

# **Astronomy 405**

## **Solar System and ISM**

### **Lecture 11**

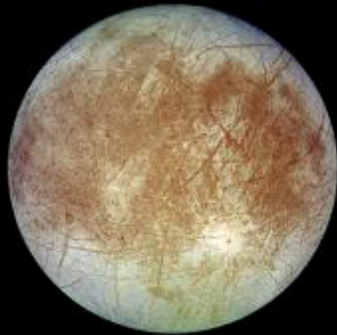
### **Jovian Moons**

**February 8, 2013**

# Jovian Moons

*Voyager, Galileo, and Cassini-Huygens* imaged the moons of giant planets.

Here are images of the Galilean moons taken by *Galileo*:



Io

yellowish-orange,  
volcanos

Europa

thin ice  
with cracks  
*no* craters

Ganymede

thick ice  
with ridges  
craters

Callisto

dust layer  
thick ice crust  
craters

← Less volatiles (water ice)  
Hotter

Older surface  
Colder →

# Tidal Effects on Io

Strong tidal interaction:

Closest to Jupiter, orbit resonance  
with Europa and Ganymede 1:2:4

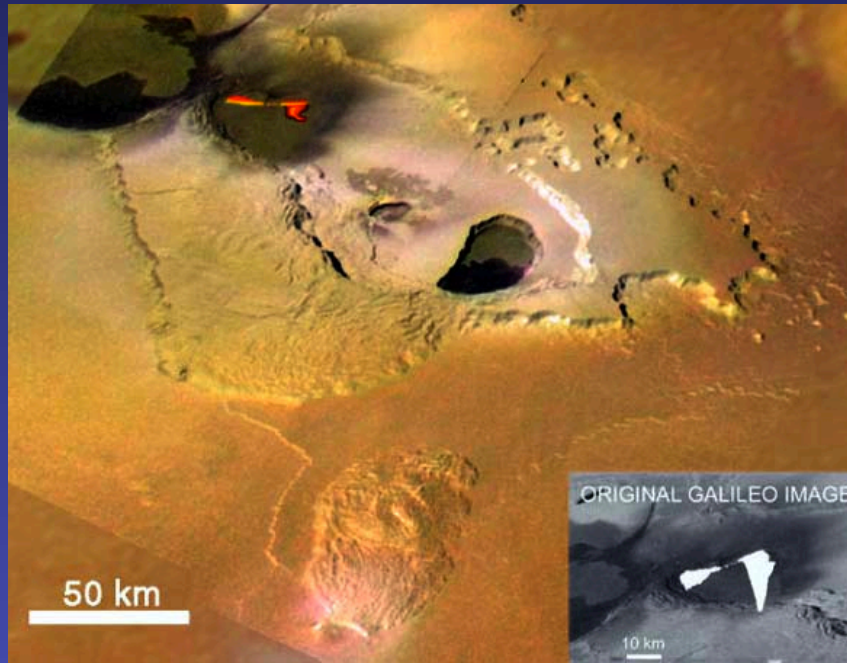
Volcanos ~ geysers

S and SO<sub>2</sub> ~ H<sub>2</sub>O

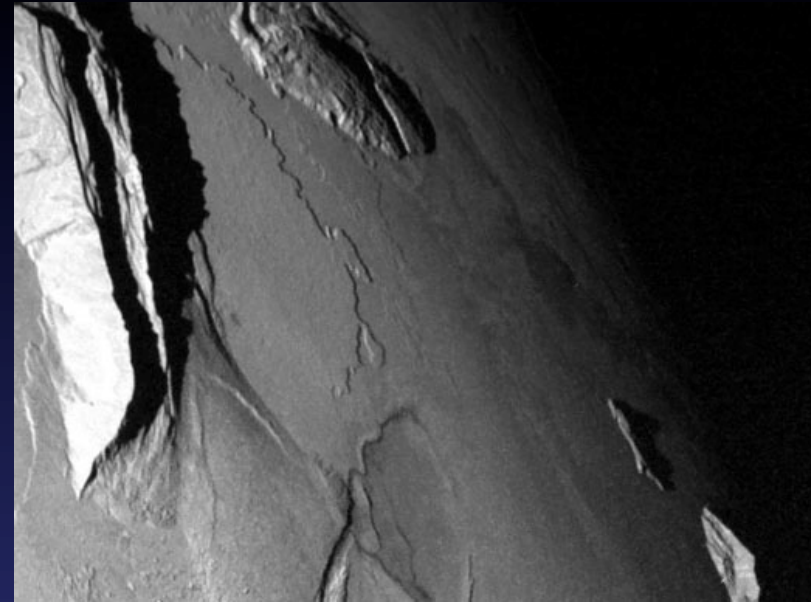
Phase transition → eruption

Gravitational field =>  $\rho \sim 3.5 \text{ g/cm}^3$   
=> iron core, chemical differentiation

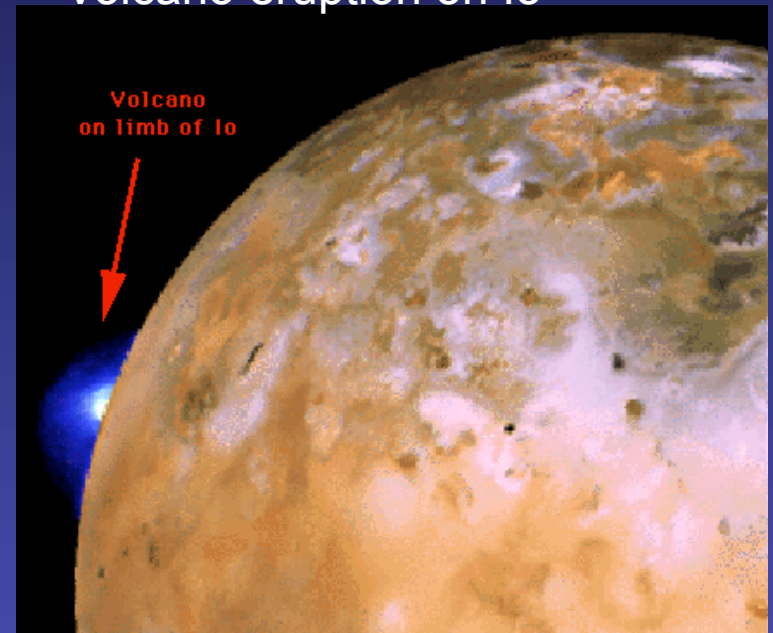
Fissure eruption (red); Tvashtar Catena

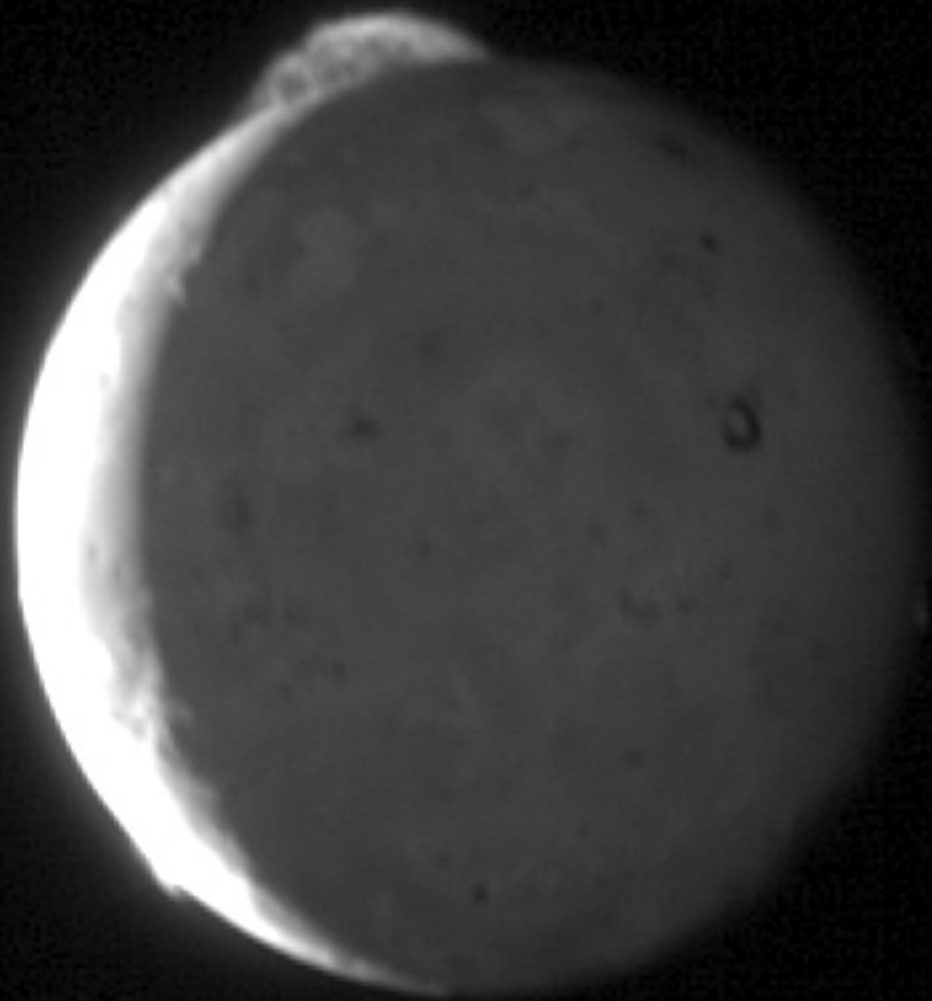


Mountains on Io at sunset



Volcano eruption on Io







# Io's Interaction with Jupiter's Magnetic Field

Jupiter's spin period  $< 10$  hr

Io's orbital period  $\sim 1.77$  days

$\Rightarrow$  Jupiter's strong magnetic field sweeps past Io at a speed of 57 km/s

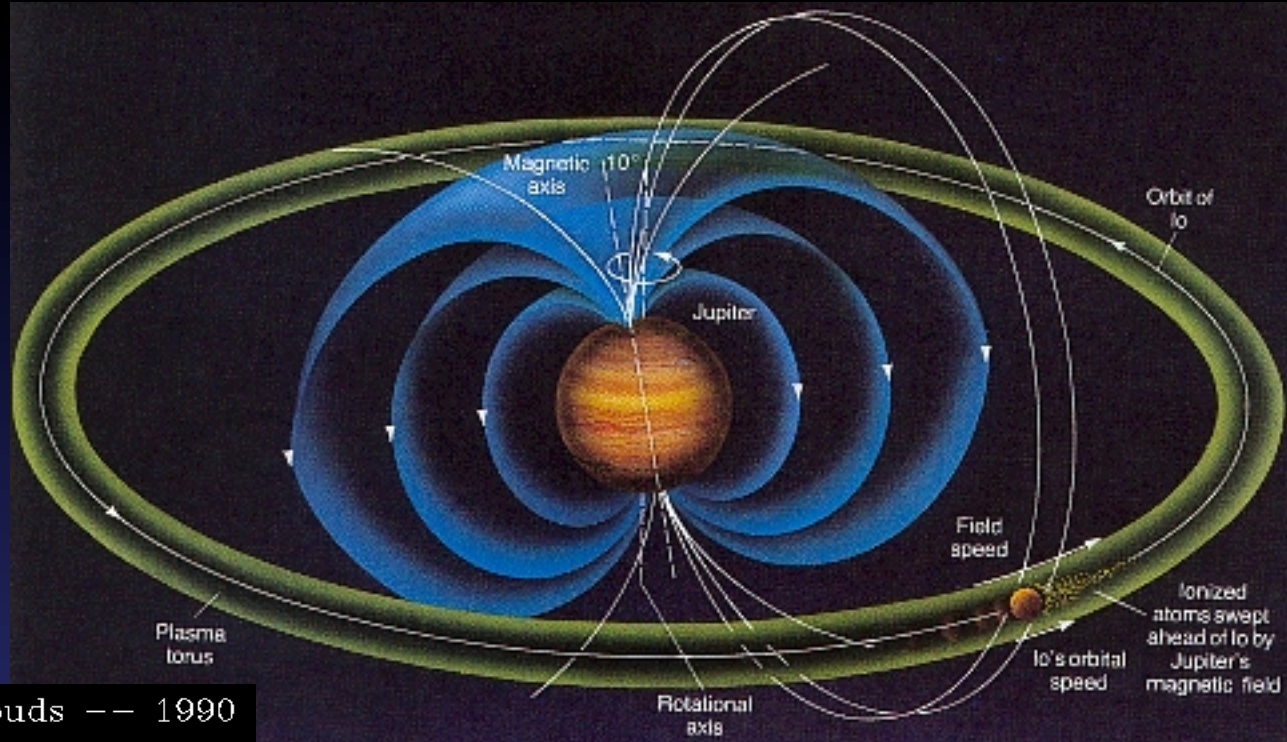
Faraday's law of induction

$\Rightarrow$  an electric potential difference of 600 kV across Io

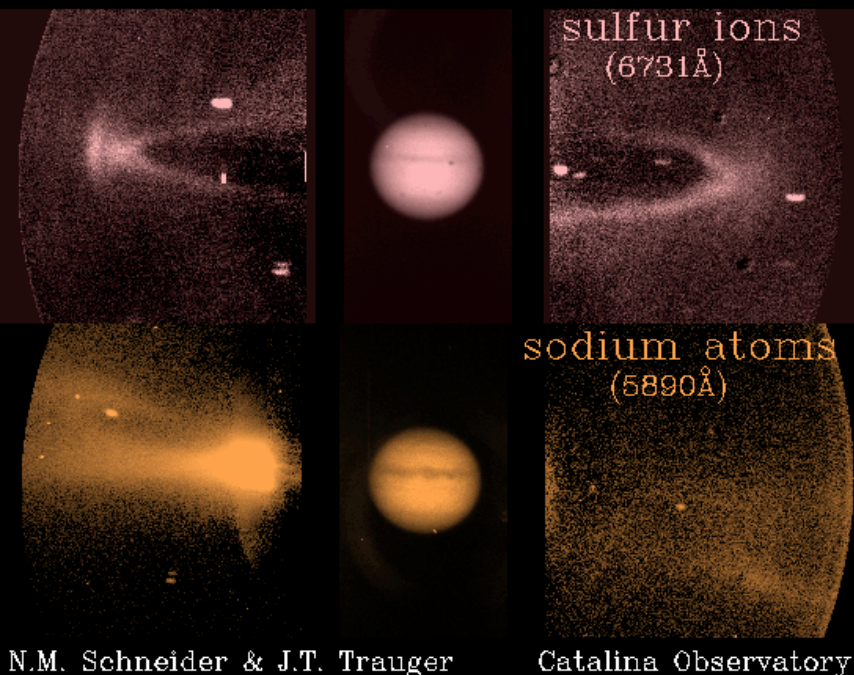
$\Rightarrow$  current of  $\sim 10^6$  amps flowing back and forth along B between Io and Jupiter

$\Rightarrow$  Joule heating of Io  $P = I V \sim 6 \times 10^{11}$  W, smaller than the  $10^{14}$  W internal heating

# Io Torus



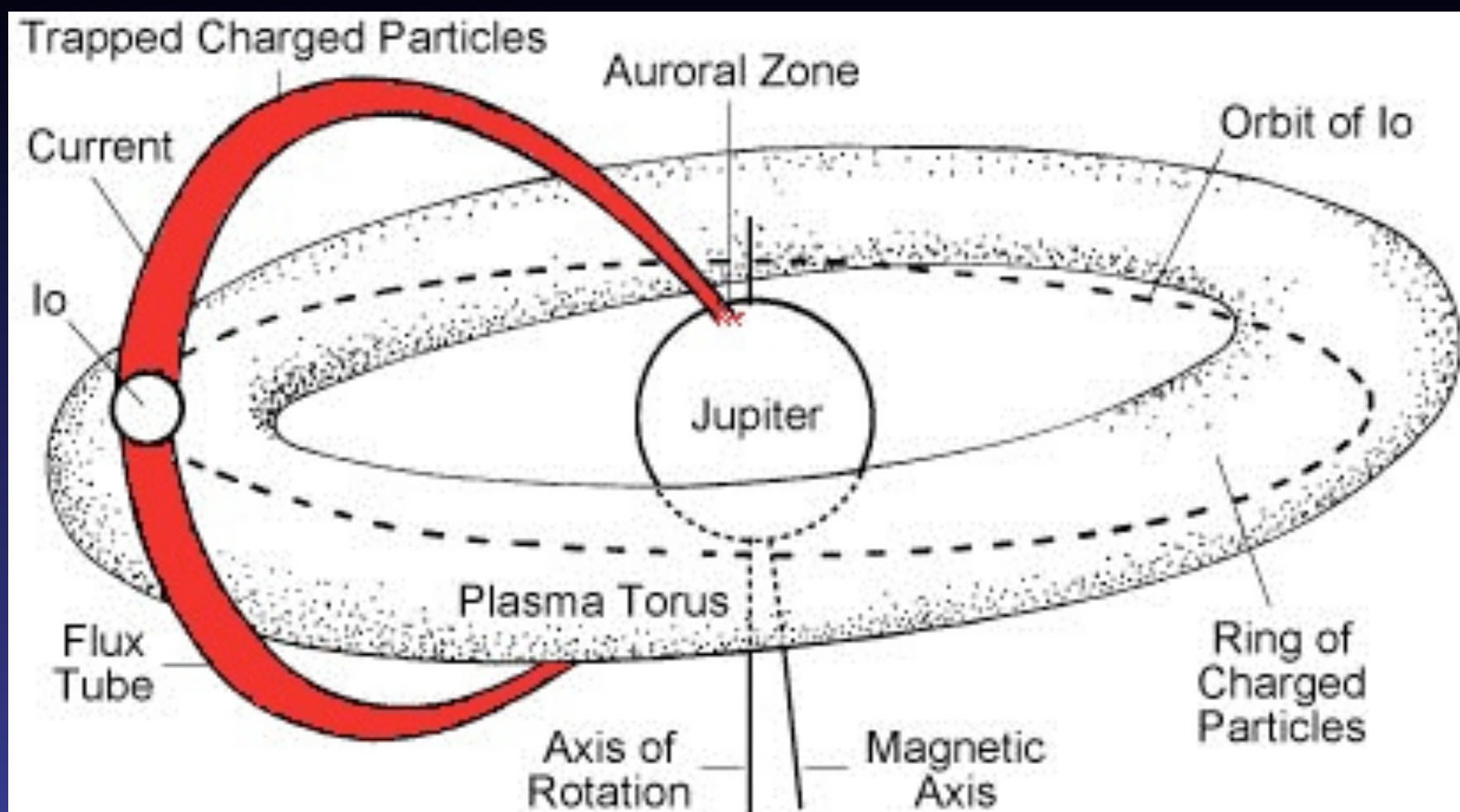
Io Plasma Torus and Neutral Clouds -- 1990

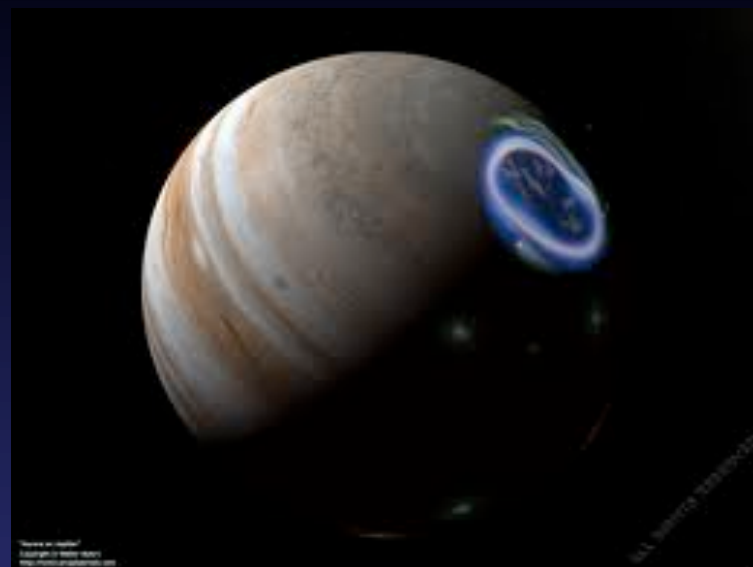
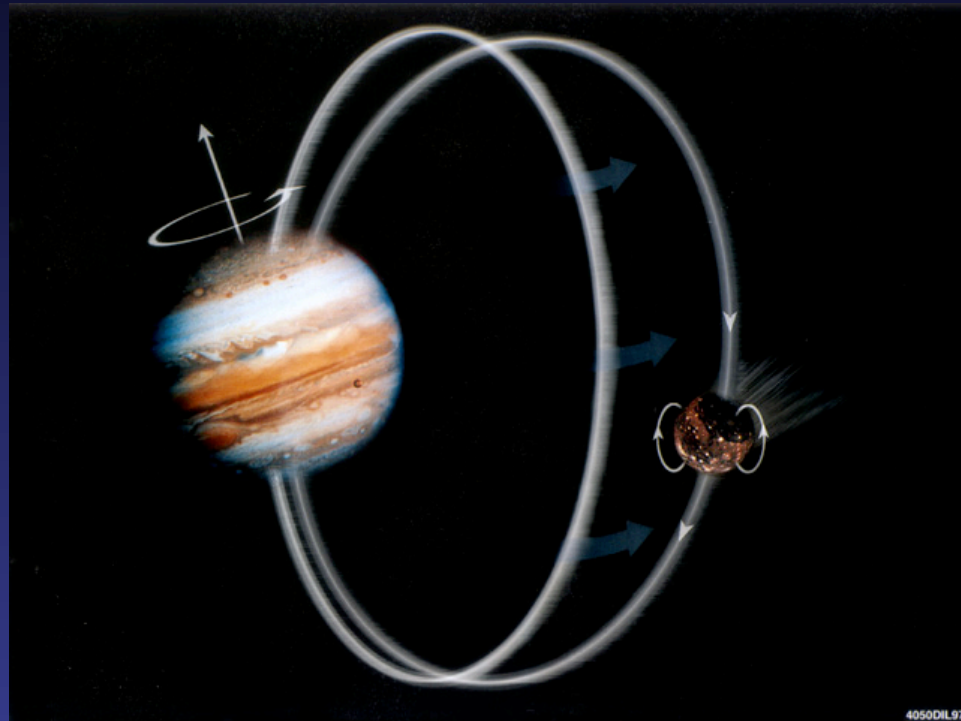


Excessive number of charged particles are trapped in Jupiter's magnetic field along Io's orbit.

Sputtering:  $O^+$  and  $S^+$  from Jupiter's magnetosphere impact and provide energy to liberate S, O, Na, K...

$10^{27} - 10^{29}$  ions are liberated per second.







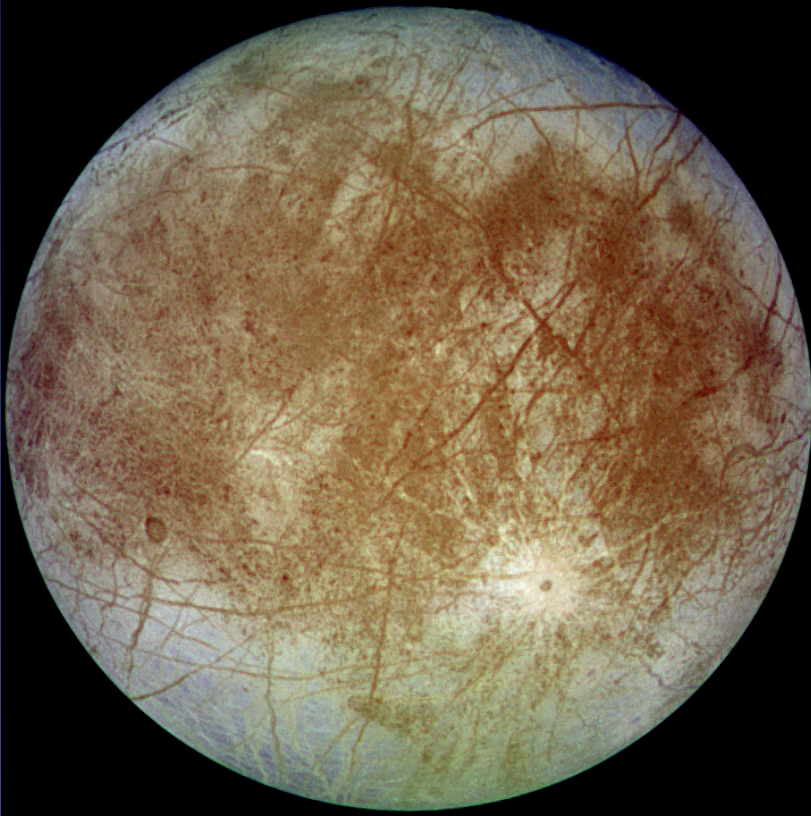
Europa's icy surface shows lots of cracks.

Fe-rich core, silicate mantle, subsurface ocean, ice crust.

Density 3.0 g/cm<sup>3</sup>.

Water ocean + ice crust ~ 150 km thick

## Europa





# Europa

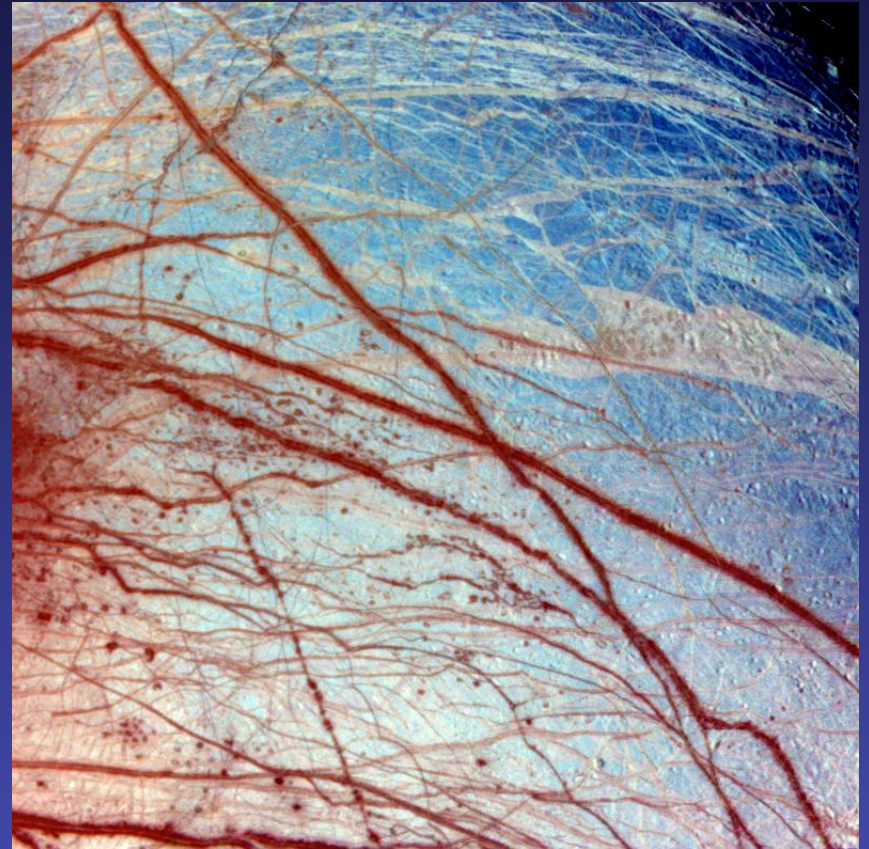
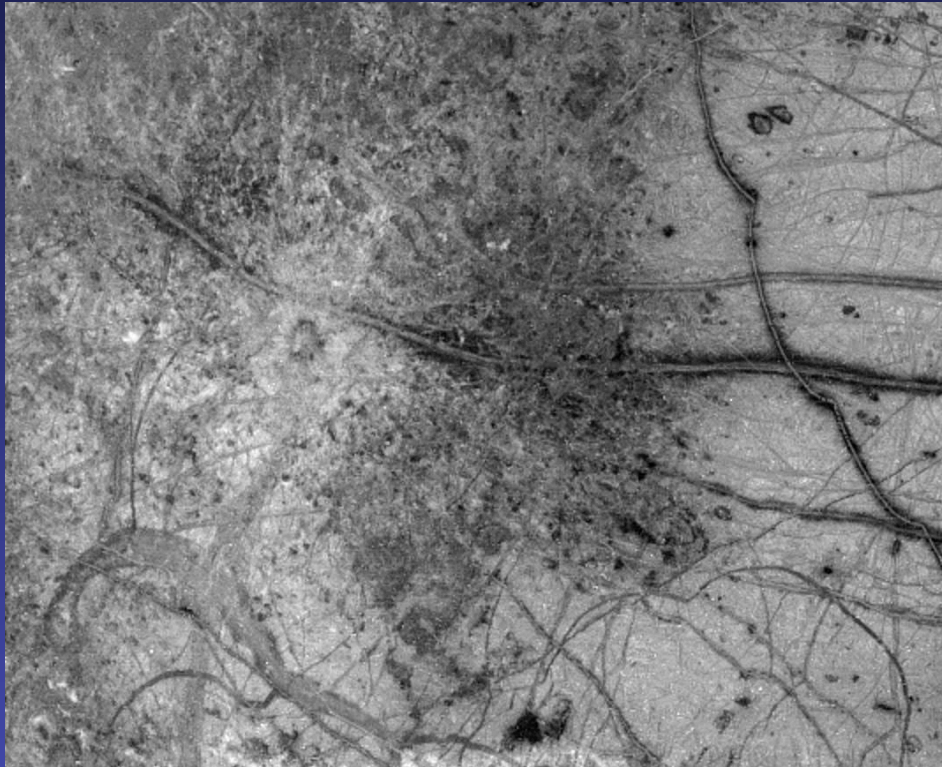
The ice plates crack, shift, and rotate.

The long red bands are cracks 10-20 km wide; water rises in the center (lighter color) and pushes the contaminants to the sides (darker color).

Tidal heating keeps the subsurface ocean warm => liquid water => life???

HST/Galileo detected  $O_2$ , Cassini detected  $O_2$  and H => sputtering

An impact crater !!!!!

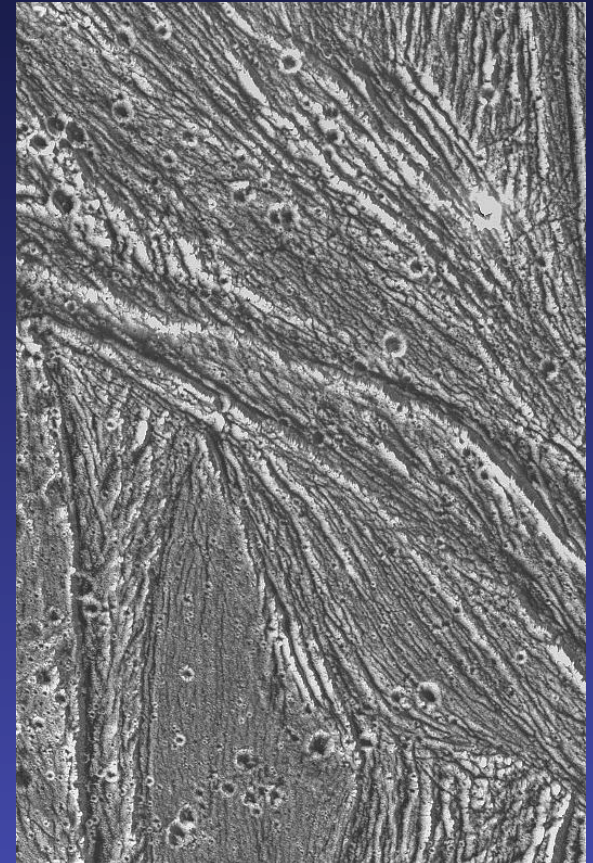
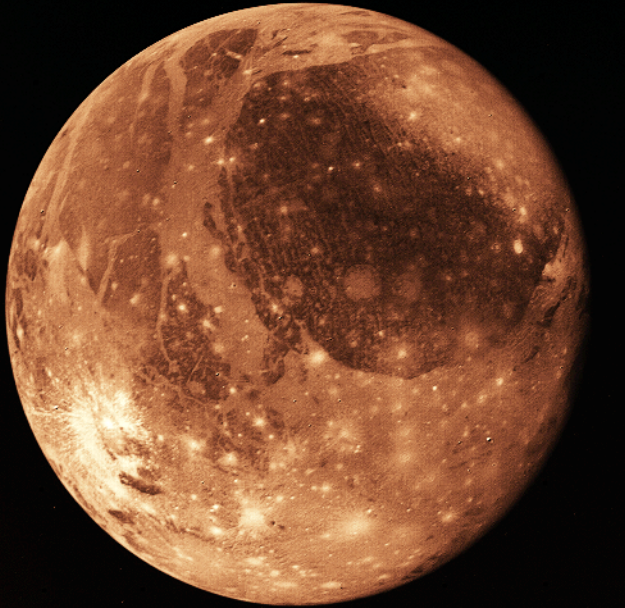




# Ganymede

Complex ridges  
and grooves  
⇒ tectonic activity

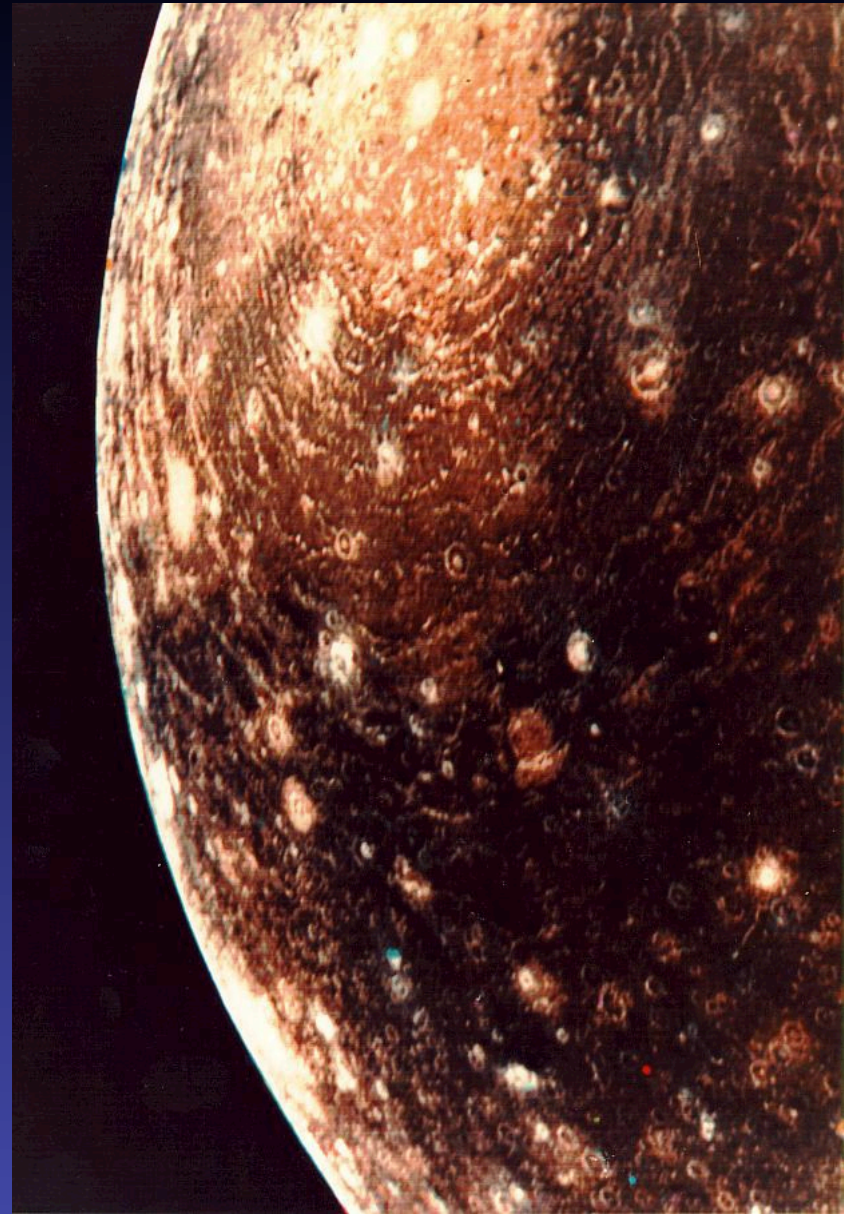
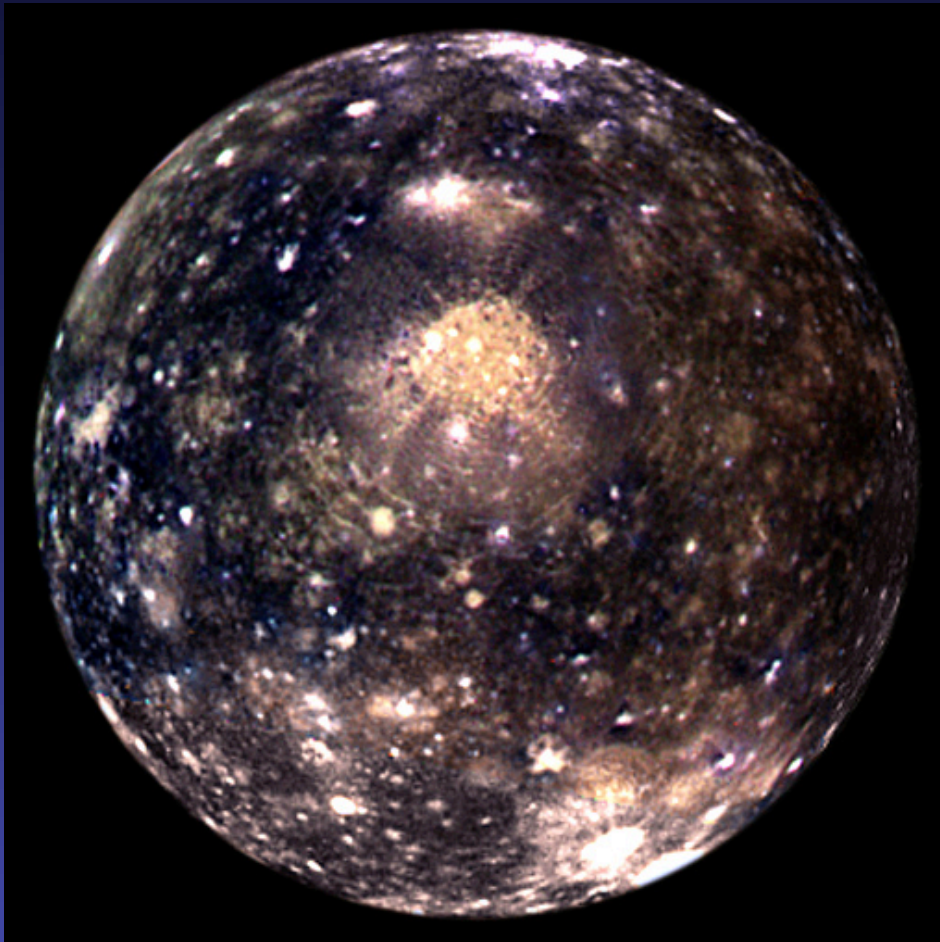
Partially molten iron core,  
silicate lower mantle, icy  
upper mantle, ice crust





# Callisto

Callisto cooled and solidified rapidly. Surface continued collecting dust (dark color). Craters expose the ice beneath (light color).





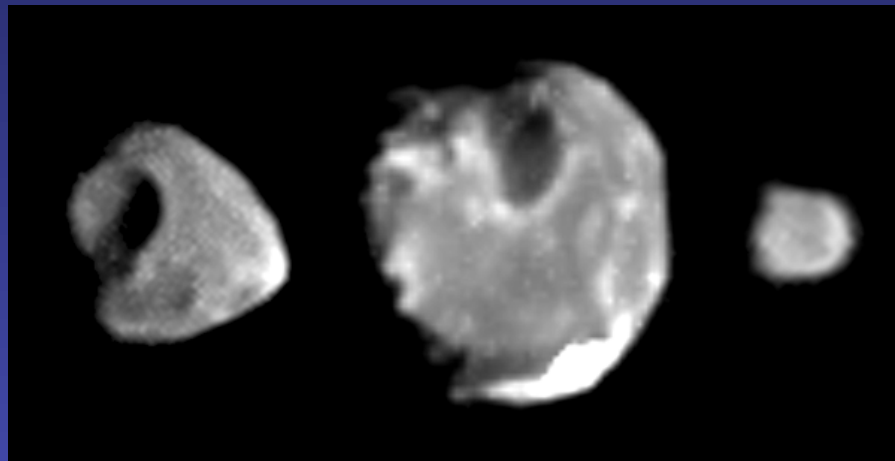
# Jupiter's Moons

The formation of moons around Jupiter is similar to the formation of planets around the Sun.

Solar nebula vs subnebula

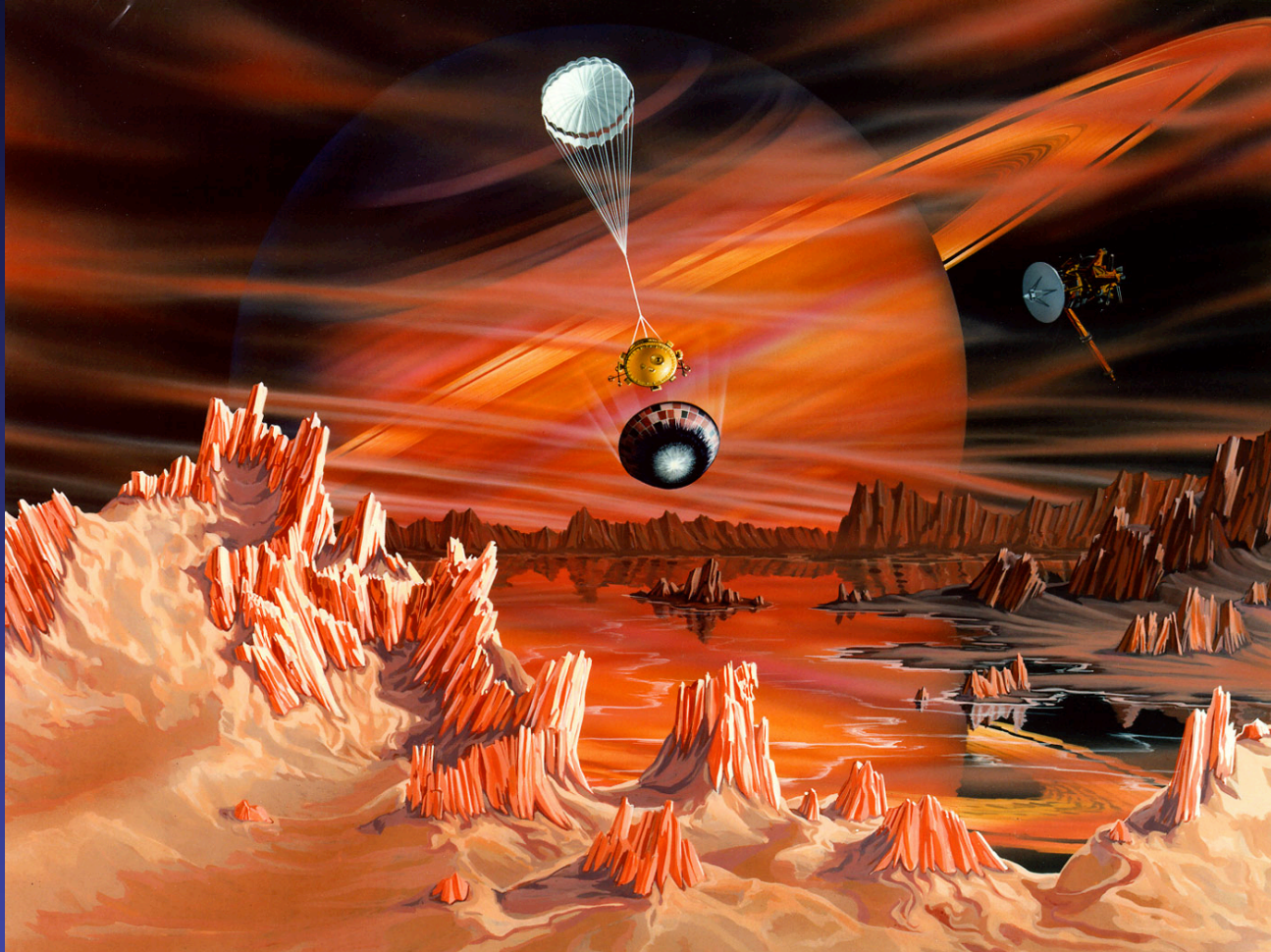
The 4 Galilean moons and many smaller moons have prograde orbits in the Jupiter's equatorial plane.

Some moons might have been captured and the smallest satellites may be collisional shards produced by meteoritic collisions with larger satellites. These have irregular orbits.

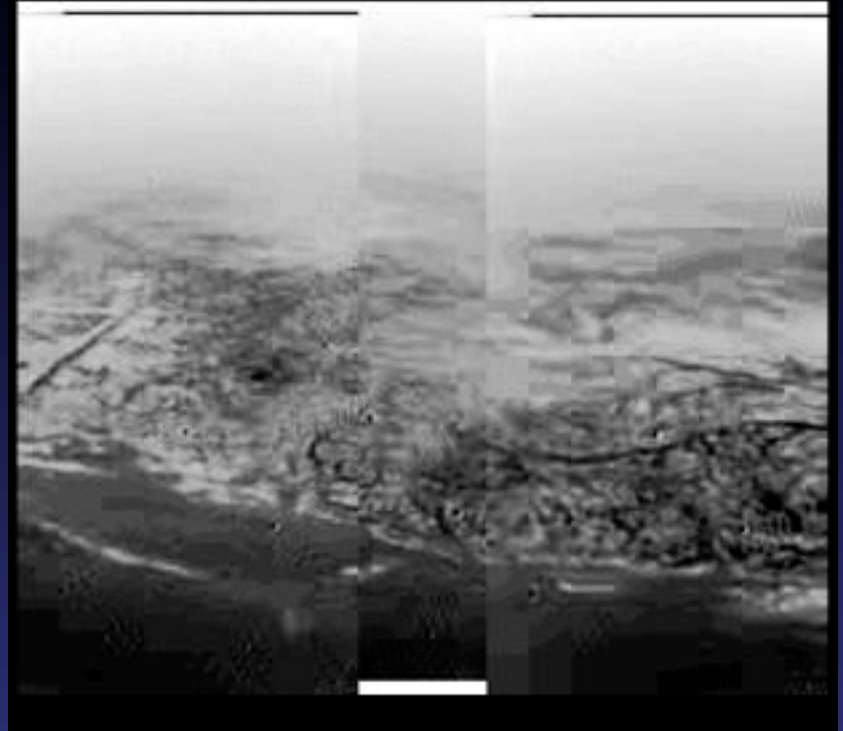
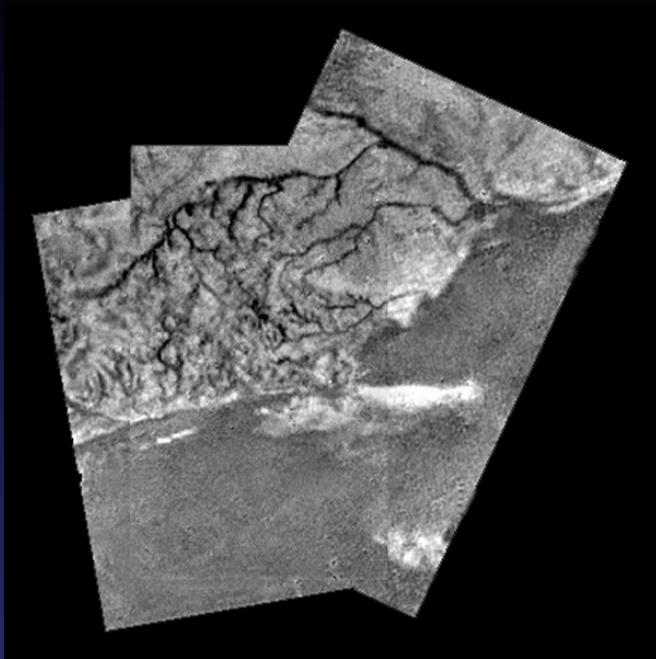


# Saturn's Titan

Cassini-Huygens Mission; Huygens probe

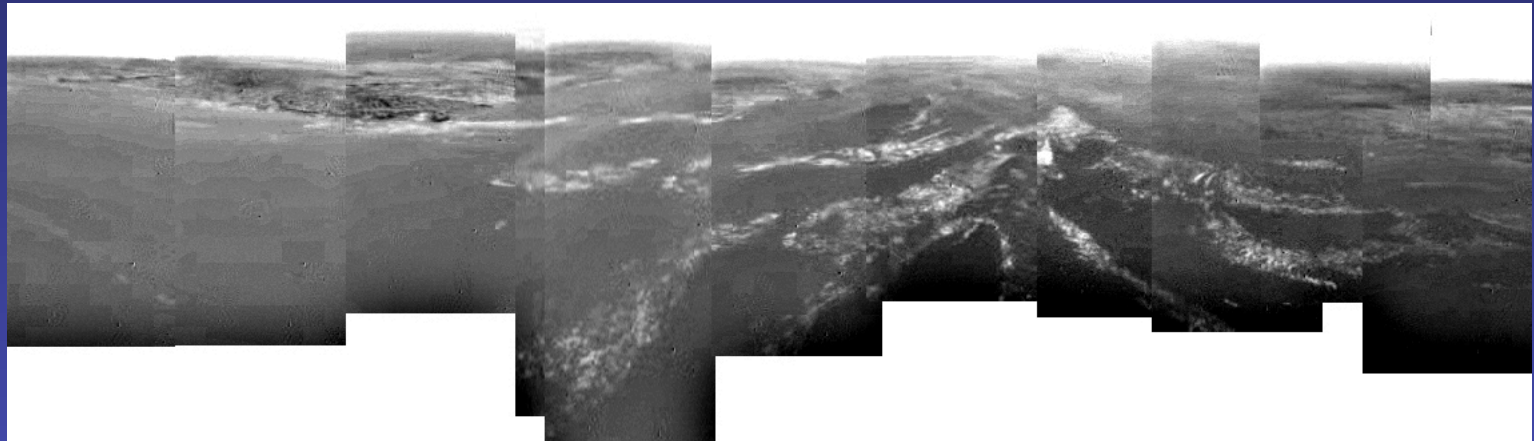


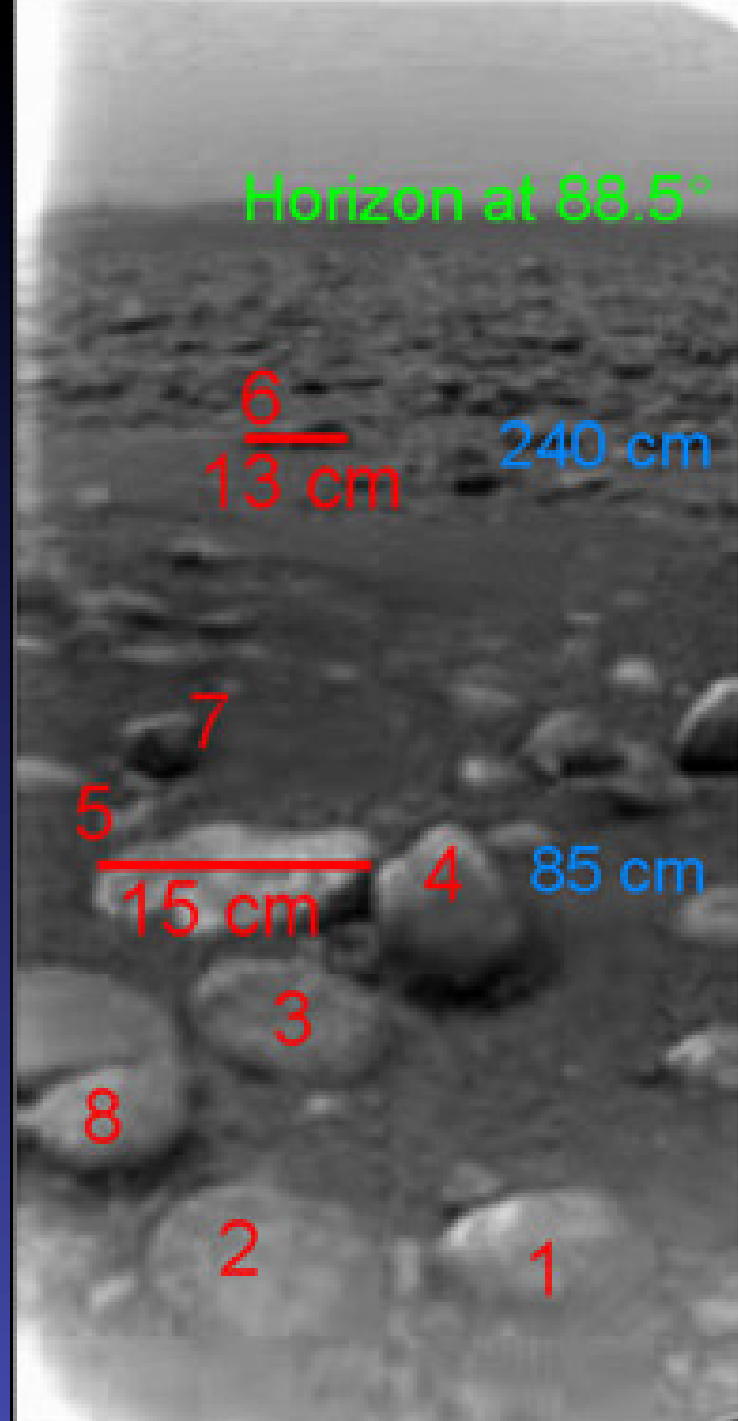
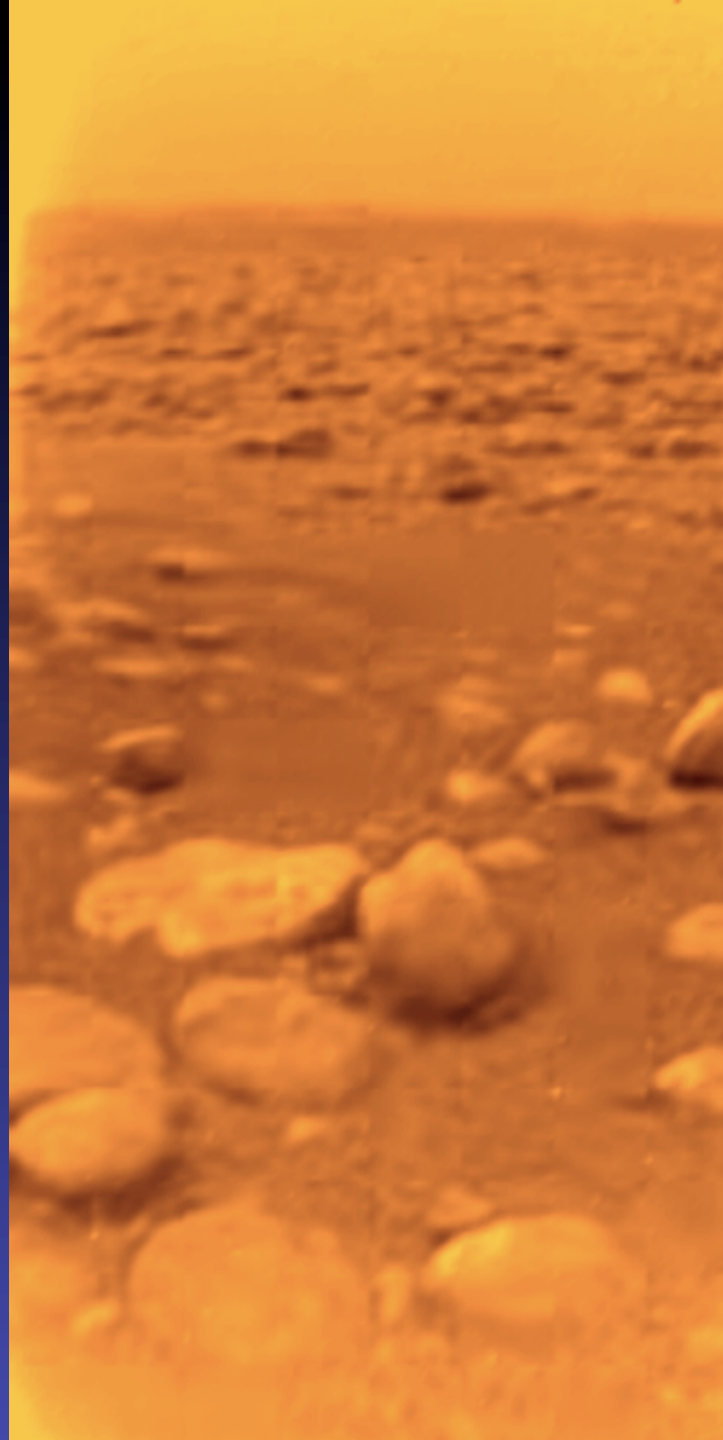
From altitude ~ 8 km.



From altitude ~ 8 km.

Vapor of methane or ethane.







Titan's atmosphere:

87-99%  $\text{N}_2$

1-5%  $\text{CH}_4$

0-6%  $\text{Ar}$

$\text{H}_2$ ,  $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{HCN}$ ,  $\text{C}_2\text{H}_2$ ,  $\text{C}_2\text{H}_4$ ,  $\text{C}_2\text{H}_6$ , etc.

form aerosols in the high-altitude smog layer.

1.5 atm, 93 K

Methane ( $\text{CH}_4$ ) is able to condense as a liquid and evaporate again.

Methane rains and river...

Huygens found moist ground with liquid methane

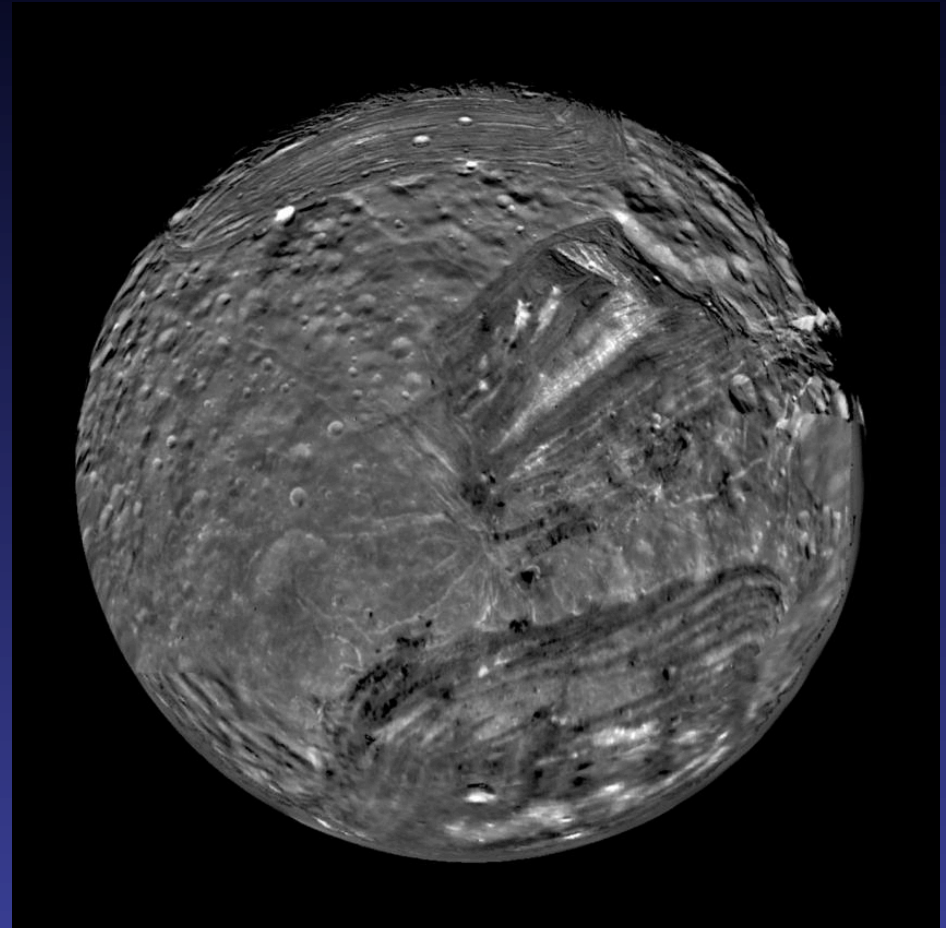
A few cm below the surface. It just rained.

## Mimas of Saturn



Herschel Crater  
“Death Star”

## Miranda of Uranus



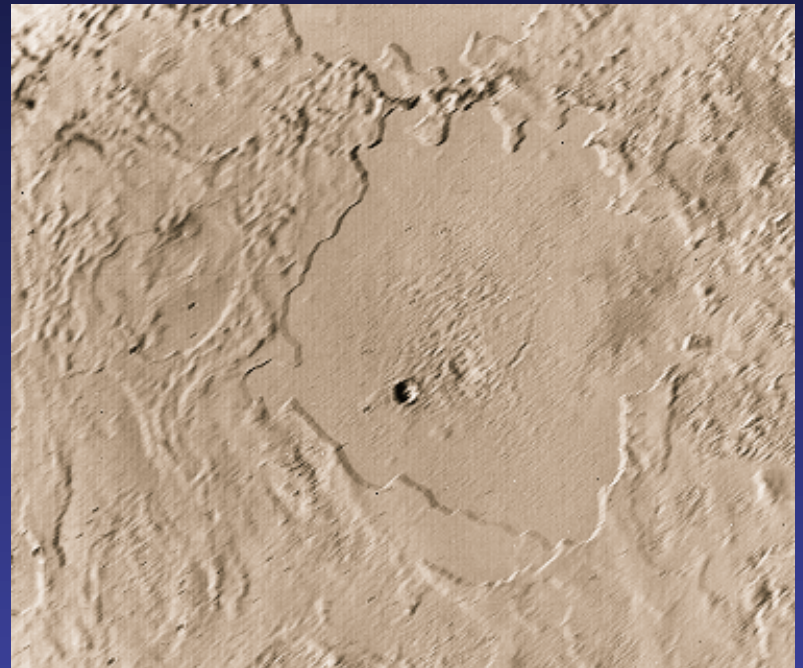
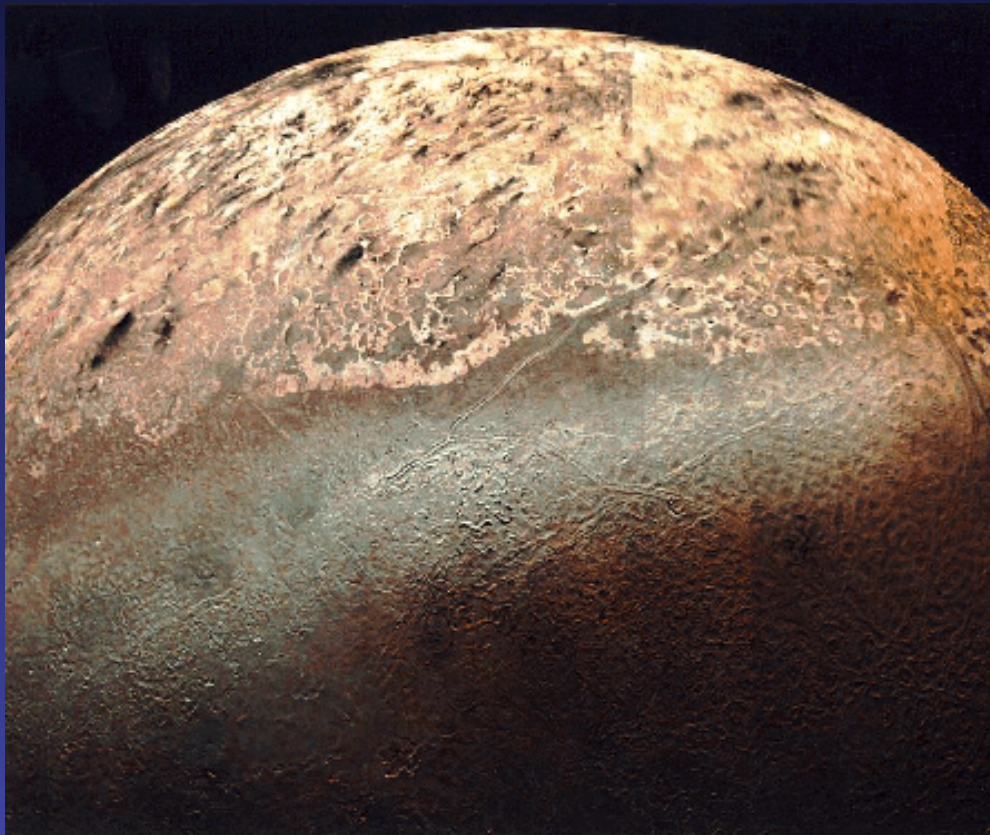
Actions of collision and gravity

# Neptune's Triton

Surface temperature  $\sim 37$  K, coldest visited.

Atmosphere is dominated by nitrogen.

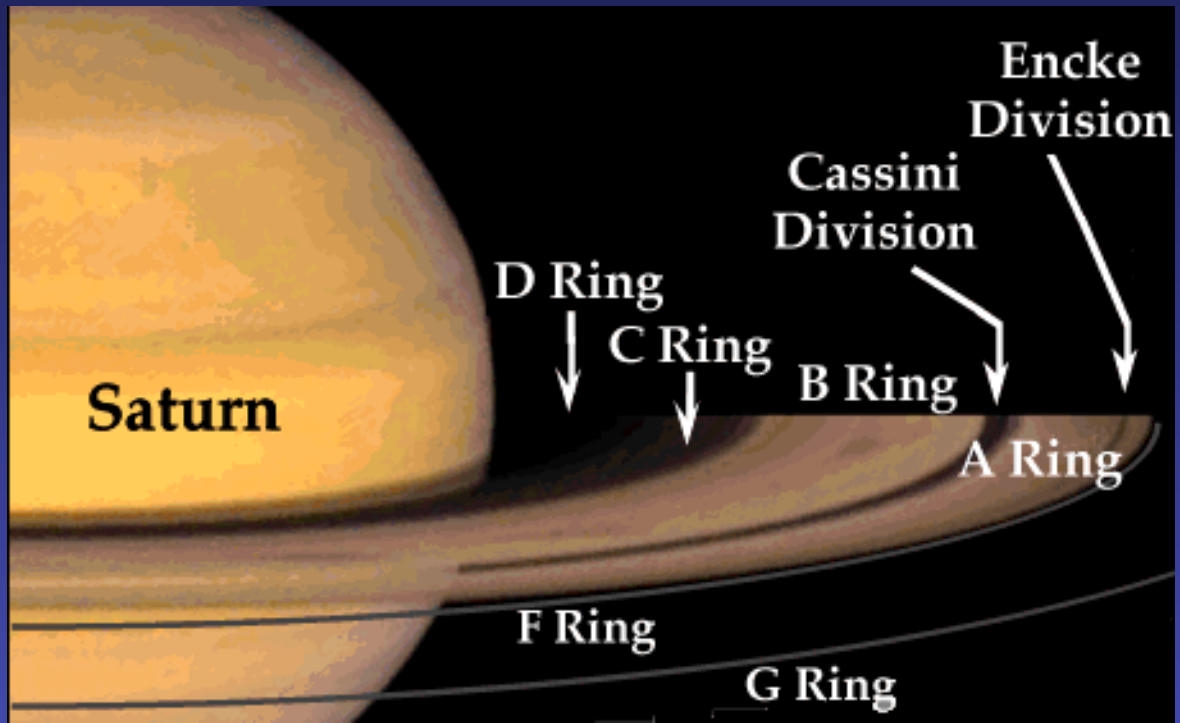
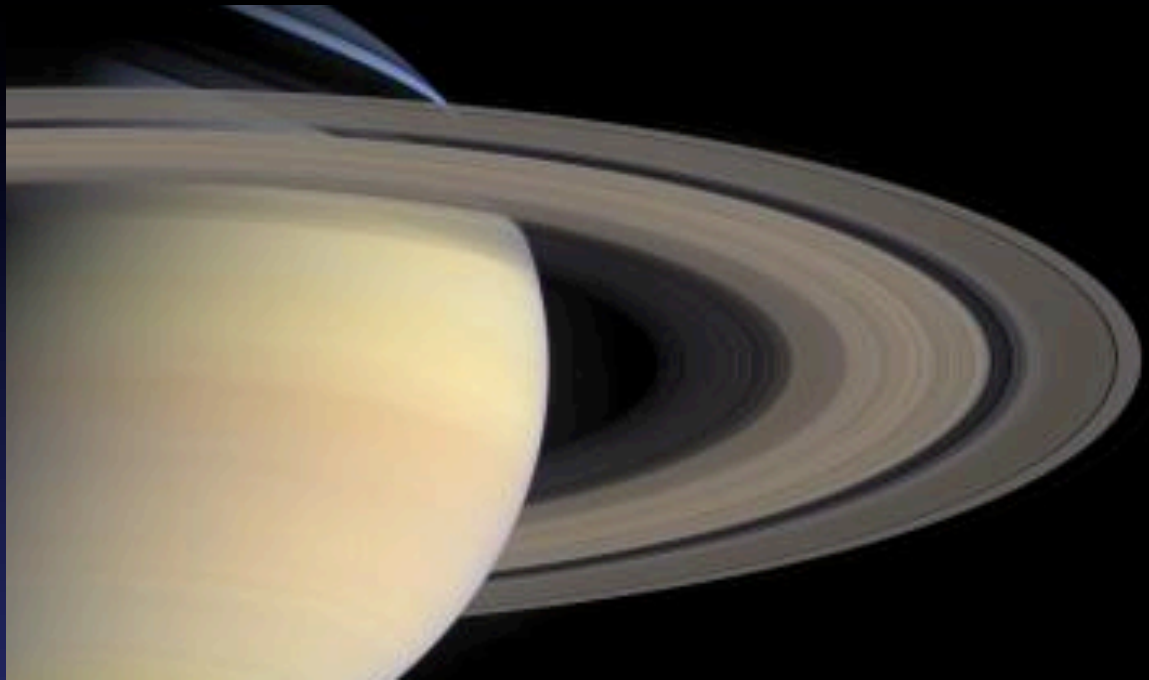
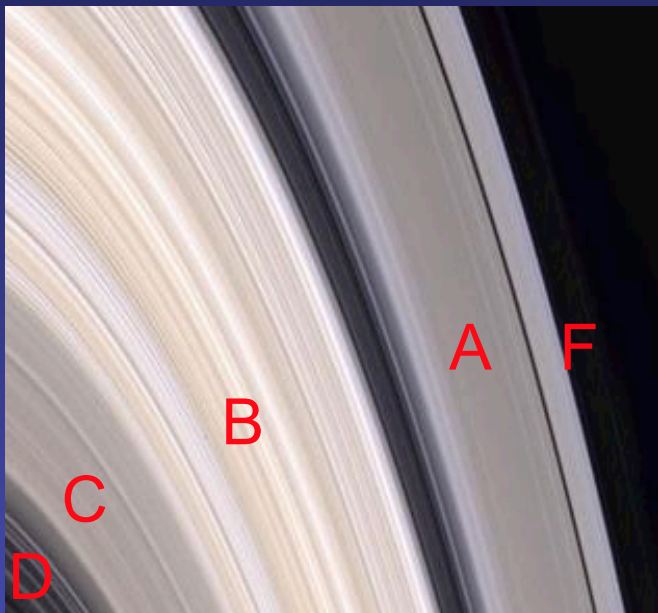
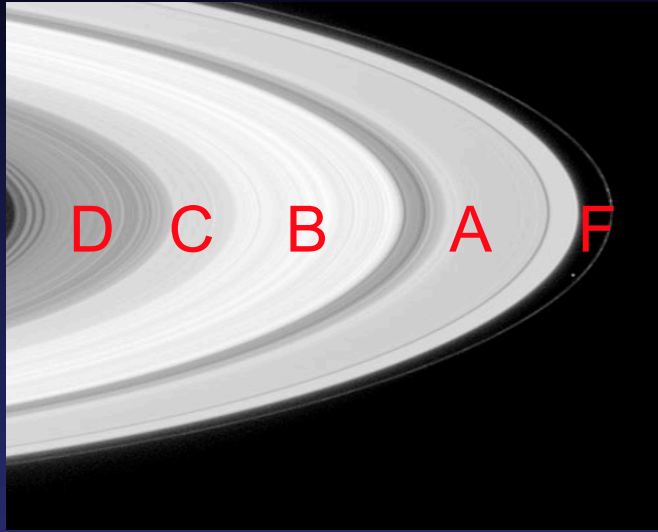
Pinkish nitrogen frost, surface ice of  $\text{CH}_4$ ,  $\text{CO}$ ,  $\text{CO}_2$ ,  
frozen lake of water ice...



A water-ice lake produced by an  
ice volcano

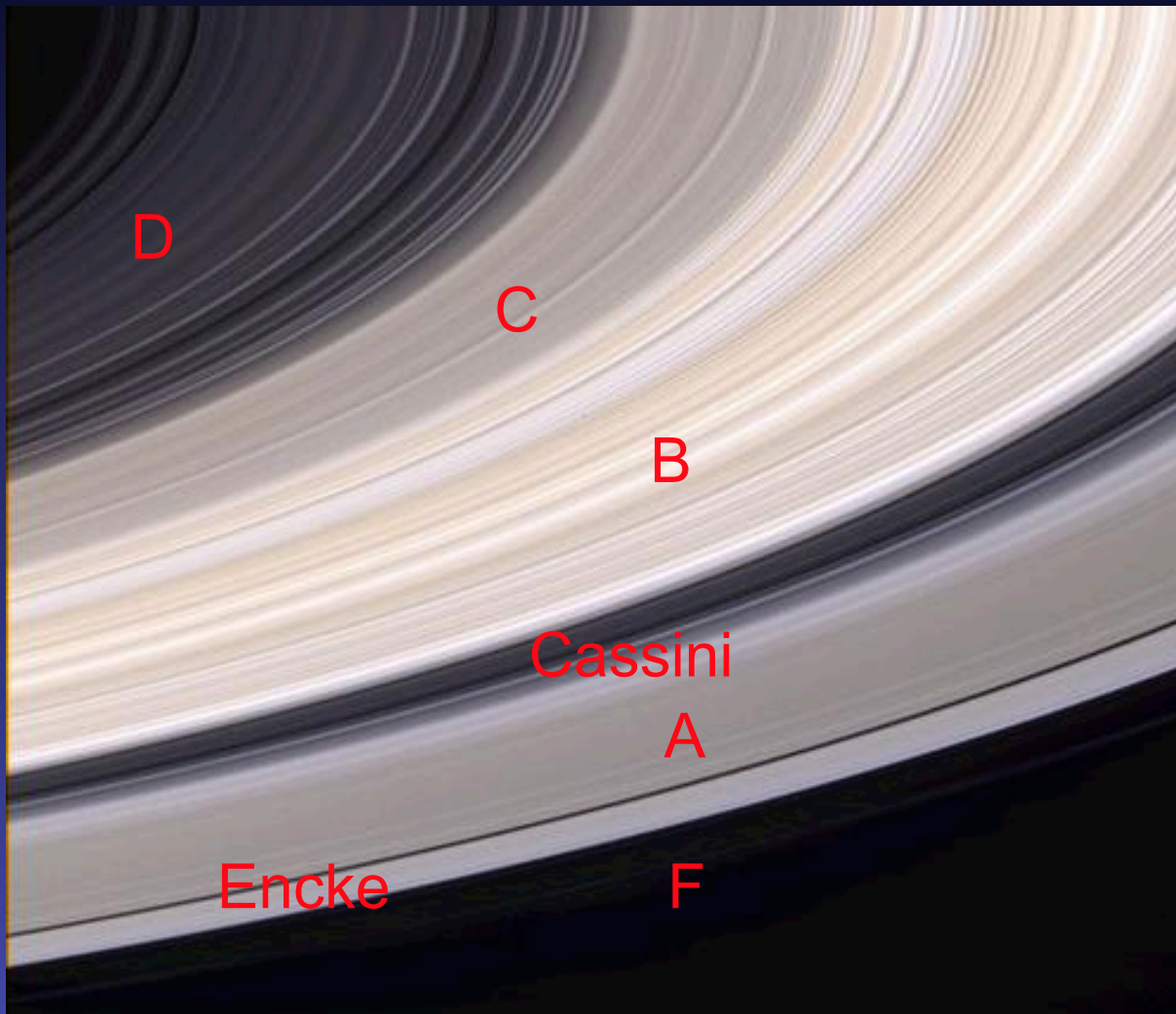


# Saturn's Rings





Rings are resolved into ringlets.  
Cassini division still contains ringlets.  
Encke gap is empty.



Ring	D (Rs)
D	1.00-1.21
C	1.21-1.53
B	1.53-1.95
Cassini	1.95-2.03
A	2.03-2.26
Roche L.	2.04
F	2.33
G	2.8
E	3-8

Roche limit:

$$r < f_R (\rho_p / \rho_m)^{1/3} R_p$$