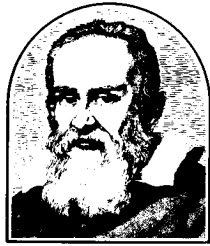


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## SECTION 3



### THE PLANET JUPITER

For thousands of years, people have watched a bright wandering light in their sky. Only one other wanderer (Venus) was brighter, but it never appeared high in the night sky. This “wandering star” or planet was named after the ruler and most powerful of the Roman gods of mythology—Jupiter.

Jupiter is the largest planet in the solar system. It is about two and a half times more massive than the other eight planets combined. If it were hollow, more than 1400 Earths could fit inside. However, Jupiter’s density is only a little more than that of water. It is a gas planet, not a rocky one like Earth.

Through a telescope, Jupiter appears as a yellowish disk, crossed with orange-red bands. Since the mid-1600s, astronomers have noted spots moving across Jupiter’s face as the planet rotates. Some of these spots and other cloud features have survived for years at a time, much longer than clouds and storm systems do on Earth. The longest observed of these spots is the “Great Red Spot.” This gigantic red oval (about three times the size of Earth) was first reported in 1664 and still exists today.

Astronomers have used these moving spots to roughly measure the planet’s rotation period. A Jupiter “day” is just under 10 hours. Jupiter has the highest rotation period of any planet, causing the slightly squashed appearance of the disk. The equatorial radius is 4300 kilometers larger than the polar radius (142,984 kilometers).

### Early Explorations

Five spacecraft from Earth have already made the journey to Jupiter. Pioneers 10 and 11, launched in 1972 and 1973, respectively, were the first spacecraft to explore space beyond the orbit of Mars, cross the asteroid belt, and provide close looks at the giant planet. The Pioneer spacecraft were “spinners.” They rotated constantly like giant tops. This design was very stable and required less complicated guidance than a non-spinning craft.

The instruments could collect data from many different directions while the spacecraft was spinning. Instruments measuring energetic particles and magnetic fields perform well on a spinning spacecraft. Other types of instruments, such as cameras, do not do as well. Imagine trying to take a picture while you were riding a merry-go-round. The Pioneers carried 11 instruments. Some were for sensing small meteoric particles and charged particles. Some were for measuring Jupiter’s magnetic field and radiation. One instrument, the imaging photopolarimeter, measured the brightness of a narrow strip of the planet. It took measurements during each spin of the spacecraft. An image of Jupiter was assembled from these strips.

Voyagers 1 and 2 were launched on their tours of the outer planets in 1977. The Voyager missions were designed to study the planetary systems in greater detail than the Pioneers had done. The Voyager spacecraft were more sophisticated and more automated than the Pioneers. Also, these spacecraft were not spinners but were “three-axis stabilized.” Voyager was able to maintain a fixed orientation, or attitude, in space. The spacecraft provided accurate and steady pointing for its instruments. However, the instruments could not continuously sample different directions. Voyager carried 10 instruments, including television-like cameras, spectrometers, particle detectors, and a magnetometer.

The latest visitor to Jupiter, Ulysses, was launched in 1990 and arrived in early 1992. Ulysses’ prime mission was to study the poles of the Sun. The spacecraft used Jupiter’s gravity to swing out of the ecliptic plane so it could examine the polar regions of the Sun. The spinner spacecraft carried nine instruments (no camera-like devices) designed to study the Sun, the solar wind, and interstellar space. These instruments supplied data about Jupiter’s magnetosphere.

<i>How We Compare</i>	Characteristic	Earth	Jupiter
	Equatorial Diameter (km)	12,756	142,984
	Mean Relative Density (g/cm <sup>3</sup> )	5.52	1.33
	Mean Distance From Sun (km)	149,600,000	778,400,000
	Orbital Rotation	365.25 days	12 Earth years
	Rotational Period	23 h, 56 min	9 h, 55 min
	Atmosphere	77% nitrogen 21% oxygen	81% hydrogen 18% helium

The Atmosphere

Based on the data obtained from the Pioneer and Voyager missions, Jupiter’s atmosphere consists of about 81 percent hydrogen and 18 percent helium. If Jupiter had been between fifty and a hundred times more massive, it might have evolved into a star rather than a planet. Our solar system could have been a binary star system. Besides hydrogen and helium, small amounts of methane, ammonia, phosphorus, water vapor, and various hydrocarbons have been found in Jupiter’s atmosphere.

Jupiter’s atmosphere displays alternating patterns of dark belts and light zones. The locations and sizes of the belts and zones change gradually with

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time. Within these belts and zones are clouds and storm systems that have raged for years. One of these giant storms, called the “Great Red Spot,” has lasted over 300 years. This spot rotates once counter-clockwise every 6 days. Since it is in the southern hemisphere of the planet, this rotational direction indicates it is a high-pressure zone (unlike Earth’s cyclones, which are low-pressure zones). The reddish color is a puzzle to scientists, but several chemicals, including phosphorus, have been proposed. In fact, the colors and mechanisms driving the appearance of the entire atmosphere are not well understood. These mysteries cannot be solved by taking pictures. Direct measurements from within the atmosphere are necessary—measurements like those made by the Galileo probe.

Jupiter is swept by about a dozen prevailing winds, reaching 150 meters per second (335 miles per hour) at the equator. On Earth, winds are driven by the large difference in temperature, more than 40 degrees Celsius (about 100 degrees Fahrenheit), between the poles and the equator. But, Jupiter’s pole and equator share the same temperature, –130 degrees Celsius (about –200 degrees Fahrenheit), at least near the cloud tops. This is another mystery being addressed by Galileo (see Probe Science Results).

*Jupiter’s  
Great Red Spot*



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## The Interior

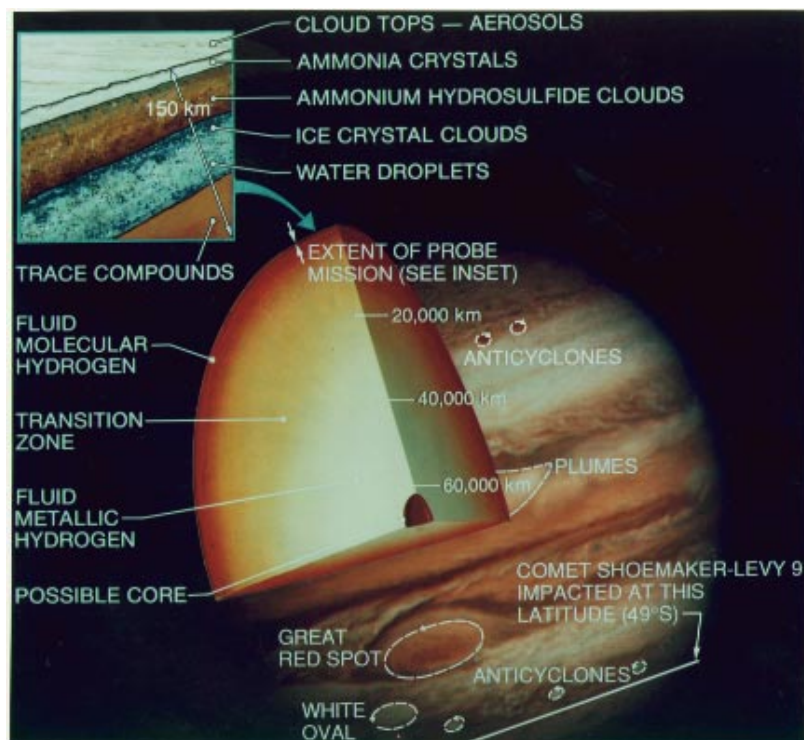
Jupiter's core is estimated to be about one-and-a-half times Earth's diameter, yet ten to thirty times more massive. The core's temperature is estimated to be 30,000 degrees Celsius (about 55,000 degrees Fahrenheit). This high temperature is the result of a pressure of as much as a hundred million atmospheres. (One atmosphere is equal to the air pressure at sea level on Earth.)

Surrounding this core is a 40,000-kilometer (25,000-mile) deep sea of liquid metallic hydrogen. Unknown on Earth, liquid metallic hydrogen forms under the extreme pressures that exist on Jupiter. At this depth, the pressure is more than three million atmospheres. Hydrogen molecules are so tightly packed that they break up and become electrically conductive. Scientists believe it is this electrically conductive liquid that causes Jupiter's intense magnetic field.

Next there is a 21,000-kilometer (13,000-mile) thick layer of hydrogen and helium. This layer gradually changes from liquid to gas as the pressure falls into the range of tens of atmospheres.

Finally, in the uppermost regions of the atmosphere, the temperatures and pressures are low enough to allow clouds to form.

*Jupiter—From  
Core to Cloud Top*



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## The Ring

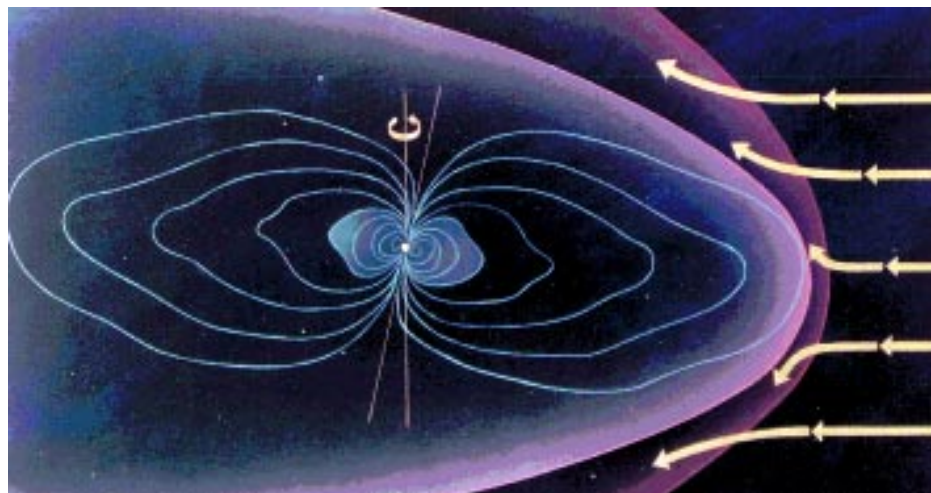
One of the surprising discoveries made by Voyager was the detection of an extremely faint ring around Jupiter. The scientists who designed Voyager's observations decided to take pictures of the area where they thought a ring might be. The lighting was just right for them to capture the ring made up mostly of dark, dust-sized particles. The ring, consisting of three bands, extends from the upper atmosphere out to about 53,000 kilometers (33,000 miles) above the cloud tops. The brightest band is at the outer edge and is 800 kilometers (500 miles) wide.

## The Magnetosphere

One of the by-products of Jupiter's ocean of liquid metallic hydrogen is a magnetic field stronger than that of any other planet. Jupiter's magnetic field has the opposite sense of Earth's. A compass would point south rather than north. The region of space dominated by a planet's magnetic field is called a "magnetosphere." Jupiter's magnetosphere is molded by the solar wind (the stream of charged particles "blown" out from the Sun) into a teardrop shape—its point directed away from the Sun. If Jupiter's magnetosphere were visible from Earth, it would be several times larger than the full Moon in the night sky.

The magnetosphere is dominated by the planet's environment, its magnetic field, and a swarm of energetic particles and gases. The low-energy ions, protons, and electrons are called "plasma." The boundary between the magnetosphere and the solar wind is the "magnetopause." A bowshock is formed in the solar wind upstream from the magnetopause. In the direction away from the Sun, the magnetosphere is drawn out in a long "magnetotail" by the drag of the solar wind.

*Jovian  
Magnetosphere  
and Solar Wind  
Interaction*



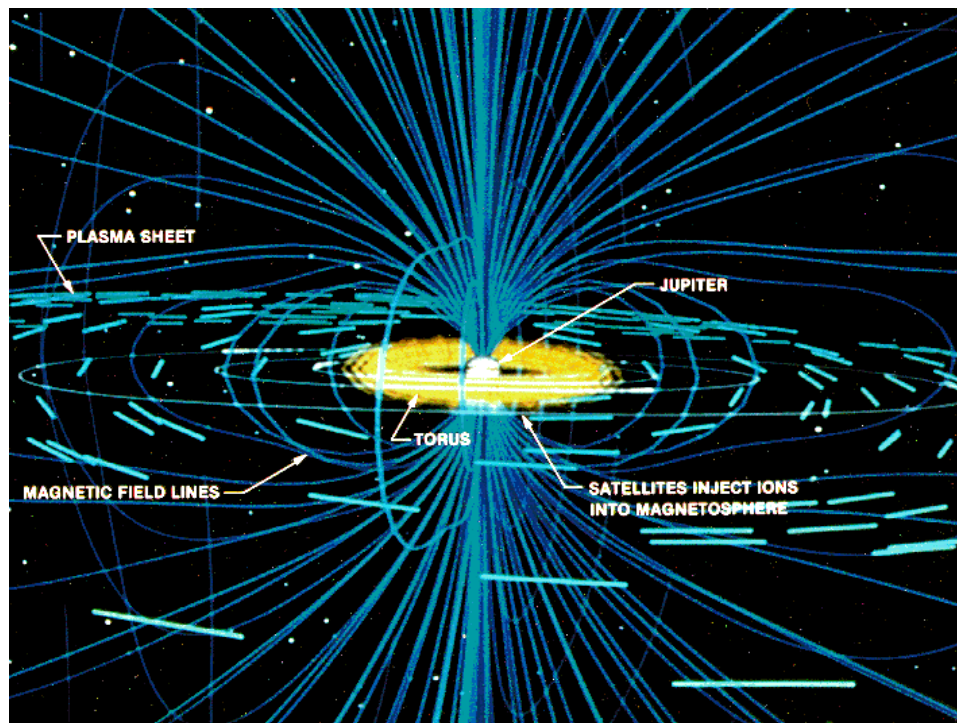
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Distributed throughout the magnetosphere is a low-energy plasma, largely concentrated within a few planetary radii of the equatorial plane. The plasma forms a sheet through which concentrated electric currents flow.

The Pioneers and Voyagers observed a giant doughnut-shaped collection of charged particles surrounding Jupiter at about the distance of the orbit of Io. This is known as “the Io plasma torus.” It results from material escaping from Io’s atmosphere or surface and then being caught up in Jupiter’s magnetic field.

At Jupiter, the plasma within the magnetosphere tends to rotate along with its rotating magnetic field . If it rotates at the same speed, it is referred to as “rigid corotation.” Processes within the magnetosphere cause the plasma to rotate at less than rigid corotation speeds in some regions.

*The Plasma Sheet  
and the Magnetic  
Field Lines  
Of Jupiter,  
Io’s Torus*










## The Satellites

Thirteen of Jupiter's 16 known moons were discovered from Earth. The other three were first seen by Voyager. The four largest moons—Io, Europa, Ganymede, and Callisto—were observed in 1610 by Galileo Galilei of Italy. He used a newly invented device called a “telescope.” These four moons are often referred to collectively as “the Galilean satellites.” What do we already know of these moons? They range in size from slightly smaller than our Moon to slightly larger than Mercury. The top figure shows the order of the satellites’ proximities to Jupiter (moon sizes are not to scale), and the bottom figure shows their size in comparison to other bodies in our solar system.

### Distances From Jupiter

				
<b>Jupiter</b>	<b>Io</b>	<b>Europa</b>	<b>Ganymede</b>	<b>Callisto</b>
778.3 x 10 <sup>6</sup> (from Sun)	421,600	670,900	1,070,000	1,880,000
71,398 (equatorial)	1,815 ± 5	1,569 ± 10	2,631 ± 10	2,400 ± 10
1.9 x 10 <sup>27</sup>	8.92 x 10 <sup>22</sup>	4.87 x 10 <sup>22</sup>	1.490 x 10 <sup>23</sup>	1.075 x 10 <sup>23</sup>
1.314	3.55	3.04	1.93	1.83
			– Mean distance (km) –	
			– Radius (km) –	
			– Mass (kg) –	
			– Bulk density (g/cm <sup>3</sup> ) –	

### Relative Size

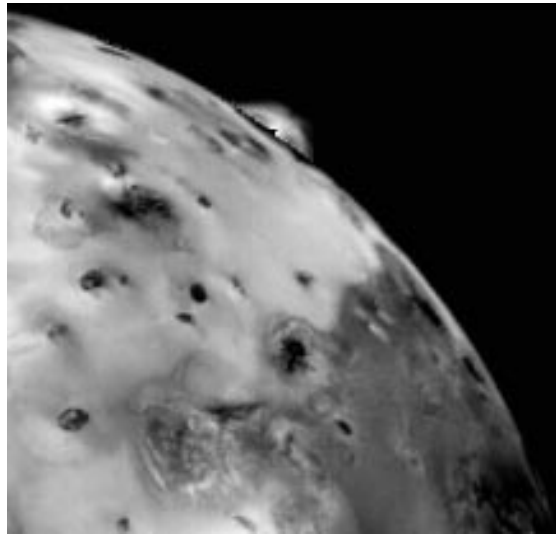


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Io

Io, the Galilean satellite nearest Jupiter, has been described as looking like a giant pizza (due to its bright reddish-orange and white markings) or the closest place to hell in the solar system. Volcanoes spew plumes of gas and solid particles hundreds of kilometers above the surface. A collection of these particles, trapped by the magnetic force from Jupiter, forms the Io torus that orbits the planet in the shape of a huge doughnut. Flows of sulfur lava radiate from the volcanoes. Approximately one third of the surface is covered with bright white sulfuric snow. It may be that the intense volcanic activity on Io results from frequent great tides caused by the gravitational influence of Jupiter. Galileo found that Io has a large, dense iron core, taking up half its diameter (see Arrival at Jupiter section).

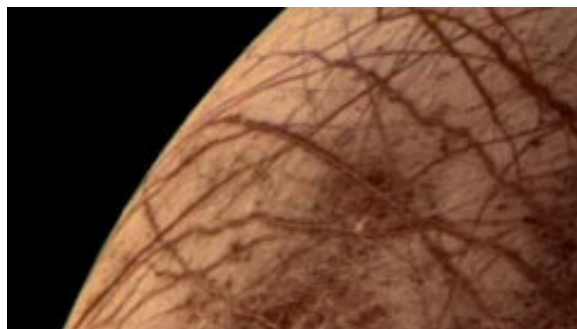
*Volcanoes Galore!*



Europa

If Io is a pizza, then Europa, the next satellite out from Jupiter, is a cracked hard-boiled egg. It has a bright white surface, crisscrossed with dark fissures. It has neither mountains nor valleys, craters nor volcanoes. Recent observations from Earth indicate the moon may have a thin atmosphere of oxygen and sodium. Some scientists think that a giant water ocean may lie beneath a layer of ice that has cracked and refrozen at temperatures of about  $-146$  degrees Celsius ( $-230$  degrees Fahrenheit). If so, it would be the only place we know of in our solar system besides Earth with a significant supply of liquid water. Still—too cold for a swim!

*Cracks in the Ice?*



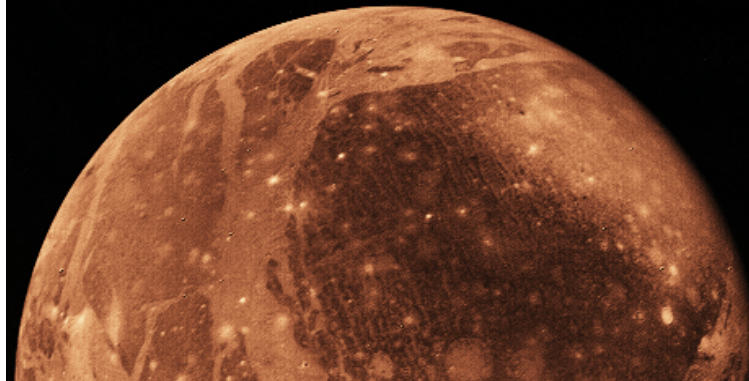


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## Ganymede

The third Galilean satellite, Ganymede, is the largest moon in the solar system. It has a variety of geological formations, including craters and basins, grooves, and rough mountainous areas. About half the surface is covered with water ice and half with dark rock. These heavily cratered dark regions are thought to be ancient. The newer, lighter regions give evidence of tectonic activity that may have broken up the icy crust. A thin layer of ozone has been detected surrounding Ganymede.

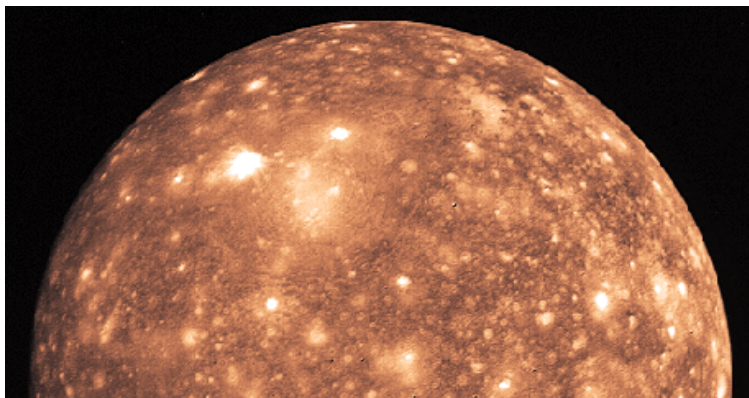
*Bigger Than  
Mercury*



## Callisto

The last and least active of the Galilean satellites is Callisto. Like Ganymede, it seems to have a rocky core surrounded by an ocean of ice. The surface is covered completely with meteoric impact craters; no “plains” show. Although the exact rate of impact crater formation is not known, scientists estimate that it would require several billion years to accumulate the number of craters found on Callisto. Therefore, the moon must have been inactive at least that long, a fine record of the past.

*Cluttered With  
Craters*



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## The Minor Satellites

All the other satellites are comparatively minor objects, up to 170 kilometers (100 miles) across. Eight are in inclined orbits far from the planet, and four are close to the planet, inside Io's orbit. In ascending order of mean distance from Jupiter, the 16 moons are Metis,Adrastea, Amalthea, Thebe, Io, Europa, Ganymede, Callisto, Leda, Himalia, Lysithea, Elara, Ananke, Carme, Pasiphae, and Sinope. Online From Jupiter (see World Wide Web in the first section, About This Guide) sponsored a contest to create a mnemonic to help you remember this long list. One winner gave us "Meteors and asteroids travel in every galaxy continuously" for the first eight moons. You may want to devise your own sentence from the initial letters of the last eight satellites!

## What Do We Hope To Learn?

Studying Jupiter may help us to understand how the solar system, and our own planet, formed and evolved. The flyby missions of the Pioneers, Voyagers, and Ulysses gave us quick glimpses of this exciting world. Now it is time to settle in and take long-term, detailed measurements of the system.

The Galileo mission is composed of two elements to do just this. The probe descended into the atmosphere to sample it directly (see two sections, The Galileo Probe and Probe Science Results). The orbiter will spend almost 2 years studying the planet, its satellites, and the vast magnetosphere up close. (Galileo's closest approaches to Jupiter will be in the altitude range of 650,000 to 800,000 kilometers.)

The composition of Jupiter's atmosphere may tell us about the original star stuff from which all the planets formed. There are many unanswered questions about Jupiter that Galileo will try to answer. What is the current state of Jupiter's atmosphere? What are its clouds made of? How do temperature and pressure change with depth? What is the strength of its winds? What are the forces behind its weather patterns? What causes the lightning that Voyager observed flashing on the night side of the planet? The Probe mission has already provided some clues. Learning more about Jupiter's atmosphere will advance our understanding of the nature of all planetary atmospheres, including our own.

By studying Jupiter's satellites we hope to determine the effects of initial conditions, size, energy sources, meteorite bombardment, and tectonic processes on the way planets evolve. Among the key questions about the satellites are the following: How did Io's volcanoes evolve and what is their chemical composition? How thick is Europa's ice crust and what lies beneath it? What causes the appearance of the terrain on Ganymede? How do the craters on Callisto compare with craters on rocky planets?

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What are the interiors of the satellites like? What are their atmospheres (if any) like? Do they have magnetic fields?

Observations of the magnetosphere will help us to understand the complex interactions between magnetic forces and matter throughout the universe. There are many questions about the magnetosphere. What is the interaction between the satellites and the magnetosphere? What are the origins of the magnetotail wind?

We should always remember that even though we have many ideas about what we anticipate Galileo will accomplish, the most exciting results are often unexpected.

***Galileo Science  
Objectives***

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**Atmosphere of Jupiter**

- Determine the chemical composition
- Determine the structure to a depth of at least 10 bars
- Determine the nature of the cloud particles and location and structure of cloud layers
- Determine the difference between the amount of energy being received from the Sun and the amount of energy coming from inside Jupiter
- Investigate the wind patterns
- Investigate the upper atmosphere and ionosphere

**Satellites**

- Characterize the appearance, geology, and physical state of the surfaces
- Investigate the surface mineralogy and surface distribution of minerals
- Determine the gravitational and magnetic fields and dynamic properties
- Study the atmospheres, ionospheres, and extended gas clouds
- Study the interactions of the satellites with the magnetosphere

**Magnetosphere**

- Characterize the energy spectra, composition, and distribution of energetic particles throughout the magnetosphere
  - Characterize the direction and strength of magnetic fields throughout the magnetosphere
  - Characterize the plasma energy spectra, composition, and angular distribution throughout the magnetosphere
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