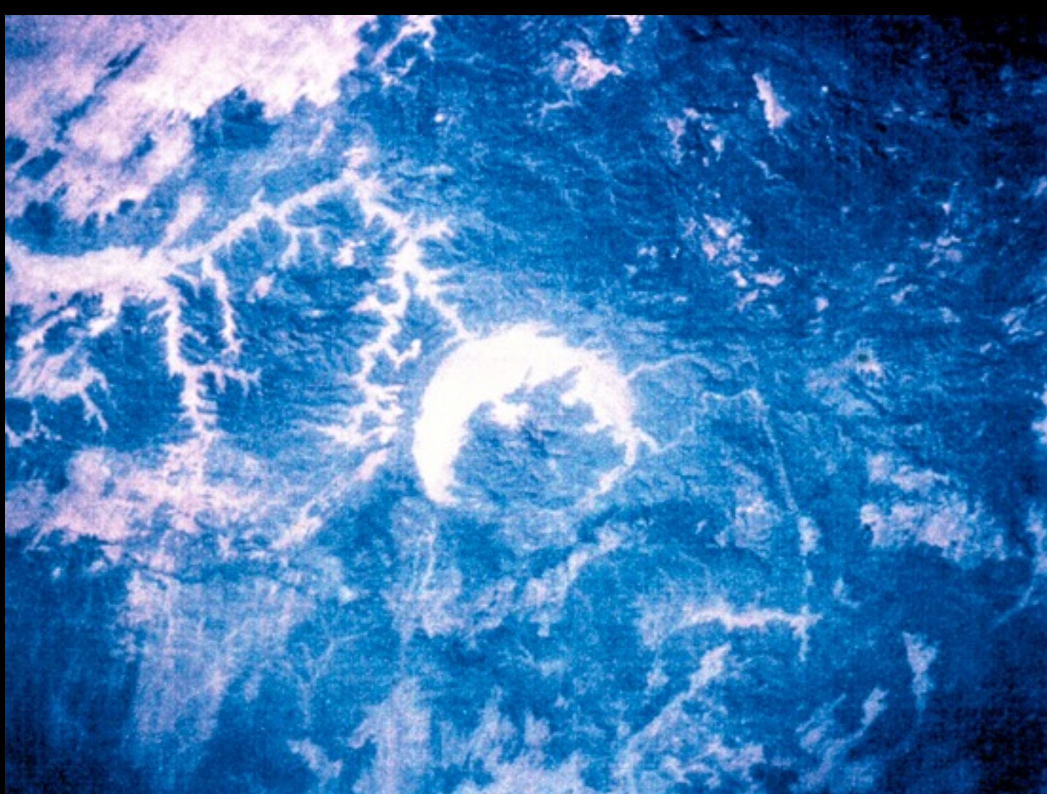
Impact Craters

Wolf Impact Crater, Australia:
Diameter 0.9 km, Age: 0.3Myr

Craters on Earth

Manicouagan, Canada:
100km, 214Myr

Gosses Bluff, Australia:
22km, 142.5Myr

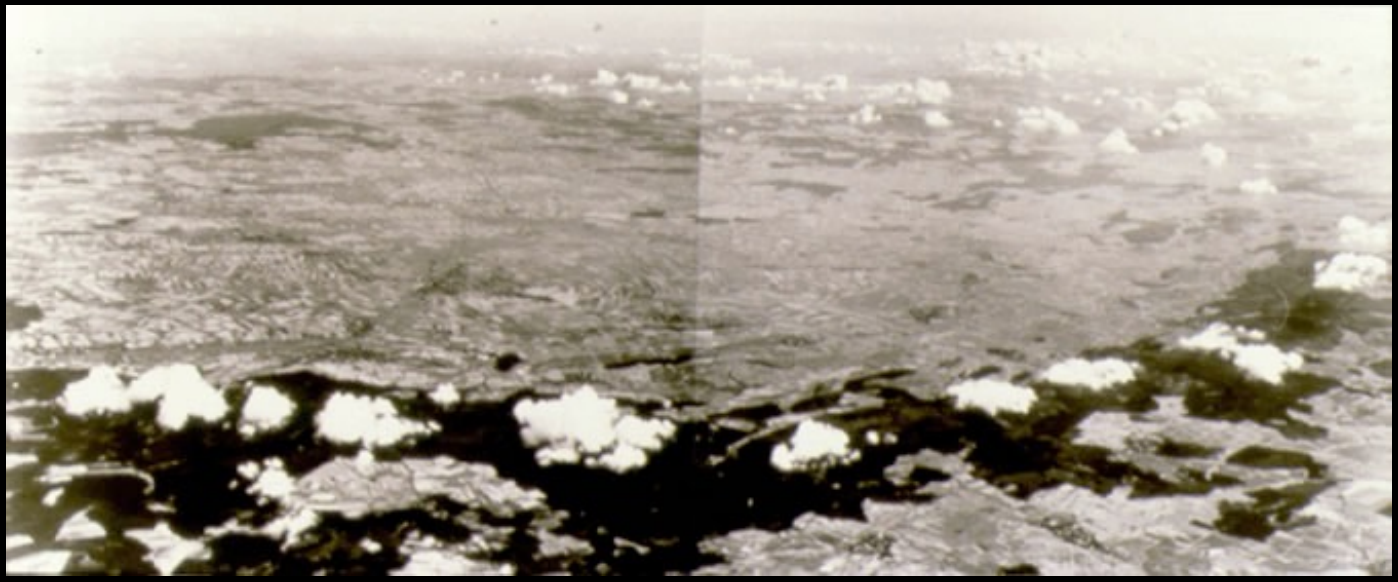


Gwen Fada, Chad:
14km, <350Myr

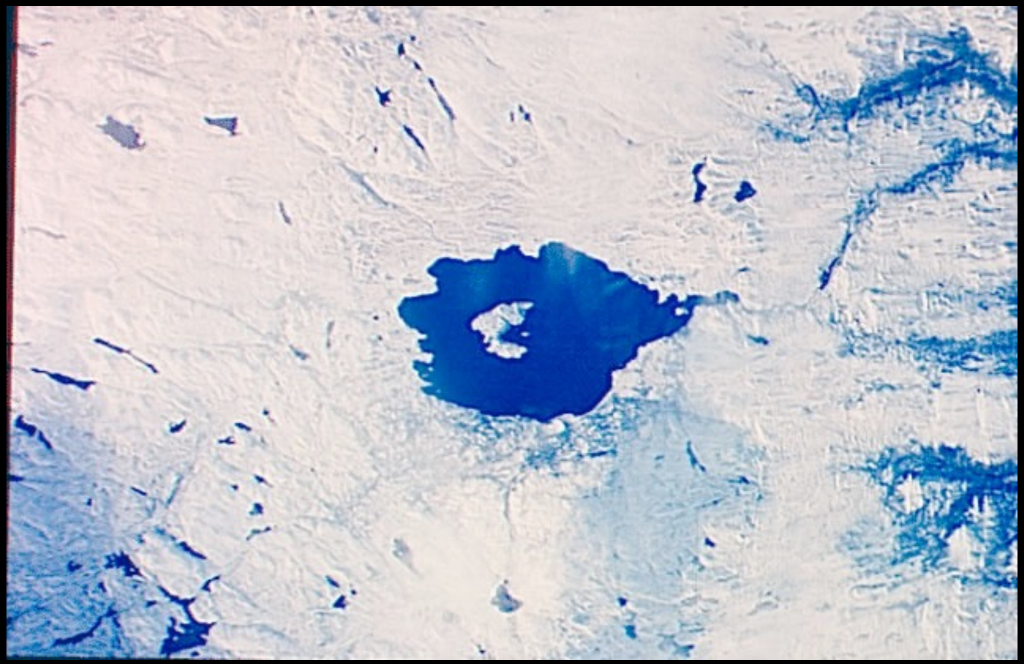
Aorounga, Chad: 10km, <350Myr

Clearwater Lakes, Canada
26km, 290Myr

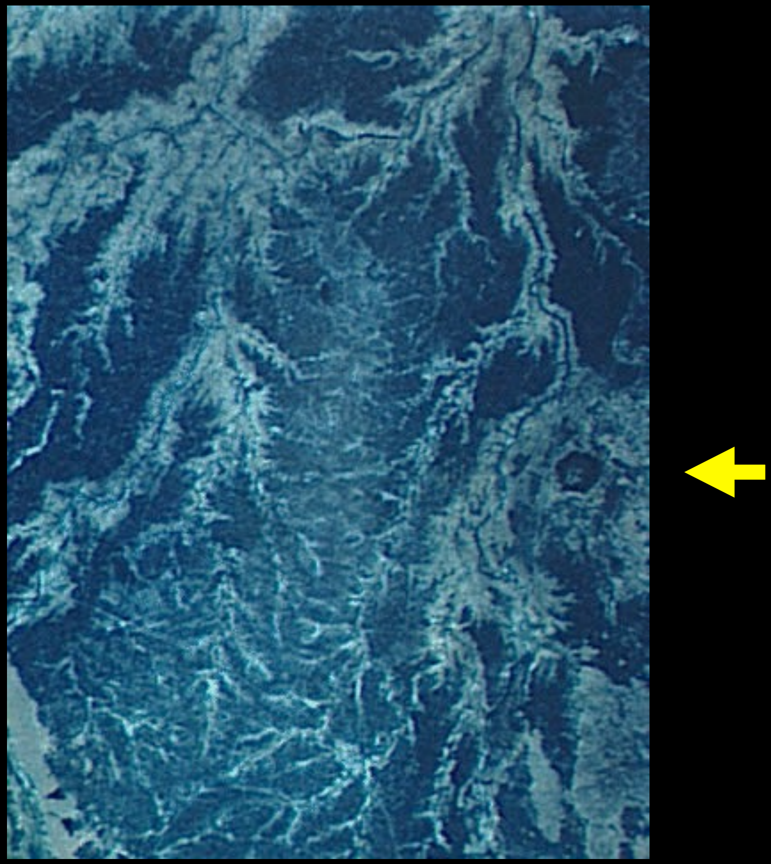
Space Shuttle!



Ries, Germany
24km, 15Myr



Mistastin Lake, Canada:
28km, 38Myr



Ramgarh, India: 5.5km, unknown

Deep Bay, Canada
5km, 100 +/- 50 Myr

Ouarkziz, Algeria: 4km, <70Myr

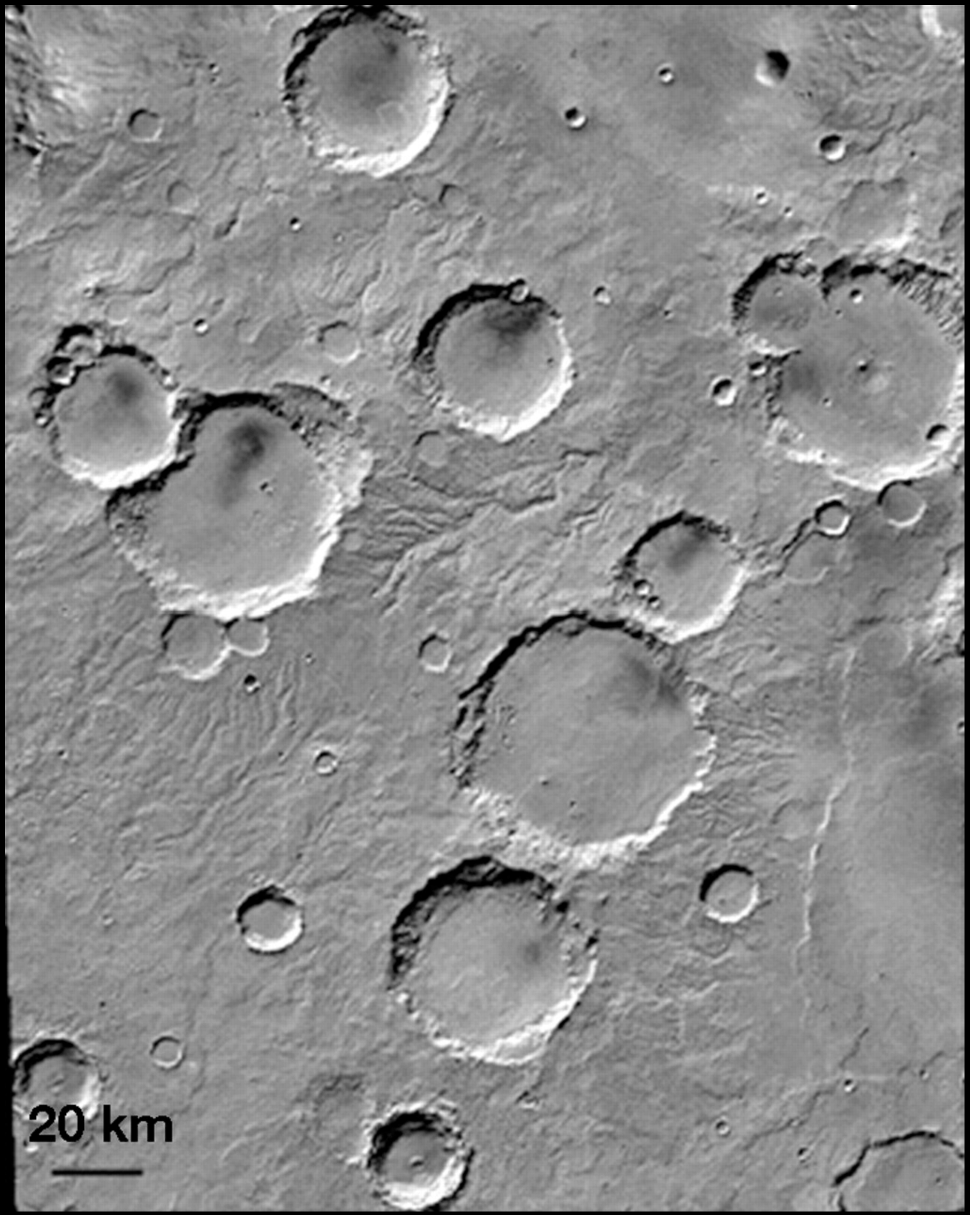
Roter Kamm, Namibia: 2.5km, 3.7Myr

Meteor Crater, Arizona: 1.2km, 49,000 yr

Wolf Creek, Australia: 850m, 0.3Myr

Goat Paddock, Australia: 5km, <55Myr

Craters on Mars



Viking Image, Mars
southern hemisphere

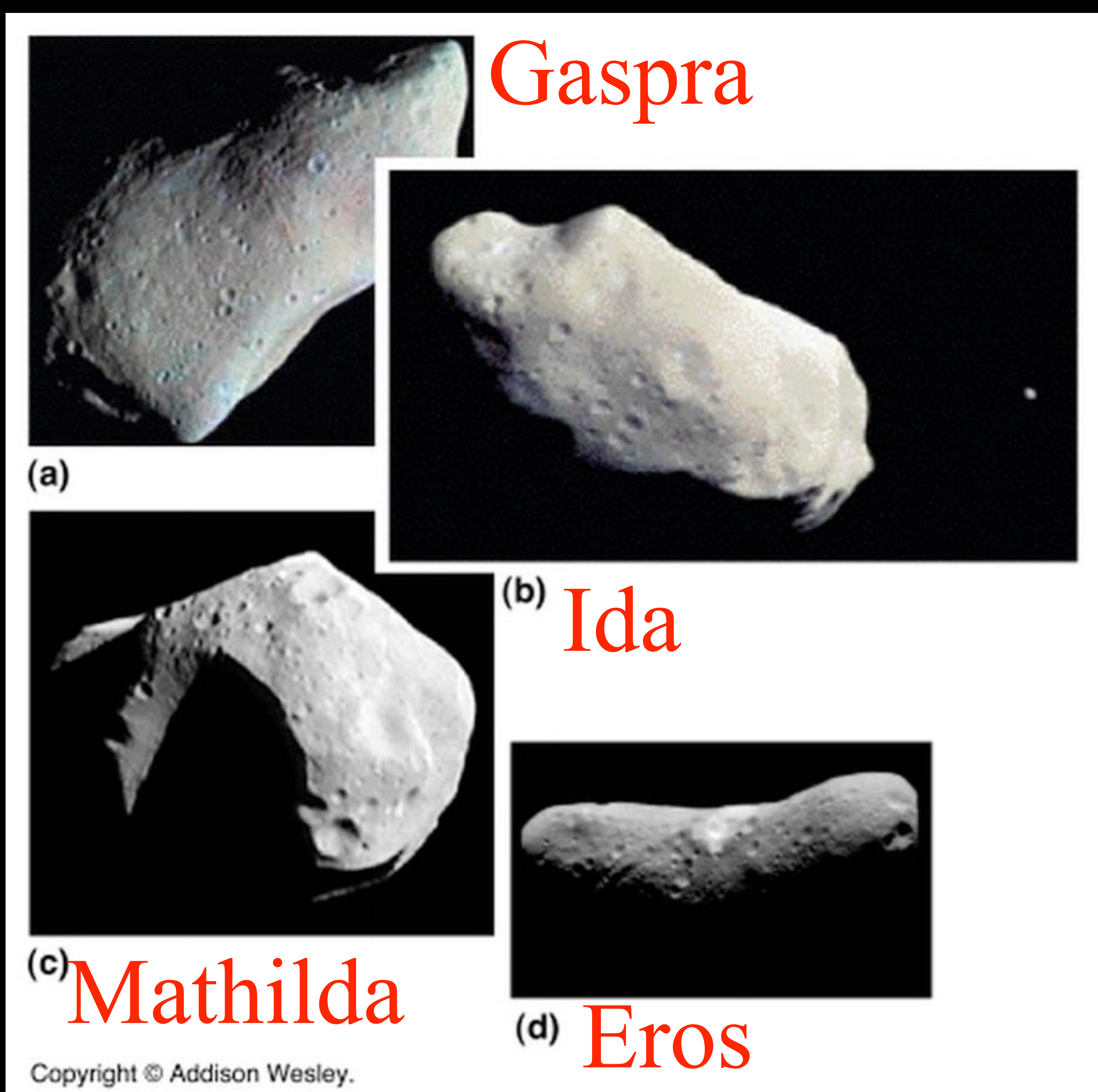
Victoria Crater, Mars: 750m

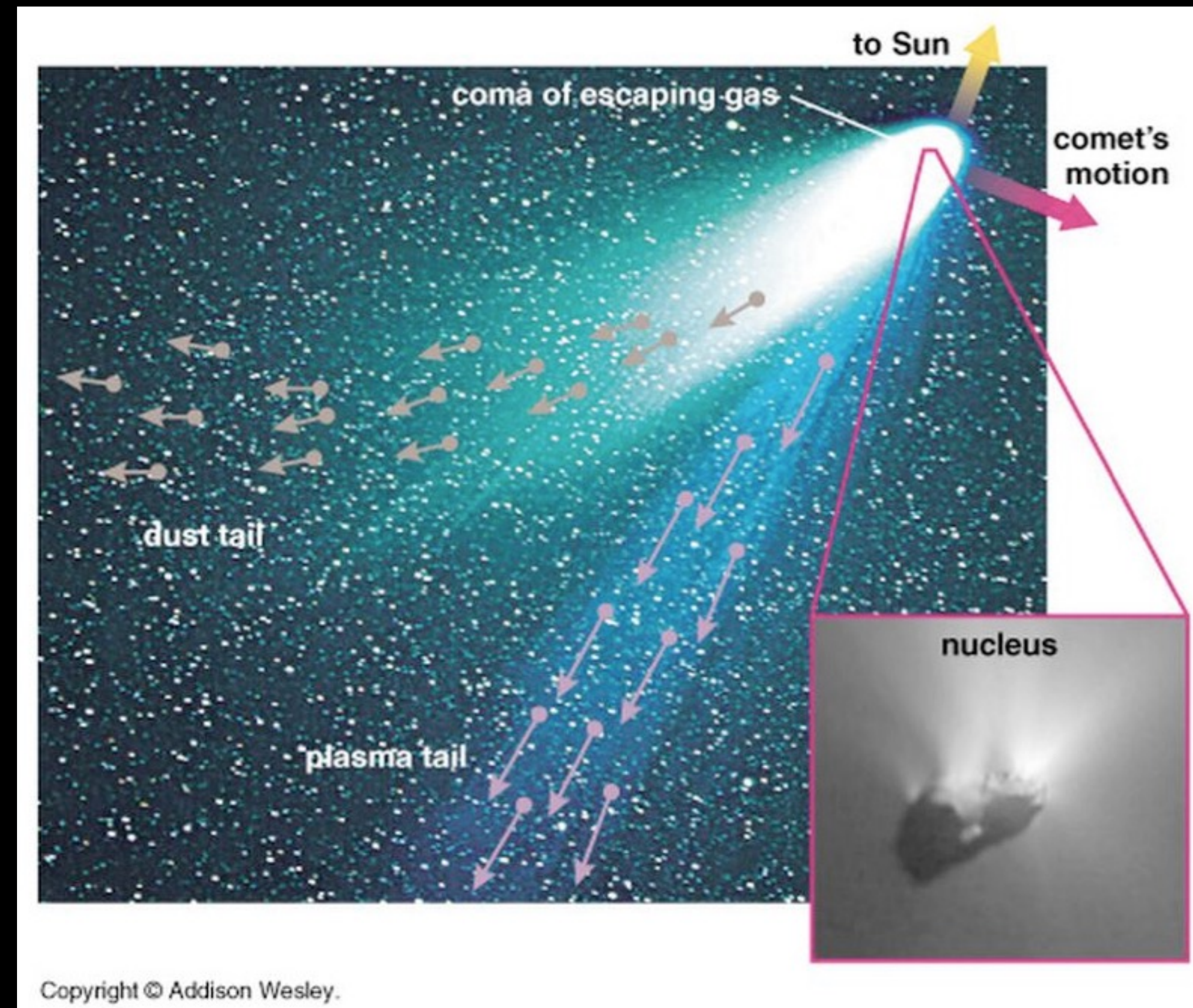
Mars, multiple strikes: 78km x 25km

Victoria Crater from the Mars Opportunity Rover

Current Impactor Population

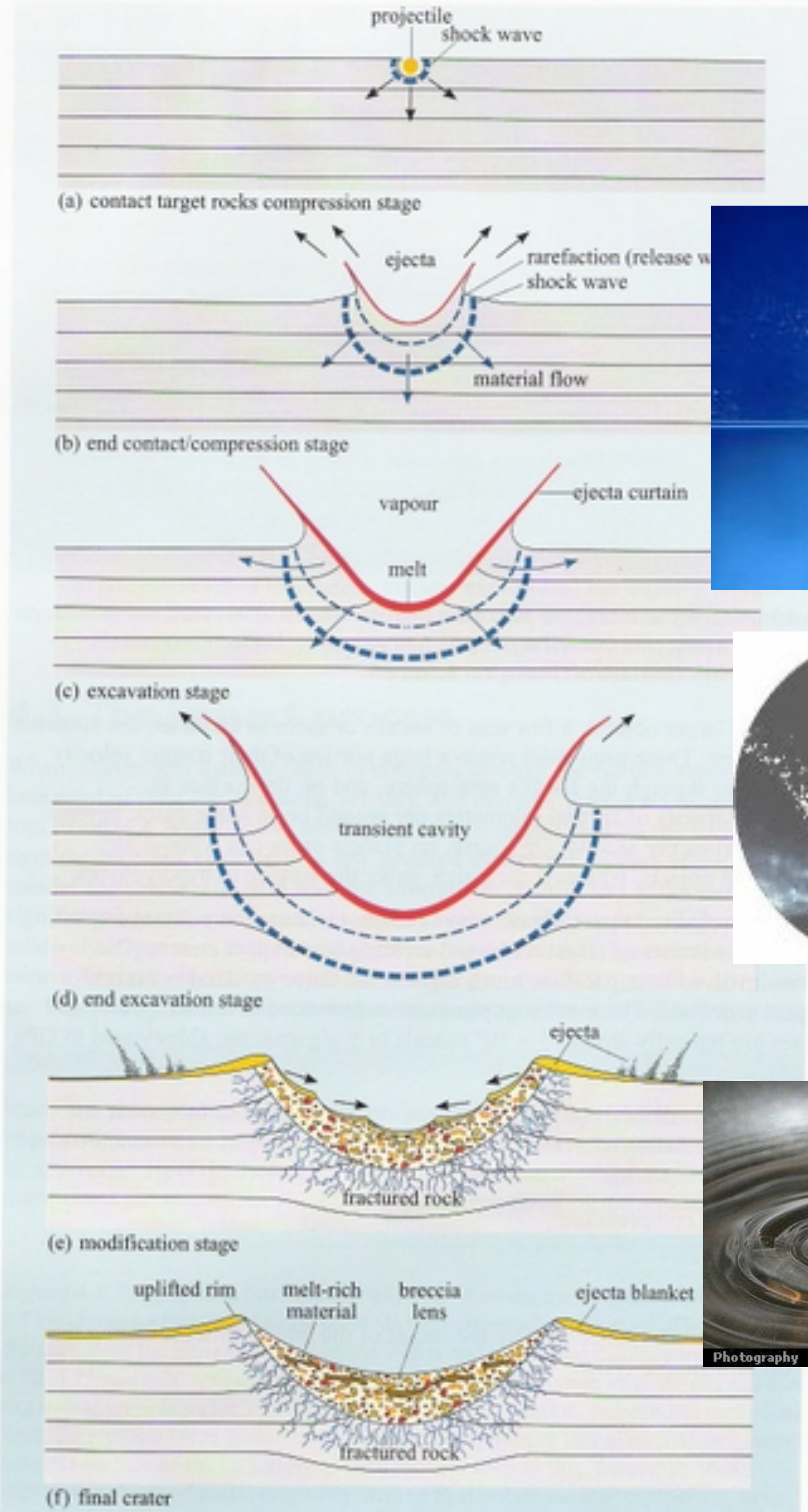
Asteroids - rocky objects inside Jupiter's orbit





Comets - icy objects begin to melt in the inner Solar System

The Cratering Process

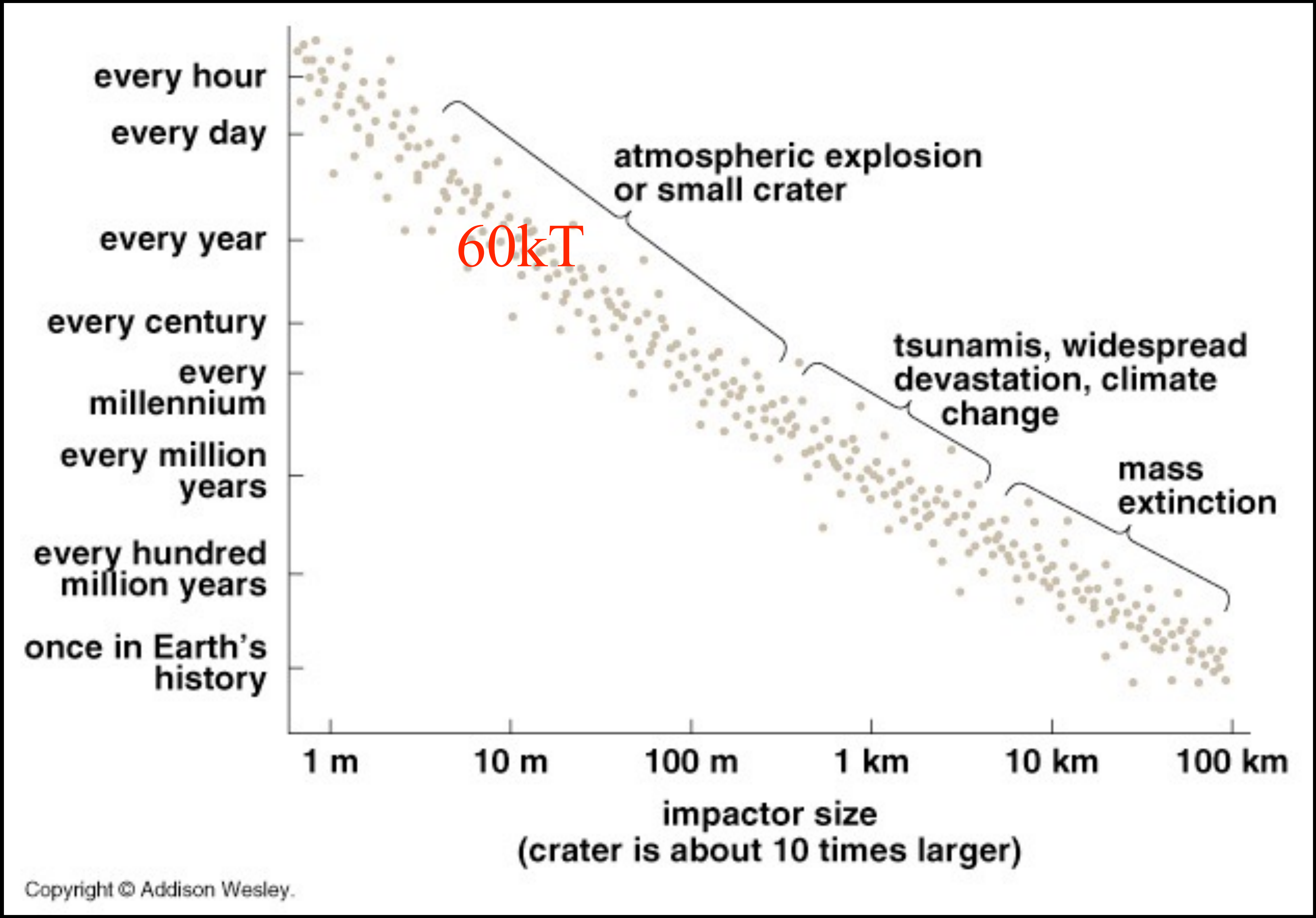


1. Contact & Compression

2. Excavation

3. Modification

Impact Frequency



Small impact happen much more often than large ones

Impactor Populations

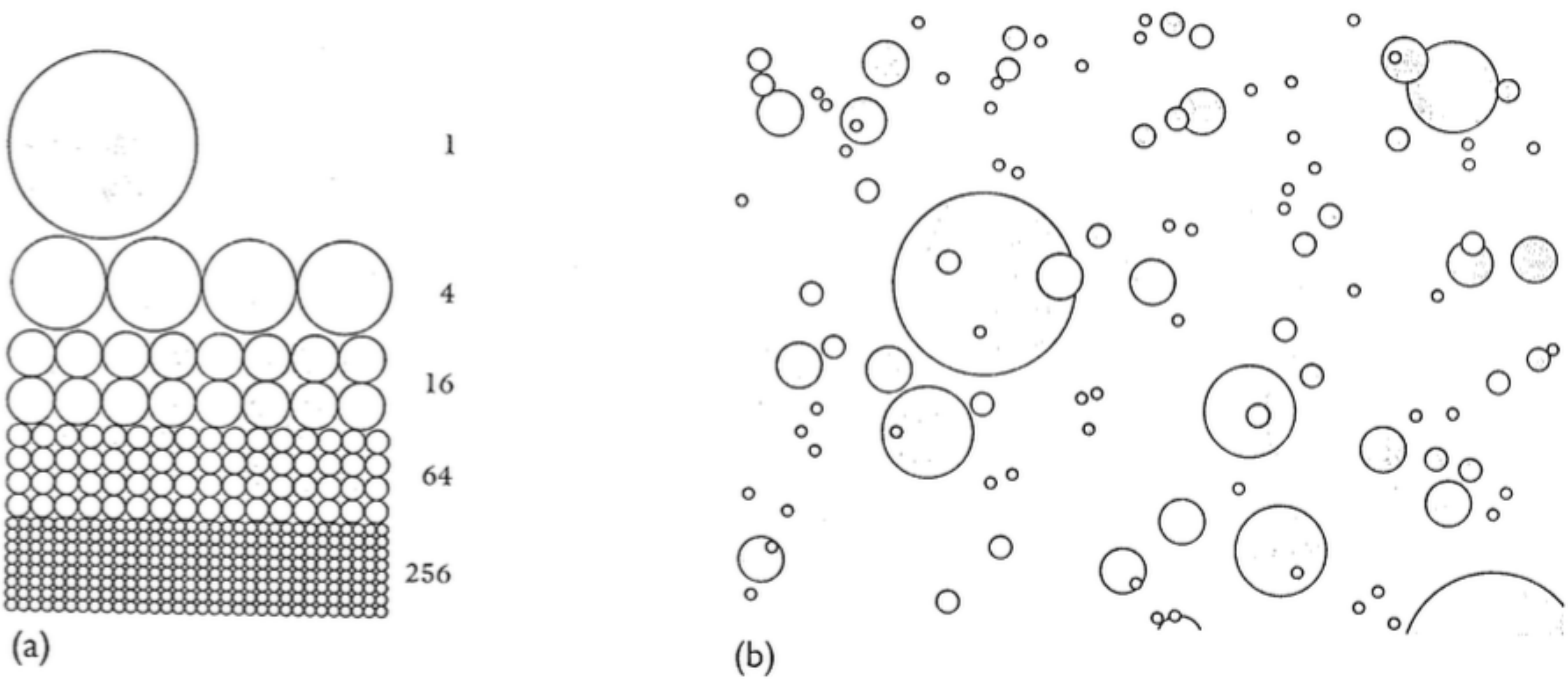


Figure 7.17 **(a)** The relative number of objects that could strike the Moon, according to a law in which the number of objects increases in inverse proportion to the square of the object's radius. **(b)** A random distribution of craters made by the population of objects shown in (a).

Estimate the Power of the Ground to stop a Meteoroid!

How much material must the meteoroid interact with to slow by 50%?

From Physics:
Momentum = (mass) (velocity) is conserved.
So velocity will be halved when mass is doubled.

Now assume that all ground in front of the impactor is plastered onto its surface.

So the impactor will penetrate into the ground by roughly its own diameter. Observed: A few diameters.

Estimate the Power of Air to stop a Meteoroid!

Assume that all air in front of the impactor is plastered onto its surface!

On Earth, air is 1/1000 as dense as water and is ~10km thick. So the impactor will penetrate into the atmosphere by roughly 1000 diameters. 10m should make it through. (10km/1000 = 10 m)
Observed on Earth: Must be ~50-100m to hit the surface

On Mars the air is 1/100 times thinner than that. So the impactor will penetrate by roughly 100000 diameters. 10cm will make it through the atmosphere (since 10km/100000 = 10cm).

Estimate the Power of the Ground to stop a Meteoroid!

How much material must the meteoroid interact with to slow by 50%?

From Physics:
Momentum = (mass) (velocity) is conserved.
So velocity will be halved when mass is doubled.

Now assume that all ground in front of the impactor is plastered onto its surface.

So the impactor will penetrate into the ground by roughly its own diameter. Observed: A few diameters.

Estimate the Power of Air to stop a Meteoroid!

Assume that all air in front of the impactor is plastered onto its surface!

On Earth, air is 1/1000 as dense as water and is ~10km thick.

So the impactor will "penetrate" into the air by roughly 1000 diameters. Thus 10m will make it through Earth's atmosphere.

Observed: Must be ~50-100 m to make it through

Estimate the Power of Air to stop a Meteoroid!

Assume that all air in front of the impactor is plastered onto its surface!

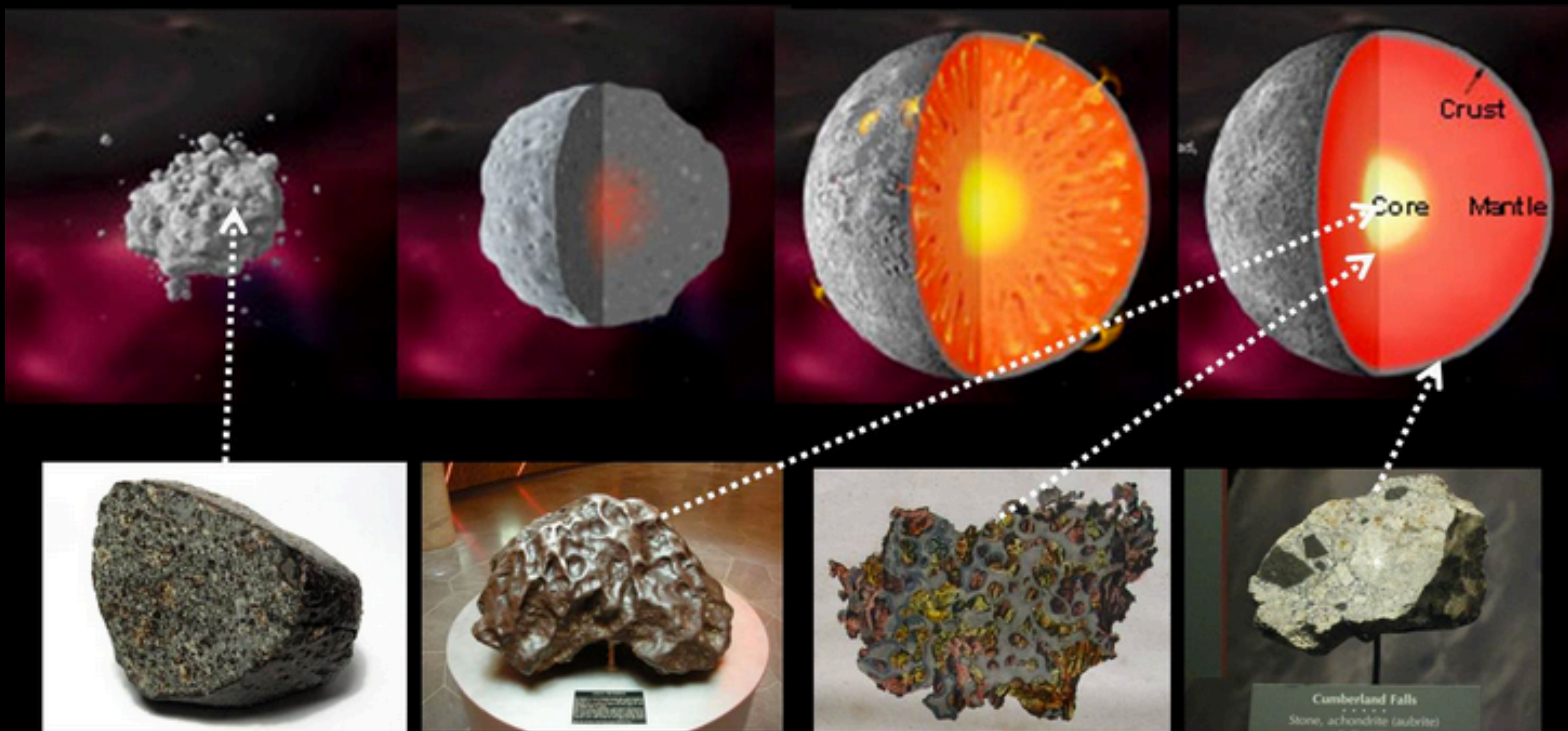
On Mars, air is 1/100,000 as dense as water and is ~10km thick.

On the impactor will “penetrate” into the air by roughly 100,000 diameters. Thus 10cm will make it through Mars’ atmosphere.

Not Yet Observed: Scaling from Earth suggests a 1m cutoff

Different Asteroid & Meteorite Types

Source: Smithsonian Museum of Natural History http://www.mnh.si.edu/earth/text/5_1_4_0.html

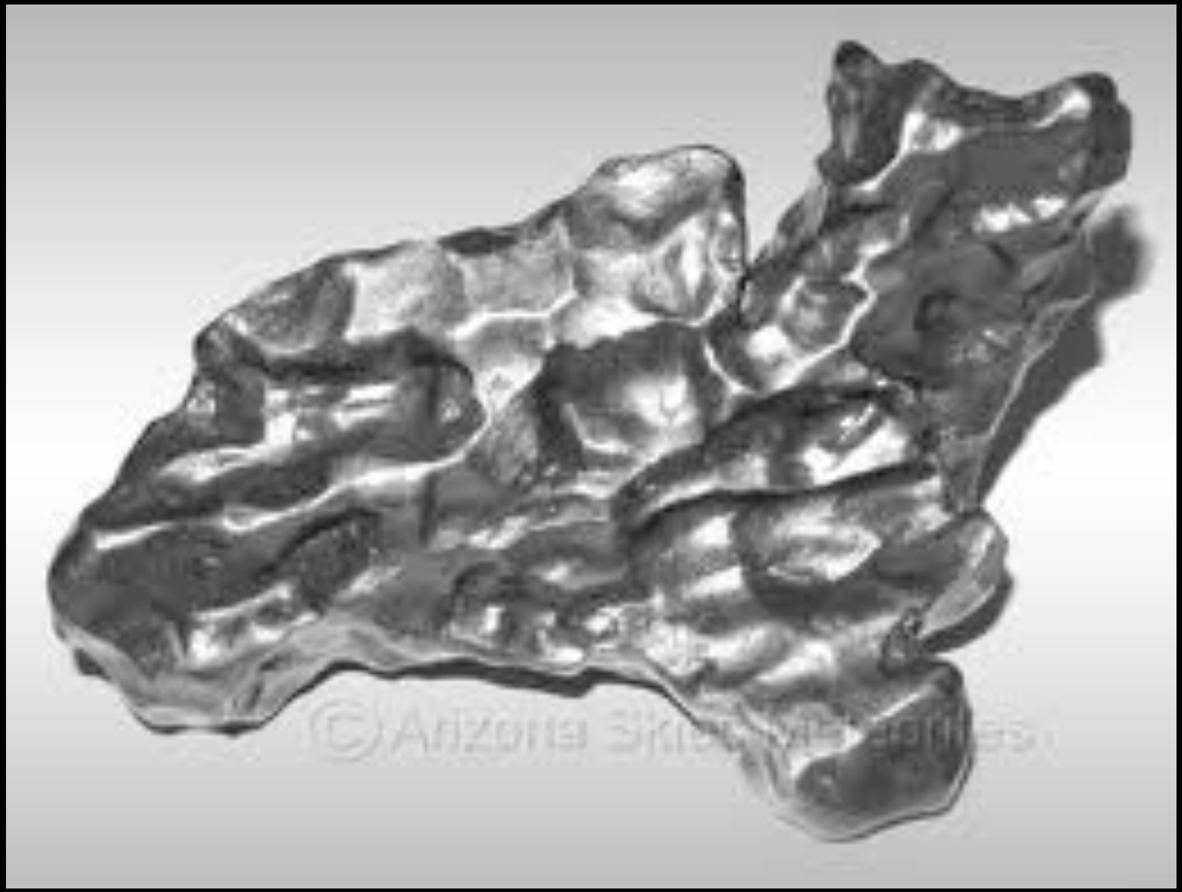


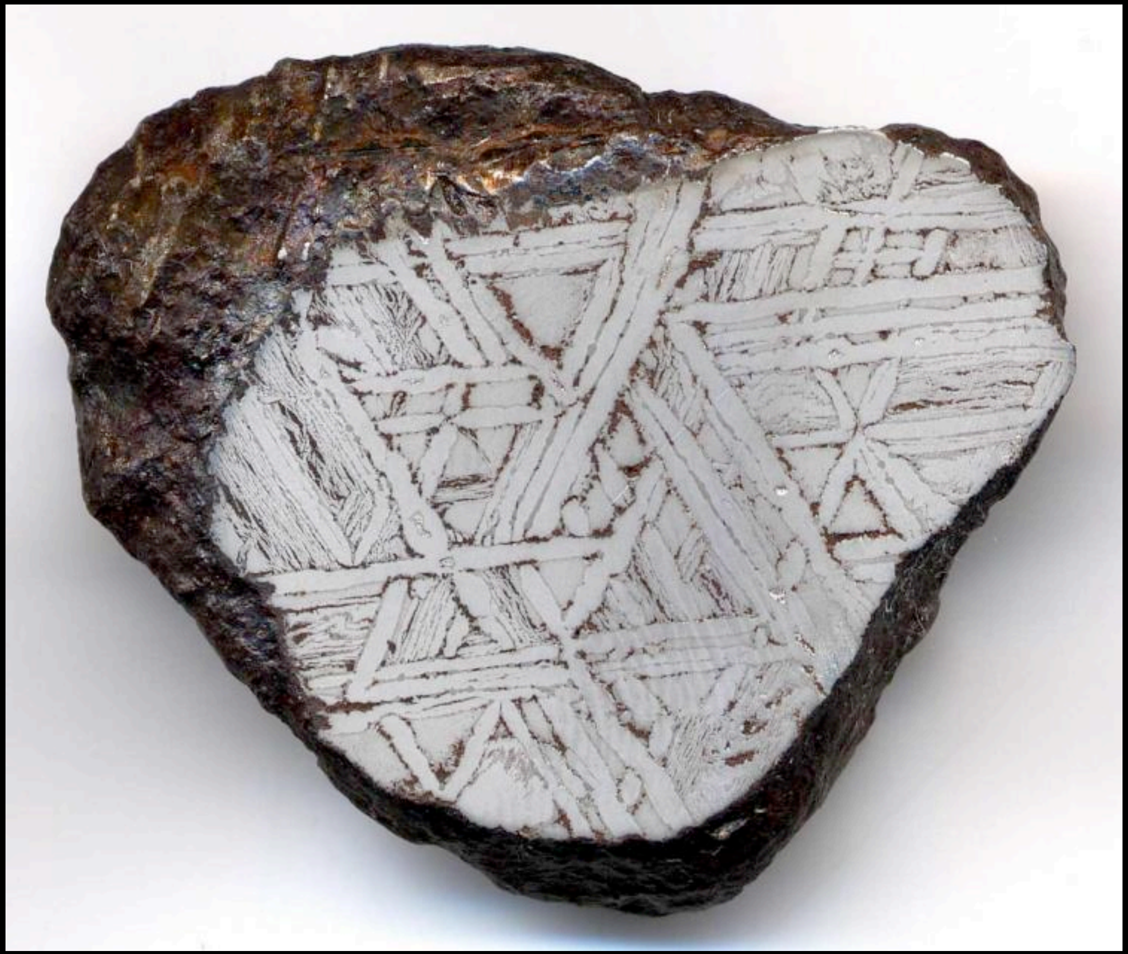
Chondritic Stony Meteorite	Iron Meteorite	Pallasite Meteorite	Achondritic Stony Meteorite
Asteroid Type C	Asteroid Type M		Asteroid Type S

Heat Shield Rock

From Opportunity

Iron Meteorites





Meteorite Features

Regmaglypts and fusion crust

Sikhote-Alin Coarsest Octahedrite, Vladivostok, Russia, 2-12-1947

(photo by New England Meteoritical Services)

Meteorite Features

Widmanstätten pattern:

Gibeon IVA fine octahedrite

Kamacite—light bands
Taenite—dark bands

(photo by New England Meteoritical Services)

Martian Meteorites

ALH84001,0 (Antarctica)

(photo from NASA Johnson Space Center)

Martian Meteorites

EETA79001,0 (Antarctica)

(photo from Lunar and Planetary Institute)

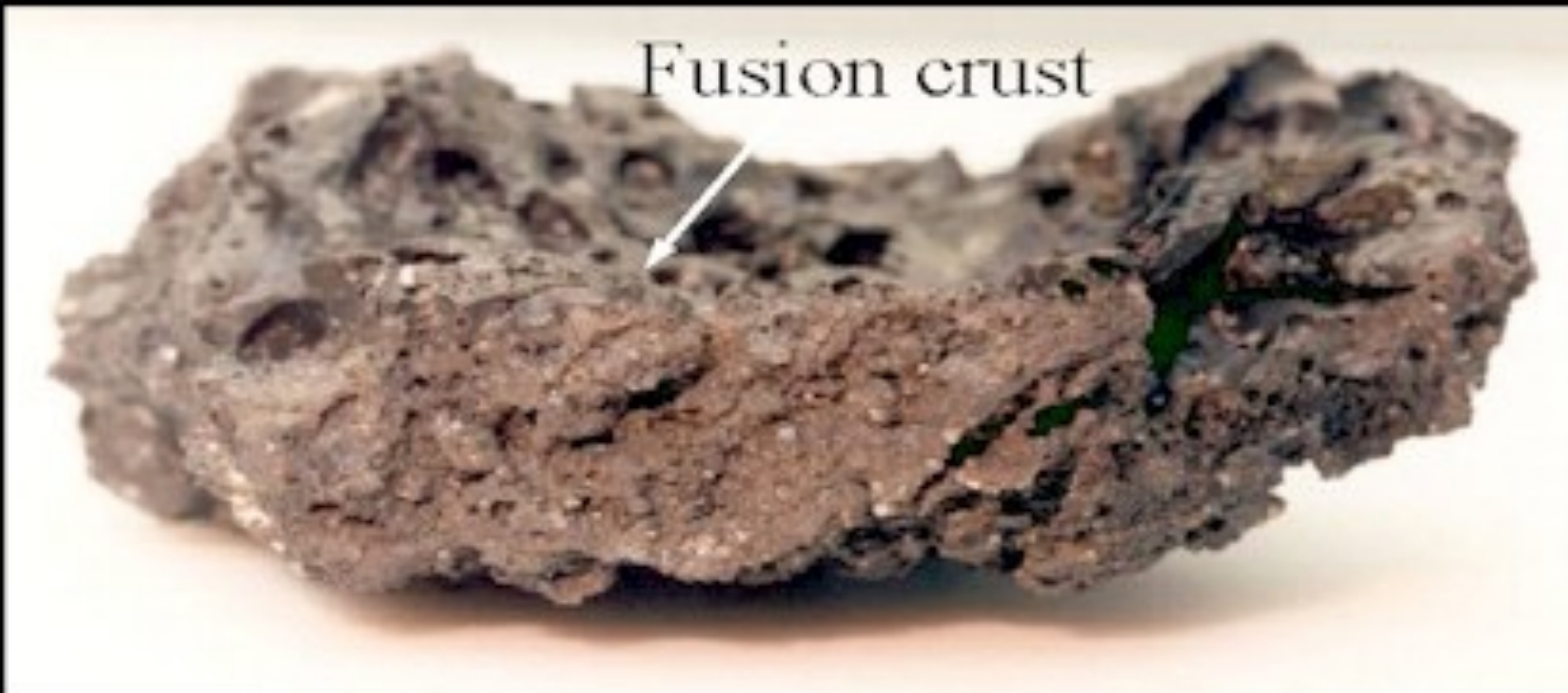
Martian Meteorites

Zagami, Nigeria

(photo by Korotev, 2002b)

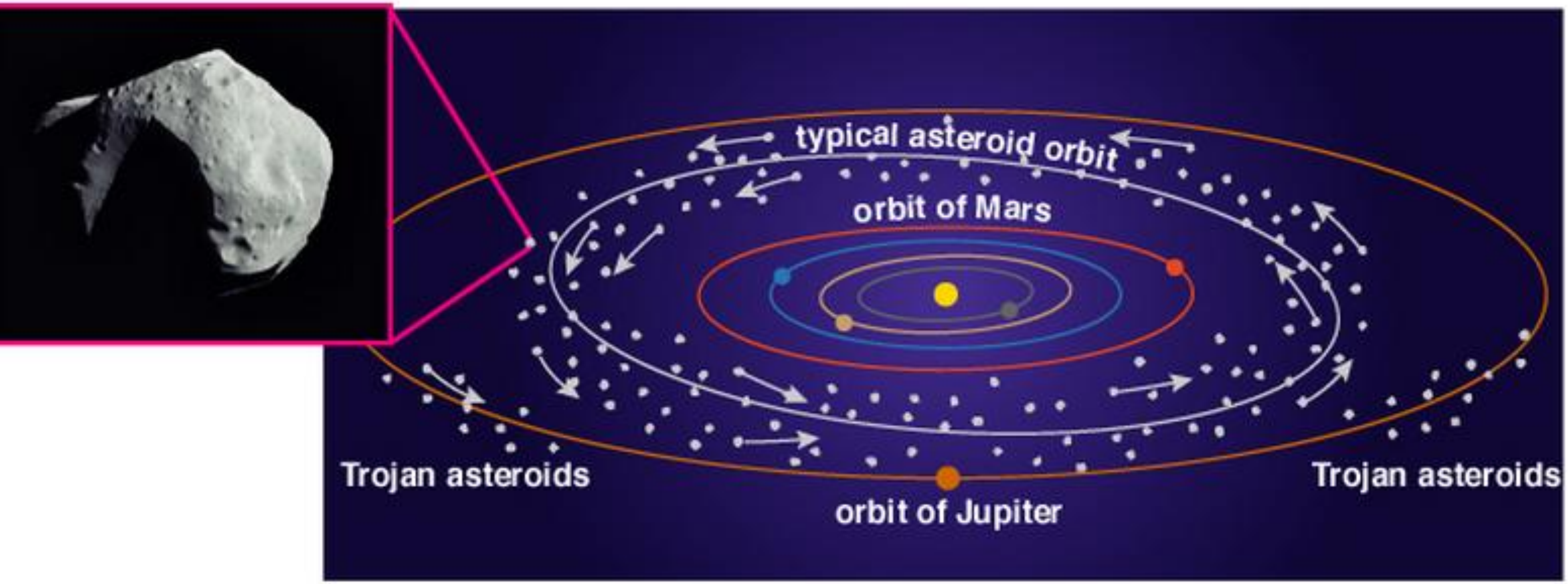
Lunar Meteorites

QUE 94281, Antarctica

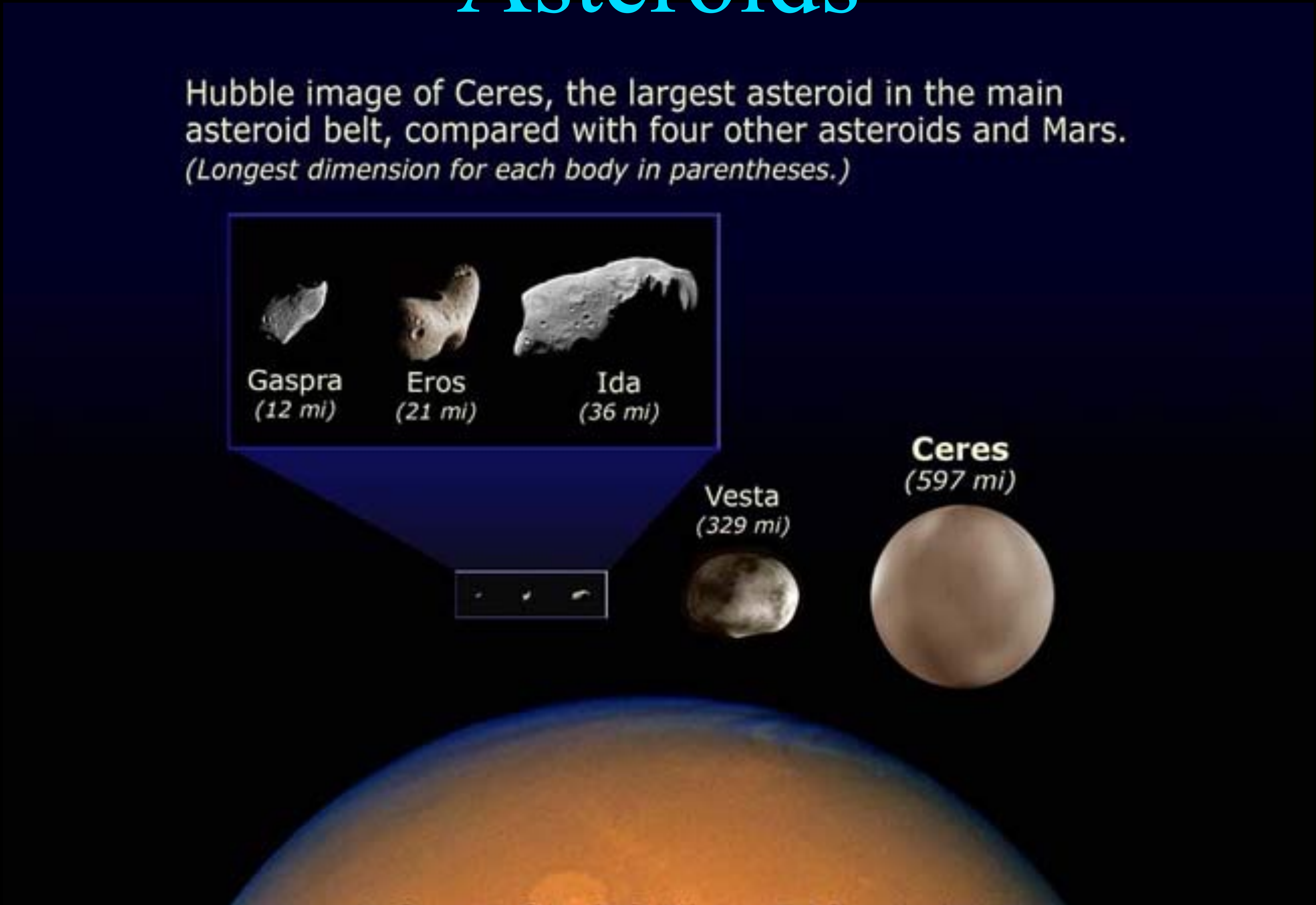


(From NASA photo S95-14590)

Asteroid Belt

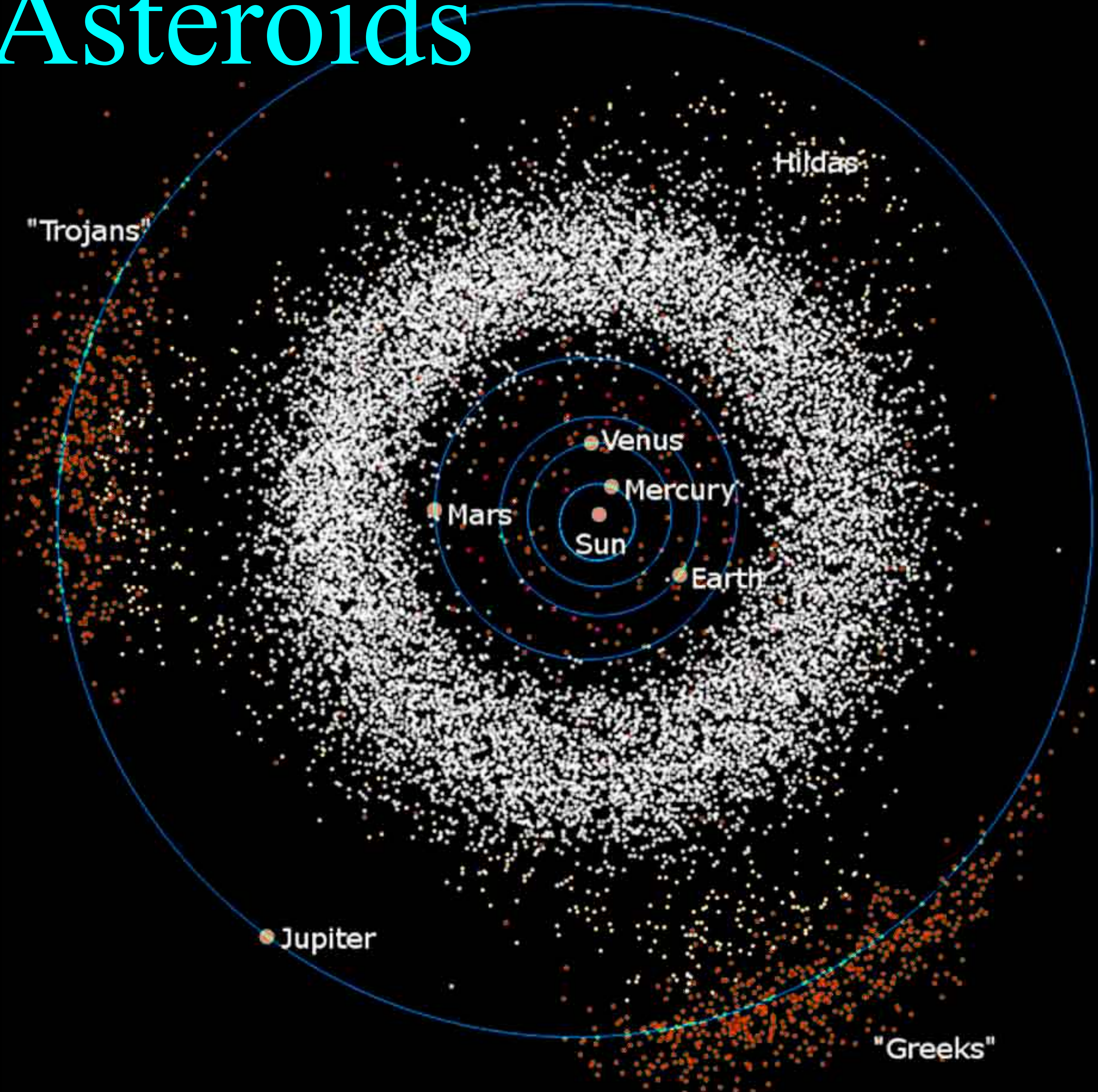


Asteroids



Hubble image of Ceres, the largest asteroid in the main asteroid belt, compared with four other asteroids and Mars.
(Longest dimension for each body in parentheses.)
Gaspra
(12 mi)
Eros
(21 mi)
Ida
(36 mi)
Vesta
(329 mi)
Ceres
(597 mi)

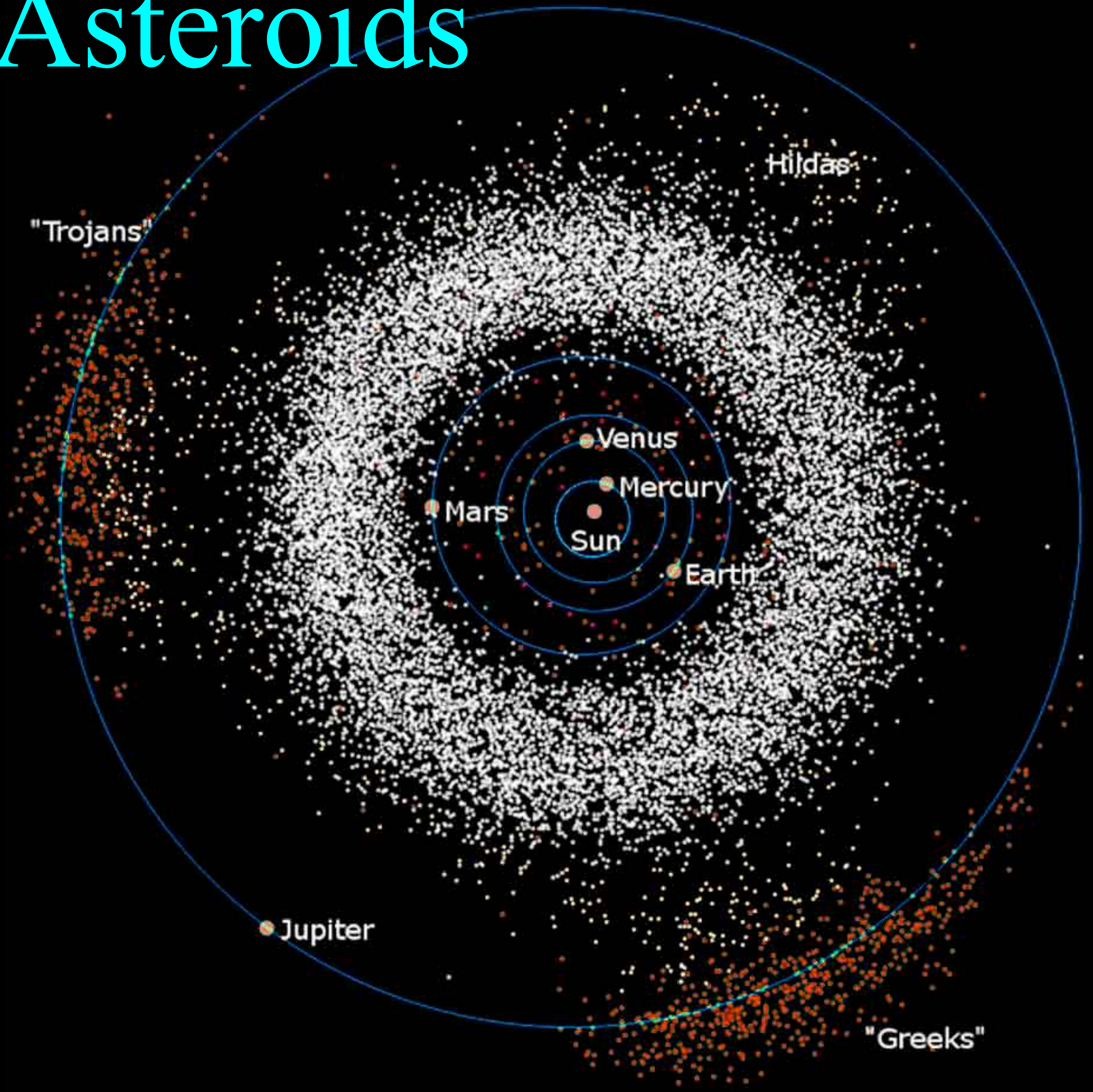
Asteroids



Three Main populations of asteroids:

1. Main Belt
2. Near-Earth
3. Trojans

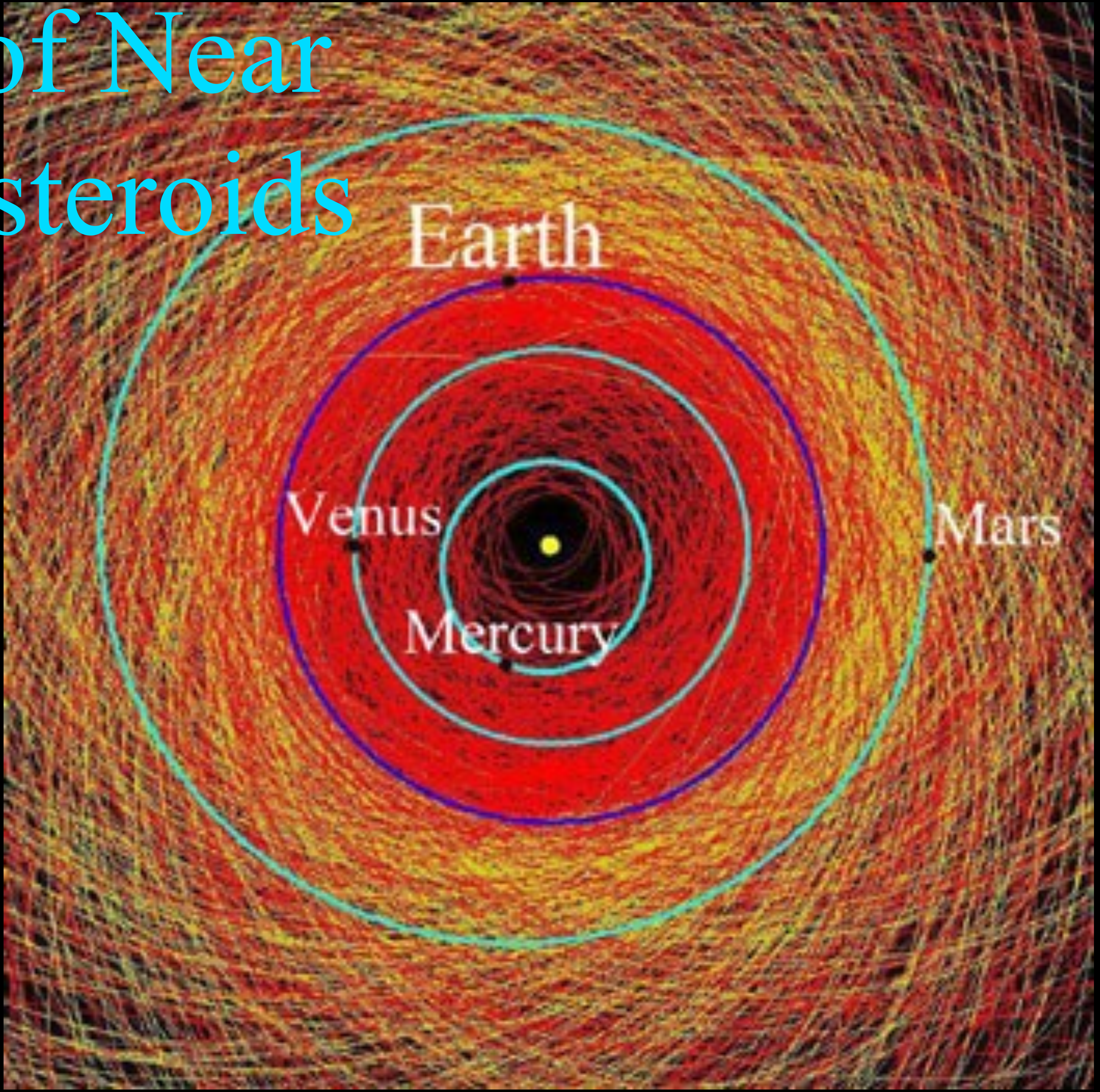
Asteroids



Three Main populations of asteroids:

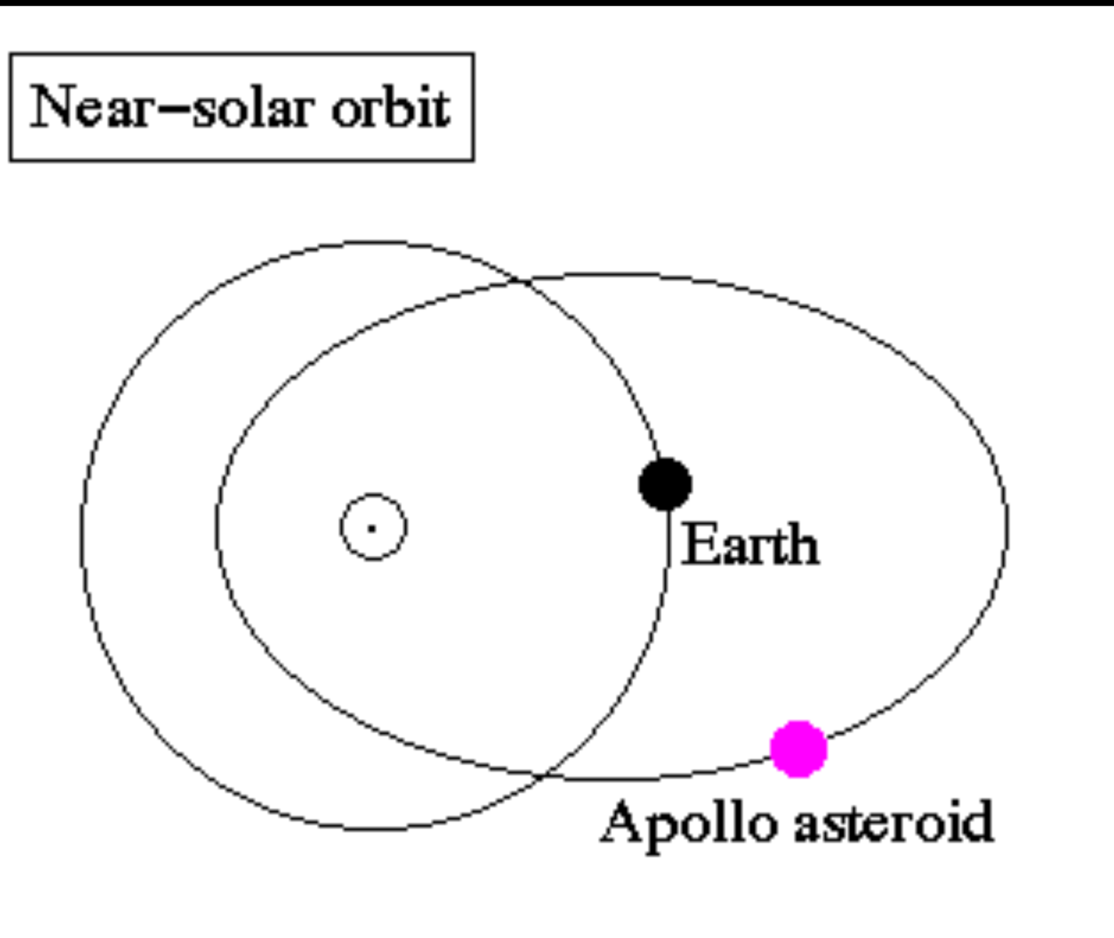
1. Main Belt
2. Near-Earth
3. Trojans

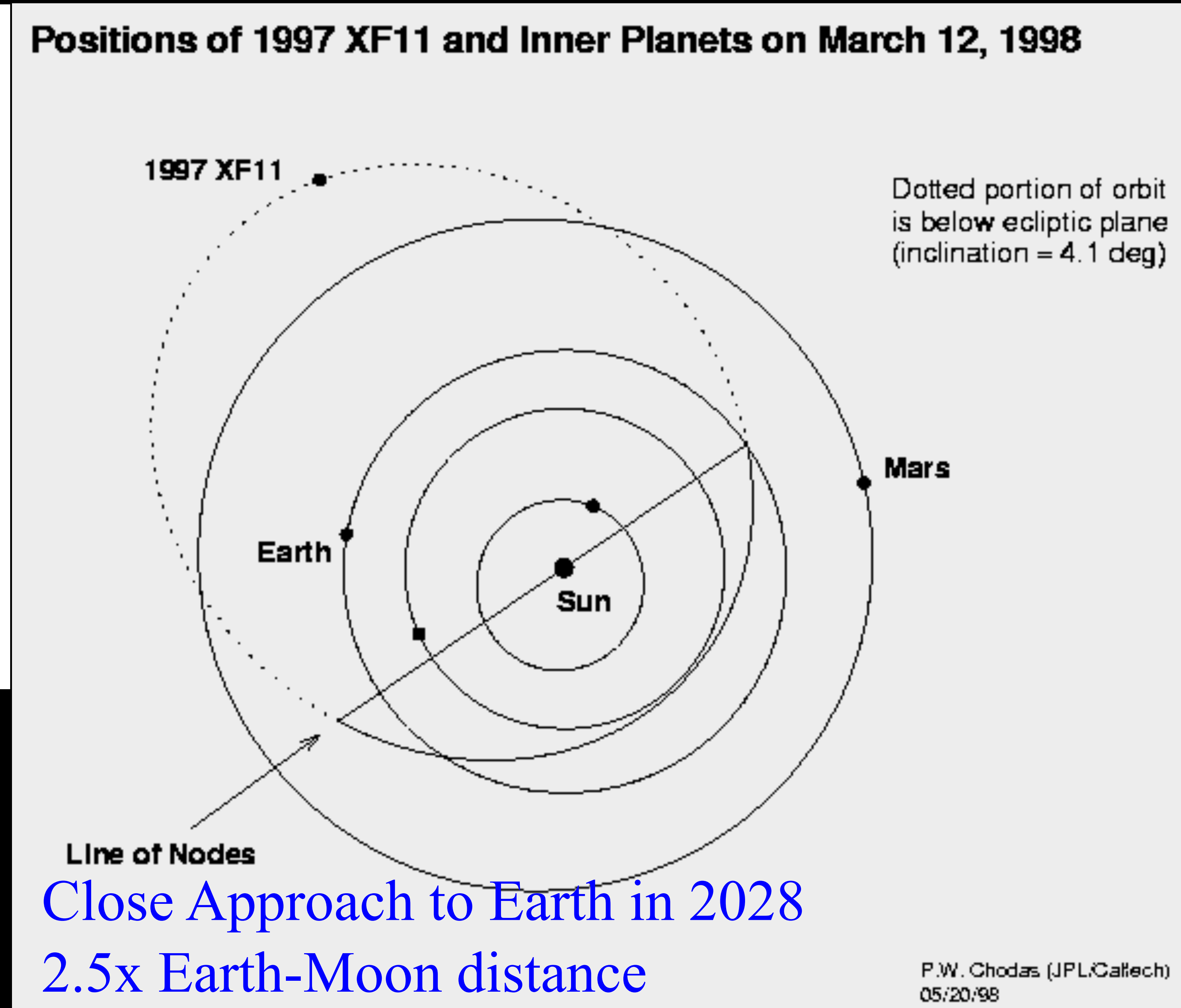
Orbits of Near Earth Asteroids



Asteroid orbits are much more elliptical than planetary orbits.

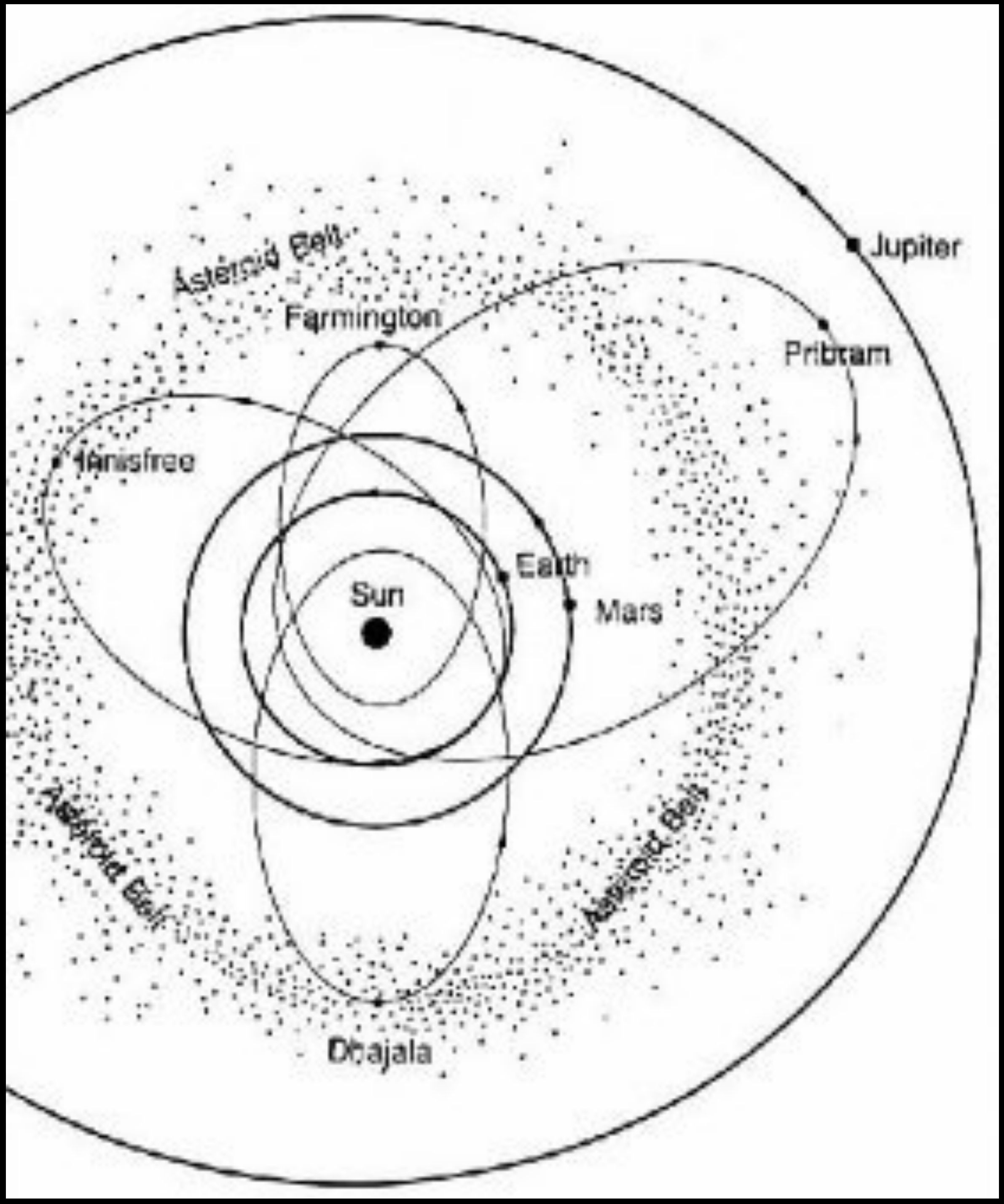
Near Earth Asteroids



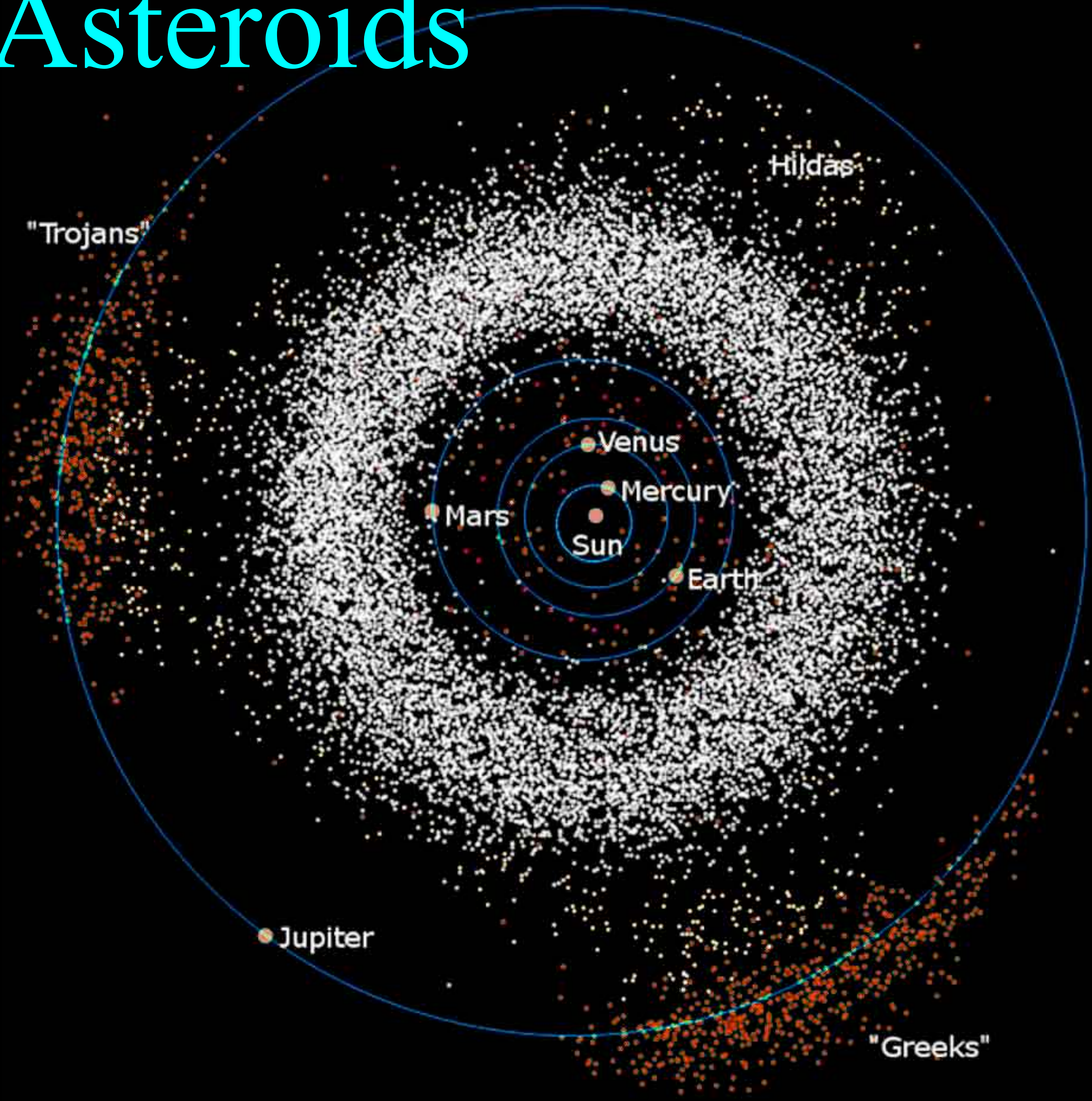


Close Approach to Earth in 2028
2.5x Earth-Moon distance

Apollos, Atens, and Amors



Asteroids



Three Main populations of asteroids:

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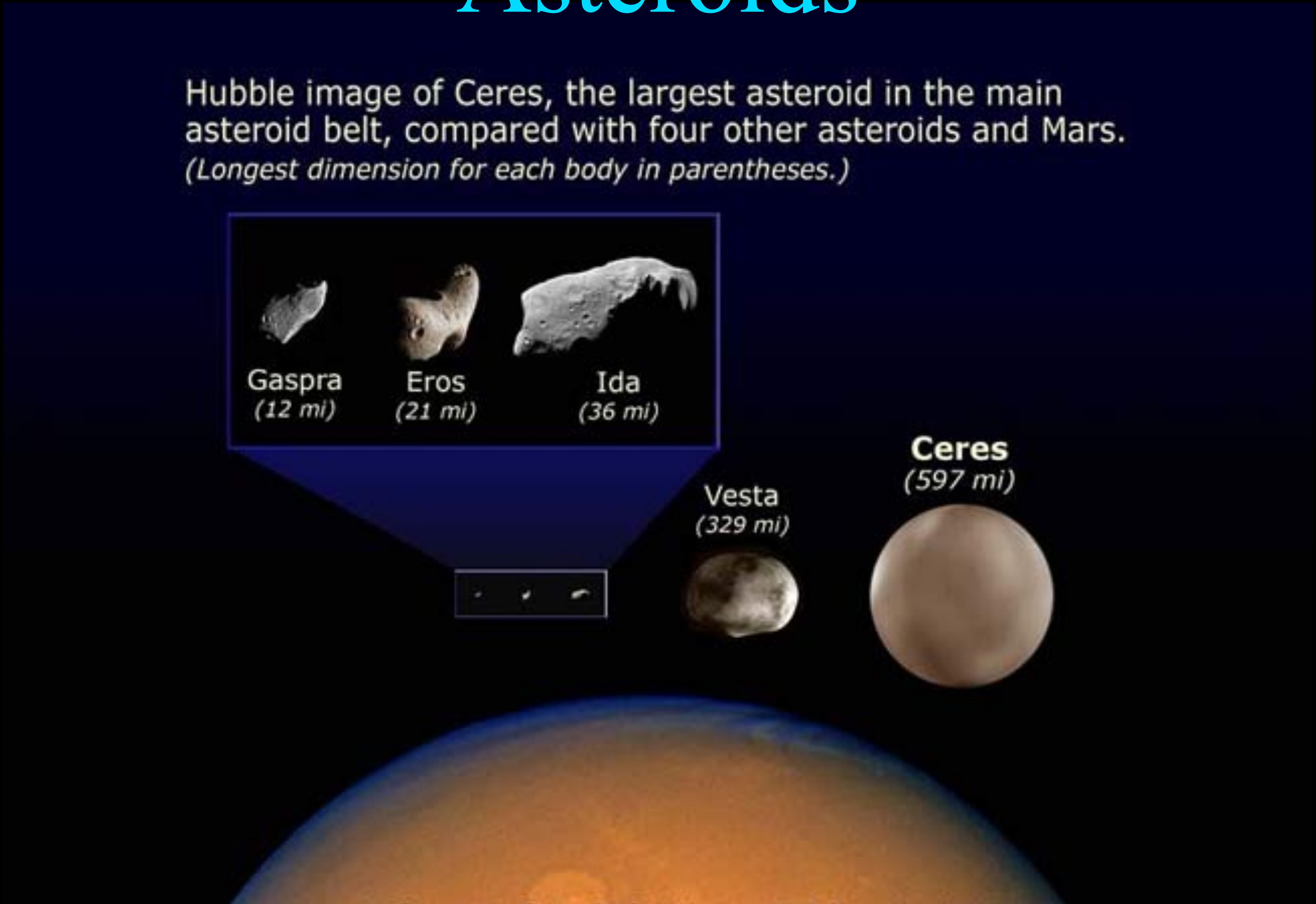
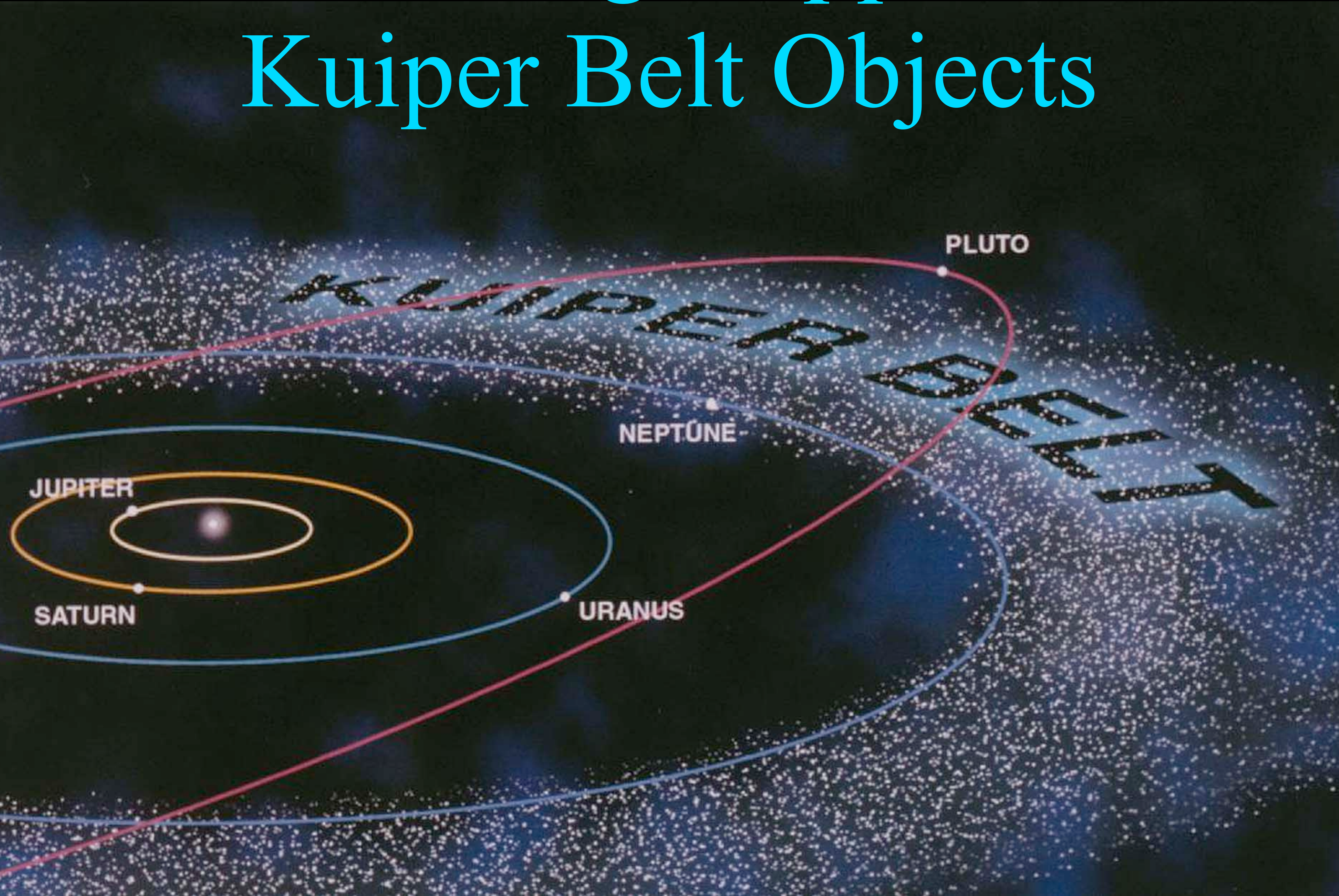
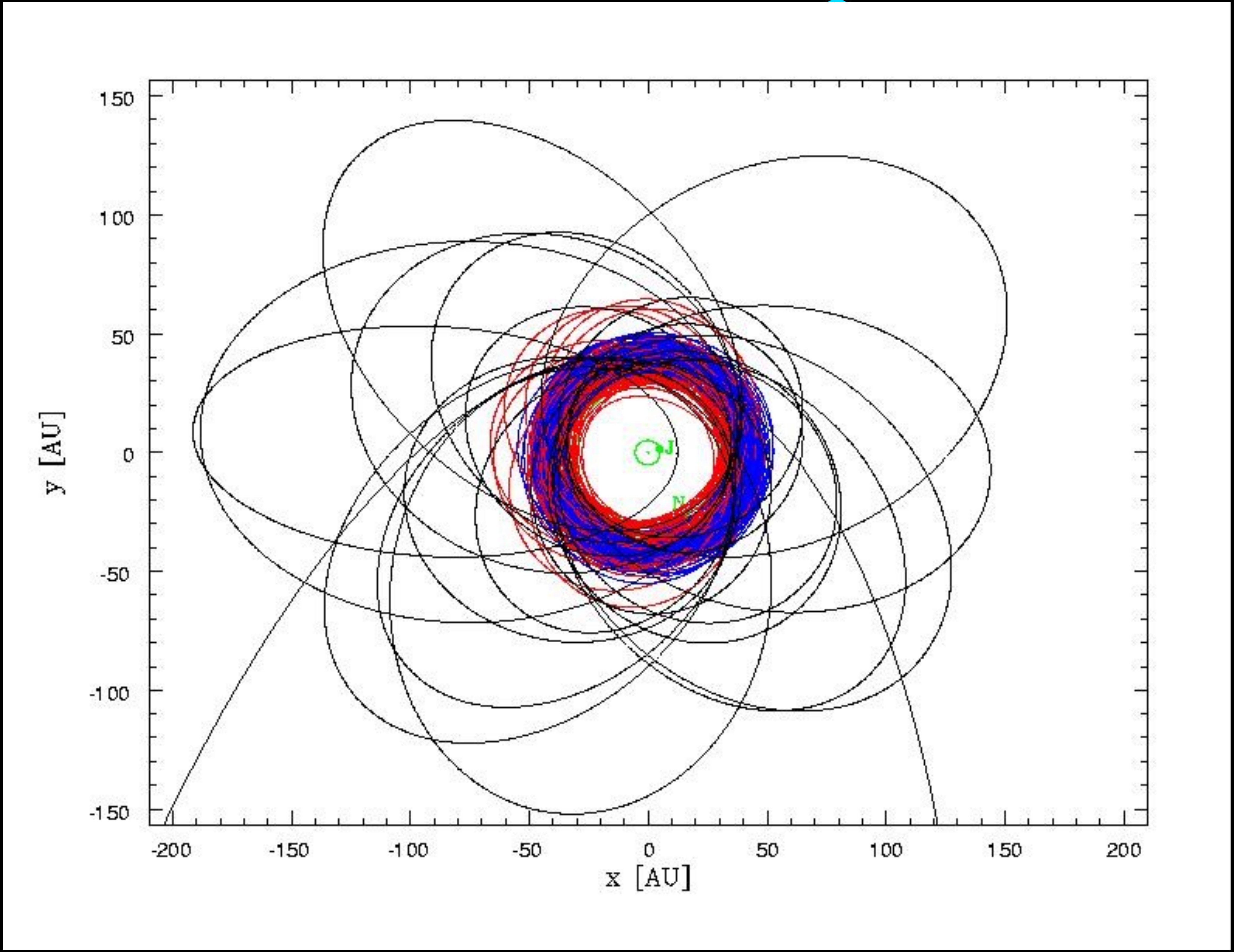
Asteroids


Hubble image of Ceres, the largest asteroid in the main asteroid belt, compared with four other asteroids and Mars.
(Longest dimension for each body in parentheses.)
Gaspra
(12 mi)
Eros
(21 mi)
Ida
(36 mi)
Vesta
(329 mi)
Ceres
(597 mi)

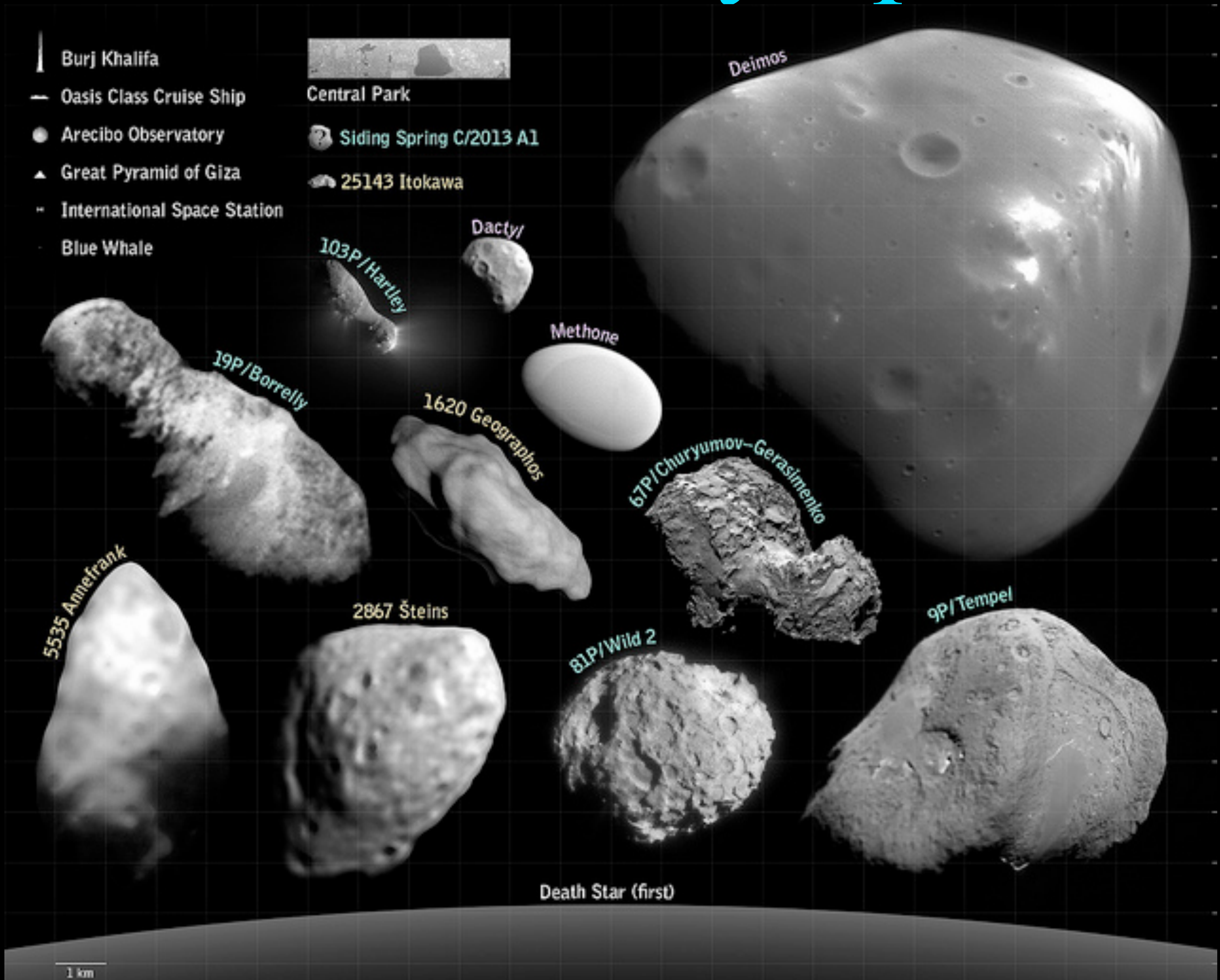
Same Thing Happens for Kuiper Belt Objects



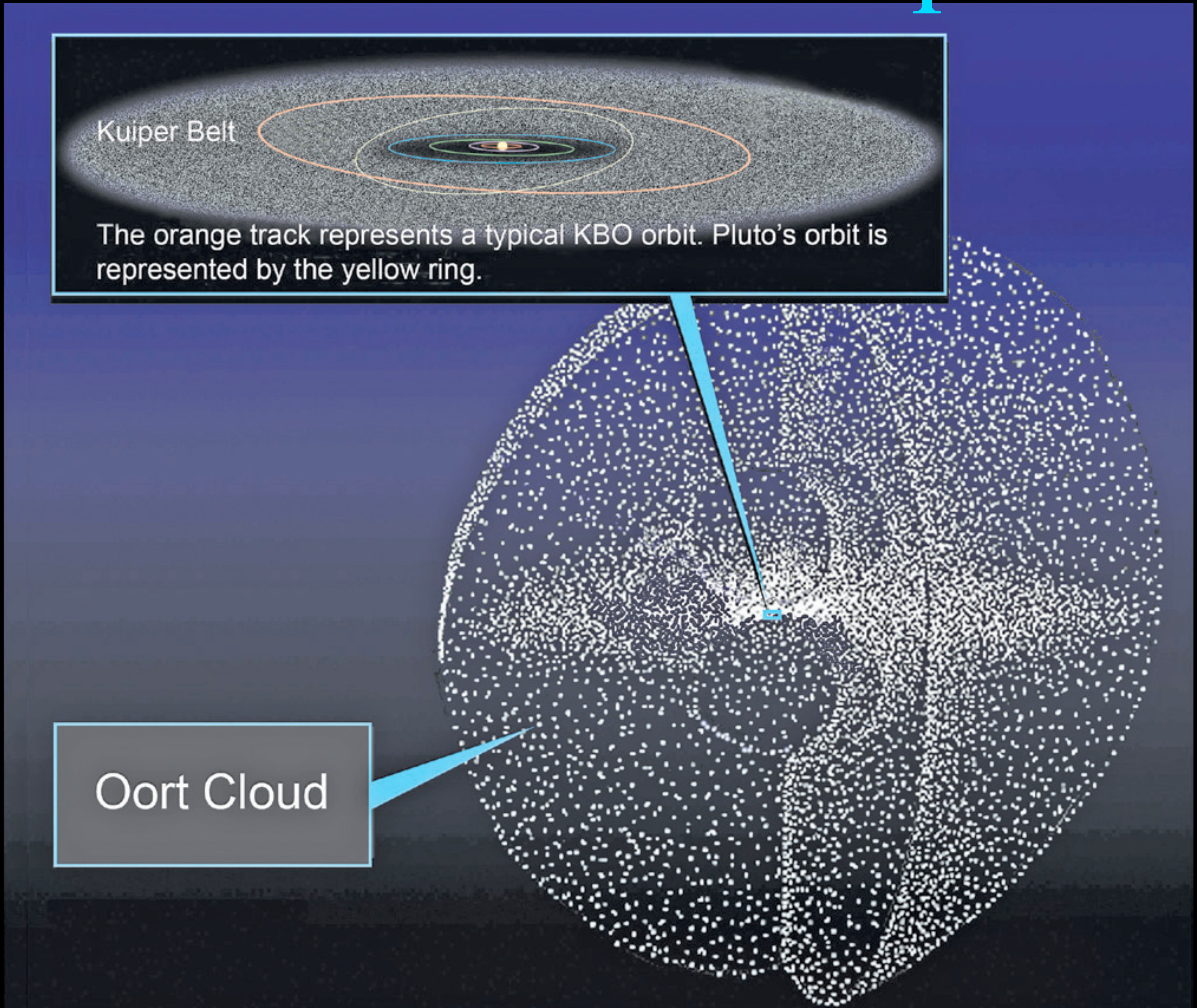
Orbits in the Kuiper Belt



Comets visited by Spacecraft

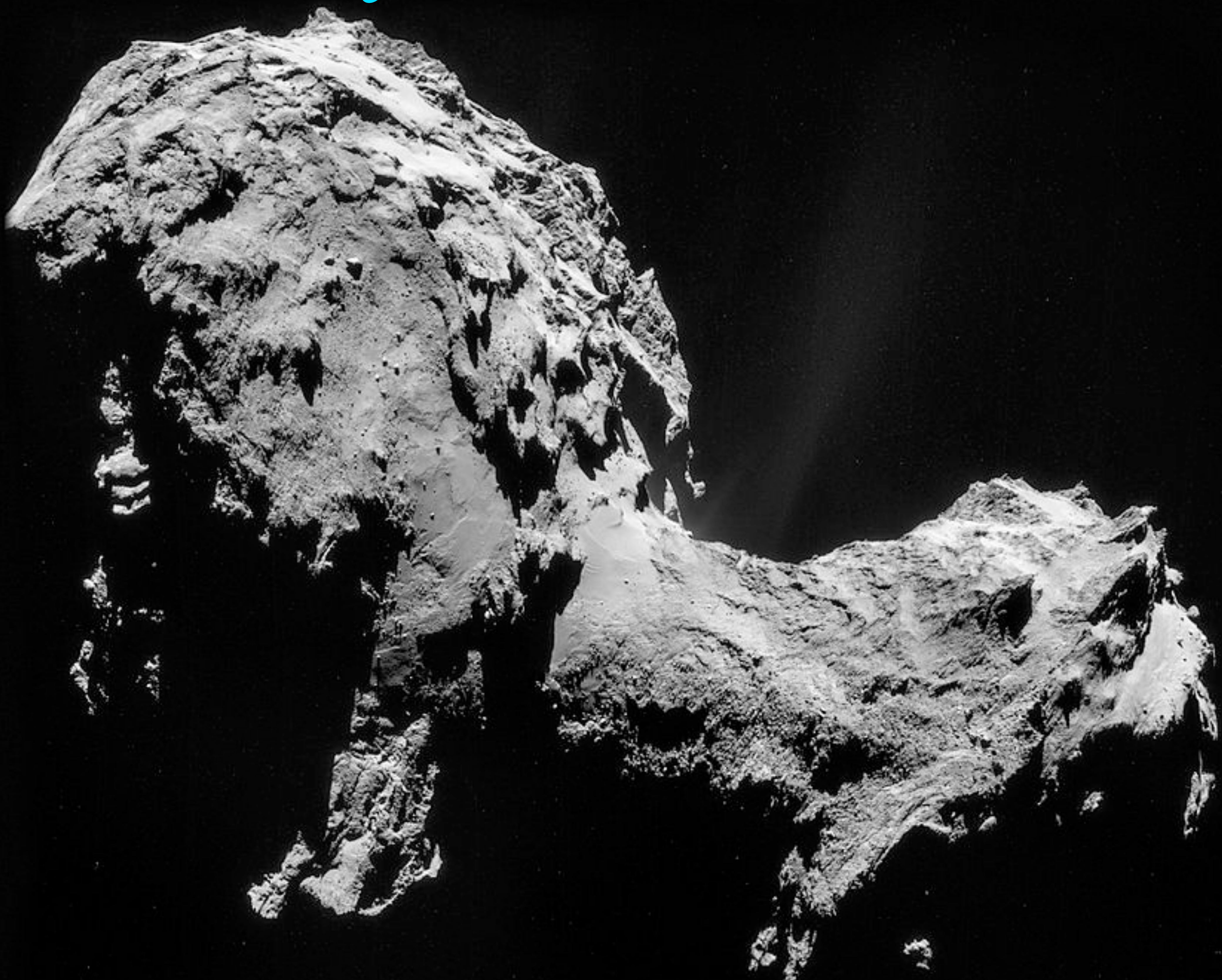


Comets from the Kuiper Belt

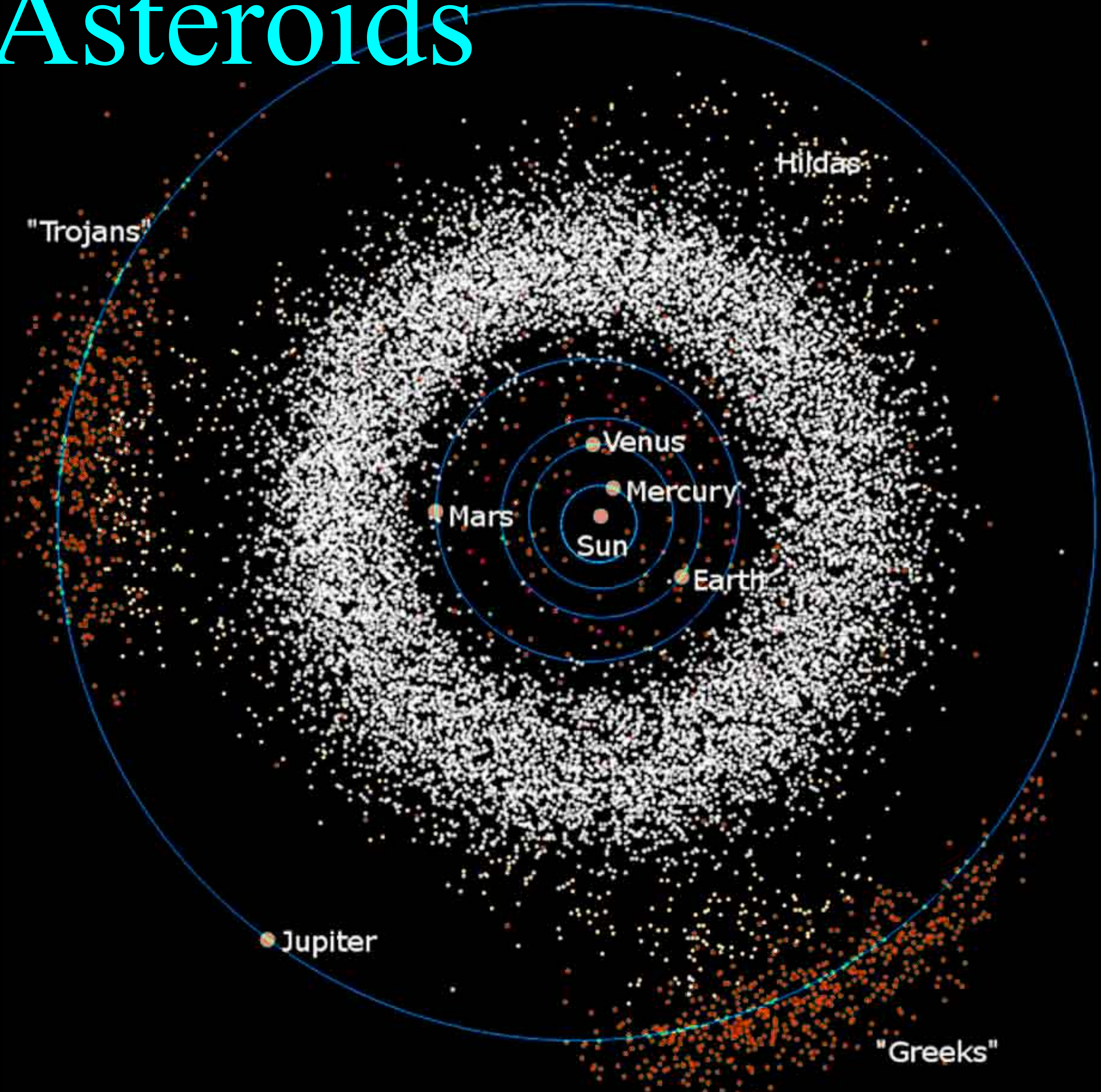


Comets are Dangerous

67P/Churyumov-Gerasimenko



Asteroids



Three Main populations of asteroids:

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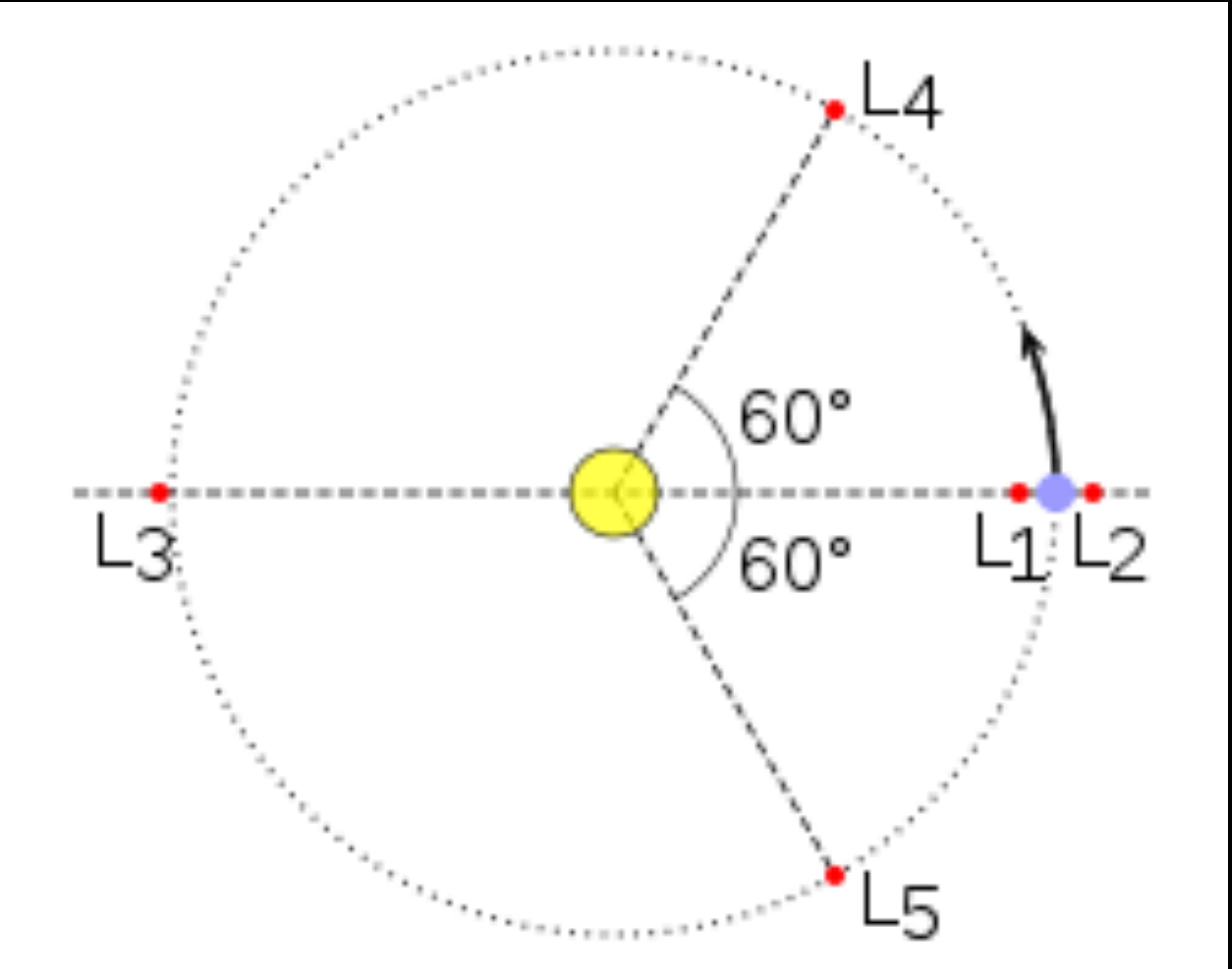
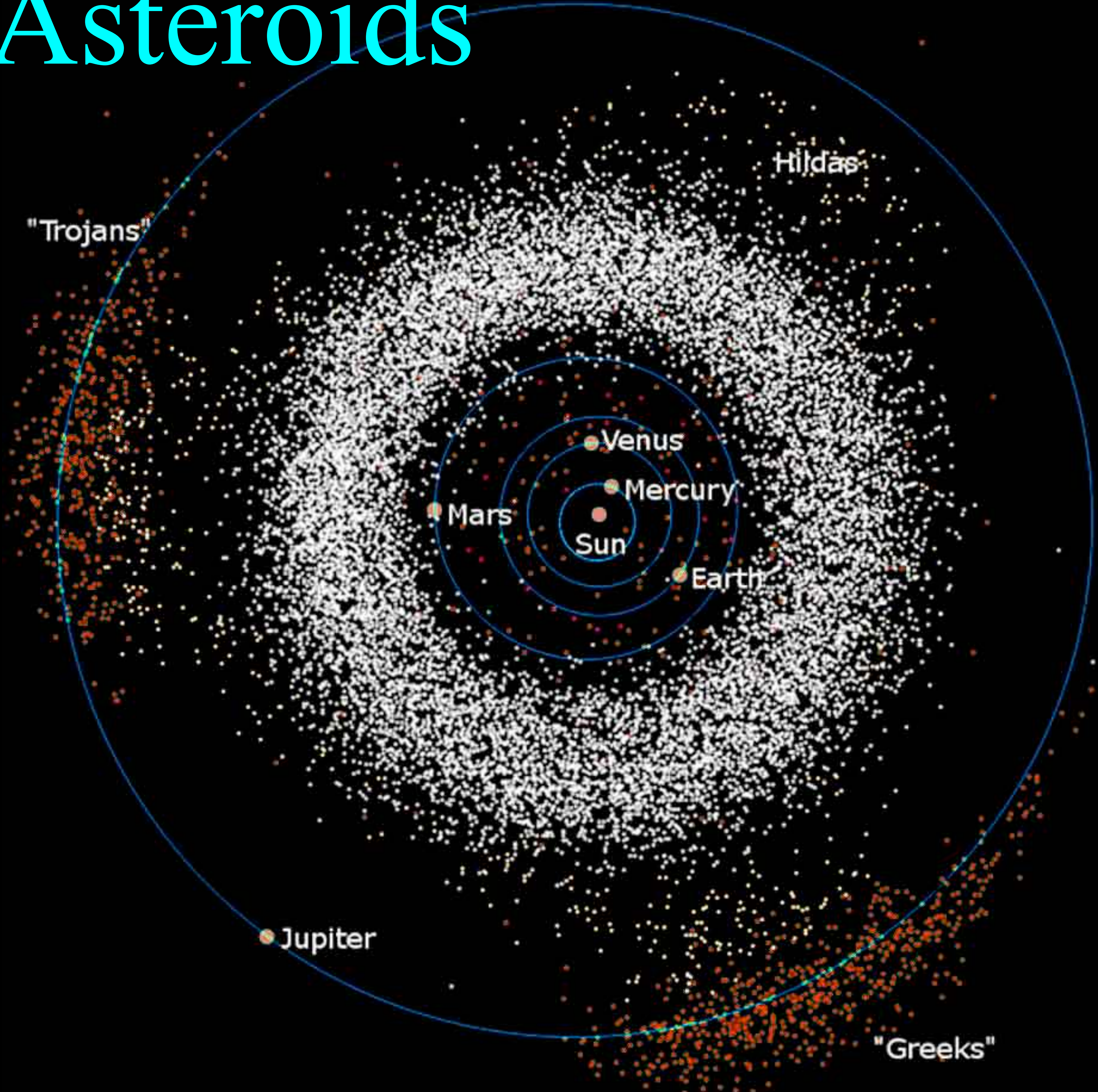
3. Trojans

3-Body Problem: Stable Orbits



Asteroids



Three Main populations of asteroids:

1. Main Belt
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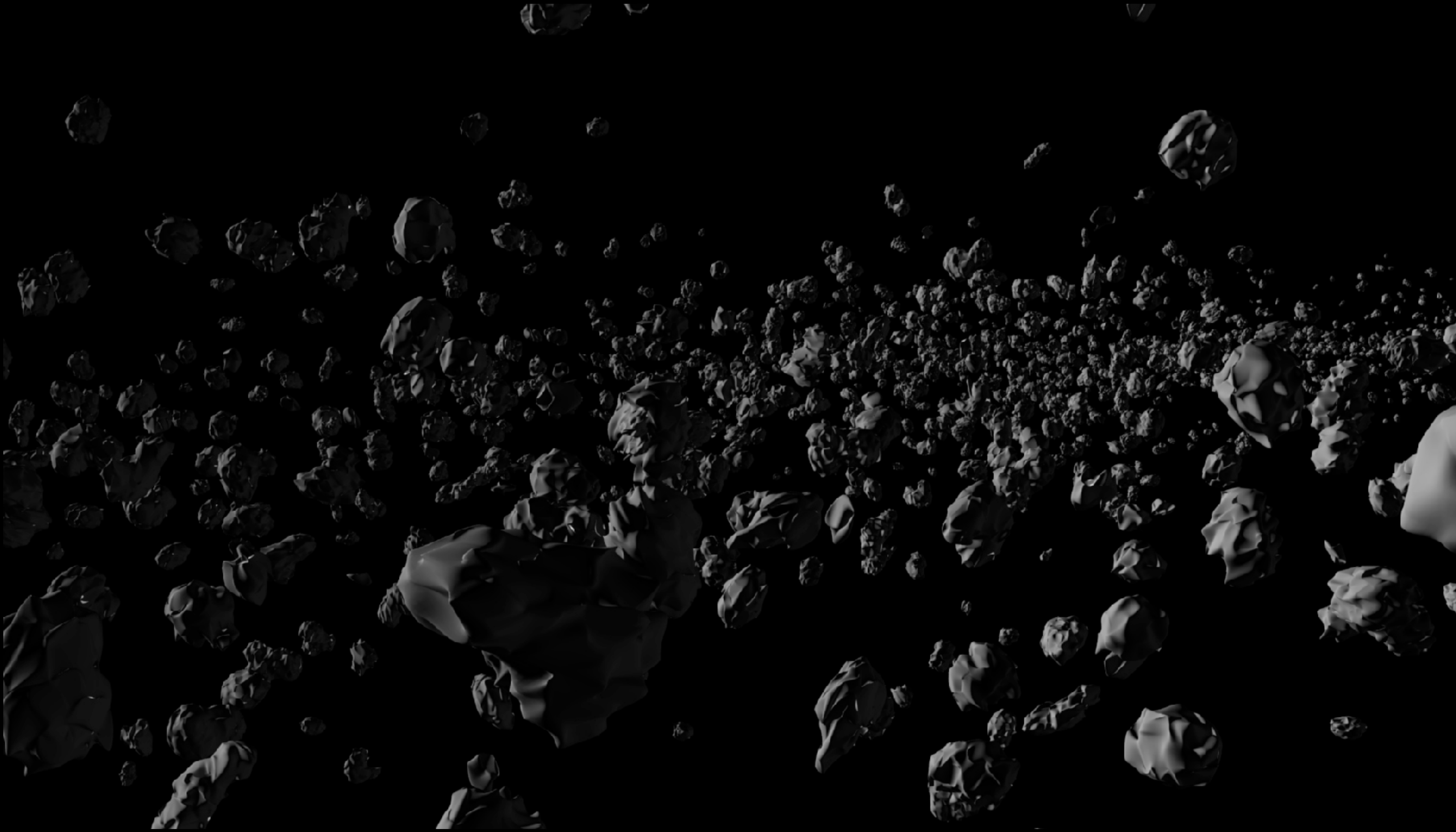
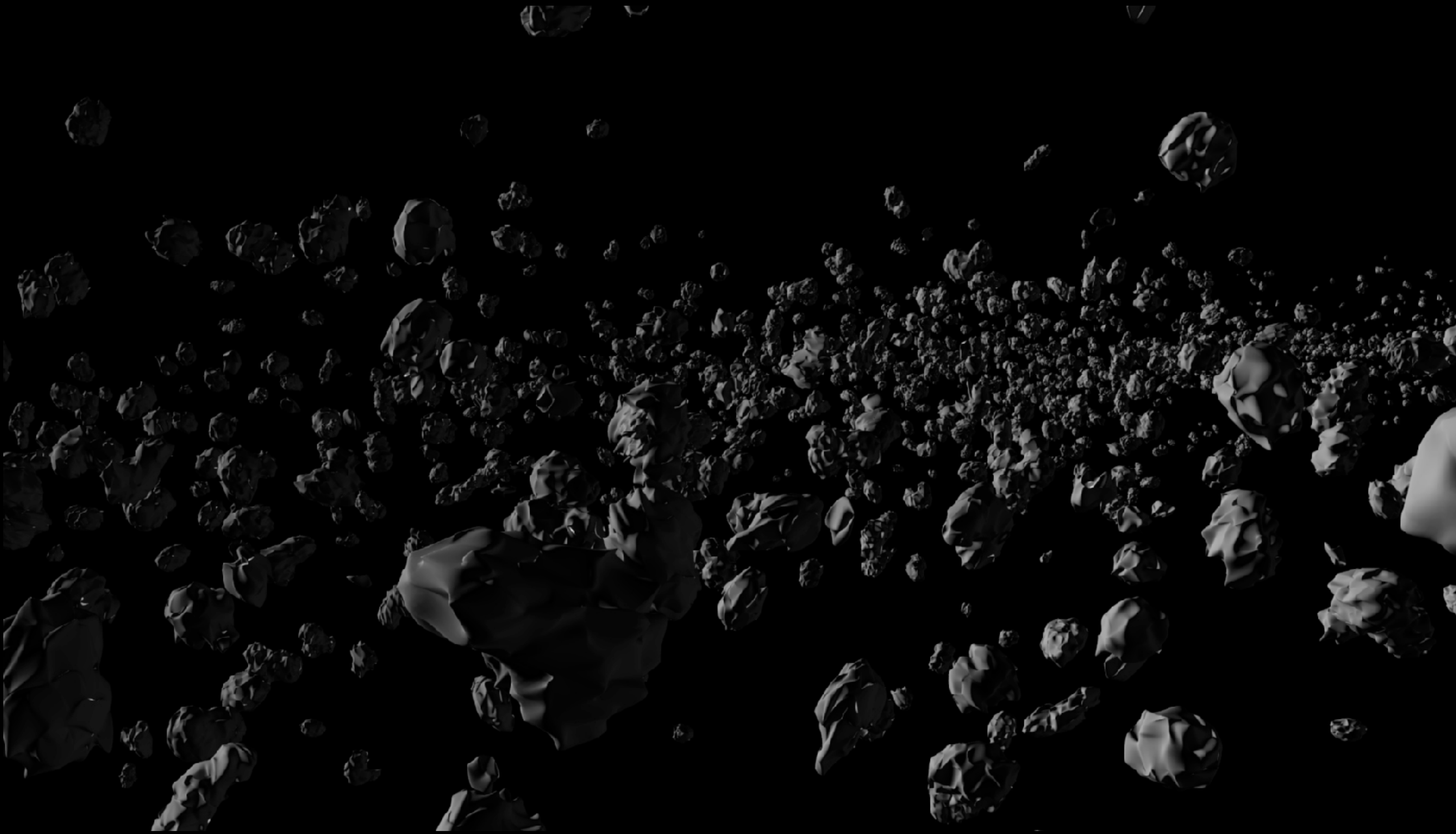
In the Asteroid Belt

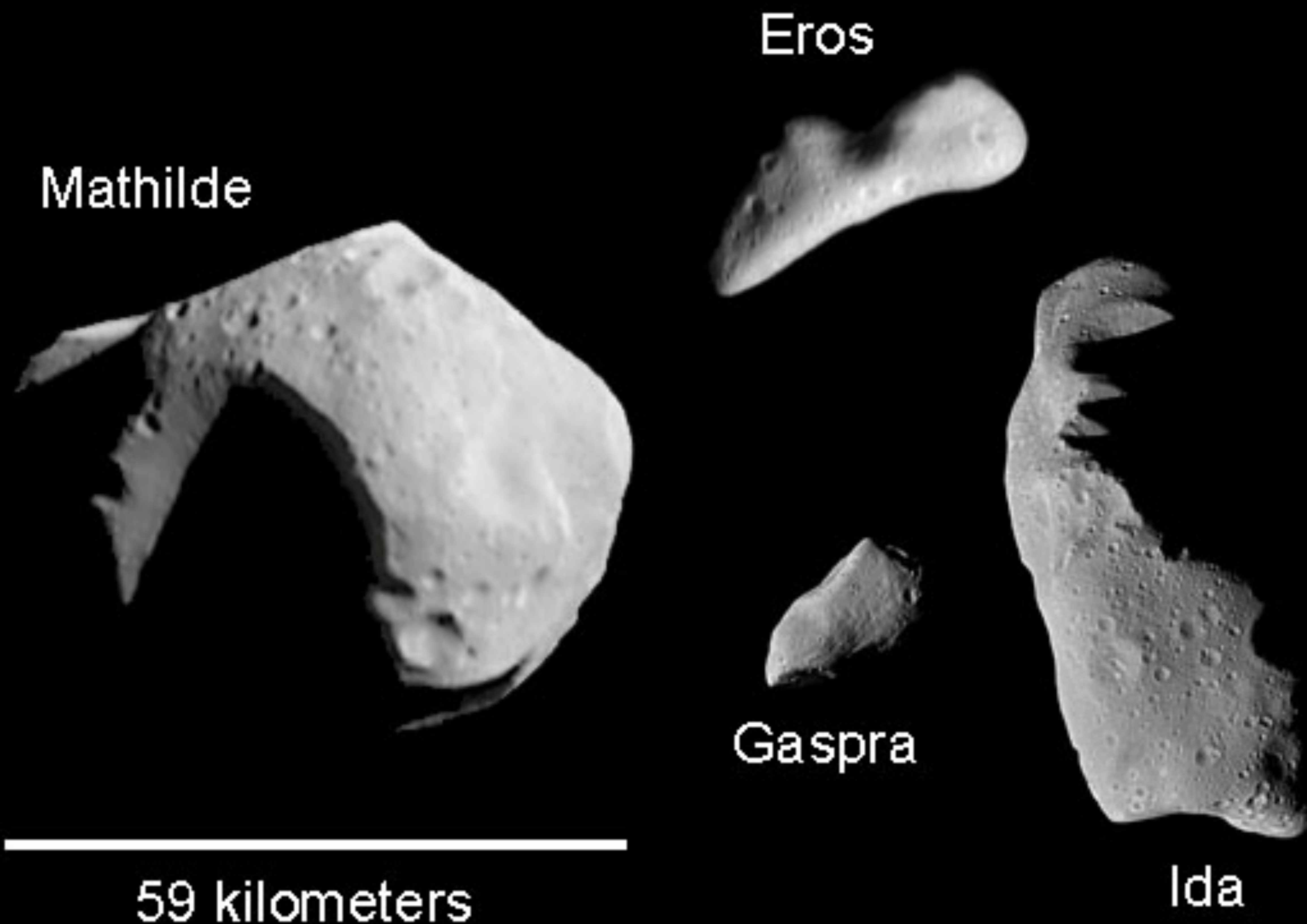


It is much more empty than this!

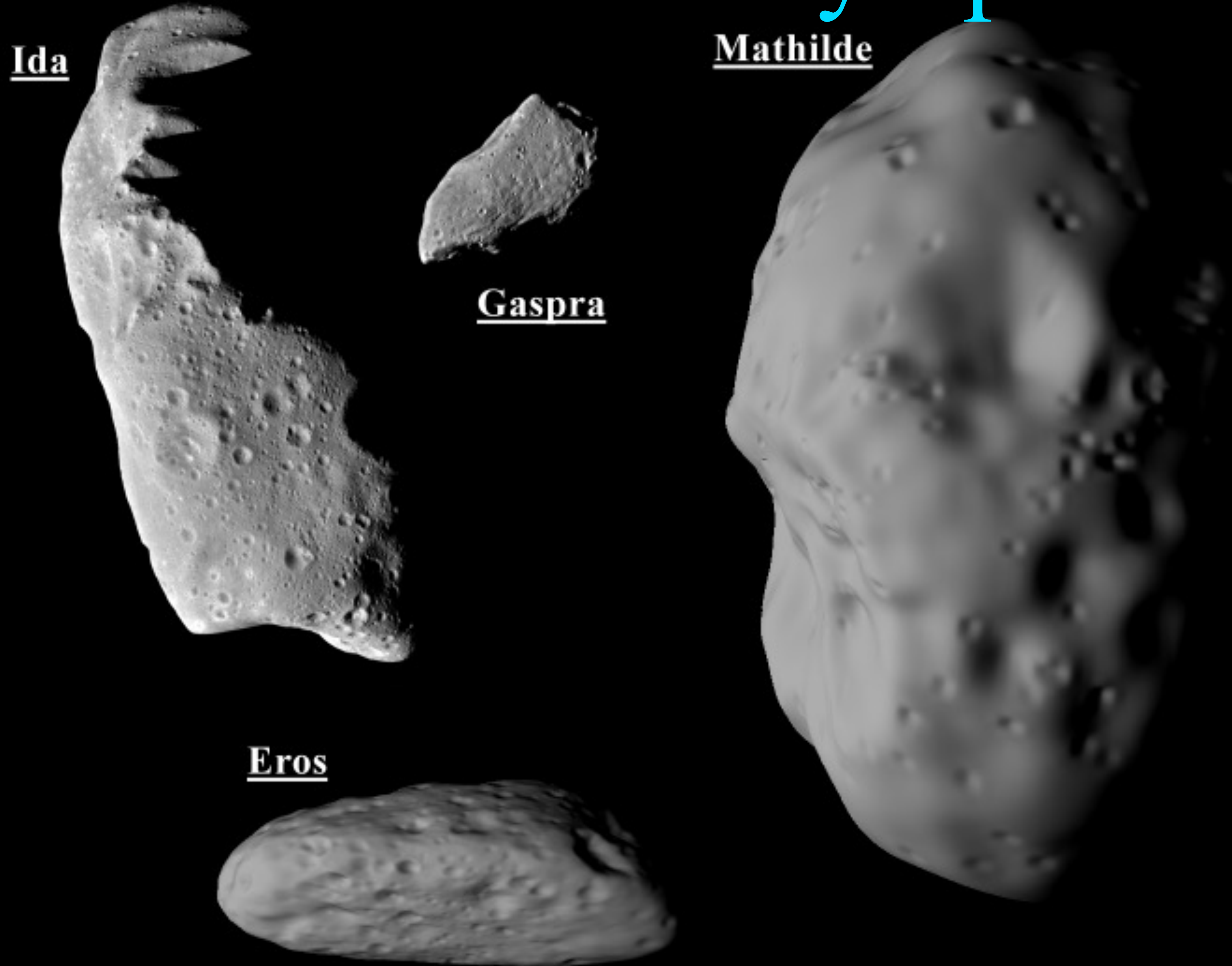
In the Asteroid Belt



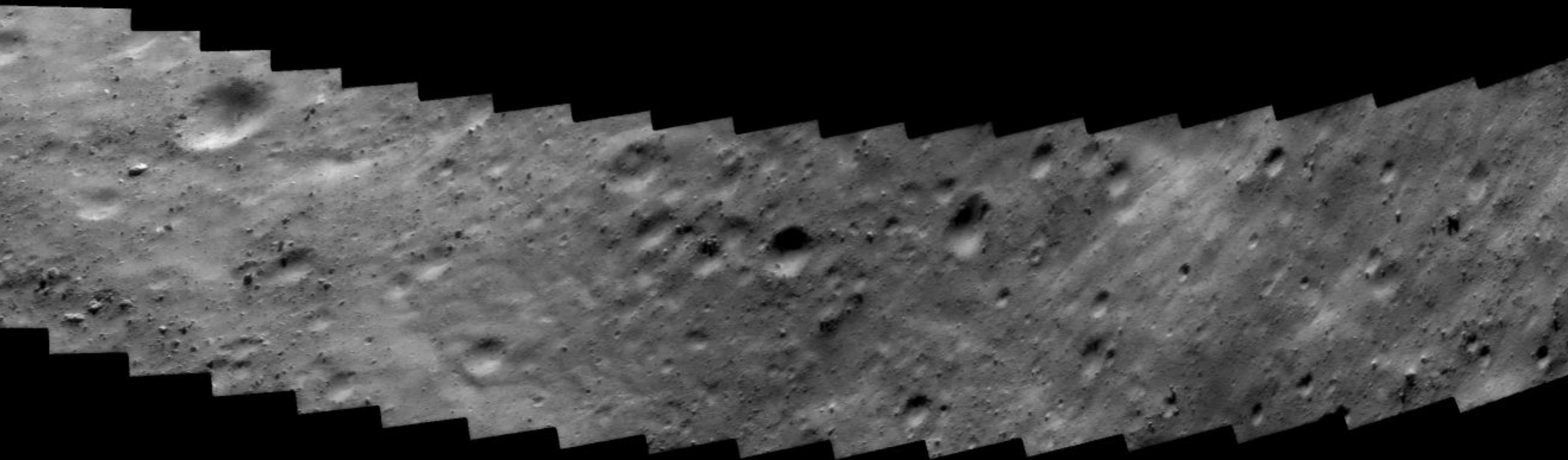
Asteroids visited by Spacecraft



Asteroids visited by Spacecraft



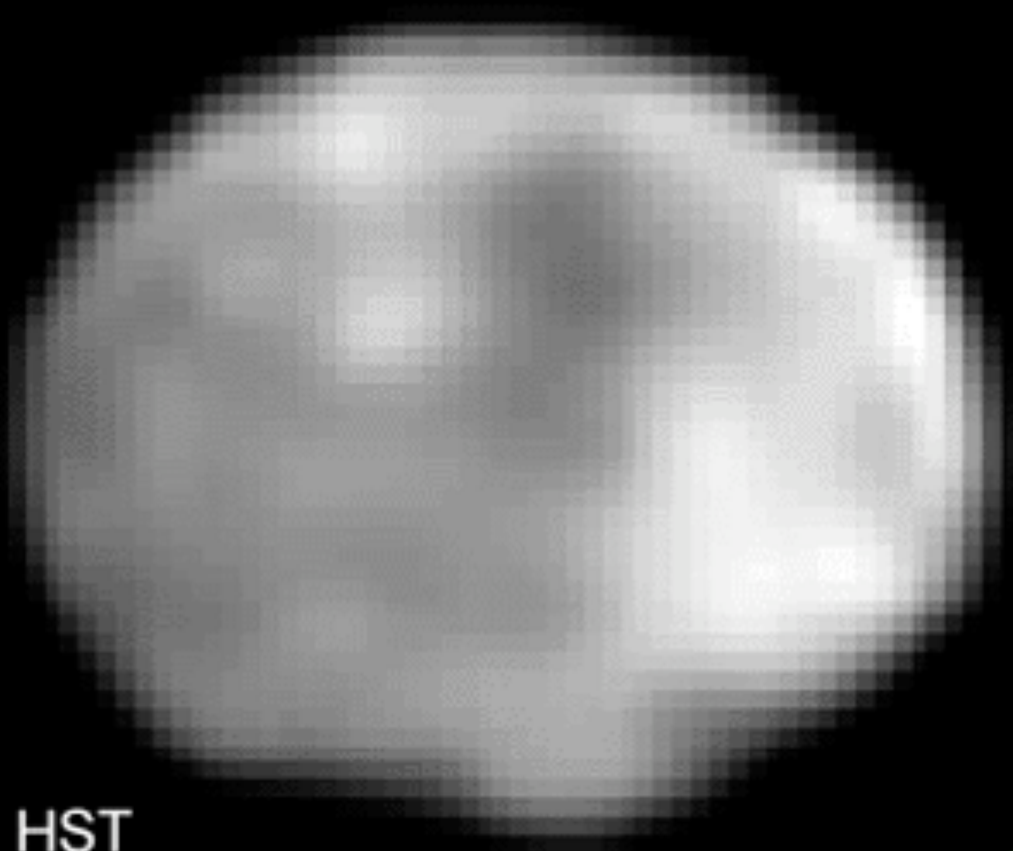
Eros

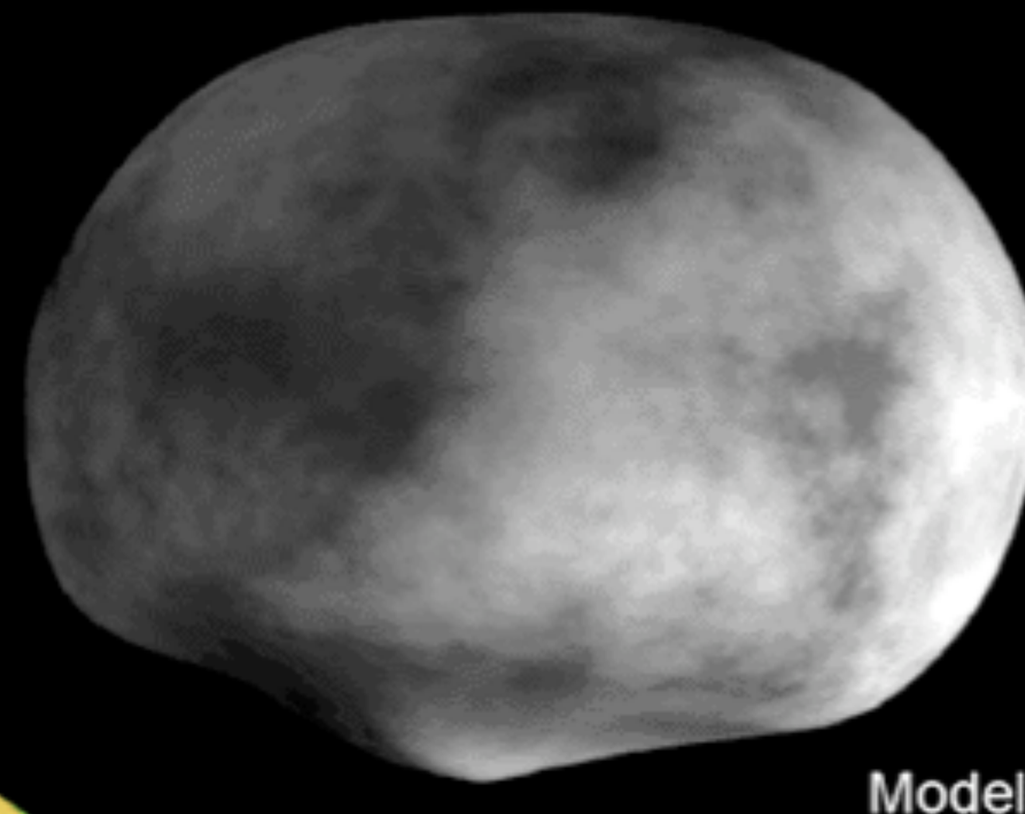


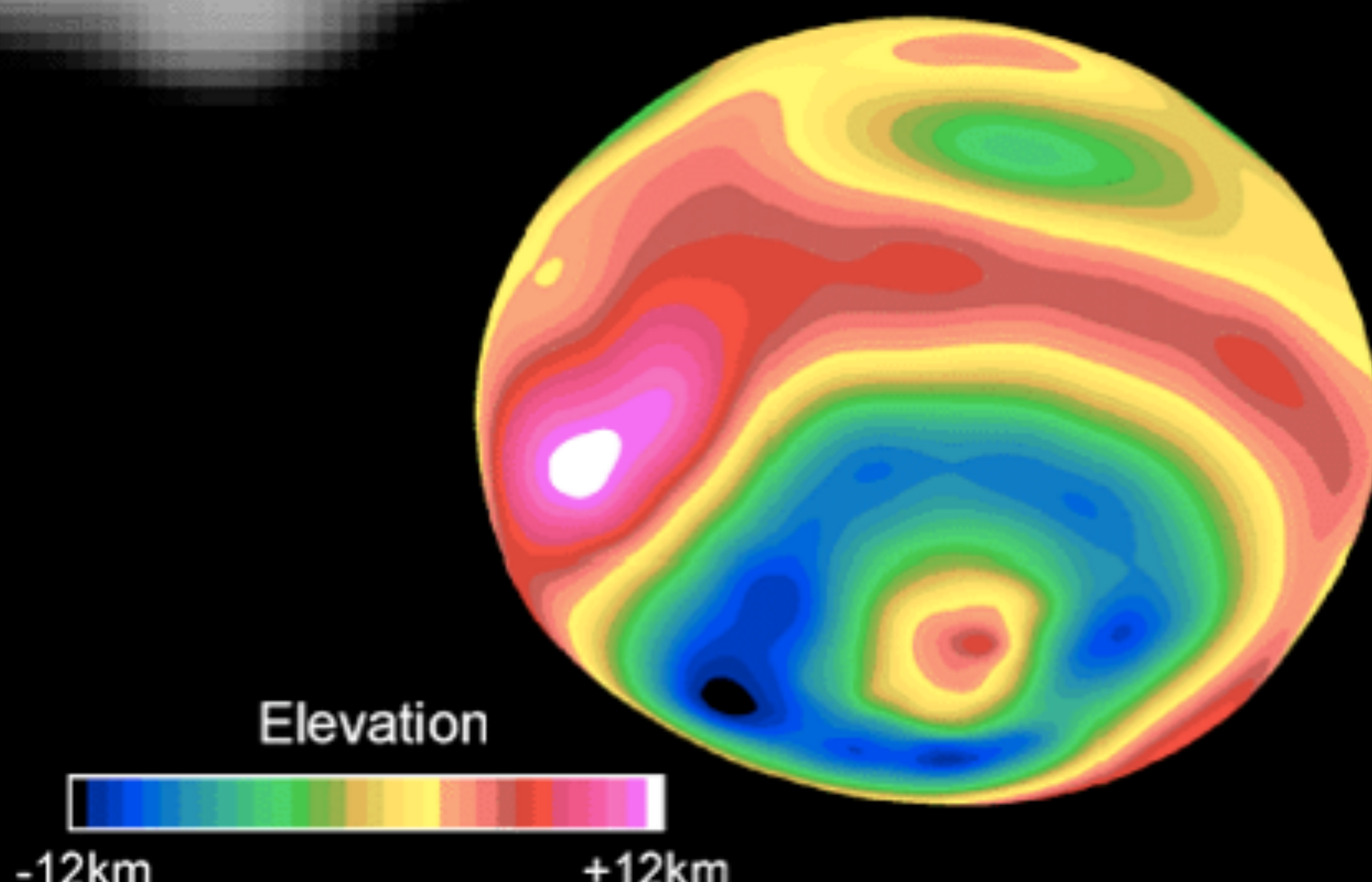
Asteroids visited by Spacecraft

Itokawa

Asteroid Vesta



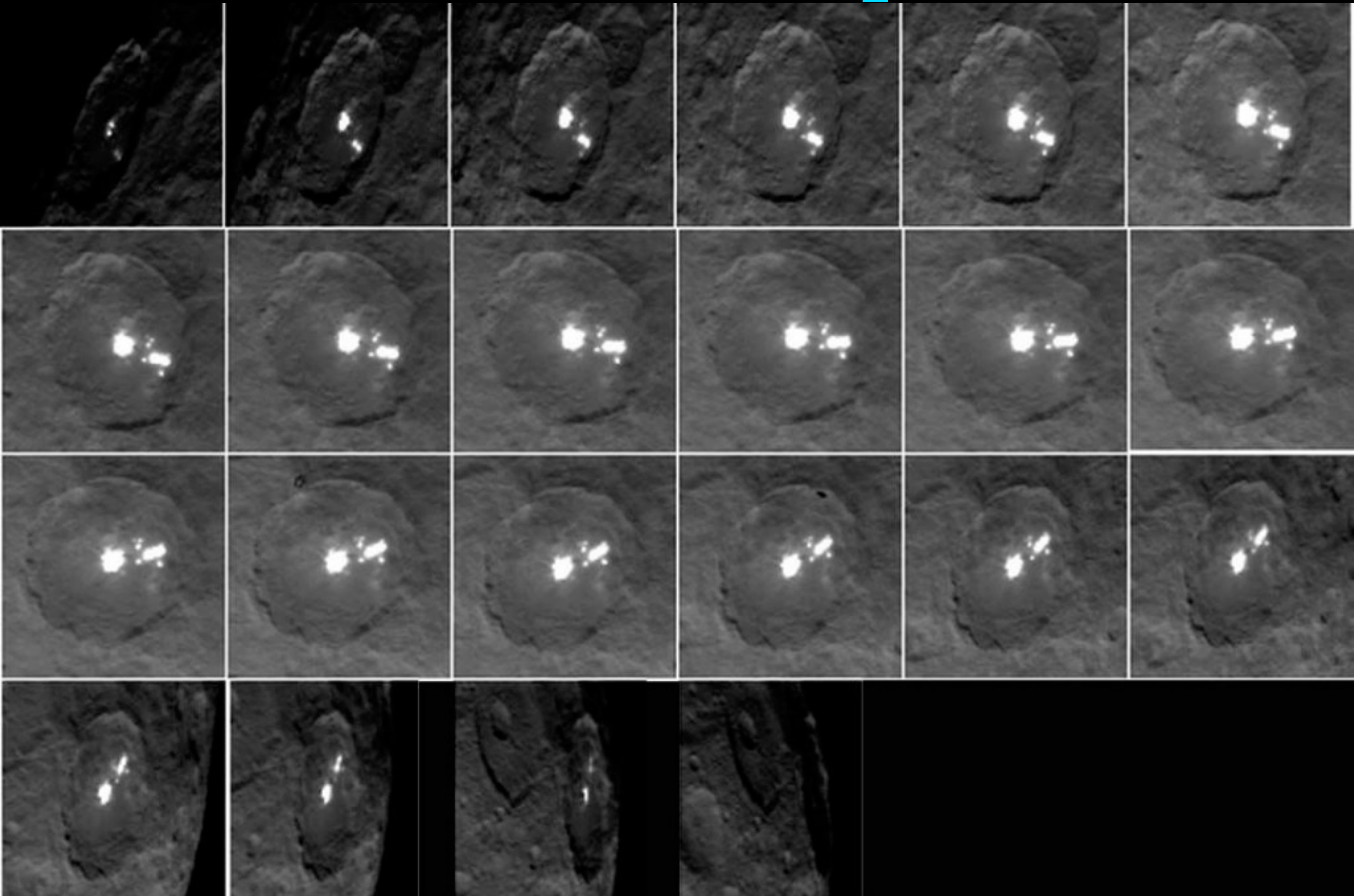




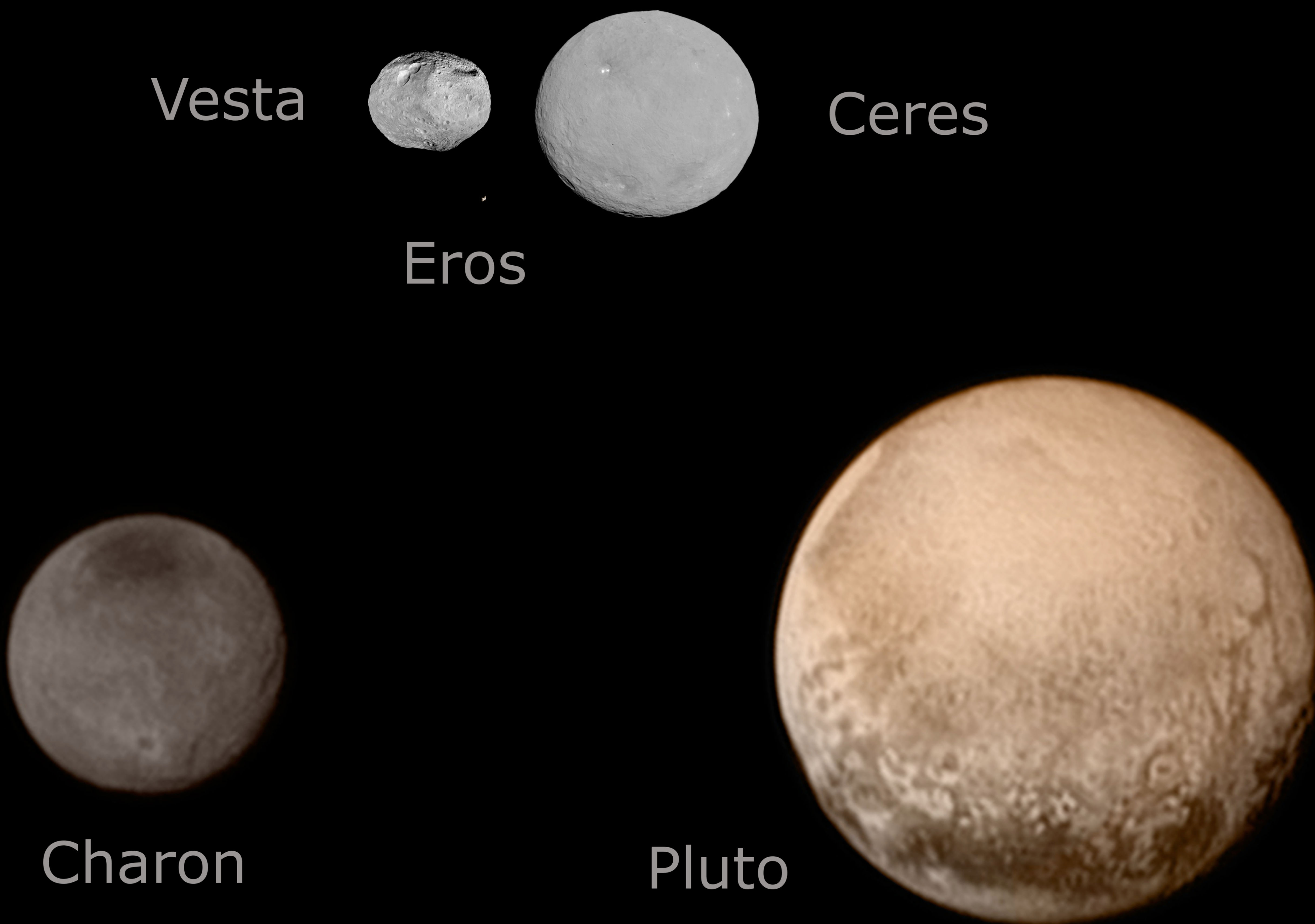
Observations and Model

Ceres, Vesta, Eros

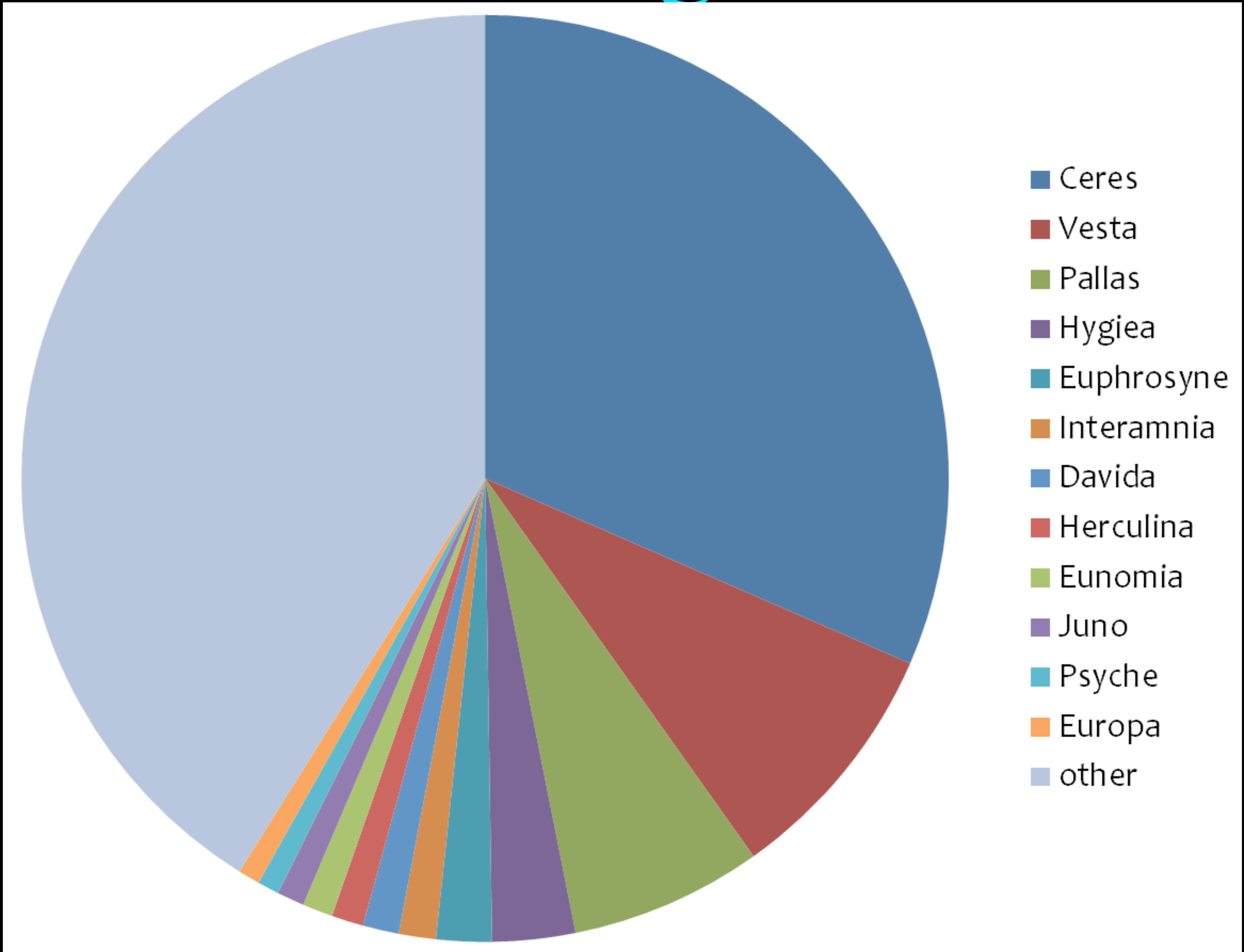
Ceres: Salt Deposits



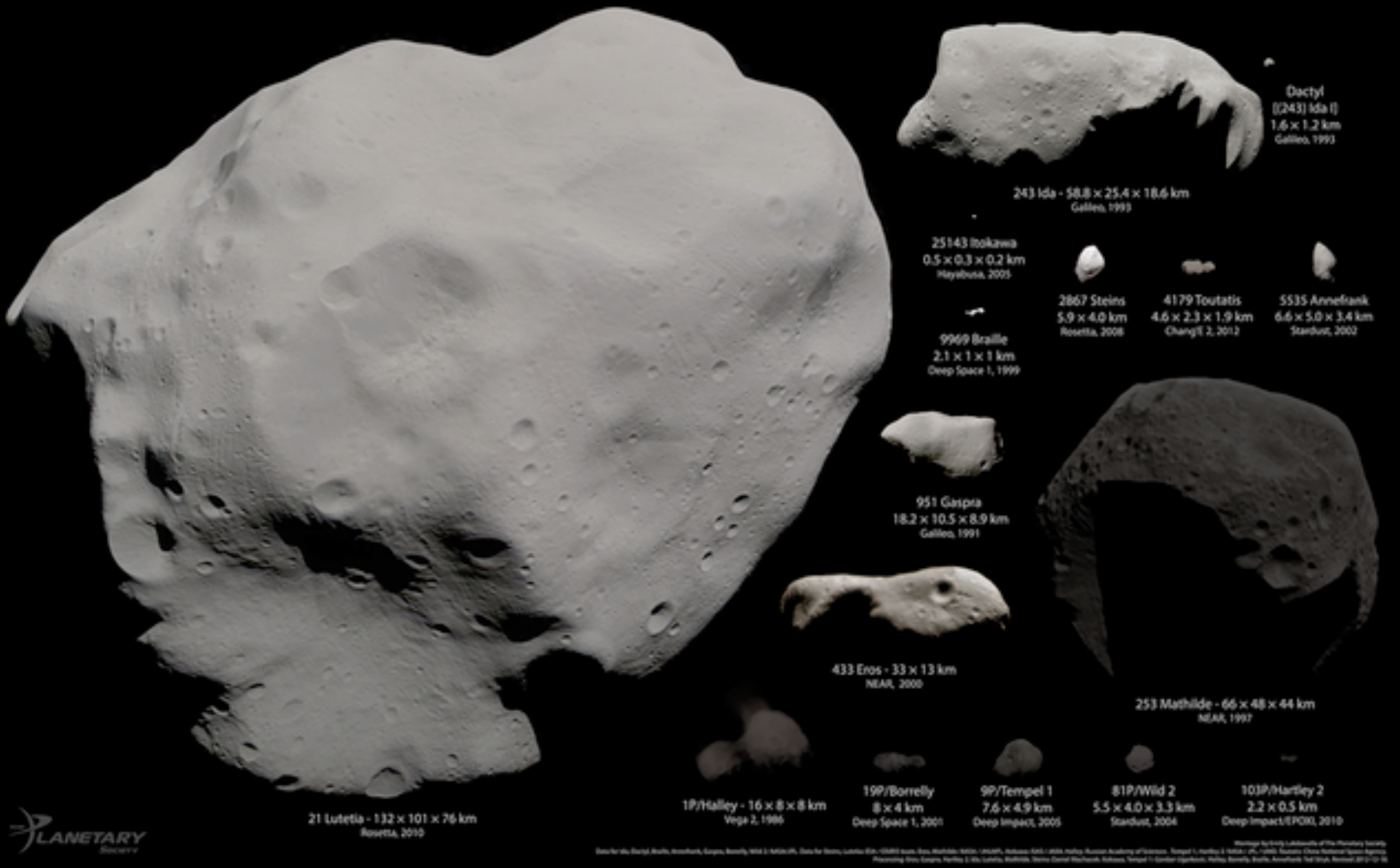
The Largest Asteroids



Mass of the Largest Asteroids



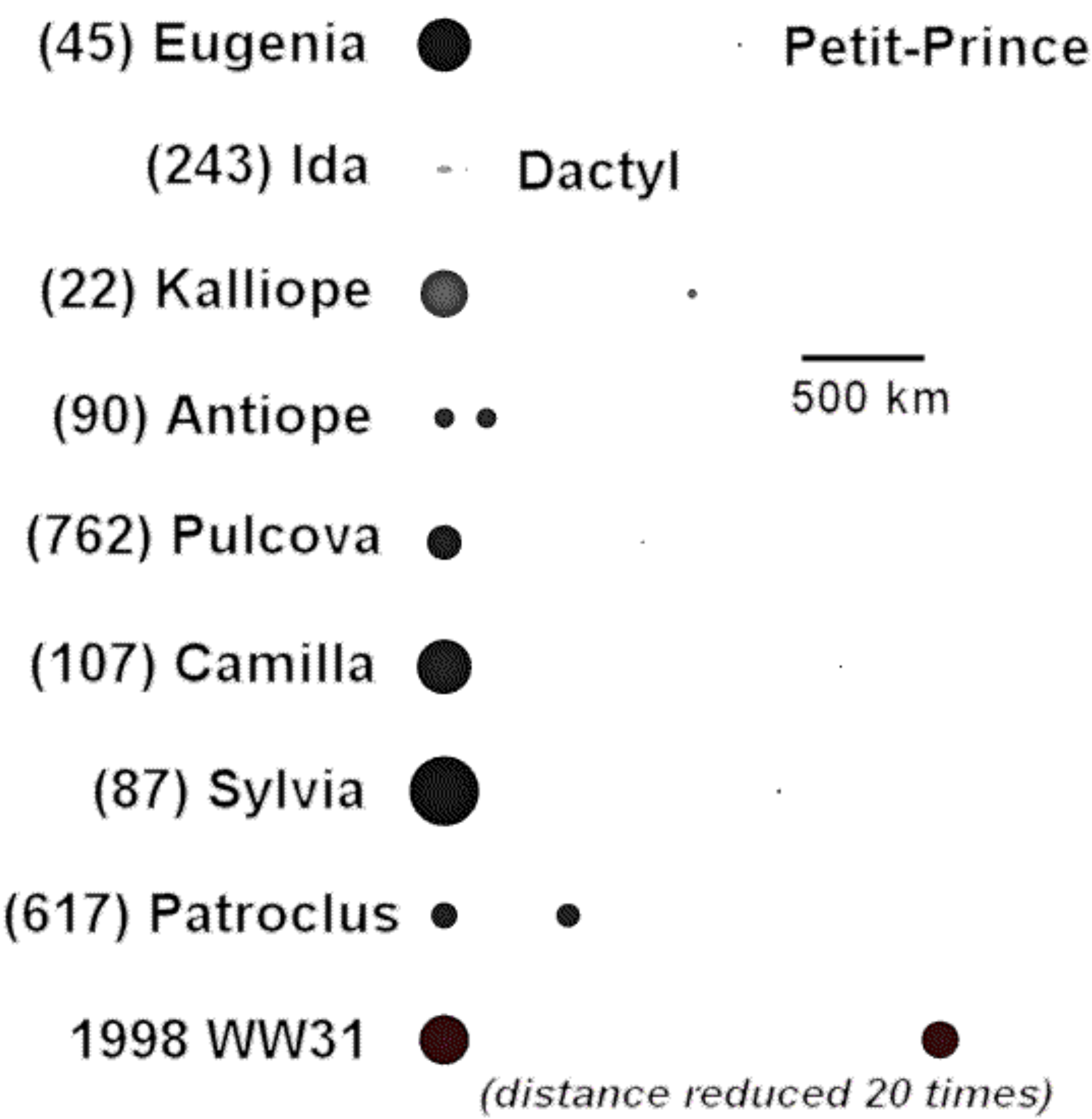
Asteroids and Comets



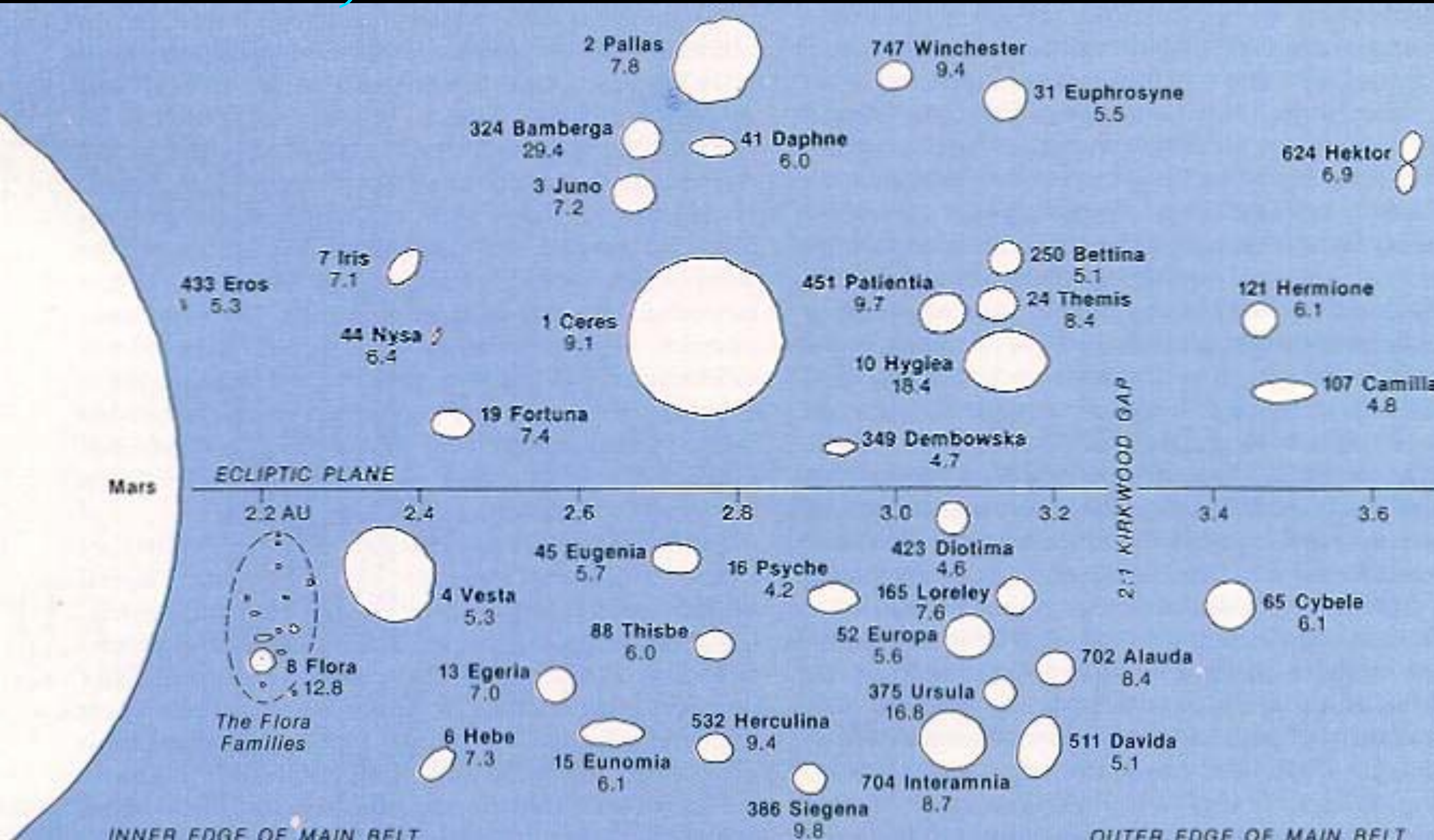
Ida and Dactyl

Binary Asteroids

Lots of asteroids have satellites!



Asteroids: Sizes, Shapes Orbits, and Rotation Periods



Gaps in the Asteroid Belt