

JUNO MISSION

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ABSTRACT

This paper aims to present NASA's Juno space mission, which was sent to Jupiter. The study addresses both the operational aspects of the Juno spacecraft and the type of orbit chosen around Jupiter, as well as the main results achieved by this mission to the largest planet in the Solar System.

The scientific instruments aboard the Juno spacecraft have analyzed the composition and dynamics of Jupiter's atmosphere, the planet's internal structure, its magnetic field, its ring system, and three of its Galilean moons—Io, Europa, and Ganymede.

Keywords: space probe, planet, atmosphere, magnetosphere, moon

Introduction

On August 5, 2011, NASA launched the Juno spacecraft on a mission to the planet Jupiter. Juno's objective was to enter orbit around this gas giant and study its atmosphere, which is riddled with numerous storms, its internal structure, gravitational field, and vast magnetosphere. While previous space probes sent beyond the asteroid belt were powered by nuclear generators, Juno relies on solar panels. These panels, however, are considerably large due to the fact that sunlight in Jupiter's region is 25 times weaker than it is near Earth.

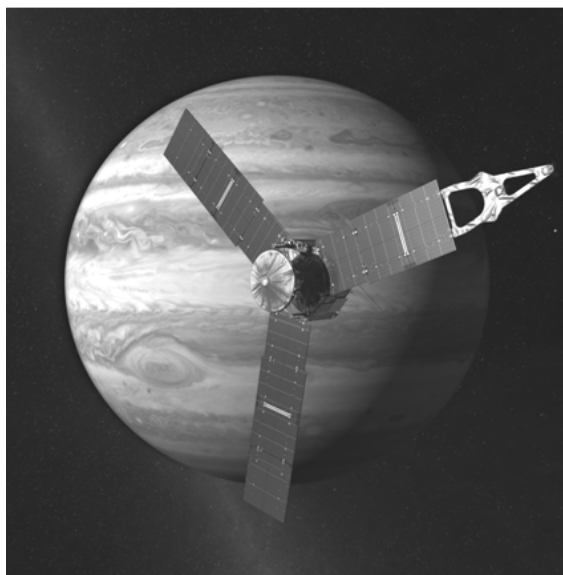


Fig. 1 – Juno spacecraft orbiting Jupiter

Juno's trajectory also included an Earth gravity assist maneuver to accelerate the spacecraft before setting its course toward Jupiter. Juno traveled for five years, covering a distance of 2.8 billion kilometers, before reaching Jupiter in July 2016. As it approached the gas giant, Jupiter's gravity accelerated Juno to a speed of 250,000 km/h, making it one of the fastest space probes ever. In order to enter orbit around Jupiter, Juno had to decelerate significantly and was placed into a highly elliptical polar orbit, making it the first probe to fly over Jupiter's poles.

Material and method

A polar orbit was chosen because it allows for a comprehensive mapping of the planet, and, importantly, it enables Juno to avoid Jupiter's equatorial radiation belt. Jupiter's magnetosphere traps electrically charged particles, sourced either from the solar wind or from the volcanic activity on its moon Io, and acts as a particle accelerator, creating intense streams of high-energy particles that move at near-light speeds around Jupiter's equator. This radiation belt can be extremely harmful to the electronic components of spacecraft. Juno's polar orbit allows it to safely fly beneath this radiation belt at its closest approach to the planet, ensuring the probe's functionality. Due to the great distance between Earth and Jupiter, communication with Juno is not instantaneous. It takes a minimum of 45 minutes for commands sent from Earth to reach the probe via radio waves, and another 45 minutes for the data collected by Juno to be transmitted back to Earth.

The camera aboard Juno has captured detailed images of the clouds that fully envelop Jupiter. However, since it photographs the planet in visible light, it only captures the uppermost cloud

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layers. These images reveal the banded structure of clouds moving in opposite directions, creating numerous hurricanes in Jupiter's atmosphere.

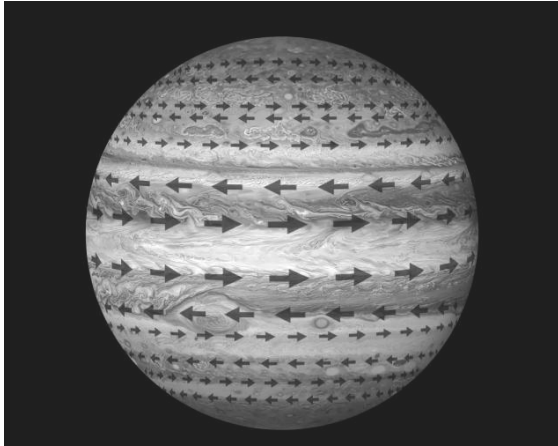


Fig. 2 – Jupiter's bands of clouds

Juno has revealed that Jupiter's large-scale atmospheric circulation is somewhat similar to Earth's. Both planets have wind belts organized into cells. However, while Earth has only three circulation cells in each hemisphere, Jupiter has eight in each hemisphere due to its much larger size and much faster rotation. Each atmospheric circulation cell on Jupiter is at least 30 times larger than Earth's.

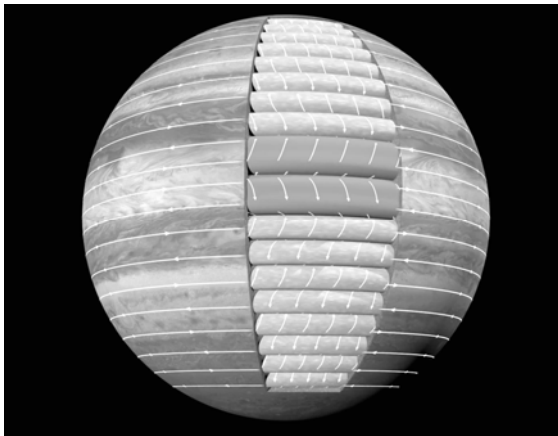


Fig. 3 – Jupiter's atmospheric circulation cells

One of the methods Juno uses to uncover Jupiter's internal structure is through microwave radiometry. The Jovian clouds emit radiation in the form of radio waves, microwaves, and infrared waves, but only the microwaves manage to penetrate the thick cloud layer and radiate outward. The frequency of microwaves emitted by the clouds depends on the depth from which they originate. Juno is equipped with six microwave radiometers,

each measuring at six different frequencies, corresponding to six different depths - from the upper cloud layer, where the pressure is similar to that on Earth, to a depth of several hundred kilometers, where the pressure is 1,000 times greater. Using this method, Juno aims to determine how deep the cloud bands and storms, such as Jupiter's Great Red Spot, extend. Before Juno's arrival at Jupiter, it was believed that the cloud band structure only reached a depth of 100 kilometers, but measurements made by Juno's microwave radiometers indicate that the cloud bands extend to at least 350 kilometers - the maximum depth the radiometers can measure. Even at this depth, the data shows that the band structure remains intact.

Another method Juno uses to "penetrate" Jupiter's interior is by analyzing the smallest variations in its gravitational field. Density variations and gas movements within the planet generate subtle shifts in the gravitational field, and Juno is able to record these fluctuations to reveal what happens beneath the thick cloud layer that envelops Jupiter. For example, through such measurements, Juno has determined that the Great Red Spot extends to a depth of about 300 km. This type of measurement can probe much deeper into the planet than the microwave radiometers, revealing that the cloud band structure persists to a depth of 3,000 km!

While Jupiter's atmosphere is composed mainly of hydrogen and helium, its clouds are primarily made of ammonia, water, and ammonium hydrosulfide. The strong friction between cloud bands moving in opposite directions creates numerous cyclones and anticyclones. The atmosphere is often pierced by rains, hail, and lightning, with bolts the size of Earth's continents - Juno captured many of these lightning strikes, especially near Jupiter's poles.

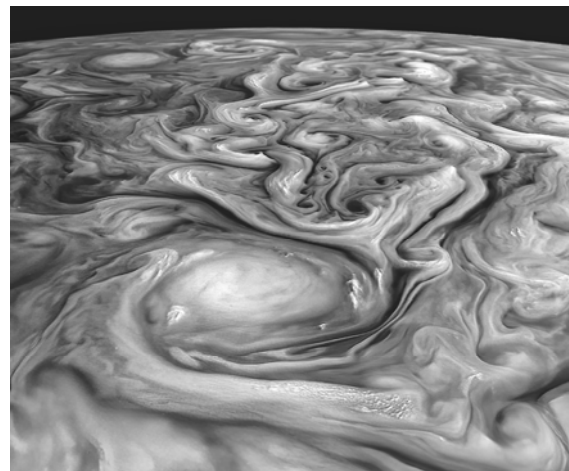


Fig. 4 – Jupiter's swirling storms

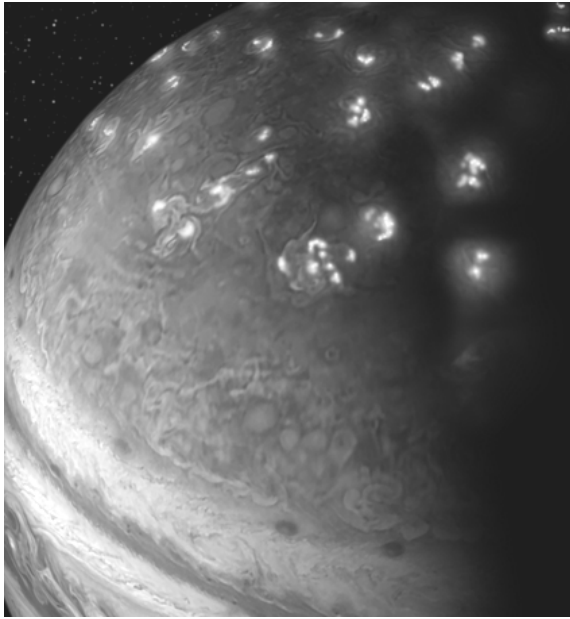


Fig. 5 – Lightning storms on Jupiter

Researchers analyzing Juno's data noted similarities between the turbulence around Jupiter's cyclones and the turbulence seen near whirlpools in Earth's seas and oceans. Juno also discovered cyclones at Jupiter's poles. Each pole has a central cyclone - at the south pole surrounded by five smaller cyclones, and at the north pole surrounded by eight cyclones, all with diameters of thousands of kilometers! The largest storm on Jupiter remains the Great Red Spot, a massive anticyclone that spans 16,000 km and has existed for at least 400 years, making it the largest storm in the Solar System. Comparing data from the Voyager probes in 1979 with recent Juno measurements, scientists have observed that the Great Red Spot has shrunk, from 1.8 times Earth's diameter to 1.3 times.

Like the Sun, Jupiter is mostly made of hydrogen and helium. Due to its massive size - about 318 times the mass of Earth - the pressure inside the planet is enormous. At about one-third of Jupiter's radius, the pressure and temperature become so high that hydrogen transforms into a metallic state. In this state, electrons are freed from atoms, allowing them to flow freely through this "superconductor." Jupiter's rapid rotation then generates a magnetic field through the dynamo effect. Juno's magnetometer has indicated that Jupiter's magnetic field at the surface is about 30 times stronger than Earth's, making it the strongest planetary magnetic field in the Solar System, second only to the Sun.

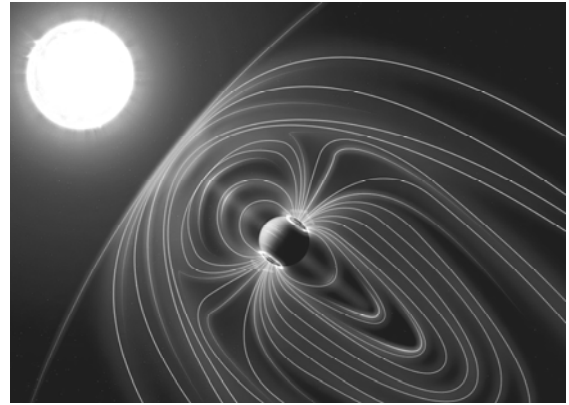


Fig. 6 – Jovian magnetosphere

Jupiter's powerful magnetic field also creates the brightest auroras in the Solar System. These auroras have been captured by Juno's UV spectrometer and infrared spectrometer. The infrared spectrometer has measured Jupiter's heat radiation at a wavelength of 4.8 microns, while mapping its auroras at a wavelength of 3.45 microns.

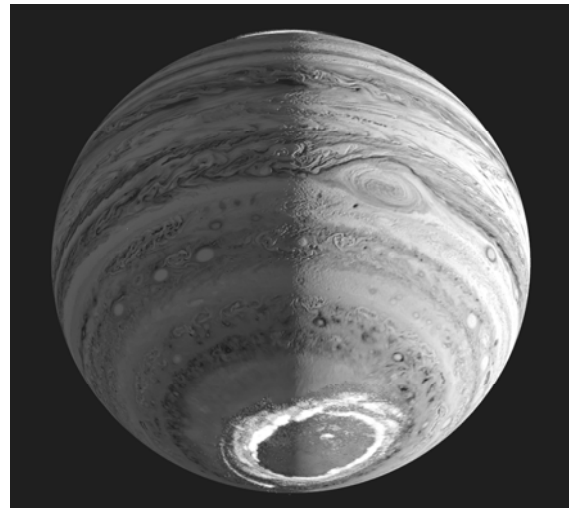


Fig. 7 – Jupiter's polar auroras

During one of its close passes in 2016, Juno managed to photograph Jupiter's faint rings. These rings were previously photographed in 1979 by Voyager 1 from a distance of 1.2 million km, but Juno captured them from within, at a distance of only 64,000 km, revealing their intricate structure.

Juno also performed close flybys of three of Jupiter's Galilean moons: Io, Europa, and Ganymede. On Io, the most volcanically active body in the Solar System, Juno photographed dark silicate lava lakes and eruptions from hundreds of volcanoes that regularly spew molten lava and emit sulfurous gases hundreds of kilometers high! Juno also captured detailed images of Europa, a moon that harbors a

salty ocean beneath its thin ice crust. The dark areas crisscrossing the ice are likely the result of dirty water erupting onto the surface. On Ganymede, the largest moon in the Solar System, Juno detected mineral salts and organic compounds, remnants of salty water that once surfaced from its underground ocean. Juno's images of Ganymede show not only impact craters but also craters that may have volcanic origins, possibly formed by cryovolcanoes that spewed water from the moon's interior.



Fig. 8 – Jupiter's volcanic moon Io

Results and discussions

Juno's many discoveries have changed our view of Jupiter's atmosphere and interior, revealing an atmospheric weather layer that extends far beyond its water clouds and a deep interior with a dilute heavy element core. Juno is also an explorer of the full Jovian system: the spacecraft executed close flybys of Ganymede, Europa, and Io; as well as the first extensive exploration of the faint rings encircling the planet.

Jupiter is the largest planet in the Solar System and, as such, played a major role in our system's formation. Studying Jupiter and its history can help astrobiologists understand the conditions

that led Earth to become habitable for life as we know it.

Conclusions

Juno's mission has been extended until September 2025, when it is scheduled to plunge into Jupiter's atmosphere to be destroyed. NASA plans this to ensure that the probe does not eventually crash onto one of Jupiter's moons, potentially contaminating them with Earth microbes.

Rezumat

Lucrarea de față își propune să prezinte misiunea spațială Juno, misiune trimisă de către NASA către planeta Jupiter. Lucrarea abordează atât aspecte ce țin de modul de funcționare a sondei spațiale Juno și a tipului de orbită ales în jurul lui Jupiter, dar și principalele rezultate obținute de această misiune spațială trimisă către cea mai mare planetă din Sistemul Solar. Instrumentele științifice de la bordul sondei Juno au analizat atât compoziția și dinamica atmosferei joviene, cât și structura internă a planetei, câmpul său magnetic, sistemul său de inele și trei din sateliții săi galileeni – Io, Europa și Ganymede.

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