

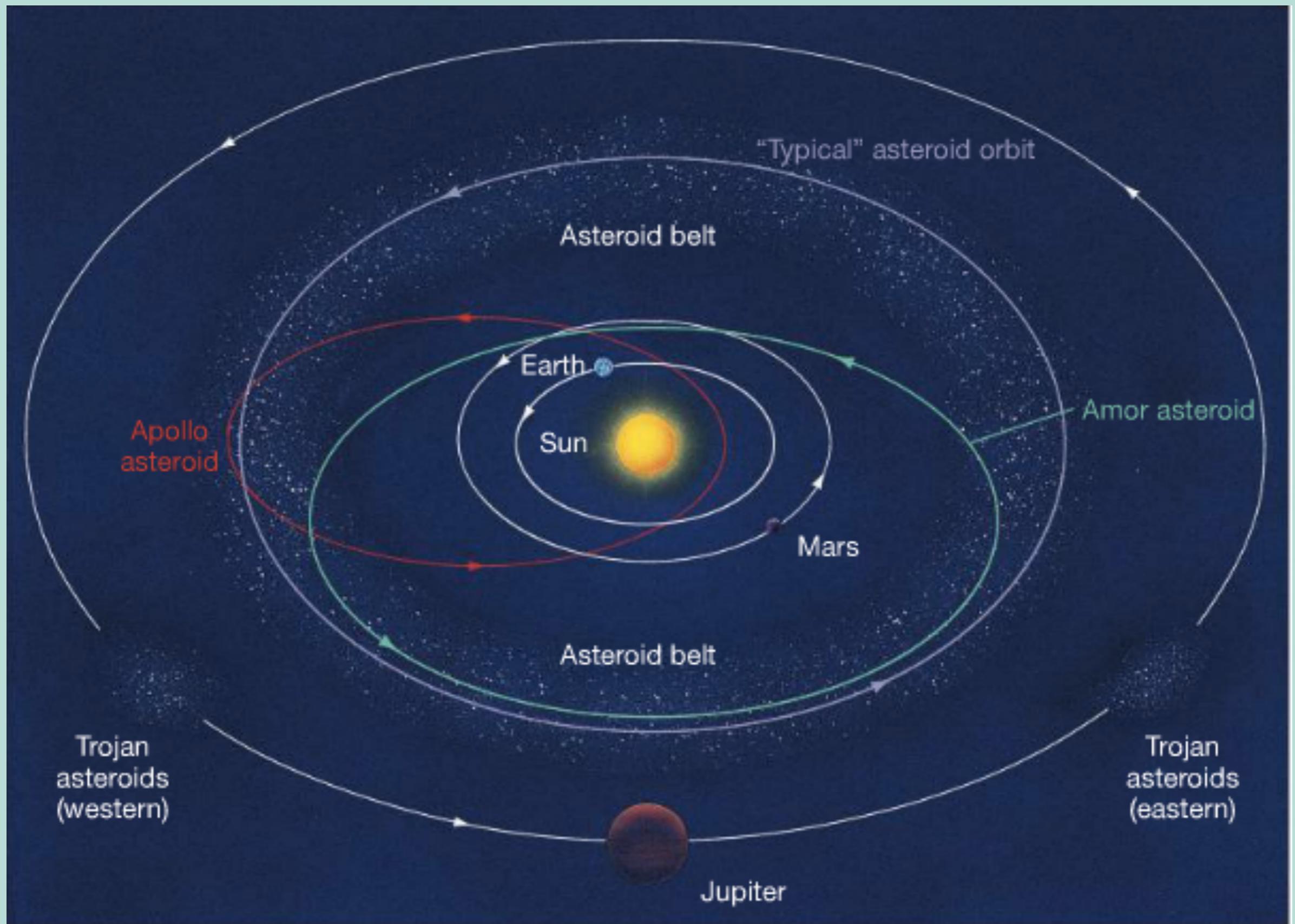


with your host:



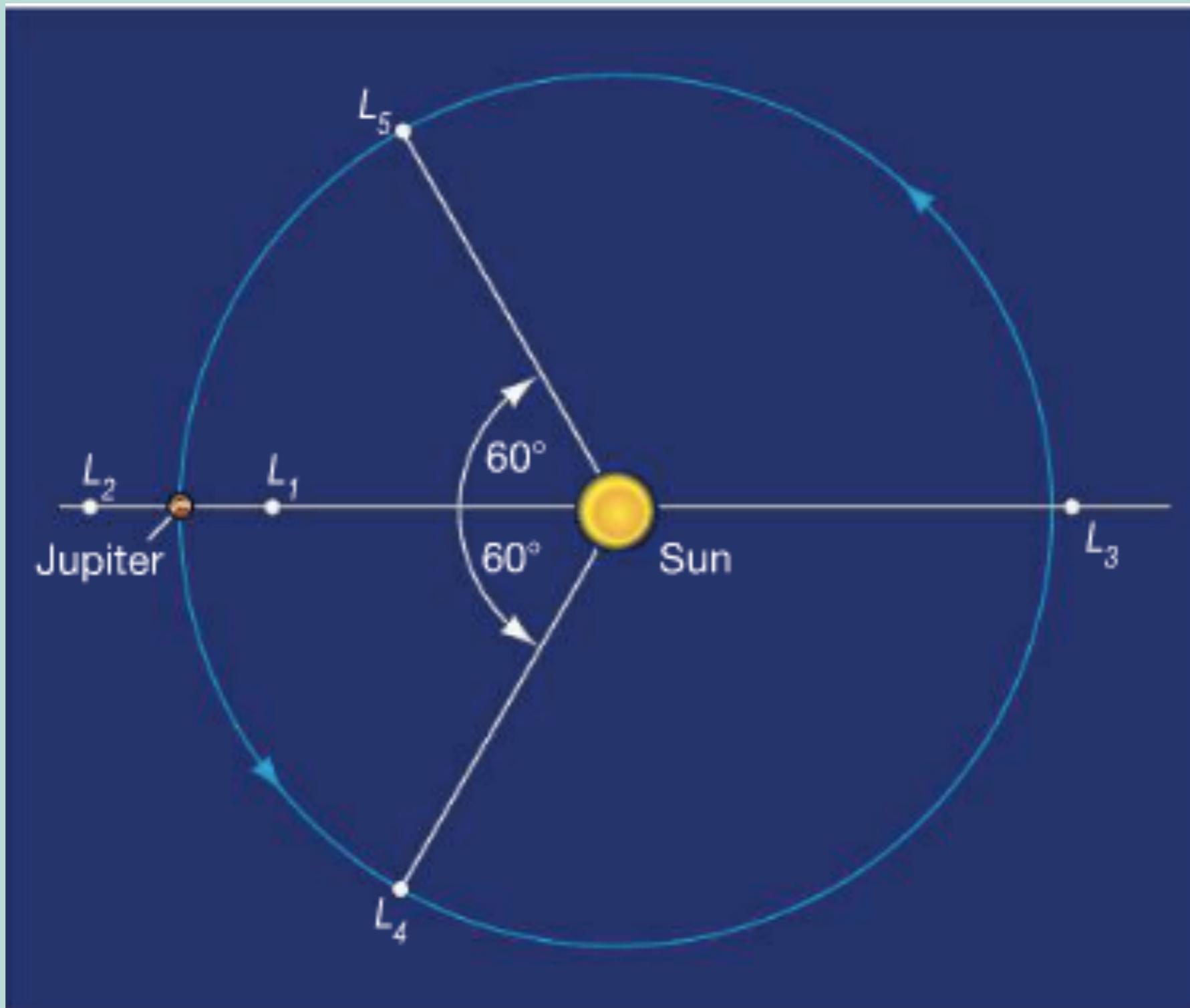
**Lecture 13:
Cosmic Debris**

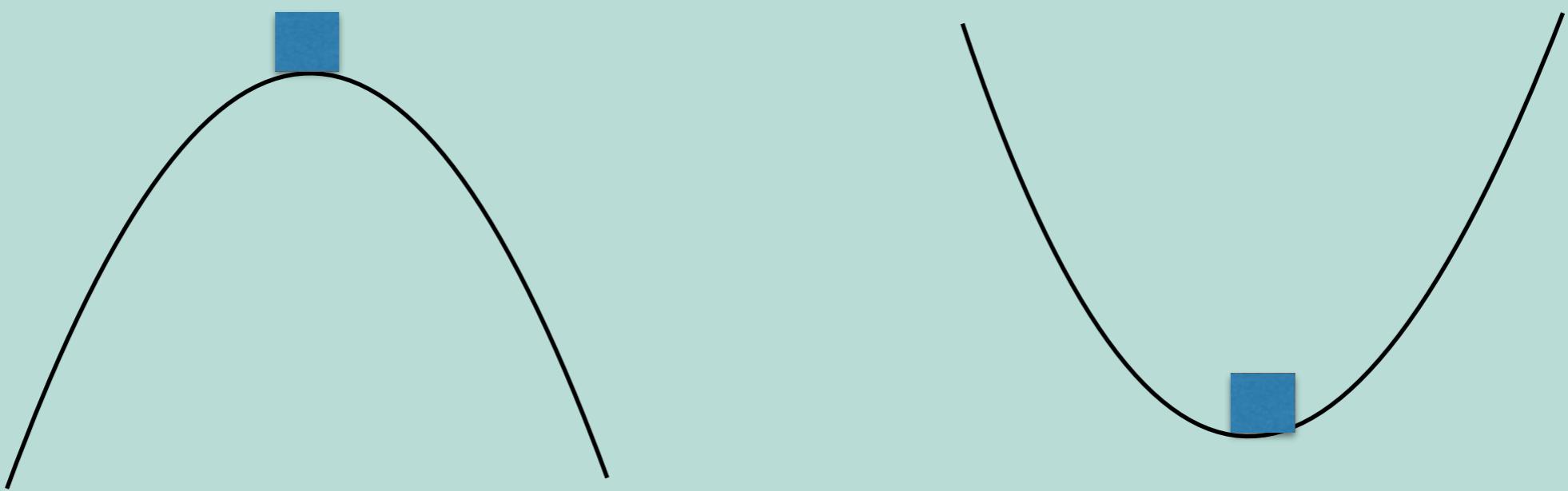
Coop



- ~ 3 AU
- 4% the mass of the moon
- Very few more than 300km across (mid size moon)
- Jupiter prevents larger objects from forming

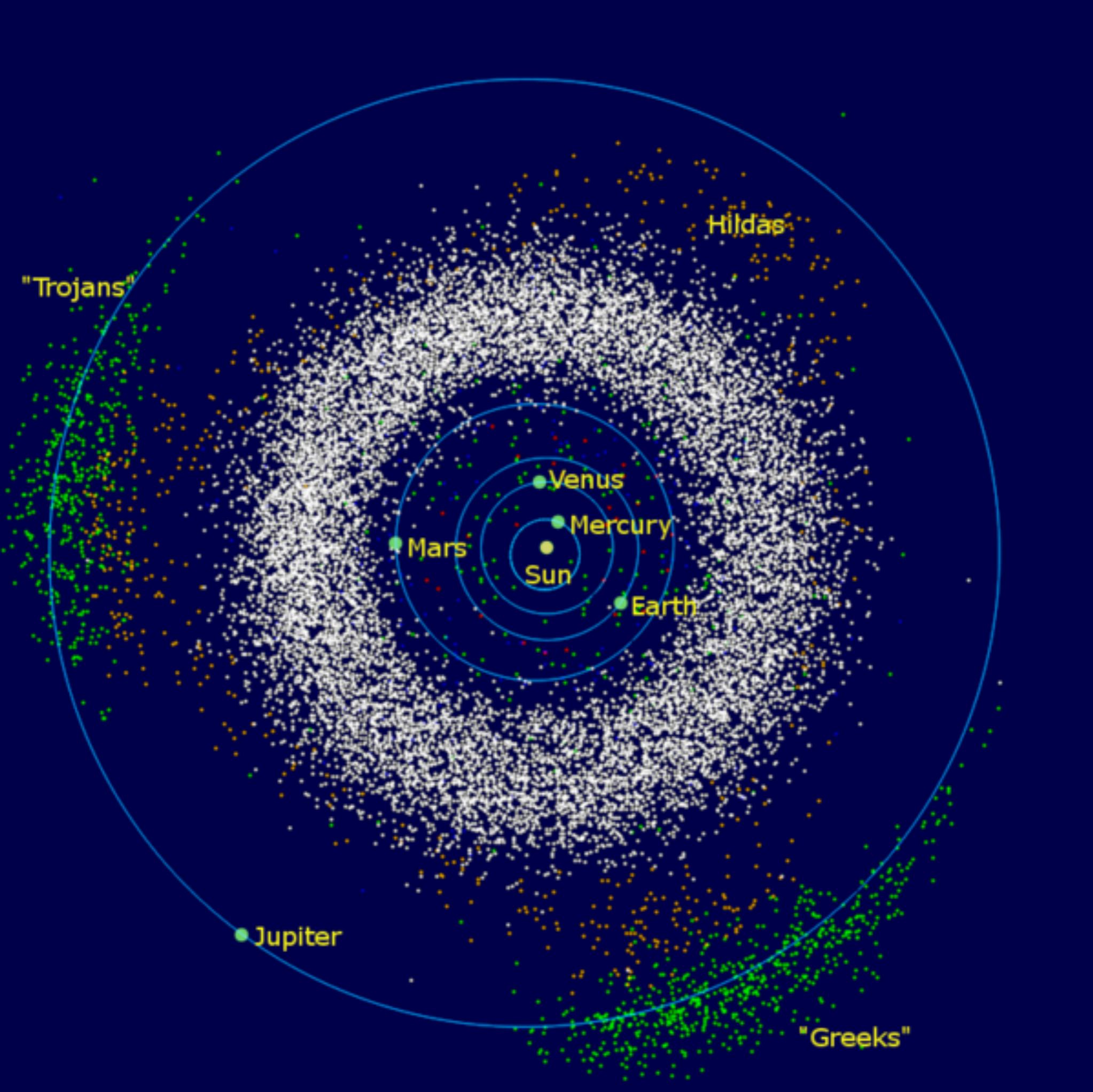
Lagrange Points Revisited





L1, L2, L3

L4, L5

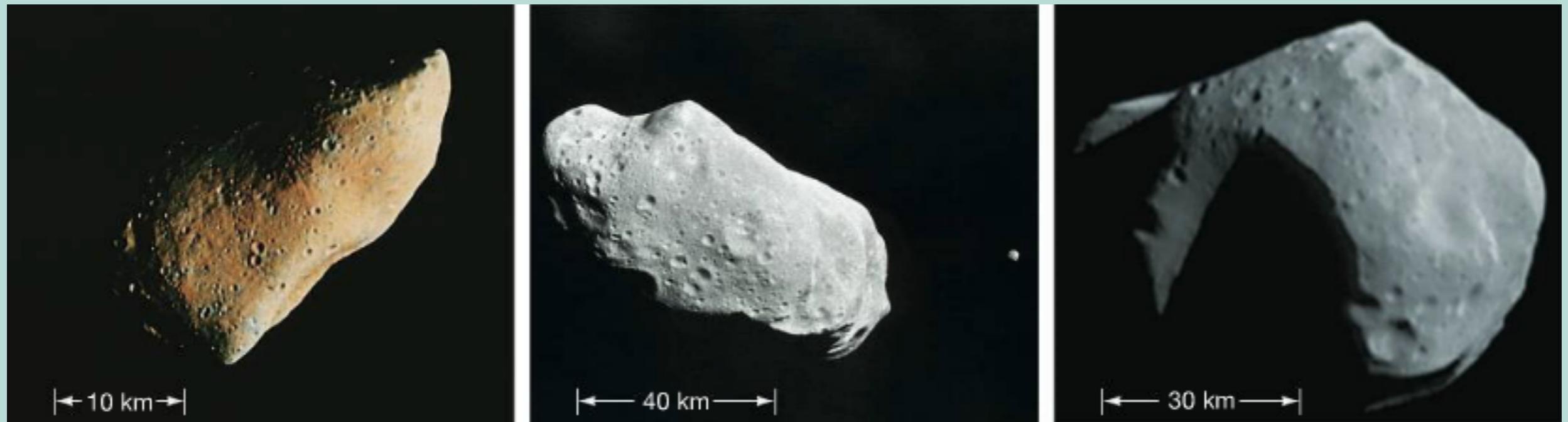


C-type: Carbonaceous, darkest (75%)

S-type: Silicate, More reflective, rocky (15%)

M-type: Nickel and Iron (10%)

Dactyl!



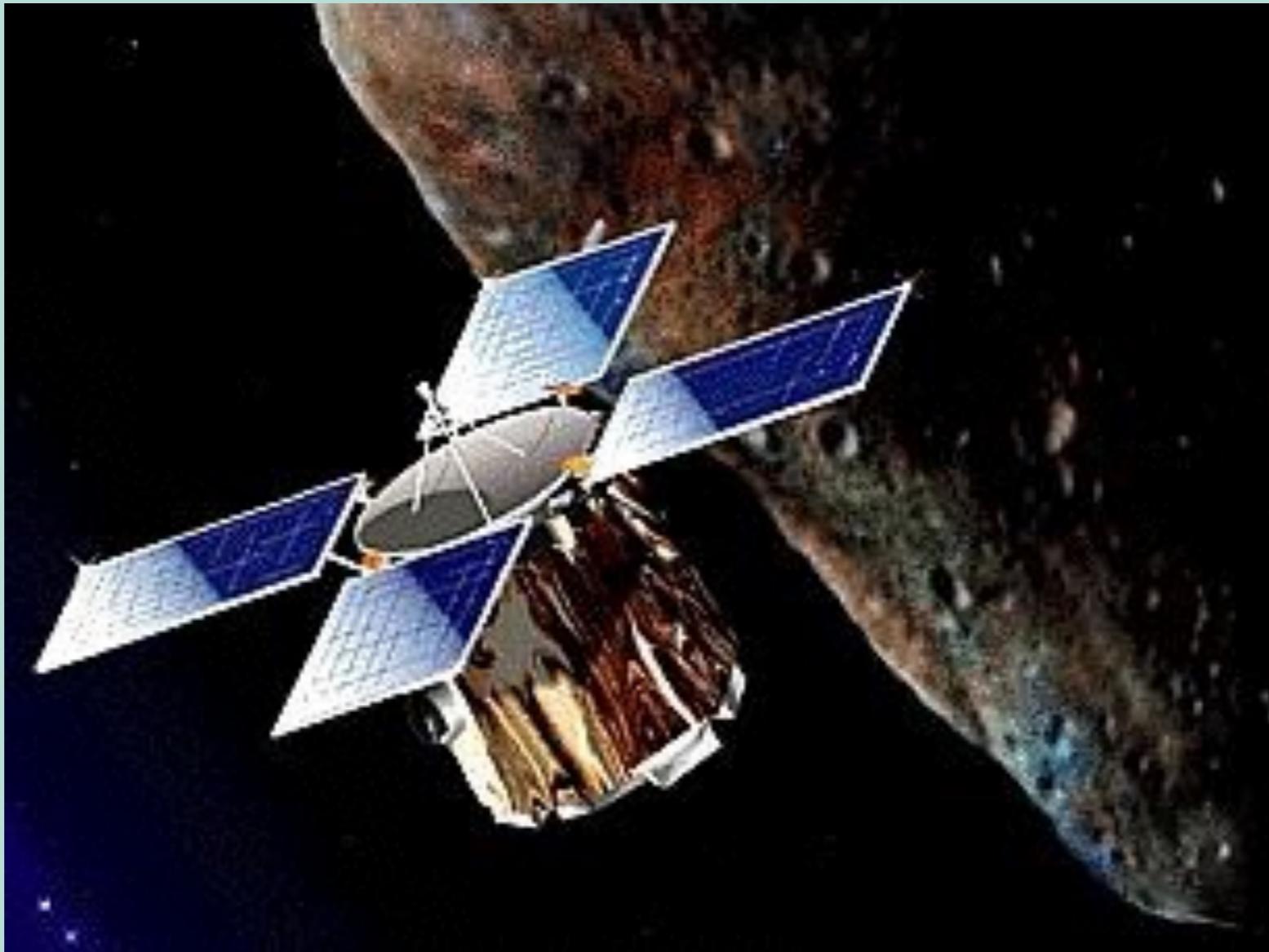
S-type: Gaspara
(Galileo)

S-type: Ida
(Galileo)

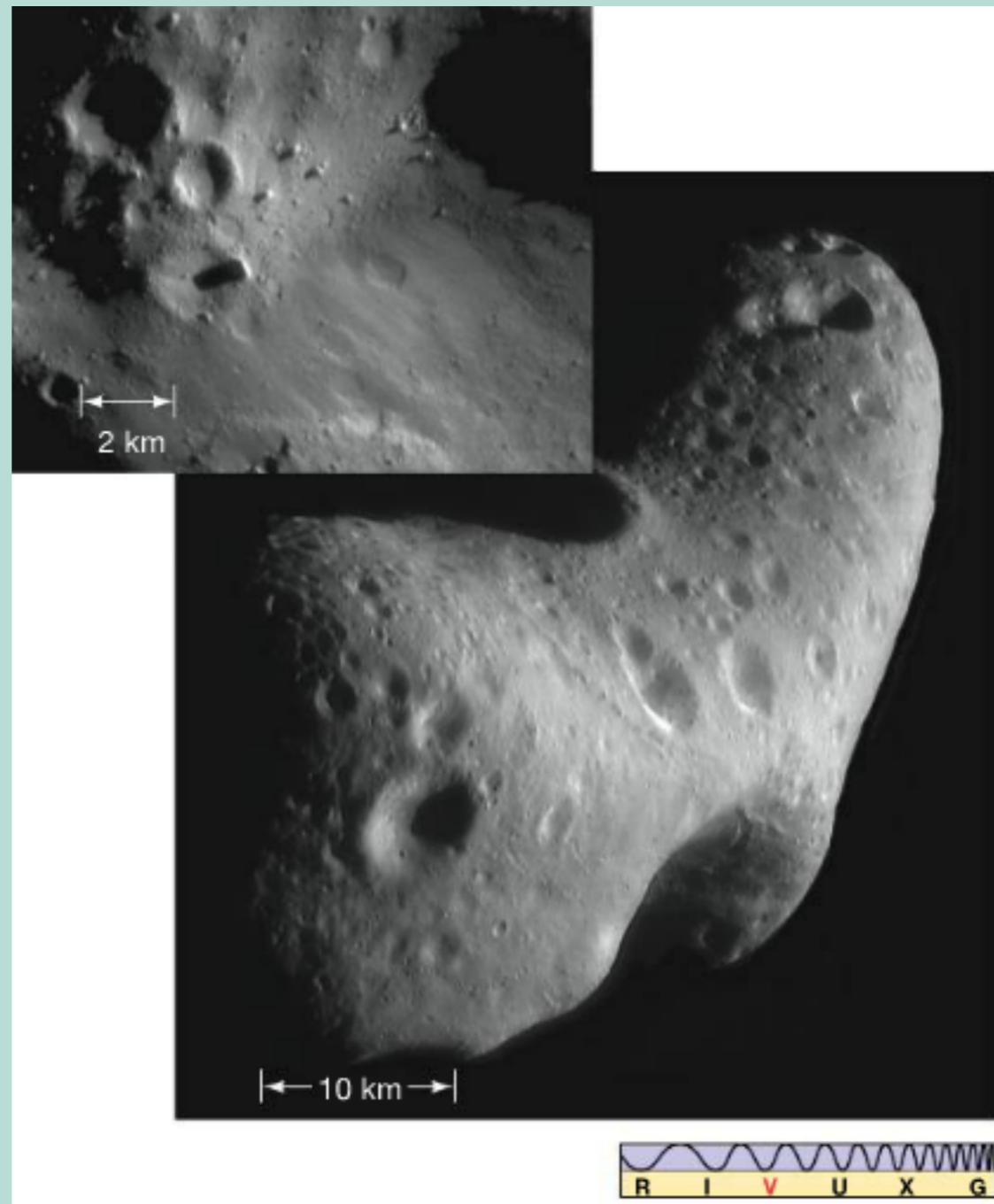
C-type: Mathilda
(NEAR)

$m \sim 10^{16}, 10^{17}$ kg

Near Earth Asteroid Rendezvous (NEAR) 1997



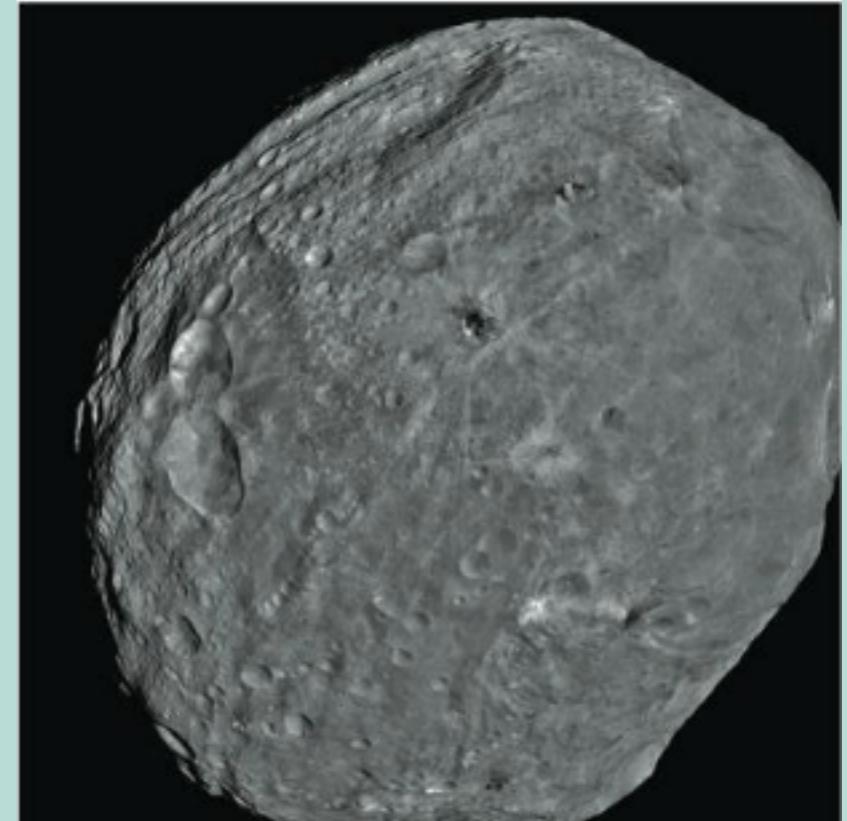
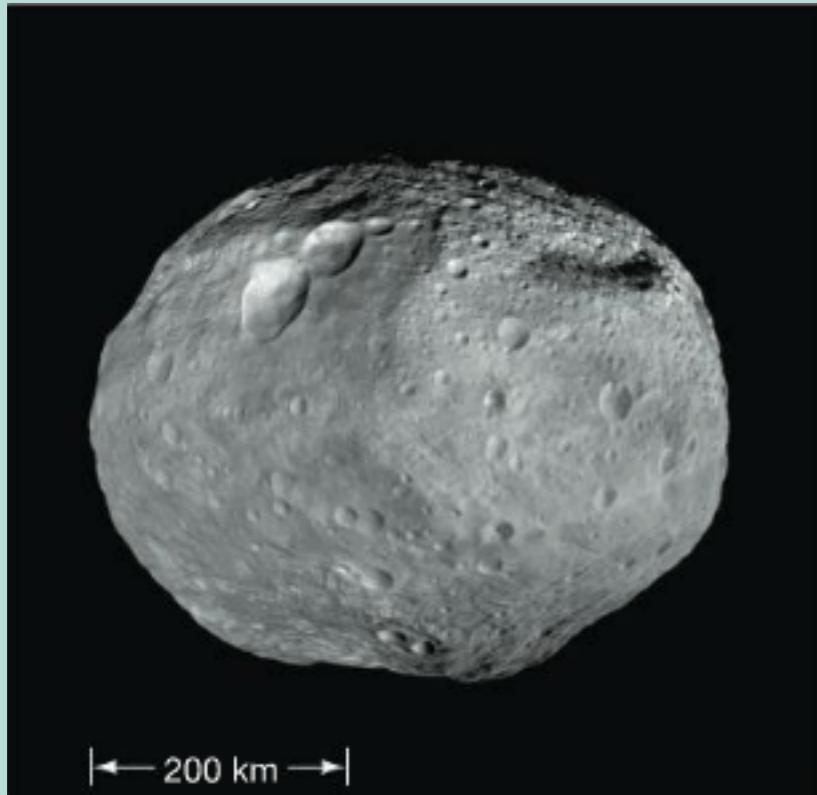
Eros (NEAR)



DAWN



Vesta

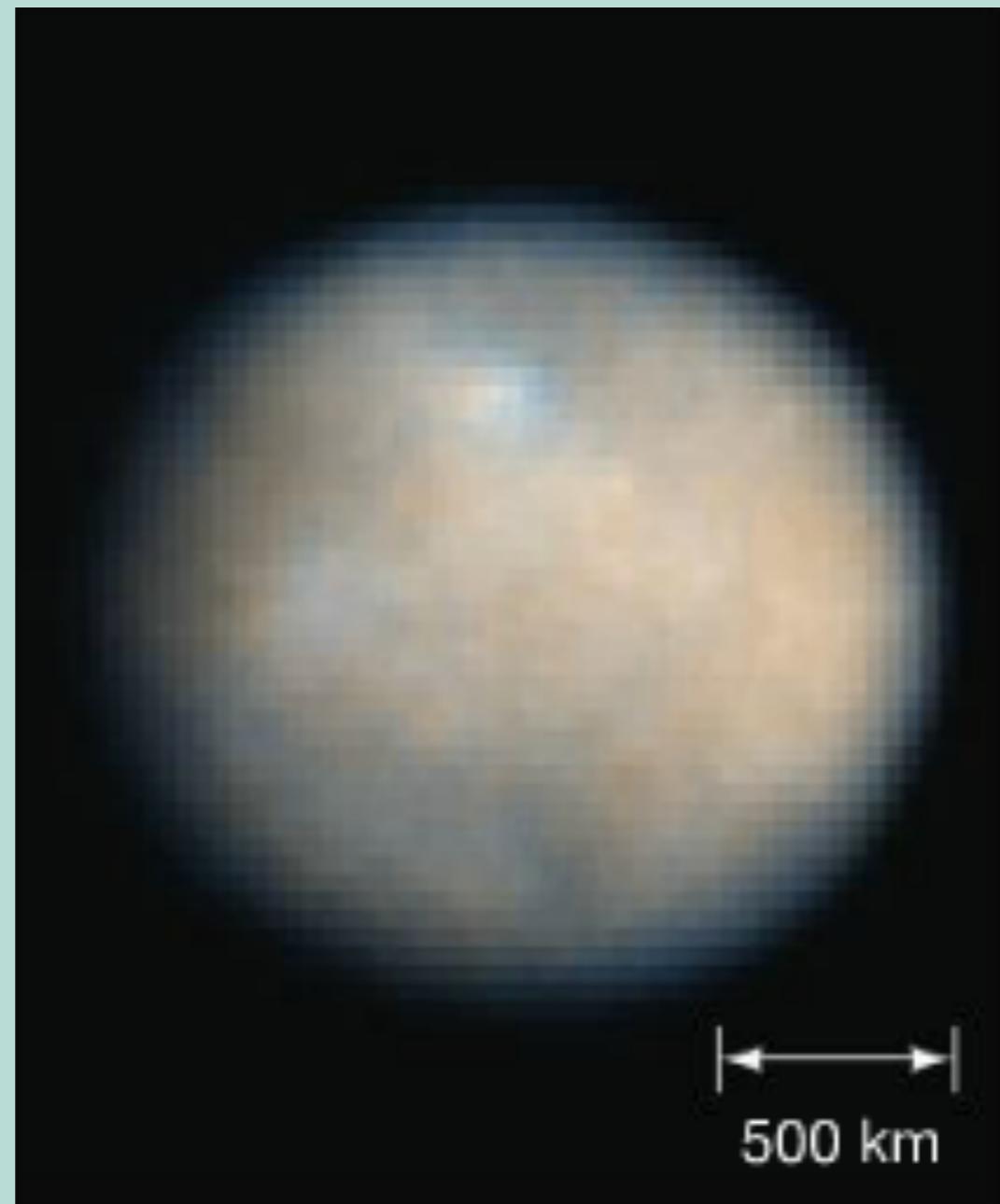


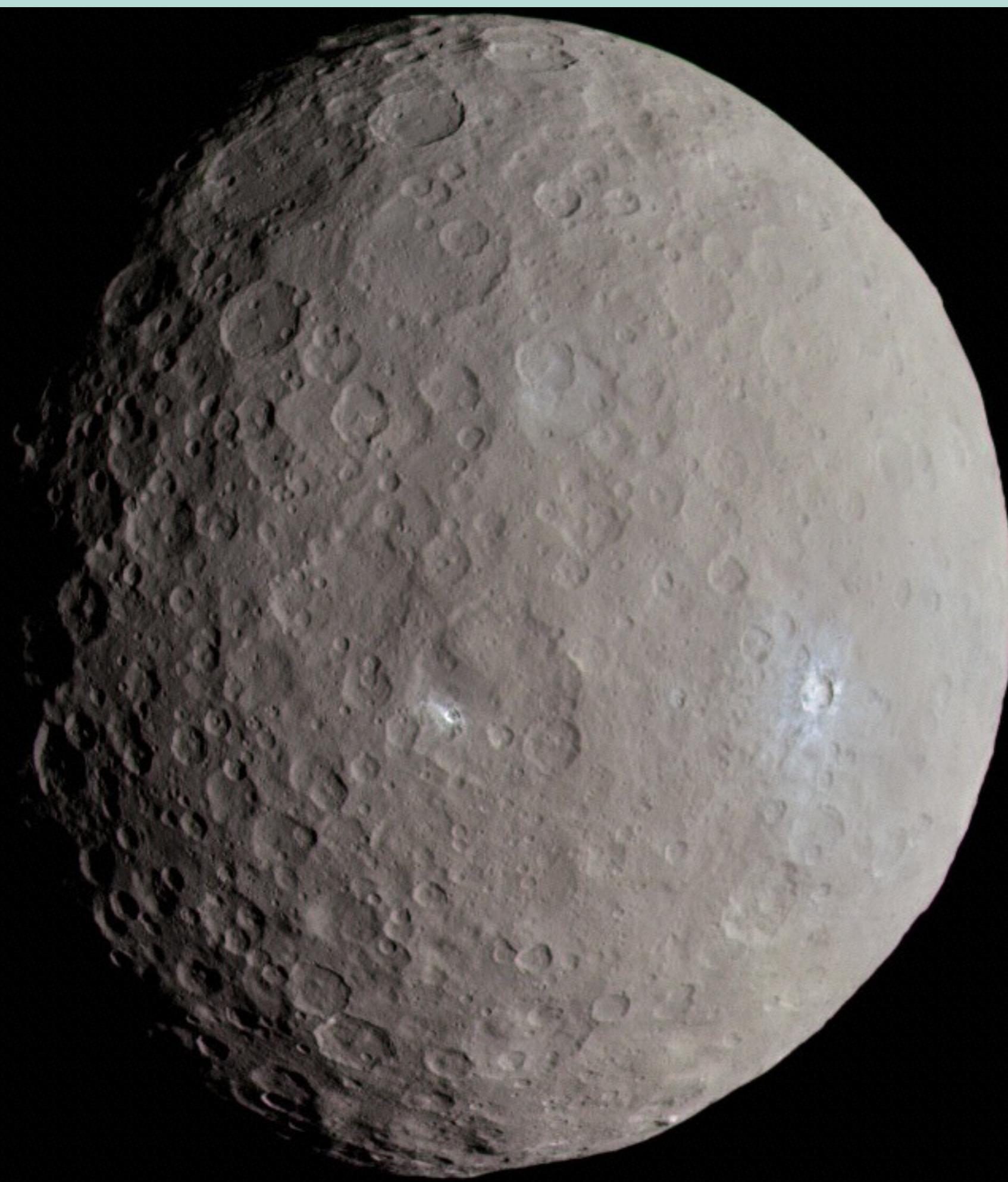
- Past Volcanism!
- $m \sim 10^{20} \text{ kg}$
- mountain in left image: 2 X the height of Everest!

Better angle



Ceres Pre-Dawn





Ceres

$m \sim 9.5\text{e}22 \text{ kg}$
 $\sim 1.5\text{e}-4 m_e$

$r \sim 475 \text{ km}$
 $\sim .075 r_e$

(5 lbs)

$d \sim 2.75 \text{ AU}$

density ~
 2000 kg/m^3

Relative Sizes

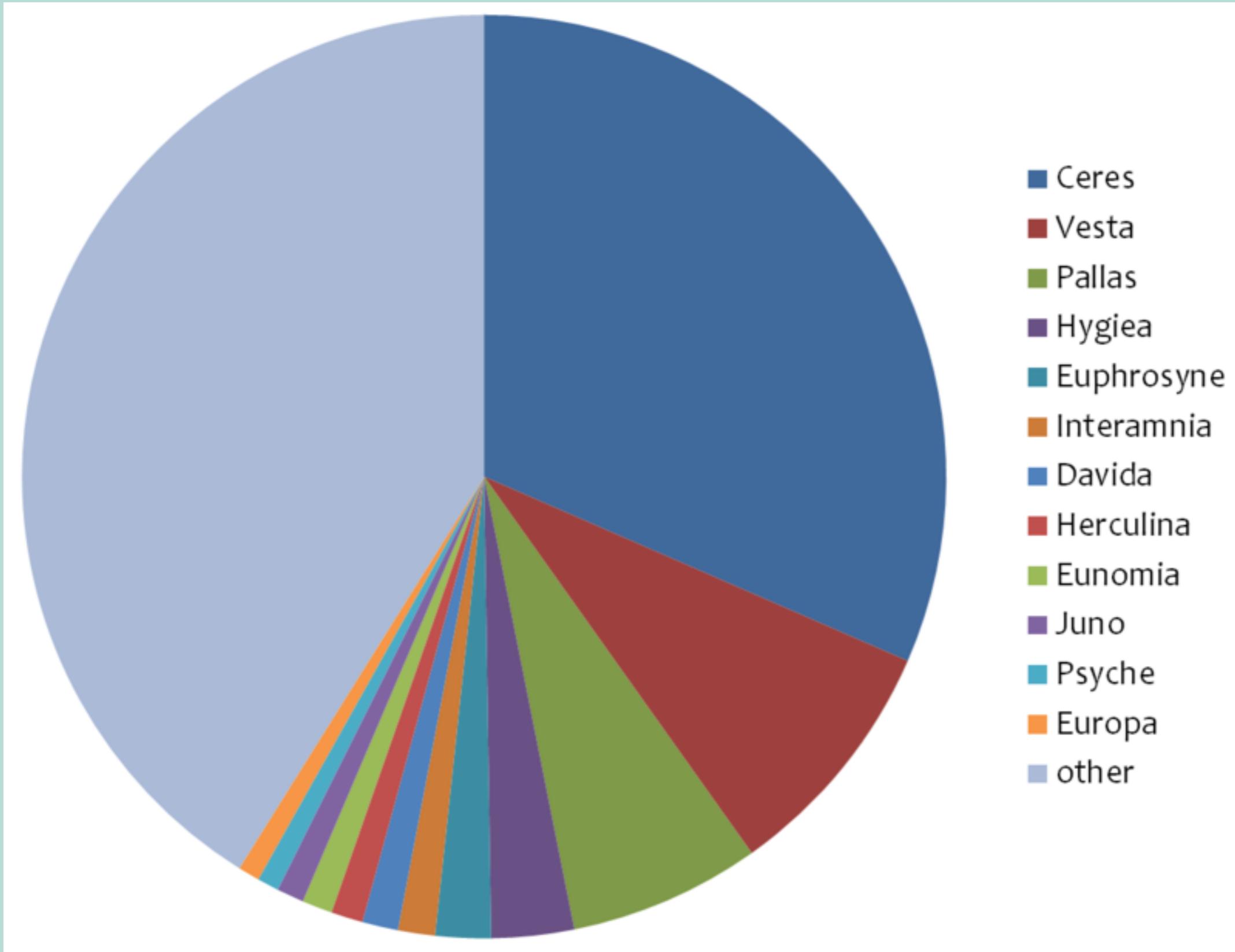


Bode's Law

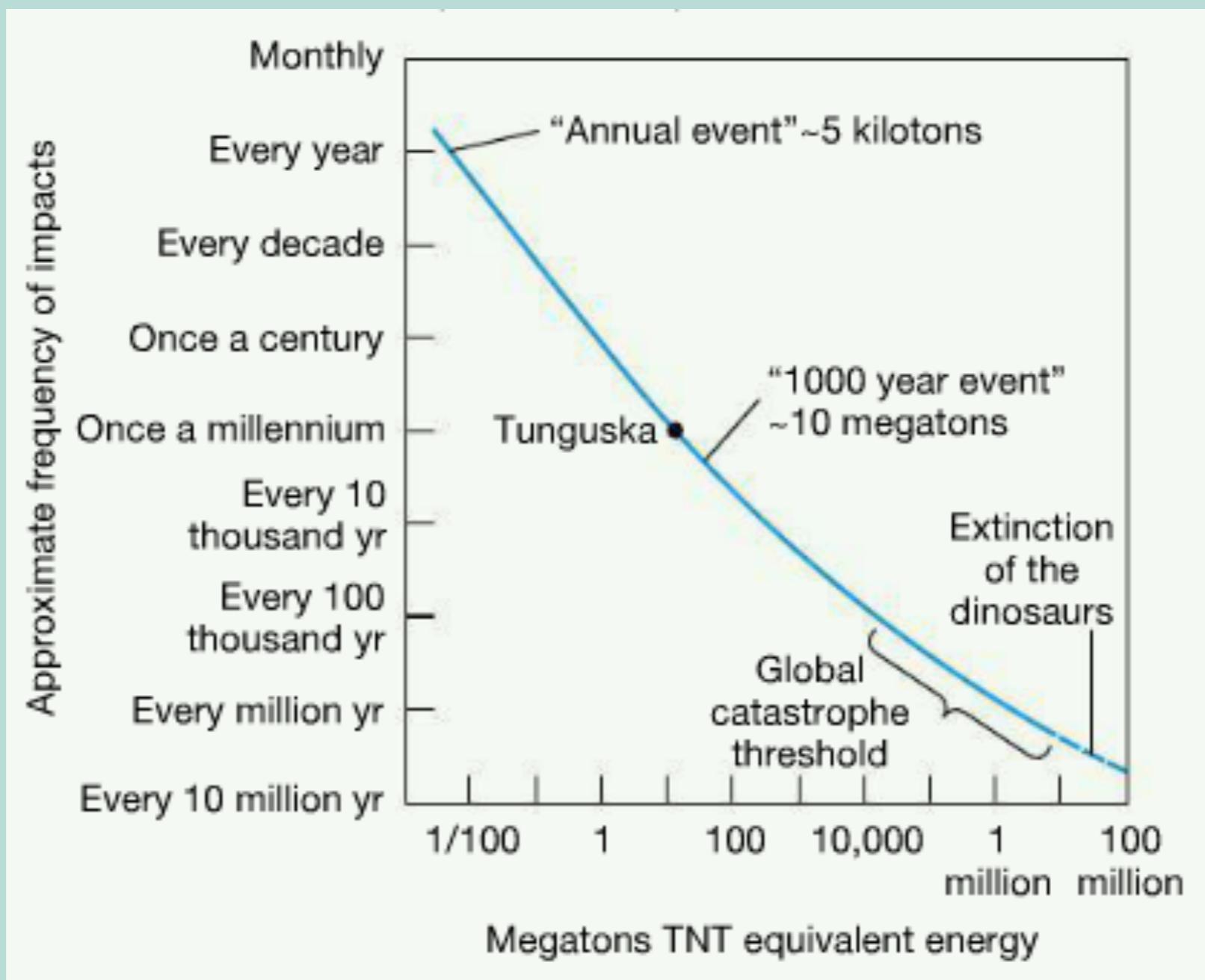


$$a = 0.4 + 0.3 \times 2^n$$

Uranus and Ceres were the gaps!

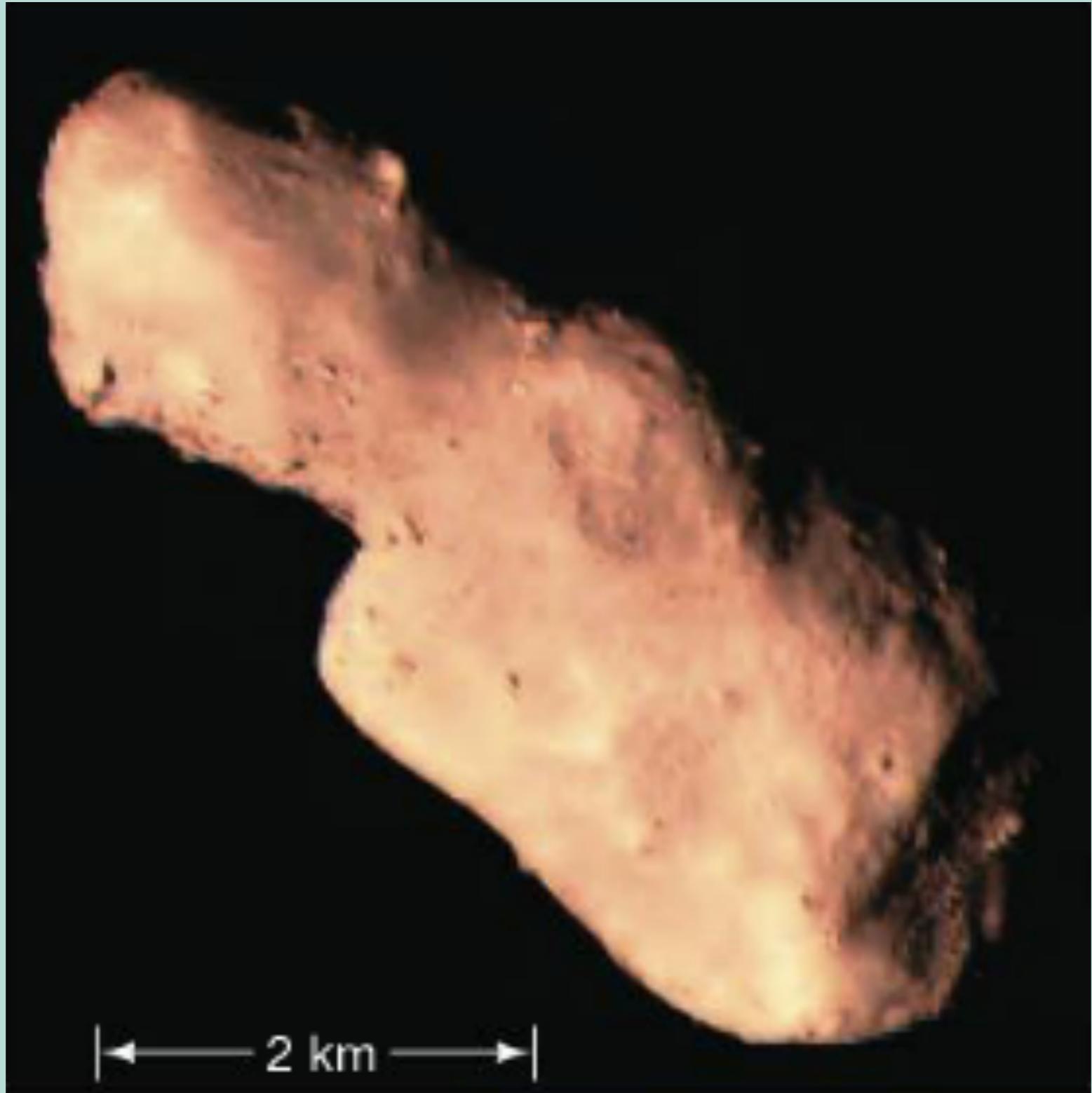


Doomsday Clock



Just a 1 km asteroid could devastate an area of some 100 km in diameter (NYC metro) with as much energy as 1 million 1-megaton nukes (100 times to total human arsenal)

Toutatis



missed us by 1.5e6 km.

1908





Manicouagan Reservoir



Museum of Natural History, NYC



34 ton

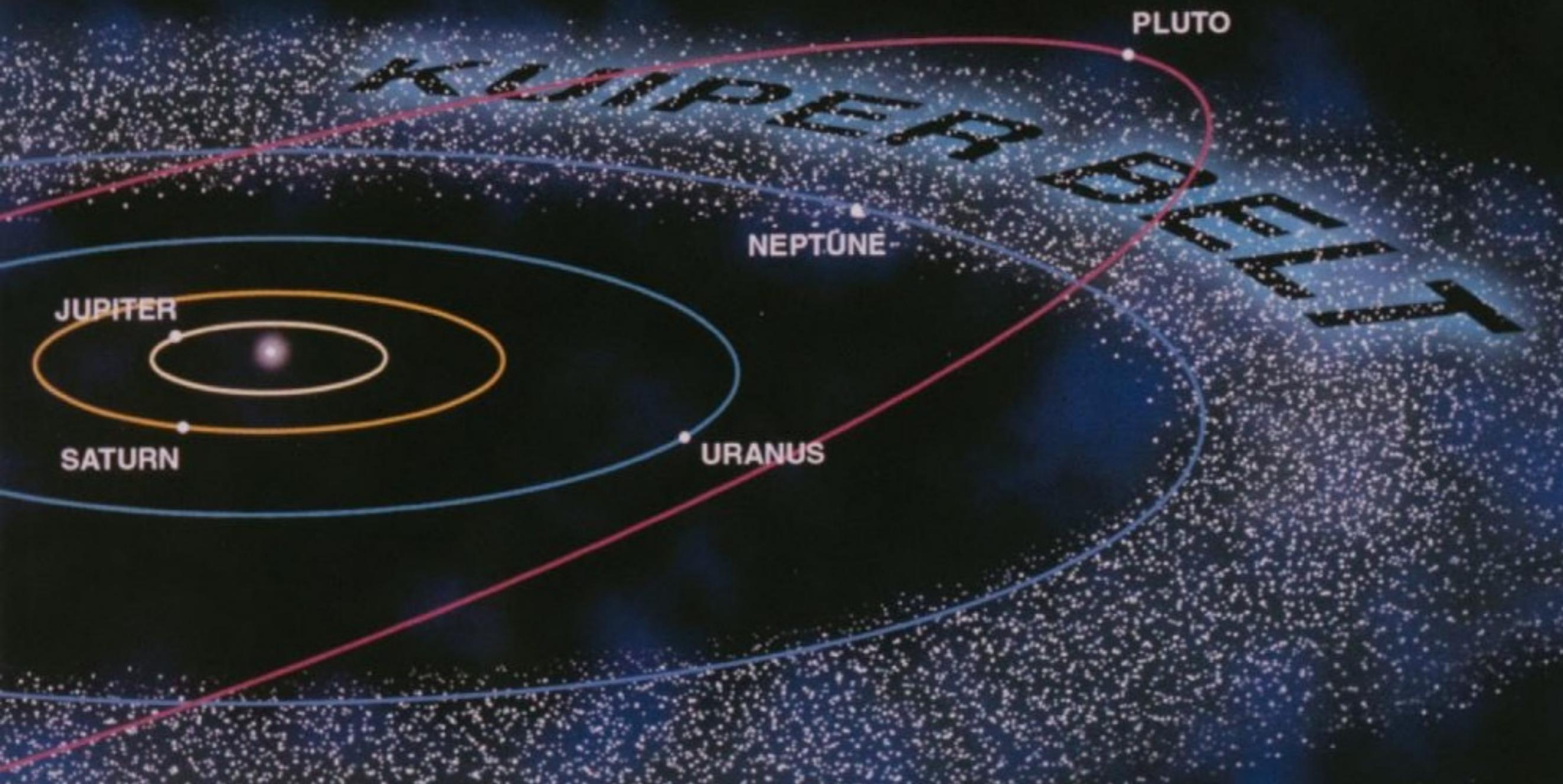
Wabar Meteorite in the Arabian Desert



Meteorites

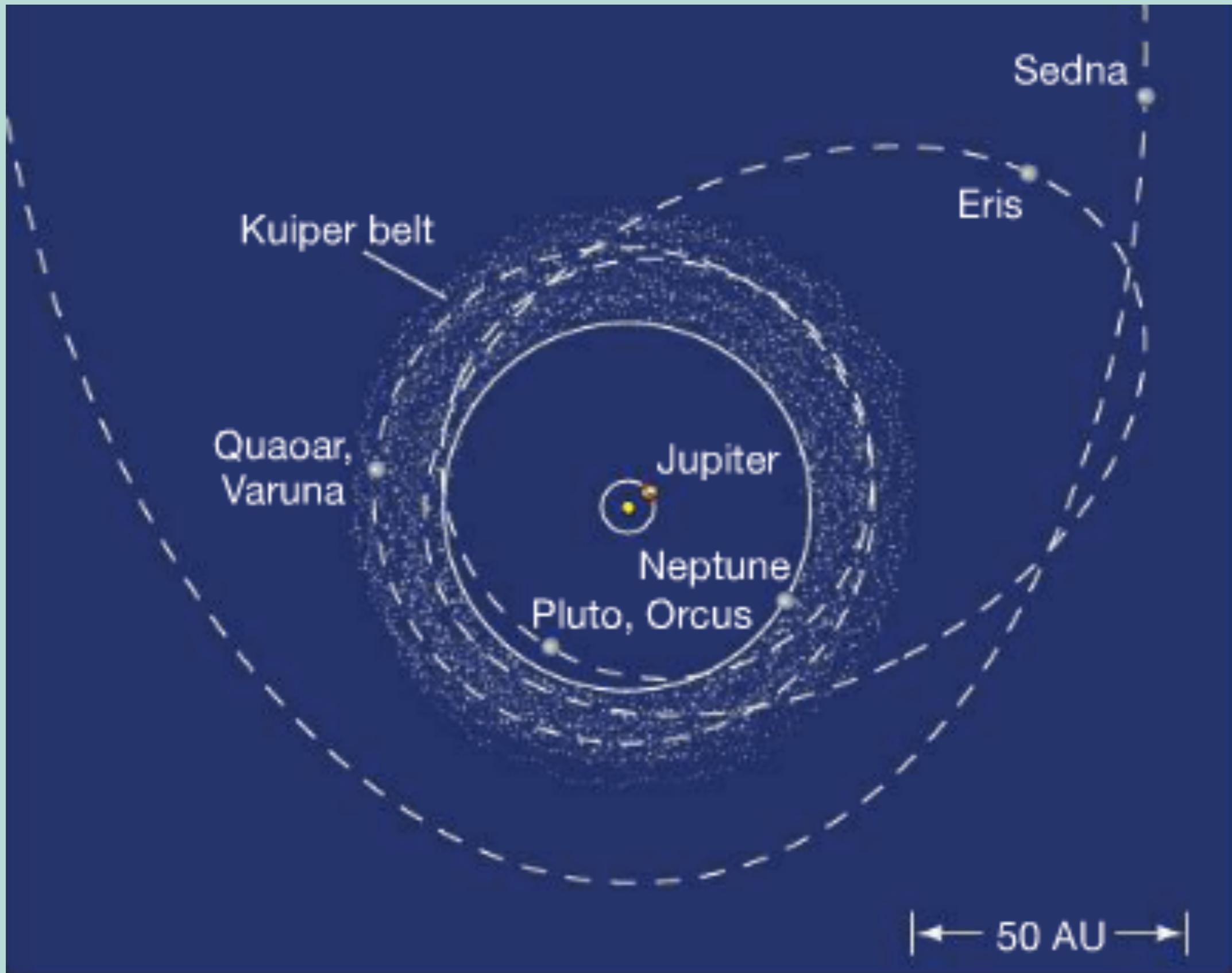


~4.4-4.6 billion years old



30-50 AU

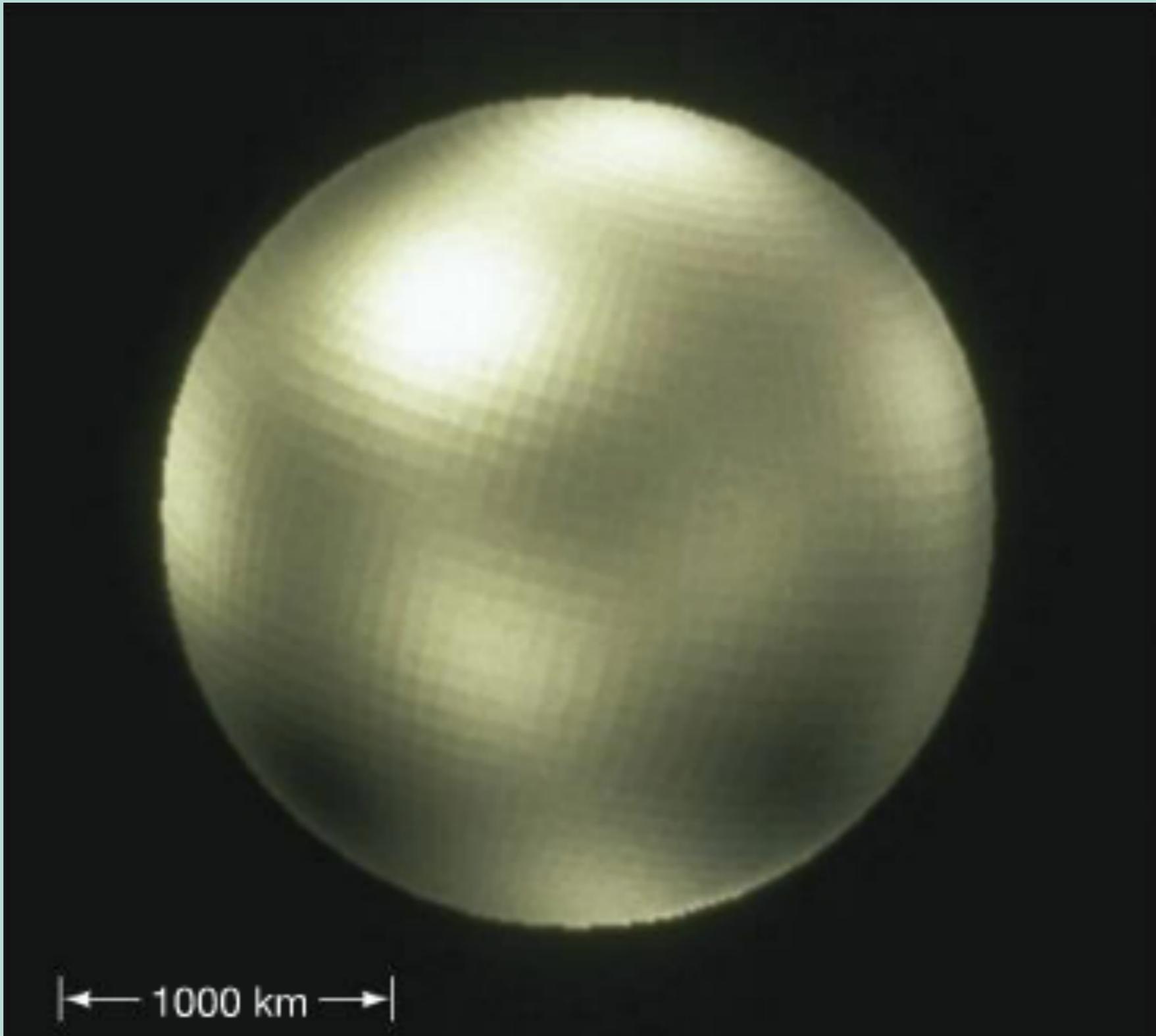
Orbits of Various Kuiper Belt Objects

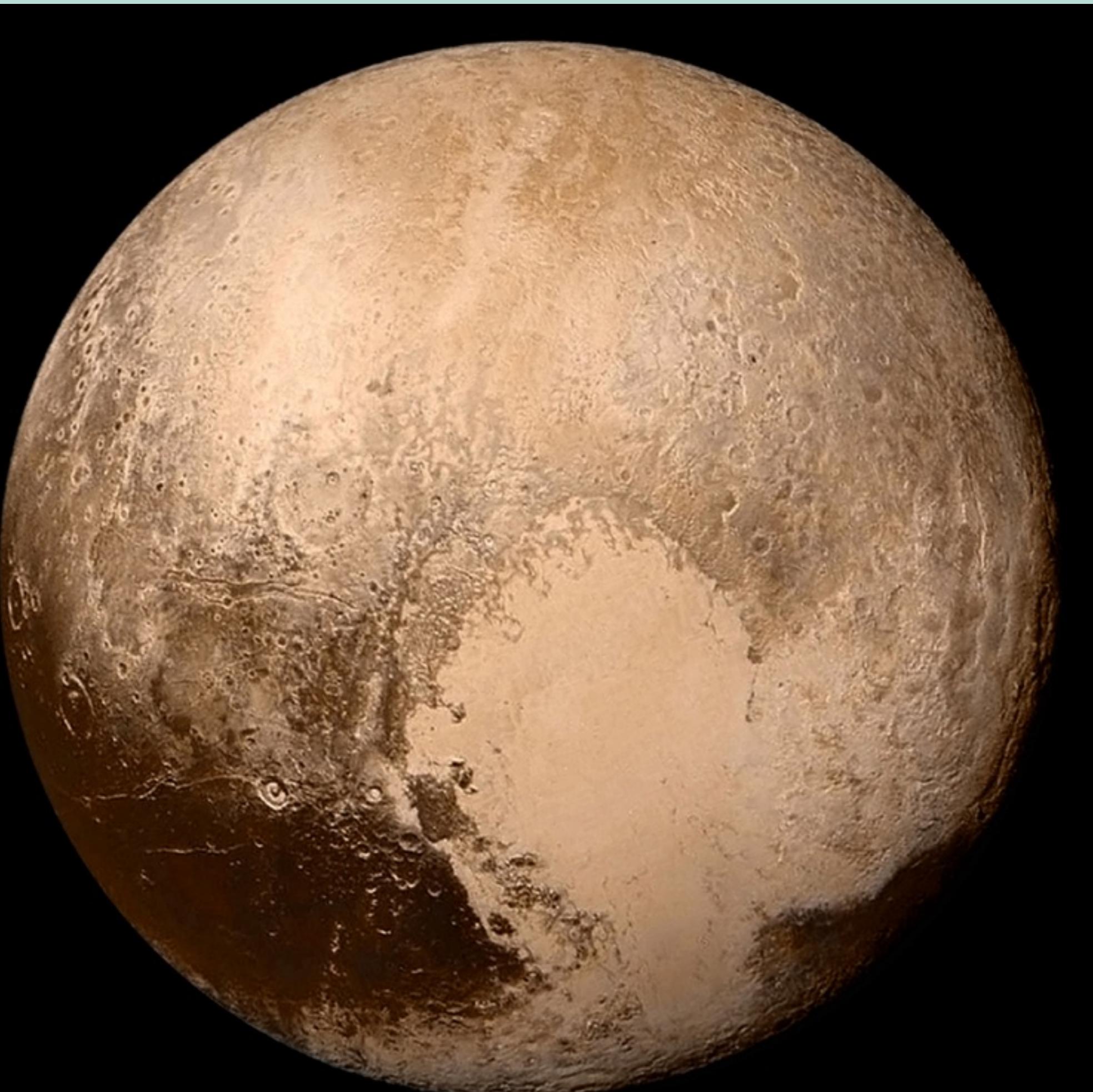




False.

Why?





Pluto

$m \sim 1.3 \text{e}22 \text{ kg}$
 $\sim .002 m_e$

$r \sim 1.1 \text{e}3 \text{ km}$
 $\sim .186 r_e$

(11 lbs)

$d \sim 40 \text{ AU}$

density ~
 2000 kg/m^3





Sun



Mercury



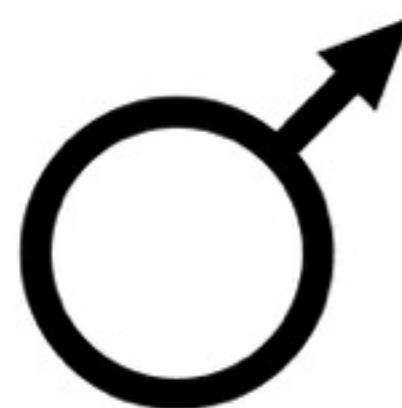
Venus



Earth



Moon



Mars



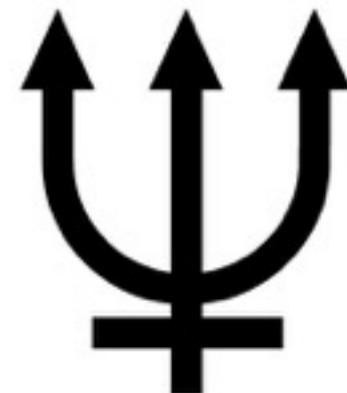
Jupiter



Saturn



Uranus



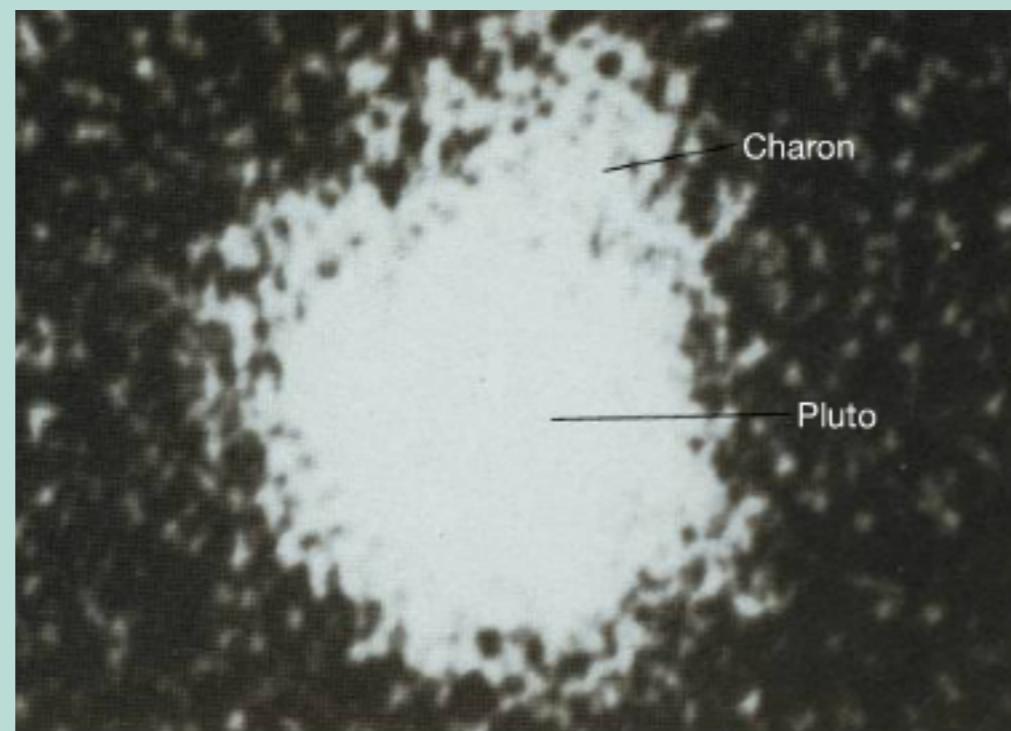
Neptune



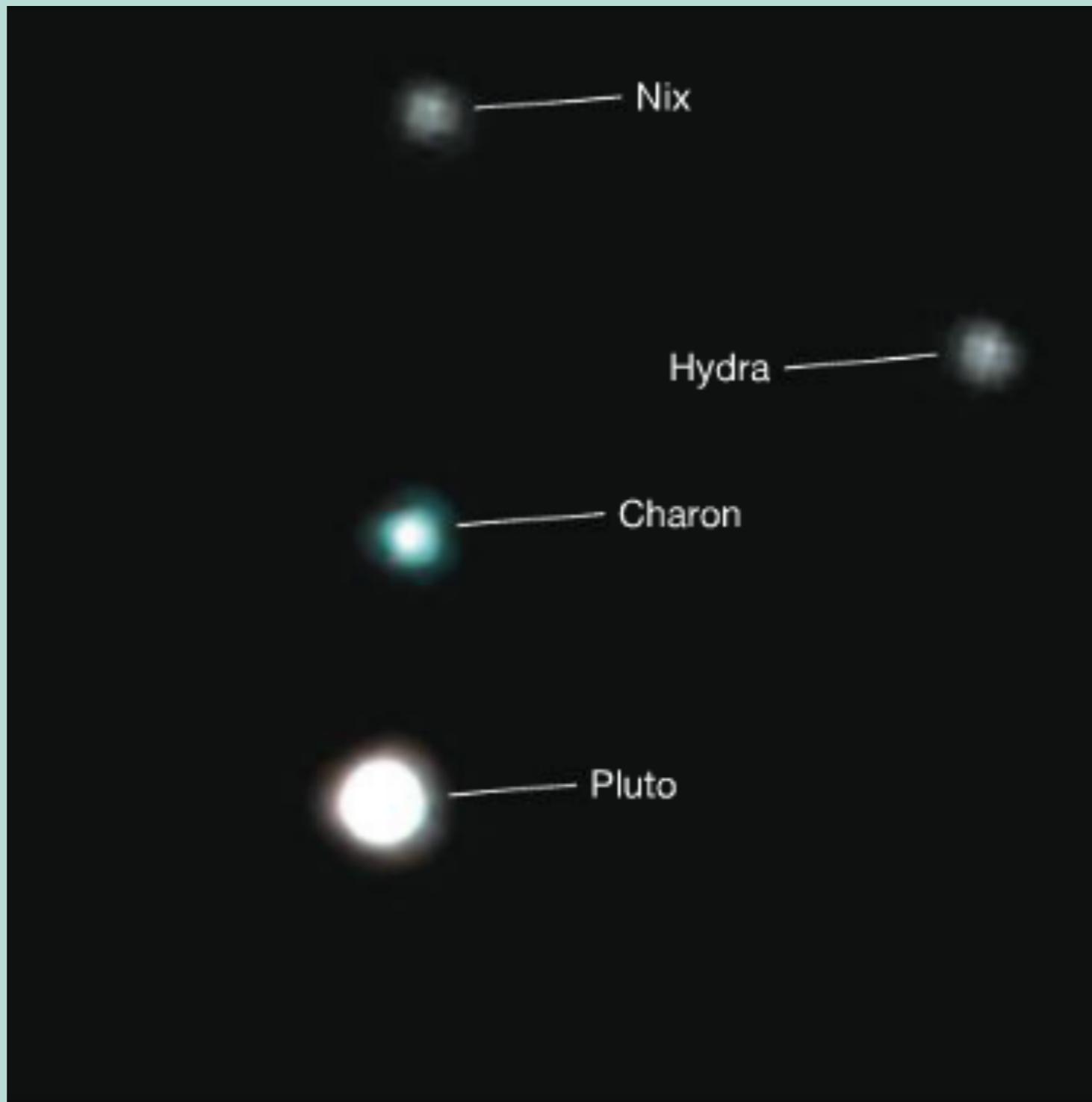
Pluto



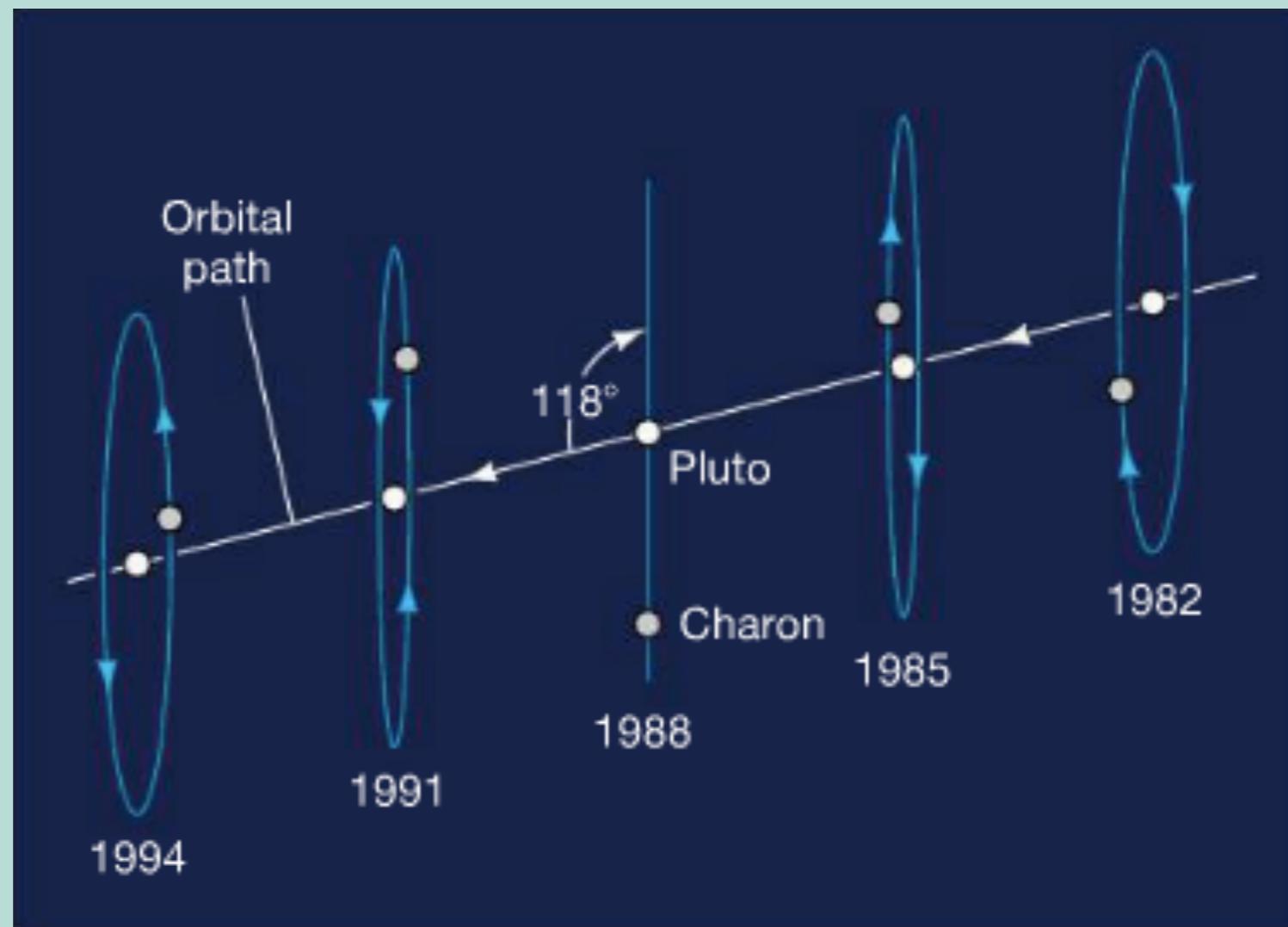
Eureka!



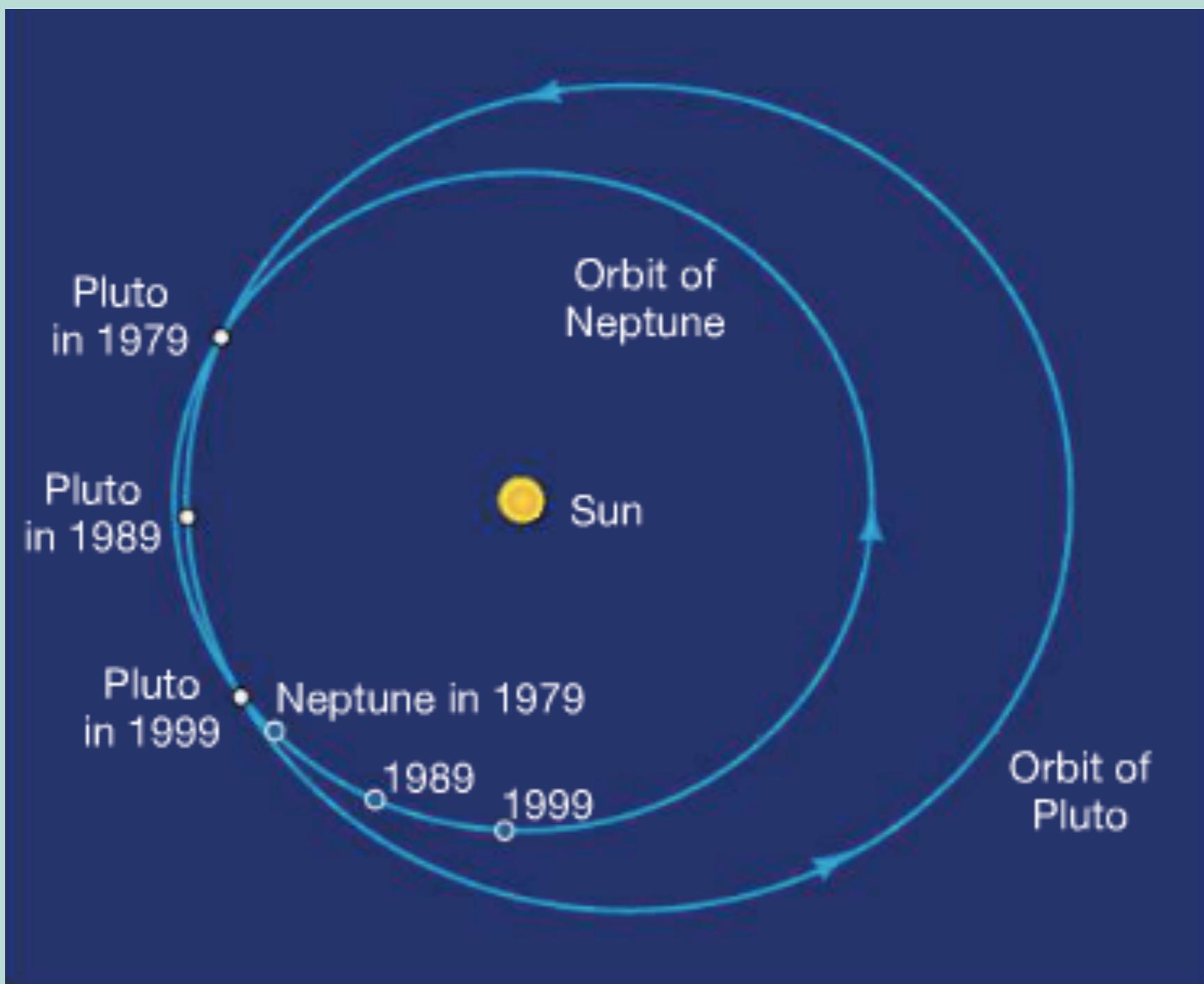
Pluto and its moons



A fortuitous event

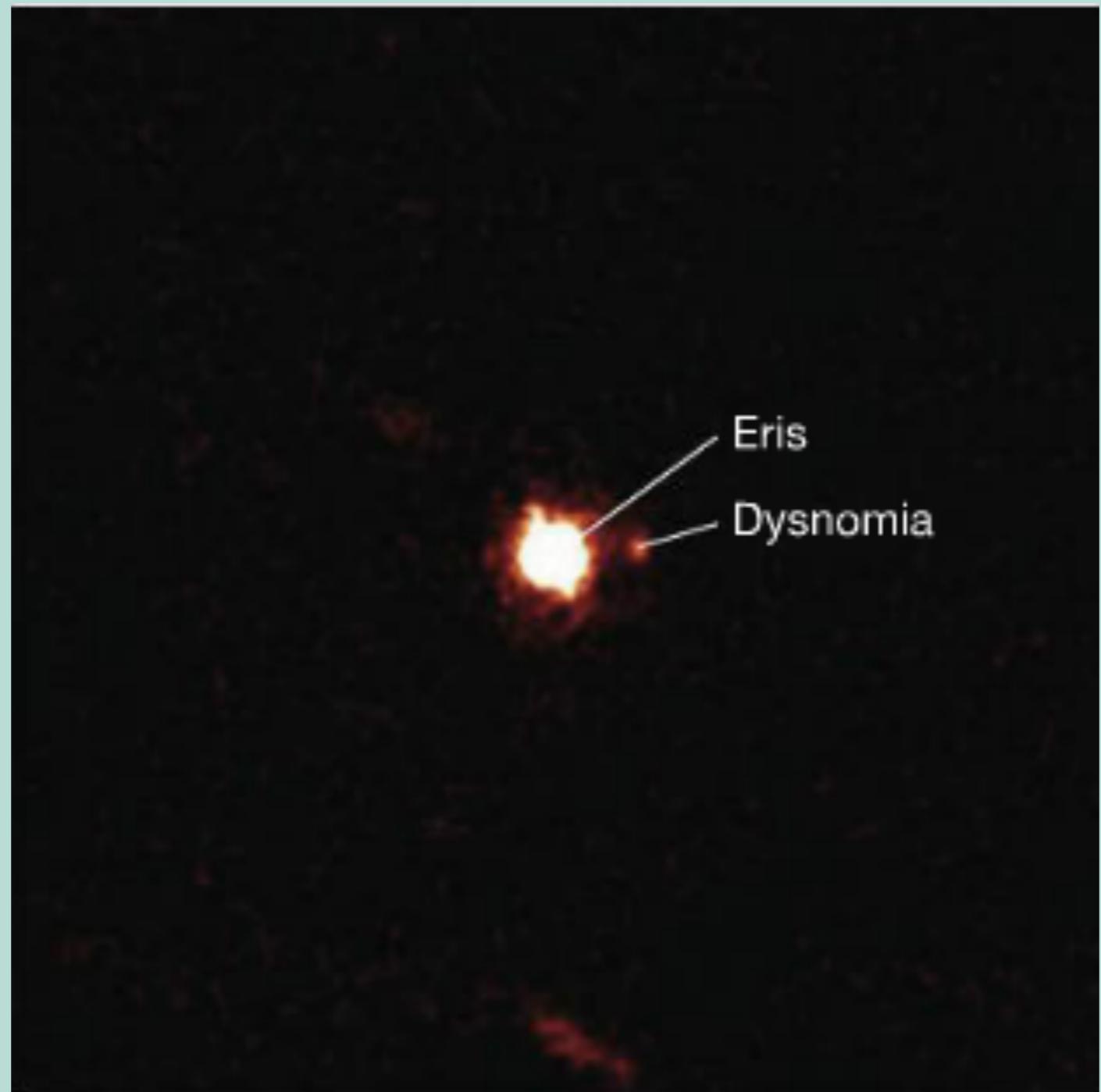


My Childhood was Confusing



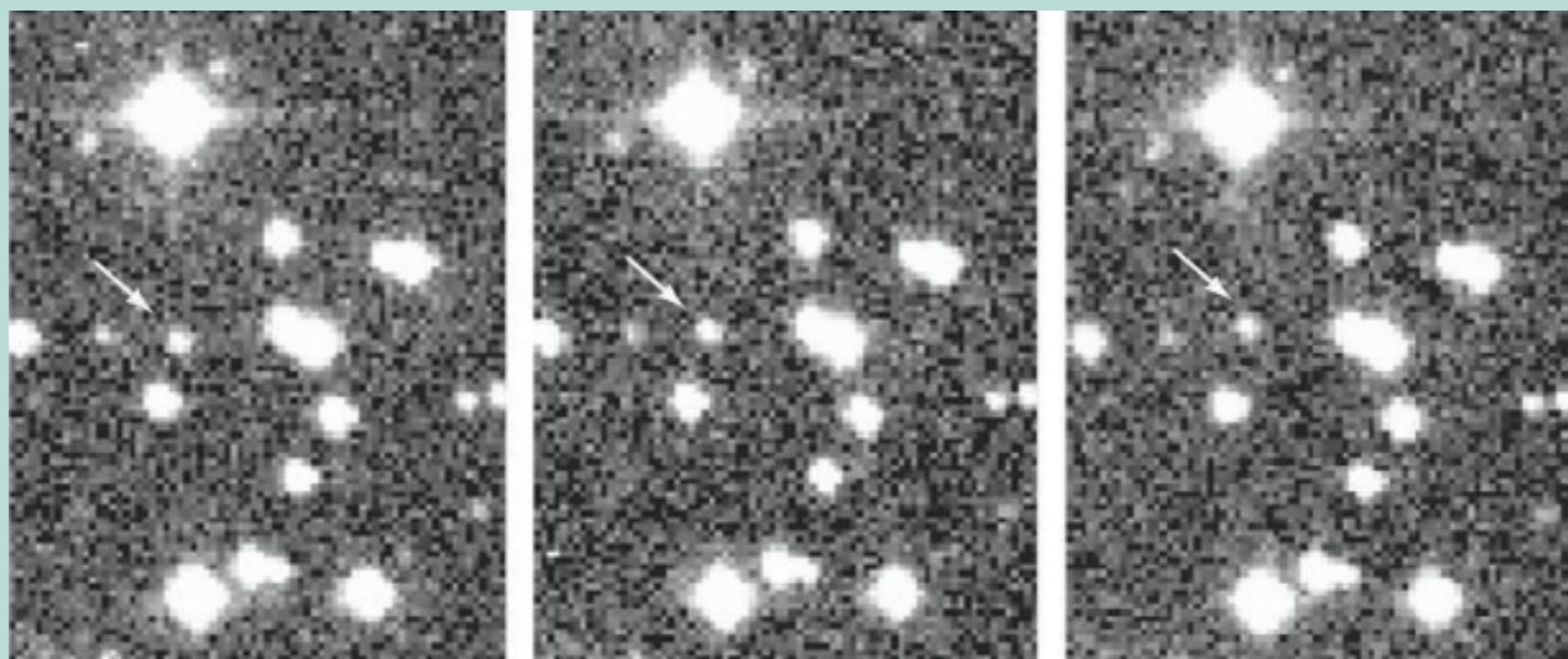
e-pluto ~ .25

e-neptune ~ .0085

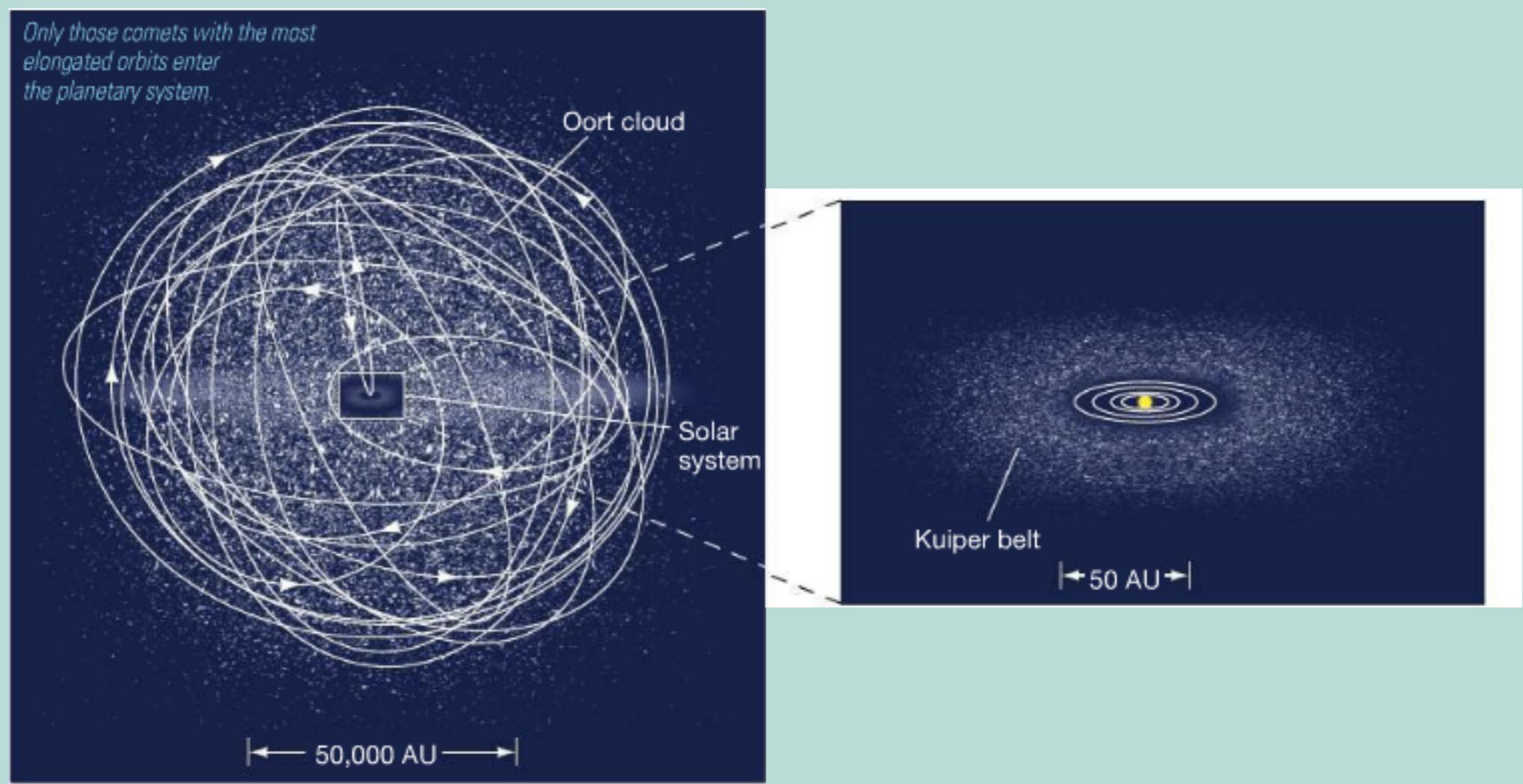


(~70 AU)

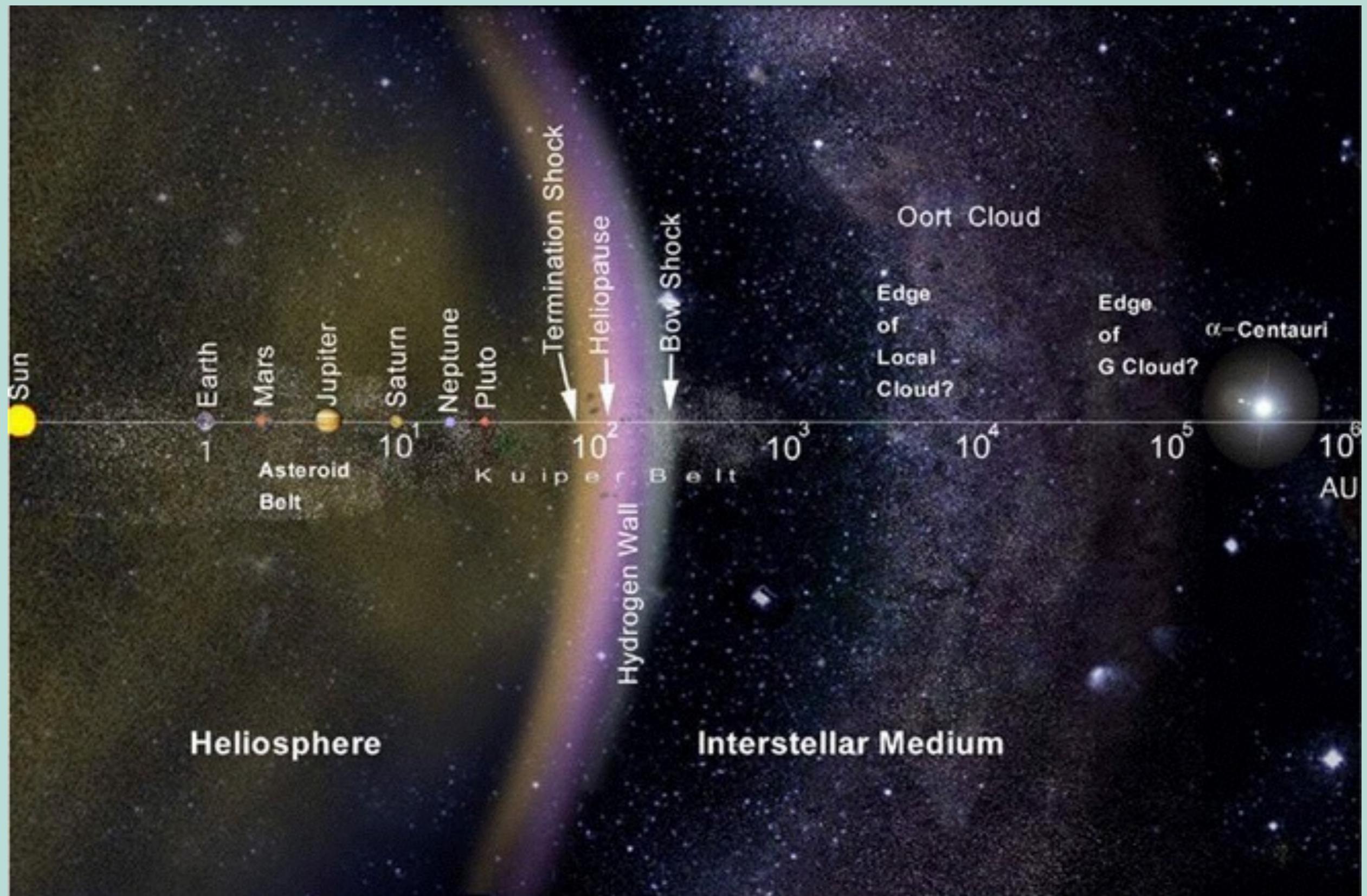
Pholus

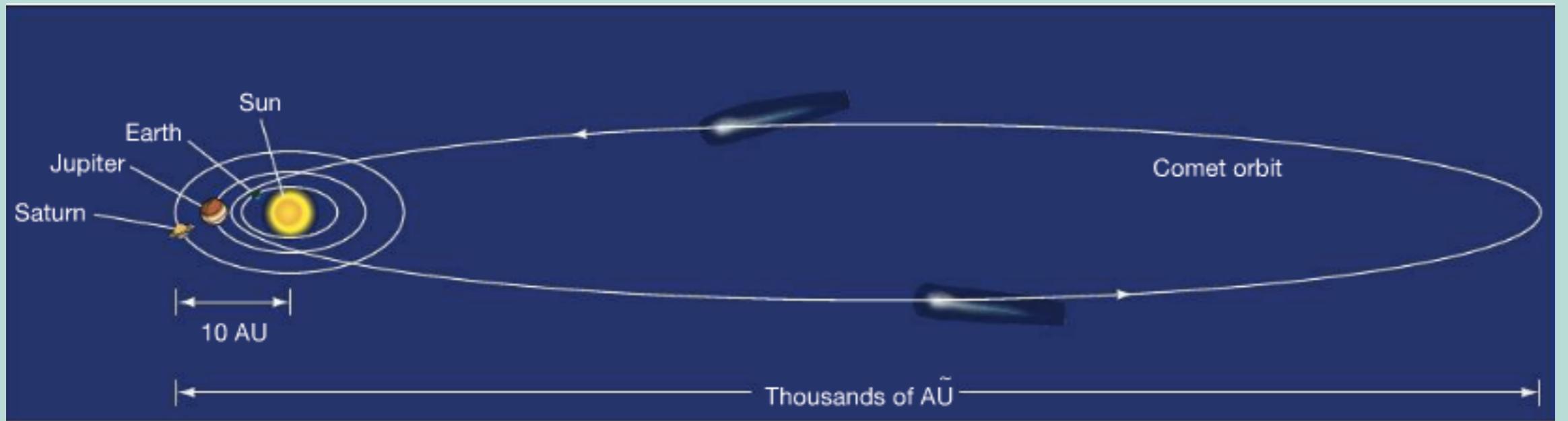


The Oort Cloud



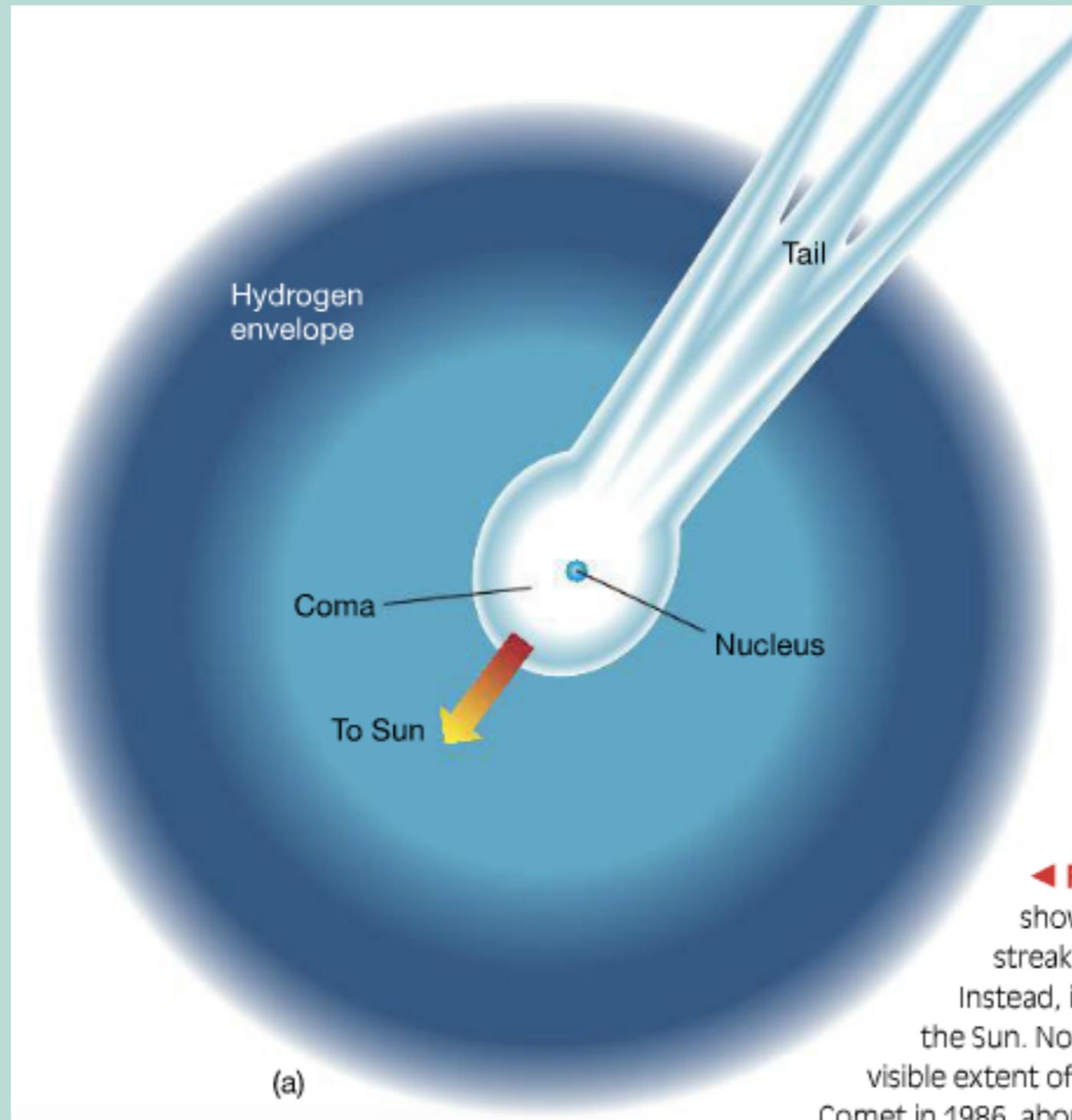
Log Plot (careful!)





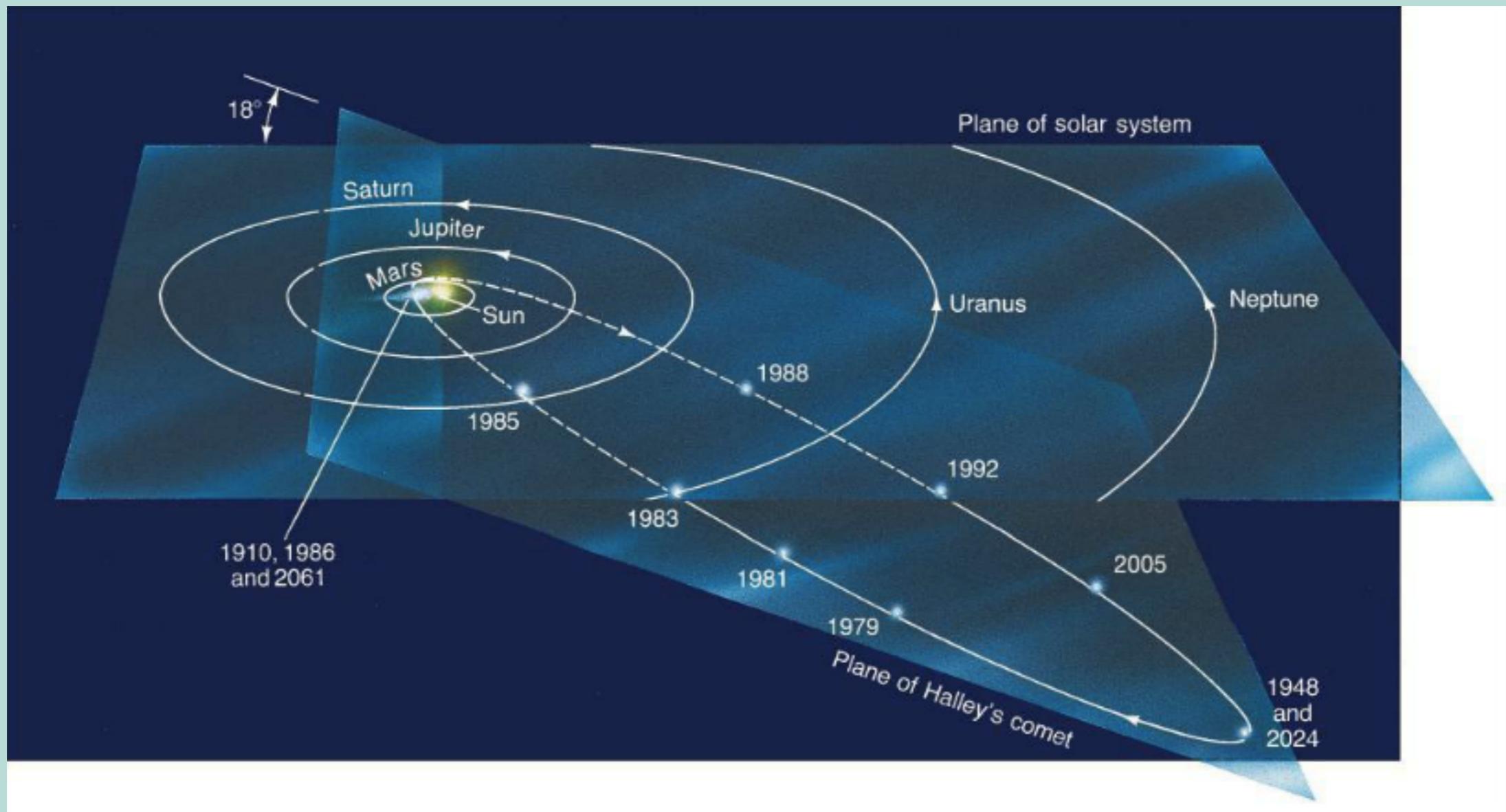
“Thousands of AU”

Comet Anatomy



- Icy nucleus obtains a coma due to sublimation near sun
- Sublimation rates reach 10^{30} molecules / second (30 tons of material!)
 - Coma can be up to the size of saturn
 - Tails span as much as an AU! ($2000 R_J$)

Halley's Comet



- 76 year period (1986 last sighting)
- Sightings go back to 240 BC

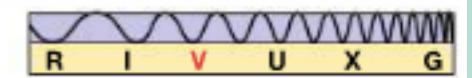
Halley Comet tails



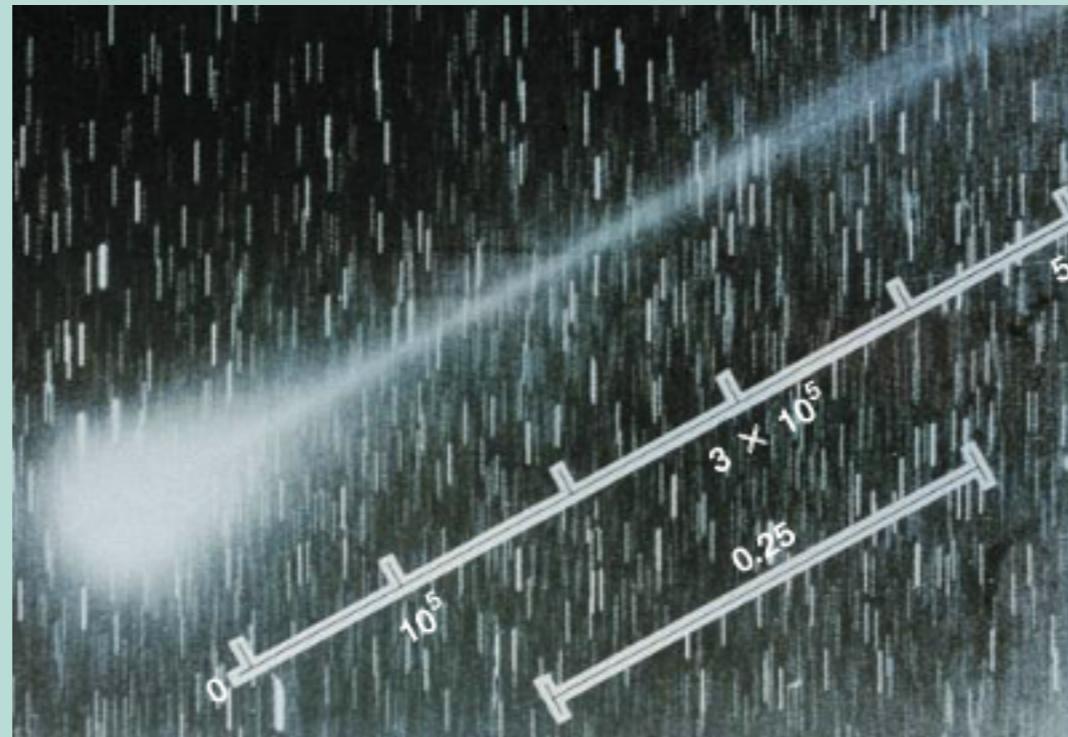
(a)



(b)



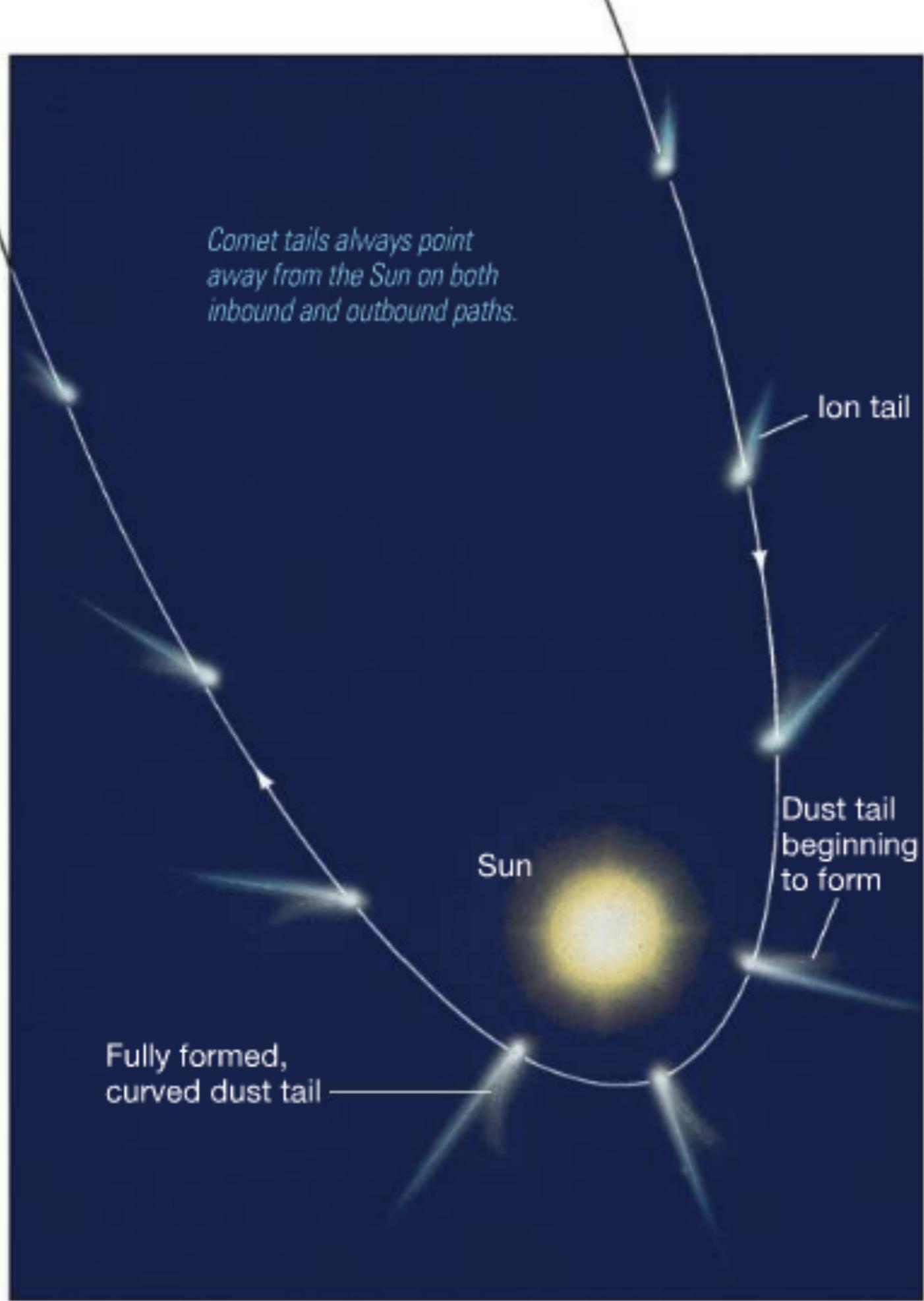
Giacobini Zinner Ion Tail



Halley Ion Tail



50,000 km



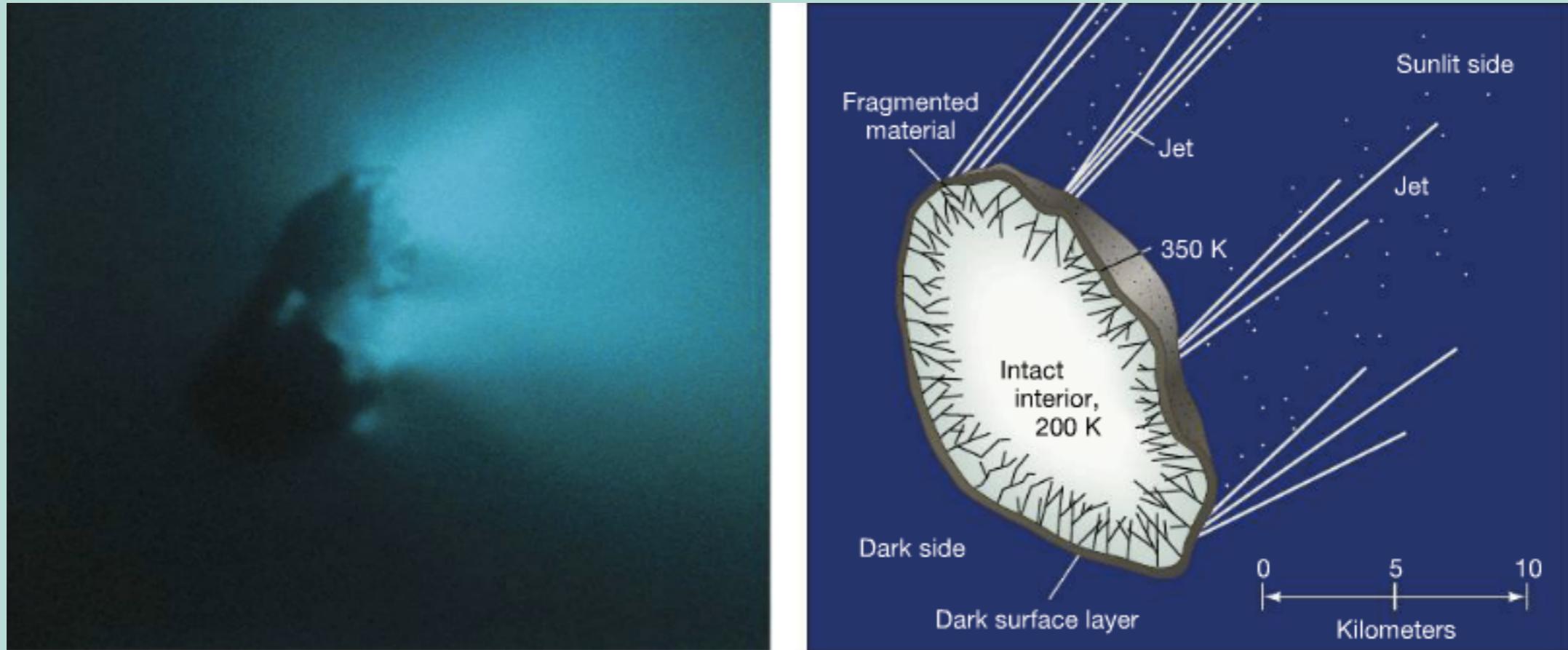
Comet Tails point towards the sun

Giotto (ESA)

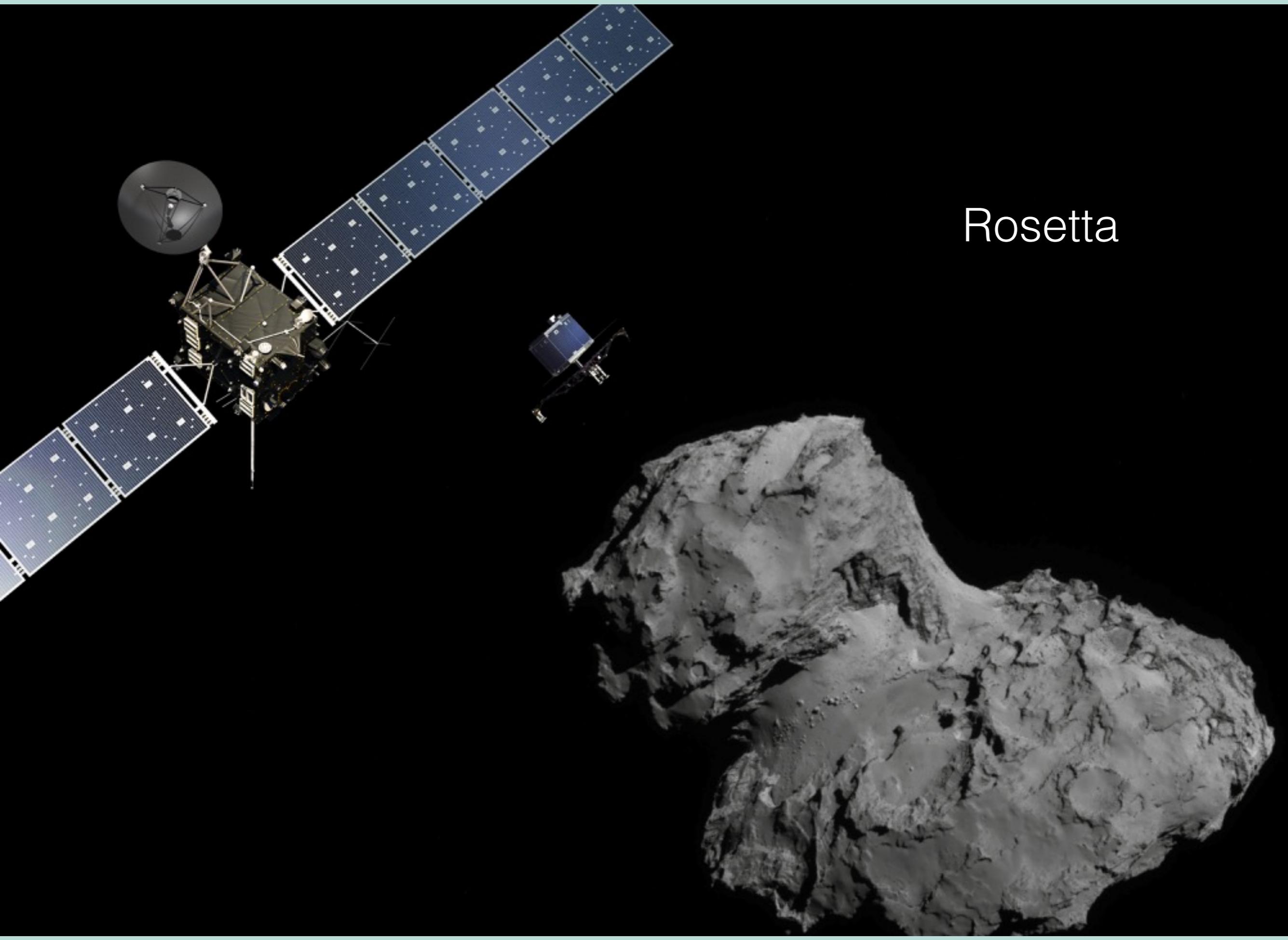


(named after 1301 Italian artist)

Halley's Nucleus

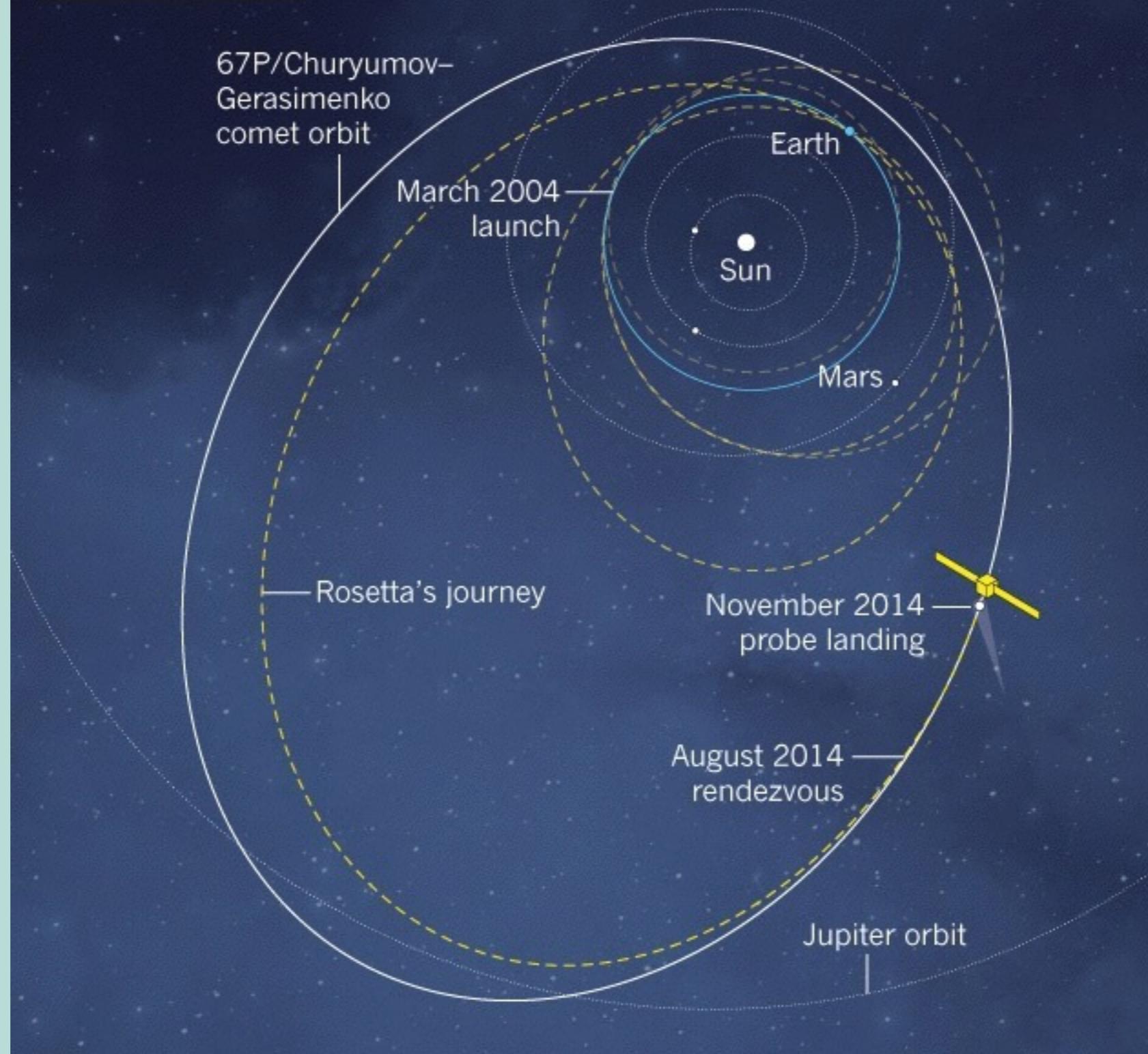


Sublimation jets cause comet to rotate



Rosetta

MISSION OVERVIEW



67P/ Churyumov-Gerasimenko



Hale-Bopp (97)

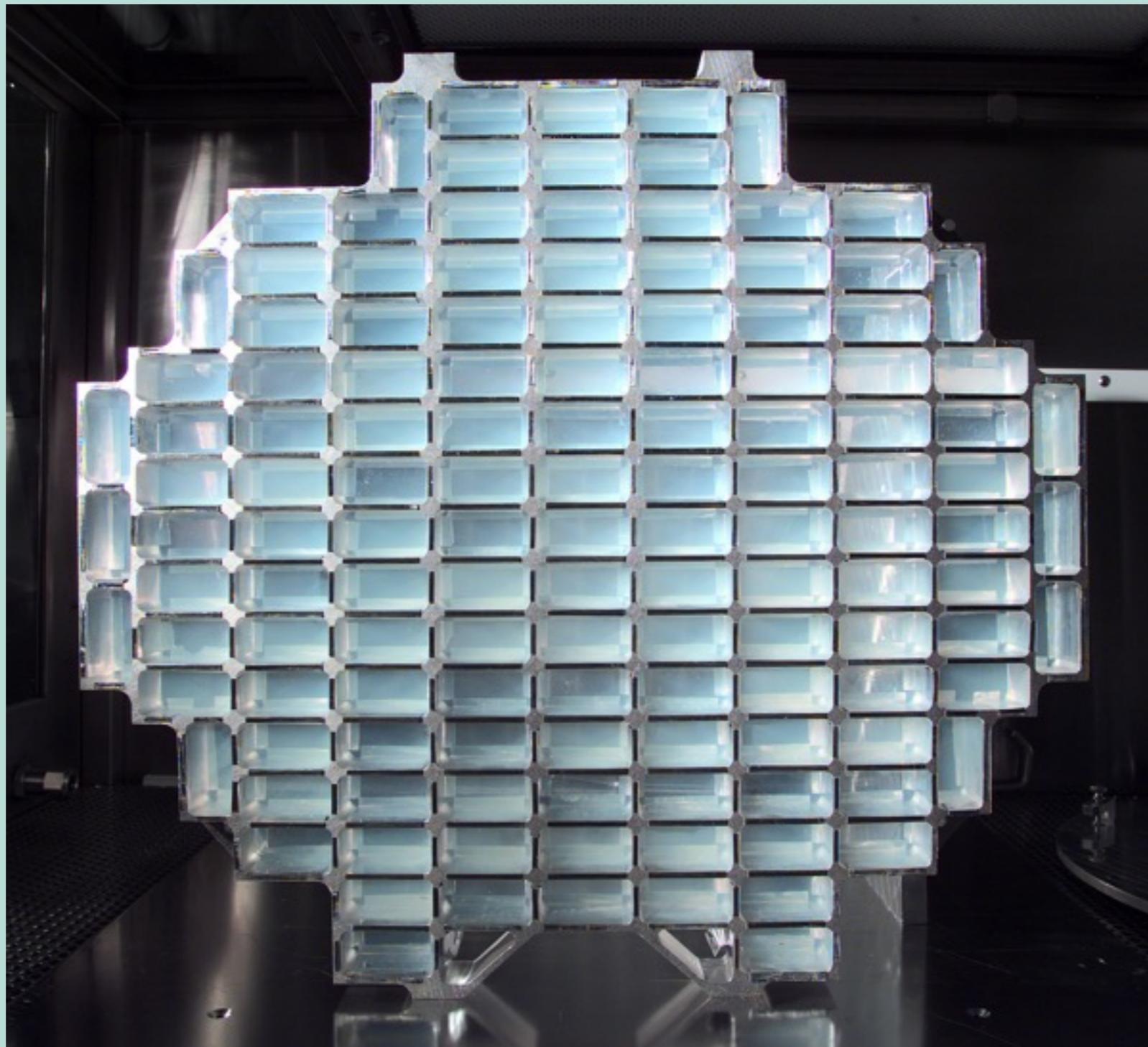


NASA Stardust Mission



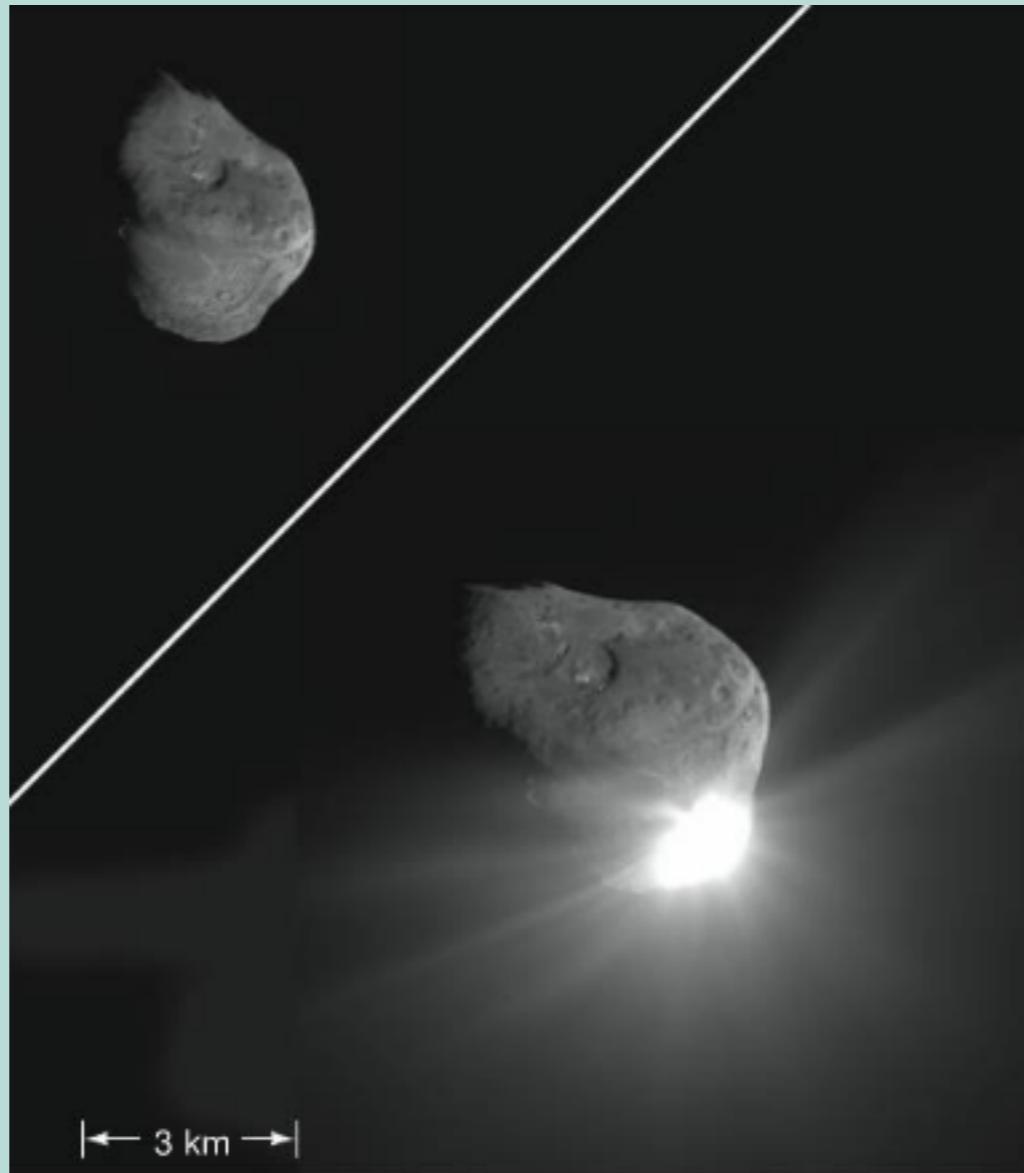
Wild-2

Stardust Collector



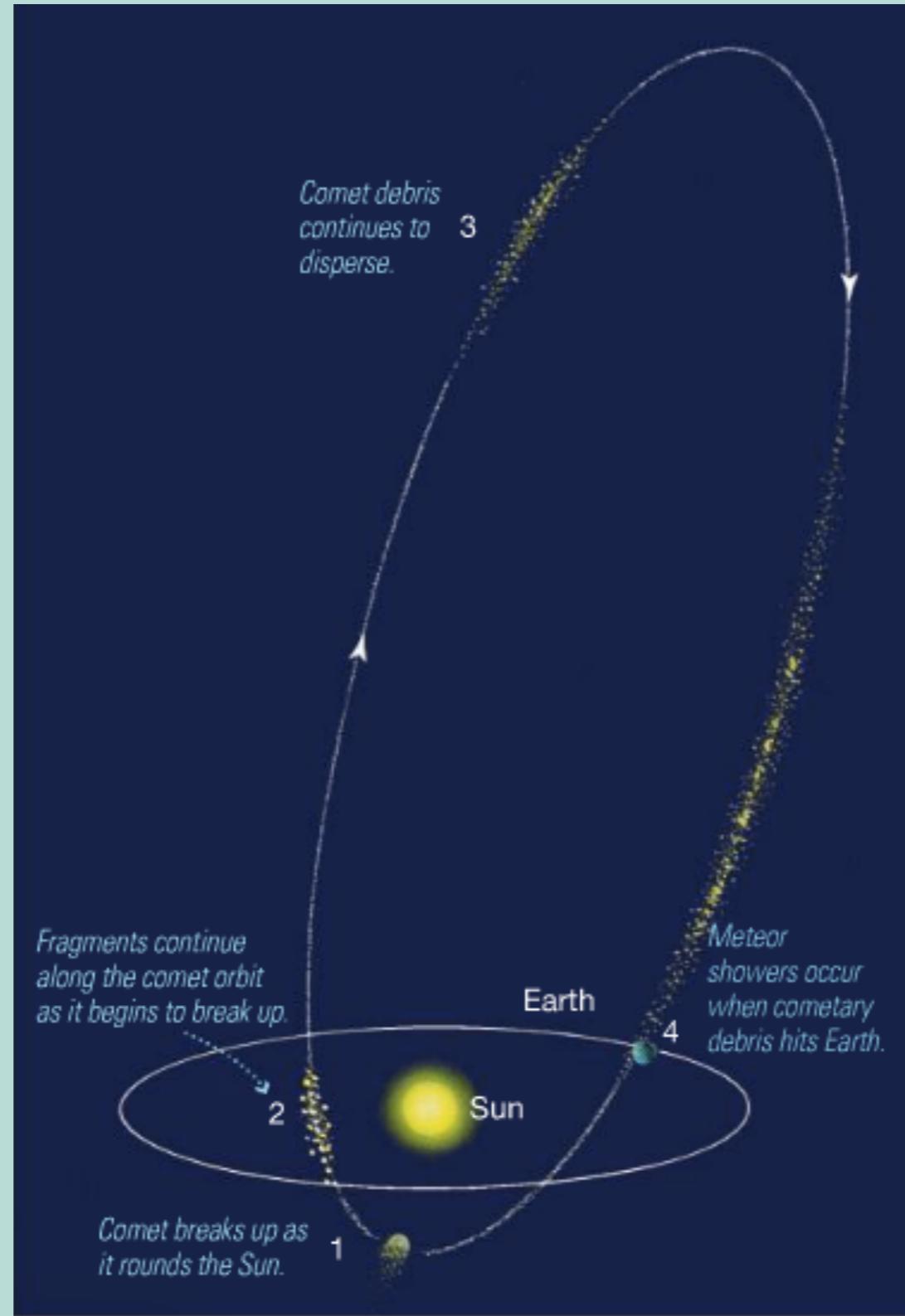


Deep Impact



“Smash and Observe” from particle physics to jupiter to comets

Meteor Rain



Meteors



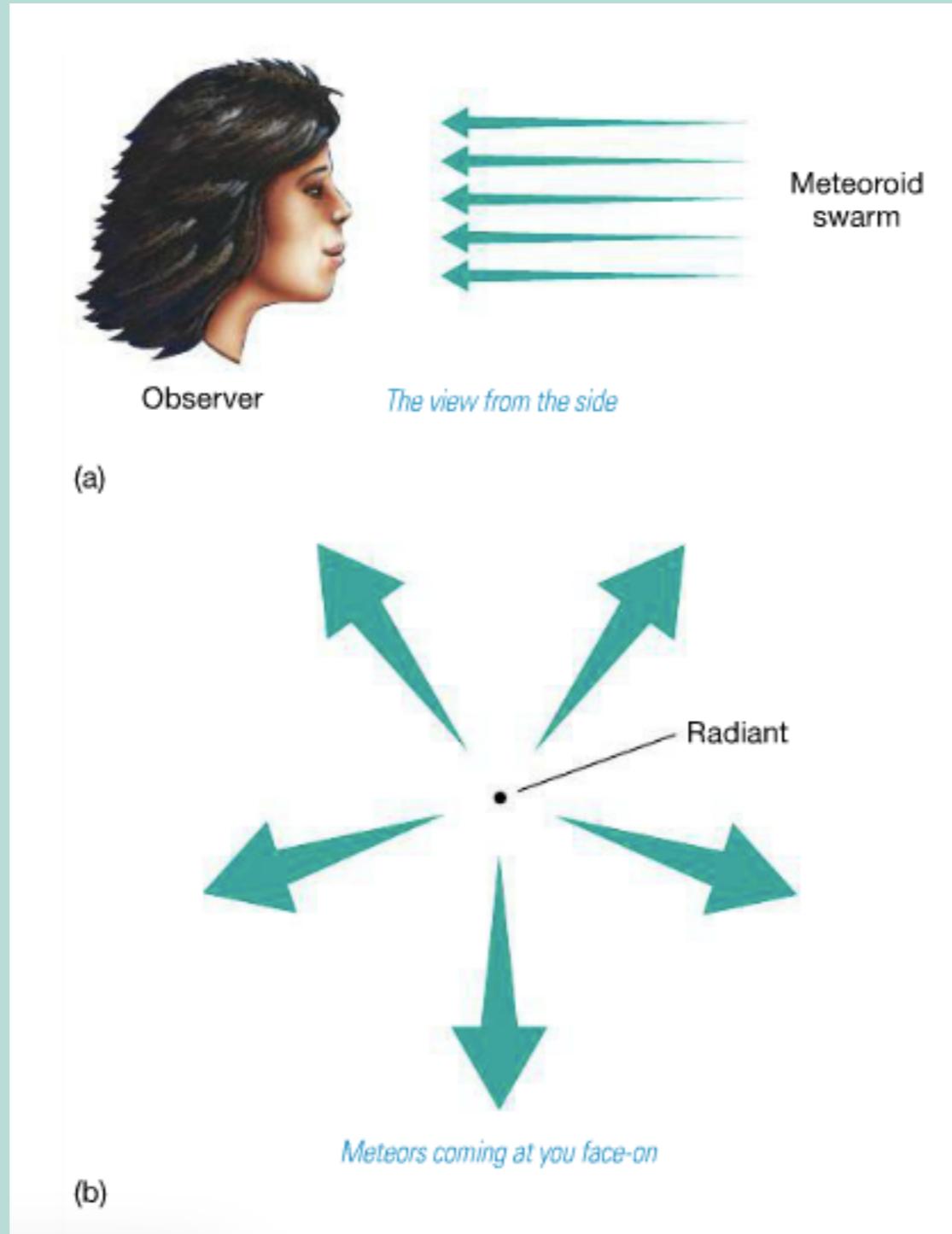


TABLE 14.1 Some Prominent Meteor Showers

Morning of Maximum Activity	Name of Shower	Rough Hourly Count	Parent Comet
Jan. 3	Quadrantid	40	—
Apr. 21	Lyrid	10	1861I (Thatcher)
May 4	Eta Aquarid	20	Halley
June 30	Beta Taurid	25 [‡]	Encke
July 30	Delta Aquarid	20	—
Aug. 11	Perseid	50	1862III (Swift-Tuttle)
Oct. 9	Draconid	up to 500	Giacobini-Zinner
Oct. 20	Orionid	30	Halley
Nov. 7	Taurid	10	Encke
Nov. 16	Leonid	12*	1866I (Tuttle)
Dec. 13	Geminid	50	3200 (Phaeton) [†]