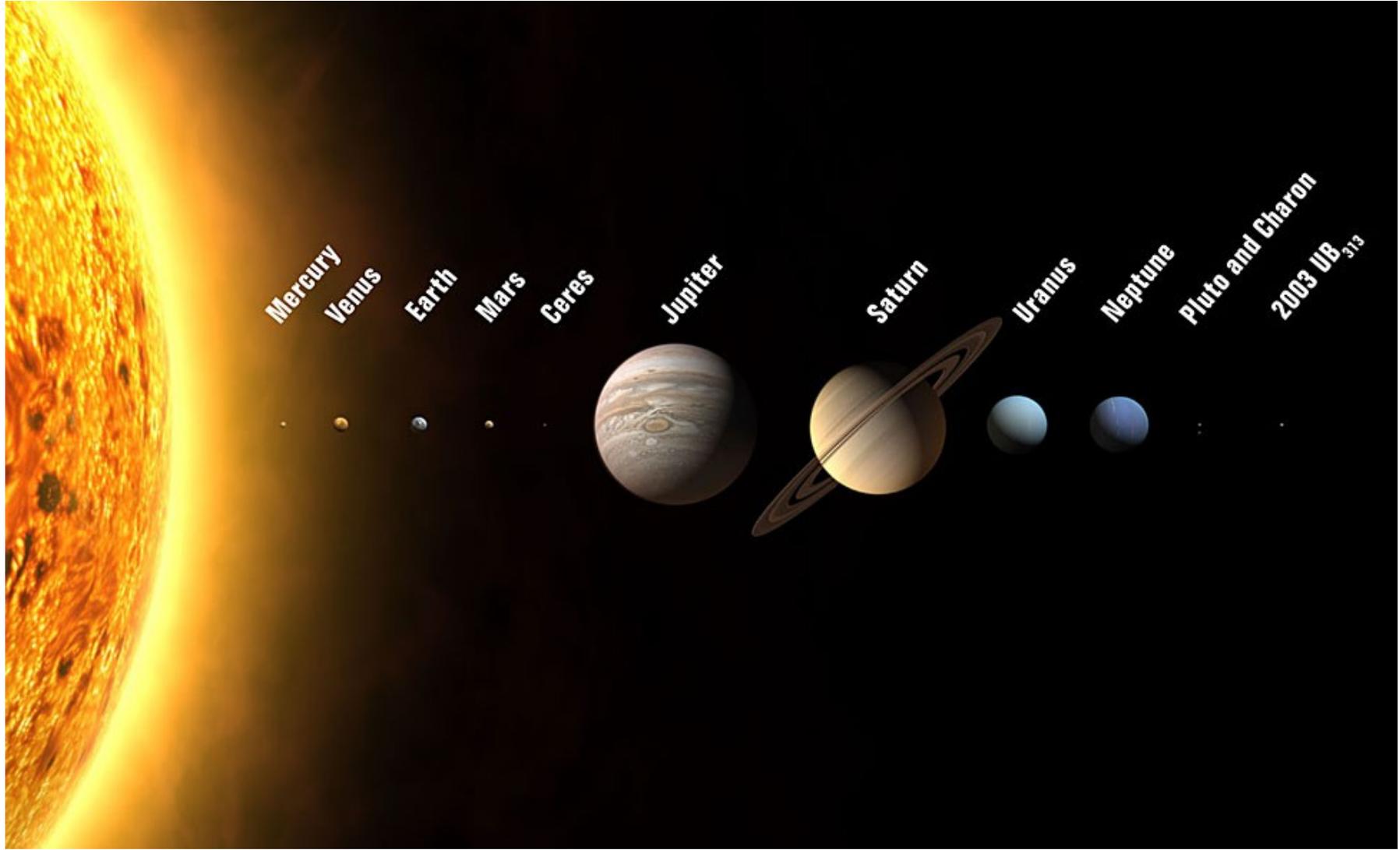

Our Home, The Solar System



Distances To Planets

- Since ancient times, astronomers measured angles on the sky – hence, **relative** distances to planets.
 - Copernicus knew relative distances to about 4%. Kepler knew them to 0.3%.
 - But they still did not know the distance to the Sun (Astronomical Unit) to better than a factor of 20 (2,000%).
-

Measuring Astronomical Unit

- Micrometry:
 - Christian Huygens measured AU to 7% in 1659; did not believe his own result.
 - Triangulation:
 - Need to measure very small angles ✓
 - Need to measure accurately distances between two widely separated points, i.e. to measure latitude ✓ and longitude? accurately
-

The Longitude Problem

- If you know the time, the sky will tell you where you are.
 - Pendulum clocks are accurate, but not on a ship
 - John Harrison, carpenter turned clockmaker, finally created an accurate marine chronometer in 1761.
 - His chronometer was more accurate than your wristwatch.
 - He never succeeded in getting his £20,000 prize.
-

Quest for the value of AU

- Transit of Venus:
 - 1672, Richter & Cassini: 140 million km (=Gm)
 - 1761/69, Jérôme Lalande: 153 ± 1 Gm
 - 1874/82, Simon Newcomb: 149.59 ± 0.31 Gm
- Radar observations:
 - Modern value: $149,597,870,691 \pm 30$ m
- Lunar Laser Ranging experiment measures the distance from the Apache Point Observatory (NM) to the reflector on the Moon with 1 mm precision.

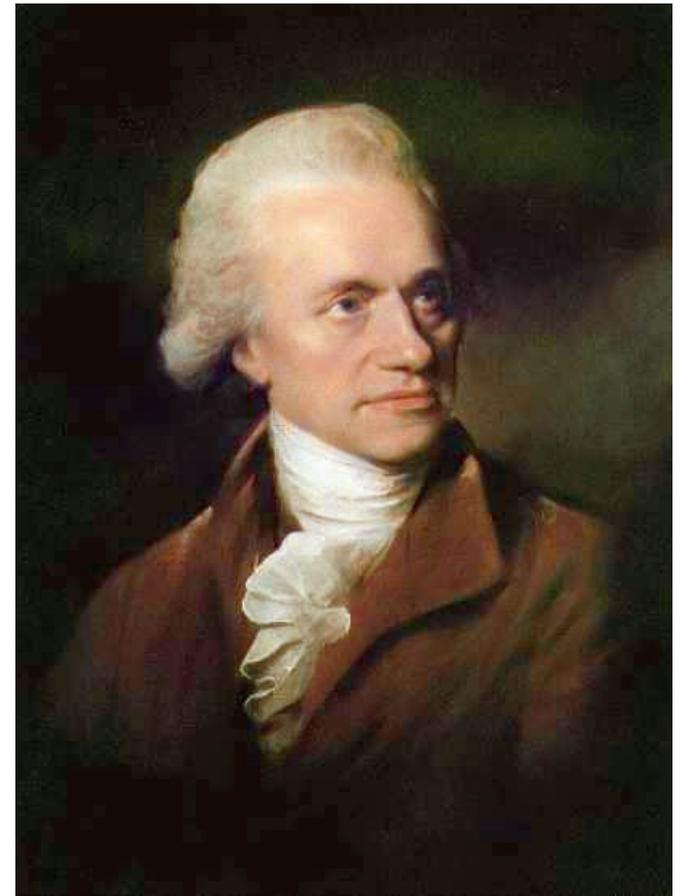
Discovery of Uranus

- 1690: John Flamsteed (“The Unlucky Guy”) catalogued Uranus as 34 Tauri and observed it at least six times.
- 1750-1769: Pierre Lemonnier observed Uranus at least twelve times between 1750 and 1769, including on four consecutive nights.



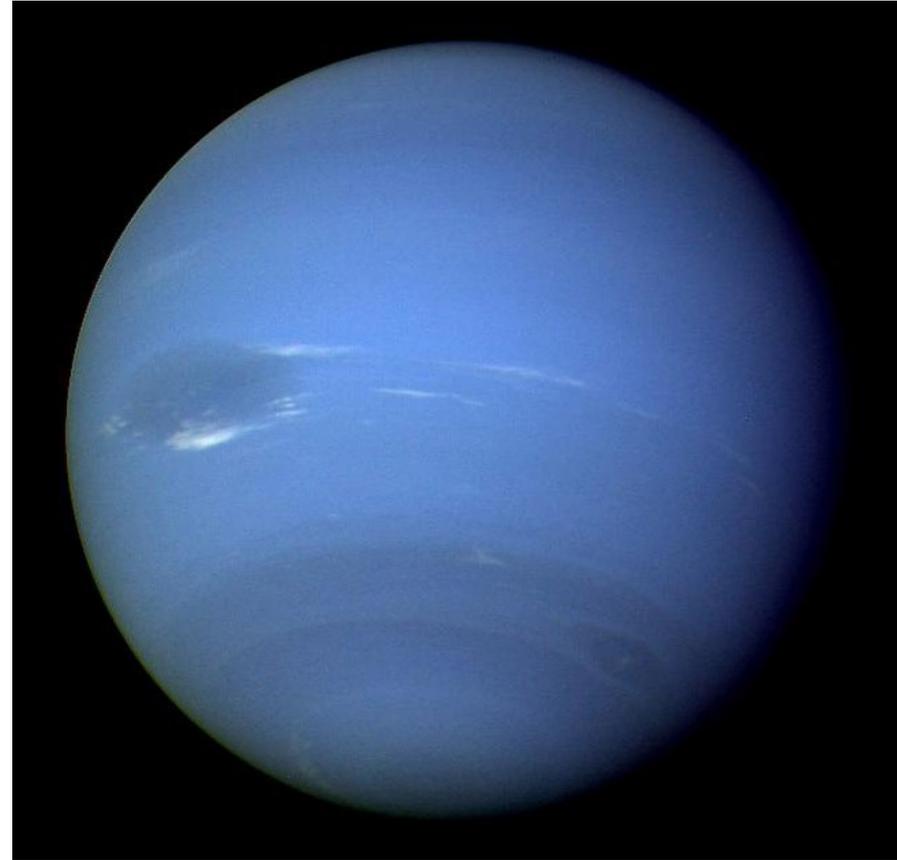
Discovery of Uranus

- 1781: William Herschel observed it and reported as a comet. Only later it became apparent it was a new planet.
- He called it “*Georgium Sidus*” (George's Star) in honor of king George III.
- Only after Herschel's death the name Uranus got widespread use.



Discovery of Neptune

- 1612: Galileo observed it twice, took for a fixed star.
- 1821: Alexis Bouvard published astronomical tables of the orbit of Uranus.
- Deviations from Kepler's laws were very significant.

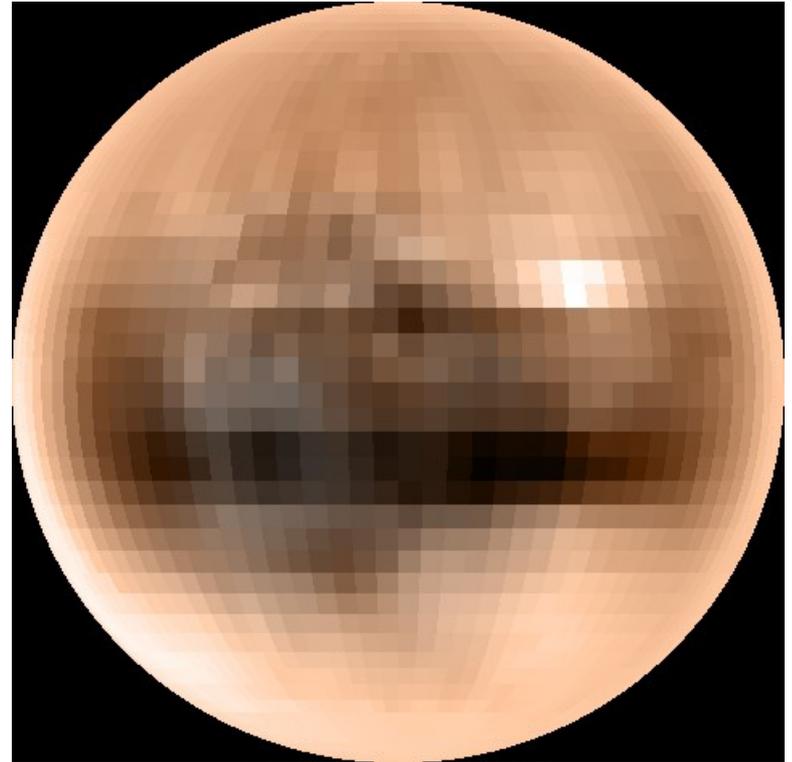


Discovery of Neptune

- 1845–46: French mathematician Urbain Le Verrier computed properties of a hypothetical planet that should be disturbing Uranus.
 - He sent a letter to Berlin Observatory, predicting the position of a new planet.
 - His letter arrived on September 23, 1846; Neptune was discovered the next night.
 - Le Verrier first proposed name “Neptune”; then changed his mind and named a new planet after himself. Too late.
-

Pluto: Its Rise and Fall

- By the end of 19th century it became clear that Neptune alone is not enough to explain anomalies in the orbit of Uranus.
- 1905-1916: Percival Lowell (AZ) spent years looking for “Planet X”.



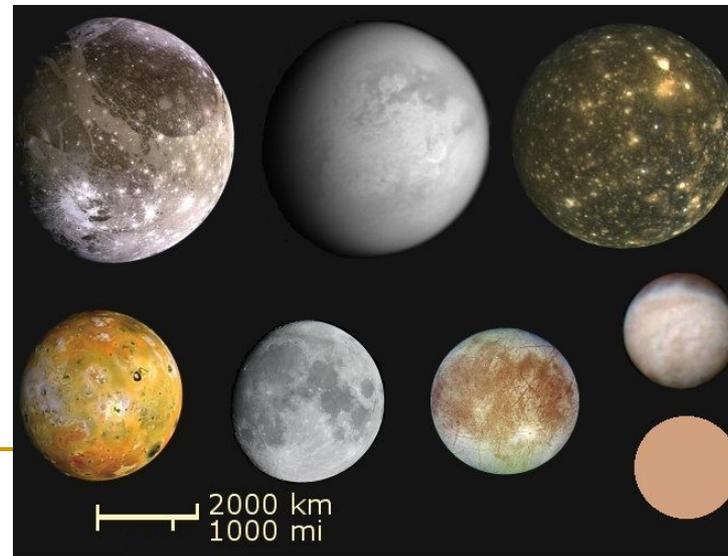
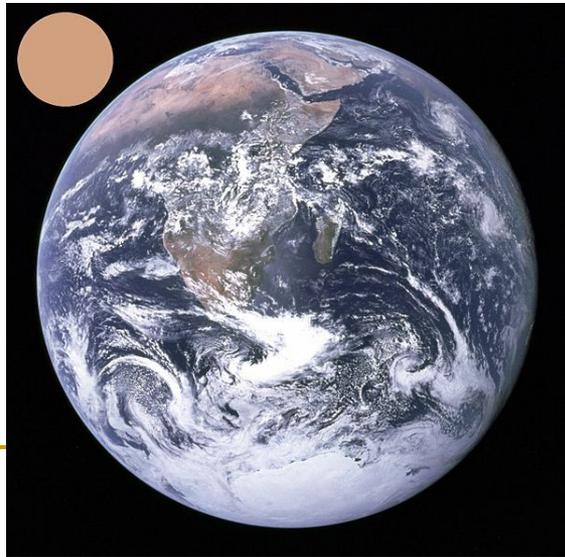
Pluto: Its Rise ...

- 1929: Vesto Slipher handed the job of looking for Planet X to a newly hired 22-old assistant Clyde Tombaugh (former farm hand in Kansas).
- 1930, Feb 18: Clyde walks into history by discovering Pluto.
- Name proposed by Venetia Burney, English schoolgirl.
- Pluto is a Greek god of underworld. In Greek underworld it is cold and dark.



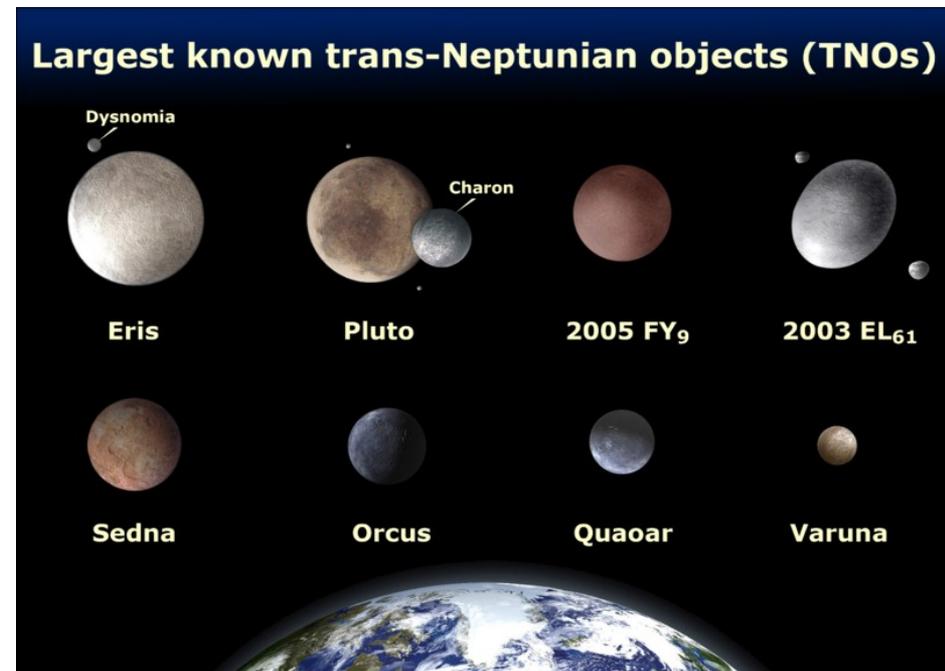
Pluto: A Weird Planet

- Pluto has nothing to do with anomalies in Uranus orbit – it is too small.
- It is smaller than large satellites of other planets; comparable in size to asteroids and *Kuiper belt* objects.



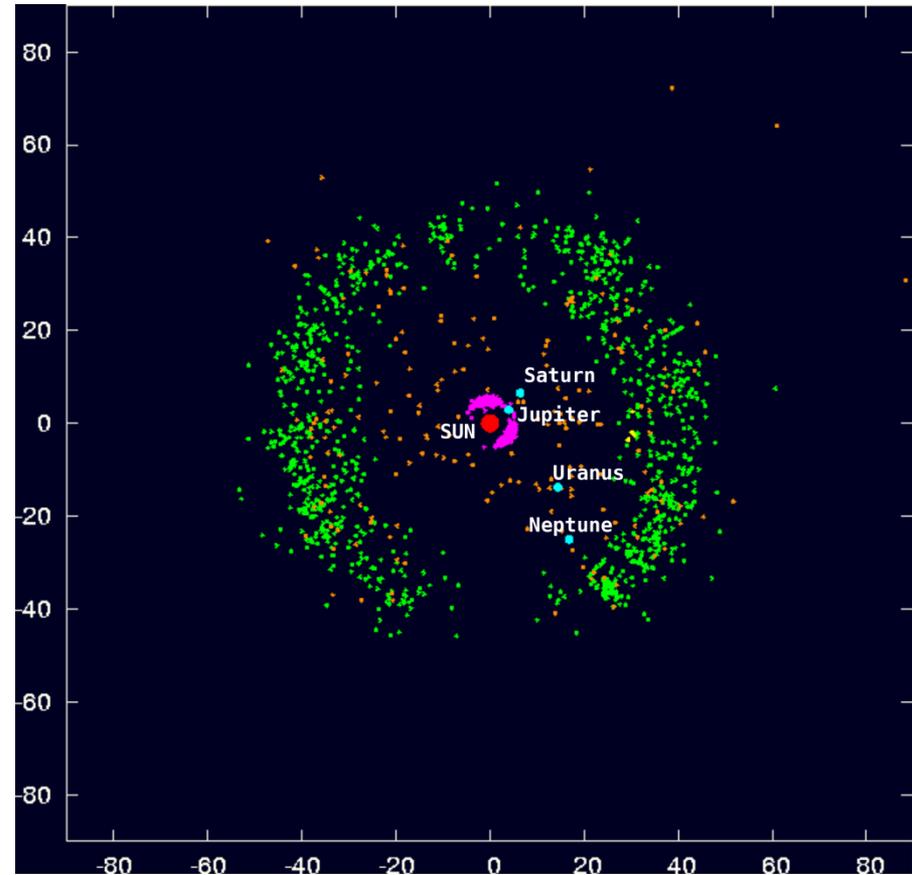
Pluto: ... and Fall

- 2006, Sep 13: Pluto is reclassified by IAU as a ***dwarf planet*** (bigger than a ***minor planet***).
- Dwarf planets:
 - ❑ Ceres (1801, planet for 50 yrs)
 - ❑ Pluto (1930, planet for 76 yrs)
 - ❑ Eris (2003, planet for ~week).

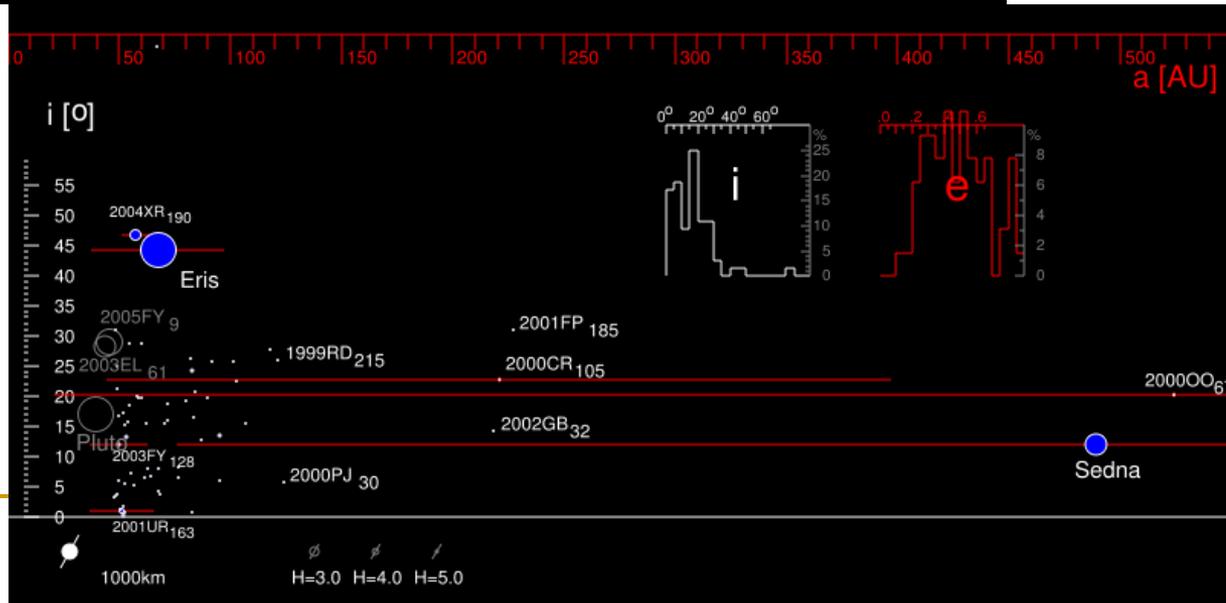
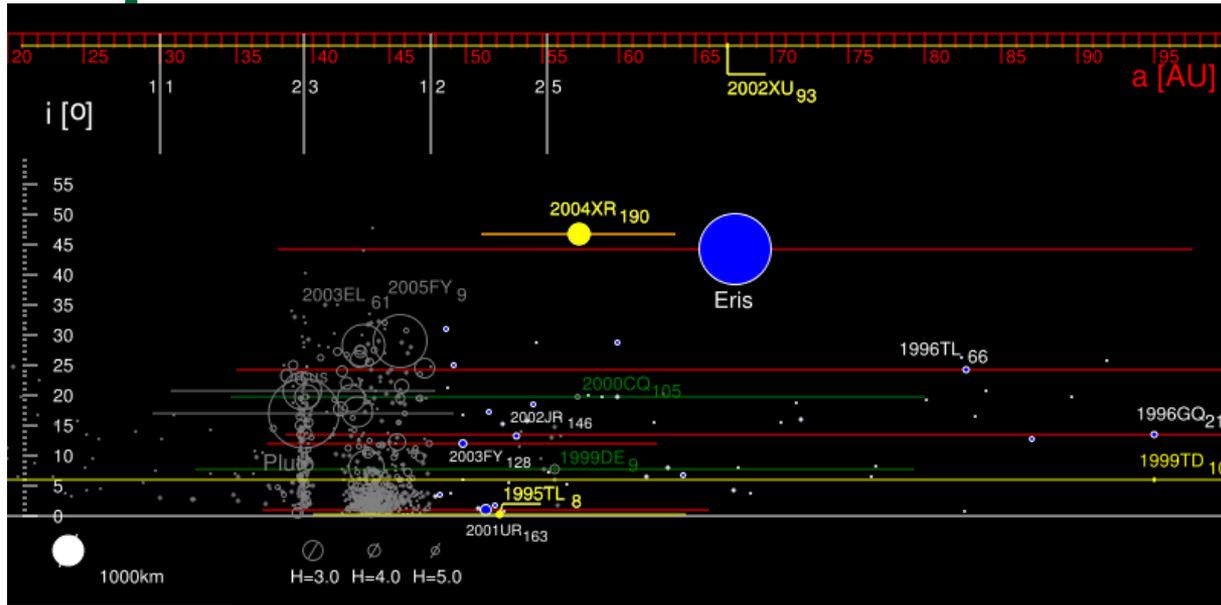


Trans-Neptunian Objects

- There is a lot of junk beyond Neptune (Pluto included).
- Most of bigger objects are located in *Kuiper belt*.
- Beyond that lies *Oort Cloud*, where the comets come from.

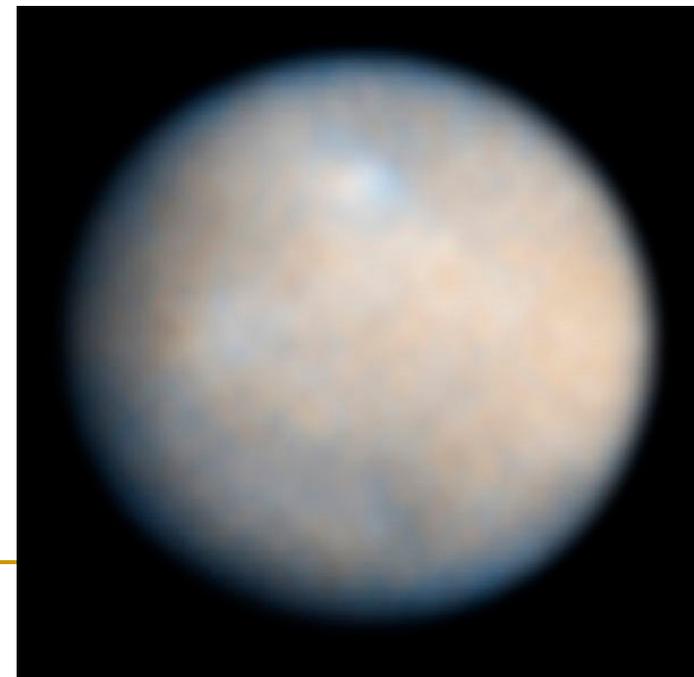
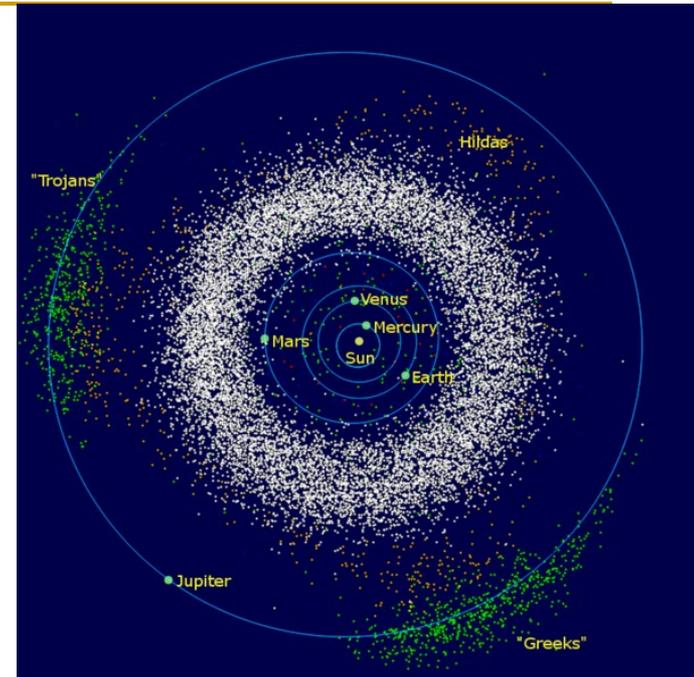


Kuiper Belt & Scattered Disk



Asteroids

- Asteroids are chunks of rock.
- Most of them are located in the **asteroid belt**.
- The largest one is ***Ceres***.
- The asteroid belt was once thought to be the debris of a destroyed planet, Phaeton.



Titius–Bode “Law”

- Named after Johann Titius and Johann Bode.
- Claims that the distances of planets from the Sun satisfy the sequence:

$$D = 0.4 + 0.1 * n$$

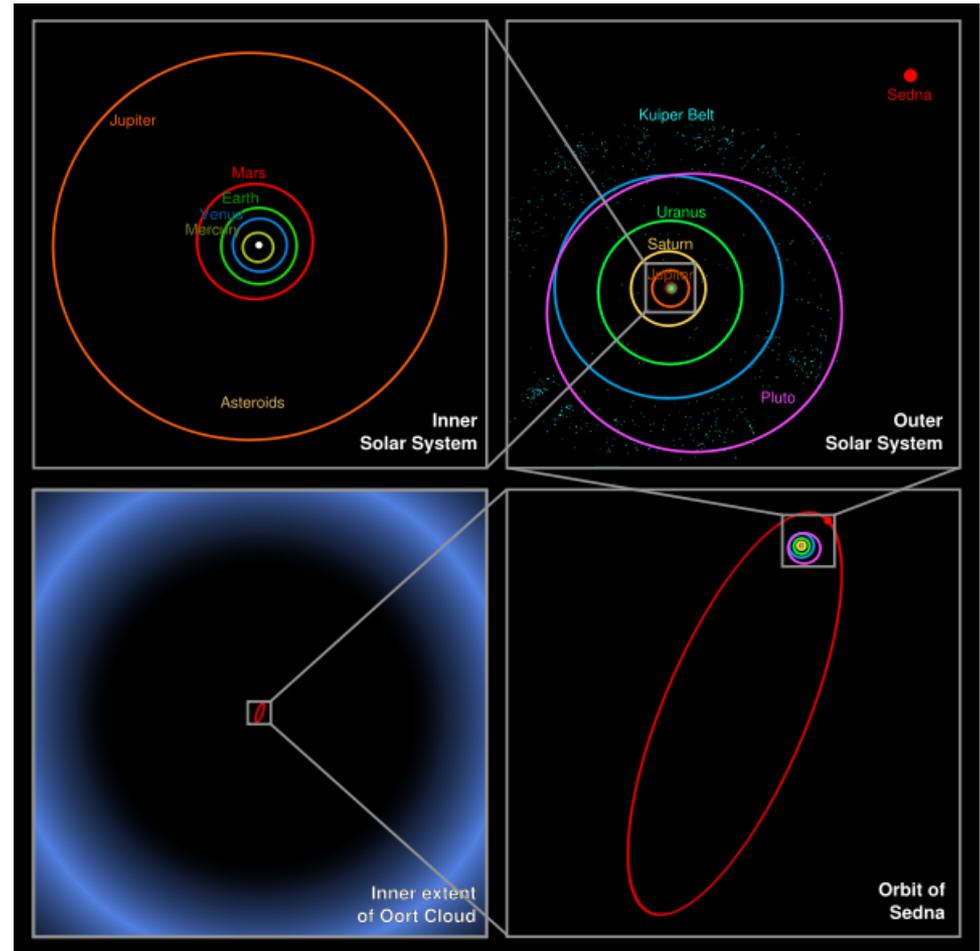
with $n=0,3,6,12,$ etc

- Doesn't actually work

Planet	k	T-B rule distance (AU)	Real distance (AU)	% error (using real distance as the accepted value)
Mercury	0	0.4	0.39	2.56 %
Venus	1	0.7	0.72	2.78 %
Earth	2	1.0	1.00	0.00 %
Mars	4	1.6	1.52	5.26 %
Ceres ¹	8	2.8	2.77	1.08 %
Jupiter	16	5.2	5.20	0.00 %
Saturn	32	10.0	9.54	4.82 %
Uranus	64	19.6	19.2	2.08 %
Neptune	128	38.8	30.06	29.08 %
Pluto ¹	256	77.2 ²	39.44	95.75 %

Comets and Oort Cloud

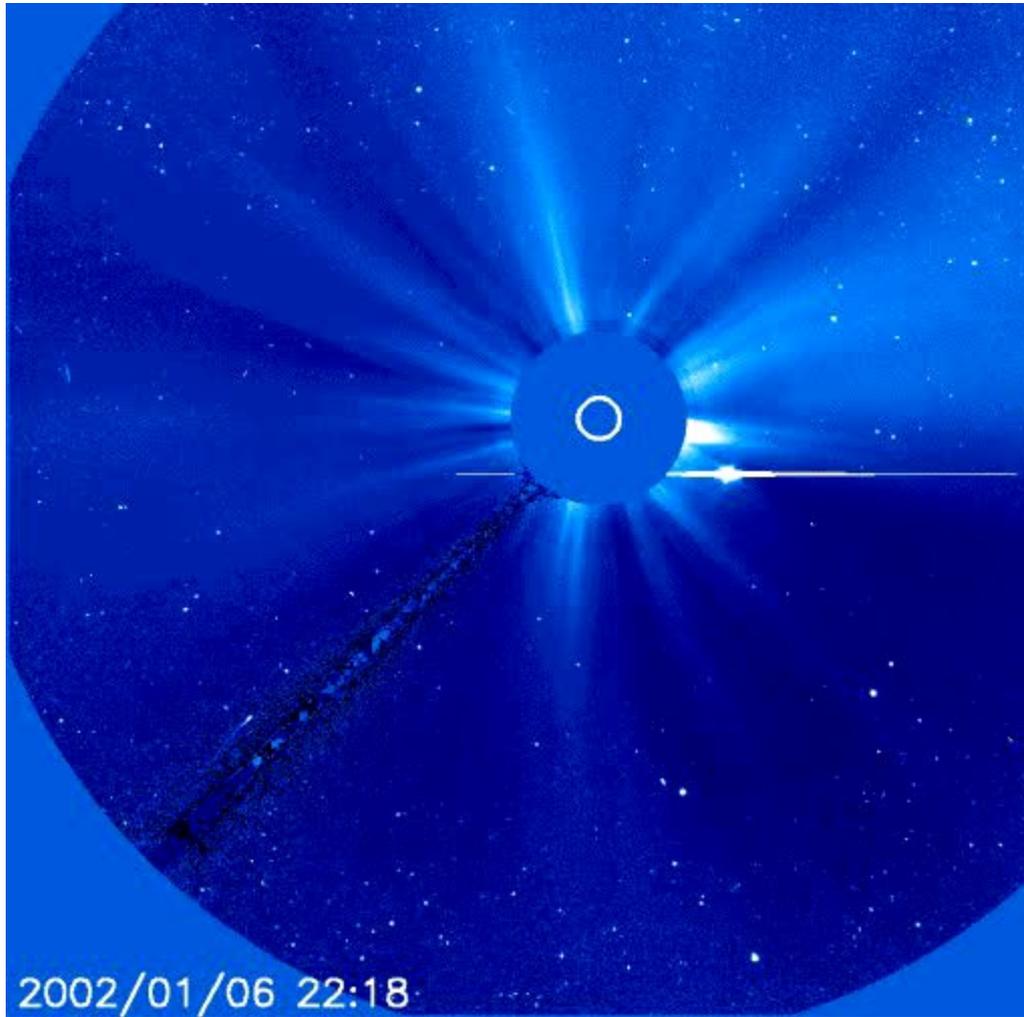
- Comets are chunks of dirty ice.
- Long-period comets are on unstable orbits, must form somewhere else – "Oort Cloud".
- Its existence is still a hypothesis.



Comets Falling Into The Sun



Comet 96P/Machholz



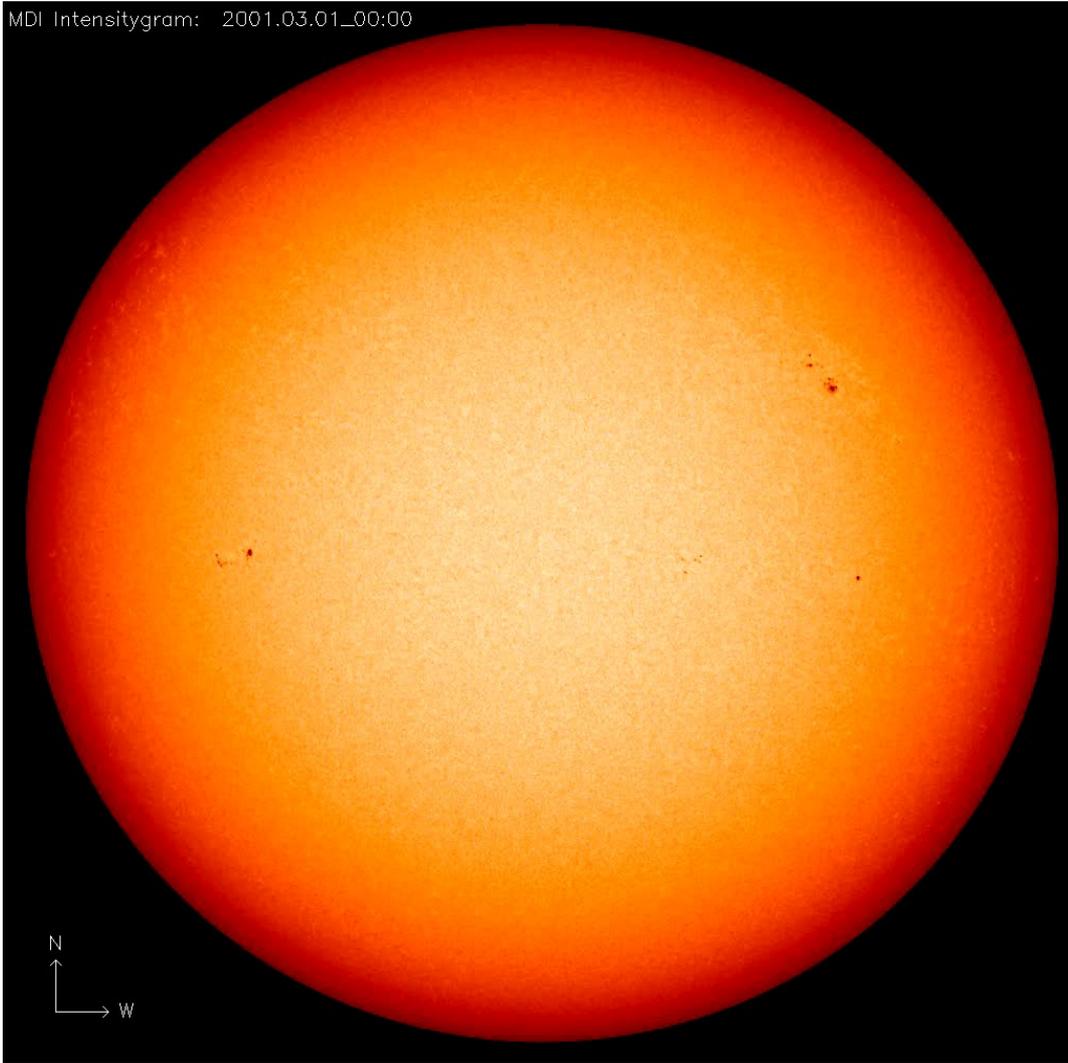
Transit of Mercury

MDI Continuum Filtergram 7-May-2003 07:45 UT ; Focus Setting 5



How Sun Got Its Spots

MDI Intensitygram: 2001.03.01_00:00



Meet Your Killer (Near Earth asteroids)

Asteroids program
