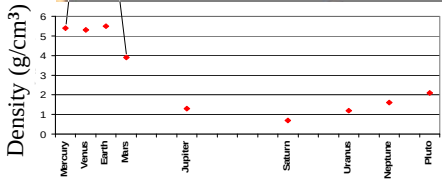
Jovian (Jupiter like) Planets

- Homework 4
  - Due Thurs, 26 Feb, 6:00am
- Test 2 is Tues, March 3rd.
  - Covers material through Tues, 2/17.
  - Missouri Club is 7:00pm, Mon., March 2nd
- Summarizing Qs

1. What is the structure of Jupiter & how is it different from Earth's?
2. Why is the interior of Jupiter hot?
3. Why does Io, Jupiter's satellite have volcanoes?
4. Why are the inner moons irregular in shape and the big moons spherical?
5. Why do the Jovian planets have rings?



Terrestrial *vs.* Jovian - Size & Density

Composition of Atmospheres
- By number of atoms/molecules

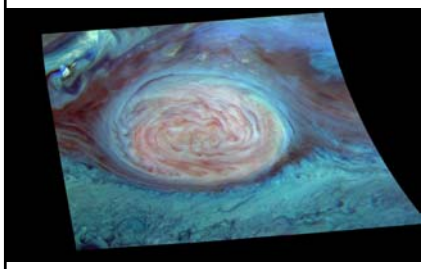
	Jupiter	Saturn	Uranus	Neptune	Outer Solar System Total	Sun
H_2	90%	97%	83%	74%	93%	86%
He	10	3	15	25	7	14
CH_4	0.2	0.2	2	1		

Jupiter

- Main constituents of gaseous atmosphere:
  - Hydrogen: 90%
  - Helium: 10%
  - Methane (CH_4): 0.2%
  - Ammonia (NH_3): 0.02%
- Clouds
  - Frozen ammonia (white)
  - Frozen ammonium hydrosulfide (brown & red)

Rotating Jupiter

Jupiter: The Great Red Spot



Color-coded image, showing which light is reflected off which type of clouds. Uses spectroscopy.
Blue = low clouds
Pink = high, thin clouds
White = high, thick clouds

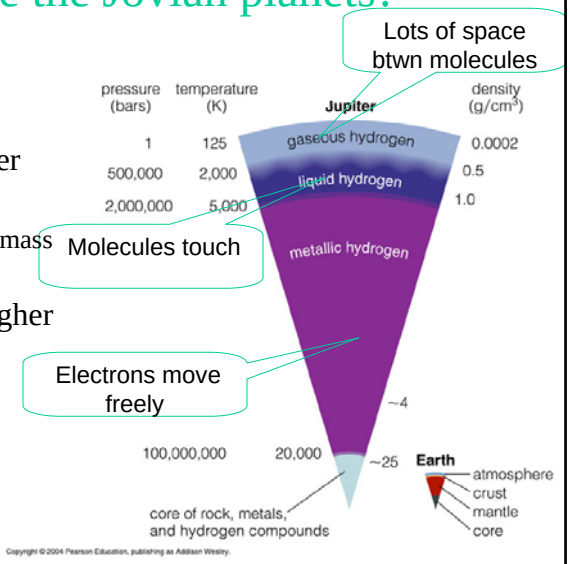
Movie red spot storm

Long-lasting storm, first seen in mid-1600's.

Earth sort of to scale:

What is inside the Jovian planets?

- Structure of Jupiter
- Why is pressure higher nearer the center?
  - Pressure supports the mass above.
- Why is the density higher nearer the center?
  - Pressure

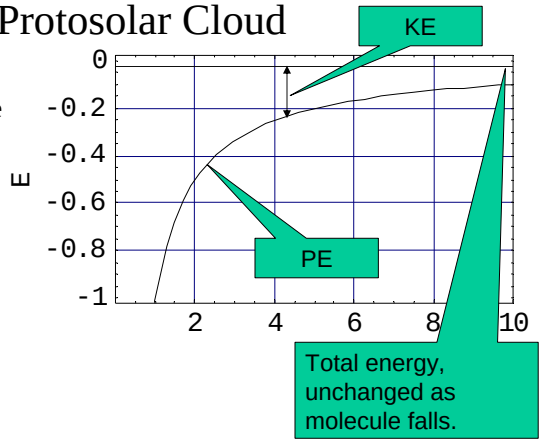


Why is Jupiter hot in the center?

- Hot means the atoms are moving faster.
- I am an atom, but think of me as a tennis ball. I am dropped from a height of 6ft. In what sense does the atom get hotter?
  - The atom is moving faster.
- Q: What is the source of the energy that heats the atom?
  a. Chemical
  b. Nuclear
  c. Gravity

Collapse of the Protosolar Cloud

- I am a hydrogen molecule in the cloud that will become the sun.
- My energy is kinetic (due to motion) and potential (due to gravity).
  - Energy = KE + PE
  - = ½ m v^2 – G M m/r^2
  - Speed v
  - Distance r to center of cloud
- Q: When I fall from r = 5 to r = 1, my KE (and temperature) increases by a factor ___
  a. About 2
  b. About 3
  c. About 5
  d. More than 10



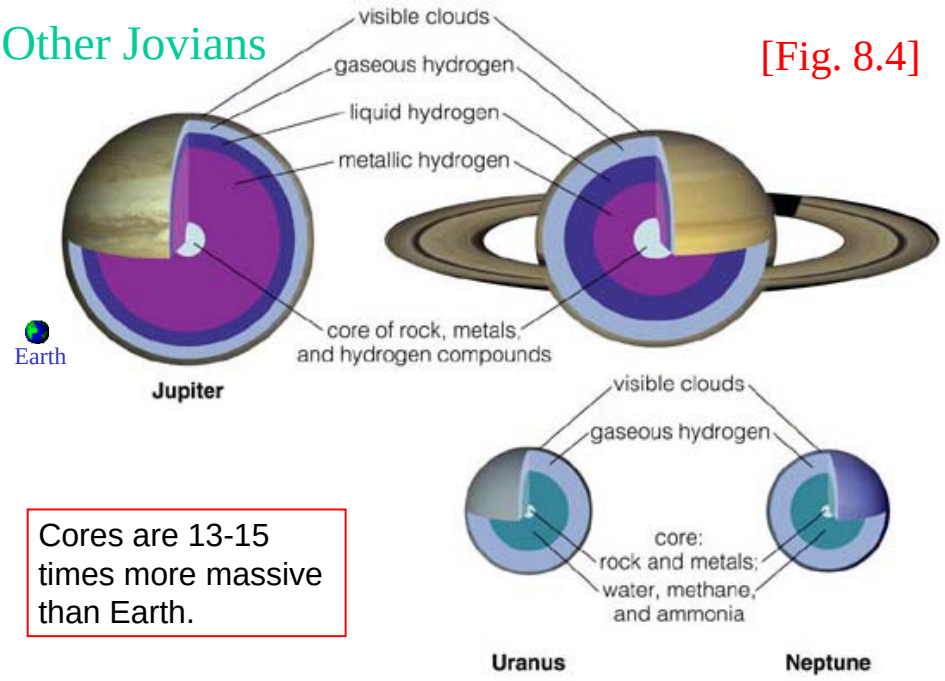
- Why is the center of Jupiter hot?
- Material fell and changed gravitational energy into energy of motion.

Jupiter's heat sources

- 50% is from solar energy
- But other 50% comes from internal heating
  - This is gravitational energy released when Jupiter formed.
  - Currently stored in interior as heat energy.
  - Slowly being radiated away.
  - Plus maybe some continuing energy release from contraction.
- Similar effect in Saturn
  - But additional effect of same magnitude from ongoing differentiation.
    - Separation of H from He.

Other Jovians

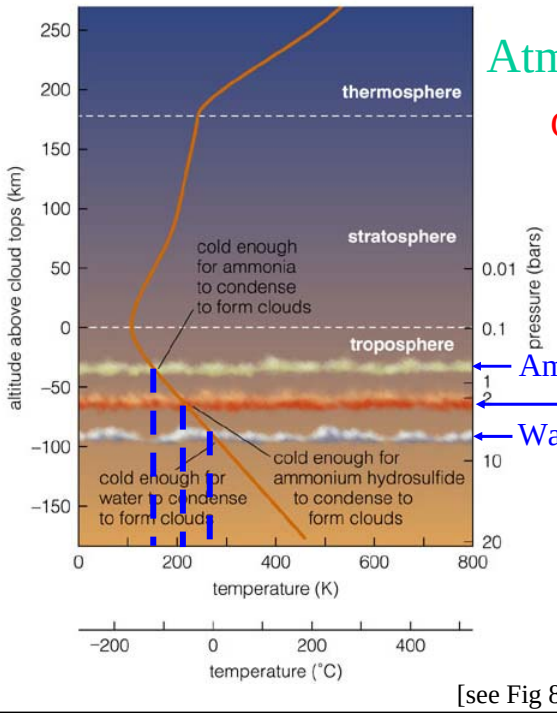
[Fig. 8.4]



Cores are 13-15 times more massive than Earth.

Atmospheric Structure

Cloud layers, in the Hydrogen-Helium atmosphere.



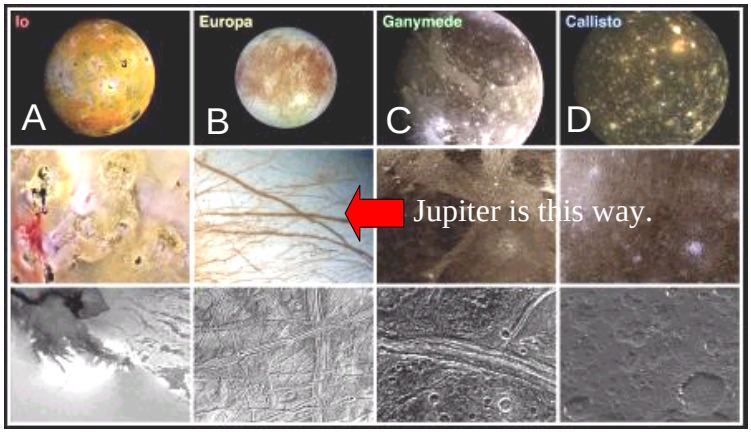
Ammonia (NH_3)

NH_4HS

Water (H_2O)

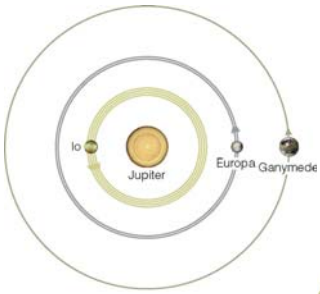
[see Fig 8.6]

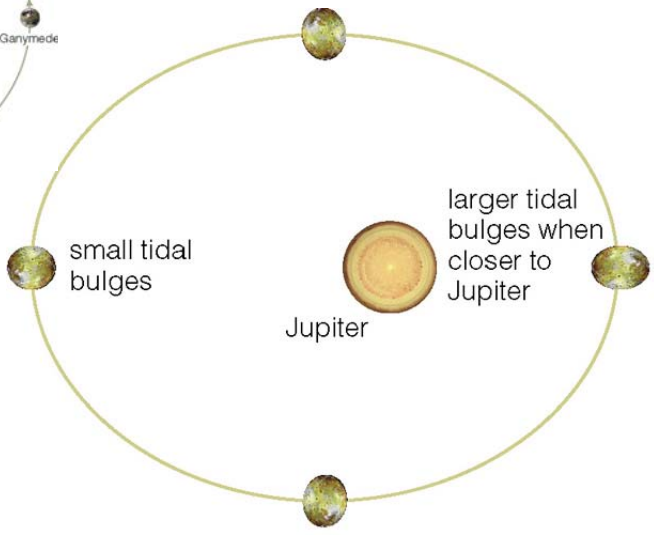
Moons of Jupiter – Age of Surface



1. The moons are placed in order of the age of the surface. Which moon has the youngest surface? [Hint: Compare the appearance of surfaces of earth & moon. Earth & moon had similar number of meteors. Craters on earth have been erased by weathering & tectonics.]

Tidal Heating of Jupiter's Galilean Moons

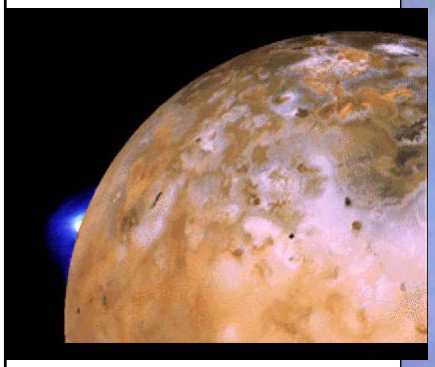


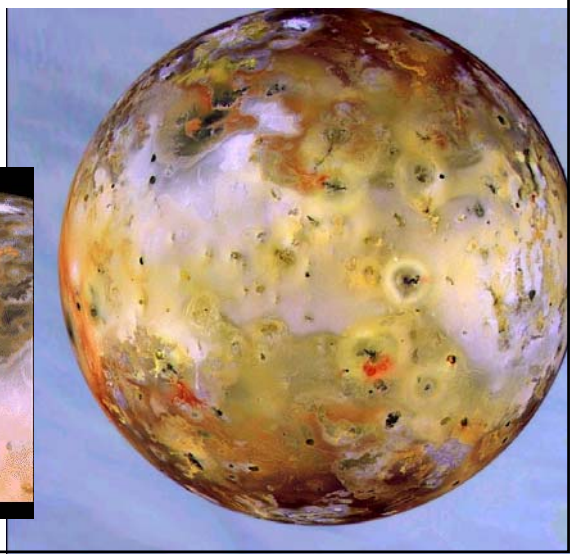


[Fig. 8.15]

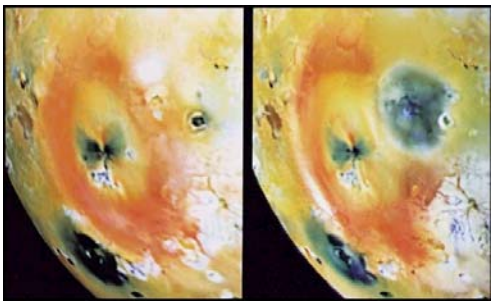
Io

- Closest to Jupiter (of Galilean Satellites)
  - Strongest tidal forces.
- Active volcanoes
  - hot silicate lava, similar to Earth.

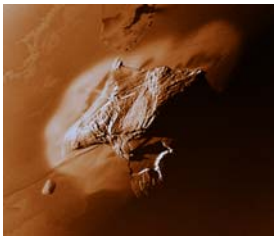




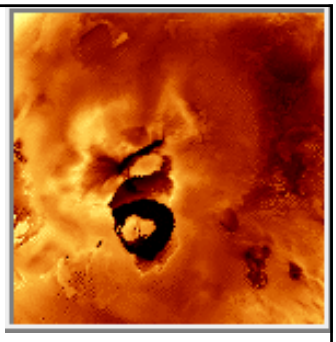
More Io



Images of same region, 5 months apart.



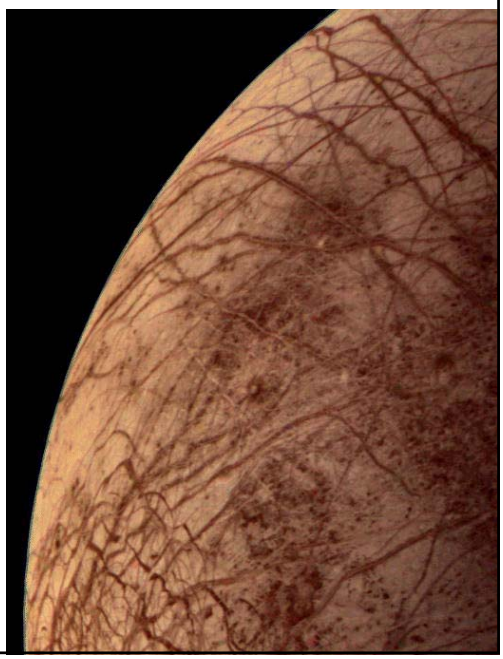
Haemus Mons - a volcanic cone



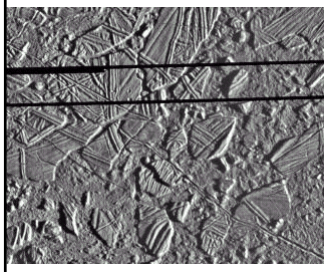
Loki Patera
Thought to be a liquid sulfur lake with a solid sulfur raft.

Europa

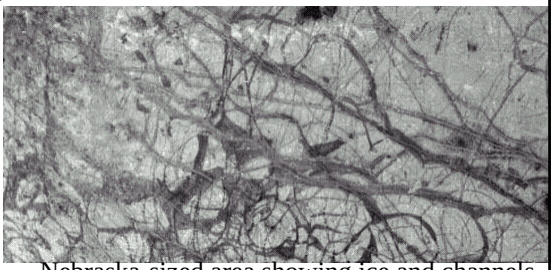
- *Not* made of ice.
  - Density similar to Moon
- Tidal forces keep it geologically active.
- Covered by layer of water ice.
  - Appears to be “pack ice” on top of an ocean.
  - Water must be warmed by heat from Europa’s interior.



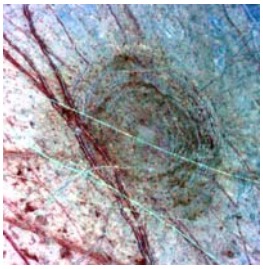
Europa’s surface



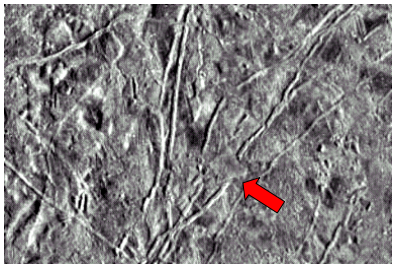
Ice rafts



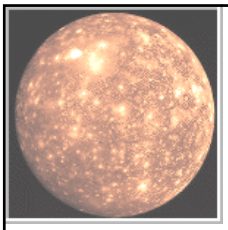
Nebraska-sized area showing ice and channels.



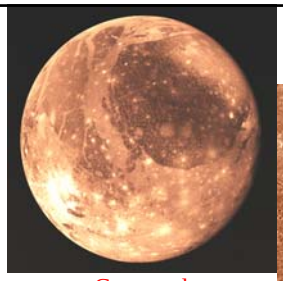
+ the occasional impact crater



Ice flow cutting across ridge



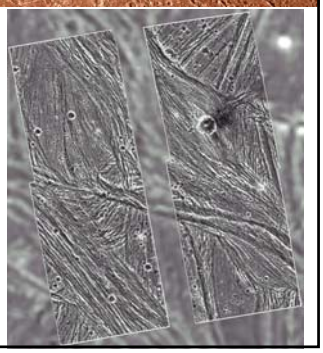
Callisto



Ganymede

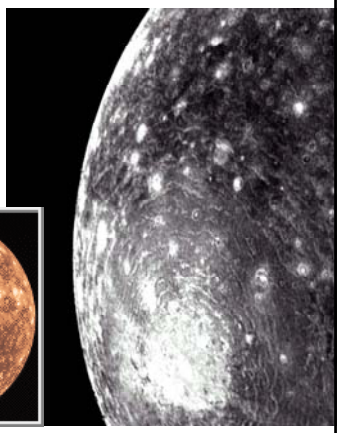
Ganymede

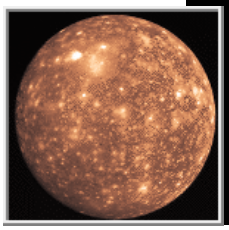
- Largest satellite in Solar System
- Fewer impact craters than Callisto ➔ geologically active.
- Differentiated
  - Rock, metal core.
    - Magnetic field present.
- Mantle, crust made of ice
  - Volcanic flows, but water rather than lava.
  - Ridges, valleys due to compression of crust.



	Diameter (km)	Relative Mass	Density (g/cm^3)	% Reflectivity
Moon	3476	1.0	3.3	12
Callisto	4820	1.5	1.8	20
Ganymede	5270	2.0	1.9	40
Europa	3130	0.7	3.0	70
Io	3640	1.2	3.5	60

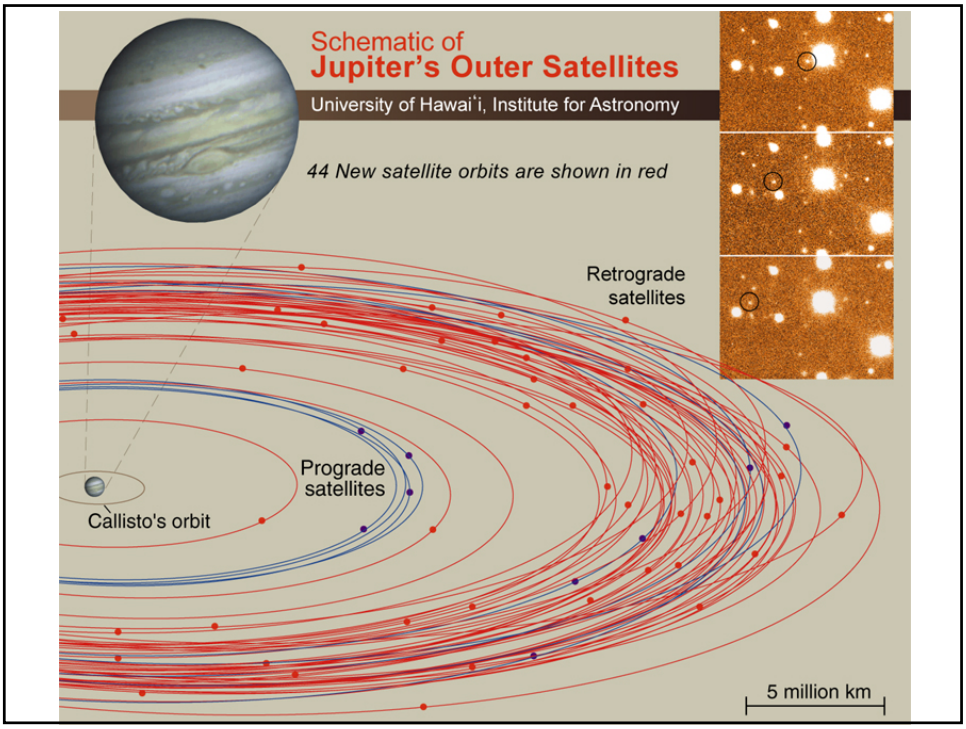
Callisto



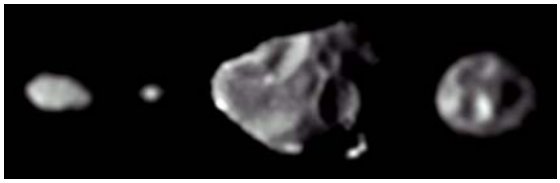


Callisto

- Orbital period: 17 days
- Tidal locking with Jupiter
- Surface temperature = -140° C
  - appears to be mostly ice.
  - 1.8 x density of water
- Many impact craters.
- Not well differentiated
  - Close Galileo flybys ➔ gravitational field ➔ no dense core.
- Geologically dead for 4 billion yrs.

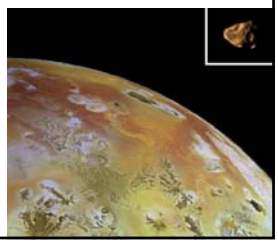


The Innermost Moons of Jupiter



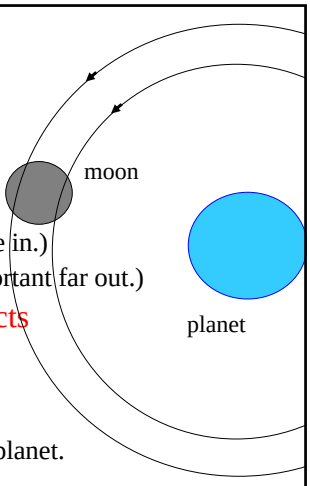
Metis Adrastea Amalthea Thebe

- Q5: What holds me together?
  a. Gravity
  b. Atomic bonds between the atoms
- Q6: What holds Io & Metis together? (Think about the shapes of Io & Metis.)
  a. Gravity for both
  b. Bonds for both
  c. Gravity for Io; bonds for Metis
  d. Gravity for Metis; bonds for Io.



Amalthea & Io

Roche limit



- For a moon in orbit around a planet,
  - $P^2 = a^3$ ➔ different parts of extended body have different orbital periods.
  - So body tends to be torn apart. (More important close in.)
  - But self-gravity tends to hold it together. (More important far out.)
- Roche's limit is where these two opposing effects are balanced:

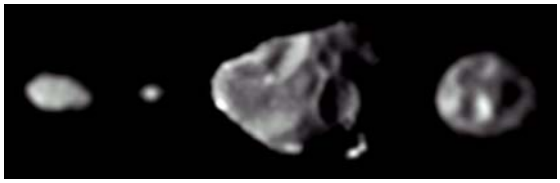
$$\mathbf{R_{Roche} = 2.5\ (\rho_{planet}/\rho_{moon})^{1/3}\ R_{planet}}$$

where ρ = density (kg/m^3) and R_{planet} = radius of planet.

- If density of planet & moon are the same, then

$$\mathbf{R_{Roche} = 2.5\ R_{planet}}$$

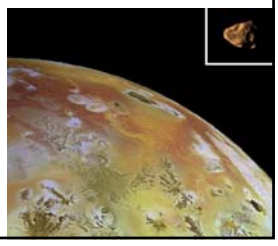
The Innermost Moons of Jupiter



	Metis	Adrastea	Amalthea	Thebe	(Io)
Size (km)	40	20	270x166x150	116	3630
Mass (kg)	10^{17}	$2x10^{16}$	$7x10^{18}$	$7x10^{17}$	$9x10^{22}$
Orbit radius (km)	128,000	129,000	181,000	222,000	422,000

Inside Jupiter's "Roche limit".

A body inside the Roche limit cannot be held together by its own gravity.



Amalthea & Io