

Introduction to Astronomy

From Darkness to Blazing Glory

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The moon Titan is in the forefront with the moon Tethys behind it.

These are two of many of Saturn's moons

Credit: Cassini Imaging Team, ISS, JPL, ESA, NASA

Introduction to Astronomy



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- **All homework assignments are located on the student DVD.**
- **Additional support items are found on the website:
Introastro.com**
- **Reports and projects are supplied by teacher.**

This book is an **introduction** to Astronomy. While providing education, the book is meant to spark passion for the science and the space industry by highlighting discoveries and outcomes. Do you want to be a part of this exciting field? Our nation needs your help to continue to reach new heights in space science and industry. Be sure to check the end of your CD for professional opportunities.

As we begin our study, take a moment to ponder where we are in space and what we live on; a very special planet.



A beautiful earthrise over our Moon
Photo courtesy of NAS

A note to the reader:

The Earthrise photo was taken by a man standing on the Moon, looking back at his home planet, Earth. The ground upon which he was standing used to be a part of Earth. The Moon used to be so close to us that much of the horizon would have been half covered by a primordial moonrise. This desolate satellite is slowly drifting away, at a rate of a little over an inch a year.

Something to ponder... If I am looking through a telescope at a man up on the Moon, and he is looking up through telescope at me on Earth at the same time, how can we *both* be looking *up* at each other? **Please discuss this dilemma.**

A virtual vacuum of space surrounds our planet. It can be airless, dark, and cold. Or it can be radiation filled, bright and hot. You will learn why and what is in the Universe and how it works.

Please explore the book and DVD much as scientists explore the Universe, with a questioning spirit and a curious mind. While reading you might want to ask yourself a few questions:

- What, or who, created the Universe?
- Does it exist for a purpose, or is it a random place that is devoid of reason?
- What unanswered questions remain about the Universe?
- What is in this book and DVD that could apply to your life?

The information in this book represents a sampling of what has been discovered about our planet, our star, our solar system, and beyond. If you find this field of study interesting there are videos, books, lectures, web sites, articles, conventions, workshops, magazines, and college courses available. Stay updated on the constant flow of information concerning new discoveries resulting from the exploration of space.

Jeff Scott

Chapter 1

Astronomy Basics



Tour Guide



**REQUIRED WORK:
HOMEWORK CD
WORKBOOK: PAGES 1 - 4
TEST PROVIDED BY
THE TEACHER**



**REQUIRED WORK:
HOMEWORK DVD
WORKBOOK: PAGES 1- 4
ASTRONOMY BASICS TEST
(TEACHER PROVIDED)**



A photo from the Hubble Space Telescope
Courtesy NASA

What is astronomy? When did it begin? Astronomy is a study of virtually everything beyond earth. The academic discipline includes studying planets, solar systems, stars, galaxies, comets, asteroids, nebulae, moons and the Universe itself. You will learn about these fields of study as you read this book.

Astronomy has produced a relatively new field: astrobiology. So far, this scientific endeavor only speculates about possible alien life. But, as you will study in this book, there are possibilities of alien life even inside our solar system. Part of the astronomical science community is actively listening for new signs of life in the **cosmos** (Another word for universe.). This organization is called the **SETI** Institute. The abbreviation stands for: **Search for Extra Terrestrial Intelligence**.

A very active part of astronomy consists of teams of astronomers looking for **exoplanets**. These exoplanets are circling stars outside our solar system. Literally hundreds of these planets have been found. Several new ones are discovered every month.

Many new discoveries that have

been made over the last 40 years have been heavily computer dependent. Modern astronomy relies upon technology, math and scientific method.

SKILLS AND TOOLS OF THE TRADE

Astronomy is a visually - based science. The skill of careful observation is essential to understanding and discovery. Many astronomical skills were developed as long as 5,000 years ago. Before written history began, people had noticed the interrelationships between the Sun, Moon and the Earth. Observations resulted in a rudimentary understanding of the timing of days, nights, monthly patterns of moonlit shapes and the seasons. Missing were scientific reasons for these events. When there were no answers for natural occurrences, observers concluded that it was caused by actions of the gods.

Astrology and its **astrologers** were cosmos based, religious fortune tellers and “the gods’ will”, messengers. They closely studied the stars, planets, the moon and sun and then tried to derive meaning for their movements. At times important decisions (war, marriages, coronations, etc.), were timed because of predictions put forth by these astrologers.

Some of their observations were quite helpful. They could advise when to plant and harvest. They could determine when the next full moon night would occur. For those who lived near coasts, they could predict tides. They learned to use star patterns for day and night time navigation.

The skills of writing and mapping drastically improved this combined religion and science of astrology and astronomy. By

mapping and writing down observations, others were able to reutilize the saved information. Soon they were able to not only observe, but also *record* and *predict* astronomical events over long periods of time.

The study of astronomy/astrology became an important development in the history of civilization. Skills of predicting weather patterns and seasons allowed man to time harvests. From this, each man no longer had to just hunt, gather and maintain flocks. Agriculture was developed, creating greater food supplies this led to larger populations, spare time to build, invent and develop communities.

Star observation and mapping allowed for the navigation of new land and sea routes. Trade and exchanges of ideas developed between cultures. Over time, ancient civilizations gained wealth, power and improved technology based on the increased amounts of food and trade, that was inspired by studying the cosmos.

Mathematics was integral to the advancement of astronomical studies. The ancient people of Egypt and Greece developed algebra and geometry. Through these math skills and little else, a Greek citizen named **Aristarchus**, in 270 BC first figured out how far the moon was from the earth.

This brings us to another important component: philosophy. Greek philosophers developed this rational process of thought. This skill is the foundation of astronomy. We now call this process: the **scientific method**:

- 1) Propose a question.
- 2) Observe and research.
- 3) Construct a hypothesis.
- 4) Check it through experimentation.

- 5) Draw a conclusion. (It may be supportive of the hypothesis, or prove the hypothesis wrong. If wrong, go back to step 3)

- 6) Record or report the results. Often the results can bring additional questions.

Maybe it was not always the “gods”: was there a natural, rational reason?

Observation, recording through pictures and writing, mapping the skies, advance mathematics, and scientific methods are the foundations of astronomy.

When paganism declined (worship of several or many gods) and the influences of monotheism which is a worship of one all powerful god, (Judaism, Christianity and Islam) arose, astrology as a popular religion declined. No more of Apollo riding the sun chariot across the sky!

Astrology, as found today, is no longer dominant over astronomy. It is looked upon as a superstition that tries to tie the cosmos to fortune telling, personality traits and daily life.

THE NEXT STEP: WESTERN ENLIGHTENMENT

Western culture suffered serious setbacks when the Roman Empire was shattered during the 5th century AD. The Dark Ages began in Western Europe and centuries of learning were lost. It took a thousand years before science in western culture regained what had been forgotten. The fifteenth and sixteenth centuries were the time of the **Renaissance** (or rebirth) of learning. This occurred mainly in Italy. It established the scholastic ground work for

modern astronomy. This was a time when ancient writings of a thousand years before found their way back into books of Western Europe.

(Some) of what was relearned turned out to be false. But other knowledge, including advanced math and the rational thought, were used as the skills needed to allow modern western culture to expand

The Catholic Church accepted the ancient philosophies of the Universe, including **Ptolemy's** theory that the sun orbited the earth and that the earth was the center of the universe. This was challenged by two men and one instrument. The men were **Nicholas Copernicus (Niclas Kopernik)** and **Galileo Galilee** and the instrument was the *telescope*.

Copernicus, a Polish mathematician, was educated in medicine, mathematics, astronomy and *astrology* in Poland and in renaissance Italy. He proved through math and observations the earth rotates on an axis and that the earth circles the sun, not visa versa. He published a treatise on this matter in 1543, the same year he died, called the De Revolution Bus Erbium (in Latin). In it he called the **heliocentric system** the logical explanation of the earth's relationship to the sun. This was first put forth by Aristarchus, a Greek philosopher who lived 1,800 years earlier than Copernicus.

Some of his views were twisted and spun by a friend who had the book published and had changed the title to include the word "theory". This same man, without consent, then wrote in the book that the heliocentric system may prove to be false. Copernicus saw his published book while he was in a very weak state on the last day of his life. He never read the revisions.

At first those who opposed Copernicus' writings were the newly rising Protestants. About 70 years later his ideas were also opposed by the Catholic Church. **Galileo Galilee** brought them forth to support his own findings. He opposed the Catholic Church backed – Platonic (**Plato**) version, that the earth was at the center of the Universe and all celestial objects circle the Earth. This belief was rather remarkable considering the fact that Galileo became a priest in his later years.

Galileo did not **invent** the original telescope, but he was the one who first turned it toward the Heavens.

He was excellent at math and had a keen scientific mind. This combination of technology and skill advanced the studies on astronomy.

Here are some Galilean quotes that best sum up his attitudes towards: science, ignorance, government and church:

1) The Cosmos and Math:
“(The universe) cannot be read until we have learnt the language and become familiar with the characters in which it is written. It is written in mathematical language and the letters are triangles, circles and other geometric figures, without which means it is humanly impossible to comprehend a single word.”

2) Governing the Scientists:
“In questions of science, the authority of a thousand is not worth the humble reasoning of a single individual.”

3) The Church and Science:
“I do not feel obliged to believe that the

same God who endowed us with sense, reason and intellect intended us to forgo their use.”

4) The Second Guessers and: Detractors:

“All truths are easy to understand once they are discovered; the point is to discover them.”

Galileo, an Italian born 21 years after the death of Copernicus, studied medicine but also had a keen interest in mathematics and astronomy. Although he is best known for his ideas on astronomy, he also discovered the secrets of the pendulum, later the basis for his ideas about making a pendulum clock. (An example of this style of time piece is the grandfather clock.)

However, his most famous invention was a telescope that could magnify up to twenty times what can be seen by the naked eye. He searched the skies and even closely observed the sun. Galileo made significant discoveries concerning the Moon and Jupiter.

Galileo thought he saw oceans or seas on the surface of the Moon. These areas he named: “mare” (sea in Latin.) They are still called by the same names today, even though there are no seas on the Moon. He found spots on the sun. He observed a **supernova**, (exploding star). He found four moons circling Jupiter. He thought that Jupiter might be a star with its own solar system. Not a bad guess at the time.

Galileo Galilee read the works of Copernicus, tried out the math and agreed with findings. He published his works concerning the verification of the heliocentric system and ended up in the **Inquisition**, a court held by the Catholic

Church to try people accused of religious **heresies** that run counter to church doctrine. He was tried twice and the second time he was convicted and spent the rest of his life under house arrest. He died in 1638, at the age of 74, a blind man. (Don’t make the mistake Galileo made when he studied the sun through a telescope!)

As time went on, the Catholic and Protestant churches accepted the new discoveries and loosened religious control over scientific research and their findings.

With the use of math and telescopes many discoveries have been made. All the planets were located. Many asteroids and comets were not only tracked but their physical characteristics were better understood. Physics was tied to astronomy by **Sir Isaac Newton** and his laws of gravity.

DID YOU KNOW?

Gravity is the glue that keeps the entire Universe together. It is a force of attraction that binds particles together to form atoms and so on, up the scale to the mass of the Universe itself.

The greater the cumulative mass, the greater the attracting power. Gravity attraction can be mutual. The greater the distance between objects the less gravitational influence or attracting power.

Edwin Hubble discovered that our galaxy was not the total Universe, but was one of many. **Albert Einstein**, a

mathematician and astrophysicist, created formulae explaining space/ time, dimensions and how they related to each other. By the mid 20th century: *nebulas*, more moons and more of the size and scope of our universe had been discovered.

Recently, a now integral organ was added to the body of astronomical studies: the *computer*. Vast amounts of information were processed, allowing more advanced explorations and the use of more tools that continue to provide amazing discoveries. Computers become more and more powerful. A hand calculator that one can buy at the store holds more computing power today than the Apollo astronauts had when their capsule went to the moon in 1969.

Without computers, **exoplanets** (planets beyond our solar system) could not have been discovered. The Big Bang theory could not be adequately studied. We could not look for asteroids and comets that are dangerous to us. **Satellites**, orbiting spacecraft that provide communications and observations, would not have been invented. Nor could probes go into the depths of space. Without the computer, the academic advancement of astronomy would have stalled some fifty years ago.

WHERE WE ARE NOW ?

The United States was at the forefront of astronomy for decades. Our engineering and advanced technologies, backed by a flourishing economy, allowed us to explore the Cosmos. The Soviet Union, (Russia) also provided important and practical additions to astronomy and space exploration. China has now entered the manned space environment. (China put a

man into space with their own rocket over forty five years after America and Russia had done so, which tells how difficult and expensive that effort was.)

Today space sciences and the associated government agencies are changing the emphases of program funding. The Shuttle Program is shutting down. Privatized, low orbit, space flights are being encouraged. American plans of revisiting the Moon have been postponed or possibly cancelled. The American plan of sending humans to Mars is being discarded. These were safety, technological, political and economic - based judgments. Robotic and computer - based probes will be emphasized. NASA will prioritize a sizable sum of its future budget to observe climate changes.

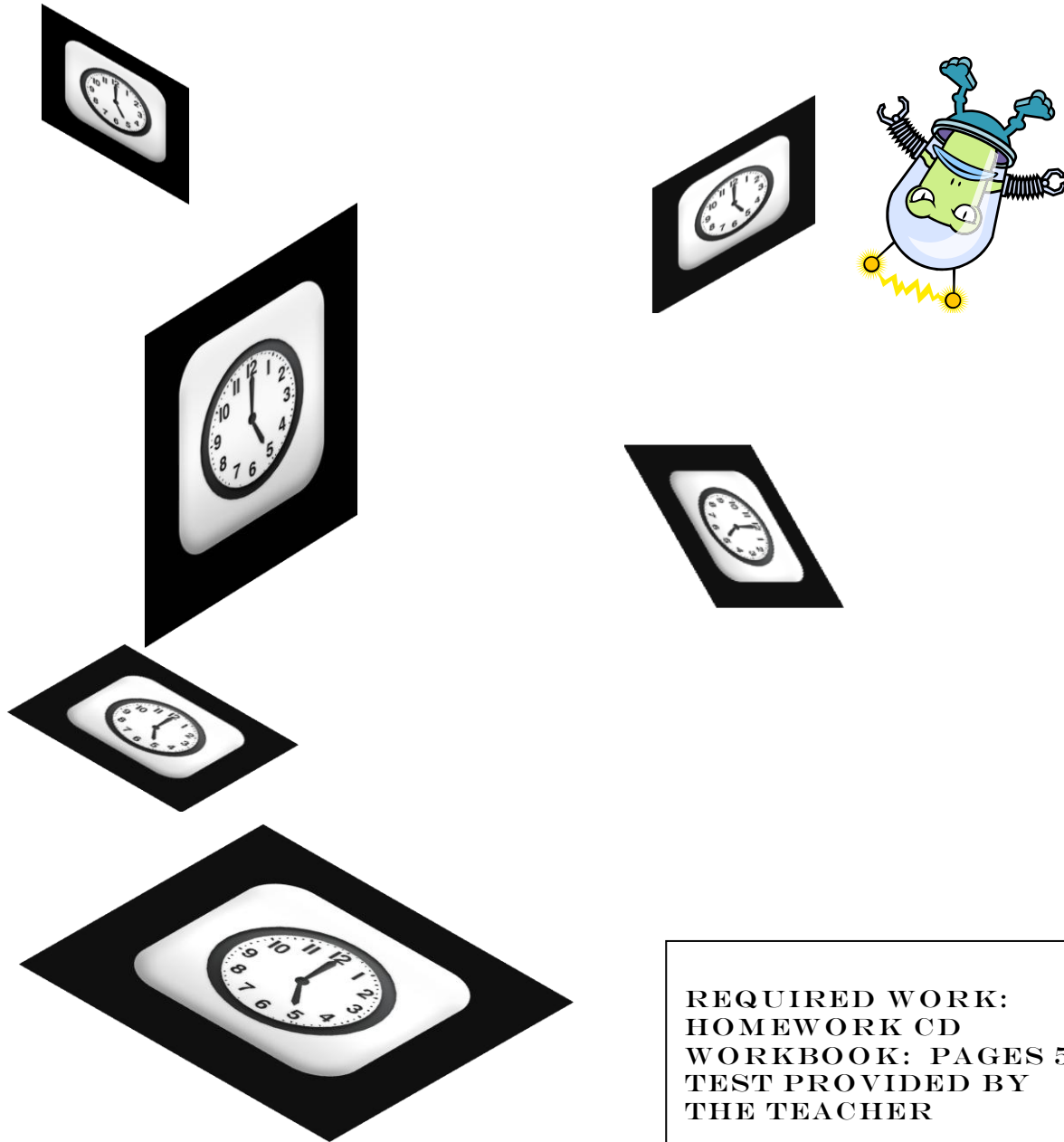
Indian, Japanese, European, Chinese and other space programs are becoming more sophisticated. In 2011, the Russian's rockets and their capsules will be providing the only way for our astronauts to get rides to and from the International Space Station. Chinese "**taikonauts**" (Chinese astronauts) may be the next to step on the Moon. Will this change again? Will America keep dwindling in its dominance in space sciences and exploration?

That will be a decision that is up to you, your fellow Americans and your elected leaders.

Workbook Pages 1 - 2

Chapter 2

Time



**REQUIRED WORK:
HOMEWORK CD
WORKBOOK: PAGES 5- 6
TEST PROVIDED BY
THE TEACHER**

There is a day and there
is a night.
There is a dark and
there is a light.
Why is it dark during
the night?
Why is the day so
very bright?

Do you know what time it is? *By the way, do you really know what “time” is?* In this section you will learn about the meaning and usage of time on Earth.

For thousands of years our ancestors did not have a scientific explanation of why there was a day and night. Usually their explanations were religious. For the Greeks, the Sun was a god named Apollo. For many ancient cultures the Moon was also a god or goddess.

Many celestial - caused events became predictable over time. An example would be the seasons: winter, fall, summer and spring, which were thought to be “gifts from the gods.” For most of human history no one knew why these seasons occurred and changed.

Mathematics proves that time can only move forward. Physics proves time can move either way. Past time and future time can be measured, but not the present.

Time is not only a sequence of events, but a measurement of speed and

relative location between objects. In earlier “times”. It was, at one point, considered only a measurement of passing moments and predictable events. Now, we know the true meaning of time.

Our modern world cultures are virtually run by the clock and the calendar.

Our Earth **rotates**, it spins around. It also **orbits**, meaning that it circles around another object. That object is the Sun. The Earth rotates once when it completes a period that we call a twenty four hour day. When the Earth circles the Sun once, we call it a **year**.

There are sixty seconds in each minute. Sixty minutes make an hour. It is approximately 24,000 miles around the middle of our planet. Planet Earth spins about one thousand miles an hour. Hence, there are 24 hours in a **day**. Three hundred sixty five and a quarter days make a year. This is an approximation; every year actually has a few extra seconds of measured time, this extra time is tracked by atomic clocks. A second or two are added every few years.

Our Earth is moving around the Sun on an invisible track, held in place by the pull of gravity. It never stops. It will continue running on this track until either the Sun changes its gravitational forces or there is an unforeseen future catastrophe.

One of the reasons our ancestors could not figure out the true mechanisms that govern cycles of days, nights or years was because they thought that the Universe was circling around the Earth. They also thought that the earth was the center of this circle. To them this seemed true.

THE SEASONS

The Earth is tilted. During its yearly orbit different parts of the planet are exposed to more daylight. During these same windows of time the opposite part of Earth has much less sun exposure. For the middle part of the earth, the **equator**, these changes are equal to approximately 12 hours of each all year long.

During the winter in the northern half of our planet or **Northern Hemisphere** there is less sunlight. It gets darker and colder. At the very top of the planet, that we call the North Pole, there can be virtual darkness for a few months. During our summer, what is known as the South Pole has the same darkening and chilling experience. Meanwhile the warmth of the increased summer sunlight is heating up the northern hemisphere.

In the northern and southern hemispheres spring starts on the day of the **vernal equinox**. A vernal equinox has a balance of hours between daylight and night. The Ancients rejoiced when this occurred; it was a day of celebration. For the growers of food this was the day to start the planting. The plant life of our planet has developed a rhythm based on the earth's orbit around the sun. The plants wither, die or sleep during the winter and then begin a renewal of life with the advent of spring.

THE MONTHS

Where we are and how fast we are going give us a measurement of the years, days, minutes, seconds and also seasons. What about the months?

Months can vary according to different cultures. In our calendar, we have twelve of them. Other calendars, such as the Mayans, have had twenty or more. Certain months have more days than others. February, which has 28 days, has an extra day during leap year, every fourth year. Generally, months were at first lined up with Moon orbits around the Earth. One orbit is about twenty nine and a half days. Every **full moon**, (when a person on Earth can see a full circle of the Moon because of reflected sunlight) marked the beginning of a new period, or month. Every week of a month is delineated by different visual effects given by sun light reflection off the Moon. These are: full moon, quarter moon, crescent, (or eighth moon), and half moon. Each one of these effects line up with a: "Moonday", or Monday.

DID YOU KNOW?

Easter Sunday is determined by the first Sunday after the first full moon and after the vernal equinox.

THE SCIENCE OF TIME MEASUREMENT

We mark our lives by location and speed. We are timed by:

- Where we are in relation to the Sun.
- Which part is getting the most or least light at a particular point on our orbital path.

To give this idea more clarity, let's change our usual terminology into a more scientific set of words.

A judge is talking to a convicted criminal. He states: "Prisoner I will see you in 14/24ths of a rotational time period for your sentencing." The next day the judge

pronounces: “I have found you guilty and here is your sentence: you shall serve 10 orbits and 3 rotations in the state prison for your crime. You may have your sentence reduced to 6 orbits for good behavior. Before you leave, you may visit with your family for a 1/24th of a rotation.”

If you were on Mercury, this would be a generous visiting time and a short sentence. Mercury orbits the sun every 176 earth days. It takes 59 earth days for it to spin (rotate) once. Maybe it is better to go to Mercury for your trial if you are arrested and convicted!

Time is relative as to where you are and the speeds you are travelling. This is defined and explained by the Theory of Relativity, which was created by **Albert Einstein**. We have all heard of $E = mc^2$. But what does that mean?

Actually, the “Theory”, are two theories. One is special relativity and the other is general relativity.

According to general relativity:

Time moves slower in higher gravitational fields. This distorts, bends, or warps time. Light will bend with gravity. Rotating masses drag surrounding space-time with it.

The Universe is expanding, and the outer areas should be moving even faster than light speed.

This theory has been confirmed many times.

According to special relativity:

If I see two events happen simultaneously, another observer of the same two events may *not* see it simultaneously.

Moving clocks tick slower than stationary clocks.

Objects are shorter in the direction they are

moving with respect to the observer. In other words, motion and rest are relative, not absolute.

Yes, time is relative. Time is different according to speed and location.

DID YOU KNOW?

It was in the year 1278 that Pope John 1 ordered Dennis the Little to create the modern Christian calendar.

The first year of our calendar is based on the birth date of Jesus Christ. Despite Dennis’ best efforts, its’ count is probably five years too few. It didn’t take into account the quarter of a day extra needed for every year. That’s why we have ended up with leap years.

UNIVERSAL TIME

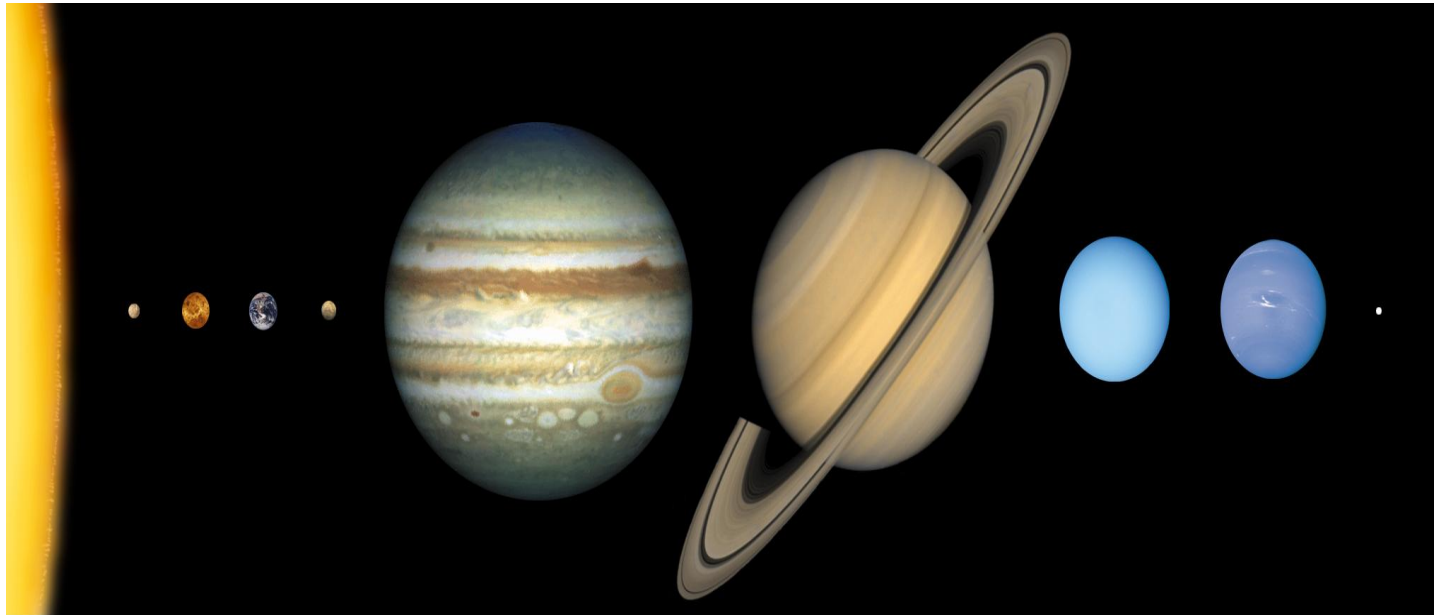
Universal time is affected by gravity and motion. It is also affected by the expansion of space and the universe itself. We’ll have three objects traveling at a certain speed. Then, one these objects accelerate. The faster the object accelerates, the more time *within* that object slows down. However the objects staying behind keep a steady pace with their previous time - speed. Time has not changed its pace for the two remaining objects, only for the faster one.

Later in this course you will get more information concerning our Universe’s outer regions expanding at an ever more rapid rate. Time is slowing for the outer reaches. We are accelerating at a lesser pace; our time is slowing at a lesser pace.

Workbook Pages 3 - 4

Chapter 3

Solar System Overview



**REQUIRED WORK:
HOMEWORK CD
WORKBOOK: PAGES 7 -12
TERRESTRIAL PLANET TEST
(TEACHER PROVIDED)**

There are several aspects to our solar

system. But then there is the body of the

solar system itself. Think of it this way, you have studied the many organs, but there is more to the body itself.

The mass of the solar system mostly lies on a disc - shaped flat plane called the **plane of the ecliptic**. Surrounding this is a gaseous, magnetic bubble.

The **Sun** (our star) makes up most of the volume of the solar system's mass (99.86%) and on its measurable energy. It is also the gravity anchor. The gas planets account for over 99% of the remaining mass of our solar system.

The majority of the planets, moons and asteroids follow the same basic gravitational rules that govern our solar system; they even travel in the same direction around the Sun. If you looked down toward the north pole of the sun, these objects would be moving counter clockwise.

The orbiting objects that dominate the Solar System can be classified into three groups:

Planets: Earth, Jupiter, Neptune (all planets) and so on.

Planetoids: Ceres, Pluto (all planetoids) and so on.

Small Solar System Celestial

Bodies: Halley's Comet, (all comets), the Moon, (all moons) and so on.

The composition of these objects fall into three general areas: They contain one, some or all, of either types of rock, gas or ice. The rock can range from sandy (**silicates**), to minerals such as salts and metals such as iron or gold. Gases range from hydrogen, oxygen (a gaseous metal), ammonia and methane to molecules such as water vapor and other molecular compositions. Ice can be composed of not only water, but also carbon dioxide,

methane, and even more exotic frozen gases. They can be large blocks or floating crystals.

Throughout the Solar System's space there are flows of particles are coming from the Sun. They move quickly at speeds up to nearly 1,000,000 miles per hour, carried by what is called **solar winds**. This creates an atmosphere to the Solar System known as the **heliosphere**.

If there is atmosphere, there should be weather! The Sun has magnetic storms and solar flares that result in solar winds of charged particles and of energy. If there is an atmosphere, does it protect and shield as ours does? The answer is yes. Our heliosphere shields out dangerous cosmic rays that emanate from outside our solar system.

Workbook Pages 5 - 6

SOLAR REGIONS

The **inner solar system** region beyond the sun is dominated by four rocky planets: Mercury, Venus, Earth and Mars. These are **terrestrial planets**. They are rocky and have very little to substantial amounts of atmosphere. In this area there are only three moons and about 1,000 other floating objects of any consequence. They do have occasional intruders, such as comets that are either in elliptical orbit around the sun or are heading into one of the planets or the Sun itself.

The next region is very distinct. Just beyond Mars and before the gas planets. This region is called the **Asteroid Belt**. It's filled with rocks that vary greatly in size and composition. There is speculation that this is debris left over from a planetary/planetoid

collision or there were other influences such as gravity influences (Jupiter) that would not allow these rocks to coalesce into a planet.

Beyond the asteroid belt lies the realm of the gas planets known as the **outer solar system**: Jupiter, Saturn, Uranus and Neptune. The Sun's influences dwindle here and the planets are very cold. There are multitudes of moons. Over 99% of all moons are found circling these planets. The moons vary from traditional in nature to captured asteroids with retrograde orbits, and there are even ice/water moons that have the potential to host life.

Next is the **Kuiper Belt**, a cold and dark region that contains rocks, ice and is quite cold. This area contains dwarf planets also known as **trans - neptunian planetoids**. The most famous resident is the one time planet called Pluto, that is now classified as a trans neptunian - plutoid. Not all of these objects, including **Pluto**, are found on the plane of the ecliptic. Pluto travels at a 17% angle of that plane while orbiting the Sun. It is populated by an estimated 100,000 objects that are 50 miles in diameter -or wider. Here, the Sun seems not much bigger or brighter than other stars. The sun's influence is limited. It is from 30 to 50 **AU** from the sun. (The measurement of 1**AU** is equal to 93,000,000 miles, or the distance from the Sun to the Earth.)

The region dominated by the planets, heliosphere and Sun is called the **interplanetary medium**. It contains two regions of dust. They are flattened and are found on the plane of the ecliptic. The inner region is called the **zodiacal dust cloud**. It is found from outside the sun to the planet Jupiter. The other zodiacal dust *zone* is found from the most outer gas planets to the Kuiper Belt.

There is another region, called the **Scattered Disk** is found at the edge of the Solar System and is populated by icy objects that will find their way into the inner parts of the Solar System. Their orbits were affected by Neptune in early formation of the solar system. Their orbital paths tend to be erratic and range from within the Kuiper Belt to as far as 150 AU from the Sun. They also do not follow the plane of the ecliptic, but rather are angled to it. Its' most famous inhabitant is the planetoid called Pluto.

The Outer Regions

Surrounding these regions is an area called the **Oort Cloud**. This is composed of **comets** that eventually head towards the inner solar system, are composed of ice and dust and **centaurs** (Objects that can reach the size of planetoids and have unstable orbits that change over time. They can be composed of ice, carbonized and dusty materials.). It does not circulate on the plane of the ecliptic. It is found in all directions. That is why it is termed a *cloud*. It is inhabited by up to a trillions bits of dust and ice. Its outer borders may be as far out as one light year from the sun. A **light year** is the amount of time light takes (at 186,000 miles a second), to travel in a year, or about 19 trillion miles! It can be influenced by the passing slight gravity pulls of stars and by the galactic tidal force of our galaxy.

Where does our Solar System end? Good question! It is not exact and varies according to the Sun's activities. It is very far from the Sun, about 155 to 160 AU. As the Sun and its system travels around the Galaxy, it has a **bow shock** that precedes it. This is much the same as a bow shock in front of a moving ship. In the direction that the sun is traveling, the bow shock is 200

AU in front of it. Behind the Sun's trail, or wake, it is only 100 AU out to the border.

The border of the Solar System where it meets interstellar space and bow shock starts is called the **heliopause**. Here, there is a collision of interstellar wind and electromagnetic particles from the Sun. It is a turbulent area. How do we know that? We have had our first probes reach this area (**Voyagers 1 and 2**), which were launched in the late 1970s to explore the outer planets and beyond. They are still transmitting!

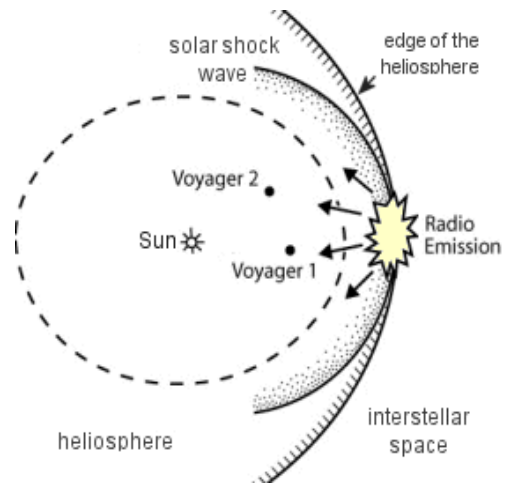
The Voyager 1 probe is now more than 9 billion miles from Earth. Voyager 2 is 7 billion miles away. Traveling at a speed of well over 3 AU a year, it takes many hours for their signal, traveling at light speed, to reach Earth. It will be several more years before they transverse the heliopause and enter interstellar space.

In interstellar space, there are still particles of dust, plasma and ionized gas, are known as the **interstellar cloud**. It is found throughout the galaxy between the solar masses and their star systems.

In 2009, Voyager detected a magnetic field at the edge of the Solar System that apparently holds the interstellar clouds together. Our solar system is currently passing through one of these clouds.

It is nicknamed the **Local Fluff**, it is about 30 light years in diameter. The cloud consists mainly of helium and hydrogen

atoms left over from an ancient supernova (exploded star).



Credit NASA

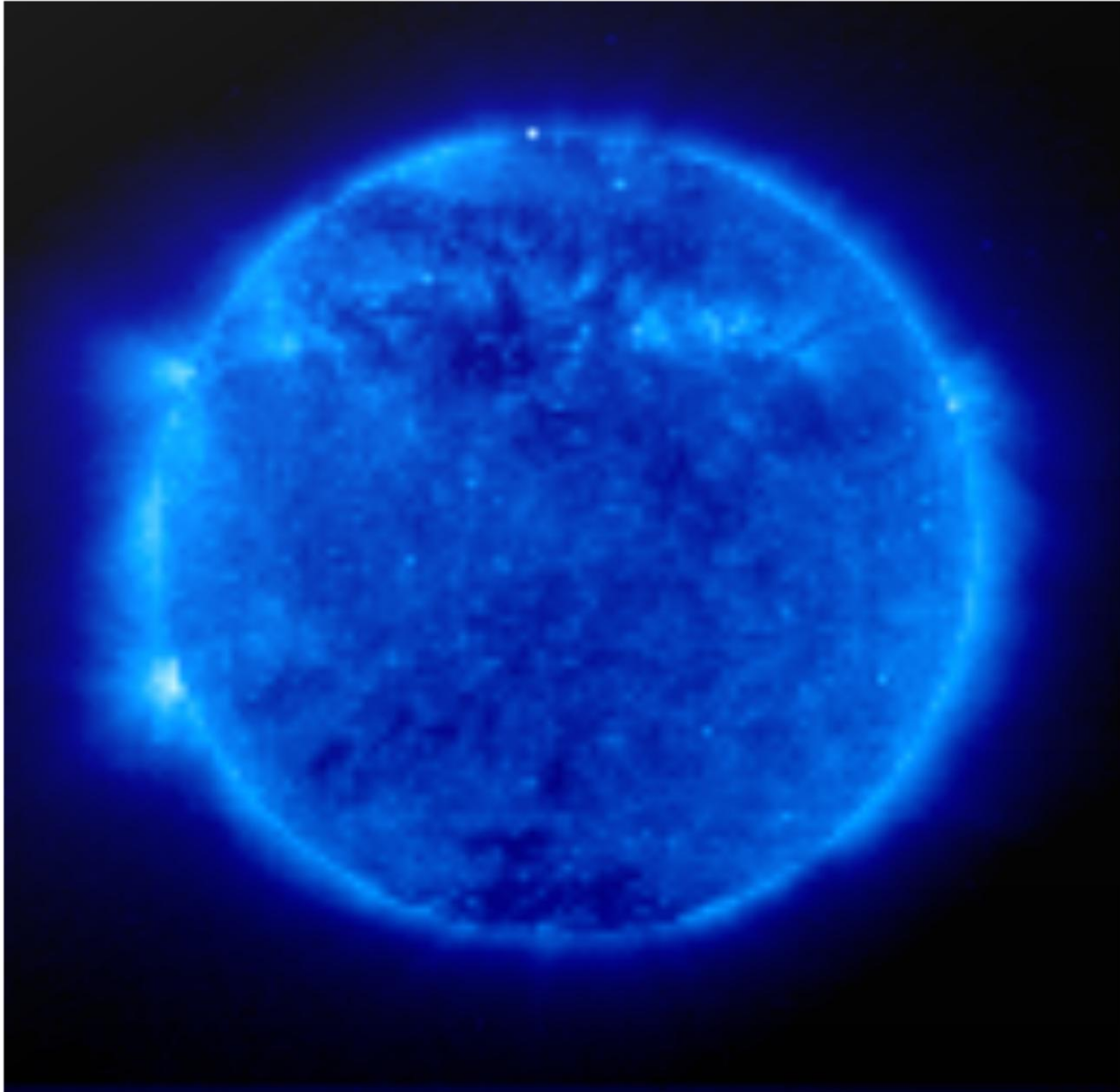
Our Sun, also named **Sol**, has gravitational influences that may extend out as far as out as two light years. Within that area, there may be many objects yet to be discovered.

Our Solar System travels on an arm of our Milky Way galaxy. The arm is called the **Orion Arm**, or the **Local Spur**. It is one of many millions of stars on this arm. Each star has its own system with its own peculiar inhabitants.

Workbook Pages 7 - 8

Chapter 4

Our Sun



**REQUIRED WORK:
HOMEWORK CD QUESTIONS
WORKBOOK: PAGES 13 - 20
SUN TEST (TEACHER PROVIDED)**

What is the Sun? Why does the Sun shine? Is it just a ball of burning gas? To us on Earth, it is much more than that; it is an anchor and protector, a heater and source of constant energy. It is dangerous and, at the same time, life providing. It is the center of our solar system. It may prove to be the instrument of doom to our Earth.

The Sun is huge. It is the most dominant object in our solar system. About 99.8% of all the mass of our solar system is in the Sun. If one adds up all the planets, moons, asteroids, comets and dust in our system, the total would equal little more than 1% of the Sun. *It is not a huge star.* After all, the largest stars can be as much as 1,000 times larger than ours. But the Sun is more massive and brighter than 95% of the stars in our galaxy.

The Sun sends out lots of energy. But what kind of energy does it emit? Most of it is light (**photons**) and infrared rays. The **infrared rays** are not only seen but are also felt. We call it heat. These are forms of **electromagnetic radiation**.

The Sun is very dangerous. Not only does it send out light, heat and radio waves, but dangerous ultraviolet rays, gamma and X rays emitted from it would kill us if it were not for the protection of our atmosphere.

The Sun is hot, so hot that it can burn our skin from 93,000,000 miles away! It is a blazing nuclear furnace. Not only is it hot, but it shoots out flames for more than two hundred thousand miles before pulling back to the Sun's fiery surface. The Sun produces light. It creates photons that speed out beyond our solar system, even beyond our galaxy. Some of these photons have now traveled nearly 5 billion years, moving at

186,000 miles per second. Someone far out in the Universe could be just now receiving this light message. It is the story of the beginning of our solar system and of the star that rules it.

It pulls in debris that could otherwise hit circling objects. Our star keeps us from wandering away and smashing into other objects.

The Sun spins, just as other large bodies in space. It takes the star's equator about 25 days to rotate. The upper and lower regions take about 28 earth days for a complete turn. Why? Because the object is made of gas is not a solid.

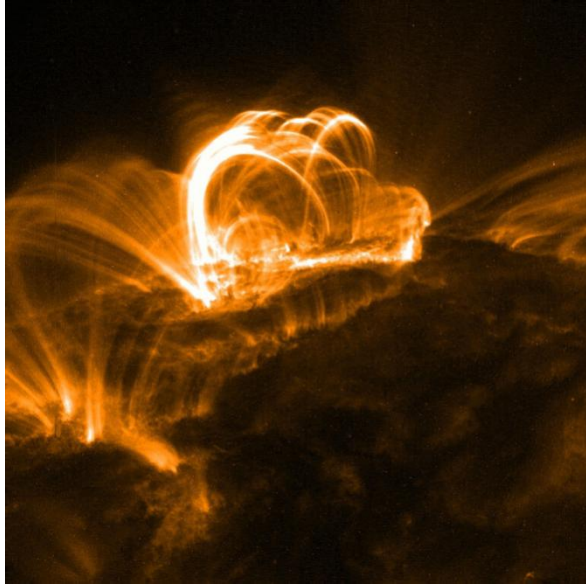
The Sun is *violent*. It does not have a stable surface area. Portions as big as Texas come to the surface, then cool and disappear in less than 5 minutes. Solar storms and explosions push out flames and winds that contain cosmic particles, known as solar cosmic rays that have effects for hundreds of millions of miles. The rays made up of mostly ejected protons, have some heavier nuclei and electrons. These rays can cause great harm to space travelers, probes and satellites. They cannot enter the earth's protective atmosphere but can create a magnetic storm when colliding with the upper atmosphere. This may lead to interference or disruptions in our electrical power grids and communications.

Cosmic Concept: Emotions

The Sun has been praised, cursed, missed and even worshipped. This object inspires emotions.

Write an essay titled: How the Sun Affects My Emotions. Include examples of its influences on your life as well as what would life be without it.

Minimum: 100 words.



Solar flares on return trips from to the surface. Photo Courtesy NASA

SOME MORE FACTS:

The Sun puts out a tremendous amount of power. The amount of energy the Earth alone receives is equal to 126 watts per square foot per second! That means that one weeks' worth of solar energy landing on Earth is equal to us using all our natural reserves of gas, oil, and coal on the entire planet during the same amount of time. The difference is that the Sun will be able to do that every week for billions of years.

The average distance between the Sun and Earth is 93,000,000 miles (1AU).

It takes about 8.3 minutes for the Sun-born light to reach us at this distance.

The diameter of the Sun is 864,000 miles.

It has a surface gravity 28 times stronger than that of Earth.

More than 70 **elements** (atoms) can be found in the Sun. The main ingredients are hydrogen (72%) and helium (26%); the core is thought to be 38% helium.

Workbook Pages 9 - 10

The Sun orbits the center of our galaxy every 250 million earth years.

Our Sun is known as a “**population one**”, star. There are three generations of stars, “population ones” being the youngest generation. They have the highest amounts of helium and heavier elements inside them.

Did you know?

The very same elements found in the Sun are found in your body.

Our star as well as all other main sequence stars, is made entirely of gas that is also sensitive to magnetism. We call this kind of gas **plasma**. The Sun has layers known as the Sun's atmosphere.

Dissecting Our Sun

The **corona** is the highest layer of the Sun's atmosphere. It reaches out several million miles into space. It is very hot and is seen as an uneven halo around the Sun during total solar eclipses.

Next is an area that is called the **transition region**. It is a hot area that cannot be detected with observations during a solar eclipse. It emits light in the ultraviolet bands. It receives most of its energy from the corona.

The **chromosphere** is a thin,

transparent layer that extends out 6,000 miles from the photosphere. One can only see it from Earth when there is a total eclipse of the Sun. A solar eclipse means the Moon is between the Earth and the Sun. The Moon will block out all but the very outer edges of the Sun from our sight.

The **photosphere** is the lowest level of the atmosphere. It is about 300 miles thick and is the visible surface of the Sun. It is about 10,000 degrees Fahrenheit.

The Sun has a grainy look on its photosphere. Its appearance resembles a leathery skin. The bright areas called **granules** have been seen as big as 625 miles wide. They are the result of rising currents from the **convection zone**. The darker surrounding areas are about 300 degrees cooler. Those dark areas are from descending gases and typically last five minutes.

The granules can be part of greater **super granules** that can be up to 19,000 miles in diameter. These are composed of a number of granules banding together. Super granules can last for several hours.

Workbook Pages 11 - 12

Beneath the photosphere is the interior of the Sun. Pressures and temperatures increase from here to the core. No liquid or solid elements can withstand these pressures and heat. Therefore, all is hot pressured gas.

Pressures farther down in the core can be as high as 200 billion Earth atmospheres. The density is over 200 times

that of water.

Nuclear reactions take place in the **core**, or center of the Sun, as hydrogen is converted in to helium. This is an area where the density of the star is 15 times that of lead. Here, the gas pressures are 2 million times that of the earth's atmosphere. **Fusion**, (when two atomic nuclei merge.) takes place here. Nuclear matter is turned into energy. Photons are created. These are the particles that, when grouped together in a moving stream, we call light. Some are absorbed. Others escape.

The radiation zone surrounds the core. It is named the **radiation zone** because the energy that passes through it is mainly radiation in nature. This makes up 48 percent of the Sun's mass. It may take a photon over 1,000,000 years to pass through this zone.

Spiricules are jets of gas that reach out as far as 6,000 miles into space and are up to 600 miles wide. Found in the chromosphere, they last anywhere from 5 to 15 minutes.

DID YOU KNOW?

It is estimated that it takes up to 1 million years for a photon to escape to the Sun's radiation zone and reach the surface. It then takes less than 9 minutes to get to Earth. That means the light you see from the Sun is about 1 million years and 9 minutes old!

Sunspots are darker areas found on the photosphere, usually found in groups of two or more, these spots can last from a few hours to a few months. They can best be

seen during sunrise or sunset. **Do not look for them without expert help and proper instruments!** The first observations of sunspots were recorded in China around 800 BC. Galileo was the first to observe them with a telescope.

Workbook Pages 13 - 14

A typical sunspot is as big as our planet. Some have been seen that are as large as 10 of our planets put together. The spots are still brighter than some surfaces of cooler stars. But they are not as hot as the surrounding areas of the Sun. They often appear where solar storms are occurring.

Sometimes there are no sunspots on the surface. At other times people have recorded as many as 250 of them. There seems to be a pattern of activity called the **sunspot cycle**. It is about 11 years from the start to end. When it is at its higher level of activity it is called the **sunspot maximum**.

The Sun, like earth, has a magnetic field. If taken as a whole, it is only twice as strong as the earth's field. But, in certain areas, there are concentrations of magnetism that can be as strong as 3,000 times that of Earth. These areas are where we find sunspots. Sunspots act like super magnets. This magnetic field shows up before the spot can be seen and it lingers for a while after the spot is gone. There is a background magnetic field around the Sun. The magnetic axis is tilted at 15 degrees from true north and south.

This field is filled with energized particles created by the Sun's rotation and gas convections. They cause outbursts of radiation and other materials.

DID YOU KNOW?

The Sun's magnetic field extends out 4 billion miles. That is beyond Pluto! When it reaches there it bends and returns to the Sun's southern hemisphere. That's a round trip of 8 billion miles!

Every 11 or so years the magnetic poles on the Sun *reverse*. This happens just after the sunspot activity reaches its height, thus creating a cycle of solar activity of 22 years.

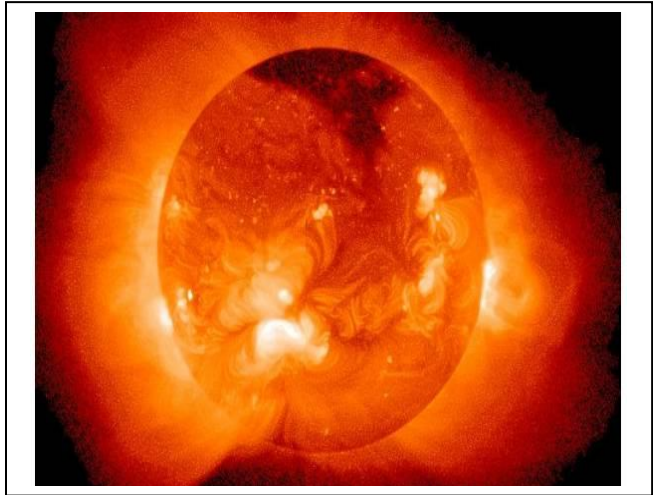
Solar flares are tremendous explosions of light, radiation and particles. They can reach a height up to 200,000 miles and can produce more energy than our world can create in 100,000 years. Flares can send out 20 billion tons of matter into space during an eruption. These flares have a life span of only a few minutes. They are mostly seen when there is an abundance of sunspot activity.

Prominences are arched ionized gases that occur on the limb of the Sun. Magnetic fields and sunspots supply the energy for them. **Solar winds** are streams of electrically charged particles flowing out from the Sun. Unlike our wind, it is very thin, hot and extremely fast, an average speed is close to 1 million miles per hour. The solar wind takes about 4 days to travel from the Sun to the Earth. Sunspot activities affect these winds. When there are sunspots, the winds are the strongest. The winds end up somewhere beyond Neptune.

The Sun will not stay forever the same as it is now. Previously, it was mentioned that the Sun will grow dimmer. As time goes on the Sun will start running

short of its main fuel, hydrogen. On the other hand, it has been developing a new fuel that will eventually power the star; *helium*. The Sun will someday switch over completely burning helium and will turn red in color. The temperature will drop, and the star will dramatically expand. It will then be a **red giant**, burning helium. The closest three planets that presently are orbiting the Sun will be actually end up within our sun! The Sun will once again change. This time it will end up as a **white dwarf**, burning the last of its hydrogen. During this phase it will burn off the last of its hydrogen. Eventually, the sunlight will flicker and dim. Finally it will end up being a black, burned out, cinder ball in space.

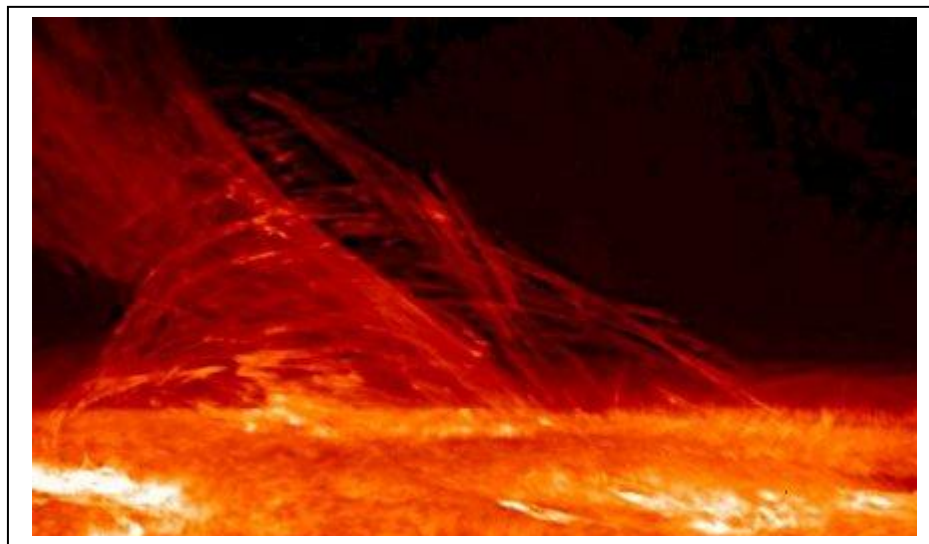
The Sun is about half way through its life cycle. It has a little less than 5 billion years of life to go. Right now it is nearly as bright as it will ever be. It is brighter now than 2 billion years ago and it is brighter than it will be 2 billion years in the future.



SOLAR PHOTO ALBUM

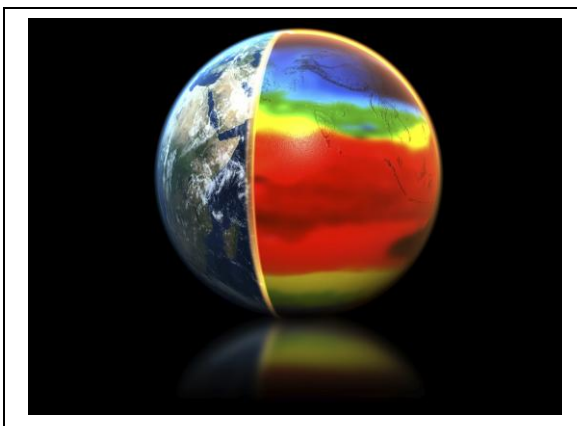
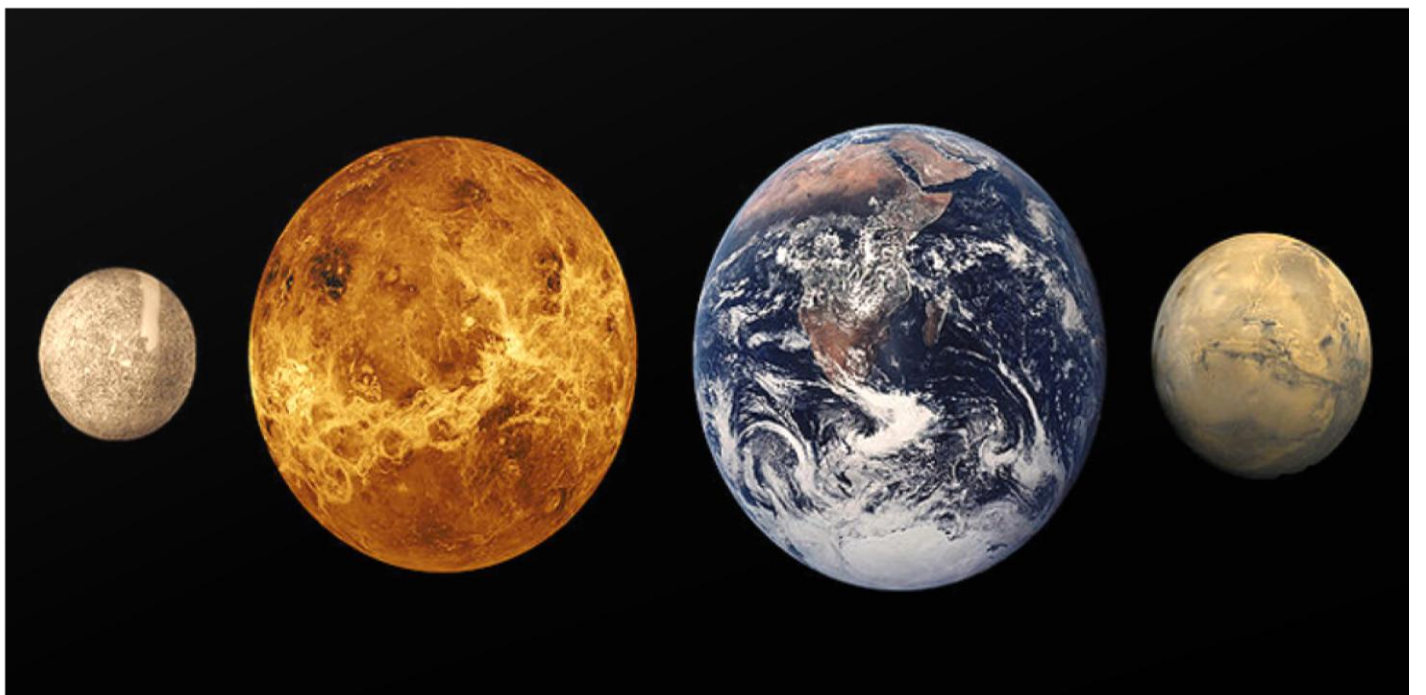
Looks at the Sun. Above the solar winds can be seen and below solar flares are photographed in 2007. Credit NASA

Workbook Pages 15 - 16



Chapter 5

Planets Introduction and the Terrestrial Planets



**REQUIRED
HOMEWORK CD
WORKBOOK: PAGES 21 - 40
ASTRONOMY BASICS TEST
(TEACHER PROVIDED)**

THE PLANETS

Planets vary in size and composition. Planets from rocks more than a few thousand miles wide to huge balls of gas that can approach star size. They may or may not have atmospheres. Distances from the central star can be near or far. Some have one moon, others have many, and still others have no moons at all. However, they all have something in common: they orbit stars and are round in shape.

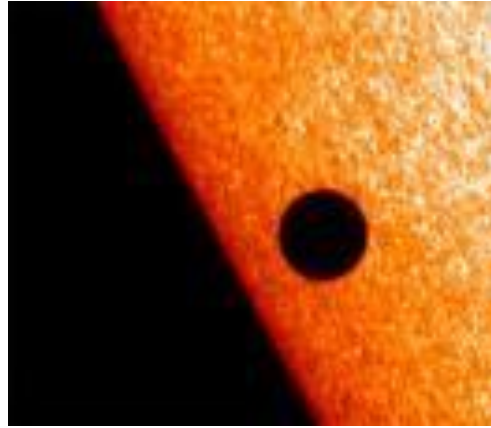
Planets are thought to have been created from left over debris of star formations. There were pieces of colliding rock and dust that stuck together, and they became planetoids, or small planets, which evolved and gradually grew larger. As their masses grew, their increased gravitational pull caused more debris to be drawn in until there was one object only. Little else was left in the general area. Gradual cooling took place, and the planets ended up rocky or liquid/ gaseous or made of gases only.

THE TERRESTRIAL PLANETS

MERCURY

Mercury is the closest planet to the Sun. It is in the outer edges of the Sun's atmosphere. Burned on one side and frozen on the other. Its' surface is pitted by numerous impacts from asteroids, comets and general space debris. There are more craters on Mercury than on our Moon. It has no atmosphere. It is hot in the day, up to 450 degrees Fahrenheit in most regions and over 840 degrees near the equator. At night lows can reach -275 degrees. Like the Moon, it

has a **synchronized rotation**: the same side always faces the Sun.



Courtesy of NASA
Mercury silhouetted against the Sun.

In ancient times Mercury was thought to be two stars. The Greeks called the morning “star” Apollo and the evening view Hermes. During the fifth century they concluded that it was just one “star.”

In 1991 radar signals were bounced off the poles of Mercury; indications are that both poles have ice sheets. The Sun stays at the horizon lines at the poles; therefore it is always below freezing in the Polar Regions.

The rotation of the planet gives it an oddly long day. Because it rotates slowly the Mercurian day is twice as long as the Mercurian year. At a speed of 30 miles per second, making it the fastest orbiting planet in the solar system, its orbital year is 88 earth days long, and the Mercurian day is 176 Earth days long. It maintains an **elliptical orbit** around the Sun with an average of 36 million miles between Mercury and the surface of our star. It does have a complete planetary rotation every 59 days, making it the second slowest in rotation, next to Venus.

Mercury is Moonlike in appearance and has no life. It has no water except for polar ice sheets. It does have a very thin atmosphere. It is made up of helium, hydrogen, oxygen and sodium.



Courtesy of NASA

The sun's rays are 7 times more powerful on Mercury than they are here on earth. It reflects only 6% of the sunlight shone on it. The sun would appear 2 ½ times larger in the sky, than it does here. It has no moons. It's a small and rocky planet. Mercury's diameter is 3,032 miles at the equator, which makes it 2/5 the size of earth. The gravity is about 1/3 of ours.

Mercury is covered by a thin layer of **silicates**, has many deep craters that look like what we have on our Moon. The largest crater is 800 miles across. There are some indirect signs of volcanism, but there are no cones or volcanic mountains. Its core may be liquid iron that it makes up as much as ¾ of its radius.



Courtesy of NASA
Cross section of Mercury

It is the closest planet to the Sun. It is difficult to send probes there. Because of the increased dangers of being so close to the Sun. Its distance from us and the unlikely ability of it providing informational benefits that could come from its exploration, no human exploration has been planned.

Workbook Pages 17 - 18

Cosmic Concepts: Proximity

Mercury is very close to the Sun. Too close for life to exist. It also resembles our Moon, with the cratered appearance.

Write a short essay on why it may be important as to the distance a planet is from the Sun and the size a planet is when considering a chance of it harboring life.

Title: Dead Planet / Live Planet

Minimum: 100 words.

VENUS



Courtesy of NASA

Known as the “planet of love and mystery”, it is the second planet from the Sun. Shrouded in a thick cover of clouds. Venus is one of the five originally known planets. In the days of the ancient Greeks, Venus was called Phosphorus. The Babylonians, Egyptians and Chinese thought they were seeing two stars. **Pythagoras** proved it was a **planet**, which means “wanderer amongst the fixed stars” in Greek. The **Mayans** used Venus as a point of calculation to construct their accurate calendar. The Romans associated the planet with love, and their goddess of love is named Venus.

Venus is the third brightest object in our sky: (First the Sun, then the Moon and then Venus).

DID YOU KNOW?

A key to discovering the distance from the Sun to the Earth was the measuring of distances between Venus and our star. This was done by Mikhail Lomonosov of Russia in the 1700s.

One rotation of Venus is equal to 243.1 Earth days, making it a very slow-turning planet. It has a 225 earth day year. So, for Venus the day is longer than the year!

Venus is a virtual twin of Earth in size. It is 7,519 miles wide at the equator.

Shrouded in a thick set of clouds partly composed of toxic sulfuric acid, it has a day- time temperature of nearly 900 degrees. The atmosphere is nearly ninety times the thickness of the air around Earth. This means that the pressures are great, and moving through its atmosphere would resemble walking in water slowly.

Storms full of lightning and sulfuric acid rain give the planet a hellish quality. Venus is suspected of having many active volcanoes. Probes have taken a set of radar images that reach below the clouds to give us a feel for the landscape. In many ways the geography resembles Earth, with one major exception; it has no water.

This second planet is about 66,000,000 miles from the Sun. Venus had virtually the same size and chemical composition as our planet did. So, why did these two planets end up so different? Venus is 25,000,000 miles closer to the Sun, putting Venus within its’ outer atmosphere, exposing it to a large volume of solar winds.

It is a cloudy, burning, acidic, pressured hell, with molten sulfur lakes dotting the surface and acid steam clouds rising up, creating sulfuric acid droplets that rain down on the landscape. Venus has carbon dioxide as the dominant gas in its atmosphere. It also has a unique feature that occurs nightly to its atmosphere. The air

glows. This is caused by the reconnecting of oxygen atoms into molecules during night time. There is atomic oxygen, hydrogen and helium in the higher clouds of Venus, but there is no measurable nitrogen in its air. These chemical clues suggest that there were ancient seas of **deuterium**, a heavy isotope of hydrogen.



Courtesy of NASA
Artist conception of weather underneath the clouds.

Even though there are thick sets of clouds and a thick atmosphere, some sunlight does reach the surface, so much so that pictures can be taken without lighting aids. This is because the Sun is closer and therefore so bright it can penetrate these dense layers of clouds.

A certain rock type has been discovered on the surface. Granite! This is another parallel with Earth. Venus is what Earth could have been. (You can see that the Sun has a very powerful influence on its planets.)

Workbook Pages 19 - 20

PLANET EARTH

Let's take a short review of some of this planet's interesting characteristics. This gives us something by which to contrast and compare, when studying the Universe.

Our planet is a wondrous thing. Full of color and life, The Earth is changing, growing and decomposing. Earth is our home, our only home for now, so let's discover it through new eyes.

What makes Earth so wonderful and unique?

The Earth is a hard and rocky planet. Our planet is covered in a rock that we call the **crust**. The scientific name is **lithosphere**, which averages a depth of twenty miles. The thinnest part of the crust is under the oceans and is usually about five miles in thickness. Its greatest thickness is where there are mountains. There it can be up to eighty miles in depth. There are different kinds of rock in the lithosphere. **Igneous** rock is found where molten rocks have reached upwards into the crust. This is part of a process called **volcanism**.

Sedimentary rocks can also be found. They were created by the pressure of sediments over long periods of time. In the crust we find **ores**, rocks containing metals, such as gold, silver and copper.

We have rocks containing **minerals** that have changed in composition and appearance due to the force of long-term pressures. A **mineral** is a naturally-occurring solid that has an orderly-crystalline structure and is of a consistent chemical composition. Examples include: diamonds, topaz, rubies, emeralds, aquamarines, and jade. (It does not include

opals, because opals do not have an orderly-crystalline structure.)

Salt is a mineral because it meets certain chemical requirements. (There are some exceptions to the inorganic rules: **Calcium carbonate** is a product found in secretions of some sea life and is considered a mineral.) Minerals generally have two or more elements in them. However some minerals, such as gold and silver, have only one element. Most minerals form in warm and shallow ocean water, but some also form through volcanic means, (such as crystallization in *magma*) and are due to a variety of temperature and pressure changes.

There are rocks that have taken the shape of dead organisms (**fossils**). There are even liquids that are found in rocks, such as water and oil. Many areas of the Earth's surface are covered in soil or sand. Soil and sand are very small grains that have broken off from larger rocks over time.

Below the Earth's crust is the level called the ***mantle*** or ***athensphere***, which averages 1,800 miles in depth. This is mineral - rich, hot, melted rock. The rock stays melted because of the pressure and heat being generated by natural radioactivity from below. When Earth rock is melted it is called ***molten***.

Beneath the mantle is the core. A 3,000 mile diameter ball of very hot liquid iron, it is actually hotter than the Sun's surface. It is about 12,000 degrees Fahrenheit. The outside part (380 miles) is liquid. The inner part is also extremely hot, but is under so much pressure that it is solid.

Workbook Pages 21 - 22

FIRE AND WATER

WATER

Our Earth has more than just rocks. We have water, lots of it. There is even a large amount of water under the rocky surfaces.

Nearly three quarters of the Earth's crust is covered with **water** (A molecule consisting of two hydrogen atoms and one oxygen atom.). Most of it has collected into very large areas called **oceans**. The rest of the water is found in lakes, streams, ponds and rivers. We have two gigantic surface areas of ice at the northern and southern end of the planet. Also, there are rivers of ice called **glaciers**. There is a big difference between the oceans (or seas) and the other watery areas. For the most part, the other areas are filled with fresh water, while the oceans and seas contain salt water.

Much of the fresh water comes from evaporation processes. Water in the ocean and land surfaces sometimes get warm enough to change and rise into our atmosphere which is full of invisible gases. When they rise, they leave behind all impurities, including the salts. These water vapors, (gases), become denser and form visible clouds.

Something called **wind**, a movement of air particles which is transference of energy that is caused by variations of pressures and/or temperatures move the clouds along.

Many times these winds push the clouds over land surfaces. When there is a cooling of these clouds, the water vapor turns into liquid drops called **rain**. When it falls on land it forms the fresh water supply for our planet.

Over a billion years ago, the oceans contained only fresh water, that is, water unsullied by salts or minerals. As rain fell on dry land, salts and minerals were washed out of the ground and were carried by streams of water into the oceans. This sediment turned fresh water into the salty oceans we have today.

Water is a very important part of the natural cycles of this planet. It is a large part of life itself and is home for aquatic animal forms. Water can be a cause of **erosion**, a process of such force that wave action, rain, flooding and fast movements results in the cracking of rocks, formation of crevasses and the turning of rocks into pebbles and sand. Weathering, abrasion, corroding and movement on parts of the Earth's surface can all be caused by erosion.

Water erosion has a direct effect on our lives. The **San Joaquin Valley**, the most fertile farming area on Earth, was partially created through water erosion. Broken rock which became soil was washed down by ancient rivers from the mineral rich Sierra Nevada Mountains. After millions of years a deep layer of top soil developed. However, by the time settlers arrived, the land was water poor and needed irrigating. Local farmers know that keeping the mineral rich top soil ensures good crop production. They use proper farming techniques to keep the waters and winds from eroding that top layer.

Water affects the life cycles of all

plants and animals but in different ways. A water cloud, under the right conditions, can produce a charge of static electric electricity. It is called lightning.

EARTH'S WAVES, CURRENTS AND TIDES

As air, land, gravity and water interact, there are some interesting resultant effects in bodies of liquid water throughout the planet.

WINDS/WAVES

Winds over water cause transferences of **kinetic**, (molecules pushing against other molecules) **energy** from the atmosphere to the water and then carried through the water are called waves. Movement of land or for instance water ice that touches water *can* also cause **waves**.

Waves can occur on small bodies of liquid, such as a cup of soup when you blow air on its surface or when you drop ice into a glass of lemonade. Wind caused waves can travel thousands of miles.

These waves affect our planet in two major ways: they cause coastal erosion and push the surface water in directions that create currents.

CURRENTS

Prevailing winds move surface currents. These currents move clockwise in the northern hemisphere and counterclockwise in the southern hemisphere. The direction and strength of the currents are affected by seasons, especially around the equatorial regions. These currents can be as much as 1,300 feet deep.

In addition to winds, variances in **salinity** (the amount of mineral content of water.), along with solar heating, gravity and something called the **coriolis force**, create movement in the ocean waters, called **currents**. Large currents, sometimes referred to as “conveyer belts”, since they transfer vast quantities of water all over the global seas. Currents have a profound effect on weather patterns, climates and therefore plants and animals around the planet.

Some currents are side to side or, horizontal. Some are vertical. **Upwelling** happens when water has had a wind blow its surface to the side. The water below rises. This can also occur when saltier, colder and therefore denser water sinks and warmer, less salty water rises, creating upwelling and **downwelling** vertical currents. Most of these currents take place near the western and eastern shores of continents.

The coriolis force changes the directions of currents, an effect that has to do with the rotation of the earth. Different parts of our planet turn at different speeds. The equator of Earth is rotating at about a 1,000 miles an hour. But when proceeding to the north or south, the speed of the spin slows. The polar zones turn quite slowly. If not, when someone would stand at the poles, they would be whirring, like a top, at a speed of a thousand miles an hour! These relative levels of speed occurring, because of our planets rotation, create a pulling effect on the oceans and winds. The pole to equator, (or equator to pole), directional winds and currents become angled, or bent over for many miles. Think of it as a straight line becoming more of the shape of a comma. In the northern hemisphere the currents are bent clockwise. In the southern hemisphere the opposite is true.

A good example of a coriolis force is shown with the famous southern to northern current in the Atlantic Ocean called the **Gulf Stream**. The current starts in the warm waters of the Caribbean then flows north along the eastern coast of the United States, as it travels farther north it veers off toward Europe. The Gulf Stream current warms Western Europe’s climate and helps create greater rainfall, (instead of snowfall), amounts. Hence, we end up with a green Ireland and a rainy London instead of an Ireland and Britain resembling Greenland.

The coriolis force occurs on all large space bodies that are spinning and have an atmosphere and / or liquid surface.

Solar heating causes large areas of surface waters to expand and rise up as much as 6 inches. This makes the water levels higher in the middle latitudes than farther north or south. As we all know, water flows downhill. There are currents that flow north and south from the middle latitudes.

Deep ocean currents (1,300 feet or more below the surface) are driven by variances of water densities and temperatures (the coriolis affect) as well as by the influences of gravity. These deep currents that circle the globe are called **thermohaline circulation**. They act as submarine rivers that flow many feet under the surface. They are powered by the seasonal effects of solar heating. Less salty, warmer water rises and colder denser and saltier water sinks. These currents make it possible to have water molecules circle the earth without leaving the ocean. The thermohaline currents also allow transfers of energy around the Earth’s oceans. These currents tend to flow the opposite direction of the surface currents.

Currents have not yet been discovered on other bodies of water in space. But, give it time. Where we find oceans of liquid on planets or moons, the chances of finding currents will probably be high.

You will learn much more about currents during your earth or physical science course.

TIDES

Gravitational interactions between the Earth, Moon and Sun create mass pulling of water that we call **tides**. The Moon's gravity literally pulls massive amounts of water towards it. As the Earth spins and the Moon orbits, different parts of the world's oceans feel the tidal effects. This means, that the coasts experience a high or low tide every 12 ½ hours. At times, the Sun and Moon align and create even more of a gravitational pull, and this creates even higher and lower tides. The ocean maintains the same amount of volume, so when the water is rushing in for high tide on one coast, on the opposite side of the planet the water is receding. The greatest daily tides align with the plain of the orbiting Moon which circles the Earth at 23 degrees above the equatorial line. The corresponding area on the Earth has the highest and lowest tides. Even atmospheric pressures can affect tides in shallower areas.

The greatest tidal swings happen in the **Bay of Fundy**, in Canada. It can change as much as 55 feet in 12 hours. (Typical tidal swings average about 2 feet.) The least tides are found in the Mediterranean and Caribbean seas. The **amphidromic point** is where there are little or no changes in tidal swings.

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FIRE

When lightning strikes trees and grasses it can cause fires. The fires allow for rebirth in the burned areas. Fire changes the plant and animal matter into carbon that fills part of the nutrient needs for new life occupying the area. This carbon used to be in the atmosphere. It was part of the molecules of carbon dioxide. The plants deconstruct and use the carbon for growth. Fully 90% of wood is made of carbon from our air and ground. When carbon is in or on the ground, the plants can once again absorb the element. The animals that eat the plants also eat carbon that has been digested by the plants.



There is much carbon on the planet. Since all Earth life has carbon in it, just as all Earth life contains water. Can life exist without carbon and water? That is a question being pondered by astrobiologists. We may have difficulty in finding such life forms because our only points of comparison come from carbon - based life on Earth. How do we find something when we don't know

what will give us clues to its existence?



THE LAND

Earth's skin, or crust, is wrinkled: It moves! The wrinkles are mostly called hills, mountains, canyons and valleys. But what causes most of these wrinkles? A condition called **plate tectonics**, a process of movement of large pieces of the crust that are lying on top of the athenosphere. This process is continuous and can cause very large pieces of land to drift to other locations on the planet.

So far, we are the only known planet in our solar system with a process of plate tectonics that are active. In some locations, old land sinks under the crust into the mantle, (We call them **trenches**.) In other areas, the land comes up from underneath, this is called **volcanic activity**. Most of this activity is under water, but a certain amount takes place on dry land. Because of this, the land acts somewhat like our skin. The crust eventually gets old and crumbly and then is "shed." It is replaced by new, nutrient filled skin that rises from below.

There are two basic types of land covering: ground covered by water and ground exposed to air. Most of the ground

not covered by water is found in very large masses. They are called **continents**. There are seven of them. The rest of the land that was not part of these masses is considered islands. These land masses move around on top of the mantle. Once in a while, (a long while), millions upon millions of years, all come together. When you next see a world map, take a look and you will see the matching coastlines between South America and Africa. Once they fitted snugly together.

Unfortunately for some plants, animals and humans, this ground movement and related volcanic activity are not always a smooth one. Sometimes the mantle rock rises and breaks through to the surface at weak points in the crust, these are called **fissures**. Some of these areas are formed by this action. **Calderas** are holes much like puncture wounds on the surfaces of mountains or on flat land where the magma rises and becomes lava. These holes, which allow the hot rock to emerge, can be calm (dormant), or can turn violent and even deadly (active). Calderas have been found not only on other planets, but on moons as well.

When **magma** (molten sub surface rock) reaches the surface area, as when it touches air or water, it is called **lava**. The lava can be thick and slow moving or fast and watery, depending on how hot it is. Thick or runny it is called **viscosity**. When the lava cools it congeals, then solidifies. Eventually it becomes cold stone and is subject to the erosion process.

Earth's rocky crust has cracks, called **faults**. These breaks in the Earth's surface allow pieces of land to drift until they bump into another land mass. When they do, they cause wrinkles (mountains, hills, valleys, etc.), to form. Many times one piece of land

going one way collides with another going in a different direction. Land masses can temporarily lock together along fault lines. A lot of energy is stored up when masses press against each other. This pressure eventually, forces the locking pieces of rock to give way and allow the two land masses to move. When this happens there are resultant vibrations called **earthquakes**. (Quaking occurs on our Moon and on Mars, but on a far smaller scale and for different reasons.) On Earth, most of the time, these movements are very small, creating micro quakes. But sometimes there is a great movement along the fault lines. Manmade structures collapse. Tsunami waves and avalanches can cause vast destruction and the loss of life.

These ruptures in the crust, and / or the resultant shaking, have occurred in every country in the Western Hemisphere. In January 2010, a 7.0 earthquake hit the western area of the island of Hispaniola. This area is where **Haiti** is located. The capital city of Port –Au- Prince was virtually ruined with over 200,000 deaths and many injuries. The infrastructure was devastated. It will take generations to recover. Most of the deaths and injuries were caused by falling masonry and collapsing buildings.

Weeks later, a much more powerful (magnitude 8.8) earthquake hit an area 200 miles south of Santiago, Chile. Although much damage was caused to the infrastructure and buildings, less than one thousand people died. The Chilean building codes that is much more stringent than that in Haiti, saved lives.

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THE WEATHER

The Earth's crust crawls and shakes. Water flows. Air is moved by wind. The winds are caused by temperature and pressure changes. Earth is a place of movement, especially in its atmosphere.

Some of Earth's storms can be violent. If they are big, warm and turn counter clockwise, they are called **hurricanes**. These storms have great amounts of wind and rain; they need warm ocean water and very warm, wet, air to form. Powerful rain storms form over hot and humid lands, pushed over oceans by steady, upper level winds. They develop into tropical storms and then **tropical depressions** which are powerful storms with sustained winds of up to 74 miles an hour. Finally, if the conditions are right, a hurricane is born. Only the watery, equatorial areas of the Earth's surface water can produce these conditions.

Most hurricanes are a hundred to two hundred miles wide. They spin so fast and have such low pressure that the rapid movement of air forms a hole in the middle, called an **eye**. It is calm in the center of the eye. There are few clouds or wind. But the hurricane's surrounding **eye walls** carry the highest amounts of wind and rain. When the warming energy runs out and the winds upper levels tear at the storm's structure, the hurricane loses its eye and power, and eventually dies out over land in cooler waters.



Courtesy NOAA

Another powerful storm, a **tornado**, develops when warm and humid air collides with much cooler and drier air. An intense air pressure drop occurs, and rapid winds blow. Tornadoes descend out of clouds that are turning in a circular manner. If they do not reach the ground they are called **funnel clouds**. Tornadoes are usually harmless to humans unless they are sucked or get hit by swirling debris caused by the tremendous winds. These storms range from a few feet wide to a mile in width at the land level. They normally last only minutes. These rain clouds can come down as one or several “dancing” funnels. The eye of the tornado is calm. Looking straight up from the bottom through the middle of the tornado, the sky is clear. But the eye is small and it disappears when the funnel starts collapsing. Dust devils that we can see here on Earth even on clear days whipping up dirt and dust have been seen on Mars.

Very few areas in the world have these storms on a regular basis. The most common place to find them is in the central United States during the spring, or when hurricanes hit land and to meet cooler and drier air.

Another type of storm with great power can only occur when the weather is cold. Cold temperatures must be from around 0 degrees to below thirty two

degrees Fahrenheit in range. These storms, called **blizzards**, are caused by relatively wetter and warmer air hitting colder air. But remember, both fronts of air must be below freezing. The outcome is a very heavy snowfall in a short period of time, accompanied by lots of wind.

Does anything else that is weather related happen on our planet? Most certainly! Sometimes there is too much water in an area, the ground cannot absorb all of it and the water runs over the natural channel’s edges, called **embankments**, and inundates the land. We call this action **flooding**. Other times not enough water can cause droughts. Ice, snow, and or, rocks can race downhill in an **avalanche**. Fog, very low clouds, can hug the water and land surfaces. Mud can move down hillsides. Yes, we live on an incredible planet!

Do other planets and moons have weather? The answer is *yes*. There can be: a windy day on Mars, a rainy, (with thunderstorms), day on Venus, a foggy and misty day on Titan, or a cloudy day on a gas planet. But, no discovered celestial body has the variety of climates, or weather conditions that we have here on Earth.

THE AIR AND SPACE SURROUNDING EARTH

We breathe air. We feel it when it moves. But, what is in it? Earth’s air is composed of gases consisting of oxygen, carbon dioxide and nitrogen.

There is something strange about our air. It dramatically affects plants and animals. Plants take in (inhale or **inspire**) air and using carbon dioxide for much of their sustenance. The plant life then releases

(exhales or **expire**) oxygen. Animals exhale carbon dioxide and inhale oxygen. *Each produces what the other needs.* Each uses what the other emits. Thus, plants and animals help to create a planet that can reconstitute its atmosphere. There is a difference in the thickness, or density, of our air as it varies in altitude. The least dense air is found where the **atmosphere** meets space.

We live in the lowest level of our atmosphere called the **troposphere**. This is also where most weather actions take place. Mountain tops can reach up to the next level called the **stratosphere** which starts at about 10,000 feet and tops off at 45,000 feet. The highest dry land mountain in the world, **Mount Everest**, rises to 29,000 feet.

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Our Air and Space Shield

Above the stratosphere, we find the **ozone layer**, a thin layer that contains particles called **ozone**. These particles block out dangerous emissions coming from the Sun. Animals do not survive at this height, because the air is not dense enough to support the animal's needs. In the ozone layer the winds can be very fast, the air very cold.

Above the ozone layer is another layer, called the **ionosphere**. This layer is important to us for two reasons: (1) it helps to protect us against dangerous rays from the Sun, and (2) it provides a barrier that allows radio waves to bounce back to Earth. The radio waves then travel farther than the line of sight.

The Earth has what is known as a magnetic field. It starts with a molten iron core and the spinning of the Earth. The core moves and causes friction. An electric charge is created. Called the "**dynamo effect**", this "field", acts as a buffer to incoming particles from the Sun carried to the Earth by solar winds. The magnetic field repels many of them.

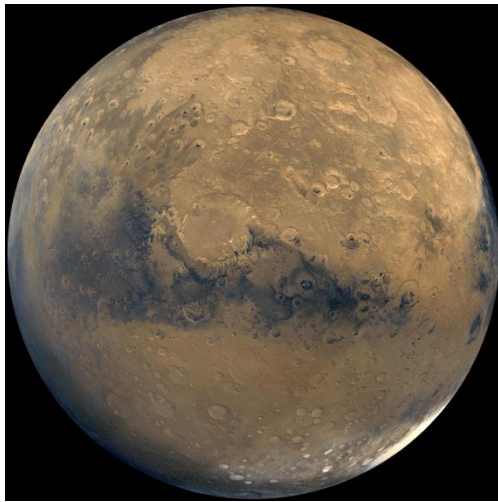
The Earth's magnetism acts like a common magnet. It has poles. The poles reverse over periods of time. In fact, they have reversed 171 times in the last 71 million years! The magnetism is preparing for a polar switch over the next 2,000 years. This means that compasses will have to be switched. The compass needles we use now will be pointing due south.

If, during this time, the magnetic field is weakened, the effect could be catastrophic for life on Earth. The powerful particles can devastate and make extinct much of animal and plant life, eventually sterilizing the surface of the earth.

For many years people thought the "Northern Lights" were caused by sunlight reflecting off the Arctic ice. However, the spectacular nightly light display, or "**Aurora Borealis**", is caused by atomic particles from Sun storms coming to Earth and colliding with the electromagnetism surrounding the planet: These particles become trapped within and are then drawn to the poles. The light show starts at about 100 miles above the Earth's surface. The most common colors are green and red. These electro magnetized particle interactions have been seen happening through telescopes and probes, on other planets as well as on Earth. Many aspects of our planet's chemical and

geographic characteristics can be found on other planets in our solar system. But no other planet or moon comes close to what Earth has when it concerns the complexity of its interactions between its integral parts. But, beyond the planetary characteristics themselves, what makes us most unique is that no other natural body in space, as far as we know now, is harboring life. That life needs a unique planet such as ours in order to occur and to survive.

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Courtesy of NASA

MARS

This is a planet with a “history and a mystery.” It has been worshipped as a God, some have speculated that it is, or was the home of an advanced civilization. Mars is named after the Roman god of war. Also known as the Red Planet, it is 141 million miles from the Sun.

A subject of many books, movies

and tabloid articles, Mars is the planet that captures our imagination.

It is the fourth planet from the Sun. Cold and dusty, it may have the potential to become a new habitat for humans. Perhaps the best way to start the description of Mars is to compare it to Earth.

- Both are rocky planets.
- Both Mars and Earth have water.
- Each has experienced volcanism and erosion.
- Both have carbon dioxide on the planet.
- Earth and Mars have frozen poles.
- Both have an atmosphere.

Mars is small in size compared to the Earth. Mars’ diameter is roughly half as big as ours. Its surface area is the same size as that of our seven continents, plus all the islands combined. Another way of looking at the numbers is to compare our Moon with Mars. Mars has twice the diameter and gravity of our Moon.

Mars’ interior has a crust, mantle and core, but the depth of each has not been determined. It is guessed that the crust is fairly thick if compared to that of the Earth, ranging from 30 to 75 miles deep. This is much thicker than Earth’s average crust depths. It is thought to have a thickness from 9 to 80 miles in depth. The core is probably made of iron and nickel.

Long ago Mars had seas, a warm atmosphere, active volcanoes, and, quite possibly, life. It was a place that resembled Earth. What happened? No one knows for sure, but there are some theories.

Mars may have been hit by a very large object. So large, in fact, that it may have blown away most of its atmosphere and even caused the loss of a large amount of water. There are remnants of the Martian magnetic pole lying on its surface, a clear indication of a catastrophic event. Nearby is the **Asteroid Belt**, where millions of objects are floating. Some of them are hundreds of miles across. One, much smaller than those, could have done much damage to Mars.

Another theory suggests that Mars simply did not have enough gravity to hold its atmosphere over billions of years. Also, the core has cooled off. This may have contributed to the loss of gas and water in some unexplained way. Most likely, there is truth in both theories.



Courtesy of NASA
A close up view of the Martian moon
Phobos.

While Earth and Mars appear to have several things in common, many of these commonalities have many specific differences when one looks closely.

When did the last lake dry up? When did the last cough spew out of a volcano? What was the last living thing left on its

surface? It is thought that Olympus Mons, (Mount Olympus) ended its last lava flow between 100 million and 800 million years ago. As for the rest of the volcanoes, the only answer seems to be “long ago”.

Cosmic Concepts: Colonizing

Life could be under the surface of Mars. If we have the will we can go and find out if there is life. What if there are microbes under the surface? Do we have the right to: claim the land, the life and explore their world? Why or why not?

Minimum: 100 words

“Martian geology” is not correct since geology is the study of earth’s land forms. The new science of studying Martian lands is called **areology**.

So what is the areological composition of Mars? So far iron, oxygen, silicon, magnesium, aluminum, sulfur, calcium, titanium, chlorine and sodium have been identified. Iron is found on the surface in large quantities, and it oxidizes to the reddish tone of Mars accounting for the redness of the planet it even has a pink tone to its atmosphere.

An unusual rock was discovered in Antarctica in the 1990s. It was a meteorite, one of many found on that continent. It was studied and found to be from Mars. How could that be? Only one way: A collision on the Martian surface launched rocks into space beyond its gravitational influence. Eventually the debris either headed for the Sun or to hit another body, such as ours. (These meteorites from Mars have names: Shergottites, Nakhla and Chassigny.). The scientists cut it in half and took a look under

a powerful microscope; something appeared that had the look of bacterial fossils. Was it a sign of life on Mars? Some say yes, some say no. Many say “maybe”.

There are three eras, epochs of Martian areological development:

Noachian: 4.6 billion to 3.5 billion years ago. This time was characterized by large meteoric impacts, flooding and seas.

Hesperian: 3.5 billion to 1.8 billion years ago. It is marked by large scale volcanism and basalt plains development.

Amazonian: 1.8 billion years ago until now. It is a time of less meteoric impacts, smaller in size, and with lava flows that occurred as few as a hundred million years ago.

Most of the Martian surface is covered in basalt, dust and clay, tinged with rusted iron. It is barren of vegetation but it has gulleys and canyons, peaks and valleys, rocks and sand dunes and ice underneath some areas of its surface. Except for the ice, it resembles much of our Sahara desert. It is a desert planet. The soil, however, could possibly support plant life under the right atmospheric and temperature conditions.

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Photos of Martian ice.
Courtesy of NASA

Mars has about 38% of the gravity earth has. Why? It is about a third the size of earth and contains only 10% of earth’s mass.

The Martian core is made up of iron and sulfur and may still be liquid.

Although Mars may have had plate tectonics in its early history, it does not have them now.

In the distant past, Mars had floods, and it looks like it rained there. There are multitudes of evidence suggesting erosion from moving water. Ice patches near the poles have been found that are as big as seas. Ancient coastlines have been discovered. A snow flake was photographed on Mars!

What happened to the liquid water?

The loss of liquid water could possibly be attributed to Mars losing its magnetic field of protection, allowing the harmful rays of the Sun to eradicate most of its

atmosphere. By losing most of its atmospheric air pressure, Mars could no longer sustain water in a liquid form. As the planet chilled, due to for loss of its tempering atmosphere, Mars became too cold and dry to support liquid water. The water simply froze or evaporated.

Although there is much water ice on the planet, no *liquid* water has been found on its surface. There still may be some under the surface due to remaining warm pockets in Mars' crust.

In summary, water needs the right amount of pressure and heat to remain in a liquid state. The surface of Mars presently cannot support liquid water.

Further Evidence?

In 2003, a probe from Europe called **Mars Express** detected something unusual in the Martian atmosphere. Methane! By itself, this would not be a direct indicator of life. After all, methane has been found in the atmospheres of many planets, most planetoids and even on moons. It can be a nonorganic, naturally-occurring gas. So what would make this discovery become more significant?

A science group, led by a man named **Michael Mumma**, from NASA's **Goddard Space Flight Center**, conducted a follow-up study, using several powerful telescopes. Using spectrometers, they made a color analysis of the gases reflected back to earth. Different gasses absorb certain light frequencies that allow such a study.

Mumma's team studied bands of the planet, running from the north polar area to the southern extreme of the planet. They observed the following:

- There were concentrations of methane that were to be not yet diluted by winds in the atmosphere.
- These concentrations appear to be where scientists think there was water at some time, and they believe water still exists in these areas.
- There was seasonality to these concentrations, the highest being in the Martian summer and disappearing during its winter.

On earth, the two main producers of methane are geothermal vents and microbes. Does this mean that Mars is *not* a cold, dead planet? Does it still have geothermic activity? Does it mean there are **microbes** (microscope life) alive on Mars?

If life exists there, it would probably be found underground, using the combined protection of the permafrost and soils above it from the solar radiation, and using underground melted water reserves during the Martian summers.

Another explanation could be that the methane was produced eons ago and, through the changes of the seasons, the gas is allowed to release into the atmosphere.

If more probes are sent to Mars, the top contending destinations will where these methane gas accumulations appear.

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Unlike Earth, Mars does not have plate tectonics, perhaps due to the planet's smaller

size. It probably cooled off much faster than Earth, thus allowing the crust to be thicker and to resist cracking. However, there were some weak points, allowing magma to reach the surface, forming volcanoes and lava flows. Large rifts can be seen, caused by molten rock influences.

Did You Know?

The surface area of Mars' tallest mountain, Olympus Mons, is equal to twice the size of France.

The closest the Earth comes to Mars is 34 million miles. The farthest away is 375 million miles when they are on opposite sides of the Sun.

Clouds and Ice

The ice caps on Mars are much smaller than those found on Earth. Growing and shrinking according to the seasons, the northern cap, which is of a mixture of carbon dioxide and water ice, is over 600 miles across. During its winter a topping of frozen carbon dioxide appears. The southern cap is one third the size of its northern cousin during its summer and is larger during its winter. This variation is caused by the southern pole being warmer in the summer and colder in the winter. The southern cap is formed from mostly frozen carbon dioxide.

The atmosphere of Mars consists of 95% carbon dioxide, 3% nitrogen, and 2% argon and has traces of water vapor, oxygen, carbon monoxide, and other gases. The air pressure varies by season. This is caused by the frosting and defrosting of carbon dioxide during the winters and summer months.

There are six major cloud types in

the atmosphere of Mars and hazes form over the poles and plains during the fall. Wave clouds hover over craters. Connective clouds gather over the highlands during midday. **Orographic** (Orographic clouds are forced to high altitudes around mountains because of winds pushing them up the slopes.), **Clouds** form around Olympus Mons and other large mountain areas during summer and spring when there are large amounts of water in the atmosphere. Ground haze can be found in lower areas at dusk and dawn. Wispy clouds are at high altitudes during those hours.

Roving

Thanks to the Mars rovers, **Spirit** and **Opportunity**, many new discoveries have been made. This twin effort of seeking geologic data has been a resounding success. Some examples are:

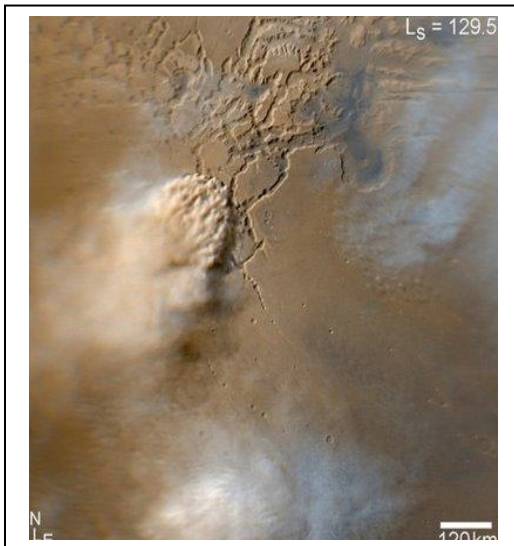
- High amounts of salt and phosphorus have been noted.
- Water-eroded rocks have been discovered.
- Types of rock/minerals that form on Earth in water areas have been found. (For more information, see NASA / J.P.L.'s, Mars Exploration Rovers Homepage on the internet.)

Mars has had a several earth visitors, all in the form of machines. Both Russia and the United States have sent probes. Pictures have been taken, tests have been run, and objects have been measured. However, many space exploration enthusiasts insist that humans must go to Mars in order to get the whole story. NASA was planning a trip to Mars as the next goal for human exploration. That plan was discarded in

January 2010, due to political and economic problems.

Information about Mars is extensive and steadily growing. For more information go the NASA web site to read related news articles and new books written about this fascinating place. For more research, read the book: "Uncovering the Secrets About The Red Planet, Mars", by the National Geographic Society, or log on to the several Mars web sites.

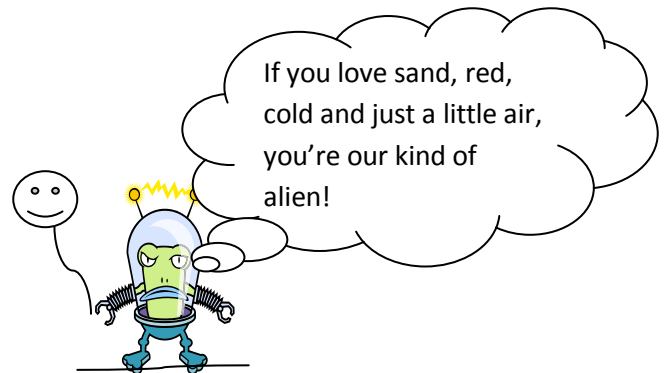
MARTIAN PHOTO ALBUM



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Above, is photograph that gives an illusion of trees or rock spike rising from hills, when these are actually streaks running down the sides of the hillsides.

To the left, a Martian dust devil photographed by NASA Rover.



A dust storm on Mars.
Credit NASA

Chapter 6

Outer, Dwarf and Exoplanets



REQUIRED WORK:
CD - HOMEWORK
WORKBOOK: PAGES 41 -50
OUTER PLANET TEST (TEACHER
PROVIDED)
TEACHER OPTIONS:
OUTER PLANET REPORT

JUPITER



Photo courtesy NASA

In a world that has storms larger than our planet, Jupiter is large enough to contain 1,000 earths. It has a diameter 1/10 the size of the sun. Gravity, from such mass, pulls in countless objects that fly too near to it. It melts moons with its electro-magnetic powers. One of the five originally recognized planets, it is the fifth planet from the Sun. It has an orbit that is equal, in completion time, to 12 earth years.

The “king” of our gas planets, Jupiter is the heaviest of all the solar planets. It has 2.4 times the gravity of earth. Gigantic in size and closest to the Sun’s chemical composition, its 86% hydrogen and about 14% helium with less than 1% other gases, including methane, ammonia, phosphine, water, acetylene, ethane, germanium and carbon monoxide. Shouldn’t this planet have what it takes to become a star? It is immense, but it would have to be eighty times larger to begin the fusion process.

Jupiter has layers of clouds. The top

layer is composed of haze and ice crystals. These clouds float over the lower layers much as foam floats on top of Earth’s oceans. It acts as a colorful, exposed skin over the gaseous planet.

On Jupiter, the temperature averages -230 degrees Fahrenheit. The lower levels of its atmosphere have higher temperatures and pressures. Where the pressures reach 10 times that of Earth’s atmosphere, the temperature averages 70 degrees Fahrenheit. This would be the only area where life, of the airborne type, would have a chance to exist in or on the planet. When descending to the core temperatures can reach 43,000 degrees Fahrenheit, hotter than the surface of the sun. Jupiter actually sends out more heat into space than it receives from the Sun!

Although the planet resembles a giant gas ball, this may not be an accurate description. Below the gas clouds, pressures are so great that the planet is an ocean of hot, liquid hydrogen. Deeper, the hydrogen resembles liquid metal. In the center there is possibly an iron and rock core that is the size of 20 to 30 Earths, with a density of Venus, Mars and Earth combined. At its’ core, it is as much as 6 times hotter than the surface of the Sun.

The “**bow shock**” of Jupiter resists our Sun’s solar winds up to 4,660,000 miles from Jupiter’s gaseous surface. Its’ magnetic field is 14 times stronger than that of earth which makes it the strongest bow shock in the solar system.

Jupiter is one of four ringed planets. The ring, not visible from Earth was spotted during a Voyager 1 fly by many years ago. Made up of dust, it is so faint that astronauts

standing on one of its moons would not be able to see it. The dust may come from ejected materials entering into its' space from the moon - **Io**'s volcanoes. The rings are (orange in color) may be leftover debris from asteroids hitting the local moons.

Jupiter has some of the most interesting moons in our solar system. The biggest are called Io, Ganymede, Europa, and Callisto. When Galileo first saw the planet he thought that he saw little stars around it. Those "stars" turned out to be some of Jupiter's moons and can be seen with binoculars on a clear, dark night. (In the Moons chapter you will learn more about these fascinating worlds).

The major feature on the giant planet is the **Great Red Spot**, which has been visible for hundreds of years. This spot is actually a storm that turns counter clockwise. It completes a full rotation every 12 Earth days. The red color is probably from churned - up phosphorus. This storm is bigger than the circumference of two of our Earths combined.

Days on Jupiter are different than days on Earth. One would suspect that the "**Jovian**" days would be quite long. After all, it is a huge planet and it must take much time to turn all the way around. However, its day is only 9 Earth hours and 55 ½ minutes for a complete rotation at the equator. That makes it the fastest rotating planet in the solar system. This rapid spin produces bands of atmosphere and actually flattens out the poles. The equatorial diameter is 89,015 miles. The north to south diameter is only 84,208 miles.

Jupiter is a noisy planet. It emits more natural noise than any other object in our solar system, with the exception of

course, of the Sun.

DID YOU KNOW?

During the 1990s, astronomers witnessed an historic event on Jupiter. A passing comet, Shoemaker – Levy 9, came too close to the planet. Jupiter caught it with its powerful gravity and broke it into pieces. The comet was pulled further into its influence and finally collided with the giant. It was the first witnessing of this type of collision.

One piece made a bruise mark on Jupiter the size of our planet. It took over one Earth year for all traces of the impact to disappear. It served as a warning sign to many on Earth. It also posed questions: Should we be watching the skies for danger? How many times has Jupiter saved Earth?

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SATURN



Courtesy NASA

When viewed through a telescope,

Saturn stands out like a beautiful jewel. It resembles a pearl surrounded by a gold ring, resting on black velvet. With the power of the telescope, you see tiny specks shimmering around it. Those are the moons of Saturn. It very well may be one of the most beautiful sights in our solar system.

Saturn is the second largest of our system's planets. Approximately nine times the size of Earth, the planet is composed of hydrogen, helium, methane and ammonia.

With powerful telescopes one can see more planet and ring definition. Belts and shades appear. The "ring" is actually "rings." The planet surface looks banded.

DID YOU KNOW?

If you could find an ocean big enough and set Saturn on it, Saturn would float! It has low enough density for its size to make that possible.

Until a probe came near to the planet it was not known that there were actually 3,000 ringlets around the planet. The width of the ring bands add up to more than 30,000 miles. But the *thickness* of them measures less than 500 feet!

The interior is thought to be much like that of Jupiter. It seems to have a liquid hydrogen interior, with liquid metal characteristics near its core. A small iron core probably exists.

Even though the planet's size is 815 times that of Earth, its mass is only 95.2 times more. It has a rapid rotation of once every 10 Earth hours and 14 minutes at the

equator. Because of this, it tends to flatten at the poles, much like Jupiter. The equatorial radius is 37,488 miles and the polar radius is 33,555 miles.

Although Saturn is hundreds of millions of miles away, Jupiter throws off Saturn's orbital path around the Sun by as much as 10,000,000,000 miles. The distance from Jupiter to Saturn is almost the same as Jupiter to the Sun.

This planetary jewel is nine times farther away from the Sun than the Earth. A truly cold place for the planet and its moons, the average temperature on the moons and the rings is -330 degrees Fahrenheit.

Saturn has 61 moons, the largest moon, called Titan, and has some things in common with our planet. Both have an atmosphere, rain, snow and accumulations of liquid on the ground. Other major moons include: Iapetus, Mimas, Dione, Tethys, Enceladus, and Rhea. At least 19 moons have been spotted to date. Several of the smaller moons are probably asteroids caught by gravity while passing by. The greater the distance from Saturn, the bigger the moons.

The planet actually emits more heat from its interior than it receives from the Sun. It receives only 1% of the Sun produced heat that Earth receives.

Saturn is named after Saturnus, God of Agriculture. The rings of Saturn were not discovered until 1659 when astronomer **Christian Huygens** identified them. Galileo thought that Saturn was composed of three stars in very close proximity to each other.

The rings were thought to be solid discs until 1895, when astronomers theorized that solid rings could not hold

together, that close to a planet. Until just a few years ago, Saturn was thought to be the only ringed planet; now it has three companions. This discovery was made by the spacecraft Voyager I which found two rings around Jupiter and five around Uranus. Neptune also has rings.

The **rings** are composed of objects as small as tiny icy particles, clear ice chunks resembling mid-sized asteroids. The ice contains dirt contaminants. There are theories about where the rings originated. One is that a comet may have destroyed one of the moons eons ago, and that the resulting rubble formed the rings. Another is that two of Saturn's original moons may have collided with each other repeatedly and left the resulting devastation to orbit the mother planet. It is estimated that the rings will eventually fall onto Saturn; this may take billions of years.

Each major ring structure has a name. The outer ring is known as **Ring "A"**. The gap between the rings is known as the **Cassini Division**. The closest visible ring structure is the **"C" Ring**.

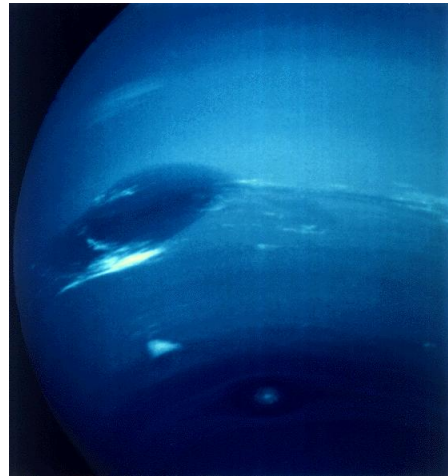
Saturn's belts, like those of Jupiter, emit radio waves. Its magnetic fields are much weaker than can be judged by its size. At cloud tops, the belts are weaker than those found on the Earth. However, they do create a bow shock that resists solar winds.

The atmosphere appears to be stormy, with white oval shapes that resemble storms found on Jupiter. There is a thin haze surrounding the upper atmosphere. Saturn's wind speed, up to four times stronger than that of Jupiter's wind speeds, range up to 1,100 miles per hour at the equatorial area, but they drop to nearly zero at the higher and lower latitudes.

Lightning has been detected in the atmosphere of Saturn.

Workbook Pages 39 - 40

URANUS



Courtesy NASA

The seventh planet from the Sun, located between Saturn and Neptune, Uranus was accidentally discovered in 1781, by **Sir William Herschel** of Great Britain. The original name was *Georgium Sidus*, in honor of the king George III of England. The Uranus name was adopted in the late 1800s.

Uranus is invisible to us with unaided eye. It appears blue/green when seen up close. Because of its diffuse covering, it is difficult to figure out its rotation from afar. Voyager 2 made a rotational observation of the planet in 1986 and found different parts turning at different speeds. The day is 14 Earth hours long at higher and lower latitudes on the planet, while it is 17

hours long around its middle.

No colorful cloud bands surround this planet. A covering fog of methane gas crystals hide what is underneath. Occasionally some clouds tower above the layers below. Other than this there are no real definable features.

The core of Uranus is rocky and is about the same size as that of our Earth. This core is covered by a great mass of icy slush mix of liquid methane and water. Over this layer is an atmosphere of 85% hydrogen and 15% helium that is pressurized and has a soupy quality. On top is a smog blanket of methane.

Uranus has a **rotational axis** (angle of the spin.) that is quite odd. It turns almost completely sideways instead of in an east/west movement. It would be as if Earth's rotation was from the north to the south. Why the planet is rotating that way is speculative. One theory suggests that it collided with something so big that it was knocked sideways. This motion gives Uranus the appearance of "rolling" rather than spinning.

Uranus has a total of nine skimpy rings. Five were discovered in 1977; the rest were found by Voyager 2. Narrow and black, there seems to be little dust in them. They are filled with ice blocks about the size of refrigerators.

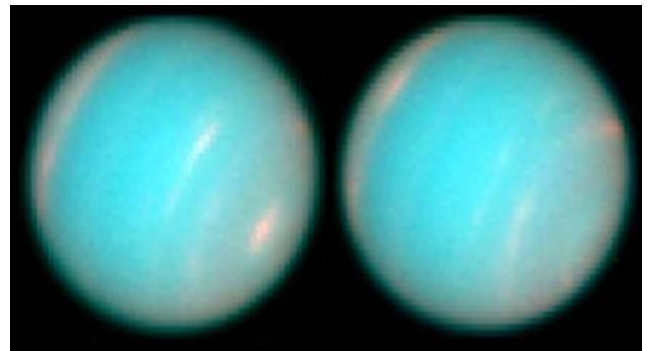
The diameter of Uranus is 31,771 miles at the equator. It is typically about 1.78 billion miles from the Sun. It takes about 84 years for it to make one orbit around the Sun. The far northern and southern regions have the same summer and winter tendencies as does our own planet. Therefore, 42 years there is more darkness

and 42 years more light, which alternates at each polar season.

Uranus is 14.5 times greater in mass than Earth. Its volume is 67 times larger than our planet, its gravity is little more than ours. It is not a dense planet.

The planet has 27 moons that have been discovered so far. Ten were discovered by Voyager II. Fifteen of them orbit around the equator in an east - west direction. The other two move from west to east at a higher angle from the equator. Two of the moons are irregularly shaped.

NEPTUNE



**These two pictures taken by the Hubble Telescope, allows you to see the rotation of Neptune.
Courtesy NASA**

From Neptune, Earth looks like another faint star in the far reaches of space. During daylight hours the glare of the Sun *obscures*, (covers from us), from our view of the planet.

When sunlight reaches Neptune it shines with 1/400th of the power shining on Earth. It is 30 times farther away than the Sun is to us. The temperature is low, is only 70 degrees above absolute zero.

Neptune is nearly 30 times the

distance from the Sun as is our Earth. It is so far away from us that it was not discovered until 1846 by the use of mathematical calculations by French astronomer **Urbain Leverrier**. From these calculations, German astronomer **Johann Galle** spotted the planet that same year.

The big blue planet is so far away from the Sun, with an orbit so large, that 1 Neptunian year is equal to 165 Earth years. During that time Neptune travels 2,793,100,000 miles.

Neptune has 13 moons, two of which can be seen by our most powerful telescopes. The rest were discovered by Voyager 2 in 1989. The largest has been named Triton. In 1989 Voyager 2 spacecraft took extraordinary pictures of Neptune, providing new information.

The planet is a deep blue. It had a “**Great Dark Spot**” akin to Jupiter’s greatest storm spot. It had the same proportions and was located at the same latitude as Jupiter’s spot. But, unlike Jupiter, its spot lasted only a few years. By 1994, it was no longer visible.

Methane clouds cover this planet. These clouds absorb red light, while reflecting the blue ends of the Sun’s light spectrum. The *albedo*, or reflectivity of the planet, is high. Eighty five percent of all incoming light is reflected. However, even this much reflected light is not enough to make Neptune visible to unaided eyes on Earth.

The upper atmosphere of Neptune is at – 280 degrees Fahrenheit, a temperature in which methane is liquid. (A few degrees less and it will freeze.) Because of this, tiny droplets of methane form a blue mist

covering the lower layers of the planet. The lower levels of the atmosphere appear to be composed of hydrogen sulfide. Occasionally a white methane cloud can be seen zooming above the blue layer. Winds moving these clouds have been clocked at speeds of up to 700 miles per hour in the upper atmosphere.

Its 30,700 mile equatorial diameter makes it a virtual tie for third in size with Uranus. It is 72 times larger than Earth but only has 17 times the *mass* of our planet.

Neptune is also known as a “gas planet”. Although it may have a solid core of rock and metal, perhaps more substantial than the other gas planets, its magnetic poles are tilted 50 degrees from the rotation axis.

The layer below the methane clouds there is an atmosphere of hydrogen and helium, thousands of miles thick. Below that is slush of warmer hydrogen, helium and water ice. The upper parts of this layer rotate at different speeds. One rotation of these levels takes 16 hours and 7 minutes earth time. However the upper areas move more slowly. Because of this there is friction between the layers that causes some heating. The heat rises and creates Neptune’s wind and weather. This heat rising upward actually exceeds the heat the planet receives from the Sun. If this did not occur there would be no features visible looking from space to the outside layers.

Neptune has rings - five of them. They are very thin. The wider ones are diffuse, meaning they are so lacking in density that they are almost transparent. The three smaller rings seem to be uneven in thickness. The reason why this uneven clumping occurs is not known.

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THE DWARF PLANETS

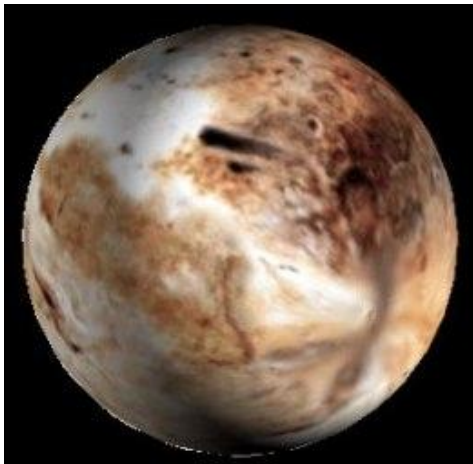
The International Astronomical Union defines a **planetoid**, or **dwarf planet** as: orbiting around the Sun, having its own gravity, having a rigid body, a hydrostatic balance, a spherical or semi spherical shape, has not cleared its neighborhood of debris and is not a satellite.

A **plutoid** has the above characteristics and also is beyond Neptune's orbital, partly or all of the time. (**Trans-Neptunian**). So far, five objects have been found that meet this description. According to these definitions, Ceres is a dwarf planet but not a plutoid.

PLUTOIDS

All **plutoids** are also defined as dwarf planets.

PLUTO



Courtesy NASA

This **planetoids** (now plutoids) existence was first theorized in 1905. Once again, calculations through physics and mathematics found a planet. The actual

discoverer of Pluto was **Clyde Tombaugh** in 1930. It was defined as a planet until 2006, when scientists decided to create a new class of objects in our solar system and Pluto thus became a **plutoid**.

It takes this rocky planetoid 247.7 Earth years to orbit the Sun. Pluto is usually over 3.6 billion miles from the Sun. This makes Pluto 30 times farther from the Sun from than Earth. Occasionally Pluto comes closer to Saturn and Neptune. This lasts about 20 Earth years of each of Pluto's yearly orbits.

Pluto has a different angle of orbital path from Neptune, so Neptune and Pluto will never collide. Pluto's orbit is at a 17% **inclined plane** (an angle to the plane of the ecliptic, which is the level of angle the planets orbits the Sun. as compared to the rest of the solar system. If the planet had a stable and regular orbit on the same plane as the rest of the planets, it is possible that Neptune's gravitational influence could have thrown Pluto out of the solar system.

Pluto's average temperature in the summer is -387 degrees Fahrenheit and summer last about 50 years. Its winter is nearly 100 years long. The Sun looks like the head of a pin at the distance of the length of one's arm when Pluto and the Sun are at their closest respective locations.

Pluto cannot be seen by the unaided eye; only a large telescope can find it. It seems to have a yellowish color. The Hubble telescope gave us pictures that reveal an unusual landscape, with very bright areas next to very dark ones. The bright areas are probably shifting fields of nitrogen ice; the dark areas could be methane ice interacting with sunlight. Some other areas that are dark could be from impact craters. There may be

large ice caps at the poles.

The density of this planetoid is about twice that of water. The low density of the rock may have to do with the very cold temperatures and the low pressures experienced when Pluto was forming.

In 1978, astronomers discovered that Pluto has a moon. They named it **Charon**. It is unusual because it is so close to the planet, only 12,000 miles away. They are so close in size that they could be considered a double planetoid.

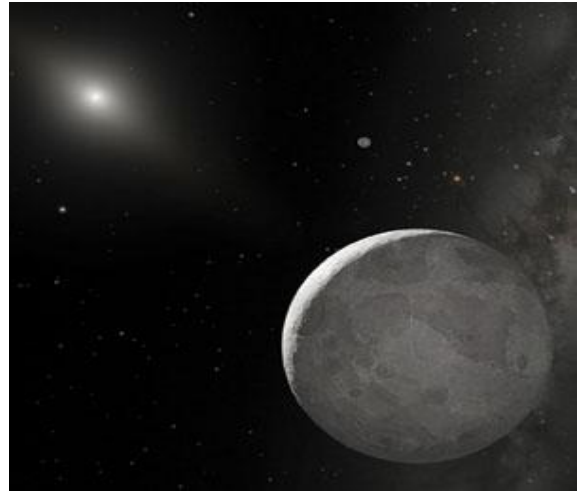
In 1994 astronomers pointed the Hubble telescope at this lonely pair and came up with a size of Pluto. It has a 1,440 mile equatorial diameter. It also has a thin atmosphere of methane nitrogen. The air pressure on the planet is approximately 100,000 times less than ours is at sea level.

There is a popular astronomical theory that Pluto was once a moon of Neptune that was knocked away and that Charon, its moon, was made up of the leftover debris from the collision. Remember, both Neptune and Uranus have angled poles that give the impression that those planets were somehow knocked sideways. Could this be true?

There is now a probe heading for Pluto. The mission called **New Horizons** was launched January 16, 2006, at Cape Canaveral, Florida. It will arrive at Pluto in July, 2015. From there, the spacecraft will enter the **Kuiper Belt** (the area outside the last planet that contains icy objects, plutoids and asteroids), and travel through it for the next five years. On board are seven different instruments able to take measurements of Pluto and Charon. Along the way, the probe will be dormant for seven years in order to save energy.

Workbook Pages 43 - 44

ERIS



Artist's Rendition of Eris
Notice how weak and distant the Sun looks. Courtesy NASA

This dwarf planet, or *planetoid*, is named after the Greek goddess of warfare. It was discovered in 2005 by planetoid hunters **Mike Brown** and **Brad Trujillo**. It was originally called Xena.

Eris has a moon named **Dysnomia**. In Greek mythology Dysnomia is the daughter of Eris and is the demon spirit of lawlessness.

Eris is the largest object orbiting the sun that has been discovered since Neptune was found in the 19th century. Larger than Pluto, its exact size has yet to be determined but is probably about 1400 miles in diameter.

Eris is in the Kuiper Belt when it is at its farthest point from our sun, 10 billion

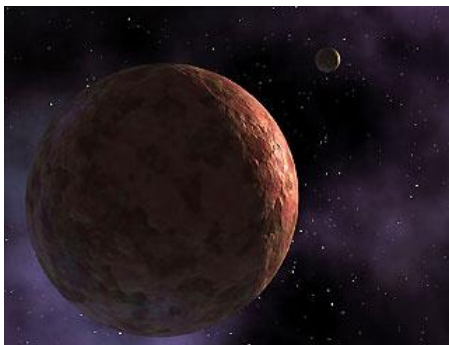
miles from it or approximately 97 AU in distance. Eris is three times farther away from the sun than is Pluto and takes 560 earth years to complete one orbit around our star. This is twice as long as Pluto takes. It is so far away that a photon of light takes twenty four earth hours to go from the sun to Eris and then reflect back to earth.

Eris is an extremely cold planetoid. When it is farthest from the sun, the surface temperature is -405 degrees Fahrenheit. When it's nearest to the sun, during its elliptical orbit, the surface temperature will rise to -360 degrees. This temperature variation is the most dramatic of any major orbiting object in the solar system.

The surface is more reflective and smoother than that of Pluto. As a matter of fact is the second most reflective object in our solar system. Only the moon Enceladus is more reflective. The surface seems to be covered with frozen methane. When Eris comes closer to the sun and reaches a warmer temperature, the frozen methane will turn to gas and become its atmosphere.

It is speculated that its interior is probably composed of ice and rock.

MAKEMAKE



Artist's Rendition of Makemake
Courtesy NASA

This dwarf planet was also discovered in 2005. Found by planetoid hunter **Mike Brown** and his team. Makemake is named after a god who was worshipped by the inhabitants of Easter Island.

Makemake can be found in the Kuiper belt. It is closer to the sun than Eris and not much farther away than Pluto, but still it's very far away. It requires nearly 310 earth years to orbit the sun.

The size of the planetoid is approximately 1,000 miles in diameter. This makes it smaller than Pluto and Eris. It is about $\frac{3}{4}$ the size of Pluto.

The surface temperature averages -406 degrees. The surface appears to be composed of methane and possibly ethane. The colors of the body seem to be a mix of areas that are red and white.

When closer to the Sun, the methane will defrost and become an atmosphere around Makemake.

HAUMEA



Courtesy NASA

Haumea is another dwarf planet discovered by **Mike Brown** and his team.

Discovered in 2004, the name comes from a Hawaiian fertility and birth goddess.

Haumea has an unusual oval shape. It is presumed that it had a collision with another large object sometime in its distant past. The moons that circle the planetoid may actually be debris from that collision. Its rotation, or day, lasts only 4 earth hours.

Haumea has the distinction of having two moons, Hai'aka and Namaka. Hai'aka is the larger moon and is 190 miles in diameter. The smaller Hai'aka is further out from Haumea (38,000 miles) and circles the planetoid every 49 days. Namaka is orbiting 24,000 miles out and orbits every 37.5 days.

SEDNA



A comparison of Sedna with other Solar System objects. Courtesy NASA

This dwarf planet was discovered by **Mike Brown, David Rabinowitz and Brad Trujillo** in November, 2003. They named it after the Inuit goddess of the sea.

It has an elliptical orbit that, at times, makes it the most distant observable object in our solar system. It is found in the Oort

cloud, near the edge of the Kuiper belt. Its sun orbit takes 12,000 earth years. *Sedna may not be originally from this solar system!* It may have been “captured” which would explain the odd orbital path.

The smallest of the five planetoid, Sedna is a little less than $\frac{3}{4}$ the size of Pluto, or about 900 miles in diameter. It has a 10 hour rotation.

The surface appears to be very red in color. There has been little methane or water ice detected. Rather, the planetoid may be covered in **hydrocarbons**, a compound that is made of hydrogen, carbon and tholin. The surface seems smooth and consistent in color. This may be due to its distance away from the center of the solar system, which means it has little chance for collisions.



A Hubble photo of Pluto and Charon. Credit NASA

Cosmic Concept: Discovering

Scientists find these new worlds. They publish their findings in the name of understanding. What purpose do these findings serve? Do we always need to have an immediate material or practical justification from discoveries to justify research? Title your essay: Research and Results.

Minimum : 100 words.

THE DWARF PLANET CERES



Courtesy NASA

Ceres is the smallest dwarf planet in our solar system. It was discovered by **Giuseppe Piazzi**, of Sicily, in 1801. He first thought it was a comet. It is located in the asteroid belt, between Mars and Jupiter. For almost fifty years it was considered a planet. For the next 155 years, it was classified as an asteroid. It is now classified as both asteroid and dwarf planet, or planetoid. It is named after Ceres, the Roman goddess of motherly love, growing plants and harvests.

Ceres has a diameter of 590 miles and is the largest body in the Asteroid Belt. It contains almost one third of the total mass of the Asteroid Belt. It has about 4% of the mass of our moon. Spherical in shape, it is covered by types of clay and water ice. It is estimated that there is about 200 cubic kilometers of water ice on its surface. That is more than the amount of fresh water on our planet! There are also carbonates found on the surface. Ceres probably has a rocky core and may be layered or “*differentiated*” inside. It is also possible that the various rock, water and mineral components may be mixed together. There also may be liquid water mixed with ammonia in its interior.

There are about 10 recognizable

features on the surface of Ceres, including two large craters. The surface is coated with dust. Ceres may have an extremely thin atmosphere. Some water vapor or indirect evidence of vaporization has been detected.

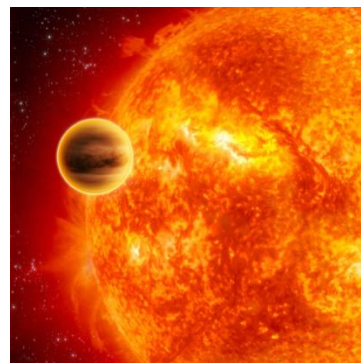
This planetoid takes 4.6 earth years to orbit the sun. It maintains its orbit within the asteroid belt. Ceres has a 9 hours, 4 minute rotational day.

Ceres is about 4.57 billion years old. It may have had a peaceful formation in the asteroid belt or may have migrated from the Kuiper belt.

There is a space probe on the way to take a closer look at each. The name of the probe is **Dawn Mission**. The probe will stop at another asteroid and then arrive at Ceres in 2015.

Workbook Pages 45 - 46

EXOPLANETS



An Artist's concept.
Courtesy NASA

There are 200 to 400 billion stars in our galaxy. How many have planets is speculative. It is not known if ours is a typical solar system or if it is rare. There could be trillions of planets in the Milky

Way galaxy, or could it be *only* fifty to a hundred billion? Double star systems may create gravitational pulls that make it difficult for planet formation to take place and young stars may also be too new for planet formation. Old stars may have destroyed them when they exploded or somehow changed their nature. Over half of the Milky Way systems seem to be **binary**, (double star systems.)

Nearly all of the **exoplanets** have been detected by indirect means and not seen. Although there is no way of knowing, it is estimated that at least 10% of the star systems in our galaxy has planets. That would mean there is a minimum of many billions of planets in our galaxy!

As of March, 2010 there were 442 known planets outside our solar system. They have been found in singular and multiple star systems.

Although theories about planets outside our solar system started in the 1800s, “extrasolar planet hunting” is a new and competitive field. Several teams of astronomers are searching the skies for signs of planets circling their stars. The common usage of **radial velocity**, (or detecting a wobble), when a planet passes a star, is the way most extrasolar planets have been found to date.

So far, most extrasolar planets found have been the size of Jupiter or larger. The majority of them that have been found are in a close orbit around their parent star. Interestingly, the majority of exoplanets found to date averaged having orbits that are less than 20 earth days. There are also many discovered planets that have large elliptical orbits. Only a few planets that are less than two to three times the size of earth have

been detected.

The first exoplanet was discovered in 1992 by **Bruce Campbell, G.A.H. Walker** and **S. Yang**. It’s a gas planet orbiting a star named **Gamma Cephe**. This discovery would not be confirmed for another 14 years.

The second exoplanet was found by **Alexander Wolszczan** and **Dale Friel**. It is known as a pulsar planet and is orbiting a neutron star that was the remnant of a super nova event.

In 1995, the first exoplanet that orbits a main sequence, or mainstream type of star, was discovered by **Michel Mayor** and **Didier Queloz**.

One technique that helps find exoplanets is called **microlensing**. It detects changes in received - light magnification when planets pass between a star and the observer. A planet passing a star will have a gravitational effect on its passing light beams. This increase and subsequent decrease in light distortion can tell us:

1. There is a planet there.
2. The size of that planet.
3. Its distance from its anchoring star.

Several planets have been discovered using this technique. One of these planets, small and rocky, is located 20,000 light years away, in the Sagittarius Constellation. Name: OGLE-2005-BLG-390Lb. Nice name! The star it orbits is only one fifth the size of our Sun. The planet is about five and a half times larger than Earth and has an average temperature of -364 degrees Fahrenheit. The hope is that rocky planets, with supportive stars that are the right distance from them, will be found.

These planets have a greater chance for hosting life.

Astrometry is another way to detect exoplanets. Astronomers take a measure of star movement and wobbling. The wobbles indicate a planet or planets orbiting. The trouble is that the process is measuring movements so tiny that it is very hard to detect the magnitude of the wobbles.

Radial Velocity or the **Doppler Method** is another strategy to discover these exoplanets. The stars in our galaxy orbit around the gravitational center of our galaxy. As they move, some change their velocity. Why? The orbiting planets affect the speed of the orbiting star when they pass by the star. This produces a color shift, known as the **Doppler Effect**. The starlight measured coming toward earth has slight changes in color. *This has now become the most successful way to find planets!*

Transit Methods work in the following way: When the planet passes between its star and earth, there is a diminishing amount of light that makes its way to us. The more diminished the light, the bigger the planet.

One can also use **Pulsar Timing**. When a neutron star has planets, the passing planets can affect the speed of the rotating star and thereby effect the frequency of radio signals that pulsating - neutron stars send out.

Eclipsing Binaries. We observe a system that has two stars; once in a while these stars eclipse each other. That means one of them comes in between us and the other star. A passing giant planet can slightly affect the speeds of those eclipses.

Circumstellar Disks Observations

are another way to detect an exoplanet. Disturbances in the dust around a star will indicate that there was disruption done by an orbiting planet.

Most planets found so far are in F, G, or K type star systems, considered non habitable planets. Scientists theorize that it is difficult for planets to form in very cool or very hot star systems. Also, stars that contain metals seem to have a better chance to have planet formations in their systems. Stars that don't contain lithium seem to not have planets.

These are the types of planets so far found:

Pulsar Planets - Circling a neutron star.

Super Earths - These planets have a mass between the amounts of earth and Jupiter.

Hot Jupiters and Hot Neptunes: Planets that are large, gaseous and orbit close to the star.

Cold Jupiters and Cold Neptunes: Planets that are large, gaseous and orbit far from the star.

Gas Giants: A large gaseous planet with a rocky core.

Eccentric Jupiters: These planets have orbital patterns that resemble comets. They swing far out and then come in close to the star. These types of planets may restrict the formation of smaller, rocky planets.

Goldilocks Planets: Planets that are found in the "habitable zone", have a greater chance for life.

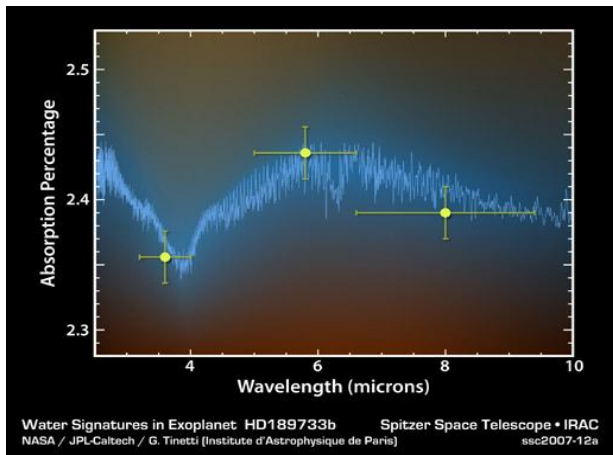
Terrestrial Planets: These are rocky planets.

Chthonian Planets: A planet that has been stripped of its gaseous layers because of the planet's proximity to the parent star. What is left is a molten core orbiting the star.

Ocean Planets: Hypothetical planets covered in liquid water.

Desert Planets: This planet has an atmosphere, no precipitation and a singular (only one) climate.

Workbook Pages 47 - 48



This graph is measuring water vapor on an exoplanet.

Credit NASA

Cosmic Concept: Chances of Life

Hundreds of planets outside of our Solar System have been found. The astronomers finding these planets are looking for ones that could harbor life.

Chapter 7 Moons



REQUIRED WORK:
CD - HOMEWORK
WORKBOOK: PAGES 51 -58
MOONS TEST (TEACHER PROVIDED)
TEACHER OPTIONS:
OUTER PLANET REPORT

IONS

REPORT

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have so many moons that we may not have counted them all. Would you like to know the solar system moon count as of 2010? The tally is up to 167 and counting.

There are different types of moon – satellites. The size and roundness of them vary. Most are formed near their partner planet. Some are asteroids that were captured by a planet’s gravity.

Here are some terms that are used in the moon exploration business that concerns how moons orbit their planets:

Inclination: Describes the orbital path of the satellite compared to the equatorial latitude of the planet.

Prograde: Is orbiting the planet in the way that a planet orbits the Sun while it is circling between 0 and 90 degrees compared to the planet’s equator. The vast majority of moons are prograded. They circle counter clockwise if looking down at the planet’s north pole.

Retrograde: Is orbiting the opposite direction of the way planet travels around the sun and/or has an orbital path that is more than a 90 degree angle than the equator. Most, if not all retrograde moons are captured asteroids.

Irregular: Moons that have elliptical orbits and are still within the 90 degree equatorial angle.

Regular: moons are all prograde, but not all prograde moons are regular. Some are irregular.

All prograde - irregular moons have an “a” at the end of their names. All retrograde moons have names that end in the letter “e”.

Below is a listing of planets and planetoids along with how many moons they have.

Mercury	0
Venus	0
Earth	1
Mars	2
Jupiter	63
Saturn	61 (+ 150 moonlets)
Uranus	27
Neptune	13

Dwarf Planets

Pluto	1
Eris	1
Haumea	2
Ceres	0

In this section, we will look at some of the more interesting moons, which include our own.

EARTH’S MOON



The Moon
Credit NASA

We see our moon at night - sometimes even by day. It is big, round and looks a little beat up. The colors are whitish-

gray, gray and some black. It can also be yellow when close to the horizon and very bright and white when high in the sky.

Our Moon had different names during ancient times when many thought of it as a goddess. Some of the given names were: Diana, Lunea, Cynthia, and Selene. It has been both worshipped and feared. It was an object representing romance. It was a light for harvesting at night. It was thought of as a factor in transforming people into werewolves. It was believed that the Moon could even cause people to become “lunatics.”

(Derived from the Latin word luna.)

DID YOU KNOW?

When seen on Earth, the Moon is 25,000 times brighter than the nearest star, other than our Sun. But it only reflects 11% of the sunlight shown on it.

We have only one moon. In English, we call it the Moon. It is one of many in the solar system. Here are some of additional Moon facts:

It has a 2,160 mile diameter at its equator.

The Moon is a little more than one quarter the size of Earth.

Its density is about sixty percent of the density of the Earth.

Its average distance is about 221,423 miles from Earth. Its orbit is elliptical (an oval shaped path). The farthest point the Moon is from Earth is 252,667 miles.

There are tremendous temperature

swings on the Moon because there is a very slight atmosphere to hold or release heat and cold.

The Moon travels around the Earth at a rate of nearly 1.5 miles *per second!*

There is water ice on the Moon.

Evolutionists age the Moon at 4.4 billion years.

It has 17% percent of earth’s gravity.

MOON TRICKS

Have you ever noticed that there can be a “halo” around the Moon? It is not what it seems to be and neither is it *where* it seems to be. The circle is caused by ice crystals high in our sky.

Another phenomenon is known as the “Moon Illusion.” No one is quite sure why, but the Moon looks much bigger when seen at the horizon level.

DID YOU KNOW?

The Moon has a synchronized rotation. A moon day rotation equals the same amount of time it takes the Moon to go around the Earth (27.3 days). Therefore, we can only see one side of the Moon at any given time.

The Moon has structure. The center, or core, is thought to be solid but could be partly molten. Moonquakes have been detected. They are very weak, leading to the belief that there might be some liquid towards the middle of the core. Moonquakes seem to be related to the tidal forces caused by interacting with Earth’s

gravitational forces.

The surface temperature averages 107 degrees Celsius in the sunlight and -135 degrees Celsius in the shadows. Sometimes the temperature drops as low as -249 degrees Celsius, which would rival temperatures found in the Kuiper belt.

Galileo thought that the dark areas on the Moon were oceans. He called them **maria**, (plural), or **mare**, (singular). The mare is actually basalt rock lava beds that have cooled from the pouring out of magma, were caused by meteorite impacts cracking the surface. The largest mare is the Mare Imbrium, 1,700 miles across.

The highest areas on the moon are known as “The Highlands” and are some of the oldest surfaces on our Moon formed, during the period of volcanism. As the Moon cooled, there were flows of volcanic basalt, which were most active between 3.2 and 1.2 billion years ago. Igneous (volcanic), rock areas covers almost 80% of the Moon’s surface. Some smaller features exhibit geographical features that appear to be caused by **out - gassing**. (An explosive leakage from subsurface gas pockets.)

Virtually all of the Moon’s mountains are walls of craters. Very few high hills or mountains are from volcanic episodes, since the Moon has no tectonic plates; no mountains were caused by plate movement.

The Moon is mostly covered with silicon dioxide, magnesium, calcium, glass and dust, which form a layer called the lunar regolith, ranging in depth from 5 to 50 feet. It is created by the smashing of the surface that result in debris from the impacts of meteorites and micrometeorites being strewn

over the surface. When brought back to earth and studied, scientists said it had the scent of gunpowder.

The crust is made of 45% oxygen, 21% silicon, 6% magnesium, 13% iron, 8% calcium and 7% aluminum. The mantle: underneath is made up of olivine, orthopyroxen and clinopyroxen. The core of the Moon is only 255 miles in diameter and seems to be made of partly molten iron and nickel. Some of the basalts on the surface also contain titanium.

The Moon is the second least dense moon in the solar system. (Only Io is less dense.) The Moon has a magnetic field that is much less potent than the one form emanating from Earth.

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The moon looks a little beat up! In a way it is just that. It has small craters called **craterlets**, larger craters, some extremely large craters more than a hundred miles across, called “**walled plains**”. Most of these craters were the result of meteor hits. The larger pieces of material ejected by these collisions caused more craters to be formed. Smaller particles blasted out, called “**rays**”, formed patterns that stretch out for hundreds of kilometers.

The far side of the moon looks far different from that facing the earth. It does not have large maria, but it does have craters and highlands.

The Moon, (La “Luna” in Spanish), is being hit constantly by space debris. With no atmosphere to protect it, the surface is

bombarded by large as well as sand-sized rocks, small meteors called “**micrometeorites**” they hit the moon at speeds up to 70,000 miles per hour. This makes the moon’s surface a very dangerous place for humans. A small grain could go right through the body of an exploring astronaut!

The micrometeorites affect changes on the surface of the moon: they can cause erosion. However, they are 10,000 times less effective in creating changes than those caused by air and water on the surface of our Earth.

Several years ago a military satellite turning toward the Moon to adjust its instruments, reported back an amazing find: water ice on the Moon! NASA sent a probe, called a “**Lunar Prospector**”, to investigate and to confirm the findings. It is now thought that ice could have come from comets that have collided with the Moon. The spacecraft **Clementine** has further confirmed these phenomena. The Indian probe, **Chandrayaan**, detected large quantities of ice.

The ice is not only in permanently shadowed craters, but it may also be found in the regolith. It seems there are literally millions of tons of ice present. One 10th of 1% of the regolith soil may be frozen water. Scientists looked again at the collected Moon rocks brought to earth by the Apollo 15 astronauts and found that there was water in some of them.

This ice could be used to support a space station on the Moon. The hydrogen and oxygen can be separated, and the elements used for drinking water, breathable air and rocket fuel.

The Moon’s atmosphere is extremely thin but has a very complicated composition. It most likely results from decay and out-gassing. These elements are: sodium, potassium, polonium, argon, oxygen, methane, nitrogen, carbon monoxide and carbon dioxide.

We have sent many “visitors” to our moon, including machine probes and manned vehicles. Later in this book, we will study these explorations.

There have been several recent discoveries, most of which were found by the lunar astronauts who brought back moon rocks. The rocks range in age from 3.1 billion years to 4.4 billion years. The rocks also reveal another important fact: The Moon has a different geologic make up than present day Earth.

The Moon has several measurable effects on Earth. One is that of the **lunar eclipse**. That’s when the Moon passes between the Sun and the Earth. The shadow of the Moon falls upon the Earth. From Earth, the Sun and Moon look the same size because the Moon blots out the sunlight when aligned with us.

A major Moon influence on Earth is the **tidal effect**. The Moon’s gravity actually pulls at our oceans. The powerful pull of our natural satellite can change the depth of the coastal waters by many feet in a few hours. (This subject is covered in the Planets / Earth section.)

Where did the Moon come from? How did it form?

There are several theories:

The Fission Hypothesis: The Moon was formed by a chunk of partly molten earth flying off into space and leaving the Pacific Ocean area as a scar.

Capture Hypothesis: The Moon was a free - wandering space object that was capture by our planet's gravity.

Co-formation Hypothesis: The earth and Moon formed at the same time.

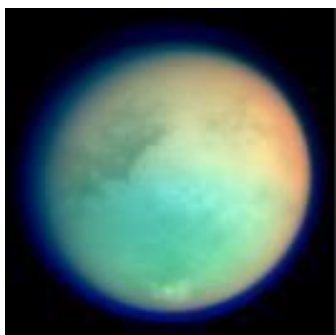
Giant Impact Hypothesis: A large object, perhaps a large as 1/3 of the earth, collided with our very young planet and debris was thrown into space. This debris coalesced into the Moon. This is presently, the most popular scientific theory.

Where is the Moon going?

It is currently drifting away from Earth at 1 ½ inches, per year. Theoretically, over billions of years, the Moon could become a planet. But the Moon and Earth, according to science timelines, would already be destroyed by the Sun.

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TITAN



Courtesy NASA

This, the largest moon in our solar system, is also the seventh largest world as well. Titan was discovered in 1655 by

Christiaan Huygens. It is the most complicated moon when considering its atmosphere and its interactions within the moon's surface.

Larger than Pluto and Mercury, Titan is one of the 22 moons of Saturn. It is famous not only for its size but also for its atmosphere. Titan is the only moon with a substantial atmosphere. Other than our own Moon, it is now one of the most studied moons in the solar system. The largest moon in the Saturn system, it orbits Saturn from a distance of about 720,000 miles. It takes 16 earth days to circle Saturn.

Its atmosphere contains 95% nitrogen and 5% methane, plus a multitude of trace gases. Its surface air pressure is actually 50% stronger than that of Earth's atmosphere. However, differences between temperatures of Titan and Earth are extreme. The average temperature of Titan is -292 Fahrenheit. Methane freezes just a few degrees below that level. Methane, on Titan, is found in frozen, gaseous and solid states. The atmosphere averages 190 miles in thickness. There are continuous strong winds in the upper atmosphere that are as fast as category 3 hurricanes. These winds make the atmosphere move around Titan five times faster than the spin of the moon itself. Its lower atmosphere tends to be calm.

It rains ethane on Titan, in very large drops (1cm). The rain drops to the ground, just like it does on earth. But because there is much less gravity, it can take as much as an hour for them to finally land. Most of the drops evaporate before they reach the ground.

From a distance one cannot see any features on Titan. It is covered with a yellowish brown -thick- haze of methane,

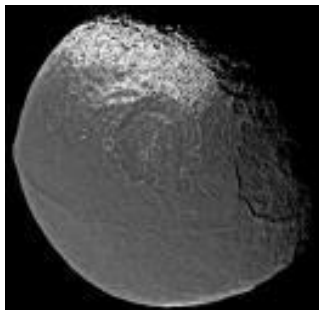
ethane, and acetylene compounds. It actually snows on this moon! The snowflakes are made of methane and fall slowly to the ground, due to the light gravity of this world.

Every day appears to be gloomy on Titan. The sky is brown and the sunlight gives little more illumination than our moonlight provides. A day on Titan is 16 Earth days long. Eight are dark and, the rest are gloomily lit.

DID YOU KNOW?

During the recent fly - by of Titan, by the space probe **Cassini**, it recorded radar images of lakes! They are filled with liquid hydrocarbons. This makes Titan the only place, other than Earth, that is known to have liquid lakes! Many of the lakes look like they may be filled in impact craters or are a result of volcanism. Others look like a typical filled - in lake on earth. Does this mean there is an equivalent to Earth's water cycle working on Titan? Time will tell. Saturn takes 29 years to orbit the sun. As observations continue, we will be able to tell whether there is seasonality to these liquid deposits.

IAPETUS



Courtesy NASA

Iapetus is the third largest moon in the Saturn system. It is a peculiar world that

is very bright on one side, very dark on the other. (One side is ten times brighter than the other side).

Iapetus is the third largest moon that orbits Saturn. It orbits at a distance of about 2.1 million miles from the planet. It takes 79.33 days to complete one orbit.

The light side looks like a typical cratered moon. The other side is as dark as charcoal and has virtually no features. The darkness may have to do with collecting dust from the moon Phoebe or maybe that part of the moon is more exposed to the sun and the ice has melted. The Cassini space probe arrived in 2004 tried to investigate why this situation exists. So far, there are no conclusions. Iapetus has polar water ice. It also has frozen carbon dioxide lying on its surface. This moon is a little less than half the size of our Moon.

Iapetus has a clearly defined equator and is marked by a mountain line around the middle. From a distance, this feature gives the moon a glued together look.

There are other moons that orbit Saturn. Mimas looks like a typical battered moon. Mimas, Rheas, Enceladus, Dione, and Tethys are midsized moons. These worlds, as well as the smaller moons, are airless and icy.





Courtesy NASA

Ariel is nearly all ice. Not only is the surface icy, but so is the interior. It has strange canyons in several areas. Probably it was partially melted in its early years. This moon is about one third the size of our own.

TRITON



Courtesy NASA

Triton, a moon of Neptune, is a very cold place that averages – 400 Fahrenheit during the day *or* night. The surface water ice is as hard as granite. There may be liquid nitrogen pools lying below the surface. This type of “ground water” is heated by decaying, radioactive particles and tidal forces from nearby Neptune.

Occasionally the liquid breaks through, and geysers shoot it above the surface. As it falls, it freezes and forms snow on the surface. Methane mixed with

liquid falls nearby, leaving purple and black stains near the vents. In essence these vents act as ice volcanoes.

Triton has an interesting and fairly unique feature; it has wind. The air is thin and clear. Sometimes a thin cloud can be seen. The atmosphere is fed by geysers.

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DID YOU KNOW?

There is a theory that a planet near Triton was once orbiting the Sun and was captured by Neptune’s gravity. One reason for this theory is that Triton orbits around Neptune in the opposite direction of the planet’s spin. (Saturn has one moon which does this and Jupiter has four.)

IO



Courtesy NASA

This is a world that is so different from the rest of the solar moons. It is a moon of constant change. A violent place, it has extraordinary events happening daily.

Io is the 13th largest space object in the solar system. Discovered by Galileo

Galilei, it is close to 30% the size of earth. It flies around Jupiter, making one orbit every 1.8 days! It circles Jupiter at a distance of a little more than 250,000 miles.

When Voyager 1 passed Jupiter in 1979, the cameras turned to it and captured one of the most stunning images ever taken. It was a moon with not one visible meteor crater. The place is orange, yellow, white and brown with touches of black. Some say it looks more like a giant pizza.

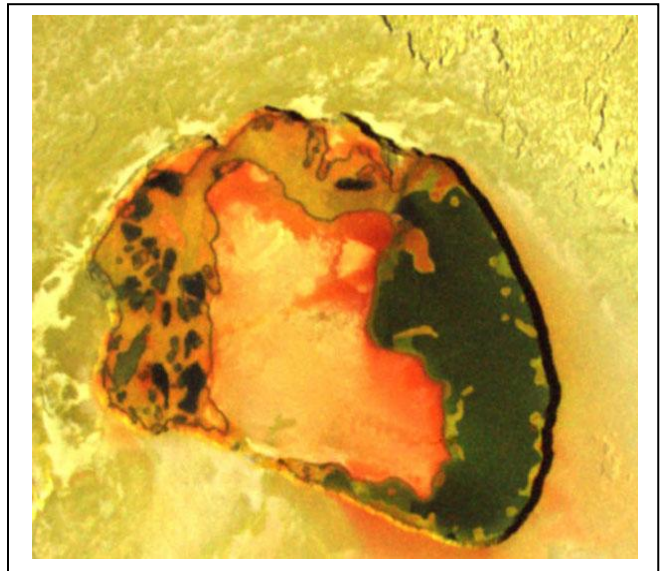
After several days of investigation the team of scientist realized they were looking at a moon with many active volcanoes. There are at least 300 hundred of them. These were the first active volcanoes ever seen outside of Earth. It has incredible volcanic lava temperatures that range from 1,400 to 1,700 degrees Fahrenheit. Most likely the magma contains a lot of magnesium, which tends to burn hot. The lava on Io is hotter than the lava on Earth. The vents shoot out both liquid rock and gaseous sulfur. Jets of gas and molten rock spout up as much as two hundred miles above the surface. There are even lakes of liquid sulfur and rivers of molten lava. This moon is the second hottest place in the solar system, second only to the Sun.

Most of Io's interior is molten. The surface is a weak, brittle and has a thin crust over a hot ball of molten sulfur dioxide. No other moon is like this one. In fact, no other moon even comes close. The gravitational forces of Jupiter and three other moons pull and mix Io into this weird state and make the moon have an elliptical orbit. It is estimated that the side of Io that faces Jupiter can be pulled out into space for as far as 6 miles.

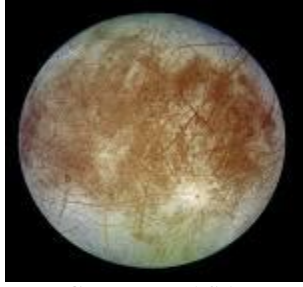
The volcanic activity is so widespread and constant that it is useless to try to map this moon, in 5 to 7 years the whole surface may look different. Every billion or so years the whole moon turns itself completely inside out!

Where the volcanoes are not spewing, there is ice and cold rock. The average temperature on Io's surface, away from the vents, is -143 degrees Fahrenheit. Magma and ice; Io is a moon of contradictions.

Below is a close up photo of a volcano on Io. Credit NASA



EUROPA



Courtesy NASA

Ice and cold are not the only interesting observation one can make about this world. When pictures of this moon were studied it was easy to compare the surface of Europa with glaciers on our own planet. The folds, crevasses and undulations look the same. It has 70% sunshine reflectivity off the icy surface, making it very visible in the sky. (Remember, our Moon has only 11% reflectivity.)

It's about 2,000 miles in diameter and orbits Jupiter from a distance of 400,000 miles. Europa takes only 3.6 earth days to orbit its planet.

The icy surface area is estimated to be, on average, 30 million years old. There are some craters, grooves and cracks on its' surface. The average temperature at the equator is -260 degrees Fahrenheit. At the poles, the temperature drops to -370 degrees. This was caused by the underlying liquid and possibly tidal forces when it passes near other moons.

There is a very slight atmosphere around Europa. The air is composed of oxygen. When charged particles from the sun hits the surface interacts with water molecules, thereby releasing some oxygen and hydrogen occurs. The hydrogen is lighter and therefore escapes more easily from the moon's grip.

But what is under all that ice? To quote a line from the movie 2010 it might be: "Something wonderful." The ice is anywhere from 10 to 100 miles thick. It replenishes itself on a continuing basis. In many ways it acts like our atmosphere; it retains heat, provides protection from cosmic projectiles and blocks out dangerous rays from penetrating the outside, protective layer.

Beneath this ice cover is a sea up to 60 miles deep. It is made up of water. The core is hot rock. Could there be life in this sea? The answer is absolutely... yes! The icy surface on Europa could very well have been liquid when Jupiter and Europa were young. Primeval life may have formed in its oceans and may still be there, under the ice. This likely would be aquatic life with no knowledge of the Universe above the ice, which is not much different from the deep sea life that never breaks the surface of our own oceans. It very well could be that our first alien contact will be with creatures living on a moon circling Jupiter. Today, there may be alien life form near a hot vent of the ore, feeding and may be able to think: "What's up there?"

There are plans to launch a spacecraft to with lasers and radars to study its' surface. This would provide additional information about subsurface conditions. It is the next step towards having a probe land on the moon and drill, or melt, the ice in order to see if organisms dwell below the surface.

Ganymede



Courtesy NASA

Ganymede, the largest of Jupiter's moons and the largest moon in the Solar System, bigger than Mercury, is pocked by many impacts. The moon is *mostly* composed of ice, with dust and dirt lying about on its surface. The Moon's has a skin of dirty ice and when objects hit it, they expose a clean ice sheet beneath. The materials from the collisions are thrown out onto the surrounding area, providing some contrast between clean ice and the dirty ice surface. There are many craters on the moon, suggesting that its surface is very old. The ice, over time, reduces the craters by relaxing the walls leaving more rounded edges and eventually flattened - circular scars on the surface. These are called **palimpsests**.

Ganymede had internal heat at some point. How much is not clear, but there can be seen some effects on the ice. This may be the reason that it has its own magnetic field.

Like Europa, it too probably might have a below - surface, saltwater sea. But the ice on this moon is much thicker than that found on Europa.

The core seems to be made of metals and rock.

Callisto



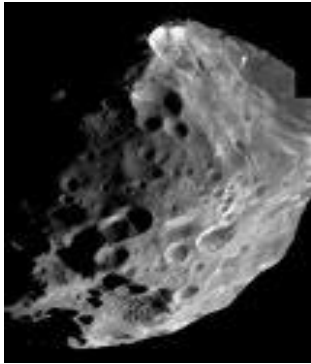
Courtesy NASA

The outermost of the Galilean, (Jupiter's) moons, Callisto has been peppered with debris. It is one of the more cratered worlds in our solar system. It is covered in water and carbon dioxide ice. This probably means that its surface and the object itself are very old. The relaxing of crater walls has occurred, as happened on Ganymede.

Our Moon and Callisto resemble each other but with a major difference; Callisto is mostly of water! They have the same strength in gravity and have no atmospheres, but a rock sampling from Callisto would melt at room temperature. The moon consists of a mixture of water ice and dirt. The ice thickness of the moon is several miles deeper than on Europa or Ganymede, making the possible liquid water below the crust impossible to reach.

The surface temperature on Callisto is around -230 Fahrenheit. It is the second largest moon of Jupiter and the 12th largest space object in the solar system. It orbits Jupiter from a distance of 1.2 million miles and completes one orbit of Jupiter in a little over 16.5 earth days. The core is most likely rock, the rest perhaps water ice, slush and liquid salt water

PHOEBE

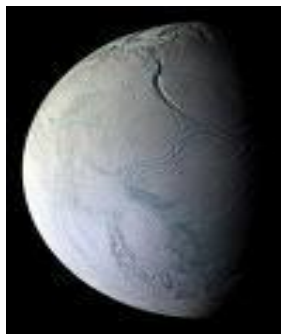


Courtesy NASA

This moon of Saturn has an orbit distance of 7.5 million miles. The 9th largest moon in Saturn's system, it is a captured asteroid that has a retrograde orbit. One trip around Saturn takes 550 earth days.

This asteroid turned- moon is pockmarked by craters. It has a water and carbon dioxide - ice, covering.

ENCELADUS



Courtesy NASA

Enceladus is the most reflective of all the moons. About 99% of the sunlight reflects from its surface. It is

also the smallest moon with an atmosphere. It has water geysers that provide the

inconsistent atmosphere and replenishes a smooth looking surface. The energy producing these actions could be tidal in nature coming from Saturn and a few nearby moons.

The average surface temperature is - 330 degrees Fahrenheit. There are less than 20 smaller craters to be found on the moon.

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MOONS PHOTO ALBUM

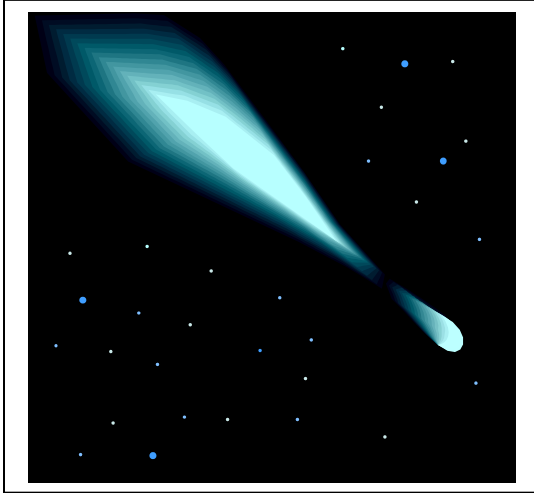
Below are the two Martian moons, Phobos and Deimos. Phobos is the one on the top.

Credit NASA

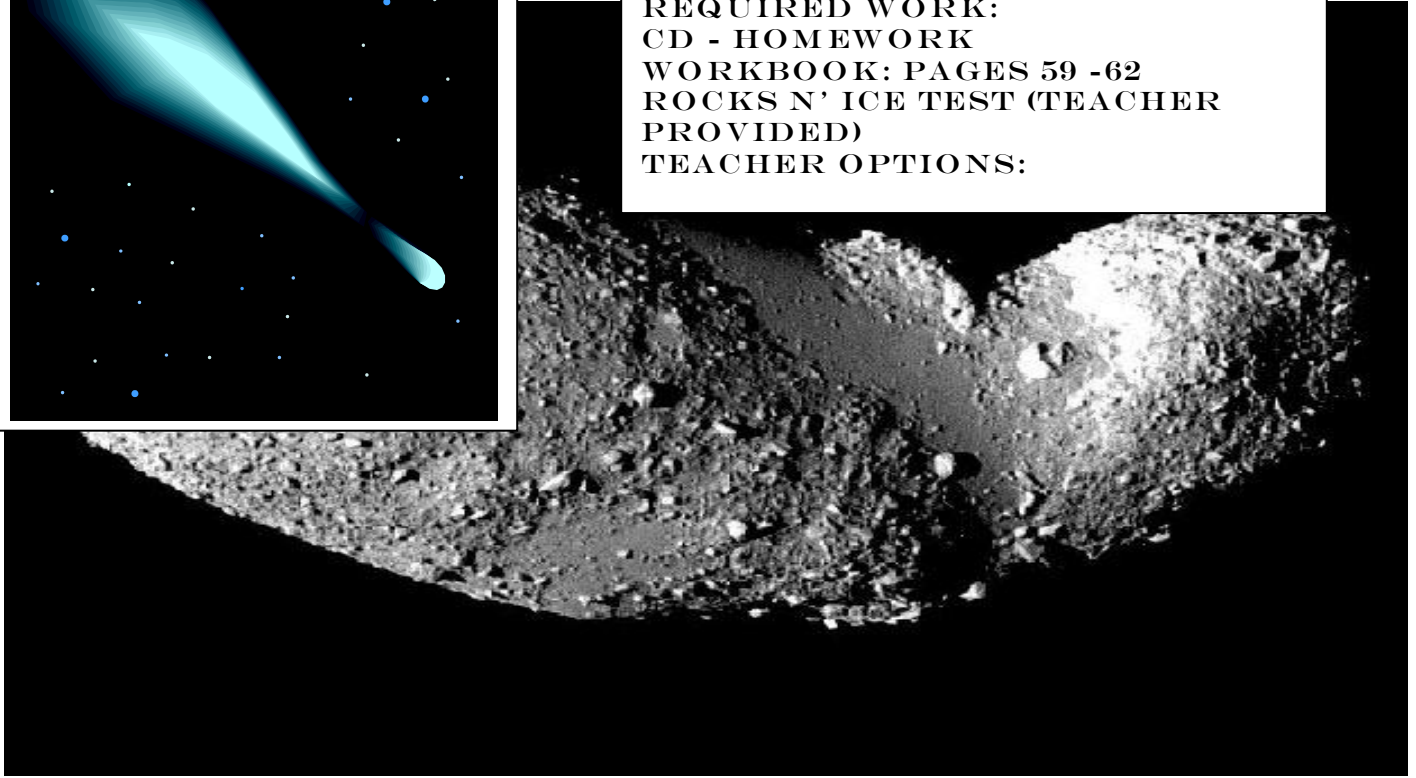


Chapter 8

Rocks N' Ice



REQUIRED WORK:
CD - HOMEWORK
WORKBOOK: PAGES 59 -62
ROCKS N' ICE TEST (TEACHER
PROVIDED)
TEACHER OPTIONS:



Asteroid 25143 – Itokawa

Courtesy: Japan Aerospace Agency

ASTEROIDS

What is an asteroid? To put it simply

it is a rock that floats through space. Sizes vary. They can be big or small and have a variety of shapes. It is thought that quite a few of these rocks are mineral - rich. They may carry rare and valuable ores. It has been estimated that there is enough mineral wealth in the Asteroid Belt, between Mars and Jupiter, to make multi billionaires of all! Much iron has been detected in some of them. Many of them are made of sandy – relatively - light silicates.

These rocks played a very important role in the formation of our solar system. In the beginning of planet formation, they often collided, melted from the heat of impact, and bonded together to form bigger hunks. Eventually they formed planetoids and then planets. Other rocks collided and became smaller planetoids which could be captured by a planet's gravity. They fell into orbit and became what we call *moons*.

There are a lot of these rocks floating about. They usually fall under the gravitational influence, or pull, of bigger objects in our solar system. Many form a “belt” between two planets: Mars and Jupiter. Some scientists think that a planet might have broken up and that these pieces are the leftovers. Others believe this is simply space junk that never got to form a new planet.

These rocks perhaps may number in the billions; some are the size of sand grains, peas and softballs. Some are the size of states. Big asteroids can even have *micro gravity*.

Japan recently scored a major success by sending a probe named **Hayabusa** to rendezvous with an asteroid. (The probe is expected to return to Earth in 2010.) Hopefully it will bring samples

collected from the surface of the asteroid.

The asteroid called *Itokawa* is 1,800 feet long by 900 feet at its widest point. Its composition seems to be silicate rock, making it a **chondrite**. Its orbital paths may cause it to be a dangerous object for Earth someday.

Space rocks can mean much in your life. They provide entertainment with “**shooting stars**” and meteor showers. Or they can kill you in gigantic collisions with Earth.



The asteroid Ida actually has its own moon! It is called Dactyl. Ida is about 36 miles long, while **Dactyl** is about 1 mile wide. Courtesy NASA

AN EXAMPLE OF CONCERN

An asteroid is assigned the name of **Apophis**. It will have a one – in - five chance of hitting Earth in 2029. Worse, it may have its flight path altered as it passes us. This is called the **keyhole effect**. If so, seven years later, when it comes by again, it may well hit us. It is about 1,000 feet in diameter and can cause problems, but in on

a regional, not global, scale.

Members of NASA have proposed sending a probe in the near future to study the composition and makeup of the PHA (Potentially Hazardous Asteroid) object. Because of monetary constraints and a feeling that the chances of a hit are about twenty percent twenty three years from now, this mission will not happen in the near term.

As of now, no asteroid has been spotted that is heading for Earth.

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COMETS



Comet Wild 2
Courtesy NASA /JPL

The word “comet”, comes from the Greek word **kometes**, meaning long hair. This refers to the long tails that comets develop when they close in on the Sun.

They wander through space, cold and dark, their jagged edges stabbing into

darkness until, one day, they move ever so slightly on a new course. Their momentum increases as a strengthening force of gravity pulls them onward.

As the gravitational influence of the sun upon the comet grows, the comet’s speed increases. Eventually, the effects of solar winds and heat come upon its icy surfaces. A brilliant tail forms. The comet becomes a glorious show of light, ice, gas, and streaming particles.

Comets have long been sources of wonder and mystery to planet Earth’s human population. They were thought of as pretenders of great events, in forms of disasters. Comets were dreaded. There are written accounts of them going back over two thousand years.

Although they can be potentially “bad news” to earthlings, they are just natural objects wandering in and around our solar system.

The comets in our solar system are found on an elliptical orbit. They are attracted by the Sun and swing by it before going way out and then coming back in again. Eventually they either run into the Sun and melt, or they hit other objects, such as us!

The famous **Halley’s Comet** comes around every seventy years; it is like a bus on a schedule. The last time it passed by Earth was in 1986. Many of you may be alive when it passes by again. It has been tracked since the Middle Ages. Another comet, Hale-Bopp, came near to us in 1996. It is over thirty miles long and shaped like an island with mountains.



Halley's Comet Courtesy NASA

The head of the comet is called the **nucleus**. When it enters far enough into our solar system it develops a **coma**, a halo of particles flying off the comet. The particles trail behind the coma and turn into a long transparent tail. Comas have been seen to extend as far as sixty thousand miles from the surface of the comet, while tails can extend millions of miles into space. An additional feature of a comet is its hydrogen cloud. This cloud surrounds the comet but cannot be seen from Earth.

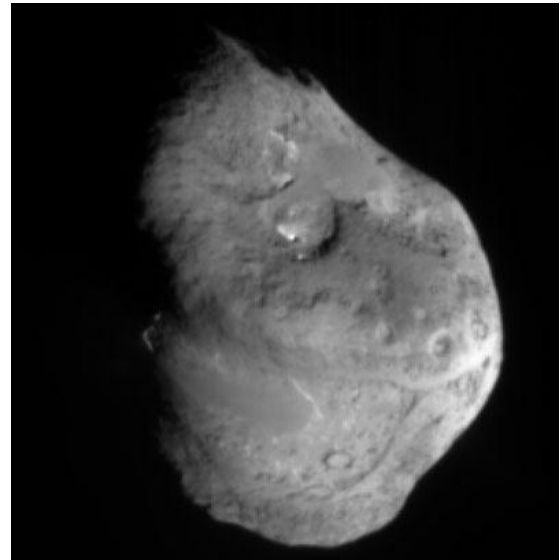
In 1950 **Fred Whipple** created a good analogy by describing a comet as "dirty snowballs." Comets are made of water ice, frozen gases, stony materials and some metal solids. They are much less dense than meteors. There is some surface gravity on larger ones.

Gases coming off the comet contain the following compounds: carbon dioxide, silicates, nitrogen, hydrogen and carbon. All of these are the building blocks of life. What causes all the surface action when a comet comes close enough to the Sun? The Sun's solar heat causes the frozen gases to defrost, and solar gravity pulls off dust. The gases

and dust cannot be held by the comet's weak gravity, so they go out into space and are captured by the same solar gravitational forces pulling the nucleus. The gases become fluorescent and the dust reflects sunlight. The comet soon becomes very visible. About twenty five of these light streaks are spotted every year.

Once ultraviolet radiation interacts with the gases, it causes the molecules to tear apart. The results are floating free radical particles known as **ions**. These ions mix with solar winds to form the long tails on the comets.

The ionized hydrogen gases flowing out at the front of the coma produce a bow shock. (This is when gases block the solar winds directly in front of the comet, forcing them off to the sides.)



Comet Tempel 1
Photo Courtesy NASA

A probe called **Giotto** came within 375 miles of Halley's Comet's head, or nucleus. It found the nucleus to be very dark, about five miles long by nine miles wide. It rotated at a speed of once every two

days. The surface was full of cracks, crevasses and possibly craters. From a portion of the surface gases, water vapor and dust were venting out toward the Sun. Parts of the surface looked blackened as if burned. Perhaps because of Halley's previous passes near the Sun, frozen surface layers were either blown away or burned off.

Where do these "snow balls" come from? Many comets lie in wait in the farthest edges of our solar system in a place called the **Oort Cloud**. It is thought to contain as many as one *trillion* comets.

It was once presumed that all comets are white because of the water ice. This has been disproved. A green comet was observed in 2007 by an amateur astronomer from China. He named it **Lulin**. It flew by the Earth in 2009.

Why green? The comet gases, containing cyanogen and diatomic carbon, cast a green glow when light hits the particles in a vacuum, such as space.

It does not take much for these comets to start a fatal freefall toward our Sun. Imagine you in front of a comet that is ten miles wide by twenty miles long. Put out your hand and flick it with your finger. You have begun its new journey! At first the motion would not even be noticeable, but over a period of time the speed would increase and thousands of years later there would be another comet in our neighborhood.

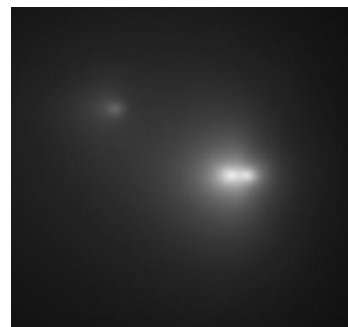
Stars occasionally pass within a few light years of our solar system. That influence, that little gravitational change in our part of the galaxy, is enough to set in motion the movement of great mountains of ice and rock, sending these comets towards

the Sun.

These comets are very dangerous to us. They are unpredictable. Many are huge. A mid-sized comet could virtually wipe out life on Earth. One, named **Shoemaker-Levy 9**, collided with Jupiter in 1994. It had been broken into fifteen chunks by Jupiter's gravity and hit the planet with one piece after another. One such piece left a bruise on Jupiter that was the size of our planet! Undoubtedly, Jupiter has saved us many times from a collision. Jupiter, the great vacuum cleaner!

The result of another comet impact with Jupiter was witnessed in late 2009. This occurred in the area of Jupiter's South Pole and left a mark similar to the Shoemaker-Levy 9 wound on that planet.

Eventually most comets die a fiery death. We can usually find these large asteroids coming in our direction. If found in time, we might be able to do something about them, but comets are different; often they appear out of the darkness within months of being near to us. There is not enough time to prepare. Don't let the movies fool you; we are not ready for a large comet!



Comet Linear – Breaking up in to three comets.
Courtesy NASA

Workbook Pages 59 - 60

METEORS AND METEORITES



Photo Courtesy NASA
Barrington crater is located in Winslow,
Arizona.

It is well known for its nearly perfect state
of preservation.

What is a **meteor**? Meteors are
objects that fall from space into our
atmosphere. They can also be called **bolides**.
What is a **meteorite**? It is a meteor that
landed on the ground and did not
disintegrate on impact.

Because of their speed these objects
become engulfed in flames when they hit
our air. They can either explode in the air or
reach the ground. When they do hit, they
cause devastation in proportion to: their size,
what they are made of, and how high the
combined speed is between Earth and the
crashing objects.

Many meteorites are stony, made of
silicate minerals (about 94% of all recovered

rocks). Some are igneous rocks, others are
mostly metal (iron meteorites) and many are
a mix of both materials. Meteorites called
Chondrites are composed of elements that
can be traced back to the times when our
solar system was being formed. Some
meteors are comets ranging from the size of
basketballs, (which fall onto our planet
daily); to objects that are miles wide and can
cause an **extinction level event**. (This is
when much, or even all, planetary life could
be destroyed by a collision).

Meteors may break up and hit the
ground like a shot gun blast, or they can land
in a single piece and create impact craters.
These small rocks entering in our
atmosphere in groups are called **meteor
showers**. Large meteors coming through the
atmosphere are accompanied by brilliant
streaks of light and loud roars. When the
meteorites are recovered after landing they
are called **falls**.

When meteors hit the atmosphere
they heat up and form a glass-like crust
called a **fusion crust**. Pieces of this type of
glass are commonly found near impact
craters.

Meteorites have been found in many
areas of the world, but most of the samples
have been located in Antarctica. So far the
samples found in that region represent about
3,000 different meteorites.

NEOs

Near Earth Objects are mainly
asteroids, but they can also be short term
comets that are orbit the Earth or crossing its
orbital path around the Sun.

There are two different types of
asteroids and comets to look for. One type

are the **NEOs** or “Near Earth Objects”. The newest term is **PHAs**, or “Potentially Hazardous Asteroids”. As of January 2010, 1,086 have been found. These rocks in space can come within 4,500,000 miles of Earth and are more than 500 feet in diameter. They represent 90% of the danger in space. They are fairly easy to find. They are in our neighborhood and therefore more readily spotted. The other dangerous space objects are called *intermediates* and *long terms*. They are mostly comets. They may take years to drop by and will give us only months of warning of their arrival.

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There are scientists watching for large asteroids that may cross our path. These scientists have developed an impact scale from 1 to 10, in case one of these objects does head for Earth. Zero implying virtually no damage, while a scale of 10 represents a catastrophe. The estimate is that there are at least two thousand NEOs cross our orbital highway every year. Many of them could cause the death of hundreds of thousands if they hit us. Some could kill us all.

Many of these objects have been spotted. However, there are few astronomers looking for them due to budgeting problems.

Over time, we see less and less of these objects because they have already been drawn in by Earth’s gravity, or they hit the Moon, or have been absorbed by the Sun. Every day many tons of this debris still hits the Earth’s atmosphere but is in pieces so small that they cause little concern and on occasion entertain us when see as “shooting stars”.

Near Earth Objects are mainly

asteroids, but could also be **short term comets** that are orbiting the Earth or crossing its orbital path around the Sun.

About every 100 years, a rather large (50 yards wide), iron asteroid may hit the earth. Every few hundred thousand years an object can reach the Earth that could cause wide destruction and radical changes in planetary climate.

A famous example of a meteoric event took place in 1908 over **Tunguska**, Siberia, Russia. A large meteor with an estimated weight of one hundred thousand tons entered the atmosphere. It is believe that it was a comet. It exploded a few miles above the surface of the Earth. The explosion knocked down over one thousand square miles of trees. It had the force of hundreds of atom bombs.

Luckily, this part of Siberia had no human population, and the loss was limited to plants and animals. But the planetary effect was so great that it was virtually day light in London during the middle of the night, even though the blast was five thousand miles away! The sound wave from the blast circled the planet twice! Had it hit the Earth five hours earlier, the Moscow area would have been wiped out.

The largest meteor crater in the United States, found near Winslow, Arizona, is called the **Barrington Crater**. About three quarters of a mile across and nearly six hundred feet deep, it was caused by the impact of an iron meteorite weighing almost thirty tons.

The most famous crater is located off the Yucatan peninsula in Mexico. Called **Chichlxu**, it is over 150 miles wide and

perhaps twenty miles deep. (Remember, that is about the average thickness of the Earth's crust.) The ejected rocks were thrown far into space. The composition of the burned rocks produced a poisonous gas. Fires throughout the Earth occurred. There was a dramatic lowering of temperature. During that time, there were no ice caps.



A Meteorite on Mars, with iron deposits.
Photo Courtesy NASA

This collision with Earth happened about sixty five million years ago, during the **Cretaceous Period**, the age of the dinosaurs. No fossils of dinosaurs can be found beyond the age of this impact. All over the Earth there is a thin line of iridium found in the sixty five million year level of rocks and soil. Once this event level is located, fossils are not being found in abundance until another level representing the Earth's surface five thousand years later.

Can this happen again? Most certainly! If a large rock or comet as big as six miles wide or more hits our planet, the devastation will be enormous. One would see earth waves hundreds of feet high. **Tsunamis** (Fast moving walls of water in the ocean) hundreds or even thousands of feet high, would sweep over much of any

nearby coastal lands. Blazing debris from the impact would fall over the surface of the earth. The showers of rocks could be as big as a twenty story office buildings, and fires would rage planet wide. Faults would open up from the tremendous shaking and creating earthquakes. The searing heat would kill most plant life. The dense, choking smoke would soon blot out all sunlight, plunging our planet into freezing cold, with darkness so deep that eyes could be useless. Our planet grows silent and still for perhaps hundreds, or even thousands of years. No structure would be left standing. Any traces of human existence would fade until only a few fossilized foot prints and bones would tell someone in the future that we once existed. We could be the next oil deposit.

Asteroids can be charted to see if they have a chance of crossing our path far in the future. By tracking these objects, we should have years of forewarning and they have chance to use technology to change their course. We could change the velocity of the asteroid comet, but not blow into pieces creating debris that cannot be controlled. When given a warning, far in advance, of an object that may collide with earth the craft sent to intercept it will need less efforts to have the object's speed and or course adjusted.

Meteorites can be seen in science museums and exhibits around the world. Some have been made into jewelry or pieces of art. Others have been worshiped; it is thought that the great **Kaba stone** in Mecca, Saudi Arabia, is a meteorite. It is located at the center in an area where millions walk in a circle as they complete their Muslim pilgrimage to Mecca.

One meteorite, discovered in

Antarctica, had a profound influence on mankind. When opened, researchers found what appear to be fossils of tiny animals (micro-organisms). The chemical composition of the rocks was traced back to Mars. Millions upon millions of years ago, a large meteor hit Mars. Some Martian rocks were hurled so far that not only did they make it into space, but they even escaped Mars' gravity. Eventually some of those rocks fell to Earth.

Comet-meteors may also account for many of our oceans. The process of billions of those "dirty snow balls" entering our atmosphere has made us water and oxygen rich. Thus, these menacing objects from the sky may support life as well as take it away.

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Cosmic Concepts: Coming Destruction

You guessed it... What if there is a comet or meteor of significant size heading for a rendezvous with Earth? Maybe we spot it with only months or weeks before impact. Describe your emotions when you think of this after looking at the picture in the upper right corner. Use some of the facts learned in this chapter.

Title the essay: The Meaning of Life When Threatened

Minimum 100 words.



This is an artist's conception of a large asteroid crashing into Earth. Credit NASA

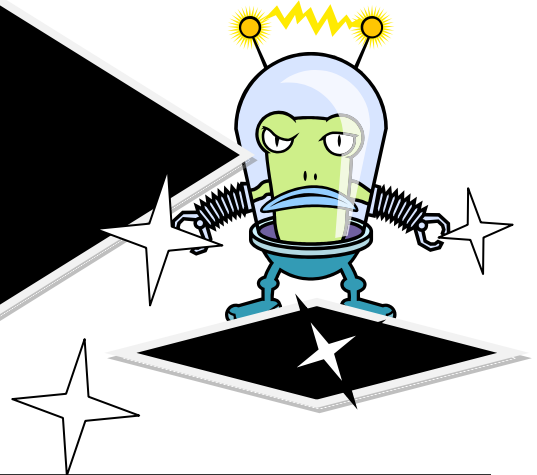


Largest meteorite found in the U.S.

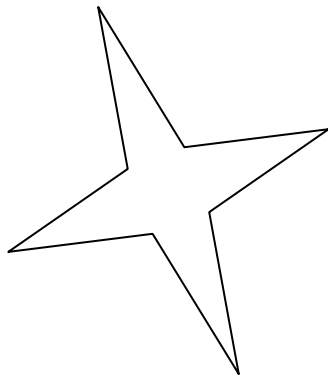
The above Willamette Meteorite was found in Oregon. It weighs 32,000 pounds.

Chapter 9

Stars



Early Stars in a Young Universe
Photo from WMAP/NASA



REQUIRED WORK:
CD - HOMEWORK
WORKBOOK: PAGES 71 -76
STARS TEST (TEACHER PROVIDED)
TEACHER OPTIONS:

When we look up on a clear night, if there is not too much Earth - based light brightening the dark sky in the way, we see thousands of stars. Some look bright, some dim. Take a look through a telescope; suddenly there are stars where it seemed there was nothing before.

You will see there are stars of many different sizes, ages and chemical compositions. In this section we will take a look at known types of stars. We will discover how they are born, live and die. (They are not truly “alive”, but they act as if they have life spans).

The Sun is about 93,000,000 miles away, a very long distances, but, what about the distance to the next star? Possibly the word “millions of miles”, should not be used. The closest star, other than the Sun, is many *trillions* of miles away. The trouble is how to measure exactly their distance from us.

The proper way to measure star distances is through the use of the **parallax technique**. Below is the explanation of how the technique used.

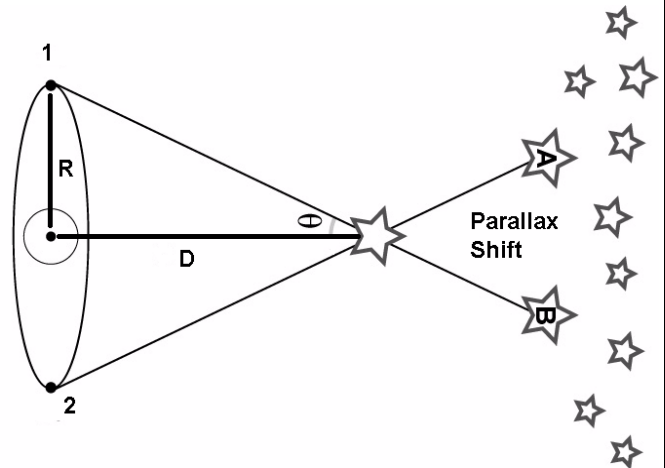
THE PARALLAX TECHNIQUE

First, carefully sight one star according to its position with other stars. Then, wait for six months. At the end of six months, spot the star and again carefully gauge its relative position with the other stars.

The closer stars look as if they have shifted positions relative to stars located farther away; this is called the **stellar parallax**. The distance is calculated from

the parallax angle. (The apparent angle of change is divided by one half and then used to figure out distances.)

These angle changes can be very small. They are measured by a term called seconds of arc. 1 inch = 3,600 seconds. Parallax movements from the nearest stars are less than 1 inches.



Credited to Dr. Sten Odenwald, NASA

One **parsec** is the distance to an imaginary star whose parallax is 1” of arc. *One parsec equals about 19 trillion miles.* That is 3.26 light years. A light year is defined as how far light travels in one year at 186,000 miles per second.

When the star is farther out, the stellar parallaxes becomes very small. They can be measured down to .01”. This equals 100 parsecs.

So far, about 100,000 stars have been accurately measured in this manner. Some 400,000 stars have been roughly estimated by using this system.

The first known astronomer to use the parallax method was **Hipparchus**. He used this idea to calculate the first known accurate measurement of the distance from the Earth to the Moon. He figured it out in

120 B.C.!

Did you know?

The “heart” of a star can be 29,000,000 degrees! A grain of sand that hot would burn a person to death at a distance of 100 miles!

Alpha Centauri is one of our closest stars. It is 4.3 light years away, that is, about 25 trillion miles. But Alpha is a little different for our star, it has *beta*!

Alpha Centauri is a double star system, and it has a little cousin hanging around just outside the dance between the bigger two stars. It is called **Proxima Centauri**. This forms a triple star system.

COLORS CAN TELL

Have you ever seen light divided? If you have seen a rainbow, or a prism with a light showing through, indeed you have. The colors tell a story. They can tell the chemical composition of the object that are creating or reflecting the light. These different colored shades of light are called **spectra**. The study of light is called **spectroscopy**.

It all starts with those little things called **atoms**, the smallest organized structures known. They are also called elements. There are over a hundred known elements.

Atoms have a center called a **nucleus**. Each atom contains at least one positive particle in the nucleus, called a **proton**. There are neutral particles in the nucleus as well, called **neutrons**. Circling this nucleus are tiny, negatively charged

particles called **electrons**. The number of electrons and protons in an atom is usually the same, giving it a neutral charge. Each atom has a distinct amount of electrons orbiting it. This tells us its energy level.

When an **atom** is undisturbed it is called “*being in a ground state.*” This is when it is giving off the least energy. When it is disturbed and an electron jumps onto another atom, the first atom becomes excited. When the electron comes back, it produces a little tiny bit of light called a **photon**. When the atom loses 2 or more electrons, the atom becomes positively charged. Then it is called an **ion**.

Bright colors are formed when the atoms actually absorb the photons instead of letting them escape. Once again, each type atom has different energy levels and produces its own color signature. Scientists have charted the color patterns of all the known elements. An astronomer, **Henry Draper**, first photographed the spectrum of a star in 1872.

Stars produce all the colors of the spectrum. What is important is how much of each color there is and where the predominance of color lies. When the star light enters our atmosphere, some photon waves are absorbed. What are left are the darker colors. When these are analyzed, scientists can tell what the atmospheres of stars contain.

Stars have been divided into seven classes, organized by the strength of hydrogen lines in the spectra. The classes are: O, B, A, F, G, K and M. One astronomer, **Annie Cannon**, classified 225,300 stars, using this system.

The difference of the amount of

dark color lines that are reproduced by stars tells the tale of the temperature of their surfaces; O stars are the hottest, M stars the coolest. Each class has sub groups ranging from O to 9, to further define temperatures.

With a spectral reading, one can tell chemical makeup and temperature. From that, we can classify stars. But this does not answer the questions as to why stars have different temperatures if they have the same basic chemical compositions. That has to do with size. The bigger the star, the hotter it gets. The hotter it gets, the less stable some of the atoms become. In cool stars, iron and nickel cannot exist at the atomic level. In the hottest stars, many more metal atoms can be detected.

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THEY ARE MOVING!

Yes, stars move, but where and how fast? In comparison to the Sun, star speed is called **space velocity**. The speed is measured in miles per second.

DID YOU KNOW?

The longest name of a star is Shurnarkabtishashutu? It is an Arabic word for, "under the southern horn of the bull."

There are two measurements of star motion, one of which is the **radial velocity**. It measures how fast the star is moving toward or away from our Sun. The other measurement is the **proper motion**. That is the lateral movement, (side to side), of the star.

The **Doppler shift**, a term created by **Christian Doppler**, measures motion. When measuring the spectra of a star, if there is a

blue color shift emphasis it means the star is moving towards us. If it is shifting to the red end, it means the star is moving away from us. More than 20 to 30 year intervals are needed to actually see a difference in shifts.

Spectrums can actually tell us how fast a star is rotating. It can even show the power of the magnetic fields.

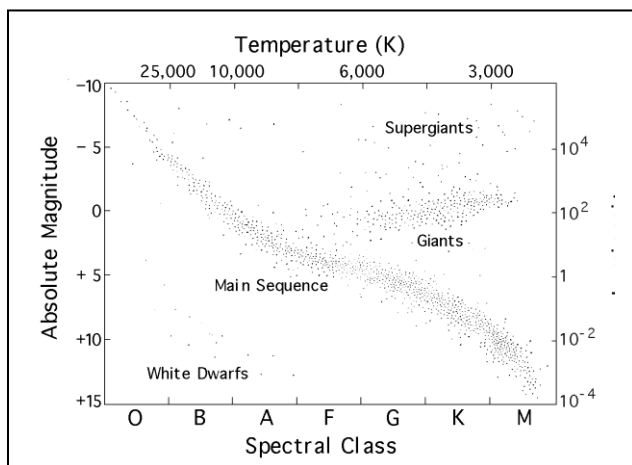
MEASURING BRIGHTNESS

Brightness can be misleading. A brighter star appears closer. A dimmer one appears far away. Its brightness is called **luminosity**. Our Sun's luminosity is equal to 3,850 billion, trillion 100 watt light bulbs shining at one time.

To measure brightness one calls it the **apparent magnitude**. It is a comparison between the brightness of the Sun and other stars. **Absolute magnitude** measures, in real terms, how bright a star truly is. All stars are compared at a theoretical distance of 10 parsecs from our Sun

"Absolute magnitude" is a tricky thing. This measurement tells how much light a star is truly putting out. (The brighter the star, the bigger it is). But, the question is not only how bright a star is, but how far away it is. The answer gives us the absolute magnitude.

We have ways to measure distance, brightness and chemical composition. We can also judge the brightness of all its properties. This will give us a very good view of star types in the Universe. Look and see how it all works:



A physical law has been developed to figure out the luminosity of the stars. It is $L = 4\pi r^2 \sigma T^4$. Here's a translation: Luminosity is proportional to the square of its radius times the 4th power of its surface temperature. Confused? Well, that's fine for now; just know that there is a formula to figure out luminosity.

The brightest star in our sky is **Sirius** (-1.42). It is twice as bright as another star, (except the Sun), we see. To compare to our Sun, with the Sun's luminosity being ranked a 1, Sirius is graded as a 23, very bright! It is part of a two star system.

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DOUBLE STARS

Some stars seen with the naked eye actually are two stars circling each other. They are called **binary stars**. They actually orbit around a common center of gravity.

When one can see these stars through a telescope they are called **visual binaries**. So far, 70,000 visual binaries have been logged. The star **Mizar** was the first binary system discovered. That was in 1650.

Quite a few binary stars are brighter stars hooked up with faint ones. When one star cannot be seen they are called **astrometric binaries**. A **spectroscopic binary** is when neither star can be clearly seen in a telescope.

Some binaries can be seen eclipsing. That is when one star passes between us and the other star. When this happens, the brightness of that system will seem to diminish until the intruding star gets out of the way.

Binary systems are thought to have very little chance of supporting life. Planet formation would be very difficult due to the tearing caused by its swirling gravitational forces. Only larger planets, well away from the stars, would be able to form. Probably these planets would be too big to allow life to exist on them. In December, 1999, astronomers from Notre Dame University discovered the first known planet to circle twin stars.

BIRTH TO DEATH

In order to have a star form, enough available building materials are needed in the amount of at least 80 times the mass of Jupiter. The Universe has taken care of this problem. Stars are formed from interstellar gases and dust. The process takes from millions to billions of years. They evolve from clouds to gas balls, from darkness to blazing glory.

These interstellar clouds of gas and dust are called **nebulae**. In fact some of these gigantic clouds can be seen on telescopes from Earth. The middle "star" in the sword of Orion the Hunter is a nebula. It

is called the **Orion Nebula**. It looks “fuzzy” when seen with one’s eyes; in a telescope it looks green. It is lit up because of some nearby hot star’s photons reflecting off of it and from light making its way to us. Many nebulas cannot be seen at all because there are no nearby stars to illuminate them.

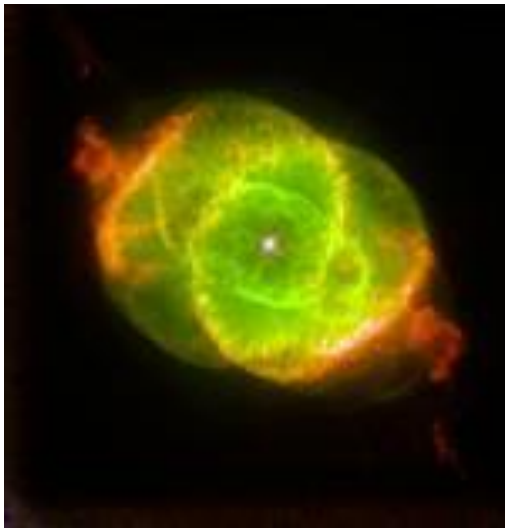


Photo of the Cat’s Eye
Courtesy NASA

Something must first happen to get a cloud of gas to evolve into a star. It is believed that nearby exploding stars provide the shock waves needed to get the process started. Gradually, particles clump together. As bigger pieces form, heat is created when they collide. The heat then melts the clumps causing the pieces to stick together. Over eons of time a very large mass is formed. With interior pressures and pulls of this size of objects nothing but gases can exist. Meanwhile, the object’s gravity draws in yet more matter.

As gravity increases and inward stirring occur, the temperature begins to rise. Heat from the interior rises to the surface, as the protostar approaches birth level. *At this point the protostar is not using nuclear fusion to produce energy. That is produced*

by gravitational energy. We call an object that is about to become a balanced adult star a **protostar**.

A cloud of flattened gas and dust orbits the protostar. This cloud is trapped by gravity but so far resists being pulled in. The external material eventually begins its own clumping and becomes what we know as asteroids, planets, and moons.

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The next phase is called the **T Tauri Stage**. It occurs when the star is one step away from becoming a main sequence star. The star has not yet produced fusion reactions but visually resembles a regular star. It may have many sunspots on its surface. It also is producing a large amount of X-rays and has powerful stellar winds. This phase could last as long as 100 million years.



Photo Courtesy NASA
Protostar

When the temperature in the core reaches 10 million degrees Kelvin, nuclear reactions begin. Energy quickly rises to the surface and into space. (The star is growing and shrinking during this process.) This outward push starts to gain balance with the tremendous gravity pull of the core of the T Tauri star. This balance produces the birth; it has reached the point of **hydrostatic equilibrium**. From now on its lifetime is measured by its size, fuel - and luck. It is an adult and will end up, usually, as a main sequence star.

Here are some observations about the life span of stars:

- Small stars last longer than big ones.
- Larger stars die a violent death after a relatively short life.
- Smaller stars tend to dwindle and die after a long life.
- A large star takes longer to mature from protostar to main sequence star.

WHY LIGHT?

Heat and gas can combine into wondrous things. When a hydrogen atom is heated enough it fuses with three other hydrogen atoms and becomes one heavy helium atom. This reduction in mass transforms into a release of energy. That energy is in a particle called a photon. We commonly call groups of photons: "light".

It takes time for this light to get through the mass and gravity. To get to the larger stars could take even longer. Once these photons surface they fly out into space at a speed of 186,000 miles per second. This is called **light speed**.

It takes a lot of fuel to keep a star shining. In order for a star the size of our sun to shine, it must convert up to 5 million tons of hydrogen into helium per second.

At some point a star will run out of hydrogen fuel. For an average-size star that may take as long as 10 billion years. Hotter and bigger stars may not even make it to their first billionth year birthday. The star **Rigel** is 60,000 times brighter than our Sun! Rigel, a blue giant star in the Orion constellation, will have less than 20 million years as an upper main sequence star; it is so massive that it is burning up its fuel very rapidly. Stars can be as large as 100 times the mass of our Sun.

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A picture taken of nebula by the Chandra X Ray observatory
Courtesy NASA

RED STARS

Red dwarf stars are the coolest and smallest of the main sequence stars. They have up to half the mass of our Sun. They burn slowly and last much longer than even our own star. Some of them could “live” up to *10 trillion years*. These are the most common types of stars.

When the core hydrogen is depleted, the main sequence star switches to its second power source: helium. When this happens the core shrinks. The outside hydrogen surrounding the core burns, and the star becomes brighter. The outside layers heat up. Suddenly, the force from the inside overwhelms the gravity holding the layer in. The star grows to many times its original size, (Up to 100 times its previous size.). It becomes a **red giant**.

Why red? When the layers go out millions of miles into space the density of the star increases, the surface area grows and the heat of the star begins to lessen. It cools down. A cooler flame tends to be red in color. **Betelgeuse**, in the Orion constellation, is a Red Giant star.

DID YOU KNOW?
Betelgeuse is 621,000,000 miles wide. That makes it 730 times bigger than our Sun. A telephone message from one side to the other would take 55 minutes to be received!

What causes this rapid expansion? Once helium fusion starts the core temperature increases quickly. Soon, the helium nuclei are fusing rapidly. As the rate increases an **explosive climax** (helium flash) takes place. The helium fusion is now overpowering gravitational forces. The core

expands.

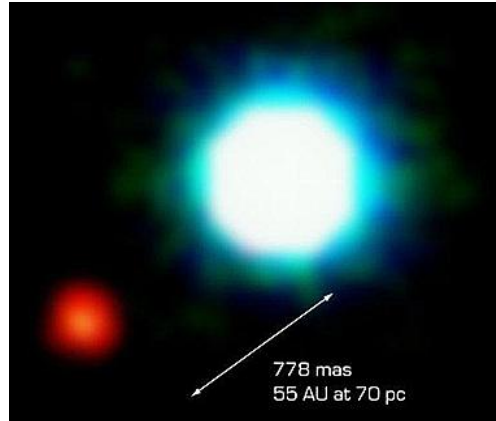


Photo Courtesy NASA
Red Dwarf near Blue White
(The stars are fifty five Astronomical Units from each other.)

Our Sun will become a Red Giant some day. Our planet will be within the outer reaches of the Sun. The Sun’s surface will be beyond Mars! The oceans will vaporize. The Earth crust will melt. When the Sun retreats, our planet will cool into a blackened cinder ball. A carbonized surface will be left. No evidence of life will remain.

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VARIABLE STARS

Once a star has become a red giant it will vary, or bounce back and forth between the main sequence and red giantism. This is the **pulsating period**. The star changes its brightness according to the type of fuels it is burning and the amount burned at that time.

Another type of star is called the **variable cepheid** that is larger than our star and more yellow in color. Its brightness hits almost a rhythm of highs and lows and can

go from low to high every 1 to 70 days. So far, more than 700 of them can be spotted in the Milky Way Galaxy. Polaris, the North Star, is the closest to Earth. The variable cepheid hits its highs and lows every 4 days.

Not all variables types of stars are yellow, yellow- white or white stars. Some are blue – white giants. They are called **RR Lyrae variables**. There are more than 4,500 of this type registered so far. They are excellent to use for measuring star clusters as far as 600,000 light years away.

Another type of variable is called the **long – period mira**. Named after the star Mira, these red giants can vary in brightness from one extreme to another, every 80 to 1,000 days. Mira is 130 light years away and can become rather bright and then later become invisible to us every 332 days.

THE END OF STARS

How the star's "life" ends depends greatly on how massive the star is. The big ones, super giants, which exist only for a few million years, usually have a grand and violent ending. (It may look spectacular from a great distance but it is catastrophic when one gets too close).

A smaller star's ending resembles a candle flickering for a while, then finally going out, leaving a dark cinder ball floating through space. During the second-to-last stage, the burning helium leaves a residue of carbon as the core. The carbon doesn't burn. Outside gases that are not burned fly away. These wispy clouds of gas are known as **planetary nebulae**. They leave the cores at thousands of mile an hour. After some 100,000 years, the gases are so spread out and thin that they become invisible. At least

1,600 of these spreading "clouds" have been noted.

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The residue is a carbon core with a helium skin that is still burning. The star is much smaller now, and the left over, burnable materials are burning at a rapid rate. The temperatures and pressures rise so high as to strip electrons off the atoms. We now have a **white dwarf**. This dwarf eventually shrinks to roughly the size of our planet. Its gravity, though, is 350,000 times greater than ours. At this stage a nova may occur. A **nova** is a flaring of a star. It is a sudden energy release, or explosion. Eventually the fuel runs out, and the star turns into a cold ball called a **black dwarf**.



A White Dwarf
Photo Courtesy NASA

Some stars fade far less meekly. If they have enough mass they may experience the ultimate explosion. They may go **supernova**. When the core rises to 600 million degrees Kelvin, carbon begins to fuse. It first becomes magnesium, then nitrogen and, silicon. Iron elements begin to

form in the core. As the core evolves into a virtually solid iron ball, the releasing of energy stops, the balance is gone; collapse begins. When it can shrink no further a gigantic explosion occurs. The amount of energy released is so tremendous that it can out-produce the brightness of all the stars in the Universe during that first second of explosion.

Even though the amount of light release is huge, most of the energy radiated is invisible. It is in the form of **neutrinos** (particles that act much like electrons but do not have electrical charges) and radiation.

The first bright Supernova was discovered by telescope in 1987 and named 1987A. This Supernova was only visible in our southern hemisphere. It was estimated that the core temperature of the exploding star had reached 200 billion degrees Kelvin.



A Super Nova
Photo Courtesy NASA

After that, what was left? Particles left in the surrounding space form into nebulas. The collapse of these giant stars produces heavy metals. Many of them we need: oxygen, nitrogen and carbon. Some are not good for us to ingest. (One example

is lead.) Others are quite useful and even decorative. Do you wear gold? **Gold** is another byproduct of a giant star that has collapsed and then exploded! As a matter of fact, most of what is in you can be traced back to the same explosion.

Some stars refuse to go away. Even after a star explodes, (super nova), there is still a core left behind. The stripped star core has lost most of the protons and electrons around its atoms. These stars, before they begin to self destruct, have a mass somewhere between 1.35 and 2.1 times the size of our Sun. They are called **neutron stars**; the star is now composed entirely of neutrons. The gravity is so strong that all the remaining electrons and protons have been crushed, squeezed and merged into neutrons. They can be a few miles wide, perhaps as small as 10 miles in diameter. The gravity on these objects is beyond human imagination. They spin rapidly and send out radio waves and gamma rays caused by their strong electromagnetic fields.

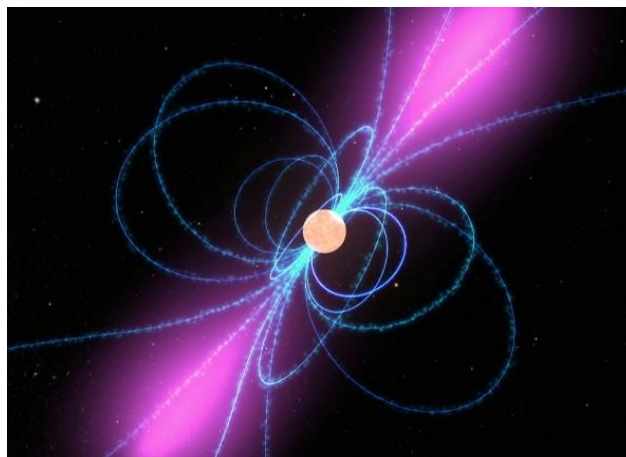


Diagram of the magnetic lines and high-energy beam (purple) emanating from a pulsar. Courtesy NASA

Known as **pulsars**, some of these stars complete a spin more than once a second and send out regular beacons that

can be tracked on Earth. Eventually these stars lose power and the pulsing slows down.

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BLACK HOLES

If the mass of the star was bigger than 2.1 times the Sun, when the star goes super nova what is left will most likely not become a neutron star, but something else... a black hole.



Artist's rendering of a black hole in a globular cluster.

Photo courtesy NASA and G. Bacon, Space Telescope Science Institute.

THE DARK SIDE

Another, more famous death of a star is a process that creates the **black hole**. A huge star may have trouble stopping the shrinking process after it has gone super nova. The density becomes so great that there is no longer an ability to have separate atoms. At this point the mass reaches a point of **singularity**. This means there is no way to distinguish any separateness of matter. The shrinking continues, and gravity becomes the prime influence. When light

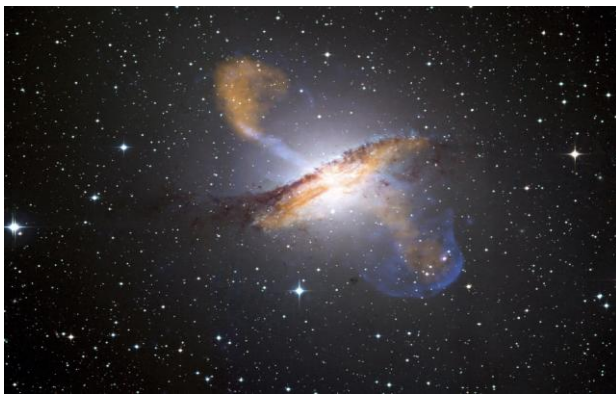
comes by it, it cannot escape. So far as we know, nothing but radiation can escape its gravity once something comes within the **event horizon**. The event horizon is where the reflection (or light) of an object can be seen permanently orbiting about in the black hole. It cannot escape. Without these tell-tale signs along the jets of escaping radiation, the black hole would be invisible. An indirect sign is the gravitational effects black hole can produce on nearby stars. Until recently, black holes were a theory. No more! They have been spotted and even photographed. They resemble flying CDs with jets of radiation spurting out from the middle of the vortex.

Some may ask: How big can black holes get? The question is interesting, but a better question may be: How much can they consume and how small can the core become? We don't know. It is believed that there is a black hole in the center of our galaxy. It has supposedly swallowed up thousands of star systems. Can all that matter just keep shrinking? Some think that black holes are actually spewing out materials into other Universes. Could these space vacuums be creating matter somewhere else? Are there black holes in other Universes that are supplying ours with new materials? No one knows, but it is hard to imagine thousands of stars ending up condensed into an area smaller than that of a point of a pin and then still keep shrinking!

To learn about black holes and the universe, please go to the computer and explore this outstanding site:
http://hubblesite.org/explore_astronomy/black_holes/home.html

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Black Hole Photo Album



A black hole in Galaxy Centaurus A

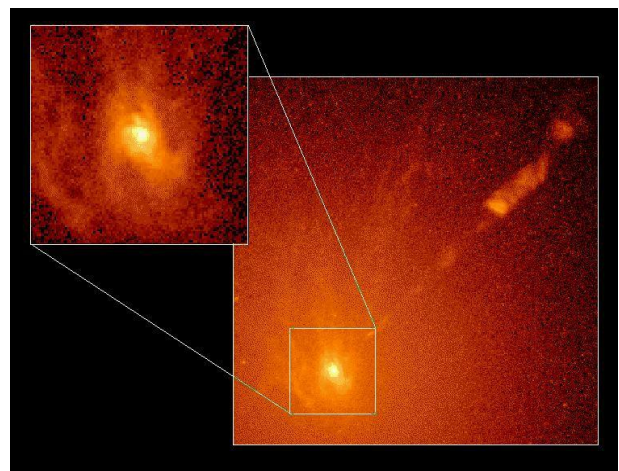


A jet of radiation coming from a black hole.

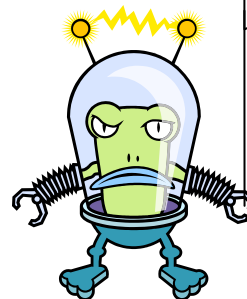
Cosmic Concept: Awareness

All metal comes from exploded star. A nebula left over from a supernova coalesced into a star and other objects in our Solar System. Look around in your life and write down examples of the influences metal has. Note: Oxygen is a metal.

Title: Stars in My Life

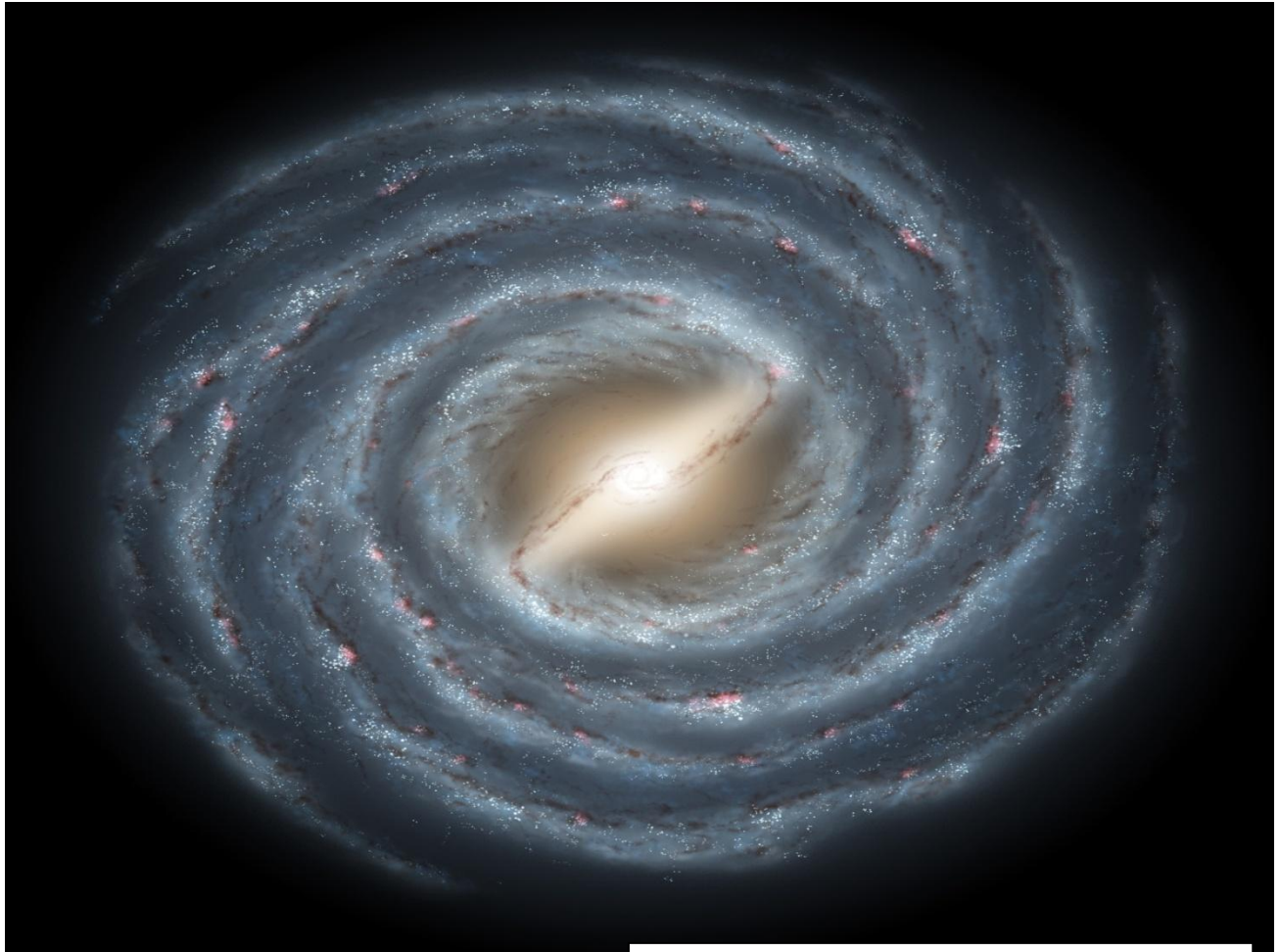


Black holes are fun!



Chapter 10

Galaxies



**Artist's concept of the Milky Way.
Credit NASA**

**REQUIRED WORK:
CD - HOMEWORK
D QUESTIONS
WORKBOOK: 71 -76
GALAXY TEST (TEACHER
PROVIDED)**



Andromeda
Spiral galaxy with globular clusters
Photo Courtesy NASA

“In a galaxy far, far, away...” Yes, as a matter of fact, they are very far away! Of course if you want to see one, you’ve got one right outside your door! That’s because you live in one. It is called the **Milky Way Galaxy**.

Our galaxy is a giant.

A century or so ago, it was believed that the “Universe” was composed of just our galaxy. It was thought that there might be a few million stars out there. Now we know there are hundreds of billions of stars in just our galaxy alone. The estimate is now at 200 billion.

What *is* a **galaxy**? It is a very large grouping of stars mixed with gas and dust (and dark matter, to be discussed later in the Universe chapter.), that is held together by gravity and comes in one of a few different shapes. The amount of stars in a galaxy ranges from tens of millions to hundreds of billions.

On a clear night, with a dark, clear sky, you can see the center of our galaxy. It looks like a milky substance that has been dropped in space. This thin “cloud”, is actually composed of thousands upon thousands of stars mixed with gas and dust. The center of our galaxy has the highest concentration of stars. It is called the **galactic center** which is made up stars and dust and contains the **nuclear bulge**. The “top” and “bottom” of our Galactic Center are called the North and South Poles.

Even though the stars are concentrated into a galaxy they are not as near to one another as you may think. For an example, the average distance between the stars in our galaxy is 5 light years.

Galaxies form in much the same way that solar systems do. However, there is much more mass in a galaxy, the distances are much greater as well. As in solar system building, most of the

mass seems to be in the center. As the galaxy matures, rotation around the core begins and a swirling galaxy forms.



Galaxy M81
Photo Courtesy NASA

When it comes to galactic research there is one outstanding astronomer's name to remember: **Edwin Hubble**. He proved that there are other galaxies beyond our own. Before him, most of the fuzzy objects seen were considered nebulas. From one galaxy before Hubble started his observations, NASA now estimates there are anywhere from 150 billion to 200 billion galaxies. A German computer model estimates as many as *500 billion* galaxies in the universe. These estimates are due to observations made through the Hubble telescope and from additional infrared observational techniques. One reason the estimates have risen is that now we can peer through the "**zone of avoidance**", the area of light, dust and gas in the center of our galaxy. We now can see more of the universe. The modern view of the Universe has most certainly changed.

Workbook Pages 83 - 84

We have trouble seeing the *shape* of our galaxy. That's because we are in it. Our galactic

shape is basically a spiral. It almost looks like a toy pinwheel. It may also have a bar structure that would indicate that it is sort of a combination of a spiral and a **barred spiral**, which has two dominant arms. It is also spinning.

The nuclear bulge of the Milky Way looks like a swollen area in the Galactic Center. It consists of older stars and 150 to 200 globular clusters. It is about 10,000 light years thick. The outlying disk area is nearly 7,000 light years thick. We are about 25,000 light years (or 10 **kilo parsecs**) from the middle of the nuclear bulge. The galaxy is about 100,000 light years or 30.69 kilo parsecs in diameter.

Our galaxy is spinning, and we are part of that spin. Our solar system is moving at a rate of 536,000 miles an hour around its center. It takes us about 220,000,000 years to make 1 orbit.

We are located at the end of an “arm”, called the **Orion Arm**, in the outer regions. We are 20 light years above the equatorial symmetry plane and between 25,000 and 28,000 light years from the Galactic Center.

The stars are not evenly spread out. Some are clumped together in **clusters**, groups of stars that stay together because of their mutual gravitational influences. These groups of stars sometimes originate out of the same nebulas. Clusters can range in size from 10 to 10,000 stars.

Large groupings of stars are called **globular clusters**. There are more than 150 globular clusters in our galaxy. These clusters contain anywhere from 100,000 to 1,000,000 stars. Inside the globular clusters can be found the oldest known stars in the Milky Way. Also found in these groups are the unusual **blue stragglers**. Large and very bright, they are the young and hot stars.

Our galaxy is bright, but much of the matter in it is not seen. It is called **dark matter**. What is it? It may be dust or scattered molecules. It could also be many undetected planets, comets and asteroids. There may be millions of burned out stars wandering about. It is now believed that nearly 90% of all matter in a galaxy is typically dark matter. Speaking of dark, it is now believed that virtually every active, (such as spiral galaxies), galaxy has one or more black holes in the middle!

Is there anything between the stars? There is a lot of nothing and yet much of “something.” There is a lot of gas, mainly hydrogen and helium. There is also a sprinkling of dust. Some clouds have been spotted. They contain different gases and can be found near stars or out on their own. They are known as **H regions**. The bigger clouds are called nebulae (plural).

The center of our galaxy contains a massive but compact object surrounded by hot gases and clouds of dust. Huge doses of x rays pour out from this area. It is thought to be a super black hole.

Many astronomers say the galaxy is about 13.2 billion years old.

Some galaxies form stars at a greater rate than others. There are about 15% of the estimated

galaxies in the universe creating stars 10 times faster than the rest. Called **starburst galaxies**, there were far more of them during the early history of the Universe. This accelerated production last only for about 10 million years. The stars tend to be massive and end up in supernovas. These galaxies may have experienced a collision with another galaxy that triggered this unusual increase of star production. Irregular galaxies have been often seen resulting from these phenomena.

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WHERE ARE WE?

The Milky Way is moving quickly through the Universe. We are speeding toward the constellation of Hydra at about a million miles per hour. But we are also moving as part of a bigger grouping of galaxies. The Milky Way is part of a gathering of galaxies called the **local group**, containing 33 galaxies in all.

Most of the galaxies are small, but there are some large ones, such as our nearest large galactic neighbor, **Andromeda**, which will collide with the Milky Way in the distant future. We are closing at a speed of 78 miles per second. It is a galactic neighbor that looks a lot like us. The major difference is that it is twice as big as the Milky Way. It is 2.5 million light years away, making it the farthest object one can see with the naked eye. Thought of as a star for many years, it is a place containing perhaps a trillion stars, along with their planets and moons.

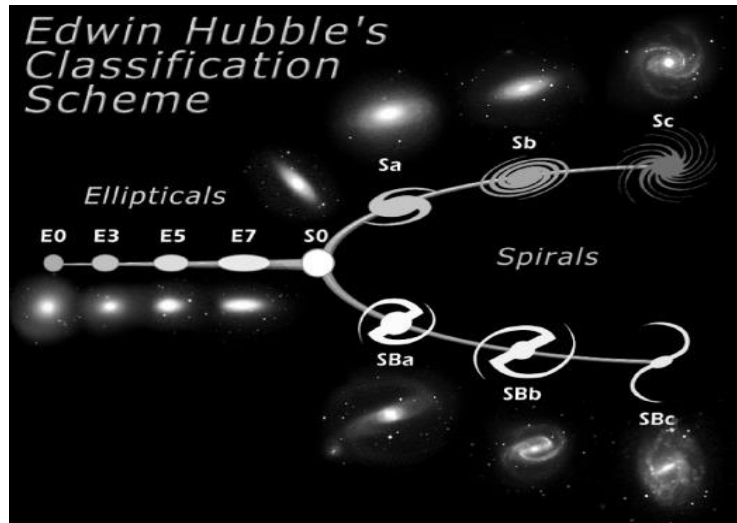
The nearest galaxy to us was discovered in 2003 is a dwarf galaxy called **Cannis Major Dwarf**. It is 25,000 light years from us and about 45,000 light years from our Galactic Center. The second closest to us, SagDEG, 50,000 light years from the Galactic Center, is now being absorbed by our Milky Way. Two other small galaxies are already orbiting ours. They are called the **large and small magellanic clouds**, or small irregular galaxies. They are at a distance of 179,000 to 210,000 light years away from us.

Our galaxy is presently consuming the SagDEG, or Sagittarius Dwarf Elliptical and Canis Major Dwarf Galaxies. Sometimes the galaxies simply collide. Can you imagine a trillion or more stars running into each others' orbits and possibly colliding? (There are pictures of such events.) The solar systems must have been thrown into utter chaos. However, it is believed that actual direct star collisions are rare.

Generally, galaxies range in size from 1,000 parsecs to 100,000 parsecs wide. Galaxies also come in different shapes.

Shown below are typical types of galaxies according to the Hubble classification system. There are some that do not fit in these categories. Their shapes have been made unusual because of gravitational influences of nearby galaxies, or as a result of collisions with another

galaxy. They are in a category called **peculiar galaxies**.



Hubble classification diagram
Courtesy NASA

The list of categories below represents the vast majority of galaxies.

Elliptical galaxies are egg shaped. They seem to be full of old stars with little dust or gas and very little star formation are taking place.

They range in shape from E0 to E7. E0 would be very compact and an E7 very elongated. Little or no structure is seen. Perhaps the description “blob”, not a scientific word, may fit when describing these galaxies’ general appearance. These galaxies may have obtained their shape as a result of merging with another galaxy, which can be often found in the middle of clusters of galaxies.

Spiral galaxies have two classifications: Some are called normal spiral galaxies. These galaxies have a nuclear and center bulge in the middle and bright arms of stars that extend outward. The galaxy spins around its center of gravity. They are classified as type S galaxies, in the Hubble classification categories. They are further categorized by the tightness of the arms and size of the center bulge. This is done with the letters: a, b, or c, following the S. Sa galaxies have a large galactic center with short and poorly defined arms. The Sc type spiral galaxy will have a smaller galactic center and longer, defined arms. The arms are areas of greater mass than between each arm, with greater mass area and density of materials. They are also called **density waves**. Stars in the arms may, on occasion, not stay in them, depending where they are located in the arms. When closer to the center, the stars move faster than the arms. When out near the ends of the arms, the

stars orbit the center at a slower pace and fall out of an arm. This affects the gravity in local regions of the arms when these stars pass through.

There is another type of spiral galaxy called **barred spiral galaxies**. It has two arms that are relatively thick. Our galaxy is a barred spiral.

Peculiar Galaxies form from tidal actions and gravitational influences, or from actual collisions and mergers with other galaxies. There are some called “**ring galaxies**”, thought to have been created from a smaller galaxy traveling through the center of a bigger galactic body. There are also some of these bodies called **lenticulars**, which look like they have a halo of stars and exhibit ill defined arms.

Dwarf galaxies, such as the **Megallanic Clouds**, (which are in the irregular category), contain usually only a few billion stars and may be as small as 100 parsecs in diameter. They often orbit larger galaxies. They can also be in shapes of elliptical, spiral or irregular. They can also be called **dwarf spheroid galaxies**. The mass of these galaxies is remarkably similar, no matter the amount of stars they contain.

Just like other objects in space, on occasion galaxies can be found clustered together (only 5% of the observed galaxies seem to be non -clustered). There can be anywhere from a few of them to thousands in the grouping together. They orbit around each other at about 600 miles per second. Our Local Group is about 3 million light years across. Three of these galaxies, including ours, are spiral shaped. The rest are elliptical, irregulars, or dwarf galaxies.

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CLUSTERS

The larger groups of galaxies, called **super clusters**, range in size from 100 million to 1 billion light years across.

Some galaxies are more active than others. They can put out far more energy than the mass of the galaxy would indicate. It may very well be that these galaxies have giant black holes in their middle. They could have several million times more mass than our Sun. They shoot out vast amounts of radiation that reaches us from millions or even billions of light years away.

Although most galaxies are **mega parsecs** (millions of parsecs) away from each other, some galaxy bashing and cannibalism does occur. When a much larger galaxy comes a little too close to a smaller one, the large one consumes it.

To help us understand distances of galaxies, the **Galaxy Evolution Explorer**, an orbiting space telescope, was launched in 2003. It was designed to measure the relative distances of galaxies from us and how fast stars are forming in each galaxy. Through observations of young, hot stars scientists hope to relate their formation to the chemical evolution of stars in our own

galaxy.



This photo shows two spiral galaxies in a collision with black holes in the centers of each.
Photo courtesy of NASA

There are many oddities in space. There are very bright objects that are as big as our entire solar system. These are called **quasars** or **Seyfert galaxies**. They emit very large doses of x-rays. They look red. But it is not because of their size, it is because of how fast they are moving away from us, causing a red Doppler shift. Speeding away from us at 90% of light speed, quasars were apparently created when the Universe was very young. They are found near the edges of the seen Universe.

Fossils in space? Yes, the oldest galaxies are known as “**fossil galaxies**”. These galaxies were born soon after the birth of the Universe. They can be seen as they were when the first stars had just formed! (These galaxies are found roughly 13.7 billion light years away.) This was just after a period of a super heated Universe with much ionization of atoms. This era is called the **Cosmic Dark Ages**, which ranged over 300,000 years.

Galaxy Iok-1 is the oldest and most distant galaxy so far discovered. It is estimated to have formed about 750 million years after the theorized Big Bang.

These early galaxies contained huge stars that were originally made up of only helium and hydrogen. Supernovas were common place and only decreased as the galaxy aged over billions of years. The forms that we now see are galaxies that have evolved and matured.

Did You Know?

The word galaxy comes from the Greek word “gala”, which means milk. The Milky Way was supposed to be spilt milk from a goddess. The “milk” is actually millions of stars that are close to each other, creating a cloud effect.

We live in the **Stellar Age**. What is after the Stellar Age?

Galaxies are running out of energy. Spiral galaxies need clouds of dust and hydrogen in their arms to produce more stars. Elliptical galaxies are running out of these materials and have lost the ability to produce more stars. Someday, far into the future, stellar production or what is called the Stellar Age will end. The starlight will fade, the present galactic structures will collapse, and the galaxy will be populated by massive black holes, neutron stars and carbonized black dwarfs. Dark cold and dead, galaxies will shrink, wither and die. That will happen many trillions of years from now.

Workbook Pages 89-90

Cosmic Concept

There are billions of galaxies in the known Universe. They vary in size, color, shape and proximity to other galaxies.

Answer the following questions in sentence form:

Why do you think there is such variety?

What have you learned as to what may make the most “livable” type of galaxy?

Minimum 50 total words.