1. Properties
- General Properties
- Formation
- Spacecraft

1609 - Galileo turned his telescope on Jupiter and discovers its moons.

Jupiter is the third brightest object in the night sky.

**Physical Properties**
- Radius = 11 R_{\text{Earth}}
- Mass = 318 M_{\oplus}
- Density = 1.3 g/cc
- Emits its own radiation
- Magnetic field 14 times earth’s

**Jupiter’s Orbit**
- Distance = 5.20 AU
- Period = 11.86 years
- Axial tilt = 3.08°
1973-1974
Pioneer 10 -11
Flew by
1979
Voyager 1-2
Flew by
1995-2003
Galileo Orbited

It takes over half an hour for light (or radio signals from a spacecraft) to get from Jupiter to the Earth.

Galileo's Selected Science Results
✓ The descent probe measured atmospheric elements
✓ Io's extensive volcanic activity
✓ Io's plasma coupling to Jupiter's atmosphere.
✓ Ganymede is the first satellite known to possess a magnetic field.

The End 2003 put on a collision course with Jupiter to eliminate any chance of an unwanted impact between the spacecraft and Jupiter's moon Europa.

Interior and Magnetic field Outline
✓ Formation
✓ 1994 Comet, Shoemaker-Levy
✓ 1995Galileo probe
✓ Interior Model
✓ Excess Infrared Emission
✓ Magnetic Field
✓ Plasma Torus, Flux tube
✓ aurorae
✓ Radio Emission and Internal rotation

The termination shock is where the solar wind, a thin stream of electrically charged gas blowing continuously outward from the sun, is slowed by pressure from gas between the stars. At the termination shock, the solar wind slows abruptly and becomes denser and hotter.
Formed from cold gas in the outer solar nebula, where ices were able to condense:

Density = 1.3 g/cc.

Composition

- 86.1% H
- 13.8% He
- CH₄, NH₃, etc.

Formation

- Formed from cold gas in the outer solar nebula, where ices were able to condense

Structure of Jupiter

- Heavy materials sink to the center
- In the interior, hydrogen becomes metallic (very good electrical conductor)
- Rapid rotation creates a strong magnetic field
- Rapid rotation and large size create belts and zones in the cloud pattern

Comet, Shoemaker-Levy, captured into an orbit round Jupiter.

the comet broke up due to Jupiter’s tidal force and created the string of pearls

As the comet fragment enters Jupiter’s atmosphere, the tremendous heat generated an explosion released energy comparable to thousands of hydrogen bombs, with a fireball hundreds of kilometers across.

Infrared
Measurements by Galileo’s probe show high wind speeds at great depths – probably due to heating from planet, not from Sun.

This image shows how it may look after 70 min, glowing with friction, it begins to break up above the cloud belts.

**Jupiter: The Star that Never Was**

The light of a star is produced by nuclear fusion reactions in its core, whereas a planet shines mostly because of light reflected from the Sun.

Nuclear reactions take place in the core of stars when the temperature is high enough, and this only happens when the star has enough mass to provide the necessary pressure.

A minimum mass is required for an object to become a star: 0.08 times the mass of the Sun, or about 75 times the mass of Jupiter.

Imagine that Jupiter was 80 times more massive. We would live in a binary star system!

The core is still emitting the heat left-over from its formation.

Jupiter radiates 1.6 times more energy than it receives from the Sun.

At infrared wavelength, the molecular hydrogen and methane gas in Jupiter’s dense lower atmosphere strongly absorb sunlight, so the normally bright, banded planet looks very dark.

The core is still emitting the heat left-over from its formation and the planet is still contracting.

Jupiter radiates 1.6 times more energy than it receives from the Sun.

**Average density** ≈ 1.3 g/cm³

- 86.1% hydrogen
- 13.8% helium

- Atmosphere gets denser and denser towards its interior:
  1. gaseous hydrogen
  2. liquid hydrogen
  3. liquid metallic hydrogen (generates large magnetic field)
  4. rocky core (15 x’s Earth’s mass)
The magnetic field of Jupiter, unlike Earth, is oriented in the opposite direction, so a compass would point south, not north. Jupiter's magnetic field is tilted 10 degrees with respect to its axis of rotation.

**Io’s Volcanoes and Jovian Magnetosphere**

- Most of the material from the eruptions just rains back down on Io, but about 0.01% or 10 tons per second escapes into space.

- $\text{SO}_2$ is quickly broken up into S and O atoms and ions by the action of UV light.

- Hence part of Io’s plasma torus is due to eruptions from Io.
As Io moves through Jupiter's magnetic field, it acts as an electrical generator, developing 400,000 volts across its diameter and generating an electrical current of three million amperes.

The current flows along the magnetic field to Jupiter's ionosphere.

Electrically charged atmosphere surrounding Jupiter and orbit of Io

Jupiter's aurorae include several bright streaks and dots. These marks are caused by magnetic flux tubes connecting Jupiter to its largest moons. Specifically, Io caused the bright streak on the far left, Ganymede caused the bright dot below center, and Europa caused the dot to its right.

auroral "footprint" created by a river of electrical current of about one million amperes flowing between Jupiter and the volcanic moon Io.

the planet's immense magnetic field, coupled with its fast, 10-hour rotation, helps generate auroras that are 1,000 times more powerful than even Earth's spectacular light shows.
Its magnetic field, tilted by ~10° from its rotation axis, co-rotates with the planet's interior (~9h 56m) and generates energetic radio emission.

**Atmosphere Outline**
- Rotation
- Belts and Zones,
- White and Brown Ovals,
- Cloud Layers,
- Red Spot,
- Thunderstorms

**Internal rotation period (true period of rotation)**
9 hr 55 min 30 s

**Equatorial rotation period**
9 hr 50 min 30 s

**Rotation period at higher latitudes**
9 hr 55 min 41 s

**Differential Rotation**

- Fast rotation flattens out the sphere--- equatorial diameter is 142,984 km
- Poles diameter is 133,708 km
- Jupiter is over 19 times more oblate than the Earth!
- Implies a 15 x's Earth's mass center

**Rapid rotation and large size create belts and zones in the cloud pattern**
Bands
Zones (light; warm, rising regions)
Belts (dark; cool, falling regions)

Colored bands are associated with vertical convective motion. Upwelling warm gas results in zones of lighter color; the darker bands overlie regions of lower pressure where cooler gas sinks back down into the atmosphere.

Jupiter’s rapid rotation channels those winds into an east-west flow pattern, as indicated by the three yellow-red arrows drawn atop the belts and zones.

Cloud motion
Alternations in wind direction are associated with the atmospheric band structure.

Coloration is due to the composition of the atmosphere and the abundance of trace elements present. The orange and brown colors in Jupiter’s clouds may be due to the presence of these organic compounds, or sulfur and phosphorus.

Three Cloud Layers
Little of the early atmosphere escaped due to its strong gravity: methane (CH₄), ammonia (NH₃), water (H₂O).

Clouds arranged in three main layers:

- The white regions are the tops of the upper ammonia clouds.
- The yellows, reds, and browns are associated with the second cloud layer, which is made of ammonium hydrosulfide ice.
- The lowest (bluish) cloud layer is water ice.
Great Red Spot

Red Spot is a hurricane in Jupiter's atmosphere – Windspeeds 650 km/hr

Diameter is over twice that of Earth (28,000 km) long and (14,000 km) wide

Discovered in 1664 by Robert Hooke.
Has been visible for over 300 years.

Formed by rising gas carrying heat from below the clouds, creating a vast, rotating storm.

High pressure region → gas flows outward.

Brown ovals Northern hemisphere "hole" allowing view deep into atmosphere persist for one or two years. Could be an opening in the upper cloud deck where warmer cloud levels may exist.

White ovals southern hemisphere live for decades: upwelling of winds in the center, which in turn leads to downwelling around it. The white oval have a very cold center at a temperature of -157 C, about one degree colder than its surroundings.
Bright white spots are energetic lightning storms.

The white area in the center is a tall, thick cloud higher than most of the surrounding clouds. Most of the wisps are ammonia clouds. The red base of this thunderstorm is a water cloud.