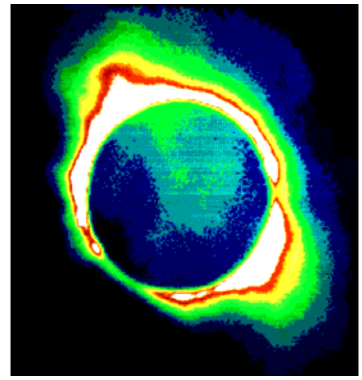
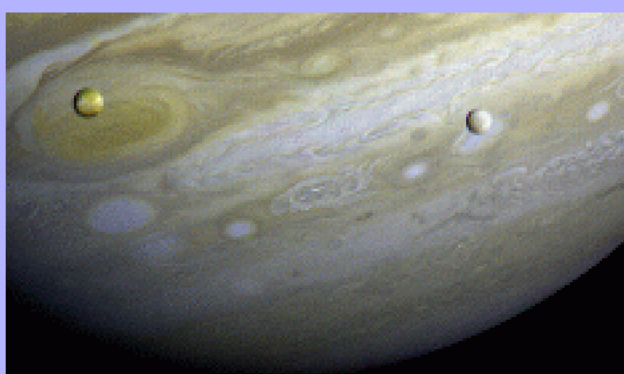
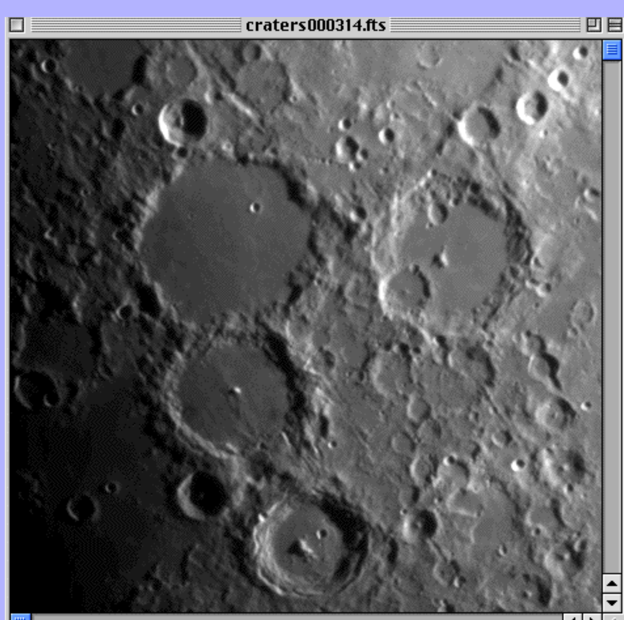
Hands-On Solar System



Produced by Hands-On Universe
A Joint Project of
Lawrence Hall of Science
Yerkes Observatory
and TERC

Student Book





Version: September, 2006

Hands-On Solar System

Contents

Lawrence Hall of Science

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. The Moon: Our Closest Neighbor

I-A. The Image Processor

1. Launch the Image Processor

Launch the program Hands-On Universe *Image Processing* (HOU-IP).

HOU-IP icon for Windows & Mac OS9

The *Image Processing* icon looks like this: 

Don't be fooled into thinking the program has not started. You can tell if the program successfully launched if the top of your screen looks something like this:

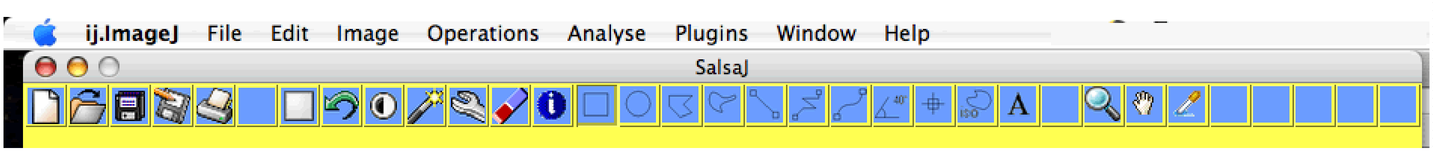
HOU-IP Windows & Mac OS9 toolbar

These pictures show the Image Processing "Tool Bar" and Menus

For SalsaJ users

SalsaJ icon

SalsaJ toolbar



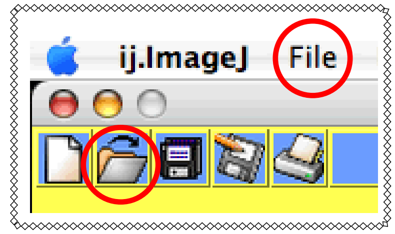
On a Macintosh OS9 computer, double-click the "Image Processing" Icon to start up.

When the Image Processing program is running, the icon appears in the extreme upper right corner of your screen (see Tool Bar picture below)

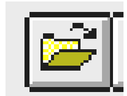
If the icon changes to some other icon, you have somehow left the Image Processing program. You can easily get back to the Image Processing program if you simply "click-and-drag" on the icon in the extreme upper right corner to select "Image Processing" You can always re-launch the program, if necessary.

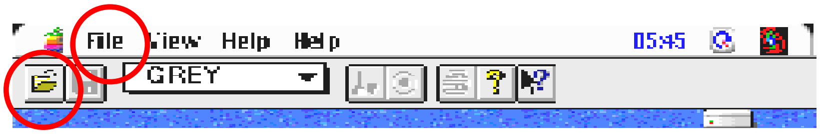
In SalsaJ, as of 2006, there is an oddity of operation: in order to make any of the menu items functional, you need to first click on the yellow toolbar.

2. Open an Image



a. Open the Moon image by

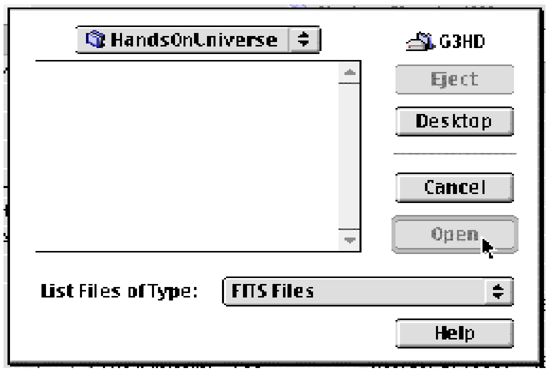
clicking on the "Open" file icon  in the upper left corner of your screen:



Another way to open a file is to use the "Open" command in the "File" menu.

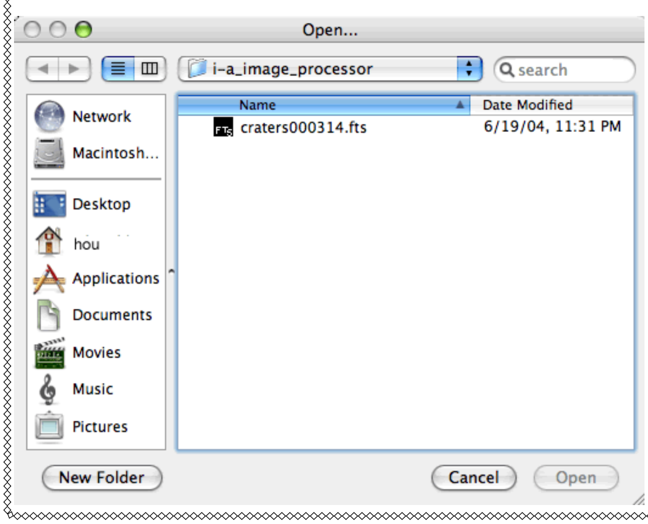
b. You should see a window like the one below.

HOU-IP Windows & Mac OS9 "Open" dialog box



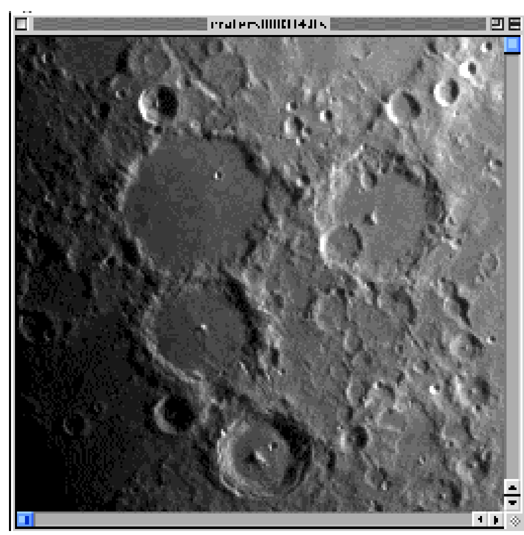
To see all the files available to you, you ***may*** need to change the selection in the box that says "List Files of Type" from "FITS Files" to "All Files."

SalsaJ "Open" dialog box



c. Find the image named "craters000314.fts" and open it.

You should see the image shown at right. The circular features are craters—places where objects have violently slammed into the Moon.



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

3. Pixels and Coordinates

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

Each pixel in an image can be located or identified by numbers that are called *the pixel's (x,y) coordinates*, This is exactly the same way that points on a graph are identified. The X-coordinate of a pixel is how many pixels it is horizontally from the lower left corner of the image. The y-coordinate of a pixel is how many pixels it is up from the lower left corner on the image. hence the coordinates of the lower left corner pixel is (0,0), also called the "origin."

In HOU IP Windows and Mac OS9, the (x,y) coordinates for the current position of the cursor on the image are shown in the Status Bar at the bottom right corner of the screen:

(

In this example, X: 134 means the cursor is 134 pixels to the right of the origin, and Y: 60 means the cursor is 60 pixels above the origin.

Status Bar

X: is the pixel number (coordinate) **from left to right**

Y: is the pixel number (coordinate) **from bottom to top**

Notice what happens to the coordinate numbers as you move your mouse around on the image.

For SalsaJ users

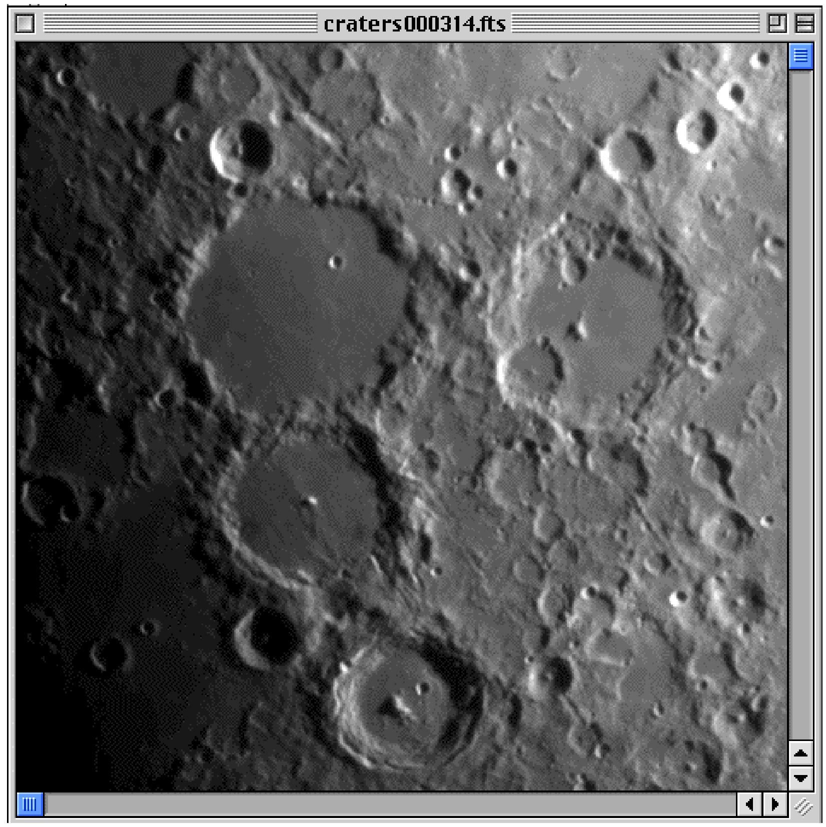
In Salsa J, the coordinates are indicated indicated in the upper left just below the toolbar.

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

Answer Box

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

Answer Box



The edge of the crater is not always well-defined. Use your best judgement in deciding where the crater starts and stops.

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

Answer Box

______ pixels wide ______ pixels tall

4. Zooming

Zooming makes the image look bigger. In HOU-IP Windows or Mac OS9, there are two ways to *zoom*:

a. Zoom Factor. Towards the right side of the tool bar, find a number by the word "Zoom."

It looks like this: 

Change the number (It's called the "Zoom Factor."). Press the "Return" key or click the "Redraw" button to make your choice of zoom happen. Try a few different values for zoom to see what they do.

If you choose a big enough zoom factor, you will see that the image is made of a bunch of little boxes—the "pixels." A pixel is the smallest piece of the picture and has a particular brightness value associated with it.

For SalsaJ users

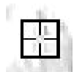
In **SalsaJ**, you can "zoom" the image using the magnifying glass tool in the tool bar. Just click anywhere in the image and it zooms. ***Can you figure out a pattern to how much it zooms on each click?***

To "Unzoom" hold doen the "Option" key while clicking on the image.

Factor is a mathematical term having to do with multiplication. If you choose a Zoom factor of 2, then the size of the image is doubled; each pixel is made twice as wide and twice as high. For higher values of zoom factor, two things begin to happen: (1) The whole image does not fit on the screen—you need to scroll to see parts that are not visible, and (2) You begin to see each pixel box.

b. Zoom Box Tool. [Not available in SalsaJ] Set the Zoom factor back to "1." With the Zoom Box tool, you can "click and drag" to zoom in on an area.

Find the Zoom Box Tool in the "Data Tools" menu:

Your cursor will change to  (Zoom Box cursor) but only when it is actually on the image. Click-and-drag the zoom box cursor over the area you would like to zoom in on. The image processor will create a new image window showing an enlarged view of the portion of the image you picked.

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

Answer Box: Maximum Zoom / #of pixels

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

Answer Box

In HOU-IP Windows and Mac OS9, every time you use the Zoom Box Tool, a new window is created. If you use the Zoom Box several times, your computer screen will become cluttered with windows, but you can easily get rid of any them by simply using the "Close Window" function. To close all zoom box images:

For Mac: Click in the box in the top left corner of each image window. Click "Don't Save" each time.

For PC: Click the box with an "x" in the top right corner of the image window.

Zoom Box Questions (HOU IP only)

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

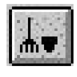
Answer Box

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

Answer Box

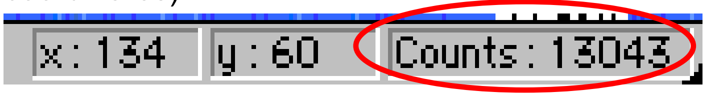
C. What do you predict the zoom factor will be after you have zoom boxed six times? Check if your prediction is correct.

Prediction | Observed Zoom

 is a cleanup tool and will get rid of red zoom boxes that clutter up an image. The cleanup tool is also in the "View" menu: "Clean Up Marks."

5. Measure Brightness

You can generally tell where bright and dark areas are just by looking at the image. But if you want to know exactly how bright or dark a particular spot on the image is, use the “Counts” display. In HOU IP Windows and Mac OS9, Counts can be found in the lower right corner of the screen (next to the X-Y coordinates):



In SalsaJ, Counts are in the upper left corner

The “Counts” number is the exact BRIGHTNESS of the pixel that the cursor is on. “Counts” is a measure of the total amount of light that the telescope received at that spot on the image.

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

Answer Box

What are its coordinates?

X = **Y =**

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

Answer Box

What are its coordinates?

X = **Y =**

Barringer Meteor Crater in Arizona Image from: http://antwrp.gsfc.nasa.gov/apod/ap971117.html
Credit: D. Roddy (LPI)

Meteor showers can be very impressive. Samuel Taylor Coleridge's famous lines from The Rime of the Ancient Mariner may have been inspired by the Leonid meteor shower that he witnessed in 1797:

The upper air burst into life!
And a hundred fire-flags sheen,
To and fro they were hurried about!
And to and fro, and in and out,
The wan stars danced between

And the coming wind did roar more loud,
And the sails did sigh like sedge;
And the rain poured down from one black cloud;
The Moon was at its edge

Explanation: What happens when a meteor hits the ground? Usually nothing much, as most meteors are small, and indentations they make are soon eroded away. 49,000 years ago, however, a large meteor created Barringer Meteor Crater in Arizona, pictured above. Barringer crater is over a kilometer (1.186 kilometers or .737 miles) across. In 1920, it was the first feature on Earth to be recognized as an impact crater.

Barringer Meteor Crater homepage: http://www.meteorcrater.com/

Today, over 100 terrestrial impact craters have been identified. Calvin J. Hamilton's web pages "Views of the Solar System" at http://www.solarviews.com/ has excellent information on terrestrial impact craters.

A ***meteor*** is a bright streak of light in the sky (a "shooting star" or a "falling star") produced by the entry of a small meteoroid into the Earth's atmosphere. If you have a dark clear sky you will probably see a few per hour on an average night; during one of the annual meteor showers you may see as many as 100/hour. Very bright meteors are known as fireballs.

Meteorites are bits of the solar system that have fallen to the Earth. Most come from asteroids; a few probably come from comets. A small number of meteorites have been shown to be of Lunar (15 finds) or Martian (13 finds) origin.

Meteoroids are bits of the solar system that are still flying around the solar system.

[From: http://www.seds.org/nineplanets/nineplanets/meteorites.html]

I-B. The Crater Game

Rules:

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

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

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

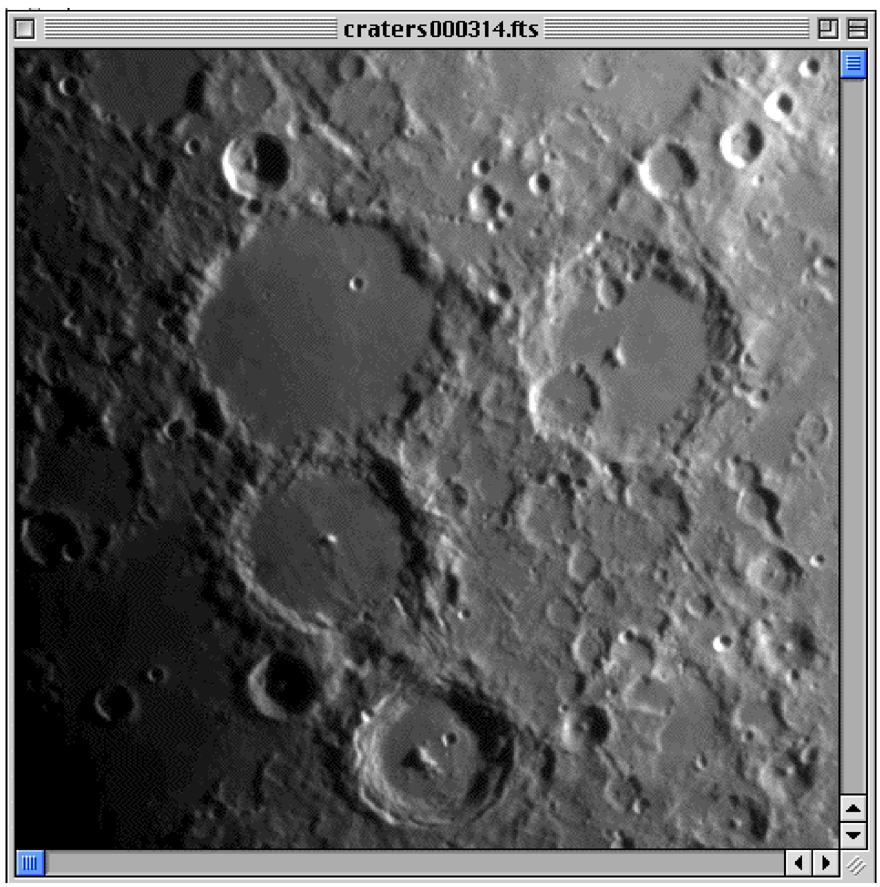
d. First player to find crater diameter picks the next crater and calls out the coordinates of its center, then back to step (c).

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.

	(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					



I-C. Moon Measure

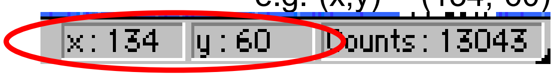
1. Moon Features. Pick any of the 6 Moon images shown on this page and do the following, recording any data, observations or computations for each on the following pages.

a. Open a Moon image.

b. Identify a crater.

c. Find (X,Y) coordinates of the crater center using status bar.

e.g. (x,y) = (134, 60)



d. Describe the feature with words and make a sketch of it.

e. Measure the diameter of the crater in pixels using the Status Bar (x,y coordinate display) or the Slice Tool (see instructions for using the Slice Tool on the next page).

f. Find the pixel to kilometer conversion factor these images by selecting “Image info” in the “Data Tools” menu of the Image Processing software. The conversion factor, in km/pixel, is towards the end to the” Image info text.

g. Compute the crater diameter in kilometers.

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

a. Measure the crater diameter (D) and use the formula for circumference: $C = 2\pi r = \pi D$

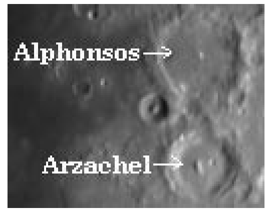
b. Use the Slice Tool (instructions on page 16) to add together a series of slices along the crater rim.

Convert to miles or kilometers.

1 mile = 1.609 km. 1 km = .6214 mi.

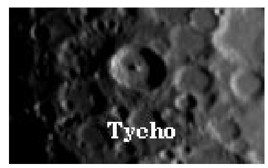
moon1.fts:

moon5.fts:

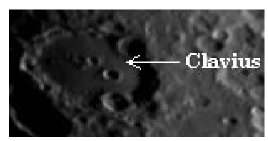


In SalsaJ

moon6.fts:



moon7.fts:



moon16.fts:

Moon Features Worksheet

Make additional worksheets as needed

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

Using the Slice Tool

a. Select the Slice tool (in the "Data Tools" menu for HOU-IP Windows and Mac OS9).
Your cursor will change to the drawing cursor:

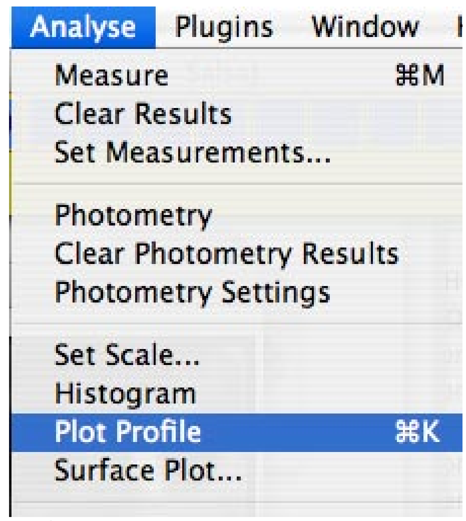
 (same as for Zoom Box)

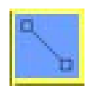
b. Using the Slice drawing cursor, draw (click and drag) a line from one point on the image to another point on the image.

c. A Slice graph will appear showing distance in pixels along the x-axis and *brightness* Counts of the pixels on the y-axis. If you drag the cursor anywhere in the graph, a corresponding dot will appear on Slice line in the image. The distance along the line (in pixels) can be read on the x-axis of the graph. This is an easy way to see the distance (in pixels) between various points along the slice line.

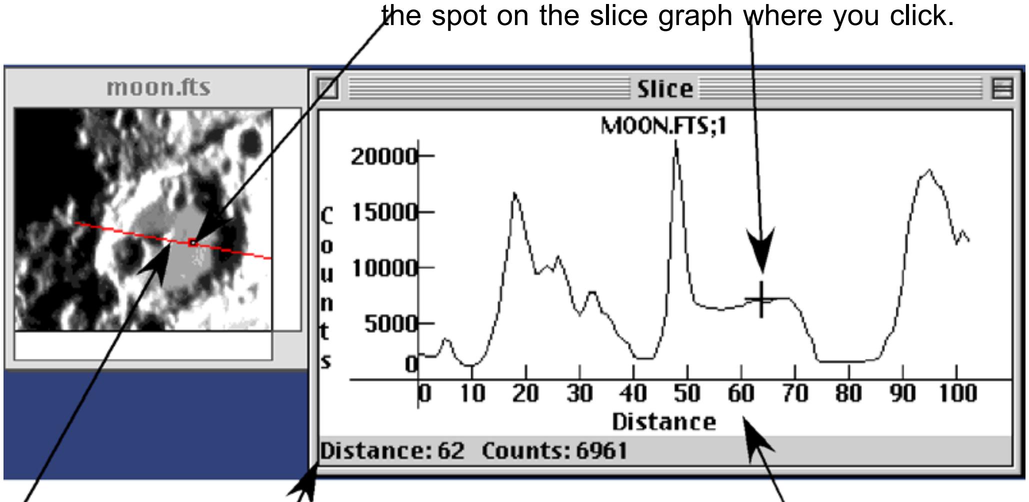
In the example below, the graph shows peak brightnesses for the crater rim at about 18 pixels and 95 pixels along the slice line. The crater diameter, in pixels, would be the difference: 95 - 18 = 77 pixels.

In SalsaJ, "Slice" is called "Plot Profile" and it's in the "Analyse" menu. [Remember to click in the yellow toolbar first, before selecting a menu item.]



In SalsaJ, you need to draw the line first with the line select tool. Click on this icon:  and then click and drag to create a line on the image. Then Choose "Plot Profile" in the Analyse Menu. The graph will appear.

The dot that appears on the slice line in the image corresponds to the spot on the slice graph where you click.



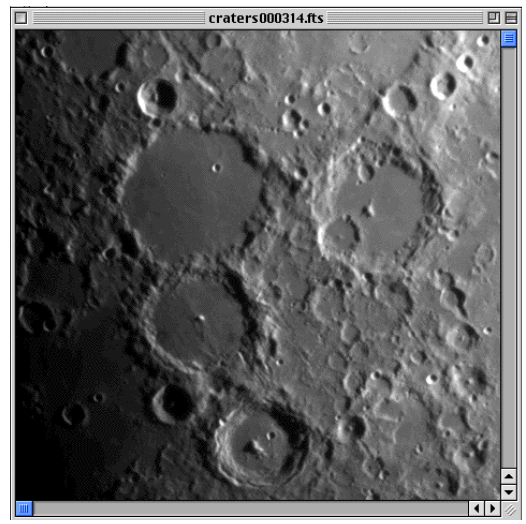
After you click and drag the slice line, the Sice graph pops up...

You can increase the number of "tick marks" on the x-axis by selecting "Axes" in the "Options" menu after you have drawn a Slice.

I-D. Making Model Craters

1. Angle of Sunlight. When you make a model of a crater based on a telescope image and try to make its appearance match the that of the telescope image, how the crater looks depends on the angle of Sun's rays on it. .

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.



2. The Moon Rotates. The Moon's rotation rate (the time it takes to spin once on its axis) equals the period of revolution around the Earth (the time it takes to orbit Earth). Because of this fact, the Moon always keeps the same face pointing towards the Earth. It wasn't until humans sent spacecraft in orbit around the Moon that we ever saw the "back-side" of the Moon. Note that the "back-side" of the Moon is ***not*** the "dark side of the Moon" (except during full Moon). There is day and night on the Moon the same as on Earth, except the length of a day on the Moon is about a month long.

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

Answer Box

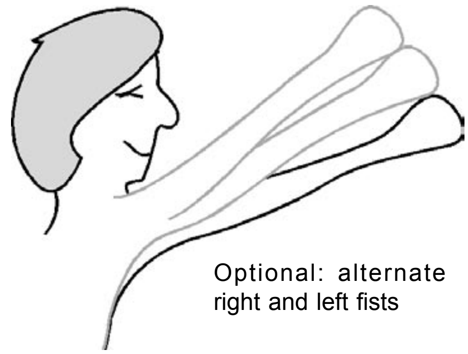
Question 12. How hot do you think it gets on the Moon during the lunar daytime?

Answer Box

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

Answer Box

I-E. Moon Phases



Optional: alternate right and left fists

1. Observing the Moon Phases. The Moon goes through a cycle of phases that lasts as long as its orbit around the Earth. For about two weeks, after full Moon, it's easiest to see it in the morning after sunrise. In the subsequent two weeks, after new Moon, it is easiest around sunset or after.

As you watch the Moon for one full cycle of phases, make a drawing in a chart (page 17) showing it's shape each day along with how far across the sky it appears from the Sun, in "fist" measurements. 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."

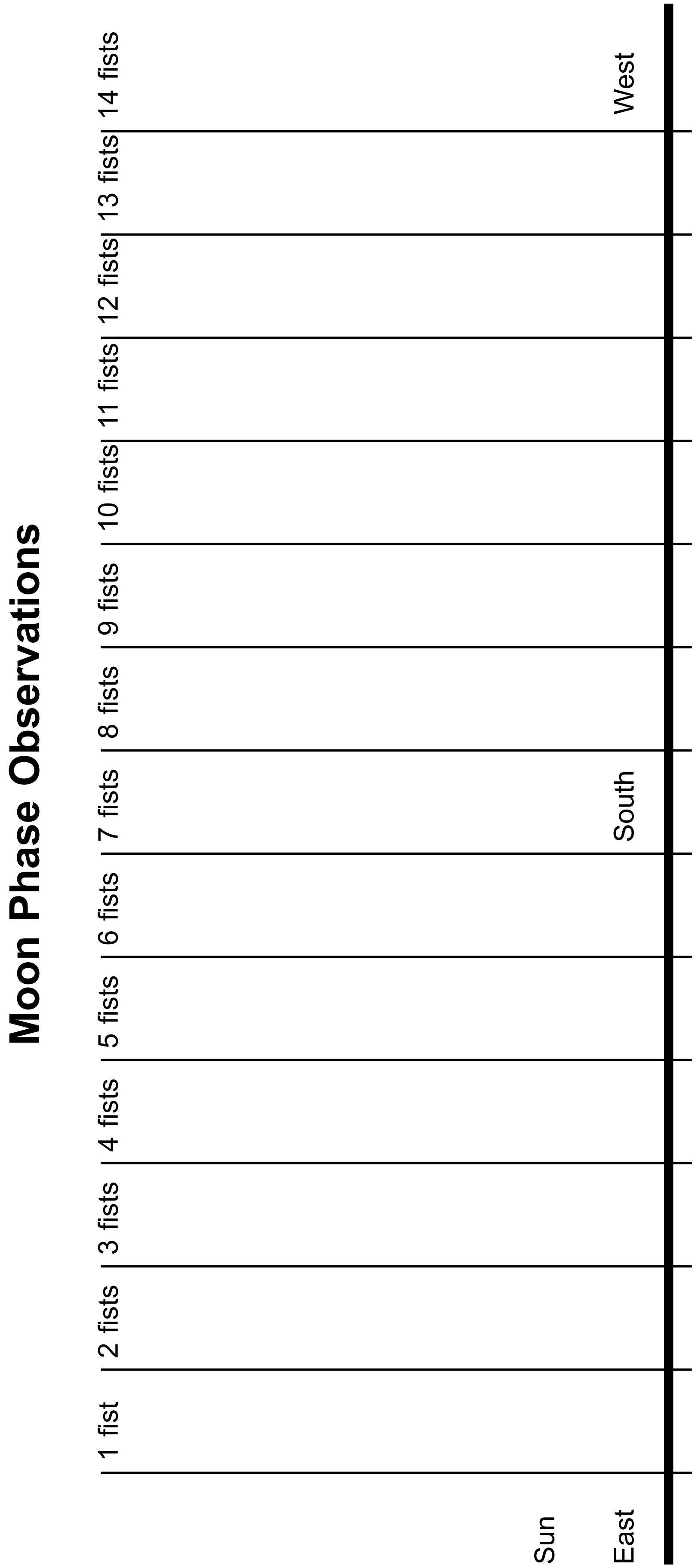
2. Modeling Moon Phases.

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?

Answer Box



For a simulation of an entire month's worth of moon phases, see http://kepler.nasa.gov/ed/SimMoon.html

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

Answer Box

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

Answer Box

II. Comets

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

1. Comet Hale-Bopp. In March 1997, the comet Hale-Bopp made a fantastic appearance in the night sky.

2. Sketch and describe the comet. Open comet image halebopp.fts or halebopp_apr97.fts. Make a sketch of the comet and write an accompanying description (below).

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

____

____

____

____

____

____

____

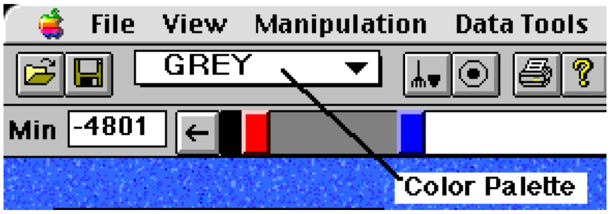
3. Comet Structure. A comet has a bright core called a *nucleus* surrounded by a diffuse but bright *coma*. The nucleus and coma combined are often referred to as the *head* of the comet. The *tail* of the comet is the part that spreads out gradually from the head. Label in your drawing the parts of the comet: nucleus, coma, head, tail.

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

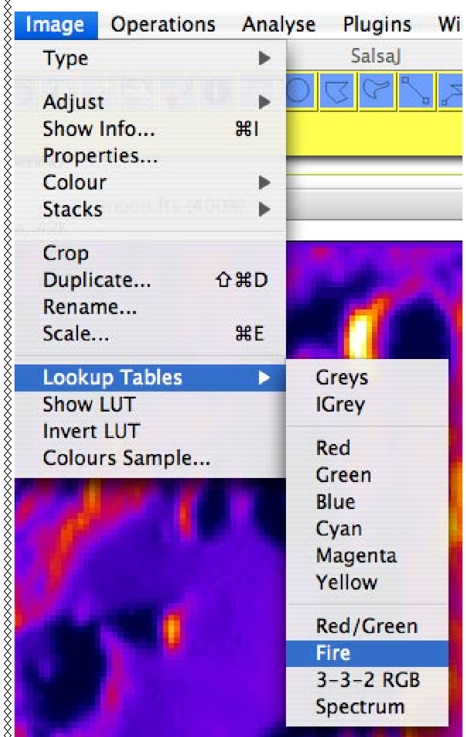
x = ________, y = ________ Counts = ________

4. False Color Comet

Change Palettes. Select a different palette from the palette menu (in HOU-IP Windows and Mac OS9). That brings out different details in the comet.



In SalsaJ, the equivalent of "Color Palette" is "Lookup Tables" (LUT) which is found in the "Image" menu. Remember to click on yellow toolbar before using any of the menus.



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

Find the pixels with the same (x,y) coordinates that you determined in Question 18 for the brightest part of the nucleus.

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?

5. Color Palette Bar. In the "View" menu (HOU-IP Windows and Mac OS9), select the Color Palette Bar. In the window that appears, colors are associated with brightness counts.

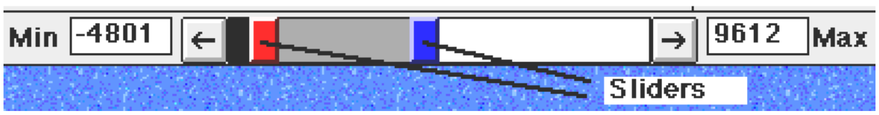
In SalsaJ, the equivalent of "Color Palette Bar" is "Show LUT" in the "Image" menu. Remember to click on the yellow toolbar before selecting any menu item.

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

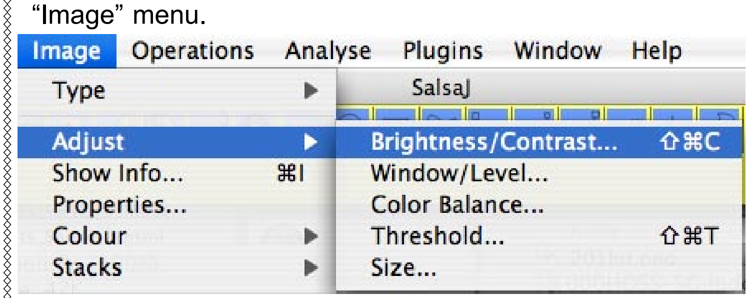
Which colors are associated with the brightest pixels?

Which colors are in the mid-range of brightness?

6. Adjust Display Brightness and Contrast: the Min/Max Tool. Slide the red and blue sliders on the Min/Max bar to bring out more detail in the image.



In SalsaJ, the equivalent of the Min/Max tool is "Brightness/Contrast" which can be found in the "Adjust" item of the "Image" menu.



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

Answer Box

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

Question 25. Where is the end of the comet's tail? Find the pixel that is at the "very end" of the comet's tail and write its coordinates, brightness counts, and color. Note the "length" of the tail can seem to change with different Min/Max settings. Record and compare (in the box above) the end of the tail for two different Min/Max settings.

7. About False Color. False color imaging is becoming a widely spread means of communication; e.g., weather maps. By creating your own color image of the comet, you control how the Image Processing software displays data to make particular details easier to see.

The Color Palette Bar (activated from the "View" menu), is a chart showing 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. It helps you see the changes in brightness over the whole image and the Counts that are associated with those changes.

When first confronted with opening a new images, it is sometimes difficult to see anything at all. Often narrowing the Min/Max range can help make the display more useful. An excellent way to start out is to look around for the brightest and dimmest pixels in the image and set the Min/Max values to those values by typing the Counts of the brightest pixel in the Max box and the Counts of the dimmest pixel in the Min box. Then narrow the Min/Max range from there.

HBV224C.JPG

8. 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, it begins to warm up and the ices vaporize (sublimate) and form the coma and tail of the comet. As it gets still closer to the Sun it becomes even hotter and radiates light and becomes visible. Comets actually have two tails: one made of dust that we can see only by sunlight reflecting off the dust particles, and another made of ions (ion tail) that glow—giving off their own light.

II-B. Comet Set

When we observe the sky from Earth, it looks like objects in the sky change position. Think about how our Sun appears to rise and set!

Sunset... July, 1990, from Lawrence Hall of Science.

Photo by Vivian Hoette

We are all familiar with spectacular sunsets.

Like the Sun, Comet Hale-Bopp also disappeared below the horizon.

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

Yes No (circle one)

Question 27. Do you* feel *the spin of Earth?

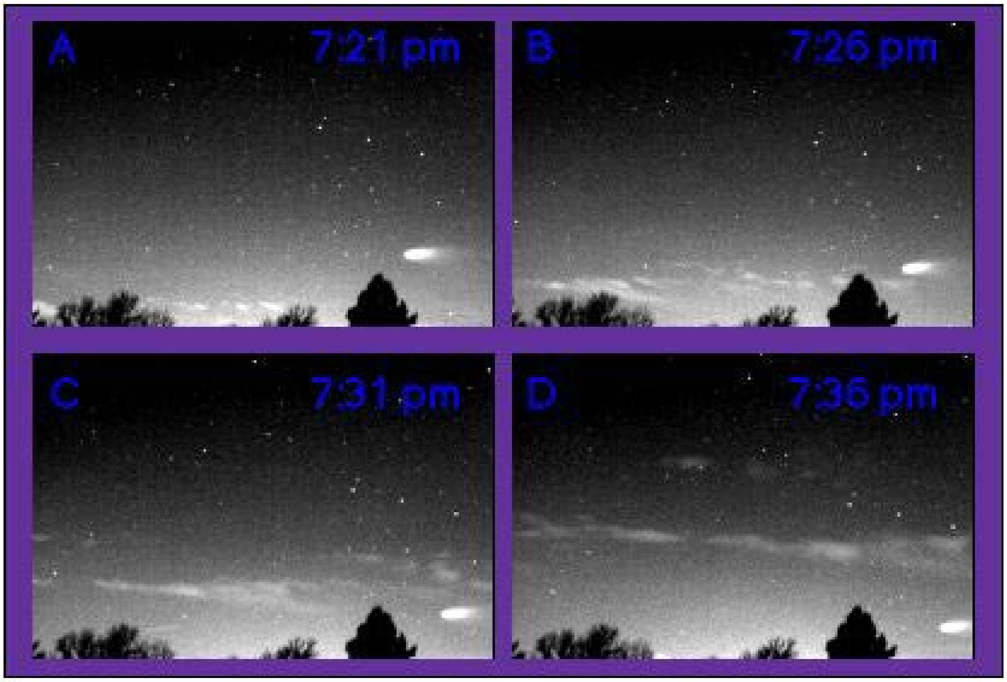
Yes No (circle one)

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

Answer Box

Evening Comet Watch...

Comet Hale-Bopp also appears to move as Earth spins. Notice the comet's changing position relative to the horizon.



Images: Yerkes Observatory, Wisconsin. March 10,

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

Answer Box

Question 30. Does the comet seem to be moving with respect to the background stars? Yes No (circle one)

Question 31. What surprises you?

Answer Box

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

Answer Box

II-C. Comet Motion

In order to determine if an object in the sky is really moving, or if it's just the Earth's spin that just makes it look like the object's moving, we need to see if the object changes position relative to other things in the sky, like the stars.

Because of how comets are shaped, many people think of them as moving very fast through the sky, much like a meteor. Meteors appear to traverse large sections of the sky in fractions of a second. Do comets move that way too? How long does it take to watch a comet cross the sky? Seconds? Minutes? Hours? Days? Months?

Many people just don't know the difference between comets and meteors and they use the words interchangeably. By the time you finish with this session, you should be able to explain the difference between a comet and a meteor to your family and friends.

Our perception of how fast something is moving depends upon its distance away from us. We see the change in the position of Hale-Bopp because it is close, part of our Solar System. The stars in these images are in our Milky Way galaxy, tens to hundreds and thousands of light years away. As a consequence, even though the stars are moving much faster than the comet, changes in their position are not seen except over millennia. You see the same effect if you compare an airplane flying at 30,000 feet with one about to land at an airport.

Comets typically have very elongated orbits resulting in a long time between appearances. Haley's Comet is an example; it comes back every 76 years.

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


HBV224C.JPG

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


HBV228B.JPG

Does a comet's position change among the stars in four days?

1. Look at the comet's position on Monday and then on Friday. In both images, East is to towards the left and South is down.

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

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?

Answer Box

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

Answer Box

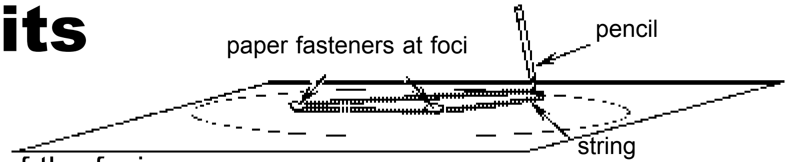
Question 35. Explain the difference between a comet and a meteor.

Answer Box

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



Keep the string taut as you draw.

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 pencil and draw the ellipse.
e. Label the ellipse (comet, Pluto, Earth, or asteroid)

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

III. Asteroids

As you know by now, our Solar System is more than just planets and moons. Anything that orbits around the Sun is a part of the Solar System. We have already looked at comets, and now we look at asteroids.

1. Sappho. Open the images sappho_a508.fts and sappho_a533.fts from the image file folder. Click and drag the image windows to move them side by side. The image sappho_a533.fts might appear quite peculiar when first opened. Adjust the Min/Max settings as needed.

These images are of the same region of the sky but were taken about 15 minutes apart. One of the objects in the image is an asteroid named Sappho. It appears to be moving relative to the background stars because it is closer to Earth.

Select a color palette and adjust min/max until you see enough objects in the image to compare and match patterns. Can you tell which object is Sappho?

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

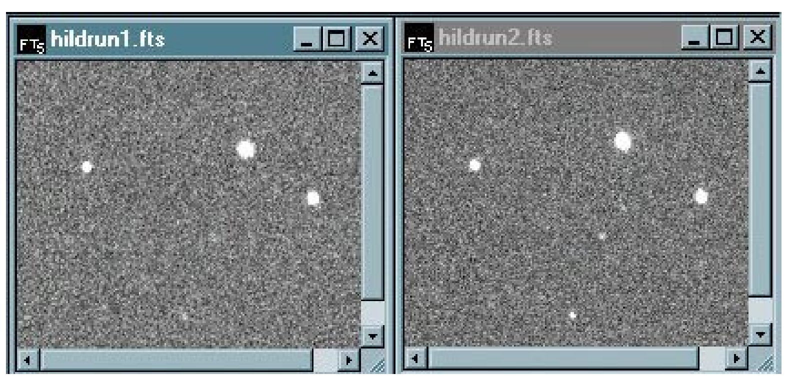
In sappho_a508:	**X= ______**	**Y= ______**
In sappho_a533:	**X= ______**	**Y= ______**

Answer Box

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

iris1: X= ______	**Y= ______**
iris2: X= ______	**Y= ______**

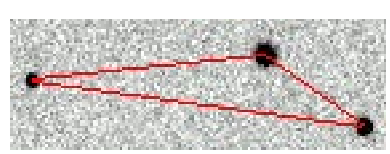
2. Hildrun. Open the files Hildrun1.fts and Hildrun2.fts.



These images were taken 15 minutes apart. Of the three bright objects, two are stars and one is an asteroid. How can we find the asteroid? Decide which one you think is asteroid Hildrun.

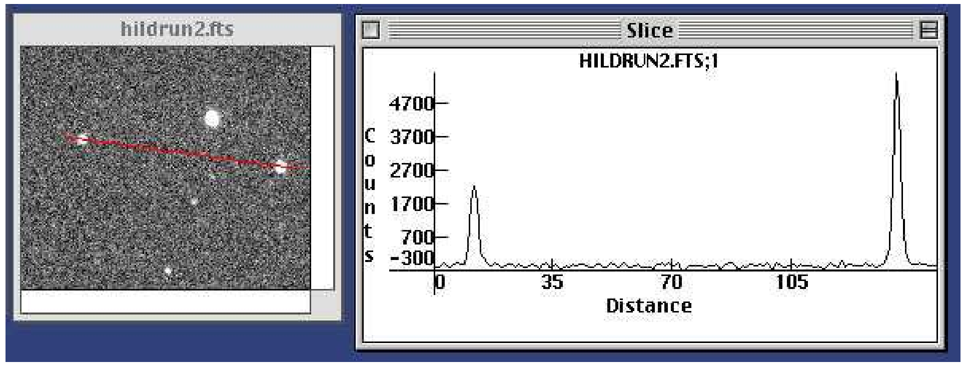
It might help if you could compare some distances between the three bright objects, since the distance between the two that are stars would not change. The distances between a star and an asteroid will change.

Use the Slice tool in the Data Tools menu to measure the distances between the three bright objects. Compare measurements in Hildrun1.fts to measurements in Hildrun2.fts to determine which object is the asteroid.



Using the slice tool (or “Plot Profile”) to measure the separation of two stars (or star and asteroid)

Question 38.
Which object is asteroid Hildrun?



In hildrun1: X= ______ Y= ______ In hildrun2: X= ______ Y= ______

3. Subtracting Images to Find Asteroids

Another nifty tool to use in finding things that have moved in two images (such as asteroids) is the ***Subtract*** tool in the ***Manipulation*** menu (HOU-IP Windows and Mac OS9).

a. Open Hildrun1.fts and Hildrun2.fts.

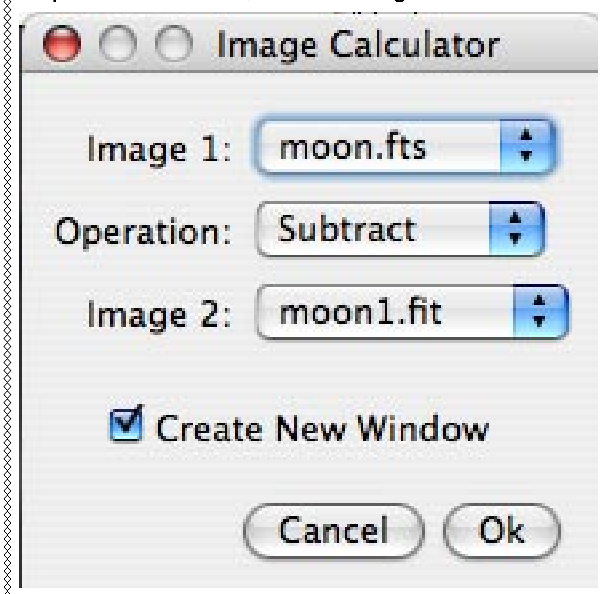
b. Click on Hildrun1.fts. In the ***Manipulation*** menu, select ***Subtract***.

c. Click on ***Displayed Image***. Choose Hildrun2.fts. Click on the down arrow for this.

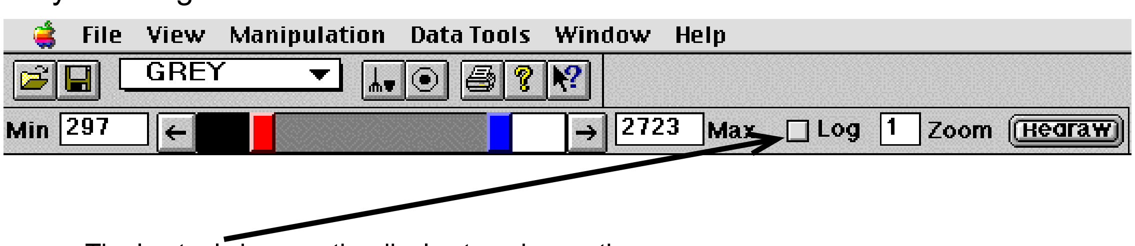
d. Click on ***Display result in a new window***. Click OK.

e. View your results. The image processor has subtracted the brightness Counts of every pixel in the first image from each corresponding pixel in the second image. Do you see an object with a double position? It will be a black object at its initial position in Hildrun1.fts and a white object at its position in Hildrun2.fts. Is this the object you thought was the asteroid?

In SalsaJ, the “Subtract” function is in the “Operations” menu, under “Image Calculator.”



Remember to click on the yellow toolbar before selecting any menu itme.



The log tool changes the display to enhance the brightness of dim objects and can help you to see those objects in certain images. Try it out on some images and see what it does...

In SalsaJ, you can find Log in the menu:
Operations > Single Image Operators > Log

4. Find asteroid Ryokan

Open Ryokan1.fts and Ryokan2.fts. These images were also taken 15 minutes apart. Most of the bright objects are stars. One is asteroid Ryokan!

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.

____

____

____

____

Asteroid Lore

A camera on the Near Earth Asteroid Rendezvous (NEAR Shoemaker) spacecraft orbiting asteroid Eros was used to construct this image of Eros on February 29, 2000 from an orbital altitude of about 200 kilometers (124 miles). The diameter of the crater near the top is 5.3-km (3.3-mi).

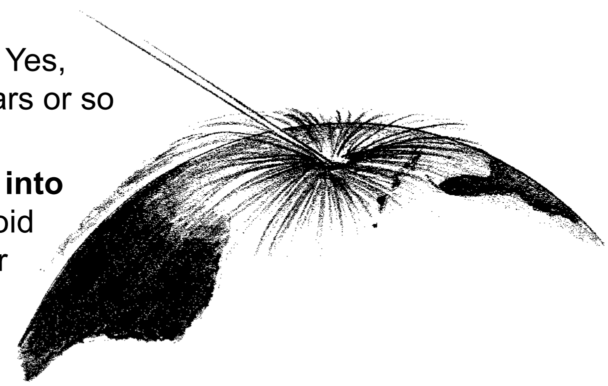
1. What are asteroids made of? All the bodies in the Solar System are made of elements in the periodic table, but which elements varies from object to object. Some asteroids have probably been around since the Solar System first formed, so analyzing the matter in asteroids helps to understand the formation of the Solar system. Asteroids are made of rock and metals like iron and nickel.

2. How do we see asteroids? They do not give off their own light, but reflect sunlight as they orbit the Sun, like planets and moons.

3. How big are asteroids? Asteroids are much smaller than most moons and planets. They range in size from a few hundred meters to a few hundred kilometers. Bodies that are a lot less than a hundred meters or so, would probably be categorized as meteoroids and not asteroids.

4. Where are asteroids found and how fast do they move? Asteroids change position in our starry sky as they orbit the Sun. Since they are part of our own Solar System, they are closer to us than the background stars. Most asteroids are found in the inner Solar System, inside the orbit of Jupiter. Even though they are moving very fast in their orbits, thousands of kilometers per hour, they appear to move slowly through the sky, since they are many millions of kilometers away from us. The asteroids that are closer to the Sun move faster than those that are farther out near the orbit of Jupiter. Our Earth also orbits the Sun and rotates on its axis, so it is the combined motions of the asteroids and Earth that cause the shift in positions of the asteroids in our images. The speed of an asteroid in its orbit does not vary as much as speed of a comet, since asteroid orbits are usually not as elongated as comet orbits.

The images of Hildrun and Ryokan were taken for HOU with the 3.5 meter telescope at Apache Point Observatory in New Mexico from the Adler Planetarium & Astronomy Museum by University of Chicago Astronomer, Dave Cole.



5. Can an asteroid or comet crash into Earth? Yes, but not very often--once every several million years or so on the average.

6. What happens when an asteroid crashes into Earth? That depends on the size of the asteroid (or comet, in the case of comet impact). A number of craters have been discovered on the Earth, such as the Barringer Meteor Crater in Arizona (photo on p. 10). That one is somewhat over a kilometer in diameter and was caused by an approximately 50 meter-sized object striking the ground at that site, one twentieth the size of the crater.

Most craters on Earth have been worn away by erosive processes due to wind and water. Craters on the Moon are still obvious because of the lack of an atmosphere and the resultant erosion.

There is a crater in the Gulf of Mexico near the Yucatan Peninsula which was found to be about 65 million years old, created just about when the dinosaurs and other species became extinct. The object was probably about 15-30 km (10-20 miles) across, created a hole about 30 km (20 miles) deep, and it was converted instantly into white hot vapor along with parts of the ground where it hit. It must have created debris that crashed down in neighboring areas, and it threw dust into the Earth's atmosphere circling the globe, dimming the sunlight. Hot debris raining down over vast areas probably caused even green vegetation to dry out and burst into flames spontaneously, causing global forest fires.

It would behoove us to seek advance warning of such an approaching body whose orbit may intersect the orbit of Earth. Such an object is called a *near Earth* asteroid or comet. An asteroid could come in quickly, but it may be technically possible to deflect an asteroid from an Earth impact course, if there is enough advance warning. The techniques you have learned in this session are the techniques astronomers use to search for such bodies.

IV. Planets

IV-A. Jupiter and Its Moons

Solar System was chosen as a name because it is the Sun's gravity that keeps the planets and other objects in orbit around the Sun. In the case of Jupiter and its moons, this is often called the *Jovian System*, a sub-system within the Solar System. *Jovian* means of or about Jupiter.

1. Finding Jupiter's bands and moons.

Open imagejup1_991101g.fts in the "jupiter_and_its_ moons" file folder.

In this image of Jupiter, the largest planet in our Solar System, you should be able to find

a. Bands on Jupiter—giant weather/climate zones.

b. The Galiliean moons of Jupiter.

You will need to adjust the Min/Max differently for each feature, to get the best view.

Question 40. What Min/Max (or Brightness/Contrast) settings are best to see bands on Jupiter?

*Min*____________ *Max*____________

Question 41. What Min/Max (or 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.

Answer Box

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

Please write all answers and coordinates:

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

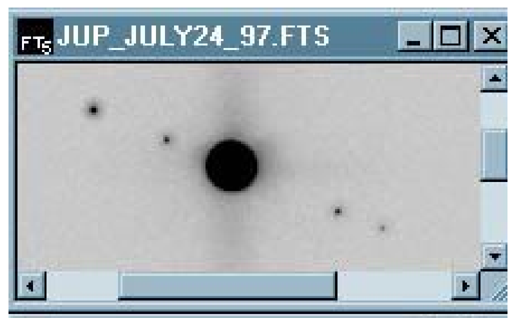
(x,y) coordinates of 2nd moon __________ , __________

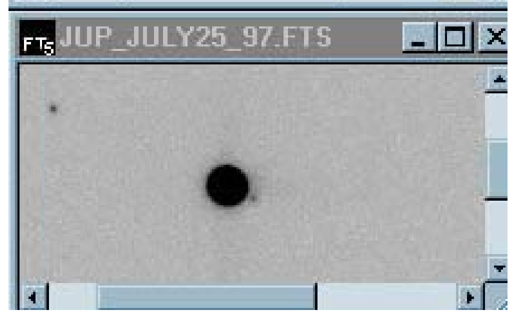
(x,y) coordinates of 3rd moon __________ , __________

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

2. The radius of Ganymede's orbit.

Open the files jup2_july24_97.fts and jup2_july25_97.fts. In jup2_july24_97.fts, the image taken July 24, 1997, all four moons are visible. From left to right they are Ganymede, Io, Europa, and Callisto. Io is near the furthest edge of its orbit from our vantage point.





In jup2_july24_97.fts, the image taken July 25, 1997, only two of Jupiter's moons are visible.

Question 44. Where are the other two?

Ganymede is near the furthest Eastern (left in the image) side of its orbit as we see it.

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

Hint: Use the slice tool to help you measure Jupiter diameter and distance to Ganymede.

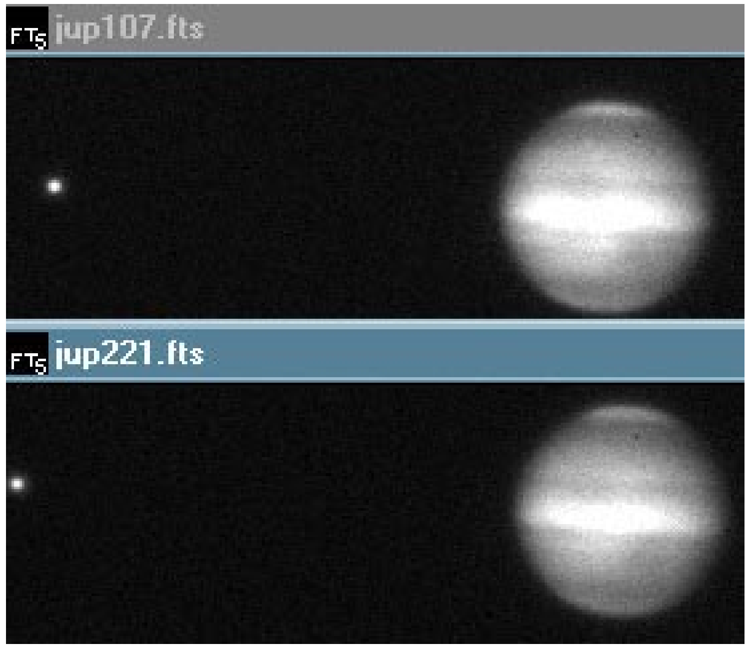
3. The radius of Io's orbit.

Open Jupiter 107.fts and Jupiter221. fts.

September 26, 1996. The first image was taken at 1:07 UT* by Walter Wild with the Yerkes Observatory 41 inch reflector telescope. The second image was taken at 2:21 UT time. Jupiter's moon, Io, was approaching its furthest position East of Jupiter from our point of view. .

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

Answer Box



Images captured at Yerkes Observatory, with 41 in reflector.

* UT stands for Universal Time. This is what all astronomers, worldwide, use and it is the time in Greenwich, England.

Describe your method.

[Hint: the center of the orbit of the moon is very near the center of Jupiter.]

IV-B. Jupiter Rotation

Does Jupiter rotate faster or slower than Earth? How many hours are in a jovian (Jupiter) day? To answer these questions,

Look for the Great Red Spot!

Open the image of jup_rotates341jb.fts. Look for the *Great Red Spot*. In this image it appears as a light gray oval shape. This is a huge storm on Jupiter that people have seen through telescopes for more than 300 years!

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

(Jupiter is about 140,000 km. diameter)

Answer Box

Open other Jupiter images from October 11th, 1998

3:41 Universal Time	jup_rotates341jb.fts
4:08 Universal Time	jup_rotates408jb.fts
4:11 Universal Time	jup_rotates411jb.fts

These images were taken for Jackie Barge from Reilly School in Chicago by University of Chicago's Yerkes Observatory with the 24 inch reflector telescope

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

Answer Box

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?

Answer Box

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

(This is called Jupiter's rotation period)

Answer Box

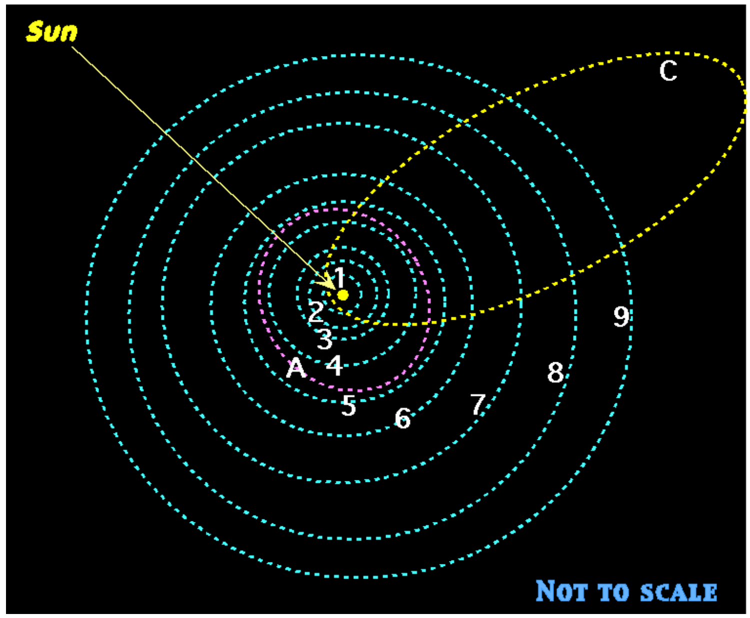
IV-C. Planet Survey

1. Use your web browser to find the web page named:
   "What Is It? How Far Is It?" It's at
   http://www.lhs.berkeley.edu/hou/activities/whatisit/)

   a. Click on "Nearby Objects." All the nearby objects for our purposes in this game are in the Solar System.

   b. In the chart of "Distances of Planets from the Sun," click on each "Select Correct Planet" in the 2nd column (Names) to make the list show all the planet names in proper order according to their distance from the Sun. When you "click-and-hold" on any of the boxes, a menu pops down with all the planets for you to choose from.

   c. In most cases, you can click on the little picture of the planet in the View column to find out if your guesses were correct, as well as to find additional interesting information about the planets.



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

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

Question 53. Write down the order of the planets in the chart below. Fill in the following:

- Planet Name
- Distance from Sun (in kilometers)
- Size (in kilometers)

In some cases, the size of the planet is not available in the Planet Survey Table. Leave the “size” column blank in those cases. You will find those diameters in the next section.

Planet Survey

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

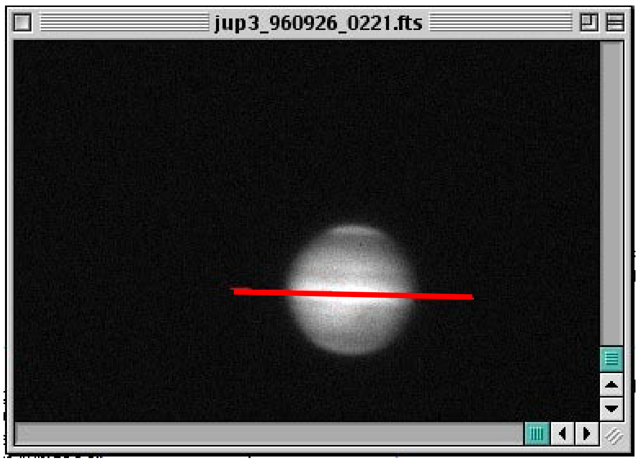
1 LIGHT MINUTE (LM) =
(0.3 million km/sec)(60 sec/min) = ____________________ million km

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

3. Using the Image Processor to measure planet sizes.

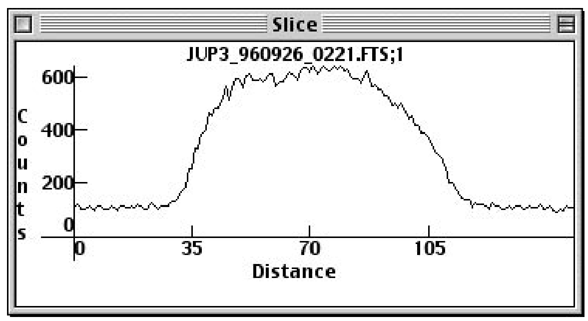
a. To finish filling in the chart on the previous page for the remaining planets, use the Image Processor to open an image of the planet whose size you want to measure. They're in the Solar System folder. Use these image names:

Planet	File Name	Pixel Scale
Mars	mars3leutsch.fth	1 pixel = 270 km
Jupiter	jupiter.fts	1 pixel = 2200 km
Saturn	saturn20010106.fts	1 pixel = 3400 km
Uranus	uranus-leutschner940429.fts	1 pixel = 2500 km
Venus	venus20010224.fts	1 pixel = 190 km



b. Find the diameter of the planet in pixels.

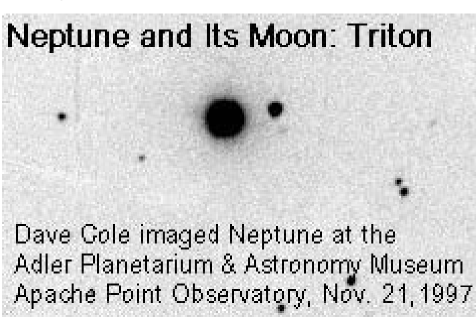
c. Find planet diameter in kilometers, by multiplying the diameter in pixels by the Pixel Scale factor (number of kilometers/pixel).



IV-D. Outer Planets

1. Neptune & Triton.

The brightest object in this image is Neptune. The star-like object next to Neptune is its largest moon, Triton.



This image was taken by Dave Cole of the University of Chicago using the Apache Point Observatory telescope in New Mexico by remote control through the Internet from Adler Planetarium on Nov. 22, 1997, 01:28 UT.

With HOU IP, open up the neptune_apo.fts image. Optional: Click on the "Log" checkbox (next to the Zoom value box in the Tool Bar)

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

Neptune:	**X=** ______	**Y=** ______
Triton:	**X=** ______	**Y=** ______

For more info on Neptune and Triton, see these websites:

Photo Gallery of Neptune & Triton:

http://nssdc.gsfc.nasa.gov/photo_gallery/photogallery-neptune.html

Fact Sheet for Neptune:

http://nssdc.gsfc.nasa.gov/planetary/factsheet/neptunefact.html

Fact Sheet for Triton:

http://nssdc.gsfc.nasa.gov/planetary/factsheet/neptuniansatfact.html

2. Uranus & Its Moons: Titania, Umbriel, and Ariel. With HOU IP, open up the uranus_apo.fts image. Click on the Log check box.

The brightest object in this image is the planet, Uranus. The three star-like objects very near Uranus are three of its moons. From left to right, they are Titania, Umbriel and Ariel. 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 December 19th, 1997 (Dec. 20, 1997, 01:28 UT)

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

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

Uranus' axis is tilted 97 degrees with respect to its orbit around the Sun. It is tilted so far over that it seems to be rolling on its side. At the time of this image, the North Pole of Uranus was pointing almost right at the Sun, and therefore towards us, since we are very close to the Sun from the viewpoint of Uranus. Since Titania revolves in the plane of the equator Uranus, from our point of view Titania never went behind or in front of Uranus, but circled around the planet, always staying the same distance away.

A. Measure the distance between Uranus and Titania in pixels.

Question 56. What is the distance between Uranus and Titania in pixels?

B. What is the distance between Titania and Uranus in kilometers (or miles)? To convert the distance between Titania and Uranus in pixels to distance in kilometers, we need to know the scale factor: how many kilometers are in each pixel. This actually depends on the distance to Uranus. The farther Uranus is from us, the *more* distance each pixel represents. At the time this image was captured, the distance between the Earth and Uranus was 20.6 AUs. (One AU = 150 million kilometers.)

Question 57. How many miles in 20.6 AUs?

At that distance, each pixel on the image represents about 9,000 km of actual space near Uranus.

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

Extra challenges:

A. Umbriel and Ariel. Find the distances between Uranus and Umbriel or Ariel. Apply the same procedure for Uranus' other two moons.

Question 59. Find the distances to:

Umbriel ____________________

Ariel____________________

B. Movement of the Uranian system.

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. Assume that Uranus was 19 Astronomical Units (AU) away when the images were taken on Sept.18, 2000. Also, for this telescope and camera, at a distance of 1 (AU), each pixel spans 440 km.

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

km

C. Find Pluto. In the "Worlds Galore" folder, you'll find four images of Pluto:

pluto20010624.fts pluto20010625.fts

pluto20010626.fts pluto20010627.fts

Find Pluto in each image and write down the coordinates you find.

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

Student Book

Version: September, 2006

Hands-On Universe

A Joint Project of
Lawrence Hall of Science
Yerkes Observatory
and TERC