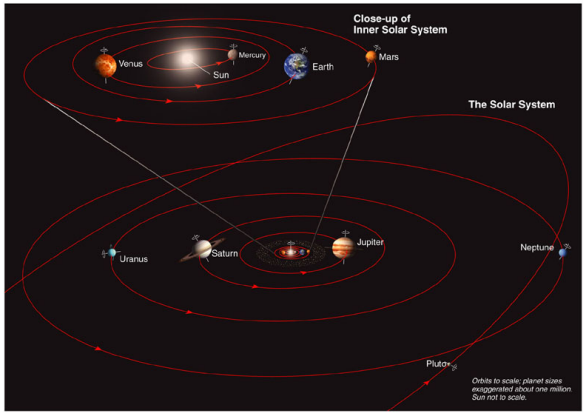
Solar System overview

1) inventory
2) spin/orbit/shape
3) heated by the Sun
4) how do we find out



Inventory
1 star
(99.9% of M)
8 planets
(99.9% of L)
- Terrestrial:
Mercury
Venus
Earth
Mars
- Giant:
Jupiter
Saturn
Uranus
Neptune

Lots of small bodies incl. dwarf planets
Ceres
Pluto
Eris

Maybe a 9th planet?

Inventory (cont'd)

Many moons & rings

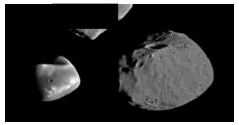
Mercury: 0
Venus: 0
Earth: 1 (1700km)
Mars: 2 (~10km)

Jupiter: 69 + rings
Saturn: 62 + rings
Uranus: 27 + rings
Neptune: 14 + rings

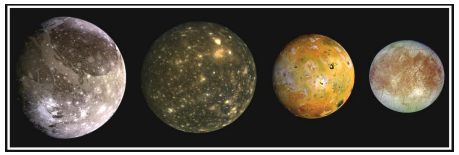
Even among dwarf planets, asteroids, Kuiper belt objects, and comets. E.g.,

Pluto: 5
Eris: 1

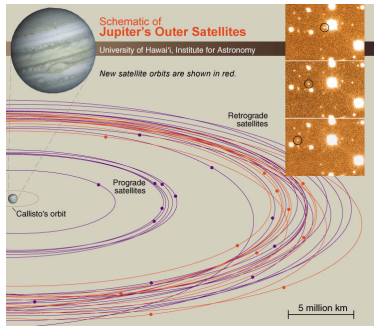
Moons of Mars:
Deimos & Phobos, ~10km

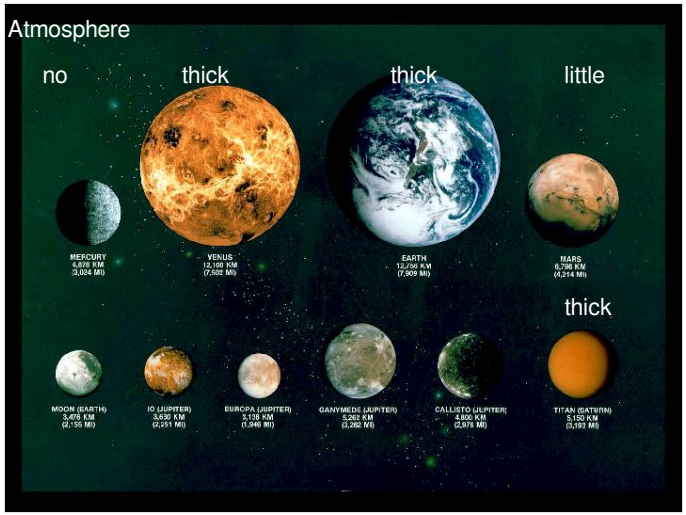


Moons of Jupiter
4 Galilean satellites (Ganymede, Callisto, Io & Europa), ~10^3 km (close to Jupiter, likely primordial)



2001J3: 4km





Inventory (cont'd)

~10^5 known small objects in the

- **Asteroid belt**
(Ceres ~300 km)

- **Kuiper belt**
(Eris, Pluto, Sedna, Quaoar, ~1000 km)

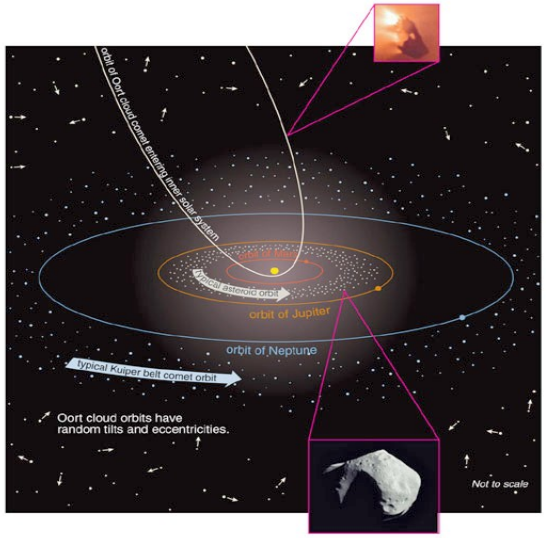
Estimated: ~10^{12} comets in the

- **Oort cloud**
(~ 10^4 AU)

Associated:

- **zodiacal dust**

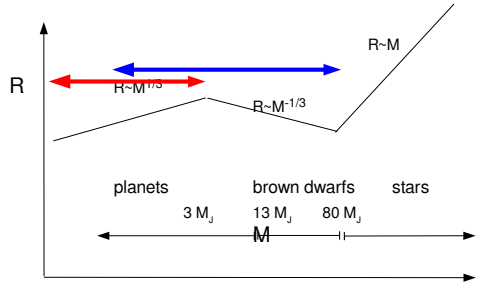
(fire-works on the sky: comets & meteorites)



What are planets?

IAU (for solar system):
Orbits Sun, massive enough to be round and to have cleared its neighbourhood.

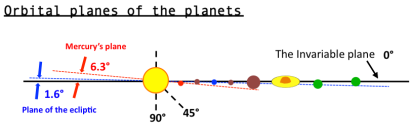
More general:
1) no nuclear fusion (not even deuterium): $T_c < 10^6$ K
2) pressure provided by electron degeneracy and/or Coulomb force
   (l ~ h/p ~ d) (d ~ atomic radius)
3) can be solid or gaseous (with solid cores) --- *similar density*



Mass & Mean ρ	M_J	[g/cm³]
Jupiter	1.0	1.33
Saturn	0.3	0.77
Neptune	0.05	1.67
Uranus	0.04	1.24
Earth	0.003	5.52
Venus	0.002	5.25
Mars	0.0003	3.93
Mercury	0.0002	5.43

Orbits

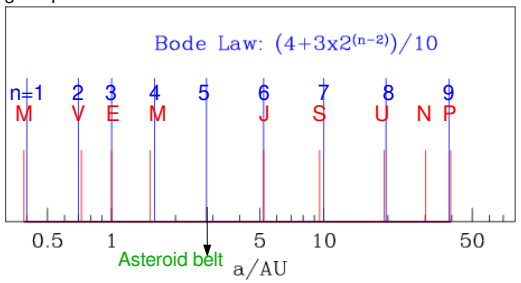
inclination: largely coplanar (history)
direction: all the same
eccentricity: a few percent
(except for Mercury)



Mercury	6.3°	Uranus	1.0°
Venus	2.2°	Saturn	0.9°
Mars	1.7°	Neptune	0.7°
Earth	1.6°	Jupiter	0.3°

Titus-Bode (fitting) law (1766)
planetary orbits appear to (almost) satisfy a single relation
'Predict' the existence of the asteroid belt (1801: Ceres discovered)
coincidence or something deeper?
other systems?

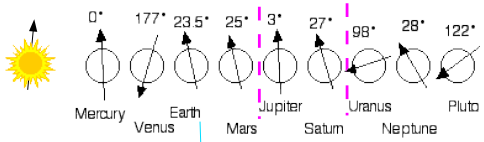
Computer simulations indicate that planets are as maximally packed as allowed by stability.



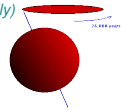
Spin (obliquity)

smaller planets:
almost random, affected by impacts and giant planets

Real giant planets (J&S):
~aligned with orbit, stable



Earth's spin-axis precesses (mildly) while Mars sweeps around wildly

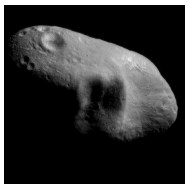


Shape --- *the bigger the rounder*

All gaseous planets are spherical.
Large rocky objects are rather spherical. Smaller ones are less so.

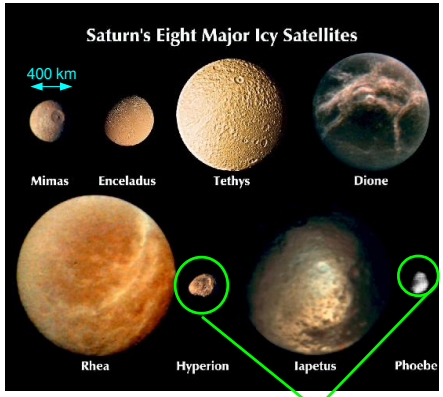
The Moon (~1700km)

an asteroid (~50km)



	h (km)	R (km)	g=GM/R² (m/s²)
Earth	8	6400	9.8
Mars	24	3400	3.7

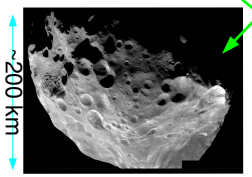
scaling: highest mountain on Earth ~8 km (on Mars ~ 24 km) **h * g ~ constant**
rough estimate: irregular body has mountain h ~ R ==> R ~ 240 km
thus: objects with R > 240 km are approximately spherical

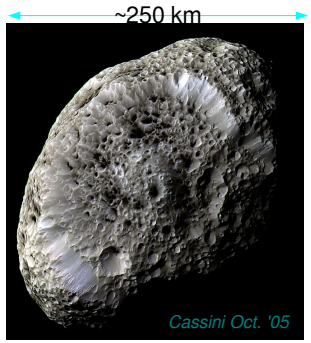


The bigger the rounder

	ΔR/R	g=GM/R²
Earth	8/6400	9.8 m/s²
Mars	24/3400	3.7 m/s²

Hyperion: 150/250 ~0.4 m/s²





Passively Heated by the Sun *--- the further the cooler*

Typically we observe objects in reflected light, however, all objects emit re-processed thermal radiation which is observable at longer wavelengths.

Blackbody temperature for a non-self-luminous spherical body at distance ***a*** away from the Sun (with albedo *A* -- reflectivity)

$$L_{abs} = (1-A)\frac{\pi R_p^2}{4\pi a^2}\, 4\pi R_s^2 \sigma T_s^4; \quad L_{em} = 4\pi R_p^2 \sigma T_p^4$$

If $L_{abs}=L_{em}$, *then* $T_p = \left(\frac{R_o}{2a}\right)^{1/2} T_s (1-A)^{1/4}$

	a (AU)	A	T_{pred}(K)	T_{act}(K)	
Mercury	0.4	0.06	422	100-725	(?)
Venus	0.7	0.77	230	733	(?)
Earth	1	0.30	255	288	(?)
Mars	1.5	0.25	218	223	good
Jupiter	5	0.51	113	125	(?)
Saturn	9	0.47	83	95	(?)
Uranus	19	0.51	60	60	good
Neptune	30	0.62	40	60	(?)
Comet at	5000	0.51	3.4		

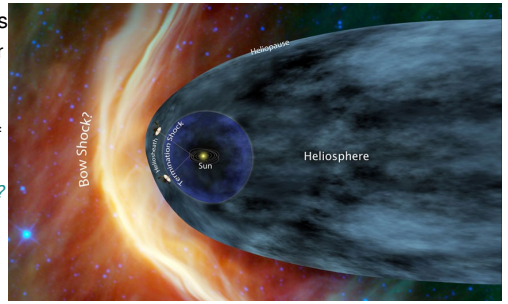
How do we know?

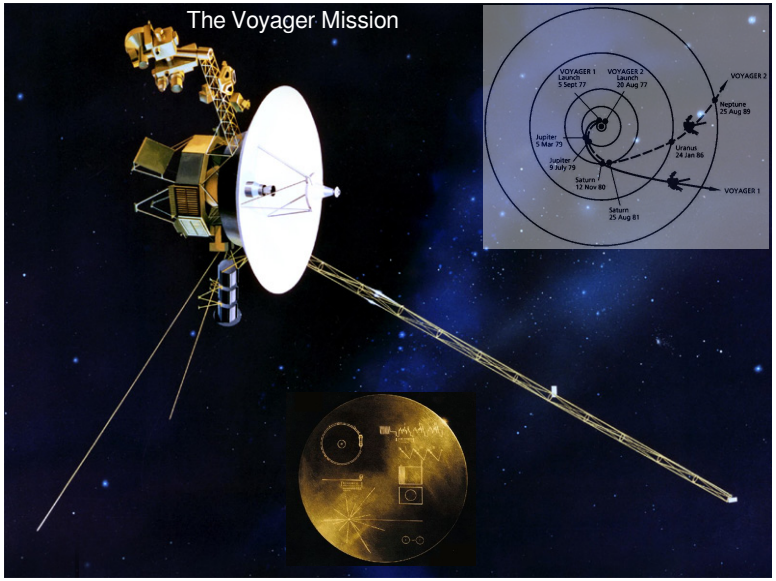
presence:
orbit:
size: angular size; occultation of a star; radar signal strength; lander; blackbody+albedo
mass: orbits of moons; perturbation on other planets; artificial moon
rotation:
magnetic field:
core:
surface composition:
rings:
...

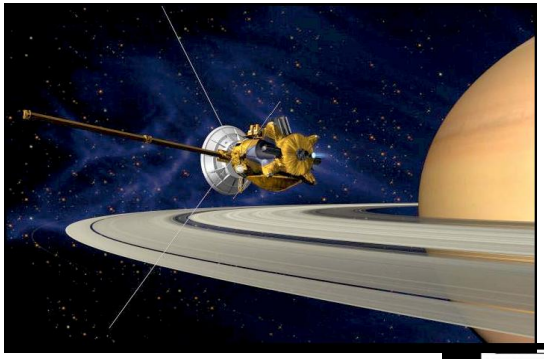
Notable planetary missions

Voyager 1 now an Interstellar Mission
interstellar material outside heliopause

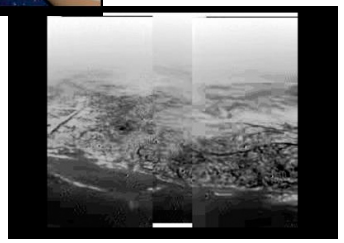
Cassini just ended its visit of Saturn & dropped Huygens probe on Titan
Ethane sea on the surface?



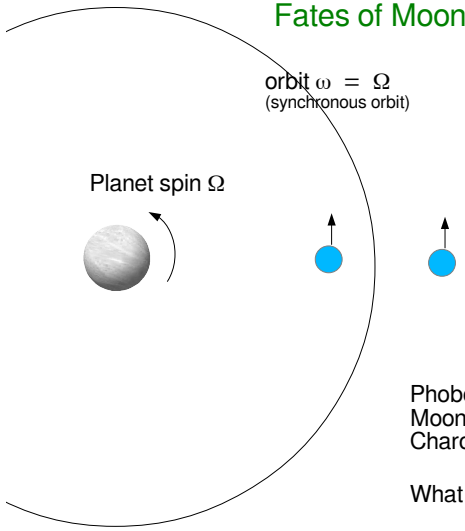




The Cassini-Huygens Mission



Fates of Moons



Phobos (@Mars): 7.6 hr
Moon (@Earth): 1 month
Charon (@Pluto): 6 day

What about retro-grade moons?