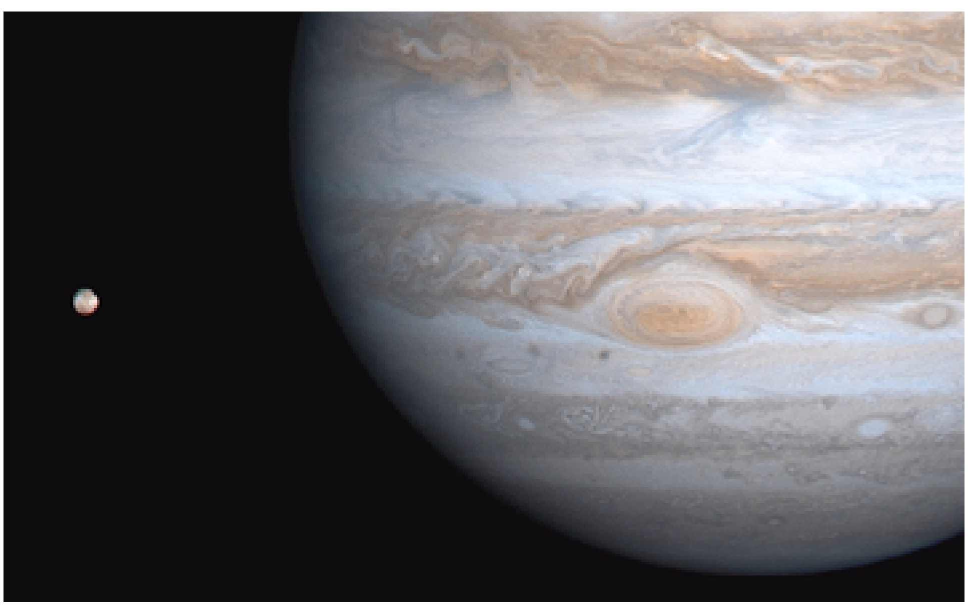
What are Jupiter and its moons like?

The challenge

Astronomers have been studying the planet Jupiter and its four largest moons. To their amazement, they have found evidence that one of Jupiter's moons, named Europa, has a salt-water ocean. That could make Europa the best place to search for life beyond Earth. The problem: Europa's ocean is covered by ice.

The Space Agency would like to send a team to explore Jupiter and its moon Europa. As a first step, they would like to set up base camps on Jupiter and Europa. But first, they want you to present evidence for what kind of environments to expect on Jupiter and Europa.

The first part of your challenge is to use the telescope to image



The planet Jupiter and its innermost moon, Io. One of Jupiter's moons, named Europa, is believed to have a salt-water ocean under its icy surface. *Image: NASA / Galileo Mission.*

Jupiter and its four largest moons, and to create a digital movie of the moons' motions. Then identify the moon Europa.

The second part of your challenge is to determine, by measuring your images: How large is Jupiter, compared to Earth? How far from Jupiter is its moon Europa? How long does it take Europa to orbit Jupiter once?

The third part of your challenge is to use your measurements, and your knowledge of physics, to calculate: How much would you weigh on Jupiter's surface, and could you survive that? How dense is Jupiter—and would it be solid enough to support your landing?

The final part of your challenge is to examine images of Europa taken by a space probe, and to see what you can tell about Europa's environment from the images. Good luck!

HEADS UP!

Next time you find yourself under the stars, look for the planet Jupiter. When it's above the horizon, Jupiter is easy to spot, even in the city, because it often appears brighter than even the brightest stars.

If the other planets or the Moon are also visible, you'll see that they all lie along a nearly straight path across the sky. If extended below the horizon, this line would also pass through the Sun. That's because the Sun, planets and their moons lie in nearly the same plane. When seen from a point within that plane, they appear to lie along a line.

Try this dizzying feat: Look up at the sky and picture the plane that the planets lie in. You'll suddenly become aware that you're standing at an angle to that plane. When it comes to outer space, which direction is "up"?!

Part 1. Your ideas about planets and moons

The days of the week are named after the Sun, Moon, and the five planets visible to the unaided eye. Why do you think the planets were so important to people thousands of years ago?

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If you had the opportunity to go to another planet or its moons, would you go? To which one and why?

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What do you think are the prospects for finding life on another planet or its moon? What kind of evidence for life would you look for?

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Part 2. Planning your exploration

In this challenge, you've been asked to evaluate the planet Jupiter and its moon, Europa, as potential landing sites to set up a base camp.

Below are some questions to be addressed in your mission report. To answer these questions, you'll need to make the measurements shown in column 2 of the table. Discuss with your team how you will go about making the measurements needed.

For this challenge, use *only:*

- the telescope, to take images of Jupiter's moons as they orbit Jupiter
- the relationship describing circular orbits, which your teacher will show you
- the law of gravity
- images (provided) of the surface of Europa, taken by a NASA space probe orbiting Europa

Remember, "Don't look it up... look *up*!" Good luck.

To answer these questions...	You'll need these...	But how will you determine them?
How far am I going? How long will it take to get there? How much sunlight will there be?	**Distance** from Earth to Jupiter **Distance** from the Sun to Jupiter	____________________ ____________________ ____________________ ____________________
How much will I weigh on Jupiter's surface?	Jupiter's **mass** compared to Earth's Jupiter's **size** compared to Earth's	____________________ ____________________ ____________________ ____________________
How dense is Jupiter? Will I sink in when I land?	Jupiter's **mass** compared to Earth's Jupiter's **size** compared to Earth's	____________________ ____________________ ____________________ ____________________
How far is Europa from Jupiter?	(**Distance** from Jupiter to Europa.)	____________________ ____________________ ____________________
On Europa, how often does it get dark? How long is night on Europa? How often will I be out of touch with Earth?	**Period** of Europa (the time it takes Europa to orbit Jupiter once.)	____________________ ____________________ ____________________ ____________________

Size and scale of Jupiter and its moons

If you know how far away Jupiter and its moons are, how could you figure out how large they are from your image? What will you need to know? What will you need to measure?

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Density and gravity on Jupiter

Before you try to land on a planet, you'd better figure out how dense it is, and what its surface gravity is, compared to Earth's.   What factors affect the gravity you would feel on the surface of Jupiter?   What do you need to know to figure out how dense something is?

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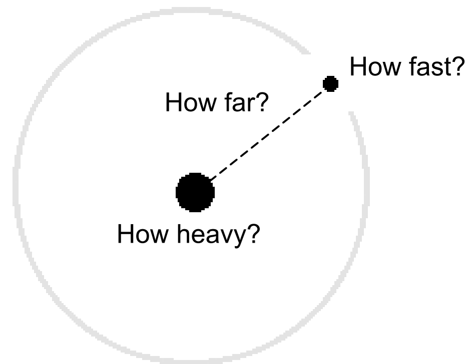
Kepler's Relation

In nature, there are many examples of one object in circular orbit around a much heavier object. For example, the Moon orbits the Earth. The Earth orbits the Sun. There are even stars that orbit a giant black hole at the center of our galaxy!



How fast a moon orbits depends on how far it is from the planet, and on how heavy the planet is.

For all of these motions, there is a simple relationship — called Kepler's relation — that connects the mass of the central object with the speed and distance to the orbiting object.

Kepler's relation says that *how fast* an object orbits depends on *how far* it is from the central object, and on *how heavy* (massive) the central object is. Kepler's relation can be written as an equation

$$\mathbf{M} \sim \mathbf{d}^3 / \mathbf{T}^2$$

where

- **d** is the **distance** between moon and planet
- **T** is the **time** it takes the moon to orbit once (called the moon's **period**)
- **M** is the **mass** of the planet

(Note that we haven't yet specified the *units* for measuring mass, distance, and time. That's because we will only be looking at changes, not absolute amounts.)

Does it make sense?

Always see if an equation makes sense before you use it. Does Kepler's relation make sense?

This relationship says, “For a given mass, the more *distant* the moon, the *more time* it will take to orbit.” That makes sense, because the farther the moon is, the *less* the pull of gravity, so the slower the moon must move to stay in orbit. Also, the moon has farther to travel, so it takes longer to orbit.

The relationship also says, “The greater the mass of the planet, the less time it will take for the moon to orbit.” That makes sense, because the greater the planet’s mass, the greater its inward pull of gravity. The moon must whip around faster to stay in orbit.

This relationship is based on many observations of the motions of moons around planets, or planets around the Sun. But the relationship can also be derived from Newton's laws of motion.

If you know any two parts of the relationship, you can determine the third. For this challenge, you will measure the period of the moon and its distance from the planet. Using the relationship, you can then "weigh" Jupiter—that is, determine its mass.

Relationships in physics

One of the goals of physics is to discover relationships between different quantities in nature—and to understand why nature chooses these relationships and not some other.

One way to describe these relationships is with equations. For example, the "period" of a moon—the time it takes to orbit its planet—depends on how far apart the moon and planet are, and also on how massive the planet is.

Using the Orbit Simulator

The Orbit Simulator lets you explore Kepler's relation visually—rather than as an equation. By experimenting with the simulator and referring back to the equation that it represents, you'll see that equations are just a shorthand way to describe relationships observed in nature.

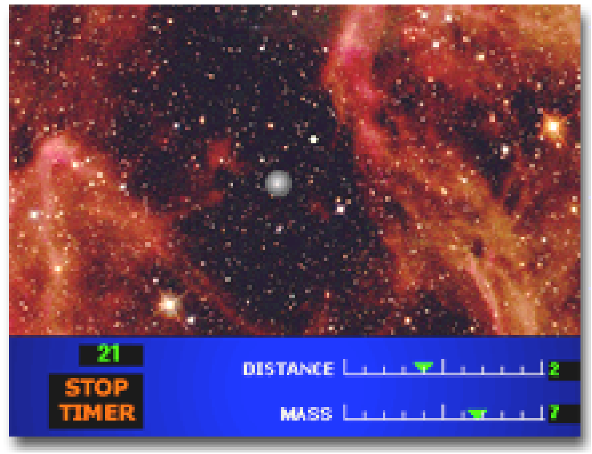
How to access the simulator

Access the Orbit Simulator at this Web address:

http://cfa-www.harvard.edu/webscope/inter/jupiter

The simulator lets you *change*

- the **distance** between moon and planet
- the **mass** of the planet



and you can *measure* or *observe*

- the **time** it takes the moon to orbit once (called the moon's **period**)

(Note that the Simulator doesn't specify the *units* for measuring mass, distance, and time. That's because we will only be looking at changes, not absolute amounts.)

Experiment 1: Effect of planet's mass on moon's period

If you could magically change a planet's mass, how would that affect its moon's period? Try using Kepler's relation to *predict* what you will observe using the orbital simulator:

Procedure

On the "Observe Orbit" controls:

Set the moon's **distance** at 4 (if it is not already there).

Set the **mass** of the planet = 1.

Use the timer to measure the moon's **period**. Record your observation in the box below.

Now use the Kepler's relation to try to *predict* : For the moon's **period** to be 3 times faster than what you measured

above, how many times more **mass** must the planet have?
Record your prediction in the box below.

Observe Orbit:	***Predict Orbit:***
Keep **distance** = 4 units Set **mass** of planet = 1 unit Measure **period** of moon: ____________________________	Keep **distance** = 4 units If **mass** of planet = ___ ? Then moon's **period** will be: (3 times less than observation A)

Test your prediction

Use the "Predict Orbit" simulator to test your prediction. Set the **mass** of the planet to the value you predicted above. Then use the timer to measure the moon's **period**. Is the **period** 3 times faster?

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Experiment 2: Effect of distance on period

If you change the **distance** between a planet and one of its moons, what effect will that have on the moon's **period**?

Procedure

First make the measurement in the Observe Orbit box below.

Then use Kepler's equation to *predict* what the moon's period will be if you triple the moon's distance from its planet.

Observe Orbit:	***Predict Orbit:***
Set **distance** = 3 units Set **mass** of planet = 2 units Measure **period** of moon: ______________________________	Change **distance** = 9 units Keep **mass** of planet = 2 units Predict **period** of moon: ______________________________

Test your prediction

Use the timer on the "Predict Orbit" simulator to test your prediction. How does your observation of the moon's period compare with your prediction in part B?

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How far is the planet Jupiter?

For your mission to Jupiter, you'll need to know how far away Jupiter is. You can use Kepler's relation to find out. See if you can apply what you've just learned.

Start with this observation:

Jupiter is observed to take 12 years to orbit the Sun.

Based on the time it takes Jupiter to orbit the Sun, which planet do you think is farther from the Sun: Jupiter or Earth? How do you know?

How many times farther from the Sun is Jupiter, compared to Earth? (Use either the relationship, or the Simulator, to find out.)

$$\mathbf{M} = \mathbf{d}^3 / \mathbf{T}^2$$

M is mass,
in units where Sun's mass = 1

d is distance,
where Earth--Sun distance = 1

T is the period,
where period of Earth = 1

The Earth is about 93 million miles from the Sun. How far is Jupiter from the Sun?

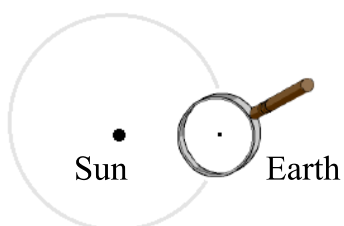
Record your result in the box below and on the DATA SHEET for the mission to Jupiter. You'll need this result later.

	Jupiter and Earth orbits around Sun, compared	
	Earth	***Jupiter***
Period to orbit around Sun	1 year	12 years
Relative distance from Sun	1	? ___________
Actual distance from Sun	93 million miles	? ___________

A map for your mission: Jupiter and Earth orbits compared

Using your result for the distance from the Sun to Jupiter, sketch in Jupiter's orbit on the drawing below. (Assume Jupiter and Earth have circular orbits.)

Make your drawing approximately to scale: In the drawing, 1/2 inch represents about 100 million miles.



Reflecting on your map

Based on your scale drawing, discuss with your team: What is the *closest* that Jupiter gets to Earth? What is the farthest?

About how long will it take you to get to Jupiter? Assume that you travel in a straight line and your spacecraft can average about 100,000 miles per hour. (This is 3 times faster than current spacecraft.)

How would you choose your crew members for a trip this long? What qualities should they have?

How much sunlight would you expect to find at Jupiter, compared to Earth? (Note: As you get farther from a light source, the brightness decreases by the square of your distance from the light.)

How are the temperatures on Jupiter and its moons likely to compare to the temperatures on Earth?

How will you "weigh" Jupiter?

For your mission, you'll need to know how Jupiter's **mass** compares with Earth's.

Discuss with your team how you could find Jupiter's mass, using: the telescope, your knowledge of Kepler's relation for circular orbits, and the following information:

	Earth	***Jupiter***
Period of its moon	27 days	? ________days
Distance to its moon	230,000 miles	?________ miles
Mass of planet	1 Earth mass	?________Earths

What information about Jupiter and one of its moons could you obtain with the telescope that will help you compare Jupiter's mass with Earth's?

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How will you get this information from your images of Jupiter and its moons?

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Part 3. Using the telescope to image Jupiter and its moons

Now you are ready to use the telescope to image Jupiter and to follow the motions of Jupiter's four largest moons.

Imaging Jupiter: With your team, take *four to six images* of Jupiter and its moons, over the course of *six hours*. Use the 'Scope it Out section to find out when and how to image Jupiter.

Downloading Your Image: You should be able to see Jupiter and its moons clearly in the GIF-format image on the Web, without any image processing.

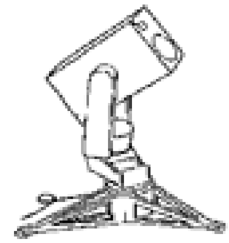
IMPORTANT: Be sure to download both the image AND its Image Info file, because this contains the information about how and when you took the image. You'll need this information later.

It's a good idea to also download the FITS file for each image as well for your records. (Click and HOLD on the underlined link, then select "Save As…SOURCE" and download

Printing the Image: The simplest way to compare your images is to print them. TIP: Use the MOImage program to INVERT your image — that is, to reverse black and white. Then when you print, Jupiter and its moons will appear black against a white background. That's much easier to measure, and you'll be saving your printer's ink as well!

Making Measurements: You can make measurements directly from your computer monitor, or from printed images. For an image printed at 100% scale, 1 inch = 72 pixels.

'Scope it out!:
How to image Jupiter and its moons.



When to observe: Use the chart at right to determine when to begin your observations. You'll need to take images about once an hour for six hours.

Selecting the Target: Use the pull-down menu to select Jupiter. (The telescope's computer will automatically determine Jupiter's location in the sky for the time you selected. Jupiter does not have a permanent "address" —or RA and DEC — in the sky, because it moves from night to night relative to the background stars. In fact, the word "planet" means "wanderer.")

Camera: Use the MAIN camera, ZOOMED IN. (If some of the moons are out of the field of view, you can use ZOOMED OUT instead.)

Filter: Try using the grey filter ("ND-40") to cut down on Jupiter's glare.

Exposure time: Use a 10 second exposure if you are using the grey filter. If Jupiter is over-exposed, try using a shorter exposure time.

When is Jupiter visible?

This chart shows the approximate times when Jupiter rises and sets for the first of each month. The actual time will depend on the telescope's location:

For the telescope in Arizona, add 20 minutes
For the telescope in Boston, subtract 25 minutes

Date	Jupiter rises...	Jupiter highest	Jupiter sets...	Distance from Earth
2003				
Dec	12 23a	6 43a	1 03p	5.5 a.u.
2004				
Jan	10 25p	4 47a	11 07a	4.8 a.u.
Feb	8 17p	2 41a	9 02a	4.5
Mar	6 05p	12 35a	7 00a	4.4
Apr	3 45p	10 16p	4 48a	4.5
May	1 39p	8 12p	2 46a	4.9
Jun	11 44a	6 14p	12 48a	5.4
Jul	10 03a	4 28p	10 54p	5.8
2005				
Jan	12 45a	6 29a	12 14p	5.4 a.u.
Feb	10 47p	4 33a	10 16a	5.0
Mar	8 50p	2 39a	8 23a	4.6
Apr	6 31p	12 25a	6 13a	4.5
May	4 16p	10 10p	4 06a	4.6
Jun	2 05p	8 01p	1 59a	4.9
Jul	12 13p	6 07p	12 04a	5.3
2006				
Jan	2 51a	8 09a	1 24p	5.9 a.u.
Feb	1 11a	6 23a	11 35a	5.4
Mar	11 25p	4 38a	9 49a	5.0
Apr	9 17p	2 32a	7 43a	4.6
May	7 03p	12 22a	5 36a	4.4
Jun	4 43p	10 01p	3 23a	4.5
Jul	2 30p	7 57p	1 19a	4.8

Reflecting on your images.

Size of Jupiter. Why does Jupiter appear so small, compared to, say, an image of our Moon?

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Point of view. Why do we see Jupiter's moons arranged on a more or less straight line?

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Forces and motion. What keeps the moons in orbit around Jupiter? Why don't they fly off into space?

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Universal gravity. How far into space do you think Jupiter's gravity extends? What about Earth's?

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Speed of the moons. Which moons appear to have moved, from image to image? Why have some moons moved more than others?

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Getting the big picture. Jupiter and its moons look like a miniature "solar system." How does the plane of the moons compare to the plane of the solar system? Why might that be?

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Orbits, Life, and Planets Beyond our Solar System

The shape of a planet's orbit can influence whether life is possible there. As a planet... (more here).

End side bar.

Create a movie of Jupiter and its moons

You can turn the images you took into a digital movie that will help you figure out which moon is which.

Procedure

1. On your computer, launch the MOImage processing software, and close any other programs.

2. From the MOImage program, open each of your Jupiter images, one after the other.

3. From the **Edit** menu, select **Shift**. This features lets you move each of the images relative to each other, so that the Jupiters line up on top of each other. Choose one of the images as a background image. Carefully align the other images, one by one, using the mouse and arrow keys.

4. When you are satisfied that all the Jupiters are in the same spot in each of your images, then go to the **Edit** menu and select **Stack / Create Stack**.

5. To see your animation, select **Edit / Play Animation**.

6. To save your movie as an "animated GIF" file, which can played in any web browser, select **Edit / Save as Animated GIF**.

Which moon is Europa?

For your mission, you'll need to identify the moon Europa in the images you made. The diagram (opposite page) shows the challenge you face. Jupiter's four largest moons, including Europa, all orbit in the same plane. Europa is the *second-nearest* moon to Jupiter. The challenge is that, from Earth, you are observing the plane of the moon's orbits *edge-on*. That makes it tricky to tell which moon is which.

From the diagram you can see that Callisto is farthest from Jupiter of the four moons. But in the edge-on view, as we would see it from Earth, Callisto *appears* closest to Jupiter at that moment!

> On the World Wide Web, watch the simulation of a moon's motion at:
>
> http://cfa-www.harvard.edu/webscope/inter/jupiter2
>
> Note that the moon appears to move away from Jupiter, then reach a *turning point* and move towards Jupiter again. At its turning point, the moon's *apparent distance* from Jupiter equals it *actual* distance from Jupiter.

Discuss with your team: How can you figure out which moon is which by following the moons through several images?

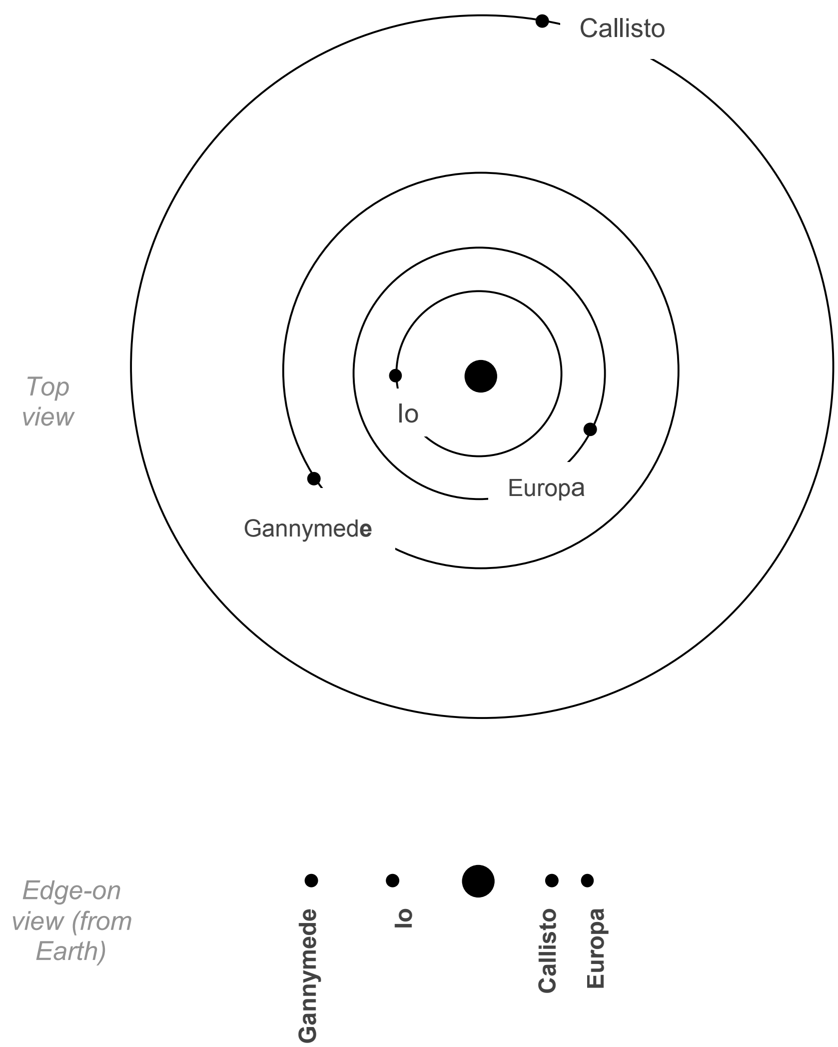
Use two lines of evidence to help you:

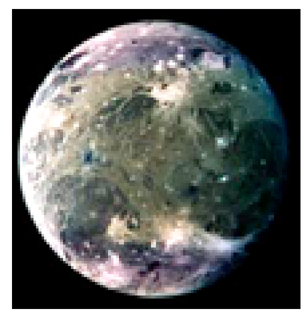
1. The *turning-point* charts on the next pages show the *farthest* that each of the moons appears to move from Jupiter. To use them, follow the instructions on the charts.

2. You may also need to consider the *speed* of the moons in helping you decide which moon is Europa. Use your digital movie as evidence, or use "Chart the Motions of Jupiter's Moons" on p. X.

When your team is confident that you know which moon is Europa, then label Europa in your image. How did you arrive at your conclusion?

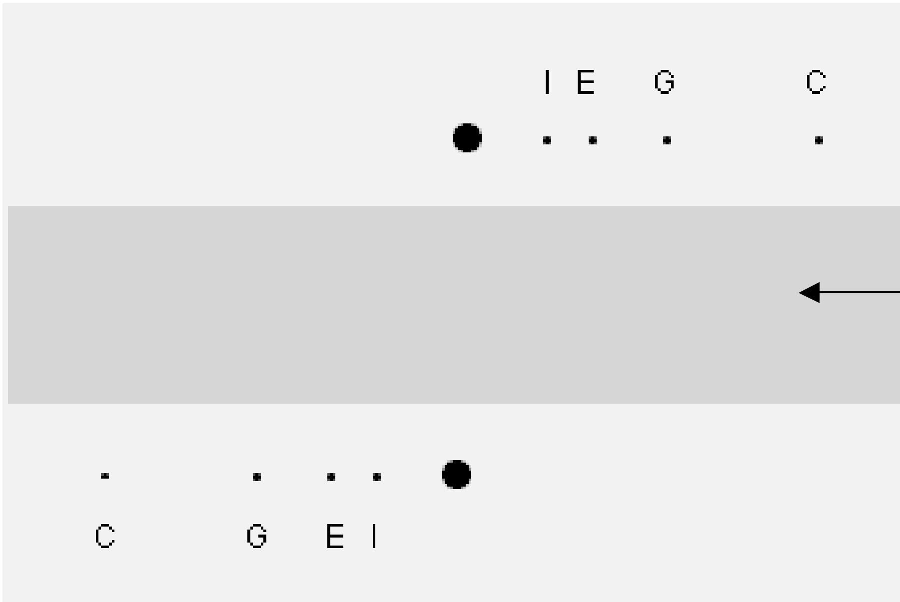
The four largest moons of Jupiter





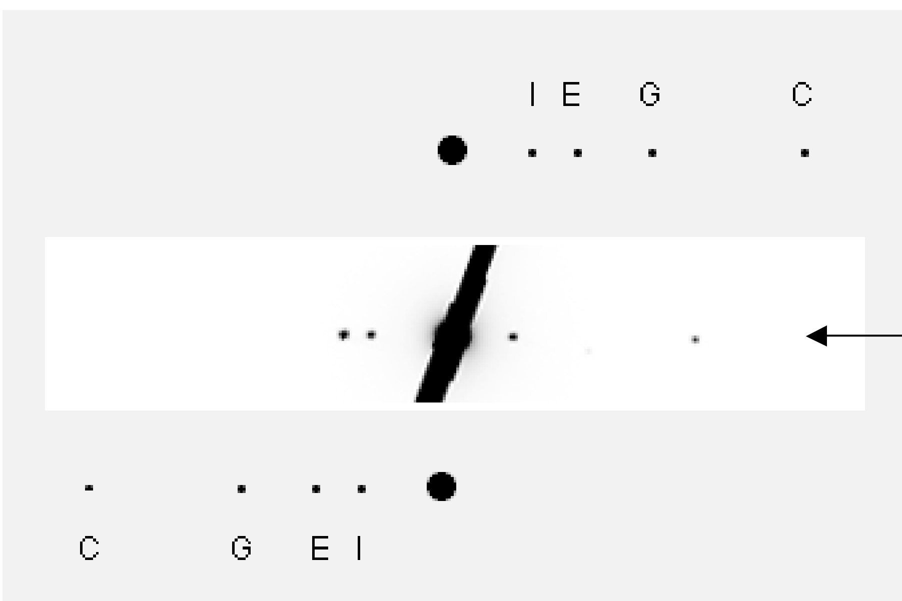
Four very different worlds. **Top to bottom:** Io, Europa, Gannymede, Callisto. *NASA.*

Turning-point guide for a zoomed-out image



Place your image here

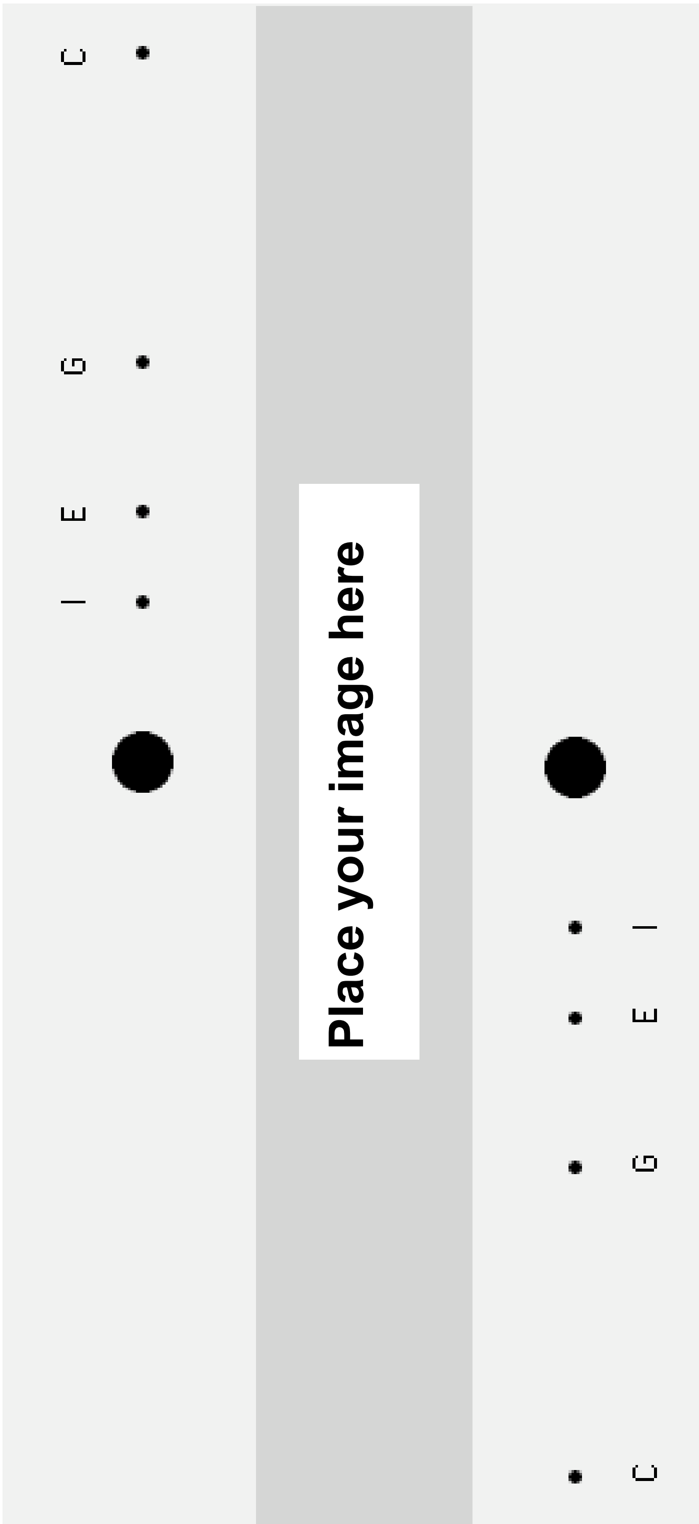
Use this chart to help you figure out which moon is Europa. Cut out your image of Jupiter and its moons. Place it between the diagrams as shown. The two diagrams show the *farthest* from Jupiter that each of the moons can appear in your image. See the example below for help.



Sample image

In the sample image, the moon at the right must be Callisto, because it appears farther from Jupiter than any of the other moons can go. The moon at the left could be Europa or Ganymede, but not Io. To determine which moon is definitely Europa, you'd need to examine the moons' motions through several images.

Turning-point guide for a zoomed-in image

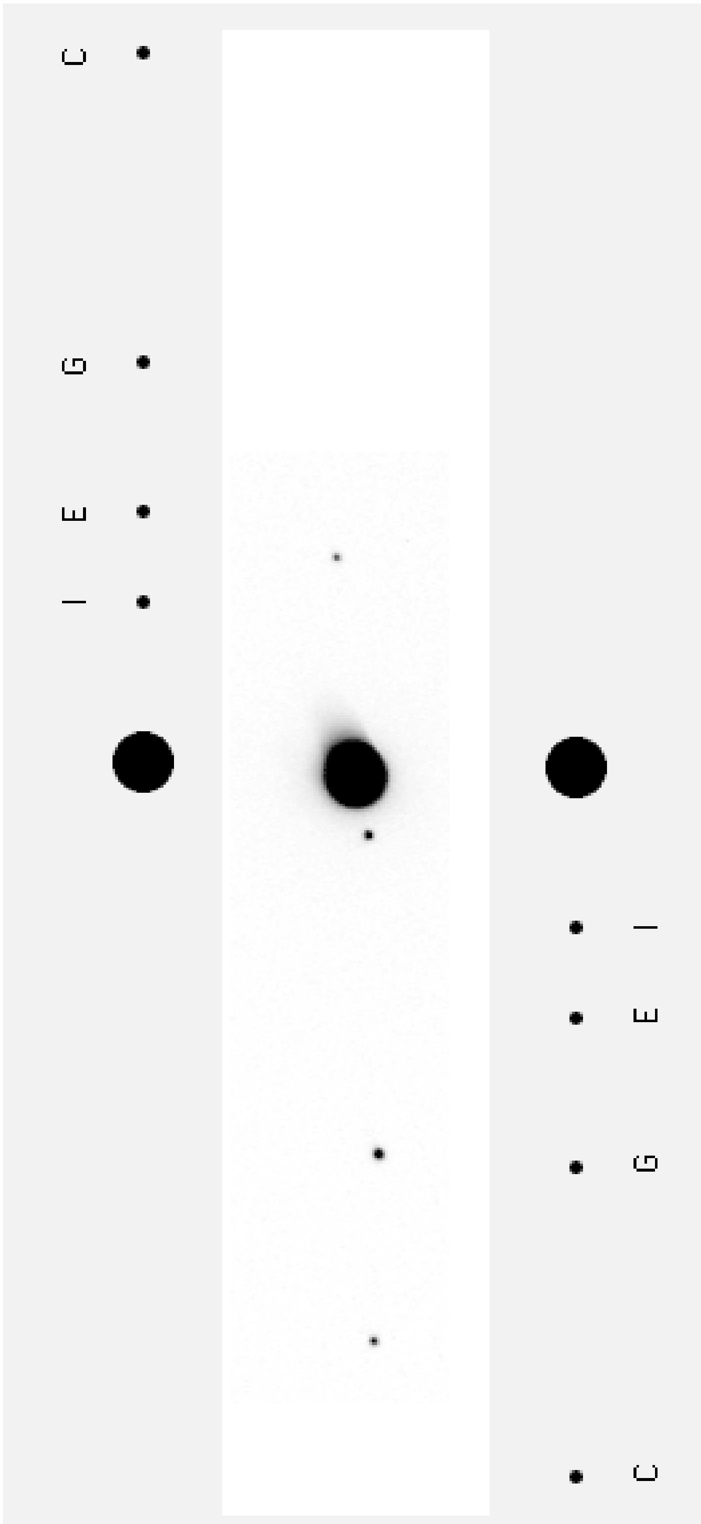


Use this chart to help figure out which of the moons in your image is Europa.

Cut out the part of your image showing Jupiter and its moons. Place it between the two diagrams as shown.

The diagrams show the *farthest* that each moon can appear from Jupiter in your image.

The letters stand for the names of the moons: Io, Europa, Ganymede, and Callisto.



Turning point guide for a sample image

Can you tell which moon is which, for this sample image?

The diagrams show the *turning points* for Jupiter's four largest moons. These points are the farthest from Jupiter that each moon can appear in your image.

The first moon on the left must be Callisto, because it appears farther from Jupiter than the other moons can go. (Its orbit is beyond that of the other three moons.)

Can you figure out which moon is Europa?

Chart the motions of Jupiter's moons

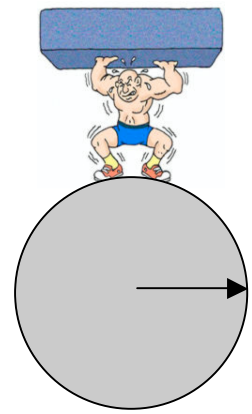
	Distance (# of pixels) from center of Jupiter to...			
	1st moon (on left)	**2nd moon**	**3rd moon**	**4th moon (on right)**
Image 1 (earliest)				
Image 2				
Image 3				
Image 4				
Image 5				
Image 6 (latest)				
No. of pixels the moon has moved, from 1st to last image				

Instructions

1. Open your first Jupiter image using the MOImage program.
2. Make sure the line-measuring tool is clicked (arrow icon).
3. Click and drag the mouse to measure between two points.
4. Measure the distance from the center of Jupiter to each moon in your image.
5. Record the results in the chart above.
6. Do the same for each image.
7. Can you tell which moon has moved the most? Next most? Which moon do you think is Europa?

MEASURING *UP!*

Part 4. What can I tell from my images?

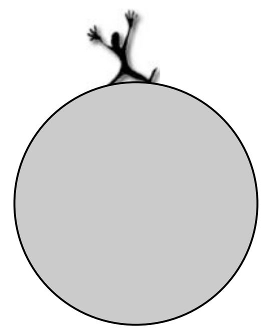


How much would you weigh on the planet Jupiter? Could you stand up?

Congratulations! You've imaged Jupiter and its moons and you've identified the moon Europa. The next part of your challenge is to use your images to figure out what it would be like to land on Jupiter or Europa.

> If you could land on Jupiter, how much gravity would you find there? Could you stand up, or would you be too heavy?
>
> Is Jupiter dense enough to land on—or would you sink in?

To answer these questions, you'll need to determine how large and how heavy Jupiter is, compared to Earth. You can determine Jupiter's size directly from your image. To determine how heavy Jupiter is, you'll first need to determine: How far is Europa from Jupiter? And how long does Europa take to orbit Jupiter? Then you can apply Kepler's relation to find Jupiter's mass compared to Earth.



How dense is Jupiter? Would you sink in?

How large is Jupiter?

How does Jupiter's size compare to Earth's? You can find out by measuring your image of Jupiter.

Remember that you can tell how large something is if you know

1) how far away it is, and
2) its angular width in degrees.

The rule is: "An object that appears 1 degree wide, is 57 times farther away than it is wide. If the object appears narrower than 1 degree wide, it will be proportionally farther away." (See "A Wrangle with Angles.")

You already know how far away Jupiter is. In this activity, you'll measure how wide it is, in degrees, in your image. Then you'll be able to figure out how large Jupiter is.

Work with *either* a printed Jupiter image, *or* a Jupiter image on your computer monitor.

Method A: Working with your printed image

If you are working from an image printed at normal size, use this method. If you are working from an image on the computer monitor, use Method B below.

1. Using a ruler, measure the diameter of Jupiter in your image in millimeters (preferably) or in inches. Record the result here:

Jupiter is ______________________________ (mm / in) wide.

2. To determine how many degrees this is, you'll need to know the *scale of your image*, in degrees per inch, or degrees per millimeter:

For a zoomed-out image:
A *zoomed-out* image contains 720 pixels per degree.
Standard sized printing is 72 pixels per inch, so
1 inch = 0.1 degree
1 millimeter = 0.004 degree

For a zoomed-in image:
A *zoomed-in* image contains 1440 pixels per degree.
Standard sized printing is 72 pixels per inch, so
1 inch = 0.05 degree
1 millimeter = 0.002 degree

3. Using your measured width of Jupiter, in inches or millimeters, and the scale of your image, how wide in Jupiter in degrees?

Jupiter is ______________________________ degrees wide.

4. Skip Method B and go on to the next section.

Method B. Working with your image onscreen

If you are working with your image on a computer monitor, use this method. If you are working from a printed image, use Method A above.

1. Open your image in the MOImage processing program. Using the mouse, click and drag a line across a diameter (the widest part) of Jupiter. This width, in pixels, in displayed in the box above the image. Record the result here:

Jupiter is _______________________________ pixels wide.

2. To determine how many degrees this is, you'll need to know the *scale of your image*, in degrees per pixel:

   For a zoomed-out image:

A *zoomed-out* image contains 720 pixels per degree.
So 1 pixel spans 1/720 degree = 0.00139 degree.
1 pixel = 0.00139 degree

For a zoomed-in image:
A *zoomed-in* image has 1440 pixels per degree.
So 1 pixel spans 1/1440 degree = 0.000694 degree.
1 pixel = 0.000694 degree

3. Using your measured width of Jupiter, in pixels, and the scale of your image, how wide in Jupiter in degrees?

Jupiter is _____________________________ degrees wide.

4. Go on to the next section.

Determining the size of Jupiter in miles

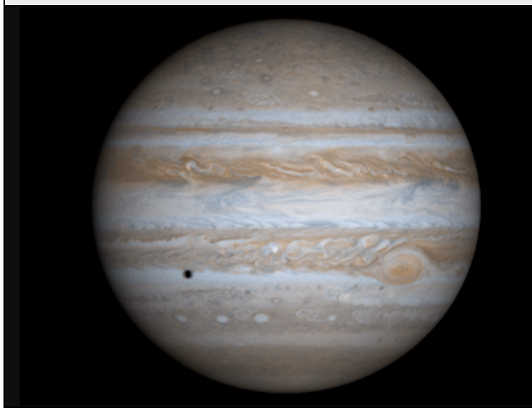
Now you know the angular width of Jupiter, in degrees, and you know its distance, in miles. Discuss with your team how you will use these to determine the diameter of Jupiter, in miles.

Record your result here, and also on the DATA PAGE:

Diameter of Jupiter = ______________________ miles

How does Jupiter's size compare to Earth's? (Earth is about 8000 miles in diameter.)

Jupiter is about _______________ times wider than Earth.

If Jupiter is this size...	Then draw Earth to the same scale:
	

How many Earths would fit inside Jupiter? (How much larger is Jupiter's *volume* than Earth's?)

Jupiter has about____________________ times the volume of Earth.

Record your results on the mission DATA PAGE.

Does the size of Jupiter alone tell you anything about how strong the gravity will be at Jupiter's surface? What other information would you need?

____

How far is Europa from Jupiter?

For your mission, you'll need to know the distance from Jupiter to Europa—that is, the radius of Europa's orbit.

To find out, use any of the previous diagrams showing the orbits of Jupiter's moons. These diagrams are drawn to scale. Just measure the distance between the *center* of Jupiter and the *center* of Europa in one of these diagrams (preferably in millimeters). Then measure the diameter of Jupiter in the diagram (preferably in millimeters). Since you have already determined the actual diameter of Jupiter, in miles, you can set up a proportion to tell you the actual distance from Europa to Jupiter, in miles.

Record your result here and on the DATA PAGE:

Europa is __________ miles from Jupiter.

How does this distance compare with the distance between Earth and our own Moon?

____

____

Why do you think Europa orbits Jupiter so much faster than our Moon orbits Earth, considering that Europa is farther from its planet?

____

____

Revisit your ideas after the next activity.

How long does it take Europa to orbit Jupiter?

For your mission, you'll need to know how long it takes Europa to orbit Jupiter. This information will help you figure out:

Our own Moon takes about one month to orbit the Earth. That's where the name "month" came from!

- How heavy is Jupiter? (Europa's period depends on its distance from Jupiter and on Jupiter's mass.)
- How often would I lose sight of Earth—and lose communication with Earth—from a base camp on Europa? (Europa passes behind Jupiter once each orbit.)
- How often would a base camp on Europa be in total darkness? (Europa moves into Jupiter's shadow once each orbit.)

Use your images to estimate the period of Europa's orbit. Just follow the instructions on the next few pages. Be sure to:

Look first at the example on the next page.

Use your *earliest* and *latest* images of Jupiter.

Note the time elapsed between these two images.

Line up the images carefully when using the charts.

Do your figuring here:

The time between the two images is ___________ hours.

Europa moved ____________ (fraction of an orbit) in that time.

The period of Europa's orbit is *approximately* _________ hours or _____________ days.

Record your result on the DATA PAGE.

ZOOMED-OUT IMAGE

How to estimate the period of Europa's orbit (example)

1. Cut out your earliest and latest images of Jupiter.

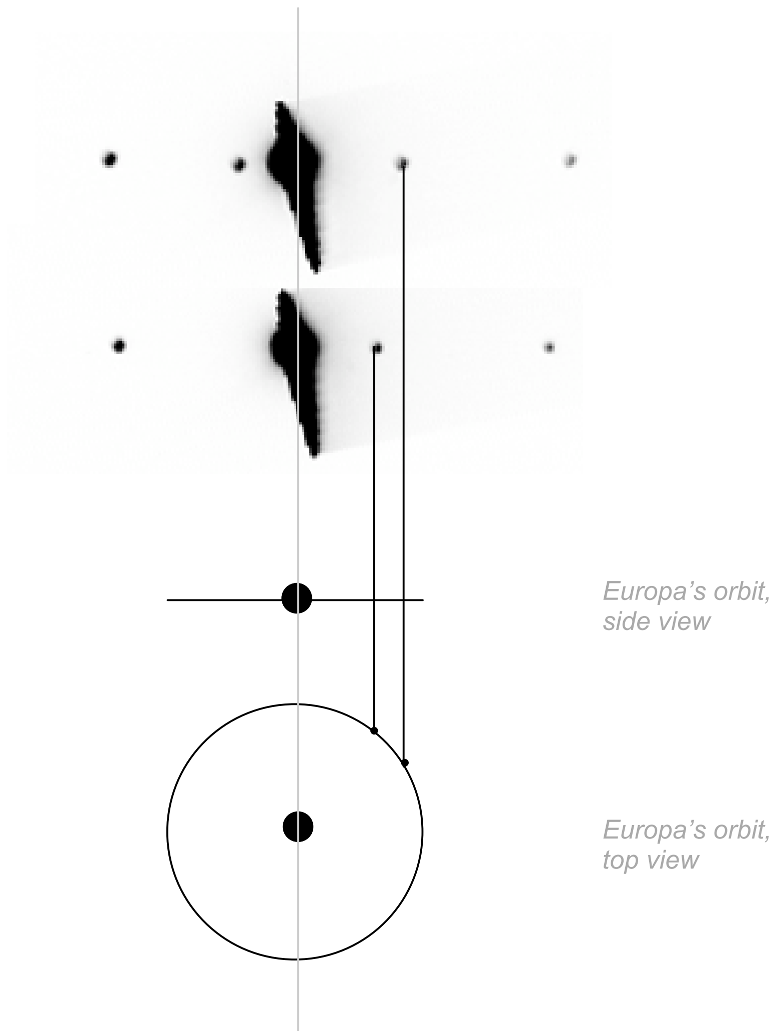
2. Place the images so the *center of Jupiter* in each image line up with the drawings of Jupiter in the diagrams.

3. For each image, *carefully* draw a straight line from Europa to the diagrams. Make sure the lines are parallel.

4. These lines will help you see how far Europa has moved in its orbit, during the time between your first and last image.

5. Now figure out, *What fraction of its entire orbit has Europa moved during this time?* How you estimate this fraction is up to you.

6. Finally, estimate how long it would take Europa to orbit Jupiter once.



ZOOMED-OUT IMAGE

How to estimate the period of Europa's orbit

1. Cut out your first and last images of Jupiter.

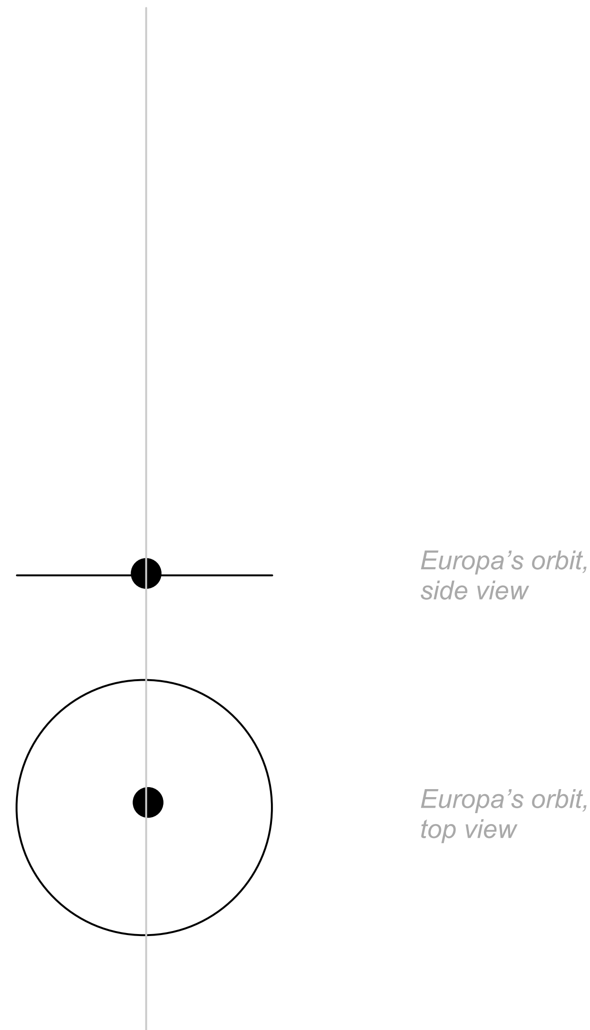
2. Place the images so the *center of Jupiter* in each image line up with the drawings of Jupiter in the diagrams.

3. For each image, *carefully* draw a straight line from Europa to the diagrams. Make sure the lines are parallel.

4. These lines will help you see how far Europa has moved in its orbit, during the time between your first and last image.

5. Now figure out, *What fraction of its entire orbit has Europa moved during this time?* How you estimate this fraction is up to you.

6. Finally, estimate how long it would take Europa to orbit Jupiter once.



ZOOMED-IN IMAGE

How to estimate the period of Europa's orbit

1. Cut out your first and last images of Jupiter.

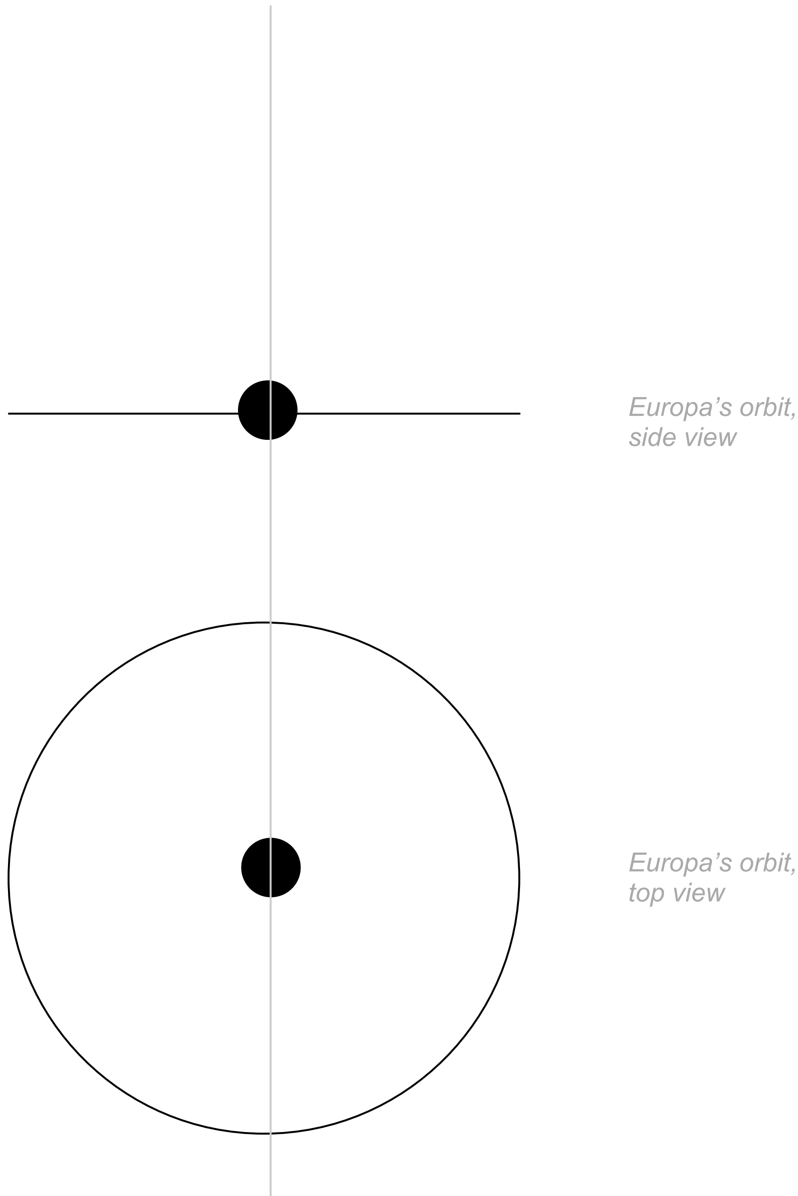
2. Place the images so the *center of Jupiter* in each image line up with the drawings of Jupiter in the diagrams.

3. For each image, *carefully* draw a straight line from Europa to the diagrams. Make sure the lines are parallel.

4. These lines will help you see how far Europa has moved in its orbit, during the time between your first and last image.

5. Now figure out, *What fraction of its entire orbit has Europa moved during this time?* How you estimate this fraction is up to you.

6. Finally, estimate how long it would take Europa to orbit Jupiter once.



Thinking about your results

How does the period of Europa's orbit compare with the time it takes our own Moon to go around the Earth?

____

____

Why do you think that Europa orbits Jupiter so much faster than our own Moon orbits Earth?

____

____

If you were exploring Europa, how long would you have before you were plunged into night, as Europa passes into Jupiter's shadow? How often would you be out of sight of Earth?

____

____

How heavy is Jupiter?

Knowing how Jupiter's mass compares to Earth's will help you determine how much gravity you'll feel at its surface. Jupiter's mass is also a clue to what it might be made of.

What information about the moons will you need to determine the mass of Jupiter? Why?

____

____

____

Since you don't need to find Jupiter's mass in grams, but only its mass *relative to Earth*, you can use the simple relationship:

$$\mathbf{M} = \mathbf{d^3 / T^2}$$

M is mass, in units where Earth's mass = 1
d is distance, where Earth-Moon distance = 1
T is the period, where period of Earth's Moon = 1

Set **d** = distance to Europa, *compared to* Earth-Moon distance
= (__________ miles / 230,000 miles) = ______________.

Set **T** = period of Europa *compared to* period of Moon
= (_____________ days / 27.3 days) = ________________.

Calculate **M =** mass of Jupiter *compared to* Earth
= ___________________ times more massive.

Record these results on your missions DATA PAGE.

How much would you weigh on Jupiter?

How much stronger is Jupiter's gravity than Earth's (at the surface of each planet)?

To answer this question, discuss with your team what factors influence the gravitational pull you feel from a planet. What equation describing the relationship between these factors will you need? Which of your previous results will you need?

____

____

____

How much would you weigh at the surface of Jupiter?

____

____

If Jupiter is so much more massive than Earth, why isn't your weight proportionately that much more?

____

____

In your report, indicate whether you recommend trying to land on Jupiter, based on its surface gravity.

____

____

How dense is Jupiter?

Can you land on Jupiter, or would you sink right in? Is Jupiter solid rock? Is it liquid or gas? One line of evidence to use is the average **density** of Jupiter.

What information will you need to determine Jupiter's density? Looking back on your results so far, do you have that information?

____

____

Using your results, how does Jupiter's **density** compare to Earth's?:

Jupiter is ________________ times as dense as Earth.

Since Earth's density is about 5.5 grams per cubic centimeter, how dense does this make Jupiter?:

Jupiter's density is _______________grams per cubic centimeter

Compare your result with the densities of the materials in the table at right.

Material	Density
Liquefied natural gas	1 g/cc
Water	1 g/cc
Rock	3 g/cc
Iron	5 g/cc

How does the density of Jupiter compare to Earth density (about 5.5 grams/ cubic centimeter)? Could Jupiter be solid rock?

____

____

In your judgment, is it safe or unsafe to attempt to land on Jupiter?

____

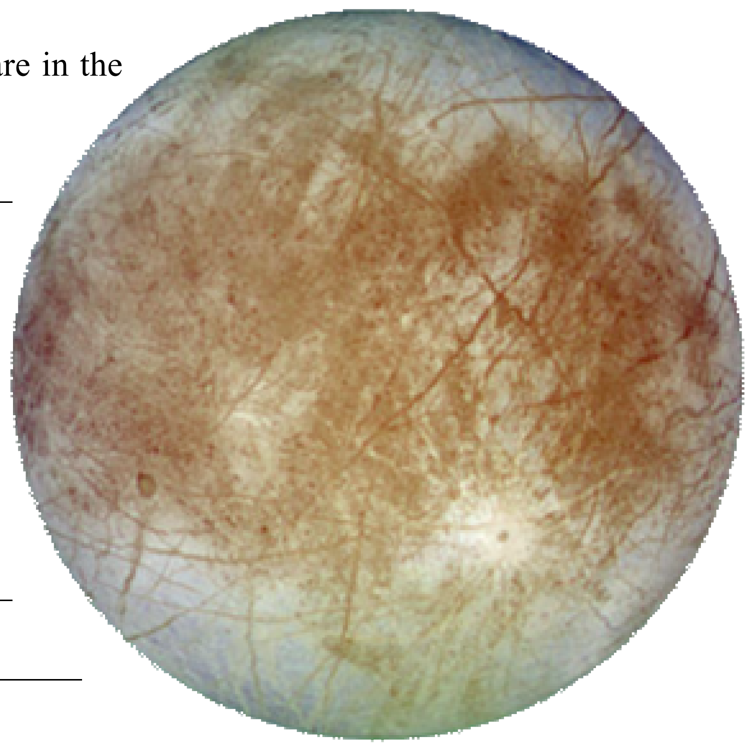
____

What is the surface of Europa like?

NASA's *Galileo* spacecraft orbited the moon Europa, and sent back images of its surface. See what you can conclude about Europa from studying these images. You'll find additional color images at:

http://www.jpl.nasa.gov/galileo/images/europa/eurimages.html

Diameter of Europa: 1882 miles
Mass compared to Earth (Earth = 1): .0083
Density of Europa: 3.01 (grams/ cubic centimeter)



What do you think the bright spot and dot are in the lower right portion of this image of Europa?

____

____

How does this image compare to Earth's moon? What might account for the lack of many craters?

____

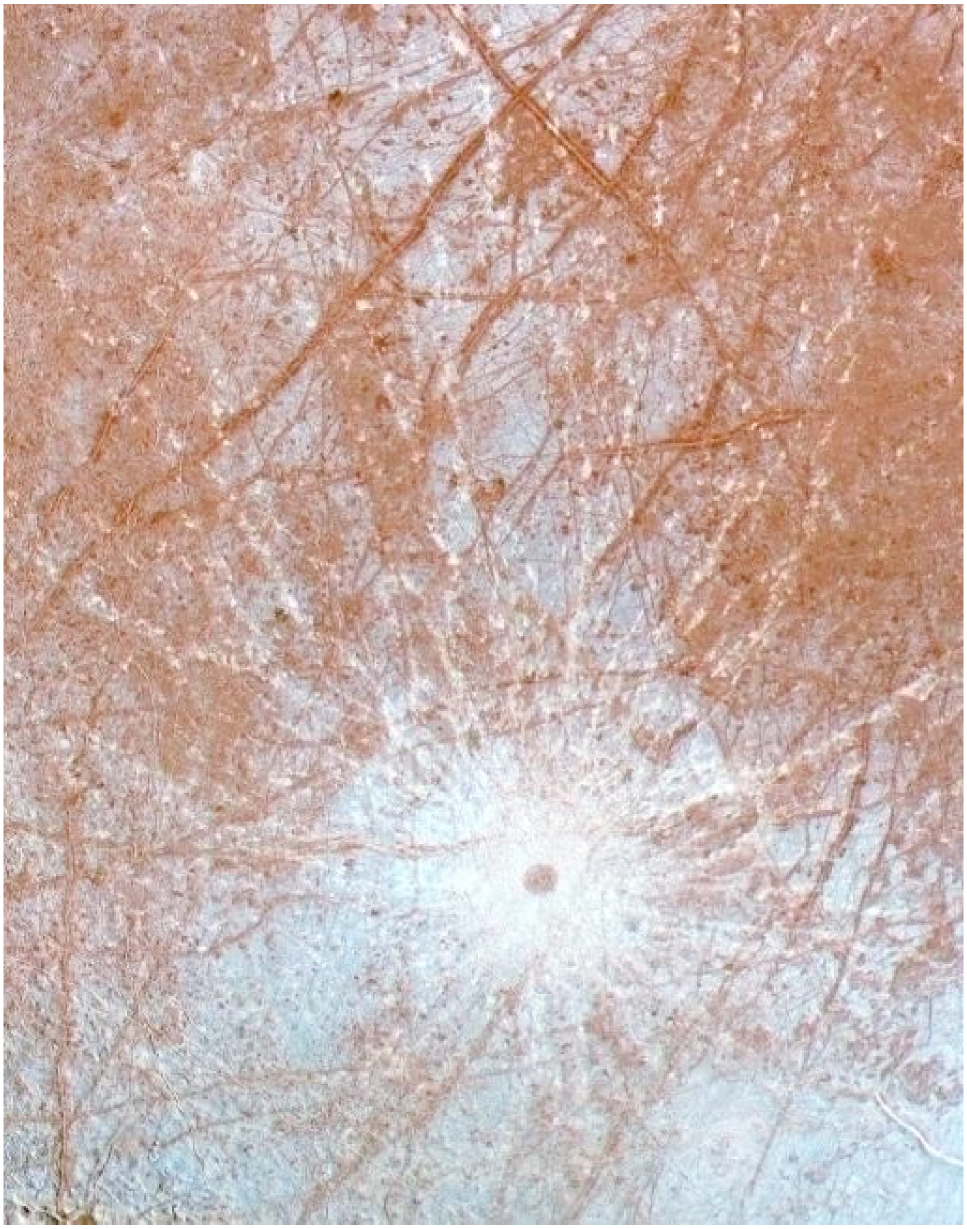
____

What might the dark, reddish-brown material be? What are possible sources of this material? What evidence would you need to support your hypotheses?

____

____

Surface of Europa (cont'd.)



A close-up view of the Pwyll impact crater on Europa. The crater was likely caused by an asteroid or comet crashing onto the surface . The image shows an area about 800 miles across. *Image courtesy NASA.*

Surface of Europa (cont'd.)

The surface of Europa is very bright. What might this indicate?

____

____

____

____

____

____

What might the cracks on the surface indicate? Where are on Earth might you see cracks like this?

____

____

____

____

____

____

This close-up of Europa shows an area roughly 19 miles across and 44 miles top to bottom.

Part 5. Making sense of your results

Congratulations! You're now ready to write your report. Be sure to include the following advice:

- How easy or dangerous would it be to use Jupiter as a landing site for a base camp? Support your conclusions with the evidence that your team has gathered.

- Do you think it would be safe to land on Europa? Is there any particular spot on Europa you would recommend as a base camp?

- Create a "portrait" of Europa and its environment—for example, create a postcard to a friend describing what it would be like for an expedition team on the moon Europa. Your portrait should be based in part on information from your own images and measurements, and in part on your interpretation of the images taken by a NASA space probe orbiting Europa.

  (Your portrait might consider: From Europa, how big does Jupiter look in the sky, in comparison to our Moon or sun from Earth? How much sunlight would there be compared to Earth? How long would there be sunlight before night fell?)

In your report, be sure to include the evidence your have gathered, including your images of Jupiter and its moons, your measurements, and your calculations.

VOYAGE TO EUROPA
DATA PAGE

Distance to Jupiter:

Jupiter is _______________ times further from the Sun than is Earth.

Jupiter is _______________ miles from the Sun.

Jupiter's closest approach to Earth is _____________ miles.

Size of Jupiter:

Jupiter is ___________________ miles wide, compared to 8000 miles wide for Earth.

Jupiter's volume is_________________ times the volume of Earth.

Mass and density of Jupiter:

The mass of Jupiter is _________________ grams

The density of Jupiter is ______________ grams per cubic centimeter

Gravity on Jupiter:

A 100 pound person would weigh_______________ pounds at the surface of Jupiter.

Size of Europa:

Europa is less than _________________ miles wide

Radius of Europa's orbit:

The distance from Europa to Jupiter is about _______________ miles

Period of Europa's orbit:

It takes Europa _____________ days (hours) to orbit once around Jupiter.

BRIEFING ROOM
TIMELINE

Ancient Roman times: The planet Jupiter is named after one of the Roman gods.

1610. Using one of the first telescopes, Galileo Galilei discovers four moons orbiting the planet Jupiter. This shows that Earth is not the only "center of attraction" in the heavens, and makes it easier to accept Copernicus' conclusion that the Earth orbits the Sun.

Some townspeople refuse to look through Galileo's telescope, calling it a distortion of reality.

1979. Three scientists from the Jet Propulsion Laboratory conclude that Jupiter's strong gravity may flex and heat its nearby moons.

1979. Three days later, the Voyager spacecraft sends the first images of volcanoes on Io, the closest moon to Jupiter.

1996. NASA's *Galileo* spacecraft, is launched to explore the planet Jupiter and its moons.

2000. The Galileo spacecraft arrives at Jupiter sends back images and data about the planet Jupiter and several of its moons.

2000. Margaret Kivelson and her team from the University of California conclude that an ocean exists under the surface of Europa. Evidence: Telltale magnetic fields from the sloshing of salt-water inside Europa.

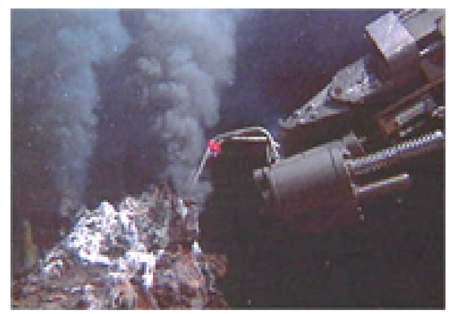
Additional projects

Is there life under the ice on Europa?

No one knows whether Europa's deep ocean contains bizarre life forms—or no life at all. But we do know that life forms on Earth can survive extreme environments. Your challenge is to research and briefly report on one of these extreme environments and the kinds of life found there. Examples include life surrounding deep-sea volcanic vents; life forms growing in Antarctic ice; and life in very hot springs, such as at Yellowstone National Park.

Then make a case for the likelihood of finding life on Europa, in an ocean covered with ice. Consider these questions:

- Does life need an energy source — and if so, what kinds of energy will do?
- Does life need light to exist? Does life need oxygen? What kinds of creatures could live there?



What are the most extreme conditions on Earth, and what kinds of living things thrive under those conditions?.

In support of the view that there may be life, you may wish to research and report on the following:

On Earth, is there life near deep-sea volcanic vents? E.g., see the Web site:

http://www.discovery.com/stories/science/seavents/archive/entry1.html

For a skeptic's view, visit the following site and discuss with your team the reports found there:

http://www.spaceviews.com/1999/08/05a.html

In your view, would it be worth exploring Europa if only microscopic life — but no larger life forms — existed? Why?

Can you prove that the planet Venus orbits the Sun?

Venus—the second planet from the Sun—is the nearest planet to Earth. It is one of the brightest objects in the evening or dawn sky, aside from the Moon. If you follow it over several months, you'll see that it appears to "wander" relative to the fixed background stars. But how do we really know that Venus orbits the Sun?

Your challenge is to use the telescope to take images of Venus over the course of several months, to see if you can observe the changing *phases of Venus*. If Venus orbits the Sun, then from Earth we should observe different portions of Venus lit by the Sun, depending on where Venus is relative to the Sun and to Earth. First make a drawing or model showing Earth's orbit and the (claimed) orbit of Venus around the Sun. For various places in Venus' orbit, indicate:

- the pattern of light and shadow we would expect to see from Earth

- the relative size of Venus we would expect to see from Earth (i.e., where in its orbit would Venus look biggest, where would it look smallest?)

Using the telescope, take images of Venus every 3 or 4 weeks for 5 months or so. (Use the grey filter and try several exposures so that your images are not overexposed.) Does Venus go through phases, with a crescent shadow like the Moon? Does it appear larger and smaller as the year progresses? Do your images support your predictions from the drawing or model you created?

Weigh the black hole at the center of our galaxy.

Here's a weighty matter if ever there was one! Astronomers have detected a strange object at the center of our Milky Way Galaxy. They think this object may be a black hole. They can't see the object directly (since it is black!) but they *can* observe its effect on nearby stars. Help them present evidence for or against this being a black hole. For your report:

1. Take a zoomed-out image of the center of our Milky Way galaxy, which is in the direction of the constellation Sagittarius. These are the coordinates for the galaxy's center:

   Right Ascension: 17h 45.7m | Declination -29º 00min

2. The object at the center of the galaxy is about 30,000 light-years from Earth. Assuming that a zoomed-out image shows *roughly* a one-degree field of view, then how wide is this field-of-view, in light-years, at a distance of 30,000 light-years from Earth? (If you need help figuring this out, use the how-to guide, *A Wrangle With Angles*, in your science journal.)

3. Astronomers have followed the motions of stars in orbit around the possible black hole—for more than ten years! They've made a speeded-up animation of this motion. Download the movie from

   http://www.location of the movie

   Note the *scale marker* for this movie, in the upper right corner. This movie shows just a tiny portion of the scene in the zoomed-out image you took! From the *scale marker*, estimate the radius of the star's orbit around the mystery object. (As you can see, the star's orbit is not a circle, but assume for this estimate that it is a circle.)

   Note the *time marker* for this movie, in the upper left corner. This shows the years that the images were taken. From this *time marker*, estimate the period of the star's orbit—that is, the time it takes to orbit once around the mystery object.

4. Now use Kepler's relation to estimate the mass of the mystery object, compared to mass of our Sun.

   $$\mathbf{M \sim d^3 / T^2}$$

   Use your figures for the time it takes the star to orbit, and the distance between star and mystery object. You can use the following table, or the handy nomogram (a calculating device) on the following page.

	Earth orbiting Sun	***Star orbiting Mystery object***
Period for 1 orbit	1 year	? ________years
Distance from central object to orbiting object	93,000,000 miles = 8 light-minutes = 0.0056 light-days	?________ light-days
Mass of central object	1 Sun mass	?________ times mass of the Sun

5. How much more massive than our Sun is the mystery object at the center of our galaxy? Astronomers believe that an object this massive, in such a small volume of space, can only be a black hole.

6. For your report, include an image of the region around the black hole taken by the Chandra X-ray Observatory. (This is a space-based telescope that has detected x-rays from explosions taking place around the black hole.) The image, reproduced here, is available at

   http://chandra.harvard.edu

   On your MicroObservatory image, indicate the region covered by the Chandra X-ray Observatory image.