Today's Topics

Friday, October 25, 2019 (Week 8, lecture 22) – Chapters 11, 12.

1. Jupiter

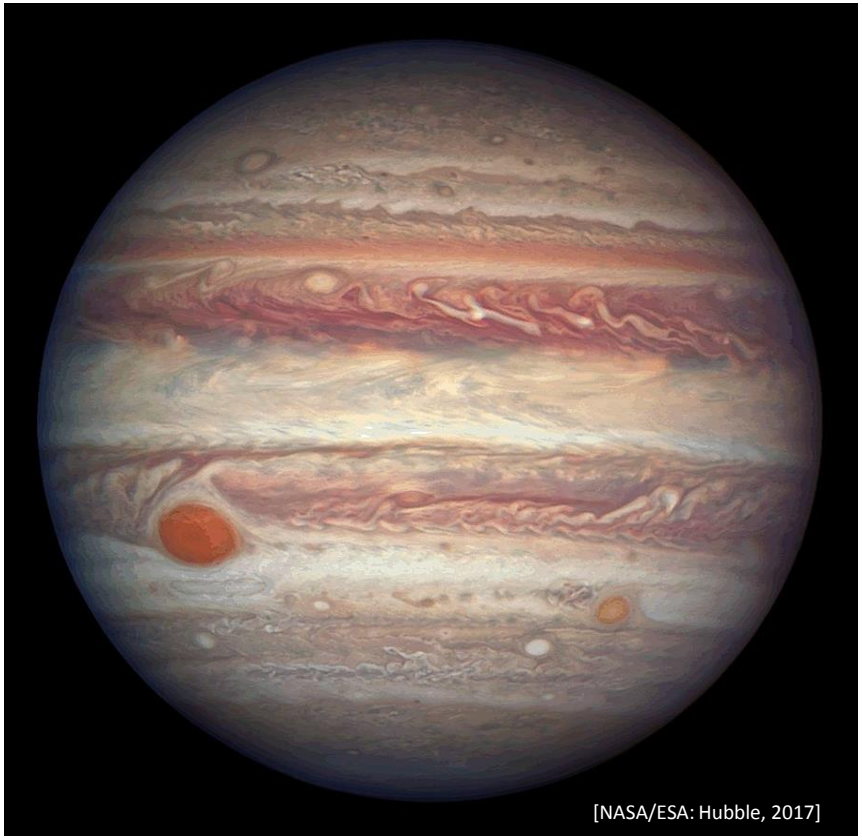
2. Galilean Moons

3. Saturn

Jupiter

- **Largest & heaviest** planet in Solar System.
  → $M_{Jupiter} \approx 318\ M_{earth}$.
  → $R_{Jupiter} = 70{,}000\ km \approx 11\ R_{Earth}$.

- Orbit demarcates approximate outer range of **"frost line."**
  → Orbital period = 11.9 years
  → Semimajor axis = 5.20 AU


[NASA/ESA: Hubble, 2017]

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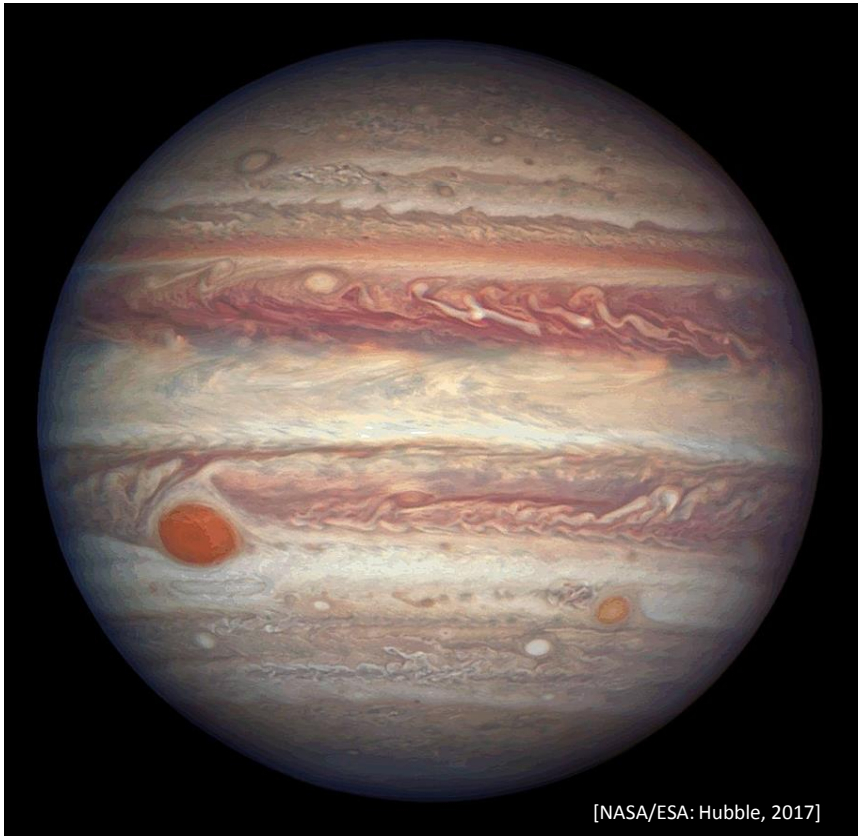
- **Largest magnetosphere** of all the planets.

- Very rich atmospheric structure.
  → Thought to be due to **internal heat**.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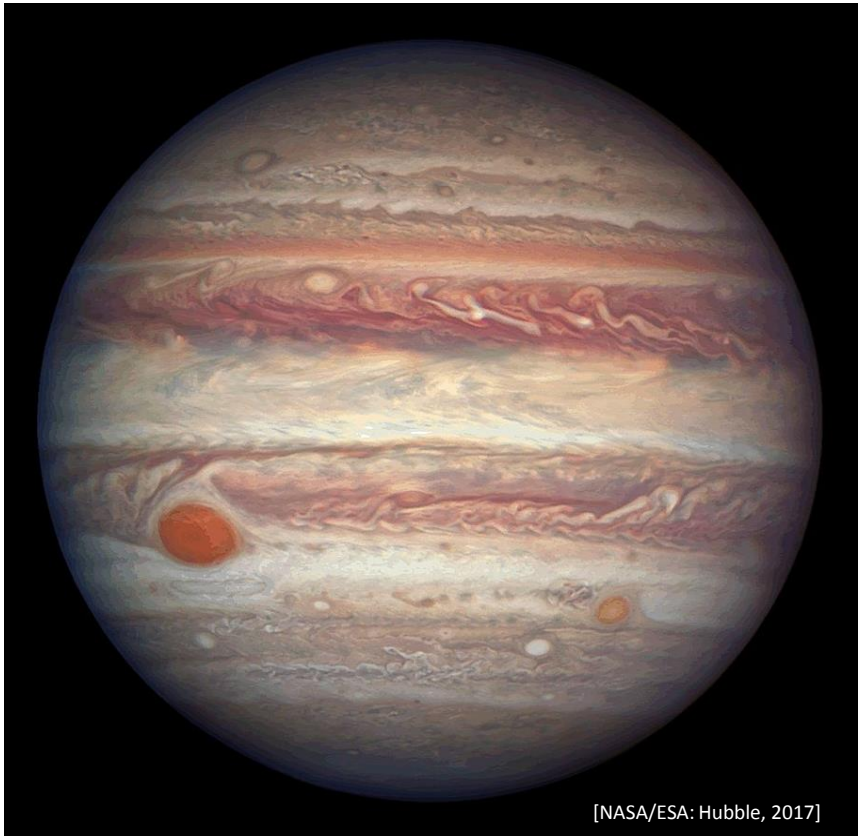
- 4 large moons and 75 very small moons.
  → **Galilean moons**: Ganymede, Callisto, Io, and Europa.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Jupiter: “cosmic vacuum cleaner”

Jupiter attracts and “eats” comets and asteroid.

→ Removes small bodies from Solar System.

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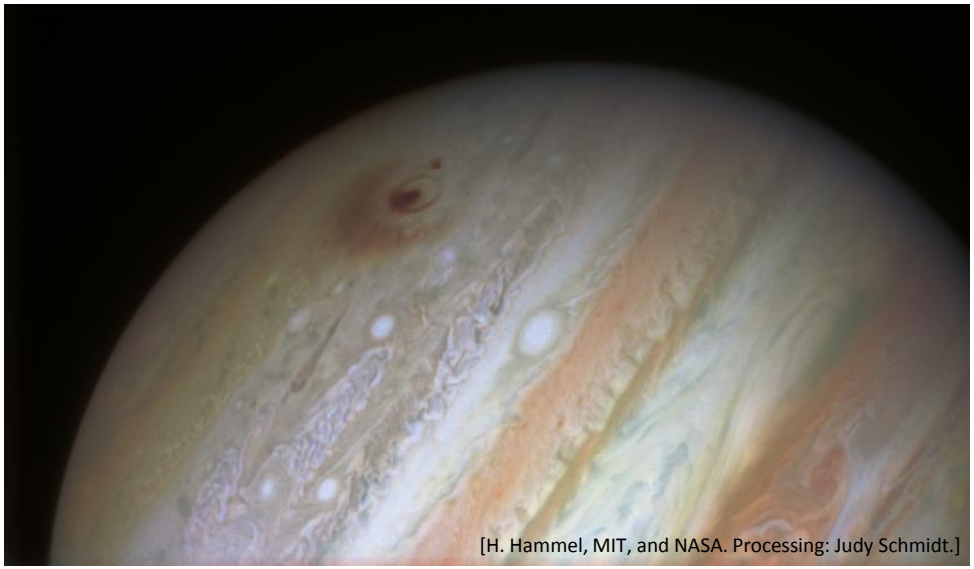

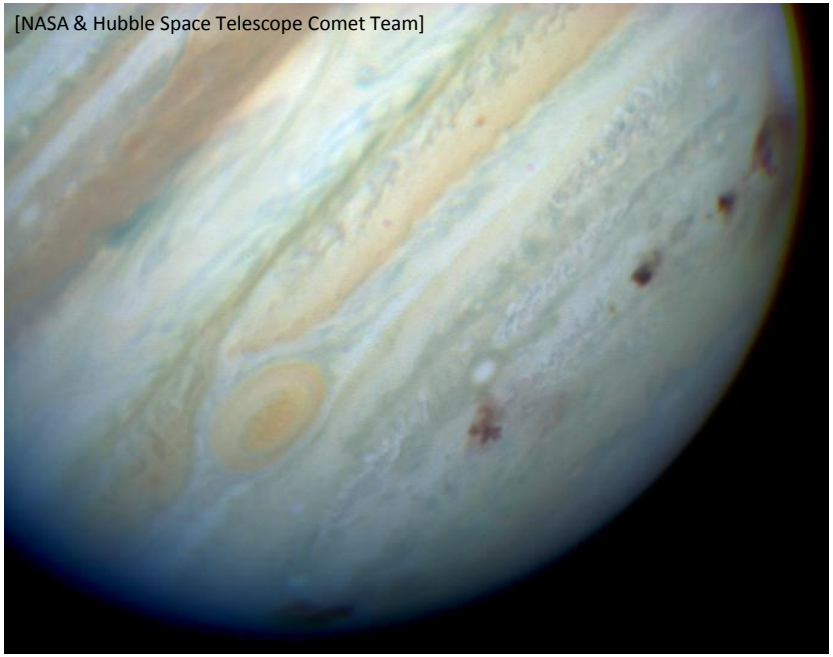

Comet Shoemaker-Levy impact on Jupiter in 1994

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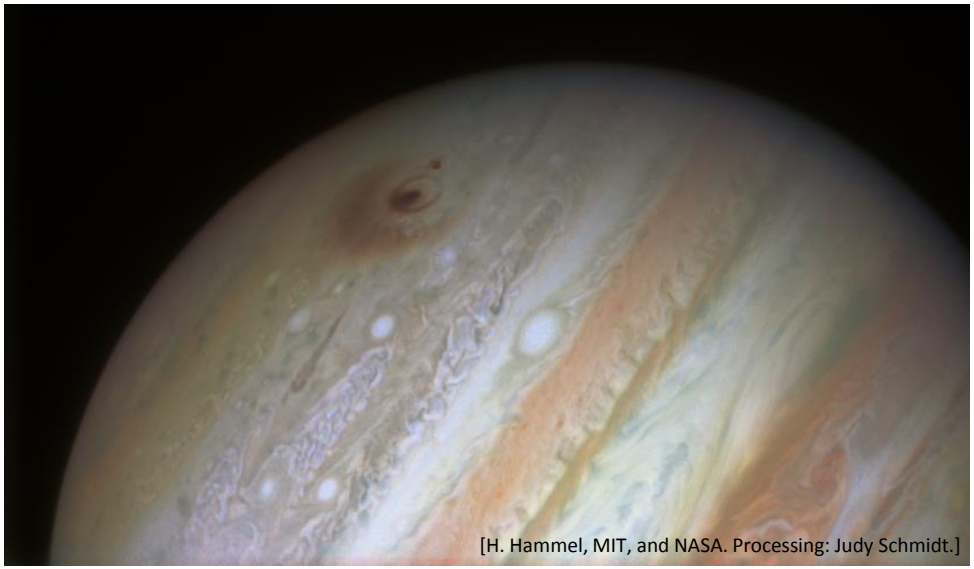
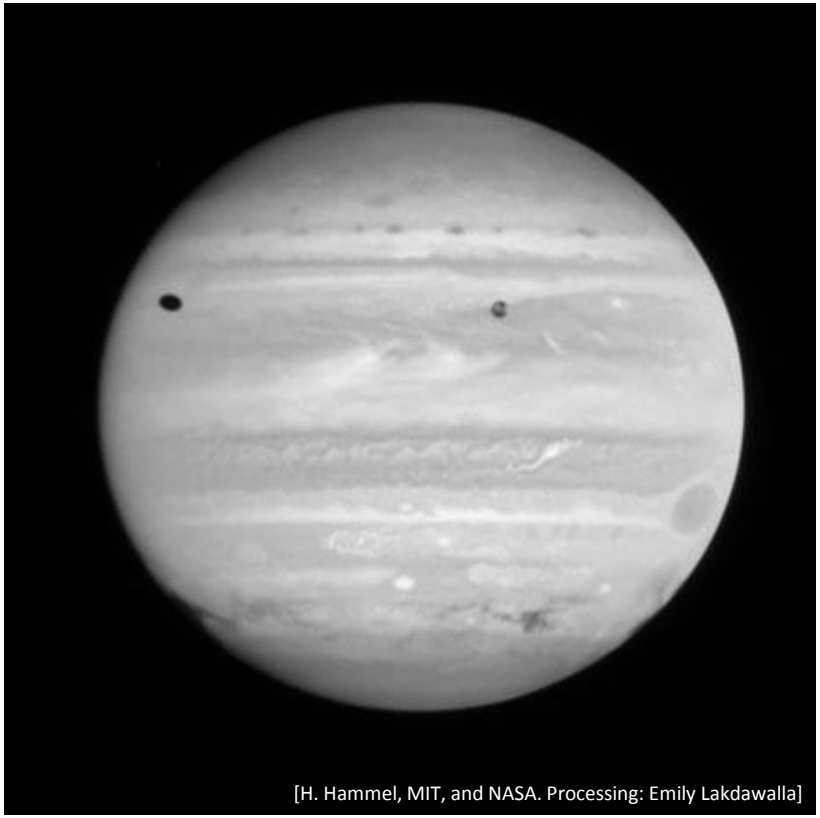
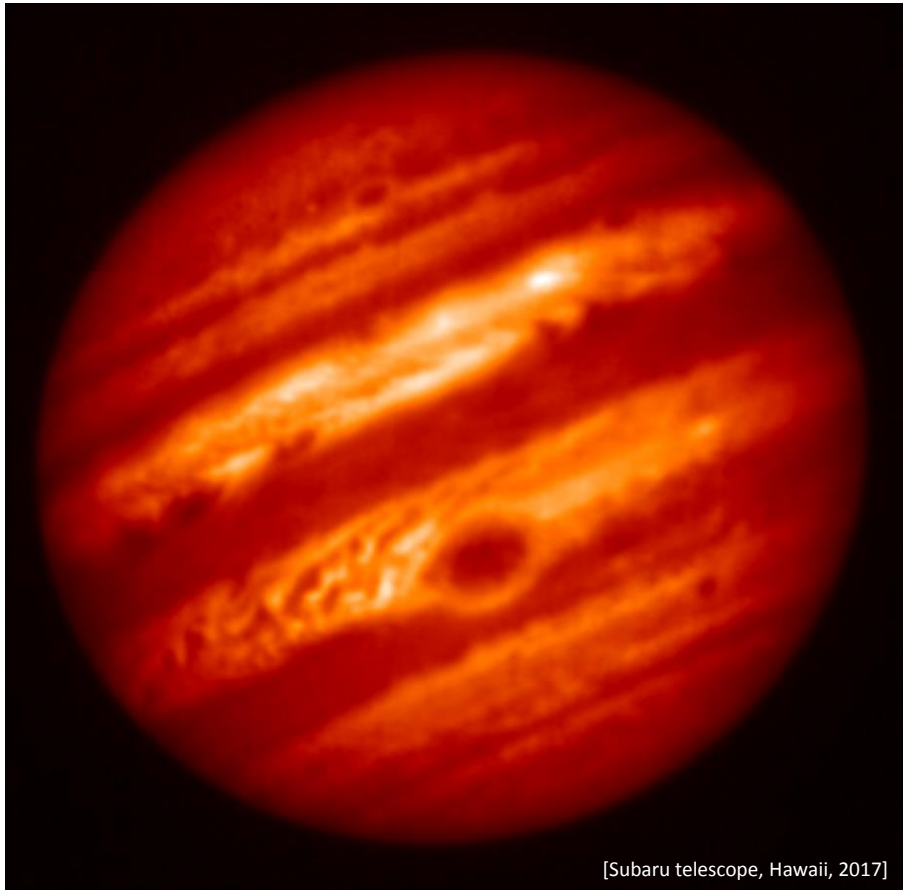




Comet Shoemaker-Levy impact on Jupiter in 1994

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.



Jupiter in the mid-infrared (λ = 8.8 μm)

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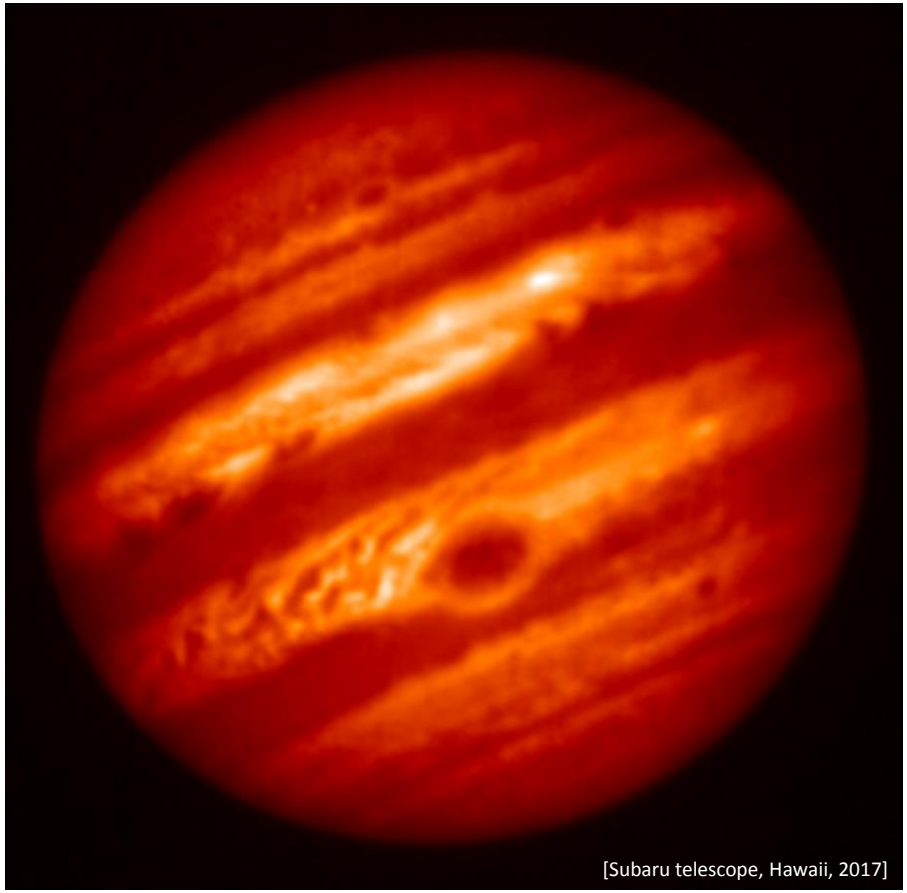
- **Saturn** also emits more power than it receives.
  → Planet is still **differentiating** (helium "rain" falling into Saturn) and converting gravitational energy to thermal energy.
- **Neptune** also emits more power than it receives: planet is still contracting.



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Jupiter's Galilean Moons

[NASA: Juno mission, 2016]

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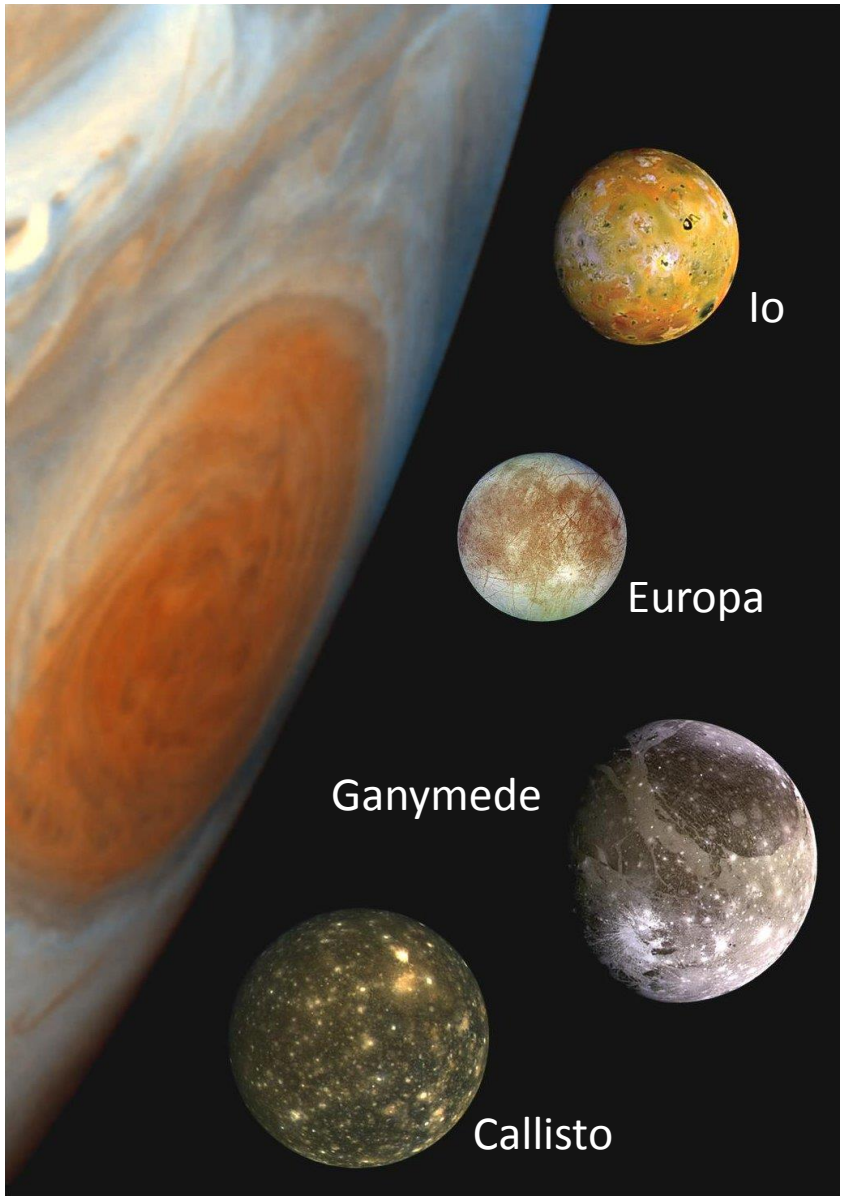
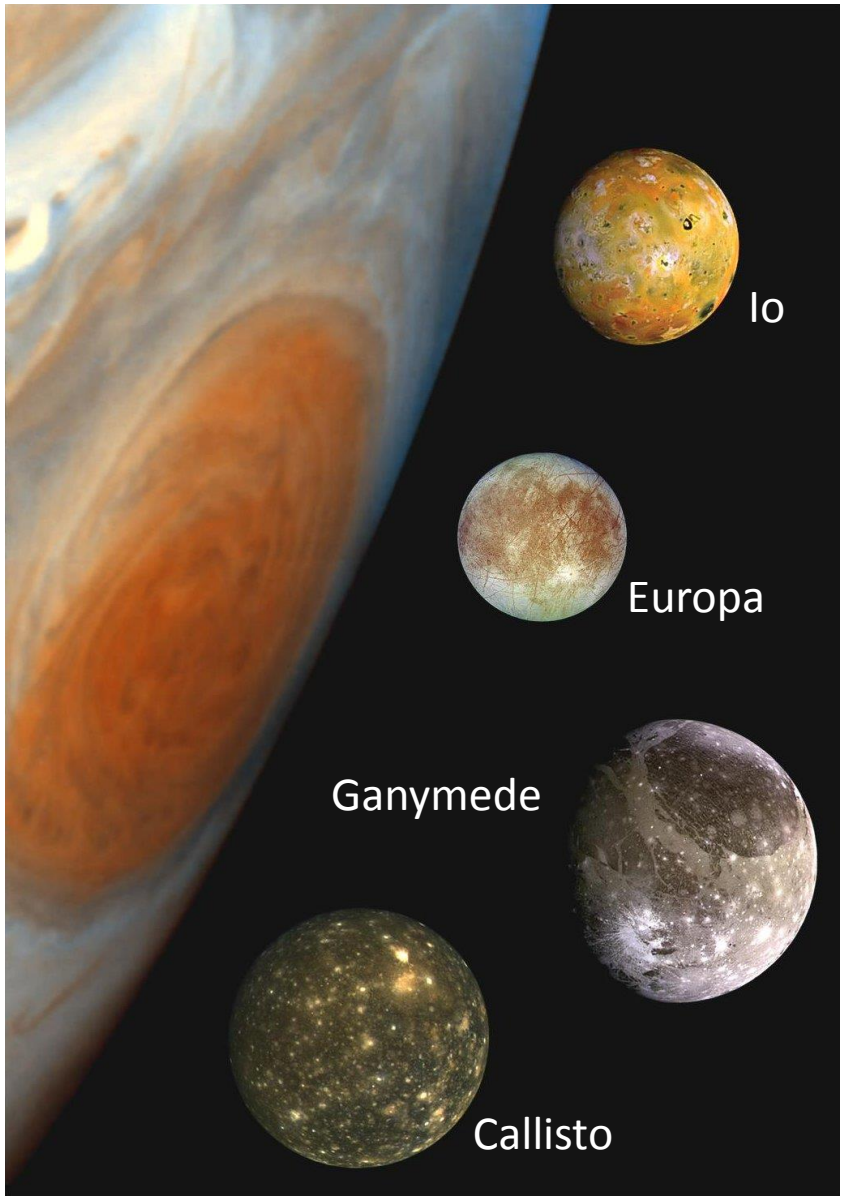


[NASA/JPL/DLR - NASA planetary photojournal]

- Comparable in size to the Moon.

Jupiter's Galilean Moons



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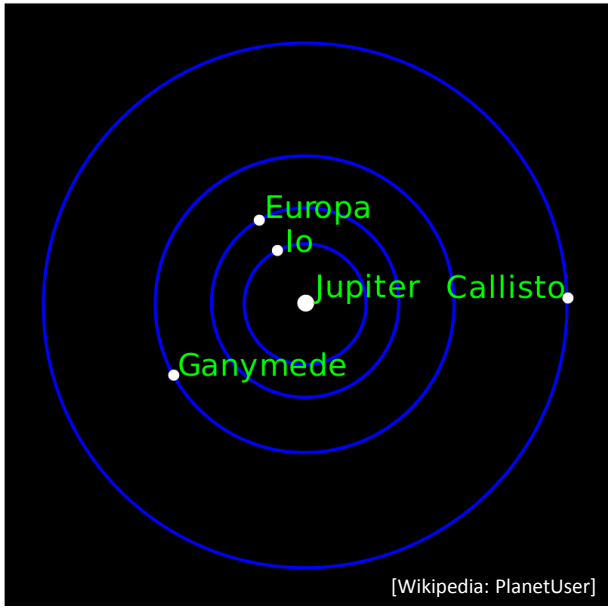

- Comparable in size to the Moon.
- Fairly circular orbits.
- Inner three moons are in a stable (self-correcting) 4:2:1 resonance.

  → *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
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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.

Callisto & Ganymede

Callisto

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

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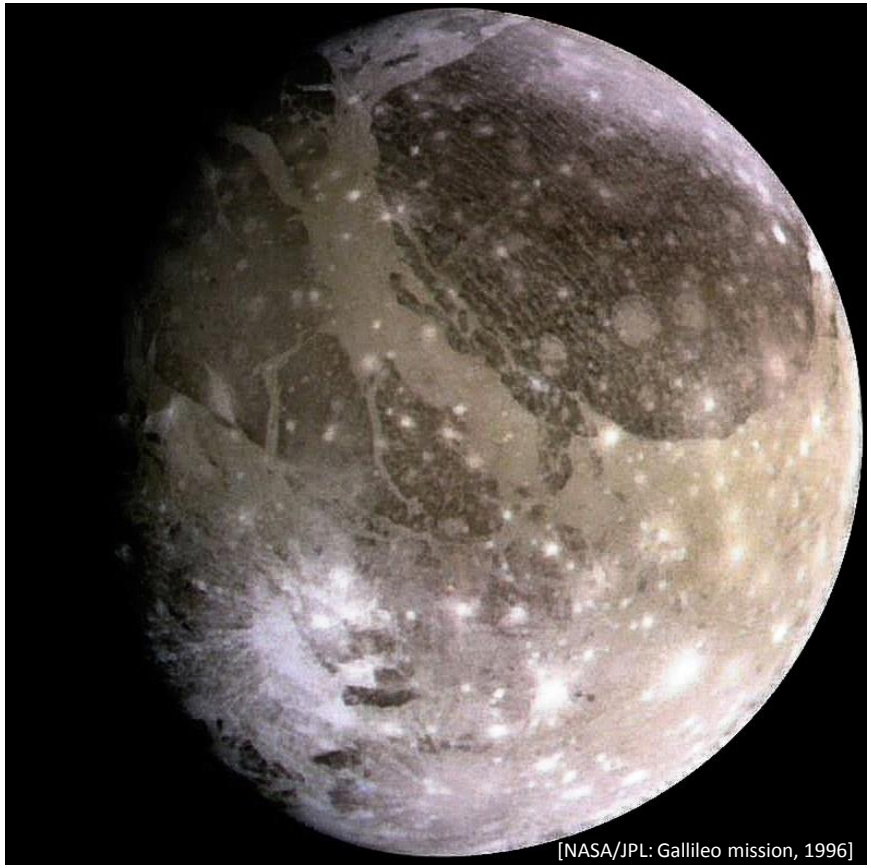
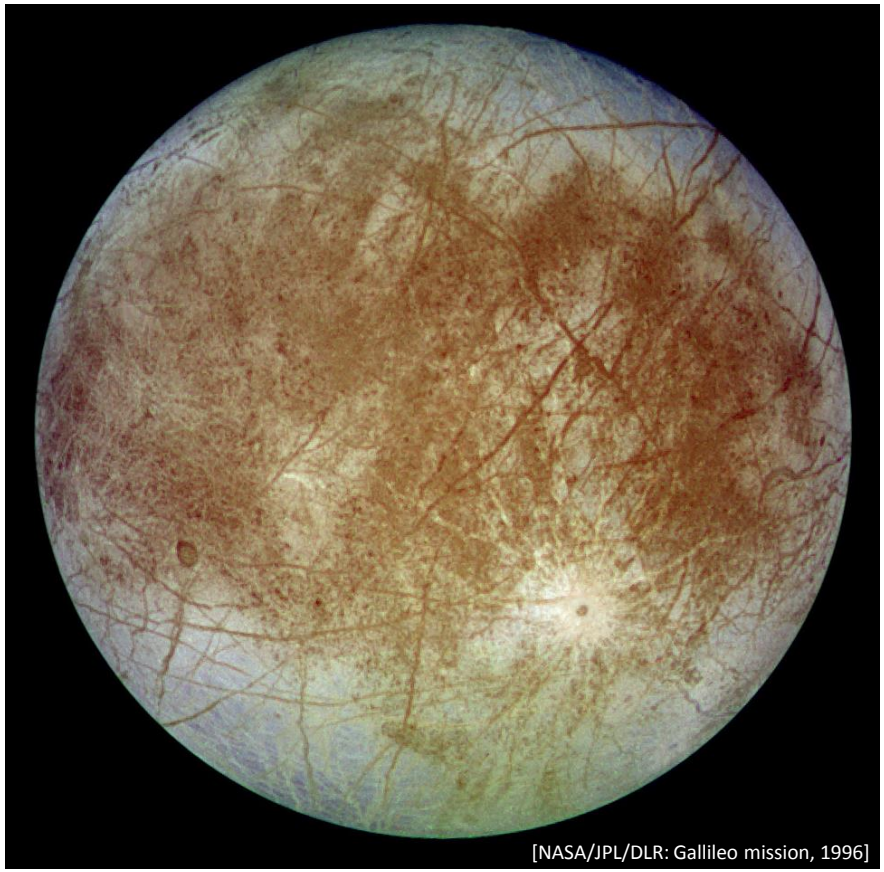


Ganymede

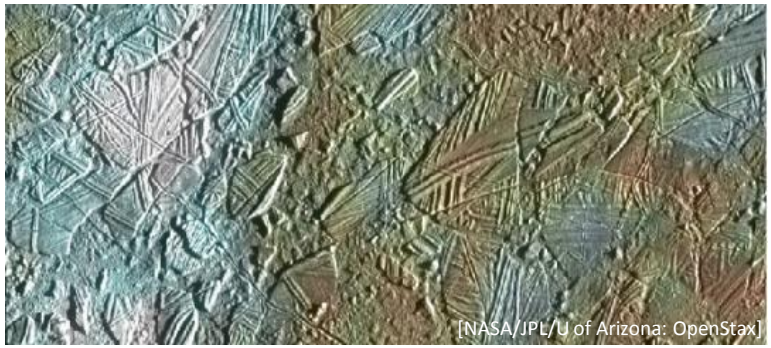
- **Largest moon in Solar system.**
- **Tidal locking:** same side always faces Jupiter.
- Differentiated interior with molten core.
  → ***Tidal heating***, *geologically active, possible liquid H_2O inside, magnetic field.*

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.


[NASA/JPL/DLR: Gallileo mission, 1996]

Geologically active water ice surface


[NASA/JPL/U of Arizona: OpenStax]

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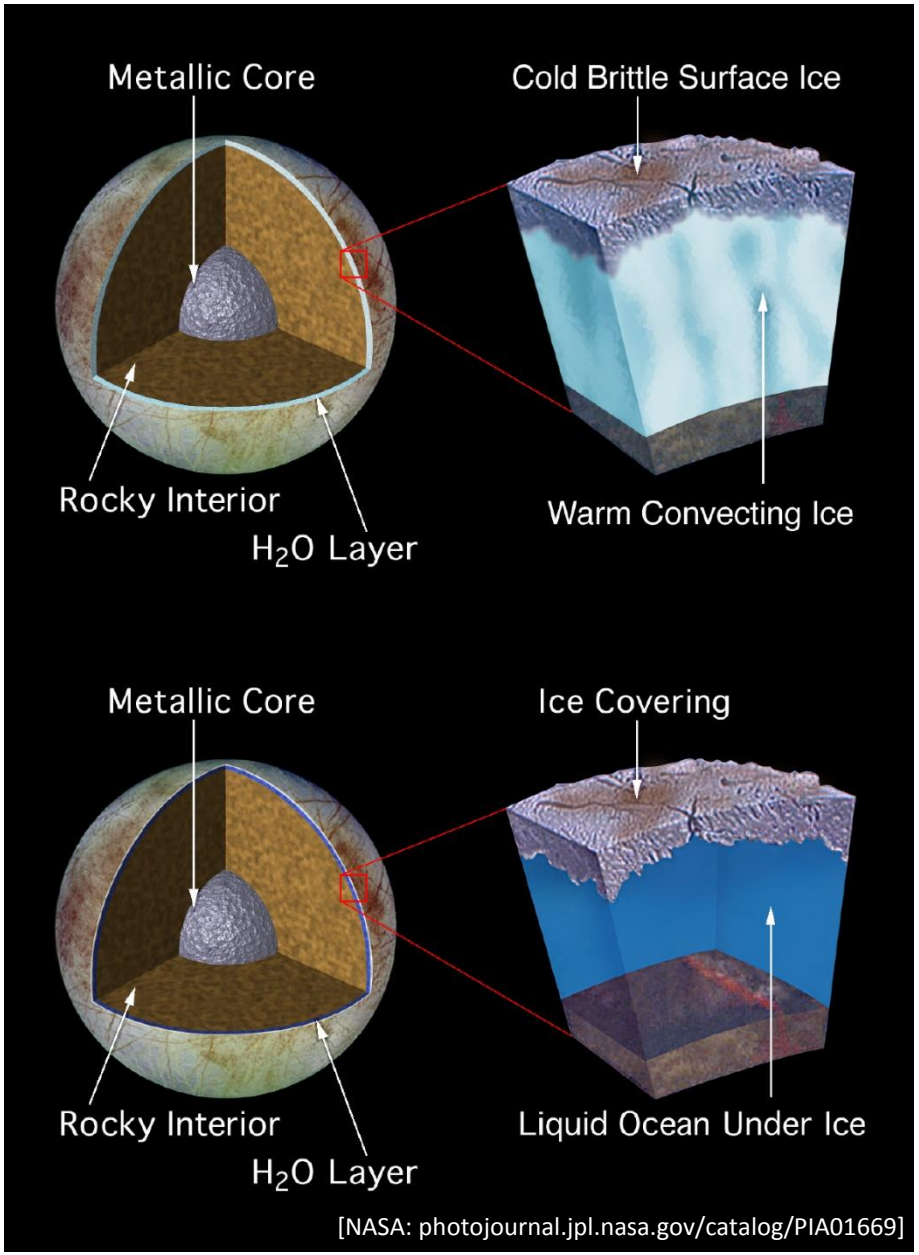
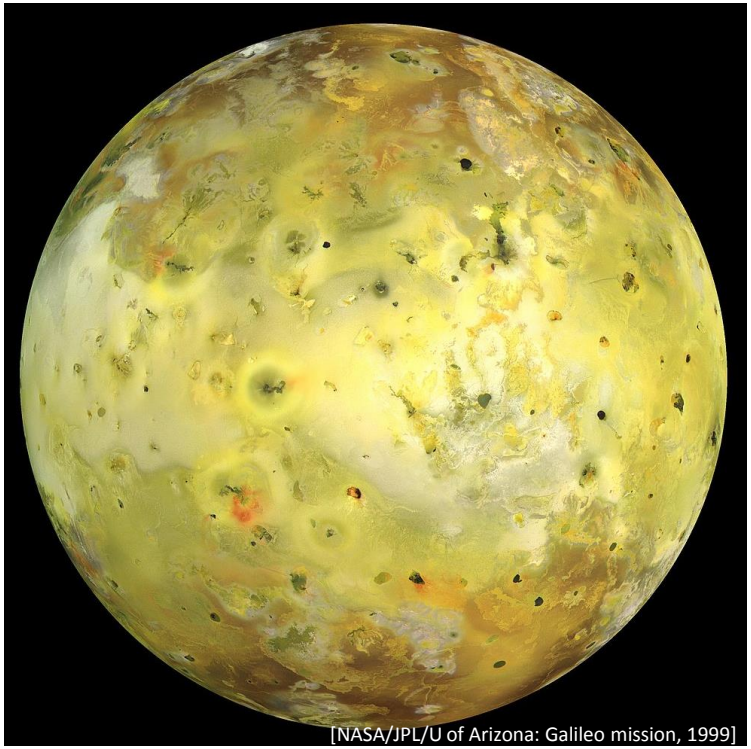
- Europa may have **liquid water ocean** under its icy crust.



[NASA: photojournal.jpl.nasa.gov/catalog/PIA01669]

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]

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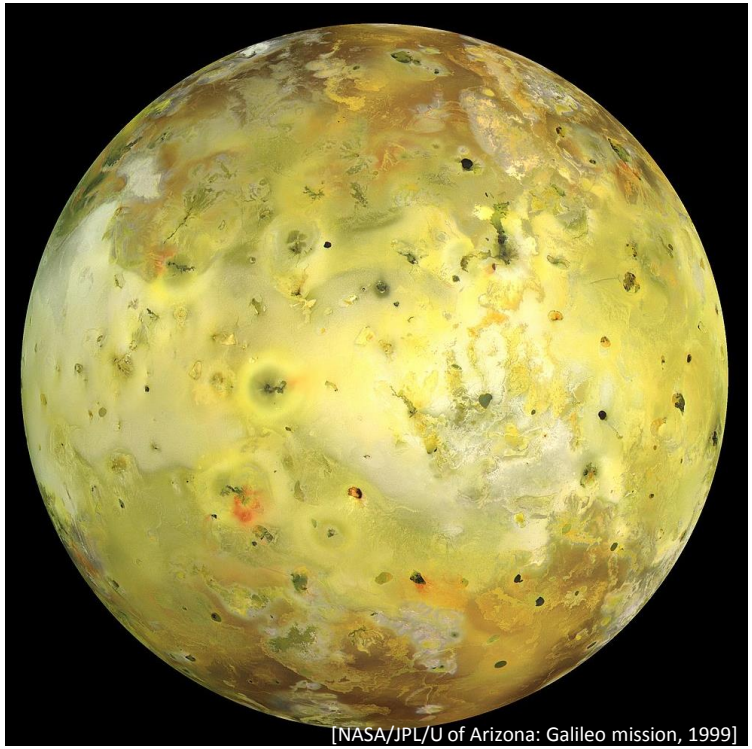
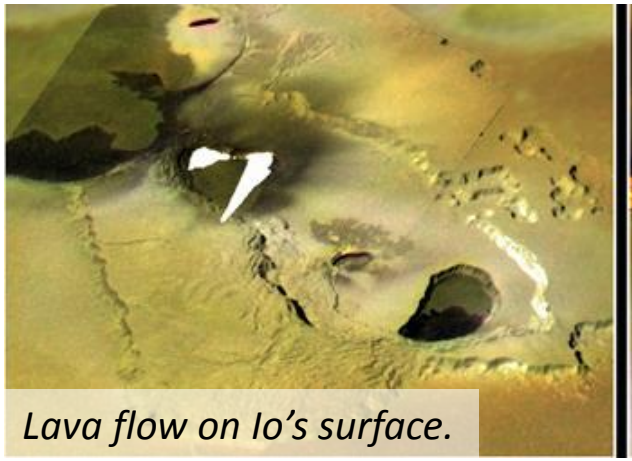
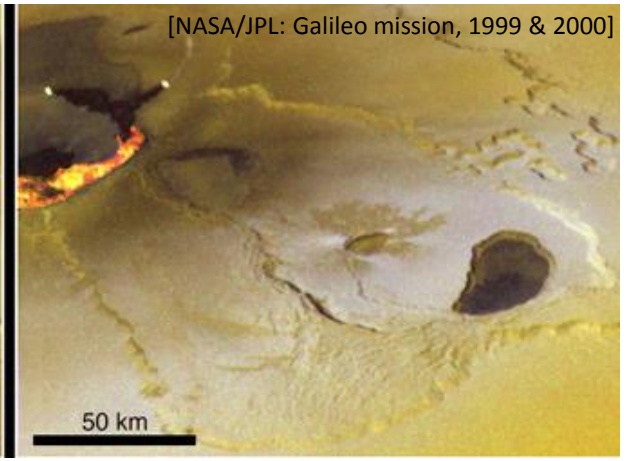
- Most geologically active body in Solar System
- More than **400 active volcanoes**.
- Composition is silicate rock with an **iron-sulfur liquid core**. Crust has a lot sulfur.
- Volcanic plumes feed a **plasma torus** in Jupiter's magnetosphere.



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

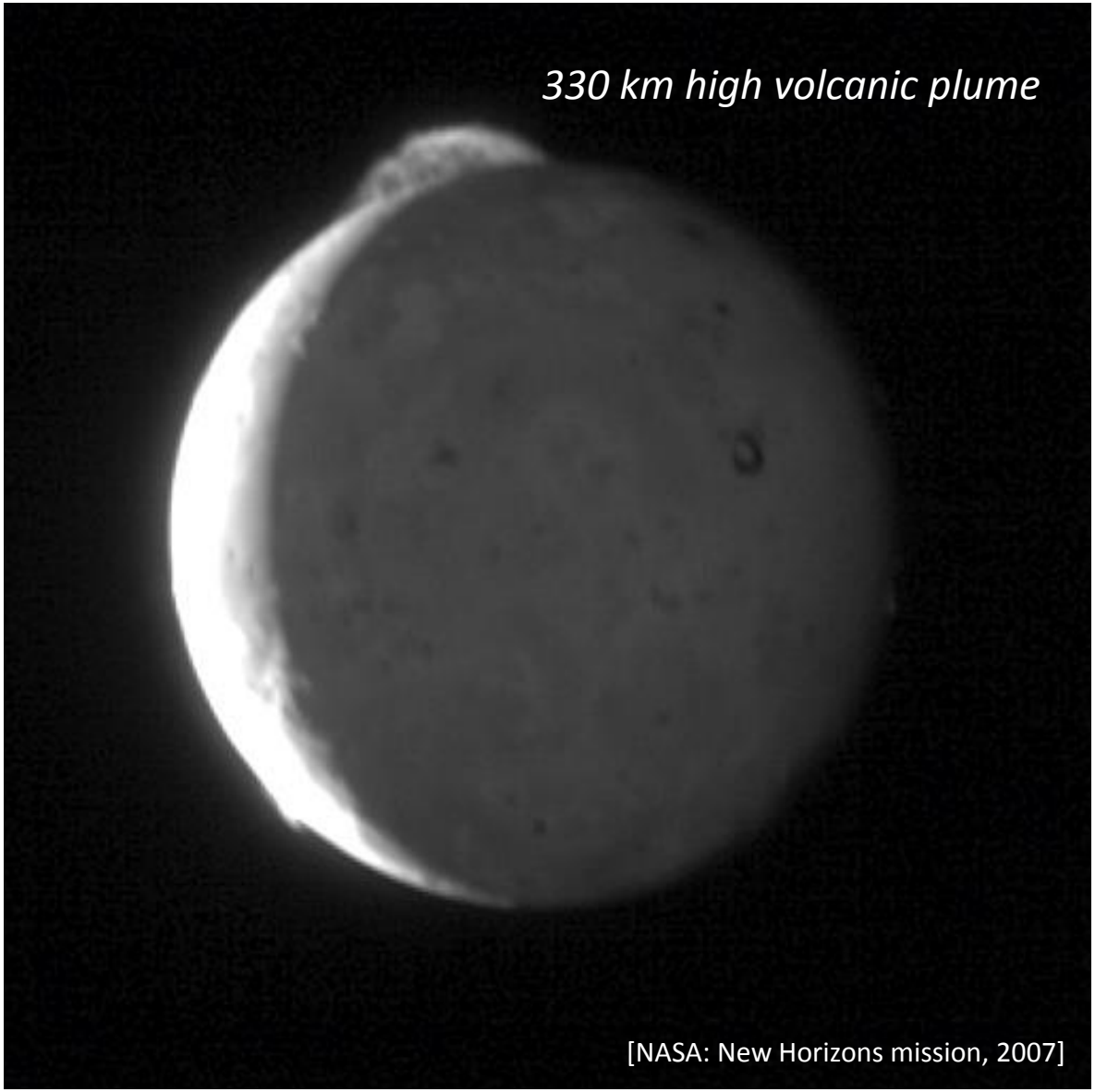


Lava flow on Io's surface.



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

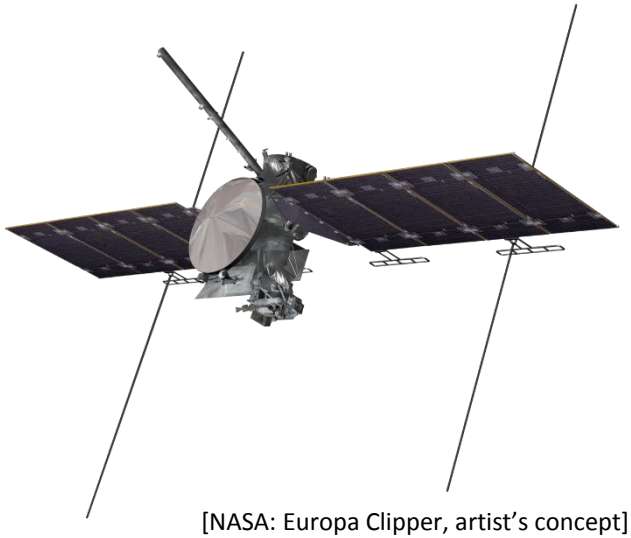
Io: Active Volcano



Future Missions to Galilean Moons

Europa Clipper

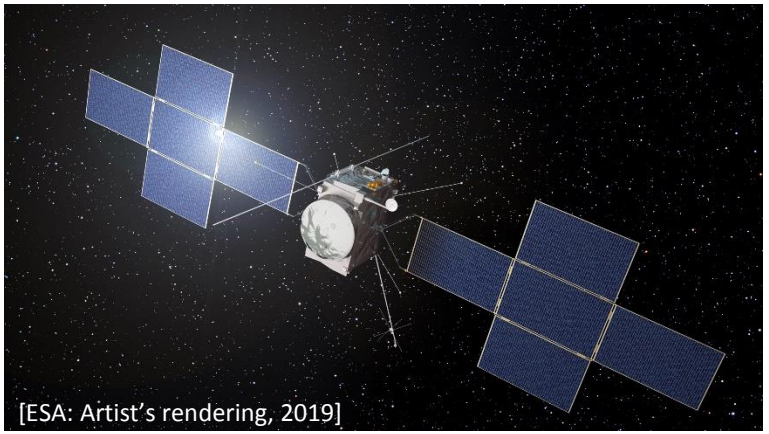
- Planned launch 2025.
- Orbits of Jupiter with 45 Europa flybys.
- Search for sub-crust **water ocean**.
- Study composition & chemistry.
- Find a suitable future **lander location**.



[NASA: Europa Clipper, artist's concept]

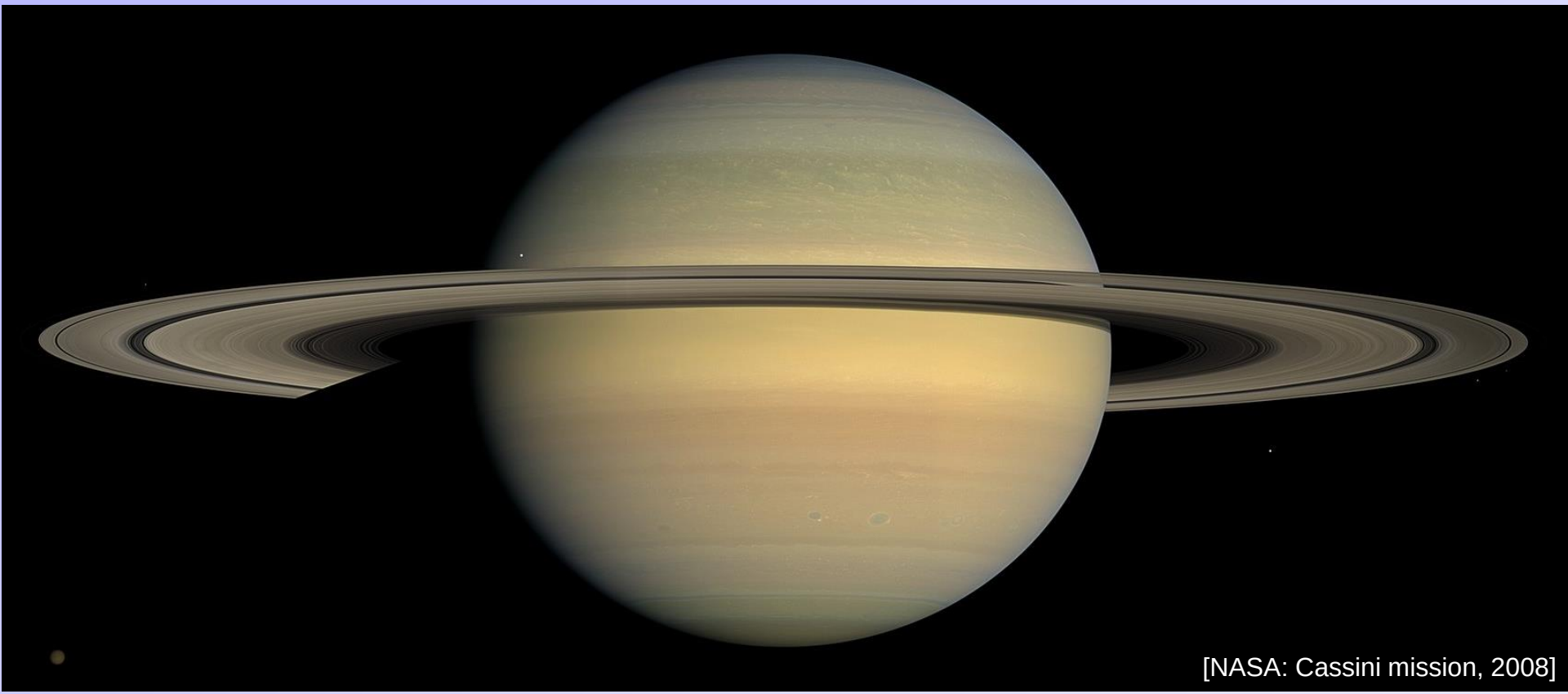
JUICE: JUpiter ICy moons Explorer

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



[ESA: Artist's rendering, 2019]

Saturn: “Lord of the Rings”



[NASA: Cassini mission, 2008]