Extraordinary Sights

What You Can See in The Night Sky

A Guide by Cosmic Pursuits

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Please email, tweet, blog, and pass this e-book around to your friends, family, students, or astronomy club to help as many people as possible discover and enjoy the night sky.

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What You Will Discover in this Guide

In this short e-book, you will discover a little about the astonishing range of beautiful objects you can see with binoculars, a small telescope, or in some cases, simply with your unaided eye. From the Moon and rings of Saturn, to comets and meteor showers, from diamond-dust star clusters to swirling galaxies far outside our own, the contents of the night sky is as varied as the wildlife in a tropical jungle.

As you read this guide, you will come to understand a little about the nature of star clusters, comets, nebulae, and galaxies… sights you can see for yourself from your own backyard. This knowledge will be a huge help with your stargazing sessions. Because understanding the celestial objects you see in your binoculars or telescope is sometimes as much fun as seeing them. The faint textured smudge you see in your eyepiece is far more interesting when you know it's the combined light of a trillion stars, for example, or the birthplace of a cluster of new stars in our own galaxy.

What's more, you'll find the sights of the night sky are not strange and incomprehensible. Rather, they operate by the same laws, the same science, as the stuff here on Earth. And they're made from the same kinds of atoms that make up everything we know, atoms created just after the beginnings of the universe, or cooked later inside long-dead stars billions of years ago.

After all, we're part of the universe, too, small bits and pieces that pulled themselves together and now take time to look back at the rest.

Wishing you clear skies,

Brian Ventrudo, Ph.D.
Publisher, Cosmic Pursuits
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Sights of the Solar System

Seas, Craters, and Mountains on the Moon

Aside from the Sun, the Moon is the brightest and most recognizable object in the sky. The Moon has no air or water so its surface has been nearly unchanged from the earliest days of the solar system some 4 billion years ago. Many skilled stargazers have examined the surface of the Moon in detail for decades and still never tire of its stark beauty, and professional and amateur astronomers continue to study the history of our solar system as written into its rocky face.

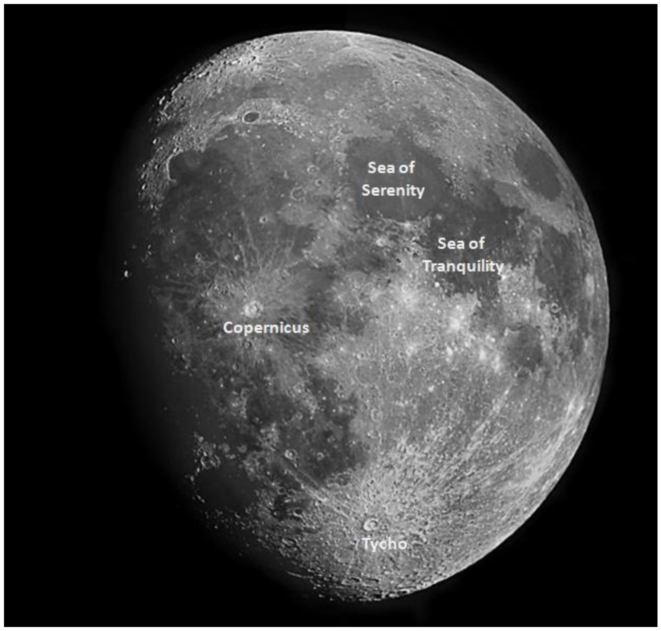
At about 1/4 the diameter of the Earth and some 250,000 miles away, the Moon spans just a tiny slice of sky, about half the width of your little finger held at arm's length. Even with your unaided eye, you can see light and dark areas on the Moon. The light-colored areas are the lunar highlands, the oldest parts of the Moon's surface. The highlands are peppered with craters made mostly by stray asteroids and comets left over from the solar system's formation about 4 billion years ago.

The Moon cycles through phases once every 27 days or so. As it waxes from its "new" phase to full, it's visible in the evening or night sky; as it wanes back to new, it's mostly visible in the daytime.

The darker patches on the Moon are newer, about 3 billion years old. They are called the lunar *maria* ("MAH-ree-ah") or seas, a misnomer since they are bone-dry and covered with fine dust. The *maria* were flooded with lava after the solar system had been mostly cleared out of stray material that smashed into the Moon's surface. That's why these younger regions are smoother and have far fewer impact craters.

The crescent Moon as it appears in binoculars. The dark areas are the "maria" or seas; the cratered lighter areas are the lunar highlands.

The seas of the Moon come into clear view with a pair of binoculars. So do about a dozen large craters. When the Moon is nearly full, you can see near the south-central part of the Moon ("south" is "down" for observers in the northern hemisphere) the crater Tycho, which has a series of "rays" that shoot out in all directions, giving the Moon the appearance of a peeled orange, with Tycho as the "pip". The rays are material ejected when Tycho was created by a large asteroid impact about 111 million years ago.



The craters Copernicus and Tycho, and the Seas of Serenity and Tranquillity, just a few of the hundreds of features visible on the surface of the Moon

When the Moon is about a day or two past "first quarter" (when it appears half lit), another large crater comes into view near the equator of the Moon. This is the crater Copernicus, a large crater nearly 100 km across.

While binoculars show dozens of sights on the Moon, a small telescope reveals thousands, including craters of all shapes and sizes, arcing mountain ranges that tower thousands of feet above the lunar surface, and cracks and fault lines and strange domes that hint at past geological activity.

Beginners often believe the best time to observe the Moon is when it's full. But that's almost always the worst time. You'll get the best views of the Moon along the *terminator*, the line that separates night from day. On the terminator, the craters and mountains stand out more clearly in the long shadows of lunar sunset or sunrise.

Seeing the Planets

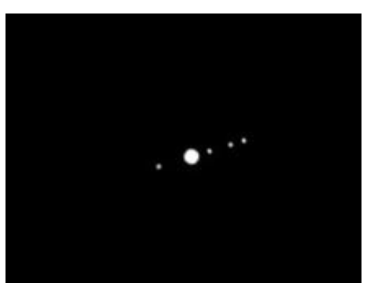
There are eight major planets in our solar system including Earth; Pluto was demoted to the status of a "dwarf planet" in 2008. The planets are fascinating sights for stargazers. With no optics, you can watch the five bright planets Mercury, Venus, Mars, Jupiter, and Saturn move slowly with respect to the background stars from day to day and week to week. The apparent motion of the planets is caused by their revolution around the Sun, as well as the motion of the Earth with respect to the planets.

The two planets closer to the Sun than Earth, Mercury and Venus, appear bright and fast moving in the sky. When they are visible, they always lie not far from the Sun before sunrise or after sunset. The outer planets have a little more freedom to move around the sky. They can be found anywhere on a narrow band around the sky called the *ecliptic* which passes through the twelve constellations of the *zodiac*. All eight major planets always appear in or very near these constellations.

Saturn as it appears in a small telescope

With your unaided eye, you can see Mercury, Venus, Mars, Jupiter, and Saturn. If you know just where to look, you might see Uranus too. Binoculars are not powerful enough to reveal much detail on the face of any planet, though they will reveal the four largest moons of Jupiter that move like clockwork around the planet from hour to hour and night to night (see image below). Saturn's largest moon, Titan, is also visible in binoculars and any telescope. But to see any detail of the face of the planets, or to see the phases of Mercury and Venus, you will need a telescope.

To an observer with a small telescope, Mars, Jupiter, and Saturn reveal an astonishing array of detail on their disks. On Mars, you can see the white polar caps, darker and lighter orange-red rocky and sandy regions, and even the hint of clouds sometimes. Jupiter and Saturn in a telescope show bands of icy clouds on their faces and occasional oval "spots" which are local storms larger than the Earth. Saturn has a stunning system of rings which can be seen even in a small telescope. These rings are barely more than 10 meters thick and are made of small icy particles. Uranus and Neptune can be resolved into featureless white disks without detail; it's an accomplishment for a beginner to see these distant and icy giants at all. Pluto is too faint to see in all but the largest backyard telescopes.



Jupiter and its 4 largest moons in binoculars

Usually at least one bright planet is visible in the night sky, and sometimes two or three are visible at sometime during the night.

The Moon and Venus after sunset

Meteors and Meteor Showers

Our solar system is littered with trillions of small pieces of ice and rock called *meteoroids*. When the Earth runs into one of these little pieces, it falls through the atmosphere where it grows hot and burns up in a few seconds, igniting a sudden trail of light across the sky. Such burning bits of rock and ice are called *meteors*. Look up on any night and you might see 3 or 4 meteors each hour shoot randomly across the sky.

Most meteors burn up before they hit the ground. The fainter meteors are the size of sand grains. Brighter ones range from the size of a pea to a golf ball, and very bright meteors might be the size of a softball. Very rarely, large meteors, perhaps the size of a basketball or a little larger, and especially if they are made of iron and nickel, will burn through the atmosphere and hit the ground, or explode before they hit the ground. When it hits the ground, it's called a *meteorite*.

Meteors from the Perseid meteor shower

Sometimes, on fixed dates throughout the year, the Earth passes through the path of a comet which has left behind small clouds of icy pellet-sized debris as it orbits the Sun. When this happens we're treated to a meteor shower during which you may see dozens or even hundreds of meteors each hour. Perhaps the finest meteor shower each year occurs around August 12 when the Earth passes through the path of Comet Swift-Tuttle. This shower is called the Perseids, since the trails of meteors all trace their paths back to a point in the constellation Perseus (see image above).

There are dozens of conspicuous meteor showers during the year. Some of the best are listed below along with dates when the most meteors are visible. The name of each shower refers to the constellation back to which the meteors trace their apparent paths. You don't need to see each con-stellation to see the meteors. They can appear anywhere in the sky.

- Lyrids, April 21-22
- Perseids, August 11-12
- Orionids, October 21-22
- Leonids, November 16-17
- Geminids, December 13-14

Watching a meteor shower is one of life's under-appreciated pleasures. You don't need binoculars or a telescope. You just need to lay back and look up at the sky. Depending on the shower and on the time of night, you might see a meteor every 5 or 10 minutes. Or you might see one or more meteors every minute. You will see more in dark sky away from the light-pollution of the city, and look in the part of the sky away from a bright Moon if it's out. Because the Earth usually turns into streams of meteors after midnight, most meteor showers show more action between midnight and dawn.

Comets: Visitors from the Outer Solar System

Comets are small, dark, icy bodies that are likely remnants of the formation of the solar system. Most comets lie far from the Sun, frozen and dark in a halo of trillions of comets past the orbit of Neptune. Sometimes a comet is sent plunging towards the inner solar system by a little gravitational push from another comet or a passing dust cloud. As the comet nears the Sun, it heats up and forms a halo of gaseous material called a *coma*, and in some cases, a *tail* which is pushed away from the Sun by the solar wind, a stream of charged particles ejected from the Sun. The central massive part of a comet is called the *nucleus*. It's usually just a few kilometers across. It consists of a mixture of icy material such as ammonia, water, carbon dioxide, and methane, along with traces of rock, dust, and carbon-based debris left over from the formation of the solar system. Comets are often described, more or less accurately, as dirty snowballs.

The dusty tail of Comet McNaught in 2007 (credit: ESO)

As seen from Earth, comets are far less common than meteors. There might be a half-dozen comets visible each year, though they are usually faint enough to require a telescope to see well. Every 10 years, on average, a comet grows bright enough to become easily visible with the naked eye. Comet Hale-Bopp in 1997, and Comet McNaught in 2007 were examples.

The Sights of the Deep Sky

Our solar system holds splendid sights for stargazers-- the Moon, planets, the moons of the planets, comets, meteors, and so forth—enough for a lifetime of observing. But beyond our solar system lies the rest of our home galaxy, the Milky Way, a vast collection of some 200 billion stars, clouds of dark gas and dust, and untold number of planets. While our solar system might seem big, the Milky Way's size is almost impossible to comprehend. If the Milky Way galaxy were shrunk to a scale where the Earth was just one inch from the Sun and Pluto was 40 inches away, the Milky Way would still be 100,000 miles across. And that's just one galaxy. There are perhaps 100 billion more galaxies in the universe.

When stargazers look beyond the solar system at the constituents of the Milky Way and other galaxies, they speak of looking at the "deep sky", and the objects they see are "deep-sky objects" or DSOs. Let's take a look at the main types of deep-sky objects visible in the heavens with binoculars or small telescope.

(NOTE: In this guide, you will not learn how to find these objects, but rather you will learn what they are, and you will get examples of the more accessible deep-sky objects for a small telescope which you can try to find for yourself with your star maps or planetarium apps… or with a go-to computerized telescope mount if you have one).

Stars

Stars are the most numerous objects visible in the sky. On a clear dark night, you'll see about 3,000 stars with your unaided eye. Binoculars or a telescope reveal tens of thousands more. Every star you see belongs to our own galaxy, the Milky Way, which holds some 200 billion stars altogether.

Stars along the plane of the Milky Way Galaxy

Take a look at the stars on the next clear night. Aside from differences in brightness from star to star, you will also see differences in color. Some stars, like Rigel in the constellation Orion, are blue. Others, like Altair in Aquila, are white. Arcturus, a bright star in the northern spring sky, is yellow-orange. Yet others, like Betelguese in Orion or Antares in Scorpius are a deeper orange-red.

The red-orange star Betelgeuse (upper middle) contrasts with the blue-white stars of the constellation Orion

These color differences are real. Just as hot coals in a fire will glow red, and hotter coals will glow white, the color of a star depends on its temperature. Red stars are coolest. They have a temperature of 4,000-5,000 Kelvin at their surface. Yellow-white stars like our Sun are hotter… about 6,000-10,000 K. And blue stars are the hottest of all, with surface temperatures of 15,000 to 30,000 K.

Blue stars are massive… some 5x to 20x the mass of our Sun or more. Massive stars burn hottest and emit most of their light in the blue and ultraviolet part of the spectrum. White and yellow stars are young-to-middle-aged middleweights. Most of the red stars you can see in the night sky were once massive blue or white stars that now near the end of their lives. Most of the stars of the galaxy are dim red stars, much less massive than our Sun, and too faint to see without a large telescope.

Stars have “life cycles”. They are born out of cold dust and gas in the Milky Way, then begin shining when they become hot enough in their cores to start turning hydrogen into helium, a process called nuclear fusion in which a huge amount of energy is released. The biggest stars burn for a few tens of millions of years before running out of fuel, and mid-sized stars like our Sun burn for some 10 billion years. While the details are complex, each star changes drastically as it runs out of fuel, then eventually goes dark. Some of its material is returned to the galaxy where it eventually gets “recycled” into new stars.

Many stars—astronomers suspect most stars—are born together and gravitationally connected to one or more companion stars. Some stars with widely-spaced companions, especially if they are nearby, can be resolved directly with a small telescope. Many of these “double star” and “triple star” systems are quite lovely in a small telescope, particularly when there is a vivid color contrast between the stars. Other stars, especially as they get older, go through a period where they change brightness over days, months, or years. These are the so-called *variable stars*, many of which can be seen in a small telescope or binoculars.

The double-star Albireo in the constellation Cygnus as it appears in a telescope

Some stars look bright because, well, they ARE bright. Others appear bright because they are close to us. Deneb, the brightest star in Cygnus, is one of the brightest stars known… about 60,000x brighter than our Sun. Deneb is 1,500 light years away (one light year is the distance light travels in one year, about 9.5 trillion kilometers). The star Sirius, on the other hand, appears even brighter than Cygnus (in fact Sirius is the brightest star in the sky as seen from Earth). But it's only 25x brighter than our Sun and only 0.0004x as bright as Deneb. Sirius only appears brighter than Deneb because it's 175 times closer… just 8.6 light years away.

Stars are organized into constellations, groupings of stars first conceived by ancient astronomers. Some constellations are large and obvious, such as Orion and Pegasus and Scorpius. Some are dim and small such as Triangulum, Lynx, and Lepus. Modern astronomers now recognize 88 constellations in total, and every object in the night sky lies within a constellation.

An *asterism* is a recognizable group of stars within a constellation, or which may comprise stars of more than one constellation. The Big Dipper is an example. It's made of a subset of stars of the constellation Ursa Major. The "Great Square" of Pegasus is also an asterism. So is the "Summer Triangle" (or the Northern Triangle), which is made from the bright stars Vega, Altair, and Deneb in the constellations Lyra, Aquila, and Cygnus. There are many more asterisms.

Dark Nebulae

On a dark night, as you gaze along the arc of the Milky Way, you will see patches where there appear to be few stars. Many of these patches are so-called *dark nebulae* where cool gas and interstellar dust block the view of the background stars. These nebulae are laced across the spiral arms of the Milky Way in irregular patches and rivulets without definite shape or boundaries.

Dark nebulae are part of cool, giant molecular clouds where dust and gas from old stars and gas from the earliest days of the universe slowly pull themselves together by gravity. The icy dust grains are less than 1/1,000 of a millimeter across, but they have an interesting chemistry, consisting of frozen nitrogen, carbon monoxide, ammonia, formaldehyde, and more complex organic molecules (even ethyl alcohol).

Because dark nebulae are the birthplace of stars and planets, astronomers find them intensely interesting. Computer modeling shows that although the nebulae are tenuous, with only a few particles per cubic centimeter, passing stars push and pull on the particles, causing them to coalesce into denser patches that begin to fall in on themselves and heat up. Hundreds of tiny globules in a dark nebula may eventually become hot enough to start the process of nuclear fusion, where hydrogen in the center of the Rglobule begins to burn into helium, releasing huge amounts of energy. When this happens, dense globules of gas and dust turn into clusters of new stars which light up the remaining dust and gas into what astronomers call *diffuse nebulae*.

Dark Nebula in the foreground of stars along the Milky Way

Diffuse Nebulae

After a dark cloud of gas and dust collapses into dense globules that ignite into stars, the leftover material is set aglow by the intense blue and ultraviolet light from newly formed stars. The glowing hydrogen gas surrounding the stars is called an "emission nebula".

These nebulae usually glow a reddish-pink color. That's because the new stars excite the atoms of hydrogen gas that remain in the cloud, and the atoms relax again by emitting red light at 656 nm, a wavelength set by the structure of the hydrogen atom. Emission nebulae also have traces of ionized oxygen which also emit light at a characteristic wavelength near 500 nm (blue-green). In a way, emission nebulae are much like the neon lights you see on buildings and billboards. The lights use electricity to make gases glow, while an emission nebula gets its energy from the light of new stars embedded within.

These nebulae also contain a fair bit of dust that reflects the blue light of the new stars. The reflective dust is called a "reflection nebula"; in many cases, the two nebulae occur in the same area of star formation (see the image of the Trifid Nebula, below).

Both emission nebulae and reflection nebulae are sometimes called *diffuse nebulae*.

The Trifid Nebula in the constellation Sagittarius. Red light comes from hydrogen gas atoms excited by the light from stars within the nebula; blue light from these stars is reflected off fine dust particles back into our line of sight.

Even a random search with a small telescope along the plane of the Milky Way reveals many diffuse nebulae which look like hazy patches of silver-white light. The sword of the constellation Orion contains one of the brightest and most famous such nebulae. It's often just called the Orion Nebula. A telescope gives you an astoundingly beautiful view of the Orion Nebula; no amount of observation is enough to reveal all its detail. You can see many more such nebulae such as the Swan, Lagoon, Trifid, and eta Carina nebulae with a small telescope or pair of binoculars. Just remember, you won't see color when you observe such nebulae visually; there isn't enough light to stimulate the color-sensing cells in your eye. But in dark sky, these objects are still quite striking.

Diffuse nebulae don't last long, at least on astronomical time scales. After a few million years, the hot young stars burn off the remaining gas and dust, leaving a small loose cluster of gravitationally-associated stars. We turn next to these star clusters...

Open Star Clusters

After the hot stars near the center of an emission nebula push away the remaining gas and dust, a group of a few dozen to a few hundred young stars remain clustered together. These groups are called *open star clusters*. They are beautiful to observe, especially in dark sky where they look like dazzling jewels set against the black velvet of deep space.

An open star cluster

Open star clusters are found mostly near the arms of spiral and irregular galaxies where there is abundant gas and dust for new star formation. For that reason, they're sometimes called "galactic star clusters". The greatest concentration of open clusters in our sky lies along the band of the Milky Way in the constellations Cygnus, Scutum, Scorpius, Sagittarius, Crux, Centaurus, Cassiopeia, and Perseus.

There are nearly 1,000 known open clusters in our skies, and likely 10,000 more hidden behind the dusty disk of our galaxy. Some famous open clusters include the Pleiades (M45) and Hyades in Taurus, the Beehive (M44) in Cancer, and the Double Cluster in the constellation Perseus.

Since all the stars in an open cluster are about the same distance from us, their relative brightness is proportional to their true brightness, which in turn depends on their mass and chemical composition. The stars also form at about the same time. So open clusters are like laboratories that help astronomers learn more about the evolution of stars.

Over many tens of millions of years, as an open cluster revolves around the galaxy, it encounters other stars and dust clouds that disrupt the cluster and eject its members into the spiral arms of the galaxy. There, they continue to revolve about the galactic center by themselves or in loose *associations* of stars. Some of the stars of Ursa Major are part of an association and were once members of an open cluster. The Sun was likely once a member of an open cluster whose members have long scattered into the plane of the Milky Way galaxy.

Globular Star Clusters

Globular star clusters are different in size and nature from open star clusters. Where open clusters contain a few dozen to a few hundred new stars, globular clusters are each populated by hundreds of thousands of the oldest stars in the universe.

Globular clusters formed 12-13 billion years ago, not long after the universe began. They likely collapsed from clouds of gas too small to form a galaxy but too large to form an open star cluster. In a sense, globular clusters are a little like “micro-galaxies” left over from the formation of larger galaxies.

Our Milky Way retains some 180 globular clusters. In the early 1900’s, famed astronomer Harlow Shapley figured out most globular clusters in the Milky Way are found in a halo around the nucleus of our galaxy. He used the distance and position of globular clusters to determine the size of the Milky Way and the Sun's position on its outskirts.

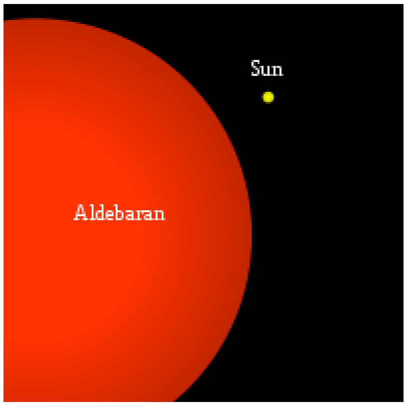
Because they're so old, stars in globular clusters are quite different from younger stars in open clusters. Younger stars contain traces of heavier elements like calcium, silicon, iron, and carbon… what astronomers call "metals". But the stars in globulars formed long before such elements were formed in the innards of massive old stars. The stars in globulars are called "metal poor" and consist almost entirely of hydrogen and helium.

Unlike open star clusters, globular clusters are strongly bound by gravity and are stable over time. Eventually, most of the stars in globular clusters will die off and fade from view. But as far as we know, globular clusters… even as they darken… will remain bound forever.

The globular cluster M5 as it might appear in a small telescope

You can see dozens of these spherical, tightly-bound clusters with binoculars or a small telescope. In the northern hemisphere, the brightest and prettiest globular clusters include the Great Cluster in Hercules, also known as M13, and the clusters M3 and M5 in the constellations Canes Venatici and Serpens, respectively. The two brightest globular clusters in the sky, the Omega Centauri cluster and 47 Tucanae (in Centaurus and Tucana, respectively) are only visible south of the tropics.

As you learn to observe globular clusters, you might at first think they're all the same: just fuzzy, grainy white balls in the eyepiece of your telescope. But as you look closer, you'll see that each differs in shape and structure, as distinct as a human face.



The red-orange giant star Aldebaran compared to the Sun

Red Giant Stars, Planetary Nebulae, and White Dwarfs

As you have discovered in the last sections, stars are born in emission nebulae like the Great Orion Nebula, grow up in open star clusters like the Pleiades, then disperse into the galaxy where they glow for tens of millions to tens of billions of years with energy created from atoms fusing in their hot cores.

But much like living things, stars also have an end. Eventually, nearly all the hydrogen atoms in the core of a star get fused into helium atoms. When the hydrogen in the core runs out, fusion burning slows and the core shrinks, heating up to over 100 million degrees. If it gets hot enough, helium starts fusing into heavier atoms like carbon and oxygen. This new burning generates more energy and stops the core from contracting. The hot core pushes out the star's outer layers. The star balloons in size by a hundred times or more and becomes a cool and luminous *red giant*. The bright stars Arcturus, Aldebaran, and Gacrux in the constellations Bootes, Taurus, and Crux are examples of red giants (or orange giants… same idea) you can see with your unaided eye.

Eventually, the helium runs out and the core shrinks again. But in small and mid-sized stars, the core does not get hot enough to burn carbon and oxygen, so fusion stops. Only a thin shell of helium around the core continues to burn for a short time. This hot shell drives the star's outer layers into interstellar space where they escape forever. We see this glowing shell of ejected gas– heated and ionized by the star's scorching-hot core– as a *planetary nebula*.

The name "planetary nebula" came from William Herschel, the 18th-century astronomer who suggested these disk-like nebulae looked like planets, especially the blue-green disk of the planet Uranus. Herschel understood these objects weren't planets, but he had no idea what they were at the time.

The Dumbbell Nebula in the constellation Vulpecula is a bright planetary nebula accessible in a small telescope. The faint star casting off the nebula is visible near the center of the narrow waist of the nebula.

A planetary nebula ejects hydrogen gas and trace amounts of heavier atoms like carbon, nitrogen, and oxygen into space. Some of these atoms may coalesce into dense clouds that form new stars and planets. In a way, this is how the galaxy recycles itself. In fact, some atoms of the lighter elements in your body may have been shed by a planetary nebula billions of years ago.

At the center of a planetary nebula, the expose core of the star glows with a temperature of 50-100,000 degrees. The core, which has stopped burning, will settle down as a dim, hot, Earth-sized lump of carbon and oxygen called a *white dwarf*. These stars are very dim and hard to see, even with a small telescope.

Most mid-sized stars in the galaxy will go on to become planetary nebula. So why can't we see more of them in the sky? Because they don't last very long. Computer models of stars show a planetary nebula lasts just 50,000 years, a tiny fraction of a star's 1-10 billion year life span.

Galaxies

All the stars, nebulae, and star clusters you see at night are part of a single galaxy: our Milky Way. But the Milky Way is just one of hundreds of billions of galaxies in the universe. The Hubble Space Telescope and large earth-based telescopes have mapped and catalogued galaxies out to a distance of some 12-13 billion light years. The light from these galaxies left just a couple of billion years after the formation of the universe. Where stars are the constituents of galaxies, galaxies are the constituents of the universe.

Small telescopes don't show the most distant galaxies, but hundreds of nearby galaxies lie within reach of a 3" or 4" scope. A dozen or so can be seen with binoculars. Though galaxies tend to be dim in small optics, a practiced eye can still detect a surprising amount of detail if the sky is dark and free of light pollution.

Face-on spiral galaxy Messier 101 (image credit: Terry Hancock)

Galaxies come in a number of shapes and sizes. Our Milky Way is a slightly larger than average spiral galaxy, spread out in a flat plane of stars, with spiral arms winding like a pinwheel from a concentrated nucleus at the center. The spiral arms contain gas and dust out of which new stars are formed, which means diffuse nebulae, dark nebulae, and open star clusters also concentrate in the spiral arms. The image above of the spiral galaxy Messier 101 in Ursa Major shows reddish-pink emission nebulae and bright blue stars along the spiral arms. The Milky Way would look much like this if you could see it from high out of the plane of the spiral arms.

Seen from edge-on, a spiral galaxy reveals the dust lanes of its spiral arms and the bulge of its nucleus, which contains older yellow-red stars left over from the early days of the galaxy's formation. The image of the galaxy NGC 891 below shows what the Milky Way might look like from the side. In fact, our Milky Way looks much like this in wide-angle photographs, since we see our galaxy edge-on from a point out near its edge, about 25,000 light years from the center.

Edge-on spiral galaxy NGC 891 in the constellation Andromeda

Most spiral galaxies contain at least 50-100 billion stars and are roughly 50,000 to 100,000 light years across. Two nearby galaxies, the Andromeda galaxy and the Triangulum galaxy, are also spirals and are well within the reach of backyard telescopes and binoculars.

Elliptical galaxies have a much wider range of mass and size, and have a much less complex structure than spiral galaxies. A dwarf elliptical might have a few million stars, not much bigger than a globular cluster. A giant elliptical like M87 might have a trillion stars. Elliptical galaxies may have formed by gobbling up smaller elliptical and spiral galaxies after repeated gravitational encounters over billions of years. Because they lack the gas and dust of a spiral galaxy, elliptical galaxies don't have much new-star formation going on.

The Magellanic Clouds, two nearby irregular galaxies visible only from the southern hemisphere

Irregular galaxies are neither spiral nor elliptical: they have an indeterminate shape. They are usually small galaxies, like the Magellanic Clouds, which are visible from the southern hemisphere, without the gravitational capacity to assume a regular form. Or they may be a large galaxy like

M82 in Ursa Major that's been mangled by major gravitational disturbances.

Appendix – Naming Systems of Stars and Deep-Sky Objects

Many new stargazers are perplexed by the naming system of stars and deep-sky objects (DSOs) like star clusters, nebulae, and galaxies. Names like M76, NGC 4565, and upsilon Andromedae can all get a bit overwhelming when you're just trying to find your way around the night sky. So here's a quick primer on the names and common catalog numbers of stars and DSOs…

Star Naming Systems

Of all the stars in our galaxy, only 100 or so of the brightest stars have proper names. Rigel in Orion, Vega in Lyra, Altair in Aquila, all have names handed down from Greek, Roman, and Arab astronomers from antiquity.

In the early 1600's, just before the invention of the telescope, the astronomer Johann Bayer developed a system to name hundreds more stars using Greek letters. He usually named the brightest star in a constellation alpha (α), the second brightest beta (β), the third brightest gamma (γ), and so on through to the last letter omega (ω). Bayer's system is still in use today. And it did not supersede the ancient names of the stars, so Vega in Lyra is also named α Lyrae, and the star Mintaka in Orion is called δ (delta) Orionis, for example.

Of course, with only 24 letters in the Greek alphabet, Bayer's system ran out of names. So more systems were devised. The British astronomer John Flamsteed numbered the stars in each constellation in order from west to east. Flamsteed cataloged up to a hundred or more stars in some constellations, though stars in the Bayer catalog were not given numbers. The nearby star 61 Cygni is an example of a star in Flamsteed's catalog.

As more stars were discovered and mapped, more catalogs were developed. The Bonner Durchmusterung (BD) catalog, the Henry Draper (HD) catalog), and the Smithsonian Astrophysical Observatory (SAO) catalog are all examples, and you will come across these designations in star atlases. Nearly all of the stars you see with a backyard telescope will be listed in at least one of these catalogs.

Deep-Sky Catalogs

In the late 18th century, the French comet hunter Charles Messier became frustrated when he kept sighting faint, diffuse celestial objects he mistook for comets. To prevent confusion, he cataloged the positions of 103 of these objects. Armed only with a tiny telescope, Messier had no idea what these objects were. But more than 200 years later, his catalog is now the most well-known list of galaxies, stars clusters, and nebulae accessible with small telescopes.

Objects in the Messier list are designated with an M and a number. The Crab Nebula in Taurus, for example, is M1. The Pleiades is listed as M45. And the lovely "Wild Duck" star cluster in Scutum is M11. Since Messier was based in the northern hemisphere, all the objects in the catalog are in the northern and near-southern sky, though many of the objects can be seen in populated areas of the southern hemisphere. Messier's catalog was later expanded to 110 objects. With dark sky, you can see all 110 objects in a 3" or 4" telescope, though usually not all in one night. (Although there is a window in March when observers in some parts of the world can see all the Messier objects in one night... an astronomical endurance event known as a "Messier Marathon").

Of course, there are far more than 110 sights to see in the night sky, and later astronomers compiled more extensive catalogs. J. Dreyer developed the New General Catalog (NGC), which contains the positions of 7,840 objects observed by William Herschel and others. Like the Messier catalog, the NGC lists galaxies, star clusters, and nebulae. Unlike the Messier catalog, not all objects are accessible with backyard scopes, though you can see hundreds or thousands of NGC objects, depending on your skies, your skill, and your telescope.

There are other catalogs, including the Index Catalogs (IC), which extend the NGC, the Collinder and Melotte catalogs of open star clusters, and E. E. Barnard's catalog of dark nebulae. You will come across objects in these catalogs from time to time in your exploration of the night sky.