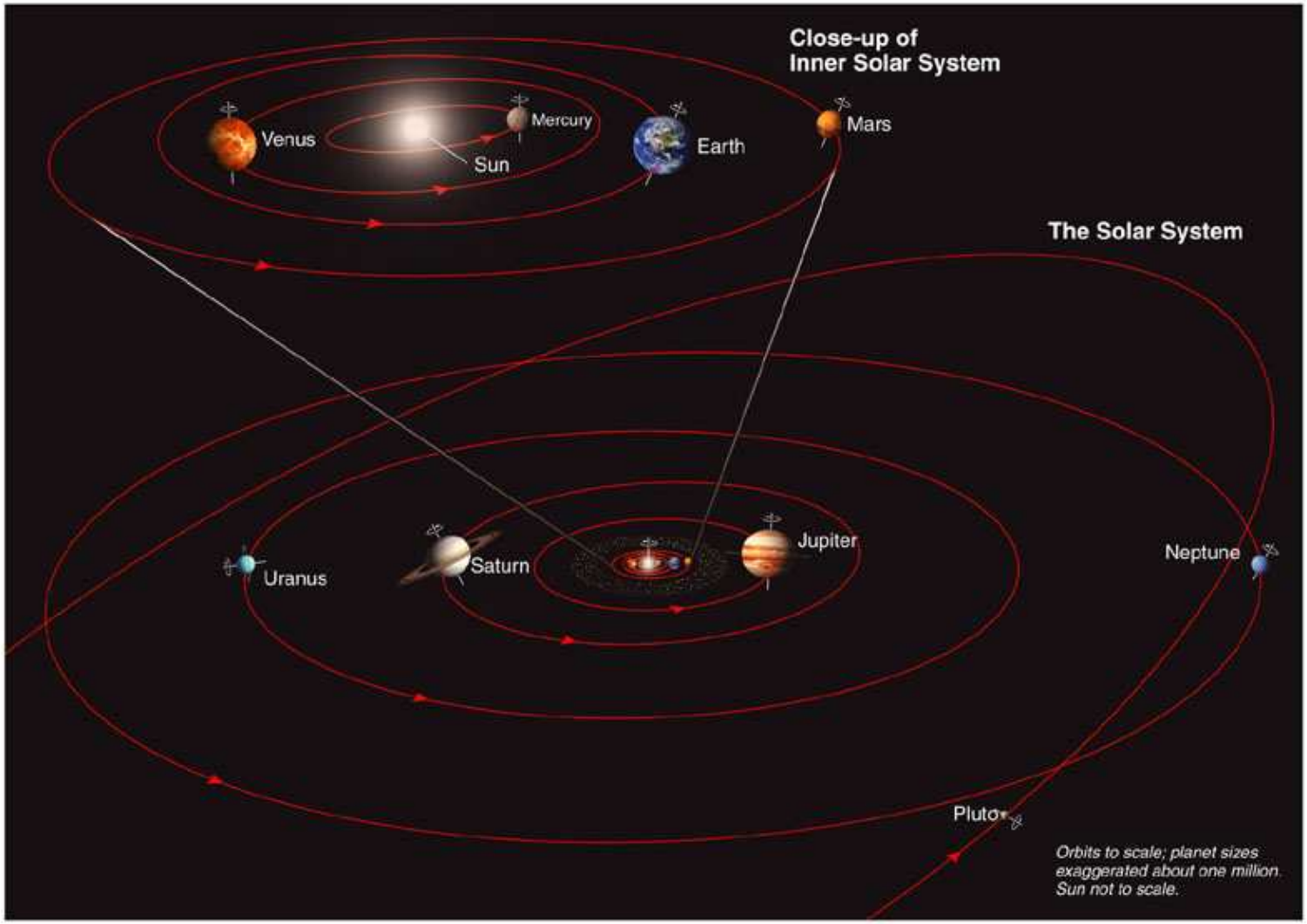
Solar System overview

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

Inventory (cont'd)

Many moons & rings

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

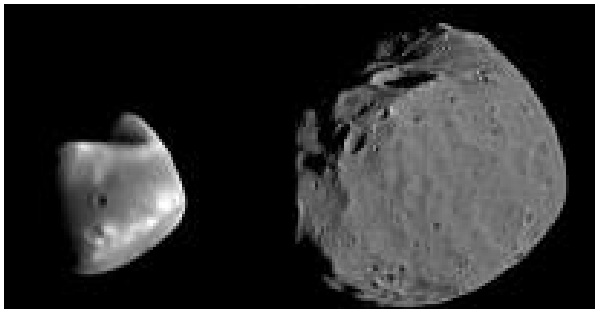
Jupiter: 63 + rings
Saturn: 60 + rings
Uranus: 27 + rings
Neptune: 13 + rings

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

Pluto: 3
Eris: 1

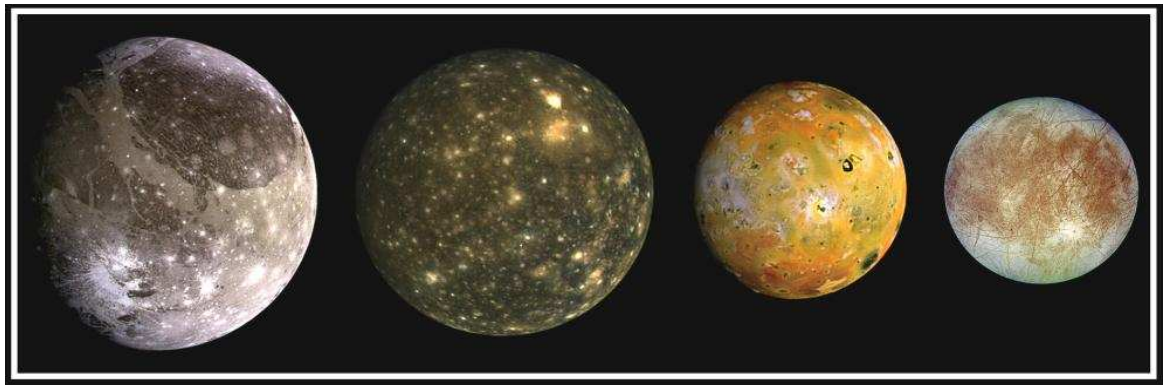
Moons of Mars:

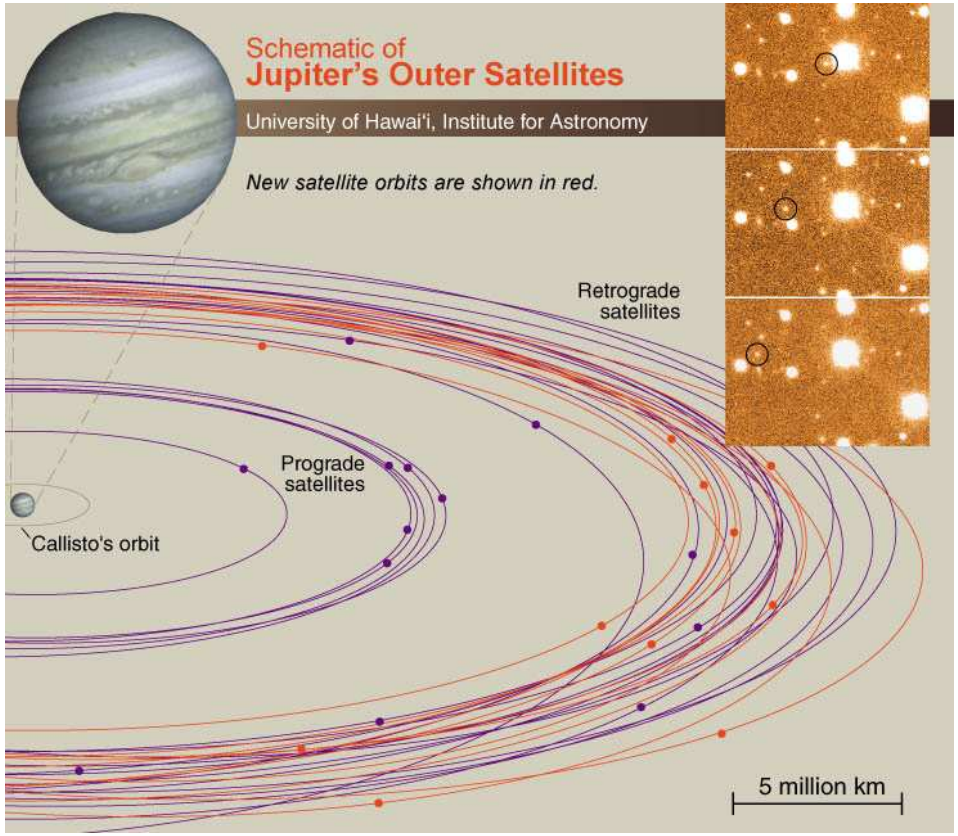
Deimos & Phobos, ~10km



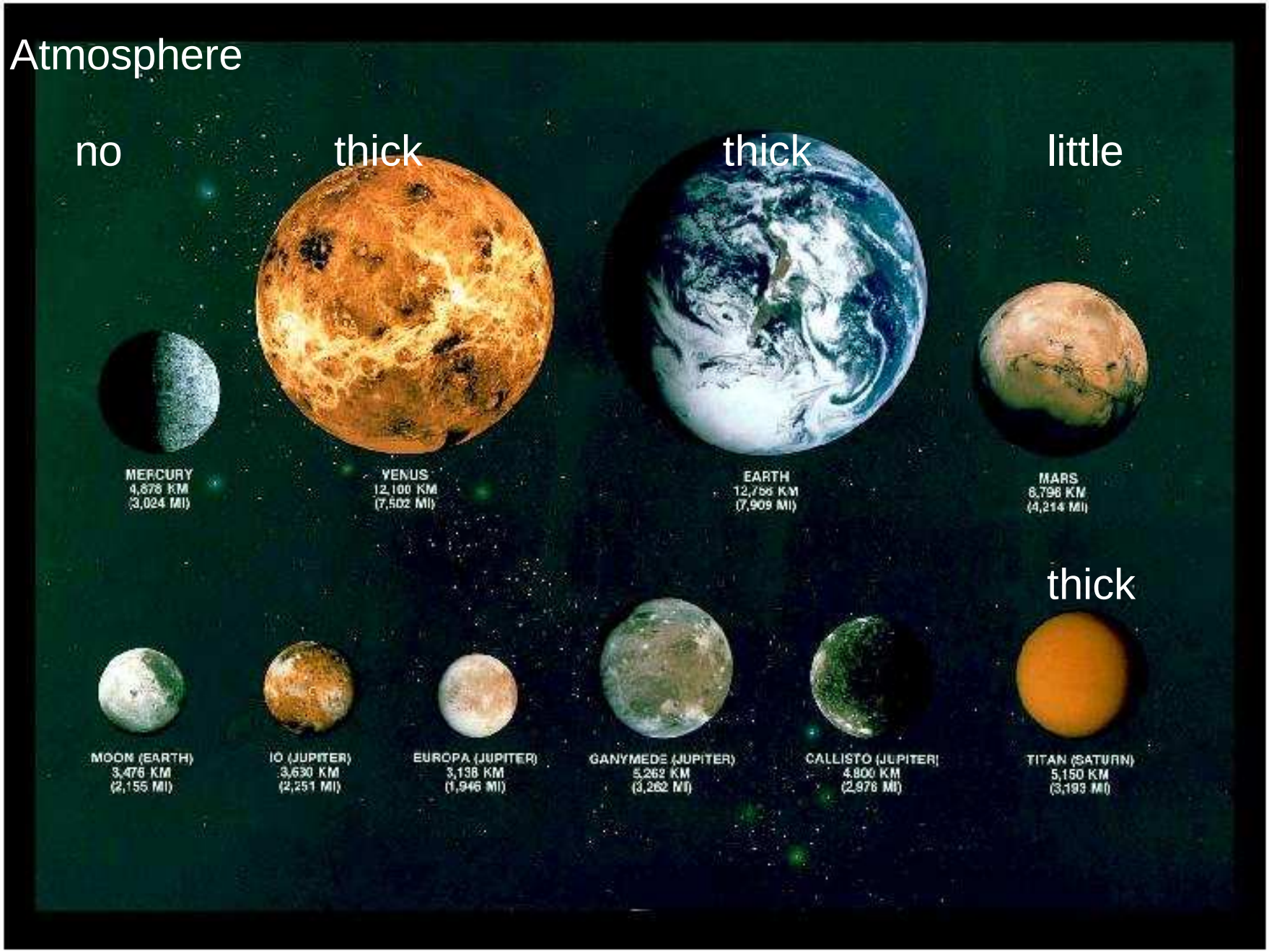
Moons of Jupiter

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





2001J3: 4km


Atmosphere
no
thick
thick
little
MERCURY
4,878 KM
(3,024 MI)
VENUS
12,100 KM
(7,502 MI)
EARTH
12,756 KM
(7,909 MI)
MARS
6,796 KM
(4,214 MI)
thick
MOON (EARTH)
3,476 KM
(2,155 MI)
IO (JUPITER)
3,630 KM
(2,251 MI)
EUROPA (JUPITER)
3,138 KM
(1,946 MI)
GANYMEDE (JUPITER)
5,262 KM
(3,262 MI)
CALLISTO (JUPITER)
4,800 KM
(2,976 MI)
TITAN (SATURN)
5,150 KM
(3,193 MI)

Inventory (cont'd)

~10^5 known small objects in the

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

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

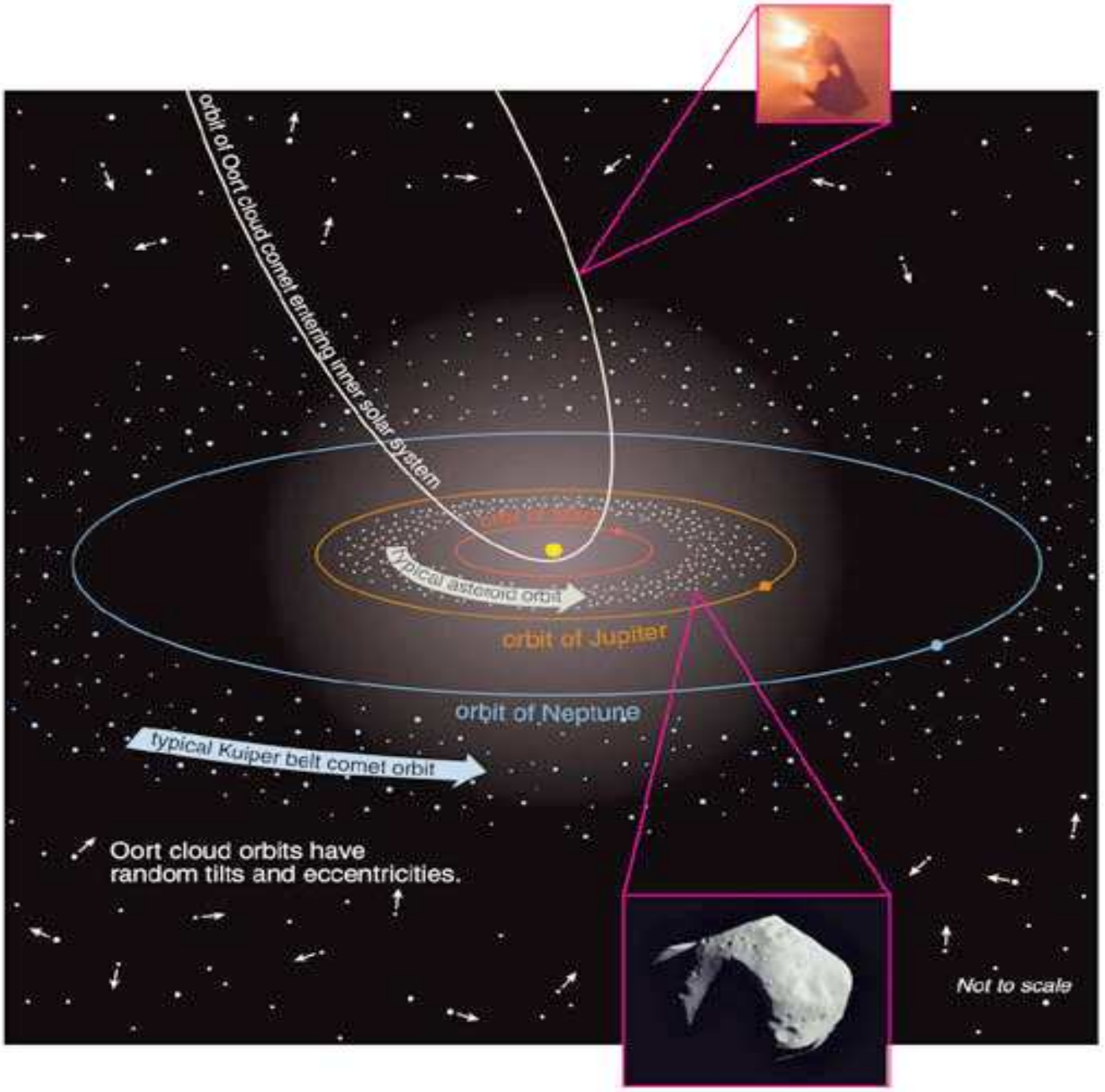
Estimated: ~10^{12} comets in the

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

Associated:

- **zodiacal dust**

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

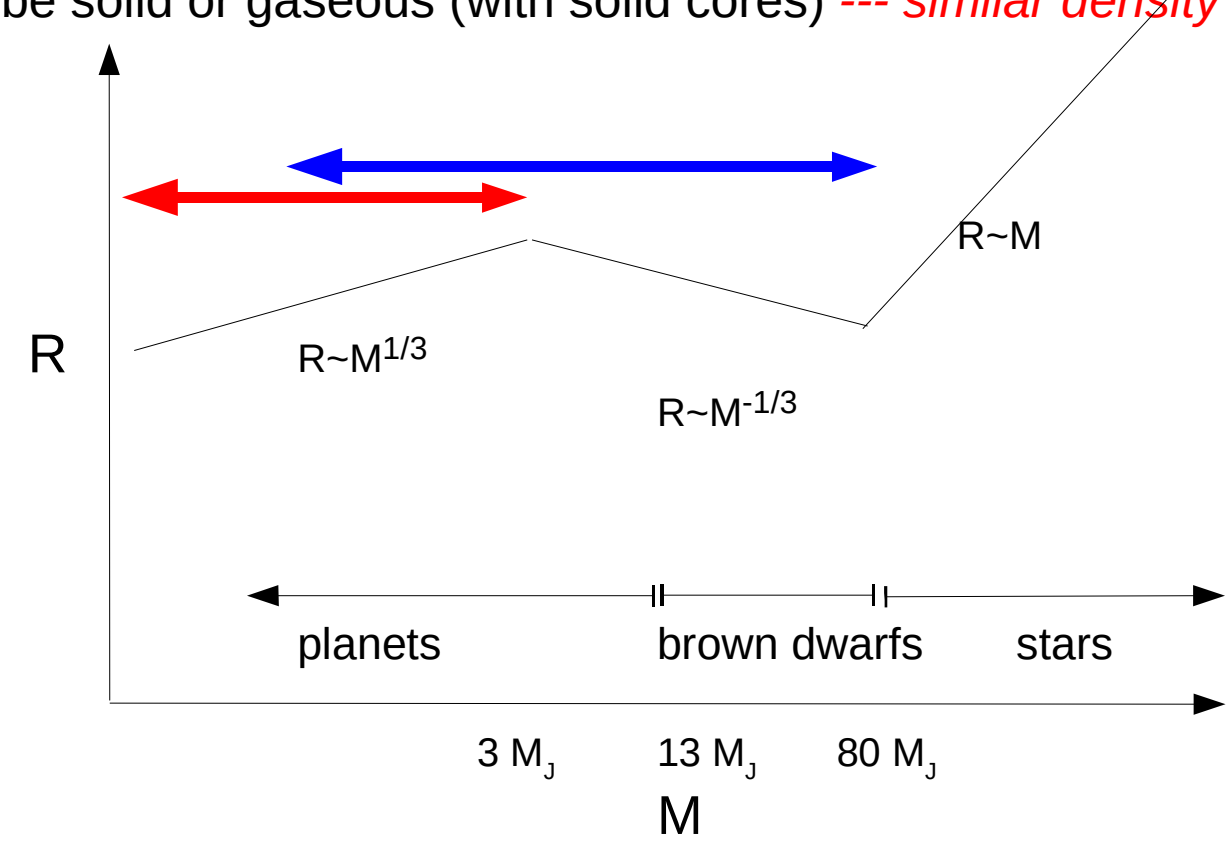


What are planets?

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/cm^3]
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

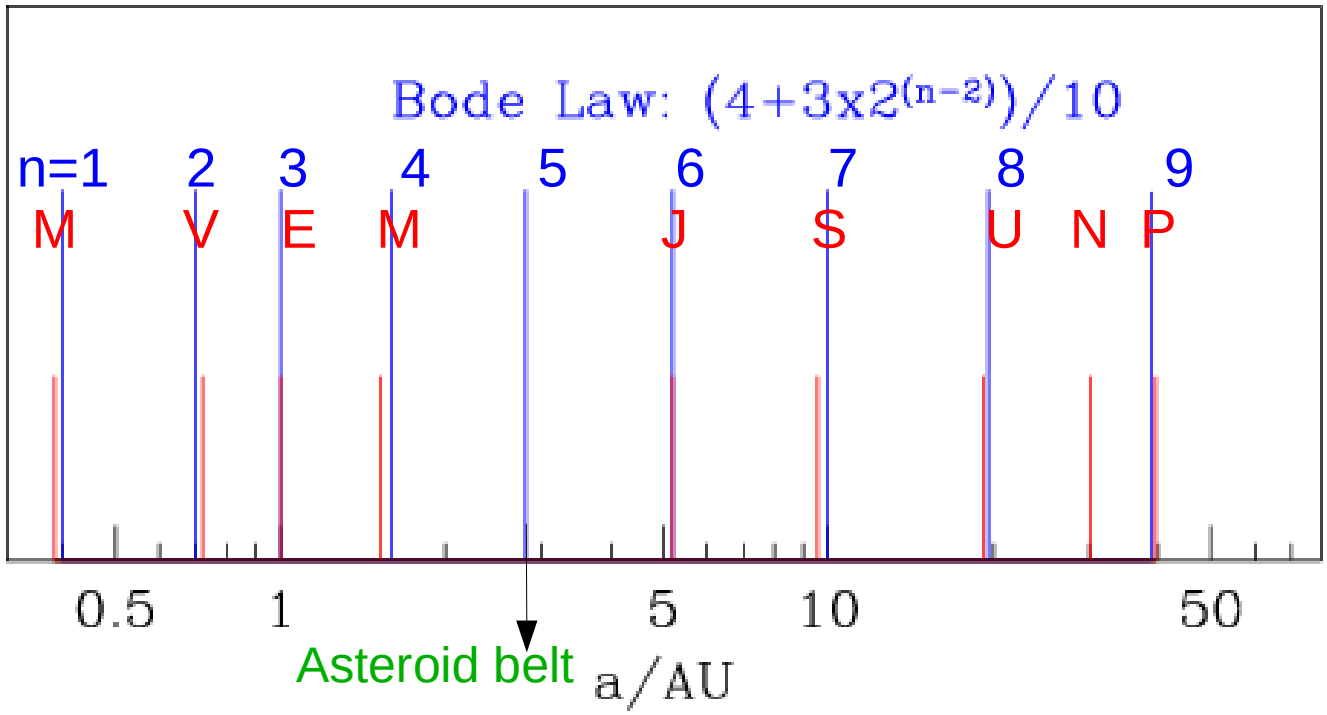
Orbits

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

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?

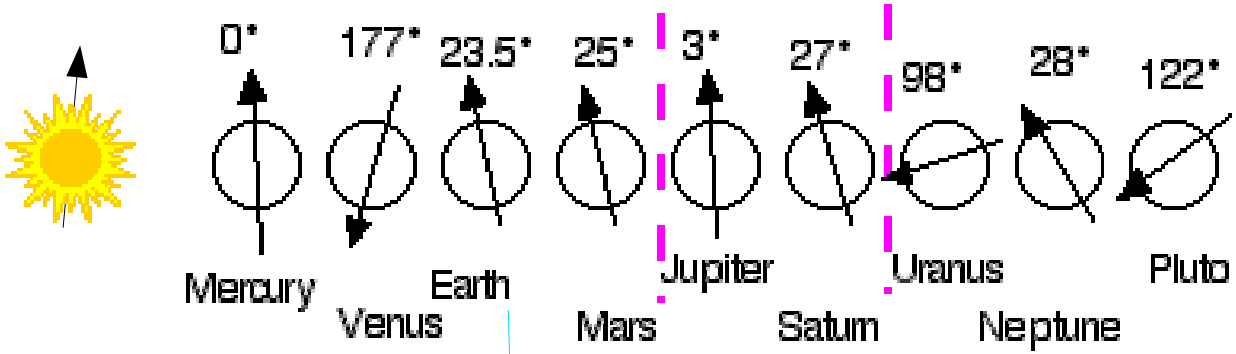
computer simulations indicate that planets are as maximally packed as allowed by stability



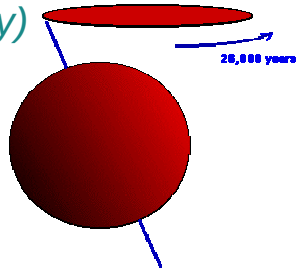
Spin (obliquity)

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

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

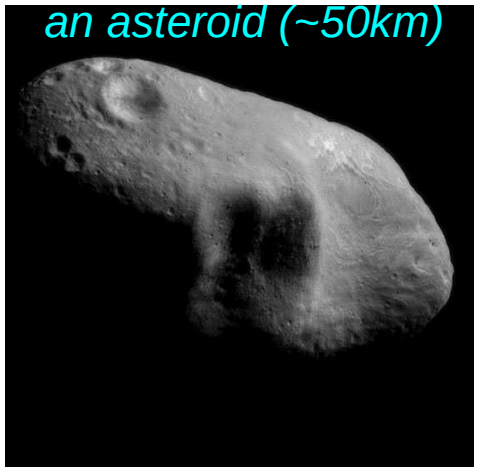


Earth's spin-axis precesses (mildly) while Mars sweeps around wildly



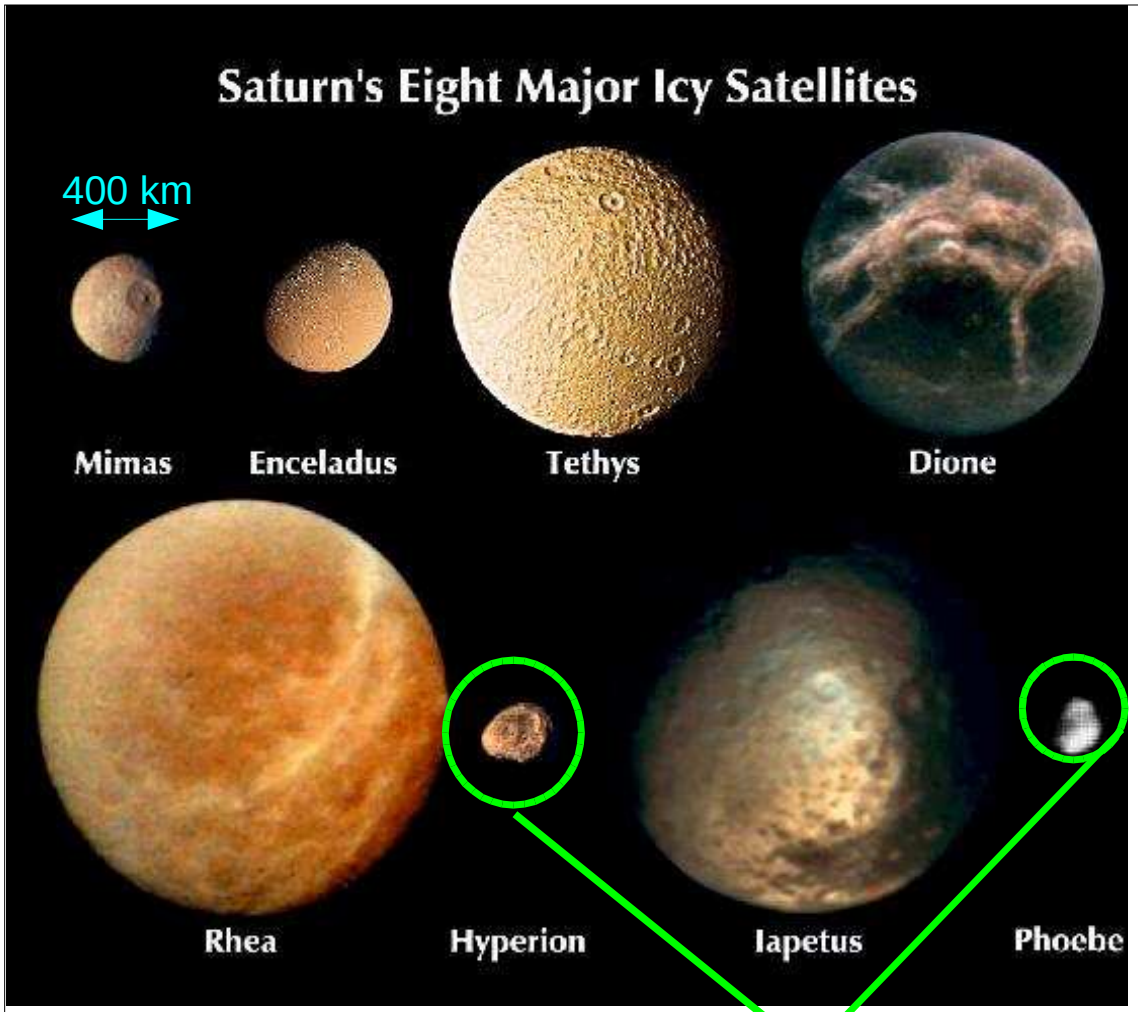
Shape *--- the bigger the rounder*

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



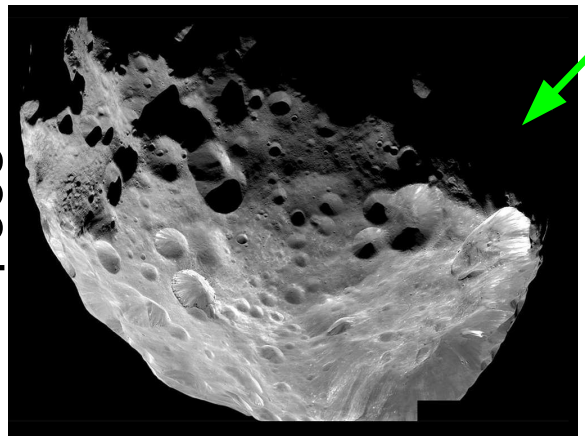
	h (km)	R (km)	$g=GM/R^2$ (m/s^2)
Earth	8	6400	9.8
Mars	24	3400	3.7

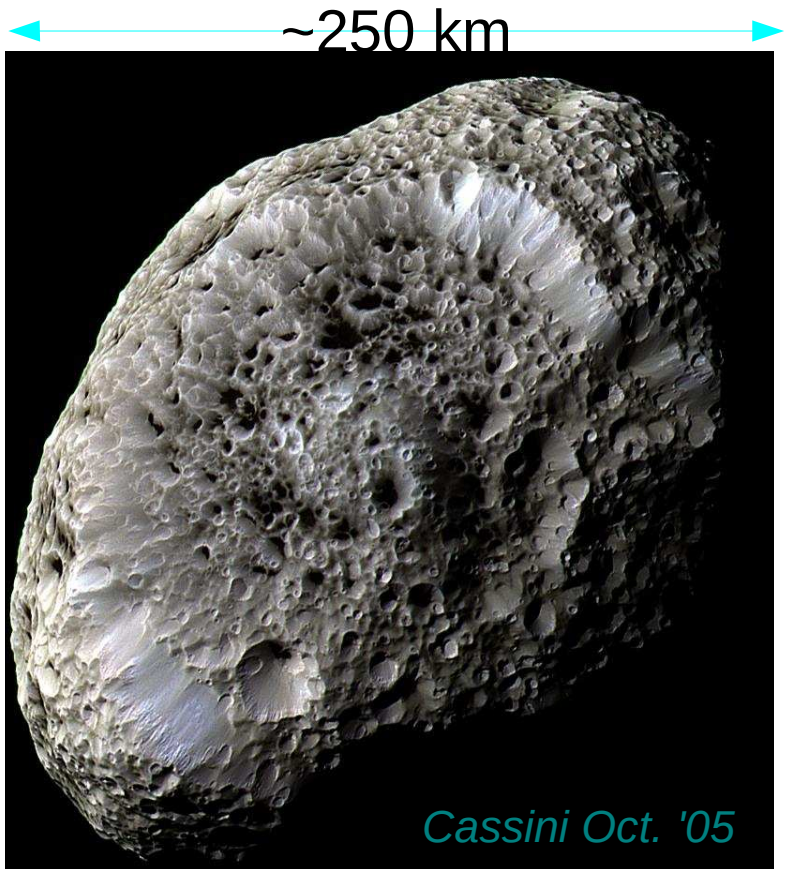
scaling: highest mountain on Earth ~8 km (on Mars ~ 24 km) **h * g ~ constant**
rough estimate: irregular body has mountain h ~ R ==> R ~ 240 km
thus: objects with R > 240 km are approximately spherical



The bigger the rounder

	$\Delta R/R$	$g=GM/R^2$
Earth	8/6400	9.8 m/s^2
Mars	24/3400	3.7 m/s^2
Hyperion: 150/250		~0.4 m/s^2





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)

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

If $L_{\text{abs}} = L_{\text{em}}$, 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 K	100-725	(?)
Venus	0.7	0.77	230K	733	(?)
Earth	1	0.30	255K	288	(?)
Mars	1.5	0.25	218K	223	good
Jupiter	5	0.51	113K	125	(?)
Saturn	9	0.47	83K	95	(?)
Uranus	19	0.51	60K	60	good
Neptune	30	0.62	40K	60	(?)
Comet at	5000	0.51	3.4K		

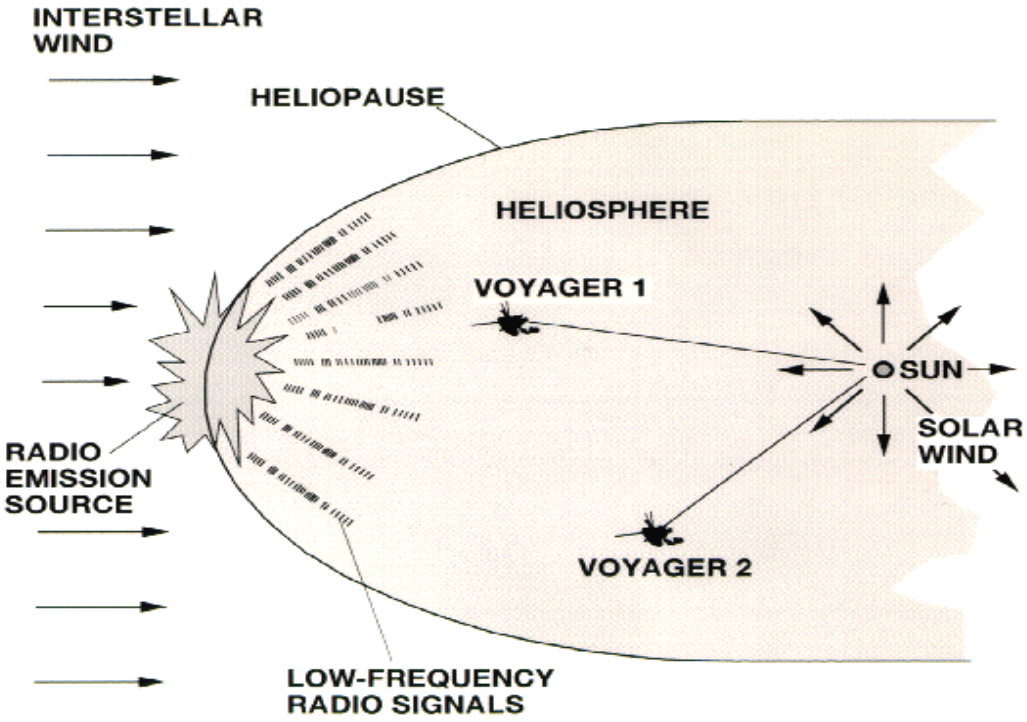
How do we know?

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:
...

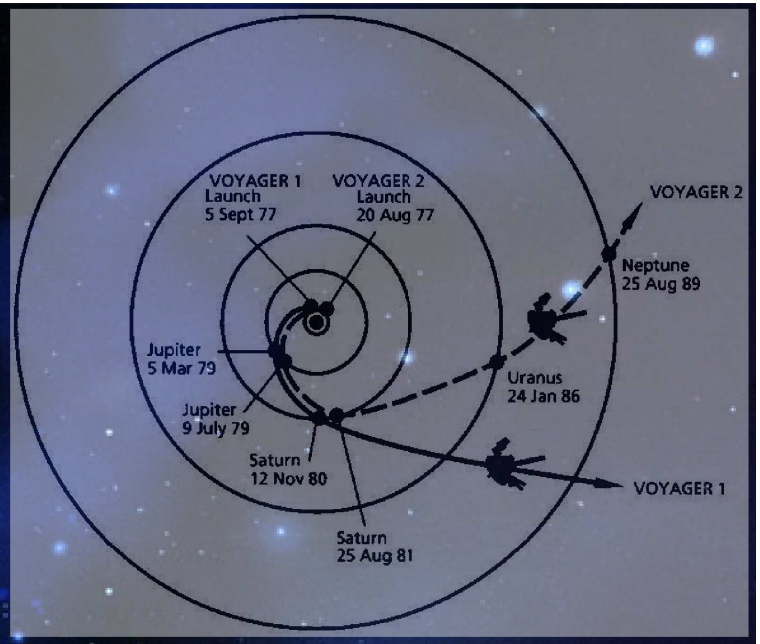
Notable planetary missions

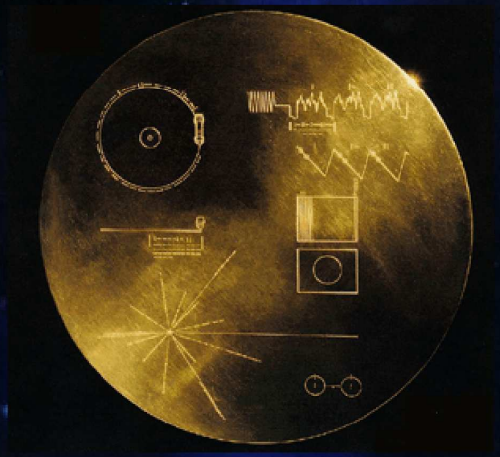
Voyager 1 & 2 are now formally Interstellar Missions
interstellar material outside heliopause

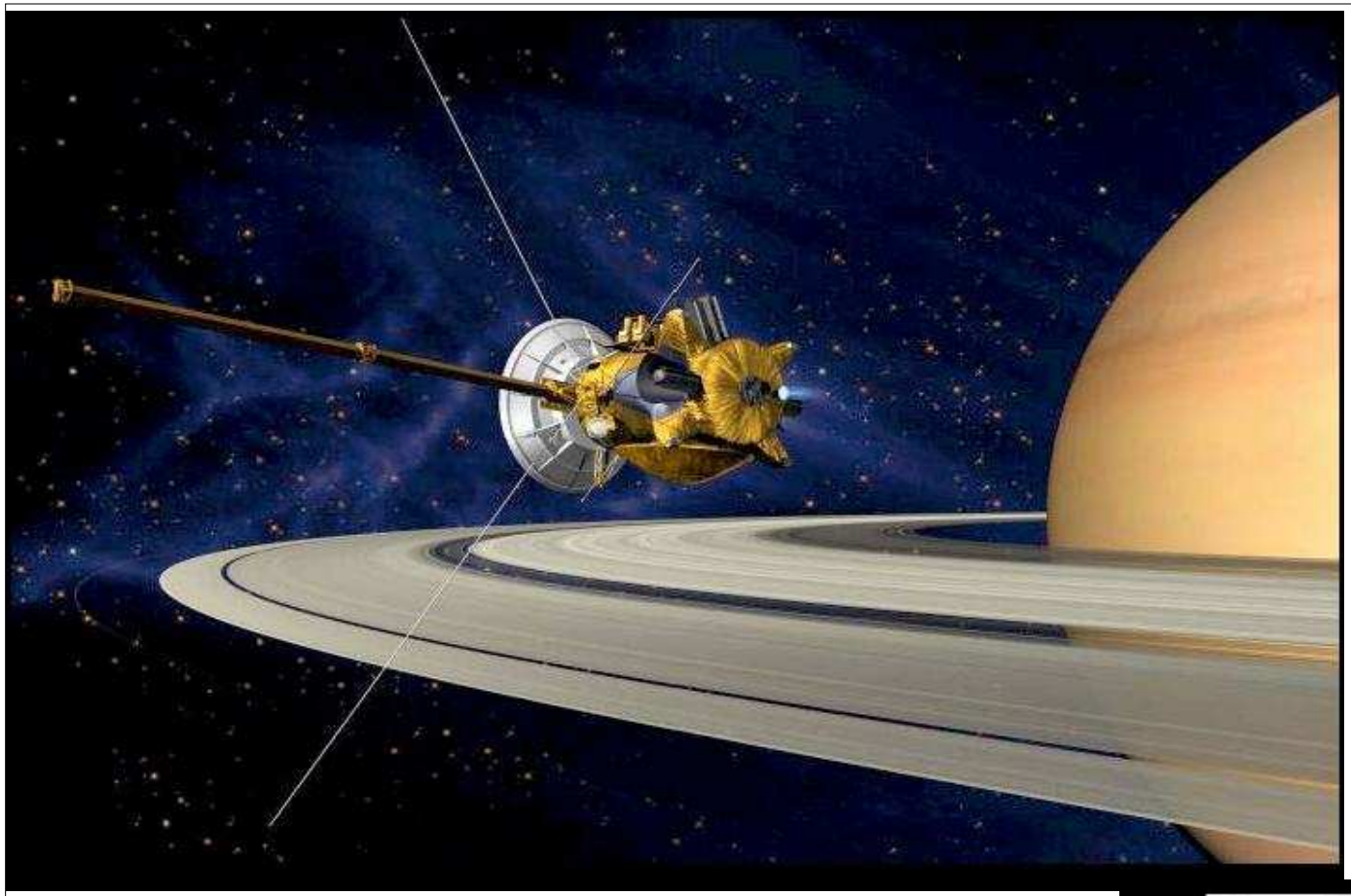
Cassini is currently visiting Saturn & dropped Huygens probe on Titan
sea on the surface of Titan?



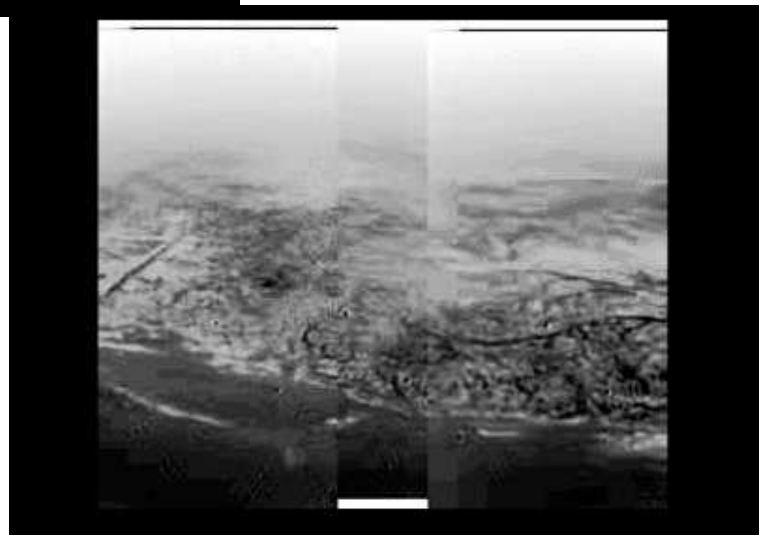
The Voyager Mission







The Cassini-Huygens Mission



Fates of Moons

orbit $\omega = \Omega$
(synchronous orbit)

Planet spin Ω

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

What about retro-grade moons?