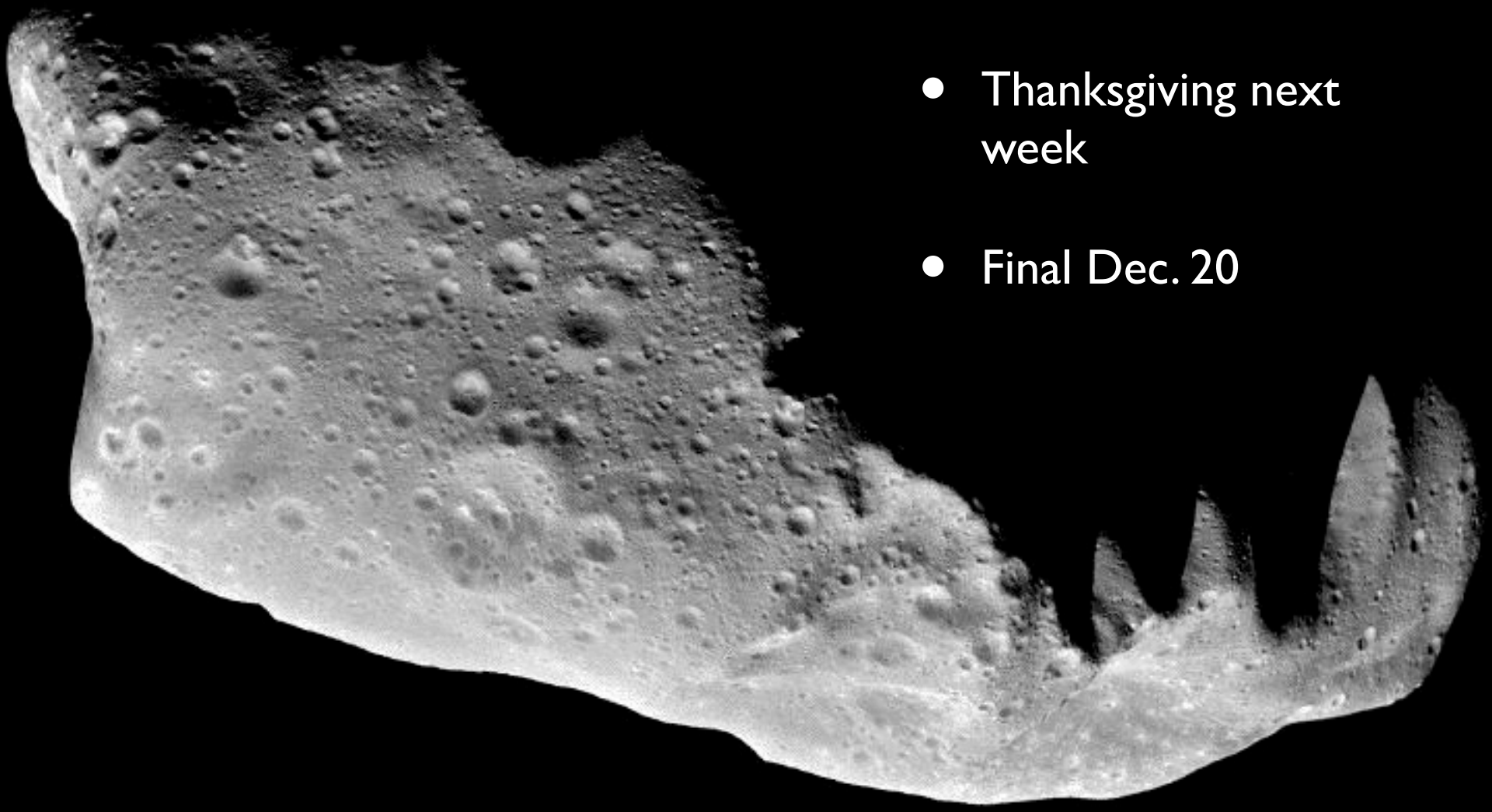
Today

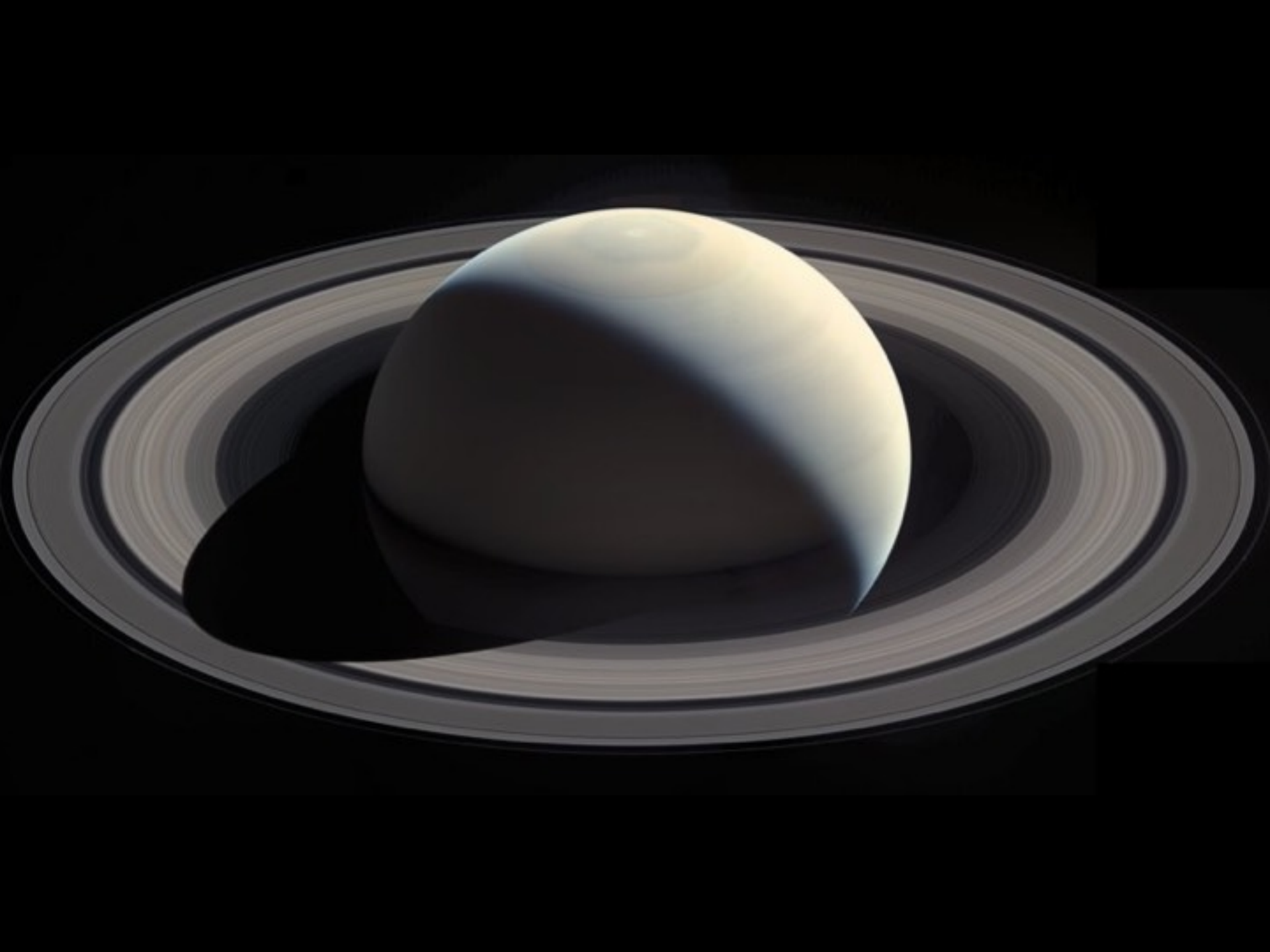
- Rings, asteroids, meteorites

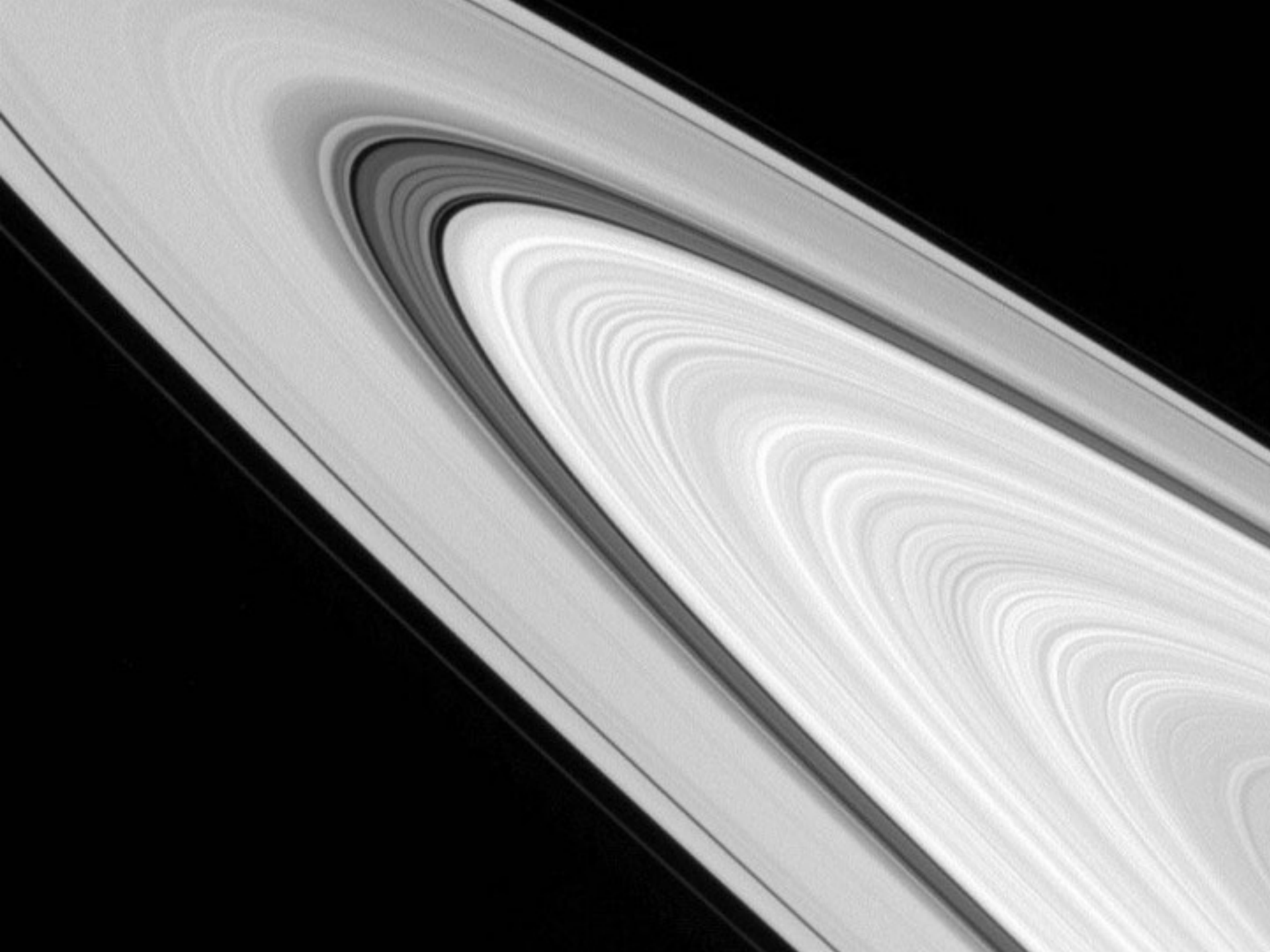
Events

- Homework 5 Due
- Thanksgiving next week
- Final Dec. 20

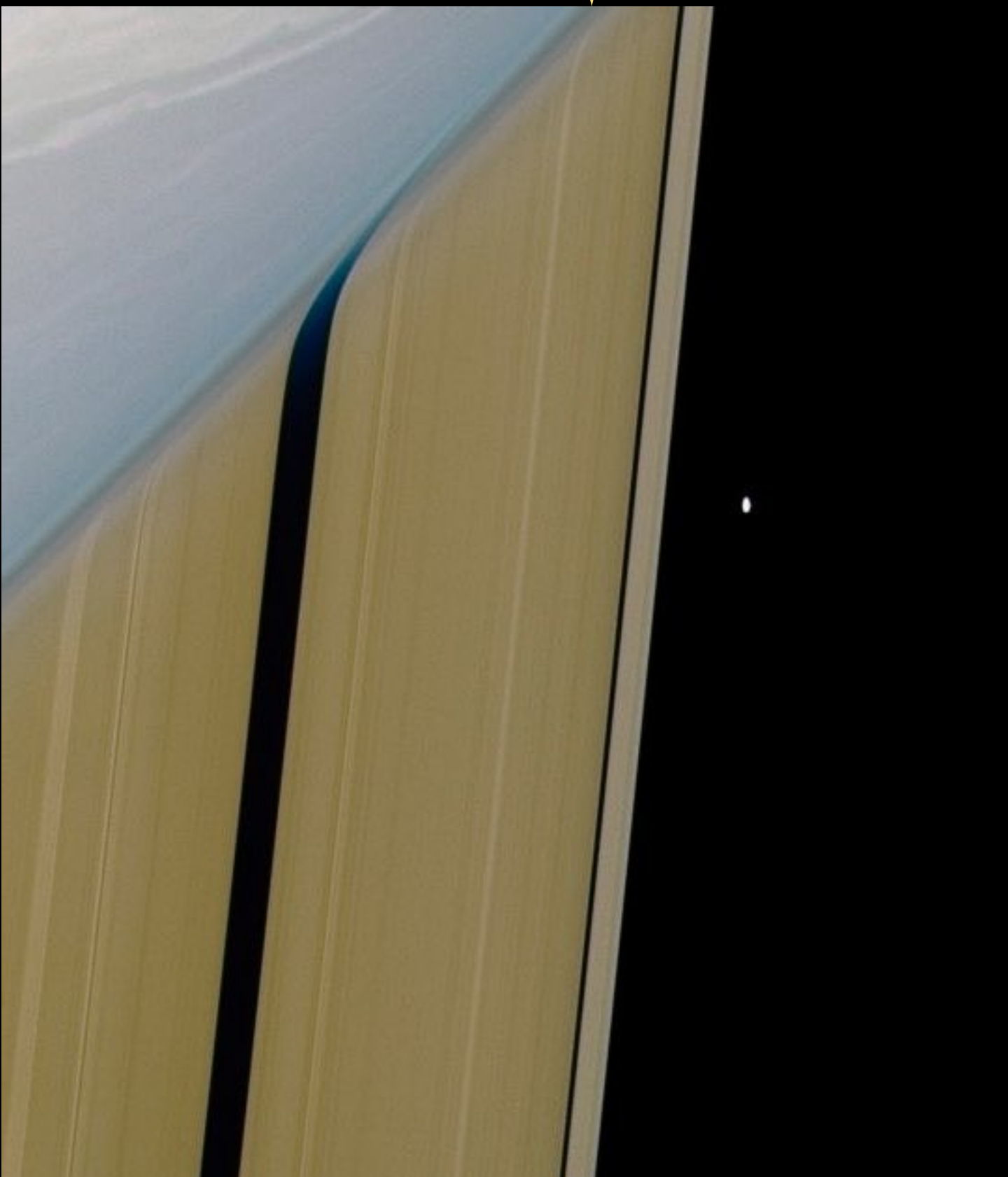


Saturn's rings





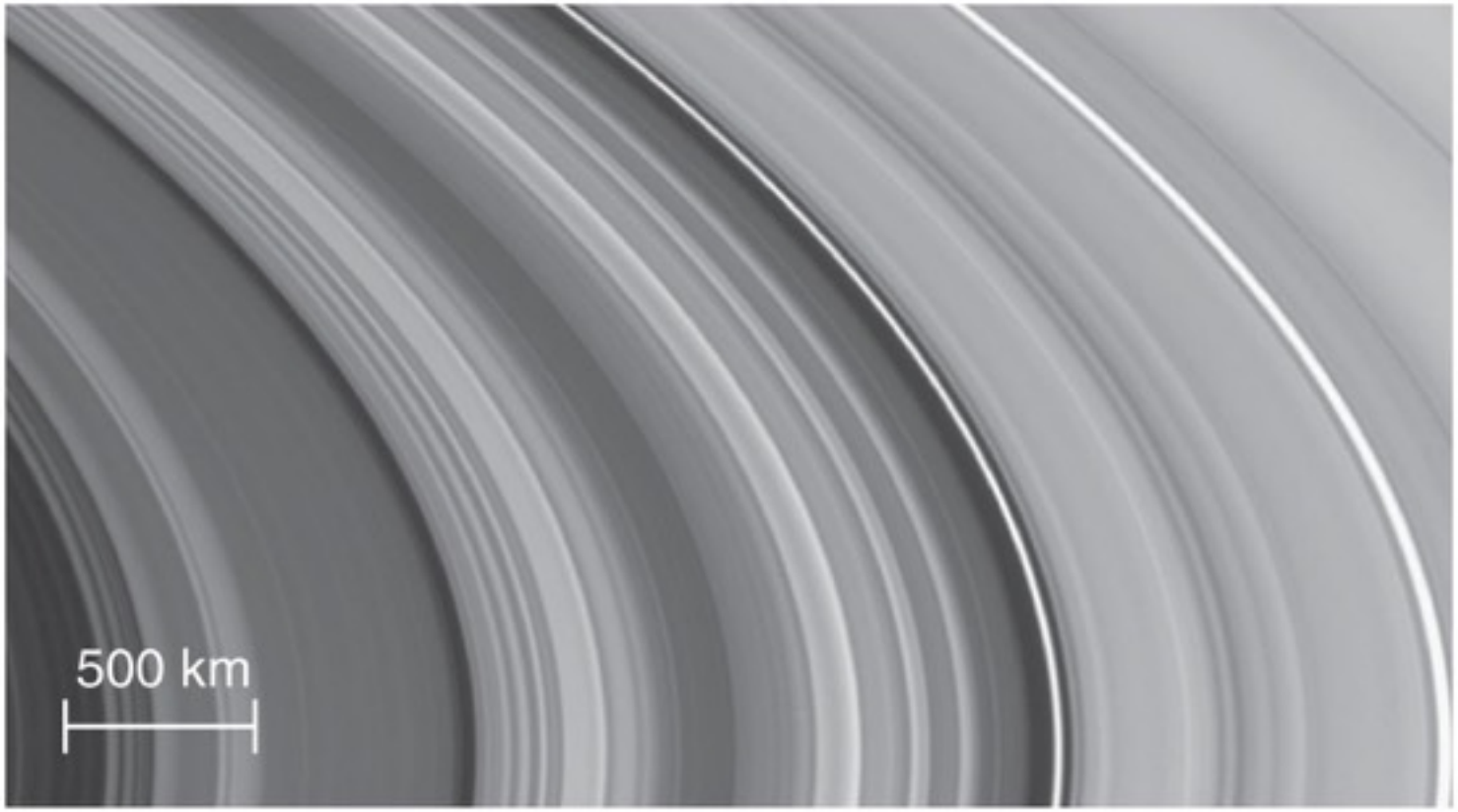
Note refraction in atmosphere



What are Saturn's rings like?

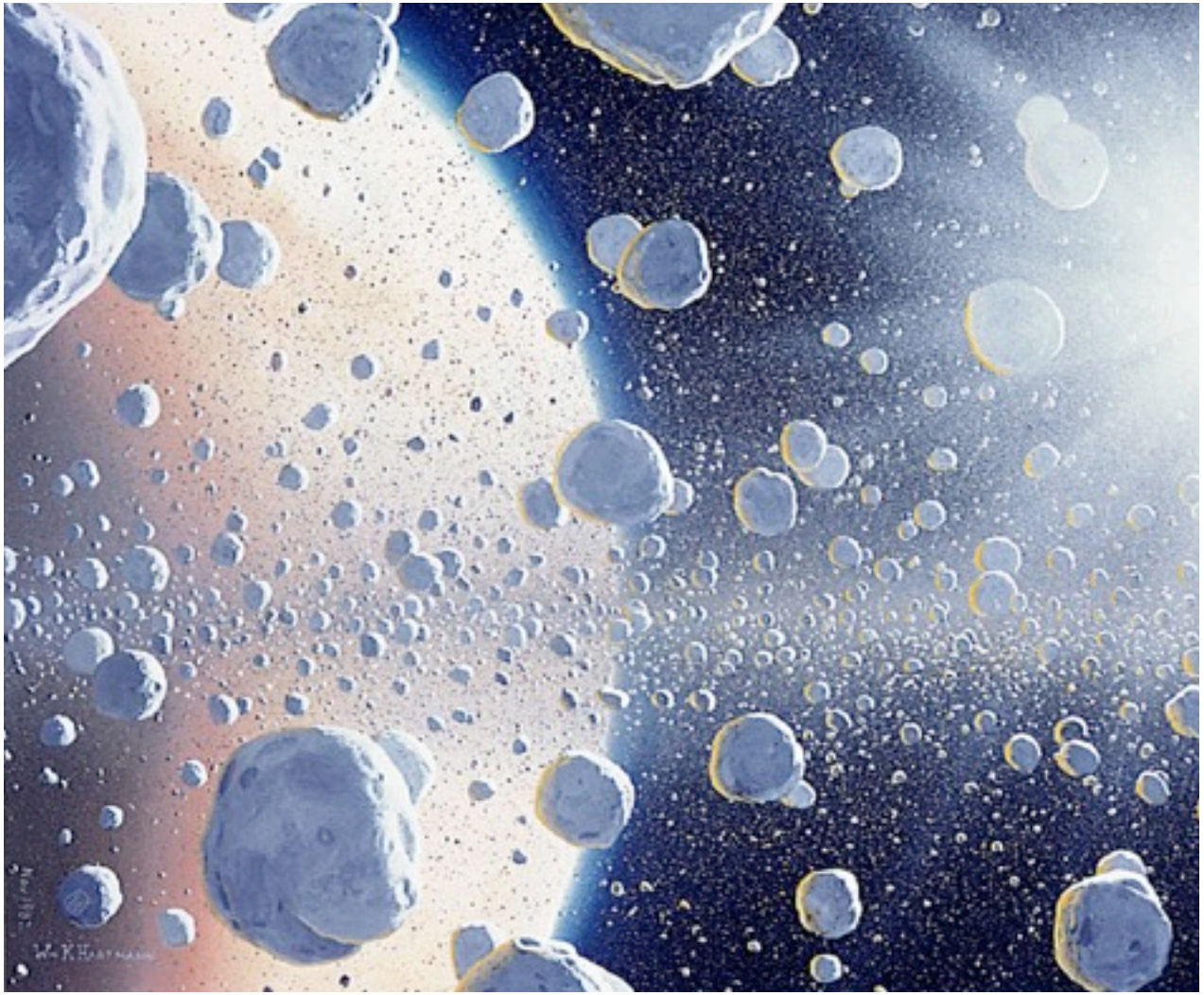
- They are made up of numerous, small, icy particles (boulder size & smaller).
- They orbit over Saturn's equator.
- They are very thin (~ 10 m).

Spacecraft View of Ring Gaps



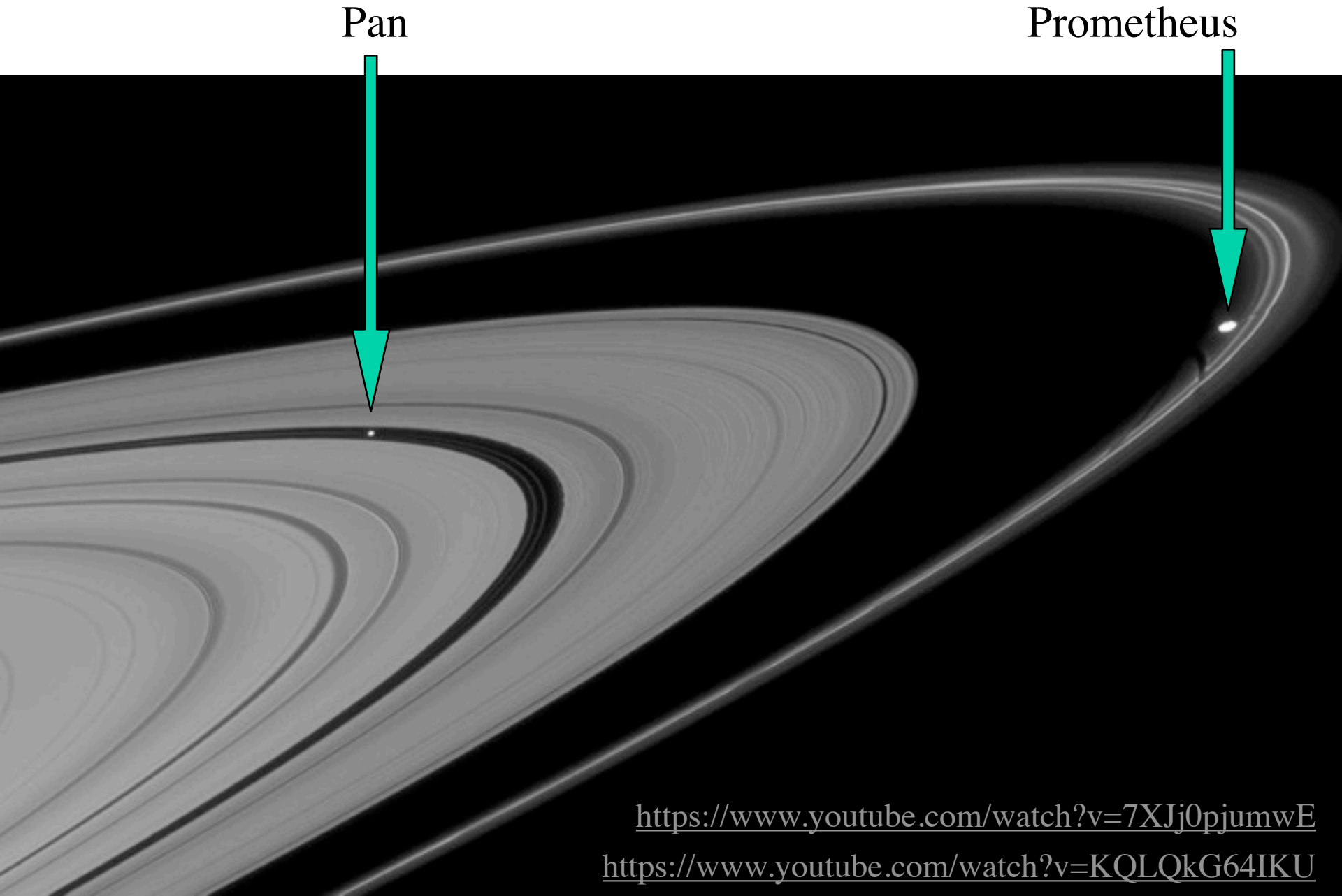
b This image of Saturn's rings from the *Cassini* spacecraft reveals many individual rings separated by narrow gaps.

Artist's Conception in Ring



IF_11_33_ZoomSaturnRings

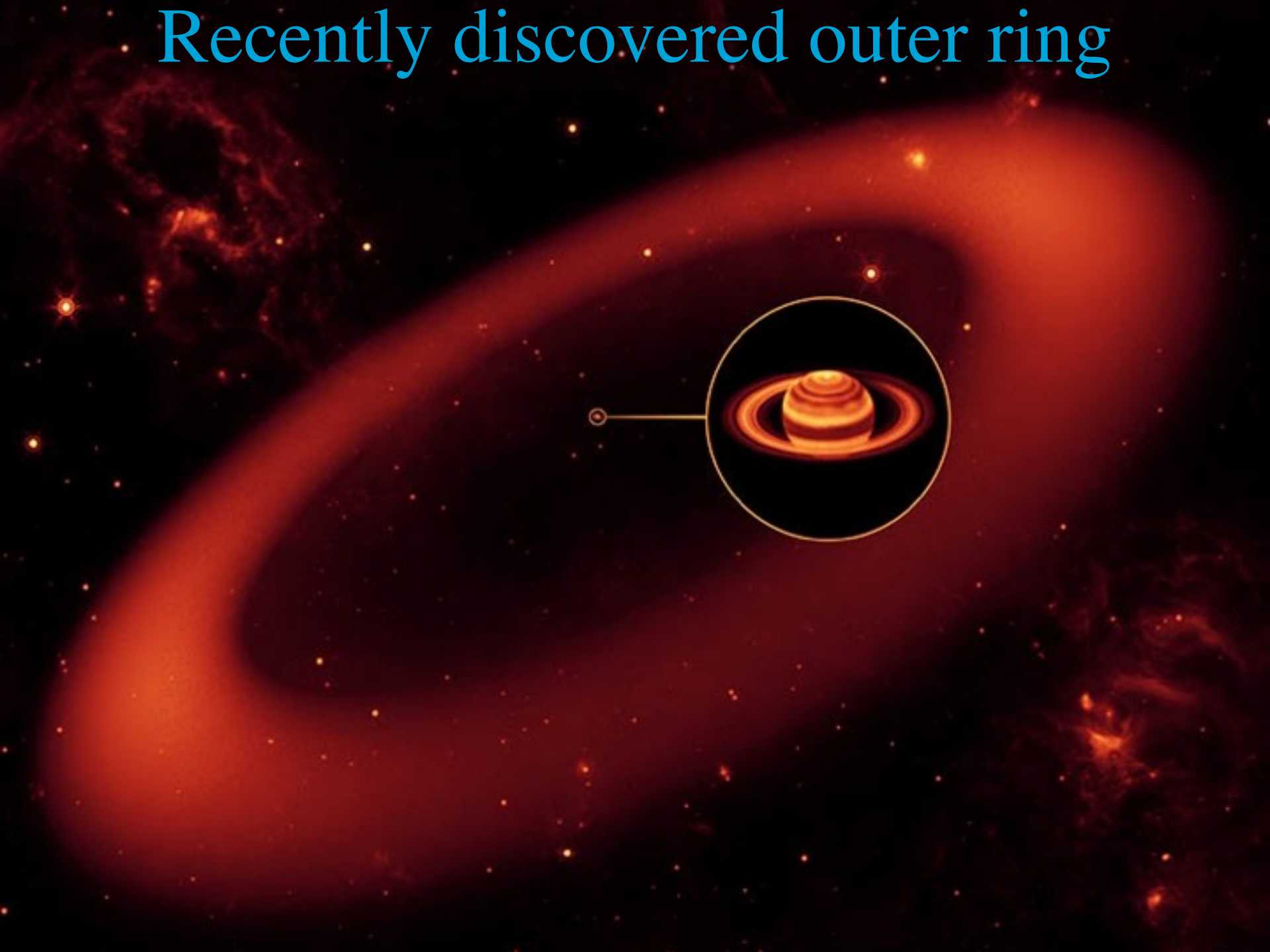
Elaborate structure in rings controlled by the gravity of “shepherd” moons

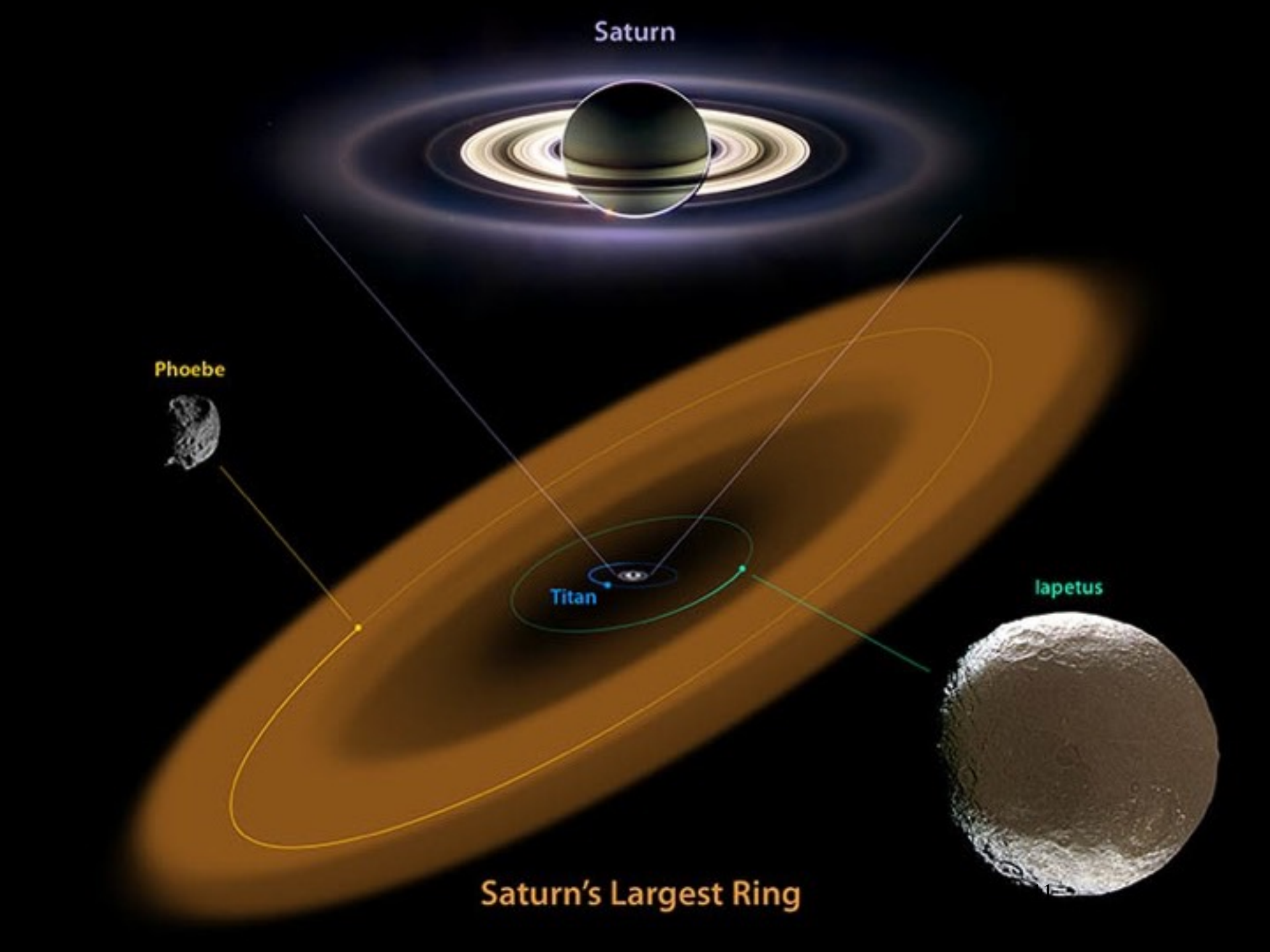


https://www.youtube.com/watch?v=7XJj0pjumwE

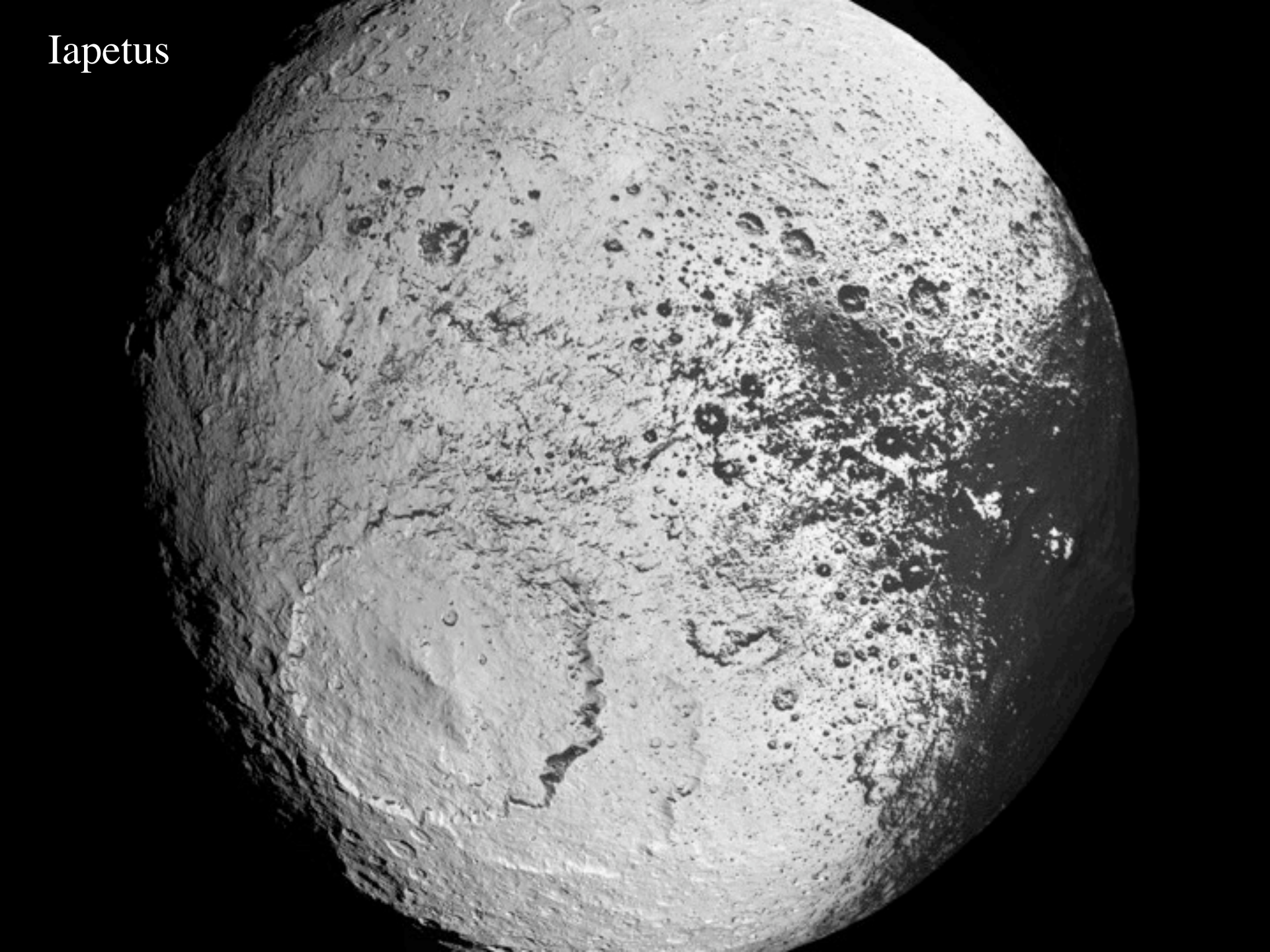
https://www.youtube.com/watch?v=KQLQkG64IKU

Recently discovered outer ring



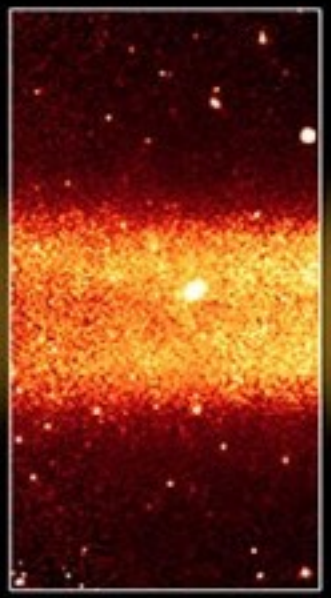

Saturn
Phoebe
Titan
Iapetus
Saturn's Largest Ring

Iapetus



Saturn

actual data

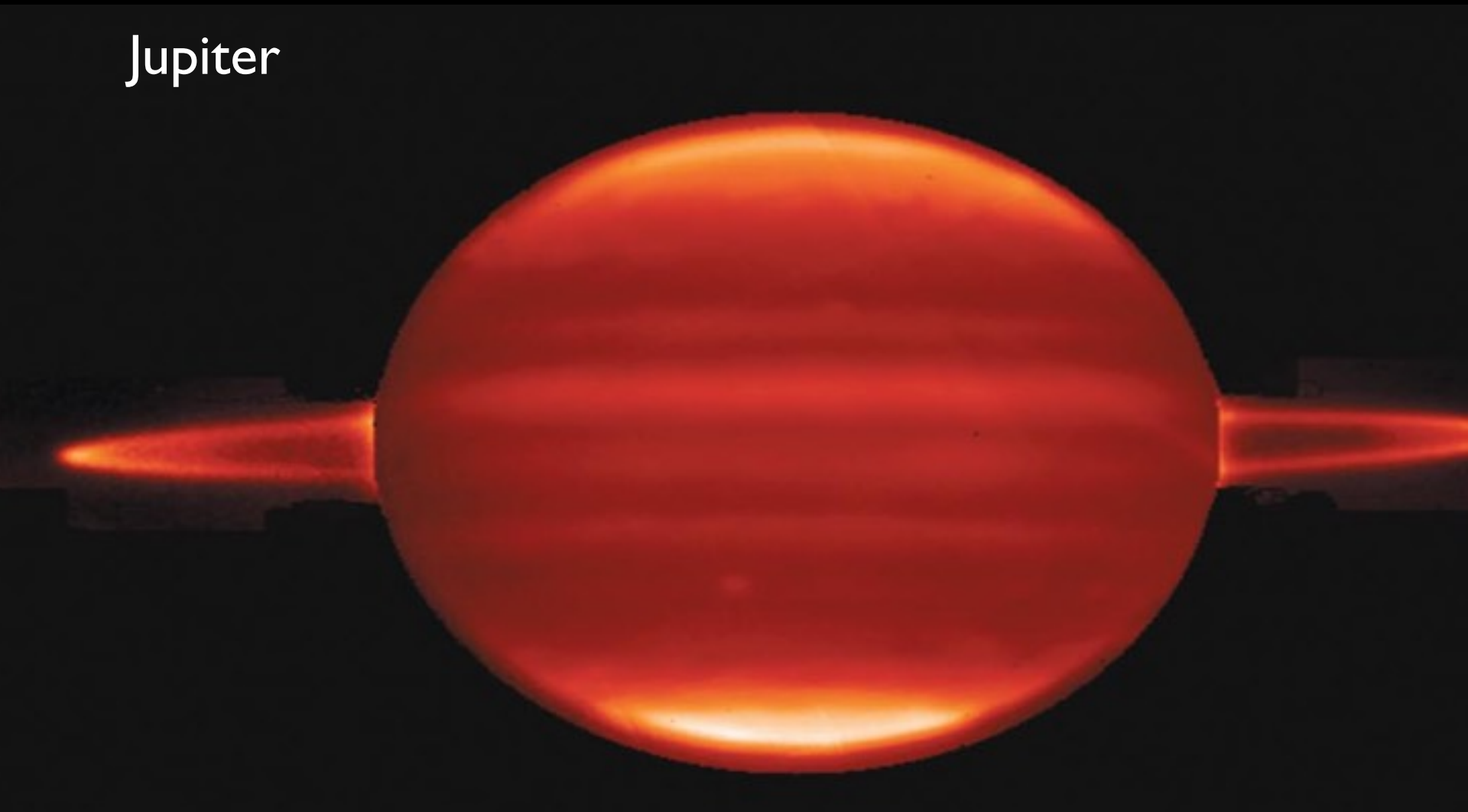


Dust Ring

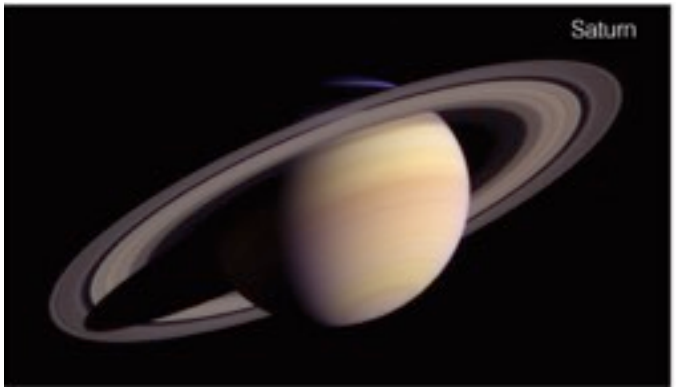
Infrared View of Saturn's Largest Ring
NASA / JPL-Caltech / A. Verbiscer (Univ. of Virginia)

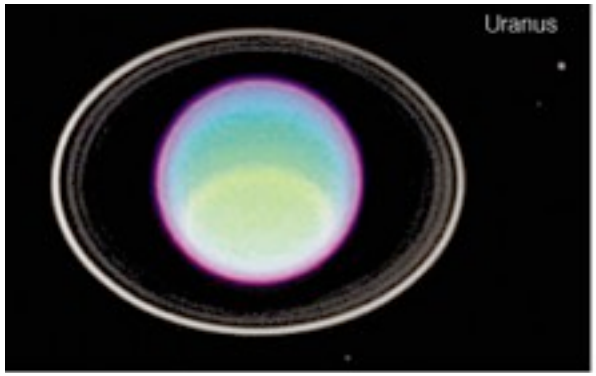
Spitzer Space Telescope • MIPS
ssc2009-19a

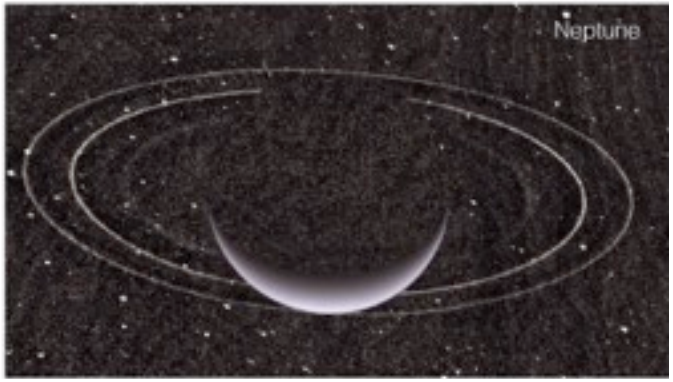
How do other jovian ring systems compare to Saturn's?



Jovian Ring Systems







- All four jovian planets have ring systems.
- Others have smaller, darker ring particles than does Saturn.
- Rings and moons ubiquitous around Jovian planets
  - like small solar systems.

Rings are short-lived yet ubiquitous

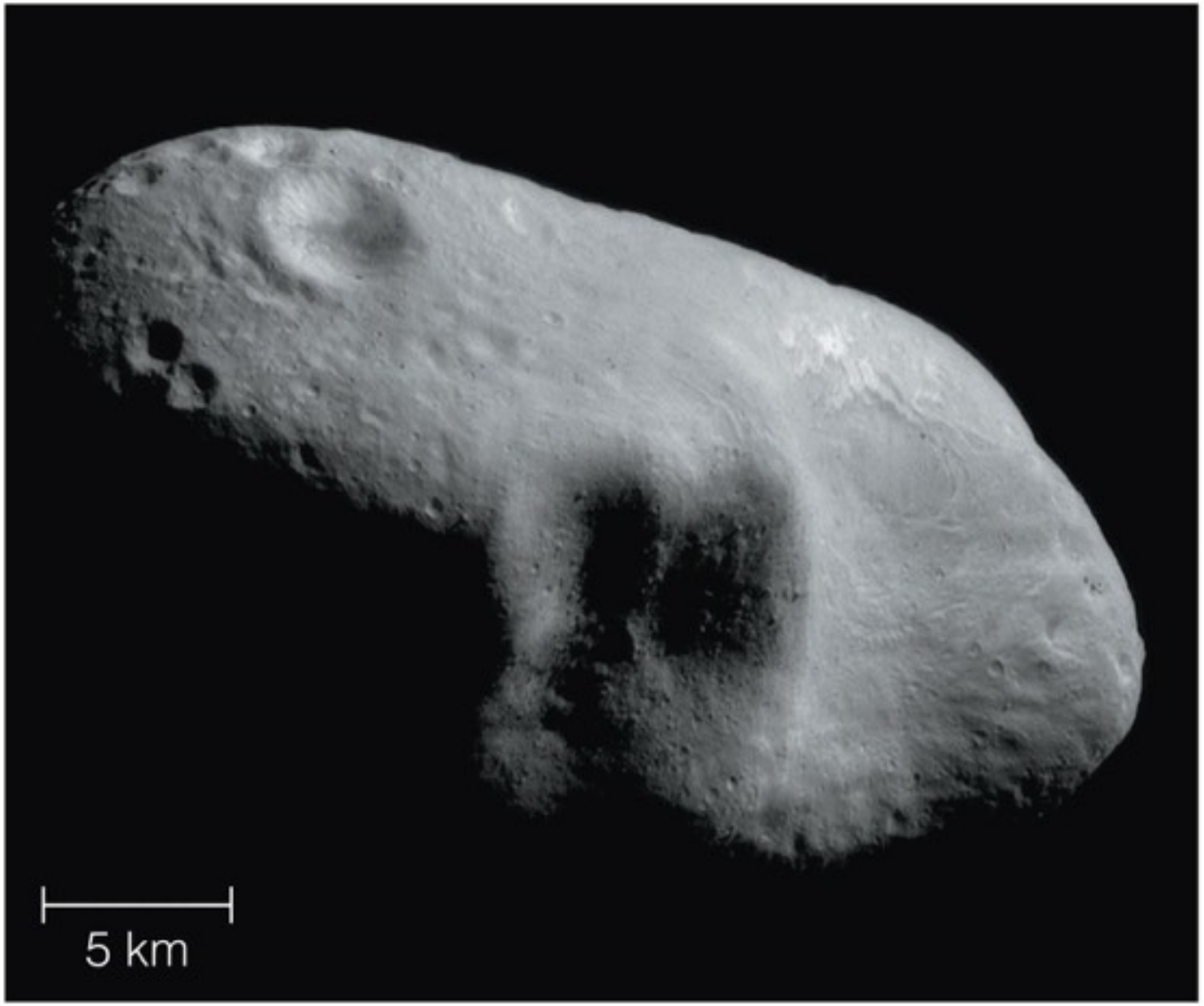
- Rings form from dust created in impacts on moons orbiting the Jovian planets.
- There must be a continuous replacement of tiny particles.
  - The tiny particles that make up the rings are subject to non-gravitational forces (photon pressure, solar wind) that push them out of orbit.
- The most likely source is impacts with jovian moons.
  - The dust emitted by Phoebe is an example of ring building in progress.

Ring Formation

- Jovian planets all have rings because they possess many small moons close in.
- Impacts on these moons are random.
  - rings come and go
- Saturn's incredible rings may be an "accident" of our time.
  - i.e., a recent ice-shattering event

Asteroids, Comets, and Dwarf Planets: Their Nature, Orbits, and Impacts

What are asteroids like?

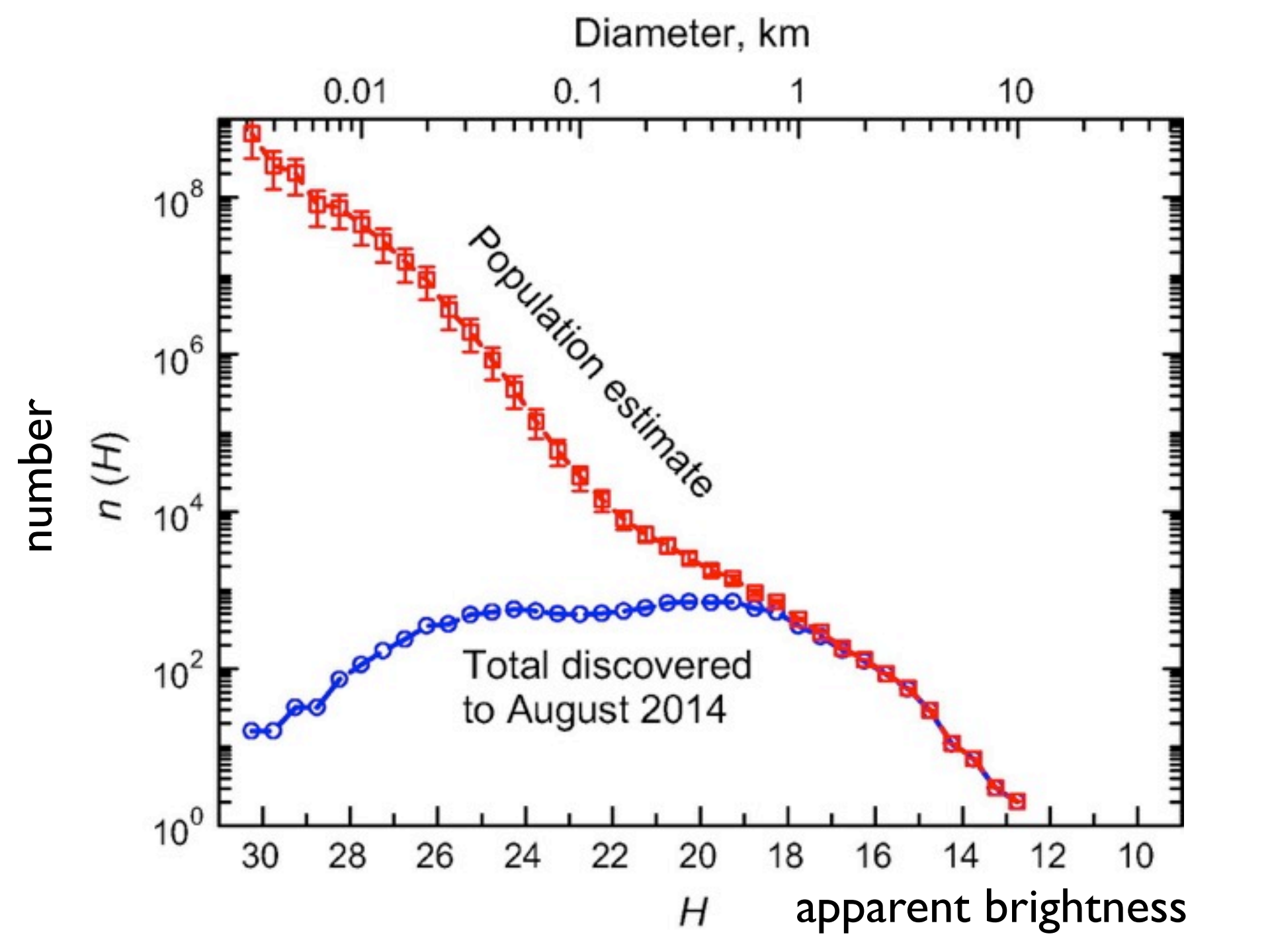


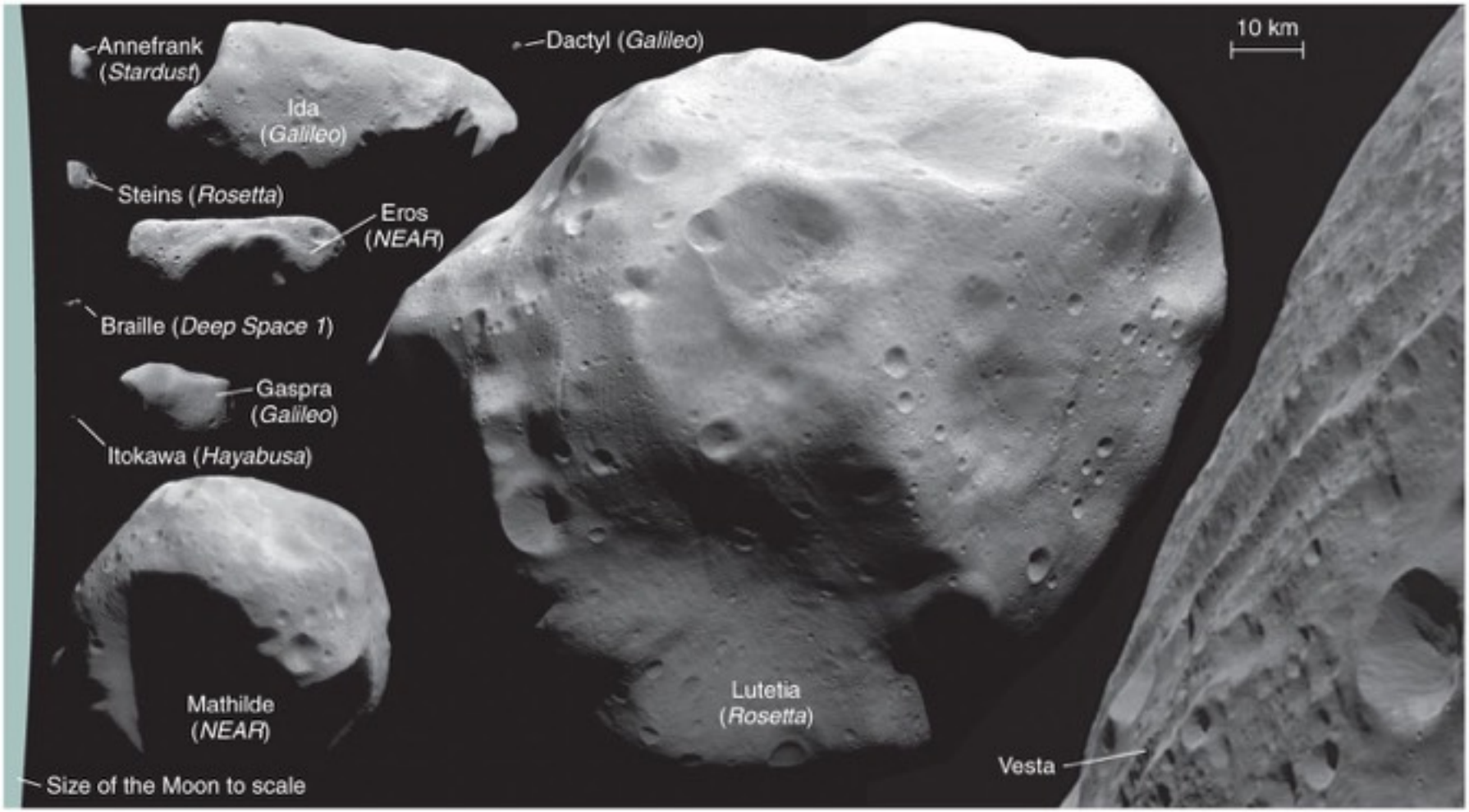
Asteroid traversing sky due to orbital motion (time lapse)

Asteroid Facts

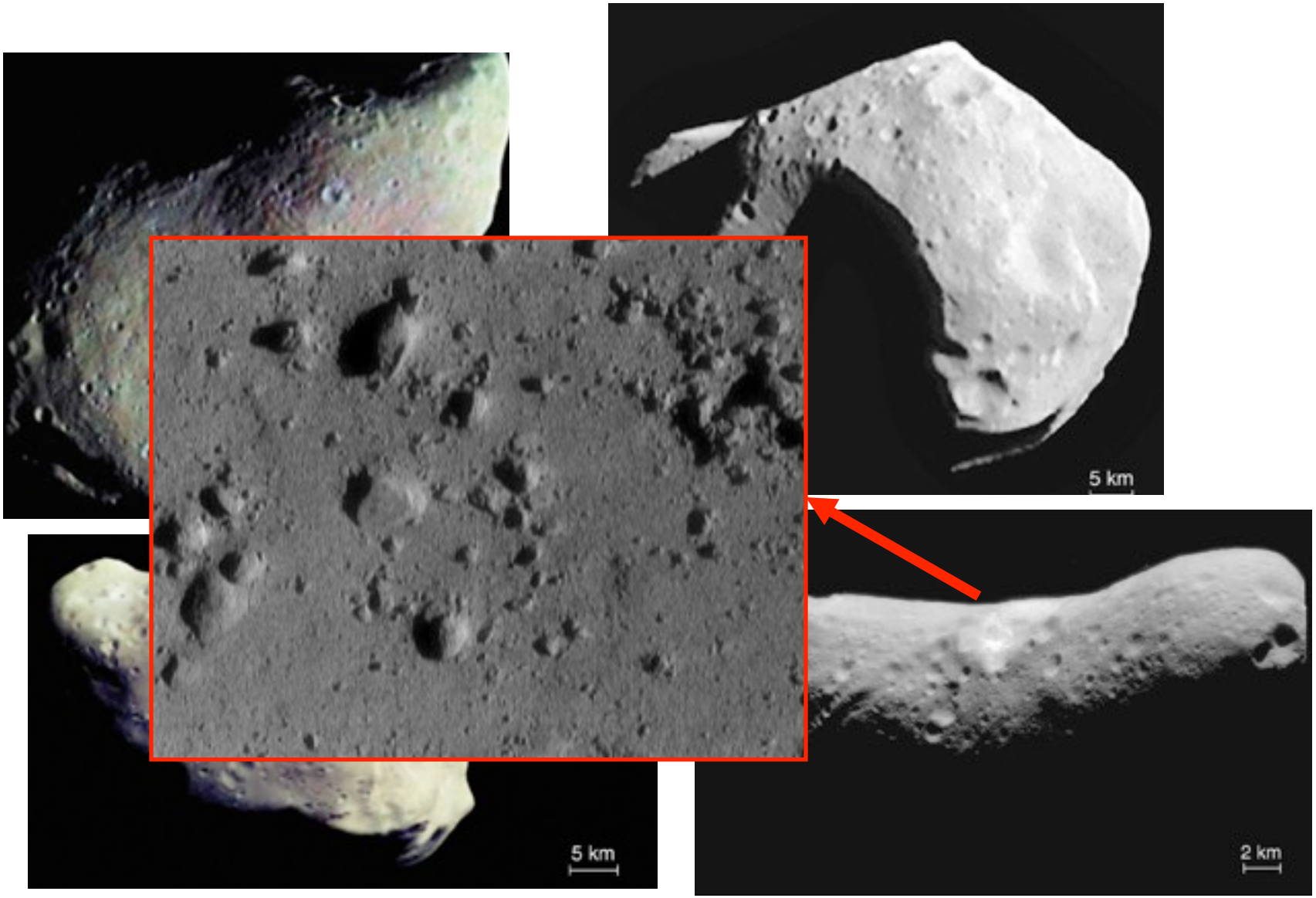
- Asteroids are rocky leftovers of planet formation.
- "Rubble Piles"
  - loose collection of rocks; not one big one.
- The largest is Ceres, diameter ~1,000 km.
- There are 150,000 in catalogs, and probably over a million with diameter >1 km.
- Small asteroids are more common than large asteroids.
- All the asteroids in the solar system wouldn't add up to even a small terrestrial planet.

Lots of small bodies, but not much mass.


Diameter, km
0.01
0.1
1
10
number
n (H)
10^8
10^6
10^4
10^2
10^0
Population estimate
Total discovered
to August 2014
30
28
26
24
22
20
18
16
14
12
10
H
apparent brightness



- Asteroids are cratered and not round.



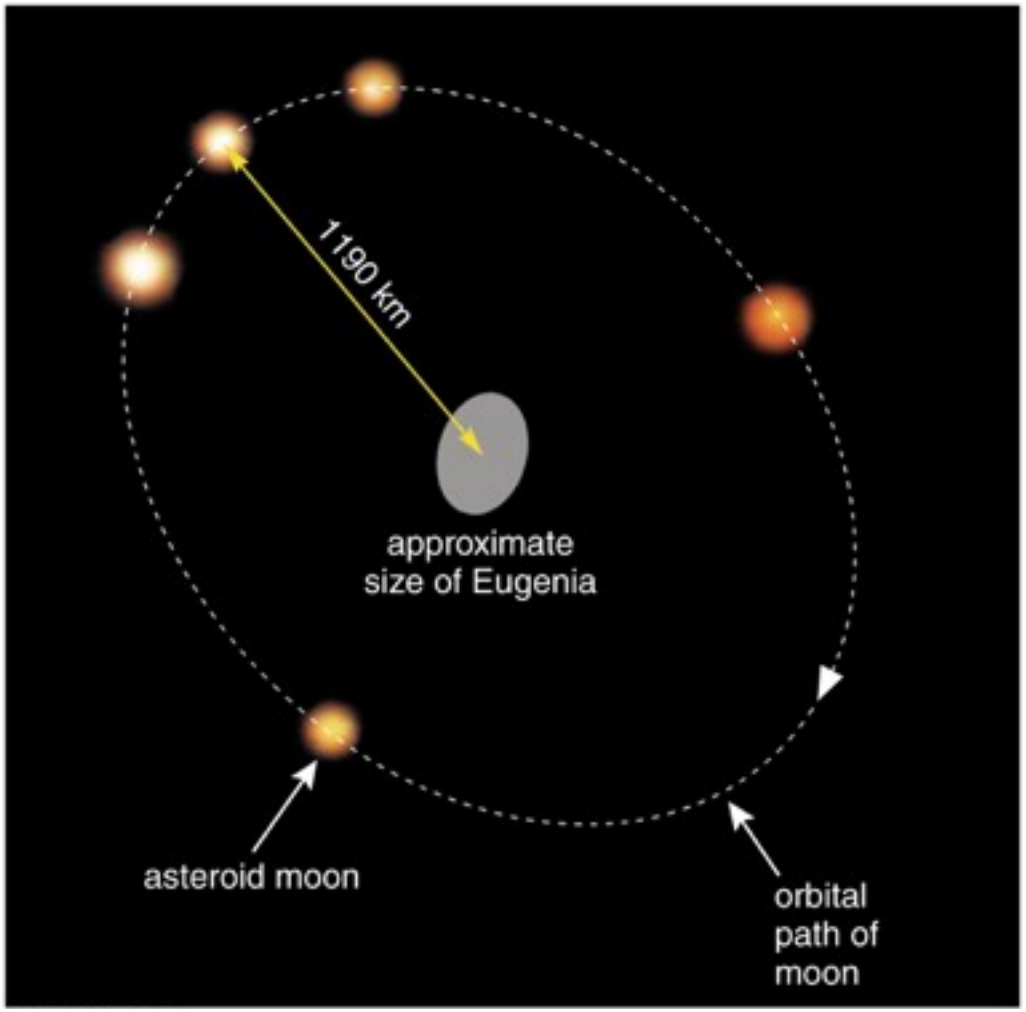
Asteroids are cratered and not round.

NEAR movie https://svs.gsfc.nasa.gov/2061

Asteroids with Moons

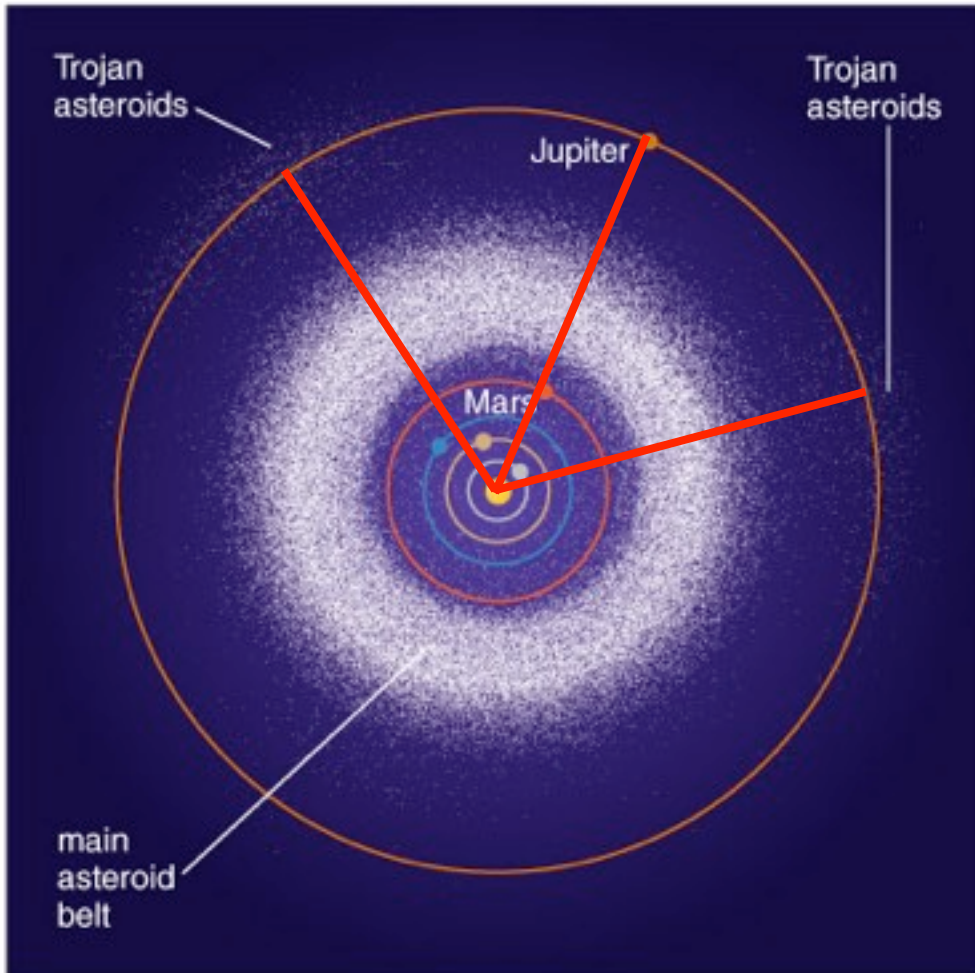
- Some large asteroids have their own moon.
- Asteroid Ida has a tiny moon named Dactyl.
- Sometimes asteroids are binary, with two roughly equal size partners.

Density of Asteroids



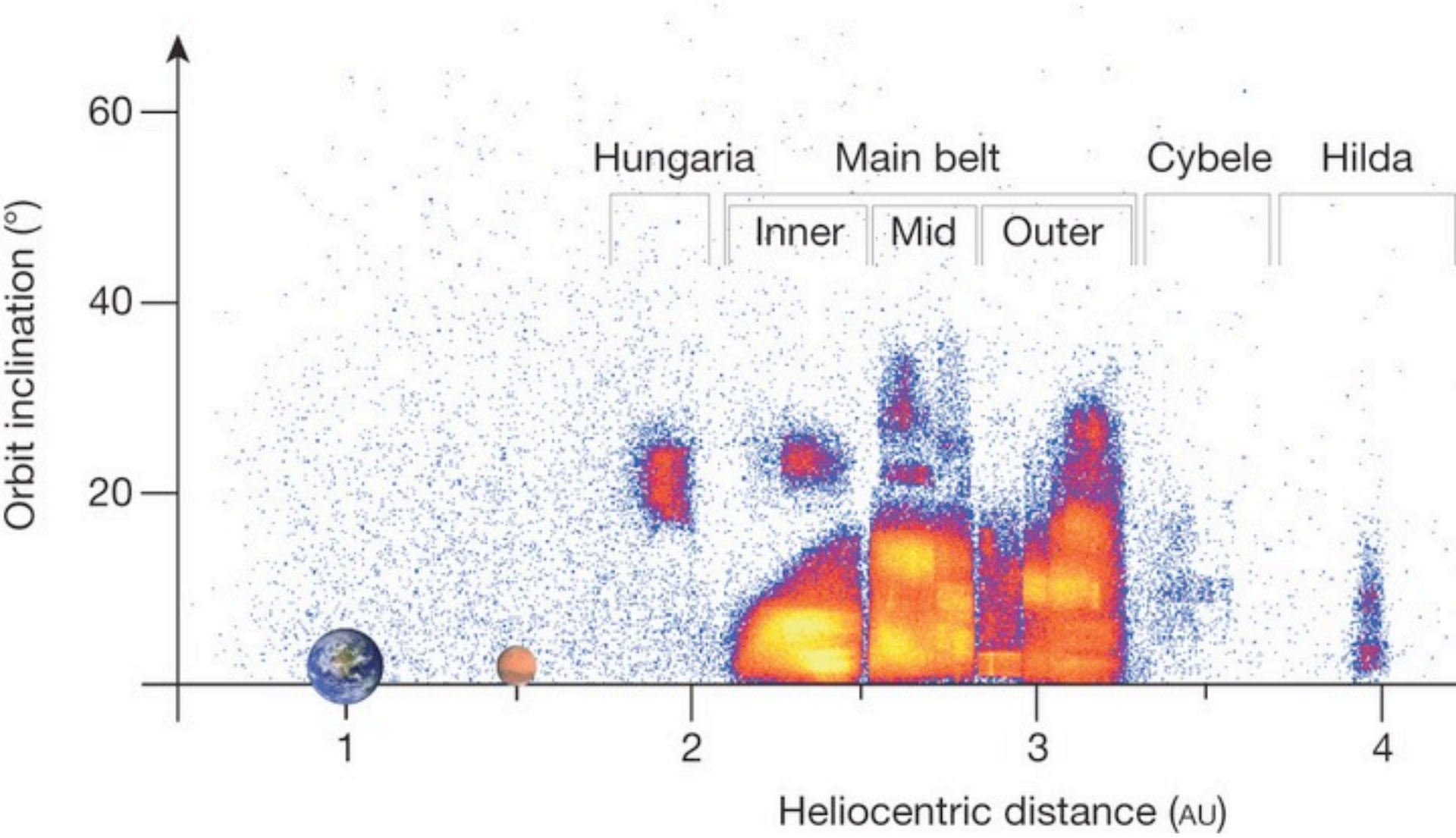
- Measuring the orbit of asteroid's moon tells us an asteroid's mass.
- Mass and size tell us an asteroid's density.
- Typical densities ~2 g/cc - rock with gaps - “rubble piles”

Asteroid Orbits



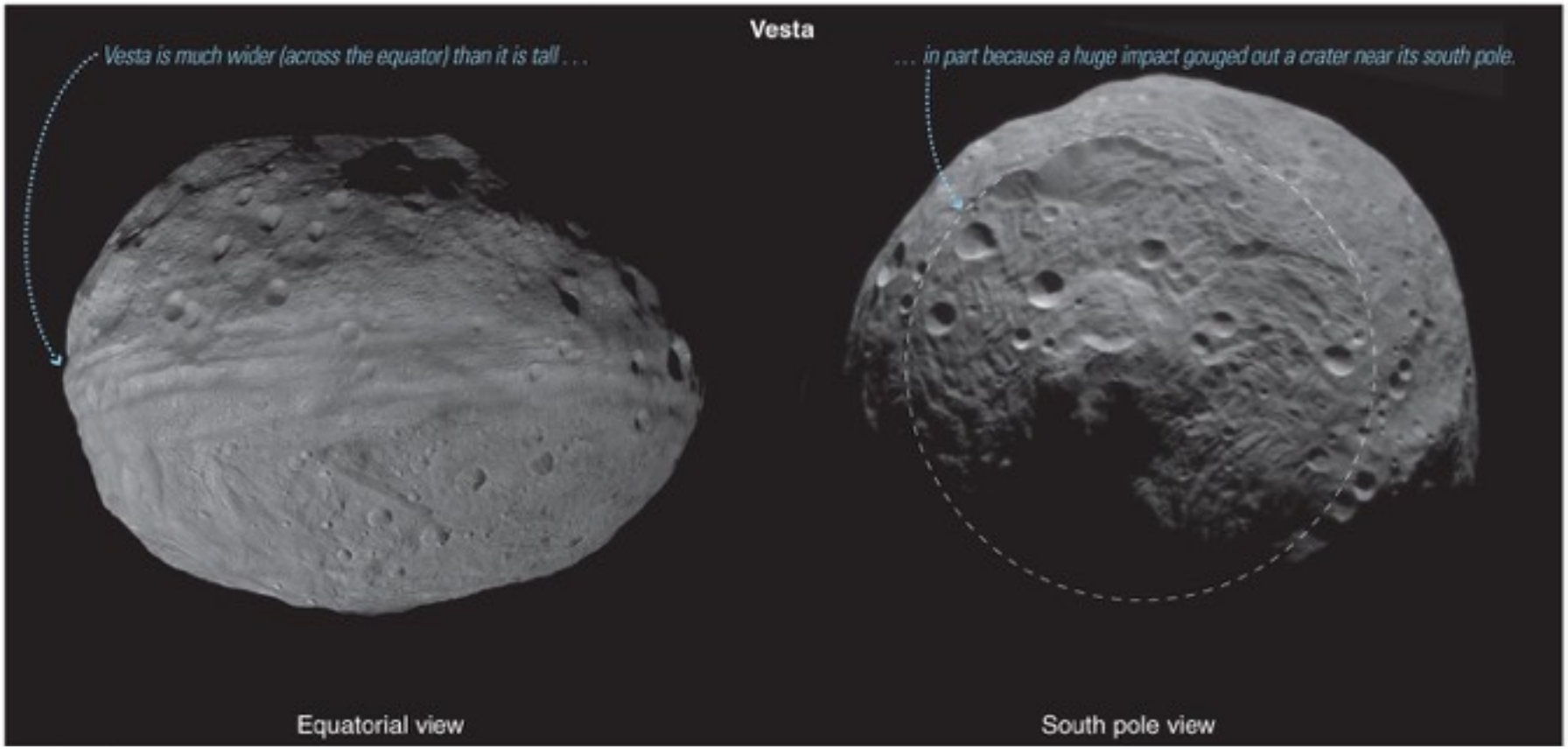
- Most asteroids orbit in a **belt** between Mars and Jupiter.
- *Trojan asteroids* follow Jupiter's orbit.
  - 60 degrees ahead or behind
- *Apollo asteroids* cross Earth's orbit

Asteroid belt(s)



Biggest asteroids: Vesta & Ceres

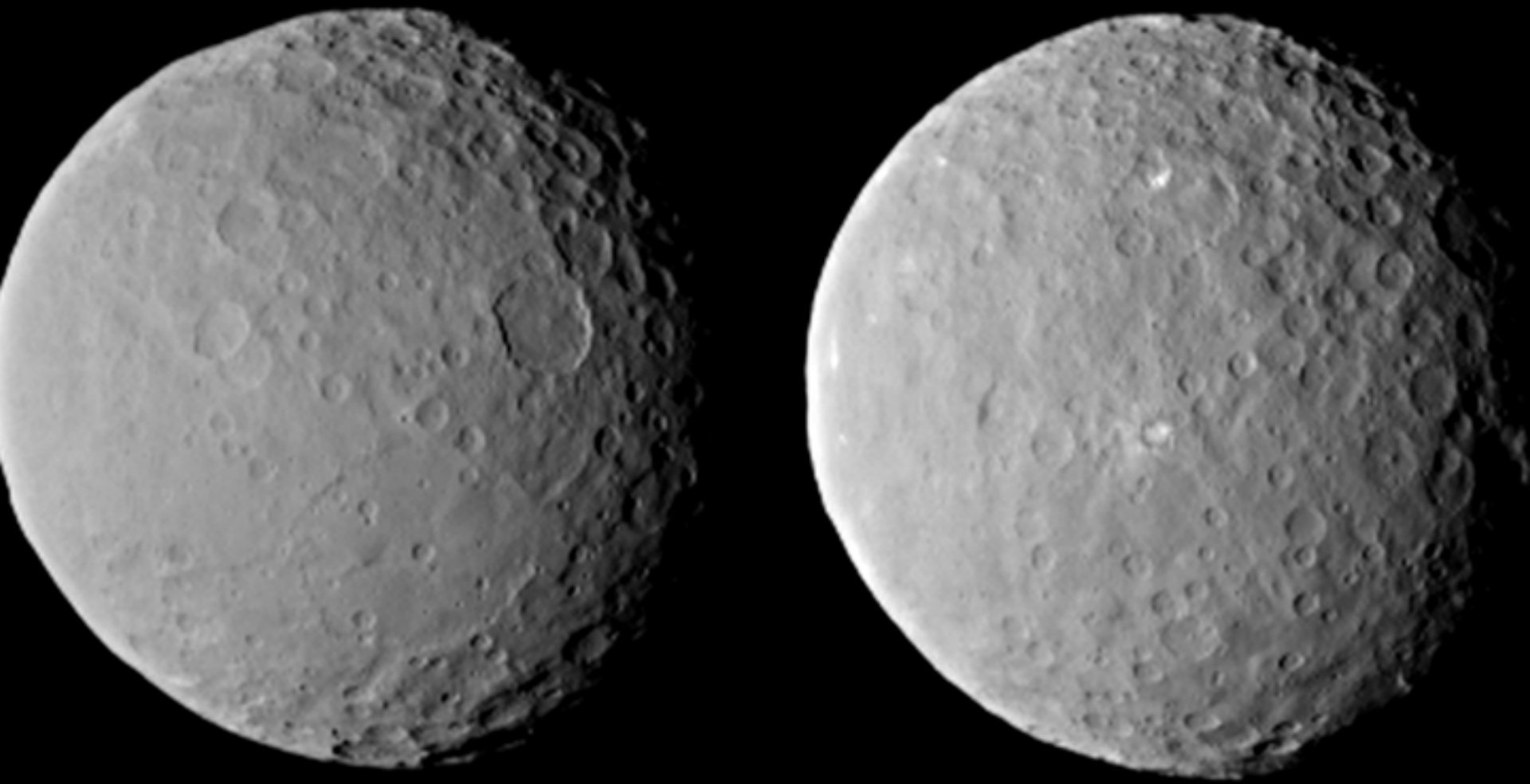
Vesta as seen by the Dawn Spacecraft



https://www.youtube.com/watch?v=84vz6J8cnc8

http://vestatrek.jpl.nasa.gov/

Ceres



Largest asteroid in solar system (~1000 km diameter); qualifies as a dwarf planet

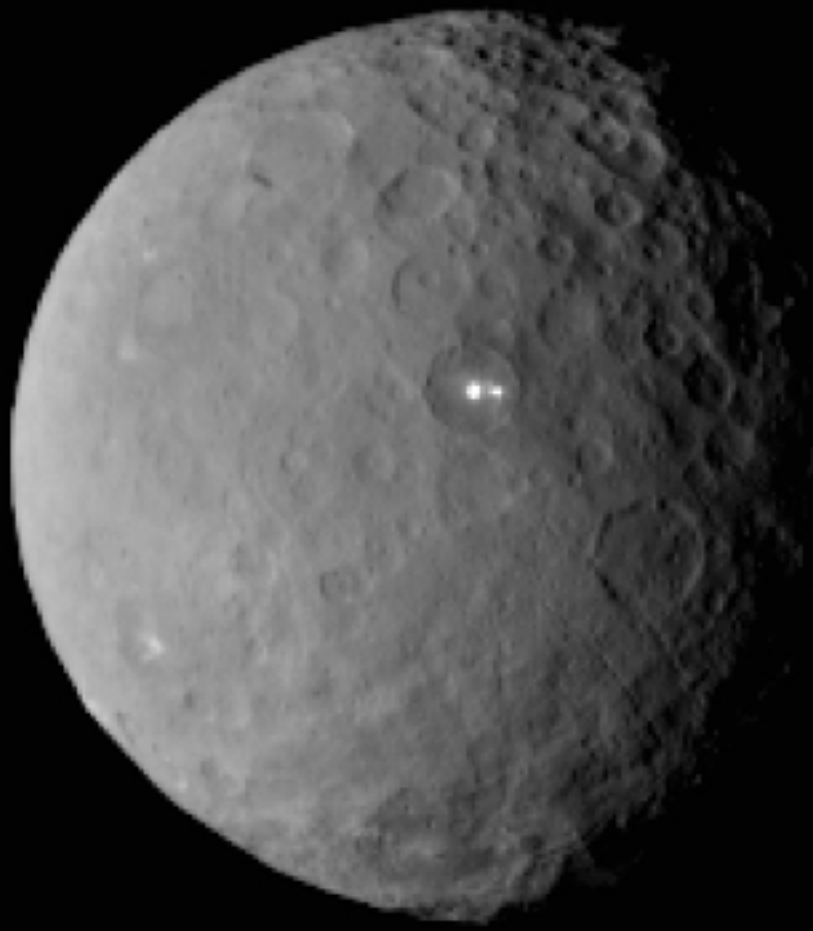
White spots
discovered by
Dawn spacecraft

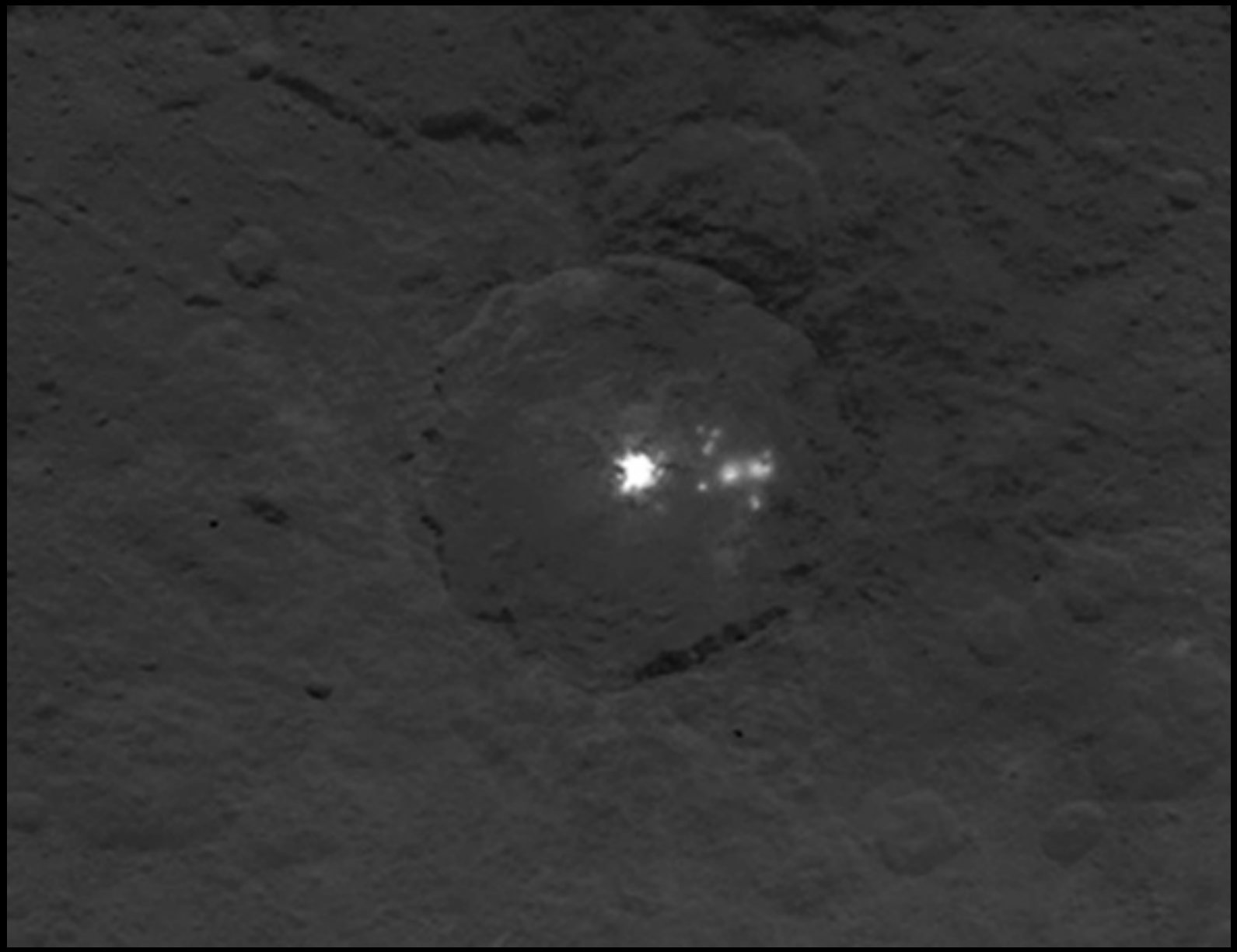
high albedo > 40%

low albedo
surroundings
< 10%

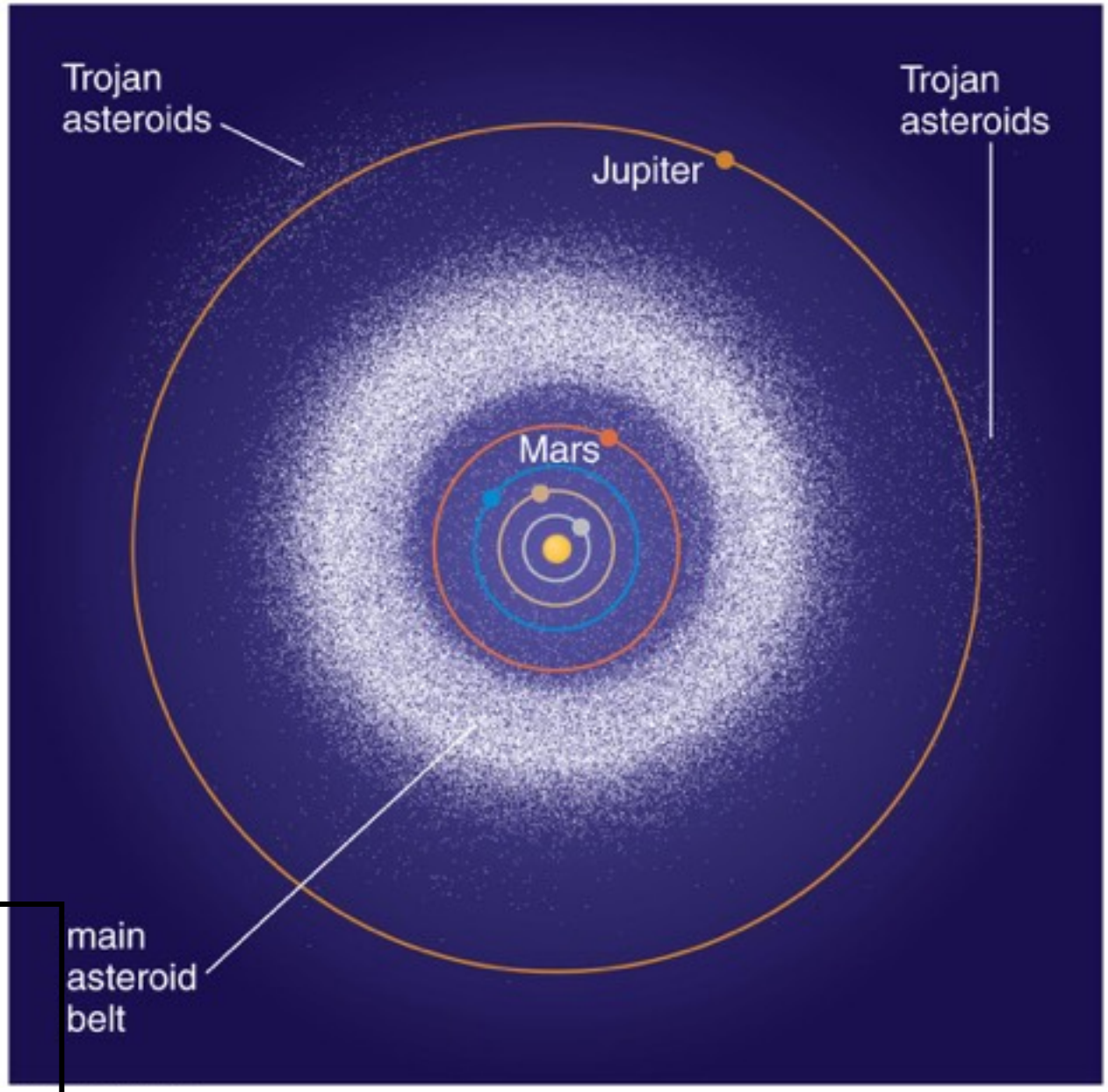
Salty ice?
A hint of
subsurface water?

Dawn in orbit



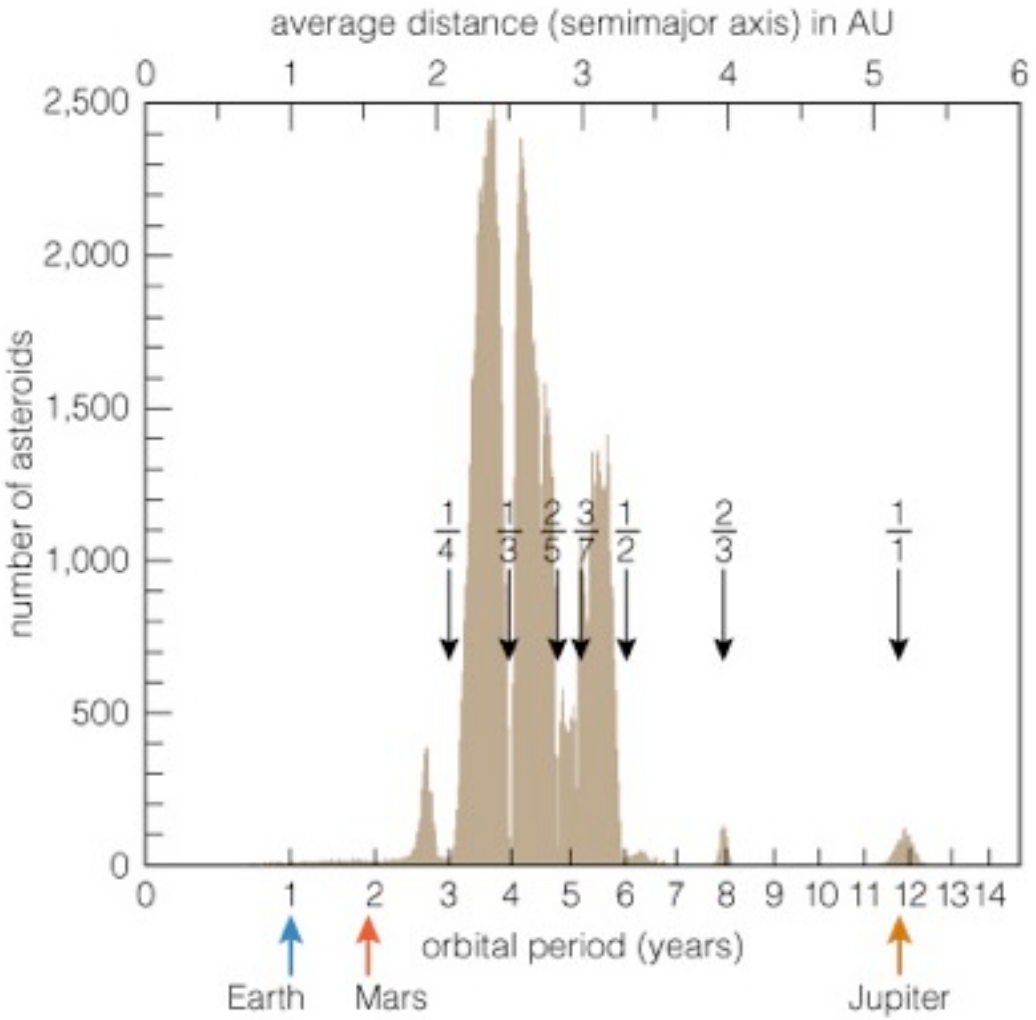


Why is there an asteroid belt?



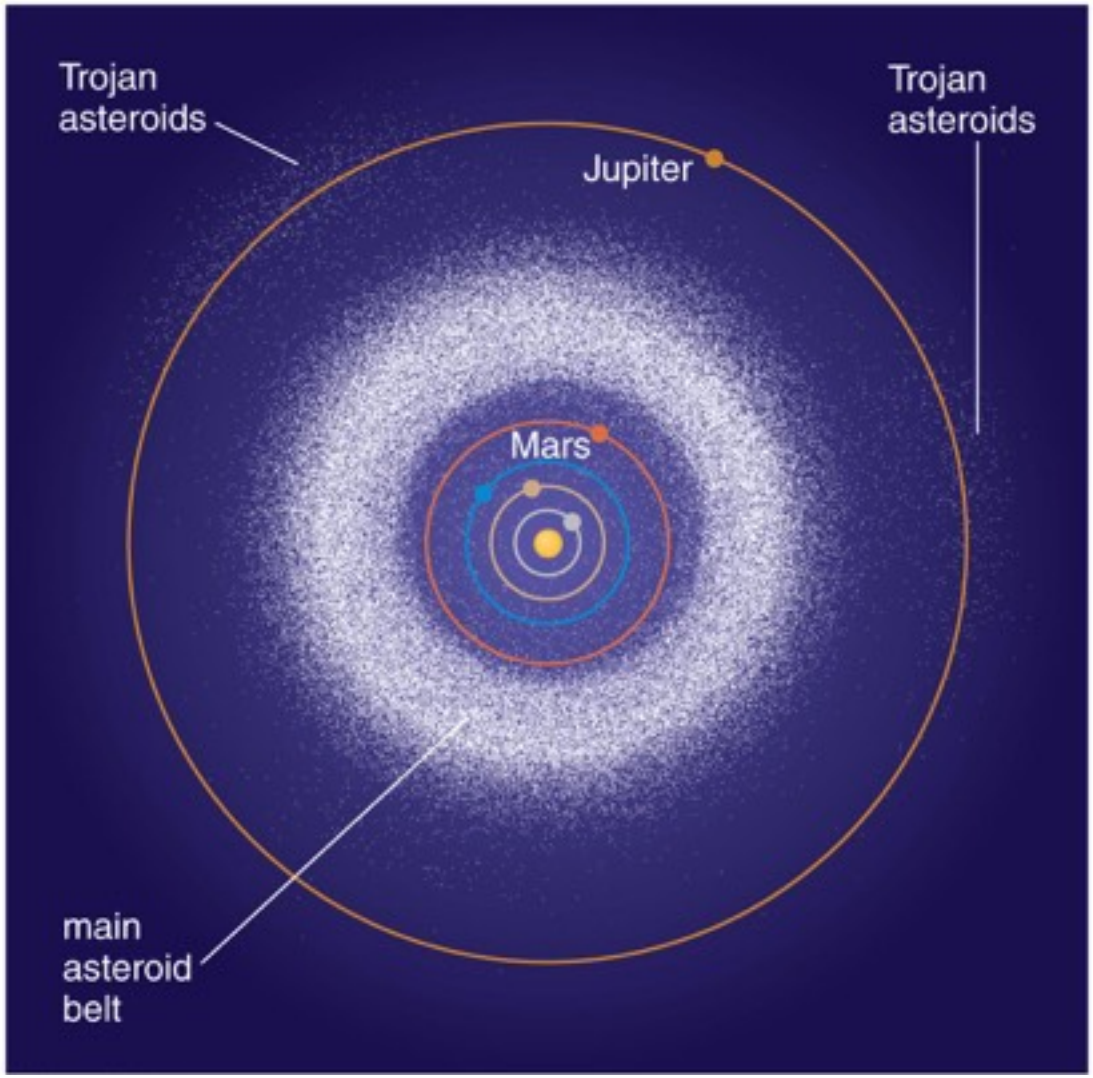
WHY didn't they form a planet?

Orbital Resonances



- Asteroids in orbital resonance with Jupiter experience periodic nudges.
- Those nudges clear asteroids out of resonant orbits, leaving gaps in the belt.
- Same physics as rings of Saturn

Origin of Asteroid Belt



- Rocky planetesimals between Mars and Jupiter did not accrete into a planet.
- Jupiter's gravity, through influence of orbital resonances, stirred up asteroid orbits and prevented their accretion into a planet.

How are meteorites related to asteroids?

Rocks that fall from the sky...

- **Meteorite:** A rock from space that falls through Earth's atmosphere.

- **Meteor:** The bright trail seen as a shooting star.
  Typically only a grain of sand.

- **Meteoroid:** A rock in space prone to become a meteor.

Meteorite Impact

Chicago, March 26, 2003

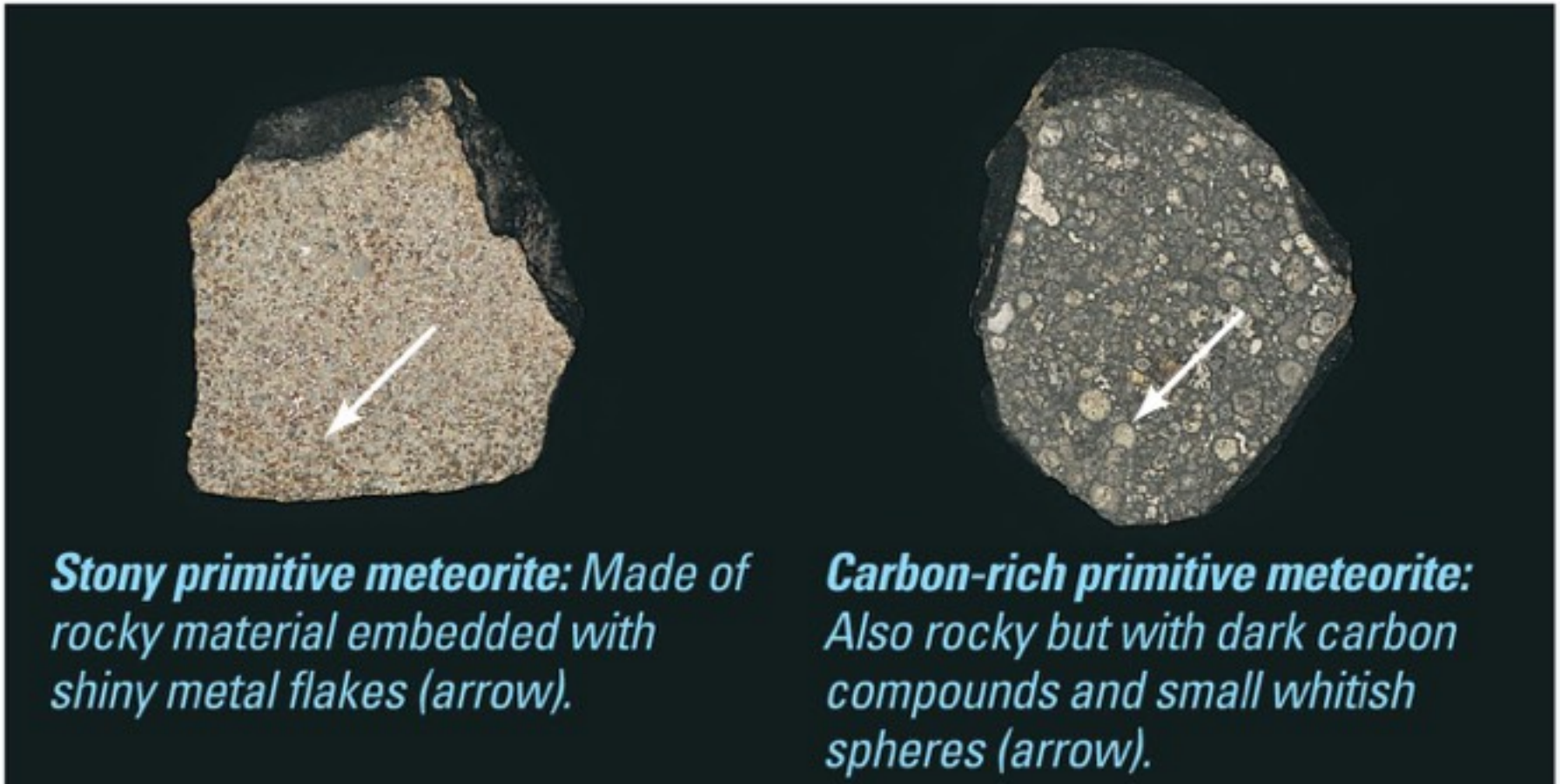
Meteorite Types

1) Primitive: unchanged in composition since they first formed 4.6 billion years ago

2) Processed: younger; have experienced processes like volcanism or differentiation

Primitive Meteorites

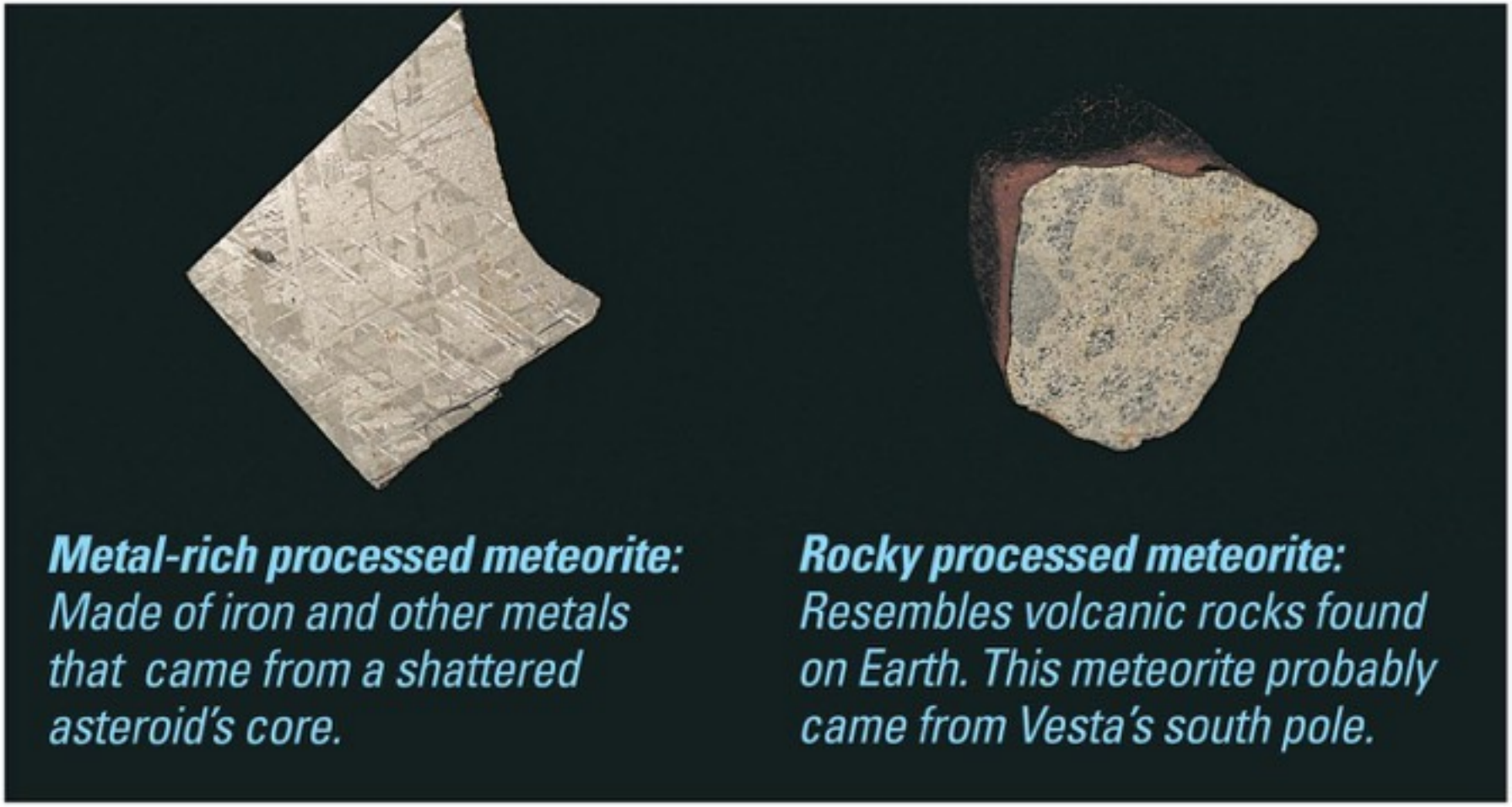
Primitive: Unchanged in composition since they first formed 4.5 billion years ago - key to measuring the composition of the solar system



Stony primitive meteorite: *Made of rocky material embedded with shiny metal flakes (arrow).*

Carbon-rich primitive meteorite: *Also rocky but with dark carbon compounds and small whitish spheres (arrow).*

Processed Meteorites



b Processed meteorites.

Meteorites from Moon and Mars

- A few meteorites arrive from the Moon and Mars.
- Composition differs from the asteroid fragments.
- A cheap (but slow) way to acquire Moon rocks and Mars rocks

What have we learned?

- What are asteroids like?
  - They are rocky, small, potato-shaped leftovers from the era of planet formation.
- Why is there an asteroid belt?
  - Orbital resonances with Jupiter prevented planetesimals between Jupiter and Mars from forming a planet.

What have we learned?

- How are meteorites related to asteroids?
  - Primitive meteorites are remnants from solar nebula.
  - Processed meteorites are fragments of larger bodies that underwent differentiation.

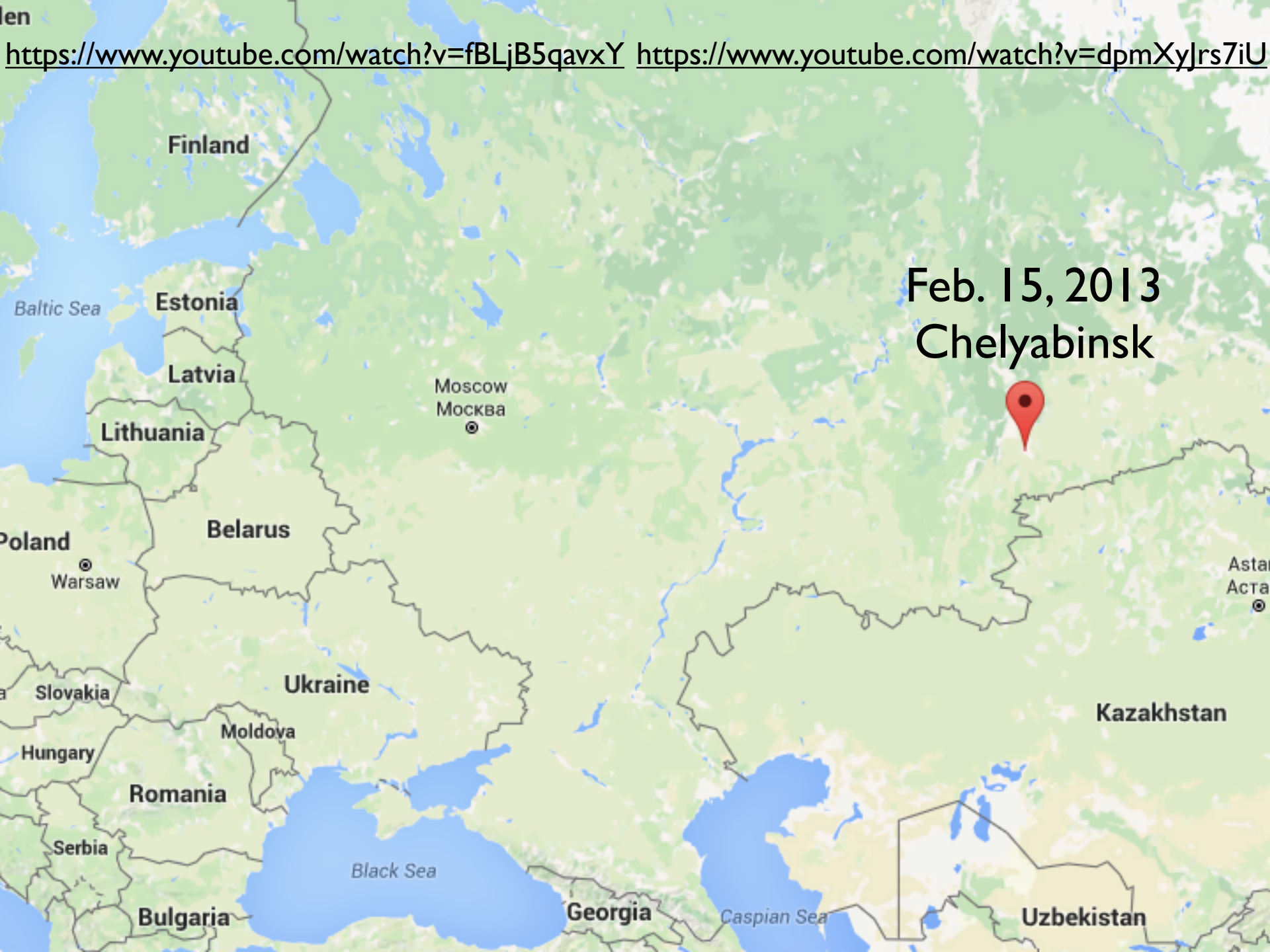
Facts About Impacts on Earth

- Asteroids and comets have hit the Earth.
- A major impact is only a matter of time: not IF but WHEN.
- Major impacts are very rare.
  - A major impact is thought to have contributed to the extinction of the dinosaurs 65 Myr ago.
- Something large enough to harm a city might occur every century or so.

Tunguska, Siberia: June 30, 1908

A ~40 meter object disintegrated and exploded in the atmosphere

https://www.youtube.com/watch?v=fBLjB5qavxY https://www.youtube.com/watch?v=dpmXyJrs7iU



Meteor Crater, Arizona: 50,000 years ago (50 meter object)