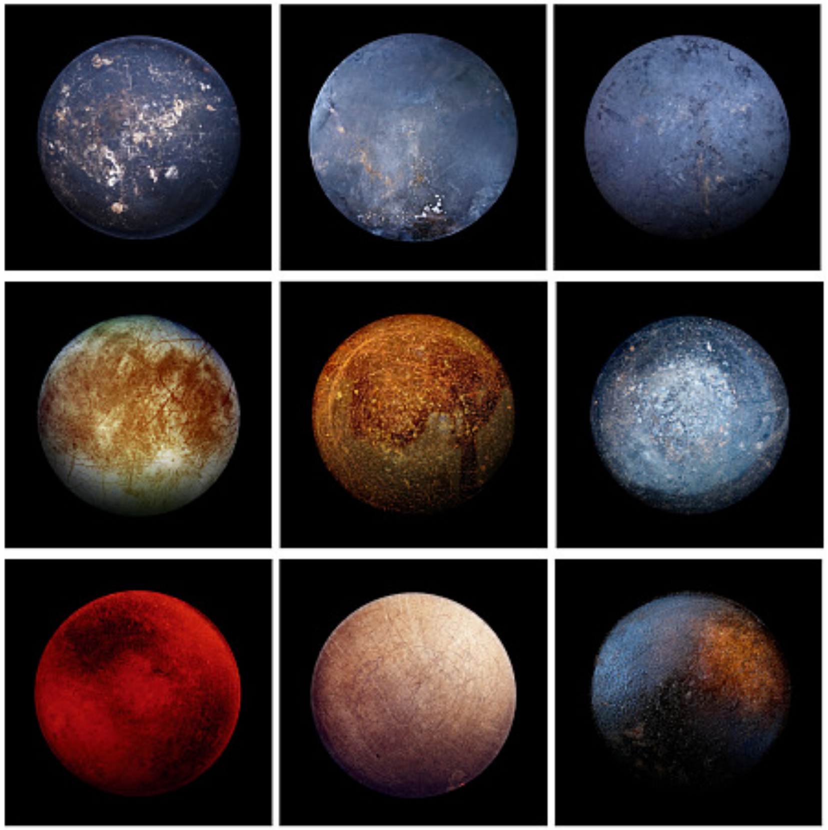
[19] Jovian Planet Moons and Rings (11/2/17)

Upcoming Items

1. Read Ch. 8.3 and 12.1–12.3 by next Thursday and do the self-study quizzes
2. Midterm #2 on Tuesday!

Which of these is Europa?

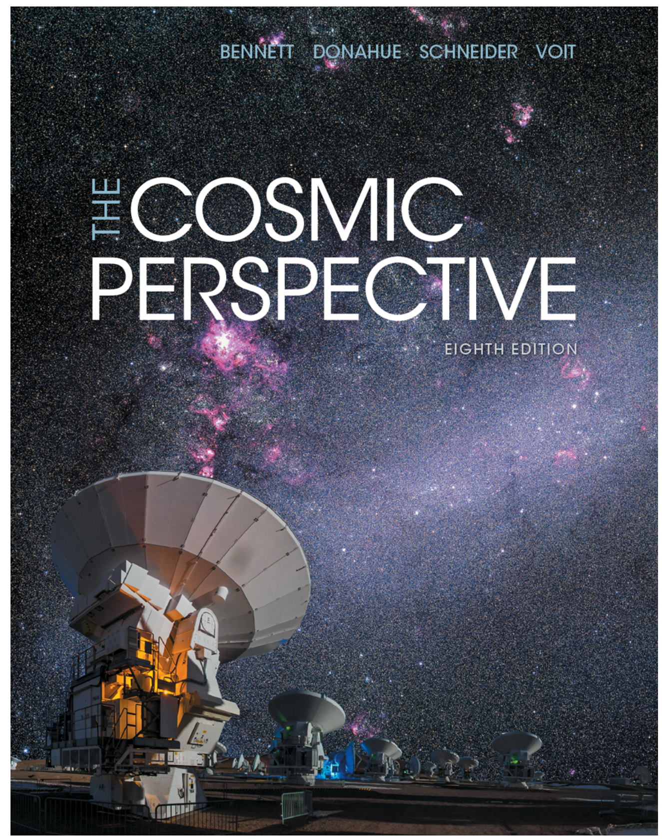


LEARNING GOALS

Chapters 11.2–11.3

For this class, you should be able to…

- … *predict the likely origin of a jovian planet moon, and whether it is expected to be geologically active, based on its size, shape, and orbit;*
- … *use the Roche limit to predict how far planetary rings may extend from a planet.*



Any astro questions?

In-class quiz

1. All of the following are reasons why Io is so active compared to the other Galilean satellites, EXCEPT

A. Io is the closest major satellite to Jupiter.
B. Io is in an eccentric orbit.
C. Io is deep inside Jupiter's magnetic field.
D. Io is in an orbital resonance with Europa and Ganymede.

2. The following are characteristics of jovian planet ring systems, EXCEPT

A. Ring particles closer to the planet orbit faster than ring particles farther from the planet.
B. The vertical extent of the rings is usually far less than the orbital extent.
C. They are made of particles ranging in size from tiny grains to large boulders.
D. Particles in rings never collide.

Jovian Planet Moons

1. Moon systems are like mini solar systems.
   - Large moons show orderly patterns of motion, likely formed in disk.
   - Small moons have irregular orbits, likely captured bodies.
   - But how could they be captured?
2. Many jovian planet moons are surprisingly active.
   - Tidal forces can heat interiors.
   - Ice geology is possible at far lower temperatures than rock geology.

The Roche Limit

- A loose collection of materials cannot hold together within the **Roche limit** of a planet,

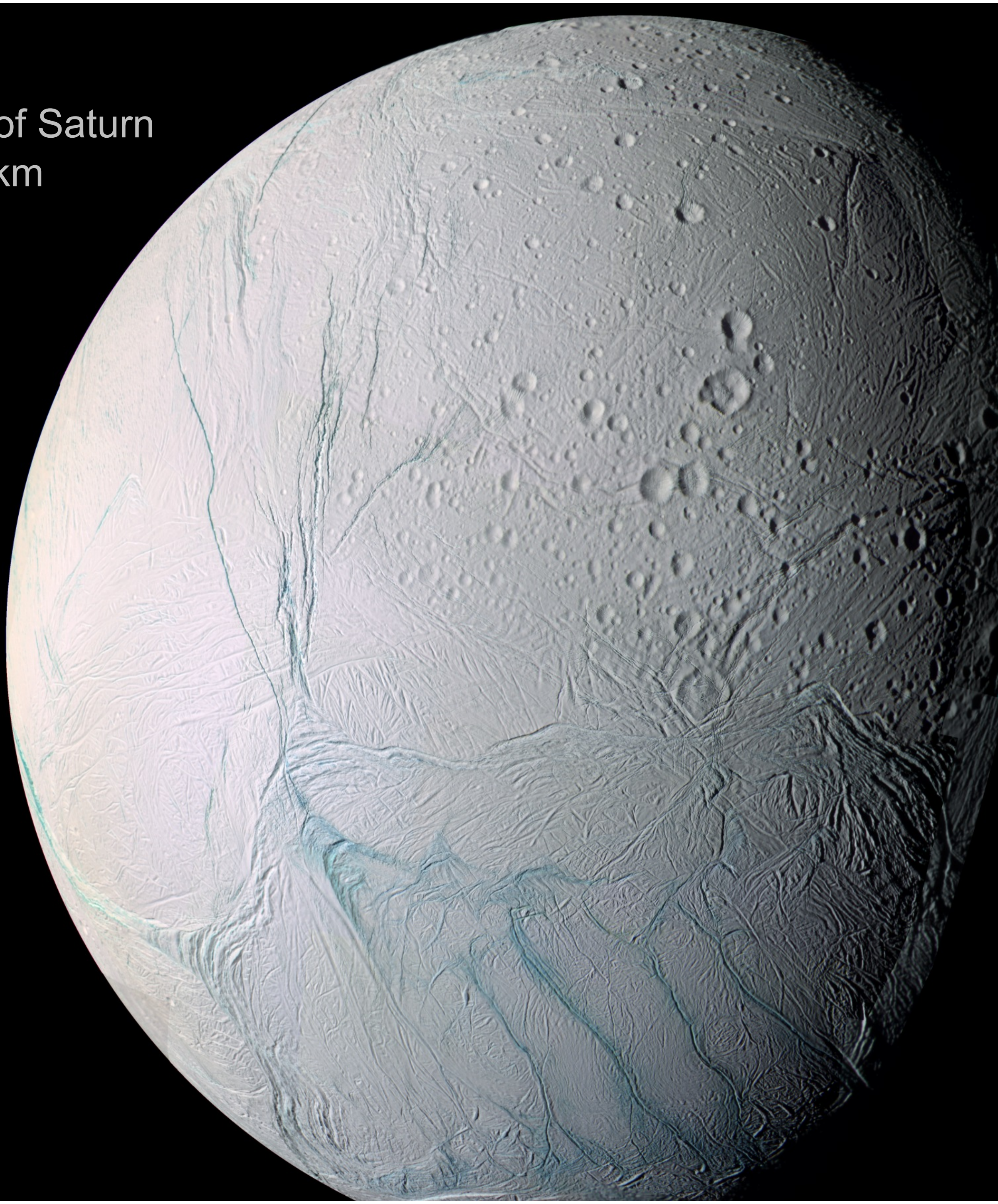
$$d \approx 1.26 R \left(\frac{\rho}{\rho_m} \right)^{1/3}.$$

- Here R and ρ are the radius and bulk density of the planet, and ρ_m is the bulk density of the material.

Jovian Planet Rings

1. All the jovian planets have ring systems.
   - Rings are made of many tiny orbiting particles, rocks, and ice balls.
   - Most rings are inside the ***Roche limit*** of the host planet.
   - Rings flatten and spread due to collisions, but embedded moonlets and larger exterior moons can keep ring segments in place.
2. Rings have two likely origins.
   - Breakup of a small moon, perhaps due to a violent collision.
   - Ejecta from micrometeorite impacts on a small moon.

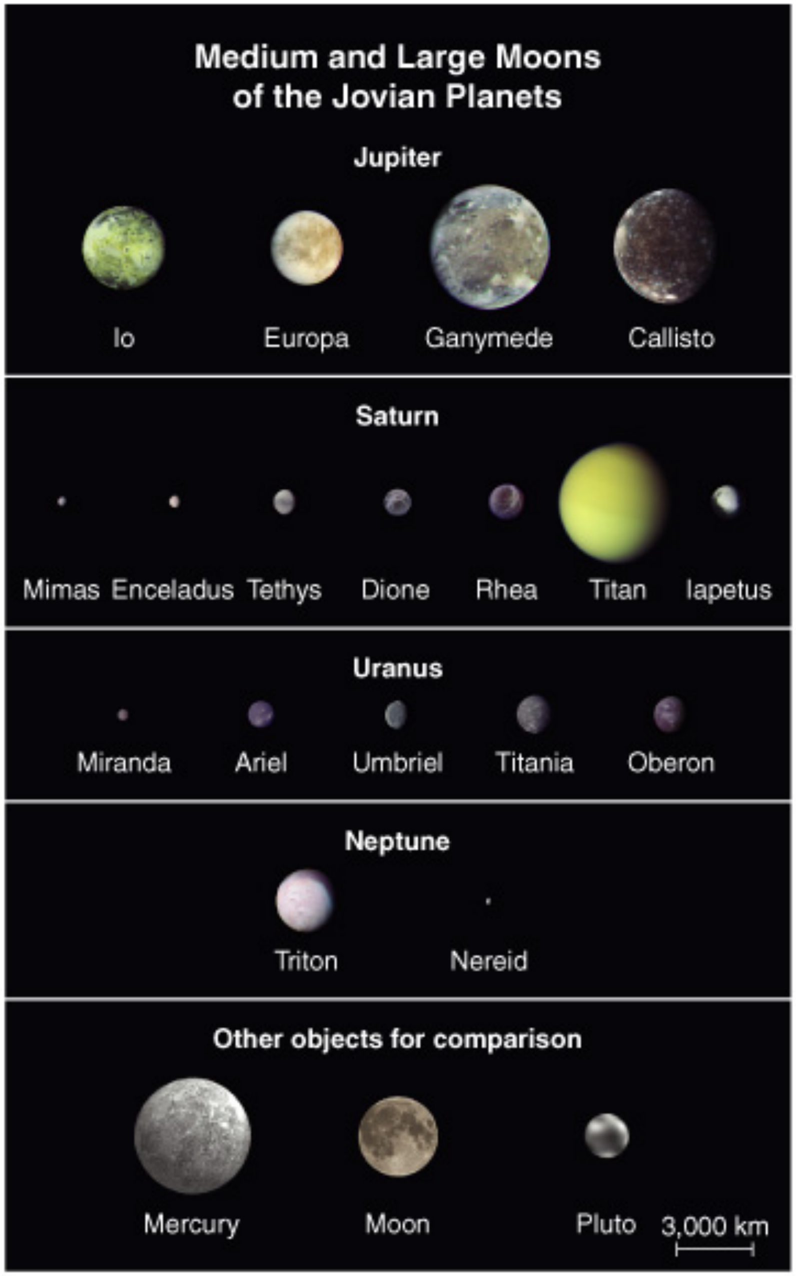
Enceladus
Medium moon of Saturn
Diameter: 500 km



Sizes of Moons

- Small moons (diameter < 300 km)
  - No geological activity.
- Medium-sized moons (300–1,500 km)
  - Geological activity in past.
- Large moons (> 1,500 km)
  - May have ongoing geological activity.

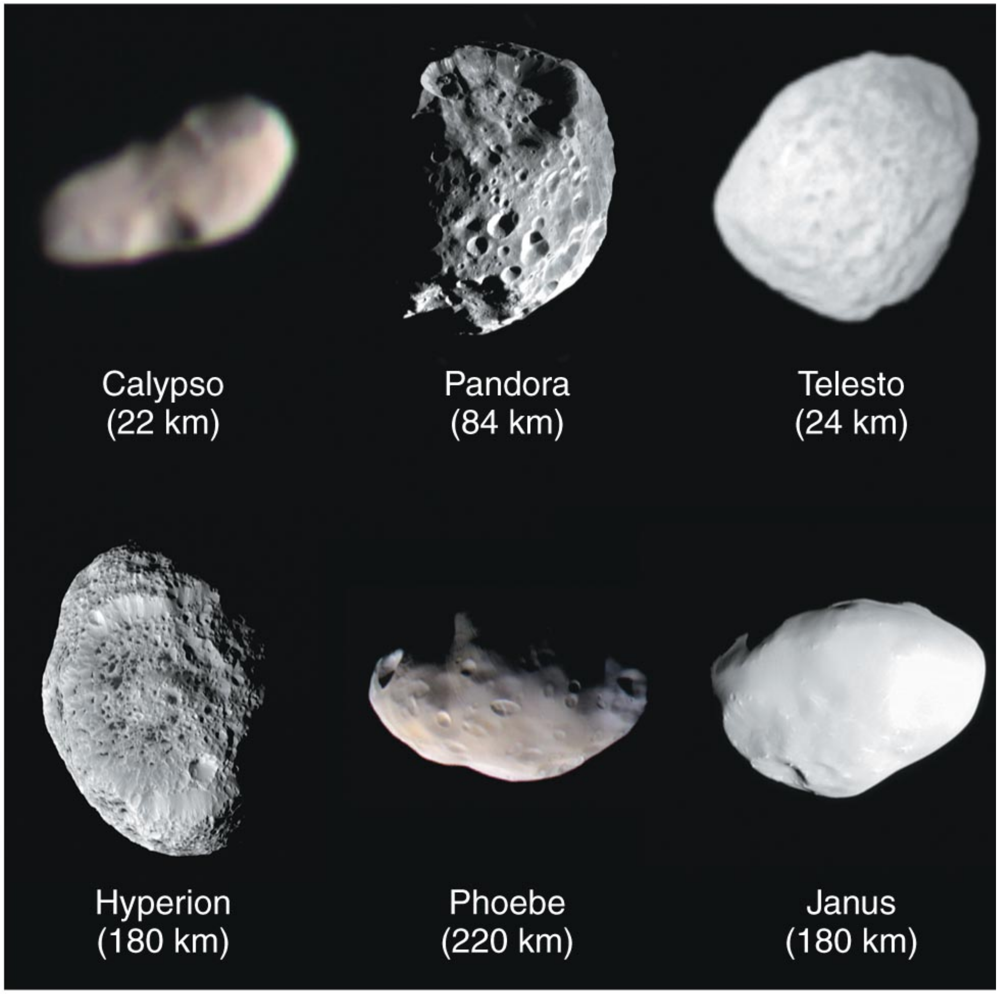
Exception: Enceladus (diameter 500 km) definitely active!



Medium and Large Moons

- Enough self-gravity to be spherical.
- Have substantial amounts of ice.
- Formed in orbit around jovian planets.
- Circular orbits in same direction as planet rotation.

Small Moons



- Far more numerous than the medium and large moons.
- Not enough gravity to be spherical: “potato-shaped.”
- They are captured asteroids or comets, so their orbits do not follow usual patterns.

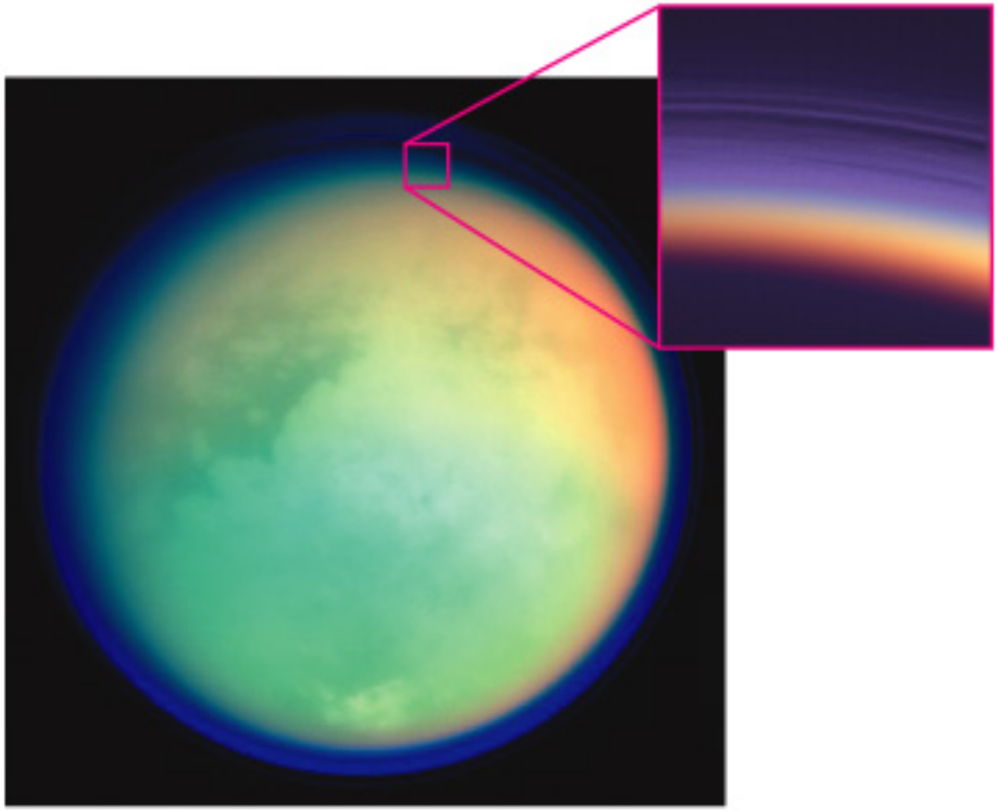
Can We Understand Moon Shapes?

- Group question!
- Highest mountain on Earth: ~10 km
  Earth's radius: about R=6400 km
- Grav. accel: $g=GM/R^2$
  Mass = density times volume: $M \sim \rho R^3$
  So how does grav. accel scale with R for constant density?
- We argued earlier that the maximum height of a mountain scales as 1/g, all else being equal (do you remember why?)
- Thus your group question is: for what R do you expect that the maximum height of a mountain is roughly R?
  Works as a rough measure of when moons can be very non-spherical

Titan (Moon of Saturn)

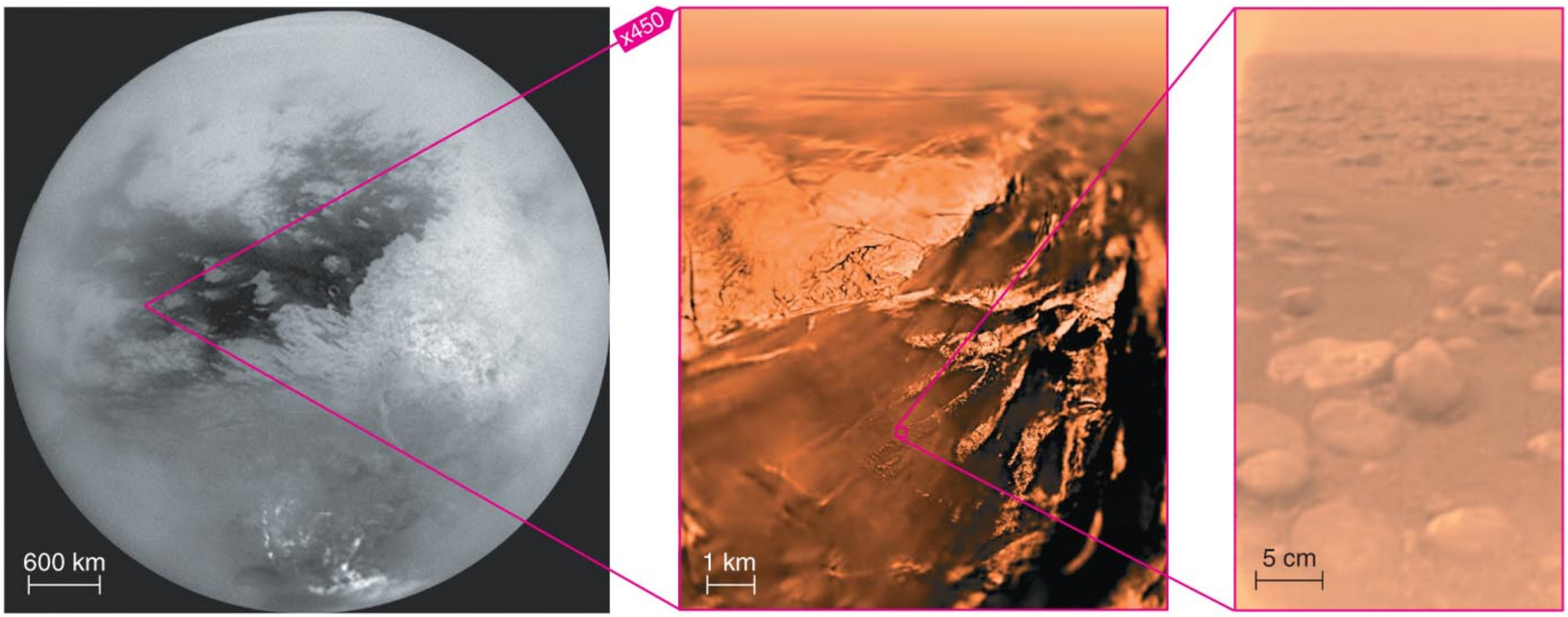
- Only moon with a thick atmosphere (~95% N_2, most of the rest is CH_4).
- Surface pressure of 1.4 atm.
- Surface temperature 95K (greenhouse!).
- Exotic methane-based "weather."
  - Past and present rivers and lakes of methane/ethane.
  - UV + $2NH_3 \rightarrow N_2 + 3H_2$ (escapes).
  - UV + $CH_4 \rightarrow$ hydrocarbons, e.g., C_2H_6.

Titan's Atmosphere



- Haze layers extend ~100 km above surface.
- Can peer through veil at specific IR wavelengths.

Titan's Surface



- The *Huygens* probe provided a first look at Titan's surface in early 2005.
- It has liquid methane and "rocks" made of ice.

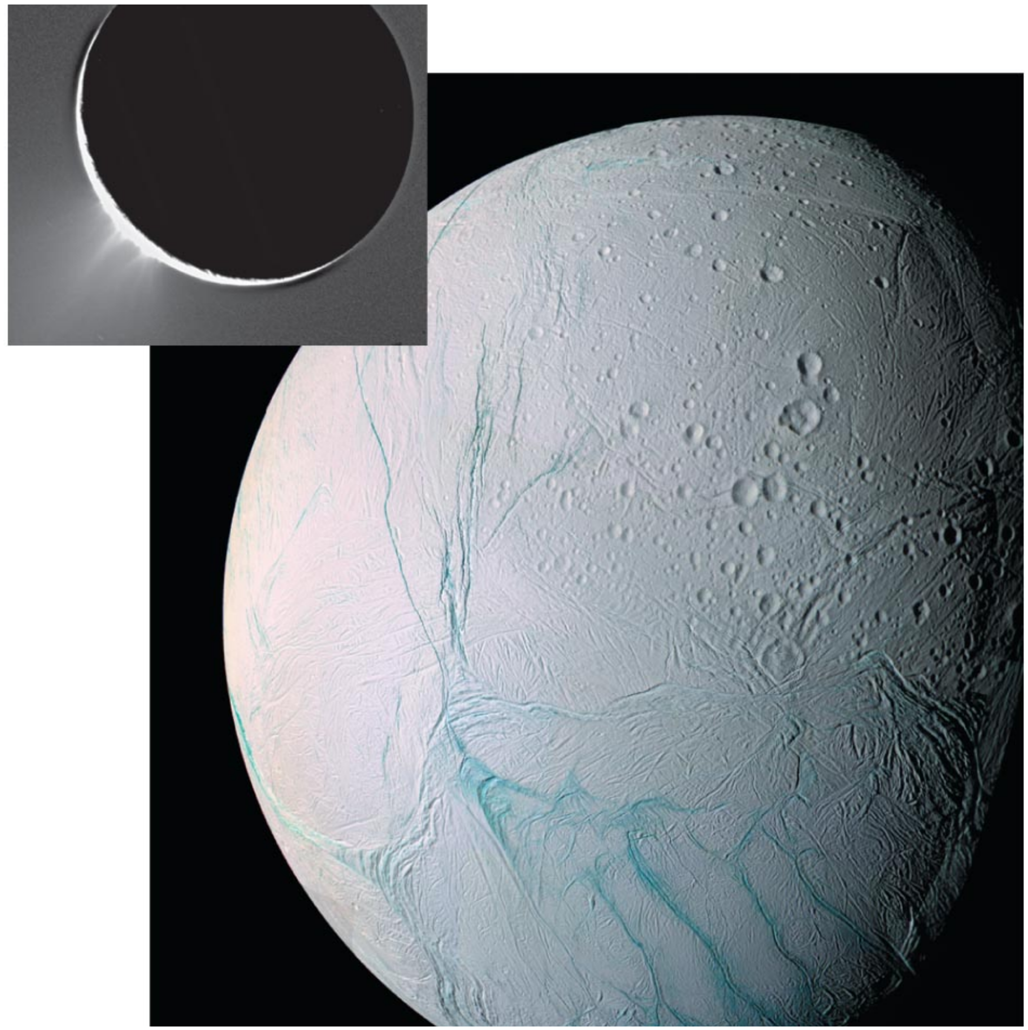
The Big Picture

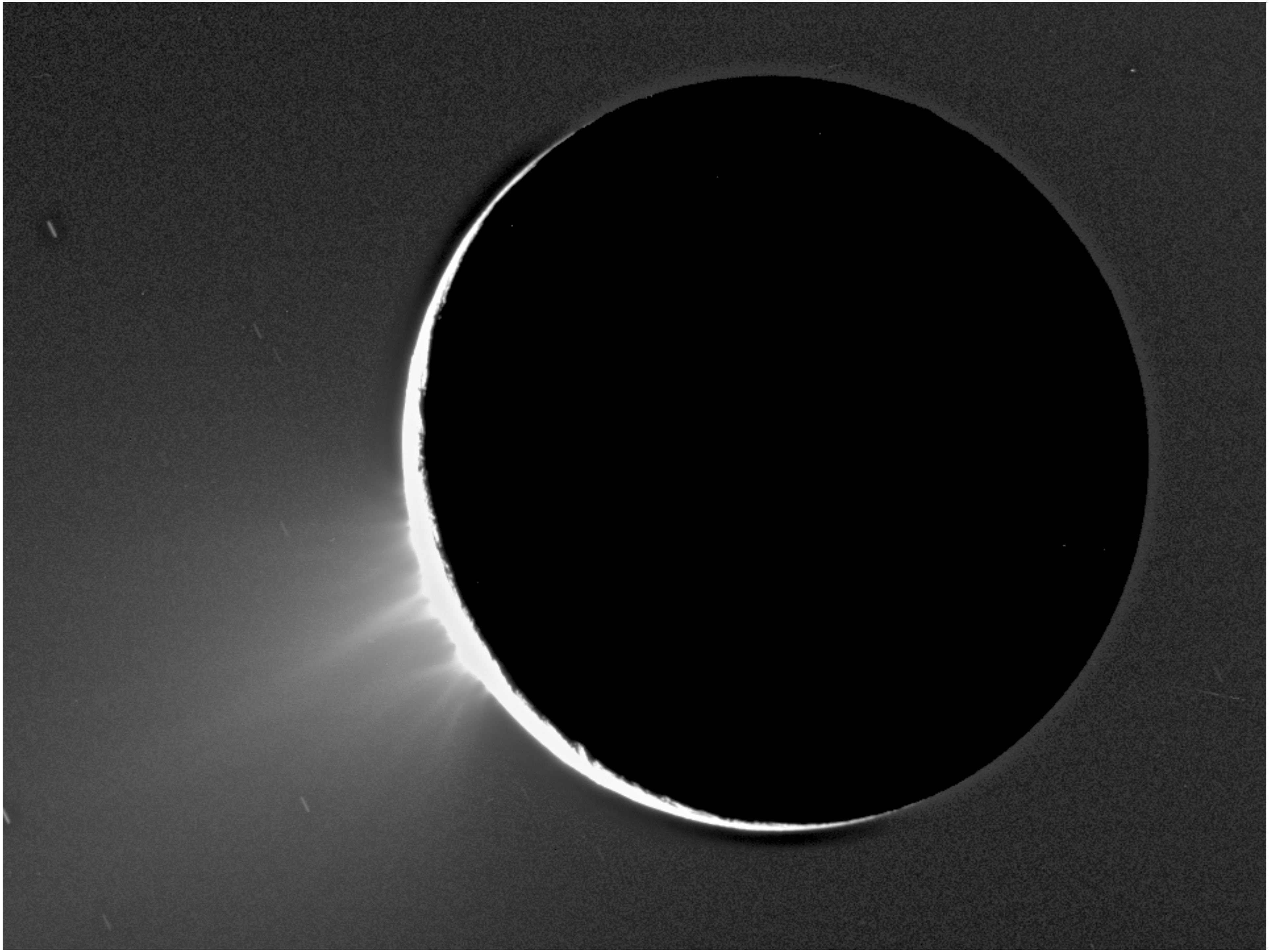
- Earth and Titan are the only two objects in the solar system that have stable bodies of liquid at the surface
- Similar processes help maintain surface liquids and atmospheric compositions, despite very different temperatures and materials at each body
- Surface liquids facilitate erosion, and can create ‘Earth-like’ landscapes (e.g. sedimentary layers, river beds, …)
- Surface liquids may exist on a variety of bodies orbiting other stars, and not be restricted to ‘Earth-like’ bodies

Photograph taken from the space shuttle of glinted sunlight from Earth’s oceans.

Ongoing Activity on **Enceladus**

- Fountains of ice particles and water vapor from the surface of Enceladus indicate that geological activity is ongoing.

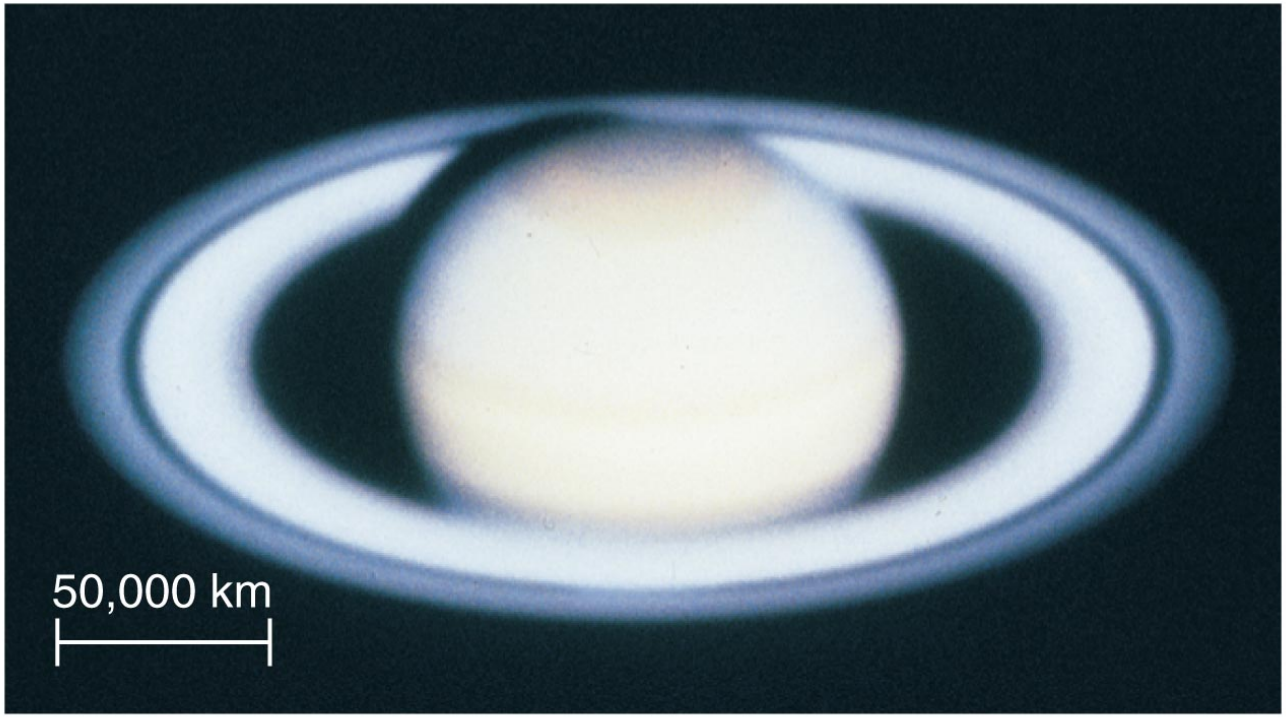




Saturn's Rings

- Saturn is famous for its rings…
  - Galileo discovered them in 1610.
  - Huygens first identified them as flat rings.
  - Maxwell showed that they can't be solid… must be composed of many small particles in orbit around Saturn's equator.
  - Found to have spectral signatures of water in 1970s.
- Basic characteristics of Saturn's rings
  - Very thin… just 50 m or less!
  - Composed of ice particles ranging from dust-sized to ~ 5 m.
  - Very complex structure driven by resonances between ring orbits and various satellites.
- Possible origin of rings… two ideas
  - Rings are short-lived… we just happen to be catching Saturn at a time after a small satellite has been disrupted.
  - Rings are long-lived… ancient debris, continually replenished by new material from satellites.

Earth-based View of Saturn



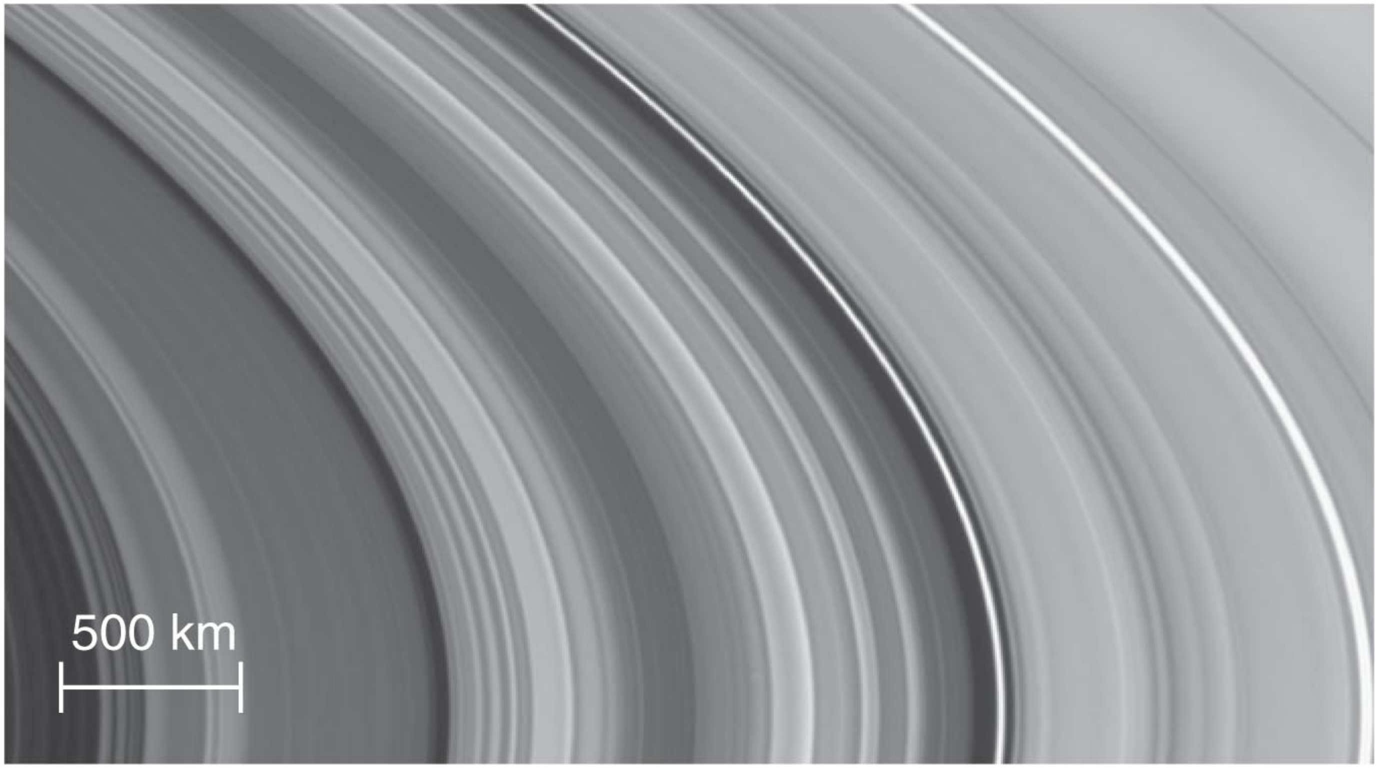
a This Earth-based telescopic view of Saturn makes the rings look like large, concentric sheets. The dark gap within the rings is called the *Cassini division*.

Spacecraft View

On a scale in which Saturn's main rings are as thin as a sheet of paper, how large an area would they cover?

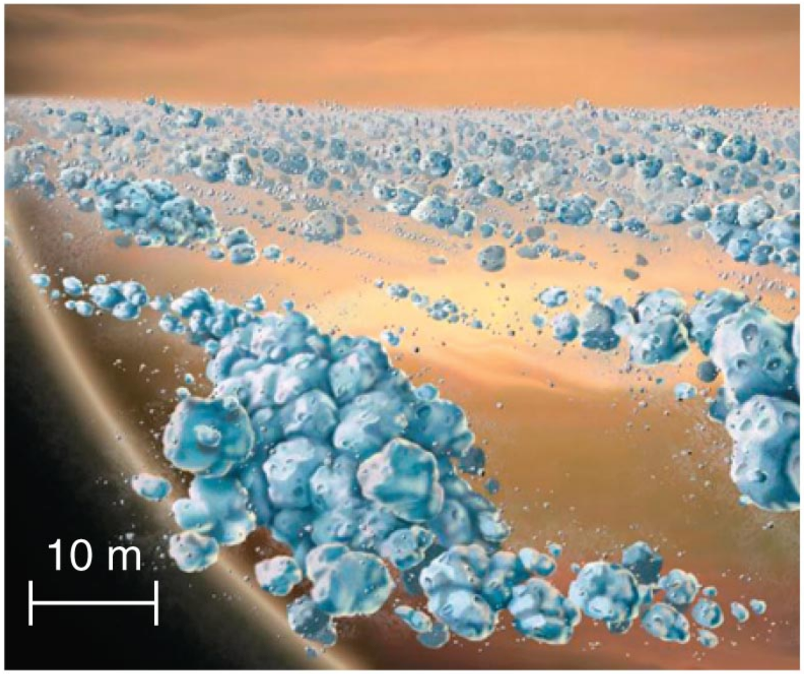
A. A sheet of paper
B. A football field
C. Our campus
D. The United States

Spacecraft View of Ring Gaps What could cause the gaps?



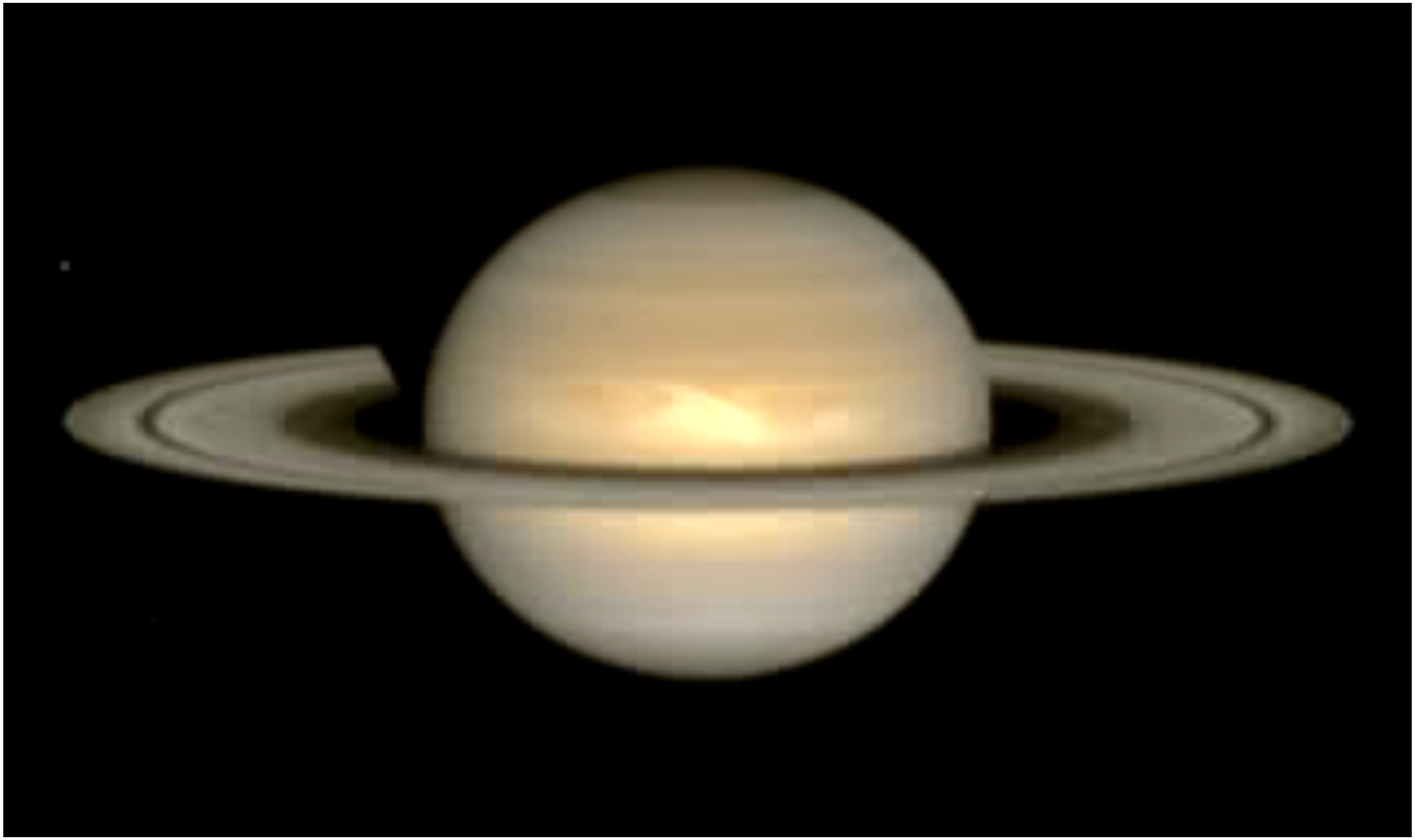
b This image of Saturn's rings from the *Cassini* spacecraft reveals many individual rings separated by narrow gaps.

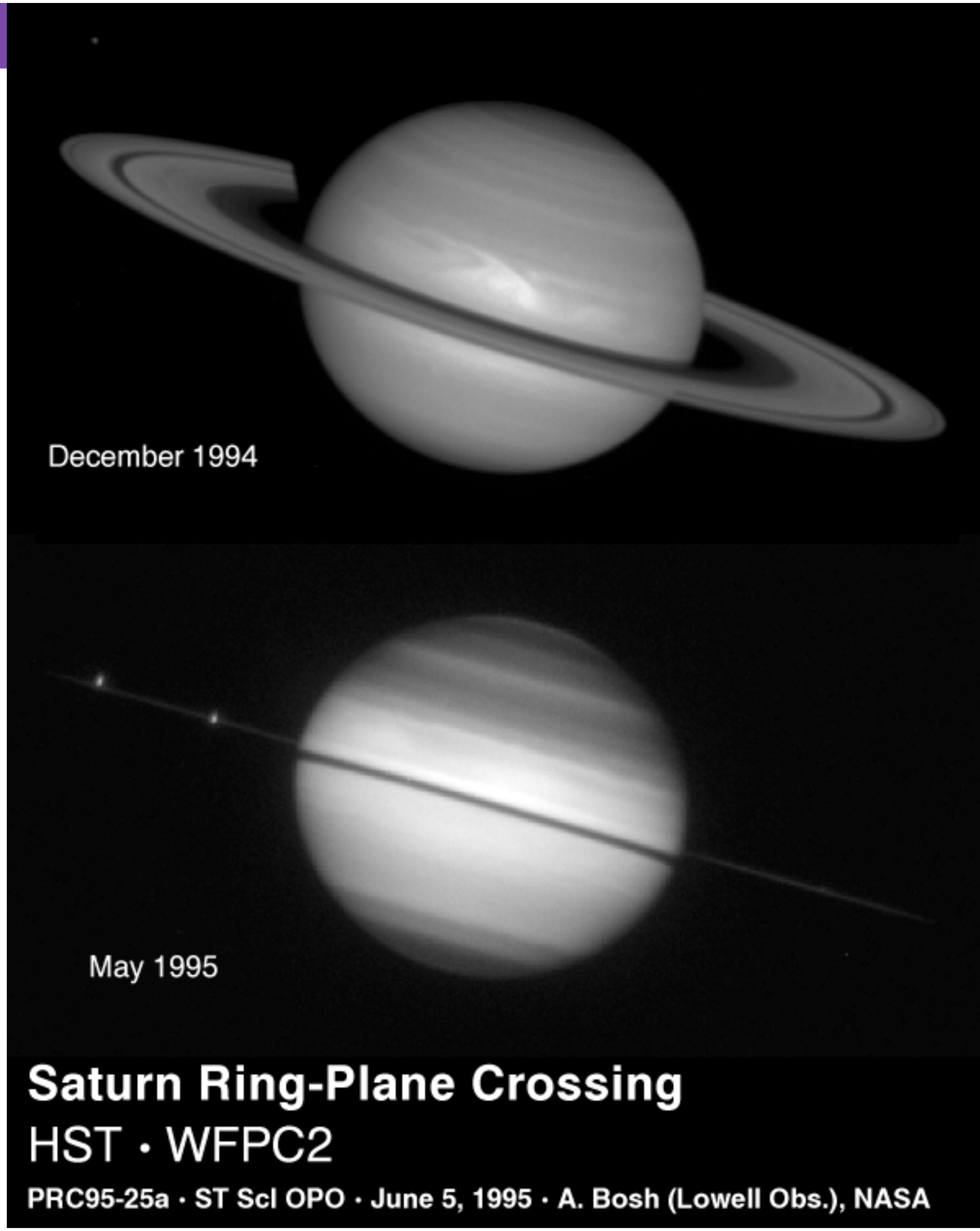
Artist's Conception of Rings Close Up



c Artist's conception of particles in a ring system. Particles clump together because of gravity, but small random velocities cause collisions that break them up.

Effect of Viewing Angle




December 1994
May 1995
Saturn Ring-Plane Crossing
HST • WFPC2
PRC95-25a • ST ScI OPO • June 5, 1995 • A. Bosh (Lowell Obs.), NASA

Cassini Ring Plane Crossing