always aware that Mercury and Venus in the west during evening twilight were the same bodies observe in the east during morning twilight.

Planets and the Zodiac

As the planets orbit the sun, they stay very close to the ecliptic in the sky. This is due to the fact that their orbital planes are nearly coincident. As a result, planets will always be found among the constellations through which the sun appears to move over the course of a year – the zodiac.

Many people hold to the mistaken belief that the position of the sun, moon, and planets among the background "signs and houses" influences life on Earth. While there are celestial events that correlate well with terrestrial events (e.g., fewer household breakings and enterings occur during the full light of the moon), the reasons are clearly evident. The breaking and entering correlation has nothing to do with "astral influences" – merely the fact that breaking and entering is going to more frequently occur during the dark of the moon when the perpetrators are less likely to be seen. Astrology is bunk – a pseudoscience – completely unsubstantiated by meaningful empirical evidence.

Using Binoculars and Telescopes

While sky interpretation does not require the use of binoculars or telescopes, it is enhanced by their use. Both instruments gather more light than the unaided human eye so that objects too faint to be viewed without them can be observed. Binoculars provide magnified images that can be viewed to observe detail not otherwise visible. Some sky interpreters will use 7X50 binoculars to advantage. Such binoculars provide a magnification of 7 times and have an aperture of 50mm. This is about 7 times larger than the fully dilated pupil. As a result, such binoculars can gather about 49 times (7X7) more light than a single human eye. Of course, the magnification of 7X makes images 7X taller and 7X wider which makes the surface brightness of the image 1/49 as bright as seen in the sky with the eye alone. Fortunately, the magnifying and light-gathering powers offset one another. Binoculars produce reasonably bright, wide-field images for viewing.

Telescopes generally have more magnifying and light gathering power than do binoculars. It is interesting to note, however, that nearly all telescopes produce images that are actually dimmer than visible to the unaided eye. Not to worry, because the images appear considerably larger than in binoculars much more detail can be seen with them – despite the dimmer image – than without them. Why else would anyone want to use a telescope?

The best amateur telescopes for sky viewing are typically of 8-inches aperture or larger. They will come with a collection of eyepieces that provide for different magnifications and provide fields inversely proportional to their magnification, all things being equal. Using a low-power eyepiece will provide a wider field of view than a high-power eyepiece and make for easy finding of celestial objects such as the moon, star clusters, and galaxies. Reasonable quality, larger aperture telescopes might come with an inexpensive rocker box known as the Dobson mount. The best telescopes, however, will come with a motor drive that allows the telescope to track celestial objects as they move across the sky as a result of Earth's rotation. Such is not the case with the Dobson mount.

It should be noted that the purchase of cheap "toy" telescopes will result in a waste of money. Such telescopes commonly have wobbly mounts, small apertures, excessive magnifications, and narrow fields of view. All these combined will make for an instrument that is essentially useless because objects will be next to impossible to find and, when found, will be too dim to show any detail. Avoid spending any money on a telescope unless you know what you are doing. If you don't, consult with a well-qualified amateur astronomer who can make appropriate recommendations given your budget.

If you have a decent telescope and plan to make daytime observations of the sun (and these are great ways to encourage attendance at nighttime programs), then *get expert help in purchasing high quality solar filters.* The ones to buy are those that fit in front of the main lens or mirror of the telescope. Never use solar filters that screw into the eyepiece. These will absorb a huge amount of heat from the sun and could explosively shatter subjecting the observer to intensely bright and therefore damaging rays from the sun. Alternatively, consider using only indirect means of viewing the sun such as sun funnels or projecting the sun's image on a screen. Care must be used here too as serious damage to the telescope can result if the telescope is not designed for unfiltered solar viewing.

Observing Solar System Objects

While whole books have been written about what might observed in a telescope in relation to the sun, moon, planets, asteroids, and comets, sky interpreters might want to focus on solar system observations that Galileo first made in 1609 and shortly thereafter. His observations shook the world, and they will still impress park visitors. Observations of the moon will show it to have valleys, mountains, and plains just like Earth. Observations of the sun will reveal sunspots. Observations of Venus will show that it exhibits a complete set of phases just like the moon and that these phases are proof positive that the planet orbits the sun. Over the period of several months, Mars varied tremendously in size – by a factor of at least 5 times – showing clearly that it too orbits the sun. Observations of Jupiter will show its four prominent moons – Io, Europa, Ganymede, and Callisto. Saturn will show its spectacular rings that Galileo once thought were "ears" or moons – his poor quality telescope couldn't help him determine the difference.

Observing Deep Space Objects

There is much more in the sky than solar system objects. The sky beyond the solar system is filled with readily observed single and binary stars, star clusters, nebulae, remnants of stellar explosions, and galaxies. Where there are more of these out there than can be imagined, it's probably best for sky interpreters to feature a number of showcase objects such as the following that are usually visible on a late summer's evening. Consult a sky map from www.skymaps.com to see what is visible in the sky by season and time of night. The sky maps, on the reverse, describe objects easily seen on any particular evening with the naked eye, or with binoculars and telescopes.

Because these objects are a bit harder to find, it would behoove the sky interpreter to gain the assistance of experienced amateur astronomers in showcasing these objects. They will have their own high-quality telescopes and should be able to find and explain them. They probably have had a vast amount of experience doing so. Consult your local astronomy club or planetarium for assistance if necessary.

The Milky Way

While the stars visible from truly dark sky sites "almost seem to touch the Earth" and really impress park visitors, observers of the night sky are frequently taken aback even more so by the impressive glow of the Milky Way. The Milky Way circles the heavens as seen from Earth. The Milky Way is composed of hundreds of billions of stars and huge clouds of dust and gas. The faint glow we see at night is the plane of the galaxy – a swirling pinwheel of stars seen edge on from within. Our solar system is located a bit more than half way out from the center to the edge of the galaxy. As a result, not all sections of the Milky Way are equally bright. The brightest region is the galactic center located roughly in the region of Sagittarius the Archer. The faintest region is roughly opposite in the region of Perseus the Hero and savior of Andromeda the Chained Maiden. The Milky Way contains so much starlight-blocking dust that the region running from Cygnus the Swan to Sagittarius appears to be split almost in half. So pronounced are some of these dark regions that some cultures even created "dark constellations" from them. Heavy concentrations of stars – star clouds – also exist along the Milky Way. These show up as brighter regions here and there. Nowhere is this more evident than in the summer constellation of Scutum the Shield which is located just southwest of Aquila the Eagle.

It is in and near the plane of the Milky Way that those viewing with binoculars and telescopes will see the greatest number of stars, open and globular clusters, star clouds, and bright and dark nebulas. Because of the Milky Way itself, it is not possible to peer farther out into space here because our galaxy blocks the view. Only when the Milky Way is out of the way can we see the distant galaxies. Spring evenings – when the Milky Way is low to the horizon and the north pole of our galaxy is high in our sky – is the best time for viewing galaxies external to the Milky Way.

It is important to realize that everything we see at night is part of the Milky Way with but a few rare exceptions. These exceptions are companion galaxies to our own. Most prominent among these galaxies visible to the unaided eye is the Great Galaxy of Andromeda. This companion, also known as Messier 31 (or M31) is some 2,500,000 light years distant. It can be seen as a small luminous smudge of light near the right hand of Andromeda the Maiden in a dark autumn evening sky. Another companion galaxy is the Triangulum Galaxy (M33) located in the small, faint constellation Triangulum the Triangle located not too far away from Andromeda. M33 is fainter than M31, and at the very limits of visibility. It can be viewed only under very dark conditions with fully dark-adapted eyes. Binoculars can help with the view. Two other galaxies, the Magellanic Clouds, are visible from Earth's southern hemisphere. It's almost frightening to think that if the Milky Way objects were entirely removed from view – the moon, stars, planets, comets, asteroids, clusters, nebulas – the only things visible to our eyes would be M31, M33, and the large and small Magellanic Clouds.

The best time to view the Milky Way is after the end of evening during late summer. At this time our place on Earth is turned toward the center of the galaxy (located roughly in the vicinity of Sagittarius the Archer) where it is brightest and most expansive. Of course, Sagittarius is best viewed when it is due south in the sky (for then it is at its highest) and this will occur at different times of night throughout the year. For instance, this occurs before the start of dawn in April, around midnight in July, and after the end dusk around Labor Day.

While visible only under dark conditions, darkness is not the only condition necessary for seeing the Milky Way. At times the Milky Way runs along the horizon. This is the case after it gets dark during the spring. In fact, May is often called "the month without the Milky Way". Despite this fact, it is probably better to note that the Milky Way is difficult to view anytime the Big Dipper is located overhead. This situation occurs at different times of night throughout the year. It is then that the views of the distant galaxies are at their best. Another requirement for seeing the Milky Way is having dark-adapted eyes.

Dark Adaption

We have all had the experience of walking into a building on a bright, sunlit day and not being able to see much once indoors – at least at first. We've all had the experience of stepping outside at night not being able to seen as much as we can after our eye get "used" to the dark. This "getting used to the dark" is really the eye adapting to the faint-light conditions. Once we get into a dark setting, the eye's pupil opens (or dilates) to its maximum extent thereby admitting additional light to the sensitive retina at the back of the eye. At the same time, the retina is undergoing a chemical change. Under dim light conditions the retina produces the light-sensitizing chemical rhodopsin (a.k.a. visual purple). Once these adaptations are made, we are much more sensitive to the ambient light and can see far better than before we became dark-adapted. It takes about 10-15 minutes for a person to become tolerably dark adapted, and about 30 minutes to become well dark-adapted. Anyone serious about observing the night sky will protect their eyes from light sources that will work to reduce dark adaption – indoor lighting, bright flashlights, vehicular headlights, and so forth.

The Blue Sky of Day

Why is the sky an "opaque blue" by day and a "transparent black" at night? This is for some people a profound mystery when they begin thinking about it. The sky is blue by day because the molecules making it up preferentially scatter blue sunlight over red sunlight. When the sun is 18° or more below the horizon, the scattering of sunlight does not occur. As a result, the sky becomes transparent. As the contrast between sky and stars increases, the stars become visible.

With regard to the blue of day, it's not at all uncommon to hear the question, "What's beyond the blue?" The simple answer is "stars – the familiar constellations". Yes, they are there during the day as well as night; it's just that we can't seem them due to the greater brightness of the daytime sky. The contrast is too low to see stars during the daytime with unaided eyes. It comes as a surprise to many when they find out that a properly aimed telescope at high power can reveal some of the brighter stars during the day.

Twilight

Twilight is the boundary between day and night. When the sun is less than 18° below the horizon, its light rays can still be bent and scattered by Earth's atmosphere so that they are visible to those located on the night side of the planet. As the sun's light passes through a thicker layer of atmosphere around the time of sunset, and as bending and scattering continues even after the sun sets, the blue end of the sun's spectrum tends to get filtered out giving us the spectacular orange and red sunsets to which we have grown accustomed.

Evening twilight takes us from the bright sky of day to the dark sky of night. During this transition period there are things worthy of note. Birds stop flying and bats start appearing. The temperature begins to drop. As the sky darkens, first planets and then stars begin to shine in the vault of the heavens. When the sun sinks below the western horizon a look to the east even minutes after sunset will show there a rising blue-gray band paralleling the horizon. This is Earth's shadow. It continues to rise in the east until it merges with the growing darkness of the night sky about 30 minutes after sunset. Above Earth's shadow during early twilight is a pinkish purple glow known as the anti-twilight arch. Also known as the Belt of Venus, the arch's color is due to backscattering of reddened light.

Sunset officially occurs when the sun's upper limb disappears from view. The time period from sunset until the sun's center is 6° below the horizon is known as civil twilight. Its duration is from 33 to 42 minutes for central Illinois. The time when the sun moves from 6° to 12° below the horizon is known as nautical twilight. At the end of nautical twilight it is not possible to see the ocean horizon; its duration is about 33-42 minutes. The time when the sun moves from 12° degrees to 18° degrees below the horizon is known as astronomical twilight. At the end of astronomical twilight, the sun is no longer contributing light to the night sky in any form. Its duration is about 33-42 minutes. Ergo, the night sky doesn't get as dark as it's going to get until about 99-126 minutes after sunset.

The durations of twilight are dependent upon both date and latitude. Twilights are longest on the first day of summer and shortest on the first day of winter. The areas to the distant north are well known for their very long twilights. Above about 48.5° north latitude the twilight does not come to an end before the sun rises again on the first day of summer.

Preparing for Interpretive Sessions

Right now you probably feel that your brain is about to explode! This is not unexpected due to the fact that you have just received a crash course in observational astronomy. Learning so many new and varied concepts at one time is a bit difficult to do. While this information might now seem almost to be overwhelming, if it is reviewed periodically the sky interpreter will learn it well.

It's now time to turn our attention to the process of sky interpretation. The most fundamental question before us is, "What is interpretation?" The etymology of the word tells us that it comes from the Latin word *interpreter* meaning "to explain" or "to expound". Another question is, "What is sky?" While the sky might include weather phenomena, for the sake of the current discussion we have limited ourselves primarily to astronomical rather than meteorological phenomena. Assuming that you now know what you will be talking about, how do you do the work of sky interpretation? What follows are some suggestions based on more than 40 years of experience by the author and other experienced sky interpreters.

There are fundamentally two types of sky interpretation – daytime and nighttime. Daytime talks and observations might well focus on the sun and moon, both of which can be observed during the day time if the sky is clear and the moon phase is "just so". These tend to be very informal sessions, and they are usually conducted on a catch-as-catch-can basis. Telescopes outfitted with safe solar filters (or light cones) are focused on the sun. Without any filters, telescopes can be trained on the daytime moon. A daytime observing session can be set up outside of a visitor center or other busy place in a park. As visitors come and go, they can learn about the more formal evening sky interpretation session by stopping by the display. People love to look through telescopes, and are very approachable when you offer a free view of the sun or moon. They will be delighted to learn about your astronomy-related night program and will be much more likely to attend once they have met you.

Nighttime sky interpretation sessions are especially desirable if the park has a campground and people are looking for evening activities. During the day they will be busy hiking, boating, touring, visiting with one another, doing photography, and so forth. An evening event provides them with a reprieve from an often too-busy day. During the late afternoon, sky interpreters might want to walk through the campground inviting campers to the evening session and handing out handbills with the necessary information. For a handbill to be useful, it should provide visitors with all necessary information – type of clothing to wear, insect repellant (if needed), flashlights (if desirable), time and location of start, duration of program, starting and end points, distances, cautions about moving around in the dark, weather and other factors that might lead to the cancellation of the event, and so forth.

Interpretive Sessions

There are three common types of interpretive sessions related to the night sky: lecture hall/amphitheater, campfire circle, and evening stroll/star walk.

Lecture hall and *amphitheater presentations* are typically mediated programs in more formal settings. Lecture halls have the advantage that they provide shelter so that events need not be cancelled in the event of rain. Amphitheaters have the advantage of allowing attendees to view the night sky as the interpreter is talking about it. Both settings typically will have a large screen and tolerably comfortable seating. Have all your media (laptop computer, video projector, screen, and speaker system if necessary) set up and checked out in advance so you don't waste the audience's time at the start of the program. If possible, get others such as park rangers to assist with crowd control. Amateur astronomers from the community might be willing to help out if only you enlist their aid. Telescopes, if used, should be set out in a wide-open area where there is little direct light and everyone can view the sky down to the horizon if possible.

Evening events conducted in lecture halls and amphitheaters typically include the following: a slide show focusing on the topic of that evening, a laser-pointer-mediated sky lecture in which constellations, stars, planets, and other celestial objects of interest are pointed out, and – if possible –a telescopic viewing session. The talk begins at dusk – perhaps 30 minutes after sunset. (To find local sunset times, consult the Internet.) It's still bright enough for visitors to find the location of the session, yet dim enough so that you can show slides as you give introductory remarks. The later start will also allow for an opportunity for dark adaption to begin.

Unfortunately, in such settings the communication often tends to be one way – from interpreter to audience. The advantage of these presentations is that they can accommodate larger groups. People are visual learners and astronomy is a visual topic. PowerPoint presentations, physical models, and sky maps are essential to interpreters working in these settings. When working with media, be careful not to block visuals with your body. If you are dealing with manipulatives, hold them high so everyone can see them. The emphasis of a talk can vary from session to session, but often focuses on a single topic during a given session. Pick your topics wisely. It's best to focus attention on a visual topic such as "The Constellations", "The Ring Nebula", "Star Clusters", "The Andromeda Galaxy", or "The Great Nebula of Orion", rather than something as esoteric as "Weakly Interacting Massless Particles" or "Black Holes".

The talk should be about 30 minutes long, and lavishly illustrated. Small children have a hard time sitting still for much longer than this but will do so if the program is lively and interesting. PowerPoint presentations, if used, should contain a minimum of text and a maximum of imagery. Limit the follow-up questions to a very few, reminding the audience members you will be available to answer questions on a one-to-one basis once telescope observing begins. To do otherwise will risk losing a large part of the audience, as one or two individuals sometimes tend to tie up the conversation while others drift away disappointed. The follow-up constellation study should last only about 15 minutes. (If the sky is overcast, distribute sky maps and teach the audience how to use them instead.) Following this, open up the telescopes for viewing objects in the night sky. People will slowly depart with the passing of time for any of a variety of reasons. Nonetheless, plan on about two hours from start to finish.

Campfire circle presentations are typically presented in smaller, more intimate settings. Different interpretive technics are therefore used. While lecture hall and amphitheater presentations commonly focus on the more scientific aspects of astronomy as the subject matter of interpretation, campfire circles provide the more personal atmosphere ideal for traditional story telling. Not that campfire presentations can't be mediated – they can be. It's just the nature of the medium changes. These presentations can be augmented with the use of stuffed animals, flannel boards, and story boxes.

The overhead night sky serves as a canopy during campfire circle presentations and can be referenced at will. This setting is ideal for audience participation. For instance, during storytelling, it's not uncommon for children to hiss upon hearing the name of bad characters or cheering upon hearing the name of good characters. Songs and physical motions also can be used to advantage. When telling stories in the tradition of the ancients, it is most appropriate to draw practical lessons from the stories related. This allows for an active two-way banter between interpreter and participants that adds to the fun and meaning of the session.

When conducting a campfire circle presentation, avoid large, smoky fires. It is best to have a fire pit that includes no active flame, just glowing coals and embers. The goal is to avoid letting a campfire becoming a distraction during the talk, and not allowing flames to ruin dark adaption.

Twilight stroll and *skywalk presentations* are interpretive activities that take place on the go and occur between sunset and the end of twilight. Both are designed to help park visitors become familiar with changes in nature during the twilight period. In the presence of hills, the theme can be a skywalk where participants climb the landscape to a vantage point with a clear horizon ideal for viewing the night sky all around. Starting in a campground and pausing in a wide-open field or a hilltop under the canopy of night to view the sky is the goal of these two types of on-the-go presentations.

These presentations should start near sunset at locations that take advantage of the beauty of the nature setting. The interpreter can draw attention to visible clouds and cloud types, lightning, rainbows, halos, and sundogs. Later, attention can be drawn to the setting sun and the group can be reminded of important Earth-Sun relationships. As the walk progresses, interesting plants and animals are pointed out along the way. For instance, evening primroses with their lemon scents begin to open, daytime birds stop flying and go to roost, and bats and nighthawks begin to fly. As the sky darkens and the walk continues, attention is drawn to the colors of the twilight glow and the rising Earth shadow along the eastern horizon. Planets and stars – and Earth-orbiting satellites – are pointed out as they make their appearances. The main stop will be at the end of the trail where there will be few features of the landscape to block views of the night sky. Encountering a dark nighttime sky for the first time can be an exhilarating experience for urban visitors; give the visitors a chance to "soak up the view" before starting your onsite interpretation. The experience will be enhanced if binoculars and telescopes are on hand for use. Be certain to end twilight stroll and skywalk presentations at the place where they started. This will help prevent people getting lost and wondering around in the dark.

Giving a Sky Lecture

No matter the type of presentation, constellation studies should be included under a dark, nearly moonless sky with the aid of a bright green laser pointer; there simply is no better way to point out the stars when dealing with large groups. Use a 20mW to 30mW laser keeping in mind that brighter is often better. Moderately powerful lasers can be purchased online for a small cost nowadays. Because a laser pointer is exceedingly bright, be certain never to carelessly aim it at people, wildlife, or airplanes.

Start a sky lecture with something familiar such as the Big Dipper. Then show how its pointer stars direct one's sight to Polaris the North Star that is located at the end of the handle of the Little Dipper. A line drawn down to the ground beneath Polaris indicates the direction north. From there, indicate the other directions. Returning to the Big Dipper, focus the audience's attention of only a few of the major constellations or asterisms. Moving to the south, one encounters Leo the Lion. Following the handle of the Big Dipper, one can "Arc to Arcturus and speed to Spica." It is better to go into depth with a few constellations rather than skim over a lot of them. People find it hard to remember constellations, and focusing on a few – by showing outlines, pointing out the various parts, giving names to prominent stars, denoting star colors and distances, and telling stories – will prove to be the more memorable approach. Relating star stories is a universal joy in both the hearing *and* the telling; so, have a good time when you do so.

Use Voice Inflections

Astronomy is exciting stuff, so show it. Use the dynamic range of your voice, different intonations, and show excitement – and fear – as appropriate. Tailor your comments to children, and even adults will appreciate and understand. When delivering talks, be animated – show your enthusiasm by performing the same actions of those who you speak about in the story. Project your voice. Speak clearly and loudly enough so that those in the most distant reaches of the audience can hear without difficulty. If telling a story that includes different characters, use different intonations of the voice to represent them distinctly. Interact with the audience by maintaining a lively banter with them. Engage people young and old with questions. Use comedy when appropriate, and don't be afraid to show raw emotion during storytelling.

Employ Comparisons

Things in astronomy are nearly incomprehensible due to vast scales of distance and time. Audiences understand this vastness best when the sky interpreter makes use of comparisons. For instance, if the sun were the size of a ping pong ball, then Sirius the Dog star would be a tennis ball located a thousand miles away. The sun is so far away (93,000,000 miles), it would take nearly 200 years to get there driving at 55 mph; a fast commercial jet traveling at 600mph would take more than 17 years. The solar system is some 4.6 billion years old and the universe 13.8 billion years old. At the start of cosmic calendar that spans the entire history of the cosmos, on January 1st the Big Bang occurred. On May 11th the Milky Way galaxy formed. On September 1st, the solar system formed. On September 16th the oldest rocks of Earth formed. Humans appeared 5 minutes to midnight on the last hour of the last day of the year, December 31st, some 200,000 years ago… These types of comparison are just about as amazing as the universe itself.

Talk about Light Pollution

All the light that's visible at night doesn't come from the stars, moon, planets, and Milky Way. Too frequently the night sky is illuminated by wasteful stray light from streetlights, parking lot lights, building lights, outdoor display advertising, illuminated billboards, and sports venues (e.g. driving ranges, stadiums, and arenas). Reducing the contrast between the stars and the background sky, light pollution makes it more difficult (if not impossible) to see the stars and Milky Way at night.

Just how many stars can be seen at night with fully dark-adapted eyes? That depends almost entirely on the brightness of the background sky. As the sky gets brighter, fewer stars are visible. At one extreme, the daytime sky is so bright as to make even the brightest stars impossible to observe without anything other than a high-powered telescope. At night, under a very dark and transparent sky, stars to the 6th magnitude might be observed.

Magnitude is a rating scale used by astronomers to compare the brightness of stars. Very roughly put, the brightest stars are typically of 1st magnitude (though some are brighter with 0 and even –1 magnitude). The next groups of increasingly dimmer stars are of the 2nd, 3rd, 4th, 5th, and 6th magnitude. Stars of the 6th magnitude are the dimmest visible under good dark-sky conditions with fully dark-adapted vision. This historic six-step magnitude system is a qualitative measurement based upon the logarithmic response of the human eye to light. If measured with a modern light-sensing device, stars of the 1st magnitude are 100 times brighter than stars of the 6th magnitude. Each magnitude represents a brightness difference of about 2.512 times ($2.512^5 = 100$). Sirius the Dog Star in Orion, the brightest star in the night sky (note that it's NOT Polaris the North Star – the 49th brightest star in the sky) is so bright that it has a magnitude of *negative* 1.44. Stars like Vega in Lyra the Harp, Arcturus in Boötes the Bear Drive, and Capella in Auriga the Charioteer are bright enough to qualify as zero-magnitude stars. Aldebaran in Taurus the Bull, Spica in Virgo the Maiden of the Harvest, and Antares in Scorpius the Scorpion qualify as 1st magnitude stars. Relatively speaking, very few 2nd magnitude stars and those dimmer are known by their proper names.

A Word about Limiting Magnitudes

The first column in Table 4 below gives magnitude names. The second column gives magnitude ranges. The third column gives the number of stars within a particular magnitude range. The fourth column gives the total number of stars visible by limiting magnitude – the magnitude of the faintest star visible. The higher the limiting magnitude, the more the stars there are visible to the unaided eye.

Magnitude	Magnitude Range	No. of Stars in Range	Cumulative No. of Stars
–1	–1.50 to –0.51	2	2
0 (0th)	–0.50 to +0.49	6	8
+1 (1st)	+0.50 to +1.49	14	22
+2 (2nd)	+1.50 to +2.49	71	93
+3 (3rd)	+2.50 to +3.49	190	283
+4 (4th)	+3.50 to +4.49	610	893
+5 (5th)	+4.50 to +5.49	1,929	2,822
+6 (6th)	+5.50 to +6.49	5,946	8,768

Table 4. *Numbers of stars visible as a function of limiting magnitude.*

On a really dark, clear night with no moon, no light pollution, and fully dark-adapted eyes, the limiting magnitude is about +6.5. Under such conditions 8,768 stars are potentially visible. Because about half of these stars will be below the observer's horizon at any one time, and those near the horizon will be dimmed by Earth's atmosphere, it's easy to understand why we will see only about ⅓ of that number or some 2,500 – 3,000 stars at any one time. By the time the limiting magnitude reaches +3.5 (say in a small rural town), the number of stars visible drops to less than 100. In small cities (Springfield, Bloomington-Normal, Decatur, etc.) the limiting magnitude is often +2.5, and the number of stars visible is reduced to only about 30. In larger cities (Peoria, Rockford, and metropolitan Chicago) where the limiting magnitude is often +1 or brighter, the number of stars visible drops to 7 or fewer.

Limiting magnitude will vary by proximity to outdoor light sources as well as weather conditions. The closer one is to outdoor lighting, the lower the limiting magnitude and the fewer the number of stars visible. (Recall that the higher the magnitude number, the dimmer the star.) As a result of this, it's not unusual to find "light domes" from nearby towns and cities when observing from a rural setting. Few stars might be visible in the light dome but other parts of the sky will be less light polluted and more stars visible there. Sky transparency also plays a role in the number of stars visible. It is possible to have a pitch-black night and not see a single star because the sky is covered with clouds. The greater the relative humidity and the amount of dust suspended in the air, the lower the transparency and the smaller the number of visible stars regardless of sky darkness.

Fight the Light!

The spectacular view of the moonless night sky – one in which several thousand stars are seen and the Milky Way is visible nearly all the way down to the horizon – is disappearing due to light pollution. The sky that once inspired scientists, saints, artists, and poets is nearly extinct in many places due to light pollution. Clearly, if anyone is intent on seeing or showing the night sky in all its glory, he or she must remove themselves from the towns and cities and head to rural settings where there is less light pollution. Fortunately, many of Illinois' state parks are in rural settings. As sky interpreters we must work to preserve the darkness of night if for no other reason than to allow our fellow citizens the right to see a pristine sky.

Unnatural nighttime light harms wildlife adapted to flying, hunting, foraging, and mating in the darkness. Bright lights confuse animals that rely on natural sources of night light such as the moon and stars to navigate, and many fly into brightly illuminated buildings at night with death tolls ranging into the tens of thousands annually. Moths and other night-flying insects are confused by the presence of bright lights and fly around them all night long becoming ready targets to predatory night birds which themselves fly until they are exhausted.

The circadian rhythms of all humans and fertility cycles of women can be adversely affected by this unnatural nighttime lighting. Scientific studies have shown that poor night lighting can affect sleep-wake cycles in humans who are subject to it. This can lead to sleep disorders, obesity, depression, diabetes, and an increased growth of cancer cells – specifically breast cancer. There is no doubt whatsoever that artificial illumination at night has the potential to adversely affect mammals, birds, amphibians, reptiles, insects, *and* humans.

While some night lighting is appropriate for safety, it should be judiciously used to prevent light pollution and the waste of electrical energy. Proper intensity lighting that is appropriately shielded so that light is directed downward will not only protect the night sky, but will also allow for better ground lighting. (To learn more about these deleterious effects and what can be done about it, visit the International Dark-Sky Association website: www.darksky.org.)

Master Naturalists who understand the very serious problems presented by light pollution will "fight the light" when they interpret the sky. The goal is to enhance public understanding of the deleterious nature of light pollution, and encourage the general public to be more careful in their use of outdoor lighting.

How am I Doing?

It's not at all uncommon for novice sky interpreters to wonder how well they are doing. Are they getting their points across clearly and concisely? Has the audience learned the value of the constellations? Have they come to understand and appreciate the beauty of the night, and learned about the problem of light pollution? Absent an experienced sky interpreter, novice sky interpreters are left pretty much to their own devices to figure out the answers to such a questions. Still, there are things for which to watch.

Von Del Chamberlain, an astronomer and renowned sky interpreter who spent many years working in national parks as a volunteer, described two tests to help all sky interpreters – not just novices – figure out if they are having a positive impact. The first of these is the "stumble test"; the second might be called the "irritation test".

If people leave your sky interpretation sessions with their eyes turned heavenward and stumble over things as they return to their campsites or cars in the dark, then the sky interpreter has passed the stumble test. If people return to their camp or parking lots and express irritation with the presence of light pollution, then the sky interpreter has passed the irritation test.

On the down side, one of the most common complaints novice sky interpreters receive is about the failure to start and end on time. People plan their schedules around start and end times, and when these are not observed, this causes people to lose interest and drift away. These problems can be prevented by carefully adhering to the schedule.

Sky interpreters should never self-assess on the basis of their ability to answer questions. Even experienced sky interpreters are confronted with seemingly innocent questions to which there are no good answers. There are many things about which even professional astronomers don't know.

Sky interpretation is wildly popular in state and national parks where it is made available, and it is easy to see why. The subject matter is so very majestic and interesting! No matter how well you do at the outset as a novice sky interpreter, so long as you show enthusiasm for your topic, you'll win over your audience. Whatever you do, if you as a sky interpreter enjoy what you are doing, the enjoyment will be catching.

Astronomical Glossary

Annual motion – Relating to yearly as in yearly motion of the sun caused by Earth's revolution about the sun.
Asterism – An unofficial star grouping composed of the stars within a single constellation (e.g., The Big Dipper within Ursa Major) or several constellations (e.g., the Summer Triangle formed with the three brightest stars of Lyra, Cygnus, and Aquila).
Asteroid – Rocky and metallic bodies left over from the formation of the solar system, most of which orbit between Mars and Jupiter.
Binary Star – This is double star system in which two stars revolve around each other.
Comet – A frozen body left over from the formation of the solar system. These sometimes sprout long glowing tails as they pass nearest the sun.
Constellation – One of 88 officially recognized star patterns with specific boundaries established by the International Astronomical Union.
Dark Nebula – These are regions of dust and gas in the plane of our galaxy where new stars typically form.
Diurnal motion – Relating to the daily motion of the sun, moon, stars, and planets caused by the rotation of Earth.
Ecliptic – The apparent path of the sun's motion among the background constellations over the course of one year.
Elevation – The angular distance of an object above the horizon. Objects on the horizon have an elevation of 0°; the zenith has an elevation of 90°.
Elongation – The angular distance between two bodies measured in degrees. Elongations of planets are measured east and west of the sun.
Emission Nebula – These are clouds of gas in space forced to glow due to the presence of nearby stars. The Great Nebula of Orion, Messier 42, is a classic example.
Galaxy – A swirling mass of typically hundreds of billions of stars. The Andromeda Galaxy, Messier 31, is a classic example.
Globular Cluster – A swarm of about 100,000 stars left over from the early formation of our galaxy. The Hercules Cluster, Messier 13, is a classic example.
Light Year – The distance that light can travel in one year – about 5.9 trillion miles.
Magnitude – A logarithmic scale of apparent brightness used to classify stars. Low numbers (e.g., 0, 1, 2) represent brighter stars; high numbers (e.g., 5, 6, 7) represent dimmer stars.
Messier Object – Any of 110 celestial objects discovered by Charles Messier who cataloged them so they wouldn't be confused with comets. Typically these are some of the most prominent clusters, nebulas, and galaxies in the sky.
Meridian – An imaginary north-south line in the sky that passes through the observer's overhead point or zenith.
Meteor – A streak of light seen in the night sky when a meteoroid enters Earth's atmosphere at high speed forcing the air to glow.
Milky Way – Our galaxy seen from within and edge on. A faint glowing band of light seen in the night sky and composed of hundreds of billions of stars.
NGC Object – A New General Catalog listing thousands of objects not identified by Messier. The work of William and John Herschel.
Open Cluster – A loose gathering of dozens to hundreds of stars formed out of a single cloud of gas. The Hyades marking the face of Taurus the Bull and the Pleiades on the Bull's back are classic examples.
Planet – Any of 8 officially recognized "self-gravitating" bodies that orbit the sun and have cleared their region of space of debris left over from the formation of the solar system. Pluto is no longer considered a planet.
Planetary Nebula – These are the end states of stars like our sun that have died leaving a shell of gas. The Ring Nebula, Messier 57, is a classic example.
Precession – The wobbling of the Earth's axis that causes the north celestial pole to describe a circular motion among the stars over a 25,800 year period of time. As a result of precession, different stars serve as the North Star. Today it is the star Polaris among the stars of Ursa Minor the Little Bear. In the distant future the North Star will be Vega among the stars of Lyra the Harp.
Reflection Nebula – These are clouds that merely reflect starlight emitted most commonly by clusters. The Pleiades star cluster, Messier 45, contain a classic example.
Revolution – Moving around an exterior axis such as Earth orbiting the sun.
Rotation – Spinning on an interior axis such as Earth turning motion.
Variable Star – These are stars that brighten and dim due to pulsations or eclipses by companion stars.
Zenith – The highest point in the sky located directly over the observer.

Zodiac – The band of 12 traditional constellations that form the background of the ecliptic. It is among these constellations that planets are found.

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