

The Jovian System: A Scale Model

Middle grades

Lesson Summary

This exercise will give students an idea of the size and scale of the Jovian system, and also illustrate the Galileo spacecraft's arrival day trajectory.

Prior Knowledge & Skills

- Characteristics of the Jupiter system
- Discovery of Jupiter's Galilean satellites
- The Galileo probe mission

AAAS Science Benchmarks

The Physical Setting

The Universe

Common Themes

Scale

NSES Science Standards

- **Earth and space science:** Earth in the Solar System
- **Science and technology:** Understandings about science and technology

NCTM Mathematics Standards

- **Number and Operations:** Compute fluently and make reasonable estimates

Teaching Time: One 45-minute period

Materials

To share with the whole class:

- Materials for scale-model moons (optional, may include play-dough or cardboard)
- Rope marked with distance units
- Copy of arrival day geometry figure

Advanced Planning Preparation Time: 30 minutes

1. Decide whether to use inanimate objects or students to represent the moons
2. If using objects, gather materials
3. Mark off units on rope
4. Review lesson plan

Source: Project Galileo, NASA/JPL

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Objectives:

This exercise will give students an idea of the size and scale of the Jovian system, and also illustrate the Galileo spacecraft's arrival day trajectory.

1) Set the Stage

Before starting your students on this activity, give them at least some background on Jupiter and the Galileo mission:

- Jupiter's mass is more than twice that of all the other planets, moons, comets, asteroids and dust in the solar system combined.
- Jupiter is looked on as a "mini solar system" because it resembles the solar system in miniature-for example, it has many moons (resembling the Sun's array of planets), and it has a huge magnetosphere, or volume of space where Jupiter's magnetic field pushes away that of the Sun.
- There are currently 61 known moons.
- The four largest moons--Io, Europa, Ganymede and Callisto--are named the Galilean satellites, after Galileo Galilei, the Italian astronomer who discovered them in 1610.
- NASA's Galileo spacecraft entered Jupiter's orbit in 1995. Galileo's mission included a 23-month, 11-orbit tour of the jovian system, including 10 close encounters of Jupiter's major moons.
- Before Galileo, five spacecraft had previously flown by Jupiter (Pioneers 10 and 11, Voyagers 1 and 2, and Ulysses).
- One part of Galileo-the Probe descended into Jupiter's atmosphere, a first, while another part-the Orbiter-will become the first artificial satellite of Jupiter, sending back its observations for two years.

2) Setting up the system

This might be easiest if you have a piece of rope with the appropriate units marked off.

Besides Jupiter, arrange the moons as follows (scale-free units; Jupiter's radius, 71492 km, is 1 "unit"):

Distance

<i>Body</i>	<i>(to Jupiter's center)</i>	<i>Radius</i>
Jupiter	--	1
Io	6	3/100ths
Europa	9	2/100ths
Ganymede	15	4/100ths
Callisto	26	4/100ths

You have several options for arranging the moons:

- Use inanimate objects (in which case all of the moons can be to scale; play dough or cardboard can be useful here)
- Use students
- Use an inanimate object for Jupiter and students as moons (in which case the object sets the distance scale). In the latter case, to get enough room between moons, you will either have to use a fairly large object for Jupiter (e.g. a 2' diameter beach ball).

Remind the students that there are many more moons, both closer and further away. To establish the extent of where moons can be found, Metis (innermost satellite) is 2 units away, Sinope (outermost satellite) is 332 units away. The magnetotail extends beyond Saturn's orbit, or at least 650 million kilometers (9090 "units").

You may want to briefly describe some of the characteristics of each moon. Pictures of each of the moons will help with this activity. If you're using human moons, have them "act out" their moon: Io's volcanism, Europa's surface stripes, Ganymede's mottled appearance where fresh craters uncover ice, Callisto's dark, cold, and heavily cratered surface.

3) The Spacecraft's Path

This is a kinesthetic exercise for the students that contains both simpler and more complex activities.

Using a copy of the arrival day geometry figure, have the students arrange the moons into their positions on arrival day, and identify where the spacecraft will be

coming from (for younger students, the teacher will have to do this). Older students can arrange the moons into their arrival day positions (though only the position of Io is critical for this activity).

Have two students be the Probe and Orbiter. Explain how the Probe will go diving into Jupiter's atmosphere (here's where it's useful to have an inanimate Jupiter), and that the Orbiter will orbit.

Walk the Probe through its path. Explain how it must send its information to the Orbiter, so the Orbiter needs to be "overhead" to receive the data. You could have the Probe throw a line (holding onto one end) or a small ball to the Orbiter to help convey this idea.

Next, walk the Orbiter through its trajectory. For advanced students, explain how passing near Io will help slow the Orbiter down, helping to put on the brakes so it won't go flying past the system. Show how the orbiter will fly over Jupiter, picking up the Probe relay (but don't have the Probe doing its thing at this time). To make this exercise slightly more complicated, make sure that the Orbiter keeps its "relay antenna" (perhaps the "spacecraft's" eyes, or perhaps its hands) pointed towards the Probe. Finally, (once again for more advanced students), show how the Orbiter will slow down with a long burn in order to start orbiting around Jupiter.

You can next try showing the motion of the two spacecraft at the same time, with the goal being for the Probe to get its data to the Orbiter. It might well take a few tries until the Probe manages to relay to the Orbiter. Different student Probe/Orbiter teams can try out the procedure-who can do it "right" the first time? Emphasize to the students that on the real spacecraft, we don't get a few practice tries--we have to get it right the first time!

4) Shoemaker/Levy-9

An augmentation of this exercise can include Comet Shoemaker-Levy, which would start from 660 units away from Jupiter and crash into it.

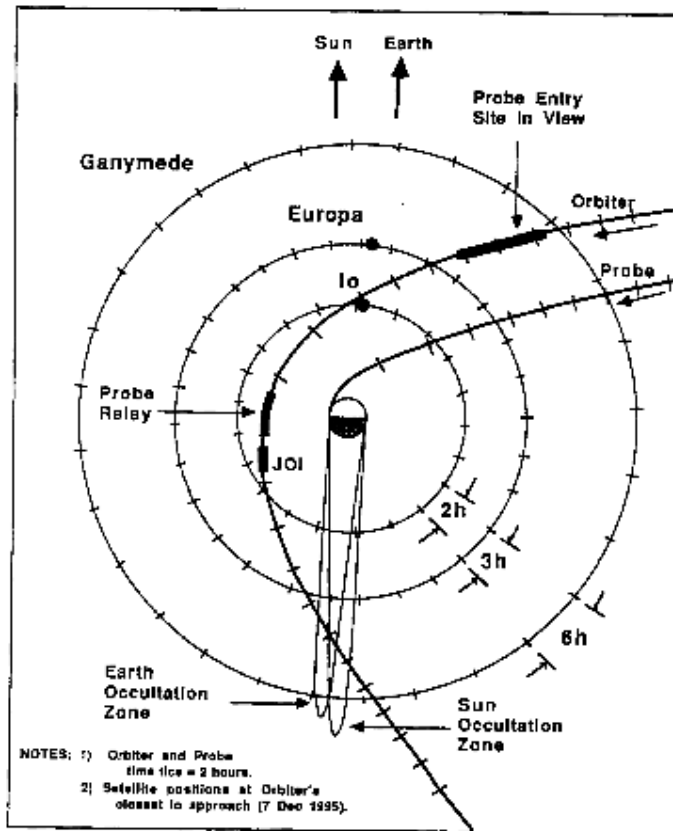


Figure 1. Arrival Day Geometry