

# 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

*Observations Jupiter*  
1610

2. J. Febr. marc H. 12	○ **
30. marc	** ○ *
2. Febr.	○ ** *
3. marc	○ * *
3. Ho. 5.	* ○ *
7. marc	* ○ **
6. marc	** ○ *
8. marc H. 13.	* * * ○
10. marc	* * * ○ *
11.	* * ○ *
12. H. 4 uesp.	* ○ *
13. marc	* ** ○ *
14. Febr.	* * * ○ *

# Galileo's proper publication

RECENS IRAMITAE, 13  
 distans proxima min. 2. ab hac vira elongatur oc.



distans circa min. 27. extra pericel in radem 12-  
 04. in magnitudine apparet.

Die quarta hora secunda circa horam quartam ha-  
 bentur, orientales duo, ac duo occidentales in



eadem ad vespem recta linea distans, et in peri-  
 odo signa. Orientales distans 4. superius min. 3. huc  
 vero 4. huc ab hac min. 2. loc. 4. huc 4. huc 4. huc 4.  
 occidentali min. 4. huc ab occidentali min. 6. ma-  
 gnitudine erant solis quatuor, periceliorum huius reliquis  
 paulo minus apparet. Hora autem septima orien-  
 tales Stella distans tantum min. 2. loc. 1. huc 1.



ab orientali viciniori ab hac min. 2. ab occidentali ep-  
 ro superius min. 4. huc vero ab occidentali dista-  
 ns min. 1. quatuor a quibus vincta, et in distans circa  
 secundam horam vespem vincta.

Die quinta Luna huius vincta.  
 Distans duo huiusmodi apparetur Stella me-

# *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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A. Yes

B. No

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

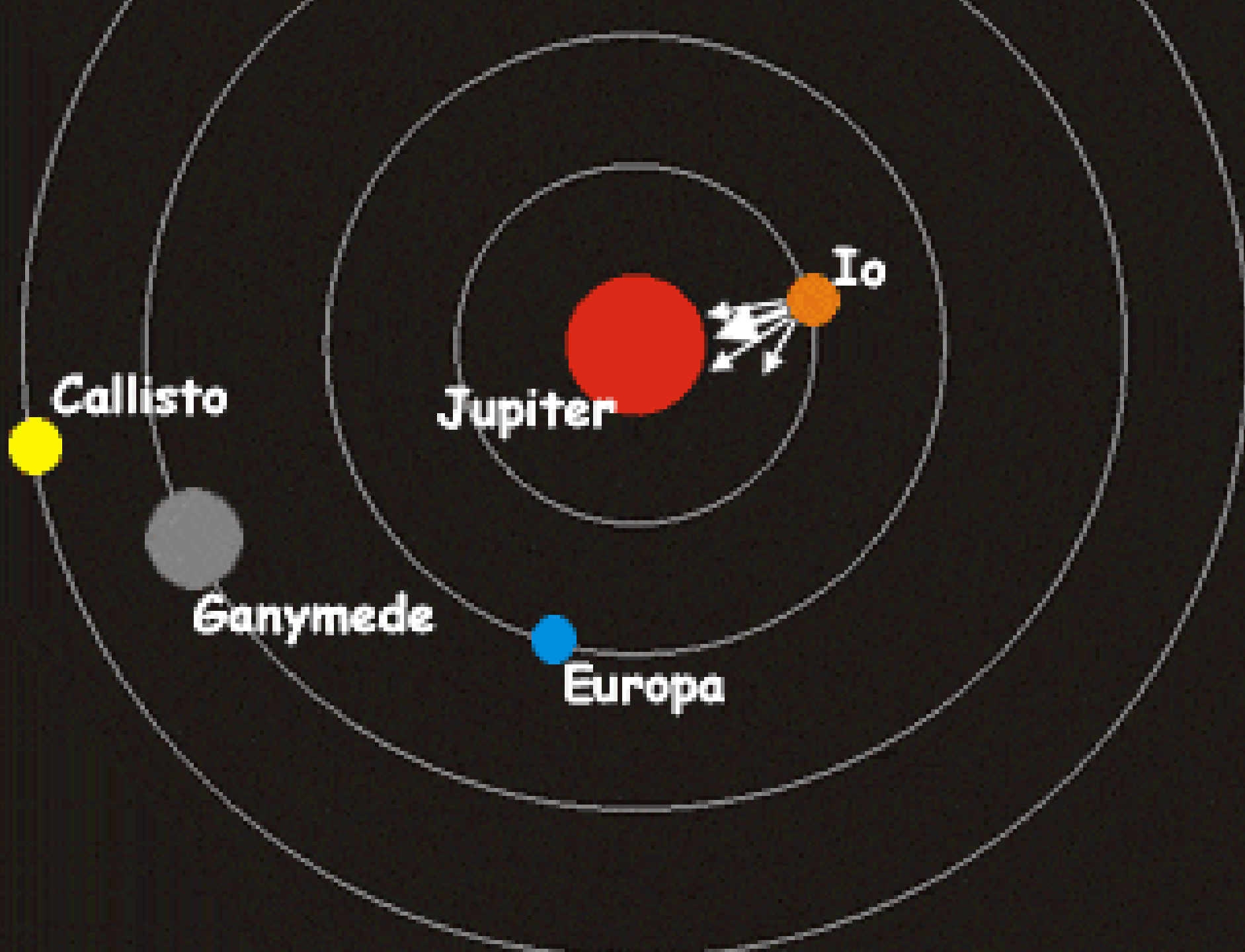


# *Satellites of gas giants*

- 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



Jupiter

Io



Europa



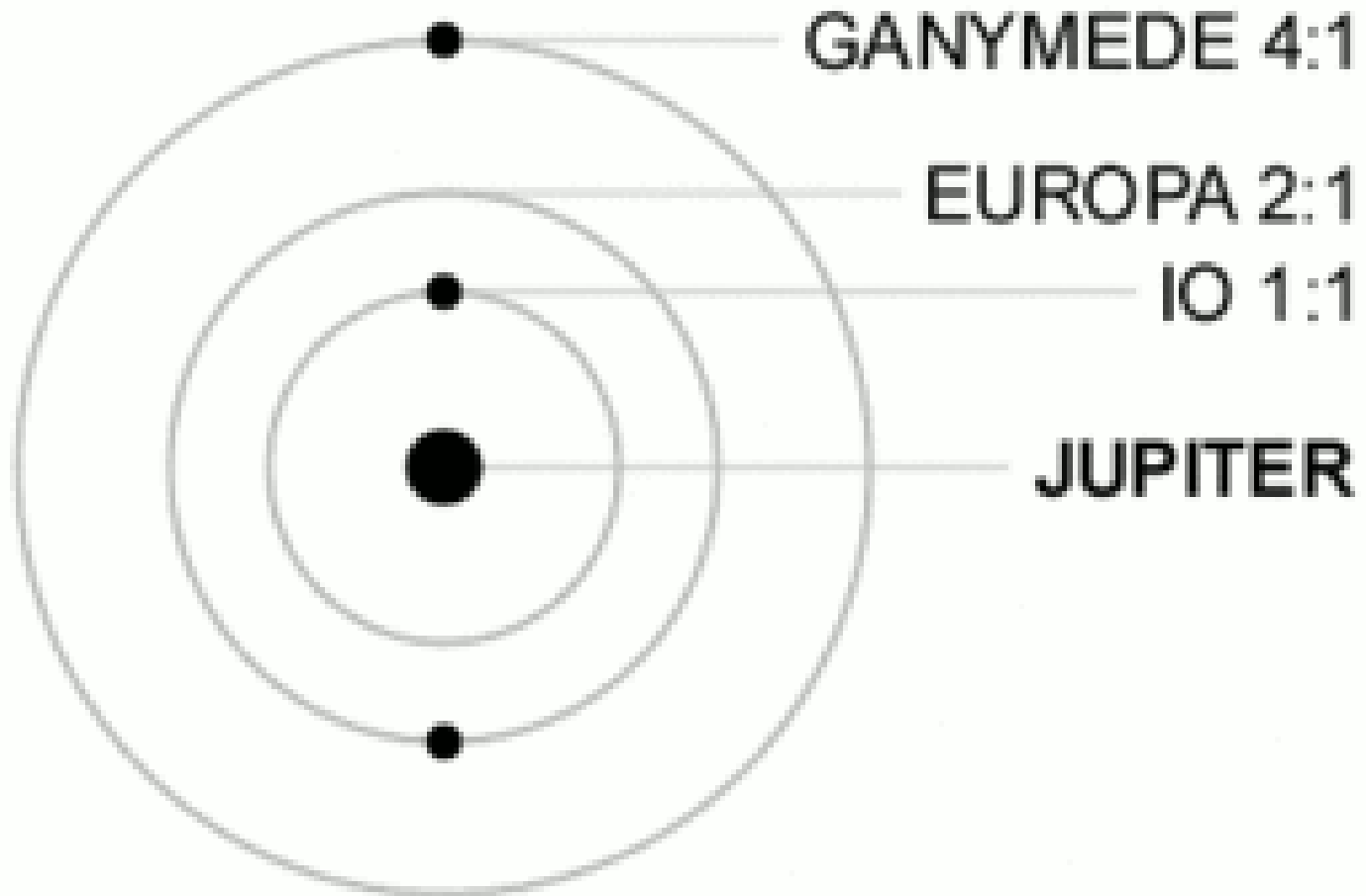
Ganymede



Callisto



# *Galilean moons*

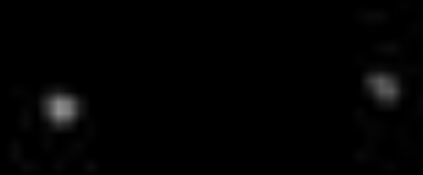


# *Galilean satellites*

- 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*

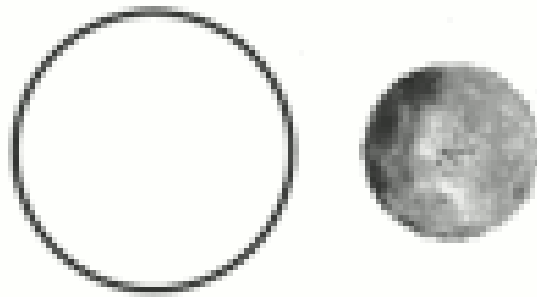


Which one  
is correct?

**A.**

**B.**

# *Our Moon around the Earth*



Which one  
is correct?

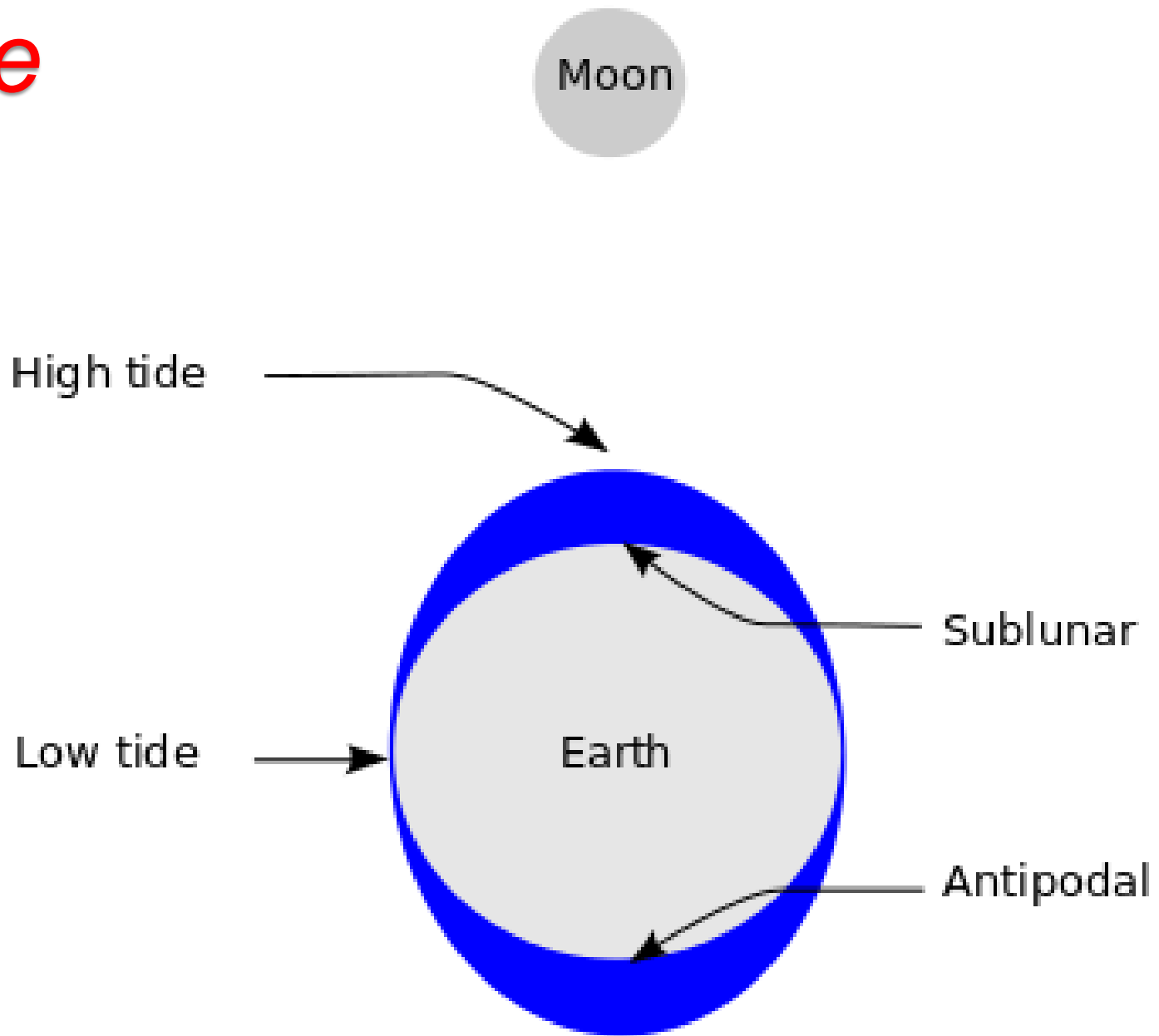
A.



B.

**Tidal locking**

# *Tide*





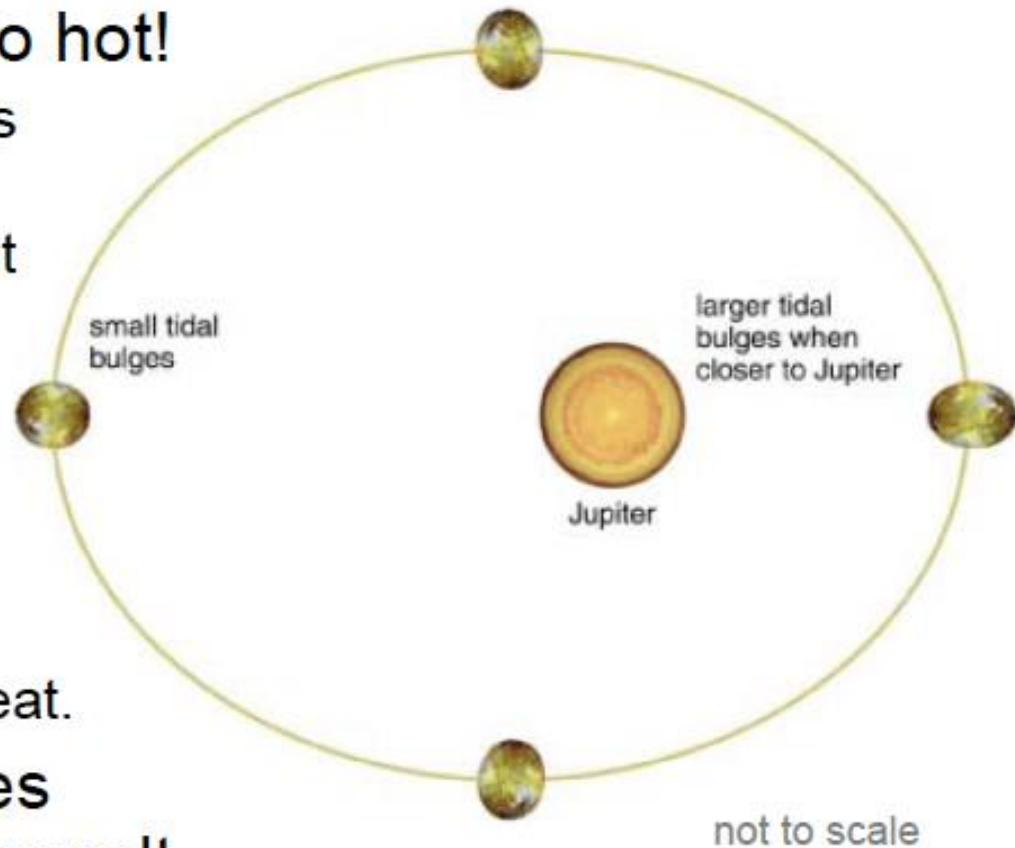
# Why So Hot? Tidal Heating!



- **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.

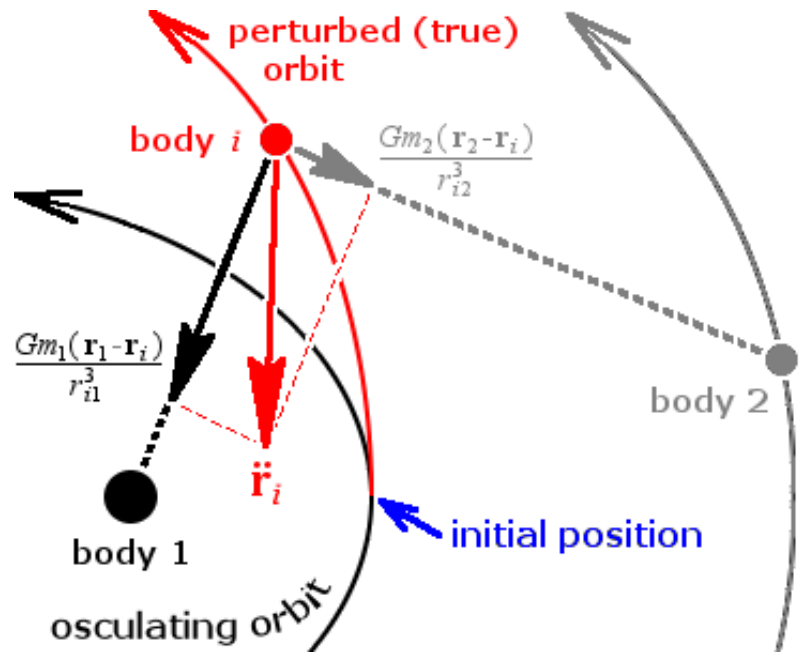
- Tidal heating generates enough heat energy to melt rock and power Io's volcanoes.



# Properties of Galilean moons

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

$\rightarrow$  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 it has liquid water on the surface

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# *Example*

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

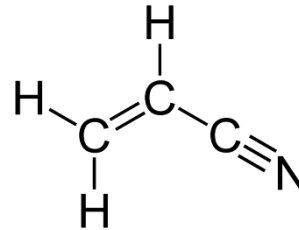
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→  $x=0.41$

# *Properties*

- Expected boring surface structure...
- Kuiper (1950): Titan: volatile atmosphere
- Uranus: CO<sub>2</sub> and ?ammonia
- Neptune's moon Triton: CO, CH<sub>4</sub>, HCN
- Pluto: CH<sub>2</sub>CHCN

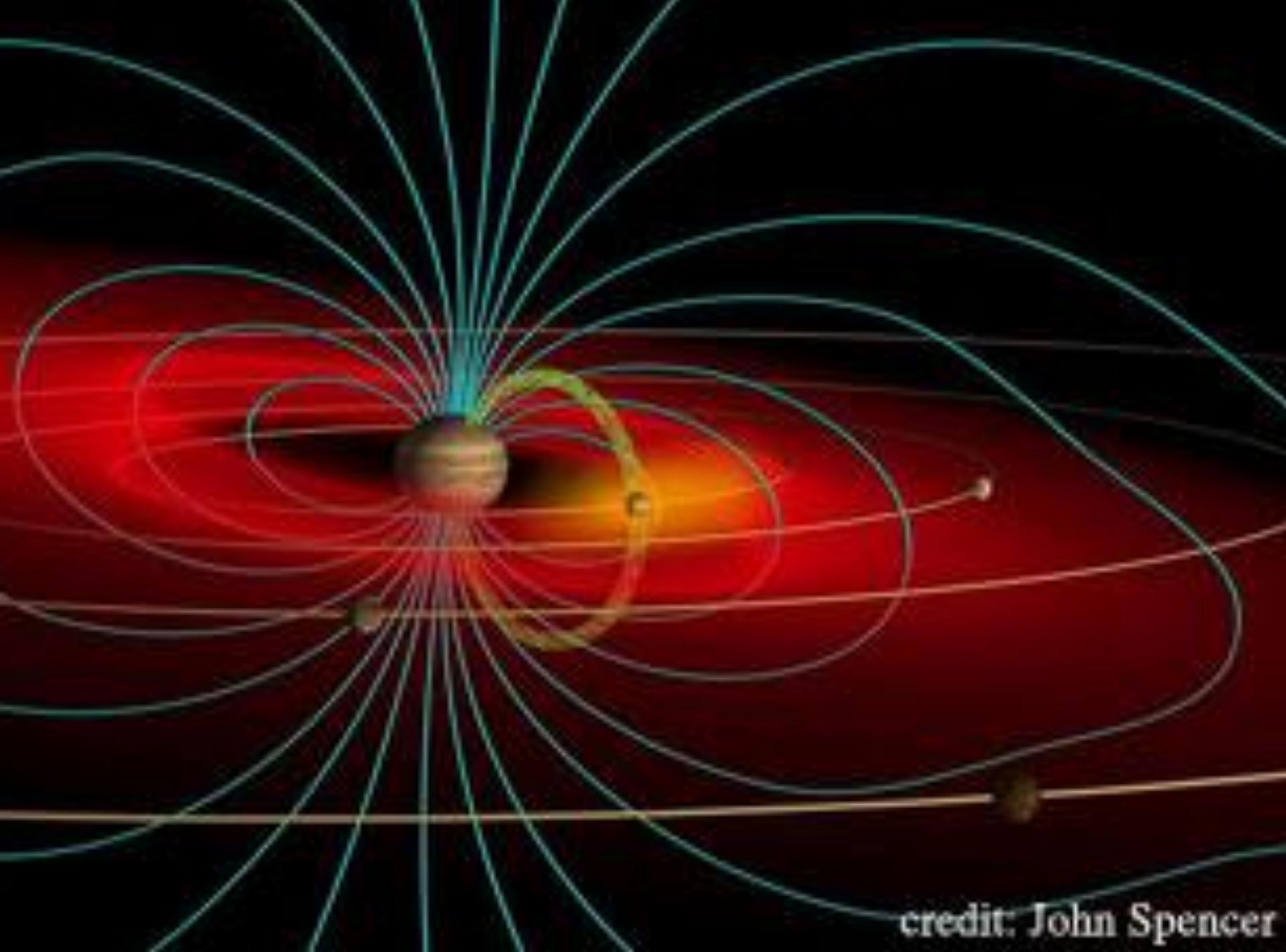


Acrylonitrile

# *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?*

- A. Io: 36 Sv/day
- B. Europa: 5.40 Sv/day
- C. Ganymede: 0.08 Sv/day
- D. Callisto: 0.0001 Sv/day

# *Tolerable for humans?*

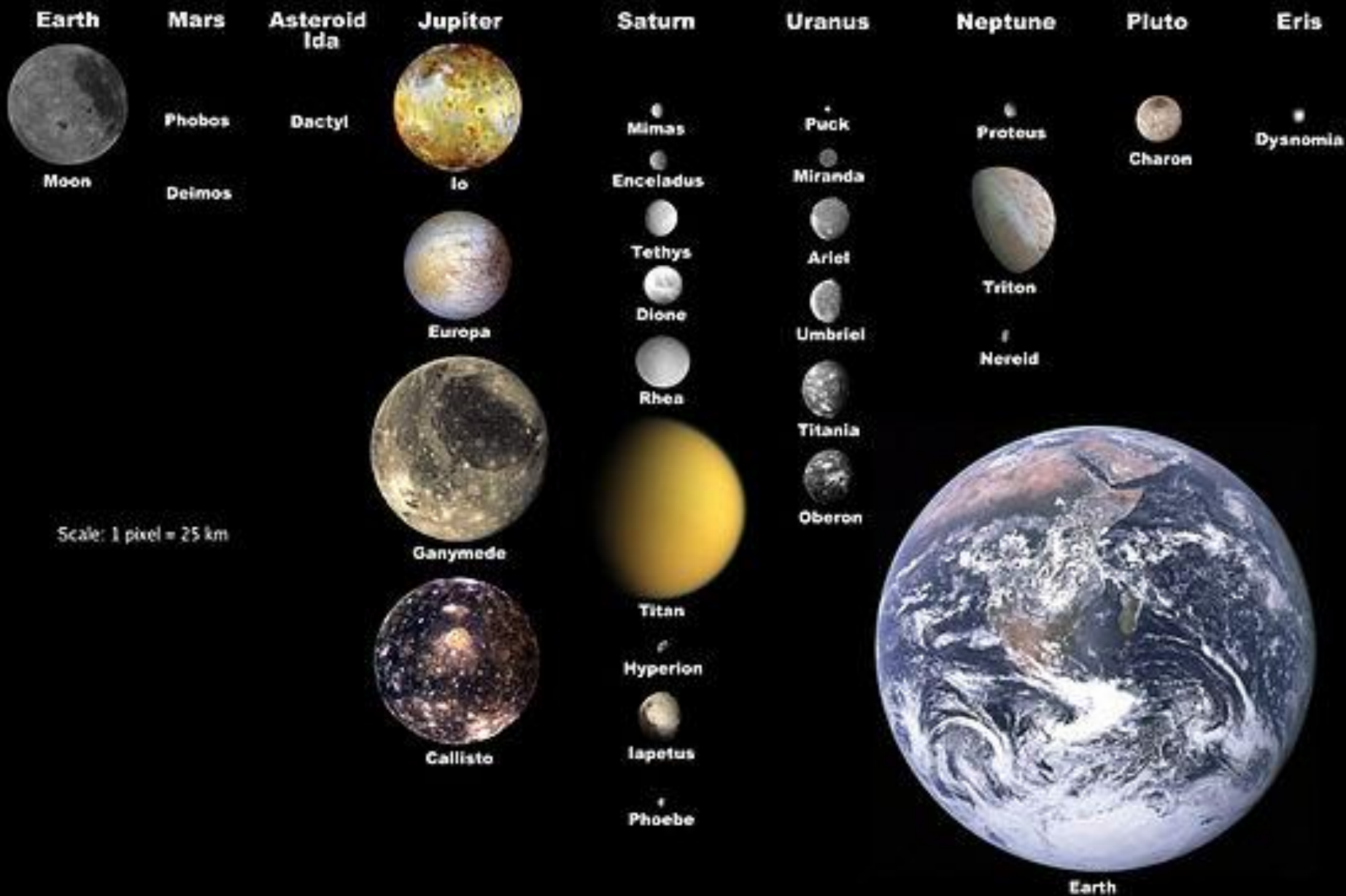
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**D. Callisto: 0.0001 Sv/day**

# Selected Moons of the Solar System, with Earth for Scale



# Io Surface Changes

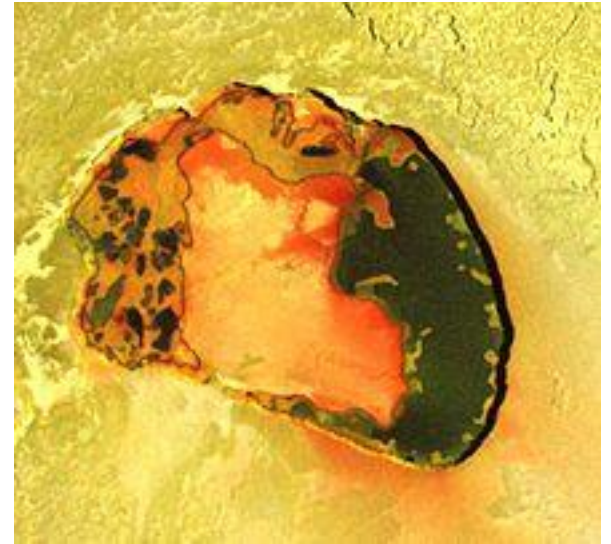
Galileo 1999

New Horizons 2007



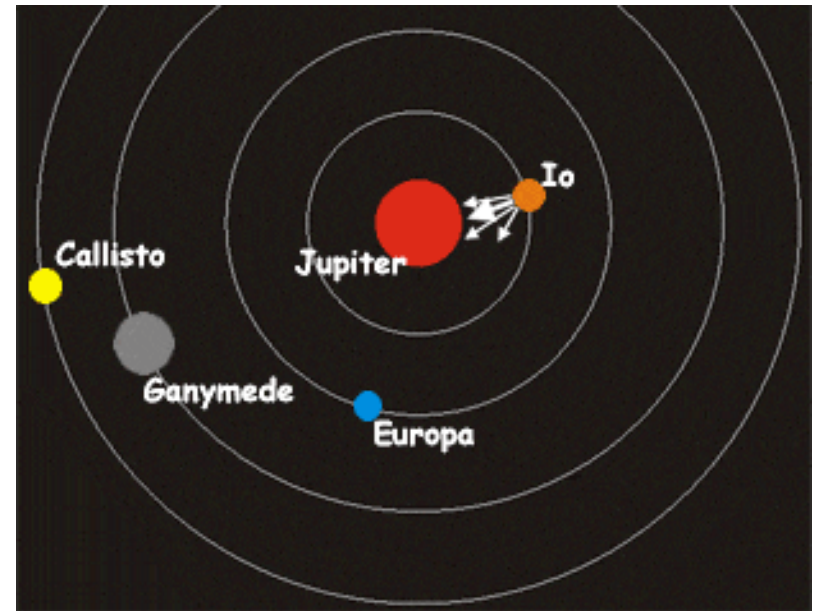
# Io

- 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



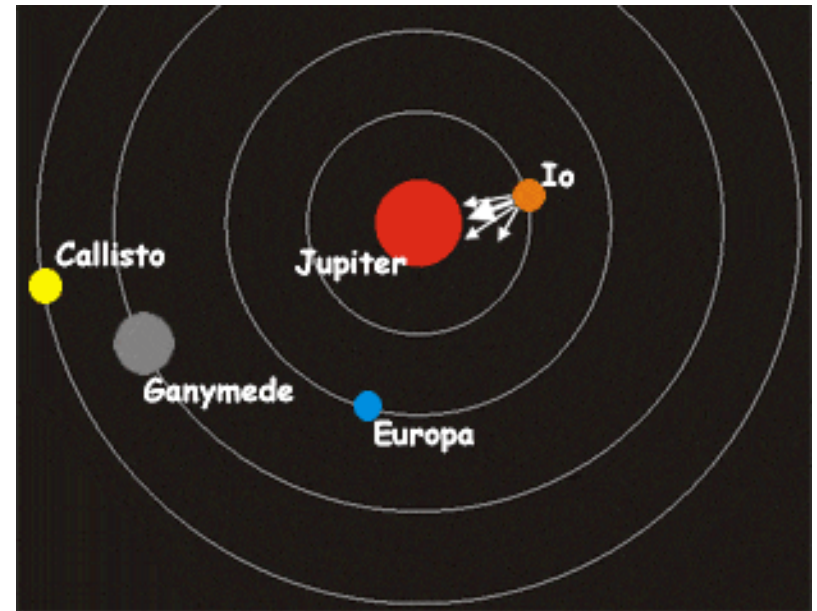
# *What heats up Io?*

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



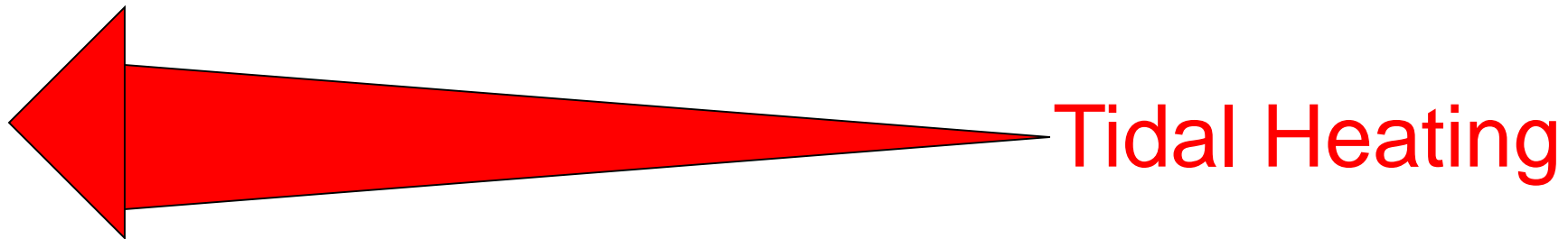
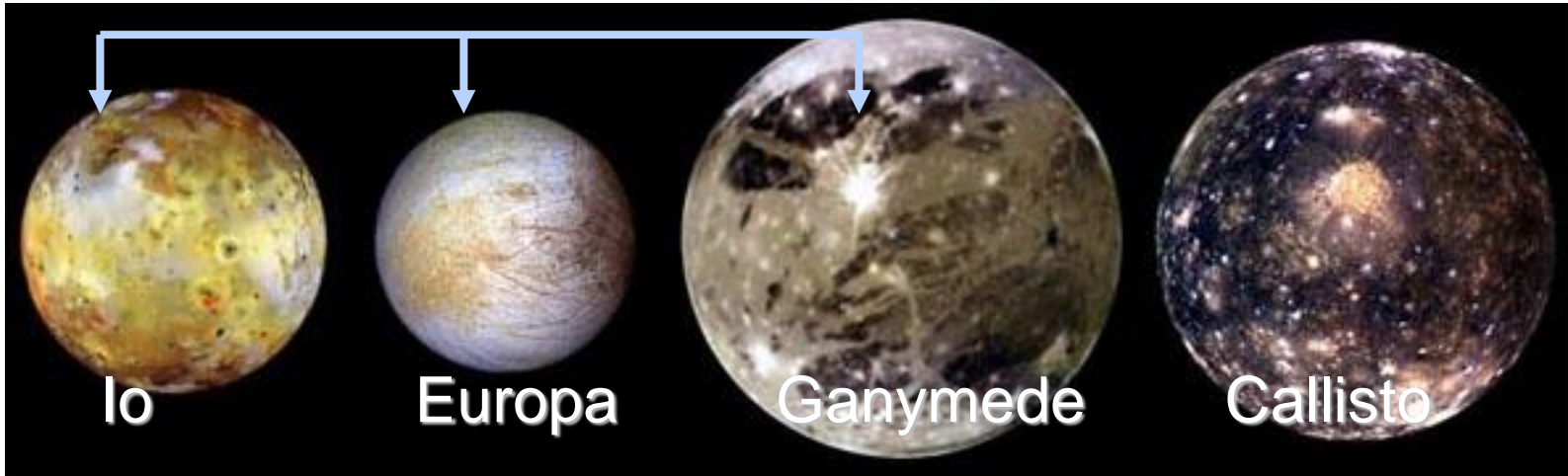
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## Orbital Resonance



# *Wednesday*

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