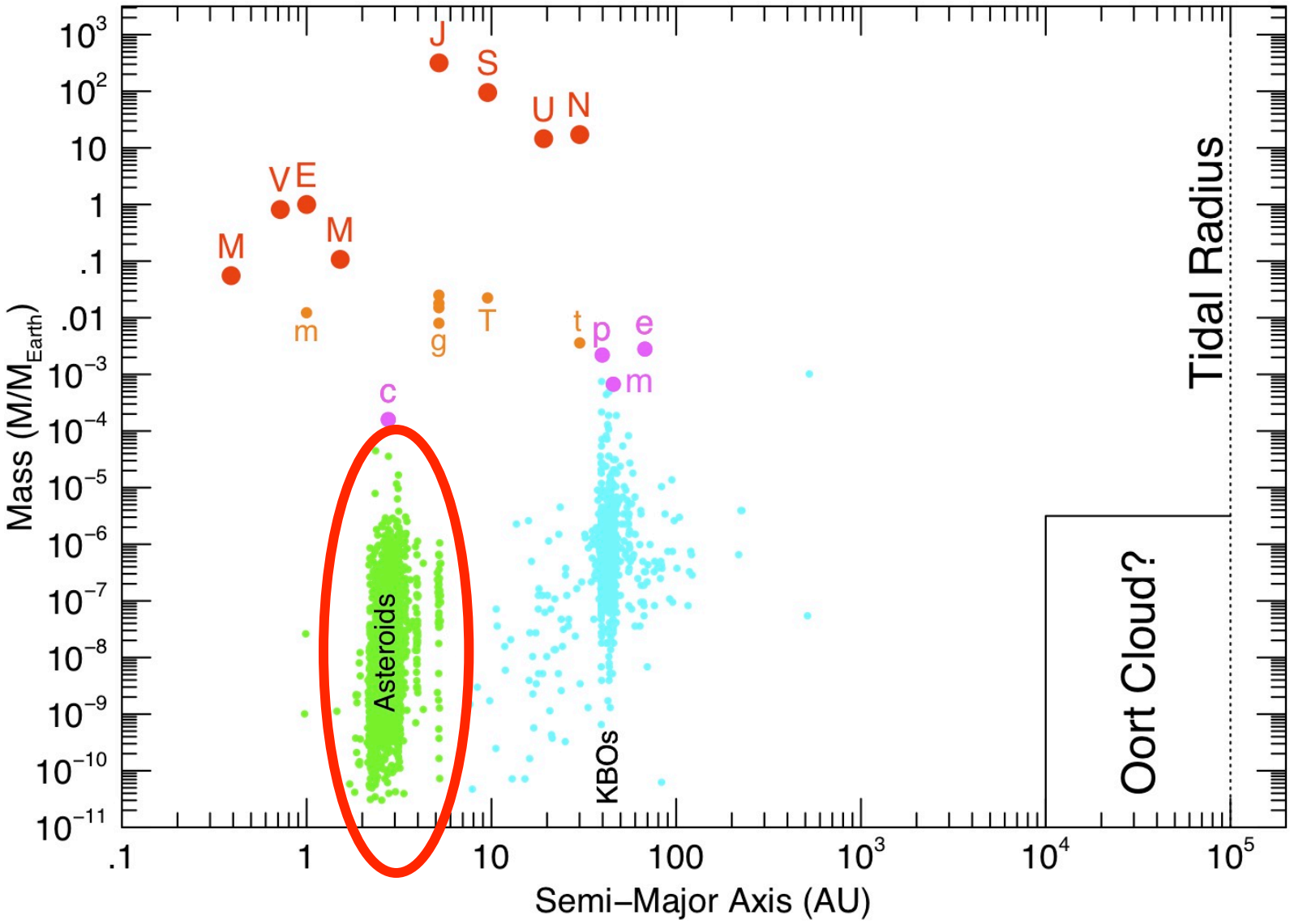
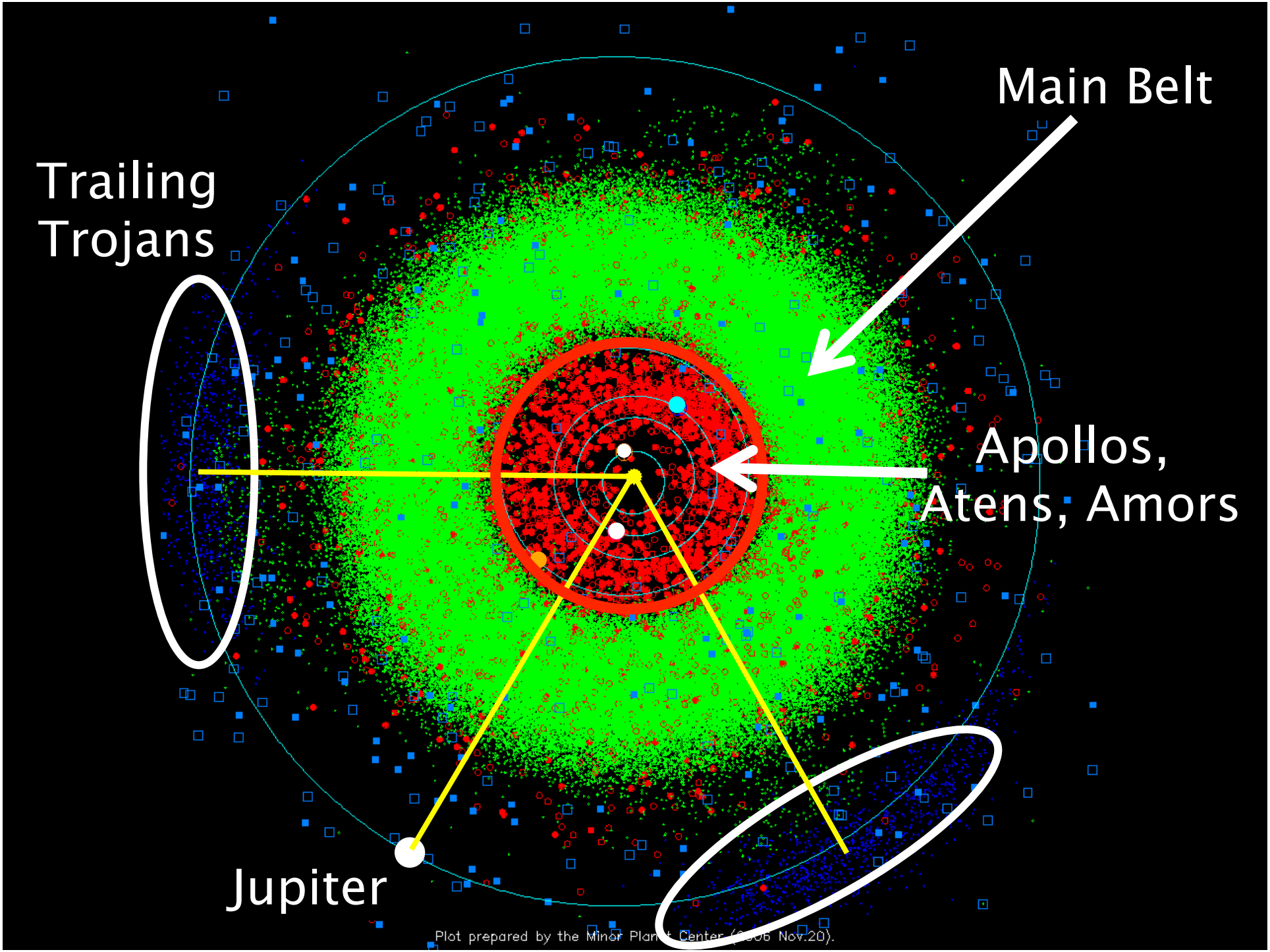
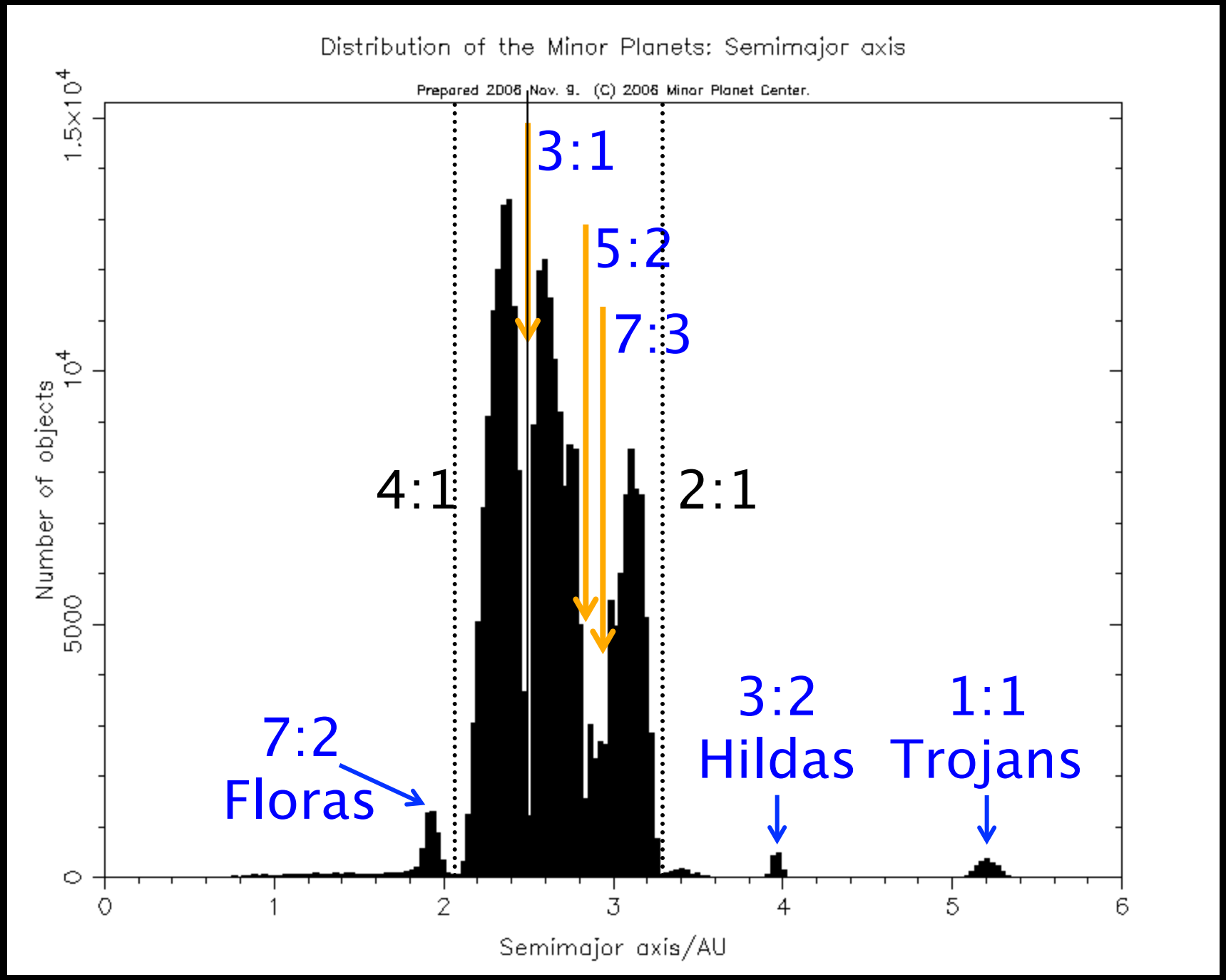

Mass (M/M_Earth)
Semi–Major Axis (AU)
J
S
U
N
V
E
M
M
m
g
T
t
p
e
m
c
Asteroids
KBOs
Tidal Radius
Oort Cloud?

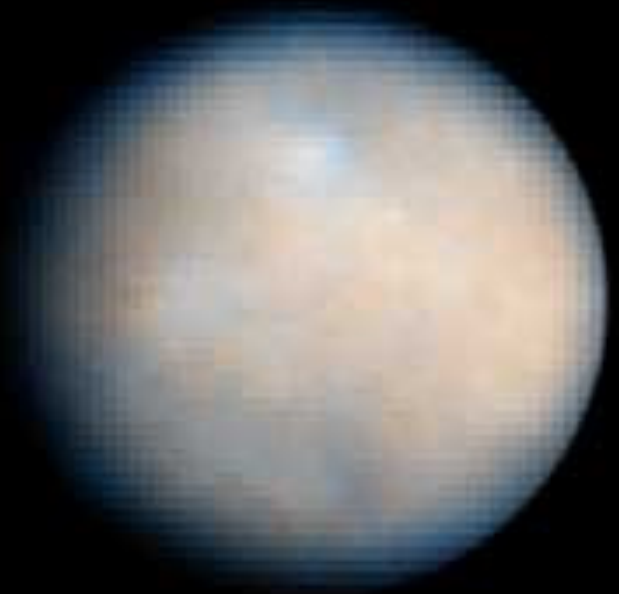

Main Belt
Trailing Trojans
Apollos, Atens, Amors
Jupiter
Plot prepared by the Minor Planet Center (2006 Nov.20).


Distribution of the Minor Planets: Semimajor axis
Prepared 2006 Nov. 9. (C) 2006 Minor Planet Center.
Number of objects
1.5×10^4
10^4
5000
0
3:1
5:2
7:3
4:1
2:1
7:2
Floras
3:2
Hildas
1:1
Trojans
0
1
2
3
4
5
6
Semimajor axis/AU

Some Named Asteroids

1 Ceres
2 Pallas
3 Juno
4 Vesta
5 Astrea
439 Ohio
1814 Bach
1815 Beethoven
1818 Brahms
4147 Lennon
4148 McCartney
4149 Harrison
4150 Starr
4305 Clapton
4442 Garcia
6433 Enya
10185 Gaudi
110393 Rammstein

Sizes of Asteroids

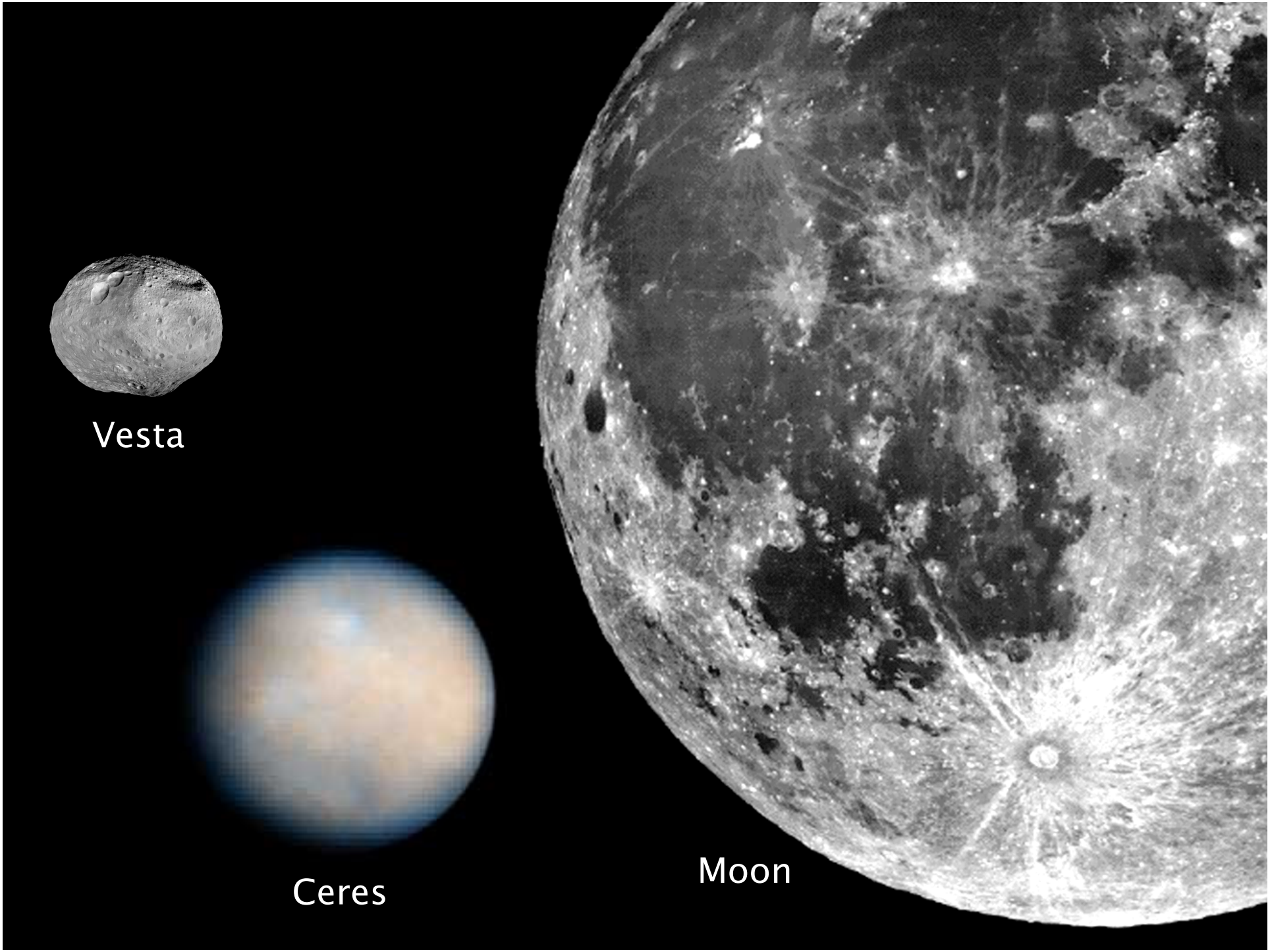


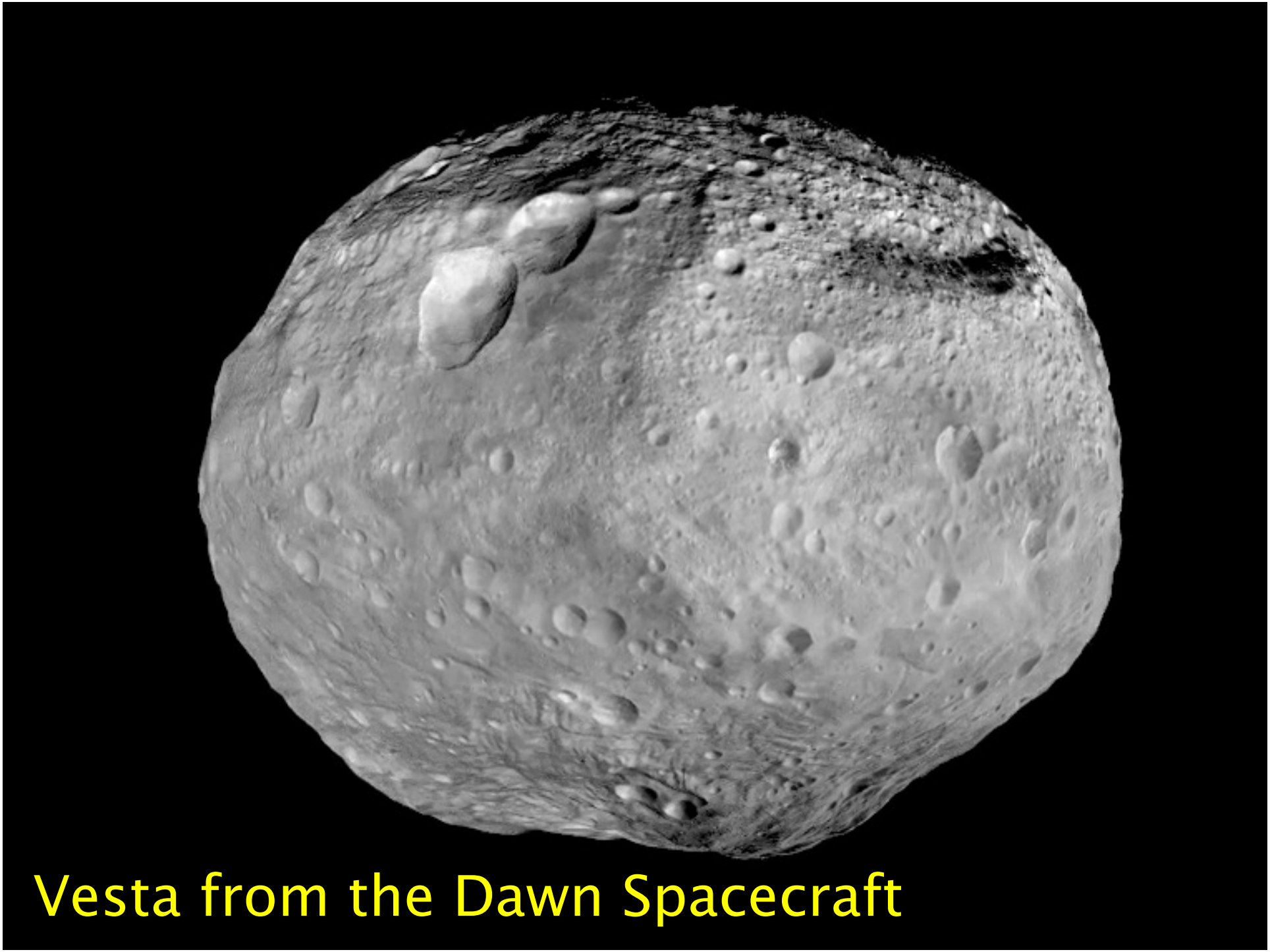
Largest asteroid is Ceres:

- 914 km across
- Mass of 0.0002 M_{Earth}
- Dwarf Planet

Most are much smaller:

- Only ~100 are >140 km across.
- ~1.2 Million are >1 km across.
- Total mass in asteroids is only ~0.0006 M_{Earth} enough for a small rocky body
- Half the mass is in the largest 4 asteroids.


Vesta
Ceres
Moon



Vesta from the Dawn Spacecraft

Moons of Asteroids

Ida and Dactyl

Composition

Classify asteroids by their colors

- C-type: Carbonaceous – dark in color, composed of carbonaceous materials (~75%)
- S-type: Silicaceous – reddish in color, stony or stony iron (~16%)
- M-type: Metallic – bluer than S-type & probably iron-rich

Rest are oddball types.

Monoliths or Rubble Piles?

Some asteroids are clearly solid:

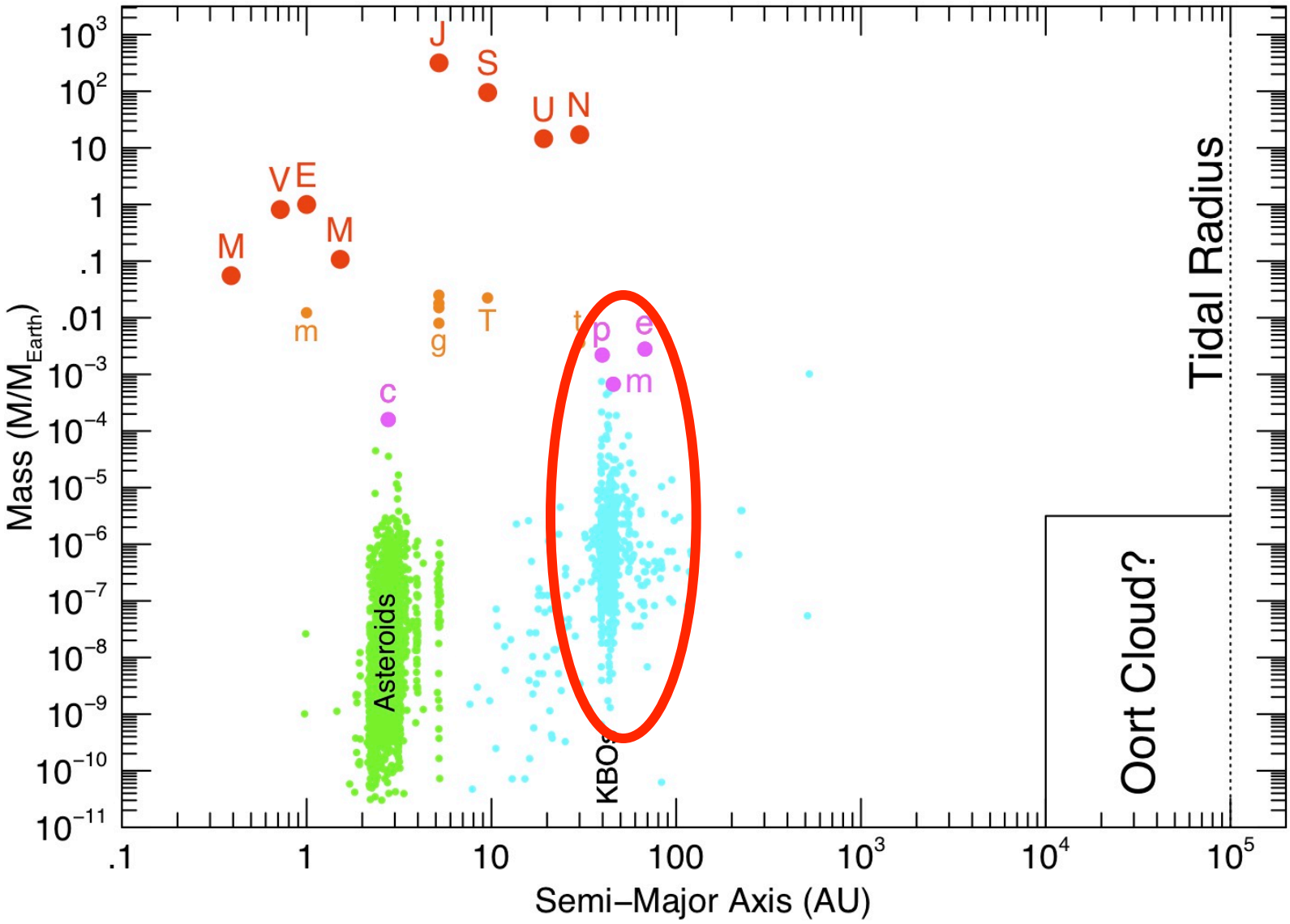
- Densities of 3–5 g/cc, like solid rock/metals
- Heavily cratered surfaces & dusty regoliths

Others appear to be rubble piles:

- Lower in density (1–2 g/cc)
- Loose aggregates of rock held together by mutual gravity
- Formerly solid but shattered by impacts?

253 Mathilda
density ~1.3 g/cc

25143 Itokawa
density ~2.3 g/cc


Mass (M/M_Earth)
Semi–Major Axis (AU)
J
S
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V
E
M
M
m
g
T
t
p
e
m
c
Asteroids
KBOs
Tidal Radius
Oort Cloud?

Trans-Neptunian Objects

Class of icy bodies that orbit beyond Neptune:

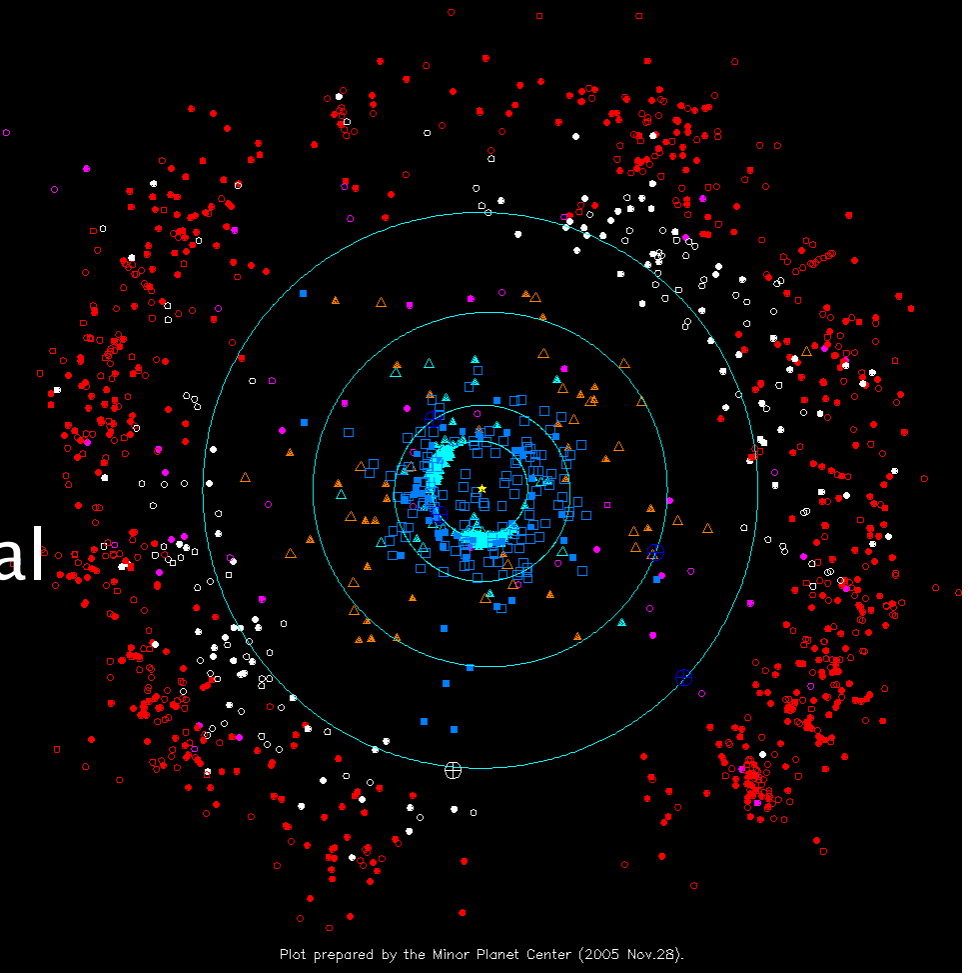
- Range from 30 AU outward

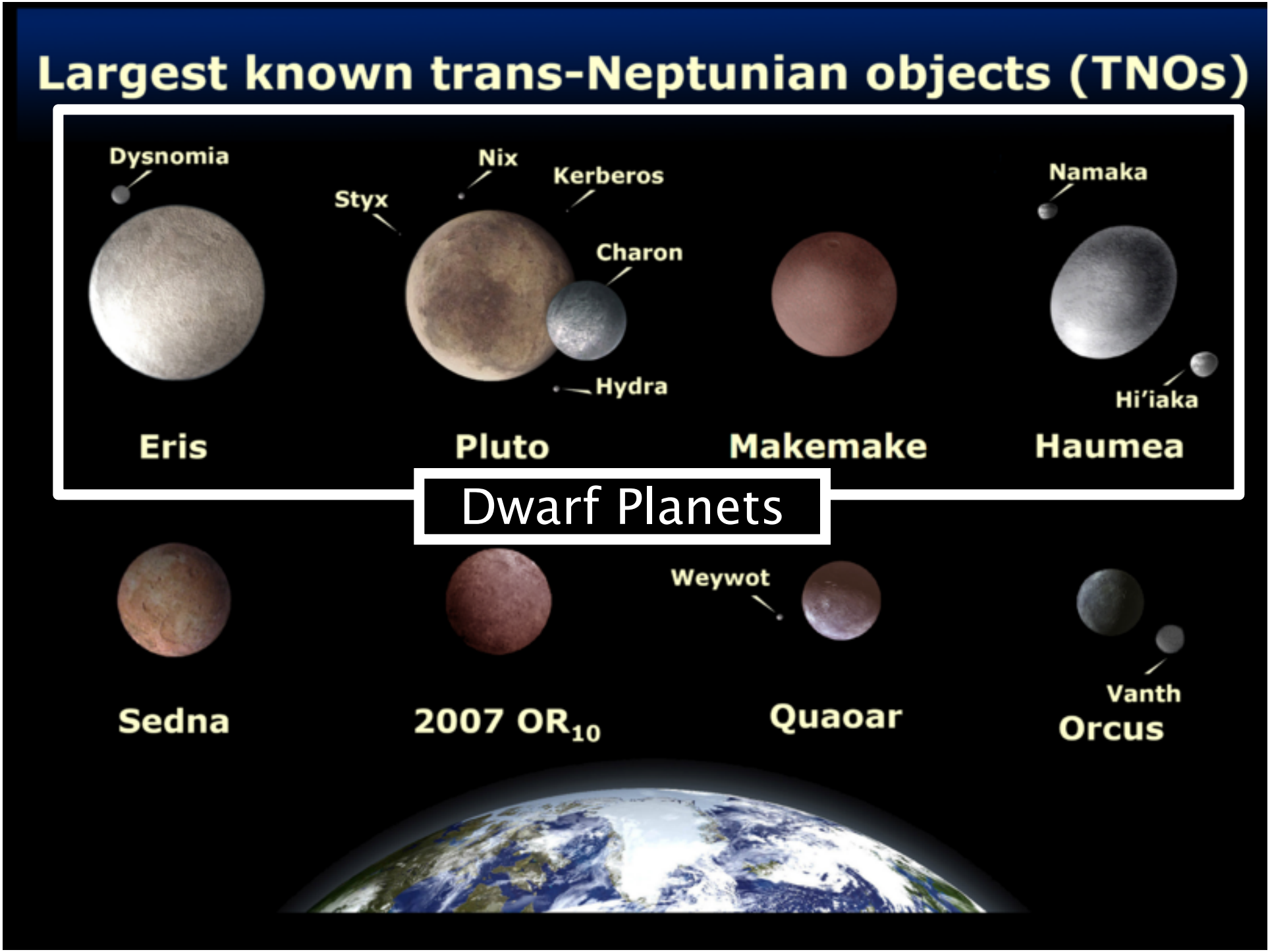
Dwarf planets:

- Pluto, Eris, Haumea, Makemake

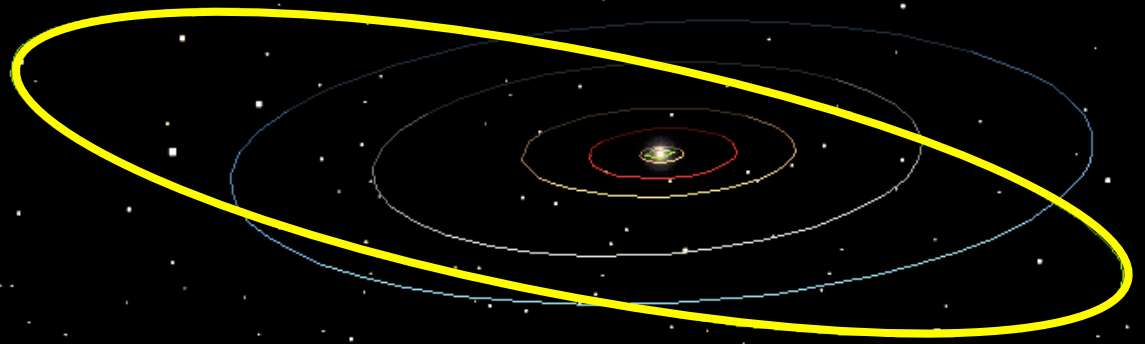
Divided into various orbital classes:

- Kuiper Belt Objects
- Plutinos ("little Plutos")
- Scattered Disk Objects



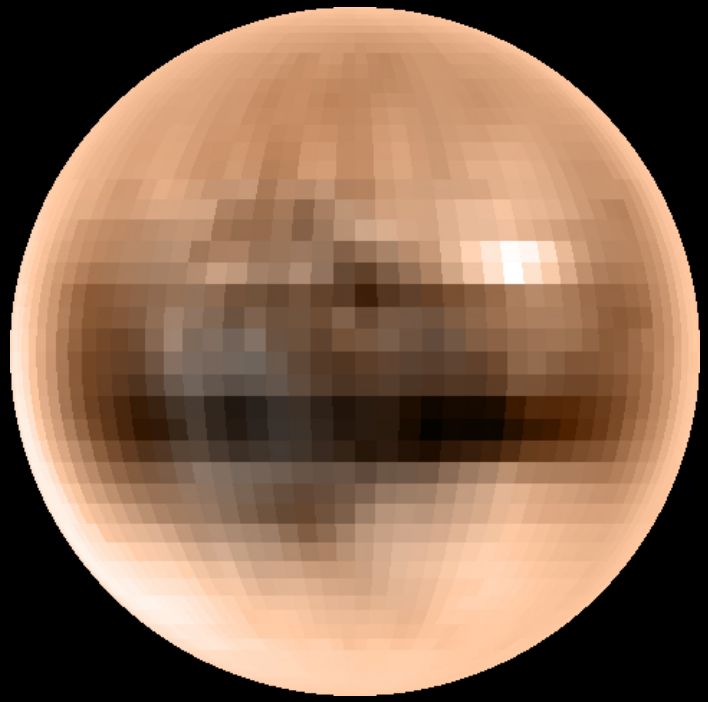

Largest known trans-Neptunian objects (TNOs)
Dysnomia
Nix
Kerberos
Styx
Namaka
Charon
Hydra
Hi'iaka
Eris
Pluto
Makemake
Haumea
Dwarf Planets
Weywot
Sedna
2007 OR10
Quaoar
Vanth
Orcus

Pluto



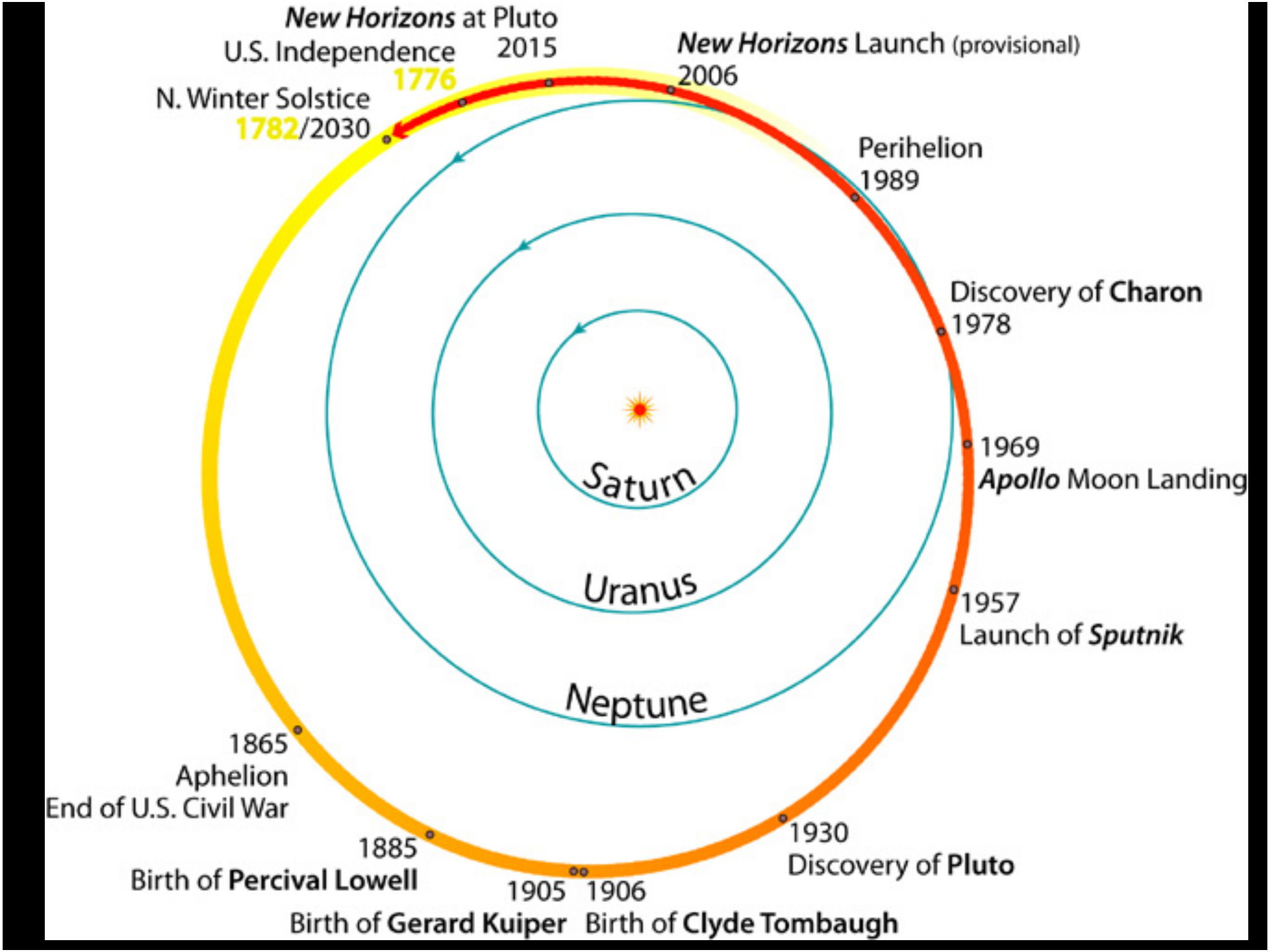
Orbit

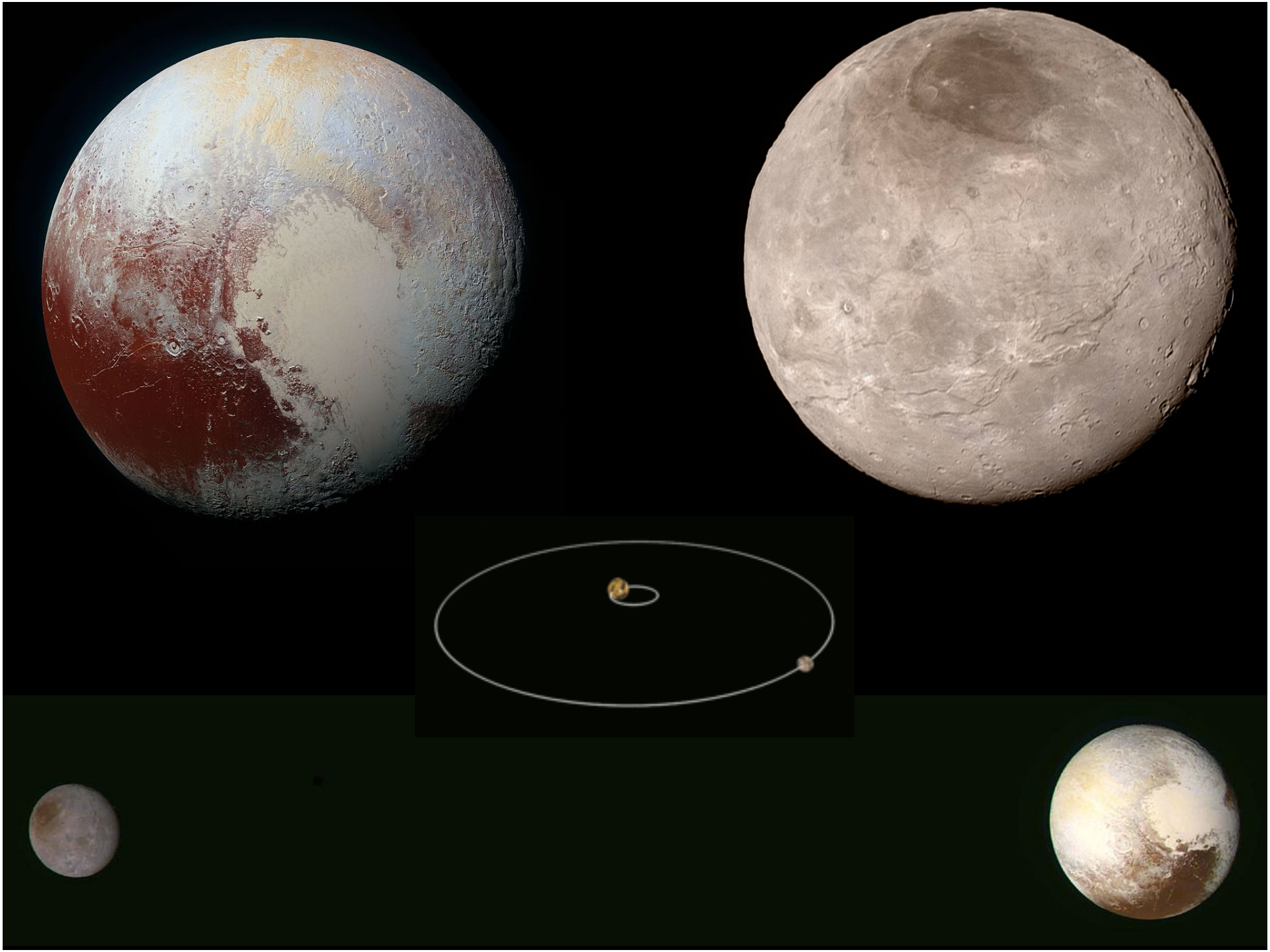
- a=39.48 AU, P=366.7 yr
- Orbit is very tilted (17°) & very elliptical (e=0.249)



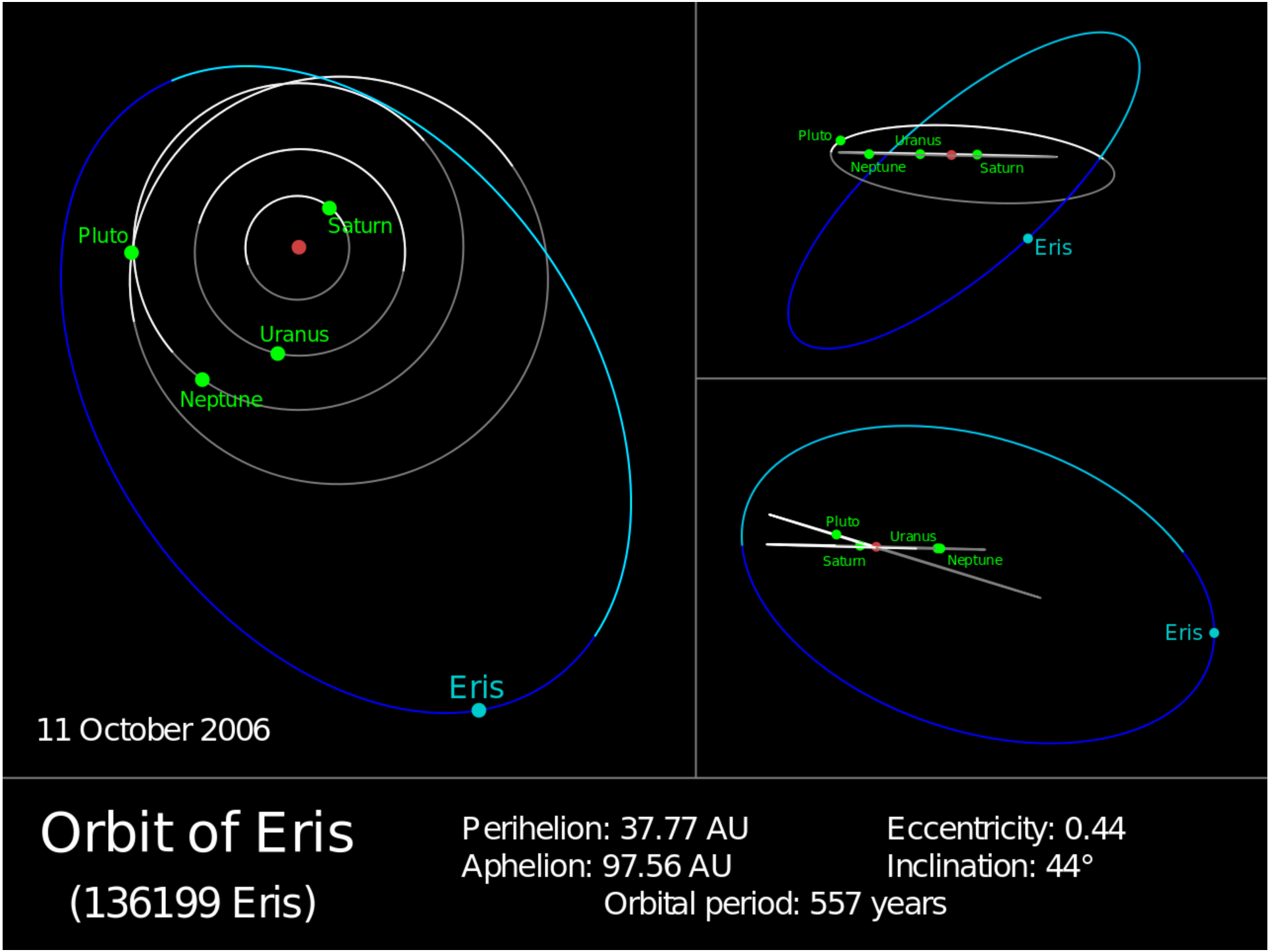
Surface

- Barely resolved even with HST
- Best resolution from eclipses


New Horizons at Pluto
2015
New Horizons Launch (provisional)
2006
U.S. Independence
1776
N. Winter Solstice
1782/2030
Perihelion
1989
Discovery of **Charon**
1978
Saturn
1969
Apollo Moon Landing
Uranus
1957
Launch of ***Sputnik***
Neptune
1865
Aphelion
End of U.S. Civil War
1885
Birth of **Percival Lowell**
1905
Birth of **Gerard Kuiper**
1906
Birth of **Clyde Tombaugh**
1930
Discovery of **Pluto**



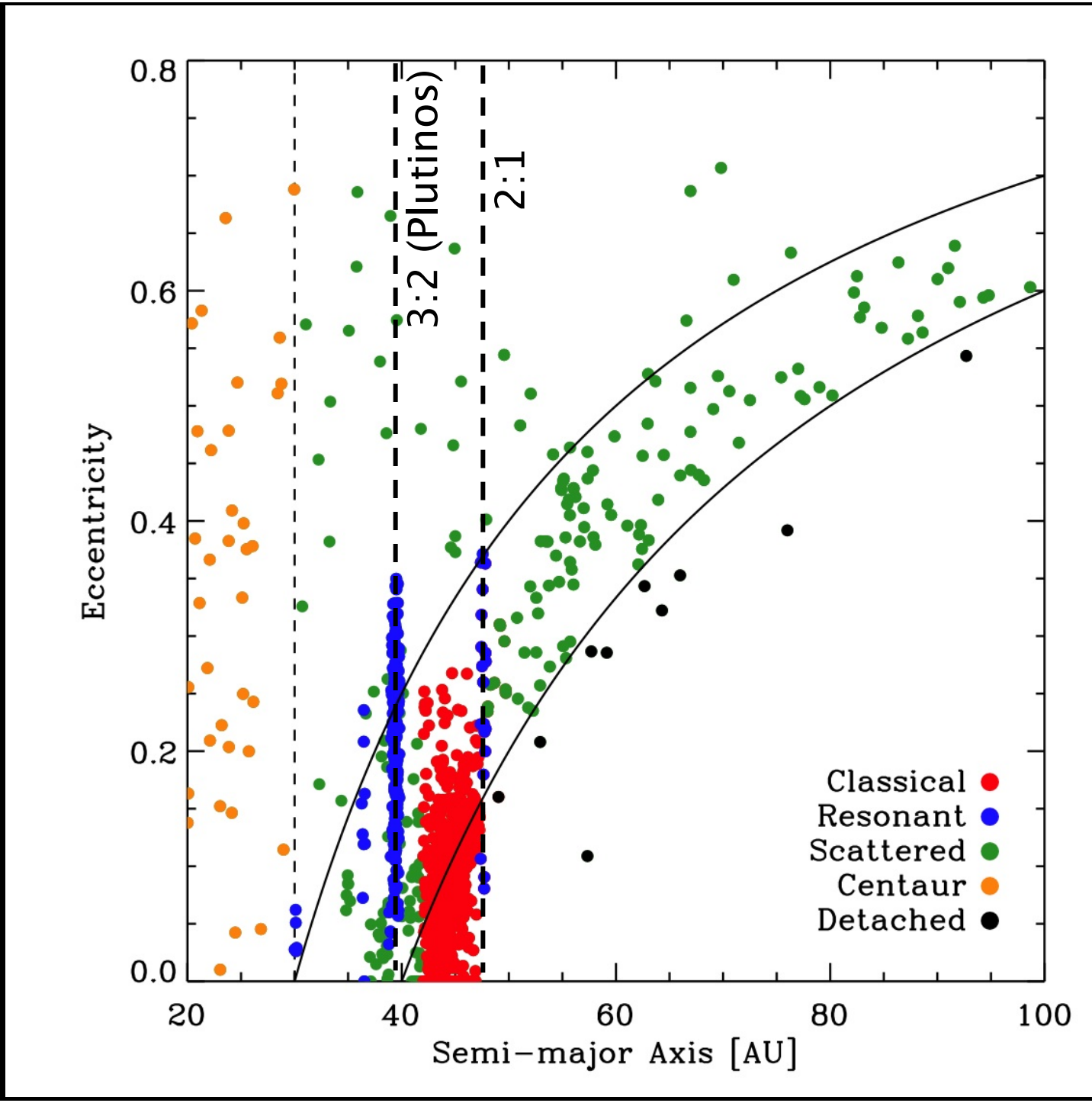
Charon and the Small Moons of Pluto

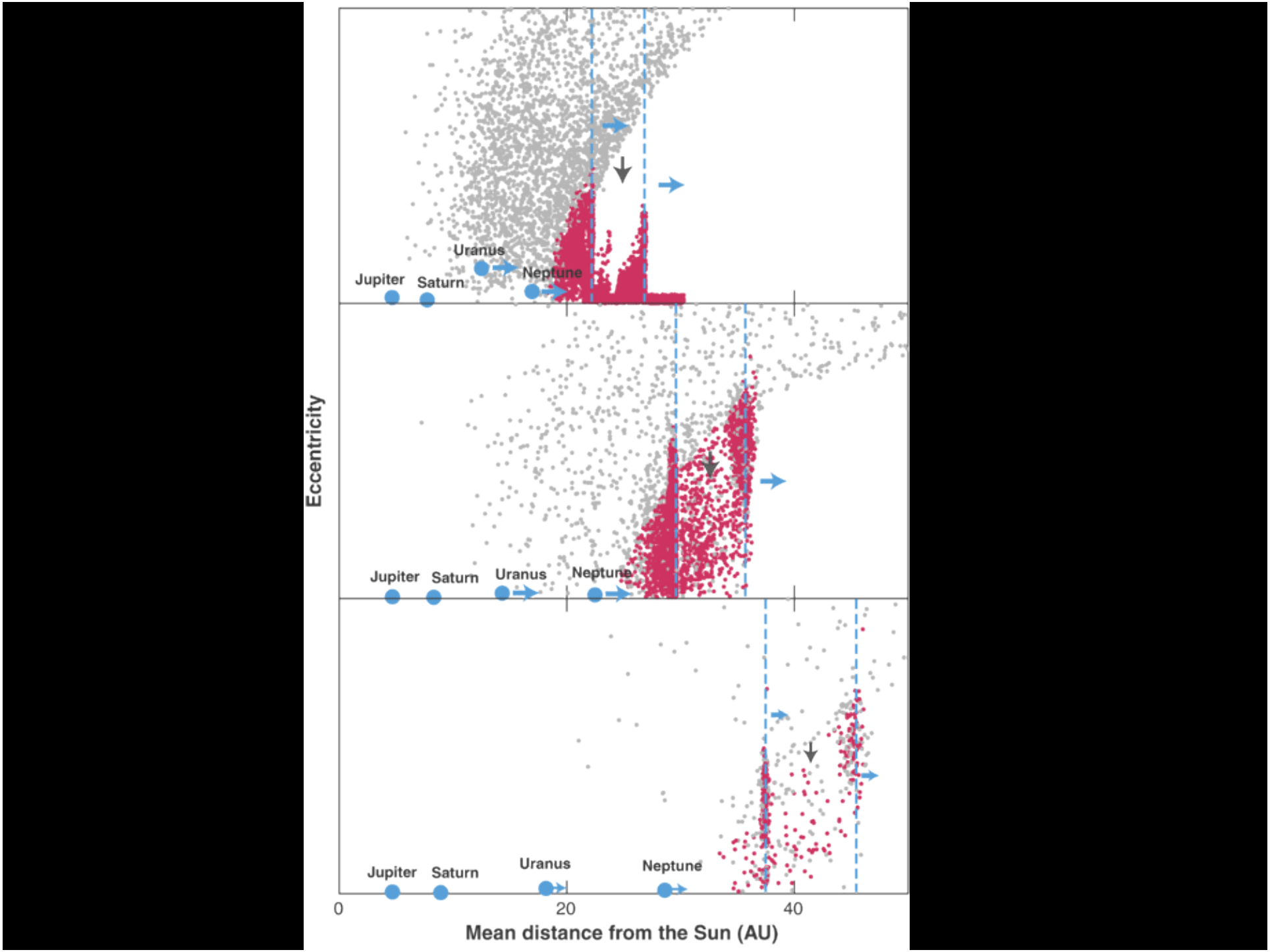


Orbit of Eris

(136199 Eris)

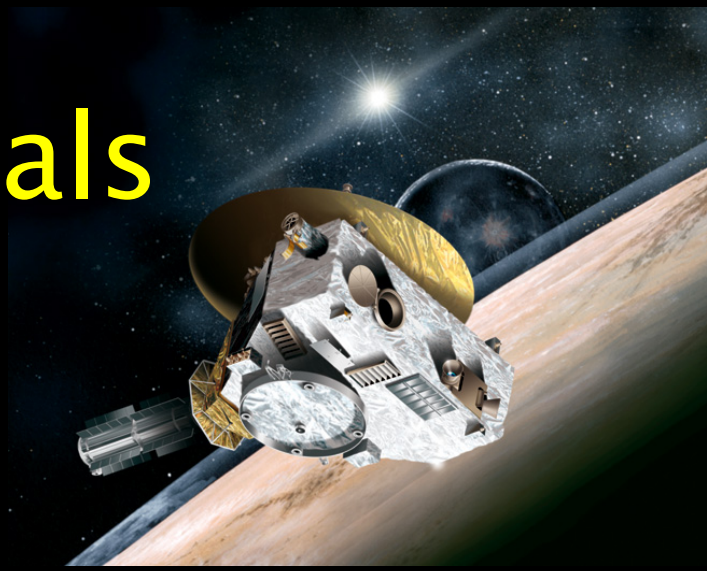
Perihelion: 37.77 AU
Aphelion: 97.56 AU
Eccentricity: 0.44
Inclination: 44°
Orbital period: 557 years


0.8
0.6
0.4
0.2
0.0
Eccentricity
20
40
60
80
100
Semi−major Axis [AU]
3:2 (Plutinos)
2:1
Classical
Resonant
Scattered
Centaur
Detached


Eccentricity
Jupiter
Saturn
Uranus
Neptune
Jupiter
Saturn
Uranus
Neptune
Jupiter
Saturn
Uranus
Neptune
0
20
40
Mean distance from the Sun (AU)

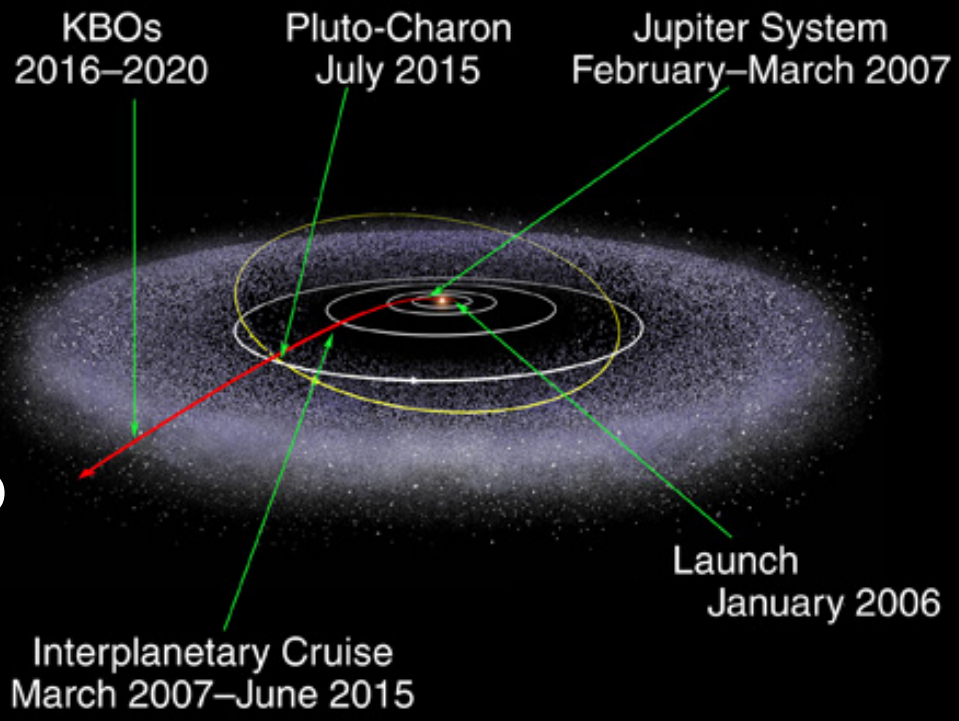
Leftover Raw Materials

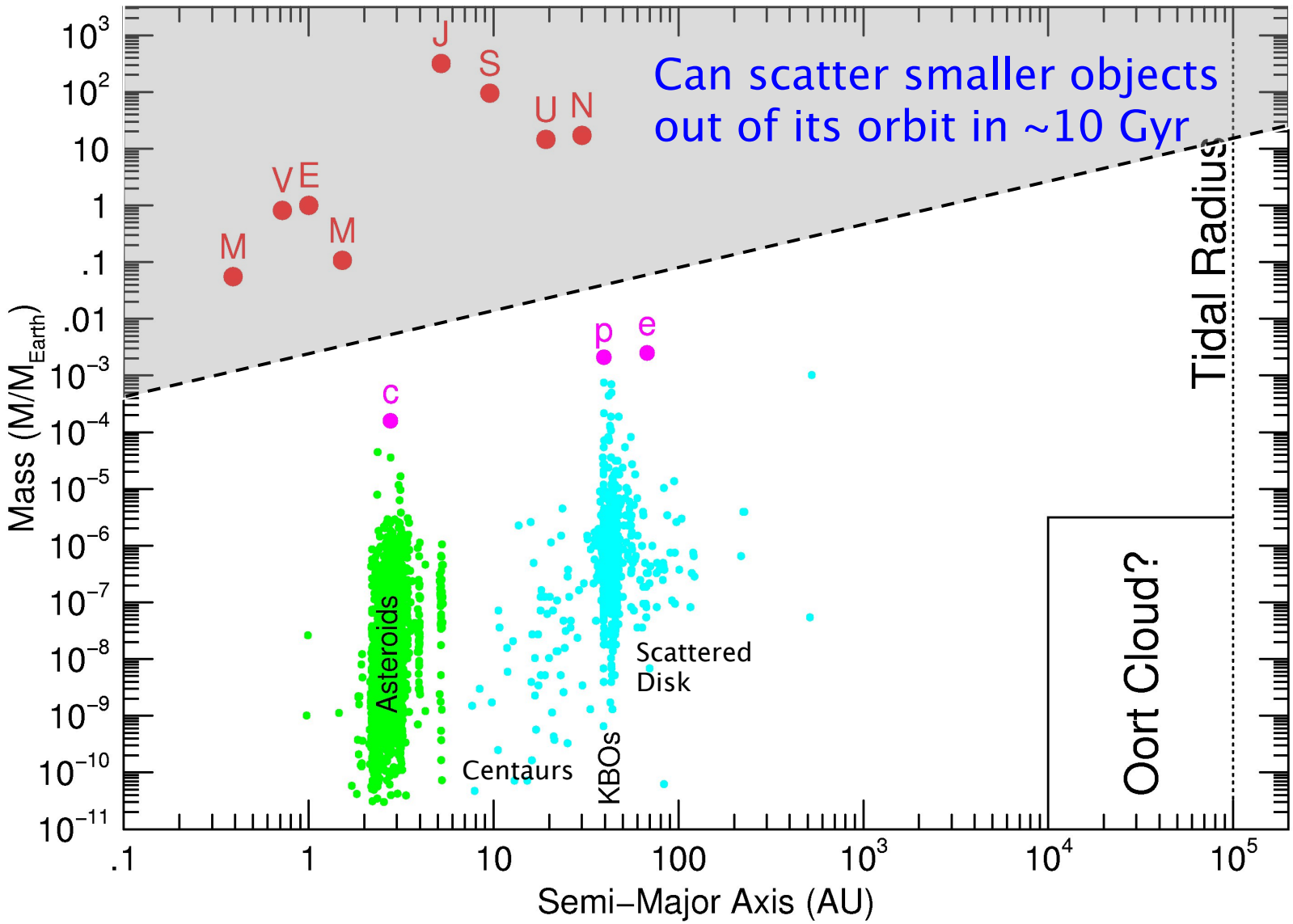
Trans-Neptunian Objects are the icy planetesimals leftover from the formation of the Solar System.

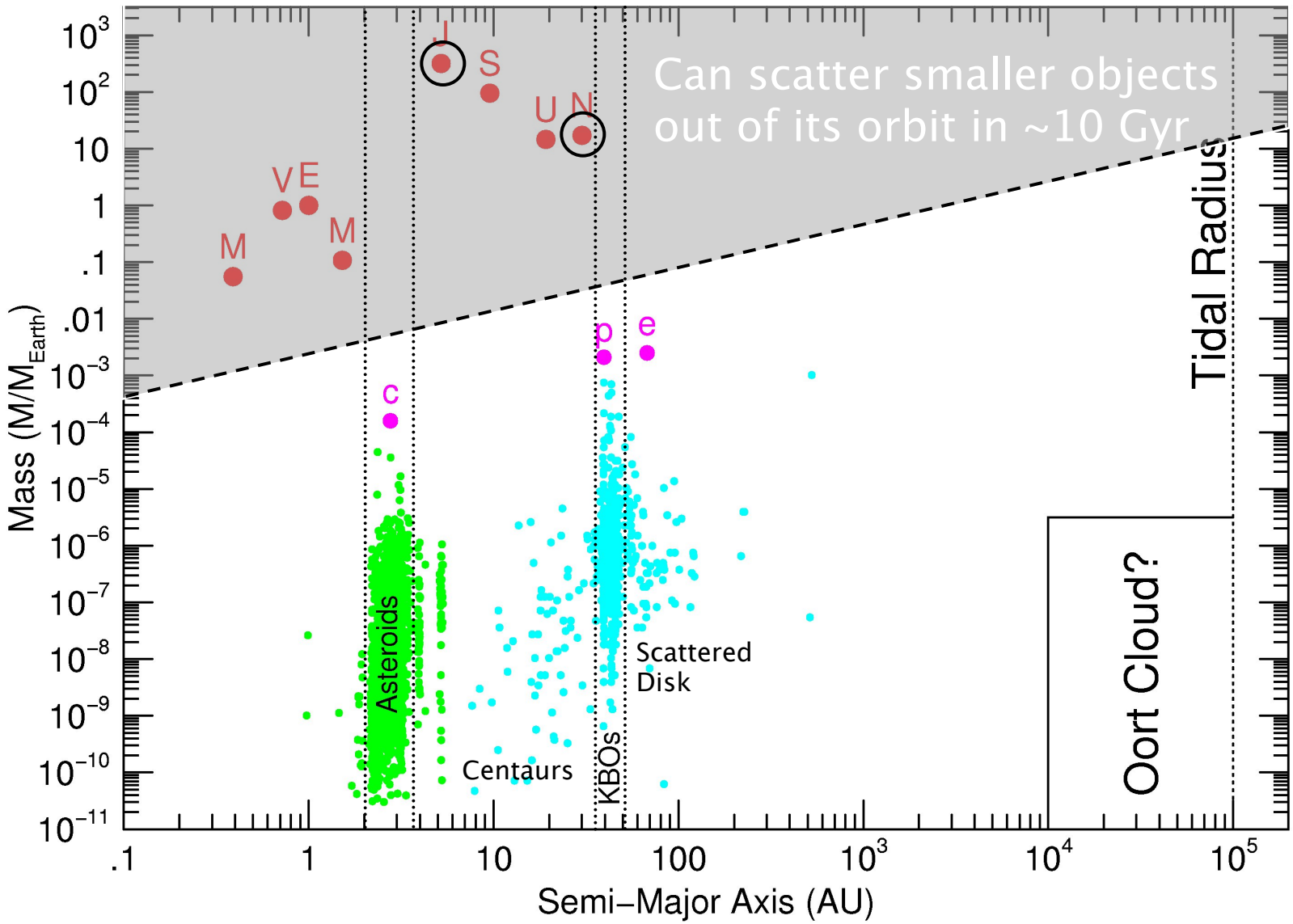


New Horizons Mission:

- January 2006 Launch
- 2015 Pluto fly-by
- Rendezvous with another KBO in 2019




Can scatter smaller objects
out of its orbit in ~10 Gyr
Tidal Radius
Oort Cloud?
J
S
U
N
V
E
M
M
p
e
c
Asteroids
Centaurs
KBOs
Scattered
Disk
Mass (M/M_Earth)
Semi-Major Axis (AU)
10^3
10^2
10
1
.1
.01
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
.1
1
10
100
10^3
10^4
10^5


Can scatter smaller objects out of its orbit in ~10 Gyr
Tidal Radius
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Asteroids
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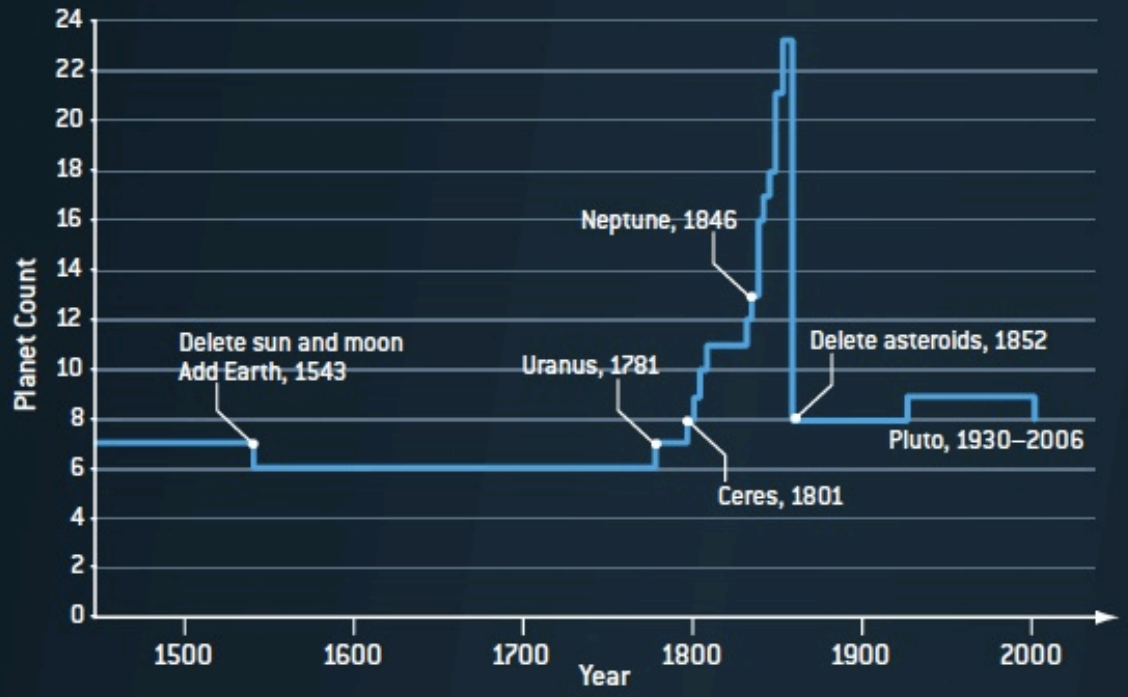
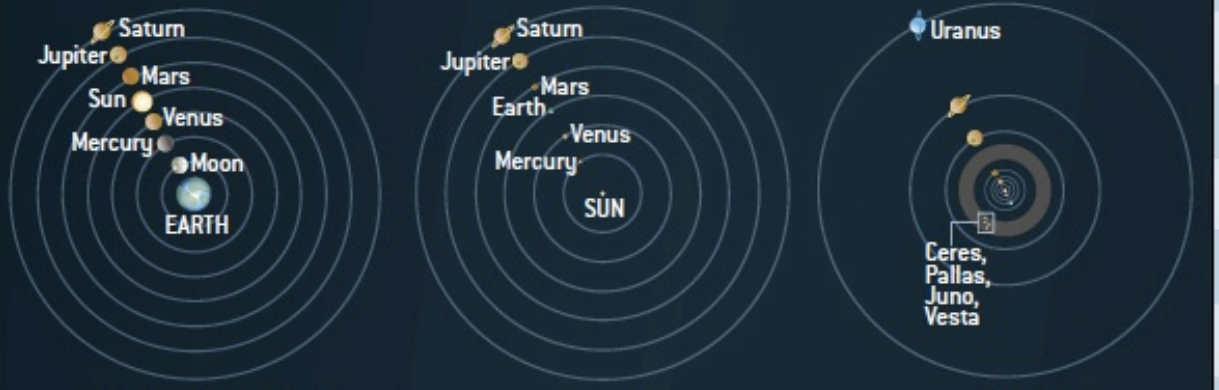
Scattered Disk
J
S
U
N
V
E
M
M
c
p
e
Mass (M/M_Earth)
Semi-Major Axis (AU)
10^3
10^2
10
1
.1
.01
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
.1
1
10
100
10^3
10^4
10^5

HISTORICAL COUNT OF PLANETS

Planets come, planets go as a result of new discoveries and changing conceptions of what a "planet" is. The decision to recategorize Pluto is simply another step in this historical progression.





DATE	PLANETS
Pre-1543	Mercury, Venus, Mars, Jupiter, Saturn, sun, moon
1543	Earth added sun, moon deleted
1781	Uranus
1801	Ceres
1802	Pallas
1804	Juno
1807	Vesta
1845	Astraea
1846	Neptune
1847	Hebe, Iris, Flora
1848	Metis
1849	Hygiea
1850	Parthenope, Victoria, Egeria
1851	Irene, Eunomia
1852	Asteroids deleted
1930	Pluto
2006	Pluto deleted