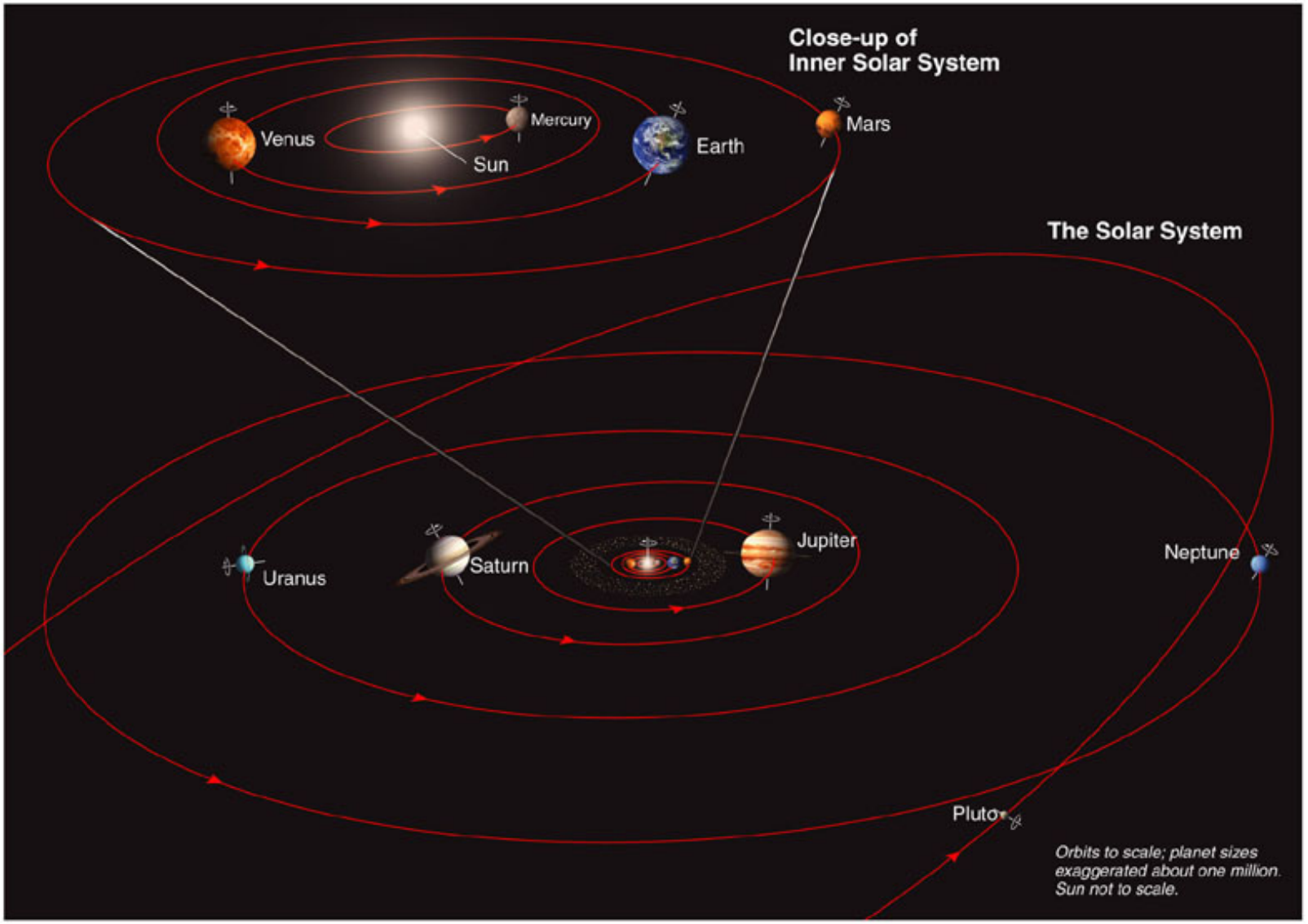
Solar System overview

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)

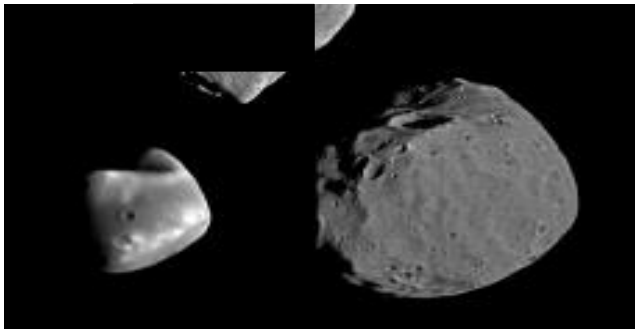
Jupiter: 69 + rings
Saturn: 62 + rings
Uranus: 27 + rings
Neptune: 14 + rings

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

Pluto: 5
Eris: 1

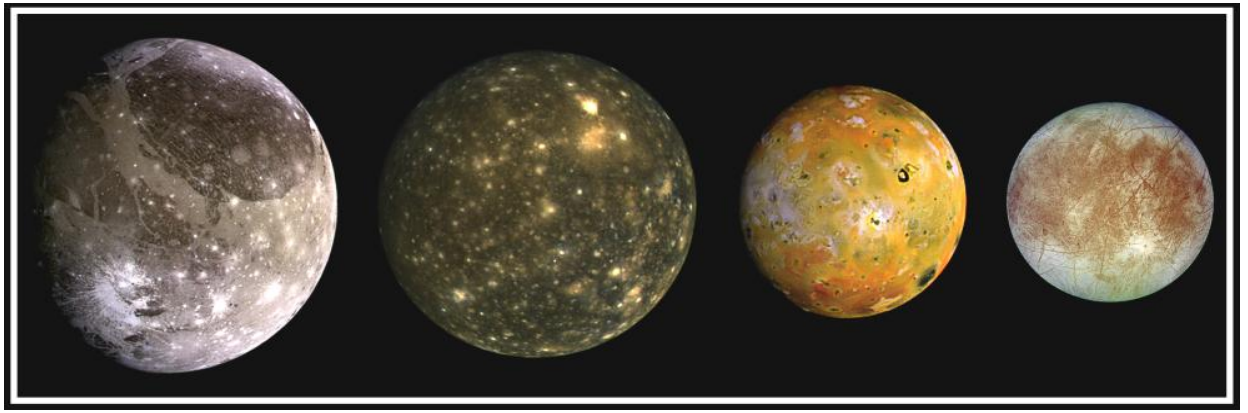
Moons of Mars:

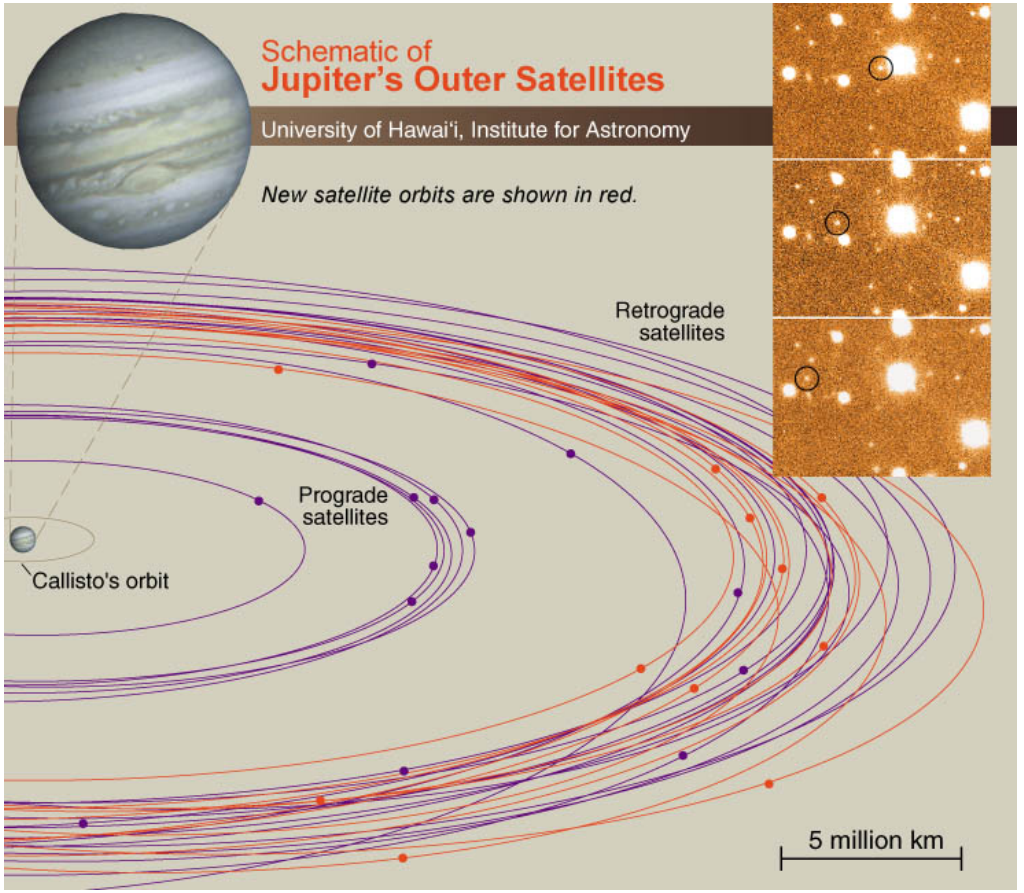
Deimos & Phobos, ~10km



Moons of Jupiter

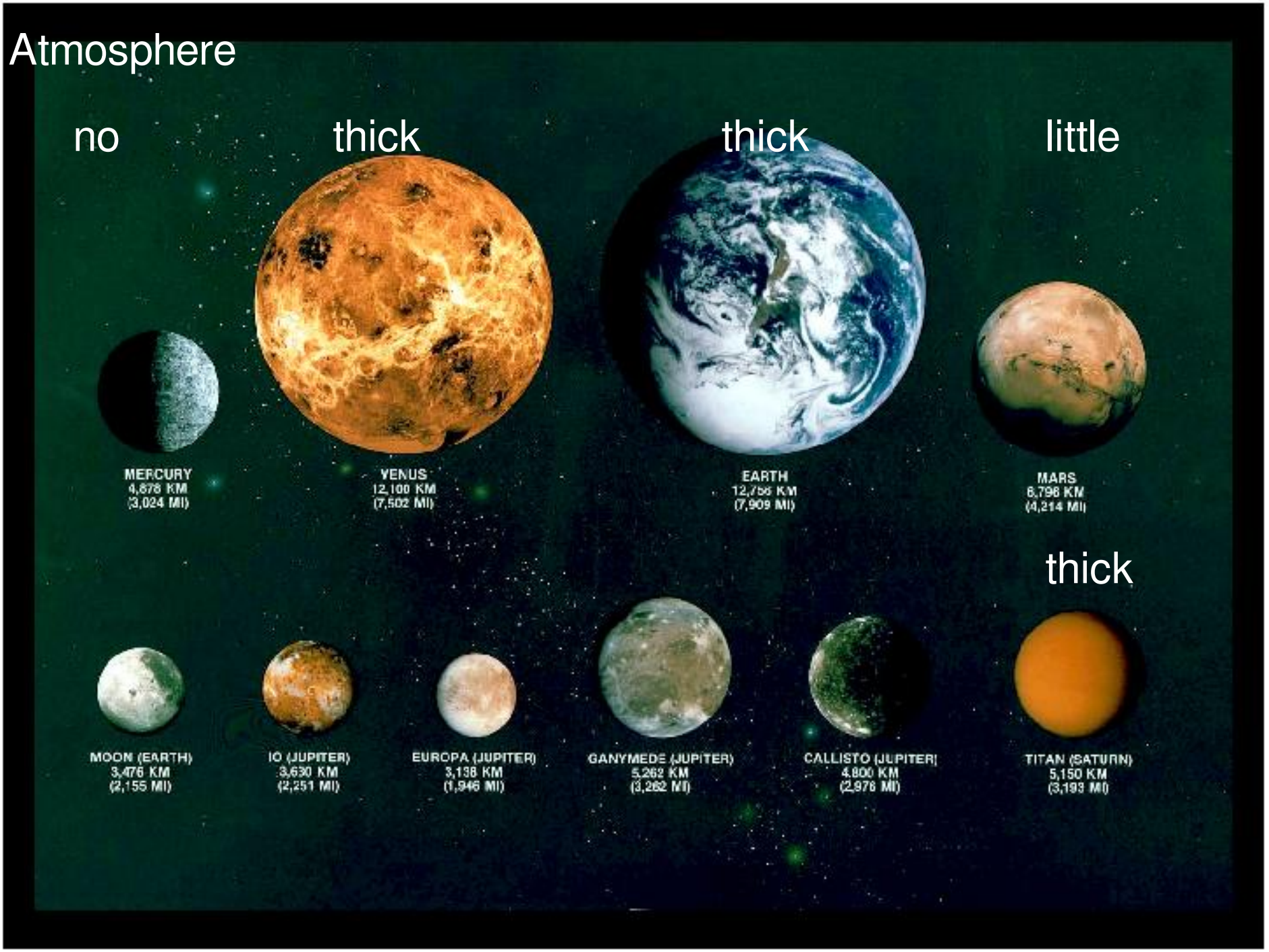
4 Galilean satellites (Ganymede, Callisto, Io & Europa), ~10^3 km (close to Jupiter, likely primordial)





2001J3: 4km

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
(2,978 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)

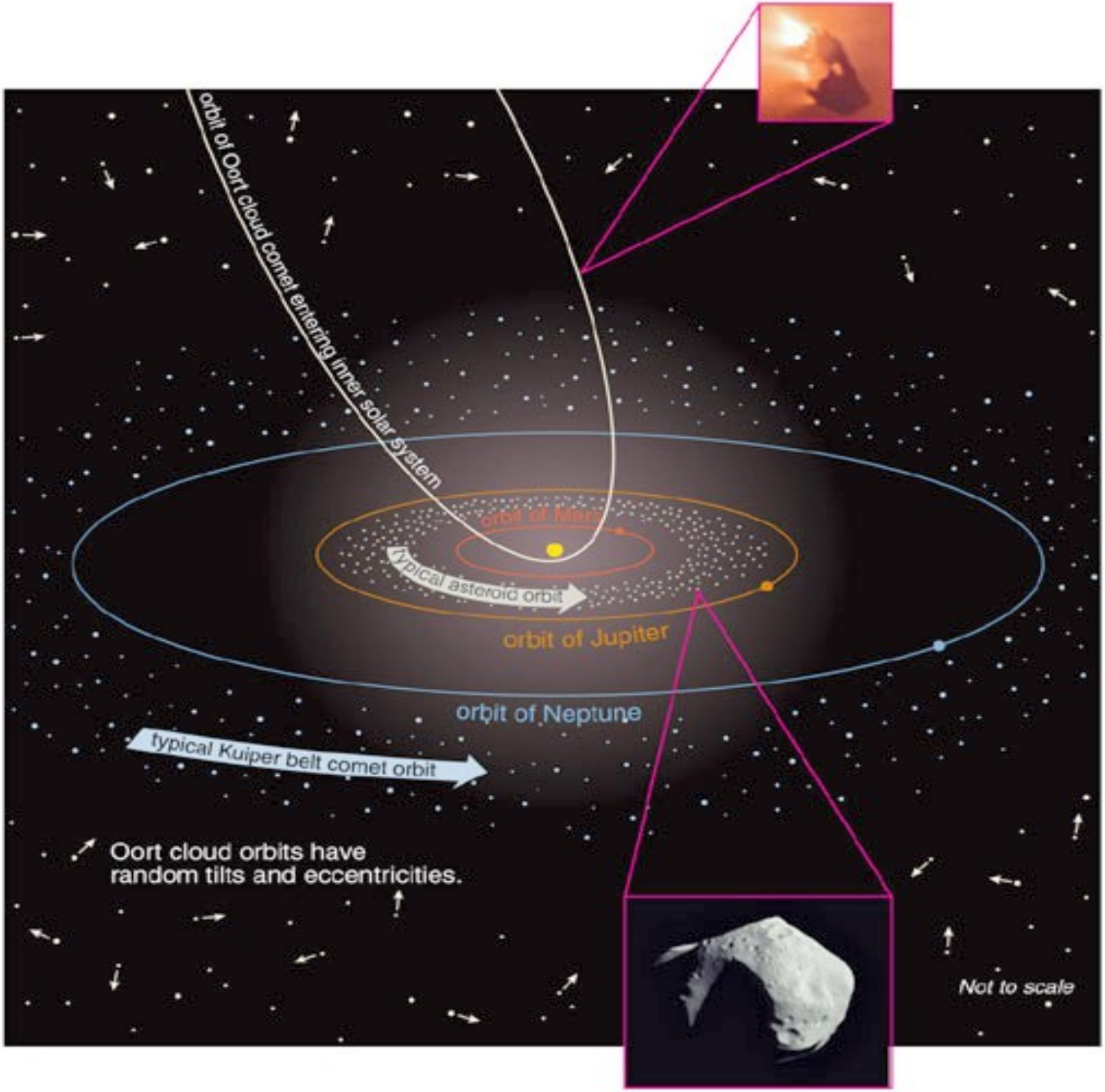
Estimated: ~10^{12} comets in the

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

Associated:

- **zodiacal dust**

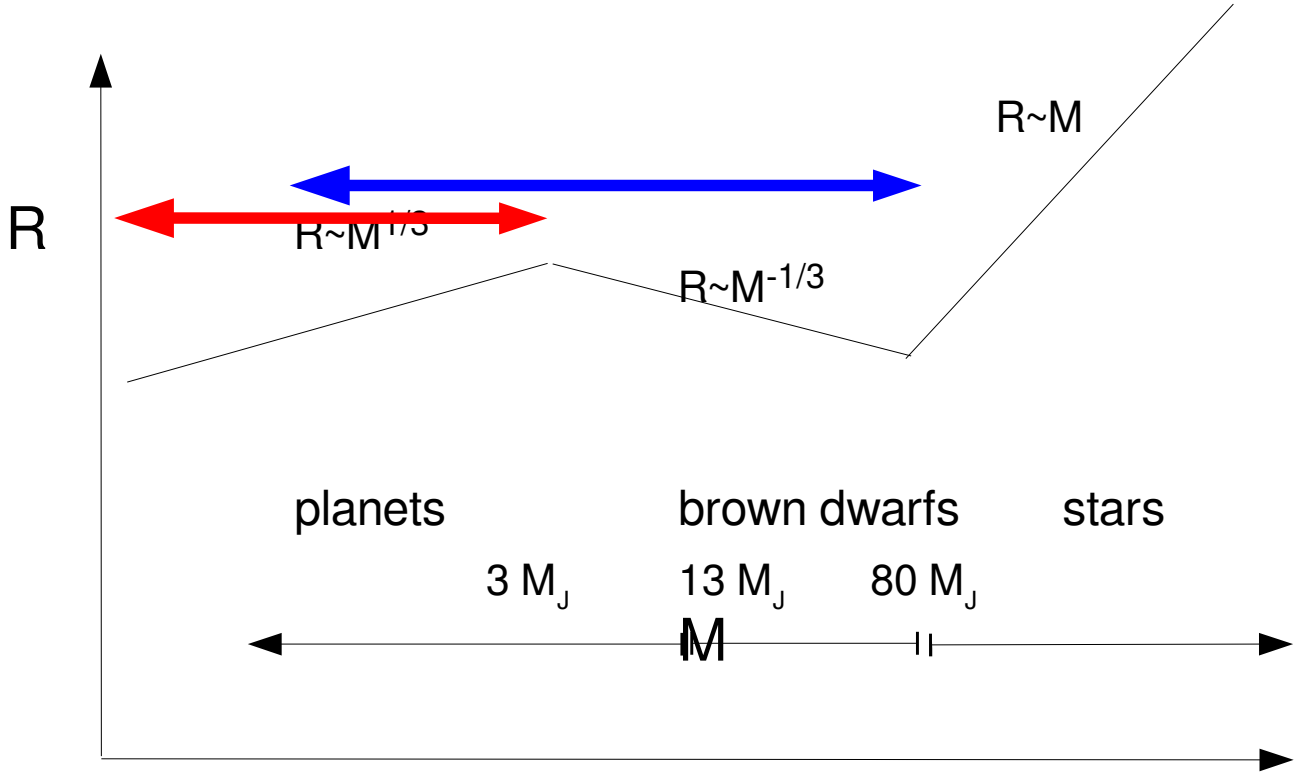
(fire-works on the sky: comets & meteorites)



What are planets?

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

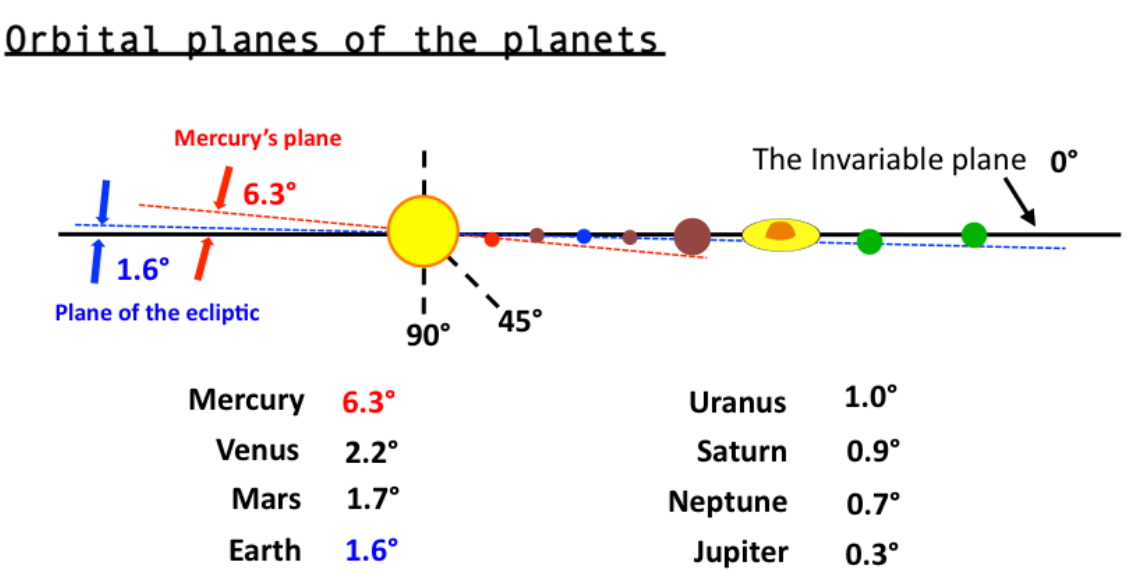
More general:
1) no nuclear fusion (not even deuterium): $T_c < 10^6$ K
2) pressure provided by electron degeneracy and/or Coulomb force
(l ~ h/p ~ d) (d ~ atomic radius)
3) can be solid or gaseous (with solid cores) --- *similar density*



Mass & Mean ρ	M_J	[g/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

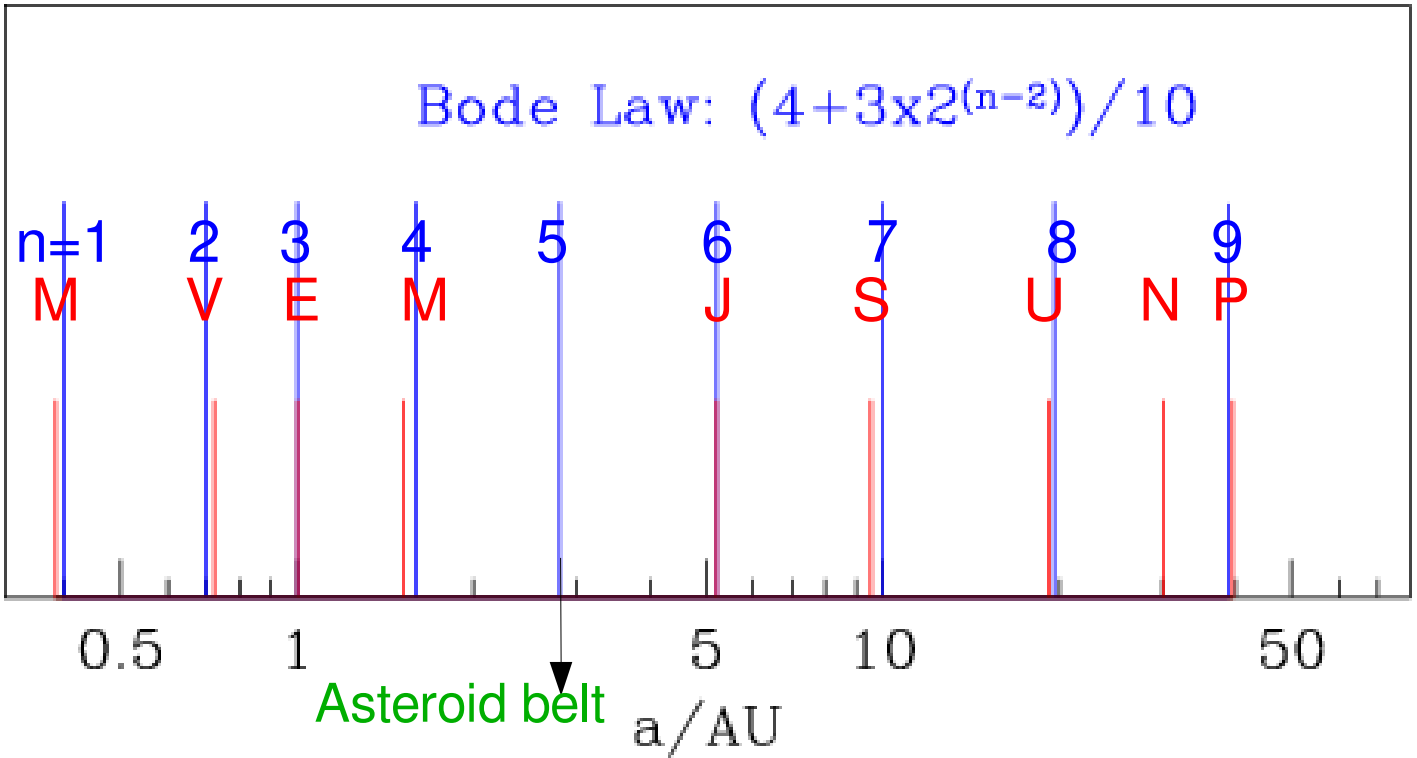
inclination: largely coplanar (history)
direction: all the same
eccentricity: a few percent
(except for Mercury)



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?

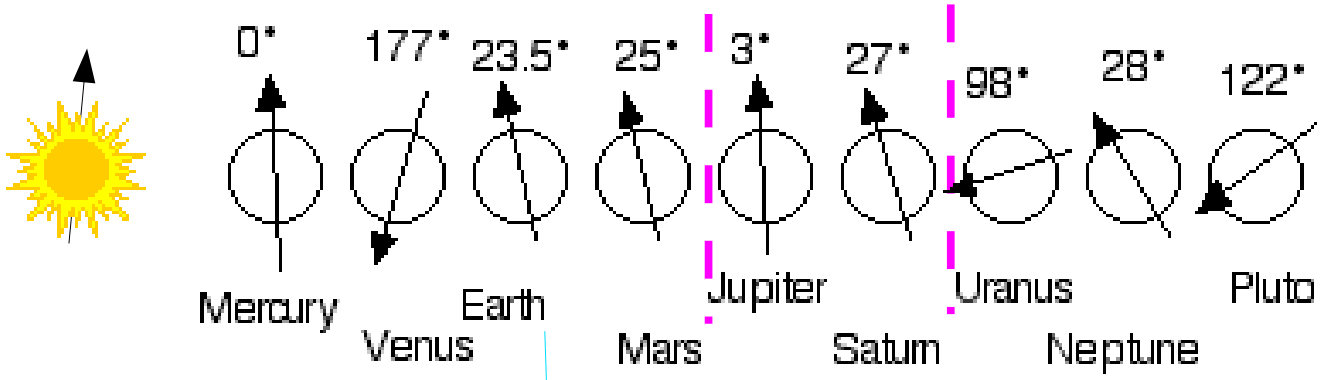
Computer simulations indicate that planets are as maximally packed as allowed by stability.



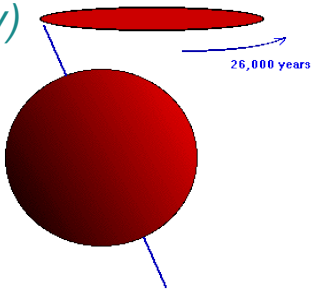
Spin (obliquity)

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

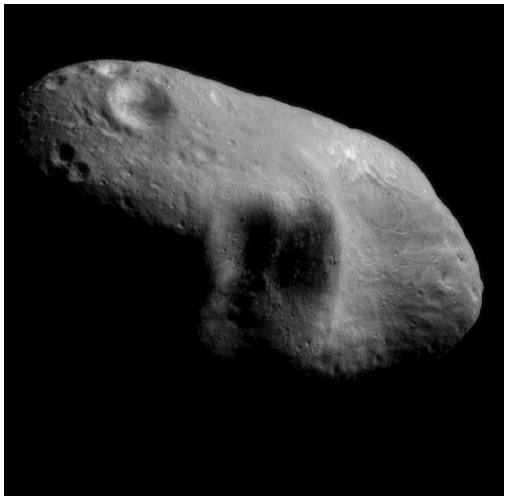


Shape *--- the bigger the rounder*

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

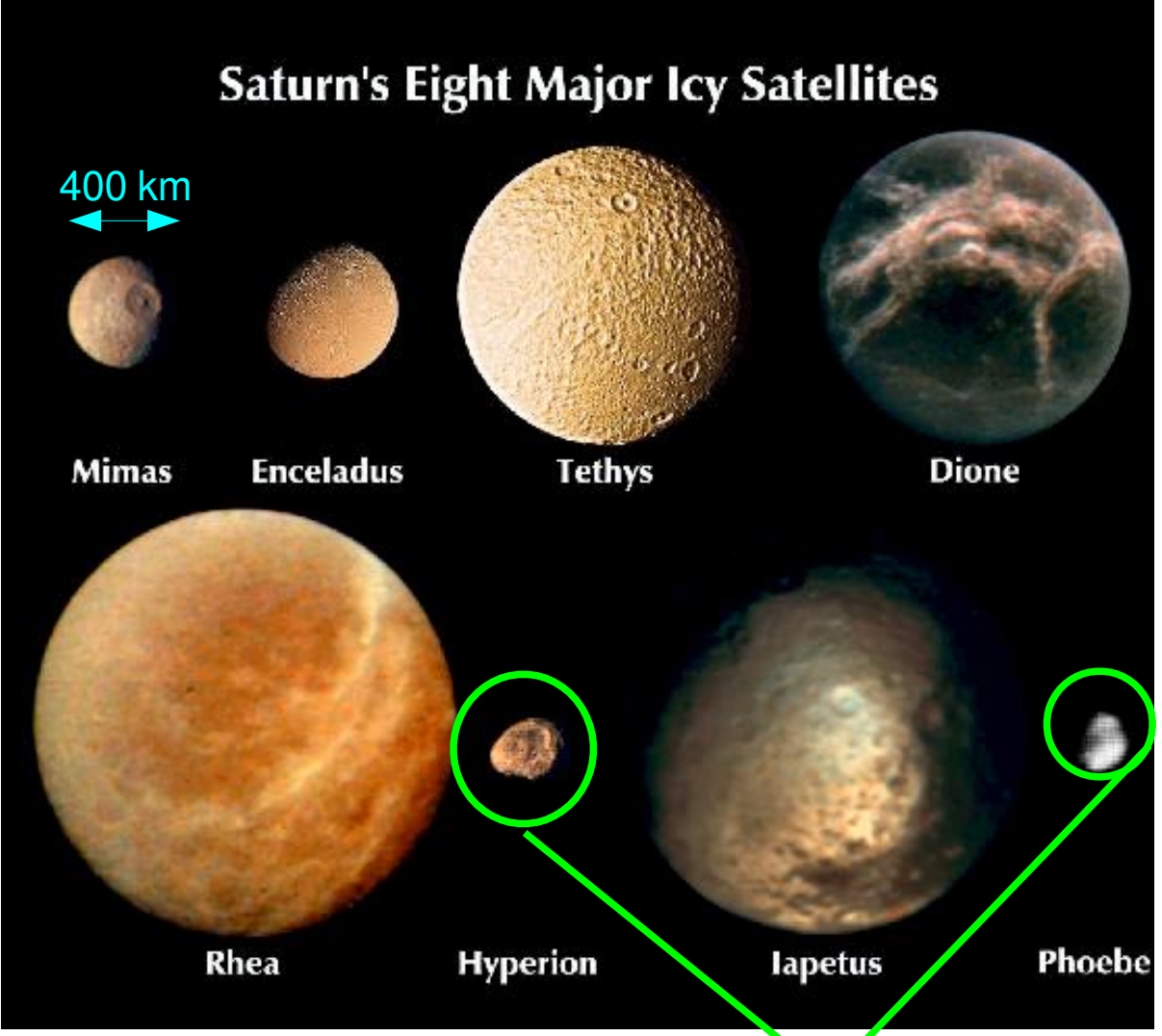
The Moon (~1700km)

an asteroid (~50km)



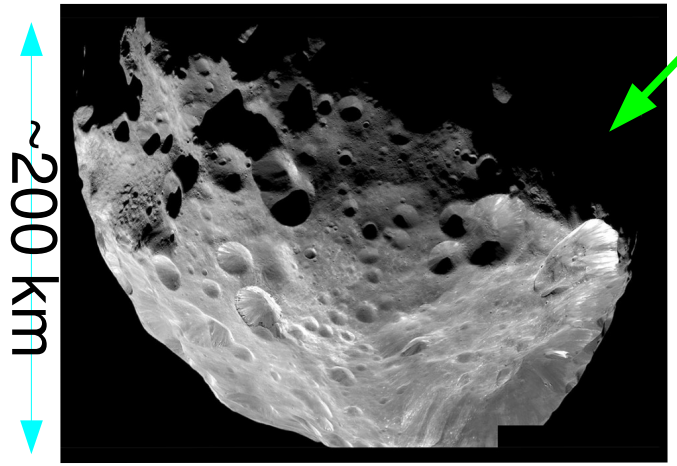
	h (km)	R (km)	$g=GM/R^2$ (m/s^2)
Earth	8	6400	9.8
Mars	24	3400	3.7

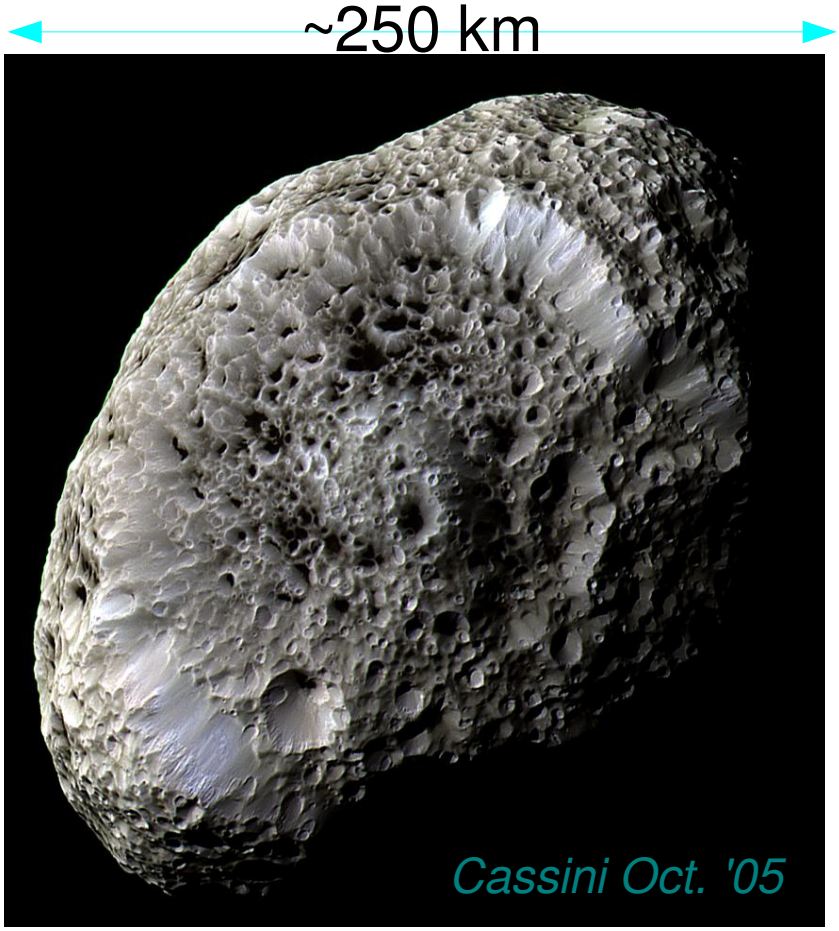
scaling: highest mountain on Earth ~8 km (on Mars ~ 24 km) **h * g ~ constant**
rough estimate: irregular body has mountain h ~ R ==> R ~ 240 km
thus: objects with R > 240 km are approximately spherical



The bigger the rounder

	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)

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

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

	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		

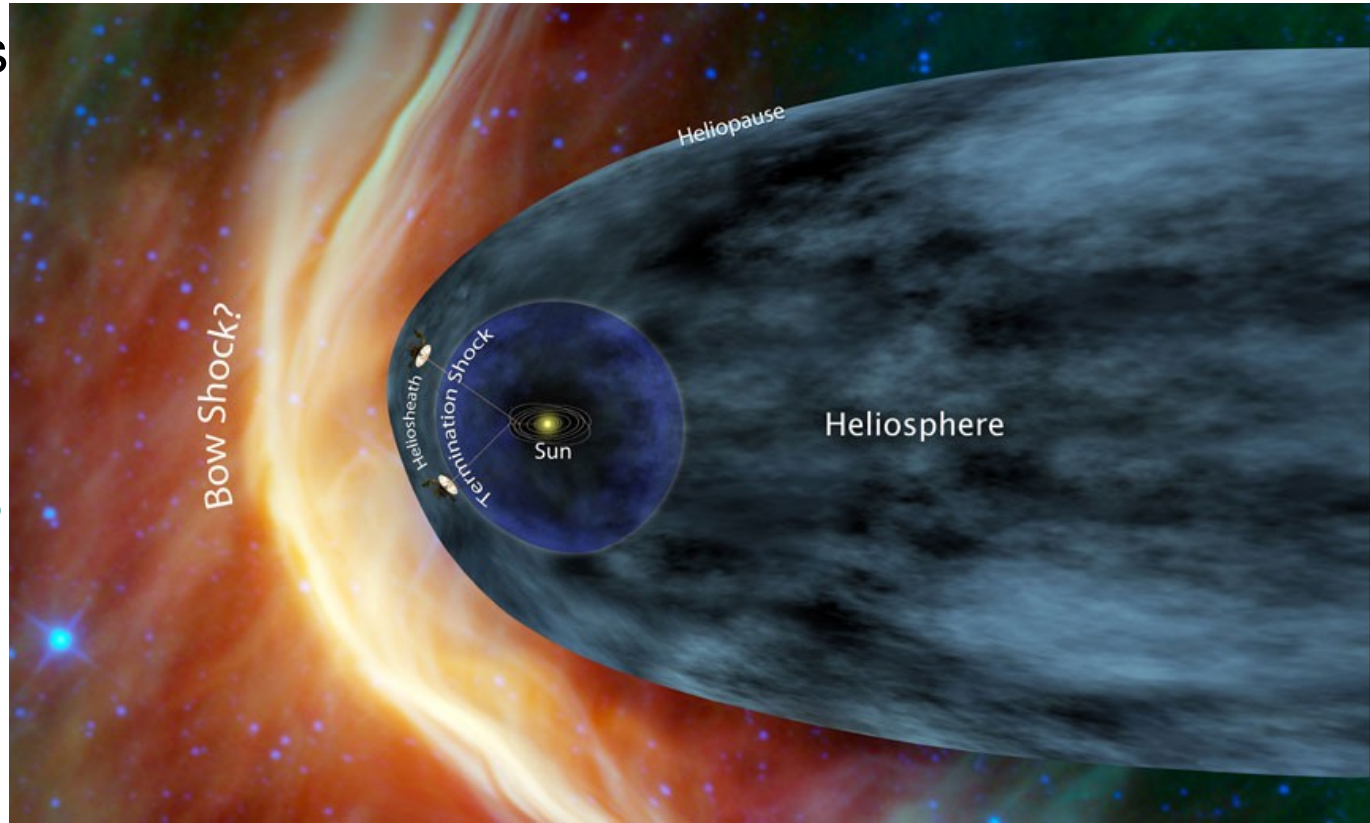
How do we know?

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:
...

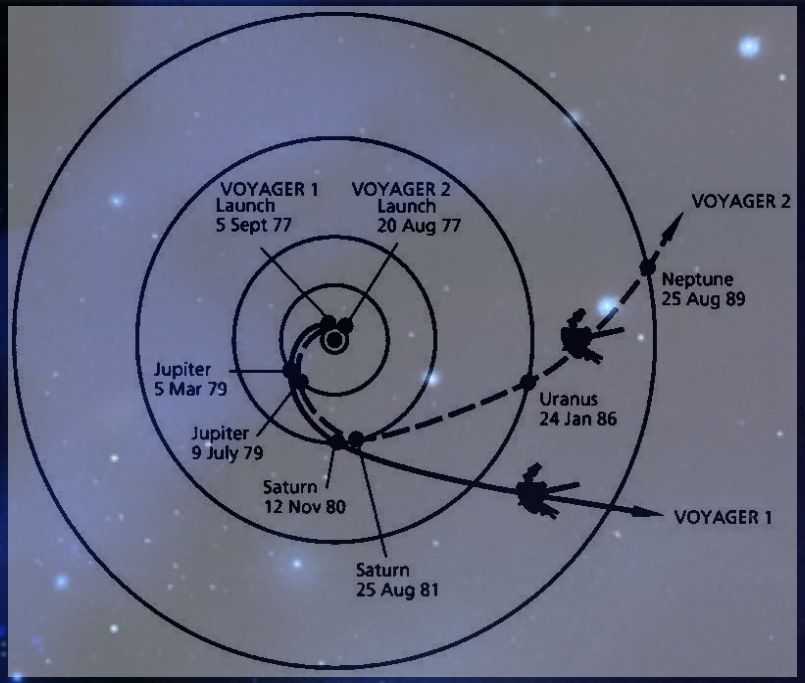
Notable planetary missions

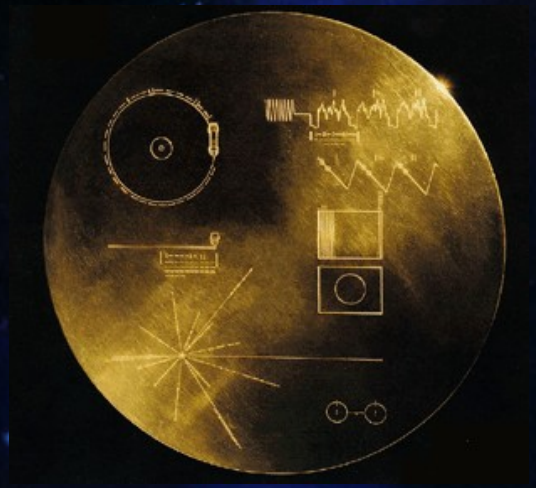
Voyager 1 now an Interstellar Mission
interstellar material outside heliopause

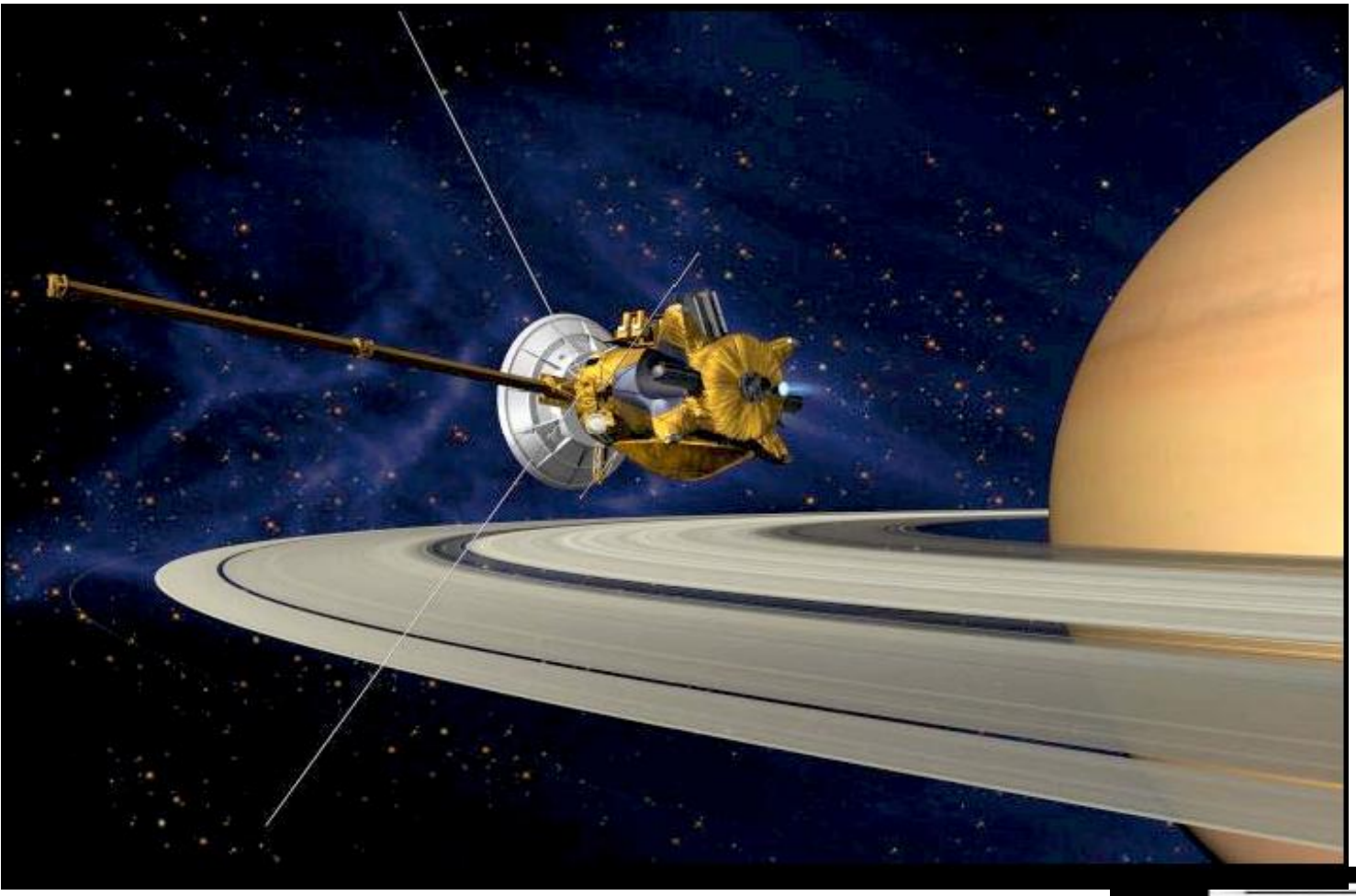
Cassini just ended its visit of Saturn & dropped Huygens probe on Titan
Ethane sea on the surface?



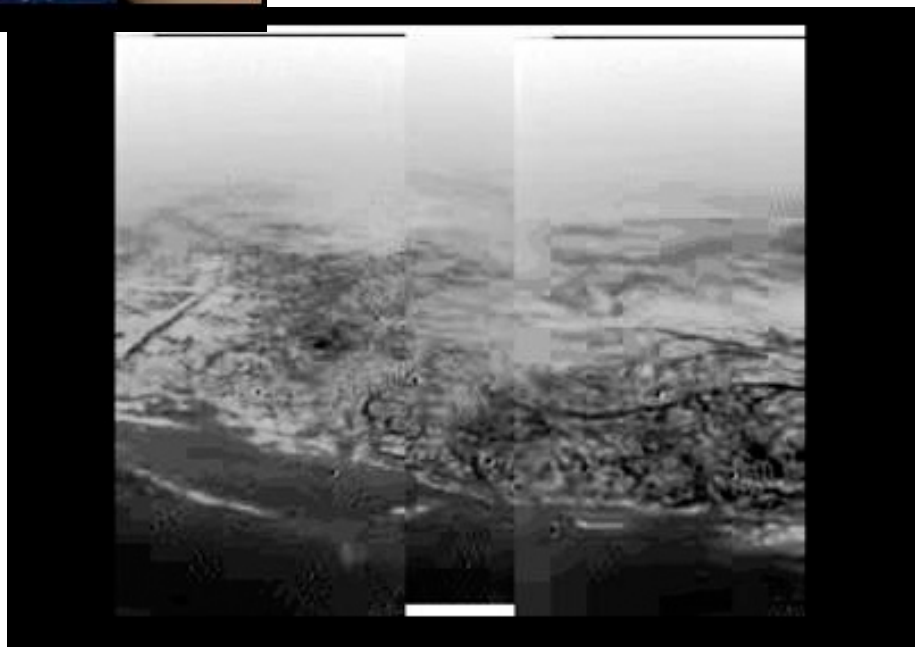
The Voyager Mission



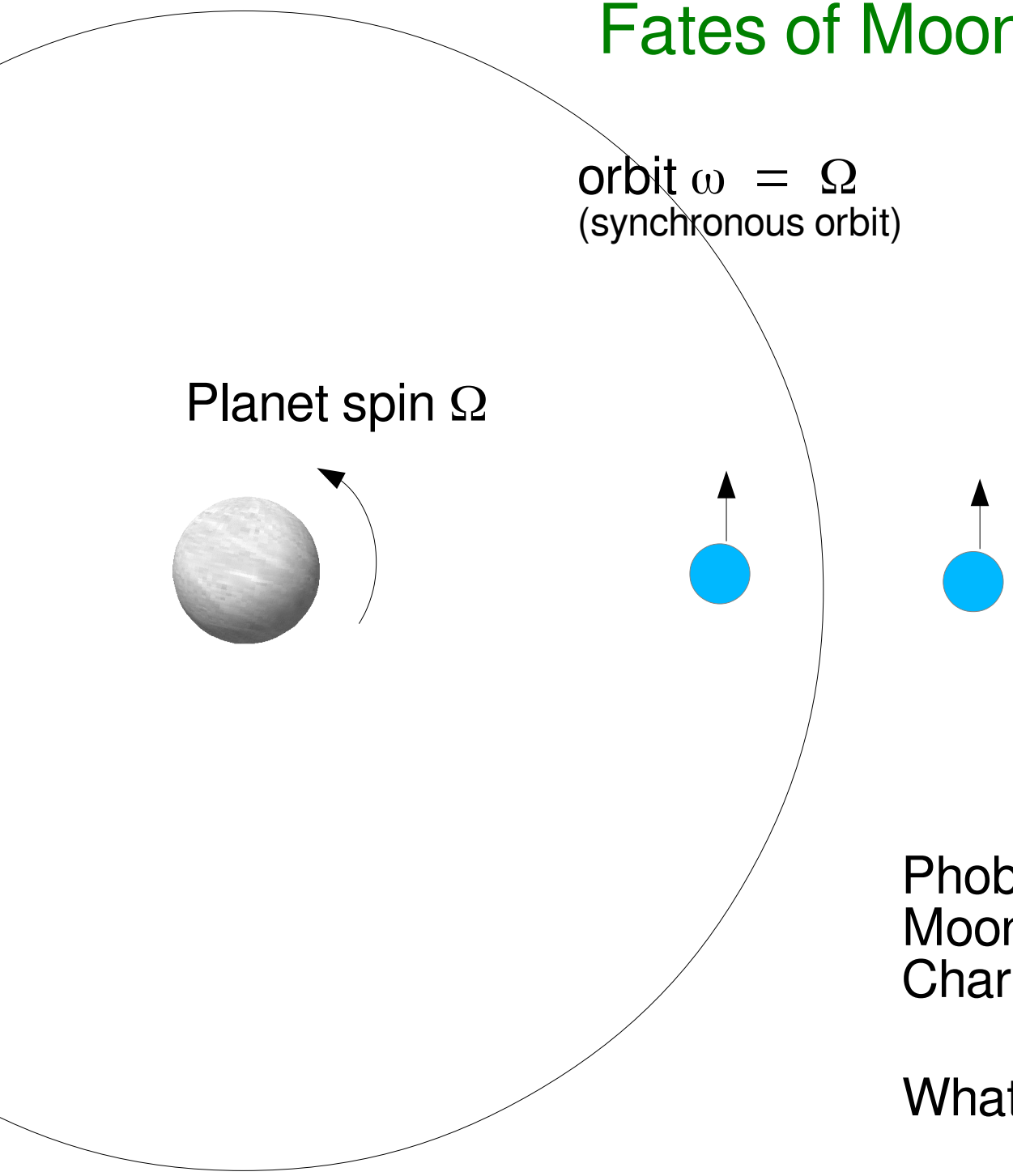




The Cassini-Huygens Mission



Fates of Moons



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

What about retro-grade moons?