Determining Concept Dependencies and Developing Five Course Lab Activities for an Introductory Astronomy Course

Katherine Pittman, Applied Physics, PCSE 499
Christopher Newport University
May 1, 2006

Mentor: Dr. J. Hardie
Advisor: Dr. R. Caton

Final Report

Developing five course lab activities and determining concept dependencies for an introductory astronomy class syllabus outline

Katherine Pittman, Applied Physics, PCSE 499

Mentor: Dr. J. Hardie, CNU
Advisor: Dr. R. Caton, CNU

Start date: January 30, 2006
Finish date: April 21, 2006

Abstract:
Christopher Newport University will be implementing an introductory astronomy course into its general curriculum. The proposed senior project is to develop five course lab activities to be conducted by students in teams during the span of the semester as well as identifying concept dependencies, or identifying the order of topics, and their dependence on one another. The lab activities will be designed to be readily understandable, relevant to the course material, and inexpensive. In order for students to get the most out of an introductory course, interactive, hands-on activities are required to demonstrate the scientific ideas. The goal of these lab activities is to get students used to observing phenomena for themselves and to add some interest to the classroom. The syllabus should contain relevant astronomy topics that have an obvious flow from one to the next and a broad foundation in order to convey the many different subjects of astronomy. The tools needed for this project will be, primarily, the Internet, computer simulations and software and astronomy reference texts.

Project Description:
Astronomy is a challenging topic for a novice and is not conveyed through lecture as clearly as other courses. In order to truly grasp the abstract theories of astronomy, students need to learn by varying teaching techniques, such as group work, and observation. It has been proposed that hands-on lab activities will be instrumental in teaching students difficult topics that are hard to convey through in-class lecture. This project will produce five labs to be completed in small groups by the students and will include simulation or outdoor observation of the sky, both actual and simulated.

It will be necessary for the labs to follow, in tandem, with the topics being taught in lecture in order to have the most influence on the students' learning. So, it is important to have a clearly written syllabus that is written in a logical order with the concept dependencies well defined. This project will also involve examining the concept map for the course, specifically, the order in which topics will be presented and the dependencies of one topic to another.

This course is not intended to train world-renowned scientists in one semester. In fact, any student, regardless of academic background is eligible to enroll in this course. The course lectures will forego the explicit analysis of astronomical theories in exchange for a basic, qualitative understanding by the student. The ultimate goal of the course is to instill an interest that may serve the students in their future endeavors.

Project Plan:
To meet the needs of this project, substantial research must be conducted. There are four different directions that the appropriate research can take: typical lab activities, instructions on how to compose a syllabus, how people learn and teach, and how to ask effective questions.

There exists an abundance of ideas concerning astronomy lab activities. Actual sky observation is the most frequently mentioned and the most conventional means to learn about astronomy. It can encompass lecture topics such as real-life demonstration of the movement of astronomical bodies, astronomical phenomenon, telescope handling, and backyard observing. These all require follow-up questions to ensure student understanding.

A syllabus is a basis for a common understanding between instructor and student. It can alleviate anxiety in the student by giving clear guidelines for grading, the course content, policies and expectations, and a schedule. Probably the most important part to a student, and the largest section, will be the course content. It is important to have a clear concept map outlined for the students, and in this case, have it link to the lab activities.

Knowing how people learn and teach effectively is necessary to understand in order to build effective lab exercises. Lab exercises must be tailored to how students learn. They need to be clear, well-ordered and effective to teach concepts. Questions are vital to any lab activity. They can: reflect what a student retains, guide a student to a conclusion, or test the effectiveness of the lab.

Project Implementation:
Taking an "inside out" approach to teaching astronomy, the course can be broken into five sections: Earth and Moon, Planets and Planetoids, Stars, Galaxies, and the Universe and Cosmology. Each of these sections has topics that are important to understanding astronomy and revealing the breadth of the subject.

From these five identified sections, a concept map can be drawn. Concept mapping is used to organize related information in a visual manner. Study maps clearly and concisely demonstrate hierarchical relationships among the topic, main ideas, and supporting details or pertinent course material. Mapping is a way of picturing course content that enhances retrievability of the information on a test. Maps are useful because they reduce large amounts of information.

The Concept Description is meant to be a brief reference source of the topics identified in the Concept Map. Each of the five sections includes short explanations of pertinent sub topics, online sources that may be used in class or separately to supplement lecture, diagrams, tables, and an activity for students. Below, is an excerpt of the Concept Description including the first section:

I. Earth and Moon

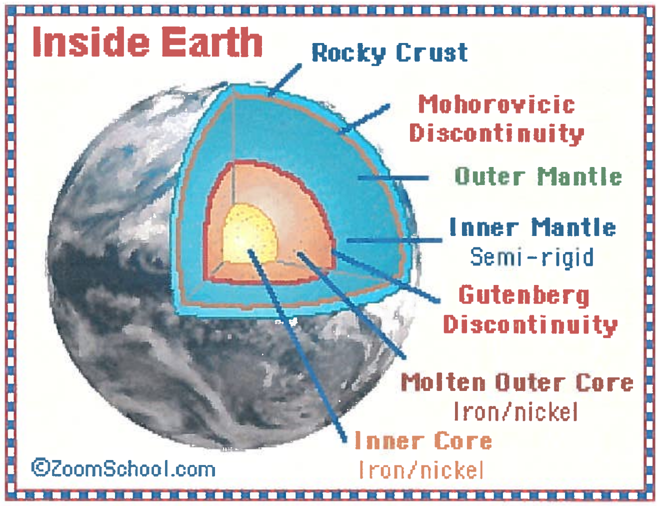
Some Properties of Earth and Moon (1):

	Mass (kg)	Radius (km)	Density (kg/m^3)	Surface Gravity (Earth=1)	Escape Speed (km/s)	Rotation Period
Earth	$6.0*10^{24}$	6400	5500	1.00	11.2	23^h56^m
Moon	$7.3*10^{22}$	1700	3300	0.17	2.4	27.3days

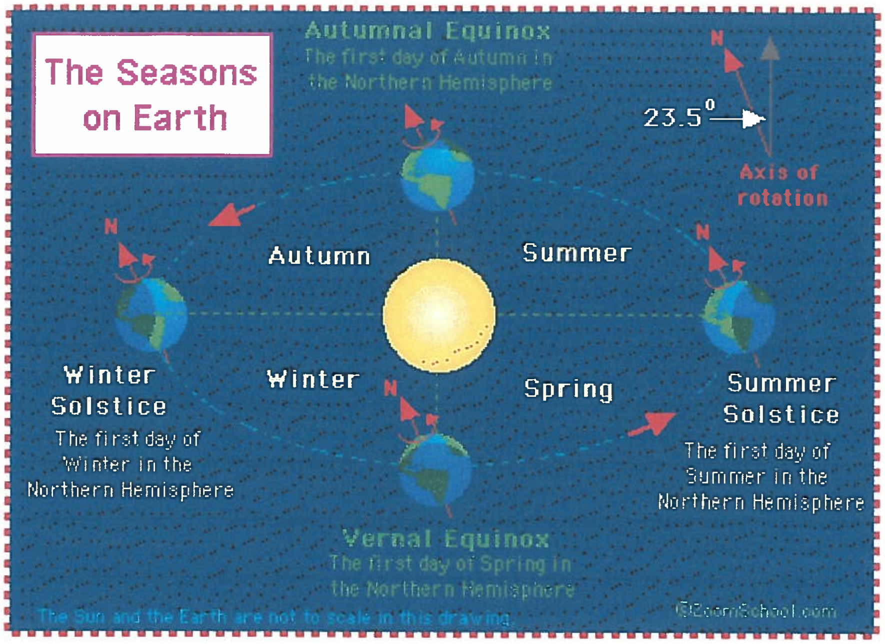
The Earth

- The Earth is 4.5 to 4.6 billion years old, but the oldest known rocks are about 4 billion years old and rocks older than 3 billion years are rare. The oldest fossils of living organisms are less than 3.9 billion years old. There is no record of the critical period when life was first getting started (2).

- Earth is the third planet from the sun and the fifth largest (2). The Earth can be divided into six regions: core, mantle, crust, hydrosphere, atmosphere, and magnetosphere. The core is surrounded by the thick mantle, and coated with the thin crust, comprising the solid continents and the seafloor. The hydrosphere contains the liquid oceans and accounts for 70% of Earth's total surface area. The air that lies above the surface is the atmosphere. And, at higher altitudes, a layer of charged particles trapped by Earth's magnetic field forms the magnetosphere (1).



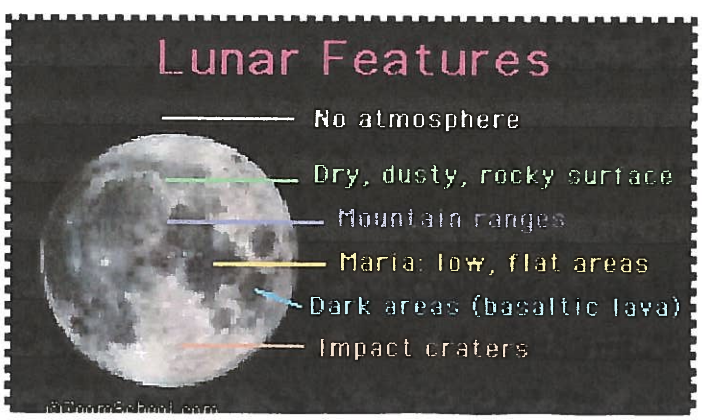
- The Earth's atmosphere is very different from its two neighboring planets. Both Mars and Venus have atmospheres composed of mostly carbon dioxide. The Earth's atmosphere contains very little carbon dioxide, and instead is comprised of nitrogen (77%) and oxygen (21%) (3).
- Because the Earth orbits the Sun, the Sun appears to move relative to the background stars. This apparent motion of the Sun, over the course of a year, traces out a path on the celestial sphere known as the ecliptic. The point on the ecliptic where the Sun is at its northernmost point above the celestial equator is the summer solstice, where Earth's North Pole points closest to the Sun (on or near June 21). Six months later, the Sun has reached its southernmost point, and the winter solstice (on or near December 21). The height of the Sun above the celestial equator and the length of the day combine to account or the seasons. In northern summer, the Sun is high in the sky and the days are longer, with the result that temperatures are much higher than in winter, when the Sun is low and the days are short. The two points where the ecliptic intersects the celestial equator are known as equinoxes, where the day and night are of equal duration. The autumnal equinox (the Sun crosses the celestial equator moving south) is on or near September 21, and the vernal equinox (the Sun crosses the celestial equator moving north) is on or near March 21 (1).



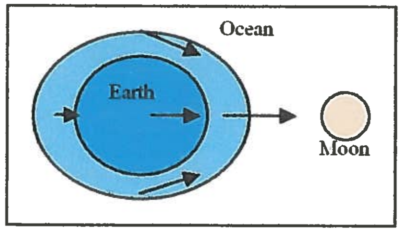
The Moon

- The Moon rotates once on its axis in 27.3 days, which is the same time that it takes to complete one revolution around the Earth. This results in the Moon always presenting the same face toward Earth at all times (1).

- There are several different theories as to the origin of the Moon. The most popular today, however, is the collision-ejection theory, which stated that a sizable object collided with the Earth and ejected debris into space that collected and formed the Moon (3).
- The two main types of the lunar terrain constitute dark plains, or maria, and heavily cratered highland terrain, including mountain ranges and valleys. The craters were formed from meteoritic impacts long ago. The maria are resultant of lava flows that filled the low-lying portions of the Moon's surface about 3.5 billion years ago (3).

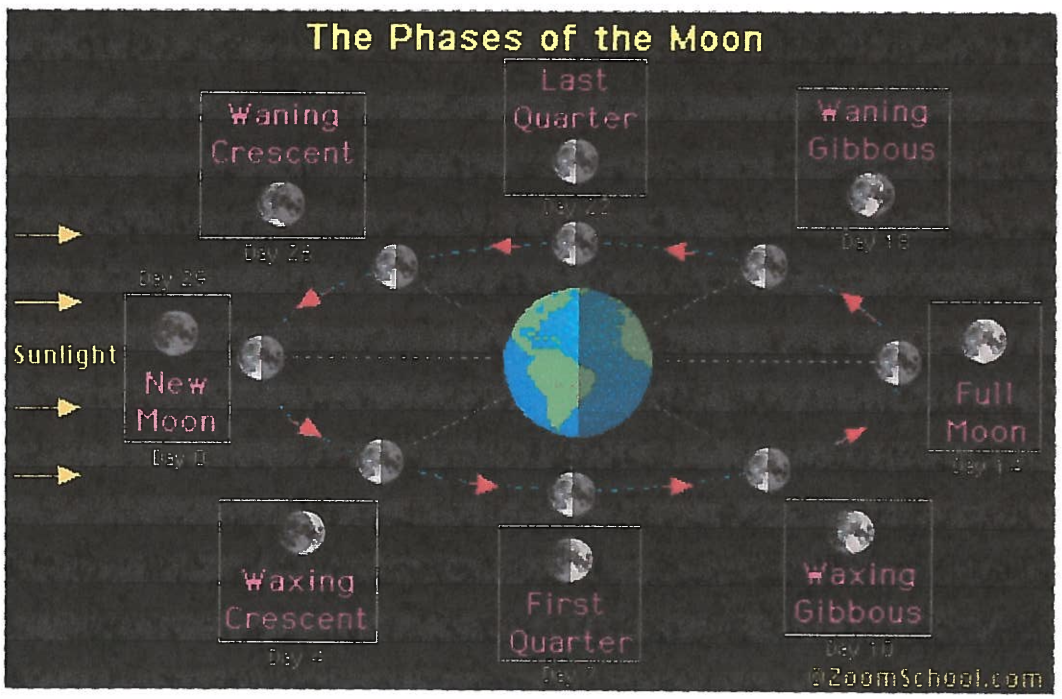


- Tides are created because the Earth and the moon are attracted to each other gravitationally. Each day, there are two high tides and two low tides. The gravitational attraction of the moon causes the oceans to bulge out in the direction of the moon. Another bulge occurs on the opposite side, since the Earth is also being pulled toward the moon (and away from the water on the far side) (4).



The Figure above is an exaggerated illustration that shows how the Moon induces tides on both the near and far sides of Earth. It describes the lunar gravitational forces acting on several locations on and inside Earth. The force is greatest on the side nearest the Moon and smallest on the opposite side. The lengths of the arrows indicate the relative strengths of the Moon's gravitational pull on various parts of Earth (1).

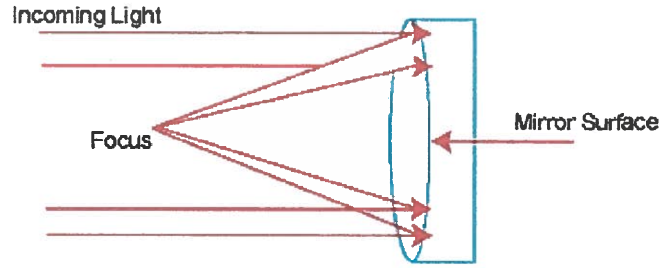
- As the moon circles the Earth, the shape of the moon appears to change; this is because different amounts of the illuminated part of the moon are facing us. The shape varies from a full moon (when the Earth is between the sun and the moon) to a new moon (when the moon is between the sun and the Earth) (4).



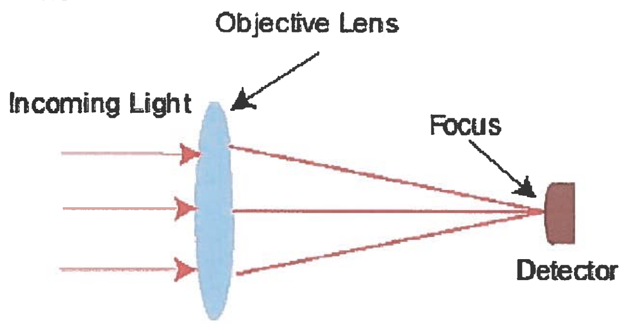
Making Observations

- A telescope is an instrument whose main function is to gather as much light as possible from a specific area of sky and concentrate it into a focused beam. An optical telescope is meant to collect wavelengths visible to the human eye. Optical telescopes fall into two basic categories: reflectors and refractors. Reflectors use a curved mirror, or primary mirror, to gather a beam of light. Refractors use a lens to focus the beam of light. Radio telescopes are built to detect cosmic radio waves (1).

Reflector



Refractor



- The analysis of the ways in which matter emits and absorbs radiation is called spectroscopy. Spectral lines are indicators of chemical compositions. Every chemical composition has its own individual light signature, like a thumbprint. The composition of an object is determined by matching its spectral lines with the laboratory spectra of known atoms and molecules (1).

Online Sources:
Google Earth (www.earth.google.com)
Earth and Moon viewer (http://www.fourmilab.ch/earthview/)
Enchanted Learning (http://www.enchantedlearning.com/subjects/astronomy/)

Activity:
Watch the Moon over a period of hours on a night when you can see one or more bright stars near it. Estimate how many Moon diameters the Moon moves per hour. Knowing the Moon is about 0.5 degrees in diameter, how may degrees per hour does it move? What is your estimate of its orbital period (1)?

Sources:
1. Chaisson, Eric and Steve McMillan. Astronomy. Second Edition. Upper Saddle River, New Jersey: Prentice Hall, 1998, Chapter 5: Earth and Its Moon.
2. Arnett, Bill. 11 Feb, 2005 <http://www.nineplanets.org/earth.html>.
3. Jones, Brian. The Practical Astronomer. Simon and Schuster, Fireside, 1990.
4. Enchanted Learning. 1999-2005. <http://www.enchantedlearning.com/subjects/astronomy/moon/Tides.shtml>.

******

Lab Exercises:
There are three types of learning: visual, auditory, and tactile. Assuming that these learning styles are distributed evenly among students, in order to maximize the effectiveness of the astronomy labs, the activities must incorporate traits of all three.

Students who learn visually need displays including: diagrams, illustrated textbooks, videos, flipcharts, and handouts. This will probably be the easiest to provide because astronomy tends to be very visual in nature. Students who learn best through verbal lectures, discussions, and listening to others need auditory stimulation. This will primarily be met through class lectures. Working with teams to complete the labs will also be stimulating to the student as the team discusses the lab. Tactile students learn best through a hands-on approach. Out-of-class observations and experiments will be the best solution to create an effective lab activity.

The aim is to create activity labs that will effectively teach as well as entertain students. The subsequent goal of the activities is to get students used to observing phenomena for themselves and to add some fun to the classroom.

Engineering questions to fit these learning types is one of the challenges for the project. Through thoughtful questioning, teachers can guide students to connecting concepts, encouraging critical thinking, and understanding. There are five types of questions: factual, convergent, divergent, evaluative, and combination.

1. Factual questions solicit simple, straightforward answers based on obvious facts or awareness.
   Example: How many moons does Earth have?
2. Convergent questions ask for answers that have a very narrow range of answers.
   Example: What are the different possibilities concerning what dark matter is made of?
3. Divergent questions allow students to explore different directions and create variations or alternative answers or scenarios.
   Example: What do you think will happen to the Universe in the future?
4. Evaluative questions require sophisticated levels of cognitive judgment.
   Example: How do Kepler's laws relate to how the planets move across the sky from Earth's viewpoint?
5. Combination questions are any combination of the previous types of questions.
   Example: What are the different possibilities concerning what dark matter is made of and which theory do you think is correct?

As students mature, they gradually change from passive to active learning. Active learning occurs when the students take responsibility for their own learning by taking the initiative to learn. The questions in this lab will aim to promote critical thinking and active learning with the goal of helping to graduate students to the next level of thinking. The labs will have specific sections that will inform the student, explicitly, what the learning goals are, the procedural objectives, the background information, materials needed, and the procedure. Below are examples that would be found in the labs.

Lab Sections:

Learning Goals

- The student should be able to name several elements seen in supernova remnants
- The student should be able to understand that heavy elements such as iron are created in supernovae, in quantities sufficient to account for the content in stars like the Sun

- The student should be able to say how spectroscopy helps us understand the composition of astronomical objects
- The student should see that different elements have different spectral characteristics

Procedural Objectives

If the student learns to…

- Take spectra of the supernova remnant
- Compare the spectra with a model of that spectrum using various parameters (abundances, temperature, absorption)
- Calculate the abundances of elements in the remnant

They should be able to…

- Convert the elemental abundances to total masses in the remnant
- See how changing the physical parameters in the gas changes the appearance of the spectrum

Lab Example:

Lab Exercise 1

Est. Time: 2 hrs

Introduction to the Night Sky

Observing the Night Sky

I. Observation

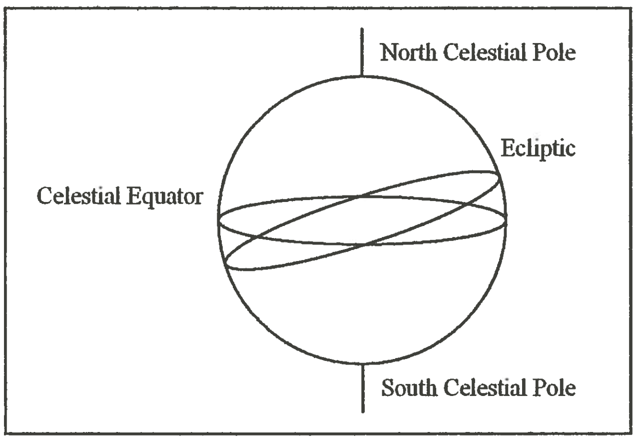
Whether through telescopes, the naked eye, or simulation programs, most of an astronomer's time is spent observing the sky and its changes over time. Astronomy is a vast subject that encompasses everything from the Earth to the farthest galaxy. Astronomy holds many attractions, but the greatest one is that it is new, and at the same time, old.

As early as 3000 B.C.E. the Babylonians were actively studying the stars and planets. They identified constellations and calculated a calendar based on astronomical events. The Chinese were the next astronomers in the timeline by conceptualizing the 365-day year before 2500 B.C.E., based on observations of the sun across the background stars. The ancient Egyptians used astronomy to guide their dead into the afterlife. Hieroglyphics on pyramid walls show prayers making reference to the stars and the pharaohs' ascents into them. Between 2800 B.C.E. and 1550 B.C.E., the people of Britain built Stonehenge as an astronomical observatory and a calendar. The Mayans created a very detailed calendar as well by using celestial observation around 700 C.E.

The Greeks, however, left the most detailed account of their celestial interests. As early as 500 B.C.E., the Sun was identified to be a large, red-hot body, that the Moon was much like Earth, with mountains and ravines, and that solar eclipses were caused by the passage of the Moon between the Sun and Earth. We also owe, indirectly, our knowledge of the structure of the solar system to the Greeks (See Lab Exercise 3).

The celestial observations made by the ancients were based on the idea that all of the stars were fixed on a bowl that surrounded the Earth. Today, we know that this is not true; however, if we apply the concept, we can use the idea to orientate ourselves to the stars easily. The celestial sphere is an imaginary sphere that we picture surrounding Earth upon which the stars are fixed.

We can orient our gaze into the heavens by thinking of the point of sky directly above Earth's North Pole as the north celestial pole, and the point below the South Pole as the south celestial pole. The celestial equator lies midway between these points.



The Celestial Sphere

Astronomers have assigned the same system of latitude and longitude to the celestial sphere that is in use on the surface of the Earth. The lines of latitude run parallel to the celestial equator. Declination corresponds to latitude and measures the angular distance above or below the celestial equator. Declination is expressed in degrees + (above) or – (below) the celestial equator. For example, the constellation Orion is at a declination of $+5^{\circ}$.

The lines of longitude run vertically from pole to pole. On the celestial sphere, right ascension is similar to longitude, and measures the angular distance east or west in hours, minutes, and seconds, increasing from west to east, starting at zero. The zero point is taken to be the position of the Sun in the sky at the vernal equinox. Earth rotates once every 24 (approximately) hours, which means that stars will return to their staring positions in the sky at the same time (approximately) every day. After 24 hours, Earth has rotated through 360 degrees, so that each hour of right ascension corresponds to 15 degrees on the sky.

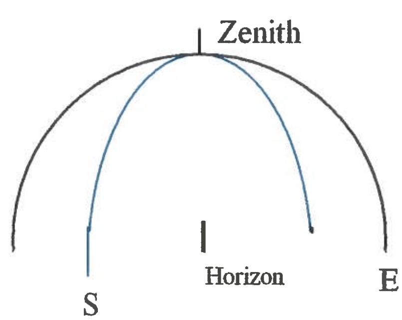
Hopefully, you're asking yourself about the relationship of longitude to right ascension and why astronomers don't just imaging right ascension as a projection of Earthly longitude. There are good reasons why astronomers don't mix the two. The stars in the winter sky are different than the stars in the summer sky. For example, Orion is visible in the winter, but in the summer, it is trapped in the bright glare of the Sun. The stars above are changing locations, but are you? Does New York, NY change its position? Because the stars are changing, they cannot be fixed to the coordinates of the surface of the Earth.

Why do you think this difference happens?

Celestial coordinates are valuable to learn because they give an absolute system of coordinates to astronomers. Using this system, any two astronomers, anywhere in the world, can find the same star with the same coordinates. However, celestial coordinates can be confusing to an amateur sky watcher.

Using the altazimuth coordinate system is an easier way to measure the location of an object in the sky as observed from your location at a particular time that includes two angles: azimuth and altitude. Astronomers use angles to divide the horizon by imagining themselves located in the center of a circle that is flat on the ground. A circle an be divided into 360 degrees, and a degree can be subdivided into 60 minutes, and a minute sliced into 60 seconds. The astronomer decides which direction is 0 degrees, usually due north. Imagine another circle that starts at the decided horizontal direction and bisects the surrounding circle. The topmost point, at 180 degrees, is the zenith. An object's altitude is its angular distance above the horizon, and its compass direction, azimuth, is measured in degrees increasing clockwise from due north (east is at 90 degrees, south is at 180 degrees, and west is at 270 degrees).

What is the downside of the altazimuth coordinate system?



II. Objective

Students gain an understanding of celestial and altazimuth coordinates through experiment and observation.

III. Learning Goals

*Learn how to navigate the night sky by using celestial and altazimuth coordinates, star charts and the naked eye
*Identify sources of astronomical information with respect to locating celestial objects
*Identify major constellations and stars

IV. Equipment

Your eyes	Binoculars	Internet Access
Pencil and Paper	Flashlight (optional)	
Star Chart	Small Telescope (optional)	

V. Procedure

This section of the lab can be completed with planetarium software or by outdoor observation. Some parts can even be done with Google Earth, by zooming out and locating constellations (hint: major constellation stars are brighter than others in this program). All of the objects listed below can be found and observed with binoculars and a steady hand.

1. Find the below astronomical objects. Use celestial coordinates, altazimuth coordinates, a star chart, and the naked eye. You must use each of these at least twice. Only use one method per object. You will need to use some astronomical resources (internet, textbook, almanac, planetarium software, etc…) to find coordinates or locations of the below objects. Plan your time wisely if you are observing outdoors, check the time vs. position of the objects before you go out.

Bright Stars:

Betelgeuse	Rigel	Arcturus
Sirius	Polaris	Deneb

Constellations:

Orion	Ursa Major	Cygnus
Cassiopeia	Ursa Minor	Taurus

Other Neat Objects:

Pleiades (Open Cluster)	**Jupiter
**Mizar and Alcor (Binary Stars)	**Saturn

*At different times of the year, some of these objects may be more easily spotted than others. Check with your professor to see if there are any changes.

**Draw a sketch of what you see to turn in to your professor.

Questions:
Why are Polaris, Sirius, Betelgeuse, and Arcturus special?

____

____

____

____

____

____

____

Note the positions of the Polaris, Jupiter, and Betelgeuse at the beginning of the lab. Are there changes to their positions at the end (If using a planetarium simulator, fast forward the time step option and see what happens.)? How are the objects moving in the celestial sphere? Write your observations below.

____

____

____

____

____

____

____

____

VI. Useful Definitions

Altitude_______________The angular distance of a celestial object above or below the observer's horizon. Altitude is 0° at the horizon and 90° at the zenith.

Angular separation______The apparent distance between two objects, such as two stars, expressed in degrees, minutes, or seconds of arc.

Azimuth_______________The direction to a celestial object measured in degrees, clockwise from north around the observer's horizon. Azimuth is 0° for an object due north, 90° due east, 180° due south, and 270° due west.

Celestial equator________The great circle on the celestial sphere that lies directly above the equator of the Earth. Any point on the celestial equator is equidistant from the north and couth celestial poles.

Celestial sphere_________An imaginary sphere of indefinite size, used as a background for assigning positional coordinates to celestial objects. The sphere may be centered on the Earth, the observer, or any other point which acts as the origin of the chosen system of coordinates.

Declination____________A coordinate on the celestial sphere, the equivalent of latitude on Earth. Declination is measured in degrees north or south of the celestial equator, from 0° at the celestial equator to +90° at the north celestial pole and -90° at the south celestial pole.

Ecliptic______________The apparent path of the Sun against the star background over the course of a year. The movement of the Sun along the ecliptic is actually a result of the Earth's movement in its orbit around the Sun. Therefore the ecliptic is actually the plane of the Earth's orbit projected on to the celestial sphere. Because of the Earth's axial tilt, the ecliptic is inclined at about 23°.4 to the celestial equator.

Right ascension________A coordinate on the celestial sphere, the equivalent of longitude on Earth. Right ascension is measured clockwise around the celestial equator, in hours, minutes, and seconds starting from 0h at the vernal equinox.

Zenith________________The point on the celestial sphere directly above an observer.

******

Conclusions:

This project was a surprise to me. I had planned to spend most of my time researching, but until I started researching, I did not realize how much I did not know about teaching or writing an effective lab. From my experiences, I conclude that it takes quite a bit of work to teach, including research, thinking ahead, organizing a course, formulating questions, and then answering asked questions.

For the most part, I completed everything I proposed and planned to do for this project. If I had had more time, I would have liked to include a teacher's version of the lab exercises with answers and supplemental information. However, I feel that the labs would be self-explanatory to an astronomy professor without them.

All told, this wasn't just an interesting project with a defined deliverable; it was a fun project! I enjoy astronomy and observing whenever I can squeeze it into my schedule. I thoroughly relished the opportunity to research and write about astronomy for my senior project. I feel confident that introducing an astronomy course to the general curriculum will encourage other students to feel the same appreciation I have for astronomy.

Sincerely,
*Kate Pittman

References

Altman, Howard B. Writing A Syllabus. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/writesyl.htm>.

Arny, Thomas T. *Explorations*: Stars, Galaxies, and Planets Updated. Boston: McGraw Hill, 2004.

Becker, Lana, and Kent N. Schneider. Motivating Students: 8 Simple Rules for Teachers. August/September 2004. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/motiv8rules.htm>.

Cashin, William E. Answering and Asking Questions. January 1995. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/askquest.htm>.

Center for Learning & Technology, Cornell University. <http://www.clt.cornell.edu/campus/learn/LSC%20Resources/conceptmapping.pdf>.

Chaisson, Eric, and Steve McMillan. *Astronomy*: A Beginner's Guide to the Universe. New Jersey: Prentice Hall, 1998.

Chapter 3 – Creating a Syllabus. Florida State University. <http://online.fsu.edu/learningresources/handbook/instructionatfsu/PDF-Chptr3.pdf>.

Common Teaching Methods. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/comteach.htm>.

Common Visual Aids. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/visuals.htm>.

Coyle, Harold P., et al. *Project STAR*: The Universe in Your Hands. Iowa: Kendall/Hunt Publishing Company, 1993.

Davis, Barbara Gross. Motivating Students. September 1, 1999. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/motiv.htm>.

Davis, Barbara Gross. Preparing or Revising a Course. September 1, 1999. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/prepcors.htm>.

DePree, Christopher, and Alan Axelrod. The Complete Idiot's Guide to Astronomy. Third Edition. Alpha, 2004.

Ferguson, Dale C. Introductory Astronomy Exercises. First Edition. Brooks/Cole, 1990.

Ferguson, Dale C. Introductory Astronomy Exercises. Second Edition. Brooks/Cole, 2001.

Fink, L. Dee. Active Learning. July 19, 1999. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/active.htm>.

Fink, L. Dee. Fink's Five Principles of Good Course Design. July 19, 1999. http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/finks5.htm >.

Gardiner, Lion F. How Students Learn vs. How we Teach. August 1998. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/gardiner.htm>.

Haugen, Lee. Learning-Centered Syllabi Workshop. April 22 & April 29, 1998. <http://www.celt.iastate.edu/teaching/syllabi.html>.

Hester, Jeff, et al. 21st Century Astronomy. New York: W.W. Norton & Company, 2002.

Ideas to Encourage Student Retention. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/studretn.htm>.

Jones, Brian. The Practical Astronomer. Simon and Schuster/Fireside, 1990.

Learning Disabilities, LdPride.net. 17 March 2006 <http://www.ldpride.net/learningstyles.MI.htm>.

Luce, Ronald W. Motivating the Unmotivated. March 8, 1990. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/unmotiva.htm>.

Melby, Ernest O. The True Teacher Accepts all Students. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/truteach.htm>.

Montenbruck, Oliver, and Thomas Pfleger. Astronomy on the Personal Computer. Springer-Verlag, 1989.

Nave, C. R. HyperPhysics Concepts. 2005. http://hyperphysics.phy-astr.gsu.edu/Hbase/hph.html

"Our oncept of Critical Thinking." Foundation for Critical Thinking. 2004. <http://www.criticalthinking.org/aboutCT/ourConceptCT.shtml>.

Ridpath, Ian. A Dictionary of Astronomy. New York: Oxford University Press, 1997.

Schlosser, W., Schmidt-Kaler, T., and Milone, E. F. Challenges of Astronomy. New York: Springer-Verlag, 1991.

Sizer, Theodore R. Good Teaching. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/goodteac.htm>.

Slater, Timothy F., and Jeffrey P. Adams. *Learner-Centered Astronomy Teaching*: Strategies for Astro 101. New Jersey: Prentice Hall, 2003.

Socratic Questions. ChangingMinds. Org. Syque 2002-2006. <http://changingminds.org/techniques/questioning/socratic_questions.htm>.

Source Unknown. Developing a Course Syllabus. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/develsyl.htm>.

Source Unknown. General Principles of Motivation. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/motivate.htm>.

Source Unknown. Learning Skills Program. http://www.coun.uvic.ca/learn/program/hndouts/map_ho.html

Source Unknown. Lesson Planning Procedures. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/lesspln1.htm>.

Source Unknown. Selecting a Delivery Strategy. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/delivery.htm>.

Source Unknown. Syllabus Example – Classroom Course. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/syllab-4.htm>.

Source Unknown. The Syllabus as a Learning Tool. <http://cit.necc.mass.edu/atlt/Syllab2.htm>.

Wilen. Effective Techniques of Questioning. 1986. <http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/effquest.htm>.

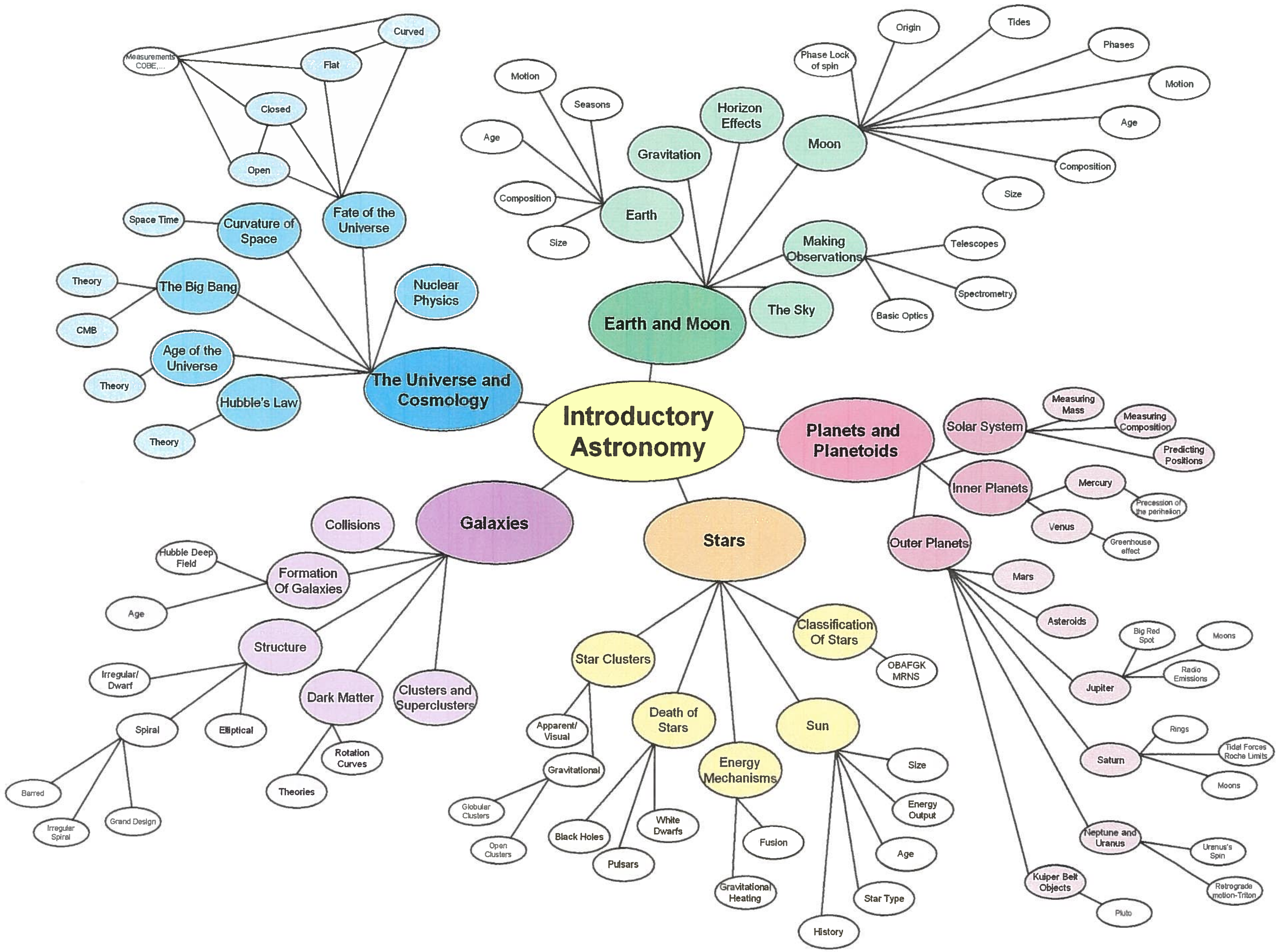
Wilson, Leslie Owen. Five Basic Types of Questions. 1997. <http://www.uwsp.edu/education/lwilson/learning/quest2.htm>.

Wooley, Jon K. Voyages through Space and Time. California: Wadsworth Publishing Company, 1992.

Concept Map

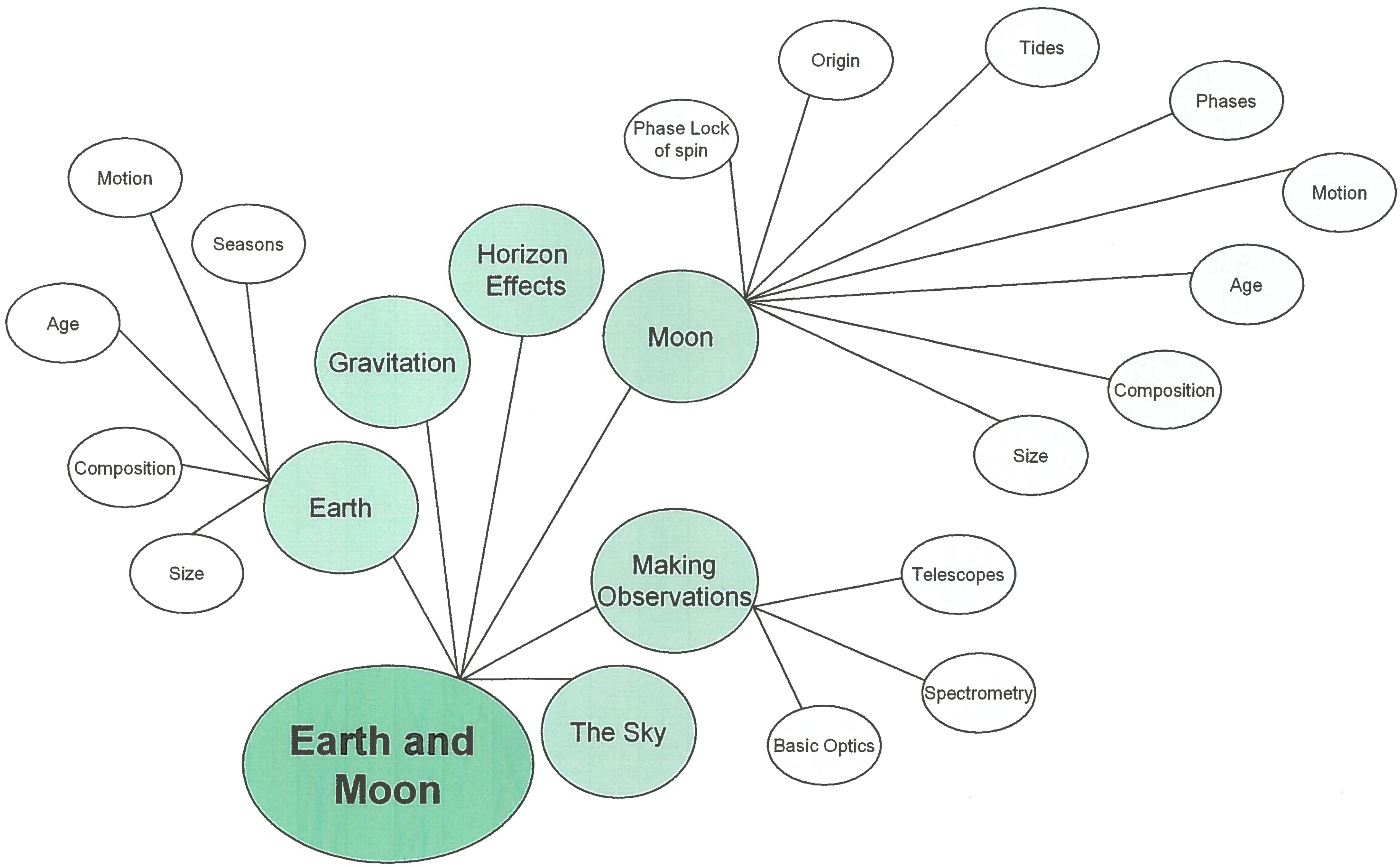
Katherine Pittman, Applied Physics, PCSE 499
Christopher Newport University
May 1, 2006

Mentor: Dr. J. Hardie
Advisor: Dr. R. Caton



Introductory Astronomy
Earth and Moon
Earth
Motion
Seasons
Age
Composition
Size
Gravitation
Horizon Effects
Moon
Phase Lock of spin
Origin
Tides
Phases
Motion
Age
Composition
Size
Making Observations
Telescopes
Spectrometry
Basic Optics
The Sky
Planets and Planetoids
Solar System
Measuring Mass
Measuring Composition
Predicting Positions
Inner Planets
Mercury
Precession of the perihelion
Venus
Greenhouse effect
Outer Planets
Mars
Asteroids
Jupiter
Big Red Spot
Moons
Radio Emissions
Saturn
Rings
Tidal Forces Roche Limits
Moons
Neptune and Uranus
Uranus's Spin
Retrograde motion-Triton
Kuiper Belt Objects
Pluto
Stars
Classification Of Stars
OBAFGK MRNS
Sun
Size
Energy Output
Age
Star Type
History
Energy Mechanisms
Fusion
Gravitational Heating
Death of Stars
White Dwarfs
Pulsars
Black Holes
Star Clusters
Apparent/ Visual
Gravitational
Globular Clusters
Open Clusters
Galaxies
Collisions
Formation Of Galaxies
Hubble Deep Field
Age
Structure
Irregular/ Dwarf
Elliptical
Spiral
Barred
Irregular Spiral
Grand Design
Dark Matter
Rotation Curves
Theories
Clusters and Superclusters
The Universe and Cosmology
Nuclear Physics
Fate of the Universe
Curved
Flat
Closed
Open
Measurements COBE,...
Curvature of Space
Space Time
The Big Bang
Theory
CMB
Age of the Universe
Theory
Hubble's Law
Theory

Concept Map Subsections
with
Concept Descriptions Reference


Earth and Moon
Earth
Motion
Seasons
Age
Composition
Size
Gravitation
Horizon Effects
Moon
Phase Lock of spin
Origin
Tides
Phases
Motion
Age
Composition
Size
Making Observations
Telescopes
Spectrometry
Basic Optics
The Sky

Introductory Astronomy Course – Concept Descriptions
Compiled by: Kate Pittman

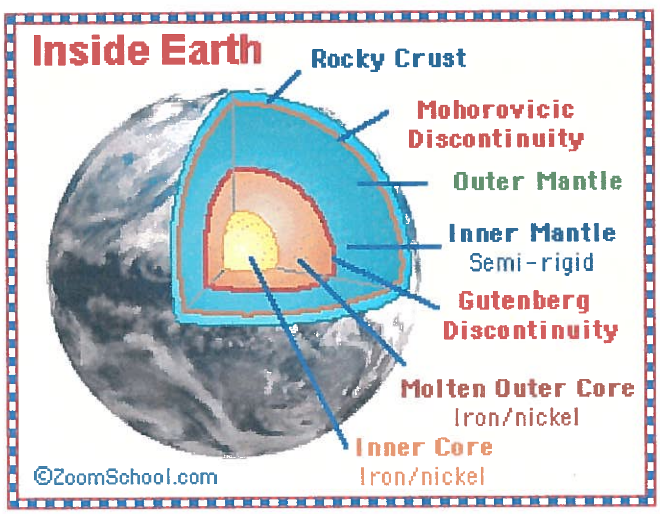
I. Earth and Moon

Some Properties of Earth and Moon (1):

	Mass (kg)	Radius (km)	Density (kg/m^3)	Surface Gravity (Earth=1)	Escape Speed (km/s)	Rotation Period
Earth	$6.0*10^{24}$	6400	5500	1.00	11.2	23^h56^m
Moon	$7.3*10^{22}$	1700	3300	0.17	2.4	27.3days

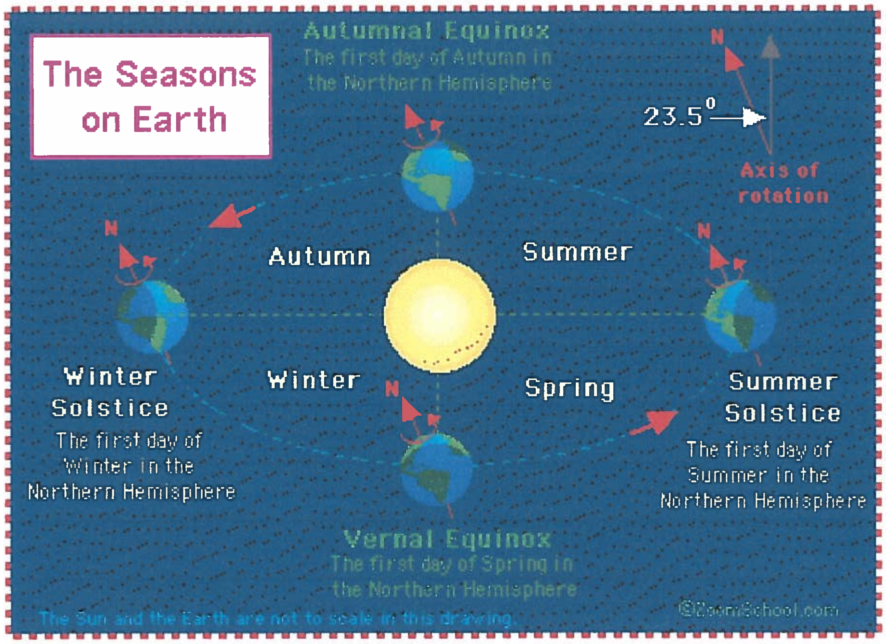
The Earth

- The Earth is 4.5 to 4.6 billion years old, but the oldest known rocks are about 4 billion years old and rocks older than 3 billion years are rare. The oldest fossils of living organisms are less than 3.9 billion years old. There is no record of the critical period when life was first getting started (2).
- Earth is the third planet from the sun and the fifth largest (2). The Earth can be divided into six regions: core, mantle, crust, hydrosphere, atmosphere, and magnetosphere. The core is surrounded by the thick mantle, and coated with the thin crust, comprising the solid continents and the seafloor. The hydrosphere contains the liquid oceans and accounts for 70% of Earth's total surface area. The air that lies above the surface is the atmosphere. And, at higher altitudes, a layer of charged particles trapped by Earth's magnetic field forms the magnetosphere (1).



- The Earth's atmosphere is very different from its two neighboring planets. Both Mars and Venus have atmospheres composed of mostly carbon dioxide. The Earth's atmosphere contains very little carbon dioxide, and instead is comprised of nitrogen (77%) and oxygen (21%) (3).
- Because the Earth orbits the Sun, the Sun appears to move relative to the background stars. This apparent motion of the Sun, over the course of a year, traces out a path on the celestial sphere known as the ecliptic. The point on the ecliptic where the Sun is at its northernmost point above the celestial equator is the summer solstice, where Earth's North Pole points closest to the Sun (on or near June 21). Six months later, the Sun has reached its southernmost point, and the winter solstice (on or near December 21). The height of the Sun above the celestial equator and the length of the day combine to account or the seasons. In northern summer, the Sun is high in the sky and the days are longer, with

the result that temperatures are much higher than in winter, when the Sun is low and the days are short. The two points where the ecliptic intersects the celestial equator are known as equinoxes, where the day and night are of equal duration. The autumnal equinox (the Sun crosses the celestial equator moving south) is on or near September 21, and the vernal equinox (the Sun crosses the celestial equator moving north) is on or near March 21 (1).

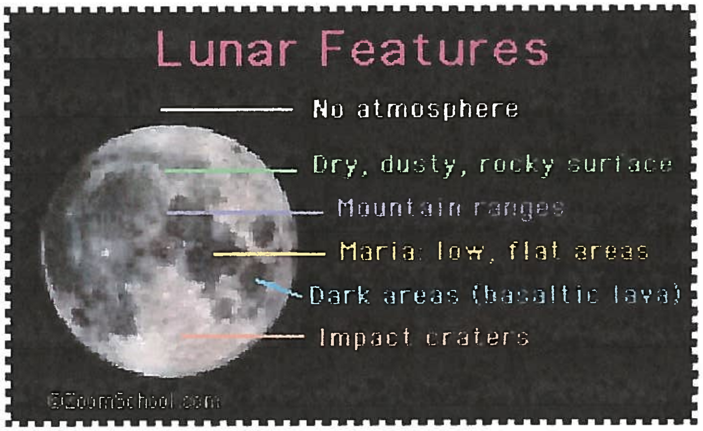


The Moon

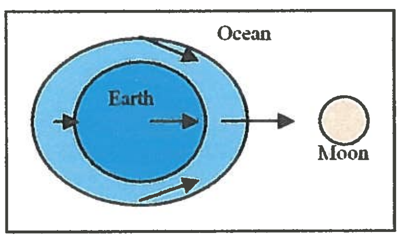
- The Moon rotates once on its axis in 27.3 days, which is the same time that it takes to complete one revolution around the Earth. This results in the Moon always presenting the same face toward Earth at all times (1).

- There are several different theories as to the origin of the Moon. The most popular today, however, is the collision-ejection theory, which stated that a sizable object collided with the Earth and ejected debris into space that collected and formed the Moon (3).

- The two main types of the lunar terrain constitute dark plains, or maria, and heavily cratered highland terrain, including mountain ranges and valleys. The craters were formed from meteoritic impacts long ago. The maria are resultant of lava flows that filled the low-lying portions of the Moon's surface about 3.5 billion years ago (3).

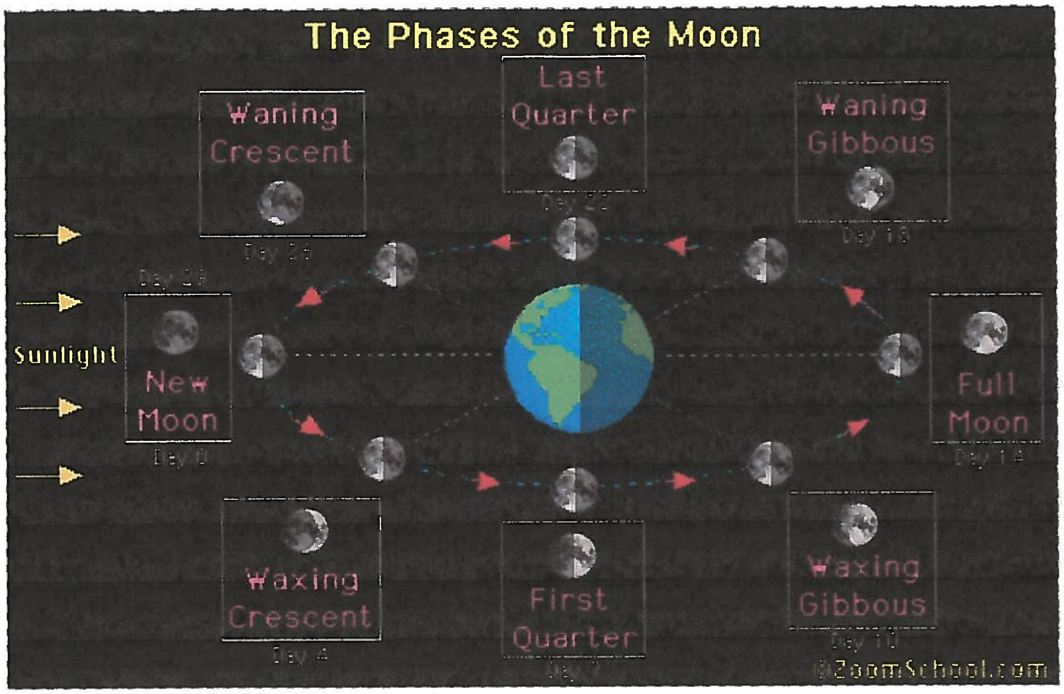


- Tides are created because the Earth and the moon are attracted to each other gravitationally. Each day, there are two high tides and two low tides. The gravitational attraction of the moon causes the oceans to bulge out in the direction of the moon. Another bulge occurs on the opposite side, since the Earth is also being pulled toward the moon (and away from the water on the far side) (4).



The Figure above is an exaggerated illustration that shows how the Moon induces tides on both the near and far sides of Earth. It describes the lunar gravitational forces acting on several locations on and inside Earth. The force is greatest on the side nearest the Moon and smallest on the opposite side. The lengths of the arrows indicate the relative strengths of the Moon's gravitational pull on various parts of Earth (1).

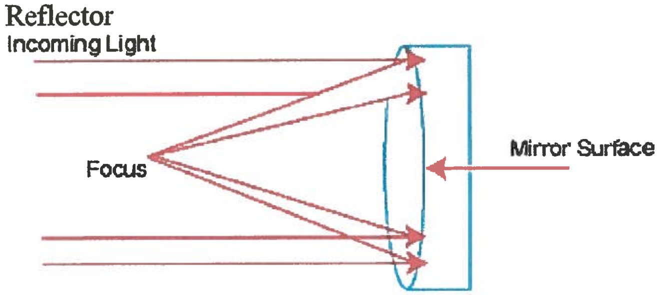
- As the moon circles the Earth, the shape of the moon appears to change; this is because different amounts of the illuminated part of the moon are facing us. The shape varies from a full moon (when the Earth is between the sun and the moon) to a new moon (when the moon is between the sun and the Earth) (4).



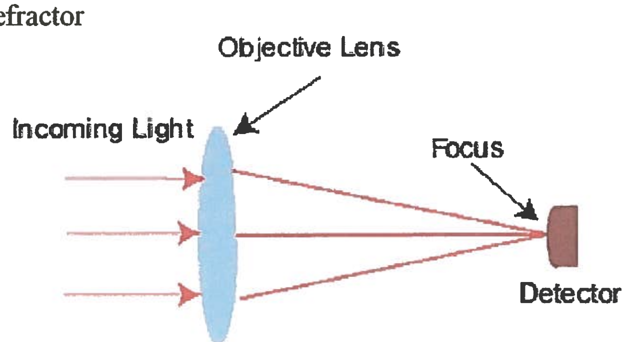
Making Observations

- A telescope is an instrument whose main function is to gather as much light as possible from a specific area of sky and concentrate it into a focused beam. An optical telescope is meant to collect wavelengths visible to the human eye. Optical telescopes fall into two basic categories: reflectors and refractors. Reflectors use a curved mirror, or primary mirror, to gather a beam of light. Refractors use a lens to focus the beam of light. Radio telescopes are built to detect cosmic radio waves (1).

Reflector



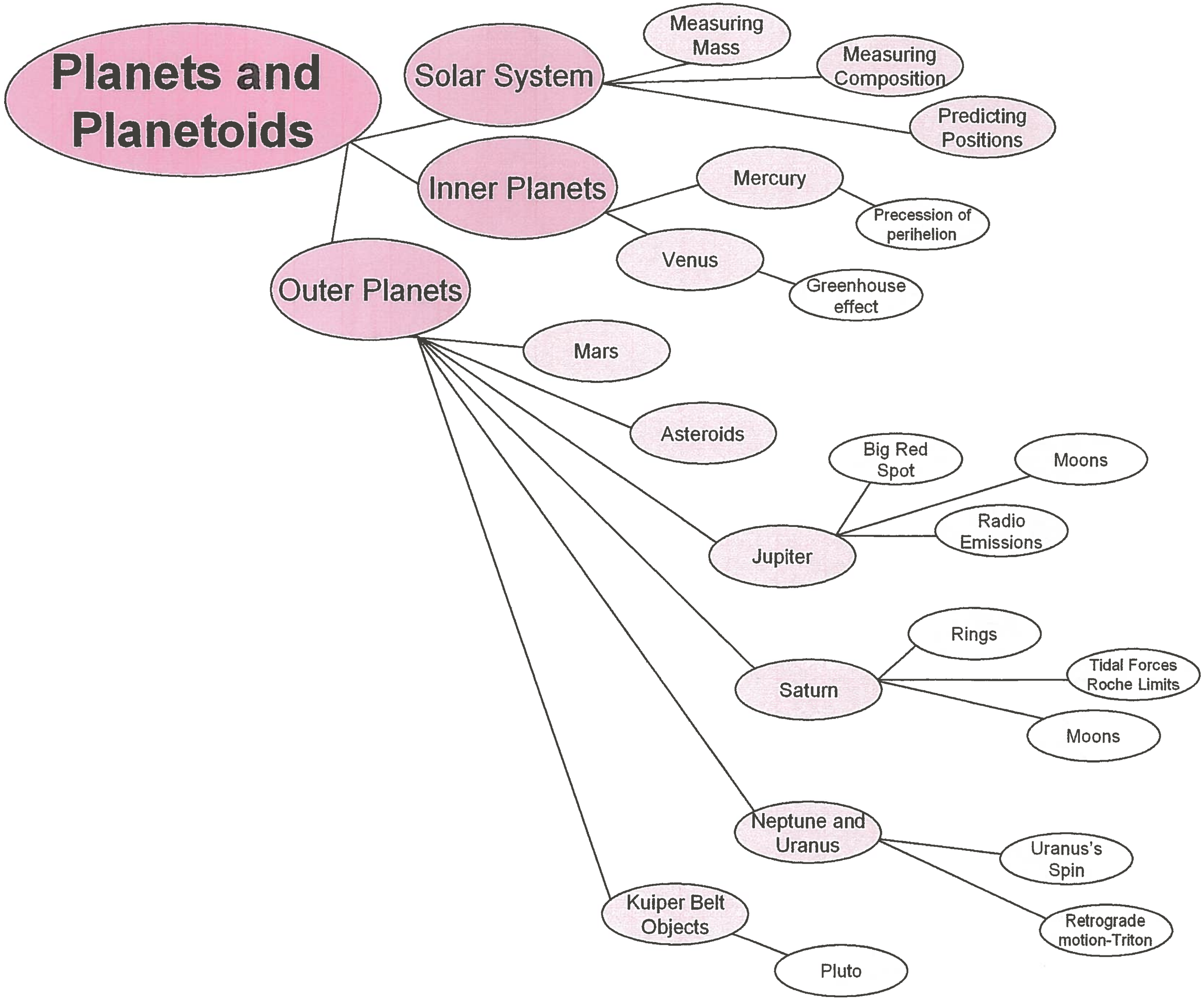
Refractor



- The analysis of the ways in which matter emits and absorbs radiation is called spectroscopy. Spectral lines are indicators of chemical compositions. Every chemical composition has its own individual light signature, like a thumbprint. The composition of an object is determined by matching its spectral lines with the laboratory spectra of known atoms and molecules (1).

Online Sources:
Google Earth (www.earth.google.com)
Earth and Moon viewer (http://www.fourmilab.ch/earthview/)
Enchanted Learning (http://www.enchantedlearning.com/subjects/astronomy/)

Activity:
Watch the Moon over a period of hours on a night when you can see one or more bright stars near it. Estimate how many Moon diameters the Moon moves per hour. Knowing the Moon is about 0.5 degrees in diameter, how may degrees per hour does it move? What is your estimate of its orbital period (1)?



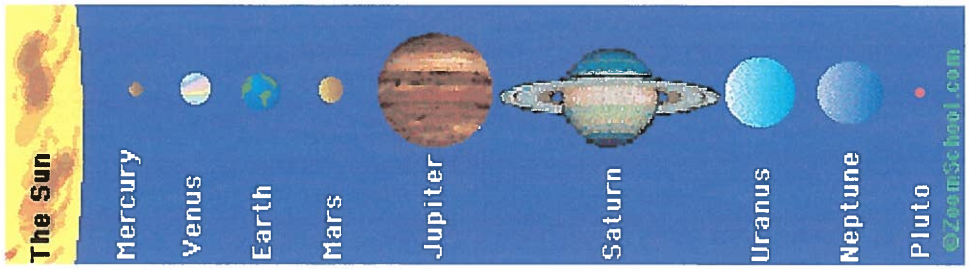
Planets and Planetoids
Solar System
Measuring Mass
Measuring Composition
Predicting Positions
Inner Planets
Mercury
Precession of perihelion
Venus
Greenhouse effect
Outer Planets
Mars
Asteroids
Jupiter
Big Red Spot
Moons
Radio Emissions
Saturn
Rings
Tidal Forces Roche Limits
Moons
Neptune and Uranus
Uranus's Spin
Retrograde motion-Triton
Kuiper Belt Objects
Pluto

II. Planets and Planetoids

The Solar System

- The Solar System contains 1 star, 9 planets, ~63 moons orbiting those planets, 6 asteroids larger than 300 km in diameter, more than 4000 smaller asteroids, myriad comets, and countless meteoroids.

The Relative Sizes of the Planets and the Sun



Properties of some Solar System Objects (1):

Object	Orbit Semi-Major Axis (AU)	Orbit Period (Earth Years)	Mass (Earth masses)	Radius (Earth radii)	Number of known Moons	Average Density (kg/m^3)
Mercury	0.39	0.24	0.055	0.38	0	5400
Venus	0.72	0.62	0.81	0.95	0	5200
Earth	1.0	1.0	1.0	1.0	1	5500
Moon	1.0	---	0.012	0.27	---	3300
Mars	1.5	1.9	0.11	0.53	2	3900
Jupiter	5.2	11.9	318	11.2	16	1300
Saturn	9.5	29.5	95	9.5	20	700
Uranus	19.2	84	15	4.0	15	1200
Neptune	30.1	165	17	3.9	8	1700
Pluto	39.5	249	0.003	0.2	1	2300
Sun	---	---	332,000	109	---	1400

The Inner Planets

- Mercury orbits the Sun once every 87.97 days, at a mean distance of 58 million km. The theory of relativity predicts that, as it orbits the Sun, Mercury does not exactly retrace the same path each time, but rather swings around over time. We say therefore that the perihelion, the point on its orbit when Mercury is closest to the Sun, advances (3).
- Venus is the second planet out from the Sun, which it orbits every 225 days as a mean distance of 108 million km. It is the planet which can come closest to Earth and it is the brightest object in the sky, excepting the Sun and the Moon. It is so bright because it is covered with clouds, which reflect most of the sunlight. The principle constituent of the Venusian atmosphere is carbon dioxide. The atmosphere extends to a height of around 250 km above the Venusian surface, although 90 % of it is concentrated within 28 km of the surface. The result is a surface pressure of 90 times that on Earth. The temperature is over 400 degrees Celsius. This extreme temperature is due to a runaway greenhouse effect: the heat received from the Sun at the surface is trapped by carbon dioxide and is unable to escape back into space (3).

The Outer Planets

- Mars is the outermost of the terrestrial planets, orbiting the Sun once every 687 days at a mean distance of 228 million km (3).

- Astronomers have so far catalogues over 4000 asteroids with well-determined orbits. The vast majority are found in a region of the solar system known as the asteroid belt, roughly midway between Mars and Jupiter (1).
- Jupiter is the largest of the planets and the first of the gaseous planets. The mass of Jupiter is about 70% of the mass of the solar system, excluding the Sun. Jupiter is one of the most interesting planets to view telescopically, namely that it sports numerous belts and the Great Red Spot. The belts are regions of gases where cooler material is descending. The lighter bands, or zones, are regions where gases from within the planet are rising the surface to cool. The Great Red Spot is a huge feature on the surface of the planet spanning 25,000 miles that acts much like a hurricane, except that it is at least 300 years old. Jupiter has a total of 16 satellites, the four largest of which were discovered by Galileo in 1610, namely, Io, Europa, Callisto, and Ganymede. Io has a diameter of 3,630 km and orbits Jupiter once every 1.77 days at a mean distance of 422,600 km. It has the highest density of the Galilean satellites and is subject to frequent volcanic activity. Europa is the smallest of the Galilean satellites, with a diameter of 3,140 km. It is covered be a layer of water ice thought to be around 100 km thick (3).

Composite Photo of Jupiter with 4 moons, Io, Ganymede, Callisto, and Europa

- Saturn is known as the jewel of the solar system because of its rings. The rings are composed of countless tiny particles that range in size from several meters down to a few microns (3). The Roche limit is the closest distance an object can come to another object without being pulled apart by tidal forces. If a planet and a moon have identical densities, then the Roche limit is 2.446 times the radius of the planet. A large moon orbiting inside the Roche limit will be destroyed. The Earth's Roche limit is 18,470 km. If our Moon ever ventured within this Roche limit, it would be pulled apart by tidal forces and the Earth would have rings. The four gaseous outer planets do have their rings systems inside of their respective Roche limit. The Roche limits for the gaseous planets are: Jupiter - 175,000 km, Saturn - 147,000 km, Uranus - 62,000 km, and Neptune - 59,000 km (5). Saturn has 21 known satellites, the largest of which is Titon. Titon has an atmosphere, in which nitrogen is the most abundant gas. The atmosphere is so thick that the satellite mission, Voyager, was unable to see its surface. The conditions on Titan are similar to what conditions may have been like on pre-life Earth (3).

- Uranus posesses an unusual axial tilt, amounting to under 98 degrees, putting its poles very close to the plane of its orbit around the Sun. The pole point alternately toward the Sun: northern summer lasts for 42 years, with the Sun above the horizon all the time (3).
- Neptune can almost be classified as a twin of Uranus. It is slightly smaller, with a diameter of just under 48,600 km. Triton is the larger of Neptune's eight known satellites (3). Triton is the only large satellite in the solar system to circle a planet in a retrograde direction. It also has a density of about 2.066 grams per cubic centimeter (the density of water is 1.0 gram per cubic centimeter). This means Triton contains more rock in its interior than the icy satellites of Saturn and Uranus do. The relatively high density and the retrograde orbit has led some scientists to suggest that Triton may have been captured by Neptune as it traveled through space several billion years ago. If that is the case, tidal heating could have melted Triton in its originally eccentric orbit, and the satellite might even have been liquid for as long as one billion years after its capture by Neptune (6).
- Pluto is the smallest planet. There is also much debate on whether or not Pluto should be classified as a planet. Many claim that it is a Kuiper Belt Object. The International Astronomical Union (IAU) is the reigning organization with the official say on what the definition of the objects in the solar system are. However, the IAU has not made any move to change Pluto's status as a planet. Many astronomers have since been content to let the IAU and the public call Pluto a planet, while most of them think of it as a Kuiper Belt Object (7).

Online Sources and Activites:
Enchanted Learning (http://www.enchantedlearning.com/subjects/astronomy/)

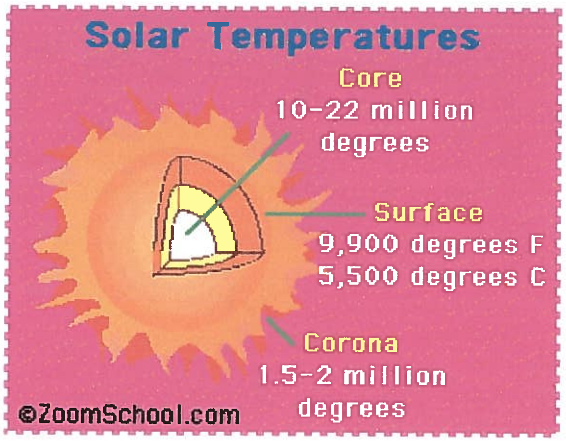
Activity:
Saturn moves more slowly among the stars than any other visible planet. It crosses a constellation boundary only once every few years. Look in an almanac to see where the planet is now, and find Saturn in the sky. What constellation is it in? Can you explain why it moves so slowly, in contrast to Mars or Jupiter? How many stars in the night sky are brighter than Saturn at its brightest? What do you notice about the difference in appearance between Saturn and a star of about equal brightness (1)?

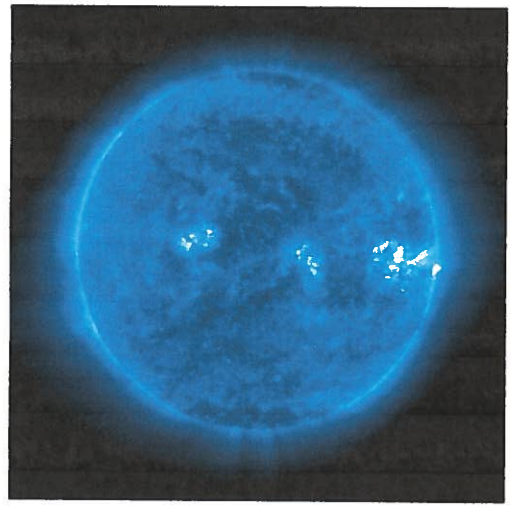

Stars
Star Clusters
Death of Stars
Energy Mechanisms
Sun
Classification Of Stars
OBAFGK MRNS
Apparent/ Visual
Gravitational
Globular Clusters
Open Clusters
Black Holes
Pulsars
White Dwarfs
Fusion
Gravitational Heating
Size
Energy Output
Age
Star Type
History

III. Stars

The Sun

➢ The Sun contains about 98 % of the mass in the solar system. The Sun is classified as a yellow dwarf and falls in the middle of the range of stars in the Galaxy. The Sun is about 4.5 billion years old and is in the middle of its lifespan. The temperature of the visible surface, photosphere, of the Sun is around 6,000 degrees Celsius, and this is where the heat and light of the Sun is emitted. The energy that leaves the Sun is created in the core by nuclear reactions, where the pressure is so high that molecules and atoms are fused together (3).





Formation of Stars

➢ Stars are born inside nebulae, large clouds of gas and dust, through the process of gravitational collapse. The first stage in the formation of a star cluster from a nebula is fragmentation, in which clumps of matter form from denser portions of the cloud. These denser regions are the result of the stability of the nebula being disrupted. The clumps continue to collapse, as their densities and internal temperatures increase. Internal pressure increases until it balances gravity and fragmentation stops. The nebula now contains a number of hot and relatively dense stable regions, called protostars. The mass of the protostar dictates the next stage of development. In protostars with masses comparable to that of our Sun, nuclear reactions are triggered off at the core when its temperature reached a value of 15 million degrees Celsius. During these reactions, four hydrogen atoms are combined to form one atom of helium. However, because the resulting helium atom is lighter than the original four atoms of hydrogen, a little mass is left over from the reaction. This is converted into energy that gradually makes its way to the surface of the star and escapes as light and heat. The resulting outward-acting radiation pressure prevents any further gravitational collapse and the star becomes stable (3).

Death of Stars

➢ White Dwarfs: As a star (more that 1.4 solar mass) is dying, nuclear reactions will slow and finally cease, and gravity becomes the last source of energy left. A star that is not too massive will collapse until it becomes and incredibly dense white dwarf. The compression of the star is so intense that the star is crushed to immense densities. Gravitational energy released during the collapse is converted to heat and the white dwarf will continue to shine. However, this energy eventually radiates into space, leaving a dead star called a black dwarf (3).

➢ Neutron Stars and Pulsars: Stars between 1.4 and 3 solar masses collapse beyond the white dwarf stage. The gravitational pull was so great that the protons and electrons are smashed together to form neutrons, giving rise to a neutron star. Neutron stars give off periodic bursts of radio emission. Astronomers originally thought these bursts came from a pulsating star, or pulsar. Later the connection was made between neutron stars and pulsars (3).

- Black Holes: Stars that have more than 8 solar masses collapse to a sphere of increasing density and decreasing size. As the density grows, the escape velocity becomes steeper, until it eventually exceeds the speed of light forming a great suction in space (3).

Star Clusters

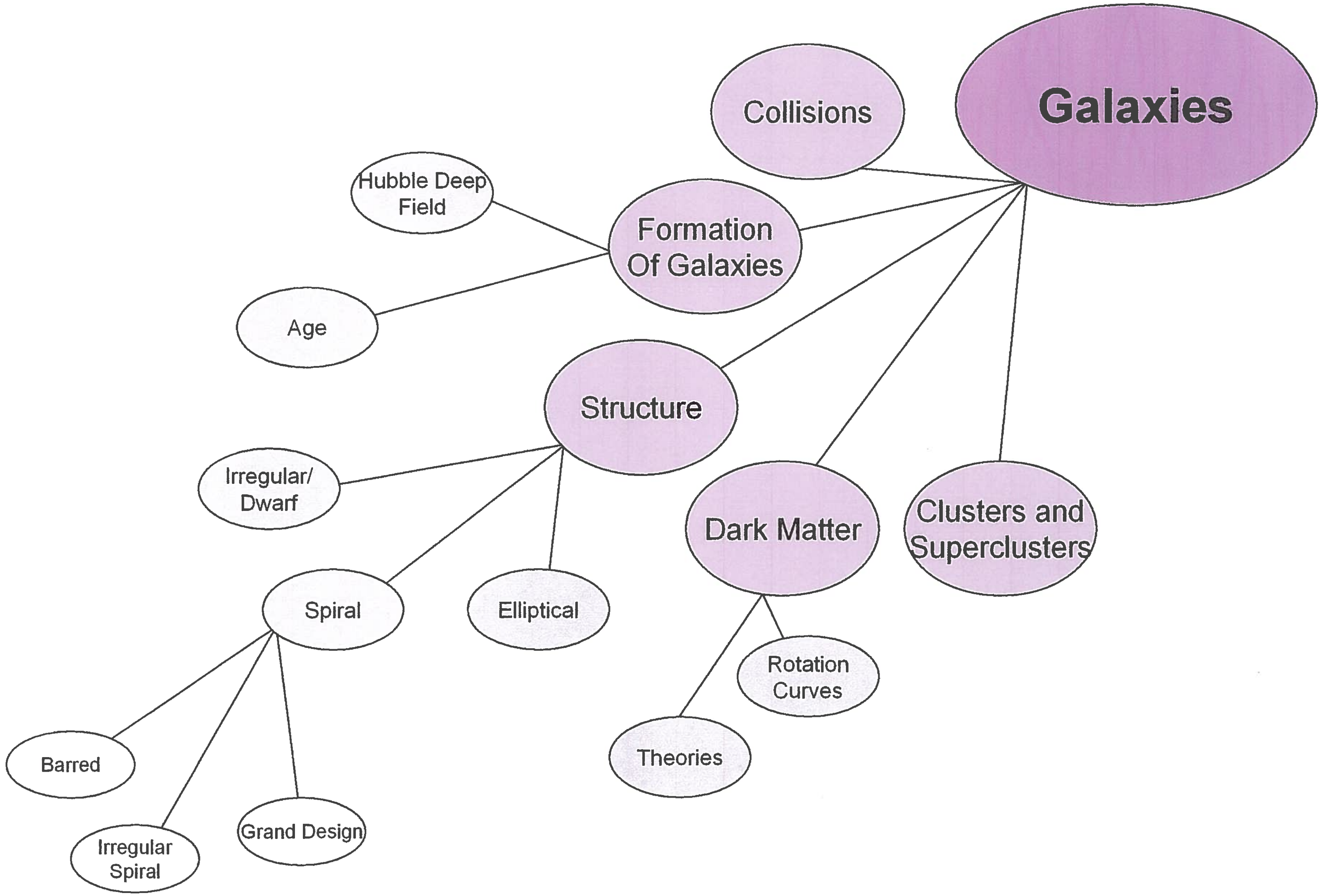
- There are two main types of star clusters: open and globular. Open clusters are found within the spiral arms of our Galaxy and as such are referred to as galactic clusters. They are irregular in shape with diameters of no more than a few tens of light years. They contain anything from around a dozen to many hundreds of stars. Open clusters are generally made up of young, hot stars, and they often contain traces of the original nebulosity from which the stars are formed. Globular clusters differ greatly from open clusters not only in shape and size but in distribution. Globular clusters are spherical collections of stars that are located in the galactic halo, a spherical volume of space surrounding the Galaxy. The stars are relatively tightly packed leading to a gravitational attraction strong enough to allow the cluster to retain its shape (3).

Open Star Cluster

Globular Star Cluster

Online Sources and Activites:
NASA GSFC SOHO Images (http://umbra.nascom.nasa.gov/)
Enchanted Learning (http://www.enchantedlearning.com/subjects/astronomy/)

Activity:
The Constellation Orion the Hunter is prominent in the evening sky of winter. Its most noticeable feature is a short, diagonal row of three medium-bright stars: the famous Belt of Orion. The line of stars beginning at the middle star of the Belt and extending toward the south represents Orion's sword. Toward the bottom of the sward is the sky's most famous emission nebula, M42, the Orion Nebula. Observe it with your eye, with binoculars, and with a telescope. What is its color? How can you account for this color? With the telescope, try to find the Trapezium, the grouping of four stars in the center of M42. These are hot, young stars; their energy causes the Orion Nebula to glow (1).


Galaxies
Collisions
Formation Of Galaxies
Hubble Deep Field
Age
Structure
Irregular/ Dwarf
Spiral
Elliptical
Barred
Irregular Spiral
Grand Design
Dark Matter
Rotation Curves
Theories
Clusters and Superclusters

IV. Galaxies

Galactic Structure

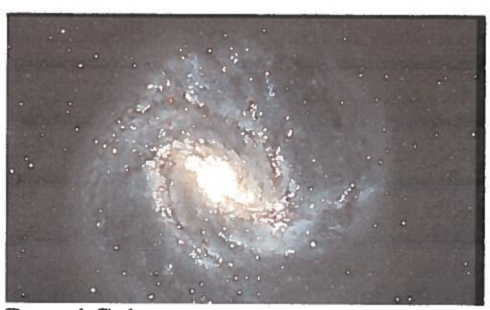
- Spiral galaxies have spiral arms radiating from a central bulge. Barred spirals have arms that emanate from the ends of a bar that extends through the center of the system. Elliptical galaxies have no spiral pattern and are uniform in appearance. Ellipticals are the most numerous galaxies, generally made up of old, cool, and massive stars with little or no interstellar material. These three classes of galaxies are further subdivided: spirals and barred spirals can have either tightly wound spiral arms, together with small or large central bulges, or more loosely wound arms with smaller central bulges. Another two classes of galaxy are recognized: irregular galaxies are loose collections of stars with no well defined shape, while lenticular galaxies resemble the flattened center of a spiral galaxy without its spiral arms (3).


Elliptical Galaxy


Spiral Galaxy


Lenticular Galaxy


Irregular Galaxy


Barred Galaxy

Dark Matter

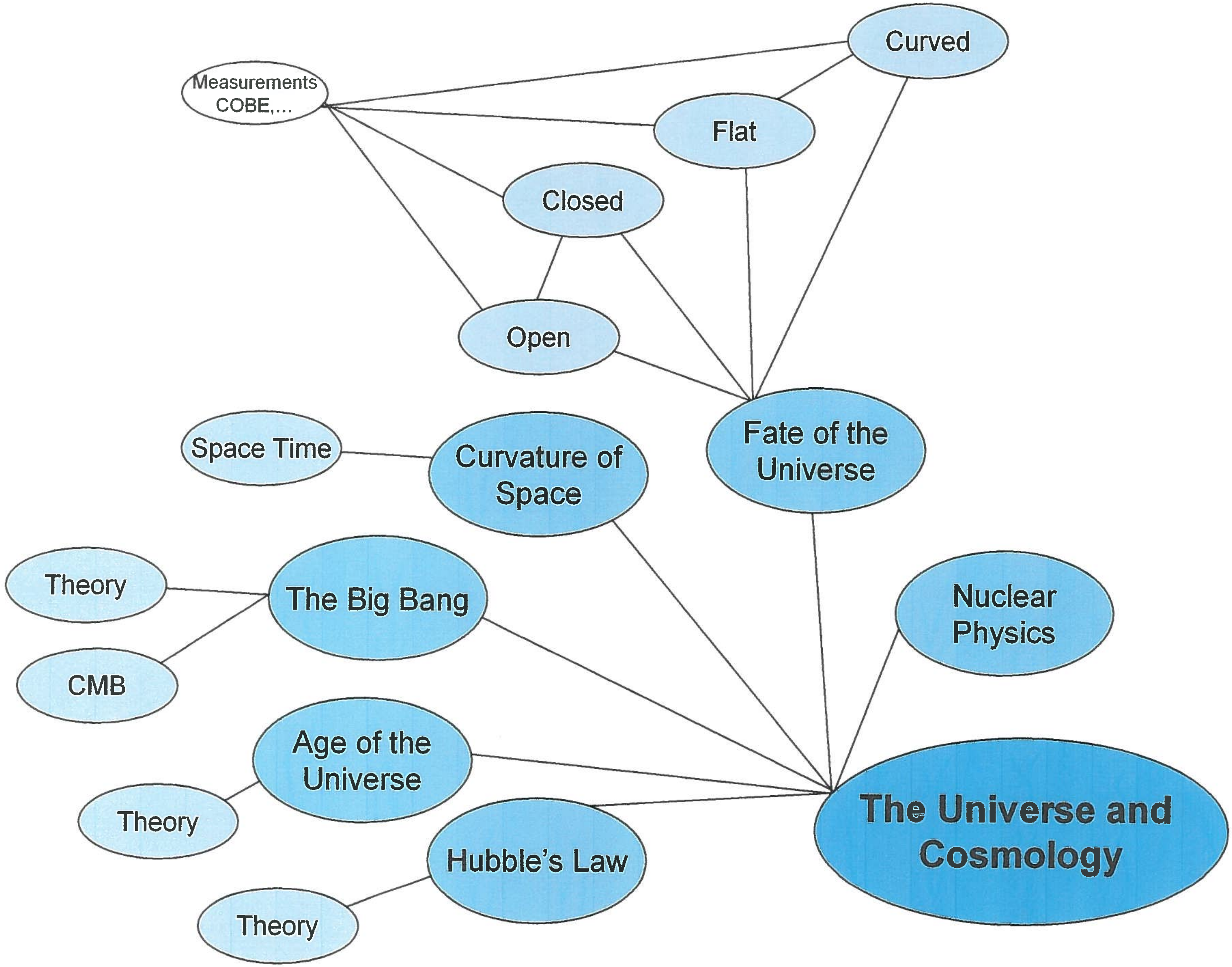
- Most of the matter in the Universe is invisible and is known as dark matter. Dark matter has been so far undetected by all wavelengths, from radio to gamma rays. The only way astronomers know dark matter is there is by its gravitational pull (1).
- The galactic rotation curve plots the orbital speed of matter in the disk against distance from the galactic center. By applying Newton's laws of motion, astronomers can determine the mass of the Galaxy. The Galactic mass continues to increase beyond the radius defined by the globular clusters and the spiral structure we observe. The rotation curves of our own and other galaxies show that any, if not all, galaxies have an invisible dark halo containing far more mass than the visible portion of the galaxies. The dark matter making up these dark halos is of unknown composition. Leading candidates include low-mass stars and exotic subatomic particles (1).

Clusters of Galaxies

- Galaxy clusters can contain hundreds to thousands of individual members, while superclusters contain many groups of galaxies (1).

Neat Online Sources:
Enchanted Learning (http://www.enchantedlearning.com/subjects/astronomy/)
Cambridge Cosmology: Galaxies (http://www.damtp.cam.ac.uk/user/gr/public/gal_home.html)

Activity:
Look for the Virgo Cluster. An 8-inch telescope is a perfect size for this project, although a smaller telescope will work. The constellation Virgo is visible from the United States during much of the fall, winter, and spring. To locate the center of the cluster, first find the constellation Leo. The eastern part of Leo is composed of a distinct triangle of stars – Denebola, Chort, and Zosma. Move your eye eastward from Chort to Denebola and then continue along that same line until you have moved a distance equal to the distance between Chort and Denebola. You are now looking at the approximate middle of the Virgo Cluster. Look for the following Messier objects that make up some of the brightest galaxies in the cluster. M49, 58, 59, 60, 84, 86, 87 (which is a giant elliptical thought to have a massive black hole at its center), 89, and 90. Examine each galaxy for unusual features; some have very bright nuclei (1).


Measurements
COBE,...
Curved
Flat
Closed
Open
Fate of the Universe
Space Time
Curvature of Space
Theory
The Big Bang
CMB
Nuclear Physics
Age of the Universe
Theory
Hubble's Law
Theory
The Universe and Cosmology

V. The Universe and Cosmology

- Hubble's Law: The rate at which a galaxy recedes is directly proportional to its distance from us (1).
- Hubble's Law describes all the galaxies in the universe rushing away from us.

Recession velocity = Ho * distance

Where Hubble's constant, Ho, is 75 km/s/Mpc. Assuming that all the galaxy's velocities have remained constant in time, one can calculate how long it has taken for any given galaxy to reach its present displacement. Using Hubble's Law:

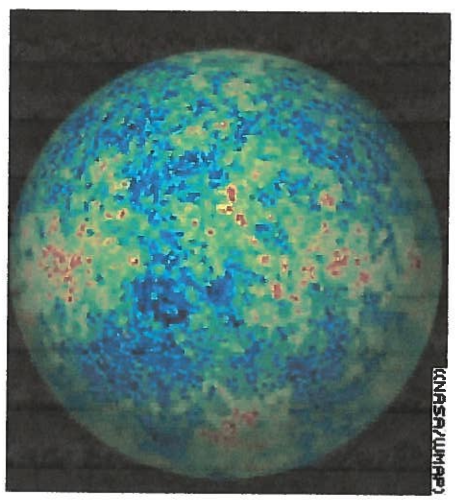
time = distance/velocity

time = distance/(Ho * distance)

time = 1/Ho

This time turns out to be about 13 billion years. This implies that at one point, 13 billion years ago, all the galaxies in the universe lay right on top of one another, or even condensed into a single point. Then the universe began when that point exploded, leading to the present locations and velocities of present day galaxies. The explosion is known as the Big Bang (1).

- Arno Penzias and Robert Wilson discovered a faint constant background noise while studying the Milky Way's emission at radio wavelengths. Known now as the cosmic microwave background, this background noise is thought to be the radiation remnants of the creation of the universe (1).



- If the universe emerged from the Big Bang with a density above the critical value, then it contains enough matter to halt its own expansion. The recession of the galaxies will eventually stop and the universe will start to contract. The universe will recollapse to a point, requiring just as much time to fall back as it took to reach its maximum size. The entire universe will grow progressively denser and hotter as the end of the contraction is neared. The universe will shrink toward as superdense, superhot singularity, much like the one from which it originated. With both density and temperature increasing as the contraction nears completion, the pressure might somehow be sufficient to overcome gravity, pushing the universe back out into another cycle of expansion. The universe may undergo a series of expansions with subsequent contractions (1).

- If the universe emerged from the Big Bang with a density below the critical value. In this case, the density will always be too small for gravity to cause it to recontract. This low density universe will expand forever (1).
- If the universe emerged from the Big Bang with a density equal to the critical value, it will contain just enough matter to eventually halt the expansion (1).

Neat Online Sources:
Enchanted Learning (http://www.enchantedlearning.com/subjects/astronomy/)
Universe Today (http://www.universetoday.com/)
Cosmology 101 (http://map.gsfc.nasa.gov/m_uni.html)

Activity:
Make a model of a two-dimensional universe and examine Hubble's law on it. Find a balloon that will blow up into a nice large sphere. Blow it up about halfway and mark dots all over its surface; the dots represent galaxies. Arbitrarily choose one dot as your home galaxy. Using a cloth measuring tape, measure the distances from your home galaxy to various other galaxies, numbering the dots so you do not confuse them later. Now blow the balloon up to full size and measure the distances again. Calculate the change in the distances for each galaxy; this is a measure of their speed (=change in position/change in time; the time is the same for each and is arbitrary). Plot their speeds against their new distances. Do you get a straight-line correlation? Try this again using a different dot for your home galaxy. Do you still get a plot that obeys Hubble's law? Does it matter which dot you choose as home? (1)

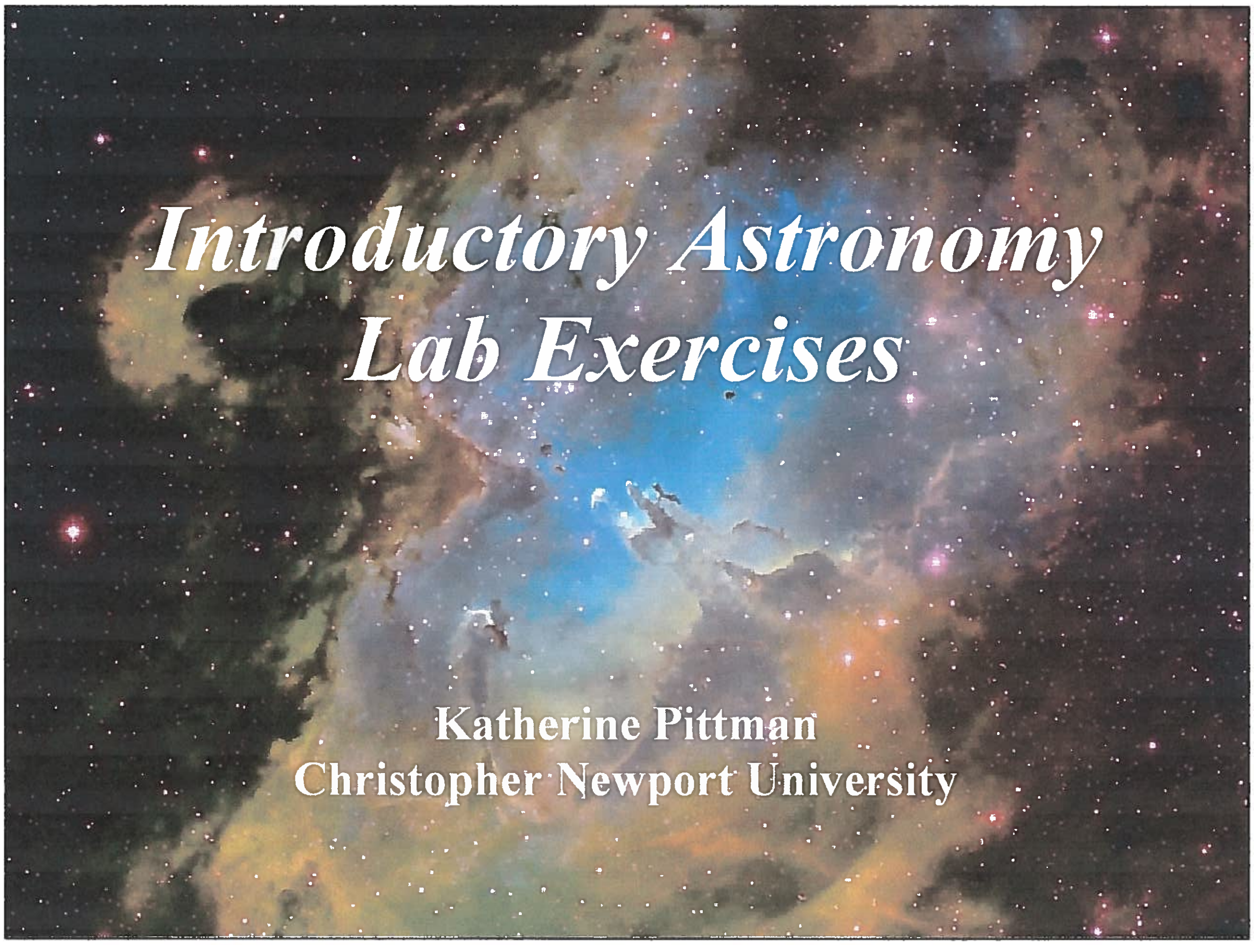
Sources:

1. Chaisson, Eric and Steve McMillan. Astronomy. Second Edition. Upper Saddle River, New Jersey: Prentice Hall, 1998, Chapter 5: Earth and Its Moon.
2. Arnett, Bill. 11 Feb, 2005 <http://www.nineplanets.org/earth.html>.
3. Jones, Brian. The Practical Astronomer. Simon and Schuster, Fireside, 1990.
4. Enchanted Learning. 1999-2005. <http://www.enchantedlearning.com/subjects/astronomy/moon/Tides.shtml>.
5. Baalke, Ron. <http://www2.jpl.nasa.gov/saturn/faq.html#roche>.
6. Hamilton, Calvin J. 1997-2001, <http://www.solarviews.com/eng/triton.htm>.
7. Britt, Robert Roy. 17 March, 2004. Pluto's Planet Status. <http://www.space.com/scienceastronomy/sedna_pluto_040317.html>.

Introductory Astronomy Lab Exercises

Katherine Pittman, Applied Physics, PCSE 499
Christopher Newport University
May 1, 2006

Mentor: Dr. J. Hardie
Advisor: Dr. R. Caton



The Eagle Nebula (Astronomy Picture of the Day, February 26, 2006)

Contents

Lab Exercise 1

Est. Time: 2 hrs

Introduction to the Night Sky

Observing the Night Sky

I. Observation

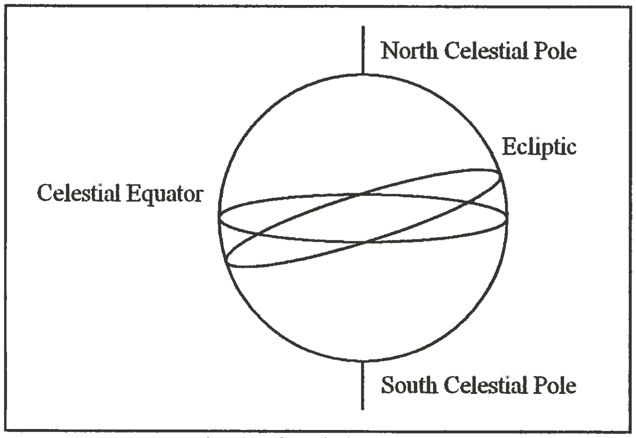
Whether through telescopes, the naked eye, or simulation programs, most of an astronomer's time is spent observing the sky and its changes over time. Astronomy is a vast subject that encompasses everything from the Earth to the farthest galaxy. Astronomy holds many attractions, but the greatest one is that it is new, and at the same time, old.

As early as 3000 B.C.E. the Babylonians were actively studying the stars and planets. They identified constellations and calculated a calendar based on astronomical events. The Chinese were the next astronomers in the timeline by conceptualizing the 365-day year before 2500 B.C.E., based on observations of the sun across the background stars. The ancient Egyptians used astronomy to guide their dead into the afterlife. Hieroglyphics on pyramid walls show prayers making reference to the stars and the pharaohs' ascents into them. Between 2800 B.C.E. and 1550 B.C.E., the people of Britain built Stonehenge as an astronomical observatory and a calendar. The Mayans created a very detailed calendar as well by using celestial observation around 700 C.E.

The Greeks, however, left the most detailed account of their celestial interests. As early as 500 B.C.E., the Sun was identified to be a large, red-hot body, that the Moon was much like Earth, with mountains and ravines, and that solar eclipses were caused by the passage of the Moon between the Sun and Earth. We also owe, indirectly, our knowledge of the structure of the solar system to the Greeks (See Lab Exercise 3).

The celestial observations made by the ancients were based on the idea that all of the stars were fixed on a bowl that surrounded the Earth. Today, we know that this is not true; however, if we apply the concept, we can use the idea to orientate ourselves to the stars easily. The celestial sphere is an imaginary sphere that we picture surrounding Earth upon which the stars are fixed.

We can orient our gaze into the heavens by thinking of the point of sky directly above Earth's North Pole as the north celestial pole, and the point below the South Pole as the south celestial pole. The celestial equator lies midway between these points.



The Celestial Sphere

Astronomers have assigned the same system of latitude and longitude to the celestial sphere that is in use on the surface of the Earth. The lines of latitude run parallel to the celestial equator. Declination corresponds to latitude and measures the angular distance above or below the celestial equator. Declination is expressed in degrees + (above) or – (below) the celestial equator. For example, the constellation Orion is at a declination of $+5^{\circ}$.

The lines of longitude run vertically from pole to pole. On the celestial sphere, right ascension is similar to longitude, and measures the angular distance east or west in hours, minutes, and seconds, increasing from west to east, starting at zero. The zero point is taken to be the position of the Sun in the sky at the vernal equinox. Earth rotates once every 24 (approximately) hours, which means that stars will return to their staring positions in the sky at the same time (approximately) every day. After 24 hours, Earth has rotated through 360 degrees, so that each hour of right ascension corresponds to 15 degrees on the sky.

Hopefully, you're asking yourself about the relationship of longitude to right ascension and why astronomers don't just imaging right ascension as a projection of Earthly longitude. There are good reasons why astronomers don't mix the two. The stars in the winter sky are different than the stars in the summer sky. For example, Orion is visible in the winter, but in the summer, it is trapped in the bright glare of the Sun. The stars above are changing locations, but are you? Does New York, NY change its position? Because the stars are changing, they cannot be fixed to the coordinates of the surface of the Earth.

Why do you think this difference happens?

____

____

____

Celestial coordinates are valuable to learn because they give an absolute system of coordinates to astronomers. Using this system, any two astronomers, anywhere in the world, can find the same star with the same coordinates. However, celestial coordinates can be confusing to an amateur sky watcher.

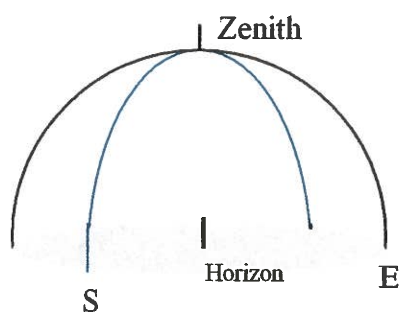
Using the altazimuth coordinate system is an easier way to measure the location of an object in the sky as observed from your location at a particular time that includes two angles: azimuth and altitude. Astronomers use angles to divide the horizon by imagining themselves located in the center of a circle that is flat on the ground. A circle an be divided into 360 degrees, and a degree can be subdivided into 60 minutes, and a minute sliced into 60 seconds. The astronomer decides which direction is 0 degrees, usually due north. Imagine another circle that starts at the decided horizontal direction and bisects the surrounding circle. The topmost point, at 180 degrees, is the zenith. An object's altitude is its angular distance above the horizon, and its compass direction, azimuth, is measured in degrees increasing clockwise from due north (east is at 90 degrees, south is at 180 degrees, and west is at 270 degrees).

What is the downside of the altazimuth coordinate system?

____

____

____



II. Objective

Students gain an understanding of celestial and altazimuth coordinates through experiment and observation.

III. Learning Goals

*Learn how to navigate the night sky by using celestial and altazimuth coordinates, star charts and the naked eye
*Identify sources of astronomical information with respect to locating celestial objects
*Identify major constellations and stars

IV. Equipment

Your eyes	Binoculars	Internet Access
Pencil and Paper	Flashlight (optional)	
Star Chart	Small Telescope (optional)	

V. Procedure

This section of the lab can be completed with planetarium software or by outdoor observation. Some parts can even be done with Google Earth, by zooming out and locating constellations (hint: major constellation stars are brighter than others in this program). All of the objects listed below can be found and observed with binoculars and a steady hand.

1. Find the below astronomical objects. Use celestial coordinates, altazimuth coordinates, a star chart, and the naked eye. You must use each of these at least twice. Only use one method per object. You will need to use some astronomical resources (internet, textbook, almanac, planetarium software, etc…) to find coordinates or locations of the below objects. Plan your time wisely if you are observing outdoors, check the time vs. position of the objects before you go out.

Bright Stars:

Betelgeuse	Rigel	Arcturus
Sirius	Polaris	Deneb

Constellations:

Orion	Ursa Major	Cygnus
Cassiopeia	Ursa Minor	Taurus

Other Neat Objects:

Pleiades (Open Cluster)	**Jupiter
**Mizar and Alcor (Binary Stars)	**Saturn

*At different times of the year, some of these objects may be more easily spotted than others. Check with your professor to see if there are any changes.
**Draw a sketch of what you see to turn in to your professor.

Questions:
Why are Polaris, Sirius, Betelgeuse, and Arcturus special?

____
____
____
____
____
____

Note the positions of the Polaris, Jupiter, and Betelgeuse at the beginning of the lab. Are there changes to their positions at the end (If using a planetarium simulator, fast forward the time step option and see what happens.)? How are the objects moving in the celestial sphere? Write your observations below.

____
____
____
____
____
____
____

VI. Useful Definitions

Altitude______________	The angular distance of a celestial object above or below the observer's horizon. Altitude is 0° at the horizon and 90° at the zenith.
Angular separation______	The apparent distance between two objects, such as two stars, expressed in degrees, minutes, or seconds of arc.
Azimuth______________	The direction to a celestial object measured in degrees, clockwise from north around the observer's horizon. Azimuth is 0° for an object due north, 90° due east, 180° due south, and 270° due west.
Celestial equator_______	The great circle on the celestial sphere that lies directly above the equator of the Earth. Any point on the celestial equator is equidistant from the north and couth celestial poles.
Celestial sphere________	An imaginary sphere of indefinite size, used as a background for assigning positional coordinates to celestial objects. The sphere may be centered on the Earth, the observer, or any other point which acts as the origin of the chosen system of coordinates.
Declination____________	A coordinate on the celestial sphere, the equivalent of latitude on Earth. Declination is measured in degrees north or south of the celestial equator, from 0° at the celestial equator to +90° at the north celestial pole and -90° at the south celestial pole.
Ecliptic_______________	The apparent path of the Sun against the star background over the course of a year. The movement of the Sun along the ecliptic is actually a result of the Earth's movement in its orbit around the Sun. Therefore the ecliptic is actually the plane of the Earth's orbit projected on to the celestial sphere. Because of the Earth's axial tilt, the ecliptic is inclined at about 23°.4 to the celestial equator.
Right ascension________	A coordinate on the celestial sphere, the equivalent of longitude on Earth. Right ascension is measured clockwise around the celestial equator, in hours, minutes, and seconds starting from 0h at the vernal equinox.
Zenith________________	The point on the celestial sphere directly above an observer.

Lab Exercise 2

Est. Time: 2 hrs

The Planets

I. The Planets

There are nine planets in our solar system orbiting around the Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. Most of these planets have at least one satellite in orbit around it. There are over 6,000 large asteroids, most found in the asteroid belt between Mars and Jupiter. In addition, the solar system contains a great many comets and billions of smaller, rock-size meteoroids.

The orbits of the planets lie nearly in the same plane, except for Mercury and Pluto, which deviate from this plane by 7° and 17°, respectively. The orbits of the planets are not evenly spaced, tending to double between adjacent orbits moving away from the Sun.

Astronomers think of the planets as falling into two broad categories. The four planets closest to the Sun, Mercury, Venus, Earth, and Mars, are termed terrestrial planets. The next four, Jupiter, Saturn, Uranus, and Neptune, are considered jovian planets. Pluto's classification is still being debated among astronomers. Its size and composition suggest terrestrial classification, but it is located in the jovian region.

The terrestrial planets are so named because they all possess Earth-like qualities, such as close proximity to the Sun, relatively closely spaced orbits, relatively small masses, relatively small radii, and high density. Compared to the jovian planets, terrestrial planets rotate more slowly, possess weak magnetic fields, lack rings, and have few or now moons.

The jovian planets are further from the Sun and travel in widely spaced orbits. They are massive planets with low density, gaseous compositions, large radii, and no solid surface. They rotate faster, possess strong magnetic fields, have rings, and are orbited by many large moons, in comparison to the terrestrial planets.

Located in the asteroid belt, thousands of asteroids orbit. Asteroids are composed of stony as well as metallic materials (mostly iron) and are basically tiny planets without atmospheres. Theoretical studies show that no planet could have formed at the radius of the asteroid belt because it is dominated by the gravitational influence of Jupiter. The gravitational force caused the potential planet-forming material to behave erratically, making it to collide and break up instead of collecting to build a planet.

II. Objective

Students investigate the planets of the Solar System and become familiar with its features.

III. Learning Goals

*Distinguish features of the planets in the Solar System
*Observe the planets and record sightings

IV. Equipment

Telescope (recommended)	pencil
Sketchbook or paper	colored pencils (optional)

V. Procedure

1. Look at the diagram of Venus below (Figure 1). How does the planet's appearance change over time? How is this effect similar and different from the phases of the Moon?

____
____
____
____

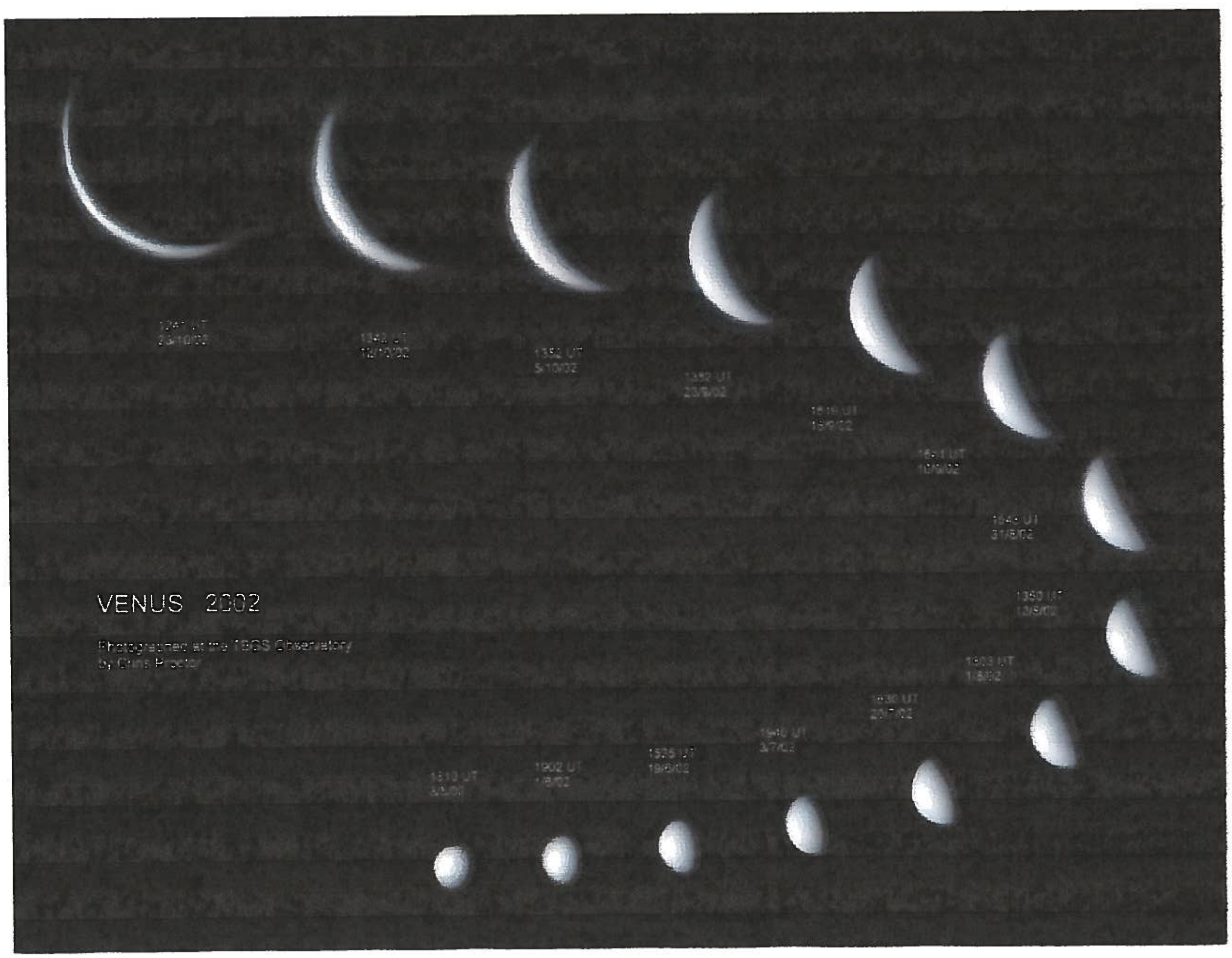


Figure 1

Would any other planets in the solar system appear this way to Earth? Which one(s) and why?

Look at the photographs of Mars found below (Figure 2). Is there evidence of seasonal change on Mars? What is it?

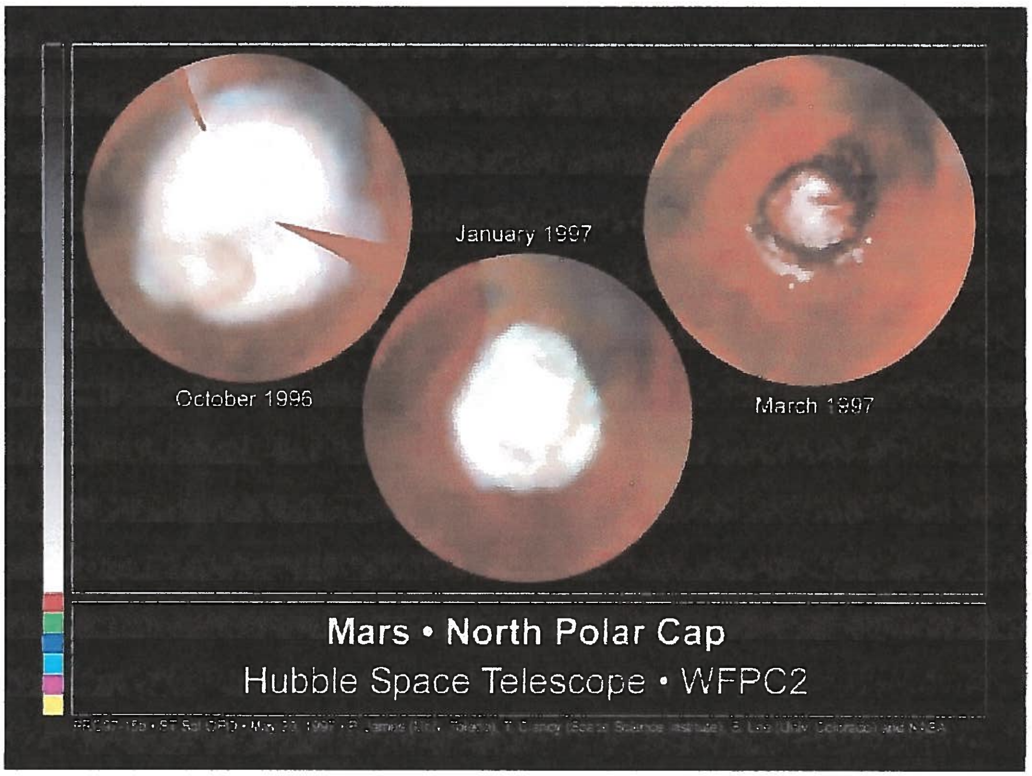


Figure 2

Take a close look at the photograph of Jupiter found below (Figure 3). Identify and describe at least three features of the upper layers if its atmosphere.

How could astronomers use features of Jupiter to determine its sidereal rotation period?

How are the bands (light and dark) running across the disk of Jupiter related to the motion of Jupiter?

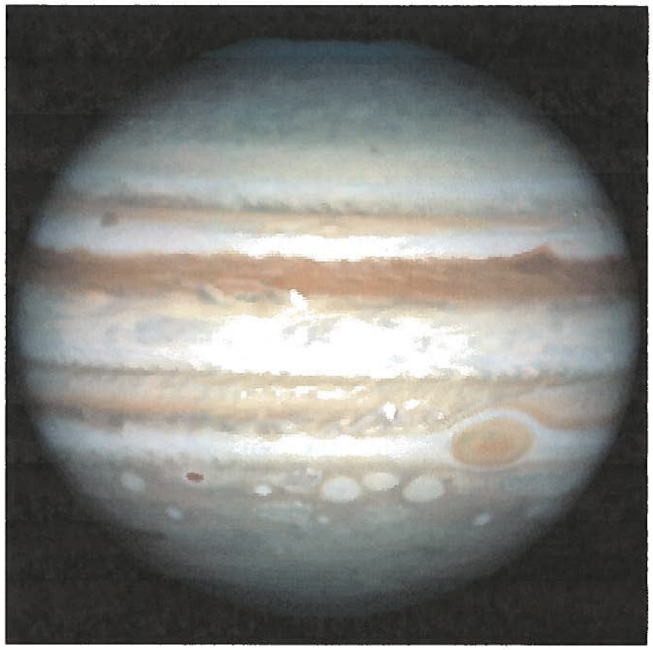


Figure 3

Look at the photograph (Figure 4) below of Jupiter's rings taken by Voyager 1 during its solar eclipse. It is thought that the rings were formed by meteoroid collisions with Jupiter's moons. From that information, can you conclude what the rings are made of? Why are they so hard to detect?

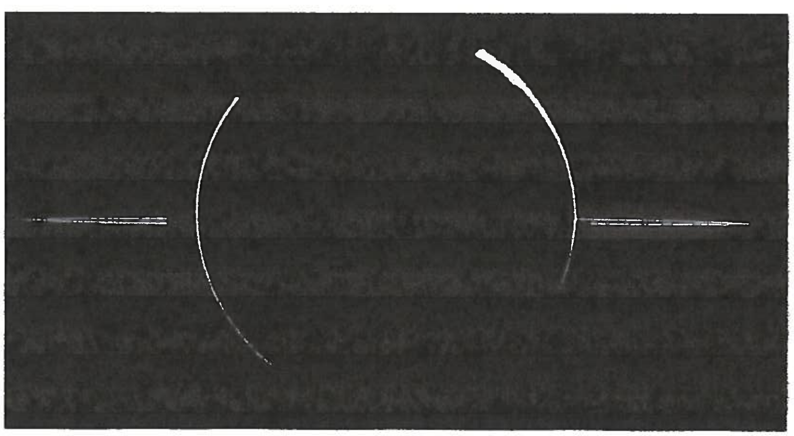


Figure 4

While examining the photographs of Saturn below (Figures 5 & 6), consider how its rings were formed and why they are so visible. What do you conclude?

____

____

____

____

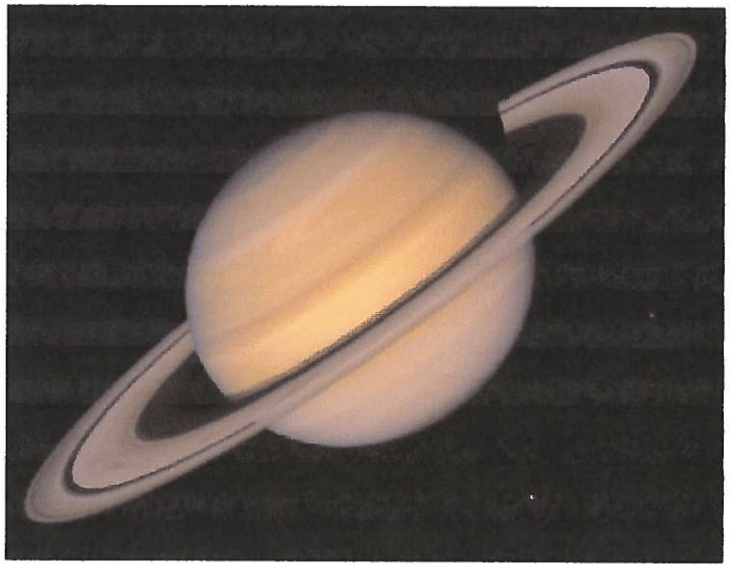


Figure 5

Between Saturn's outer two rings is a gap know as Cassmi's division (Figure 6). How do you think this gap was created? Hint: consider gravitational forces.

____

____

____

____

Figure 6

There are some astronomers who argue that Pluto is not a planet. What classifies a planet in your opinion? Do you think Pluto should be classified as a planet?

____

____

____

____

____

2. In this part of the exercise, you will be looking at planets and observing their more noticeable features. You may do this part of the lab with a simulation program; however, it is recommended that you observe outdoors for the full effect.

Look up online, or ask your professor, which planets are visible in the sky at this time of year and what times they will be available for optimal viewing. *Astronomy* magazine gives a monthly star chart that includes the positions of the planets. It may prove to be a useful tool.

What is available for observation during this lab?

____

____

Use your skills of observation and find the planets that are visible. Find as many as you can. Again, a small telescope is useful; however, you may use binoculars for this exercise. It is common practice for astronomers to take photographs or draw sketches of what they observe and make a visual journal. Draw sketches of what you see being as detailed as possible. Use colors to show planetary features and remember to mark the date and time on your sketch. Turn these in to your professor.

VI. Useful Definitions

Sidereal period____________The time taken for a planet or satellite to complete one orbit relative to the stars.

Semimajor axis____________Half the longest diameter of an ellipse. The semimajor axis is the average distance of an orbiting object from its primary.

Great Red Spot____________A large oval marking in Jupiter's clouds at about 22° south latitude. Its dimensions are about 26,000 km east-west and 14,000 km north-south.

Meteoroid________________A small particle from a comet or asteroid in orbit around the Sun.

Lab Exercise 3

Est. Time: 45 min

Kepler's Laws and Mass

I. Planetary Motion

Ancients could watch the stars glide predictably across the sky, but there were five (from what the ancients could see) heavenly bodies that they couldn't account for. These celestial objects behaved strangely and irregularly. Mercury, Venus, Mars, Jupiter, and Saturn looked like stars to the ancients, but, in contrast to the stars, the celestial objects wandered across the sky. The Greeks called these heavenly bodies *planetes*, or "wanderers." The planets appear to slow down and speed up, moving along the ecliptic. The planets also seem to drift eastward (prograde motion) or westward (retrograde motion) relative to the background stars.

The ancient Greeks conjured many theories designed to explain this strange behavior of the planets. Aristotle (384 – 322 BC) theorized a geocentric universe in that the Earth was in the center of the heavens, with the celestial bodies orbiting in circles around it. This theory, however, did not explain the movement of the planets. Ptolemy (2^{nd} century AD) developed the geocentric model into an impressively complex system of large circular orbits centered on Earth (deferents) and small circles whose centers traveled around the circumferences of the deferents (epicycles). This system was complicated enough to include about 80 deferents and epicycles and complex geometric arrangements. This system enabled Ptolemy to account for the movement of the planets; however, it was incredibly complicated.

Much later in history, Nicolaus Copernicus (1473 – 1543) suggested a heliostatic universe. He argued that all of the motion in the heavens is the result of Earth's daily rotation on its axis and yearly revolution around the Sun, which is motionless at the center of the planetary system. This theory accounted for planetary motion more accurately than before. However, it will not be until Johannes Kepler (1571 – 1630) suggests elliptical orbits as opposed to circular orbits that planetary motion is completely accounted for.

Kepler continued his theory into three basic laws of planetary motion.

1. Planets move in elliptical orbits with the Sun at one focus of the ellipse.
2. An imaginary line connecting the Sun to any planet will sweep out equal areas in equal amounts of time.
3. The square of a planet's orbital period, P, is proportional to the cube of its semi-major axis, a.

$$P^2 = a^3$$

Kepler did not explain, however, how the planets orbited the Sun without flying off into space, and why they traveled in ellipses. Isaac Newton (1642 – 1727) later explained this with Three Laws of Motion. Newton's First Law of Motion states that, unless acted upon by some external force, a body at rest remains at rest and a moving object continues to move forever in a straight line and at a constant speed. This property is known as inertia. The measure of an object's inertia is its mass. The more massive an object is, the greater its inertia. This law explains why the planets move in nearly circular orbits – essentially because an external force, gravity, acts on each planet. Without gravity, the planets would fly off into space in straight lines.

Newton's Second Law of Motion states that the acceleration of an object is directly proportional to the force applied to the object and inversely proportional to the mass of the object. For example, pull two objects with the same force, and the more massive object will accelerate more slowly than the less massive one. Newton's Third Law of Motion states that forces do not act in isolation. If object A exerts a force on object B, object B exerts and equal but opposite force on object A.

Newton found that for any two bodies orbiting each other, the constant of proportionality between P^2 and a^3 involved the masses of the two bodies.

$$P^2 = a^3 / (m_1 + m_2)$$

Where, m_1 is the mass of one body and m_2 is the mass of the other body. Whenever two bodies orbit each other, we can use Kepler's third law to determine the sum of the masses of the orbiting bodies. For example, we can calculate the mass of planets and their satellites as described in this lab.

*Note: P is measured in years [yrs], a is measured in astronomical units [AU], and m is measured in solar masses [$M_{\odot}$].

II. Objective

Students gain an understanding of planetary motion by investigating Kepler's Laws of Planetary Motion, and calculate masses by applying Newton's Laws of Motion.

III. Learning Goals

*Understand planetary motion through investigation of Kepler's and Newton's Laws
*Calculate mass of planets and their satellites

IV. Equipment

Calculator
Internet access

V. Procedure

1. Determine Jupiter's mass using its satellite, Europa. To do this, you will need to do some searching for measurements. These may be found in your text, or on the internet.
Find:
Europa's semimajor axis (km): ____

Convert the semimajor axis distance into AU: a = ______________________________
1 AU = 149,597,870 km

Orbital period of Europa (days): ____

Convert the orbital period into years: P = ____
*Note: 1 year = 365.25 days

Apply Kepler's third law to determine the sum of the masses of Jupiter and Europa.

$$(m_{Jupiter} + m_{Europa}) = a^3 / P^2$$

$(m_{Jupiter} + m_{Europa})$ = ____ $M_☼$

The mass of the sun is 1.989×10^{30} kilograms. Find the mass of Jupiter, ignoring Europa's mass.

$m_{Jupiter}$ = _________________________ $M_☼$

2. Astronomers are able to determine the orbits of binary stars around each other by plotting the positions of the stars relative to each other over a span of years. Each star is located at the focus of the other's orbit.

A certain binary star system has a semimajor axis, α, of 4.9" arc. The distance, d, of the binary system is 5.9 pc.

Calculate the semimajor axis, a, in AU.

$a = \alpha * d$ = ____ AU

*Note: The units of distance (pc) are chosen so that the angular size in arc seconds, multiplied by the distance parsecs, yields the true size in AU.

The period of this binary star system is 76.8 years. Using Kepler's third law, determine the sum of masses of the stars in this system.

$(m_{Star1} + m_{Star2})$ = ____ $M_☼$

If m_{Star1} is 4.0 $M_☼$, calculate m_{Star2}.

m_{Star2} = ____ $M_☼$

Why are measuring the masses of Binary Star Systems in this way important? What do they tell us about other stars?

____

____

____

____

VI. Useful Definitions

Astronomical unit (AU)_____A unit of length, formerly the mean distance of the Earth from the Sun equal to 149,597,870 km.

Geocentric_______________Described by Ptolemy, a system where the Earth is places at the center of the Universe, and around it revolve the Moon, Mercury, Venus, the Sun, Mars, Jupiter, and Saturn.

Heliocentric_____________A model of the Solar System proposed by Nicolaus Copernicus in which the Sun lay at the center with the planets orbiting around it.

Inertia__________________The tendency of a body in motion to remain in motion in a straight line and at a constant velocity unless acted on by an external force; it is also the tendency of a body at rest to remain at rest unless acted upon be an external force.

Mass____________________A measure of the amount of matter in a body.

Prograde motion__________The movement of a body such as a planet from west to east on the celestial sphere; the normal direction of orbital motion and axial rotation of bodies in the Solar System.

Retrograde motion________The movement of a body such as a planet from east to west on the celestial sphere.

Solar mass_______________A unit of mass used in stellar and galactic astronomy, equal to the mass of the Sun, 1.989×10^{30} kg.

Lab Exercise 4

Est. Time: 45 min

Pulsars and Galaxies

I. Objective

Students gain an understanding of the properties of pulsars and the classification of galaxies.

II. Learning Goals

*Students examine the properties of pulsars including mass and brightness
*Students identify different types of galaxies

III. Equipment

Internet
Calculator

IV. Pulsars

When large mass stars reach the end of their lives, a supernova occurs. Supernovas can result in either black holes or neutron stars. Neutron stars are highly dense balls of neutrons. A neutron star is small and dim by astronomical standards; it would have a diameter of about 12 miles and its density of 10^{17} kg/m^3. They also rotate very rapidly because it has collapsed from a much larger mass – this is due to the concept of Conservation of Angular Momentum. In addition to its increased rotation speed, the magnetic field becomes stronger. This is due to the proportional compression of the magnetic field to the compression of the core.

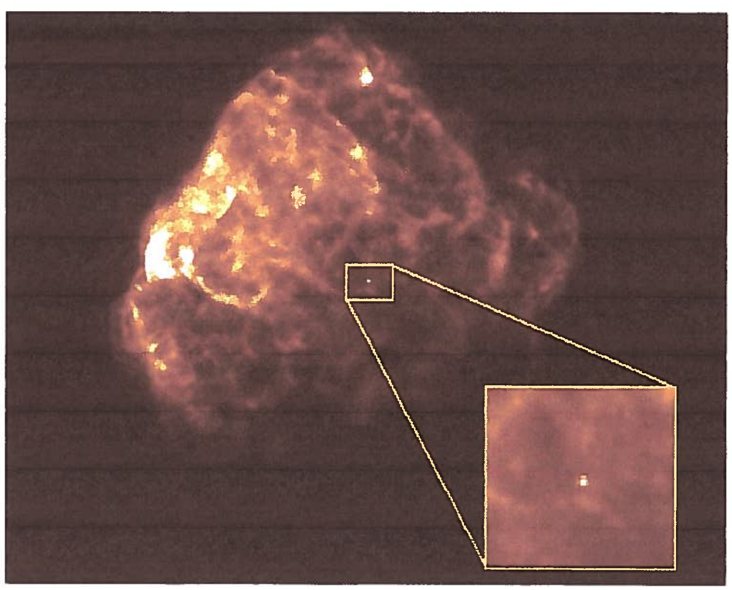


Figure 1: Supernova Remnant and Neutron Star

In the late 1960s, S. Jocelyn Bell Burnell was a graduate student at Cambridge University working with Anthony Hewish looking for interesting sources of radio emission. One very strange signal was detected: a short burst of radio emission followed by a brief pause, and then another pulse. The pulses and pauses alternated with great precision—as it turns out, with a precision greater than that of the most advanced and accurate timepieces in the world.

In 1974, Hewish received the Nobel Prize in Physics for the discovery of the radio signals now called pulsars. A pulsar is a rapidly rotating neutron star whose magnetic field is oriented such that it sweeps across Earth with a regular period. When pulsars were first detected, their signals were so regular that some astronomers thought they might be a sign of extraterrestrial intelligence. However, the large number of pulsars detected and the neutron star theory of pulsars provided an adequate and simpler explanation.

All pulsars are neutron stars, but not all neutron stars will necessarily be pulsars (from our vantage point). If the beam of a particular neutron star doesn't sweep past Earth, we will not detect its radio pulsations. Pulsar periods can range anywhere from milliseconds to a few seconds.

Pulsars emit a pulse, on average, in very short periods ranging from milliseconds to a few seconds. How does the period of a pulsar compare with the period of most variable stars?

____

____

____

What sort of assumptions about a pulsar's mass can astronomers make based on the frequency of its pulses?

____

____

____

Astronomers make the assumption that nothing astronomical can vary significantly in a time shorter than it takes for light to travel across it. Based on this assumption, calculate the maximum size, d, of a pulsar. A typical time, t_{var}, for a pulsar light variation is 0.02 seconds, and the speed of light, c, is 3×10^{10} cm/second.

$$d < t_{var} * c$$

d = ____

Do you think that the brightest pulsars have longer or shorter periods than the faint ones? Why?

____

____

____

V. Galaxies

When viewed with the naked eye, some "stars" appear fuzzier than other surrounding stars. After telescopes became frequently used, some "stars" were discovered to be disks of planets, regions where stars are forming, and collections of old stars. However, one class of objects observed, called spiral nebulae caused much disagreement. These objects were not stars, but there was no way to figure out how big they were without knowing first how far away they were.

Before Edwin Hubble (1889 – 1953) extended our conception of the size of the universe in the 1920s, these objects were classified as various nebulae and were generally thought to lie within the Milky Way, which, in turn, was believed to be synonymous with the universe. We now know that our Galaxy is one of many, and that the spiral nebulae are entire other galaxies, containing hundreds of billions of stars. We see galaxies no matter where we look in the sky depending how deeply an observer looks.

Before the determination of whether it was nebulae or galaxies that caused so much disagreement among astronomers, Edwin Hubble observed at the Mount Wilson Observatory in California. He wanted to answer the question: were spiral nebulae as big as our Galaxy and incredibly distant, or were they mundane, relatively nearby objects?

After intrinsic variable stars were identified in some of these "nebulae," the relationship between period and luminosity could be used to determine their distance. And Hubble's distances, calculated from Cepheid variable stars, prompted him to conclude in 1924 that many of the nebulae were not part of the Milky Way, but were galaxies. Andromeda, for example, was thought to be about a million light years away, which extending far outside the boundaries of the Milky Way.

Hubble then began classifying the galaxies he saw. Hubble's classifications are based on appearance and fall into three broad categories: spiral, elliptical, and irregular.

Hubble labeled all spiral galaxies with the letter "S" and added an a, b, or c; depending on the size of the galactic bulges. Sa galaxies have large bulges, Sb medium-sized bulges, and Sc the smallest bulges. Very clearly defined, tightly wrapped spiral arms are also associated with Sa galaxies, whereas Sb galaxies exhibit more diffuse arms, and Sc galaxies have even more loosely wrapped, less clearly defined spiral arms.

Another subtype of the spiral galaxy is the barred-spiral galaxy, which exhibits a linear bar of stars running through the galactic disk and bulge out to some radius. The spiral arm structure begins at the ends of the bar. This spiral subgroup, designated SB, also includes the a, b, and c classifications based on the size of the galactic bulge and the winding of the arms.

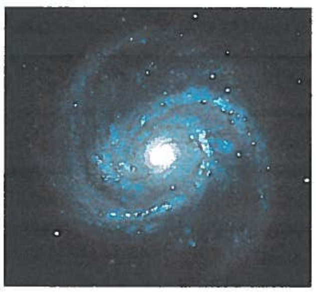
Elliptical galaxies present a strikingly different appearance from the spirals. When viewed through a telescope, they look a bit dull compared to spirals. There are no spiral arms, not and discernable bulge or disk structure. These galaxies appear as nothing more than round or football-shaped collections of stars, with the most intense light concentrated toward the center and becoming fainter and wispier toward the edges.

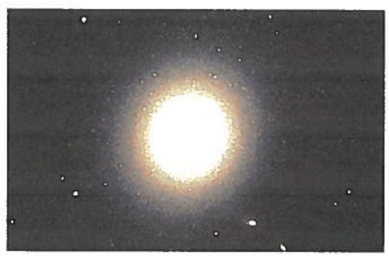
The orientation of an elliptical galaxy will influence its shape in the sky. Its apparent shape may not be its true shape. Hubble differentiated within this classification by apparent shape, where, E0 galaxies are almost circular, counting up to E7 galaxies which are very elongated.

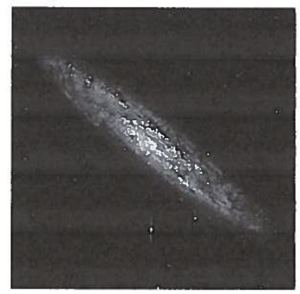
There are also some cross-galaxies, meaning that they have features of more than one type. Some elliptical galaxies exhibit more structure than others, showing evidence of a disk, a galactic bulge, and they lack spiral arms. This type of galaxy is designated S0. Some of these galaxies even contain a bar, and are designated SB0.

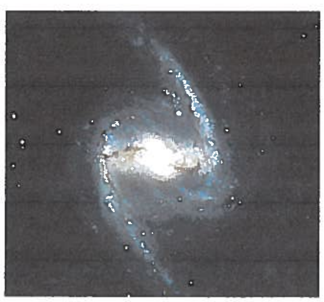
Irregular galaxies lack any regular structure and often look as though they are coming apart at the seams. They frequently just look messy. Unlike the ellipticals, irregulars are rich in interstellar material and are often sites of active star formation. Two of the most famous irregular galaxies are very close to us: the Large and Small Magellanic Clouds.

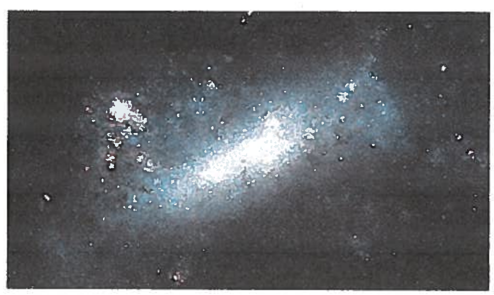
Classify the following galaxies:

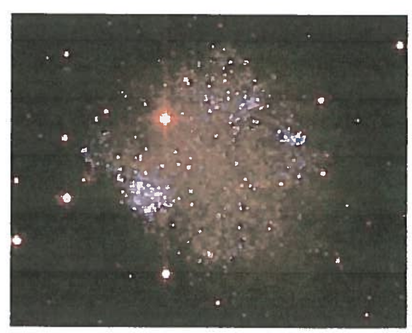












Looking back to methods used in previous labs, how do astronomers measure the mass of galaxies?

____

____

____

Are spirals and ellipticals generally located in the same regions or are they found in different parts of a cluster?

____

____

____

VI. Useful Definitions

Galactic bulge____________ The roughly spherical distribution of stars that forms the central hub of spiral and lenticular galaxies. The bulge is much less noticeable, relative to the disk, in the later spiral types Sc and Sd.

Supernova_______________ A violent explosion in which certain stars end their lives. In a supernova explosion, the star may become over a billion times brighter than the Sun, and for weeks may outshine the entire galaxy in which it lies.

Variable star_____________ A star that varies in brightness. Two broad categories are recognized: extrinsic variables, which vary for a mechanical reason (e.g., rotation); and intrinsic variables, which undergo a real change in luminosity or either an individual star or some element in a binary system. Certain stars may combine both forms of variation.

Lab Exercise 5

Est. Time: 45 min

Radial Velocity and Hubble's Law

I. The Expansion of the Universe

The Doppler Shift is the change in wavelength of electromagnetic radiation as a result of relative movement between the source and the observer. If the source is moving towards the observer, the wavelengths become shorter and the spectral lines are shifted towards the blues end of the spectrum (a blueshift). If the source is receding, the wavelengths become longer and spectral lines are moved towards the red end of the spectrum (a redshift). You may have noticed a similar effect when an ambulance, with its siren on, passes you. Sound and light waves act very similarly. The sound waves of the approaching train are made shorter by the approach of the sound and made longer by the receding of the sound source. The siren does not actually change pitch.

By measuring the degree of a blueshift or redshift, astronomers can calculate the oncoming or receding velocity (the radial velocity) of a star. It has been known since the early twentieth century that every spiral galaxy observed exhibits a redshifted spectrum. Astronomers reached the conclusion that if all galaxies were moving away from us, then all galaxies partake in a universal recession. This observation does not mean that we are at the center of the expansion. Any observer located anywhere in the universe would see the same redshift.

In 1931, Edwin Hubble and Milton Humason first plotted the distance of a given galaxy against the velocity at which it receded. The resulting plot was dramatic. The rate at which a galaxy is observed to recede is directly proportional to its distance from us; that is, the farther away a galaxy is from us, the faster it travels away from us. This relationship is called Hubble's Law.

Imagine a bunch of dots on the surface of a balloon. Label one of the dots as our galaxy, and all the other dots represent the other galaxies in the universe. As you inflate the balloon, the surface of the balloon stretches, and it appears that from the point of view of any one dot, all the other dots are moving away. The farther away the dot, the more balloon there is to stretch, so the faster the dot will appear to recede.

Universal recession in time means the universe is expanding, and expansion implies an origin time. George Gamow was the first to propose that the recession of galaxies implied that the universe began in a spectacular explosion. It was not an explosion in space; it was an explosion of all space. The entire universe was filled with the explosion that started the universe. This theory was termed the Big Bang.

Astronomers believe that at its origin, the universe was unimaginably dense. The entire universe was a point, with nothing outside the point. Almost 15 billion years ago, the entire universe exploded in the Big Bang, and the universe has been expanding ever since, cooling and coalescing into ever more organized states of matter.

II. Objective

Students gain an understanding of the expansion of the universe.

III. Learning Goals

*Students calculate radial velocities of celestial objects
*Students calculate the distances to galaxies
*Students investigate Hubble's Law

IV. Equipment

Calculator

V. Procedure

1. For radial velocities much smaller than the speed of light, the formula used to find the radial velocity is

$$V_r / c = (\lambda - \lambda_o) / \lambda_o$$

where λ is the astronomically measured wavelength of a certain line of a specific element, λ_o is the wavelength measured in the laboratory, V_r is the radial velocity, and c is the speed of light (3.00×10^5 km/sec). This formula is only valid for small radial velocities, however (for V_r / c less than about 0.1).

Calculate V_r / c for a galaxy moving 30 km/sec away from us.

$V_r / c =$ ______________________________

Is the formula valid for a velocity this great? ______________________________

Would the formula be valid for a velocity 300 times greater? ______________________________

A formula that is valid for any value of radial velocity is found from Einstein's theory of relativity to be:

$$V_r / c = [(\lambda / \lambda_o)^2 - 1] / [(\lambda / \lambda_o)^2 + 1]$$

Using Table 1, calculate the redshift of the wavelengths of the H and K lines of ionized calcium (prominent in the spectra of all galaxies). Fill in the blanks in Table 1 using the values given.

Table 1: Apparent Magnitudes of Galaxies

Galaxy	Apparent Magnitude m	H Line λ	(λ / λ_o)	V_r / c	K Line λ	(λ / λ_o)	V_r / c	Average V_r / c
1	14.2	4023.4			4098.7			
2	8.8	3867.4			3892.9			
3	17.6	4478.3			4523.8			

H Line of CaII $\lambda_o = 3953.7$ Å
K Line of CaII $\lambda_o = 3868.5$ Å
C = 3.00×10^5 km/sec

Determining the distances to galaxies is difficult to do. They are too far away to use trigonometric parallaxes, or to gauge the brightness of individual stars. Galaxies come in all sizes and shapes, so there is no standard that astronomers can use to this effect. It has been found that the brightest in clusters of galaxies has a similar brightness from cluster to cluster. So, astronomers can use this distinction to measure distances.

Assume that the galaxies from which we have measured the redshifts are all about the same absolute magnitude, M = -22.0 (27 magnitudes brighter than the sun).

How many times the solar luminosity does each of the galaxies have?
***Note: 1 magnitude is a factor of 2.5 and every 5 magnitudes is a factor of 100.**

L = ________________________________ $L_{\odot}$

Knowing the absolute magnitude, we can use the apparent magnitude, m, to derive their distances, using this relation:

$m - M = 5 \log d - 5$

Find the distance to the galaxies:

Galaxy 1: d = ___________________________ pc

Galaxy 2: d = ___________________________ pc

Galaxy 3: d = ___________________________ pc

VI. Useful Definitions

Electromagnetic radiation___Energy arising from the acceleration of electrically charged entities. Electromagnetic radiation can be considered to be composed of waves or particles, since it displays properties of both; this is referred to as the wave-particle duality. Electromagnetic waves are composed of oscillating electric and magnetic fields which lie at the right angles to each other and to the direction of travel. They propagate through a vacuum at the speed of light, c.

References

DePree, Christopher, and Alan Axelrod. The Complete Idiot's Guide to Astronomy. Third Edition. Alpha, 2004.

Ferguson, Dale C. Introductory Astronomy Exercises. Second Edition. Brooks/Cole, 2001.

Ridpath, Ian. A Dictionary of Astronomy. New York: Oxford University Press, 1997.

Presentation Slides
April 28, 2006

Determining Concept Dependencies and Developing Five Course Lab Activities for an Introductory Astronomy Course

Katherine Pittman, Applied Physics, PCSE 499
Christopher Newport University
Mentor: Dr. J. Hardie
Advisor: Dr. R. Caton

1

Agenda

- An Astronomy Course
- Concept Map
- Concept Descriptions
- Lab Exercises
- REDSHIFT 5
- Questions & Comments

2

Introductory Astronomy

- Included in new general curriculum
- Open to non-science majors
  - Different focus and goals
  - Qualitative understanding
  - Convey "magic" of astronomy

3

Introductory Astronomy

Problem?
- Challenging subject
- Intimidating topics

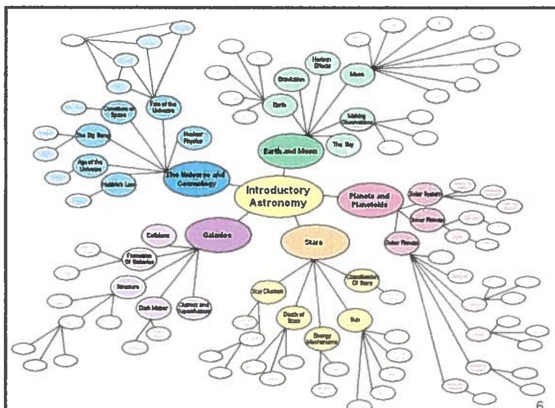
Solution:
- Break it down
- Hands On Approach

4

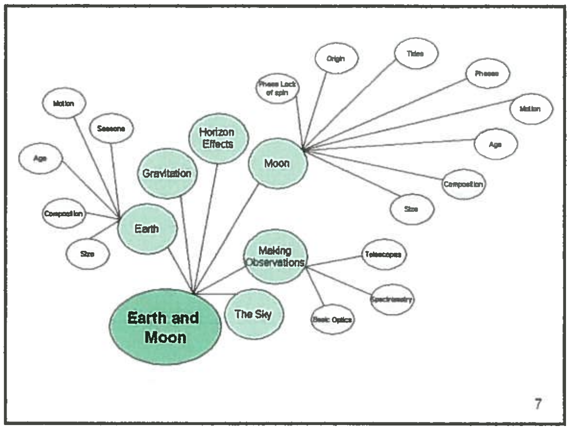
The Concept Map

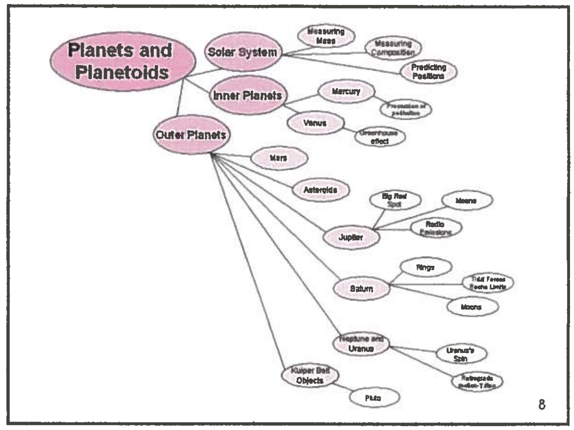
- Order in which topics are presented
- Dependencies of one topic on another

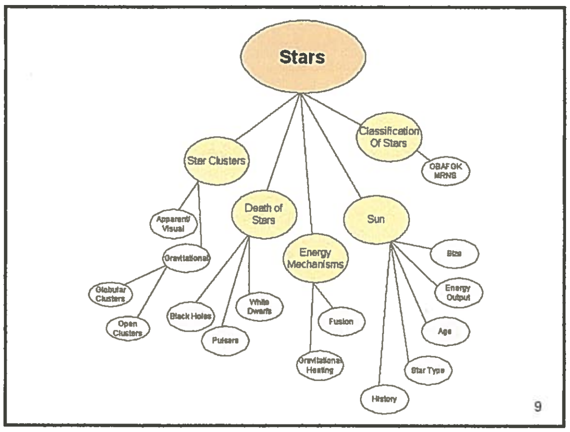
5

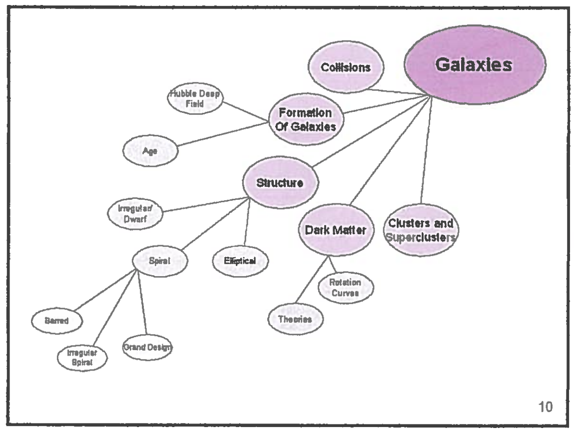


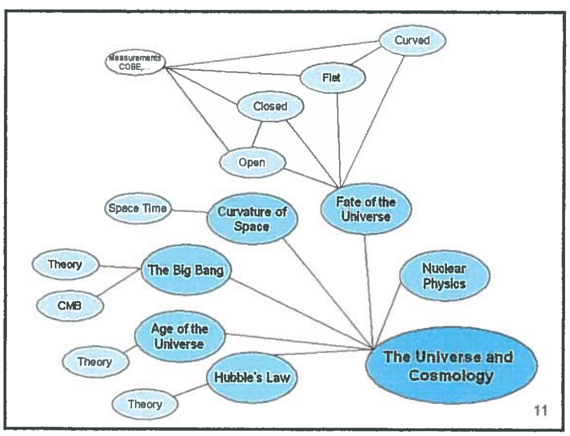
6











The Concept Description

For Teaching

- Meant to be a quick reference
- Brief descriptions of each topic
- Diagrams and Pictures
- Class Activity
- Neat Online Sources
  - Earth and Moon Viewer (http://www.fourmilab.ch/earthview/)

12

The Lab Exercises

Five Activities

- Adaptable
  - Fall and Spring Semester
  - Used with Simulation Program or Outdoor Observation

13

The Lab Exercises

Lab Exercise 1: Introduction to the Night Sky

Lab Exercise 2: The Planets

Lab Exercise 3: Kepler's Laws and Mass

Lab Exercise 4: Pulsars and Galaxies

Lab Exercise 5: Radial Velocity and Hubble's Law

14

The Lab Exercises

Each Lab Contains These Helpful Sections:

Background
Objective
Learning Goals
Equipment Needed
Procedure
Useful Definitions

15

REDSHIFT 5

- 20,000,000 stars
- 70,000 deep space objects, including nebulae, galaxies & quasars
- 50,000+ asteroids
- 1,500+ comets
- All planets & moons, including all recently discovered moons of Jupiter, Saturn, Uranus & Neptune

16

Questions & Comments