The Jovian Planets (Gas Giants)

Jupiter

Saturn



Uranus





(roughly to scale)

Neptune



Discoveries

Jupiter and Saturn known to ancient astronomers.

Uranus discovered in 1781 by Sir William Herschel (England).

Neptune discovered in 1845 by Johann Galle (Germany). Predicted to exist by John Adams and Urbain Leverrier because of irregularities in Uranus' orbit. Almost discovered by Galileo in 1612

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Remember that compared to Terrestrial planets, Jovian planets: are massive

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are less dense (0.7 - 1.3 \text{ g/cm}^3)
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are mostly gas (and liquid)
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rotate fast (9 - 17 hours rotation periods)

have rings and many moons

	Mass (M _{Earth})	Radius (R _{Earth})	Known Moons	
Jupiter	318 (0.001 M _{Sun})	11	63	
Saturn	95	9.5	61	
Uranus	5 15	4	27	
Neptur	ne 17	3.9	13	

Orbital Properties:	Distance from St (AU)	un Orbital Period (years)
Jupiter	5.2	11.9
Saturn	9.5	29.4
Uranus	19.2	84
Neptune	30.1	164
Major Missions:	Launch	Planets visited
Voyager 1	1977	Jupiter, Saturn
Voyager 2	1977	Jupiter, Saturn, Uranus, Neptune
Galileo	1989	Jupiter
Cassini	1997	Jupiter, Saturn

Jupiter's Atmosphere

<u>Composition</u>: mostly H, some He, traces of other elements (true for all Jovians). Gravity strong enough to retain even light elements. Mostly molecular.



Altitude 0 km <u>defined</u> as top of troposphere (cloud layer)

Ammonium hydrosulfide (NH_4SH) ice should form here, somehow giving red, yellow, brown colors.





Optical – colors dictated by how molecules reflect sunlight

Infrared - traces heat in atmosphere.

So white colors from cooler, higher clouds, brown and red from warmer, lower clouds.

On other Jovian planets, different chemistry causes different coloration.

Saturn - predominant yellow color due to haze and ammonia ice layer





Blue/green color of Uranus and blue color of Neptune due to methane. Colder than Jupiter and Saturn, their ammonia has frozen and sunk lower. Methane still in gas form. It absorbs red light and reflects blue.

Jupiter's Bands

Lighter-colored "zones" and darker-colored "belts".



- Zones and belts are Jupiter's high and low pressure systems, respectively.

- They mark a <u>convection</u> cycle.

- Zones were thought to be where warm gas rises and are higher than the belts, where cooled gas sinks. However, Cassini data indicates the opposite! Most upwelling occurs in belts, gas falls back down in zones.

- Jupiter's rapid rotation stretches them horizontally around the entire planet.
- Winds flow in opposite directions in zones vs. belts.
 Differences are 100s of km/hr.





Jupiter's atmosphere is primarily made up of:

- A: hydrogen
- B: helium
- C: carbon dioxide
- D: ammonia

Which planets have we found water (liquid or frozen) on:

- A: Mercury, Venus and Earth
- B: Mercury, Earth, Mars and Jupiter
- C: Only the Earth
- D: Mars and Venus
- E: All terrestrial planets Mercury, Venus, Earth and Mars.

It takes 8 minutes for light to travel 1 AU, how long does it take for light to travel from Earth to Jupiter and back again at its closest point to Earth in its orbit?

- A: 2 minute
- B: 10 minutes
- C: 60 minutes
- D: 2 days
- E: 1 year

Banded structure on other Jovian planets is present, but not as distinct due to more uniform cloud coverage.



Saturn

Uranus



Neptune

Storms on Jovian Planets







New storm "Oval BA"

Jupiter's Great Red Spot: A hurricane twice the size of Earth. Has persisted for at least 340 years.





"brown ovals" - only seen near 20° N latitude. Not known why. May last years or decades

"white ovals" - may last decades



Storms on Jovian Planets



Lightning on Jupiter: Cassini captured images of lightning during a nighttime pass over the planet. Each stroke is about 10,000 times more energetic than one on Earth.



<u>Neptune's Great Dark Spot</u>: Discovered by Voyager 2 in 1989. But had disappeared by 1994 Hubble observations. About Earth-sized.

Why do storms on Jovian planets last so long?

On Earth, land masses disrupt otherwise smooth flow patterns. Not a problem on Jovian planets.

Jupiter's Internal Structure

Can't observe directly. No seismic information. Must rely on physical reasoning and connection to observable phenomena.



Other Jovians similar. Interior temperatures, pressures and densities less extreme.

Jupiter has a strong magnetic field



detection of the magnetic belts around Jupiter

synchrotron emission from energetic particles in magnetic fields

Jupiter has a strong magnetic field



detection of aurorae

Impact of high-energy Particles at the poles.

Jupiter has a strong magnetic field



Low Frequency Detection of Exo-Planets

- Below 40 MHz, Jupiter is the brightest object in the solar system.
- The LWA has a good chance of detecting emission from extra-solar "Jupiters".
 - Would provide independent verification of planetary systems.
 - Would confirm presence of magnetic field pre-requisite for life as shield against cosmic rays.



Interaction of Jupiter's magnetosphere with the Solar Wind.



Rapid rotation causes Jupiter and Saturn to bulge:



Jupiter and Saturn rotate every ~10 hours. Radius at equator several % larger due to bulge.

Which gas giant has the lowest average density:

- A: Jupiter
- B: Saturn
- C: Uranus
- D: Neptune

The Great Red Spot is:

A: A large basin on Mars

B: A long-lived high-pressure storm in Jupiter's atmosphere.

- C: The colored polar cap of Jupiter
- D: Clouds of dust swirling around Jupiter's largest volcano

Saturn is less massive than Jupiter but almost the same size. Why is this?

- A: Saturn's interior is hotter than that of Jupiter's.
- B: Saturn is composed of lighter material than Jupiter.
- C: Saturn is rotating faster than Jupiter so the increased centrifugal force results in a larger size
- D: Saturn's smaller mass provides less gravitational force to compress it.

Differential Rotation

Rotation period is shorter closer to the equator:

	Near poles	At equator
Jupiter	9 ^h 56 ^m	9 ^h 50 ^m
Saturn	10 ^h 40 ^m	10 ^h 14 ^m
Uranus	16 ^h 30 ^m	14 ^h 12 ^m

How do we know?

Differential Rotation

Rotation period is shorter closer to the equator:





Uranus' rotation axis is tilted by 98°



Why? Unknown. Perhaps an early, grazing collision with another large body.

The Ice Giants - Uranus and Neptune

15 to 17 times the mass of the Earth Slushy water and methane ice atmospheres Rocky cores of ~1 Earth mass Off axis magnetic fields

No large moons Not much internal heating



large moon (Triton) times more internal power than solar



Neptune

Magnetic Fields of Jovian Planets



Uranus: The Weirdest Object in the Solar System

It "rotates on its side"

It has faint, thin rings that are aligned with the planet's equator

It does not appear to have significant internal heating, unlike the other 3 Jovian planets

Its magnetic field is offset from the planet's rotation axis by 60 degrees, AND it is offset from the center of the planet

It has no large moons, but it does have the strangest moon in the entire solar system...

Miranda



The moon "put together by committee"

Close-up of Miranda



Cracks in the surface

Different colors of surface features

Scarps and Cliffs on Miranda



Photograph by NASA



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The Rings and Moons of Uranus



Near-IR HST image

The Major Moons of Uranus



Can anyone guess the naming scheme?