

Jupiter and the Galilean Moons Curriculum **9th through 12th grades (14 to 18 years old), 40 to 60 minutes**

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Objectives

Students will learn:

- Basic definitions of the terms “planet,” “moon,” and “orbit;”
- The historical relevance and a few facts about the life of Galileo Galilei;
- Some characteristics of Jupiter and its four largest moons, the Galilean moons;
- How Galileo's observations of the Galilean moons provided evidence for the heliocentric model of the solar system; and
- Facts about recent, ongoing, and future missions to Jupiter or any of the Galilean moons.

Materials required

- Flashlight and extra batteries
- **OPTIONAL:** Poster of portrait of Galileo Galilei
- **OPTIONAL:** Poster(s) of Jupiter and the Galilean moons
- Digitarium[®] system set for January 7, 1610 at 2 pm, with atmospheric effects and landscape on

I) Introduction (10 minutes)

A) Inform students that you'll be learning about the planet Jupiter and its four largest moons today. You'll be discussing some topics outside the planetarium, then going inside to learn more.

B) Define the terms "planet" and "moon." Ask students what they know about the planet Jupiter, and show some posters if you have them. *[For information on Jupiter, see <http://www.nineplanets.org/jupiter.html>]*

C) How many moons does Jupiter have? *[63 as of August 25, 2008.]* When were the first moons of Jupiter discovered? *[The four largest were first observed with a telescope in December, 1609 or January, 1610.]* Who observed them? *[Galileo Galilei, which is why these are called the Galilean moons.]* Share some facts about Galileo's life such as:

- He lived from February 15, 1564 – January 8, 1642.
- He was a mathematician, philosopher, and physicist.
- He died under house arrest for heresy, which they'll learn more about later in the lesson.

D) Prepare students for entering the planetarium--method of entry, rules for behavior, etc.

II) Introduction to Galileo's Sky (10 minutes)

A) Inform students that the sky is currently set for 2 pm on January 7, 1610. Does anyone know why we're using this date? *[It's the date of Galileo's earliest known written recordings of the positions of the Galilean moons.]*

Obviously Galileo was not able to observe Jupiter and the Galilean moons in the middle of the afternoon, so let's move forward in time until the sun sets. *[Speed up time to get past sunset, slowing to real time at about 9:30 pm. Turn off the atmospheric effects and landscape.]* What do the students notice as they look around?

B) Ask students how Galileo knew where to aim his telescope for his Jupiter observations. *[People had been observing the sky for thousands of years before Galileo, so the positions of the planets were well-known.]* Can they tell which dot in the sky is Jupiter? Turn on the planet labels. If time allows, discuss how to recognize planets in the sky. *[See the "Planets" lesson plan for 3rd-5th grade students for more information.]*

C) Select and zoom in on Jupiter, just far enough for the moons to be visible as small dots, then speed up time to show the moons orbiting Jupiter. *[Manual zoom works better for this activity than auto zoom.]* What do the students notice? **[Note: The software will show 16 moons of Jupiter. Point out which four are the Galilean moons.]**

Slow down to real time, then jump forward in time day by day to show how the positions of the moons change. What did Galileo conclude from this? *[That those dots were moons orbiting Jupiter.]* Why was this conclusion important? *[The prevailing belief of the time was that everything orbited the earth—the geocentric model, also known as the Ptolemaic system. Galileo's observations contradicted this, as the most logical explanation was that the Galilean moons were not orbiting Earth but Jupiter.]*

Galileo concluded from his observations of the Galilean moons and the phases of Venus that the sun was at the center of the solar system—the heliocentric model, also

known as the Copernican theory. *[There are more details about the geocentric versus heliocentric debate in the "How Do We Know?" lesson plan for 9th-12th grade students.]*

At first Galileo tried to avoid the controversy by not making public statements that the heliocentric model was correct. His reluctance was due to the fact that this position conflicted with the prevailing Catholic Church's interpretation of the Scriptures, and Galileo was Catholic. However, avoiding the controversy eventually became impossible. Plus:

Pope Urban VIII invited Galileo to papal audiences on six occasions and led Galileo to believe that the Catholic Church would not make an issue of the Copernican theory. Galileo, therefore, decided to publish his views believing that he could do so without serious consequences from the Church. However by this stage in his life Galileo's health was poor with frequent bouts of severe illness and so even though he began to write his famous *Dialogue* in 1624 it took him six years to complete the work.

[From <http://www-groups.dcs.st-and.ac.uk/~history/Biographies/Galileo.html>.]

In 1632 Galileo published his Dialogue Concerning the Two Chief Systems of the World - Ptolemaic and Copernican. Shortly after its publication, Galileo was ordered to appear before the Inquisition, found guilty of heresy, and sentenced to lifelong house arrest. He died on January 8, 1642.

D) **OPTIONAL:** Discuss how the students feel about the actions of Galileo and the Catholic church. If they had been in Galileo's position, what would they have done, and why? Can they think of any similar debates or controversies in the present day?

III) Features of Jupiter and the Galilean Moons (10 to 15 minutes)

A) Zoom out to the full sky view, then jump to the current date and time. Point out where Jupiter is now; speed up time as needed to make Jupiter visible. If it is visible at night, tell students at what time and where in the sky to look.

B) Select and zoom in on Jupiter, so that surface features are visible. Speed up time to show the rotation of Jupiter, and pause when the Great Red Spot is visible. Ask students what they know about the Great Red Spot, and share some facts about it, such as:

- It's an oval about 7,200 x 15,000 miles/12,000 x 25,000 km, big enough for two Earths.
- It is a storm that has lasted more than 300 years. Over time it changes size and color. Its energy source is not known.

Share some other interesting facts about Jupiter, such as:

- It has rings, but they are much fainter and smaller than Saturn's. The rings were discovered by accident by Voyager 1 in early 1979. The rings are probably composed of very small grains of rocky material, and unlike the rings of Saturn, do not seem to contain any ice. *[Note: the software does not show the rings.]*
- It is a gas giant, which means it does not have a solid surface. The gaseous material gets denser with depth.
- When we look at Jupiter (or any other gas giant), we are seeing the tops of the clouds high in the atmosphere.
- Our knowledge of Jupiter's core is indirect. Data collected during the Galileo mission is from only about 90 miles/150 km below the cloud tops. Jupiter probably has a rocky core about 10 to 15 times the mass of the earth.
- Jupiter's magnetic field is huge and much stronger than Earth's.
- Above the core lies the bulk of Jupiter, in the form of liquid metallic hydrogen. Liquid

metallic hydrogen conducts electricity, and it is the source of Jupiter's magnetic field.

C) Select and zoom in on each Galilean moon, then share some facts about each. Show an image of each moon with the prominent features labeled [*available to Digitalium® users on the Digitalis community website*]. Below are some facts about each moon.

Io:

- Closest Galilean moon.
- Named after a priestess of Hera who became one of the lovers of Zeus.
- Most volcanically active body in the solar system. As Io travels in its slightly elliptical orbit, Jupiter's immense gravity causes 'tides' in the solid surface 325 ft/100 m high on Io, generating enough heat to give rise to the volcanic activity and drive off any water. Io's volcanoes are driven by hot silicate magma.
- Loki Patera is the largest crater on Io, 121 miles/202 km in diameter. It contains an active lava lake, with an episodically overturning crust. The level of activity seen is similar to a super-fast spreading mid-ocean ridge on Earth.
- Pele is a volcano on the surface of Io; it is named after the Hawaiian volcano goddess. It consists of a volcanic depression 18 miles/30 km long by 12 miles/20 km wide. A lake consisting of basaltic lava fills part of the depression. This lava lake is also the source of a plume of gas and dust that reaches as high as 180 miles/300 km above the surface before the material is deposited in a ring of red material as far as 360 miles/600 km from the volcano.

Europa:

- Second closest Galilean moon.
- Named after a woman who was courted by Zeus and who became the queen of Crete.
- One of the smoothest objects in the solar system.
- May have oceans under its icy surface. Thought to have twice as much water as Earth.
- The impact crater Pwyll (a name from Celtic Mythology) is thought to be one of the youngest features on the surface of Europa. Pwyll's visible dark central region is about 24 miles/40 km in diameter. The bright white color suggests a composition of fresh water ice particles.
- Linea is Latin for 'line'. In planetary geology it is used to refer to any long marking, dark or bright, on a planet or moon's surface. Europa has prominent lineae.
- Most European lineae are named after characters and places in the legends of Cadmus and Europa; others are named after important megalithic stone rows built by the Neolithic peoples of Britain and France.

Ganymede:

- Third closest Galilean moon.
- Named after the cup-bearer of the Greek gods and Zeus's beloved.
- It is the largest moon in the solar system and is bigger than the planet Mercury.
- The only moon known to have a magnetosphere.
- Its surface is a mixture of old and young regions. Dark regions are older and called regio. Lighter areas are newer and called sulcus.
- Tros crater is 56.3 miles/93.9 km in diameter and named after king Tros, father of Ganymede.

Callisto:

- Farthest Galilean moon.

- Callisto was a nymph, the daughter of Lycaon, who was associated with the goddess of the hunt, Artemis.
- One of the most heavily cratered objects in the solar system.
- Oldest surface of any known object in the solar system. Callisto's surface is about 4 billion years old.
- Valhalla is the largest multi-ring structure impact crater on Callisto. It has a bright central region 360 miles/600 km across, an inner ridge and through zone, and concentric rings extending to a diameter of approximately 2,280 miles/3,800 km around that. The ring fracture system may have formed as semi-liquid material slumped towards the center of the crater following impact. The crater is named after Odin's hall in Norse mythology.

IV) Missions to Jupiter and/or the Galilean Moons (5-15 minutes)

A) Discuss a few of the past, present, and future missions to Jupiter and/or the Galilean moons. If possible, display images of the spacecraft or some of their discoveries. Digitalis customers can download images from the community website.

[The following is from: <http://www.planetary.org/explore/topics/jupiter/missions.html>]

Past missions in chronological order

Pioneer 10 (NASA):

- Successful Jupiter flyby
- Launch: March 2, 1972; Jupiter flyby: December 3, 1973
- Pioneer 10 was the first spacecraft to pass through the Asteroid Belt and explore the outer solar system. It flew within 124,000 miles/200,000 km of the Jovian cloud tops.
- Scientists were surprised at the tremendous radiation levels experienced by the spacecraft as it passed the gas giant planet.
- Once past Jupiter, the spacecraft headed out of the solar system. Routine communication with Pioneer 10 ended on March 31, 1997. Controllers occasionally checked in with it until contact was lost on April 28, 2001.
- It is now heading in the general direction of Aldebaran, the red giant star in Taurus. At its current speed, it would take about 2 million years to get to Aldebaran.

Pioneer 11 (NASA):

- Successful Jupiter and Saturn flyby
- Launch: April 5, 1973; Jupiter flyby: December 2, 1974
- Pioneer 11 flew within 21,100 miles/34,000 km of the Jovian cloud tops. The spacecraft studied the planet's magnetic field and atmosphere and took pictures of the planet and some of its moons.
- It then flew by Saturn on September 1, 1979 and continued on out of the solar system. Instruments were finally shut down on September 9, 1995, when there was no longer enough power.

Voyager 1 (NASA):

- Successful Flybys of Jupiter and Saturn
- Launch: September 5, 1977; Jupiter encounter: January 4 to April 13, 1979
- Launched 16 days after Voyager 2, Voyager 1 was on the fast track to Jupiter and actually arrived four months ahead of the other spacecraft.
- Voyager 1 flew by Jupiter on March 5, 1979, taking more than 18,000 images of planet

and its moons.

Voyager 2 (NASA):

- Successful “Grand Tour” flybys of Jupiter, Saturn, Uranus, and Neptune
- Launch: August 20, 1977; Jupiter encounter: April 25 to August 5, 1979
- Ten months into the flight, well before the spacecraft reached the planet, Voyager 2's primary radio receiver failed. The backup receiver kicked in, but it proved unreliable. Controllers tried to revive the primary receiver, without any luck. They were forced to continue with the backup.
- Despite its irregularities, the backup receiver worked admirably during the Jupiter fly by. Voyager 2 flew by Jupiter on July 9, 1979, taking about the same number of images as Voyager 1 (18,000 images of Jupiter and its moons).
- Between the two spacecraft, three new moons were discovered as well as a thin, dark ring around Jupiter. Voyager images of Jupiter's moon Io revealed active volcanoes, the first ever discovered on another body besides Earth.

Galileo (NASA):

- Successful Jupiter orbiter & probe
- Launch: October 18, 1989; Jupiter probe descent: December 7, 1995; Jupiter orbit insertion: December 8, 1995; plunge into Jupiter: September 22, 2003
- Galileo suffered a crippling malfunction early in its mission when its high-gain antenna failed to open. Despite this setback, it returned more science and survived four times longer than anyone expected.
- Galileo was the first spacecraft to deploy a probe into an outer planet's atmosphere. When the Jupiter Probe plunged into the Jovian clouds, it sent back information about the temperature, wind speeds, and pressure as it descended.
- It finally succumbed to the incredible pressure (24 times Earth's pressure at sea level) one hour after it began its descent.
- Galileo was the first spacecraft to dwell in a giant planet's magnetosphere long enough to identify its global structure and investigate the dynamics of Jupiter's magnetic field.
- It revealed that Jupiter's ring system is formed by dust kicked up as interplanetary meteoroids smash into the planet's four small inner moons and that the planet's outermost ring is actually two rings, one embedded within the other.
- The spacecraft's mission was extended three times in order to study the Galilean moons.
- Galileo made many discoveries about these moons:
 - Io's extensive volcanic activity is 100 times greater than that found on Earth.
 - Europa harbors a salty ocean up to 60 miles/100 km underneath its frozen surface, containing about twice as much water as all the Earth's oceans.
 - Callisto and Ganymede may also feature a liquid-saltwater layer.
 - Ganymede has an iron core, like Earth, and a magnetic field, making this moon the first satellite known to possess a magnetic field.
- In order to avoid any possibility of the spacecraft contaminating Europa's salty ocean with material brought from Earth, the spacecraft was deliberately destroyed by sending it onto a collision course with Jupiter.

Ulysses (NASA):

- Successful Solar polar orbiter
- Launch: October 6, 1990; Jupiter flyby: February 8, 1992
- The primary mission of Ulysses was to study the north and south pole of the Sun. However, getting to those solar poles required the spacecraft to perform some

interplanetary gymnastics. The spacecraft first went to Jupiter, where the strong Jovian gravity helped redirect it, placing it on its proper course.

- As Ulysses flew by the planet, instruments onboard the spacecraft studied Jupiter's strong magnetic field and radiation levels.

Cassini-Huygens (NASA/ESA/ASI):

- Successful Saturn orbiter & probe
- Launch: October 15, 1997; Jupiter flyby: December 30, 2000
- Cassini-Huygens' path to Saturn required flybys of Venus, Earth, and Jupiter.
- Engineers used the Jupiter encounter to test the spacecraft's instruments and operations. During the flyby, Cassini captured incredible images of the gas giant and its larger moons in a science plan that was coordinated with Galileo observations.

New Horizons (NASA):

- Pluto / Kuiper Belt flyby
- Launch: January 19, 2006; Jupiter flyby: January-May, 2007
- New Horizons is the result of a long battle to take advantage of a once-in-a-lifetime opportunity for a Jupiter gravity assist trajectory to Pluto.
- It observed Jupiter over five months around the flyby in early 2007, with its closest approach on February 27.
- It was the first spacecraft to observe the newly formed Little Red Spot, and also caught Io's north polar volcano Tvashtar in the middle of a spectacular eruption.

Future Missions

Juno (NASA):

- Future Jupiter polar orbiter
- Launch: Planned for August 2011; Jupiter arrival: Planned for August 2016
- Juno will survey Jupiter from a polar orbit, carrying a suite of instruments designed to study the planet's interior.
- It will investigate the existence of an ice-rock core; determine the amount of global water and ammonia present in the atmosphere; study convection and deep wind profiles in the atmosphere; investigate the origin of the Jovian magnetic field; and explore the polar magnetosphere.

B) Ask students what they would like to find out about Jupiter or any of the Galilean moons. What questions would they design a spacecraft to answer? What sorts of instruments would help them answer these questions?

C) Remind students where to look for Jupiter at the current time, then exit the dome and regroup outside.

V) Conclusion (5 minutes)

A) When all have exited, review the key concepts of the lesson. Why are the four largest moons of Jupiter called the Galilean moons? What other achievements is Galileo known for? What role did the Galilean moons play in our understanding of the universe? What do scientists hope to learn from future missions to Jupiter or its moons?