STARS RESOURCES

Teacher notes

Jupiter and the Galilean Moons

ACTIVITY

Calculate the mass of Jupiter by observing and collecting data on the orbits of its four largest moons.

By the end of this activity students will:

- be familiar with using a telescope and using it to collect scientific data

- have learnt how to make valid and scientific measurements using a telescope

- be comfortable applying mathematical curves to real-life data and

- understand the importance of comparing calculations to established mathetical relationships and accepted constants.

NOTE: This activity takes about a month of data collection to complete. Teacher supervision is required at all times.

BACKGROUND INFORMATION

The students will be recreating some of the work done by Galileo, and applying mathematics developed by Kepler.

In order to set the scene of Galileo's work, here are some suggested articles to read.

- 'Galileo's Place in Science', PBS NOVA website, https://www.pbs.org/wgbh/nova/article/galileo-sobel/

- 'Galileo's Revolutionary Vision Helped Usher In Modern Astronomy', Smithsonian Magazine website, https://www.smithsonianmag.com/science-nature/Galileos-Revolutionary-Vision-Helped-Usher-In-Modern-Astronomy-34545274/

PLAN AHEAD

You need to pick the right time to see Jupiter, namely, when Earth is closet to the planet. That time is when Jupiter is at *opposition*, when it is opposite the Sun in the sky. At opposition, the planet rises in the east as the Sun sets in the west. But Jupiter is large enough to look good for a few months on either side of opposition, so there's still plenty to see.

This site provides an interactive Night Sky Map. You can use it to locate the best date and time throughout the year to view Jupiter. https://www.timeanddate.com/astronomy/night/

Consider purchasing Dawes, Glen; Northfield, Peter and Wallace, Ken, 'Astronomy (year)', Quasar Publishing. www.quasarastronomy.com.au. This is an excellent guide to the night sky.

CURRICULUM LINKS

AUSTRALIAN CURRICULUM - YEAR 10 SCIENCE

Science Understanding

The universe contains features including galaxies, stars and solar systems, and the Big Bang theory can be used to explain the origin of the universe. (ACSSU188)

The motion of objects can be described and predicted using the laws of physics. (ACSSU229)

Science as a Human Endeavour

Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries. (ACSHE192)

People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities. (ACSHE194)

Science Inquiry Skills

Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods. (ACSIS199)

Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately. (ASIS200)

Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies. (ACIS203)

Use knowledge o scientific concepts to draw conclusions that are consistent with evidence. (ACSIS204)

Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data. (ACSIS205)

Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations. (ACSIS208)

AUSTRALIAN CURRICULUM - SENIOR MATHEMATICS

Model periodic motion using sine and cosine functions and understand the relevance of the period and amplitude of these functions in the model. (ACMSM050)

CURRICULUM LINKS

AUSTRALIAN CURRICULUM - SENIOR PHYSICS

Science Inquiry Skills

Conduct investigations, including the manipulation of devices to measure motion and the direction of light rays, safely, competently and methodically for the collection of valid and reliable data. (ACSPH047)

Represent data in meaningful and useful ways, including using appropriate SI units and symbols; organise and analyse data to identify trends, patterns and relationships; identify sources of random and systematic error and estimate their effect on measurement results; identify anomalous data and calculate the measurement discrepancy between the experimental results and a currently accepted value, expressed as a percentage; and select, synthesise and use evidence to make and justify conclusions (ACSPH048)

Select, use and interpret appropriate mathematical representations, including linear and non-linear graphs and algebraic relationships representing physical systems, to solve problems and make predictions. (ACSPH051)

Science as Human Endeavour

Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions. (ACSPH058)

Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power. (ACSPH123)

Science Understanding

Waves may be represented by time and displacement wave diagrams and described in terms of relationships between measurable quantities, including period, amplitude, wavelength, frequency and velocity. (ACSPH069)

A ray model of light may be used to describe reflection, refraction and image formation from lenses and mirrors. (ACSPH075)

Developing understanding of planetary motion.

Ptolemaic astronomy proposed a geocentric model of the solar system that used the idea of epicycles to explain planetary movement. This model was used until Copernicus proposed a heliocentric model of the solar system (ACSPH087) which was later championed by Galileo, causing conflict with the Catholic Church (ACSPH088). Johannes Kepler proposed three laws of planetary motion which form the basis of our modern understanding of orbits.

RECOMMENDED PRE-LAB ACTIVITY

To set the scene, and to ascertain the level of prior knowledge in the class, try this online trivia activity 'Imaging the Universe. Pre-lab Quiz: Jupiter Stupor', University of Iowa Department of Physics and Astronomy website, http://astro.physics.uiowa.edu/ITU/labs/professional-labs/the-mass-of-jupiter---part/galiean-trivia.html

HOW TO SET UP THE TELESCOPE

Watch these tutorials.

'How to set up a Dobsonian Telescope', ASTRO 3D YouTube (5:37 mins), https://youtu.be/pvb-_WqNkPQ (31 March 2020)

'Tools and Accessories for a Dobsonian Telescope', ASTRO 3D YouTube (11:06 mins), https://youtu.be/M7kDzUK7ZHE (31 March 2020)

SUGGESTED ANSWERS

1. *Compare each calulation you made for each moon to the actual mass of Jupiter. Which moon was the closest and why do you think that was?*

Your measurements of the distances may not be accurate. This includes the measurement of the diameter of Jupiter, and the distance between Jupiter and each of the moons. This introduces error, and will lead to slightly different answers for each student, and each moon. Extension question: How could you reduce the amount of error? Answer: Increase the number of observations, or combine your data with observations made by other astronomers to increase the accuracy.

2. *Can you determine which of your moons is Io, Callisto, Ganymede and Europa? Explain how you know. (You may have to look up their distance from Jupiter to help you.)*

Use this table to distinguish which curve belongs to which moon.

Moon	***a*** radius (semi-major axis) (km)	***a*** radius (semi-major axis) (AU)
Io	421 700	0.0028
Europa	670 900	0.0045
Ganymede	1 070 400	0.0072
Callisto	1 882 700	0.0126

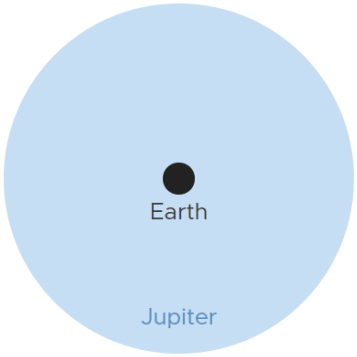
SUGGESTED ANSWERS cont'd

3. *How much bigger is Jupiter compared to the Earth? What about other planets in our Solar System?*

Use this website to compare Earth to Jupiter. Think about what might be meant by 'bigger'. Is it diameter or mass?

'Earth | Solar System Exporation', NASA Science website, https://solarsystem.nasa.gov/planets/earth/by-the-numbers/

SIZE COMPARISON



Earth is 11.0x smaller than Jupiter

VOLUME	
1,083,206,916,846 km^3	1,431,281,810,739,360 km^3
DENSITY	
5.513 g/cm^3	1.326 g/cm^3
MASS	
5,972,190,000,000,000,000,000,000 kg	1,898,130,000,000,000,000,000,000,000 kg
EQUATORIAL RADIUS	
6,371.00 km	69,911 km

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SUGGESTED ANSWERS - cont'd

4. What did you notice about the way Jupiter and the Galilean Moon's moved?

Students observations may include:

- on some nights, not all of the moons were visible. This could be that a moon is in front or behind Jupiter.

- sometimes shadows were cast onto Jupiter by the moons.

- sometimes all of the moons are one side of Jupiter. The appear to move from side to side. Every night their positions are different.