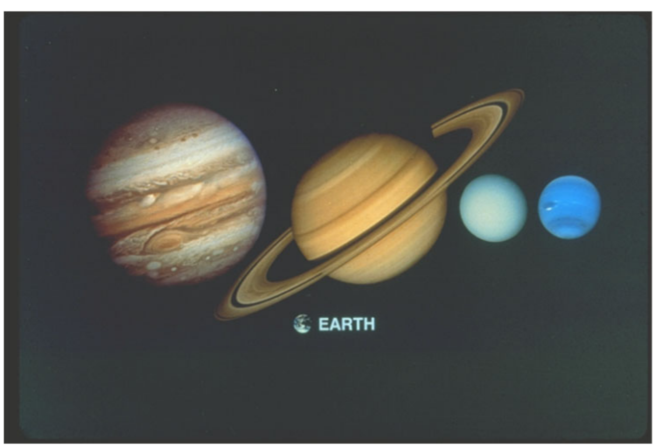
JUPITER

NASA

The Giant

The Jovian Planets



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Jovian Planet Chemistry

Past the asteroid belt, there is a region of different planetary composition. Beyond about 4 AU from the Sun, **water ice** was able to condense and thus to become available as a raw material, in addition to the silicates and metals present in the inner Solar System.

Since the atoms that constitute water are among the most abundant, a great deal of water ice is formed. [H is most abundant, O is 3^{rd} most abundant.]

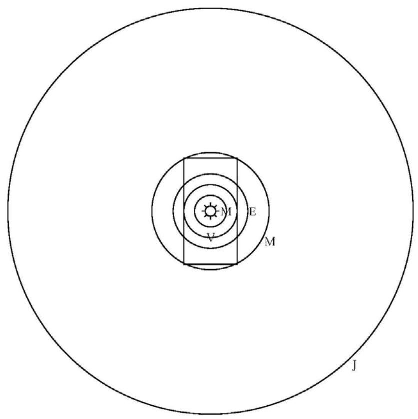
Jovian Planet Chemistry

The second major chemical distinction in the outer Solar System is the result of the **larger spacing** between planets and the accumulation of **more massive cores** of rock and ice.

The developing cores of Jupiter and Saturn grew large enough before the dissipation of the gaseous solar nebula to attract and hold the hydrogen and helium from large volumes of space.

Uranus and Neptune captured much less hydrogen and helium; this is why these two planets are both smaller than, and different in composition from, Jupiter and Saturn.

Scale of the Solar System

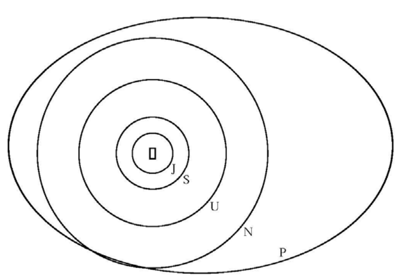


Shrink the Sun down to the size of a basketball.

Put it on the 50 yard line of the GT football field.

Note the spacing of the inner planets – all would fit on the football field.

Scale (cont.)



Note the spacing of the outer planets – much larger than the football field.

Jovian Planet Chemistry

With so much hydrogen available, the chemistry of the outer Solar System is **reducing**. Most of the oxygen present is chemically combined with hydrogen to make water, and it is therefore unavailable to form many oxidized compounds with other elements.

The compounds detected in the atmospheres of the giant planets are thus hydrogen-based gases, such as methane (CH_4) and ammonia (NH_3).

Exploration

Pioneers 10 and 11 in 1973 & 1974.
Primarily took a few pictures and measured magnetic fields.

Voyagers 1 and 2 were in 1979.
The Voyagers carried 11 instruments.

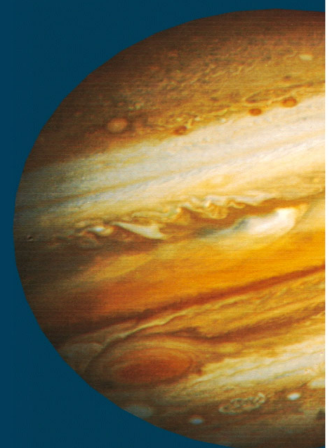
Galileo operated from 1995 to 2003.
Its probe entered the Jovian Atmosphere.

New Horizons (Pluto) flyby in 2007.

Juno arrived in 2016.

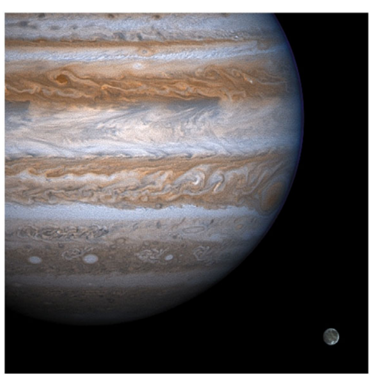
Table 13-1 Jupiter Data

Average distance from Sun:	5.203 AU = 7.783 × 10^8 km
Maximum distance from Sun:	5.455 AU = 8.160 × 10^8 km
Minimum distance from Sun:	4.950 AU = 7.406 × 10^8 km
Eccentricity of orbit:	0.048
Average orbital speed:	13.1 km/s
Orbital period:	11.86 years
Rotation period:	$9^h\ 50^m\ 28^s$ (equatorial) $9^h\ 55^m\ 29^s$ (internal)
Inclination of equator to orbit:	3.12°
Inclination of orbit to ecliptic:	1.30°
Diameter:	142,984 km = 11.209 Earth diameters (equatorial) 133,708 km = 10.482 Earth diameters (polar)
Mass:	1.899 × 10^{27} kg = 317.8 Earth masses
Average density:	1326 kg/m^3
Escape speed:	60.2 km/s
Surface gravity (Earth = 1):	2.36
Albedo:	0.44
Average temperature at cloudtops:	−108°C = −162°F = 165 K



(NASA)

Appearance and Rotation



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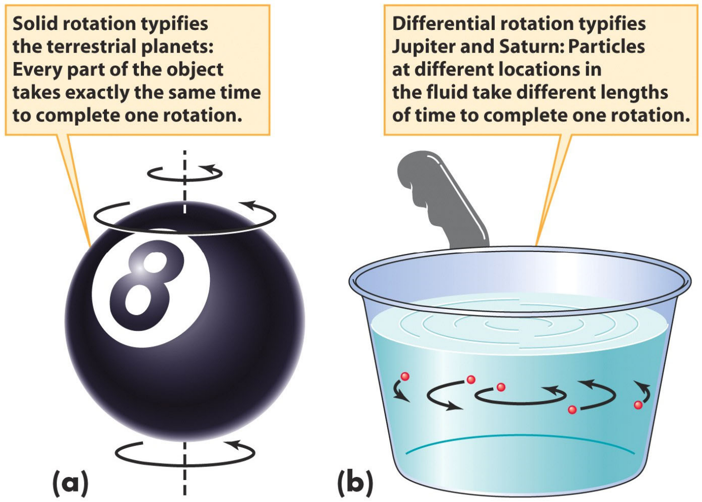
Jupiter is a colorful and dynamic planet. Distinct details in its cloud patterns allow us to determine the rotation rate of the atmosphere.

Much more fundamental is the rotation of the mantle and core, as indicated by periodic variations in the magnetic field. **This period of 9^h56^m gives Jupiter the shortest day of any planet.**

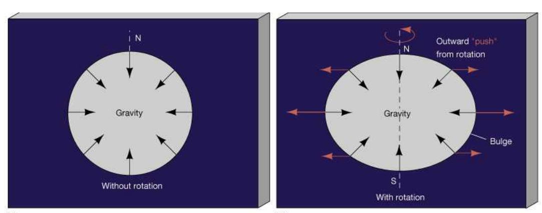
However, Jupiter experiences **differential rotation**.

Differential Rotation



Universe by Freedman, Geller, and Kaufmann

Rotational Flattening

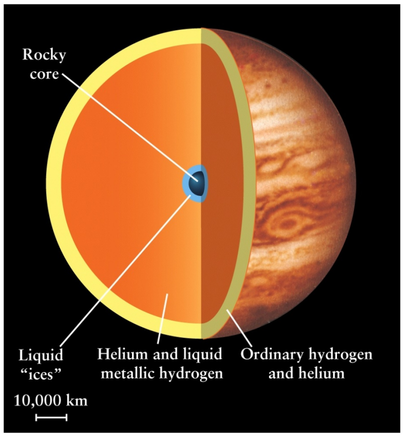


Astronomy Today by Chaisson and McMillan

All spinning objects develop an **equatorial bulge** because rotation causes matter to push outward against the inward-pulling gravity.

The size of the bulge depends on the mechanical strength of the matter and the rate of rotation.

Composition and Structure



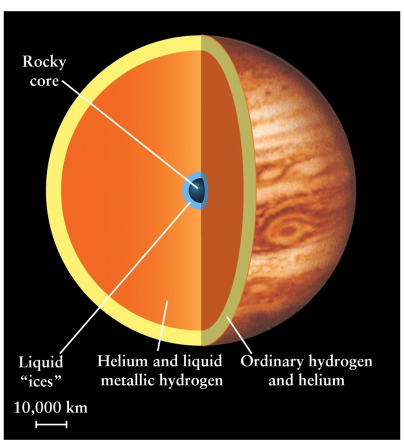
Universe by Freedman, Geller, and Kaufmann

The internal structure is different than that of the terrestrial planets.

At depths of only a few thousand km, pressures become so high that hydrogen changes from **gaseous** to a **liquid** state.

Still deeper, this liquid hydrogen can act like a **metal**. The greater part of the interior is **liquid metallic hydrogen**.

Composition and Structure



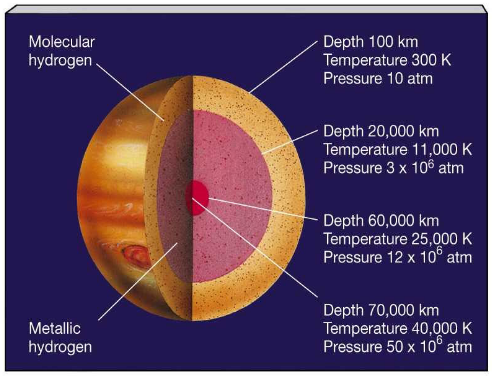
Universe by Freedman, Geller, and Kaufmann

The core is composed of heavier materials, presumably the original rock-and-ice small bodies.

Models predict a central pressure of over 100 million bars and a central density of about 31 g/cm^3.

[Much greater than the Earth's, but not nearly enough to be a star.]

Interior Structure



Astronomy Today by Chaisson and McMillan

Icy/Rocky Core	3,000 km
Liquid, Metallic H Mantle	56,000 km
Gaseous H Atmosphere	7,000 km

Internal Heat Source

Jupiter has an internal source of heat, due to **gravitational contraction**.

Shrinking in diameter by as little as 1 mm per year can liberate substantial gravitational energy. This amount of energy is about the same as the total solar energy absorbed.

The Jovian atmosphere is therefore a cross between a normal planetary atmosphere, which obtains most of its energy from the Sun, and the atmosphere of a star, which is entirely heated from below.

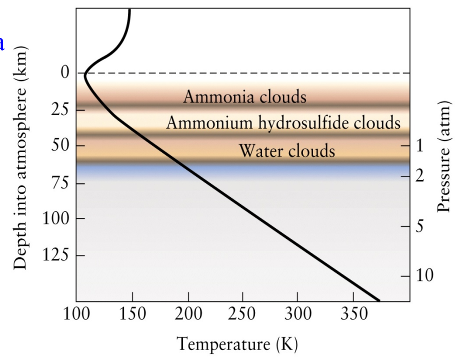
Most of the internal energy is primordial heat, left over from the formation 4.5 billion years ago.

Atmosphere and Clouds

Composition is primarily H and He, although methane (CH_4) and ammonia (NH_3) were identified first.

At the temperatures and pressures of the upper atmospheres of Jupiter, methane remains a gas, but **ammonia** can condense to produce **clouds**.

The ammonia cloud deck marks the upper edge of the convective troposphere; above it is the cold stratosphere.



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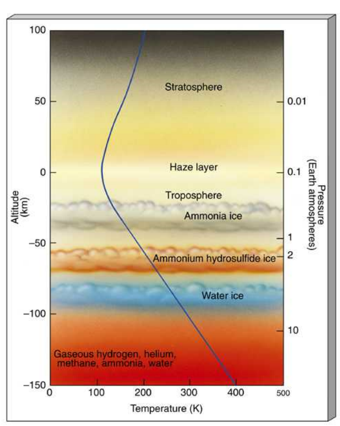
Atmosphere and Clouds

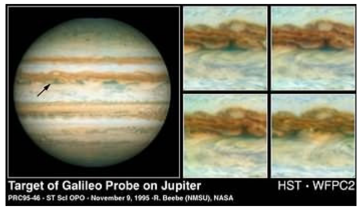


Astronomy Today by Chaisson and McMillan

Temperature at the cloud tops is **140 K**. Within the troposphere, the temperature and pressure increase with depth. Above the visible ammonia clouds the atmosphere is clear and cold, reaching a low near 120 K.

Another mystery is the cause of the ***colors*** of the clouds, for ammonia clouds should be white. Various photo-chemically produced organic compounds have been suggested, as well as sulfur and red phosphorus.

Galileo Observations



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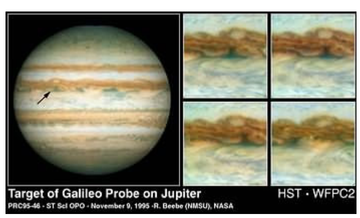
The Galileo probe operated for 57 minutes. (a) It first entered the ammonia (NH_3) cirrus clouds. (b) The layer of ammonium hydrosulfide (NH_4HS) was possibly seen. (c) The predicted layer of water ice was not detected, though. The probe reached a depth of 160 km and a pressure of 22 bars.

Galileo Observations



NASA

The abundance of He was found to be 24%, whereas in the Sun it is 28%. The argon abundance was similar to the Sun's. Galileo detected winds all the way down. Apparently, internal heat drives the weather.

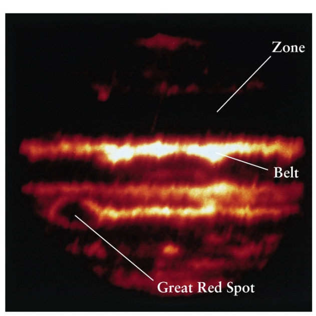
Winds and Weather

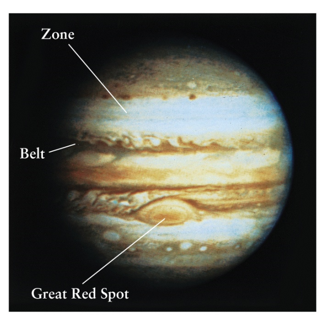
The atmospheric dynamics observed on the Jovian planets differ from those of the terrestrial planets. The three primary reasons are:

1. These planets have much deeper atmospheres, with no solid lower boundary,
2. They spin faster than the terrestrial planets, suppressing north-south circulation patterns and accentuating east-west airflow, and
3. On all except Uranus, internal heat sources contribute about as much energy as sunlight, forcing the atmospheres into deep convection to carry the internal heat outward.

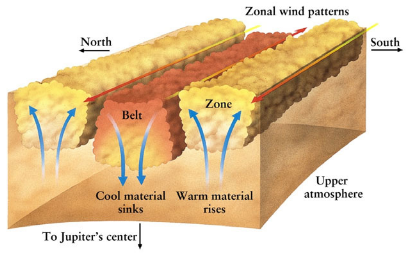
Bands and Zones

The main features of the visible clouds of Jupiter are alternating (warm) **dark belts** and (cool) **light zones** that stretch around the planet parallel to the equator.





Bands and Zones



Universe by Freedman, Geller, and Kaufmann

Generally, the light zones on Jupiter are regions of upwelling air, capped by white ammonia cirrus clouds. They apparently represent the tops of upward-moving convection currents.

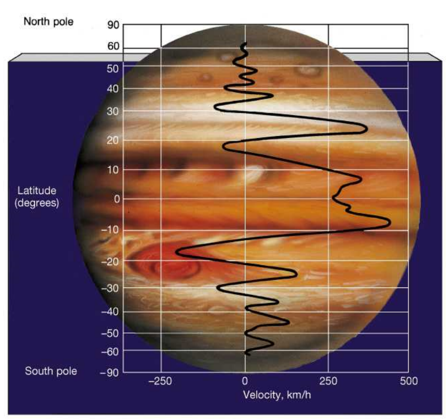
The darker belts are regions where the cooler atmosphere moves downward. They are darker because there are fewer ammonia clouds and it is possible to see deeper in the atmosphere.

Bands and Zones

More fundamental than these bands are the underlying east-west patterns in the atmosphere, which do not appear to change, even over decades.

The main such feature on Jupiter is an eastward-flowing equatorial jet stream with a speed of 300 km/hr.

At higher latitudes there are alternating east- and west-moving streams.



Astronomy Today by Chaisson and McMillan

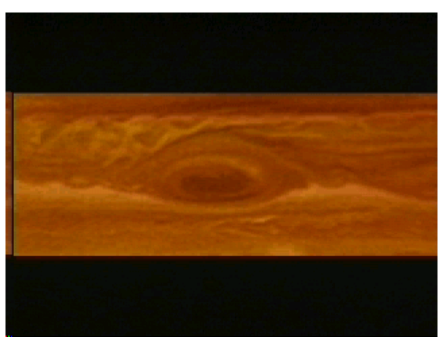
Storms

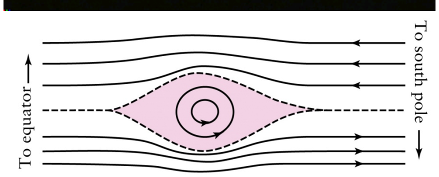

NASA

The most famous storm on Jupiter is the **Great Red Spot**, a reddish oval that is big enough to hold two Earths side by side. It has existed for over 300 years.

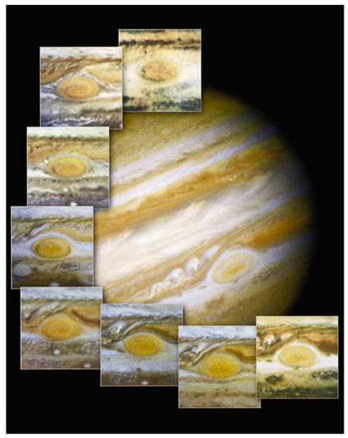
There are also three smaller, white ovals, which formed in the 1940s. The cause is unknown. They last long times because there are no solid surfaces to slow down atmospheric disturbances. Furthermore, their large size lends to stability.

Red Spot Movie





Red Spot Mosaic



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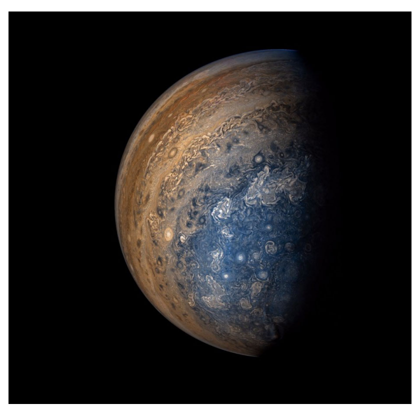
Juno Images

Juno's Polar Pictures

NASA



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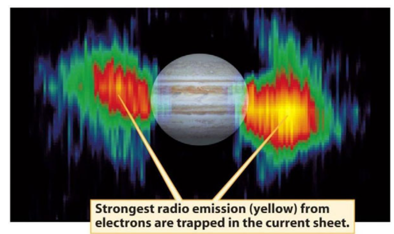
Magnetosphere

In the 1950s, radio energy was observed from Jupiter that was more intense at longer than at shorter wavelengths – just the reverse of what is expected from thermal radiation. This is typical of the radiation emitted by electrons accelerated by a magnetic field, called **synchrotron radiation**.

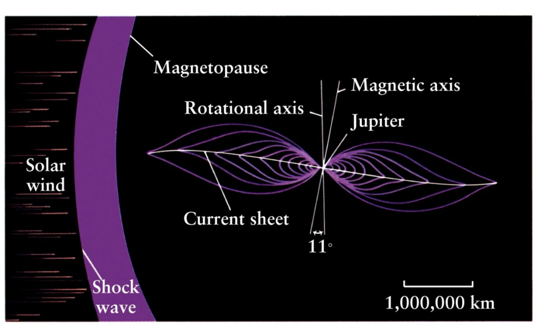
Later observations showed that the radio energy originates from a region surrounding the planet whose diameter is several times that of Jupiter itself.

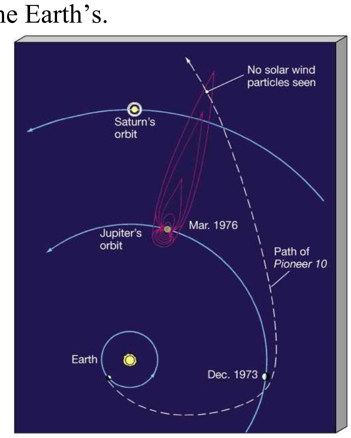
The evidence suggests that there are a vast number of charged atomic particles circulating around Jupiter, spiraling through the lines of force of a magnetic field associated with the planet.



Magnetosphere

Jupiter's magnetic field is 20 to 30 times stronger than the Earth's. Its magnetic axis is tilted by 11°, and is offset from the center of the planet. Strength at the surface is 19,000 times that of the Earth's.





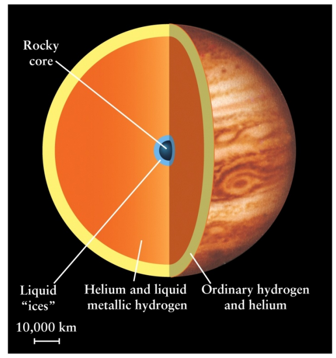
Astronomy Today by Chaisson and McMillan

Magnetosphere

Presumably the magnetic fields of the outer planets are generated in much the same way as the field of the Earth.

All of these planets **spin rapidly**, so there is a ready source of energy to power their internal magnetic generators.

Jupiter has a large interior region of metallic liquid hydrogen that acts like the liquid iron core of the Earth.



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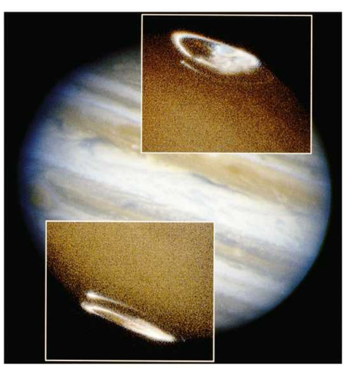
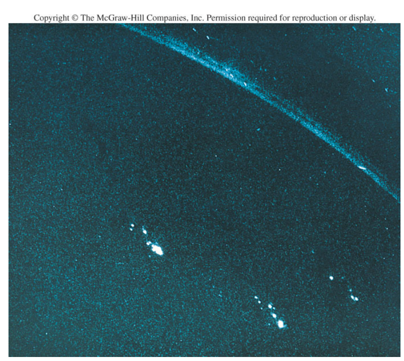
Aurorae and Lightning





Universe by Freedman, Geller, and Kaufmann

The oval-shaped aurorae, extending hundreds of km above Jupiter's limb, are created by charged particles escaping from the magnetosphere and colliding with the atmosphere, which causes the gas to glow.

Rings

A ring is a collection of vast numbers of particles – a ring is not a solid "washer". Each particle obeys Kepler's Laws as it follows its own orbit around the planet. Thus the inner particles orbit faster than those farther out, and the ring as whole does not rotate as a solid body.

Jupiter's ring was discovered by Voyager 1 in a single image that was targeted specifically to search for a faint ring system. Subsequently, Voyager 2 was reprogrammed to take a more complete set of images.

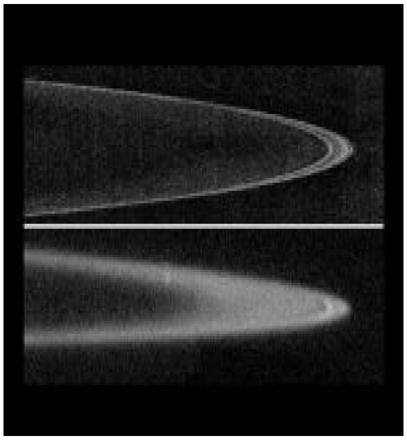
Rings of Jupiter

NASA

The ring is now known to be composed of three major components. The "Main" ring is about 7,000 km wide. The main ring encompasses the orbits of two small moons, Adrastea and Metis, which may act as the source for the dust that makes up most of the ring.

At its inner edge the main ring merges gradually into the "Halo." The halo is a broad, faint torus of material about 20,000 km thick and extending halfway from the main ring down to the planet's cloudtops.

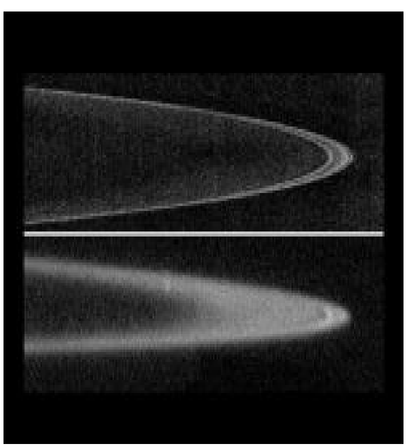
Newest Ring Images



NASA

The New Horizons spacecraft took the best images of Jupiter's charcoal-black rings as it approached and then looked back at Jupiter. The image is sharply focused, though it appears fuzzy due to the cloud of dust-sized particles enveloping the rings.

Newest Ring Images



NASA

Just outside the main ring is the broad and exceedingly faint "Gossamer" ring, which extends out beyond the orbit of the moon Amalthea.

It is probably composed of dust particles less than 10 microns in diameter − about the size of cigarette smoke particles.

The origin of the ring is probably from micrometeorite bombardment of the tiny moons orbiting within the ring.