

Jovian Planets—24 Jan

- What is the composition and state (gas, liquid, solid) of the jovian planets?
 - Measuring mass
- Why does Saturn have rings and not moons?

Measurements & models

- Models: The pressure is so high that the phase of the gas giants is not gas in the interior.
 - Thermodynamic modes: Pressure vs density.
 - Phase transitions, e. g., gas to liquid.
- Measurements
 - Mass
 - Radius

Measuring the radius of a planet

1. When it is closest, the angle between one edge of Jupiter and the other is 24arcsec. If the distance were greater, the radius of Jupiter would be _____. I am using _____ to figure this out.
 - A. Greater. Physics
 - B. Greater. Geometry
 - C. Smaller. Physics
 - D. Smaller. Geometry

Measuring mass

- The gravitational acceleration between me and Earth is $-GM/R^2$
- To find Earth's mass, what can I measure ?
 - Measure the period P and radius of the moon's orbit R and use Newton's form of Kepler's 3rd Law

$$P^2 = \left(\frac{4\pi^2}{G}\right) R^3 / M$$

$$\left(\frac{4\pi^2}{G}\right) = 1 \text{ for } P \text{ in year, } R \text{ in AU, } M \text{ in } M_{\text{sun}}$$

- Drop a ball from rest at height h and measure the time t to fall.

$$h = \frac{1}{2} \left(\frac{GM}{R^2}\right) t^2$$

The mass of Pluto

- Why did the measurements of the mass of Pluto change by a lot until 1978?

Year	Mass [M_{earth}]	Notes
1931	1	Nicholson & Mayall [38] [39] [40]
1948	.1	Kuiper [41]
1976	.01	Cruikshank, Pilcher, & Morrison [42]
1978	.002	Christy & Harrington [43]

1. Which planet did not have accurate masses measured before the advent of satellites?
 - A. Venus
 - B. Mars
 - C. Jupiter
 - D. Saturn

Models

- Models
 - Assume composition
 - H
 - H+ He
 - Ice: water H₂O, methane CH₄, and ammonia NH₃
 - Rock
 - Use physics of material at high pressure
 - Compute mass and radius
 - Cold means motion is caused by Heisenberg's Uncertainty Relation $px \geq \hbar$
 - Isentropic means planet has not cooled since its formation.

1. The measurements of mass and radius and the models show Uranus is made primarily of

- A. H
- B. H and He
- C. Ice (H₂O, CH₄, and NH₃)
- D. Rock

Figure 3 The mass-radius relationship for self-gravitating bodies of the same compositions as in Figure 2. The solid lines are for cold matter ($T = 0$ K); the dashed lines correspond to the isentropes of Figure 2. The insensitivity of radius or mass for hydrogen and hydrogen-helium is a consequence of the approximate validity of $P \propto \rho^2$ (see text for discussion). The positions of the giant planets are labelled by J, S, U, and N.

Stevenson, D. J., 1982, Ann. Rev. Earth Planet. Sci. 10, 257

Models

- Models
 - Assume composition
 - H
 - H+ He
 - Ice: water H₂O, methane CH₄, or ammonia NH₃
 - Rock

1. The measurements of mass and radius and the models show Jupiter and Saturn are made primarily of

- A. H
- B. H and He
- C. Ice (H₂O, CH₄, and NH₃)
- D. Rock

2. A planet made of H and He with the same mass as Earth has a radius ___ that of Earth

- A. 1
- B. 1.5
- C. 2
- D. 2.5

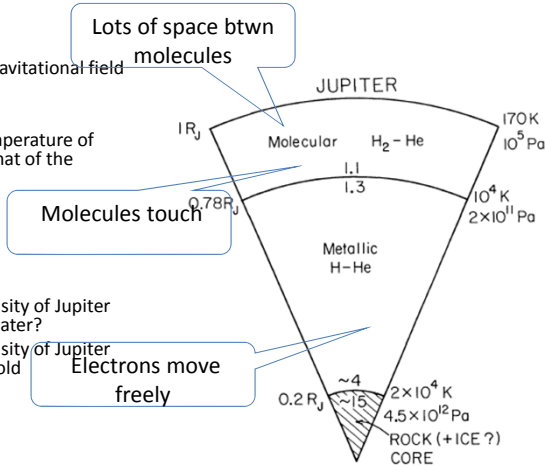
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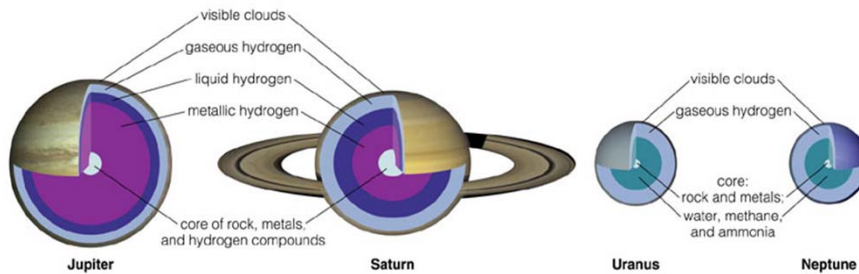
Models with more information

- Angular dependence of gravitational field
- Temperature vs. radius
- Convection

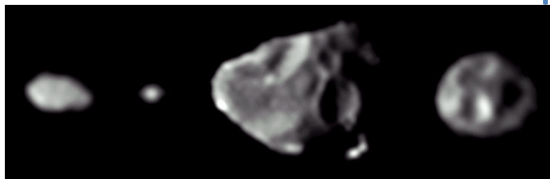
1. At what point is the temperature of Jupiter approximately that of the surface of the sun?
 - A. Surface
 - B. $0.2R_J$
 - C. $0.5R_J$
 - D. $0.8R_J$
 - E. Center
2. At what point is the density of Jupiter approximately that of water?
3. At what point is the density of Jupiter approximately that of gold (19gm/cm^3)?



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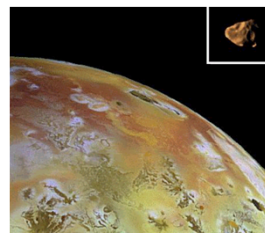


The Innermost Moons of Jupiter



Metis Adrastea Amalthea Thebe

- Q5: What holds me together?
 - a. Gravity
 - b. Atomic bonds between the atoms
- Q6: What holds Io & Metis together?
(Think about the shapes of Io & Metis.)
 - a. Gravity for both
 - b. Bonds for both
 - c. Gravity for Io; bonds for Metis
 - d. Gravity for Metis; bonds for Io.



Amalthea
& Io