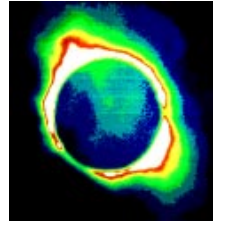




**Hands-On Universe
Middle School Curriculum**



Teacher's Guide to Hands-On Solar System

*Developed at Lawrence Hall of Science,
University of California,
in collaboration with TERC,
Yerkes Observatory,
and Adler Planetarium*

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This image and cover image of Comet Hale-Bopp,
by Vivian Hoette

Hands-On Solar System is part of the Hands-On Universe (HOU) project's middle school curriculum materials.

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The following Lawrence Hall of Science (LHS) staff gave critical support in development of Hands-On Solar System:

Carl Pennypacker (HOU Founder and Co-Director)

Amelia Marshall (HOU Staff Research Associate)

Miho Rahm (HOU Project Manager)

To procure Hands-on Solar System Student Books or to purchase the HOU Image Processing computer program, please visit the HOU website:

<http://hou.lbl.gov>.

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Lawrence Hall of Science



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Hands-On Solar System

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Earth

Hands-On Universe Middle School Curriculum

Overview of *Hands-On Solar System*

Using images from professional telescopes along with image processing software developed for use in the classroom, your students pursue guided investigations of astronomical objects and phenomenon. Hands-On Universe (HOU) blends content learning with critical thinking skills and processes such as data interpretation, measurement techniques, and using appropriate tools for exploration. Hands-On Solar System (HOSS) is part of the HOU project. HOSS requires frequent sessions in a computer lab. Time estimates given for computer lab sessions are deliberately *LESS* than 40 minutes, since in practice, most classes must allow travel time to the computer lab and “settling in time” to get going once in the computer lab.

HOU and National Standards

HOU embraces the inquiry-based approach to learning outlined in the NRC National Science Education Standards which state that in grades 5-8 students should develop the ability to:

- Clarify questions and inquiries and direct them toward objects and phenomena that can be described, explained, or predicted by scientific investigation.
- Formulate questions, design investigations, execute investigations, interpret data, use evidence to generate explanations, propose alternative explanations, and critique explanations and procedures.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Communicate scientific procedures and explanations.

Content-wise, the HOU middle school curriculum pays heed to NRC National Science Education Content Standards for Earth and Space Science (CONTENT STANDARD D) which states that

“A major goal of science in the middle grades is for students to develop an understanding of earth and the solar system as a set of closely coupled systems.”

Specific elements of the Content Standards in Earth and Space Science are

- The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system.[See Unifying Concepts and Processes]

- Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses.

The National Standards also include in Science and Technology (CONTENT STANDARD E) which is clearly the realm of this HOU unit:

“Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that enable observations

of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.”

Upon completion of *HOSS*, students should be acquainted with how astronomers use image processing software to investigate celestial objects. They should also be familiar with these astronomical objects:

- * Earth’s Moon
- * Planets
- * Moons of Planets
- * Comets
- * Asteroids



Mercury

Hands-On Solar System Course Summary

Introduction: What’s Out There

(CLASSROOM — 10 min)

Students brainstorm a list in answer to the question, “What types of things do we find in the night sky?”

Part I. The Moon—Our Closest Neighbor

A. The Image Processor

(COMPUTER LAB — 35 min)

Students learn how to use the HOU Image Processing software while exploring characteristics of craters on the Moon. Image Processor functions: Open, Zoom, Pixels, Coordinates, Brightness (TERC/LHS)

B. Crater Game (COMPUTER LAB — 20-30 min)

In this game, students get practice using their Image Processing software to determine diameters of craters.

C. Moon Measure

(COMPUTER LAB — 20-30 min)

Students investigate images of Moon craters, valleys and mountains and walls. They measure the diameter of a crater and its circumference using Image Processing tools.

D. Model Craters (CLASSROOM — 20-30 min)

To really see more of how craters appear, students make model Moon craters and see how the pattern of shadows associated with craters is affected by the angle of sunlight shining on them. Optional: Cratering Experiments—Students toss meteoroids (pebbles) into basins of flour to simulate crater formation.

E. Moon Phases (CLASSROOM — 15 min)

With the Moon being a white polystyrene ball and the Sun being a bright light at the center of the room. Each student's head represents the Earth. Students can also observe and record the real phases of the Moon over a period of a couple of weeks (can be homework).

Part II. Comets

A. False Color Comet

(COMPUTER LAB — 30 min)

Students learn the Image Processor functions: Min-max, color palette

B. Comet set — Earth's rotation (CLASSROOM — 10 min)

Students learn that because Earth is a spinning planet, when we watch the sky, it looks like objects in the sky change position.

C. Comet motion (CLASSROOM — 10-20 min)

Students learn how, since a comet is in orbit around the Sun, it appears to move with respect to background stars. Optional activity: ellipse drawing—the shapes of orbits.

D. Comet Orbits (CLASSROOM — 30 min)

Students draw ellipses to compare the shapes planet, comet and asteroid orbits.

Part III. Asteroids

(COMPUTER LAB — 30 min)

Students learn how asteroids can be discovered by comparing two images of the same place in the sky. They also learn the difference between an asteroid and a comet.

Part IV. Planets

A. Jupiter and Its Moons

(COMPUTER LAB — 20-30 min)

Students measure the radius of the orbits of some of Jupiter's moons.

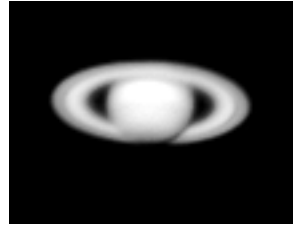
B. Jupiter Rotation

(COMPUTER LAB — 15-20 min)

Students see evidence of rotation of Jupiter by observing the Great Red Spot.

C. Planet Survey (COMPUTER LAB — 20-30 min)

Students review (or learn) all the types of bodies in the solar system. They arrange the planets in order and record planet sizes and distances to the Sun. For this part, students use the HOU “What Is It? How Far Is It?” web pages—“Nearby Objects.” The solar system web pages have all distance and size data EXCEPT for 5 conspicuously missing planet sizes (Jupiter, Saturn, Venus, Mars, Uranus). To find those planet sizes, students must use their Image Processing software to determine first the planet size in pixels, and then compute the planet size in kilometers, once they are given the pixel scale size (e.g. for Jupiter image 1 pixel = 2200 km)



does not treat the Sun, which is a key mention in National Standards for middle school. The new LHS GEMS The Real Reasons for the Seasons is an excellent set of middle school activities that deals with seasons and Sun-Earth Connections. We also recommend you visit NASA’s Sun-Earth Education Forum (SECEF) website <http://sunearth.gsfc.nasa.gov> or <http://sunearth.ssl.nasa.gov> for educational resources about the Sun. If you have access to a planetarium, permanent or portable, you can check out the Planetarium Activities for Student Success (PASS) series of programs, in particular Volume 2, *Activities for the Planetarium*, Volume 12, *Stonehenge*, and Volume 6, *Red Planet Mars*. See <http://www.lhs.berkeley.edu/pass>

D. Outer Planets (COMPUTER LAB — 20-30 min)

Students use proportion and/or algebra to calculate the orbit radius of a moon.

Time Frame

We anticipate that this unit will take about 2 weeks @ 40 min/day. There is frequent use of the Computer Lab needed in this time period, so if computer lab access is limited, then the unit may be spread over a longer period of time.

You may include *Hands-On Solar System* (HOSS) in your astronomy unit in a number of ways. In particular, HOSS

Background Computer Knowledge Needed

This unit assumes students are familiar with the following computer terms and processes:

- * Cursor
- * Click
- * Drag
- * Icon
- * Window
- * Scrolling
- * Closing a window
- * Changing window size

Familiarity with (x,y) coordinates is helpful, but can be taught along with this unit.

Good websites for you to start getting background information on the Solar System include:

<http://www.lhs.berkeley.edu/sii/URLs/URLs-AstroSolarSys.html>

<http://seds.lpl.arizona.edu/nineplanets/nineplanets/>

Preparation for Hands-On Solar System

You need to acquire (photocopy or purchase) Hands-On Solar System Student Books. A cost-saving measure is to NOT have students write in their student books, but to reproduce the “HOSS Answer Sheets” from the the last 20 pages of this Teachers Guide. Student books can then be reused with other classes. You also need to purchase the HOU Image Processing computer program. Contact HOU Project Manager at 510-642-0552 or e-mail houstaff@hou.lbl.gov to get your copy.

Student Books

Each of your students will need a copy of HOU Student Book. Current version along with the Teacher Guide can be obtained from the HOU website--<http://hou.lbl.gov/ms>

You may either purchase a license to photocopy the Student Books locally, or purchase them from HOU (contact HOU Project Manager at 510-642-0552 or e-mail mihorahm@uclink.berkeley.edu)

The Computer Lab

Some of the sessions require use of a computer lab. Plan to have two (or three) students at each computer. You will need to load the HOU Image Processor program on each computer, or have a server capable of running the program on all the computers in the lab. You also need to load the telescope images required for this unit. The following

preparation may take a few hours, which is why it is important to do it ahead of time. Once completed it will be a available forever unless you trash it or get new computers.

1. Use the HOU CD-ROM to install the image processor. HOU-IP should be installed either on a network or on each computer.
2. Within the HOU-IP folder there should be a subfolder called Images. Load images for this unit from the IP CD-ROM or download images from the Hands-On Universe Web Site: <http://hou.lbl.gov/ms/lhs/download.html>. These are images captured from professional grade telescopes with CCD (Charge Coupled Device) cameras that collect image information as digital files. The information is an electronic representation of how many photons of light were gathered in each picture element (pixel) of the CCD camera. They are recordings of brightness only and so are black and white representations. Color analysis in astronomy is usually accomplish with the use of a variety of color filters with the CCD cameras.
3. On a Mac, you may wish to make an alias of the HOU-IP application icon to place on the computers desktop. If you do not make an alias, you should print out and post instructions for accessing the application program, HOU-IP. This will avoid confusion while getting started or if students accidently close (or crash) the program mid-stream.

Hands-On Solar System

(Classroom)

Introduction: What's Out There?

Materials

For every student:

- Student Book
- Optional HOSS Answer Sheets

Preparation

—Make a photocopy of the HOU Student Book for each student.

Optional: make a copy of the HOSS Answer Sheets where students can do all their writing. Students will read directions in the Student Book and answer questions either directly in the Student Books or on the HOSS Answer Sheets.

In Class

1 What's in the sky? As an introduction to the entire Hands-On Solar System unit, ask,

What things do we see in the night sky?

Accept any answers and have students write down each answer on their worksheets.

2. How far away are they? After getting a dozen or more entries, return to the first entry and have students mark

on their sheets whether they consider the object nearby (within our Solar System), or really far away (outside our Solar System).

3. Explain,

We will be looking at these objects with telescope images using Image Processing software to find out things about each one.



The Ring Nebula, M57, first observed by Charles Messier: 31 Jan 1779. This is one of the best examples of a “planetary nebula,” These objects are NOT in our solar system, though early observers mistook them for planets because of their disk-like shapes.

Part I. The Moon—Our Closest Neighbor

I-A. The Image Processor

Materials

For every 2-3 students:

- 1 computer.
Minimum requirements: Mac with Operating System 7.1 or higher;
PC with 386 processor. Ideally, have Mac Power PCs or Pentiums with CD-ROM drives and computers all networked together.

For every student:

- 1 Hands-On Solar System Student Guide Book
- Optional: HOSS Answer Sheets

Image needed:

craters000314.fts

Preparation

If graphing is the only context where students have used (x,y) coordinates, this both broadens and reinforces their understanding. In graphing, the origin is the place where the x and y axes cross at (0,0). This is also true on the image display.

1. If you have not already done so, load HOU Image Processing software and the HOU middle school images on each computer. If the computers are

networked, the files can be loaded over the network. See further instructions in the “Preparation for Hands-On Solar System” section, page 8 of this Teacher Guide.

2. Optional: It is helpful to have a display to point out various icons and menus on the computer screen. This is easiest and best if there is a video projector or other large computer display in your computer lab that the whole class can easily see. A lower tech alternative is to prepare large hand-drawn charts that show the students where to find:



—the Image Processing icon (Launch in Step A),



—the Open File icon (Open Moon image—step B)



— the Zoom Box cursor



—the Zoom control. Click on “Redraw” to apply the zoom value entered.

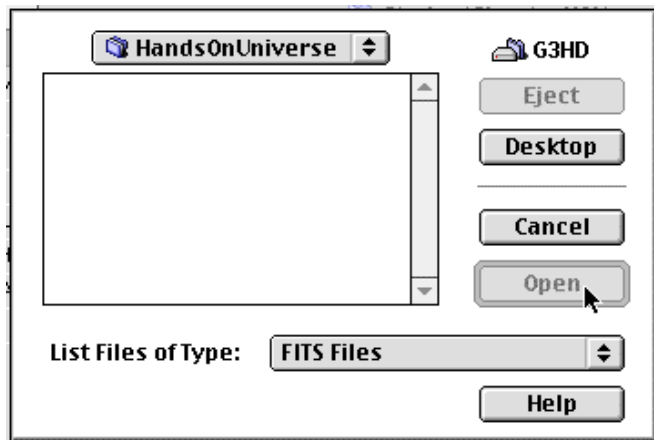


—clean up tool (to erase red zoom boxes)

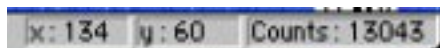
- the Menu Bar (top), Tool Bar (middle), and Display Controls (bottom)



- the “Open file” dialog box and the “List Files of Type” option where they will need to select “All Files” every time they want to open a new image



- the Status Bar which displays x, y coordinates and brightness counts for the pixel at the cursor position.



3. For each student, make a photocopy of the *Hands-On Solar System Student Book* and (optional) *HOSS Answer Sheets*.

In Class (Computer Lab)

1. Our closest neighbor. Ask,

What is our closest neighbor in space?

[Aside from things in Earth’s atmosphere and satellites, it’s the Moon]

2. Living on the Moon. Tell the class that there are some people interested in going to live on the Moon for short periods of time. Ask,

“What sorts of things would you need in order to live on the Moon for a few weeks or more?” [Accept all answers.]

3. Ice on the Moon? Explain,

Recent spacecraft missions to the Moon (Clementine and Lunar Prospector) have found evidence that there might be water on the Moon! It’s impossible for there to be liquid water on the Moon, so the water is probably in the form of ice.

Given that during the lunar daytime temperatures get up to 600 degrees and that during the lunar night, temperatures plummet to –200 degrees, where might we find water on the Moon?

[If students do not suggest that water might be in the darkest shadow areas of the Moon, suggest it yourself.]

How long is a day on the Moon? [about 29.5 Earth days]

We will be looking for the darkest shadows on the Moon as possible places to look for water ice. You will need to use computers with Image Processing software to determine where the darkest places are.

4. Hand out HOSS Student Books (and optional Answer sheets). The instructions in this first activity are written to allow students to proceed without your help. However, this is an example where having 2 or 3 students at each computer is important. With students working together, when questions arise the students can work with each other and solve their problems. When working alone, the student typically raises a hand and waits for your help. We recommend giving a minimal introduction to using the image processor and then allowing students to get going with the unit. They may struggle at first, but they will learn through their own exploration rather than expecting their teacher to be ready with the answers.

Optional: If you are having your students write answers on HOSS Answer Sheets, caution them NOT to write in the Student Books.

5. Give them a few pointers to help smooth over some initial rough places:

- a. Point out the Open (File folder) icon in the upper left corner of the computer screen.
- b. Show where the “File Type” spot is in the “Open file” dialog box, where they may need to select “All Files”

every time they want to open a new image (in the Mac 1998 version of IP software).

c. Explain to the students:

In some sections of the instructions, there are key questions that you should answer. Remind them to **not** write in the Guide Books—write **only** in the Notebooks. OK, now go ahead, launch your Image Processor and experiment for a while. Try to find where the darkest shadows in your image are located.

6. Circulate around the room and if students have questions about what they are supposed to be doing, Direct their attention to the instruction booklets if they are ignoring them. Encourage them to write down the answers to the questions on the Lunar Imagery Questions sheet.

7. As needed, stop the class to answer questions when you see many students having the same difficulties. For example,

- a. You may need to stop to explain about the meaning of coordinates by drawing a grid on the board and showing how boxes in the grid can be numbered in x-y coordinates. And in part 5—Measuring brightness, you may need to stop and explain that in the “Counts” box, the higher the number is, the brighter the pixel is, and that the lowest numbers indicate the darkest pixels.
- b. On question 4 e: How many pixels wide is the crater? You may need to give hints. There are two ways to go about this. The hard way is to zoom the crater until you can see the pixels and simply count the number

I-B. The Crater Game

of pixels across the crater. The difficulty is that in order to zoom enough to see the pixels, the crater may become wider than the computer screen making it necessary to divide the counting in two or more scroll widths. The easy way is to simply:

- (1) Place the cursor on the right side of the crater and read the (x,y)-coordinates in the status bar
- (2) Place the cursor on the left side of the crater and read the x-coordinate in the status bar, keeping the y-coordinate the same.
- (3) Subtract x-coordinate (2) from x-coordinate (1)

8. Time filler. When students finish finding the darkest pixel on the image, tell them they can explore other images in the Hands-On Solar System images folder until the other students finish.

9. How dark? When most of the students have finished, ask:

How dark was the darkest place on your image?

Zooming is analogous to looking through a magnifying glass or microscope. In each case, the purpose is to see details you cannot resolve with the naked eye.

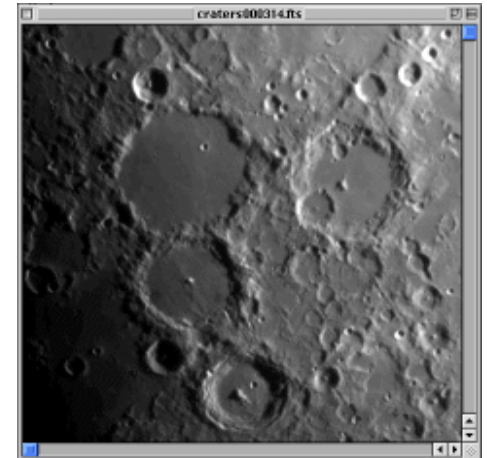
Materials

For every student:

- HOSS Student Book;
optional HOSS
Answer Sheets

Image needed:

craters000314.fts



Preparation

Reserve Computer Lab; make sure students have their HOSS Student Books; optional Answer Sheets

In Class (Computer Lab)

1. Review with the students how to measure the diameter of a crater on the Moon, in pixels. First, by way of review, ask

What is a pixel?

Then review the method of measurement/computation of diameter of crater.

- a. Put the cursor on the **left** side of the crater.
- b. Write down the (x, y)-coordinates of the **left** side of the crater.
- c. put the cursor on the **right** side of the crater, keeping the y-coordinate the same.

- d. Write down the x-coordinate of the **right** side of the crater.
- e. Subtract the left side x-coordinate from the right side x coordinate.

Note: this procedure is identical to one that will be used later in section IV-D. Planet Sizes section.

2. Explain the Rules of the Game, as laid out in p. 11 of the Student Book:

- a. Set the zoom factor to “3” on the Moon picture.
- b. Teacher picks a crater and calls out the coordinates of the center of the crater.
- c. Write the crater center coordinates on chart and put the crater number at the proper location in the Moon image.
- d. Measure the crater diameter in pixels, write it in the chart, and raise your hand to indicate you have found the answer.
- e. First player to find correct answer picks the next crater and calls out the coordinates of the center of a new crater—then back to step (c).
- f. Compute crater diameters in kilometers, using the conversion factor: 2 km/pixel (each pixel representsw 2 km on the Moon). Write the diameters in the chart.

$$\text{Diameter (D)} = (N \text{ pixels}) \times (2 \text{ km/pixel}).$$

- g. Use 1 mi = 1.6 km to convert to miles.

3. Algebra. Steps 2 f and 2g are actually a bit of algebra, so make sure to call students attention to the equation in 2f and take time to work through examples as needed so they understand the concept. For step 2g, computing

crater diameter(s) in kilometers (1 mile = about 1.6 km) explain the idea of “conversion factor”:

- a. 1 pixel = 2 kilometers ...divide both sides by “pixel” to get

$$\longrightarrow 1 = (2 \text{ kilometers/pixel})$$

This is known as a “Conversion Factor”.

- b. Multiply crater diameter (in pixels) by the Conversion Factor:

$$\text{Crater Diameter } D = (X \text{ pixels})(2 \text{ km/pixel}) = 2X \text{ km.}$$

- c. Plug in the value “X” (crater diameter in pixels) to get crater diameter (D) in kilometers. This is the “algebra” of conversion factors.

Note: This process can also be thought of in terms of ratios or proportions:

$$D \text{ (km)}/X \text{ (pixels)} = 2 \text{ km}/1 \text{ pixel}$$

or alternatively

$$D \text{ (km)}/2 \text{ km} = X \text{ pixels}/1 \text{ pixel}$$

4. Play the game.

5. Ask,

Does that tell us how big the crater really is?

(No, because pixel size changes for different telescopes, CCD cameras, and for objects at different distances.)

How might we tell how big the crater really is?

(We need to know how many miles each pixel represents.)

6. Have students read the information about Barringer Meteor Crater in Arizona on page 7 of their Notebooks. See if they have questions about it and discuss any issues that arise.

7. Analog versus digital. Explain the difference between analog versus digital data: Analog data is continuous, digital data is discrete. The pixels on an image represent discrete data; e.g., there are no fractional values for the (x,y) coordinates. If the x coordinate is 140, the next value will be 141; there is nothing in between. Examples of analog data are distance traveled as a function of time, and pitch of a sung note while going up the scale.

(Computer Lab)

I-C. Moon Measure

This activity is adapted from Vivian Hoette’s Moon Measure activity at <http://hou.lbl.gov/~vhoette/Explorations/MoonMeasure>. Students investigate Images of Moon craters, valleys, mountains, and walls. In studying the images of the Moon, students can see lunar structures: craters, maria (the dark “seas” that are actually darker rock on the moon’s surface) and mountain ridges.

Materials

For every student:

Hands-On Solar System Student Notebook and Student Guide Book

Images needed:

- moon1.fts moon7.fts
- moon5.fts moon16.fts
- moon6.fts moon17.fts

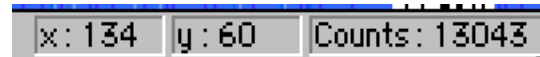
Preparation

Reserve Computer Lab; make sure students have their HOSS Books (and optional HOSS Answer sheets).

In Class

1. Challenge your students to investigate the craters of these 6 Moon images. Explain that they will:

- a. Open a Moon image.
- b. Identify a feature that is a crater.
- c. Find (X, Y) coordinates of the crater. To determine coordinates of a point on the image, look at the status bar at the bottom of the Image Processor. It tells you the position of your cursor on the image with an x value and a y value. (x,y)
- d. Describe the feature with words and make a sketch of it.



moon1.fts:



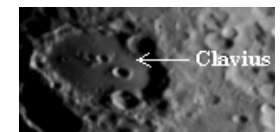
moon5.fts:



moon6.fts:



moon7.fts:



moon16.fts:



moon17.fts:



e. Measure the diameter of the crater in pixels and compute the diameter in kilometers. They will be learning a new technique for measuring distance or diameter of features on telescope images: the Slice Tool.

2. Slice Tool. Explain and show students how to use the Slice tool.

Select the Slice tool from the Data Tools menu, then click and drag across a feature that you want to measure. A graph will pop up in a new window that shows the line you drew as length in pixels along the x-axis. The y-axis indicates the brightness of each of the pixels along the x-axis. You can often tell where the edge of a feature is by brightness change due to shadows. Be careful to explain that the graph does NOT show height of the feature, only brightness and distance along the line in pixels.

3. Optional: Determine the Conversion Factor for these Moon images, have the students open the moon1.fts image and identify the crater Plato—it's the largest crater, over towards the left side of the image. Have them measure the diameter of Plato in pixels with the Slice tool. [It's about 36 pixels] Tell the class that Plato is about 100 kilometers in diameter. Can they figure out the Conversion Factor?

[X km/1 pixel = 100 km/36 pixels = 2.8 km/pixel.]

4. Demonstrate how to measure the diameter of a crater with the slice tool, then convert to kilometers using the Conversion Factor 2.8 km/pixel.

5. Tell the students to follow the instructions on page 9 of their HOSS Books, *Moon Measure*. Go around, help and encourage as needed. As students finish describing, sketching and measuring one crater, have them go on to identify other craters. Have them identify, describe, sketch and measure the features.

6. Measure the *circumference* of a crater by one of the following methods:

- adding together slices along the crater rim.
- use the formula for circumference: $C = 2\pi r = \pi D$
($\pi \approx 3.14$)

Convert to miles or kilometers.

7. Locate craters. Optional: If you have a map of the Moon with craters labeled, look up each of these craters on a moon map.

Note: these measurements are only valid for craters near the center of the lunar face ... near the sides the viewing angle would need to be taken into account also. Measurement must be along the longest axis.

(Classroom)

I-D. Making Model Craters

Science concept: Light and Shadows—Craters in images have dark and lighted sides. These depend upon the relative position of the Moon, Earth and Sun.

Images for Going Further:

Copernicus000521.fts

Copernicus000724.fts

Copernicus000725.fts

Copernicus001020.fts

Materials

For every student:

- HOSS Student Book (and Optional Answer sheets)
- water and 2 sheets of scrap paper or newspaper at least 8.5"x11"

Fancier (but costlier) alternatives:

- 1 sheet of scrap paper 1/4 cup of flour and some water
- 1/8 pound of plasticene clay (half of a 1/4 lb stick); and clay-forming tool (Popsicle stick)
- crayola modeling magic

For the class:

- 1 clamp-on light (100-300W bulb)
- 1 large Moon globe model with craters at the equator and north pole.
- 1 Overhead projector and overhead transparency of the moon.fts image

Image Needed:

moon.fts

Preparation

- Decide whether you will use water-soaked paper, clay, or flour and water for the model craters and gather needed materials. Lids of cottage cheese or yogurt containers work well as “work dishes” but scrap paper works well too.
- If you choose to do the OPTIONAL Cratering Experiments (step 1 below), you can use dry flour for the experiments and then wet the flour later for molding model craters.
- Set up the clamp-on light near the front of the room.
- Set up the overhead projector with moon crater transparency.
- A large moon globe model can be made from an inexpensive Earth globe painted gray. Instead of painting gray, you can invoke student imagination to PRETEND the globe is a gray Moon globe. Press on clay at the equator and north pole and form the clay into craters.
- Get classroom as dark as possible with room lights off.

In Class

1. Explain,

To really see more of how craters appear, we are going to make model Moon craters.

OPTIONAL: Cratering Experiments

(1 class period—40 min)

Experiments on how craters form can be found in Planetarium Activities for Student Success (PASS) Vol. 7, pages 25-32—available from <http://www.lhs.berkeley.edu/pass>.

Students toss meteoroids (pebbles) into basins of flour to simulate crater formation. They can test variables such as size of meteoroid, speed at impact, angle of incidence. To do this, you need pebbles of different sizes and several basins (shallow bowls or dish tubs work well) filled about 2" deep with flour or sand. If you use sand, sprinkle with flour on top to defined the surface well. Create your own data sheet for these meteor experiments or let students create their own data sheets.

2. How to make model craters. Explain,

Please use the water-soaked paper (or small dishes of flour mixed with water, or clay) to make three-dimensional models of craters. Try to make craters that look like the ones in your moon images. I will leave the overhead projector display on for you to look at while making your clay crater models.



Photo of paper crater model by Alan Gould

Give out sheets of scrap paper as work surfaces and give each student materials to make craters (water-soaked paper, clay or flour and water). Give the class 5 minutes or so to make crater models. Give 1-minute warning to let them know how much time they have left.



3. Lighting. Explain,

Your craters look great, but they still do not look just like the craters in the Moon image. In order to make your craters look more realistic we need a model Sun to shine on them rather than all these ceiling lights. I will turn on this bright light to represent the Sun. Please lift your model

craters and tilt them different ways until they look just like the craters on the moon image. Watch the changing shadows in the deepest areas and from the highest peaks.

4. Turn on 100-300W light. Turn off ceiling lights. Go around and admire the craters. Point out how shallow the Sun angle has to be to make them look like the moon image craters.

Have students make a sketch in their books, showing the model crater, model Sun, and the angle that the rays of sunlight must be to make the shadows look right for the moon.fts image.

5. Demonstration Using Large Moon Globe:

Hold up the large Moon model. Slowly rotate it.

How long is a day on the Moon?

A day on the Moon is about 29.5 days. It takes the Moon the same amount of time to rotate as it does to orbit around the Earth.

Demonstrate by moving the Moon in orbit around yourself as the Earth. Point out how the crater feature on the Moon slowly points in different directions, indicating that the Moon is rotating as it orbits.

6. Rotate the globe until the crater approaches the “sunrise” position.

Notice that as the Moon turns, this crater is now experiencing sunrise. The shadows at this angle of sunlight look a lot like the crater on your moon images. As the crater progresses through the lunar day, the shadows get smaller and smaller and the crater becomes fully illuminated.

Remember what the temperature can get to during the lunar day? [600 °F]

Where do you think we might find ice on the Moon?

7. Demonstrate how the craters at the north pole of the Moon can remain in perpetual shadow. It’s easiest to show this if you change the orientation of rotation so the axis is horizontal and pointing towards the back of the room so all students can see the polar region.

Where do we find most of the ice on the Earth? [The polar regions.]

Ask if student have any questions...

Going Further:

In the computer lab, have students open the images: craters001020.fts and craters000314.fts

Have them compare the images and discuss why they look different. Discussion should lead to the realization that the terminator line (the line of demarcation between the night and day on the Moon) is moving as the Moon rotates and orbits Earth. You may also have them look at the Copernicus series for similar analysis:

copernicus000521.fts copernicus000725.fts
copernicus000724.fts copernicus001020.fts

(Classroom)

I-E. Moon Phases

This activity is based on phases of the Moon activities in the GEMS Teacher Guide, *Earth Moon and Stars*, and the activity in *Planetarium Activities for Student Success* (PASS) Vol. 7: *Moons of the Solar System*, from Lawrence Hall of Science.

Materials

For every student:

- HOSS Student Book (and optional Answer sheets)
- 1 polystyrene white ball about 2–3" diameter, mounted on a pencil

For the class:

- 1 clamp-on light (100-300W bulb—for model Sun)

Preparation

It is most effective to do the Moon phase modeling after the students have observed the real Moon phases daily for a couple of weeks. This can be done either during the school day for the waning portion of the Moon cycle (Moon phase decreasing—after full Moon) or as homework with students making daily observations just after sunset for the waxing portion (Moon phase increasing—after new Moon.)

- To do observations of the *real* Moon, it's best to start one of two ways
 - a. For observations during the school day, start a day or two after full Moon.

- b. For observations as homework, just after sunset, start two or three days after new Moon.

Find out when full Moon or new Moon is from a calendar, the weather page in the newspaper, or from Virtual Reality Moon Phase web page at <http://tycho.usno.navy.mil/vphase.html>

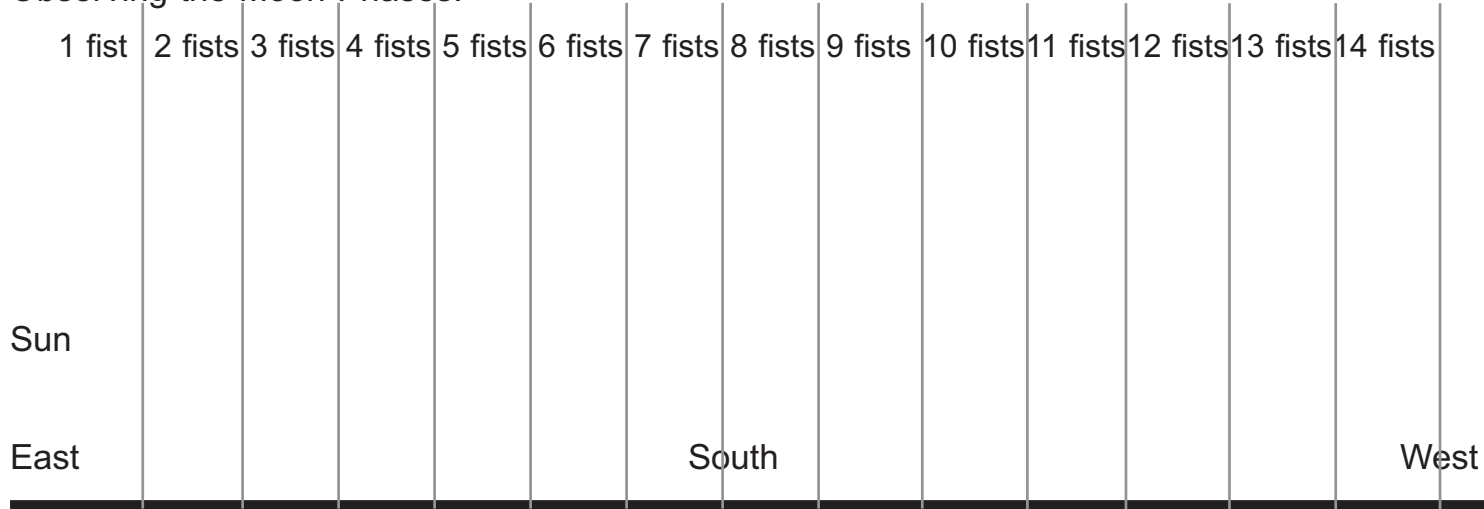
- Set up the clamp-on light near the front of the room.
- Set up the overhead projector with moon crater transparency.
- Get classroom as dark as possible.

In Class

1. **Assign students to observe and record** the real phases of the Moon over a period of a couple of weeks. They can record their observations in their HOSS Books (or an Answer sheet). Each day (either in the morning before class or in the evening after sunset) students go outside, measure how far the Moon is from the Sun in fists, and draw the shape of the Moon in the appropriate column on their Moon Phase Observations chart.
2. **Take the students outdoors** to practice measuring angles in the sky in fists. To measure in fists, you hold your fist out at full arm's length, place the bottom of your fist at the "starting place" and notice where the top of your fist is. Then move your fist one "fist-length" so that the bottom of your fist in its new position is where the top of the fist was in the first position. Continue moving fist-length by fist-length, counting as you go, until you reach the "stopping place." For practice, have students measure how many fists it

Hands-On Solar System Teacher's Guide

Observing the Moon Phases.



Going Further

Engage the students in Moon phase discussions in the computer lab, using the images `waning_gibbous.fts` and/or `moonphase.fts`. Compare `waning_gibbous.fts` to `craters000314.fts`.

takes to go from the horizon to the zenith, the point straight overhead, for a measure of a 90° angle.

- 3. After a couple of weeks** of Moon observations, ask the class to look at their records and ask

Why does the Moon seem to change its shape from day to day? [consider any explanations as possibilities]

- 4. Model phases.** Tell the class they will now make a model to help answer that question. Hand out a Moon ball to each student and turn on a bright light at the center of the room to represent the Sun. Each student's head is the Earth, and each student holds their own white polystyrene ball as a Moon model. By moving the ball in orbit around Earth (student's head), students clearly see the progression of Moon phases from an excellent egocentric viewpoint.

- 5. Dark side of the Moon.** Recall that the Moon's rotation rate (the time it takes to spin once on its axis) equals its period of revolution around the Earth (the time it

takes to orbit Earth). Because of this fact, the Moon always keeps the same face pointing towards the Earth. It wasn't until humans sent spacecraft in orbit around the Moon that we ever saw the "back-side" of the Moon. Note that the "back-side" of the Moon is **not** the "dark side of the Moon" (except during full Moon). There is day and night on the Moon the same as on Earth, except the length of day-night cycle on the Moon is about a month long. How many Earth days is that?

6. Have the students use their Sun-Earth-Moon model to explain the difference between the phrases "dark side of the Moon" and the "back-side or far side of the Moon." Also, ask

During what Moon phase could there be a solar eclipse, when the Moon blocks the Sun?

During what Moon phase could there be a lunar eclipse, when the Moon goes into Earth's shadow?

Have them answer these questions in their *HOSS Books* (or Answer sheets).

II. Comets

(Computer Lab)

II-A. False Color Comet

This activity is adapted from “Going to a Comet: Bright and Dark pixels” in the Tour of the Solar System module developed by TERC.

Materials

For every student:

HOSS Student Book (and optional Answer sheets)

Images needed:

halebopp_april97.fts

Preparation

Reserve Computer Lab; make sure students have their HOSS Student Books

In Class

1. Comet Hale-Bopp—Sketch and describe the comet.

Tell the students,

In March 1997, the comet Hale-Bopp made a fantastic appearance in the night sky. They will examine the comet closely by opening the image named halebopp_april97.fts.

Have the students open halebopp.fts or halebopp_april97.fts, make a sketch of the comet and write an accompanying description in their HOSS Books.



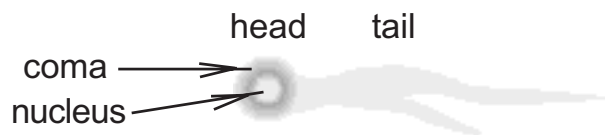
Photo of Comet Hale-Bopp by Vivian Hoette, Eden Canyon Road, East of San Francisco, February 28, 1997, 5:00 a.m

2. Class discussion of comet features. Ask the students,

How would you describe the structure of a comet?

In the ensuing discussion, give them the following terms:

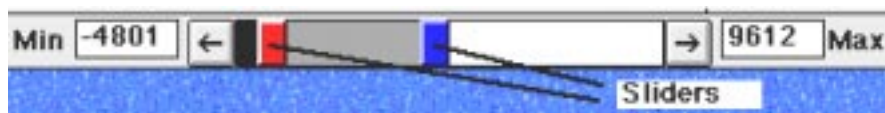
A comet has a bright core called a *nucleus* surrounded by a diffuse but bright *coma*. The nucleus and coma combined are often referred to as the *head* of the comet. The *tail* of the comet is that part that spreads out gradually from the head. Have the students label in their drawings the parts of the comet: nucleus, coma, head, tail.



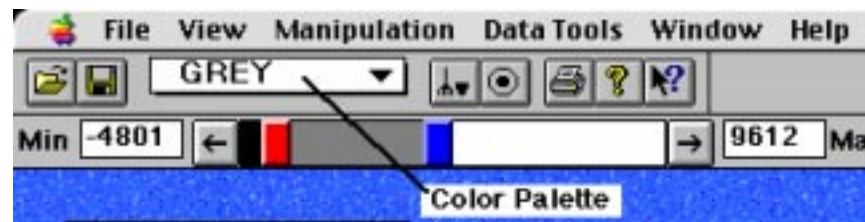
Now let the students proceed through steps 3-8 in their Student Books and record their results.

3. The Brightest Pixel. Find the brightest pixel in the nucleus of the comet. Record the (x,y) coordinates and the brightness Counts of that pixel in their Notebooks. In halebopp.fts, (x,y) coordinates and Counts of a bright pixel in the nucleus of the comet occur at around (104,424) with brightness Counts at that pixel over 5000. Other pixels in the area would qualify also. In halebopp_apr97.fts, pixel (324, 236) has brightness Count of 1021 with others almost as bright nearby.

4. The End of the Comet's Tail. Find the pixel that is at the "very end" of the comet's tail and write its coordinates and brightness counts. This is more subtle than it may seem at first, since the length of the comet's tail depends critically on the Min-Max display settings. For that reason, it's difficult to assert any single "right" answer so accept any reasonable answer..



5. Color the Comet: Change Palettes. Let the students select a different palette from the palette menu that makes the comet appear interesting.



6. Did the Brightness Counts Change? Find the pixels with same (x,y) coordinates of the brightest part of the nucleus and "very end" of the tail of the comet.

Did the brightness Counts change?

[Brightness Counts do not change when the color palette is switched.]

What color are these pixels now?

Is there any relationship between the colors and the brightness of the comet in the colored image?

7. Adjust Display Brightness and Contrast: the Min-Max Tool. Slide the red and blue boxes on the Min/Max bar to bring out more detail in the image. Students should notice that when they raise the min, more pixels are colored black (or the lowest color on the palette) and when they lower the max, more pixels are colored white (or the highest color on the palette). The question, "Is there and relationship between the colors and the brightness of the comet in the colored image" is open ended. Students may note that the colors are used to represent the different brightness...but also, when they change the color palette, the brightness doesn't change.

8. Personal experience. Some students may have seen Hale-Bopp since it was often visible to the naked eye. Ask students who saw it to describe what they saw.

10. About False Color. False color imaging is becoming a widely spread means of communication; e.g., weather maps. By creating their own color image of the comet, students see that the representation of the data is under their own control and many students can start with the same data but come out with very different pictures.

Light and Temperature. Comets cannot be detected when they are far away. At great distances from the Sun, a comet is just a body of solid material, frozen ices and rock of various sorts. As the comet gets closer to the Sun, the ices vaporize (sublimate) and form the coma and tail of the comet. As it gets still closer to the Sun it becomes hotter and radiates light and becomes visible.

Going Further

Open one of the comet images and open the “Color Palette Bar” in the “Views” menu. A palette window will pop up, showing a chart of the relationship between either (a) shade of grey and pixel brightness or (b) color and pixel brightness, depending on what palette is selected in the Palette Menu. Hint: sometimes it helps to look for the brightest and dimmest pixels in the image and then set the Min-Max values to those maximum values by typing the Counts of the brightest pixel in the Max box and the Counts of the dimmest pixel in the Min box.

(Classroom)

II-B. Comet Set

This activity is based on Vivian Hoette’s Comet Flipbook activity in the HOU Explorations web pages -- http://hou.lbl.gov/~vhoette/Explorations/Comets/comet_flipbook.html.

Materials

For every student:

- HOSS Student Book (and optional Answer sheets)

Preparation

Have HOSS Student Book (and optional Answer sheets) ready.

In Class

1. Spinning Earth. Ask the students,

Do you think Earth is a spinning planet? [Yes.]

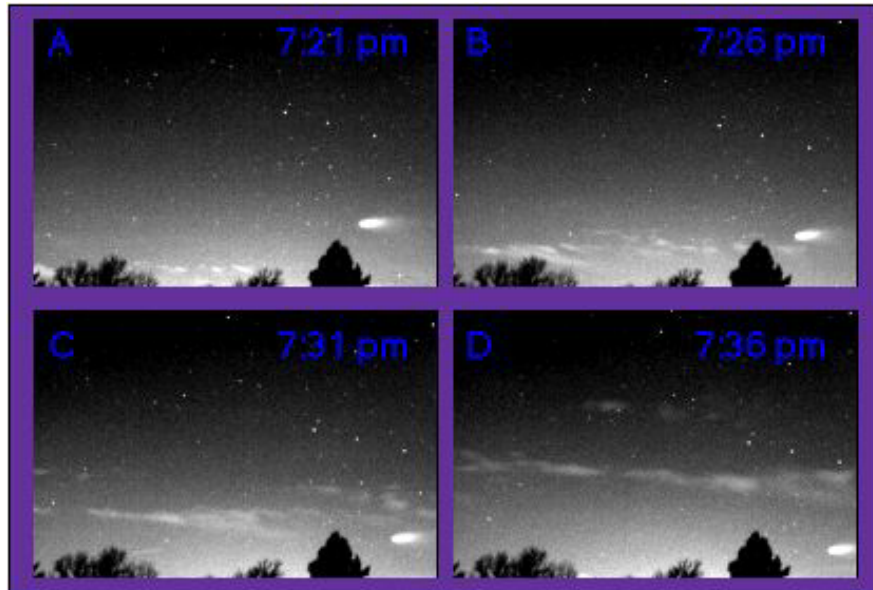
Do you feel the spin of Earth? [No.]

Does the spin of the Earth affect how we see the sky from Earth? How? [Yes. When we watch the sky, it looks like objects in the sky change position —towards the west.]

Sunset...July, 1990, from Lawrence Hall of Science. Photo by Vivian Hoette.



2. Rising and setting. Ask the students to think about how our Sun appears to rise and set. Have them look at the setting Sun photo in their Hands-On Solar System Student Books. We are all familiar with spectacular sunsets. Like the Sun, Comet Hale-Bopp also disappeared below the horizon.



Comet Hale-Bopp also appears to move as Earth spins. Notice the comet's changing position relative to the horizon. Yerkes Observatory, Wisconsin. March 10, 1997

3. Have students answer the questions on page 25 of their HOSS Books.

- a. Compare the position of the comet to the tree as the minutes pass. Describe it's motion. [North and down.]
- b. Does the the comet seem to be moving with respect to the background stars? [No.]
- c. What surprises you?
- d. Explain in your own words why the comet appears to move as it does in these images.

Going Further

On the web page: http://hou.lbl.gov/explorations/~vhoette/Comets/comet_flipbook.html, students construct a Comet Set Flip Book:

* Print and cut out the following pictures of Comet Hale-Bopp:

- halebopp118.fts halebopp122.fts halebopp126.fts
- halebopp130.fts halebopp134.fts halebopp138.fts
- halebopp142.fts halebopp146.fts

- * Paste each one onto a note card.
- * Stack the cards in order of time. Then slightly stagger the stack.
- * Paste, tape, or staple the cards together to make a flip book!

All these images are in the *hb-flipbbook* folder in the *Comet Images* for this unit.

(Classroom)

II-C. Comet Motion

This activity is adapted from Vivian Hoette's activity, Comet Hale-Bopp Monday to Friday which can be found on the HOU Explorations web pages at http://hou.lbl.gov/~vhoette/Explorations/Comets/comet_4days.html

Materials

For every student:

HOSS Student Book (and optional Answer sheets)

Images for Going Further in the Computer Lab:

linears4_7240355.fts linears4_7240403.fts

as well as the images in the *linear4_7july* folder

Preparation

Make sure students have *HOSS Student Books*.

In Class

1. Review how things in the sky appear to move because of the spinning of the Earth. Ask,

Since we saw how a comet can appear to move just because the Earth is spinning, how could we tell if the comet is really moving at all? (Compare the comet's position in the sky with the positions of other objects in the sky that do not move—stars)

2. Ask, *What is difference between a comet and a meteor? (A meteor is a streak of light that flashes through the sky, caused by vaporization of a meteoroid, a chunk of space rock, as it enters Earth's atmosphere. A comet is a glowing cloud of gas surrounding a body that is composed of ices and rock.)*

3. Have the students read the Comet Motion section of their HOSS Books and record observations and answers to questions in their HOSS Books.

Monday, Feb. 24, 1997 5 a.m. Friday, Feb. 28, 1997 5 a.m.



Students sketch and label the motion of Comet Hale-Bopp.

4. Ask, *Which appears to move faster across the sky, a comet or a meteor?*

Going Further

You may replace the classroom work with a computer lab session, using the images linears4_7240355.fts linears4_7240403.fts instead of the ones shown in on this page and in the Student Book. There are also images in the *linear4_7july* folder which you may use the more advanced function *Add* (under the *Manipulation* menu) for adding together comet images to create a montage that shows the motion over several days.

(Classroom)

II-D. Comet Orbits

This activity is adapted from the LHS GEMS Teacher Guide, *The Real Reasons for Seasons--Sun-Earth Connections*, Activity 4: What Shape is Earth's Orbit?.

Materials

For every of student:

- HOSS Student book; optional Answer sheets.

For every pair of students:

- a 25 cm piece string or twine—not stretchy
- 1 pencil (optional 4 colors of pencils)
- 2 paper fasteners

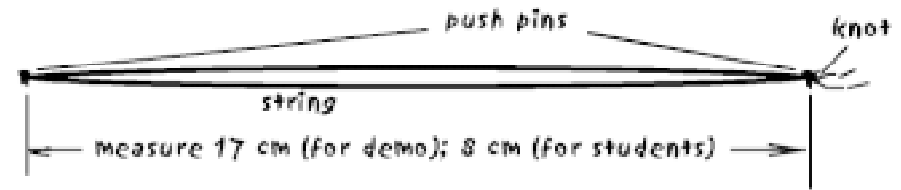
For the class:

- 1 hula hoop, large embroidery hoop, or large circle drawing on heavy paper or cardboard.
- a 40 cm piece string or twine—not stretchy
- large piece of paper—at least 11" x 17"

Preparation

1. For each student, make a 25 cm piece of string into a loop by tying the ends together so that the loop measures about 11 cm long when stretched flat. An easy way to do this is to stick two paper fasteners in a thick piece of cardboard, 11 cm apart, and tie the string around the paper fasteners. Test to make sure the knot won't slip. Make one extra loop out of a 40 cm piece of string or twine. Once you have made a set of string loops, they may be used over and over again for many classes. If you would rather have students tie the loops at the beginning of the

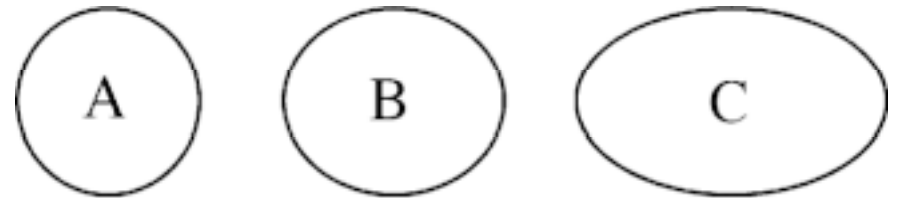
activity, you'll need to provide rulers for them to measure the loops.



2. Optional: draw, on a blank transparency, orbits with ellipse foci separations given in step 7 of this activity. Use different pen colors and label the orbits "comet," "asteroid," "Pluto" and "Earth."

In Class

1. **Orbit shapes.** Tell the class that in this session, they will learn about the shape of the orbits of things going around the Sun. Draw on the board three orbit shapes and label them as shown below:



2. **Poll the students,**

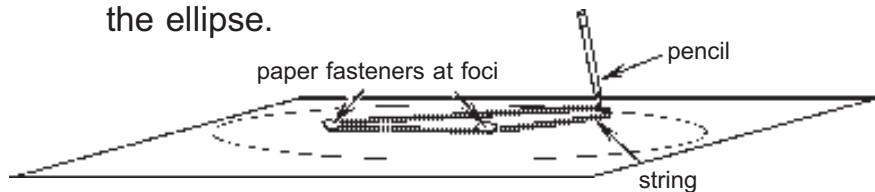
Which drawing most correctly shows the shape of the Earth's orbit around the Sun: A, B, or C? (If they have heard that it is an ellipse or oval, it is likely they will choose B or C.)

Which drawing most correctly shows the shape of a comet's orbit around the Sun: A, B, or C?

3. Explain that an **ellipse** is an oval shape, but a very precise and symmetrical oval. Tell the class they will draw some ellipses representing real orbits of a comet, Earth, an asteroid, and Pluto, all of which revolve around the Sun in the solar system. The goal is to find out the shape of each orbit. Tell the students that you will demonstrate how to draw an ellipse by drawing the orbit of a comet.

4. Demonstrate how to draw an ellipse as follows:

- Ask for a volunteer to help hold the paper up against the board for display.
- Make two marks 12 cm apart on a large piece of paper.
- Stick a paper fastener through each mark.
- Drape the string loop you made from a 40cm piece of string over the paper fasteners.
- Pull the string taut with the tip of a pencil.
- Draw the ellipse, keeping the string taut at all times. Emphasize while you are drawing the importance of keeping the string taut as you draw the ellipse as well as having two people work together to make sure the push pins stay firmly in place while making the ellipse.



5. Focus/foci. Explain that each point where a push pin goes in is called a **focus** of the ellipse. Mention that the plural of focus is foci (FOE- sigh). Point out that the comet orbit that you drew is fairly “skinny, or elongated, not circular. Explain also that in the orbits of planets (as well as comets or asteroids) the Sun remains fixed at only one of the foci of the ellipse.

6. Drawings not to scale. Explain that they will each draw the shapes of orbits of a comet, Earth, and Pluto around the Sun. Emphasize that the drawings are not to scale—that Pluto’s orbit is actually almost 40 times the diameter of Earth’s orbit, but for now we only want to compare the *shapes* of the orbits. They will work with a partner, and take turns; one will help keep the paper steady and flat while the other is drawing. Each pair of students will get a string loop, and two paper fasteners.

7. Write the following separations of ellipse foci on the board:

comet: 10 cm. Pluto 5 cm.

Earth: 0.4 cm. asteroid: 7 cm.

Distribute materials to each pair and have them begin. *Optional:* Ask those who finish quickly to draw additional orbits on scratch paper with foci separations of 2, 3, 4, or 6 centimeters.

8. Ask,

Is Earth’s orbit really larger than Pluto’s? [No, it’s actually much smaller.]

Remind them that we are concentrating here only on the shapes of the orbits.

Optional: Put the transparency of orbits on the overhead projector.

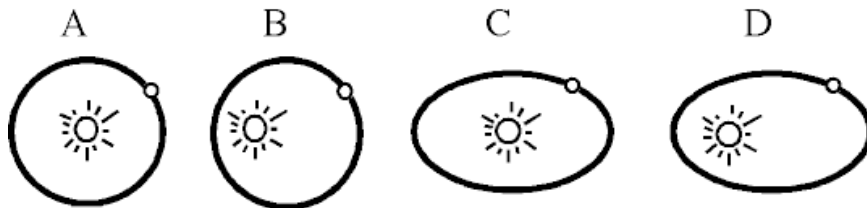
Ask,

Which orbit is more circular, that of a comet or Earth's? [Earth's]

Explain that, while it is true that Earth's orbit is slightly elliptical, it is very nearly a circular ellipse. Pluto has the least circular orbit of all the planets, and it still looks pretty circular. Comets have orbits that are more skinny ellipses than the orbits of planets.

9. On the board, make four orbit drawings shown below and ask,

Which of the four drawings do you think best shows the shape of Earth's orbit around the Sun?



[We've just found that the Earth's orbit is very close to a circle.]

Tell students that even though they may see Earth's orbit shown as an ellipse in books, those drawings represent a

tilted view of Earth's orbit. Demonstrate by holding up a hoola hoop, large embroidery hoop, or large circle drawn on heavy paper or cardboard. Hold the circle at different angles so that the student see that it only looks circular when you look at it from directly "above" the orbit.

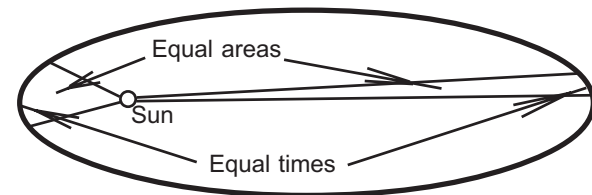
10. Ask,

Which orbit is more circular, that of a Pluto or Earth's? [Earth's]

Optional: Explain about Kepler's Laws

Law I: Each planet revolves around the Sun in an elliptical path, with the Sun occupying one of the foci of the ellipse.

Law II: The straight line joining the Sun and a planet sweeps out equal areas in equal intervals of time.



Law III: The squares of the planets' orbital periods are proportional to the cubes of the semimajor axes of their orbits (or approximately cube of the diameter or radius for a nearly circular orbit).

III. Asteroids

This activity is adapted from

- the TERC activity, *Searching for an Asteroid: Combining Tools*, in the *Tour of the Solar System* (on the HOU website <http://hou.lbl.gov/ms/>)
- Vivian Hoette's activity, *Finding Asteroids!* on the Explorations pages of the HOU website <http://hou.lbl.gov/~vhoette/Explorations/Asteroids/>

Materials

For every student:

HOSS Student Book (and optional Answer sheets)

Images needed:

sappho_a508.fts; sappho_a533.fts; hildrun1.fts; hildrun2.fts; ryokan1.fts; ryokan2.fts; iris1.fts; iris2.fts

Preparation

Reserve Computer Lab; make sure students have their Hands-On Solar System Student Notebooks and Guide Books

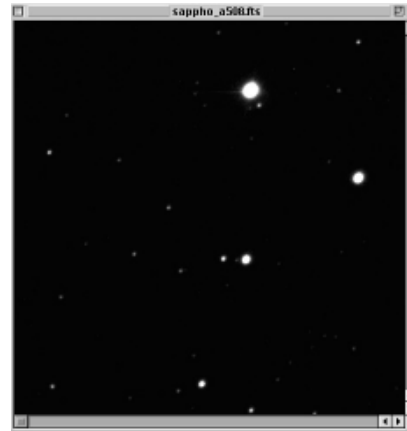
In Class (Computer Lab)

1. Ask the class,

What's the difference between an asteroid and a comet? (They may not know, but accept any ideas they have. You will repeat this question later, when they have more information.)

2. Have the student read the Asteroid section of their HOSS Books and record any observations and answers

to questions. Help any students as needed, e.g. with how to use the image processing tool, *slice*, or the process of *subtraction*. You may need to explain how these work, in addition to students reading about them in their books. After subtraction, one asteroid position is white and the other black, since the process subtracts the brightness Counts of each pixel in one image from each corresponding pixel in the other image.



Approximate answers:

Coordinates of Sappho:

(392,291) in Sappho_a508; (413,300) in Sappho_a533

Coordinates of Hildrun:

(126, 126) in Hildrun1; (120,130) in Hildrun2.

Coordinates of Ryokan:

(160, 150) in Ryokan1; (153,157) in Ryokan2.

Coordinates of Iris:

(226, 145) in Iris1; (191,176) in Iris2.

Optional: Explain the Log tool—when and why to use it. Sometimes it can bring out features in an image that are hidden.

IV. Planets

(Computer Lab)

IV-A. Jupiter and Its Moons

This activity is adapted from

- the TERC activity, *Heading off to Jupiter: Adjusting Min/Max*, in the *Tour Through the Solar System* (on the HOU website <http://hou.lbl.gov/ms/>)
- Vivian Hoette's activity, *Jupiter's Orbiting Moons* on the Explorations pages of the HOU website (or HOU CD-ROM) at <http://hou.lbl.gov/~vhoette/Explorations/> under Planets

Materials

For every student:

HOSS Student Book (and optional Answer sheets)

Optional--for the class

A ball tied on a string.

Images needed:

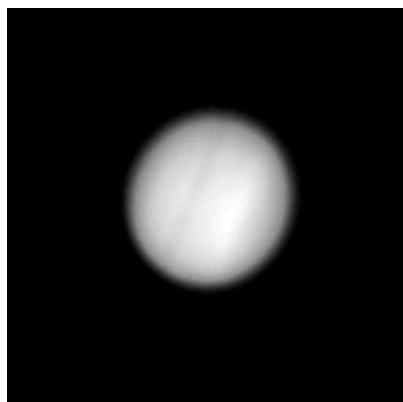
jupiter.fts

Jupiter221.fts

jup107.fts

JUP_JULY24_97.FTS

JUP_JULY25_97.FTS



Preparation

Reserve Computer Lab; make sure students have their HOSS Student Books.

In Class (Computer Lab)

1. Jupiter through a telescope--finding Jupiter's Bands and moons. Explain that Galileo Galilei, using a simple telescope he made in the 17th century, was the first person known to have looked at Jupiter through a telescope. The most prominent features you can see are

- a. Bands stretching across the planet--huge climate zones similar to smaller ones that we have here on Earth and
- b. Four large moons orbiting Jupiter.

Jupiter's four largest moons are called the Galilean Moons, named after Galileo who discovered them. Galileo observed the moons undergoing *periodic motion*, and was able to deduce the period (how long it took to orbit once) for each of the moons. Galileo's discovery of moons orbiting Jupiter caused a huge stir, since up until that time, most people believed that everything orbited around Earth, with Earth as the center of the Universe. Moons orbiting Jupiter supported the idea that Earth is *not* the center of the universe and that planets are orbiting the Sun. It was a hard sell. The Inquisition forced Galileo to recant his theory that the Sun is the center of the Universe. As he left however, he is supposed to have muttered: "But it's true."

Answers:

The (x,y) coordinates of each moon in jupiter.fts from the lower left corner to the upper right are approximately:

- First moon (lower left one): (195, 122)
- Second moon: (232 , 220)
- Third moon: (308, 353)
- Fourth moon: (342, 497)

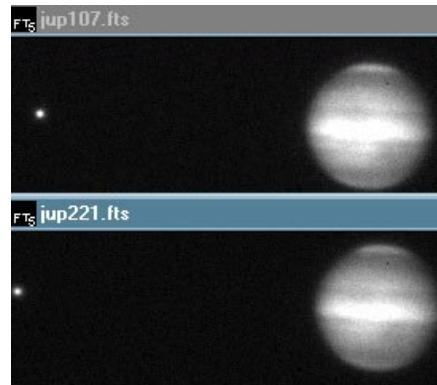
2. Determining the radius of Ganymede's orbit. Have students read their HOSS Books and go through the "Jupiter and Its Moons" section, recording observations and answering questions. They will need to open JUP_JULY24_97.FTS and JUP_JULY25_97.FTS in the Image Processing software. In the July 24, 1997 image, all four moons are visible. From left to right they are Ganymede, Io, Europa, and Callisto. Io is near the furthest edge of its orbit from our vantage point. You may need to explain a bit if they have questions about determining the radius of Ganymede's orbit in Jupiter diameters. The idea is that we are using the planet diameter as a "yardstick" for measuring orbit radius.

Answer: About 5 Jupiter diameters.

In the image JUP_JULY25_97.FTS, the other two moons are either in front of Jupiter, in what is known as *transit*, or behind Jupiter, eclipsed.

3. Determining the radius of Io's Orbit. In step 3, students open the image of Jupiter from September 26, 1996 and determine the radius of the orbit of Jupiter's moon, Io, in Jupiter diameters.

Answer: 2.5 Jupiter diameters. These measurements are valid only when the moon reaches an extreme lateral position in its orbit.



4. More about moons.

Jupiter's moons show that our Moon is not unique as was believed before they were discovered by Galileo. Here Jupiter provides the gravitational force to accelerate the moon in a rotational motion around the planet.

The origin of these moons, and of our Moon, is still being debated. Are moons formed at the same time as the planet from the same initial disk of dust or are moons formed when another large object crashes into the planet?

Orbital Motion: The period is the time it takes a moon to go once around the central body. The period of a moon's orbit depends upon its distance away and the Mass of the central body. Io, the closest of the four Galilean moons of Jupiter, completes one orbit around Jupiter in 1 day and 18 hours. Callisto, the furthest away of the four Galilean moons, completes one orbit in 16 days and 17 hours. By comparison, our Moon takes 27 days to orbit the Earth and it is about 30 Earth diameters away from Earth. Optional: You can demonstrate the effect of a central force to create circular motion by using a ball (or rubber stopper) tied to the end of a string. Swing the object in a horizontal circle, keeping your hand fixed in the center of the circle. In this example the tension in the string is providing the central force to keep the ball in circular motion. If the string broke, the ball would fly off in the direction of its motion at the time of breakage. Similarly, if gravity were suddenly "turned off" from the Sun, the planets would fly out in the

direction of their motion at that instant (neglecting other forces such as the mutual gravity between planets).

Going further

1. Check in monthly magazines, such as *Astronomy* or *Sky and Telescope* for charts showing the orbits of Jupiter's moons all plotted on the same axis.

2. Try Vivian Hoette's Explorations activity *Jupiter's Bright Moons*. Students identify the four Galilean moons based on measurements of their brightness.

See <http://hou.lbl.gov/~vhoette/Explorations/> under Planets

(Computer Lab)

IV-B. Jupiter Rotates

This activity is adapted from Vivian Hoette's activity, *Jupiter Rotation* on the Explorations pages of the HOU CD-ROM or website <http://hou.lbl.gov/~vhoette/Explorations/> under Planets.

Materials

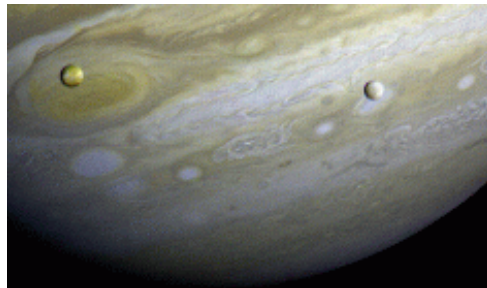
For every student:

HOSS Student Book (and optional Answer sheets)

Images needed:

jup_rotates341.fts jup_rotates408.fts
jup_rotates411.fts

Jupiter with moons Io (left), and Europa (right). This unusual image, with two of Jupiter's Galilean moons appearing right in front of the planet, was captured by the Voyager I spacecraft in its encounter with Jupiter, March 5, 1979.



Preparation

Reserve Computer Lab; make sure students have their Hands-On Solar System Student Notebooks and Guide Books

In Class (Computer Lab)

1. Everything rotates. Explain to the class that just about everything in the universe rotates.

Ask the class,

Does Jupiter spin faster or slower than Earth? How would you go about determining the spin rate of Jupiter? (Find a surface marking and time how long it takes to return to its original position.)

2. Have the students read their HOSS Books and record observations/answer questions.

Answers to Questions:

- 47. How big does this storm seem...? $1/6$ Jupiter diameter.
- 48. Do you see evidence of rotation? Yes. Right.
- 49. How did Jupiter look an hour before the first image? Red spot more centered
- 50. How about two hours after the last image? Red spot closer to the right edge.
- 51. Will you always see the red spot? No.
- 52. Make an estimate of how long it takes Jupiter to rotate once? 10 hours.

IV-C. Planet Survey

Materials

For every student:

HOSS Student Book (and optional Answer sheets)

Images needed:

mars3leutsch.fth uranus(Leutschner940429).fth

jupiter.fts Venus_Kittpeak.fts

saturn4m_000918.fts

Preparation

Reserve Computer Lab; make sure students have their HOSS Student Books (and optional Answer sheets)

In Class (Computer Lab)

1. Review types of objects that are in the Solar System.

Explain,

In the big picture of our universe, the most nearby objects are those in our Solar System.







*What objects do we find in the Solar System?
(planets, comets, asteroids.)*

Let's see if we can find out how far away these objects are, and how big they are. Go to the HOU Middle School page at <http://hou.lbl.gov/ms/lhs> and click on the "What Is It—How Far Is It?" link.

2. Planet Survey charts. Have the students read their HOSS Books and record their observations/answer questions. Give hints as needed; e.g. tell them that the

"pop-up menus" list all the planets in the second column of the table. The goal is to put planets in order corresponding with the order number in the first column of the table and distance from the Sun.

Distances of Planets from the Sun
(click in "view" column to check your answers and to find some of the planet diameters)

#	Name	Type	Distance from Sun	View
1	Select Correct Planet	Rocky	58 million kilometers	
2	Select Correct Planet	Rocky	109 million kilometers	
3	Select Correct Planet	Rocky	150 million kilometers	
4	Select Correct Planet	Rocky	228 million kilometers	
A	Select Correct Planet	Rocky	Most are in the range of 200-700 million kilometers	
5	Select Correct Planet	Gas Giant	778 million kilometers	

Have the students fill in the Planet Survey Chart:

- the name of each planet next to the appropriate order number.
- the distance (in kilometers) of each planet from the Sun.
- the size of the planet, if available.

If necessary, give them the hint that clicking on the planet icons in the last column will show additional information about each planet.

3. Introduce the concepts of light-seconds, light-minutes, and light-hours:

How long ago were astronauts on the Moon? [over 30 years.]

How did the mission control people communicate with the astronauts on the Moon? [Radio.]

Radio wave travel at a certain speed. It's actually the speed of light. Let's pretend a person on Earth asked an astronaut on the Moon, "Quick, what 2+2?" [4]

What actually would happen is like this: "Quick, what is 2+2?" [count to 3 by snapping your fingers or counting one-thousand-one, one-thousand-two, one-thousand-three] ... then the astronaut on the Moon says "FOUR!"

What caused the delay in answer? Is the astronaut stupid? [It takes time for the radio waves to reach the Moon and for the astronaut's reply to travel back to Earth.]

It takes a little over 1.3 seconds for radio waves to get to the Moon. (Write "1.3 sec" on the board.)

How fast are radio waves traveling? [300,000 km/sec; 186,000 mi/sec].

If your students are not familiar with kilometers, take a minute to discuss what a kilometer is (1 km = 0.62 mi.) Write 300,000 km/sec beside the 1.3 sec on the board.

From these numbers, can we figure out how far away the Moon is? [About 400,000 km or 250,000 mi]

The DISTANCE that light travels in a second is called a "light-second."

We can express distances in light seconds.

What is the distance to the Moon in light-seconds? [1.3 light seconds. If necessary, back up and ask how long it took radio waves/light to get to the Moon when astronauts were trying to communicate with Earth]

Do you remember the mission that recently went to Mars? [Mars Odyssey, or whichever mission is current.]

Can you guess how long it took radio waves to travel from mission control on Earth to the spacecraft on Mars? [5 to 15 minutes, depending on where Earth and Mars were in their orbits.]

Have the students compute the number of kilometers in a light-minute and in a light-hour and record their answers in their Planet survey pages of their HOSS Books. Then have them compute the distances to all the planets in light-minutes or light-hours and record them in the Planet Survey table.

Answers:

1 light minute (LM) = 18 million km

1 light hour (LH) = 1,080 million km \approx 1 billion km

Mercury (58 M km)/(18 M km/LM) = 3.2 LM

Venus (109 M km)/(18 M km/LM) = 6 LM

Earth (150 M km)/(18 M km/LM) = 8.3 LM

Mars (228 M km)/(18 M km/LM) = 12.7 LM

Jupiter (778 M km)/(18 M km/LM) = 43.2 LM

Saturn (1,400 M km)/(18 M km/LM) = 78 LM

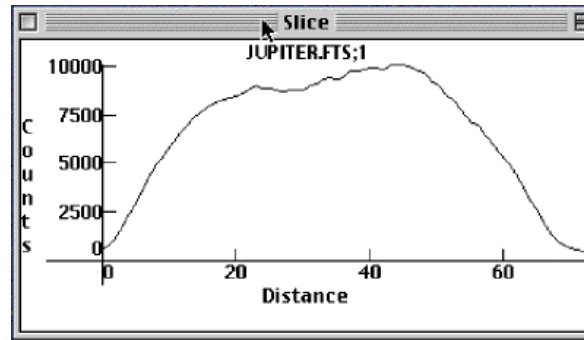
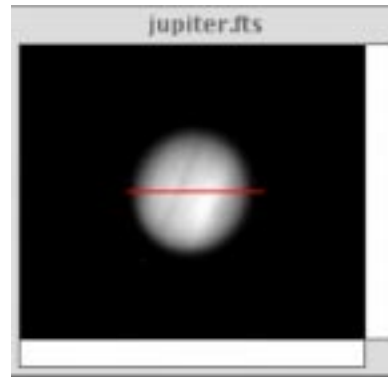
Uranus (2,900 M km)/(1080 M km/LH) = 2.7 LH

Neptune (4,500 M km)/(1080 M km/LH) = 4.17 LH

Pluto (5,900 M km)/(1080 M km/LH) = 5.46 LH

Optional: An astronomical unit (AU) is the distance from Earth to the Sun. have the students add the distances from the Sun to each planet in terms of AUs; e.g. The distance of Earth is 1 AU from the Sun.

4. Challenge the students to fill in the missing planet diameters in their Planet Survey Charts, following the guidance in their Hands-On Solar System Guide Books. One method they can use involves the slice tool that they learned to use in the Asteroid section.



(Computer Lab) In Class

IV-D. Outer Planets

This activity is adapted from Vivian Hoette's activities, *Neptune and Trion, Uranus & Its Moons: Titania, Umbriel, and Ariel*, and *Finding Pluto* on the Explorations pages of the HOU CD-ROM or website <http://hou.lbl.gov/~hoette/Explorations> under Planets: Neptune, Uranus, Pluto.

Materials

For every student:

1 each HOSS Student Book (and optional Answer sheets)

Images needed:

neptune_apo.fts uranus_apo.fts

uranus_0439.fts uranus_0539.fts

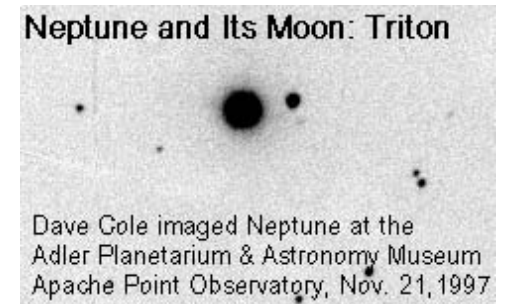
Preparation

Reserve Computer Lab; make sure students have their HOSS Student Books (and optional Answer sheets). Check planet websites to get other tidbits on the Solar System for your students:

<http://www.lhs.berkeley.edu/sii/URLs/URLs-AstroSolarSys.html>

<http://seds.lpl.arizona.edu/nineplanets/nineplanets/>

1. Neptune & Triton. Tell the students that they will be looking at telescope images of the outer planets in the Solar System, the gas giants, Neptune and Uranus. Give them a few interesting tidbits of information to spark interest.; e.g., because Pluto's orbit is a flatter oval shape than Neptune's, Pluto sometimes crosses the orbit of Neptune making Neptune the most distant planet from the Sun for a few years. This condition existed in the 1990's.



This image was taken by Dave Cole of the University of Chicago using the Apache Point Observatory telescope in New Mexico. Dave operated the telescope by remote control using the Internet from Adler Planetarium in Chicago on the evening of November 21st, 1997 (Nov. 22, 1997, 01:28 UT. UT stands for Universal Time, the time in Greenwich England, taken as a standard of timekeeping by astronomers.)

Have students read their HOSS Books and record their observations of Neptune's and Triton's (x.y) coordinates.

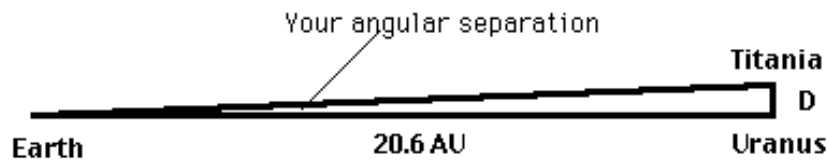
2. Uranus & Its Moons: Titania, Umbriel, and Ariel. Give tidbit(s) of information about Uranus; e.g., there's an ongoing battle over which of Uranus' poles is its north pole! That's because its axis is tilted a bit over 90 degrees from the plane of its orbit around the Sun.

Have students read their HOSS Books and record (x,y) coordinates of Uranus and each of its 4 moons.

3. Find out the distance between Uranus and Titania. How far does Titania orbit from Uranus?

Students continue reading their HOSS Books and writing answers to their questions.

Optional: In the Student Book there is a statement that the farther away Uranus is, the greater the scale factor is (km/pixel). You can add a little extra math content on this by drawing the following picture on the board and discussing why that statement in the Student Book is true.



The concept is “similar triangles.” The pixel size essentially represents a particular very small angle. This “pixel angle” is the same whether the triangle is large or small. If we were to draw a second triangle with Uranus at 21 AUs distance, it would be a slightly larger triangle, so D would be slightly larger.

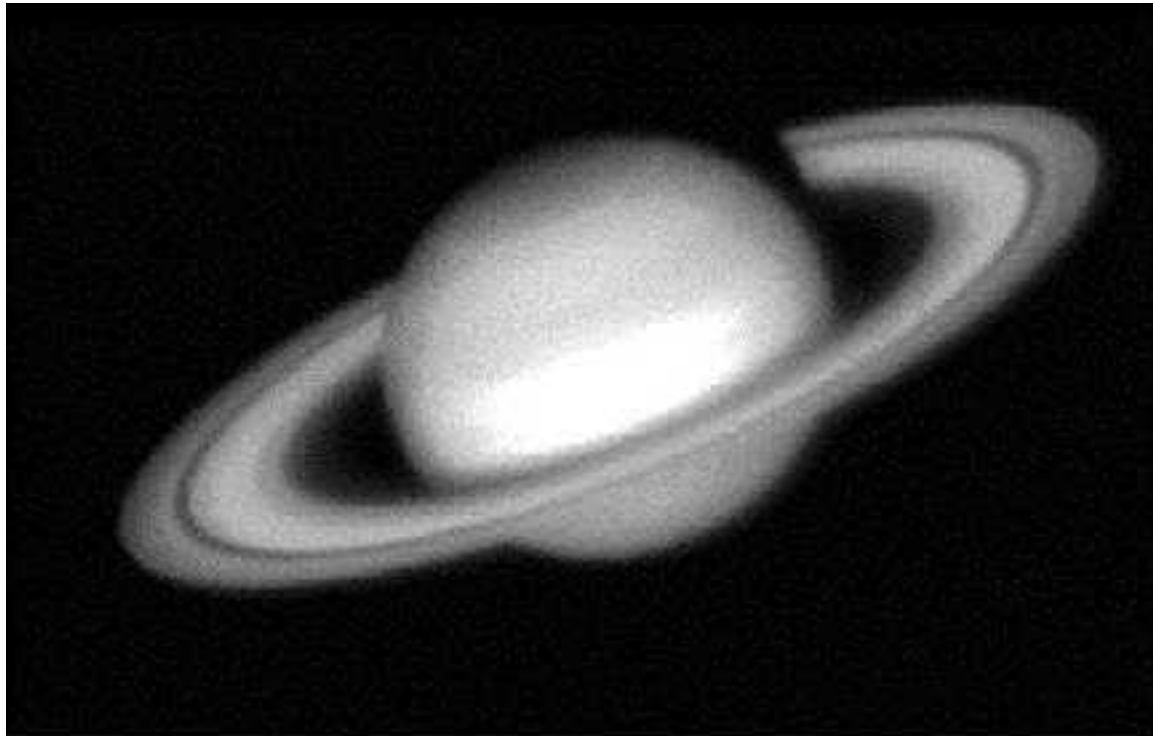
4. Challenge the students to find the distances between Uranus and Umbriel or Ariel—this can be for students who “finish early.”

5. Optional: Have student use images `uranus_0439.fts` and `uranus_0539.fts` to distinguish Uranus’s moons from background stars. The way to do this is to use the *Add* or *Subtract* function (in the *Manipulation* menu) on these two images to detect movement of the Uranian system against the background stars.

6. See Vivian Hoette’s *Finding Pluto* activity on the Explorations pages of the HOU CD-ROM or website (<http://hou.lbl.gov/~vhoette/Explorations/>)

Look under Planets: Pluto.

Hands-On Solar System Answer Sheets



I-A-2. Open an Image

Question 1. How many craters do you see in the image?

I-A-3. Zooming

Question 2. What zoom factor makes the image fill your computer screen without having to scroll to see the whole image?

Question 3. Do another zoom box in the new zoom box window. What is the zoom factor for the new zoom box window?

Question 4. Zoom box again inside the second zoom box window. What is the zoom factor?

Question 5. What do you predict the zoom factor will be after you have zoom boxed six times? Check if your prediction is correct.

Prediction

Observed Zoom

I-A-4. Pixels and Coordinates

Question 6. Describe what a pixel is.

Question 7. At what zoom factor is each pixel as big as your thumbnail?

Question 8. Choose a small crater and find how many pixels wide it is.

Question 9. What are the coordinates of the center of the largest crater?

Question 10. How many pixels wide is the crater?

I-A-5. Measure Brightness

Question 11. How bright is the brightest pixel in the image?

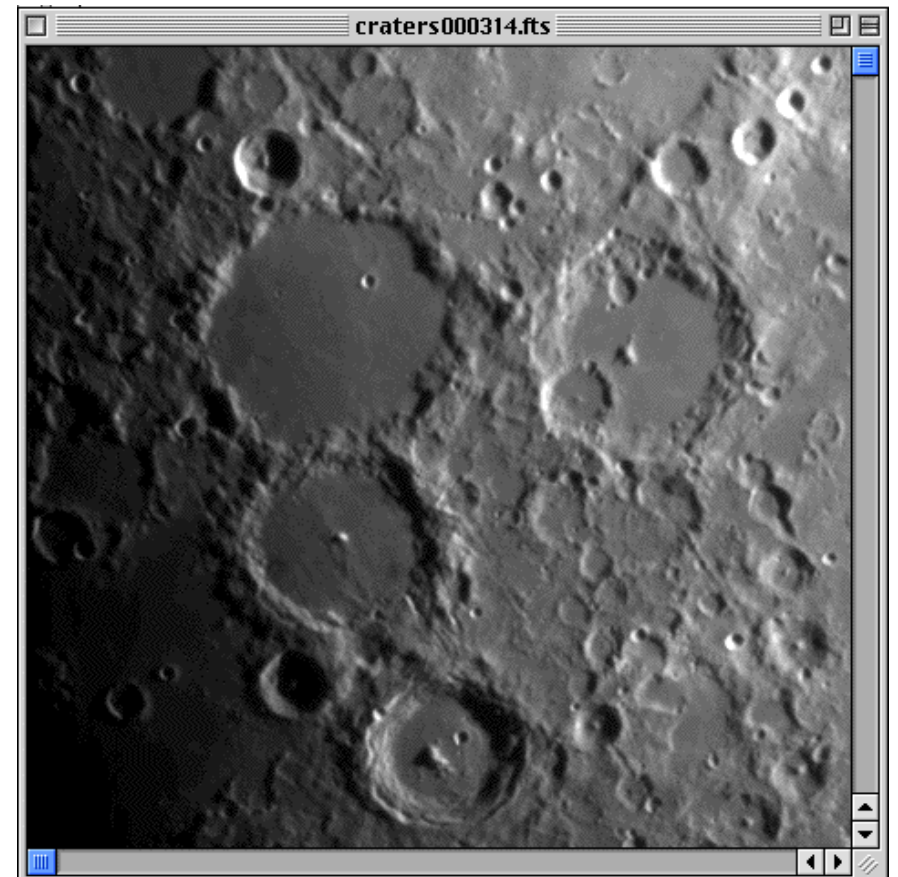
What are its coordinates?

Question 12. How bright is the darkest pixel in the image?

What are its coordinates?

I-B. The Crater Game

	x-y Coordinates of crater center		Diameter in pixels	Diameter in km*	Diameter in miles*
	X	Y			
1					
2					
3					
4					
5					
6					
Largest Crater					



2. Moon Features

a. Moon image b. Coordinates of crater center

_____.fts X= _____ Y= _____

c. Sketch



d. Feature type/Description:

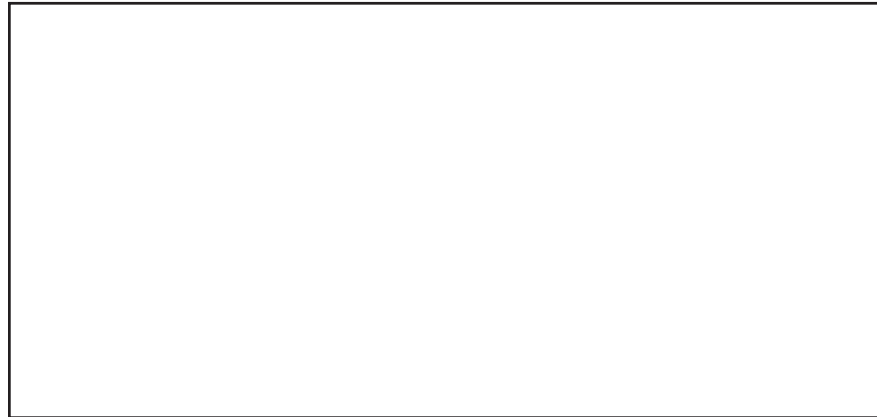
e. Diameter/dimension _____ pixels

f. Conversion Factor: _____ km/pixel g. Diameter/dimension _____ km

a. Moon image b. Coordinates of crater center

_____.fts X= _____ Y= _____

c. Sketch



d. Feature type/Description:

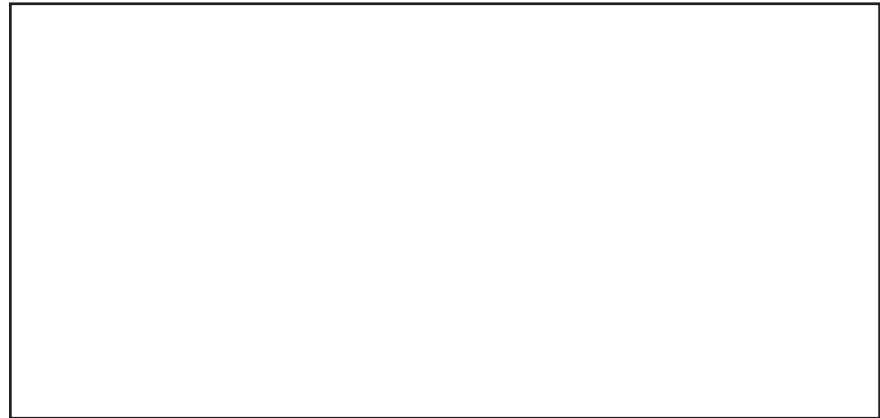
e. Diameter/dimension _____ pixels

f. Conversion Factor: _____ km/pixel g. Diameter/dimension _____ km

2. Moon Features

a. Moon image _____ .fts b. Coordinates of crater center
X= _____ Y= _____

c. Sketch



d. Feature type/Description:

e. Diameter/dimension _____ pixels

f. Conversion Factor: _____ km/pixel g. Diameter/dimension _____ km

a. Moon image _____ .fts b. Coordinates of crater center
X= _____ Y= _____

c. Sketch



d. Feature type/Description:

e. Diameter/dimension _____ pixels

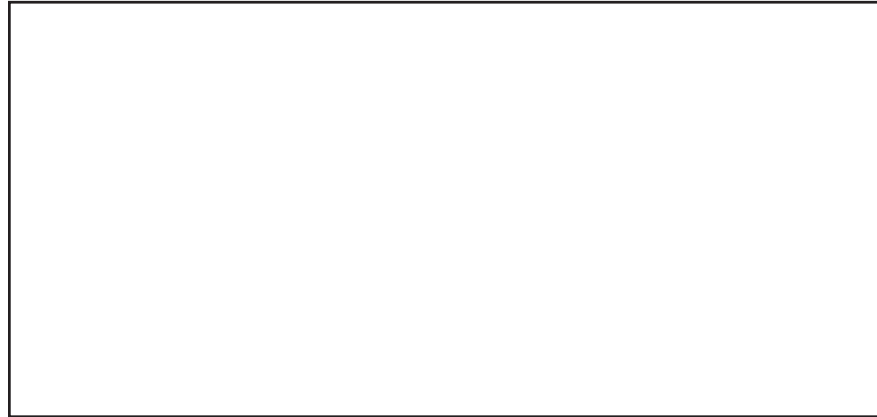
f. Conversion Factor: _____ km/pixel g. Diameter/dimension _____ km

2. Moon Features

a. Moon image b. Coordinates of crater center

_____ .fts X= _____ Y= _____

c. Sketch



d. Feature type/Description:

e. Diameter/dimension _____ pixels

f. Conversion Factor: _____ km/pixel g. Diameter/dimension _____ km

a. Moon image b. Coordinates of crater center

_____ .fts X= _____ Y= _____

c. Sketch



d. Feature type/Description:

e. Diameter/dimension _____ pixels

f. Conversion Factor: _____ km/pixel g. Diameter/dimension _____ km

I-D. Making Model Craters

Question 13. Make a sketch showing your model crater, the model Sun, and the angle that the rays of sunlight must be to make the shadows look right for the moon.fts image.



Question 14. How many Earth days equal one Moon day?



Question 15. How hot do you think it gets on the Moon during the lunar daytime?



Question 16. Where is the most likely place for us to find water ice on the Moon?



I-E. Moon Phases

Question 17. How many Earth days equal one Moon day?



Moon Phase Observations

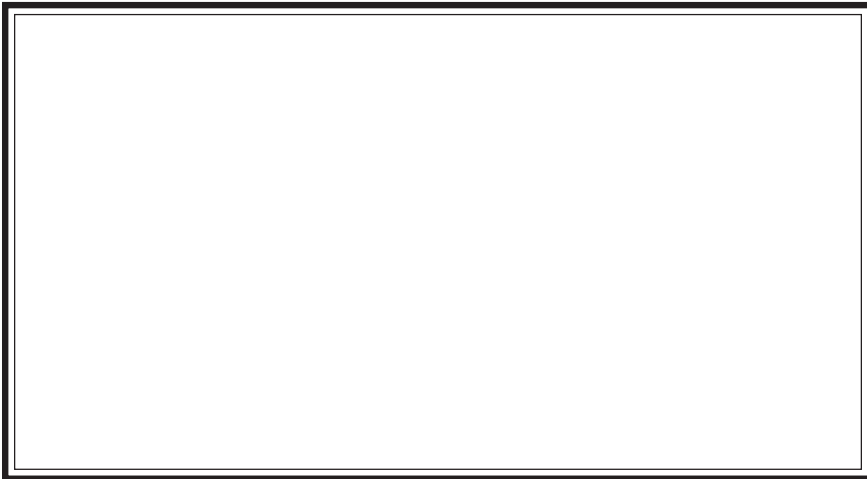
	1 fist	2 fists	3 fists	4 fists	5 fists	6 fists	7 fists	8 fists	9 fists	10 fists	11 fists	12 fists	13 fists	14 fists
Sun														

East

South

West

II-A False Color Comet



Sketch the comet (above) and describe it (below).

4. The Brightest Pixel. Record the (x,y) coordinates and the brightness Counts of that pixel:

x = _____, y = _____ Counts = _____

The End of the Comet's Tail.

x = _____, y = _____ Counts = _____

Question 21. What Color Palette makes the comet look most interesting?

Answer Box

Question 22. Do the brightness Counts change when you switch color palettes?

Yes No (circle one)

Question 23. What color is the brightest pixel in the nucleus?

--

Question 24. What color is the "end" of the comet's tail?

--

Question 24. Is there any relationship between the colors and the brightness of the comet in the colored image?

Question 25. Describe what happens when you adjust Min and Max. When I move the Min (red) slider, this is how the color of the pixels in the image change:

II-B. Comet Set

Question 26. Do you think Earth is a spinning planet?

--

Question 27. Do you feel the spin of Earth?

--

Question 28. Does the spin of the Earth affect how we see the sky from Earth? How?

Question 29. Compare the position of the comet to the tree as the minutes pass. Describe its motion.

Question 30. Does the the comet seem to be moving with respect to the background stars?

Yes No (circle one)

Question 31. What surprises you?

Question 32. Explain why the comet appears to move as it does in these images.

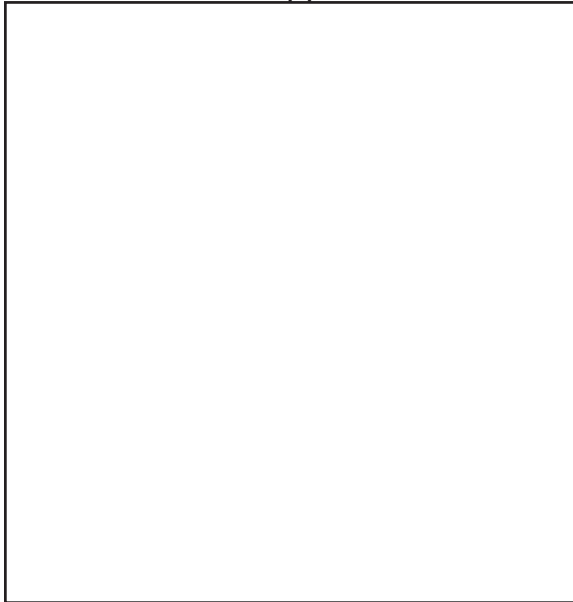
II-C. Comet Motion

Question 33. Write about Comet Hale-Bopp. What surprises you? Explain what you think is happening. What are your questions?

Question 34. Which way is the comet moving, towards the North, East, South or West?

--

In this box, sketch combine details from both images to show the motion of Comet Hale-Bopp.



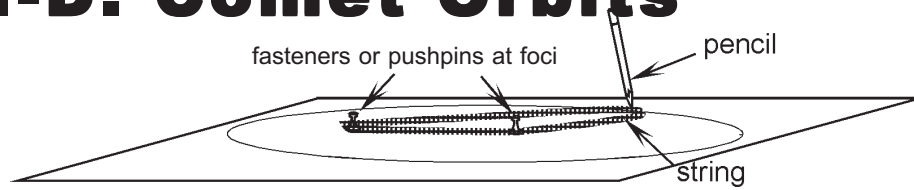
Question 35. Explain the difference between a comet and a meteor.

Question 36. How long does it take to watch a comet cross the sky? (Circle correct answer)

Seconds Minutes Hours Days Months

Answer Box

I-D. Comet Orbits



To draw an ellipse:

- With pen, mark the separation of the foci.
- Stick a fastener through each focus.
- Drape a string loop over the fasteners.
- Pull the string taut with the tip of a pen and draw the ellipse. Keep the string taut as you draw.

III. Asteroids

Question 37. What are the (x,y) coordinates of Sappho?

In sappho_a508:	X= _____	Y= _____
In sappho_a533:	X= _____	Y= _____

Can you also find the asteroid Iris in the images iris1.fts and iris2.fts?

In Iris1:	X= _____	Y= _____
In Iris2:	X= _____	Y= _____

Question 38. Which object is asteroid Hildrun? Write its coordinates:

In hildrun1:	X= _____	Y= _____
In hildrun2:	X= _____	Y= _____

Question 39. Which object is asteroid Ryokan?

Please write its coordinates:

In ryokan1:	X= _____	Y= _____
In ryokan2:	X= _____	Y= _____

Explain your reasons and methods of analysis.

IV. Planets

IV-A. Jupiter and Its Moons

Question 40. What Min-Max settings are best to see bands on Jupiter?

Question 41. What Min-Max settings are best to see moons of Jupiter?

Question 42. Sketch the image showing bands and the moons of Jupiter.

Question 43. Record the (x,y) coordinates of each moon.

(x,y) coordinates of 1st moon _____ , _____

(x,y) coordinates of 2nd moon _____ , _____

(x,y) coordinates of 3rd moon _____ , _____

(x,y) coordinates of 4th moon _____ , _____

Question 44. Where are the other two?

Question 45. What is the radius of Ganymede's orbit in Jupiter diameters?

Question 46. What is the radius of Io's orbit in Jupiter diameters?

Describe your method.

Question 48. Do you see evidence of rotation? If so, which way?

Question 49. How do you think Jupiter looked an hour before the first image (3:41)?

Question 50. How about two hours after the last image (4:11)?

IV-B. Jupiter Rotation

Question 47. How big does this storm seem compared to Jupiter itself?

(Jupiter is about 140,000 km. diameter)

Question 51. Will you always see the red spot?

Question 52. Make an estimate of how long it takes Jupiter to rotate once?

IV-D. Outer Planets

Question 54. Write down the (x,y) coordinates for Neptune and for its moon, Triton.

Neptune:	X= _____	Y= _____
Triton:	X= _____	Y= _____

Question 55. Write down the (x,y) coordinates for Uranus and each of the moons.

Uranus:	X = _____	Y = _____
Titania:	X = _____	Y = _____
Umbriel:	X = _____	Y = _____
Ariel:	X = _____	Y = _____

Question 56. What is the distance you measured in pixels?

--

If the distance between the Earth and Uranus was 20.6 AUs. (One AU = 93 million miles or 150 million kilometers.)

Question 57. How many kilometers is that?

--

Question 58. What is the distance between Uranus and Titania?

--

Work out the distances between Uranus and Umbriel or Ariel.

Umbriel _____

Ariel _____