

Today's Topics

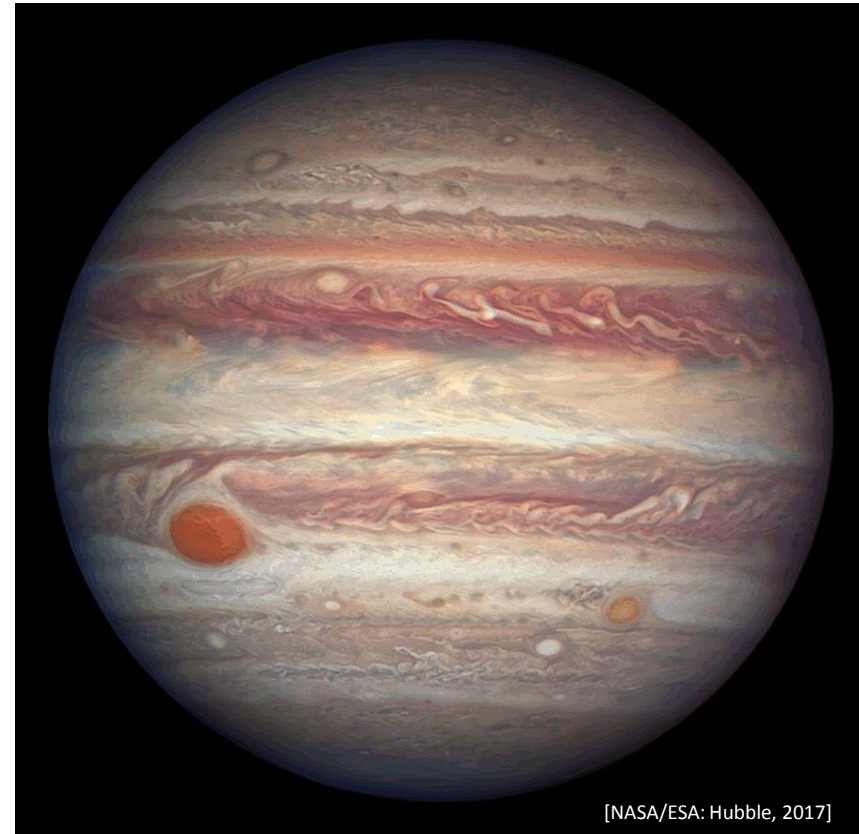
Friday, October 9, 2020 (Week 7, lecture 22) – Chapters 11, 12.

Jupiter

- A. Basic properties
- B. The “cosmic vacuum cleaner”
- C. Energy puzzle
- D. Galilean Moons: an overview
- E. Galilean Moons: the details
- F. Upcoming jovian missions

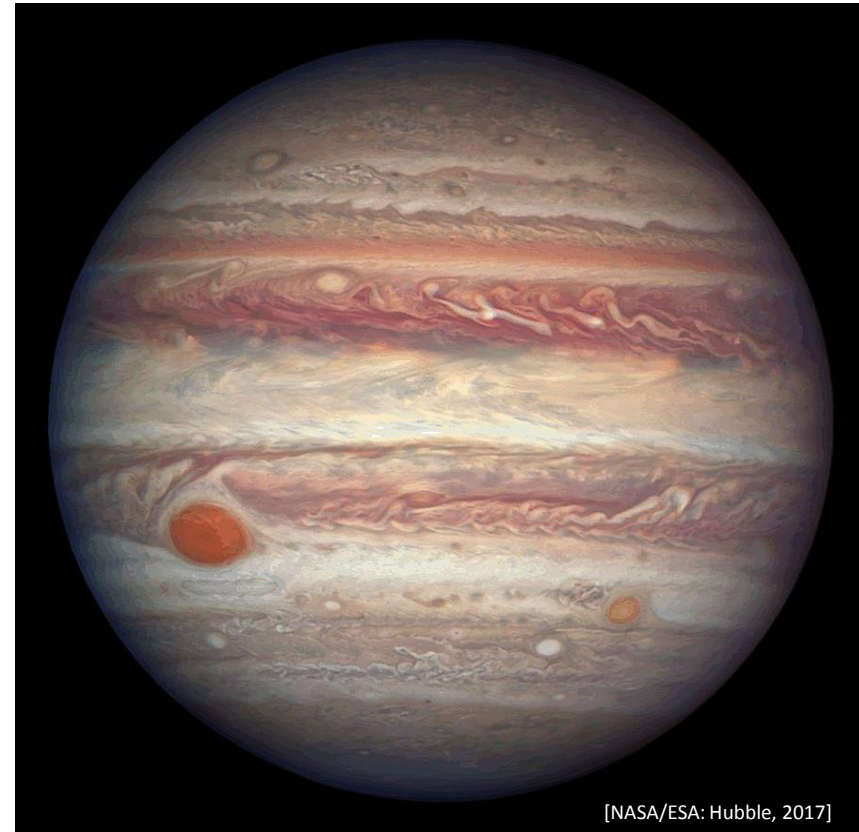
Jupiter

- **Largest & heaviest** planet in Solar System.
 - $M_{\text{Jupiter}} \approx 318 M_{\text{Earth}}$.
 - $R_{\text{Jupiter}} = 70,000 \text{ km} \approx 11 R_{\text{Earth}}$.
- Orbit demarcates approximate outer range of **“frost line.”**
 - Orbital period = 11.9 years
 - Semimajor axis = 5.20 AU



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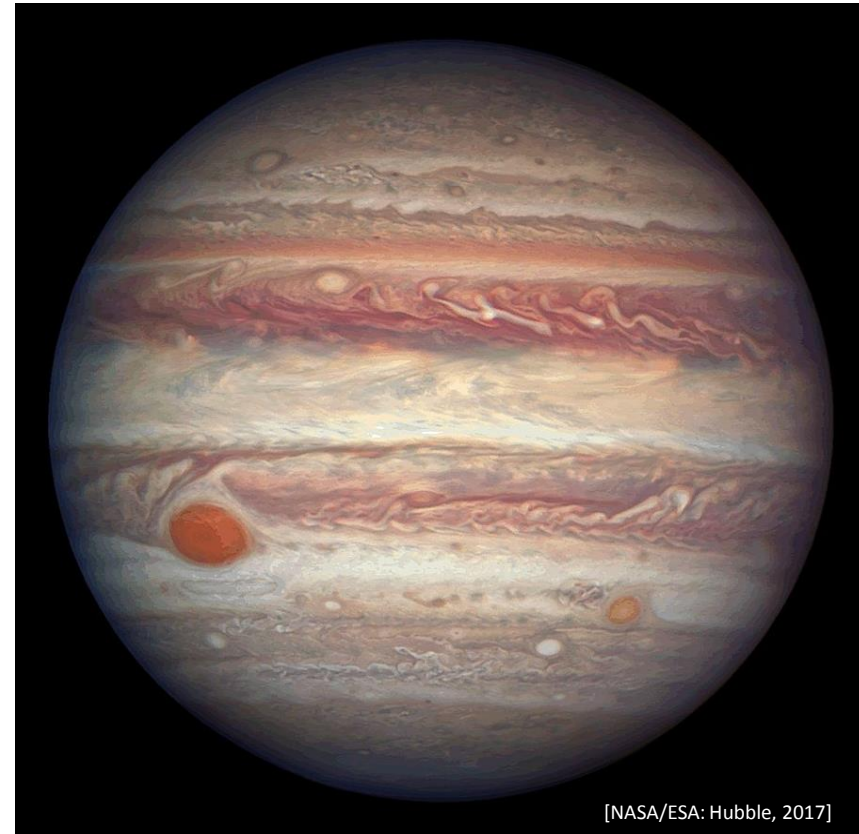
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- Rotates very quickly: $T_{\text{rotation}} = 9.9 \text{ hrs.}$
- **Largest magnetosphere** of all the planets.
- Very rich atmospheric structure.
 - Thought to be due to **internal heat**.



[NASA/ESA: Hubble, 2017]

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- 4 large moons and 75 very small moons.
 - **Galilean moons**: **Ganymede**, **Callisto**, **Io**, and **Europa**.



Jupiter: “cosmic vacuum cleaner”

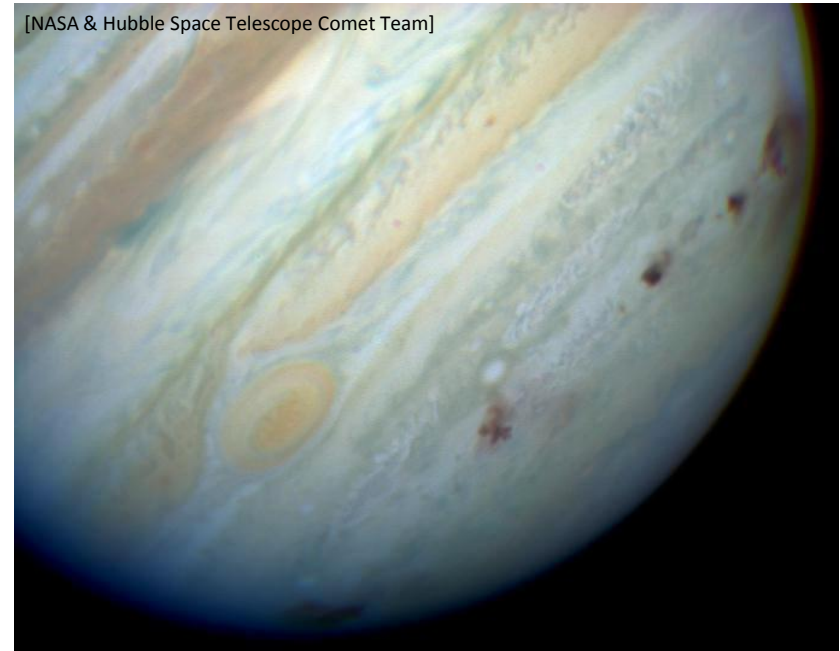
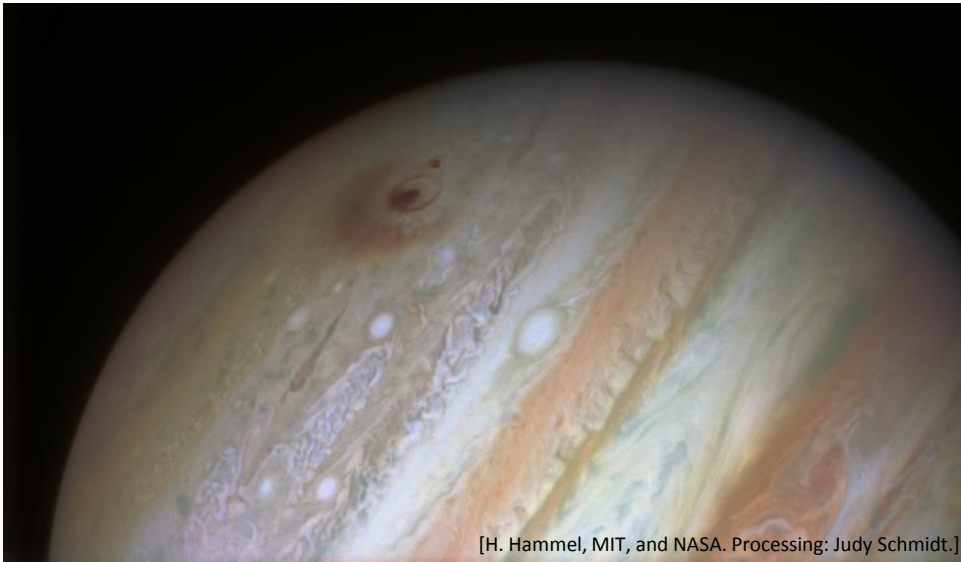
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- Removes small bodies from Solar System.
- Reduces impacts on other planets.

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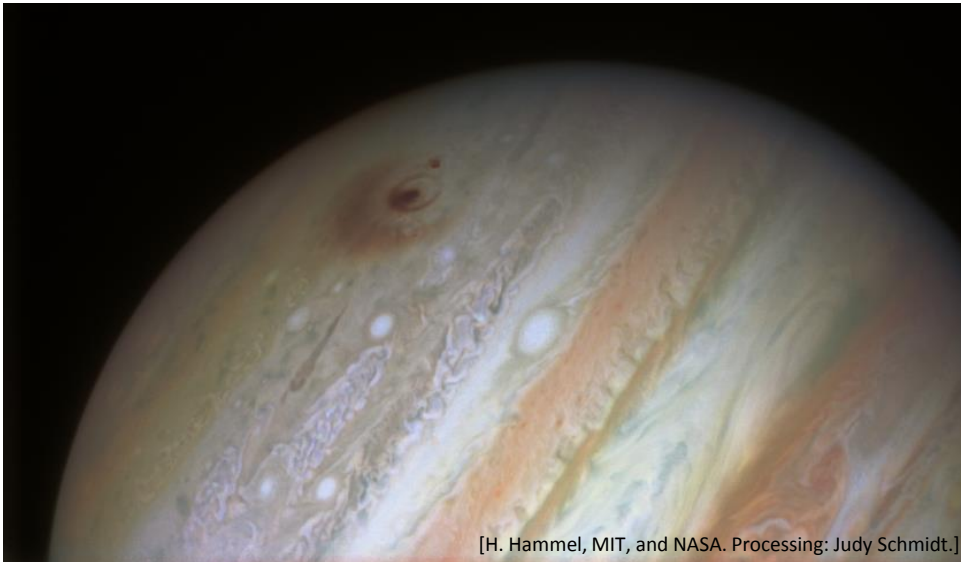
Comet Shoemaker-Levy impact on Jupiter in 1994

Jupiter: “cosmic vacuum cleaner”

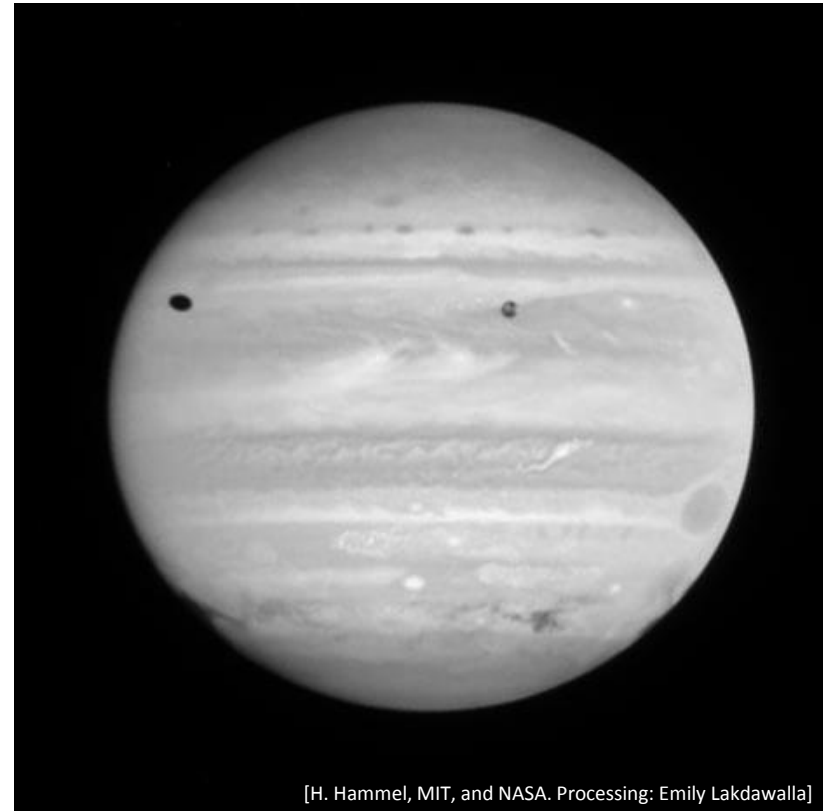
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[H. Hammel, MIT, and NASA. Processing: Judy Schmidt.]



[H. Hammel, MIT, and NASA. Processing: Emily Lakdawalla]

Comet Shoemaker-Levy impact on Jupiter in 1994

Jupiter emits more energy than it absorbs

- Jupiter **emits twice the power** that it receives from the Sun!
- **Explanation 1:** Left over **primordial heat** is radiated by planet.
- **Explanation 2:** Jupiter may be gradually **contracting**.
 - Gravitational potential energy is converted to kinetic thermal energy.
- Jupiter's core is estimated to be at 36,000 K.

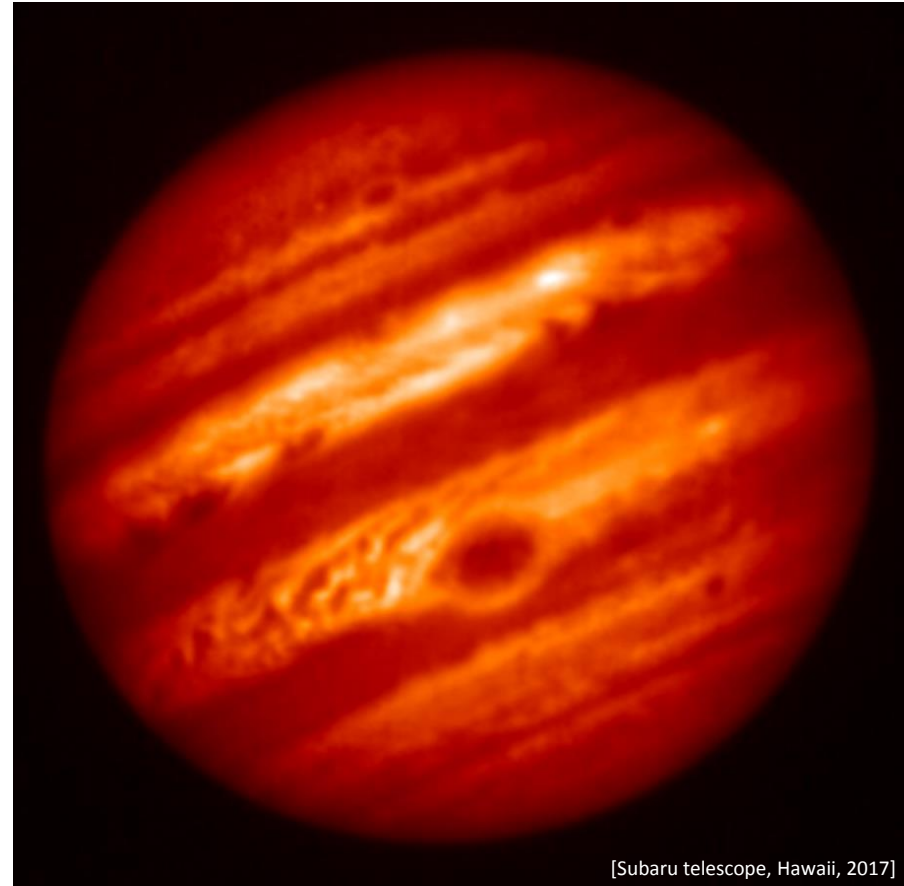


[Subaru telescope, Hawaii, 2017]

Jupiter in the mid-infrared ($\lambda = 8.8 \mu\text{m}$)

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- **Saturn** also emits more power than it receives.
 - Planet is still **differentiating** (helium "rain" falling into Saturn) and converting gravitational energy to thermal energy.
- **Neptune** also emits more power than it receives: planet is still contracting.



[Subaru telescope, Hawaii, 2017]

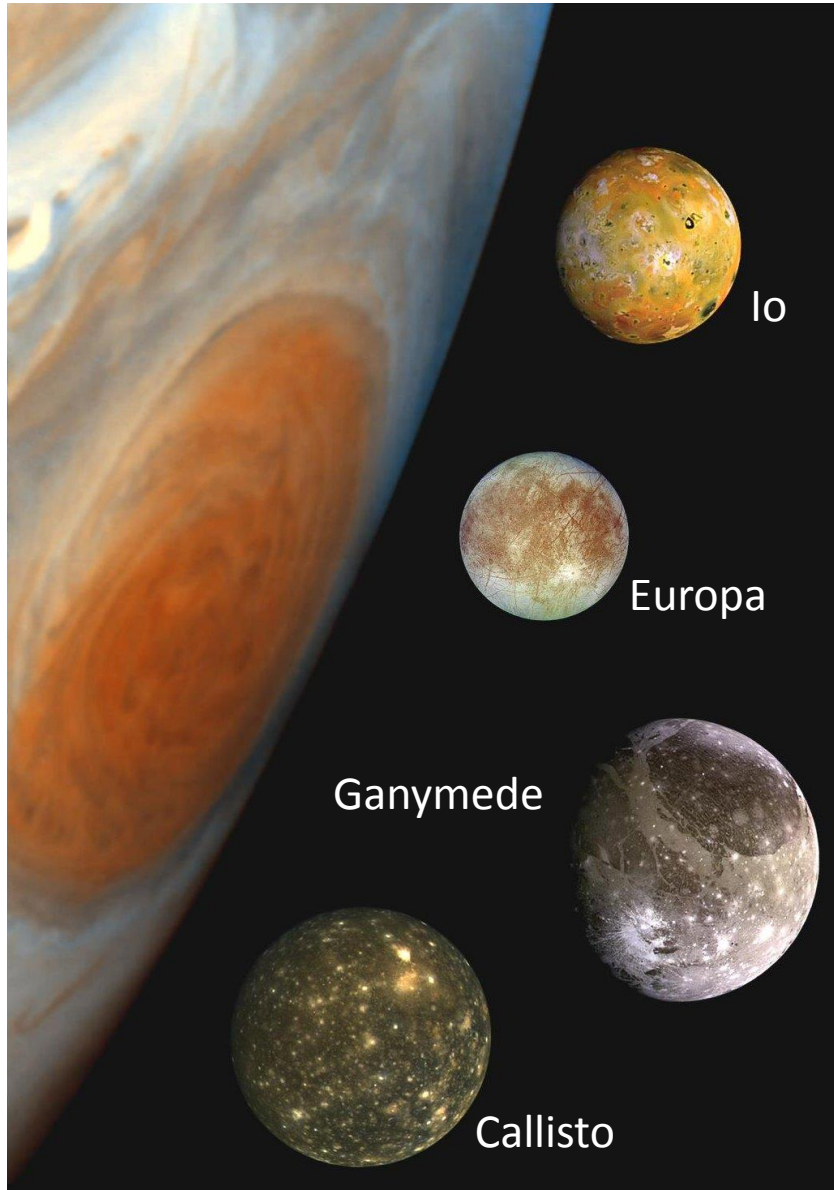
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Jupiter's Galilean Moons



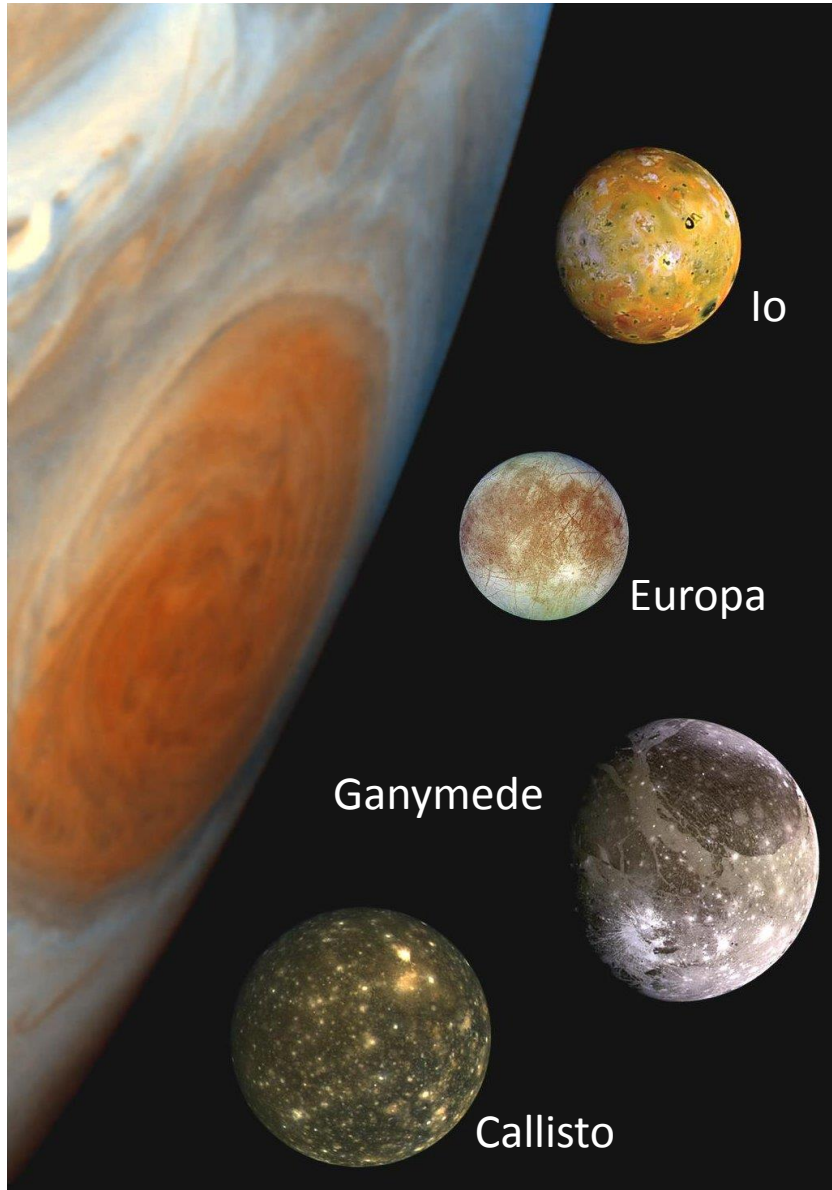
[NASA: Juno mission, 2016]

Jupiter's Galilean Moons

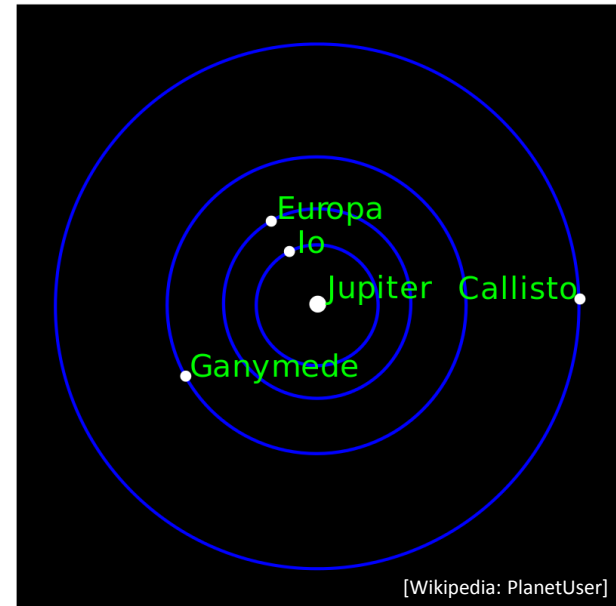


- Comparable in size to the Moon.

Jupiter's Galilean Moons



[NASA/JPL/DLR - NASA planetary photojournal]



[Wikipedia: PlanetUser]

- Comparable in size to the Moon.
- Fairly circular orbits.
- Inner three moons are in a stable (self-correcting) 4:2:1 resonance.
 - For each Ganymede orbit, Europa completes 2 orbits, and Io makes for 4 orbits.

Galilean Moons Comparison

Name	Diameter (km)	Mass (Earth's Moon = 1)	Density (g/cm ³)
Moon	3476	1.0	3.3
Callisto	4820	1.5	1.8
Ganymede	5270	2.0	1.9
Europa	3130	0.7	3.0
Io	3640	1.2	3.5

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Formation of Jupiter and its moons

- Similar to a **mini solar nebula**, except Jupiter never became a star.
- **Outer moons are icier**, **inner moons are rockier**.

Historical Importance

Galileo discovered the 4 moons in 1609-1610 with his 20x telescope.

- Communicated the discovery to Kepler.
- Confirmation that not all celestial bodies circle the Earth or Sun.
- Confirmation of the heliocentric view.



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Cassini (1625-1712) measured the periods & eclipses of the 4 moons very precisely.

- Development of a celestial clock.
- Solution to the “longitude problem.”
 - Substantial improvement to measurements of distances on Earth.
 - Improved maps of Europe.
- This “longitude problem” solution spurred the development of high accuracy mechanical clocks.



Callisto & Ganymede



[NASA/JPL/DLR: Galileo mission, 2001]

Callisto

- **Tidal locking:** same side always faces Jupiter.
- Not fully differentiated: rocks & ices mix.
- Geologically inactive (ice does not “flow”).
(when very cold)

Callisto & Ganymede



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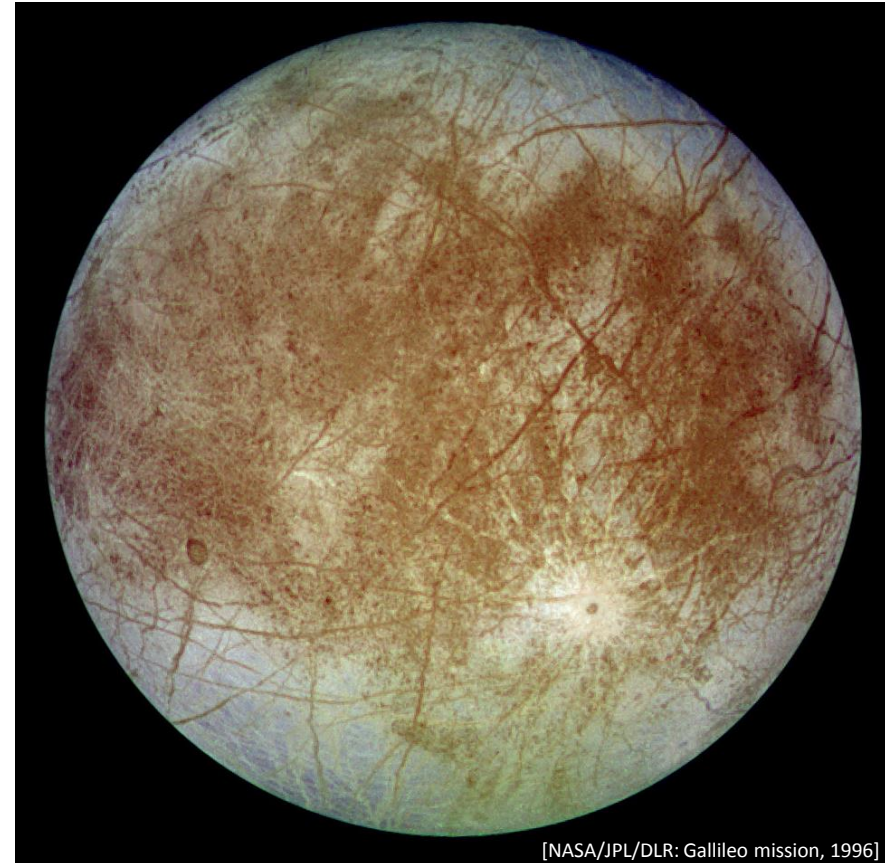


Ganymede

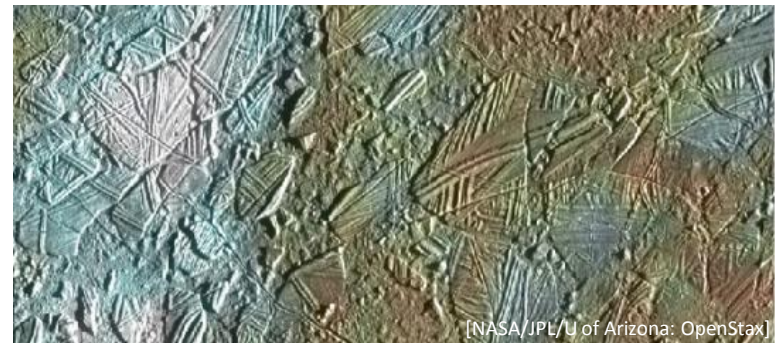
- **Largest moon in Solar system.**
- **Tidal locking:** same side always faces Jupiter.
- Differentiated interior with molten core.
→ **Tidal heating**, geologically active, *possible liquid H₂O inside*, *magnetic field*.

Europa

- **Tidal locking:** same side always faces Jupiter.
- **Tidal heating:** gravity gradients from Jupiter (and also Io, and Ganymede) periodically deform moon and heat its interior.
→ *Tidal forces are about 1000 stronger than in Earth-Moon system.*
- Surface is geologically young (very few craters).
- Composition is a rocky core with a **large mantle and crust of water** (ice, maybe liquid).
- Water cryogeisers detected.

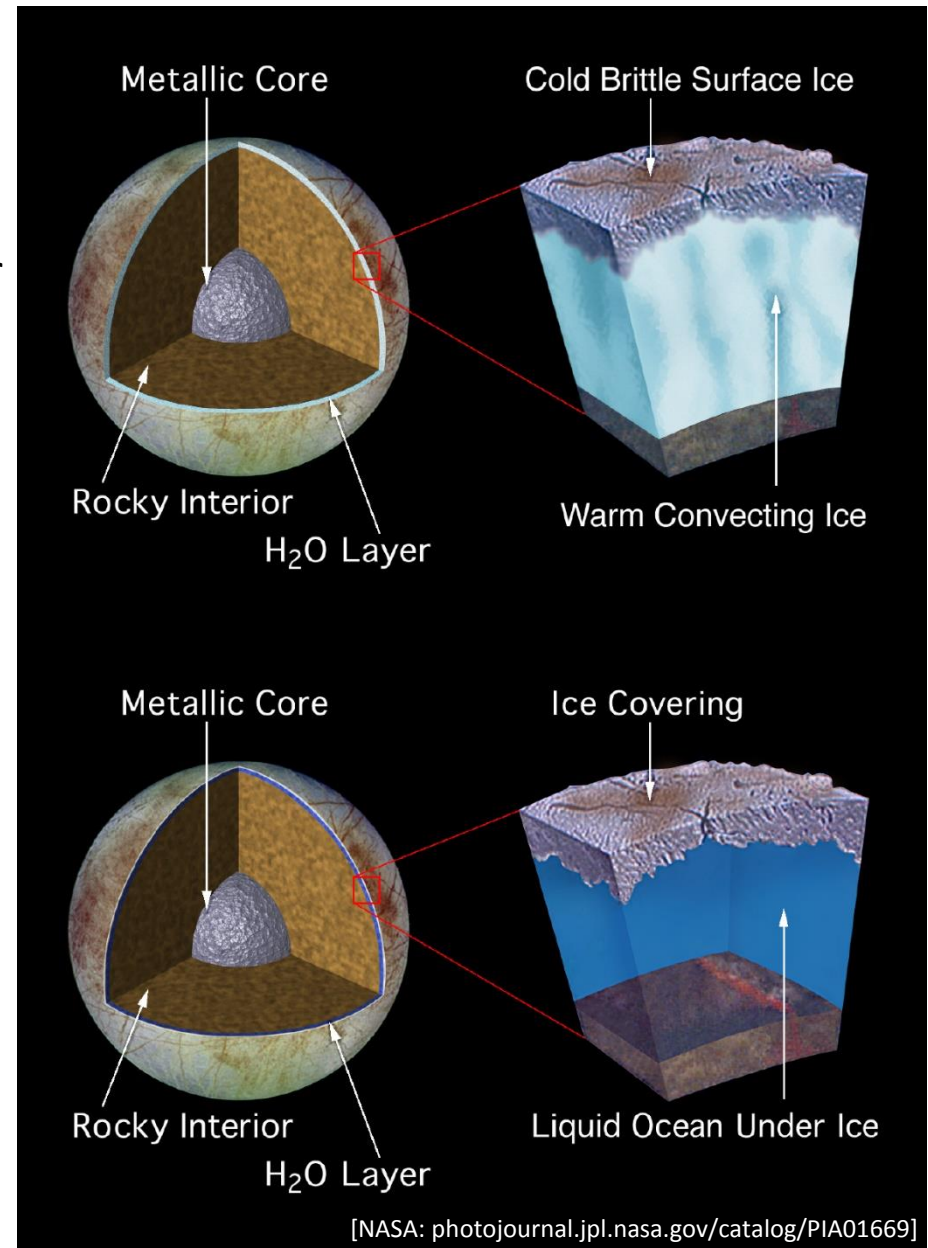


Geologically active water ice surface



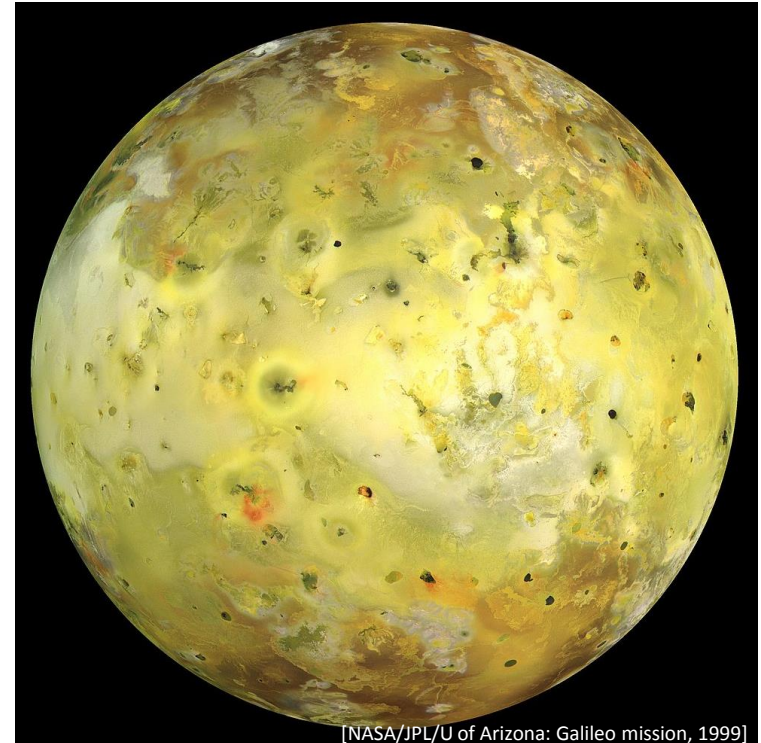
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- Europa may have **liquid water ocean** under its icy crust.



Io

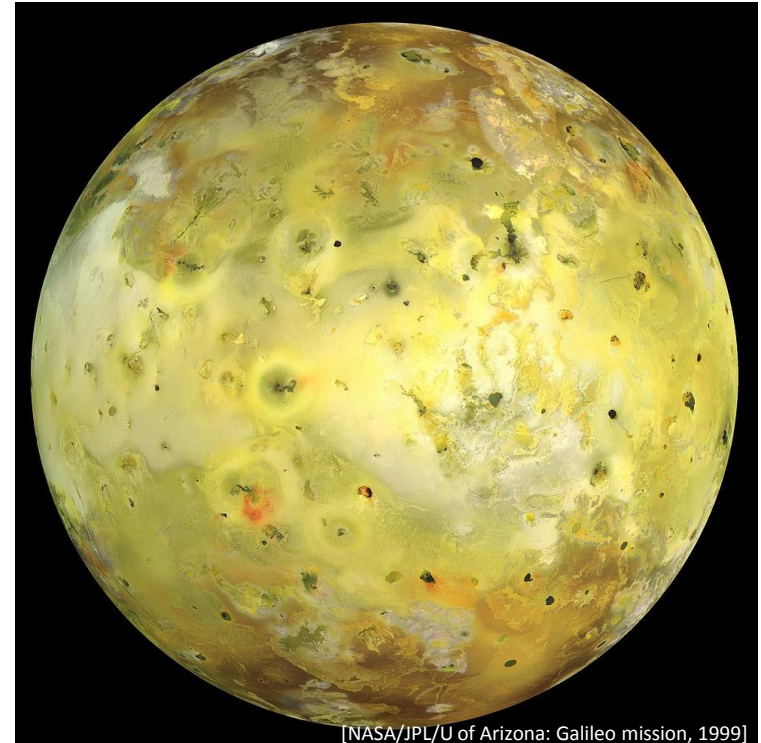
- **Tidal locking:** same side always faces Jupiter.
- **Extreme tidal heating:** gravity gradient primarily from Jupiter periodically deforms moon and heat its interior due to orbital eccentricity.
→ *Tidal bulge is several kilometers.*
- Most geologically active body in Solar System.



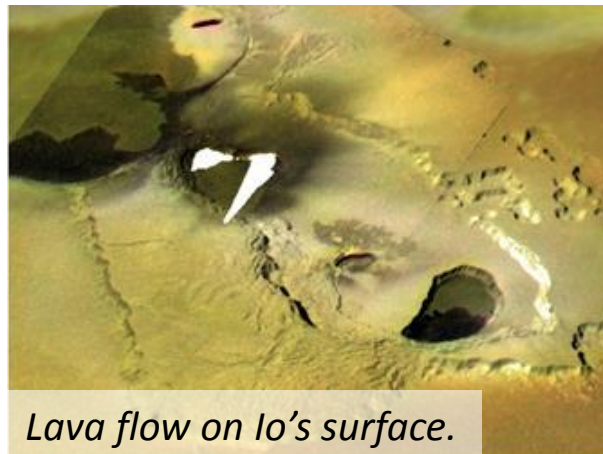
[NASA/JPL/U of Arizona: Galileo mission, 1999]

Io

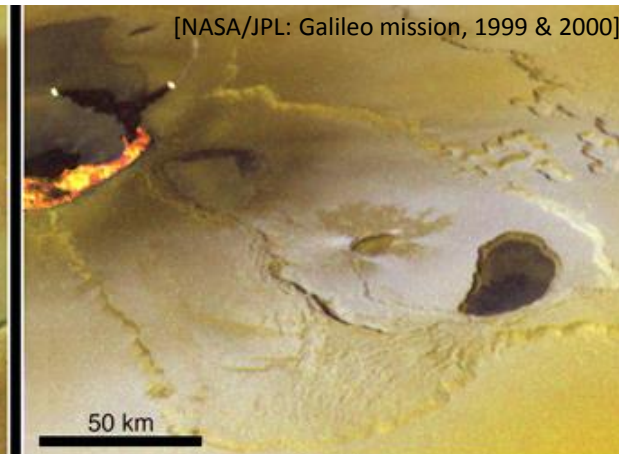
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- Most geologically active body in Solar System
- More than **400 active volcanoes.**
- Composition is silicate rock with an **iron-sulfur liquid core.** Crust has a lot sulfur.
- Volcanic plumes feed a **plasma torus** in Jupiter's magnetosphere.



[NASA/JPL/U of Arizona: Galileo mission, 1999]



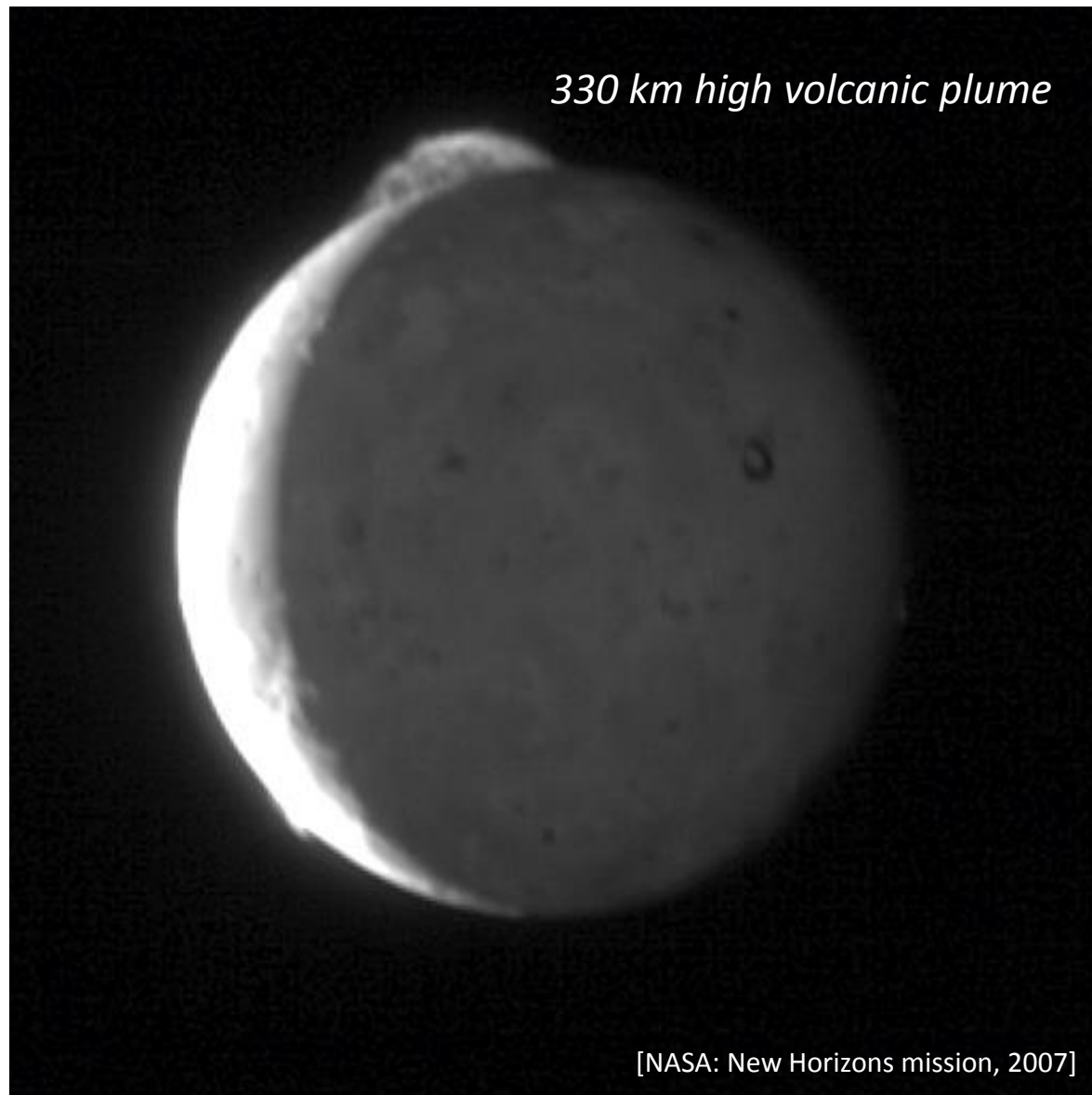
Lava flow on Io's surface.



[NASA/JPL: Galileo mission, 1999 & 2000]

50 km

Io: Active Volcano



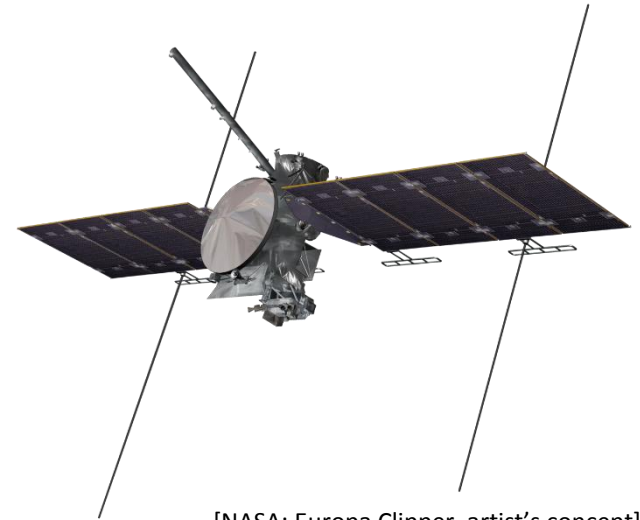
Io & Jupiter



Future Missions to Galilean Moons

Europa Clipper

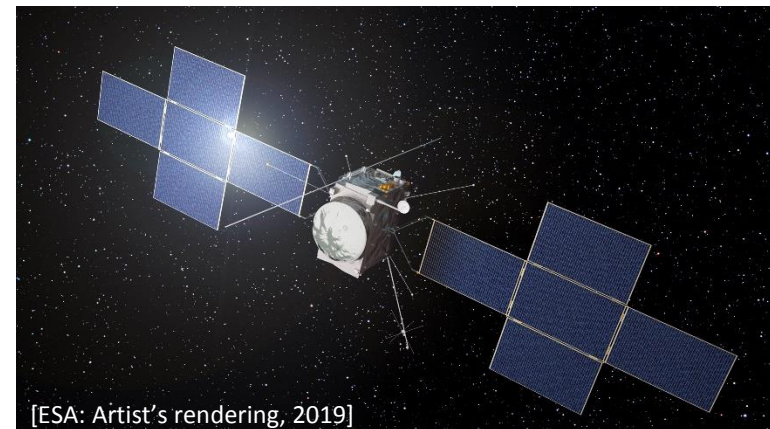
- Planned launch 2025.
- Orbits of Jupiter with 45 Europa flybys.
- Search for sub-crust **water ocean**.
- Study composition & chemistry.
- Find a suitable future **lander location**.



[NASA: Europa Clipper, artist's concept]

JUICE: JUpter ICy moons Explorer

- Planned launch 2022.
- Enter Ganymede orbit in 2032.
- Study Ganymede.
- Also study Europa and Callisto.



[ESA: Artist's rendering, 2019]