# Small Bodies in our Solar System (Ch. 14)

**Asteroids**

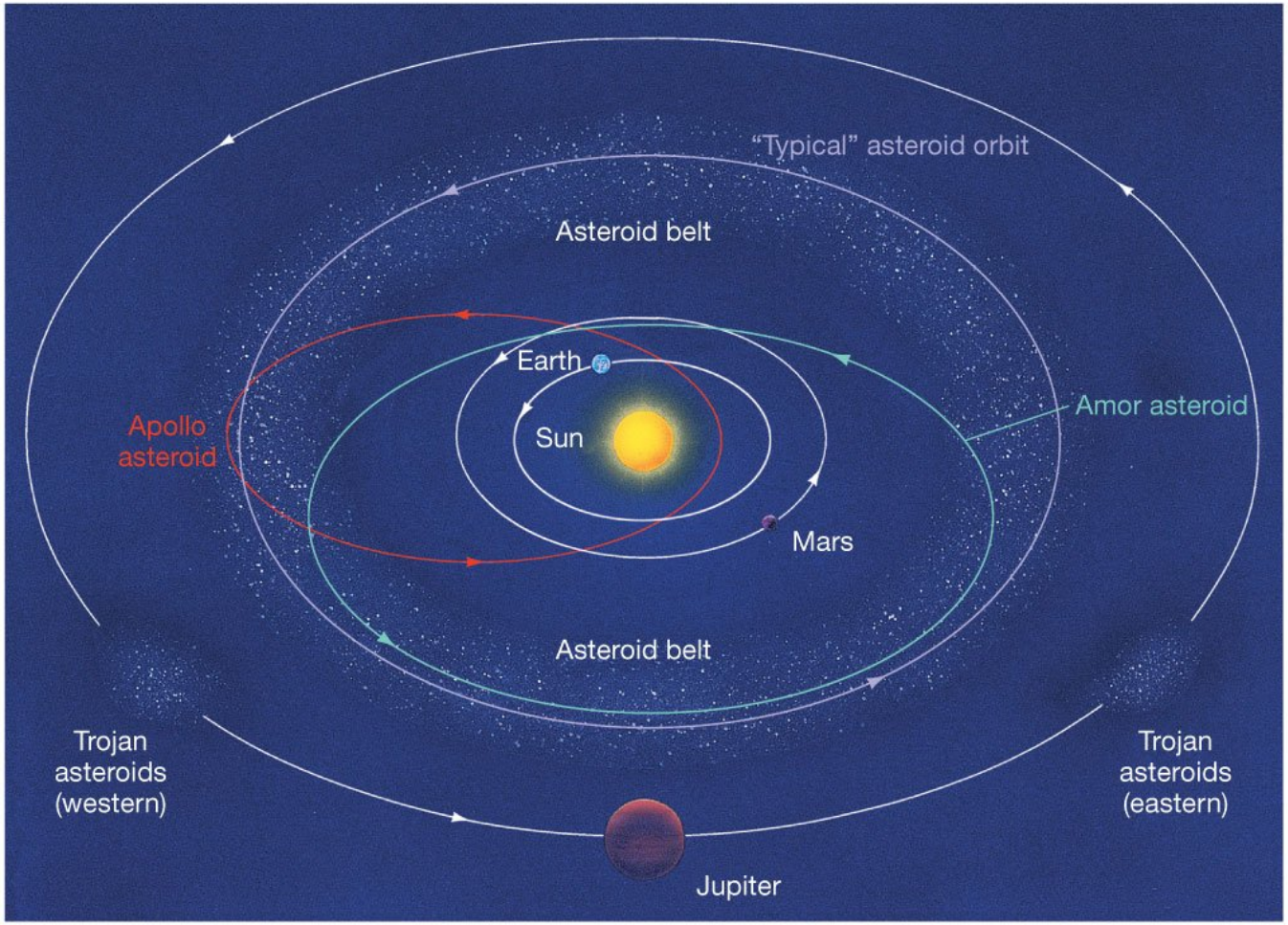
**Comets**

**Trans-Neptunian Objects**

Small but not insignificant – they are leftover “planetesimals” from the formation of the solar system.

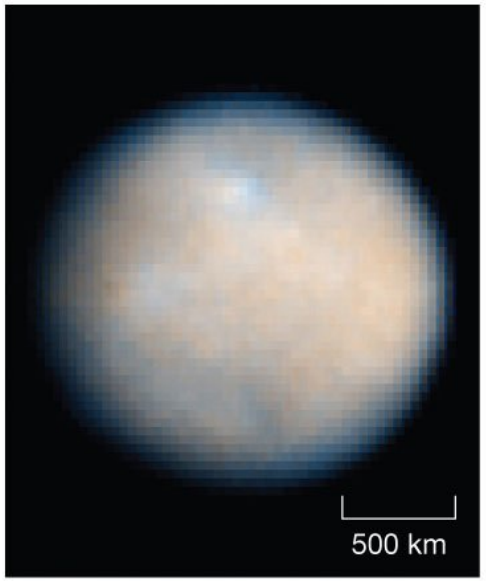
# Asteroids

Asteroids are small, rocky bodies originating in the asteroid belt between Mars and Jupiter.




(a)

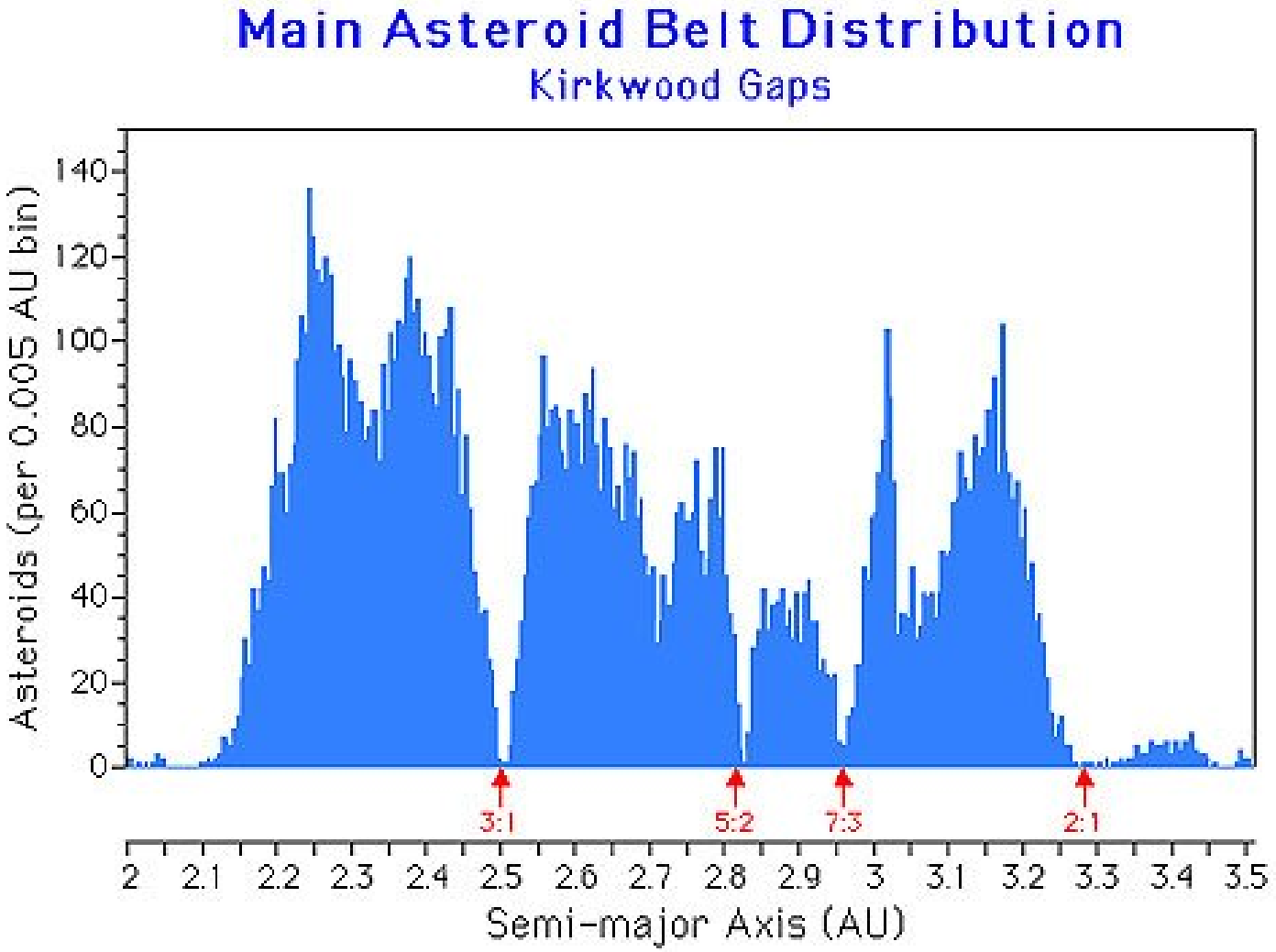
**Ceres – the biggest asteroid.**




(b)

# Asteroids

Asteroid orbits are heavily influence by the planet Jupiter. Very few are found at the orbital resonances.



# Asteroids

Asteroids are small compared to the terrestrial planets.

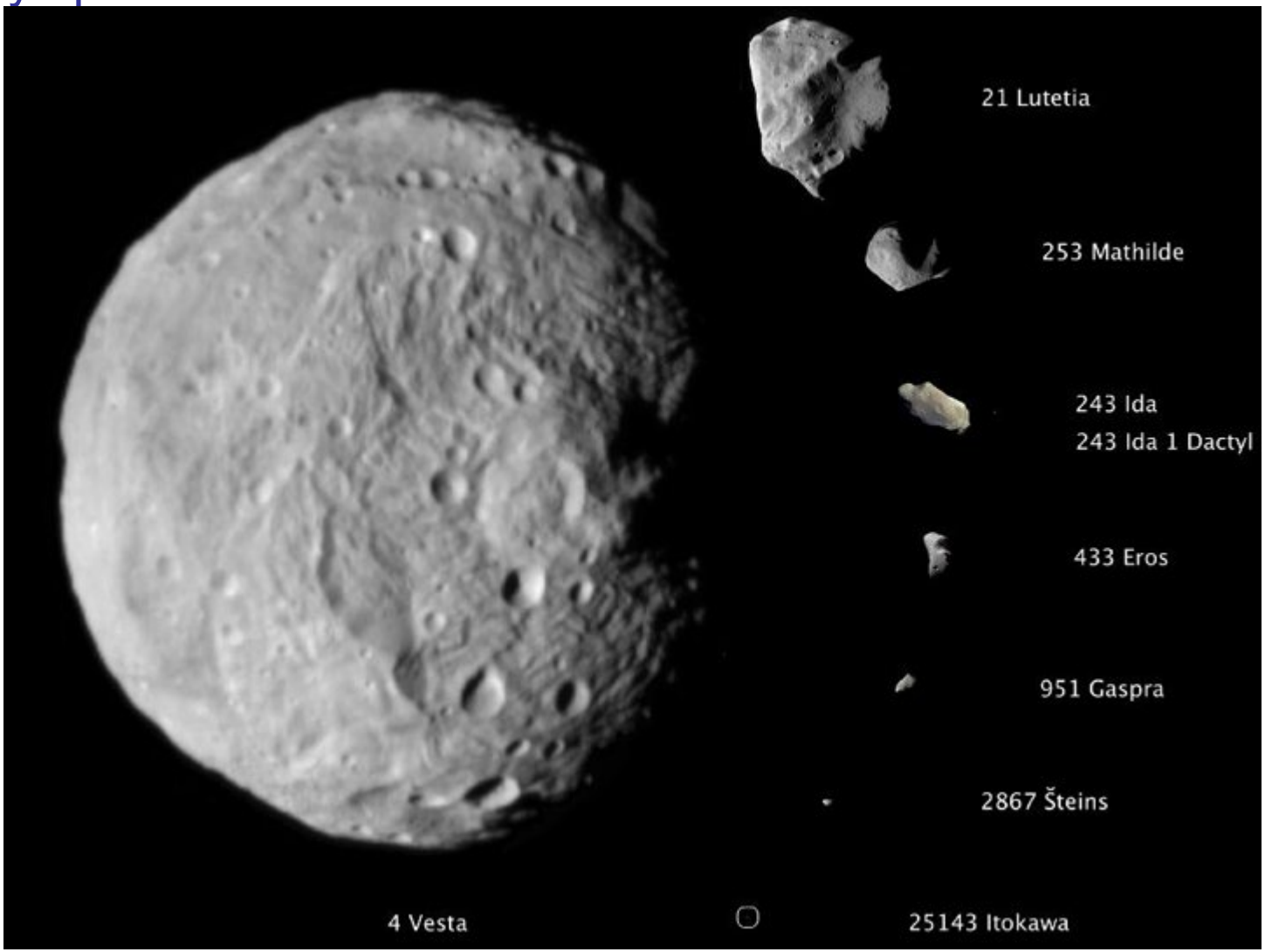
Ceres has also been classified as a “dwarf planet”.

Total mass of asteroids: 4% of Moon's mass.

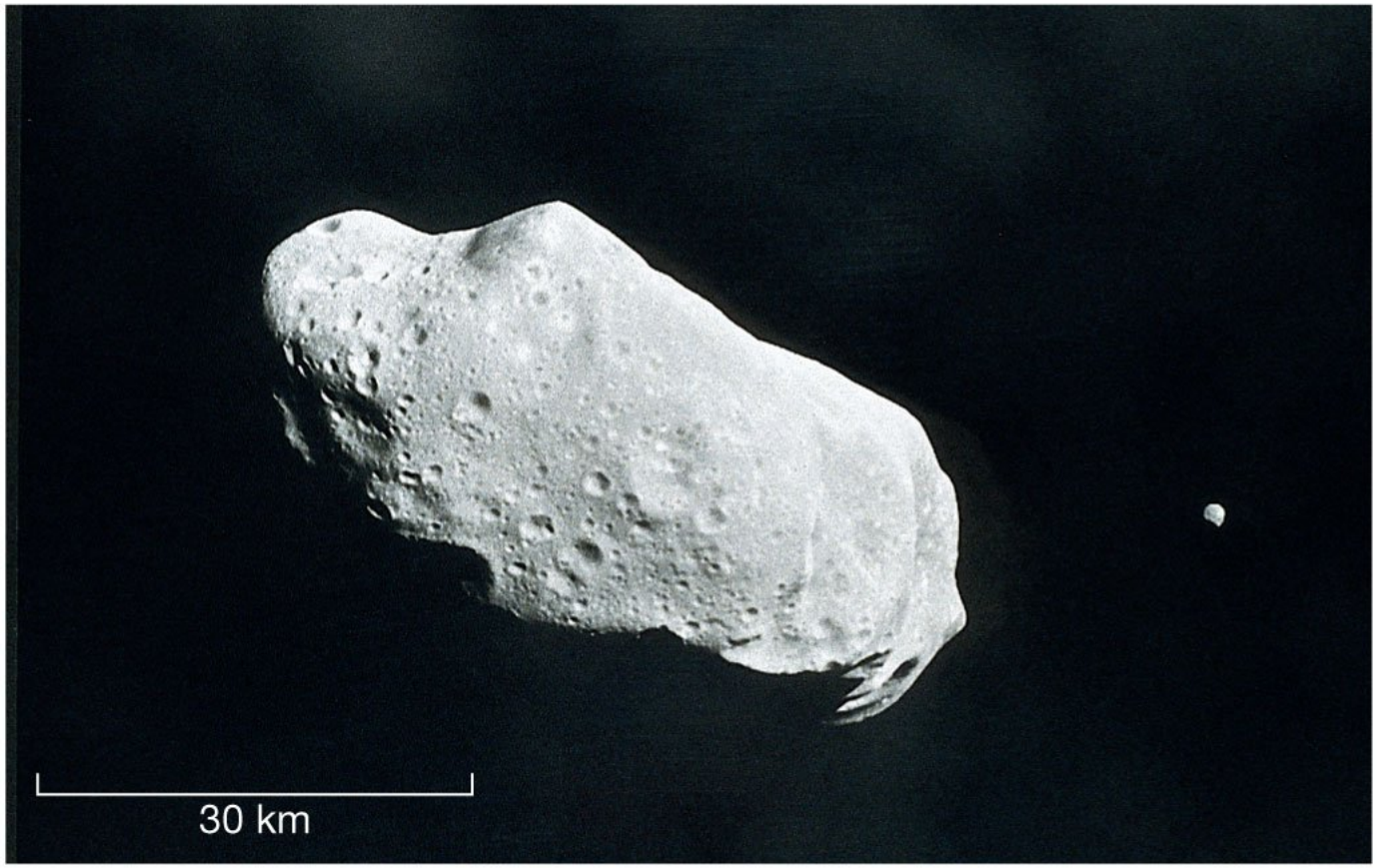
4 biggest (Ceres, Vesta, Pallas, Hygeia) make up 50% of that mass.

# Asteroids

A collage of asteroids which have been imaged close-up by spacecraft.



# Asteroids

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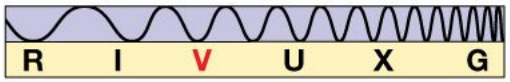





**Ida and its moon Dactyl. As seen from Galileo.**

# Asteroids

**Asteroids are spectrally classified based on composition:**

**C-type: carbonaceous; dark; 75% of (main belt) population**

**S-type: silicate (rocky); brighter; 15%**

**M-type: metallic; iron and nickel; <10%**

**These correlate with classes of meteorites found on Earth:**

**Carbonaceous chondrites**

**Stony (including chondrites and achondrites)**

**Stony-iron**

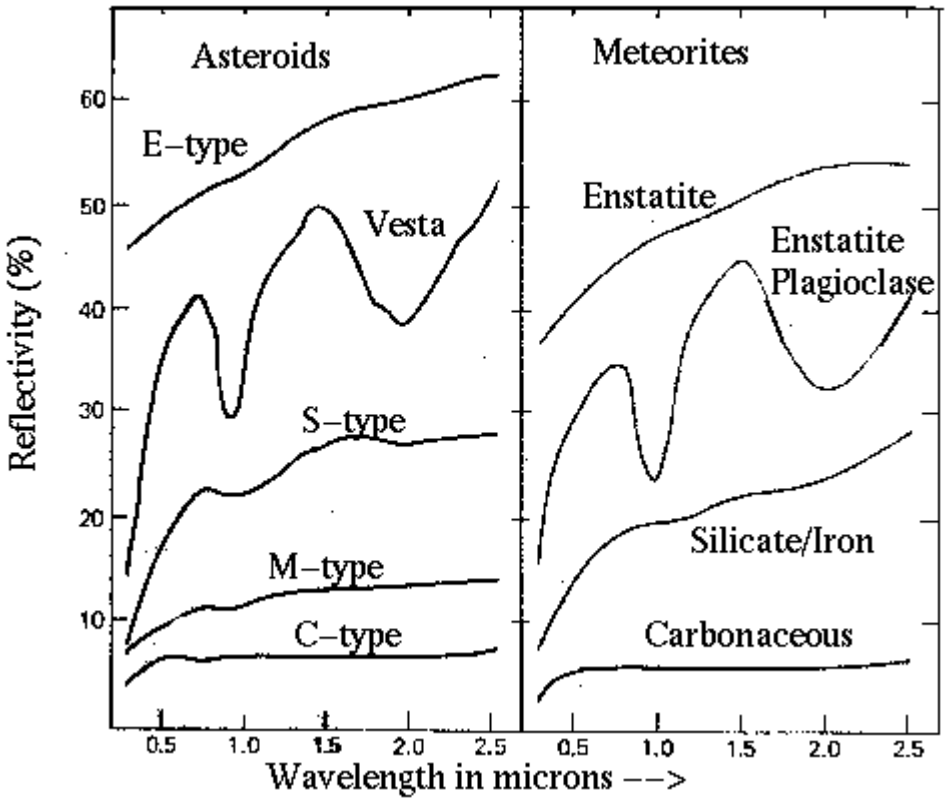
**Iron**

# Asteroids

**Asteroid Spectrally compared to meteorite spectra...**

**C-type: carbonaceous S-type: silicate M-type: metallic. Many other subclasses exist (E,Q,HED,etc).**

Figure 27 - 2: Asteroid and Meteorite Spectra



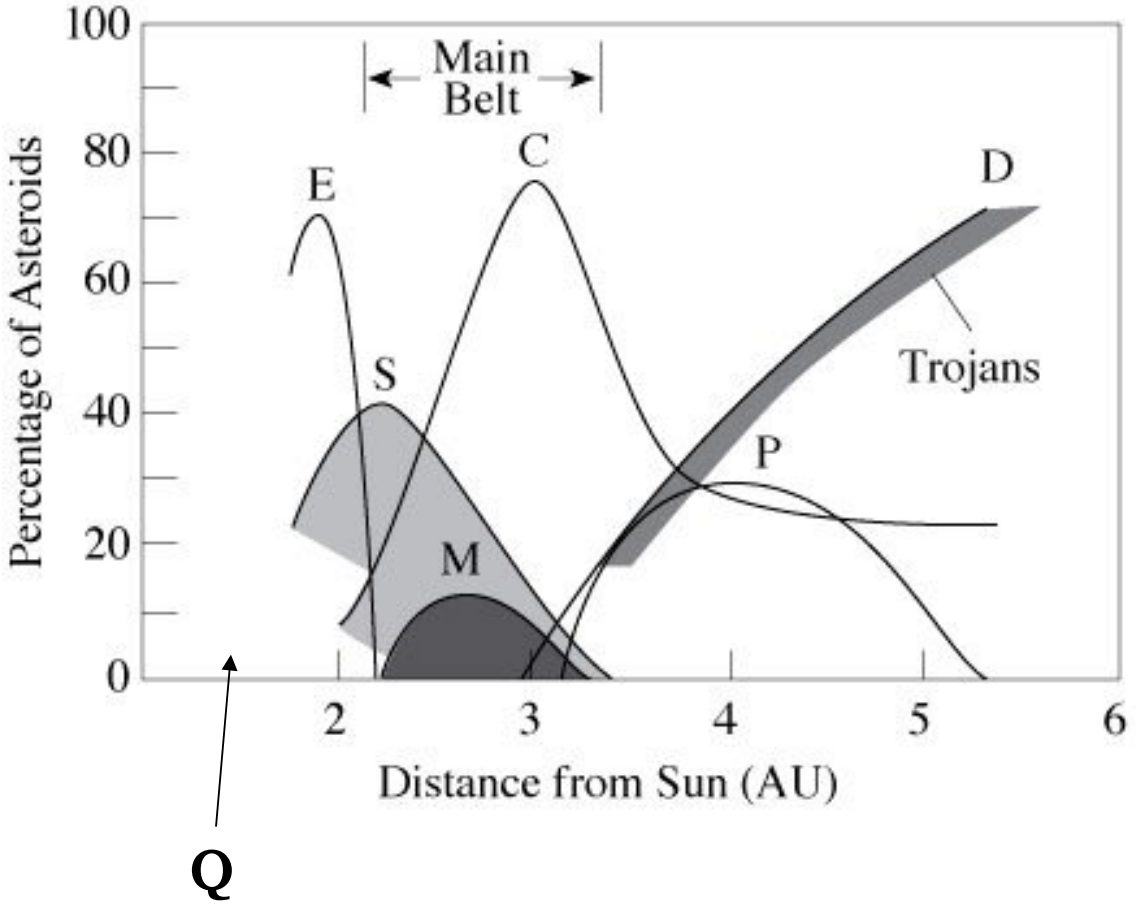

Recent work on Near-Earth Asteroids (NEA) shows that the ones which pass close to Earth are “Q-type”.

These are like S-type asteroids which have lost their old red surface by close encounters with the Earth.

# Asteroids

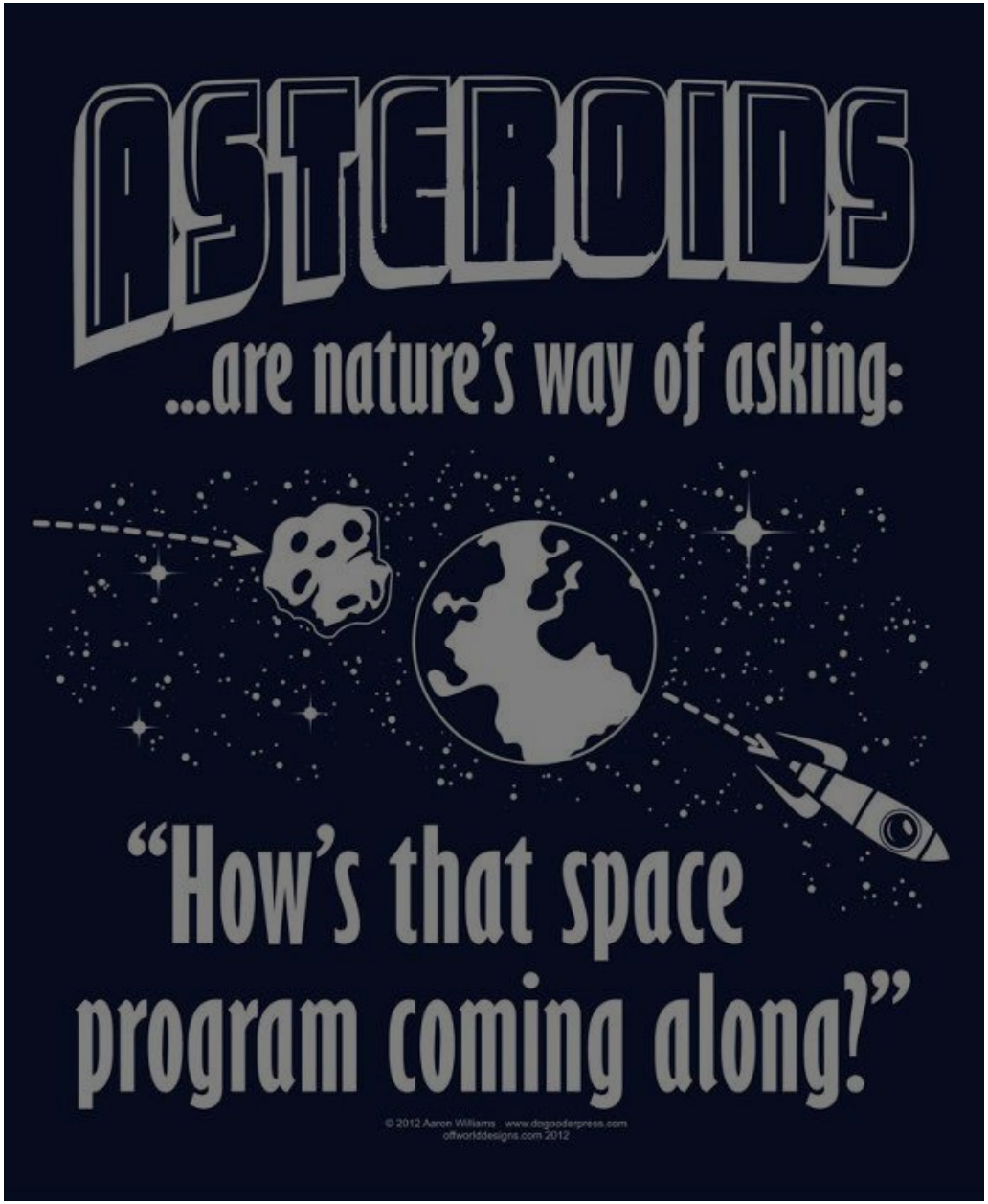
**Asteroid Spectra correlate with orbit size.**

**C-type: carbonaceous S-type: silicate M-type: metallic.**



# Asteroids

**Asteroids – a threat to life on Earth?**

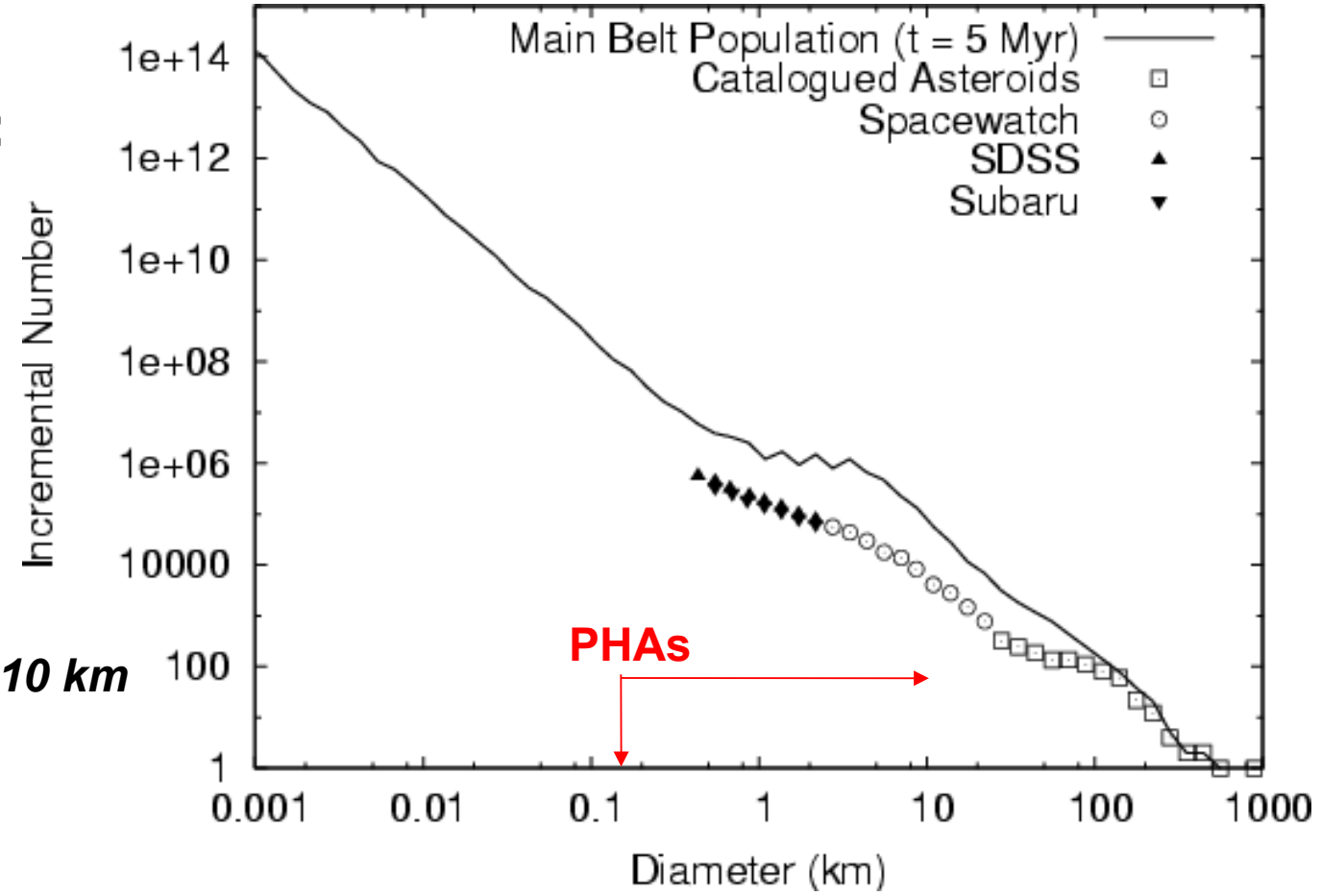


# Asteroids

**Asteroids as a threat to life on Earth.**

**NEAs, PHA, Amor (cross Mars), Apollo (cross Earth), Aten (inside Earth's orbit).**

**Size distribution:**

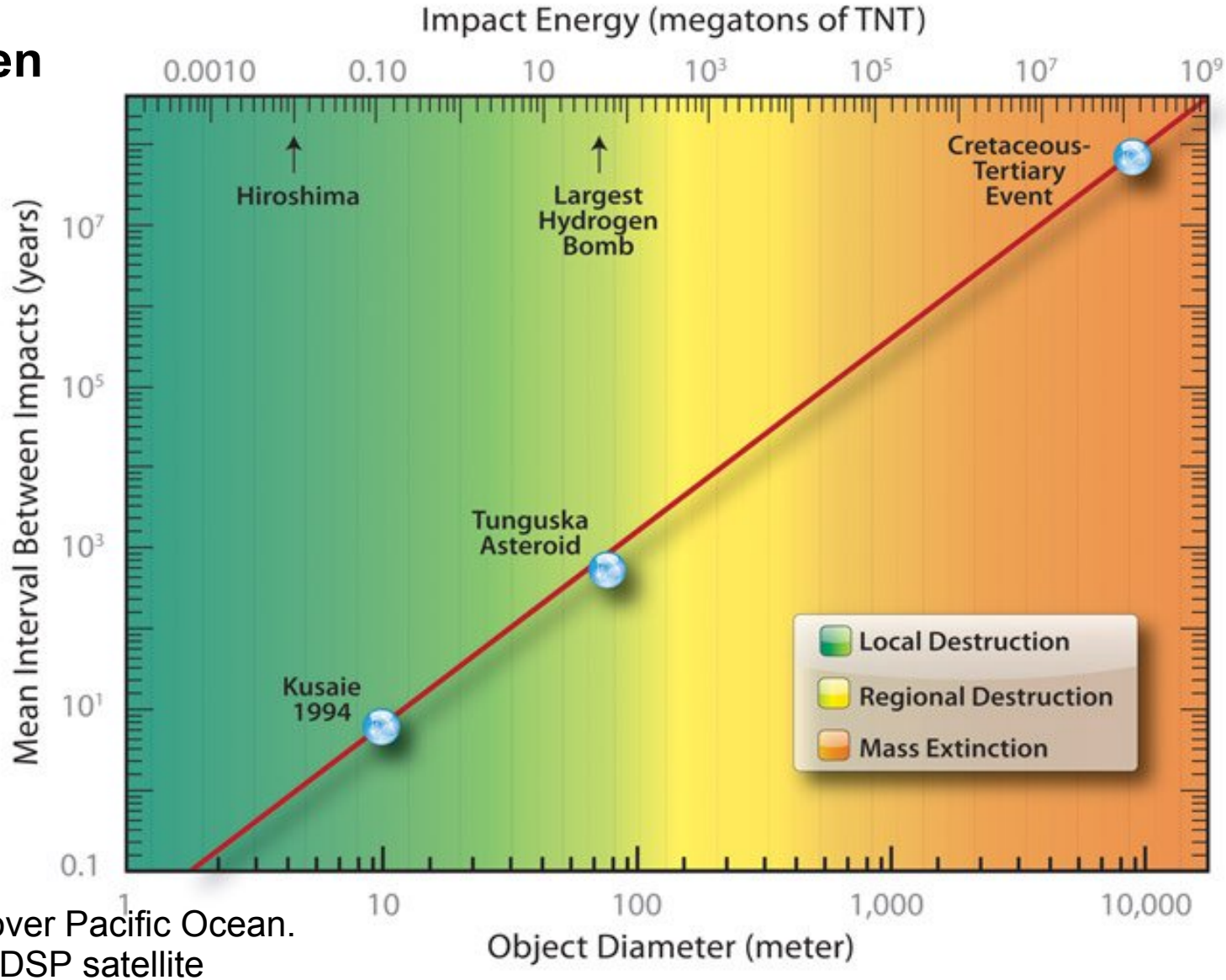



***Only about 10% of asteroids around 5-10 km are discovered.***

# Asteroids

## Asteroids as a threat to life on Earth.

**Time between collisions:**




Kusaie – explosion over Pacific Ocean.
Largest detected by DSP satellite

# Asteroids

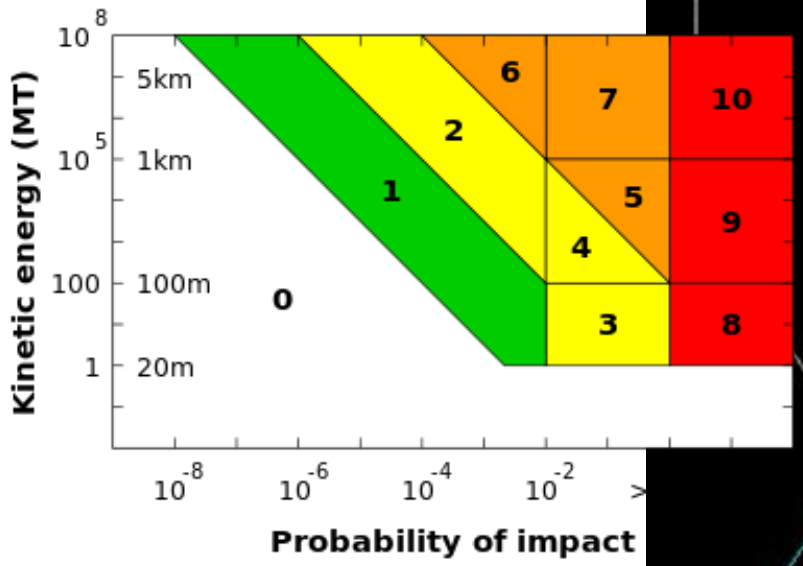
**Tunguska impact (1908, Siberia).**

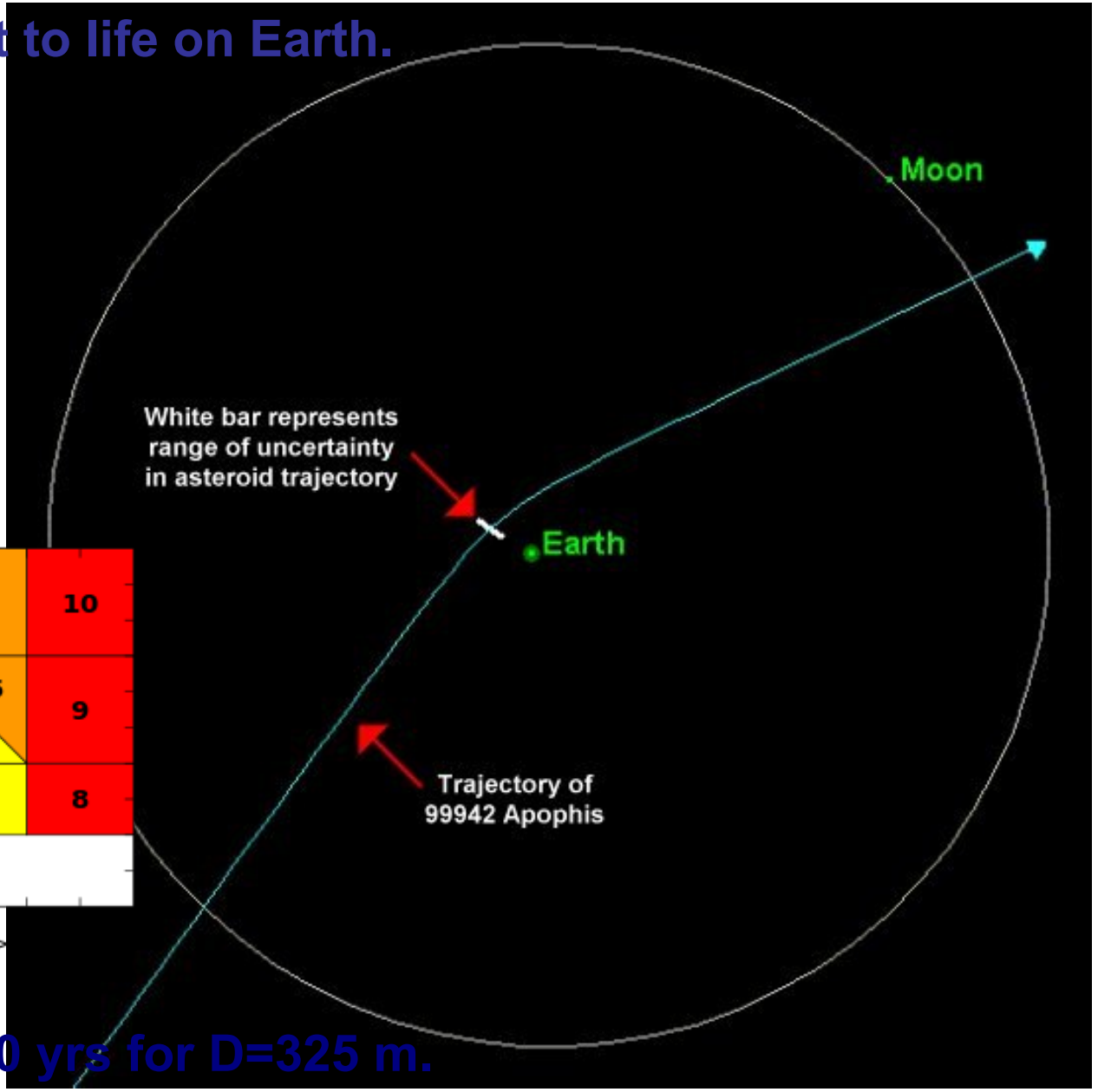
# Asteroids

**Asteroids as a threat to life on Earth.**

**Next close-call expected: Apophis! Oct 7, 2029.**

**325 m across. Reached Torino scale 4.**




**Impact freq ~1/80,000 yrs for D=325 m.**

# Asteroids

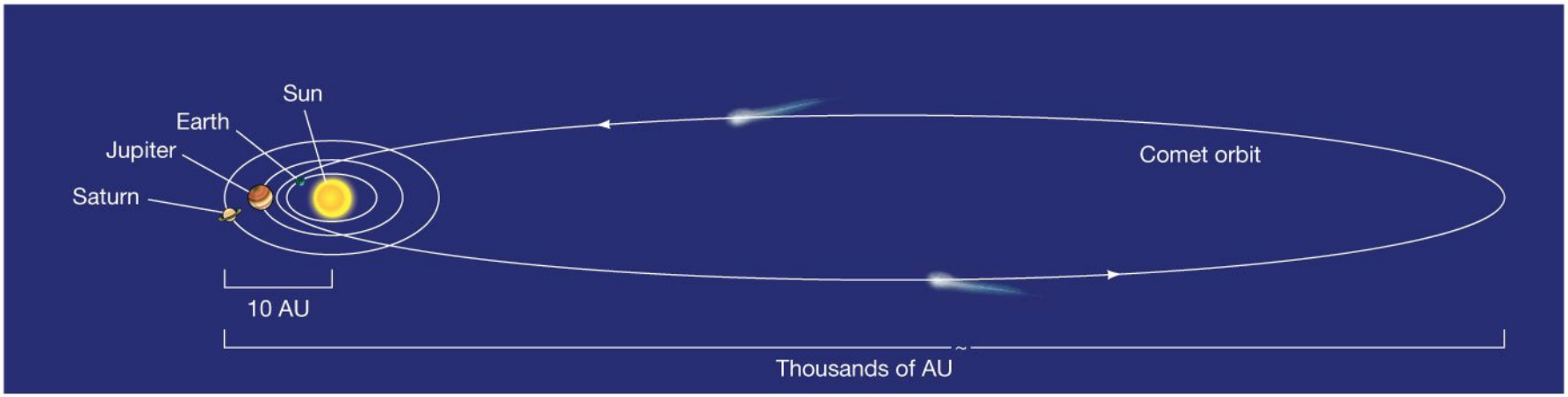
**What we can conclude:**

- **Different colors/spectral types have different histories:**
  **C-type: very unchanged, primitive, undifferentiated asteroids most numerous in outer belt.**
  **M-Type: nickel-iron cores of differentiated planetesimals which broke apart in collisions.**
  **S-Type: outer mantle, crust of differentiated bodies**
  **E-type: mantle of differentiated bodies**
- **Collisions (w/ each other) have occurred but are now rare!**
- **Asteroids can have moons!**
- **Can be "rubble piles" (e.g., Mathilde, Itokawa).**
- **Smaller ones more numerous.**

**Those with smaller orbits ("Earth-crossing") most dangerous.**

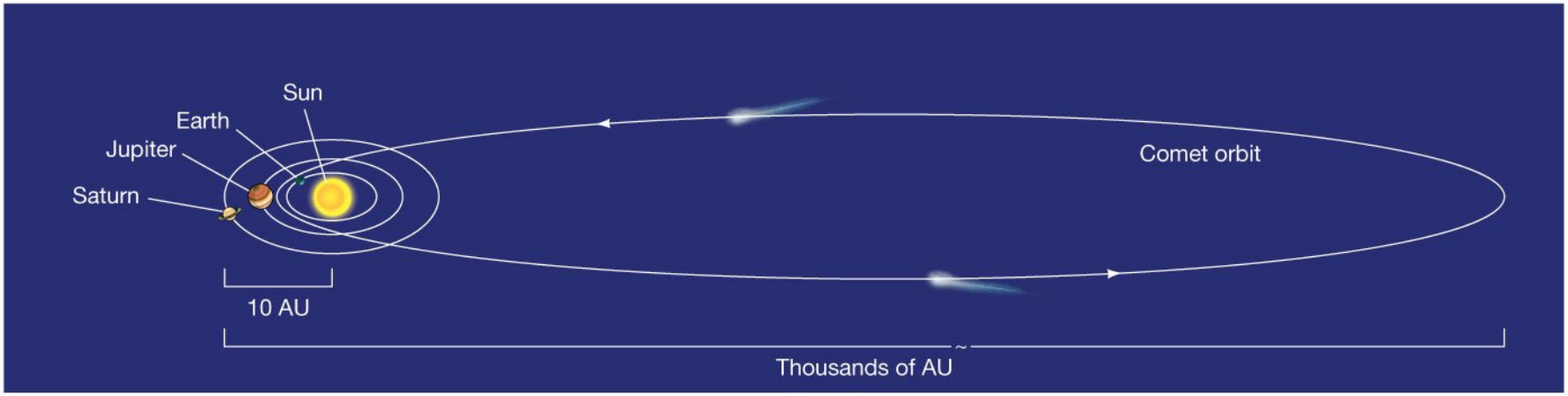
# Comets

Comets that come close enough to the Sun/Earth to look bright from Earth tend to have very eccentric orbits



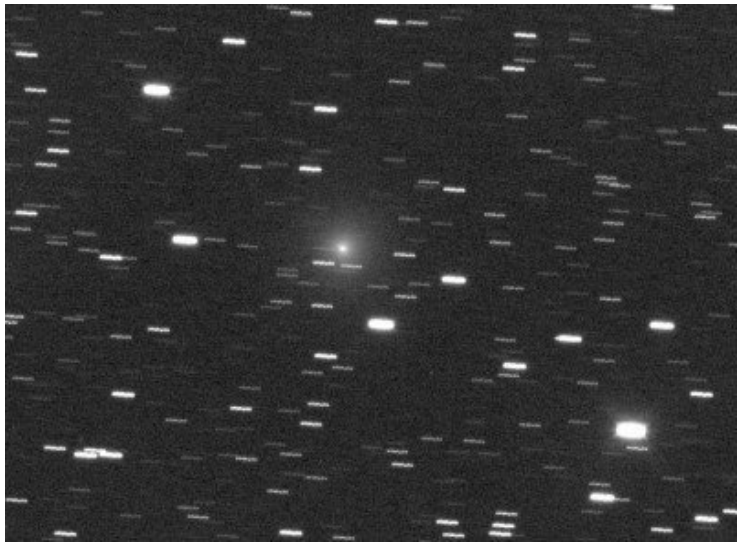
# Comets

Comets that come close enough to the Sun to look bright from Earth have very eccentric orbits






Comet just starting to Grow a coma, but without a tail.

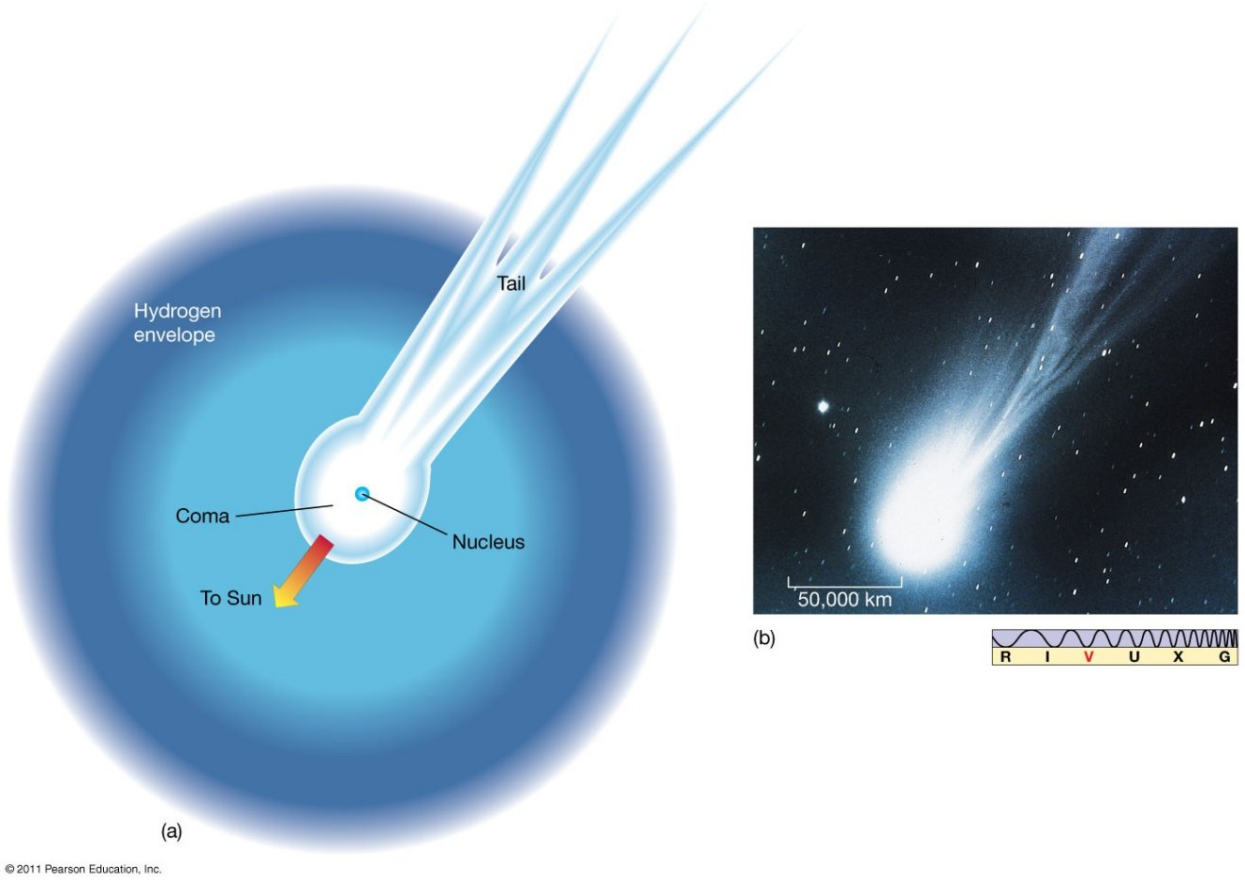


# Comets


Comet McNaught was visible near perihelion from the S. Hemisphere.

# Comets

Comets have a very small nucleus, a coma of gas and dust that is the most visible part and can be very large, a hydrogen envelope, a dust tail, and an ion tail




***See images and videos online!***

# Comets

Fairly accurate colors for a comet photo.  (Comet ISON?)

# Comets

Obvious separation of gas (ion) tail from dust tail.  Hale-Bopp 1996.

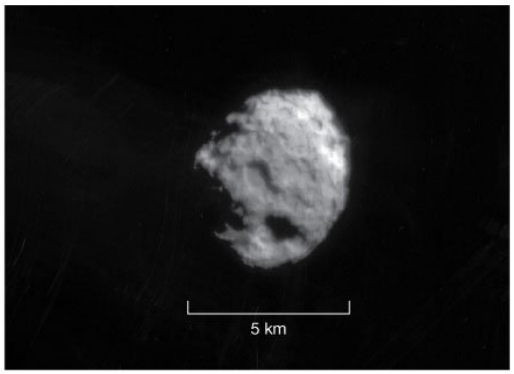
# Comets

Space Missions to comets

There have been 8 comets that have been closely observed. (6 missions)

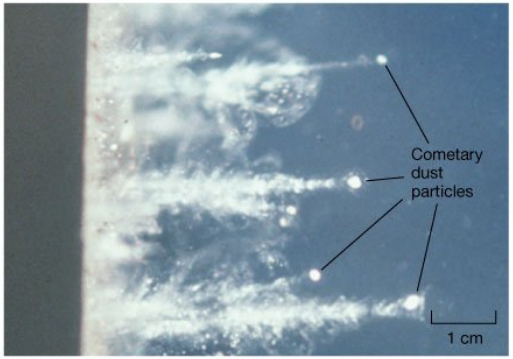
Comet Halley was visited by ICE and Giotto in 1986.

The *Stardust* mission flew through the tail of comet Wild-2, gathering dust particles in detectors made of aerogel and returning them to Earth.




(a)

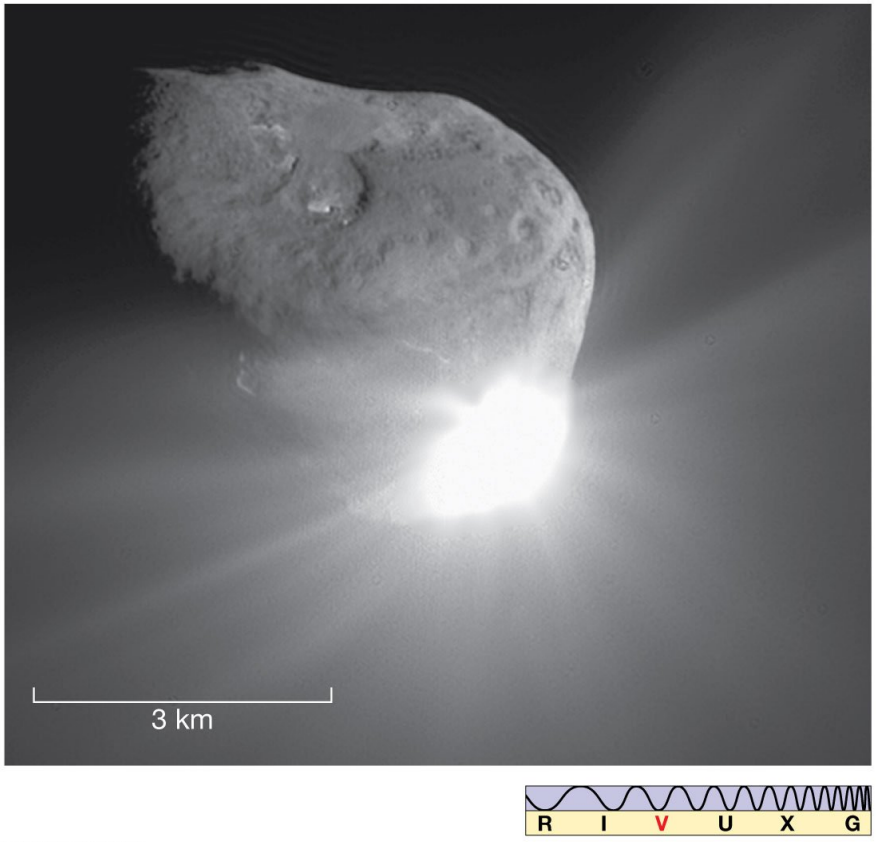
(b)




(c)

# Comets

**The Deep Impact mission slammed a projectile into comet Tempel 1 and studied the material expelled in order to analyze the composition of the comet**



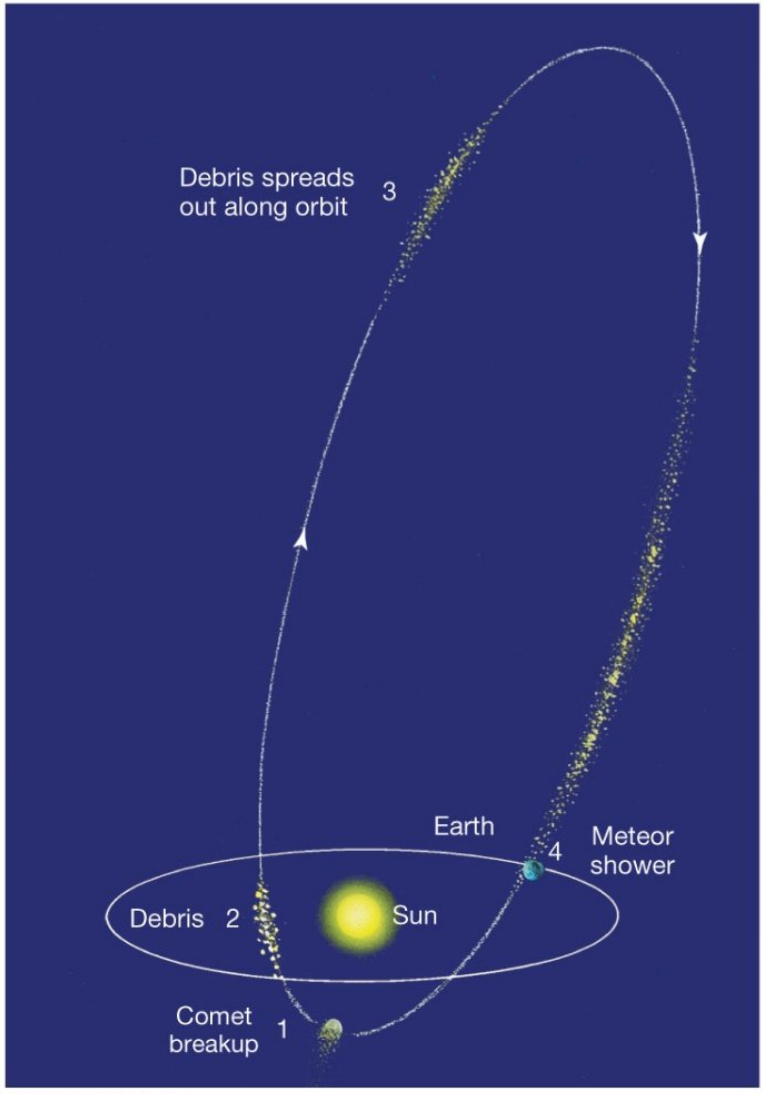
# Meteoroids

**Meteoroid** was a term given to objects larger than microscopic dust and smaller than asteroids. The upper limit has been set at 10m (1995), 1m* (2010), and 100 m (our textbook).

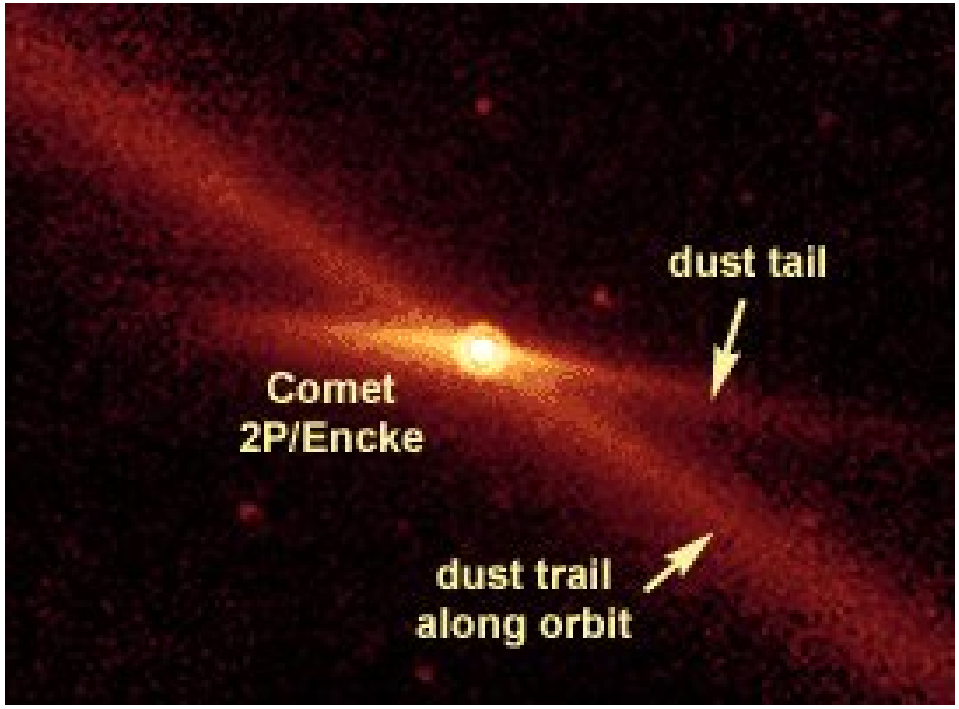
Most of the smaller ones outside of the asteroid belt are the remnants of **comets**.

If the Earth's orbit intersects the comet's, **meteor showers** will occur every year on the same date.

* Rubin & Grossman (2010) say 1m.



Meteoroid trail revealed by Spitzer in the IR.



# Meteor nomenclature

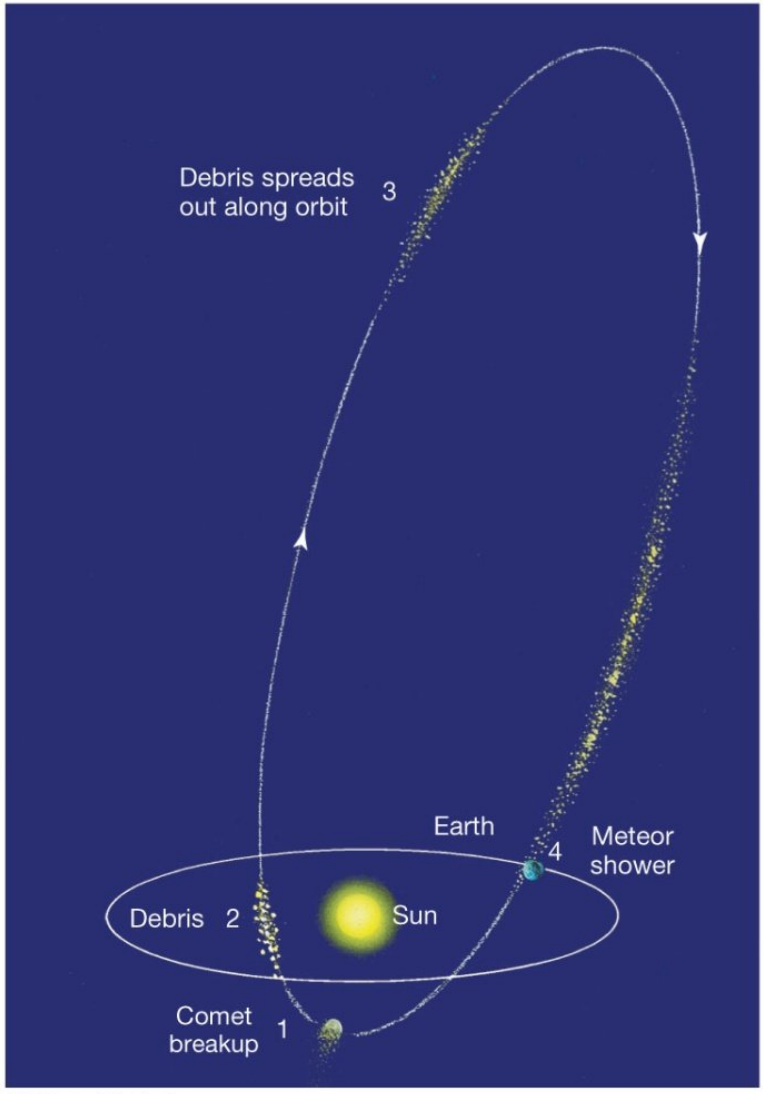
**Meteoroid** Object before it enters Earth's atmosphere

**Meteor** Bright streak that we see as a "shooting star". Sporadic vs annual

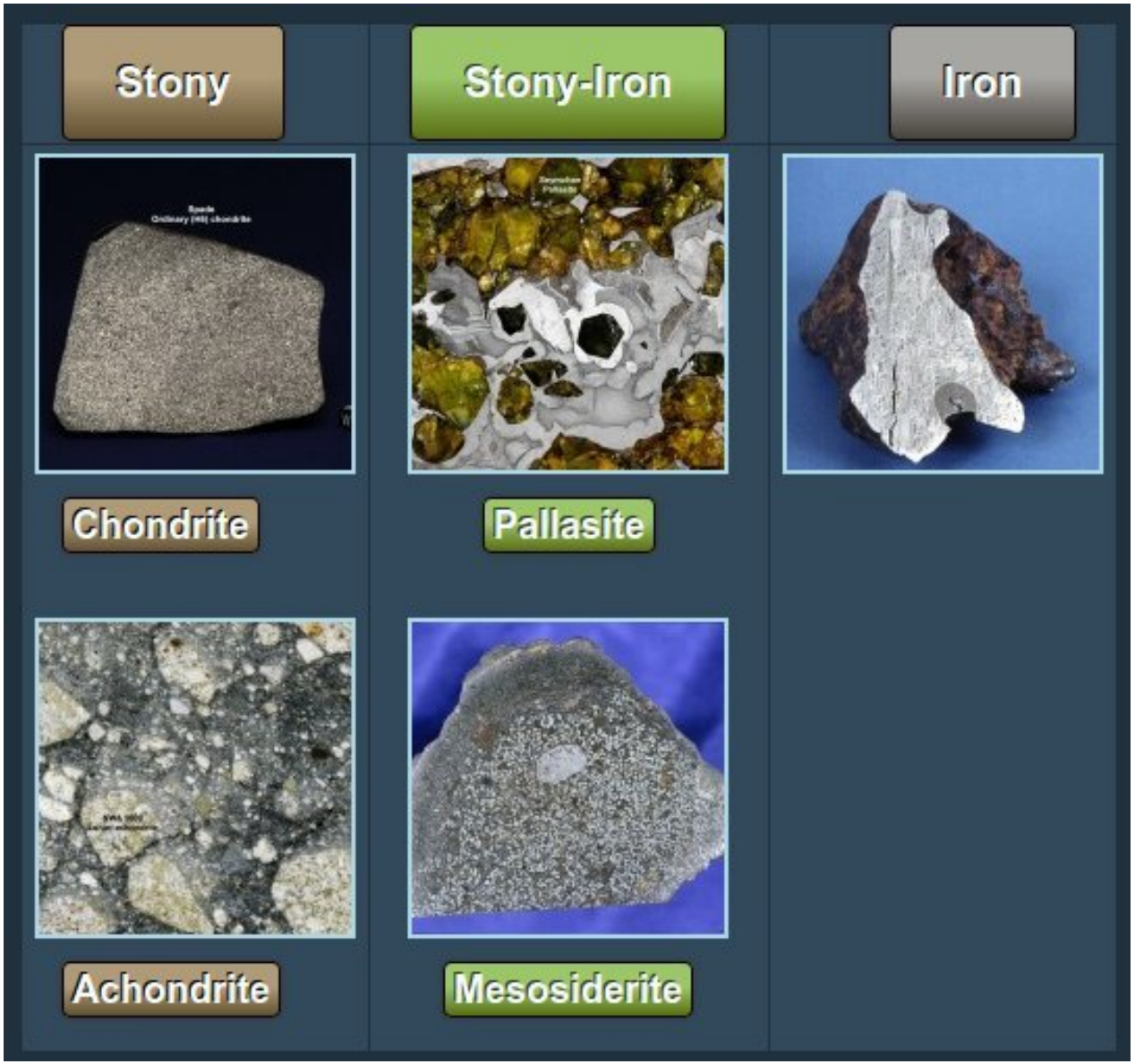
**Meteorite** Rock that survives the fall and can be found on the ground.

**Major Annual Meteor Showers:**

| Name | Date of Peak |
|---|---|
| Quadrantids | Night of January 2 |
| Lyrids | Night of April 21 |
| Eta Aquarids | Nights of May 4/5 |
| Perseids | Nights of August 11/12 |
| Orionids | Night of October 21 |
| Leonids | Night of November 16 |
| Geminids | Nights of December 12, 13 |



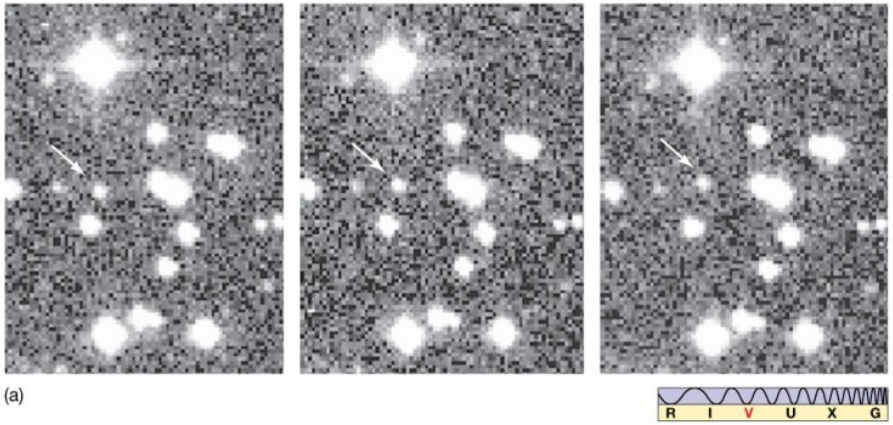
# Meteorites

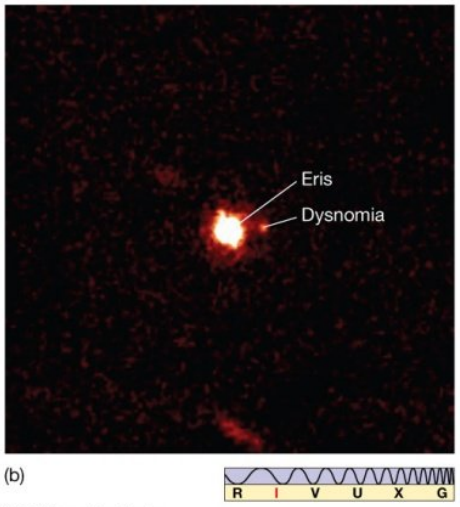

Stony
Stony-Iron
Iron
Chondrite
Pallasite
Achondrite
Mesosiderite

# Beyond Neptune

No objects have been observed in the Oort cloud—it is simply too far away.

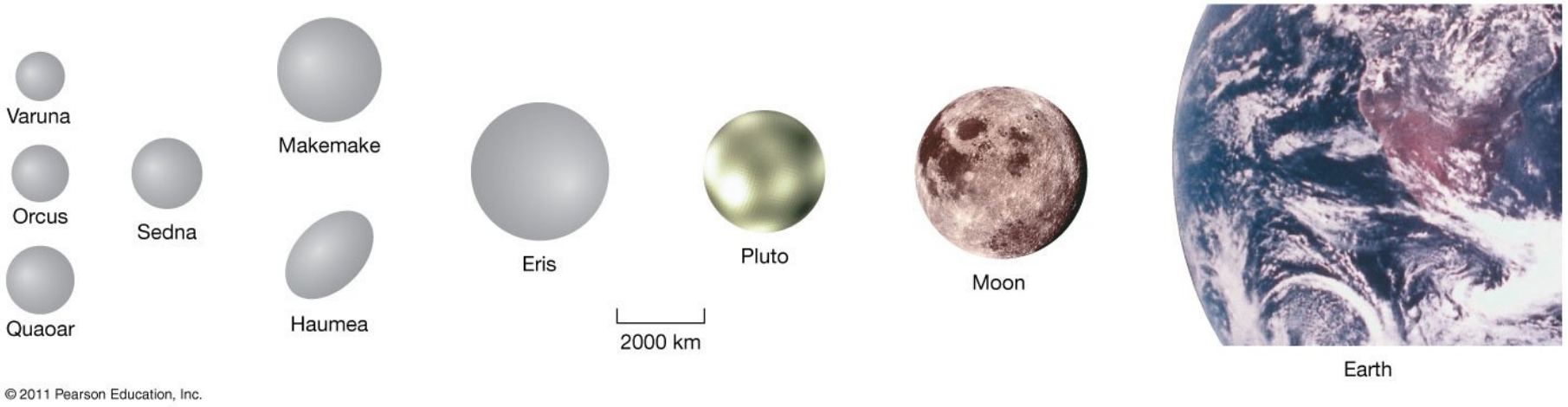
However, some Kuiper belt objects (KBOs) have been observed—over 1000 so far. Here are Pholus and Eris.



# Beyond Neptune

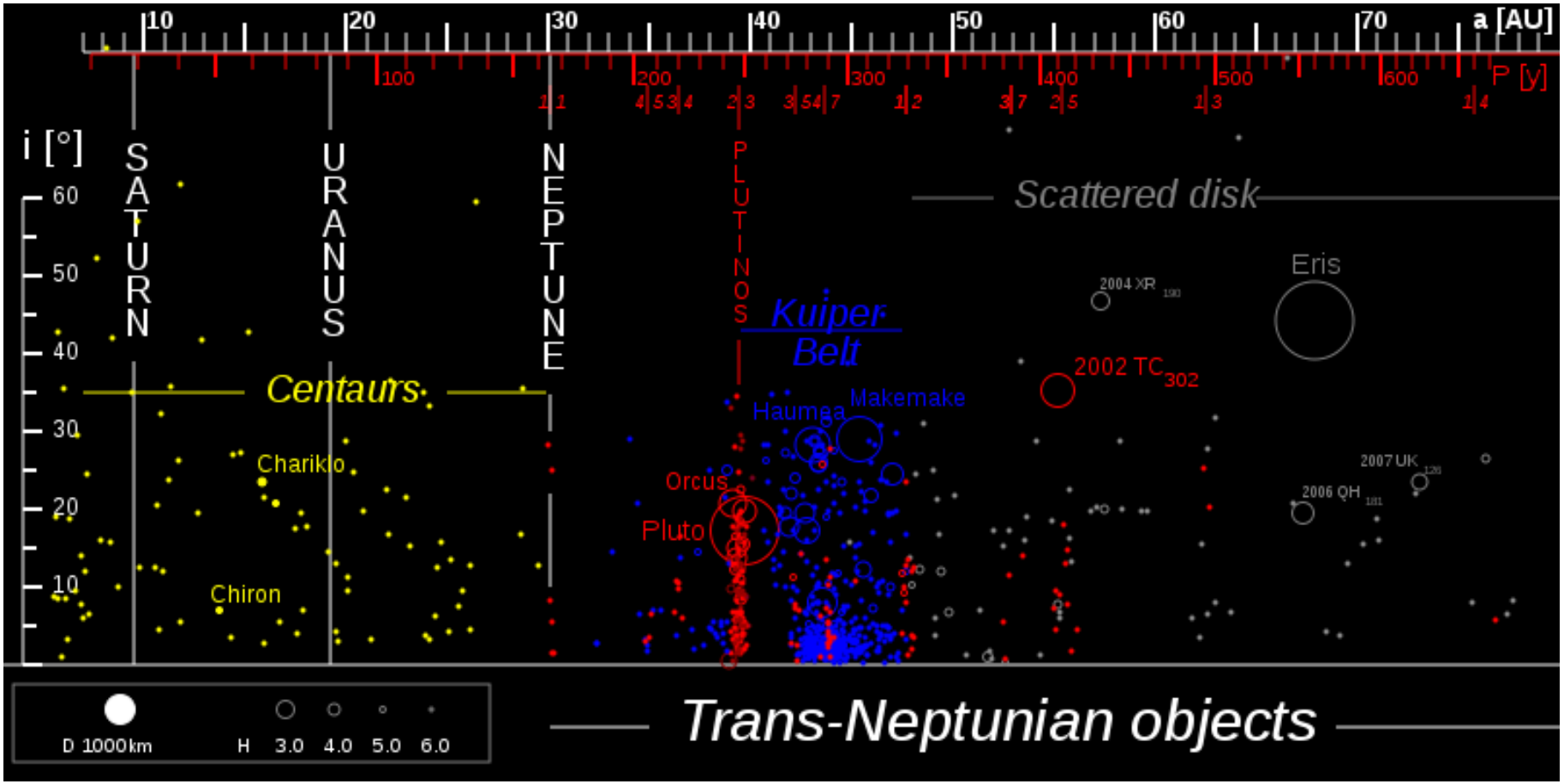
**Comparison of several trans-Neptunian objects with Earth and its moon**






(Pluto is actually bigger than Eris!)

# Beyond Neptune




*From Wikipedia. 2012.*

# Extraterrestrial Life

We only know of one place with life, so far.

The predominate opinion among scientists on UFO's is that they are not ETs.

Promising sites in the solar system:
Mars, Europa, Titan.

Promising sites in the Galaxy:
Exoplanets found within the "habitable zone" of stars.

We have research programs to "listen" for intelligent life with radio telescopes.
SETI = Search for Extraterrestrial Intelligence

Drake equation: estimates the number of intelligent life-bearing worlds in Milky Way.