Today's Topics

Wednesday, October 30, 2019 (Week 9, lecture 24) – Chapters 12, 13, 14.4.

1. Dwarf planets
2. Comets
3. Exoplanets

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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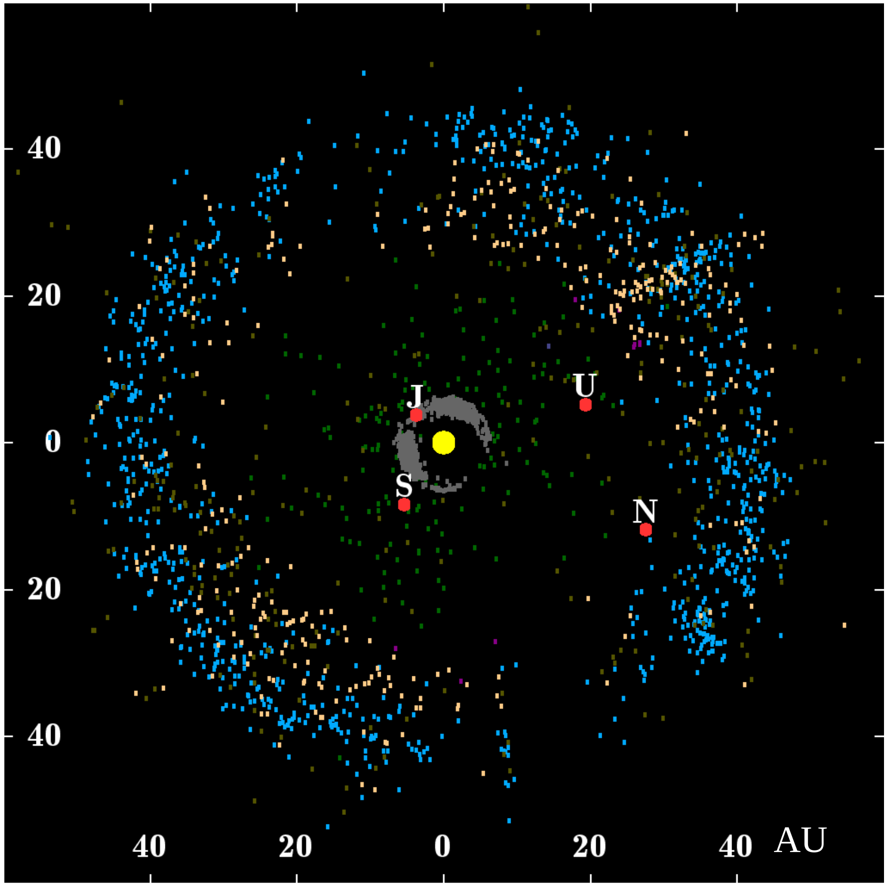
	Well-Studied Dwarf Planet	Semimajor Axis (AU)	Orbital Eccentricity	Inclination of Orbit to Ecliptic (°)	Diameter (Earth = 1)	Mass (Earth = 1)	Mean Density (g/cm^3)
asteroid belt	Ceres	2.77	0.08	11	0.07	0.0002	2.2
Trans-Neptunian Objects in Kuiper belt	Pluto	39.5	0.25	17	0.18	0.0024	1.9
	Haumea	43.1	0.19	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

Kuiper Belt

Outer Solar System with Gas Giants

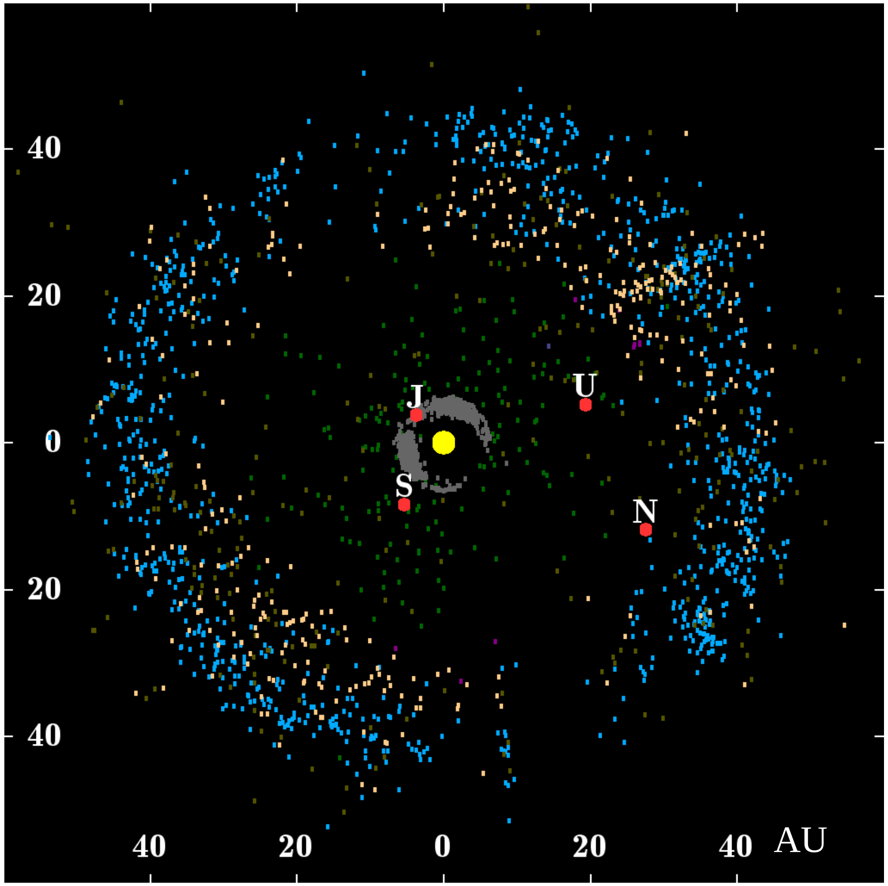


[By WilyD at English Wikipedia, CC BY-SA 3.0]

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



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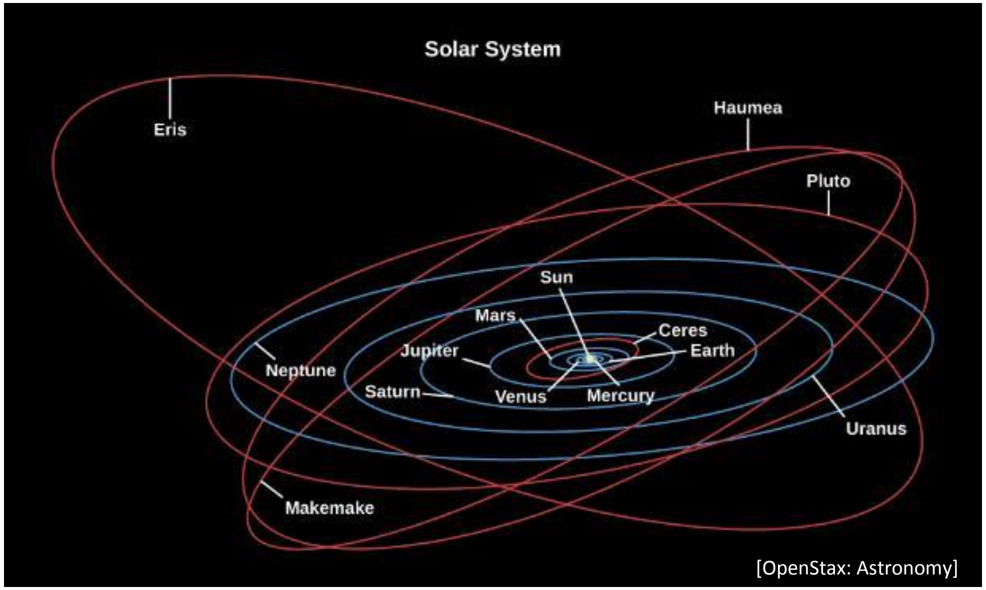
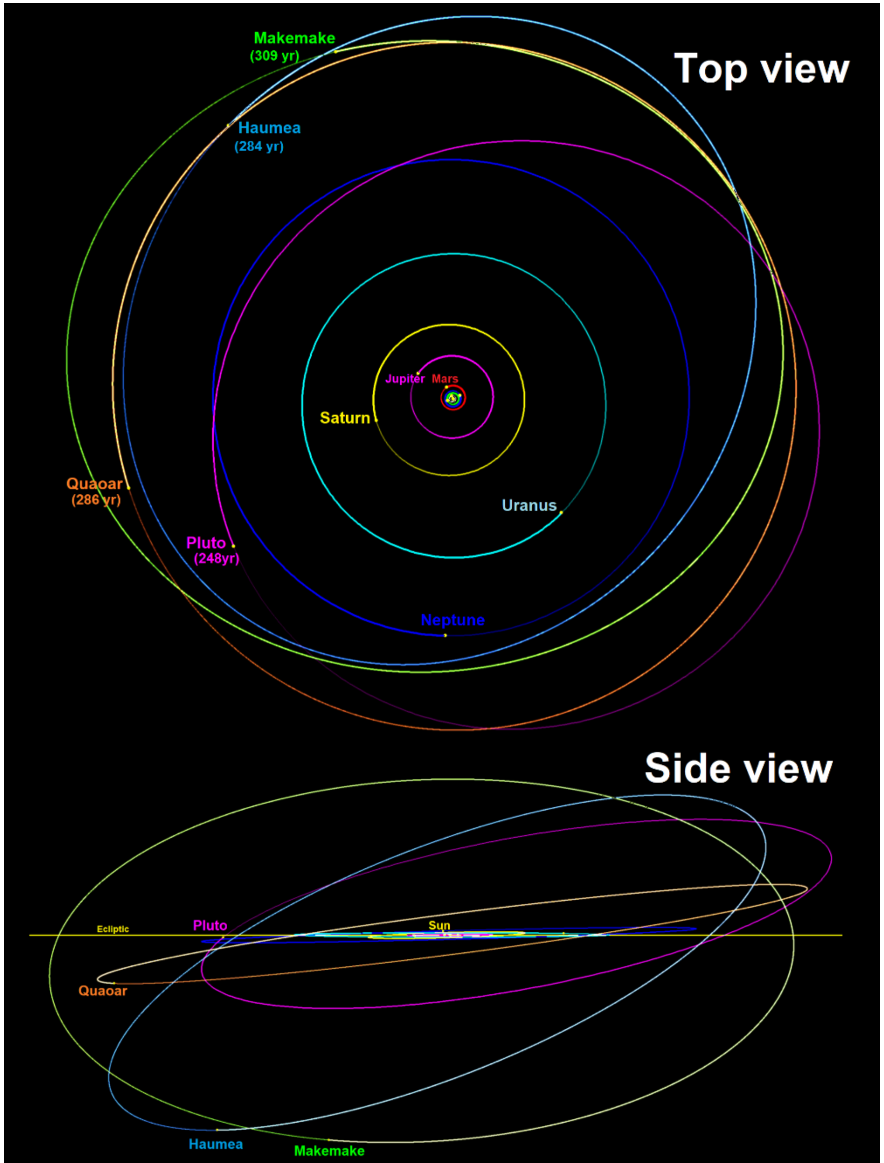


Kuiper belt objects (blue, beige, green) are **icy left over planetesimals** in the region of the gas giants and beyond.

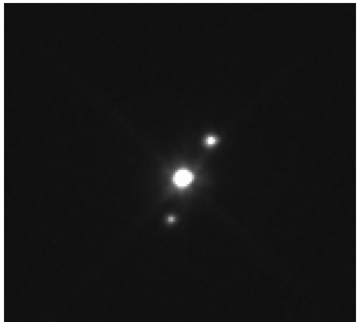
A number of **trans-Neptunian dwarf planets** (red) are in the Kuiper belt:

Pluto	*Eris (heaviest)*
Haumea	*Makemake*

Trans-Neptunian Objects (Kuiper Belt)



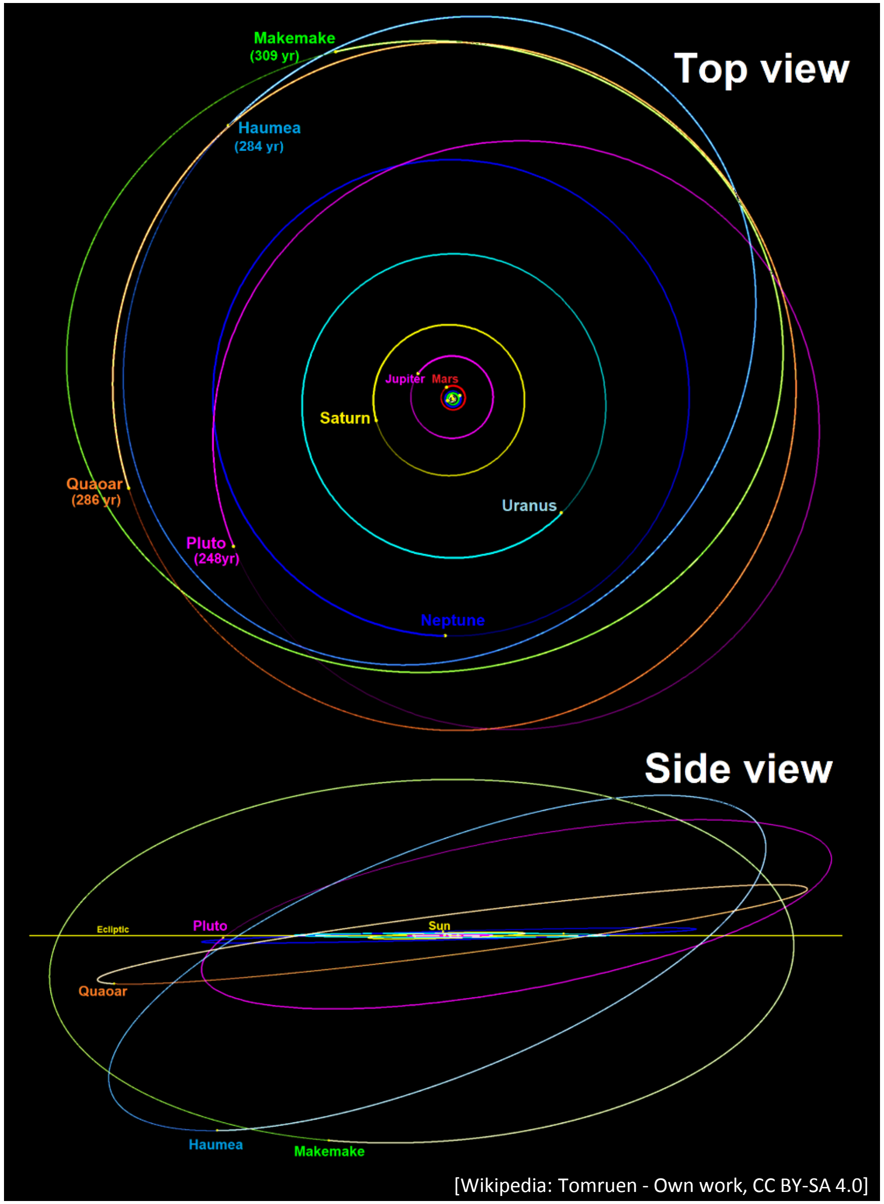
[Wikipedia: Tomruen - Own work, CC BY-SA 4.0]



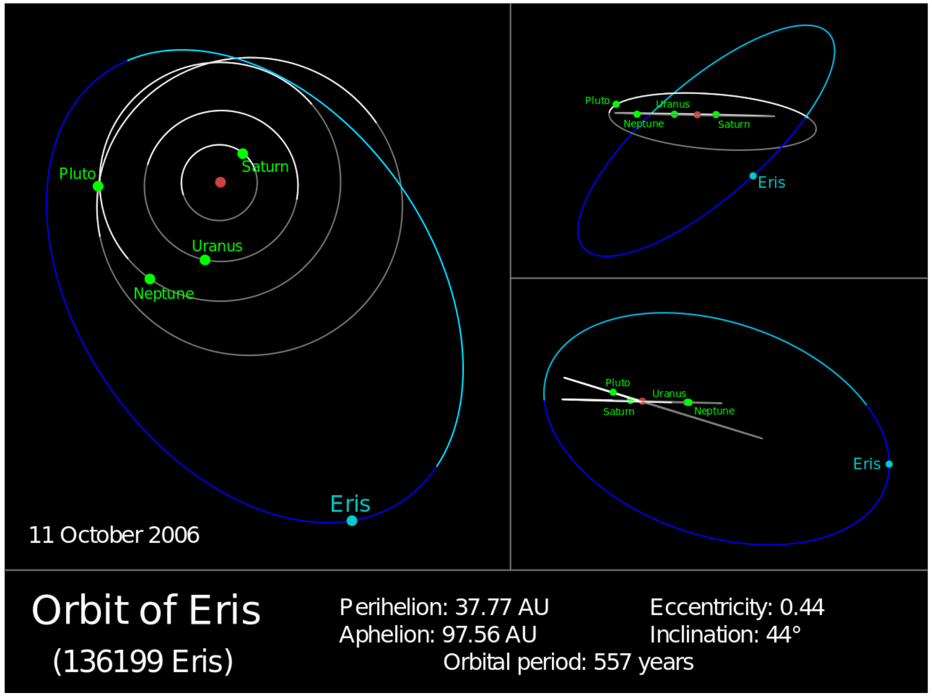
[NASA, Hubble, Renerpho]

Haumea with moons
Hiʻiaka (above), Namaka (below)

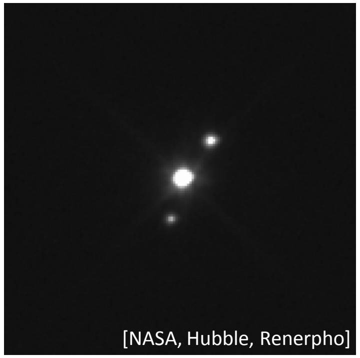
Trans-Neptunian Objects (Kuiper Belt)



[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]



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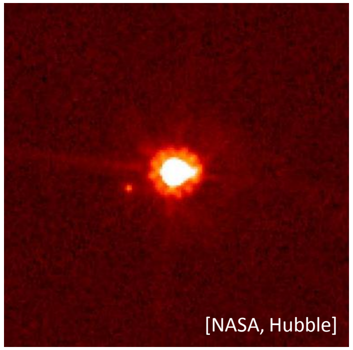


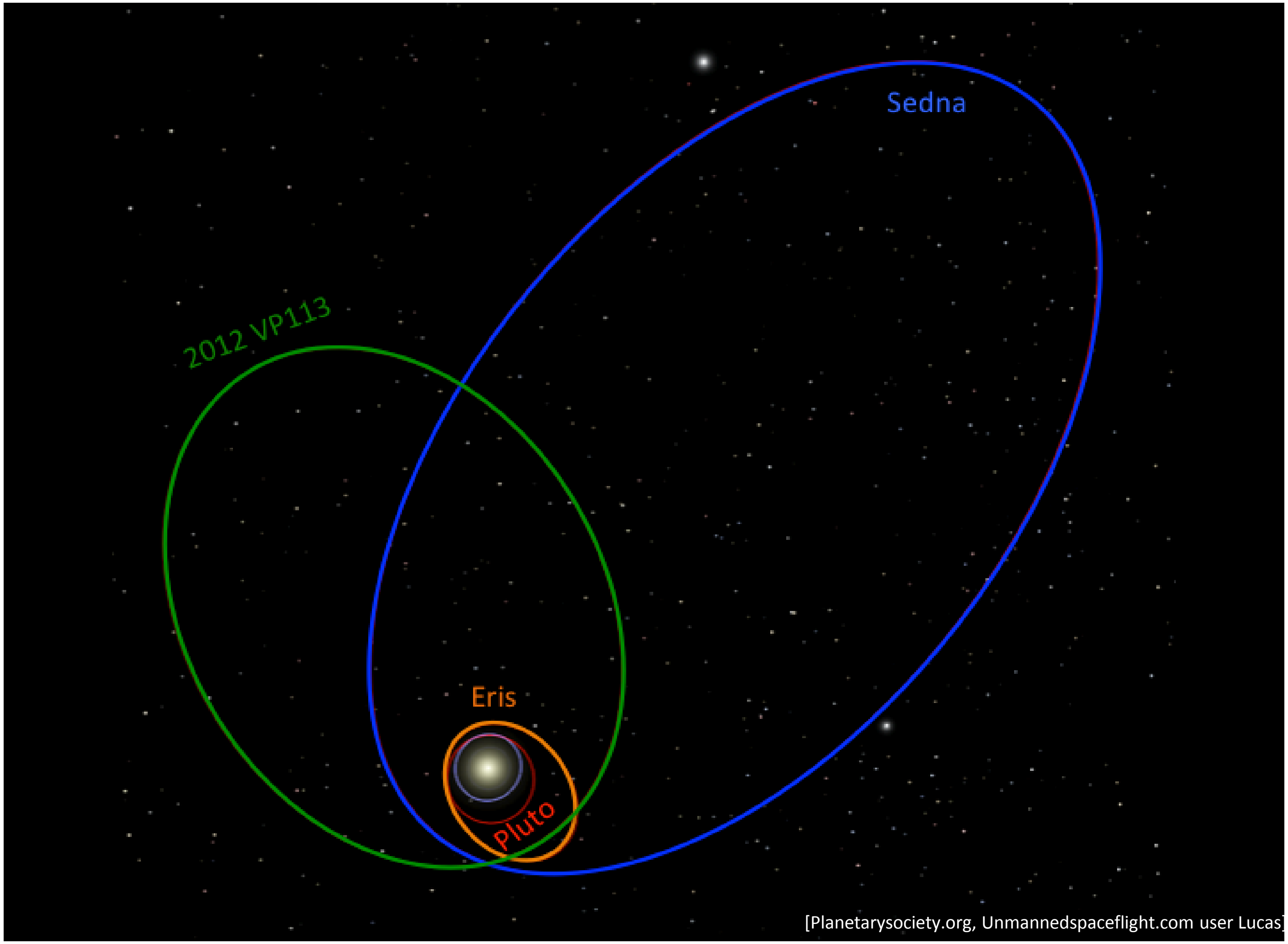
[NASA, Hubble]

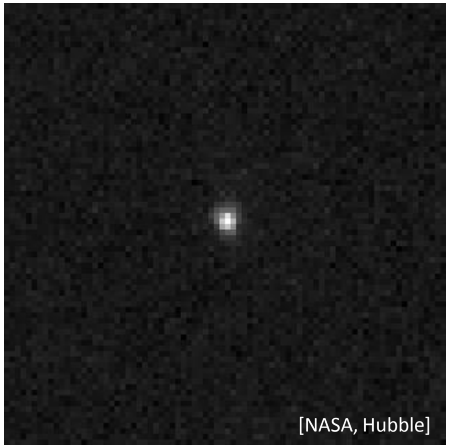
Eris
and Disnomia (moon)

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.

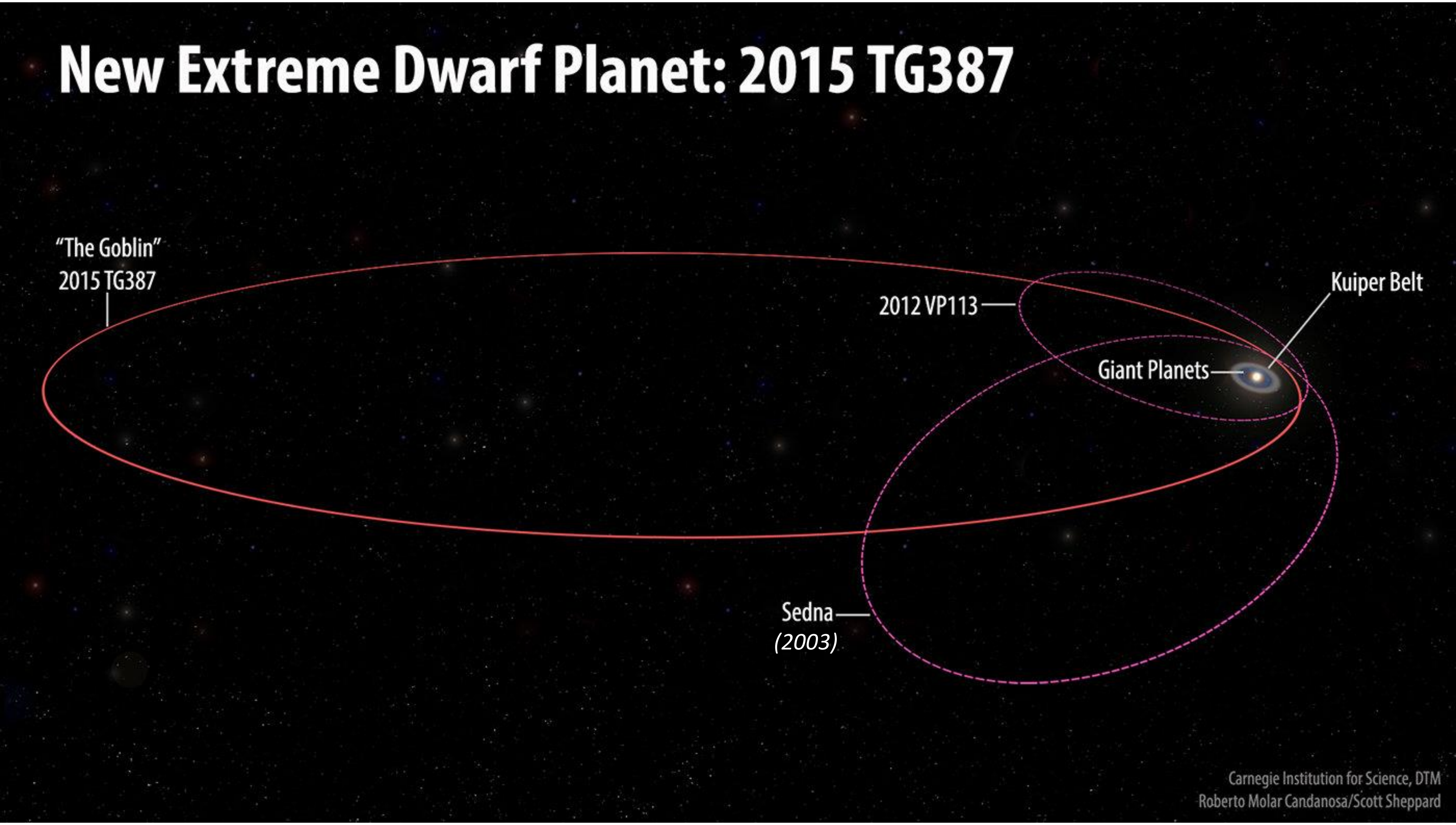
Semimajor axis = 507 AU
Orbital period ≈ 11,400 yrs
Eccentricity = 0.85



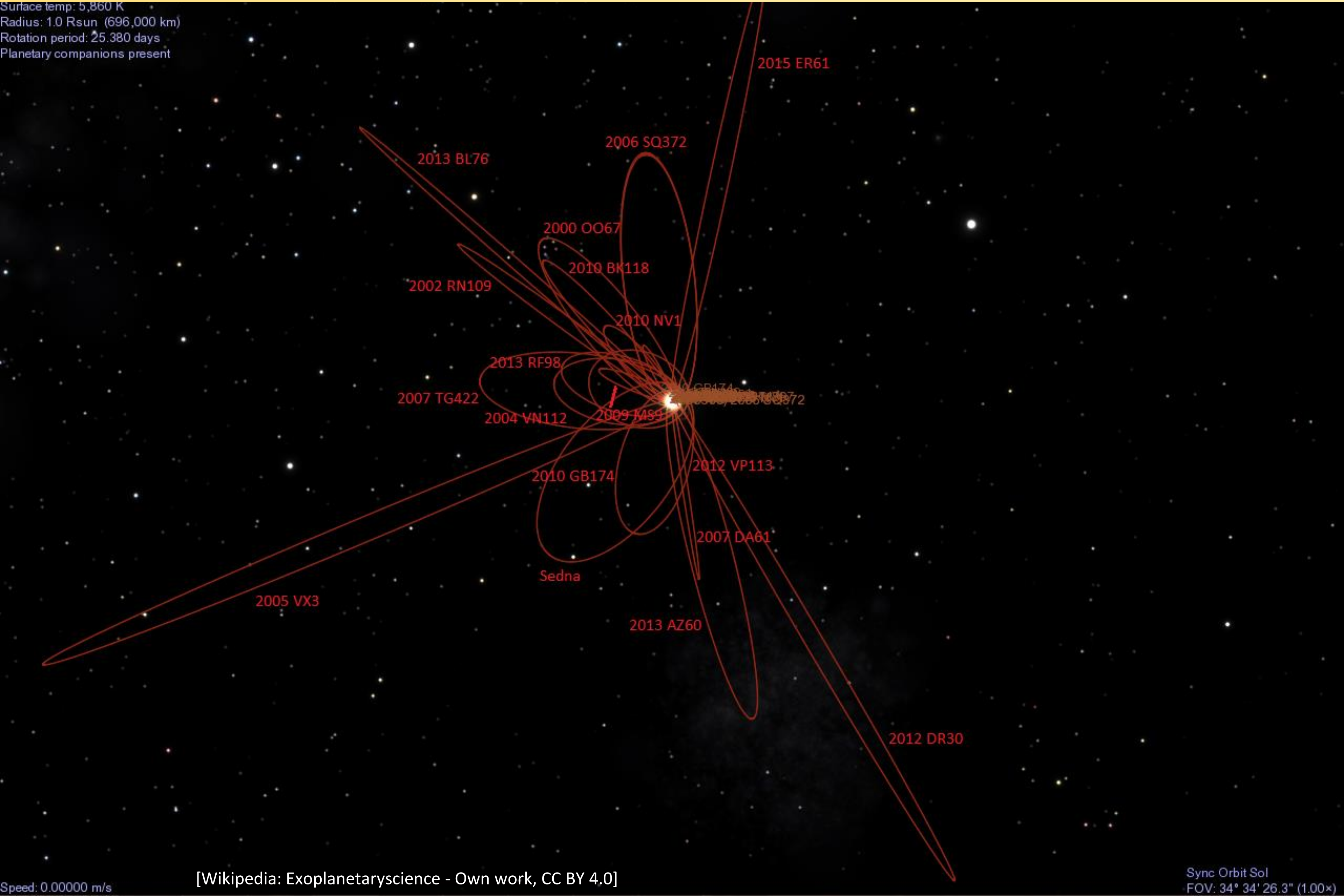


Sedna

Beyond Sedna

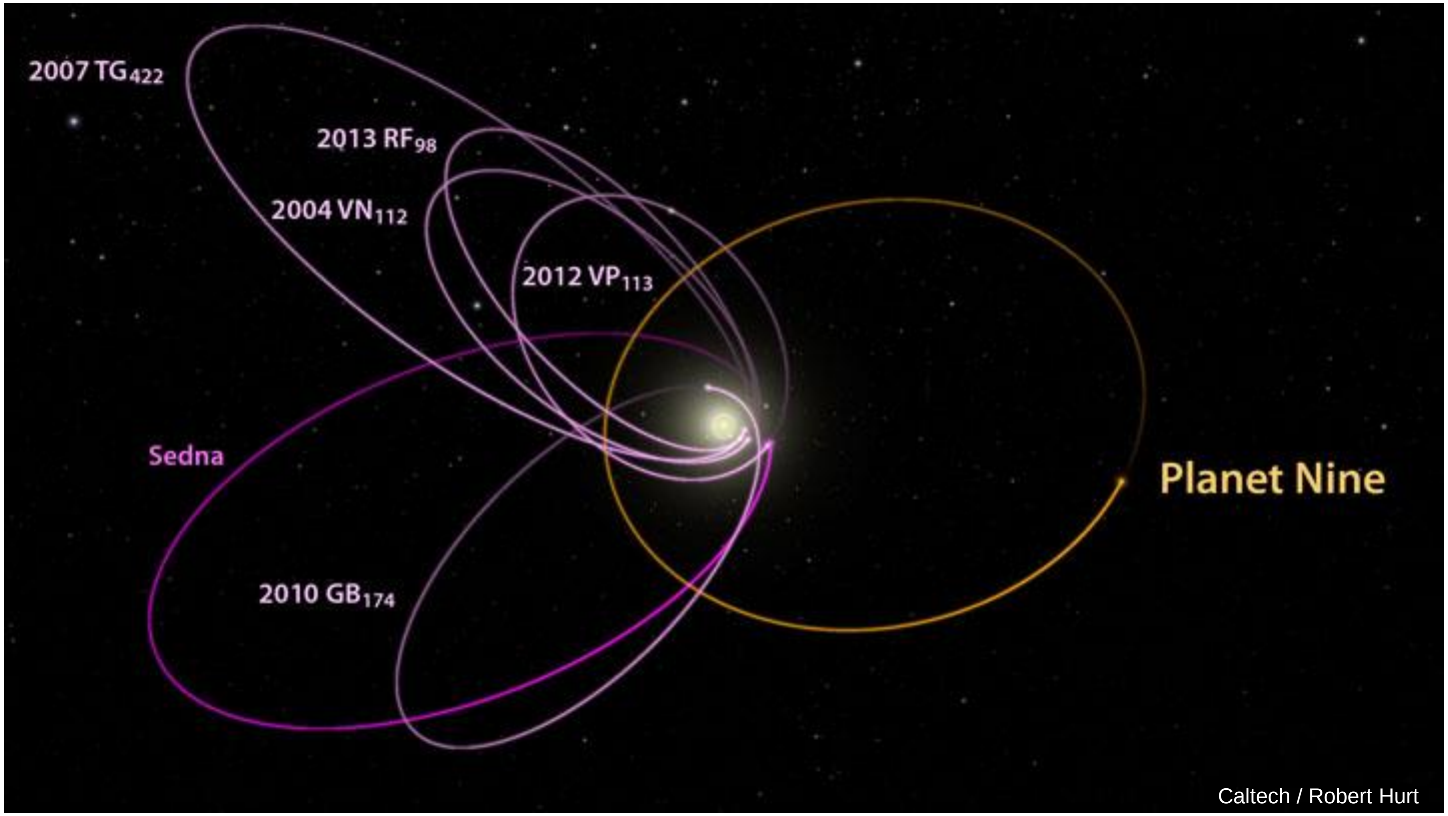


Beyond Sedna



Planet "Nine" ???

- There is speculation that an undetected planet his "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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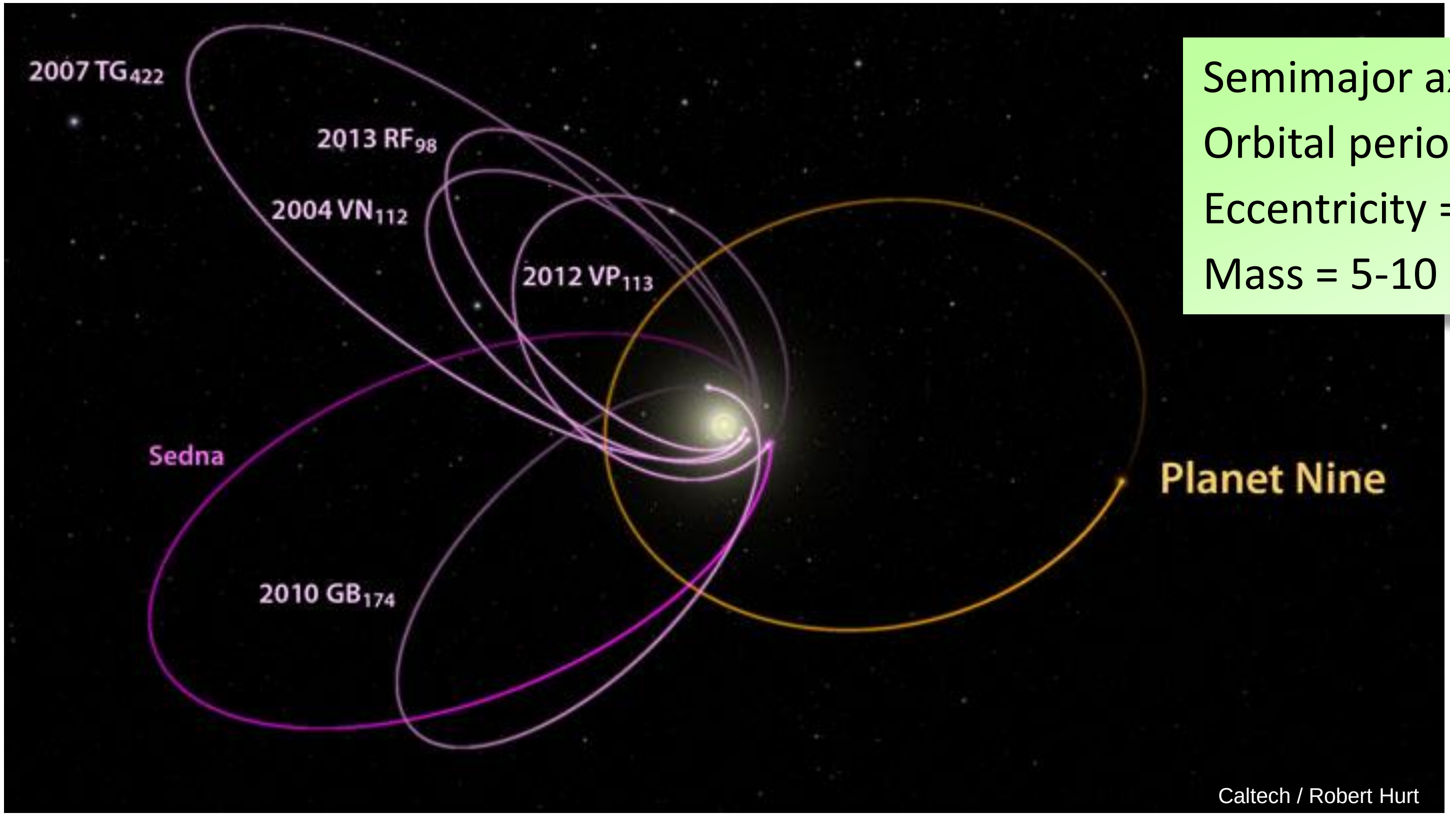


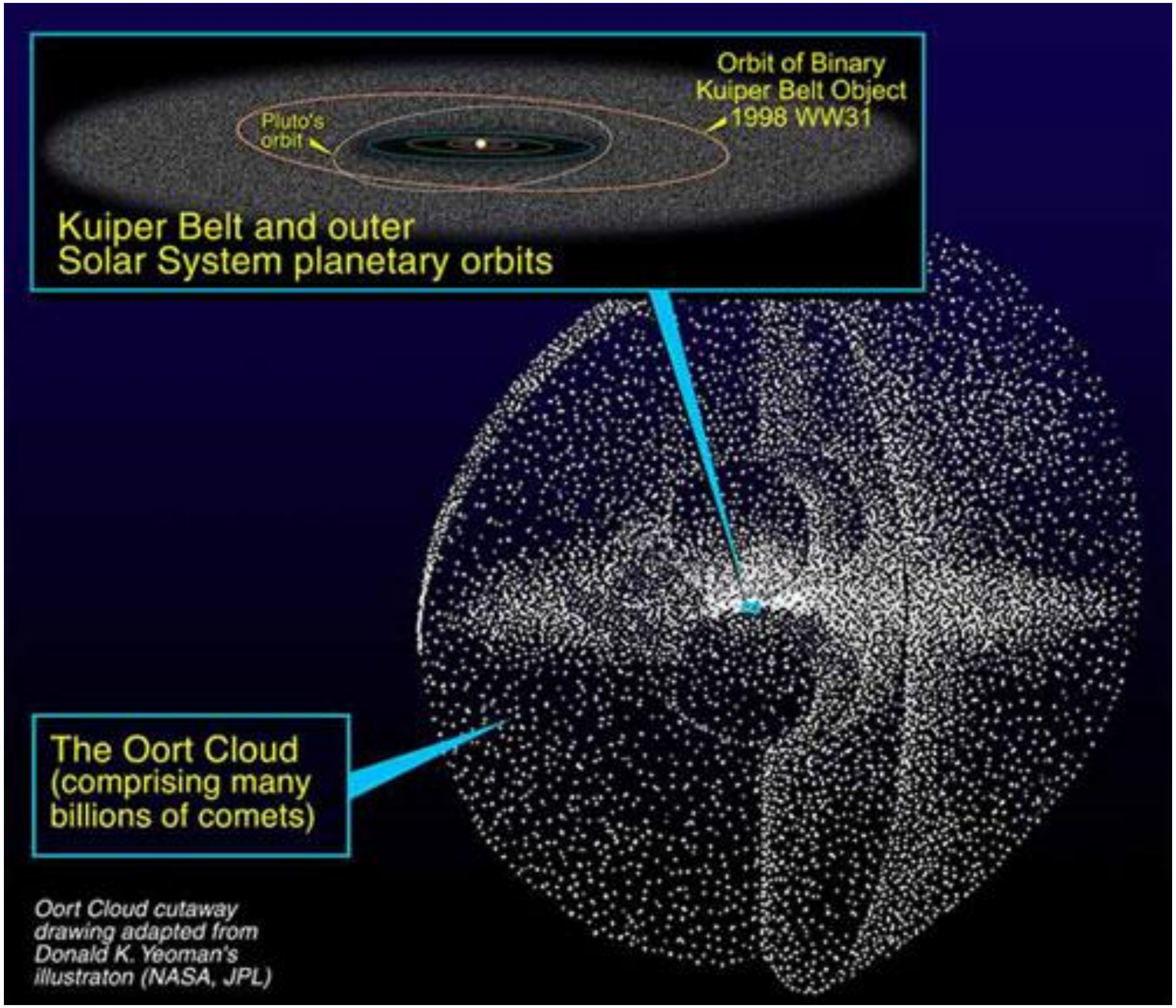
Caltech / Robert Hurt

Semimajor axis = 400-800 AU
Orbital period = 8000-23,000 yrs
Eccentricity = 0.2-0.5
Mass = 5-10 M_{Earth}

Oort Cloud

Theoretical cloud of icy objects that were expulsed 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.
- Billions – trillions of objects.
- Total mass ~ 5 M_{earth}.



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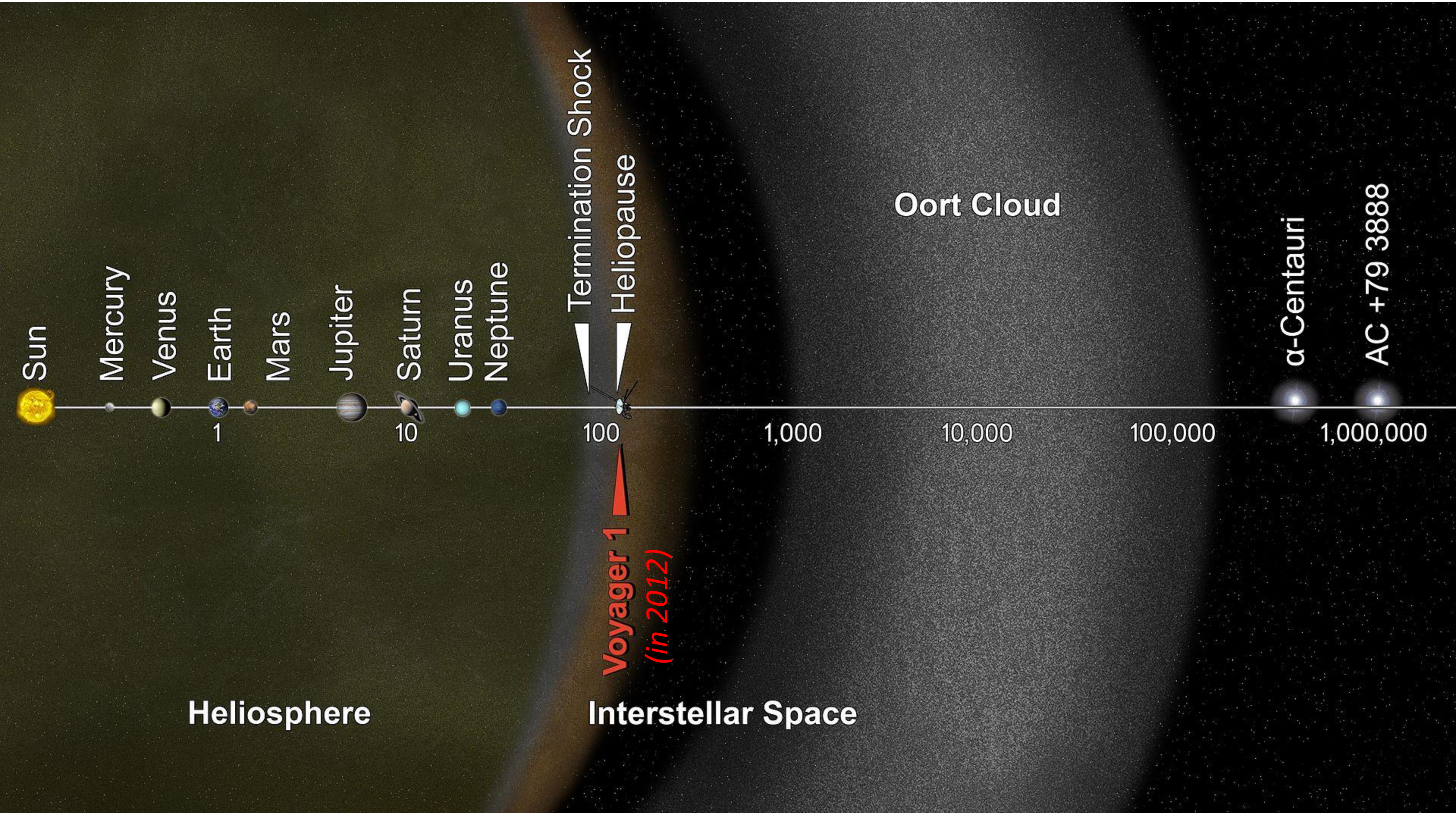

[NASA / JPL-Caltech - http://photojournal.jpl.nasa.gov/catalog/PIA17046]

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).

Hailey’s comet, 1986

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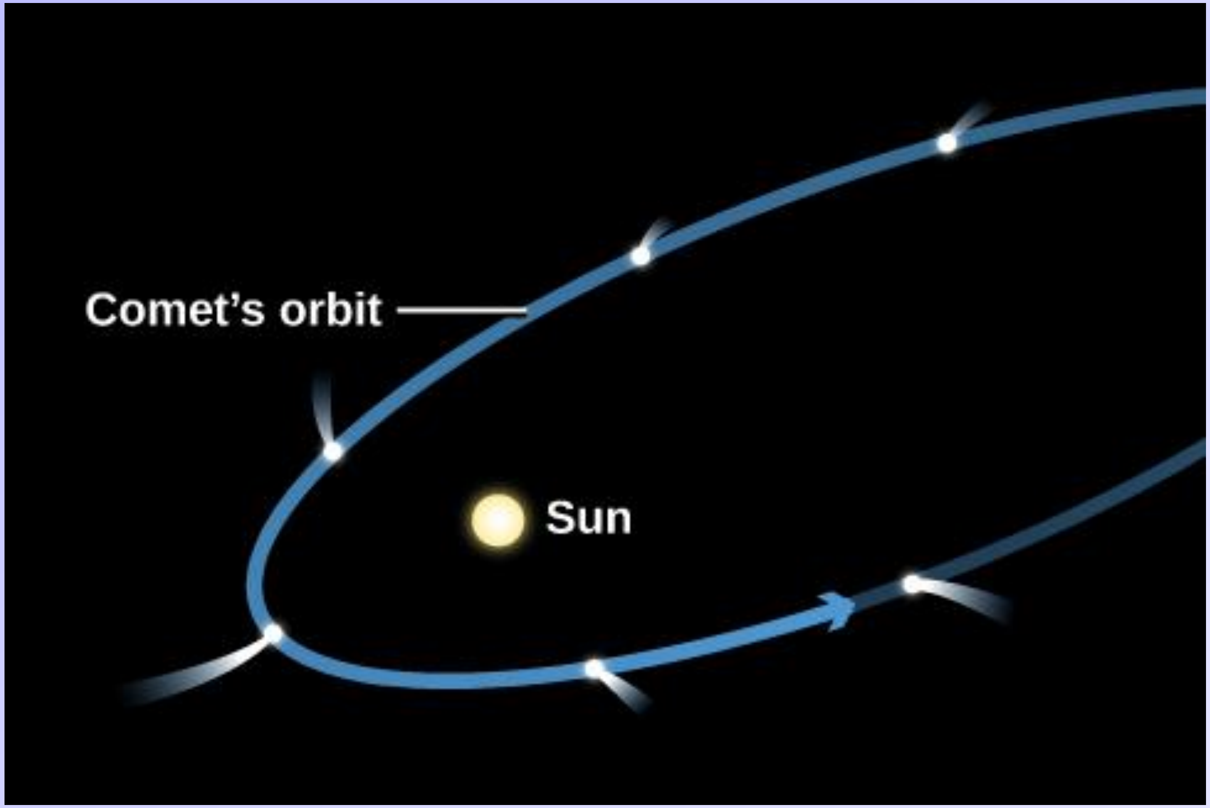
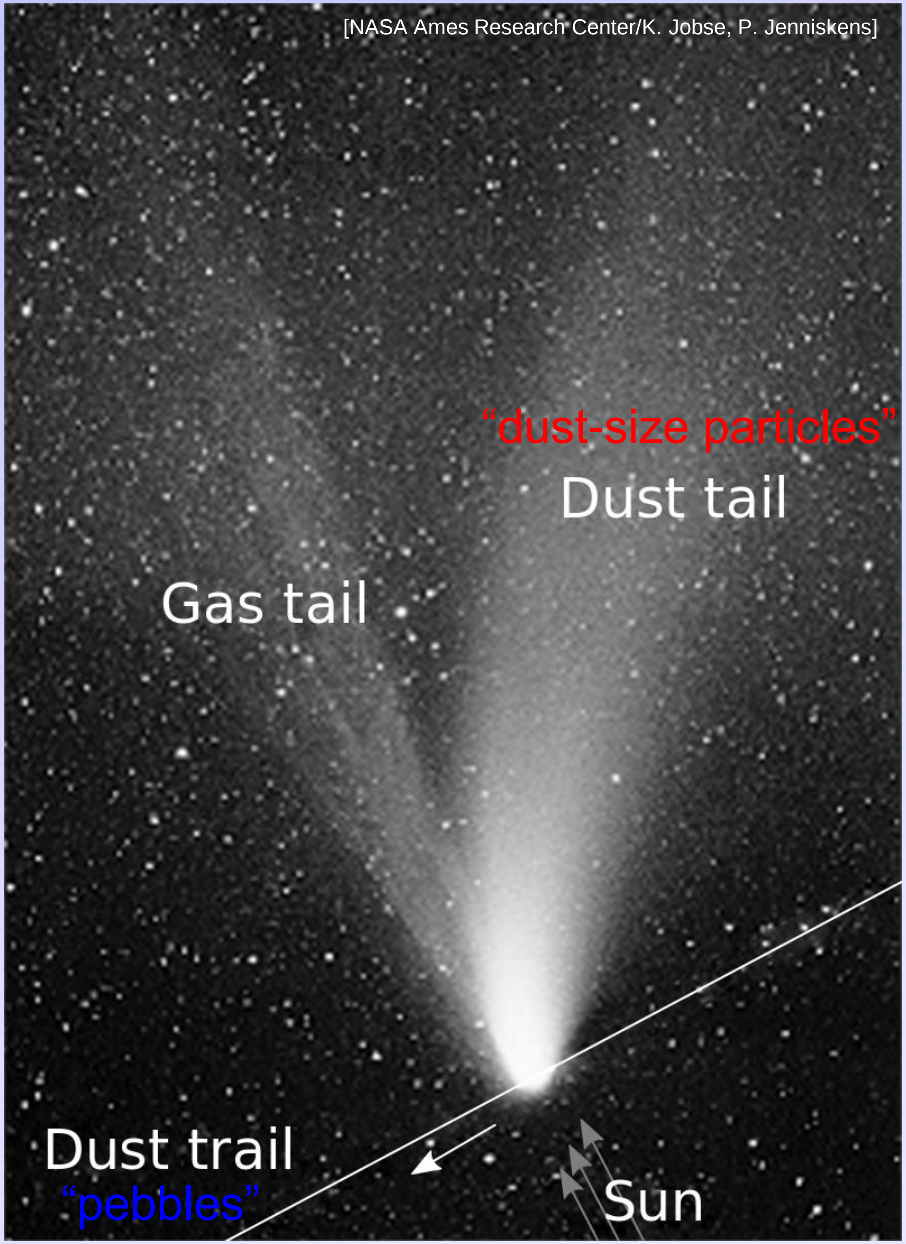


- The **tail** of the comet always points **away from the Sun**.
- The tail is pushed away by the **solar wind.**

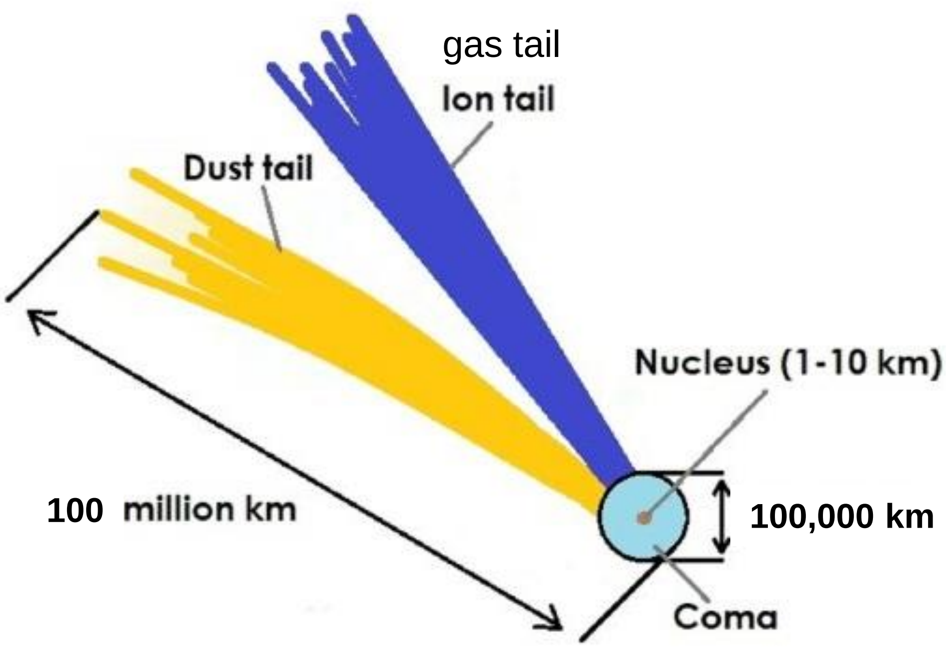
Comets

[NASA: Comet Lovejoy from International Space Station, 2011]

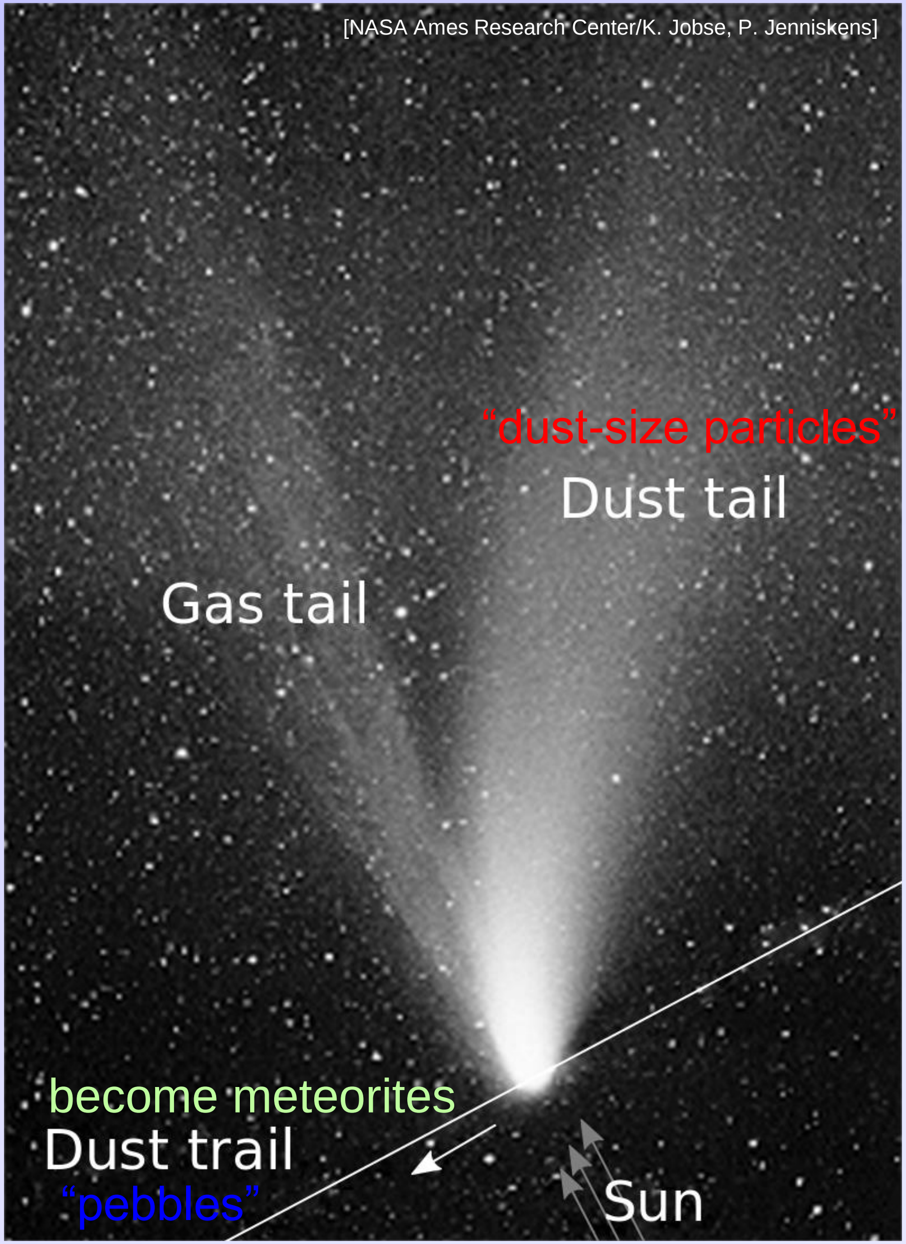


[NASA Ames Research Center/K. Jobse, P. Jenniskens]

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 (H_2O),carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), ammonia (NH_3).
- Rocks, pebbles.
- Left overs from formation of Solar System.

Exoplanets

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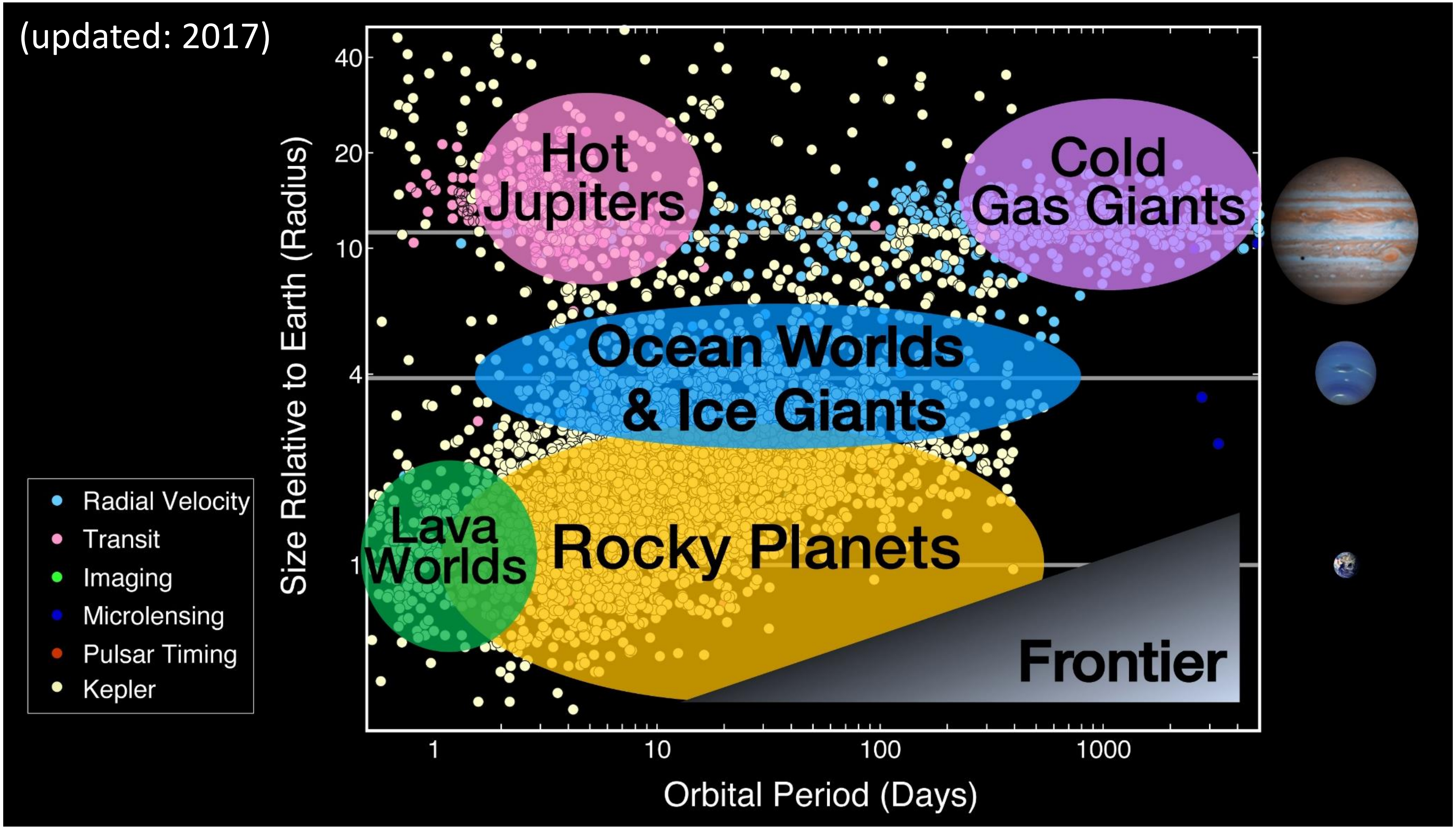
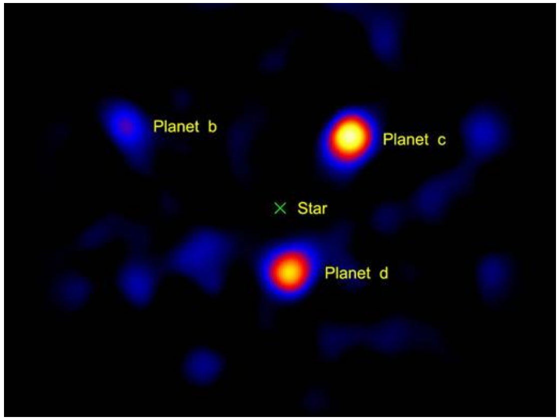


[https://www.nasa.gov/image-feature/ames/kepler/exoplanet-populations]

Exoplanets
What we know so far

- **Most stars (possibly all) have planets.**



3 planets around star HR8799 (120 ly)
Orbits: 24 AU, 38 AU, 68 AU.
[Hale telescope, 2010]

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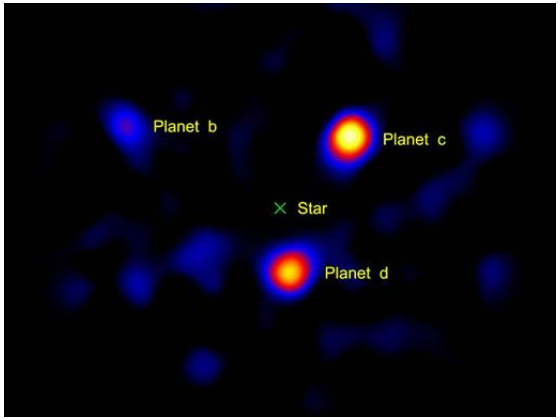
- **Most stars (possibly all) have planets.**
- We see many **gas giants** inside the frost line.

  Models of evolution for solar systems show that planets often perturb the orbits of other planets and **move them towards the star** (or shoot them out).



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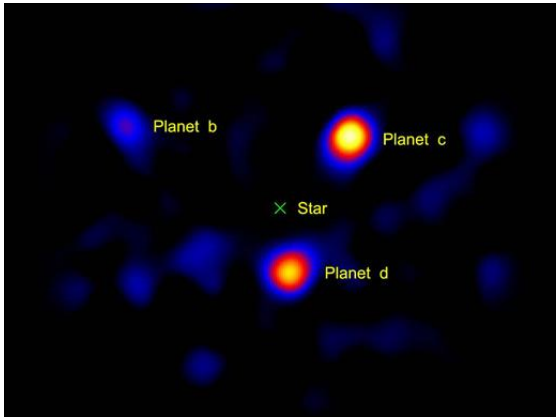
- Roughly 40% of Sun-like stars have terrestrial planets in the **"goldilocks"** region.

  → Above freezing and below boiling for water.

- **Earth-like** planets are very common

  They are harder to detect than larger ones, so we have not seen very many yet.



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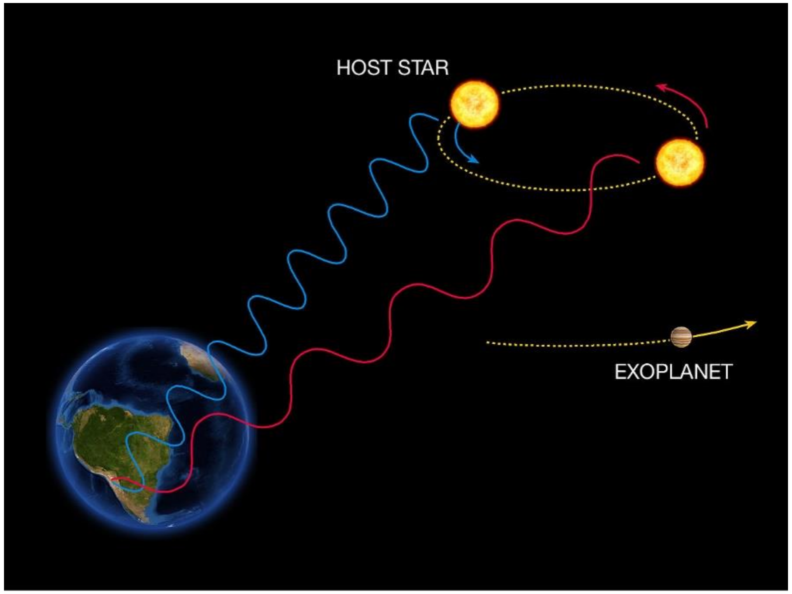
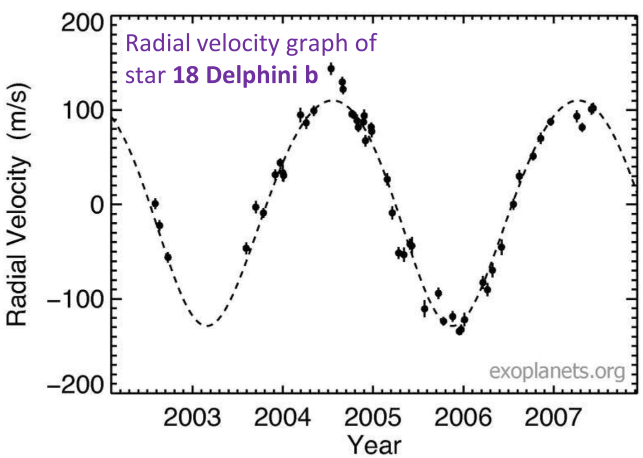
Main Detection Methods



The Radial Velocity Method

ESO Press Photo 22e/07 (25 April 2007)



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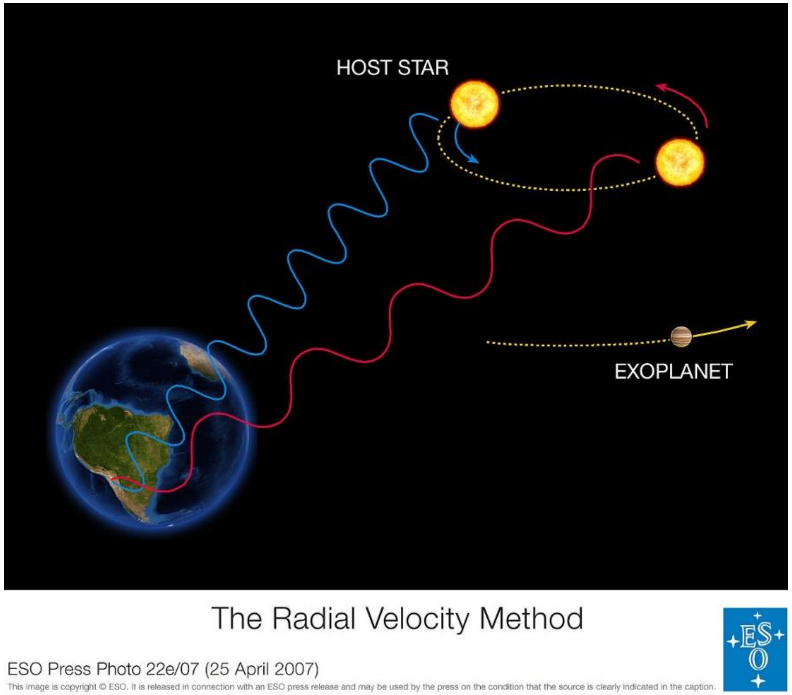
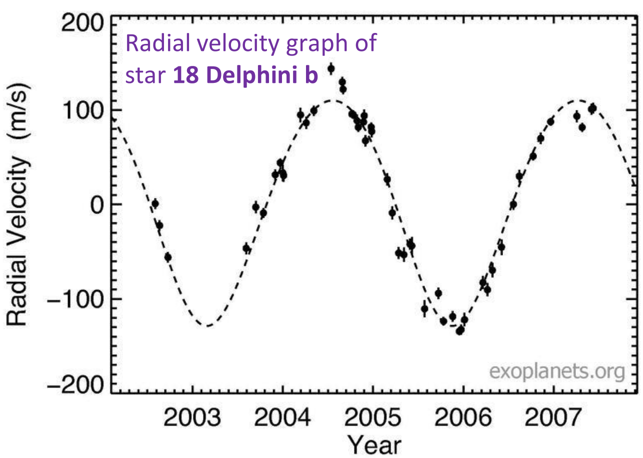
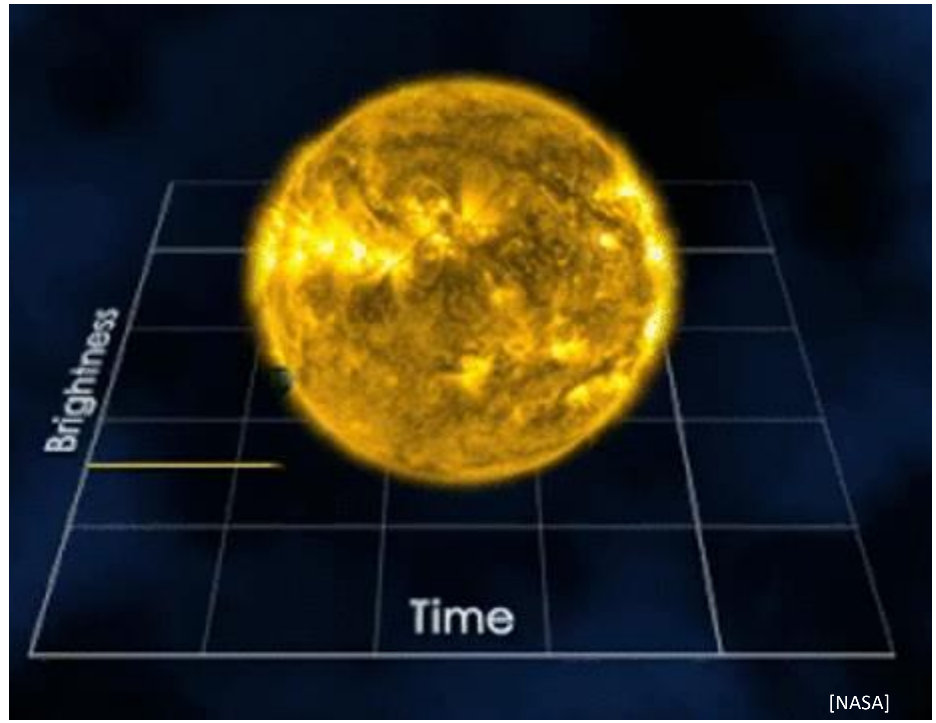




Transit Photometry



Signal is typically 1 part per 10,000 dimming.