

# Today's Topics

Friday, October 16, 2020 (Week 8, lecture 24) – Chapters 12, 13

A. Pluto & dwarf planets

B. Asteroids

C. The Kuiper belt

D. The Oort cloud

E. Comets

# Pluto

## Orbit

Semimajor axis: 39.5 AU

Orbital period: 248 years

Eccentricity: 0.25

Axial tilt:  $120^\circ$

*Satellites: 5 moons.*

## Basic properties

Radius =  $0.19 R_{\text{Earth}}$

Mass =  $0.002 M_{\text{Earth}}$

Density:  $1.85 \text{ g/cm}^3$

*Composition: water ice,  
nitrogen ice, silicate core.*

True color





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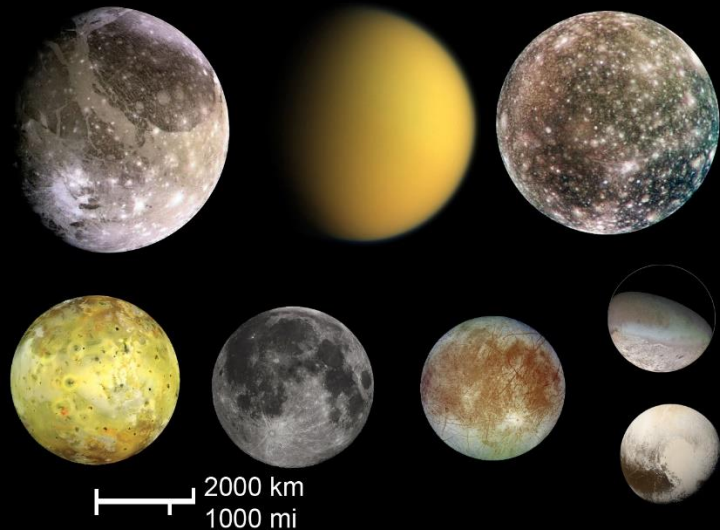
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[NASA, Johns Hopkins U: New Horizons, 2015]



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[Wikipedia: Eurocommuter, NASA]



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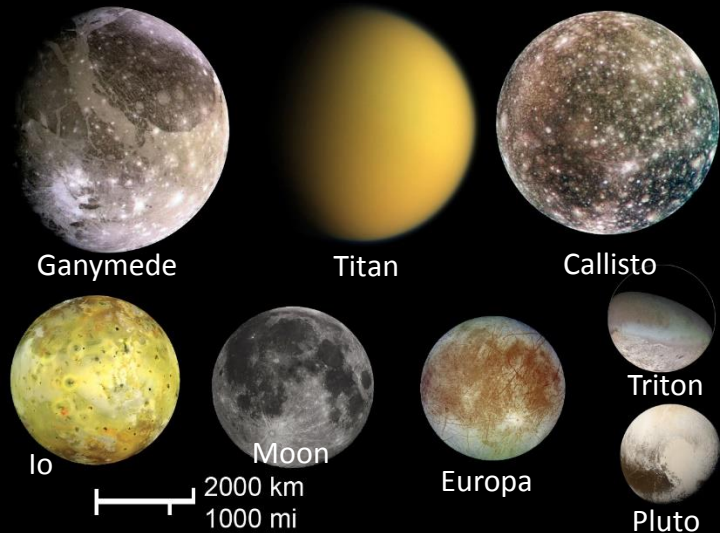
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Pluto was “demoted” to a  
**dwarf planet** in 2006.

False color



[NASA, Johns Hopkins U: New Horizons, 2015]

[Wikipedia: Eurocommuter, NASA]

# Dwarf Planets

## Definition of a Planet (International Astronomical Union 2006)

Body **orbiting the Sun** with sufficient self-gravity to be **spherical-like**, and massive enough to have **cleared its orbital neighborhood**.

← Generally not satisfied by dwarf planets.

## Definition of a Dwarf Planet

“Planet” that has **NOT** cleared its orbital neighborhood.

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“Planet” that has **NOT** cleared its orbital neighborhood.

asteroid belt

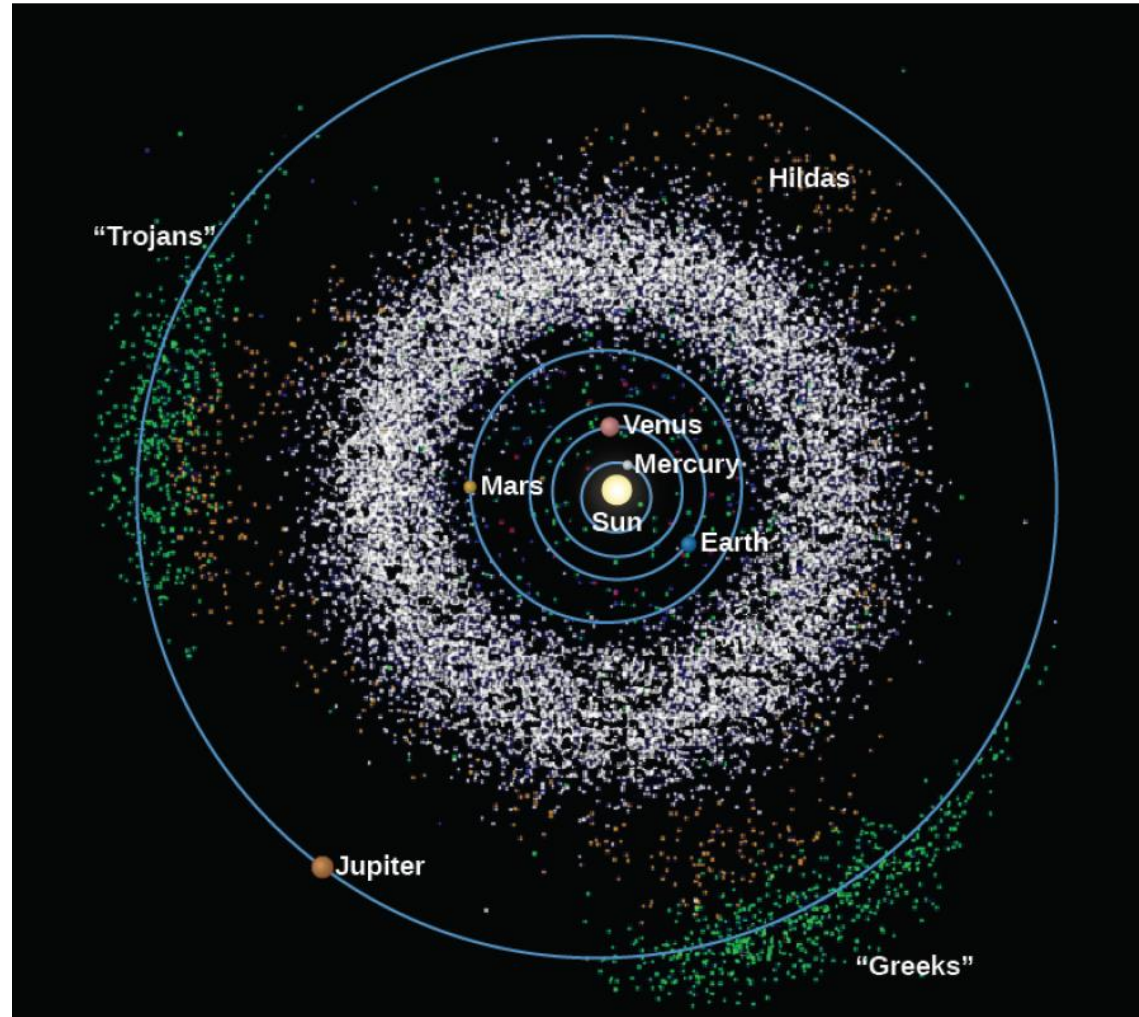
Trans-Neptunian  
Objects  
in  
Kuiper belt

Well-Studied Dwarf Planet	Semimajor Axis (AU)	Orbital Eccentricity	Inclination of Orbit to Ecliptic (°)	Diameter (Earth = 1)	Mass (Earth = 1)	Mean Density (g/cm <sup>3</sup> )
Ceres	2.77	0.08	11	0.07	0.0002	2.2
Pluto	39.5	0.25	17	0.18	0.0024	1.9
Haumea	43.1	0.19	28	0.13	0.0007	3
Makemake	45.8	0.16	29	0.11	0.0005	2
Eris	68.0	0.44	44	0.18	0.0028	2.5



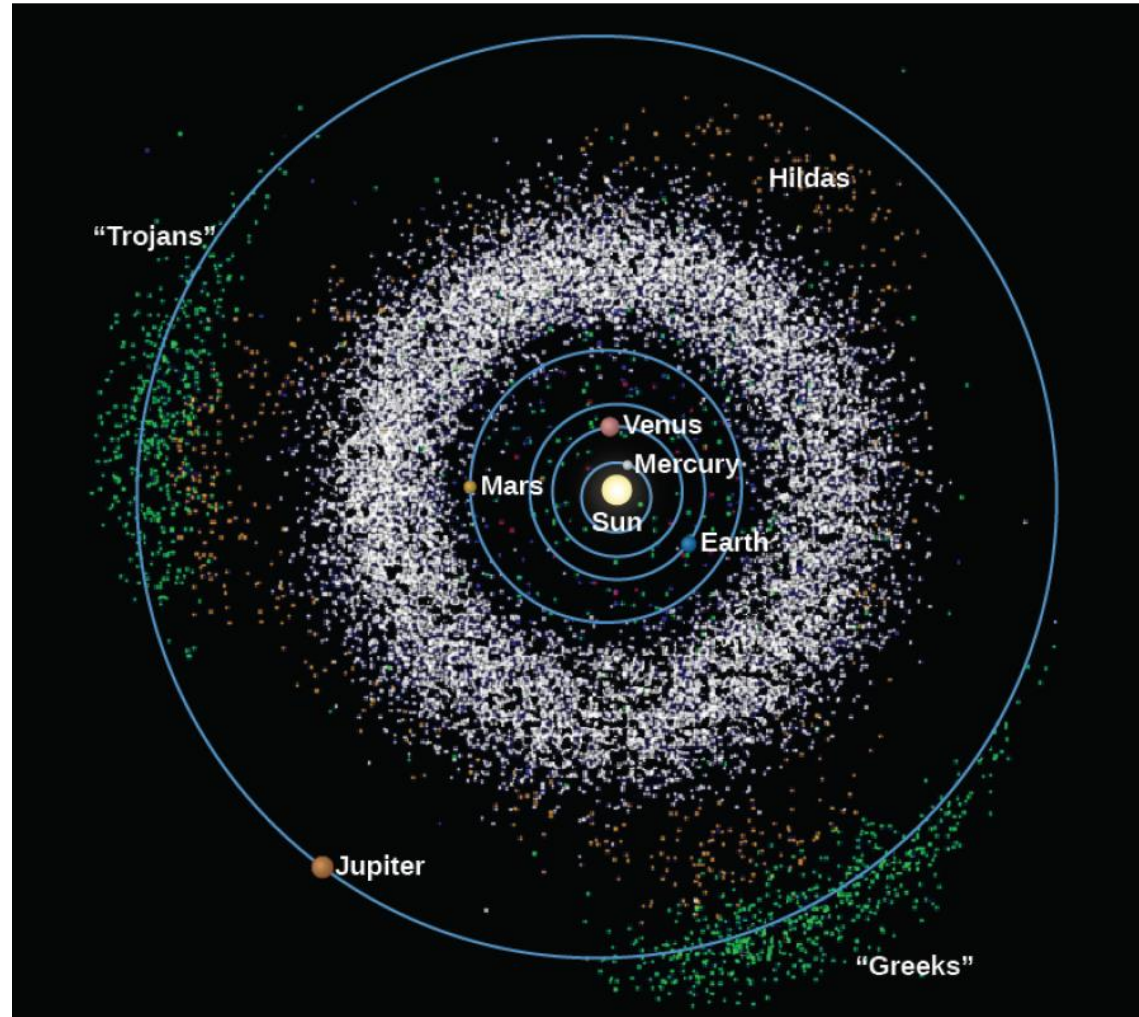
# Asteroids & Ceres

- Asteroids orbit the Sun primarily between Mars and Jupiter.
- Relatively rocky:  $\sim 2 \text{ g/cm}^3$  (up to  $5 \text{ g/cm}^3$ )
- Left over from formation on Solar System.
- Some are hard bodies, others are rubble piles.

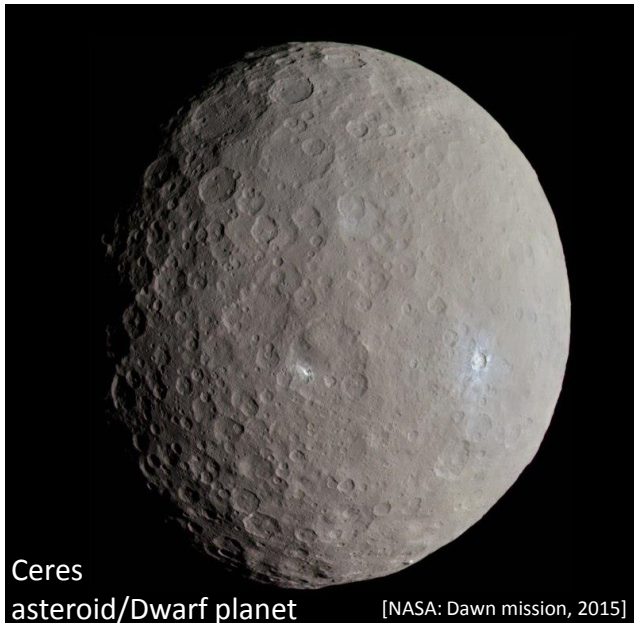


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[OpenStax: Astronomy]



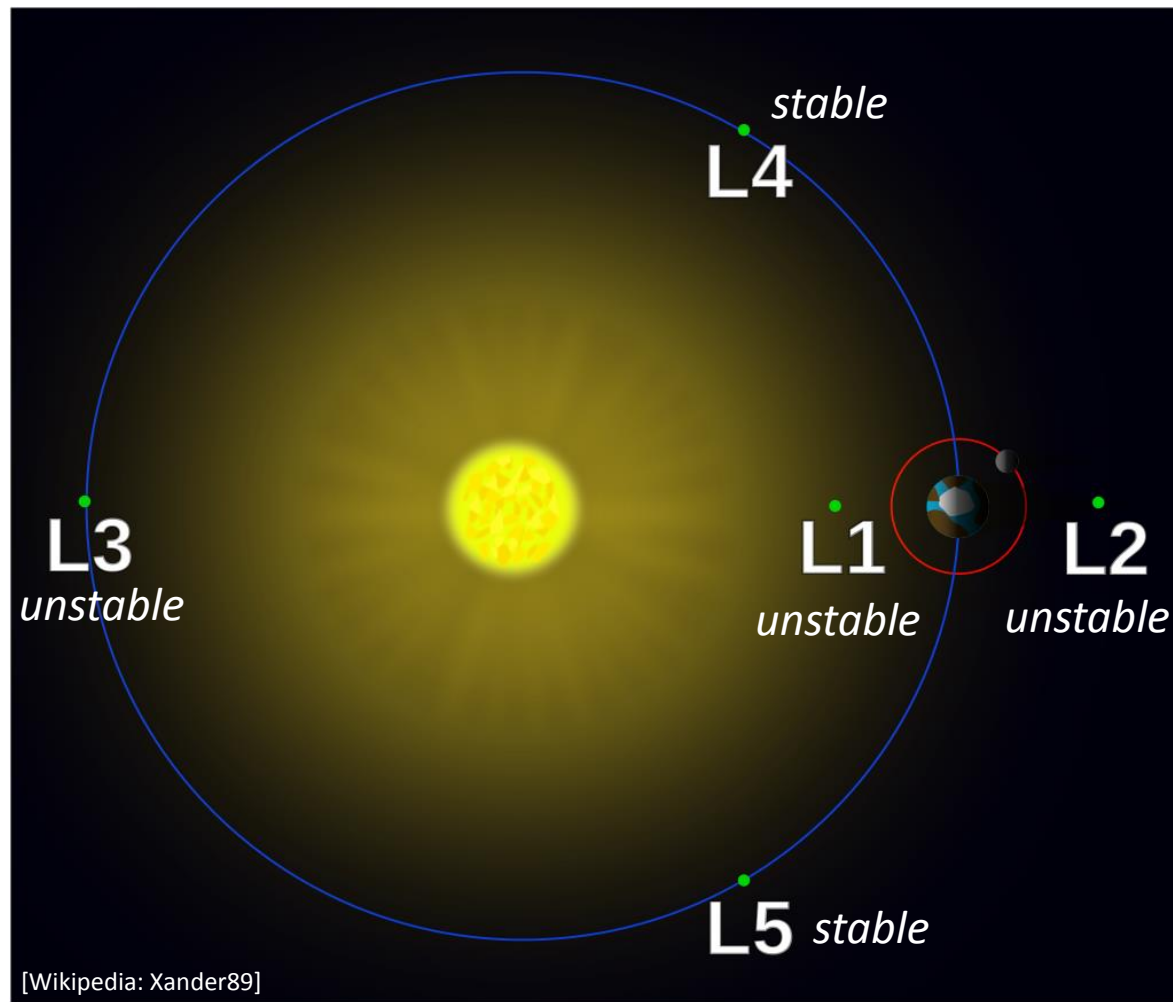
Ceres  
asteroid/Dwarf planet

[NASA: Dawn mission, 2015]



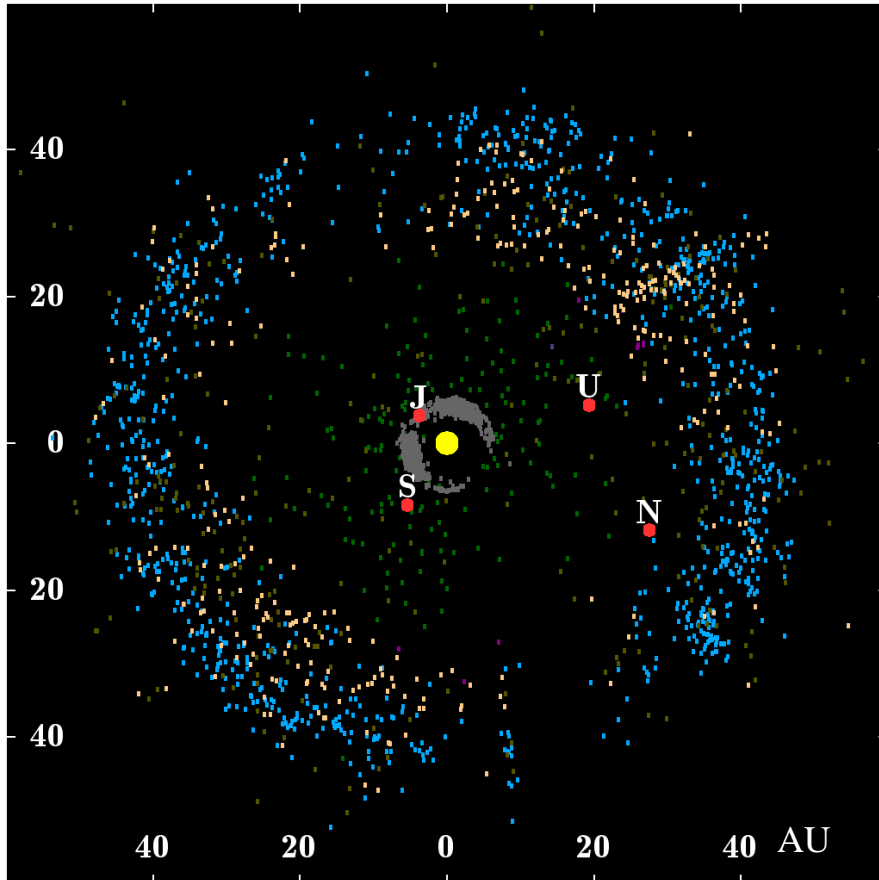
# Lagrange Points

Gravity from Sun and planet + centripetal motion generate a somewhat attractive point



# Kuiper Belt

Outer Solar System with Gas Giants



[By WilyD at English Wikipedia, CC BY-SA 3.0]

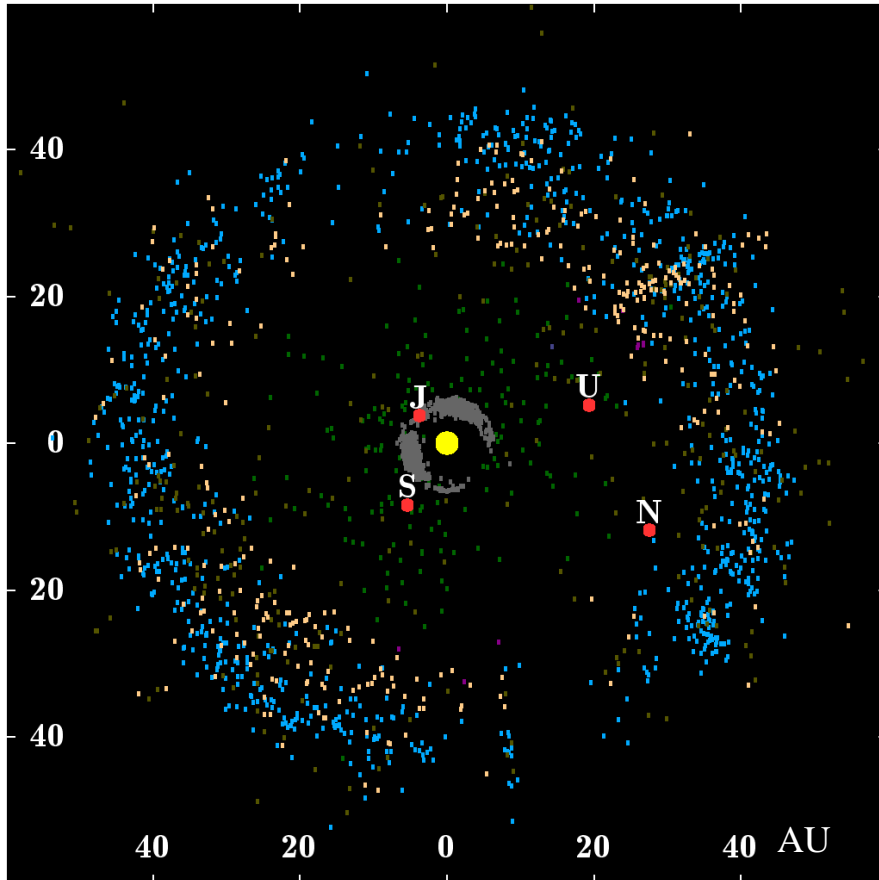


Kuiper belt objects (blue, beige, green) are **icy left over planetesimals** in the region of the gas giants and beyond.



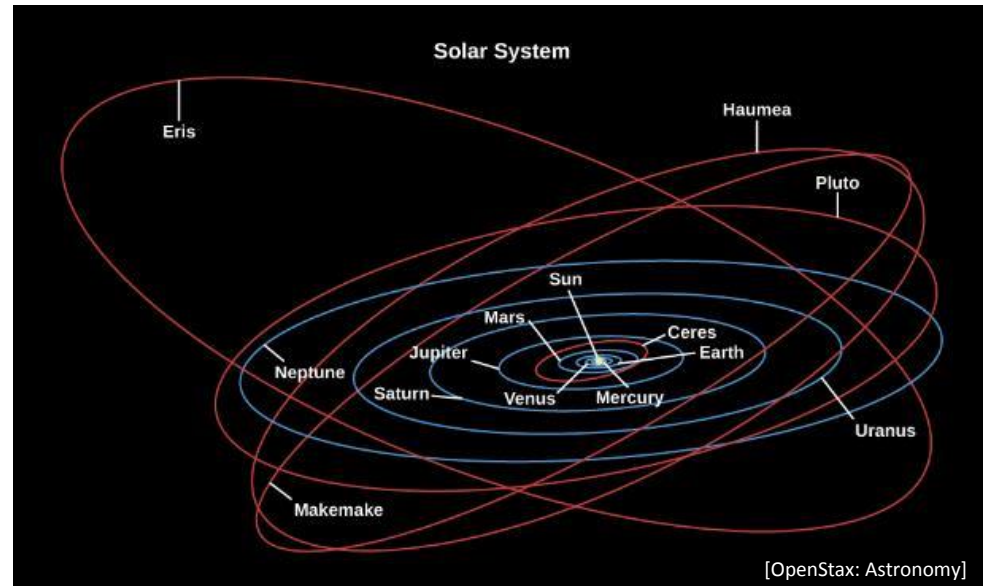
# Kuiper Belt

## Outer Solar System with Gas Giants



[By WilyD at English Wikipedia, CC BY-SA 3.0]

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A number of **trans-Neptunian dwarf planets** (red) are in the Kuiper belt:

*Pluto*

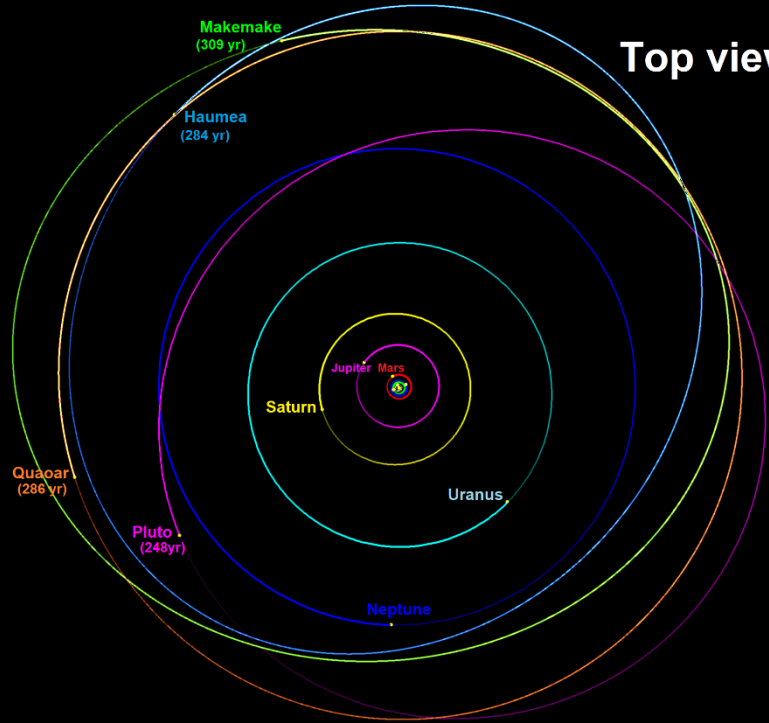
*Eris (heaviest)*

*Haumea*

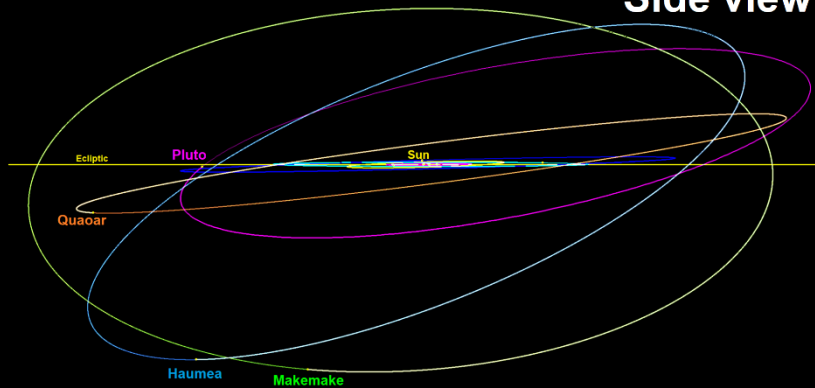
*Makemake*

# Trans-Neptunian Objects (Kuiper Belt)

Top view



Side view



[Wikipedia: Tomruen - Own work, CC BY-SA 4.0]

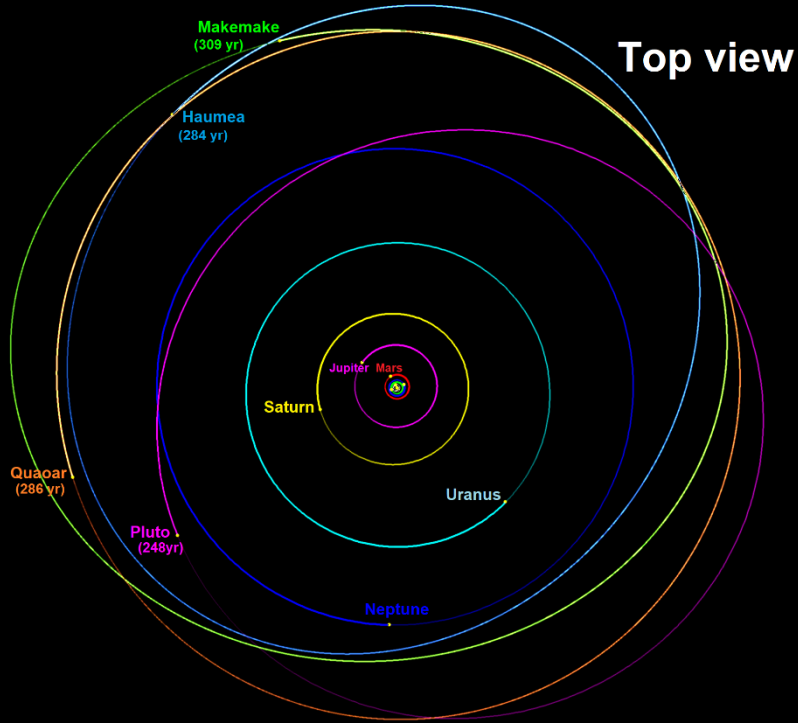


**Haumea with moons**  
Hi'iaka (above), Namaka (below)

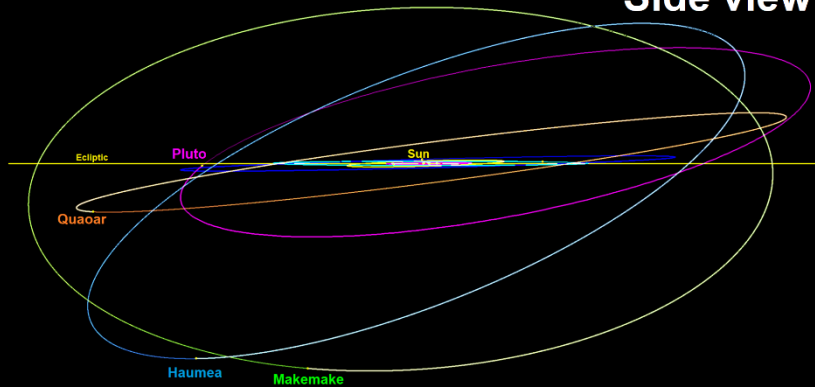


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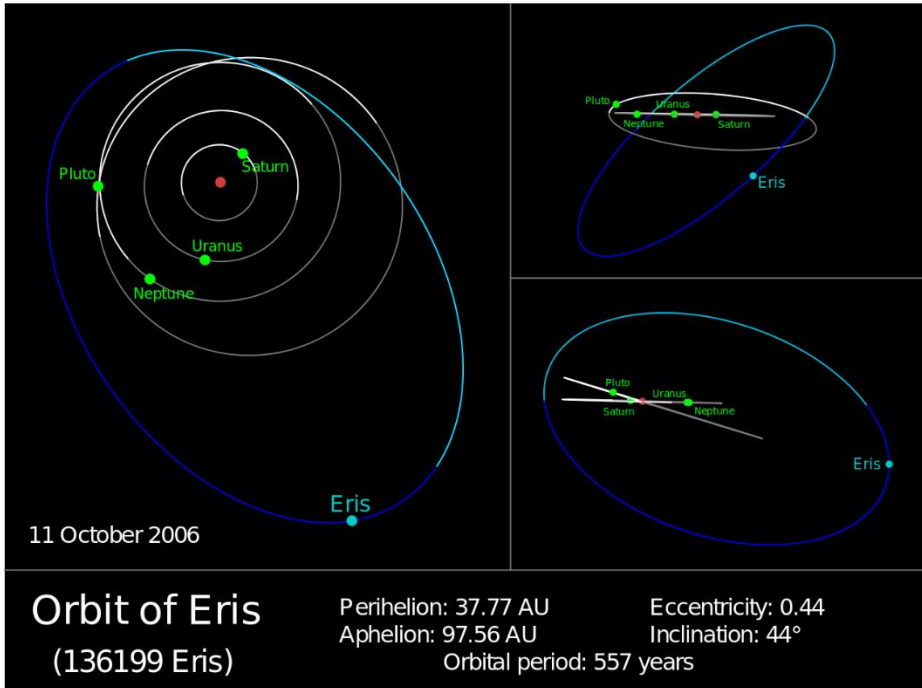
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Side view



[Wikipedia: Tomruen - Own work, CC BY-SA 4.0]

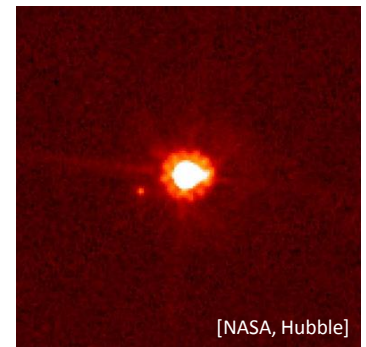


[Wikipedia: Orionist - Own work, Based on data obtained from:  
<http://neo.jpl.nasa.gov/orbits/2003ub313.html>]



[NASA, Hubble, Renerpho]

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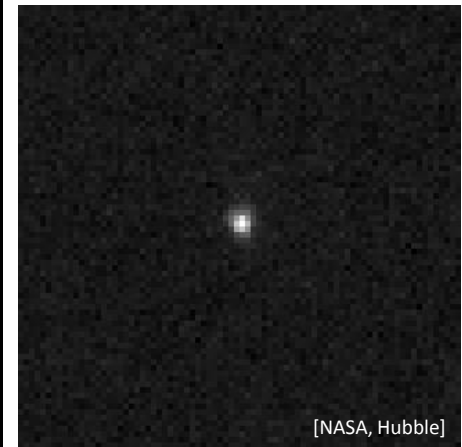
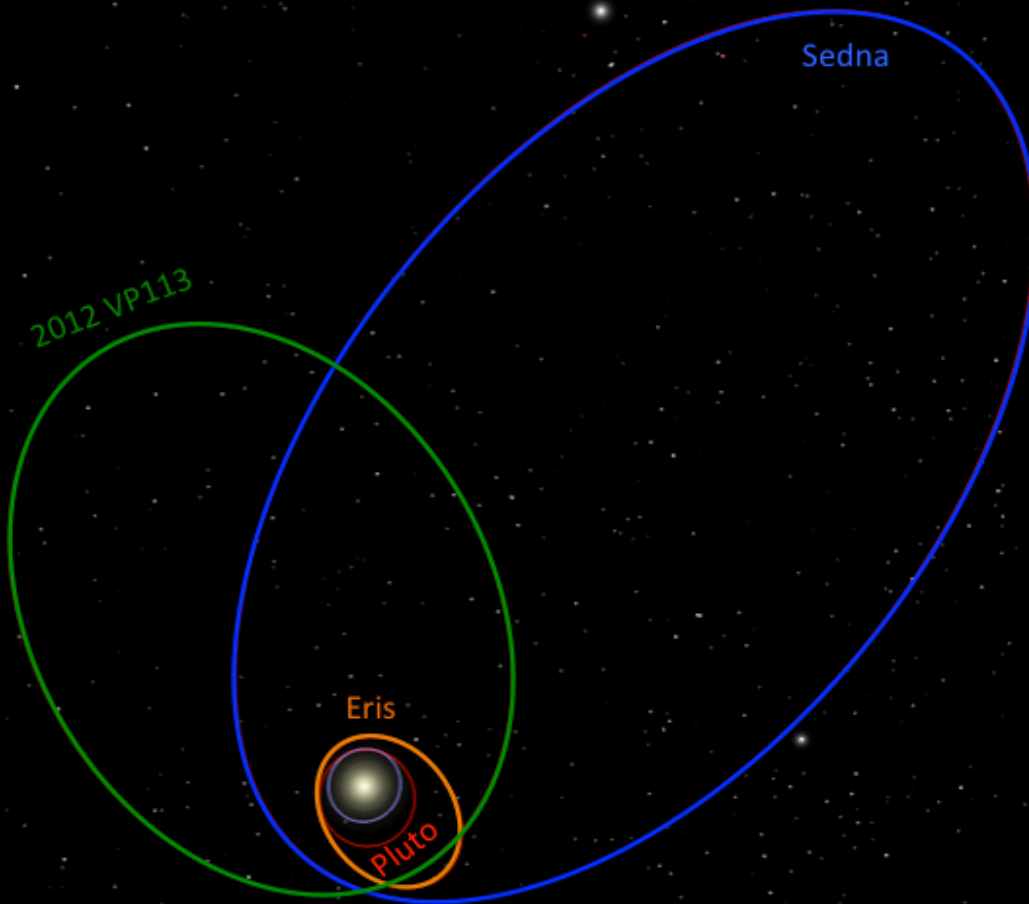
**Eris**  
and Disnomia (moon)

# Sedna

Dwarf planet outside the Kuiper belt with a diameter of about 1000 km (~ Charon size) – discovered in 2004.

*Composition: water, methane, and nitrogen ices.*

Semimajor axis = 507 AU  
Orbital period  $\approx 11,400$  yrs  
Eccentricity = 0.85

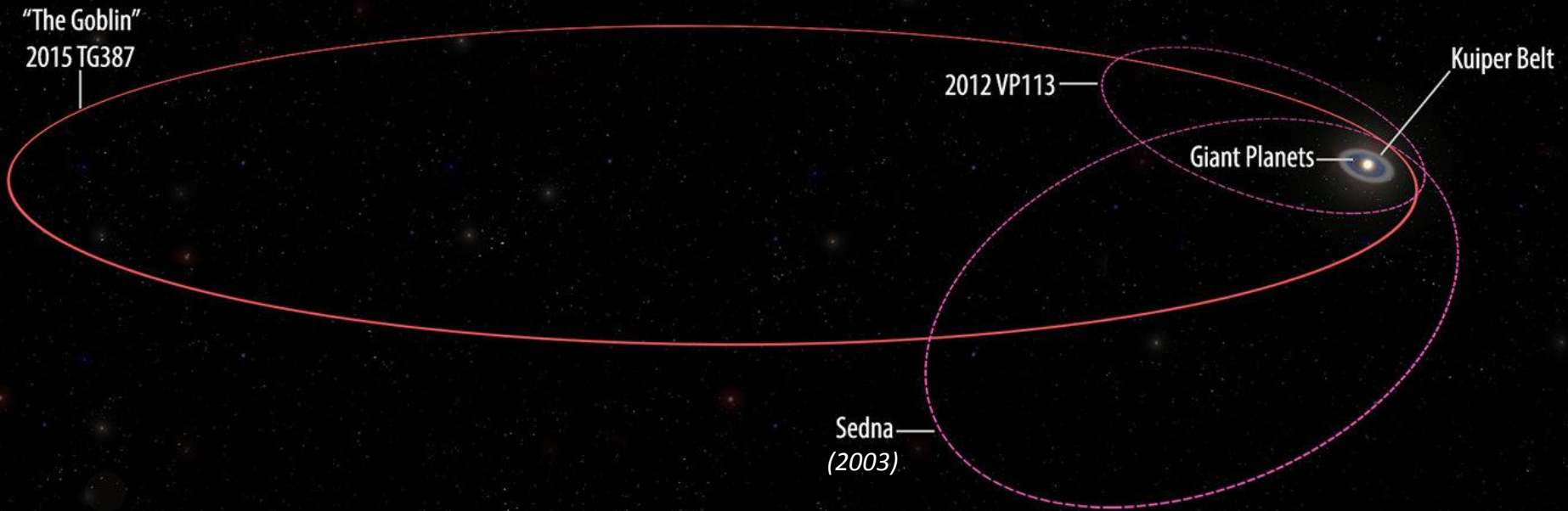


*Sedna*



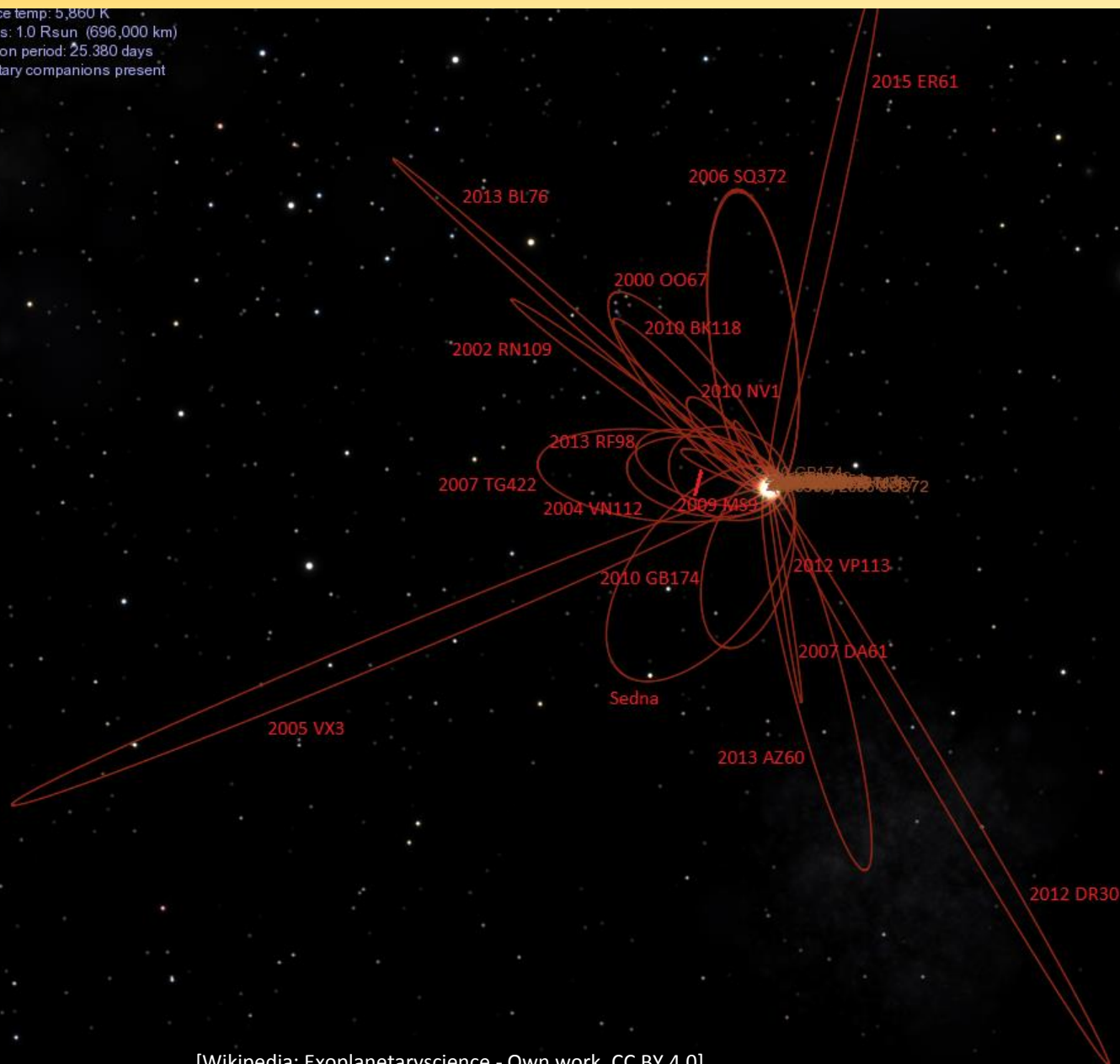
# Beyond Sedna

## New Extreme Dwarf Planet: 2015 TG387



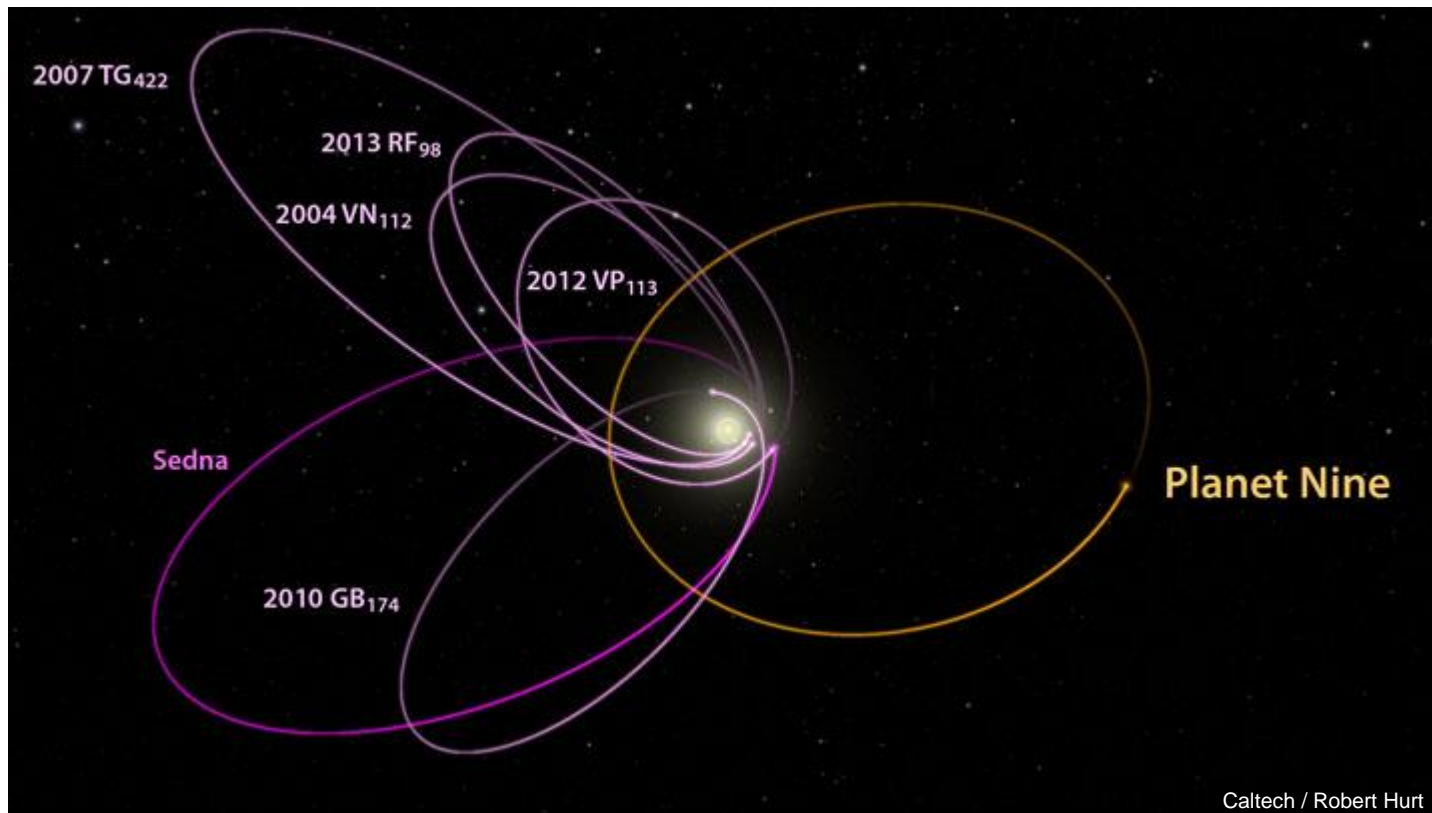
# Beyond Sedna

Surface temp: 5,860 K  
 Radius: 1.0 R<sub>sun</sub> (696,000 km)  
 Rotation period: 25.380 days  
 Planetary companions present



# Planet “Nine” ???

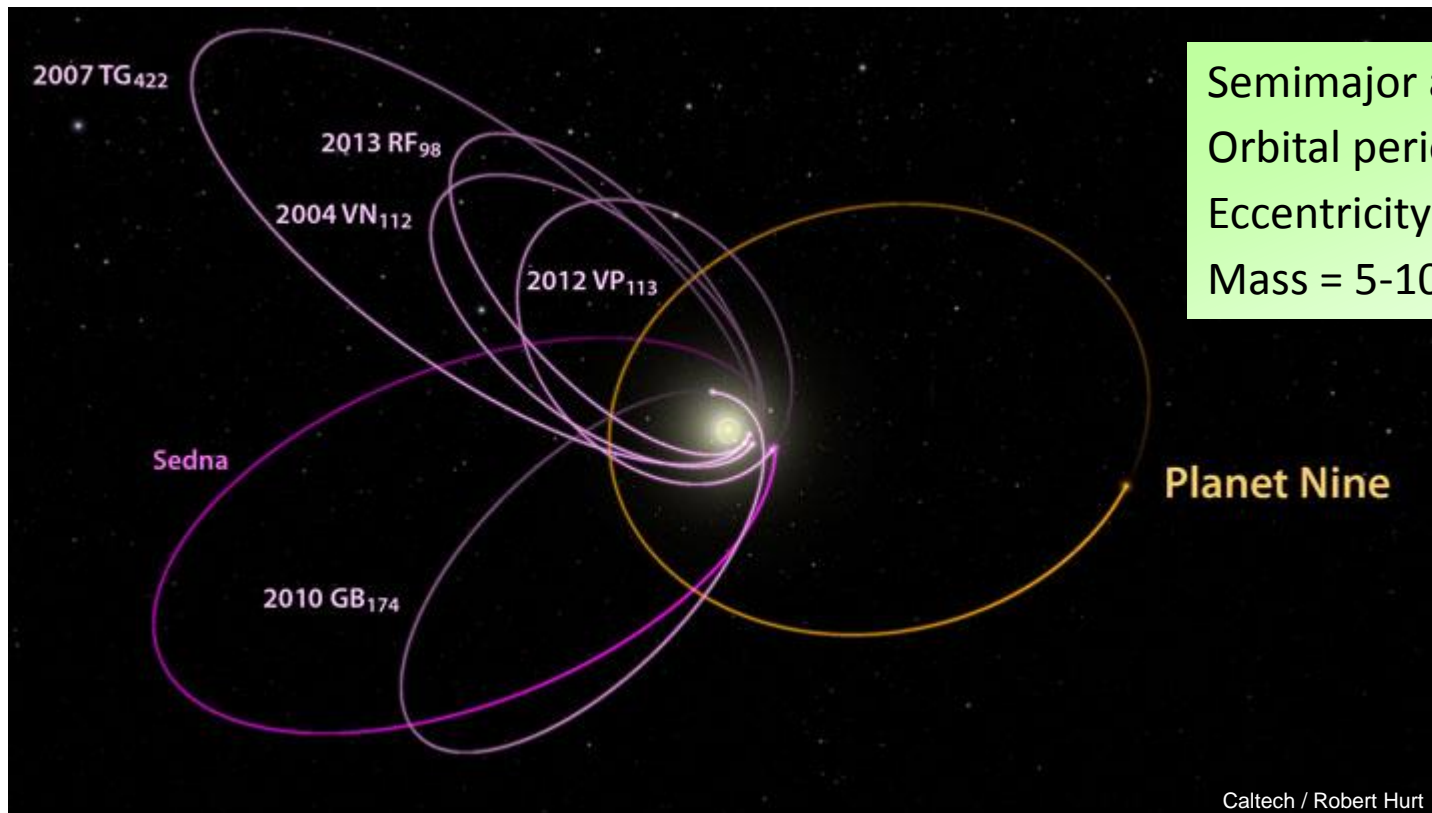
- There is speculation that an undetected planet is “herding” the dwarf planets to one side of the Sun (proposed by M. Brown and K. Batygin, 2016).
- On their own, the known dwarf planets/objects are expected to interact over millions of years so that their orbits spread out more (i.e. not all on one side of Sun).





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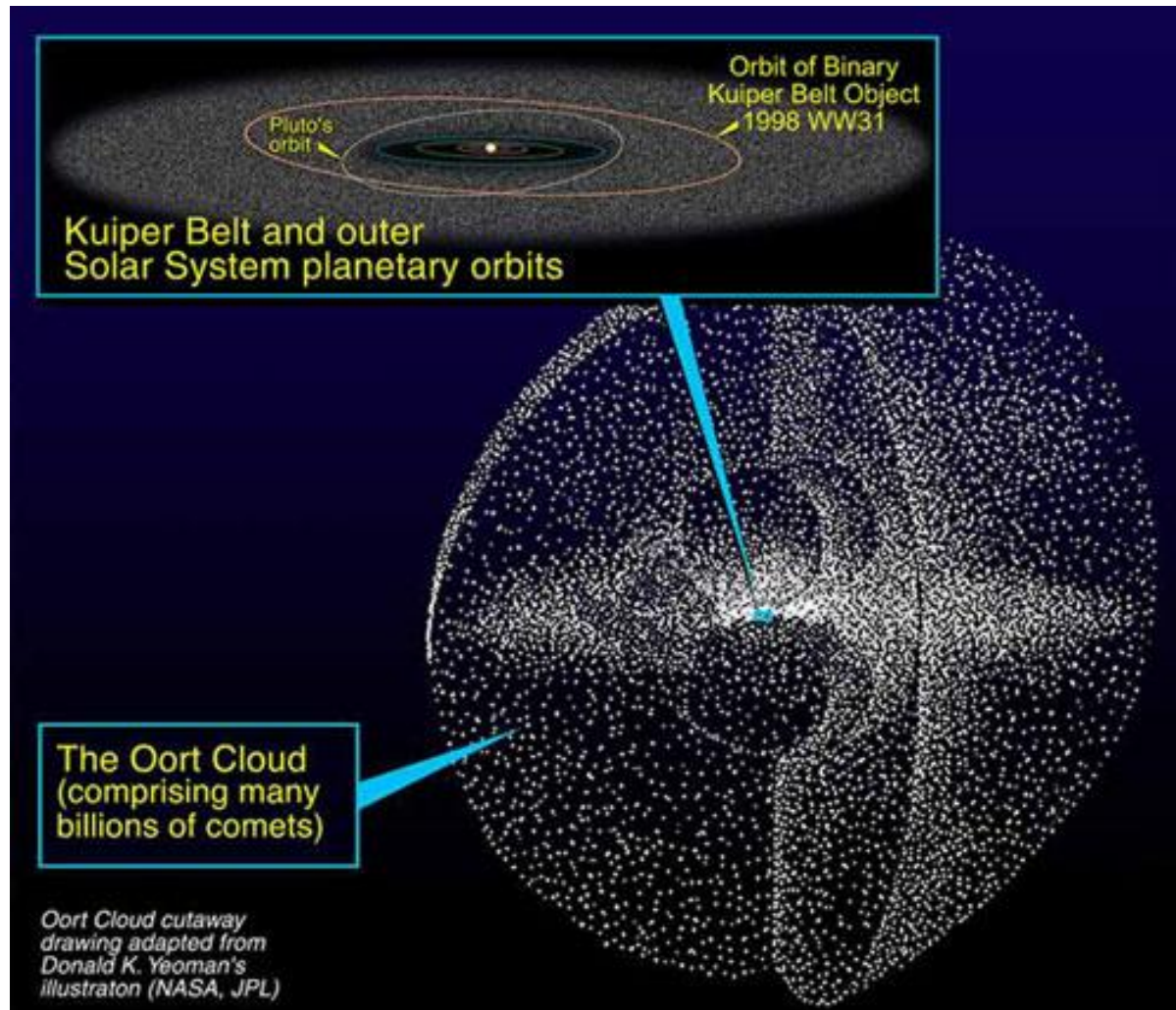
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# Oort Cloud

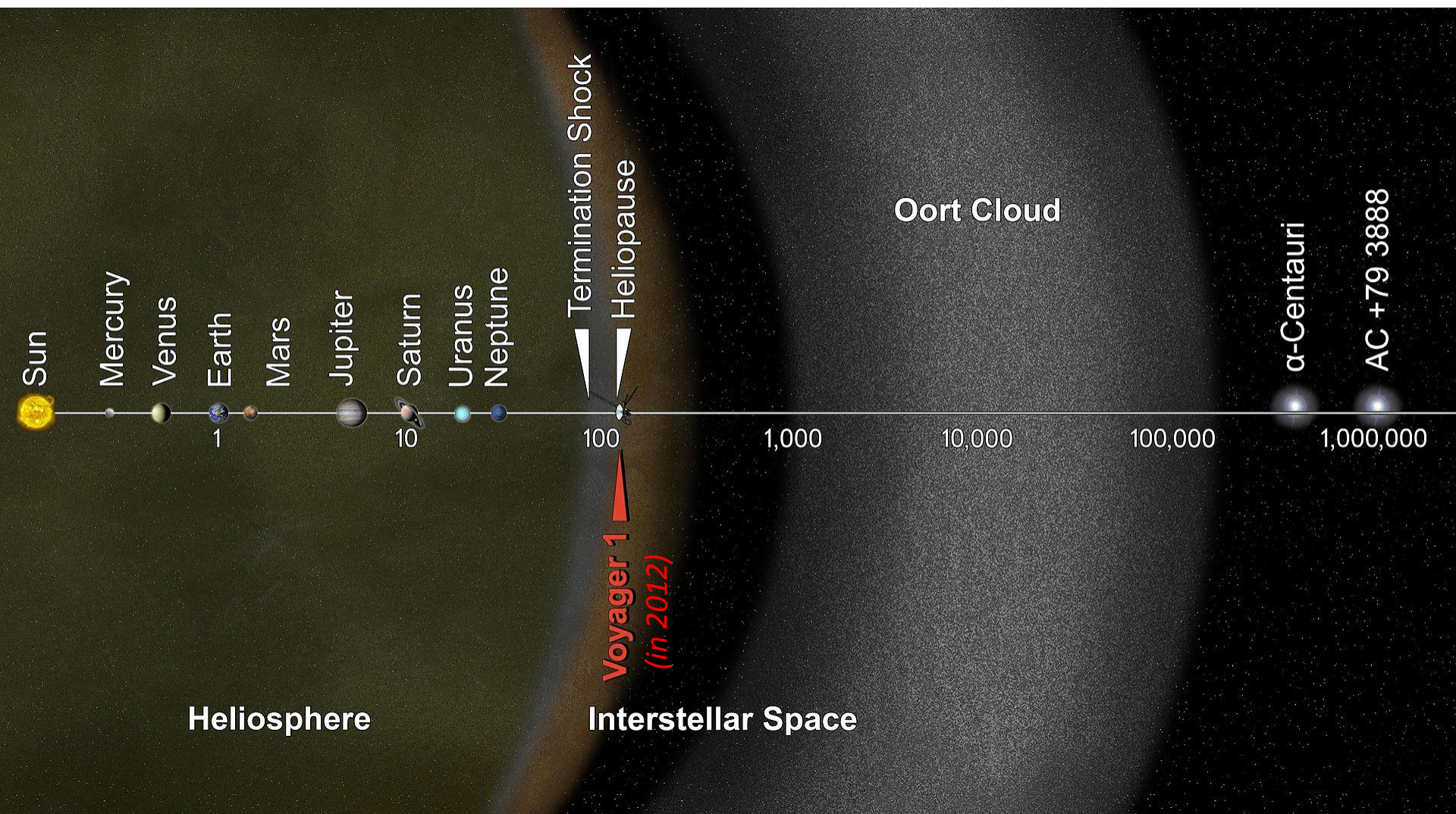
Theoretical cloud of icy objects that were expelled by the larger planets and dwarf planets during the formation of the Solar System.

- Objects orbit in 3D.  
(*i.e. not in a plane/disk*)
- Objects orbit Sun & Solar System, but are also affected by the **gravity of the Milky Way**.
- Thought to be the **source of comets**.
- No Oort cloud “comet objects” have been observed.
- “~Trillions” of objects.
- Total mass  $\sim 5\text{-}1000 M_{\text{earth}}$ .





# Oort Cloud





# Comets

## Two Comet Types

- Comet orbits Sun in ecliptic plane (short orbital period, from inner Oort cloud, Kuiper belt).
- Comet orbits Sun outside of the ecliptic plane, i.e. 3D orbit (long orbital period, from outer Oort cloud).



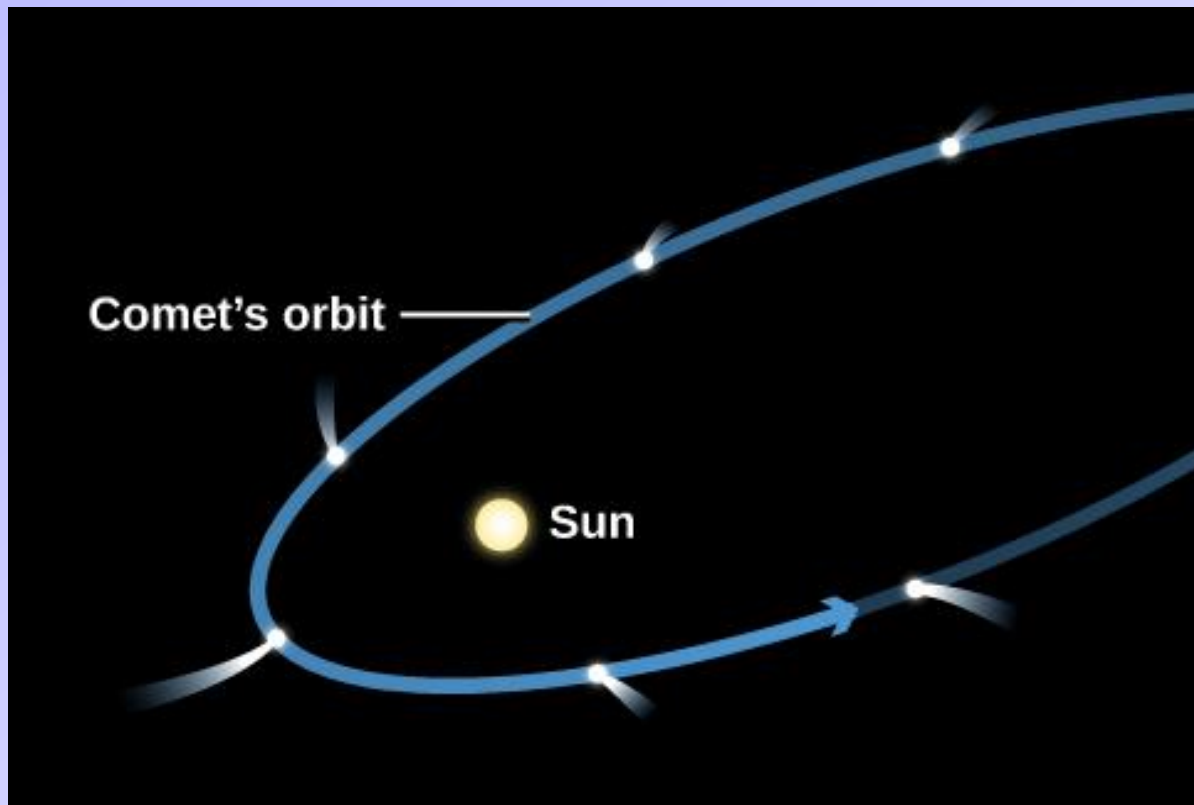
[OpenStax, NASA, W. Liller]

Hailey's comet, 1986

# Comets

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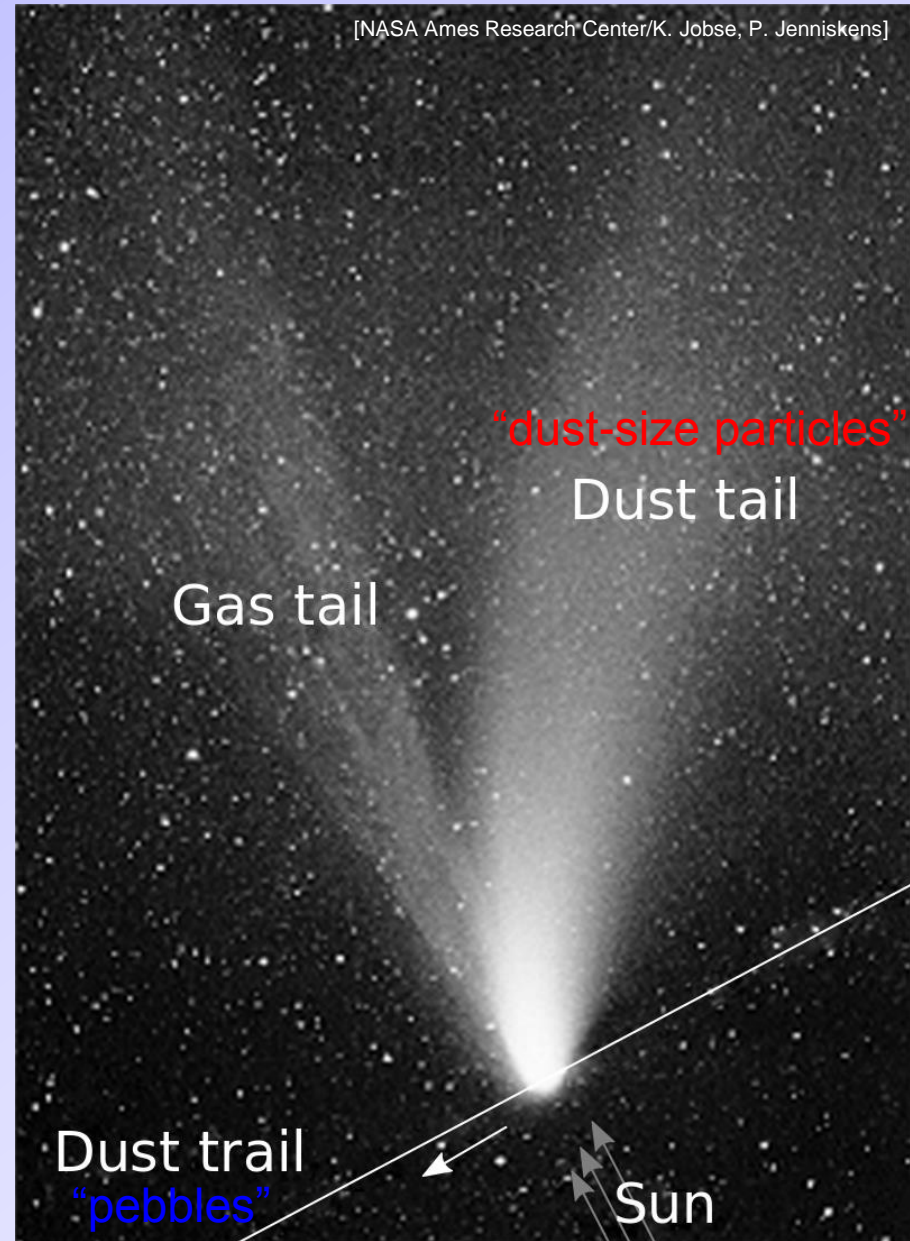
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- The **tail** of the comet always points **away from the Sun**.
- The tail is pushed away by the **solar wind**.

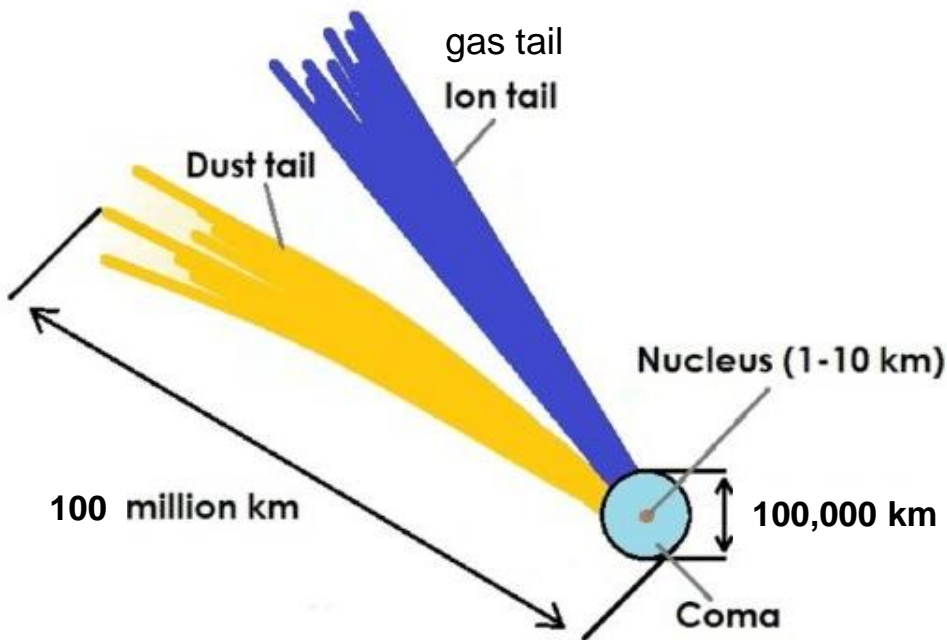


# Comets





# Comet Structure



Modified by Helen Klus, <http://www.thestargarden.co.uk/History-of-comets.html>,  
original image by NASA/JPL-Caltech/UMD/

## Composition: “Dirty Snowball”, “Icy Dirtball”

- Frozen water ( $\text{H}_2\text{O}$ ), carbon dioxide ( $\text{CO}_2$ ), carbon monoxide ( $\text{CO}$ ), methane ( $\text{CH}_4$ ), ammonia ( $\text{NH}_3$ ).
- Rocks, pebbles.
- “Leftovers” from formation of Solar System.

