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Getting to know our Solar System

Los Alamos Space Science Outreach

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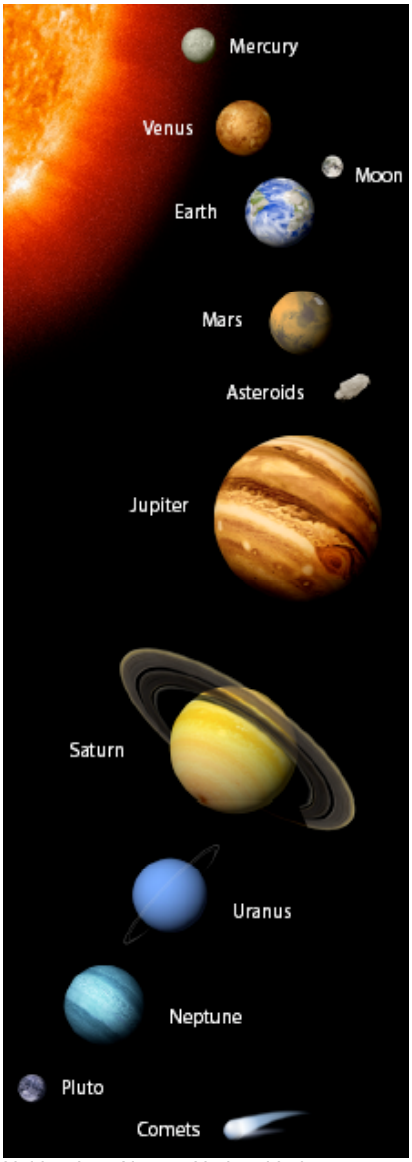

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Getting to Know Our Solar System

This teaching unit consists of a series of activities and lesson plans, which guide students through a study of the Sun, Space Weather as it affects the Earth and other planets. Throughout the unit teachers will be able to adapt the lessons to their own students as appropriate.

The unit begins with an introduction to the varied missions conducted by the National Aeronautics Administration (NASA) to study space weather phenomena. Our quest to understand how the Sun affects the rest of the Solar System begins with a lesson about the Sun, the source of space weather. Following lessons continue building an understanding of the Sun as the source of energy in the Sun-Earth system and then move outward into space, looking at plasma and ions, the magnetosphere, auroras, problems created on the Earth by solar storms, solar wind data analysis, and development of craters on Mars.

The Sun has a complex structure. The teacher may wish to briefly study the various layers/structures of the Sun, but the main focus of this unit is on CMEs (Coronal Mass Ejections), Solar Wind and the Plasma ejected from the Sun. Activities and lessons are included to build an understanding of differences in the various bodies of the Solar System.

Student interest can be engaged through the use of visual images followed by brainstorming and discussion. Numerous web sites are available with photos that can be used with this unit plan. They contain satellite images and ground-based photos of aurora and a number of excellent graphics. The “Internet Resources” section has a list of sites with numerous photos of aurora. Movie clips are available on some sites as well.

After viewing images, students should conduct a ‘brainstorming’ session. This enables them to discuss what they already know and alerts the teacher to misconceptions students have about the Sun and the Solar System. Hopefully, misconceptions will be changed as students learn more about the Sun, Space Weather, Aurora, and about special features on some of the planets.

When the ‘brainstorming’ sessions reach a natural conclusion, the class should categorize the ideas gleaned from the session. Divide the students into small groups and assign a category to each group. Have the groups organize the information making a concept web (*Inspiration* or some other graphic organizing software can be used to make a web of the ideas). Hang these documents up in the room. They can be referred back to as the unit of study progresses.

This unit can be used as a complete teaching unit, or as individual lessons. Also included are additional resources and suggestions for expansion of the lessons/unit.

There are several presentations prepared by Los Alamos Space Physicists for the LASSO Space Science Outreach 2003 Teacher’s Workshop which you may find helpful: *Aurora, Solar Wind, Space Weather.* These may be downloaded from the LASSO web site (http://education.lanl.gov/programs/lasso).

Documents in the Appendix Section of this unit, provide additional information for the teacher and/or the students. If you are interested in more background material, you can view a PDF file of photos and drawings of the structure of the Sun in the Resources section found on the LASSO web site.

NASA Space Mission Activity

Time:
3-4 hours

Content Standards:
- Science as Inquiry
  - abilities necessary to do scientific inquiry
- Earth and Space Science
  - earth in the solar system
- Science and Technology
  - understandings about science and technology

Objective:
Using the Internet, students will work in pairs to discover the number of space missions that NASA currently has operating and how many missions involve a Sun/Earth connection. Students will input data into an electronic worksheet such as Excel to provide a visual graph of their findings. In addition each student will choose one NASA mission that involves a Sun/Earth connection and explore it in more detail.

Equipment, Materials and Tools:

For the teacher:

Materials to reproduce
- Space Mission Activity Worksheet 2 copies per student
- Space Mission Activity Worksheet Instructions - 1 per student

For the students:
- Notebook paper, pencils/pens
- At least 1 computer for every 2 students
- Access to the Internet
- Access to Microsoft Excel or other spreadsheet program
- Printer (for students to print out graphs/spreadsheets)

Prerequisite Skills:
- Working in groups
- Internet Navigation
- Experience working with Microsoft Excel or other electronic spreadsheet programs
  - On-line tutorials for Microsoft Excel include:
    - http://www.compusmart.ab.ca/alummis/excel/exceltutorial.html
    - http://www.bcschools.net/staff/ExcelHelp.htm
    - http://www.baycongroup.com/el0.htm
    - http://www.fgcu.edu/support/office2000/excel/
- Sorting and ordering data
- Knowledge of Sun-earth terminology

Visit http://spacescience.nasa.go/missions/index.htm prior to teaching this lesson to familiarize yourself with the different missions that NASA is currently operating. Also visit http://sec.gsfc.nasa.gov/sec_missions.htm to familiarize yourself with the specific missions that involve Sun-Earth connections.

NASA Space Missions

1. Give each student a copy of the *Space Mission Activity* worksheet and *Space Mission Activity* instructions. Students will form pairs to work on this assignment. Allow students time to read instructions and ask any questions about the assignment.

2. Direct students to http://spacescience.nasa.go/missions/index.htm to begin the activity. Give students time to record data on the worksheet before directing them to create an Excel worksheet.

3. After the groups have completed the Internet search and have developed an Excel graph, discuss the findings in a large group setting.

4. Questions that you can ask students:
   - Were there any findings in regards to the missions that surprised you?
   - What new information regarding the missions proved interesting to you?
   - What types of missions do you want to learn more about?

5. See Figure 1 for the Data Worksheet and Figure 2 for a sample Graph of Space Missions.

Assessment:

1. Students will work individually on this assignment. Direct students to http://spacescience.nasa.go/missions/index.htm. Students will choose to work with data involving missions under study, in development, or past missions.
2. Give each student a copy of the *Space Mission Activity* worksheet (Figure 1). Using the data of their choice, students will develop an Excel graph with this information.
3. Students will find one Sun-Earth connection mission and answer the following questions about the mission. Write these questions on the chalkboard:
   - What is the name of the mission?
   - What is the purpose/goal/objective of the mission?
   - What is the current status of the mission?
   - What organization is in charge of the mission?
   - What did you like about this particular mission?

Assessment Criteria

1. The worksheet has all relevant missions listed, each type of mission is stated, and each mission's objective is stated.
2. The graph is labeled correctly and each mission is represented accurately.
3. The students have answered the questions correctly and completely.

Figure 1: Space Mission Activity Worksheet

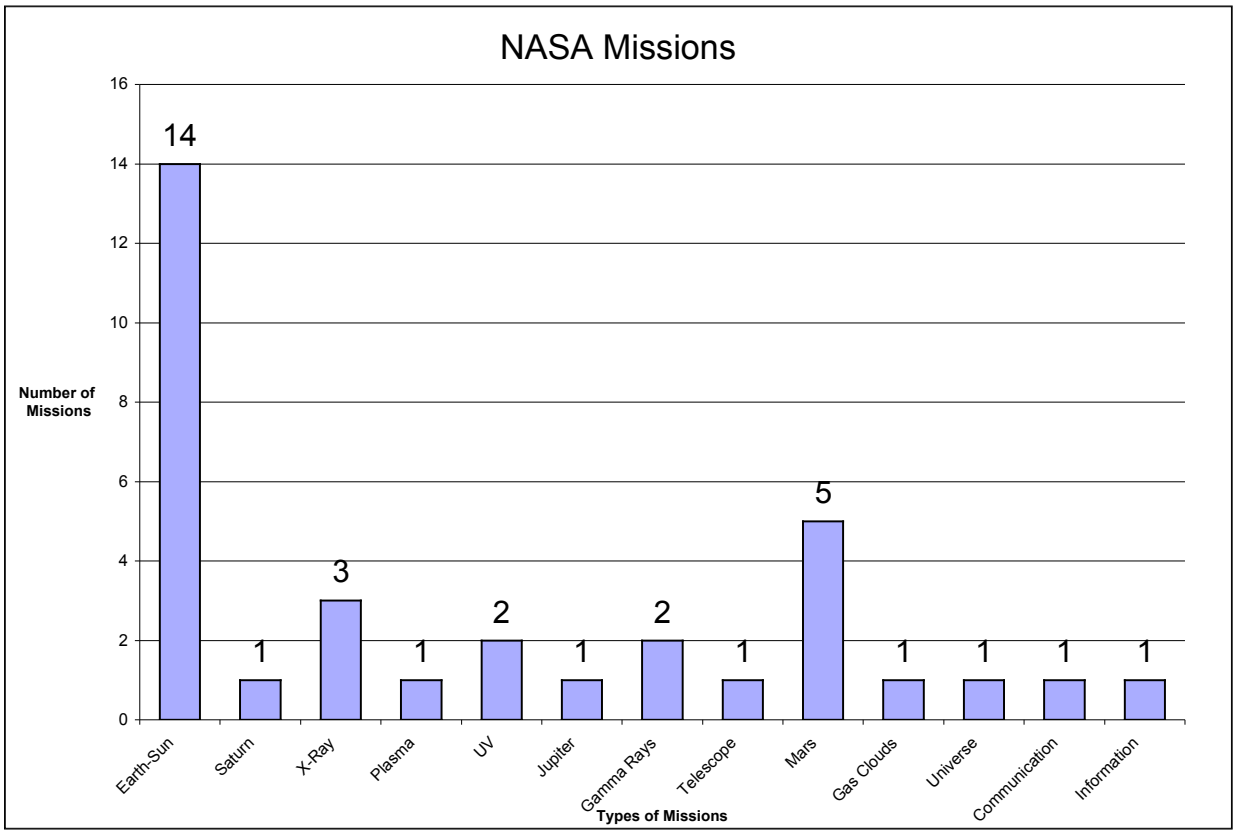
Name: _____ Period: _____ Date: _____

Name of Mission	Type of Mission	Mission Objective

On a separate sheet of paper, write a paragraph that describes the current status of a particular mission identified above.

- Has the mission completed its objectives?
- Are there any problems that the mission has encountered?
- What is your overall impression of the mission?

Figure 2: Teachers Key– Graph & List of NASA Missions



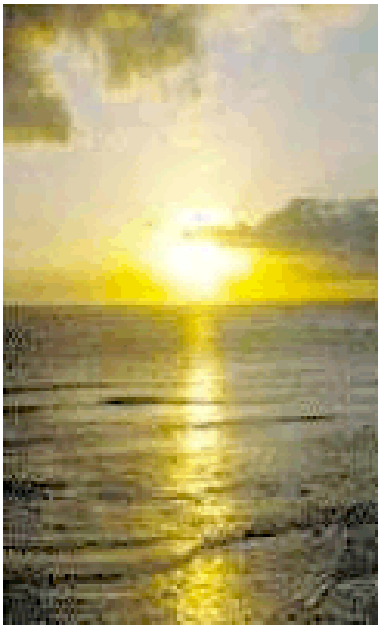
ACE – Earth-Sun	Global – Mars	Number of and
Cassini – Saturn	Odyssey – Mars	Types of missions
Chandra – X-ray	Nozomi – Mars	
CHIPS – Plasma	Polar – Earth-Sun	Earth-Sun – 14
Fast – Earth-Sun	Rhessi – Earth-Sun	Saturn – 1
Cluster – Earth-Sun	RXTE – X-ray	X-ray – 3
Fuse – Ultra-violet	SOHO – Earth-Sun	Plasma – 1
Galex – Ultra-violet	Stardust – Comets	Ultraviolet – 2
Galileo – Jupiter	SWAS – Gas clouds	Jupiter - 1
Genesis – Earth-Sun	TIMED – Earth-Sun	Gamma ray – 2
Geotail – Earth-Sun	TRACE – Earth-Sun	Telescope – 1
HETE-2 – Gamma rays	Ulysses – Earth-Sun	Mars – 5
Hubble – Telescope	Voyager – Universe	Gas clouds – 1
IMAGE – Earth-Sun	Wind – Earth-Sun	Universe – 1
Integral – Gamma rays	Xmm-Newton – X-ray	Communications – 1
Rovers – Mars	Deep Space - Communication	Information - 1
Express – Mars	Space Station - Information	

The Sun

Teacher led discussion on the Sun as the source of energy and particles.

Time:

30+ Minutes



Content Standards:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
  - Identify questions and concepts that guide scientific investigation
  - Formulate and revise scientific explanations and models using logic and evidence
  - Recognize and analyze alternative explanations and models
  - Understandings about scientific inquiry
- Physical Science – Content Standard B
  - Structure of atoms
  - Structure and properties of matter
  - Motions and forces
  - Interactions of energy and matter

Objective:

This unit's purpose is to provide the foundation for understanding the connection between space weather and geomagnetic storms. Students will be introduced to terminology related to the Sun and will complete several activities designed to enhance terminology comprehension. This material could be introduced with the questions: What is space weather? Where does the energy and matter for “space weather” come from?

The objective is not to get bogged down in a major discussion and work on learning all the details of the Sun’s structure. The main idea is to build an understanding that the Sun is not simply a large simple “burning ball”. Rather, it is a very complex, structured object, in which nuclear reactions in the core area provide the energy that everything in the solar system is affected by and that large amounts of material are continually ejected, creating the “solar wind”. Somewhat regularly, large events happen on the Sun that lead up to larger ejections, which in turn lead to the events that are analogous to storms in our space weather system.

Presentation of pictures should include information brought by the teacher, comments and questions from the students in an open forum type setting. The teacher may want to do more research.

Equipment, Materials, and Tools:

Background:

The Sun is a star. Although it looks very different to the stars we see it night, it is one of 100 billion stars in our galaxy alone. It is considered a rather ordinary star, classified as a yellow dwarf, but is in the top 10% of all stars by mass.

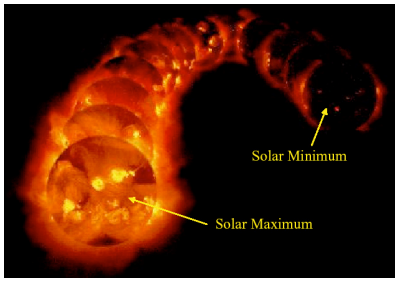
The Sun is located in a rather quiet neighborhood of space. It lies some 32,000 light-years (32,000 X 9 trillion km) from the center of our galaxy. The Sun's period of revolution around the galactic center takes 225 million years. It is about 4.5 billion years old and has used up about half of the hydrogen in its core. It will continue to peacefully radiate for another 5 billion years when it will eventually run out of hydrogen fuel causing radical changes that will result in the total destruction of the terrestrial planets and probably creating a planetary nebula.

The Sun is the largest object in the Solar System, containing more than 99.8% of the total mass (1.989^{30} kg)of the Solar System. It's diameter is 1,390,000 km. The temperature at the Sun's core is 15,600,000 K^{o}, while at its surface it is 5800 K^{o}. The Sun at present is made up of about 75% hydrogen and 25% helium by mass, everything else amounts to only 0.1%. This changes slowly over time as the hydrogen is converted to helium in the Sun's core.

Scientists have seen that features on the Sun appear to move from one side to the other. This is because the Sun actually rotates. The Sun's rotation period is approximately 27 Earth days. The Sun actually demonstrates differential rotation: at the equator it rotates once every 25.4 days while near the poles it is as much as 36 days. This is due to the fact that the Sun is not a solid body. Similar effects are seen in the gaseous planets.

The Sun emits energy as different electromagnetic wavelengths. Each wavelength can be viewed with different types of instruments, one being our eyes. The wavelengths visible to our eyes are referred to as the 'visible light spectrum' that is comprised of seven colors: red, orange, yellow, green, blue, indigo, and violet. Invisible to us are wavelengths shorter and longer than the visible spectrum and can be seen only with special instruments.

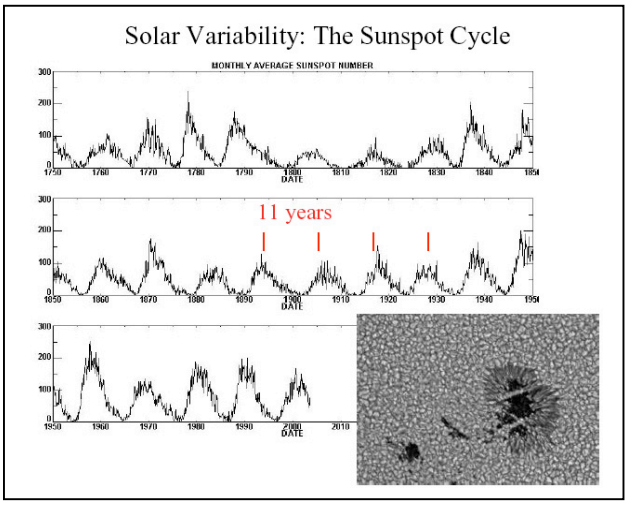
Scientists look at the Sun with special instruments that are designed to see only specific colors of light, even the wavelengths that are invisible to our eyes. The Sun looks different, depending on which wavelengths we choose to view. Scientists are able to describe the different layers of the Sun by viewing different wavelengths of light from the Sun. The layers most easily seen are the photosphere, the chromosphere, and the corona.

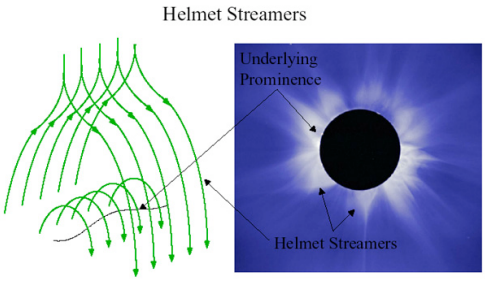


The corona of the Sun, the outermost layer, is a real puzzle. We can see the corona only when the photosphere has been occulted (blanked out), i.e., a solar eclipse or mechanically induced eclipse. The only way the corona can be studied is through the use of X-ray sensing instruments. X-ray images show scientists the parts closer to the Sun.

The corona is the only layer that is hot enough to emit X-rays. It is millions of degrees hotter than the surface of the Sun.

The Sun has a complex magnetic field. This magnetic field is very strong (by terrestrial standards) and very complicated. The Sun's magnetosphere extends well beyond Pluto. When matter from the Sun interacts with the field, the results are Sunspots, solar flares and coronal mass ejections. Activity on the Sun follows an eleven-year cycle when the activity increases and decreases. This period of activity is not constant but varies between 9.5 and 12.5 years. During the cycle, changes occur in the Sun's magnetic field and in the surface disturbance level. The quieter period is termed "solar minimum," while the most active time refers to "solar maximum." Periods of high activity may be associated with magnetic storms on the Earth and with other injurious effects.

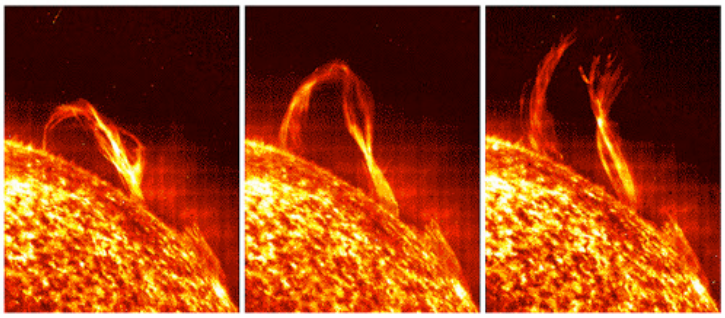




At the beginning of the solar cycle, the Sun's magnetic field resembles a dipole with its axis aligned with the Sun's rotational axis. Helmet streamers can be seen forming a continuous belt around the Sun's equator and coronal holes are seen near the Sun's poles. Towards the solar maximum period, this configuration is totally destroyed, leaving the Sun, magnetically, disorganized with streamers and holes scattered all over different latitudes.

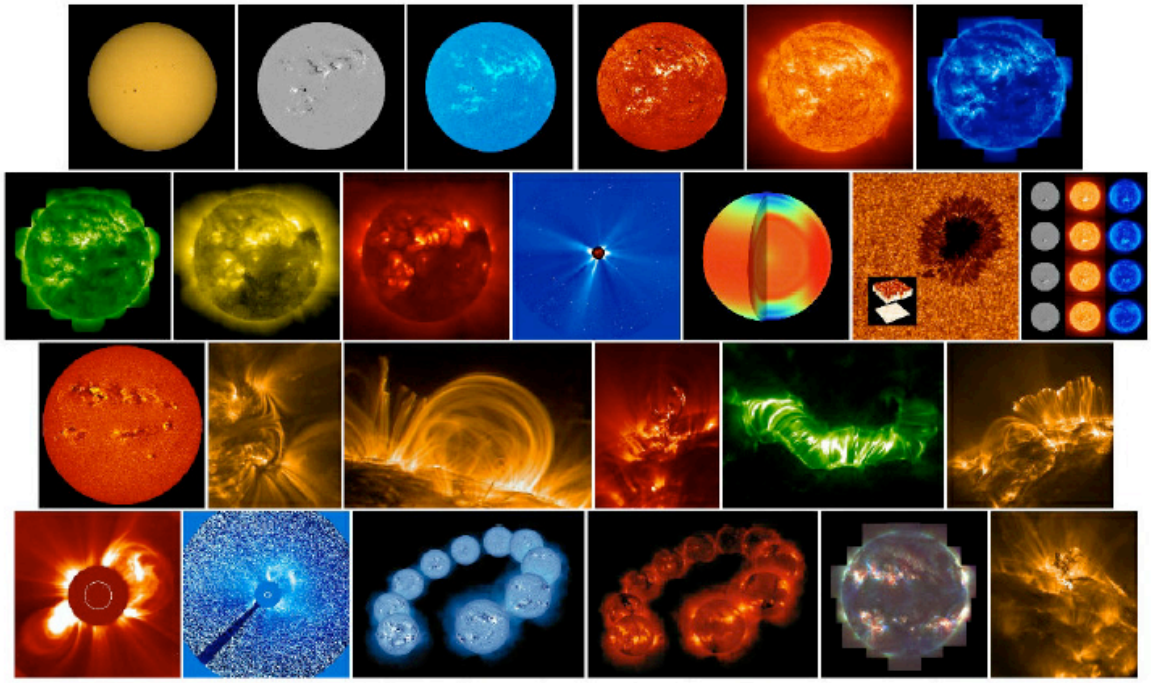
In addition to heat and light, the Sun also emits a stream of charged particles (mostly electrons and protons) known as the solar wind. This solar wind propagates throughout the solar system and has dramatic effects on the Earth ranging from power line surges to radio interference and creates the beautiful auroras seen in the northern and southern latitudes. In addition to the solar wind, scientists have studied spectacular loops and prominences on the Sun's surface.

Erupting Prominence



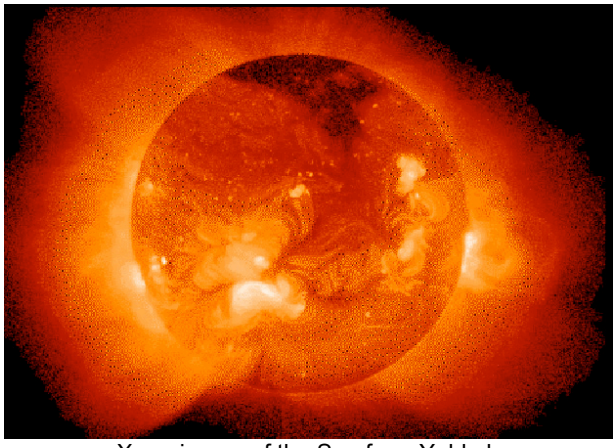
Our Sun provides an exciting 'laboratory' in which to do experiments. Scientists are able to investigate its behavior with various instruments from space as well as from Earth.

The following activities will explore sunspots, solar flares, and coronal mass ejections (CME's). They are designed to instill a greater understanding of the Sun and its affects on the bodies within the Solar System. We have learned that we live with a very dynamic star.



Views of the Sun demonstrating its dynamic nature.

Creation of Plasma – Teacher Demonstrations


X-ray image of the Sun from Yohkoh

Time:

10 minutes – Part 1 - Modeling creation of plasma
15 minutes – Part 2 - Creating plasma

Objective:

To build an understanding of how energy translates to temperature. How collisions between particles at high velocity strip or gain electrons from other atoms and molecules making them “ions”.

Content Standards:

Abilities necessary to do scientific inquiry

- Identify questions and concepts that guide scientific investigations
- Design and conduct scientific investigations
- Formulate and revise scientific explanations and models using logic and evidence
- Recognize and analyze alternative explanations and models
- Use Technology and Mathematics to improve investigations and communications
- Formulate and revise scientific explanations and models using logic and evidence
- Communicate and defend a scientific argument

Equipment, Materials, and Tools

Part 1

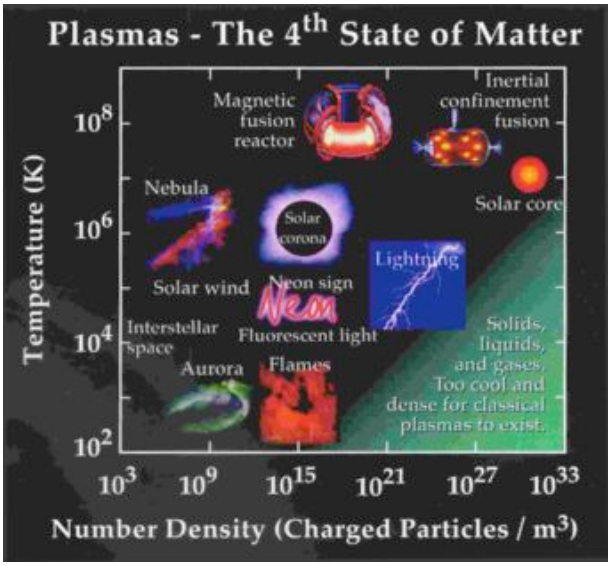
- Hard, over-baked, cookies.
- A brush and pan to pick up the crumbs.

Part 2

- Tesla Coil (spark generator)
- Pieces of metal and various non-conductors

Background Information:

The plasma in space is significantly different from that in stars because of the extremely low density. The particles, though traveling at extremely high speeds (high temperature) seldom, if ever, collide with anything, and therefore do not have a chance to de-ionize. The fact that they are ions, that is, charged particles, and that they have great velocity and a relatively consistent direction, in effect makes them a powerful electric current through space.

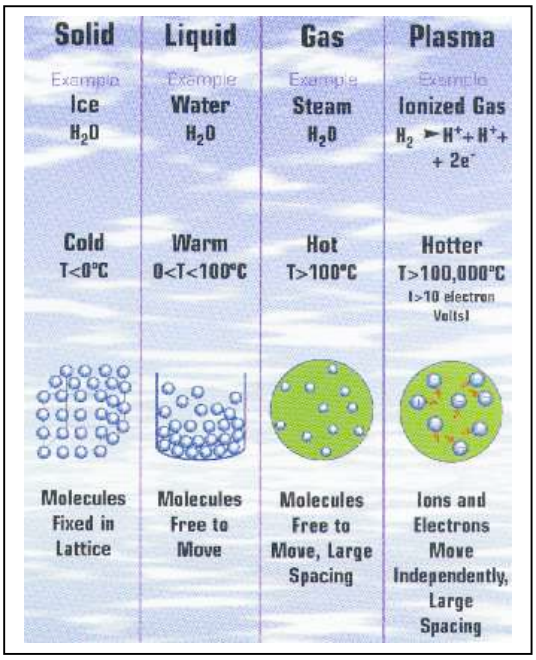


Plasmas are conductive assemblies of charged particles, neutrals and fields that exhibit collective effects. Further, plasmas carry electrical currents and generate magnetic fields. Plasma is by far the most common form of matter. Plasma in the stars and in the tenuous space between them makes up over 99% of the visible universe and perhaps most of that which is not visible.

On earth we live upon an island of "ordinary" matter. The different states of matter

generally found on earth are solid, liquid, and gas. We have learned to work, play, and rest using these familiar states of matter. Sir William Crookes, an English physicist, identified a fourth state of matter, now called plasma, in 1879.

Plasma temperatures and densities range from relatively cool and tenuous (like aurora) to very hot and dense (like the central core of a star). Ordinary solids, liquids, and gases are both electrically neutral and too cool or dense to be in a plasma state.



The word "PLASMA" was first applied to ionized gas by Dr. Irving Langmuir, an American chemist and physicist, in 1929.

Plasma consists of a collection of free-moving electrons and ions - atoms that have lost electrons. Energy is needed to strip electrons from atoms to make plasma. The energy can be of various origins: thermal, electrical, or light (ultraviolet light or intense visible light from a laser). With insufficient sustaining power, plasmas recombine into neutral gas.

Plasma can be accelerated and steered by electric and magnetic fields that allow it to be controlled and applied. Plasma research is yielding a greater understanding of the universe.
The full range of possible plasma density, energy (temperature) and spatial scales go far beyond this illustration. For example, some space plasmas have been measured to be less than $10^{-1}/m^3$ (13 orders of magnitude less than the scale shown in the figure!). On one extreme, quark-gluon plasmas (although mediated via the strong force field versus the electromagnetic field) are extremely dense nuclear states of matter. For temperature (or energy), some plasma crystal states produced in the laboratory have temperatures close to absolute zero. On the other extreme, space plasmas have been measured with thermal temperatures above 10^9 degrees Kelvin and cosmic rays (a type of plasma with very large gyroradii) are observed at energies well above those produced in any man-made accelerator laboratory.

Instructions: part 1 – Teacher Demonstration

Modeling the creation of plasma (ions)

1. Drop a “hard” cookie – modeling of gas collisions
   - Atoms and molecules are always running into each other in the gas phase, but seldom is there enough energy in those collisions under “gas” like temperatures for electrons to be exchanged.
2. Throw cookie to hit table or floor – modeling of plasma collisions
   - At the very high temperatures in a star, which translate in the case of atoms and molecules to very high speeds, the collisions are sufficiently energetic to in this case break up the cookie, in the case of a plasma strip or gain electrons.
3. Conduct a class discussion to further build understanding of gas collisions and the creation of ions.

Creating a Plasma – Teacher Demonstration

Part 2: Creating a Plasma

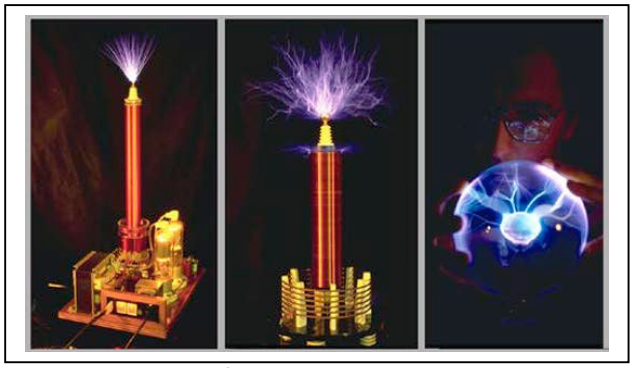
Background Information:

The Tesla Coil uses a very high voltage to generate sparks in ordinary atmosphere. The color of the sparks generated is usually purple. One can smell the ozone ions being created; the very high voltage is ionizing the atmosphere in the vicinity. These are actually mini-lightning charges. Besides being able to smell ions the students will hear the constant, very small discharges occurring while the Tesla Coil is on. This device is safe to humans, but does deliver a sharp unpleasant jolt. Ask the students to suggest ways to test the device. After one grabs it there is no further great effect, but the courage to grab it is difficult to muster.

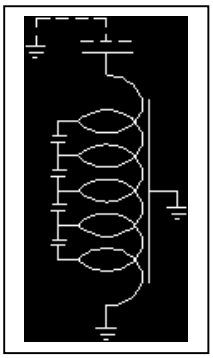
The ions show up better if the classroom lights are off. Some student invariably thinks of putting a piece of paper in position so that the sparks can pass through it. If done so for a few seconds, the paper will light on fire, demonstrating the “heat” of the ions in the sparks though no great amount of heat is felt near the tip. If time and interest allow, the students can investigate where on the shape of the tip of the device do the sparks prefer to emanate. Also be sure to demonstrate how the sparks go further and are longer toward electrical conductors and especially objects that are electrically grounded such as the faucets. It does no harm to the running water, as the spark actually prefers the metal.

(The following is from http://www.apc.net/bturner/coils.htm)

What is a Tesla Coil? It is an air-cored, resonant transformer that is capable of producing a very high voltage and visual discharges.



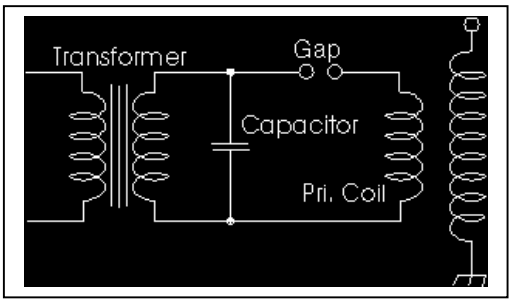
How does it work?
As mentioned, Tesla coils are resonant transformers. This implies that there is a specific frequency at which they operate - *the resonant frequency*. There is no "special" universal Tesla coil frequency - rather, you either target a frequency in the design, or tune a coil into whatever frequency it happens to be happy with.



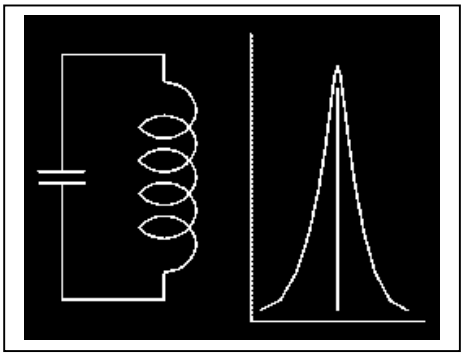
What determines this resonant frequency is the secondary coil - a complex LCR network. The inductive (L) component is the physical coil itself, and is based upon the number of turns, the diameter and length of the coil. The capacitive (C) component is comprised of several *isotropic* values: the surface of the secondary wire and the terminal electrode. (Isotropic capacitance in essence is 'virtual' capacitance - there is a capacitive effect even though it appears that there aren’t any physical plates to create the capacitor.) The resistive (R) component consists of the wire itself, and identifies the physical resistance of the secondary coil *at the resonant frequency*.

To get the secondary to resonate, pulses of energy have to be fed at just the right rate and frequency. A good analogy is that of a bell. To get the bell to ring, you need to tap it with a

hammer. If you tap too hard, you can crack the bell. If you tap and hold the hammer on the bell too long, you don't get a clean, pure tone out of the bell.



Energy pulses come from the primary circuit. This circuit is made up of (1) the high-voltage transformer, (2) the primary capacitor, (3) the spark gap and (4) the primary coil. Together, these parts form a crude type of oscillator. What happens is thus: the transformer charges the capacitor up until there is a high enough voltage across the spark gap to jump the air gap. When this spark occurs, the energy stored in the capacitor is 'dumped' into the primary inductor. The primary inductor then builds a magnetic field as the capacitor's energy flows through it. The magnetic field will eventually collapse, and will in turn dump what energy is left back into the capacitor. This see-saw activity continues until there isn't enough voltage left to jump the spark gap.



The oscillation frequency is determined by the value of the primary capacitor and the primary inductor. Together, they form what is called a *parallel-resonant* circuit. In typical Telsa coil designs, the frequency is adjusted by altering the primary coil's inductance.

If the energy bursts are of the same frequency as the secondary, the energy transferred by the primary's magnetic field will start to build up in the secondary coil. Much like a laser, this energy grows and amplifies itself until there is an incredible voltage built up at the top of the coil, which dissipates into the air in the form of electrical sparks.

Curious about Tesla Coils? Brent Turner has compiled 198 pages of useful information complete with pictures, drawings and illustrations. His book covers not only the traditional spark gap Tesla Coil, but touches on vacuum tube designs as well as modern solid-state systems. He is making the book available for $26.95 plus postage (order form below).

Disclaimer of Endorsement:

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I've enclosed a check or money order for $26.95 plus the following postage (all funds in US dollars, please!)

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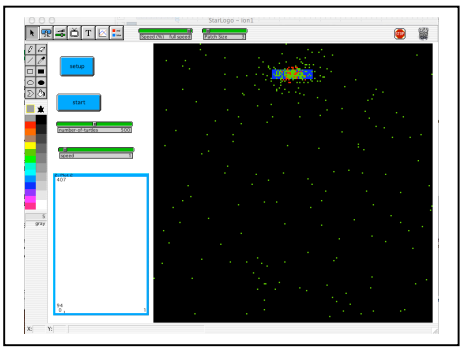
__ Air (Canada) - $2.19

Send to : Brent Turner
PO Box 3612
Fullerton, CA 92834-3612 USA

Simulated Ion Development



Time:
30 minutes

Objective:
Through a 'Starlogo' simulation (modeling), students will develop an understanding of the differences between a model and real life.

Teacher note
This is a simulation where the students can modify some of the parameters, but this is more of a demonstration and should be used in conjunction with lecture and hands on experiments. Advanced students are welcome to investigate the programming in the Starlogo models. They may modify the programs to make the simulation more real.

Content Standards:
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
  - Identify questions and concepts that guide scientific investigations
  - Design and conduct scientific investigations
  - Use Technology and Mathematics to improve investigations and communications
  - Formulate and revise scientific explanations and models using logic and evidence
  - Understandings about scientific inquiry
- Physical Science – Content Standard B
  - Structure of atoms
  - Structure and properties of matter
  - Motions and forces
  - Conservation of energy and increase in disorder
  - Interactions of energy and matter

Equipment, Materials, and Tools:
- Computer with Starlogo downloaded from: http://education.mit.edu/starlogo/
- The Starlogo code file (ion1.slogo) is included in the Appendix section

Background Information:
An ion is a charged particle formed from a neutral particle by the addition or subtraction of one or more electrons. The word was coined by Michael Faraday and comes from the Greek word meaning "wanderer."

Plasma, such as the plasma found in stars, consists of electrons and bare nuclei. The plasma then contains a swirling mass of positive ions and electrons. Although the ions themselves are charged, the plasma as a whole has no charge. It contains as many positive charges as negative charges. The main difference between a gas and plasma is that plasma can conduct an electric current while a gas cannot.

Since 1949, scientists have assumed that ions in plasma must achieve a velocity known as the ion-sound, or Bohm, velocity before they flow out of the plasma. Back then, academic and theoretical physicist David Bohm showed that the ions must drift at a certain velocity based on

electron temperature and ion mass—even if the ions have a zero temperature in the bulk plasma.

But what scientists didn't know is how the ions sped up. Bohm suggested it was the result of weak electric fields that formed in the plasma away from the thin boundary, or sheath, at the plasma's edge. Normally, that sheath is positively charged, while the rest of the plasma is electrically neutral.

In the theoretical literature describing the phenomenon, Professor Noah Hershkowitz says the region in which ions are accelerated is often called the presheath.

Although determining the details of the plasma potential profile near boundaries is one issue critical to basic understanding of confined plasmas, until recently, no one had experimentally verified Bohm's theory and subsequent models of presheaths.

In a fusion device, loss of plasma at a limiter or diverter determines both the heating and particle recirculation at that point and provides basic limits as to how much current researchers can extract, what density level they can achieve, how long materials last, and more. The details of what happens near the sheath can determine what happens to a satellite in space: what the electric fields near the satellite look like, when particles are emitted by photoemission or by interaction with the surroundings, how that plasma is lost and so on. Understanding what's going on is an important thing to do.

Instructions:

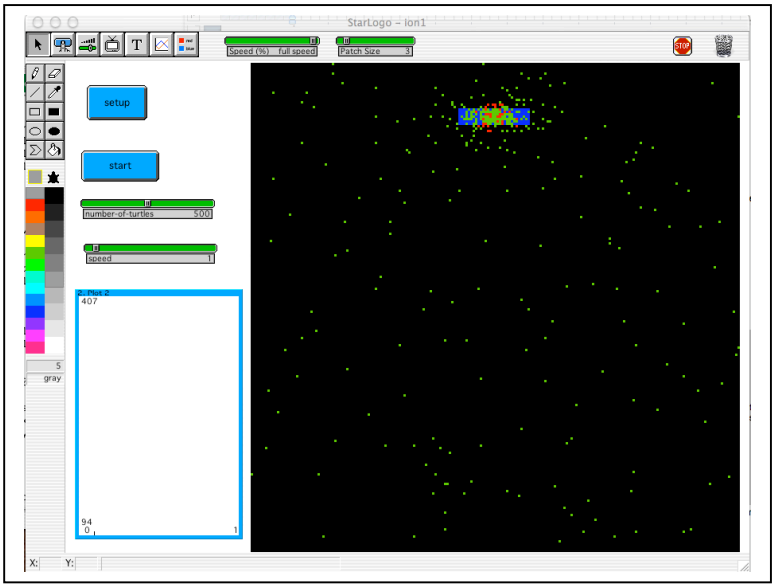
1. Download and install StarLogo software from http://education.mit.edu/starlogo/ on your computer.

StarLogo is a programmable modeling environment for exploring the workings of decentralized systems -- systems that are organized without an organizer, coordinated without a coordinator. With StarLogo, you can model (and gain insights into) many real-life phenomena, such as bird flocks, traffic jams, ant colonies, and market economies.

In decentralized systems, orderly patterns can arise without centralized control. Increasingly, researchers are choosing decentralized models for the organizations and technologies that they construct in the world, and for the theories that they construct about the world. But many people continue to resist these ideas, assuming centralized control where none exists -- for example, assuming (incorrectly) that bird flocks have leaders. StarLogo is designed to help students (as well as researchers) develop new ways of thinking about and understanding decentralized systems.

StarLogo is a specialized version of the Logo programming language. With traditional versions of Logo, you can create drawings and animations by giving commands to graphic "turtles" on the computer screen. StarLogo extends this idea by allowing you to control thousands of graphic turtles in parallel. In addition, StarLogo makes the turtles' world computationally active: you can write programs for thousands of "patches" that make up the turtles' environment. Turtles and patches can interact with one another -- for example, you can program the turtles to "sniff" around the world, and change their behaviors based on what they sense in the patches below. StarLogo is particularly well-suited for Artificial Life projects.

2. Start StarLogo. Select File, Open Project and select "ion1.slogo" (you must copy the program code from the Appendix and save as "ion1.slogo." From the "Windows" select tool, select "Interface." You should see the following screen:



You can set the number of 'Turtles' and the 'Speed' at which they move with the set-up button. The blue rectangle represents a magnet.

This simulation sheds some light on ion creation. Green turtles, representing the non-ions, will randomly wander around. When they hit each other they turn into a Red turtle, an ion. These ions are then attracted to the blue magnet at the top of the screen. Once the Red turtles (ions) hit the blue magnet, they turn back into Green turtles (non-ions). One point of this simulation is the relative amounts of ions to non-ions depending on the total amount of turtles and the speed.

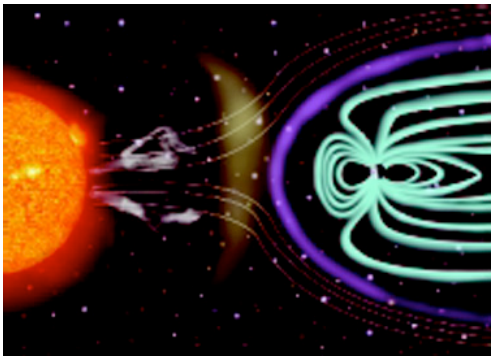
Assessment:

Have students explain the difference between a model and real life, how the model is not a perfect representation of reality.

Questions:

What would happen if you increase the initial number of particles? What happens to the display graph?

Sun-Earth Connection
Relative Sizes and Distances



Time:
50 minutes

Objective:
This activity begins to look at the space between the Sun and Earth, or space in the solar system in general. This is where the satellites that measure the solar wind reside. Before we look at the interaction between the solar wind and the Earth's magnetosphere, we want the students to develop an understanding of the relative sizes and distances between planetary bodies.

Content Standards:
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
  - Identify questions and concepts that guide scientific investigations
- Communications
  - Recognize and analyze alternative explanations and models
  - Communicate and defend a scientific argument
  - Understandings about scientific inquiry

Equipment, Materials and Tools:
- Graph paper,
- Scissors,
- Ruler,
- String [optional]

Background Information:
For thousands of years inhabitants of the Earth have been gazing out into the Cosmos. Observations and imagination have led to many important milestones in human history. Early star gazers began to identify certain patterns of stars helped them identify times of the year. They saw that the stars moved across the sky during the night but always remained in the same positions, all but four that appeared to move among the others. They called these moving points of light planets, meaning wanderers and named them after their deities. The largest was named after the king of gods, Jupiter. The red colored planet named after the god of war, Mars, the brightest after the goddess of love and beauty, Venus and the last after the god of agriculture, Saturn. They also observed other objects that moved in the night skies but were not permanent: comets with their sparkling tails and meteors shooting through the night skies.

They were not able to observe the other planets, as they did not possess the tools needed to see distant objects. The invention of the telescope changed the astrological world as more star gazers began to see objects never seen before. Uranus was first observed in 1781, Neptune in 1846, and Pluto in 1930. To enhance their ability to observe the skies, they began to find ways to improve the telescope.

Of the nine planets, four are known to have solid rocky surfaces and are located closest to the Sun. Mercury, Venus, Earth and Mars are called the terrestrial planets. Beyond the orbit of Mars

are the gas giants, Jupiter, Saturn, Uranus and Neptune. The ninth and most distant planet, sometimes called a proto-planet, has a solid but icier surface.

Many of the planets have natural satellites (moons) revolving around them. More than 120 have been identified and the number is still growing. The Earth has one satellite. Some of the moons orbiting the other planets are much larger than the Earth's moon while many are just small pieces of debris. The origin of many of these moons is still questioned. Were they left over debris from the formation of the Solar System, parts of the planet that were lodged from the planet by a catastrophic collision, or asteroids captured by the planets gravitational field.

Three planets are now known to have rings: Jupiter, Saturn, and Uranus. Saturn's rings are by far the most known and observed as they lie at an angle easily seen from Earth. These rings are composed of particles ranging in size from dust to house sized boulders and may be rocky or icy.

In early human history, it was believed that the Earth was the center of the Universe and that all celestial bodies revolved around the Earth. This belief was disproved through observations and calculations made by Copernicus. We now know that the Earth is but one of the nine planets that revolve around the Sun and that the Sun is just one star of billions of stars in the Milky Way Galaxy and that it too is moving through space.

Our perceptions of the Solar System and of the Universe are constantly changing as we develop better tools to collect data. The use of new technologies and our own reasoning powers have helped to further our knowledge and understanding of 'heavens.'

The following activity will ask what celestial body appears largest in the sky. Students will develop an understanding of the relative sizes of large and distance objects.

Instructions:

1. Give each student a copy of the 'Relative Size and Distance' worksheet (Figure 1). Have students complete the worksheet.

Body	Distance from Sun	Distance from Earth	Diameter	Number of Satellites
Sun	0	1 AU		
	0.387 AU			0
		.277 AU	12,103 Km	
Earth	1 AU			1
Mars		.524 AU		
Jupiter	5.20 AU		142,984 Km	
				31+
	19.191 AU			
			49,528 Km	
		38.48 AU		1

Discussion Questions for Students

The planet Mars is .524 AU from the Earth while earth is 1 AU from the Sun. How far is Mars from the Sun?

The planet Jupiter is 5.2 AU from the Sun while earth is 1 AU from the Sun. How far is Jupiter from Earth?

2. Relative Sizes

Have students plot, to scale, the information for Earth, Mars and Jupiter on graph paper. Place the Earth to one side and Jupiter on the other with Mars in between. Remember, Jupiter is 5.2 AU away from Earth. What scale will you use to put Jupiter on the other side of the paper from Earth?

FOR THE TEACHER
This activity can be done on one sheet of graph paper or the planets can be cut out.

Now draw a cone from the center of the Earth's surface to one of the other planets. Ask the students which would look bigger from earth?

Put a Sun (2-8' diameter depending on room size) on one wall. Use a small moon cut out and have student close one eye and hold out the moon to the correct distance in order to make an eclipse. Have student reflect on the relative distances between the moon and eye and Sun and eye.

High school students can use arc length and trigonometry to reach their conclusions.

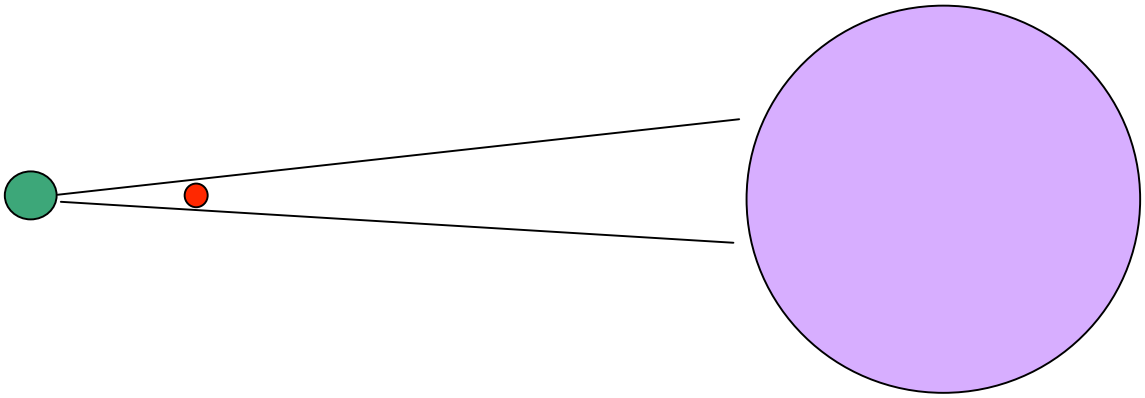


Figure 1. Relative Sizes and Distances of Solar System Bodies

Solar System Body	Distance from Sun	Distance from Earth	Diameter	Number of Satellites
Sun	0	1 AU		
	0.387 AU			0
		.277 AU	12,103 Km	
Earth	1 AU			1
Mars		.524 AU		
Jupiter	5.20 AU		142,984 Km	
				31+
	19.191 AU			
			49,528 Km	
		38.48 AU		1

Placement of Satellites

Teacher Demonstration

Time:

30 minutes

Objectives:

Students will develop an understanding that gravitational forces between the Sun and other Solar System bodies determines the point of placement for man-made satellites.

Content Standards:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
  - Identify questions and concepts that guide scientific investigations
  - Formulate and revise scientific explanations and models using logic and evidence
  - Recognize and analyze alternative explanations and models

Equipment, Materials, and Tools:

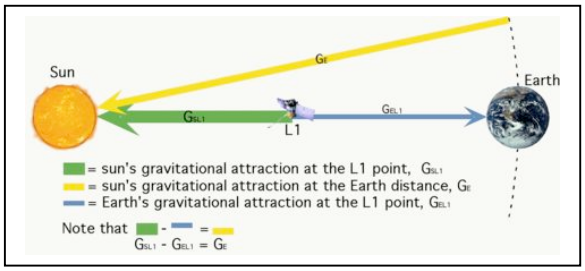
- A small but heavy object – like a ball or rectangular piece of metal
- Rubber bands with varying thicknesses. The tricky part is to find a way to securely attach one end of each of two different rubber bands to the ball or piece of metal
- A spring scale
- A variety of objects of varying mass
- Overhead projector.

Background Information:

A number of satellites have been launched into space to monitor space weather. When they are located in a position of space distant to the planets, they are able to observe materials ejected from the sun as there is nothing in the way to stop the ejecta. If a place can be located where the satellites escape Earth's gravitational force, the satellites essentially become orbiters of the Sun, the largest source of gravity in our system. But where is this point located?

If a spacecraft is placed between the Earth and the Sun, the opposing pull of the Earth reduces the effective pull of the Sun, allowing the spacecraft to orbit the Sun more slowly. If the distance is properly chosen, the orbital motion will match that of Earth, allowing the two to stay together throughout the Earth's annual journey around the Sun.

There is a point in space where the gravitation pulls of the earth and the Sun exactly balance. It is a good place to send satellites because once there, it takes little to no energy to keep them there. The point where this happens is the L1 Lagrangian point (after Joseph Lagrange, the Italian-French mathematician who pointed it out). It is about 4 times more distant than the Moon, at about 1/100 (1%) of the distance of the Sun. The L1 point provides a very useful position for monitoring the solar wind before it reaches Earth and for other purposes. Currently two spacecraft are stationed near L1-- ACE, studying "anomalous cosmic rays" and also observing the solar wind, and SOHO, which observes the sun.



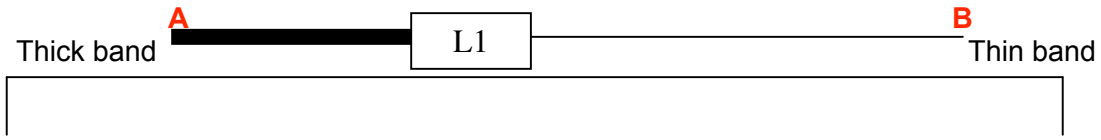
Demonstration: The point of this demonstration is to show that the gravitational forces of the Sun and the Earth determine where the L1 point is located.

Have students observe as you weigh a number of objects. Have them record the weight of each object. Ask the students to explain how the force or pull exerted by each object stretches the spring proportionally. Have the students check out that the pull is directly proportional to the amount of stretch.

Have the students attach a rubber band to a ball or piece of metal (students must be careful as the ball or metal can become projectiles). Have the students exert an opposing force by pulling on the rubber band while holding the ball or metal. How does the students' effort in holding the ball or metal change as greater forces are exerted on the rubber band? Have students record their observations and make conclusions to the amount of force placed on the ball by the amount of stretch on the rubber band. Have the students repeat the process with varying thicknesses of rubber bands. Have students record their conclusions on the board.

Now ask the students how they might model the pulls of the Earth and the Sun on an object? After a few guesses, you want the class to figure out or recall that the gravitational force exerted on an object relates both to the size (mass) of the objects and the distance between the objects. Students must develop an understanding of the fact that the pull of the Sun is much greater than the Earths and to compensate for the fixed gravitational forces, the distance between objects is the factor that can be adjusted to obtain balanced forces. Remind students that gravitational force, decreases with greater distance. Ask students if they would expect L1 to be located nearer to Earth or the Sun? Why?

Take a piece of metal and attach a thick rubber band to one side and a thin rubber band to the other side. Place on an overhead projector. Turn on the light. Slightly pull in opposing directions. Have students record their observations (Which direction does the object move? How much does it move?) Now pull to different degrees on the object. Have students record their observations. How can they explain what they observe.



When you stretch the rubber bands and hold for a short time, the system will settle down as pictured with the object staying at one position – our L1. Establish that when the system is at rest, that the pulls exerted by the two rubber bands must be equal (forces at equilibrium), otherwise the system would continue to move.

Now for some counter intuitive thinking and questioning! Many may be surprised at this point because they expected the thin rubber band to represent the Earth's gravitational force as it exerts less force and to have L1 closer [which is correct]. Since L1 is relatively much closer to point A, the force exerted by the thick rubber band must represent the Earth's gravitational force, as objects at L1 are closer to the Earth!

Have the students' debate that when an object is at a distance much closer to the Earth than the Sun, than the gravitational pull of the Earth must be proportionally stronger than the Sun's as

represented by the thick rubber band and the Sun's greater distance produces a weaker "pull", thus the thin rubber band must be stretched more to equalize the force exerted by the Earth.

Decrease of Force or Matter Relative to Distance

Time:
30 minutes

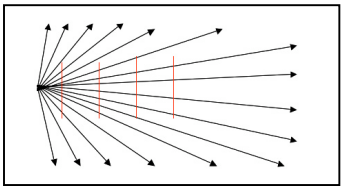
Objective:
The student individually and as a class will come to see that for matter or energy that emanates equally in all directions from a source will decrease in density in a regular manner. It is hoped that the high school student can be led to find the inverse square relationship that the numbers should approximate.

Content Standards:
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
  - Identify questions and concepts that guide scientific investigations
  - Recognize and analyze alternative explanations and models

Equipment, Materials, and Tools:
- Paper, rulers,
- Protractors, and
- Colored pencils for whole class.

Instructions:
Students may work individually or in groups.

Have each student take piece of paper and draw a point in the middle of the left edge. From this point have students draw lines (arrows) with a protractor radiating out every 5 degrees.



Have students draw a three inch long line at a distance of two inches in from the point and parallel to the edge using a different color to represent a detector = D1.

Have students draw three more detectors (D2, D3, D4) parallel at distances four, six and eight inches respectfully. (More detectors and counts can be added as time permits.)

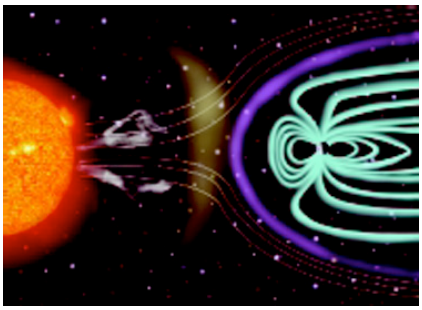
Have students count the number of rays that cross each detector and record that number by their detector (C1 # of counts, C2 # of counts, C3 # of counts, C4 # of counts).

Have students calculate the ratios D2/D1, D3/D1, D4/D1, C2/C1, C3/C1, C4/C1 (If these ratios are calculated on a spreadsheet the graphs of them with the D's being on the x axis and the C's being on the axis will show the quadratic nature of the decrease.)

Have students record their results on the board. When all of the results have been recorded, have student look to see if the results reveal a 1/distance squared relationship (look at C ratios)

Conduct a class discussion on the results.

Direction of Solar Wind at the Earth



Time:
30 minutes

Objective:
The student will come to discover that the standard picture or model of light and/or particles rays coming from the Sun as parallel is very realistic.

Content Standards:
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
  - Identify questions and concepts that guide scientific investigations
  - Formulate and revise scientific explanations and models using logic and evidence
  - Recognize and analyze alternative explanations and models

Equipment, Materials, and Tools:
- Paper,
- Rulers,
- Protractors, and
- Colored pencils for whole class.

Instructions:
Divide the class into pairs. Have the student pairings form two lines with strings, about 4 to 7 feet long between the pairs of students, pulled taunt. The strings represent direction of line of particle movement.

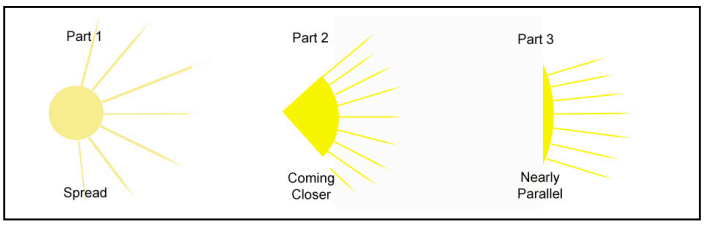
A1>-----<B1
A2>-----<B2
A3>-----<B3
A4>-----<B4
A5>-----<B5

An>-----<Bn

Part 1. The first line represents the surface of the Sun – a curve. Have students in line A form a half circle, each member facing out from the center of the Sun.
The second line always moves to line up facing the first (the lines are perpendicular to the surface of the Sun). Have a recorder sketch a birds-eye view of the rays on the board (divide the board into three equal sections) in section one.

Part 2. The first line represents a quarter arc of the Sun's surface. Students in the second line should move to perpendicular positions. Have the recorder sketch the directions of lines on board in section two.

Part 3. The first line represents a "small" arc (almost straight) and the second line adjusts to perpendicular positions. The recorder sketches the direction of lines on the board in section three.



Expected board recording or results. There is a person facing each other at each end of each line. The closing question to the class should determine if everyone agrees that the model representing movement of particles or photons from the Sun should be in parallel lines since the Sun is so distant to the Earth.

Collection of Particles

Simulated Satellite Measurement Device for Ions, Neutrons, Electrons, …

Time:

50 minutes

Objective:

Through a 'StarLogo' simulation, students will develop an understanding of how solar particles are captured by instruments on orbiting satellites.

Teacher note

This is a simulation where the students can modify some of the parameters, but this is more of a demonstration and should be used in conjunction with lecture and hands on experiments. Advanced students are welcome to investigate the programming in the Starlogo models. They may modify the programs to make the simulation more real.

Content Standards:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
  - Identify questions and concepts that guide scientific investigations
  - Design and conduct scientific investigations
  - Use Technology and Mathematics to improve investigations and communications
  - Formulate and revise scientific explanations and models using logic and evidence
- Physical Science – Content Standard B
  - Structure of atoms
  - Structure and properties of matter
  - Motions and forces
  - Interactions of energy and matter

Equipment, Materials and Tools:

- Computer – Mac or PC with Starlogo program from http://education.mit.edu/starlogo/
- StarLogo code file (neutroncollector1.slogo) located in the Appendix section

Background Information:

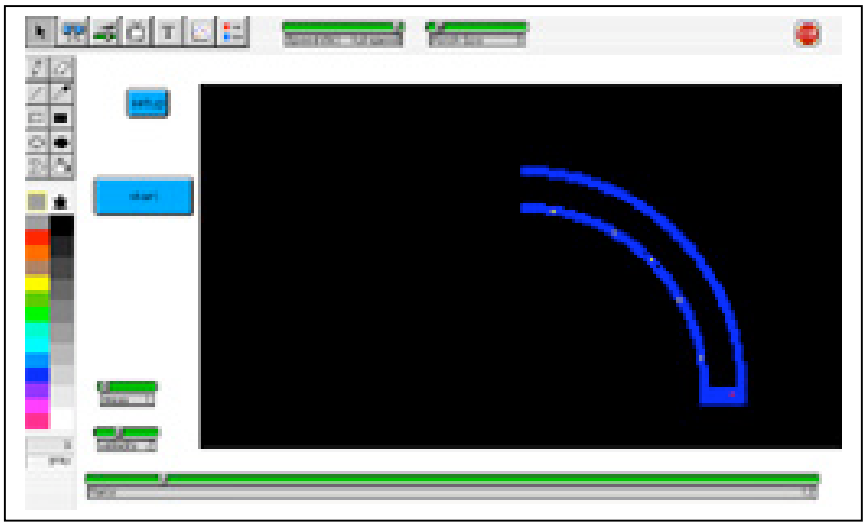
The plasma of the solar wind is comprised of ions. The temperature assigned to this plasma is a measure of how fast these particles are traveling. Since they are physically so far apart in interstellar space, they seldom collide with anything and thus remain charged. The particles are still classified plasma while the conditions in which they were created; high speed and density, no longer exist. Because they are charged particles, they both create and follow magnetic field lines in their travels and are affected by other magnetic fields. The sophisticated and complex measuring devices on-board deep space satellites are based on relatively simple electro-dynamics. The moving charges are pushed by magnetic fields in a direction perpendicular to their motion. The amount of force they feel (how much they are pushed) depends on how long they are in a field (determined by their speed) and how much mass they have (what ion they are).

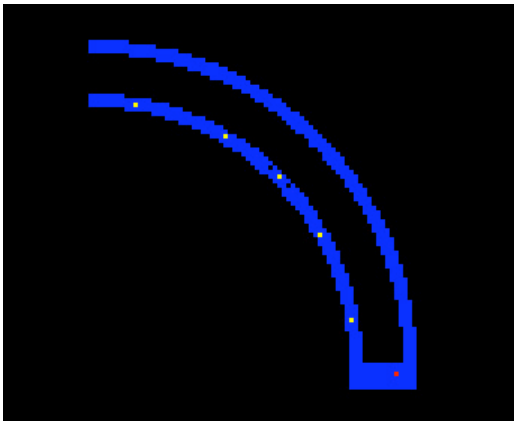
Instructions:

1. Download and install StarLogo software from http://education.mit.edu/starlogo/ on your computer.

2. Start StarLogo. Select File, Open Project and select “neutroncollector1.slogo” (you must copy the program code from the Appendix and save as “neutroncollector1.slogo.” From “Windows”, Select Tool, select “Interface.” You should see the following screen:

The Starlogo model allows the student to vary the force on the field in the measuring device to ensure a certain particle (specific mass and specific speed) makes it to the end of the curved device where it is then detected. By changing the strength of this field, the experimenter sees how too much field force causes a particle to curve too much and vice versa.



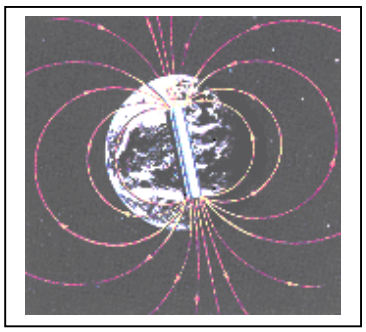


The red dot at the base of the curved tube represents a particle that has been collected on the magnetic plate. For a given mass and velocity, the correct force must be found.

This activity simulates the collection device that measures count of neutrons. A semicircular (or some arc of a circle) chamber modifies or bends the trajectory of incoming particles with a electric charge. The model simulates particle velocity, particle mass (1 = hydrogen, 2 = helium, ect...) and electric charge on the semicircular plates. Given particle velocity and mass the student adjusts the electric charge (i.e. force) in order to attract the incoming particle to the base of the collector.

Magnetic Field Lines

Simulation of Iron Fillings around a Magnet



Time:

40 minutes

Objective:

Students will gain an understanding of the mechanics of magnetic field lines as demonstrated with iron fillings and a magnet and through a simulation model.

Teacher note

This is a simulation where the students can modify some of the parameters, but this is more of a demonstration and should be used in conjunction with lecture and hands on experiments. Advanced students are welcome to investigate the programming in the Starlogo models. They may modify the programs to make the simulation more real.

Content Standards:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
  - Use Technology and Mathematics to improve investigations and communications
  - Formulate and revise scientific explanations and models using logic and evidence
  - Recognize and analyze alternative explanations and models
- Physical Science – Content Standard B
  - Structure of atoms
  - Structure and properties of matter
  - Motions and forces
  - Conservation of energy and increase in disorder
  - Interactions of energy and matter

Equipment, Materials, and Tools:

- Computer – Mac or PC with Starlogo program from http://education.mit.edu/starlogo/
- StarLogo code file (magnet2.slogo) located in the Appendix section

Background Information:

The ancient Greeks and the early Chinese knew about strange and rare stones with the power to attract iron. A steel needle stroked with such a "lodestone" became "magnetic" as well, and around 1000 AD the Chinese found that such a needle, when freely suspended, pointed north-south. A simple observation that lead to the beginning of the magnetic compass.

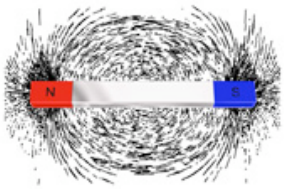
The magnetic compass soon spread to Europe. Columbus noted that the needle deviated slightly from exact north (as indicated by the stars) and that the deviation changed during the voyage. Around 1600 AD, William Gilbert proposed an explanation: the Earth itself was a giant magnet, with its magnetic poles some distance away from its geographic poles (i.e. near the points defining the Earth's axis).

On Earth one only needs a sensitive needle to detect magnetic forces, but out in space they are usually much, much weaker. Beyond the Earth's dense atmosphere, such forces have a much larger role, and a region exists around the Earth where these forces dominate the environment,

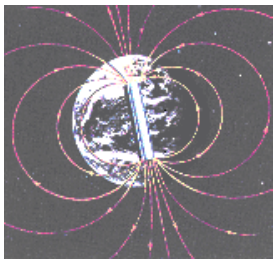
a region known as the Earth's magnetosphere. This region contains a mix of electrically charged particles, and electric and magnetic phenomena rather than gravity determine its structure.

Until 1821, magnetism produced by iron magnets was the only one known. Hans Christian Oersted, a Danish scientist, while demonstrating the flow of an electric current in a wire, noticed that the current caused a nearby compass needle to move. Andre-Marie Ampere in France studied this newly described phenomenon. He concluded that the nature of magnetism was quite different from what everyone had believed. It was basically a force between electric currents: two parallel currents in the same direction attract, in opposite directions they repel. Iron magnets are a very special case, which Ampere was also able to explain.

Michael Faraday, credited with fundamental discoveries on electricity and magnetism, also proposed a widely used method for visualizing magnetic fields. Imagine a compass needle freely suspended in three dimensions, near a magnet or an electrical current. We can trace in space the lines one obtains when one "follows the direction of the compass needle." Faraday called them lines of force, but the term field lines is now in common use.



Magnetic field lines describe magnetic fields. Magnetic field lines move in all directions but converge where the magnetic force is the strongest and spread out where it is weaker. When demonstrating magnetic field lines with a magnet and iron fillings, you can see that the magnetic force is the strongest at the ends of the magnet, the poles. Magnets are dipoles, having one pole at each end. The behavior of the Earth’s magnetic field is similar to that of the magnet as the Earth acts as a dipole.



To Faraday, field lines were mainly a method of displaying the structure of the magnetic force. In space research, however, they have a much broader significance, because electrons and ions tend to stay attached to them, like beads on a wire, even becoming trapped when conditions are right. Because of this attachment, they define an "easy direction" in the rarefied gas of space, like the grain in a piece of wood, a direction in which ions and electrons, as well as electric currents can easily move.

Faraday not only viewed the space around a magnet as filled with field lines, but also developed an intuitive notion that such space was itself modified. James Maxwell, the great Scottish physicist, placed this notion on a firm mathematical footing, including in it electrical forces as well as magnetic ones. Such a modified space is now known as an electromagnetic field.

Today electromagnetic fields are a cornerstone of physics. Their basic equations, derived by Maxwell, suggested that they could undergo wave motion, spreading with the speed of light. Maxwell correctly guessed that this actually was light and that light was an electromagnetic wave.

Heinrich Hertz in Germany produced such waves by electrical means, in the first laboratory demonstration of radio waves. Today, a wide variety of such waves are known, from radio (very long waves) to microwaves, infra-red, visible light, ultra-violet, x-rays and gamma rays (very short waves).

Radio waves produced in our magnetosphere are often modified by their environment and tell us about the particles trapped there. Other such waves have been detected from the magnetospheres of distant planets, the Sun and the distant universe. X-rays, too, are observed to come from such sources and are the signatures of high-energy electrons there.

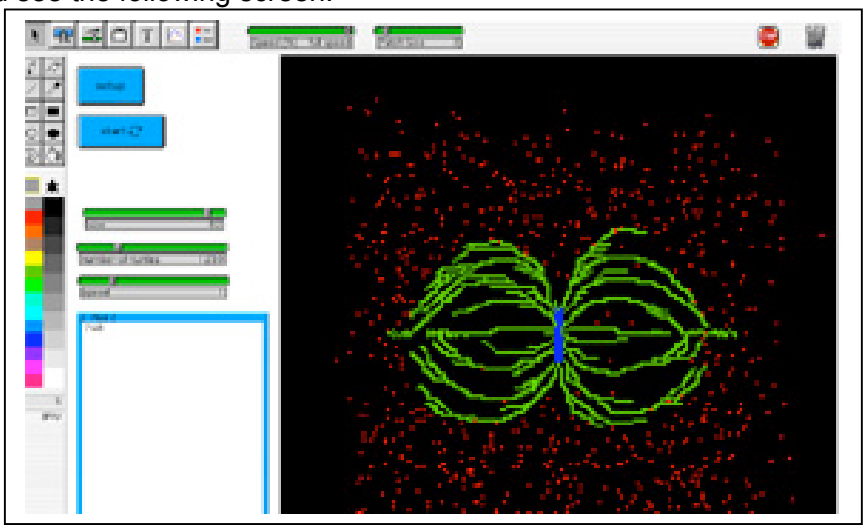
Only a few of the phenomena observed on the ground come from the magnetosphere: fluctuations of the magnetic field known as magnetic storms and sub-storms, and the polar aurora or "northern lights," appearing in the night skies of places like Alaska and Norway. Satellites in space, however, sense much more: radiation belts, magnetic structures, fast streaming particles and processes that energize them.

In space, magnetic field lines are fundamental to the way free electrons and ions move. These charged particles become attached to field lines and spiral around them while they slide along them. The behavior of plasma, electrified gas of free ions and electrons, is dictated by field lines in space. Electric currents find it easiest to flow along such lines. It is along the field lines which particles, electric currents, heat and certain types of waves prefer to flow.

Instructions:

1. Download and install StarLogo software from http://education.mit.edu/starlogo/ on your computer.
2. Start StarLogo. Select File, Open Project and select “magnet2.slogo” (you must copy the program code from the Appendix and save as “magnet2.slogo.” From the “Windows” select tool, select “Interface.” You should see the following screen:

This activity simulates the the alignment of particles (the red dots) along lines of magnetic force (the green lines). As the particles align you see them disappear. Notice the movement toward the stronger polar regions.

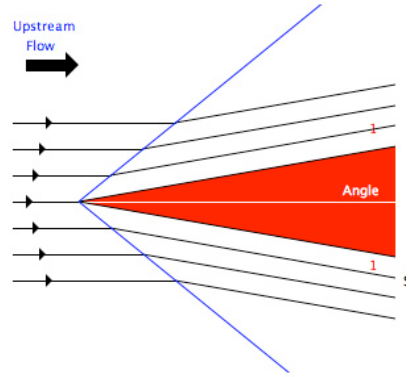


This computer simulation will help demonstrate the mechanics in how iron fillings represent the magnetic field lines. Often the dropping of iron fillings on a plastic sheet or piece of paper gets very messy and sometimes does not even show exactly what you want because of things like the magnet being too weak or strong.

NOTES FOR TEACHER This is a simulation where students can modify some of the parameters, but this is more of a demonstration and should be used in conjunction with lecture and hands on experiments.

Place a bar magnet on a table. Place a piece of paper over the bar magnet. Spread iron fillings on the paper and have the students observe what happens to the fillings. Have students sketch the shapes observed.

Modeling Shock Waves
Demonstration



Time:
50 minutes

Objective:
The students will know and understand the general look and shape of a shock wave.

Content Standards:
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
  - Identify questions and concepts that guide scientific investigations
  - Design and conduct scientific investigations
  - Recognize and analyze alternative explanations and models
- Physical Science – Content Standard B
  - Motions and forces
  - Conservation of energy and increase in disorder
  - Interactions of energy and matter

Equipment, Materials, and Tools:

Part 1
- Wave tank (or rectangular flat glass baking pan)
- Mini pump (small fish tank or fountain water pump)
- Objects to interrupt flow
- High intensity lamp and a way to attach it above that tank.
- Support for pan and prop to set negative angle (gentle reverse slope) to provide background flow
- Large pieces of white paper for the students to trace the shapes of the waves

Part 2
- Fan with fan guard
- Long pieces of string [3-5 feet]

Background Information:
Shock waves that we now call sonic booms first made their impression on mankind in the form of thunderclaps. Before long, man learned to create his own sonic boom by cracking a whip, in which the tip of the whip exceeds the speed of sound.

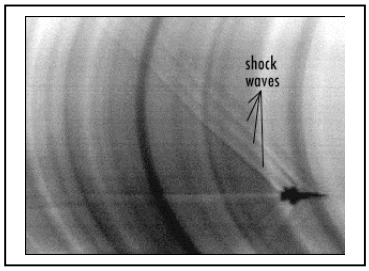
The concept behind shock waves is that some object stops the flow of a medium (gas, liquid, or plasma) causing the medium to move around the object. However, the relative speed is such that the medium does not have time to move out of the way. A "shock wave" is set up in the medium that informs the medium and does the job of moving it away with a characteristic shape.

Whether fluids are composed of air or water, they behave similarly. Fluids move as thin sheets that move, bend, and slide past one another. Such turbulent flow creates spinning pockets of

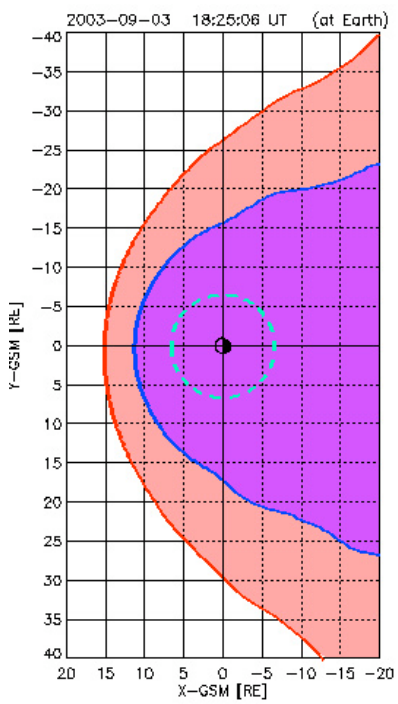
fluid called vortices; air passengers encounter this effect as turbulence. The aerodynamics of fluid motion is another concept central to science and engineering.

We are confronted with shock waves all the time. Ordinarily, when we think of sonic booms, we picture a supersonic-airplane flying overhead. The sonic boom tracks along the ground at the same speed as the aircraft--the faster the plane, the more the boom lags behind. Larger meteors entering the atmosphere create shock waves that can be detected on the ground as low-frequency vibration known as infrasound.

As an airplane flies faster than the speed of sound, it "pushes" on the sound waves in front of it. But sound waves obey the speed limit--they can't travel faster than the speed of sound. So the waves pile up against each other as they are created. These "piled up" waves are called shock waves. The greatest shock waves are at the tip and tail of the plane. This NASA photograph shows the shock waves created by a plane in flight (The "rings" in the photograph are camera artifacts and are not part of the shock waves).



Shock waves result when the matter through which the wave is passing is compressed and the molecules collide and vibrate. When the velocity of the disturbance is extreme, such as in the case of a meteor, electrons are knocked loose and the molecules are ionized.



Depiction of the Earth's bow shock and magnetosphere emanating from solar wind traveling left to right. The Earth is at the center.

In space, explosions are constantly occurring. It is somewhat paradoxical that the ultimate explosion, the "Big Bang" from which the universe is believed to have been created some 20 billion years ago, could not have produced a shock wave. Although "things" were sent flying in every direction, space was a total vacuum then and there was nothing to compress. Now, there are a few particles in every cubic centimeter of space and shock waves are abundant.

The shock waves that affect us most directly originate from solar flares on the sun. When a large solar flare erupts, electromagnetic radiation in the form of X-rays and radio waves travel to the earth at the speed of light and arrive here in about 8 minutes. The shock wave, however, is produced by an expanding, teardrop-shaped "piston" of ionized gases driving toward the earth at about 600 miles a second (the shape traces out magnetic field lines of the sun).

On arrival, the shock wave and the ionized solar gases interact with the earth's magnetic field. The hot gas is so tenuous that it scarcely affects conditions in our atmosphere, but it profoundly affects radio communications, often resulting in a total "blackout." It is also during times of large solar flares that we are likely to experience the most brilliant and spectacular auroras.

Instructions:

Part 1: Water flow

Setup small water pump to flow into rectangular wave tank. Mount intense light above so that image of waves is projected onto white paper on table. Sketch waves right onto paper. Note the shape of the shock wave. Have students sketch results of several different angle settings. Place different objects in the tank to disrupt the flow. Sketch the results. Possible modification is to have iron filings in water with strong magnet taped to bottom of tank to observe interaction of magnetic field with an on-coming flow.

Part 2: Air flow

Attach strings to fan guard. Turn fan on slow and observe the strings. The strings show flow with good examples of turbulence at far end. Discuss the shape of the turbulent area and the crossing of the "field" lines. Model a storm by increasing the flow of air. Compare shapes before and after.

To view simulations on the web, visit the following sites:

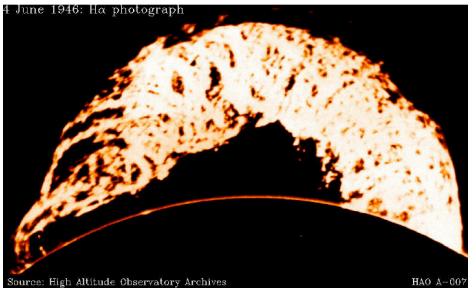
Moving Point Source:Doppler effect and shock wave
http://www.phy.ntnu.edu.tw/java/Doppler/Doppler.html

Interplanetary Shock Wave Passes Earth
http://www.southpole.com/headlines/y2000/ast21feb_1.htm

Shock wave simulator
http://www.grc.nasa.gov/WWW/K-12/airplane/shock.html

Modeling of the Earth's Bow Shock and Magnetosphere
http://pixie.spasci.com/DynMod/

Coronal Mass Ejections Lesson



Time:

7 to 10 days (one 55-60 minute period per day)

Objective:

The students will develop skills in conducting research, making calculations based on scientific data, and interpreting scientific data and photographs. Students will develop an understanding of Coronal Mass Ejections and their formation and movement through space through the use of real time satellite data.

Content Standards:

- *Content Standard B*, Motions and Forces, Transfer of Energy: The sun is a major source of energy for changes on the earth's surface. A tiny fraction of that light reaches the earth, transferring energy from the Sun to the Earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.
- *Content Standard D*, Earth in the solar system: The Sun, an average star, is the central and largest body in the solar system. Most objects in the solar system are in regular and predictable motion.
- *Content Standard E*, Abilities of technological design, Understandings about science and technology Developing Student Abilities and Understanding: Design a solution or product, implement a proposed design, evaluate completed technological designs or products
- *Content Standard F*, Science and technology in society: Science influences society through its knowledge and worldview. Scientific knowledge and the procedures used by scientists influence the way many individuals in society think about themselves, others, and the environment. Technology influences society through its products and processes. Technology influences the quality of life and the ways people act and interact. Science cannot answer all questions and technology cannot solve all human problems or meet all human needs. Students should understand the difference between scientific and other questions.

Equipment. Materials, and Tools:

- Calculators
- Encyclopedias, library reference material
- Computer lab with internet access
- *Inspiration* software
- *MS PowerPoint* software

Student Skills

- Use of mathematical formulas for speed, velocity and acceleration
- Calculator use
- Basic computer use
- Some knowledge of *MS Power Point* would be helpful, but not necessary.
- *Inspiration* software use (Internet tutorials are available if students are not familiar with this program)
- Internet Use: competence in search skills and http address use

Notes for the Teacher

A general search of coronal mass ejections by students will bring up NASA, SOHO, the Navy and other government and university sites. Most of these are excellent and contain photos, information, tutorials and lesson plans.

You might want to go to the websites prior to student research and data collection. That way you will be familiar with the site and be able to assist students, as well as preview the material to assure it is appropriate and will be useful for your students.

A word document, "CME Information" is in the Appendix section of this document. It gives some additional information about CME's that may be helpful to teachers and students. It reflects information from the website: http://istp.gsfc.nasa.gov/istp/outreach/.

If students have not used *MS PowerPoint*, you will need to prepare a brief introduction, or use one of the tutorials available on the internet.
http://www.fgcu.edu/support/office2000/ppt/ (Office 2000)
http://www.bcschools.net/staff/PowerPointHelp.htm (Office 2000)
http://sun3.lib.uci.edu/~mclweb/ppt1.htm (Office 97 Tutorial)
http://www.actden.com/pp/ (PowerPoint in the Classroom)

Background Information:

The core of the Sun is a nuclear fusion reactor. Reactions in the Sun combine Hydrogen to form Helium, and in the process release energy. A constant stream of ionized particles is ejected from the Sun with temperatures around a million degrees. The particles are collectively referred to as plasma and have a low density and a very high temperature. This ejected plasma is referred to as Coronal Mass Ejections (CME).

Coronal mass ejections are solar equivalents to hurricanes on Earth. They are huge bubbles of gas threaded with magnetic field lines that are ejected from the Sun outer atmosphere over the course of several hours. Complicated magnetic fields burst from the interior of the Sun and extend above its surface as great arches and loops. The buildup and interaction of these magnetic loops seems to supply the energy to heat the Sun's corona and produce the violent explosions of CME's. CME's are billion-ton clouds of electrified, magnetic gas hurled into space at speeds ranging from a few hundred to two thousand km per second with the fastest CME's accelerating to 5 million miles per hour. CME's can take 4 to 5 days to reach the Earth. Particles from the Sun constitute the solar wind that can blow gas and dust from a comet nucleus creating the visual comet tail. The tails always face away from the Sun. This is evidence of the phenomenon of solar wind. (Solar wind is 95% hydrogen and 5% helium.)

The existence of CME's was not realized until the space age. Coronal Mass Ejections disrupt the flow of the solar wind. As CME's plough into the solar wind, they can create a shock wave that accelerates particles to dangerously high energies and speeds. Behind the shock wave, CME clouds fly through the Solar System bombarding planets, asteroids, and other objects with radiation and plasma. Disturbances produced by CME's can strike the Earth and can have catastrophic results. Earth directed CME's can trigger magnetic storms upon entering the Earth's magnetic field, distorting its shape accelerating charged particles trapped within. They are potentially harmful to advanced technology including satellites, radio communications and

power systems. The earliest evidence of these dynamic events came from observations made with a coronagraph from 1971 to 1973. The first solar wind observations were made from Mariner 2 in 1962. Understanding what happens to CME's on their way to Earth is important for assessing their impact on the near-Earth environment.

CME's occur at a rate of a few times a week to several times per day. The size of the plasma clouds ensures that the Earth will be hit on occasion. Fortunately, the Earth is protected from the harmful effects of the radiation and plasma by its atmosphere and its magnetic shield, the magnetosphere that deflects most of the plasma into space. But some particles do enter the magnetosphere funneling in near the north and south poles where the magnetic field is the weakest and partially open to space. It is from this infusion of particles into the magnetosphere that the phenomena known as auroras are produced.

Auroras are the visible sign of the magnetic mayhem in our atmosphere caused by the CME's. The only other way that we can detect this disruption we call space weather, is with special cameras and instruments designed to detect portions of the electromagnetic spectrum outside of the visible portion. Scientists throughout the world utilize highly refined instrumentation and cameras as they participate in a global effort to observe and understand the Sun and its effects on our environment. In addition, more than 25 satellites have been launched into space to observe all key regions of Earth's space; the Sun, the Earth and the space between them. Working together with ground observatories, these spacecraft can now track CME's and other space weather events from cradle to grave. A goal of these endeavors is to someday be able to predict the arrival and effects of CME's.

Included in this unit are several files. The file on *Solar Wind* and *Space Weather* will be helpful background information for the teacher. They can also be given to students as material.

Lesson Overview

This lesson is about CME's (Coronal Mass Ejections) and includes a number of activities. The first activity is calculating the speed of a CME. Then students will do research. The next activity is calculating the velocity and acceleration of a CME. This activity is from the LASCO website. When the calculations have been completed, the students will view data, photos and movie clips from several satellites to help them understand the movement, travel and speed of CME's as they compare the visual information with their calculations. Students will use real satellite data from specific websites and general research from several sources. They will put their findings together in a Microsoft PowerPoint Presentation. They will follow specific directions of what to include. The organization and format of the presentation will be of their design. This is a good way to introduce students to and give them an opportunity to use presentation software as well as apply their knowledge of CME's to a specific project. The final activity will be student presentations of the slide shows to the class.

Classroom Activities:

Activity 1: Create Electronic Portfolio

The students should create a CME electronic portfolio so they have a place to save their electronic documents and photos as they work through this activity. Contact your school technology coordinator for help as needed.

Activity 2: *"Catch a CME"*

This is a lesson from NASA's 'Thursday's Classroom' (http://www.thursdaysclassroom.com/08jun00/teach10.html.
The teacher directions, worksheet and answer sheet are included on the following pages. This is a math lesson calculating the speed of CME's. One class period will be enough, including discussion/debriefing time.

Materials:
- "Catch a CME" Student Worksheet (reproduce and give a copy to each student)
- Pencil or pen
- Calculators

Teacher Lesson Plan – "Catch a CME"

Objective:
The student will use calculators to solve problems concerning fractions and conversions between metric and English units.

Materials:
The students will need calculators and a copy of the activity sheet. There is also an answer key.

Estimated Time:
Although there are not many problems, this could take some students 30 minutes.

Procedure:
1. Distribute the activity sheet. Read the directions and the first problem. Read the problem more than once. Talk about it.
2. Distribute the calculators and let students complete the work with partners or individually.
3. Discuss the results. Which was the hardest problem? Why?

Rationale:
This lesson reinforces calculator skills and familiarizes students with the speeds at which objects in our solar system move.

Resources:
"What Happens on the Sun?" is a web lesson that goes into more detail about CME's and the Sun. It also has a lesson about sunspots. You can view this document at http://education.lanl.gov/programs/lasso/LASSOtchr/Bonnie/sun.htm

Catch a CME -- Answer Key for Student Worksheet (page 43)

Name: _____ Period: _____ Date: _____

Directions: Whip out your calculator and answer the following questions. (Show your steps)

1. A coronal mass ejection (CME) is a gigantic bubble of gas ejected from the Sun. A CME on June 6 headed toward Earth at 908 kilometers per second. How fast is that in kilometers per hour?

There are 60 minutes in an hour and 60 seconds in a minute. So the speed of the CME in km/hr is:

908 km/s X 60 seconds/minute X 60 minutes/hr = 3,268,800 km/hr

2. One kilometer equals 0.6 miles. How many miles per hour was the CME traveling when it left the Sun?

3,268,800 km/hr x 0.6 miles/km = 1,961,280 mph

3. A very fast runner can travel 10 miles in one hour. Is that slower or faster than a CME? How many miles did the June 6th CME travel in one hour?

Its speed is 1,961,280 mph, so in one hour the CME travels 1,961,280 miles.

4. The distance between the Earth and the Sun is 149,597,900 km. If the CME left the Sun traveling at 908 km/s and didn't slow down until it reached Earth, how many seconds would it take to travel from the Sun to the Earth?

149,597,900 km / 908 km/s = 164,755 seconds

5. How many minutes is that?

There are 60 seconds in a minute, so
164755 seconds / 60 = 2746 minutes

6. How many hours is that?

There are 60 minutes in an hour so 2746 minutes/60 = 45.8 hours

7. How many days would it take the CME to reach Earth?

There are 24 hours in a day so 45.8 hrs/24 = 1.91 days

Student Worksheet: Catch a CME

Name: _____ Period: _____ Date: _____

Directions: Whip out your calculator and answer the following questions. (Show your steps)

1. A coronal mass ejection (CME) is a gigantic bubble of gas ejected from the Sun. A CME on June 6 headed toward Earth at 908 kilometers per second. How fast is that in kilometers per hour?

2. One kilometer equals 0.6 miles. How many miles per hour was the CME traveling when it left the Sun?

3. A very fast runner can travel 10 miles in one hour. Is that slower or faster than a CME? How many miles did the June 6th CME travel in one hour?

4. The distance between the Earth and the Sun is 149,597,900 km. If the CME left the Sun traveling at 908 km/s and didn't slow down until it reached Earth, how many seconds would it take to travel from the Sun to the Earth?

5. How many minutes is that?

6. How many hours is that?

7. How many days would it take the CME to reach Earth?

Activity 3: Conducting Research

Have the students search for information about Coronal Mass Ejections. Inform the students to find not only information but to also look for newspaper and magazine articles that covered CME's and their effects on the Earth. Conduct a brief brainstorming session with the students to identify possible sources of information and photographs.

As the students conduct their research, they need to take notes. This can be done electronically, with paper and pencil, or both. Students may need to spend 2 days on this activity.

The students will begin by researching CMEs. They could start with encyclopedias, library books and textbooks, and then extend their search to the Internet. Following are three excellent web sites for student information and instruction. They should be recording their notes in their electronic portfolio. As they find useful photos and movie clips, have them save those to their CME electronic folder for later use when they put the slide show together.

SOHO site
http://sohowww.nascom.nasa.gov/
Select Resources/classroom
Students should view the "Our Start the Sun" and "Terms, concepts, & definitions" choices.

CME's: Solar Flares, and the Sun-Earth Connection
http://hesperia.gsfc.nasa.gov/sftheory/cme.htm

Mission to Geospace
http://istp.gsfc.nasa.gov/istp/outreach/

Activity 4: Measuring a Coronal Mass Ejection

This lesson is from the SOHO site: "Sun Fun Activities" / Measuring a Coronal Mass Ejection, http://sohowww.nascom.nasa.gov/explore/lessons/cme_motion.html

Everything you need to do this activity is on the web page document, or you can use the directions and activity sheets included in the Resources section of this unit plan. It is titled "Measuring a Coronal Mass Ejection." The chart the students need to fill out is imbedded in the directions. The students can make their own chart, or the teacher could make a chart page, copy it, and hand it out to the students, or the chart included with the directions can be used.

Materials Needed:

- Computer with internet access
- Activity directions and worksheet
- SOHO CME Images

Student Questions: (in addition to the worksheet questions)

1. Identify the forces acting on the mass.
2. As the gas bubble moves away from the sun, how does the size change? How do you account for this?
3. In the second frame, there is a portion of the gas that appears to be separating from the rest. In terms of forces, how do you account for the motion?
4. Would you expect the acceleration of the main body and this other portion to be the same? Why or why not?

Student Worksheet
Measuring the Motion of a Coronal Mass Ejection

In this activity you will calculate the velocity and acceleration of a coronal mass ejection (or *CME*) based on its position in a series of images from the LASCO instrument on SOHO.

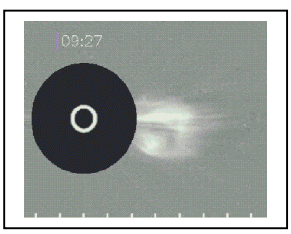
A coronal mass ejection occurs when a significant amount of relatively cool, dense, ionized gas escapes from the normally closed, confining, low-level magnetic fields of the Sun's atmosphere to streak out into the interplanetary medium, or heliosphere. In other words, a large quantity of mass is accelerated by the magnetic field of the corona and travels through space, sometimes towards the Earth. Eruptions of this sort can produce major disruptions in the near Earth environment, affecting communications, navigation systems and even power grids. SOHO with its uninterrupted view of the Sun, can observe such events continually, and allow us for the first time to get a better understanding of how such violent events occur.

Scientists do not yet really understand why CME occur and how to predict them. One important part of the research is to measure the velocity of the CME and trace its acceleration as it leaves the Sun. This is done by tracing individual features in the CME and measuring their positions as a function of time.

One of the main ways we observe CME's is with *coronagraphs*. Coronagraphs are telescopes that simulate total solar eclipses by blocking out the disk of the Sun so we can see its fainter outer atmosphere, the *corona*. On Earth this can be difficult because the Earth's atmosphere scatters the light from the solar disk (that's why the sky is blue). In space, however, this is not a problem. LASCO consists of three coronagraphs with three different occulting disks, each one a different size so we can see a different part of the corona.

Materials:

- SOHO CME IMAGES
- Ruler
- Calculator



At left is an image taken from one of the coronagraphs on LASCO. To the right of the disk, you can see a CME erupting from the Sun. The white circle indicates the size and location of the Sun. The black disk is the occulting disk blocking out the disk of the Sun and the inner corona. The tick marks along the bottom or the image mark off units of the Sun's diameter.

In the following five images, select a feature that you can see in all of the images, for instance the outermost extent of the bright structure or the inner edge of the dark loop shape. Measure its position in each image. Measurements on the screen or page can be converted to kilometers using the simple ratio:

$$D_{image} / d_{actual} = S_{image} / S_{actual}$$

where:

d_{image} is the diameter of the Sun measured on the image

d_{actual} is the actual diameter of the Sun
S_{imag} is the position of the mass as measured on the image
S_{actual} is the actual position of the mass.

The diameter of the Sun = 1.4 X 10^6 (1.4 million) km.

Using the position and time, you can calculate the average velocity. Velocity is defined as the rate of change of position. Using the change in position and the change in time, the average velocity for the time period can be calculated using the following equation:

$$v = (s_2 - s_1)/(t_2 - t_1)$$

where:
s_2 is the position at time, t_2.
s_1 is the position at time, t_1.

The acceleration is the change in time of the velocity:

$$a = (v_2 - v_1)/(t_2 - t_1)$$

where:
v_2 is the velocity at time, t_2.
v_1 is the velocity at time, t_1.

You can record your results in this table:

Universal Time	Time Interval	Position	Average Velocity	Average Acceleration
08:05				
08:36				
09:27				
10:25				
11:23				

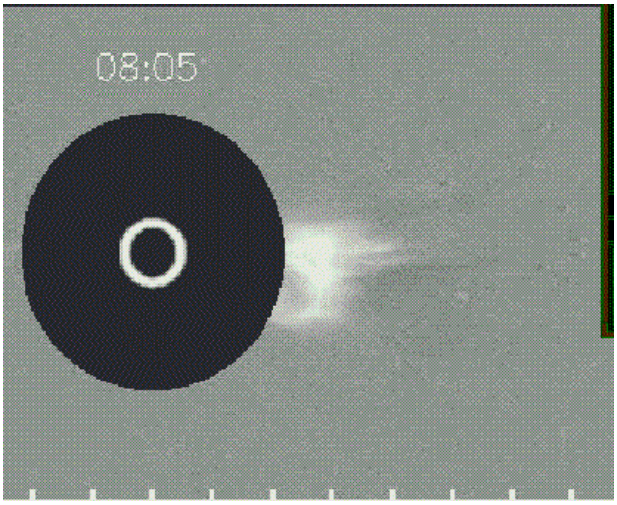
Further Questions and Activities

1. Select another feature, trace it, and calculate the velocity and acceleration. Are they different from those for the last feature you selected?
   Which one is "right"? Scientists often look at a number of points in different parts of the CME to get an overall idea of what is happening.
   Sometimes it can be tough to trace a particular feature. How much error do you think this introduces into your calculations?
2. How does the size of the CME change with time?
3. What kind of forces do you think might be acting on the CME? How would these account for your data? These are important questions in CME research!

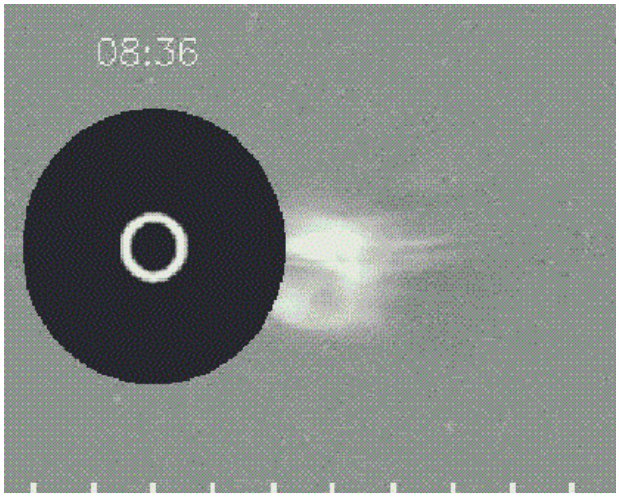
Exploring SOHO data

If you look at the data available from LASCO in the SOHO Gallery (http://sohowww.nascom.nasa.gov/, select Data/Gallery), you will see that the images usually have a circle in the center of the coronagraph disk representing the size and position of the Sun. Using this to find the scale of the image, you can make calculations similar to the one you just did for most sequences of LASCO images. LASCO also observes comets. You can measure their velocities and accelerations too.

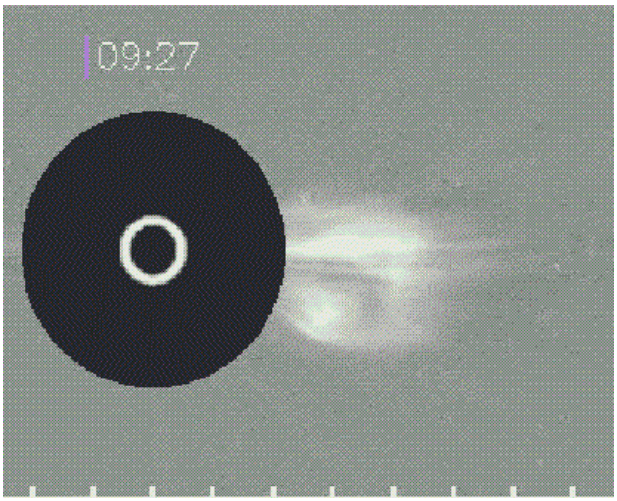
SOHO CME IMAGES



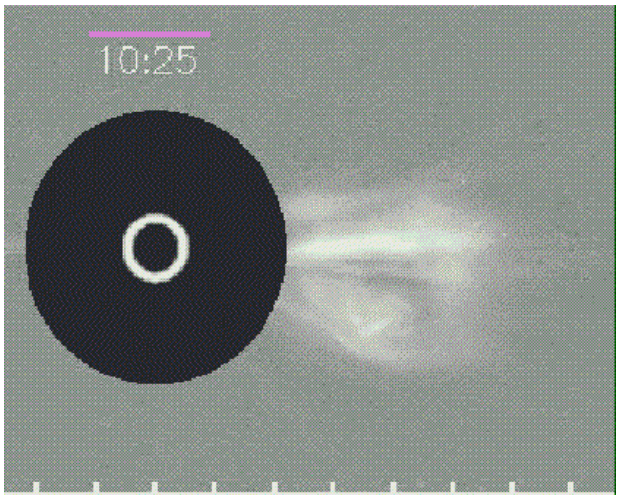
08:05



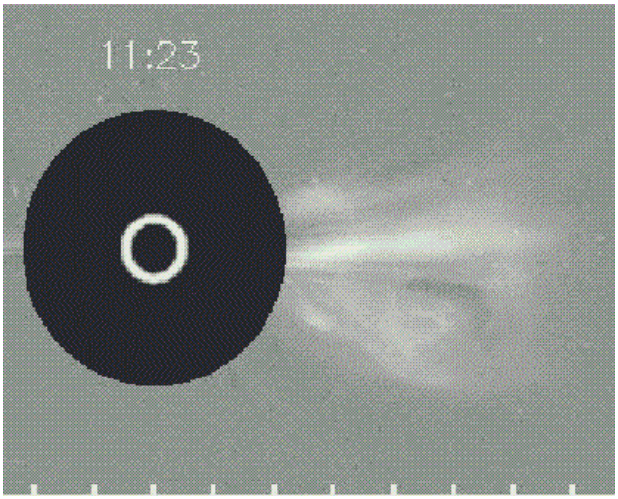
08:36



09:27



10:25



11:23

(images were obtained by the LASCO on the SOHO spacecraft)

Activity 5: Using Satellite Data

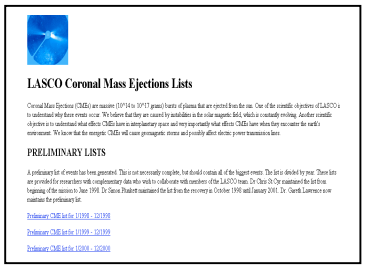
Materials:

- Computer with Internet access
- Pencil and paper

Students or student groups at individual computers or the teacher can do the following activity with an LCD projector and whole class participation. A very important part of this lesson is the discussion of student observations comparing the camera images and the data charts. The teacher may want to preview some of the selections, looking for a particularly active SXT movie clip, so that the students will find comparisons to the charts more easily.

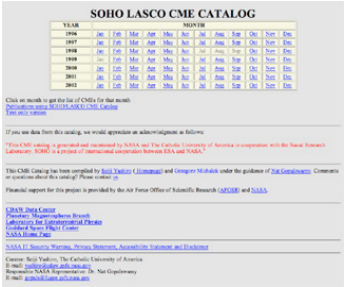
Coronal Mass Ejections (CMEs) are massive (10^14 to 10^17 grams) bursts of plasma that are ejected from the sun. One of the scientific objectives of LASCO is to understand why these events occur. We believe that they are caused by instabilities in the solar magnetic field, which is constantly evolving. Another scientific objective is to understand what effects CMEs have in interplanetary space and very importantly what effects CMEs have when they encounter the earth's environment. We know that the energetic CMEs will cause geomagnetic storms and possibly affect electric power transmission lines.

Begin with the LASCO website.
http://lasco-www.nrl.navy.mil/cmelist.html
You are looking for data from the LASCO lab. Scientists at LASCO have instruments on the SOHO satellite. They download the data from the satellite and make charts and graphs reflecting solar activity.



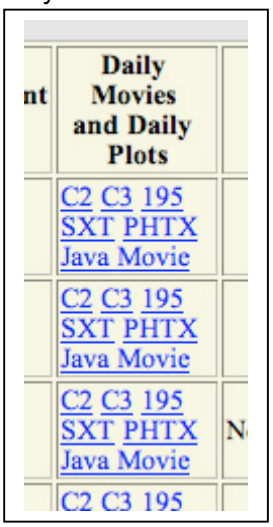
Scroll down to the bottom and select 'CME Catalog'.

This screen will appear:



Select any month and the next screen will look like this:

This activity will be referring to the C3, SXT and PHTX selections from the 'Daily Movies and Daily Plots' column.



nt	Daily Movies and Daily Plots	
	C2 C3 195 SXT PHTX Java Movie	
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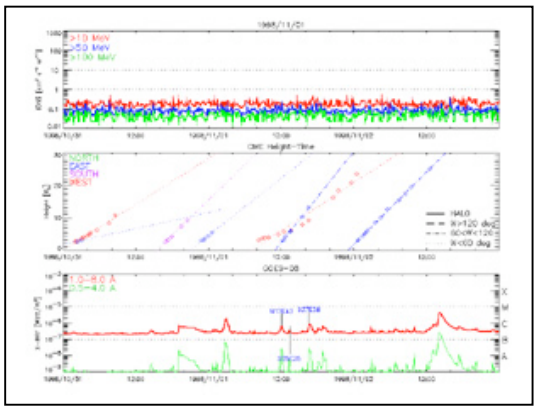
	C2 C3 195	

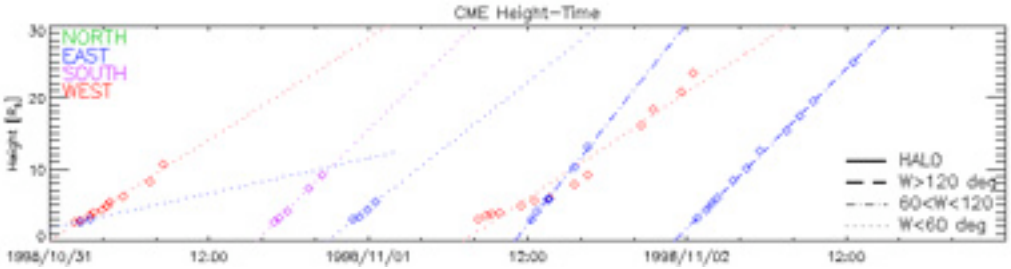
The first selection to go to is C3. These are images taken by the LASCO camera that is on the SOHO satellite. The movie clips move very fast. It is recommended that they be viewed over and over, quickly, then slowly, using the bar at the bottom of the screen. This will enable the eye to have a better chance at grasping the changes taking place. When in slow mode, point out the time lapse of the photos. Students could record those times. The students should be looking for CMEs similar to the one they used to calculate velocity and acceleration. Use the images and worksheets from Activity #3 as a reference for observing CME motion. Discuss how many are occurring and where they are located. This is a movie clip of plasma material moving away from the Sun. Talk about perspective and motion (location of the camera on SOHO compared to the action seen in the clip). Compare it to the previous activity. Discuss student observations and theories of why the clip looks the way it does.

This next selection is SXT. This is a QuickTime movie from the SXT camera on the Yohkoh satellite launched by Japan. It is in low Earth orbit and takes x-ray pictures of the sun. View the movie several times, looking for the fast moving hot spots. Then view it in slow motion, looking for the same hot spots. The students should try to pick out areas of great activity, not necessarily the large, bright areas that do not change. Encourage discussion, sharing of observations and theories.



The third selection, PHTX is plots of proton flux, CME height-time and X-ray flux from the GOES satellite. It shows graphs made from data downloaded from satellites. The students will be using the 2nd and 3rd graphs on this page. (Note: if you are using Internet Explorer, you may need to download the .png file to your desktop and then open with your viewer.)

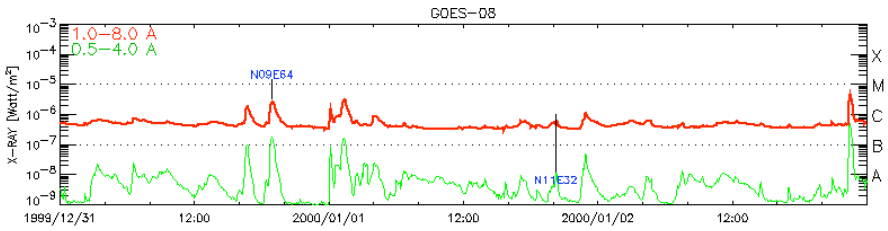
The second graph shows height and time of CMEs. Using that data, velocity and acceleration of CMEs can be calculated. (Keeping in mind Activity #3) The data can be compared to the 'Measuring a Coronal Mass Ejection' activity.



This graph shows the height of the leading edge of CMEs in the corona. Ask the students to select a day from the CME catalog page. If they view the C3 movie and look at the PHTX for that date, they will be looking at a time-lapsed view of solar activity and viewing the data chart

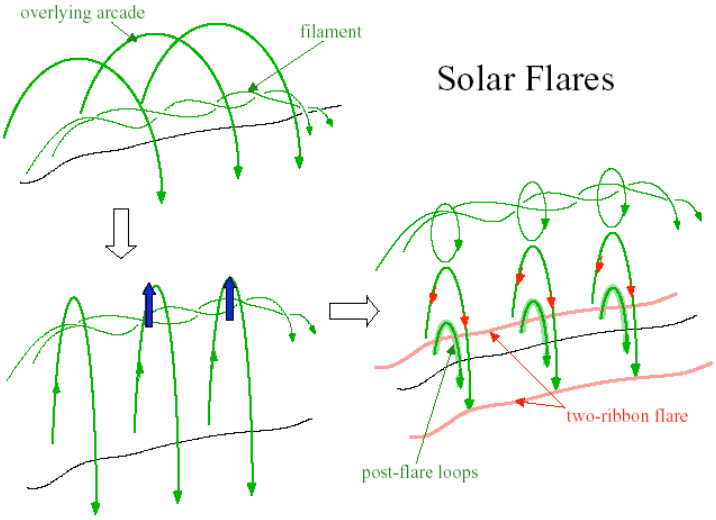
from the same period of time. They should be able to make some comparisons. For example, look at the blue line. The squares are the actual data. The dashed line represents an averaged line. The squares show that the acceleration is not uniform, but the velocity is increasing, because the angle of the line increases. Go back and forth between the SCT movie clip, Activity #3 worksheets and the chart, guiding students to draw conclusions about their observations.

The last data chart on the PHXT choice represents the hottest spots on the corona. It can be compared to the solar activity in the SXT movie clip. This chart is showing x-ray intensity, the SXT is a movie clip of the same activity.



It may help to refer to an Electromagnetic Spectrum chart and locate x-rays. The red line is a lower energy level than the green line. Students could decide where in the x-ray section these two lines might occur. High school students may be able to relate it to angstroms and have a discussion about energy levels, frequency and wavelength as represented on the electromagnetic spectrum. This last chart is showing solar flare activity. Solar flares are an indicator of where CMEs may occur.

Following is a diagram of solar flare activity and how CME's become detached and sent out into space. The filament rises, hits the top of the overlying arcade and becomes a reconnection event resulting in great heat at the reconnection point. The material in the post-flare loop is pulled back down into the sun, but the disconnected material is thrown out into space as a CME. So, as scientists analyze solar data, they look for energy jumps such as in the chart above, then go back and look in the data for that date, looking for CMEs. Solar flare activity is an indication that a CME may occur.



For the Teacher:
Discussion is a very important aspect of this activity. It can be small group directed, or whole class directed. Help the students to see correlations between the visual clip and the graphs. Students should look at several examples. They need to look for jumps in energy, then go to the SXT clip and look for solar flares. Then they can look at the C3 clip and see whether or not there was any CME activity on that date.

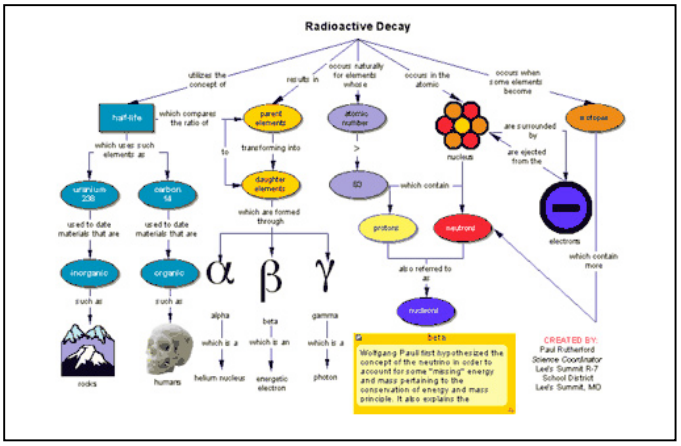
Student Questions:
1. How often do CMEs occur on the Sun?
2. Is there a pattern in the frequency of CMEs?
3. How are solar flares and CMEs related?
4. How are CMEs detetected?

Related Activities/Extensions
Explore how the data is collected.
1. Where are the detectors/instruments? How did they get there? Who designed and built them?
2. What kind of data is sent back to Earth? Or collected on Earth?
3. How is the data translated to charts and graphs?
4. How many satellites have solar data instruments? Where are they? What are they measuring?

Make models of the detectors and/or satellites.
Make solar system maps showing the location and nationality of the solar data satellites.
Set up a solar event reporting mechanism, or add a solar report to the school newspaper.

Activity 6: PowerPoint Presentation

Using *Inspiration* software (a 30 day free trial version of Inspiration software can be downloaded at http://www.inspiration.com/home.cfm) to help brainstorm, plan, organize, outline, diagram, and write, the student groups will be planning and assembling a slide show about CME's. Their first task is to make an *Inspiration* document brainstorming the ideas to include in their slide show. *Inspiration* will help students to organize and categorize their ideas. This will be a graded assignment. The students should make at least 3 levels of idea bubbles past the central idea, CME's.



The students should use their notes as they work on this *Inspiration* document, and as they put the slide show together. Remind students that a *PowerPoint* presentation is visual. The slides can contain text, but not long sentences and paragraphs. They should be encouraged to use words, phrases, lists, bulleted lists, word bubbles, etc. They can think of it as a photo essay with some explanation. Before students actually begin the slide show production, they should meet with the teacher for approval of their plan. The teacher could make suggestions for improvement at that time.

The Project

The groups can divide up the tasks, or make the slides together. They could work on individual machines and combine the slides by using the network. Implement the project in a suitable way for your students and equipment. A *PowerPoint* presentation usually becomes too large for floppy disks after a number of photos (memory hogs) have been added. So, be sure you have an alternate plan for saving and sharing the students' work (Zip disks, CD's, folder on the schools server, etc.). Your Technology Administrator should be able to help with this.

Information to be included in the slide show:

- Description/explanation of a CME
- Vocabulary
- Photos
- Movie clips
- Real data, graphs or charts

Techniques that can be included in the slide show are:

- Insert, position and format text (font, font style, size, color)
- Use a variety of text fields, graphics, sounds and slide transitions
- Insert, position and size clip art and/or photos/charts/diagrams
- Animate (text and/or clip art and/or photos, charts, diagrams)
- Insert action buttons (not necessarily on each slide)

Communication/Content:

- Specific information included
- Ideas clear
- Appropriate use of text (not paragraphs! Who will read them?)
- Background: theme and continuity obvious

Assessment

Grades given for the initial/introductory assignments:
- Notes
- Inspiration web plan
- 2 worksheets completion/evaluation (Catch a CME, Measuring a Coronal Mass Ejection)

Final Grade
- Power Point Presentation (see sample rubric)
- Oral Presentation of slide show to class

Reflection/Extensions

High School students (possible middle school students) could go to one of the satellite data sites, or the LANL (Los Alamos National Laboratory) site and use current chart data and interpret the latest information in terms of CME activity. It could be looked at for the past few months, or the same month for the past few years. They could also make their own 'Measuring a Coronal Mass Ejection' calculations using current data from the LASCO site.

Middle or High School students could look up aurora activity data and compare it to CME activity. They could make a *Microsoft Excel* document that will then generate charts to compare the information more easily.

Middle or High School students could investigate the types of particles that make up CMEs. They would need to know the characteristics of each particle and the average speed of the particles. Students would have to explore the characteristics of the space environment in space the particles travel through. Then ask the students to imagine themselves as one of the CME particles and write a story about their trip toward the Earth. First, the student would decide which particle they would be. Then, as they near the Earth, the student would need to decide where the particle will go: around the Earth and its magnetosphere and out into space, into the magnetosphere to become part of an aurora display or a power/communications interruption event on Earth, or to become entangled within the Earth's magnetosphere.

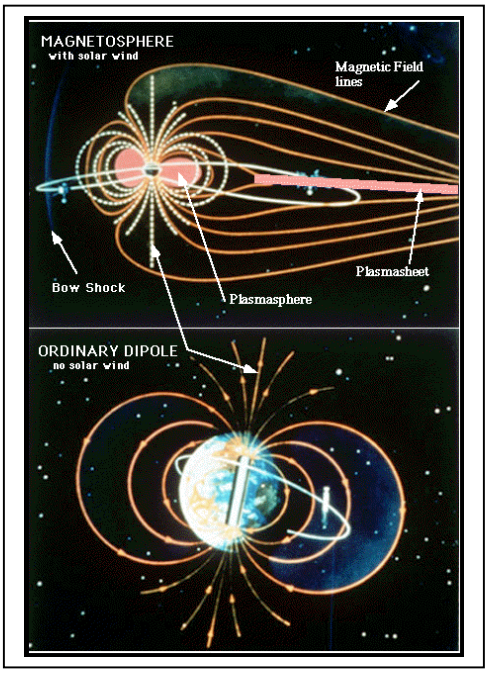
POWERPOINT PRESENTATION RUBRIC

Name: _____ Period _____ Date: _____

Criteria to be assessed	Exemplary 5	Acceptable 4	Partial Success 3	Needs Work 2
Format • Student's Name • Student info included	• Completely correct grammar and spelling • Title pages and slides easy to read • Creative use of technological resources	• Mostly correct grammar and spelling • Title pages and slides easy to read • Some use of technological resources	• Has no more than 5 grammar & spelling errors • Title pages and slides can be read with difficulty • Little use of technology	• Has more than 5 grammar and spelling errors • Title pages and slides can't be read • No additional technology
Communication /Content • TLM skills gained • Projects shown/described	• Specific information provided • Ideas, conclusions, summaries complete • Appropriate use of text (words, bullets, no sentences)	• Some information provided • Ideas, conclusions, summaries not complete • Acceptable use of text (lists, bullets… few sentences)	• Information general • Ideas, conclusions, summaries inadequate • Too much text/too little text	• Little or no information provided • Ideas, conclusions, summaries not present • Text insufficient
Organization • Photo/ illustration of work • Labels included • Final Project	• Order of presentation completely logical • Elements of slide in proper order • Bullets and other organizing aids used appropriately	• Order of presentation mostly logical • Elements of slides mostly in proper order • Bullets and other organizing aids used mostly appropriately	• Order of presentation somewhat confusing • Elements of slides in some proper order • Bullets and other organizing aids used somewhat appropriately	• There was no logical order to the presentation • Elements of slides not in order • Bullets and other organizing aids not used or not used appropriately
Technical Quality of Presentation • Tells the story of your Tech Lab experience	• Background used, theme and continuity obvious • Presentation includes a variety of text fields, graphics, sounds and transitions	• Background used, some theme and continuity obvious • Presentation includes some variety of text fields, graphics, sounds and transitions	• Background used, little theme or continuity obvious • Presentation includes little variety of text fields, graphics, sounds and transitions	• No background • Presentation includes no variety of text fields, graphics, sounds and transitions
Row Totals				

Total Score _____ out of 20 Possible Points = _____%

Earth's Magnetosphere Internet Field Trip



Time:
2 1/2 - 3 1/2 hours

Objective:
The purpose of this activity is to give students exposure to the concepts involving the Earth's Magnetosphere. Students will learn key vocabulary related to the Earth's Magnetosphere and create a cutout magnetosphere. Students will also navigate the Internet to investigate the Earth's Magnetosphere and its importance as related to the sun-earth connection

Content Standards:
Science as Inquiry
- abilities necessary to do scientific inquiry

Earth and Space Science
- earth in the solar system

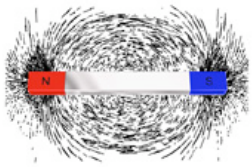
Science and Technology
- understandings about science and technology

Equipment, Materials, and Tools:
- Notebook paper
- Pencils/pens
- One computer per student (or teams of students)
- Scissors (1 pair per student)
- Crayons/Markers/Colored Pencils

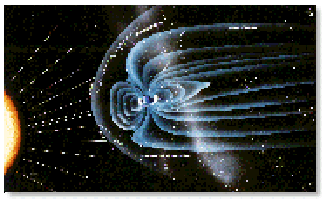
Materials to reproduce
- Earth's Magnetosphere cutout & instruction sheet (1 copy per student)
- Earth's Magnetosphere Vocabulary worksheet (1 copy per student)

Prerequisite Skills:
Internet navigation skills

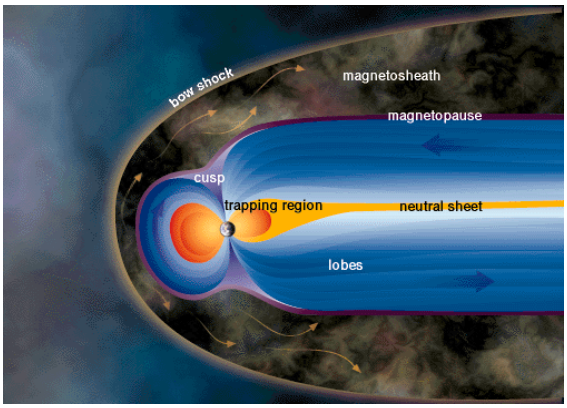
Background Information:
The Earth has a strong internal magnetic field. It is through the use of special instruments that we know this magnetic field exists. The earliest used instrument and probably the simplest is a magnetic compass. The Earth's core, made up of nickel and iron, acts as a giant dipole bar magnet. Its' magnetic field affects the needle of the compass. Without instruments, the Earth's magnetic field is invisible, only the effects on things we can see allow us to realize that it exists.



The Earth's magnetic field extends beyond the surface of the Earth. We know that its magnetic field extends thousands of miles into the area of space surrounding the Earth. The area of space controlled by the Earth's magnetic field is called the magnetosphere. With instrumentation that measures streaming particles, electromagnetic radiation and constantly changing electric and magnetic fields, we have been able to model what the magnetosphere looks like. The Earth's magnetosphere plays a very important part in protecting the Earth's environment as it helps to shield the Earth from the Sun's solar wind.



The solar wind is composed of particles ejected from the Sun. These particles flow from the Sun out into space and can encounter other solar bodies as they move out through the solar system. The Earth's magnetosphere acts as an obstacle to the solar wind particles just as rocks act as obstacles to the flowing water in a river. The particles must move around the obstacle. The solar wind particles are moving at a great velocity that means they cannot move around the obstacle easily. Their movement is disrupted by the magnetosphere and a bow shock region is created and their direction is abruptly changed. The solar wind particles squash the Earth's magnetic field on the solar side and seem to stretch the magnetosphere on the side away from the Sun.



The speed and motion of the particles are changed with most of the particles moving around the magnetosphere in the area known as the magnetosheath, effectively shielding the Earth from the solar wind. Although the solar wind particles cannot travel across the Earth's magnetic field lines, they can travel along them. After passing through the shock wave created at the bow shock, some of the solar wind particles travel along the Earth's magnetic field lines and enter the Earth's upper atmosphere through funnel shaped areas known as the polar cusps. As they hit the upper atmosphere, they release tremendous amounts of energy emitting varying colors of visible light, the auroras.

The magnetosphere is a complex configuration of regions and is a dynamic, constantly changing system guided by the Earth's magnetic field. Within the magnetosphere, we find cold plasma from the Earth's ionosphere, hot plasma from the Sun, and even hotter, highly accelerated plasma entering the Earth's upper atmosphere causing the auroras. The magnetosphere's many regions are; the bow shock, magnetosheath, magnetotail, plasmasheet, lobes, plasmasphere, radiation belts, and many electric currents.

Through the use of spacecraft bourn instruments, we are able to chart the Sun's activity and the responses of the magnetosphere and upper atmosphere over long periods of time. We are striving to understand the physical processes that control this vast, dynamic system, looking for the magnetic link between the Earth's magnetosphere and its atmosphere. The better we understand the processes governing interactions in the solar system, the better we will be able to forecast and accommodate future events that can drastically affect life on Earth.

Lesson Plan:

1. Give every student a copy of the *Vocabulary = Earth's Magnetosphere Student Worksheet* and *Earth's Magnetosphere cutout/instruction sheet*. Write vocabulary terms on the board. Provide approximately 5-10 minutes for students to brainstorm ideas about what the vocabulary terms mean. Read the correct definitions to the students.
2. Instruct students to locate the vocabulary words that are included in the *Earth's Magnetosphere cutout*. As vocabulary words are introduced, students can color in those areas per the *Earth's Magnetosphere instruction sheet*. The students can take notes if they want but do not have to complete the vocabulary worksheet at this time.
3. Explain to students that they will be embarking on an Internet Field Trip of the Earth's Magnetosphere. The purpose of this field trip is to have a better understanding of the Earth's Magnetosphere and its importance to us.
4. Direct students to start at either http://www.windows.ucar.edu/tour/link=/earth/Magnetosphere/overview.html&edu=elem or http://science.nasa.gov/SSL/PAD/SPPB/Edu/magnetosphere/ to begin the on-line Earth's Magnetosphere tutorial. Permit students to explore this site at their own pace but remind them to complete all parts of the tutorial.
5. Encourage students to take notes and to find the definitions for the vocabulary words that were presented earlier in the lesson. Tell students to pay particular attention to these vocabulary words:
   - subsolar point
   - inner radiation belt
   - low latitude boundary layer

   Challenge them to individually find the definitions for these words using the Internet.
6. Make sure that students complete the on-line tutorial for each site. While students are still at their computers, make sure to facilitate a discussion concerning their findings. If a "Smart Board" (electronic white board) is available or a projector is available, use the visual source to complete as a whole group activity.
7. Using the *Earth's Magnetosphere instruction sheet* (you may have to model for students the correct way to build the cutout model) assemble the *Earth's Magnetosphere cutout*. Allow time for students to put together their own models. Provide teacher assistance and/or peer assistance as necessary to complete the model.
8. When students are done with the model, discuss the project with the students as a group. Be sure to include discussion about the on-line tutorial as well. Some questions to ask:
   - How did the on-line tutorial/model give you a clearer picture of the Earth's Magnetosphere?
   - Was one site more helpful than another one? Why or why not?
   - What vocabulary words are easy for you to remember?
   - What vocabulary words are you having difficulty understanding?
   - If you could make your own model of the Earth's Magnetosphere how would it be different or similar to the on-line models or cutout models?
   - What kinds of other materials could you use to make a different model of the Earth's Magnetosphere?
   - What part of the magnetosphere would you like to learn more about?

Assessment:

- Students will work individually on this assignment.
- The students will create an original model of the Earth's Magnetosphere.
- They are to provide accurate labels for each aspect of the model.
- **No paper drawings will be accepted**. Invite students to use their imagination to create the Earth's Magnetosphere models (Computer models, 3-D models, cutout models are some examples).

- This assignment could be an in-class assignment or a homework assignment at the teacher's discretion.

Assessment Criteria for Models:

- The Earth's Magnetosphere model has all components and is labeled accurately.
- Students have created an original model (not copied).

Extensions:

Students may visit the site or find sites on their own to explore further the Earth's Magnetosphere.
http://www-istp.gsfc.nasa.gov/Education/wms1.html

Teacher key - Vocabulary terms and definitions (see student worksheet):

Atmosphere: The layer of gas surrounding the earth or other planets. The *upper* atmosphere is the region of the Earth's atmosphere above the troposphere (which extends to about 20 km). Regions of the upper atmosphere are the stratosphere, mesosphere and thermosphere.

Bow Shock: a sharp front formed in the solar wind ahead of the magnetosphere, marked by a sudden slowing-down of the flow near Earth. It is quite similar to the shock forming ahead of the wing of a supersonic airplane. After passing near Earth, the slowed-down flow gains speed again, to the same value as the surrounding solar wind.

Convection (magnetospheric): large-scale plasma flow, circulating in the magnetosphere and driven by the solar wind. Plasma physics requires such circulation to be associated with an electric field. Assuming that the electric field propagates along magnetic field lines (as it would along good conductors of electricity) and reaches the polar ionosphere, corresponding electric fields should be observed above the polar caps, and such fields exist.
In the view proposed in 1961 by Axford and Hines, plasma near the flanks is dragged tailwards by the adjoining solar wind flow, through the action of "viscous-like forces"; in the view suggested that same year by Dungey, plasma travels tailward on "open" field lines following reconnection. Evidence suggests both processes contribute. In both models the plasma returns earthward in the plasma sheet near midnight, a process that could be not continuous but intermittent, associated with substorms.

Cusps (of the magnetosphere)**:** two regions of weak magnetic field, on the sunward boundary of the magnetosphere, one on each side of the equator. They separate magnetic field lines closing on the front from those swept into the Earth's magnetotail.

Electron: a lightweight particle, carrying a negative electric charge and found in all atoms. Electrons can be energized or even torn from atoms by light and by collisions, and they are responsible for many electric phenomena in solid matter and in plasmas.

Electromagnetic Field (EM field)**:** the regions of space near electric currents, magnets, broadcasting antennas etc., regions in which electric and magnetic forces may act. Generally the EM field is regarded as a modification of space itself, enabling it to store and transmit energy.

Ion: usually, an atom from which one or more electrons have been torn off, leaving a positively charged particle. "Negative ions" are atoms that have acquired one or more extra electrons and clusters of atoms can also become ions.

Ionosphere: a region covering the highest layers in the Earth's atmosphere, containing an appreciable population of ions and free electrons. The ions are created by sunlight ranging from the ultra-violet to x-rays. In the lowest and least rarefied layer of the ionosphere, the D-layer (around 70 km or 45 miles), as soon as the Sun sets the ions and electrons recombine, but in the higher layers, collisions are so few that its ion layers last throughout the night

Magnetopause: The boundary of the magnetosphere, separating plasma attached to Earth from the one flowing with the solar wind.

Magnetosheath: the region between the magnetopause and the bow shock, containing solar wind that has been slowed down by passage through the bow shock. As the magnetosheath plasma streams away from the bow shock, it gradually regains its former velocity.

Magnetosphere: The region around Earth, bounded by the magnetopause, whose processes are dominated by the Earth's magnetic field.

Magnetotail: The long stretched-out nightside of the magnetosphere, the region in which substorms begin. It starts about 8 Earth radii (RE) nightward of the Earth and has been observed to distances of at least 220 RE.

Particle: in general, a charged component of an atom, that is, an ion or electron.

Plasma: a gas containing free ions and electrons, and therefore capable of conducting electric currents. A "partially ionized plasma" such as the Earth's ionosphere is one that also contains neutral atoms.

Plasma Sheet: a near-equatorial layer of denser plasma in the tail of the Earth's magnetosphere. It separates the two tail lobes, the two bundles of magnetic field lines connected to the regions around the Earth's magnetic poles.

Solar Corona: the outermost layer of the Sun's atmosphere, visible to the eye during a total solar eclipse; it can also be observed through special filters and best of all, by X-ray cameras aboard satellites. The corona is very hot, up to 1-1.5 million degrees centigrade, and is the source of the solar wind.

Solar Flare: a rapid outburst on the Sun, usually in the vicinity of active sunspots. A sudden brightening (only rarely seen without special filters) may be followed by the signatures of particle acceleration to high energies--x-rays, radio noise and often, a bit later, the arrival of high-energy ions from the Sun.

Solar Wind: hot solar plasma spreading from the solar corona in all directions, at a typical speed of 300-700 km/sec. It is caused by the great heat of the corona.

Tail lobes: the two bundles of nearly parallel magnetic field lines which stretch into the magnetotail, on opposite sides of the plasma sheet. The northern lobe contains field lines entering the North Polar Region of Earth, while the southern lobe contains lines emerging from the southern polar region.

Name: _____ Period: _____ Date: _____

STUDENT WORKSHEET
VOCABULARY - EARTH'S MAGNETOSPHERE

Atmosphere:

Bow Shock:

Convection:

Cusps:

Electron:

Electromagnetic Field:

Ion:

Ionosphere:

Magnetopause:

Magnetosheath:

Magnetosphere:

Magnetotail:

Particle:

Plasma:

Plasma sheet:

Solar corona:

Solar flare:

Solar wind:

Tail lobes:

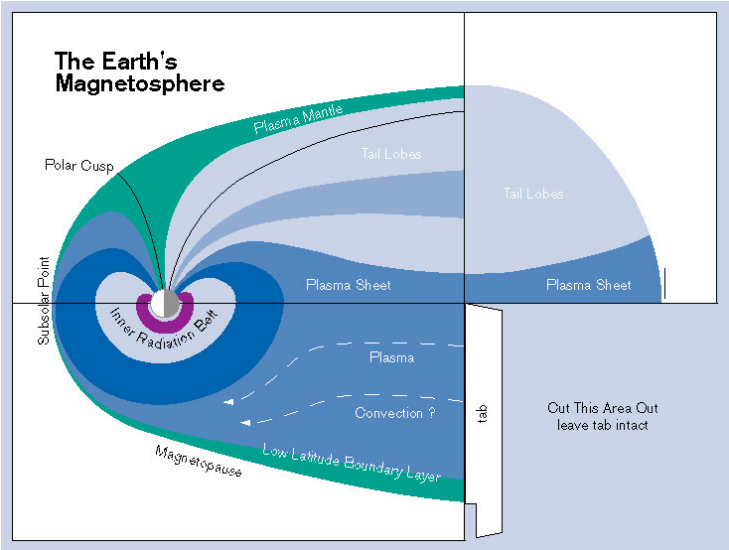
Folding Paper Model of the Magnetosphere

Below are instructions for making a simple paper model of the magnetosphere, out of a single sheet of paper.

Print the image, and then fold the printout or a Xerox copy of it (preferably, one copied onto thick "construction" paper) according to the instructions.

Instructions

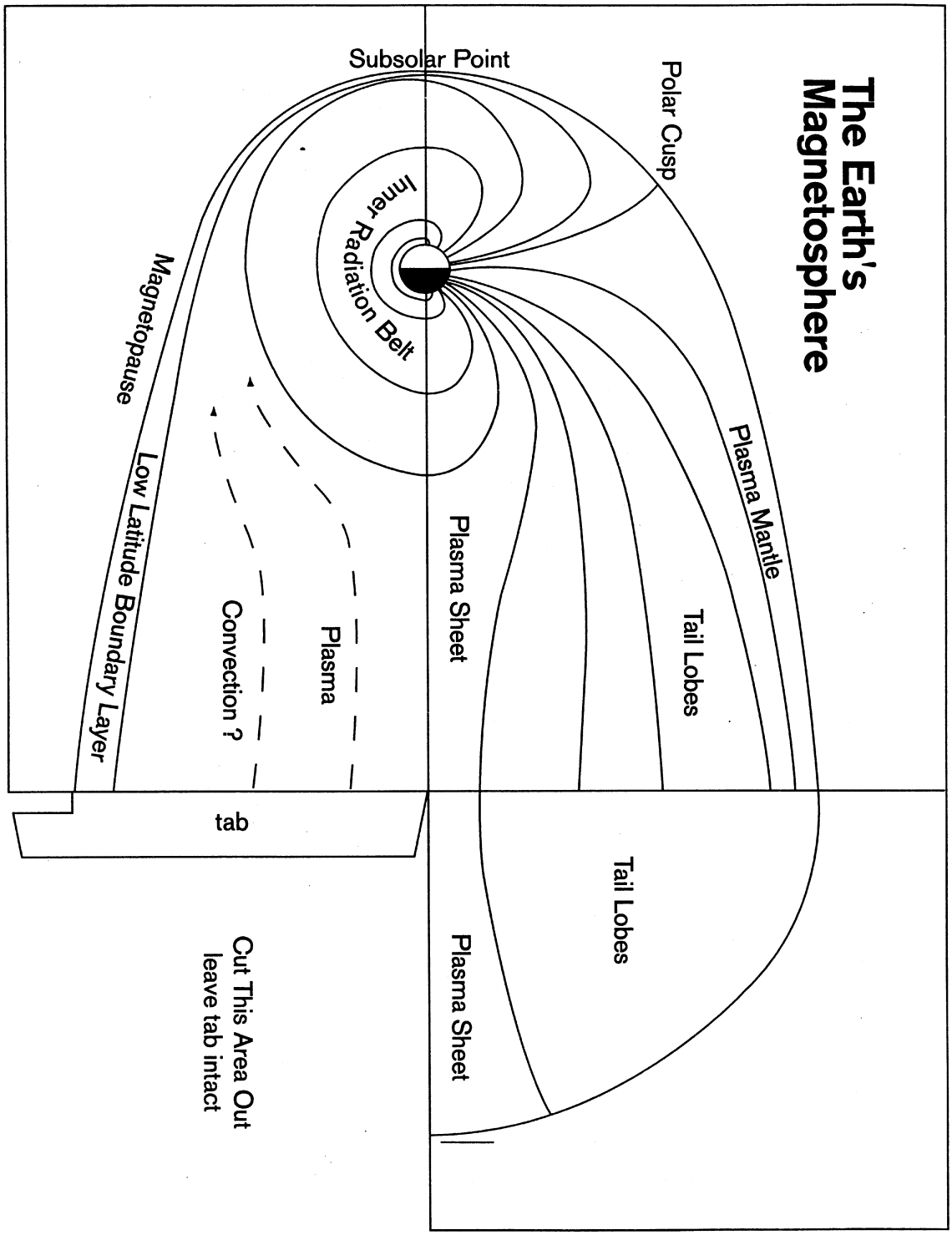
- If the black-and-white image is used and you wish to color different regions, do that first. Colors may distinguish the Plasma Sheet (including area marked "Plasma Convection?"), Plasma Mantle and Low Latitude Boundary Layer (use same color), Tail Lobes and Inner Radiation Belt. The region outside the magnetosphere (in the solar wind) may be left white or given a light color. You may link to the color image above and use it as a guide.
  - **Note** that lines on the bottom of the model (the part which will be horizontal after assembly) are boundary lines between regions, while lines on the long vertical section are magnetic field lines. However, those field lines that connect to boundary lines on the bottom piece also form part of the region boundaries.
- Using a straightedge, score the paper by drawing hard lines along the two main crossed lines with a ballpoint pen (preferably black) or with a stylus.
- Cut out the area marked "Cut Out" but leave tab intact.
- Crease along the scores, and then fold to produce a three-sided corner with the printed picture on the inside.
- Use tape to attach the tab to the backside of the panel carrying the words "Tail Lobes" and "Plasma Sheet," to hold the paper in its folded position. If no tape is available, carefully cut a slot in the marked place to the right of the words "Plasma Sheet" and insert the end of the tab.



Sample of color version available on web at
http://istp.gsfc.nasa.gov/Education/figures/cutout2.jpg

The Earth's Magnetosphere Cutout/Instructions courtesy of:
http://istp.gsfc.nasa.gov/Education/wfold.html

Student Worksheet – The Earth's Magnetosphere - Cutout



Space Weather Effects

Time:
4 hours

Objective:
Using the Internet, students will investigate some of the other effects of space weather. This lesson is designed to present an overview of some of the effects of space weather. It is also designed to allow students to use the data and information they gain to present a Space Weather forecast. This lesson will work best if groups of 4-5 students are formed.

Content Standards:
Meets National Science Education Standards:
- Science as Inquiry
  - abilities necessary to do scientific inquiry
- Earth and Space Science
  - earth in the solar system
- Science and Technology
  - understandings about science and technology

Equipment, Materials, and Tools:
- Pencils/pens
- Notebook paper
- One computer per student
- Access to Internet

Materials to reproduce
- Space Weather Effects worksheet
  1 copy per group

Prerequisite Skills:
Internet navigation skills

Background Information:
Although the interplanetary medium between the Sun and the planets was once considered a perfect vacuum, we now know that it is actually a turbulent region dominated by the solar wind. Changing conditions on the Sun affects the characteristics of the interplanetary medium and its effect on bodies that the solar winds encounter.

As the solar wind flows around obstacles it too is affected by magnetic field lines such as those created by the Earth's magnetic core. Under the influence of the solar wind, the Earth's magnetic field lines are compressed on the solar side and stretched on the downwind side, the Earth's magnetosphere. The interface between interplanetary space and the Earth's magnetosphere is very dynamic. As the magnetosphere extracts energy from the solar wind particles, internal processes produce major terrestrial results such as aurora, proton events, and geomagnetic storms.

Solar wind particles entering the Earth's upper atmosphere strike the molecules of the thin atmosphere transferring energy and giving off a glow of different colors. Although beautiful, the aurora created by the energized solar wind particles are a visible sign of atmospheric changes that can wreak havoc on modern technological systems.

Energetic protons sloughed off during major solar flares can reach the Earth within 30 minutes. These protons can shower the Earth, spiraling down to the Earth's magnetic field lines, penetrating the upper atmosphere and producing additional ionization that can produce significant increases in the level of radiation in the environment.

These geomagnetic storms can have dire effects on modern communication systems utilizing the ionosphere to reflect radio signals from one location on the Earth to countless others. Ionospheric storms can affect radio communication at all latitudes by causing rapid fluctuating signals and unexpected propagation paths. High frequency communications disrupted include: ground-to-air, ship-to-shore, Voice of America, Radio Free Europe, and amateur radio. High frequency operations rely upon solar and geomagnetic alerts to keep their circuits running. In addition, some military early-warning and detection systems can be affected, as can aircraft communications. It is important that operators of these types of systems receive alerts of a proton or geomagnetic storms in progress so they can switch to backup systems thus protecting their main systems.

Geomagnetic storms can also cause the orbits of satellites to change as the Earth's upper atmosphere is heated by solar particles, causing it to rise and increase the density at the satellites orbital path. The increased density produces increased drag causing the satellites to slow down and change orbit slightly. Miniaturized instrumentation and communication systems on spacecraft are highly susceptible to energetic solar particles.

Humans in space are also susceptible to highly energetic particles. Although we are protected on the surface by the Earth's atmosphere and magnetosphere, astronauts (and cosmonauts) can be subjected to lethal doses of radiation. Taking a space walk during a geomagnetic storm is a high-risk adventure and not recommended.

Geomagnetic storms can generate nearly direct current flow across conductors normally transmitting alternating currents. These direct currents are harmful to electrical transmission lines and can cause wide spread electrical outages. Fluctuating geomagnetic fields can induce currents in pipelines causing transmission of erroneous flow information and even increasing the corrosion rate of the pipeline itself. The result can be catastrophic leaks.

We have only begun to realize the affect that magnetic storms have on our daily lives. As our technological expertise advances, and our dependence on technology grow, the list of consequences grows proportionally. Thus there will be a need for continuing our efforts to understand our space environment.

Visit these links to find out about the other effects that space weather has on Earth:
http://www.sel.noaa.gov/primer/primer.html
http://www.sel.noaa.gov/Education/
http://www.sel.noaa.gov/Data/

Lesson Plan:

1. Provide 5-10 minutes for a brainstorm session with students about some of the other effects (besides auroras) that space weather might have on earth. Make sure to write students' answers on an overhead/board.
2. Handout the *Space Weather Effects* worksheet to every group.
3. Direct students to http://www.sel.noaa.gov/Education/ to begin this lesson.
4. Students are to investigate the website to find out more about the effects of Space Weather and to complete the worksheet.
5. Students should also focus on the data that helps monitor and predict Space Weather.
6. After students have completed the worksheet, allow time to discuss their findings in a large group setting.

Assessment:

1. In groups or individually, students will produce a simulated newscast for the evening news that discusses today's Space Weather and forecasts the following week's Space Weather. To prevent duplicity you might want to assign specific dates for each group's newscast.
2. Students should follow a news channel's weather format to create their newscast. Assign each group a news channel to watch at home to find out what type of format is used. Each group should have a script to work from and they should also provide pictures and/or videos to accompany the forecast.
3. Students will need to talk about the forecast in terms of the effect that it will have on Earth, if any. If there are no predicted effects on Earth for that day or week then that should be mentioned in the broadcast.
4. The following site has links to other Space Weather web-sites for students to find out information for their project:
   - http://www.sel.noaa.gov/sources.html

   Assessment Criteria:
   - Every group member has contributed to the newscast.
   - Newscast follows a news channel's format.
   - Information about Space Weather forecast is accurate.
   - Script and pictures are used in presentation.
   - Students talk about how the Space Weather forecast will impact the Earth.

Space Weather – Student Worksheet

Name: _____ Period: _____ Date: _____

1. What types of systems on Earth does Space Weather affect?

2. How do these systems relate to the functioning of our society? How are you affected individually?

3. What types of Space Weather warnings are in effect for today? This week? This month?

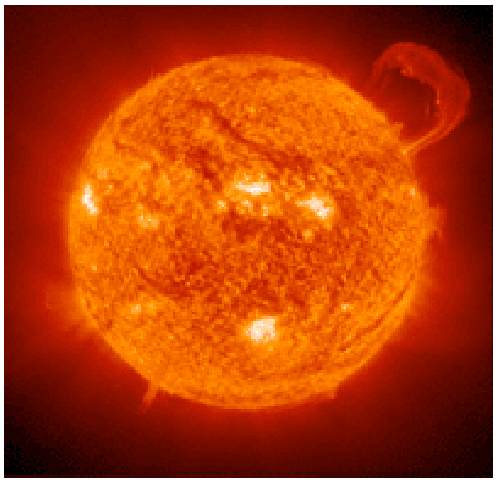
4. What types of satellites monitor Space Weather?

5. Identify one Space Weather satellite that is currently in use. What instruments are used on that satellite to collect data on Space Weather? What type of data do the instruments collect?

SOLAR WIND DATA ANALYSIS

Objectives:

Students will learn how to understand and interpret solar wind data. Students will plot temperature and speed on semi-log graphing paper while working in cooperative groupings. The students/teacher will compile and compare results and discuss their findings.

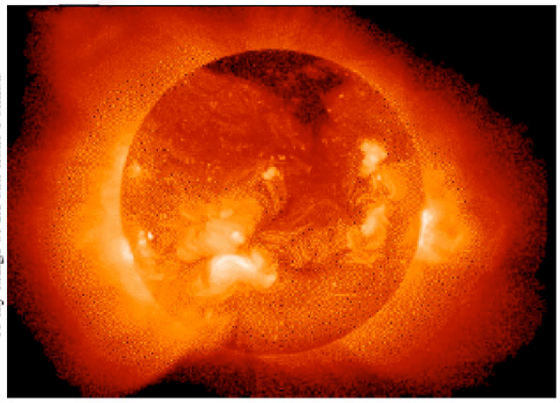


Prerequisite Skills for Students

1. Students must have a basic understanding of the solar system; the Sun being the heart of the solar system with the planets revolving around it.
2. Students must have an understanding of solar dynamics.
3. Students must have a basic understanding of atomic structure (protons, electrons, and
4. nuclei).
5. Student must have basic graphing skills.
6. Student must have knowledge of Scientific notation.
7. Student must have a basic understanding of satellite uses.
8. Students must understand the concept of solar wind.
9. Student will need to be introduced to solar wind data sheets, and the symbols used to identify each measurement.

Background Information:

The Sun is the Heart of the Solar System



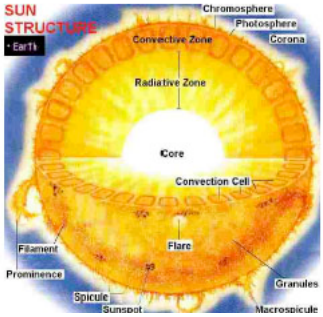
X-ray image of the sun from Yohkoh

The Sun is the heart of the solar system. The Sun is a dynamic, bright sphere, of mostly ionized gas. It is approximately 4.5 billion years old. It is the closest star to the earth.

The Sun supports life on earth by powering photosynthesis in green plants and is the source of all food. The Sun is the driver of earth's seasons, currents in the ocean, weather, and climate.

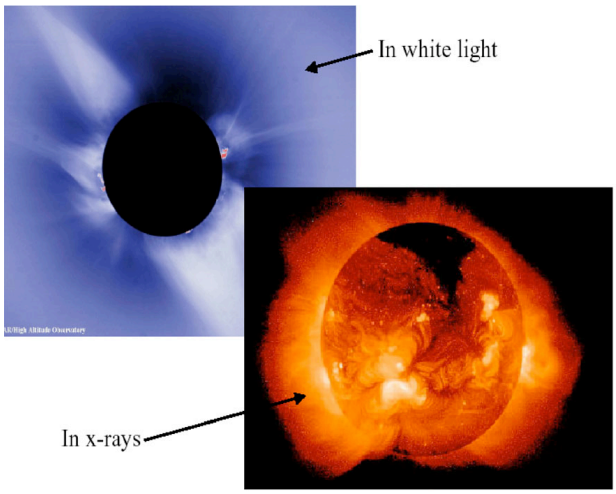
The temperature at the Sun's core is 16 million degrees Kelvin (K). This temperature is sufficient to sustain thermonuclear fusion reactions. The released energy prevents the collapse of the Sun and keeps it in gaseous form. The energy at the core of the Sun is equivalent to the energy generated by 100 billion tons of TNT exploding each second.

The interior of the Sun has two distinct regions. There are two zones known as a Radiative Zone and a Convective Zone. The temperature from the core decreases as it travels through these zones to the surface.



The surface of the Sun is known as the Photosphere. Above the Photosphere lies the Chromosphere. ("sphere of color") Above the Chromosphere lies the Corona ("crown"). This Corona extends outward from the Sun in the form of the "solar wind" to the edge of the solar system.

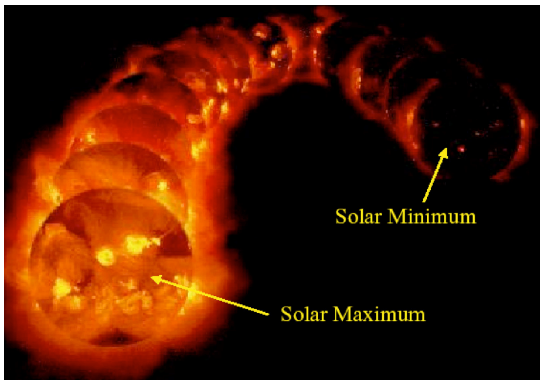
The Corona: Gateway to Interplanetary Space



Solar flares occur when magnetic energy that has built up in the solar atmosphere is suddenly released. During a flare, particles, including electrons, protons, and nuclei are heated, accelerate in the solar atmosphere, and large flares of x-rays are emitted. The amount of energy released is equal to millions of 100-megaton hydrogen bombs exploding at the same time. Another major dynamic event that occurs when magnetic energy is released is coronal mass ejections (CME's). Coronal mass ejections are huge bubbles of gas ejected from the corona over the course of several hours.

The following figure displays the solar variability during Solar Minimum and Solar Maximum. The brightest areas seen are known as Sunspots. Sunspots are dark regions of relatively cool material located within areas of strong magnetic fields known as active regions.

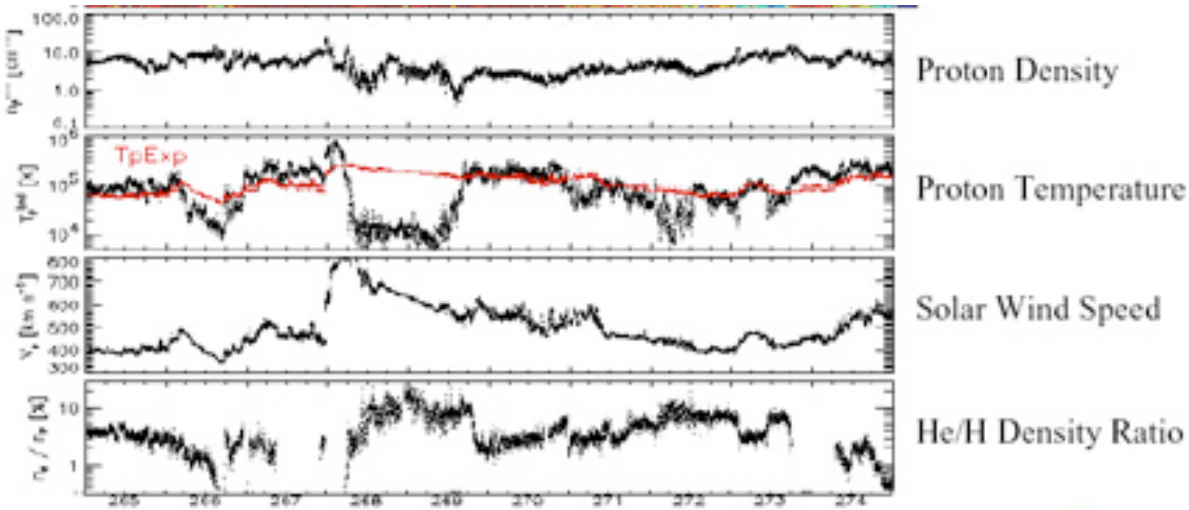
The number of Sunspots exhibits an 11-year cycle, known as the Sunspot cycle. There are two references for the cycle labeled solar minimum and solar maximum. Solar minimum will contain few Sunspots whereas the solar maximum is the most active range in the cycle containing several to many Sunspots. During solar maximum, the frequency of solar activity, like flares and CME's, increases; and there are correspondingly more disturbances in the solar wind.



Solar wind and solar storms are monitored by satellites and studied by Space Scientists because the wind causes effects on the earth's magnetic field. The "space weather" phenomena generally do not effect people on the Earth's surface, although they can occasionally cause power outages and damage to pipelines at high latitudes. They do produce hazards for spacecraft and they alter the communications properties of the Earth's atmosphere.

Solar wind is monitored and measured by various satellites (ACE, Genesis, and Ulysses). Instruments on these satellites collect data from which we derive the solar wind velocity, density, and temperature.

The following diagram displays actual data from the ACE satellite in 1998. The device sending the data to the scientists is called an electronic analyzer (or a plasma spectrometer) developed at the Los Alamos Laboratories. The measured solar wind properties are labeled at the right of the figure. (He = Helium, H = Hydrogen)



HELPFUL NOTES FOR THE TEACHER

(The following information is a short review for the students)

Atom: Smallest unit of matter that can be identified as a given *element*

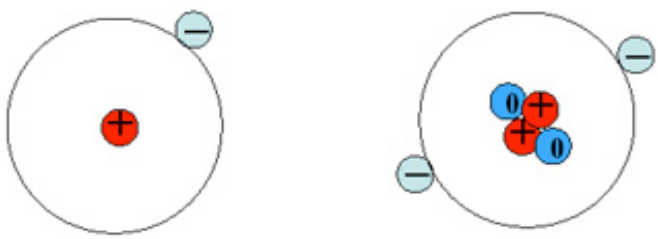
Nucleus includes:

positively charged particles – protons ⊕

electrically neutral particles – neutrons 0

Negatively charged particles – electrons ⊖ – "orbit" the nucleus

Number of protons determines which element the atom is



Protons ⊕

positive electrical charge

mass = 1.67×10^{-27} kg

Neutrons 0

no electrical charge

mass = 1.67×10^{-27} kg (approx. same as proton)

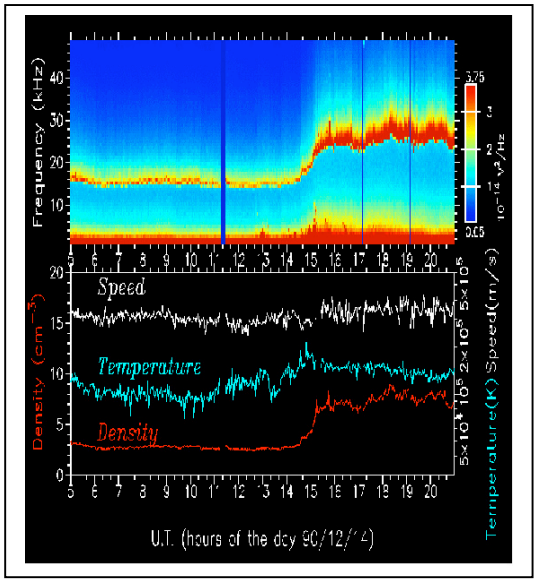
Electrons ⊖

negative electrical charge

mass = 9.11×10^{-31} kg = proton mass / 1800

Solar Wind Graphing and Analysis

Lesson Plan - Solar Data Plots and Graphing



Time:

3 hours

Objective:

Students will complete activities discovering the correlation between the temperature and speed of solar wind. Students will be able to plot data on a semi-log graph, analyze results from the graph, and then draw conclusions.

Content Standards:

For grades 7th through 12th (can be adapted to lower grade levels)

K-4:

- Earth and Space Science Standards 2 and 3;
- Science and Technology 2 and 3;
- Physical Science full standard

Grades 5-8:

- Physical Science 2;
- Science as Inquiry 1 and 2
- Science and Technology 1 and 2

Grades: 9-12:

- Science as Inquiry 1 and 2;
- Earth and Space Science Standards 1;
- Science and Technology 1 and 2;
- History and Nature of Science Standards full standard

Equipment, Materials and Tools:

For the teacher:

- Photocopier (for transparencies and copies)
- Overhead projector
- Questions and answers

For the students:

- Transparency copy of Figure 6 (semi-log graph worksheet) (one per group or pair)
- Transparency marker (one per group or pair)
- Figure 4 Velocity and Temperature Data Pages (7 pages of various months and days) (one per group or pair)

Materials to reproduce:

- Figure 4: Speed and Temperature Data Pages (7 pages of various days in 1999 and 2000)
- Figure 6: (semi-log graph worksheet) make transparency
- Figure 7: Solar Wind Plot (ACE/SWEPAM data Sheet)

Additional materials for the teacher:

- Facts for the Teacher: Part I (Auroras)
- Facts for the Teacher: Part II (Multicultural Mythology)

Procedures:

PART 1:

Explain to students the objective of this lesson – the students will learn how to read and analyze solar wind data relayed from a satellite. The students will then graph specific solar wind speeds and temperatures on semi-log graph paper, then analyze and discuss results.

PART 2:

A. Hand out copies of Solar Wind Plot - Figure 7 (ACE/SWEPAM data sheet) (one per student)

B. Review and discuss each part of the Plot
(Plot = a measurement of solar wind properties):

- Na/Np = percent of Helium in the solar wind. (More precisely the ratio of Helium to Hydrogen. Note the solar wind is mostly Hydrogen.)
  - N = density,
  - a = alpha particles which are Helium with two electrons removed,
  - p = protons which are Hydrogen with one electron removed.

- Bz (nT) = indicates whether the magnetic field within the solar wind is pointing north or south. If the magnetic field is pointing south it will have a negative charge. When a solar wind has a negative charge, there is a higher chance the solar wind will effect the Earth's system.
  - (nT = nano-tesla, a unit of magnetic field strength)

- Vp = speed of solar wind (this will be plotted on the x-axis of a semi-log graph in part 4 of this lesson)

- Tp = temperature (measured in Kelvin) of solar wind (this will be plotted on the y-axis of a semi-log graph in part 4 of this lesson)

- B (nT) = measures the strength of the magnetic field within the solar wind.

  Np (cm^{-3}) = Density of Hydrogen in the solar wind. The number of protons (per unit volume) centimeters

PART 3:

A. Hand out Figure 6, transparency of Semi-log Graph Sheet (one per group or pair)

- Guide students in the process of labeling the Semi-log Graph transparency.
  - Instruct the students to title the graph *Solar Wind Temperature and Speed*
  - Instruct students to label the y-axis as *Temperature in Kelvin (K^0).* Explain the scientific notation on this y-axis:
    - y-axis starts with 10,000, this represents 1×10^4, each line going up increases, starting with 2×10^4, 3×10^4, 4×10^4 and so on. Thus, 100,000 represents 1×10^5, each line going up increases 2×10^5, 3×10^5, 4×10^5 and so on. 100,000 is 1×10^6.
  - Instruct the students to label the x-axis as *Speed in kilometers per second (km/s) Explain* that the x-axis increases in value by 20:
    - *x*-axis starts with 300, each line represents an increase of 20: **300**, 320, 340, 360, 380, **400**, 420, 440, 460, 480, **500** etc.

PART 4:

A. Hand out Figure 4: Speed and Temperature Data Pages (one per group or pair)

- Explain to students they are now specifically reading solar wind speed and temperature data from a given day in 1999 or 2000.
- Ask students to look for a possible correlation between speed and temperature.
- Students should work in small groups of 3 or in pairs to complete graph. Each group or pair should be given a different symbol to use to show their solar wind information on the graph (i.e. "+", "x", "**.**", "#", etc.).
- Each group or pair of students should use a different color marker to distinguish data more clearly between each transparency graph.

PART 5:

A. After each group has completed the graph, each group or pair will place their completed graph on the overhead.
B. Ask students to locate:
   - the highest temperature,
   - highest speed,
   - lowest temperature, and
   - lowest speed on their graph,
   - have students write it on the board under their year/day (example: 1999/364: highest temperature 3×10^5).

PART 6:

A. After each group or pair has discussed their graph, collect all completed graphs; overlay each graph consecutively on the overhead projector beginning with 1999/364.
B. Ask students if they notice any patterns, similarities, differences, or points of significance. (*Note: This is the vital point in making sure all groups use different color markers when graphing onto transparency)

PART 7:

Analysis and conclusions: Questions for reflection

1. Is there a relationship between speed and temperature of solar wind?
   (*Note: This is not an absolute but only a general trend - higher speeds mean higher temperature and lower speeds mean lower temperatures)

2. What deductions can be made with all the graphs put together?

3. What does this pattern tell us?

4. What conclusions can be made after looking at this data?

5. Can you use this graph as a predictive tool when observing solar wind activity?
   (Reminder: This is a general trend not an absolute of how temperature and speed interact with one another, therefore only general predictions can be made from the data on the graph)

6. If the speed of solar wind was 450, what could you predict your temperature to possibly be?
   (Note: Possible answer 7×10^4)

Materials for Activity:

Figure 1: Solar Wind Spectrogram from ACE

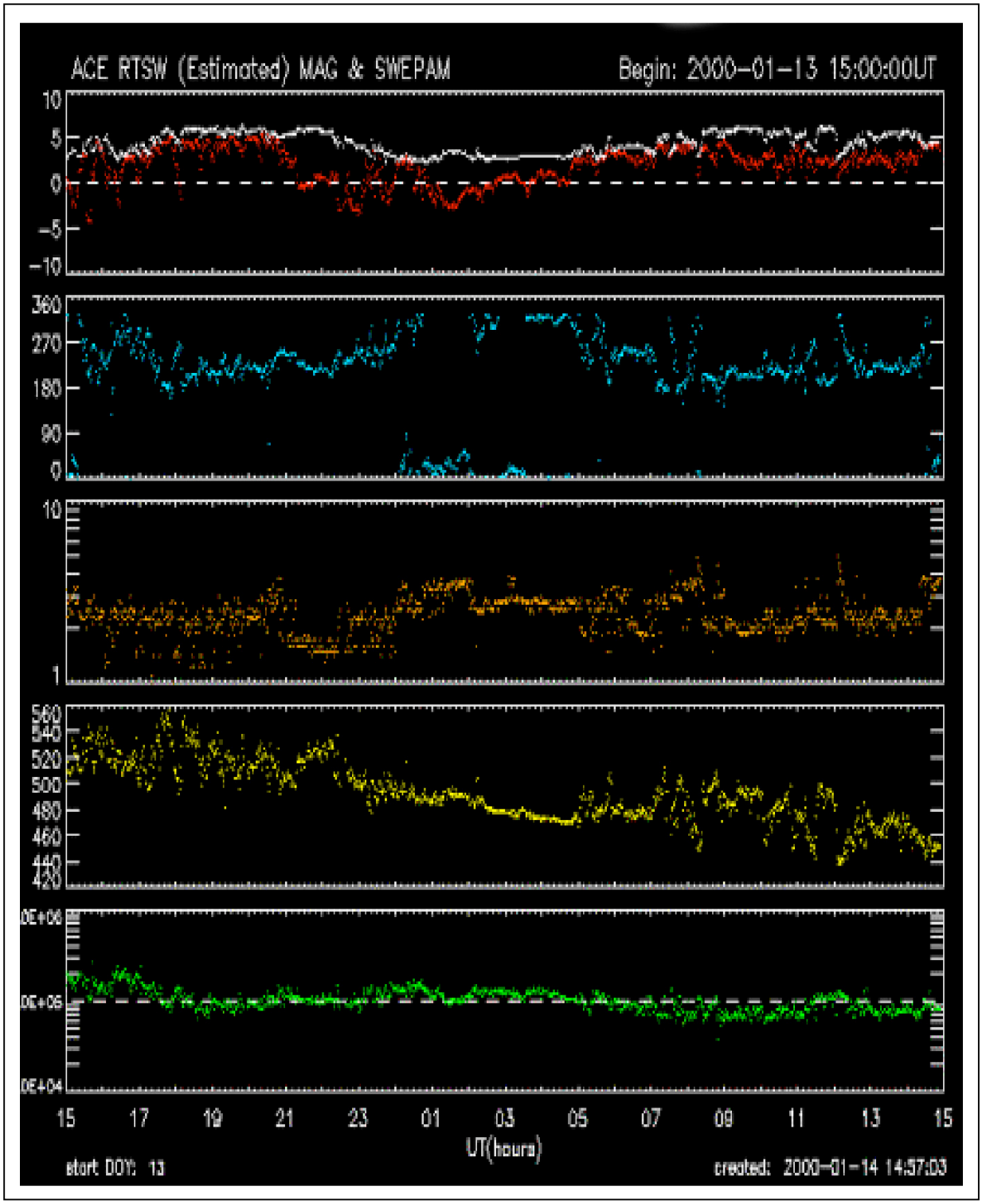


Figure 2: Solar Wind Spectrogram from Genesis

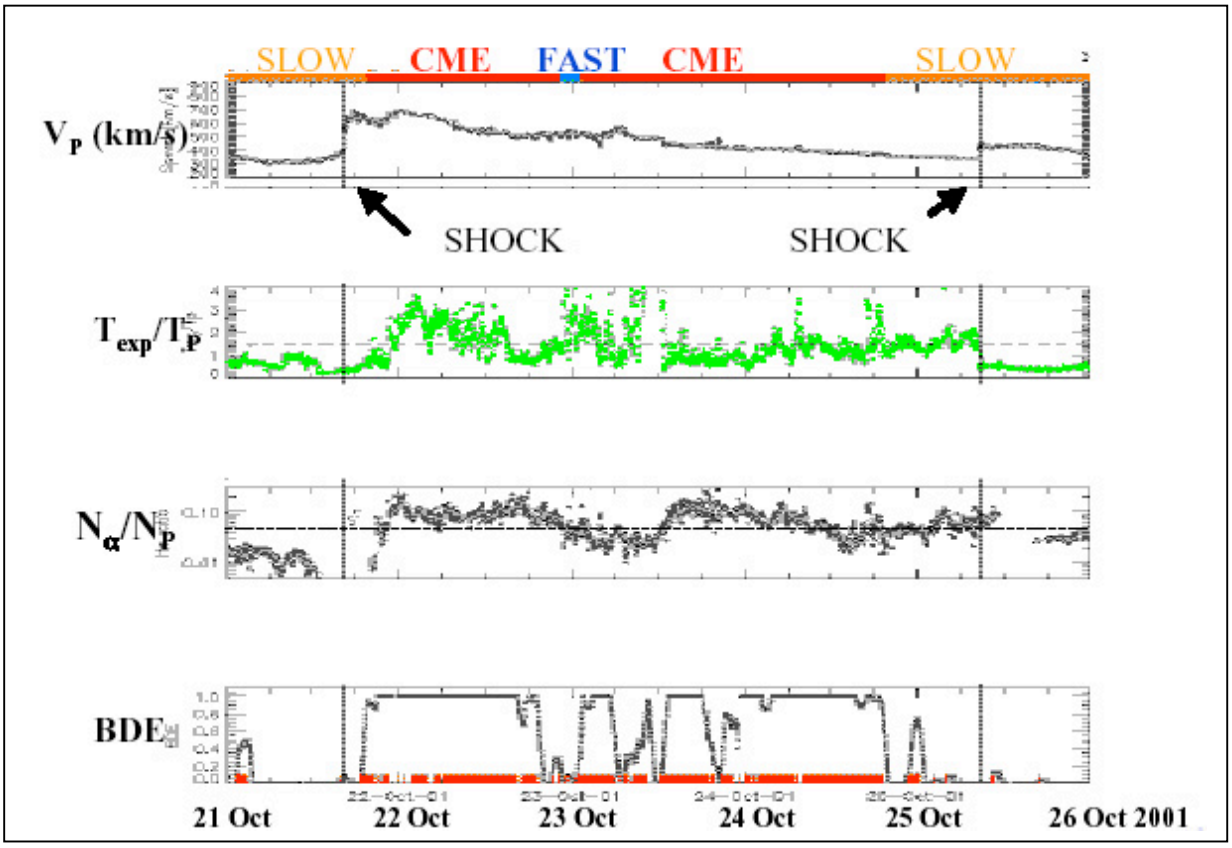


Figure 3: Solar Wind Spectrogram from Ulysses

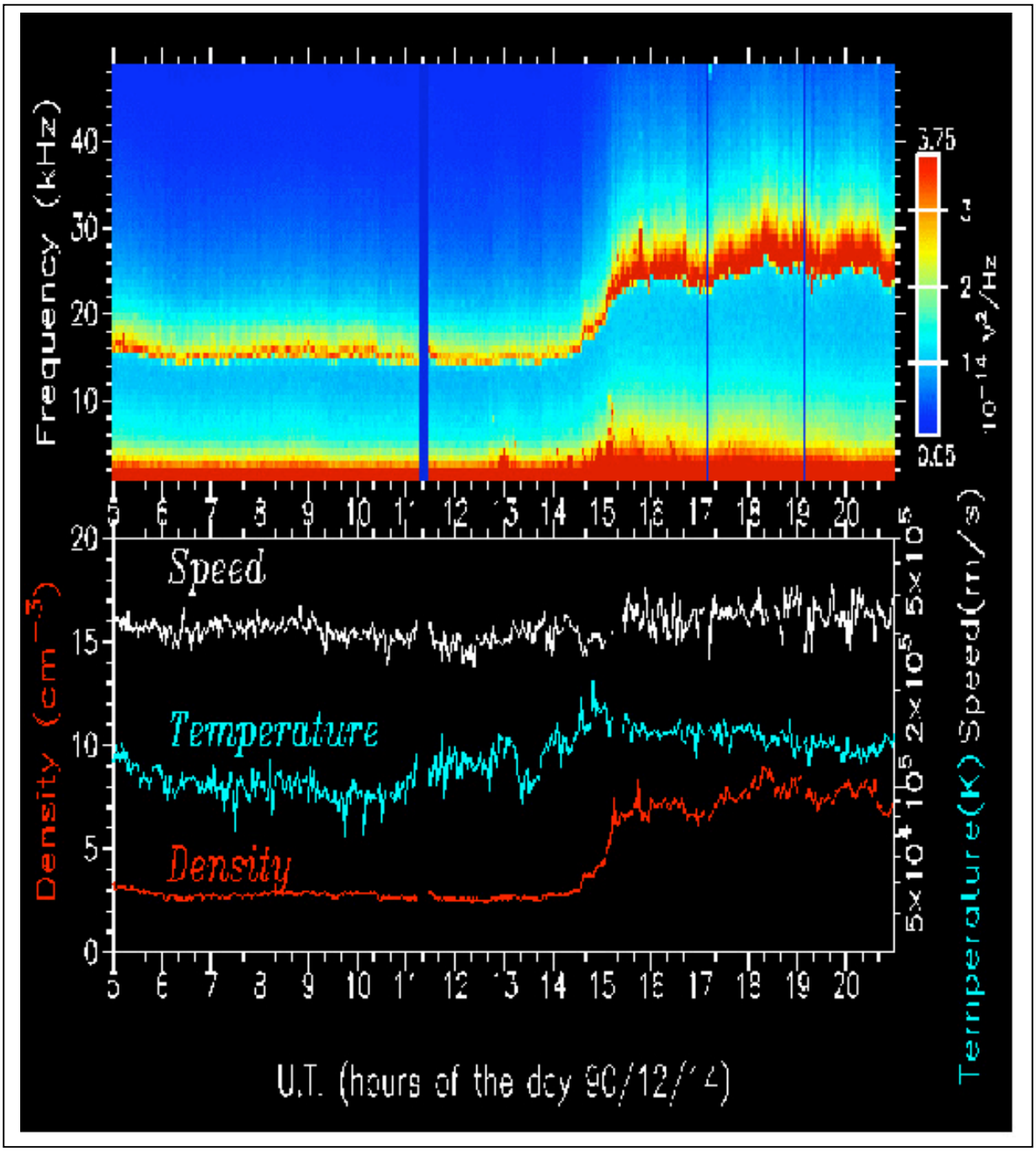


Figure 4: Velocity and Temperature Data (sheet 1)

Year	DAY/TIME	V	T
1999	364.021	370	3.9 e+04
1999	364.062	370	4.5 e+04
1999	364.104	380	7.0 e+04
1999	364.146	380	8.9 e+04
1999	364. 187	370	8.5 e+04
1999	364.229	380	1.1e +05
1999	364.271	380	1.2e +05
1999	364.312	400	1.3e +05
1999	364.354	390	1.1e +05
1999	364.396	390	1.1e +05
1999	364.437	390	9.3e +04
1999	364.479	380	7.4e +04
1999	364.521	390	6.5e +04
1999	364.562	400	5.3e +04
1999	364.604	390	4.9e +04
1999	364.646	390	5.4e +04
1999	364.687	420	7.8e +04
1999	364.729	450	9.9e +04
1999	364.771	550	2.3e +05
1999	364.812	600	3.2e +05
1999	364.854	610	3.0e +05
1999	364.896	650	3.7e +05
1999	364.937	640	4.1e +05
1999	364.979	630	4.2e +05

Note: DAY/TIME given as Day of year plus fraction of day.
Solar wind speed V in km/s.
Solar wind temp. T in K.

Figure 4: Velocity and Temperature Data (sheet 2)

year	DAY/TIME	V	T
1999	365.021	660	4.7e +05
1999	364.062	640	3.8e +05
1999	365.104	650	3.3e +05
1999	365.146	660	4.0e +05
1999	365 .187	700	4.0e +05
1999	365.229	660	3.1e +05
1999	365.271	660	2.9e +05
1999	365.312	680	3.2e +05
1999	365.354	660	3.1e +05
1999	365.396	670	3.2e +05
1999	365.437	630	2.2e +05
1999	365.479	620	2.2e +05
1999	365.521	620	2.2e +05
1999	365.562	640	2.3e +05
1999	365.604	650	2.7e +05
1999	365.646	650	2.7e +05
1999	365.687	630	2.2e +052.4e +05
1999	365.729	640	1.9e +052.
1999	365.771	640	3.6e +05
1999	365.812	650	2.9e +05
1999	365.854	670	2.8 e+05
1999	365.896	690	3.6 e+05
1999	365.937	670	2.9 e+05
1999	365.979	670	3.0 e+05
Note: DAY/TIME given as Day of year plus fraction of day.			
Solar wind speed V in km/s.			
Solar wind temp. T in K.			

Figure 4: Velocity and Temperature Data (sheet 3)

Year	DAY/TIME	V	T
2000	1.021	670	2.5 e+05
2000	1.062	700	2.8 e+05
2000	1.104	710	3.1 e+05
2000	1.146	720	3.5 e+05
2000	1.187	710	3.6 e+05
2000	1.229	720	3.4 e+05
2000	1.271	750	3.4 e+05
2000	1.312	760	3.4 e+05
2000	1.354	750	2.8 e+05
2000	1.396	770	2.6 e+05
2000	1.437	730	2.4 e+05
2000	1.479	730	2.3 e+05
2000	1.521	740	2.2 e+05
2000	1.563	730	2.0 e+05
2000	1.604	720	2.0 e+05
2000	1.646	720	1.8 e+05
2000	1.688	710	1.9 e+05
2000	1.729	710	1.8 e+05
2000	1.771	740	2.2 e+05
2000	1.813	720	2.1 e+05
2000	1.854	710	1.8 e+05
2000	1.896	720	1.7 e+05
2000	1.938	700	1.9 e+05
2000	1.979	700	1.9 e+05

Note: DAY/TIME given as Day of year plus fraction of day.
Solar wind speed V in km/s.
Solar wind temp. T in K.

Figure 4: Velocity and Temperature Data (sheet 4)

Year	Date/Time	V	Temp
2000	2.021	700	1.9 e+05
2000	2.063	700	1.9 e+05
2000	2.104	690	1.8 e+05
2000	2.146	680	1.7 e+05
2000	2.188	690	1.7 e+05
2000	2.229	690	1.9 e+05
2000	2.271	670	1.9 e+05
2000	2.313	670	1.9 e+05
2000	2.354	660	1.9 e+05
2000	2.396	660	1.8 e+05
2000	2.438	670	2.1 e+05
2000	2.479	680	2.4 e+05
2000	2.521	710	2.4 e+05
2000	2.563	660	2.0 e+05
2000	2.604	660	2.1 e+05
2000	2.646	690	1.9 e+05
2000	2.688	680	2.1 e+05
2000	2.729	680	1.6 e+05
2000	2.771	670	1.4 e+05
2000	2.813	680	2.0 e+05
2000	2.854	670	1.9 e+05
2000	2.896	670	1.8 e+05
2000	2.938	660	1.3 e+05
2000	2.979	670	1.1 e+05

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Note: DAY/TIME given as Day of year plus fraction of day.
Solar wind speed V in km/s.
Solar wind temp. T in K.

Figure 4: Velocity and Temperature Data (sheet 5)

Year	DAY/TIME	V	T
2000	3.021	650	1.2 e+05
2000	3.063	620	1.0 e+05
2000	3.104	630	1.1 e+05
2000	3.146	620	1.1 e+05
2000	3.188	620	1.4 e+05
2000	3.229	610	1.3 e+05
2000	3.271	600	1.3 e+05
2000	3.313	590	1.4 e+05
2000	3.354	590	1.7 e+05
2000	3.396	590	1.5 e+05
2000	3.438	600	1.5 e+05
2000	3.479	590	1.4 e+05
2000	3.521	580	1.1 e+05
2000	3.563	560	1.3 e+05
2000	3.604	540	1.3 e+05
2000	3.646	550	9.5 e+04
2000	3.688	540	1.0 e+05
2000	3.729	550	1.2 e+05
2000	3.771	540	1.5 e+05
2000	3.813	580	1.7 e+05
2000	3.854	570	1.9 e+05
2000	3.896	570	1.7 e+05
2000	3.938	590	1.5 e+05
2000	3.979	590	1.6 e+05

Note: DAY/TIME given as Day of year plus fraction of day.
Solar wind speed V in km/s.
Solar wind temp. T in K.

Figure 4: Velocity and Temperature Data (sheet 6)

Year	DAY/TIME	V	T
2000	4.021	590	1.5 e+05
2000	4.062	590	1.6 e+05
2000	4.104	590	1.5 e+05
2000	4.146	590	1.4 e+05
2000	4.187	600	1.4 e+05
2000	4.229	600	1.6 e+05
2000	4.271	590	1.6 e+05
2000	4.312	600	1.5 e+05
2000	4.354	630	2.5 e+05
2000	4.396	630	2.4 e+05
2000	4.437	600	1.5 e+05
2000	4.479	600	1.3 e+05
2000	4.521	590	1.6 e+05
2000	4.562	580	1.8 e+05
2000	4.604	560	1.8 e+05
2000	4.646	570	1.2 e+05
2000	4.687	570	1.0 e+05
2000	4.729	530	1.0 e+05
2000	4.771	550	9.5 e+04
2000	4.812	560	8.6 e+04
2000	4.854	540	9.9 e+04
2000	4.896	510	1.1 e+05
2000	4.937	520	9.8 e+04
2000	4.979	520	1.2 e+05

Note: DAY/TIME given as Day of year plus fraction of day.
Solar wind speed V in km/s.
Solar wind temp. T in K.

Figure 4: Velocity and Temperature Data (sheet 7)

Year	DAY/TIME	V	T
2000	5.021	530	8.3 e+04
2000	5.062	520	7.2 e+04
2000	5.104	540	7.8 e+04
2000	5.146	510	9.8 e+04
2000	5.187	510	9.5 e+04
2000	5.229	520	9.3 e+04
2000	5.271	510	1.3 e+05
2000	5.312	520	1.4 e+05
2000	5.354	540	1.1 e+05
2000	5.396	520	1.1 e+05
2000	5.437	510	1.3 e+05
2000	5.479	510	1.5 e+05
2000	5.521	520	1.4 e+05
2000	5.562	520	1.6 e+05
2000	5.604	530	1.5 e+05
2000	5.646	520	1.6 e+05
2000	5.687	510	1.6 e+05
2000	5.729	520	1.6 e+05
2000	5.771	530	1.4 e+05
2000	5.812	540	1.1 e+05
2000	5.854	520	1.7 e=05
2000	5.896	520	1.5 e+05
2000	5.937	510	1.5 e+05
2000	5.979	520	1.3 e+05

Note: DAY/TIME given as Day of year plus fraction of day.
Solar wind speed V in km/s.
Solar wind temp. T in K.

Figure 5: ACE/SWEPAM graph

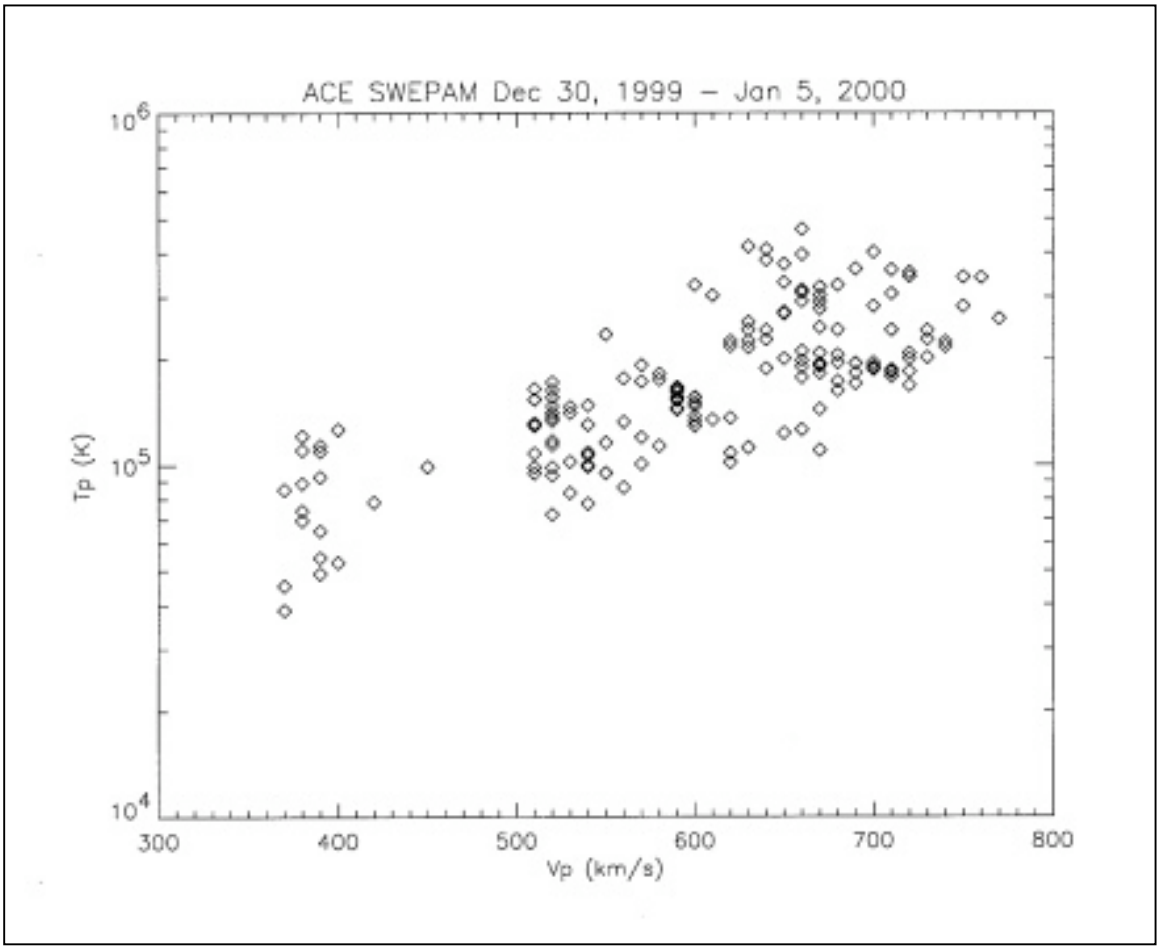


Figure 6: Semi-log Graph Paper

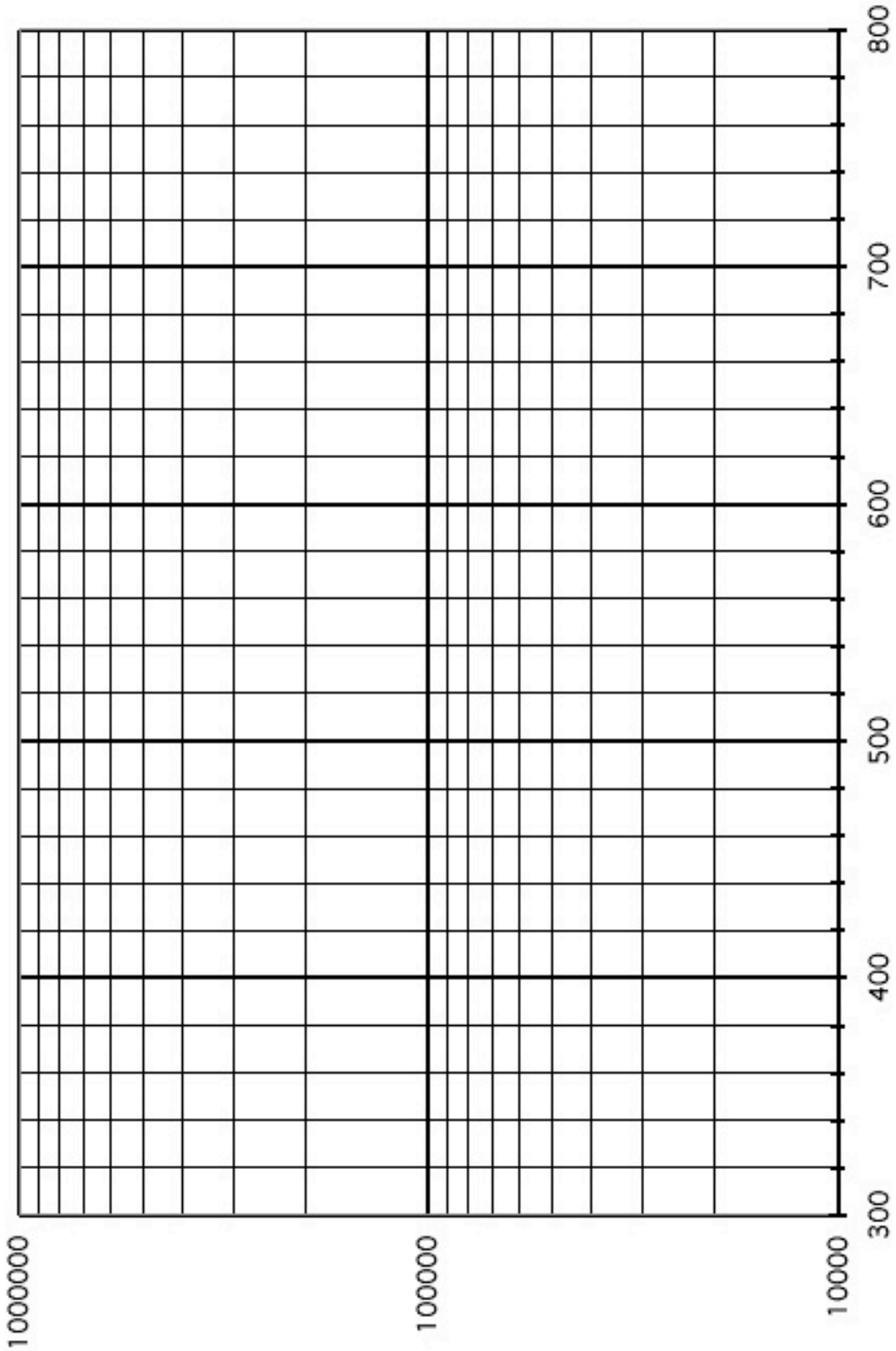
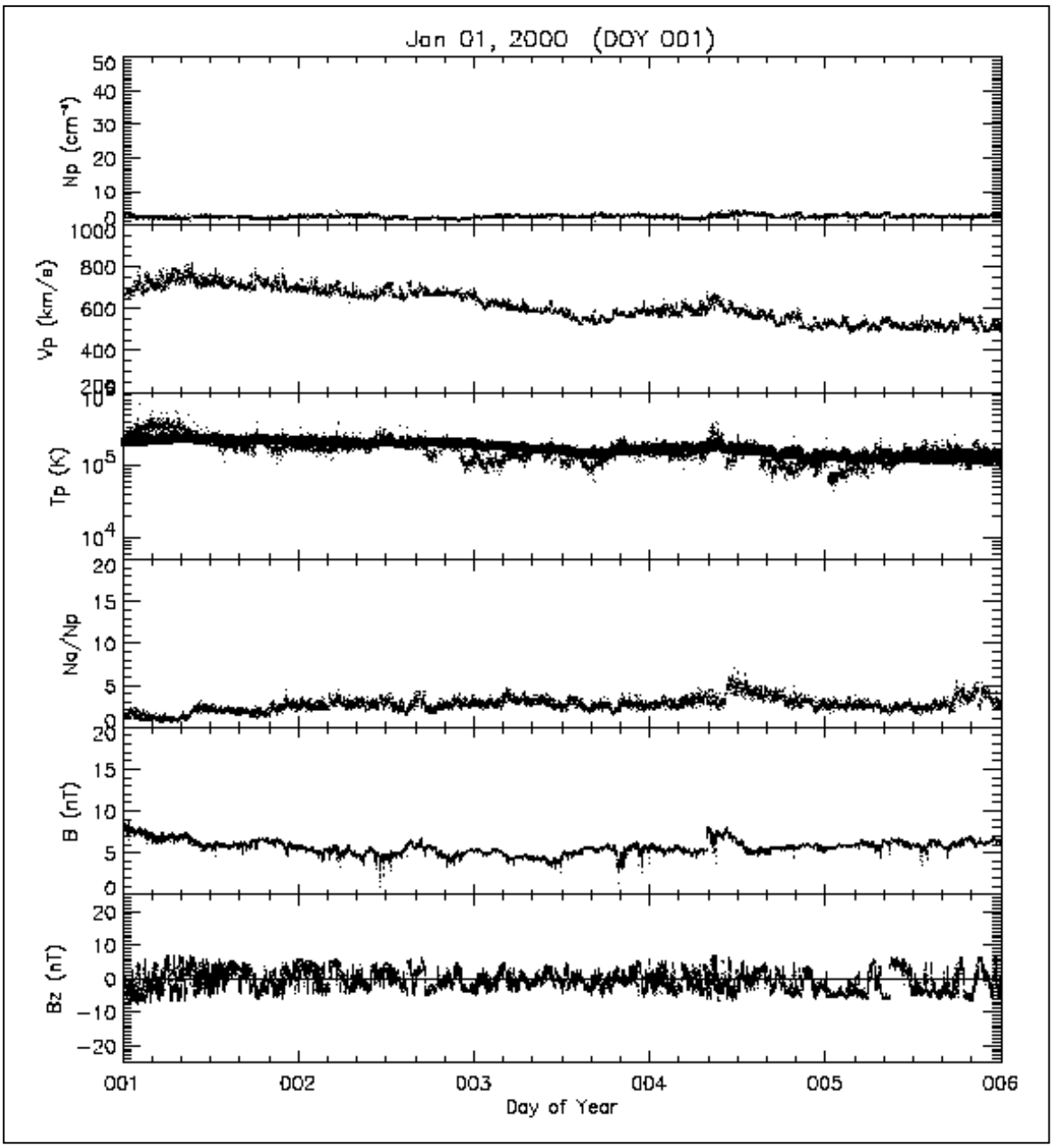


Figure 7: ACE/SWEPAM Data Sheet



Assessment:

- Can the student complete the plots on graph in a small group or pair?
- Did the student participate in class discussion or ask questions?
- Can the student take a short quiz and/or complete worksheet of questions on solar wind graphing and analysis?
- Ask students to write a paragraph on how temperature and speed of solar wind interact with each other.
- Ask students to make journal entries during the lesson.

Teacher Key to Student Worksheet: **Solar Wind Graphing and Analysis Questions:**

Name: _____ Period: _____ Date: _____

Teacher note: The following questions and answers can be used to build background for teachers or to explore prior knowledge and facilitate discussions with students.

1. What is solar wind?
   - Solar wind is charged particles emitted from the Sun. Answers will vary-the teacher can expand as necessary.
2. What is the measure of a moderate solar wind storm? A major storm?
   - The measurements of moderate and major storms will vary depending on the data sheets.
3. What effect does temperature have on increasing speed?
   - Usually the higher the temperature, the higher the speed.
4. How is the magnitude of the solar wind measured?
   - Instruments on satellites collect solar wind samples.
5. Why is the temperature in Kelvin and not Celsius?
   - Kelvin (K^0) is the unit used for high temperatures in the scientific community.
6. What are the units that define velocity?
   - Kilometers/second (km/s) are the units used to define velocity.

Matching:

1. __e__ B	a. measures whether the magnetic field within the solar wind is pointing north or south
2. __h__ Na/Np	b. nano-tesla
3. __a__ Bz	c. speed
4. __g__ T	d. horizontal (plane of graph)
5. __b__ nT	e. strength of magnitude of solar wind
6. __c__ V	f. vertical (plane of graph
7. __d__ *x*-axis	g. temperature in Kelvin
8. __f__ y-axis	h. percent of helium in solar wind

Student Worksheet: **Solar Wind Graphing and Analysis Questions:**

Name: _____ Period: _____ Date: _____

1. What is solar wind?

2. What is the measure of a moderate solar wind storm? A major storm?

3. What effect does temperature have on increasing speed?

4. How is the magnitude of the solar wind measured?

5. Why is the temperature in Kelvin and not Celsius?

6. What are the units that define velocity?

Matching:

1. _____ B	a. measures whether the magnetic field within the solar wind is pointing north or south
2. _____ Na/Np	b. nano-tesla
3. _____ Bz	c. speed
4. _____ T	d. horizontal (plane of graph)
5. _____ nT	e. strength of magnitude of solar wind
6. _____ V	f. vertical (plane of graph
7. _____ *x*-axis	g. temperature in Kelvin
8. _____ y-axis	h. percent of helium in solar wind

Facts for the Teacher: Part 1 (Auroras)

Phenomena associated with "solar weather" include Auroras. The following figures describe what auroras are, what they look like to the naked eye, and what they are called.

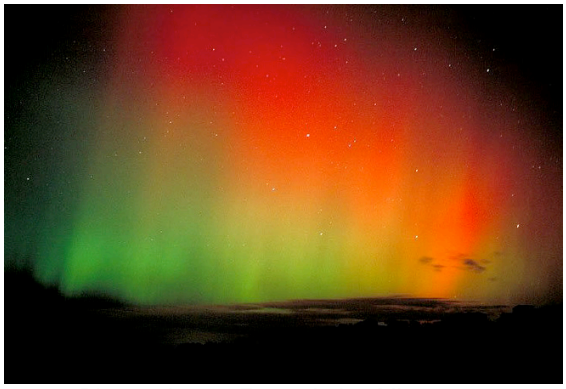
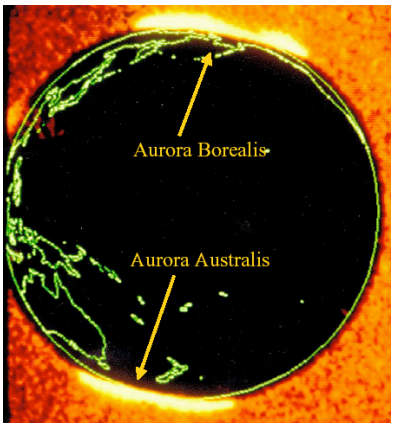


Photo taken at Forest Lake, Minnesota

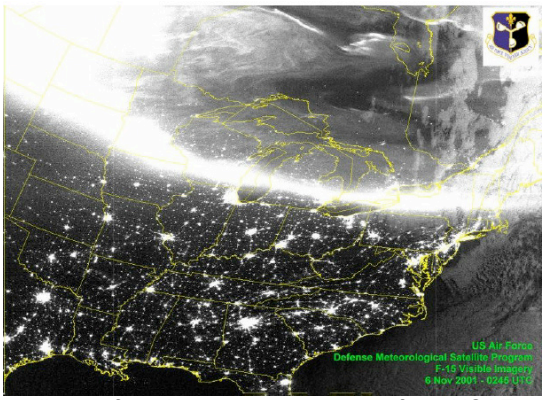
What the colors tell you:

- Different transitions are favored at different altitudes.
- Precipitating electrons with more initial energy penetrate to lower altitudes.
- So the color is related to the energy of the precipitating electrons.

Energized electrons enter the Earth's atmosphere around the polar regions. The resulting northern aurora displays are most often seen in the northern regions of the United States and Canada.

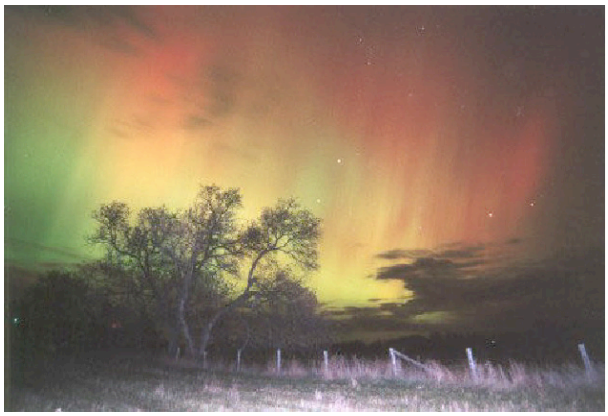


Location of Auroras



Common limits of northern auroras as seen from USAF satellite.

Aurora view from the Shuttle Discovery



Aurora photo taken in Menominee, Wisconsin

Part II. Multi-cultural mythology

The Sun has inspired mythological, spiritual, folkloric beliefs in many cultures; including ancient Greeks, Romans, Egyptians, Aztecs, Native Americans, and Chinese. Students will be very interested to learn some of these stories surrounding beliefs about the Sun. The teachers can relate the following tales to the students as an 'anticipatory set' and to increase interest in learning about the Sun and solar wind.

A. Greek and Roman Mythology

Helios, Greek God of the Sun

Helios was the Sun god of the Greeks, usually depicted as a beardless charioteer, crowned with the aureole of the Sun. He drove the Sun across the earth from east to west each day, thus bringing light and warmth to the earth and its people.

Eos, the Greek goddess of dawn, heralded the daily journey of Helios as he prepared to drive the chariot that carried the Sun. Each morning, after being aroused from slumber by the crowing of the rooster, she would rise to announce the start of his journey. She is often represented driving a rose-colored chariot drawn by white horses.

Helios fell in love with a nymph, Clymene. One of their children, Phaeton, became notorious for his clumsy driving of the chariot of the Sun. Phaethon had golden eyes, as did all of Helios' children. One day he had asked Helios, his father, for permission to command his chariot, and pull the Sun across the sky. Helios tried to warn Phaeton that the road from the sea each morning was very steep and difficult and the horses were hard to control. Phaethon stubbornly insisted and Apollo, wanting to please his child, reluctantly agreed. Phaethon lost control of the Sun chariot and crashed, burning and scorching much of the earth. Zeus, the ruler of the gods, saw what was happening. In order to save the earth, Zeus threw a lightening bolt at the chariot. Phaeton was killed and the horses splashed into the sea. Waves poured over the land and put out the fire. From then on, only Helios would ever drive the Sun's chariot across the sky.

*Note: In later times, Helios is often identified with Apollo. Apollo is the only god to have the same name in both Greek and Roman Mythology.

Literature selections appropriate to read to students:
Random House Book of Greek Myths, by Joan Vinge. Random House: 1999. Pages 65-68.
Greek Gods and Goddesses, Retold by Geraldine McCaughrean. Simon and Schuster: 1997. Pages 30-34

B. Aztecs

Aztec mythology began with four Suns (epochs) prior to our current Sun (The Aztec calendar is based on the four gods and the directions they dominated). The earth destroyed the first Sun; the second Sun was destroyed by the wind; the third was destroyed by fire; and the fourth destroyed by water (The current Sun is the fifth).

The god of Sun and war was named Huiltzilopochtli (hummingbird on the left); he was depicted as a blue man armed with feathers on his head.

Aztecs would offer human sacrifices to Huiltzilopochtli. The sacrificial victims would often be captured prisoners during wars with neighboring people. The sacrifices were offered to secure rain, good harvests, and success in war.

The current Sun god is Nanahuatl. He sacrificed himself in a fire, and became the god of the fifth Sun.

C. Sun dogs

August is generally known around North America as the "Dog Days of Summer." The origin of this term has been attributed to the month's extremely hot weather causing dogs to lie about panting as well as to an ancient Egyptian belief that the bright star Sirius, the Dog Star, prominent in this month, added to the heat of August days.

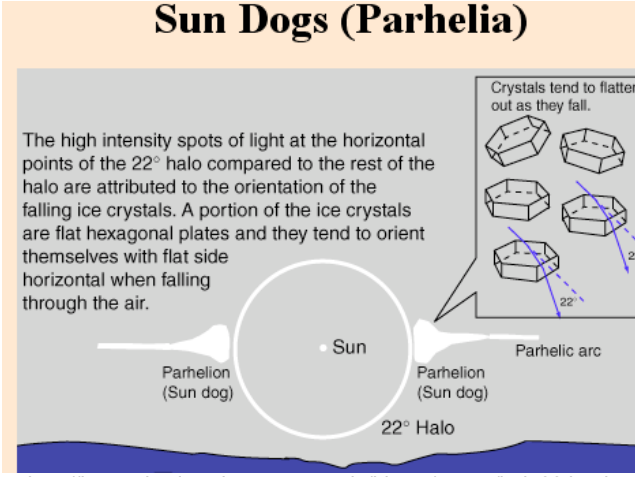
Photo by Clay S. Turner. Used by permission.

The topic focused upon however, is another weather dog: the Sun dog, though Sun dogs in the plural form seems more sufficient since they come in pairs. Sun dogs sit on each side of the Sun along a horizontal line through the solar orb.

Sun dogs appear in August (October, January, April - the month does not matter), but they are most regularly seen close to their solar master during winter months and when the Sun is low in the sky. View http://www.suite101.com/article.cfm/science_sky/77278.

Sun dogs, or mock Suns, are technically called solar parhelia (parhelia meaning "with the Sun"). Sun dogs reveal that the clouds are hosting horizontal plate crystals. These plates drift slowly downwards like leaves with their large faces almost horizontal. View http://www.Sundog.clara.co.uk/halo/parhelia.htm.

Sun dogs can appear as bright bursts of light formed when Sunlight passes through ice crystals at the proper angle. They are often bright white but may show a partial spectrum of color with the red wavelengths on the edge nearest the Sun. Sun dogs often have comet-like appearance with a bluish-white tail facing away from the Sun. The degree to which colors are visible depends on the amount of wobble in the ice crystal as it falls: the more wobble, the more color. The Sun dog's tail is formed by light passing through the ice crystals at different angles.



http://hyperphysics.phy-astr.gsu.edu/hbase/atmos/halo22.html

Sun dogs typically appear when the Sun is low to the horizon, usually just prior to Sunset or after Sunrise, or during the winter months at mid-latitudes. If the Sun is low (horizon to about 15° above it), each Sun dog is separated from the Sun by 22°. As the Sun rises the Sun dogs appear to be off the 22° mark. At 61° solar-altitude, the Sun dogs disappear. View http://www.suite101.com/article.cfm/science_sky/77278.

Traditionally, Sun dogs foretold a weather change or rain. The brighter the Sun dog the heavier the showers. Among North American farmers if the Sun dog on the north side of the Sun is the brighter of the two, this indicates colder temperatures in the forecast. If the southern Sun dog is the brighter optical image, warmer temperatures are predicted. To the Native American Blackfeet people, Sun dogs were thought to be a warning sign of approaching danger. View http://www.sharlot.org/archives/history/dayspast/text/1999_12_12.shtml.

Today the appearance of these optical images is still an indication of a weather change. Strong vertical air currents associated with low-pressure storms carry moist air skyward, where water freezes. High-speed winds above the storm system push the ice crystals on ahead. When you see haloes around the Sun or moon, you can be sure of two things; there are cirrostratus clouds above and, in a day or two, the skies will darken with an approaching storm. View http://www.freestudentessays.com/science/25.shtml.

4. Navajo

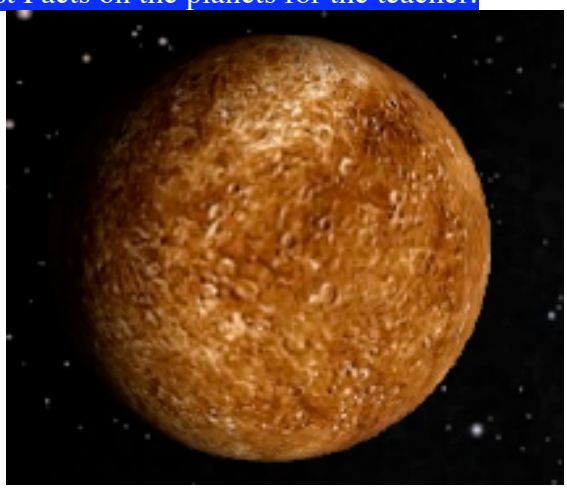
Navajo Sun Legend

The Sun, johona'ai, and the moon, olje' are borne across the skies by immortal bearers, which are considered masculine. Thirty-two trails have been created for their travels and summer and winter solstice occur as they return from the northern or southern trails. The bearers carried out their threat of taking a human life on every journey, by introducing man-eating monsters. There were many but the big yei, yeitso', was the son of the Sun. The monster crane, formed from a white eagle and white thunder, made by the Sun, lived on the cliffs of tsebitai', the winged rock Shiprock. The monster slayer finally killed the monsters and the Sun personally killed his son, yeitso', making it safe for the Dine' to live in the present, twelfth world.

An eclipse is caused by the "death" of the orbs, the Sun and moon and the immortal bearers revive them. All journeys and work ceases during an eclipse and its passing is awaited in silence.

The Sun is instrumental in being used to tell time by pointing out its position in the sky. Direction and directional assignments in the home and ceremonies are Sunwise.

Fast Facts on the planets for the teacher:



Mercury

- 0.387 Astronomical Units (AU) from the Sun (57,909,175 km)
- Diameter is 4,879 kilometers (km)
- Mass is 0.3302 x 10^{27} g
- Density is 5.43 gm/cm^3
- Surface gravity is 370 cm/s^2
- Average Surface Temperature is 440 K^0
- Surface features dominated by early crust formation and possibly early volcanism.
- Rotational period is 58.646 Earth days
- Orbital period is 0.2408 sidereal years
- No natural satellites
- No major atmospheric constituents

Venus

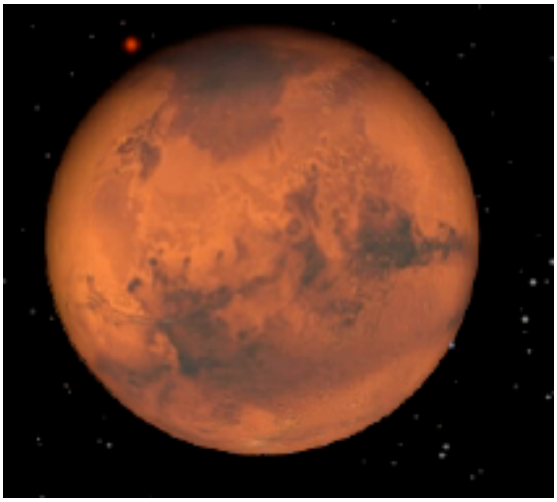
- 0.723 AU from the Sun (108,208,930 km)
- Diameter is 12,104 km
- Mass is 4.869 x 10^{27} g
- Density is 5.24 gm/cm^3
- Surface gravity is 887 cm/s^2
- Average Surface Temperature is 730 K^0
- Surface features dominated by volcanism
- Rotational period is -243.02 days retrograde. ("backwards" or spinning in the opposite direction of its orbit around the Sun)
- Orbital period is 0.6159 sidereal years
- No natural satellites
- Major atmospheric constituents include CO_2 and N_2

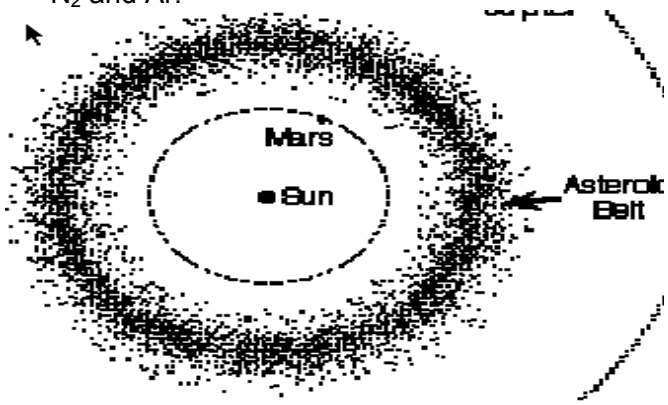
Earth

- 1.00 AU from the Sun (149,597,890 km)
- Diameter is 12,756 km
- Mass is 5.9742 x 10^{27} g
- Density is 5.515 gm/cm^3
- Surface gravity is 980 cm/s^2
- Average Surface temperature is 288-293 K^0
- Rotation period is 0.99726968 day
- Orbital period is 1.0000174 sidereal years
- Surface dominated by plate tectonics and volcanism.
- Earth has one natural satellite (moon).
- Major atmospheric constituents include N_2 and O_2

Mars

- 1.524 AU from the Sun (227,936,640 km)
- Diameter is 6794 km
- Mass is 0.6419 x 10^{27} g
- Density is 3.94 gm/cm^3
- Surface gravity is 371 cm/s^2
- Average Surface temperature is 186-268 K^0
- Rotation period is 1.02595675 days
- Orbital period is 1.8808476 sidereal years
- Surface dominated by early crustal formation, volcanism, later fluid erosion and transport
- Mars has two natural satellites which are probably two captured asteroids
- Major atmospheric constituents include CO_2, N_2 and Ar.



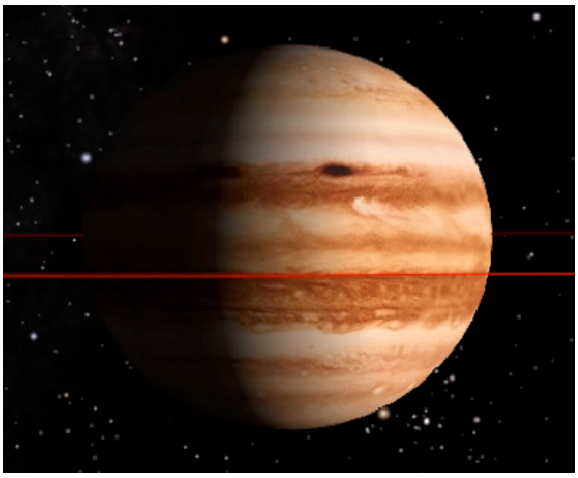


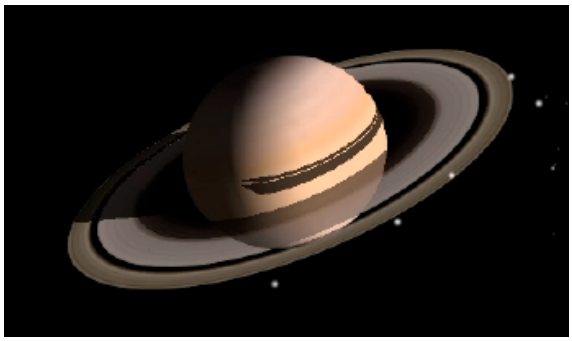
Main Asteroid Belt

- 2.7 AU from the Sun (403,914,300 km)
- largest asteroid is Vesta – composed of basalt
- second largest asteroid is Ceres – composed of ice and water

Jupiter

- 5.20336 AU from the Sun (778,412,010 km)
- Diameter is 142,948 km
- Mass is 1.898.7 x 10^{27} g
- Density is 1.33 gm/cm^3
- Surface gravity is 2312 cm/s^2
- Average Surface temperature is 288-293 K^0
- Rotation period is 0.41354 day
- Orbital period is 11.8626 sidereal years
- No surface as such, probably a rocky core
- Jupiter has sixty-one (61) natural satellites and counting, many are captured asteroids
- Major atmospheric constituents include H_2, and He.



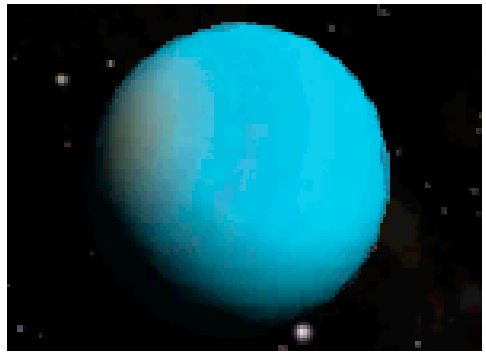


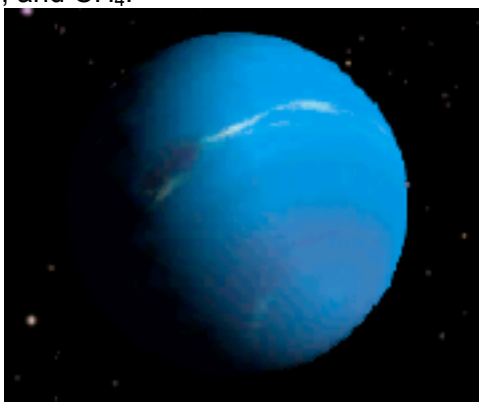
Saturn

- 9.537 AU from the Sun (1,426,725,400 km)
- Diameter is 120,536 km
- Mass is 568.51x 10^{27} g
- Density is 0.70 gm/cm^3
- Surface gravity is 896 cm/s^2
- Average Surface temperature is 134 K^0
- Rotation period is 0.44401 day
- Orbital period is 29.447498 sidereal years
- No surface as such, probably a rocky core
- Saturn has thirty-one (31) natural satellites and counting, many are captured asteroids; “Shepard” moons for rings
- Major atmospheric constituents include H_2, and He.

Uranus

- 19.191 AU from the Sun (2,870,972,200 km)
- Diameter is 51,118 km
- Mass is 86.849 x 10^{27} g
- Density is 1.30 gm/cm^3
- Surface gravity is 869 cm/s^2
- Average Surface temperature is 76 K^0
- Rotation period is -0.71833 day (retrograde)
- Orbital period is 84.0168 sidereal years
- No surface as such, probably a rocky core and ice
- Uranus has twenty (20) natural satellites and counting; coarse rings
- Major atmospheric constituents include H_2, He, and CH_4.

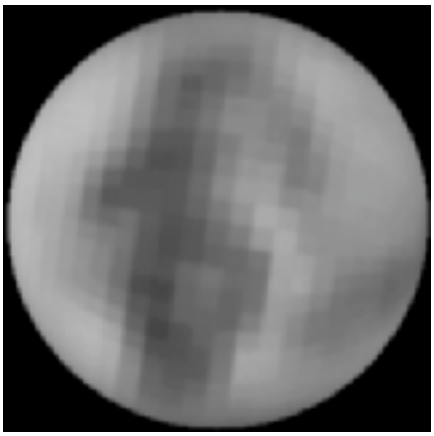




Neptune

- 30.06896 AU from the Sun (4,498,252,900 km)
- Diameter is 49,528 km
- Mass is 102.44 x 10^{27} g
- Density is 1.76 gm/cm^3
- Surface gravity is 1100 cm/s^2
- Average Surface temperature is 73 K^0
- Rotation period is 0.67125 day
- Orbital period is 164.79 sidereal years
- No surface as such, might have a rocky core and ice
- Neptune has eleven (11) natural satellites and counting; coarse rings
- Major atmospheric constituents include H_2, He, and CH_4.

Pluto



- 39.481686 AU from the Sun (5,906,376,200 km)
- Diameter is 2300 km
- Mass is 0.013 x 10^{27} g
- Density is 2.0 gm/cm^3
- Surface gravity is 60 cm/s^2
- Average Surface temperature is --
- Rotation period is –6.38718 day (retrograde)
- Orbital period is 247.92 sidereal years
- No surface as such, probably has a rocky core and ice
- Pluto has one (1) natural satellite - Charon
- Major atmospheric constituents unknown

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Craters on Mars

Time:

two separate 45-minute sessions

Objectives:

The lesson prepares students to interpret remote sensing images of craters for the presence of water or the lack thereof on the surface features of Mars.

Students will analyze and interpret the cause of crater formation on Mars (and other celestial bodies) and be able to predict the:

- relative age of the craters
- erosion processes
- relative water content of local impact areas
- relative mass and speed of impactors.

Content Standards

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry
- Understand how to measure using non standard and standard units
- Select an appropriate unit and tool for the attribute being measured.
- Use tools to measure
- Develop common referents for measures to make comparisons and estimates. Understand that measurements are approximations and how differences in units affect precision.
- Solve simple problems involving rates and derived measurements for such attributes as velocity and density.
- People have always had questions about their world. Science is one way of answering questions and explaining the natural world and solar system.
- Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.
- Apply and adapt a variety of appropriate strategies to solve problems.

Equipment, materials, and tools:

For the teacher:

- 2-3 five pound bags of flour
- 1 can of hot cocoa mix or brown tempera paint
- 1-2 large deep dish pans or containers (at least 3-4 inches deep)
- a variety of projectiles of varying mass and size:
  - BBs,
  - marbles,
  - plastic beads,
  - steelys (steel marbles).
- a variety of pictures of craters on Mars taken by remote sensing orbiters.
- OPTIONAL: slingshot for increasing speed to projectiles (protective goggles should be used if a slingshot is used.)

For the student:

- pen or pencil
- 2 sheets of paper
- metric ruler

Materials to reproduce:

(suggest 1 copy per group of students)

- Figures 1-23

Student Skills:

- comparing models of terrain morphology to remote sensing images of Mars
- interpreting surface features of Mars
- understanding of the role of mass and speed on impactors

Background Information:

The relative age of craters:

With a few exceptions, craters have been found on all terrestrial planets and moons that have been imaged so far. Some are so densely cratered that further impacts simply wipeout or cover previous craters. The relative age of a crater in relation to others surrounding it can be determined by studying processes of erosion, the overlapping of craters on top of craters or crater ejecta over other craters.

Fresh, recently created craters have these similarities:

- a concave, bowl-shaped depression in the middle
- a raised rim higher than the surrounding topography
- a layer of ejecta (material thrown out of the crater at the time of impact) that surrounds the rim and covers other topographical features.

Older craters typically:

- have flatter depressions in the middle due to erosion filling them in
- have rims more rounded and flattened due to erosion
- have less noticeable ejecta due to erosion or being covered by newer impacts or ejecta.

The Mass and Speed of Impactors

When American astronauts visited Earth's moon, they reported that craters were everywhere (see Figure 23), ranging from millimeter wide pits to 50 miles across, all due to meteorite impact. Two factors determine the size of a crater: mass and speed. The greater the impactors mass and the faster its speed, the larger the crater formed.

The presence of sub-surface water or water-ice.
Water at the point of an impact influences the formation of the resultant crater and the pattern of the ejecta. Planetary scientists postulate that some craters on Mars that have a "splash" pattern of ejecta surrounding the crater are the result of the flash heating of sub-surface ice. These "splash" patterns differ significantly from typical Mars craters and are almost non-existent on other planets where there is virtually no surface or sub-surface ice.

Lesson Plan: Part 1 - What causes a crater on Mars?

1. Preparation before the lesson: Pour the flour into the deep-dish pan filling it to within one inch of the lip of the pan. Smooth the flour flat. Cover the surface of the flour with a one-quarter inch layer of hot cocoa mix or brown tempera paint. Cover it well enough so as not to see any flour.

2. Have the students review various pictures of craters, volcanoes, and erosion features of Mars (Figures 1-21). Ask them to brainstorm what forces created some of these features. Ask the students, "Which of these features was caused by something that was not a part of the planet?" (Answer: Craters).

   Questions to get the students thinking:
   a. What types of things impact planets?
   b. What are they made of?
   c. How big are they?
   d. How fast are they going?
   e. What causes them to speed up when approaching a planet?
   f. Why do some of them make small craters while others make much larger craters?

3. Have the students take a sheet of paper and fold it into 8 equal sections. In each of the boxes have the students write:
   a. Impactor:
   b. Mass:
   c. Speed at impact:
   d. Crater size:

4. Place the pan on a table or the floor (much more dramatic on the floor). Tell the students that you (or one of the students, if you dare) will be dropping projectiles onto the surface of "Mars". After each impact they will record information based on their observations. They will write one of the following for each impact:
   a. Impactor: Plastic bead, BB, marble, or steely based on what was dropped.
   b. Mass: Low for the plastic bead and BB, medium for the marble, and high for the steely.
   c. Speed at impact: Low or high, low for dropping the projectile and high for throwing or using a slingshot.
   d. Size of crater: Have one student measure the diameter of each crater after its formation with a metric ruler.

Note to Teacher:

There are many variations that can be used for the speed factor. Have students brainstorm the best method to ensure constant velocities during their experiment. They can drop the projectiles from different heights recording the height for each drop. They can simulate oblique angle impacts by using a PVC pipe or a flat surface (board, etc.) folded to form a trough. At the appropriate student level, the velocity at impact can be determined mathematically. You may have the students calculate the speed using the equation for free-falling objects:

$$V = V_o - g\,(t)$$

V = velocity, V_o = velocity at time 0, g = acceleration constant ($9.8 m/s^2$)

5. From a standing position or standing on a step stool or table, drop the first projectile. Have the students observe the crater, measure the diameter, and record the data. Then proceed to the next projectile. After finishing all 4 types of projectiles, repeat, but at a higher speed (It's highly recommended that the teacher perform this portion of the projecting ☺). Add extra force when dropping by throwing, using a slingshot, or dropping from a greater height. For safety sake, keep the students at a distance during the impacting. Have them observe the newly formed craters and record their data.

6. Lead the students in a discussion on what factors produced the largest craters.

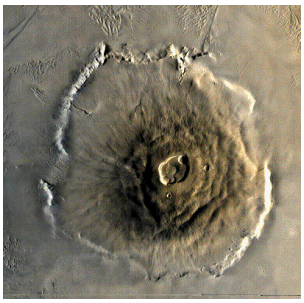
   Questions to consider?
   a. Which seems to have a greater effect, speed or mass of the projectile?
   b. What can cause a projectile to move faster?
   c. Where do these projectiles come from?
   d. What elements are found in asteroids, meteoroids, and comets?
   e. What are the real speeds of actual impactors?

7. Save the impacted flour mix for part 2 of the lesson.

Lesson Plan: Part 2 – What causes a crater on Mars?

1. Preparing for the lesson: Lightly tap or shake the pan so as to gently "erode" and cave in some of the craters. Then make some more craters. Try to place some of them close to the pre-existing craters. Don't be afraid to overlap some of them. Don't let the students watch you make the additional craters.

2. Using photos of craters (Figures 6, 7, 8, 16, 17, 18, 22) on the Moon and Mars have the students postulate which of the craters in the photos are relatively younger or older in comparison with others. Ask students to consider:
   a. What features show aging?
   b. If ejecta from crater "A" covers crater "B", which crater is more recent?
   c. The presence of rounded rims usually indicate what?



3. Show the students the newly created crater field (flour/cocoa mix) and see if they can organize the craters from youngest to oldest.

Note to Teacher: Many of the craters on the moon and Mars have been named. The students may enjoy naming the craters in the homemade crater field and then putting them in a list in order of age.

4. Fill the second deep-dish pan with sand or dirt. Fill it to about the same depth as the flour/cocoa mix. Wet the sand down thoroughly. Do not leave any standing water on the surface. That will make it too wet and messy.

   Discussion: What difference will a wet substrate make versus a dry substrate during the cratering process? What features can be expected? Have student make predictions.

5. Have student make craters on the wet substrate. The same process (four low speed, four high speed) as used in part 1 can be followed with the option to make just a few craters if time is short. The main idea to get across is that a wet substrate causes different features during cratering. Have students observe the new craters and record their observations
6. Using Figures 1, 6, 7, 8, 10, 11, 16, 17, and 21, show the students examples of craters on Mars. Have them guess which show possible evidence for water on Mars
   (The craters that scientists believe show evidence of sub-surface ice melt are: 1, 7, 10, 11,16).

NOTE: The results of the wet impact activity will not duplicate the suspected "wet impacts" seen on Mars. Scientists believe the features seen on Mars (e.g. Figure 16) are due to subsurface ice being super heated by meteor impact, melted and splashed out on the surface. This would be extremely difficult to replicate in the classroom ☺. However, some features will be evident and students should be able to predict which photos show evidence for water on Mars.

NOTE TO TEACHER: Teachers should feel free to experiment and try various ways to replicate the wet impact. Pudding, Jello, whipped cream, etc. Many different things can be added to sand and dirt to get substrate that mocks the remote sensing images from Mars.

Assessment: Criteria rubric (see figure 24 for duplication)

Name: _____ Teacher: Mr. J

Date : _____ Title of Work: _____

	Criteria				Points
	1	2	3	4	
Students will realize the importance of mass and speed of an asteroid or comet when it strikes a celestial body.	Student understands that speed and mass play a role in the cratering process.	Stundent understands that the higher the mass and speed, the wider and deeper the crater will be.	Student can predict crater sizes based on the given speed and mass of the impactor.	Student can apply information to a planetary scale and predict cratering processes on celestial bodies.	___
Students will be able to distinguish the relative ages of craters in a given area.	Student understands that there are ways to notice if a crater is older or younger than another.	Student can explain the methods of determining the relative ages of craters.	Student can tell which craters in a given area are older or younger than others.	Student can explain the erosional processes that "age" craters and therefor makes them different than other craters.	___
Students will be able to predict the water content of an area based on crater ejecta and structure.	Student understands that water has an influence on crater formation.	Student understands that watery impacts cause certain patterns in crater formation.	Student sees and notices the predicted patterns in orbital pictures taken from spacecraft.	Student can accurately select and predict which craters (out of a given selection) involve a watery substrate.	___
					___
					___
				Total---->	___

Teacher Comments:

_____

Questions:

1. What are craters?
2. What causes craters?
3. Where have craters been discovered on Earth?
4. Where have craters been discovered besides Earth?
5. What is the composition of the objects (impactors) causing craters?
6. What types of impactors have been found on Earth?
7. How fast are these objects traveling at impact?
8. How large can these objects get?
9. How small can these objects get?
10. Why do some planets and moons have more craters than others?
11. How often does Earth experience an impact?
12. What are the differences between a continental impact and an oceanic impact?
13. How would an impact on Earth from a large extra-terrestrial object affect human life?
14. What must be considered in spacecraft design for the investigation of asteroids and comets?
15. If scientists identify a possible extra-terrestrial impact in the future, can we stop it?

Figure 1

Figure 2

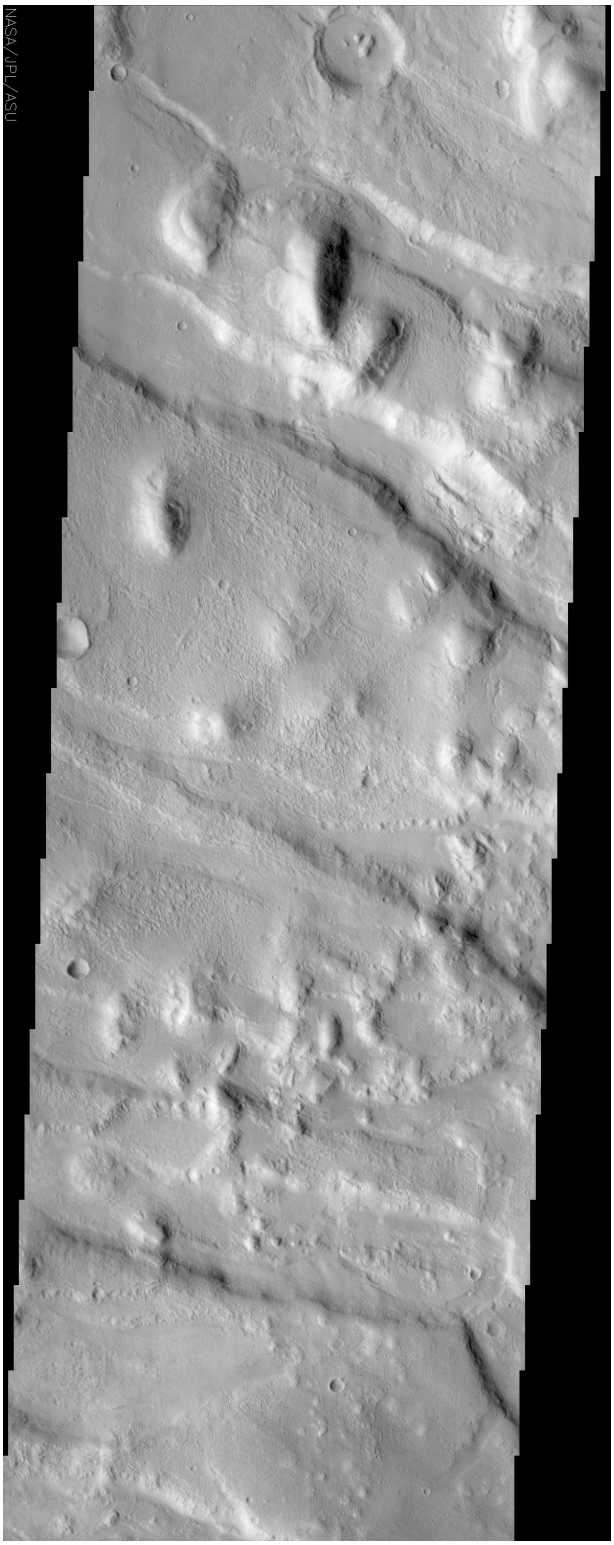


Figure 3

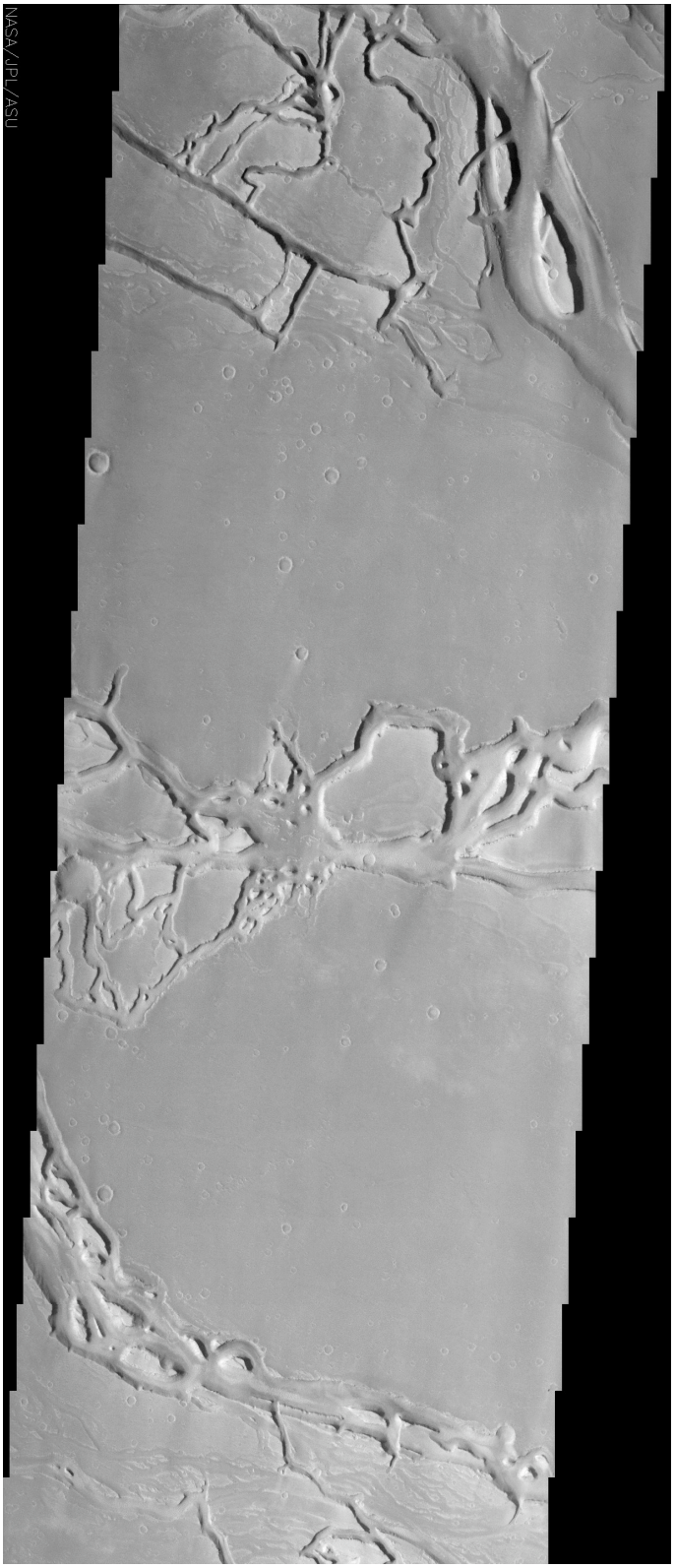


Figure 4

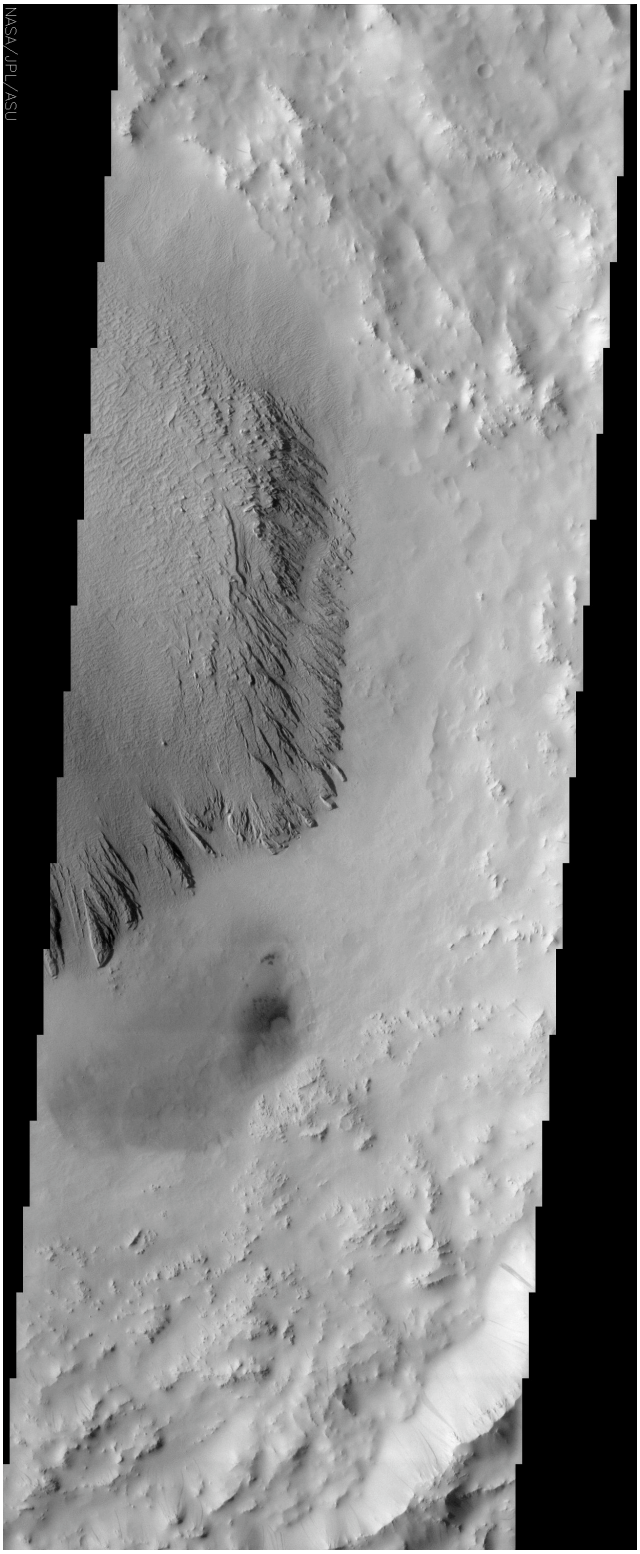


Figure 5

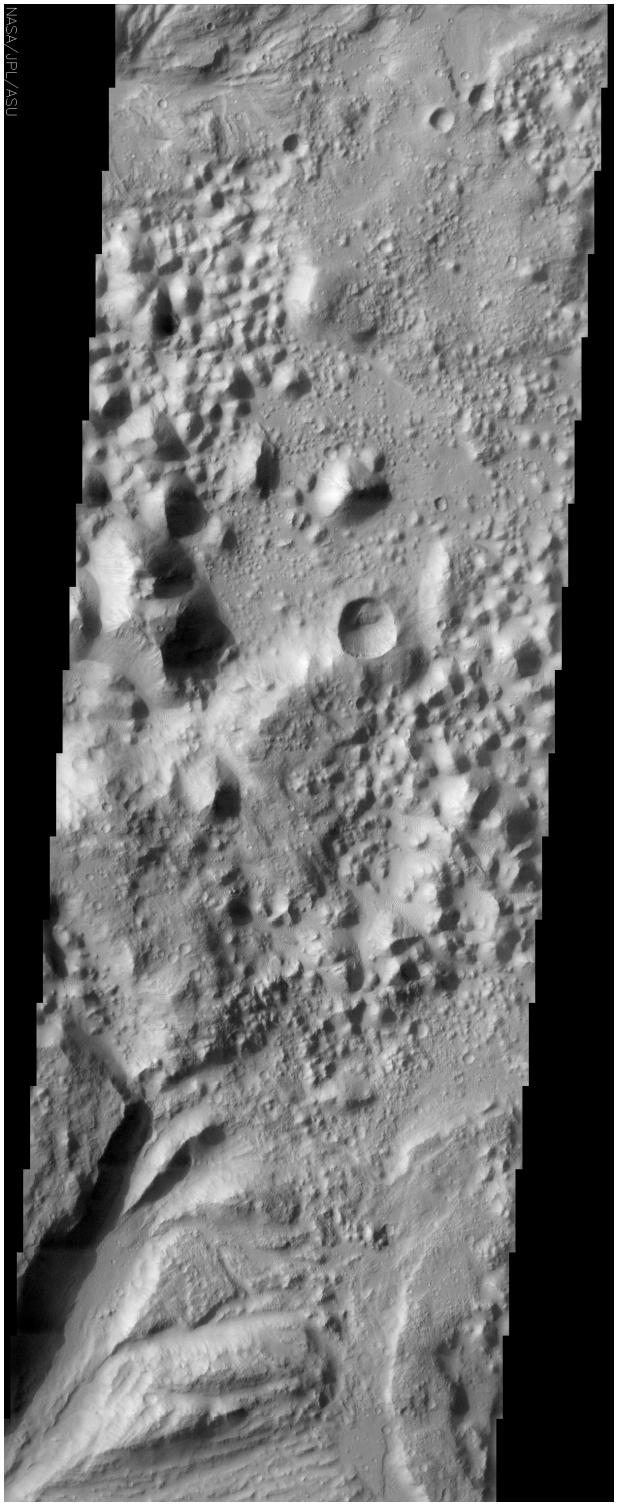
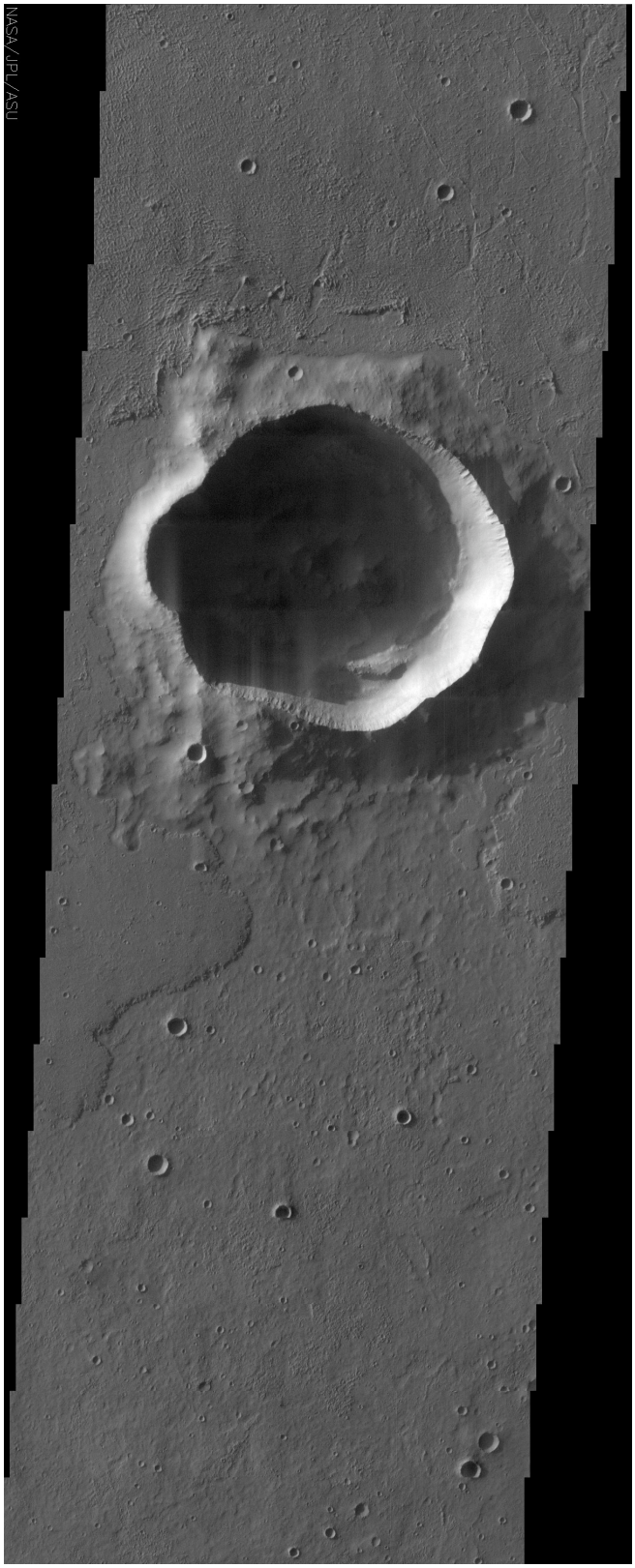


Figure 6



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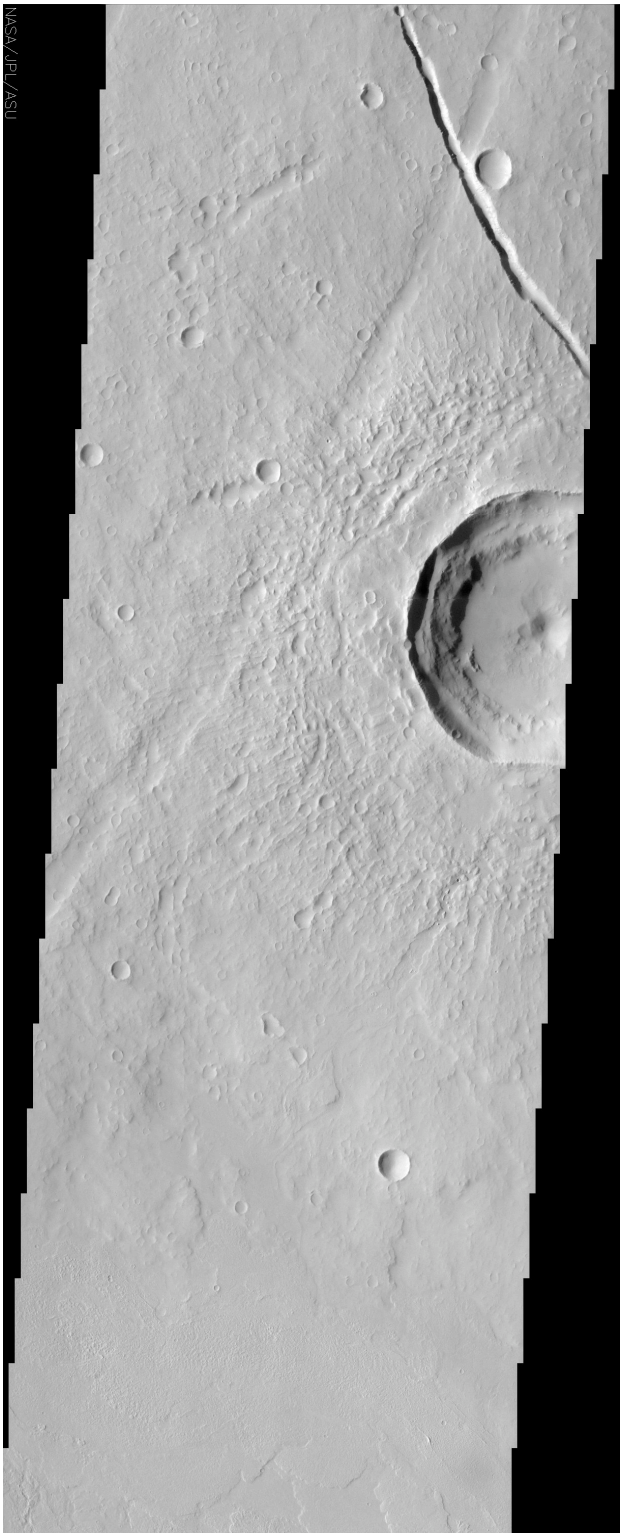
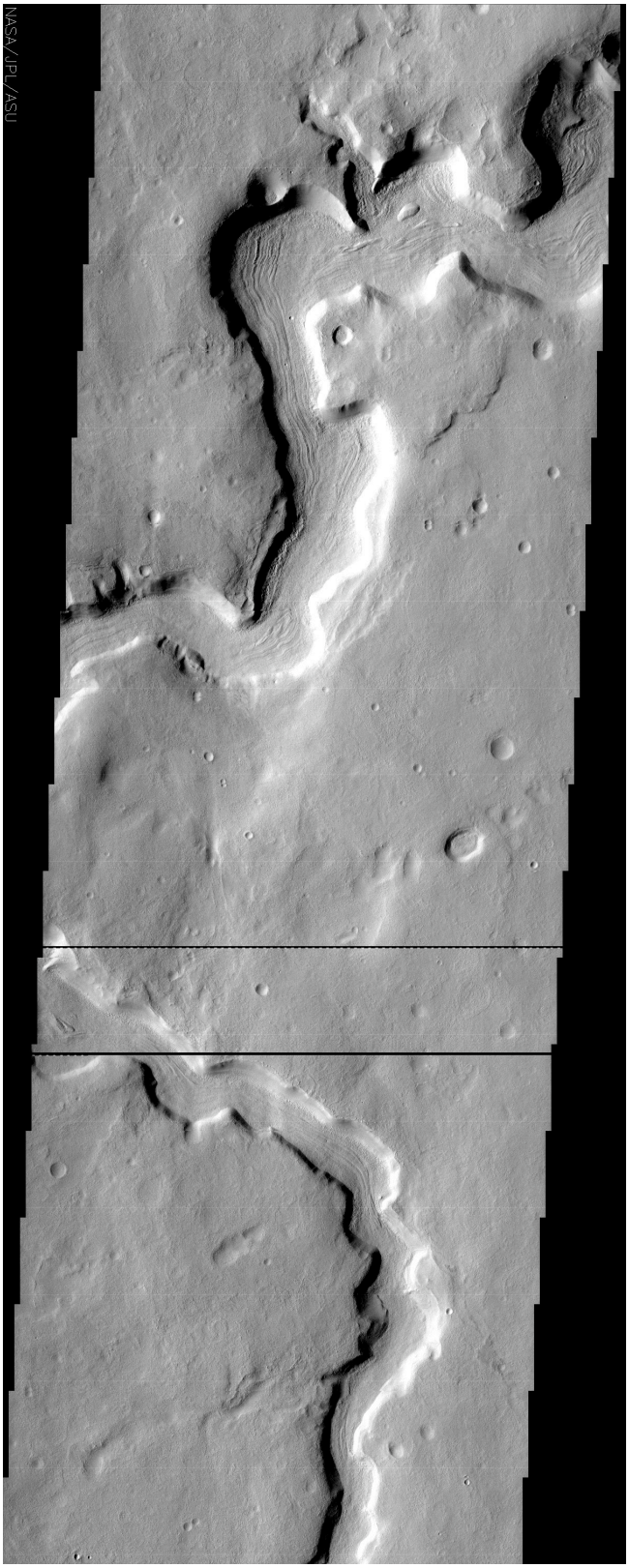


Figure 8

Figure 9



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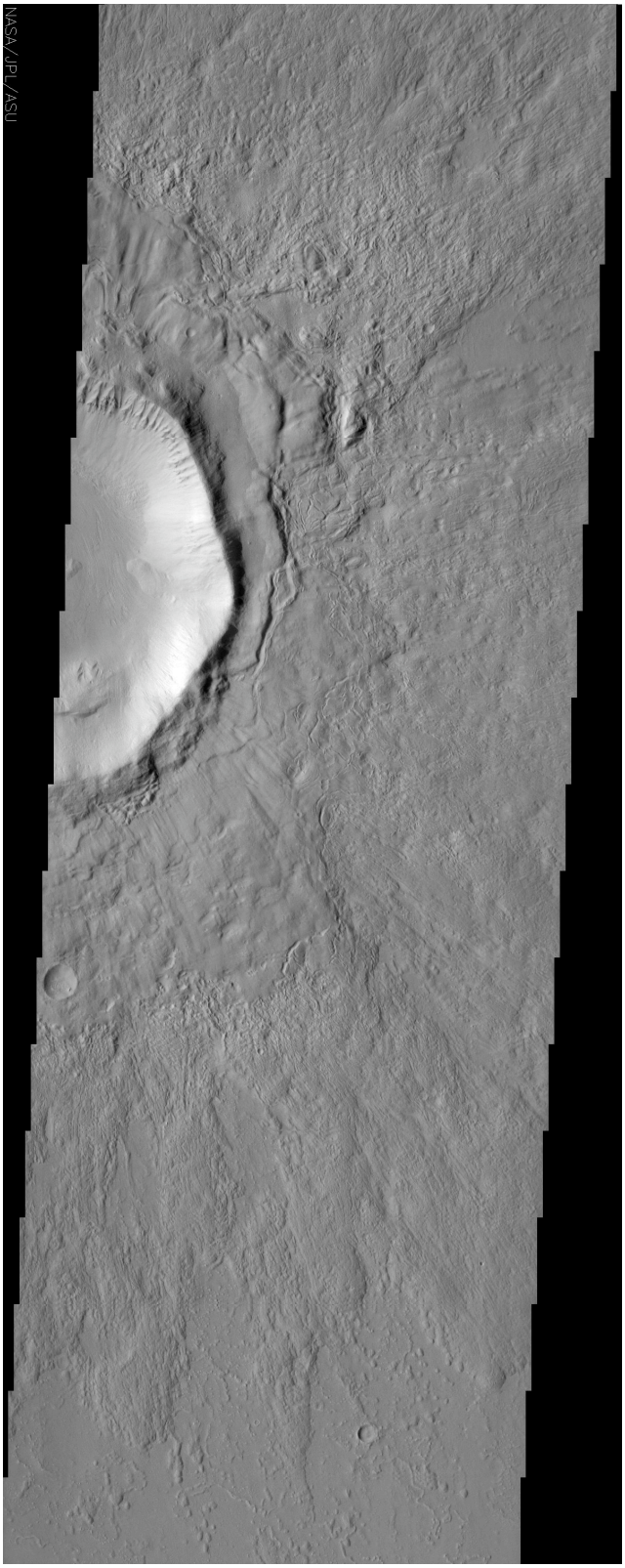


Figure 11

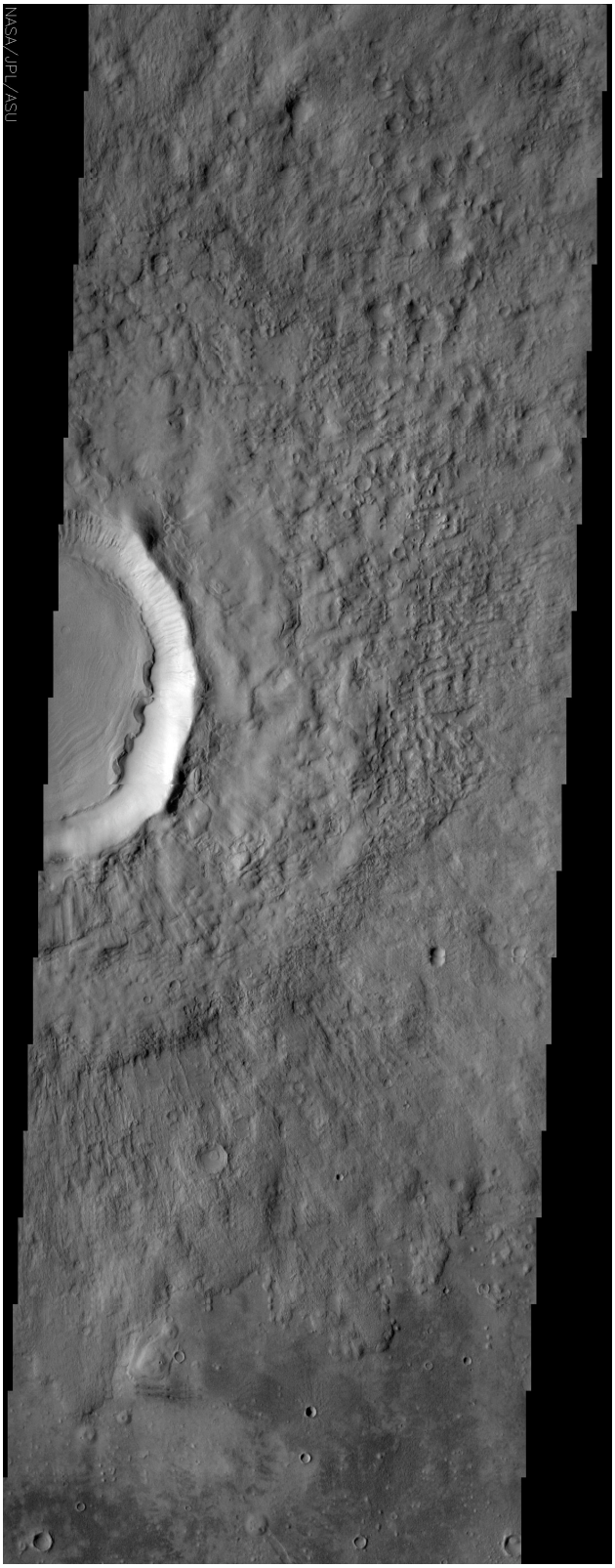


Figure 12

Figure 13

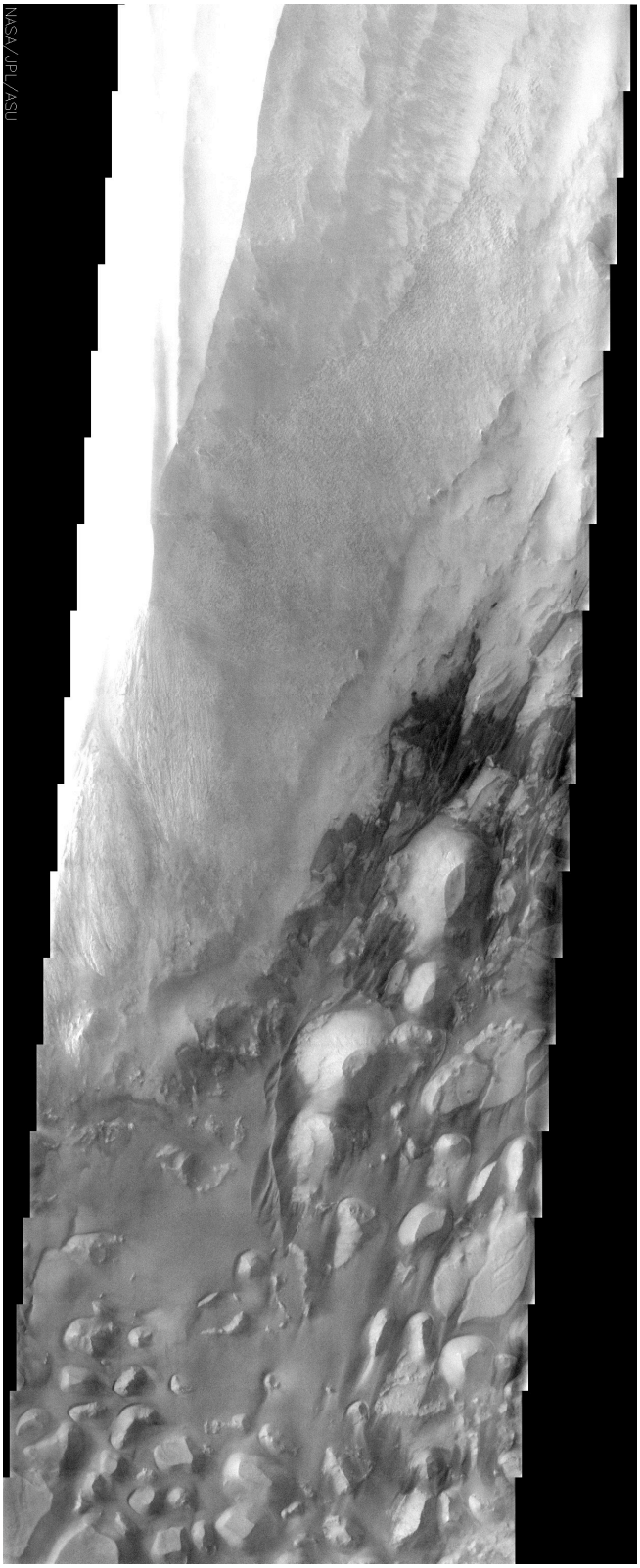


Figure 14

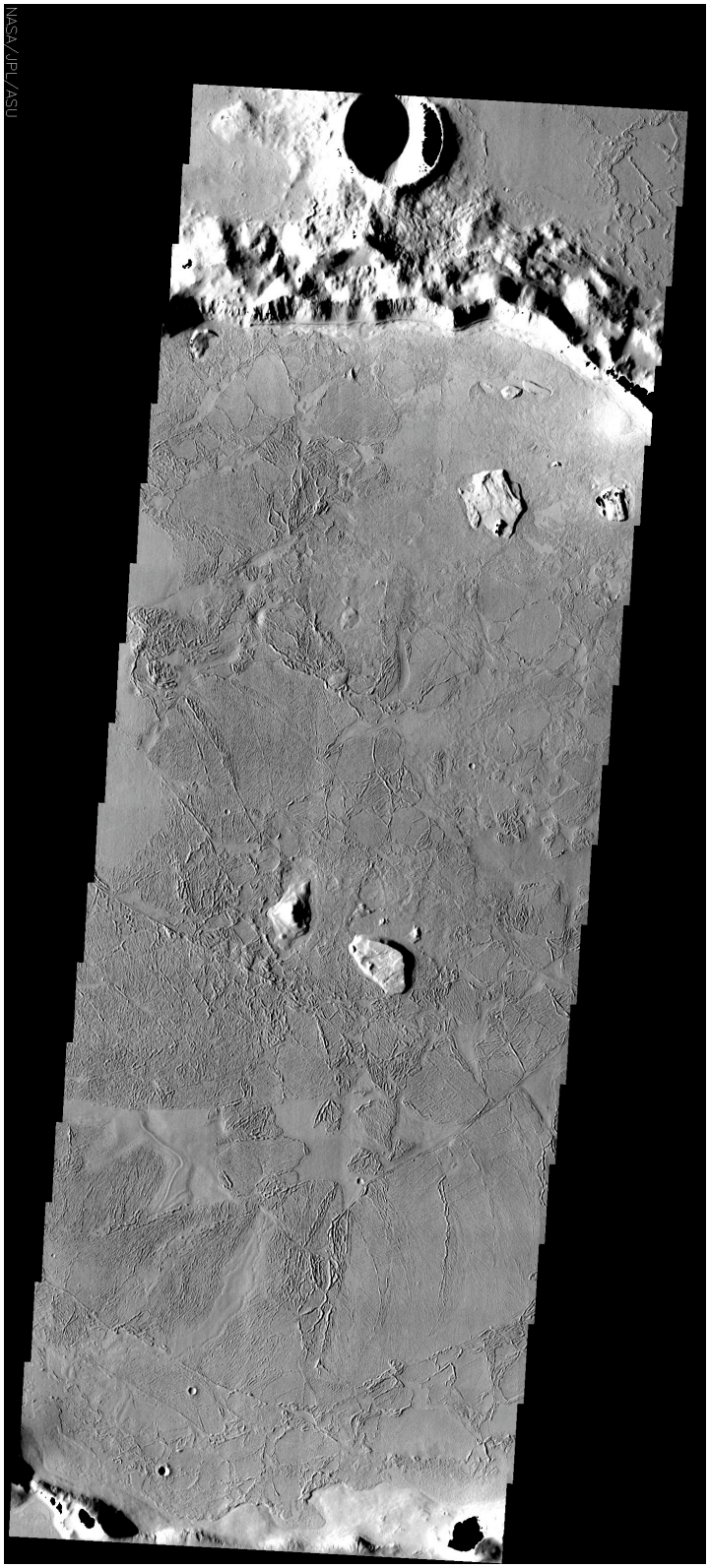


Figure 15

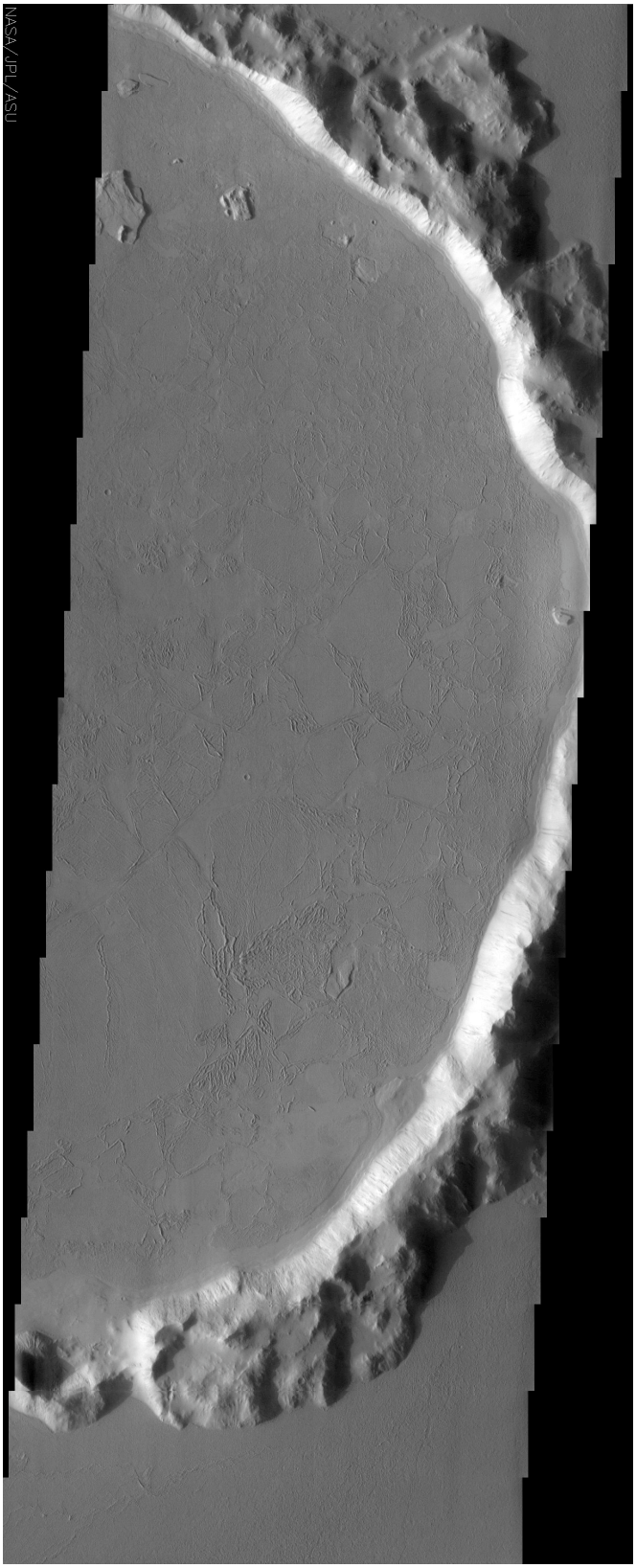


Figure 16

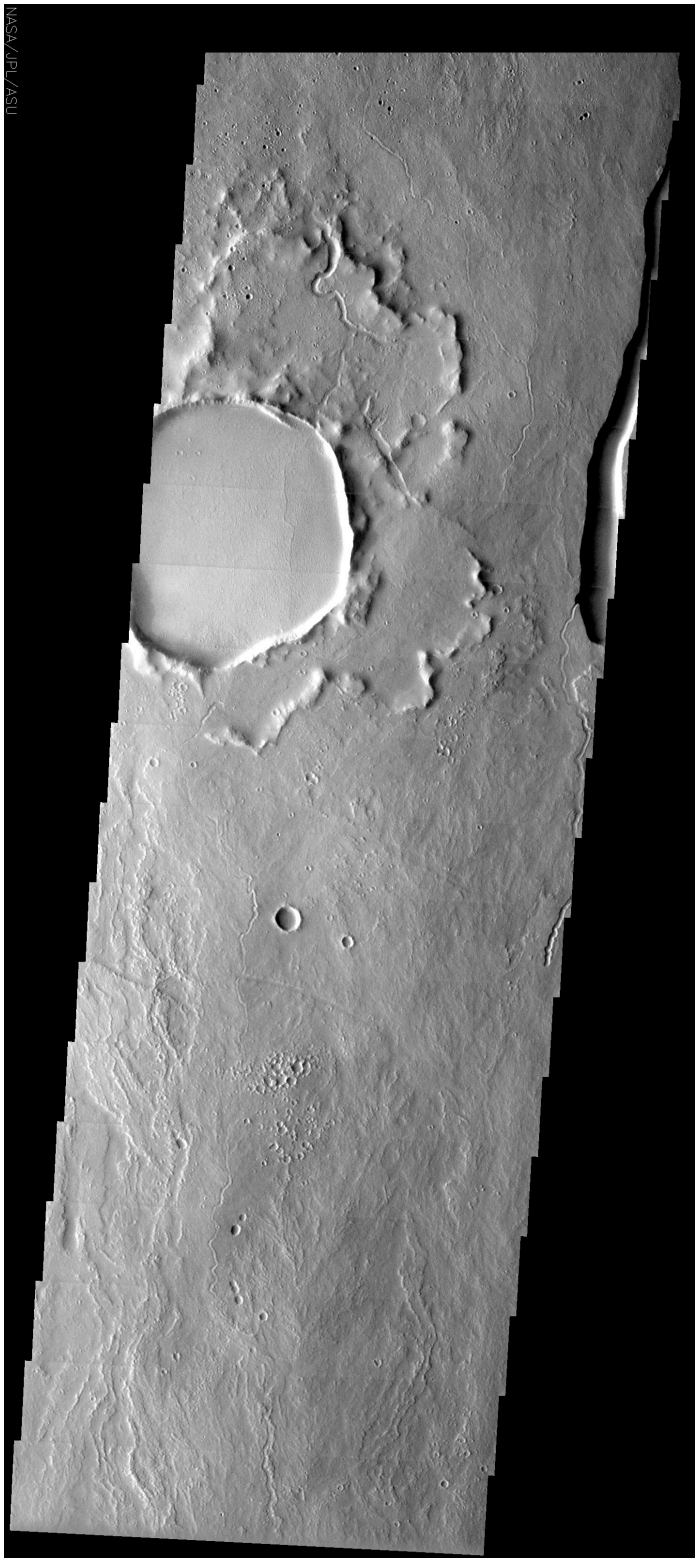


Figure 17

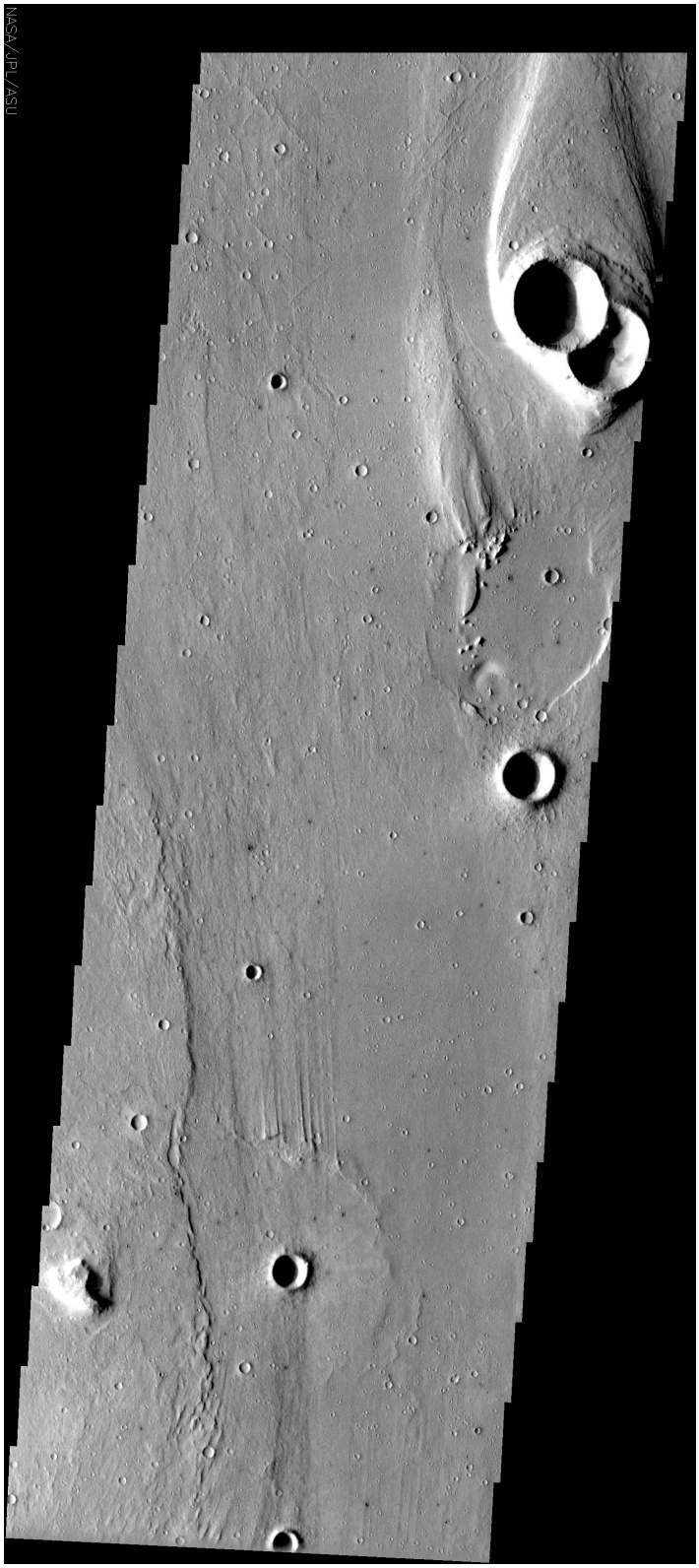


Figure 18

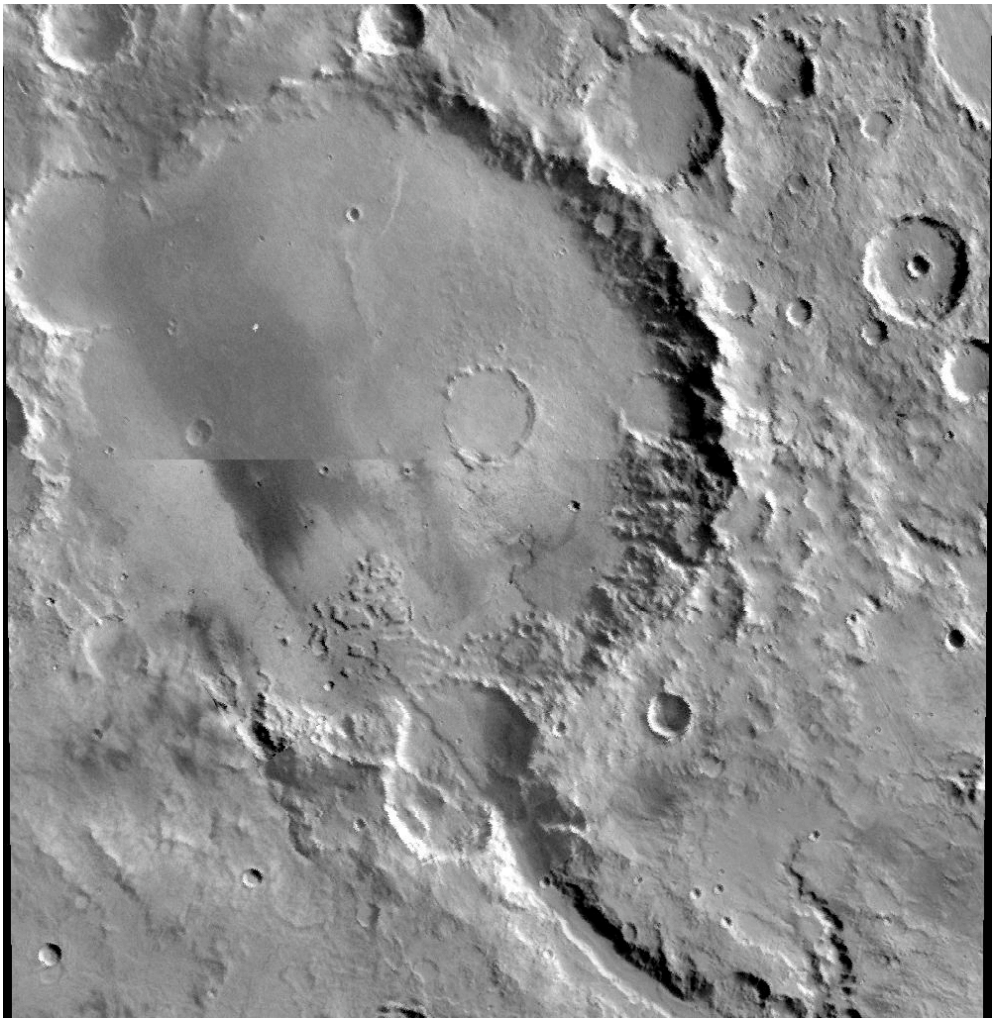


Figure 19

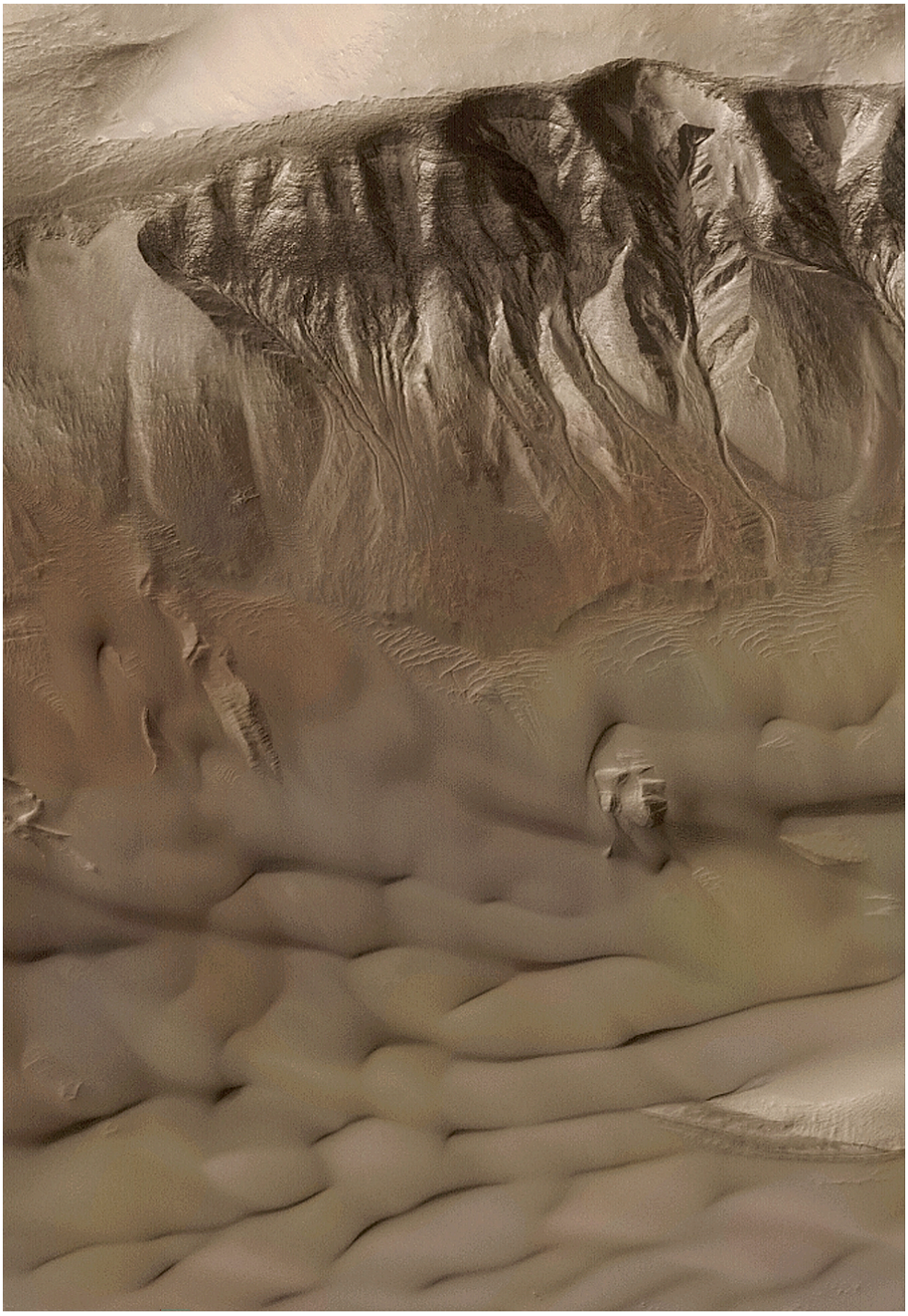


Figure 20

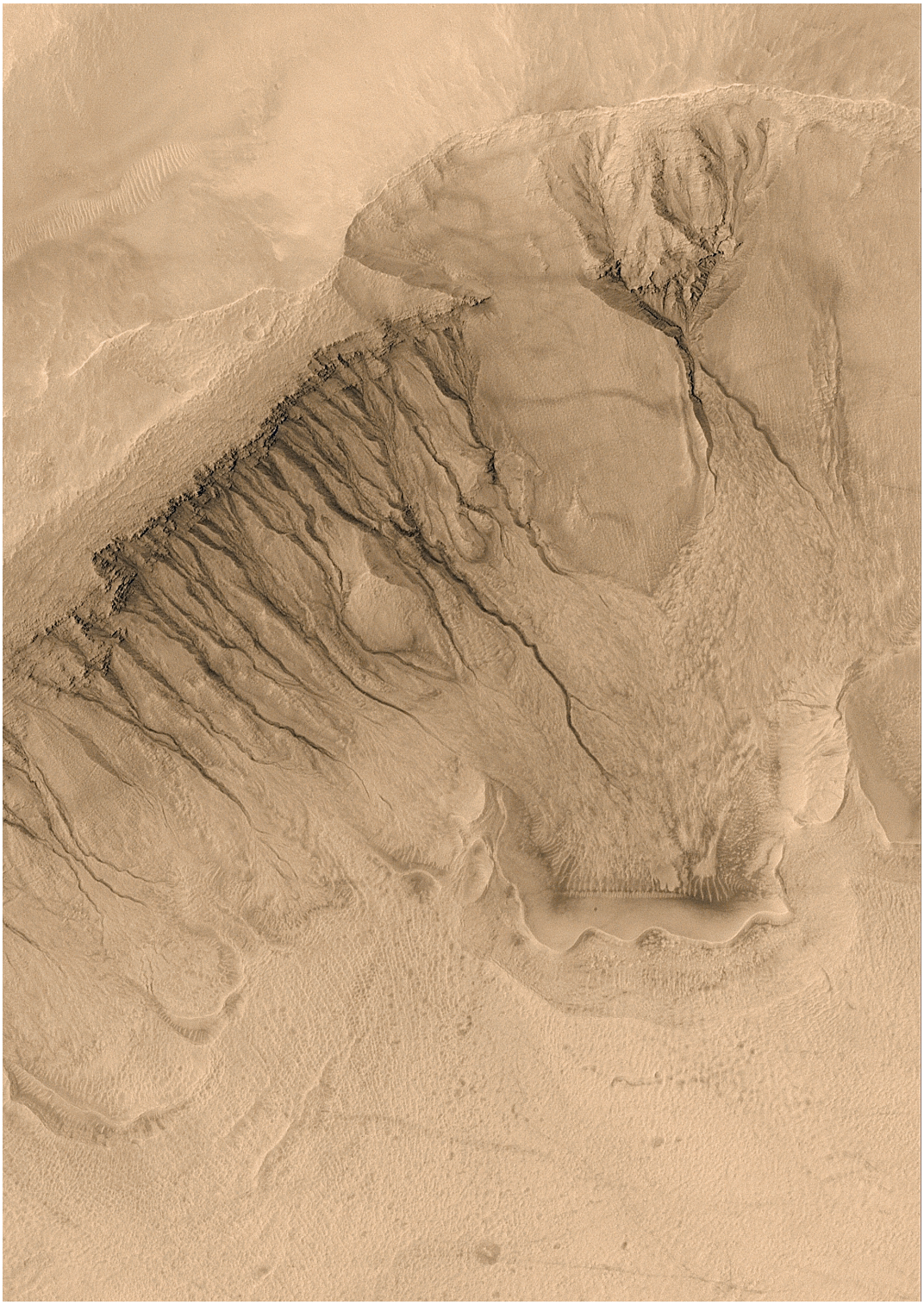


Figure 21

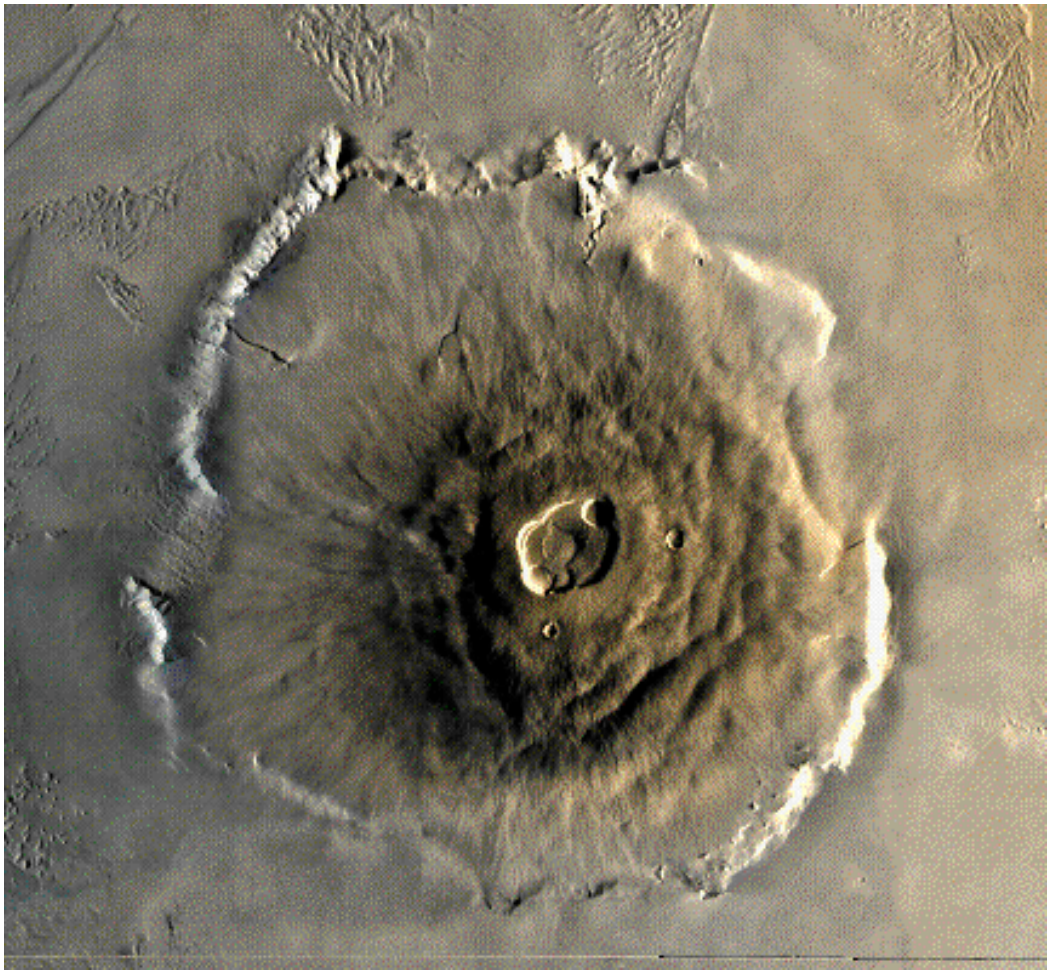


Figure 22

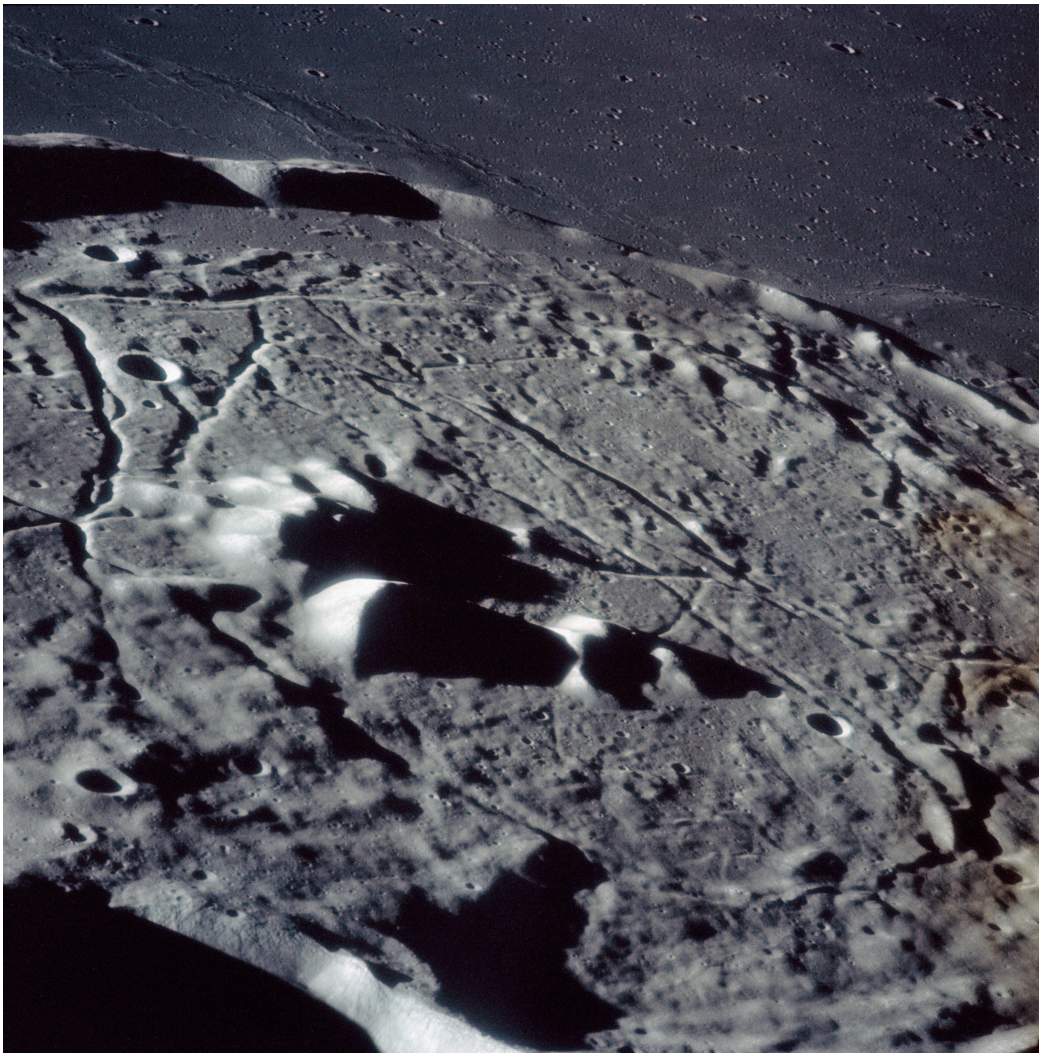


Figure 23

Figure 24 – **Assessment Rubric**

Name: _____ Teacher: _____

Date: _____ Title of Work: _____

	Criteria				**Points**
	1	2	3	4	
Students will realize the importance of mass and speed of an asteroid or comet when it strikes a celestial body.	Student understands that speed and mass play a role in the cratering process.	Student understands that the higher the mass and speed, the wider and deeper the crater formed.	Student can predict crater sizes based on the given speed and mass of the impactor.	Student can apply information to a planetary scale and predict cratering processes on celestial bodies.	
Students will be able to distinguish the relative ages of craters in a given area.	Student understands there are ways to notice if a crater is older or younger than another.	Student can explain the methods of determining the relative ages of craters.	Student can tell which craters in a given area are older or younger than others.	Student can explain the erosion processes that "age" craters and therefore makes them different than other craters.	
Students will be able to predict the water content of an area based on crater ejecta and structure.	Student understands that water has an influence on crater formation.	Student understands that watery impacts cause certain patterns in crater formation.	Student sees and notices the predicted patterns in orbital pictures taken from spacecraft.	Student can accurately select and predict which craters (out of a given selection) involve a watery substrate.	
				Total points →	

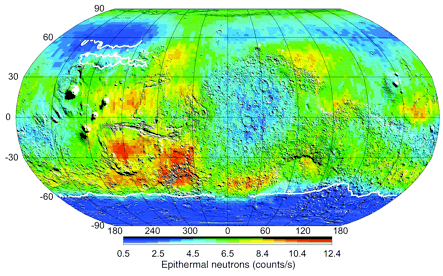
Teacher comments:

Detecting Water on Mars

Time:

4-5 class periods

Objectives:



The lesson prepares students to interpret remote sensing images, a spectrograph image of Hydrogen, and a neutron spectrograph that will be used to analyze and detect the probability of water on Mars.

Students will analyze various methods of detecting the presence of water on Mars. Students will utilize remote sensing photographs, geologic models, neutron spectroscopy graphs, spectroscopy images, concept activities and current mission findings (Spirit and Odyssey), in substantiating the existence of water on Mars.

Content Standards:

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry
- The position of an object can be described by locating it relative to another object or the background.
- Vibrating objects produces sound. Changing the rate of vibration can vary the pitch of the sound.
- Electricity in circuits can produce light, heat, sound, and magnetic effects. Electrical circuits require a complete loop through which an electrical current can pass.
- People have always had questions about their world. Science is one way of answering questions and explaining the natural world and solar system.
- Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.
- Describe the shape and important features of a set of data and compare related data sets with an emphasis on how the data are distributed
- Propose and justify conclusions and predictions that are based on data and design studies to further investigate the conclusions or predictions.
- Apply and adapt a variety of appropriate strategies to solve problems.
- Represent data using tables and graphs such as: line plots, bar graphs, and line graphs.

Equipment, materials, and tools:

For the teacher:

Visuals of:

- a Neutron Spectrograph Map of the Mars
- Images of ***Spirit*** and ***Opportunity Spacecraft*** and their instrumentation (optional)
- http://www.space.com/php/multimedia/imagedisplay/img_display.php?pic=h_roverdetail_02.jpg

- A neutron spectrograph
- For demonstration on neutron reaction activity:
- Magnet (10), 3 jars with different levels of water, steely (12), glass marble (3), a tray or boundary for catching marbles.
- Optional: representative rock samples of iron (basalt), magnesium (Olivine), and silicon (quartz).
- Evaluation of Spectroscopy

The teacher will demonstrate knowledge and use of spectroscopy, neutron spectroscopy, core sampling, stratigraphy, and hydro-porosity of soils.

For each group of 3 to 4 students:

Copies of:

- Epithermal Neutron map image
- Epithermal Core Neutron Data (Assign one core sample per group),
- a blank Neutron Data Graph,
- Epithermal Neutron Count Graph (for normalizing data), and
- a blank Weight Percentage of Water Graph

Background Information:

Data collected from the use of the Gamma-Ray Spectrometer on the Mars Odyssey provides evidence of areas on Mars that are enriched in Hydrogen (H). The presence of Hydrogen on Mars does not provide proof of the existence of water, Hydrogen present in the form of physically or chemically bound H_20, but the evidence suggests a strong volatility dependence similar to that expected for ice.

Three instruments used on the Mars Odyssey mission are the Gamma Subsystem, the Neutron Spectrometer, and the High Energy Neutron Detector. The techniques of gamma ray and neutron spectroscopy rely on cosmic-ray particles acting as an excitation source. Through a process of excitation and de-excitation, emission of detectable gamma rays provide evidence of varying chemical elements. Hydrogen is especially effective at moderating neutrons.
When stars in our galaxy die they generate waves that accelerate cosmic rays that enter our solar system and hit planet surfaces. After a cosmic ray hits a surface it generates neutrons. These neutrons then hit other elements, and send out gamma rays that have different "sounds"(which represent gamma ray energies). Each element that is hit has its own signature sound. Gamma Ray Spectrometers detect the gamma ray that is unique to each element.

The neutron spectrometer allows scientists to count the number of neutrons that are scattered by the collisions. Some of the different elements scientists are looking for are: Hydrogen (H), Carbon (C) Oxygen (O), Magnesium (Mg), Aluminum (Al), Silicon (Si), Calcium (Ca), Chlorine (Cl), Titanium (Ti), Iron (Fe), Potassium (K), Thorium (Th), and Uranium (U).

Lesson Plan:

Student Skills

Students need an understanding of spectroscopy as a way of studying which atoms absorb and emit electromagnetic radiation. Spectroscopy allows astronomers to study the chemical composition of planets, moons, stars and so on from afar because of the way atoms absorbs and emits light.

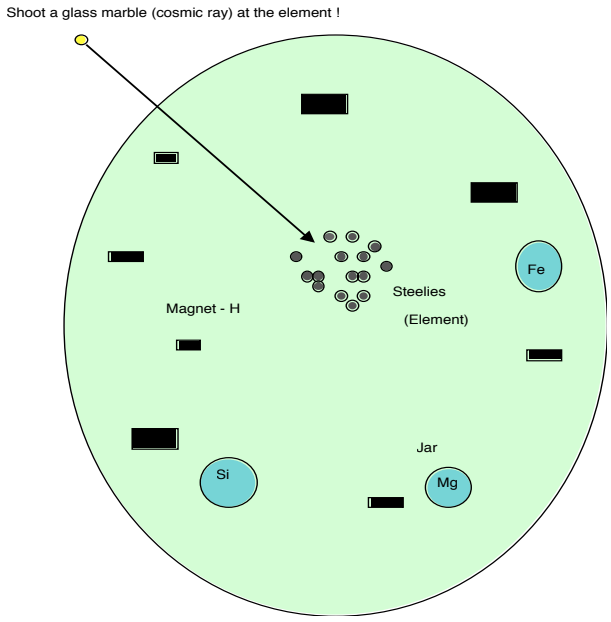
To look at a Mars Surface Spectrograph go to: http://www.iki.rssi.ru/hend/e_page2_main.htm

Students should understand the basic sub-atomic particles that make up atoms and hydrogen in particular. In this lesson, students will model neutron interactions between different elements, and interpret an epithermal neutron map of Mars. Students will also graph epithermal neutron data from a hypothetical core sample, normalize their data, and produce a graph of stratigraphic water content.

Questions about Mars Spectroscopy

- What does the surface of Mars consist of?
- How did Mars form and how has it changed?
- Is there a water table within three feet of the Martian surface?
- Has there been standing water on the surface of Mars?
- What will Mars be like in the future?
- What is a spectrograph?
- What does a map of epithermal neutron fluxes from a neutron spectrograph tell us about hydrogen on Mars?
- What previously unknown information can be collected from a Mars core sample neutron spectrograph?
- Why is it important that we look for water/hydrogen on Mars?
- Where are the best places on Mars to look for the fossil remains of life or microbial communities?

Demonstration Activity



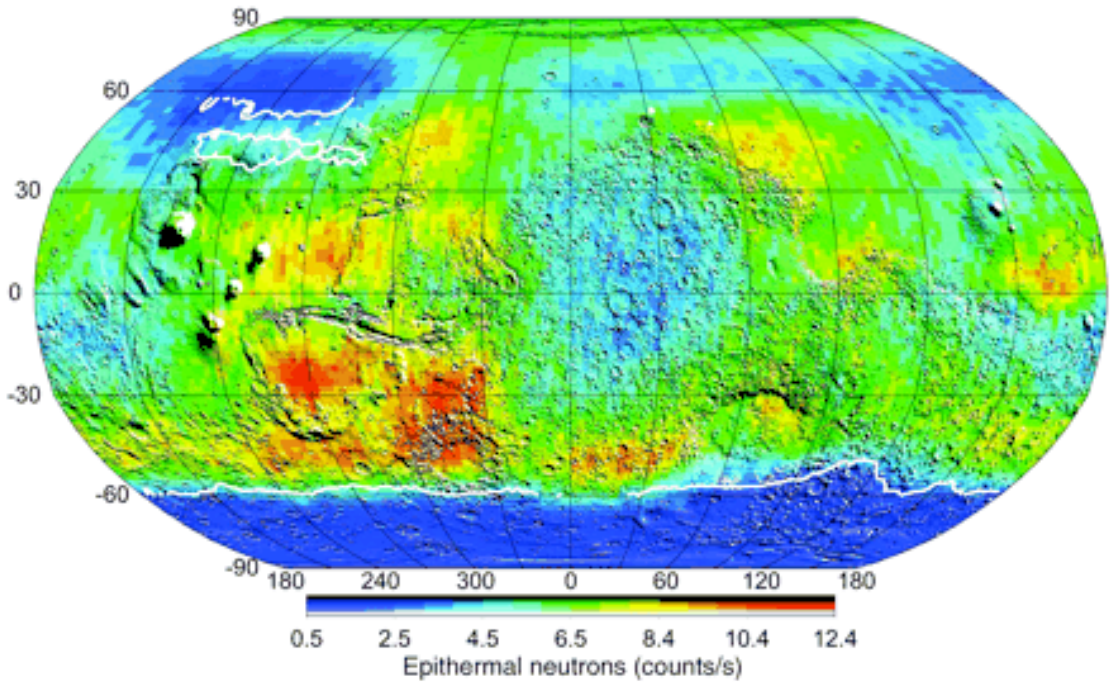
Place several magnets representing Hydrogen (H) atoms, a one-quarter filled jar of water representing Silicon (Si), a one-half filled jar representing Magnesium (Mg), and a three-quarter filled jar representing Iron (Fe), in a circular pattern along the periphery, each about 5 inches away from of a cluster of steel marbles. Set a cluster of a dozen or so steel marbles in the center of the model. Explain to students that you will be shooting a marble to represent a cosmic ray striking an element on the Mars surface that is represented by the cluster of steely marbles. The steel marbles represent the neutrons in this element. When it is bombarded by a cosmic ray, it will shoot out neutrons that then collide with other elements on the Martian surface. The jars and magnets represent other elements in the crust. As the neutrons hit the different jars,

they will make different sounds representing the different neutron signature sounds that a neutron spectrometer records from different elements. Since Hydrogen (H) is merely a proton with an orbiting electron, it will absorb a bombarding neutron and therefore not produce any signature sound. For this reason Hydrogen (H) has a low epithermal signature.

Challenge

Show students the following Epithermal Neutron Map of the Mars surface Analyze the low epithermal fluxes for Hydrogen (H). Ask students to describe any patterns or logic in the image map. Are there any similarities with earth?

To explain how the mapping was acquired from Odyssey, go to:
http://www.lanl.gov/orgs/pa/News/MarsOdyssey.html

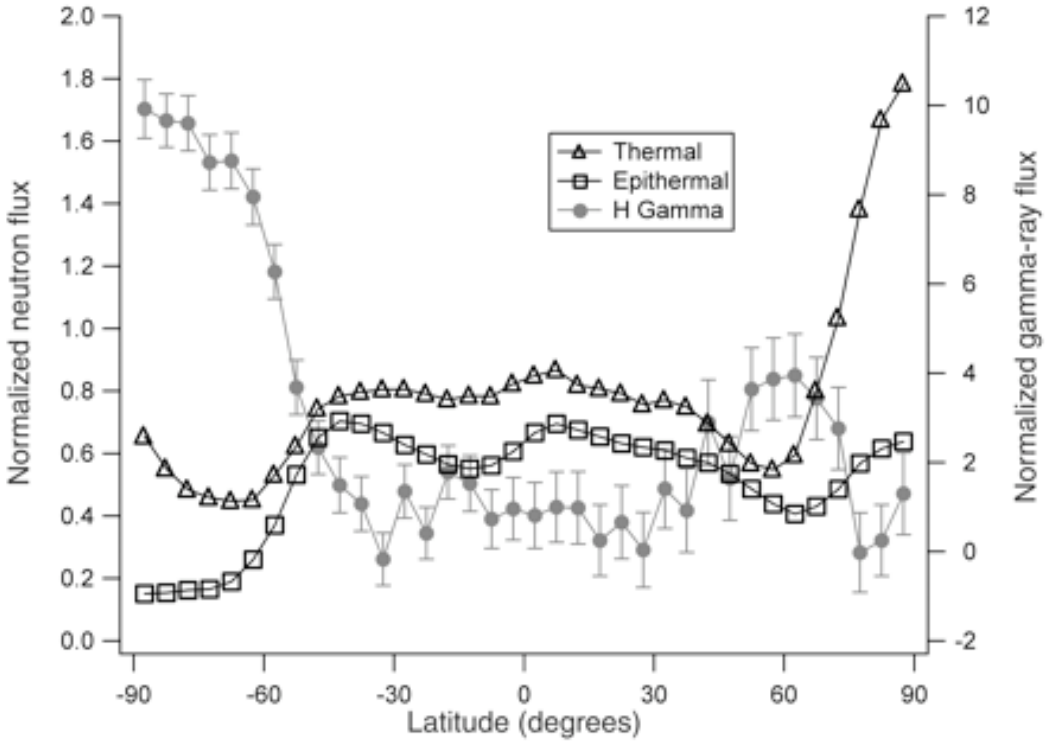


To provide students with a larger image of this map, see Figure 1.

More information can be found at:

http://www.sciencemag.org/cgi/content/full/297/5578/81?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&searchid=1060273802703_5117&stored_search=&FIRSTINDEX=0&volume=297&firstpage=81&fdate=10/1/1995&tdate=8/31/2003

For additional imaging go to:
http://grs.lpl.arizona.edu/results/agu1202/



Normalized fluxes of neutrons and H gamma rays versus latitude. The data are averaged over longitudes 90° to 210°E. These longitudes were chosen to be as far as possible from the residual CO2 cap in the south, which could have a major effect on the flux of thermal neutrons, similar to that observed in the north due to the seasonal CO2 frost. The increase in H gamma-ray emission south of about -45° is clearly evident, as is an enrichment in the north. The enrichment in the north does not continue to the pole because the north polar region is currently covered by a thick seasonal CO2 cap. Note the anticorrelation between the H gamma-ray flux and the epithermal neutron flux.

Emphasize that Hydrogen (H) has a low epithermal signature because it absorbs neutrons. This graph (Figure 2) was produced during a Northern hemisphere winter, during which time CO_2, or dry ice, covered the North Pole. Notice the data reversal in the northern polar region. As the gamma ray hits the surface, it only comes into contact with the dry ice, no Hydrogen (H). Even in areas without the dry ice, the map only detects at the surface. Scientists want to know more about the underlying stratigraphic layers of Mars. Is there any subsurface water? How could we explore Mars more? How do we find out about underlying stratigraphy on earth? Normally we would drill! Can we drill on Mars? Well that is what the Mars Rover on the Spirit and Opportunity Missions are planning to do after landing on January 4th and 25th, 2004!

To find out about the constituents of the underlying layers of Mars, the new missions are carrying probes for conducting Gamma Ray Spectrometry (GRS). The instruments are designed to drill a 30-cm core hole and insert a gamma ray spectrometer (GRS). The epithermal neutron signatures for the different layers of rock and soil will be retrieved and relayed to earth.

For more information on how the GRS works:
http://mars.jpl.nasa.gov/odyssey/technology/grs.html

For the following activity, we will assume that the students are scientists at the Los Alamos National Laboratory, who developed the Gamma Ray Spectrometer for these missions, and are

now receiving and interpreting the data. Give each group of students one of the sample core readings and ask them to identify the stratigraphic layers by using Table 1 for comparison.

For more information on the Gamma Ray Spectrometer built by Dr. William Feldman at Los Alamos Laboratories: http://grs.lpl.arizona.edu/instruments/ns/

Epithermal Neutron Core Data from Mars

Depth	Sample A	Sample B	Sample C
0		1	0.68
2	1		
4		0.43	1
6	0.98	1	
8		0.42	0.98
10	0.67		
12			
14		1	0.87
16	0		
18			0
20	0.41		
22		0.44	
24			0.41
26	0.99		
28			
30			

Depth	Sample D	Sample E	Sample F
0	0.46	0.63	0.68
2			
4		0	1
6	0		
8	0.28	0.47	0.98
10			
12	0.99		
14		0	0.87
16	0		
18		0.42	0
20	0.45		
22			
24		0.22	0.41
26			
28			
30			

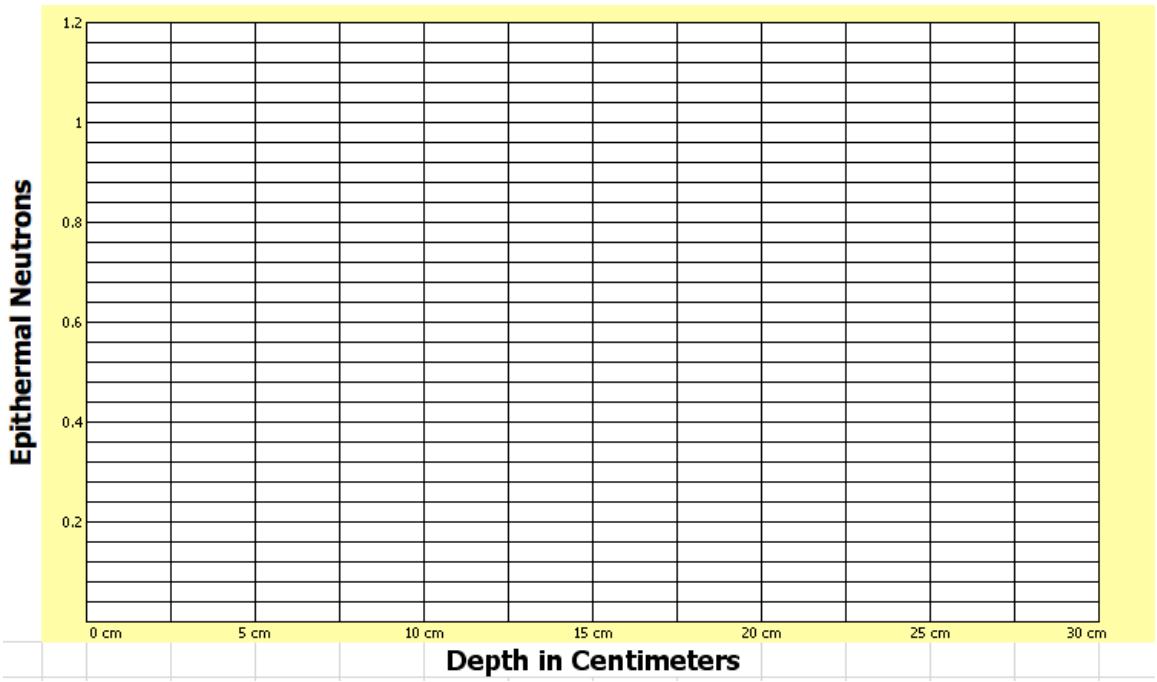
Table 1

Rounded Epithermal Neutron Signatures	"Hypothetical" Stratigraphy
1.0	Basalt
0.8	Olivine
0.6	Volcanic Ash/Tuff
0.4	Sandstone
0.2	Sand
0	Alluvial Mix

Hypothetical Stratigraphy and representative Epithermal Neutron Signatures. Note that the lower the epithermal signature, the greater the abundance of Hydrogen and porosity of the stratigraphic layer.

Have students graph their epithermal neutron counts from their core sample onto a blank Neutron Data Graph.

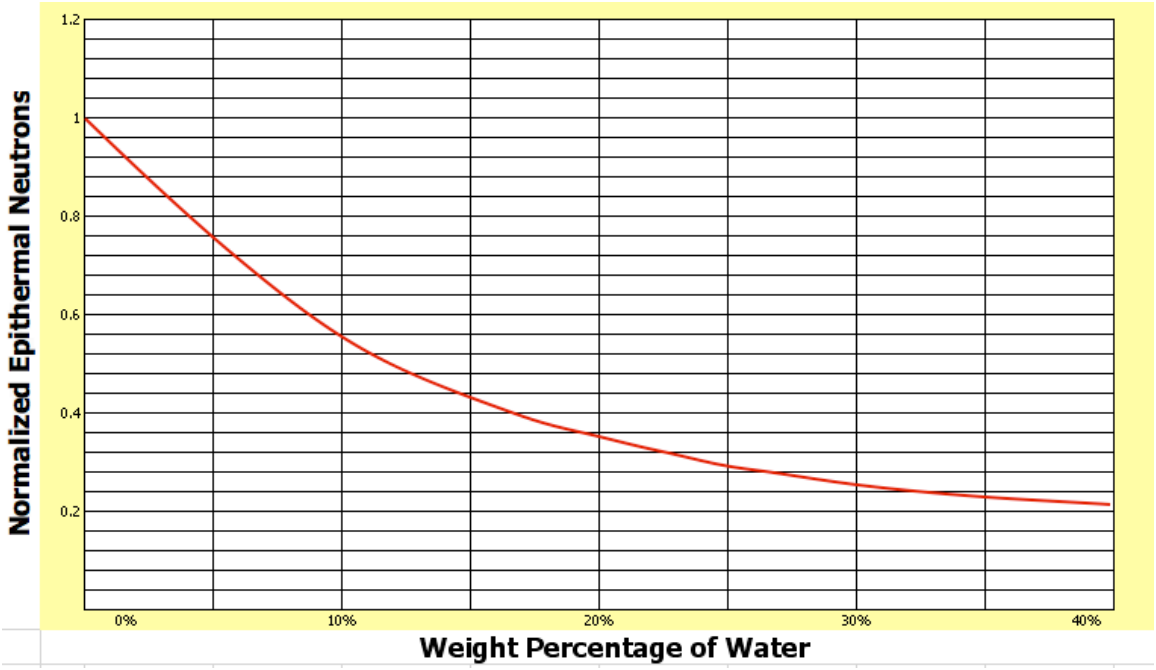
Neutron Data Graph
(see Figure 2 for larger copy)



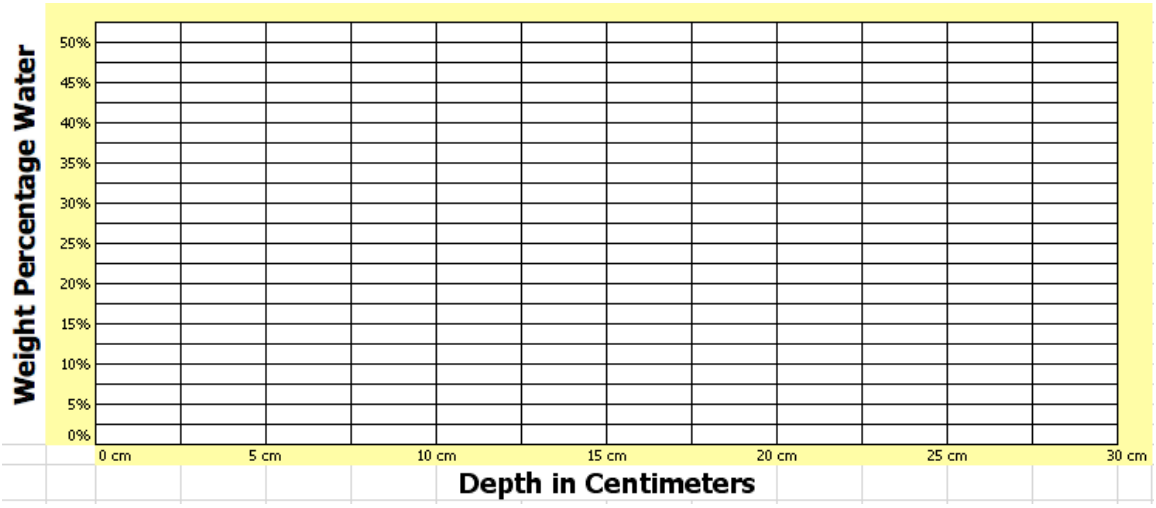
Ask students to extrapolate information from their Neutron Data Graphs. What can they infer from the data?

Refer to the Epithermal Neutron Counts Graph. Students will use this graph to normalize their data. Students are to predict the water content of each stratigraphic layer of rock and soil. Students will then plot the percentage by weight of water in their Core Sample onto another graph.

Epithermal Neutron Counts
(see Figure 3 for larger copy)



Percentage of Water in Core Sample
(see figure 4 for larger copy)



The data in this activity is hypothetical. More realistic data will be relayed back to earth when Spirit and Opportunity land on Mars in January 2004, so stay tuned! What do you think they will find? Ask students to create their own hypothetical data set of what they think scientists will find.

Assessment:

Create a hand drawn stratigraphic layer with at least 5 different stratigraphic layers. Identify the latitude of your core sample in your Title. Using your own graph paper graph the corresponding Epithermal Neutron Count and Percentage by Weight of Water for your particular core sample.

Questions & Closure:

Assume we find more evidence of water on Mars. Why is this important? Would it be possible for life to exist on Mars? Why or why not?

For demonstration purposes, create a model of a short strand of DNA (Magz@ magnets work well). Fire a model radiation particle (foam ball with a slingshot) at the DNA and watch it break. Explain to students that this is what radiation does to DNA.

Is it possible for life to exist on Mars? Discuss.

Extension:

Split the class in half. Ask students to use the scientific method in establishing evidence proving or disproving the possible existence of life on Mars now or in the past. Use the Internet to look for information about the planet that either supports or diminishes the theory that life could exist or has existed on Mars! Be sure to study the magnetosphere, the planet's origin, weather and other parameters about Mars.

Figure 1

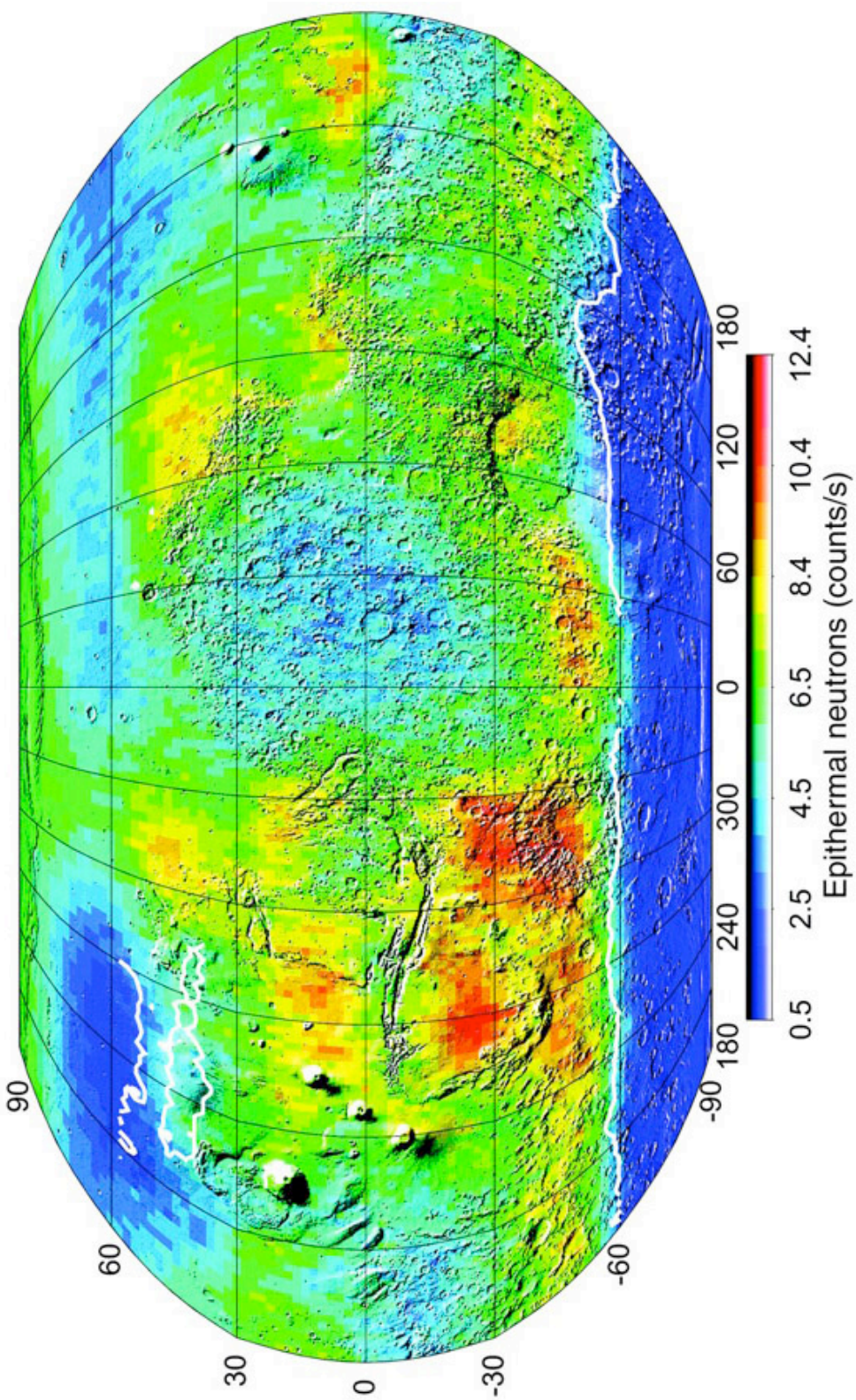

90
60
30
0
-30
-60
-90
180
240
300
0
60
120
180
0.5
2.5
4.5
6.5
8.4
10.4
12.4
Epithermal neutrons (counts/s)

Figure 2

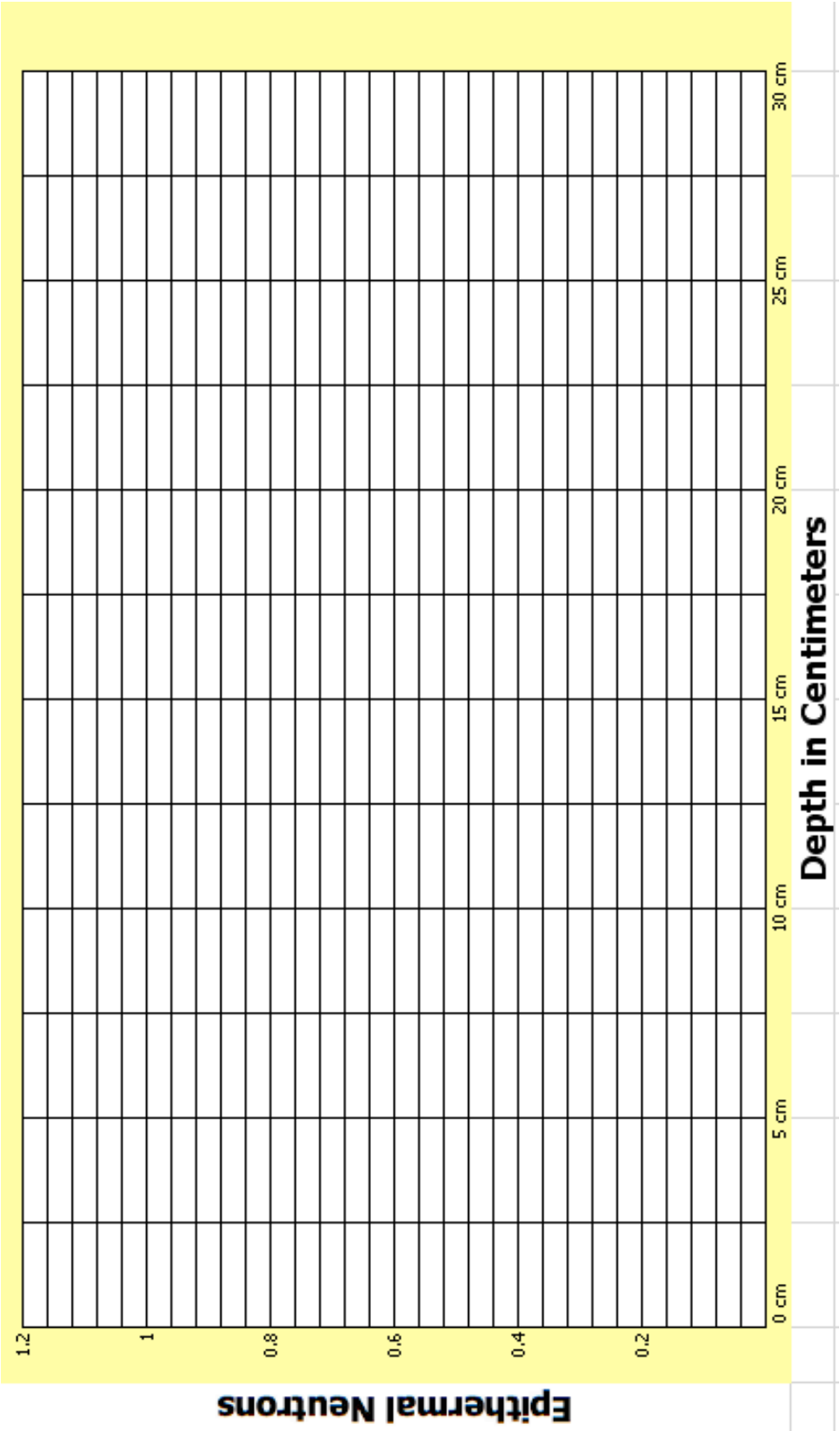

Epithermal Neutrons
1.2
1
0.8
0.6
0.4
0.2
0 cm
5 cm
10 cm
15 cm
20 cm
25 cm
30 cm
Depth in Centimeters

Figure 3

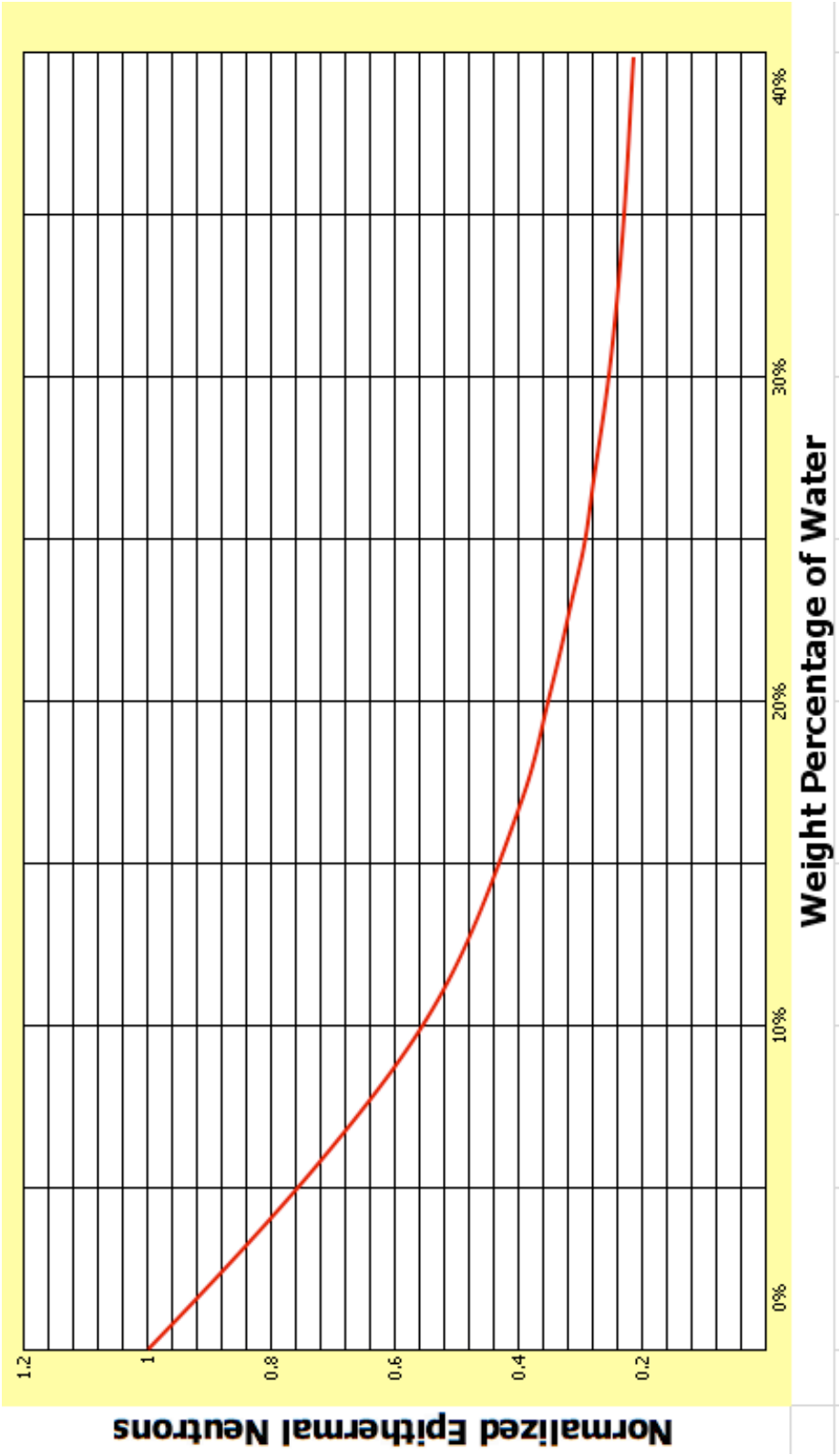
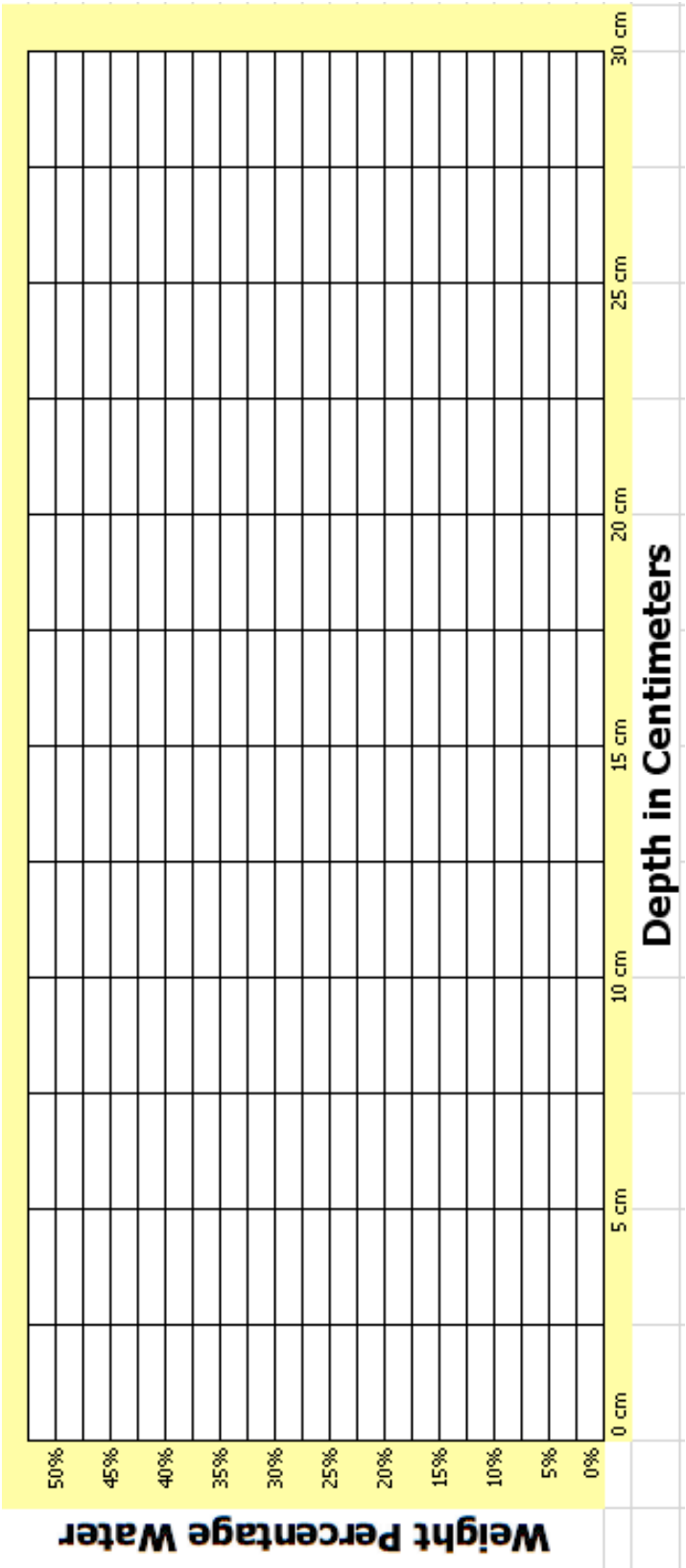

Normalized Epithermal Neutrons
1.2
1
0.8
0.6
0.4
0.2
0%
10%
20%
30%
40%
Weight Percentage of Water

Figure 4


Weight Percentage Water
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0 cm
5 cm
10 cm
15 cm
20 cm
25 cm
30 cm
Depth in Centimeters

Exploring A Rocket's Propulsion

A Science Brief With Exercise for Grades 6-12

Conent Standards:

The following national standards for teaching science, mathematics, and technology are applicable to this exercise.

NS.5-8.1 and NS.9-12.1 SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

NS.5-8.2 and NS.9-12.2 PHYSICAL SCIENCE

- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

NS.5-8.5 and NS.9-12.5 SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

NT.K12.3 TECHNOLOGY PRODUCTIVITY TOOLS

- Students use technology tools to enhance learning, increase productivity, and promote creativity.
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepares publications, and produce other creative works.

NM-NUM.6-8.3 and NM-NUM.9-12.3

- Compute fluently and make reasonable estimates

References

- Ecucation Standards from Education-World.com
- Much of the introduction from HowStuffWorks.com

ACTIVITY – Trajectory as a Result of Decreasing Mass of Fuel

Objective:
Students will develop an understanding of rocket trajectory.
Students will develop and understanding of the effect of the decreasing mass of fuel on the rocket's acceleration.

Time:
One to two hours

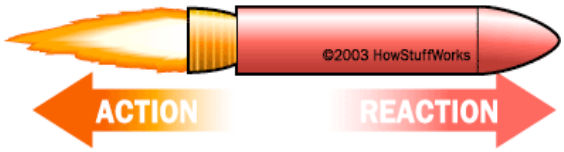
Keywords:
Rocket, Propulsion, Acceleration, Conservation of Momentum, Approximation and Estimation

Materials:
Grades 5-8: Four-function calculator
Grades 9-10: Personal computer with a spreadsheet program
Grades 11-12: Personal computer with a high level programming language

Background:
One of the most amazing endeavors man has ever undertaken is the exploration of space. A big part of the amazement is the complexity. Space exploration is complicated because there are so many problems to solve and obstacles to overcome. The biggest problem of all is harnessing enough energy simply to get a spaceship off the ground. That is where rocket engines come in.

Rocket engines are, on the one hand, so simple that you can build and fly your own model rockets very inexpensively. On the other hand, rockets are so complicated that only two countries have actually ever put people in orbit. The exercise in this lesson will help students understand a rocket's propulsion.

When most people think about motors or engines, they think about rotation. For example, the gasoline engine in a car produces rotational energy to drive the wheels. An electric motor produces rotational energy to drive a fan or spin a disk.
Rocket engines are fundamentally different. Rocket engines are ***reaction*** engines. The basic principle driving a rocket engine is Newton's famous principle that "to every action there is an equal and opposite reaction." A rocket engine is throwing mass in one direction and benefiting from the reaction that occurs in the other direction as a result.



This concept of "throwing mass and benefiting from the reaction" can be hard to grasp at first, because that does not seem to be what is happening. Rocket engines seem to be about flames and noise and pressure, not "throwing things." So let's look at a few examples to get a better picture of reality:

If you have ever shot a shotgun, especially a big 12-gauge shotgun, then you know that it has a lot of "kick." That is, when you shoot the gun it "kicks" your shoulder back with a great deal of force. That kick is a reaction. A shotgun is shooting about an ounce of metal in one direction at about 700 miles per hour, and your shoulder gets hit with the reaction. If you were wearing roller

skates or standing on a skateboard when you shot the gun, then the gun would be acting like a rocket engine and you would react by rolling in the opposite direction.

If you have ever seen a big fire hose spraying water, you may have noticed that it takes a lot of strength to hold the hose. The hose is acting like a rocket engine. The hose is throwing water in one direction, and the firefighters are using their strength and weight to counteract the reaction. If they were to let go of the hose, it would thrash around with tremendous force. If the firefighters were all standing on skateboards, the hose would propel them backwards at great speed!

When you blow up a balloon and let it go so that it flies all over the room before running out of air, you have created a rocket engine. In this case, what is being thrown is the air molecules inside the balloon. When you throw them out the nozzle of a balloon, the rest of the balloon reacts in the opposite direction.

Imagine the following situation: A boat gliding along a smooth lake firing cannonballs off the back. With each fire, the boat will react by moving in the opposite direction of the ball. The amount of speed the boat gains is determined by the ***mass*** of the cannonball and the ***speed*** of its fire. We say that the cannonball leaves with ***momentum*** equal to the product of the mass and speed. The principle of ***Conservation of Momemtum*** then tells us that the boat must gain an equal momentum in the opposite direction. Leaving out the friction our boat experiences from wind resistance and drag against the water, we can calculate the speed the boat gains using the Conservation of Momentum. (See the procedure section below for the details)

Now the boat gets lighter with each fire of the canon, lighter by the mass of the cannonball that's sent off the back. The first cannonballs that are fired have to work both to speed up the boat and the cannonballs remaining on board, so the boat doesn't gain a lot of speed. As the load of cannonballs carried by the boat gets lighter, each fire of the canon can work more directly on the ship. For a rocket such as the Space Shuttle, the mass of the fuel (the cannonballs) is much greater than the mass of the ship (our boat) itself. This creates one of the interesting problems encountered by a rocket where you need a lot of fuel just to move the fuel.

You can see this weight equation very clearly on the Space Shuttle. If you have ever seen the Space Shuttle launch, you know that there are three parts:

- **The orbiter**
- **The big external tank**
- **The two solid rocket boosters**

The Orbiter weighs 165,000 pounds empty. The external tank weighs 78,100 pounds empty. The two solid rocket boosters weigh 185,000 pounds empty each. But then you have to load in the fuel. Each SRB holds 1.1 million pounds of fuel.

The external tank holds 143,000 gallons of liquid oxygen (1,359,000 pounds) and 383,000 gallons of liquid hydrogen (226,000 pounds). The whole vehicle -- shuttle, external tank, solid

rocket booster casings and all the fuel -- has a total weight of 4.4 million pounds at launch. 4.4 million pounds to get 165,000 pounds in orbit is a pretty big difference! To be fair, the orbiter can also carry a 65,000 pound payload (up to 15 x 60 feet in size), but it is still a big difference. The fuel weighs almost 20 times more than the Orbiter.

All of that fuel is being thrown out the back of the Space Shuttle at a speed of perhaps 6,000 mph (typical rocket exhaust velocities for chemical rockets range between 5,000 and 10,000 mph). The SRBs burn for about two minutes and generate about 3.3 million pounds of thrust each at launch (2.65 million pounds average over the burn). The three main engines (which use the fuel in the external tank) burn for about eight minutes, generating 375,000 pounds of thrust each during the burn.

What follows is an exercise using our hypothetical boat with a cannon to help make this situation clearer.

Facts You Need

The Law of Conservation of Momentum: Total momentum before equals total momentum after for any physical process. The momentum of any object is equal to its mass multiplied by it velocity.

Procedure

Using the attached worksheet, we are going to simulate our boat firing cannonballs off its back, calculating the change in the boat's speed through several fires of the cannon.

1. First decide on the starting values we need at the top of the worksheet. We need values for the mass of the boat and each cannonball, the number of cannonballs on board, the speed the cannon fires them, and the boat's initial speed (which you can just make 0 for the boat starting at rest). To make the calculations we'll do interesting and something like a real rocket, the mass of the cannonballs should be larger than the boat. For example, make the boat's mass 1000 kg with 10 cannonballs of mass 500 kg.

2. Fill down the column for **Cannon Fires** starting with 0 on the first line (for when the cannon hasn't been fired at all yet) down to the total number of cannonballs you decided on in step #1.

3. Fill down the column for **Cannonballs On Board** starting with the total number on the first line down to 0 for when all of the cannonballs have been fired.

4. Now we're ready to start across the first row, using the starting values you chose above:
   a) In the **Mass of Boat + Cannonballs On Board Before Firing** column put the total mass of all the cannonballs added to the mass of the boat.
   b) In the column **Boat's Speed Before Firing** just put the value you chose above.
   c) Multiply those two to get the value for the next column for **Momentum of Boat** + **Cannonballs On Board Before Firing**.
   d) After the cannon fires, the total mass of and in the boat is subtracted by the mass of one cannonball, so subtract that value from the value in the **Mass of Boat + Cannonballs On Board Before Firing** column for the **Mass of Boat + Cannonballs Remaining After Firing** column.
   e) The cannonball fired takes away an amount of momentum equal to its mass multiplied by its firing velocity, so the **Momentum of Boat + Cannonballs**. **Remaining After Firing** is

that subtracted from the value in the **Momentum of Boat + Cannonballs On Board Before Firing** column. (Why is this negative?)

f) Now for the good part. We're ready to calculate the boat's new velocity for the **Boat's Speed After Firing** column by dividing the **Momentum of Boat + Cannonballs Remaining After Firing** value by the **Mass of Boat + Cannonballs Remaining After Firing**.

g) For the **Change in Speed**, just subtract the **Boat's Speed Before Firing** from the **Boat's Speed After Firing**.

5. To complete the table, do the calculations for each row, adding up the total mass of and remaining on the boat for the **Mass of Boat + Cannonballs On Board Before Firing** column and using the value from **Boat's Speed After Firing** from the previous line for the new value of **Boat's Speed Before Firing** and then working across as in step 4.

Extensions

- Students who are familiar with spreadsheets through a program such as Excel can create a spreadsheet that will do all the calculations in the worksheet.
- Students familiar with a programming language such as Java or C++ can write a computer program that will do all the calculations in the worksheet.

Student Worksheet for Exploring a Rocket's Propulsion

Values About the Boat

Mass: _____

Initial Speed: _____

Values About the Cannon

Cannonballs: _____

Mass of Each: _____

Firing Speed: _____

Cannon Fires	# Cannonballs On Board	Mass of Boat + Cannonballs On Board Before Firing	Boat's Speed Before Firing	Momentum of Boat + Cannonballs On Board Before Firing	Mass of Boat + Cannonballs Remaining After Firing	Momentum of Boat + Cannonballs Remaining After Firing	Boat's Speed After Firing	Change in Speed

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Glossary of Space Science Terminology

A

Accretion - Accumulation of dust and gas into larger bodies such as stars, planets and moons

Accretion disk - A relatively flat sheet of gas and dust surrounding a newborn star, a black hole, or any massive object growing in size by attracting material

Actinide - any of a series of chemically similar, mostly synthetic, radioactive elements with atomic numbers ranging above 89

Active galactic nuclei (AGN) - It is believed that these are normal galaxies with a massive black hole accreting gas at its center, thus producing enormous amounts of energy at all wavelengths of the electromagnetic spectrum

Alluvium - clay, silt, sand, gravel or similar detrital material deposited by running water

Angular size - width or diameter of an object measured as an angle from the observer's eyes, a way of stating the diameter/distance ratio for an object

Angstrom - A unit of length equal to 0.00000001 centimeters. Scientists sometimes write this as 1 x 10-8 cm (see scientific notation)

Apoapsis - The point in an orbit when the two objects are farthest apart. Special names are given to this orbital point for commonly used systems. For example, the point of greatest separation of two stars, as in a binary star orbit, is called apastron; the point in its orbit where a planet is farthest from the Sun is called aphelion; the point in its orbit where an Earth satellite is farthest from the Earth is called apogee

Apparent brightness - brightness of an object as seen by an observer dependent upon the object's wattage, if it is self-emitting, or upon the amount of light scattered or reflected

Apparent magnitude - a measure of the apparent brightness of an astronomical object, as observed from Earth. The scale of magnitudes is logarithmic

Asteroid - Chunks of rock that travel through space. The biggest asteroids are hundreds of miles wide, but most are as small as pebbles. Most asteroids lie in a ring, or belt, around the sun between the planets Jupiter and Mars

Astronaut - a person who travels in a spacecraft, esp. a crew member

Astronomical unit - (AU.) a unit of distance equal to the average distance between the earth and the sun, about 93 million miles; 149,597,870 km

Astronomy - The scientific study of matter in outer space, especially the positions, dimensions, distribution, motion, composition, energy, and evolution of celestial bodies and phenomena

Astrophysics - The part of astronomy that deals principally with the physics of stars, stellar systems, and interstellar material

Atmosphere - the gaseous mass or envelope surrounding a celestial body in space; The gas that surrounds a planet or star. The Earth'satmosphere is made up of mostly nitrogen, while the Sun's atmosphere consists of mostly hydrogen

Atom - a unit of matter, the smallest unit of an element, consisting of a dense, positively charged nucleus surrounded by a system of negatively charged electrons

Atomic – (1) of or relating to an atom, (2) of or employing nuclear energy, 3) very small

B

Binary stars - Binary stars are two stars that orbit around a common center of mass. An X-ray binary is a special case where one of the stars is a collapsed object such as a white dwarf, neutron star, or black hole. Matter is stripped from the normal star and falls onto the collapsed star, producing X-rays

Black hole - An object whose gravity is so strong that not even light can escape from it.

Black-hole dynamic laws - laws of black-hole dynamics: (1) First law of black hole dynamics: For interactions between black holes and normal matter, the conservation laws of mass-energy, electric charge, linear momentum, and angular momentum, hold. This is analogous to the first law of thermodynamics. (2) Second law of black hole dynamics: With black-hole interactions, or interactions between black holes and normal matter, the sum of the surface areas of all black holes involved can never decrease. This is analogous to the second law of thermodynamics, with the surface areas of the black holes being a measure of the entropy of the system

Blackbody radiation - The radiation or the radiance at particular frequencies all across the spectrum produced by a blackbody ,that is, a perfect radiator (and absorber) of heat. Physicists had difficulty explaining it until Planck introduced his quantum of action

Blackbody temperature - The temperature of an object if it is re-radiating all the thermal energy that has been added to it; if an object is not a blackbody radiator, it will not re-radiate all the excess heat and the leftover will go toward increasing its temperature

Blueshift - An apparent shift toward shorter wavelengths of spectral lines in the radiation emitted by an object caused by the emitting object moving toward the observer. See also Doppler effect

Boltzmann constant; k - A constant which describes the relationship between temperature and kinetic energy for molecules in an ideal gas. It is equal to 1.380622 x 10-23 J/K (see scientific notation)

Brahe, Tycho - 1546 - 1601 - (a.k.a Tyge Ottesen) Danish astronomer whose accurate astronomical observations formed the basis for Johannes Kepler's laws of planetary motion

Bremsstrahlung - "braking radiation", the main way very fast charged particles lose energy when traveling through matter. Radiation is emitted when charged particles are accelerated. In this case, the acceleration is caused by the electromagnetic fields of the atomic nuclei of the medium

C

Calibration - A process for translating the signals produced by a measuring instrument (such as a telescope) into something that is scientifically useful. This procedure removes most of the errors caused by environmental and instrumental instabilities

Chandrasekhar limit - (S. Chandrasekhar; 1910 - 1995) - A limit which mandates that no white dwarf (a collapsed, degenerate star) can be more massive than about 1.4 solar masses. Any degenerate object more massive must inevitably collapse into a neutron star

Cluster of galaxies - A system of galaxies containing from a few to a few thousand member galaxies which are all gravitationally bound to each other

Collecting area - The amount of area a telescope has that is capable of collecting electromagnetic radiation. Collecting area is important for a telescope's sensitivity: the more radiation it can collect (that is, the larger its collecting area), the more sensitive it is to dim objects

Comet - Comets are made of dust and ice and look like dirty snowballs. There are millions of them traveling through space

Compton effect - (A.H. Compton; 1923) - An effect that demonstrates that photons (the quantum of electromagnetic radiation) have momentum. A photon fired at a stationary particle, such as an electron, will impart momentum to the electron and, since its energy has been decreased, will experience a corresponding decrease in frequency

Concave - hollowed or rounded inward like the inside of a bowl

Constellation - A group of stars that makes a pattern. There are 88 constellations in our sky. Constellations seem to twinkle in the sky. This happens because moving air blurs starlight as it travels to Earth

Copernicus, Nicolaus - 1473 - 1543 - Polish astronomer who advanced the heliocentric theory that the Earth and other planets revolve around the Sun. This was highly controversial at the time as the Ptolemaic view of the universe, which was the prevailing theory for over 1000 years, was deeply ingrained in the prevailing philosophy and religion. (It should be noted, however, that the heliocentric idea was first put forth by Aristarcus of Samos in the 3rd century B.C., a fact known to Copernicus but long ignored.

Corona - (plural: coronae) The uppermost level of the solar atmosphere, characterized by low densities and high temperatures (> 1,000,000 degrees K)

Cosmic background radiation - primal glow - The background of radiation mostly in the frequency range 3 x 108 to 3 x 1011 Hz (see scientific notation) discovered in space in 1965. It is believed to be the cosmologically redshifted radiation released by the Big Bang itself.

Cosmic rays Atomic nuclei (mostly protons) and electrons that are observed to strike the Earth's atmosphere with exceedingly high energies

Cosmological constant - G + Lambda g = 8 pi T

Cosmological distance - A distance far beyond the boundaries of our Galaxy. When viewing objects at cosmological distances, the curved nature of spacetime could become apparent. Possible cosmological effects include time dilation and redshift

Cosmological redshift - An effect where light emitted from a distant source appears redshifted because of the expansion of spacetime itself

Cosmology - The astrophysical study of the history, structure, and constituent dynamics of the universe

D

De Broglie wavelength - (L. de Broglie; 1924) - According to quantum mechanics all particles also have wave characteristics, where the wavelength of a particle is inversely proportional to its momentum and the constant of proportionality is the Planck constant

Declination - A coordinate which, along with Right Ascension, may be used to locate any position in the sky. Declination is analogous to latitude for locating positions on the Earth

Deconvolution - An image processing technique that removes features in an image that are caused by the telescope itself rather than from actual light coming from the sky

Density - The amount of mass of any substance which can be contained in one cubic centimeter. Measured in grams per cubic centimeter (or kilograms per liter); the density of water is 1.0; iron is 7.9; lead is 11.3

Disk - (of planet or other object) - The apparent circular shape that the Sun, a planet, or a moon displays when seen in the sky or through a telescope

Doppler effect - (C.J. Doppler) - The apparent change in wavelength of sound or light caused by the motion of the source, observer or both. Waves emitted by a moving object as received by an observer will be blueshifted (compressed) if approaching, redshifted (elongated) if receding. It occurs both in sound and light. How much the frequency changes depends on how fast the object is moving toward or away from the receiver. Compare cosmological redshift

E

Eccentric - on-circular; elliptical (applied to an orbit)

Eccentricity - A value that defines the shape of an ellipse or planetary orbit. The eccentricity of an ellipse (planetary orbit) is the ratio of the distance between the foci and the major axis. Equivalently the eccentricity is (ra-rp)/(ra+rp) where ra is the apoapsis distance and rp is the periapsis distance

Eclipse - The cutting off, or blocking, of light from one celestial body by another

Ecliptic - The plane of Earth's orbit about the Sun

Eddington limit - (Sir A. Eddington) - The theoretical limit at which the photon pressure would exceed the gravitational attraction of a light-emitting body. That is, a body emitting radiation at greater than the Eddington limit would break up from its own photon pressure

Einstein, Albert - 1879 - 1955 - German-American physicist; developed the Special and General Theories of Relativity which along with Quantum Mechanics is the foundation of modern physics

Ejecta - Material that is ejected. Used mostly to describe the content of a massive star that is propelled outward in a supernova explosion

Electromagnetic spectrum - The full range of frequencies, from radio waves to gamma-rays, that characterizes light

Electromagnetic waves - (radiation) - Another term for light. Light waves are fluctuations of electric and magnetic fields in space

Electron - A particle commonly found in the outer layers of atoms with a negative charge. The electron has only 0.0005 the mass of the proton

Electron volt - The change of potential energy experienced by an electron moving from a place where the potential has a value of V to a place where it has a value of (V+1 volt). This is a convenient energy unit when dealing with the motions of electrons and ions in electric fields; the unit is also the one used to describe the energy of X-rays and gamma-rays. A keV (or kiloelectron volt) is equal to 1000 electron volts. An MeV is equal to one million electron volts. A GeV is equal to one billion (109) electron volts. A TeV is equal to a million million (1012) electron volts

Elements - The fundamental kinds of atoms that make up the building blocks of matter, which are each shown on the periodic table of the elements. The most abundant elements in the universe are hydrogen and helium. These two elements make up about 80 and 20 % of all the matter in the universe respectively. Despite comprising only a very small fraction in the universe, the remaining heavy elements can greatly influence astronomical phenomena. About 2 % of the Milky Way's disk is comprised of heavy elements

Ellipse - Oval. That the orbits of the planets are ellipses, not circles, was first discovered by Johannes Kepler based on the careful observations by Tycho Brahe

Erg/sec - A form of the metric unit for power. It is equal to 10-10 kilowatts (see scientific notation)

Erosion - the process of wearing away by the action of water, wind or ice

Event horizon - The radius that a spherical mass must be compressed to in order to transform it into a black hole, or the radius at which time and space switch responsibilities. Once inside the event horizon, it is fundamentally impossible to escape to the outside. Furthermore, nothing can prevent a particle from hitting the singularity in a very short amount of proper time once it has entered the horizon. In this sense, the event horizon is a "point of no return"

Evolved star - A star near the end of its lifetime when most of its fuel has been used up. This period of the star's life is characterized by loss of mass from its surface in the form of a stellar wind

Expanding Universe - Astronomers have discovered that distant galaxies are moving away from the Milky Way and also from each other. The whole universe is expanding or becoming bigger

Extragalactic - Outside of, or beyond, our own galaxy.

F

False Color - Color added to a photograph of an object, such as a galaxy, to make it look clearer

Fermi acceleration - In order to explain the origins of cosmic rays, Enrico Fermi (1949) introduced a mechanism of particle acceleration, whereby charged particles bounce off moving interstellar magnetic fields and either gain or lose energy, depending on whether the "magnetic mirror" is approaching or receding. In a typical environment, he argued, the probability of a head-on collision is greater than a head-tail collision, so particles would be accelerated on average. This random process is now called 2nd order Fermi acceleration, because the mean energy gain per "bounce" is dependent on the "mirror" velocity squared. Bell (1978) and Blandford and Ostriker (1978) independently showed that Fermi acceleration by supernova remnant (SNR) shocks is particularly efficient, because the motions are not random. A charged particle ahead of the shock front can pass through the shock and then be scattered by magnetic inhomogeneities behind the shock. The particle gains energy from this "bounce" and flies back across the shock, where it can be scattered by magnetic inhomogeneities ahead of the shock. This enables the particle to bounce back and forth again and again, gaining energy each time. This process is now called 1st order Fermi acceleration, because the mean energy gain is dependent on the shock velocity only to the first power

Fluvial - of or relating to living in streams, produced by stream action

Flux - flowing of fluid from the body, or an excessive abnormal discharge from the bowels

Frequency - A property of a wave that describes how many wave patterns or cycles pass by in a period of time. Frequency is often measured in Hertz (Hz), where a wave with a frequency of 1 Hz will pass by at 1 cycle per second

G

Galactic halo - A spherical region surrounding the center of a galaxy. This region may extend beyond the luminous boundaries of the galaxy and contain a significant fraction of the galaxy's mass. Compared to cosmological distances, objects in the halo of our galaxy would be very nearby

Galaxy - A component of our universe made up of gas and a large number (usually more than a million) of stars held together by gravity

Galilei, Galileo - (1564 - 1642) - An Italian scientist, Galileo was renowned for his epoch making contribution to physics, astronomy, and scientific philosophy. He is regarded as the chief founder of modern science. He developed the telescope, with which he found craters on the Moon and discovered the largest moons of Jupiter. Galileo was condemned by the Catholic Church for his view of the cosmos based on the theory of Copernicus

Gamma-ray - The highest energy, shortest wavelength electromagnetic radiations. Usually, they are thought of as any photons having energies greater than about 100 keV

Gravitational collapse - When a massive body collapses under its own weight. (For example, interstellar clouds collapse to become stars until the onset of nuclear fusion stops the collapse.)

Gamma-Ray Burst (GRB) - Plural is GRBs. A burst of gamma-rays from space lasting from a fraction of a second to many minutes. There is no clear scientific consensus as to their cause or even their distance

General relativity - The geometric theory of gravitation developed by Albert Einstein, incorporating and extending the theory of special relativity to accelerated frames of reference and introducing the principle that gravitational and inertial forces are equivalent

Giant Molecular Cloud (GMC) - Massive clouds of gas in interstellar space composed primarily of hydrogen molecules (two hydrogen atoms bound together), though also containing other molecules observable by radio telescopes. These clouds can contain enough mass to make several million stars like our Sun and are often the sites of star formation

Gravity - A mutual physical force between two bodies. Most agree that it is an attracting force while some think that it may be a force that pushes the bodies together

Guest star - The ancient Chinese term for a star that newly appears in the night sky, and then later disappears. Later, the Europeans called this a nova

H

Hawking radiation - (S.W. Hawking; 1973) - The theory that black holes emit radiation like any other hot body. Virtual particle-antiparticle pairs are constantly being created in supposedly empty space. Occasionally, a pair will be created just outside the event horizon of a black hole. There are three possibilities: (1) both particles are captured by the hole; (2) both particles escape the hole; (3) one particle escapes while the other is captured. The first two cases are straightforward; the virtual particle-antiparticle pair recombine and return their energy back to the void via the uncertainty principle. It is the third case that interests us. In this case, one of the particles has escaped (and is speeding away to infinity), while the other has been captured by the hole. The escapee becomes real and can now be detected by distant observers. But the captured particle is still virtual; because of this, it has to restore conservation of energy by assigning itself a negative mass-energy. Since the hole has absorbed it, the hole loses mass and thus appears to shrink. From a distance, it appears as if the hole has emitted a particle and reduced in mass. The rate of power emission is proportional to the inverse square of the hole's mass; thus, the smaller a hole gets, the faster and faster it emits Hawking radiation. This leads to a runaway process; what happens when the hole gets very small is unclear; quantum theory seems to indicate that some kind of "remnant" might be left behind after the hole has emitted away all its mass-energy

Hawking temperature - The temperature of a black hole caused by the emission of Hawking radiation

Herschel, Sir William - (1738 - 1822) - Sir William Herschel was a renowned astronomer who first detected the infrared region of the electromagnetic spectrum in 1800

Hertz, Heinrich - (1857 - 1894) - A German physics professor who did the first experiments with generating and receiving electromagnetic waves, in particular radio waves. In his honor, the units associated with measuring the cycles per second of the waves (or the number of times the tip-tops of the waves pass a fixed point in space in 1 second of time) is called the hertz.
Hertz Hz (after H. Hertz, 1857 - 1894) - The derived SI unit of frequency, defined as a frequency of 1 cycle per second

Hubble, Edwin P. - 1889 - 1953 - American astronomer whose observations proved that galaxies are "island universes", not nebulae inside our own galaxy. His greatest discovery was the linear relationship between a galaxy's distance and the speed with which it is moving. The Hubble Space Telescope is named in his honor

Hubble constant - Ho (E.P. Hubble; 1925) - The constant which determines the relationship between the distance to a galaxy and its velocity of recession due to the expansion of the Universe. Since the Universe is self-gravitating, it is not truly constant. In cosmology, it is defined as H = (da/dt)/a, where a is the 4-radius of the Universe. When evaluated for the present, it is written H0 = Hnow. The Hubble constant is not known to great accuracy (only within about a factor of 2), but is believed to lie somewhere between 50 and 100 km/s/Mpc

Hubble's law - (E.P. Hubble; 1925) - A relationship discovered between distance and radial velocity. The further away a galaxy is from us, the faster it is receding from us. The constant of proportionality is the Hubble constant, H_0. The cause is interpreted as the expansion of spacetime itself

Huygens, Christiaan - (1629 - 1695) - A Dutch physicist who was the leading proponent of the wave theory of light. He also made important contributions to mechanics, stating that in a collision between bodies, neither loses nor gains ``motion'' (his term for momentum). In astronomy, he discovered Titan (Saturn's largest moon) and was the first to correctly identify the observed elongation of Saturn as the presence of Saturn's rings

I

Implosion - A violent inward collapse. An inward explosion

Infrared - Electromagnetic radiation at wavelengths longer than the red end of visible light and shorter than microwaves (roughly between 1 and 100 microns). Almost none of the infrared portion of the electromagnetic spectrum can reach the surface of the Earth, although some portions can be observed by high-altitude aircraft (such as the Kuiper Observatory) or telescopes on high mountaintops (such as the peak of Mauna Loa in Hawaii)

Inclination - The inclination of a planet's orbit is the angle between the plane of its orbit and the ecliptic; the inclination of a moon's orbit is the angle between the plane of its orbit and the plane of its primary's equator

Image - in astronomy, a picture of the sky

Interstellar medium - The gas and dust between stars, which fills the plane of the Galaxy much like air fills the world we live in. For centuries, scientists believed that the space between the stars was empty. It wasn't until the eighteenth century, when William Herschel observed nebulous patches of sky through his telescope, that serious consideration was given to the notion that interstellar space was something to study. It was only in the last century that observations of interstellar material suggested that it was not even uniformly distributed through space, but that it had a unique structure

Ions - An atom with one or more electrons stripped off, giving it a net positive charge

Ionic (or ionized) gas - Gas whose atoms have lost or gained electrons, causing them to be electrically charged. In astronomy, this term is most often used to describe the gas around hot stars where the high temperature causes atoms to lose electrons

J

Jets - Beams of particles, usually coming from an active galactic nucleus or a pulsar. Unlike a jet airplane, when the stream of gas is in one direction, astrophysical jets come in pairs with each jet aiming in opposite directions

K

Kelvin - (after Lord Kelvin, 1824 - 1907) - A temperature scale often used in sciences such as astronomy. The fundamental SI unit of thermodynamic temperature defined as 1/273.16 of the thermodynamic temperature of the triple point of water. The Kelvin temperature scale is just like the Celsius scale except that the freezing point of water, zero degrees Celsius, is equal to 273 degrees Kelvin. (K = C + 273o) (F = 9/5C + 32o)

Kepler, Johannes - 1571 - 1630 - German astronomer and mathematician. Considered a founder of modern astronomy, he formulated the famous three laws of planetary motion. They comprise a quantitative formulation of Copernicus's theory that the planets revolve around the Sun

Kepler's laws - (J. Kepler) (1) Kepler's first law - A planet orbits the Sun in an ellipse with the Sun at one focus, (2) Kepler's second law - A ray directed from the Sun to a planet sweeps out equal areas in equal times, (3) Kepler's third law - The square of the period of a planet's orbit is proportional to the cube of that planet's semimajor axis; the constant of proportionality is the same for all planets

Kilogram (kg) - One kilogram is equivalent to 1,000 grams or 2.2 pounds; the mass of a liter of water. The fundamental SI unit of mass, it is the only SI unit still maintained by a physical artifact: a platinum-iridium bar kept in the International Bureau of Weights and Measures at Sevres, France

Kinematics - Refers to the calculation or description of the underlying mechanics of motion of an astronomical object. For example, in radioastronomy, spectral line graphs are used to determine the kinematics or relative motions of material at the center of a galaxy or surrounding a star as it is born

Kirchhoff's law of radiation - (G.R. Kirchhoff) The emissivity of a body is equal to its absorbance at the same temperature

Kirchhoff's laws - (G.R. Kirchhoff) (1) Kirchhoff's first law. An incandescent solid or gas under high pressure will produce a continuous spectrum (2) Kirchhoff's second law - A low-density gas will radiate an emission-line spectrum with an underlying emission continuum. (3) Kirchhoff's third law - Continuous radiation viewed through a low-density gas will produce an absorption-line spectrum

L

Lagrange, Joseph - (1736 - 1813) - A French mathematician of the eighteenth century. His work Mecanique Analytique (Analytical Mechanics; 1788) was a mathematical masterpiece. It contained clear, symmetrical notation and covered almost every area of pure mathematics. Lagrange developed the calculus of variations, established the theory of differential equations, and provided many new solutions and theorems in number theory. His classic Theorie des fonctions analytiques laid some of the foundations of group theory. Lagrange also invented the method of solving differential equations known as variation of parameters

Lagrange points - Points in the vicinity of two massive bodies (such as the Earth and the Moon) where each others' respective gravities balance. There are five, labeled L1 through L5. L1, L2, and L3 lie along the centerline between the centers of mass between the two masses; L1 is on the inward side of the secondary, L2 is on the outward side of the secondary; and L3 is on the outward side of the primary. L4 and L5, the so-called Trojan points, lie along the orbit of the secondary around the primary, sixty degrees ahead and behind of the secondary. L1 through L3 are points of unstable equilibrium; any disturbance will move a test particle there out of the Lagrange point. L4 and L5 are points of stable equilibrium, provided that the mass of the secondary is less than about 1/25.96 the mass of the primary. These points are stable because centrifugal pseudo-forces work against gravity to cancel it out

Light - Electromagnetic radiation that is visible to the human eye

Light curve - A graph that displays the time variation in light or magnitude of a variable or eclipsing star

Light year - A unit of length used in astronomy which equals the distance light travels in a year. At the rate of 300,000 kilometers per second (671 million miles per hour), 1 light-year is equivalent to 9.46053 x 1012 km, 5,880,000,000,000 miles or 63,240 a.u

Limb - The outer edge of the apparent disk of a celestial body

M

Magnetic field - A condition found in the region around a magnet or an electric current, characterized by the existence of a detectable magnetic force at every point in the region

Magnetic pole - Either of two limited regions in a magnet at which the magnet's field is most intense

Magnetosphere - The region of space in which the magnetic field of an object (e.g., a star or planet) dominates the radiation pressure of the stellar wind to which it is exposed

Magnetotail - The portion of a planetary magnetosphere which is pushed in the direction of the solar wind

Magnitude - The degree of brightness of a celestial body designated on a numerical scale, on which the brightest star has magnitude -1.4 and the faintest visible star has magnitude 6, with the scale rule such that a decrease of one unit represents an increase in apparent brightness by a factor of 2.512; also called apparent magnitude

Mass - A measure of the total amount of material in a body, defined either by the inertial properties of the body or by its gravitational influence on other bodies

Matter - A word used for any kind of stuff which contains mass

Mega-ton - A unit of energy used to describe nuclear warheads. The same amount energy as 1 million tons of TNT. 1 mega-ton = 4 x 1016 ergs = 4 x 109 joules

Meteor or shooting stars - Small rocks and dust left behind from comets that enter the Earth’s atmosphere

Meteorite - Chunks of rock that don't burn up when they enter the atmosphere and fall to earth

Meteoroid - any solid object moving in interplanetary space that is smaller than a planet or asteroid but larger than a molecule. If a meteoroid enters Earth's atmosphere, we call it a meteorite after it falls to the surface. The light that it produces as it passes through the atmosphere is commonly called a shooting star.

Meter - (m) The fundamental SI unit of length, defined as the length of the path traveled by light in vacuum during a period of 1/299 792458 s. A unit of length equal to about 39 inches. A kilometer is equal to 1000 meters

Microwave - Electromagnetic radiation which has a long wavelength (between 1 mm and 30 cm). Microwaves can be used to study the Universe, communicate with satellites in Earth orbit, and cook popcorn

Milky Way - A spiral shaped galaxy in which the Earth is located. The sun and the earth lie in one of the spiral arms near the edge of the galaxy

Moon - A natural object in space that travels around a planet. A moon is smaller than its planet

Morphology - the external structure of rocks in relation to the development of erosion forms or topographic features

N

Nebula - A diffuse mass of interstellar dust and gas inside a galaxy

Neutrino - A fundamental particle produced in massive numbers by the nuclear reactions in stars; they are very hard to detect because the vast majority of them pass completely through the Earth without interacting

Neutron - A particle commonly found in the nucleus of atoms with approximately the mass of a proton, but zero charge

Neutron star - The imploded core of a massive star produced by a supernova explosion. (typical mass of 1.4 times the mass of the Sun, radius of about 5 miles, density of a neutron.) According to astronomer and author Frank Shu, "A sugar cube of neutron-star stuff on Earth would weigh as much as all of humanity!" Neutron stars can be observed as pulsars

Newton, Isaac - 1642 - 1727 - English cleric and scientist; discovered the classical laws of motion and gravity; the bit with the apple is probably apocryphal

Newton's law of universal gravitation - (Sir I. Newton) - Two bodies attract each other with equal and opposite forces; the magnitude of this force is proportional to the product of the two masses and is also proportional to the inverse square of the distance between the centers of mass of the two bodies

Newton's laws of motion - (Sir I. Newton) (1) Newton's first law of motion: A body continues in its state of constant velocity (which may be zero) unless it is acted upon by an external force. (2) Newton's second law of motion - For an unbalanced force acting on a body, the acceleration produced is proportional to the force impressed; the constant of proportionality is the inertial mass of the body. (3) Newton's third law of motion - In a system where no external forces are present, every action force is always opposed by an equal and opposite reaction

Noise - The random fluctuations that are always associated with a measurement that is repeated many times over. Noise appears in astronomical images as fluctuations in the image background. These fluctuations do not represent any real sources of light in the sky, but rather are caused by the imperfections of the telescope. If the noise is too high, it may obscure the dimmest objects within the field of view

Nova - (plural: novae) - A star that experiences a sudden outburst of radiant energy, temporarily increasing its luminosity by hundreds to thousands of times before fading back to its original luminosity

Nuclear fusion - nuclear process whereby several small nuclei are combined to make a larger one whose mass is slightly smaller than the sum of the small ones. The difference in mass is converted to energy by Einstein's famous equivalence "Energy = Mass times the Speed of Light squared". This is the source of the Sun's energy

O

Occultation - The blockage of light by the intervention of another object; a planet can occult (block) the light from a distant star

Opacity - A property of matter that prevents light from passing through it; non-transparent. The opacity or opaqueness of something depends on the frequency of the light. For instance, the atmosphere of Venus is transparent to ultraviolet light, but is opaque to visual light

Orbit - The path of an object that is moving around a second object or point

P

Pair production - The physical process whereby a gamma-ray photon, usually through an interaction with the electromagnetic field of a nucleus, produces an electron and an anti-electron (positron). The original photon no longer exists, its energy having gone to the two resulting particles. The inverse process, pair annihilation, creates two gamma-ray photons from the mutual destruction of an electron/positron pair

Parallax - The angle between the two straight lines that join a celestial body to two different points of observation; e.g., two different points on the Earth as it moves through space

Parsec - A large distance often used in astronomy, it is equal to 3.26 light years, or 3.1 x 1018 cm (see scientific notation). A kiloparsec (kpc) is equal to 1000 parsecs. A megaparsec (Mpc) is equal to a million (106) parsecs. An object is at a distance of 1 parsec from us if its parallax is 1 second of arc

Periapsis - The point in the orbit closest to the planet

Periastron - The point of closest approach of two stars, as in a binary star orbit

Perigee - The point in the orbit closest to the Earth

Perihelion - The point in its orbit where a planet is closest to the Sun. when referring to objects orbiting the Earth the term perigee is used; the term periapsis is used for orbits around other bodies. (opposite of aphelion)

Photoelectric effect - An effect explained by A. Einstein which demonstrates that light seems to be made up of particles, or photons. Light can excite electrons (called photoelectrons in this context) to be ejected from a metal. Light with a frequency below a certain threshold, at any intensity, will not cause any photoelectrons to be emitted from the metal. Above that frequency, photoelectrons are emitted in proportion to the intensity of incident light. The reason is that a photon has energy in proportion to its wavelength, and the constant of proportionality is the Planck constant. Below a certain frequency -- and thus below a certain energy -- the incident photons do not have enough energy to knock the photoelectrons out of the metal. Above that threshold energy, called the work function, photons will knock the photoelectrons out of the metal, in proportion to the number of photons (the intensity of the light). At higher frequencies and energies, the photoelectrons ejected obtain a kinetic energy corresponding to the difference between the photon's energy and the work function

Pi - The constant equal to the ratio of the circumference of a circle to its diameter, which is approximately 3.141593

Planck constant - h - The fundamental constant equal to the ratio of the energy of a quantum of energy to its frequency. It is the quantum of action. It has the value 6.626196 x 10-34 J s

Planck equation - The quantum mechanical equation relating the energy of a photon E to its frequency nu: E = h x nu

Planet - A large round object in space, such as Earth, that travels around the sun or another star

Planetary nebula - A shell of gas ejected from, and expanding about, a certain kind of extremely hot star

Plasma - A low-density gas in which the individual atoms are ionized (and therefore charged), even though the total number of positive and negative charges is equal, maintaining an overall electrical neutrality

Polarization - A special property of light; light has three properties, brightness, color and polarization. Polarization is a condition in which the planes of vibration of the various rays in a light beam are at least partially aligned

Pole Star - The name of the star that lies almost directly above the North Pole, which is the most northern place on planet Earth

Positron - The antiparticle to the electron. The positron has most of the same characteristics as an electron except it is positively charged

Postulate - to assume

Probe - to investigate thoroughly, to make an exploratory investigation

Projectile - a body projected by external force and continuing in force by its own inertia

Prominence - a huge tongue or loop of gas that rises high above the sun's surface

Proton - A particle commonly found in the nucleus of atoms with a positive charge

Protostar - Very dense regions (or cores) of molecular clouds where stars are in the process of forming

Ptolemy - (ca. 100-ca. 170) - a.k.a.Claudius Ptolemaeus. Ptolemy believed the planets and Sun to orbit the Earth in the order Mercury, Venus, Sun, Mars, Jupiter, Saturn. This system became known as the Ptolemaic system and predicted the positions of the planets accurately enough for naked-eye observations (although it made some ridiculous predictions, such as that the distance to the moon should vary by a factor of two over its orbit). He authored a book called Mathematical Syntaxis (widely known as the Almagest). The Almagest included a star catalog containing 48 constellations, using the names we still use today

Pulsar - A rotating neutron star which generates regular pulses of radiation. Pulsars were discovered by observations at radio wavelengths but have since been observed at optical, X-ray, and gamma-ray energies

Q

Quasar - A specific type of quasi-stellar source

Quasi-stellar source (QSS) - Sometimes also called quasi-stellar object (QSO); A stellar-appearing object of very large redshift that is a strong source of radio waves; presumed to be extragalactic and highly luminous

R

Radial velocity - The speed at which an object is moving away or toward an observer. By observing spectral lines, astronomers can determine how fast objects are moving away from or toward us; however, these spectral lines cannot be used to measure how fast the objects are moving across the sky

Radian; rad - The supplementary SI unit of angular measure, defined as the central angle of a circle whose subtended arc is equal to the radius of the circle

Radiation - Energy radiated in the form of waves or particles; photons

Radiation belt - Regions of charged particles in a magnetosphere

Radio Electromagnetic Radiation - Has the lowest frequency, the longest wavelength, and is produced by charged particles moving back and forth; the atmosphere of the Earth is transparent to radio waves with wavelengths from a few millimeters to about twenty meters

Rayleigh-Taylor instabilities - Rayleigh-Taylor instabilities occur when a heavy (more dense) fluid is pushed against a light fluid -- like trying to balance water on top of air by filling a glass 1/2 full and carefully turning it over. Rayleigh-Taylor instabilities are important in many astronomical objects, because the two fluids trade places by sticking "fingers" into each other. These "fingers" can drag the magnetic field lines along with them, thus both enhancing and aligning the magnetic field

Red giant - A star that has low surface temperature and a diameter that is large relative to the Sun

Redshift - An apparent shift toward longer wavelengths of spectral lines in the radiation emitted by an object caused by the emitting object moving away from the observer. See also Doppler effect

Reflection law - For a wavefront intersecting a reflecting surface, the angle of incidence is equal to the angle of reflection, in the same plane defined by the ray of incidence and the normal

Relativity principle - The principle, employed by Einstein's relativity theories, that the laws of physics are the same, at least locally, in all coordinate frames. This principle, along with the principle of the constancy of the speed of light, constitutes the founding principles of special relativity

Relativity, theory of - More accurately describes the motions of bodies in strong gravitational fields or at near the speed of light than Newtonian mechanics. All experiments done to date agree with relativity's predictions to a high degree of accuracy. (Curiously, Einstein received the Nobel prize in 1921 not for Relativity but rather for his 1905 work on the photoelectric effect.)

Resolution (spatial) - In astronomy, the ability of a telescope to differentiate between two objects in the sky which are separated by a small angular distance. The closer two objects can be while still allowing the telescope to see them as two distinct objects, the higher the resolution of the telescope

Resolution (spectral or frequency) - Similar to spatial resolution except that it applies to frequency, spectral resolution is the ability of the telescope to differentiate two light signals which differ in frequency by a small amount. The closer the two signals are in frequency while still allowing the telescope to separate them as two distinct components, the higher the spectral resolution of the telescope

Resonance - A relationship in which the orbital period of one body is related to that of another by a simple integer fraction, such as 1/2, 2/3, 3/5

Retrograde - The rotation or orbital motion of an object in a clockwise direction when viewed from the north pole of the ecliptic; moving in the opposite sense from the great majority of solar system bodies

Right Ascension - A coordinate which, along with declination, may be used to locate any position in the sky. Right ascension is analogous to longitude for locating positions on the Earth

Ritter, Johann Wilhelm - (1776 - 1810) - Ritter is credited with discovering and investigating the ultraviolet region of the electromagnetic spectrum

Roche limit - The smallest distance from a planet or other body at which purely gravitational forces can hold together a satellite or secondary body of the same mean density as the primary; at less than this distance the tidal forces of the primary would break up the secondary

Roche lobe - The volume around a star in a binary system in which, if you were to release a particle, it would fall back onto the surface of that star. A particle released above the Roche lobe of either star will, in general, occupy the `circumbinary' region that surrounds both stars. The point at which the Roche lobes of the two stars touch is called the inner Lagrangian or L1 point. If a star in a close binary system evolves to the point at which it `fills' its Roche lobe, theoretical

calculations predict that material from this star will overflow both onto the companion star (via the L1 point) and into the circumbinary environment

Roentgen, Wilhelm Conrad (1845 - 1923) - A German scientist who fortuitously discovered X-rays in 1895

S

Satellite - A body that revolves around a larger body

Schwarzschild radius - The radius r of the event horizon for a Schwarzschild black hole

Scientific notation - A compact format for writing very large or very small numbers, most often used in scientific fields. The notation separates a number into two parts: a decimal fraction, usually between 1 and 10, and a power of ten. Thus 1.23 x 104 means 1.23 times 10 to the fourth power or 12,300; 5.67 x 10-8 means 5.67 divided by 10 to the eighth power or 0.0000000567

Second; s - The fundamental SI unit of time, defined as the period of time equal to the duration of 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium-133 atom. A nanosecond is equal to one-billionth (10-9) of a second

Semimajor axis - The semimajor axis of an ellipse (e.g. a planetary orbit) is 1/2 the length of the major axis which is a segment of a line passing thru the foci of the ellipse with endpoints on the ellipse itself. The semimajor axis of a planetary orbit is also the average distance from the planet to its primary. The periapsis and apoapsis distances can be calculated from the semimajor axis and the eccentricity by rp = a(1-e) and ra = a(1+e)

Sensitivity - A measure of how bright objects need to be in order for that telescope to detect these objects. A highly sensitive telescope can detect dim objects, while a telescope with low sensitivity can detect only bright ones

Seyfert galaxy - A spiral galaxy whose nucleus shows bright emission lines; one of a class of galaxies first described by C. Seyfert

Shock wave - A strong compression wave where there is a sudden change in gas velocity, density, pressure and temperature

Singularity - The center of a black hole, where the curvature of spacetime is maximal. At the singularity, the gravitational tides diverge; no solid object can even theoretically survive hitting the singularity. Although singularities generally predict inconsistencies in theory, singularities within black holes do not necessarily imply that general relativity is incomplete so long as singularities are always surrounded by event horizons. A proper formulation of quantum gravity may well avoid the classical singularity at the centers of black holes

Solar flares - Violent eruptions of gas on the Sun's surface

Solar mass - A unit of mass equivalent to the mass of the Sun. 1 solar mass = 1 Msun = 2 x 1033 grams

Special relativity - The physical theory of space and time developed by Albert Einstein, based on the postulates that all the laws of physics are equally valid in all frames of reference moving

at a uniform velocity and that the speed of light from a uniformly moving source is always the same, regardless of how fast or slow the source or its observer is moving. The theory has as consequences the relativistic mass increase of rapidly moving objects, gravitational sources bending light, time dilatation, and the principle of mass-energy equivalence. See also general relativity

Spectral line - Light given off at a specific frequency by an atom or molecule. Every different type of atom or molecule gives off light at its own unique set of frequencies; thus, astronomers can look for gas containing a particular atom or molecule by tuning the telescope to one of its characteristic frequencies. For example, carbon monoxide (CO) has a spectral line at 115 Gigahertz (or a wavelength of 2.7 mm)

Spectrometer - The instrument connected to a telescope that separates the light signals into different frequencies, producing a spectrum. A Diversive Spectrometer is like a prism. It scatters the X-rays of different energies to different places. We measure the energy by noting where the X-rays go. A Non-Dispersive Spectrometer measures the energy directly

Spectroscopy - The study of spectral lines from different atoms and molecules. Spectroscopy is an important part of studying the chemistry that goes on in stars and in interstellar clouds

Spectrum - (plural: spectra) - A plot of the intensity of light at different frequencies. Or the distribution of wavelengths and frequencies

Speed of light - (in vacuo) - The speed at which electromagnetic radiation propagates in a vacuum; it is defined as 299,792,458 m/s (186,000 miles/second). Einstein's Theory of Relativity implies that nothing can go faster than the speed of light

Star - A large ball of gas that creates and emits its own radiation

Star cluster - A bunch of stars (ranging in number from a few to hundreds of thousands) which are bound to each other by their mutual gravitational attraction

Stellar classification - Stars are given a designation consisting of a letter and a number according to the nature of their spectral lines which corresponds roughly to surface temperature. The classes are: O, B, A, F, G, K, and M; O stars are the hottest; M the coolest. The numbers are simply subdivisions of the major classes. The classes are oddly sequenced because they were assigned long ago before we understood their relationship to temperature. O and B stars are rare but very bright; M stars are numerous but dim. The Sun is designated G2

Stellar wind - The ejection of gas off the surface of a star. Many different types of stars, including our Sun, have stellar winds; however, a star's wind is strongest near the end of its life when it has consumed most of its fuel

Steradian; sr - The supplementary SI unit of solid angle defined as the solid central angle of a sphere that encloses a surface on the sphere equal to the square of the sphere's radius

Stratigraphic - geology that deals with the origin, composition, and distribution

Substrate - the base in which an organism lives

Supernova - (plural: supernovae) - The death explosion of a massive star, resulting in a sharp increase in brightness followed by a gradual fading. At peak light output, supernova explosions

can outshine a galaxy. The outer layers of the exploding star are blasted out in a radioactive cloud. This expanding cloud, visible long after the initial explosion fades from view, forms a supernova remnant (SNR)

Sunspots - Cooler (and thus darker) regions on the sun where the magnetic field loops up out of the solar surface

Synchronous rotation - aid of a satellite if the period of its rotation about its axis is the same as the period of its orbit around its primary. This implies that the satellite always keeps the same hemisphere facing its primary (e.g. the Moon). It also implies that one hemisphere (the leading hemisphere) always faces in the direction of the satellite's motion while the other (trailing) one always faces backward

Synchrotron radiation - Electromagnetic radiation given off when very high energy electrons encounter magnetic fields

Systeme Internationale d'Units (SI) - The coherent and rationalized system of units, derived from the MKS system (which itself is derived from the metric system), in common use in physics today. The fundamental SI unit of length is the meter, of time is the second, and of mass is the kilogram

T

Terrestrial - of or relating to the Earth or its inhabitants

Thomson, William - 1824 - 1907 - Also known as Lord Kelvin, the British physicist who developed the Kelvin scale of temperature and who supervised the laying of a trans-Atlantic cable

Time dilation - Stretching of time produced by relativity. Time dilation is a predicted effect of the cosmological paradigm

Topography - the art or practice of graphic delineation in detail usually on maps or charts of natural or man-made features of a place or region especially in a way to show their relative positions and elevations

U

Ultraviolet - Electromagnetic radiation at wavelengths shorter than the violet end of visible light; the atmosphere of the Earth effectively blocks the transmission of most ultraviolet light

Universe - Everything in space is part of the universe. Scientists think it was formed 10 to 15 billions years ago with a big explosion. When the universe cooled down, huge swirls of dust and gas clung together to form galaxies

Universal constant of gravitation; G - The constant of proportionality in Newton's law of universal gravitation and which plays an analogous role in A. Einstein's general relativity. It is equal to 6.664 x 10-11 newtons per square meter per kilogram squared (see scientific notation)

V

The Venera satellite series - The Venera satellites were a series of probes (fly-bys and landers) sent by the Soviet Union to the planet Venus. Several Venera satellites carried high-energy astrophysics detectors

Visible - Electromagnetic radiation at wavelengths which the human eye can see. We perceive this radiation as colors ranging from red (longer wavelengths; ~ 700 nanometers) to violet (shorter wavelengths; ~400 nanometers.)

W

Wave-particle duality - The principle of quantum mechanics which implies that light (and, indeed, all other subatomic particles) sometimes act like a wave, and sometimes act like a particle, depending on the experiment you are performing. For instance, low frequency electromagnetic radiation tends to act more like a wave than a particle; high frequency electromagnetic radiation tends to act more like a particle than a wave

Wavelength - A property of a wave that gives the length between two peaks of the wave

White dwarf - A star that has exhausted most or all of its nuclear fuel and has collapsed to a very small size. Typically, a white dwarf has a radius equal to about 0.01 times that of the Sun, but it has a mass roughly equal to the Sun's. This gives a white dwarf a density about 1 million times that of water!

Wien's displacement law - For a blackbody, the product of the wavelength corresponding to the maximum radiancy and the thermodynamic temperature is a constant. As a result, as the temperature rises, the maximum of the radiant energy shifts toward the shorter wavelength (higher frequency and energy) end of the spectrum

X

X-ray - Electromagnetic radiation of very short wavelength and very high-energy; X-rays have shorter wavelengths than ultraviolet light but longer wavelengths than cosmic rays

Y

Z

Zenith – the point on the celestial sphere vertical above a given position or observer

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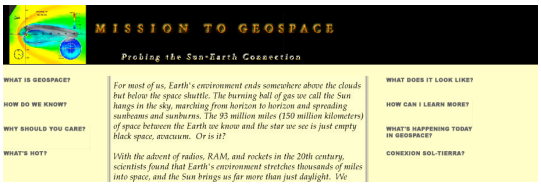
CME INFORMATION

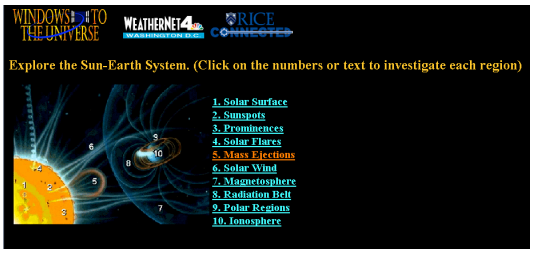
Effects of the Sun: Space Weather – Coronal Mass Ejections

Go to the website: Mission to Geospace at http://istp.gsfc.nasa.gov/istp/outreach/

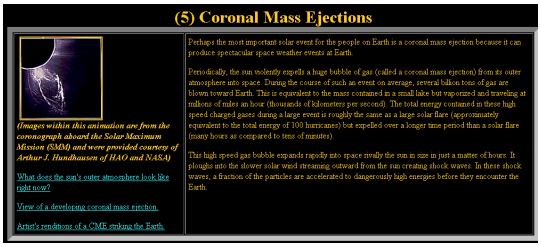


Select 'Why Should You Care?'

Then select 'Space Environment Center – Space Weather Effects Education'. This is what you will see:



Select #5 Mass Ejections. It will take you here:



As you read this section, be sure to take notes, keeping your *Power Point* presentation in mind. Go to all of the links in blue in the left column. If you find pictures you think you might want to use, you can use 'Save As', or make a printscreen copies and save them to your electronic folder.

Ion Simulation StarLogo code

The coding for this simulation is to long to publish in this document, therefore it is available for you to copy at http://education.lanl.gov/programs/lasso/StarLogo/ion1.slogo. Copy the entire page, paste into a word processing document and save as **ion1.slogo** . Open your StarLogo software, go to file, Open Project. Find the document ion1.slogo you just saved, and select it. Once it has opened, select Interface under the Windows select tool. Set your parameters and then 'Start'.

Collection of Particles Simulation StarLogo code

The coding for this simulation is to long to publish in this document, therefore it is available for you to copy at http://education.lanl.gov/programs/lasso/StarLogo/neutroncollector1.slogo. Copy the entire page, paste into a word processing document and save as **neutroncollector1.slogo** . Open your StarLogo software, go to file, Open Project. Find the document ion1.slogo you just saved, and select it. Once it has opened, select Interface under the Windows select tool. Set your parameters and then 'Start'.

Simulation of Iron Fillings around a Magnet StarLogo code

The coding for this simulation is to long to publish in this document, therefore it is available for you to copy at http://education.lanl.gov/programs/lasso/StarLogo/magnet2.slogo. Copy the entire page, paste into a word processing document and save as **magnet2.slogo** . Open your StarLogo software, go to file, Open Project. Find the document ion1.slogo you just saved, and select it. Once it has opened, select Interface under the Windows select tool. Set your parameters and then 'Start'.

Internet Resources

(The URL addresses for the following web sites were verified as still active on Sept. 11, 2003.)

A

ACE News Archives (http://www.srl.caltech.edu/ACE/ACENews_Archives.html) - Archived pages on the Advanced Composition Explorer

ACE Photos (http://helios.gsfc.nasa.gov/ace/gallery.html) - photos of the Advanced Composition Explorer spacecraft and its related instruments.

The ACE/SWEPAM page (http://swepam.lanl.gov/) - The Earth is constantly bombarded with high speed particles coming not only from the sun, but also from outside of the solar system. Studying these energetic particles can help us understand the origin and evolution of our solar system.

Ask a Physicist (http://helios.gsfc.nasa.gov/physicist.html) - Do you have questions about cosmic and heliospheric space science? You can also learn more about the immense magnetic bubble containing our solar system.

Astronomy Picture of the Day (http://antwrp.gsfc.nasa.gov/apod/astropix.html) - Discover the cosmos! Each day a different image or photograph of our fascinating universe is featured, along with a brief explanation written by a professional astronomer.

Astronomy (Science) (http://www.einet.net/galaxy/Science/Astronomy.html) - a list of astronomy Internet sites.

Astronomy and Space for Kids (http://www.KidsAstronomy.com/)- Kid's Astronomy includes many links for kids of all ages to learn more about the universe, space exploration, and the solar system. The site includes a free on-line astronomy academy (you must register by specific deadlines to be included in 6-10 week courses).

Astronomy Today (http://www.astronomytoday.com/) - Here at Astronomy Today you'll find lots of articles on astronomy, cosmology, space exploration plus regularly updated space news and a monthly sky guide.

Astronomy web site presentation (http://www-ed.fnal.gov/linc/projects/white/presentation.html) - OUT OF THIS WORLD AND INTO OUR CLASSROOM

The Aurora Page (http://www.geo.mtu.edu/weather/aurora/) - Informative reading on the aurora.

B

C

"CERES Project," (http://btc.montana.edu/ceres/) or the Center for Educational Resources, is an extensive library of online & interactive K-12 science education materials for teaching astronomy. The site offers both classroom science projects & reference materials. (NASA)

The Cosmic and Heliospheric Learning Center (http://helios.gsfc.nasa.gov/) - Produced by the ACE project at NASA Goddard Space Flight Center, this site is designed to increase interest in cosmic rays and heliospheric science. (The heliosphere is the HUGE area in space affected by

the Sun.) It also includes some astrophysics basics, a Index, a history of cosmic ray studies, and the chance to "Ask a Physicist." Middle school level or above.

D

E

Earth from Space (http://earth.jsc.nasa.gov/sseop/efs/) - View some of the best images from the NASA Space Shuttle Earth Observations Photography database. These images were compiled to illustrate interesting Earth features and processes as seen by Astronauts from space. You may select images by geographic location or area of interest such as cities, Earth landscapes, or Earth's water habitats.

Education Resources (http://eosweb.larc.nasa.gov/EDDOCS/) from the Distributed Active Archive Center offers, by way of the NASA Langley Atmosphere Sciences Center, educational projects & fact sheets on matters pertaining to the earth's atmosphere. Videos & educational kits are available to teachers by post. (NASA)

The Exploration of the Earth's Magnetosphere (http://www-spof.gsfc.nasa.gov/Education/Intro.html) looks at the hot (but usually rarefied) gases which fill most of space, which are ruled by magnetic and electric forces rather than by gravity. The site discusses such phenomena as the polar aurora, the radiation belts, the solar wind, magnetic storms, "space weather", and cosmic radiation. It includes a quick overview of the relevant physical sciences, such as magnetism, ions & electrons, & plasmas, as well as tidbits of history. (NASA)

Exploration of the Solar System (http://sse.jpl.nasa.gov/index.cfm) - Let's explore the Solar System! Come along and learn how our solar system formed, and understand whether planetary systems are a common phenomenon throughout the cosmos. Explore the diverse changes that planets have undergone throughout their history and that take place today.

F

Female Frontiers (http://quest.arc.nasa.gov/space/frontiers/) and NASA Quest (http://quest.arc.nasa.gov/) have profiles and weekly web chats with women of NASA who have achieved a variety of women firsts (such as first woman programmer and first woman shuttle commander). Participants have the opportunity to communicate with the featured mentor during the chats and will find the profiles and archived chats a source of information on the NASA women and their work. (NASA)

FoilSim (http://www.grc.nasa.gov/WWW/K-12/aerosim/) - Check out this interactive simulation software that determines the airflow around various shapes of airfoils. Students change the position and shape of the wing. The software displays plots of pressure or airspeed above and below the airfoil surface and calculates the lift of the airfoils, allowing students to learn the factors that influence lift.

From Stargazers to Starships (http://www-spof.gsfc.nasa.gov/stargaze/Sintro.htm) deals with the world of gravity, massive planets and stars, and the way spaceflight is achieved despite their strong pull. The material is suitable for high school students and gives historical background as well as the latest scientific findings. (NASA)

G

Galileo Model (http://www.jpl.nasa.gov/galileo/model.html) - Do you like a challenge? Try constructing this detailed model of the Galileo Spacecraft, one of the most complex robotic spacecraft ever flown!

GENESIS mission information (http://www.genesismission.org/) developed by NASA

H

Hands-On Universe (http://www.handsonuniverse.org/) is an educational program that enables students to investigate the universe while applying tools and concepts from science, math, & technology. Using the Internet, HOU participants around the world request observations from an automated telescope, download images from a large image archive, and analyze them with the aid of user-friendly image processing software. (NSF)

Hubble Deep Field Academy (http://amazing-space.stsci.edu/) - Train to be a scientist by enrolling in the Hubble Deep Field Academy. Become a Stellar Statistician, Cosmic Classifier, and a Galactic Guide. Then take the final challenge and become a Universal Graduate.

Hubble Heritage Project (http://heritage.stsci.edu/) - Take a peek over the shoulders of astronomers who use the Hubble Space Telescope to study the heavens.

Hubble Space Telescope Public Pictures (http://hubblesite.org/newscenter/) - Like a traveler sharing their best snapshots, HST evokes a new sense of awe and wonder about the infinite richness of our universe in dramatic, unprecedented pictures of celestial objects.

Human Spaceflight (http://spaceflight.nasa.gov/) gives real-time positions and news about the Space Station and the Space Shuttle. Videos using Quick Time plug-in are shown as well as photos. The site also provides extensive background information. (NASA)

I

Interesting Facts and Educational Material (http://www.ips.gov.au/) - This area contains a series of occasional articles by IPS staff and their colleagues. Everything you always wanted to know about the Sun, space weather and much more.

Ionosphere Home Page (http://www.ngdc.noaa.gov/stp/IONO/ionohome.html) - The Ionospheric Physics Group of NGDC has the mission of operating the World Data Center-A for Ionosphere portion of the WDC-A for STP, which is to seek out and archive all data, data products, and information related to the Ionosphere.

J

J-Pass (http://liftoff.msfc.nasa.gov/RealTime/JPass/) - J-Pass allows you to track satellite passes through your night sky (includes stars, planets, sun and Moon).

J-Track Tracking System (http://liftoff.msfc.nasa.gov/RealTime/Jtrack/welcome.html) - Use your Web browser to track the orbit of Hubble, Mir, the Shuttle or other satellites in real time. This tracking system uses a Java applet to calculate and display spacecrafts and satellites against a world map.

Just For Fun (http://lsda.jsc.nasa.gov/forfun.cfm) - This site has games and activities to teach you about space flight, and what happens to your body in space. Learn about the many different kinds of animals that have flown in space, and why. Try the Hangman! But don't get HUNG!

L

Liftoff (http://liftoff.msfc.nasa.gov/) - Liftoff to Space Exploration is the source for satellite tracking on the web, the Space Academy, Kids Space Art Gallery and much more!

Live From the Sun (http://passporttoknowledge.com/sun/) - Passport to Knowledge (PTK) is an ongoing series of "electronic field trips to scientific frontiers" targeted at middle school students. Debuting in Spring 1999 and continuing into 2001, "Live From the Sun" explores 4 main themes: Our Sun as a Star, How the Sun Works (We Think!), The Sun-Earth Connection, and The Sun in Human History. Live From the Sun is a part of NASA's Learning Technologies Project.

Lunar and Planetary Institute (http://www.lpi.usra.edu/) - A NASA funded institute in Houston devoted to studying the solar system and sharing the excitement of space exploration with the public. Something for the teacher, student, scientist, or anyone interested in the planets.

M

Make a Balloon-powered Nanorover (http://spaceplace.jpl.nasa.gov/muses1.htm) - The Japanese are sending a spacecraft to Asteroid 4660 Nereus in 2002. With the spacecraft will be a little rover just a couple of inches high. The rover will explore the surface of the asteroid and take pictures. To build your own nanorover ("nano" meaning very tiny) from three styrofoam meat trays, follow these directions. This project is a little bit hard, so a child will need some assistance.

Mars and Beyond (http://spaceflight.nasa.gov/) - The first human to set foot on the surface of Mars is probably alive today. Find out what NASA is doing to get ready for the next adventures in human exploration.

Mars Pathfinder Poster
(http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Mars.Pathfinder.Poster/) - View the Pathfinder Poster here.

Mullard Space Science Laboratory Space Plasma Physics Group
(http://www.mssl.ucl.ac.uk/pages/) - pursuing excellence in education and research.

N

NASA's Earth Observatory (http://earthobservatory.nasa.gov/) - Monitor regional and global changes on Earth almost as they happen. Visit the Laboratory to learn how and why Earth changes. Discover the art and science of space-based remote sensing in the Lab. Then, spend some time on the Observation Deck comparing and contrasting data from satellites to see if our planet actually behaves as the Laboratory models suggest.

The NASA Image Exchange (NIX) (http://nix.nasa.gov/) - Visit NIX, a web-based search engine that puts over 300,000 NASA online images from the various NASA centers at your fingertips.

NASA/Marshall Solar Physics (http://science.nasa.gov/ssl/pad/solar/) - Branch of Marshall Space Flight Center's (MSFC) Space Sciences Laboratory (SSL) is composed of 15 scientists involved in various studies of the physics of the Sun.

NASA Reduced Gravity Student Flight Opportunities (http://microgravityuniversity.jsc.nasa.gov/) - Would you like to fly an experiment on NASA's reduced gravity laboratory? Explore what it's like to work and live in zero-gravity, and find out how students compete for a seat on the Johnson Space Center's reduced-gravity aircraft!

NASA's Space Physics Data System - An Introduction (http://spds.gsfc.nasa.gov/) - The SPDS is was initiated in 1994 by NASA's former Space Physics Division to preserve historical data and provide improved access to space physics data. The SPDS is a distributed system whose services are existing data systems serving the disciplines of space physics,...

The Nine PlanetsU (http://seds.lpl.arizona.edu/nineplanets/nineplanets/nineplanets.html) - The Nine Planets is an overview of the history, mythology, and current scientific knowledge of each of the planets and moons in our solar system. Each page has text and images, some have sounds and movies, most provide references to additional related information.

NRL, Solar Physics Branch Home Page (http://wwwsolar.nrl.navy.mil/) - Researchers in the Solar Physics Branch have been involved in observational and theoretical studies of the solar atmosphere since the early years of the space age. Experiments developed at NRL have flown on NASA missions.

O

Off to a Flying Start (http://ltp.larc.nasa.gov/flyingstart/) - This online telecommunications project incorporates aeronautics, math, science, technology, and FUN! Students learn about the principles of flight, build and fly their own Falcon Flyer, and create and test their own airplane design.

P

Payload and Orbiter Virtual Tour (http://science.ksc.nasa.gov/shuttle/missions/sts-90/vrtour/) - The STS-90 Virtual Tour allows anyone to see what it looks like inside the Space Shuttle Columbia. Tour in the cockpit, go through the airlock and see the inside of the Neurolab payload. Proceed to Entry Checkpoint.

Principles of Aeronautics (http://wings.avkids.com/Book/) - Select a reading level for mythological stories, activities, and lesson plans related to the history of flight. The K-8 Aeronautics Internet Textbook is a cooperative agreement between NASA and Cislunar Aerospace, Inc. with additional support from UCDavis.

Public Outreach, Education, Teaching and Reaching Youth (POETRY) (http://image.gsfc.nasa.gov/poetry/) - Hear sounds from space, find science fair projects and suggestions, view the Earth magnetosphere art gallery, and check out space weather for today. Locate several classroom activities and numerous resources. If all else fails, Ask the Space Scientist about the Moon, Earth, the Solar System, the Cosmos, and Everything Else!

R

Robotics – (http://education.lanl.gov/newEPO/K12/robotics/main.html) - This site was designed to students and teachers to provide information to those interested in the field of robotics.

S

SDAC Home Page (http://umbra.nascom.nasa.gov:80/sdac.html) - The Advanced Solar Coronal Explorer is one of five MIDEX missions selected by NASA for Phase A studies. The final selection of two MIDEX missions for launch in 2003 and 2004 is scheduled to be made in 1999 September.

Solar Classroom (http://www.lmsal.com/YPOP/Classroom/) - Create unique on-line X-ray movies, view real-time images of our Sun, peruse electronic flip-books filled with exciting solar facts, or utilize investigative learning activities in the YPOP solar classroom. This site is provided by Yohkoh Public Outreach Project (YPOP), a NASA funded educational outreach project.

Solar Connections: Strategic Theme (http://umbra.nascom.nasa.gov/solar_connections.html) - Space physics is the study of the heliosphere (the sphere of influence of the Sun) as one system. It seeks to explore and understand the dynamics of the Sun and its interactions with the Earth and other planetary bodies and with the interstellar medium.

Solar Flare Theory (http://hesperia.gsfc.nasa.gov/sftheory/) - These pages are about solar flares, the biggest explosions in the solar system. Their purpose is to providesome general information about solar flares, a "feel" for scientific research into the energetic emissions from flares, and a glance into the future of solar flare research.

SOHO: The Solar and Heliospheric Observatory (http://sohowww.nascom.nasa.gov/) - SOHO was launched on December 2, 1995. The SOHO spacecraft was built in Europe by an industry team led by Matra, and instruments were provided by European and American scientists.

Solar System Simulator (http://space.jpl.nasa.gov/) lets the reader order a simulated photograph of the Sun and planets and their satellites as seen from any other vantage point. Create simulated images of any body from any point in space at any time in full-color graphics. Be sure to read the Simulator FAQ for tips and tricks.The reader can choose any time in 5 minute intervals from 1600 to 2399. This is one of NASA's most popular sites and receives 36,000 requests per day. (NASA)

Solar-Terrestrial Physics Division of the National Geophysical Data Center (http://www.ngdc.noaa.gov/stp/stp_noframes.html) - Solar-terrestrial data come to NGDC through a variety of sources, both domestic observatories and world wide sources under the World Data Center exchange program.

The 60-Foot Solar Tower (http://physics.usc.edu/solar/) - The HiDHN project is a network of two sites whose primary purpose is to study the high order oscillations of the sun in the narrow sodium D-line wavelengths.

Space Calendar (http://www.jpl.nasa.gov/calendar/) - Covers space related activities and anniversaries for the coming year.

Spacekids (http://spacekids.hq.nasa.gov/) - Explore Mars, check out the latest Space Science News or share your astronomy images.

Space and Astronomy Photos and Clipart (http://desktopPublishing.com/spacen.html)

Space Place (http://spaceplace.jpl.nasa.gov/index.shtml) - Make spacey things. Do spacey things. The Space Place contains fun activities and related informative technical/scientific fun facts, and introduces some of the latest and most advanced technologies being tested for use on space missions in the future.

Space Plasma Physics - Particles & Imaging Research (http://www-pi.physics.uiowa.edu/) - This is The University of Iowa, Department of Physics & Astronomy, Space Plasma Physics Research Group led by Dr. Louis A. Frank. Van Allen Hall is named after Dr. James A. Van Allen, a leading pioneer in Space Plasma Physics Research. His instruments were the very first flown in space by US rockets in the early days of the space program, including Explorer 1 which was the United States' first successful orbiting satellite. It made measurements that lead to the discovery of the two highly charged particle, or radiation regions which encircle Earth. These were later named in his honor as the Van Allen Radiation Belts.

Space and Solar Physics, Astronomy and Astrophysics (http://sohowww.nascom.nasa.gov/spacesolarastro.html) - a list of space science Internet sites

StarChild - Travel through the Solar System and Universe with The Starchild and watch for comets, asteroids, and other space debris.

The Star Trails Society (http://www.startrails.com/) is an initiative by Science@NASA to involve readers in scientific research. Several times each month the site will announce opportunities for amateur scientists to contribute to research in astronomy, astrobiology, and other natural sciences. One doesn't need to be a professional scientist to participate -- students, teachers, novices and serious amateurs can all join in! (NASA)

The Science of Star Trek (http://ssdoo.gsfc.nasa.gov/education/just_for_fun/startrek.html) - Is Star Trek really a science show, or just a lot of "gee whiz" nonsensical Sci-Fi? Could people really DO the fantastic things they do on the original Star Trek and Next Generation programs, or is it all just hi-tech fantasy for people who can't face reality? Here's a list of the standard Star Trek features, roughly in order of increasing scientific incredibility.

The Story of a Little Rock on Mars (http://eis.jpl.nasa.gov/~skientz/little_rock/) - Check out what the "little rock" on Mars thinks of the Pathfinder.

Sun-Earth Connections Homepage (http://sec.gsfc.nasa.gov/) - Sun-Earth Connections: the thrust of space physics is to observe and interpret the variable radiations in the Earth's space environment. The Sun, its atmosphere and heliosphere, and the Earth's magnetosphere and atmosphere are coupled by physical processes that are only partially known. These processes will be explored to achieve major advances in understanding.

T

TAS Game (http://sspp.gsfc.nasa.gov/hh/tas/experiments.html) - Test your knowledge about the experiments to fly on STS-85 Shuttle Mission by playing the TAS game.

Tour The Cosmos (http://hubblesite.org/discoveries/tour_the_cosmos/) - How do planets form? Check out Hubble Space Telescope's recent findings on the evolution of extrasolar planetary systems. Hear and see the discoveries from the astronomers themselves.

Tropical Twisters (http://kids.earth.nasa.gov/archive/hurricane/) - Learn how hurricanes work and what they do, then create your own Hurricane!

U

The Ultimate Field Trip (http://eol.jsc.nasa.gov/newsletter/uft/uft1.htm) - Astronaut Kathryn D. Sullivan's Ultimate Field Trip contains incredible views of earth from space along with her observations on studying the earth from space. Come along and visit Kathy as she takes a look out of her "office" window.

V

Virtual Tour of the ISS (http://spaceflight.nasa.gov/) - Visit the International Space Station

Virtual Tour of the Universe (http://science.nasa.gov/newhome/virtualtour.htm) - From Earth's atmosphere to the aurora, sun, solar system, and out to the distant reaches of the cosmos, see what the "weather" is like today.

W

Warp Drive, When? (http://www.grc.nasa.gov/WWW/PAO/warp.htm) - Ready to Go to Warp Speed? What will it take for humans to be able to travel the vast distances between stars? Learn more about what kinds of propulsion will be needed when humans are ready to leave the Solar System.

Web Ground School (http://www.aero.hq.nasa.gov/edu/) - Learn what makes an airplane fly, a balloon float, or a spacecraft stay in orbit. This site takes an informative and entertaining look at the science of aeronautics.

Wright Flyer Online (http://quest.nasa.gov/aero/wright/) - Follow the aerodynamic testing of a replica of the Wright Brothers' plane. Learn about Orville and Wilbur Wright, their plane, wind tunnels and this aerodynamic test.