Summary

26.1 The Sun

The sun gives off tremendous amounts of energy. The sun's energy is in the form of electromagnetic radiation. The source of the sun's energy is nuclear fusion. Inside the sun, hydrogen nuclei fuse, or combine, to form helium nuclei. These reactions convert mass to energy. The energy from nuclear fusion moves outward from the center of the sun. It exerts outward thermal pressure. At the same time, the sun's center exerts inward gravitational force. These two opposing forces balance each other. As a result, the sun remains stable.

The sun has an interior and an atmosphere. The sun's interior consists of the core, the radiation zone, and the convection zone.

- The core is the central region of the sun. Nuclear fusion produces energy in the core.
- The radiation zone is the next layer of the sun's interior. It is a region of gas under pressure. Energy from the core passes into the radiation zone. The energy takes thousands of years to pass through the radiation zone because the zone is so dense.
- The convection zone is the outer layer of the sun's interior. Energy from the radiation zone passes into the convection zone. Energy passes through the convection zone to the atmosphere by convection currents.

Outside the convection zone is the sun's atmosphere. The sun's atmosphere consists of three layers: the photosphere, the chromosphere, and the corona.

- The photosphere is the innermost layer of the sun's atmosphere. It is the visible surface of the sun. It has a bubbly appearance. The bubbles are the tops of convection currents in the convection zone.
- The chromosphere is the middle layer of the sun's atmosphere. It is hotter than the photosphere.
- The corona is the outermost layer of the sun's atmosphere. It is hotter than the chromosphere. The corona is very thin. It extends outward into space for millions of kilometers.

The corona gradually thins into the solar wind. The solar wind is a stream of electrically charged particles. The stream flows outward from the sun through the solar system.

The sun's atmosphere has some striking features, including sunspots, prominences, and solar flares.

- Sunspots are relatively cool areas in the photosphere. They look like dark spots on the sun's surface. They are often found in groups, and they occur in cycles.
- Prominences are huge loops of gas that erupt from sunspot regions. They start in the photosphere. They may extend upward into the corona.
- Solar flares are sudden bursts of energy released from the sun. They usually occur near sunspots. They heat the corona and increase the solar wind.

26.2 Stars

A star is a large, glowing ball of gas in space. It produces energy through nuclear fusion in its core. The sun is the closest star to Earth.

Although stars appear to be close together in the night sky, they are actually very far apart. In fact, stars are so far apart that astronomers measure distances between them in units called light-years. A light-year is the distance light travels in one year (in a vacuum), or about 9.8 trillion kilometers.

Astronomers cannot directly measure the distance of stars from Earth. Instead, they must use an indirect method. To find a star's distance, astronomers first measure its parallax. Parallax refers to how an object appears to change position, relative to its background, when you view it from different angles. As Earth moves in its orbit, astronomers can view stars from different angles. The more a star appears to change position relative to its background, the closer the star is to Earth. The parallax method works best for nearby stars.

There are many different types of stars. Astronomers classify stars by their color, size, and brightness. A star's color depends on its surface temperature. The hottest stars appear blue. The coolest stars appear red. In between are yellow stars, like the sun. Stars vary greatly in how bright they are. Absolute brightness is how bright a star really is. Apparent brightness is how bright a star appears from Earth. A star's apparent brightness depends on its absolute brightness and its distance from Earth. Stars appear dimmer when they are farther away. Astronomers can measure a star's apparent brightness and distance. Then, they can use the information to calculate the star's absolute brightness. Astronomers also have methods for calculating the diameter, volume, and mass of stars.

Astronomers use a spectrograph to identify the elements in a star's atmosphere. A spectrograph is an instrument that spreads light from a hot, glowing object into a spectrum. Different elements absorb light of different colors. Colors that are absorbed by elements in a star's atmosphere are absent from the star's spectrum. In their place are dark lines, called absorption lines. The absorption lines show where light has been absorbed. The absorption lines can be used to identify the elements in the star's atmosphere. Astronomers have found that the atmospheres of most stars consist mainly of hydrogen and helium.

A graph that shows the surface temperature of stars on one axis and the absolute brightness of stars on the other axis is called a Hertzprung-Russell diagram, or an H-R diagram. H-R diagrams are used to estimate the size and distance of stars. The diagrams also help scientists understand how stars change over time.

Most stars fall within a diagonal band on an H-R diagram. This diagonal band is called the main sequence. It shows that cooler stars are generally dimmer and that brighter stars are generally hotter. Some stars fall outside the main sequence on an H-R diagram. Stars called giants or supergiants fall above the main sequence. They are very bright because they are large, not because they are very hot. Stars called white dwarfs fall below the main sequence. They are very dim because they are small, not because they are very cool.

26.3 Life Cycles of Stars

Scientists think that an H-R diagram represents the life cycle of stars. The first and longest part of the life cycle of a star is spent as a main-sequence star. As stars age, they become giants or supergiants. Some giants eventually become white dwarfs.

A star first forms from a nebula. A nebula is a large cloud of gas and dust spread out over space. Gravity pulls a nebula's gas and dust into a denser cloud. As the nebula shrinks, its pressure and temperature rise. Eventually, it becomes so dense and hot inside the nebula that nuclear fusion begins. At this point, a star has formed. Outward pressure from fusion balances the inward pull of gravity. These two opposing forces keep the star stable. It is now a main-sequence star.

How long a star lasts as a main-sequence star depends on its mass. High-mass stars have greater internal heat and pressure. As a result, they burn more brightly and use up fuel more quickly. They do not last as long as low-mass or medium-mass stars. High-mass stars may last only a few million years. In contrast, low-mass stars may last over 100 billion years.

Even low-mass stars do not last forever. Eventually, hydrogen in the core is used up, and energy can no longer be produced by fusion. Without the outward energy of fusion to counter the inward force of gravity, the star shrinks. This causes temperature and pressure to rise inside the star. Fusion begins again, but now in a shell outside the core. Energy flows outward from the shell and causes the star to expand. The star's atmosphere also expands. It moves away from the hot core and cools. The star becomes a red giant or a red supergiant.

Low-mass and medium-mass stars become red giants. A red giant eventually blows off much of its mass. It becomes surrounded by a glowing cloud of gas called a planetary nebula. All that remains of the star itself is its hot, dense core. This core is called a white dwarf.

High-mass stars become red supergiants. A red supergiant rapidly uses up fuel, so fusion slows and outward thermal pressure drops. Gravity causes the star's outer layers to collapse inward. This collapse produces a giant explosion, called a supernova. The dense core that remains after the explosion is called a neutron star. A neutron star is much smaller and denser than a white dwarf. Very massive stars may collapse beyond the neutron star stage and form black holes. A black hole is an object with such strong gravity that light cannot escape from it.

26.4 Groups of Stars

A group of stars that appear to form a pattern is called a constellation. The stars in a constellation are not necessarily close together. They just happen to lie in the same general direction as seen from Earth. Constellations help astronomers form maps of the sky.

Most stars actually do occur in groups. A star system is a group of two or more stars. A star system is held together by gravity. The majority of stars are members of star systems. A star system with two stars is called a binary star.

Groups of thousands or even millions of stars are called star clusters. There are three basic types of star clusters: open clusters, associations, and globular clusters.

- Open clusters are the smallest type of star cluster. They are loose groupings of stars. The stars are generally spread out. Open clusters often contain bright supergiants.
- Associations are typically larger than open clusters. Associations are temporary groupings of bright, young stars. Gravity from neighboring stars eventually breaks up associations.
- Globular clusters are large groups of older stars. The clusters are shaped like spheres, with a dense concentration of stars in the center. There may be more than a million stars in a globular cluster.

A galaxy is a huge group of individual stars, star systems, star clusters, dust, and gas. All the parts of a galaxy are bound together by gravity. There are billions of galaxies in the universe. Astronomers classify galaxies into four main types based on their shape: spiral, barred-spiral, elliptical, and irregular.

- Spiral galaxies have a bulge of stars at the center. They have arms extending outward from the center like a pinwheel.
- Barred-spiral galaxies are spiral galaxies with a bar through the center. They have arms extending outward from the bar on either side.

- Elliptical galaxies are spherical or oval. They do not have arms.
- Irregular galaxies come in many shapes. They look disorganized.

Our own galaxy is called the Milky Way. It is a spiral galaxy with billions of stars. In the arms of the Milky Way, stars are still forming. At the center of the Milky Way, there may be a huge black hole.

Quasars are extremely bright centers of distant young galaxies. Quasars produce more light than hundreds of galaxies the size of the Milky Way. In a quasar, matter is pulled into a massive black hole. As matter falls into the black hole, its gravitational potential energy is changed into electromagnetic radiation.

26.5 The Expanding Universe

As a light source moves toward or away from an observer, its wavelength appears to change. This is due to the Doppler effect. This effect can be used to determine how fast stars or galaxies are moving toward or away from Earth. Because of the Doppler effect, a star or galaxy moving toward Earth would have its spectrum shifted toward shorter (bluer) wavelengths. On the other hand, a star or galaxy moving away from Earth would have its spectrum shifted toward longer (redder) wavelengths. The shift to longer wavelengths is a red shift.

Edwin Hubble discovered that the spectra of most galaxies undergo a red shift. This means that most galaxies are moving away from Earth. Hubble also found that more-distant galaxies have greater red shifts. This means that more-distant galaxies are moving away from Earth faster than closer galaxies. From these data, astronomers know that the universe is expanding.

Most astronomers think that the universe came into being at a single moment, in an explosion called the big bang. According to the big bang theory, all the matter and energy of the universe were at one time concentrated into a tiny, incredibly hot region. Then, about 14 billion years ago, an enormous explosion occurred, and the universe began in an instant. After the explosion, the universe expanded quickly and cooled. Eventually, the temperature dropped enough for atoms to form. Gravity pulled the atoms together into clouds of gas. Gradually, the clouds of gas evolved into stars and galaxies.

The big bang theory is the best current scientific explanation for the formation and development of the universe. The theory is supported by the red shift, which shows that the universe is expanding. The theory is also supported by cosmic microwave background radiation. This radiation can be detected from every direction in space. Scientists think that cosmic background radiation is energy that was produced during the big bang.

Scientists wonder if the universe will continue to expand. If the universe has enough mass, gravity might reverse the outward expansion. However, it is hard to determine the amount of mass in the universe. Much of the matter in the universe cannot be seen. It is called dark matter. Dark matter does not give off radiation, so it cannot be detected directly. It can only be detected by observing how its gravity affects visible matter. Some astronomers think that much of the universe is made of dark matter.

Recently, astronomers discovered that the universe may be expanding faster than before. The reason is not known. A mysterious force, called dark energy, may be causing the rate of expansion to increase. If the rate of expansion is increasing, it is likely that the universe will expand forever.