Jupiter

reporters

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Outline

- Characteristics of Jupiter
- Exploration of Jupiter
- Data and Images from JUNO spacecraft

Characteristics of Jupiter

- **Orbit Size Around Sun**

  Scientific Notation: $7.7834082 \times 10^{8}\ km$

  Astronomical Units: $5.2028870\ A.U.$

- **Mass**

  Scientific Notation: $1.8981 \times 10^{27}\ kg$

  (By Comparison: $317.828 \times$ Earth)

- **Equatorial Radius**

  Scientific Notation: $6.9911 \times 10^{4}\,km$

  (By Comparison: $10.9733 \times$ Earth)

- **Volume**

  Scientific Notation: $1.43128 \times 10^{15}\,km^{3}$

  (By Comparison: $1321.337 \times$ Earth)

- **Density**

Scientific Notation: $1.3056 \times 10^{4}\, m/s$

(By Comparison: $0.438 \times$ Earth)

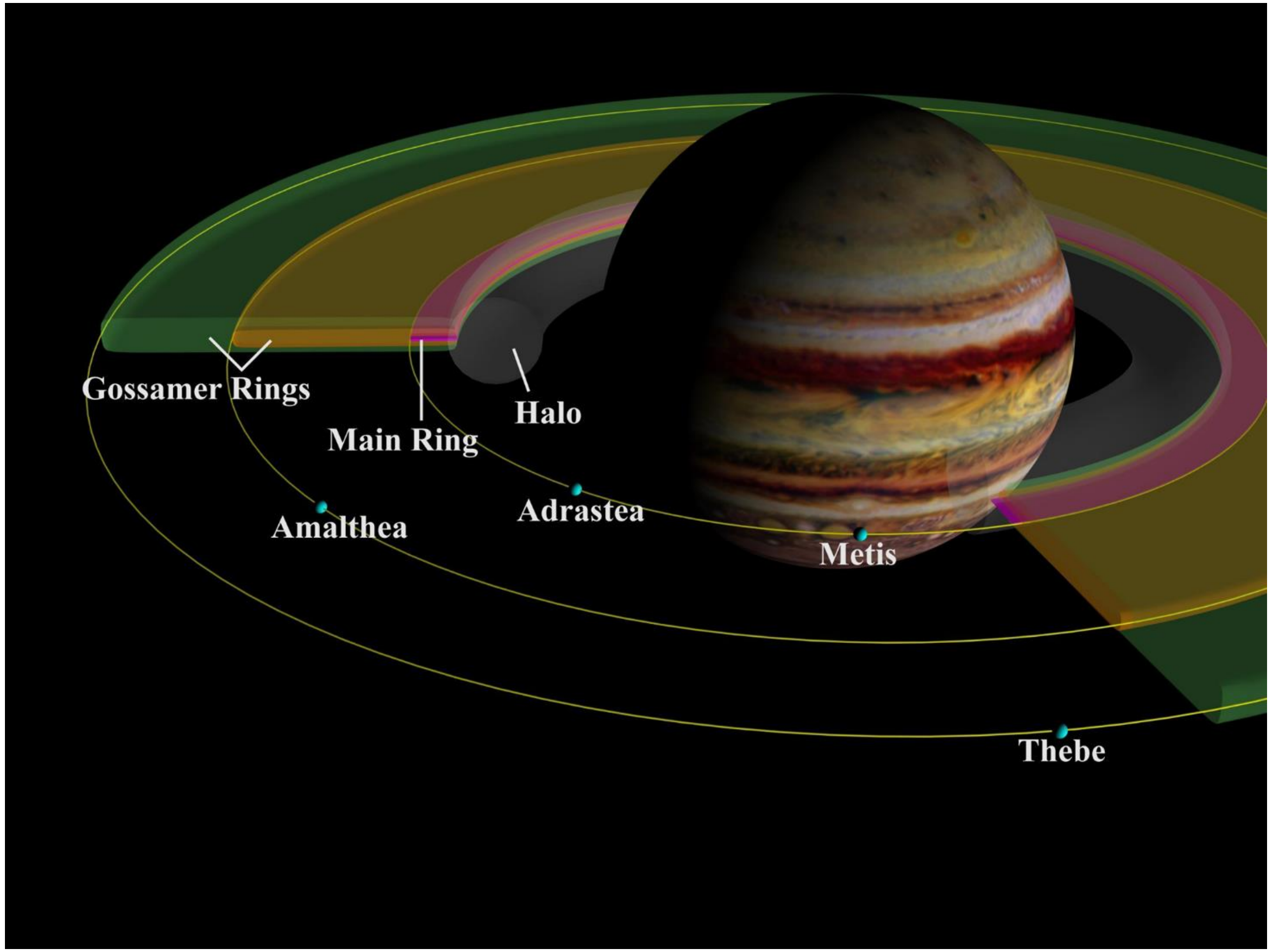
1 day (Jupiter) = 9.92 hours (Earth)

1 year (Jupiter) = 11.86 years (Earth)

Number of moons: 69

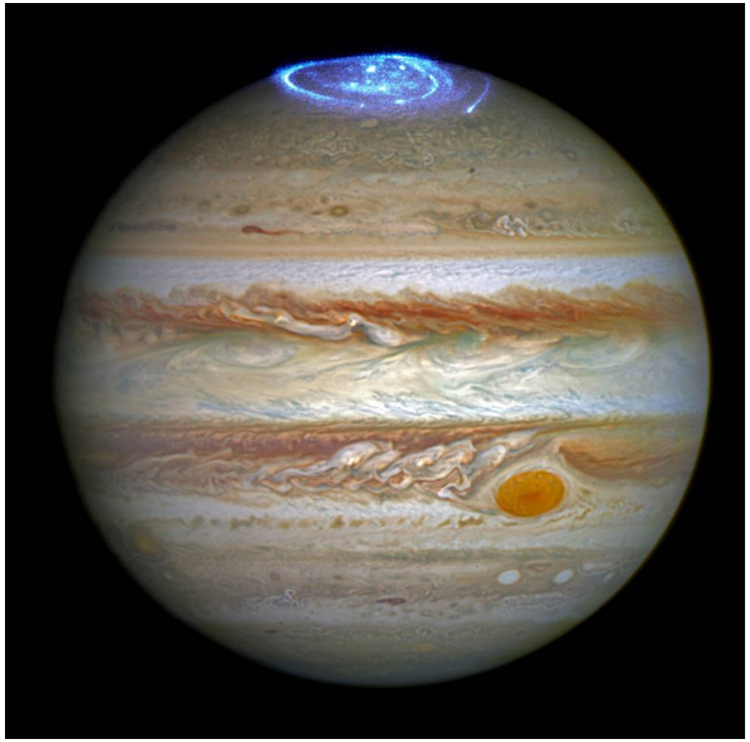
• Features

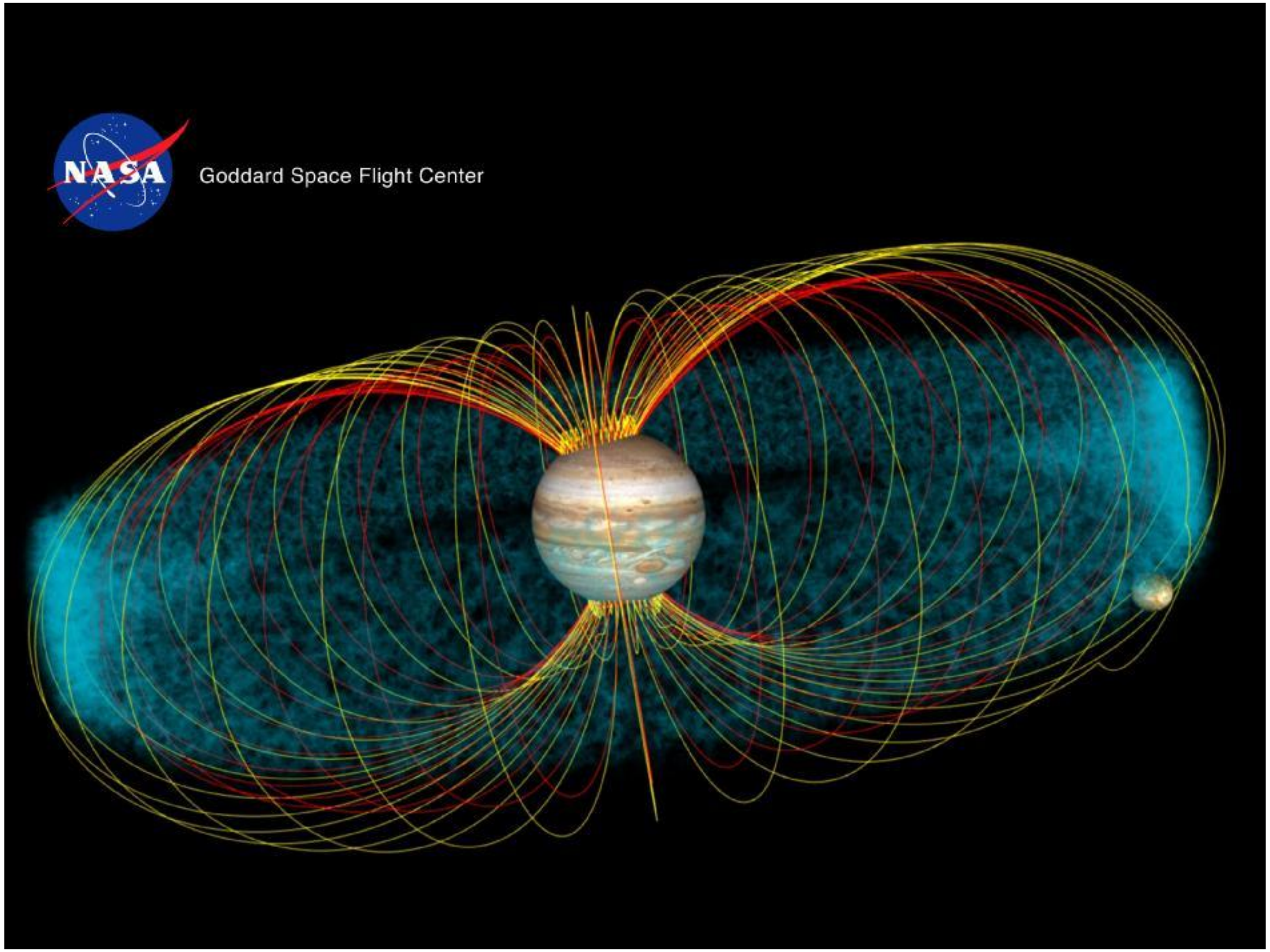
Ring



- **Features**

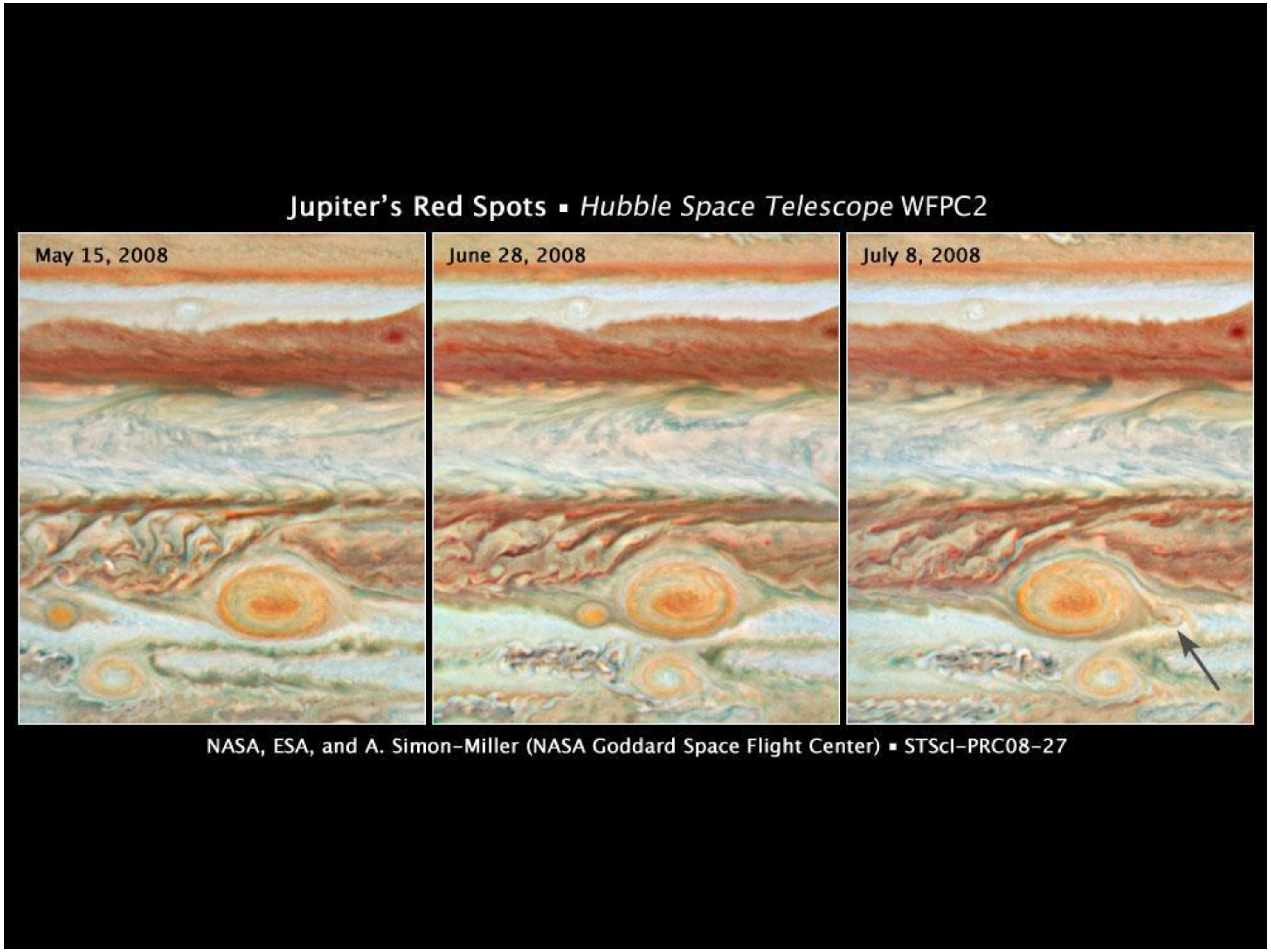
Strong magnetic field





- **Features**

Red spot



Exploration of Jupiter

Exploration of Jupiter

System / Spacecraft	Jupiter
Pioneer 10	**1973** flyby
Pioneer 11	**1974** flyby
Voyager 1	**1979** flyby
Voyager 2	**1979** flyby
Galileo	**1995–2003** orbiter; **1995**, **2003** atmospheric
Ulysses	**1992**, **2004** gravity assist
Cassini–Huygens	**2000** gravity assist
New Horizons	**2007** gravity assist
Juno	**2016**– orbiter

Exploration of Jupiter

Mission type: flyby

Pioneer 10＆11 (先鋒者 10＆11) Time: Pioneer 10 1972 launch 1973 flyby
Pioneer 11 1973 launch 1974 flyby

Launched on March 2, 1972, Pioneer 10 was the first spacecraft to pass through the asteroid belt and the first to make direct observations and obtain close-up images of Jupiter.

Pioneer 11 was launched on a similar trajectory on April 5, 1973, like Pioneer 10

Pioneer 10 was the first spacecraft to pass through the asteroid belt, considered a spectacular achievement, and then headed toward Jupiter.
Pioneer 10 also charted Jupiter's intense radiation belts, located the planet's magnetic field, and established that Jupiter is predominantly a liquid planet.

Exploration of Jupiter

Mission type: orbiter

Galileo

Time: 1989 launch 1995 Orbital insertion

In October 1989, Galileo was launched from the cargo bay of the Space Shuttle Atlantis
Galileo didn't have enough fuel to fly directly to Jupiter, but the spacecraft could borrow enough energy from Venus and Earth to make the long journey. Mission planners designed a flight path nicknamed "VEEGA" -- Venus-Earth-Earth Gravity Assist. Galileo would slingshot once by Venus, and twice by Earth, gathering enough momentum to reach distant Jupiter.

Its aim was to study Jupiter and its mysterious moons. After discoveries including evidence for the existence of a saltwater ocean beneath the Jovian moon Europa's icy surface, extensive volcanic processes on the moon Io and a magnetic field generated by the moon Ganymede, Galileo plunged into Jupiter's atmosphere on September 21, 2003 to prevent an unwanted impact with Europa.

Exploration of Jupiter

Mission type: orbiter

Time: 2011 launch 2016 Orbital insertion

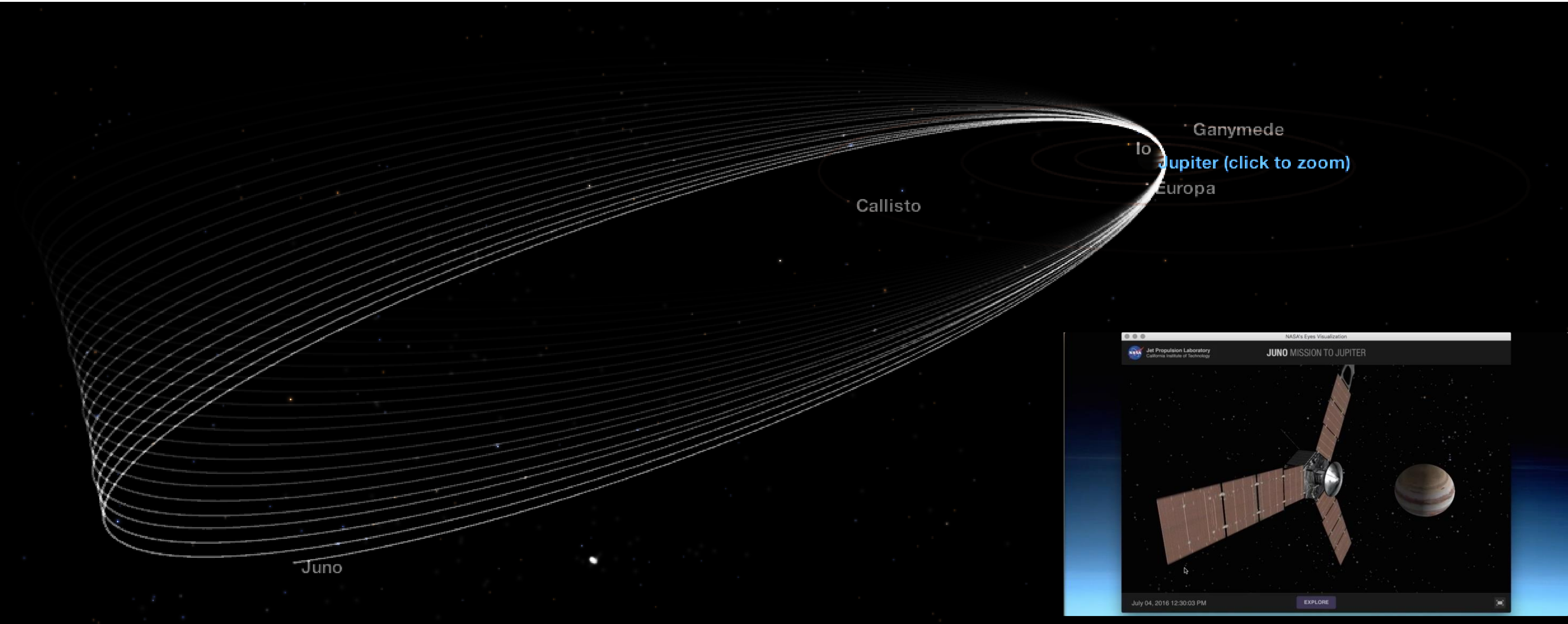
Juno

Juno‘s trajectory used a gravity assist speed boost from Earth, accomplished by an Earth flyby in October 2013, two years after its launch on August 5, 2011.

Juno will improve our understanding of the solar system's beginnings by revealing the origin and evolution of Jupiter.

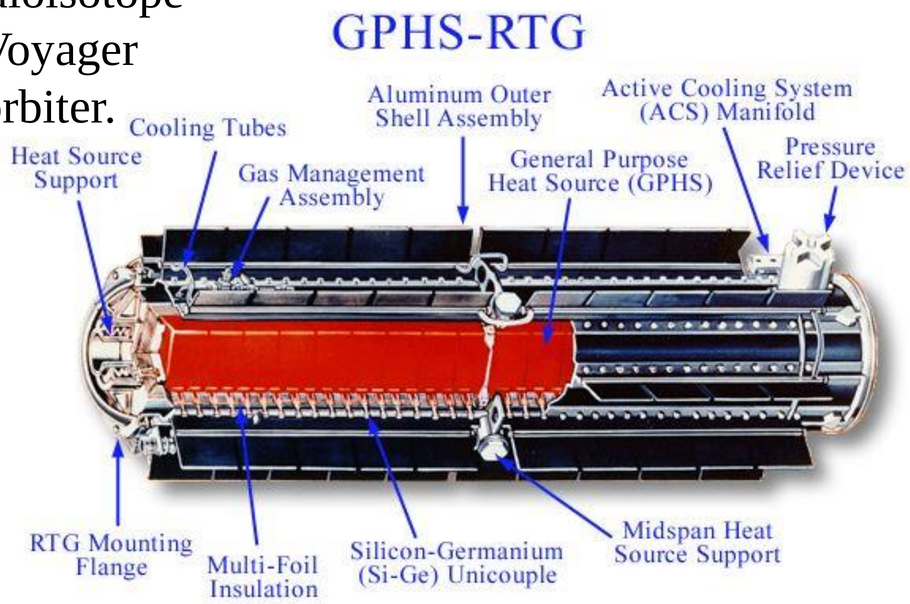
Orbit design

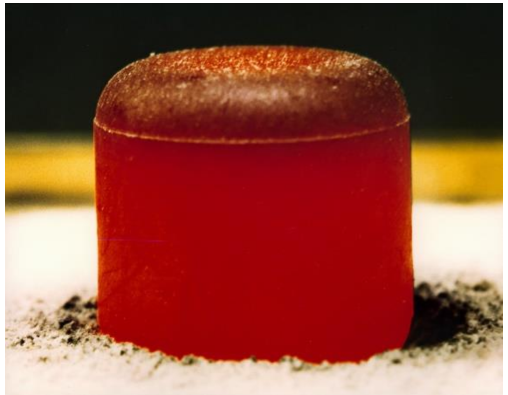
NASA’s Eyes



Solar panel & RTG

Juno is the first mission to Jupiter to use solar panels instead of the radioisotope thermoelectric generators (RTG) used by Pioneer 10, Pioneer 11, the Voyager program, Ulysses, Cassini–Huygens, New Horizons, and the Galileo orbiter.





A pellet of $^{238}PuO_2$ as used in the RTG.

Recent Exploration of Jupiter

Galileo (Mission type: orbiter)

Juno's mission is to measure **Jupiter's composition, gravity field, magnetic field, and polar magnetosphere**. It will also search for clues about how the planet formed, including whether it has a rocky core, **the amount of water present within the deep atmosphere, mass distribution, and its deep winds, which can reach speeds up to 618 kilometers per hour.**

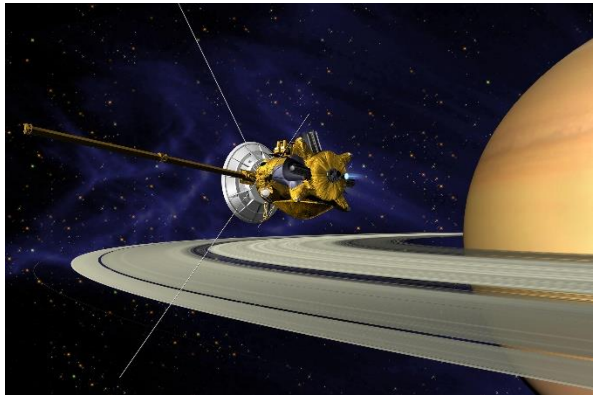
Recent Exploration of Jupiter

Galileo (Mission type: orbiter)

The data Galileo collected supported **the theory of a liquid ocean under the icy surface of Europa, and there were indications of similar liquid-saltwater layers under the surfaces of Ganymede and Callisto.**

Recent Exploration of Jupiter

Cassini–Huygens (Mission type: Flyby)

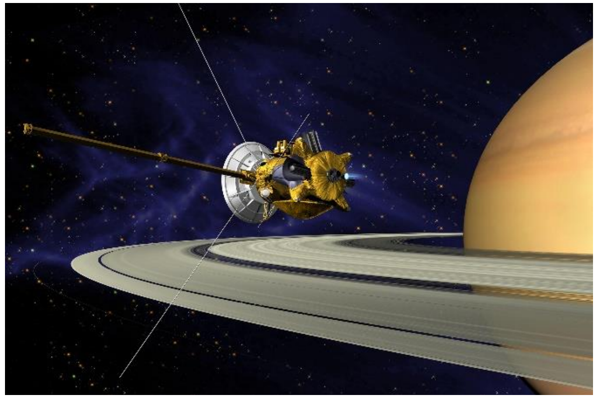


Cassini was de-orbited to burn up in Saturn's upper atmosphere.

Cassini made its closest approach to Jupiter on December 30, 2000, and made many scientific measurements. About 26,000 images of Jupiter, its faint rings, and its moons were taken during the six month flyby.

Recent Exploration of Jupiter

Cassini–Huygens (Mission type: Flyby)

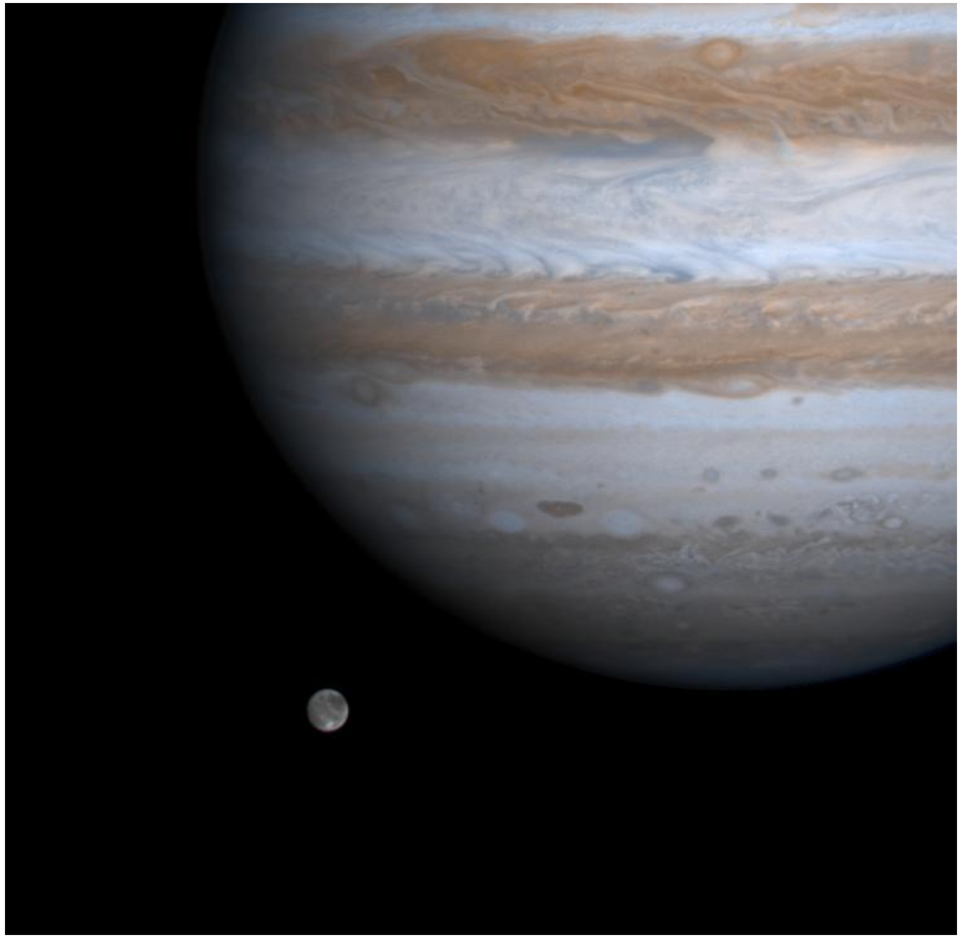


Cassini made its closest approach to Jupiter on December 30, 2000, and made many scientific measurements. About 26,000 images of Jupiter, its faint rings, and its moons were taken during the six month flyby.

It produced the most detailed global color portrait of the planet at that time, in which the smallest visible features are approximately 60 km across.

Recent Exploration of Jupiter

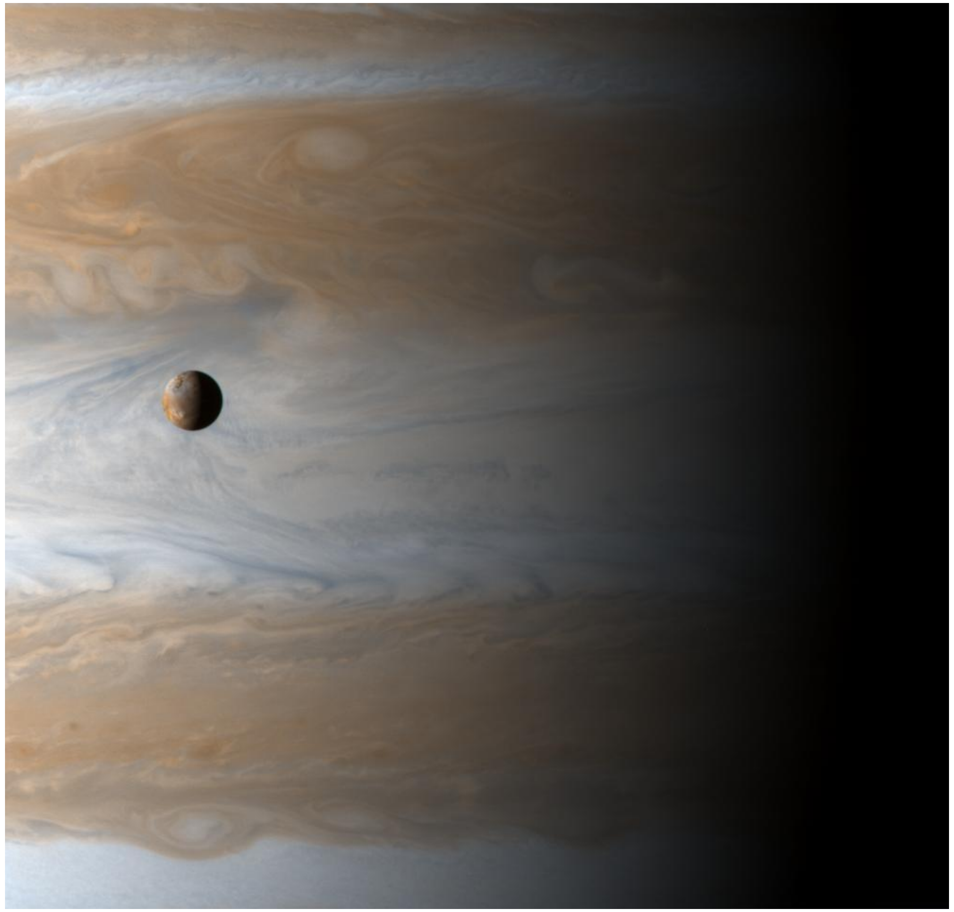
Cassini–Huygens (Mission type: Flyby)



The solar system's largest moon, Ganymede, is captured here alongside the planet Jupiter in a color picture taken by NASA's Cassini spacecraft on Dec. 3, 2000.

Recent Exploration of Jupiter

Cassini–Huygens (Mission type: Flyby)



The Galilean satellite Io floats above the cloudtops of Jupiter in this image captured on the, January 1, 2001 10:00 UTC (spacecraft time).

The image is deceiving: there are 350,000 kilometers -- roughly 2.5 Jupiters -- between Io and Jupiter's clouds. Io is the size of our Moon, and Jupiter is very big.

Recent Exploration of Jupiter

New Horizons (Mission type: Flyby)

- Explorer for Pluto
- The First Mission to the Pluto System and the Kuiper Belt
- To understand where Pluto and its moons "fit in" with the other objects in the solar system

Principal Investigator Dr. Alan Stern, of Southwest Research Institute (SwRI), leads the mission team. The Johns Hopkins University Applied Physics Laboratory (APL) manages the mission for NASA, and designed, built and operates the spacecraft.

Recent Exploration of Jupiter

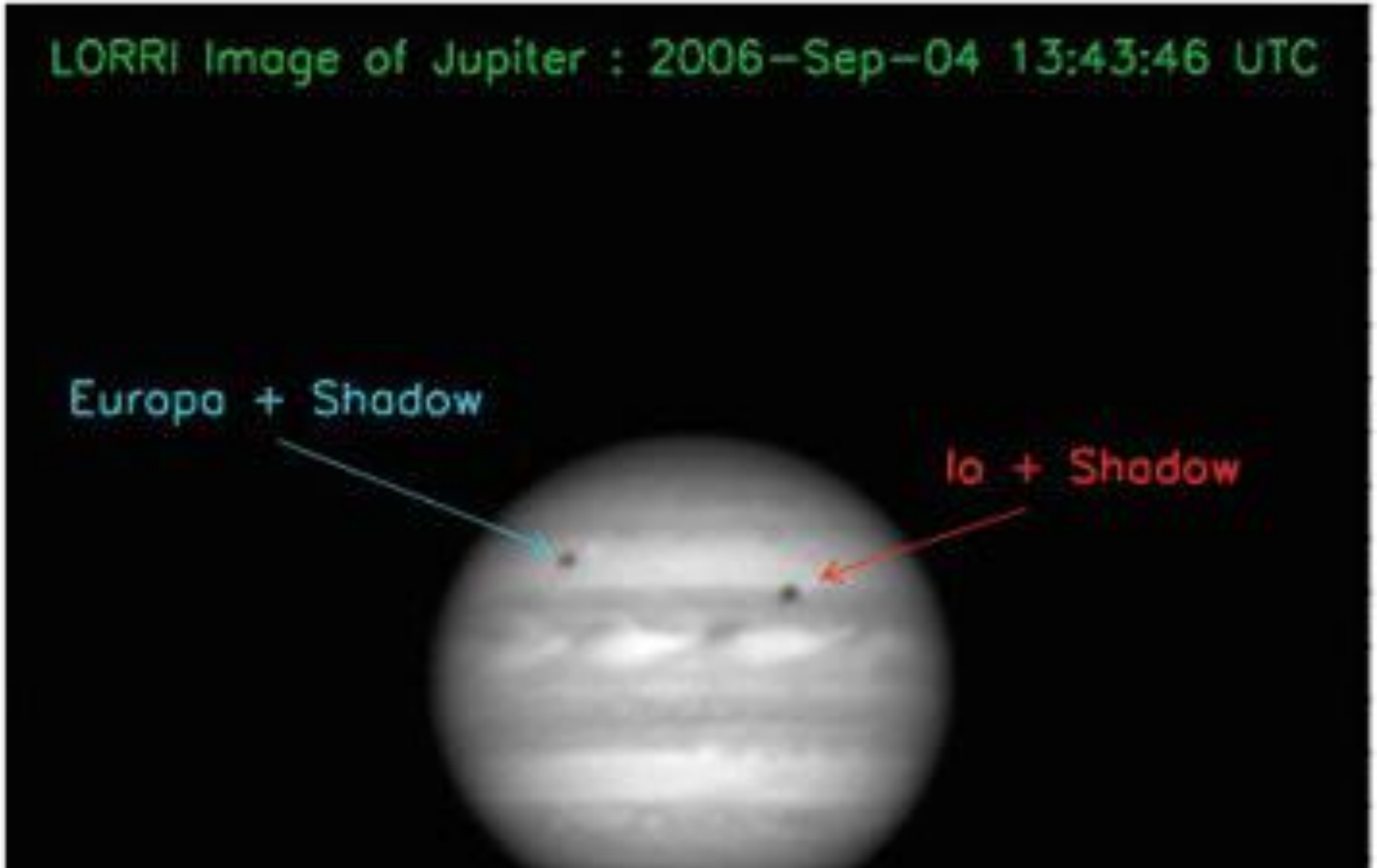
New Horizons (Mission type: Flyby)

Mission principle on Jupiter:

- Studies of Jupiter’s magnetosphere, including a history-making first flight down the tail of charged particles escaping the planet’s strong magnetic field.
- Looking at Jupiter’s atmosphere and storms (such as the Great Red Spot).
- Observations of Jupiter’s faint rings, including a search for additional satellites that generate the rings.
- Satellite observations, such as a look at how the volcanic world Io has changed since Galileo observed it in 2001, and mapping surface compositions on Europa, Ganymede and Callisto better than any previous mission.

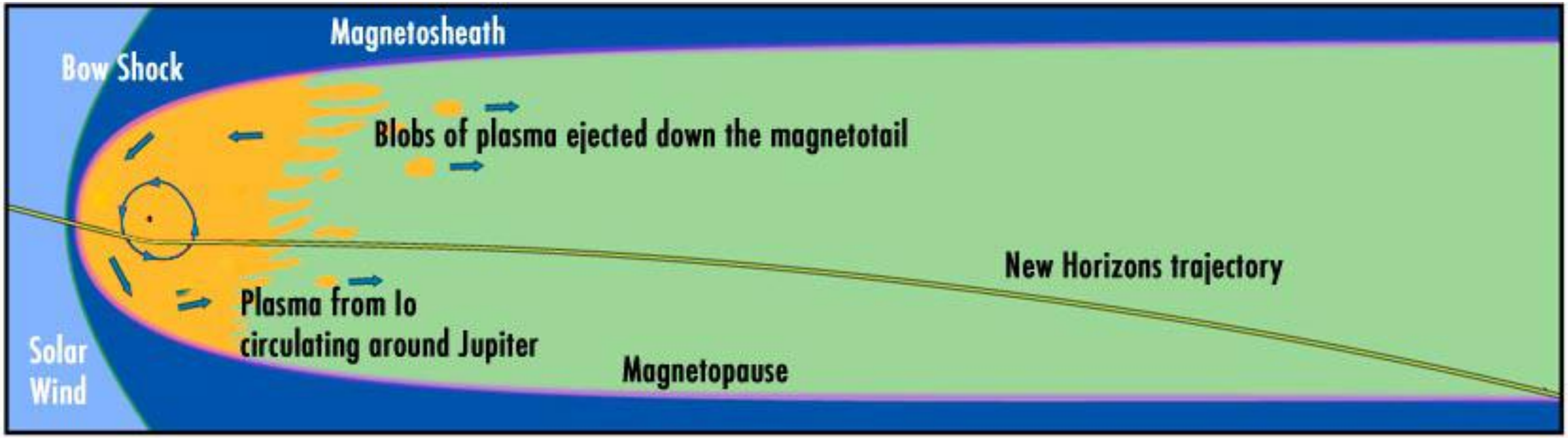
Recent Exploration of Jupiter

New Horizons watching Jupiter's moons



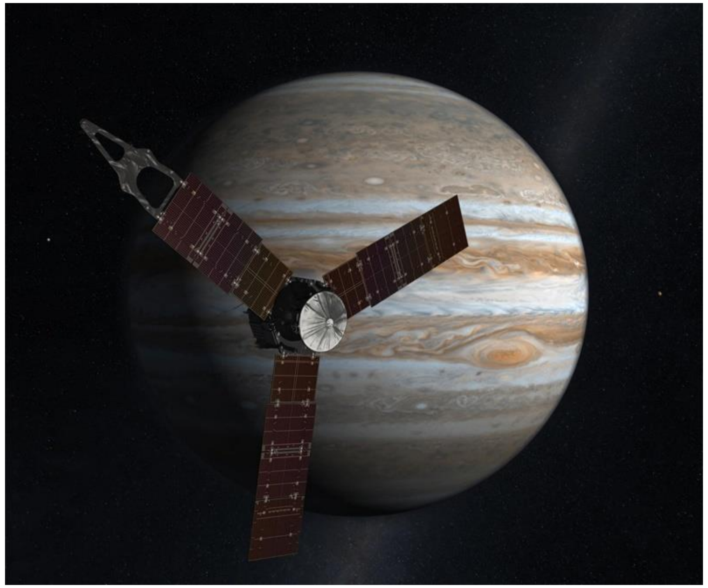
Recent Exploration of Jupiter

New Horizons's magnetic field mapping for Jupiter



Recent Exploration of Jupiter

Juno (Mission type: orbiter)

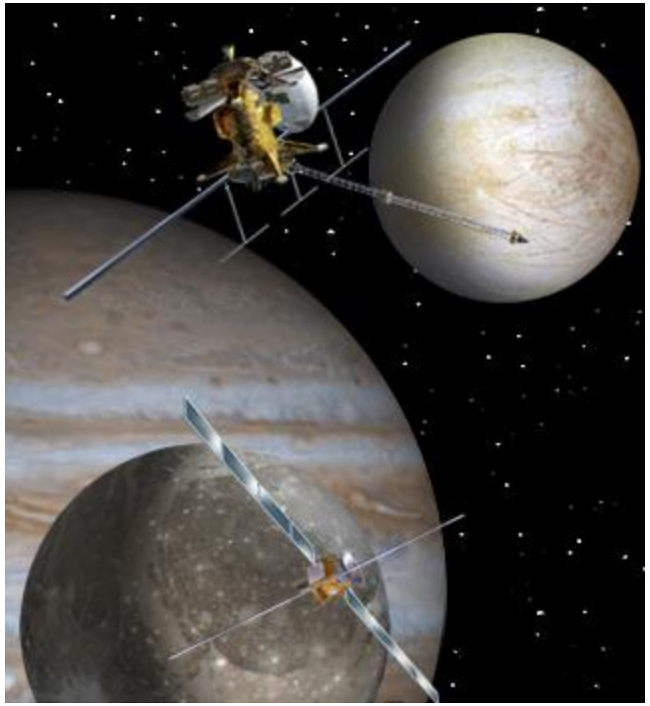


Mission principle:

- Determine how much water is in Jupiter's atmosphere, which helps determine which planet formation theory is correct (or if new theories are needed)
- Look deep into Jupiter's atmosphere to measure composition, temperature, cloud motions and other properties
- Map Jupiter's magnetic and gravity fields, revealing the planet's deep structure
- Explore and study Jupiter's magnetosphere near the planet's poles, especially the auroras – Jupiter's northern and southern lights – providing new insights about how the planet's enormous magnetic force field affects its atmosphere

Planned missions

Laplace→JUICE (Mission type: orbiter)

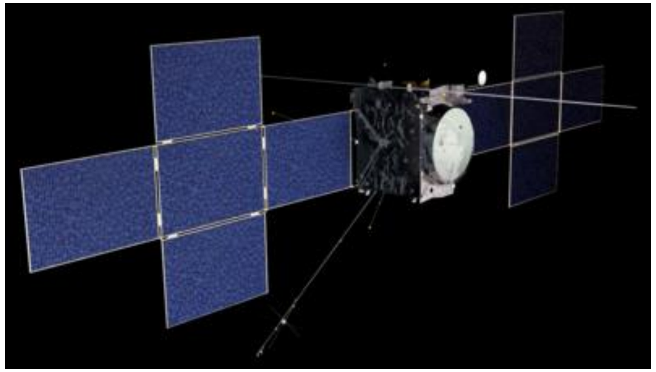


The Europa Jupiter System Mission – Laplace (EJSM/Laplace) was for the in-depth exploration of Jupiter's moons with a focus on **emergence of habitable environments, with emphasis on Europa and Ganymede, and Jupiter's magnetosphere.**

The mission would have comprised at least two independent elements, NASA's Jupiter Europa Orbiter (JEO) and ESA's Jupiter Ganymede Orbiter (JGO), to perform coordinated studies of the Jovian system.

Planned missions

Laplace→JUICE (Mission type: orbiter)



The JUpiter ICy Moons Explorer (JUICE) is designed to investigate the emergence of habitable worlds around gas giants, and scheduled to launch in five years.

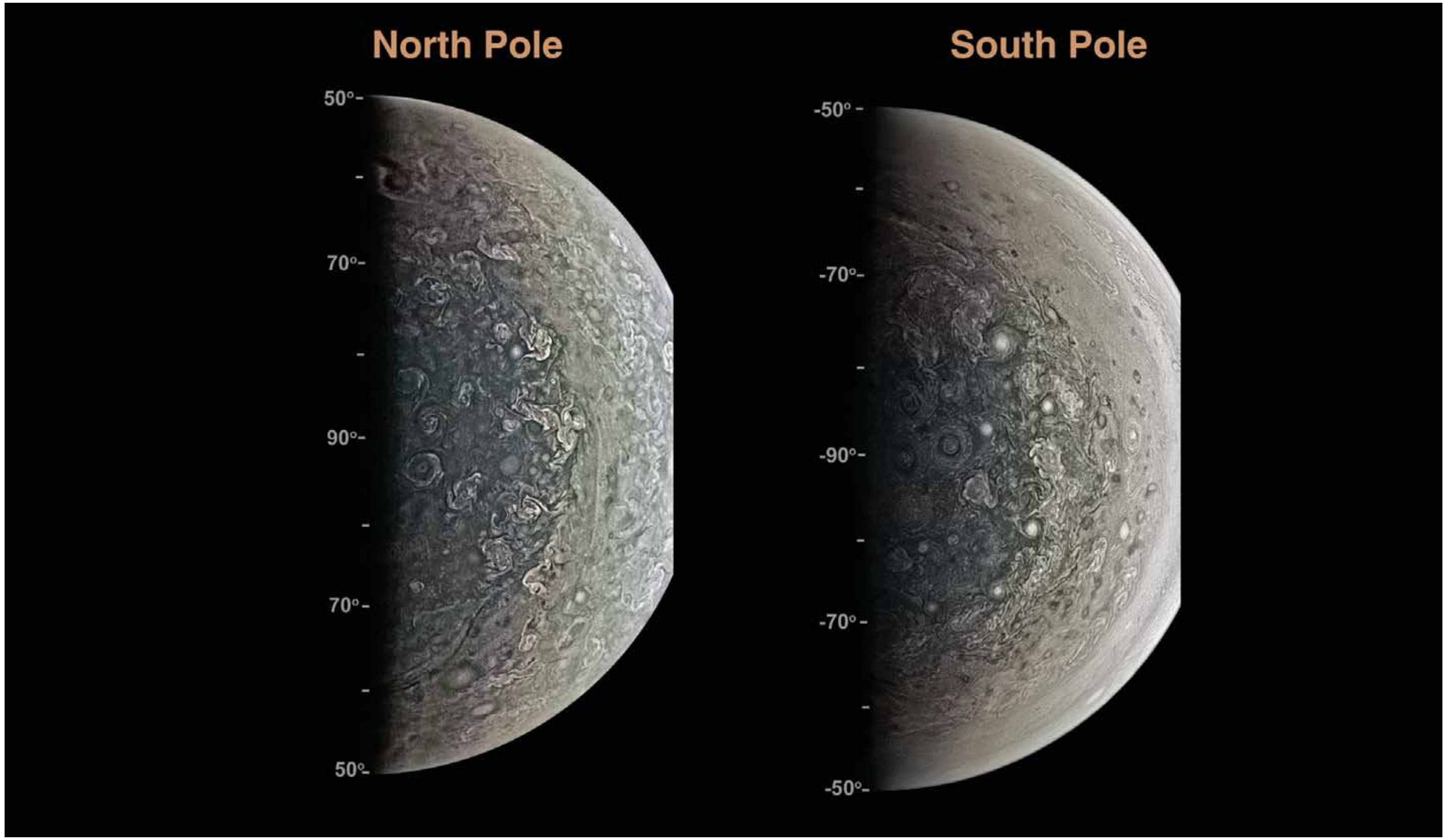
JUICE will spend almost four years studying **Jupiter's giant magnetosphere, turbulent atmosphere, and its icy Galilean moons--Callisto, Ganymede and Europa**.

A proposed timeline is launch in 2022 on an Ariane 5 carrier rocket and arrival at the Jupiter system in 2029. By 2033 the spacecraft should enter orbit around Ganymede, after completing various manoeuvres around Jupiter and the other moons.

Question about Jupiter

- How did Jupiter form?
- How much water (and therefore oxygen) is in Jupiter?
- How is Jupiter arranged on the inside? What is its deep structure?
- Does Jupiter rotate as a solid body, or is the deep interior moving at a different speed than the outside?
- Is there a dense core, and if so, how massive is it?
- How and where is its vast and powerful magnetic field generated?
- How are atmospheric features like the Great Red Spot related to the movement of the deep interior?
- What physical processes power the auroras -- Jupiter's northern and southern lights?
- What do the poles look like up close?

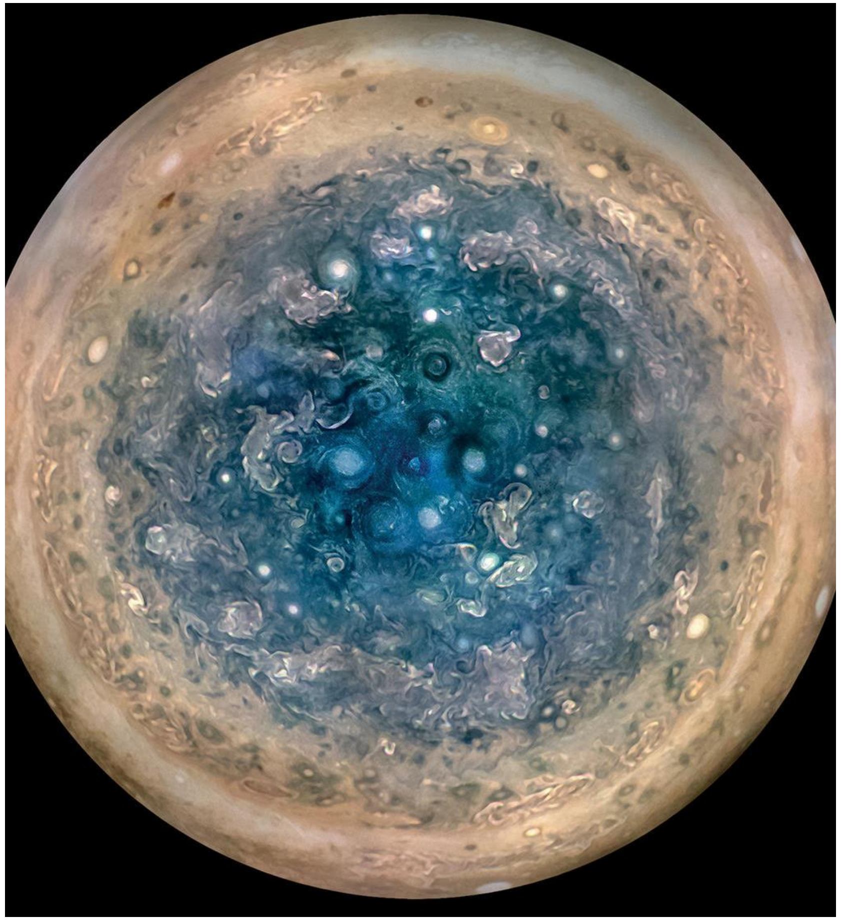
JUNO CAM



Orthographic projection of JunoCam color composite images of the north and south polar regions of Jupiter obtained 27 August 2016. The north polar image was taken at 11:59 UT when the spacecraft was 73,009 km from Jupiter's cloud deck; the south polar image was taken at 13:56 UT when the spacecraft was 95,096 km from the cloud deck.

Bolton, S.J., et al. (2017), Jupiter's interior and deep atmosphere: The initial pole-to-pole passes with the Juno spacecraft, *Science*, **356**, 821-825, doi:10.1126/science.aal2108.

JUNO CAM

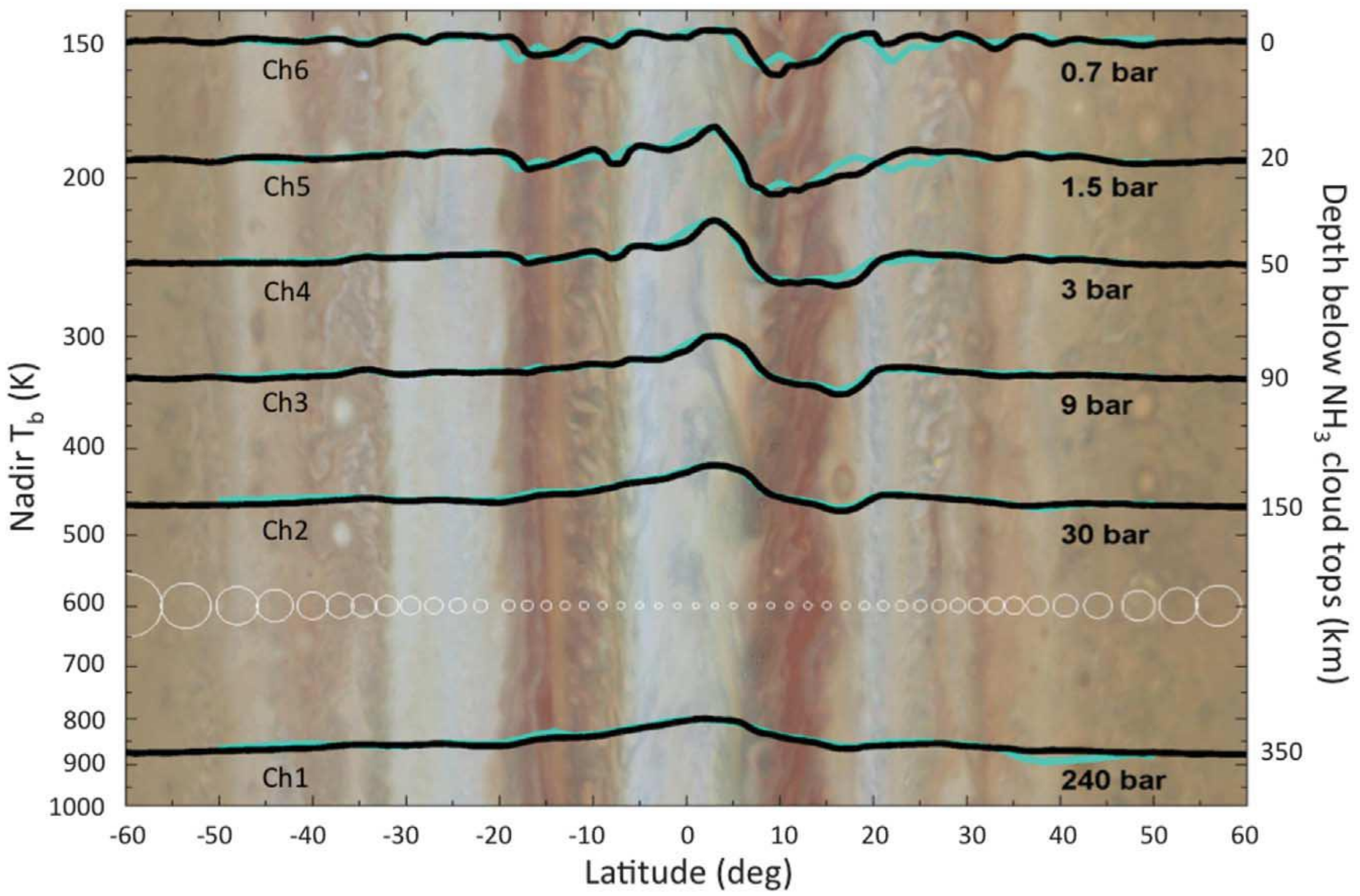


This image shows Jupiter‘s south pole, as seen by NASA’s Juno spacecraft from an altitude of 52,000 kilometers.

The oval features are cyclones, up to 1,000 kilometers in diameter.

Multiple images taken with the JunoCam instrument on three separate orbits were combined to show all areas in daylight, enhanced color, and stereographic projection.

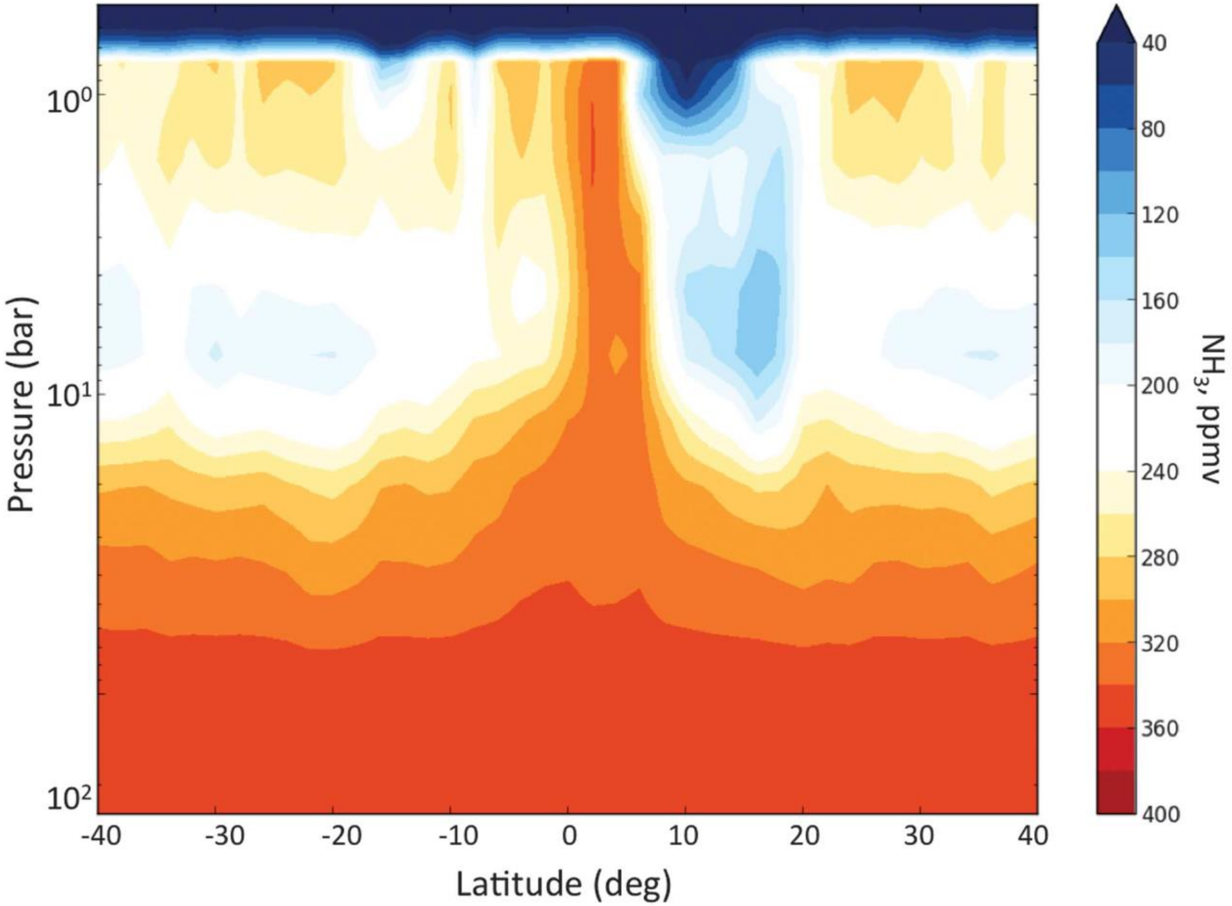
MWR DATA



Nadir brightness temperatures in the six channels of the MWR versus planetocentric latitude.

Bolton, S.J., et al. (2017), Jupiter's interior and deep atmosphere: The initial pole-to-pole passes with the Juno spacecraft, *Science*, **356**, 821-825, doi:10.1126/science.aal2108.

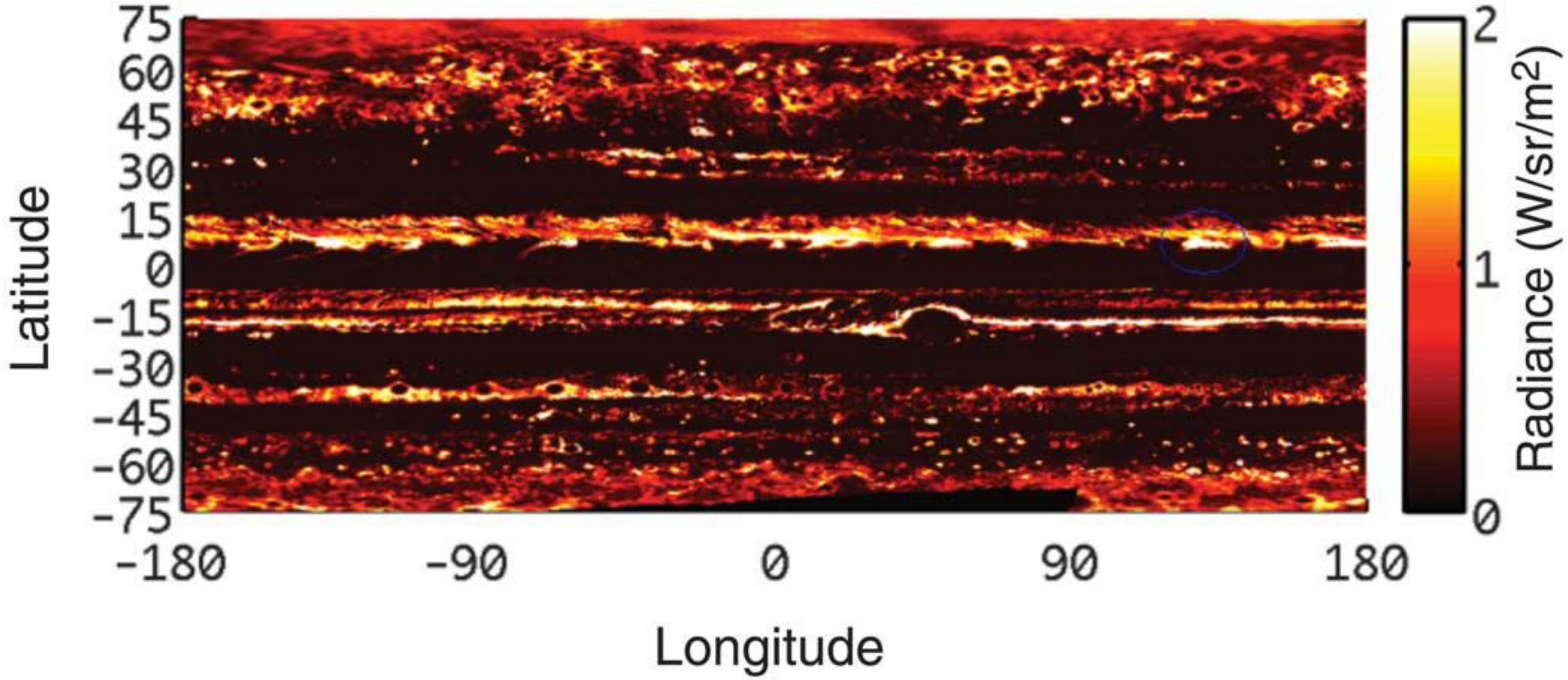
MWR DATA



Planetocentric latitude-altitude cross section of ammonia mixing ratio.

Bolton, S.J., et al. (2017), Jupiter's interior and deep atmosphere: The initial pole-to-pole passes with the Juno spacecraft, *Science*, **356**, 821-825, doi:10.1126/science.aal2108.

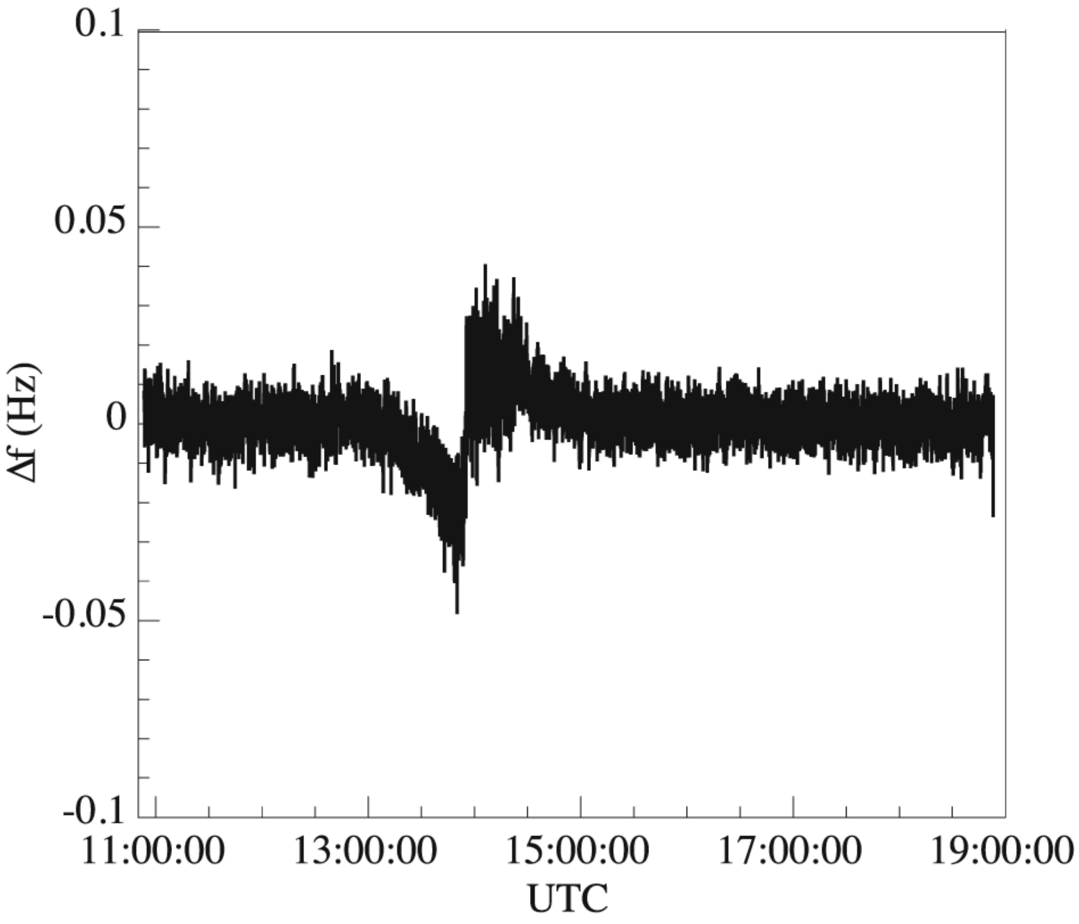
JIRAM DATA



Cylindrical map of the infrared emission from Jupiter as detected by JIRAM.

Bolton, S.J., et al. (2017), Jupiter's interior and deep atmosphere: The initial pole-to-pole passes with the Juno spacecraft, *Science*, **356**, 821-825, doi:10.1126/science.aal2108.

Gravity Field



The correction to the X-band (8 GHz) Doppler measurements for PJ1 on 27 August 2016 due to the effect of charged particles along the signal path from Juno to Earth, derived from the difference between the X-band and Ka-band measurements. The signature in the calibration near time of perijove was due to the Io plasma torus.

Folkner, W.M., et al. (2017), Jupiter gravity field estimated from the first two Juno orbits, *Geophysics Research Letters*, **44**, 4694-4700, doi:10.1002/2017GL073140.

Gravity Field

Parameter	PJ1 Estimate	PJ2 Estimate	PJ1 and PJ2 Estimate
GM(km^3/s^2)	126,686,533.0 ± 2.0	126,686,533.0 ± 2.0	126,686,533.0 ± 2.0
J_2 ($\times 10^6$)	14,697.885 ± 1.918	14,696.496 ± 0.398	14,696.514 ± 0.272
J_3 ($\times 10^6$)			−0.067 ± 0.458
J_4 ($\times 10^6$)	−586.595 ± 0.554	−586.635 ± 0.314	−586.623 ± 0.363
J_6 ($\times 10^6$)	34.336 ± 0.352	34.246 ± 0.126	34.244 ± 0.236
J_8 ($\times 10^6$)	−2.468 ± 0.415	−2.482 ± 0.159	−2.502 ± 0.311
$C_{2,2}$ ($\times 10^6$)	0.072 ± 0.174	−0.007 ± 0.067	0.005 ± 0.170
$S_{2,2}$ ($\times 10^6$)	0.128 ± 0.153	−0.013 ± 0.055	−0.010 ± 0.214
α(deg)	268.058 ± 0.010	268.057 ± 0.002	268.057 ± 0.002
δ(deg)	64.490 ± 0.011	64.497 ± 0.003	64.496 ± 0.013

[a]The zonal harmonics J_n and degree 2 tesseral harmonics $S_{i,j}$ and $C_{i,j}$ are unnormalized and dimensionless. The Jupiter spin axis direction is given by right ascension α and declination δ at epoch J2000. The value and uncertainty for the Jupiter planet mass parameter (GM) for Juno analysis are taken from *Jacobson et al.* [1999].

Estimated Jovian Gravity Field Parameters From Juno's First Two Science Orbits Individually and in Combination.

Folkner, W.M., et al. (2017), Jupiter gravity field estimated from the first two Juno orbits, *Geophysics Research Letters*, **44**, 4694-4700, doi:10.1002/2017GL073140.

Gravity Field

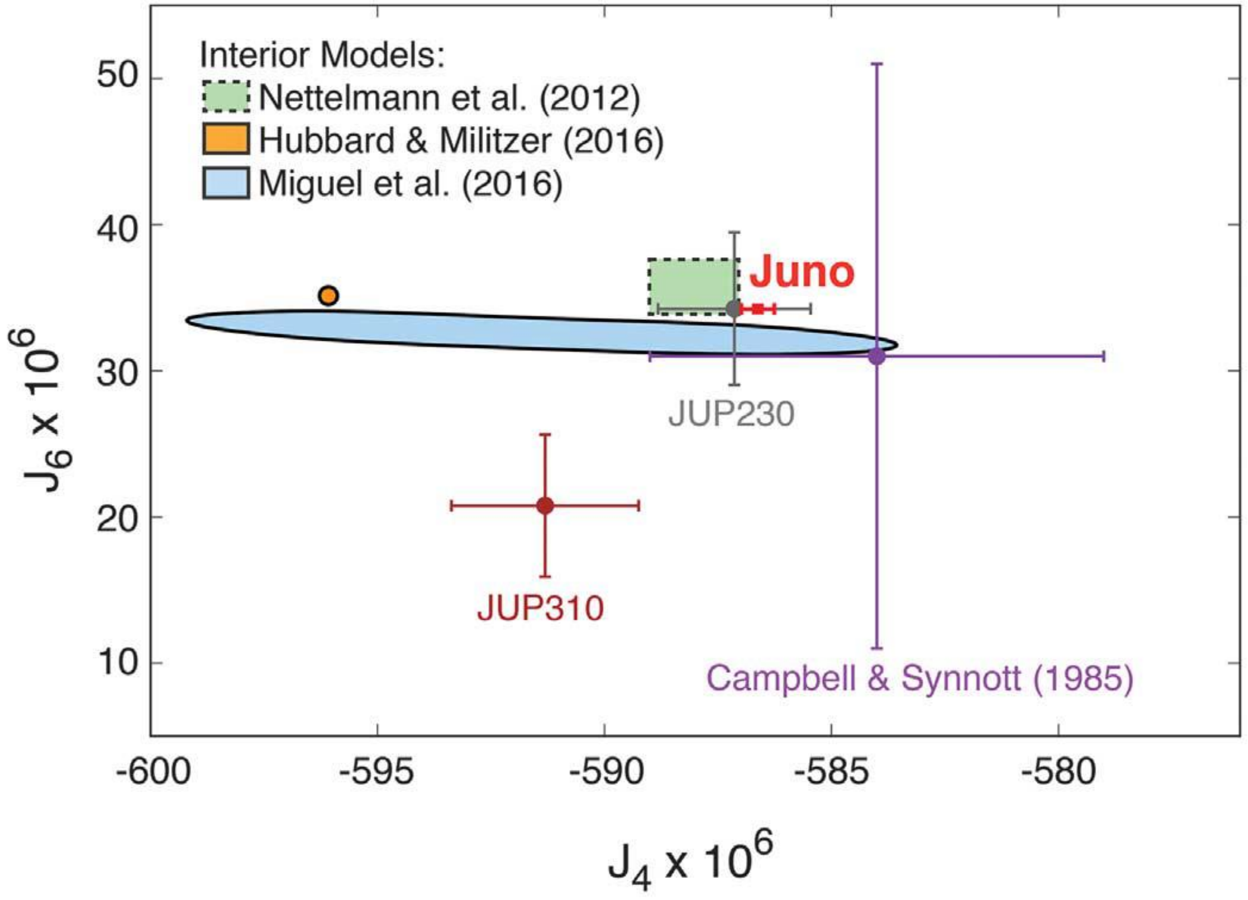
Parameter	Pioneer/Voyager	Jup230	Jup310	Juno PJ1&PJ2
GM(km^3/s^2)	126,686,537.5 ± 101	126,686,534.9 ± 1.5	126,686,534.2 ± 2.7	126,686,533.0 ± 2.0
J_2 ($\times 10^6$)	14,697.3 ± 1	14,696.43 ± 0.21	14,695.62 ± 0.29	14696.514 ± 0.272
J_3 ($\times 10^6$)	1.4 ± 5	−0.64 ± 0.90		−0.067 ± 0.458
J_4 ($\times 10^6$)	−583.9 ± 5	−587.14 ± 1.68	−591.31 ± 2.06	−586.623 ± 0.363
J_6 ($\times 10^6$)	30.8 ± 20	34.25 ± 5.22	20.78 ± 4.87	34.244 ± 0.236
J_8 ($\times 10^6$)				−2.502 ± 0.311
$C_{2,2}$ ($\times 10^6$)	−0.030 ± 0.150	0.007 ± 0.008	−0.010 ± 0.067	0.005 ± 0.170
$S_{2,2}$ ($\times 10^6$)	−0.007 ± 0.150	−0.013 ± 0.009	−0.014 ± 0.061	−0.010 ± 0.214
α(deg)	268.058 ± 0.005	268.0566 ± 0.0002	268.0571 ± 0.0003	268.057 ± 0.002
δ (deg)	64.494 ± 0.002	64.4953 ± 0.0001	64.4958 ± 0.0001	64.496 ± 0.013

[a]The zonal harmonics J_n and degree 2 tesseral harmonics $S_{i,j}$ and $C_{i,j}$ are unnormalized and dimensionless. The Jupiter spin axis direction is given by right ascension α and declination δ at epoch J2000. The gravity harmonics from Pioneer and Voyager have been scaled from the Jupiter radius originally used to the radius 71,492 km and the pole direction converted from Earth mean equator of 1950 to Earth mean equator of 2000. The value and uncertainty for the Jupiter planet mass parameter (GM) for Juno analysis are taken from *Jacobson et al.* [1999].

Estimated Jovian Gravity Field Parameters From Pioneer and Voyager; From Pioneer and Voyager Combined With Galileo (Jup230); From Pioneer, Voyager, Galileo, Cassini, and New Horizons (Jup310); and From Juno’s First Two Science Orbits in Combination

Folkner, W.M., et al. (2017), Jupiter gravity field estimated from the first two Juno orbits, *Geophysics Research Letters*, **44**, 4694-4700, doi:10.1002/2017GL073140.

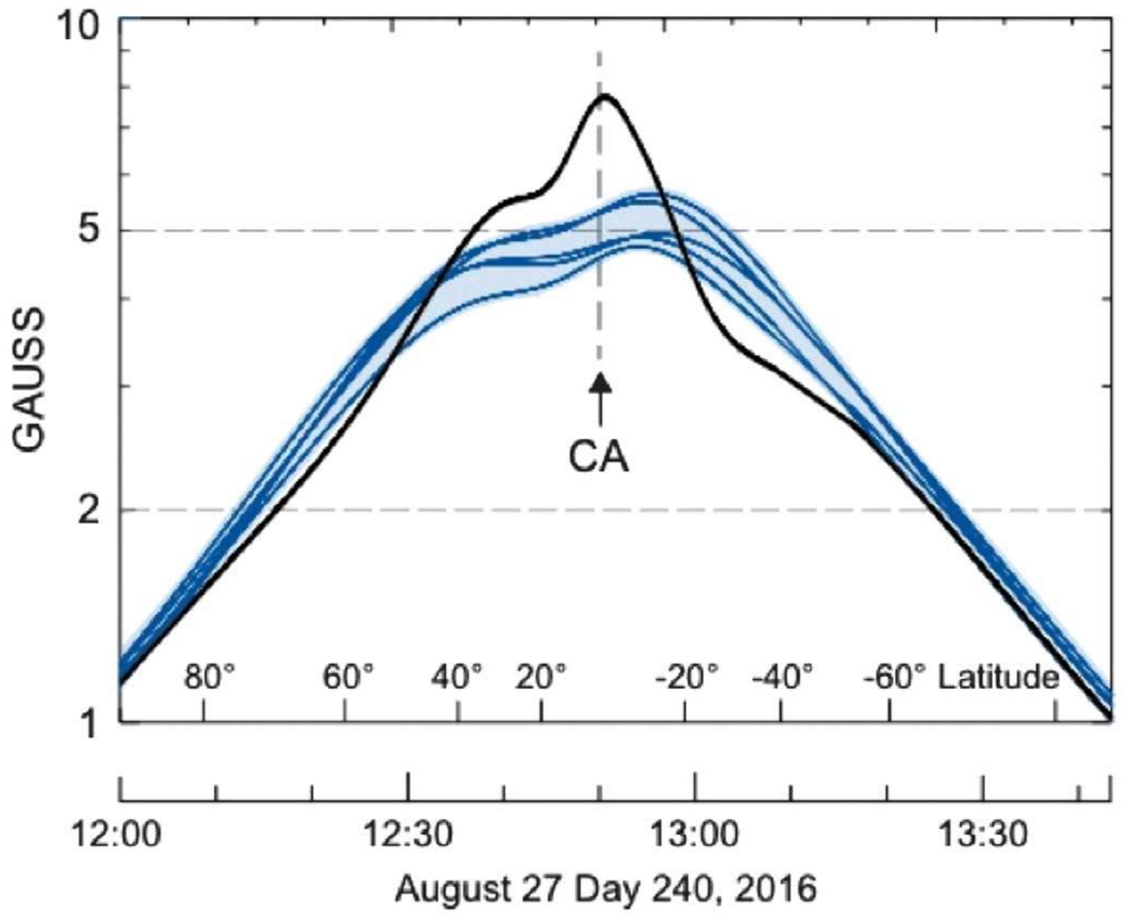
Gravity Field



Jupiter gravitational field coefficients J4 and J6.

Bolton, S.J., et al. (2017), Jupiter's interior and deep atmosphere: The initial pole-to-pole passes with the Juno spacecraft, *Science*, **356**, 821-825, doi:10.1126/science.aal2108.

MAG DATA



Magnitude of the magnetic field observed along Juno's closest approach trajectory (solid line) as a function of time and spacecraft latitude, compared with that computed from a suite of existing models.

Bolton, S.J., et al. (2017), Jupiter's interior and deep atmosphere: The initial pole-to-pole passes with the Juno spacecraft, *Science*, **356**, 821-825, doi:10.1126/science.aal2108.

Juno Captures the 'Roar' of Jupiter

https://www.youtube.com/watch?v=8CT_txWEo5I

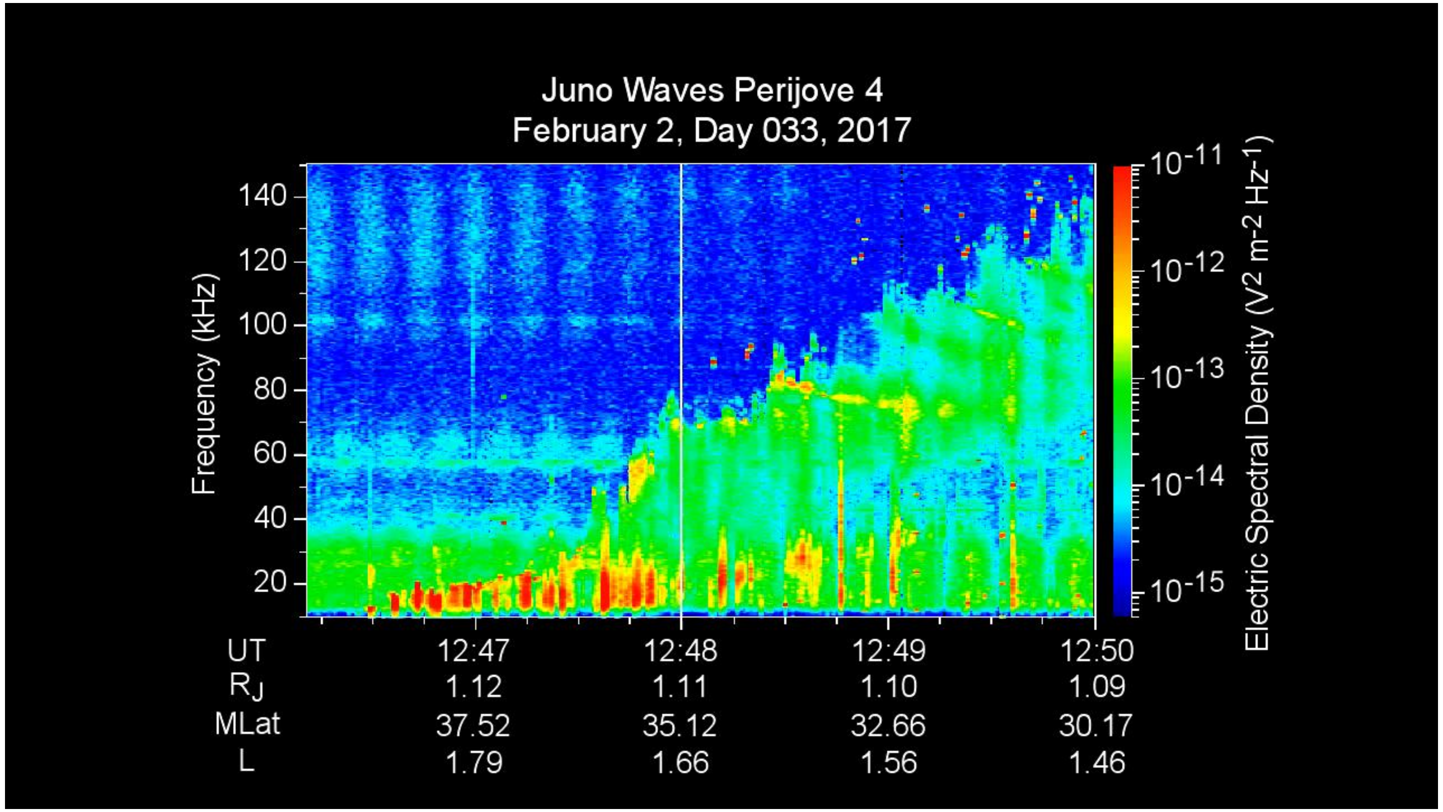
Juno has crossed the boundary of Jupiter's immense magnetic field.
Juno's Waves instrument recorded the encounter with the bow shock over the course of about two hours on June 24, 2016.
The next day, June 25, 2016, the Waves instrument witnessed the crossing of the magnetopause.
"Trapped continuum radiation" refers to waves trapped in a low-density cavity in Jupiter's magnetosphere.

Juno Listens to Jupiter's Auroras

https://www.youtube.com/watch?v=slE2i0O0pDY

Thirteen hours of radio emissions from Jupiter's intense auroras are presented visually and in sound.
The data was collected when the spacecraft made its first orbital pass of the gas giant on Aug 27, 2016, with all spacecraft instruments turned on.
The frequency range of these signals is from 7 to 140 kilohertz.
Radio astronomers call these "kilometric emissions" because their wavelengths are about a kilometer long.

Jupiter's ionosphere by JUNO



https://www.youtube.com/watch?v=lP0gpjgJBxw

This display is a frequency-time spectrogram.
The results in this figure show an increasing plasma density as Juno descended into Jupiter's ionosphere during its close pass by Jupiter on February 2, 2017.

References

- Bolton, S.J., et al. (2017), Jupiter’s interior and deep atmosphere: The initial pole-to-pole passes with the Juno spacecraft, *Science*, **356**, 821-825, doi:10.1126/science.aal2108.

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- NASA/JPL-Caltech/SwRI/MSSS/Betsy Asher Hall/Gervasio Robles

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- https://en.wikipedia.org/wiki/Pioneer_10
- https://en.wikipedia.org/wiki/Pioneer_11
- https://www.nasa.gov/centers/ames/missions/archive/pioneer10-11.html
- https://www.nasa.gov/centers/ames/missions/archive/pioneer.html
- https://en.wikipedia.org/wiki/Galileo_(spacecraft)
- https://www.jpl.nasa.gov/missions/galileo/
- https://solarsystem.nasa.gov/missions/galileo/indepth
- https://en.wikipedia.org/wiki/Juno_(spacecraft)
- https://www.nasa.gov/feature/jpl/nasas-juno-spacecraft-completes-flyby-over-jupiter-s-great-red-spot
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- https://en.wikipedia.org/wiki/Europa_Jupiter_System_Mission_–_Laplace
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- https://www.jpl.nasa.gov/news/press_kits/juno/pdf/juno-lores.pdf
- https://www.nasa.gov/pdf/139889main_PressKit12_05.pdf

Thanks.