Notes: The Art of Stargazing
Month 6: July - August 2013
Contents – The Art of Stargazing (Month 6)

What You Will Learn This Month........................................................................................................ 4
Tour of the Night Sky – Cygnus, Aquila, Scutum, Sagittarius......................................................... 5
  Overview........................................................................................................................................... 5
  The Constellation Cygnus.................................................................................................................... 5
  The Constellations Aquila and Scutum................................................................................................... 7
  The Constellations Vulpecula, Sagitta, and Delphinus....................................................................... 8
  The Constellation Sagittarius............................................................................................................. 9
The Deep Sky This Month.....................................................................................................................11
  The Milky Way.................................................................................................................................. 11
  The North America Nebula.................................................................................................................. 13
  The Veil Nebula................................................................................................................................. 15
  M29.................................................................................................................................................. 17
  The Dumbbell Nebula (M27)............................................................................................................... 17
  The “Coathanger”............................................................................................................................. 19
  M71.................................................................................................................................................. 20
  The “Wild Duck” Cluster (M11) ......................................................................................................... 21
  The Eagle Nebula (M16).................................................................................................................... 22
  The Swan Nebula (M17)..................................................................................................................... 24
  The Little Sagittarius Star Cloud (M24).............................................................................................. 25
  The Lagoon Nebula (M8).................................................................................................................... 26
  The Trifid Nebula (M20)..................................................................................................................... 28
  M22.................................................................................................................................................. 28
Observing Techniques – Eyepieces, Part I ............................................................................................ 29
  An Eyepiece Primer.......................................................................................................................... 29
  Wide-Field Eyepieces....................................................................................................................... 34
  Planetary Eyepieces.......................................................................................................................... 35
  A Few More Words of Advice........................................................................................................... 36
Solar System Observing – Meteors and Meteor Showers ................................................................. 36
  Overview........................................................................................................................................... 36
Meteoroids, Meteors, and Meteorites ................................................................. 36
Meteors Showers ..................................................................................................... 40
Science of Astronomy – Parallax; Double Stars; Dark Nebulae .................................. 42
The Distances to Nearby Stars .................................................................................. 42
Proper Motion and Radial Velocity .......................................................................... 44
Double and Multiple Stars ....................................................................................... 46
Dark Nebulae ........................................................................................................... 48
What You Have Learned This Month ..................................................................... 49
What You Will Learn This Month

Welcome to Month 6 of The Art of Stargazing!

This month, the prominent constellations of northern summer approach the meridian well before midnight. In the sky tours this month, you meet constellations rich with bright stars and more distant star clouds along the plane of the Milky Way. The tours starts with with the elegant constellation Cygnus, the Swan and moves south into Aquila, the Eagle the small but easily recognized constellations Sagitta and Delphinus, then into the star-clotted constellations Scutum and Sagittarius in which we find a dazzling arrangement of star clouds and splendid deep-sky objects.

The plane of the Milky Way blocks our view beyond our own galaxy, so this month again we see mostly star clusters and nebulae in our own galaxy, including two of the brightest nebulae visible anywhere in the heavens. If you have dark sky, you will also discover how to see the delicate lacework of a supernova remnant, the glowing residue of a massive star that detonated as a supernova just 18,000 years ago.

As for science… we ease up a bit this month. The past couple of months have been heavy going with the details of the evolution of stars. This month, we take a quick look at how astronomers first measured the distances to nearby stars. We’ll take a look at double and multiple stars. And we’ll examine the dark nebulae that lace through the starry plane of the Milky Way.

Over the past two months you got an overview of telescopes and telescope mounts. A telescope collects light and brings it to a focus as a bright image. But you still need another lens or set of lenses, what we call an eyepiece, to magnify this image for visual observation. This month we start to make sense of the bewildering array of eyepiece designs and configurations available on the market, and give some advice about which eyepieces work best for various types of telescopes, budgets, and observational inclinations.

And since August holds the famous annual Perseid meteor shower, we take a look at meteors in the section on solar system observation. You learn how to observe meteor showers, one of the most pleasant pastimes in all of amateur astronomy, and you learn about the types of meteorites that fall to Earth from time to time.

Let’s get started…
The main feature of the night sky this month is a galaxy. Not some far off sliver of light, mind you, but our own galaxy, the Milky Way, which arcs across half the sky in late July through early September. In dark sky, the stars clouds of the Milky Way are a bedazzling sight, with thick knots and clouds of unresolved stars and dozens of star clusters and nebulae visible—barely—to the unaided eye. Within these star clouds you also see dark riblike structures and pockets where few stars are visible. These dark regions are themselves part of the disk of our galaxy. They consist of fine dust grains, chilled just 10 or 15 degrees above absolute zero, and out of which new stars and star systems may one day form.

This month, the tour of the constellations follows the arc of the Milky Way starting from overhead, as seen in the northern hemisphere, and down towards the southern horizon.

The Constellation Cygnus

The bright star Vega in the constellation Lyra remains nearly overhead for northern observers in August. Find Vega then move your attention downward slightly to the northeast. Here you will find another star nearly as bright as Vega. This is Deneb, the brightest star in the constellation Cygnus, the Swan.

Cygnus is an ancient constellation. Ptolemy listed the group in his original 48 constellations in the 2nd century A.D. The main part of the constellation forms the asterism known as the “Northern Cross”, with Deneb (α Cygni) at the top of the cross and Albireo (β Cygni) at the base. The center of the cross is the star Sadr (γ Cygni), and the tips of the arms of the cross are marked by δ Cygni to the northwest and Gienah (ε Cygni) to the southeast. Viewing Cygnus as a swan, Deneb marks the tail, Albireo the nose, and delta and epsilon mark the wingtips.

From Deneb to Albireo, the constellation spans about 22°.

In Greek legend, Cygnus was a friend of young Phaeton who met his demise trying to drive the sun-chariot across the sky. When Phaeton fell into the river Eridanus, Cygnus begged Zeus to turn him into a swan so he could fly down to retrieve his friend’s body. In doing so, however, he gave up immortality. So touched was Zeus by the selfless act of Cygnus in honoring his friend, he placed the swan in a place of honor in the night sky.

Look between the stars Sadr and Albireo for a thick and bright stretch of Milky Way called the “Cygnus Star Cloud”, an unresolved mass of stars along the plane of the Milky Way. Just west of Deneb begins “The Great Rift”, a long band of darkness that runs southwest towards the horizon and appears to split the Milky Way in two. At the beginning of the Great Rift lies the
“Northern Coalsack”, a small pocket of darkness between Deneb, Sadr, and Gienah in northeastern Cygnus.

There are some memorable and unique deep-sky sights in Cygnus that await the inspection of a patient stargazer with a small wide-field telescope. One of the finest is the star Albireo. It’s a spectacular binary star for a small telescope and a stunning example of contrasting star colors. The 3rd-magnitude component of this star shines a golden-yellow; the fainter 5th magnitude component is a sapphire-blue. Any telescope, even at low magnification, will split this lovely star.

The constellation Cygnus, east of the constellation Lyra

Deneb itself is an imposing star. At magnitude 1.3, it ranks as the 19th-brightest star in the sky. But it is one of the intrinsically brightest stars known, with an absolute magnitude of -8.4. It is too far away for an accurate determination of distance, but astronomers believe Deneb to be 50,000 to 200,000 times brighter than our Sun and 20 times as massive as our Sun. Deneb is a
type A2 Ia supergiant and was once likely an O-type star. It is now quickly evolving into an M-type red supergiant.

**The Constellations Aquila and Scutum**

Look due south of Albireo in Cygnus for a bright white star. This is Altair, the brightest star in the constellation Aquila, the Eagle and the 12th-brightest star in the sky. An ancient constellation dating to the 4th-century B.C., Aquila represents the eagle that held the thunderbolts of Zeus in its talons.

Aquila parallels Cygnus and also follows the arc of the Milky Way towards the south, so the constellation holds a rich star field with several open star clusters. Attending the bright star Altair to the north and south are the stars Alshain (β Aquilae) and Tarazed (γ Aquilae). The body is marked by δ and λ Aquilae and the wings by ζ and θ Aquilae.

(A bit of trivia… the Pioneer 11 spacecraft, launched in 1973 to explore Jupiter and Saturn, is headed for the southern reaches of Aquila and neighboring Scutum. The craft will pass close to λ Aquilae in about 4 million years).

Altair is a nearby star, just 17 light years away, and about 1.7x as massive as our Sun and 11x as bright. The star still lies on the main sequence and has spectral type A7 V (recall the “V” indicates a main sequence star). Altar spins alarmingly fast. Whereas our Sun spins once every 25 days, Altair rotates once every 9 hours, so fast it’s actually squashed a little at the poles.

Altair also marks the apex of the so-called *Summer Triangle*, a large asterism that also includes the stars Vega and Deneb. Observers in the southern hemisphere, where it is winter in August, sometimes refer to this group as the Northern Triangle.

Vega and Altair also take part in the well-known Chinese legend of the Herd Boy and the Weaving Girl. The story tells of a poor herd boy (represented by the star Altair) and a humble weaving girl (the star Vega) who were once so lost in romantic distraction that they neglected their duties to their heavenly masters. As punishment, the boy and girl were placed in the sky and separated forever by the Celestial River (the Milky Way). But the heavenly spirits had some compassion… once a year, on the 7th night of the 7th moon, the lovers were allowed to meet when a bridge of magpies spanned the heavenly river of stars.

Southwest of Aquila and east of Ophiuchus lies the small, dim constellation Scutum, the Shield. This modest group of stars was first named Sobieski’s Shield after a 17th-century Polish king. It’s the only constellation with political origins still in use today. The stars of Scutum form a small distorted triangular shape.
While it has no stars brighter than 4th magnitude, Scutum’s location in the thick band of the Milky Way makes it a favorite stop for stargazers with binoculars and small telescopes. There are many fine sights here, and you will meet the finest, the star cluster M11, later this month.

**The Constellations Vulpecula, Sagitta, and Delphinus**

Between Cygnus and Aquila lie three small constellations Vulpecula, the Fox; Sagitta, the Arrow; and Delphinus, the Dolphin. Because this part of the sky is so close to the Milky Way, there is a profusion of stars here and many deep-sky objects which are often passed over for sights in better-known constellations. But there is enough here for much pleasant stargazing on late northern summer nights.
Sagitta is an ancient constellation. It was included among Ptolemy’s original 48. The shape of the constellation has caused many cultures to interpret this group as an arrow of some sort. The ancient Greeks associated the arrow with the story of Prometheus, the titan who built men out of clay and brought them to life with fire stolen from Zeus. Zeus punished the titan by chaining him to a mountain where an eagle, in some legends represented by Aquila, consumed the liver of poor Prometheus over and over again. Hercules took pity upon Prometheus and used an arrow to kill the eagle, both of which were placed in the heavens. The shaft of the celestial arrow is marked by $\gamma$ and $\delta$ Sagittae, while the tail feathers are marked by $\alpha$ and $\beta$.

Delphinus, too, is ancient. Like Sagitta, it is clearly shaped like its namesake, in this case the little Dolphin that carried the poet Arion to safety after his shipmates conspired to rob and cast him overboard.

Vulpecula, on the other hand, is a relatively recent creation. Hevelius included this completely non-descript group of stars on one of his late 17th-century star maps. This otherwise forgettable constellation, which resembles nothing, is made famous by the very fine planetary nebulae M27 which lies within its borders.

**The Constellation Sagittarius**

The constellation Sagittarius vaults above the southern horizon for northern stargazers, and lies nearly overhead for deep-southern observers in July and August each year. This large constellation, which represents a mighty centaur shooting an arrow westward into the heart of Scorpius, holds an astonishing number of deep-sky targets for stargazers with a telescope, binoculars, or with absolutely no optics at all.

The stars of Sagittarius were first recorded by the Sumerians some 5,000 years ago. The ancient Greeks, 2,000 years later, sometimes depicted this group as a satyr (half man and half goat) rather than a centaur (half man and half horse). Ancient Greek poetry associates these stars with the satyr Crotus, whose father was the god Pan, and who was said to have invented archery. But modern and renaissance star maps show these stars as a centaur with a bow drawn and aimed westward to fire an arrow into Antares, the star at the heart of Scorpius. Some books suggest Sagittarius represents the wise and noble Centaur Chiron, but most astro-historians agree that Chiron is represented by another celestial centaur, the southern-hemisphere constellation Centaurus.

It takes a little imagination to see a centaur among these stars. But most observers instantly see the much more familiar shape of a teapot in Sagittarius. Indeed, the “Teapot” asterism is one of the most familiar in the heavens, with the handle to the east, the spout to the west, and the lid pointing northward. The pot spans about 15° of sky, about half again as wide as your fist held at arm’s length. The Teapot is traced by the stars Ascella ($\zeta$ Sagittarii), Tau ($\tau$), Nunki ($\sigma$), Phi
The Art of Stargazing

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$
\phi$, Kaus Australis ($\varepsilon$), Kaus Media ($\delta$), Kaus Borealis ($\lambda$), and Alnasl ($\gamma$ Sagittarii). Above the top of the Teapot lies another star Mu ($\mu$).

Whether you see Sagittarius as a satyr, a centaur, or a pot of steaming tea, the constellation contains a staggering array of deep-sky objects arrayed along the Sagittarius Arm, one of the thick spiral arms of the Milky Way. The center of our galaxy also lies in this direction near a point about 4º west-northwest of the Alnasl ($\gamma$ Sagittarii) at the tip of the Teapot. You can’t see the galactic center because it’s obscured by nearly 30 magnitudes (!) by dark dust, but the star fields are thicker here than anywhere else in the heavens. Astronomers detect the center of the galaxy at other wavelengths including radio, microwave, and infrared.

The constellation Sagittarius

The thick clot of stars just off the tip of the Teapot is called the “Great Sagittarius Star Cloud”. Here you are looking towards the central bulge of the Milky Way, and this region is one of the innermost sections of the galaxy visible to us. As mentioned, much of our view of the center of the galaxy is obscured by dust, but this patch shines through to give us a glimpse of the central bulge. This inner part of the galaxy is devoid of dust and gas from which new stars form, so most of the stars here are K and M-type main sequence stars or evolved red giants, which is why
the region displays an orange-red color in photographs. The Sagittarius Star Cloud is simply stunning in binoculars and it is something you must see.

Image of the Milky Way in Sagittarius. The “Great Sagittarius Star Cloud” is at lower right just above the tree line, and just above and to the right of the “spout” of the Teapot.

The Deep Sky This Month

The Milky Way

The Milky Way is the highlight of the night sky this month. In fact, it is the largest single celestial object in the heavens, stretching all the way around the sky as a thin, white, mottled band of unresolved stars. Before the 20th century, the term “Milky Way” referred simply to the band itself. Since the 1920’s, astronomers deduced the existence of other galaxies far away from our own. So the term Milky Way was used since then to refer to our entire galaxy.

The Milky Way is a spiral galaxy, a nearly-flat disk with winding arms and a dense core of stars. The disk spans about 100,000 light years, and our solar system lies near the edge of the disk about 27,000 light years from the center. From our skies, the disk of stars looks like a band encircling the sky and splitting it in two equal parts. The section of band towards the center of the galaxy is thicker since there are more stars in this direction, the direction towards Sagittarius and Scorpius. When we look in the opposite direction, towards the constellation Orion, we still
see a band of stars but it is much more sparse because we are looking towards the outer edge of the galaxy with far fewer stars.

The location of the Sun in the Milky Way (NASA).

The Milky Way is the only galaxy we can see from the inside. All the stars, nebulae, star clusters, and pretty much everything else we see in the night sky without optical aid lies within the Milky Way. Only a few galaxies outside the Milky Way can be seen, as dim smudges, with the unaided eye. Because we can now see with telescopes many other edge-on spiral galaxies, it’s possible to see the similarity between these galaxies and our view of the Milky Way from its edge. Look at the close-up image of NGC 891 below and the wide-field image of the Milky Way towards Scorpius and Sagittarius. The similarity is striking.

The edge-on spiral galaxy NGC 891. All bright single stars in this image are foreground stars in our own galaxy (image credit: NASA)
The Milky Way, as seen overhead in the southern hemisphere. Sagittarius just left of center; Antares is the bright orange star just above and to the right of center (credit: Marco Lorenzi)

When we look at the Milky Way, along with stars we see dark rivulets of cold dust that block our view of the background stars further inside our galaxy. If not for this dust, the visible plane of the Milky Way in Sagittarius would be nearly twice as thick, extend as far north as Antares in Scorpius, and shine many times brighter. But of course, if there were no dust in our galaxy, there would be no heavier elements like carbon and oxygen out of which planets are made. These dark clouds are created by the dust of dying stars that throw off their outer layers into which have been mixed heavy elements from their cores. Some elements in dark interstellar dust have been formed by supernovae.

The Milky Way is an amazing sight in dark and clear sky. But it takes very little light pollution to wash out the view of our own galaxy. Make people today have never seen the Milky Way and are startled when they get their first look while traveling away from the city or during blackouts. If you are city-bound, try to get to dark sky at least once or twice a year to see the disk of your home galaxy. It will leave you energized and keen for more stargazing.

The North America Nebula

Now to another sight that’s impossible to see from the city, and which, frankly, is a little challenging even from dark sky. It is NGC 7000, a large and faint emission nebula that’s shaped very much like the continent of North America. Is it a coincidence we see this unmistakably Earthly shape so far out in the cosmos? Of course it is! But it is a lovely and challenging object and well worth a look if you can find it.

The location of this faint and sprawling nebula is easy enough to find. Its center point lies about 3° east of the star Deneb, the brightest in Cygnus, and 1° west of ξ (xi) Cygni (see map below). The nebula is large, spanning 2° of sky, but it’s not easy to see in anything but dark and clear
sky. Binoculars will do nicely to view its full extent, and you can see parts of the nebula without optics at all. A wide-field and low-power telescope enhances the view somewhat, especially with a light-pollution filter such as a UHC or OIII filter to enhance the contrast. If you have such a filter and if you can’t see the nebula with your naked eye, hold the filter up to your eye to improve contrast. It may pop right out.

NGC 7000, the North America Nebula. The Pelican Nebula is at lower left.

Like all glowing reddish-pink nebula, the North America Nebula is an HII region (pronounced “H-two”), a large cloud of hydrogen that’s ionized by hot stars embedded within the nebula. Astronomers once thought the star brilliant Deneb set this nebula aglow, but the very hot 6th-magnitude star HD 199579, one of the many stars buried within the nebula, is the culprit.

Once you see the nebula, look carefully for detail. Mexico and Florida are the faintest regions of the nebula, while Central America and Canada are the easiest to see. The coasts of the “continent” are also well defined. Look also for concentrations of stars around Washington State and the midwestern U.S. These are the open star clusters Collinder 428 and NGC 6997, respectively.

The North America Nebula appears grey to most visual observers and slightly green to others. Reds and pinks are visible only in photographs.

If you can see the North America Nebula, look for the Pelican Nebula about 1° off the “east coast” of NGC 7000. The Pelican, which is much harder to see, is part of the same HII complex and is separated from NGC 7000 by a dark lane of dust. The whole complex lies about 1800 light years away and spans some 50 light years.
The location of NGC 7000, the North America Nebula, in Cygnus (upper left).

The Veil Nebula

I’m not trying to be hard on you, but here’s another challenging object in Cygnus that few ever see visually. It’s worth the effort. This object, the Veil Nebula, a curtain-like remnant of an exploding supernova, is one of the most intricate and intrinsically beautiful sights in all the heavens. I saw a section of the Veil Nebula once through a gigantic 25” Dobsonian reflector and I was so overwhelmed at the view that I nearly fell off the ladder that led up to the eyepiece.

The Veil Nebula complex
The Veil Nebula is the shattered remains of two stars that exploded 18,000 and 5,000 years ago. The stars were only 2,500 light-years away, so each likely appeared as bright as the crescent moon in the skies of our prehistoric ancestors (and probably scared the living heck out of them). The bright optical filaments in the Veil Nebula are caused by the supernova blast wave colliding with interstellar clouds. As the shock wave slows down, it loses energy by emitting visible light.

The Veil is also called the Cygnus Loop, which consists of three structures that span an impressive 3.5° across the sky… roughly 7x the diameter of the full moon. Look for the complex a few degrees off the star ε Cygni… see the map below.

The eastern section of the nebula, also called NGC 6992, is the brightest and easiest to see. You can spot it in 7x50 binoculars if you have extremely dark sky. The fainter western section of the nebula is cataloged as NGC 6960. Though harder to see, this section is set against the lovely 4th magnitude foreground star 52 Cygni. When observing the Veil complex, use your low power eyepiece. You’ll only see one section at a time, especially in scopes with longer focal ratio.

To see the Veil through a telescope, a light-pollution filter is a huge help. We have not discussed them yet, but, briefly, these filters block the sky glow caused by light pollution and pass the very specific wavelengths of light from nebulae like the Veil. The result is a vastly improved contrast of such objects against a darkened background sky. A UHC (ultra-high contrast) works well with all telescopes, while an OIII (“oh-three”) filter works best with telescopes of 8” aperture or larger.

NGC 6960, the western section of the Veil Nebula complex
Location of the Veil Nebula around and east of the star 52 Cygni

M29

Here’s an easier object… a small open star cluster nestled against the star γ Cygni (Sadr). This open cluster, M29, must be one of the least impressive in Messier’s catalog. Many new stargazers are unsure they see this object even when they are staring right at it. The cluster is located just 1.7” south of Sadr (gamma Cygni), so it should not be hard to find. But with only six bright stars, the cluster can be mistaken for an accidental clump in the Milky Way. You can tell if you’re seeing M29 by the arrangement of the six bright stars in two groups of three that look like curved brackets facing each other like this... (A larger scope, say 6-8”, will reveal more stars, but it’s hard to sort them out from the fairly rich background.

The Dumbbell Nebula (M27)

Here’s an easy object and one that makes the list of most beginning stargazers. M27 is a beautiful planetary nebula, and even more experienced amateur astronomers enjoy stopping by this old favorite this time of year. The nebula is most famously called the “Dumbbell” because of its characteristic shape. Others have taken to calling it the “Apple Core” nebula as well.

Even in binoculars or a finder, the nebulous nature of M27 is obvious. It’s easier to find from the
star gamma (γ ) Sagittae, the tip of the arrow Sagitta, than any star in Vulpecula. Look for the nebula about 3° due north of gamma.

Through even a 60 mm scope, M27 looks rectangular. Unlike the Ring Nebula in Lyra (M57) in which we look down the axis of the nebula, M27 gives us an edge-on perspective to an evolved planetary. We see gas ejected from the central star in a bipolar fashion, possibly because of the effects of the star’s magnetic field on the stellar winds. At 75x, the “dumbbell” or “apple core” shape of M27 becomes quite evident. A brighter streak across the long diagonal of the nebula can also be seen, along with texture and brightness variations across the whole apparent surface. Color is visible only in images.

M27, the “Dumbbell” Nebula in the constellation Vulpecula

Compared to other planetaries, M27 is close (about 1,000 light years), and large (more than 1 light year across). So it appears far larger in our sky than most other such nebulae. Astronomers have had a good look at this object and distinguished two separate expanding shells of gas from the central star. A shell of ionized oxygen is hurled into space at 14 km/s, and one of ionized nitrogen expands at 30 km/s.

The central star that’s casting of the nebula is of 14th magnitude and quite a challenge in most telescopes. To see the central star of nearly any planetary nebula, you should not use a nebula or light-pollution filter since it will reduce the star’s brightness appreciably.
Red circle marks the location of M27; the Coathanger asterism and the globular cluster M71 are also indicated

**The “Coathanger”**

Now to a small and easy-to-see asterism just off the northwest tail of Sagitta. Just south of Albireo in Cygnus, look for a 4th-magnitude star. This is Anser, the brightest star in Vulpecula. This orange star has another fainter orange star just 6’ to the northeast. Now imagine a line drawn from Albireo though Anser and extended beyond the latter for about 1.5x their separation. This is the location of a remarkable asterism sometimes called Brocchi’s Cluster, sometimes Collinder 399, but which is better known as the “Coathanger”. One look at the cluster through binoculars or a low-power telescope reveals why.

You can glimpse the group with your unaided eye in good sky as a little cloud. The longest axis of the group is 1.4”, so you will need a field of view of at least that much to see the whole object. If your telescope’s lowest-power eyepiece can’t fit it all in, try observing with your finderscope. It may give a better view. This is also a good object for binoculars.
Six stars make the flat bar of the hanger, and four more make up the hook. While it was once thought to be a true star cluster, astronomers know understand this is simply a chance alignment of stars.

Here’s a bonus object, one that few stargazers know about. Just 1/3 of a degree east of the most eastern star in the Coathanger lies the true open cluster NGC 6802. The cluster is less than 1/10 of a degree across and shines at 9th magnitude. It makes a wonderful little splash of light in this rich star field.

The Coathanger, also called “Brocchi’s Cluster or Collinder 399. The small open cluster NGC 6802 lies to the left side of the image.

**M71**

Few would ever include M71 on their list of must-see objects this month. But I like it. It’s a relatively loose and faint globular cluster in Sagitta set in a fine foreground of stars along the Milky Way. Astronomers pondered for decades the true nature of M71. Some thought it was a tightly packed open cluster. Others believed it was a loose globular cluster, which is now the accepted wisdom.

The cluster is close by, about 13,000 light years. At magnitude 8.2 it is not terribly bright, especially compared to the grand M22 in Sagittarius which is only slightly closer in real terms. In a 3-4” scope, the stars are unresolved and there is a clear brightening towards the core at low power. Crank it up to 100x or more, and many stars become resolved in the halo. The shape of the cluster has been described as “arrow-like” or “Y-shaped”.

Look for M71 just south of the line between gamma (γ) and delta (δ) Sagittae, the shaft of the arrow, and slightly closer to gamma (see map above).
The "Wild Duck" Cluster (M11)

Let’s move further southward along the Milky Way now, just past the tail of the eagle Aquila and into the small constellation Scutum and just southeast of β Scuti. Here we find M11, the finest open cluster in this part of the sky. It’s the favorite of many experienced stargazers, and quite rewarding to observe in detail.

Unlike many other bright open clusters, M11 is quite compact and requires substantial magnification to resolve. In binoculars, it’s a bright 6th-magnitude smudge. In a 3” scope at 30-40x M11 remains mostly unresolved, though its smoky haze spreads across 1/5 of a degree of sky. Crank up magnification to 100x and above, and the cluster finally expands into a fan-shaped spray of dozens of white 9th and 10th-magnitude stars.

With a steady gaze, you may perceive a wedge-shaped pattern amongst the stars of M11. The British amateur stargazer Admiral William Smyth imagined M11 as a V-shaped configuration of stars that reminded him of wild ducks flying in formation. That’s why M11 is often called the “Wild Duck” cluster.
M11 is a distant cluster, nearly 5,500 light-years away and roughly 300 million years old. Most of its 2000-3000 stars are luminous giants that shine much brighter than our own sun. From Earth, the stars in M11 are 9th to 11th magnitude. If our Sun lived in M11, it would appear as a barely-visible 16th-magnitude star.

Unlike many open star clusters, M11 has not yet been dispersed by passing stars and gas clouds because it’s massive enough to hold itself together through the mutual gravitational attraction of its constituent stars. If you found yourself on a planet near the center of M11, you’d see a sky chock full of brilliant stars, more than 50 of which would range from 3 to 50 times brighter than Sirius, the brightest star in our sky.

**The Eagle Nebula (M16)**

Now let’s turn our attention south and west of Scutum and far above the Teapot of Sagittarius. Here, the stars grow thick and the deep-sky sights plentiful. We’ll tour a few in a long arc of dazzling objects down from the edge of Serpens through to above the spout of the Teapot. Let’s start with the lovely emission nebula M16, the “Eagle Nebula”.

In decent sky, M16 is visible with the unaided eye as a faint glowing blister on a line from β Scuti through α Scuti about the 6° past alpha.
Officially, M16 refers to the star cluster embedded within the nebula, which itself is cataloged as IC 4703. The cluster reveals 30-40 blue-white stars in a 4” telescope at 80-100x. This is a young cluster, certainly less than one million years of age, with some stars considerably younger than that. These stars were born out of the dust and hydrogen gas in this region, which they in turn are setting aglow with their bright blue and ultraviolet light.

![The Eagle Nebula and cluster (M16 and IC 4703).](image)

Time-exposure images of this object reveal the shape of the nebula as an eagle with wings spread in flight. This shape is harder to see in a small telescope, though the nebula clearly shows two perpendicular arms that make up the body and the wings. Most interesting is the dark nebulosity at the nebula’s heart. One “L-shaped” finger of darkness may be discerned at higher magnification. This structure is sometimes called “The Star Queen’s Throne”. Close up images reveal many more dark lanes within the nebula that are blown about by the winds and strong ultraviolet radiation from new stars, and which may harbor new protostars in the process of formation. The Hubble Space Telescope revealed a series of three long fingers within the Eagle Nebula that are famously referred to as the “Pillars of Creation”.

The Eagle Nebula is about 20,000 times the extent of our solar system. It lies about 9,000 light years away.
Location of M16 (Eagle Nebula), M17 (Swan Nebula) and M24 (Little Sagittarius Star Cloud)

**The Swan Nebula (M17)**

Just two degrees south of M16, look for another misty patch visible to the unaided eye in dark sky. This is an even brighter nebula, M17 (see map above). Along with the Orion Nebula (M42) and the Lagoon Nebula (M20), M17 is one of the three brightest nebulae visible to northern stargazers.

This is an excellent object for a small scope because it gives up more detail with a concerted gaze. The overall shape of the nebula is likened to many different shapes, so you will see M17 called the Omega Nebula, the Horseshoe Nebula, the Swan Nebula, the Checkmark Nebula, and the Lobster Nebula. I tend to call it the Swan Nebula.

It is a remarkably beautiful object, especially in dark sky or even in suburban skies with a good light pollution filter. The brightest part of the nebula, visible in any telescope, is a long silver bar that extends west-northwest to east-southeast. The neck of the swan is also easily seen extending southward from the western end of the body. These two sections give the nebula its “check
mark” appearance. But with a 3” or larger scope, the neck extends around into a curve to complete the swan-like shape. There is more nebulosity above the swan’s body, and below and off the back of the tail.

As an emission nebula, the Swan is set aglow by new stars forming within its central region. Many such nebulae, including our last stop, M16, are coincident with a cluster of newly-born stars. But the Swan reveals few of its progeny, although astronomers estimate there are more than 600 stars embedded within the nebula. M17 lies about 4,900 light years from Earth.

![M17, the “Swan Nebula”](image)

**The Little Sagittarius Star Cloud (M24)**

Unlike most objects on the Messier list, the next object this month, M24, is neither a nebula nor a star cluster nor distant galaxy. It is simply a small section of the Sagittarius Arm of our galaxy that’s clearly visible because we’re looking through a gap in the obscuring dust along the plane of the Milky Way. If there was no dust or cold gas, the entire Milky Way from Cygnus to Scutum and into Sagittarius (and beyond into Centaurus and Crux in the southern hemisphere) would appear as bright and luminescent as this small patch of pure star cloud.

As with all of the Milky Way, dark sky is essential to see M24. M24 appears as a brightening in the Milky Way just 4° north of mu (μ) Sagittarii, and spans a fairly small 1°x2° rectangular patch of sky. It is splendid in binoculars and in a telescope with a field of view of at least 2°. The individual stars range from magnitude 6 down to invisibility in a small telescope.
The Small Sagittarius Star Cloud (M24) runs from upper left to lower right in this image. B92 is at bottom, just left of center. B93 is just to its right.

The cloud appears to shimmer and take on a 3-dimensional quality in a good scope, and some observers see the color as blue or even green. As you gaze at the star cloud, you may also see a network of dark lanes and channels as your eye and brain try to make sense out of the profusion of patterns formed by thousands of sparkling stars.

M24 is over 330 light years wide and lies a fairly distant 9,400 light years from Earth, nearly as distant as some globular clusters.

M24 has within it several dark nebulae, and the bright background of the cloud make these nebulae easier to observe. Perhaps the most straightforward to see is Barnard 92 (B92), a 1/4-degree oval of darkness along the middle of the northwestern edge of M24. Once you find B92, examine it with a range of magnification to examine the numerous bright stars around it, as well as a single lone foreground star apparently embedded in the nebula.

If you can spot B92, try for B93 just 1/3 of a degree to the northeast. This nebula is narrower than B92 but nearly as long. It’s a little trickier to see because its borders are less defined. The image at the top of the page shows you the star cloud along with the two dark nebulae…

The Lagoon Nebula (M8)

Now to perhaps the two most famous objects in this part the sky, the Lagoon and Trifid Nebulae. First, the Lagoon, Messier 8, located about 6° above the spout of the Teapot of Sagittarius. In dark sky and even in suburban skies it’s clearly visible to the unaided eye.

Like most emission nebulae, the Lagoon contains a fine star cluster. This one is cataloged as NGC 6530. Try a magnification of 80-90x to find 20-30 stars of magnitude 7 and fainter. The
pattern is arranged in a triangular shape and spans perhaps 1/5 of a degree. Larger telescopes reveal more than a hundred stars in this cluster.

The nebular component of M8 is NGC 6523. You will see nebulosity around the brighter star 9 Sagittarii just west of the cluster. Look for an hourglass-shaped knot just a little west of 9. A second patch of nebulosity engulfs the cluster NGC 6530 itself. Between the two nebulous patches, look for the black gulf or channel that gives the Lagoon nebula its name. The whole view is best taken in at lower magnification, say 25-50x. The contrast of the nebulosity is greatly improved by a UHC or OIII filter, even in darker skies.

Within the M8 complex, look just 1/3 of a degree west of the cluster for the 5th-magnitude star 7 Sagittarii, and the double star Argelander (Arg) 31. Here, the nebulosity begins to fade. Arg 31 is a 7th and 9th magnitude star about 34” apart.

Even 3” scope gives a remarkable view of the nebula and dust lane. Whatever your optics, make sure to use averted vision. When you do, an astonishing amount of fleeting detail will pop out. The Lagoon is an object that should be examined carefully, a little at a time, night after night. In time, it will reveal to you nearly as much detail as you see in time exposure images. Though you will not see any color in the nebula... there is not enough light to stimulate the color-detecting cells in your retina.

*M8, the Lagoon Nebula (bottom) and M20, the Trifid Nebula (above)*
The Art of Stargazing – Month 6

**The Trifid Nebula (M20)**

Now look just 1.2° north of the Lagoon for the fainter Trifid Nebula, M20. It fits in the same low-power field as the Lagoon Nebula. Another splendid sight for a small telescope, the Trifid is smaller and fainter than the Lagoon but has a more complex network of dark dust channels that make for challenging and fascinating viewing.

The nebula is centered on the 7th-magnitude star H N 6, which has a magnitude-8.7 companion about 11” to the southwest. The emission nebula is brightest around this star, and even binoculars will reveal the nebulosity. The stars embedded in this section set the nebula aglow by ionizing hydrogen, which emits reddish light when it recombines into a lone proton and electron. The nebular part of the Trifid is NGC 6514.

The Trifid gets its name from the dark nebula Barnard 85, which appears to split the nebula into three sections. A 3” scope at moderate magnification (60-90x) can show this “trifurcation”, though it is not dead easy to see and requires careful viewing to first glimpse it. Again, a nebula filter may help with contrast. In photographs, B85 appears to split the emission nebula into four sections; this can be seen visually in larger telescopes.

Images of M20 also show a blue region of nebulosity just north of the reddish region. This is associated with the star forming region, but it shines by a different process. Fine dust particles surrounding a 7th-magnitude star reflect its bright blue light into our line of sight, so this type of nebula is called a “reflection nebula”. It exhibits the same optical spectrum as the star, so an OIII or UHC filter will not improve contrast here. But the reflection nebula is visible with some effort in a small telescope, though it is certainly fainter than the emission nebula just to the south.

The reflection nebula is included as part of NGC 6514. The sparse cluster of stars associated with M20 is often listed as Collinder 360.

Some believe the Trifid and Lagoon might be part of the same star-forming complex. The former is about 5,000 light years distant, while the latter is about 5,200 light years away. But they may also simply be aligned by chance.

**M22**

Our last stop on this month’s extended tour of the deep sky is the very fine globular cluster M22, one of the most visually appealing globs in all the heavens. The cluster is not nearly as dense at its core as M5, or even M13. So even a 2.4” or 3” telescope resolves stars in the outer halo of this fine globular, and an 8” or larger scope resolves the cluster to the core. In a telescope, the image is one of a crushed diamond, with its dust and fragments crumbled against black velvet.

The cluster is conveniently located just 2° northeast of the top of the Teapot marked by the star Kaus Borealis (λ Sagittarii).
M22 is sometimes called the “Arkenstone of the Stars”, after the description of J. R. R. Tolkien in *The Hobbit* of the jewel called the Arkenstone of Thrain, which “... was as if a globe had been filled with moonlight and hung before them in a net woven of the glint of frosty stars”.

The cluster spans half a degree of sky, as much as the full Moon. The brightness and size of the cluster are rivaled only by 47 Tucanae and Omega Centauri, two globulars in the deep southern sky. The brilliance of M22 is somewhat diminished for northern observers because it is never far above the thick air and dust near the horizon. It is a marvel from the southern hemisphere. Though even there, you can’t see the cluster’s full splendor because its light is diminished by light years of dust near the galactic plane. M22 is about 10,000 light years from Earth.

![Map of M22 in Sagittarius](image)

*The red circle marks the location of the globular cluster M22 in Sagittarius*

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**Observing Techniques – Eyepieces, Part I**

*An Eyepiece Primer*

Many telescopes come with one or two general-purpose eyepieces of average quality. They’re alright to get you going, but a couple of additional high quality eyepieces will enhance your astronomical viewing experience, much as a good set of speakers enhances the experience of
listening to a good home sound system. There’s a bewildering array of eyepiece types and manufacturers on the market now, so choosing an eyepiece can seem like an overwhelming task. But with the basics you will learn here, you can make a more informed decision when it comes to selecting eyepieces to match your equipment and interests.

Eyepieces come in dozens of optical designs and configurations like Plossl, Nagler, Erfle, Orthoscopic, and so on. Each design has pros and cons, and frankly, some designs are better than others. But all eyepieces have the following characteristics you should know:

• **Barrel diameter.** Most eyepieces today have a barrel diameter of 1.25”, and most telescopes accommodate this barrel size. Some premium low-power eyepieces use a 2” barrel rather than 1.25” to accept a wider cone of light and allow a wider field of view. You may need an adapter to accommodate these larger eyepieces in your scope. Many beginner and lower-cost scopes will not accommodate eyepieces with 2” barrel sizes.

![A set of eyepieces from Explore Scientific. Four of these eyepieces have a barrel diameter of 1.25”, while three long focal length eyepieces at back have a barrel diameter of 2”](image)

• **Focal length.** Eyepieces have focal lengths of 2 mm to 56 mm. Longer focal lengths give lower magnification. To calculate the magnification of an eyepiece, simply divide it into the focal length of the telescope. So

\[
\text{Magnification of eyepiece} = \frac{\text{Focal Length of Telescope}}{\text{Focal Length of Eyepiece}}
\]

So with a telescope of 900 mm focal length, using an eyepiece with 15 mm focal length, you get 900/15=60x (60 power).

Magnification affects how much sky you can see with an eyepiece, a quantity known as the “apparent field of view” (see next point). Using low magnification, you get a wider field of view and brighter, smaller images. Using high magnification gets you a larger image and lets you see
more detail at the cost of a lower image brightness because the same light from the object is spread over a larger image size.

As a rule of thumb, the maximum useful magnification of a telescope is 50x-60x the diameter of the objective lens or mirror in inches. If sky conditions are poor, the number might only be 20x-30x. Under very steady sky, a good quality objective might enable a magnification of 70-100x its diameter. An example… taking 50x as the limit, a 6” reflecting telescope would have a maximum useful magnification of 300x. If the telescope had a focal ratio of f/8, and so a focal length of 48” (or 1220 mm), then 300x is obtained with an eyepiece of about 4 mm.

• **Apparent and True Fields of View (AFOV and TFOV).** The *apparent field of view* of an eyepiece is the angular diameter of the circle you see when you hold an eyepiece up to your eye. It’s measured in degrees and ranges from 50° to 82° or even 100° for some premium eyepiece designs. A wider field shows you more sky for a given magnification. The image below shows a view of M42 with eyepieces of the same focal length and therefore the same magnification. But the eyepiece used for the image on the left has a wider AFOV and so shows more of the sky than the eyepiece used for the image on the right. Eyepieces with an AFOV of more than 70° show “spacewalk” views of the sky through a telescope in the sense that you perceive only space itself when you look directly through such eyepieces. You need to turn your gaze to actually see the edge of the field of view.

The AFOV of an eyepiece is usually printed on the barrel.

The true field of view (TFOV) is the amount of sky you see when you look through the eyepiece and a telescope. The TFOV is:

\[
\text{True Field of View} = \frac{\text{Apparent Field of View}}{\text{Magnification}}
\]

So if a 15 mm eyepiece has an apparent field of view 50 degrees, and you use it with a scope with 900 mm focal length to get 60x, then the true field of view is 50/60=0.83 degrees, which is about 1.6x the size of the full moon. You should calculate the true field of view of each of your eyepieces… it helps you know how big a circle of sky you can see with each eyepiece. Using an
The Art of Stargazing – Month 6

eyepiece with an 82° AFOV in this example yields a TFOV of 1.36°. That results in a viewing area about 270% larger, a huge difference. Eyepieces with a wide field of view are useful for viewing large, extended objects like nebulae, star clusters, some galaxies, and of course the Moon. They are also useful for telescopes without motor drives because the larger FOV means an image takes longer to drift out of the field before you have to move the telescope.

• **Exit Pupil.** This is the diameter of the beam of light coming out of your eyepiece. It must be such that it is not larger than the size of your eye’s pupil, nor smaller than the most sensitive part of your retina. If the exit pupil of your eyepiece exceeds the size of your eye’s pupil when it is dark adapted, which is 6-7 mm at best, then you waste light from your telescope. The consideration of exit pupil puts an upper limit on the focal length of an eyepiece for a telescope. The exit pupil is:

\[
\text{Exit Pupil} = \frac{\text{Focal Length of Eyepiece}}{\text{Focal Ratio of Telescope}}
\]

For an f/6 scope, if we use the 15 mm eyepiece, the exit pupil is 15/6=2.5 mm. That’s good… all the light will enter your eye. But a 45 mm eyepiece gives a 7.5 mm exit pupil. Your eye can’t take that in, so using such an eyepiece with an f/6 telescope gives you a low magnification but it’s a waste of light.

- **Eye Relief.** This is the distance you hold your eye from the outer lens to see the full exit pupil. Short eye relief means you have to jam your eye up close to the lens to see all the light. If your eyes suffer from astigmatism, you’ll need to wear glasses when using your telescope and you’ll need eyepieces with longer eye relief… at least 17-20 mm. Without glasses, 10-20 mm of eye relief is comfortable. As a rule, eyepieces with a shorter focal length have shorter eye relief.

The diameter of the pencil of light coming out of an eyepiece is the exit pupil
• **Size and Weight.** Some complex eyepieces weigh in at nearly 2 pounds and are the size of a hand grenade! That’s too much for many small telescope mounts to support, so you need to take this into account.

• **Aberration.** Optical aberrations limit the performance of an eyepiece. As a rule of thumb, the lower the f/number of the telescope, the greater the optical complexity of the eyepiece needed to produce good images. Scopes with longer focal ratios can work with simpler eyepieces.

Most eyepieces today do a good job of correcting for spherical and chromatic aberration. But there are a few aberrations to keep in mind, especially coma, which results in comet-shaped instead of round star images near the edge of the field. It’s often a problem with reflectors of focal ratio f/5 or less. To correct for the coma in such cases, another optical element, a coma corrector, is required.

Another aberration, astigmatism, causes stars to appear as lines, crosses, or squares at the edge of the field. It’s a problem with wide-angle eyepieces, especially with low-f/number telescopes. Using a Barlow lens (a simple lens system that extends the effective focal length of the telescope) with the eyepiece usually suppresses astigmatism.

Field curvature in an eyepiece prevents an image from being in focus at the center and edge of the field simultaneously. This is a commonly seen in lower cost eyepieces.

Speaking of cost…

• **Cost.** While a good eyepiece will certainly enhance your view of the heavens, it’s not necessary to spend $600 on an eyepiece for a $300 telescope, for example. Because of modern design techniques and manufacturing methods, this is the best time in history to buy eyepieces for your telescope. But how much should you spend? Simpler eyepieces in the range of $30-$100 work best with longer focal ratio refractors (>f/10), Schmidt-Cassegrains, and Maksutov Cassegrains. Premium eyepieces work best with ED and apochromatic refractors, short-focal-ratio Newtonians/Dobsonians, and 8” and larger Schmidt-Cassegrain telescopes. As a rule, wide-field eyepieces with an AFOV larger than 70° are more expensive than narrower-field eyepieces because they require extra optical elements to keep distortions low. Eyepieces with an AFOV of 50° are far less expensive on average because they are optically simpler.

If you have a decent telescope like a good SCT or refractor and your budget allows, don’t be shy about spending $300-$400 on a premium eyepiece. It will hold its value over time, just like a fine watch. And the views are well worth it.

Now that you know the basics of eyepieces, it’s time to look at some specific eyepieces on the market today, starting with wide-field eyepieces.
Wide-Field Eyepieces

For expansive views of star fields, nebulae, and other deep-sky objects, as well as Apollo-like views of the Moon, you’ll want a couple of good wide-field eyepieces for your telescope: one for low-power and one for medium power. There are many on the market, but here is a comparison of some superior offerings for a range of budgets.

• **Astro-Tech AF 70 Degree Field.** These wide-field eyepieces have a respectable $70^\circ$ apparent field of view. Available from 3.5 mm to 22 mm focal length. Quality and field flatness is not as good as Televue or Explore Scientific, but they cost much less. These eyepieces work better with longer focal length SCT and MCT scopes than with f/6 Dobsonian reflectors. Price $120.

• **Baader Hyperion.** Another mid-priced alternative. These wide-field eyepieces have the same $68^\circ$ apparent field of view as Televue Panoptics. At longer focal lengths they are quite large. Fixed focal length from 3.5 mm to 24 mm. Price $140. Well worth a try.

• **Meade Ultra-Wide.** Similar to the Nagler with an $82^\circ$ AFOV. Good value. Focal length 4.7 mm to 30 mm. Price $200-$450.

• **Televue Naglers.** The gold standard for medium to short focal length wide-field eyepieces. Tack-sharp images to the edge of the field. If you have the means, and if you have a short focal length reflector or refractor, get at least one. Best choice is whatever eyepiece that gives you a roughly 2 mm exit pupil (the focal length of your eyepiece divided by the f# of your telescope). Available with focal length of 2.5 mm to 31 mm. Price $300-$650. Naglers hold their value over time, and they’re worth every penny. Especially for medium focal lengths.

• **Televue Panoptics.** These are Televue’s low-power wide-angle eyepieces. Amazing contrast with a 68-degree AFOV. Great for faster focal ratio reflectors and refractors. Good eye relief. Look through the 27 mm or 24 mm focal lengths and you’ll feel like you’re looking out the window of a space ship. Available in 19 mm to 41 mm focal length. Price $260-$510.

• **Pentax XW.** These eyepieces give the folks at Televue a run for their money. Very long eye relief… great if you need to wear glasses with your scope. AFOV of 70 degrees. Focal length 3.5 mm to 40 mm. Price $340 to $549.

• **Televue Ethos.** These are like Naglers, only better, with an incredible 100-degree AFOV. Focal length 4.7 mm to 21 mm. They’re $650 each ($900 for the 21 mm)... extremely expensive, but by all accounts, well worth it for experienced observers with good quality scopes.

• **Televue Delos.** Similar to the Ethos, but trades off a narrower $72^\circ$ AFOV for a long eye relief of 20 mm. Excellent field flatness. Price $400.

• **Explore Scientific.** An innovative company, Explore produces eyepieces with $68^\circ$, $82^\circ$, and $100^\circ$ to compete directly with Televue’s Panoptic, Nagler, and Ethos eyepieces at half the price.
I have not tried them, but they are well reviewed on many astronomy equipment sites. Well worth considering.

**Planetary Eyepieces**

Because of their design, wide-field eyepieces are not the best choice for viewing bright objects like the moon and planets. To achieve a wide and flat field of view, wide-fields have 6-8 lenses, often grouped in pairs. But these lenses often bring light to focus at different points across the field of view. This isn’t a big deal for faint objects. But it becomes a problem for brighter objects. And the multiple lens surfaces scatter light, causing distracting “halos” around bright objects and reduced contrast of bright and dark features.

But some eyepiece designs have fewer optical elements and a design that gives truer color and high contrast at high magnification: perfect for planets and the moon, yes, but also great for deep-sky sights like planetary nebula, small galaxies, globular clusters, and double stars.

And the good news? With fewer lenses and a narrower field of view, planetary eyepieces often cost less than wide-field eyepieces.

Here are some good choices:

• **Plössls.** Your telescope may have come with one or two of these. Perfectly acceptable for planets and the moon, with great contrast. Not a bad all-around eyepiece. But the eye relief is not very good at short focal lengths, so beware if you must wear glasses at the telescope. Plossls are made by dozens of manufacturers. Orion, Meade, Celestron, and Televue are all recommended. You’ll find good short-focal length Plossls for less than $100.

• **Orthoscopics.** An older design, but still works well. Orthos have better eye relief than Plossls, but a narrower field of view. So these are best for the moon and planets only. About $60 each.

• **Radians.** A premium eyepiece from Televue, Radians give long eye relief, great contrast, and a fairly wide field. Expensive… around $250.

• **Specialty Eyepieces.** Companies like Williams Optics and Burgess Optical have their own special designs optimized for the moon and planets. Good value for less than $150 or so. Other good choices include the TMB Planetary II eyepieces ($60) and the Astro-Tech Paradigm Dual ED ($60).

To get higher magnification, eyepieces of these designs should be selected with a focal length of 3-15 mm or so. If you have a telescope with long focal ratio, like an f/10 Schmidt-Cassegrain, then don’t go any shorter than 5-7 mm for an eyepiece. That gives you plenty of magnification; any higher and the image will be too dim. With an f/5 or f/6 reflector or refractor, you can go as low as 3 mm, but you’ll need to get your eye up close for some eyepiece designs.
**A Few More Words of Advice**

Next month, we will look at long-eye-relief eyepieces, which are the choice for observers who wear eyeglasses while observing, and we’ll look at zoom eyepieces. But to finish this month’s discussion, here are a few words of advice…

When you expand your eyepiece collection, or add to the eyepieces you received with your telescope, don’t bother “upgrading” to a full set of 7-8 similar eyepieces. You don’t need that many. Instead, buy 3 or 4 premium eyepieces that cover low, medium, and high magnification.

As discussed above, keep in mind the tradeoffs between magnification, exit pupil, eye relief, and field of view. As a rule of thumb, if you can afford only one premium eyepiece, get one with a focal length twice the focal ratio of your telescope. This gives you an exit pupil of 2 mm which matches the most sensitive part of your retina. For example, if you have an f/10 Schmidt-Cassegrain, many celestial objects look sharpest with a 20 mm eyepiece. If you have an f/5 Dobsonian, get a good eyepiece with a 10 mm focal length.

**Solar System Observing – Meteors and Meteor Showers**

**Overview**

Barring an unexpected supernova or contact with an alien civilization, the Perseid meteor shower ranks as the main stargazing event this month, as it does every August. The Perseids is the best of dozens of meteor showers that occur each year, with dozens of meteors visible every hour during the evening of August 11 and through to the morning of August 12. Observing meteor showers is an enjoyable way to spend an evening of stargazing. No optical equipment is necessary.

Let’s take in a quick overview of meteors in general, then look at the major meteor showers throughout the year.

**Meteoroids, Meteors, and Meteorites**

Spend a few nights stargazing and you’re bound to glimpse at least one “shooting star”, a brief sliver of light that suddenly streaks across the sky before disappearing a few seconds later. Of course this is no star that’s shooting. It’s a meteor, a tiny bit of icy or rocky space debris that hits the atmosphere at up to 60,000 km/h and burns up in a few seconds by the friction created when it encounters the gas molecules in the upper atmosphere. Most meteors we see are caused by pieces of debris the size of a grain of sand, or in the case of the brighter meteors, the size of a pea. On a typical clear night, you can see perhaps four meteors per hour and slightly more before dawn as the Earth turns west to east and picks up this celestial flotsam at an accelerated rate. Meteors may appear anywhere in the sky and appear move in any direction (except up).
The terminology gets confusing here, and I’ve been known to abuse these terms. But a *meteor* is the flash of light we see when the space debris burns up. A *meteoroid* is a piece of naturally-occurring material floating around space that may one day hit our atmosphere. Some are large, the size of a school bus, but most are quite small. A *meteorite* is a piece of space stuff that makes it all the way to Earth.

Meteors were a puzzle to stargazers for thousands of years. Most western thinkers believed they originated in the atmosphere. The word “meteor” comes from the ancient Greek word for “suspended in air”, and it forms the root of *meteorology*, the science of the atmosphere. But in the early 19th century, Yale professor Benjamin Silliman investigated a meteor that fell in Connecticut and concluded it came from beyond Earth, a claim which led the otherwise astute Thomas Jefferson to say, perhaps apocryphally, "I would more easily believe that a Yankee professor would lie than that stones would fall from heaven."

But an astonishing meteor storm in November 1833 strongly suggested to astronomers the extraterrestrial nature of meteors. During this storm, thousands of meteors fell per hour for nearly a whole night. The meteors seemed to radiate from a point in the constellation Leo that seemed to move with the stars rather than remain stationary or move randomly around the sky. Scientists studied the historical records of the storm for decades and noticed it appeared, in attenuated form, at regular intervals. It was eventually linked to the path of a comet that orbited the Sun periodically, and the extraterrestrial nature of meteors was proved.

More debates ensued among scientists to explain where in space meteoroids originate. Until the mid-20th century, many astronomers and geologists believed they came from the Moon when larger bodies in the earlier days of the solar system collided with the Moon and knocked pieces...
into space. But chemical analysis of meteorites and spectroscopic analysis of asteroids suggest most meteoroids are pieces of asteroids, small rocky objects tens of kilometers across, which orbit the Sun between Mars and Jupiter. As asteroids run into each other, they grind themselves into smaller pieces, which in turn get knocked into the inner solar system where they occasionally run into our fair planet.

That’s most of the story. A smaller fraction of meteoroids are small pieces of comets that splinter off during their passage into the inner solar system. Planetary scientists have also determined some meteorites come not from the asteroid belt but from the Moon and also the planet Mars, presumably when pieces of these worlds are blasted into space by major impacts. Dozens of meteorites on Earth have been traced back to the surface of Mars because their chemical composition conforms with measurements from Mars landing expeditions such as Viking.

Iron (left) and stony (right) meteorites

Millions of meteors hit our atmosphere each day, and as much as 400 tons of residual meteoric debris hits the Earth each day in the form of dust. Take any piece of Earth the size of a sidewalk slab, and chances are that at least one piece of extraterrestrial dust will touch down each day. A tiny fraction of these many meteors are bright enough to become visible to our eye. On rare occasions, a meteor may blaze across the sky and become as bright as Venus at about magnitude -4. Such a meteor is called a fireball. A meteor that reaches magnitude -14, about 2.5x as bright as the full Moon, is called a bolide. Some astronomers use the terms interchangeably.

Meteorites are classified into three main types: stony, iron, and stony-iron. The iron meteorites are made from a blend of iron and nickel left over from the early days of planet formation. They look like, unsurprisingly, like chunks of melted metal. Stony meteorites (or chondrites) look like rocks and have several fascinating microcrystalline structures caused by melting processes that give clues about the physical nature of the early solar system. Stony-iron meteorites are conglomerations of iron and stony meteorites.
A particular sub-class of stony meteorite, the *carbonaceous chondrite*, is a dark rocky meteorite loaded with organic compounds formed during the earliest days of our solar system. Some carbonaceous chondrites, amazingly, have been found to contain more than 70 amino acids which formed in the icy cold of space, possibly even before the origin of our solar system. In the center of some such meteorites, tiny crystals of diamond have been found and traced back to material ejected by dying red giant stars millions or billions of years before the birth of our Sun. So these meteorites are repositories of the original stuff of stars.

![A carbonaceous chondrite](image)

Rarely, a large meteor hits the ground and causes small scale or large scale damage. On February 15, 2013, a 20-meter-wide stony meteoroid (an asteroid, really) blazed through the Earth’s atmosphere at 60,000 km/h and exploded over the city of Chelyabinsk, Russia. The shockwave blew out thousands of windows and injured more than 1,500, though no one was directly struck by the hundreds of smaller pieces of the object. The meteor was classified as a *superbolide* and became for a time brighter than the Sun.

The Chelyabinsk meteor was the largest body to enter the Earth’s atmosphere since the Tunguska Event, an explosion over a remote section of Siberia that leveled hundreds of square miles of forest. No impact crater resulted, and scientists suspect the culprit was a small comet that exploded 5-10 km above the Earth’s surface. This event was the largest impact event in recorded history.

A catastrophic impact by a 10-km wide asteroid some 65 million years ago led to the demise of the dinosaurs. Such impacts occur every 100 million years or so, on average, and will surely happen again unless we learn to detect and divert large asteroids from running into our fair planet.

But let’s not talk of doom. Instead, let’s turn to one of nature’s more pleasant, exhilarating, and totally harmless events, a meteor shower.
**Meteor Showers**

Several times a year, the Earth passes through the debris-strewn path of comets or asteroids that periodically orbit the Sun. When the Earth encounters the tiny bits of icy or rocky debris over the course of a few days or a week, we see a sudden surge in the number of meteors visible in the night sky. These events are called *meteor showers*. Several dozen meteor showers occur each year, and they occur at predictable intervals because the orbits of the Earth and the comets are regular and repeated over the centuries.

During the best meteor showers you may see as many as one or two meteors a minute, though most showers show fewer. The peak of meteor activity occurs after 1 a.m. local time, approximately, because that’s when Earth’s night side turns into the direction of its orbit around the Sun. When this happens, we see more meteors slam into our atmosphere, just as more raindrops slam into your face than the back of your head as you walk through a rainstorm.

![Meteor Showers Image]

*Meteors in a meteor shower trace their paths back to a single point called the radiant, which in this example lies in the lower left of this image.*

Meteors in a meteor shower can be distinguished from other meteors because they seem to trace their path back to a well defined point in the sky, a point called the *radiant*. If you’ve driven through a snowstorm, you’ve seen the same effect in your windshield because the snowflakes seem to come from a central point. The radiant of each meteor shower lies in a different part of the sky depending on the location of the cometary debris relative to the path of the Earth’s orbit. Meteor showers take their name from the constellations in which the radiant lies. The meteors can occur anywhere in the sky… their paths don’t have to originate at the radiant. But their paths always lie on an imaginary line that traces back to the radiant (see image above).
On average, the most productive and enjoyable meteor shower for northern hemisphere observers is the Perseid meteor shower, or simply, the Perseids. These meteors have been known since antiquity. In the middle ages, they were known as “The Tears of St. Lawrence” because they coincided with the martyrdom of Laurentius, a deacon of Rome, by the emperor Valerian in 258 A.D.

The Perseids build slowly, starting in late July when you might see 3-4 an hour. They peak when Earth passes through the thickest part of the debris stream from Comet Swift-Tuttle on August 11-12. At the peak of the show, in clear, dark sky, you might see as many as 60 meteors an hour. The radiant of the shower lies just north of the star η Persei, but its precise location is not critical to enjoying the show. As with all meteor showers, the Perseids may appear anywhere in the sky.

Because the radiant lies in Perseus, northern-hemisphere observers get the best view, though southerners will see some, too.

To enjoy the Perseids or any meteor shower, grab a comfortable reclining lawnchair or simply spread a blanket on the ground. Then lie back and look up. That’s about it. Binoculars or a telescope are nearly useless because they have too narrow a field of view. Avoid ambient light and moonlight if you can so your eye can detect the faintest meteors. The anticipation of waiting for bright meteors is great fun. And since specialized equipment or knowledge is not required to see a meteor shower, this is a splendid way to share the night sky with casual stargazers and to introduce newcomers to stargazing.

As you watch meteors, you will notice some are fainter than others. This is a mostly a consequence of differences in size of the tiny pieces of comet or asteroid entering the atmosphere. You can also get an idea of the angle at which each meteor enters the atmosphere. Those with long trails come into the atmosphere at an oblique angle. Those with shorter streaks enter the atmosphere at a steep angle and come more directly towards you. Occasionally, you may see a meteor come almost directly towards you and you will see a bright star-like flash with little or no trail.

If you watch a meteor shower with a beginner, you will be asked: “Will the meteors hit us?”, or, “Will the meteors hit Earth?” They will not. The pieces of cometary debris streaking through the atmosphere are soft, icy, and smaller than a pea, so they burn up very quickly in the atmosphere at an altitude of 40-60 miles long before they strike the Earth. Even during the great meteor storm of 1833, when thousands of meteors fell per hour all night long, not one meteor made it to the surface.

The Perseids is perhaps the best meteor shower to observe because of its high rate of meteors and it occurs in warmer weather. But there are many other meteor showers during the year. The Geminids and Quadrantids, which occur in mid-December and early January, respectively, come close to equaling the Perseids. But they come in winter for northerners and only hardcore
stargazers stay out all night during these months to watch meteors. The radiant of the Quadrantids lies in the now-defunct constellation Quadrans Muralis which was located between northern Boötes and the tip of the handle of the Big Dipper.

The table below shows a summary of the details of the most active meteor showers each year.

<table>
<thead>
<tr>
<th>Meteor Shower</th>
<th>Peak Night</th>
<th>Best Time to Watch</th>
<th>Maximum Rate</th>
<th>Parent Comet or Asteroid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadrantids</td>
<td>January 3-4</td>
<td>23:00 to dawn</td>
<td>60-200</td>
<td>(196256) 2003 EH1</td>
</tr>
<tr>
<td>Lyrids</td>
<td>April 21-22</td>
<td>21:30 to dawn</td>
<td>10-15</td>
<td>Comet C/1861 G1</td>
</tr>
<tr>
<td>Eta Aquarids</td>
<td>May 5-6</td>
<td>1:30 to dawn</td>
<td>40-80</td>
<td>Comet 1P/Halley</td>
</tr>
<tr>
<td>Delta Aquarids</td>
<td>July 27-28</td>
<td>21:30 to dawn</td>
<td>15-20</td>
<td>unknown</td>
</tr>
<tr>
<td>Perseids</td>
<td>August 11-12</td>
<td>dusk to dawn</td>
<td>60-100</td>
<td>Comet 109P/Swift-Tuttle</td>
</tr>
<tr>
<td>Orionids</td>
<td>October 20-21</td>
<td>22:00 to dawn</td>
<td>20-25</td>
<td>Comet 1P/Halley</td>
</tr>
<tr>
<td>Leonids</td>
<td>November 17-18</td>
<td>23:30 to dawn</td>
<td>10-15</td>
<td>Comet 55P/Tempel-Tuttle</td>
</tr>
<tr>
<td>Geminids</td>
<td>December 13-14</td>
<td>19:00 to dawn</td>
<td>60-120</td>
<td>(3200) Phaethon</td>
</tr>
</tbody>
</table>

**Science of Astronomy – Parallax; Double Stars; Dark Nebulae**

*The Distances to Nearby Stars*

Over the past few months in *The Art of Stargazing*, we’ve looked in great detail at stars—what they are made of, how they form, and how they live and die. Just a century and a half ago, this knowledge was thought beyond the reach of mankind, simply because we could never grab a hold of a piece of star to analyze it in a laboratory. But the discovery of spectroscopy made such analysis unnecessary. By analyzing the light from stars, 19th-century astronomers discovered that our Sun and other stars contain the same elements we find on Earth: hydrogen and helium mostly, but also traces of heavier elements like oxygen, carbon, iron, nitrogen, and so on. This was a great breakthrough, one that suggested the stuff of the heavens was the same as stuff down here on Earth.

Another great mystery of the stars was solved in the 19th century: their distance. In antiquity, some astronomers thought stars were simply points of light on a perfect sphere, suggesting all stars were at the same distance, perhaps hundreds or thousands of miles away. Such ideas fell out of favor during the Enlightenment when Copernicus and Galileo demonstrated the Earth was not the center of universe and the objects in the heavens were not perfect unchanging heavenly orbs, but were in fact separate bodies, worlds in their own right that moved according to predictable laws we could understand.
But in the 16th and 17th centuries, as the Earth was displaced from the center of the universe, a new controversy arose. If the Earth moved around the Sun once per year, the reasoning went, then we should see the nearby stars move back and forth slightly across the sky compared to more distant background stars. This effect is known as \textit{parallax}. It’s a common-sense effect you can easily notice when you hold a finger in front of your face and close one eye, then the other, and watch your finger appear to move against the more distant background.

Astronomers starting with Tycho Brahe looked for parallax, unsuccessfully, which suggested to some perhaps the heliocentric concept of the universe was incorrect. No parallax, said some, meant the Earth did not move. But the problem in detecting parallax was simple… the stars were simply too far away, farther than most astronomers imagined, so the parallax was very, very small and hard to measure. Many astronomers tried, most notably James Bradley in the 1720’s. Finally, in 1838, the astute German mathematician and astronomer Friedrich Wilhelm Bessel successfully detected parallax of the star 61 Cygni. He measured a parallax of about 0.3” (arc-seconds), which meant the star was about 10.4 light years away. His result was very close to the modern result of 11.4 light years. One light year works out to 63,240 astronomical units or about 6 trillion miles. This was an astonishing distance to consider, and it still is.

\textit{The concept of stellar parallax}

To get the distance to a star by measuring parallax, it’s necessary to apply a little trigonometry. From the diagram above, you see that if a star shifts by a small angle $p$ (in arc-seconds) and since
the distance from the Earth to the Sun is one astronomical unit (AU), then the distance to the star works out to:

\[ d \text{ (in AU)} = \frac{206,265}{p\text{(in arcseconds)}} \]

The parallax angles were so small, astronomers over the 19th century could only measure the distance to about 60 nearby stars. The closest star, alpha Centauri, has the largest parallax, yet it’s just 0.769”, about the angular size of an American quarter at a distance of 3 miles.

Astronomers have used the concept of parallax to define a unit of distance called a parsec. A parsec is the distance to an object that has a parallax of one arc-second. A parsec works out to a distance of 3.263 light years. No stars actually have a parallax as large as 1”, but the unit has remained in use and is preferred by professional astronomers when measuring distances. With this unit of measure:

\[ d \text{ (in parsecs)} = \frac{1}{p\text{(in arcseconds)}} \]

By the 1980’s, astronomers measured the parallax of just a few hundred nearby stars out to a distance of 100 light years or so. In 1989, the European Space Agency (ESA) launched the Hipparcos satellite to measure parallaxes, motion, and position of many more nearby stars up to about 1,600 light-years, a little more than one percent of the diameter of the Milky Way Galaxy. The ESA Gaia mission, which will launch within the year, will measure parallaxes to an accuracy of 10 micro-arcseconds, corresponding to a distance of tens of thousands of light-years from Earth.

The measurement of stellar parallax is the only way we can directly measure the distance to stars. All other methods are indirect but are based on parallax measurements of nearby stars. So the measurement of parallax underpins our understanding of distance of all objects within our galaxy and, by extension, other galaxies. We will look at other methods of inferring distances to stars and galaxies in upcoming months of the course, but they are calibrated, if sometimes indirectly, using parallax measurements of nearby stars.

**Proper Motion and Radial Velocity**

This doesn’t figure directly into backyard stargazing, but here are two more quantities to know about: *proper motion* and *radial velocity*.

Proper motion is simply the apparent lateral motion of a star across the sky over time. Not its east-to-west diurnal motion caused by our rotating planet, and not its apparent westward shift each day caused by our planet’s revolution around the Sun, but the small angular displacement over years and decades caused by a star’s true motion through the galaxy projected against the sky. Proper motion is small. It’s usually measured in arc-seconds/year, and is also given a direction relative to north, where 0° means a star moves directly north, 90° if it moves to the east,
and so on. It is called “proper” motion because it is the intrinsic motion of a star itself (though it also includes the motion of our solar system relative to the star).

Proper motion it’s not noticeable for most stars over the course of a human lifetime. Edmund Halley was the first to notice this effect in 1718 when he proved that Sirius, Aldebaran, and Arcturus were each displaced about half a degree from their position as noted by the diligent ancient Greek astronomer Hipparcus some 18 centuries earlier.

The star with the largest proper motion is Barnard’s Star, a 10th-magnitude M4 V red dwarf in the constellation Ophiuchus. It moves about 10.3” per year, or about ¼ of a degree during an average human lifetime. At a distance of 6 light years, this proper motion translates to a true lateral speed of 90 km/s. 61 Cygni, the first star for which parallax was measured, also has a speedy proper motion of about 5.2” per year. As you might expect, most stars with a large proper motion are nearby stars. More distant stars also move through the galaxy, but they appear to us to move slower, like a distant mountain appears to move slower than roadside traffic signs when you drive down a highway.

Proper motion is interesting for astronomers because it gives them an idea of motion of stars through the galaxy. It is especially important in studying open clusters and stellar associations, because stars that form together in the same time and place tend to have a similar proper motion for tens or hundreds of millions of years before they get swept up into the general flow of stars in the galaxy.

The proper motion of Barnard’s Star from 1991 to 2007.

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Over tens and hundreds of thousands of years, the proper motion of the stars will scramble the constellations as we now know them. Have a look at the short video 6-1 on the course video page to see the effect of proper motion on the stars in and around the Big Dipper from 100,000 B.C. to 100,000 A.D.


Radial velocity is another measure of the true motion of a star. As its name implies, radial velocity measures motion radially along the star’s line of sight. Unlike proper motion, which is measured by directly watching a star’s position change over time, radial velocity is detected by measuring a star’s spectrum. When a star moves away from us, its spectrum shifts to the red, or lower frequencies. If a star moves towards us; the spectrum shifts slightly to the blue, or higher frequencies. You notice the same effect, called the Doppler effect, in the sound of a train whistle as it approaches and recedes. It’s named after scientist Christian Doppler who proposed it in 1845.

Many stars have a steady radial velocity of tens or hundreds of km/s towards or away from us. Some have tiny variations in radial velocity caused by the gravitational tug of companion stars or even planets. Astronomers first detected the presences of planets around other stars by accurately measuring and analyzing small periodic variations in radial velocity of nearby stars.

Double and Multiple Stars

Most stars appear solitary, but astronomers have determined that 50% (or even as many as 80%) of all stars form as double, triple, or multiple star systems when they coalesce in their dark, dusty birthplaces. In small telescopes, most stars don’t appear as multiple stars because their components are too close to resolve visually. But about 10,000 multiple star systems are visible and resolvable with a 6” telescope, and many dozens are objects of intrinsic aesthetic beauty.

What makes for an attractive multiple star in a small scope? They must be resolvable of course, which means they must be spaced by at least 1.0” and preferably 1.5” or more. Such small separations are a challenge in even large telescopes with good optics. In theory, a 6” scope can resolve stars separated by just 0.8”. In practice, this is almost never possible because of the limitations of atmospheric seeing.

The brightness difference in multiple stars also makes for good viewing. Stars of similar brightness are pretty enough, but large difference in magnitude between the components makes for a more pleasing view, and in some cases, a greater challenge in seeing the fainter star than might otherwise be expected from their separation. The brilliant red-orange star Antares, as mentioned last month, has a companion star some 3.0” away, enough to resolve in most telescopes, but the brightness differential of some 370x makes the fainter companion very difficult to see.
The best multiple stars for visual observation have components of contrasting spectral type and therefore color. The star Albireo, mentioned in our tour of the constellation Cygnus this month, is one of most famous and beautiful double stars because of the pleasing color contrast between the brighter K2-type primary and the blue-white B8-type secondary. In stars of such contrasting colors, the eye plays tricks on us and white or blue-white stars can appear green, lilac, or violet in the presence of red-orange stars.

Another benefit of observing multiple stars? These stars are easily accessible to urban stargazers who endure light pollution that otherwise obliterates views of faint extended objects like galaxies and nebulae.

Double and multiple stars are specified by the magnitudes, their separation in arc-seconds or arc-minutes, and by the so-called position angle (PA) which specifies the angular orientation of the fainter star relative to the brighter star. A PA of 0° means the fainter secondary star is directly north of the primary, 90° if it is directly east, 180° if it lies due south, and 270° if it is to the west. So for example the very pretty double star iota Cancri, pictured above, has components of magnitude 4.02 and 6.57, a separation of 30.6", and a position angle of 308°.

Some double stars are not physically associated with each other and are simply chance alignments of two stars along a line of sight. Such pairs are called “optical doubles”.

The stars of multiple star systems tend to bunch themselves into pairs or solitary stars that orbit far from other pairs of stars. That’s because 3 or more stars in close proximity all trying to orbit a common center of mass then to be physically unstable. One or more stars in such a system tend to get kicked out to more distant orbits. Such systems might have two stars close in and one or more stars orbiting the inner pair in a much more distant orbit. The famous “Double Double” in Lyra is an example where two pairs of double stars orbit each other to form a 4-star system.

Some binary star systems have orbital planes edge on to our line of sight such that each star can eclipse each other. Even if we cannot resolve the stars, we see the effect of the eclipse in a
periodic change in brightness of the system. The most famous example of such a star is Algol in the constellation Perseus. We will meet it in the coming months.

Most binary and multiple stars have orbital planes inclined as some angle to our line of sight. Even if they are not resolvable directly in a telescope, astronomers can detect the presence of two or more stars because they see multiple spectra that can move slightly in redshift or blueshift as the stars move. A binary star system detected through its spectra is called a spectroscopic binary.

Binary stars are of intrinsic interest to professional astronomers. Tracking the motion of binary stars allows astronomers, using Newton’s Law of gravitation, to calculate the mass of the stars in a binary system, which is a very important step in calibrating models of stars and their evolution.

**Dark Nebulae**

Follow the arc of the Milky Way on a dark night away from city lights, and you’ll see knots and ribbons of darkness weaving among the bright star clouds. Many new stargazers think such dark regions are simply absences of stars. But their true nature is far more interesting. These dark regions are immense clouds of gas and cold interstellar dust, much of it made from the dregs of dead stars that exploded as supernovae or cast off their atmospheres as planetary nebulae long ago. In time, some of these so-called dark nebulae will contract, heat up, and recycle themselves by collapsing into clusters of hot, new stars.

Until the middle of the 20th century, astronomers considered these dark nebulae to be nuisances that blocked or attenuated their view of distant stars. But in time they discovered these nebulae were interesting objects of study and essential to the ecology of our galaxy. Dark nebulae appear dark because of tiny ice-covered dust grains that scatter background star light. The grains are cold, just 10K (or -263 C), and less than 1/1000 of a millimeter across. Within the cloud there may be just 100 dust grains per cubic centimeter, still nearly a vacuum by earthly standards. But these clouds are tens of light years thick, so light from background stars is slowly but surely blocked and scattered in all directions.

The nature of these dust grains was a puzzle until the 1960’s. Using radio and infrared telescopes, astronomers found they were made of frozen water, ammonia, formaldehyde, alcohol, and other more complex organic molecules... even amino acids, the chemical building blocks of proteins! Astronomers are now studying the chemistry taking place in these dusty clouds and trying to determine if the molecules therein influenced the beginning of life on Earth.

We’ve mentioned dark nebulae already this month. The “Northern Coalsack”, the “Great Rift”, and the smaller nebulae B92 and B93 in M24 are all examples of dark cold clouds of dust and gas. Dark nebulae are a little tricky to see because you’re looking for, well... nothing... an absence of stars. But in time, you learn to see these clouds as they protrude irregularly into the
starry background. The regions from Scorpius through Crux, and the band of Milky Way that
cuts through the constellation Cygnus hold dozens of dark nebulae. To get the best view, slowly
sweep these parts of the sky with binoculars and linger on each patch for a time until your eyes
and brain learn to look at voids in the starry background. Dark sky is essential. A warning… as
you see dark nebulae, you may at first find the lack of stars quite unsettling. In his 1882 novel
Two on a Tower, Thomas Hardy called dark nebulae “deep wells for the human mind to let itself
down into”.

Dark nebula Barnard 68, located at a distance of 500 light years in Ophiuchus

Many dark nebulae were first systematically mapped by the extraordinary American astronomer
E. E. Barnard who applied the (then new) technology of photography to mapping the intricate
patterns of darkness in the foreground of the star clouds of the Milky Way. Barnard mapped
hundreds of such nebulae and published his work in a photographic atlas of the Milky Way,
which has recently been republished as A Photographic Atlas of Selected Regions of the Milky
Way (2nd ed.) by E. E. Barnard and G. O. Dobek (in 2011). It’s a lovely if expensive book of
stunning images.

To get an interesting view of dark nebulae, have a look at video 6-2 at the course video page:


What You Have Learned This Month

Once you work through the notes and tours of The Art of Stargazing this month, you will have learned:
Sky Tours

- The legends, layout, position, and major stars in the constellations Cygnus, Aquila, Delphinus, Sagitta, Scutum, and Sagittarius
- The Milky Way from Cygnus to Sagittarius

Science of Astronomy

- How astronomers use parallax to measure the distance to nearby stars
- The definition of a parsec
- Proper motion and radial velocity
- Double and multiple stars
- Dark nebulae

Observing Techniques

- A look at the basics of eyepieces
- Eyepieces for wide-field and planetary observing

Deep-Sky Objects

- The Milky Way; the North America Nebula; Veil Nebula; M29; the Dumbbell Nebula (M27); the Coathanger; M71; the Wild Duck Cluster (M11); the Small Sagittarius Star Cloud (M24); emission nebulae M16 (Eagle); M17 (Swan), M8 (Lagoon); M20 (Trifid); globular cluster M22

Solar System Tour

- Meteoroids, meteors, and meteorites
- Meteor showers