COMPETENCY 1.0 UNDERSTAND GALAXIES AND STARS.

SKILL 1.1 Identify and describe characteristics of galaxies.

Spiral Galaxy: a grouping of stars arranged in a thin disk, spiraling in a geometric pattern, that has a central pivot point (nucleus) and arms radiating outward on which stars rotate around the nucleus, somewhat suggestive of the shape of a pinwheel. Spiral galaxies usually contain a great deal of interstellar gasses and dust.

Irregular Galaxy: There is no discernable pattern in the arrangement of the stars. Like a spiral galaxy, irregular galaxies tend to have a large volume of interstellar gasses and dust.

Barred Galaxy: The shape of this type of galaxy suggests a straight center core of stars joined by two or more relatively straight arms. About 30% of all galaxies are barred.

Elliptical Galaxy: The pattern of this type of galaxy centers on an elliptical shaped central mass of stars, with other stars above or below the center, giving the entire mass an overall ovoid appearance. They contain virtually not dust or gasses and rotate very slowly if at all. Most galaxies are elliptical.

SKILL 1.2 Explain the evidence for the “big bang” model.

Big Bang Theory: a theory that proposes that all the mass and energy of the universe was originally concentrated at a single geometric point and for unknown reasons, experienced a massive explosion that scattered the matter throughout the universe.

The concept of a massive explosion is supported by the distribution of background radiation and the measurable fact that the galaxies are moving away from each other at great speed. The Universe originated around 15 billion years ago with the "Big Bang," and continued to expand for the first 10 billion years. The universe was originally unimaginably hot, but around 1 million years after the Big Bang, it cooled enough to allow for the formation of atoms from the energy and particles. Most of these atoms were hydrogen and they comprise the most abundant form of matter in the universe. Around a billion years after the Big Bang, the matter had cooled enough to begin congealing into the first of the stars and galaxies. Some of the missing pieces of the puzzle may be found in extraterrestrial objects. Prevalent cosmic theory holds that all the planets and celestial bodies formed around the same time. By absolute dating meteorite fragments found on the Earth, we have been able to gather additional information and develop a better estimate of the Earth's age. The widely accepted approximate age of the Earth is estimated as 4.6 billion years old. This age is further supported by evidence collected during the United States' exploration of the moon. Moon rocks, which range in age from 3.3 to 4.6 billion years old, give further support to the cosmic theory that our solar system- including the Earth and the Moon- was formed about the same time and by the same processes.

SKILL 1.3 Know that the Sun is a typical star powered by nuclear reactions, primarily the fusion of hydrogen to form helium.

The Sun is intensely hot. At the center, it has a 140,000-kilometer diameter Core composed of hydrogen (92%) and helium (7.8%) that provide the fuel for the Sun's nuclear reaction (fusion). At approximately 15 million °C, the core gives off a tremendous amount of energy. However, the density of the Sun precludes the direct release of all this energy into space. Instead, it is slowly absorbed and re-emitted by the various layers of the Sun.

SKILL 1.4 Describe the process of the nuclear synthesis of chemical elements and how accelerators simulate the conditions for nuclear synthesis (i.e., in stars and in the early universe).

The energy of the stars originates through nuclear fusion processes. Nuclear Fusion is the process in which hydrogen atoms fuse together to form helium atoms, releasing massive amounts of energy during the fusion. It's the fusion of atoms, not combustion, which causes the star to shine. For stars like the sun, which have internal temperatures less than fifteen million Kelvin, the dominant fusion process is proton-proton fusion. For more massive stars, which can achieve higher temperatures, the carbon cycle fusion becomes the dominant mechanism. The main theme of the carbon cycle is the adding of protons, but after a carbon-12 nucleus fuses with a proton to form nitrogen-13, one of the protons decays with the emission of a positron and a neutrino to form carbon -13. More proton captures and neutron decays occur until oxygen-16 is produced and emits an energetic alpha particle to return to carbon-12 to repeat the cycle. This last reaction is the main source of energy in terms of fueling of the star. For older stars, which are collapsing at the center, the temperature can exceed one hundred million Kelvin and a third fusion process called the triple-alpha process.

Yet another class of nuclear reactions is responsible for the nuclear synthesis of elements heavier than iron. Up to iron, fusion yields energy and thus can proceed. But since the "iron group" is at the peak of the binding energy curve, fusion of elements above iron absorbs energy. Given a neutron flux in a massive star, heavier isotopes can be produced by neutron capture. Isotopes so produced are usually unstable, so there is a dynamic balance, which determines whether any net gain in mass number occurs. There is sufficient neutron capture to create isotopes up to bismuth-209, the heaviest known stable isotope. It is referred to as the "s-process" by astronomers, from "slow" neutron capture.

Current opinion is that isotopes heavier than 209Bi must be formed in the cataclysmic explosions known as supernovae. In the supernova explosion, a large flux of energetic neutrons is produced and nuclei bombarded by these neutrons build up mass one unit at a time to produce the heavy nuclei. This process proceeds very rapidly and is called the "r - process" for "rapid neutron capture". The layers containing the heavy elements may be blown off by the supernova explosion, and provide the raw material of heavy elements which condense to form new stars.

Particle accelerators use electric fields to propel electrically charged particles to speeds sufficient to cause nuclear reactions. Linear high-energy accelerators apply an alternating high-energy field to a linear array of plates. Particles approaching a plate are further accelerated towards it by the opposite charge applied to the plate. Once the particles have passed through a hole in the plate, the polarity of the particle is switched and the plate then repels the particle towards the next plate, where the same process occurs.

Black holes serve as extremely powerful and natural particle accelerators. Magnetic fields that surround black holes accelerate particles and induce high-speed collisions. These collisions produce the gamma rays characteristic of black holes. The magnetic field associated with black holes extends far beyond boundaries of the black hole, and accelerated particles that escape the black hole's gravity are further accelerated as they travel outwards. In this way, some protons are capable of reaching energies of 1000 TeV.

SKILL 1.5 Compare the use of visual, radio, and X-ray telescopes to collect data that reveal how stars differ in their life cycles.

Active Optics: a type of optical device that is composed of hexagonal pieces of mirror whose positions are controlled by a computer. Also referred to as Active Telescopes. Collectively, smaller pieces of mirror weigh less than a single large mirror and more important, they generally do not suffer from sagging problems. Small hexagonal shaped pieces of mirror are arranged next to each other to form a larger reflection surface. Computer-controlled thrusters mounted underneath the pieces control the mirror position and focus. The use of the smaller pieces working positioned so as to work in conjunction, eliminates sagging and an uneven heating and cooling problems found in extremely large, single mirror piece type telescopes.

Refractor Telescopes
Refraction: the bending of light. Example: Put a straw in a clear glass of water. Now look at straw through the side of the glass. It will appear to bend at the point where the straw enters the water. A Refractor Telescope is an optical device that makes use of lenses to magnify and display received images. Professional astronomers do not use Refractor telescopes because of two main problems: first the telescopes are affected by chromatic aberrations which make it difficult to focus on the stars, and second, because they rely solely on lenses, the telescopes have inherent weight and size restrictions.

Reflector Telescopes
Reflection: the re-emission of light oflofan object struck by the light. Example: Look at yourself in the mirror. What your eyes see is the re-emission of light waves that have struck you *and* the mirror. A Reflector Telescope is an optical device that makes us of a mirror or mirrors, to reflect light waves to an eyepiece (an ocular), thereby eliminating chromatic aberrations. There are different types of reflector telescopes; some use mirrors only, and others make use of both lenses and mirrors.

Hubble Space Telescope: Named in honor of American astronomer Edwin Hubble, who had proved the theory of an expanding universe, the **Hubble Space Telescope** although only possessing a 2.4 meter diameter reflective surface, isn't affected by atmospheric constraints, and as a result, it provides a much clearer, higher resolution image of stellar objects than is possible through the use of an Earth-based telescope.

CCD-Charged Coupled Devices
A CCD is a camera plate made up of thousands of tiny pixels. The pixels carry a slight electrical charge and when photons strike a pixel, electrons are released. The release of the electrons causes a flow of current through an attached wire, and this current is detected by a computer chip and used to construct images based on the number of strikes. The number of strikes also shows the intensity of the received image.

Radio Telescopes
Variances in radio waves received from space can be translated into usable astronomical data. The advantages offered by use of radio telescopes are many: it's cheaper to build a radio telescope than optical telescopes, they can operate 24 hrs a day and be built just about anywhere on Earth, and they open up an entirely new window of space investigation. But they initially had one major disadvantage: the useable radio waves received from space were not overly abundant and generally very weak, and you needed a huge receiving dish to detect the signals. To overcome these problems, scientists developed a technique called Radio Interferometry. Radio Interferometry is a method of amplifying weak radio waves by lying out in a Y-shaped pattern, a series of small radio telescopes all pointed at the same point in the sky. The telescopes add their received signals together to form an overlay of signals. Computers control the angle of incidence and correlate the incoming signals. This improves resolution and limits the size of the radio telescope dish needed for a single unit. We measure the intensity of the light by the ratios of the apparent presence or absence of colors. **Intensity:** the amount of light contained in a space. Intensity varies by distance. The further away you are, you will see a drop in intensity equal to 1 over the distance squared. Intensity gives off a continuous amount of colors, but the intensity of the colors seen varies in accordance with the temperature of the object. Stars follow the same principles of emission. We observe the intensity of the stars by using a red & blue filter on a photon counter mounted on a telescope. The red and blue ratio determines the color index. From the color index, we can determine the temperature, size, properties, and material composition of the star.

X-rays are a form of electromagnetic radiation with a wavelength in the range of 10 to 0.01 nanometers. X-ray detectors measure x-ray photons that react with the detector, producing a charge. Over time, these devices accumulate enough measurements of individual photons to produce an accurate measurement of the total source. X-ray photons have a higher energy than optical photons, so these individual photons are easier to detect. Currently, most x-ray telescopes use CCD x-ray detectors.

X-ray emission is the principal means of energy loss from most stellar coronas. By recording changes in a star's x-ray emission over extended amounts of time, x-ray telescopes can help scientists to study stellar life cycles because stars at different stages of the life cycle are known to emit x-rays in different amounts. Steady x-rays emitted from stars are thermal, meaning the x-ray spectrum is characterized by temperature. In older pulsars, where the neutron star has had time to cool and the amount of energy released by the current that flows to the star's surface is much less than that of a younger star, x-rays are entirely pulsed, with no thermal component.

X-rays also enable scientists to study black holes, which are formed by the gravitational collapse of massive stars. When stars approach black holes, gaseous material of the star's surface is sucked into the black hole and elevated to temperatures of millions of degrees by extreme speed and friction. These temperatures produce x-rays, which can be detected on Earth. X-rays emitted from black holes can indicate the final stage in a star's life cycle.

SKILL 1.6 Describe, in terms of color and brightness, how the evolution of a star is determined by a balance between gravitational collapse and nuclear fusion.

Stars form in Planetary Nebulae: cold clouds of dust and gas within a galaxy, and go through different stages of development in a specific sequence. This theory of star development is called the Condensation Theory.

Sequence of Development
In the initial stage, the diffuse area of the nebula begins to shrink under the influence of its own weak gravity. The cloudlike spheres condense into a knot of gasses called a **Protostar.** The original diameter of the protostar is many times greater than the diameter of our solar system, but gravitational forces causes it to continue to contract. This compression raises the internal temperature of the protostar. When the protostar reaches a temperature of around 10 million degrees C, nuclear fusion starts, which stops the contraction of the protostar and changes its status to a star.

Nuclear Fusion: the process in which hydrogen atoms fuse together to form helium atoms, releasing massive amounts of energy during the fusion.

It's the fusion of atoms, not combustion, which causes the star to shine. A star's life cycle depends on its initial mass. Red stars have a small mass. Yellow stars have a medium mass. Blue stars have a large mass. Large mass stars consume their hydrogen at a faster rate and have a short life cycle in comparison to small mass stars that consume their hydrogen at a much slower rate. All stars eventually convert a large percentage of their hydrogen to heavier atoms and begin to die. However, just as their mass determines the length of their life, it also determines the pattern they follow in the last stages of their existence.

Lower Main Sequence Stars
When small and medium mass stars (such as the Sun) consume all of their hydrogen, their inner cores begin to cool. The stars begin to consume the heavier elements produced fusion (carbon and oxygen) and the star's shell tremendously expands outward, causing the star to become a **Giant Star**: large, cool extremely luminous stars 10 to 100 times the diameter of the Sun. Example: In roughly 4.6 billion years, our Sun will become a Giant. As it expands, its outer layers will reach halfway to Venus. The dying Giant gives off thermal pulses approximately every 200,000 years, throwing off concentric shells of light gasses enriched with heavy elements. As it enters its last phases of the life cycle its depleted inner core begins to contract, and the Giant becomes a **White Dwarf Star**: a small, slowly cooling, extremely dense star, no larger than 10,000 km in diameter. The final phase of a lower main sequence star life cycle can take two paths: most main sequence white dwarfs after a few billion years completely burn out to become **Black Dwarfs**: cold, dead stars. However, if a White Dwarf is part of a **Binary Star**: two suns in the same solar system, instead of slowly cooling to become a Black Dwarf, it may capture hydrogen from its companion star. If this happens, the temperature of the White Dwarf soars and when it reaches approximately 10 million degrees C, a nuclear explosion occurs, creating a Nova: a sudden brightening of a lower main sequence star to approximately 10,000 times its normal luminosity; caused by the explosion of the star. A nova reaches its maximum brightness in a short time (one or two days) and then gradually dims as the gasses and cosmic dust cool.

Upper Main Sequence Stars
The initial sequence of the high mass, upper main sequence stars is identical to the lower mass stars, Planetary Nebulae to Protostar. However, if the protostar accretes enough material, it forms as a Blue Star. When a Blue Star has consumed all of its hydrogen it too expands outward, but on a much larger scale then experienced by a lower mass star. It becomes a **Supergiant Star**: an exceptionally bright star, 10 to 1000 times the diameter of the Sun. The Supergiant's now depleted core cannot support such a vast weight and collapses inward causing its temperature to soar. When it reaches roughly 599 million degrees C, it implodes and then explodes, creating a Supernova: the massive explosion of an upper main sequence Supergiant star; caused by the detonation of carbon within the star. A supernova releases more energy than Earth's sun will produce in its entire life cycle. The luminosity of a supernova is as bright as 500 million Suns.

Example: Chinese astronomers in 1054 recorded the sudden appearance of a new star in what is now know as the Taurus Constellation. Bright enough to be see during daytime for over a month, it remained visible for over 2 years. 90 percent of the shattered mass scatters into space, becoming planetary nebulae from which the life cycle may begin anew. The other 10 percent, the core of the star, is blown inward, becoming a Neutron Star: a very small - 10 km diameter core of a collapsed Supergiant star that rotates at a high speed (60,000 rpm) and has a strong magnetic field. A neutron star may capture gas from space, a companion star, or a nearby star and become a Pulsar: a neutron star that emits a sweeping beam of ionized-gas radiation. As the pulsar rotates, the beams of light sweep into space similar to a beacon from a lighthouse. Since first discovered in 1967, over 350 pulsars have been catalogued. The alternate product of a supernova is a **Black Hole**: a volume of space from which all forms of radiation cannot escape. Black Holes are created when a Supergiant star with a mass roughly 3 times that of the Sun implodes.

COMPETENCY 2.0 UNDERSTAND SOLAR SYSTEMS.

SKILL 2.1 Explain how the solar system was formed, including differences and similarities among the sun, terrestrial planets, and the gas planets, and cite the evidence from Earth and moon rocks that indicate that the solar system was formed approximately 4.6 billion years ago.

Formation of Earth and the Solar System

Most cosmologists believe that the Earth is the indirect result of a supernova. The thin cloud (planetary nebula) of gas and dust from which the Sun and its planets are formed, was struck by the shock wave and remnant matter from an exploded star(s) outside of our galaxy. In fact, the stars manufactured every chemical element heavier than hydrogen. The turbulence caused by the shock wave caused our solar system to begin forming as is absorbed some of the heavy atoms flung outward in the supernova. In fact, our solar system is composed mostly of matter assembled from a star or stars that disappeared billions of years ago. Nebulae spun faster as it condensed and material near the center contracted inward. As more materials came together, mass and consequently gravitational attraction increased, pulling in more mass. This cycle continued until the mass reach the point that nuclear fusion occurred and the Sun was born. Concurrently, the Proto-sun's gravitational mass pulled heavier, denser elements inward from the clouds of cosmic material surrounding it. These elements eventually coalesced through the process of Accretion: the clumping together of small particles into large masses, into the planets of our solar system. The period of accretion lasted approximately 50 to 70 million years, ceasing when the protosun experienced nuclear fusion to become the Sun. The violence associated with this nuclear reaction swept through the inner planets, clearing the system of particles, ending the period of rapid accretion. The closest planets Mercury, Venus, and Mars, received too much heat and consequently, did not develop the planetary characteristics to support life, as we know it. The farthest planets did not receive enough heat to sufficiently coalesce the gasses into solid form. Earth was the only planet in the perfect position to develop the conditions necessary to maintain life.

Prevalent cosmic theory holds that all the planets and celestial bodies formed around the same time. By absolute dating meteorite fragments found on the Earth, we have been able to gather additional information and develop a better estimate of the Earth's age. The widely accepted approximate age of the Earth is estimated as 4.6 billion years old. This age is further supported by evidence collected during the United States' exploration of the moon. Moon rocks, which range in age from 3.3 to 4.6 billion years old, give further support to the cosmic theory that our solar system- including the Earth and the Moon- was formed about the same time and by the same processes.

SKILL 2.2 Know the current evidence for the existence of planets orbiting other stars.

Extrasolar planets are detected through the influence they enact on their host stars. A planet orbiting a star causes the star to wobble, changing the wavelength of the star's light that is detected on Earth. This change is known as the Doppler effect. Using this method of detection, during the past 15 years over one hundred planets have been determined to orbit stars outside of our solar system.

The first extrasolar planets were detected in 1991, when scientists discovered three objects orbiting the star PSR B1257+12. One of these planets is Moon-sized, while the other two are 2 to 3 times the size of Earth. PSR B1257+12 is a dying pulsar star left over from a supernova explosion in the constellation Virgo, and emits radiation that would prevent any form of life in its planetary system. Its three planets were detected by measuring variations on the pulsation speed of the pulsar. These variations are assumed to be gravitational effects of the three planets.

In 1995, a slight perturbation in the position of the star 51 Plegasi was interpreted as evidence of the presence of another extrasolar planet. 51 Plegasi is located in the constellation of Pegasus, and is very similar to our Sun in temperature, size, rotation speed and emitted radiation. This star is a spectral type G2-3 V main-sequence located 42 light-years from Earth. Using a high-resolution spectrograph, scientists have recently discovered that the star's line-of-sight velocity changes approximately 70 meters per second every 4.2 days (according to a study by Michel Mayor and Didier Queloz of Geneva Observatory), indicating that the orbiting planet lies a mere 7 million kilometers from its host star. This distance, much smaller than that of Mercury to the Sun, is too close to be life-conducive. The planet of 51 Plegasi is at least half the mass of Jupiter.

It is now believed that the star Gl229 has an object 20 times the size of Jupiter orbiting at a distance of 44 AU. This object is most likely a brown-dwarf rather than an ordinary planet. Evidence also indicates that the pulsar PSR 0329+54 (PKS B0329+54) is orbited by a planet greater than 2 times Earth's mass with a period of 16.9 years. It has also been shown that the star HR3522 has an orbiting planet approximately 0.8 times the size of Jupiter.

The star Beta Pictoris may also have several orbiting planets. Beta Pictoris is surrounded by a disk of gas and dusk (protoplanetary disk) that is considerably thinner than previously thought, indicating that planets may have formed through gas accretion in the disk. This disk is also known to be warped from the gravitational influence of orbiting planets.