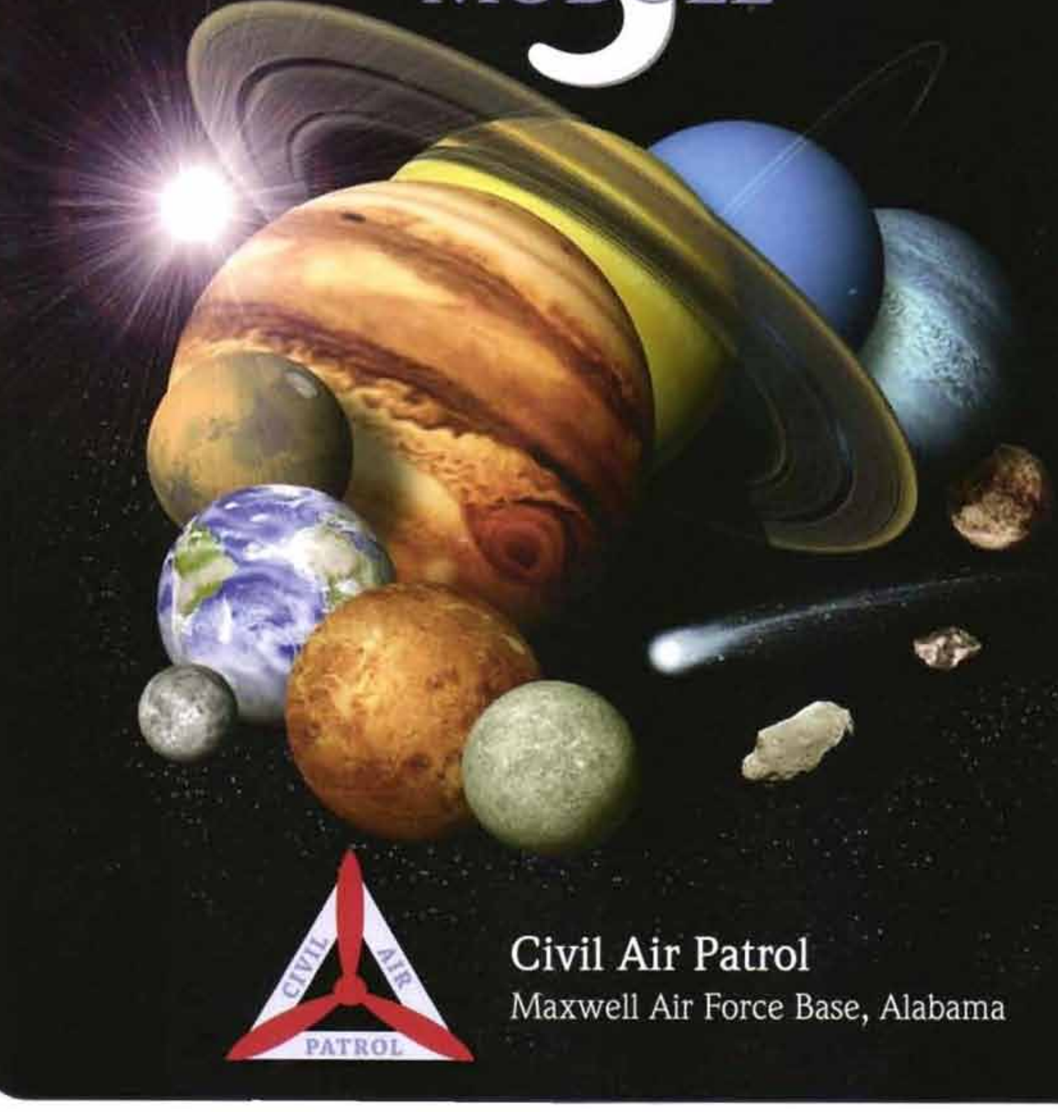
Aerospace Dimensions

SPACE ENVIRONMENT

MODULE 5



Civil Air Patrol

Maxwell Air Force Base, Alabama

Aerospace Dimensions
SPACE ENVIRONMENT

MODULE 5

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Introduction

The Aerospace Dimensions module, ***Space Environment***, is the fifth of six modules, which combined, make up Phases I and II of Civil Air Patrol's Aerospace Education Program for cadets. Each module is meant to stand entirely on its own, so that each can be taught in any order. This enables new cadets coming into the program to study the same module, at the same time, with the other cadets. This builds a cohesiveness and cooperation among the cadets and encourages active group participation. This module is also appropriate for middle school students and can be used by teachers to supplement STEM-related subjects.

Inquiry-based **activities** were included to enhance the text and provide concept applicability. The activities were designed as group activities, but can be done individually, if desired. The activities for this module are located at the end of each chapter.

Contents

National Academic Standard Alignment

Science Standards	Mathematics Standards	English Language Arts Standards	Social Studies Standards	Technology Standards
Science as Inquiry	1. Number and Operations Standard: • Understand numbers, ways of representing numbers, relationships among numbers, and number systems • Compute fluently and make reasonable estimates	1. Reading for Perspective	8. Science, Technology, and Society	1. Understanding of the characteristics and scope of technology
Physical Science: • Motions and forces • Properties and changes of properties in matter • Transfer of energy	4. Measurement Standard: • Apply appropriate techniques, tools, and formulas to determine measurements	3. Evaluation Strategies		3. Understanding of the relationships among technologies and the connections between technology and other fields of study
Earth and Space Science: • Earth in the solar system	6. Problem Solving Standard: • Solve problems that arise in mathematics and in other contexts	4. Communication Skills		6. Understanding of the role of society in the development and use of technology
Science and Technology: • Abilities of technological design	10. Representation Standard: • Create and use representations to organize, record, and communicate mathematical ideas	7. Evaluating Data		
Unifying Concepts and Processes: • Evidence, models, and explanation • Constancy, change, and measurement • Systems, order, and organization		12. Applying Language Skills		

1 SPACE

Learning Outcomes

- Describe the location of space.
- Describe characteristics of space in terms of temperature, pressure, and gravity.
- Define microgravity.
- Define cislunar space.
- Distinguish between interplanetary and interstellar space.
- Define galaxy.
- Identify three types of galaxies.
- Define universe.

Important Terms

absolute zero - the point at which all molecules no longer move or have the least amount of energy; theoretically the absolute coldest temperature
cislunar space - the space between the Earth and the Moon
galaxy - an enormous collection of stars arranged in a particular shape
interplanetary space - space located within a solar system; measured from the center of the Sun to the orbit of its outermost planet
interstellar space - the region in space from one solar system to another
Kelvin - unit of measurement based on absolute zero and commonly used by scientists to measure temperature
microgravity - small gravity levels or low gravity; floating condition
space - region beyond the Earth's atmosphere where there is very little molecular activity
universe - all encompassing term that includes everything; planets, galaxies, animals, plants, and humans
vacuum - space that is empty or void of molecules
Van Allen belts - radiation belts around the Earth filled with charged particles

Since the beginning of time, man has looked to the stars with awe and wonder. Our universe has always fascinated scientists and other observers. What was once unexplored territory has now become the new frontier. Many expeditions, missions, satellites, and probes have traveled into this overwhelming vastness we call our universe in search of knowledge and understanding. When we talk about the universe, several words may come to mind. Many people think of words like space, stars, planets, and solar systems. This volume on the space environment will define these terms and give you a basic understanding of our universe.

You might wonder why this is important. All of our volumes have been talking about aerospace, and space is certainly a part of this overall concept. We are no longer limited in our thinking or achieving to the immediate area of Earth's atmosphere. For years, travel has occurred beyond that scope. The US has participated in unmanned and manned space missions for years, and our missions have included stops at space stations. American astronauts used to assist at the Russian space station *Mir.* Missions now involve astronauts staying in space for extended periods of time on the International Space Station. It is conceivable that some of us could travel to space during our lifetime. Let's take a brief look at some basic information that we should know in our quest for learning about our space environment and the universe.

SPACE IS A PLACE

First, space is a place. It is part of the universe beyond the immediate influence of Earth and its atmosphere. This does not happen at a particular point, but, rather, happens gradually. You may have heard space described as a void or a vacuum, but no place in the universe is truly empty. Eventually the molecules and atoms become so widely spaced that there is no interaction. We call this **space**. The Air Force and NASA define space as beginning at an altitude of 50 miles (80.5 km), and anyone who reaches this height is awarded astronaut wings. However, 62 miles, or 100 kilometers, is the most widely accepted altitude where space begins. An object orbiting the Earth has to be at an altitude of 80 or 90 miles (129 to 145 km) to stay in orbit. So, many consider this to be the beginning of space. The Earth's atmosphere gradually thins with an increase in altitude, so there is no tangible boundary or exact point between the Earth's atmosphere and space.

Space is a part of the universe. The **universe** includes everything: stars, planets, galaxies, animals, plants, and humans. Let's talk about the concept of space first and then expand into a discussion of the universe.

CHARACTERISTICS OF SPACE

When we describe space as a physical place we must include its characteristics. What is the temperature like in space? What about pressure? Is there gravity in space?

Outer space is almost a **vacuum**. A vacuum is defined as a space that is empty, meaning the space has no, or virtually no, molecules. This is true of outer space. Large bodies such as planets, moons, and stars have such a large gravitational pull that they prevent molecules from floating around in the space between these large bodies. There are some wandering gas molecules with extremely low density floating in outer space, so no place in the universe is truly empty. Because these wandering molecules are so far apart from one another, though, many people think of space as a vacuum.

Oxygen

Regarding a lack of gas molecules, space is characterized by a lack of oxygen. It would be impossible for us to travel or live in space without oxygen. We compensate for this by including an oxygen supply on all manned space flight projects.

Pressure

What about the pressure in space? As explained in NASA's educational product, *Suited for Spacewalking, "In space, the pressure is nearly zero. With virtually no pressure from the outside, air inside an unprotected human's lungs would immediately rush out in the vacuum of space. Dissolved gases in body fluids would expand, pushing solids and liquids apart. The skin would expand much like an inflating balloon. Bubbles would form in the bloodstream and render blood ineffective as a transporter of oxygen and nutrients to the body's cells. Furthermore, the sudden absence of external pressure balancing the internal pressure of body fluids and gases would rupture fragile tissues, such as eardrums and capillaries. The net effect on the body would be swelling, tissue damage, and a deprivation of oxygen to the brain that would result in unconsciousness in less than 15 seconds."* We compensate for the lack of pressure by providing pressurized spacecrafts and spacesuits for humans.

Temperature

In terms of the average temperature in the darkness of outer space, generally the temperature is near absolute zero. Temperature is based on the movement of molecules, and **absolute zero** is the point at which all molecules stop moving or have the least amount of energy. Absolute zero is written as 0 K (-273° C or -459° F), which is theoretically the absolute coldest temperature that could exist. **Kelvin**, abbreviated K, is a unit of measurement based on absolute zero, and it is commonly used by scientists to measure temperature. Although there is hardly any movement of molecules in the darkness and near emptiness of much of outer space, there is still cosmic microwave background radiation (a form of electromagnetic radiation filling the uni-

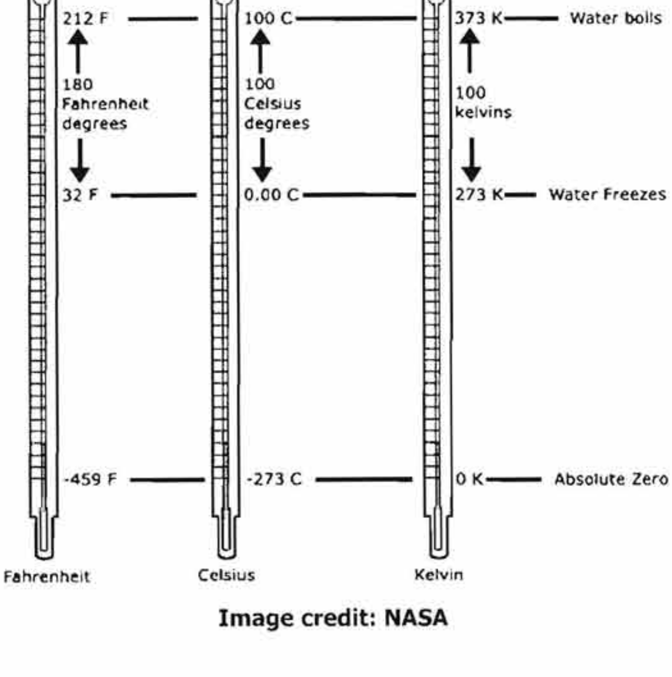


Image credit: NASA

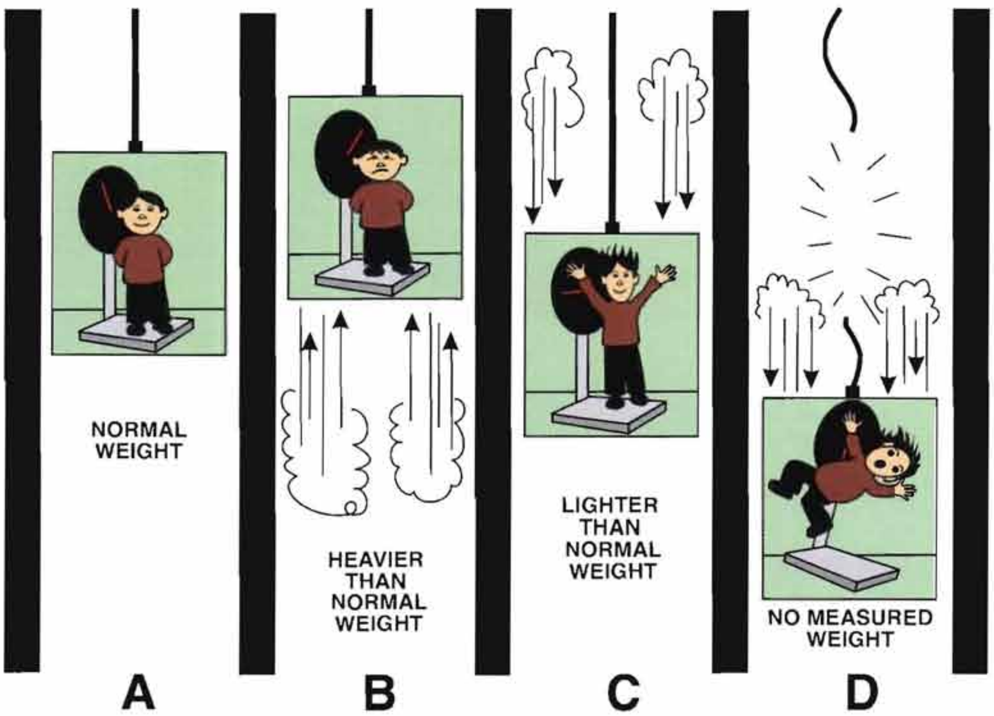
verse), which means that the temperature in space is not quite at absolute zero, but rather about 2.725 K (-270° C or -455° F). Keep in mind that this average space temperature of 2.725 K is not the temperature for every point in space. For example, objects in Earth's orbit may experience a temperature of over 393 K (120° C or 248° F) in sunlight areas and lower than 173 K (-100° C or -148° F) in Earth's shadow. To combat the temperature extremes, humans are able to control the temperature inside a spacecraft or spacesuit. (See temperature illustration on the previous page.)

Gravity

When discussing the characteristics of space, a common misconception is that there is no gravity in space. Most of us have seen pictures of astronauts floating around in space, which leads us to believe that there is no gravity in space. Floating in outer space occurs because the gravity in space is much smaller or less than on Earth. Small or low gravity is called **microgravity**.

The prefix micro really means one part in a million, but we use it all of the time to simply mean something small. That is how we use it when referring to space. To actually go into space where the Earth's gravitational pull is one-millionth of that at the surface, you would have to travel 17 times farther away than the Moon. As you know, no human has traveled beyond the Moon yet. So, why do astronauts orbiting the Earth experience a feeling of weightlessness and float? It is because they are constantly falling around the Earth as they orbit in a state of "free fall." Rather than traveling to a distance 17 times farther away than the Moon, a microgravity environment can be created by free fall.

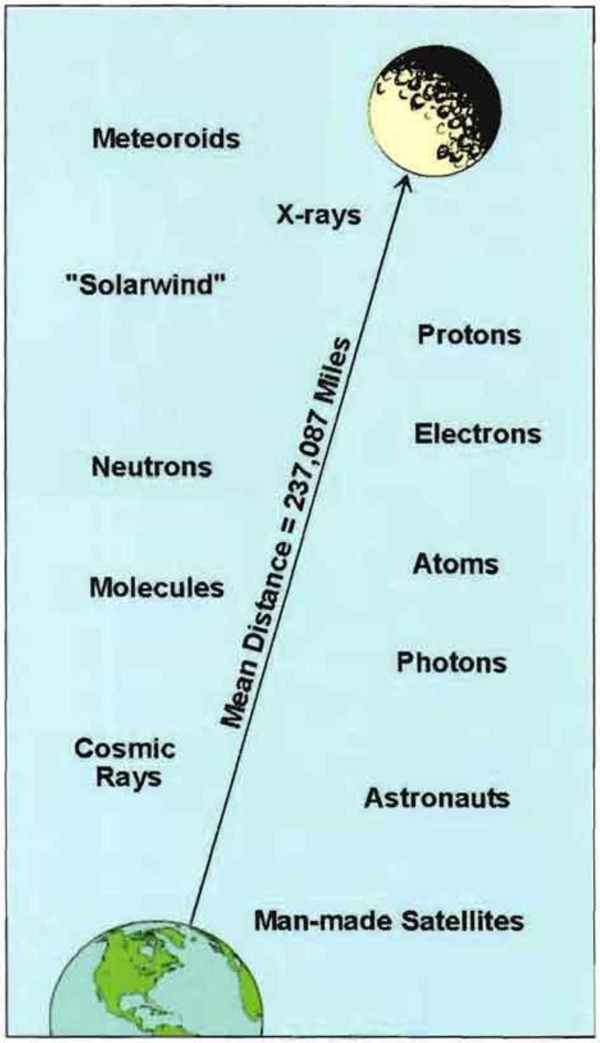
We can create a microgravity environment here on Earth. Imagine riding in an elevator to the top of a building. When you get to the top, the elevator cables break, causing the elevator and you to fall. Since you and the elevator car are falling together, you feel like you are floating inside the car. You and the car are accelerating downward at the same rate due to gravity alone. If a scale were present, your weight would not register because the scale would be falling too. NASA calls this floating condition microgravity. While orbiting the Earth, astronauts experience a microgravity environment as they constantly fall around the Earth. Because they are traveling at about 17,500 miles per hour, they are traveling fast enough to keep going around and



Picture D is an example of microgravity

around the Earth.

"Did you know," as explained in NASA's *Suited for Spacewalking*, *"that if you stepped off a roof that was five meters high, it would take you just one second to reach the ground? In a microgravity environment equal to one percent of Earth's gravitational pull, the same drop would take 10 seconds. In a microgravity environment equal to one-millionth of Earth's gravitational pull, the same drop would take 1,000 seconds or about 17 minutes."* (See associated Activities One, Two, Three, and Four at the end of the chapter.)



Dimensions and occupants of cislunar space

Regions of Space

We can further describe space as cislunar, interplanetary, or interstellar space. **Cislunar space** is the space between the Earth and the Moon. This distance varies from month to month since the Moon's orbit around the Earth is elliptical. The average distance between the Earth and its Moon is 237,087 miles (381,555 km).

Cislunar space is not a void nor a vacuum. Part of the Earth's magnetosphere is found in cislunar space. The magnetosphere contains protons, electrons, and magnetic lines of force. Radiation storms emitting from the Sun are also located here. Cislunar space also contains meteoroids, asteroids, and comets, which we will discuss in an upcoming chapter.

So, you can see cislunar space is far from being void. However, it is not overcrowded either. According to astronauts who have been there, space looks like the void it has been called. Astronaut Anders (*Apollo* 8) said, "The sky is very, very stark. The sky is pitch black and the Moon is quite light. The contrast between the sky and the Moon is a vivid dark line."

Interplanetary space is measured from the center of the Sun to the orbit of its outermost planet. In addition to the Sun, this portion of space in our solar system includes eight known planets, which we will explore in Chapter 4. It also contains numerous planetary satellites, dwarf planets, a huge belt of asteroids, charged particles, magnetic fields, dust, and more. This interplanetary space is often referred to as the Solar System. Then, **interstellar space** is the distance from one solar system to another.

Now, we know a little about what space is like. We should remember that space is a part of the universe. The universe is the all-encompassing term that includes everything. Although the universe includes plants, animals, and humans, we want to talk about the part of the universe that includes galaxies.

GALAXIES

Milky Way Galaxy - spiral galaxy

Elliptical galaxy

So, what is a **galaxy**? A galaxy is an enormous collection of stars, and these stars are arranged in a particular shape. There are three main shapes of galaxies: elliptical, spiral, and irregular. Elliptical is oval shaped. Spiral has arms spiraling outward from a center. Irregular has no particular shape.

Our galaxy is the Milky Way Galaxy. The Milky Way is a huge collection of stars arranged in a spiral shape. The picture above shows the Milky Way from a deep space view. The Milky Way has a dense central bulge with arms spiraling outward. The center of our galaxy contains older red and yellow stars, while the arms have mostly hot, younger, blue stars. Scientists estimate that the Milky Way probably contains 100 billion other solar systems and stars.

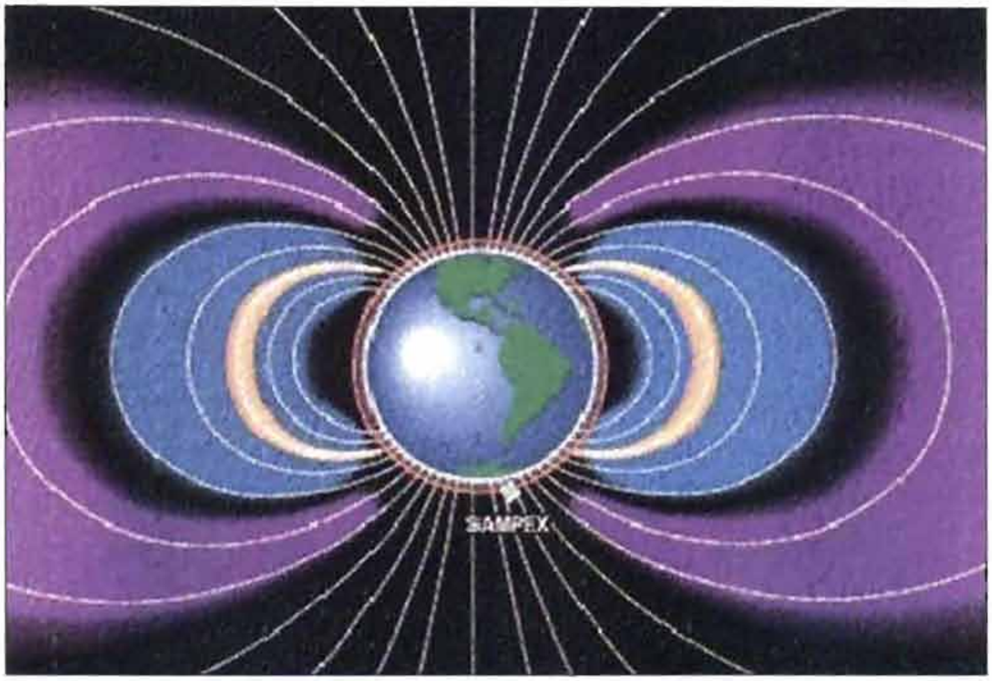
The universe contains many galaxies and is continually expanding. Our Sun, which is the center of our solar system, is but a tiny spot in our galaxy. In fact, there are 200 billion Suns in our galaxy, and our galaxy is just one of millions of galaxies. The smallest galaxies have about 100,000 stars, while the largest have about 3,000 billion stars.

Our universe is huge! One way to think about this is by using distance. Distance in space is measured in light years. A light year is about 6 trillion miles. Our galaxy is about 150,000 light years across. Again, our galaxy is only one of millions of galaxies. Our universe is so vast it is almost incomprehensible. So, let's not worry about how big it is, and instead just take a brief look at the space environment around our planet, Earth. (See associated Activity Five at the end of the chapter.)

Irregular galaxy

SPACE ENVIRONMENT AROUND THE EARTH

NASA's "Radbelts" Web site explains a great deal about the space environment around Earth (http://radbelts.gsfc.nasa.gov/). Earth is surrounded by a magnetic field that looks something like the field you see around a toy magnet when you use iron filings to make it stand out better. You have probably seen this demonstrated in a science class. Earth's magnetic field is shaped something like a comet, with a long, invisible tail of magnetism stretching millions of miles beyond the Moon on the opposite side of the Sun. This magnetic field can act like a bottle, trapping fast-moving charged particles within an invisible magnetic prison. The particles are so numerous that they form into donut-shaped clouds with the Earth at the center, and stretching thousands of miles above Earth's surface above the equator. Scientists call these the '**Van Allen Radiation Belts**' because they were first discovered by Dr. James Van Allen using one of the first satellites launched by NASA in 1958.



Van Allen Radiation Belts – Credit: NASA GSFC

The word "radiation" has to do with energy or matter moving through space. There are many forms of radiation that astronomers and physicists know about. Sunlight is a form of electromagnetic radiation produced by the Sun, but so is ultraviolet radiation, infrared radiation, and gamma radiation. Any heated body produces electromagnetic radiation. We also use the term 'radiation' to describe fast-moving particles of matter. One form of these found in space is cosmic radiation or more commonly referred to as "cosmic rays." They are not made of light energy, but are actually the nuclei of atoms such as hydrogen, helium, iron, and others which travel through space at hundreds of thousands of kilometers per second. Some electrons in the cosmic rays travel at nearly the speed of light. Like other forms of radiation, they carry energy away from the place where they were created. When they are absorbed, they deliver this energy to the body that absorbs them.

The Van Allen Belts are formed by clouds and currents of particles that are trapped in Earth's magnetic field like fireflies trapped in a magnetic bottle. Artists like to draw them as though they look like dense clouds of gas. In fact, they are so dilute that astronauts don't even see them or feel them when they are outside in their space suits. Because you can't see them from the ground at all, scientists didn't know they existed until they could put sensitive instruments inside satellites and study these clouds directly. They only had a hunch that something like them existed because they were predicted by certain mathematical models.

The Inner Belt (shown in blue above), between 600 and 3,000 miles (1,000 and 5,000 km), contains high-energy protons carrying energies of about 100 million volts, and electrons with energies of about 1 to 3 million volts. This is the belt that is a real hazard to astronauts working in space.

The Outer Belt (shown in purple), between 9,000 and 15,000 miles (16,000 and 24,000 km), consists of mostly electrons with energies of 5 to 20 million volts. This is the belt that is a hazard to communication satellites whose sensitive circuits can get damaged by the fast-moving particles.

Where do the particles in the belts come from? One line of thinking says that they might come from the Sun. The Sun is, after all, a powerful and abundant source for particles like the ones found in the belts. A second idea is that they were once cosmic rays from outside the solar system that got trapped by Earth's magnetic field as they traveled by. A third idea is that they may be atoms and nuclei from Earth's atmosphere that have been fantastically boosted in energy to millions of volts by some process we don't yet understand. The particles are not labeled with their place of origin. This makes it very difficult for scientists to sort out how each of these ideas actually contributes to the belts themselves. But if you took a survey of space scientists today, they would probably agree that the first two ideas are the most likely.

Anyone who works and lives in space, or has satellites working in space, will be very concerned about the radiation belts. Radiation belts contain very high energy particles that can pass through the skin of a satellite and damage the sensitive circuitry inside. If the circuitry controls the way the satellite is pointing its antenna, the satellite can veer out of lock with ground-based receivers and be temporarily "lost." Unless satellite operators can anticipate and correct this problem, the satellite will be permanently lost. During the current sunspot cycle, which began in 1996, we have lost over $2 billion in satellites from these kinds of problems. Scientists want to learn as much about the radiation belts as they can, so that they can better predict what will happen to satellites and humans operating in space.

Radiation belts and the particles that they contain are an important element of the space weather system. Space weather is a term that scientists use when they describe the changing conditions in the flows of matter and energy in space. These changes can have serious effects on the way that expensive and vital satellites operate. They can also have a big effect on the health of astronauts working and living in space.

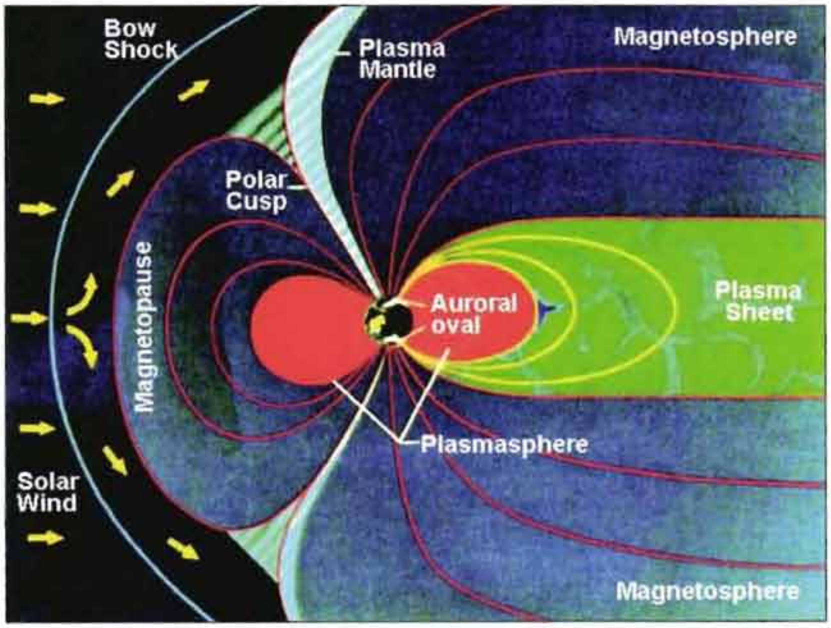
Anytime that satellite technology or astronauts are being affected by forms of radiation in space, such as fast-moving particles and X-rays, this usually causes some changes to occur. Most of the time these changes are so minor that they have no real consequences either to the way that the satellite operates or the health of the astronaut. But sometimes, and especially during a severe solar storm or "space weather event," the conditions in space can change drastically. The term "space radiation effects" has to do with all of the different ways that these severe conditions can significantly change the way a satellite operates, or the health of an astronaut working and living in space.

When a high-energy particle penetrates a satellite's metal skin, its energy can be absorbed by microscopic electrical components in the circuitry of a satellite. The switch can be changed from "on" to "off" momentarily, or, if the energy is high enough, this can be a permanent change. If that switch is a piece of data in the satellite's memory, or a digit in a command or program, it can suddenly cause the satellite to veer out of control until a human operator on the ground can correct this problem. If the particle happens to collide with one of the pixel elements in the satellite's star-tracking camera, a false star might be created and this can confuse the satellite to think it is not pointing in the right direction. Other satellite effects can be even more dramatic. When severe solar storms affect Earth's upper atmosphere, the atmosphere heats up slightly and expands deeper into space. Satellites will feel more friction with the air they are passing through, and this will seriously affect their orbits.

For astronauts, space radiation effects have to do with the amount of radiation (usually x-rays) that pass through the walls of their spacecraft or space station and penetrate into the body of the astronaut. Most people have an instinctive fear of radiation and its potential biological effects. No matter where you live, you receive a free dose each day of environmental radiation which adds up to 360 millirems (4- 5 chest X-rays) per year, and you have no control over this. The daily dosage of radiation on the *Space Station* is about equal to 8 chest X-rays per day.

But what about the Apollo astronauts who traveled the most intense regions of the belts in their journey to the Moon? Fortunately, the travel time through the belts was only about 30 minutes. Their actual radiation exposures inside the Apollo space capsule were not much more than the total dose received by space shuttle astronauts in a one-week stay in orbit. This fact counters some popular speculations that the Moon landings were a hoax because astronauts would have instantly died as they made the travel through the belts.

In reality, the Apollo astronauts might have experienced minor radiation sickness if they had been in their spacesuits on a spacewalk, but no spacewalk was ever scheduled for this very reason. The metal shielding provided by the Apollo space capsule walls was more than enough to protect the astronauts from all but the most energetic and rare particles. Consider learning more about space radiation and the Van Allen Belts at http://radbelts.gsfc.nasa.gov/outreach/index.html.



Regions of the Magnetosphere

The magnetosphere begins at about 215 miles (346 km) above the Earth's surface and extends into interplanetary space. The magnetosphere is characterized by its magnetic field of force, which surrounds the Earth. This force field is strongest at the poles and weakest at the equator.

The magnetosphere's force field is affected by solar winds. Solar winds strike the magnetosphere with such force that it forms a bow shock wave. The resulting bow shock wave distorts the Earth's magnetosphere.

You have probably heard of the aurora borealis and the aurora australis. The aurora borealis (or northern lights) flashes brilliant colors in varying patterns across the northern skies, and the aurora australis presents a similar display in the Southern Hemisphere. Observers have determined that these displays occur at heights ranging from 60 to 600 miles above the Earth's surface. It has also been determined that these displays are associated with a zone of electrically-charged layers in the upper atmosphere called the ionosphere.

The ionosphere is a part of the atmosphere divided by its electrical activity. It gets its name from the gas particles that are ionized or charged. The ionosphere was discovered early in the twentieth century when scientists learned that radio waves were transmitted in the atmosphere and were reflected back.

The ionosphere is filled with ions. Ions are atoms that carry a positive or negative electrical charge as a result of losing or gaining one or more electrons. These ions concentrate in certain parts of the ionosphere and reflect radio waves.

The ionosphere is caused by powerful ultraviolet radiation from the Sun and the ultra high frequency cosmic rays from the stars. This radiation bombards the scattered atoms and molecules of nitrogen, oxygen, and other gases and knocks some of the electrons out of the atoms.

Summary

To briefly summarize this chapter, everything is part of the universe. Space, stars, planets, galaxies, plants, animals, and humans are all part of the universe. Temperature, atmosphere, gravity, magnetic fields, and other factors vary at different places within the universe. There are even different types of galaxies in our universe, but all galaxies are made up of an arrangement of huge masses of glowing objects: stars. We will shed a little more light on our universe by looking at stars in the next chapter.

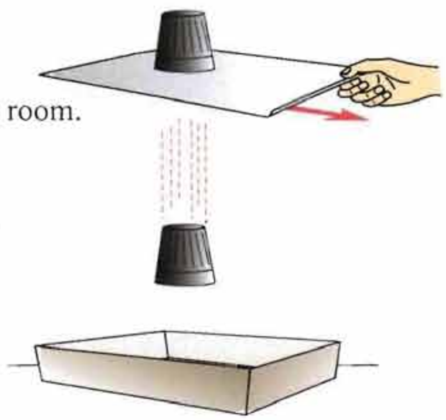
1 ACTIVITY SECTION

STOP! Safety Precautions: Water on floors or tile can create a walking hazard. Also, make sure electrical cords and appliances are removed from the area before doing these activities.

Activity One - Creating the Microgravity of Space

Purpose: The purpose of this activity is to demonstrate that free fall eliminates the local effects of gravity.

Materials: water, plastic-drinking cup, large cookie sheet with at least one edge that doesn't have a rim, empty soda pop can, a large pail (catch basin), towels (old bath towels for cleaning spills), and a step ladder



Procedure:

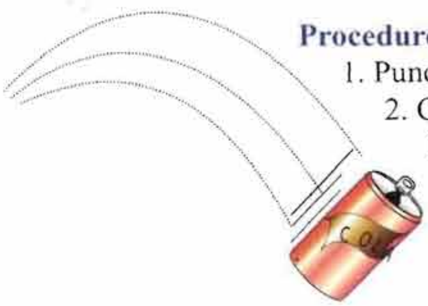
1. Place the catch basin in the center of an open area in your meeting room.
2. Fill the plastic cup with water.
3. Place the cookie sheet over the opening of the cup. Hold the cup tight to the cookie sheet while quickly inverting the sheet and cup.
4. Hold the cookie sheet and cup high above the catch basin. (This is where you may want to use the stepladder to get higher.)
5. While holding the cookie sheet level, quickly pull the cookie sheet straight out from under the cup.
6. The cup and the water will fall together.

Summary: This activity creates a microgravity environment similar to what you would find in space. In this activity, the cookie sheet holds the cup and water in place. Once the cookie sheet is removed, the water and cup fall together in a state of free fall, simulating microgravity. In space, as an object orbits the Earth the state of free fall remains constant until the object is acted on by another opposing force. Some sort of drag would lower the speed of the orbit returning the object to Earth. Some sort of thrust would make the object travel faster and end up moving out of Earth's orbit.

Activity Two - The Can Throw

Purpose: This activity also demonstrates microgravity and objects in a state of freefall.

Materials: empty aluminum soft drink can, sharp nail, catch basin, water, and towels



Procedures:

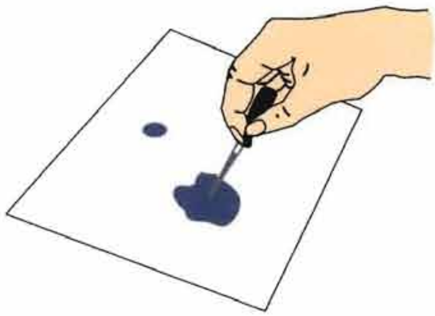
1. Punch a small hole with a nail near the bottom of an empty soft drink can.
2. Close the hole with your thumb and fill the can with water.
3. While holding the can over a catch basin, remove your thumb to show that the water falls out of the can.
4. Close the hole again and stand back about 2 meters (approx 6 ft) from the basin. Toss the can through the air to the basin, being careful not to rotate the can in flight.

5. Observe the can as it falls through the air. The water will not fall out of the can during the fall through the air.

Summary: This activity reinforced the concept of microgravity and freefall. While the cup is stationary, the water pours out, pulled by gravity; however, while the cup is falling, the water remains inside the cup the entire time it falls, as the water is falling at the same rate as the can.

Activity Three - Surface Tension and Microgravity

Purpose: Use observation skills to compare shapes and sizes of drops of water that are falling freely through the air and that are lying on a solid surface. This activity demonstrates surface tension and how it changes the shape of the fluid at rest.



Materials: water, liquid dish detergent, toothpicks, eyedroppers, wax paper squares (20 x 20 cm or 7.9 inches x 7.9 inches), paper, and pencil for sketching

Procedures:
1. Fill an eyedropper with water.
2. Carefully squeeze the bulb of the dropper to form a drop at the end.
3. As the water drops through the air, sketch the shape of the water drop. Repeat and sketch several drops. Compare the shapes and the sizes.
4. Place a small drop of water on a square of wax paper. Sketch the shape. Measure the diameter and height as best you can. Add a second drop of water. Sketch and measure.
5. Continue adding water to the first drop. What happens to the shape?
6. With the dropper, try to pull the drop over the wax paper. At some point, friction overcomes the surface tension and the drop breaks up. How large of a drop can you pull in one piece?
7. Add a small amount of liquid detergent to the drop. What happens?

Summary: Surface tension is a property of liquids wherein the surface of a liquid acts like a thin, easily bendable elastic covering. When water drops fall, they are spherical. When the water drop hits a surface, the molecules are attracted across the surface and inward. This causes the water to try to pull itself up into a shape that has the least surface area possible – the sphere. Because of gravity, the drops resting on a surface will fatten out somewhat. If liquid detergent is added, the soap molecules bond better than the water molecules, so the water molecules spread out more. The importance of surface tension research in microgravity is that surface tension driven flows can interfere with experiments involving fluids.

Activity Four - Shoot a Cannonball into Orbit

Purpose: Observe how freefall works by launching virtual cannonballs into space, and how objects stay in orbit around the Earth.

Materials: Computer with internet connection

Procedures:
1. Go to http://spaceplace.jpl.nasa.gov/en/kids/orbits1.shtml.
2. Select various amounts of gunpowder and click fire.

3. Observe what happens to the cannonball.
4. Use the chart on the next page to explain what happens to the cannonball for each amount of gunpowder used.
5. In your own words, explain what this activity teaches you about orbiting the Earth.

Summary: In order for an object to orbit Earth, a rocket must launch it to the correct height and provide the object with enough "forward" speed. If there is not enough "forward" speed, the object returns to Earth; too much speed results in the object zooming away from Earth. This activity reinforces the concepts of microgravity, freefall, and orbit.

Amount of gunpowder	What happened
1 bag	
2 bag	
3 bag	
4 bag	
5 bag	

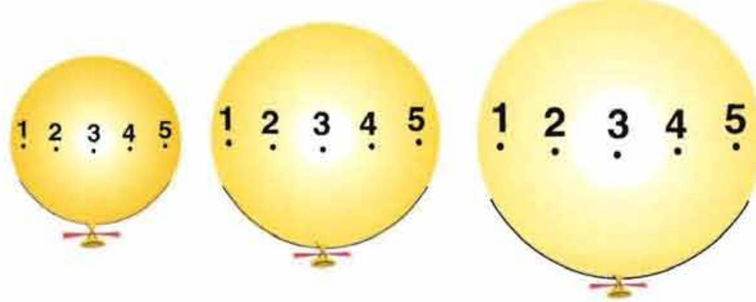
Activity Five - The Expanding Universe

Purpose: This activity demonstrates the concept of the expanding universe.

Materials: balloon, marker, twist tie or paper clip, measuring tape, paper, and pencil

Procedures:
1. Partially inflate the balloon. Fasten the neck of the balloon with the twist tie or clip.
2. Make several dots around the balloon and label each dot with numbers (1, 2, 3, and so on). See diagram below.
3. Measure and record the distance between each of the dots.
4. Remove the twist or clip, blow more air into the balloon and re-fasten the twist around the neck of the balloon.
5. Measure and record the distance between each of the dots again.
6. Remove the twist, fully inflate the balloon, and re-fasten the twist around the neck of the balloon.
7. Measure and record the distance between each of the dots a third time.
8. Discuss what happened to the dots as more air was put into the balloon. Discuss how this is like the expanding universe.

Summary: This activity simply shows that when more air is added to the balloon, the dots become farther apart. The dots represent stars, so as the air is expanded, the stars are farther apart. Some scientists believe that the universe is still expanding.



2 STARS

Learning Outcomes

- Define star.
- Define nebula.
- Describe the life cycle of a star.
- Interpret a Hertzsprung Russell diagram.

Important Terms

black hole - a region in space where no radiation is emitted
constellation - a grouping of stars, named after mythical figures and animals
light year - the distance light travels in one Earth year
magnitude - measure of the brightness of a star
nebula – gaint cloud of gas and dust
parsec – distance equal to 3.26 light years
pulsar - pulsating star that flashes electromagnetic emissions in a set pattern
star - a body of hot gases

STARS IN THE NIGHT SKY

Have you ever looked at the sky on a clear night, picked out a bright shining dot in the sky, and wondered if you were looking at a star or a planet? A **star** is a huge mass of hot gases. A star produces its own light due to nuclear reactions in its core. (A nuclear reaction in a star causes atoms in the star to change. This process results in the release of energy.) Planets and moons CANNOT create their own light. Planets and moons that appear as shining dots in the sky are reflecting sunlight. So, it may be difficult for you to determine if the light you see in the night sky is being reflected from the object or generated from within the object. When stargazing, you may want to use a star map to help you identify the stars visible in your location.

Our Sun is a star. Our Sun is the only star in our solar system, but when we look into the sky on a clear, dark night, we see a sky painted with a seemingly endless number of stars. Even though all the stars we see with our eyes are stars that are located in our own Milky Way Galaxy, they are very far away from us. In fact, the name of the closest star to us beyond the Sun is Proxima Centauri (also called Alpha Centauri C). Without a telescope, it cannot be seen in the night sky, and with a telescope, it can only be viewed from the southern hemisphere. Its stellar neighbors, Alpha Centauri A and Alpha Centauri B, are bright enough to be seen from Earth with the naked eye. Proxima Centauri is 4.2 light years from our Sun, and Alpha Centauri A and B are about 4.4 light years away. But, what is a light year?

MEASURING DISTANCES

Distances between the stars and solar systems vary and involve such high numbers of miles that it is staggering. Scientists, therefore, do not use miles, kilometers, or even astronomical units (which you will learn about later) to measure distances between stars. Instead, scientists use the unit of measurement known as light years and parsecs to measure such extreme distances. A **light year** is the distance light can travel in one Earth year. This amounts to 5 trillion 878 billion statute miles (5,878,000,000,000 miles). Just how far is that? The book *The Stargazer's Guide to the Galaxy* puts it into prospective by stating, "You would have to make 32,000 round trips to the Sun and back to travel the distance of one light year." So, our nearest star, Proxima Centauri, is 4.2 light years (25 trillion miles) away. This means that the light from Proxima Centauri takes a little over four Earth years to reach us. When the number of light years between locations gets very large, parsecs are used; one **parsec** is 3.26 light years, or 19.2 trillion miles.

Why can some stars that are far away from Earth be seen and others cannot? It is due to their brightness and distance from Earth. A star has a number of properties such as size, mass, temperature, color, and brightness. Additionally, stars vary in the amount of energy they generate in the form of light and heat energy. Different amounts of energy released result in stars having different temperatures, and the temperature of a star determines its color. So, whether or not a star is visible from Earth using our eyes only depends on the properties of the star, including the distance of the star from Earth. (See associated Activity Six at the end of the chapter.)

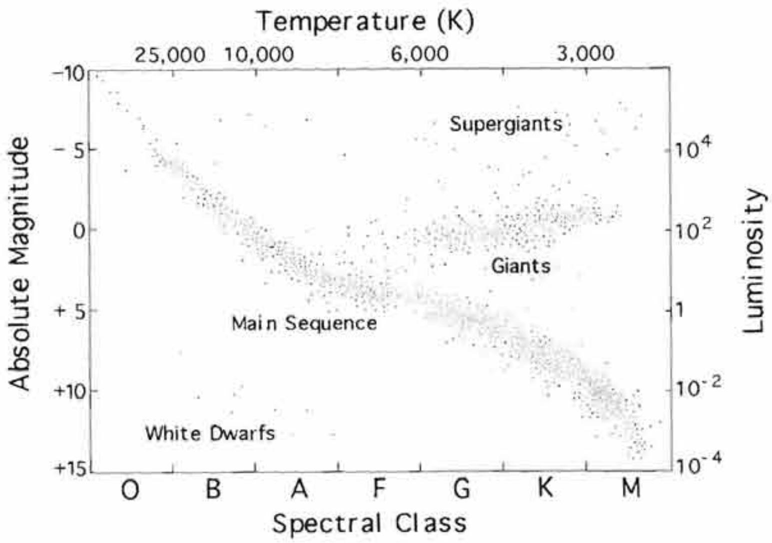
MEASURING BRIGHTNESS

Magnitude is a measure of the brightness of a star. The lower the magnitude number, the brighter the star. A higher magnitude number indicates a dimmer star. For example, a star of magnitude 1.1 is brighter than a star whose magnitude is 4.5. Some stars have a magnitude with a negative number, which indicates a really bright star.

There are two different kinds of magnitude for a star: apparent magnitude and absolute magnitude. Apparent magnitude is the measure of the brightness of a star as viewed from Earth. Absolute magnitude is the star's brightness as it would be viewed from a distance of 10 parsecs, or 32.6 light years from Earth, regardless of actually how far away the star is from Earth. Absolute magnitude gives us a better idea of the true brightness of a star. For example, the apparent magnitude of the Sun is -26.72, which indicates a very bright star. The reason the Sun appears so bright and has such a low apparent magnitude is because it is the closest star to Earth. The absolute magnitude of the Sun (the brightness of the Sun if it were viewed 32.6 light years from Earth), however, is +4.8. From Earth, a +4.8 magnitude star would appear dim.

Astronomers are scientists who study stars and other celestial bodies in space. An important tool that astronomers use to graphically organize information about stars and to see the relationships among them is the Hertzsprung-Russell diagram, called the H-R diagram. It is named after a Denmark astronomer and an American astronomer who independently developed the first kind of this type of diagram in the early 1900s. The diagram plots stars according to their absolute magnitude and surface temperature.

Many H-R diagrams also reveal a star's classification. Stars are classified according to temperature, and a star's



Hertzsprung-Russell or H-R Diagram

surface temperature is used to place it in one, single-letter classification. The letters O, B, A, F, G, K, and M each represent stars with a specific temperature range. The letters are arranged in decreasing temperature, with class O stars being the hottest and blue in color. Class M stars are the coolest in temperature and are the color red. Our Sun has a surface temperature of about 5,800 K; therefore, it is classified as a G star, where stars range in temperature from 5,500-6,000 K. (Reminder: Do not confuse this measurment of K with the star class of K. K stands for Kelvin and is a unit of measurement used by scientists to measure temperature.)

Class	Color	Temp (K)	Example	Life Span ('	Mass (x Sun)
O	deep blue	30,000+		1 million	40
B	bluish	11,000–30,000	Rigel	80 million	7
A	blue-white	7500–11,000	Sirius	2 billion	2
F	white	6000–7500	Procyon, Polaris	10 billion	1.3
G	yellow	5000–6000	Sun, Capella	20 billion	1
K	orange	3500–5000	Aldebaran	50 billion	0.8
M	red	<3500	Proxima Centauri		

Just as people go through different stages from birth to death, stars go through different stages in their life cycle. H-R diagrams reveal where stars are in their life cycle, a reflected by several characteristics, including temperture. (See associated Activity Seven at the end of the chapter.)

Nebulae

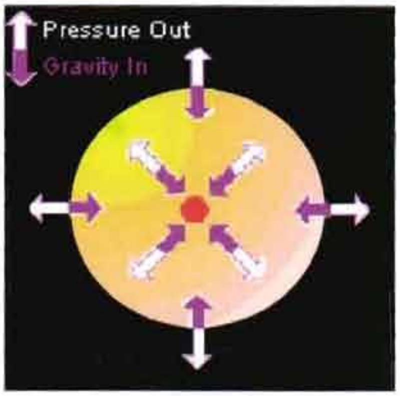
Horsehead Nebula

A STAR'S LIFE

Galaxies contain giant clouds called nebulae that are spread throughout the galaxy. A **nebula** (singular)is a cloud of gas and dust. The gases in these nebulae (plural) are made up of mostly hydrogen and a small amount of helium. Nebulae occur in regions where stars are forming, have exploded, or are shedding their outer layers toward the end of their lives. A nebula may be dark or bright. The dark nebulae are vast clouds of matter that have not yet formed into stars. The bright nebulae may be studded with stars and send forth brilliant arrays of color. Some bright nebulae, such as the Crab

Nebula, are the remnants of supernova stars that have exploded. Nebulae spin and move and give a galaxy shape. Nebulae can also produce stars.

As a star begins to form, clumps of gases and dust come together. Most stars are composed of hydrogen and helium in their gaseous state. Stars have their own gravity and this gravity brings in and holds the gases together. The gravity pulls inward and the pressure from the hot gases drives outward. This creates a balance, preventing the star from collapsing under its own weight. The intense heat of a nebulae star releases energy in the form of light and heat. A star's fuel is the hydrogen that it is converting to helium. Once the hydrogen is gone, the star can begin converting helium into carbon, which is a heavier element than hydrogen. Some massive stars can even generate elements heavier than carbon. The bottom line, however, is that once the star's fuel is gone, the balance between its gravity and pressure is gone. This will result in the star's death. Let's investigate a little further about the life cycle of stars.

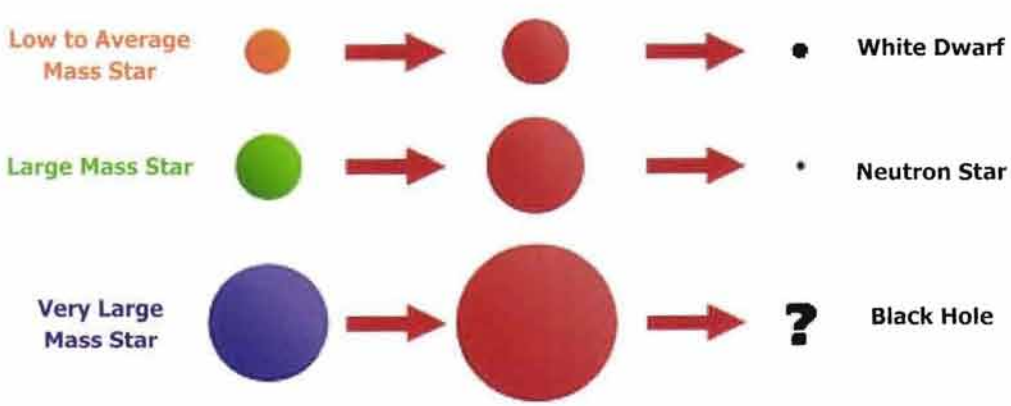


Star balance

LIFE CYCLE OF STARS

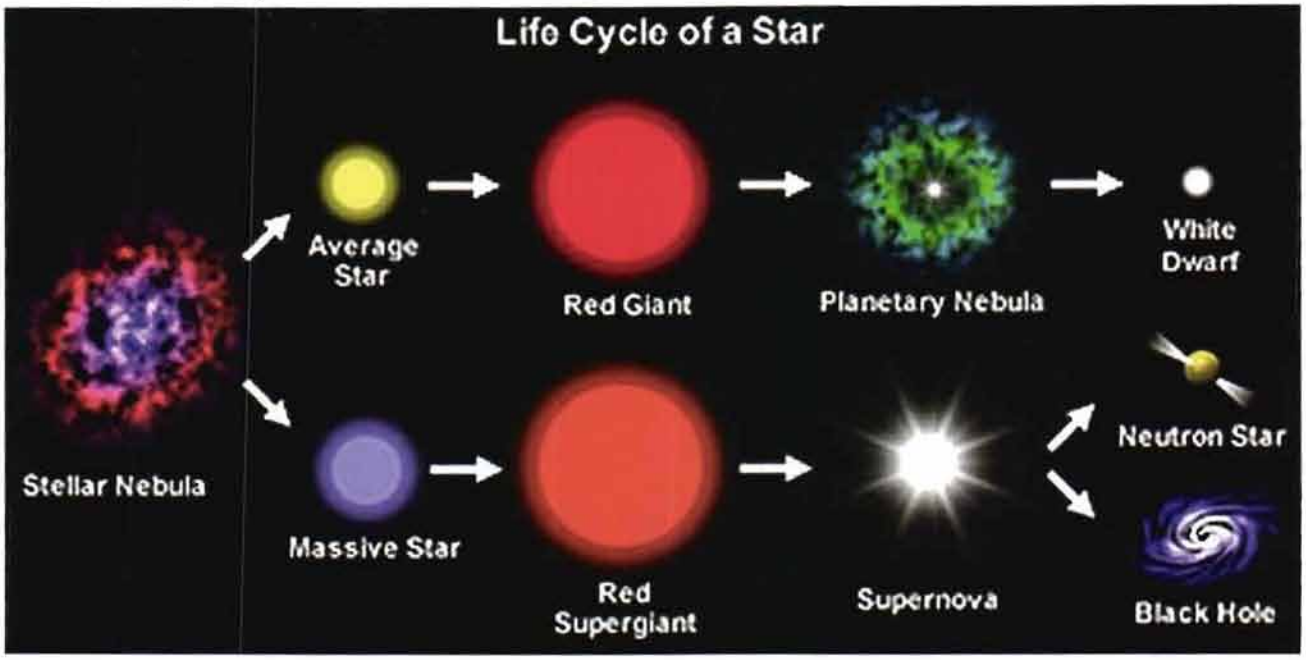
A protostar is the term used to identify a ball-shaped material within a nebula that could become a star. Just like humans begin as a fetus in the mother's womb, a star begins as a protostar in a nebula. During this time, clumps of gas and dust are coming together at a central gravitational point somewhere within the nebula, and the disk of gas and dust surrounding the protostar spins. As gravity draws in more clumps, more atoms are colliding and generating heat. Nuclear fusion, which occurs when temperatures are hot enough and pressure is great enough for the nuclei of atoms to fuse together rather than being repelled, can occur with very light elements at around 1 million Kelvin (K). This will cause the protostar to glow. Over a long period of time, the protostar may become a star if its core gets dense enough and hot enough to begin hydrogen fusion. Hydrogen fusion, a type of nuclear fusion, occurs in a star at around 10 million K. When hydrogen fusion occurs in a star, the hydrogen atoms fuse together to form the heavier element helium. When hydrogen fusion occurs, the protostar has become a star, and the mass of the new star will determine how long it lives and how it will die.

Once hydrogen fusion is occurring and the star is no longer growing, a star enters the main sequence phase, where it will spend the majority of its life. You might think of this phase as encompassing early life through adulthood. During this time the star is burning its fuel, hydrogen. This results in hydrogen atoms fusing together to form helium in the core of the star. The star will do this for the majority of its life.



The fate of a star depends on its mass (size not to scale)

If the star is a high mass star, it may spend only a few million years in the main sequence phase. A high mass star is described as a star that has 8 times or more the mass of the Sun. A medium mass star is described as having less than 8 times the mass of the Sun, but at least 0.5 times the mass of the Sun. If a star has medium mass, like our Sun, it spends billions of years in the main sequence phase. Low mass stars are described as having less than 0.5 the mass of the Sun. If the star is a low mass star, it is believed that it will spend hundreds of billions of years, perhaps even trillions of years, in the main sequence stage. The lower the mass of a star, the longer the star's life. The higher the mass of a star, the shorter the life of the star. (A short life is really millions of years, compared to billions or trillions of years.)



Medium Mass Stars

Medium-sized and medium mass stars like our Sun will live for billions of years. Stars like our Sun will expand into a red giant star toward the end of their lives. A red giant star's hydrogen fusion stops in its core, causing the star to begin to shrink inward due to gravity becoming greater than the gas pressure pushing outward. As this happens, it causes the star to heat up more, causing hydrogen outside its core to begin fusing. When that happens, the star's outer layers will expand a great deal. The surface temperature of a red giant cools to about 3,000 K as the heat spreads across a much larger surface area. The size of the star makes it appear bright, and the surface temperature of the star causes it to be red in color. (Remember that the surface temperature of a star affects its color.) The internal temperature of the red giant will get hot enough to support helium fusion in its core. Once it has burned all of its helium and once the core is no longer hot enough to support nuclear fusion, the star will begin to contract again. This time, it will cause such a great amount of energy to be released that the star will balloon out again. Just how large can a red giant become? It is believed that when our Sun becomes a red giant, it will grow so large that it could expand as far as the orbit of Earth, and maybe Mars! Think of a red giant star as a middle-aged star.

After millions of years, or maybe even close to a billion years living as a red giant star, the Sun will eventually collapse to become a white dwarf, which is the remaining core of the star. (Remember that it will collapse because its fuel supply is gone, so it can no longer maintain a balance between gravity pulling material in and the gas pressure going outward.) The outer layers of the once red giant blow off and become a nebula. The clouds of gas and dust can continue to move away revealing just the white dwarf. As a star becomes a white dwarf, it has a glowing hot temperature of around 100,000 K. White dwarfs have a mass about 1.4 times that of the Sun, and for many, their size will be about the size of the Earth. Although a white dwarf has no more fuel, it will cool very slowly. This dense star will glow until it has completely cooled, which may take billions of years. Once it no longer gives off any light, it becomes a black dwarf, marking the end of the star's life cycle. Since scientists believe that the universe isn't old enough to contain any black dwarfs yet, scientists report that there are currently no black dwarfs in existence.

High Mass Star

A high mass star will not end its life as a black dwarf. Once it moves out of the main sequence phase, it will become a red supergiant. Stars with a solar mass at least 8 times that of the Sun will be able to fuse together heavier elements. As was the case with the red giant fusing hydrogen outside its core, a red supergiant will be able to fuse helium outside of its core, and fuse hydrogen in a layer beyond the helium fusion. Different types of fusion will continue to take place in the core and in the other layers of the star due to the extreme temperature and pressure of the massive star. Elements, such as oxygen, nitrogen, and iron, will be created. The star's fuels will eventually run out, and the iron atoms will release a huge amount of energy. When this happens, the massive supergiant will explode. A star that explodes is called a supernova. When this occurs, matter is blasted out in many directions. This material can be used to create new stars in new nebulae.

Supernova

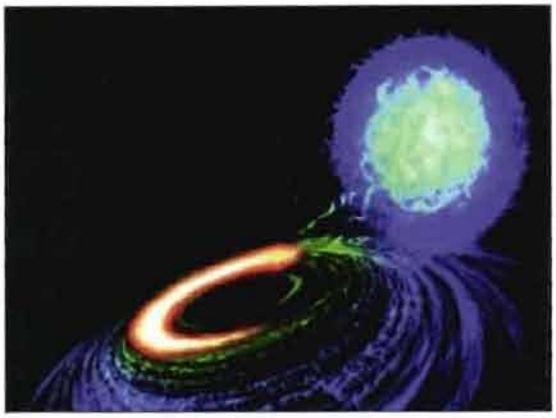
The remaining core of a supernova will either be a neutron star or a black hole. The remaining core of a supernova becomes a neutron star if it has less than 3 times the mass of the Sun. A neutron star is made up of neutrons, and its initial temperature is around 10 million K. It is difficult to detect neutron stars, however, because of their small size. They are much smaller than a white dwarf. Remember that a white dwarf is about the size of Earth. A neutron star is a sphere that is typically about 12 miles (20 km) in diameter. Although small in size, one teaspoonful of a neutron star would weigh about a billion tons on Earth. That's dense!

As NASA and World Book report, *"A neutron star actually emits two continuous beams of radio energy. The beams flow away from the star in opposite directions. As the star rotates, the beams sweep around in space like searchlight beams. If one of the beams periodically sweeps over Earth, a radio telescope can detect it as a series of pulses. The telescope detects one pulse for each revolution of the star. A star that is detected in this way is known as a pulsar."* A **pulsar** is known as a pulsating star because it flashes electromagnetic emissions in a set pattern. The astronomers who discovered a pulsar first thought Earth was being sent signals from intel-


Pulsar is in the center of the supernova Kes 75

ligent life in another solar system.

If the remaining core of a supernova has 3 or more times the mass of the Sun, it implodes creating a **black hole**. Its gravitational force is so strong, nothing can escape from it. As reported on NASA's Imagine the Universe Web site, *"But contrary to popular myth, a black hole is not a cosmic vacuum cleaner. If our Sun was suddenly replaced with a black hole of the same mass, the Earth's orbit around the Sun would be unchanged. (Of course the Earth's temperature would change, and there would be no solar wind or solar magnetic storms affecting us.) To be 'sucked' into a black hole, one has to cross inside the Schwarzschild radius. At this radius, the escape speed is equal to the speed of light, and once light passes through, even it cannot escape. If the Sun was replaced with a black hole that had the same mass as the Sun, the Schwarzschild radius would be 3 km, or 1.9 miles, (compared to the Sun's radius of nearly 700,000 km or 434,960 miles). Hence, the Earth would have to get very close to get sucked into a black hole at the center of our Solar System."*



Black Hole

Black holes can be detected by X-rays that are shed as matter is drawn towards the hole. As atoms move closer to the black hole, they heat up. When the atoms heat up to a few million K, they give off X-rays. These X-rays are released before they cross the Schwarzschild radius, and we can, therefore, detect them.

Low Mass Stars

As mentioned earlier, low mass stars have the longest lives. The low mass stars have a solar mass of about less than half the mass of the Sun down to about a 0.08 solar mass. They have a cooler temperature than intermediate and high mass stars. Red dwarfs are low mass stars and are the most common kind of stars in the universe. Our nearest star, beyond the Sun, Proximus Centauri, is a red dwarf. Red dwarfs cannot be seen using just our eyes. After their long duration as a main sequence star, they will become white dwarfs and eventually black dwarfs.

In a binary star system known as J0806, two dense white dwarf stars orbit each other. The stars seem destined to merge.

It is possible for an object with less than 0.08 solar mass to form; however, these objects are known as brown dwarfs, or failed stars. The failed stars are too cool to ever achieve hydrogen fusion. They are very hard to detect because they are so small and extremely dim.

MULTIPLE STARS

Of stars that do form, many have a second star with which they share the same center of gravity. The brighter of the two is called the primary star and the other is called the companion star. About half of all stars come in pairs with the stars sharing the same gravitational center. These are called binary stars. When looking at the night sky, a star that looks like a single shining star could actually be part of a binary system.

(a) Southern horizon, summer **(b) Southern horizon, winter**

A **constellation** is a grouping of stars. Hundreds of years ago, early astronomers divided stars into groups and made imaginary figures out of them. Things like a lion, a scorpion, or a dog were used. This is how constellations were named. The stars in these constellations are not really related; they only appear to be as we view them from Earth. There are 88 constellations in use by astronomers today. Some of the more well known ones are: Ursa Major (the Big Dipper is part of it), Orion, and Cassiopeia. (See associated Activity Eight at the end of the chapter.)

Summary

This chapter revealed to you interesting information about stars. Stars are huge masses of gases that give off light and heat energy due to nuclear fusion occurring in their cores. Remember that a star's mass will determine how long it will live and how it will die.

The next chapter begins a study on our solar system, looking specifically at our Sun, Moon, and a few other celestial bodies, such as comets, meteors, and asteroids.

ACTIVITY SECTION 2

Activity Six - Analyzing Starlight

Purpose: The purpose of this activity is to show the difference in wavelengths of various light sources by making a simple spectroscope.

Materials: You must plan ahead, and this activity involves a cost. To do this activity you must purchase diffraction grating. Edmund Scientific, 101 East Glouchester Pike, Barrington, New Jersey 08007-1830 sells it. Their phone number is (609) 573-6250 and their website is www.scientificsonline.com. Two sheets of diffraction grating measuring 6"x12" costs less than $10. These sheets will need to be cut; one sheet will make 18 two-inch squares. You also need one cardboard tube per person (paper towels, toilet tissue, or gift wrapping tubes), scissors or hobby knives, cellophane tape, colored markers or pencils, typing or computer paper, and flashlights or other light sources. (Twenty-five diffraction gratings mounted in 2"x2" cardboard slide mounts can be purchased for $21.95. These can be used straight from the package to build a set of spectroscopes.)

Procedures:

1. Cover both ends of a cardboard tube with paper and fasten with tape.
2. Make a thin slit in the paper at one end of the tube. (Only a narrow band of light should show through this slit.)
3. Make a small hole (1/8") in the paper at the other end of the tube.
4. Put the diffraction grating over the small hole and fasten it with tape.
5. Point the slit toward an available light source. Use a flashlight or other light source, do not look directly at the Sun.
6. Move the tube slowly to the right or left so as to make an image appear.
7. Using a sheet of paper, sketch the light pattern observed using the colored markers or pencils.
8. Observe two other light sources, if possible, and sketch the light patterns observed.
9. Compare and discuss each light-source pattern.

Summary: A diffraction grating is a tool that separates colors in light. Using this tool helps to create a spectroscope, which will allow you to see the light patterns and color spectrums of different light sources. Stars give off light, and as such, they have different light patterns. The spectroscope can help you see the light patterns of stars in the night sky.

Activity Seven - Measuring the Brightness of the Stars

Purpose: This activity is designed to determine approximate magnitude of stars.

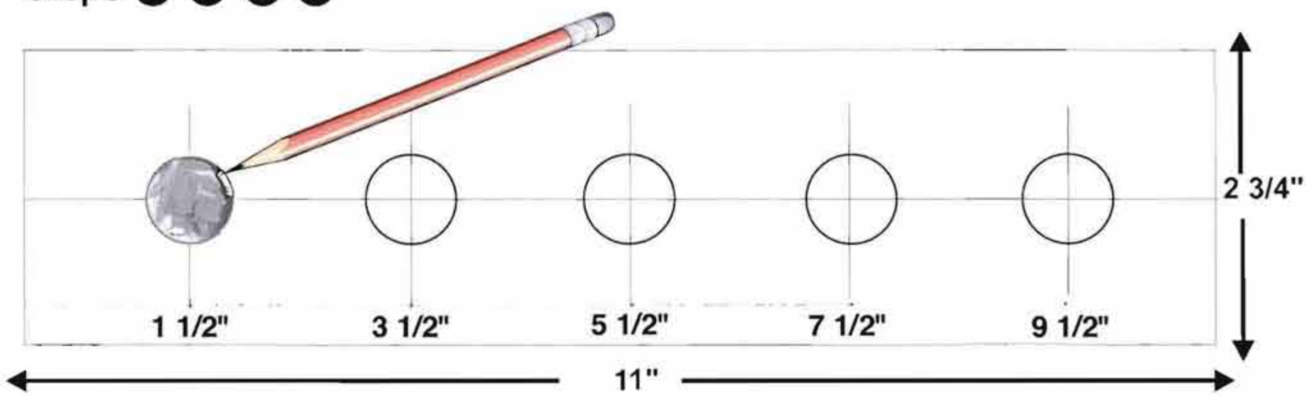
Materials: 2 pieces of cardboard (or 2 file folders), a strip of clear cellophane, nickle, pencil, scissors or exacto knife, stapler, and ruler

Procedures:

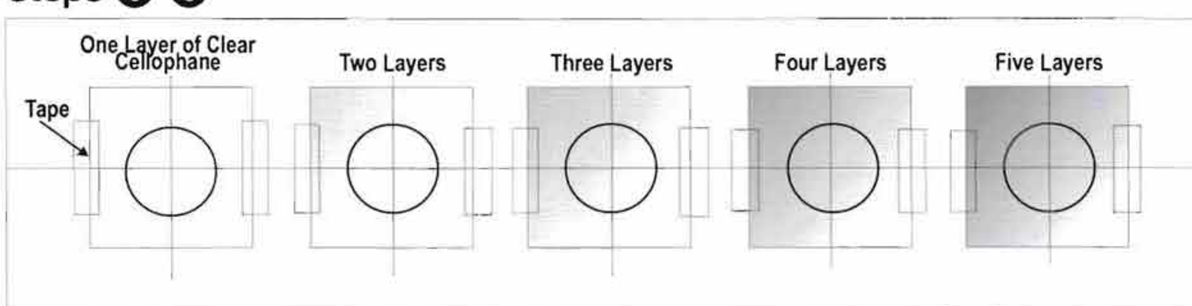
1. Cut two pieces of cardboard, 11" long by 2-3/4" wide.

2. Use a ruler to mark one cardboard at five equidistant points: 1-1/2", 3-1/2", 5-1/2", 7-1/2", and 9-1/2".
3. Use a nickel to trace a circle over each of the marks, centering the circles between the top and the bottom edges of the cardboard strip. Carefully cut out the five circles.
4. Trace the cutouts onto the second piece of cardboard. Carefully cut out these five circles, too.
5. Cut 15 squares of cellophane, each 1-1/2"x1-1/2".
6. Working with one strip of cardboard, cover the first hole with one square of cellophane; cover the second hole with two squares of cellophane; cover the third hole with three squares of cellophane, the fourth hole with four squares of cellophane; and cover the fifth hole with five squares of cellophane. Use small pieces of tape to secure the squares, as necessary.
7. Carefully place the second piece of cardboard on top of the secured cellophane squares, being certain to line up the holes in the two pieces of cardboard. Staple the cardboard strips together.

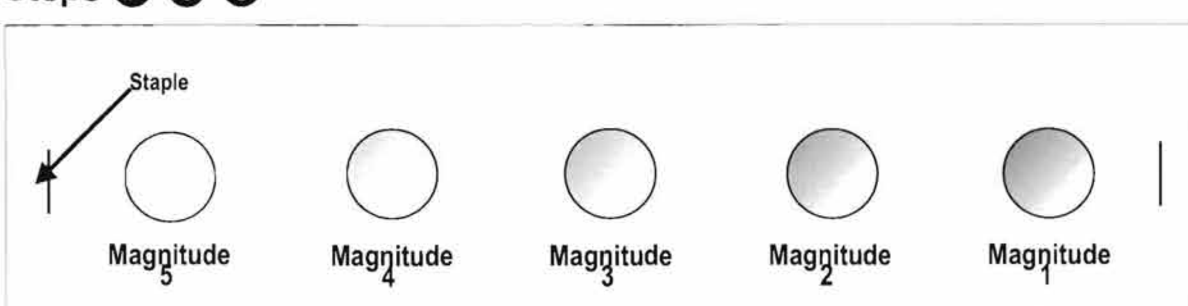
Steps ❶ ❷ ❸ ❹



Steps ❺ ❻



Steps ❼ ❽ ❾



8. Label the hole covered with five squares of cellophane as magnitude 1; label the others in order, with the hole having only one piece of cellophane over it being labeled as magnitude 5.
9. To use the magnitude strip begin by looking at a star using only your uncovered eye. Then look at the star through the magnitude strip, looking through hole 1. If you can see the star through hole number 1, the star is a first magnitude (or brighter) star. If you cannot see it, try looking through the hole 2. Keep moving down the magnitude strip until you can see the star. Stars that are seen through the 4th hole are fourth magnitude stars; stars that can not be seen through the fifth hole, but can be seen with the uncovered eye, are sixth magnitude stars.

Summary: Magnitude refers to the brightness of a star. Observing stars through the magnitude strip reveals the approximate magnitude of the stars, ranging from a first magnitude star (very bright and can be seen through five layers of cellophane) to a sixth magnitude star (dim stars that could not be seen through the magnitude 5 hole on the magnitude strip, but could only be seen with a clear view from the uncovered eye). Knowing the approximate magnitude of stars can help better judge approximate age and distance, as explained in the chapter.

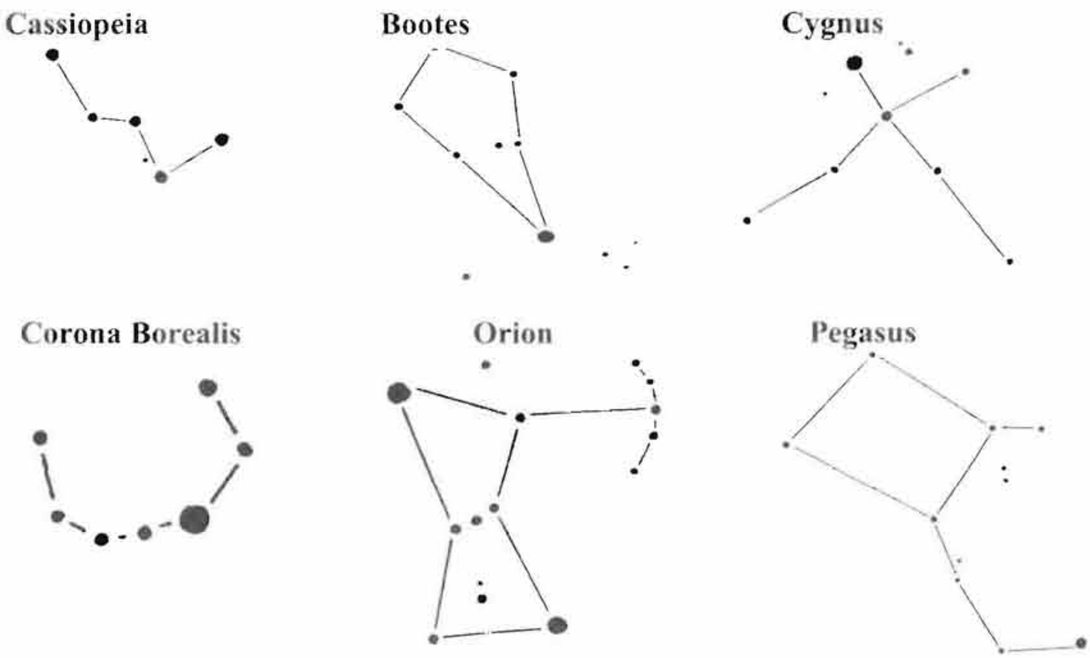
Activity Eight - Astronomy In A Tube

Purpose: Become familiar with star patterns (constellations) visible in the night sky.

Materials: an empty Pringles potato chip can with its opaque plastic lid, black construction paper, hammer, nail, push pin (or similar item), scissors, constellation pattern, silver marker (or similar writing tool)

Procedures:
1. Draw a constellation pattern from the patterns below on a 2.75 inch circular piece of black construction paper using a silver marker or some other visible writing tool.

CONSTELLATION PATTERNS



2. Use a pushpin to make a small hole in the center of each star in your constellation and cut out the circular paper pattern.
3. Using a hammer, put a nail-sized hole through the center of the metal end of the Pringles can cover. (SAFETY: Use caution hammering the nail. Adult supervision is recommended.)
4. Place your piece of circular black paper under the plastic lid of the potato chip can, put the lid on the open end of the can, point the constellation drawing toward a light source, look through the hole in the metal end of the can, and see the star pattern as it would appear in the night sky.

Summary: Stars are arranged in groups which we refer to as constellations. This activity emphasizes selected star patterns visible in the night sky. It is hoped that a greater interest in specific constellations will lead to deeper investigation into the wonderment and ever-changing night sky throughout the year.