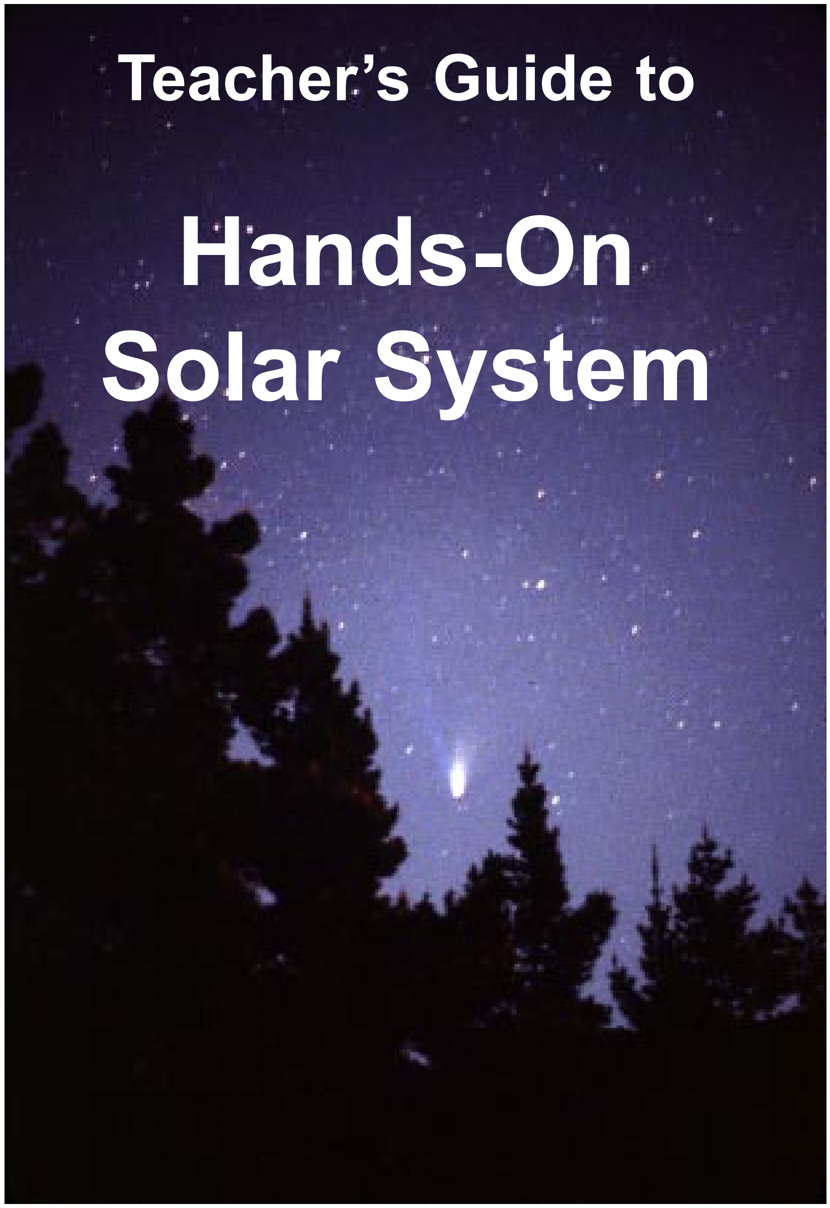
Teacher's Guide to

Hands-On Solar System



Developed at Lawrence Hall of Science,
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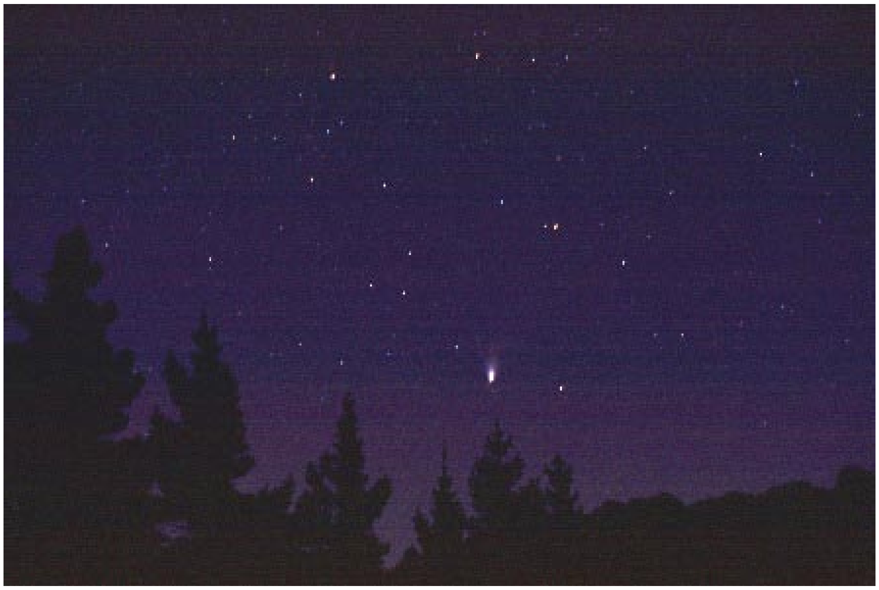
Hands-On Universe



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 and can also be used as an introduction to image processing for high school HOU courses.

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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://www.handsonuniverse.org

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TERC

Hands-On Solar System

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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.

Mercury

Earth

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.
- 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.

In Science and Technology (CONTENT STANDARD E), the following 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

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 concepts: Zoom, Pixels, Coordinates, Brightness.

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

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.

D. Comet Orbits (CLASSROOM — 30 min)

Students draw ellipses to compare the shapes of 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

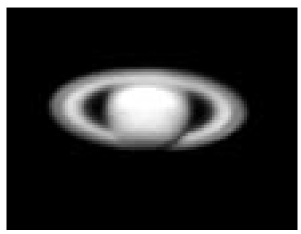
(COMPUTER LAB — 20-30 min)

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)

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. Often students get more deeply involved in an activity and the allotted time needs to be extended

Other resources that complement *Hands-On Solar System* (HOSS) to round out middle school astronomy:

- FOSS: Planetary Science unit (http://www.lawrencehallofscience.org/foss)
- LHS GEMS: The Real Reasons (http://www.lawrencehallofscience.org/gems)
- NASA's Sun-Earth Education Forum (SECEF) http://sunearth.gsfc.nasa.gov or http://sunearth.ssl.nasa.gov.
- 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.lawrencehallofscience.org/pass

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/

Background Computer Knowledge Needed

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

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

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

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 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. You may either purchase a license to photocopy the Student Books locally, or purchase them from HOU. Current version along with the Teacher Guide can be obtained from the HOU website—http://hou.lbl.gov/

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 where all HOSS images are put. Additional images for this unit may be put there as well, downloaded from the Hands-On Universe Web Site: http://lhs.berkeley.edu/hou.

   The images are 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. You may wish to make an alias of the HOU-IP application icon to place on the computers desktop.

For Macintosh Computers

For older Macintosh operating systems, through version 9, the Mac version of HOU IP will function fine. But on newer Macs with OSX, the old version will not run. You can check the HOU website for updates. European HOU (EUHOU) has developed "Salsa J" which runs on OSX. The following instructions, involving getting latest java support software from Apple (for free), have been tested with Mac OS X 10.4.6. [From the "For TEachers -> Software" area of the HOU website

http://www.handsonuniverse.org/for_teachers/software-houip.html

1. For the program to work with Mac OS X Tiger (10.4), download
   Java 2Platform: J2SE 5.0 Release 4 (PPC) at
   http://www.apple.com/support/downloads/j2se50release4ppc.html
   and install it.
2. Download the latest version of SalsaJ for Mac at:
   http://www.euhou.net/index.php?option=com_content&task=view&id=8&Itemid=10
   (SalsaJ_V1.1-Mac.tgz) 1.7 Mb
3. Un-tar and unzip (e.g. with Stuffit), and open the folder named SalsaJ.
4. To run, just double-click the file salsaj.jar inside the folder SalsaJ/

Important:

To get menu items to work, you need to click on the SalsaJ toolbar first - it's a tad bit odd, and it's easy to forget about. If you don't get used to clicking in the toolbar before accessing the menu items, you'll think the program has hung, but it hasn't. I'd say it's a bug that needs fixing. But the program is fully usable.

In this Teachers Guide, specific instructions that show how the SalsaJ Image Processing softare works are placed in boxes like the one show on this page.

For SalsaJ users

SalsaJ icon

Hands-On Solar System

Introduction: What's Out There?

(Classroom)

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.

Part I. The Moon—Our Closest Neighbor

I-A. The Image Processor

(Computer Lab)

Materials

For every 2-3 students:

- 1 computer.

  Minimum requirements: Mac with Operating System 7.1 or higher;
  PC with 486 processor. Ideally, have Mac Power PCs or Pentiums with CD-ROM drives and computers all networked together.

For every student:

- 1 HOSS Guide Book
- Optional: HOSS Answer Sheets

Image needed:

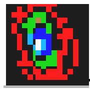
craters000314.fts

Preparation

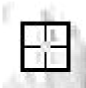
If graphing is the only context where students have used (x,y) coordinates, this both broadens and reinforces their understanding. In graphing, the origin is the place where the x and y axes cross at (0,0). This is also true on the image display.

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

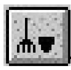
computer display in your computer lab that the whole class can easily see. A lower tech alternative is to prepare large hand-drawn charts that show the students where to find:


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

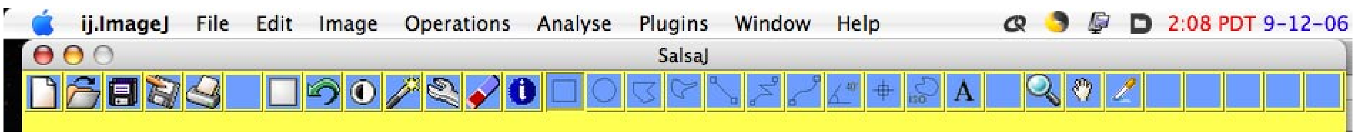

—the Open File icon (Open Moon image—step B)


— the Zoom Box cursor

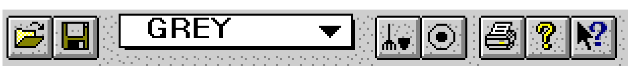
—the Zoom control. Click on "Redraw" to apply the zoom value entered.

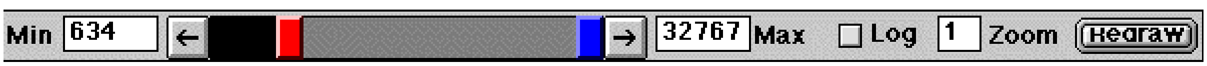

—clean up tool (to erase red zoom boxes)

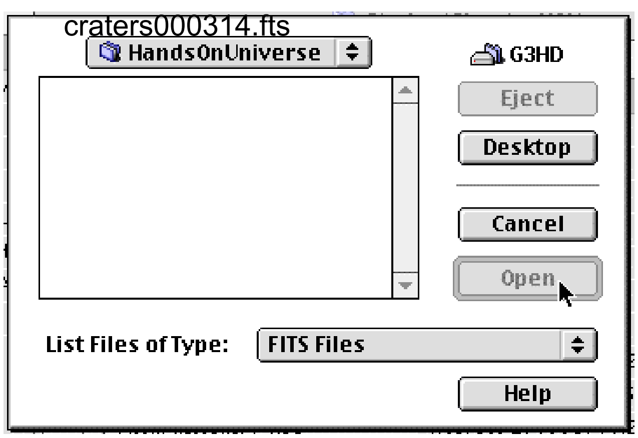
SalsaJ menu bar and toolbar



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

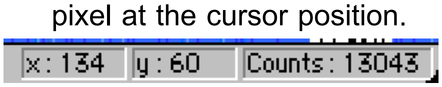






— the "Open file" dialog box and the "List Files of Type" option where they will need to select "All Files" every time they want to open a new image

— 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 *HOSS Answer Sheets. (optional)*

In Class (Computer Lab)

1. Our closest neighbor.

a. Ask, ***"What is our closest neighbor in space?"*** [Aside from things in Earth's atmosphere and satellites, it's the Moon]

b. Living on the Moon. Tell the class that there are some people who are 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.]*

c. 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.

2. 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.

3. 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” in order to open some images, especially images downloaded from the HOU archive website.

c. Explain to the students:

In some sections of the instructions, there are key questions that you should answer. ***Optional: If you are having your students write answers on HOSS Answer Sheets, caution them NOT to write in the Student Books.***

4. 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. Remind them to write down the answers to the questions on the Lunar Imagery Questions sheet.

5. 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 to 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 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 (so that you are measuring horizontal position only).

(3) Subtract x-coordinate (2) from x-coordinate (1)

6. For students who finish early. 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.

7. 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.**

Answers to questions:

Question 1. Looking at the image, what can you deduce about the objects that slammed into the Moon?

The fact that the craters are different sizes indicates the impact objects are different sizes. Larger craters have flat bottoms, indicating they may have filled up with something fluid (molten material) after the impact. Some craters are older than others, as evidenced by the fact that newer craters obliterated portions of the older craters. Also the crater walls of older craters are less well defined. The very largest craters have peaks in the centers of them, indicating that very big impact objects cause some sort of different impact process that cause central peaks.

Question 2. The word "pixel" is short for "picture element" Describe in your own words what you think that means.

[In brief, a pixel is the smallest unit of a digital image.]

Question 3. What are the coordinates of the center of the largest crater?

[x in the range of 165 to 175,]

[y in the range of 302 to 312]

Question 4. How many pixels wide is the largest crater?

[In the range of 127 to 167 pixels]

Question 5. How many pixels wide is the entire iamge? How many pixels tall?

[x (wide)=475 pixels Y (tall)=460 pixels]

Question 6. What is the maximum zoom factor possible with this software? How many "pixels" fit in the display window at that zoom factor?

[100. In SalsaJ: 3200%]

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

[Actually depends on monitor resolution. In SalsaJ, it may never get there. In HOU -IP, ***In the range from 30 to 70.]***

Question A. Do another zoom box in the new zoom box window. What is the zoom factor for the new zoom box window? *[4.]*

Question B. Zoom box again inside the second zoom box window. What is the zoom factor? *[8]*

Question C. What do you predict the zoom factor will be after you have zoom boxed six times? *[64]*

Question 8. How bright is the brightest pixel in the image?

Around pixel (413,428) there are brightnesses between 7014-7051.

Question 9. How bright is the darkest pixel in the image?

(1,111) has brightness 224.

I-B. The Crater Game

(Computer Lab)

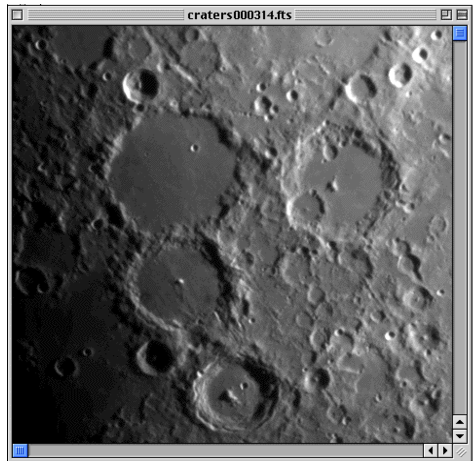
Materials

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. Teacher picks a crater and calls out the coordinates of the center of the crater.

b. Write the crater center coordinates on chart and put the crater number at the proper location in the Moon image.

c. Measure the crater diameter in pixels, write it in the chart, and raise your hand to indicate you have found the answer.

d. 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).

e. Compute crater diameters in kilometers, using the conversion factor: 1.1 km/pixel (each pixel represents 1.1 km on the Moon). Write the diameters in the chart.

Diameter (D) = (N pixels) x (1.1 km/pixel).

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

3. Algebra. Steps 2f 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 = 1.1 kilometers ...divide both sides by "pixel" to get

—> 1 = (1.1 kilometers/pixel)
This is known as a "Conversion Factor".

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

Crater Diameter D = (X pixels)(1.1 km/pixel) = 1.1X 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 (km)/X (pixels) = 1.1 km/1 pixel

or alternatively

D (km)/1.1 km = X pixels/1 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 musical note. You may have seen analog watches which have hands that move to indicate the time, as opposed to digital watches in which time is displayed as digits.

Tricks and simplifications: In actual game play, you can simplify the whole process by simply using the approximation 1.1 km/pixel ≈ 1 km/pixel. This essentially eliminates all algebra, since the number of pixels measured is then numerically equal to the diameter in kilometers. If you want to stick with 1.1, a nifty trick to perform the multiplication is to take 1/10 of the measured diameter in pixels and add that to the diameter in pixels. E.g. if the measured diameter is 20 pixels, then 1/10 of that is 2, and the diameter is 22 km.

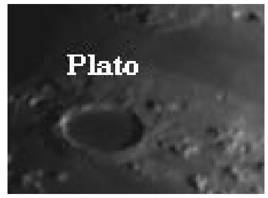
I-C. Moon Measure

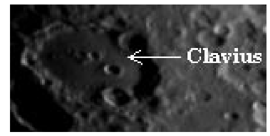
(Computer Lab)

This activity is adapted from Vivian Hoette's Moon Measure activity on the HOU Explorations pages http://hou.lbl.gov/. 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.

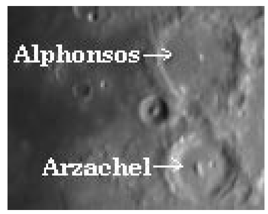
Images were taken by Dave Lane, Burke-Gaffney Observatory, in Nova Scotia, on September 21, 1996

moon1.fts:



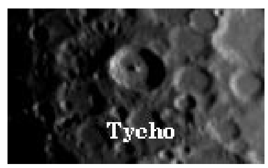


moon5.fts:



moon16.fts:

moon6.fts:



moon17.fts:

moon7.fts:

Materials

For every student:

HOSS Student Notebook; optional Answer Sheets.

Images needed:

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

Preparation

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

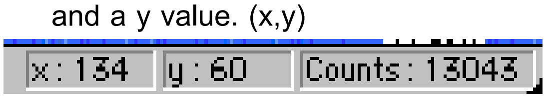
In Class

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.

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 showing the brightness of each of the pixels along the line you have drawn on the image. 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.

Point out that the axes of the slice graph are rather crude, making it difficult to determine exact distances in pixels along the x-axis and brightness along the y-axis. However, if you click and drag the cursor in the graph, numbers appearing in the bottom of the graph will display real time exact values of x-axis pixel distance and y-axis brightness.

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 or finding the difference in the x–coordinates using the cursor. [It's about 32 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 = 2.77 km/pixel ≈ 3 km/pixel—if rounding up is desired.]

4. Tell the students to follow the instructions on page 12 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.

Pixel to kilometer conversion factor in some images may be found in "Image info" in the "Data Tools" menu of the Image Processing software. The conversion factor, if there, would be towards the end to the "Image info" text.

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

a. Adding together slices along the crater rim.

b. Use the formula for circumference:
$C = 2\pi r = \pi D \quad (\pi \approx 3.14)$
Convert to miles or kilometers.

6. 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, due to curvature of the Moon. Measurement must be along the longest axis.

I-D. Making Model Craters

(Classroom)

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.

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 transparency of the craters000314.fts image (or large computer display)

Image Needed:

craters000314.fts

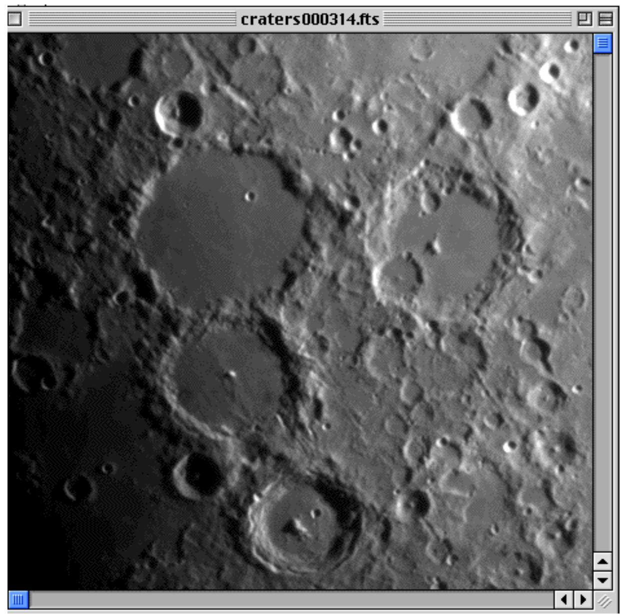
Images for Going Further:

Alabategnius-Ptolemaeus region:
craters08.28days000314.fts
craters20.57days000821.fts
craters22.28days001020.fts

Images of Copernicus:
cop16.95days010905.fts
cop17.55days000521.fts
cop20.98days001019.fts
cop22.04days000724.fts
cop22.82days010911.fts
cop23.09days000725.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 or large computer display of craters000314.fts.
- 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,

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 the moon images. Leave the overhead projector display on (craters000314.fts) for students to look at while making clay crater models.

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.

Photo of paper crater model by Alan Gould

3. Lighting. Explain,

The craters look great, but they still do not look just like the craters in the Moon image. In order to make the craters look more realistic we need a model Sun to shine on them rather than all these ceiling lights. Turn on the bright light to represent the Sun. Lift the 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 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:

craters08.28days000314.fts
craters20.57days000821.fts
craters22.28days001020.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:

cop16.95days010905.fts
cop17.55days000521.fts
cop20.98days001019.fts
cop22.04days000724.fts
cop22.82days010911.fts
cop23.09days000725.fts

Answers to questions:

Question 10. 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 image. *[Sun angle should be pretty low.]*

Question 11. How many Earth days equal one Moon day? *[29.5 days]*

Question 12. How hot do you think it gets on the Moon during the lunar daytime? *[250°F; 120°C.]*

Question 13. Where is the most likely place for us to find water ice on the Moon? *[In shady area near the north or south poles.]*

I-E. Moon Phases

(Classroom)

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

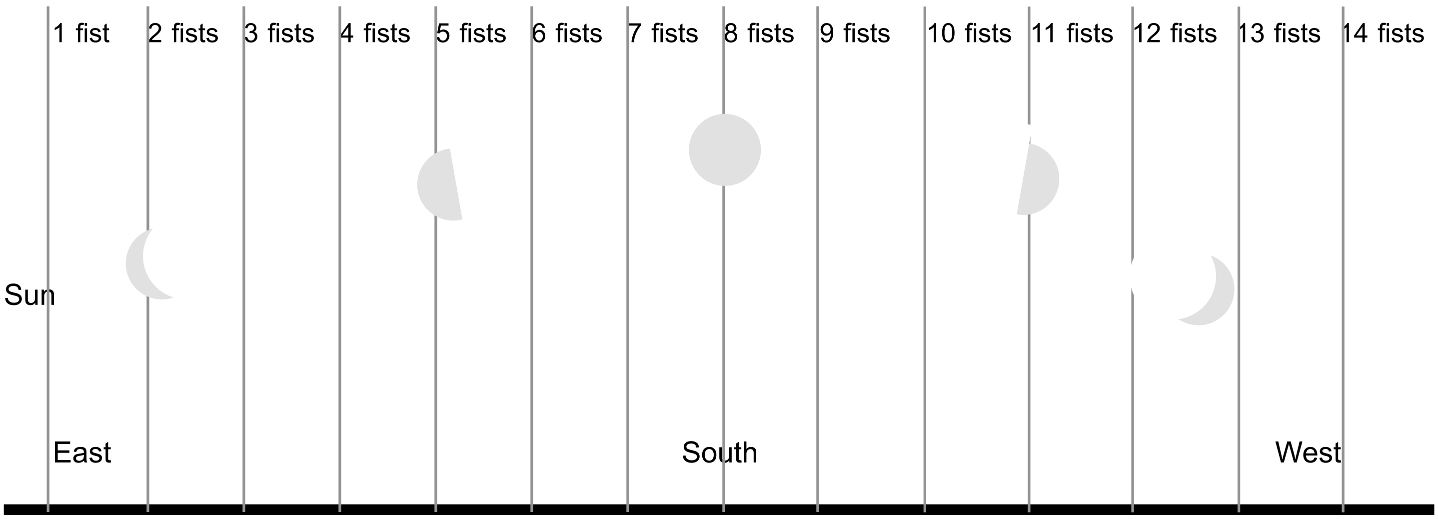
It is most effective to do the Moon phase modeling after the students have observed the real Moon phases daily for a couple of weeks. This can be done either during the school day for the waning portion of the Moon cycle (Moon phase decreasing—after full Moon) or as homework with students making daily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

If direct Moon observations are not possible, you can use the Powerpoint file for Simulated Moon Phase Observations at http://kepler.nasa.gov/ed/SimMoon.html

- 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.

Observing the Moon Phases.



Going Further

Engage the students in Moon phase discussions in the computer lab, using the images waning_gibbous.fts, moonphase.fts and others from the "more_moon_craters" folder. Notice how craters appear different, depending on the angle of sunlight, which in turn is determined by the Moon phase.

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 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 it's 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 students' 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 "backside" of the Moon. Note that the "backside" 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. Ask students if they recall how many Earth days is in a lunar day? (29.5 days—about a month)

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

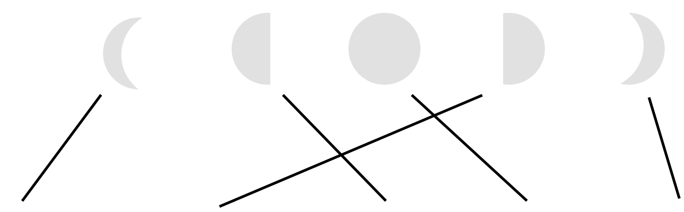
   During what Moon phase could there be a solar eclipse, when the Moon blocks the Sun?

   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)*.

Answers to questions

Question 14. Draw lines to match Moon shapes with Moon phase names.



Waning Crescent First Quarter Last Quarter Full Waxing crescent

Question 15. What is the difference between the "dark side of the Moon" and the "back-side" or "far side" of the Moon?

The "dark side of the Moon" would be the night time side, which at any given time is the side which is facing away from the Sun. This is different from the "back side" or "far side" of the Moon which is the side which always remains facing away from Earth. The far side of the Moon is sometimes dark, e.g. during full Moon phase, and sometimes light, e.g. during New Moon.

Question 16. During what Moon phase could there be a solar eclipse (Moon blocks the Sun)? *[New Moon.]*

Question 17. During what Moon phase could there be a lunar eclipse (Moon goes into Earth's shadow)? *[Full Moon.]*

II. Comets

II-A. How Long is a Comet's Tail?

(Computer Lab)

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

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

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.

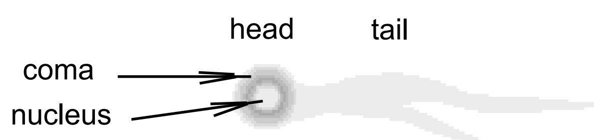
Have the students open halebopp_april97.fts, make a sketch of the comet and write an accompanying description in their HOSS Books.

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.

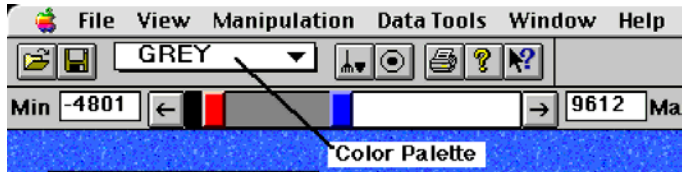
Answers to questions:

Question 18. The Brightest Pixel. In halebopp_apr97.fts, pixel (324, 236) has brightness Count of 1021 with others almost as bright nearby.

Question 19. Which Color Palette seems best for bringing out the most details in the comet? Which details?

Let the students select a different palette from the palette menu that makes the comet appear interesting and bring out different details.

Question 20. Do the brightness Counts change when you switch color palettes? [No.]



Question 21. What color is the brightest pixel in the nucleus? *[Depends on which color palette was selected.]*

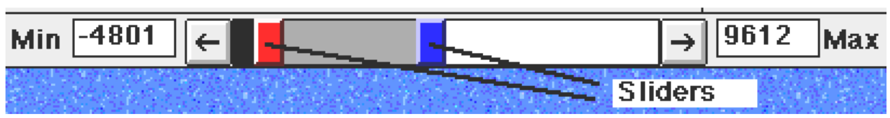
Question 22. Is there any relationship between the colors and the brightness of the comet in the colored image? *[Yes, the "Color Palette Bar," activated from the "View" menu, gives exact details of the relationship: which color corresponds to which brightness range.]*

Question 23. Which colors are associated with the dimmest pixels? *[Depends on which color palette was selected. Black is dimmest.]*

Which colors are associated with the brightest pixels? *[Depends on which color palette was selected. White is brightest.]*

Which colors are in the mid-range of brightness? *[Depends on which color palette was selected. Gray or medium tone colors.]*

Question 24. Describe what happens when you adjust Min and Max (or Brightness and Contrast in SalsaJ). When I move the Min (red) slider, this is how the color of the pixels in the image change.



When you raise the min, more pixels are colored black (or the lowest color on the palette) and when you lower the max, more pixels are colored white (or the highest color on the palette).

Question 25. Where is the end of the comet's tail?

Finding the "very end" of the comet's tail and recording its coordinates and brightness counts 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.

3. 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.

4. 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

A. More comet information can be found on the Internet. We have some links at http://www.lawrencehallofscience.org/SII/URLs/URLs-AstroSolarSys.html

B. 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.

II-B. Comet Set

(Classroom)

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

Materials/Preparation

For every student:

- HOSS Student Book (and optional Answer sheets)

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

In Class

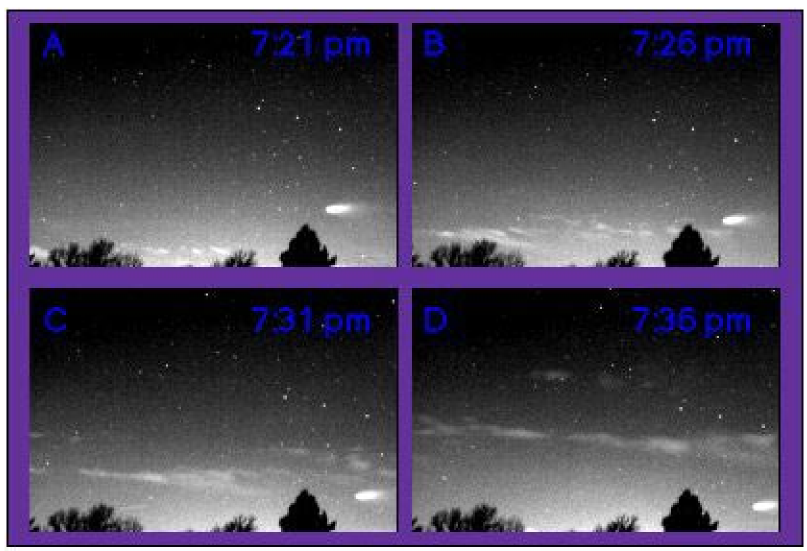
1. Spinning Earth. Ask the students,

Question 26. Do you think Earth is a spinning planet? *[Yes.]*

Question 27. Do you feel the spin of Earth? *[No.]*

Question 28. 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.]*

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.

Question 29. Compare the position of the comet to the tree as the minutes pass. Describe its motion. [North and down.]

Question 30. Does the comet seem to be moving with respect to the background stars? [No.]

Question 31. What surprises you? *[The fact that things don't set straight down is sometimes surprising. Also, the comet is not moving in the direction you would expect from the way the tail is pointing.]*

Question 32. Explain why the comet appears to move as it does.
Basically, it's the rotation of the Earth making the comet look like it's setting.

Going Further

Students can construct a Comet Set Flip Book (taken from HOU Explorations web page http://hou.lbl.gov/):

* Print and cut out the following pictures of Comet Hale-Bopp (images are on the HOSS CD-ROM):

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!

II-C. Comet Motion

(Classroom)

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

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

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

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

Answers to questions:

Question 33. Write about Comet Hale-Bopp. What surprises you? Explain what you think is happening. What are your questions? *[Accept any answers. Again, the comet is not moving in the direction you would expect from the way the tail is pointing.]*

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

Question 35. Explain the 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.)*

Question 36. How long does it take to watch a comet cross the sky? Days to months

3. Explain that so far we have noticed motion of the comet relative to the horizon. Ask, ***"Is there motion relative to the background stars?" "Why it is not noticeable in this set of images?"*** [The comet moves very slowly against the background stars.] **Ask, *Which appears to move faster across the sky, a comet or a meteor?*** *[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.

II-D. Comet Orbits

(Classroom)

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 book; optional Answer sheets.

For every pair of students:

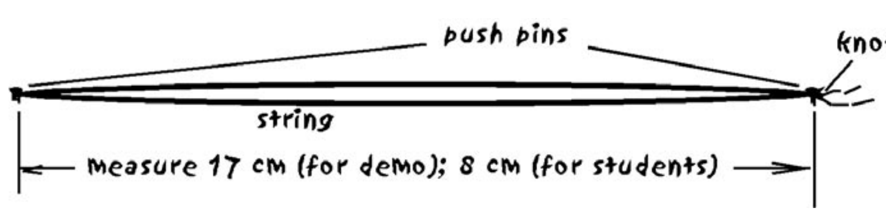
- a 25 cm piece string or twine—not stretchy
- 1 pencil (optional 4 colors of pencils)
- 2 paper fasteners

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

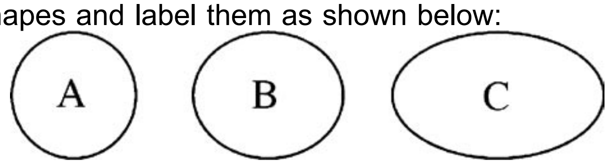
1. For each student, make a loop of string about 11 cm long from a 25 cm piece of string by tying the ends together. One way to do this is to stick two paper fasteners in a thick piece of cardboard, 11 cm apart, and tie the string around the paper fasteners. For demo, make another loop out of a 40 cm piece of string. 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:

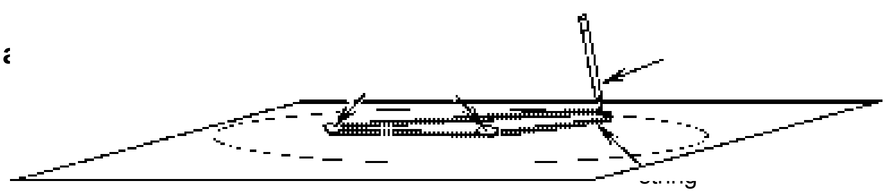


2. Poll the students,

> ***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 a follows:



a. Ask for a volunteer to help hold the paper up against the board for display.
b. Make two marks 12 cm apart on a large piece of paper.
c. Stick a paper fastener through each mark.
d. Drape the string loop you made from a 40 cm piece of string over the paper fasteners.
e. Pull the string taut with the tip of a pencil.
f. 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,

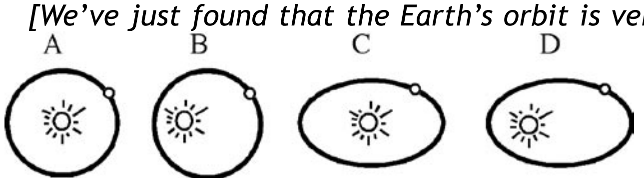
Which orbit is more circular, that of a comet or Earth's? *[Earth's]*

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 hula 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.

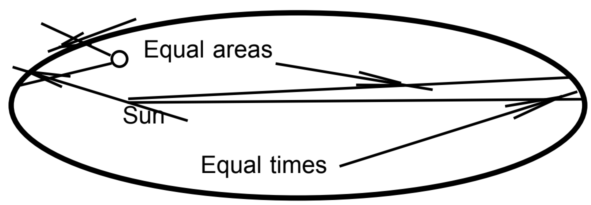
10. Ask,

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

(Computer Lab)

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:

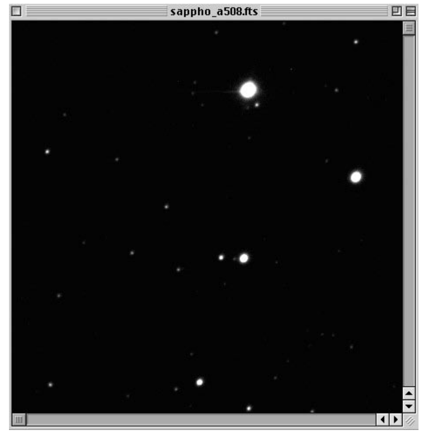
HOSS Student Book (and optional Answer sheets)

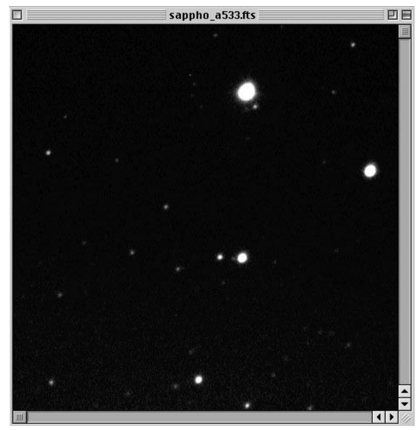
Images needed:

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 in the process one asteroid position will have positive brightness Counts and the other asteroid position will have negative brightness Counts.

Approximate answers:

Question 37. Coordinates of Sappho:

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

Coordinates of Iris:

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

Question 38. Coordinates of Hildrun:

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

Question 39. Coordinates of Ryokan:

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

Optional: Explain the Log tool—when and why to use it: essentially, sometimes it can bring out features in an image that are hidden, by skewing the display of brightness values to show more "sensitivity" at one end of the brightness scale .

IV. Planets

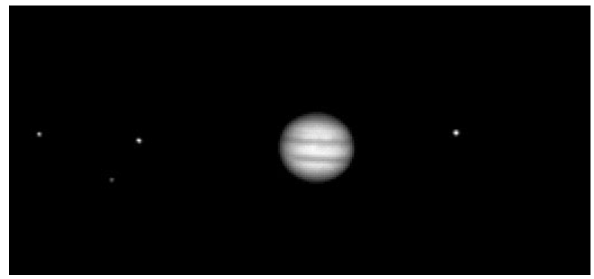
IV-A. Jupiter and Its Moons

(Computer Lab)

This activity is adapted from

- the TERC activity, *Heading off to Jupiter: Adjusting Min/Max*, in the *Tour Through the Solar System*
- Vivian Hoette's activity, *Jupiter's Orbiting Moons* on the Explorations pages of the HOU website

Materials



For every student:

HOSS Student Book (and optional Answer sheets)

Optional--for the class

A ball tied on a string.

Images needed:

jup1_991101g.fts jup2_july24_97.fts jup2_july25_97.fts
jup3_960926_0107.fts jup3_960926_0221.fts jup3_io_orbit.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."

Have students read their HOSS Books and go through the "Jupiter and Its Moons" section, recording observations and answering questions.

Answers to questions:

Question 40. What Min/Max (or Brightness/Contrast) settings are best to see bands on Jupiter? *[Many answers possible, e.g. Min=3, Max=11960]*

Question 41. What Min/Max (or Brightness/Contrast) settings are best to see moons of Jupiter? *[Narrower range, e.g. Min=-2000, Max=+2000]*

Question 42. Make a sketch of the image showing bands and the moons of Jupiter. *[No one correct answer.]*

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

- *First moon (from left edge): (27,157)* • *Second moon (below): (69, 131)*
- *Third moon: (86, 154)* • *Fourth moon (right of Jupiter): (276, 159)]*

2. Determining the radius of Ganymede's orbit.

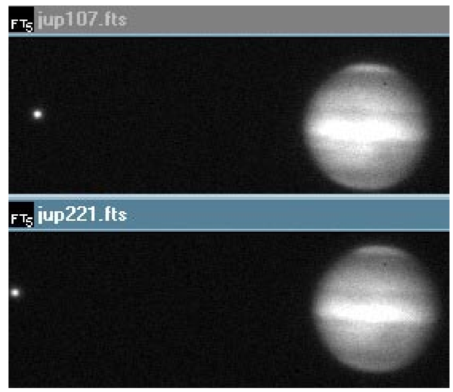
Question 44. Where are the other two moons of Jupiter in JUP_JULY25_97.FTS?

They are either in front of Jupiter, in what is known as transit, or behind Jupiter, eclipsed.

Reminder: When using the slice tool, remember you can click and drag the cursor in the slice graph and read exact values of pixel distance along the x-axis in numbers displayed at the bottom of the graph.

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

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 is about 5 Jupiter diameters.



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

These moon distance measurements are valid only when the moon reaches an extreme lateral position in its orbit.

Question 46. What is the radius of Io's orbit in Jupiter diameters? [About 2.5 Jupiter diameters.]

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)

IV-B. Jupiter Rotates

(Computer Lab)

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/

Materials

For every student:

HOSS Student Book (and optional Answer sheets)

Images needed:

jup_rotates341.fts jup_rotates408.fts jup_rotates411.fts

Preparation

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

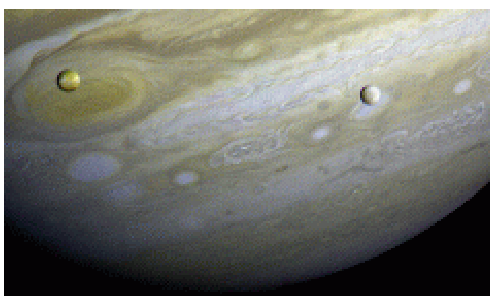
In Class (Computer Lab)

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

Ask the class,

Does Jupiter spin faster of 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.



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.

Answers to Questions:

Question 47. How big does this storm seem...? *[1/6 Jupiter diameter.]*

Question 48. Do you see evidence of rotation? *[Yes. Right.]*

Question 49. How did Jupiter look an hour before the first image? *[Red spot more centered.]*

Question 50. How about two hours after the last image? *[Red spot closer to the right edge.]*

Question 51. Will you always see the red spot? *[No.]*

Question 52. Make an estimate of how long it takes Jupiter to rotate once? *[10 hours.]*

IV-C. Planet Survey

(Computer Lab)

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)

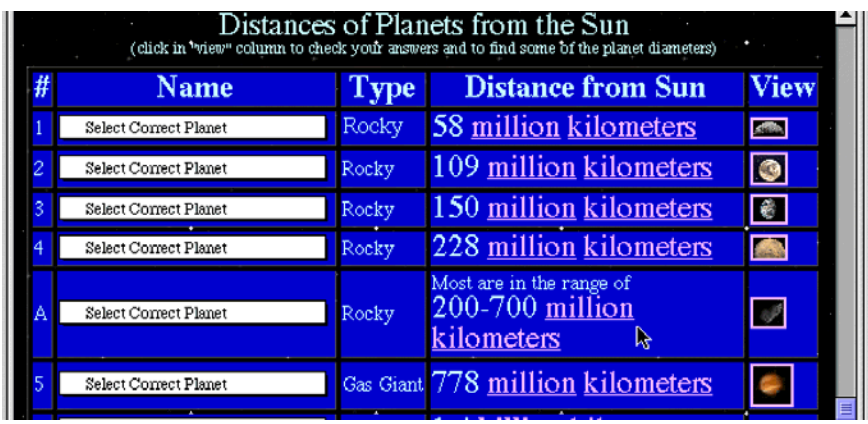
1. Review types of objects that are in the Solar System. Explain,

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.



Have the students fill in the Planet Survey Chart:

a. the name of each planet next to the appropriate order number.

b. the distance (in kilometers) of each planet from the Sun.

c. 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? *[Using the equation distance = speed x time, we get a distance of 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 ≈ 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

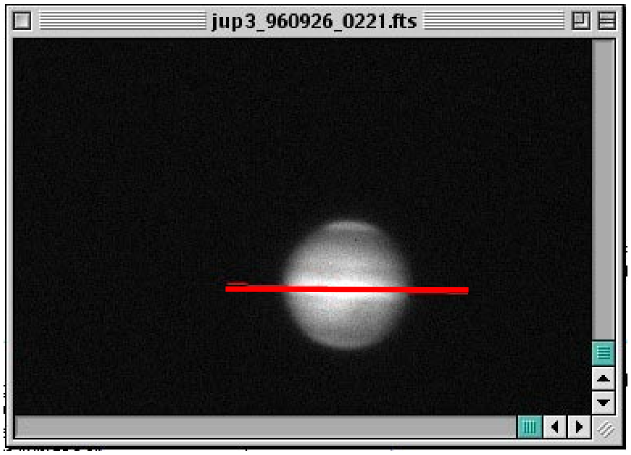
Neptune (4,500 M km)/(1080 M km/LH) = 4.17 LH

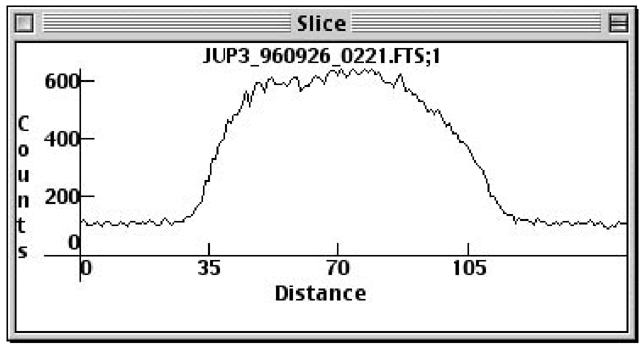
Pluto (5,900 M km)/(1080 M km/LH) = 5.46 LH

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.

When using the slice tool, it is good practice to extend the slice beyond the points you are trying to measure, e.g. begin to the left of the left edge of Jupiter and end the slice to the right of the right edge of Jupiter as shown above.





IV-D. Outer Planets

(Computer Lab)

This activity is adapted from Vivian Hoette's activities, *Neptune and Triton, 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 HOSS Student Book (& optional Answer sheets)

Images needed:

neptune_apo.fts uranus_apo.fts

uranus20000918-0425.fts

uranus20000918-547.fts

pluto20010624.fts pluto20010625.fts

pluto20010626.fts pluto20010627.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/

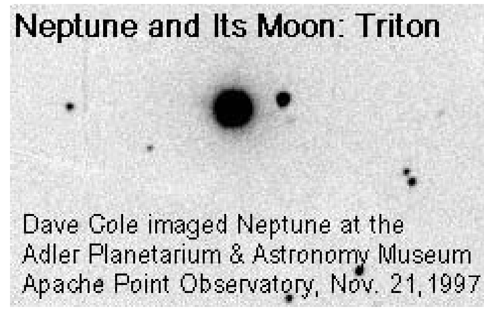
In Class

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.

Question 54. Write down the (x,y) coordinates for Neptune and for its moon, Triton. *[Approximately: Neptune (214,301); Triton (239,306)]*



Dave Cole imaged Neptune at the Adler Planetarium & Astronomy Museum Apache Point Observatory, Nov. 21,1997

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 it's axis is tilted a bit over 90 degrees from the plane of its orbit around the Sun.

Have students read their HOSS Books

Question 55. Write down the (x,y) coordinates for Uranus and each of the moons. *[Approximately: Uranus (196, 236); Titania (163,240); Umbriel (176,234); Ariel (210,228)]*

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

Question 56. What is the distance between Titania and Uranus in pixels? *[About 24 pixels from the edge of Uranus, about 30 pixels center-to-center.]*

Question 57. How many miles in 20.6 AUs?

[93,000,000 miles]

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

[270,000 km, center-to-center]

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.

Extra Challenges:

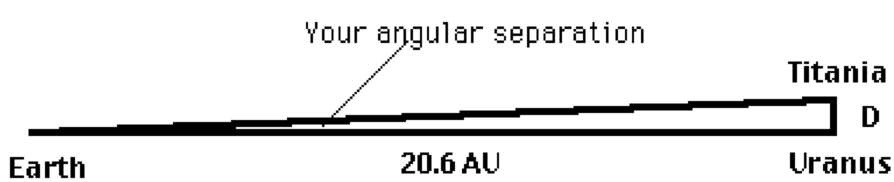
A. Umbriel and Ariel. Students can use the same method they used to find the distance between Titania and Uranus to find the corresponding Umbriel-Uranus and Ariel-Uranus distances.

Question 59. Find the distances to:

Umbriel *[about 180,000 km]*

Ariel *[about 140,000 km]*

The slice tool does not work well for these measurements because the moons are so dim and the background (sky) brightness is high. Measurement for Umbriel can be accomplish by simply subtracting x coordinate values for Uranus and Umbriel, since that are approximately lined up horizontally. For Ariel, which



is not aligned horizontally with Uranus, you may want to have students use the Pythagorean formula:

$$\text{Distance (pixels)} = (x_{uranus} - x_{ariel})^2 + (y_{uranus} - y_{ariel})^2$$

B. Movement of the Uranian system. Have students use images uranus20000918-0425.fts and uranus20000918-547.fts in the "More Uranus" folder to determine how far Uranus moves in an hour and twenty two minutes. Uranus was about 19 Astronomical Units away when the images were taken on September 18, 2000. Since this is an extra challenge, you should not need to give guidance to the students, if it is a sort of "Extra Credit" problem. The procedure involves using the *Add* or *Subtract* function (in the *Manipulation* menu) on the two images to detect movement of the Uranian system against the background stars.

Question 60. How far (in km) did Uranus move in 1 hr 22 min?

If the distance scale ~~is 440km/pixel at 1 au, then~~ it's 19 x 440 = 8360 km/pixel at 19 au. The movement is about 10 pixels, so Uranus must have moved 83,600 km in 1 hr 22 min.

C. Find Pluto.

The four images of Pluto in the "Worlds Galore" folder all have slightly different star fields, making it a real challenge to figure out which dot is the planet Pluto. However, there is enough overlap in the star fields that star patterns can be identified from image to image, and thus Pluto may be found.

Question 61. Where is Pluto in each of the four images from June 2001?

pluto20010624.fts about (250,250)

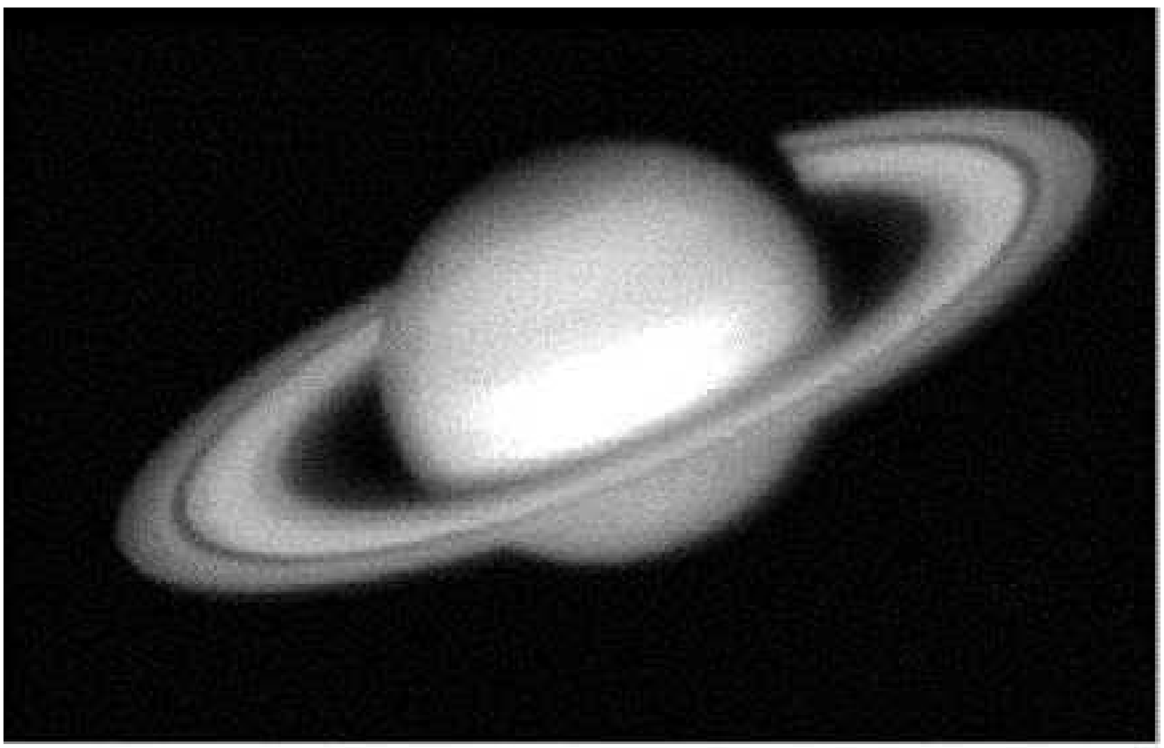
pluto20010625.fts about (250,350)

pluto20010626.fts about (186,216)

pluto20010627.fts about (166,215)

HOSS Answer Sheet

Hands-On
Solar System
Answer Sheets



Introduction: What's Out There?

Directions:

List objects you see in the night sky and put a check mark in the appropriate column to indicate whether each object is in the solar system or ouside the solar system.

Object	In the Solar System	Outside the Solar System

I-A-2. Open an Image

Question 1. Looking at the image, what can you deduce about the objects that slammed into the Moon?

I-A-3. Pixels and Coordinates

Question 2. The word "pixel" is short for "picture element" Describe in your own words what you think that means.

Question 3. What are the coordinates of the center of the largest crater?

X = *Y =*

Question 4. How many pixels wide is the crater?

Question 5. How many pixels wide is the entire iamge? How many pixels tall is it?

____ pixels wide ____ pixels tall

I-A-4. Zooming

Question 6. What is the maximum zoom factor possible with this software? How many "pixels" fit in the display window at that zoom factor?

Maximum Zoom / #of pixels

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

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

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

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

Prediction   Obnserved Zoom

I-A-5. Measure Brightness

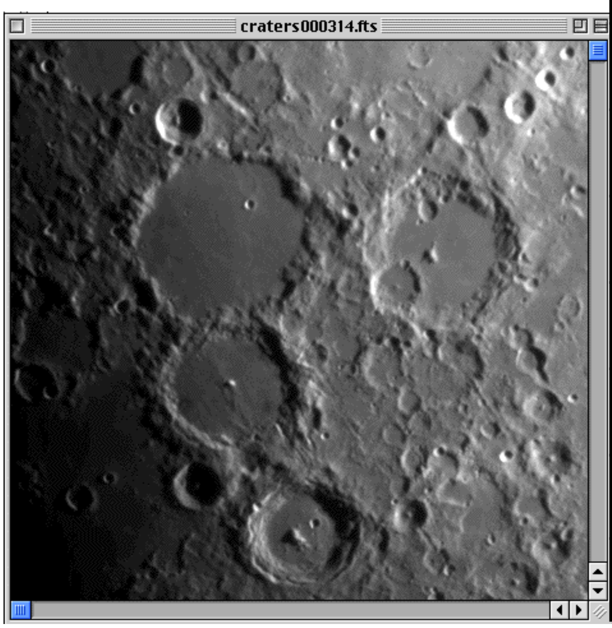
Question 8. How bright is the brightest pixel in the image?

What are its coordinates? ***X =***   ***Y =***

Question 9. How bright is the darkest pixel in the image?

What are its coordinates? ***X =***   ***Y =***

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*

Moon Feature

a. Moon image b. Coordinates of feature (e.g. crater center) c. Sketch

_______.fts X= ______ Y= ______

d. Feature type/Description:

e. Diameter/dimension ________ pixels

f. Conversion Factor: _________ km/pixel

g. Diameter/dimension _________ km

Moon Feature

a. Moon image b. Coordinates of feature (e.g. crater center) c. Sketch

_______.fts X= ______ Y= ______

d. Feature type/Description:

e. Diameter/dimension ________ pixels

f. Conversion Factor: _________ km/pixel

g. Diameter/dimension _________ km

Moon Feature

a. Moon image b. Coordinates of feature (e.g. crater center) c. Sketch

_______.fts X= ______ Y= ______

d. Feature type/Description:

e. Diameter/dimension ________ pixels

f. Conversion Factor: _________ km/pixel

g. Diameter/dimension _________ km

Moon Feature

a. Moon image b. Coordinates of feature (e.g. crater center) c. Sketch

_______.fts X= ______ Y= ______

d. Feature type/Description:

e. Diameter/dimension ________ pixels

f. Conversion Factor: _________ km/pixel

g. Diameter/dimension _________ km

Moon Feature

a. Moon image b. Coordinates of feature (e.g. crater center) c. Sketch

_______.fts X= ______ Y= ______

d. Feature type/Description:

e. Diameter/dimension ________ pixels

f. Conversion Factor: _________ km/pixel

g. Diameter/dimension _________ km

Moon Feature

a. Moon image b. Coordinates of feature (e.g. crater center) c. Sketch

_______.fts X= ______ Y= ______

d. Feature type/Description:

e. Diameter/dimension ________ pixels

f. Conversion Factor: _________ km/pixel

g. Diameter/dimension _________ km

I-D. Making Model Craters

Question 10. 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 image.

Question 11. How many Earth days equal one Moon day?

Question 12. How hot do you think it gets on the Moon during the lunar daytime?

Question 13. Where is the most likely place for us to find water ice on the Moon?

I-E. Moon Phases

Question 14. Draw lines to match Moon shapes with Moon phase names.

Waning Crescent   First Quarter   Last Quarter   Full   Waxing crescent

Question 15. What is the difference between the "dark side of the Moon" and the "back-side" or "far side" of the Moon?

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

Question 16. During what Moon phase could there be a solar eclipse (Moon blocks the Sun)?

Question 17. During what Moon phase could there be a lunar eclipse (Moon goes into Earth's shadow)?

II-A False Color Comet

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

Question 18. Find the brightest pixel in the nucleus of the comet. Record the (x,y) coordinates and the brightness Counts of that pixel:

x = _________, y = _________ Counts = __________

Question 19. Which Color Palette seems best for bringing out the most details in the comet? Which details?

Question 20. Do the brightness Counts change when you switch color palettes?

Yes *No* *(circle one)*

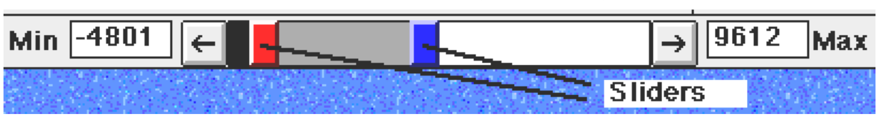
Question 21. What color is the brightest pixel in the nucleus?

Question 22. Is there any relationship between the colors and the brightness of the comet in the colored image?

Question 23. Which colors are associated with the dimmest pixels?

Which colors are associated with the brightest pixels?

Which colors are in the mid-range of brightness?



Question 24. Describe what happens when you adjust Min and Max (or Brightness/ Contrast). When I move the Min (red) slider, this is how the color of the pixels in the image change:

Question 25. Where is the end of the comet's tail?

Min/Max Setting		End of the comet tail		
Min ____________	Max ___________	x = ______,	y = ______	Counts = __________
Min ____________	Max ___________	x = ______,	y = ______	Counts = __________

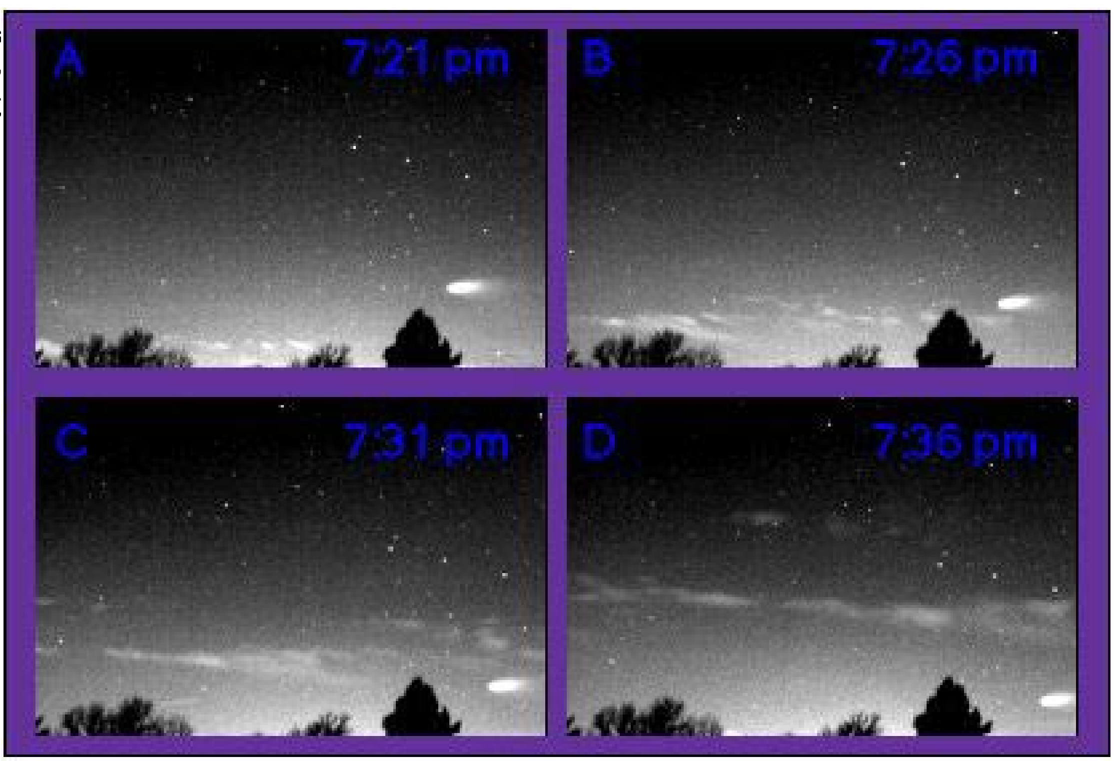
II-B. Comet Set

Question 26. Do you think Earth is a spinning planet? *Yes* *No* *(circle one)*

Question 27. Do you feel the spin of Earth? *Yes* *No* *(circle one)*

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

Images: Yerkes Observatory, Wisconsin. March 10, 1997



II-C. Comet Motion

First Observation:	Second Observation:
Monday, Feb. 24, 1997 5 a.m.	Friday, Feb. 28, 1997 5 a.m.

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

Question 30. Does 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.

II-C. Comet Motion (continued)

HBV224C.JPG

HBV228B.JPG

2. Find the same stars in both images. Use these stars as reference points. Label some of them with letters or numbers, for easy reference.

    a. Sketch several stars in the image.
    b. Show both Monday and Friday positions of the comet.
    c. Draw an arrow to show the motion of the comet.
    d. Label the date of each comet position.
    e. Use a dotted line to show the comet's path before and after the Monday and

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

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

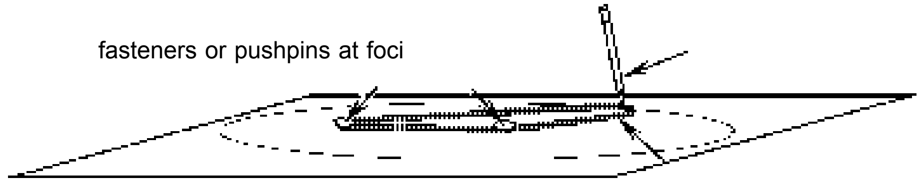
Question 34. Which way is the comet moving, towards the North, East, South or West?

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

I-D. Comet Orbits



To draw an ellipse:

a. With pen, mark the separation of the foci.

b. Stick a fastener through each focus.

c. Drape a string loop over the fasteners.

d. Pull the string taut with the tip of a pen and draw the ellipse. Keep the string taut as you draw.

Foci separations: for comet—10 cm; for Pluto—5 cm; for Earth—0.4 cm; for asteroid—7 cm

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 (Brightness/ Contrast) settings are best to see bands on Jupiter?

Min___________ Max___________

Question 41. What Min/Max (Brightness/ Contrast) settings are best to see moons of Jupiter?

Min___________ Max___________

Question 42. Make a sketch of the image showing bands and the moons of Jupiter.

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

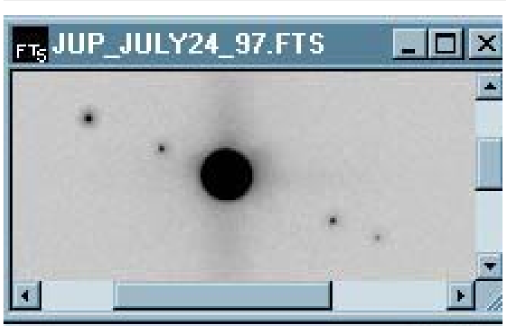
(x,y) coordinates
of 1st moon _________ , _________
(x,y) coordinates
of 2nd moon _________ , _________
(x,y) coordinates
of 3rd moon _________ , _________
(x,y) coordinates
of 4th moon _________ , _________

Question 44. Where are the other two moons of Jupiter in JUP_JULY25_97.FTS?

____

____

____



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.

IV-B. Jupiter Rotation

Look for the Great Red Spot!

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

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)?

Question 51. Will you always see the red spot? Why or why not?

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

IV-C. Planet Survey

53.

Object number or letter	**Object Name**	**Distance from Sun** millions of km	**Distance in** light-minutes (LM) or light-hours (LH)	**Size** kilometers

1 LIGHT MINUTE (LM) =
(0.3 million km/sec)(60 sec/min) = ____________________ million km

1 LIGHT HOUR (LH) =
(0.3 million km/sec)(3600 sec/hour) = ____________________ million km

IV-D. Outer Planets

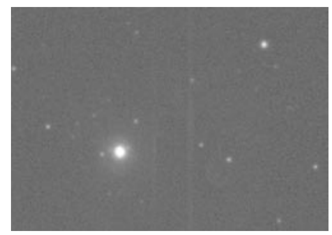
Question 54. Write down the (x,y) coordinates for Neptune and for its moon, Triton.

Neptune: 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 between Titania and Uranus in pixels?



Question 57. At the time the Uranus image was captured, the distance between the Earth and Uranus was 20.6 AUs. (One AU = 150 million kilometers.) How many miles in 20.6 AUs?

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

Question 59. Find the distances to: **Umbriel** __________________

Ariel__________________

Question 60. How far (in km) did Uranus move in 1 hr 22 min?

Question 61. Where is Pluto in each of the four images from June 2001?

June 24:	X = _______	Y = _______
June 25:	X = _______	Y = _______
June 26:	X = _______	Y = _______
June 27:	X = _______	Y = _______

Hands-On Solar System