ASTR/GEOL-2040: Search for life in the Universe: Lecture 25

- Galilean moons
- Europa
- Life in Lake Vostok

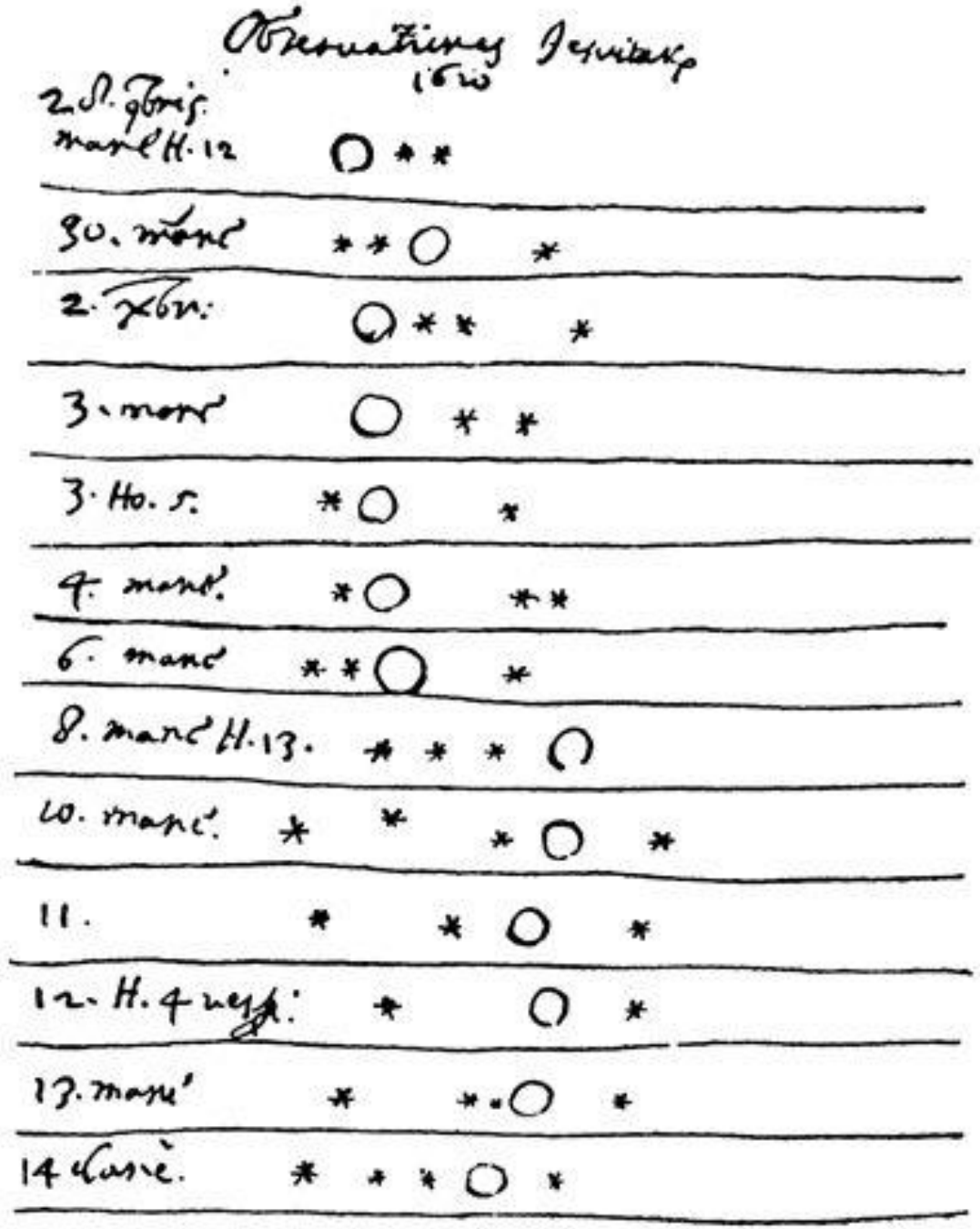
Axel Brandenburg
(Office hours: Mondays 2:30 – 3:30 in X590 and Wednesdays 11-12 in D230)

Fiske, Quiz 2, & guest lecture

- Fiske, Monday November 13
- Quiz #2, Wednesday November
- Guest lecture, Friday, Carol Cleland
  - Check out her work on Web of Science, etc.
- Fiske & Cleland lect included in final
- HW6: due Friday 3

Galilean satellites

- 4 moons
  - binoculars!
  - all in one line
  - next night…
- Orbital periods:
  - 1.769
  - 3.551
  - 7.155
  - 16.69



Galileo's proper publication

Galilean satellites

- Orbital periods:
  - 1.769
  - 3.551
  - 7.155
  - 16.69
- Distances:
  - 422,000 km
  - 671,000 km
  - 1070,000 km
  - 1883,000 km

Kepler's law

$$P = 2\pi\sqrt{R^3 / GM}$$

M is mass of Jupiter

Can we compute the masses of Galilean satellites from Kepler's law?

A. Yes

B. No

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B. No

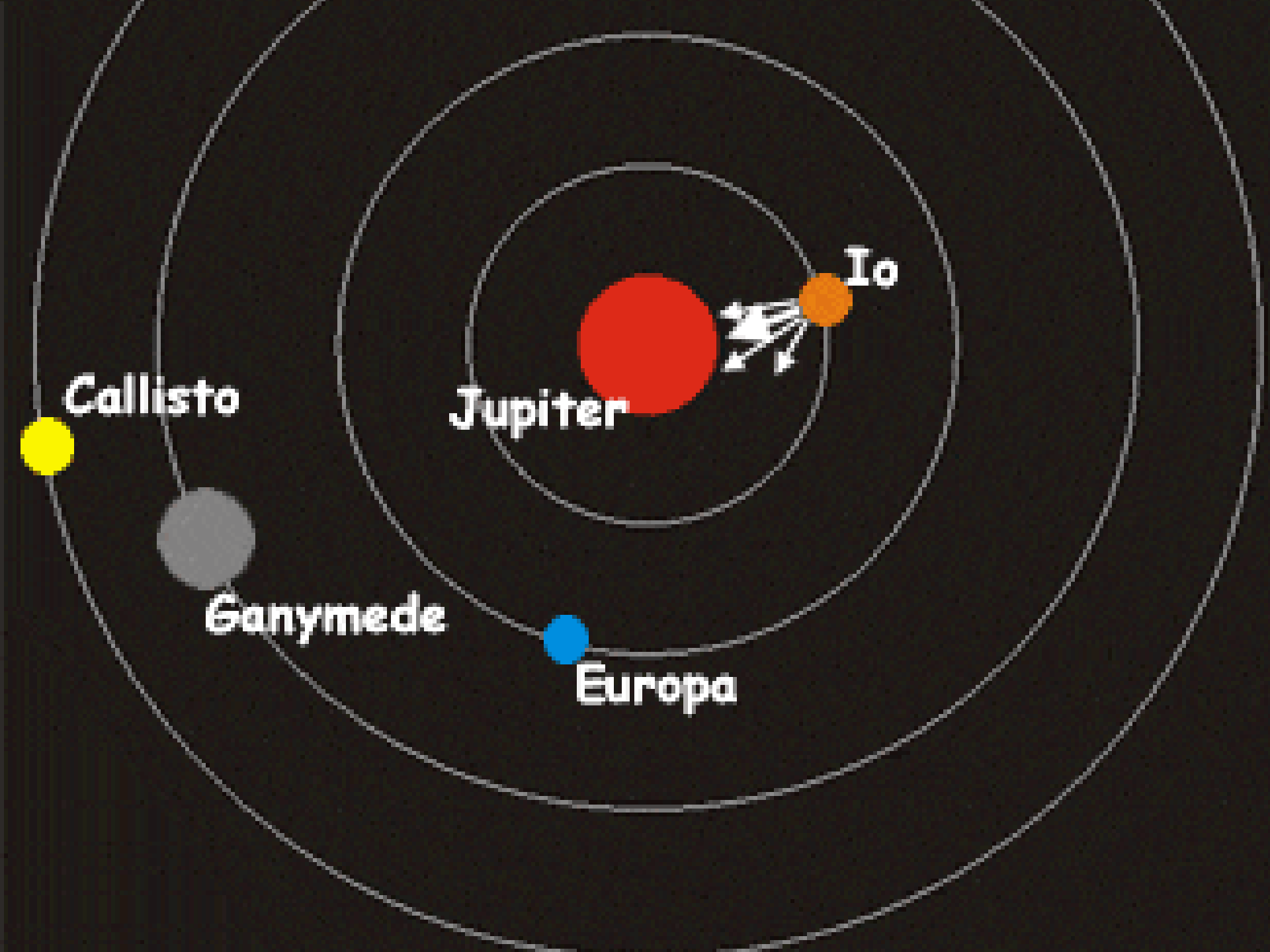
$$P = 2\pi\sqrt{R^3 / GM}$$

Satellites of gas giants

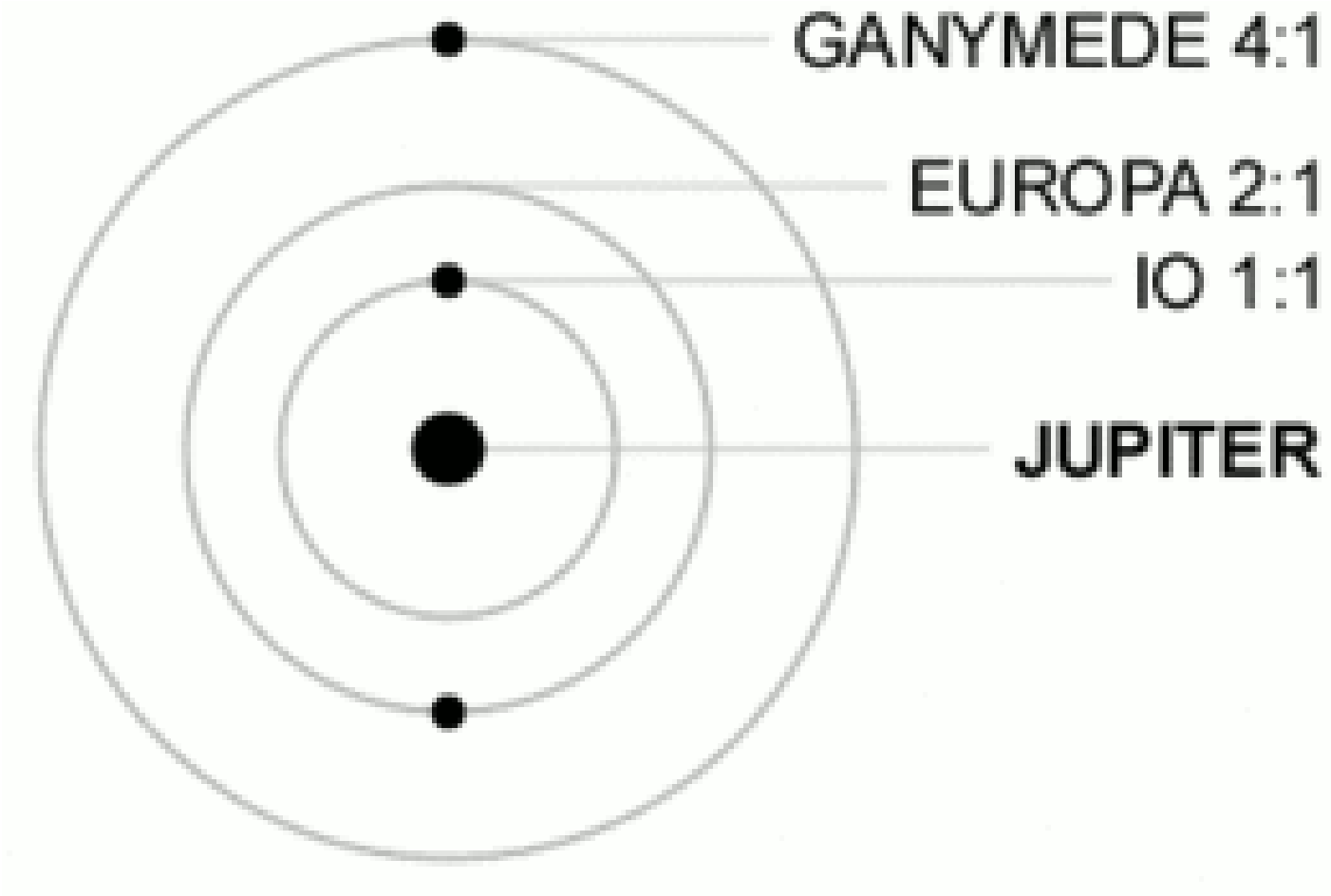
- Four Galilean satellites: 1610
- Huygens (1655): Titan
- The lead changed several times in history

	Jupiter	Saturn	Uranus	Neptune
1655	4	1		
1700		5		
1787			2	
1846				1
1950	11	9	5	2
2011	59	49	22	10
2015	170			

+4 discovered by Cassini


Io
Callisto
Jupiter
Ganymede
Europa

Galilean moons



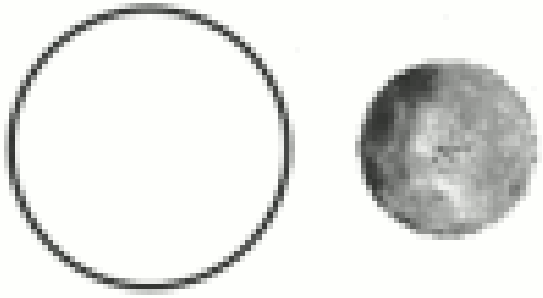
Galilean satellites

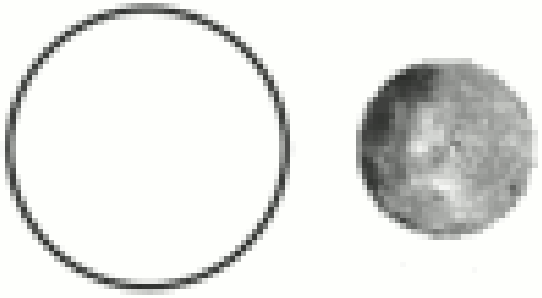
- Orbital periods:
  - 1.769
  - 3.551
  - 7.155
  - 16.69
- Ratios:
  - 1
  - 2.00735
  - 4.04466
  - 9.43471

→ resonance

Galilean satellites

Our Moon around the Earth



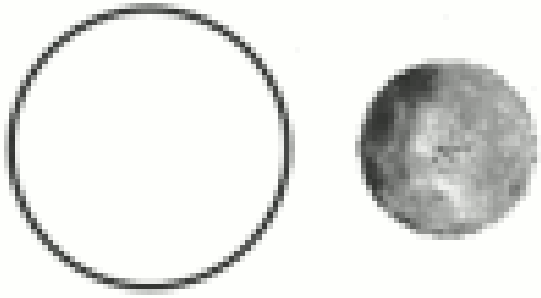


Which one is correct?

A.

B.

Our Moon around the Earth



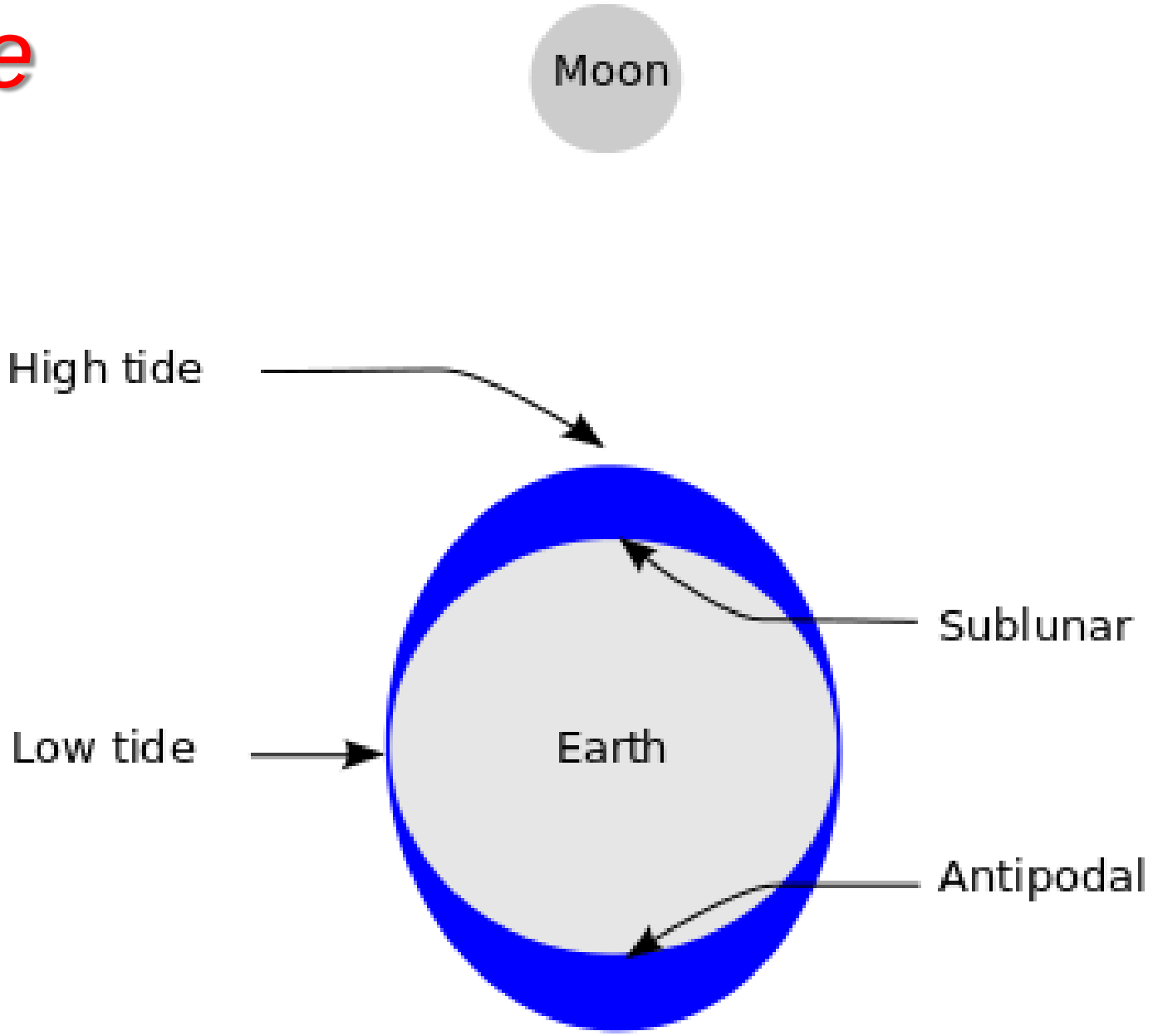
Which one is correct?

A.

B.

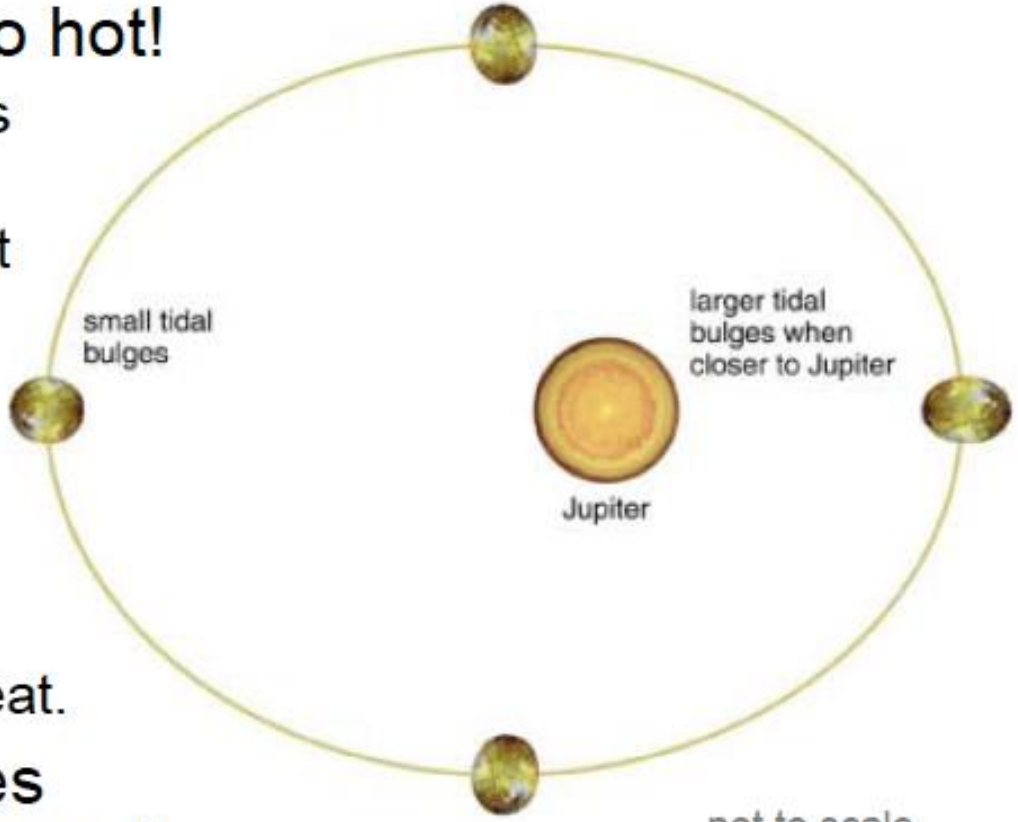
Tidal locking

Tide



Why So Hot? Tidal Heating!

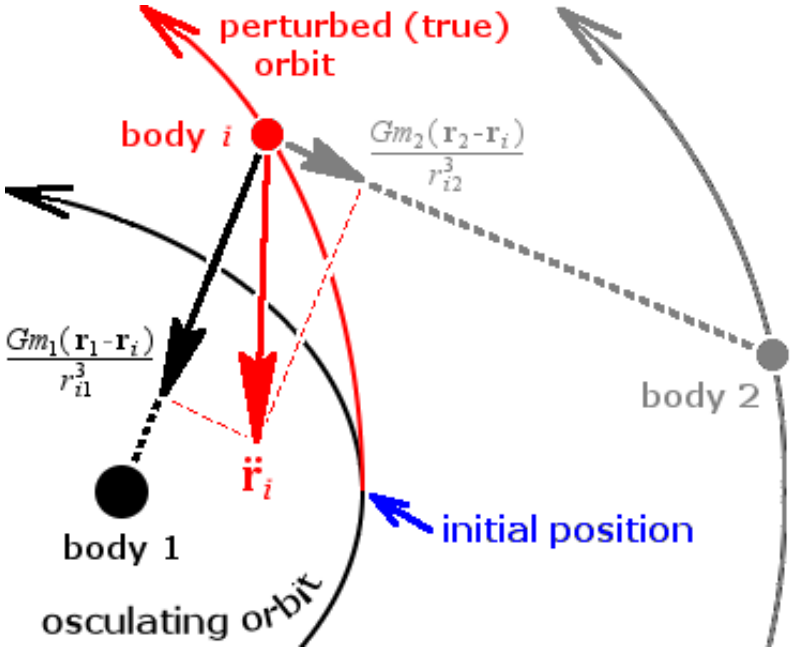
- **Tidal heating** keeps Io hot!
  - Jupiter's gravity stretches Io, creating *tidal bulges*.
  - During Io's eccentric orbit about Jupiter, the tidal bulges grow when Io is closer, and shrink when Io is farther.
  - Tidal bulges also "nod" from side-to-side.
  - This flexing generates heat.
- Tidal heating generates enough heat energy to melt rock and power Io's volcanoes.



Properties of Galilean moons

- Gravity big enough for satellites to be spherical
  - For icy body: $R > 200$ km → *picture*!!
- Most in synchronous rotation (like the Moon)
- Mass from subtle orbital perturbations

→ Mean density



Mean density tells you

A. Whether it has an atmosphere
B. Whether it has a rocky core
C. Whether it might have a magnetic field
D. Whether is has liquid water on the surface

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Example

- Callisto: 1.83×10^3 kg/m^3
- Chondritic meteorites: 3.10×10^3 kg/m^3
- Ice: 0.95×10^3 kg/m^3
- $\rho = x\,\rho_{dense} + (1-x)\,\rho_{light}$

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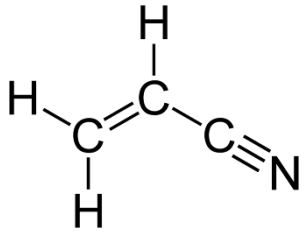
→ x=0.41

Properties

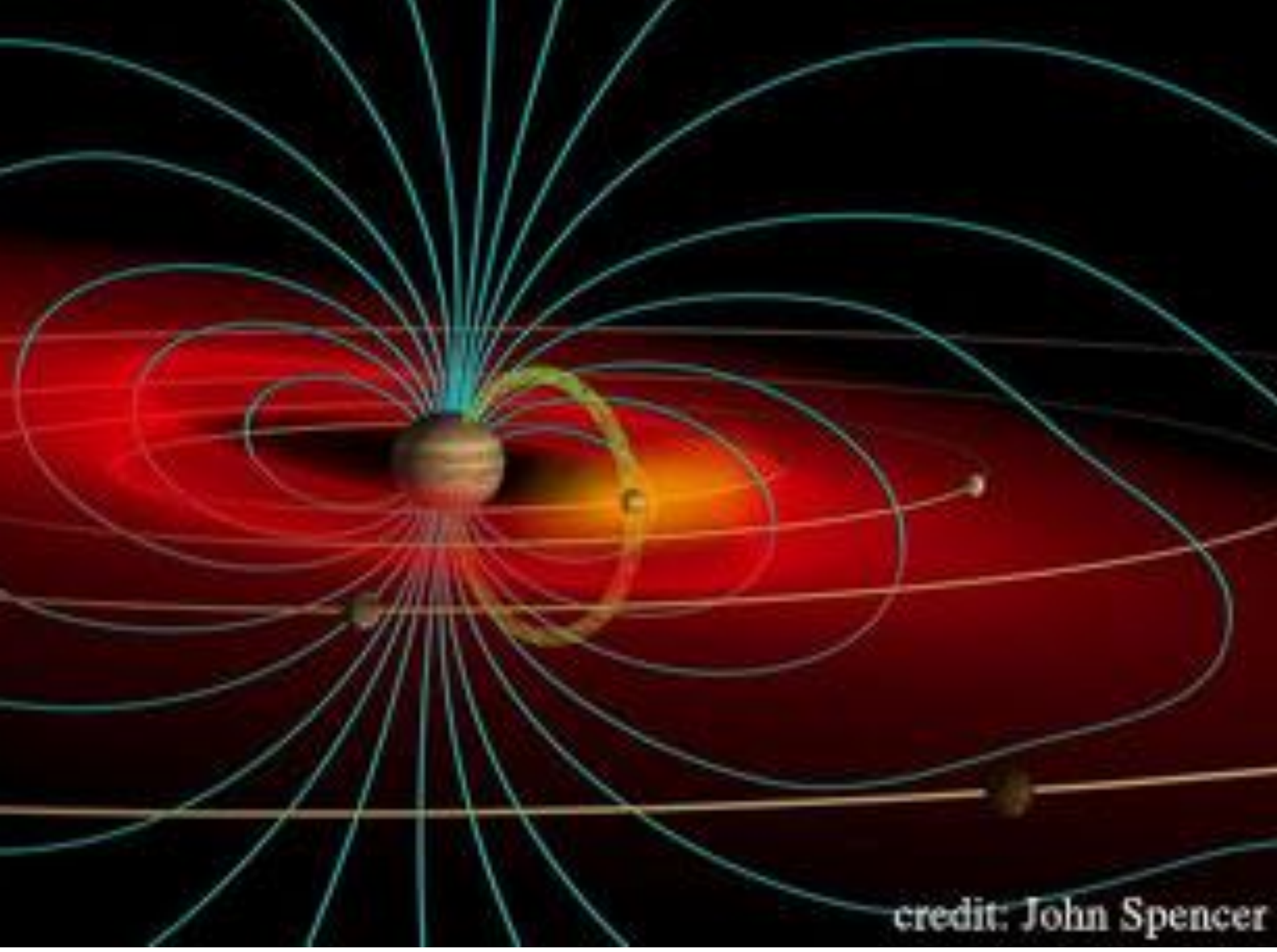
- Expected boring surface structure…
- Kuiper (1950): Titan: volatile atmosphere
- Uranus: CO_2 and ?ammonia
- Neptune's moon Triton: CO, CH_4, HCN
- Pluto: CH_2CHCN



Acrylonitrile

Radiation

- Io: 36 Sv/day
- Europa: 5.40 Sv/day
- Ganymede: 0.08 Sv/day
- Callisto: 0.0001 Sv/day


credit: John Spencer

Tolerable for humans?

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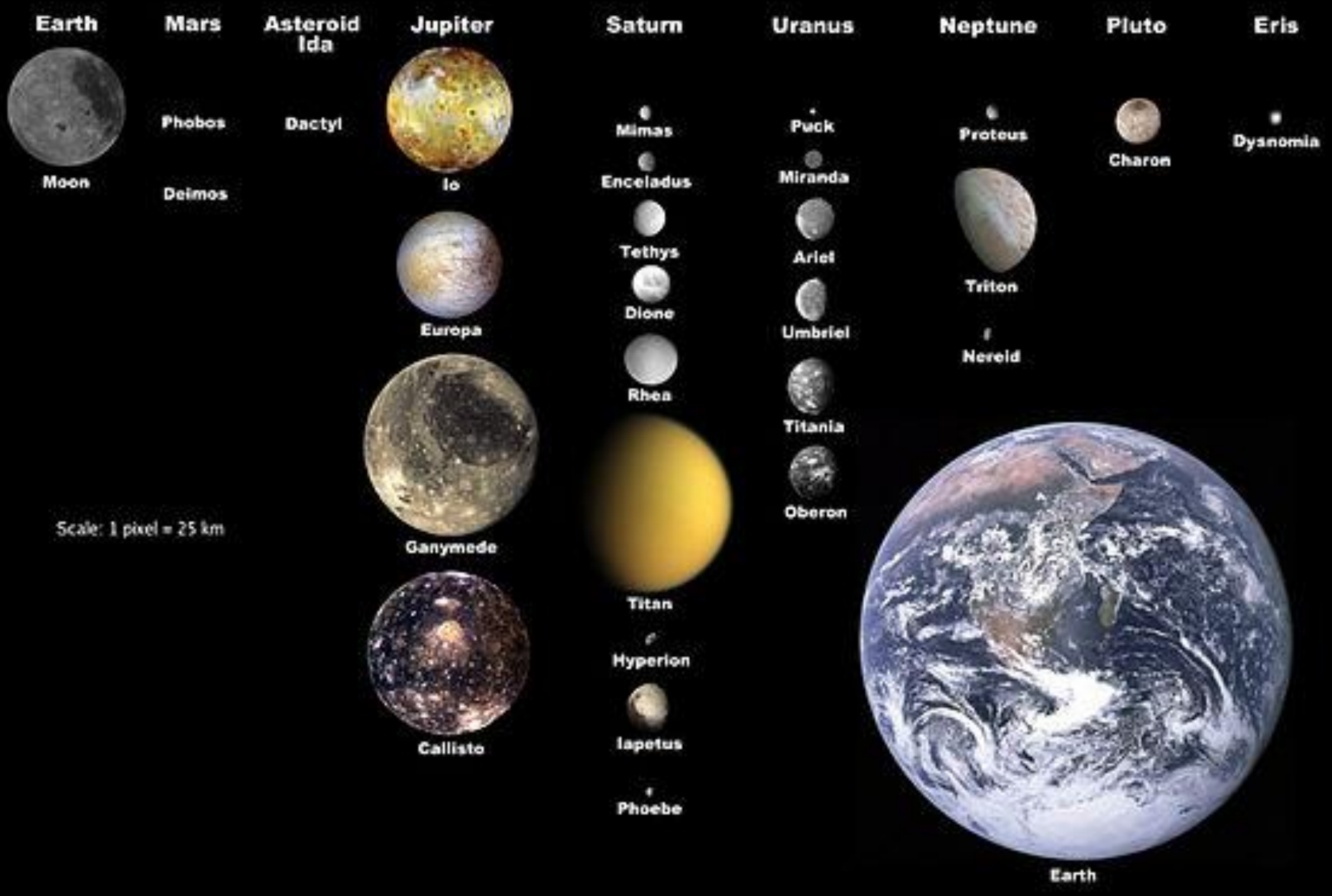
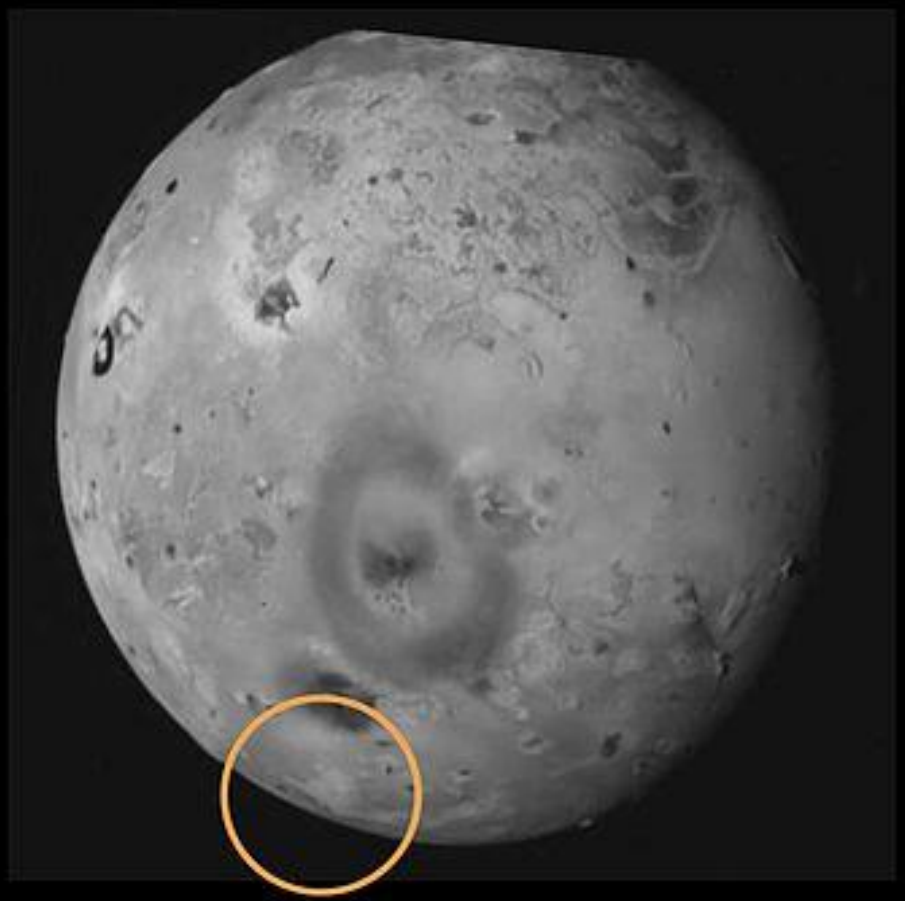
Selected Moons of the Solar System, with Earth for Scale



Io Surface Changes

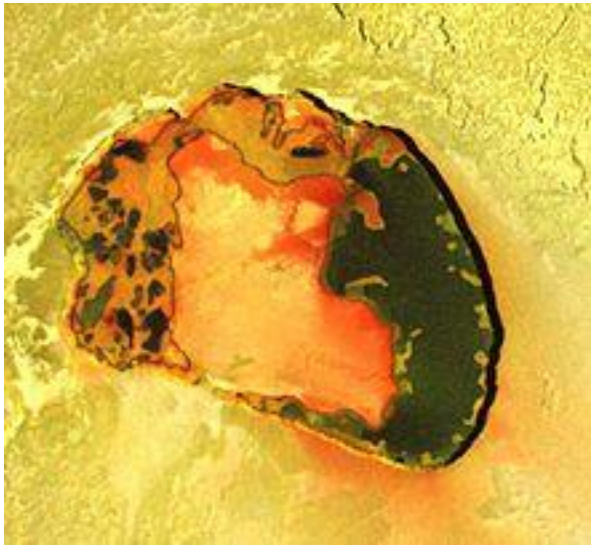
Galileo 1999

New Horizons 2007



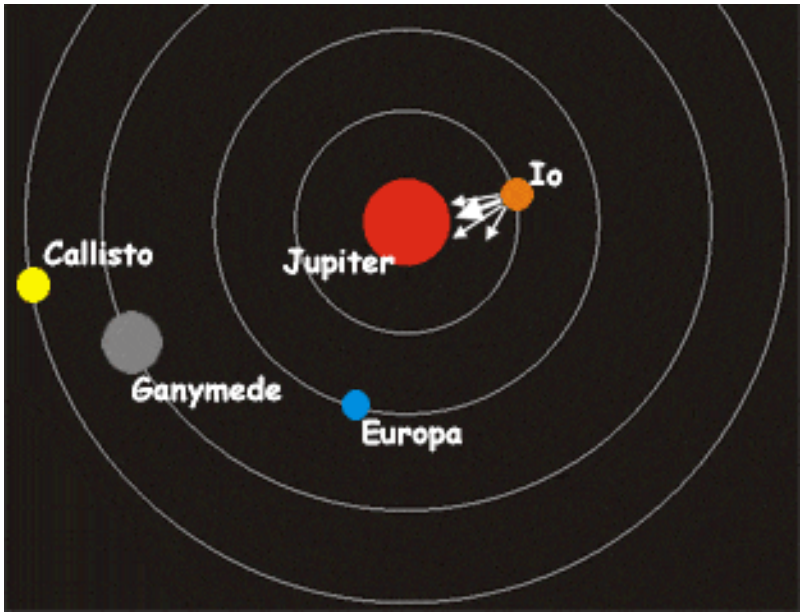
Io

- Voyager fly-bys: moons not dead
- Io, Jupiter's innermost satellite: geol. active
- Reddish color: sulfur oxide
- Erruption of Pillan Patera
- No crater
- No snow
- Erruptions all the time



What heats up Io?

A. Jupiter's magnetic field
B. Jupiter's radiation
C. Jupiter's gravity



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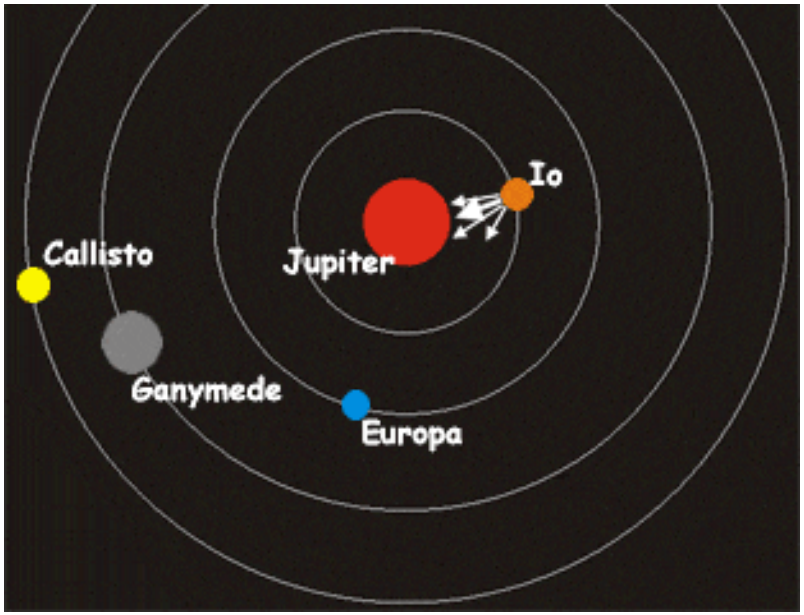
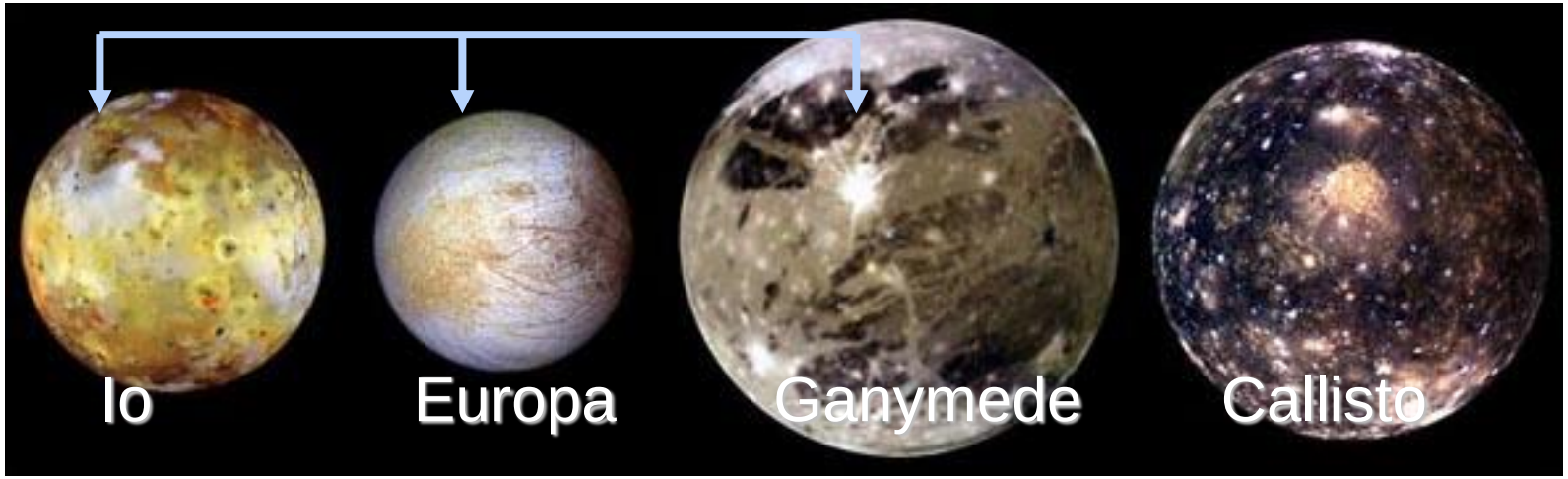
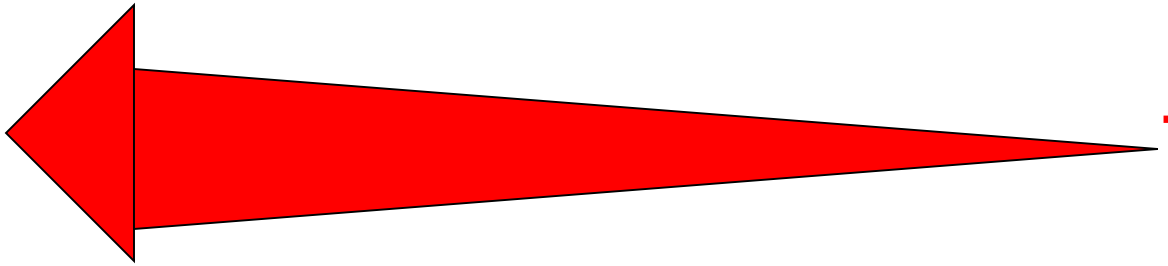


Orbital Resonance





Tidal Heating

Wednesday

- Europa
- Europa missions
- RGS pp. 141 - 165
- Box 4.3