Exam #2 Review

- Go over homework problems (6-10)
- Practice using equation sheet
- Go over class work sheets, especially since last exam. Two of them will be on the test.
- Review lectures
- Review Key Words and Key Ideas for each chapters 7-15

Exam #2 Review

- Small angle formula

$$\Theta = D/d \quad \text{radians}$$

D = Diameter of object, d = distance to object

Θ= angular size

Note 1 radian = 206265 arcseconds

- Overview of Solar System, Terrestrial vs Jovian planets' characteristics, orbital characteristics, including asteroids, comets, key concept density, chemical composition (surface/atmosphere), cosmic abundance, where in Solar System it's found, where it's not, why some planets have atmospheres and some don't.

$$V_{\text{esc}} = \sqrt{\frac{2GM}{r}}$$

$$\frac{1}{2} m V^2 = \frac{3}{2} \text{kT} \quad \Rightarrow V = \sqrt{\frac{3kT}{m}}$$

- gas will be **retained** in the atmosphere if

$$V_{\text{escape}} > 6V$$

Gas will escape if $6\text{V} > \text{V}_{\text{escape}}$

Contents of the Solar System

- Sun in center, contains most of the mass
- Planets
- Moons
- Rings
- Asteroids – mostly between Mars and Jupiter. Rocky material
- Comets – High eccentricities orbits, icy material
- Trans-Neptunian Objects

- What do we learn from crater density?

- how is a planetary magnetic field produced? (dynamo model)

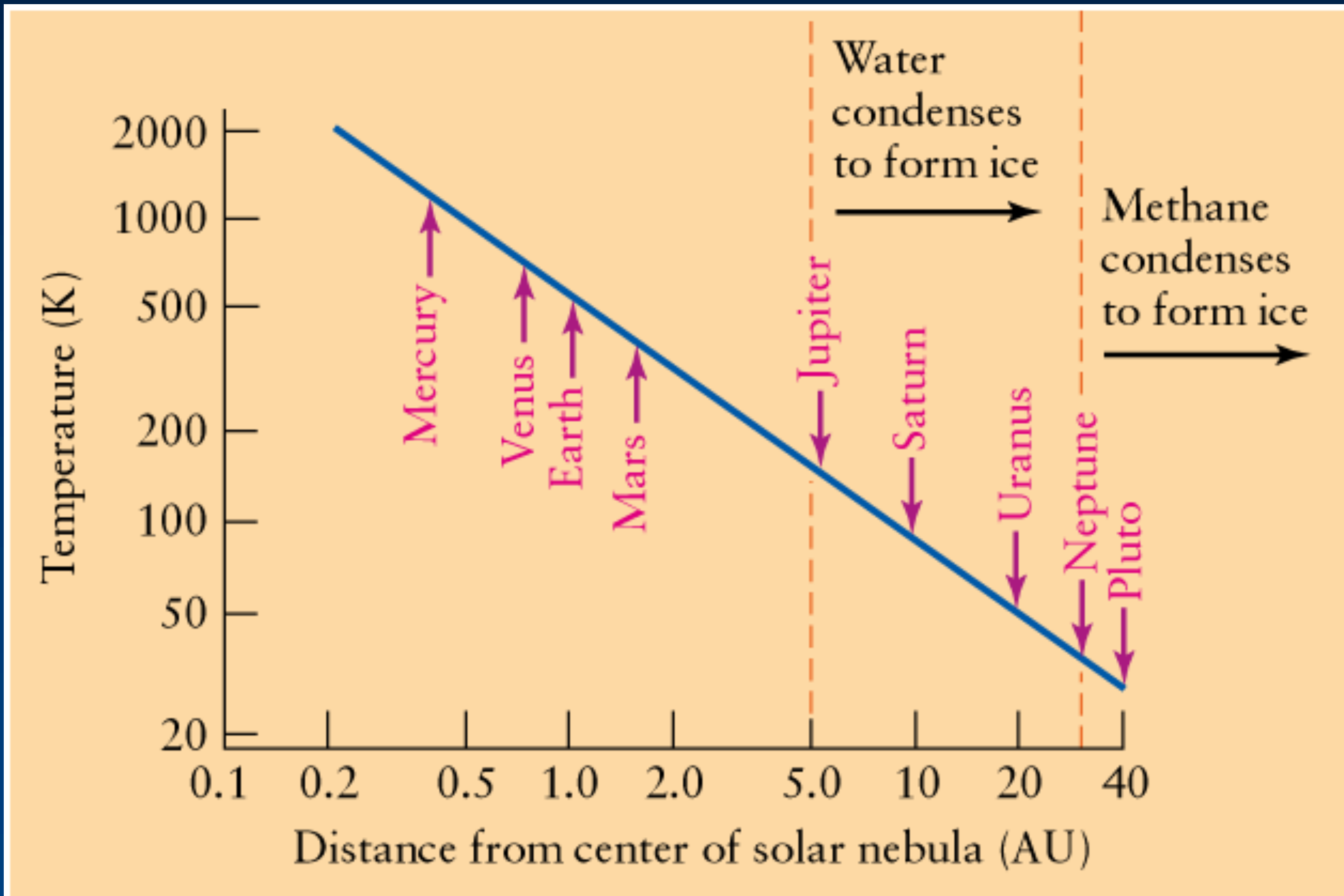
Two Kinds of Planets

"Terrestrial"	"Jovian"
Mercury, Venus, Earth, Mars	Jupiter, Saturn, Uranus, Neptune
Close to the Sun	Far from the Sun
Small (D=5000-13000 km)	Large (D=50,000-143,000 km)
Mostly Rocky	Mostly Gaseous
High Density (3.9 -5.5 g/cm^3)	Low Density (0.7 -1.6 g/cm^3)
Slow Rotation (1 - 243 days)	Fast Rotation (0.41 - 0.72 days)
Few Moons	Many Moons
No Rings	Rings
Main Elements Fe, Si, C, O, N	Main Elements H, He

General theory – the Nebular Model

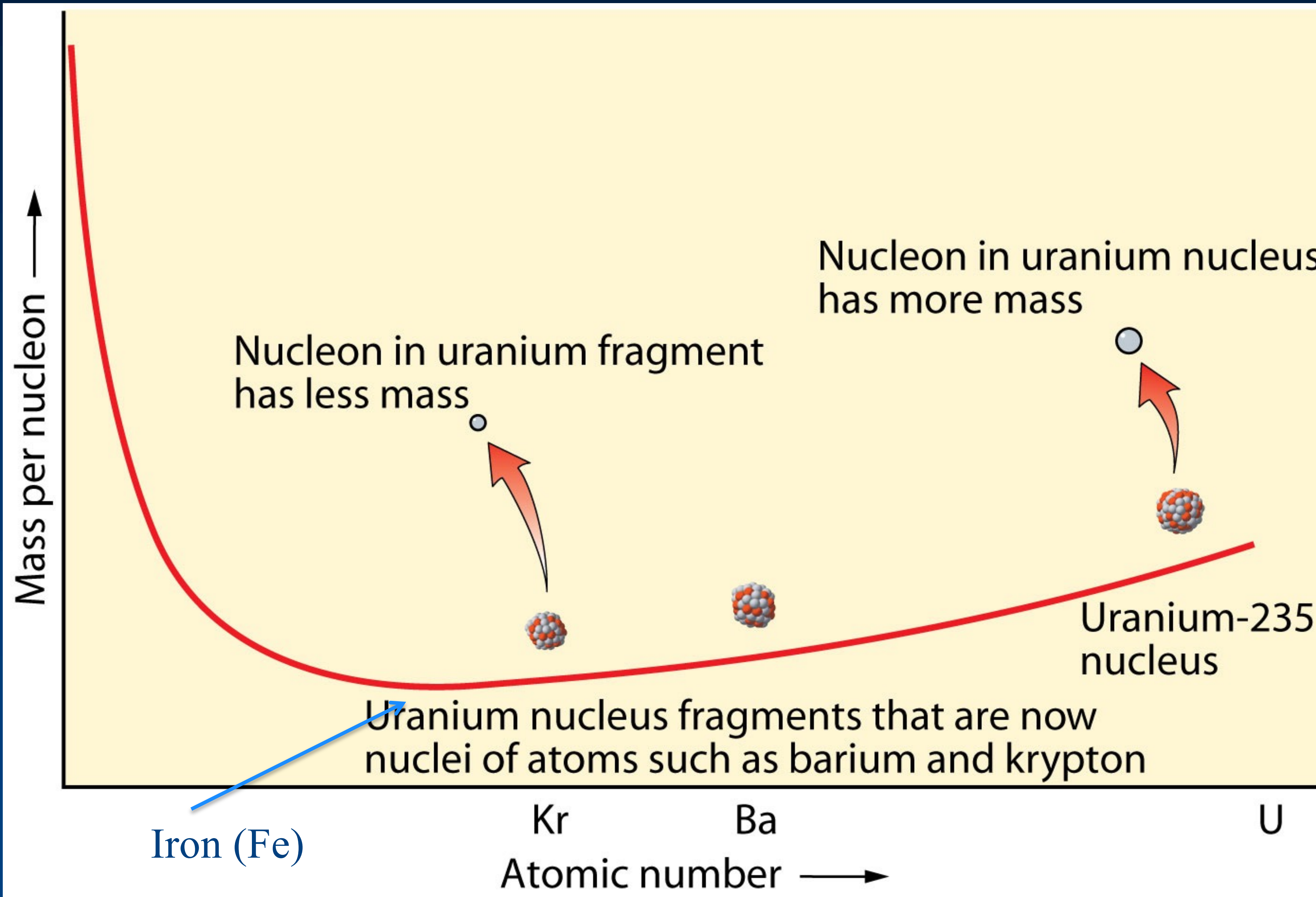
- Interstellar cloud of dust and gas
- Slow rotation, original spherical shape
- Gravitational collapse, dissipation into a plane due to conservation of angular momentum
- Differing temperature environments

Temperature distribution in Solar Nebula at time of formation of the planets



What is the temperature distribution now?

Figure 34.17



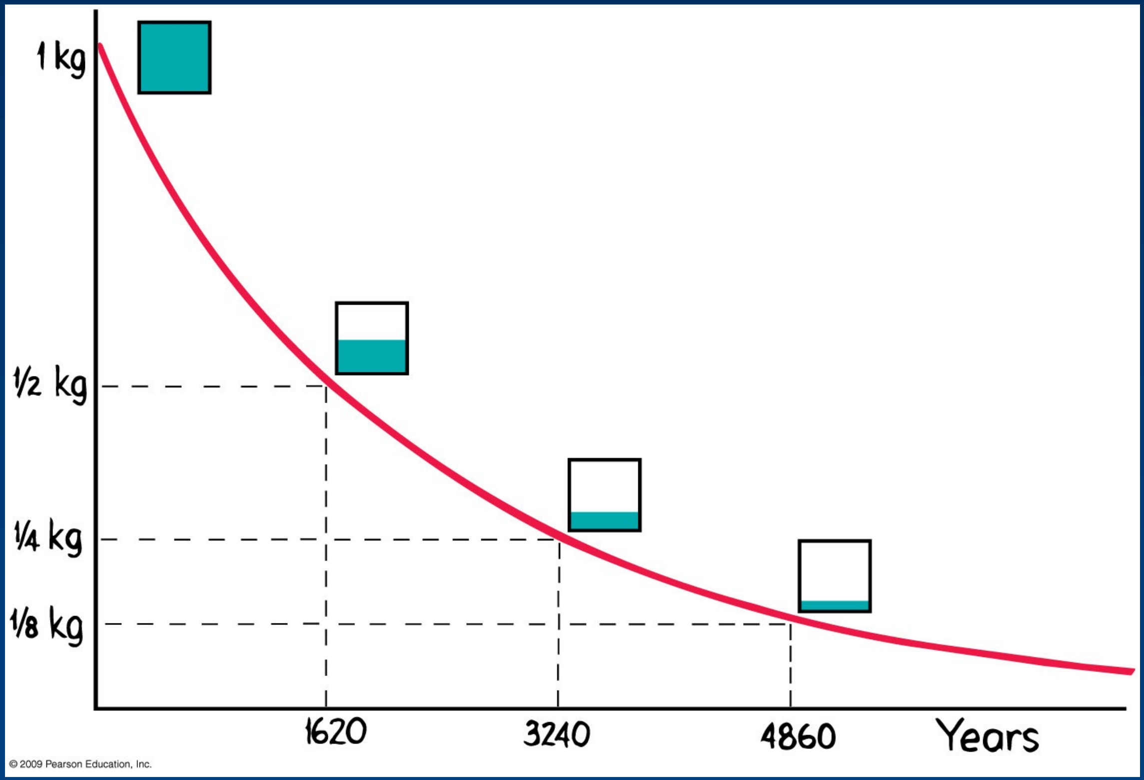
Mass per nucleon
Nucleon in uranium nucleus has more mass
Nucleon in uranium fragment has less mass
Uranium-235 nucleus
Uranium nucleus fragments that are now nuclei of atoms such as barium and krypton
Iron (Fe)
Kr
Ba
U
Atomic number

How Fast?

Its an "exponential" decay $N(t) = N_0\,(0.5)^{t/\tau}$

Half of the radioactive material will transmutate in a set amount of time

This amount of time (τ) is called the "half-life"



Half-life for radium 226 is 1620 y. 226Ra decays to radon 226Rn

How old is a sample which is 70% radon?

- Finding planets around other stars: astrometry, Doppler shifts of parent star (did example of Sun’s motion due to Jupiter), planetary transits, microlensing, low-frequency radio emission
- Earth basic data – relative size compared to other terrestials, density, what is meant by albedo, probing interior of the Earth, differentiation, temperature and density as function of distance from center, plate tectonics, what is it, what causes, convection, how plates “interact”.

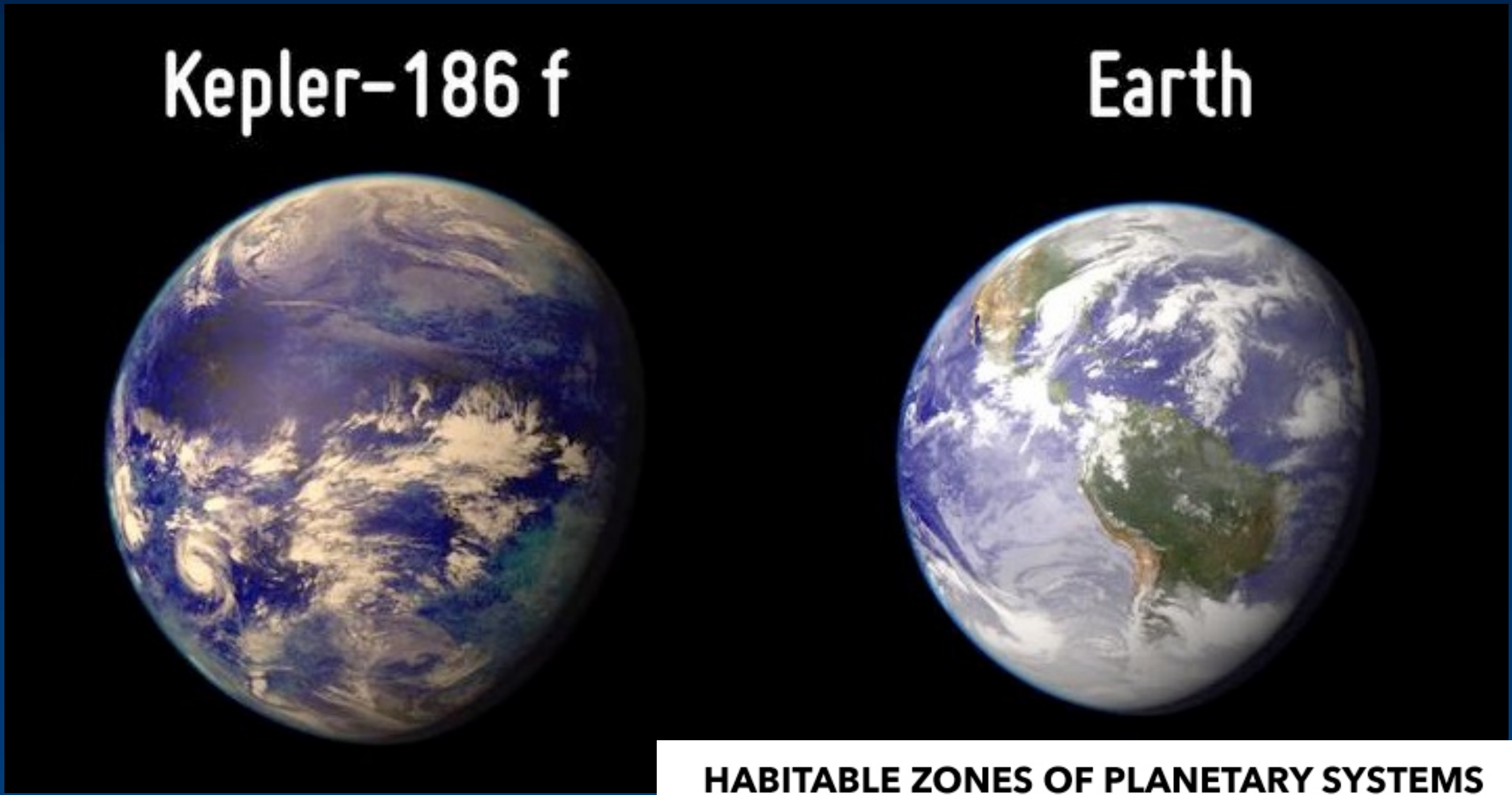
Planets around other stars

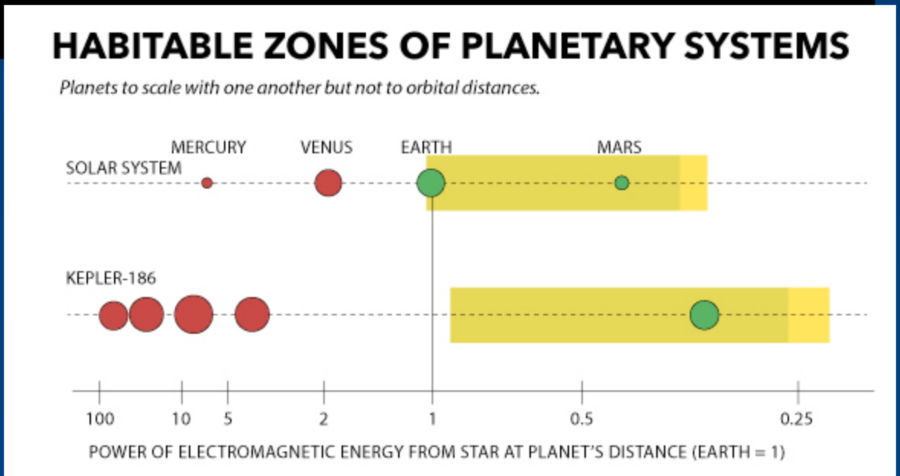
- Test solar system formation process
- Possibility of life on other planets

Techniques:

- Direct detection (images)
- Transit of star by planet
- Detection of star’s wobble by spectroscopy
- Detection of star’s wobble by imaging
- Microlensing

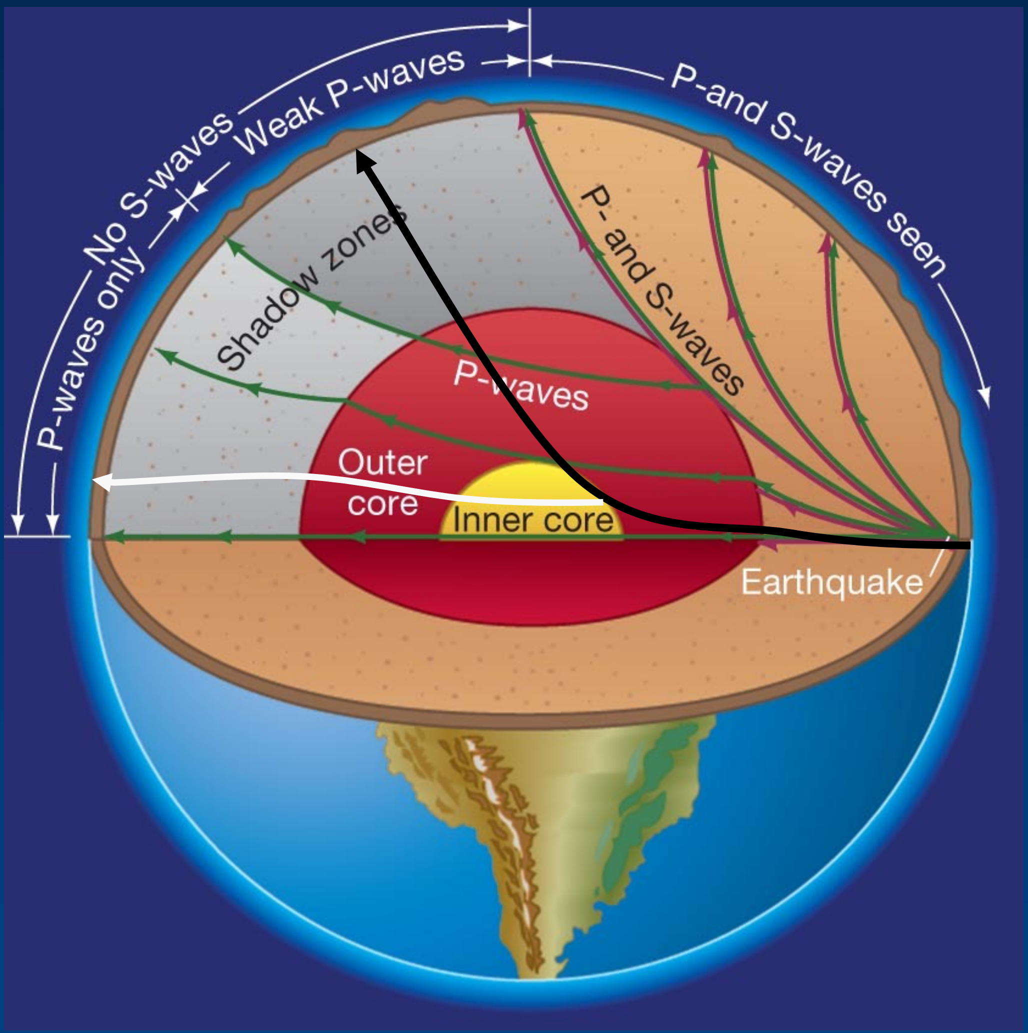
Extrasolar planet 1.1 Earth masses (Kepler-186f) found in star's habitable zone by Doppler method – April 2014





- Earth magnetic field, atmosphere, current composition, evolution, structure – pressure, temperature of layers, calculation how hot Earth should be (used Stefan-Boltzmann and Wien), Greenhouse Effect, how it works, Global Warming.
- Moon and Mercury – similarities and differences, basic data of Moon including relative mass compared to Earth, what crater density tells us about surface age, maria, highlands, surface features, lack of plate tectonics because cooled: cooling time $\propto$ heat content/rate of cooling $\propto$ volume/surface area $\propto R^3/R^2 \propto R$ (cooking a turkey vs a meatball)

P and S waves measured around the surface reveal interior structure



⇒ The Earth must have a liquid core! Also fairly sharp density increase when you hit the core.

Later, faint P waves found in part of shadow zone – solid inner core inferred

Layered structure of interior:

1. central very dense solid **core** of almost pure iron, density ~ 13 gm/cm^3
2. Outer liquid core ~11 gm/cm^3
3. surrounded by **mantle** of dense (~4 gm/cm^3, iron-rich minerals (also magnesium, silicon)
4. surrounded by **crust** of relatively light silicon-rich minerals. Density ~ 3 gm/cm^3 (You are here.)

Earth is ***differentiated***.

Plate tectonics

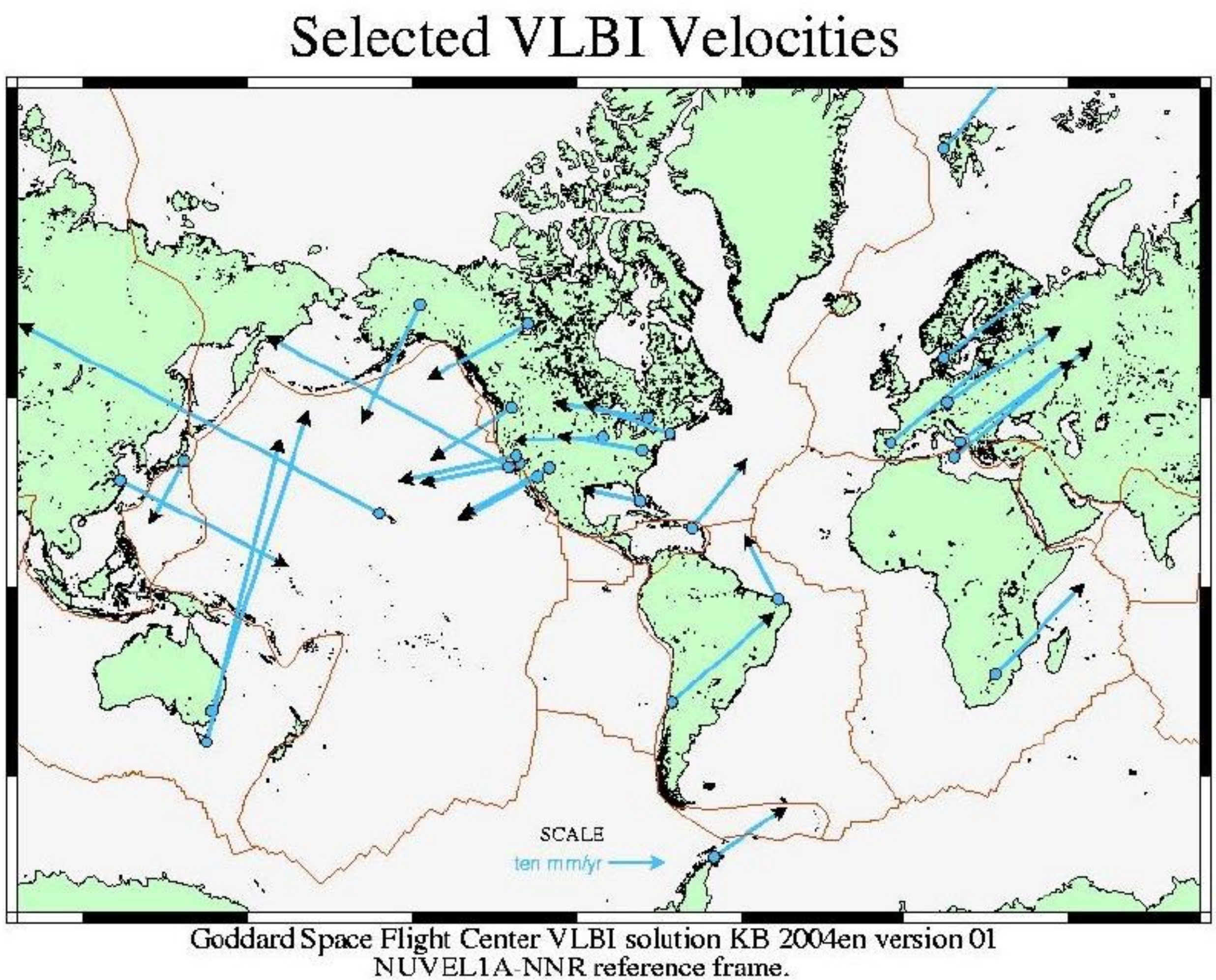
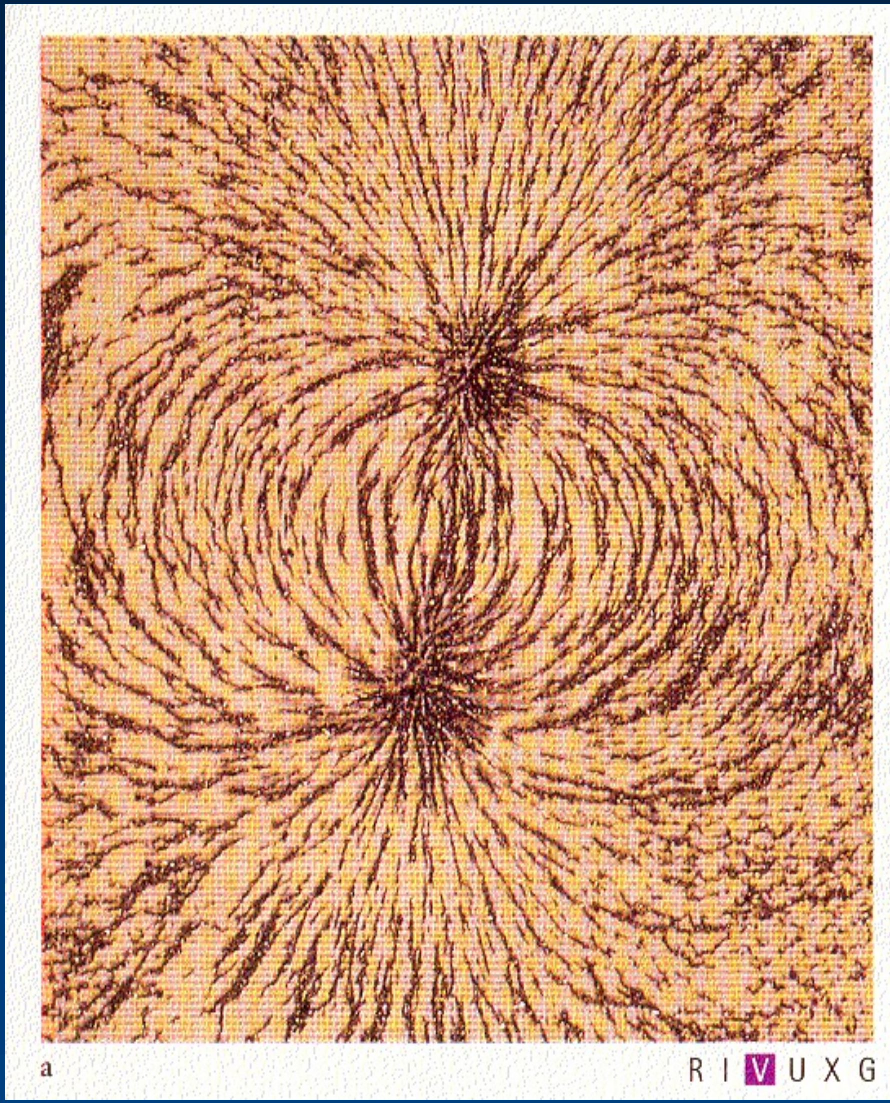
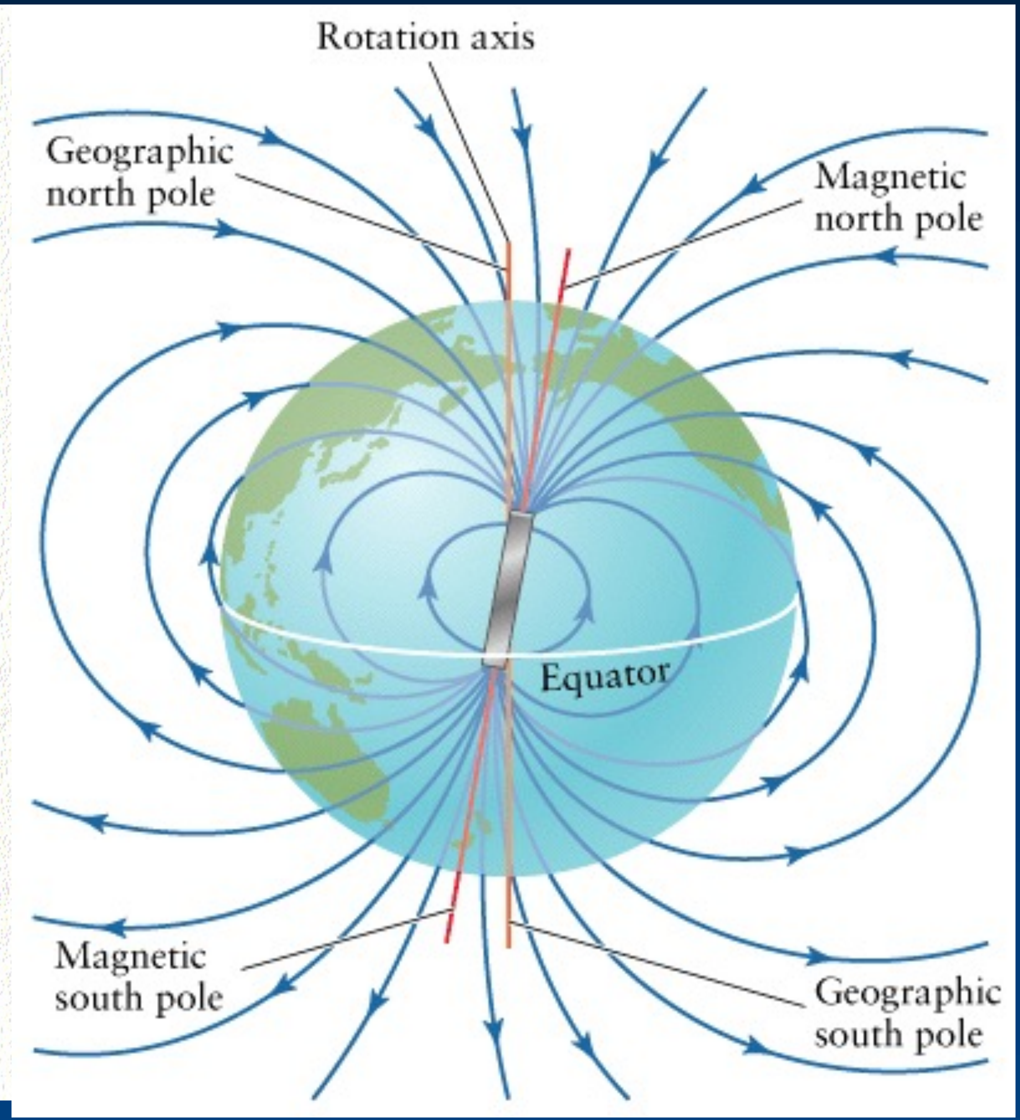


Plate motion ~ a few cm/year driven by convection in the mantle

Magnetic field around Earth has *dipole* shape.





The Earth's atmosphere - unique in Solar System

Table 9-4 Chemical Compositions of Three Planetary Atmospheres

	Venus	Earth	Mars
Nitrogen (N_2)	3.5%	78.08%	2.7%
Oxygen (O_2)	almost zero	20.95%	almost zero
Carbon dioxide (CO_2)	96.5%	~~0.035%~~	95.3%
Water vapor (H_2O)	0.003%	about 1%	0.03%
Other gases	almost zero	almost zero	2%

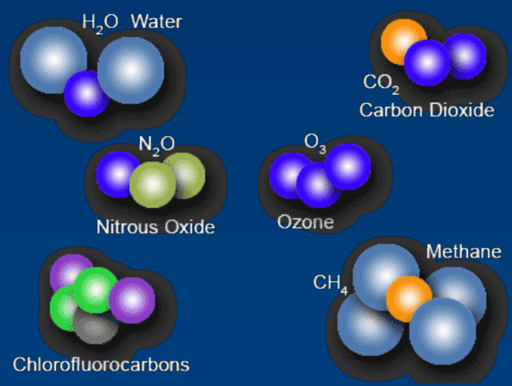
0.042%

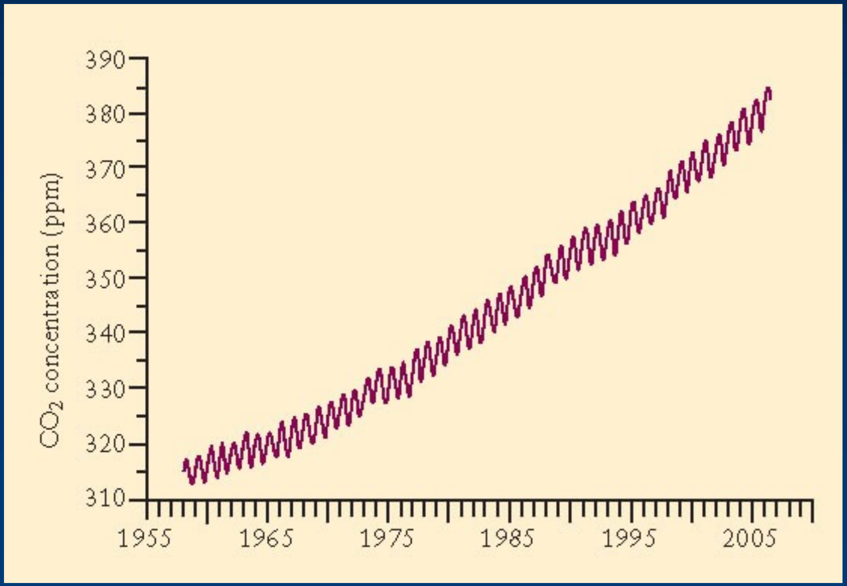
Earth's atmosphere has changed over time

Greenhouse gases

- CO_2 increases through use of petroleum products, fuel and biomass burning.

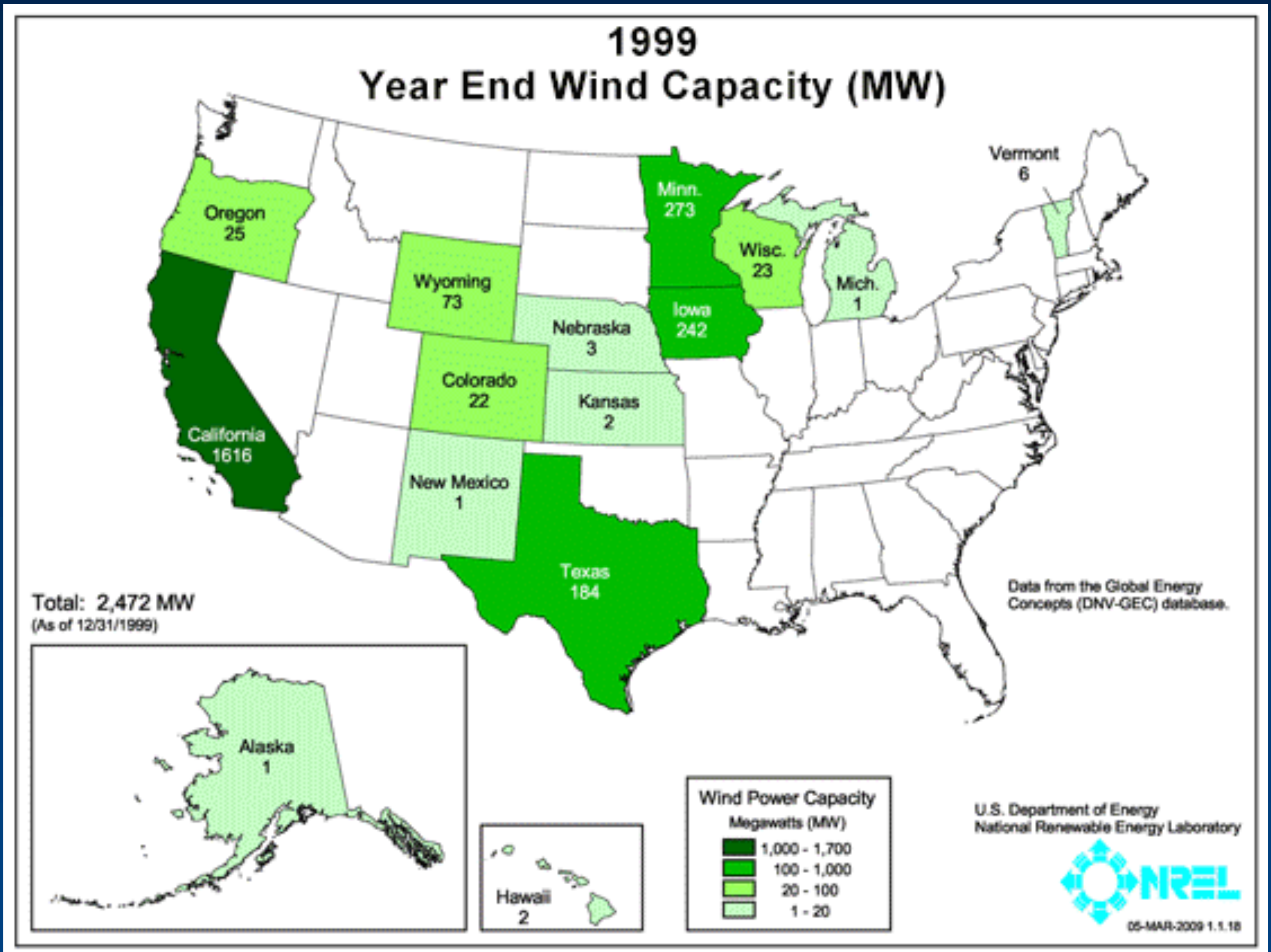
- Increased 35% since 1958:
  (and 11% since 2007)





- CH_4 increases from grazing ruminant animals, sewage, biomass decay

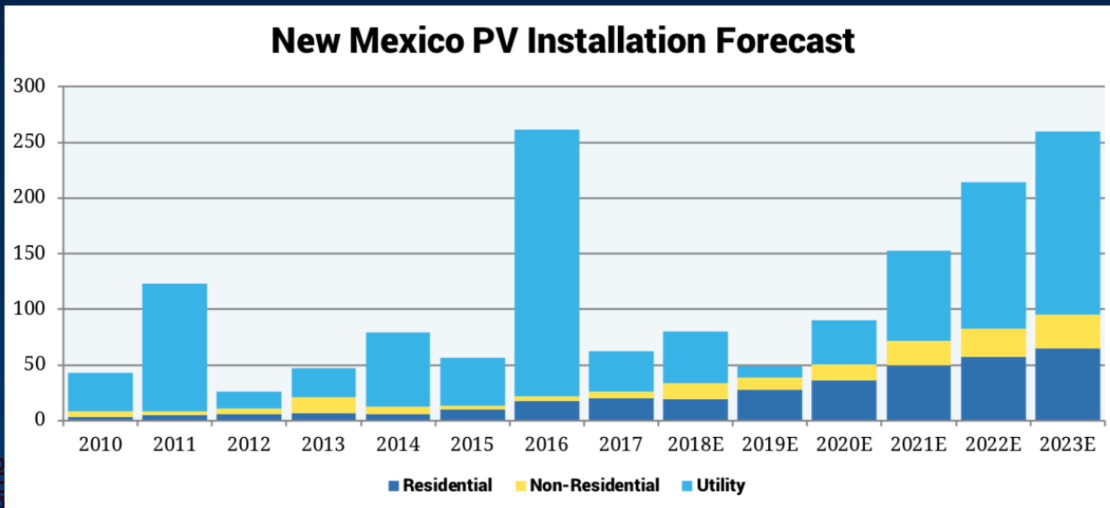
Wind Power

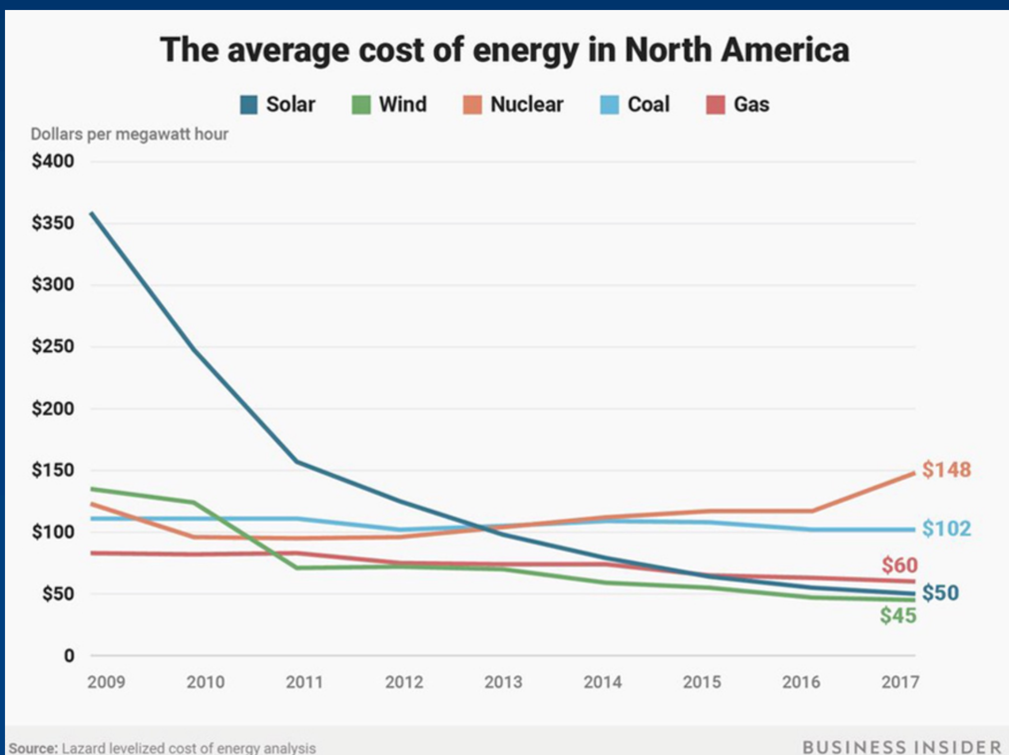


NM wind:
4000 MWatt
as of 2022
(ranked 14th
Nationwide)

US Total:
122,478 MW

Solar Power



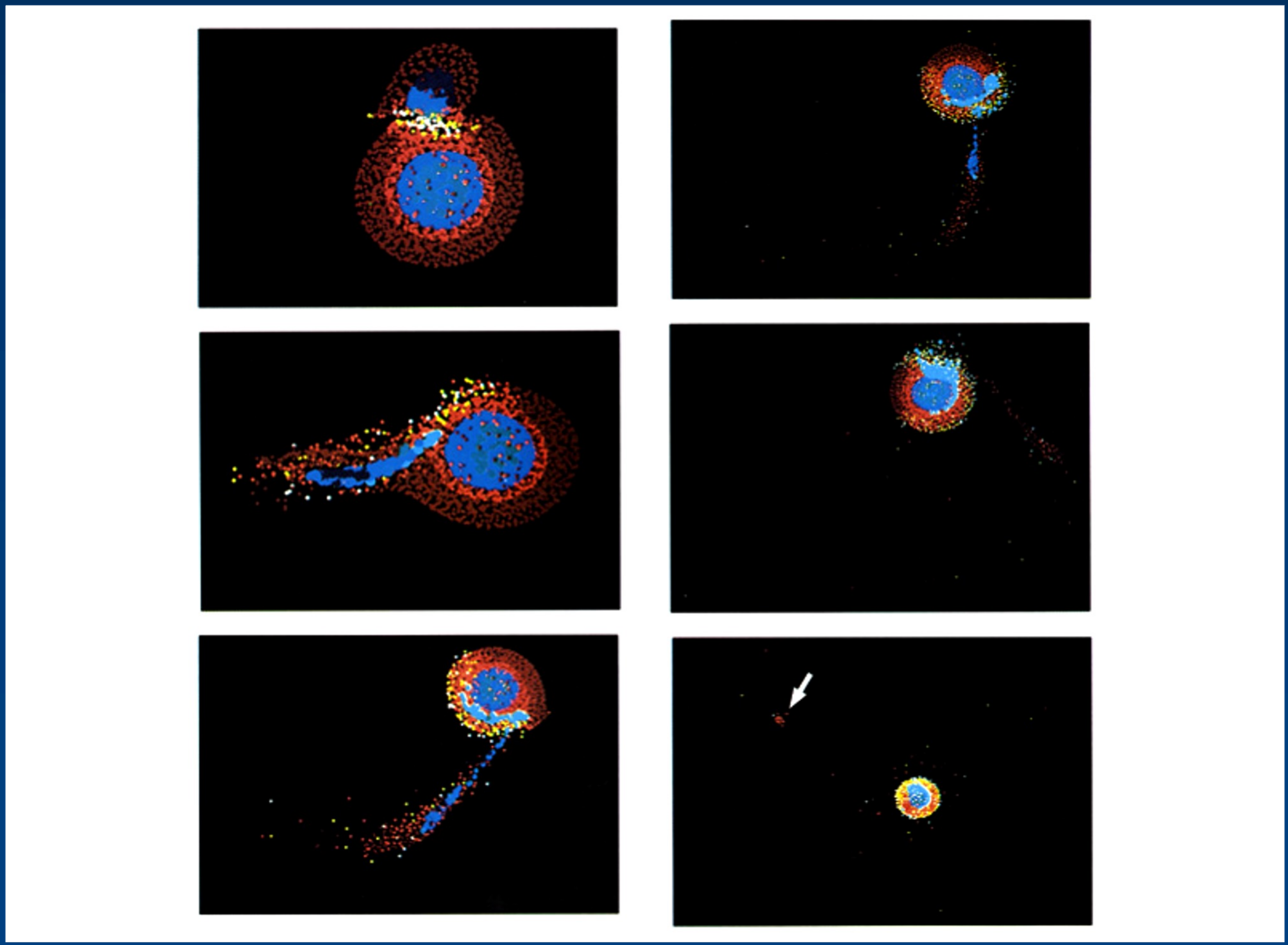


NM solar: 1900 MWatt as of 2024 (ranked 21st Nationwide)

Other clean energy sources: Hydro, geothermal, nuclear

So now, Impact theory preferred:

Early in Solar System, when many large planetesimals around, a Mars-sized object hit the forming Earth, ejecting material from the upper mantle which went into orbit around Earth and coalesced to form Moon. Computer simulations suggest this is plausible.



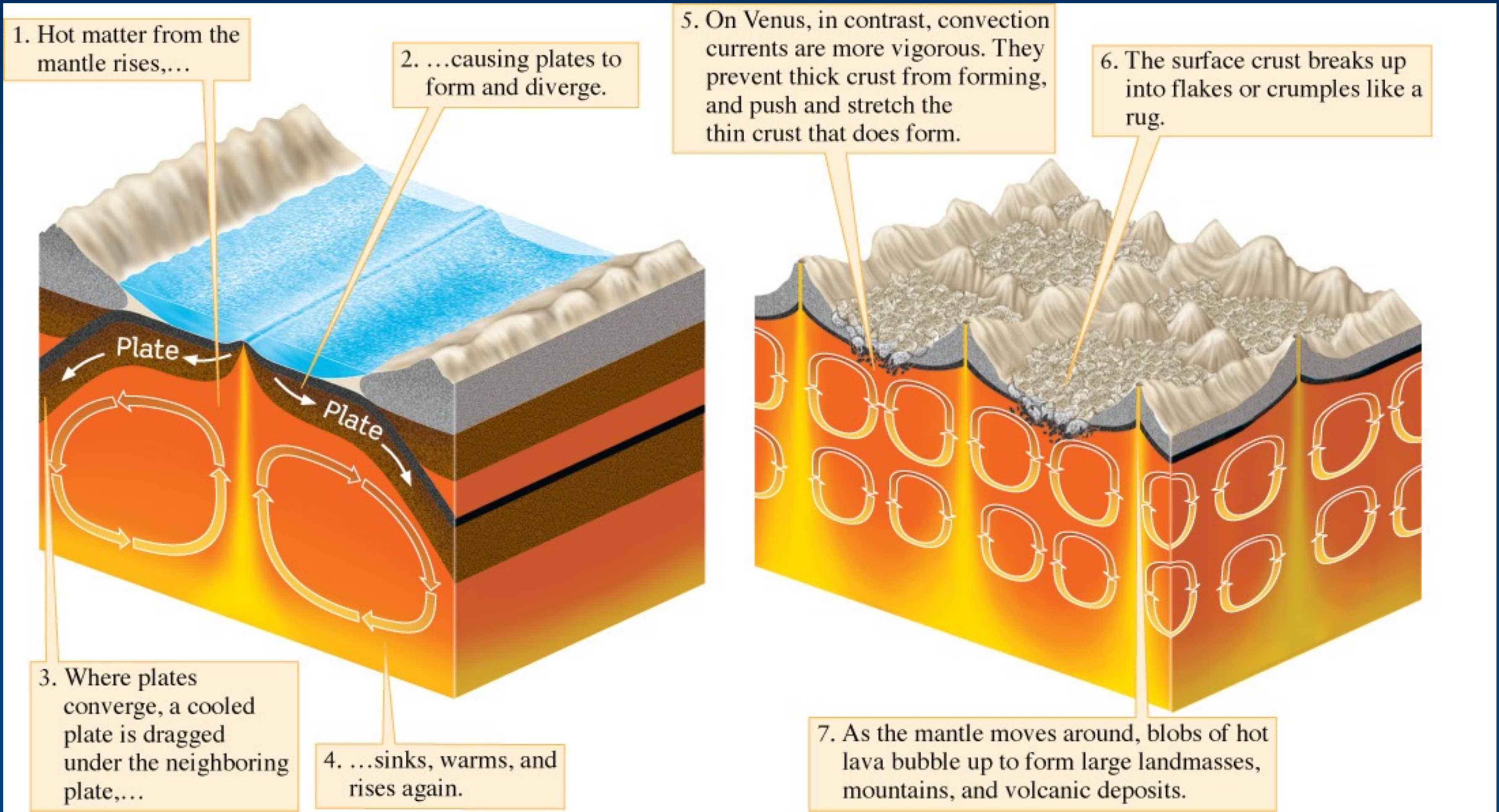
Mercury's surface compared to Moon

- No significant atmosphere (like the Moon) [but tenuous (pressure $<10^{-12}$ that of Earth's) *exosphere* of gas generated and maintained by the interaction of the solar wind with the planet's surface and magnetic field]
- Heavily cratered (like the Moon)
- 3.8 - 4 Gyrs old (similar to lunar highlands)
- No plate tectonics, water or wind erosion (like the Moon)
- Surface well preserved (like the Moon)

- Venus basic data, similarities, differences from Earth. Venus' atmospheric composition, temperature, pressure, history (*Runaway Greenhouse Effect*). Radar to study surface, surface features, uniform age of surface (how do we know?), *flake tectonics*, lack of magnetic field, retrograde rotation.
- Mars basic data, similarities, differences from Earth. Surface features, crustal dichotomy, big extinct volcanoes. No plate tectonics, no magnetic field. Thin atmosphere, composition, history (*Runaway Icehouse Effect*). Evidence of past water, current permafrost.

How is Venus different from Earth?

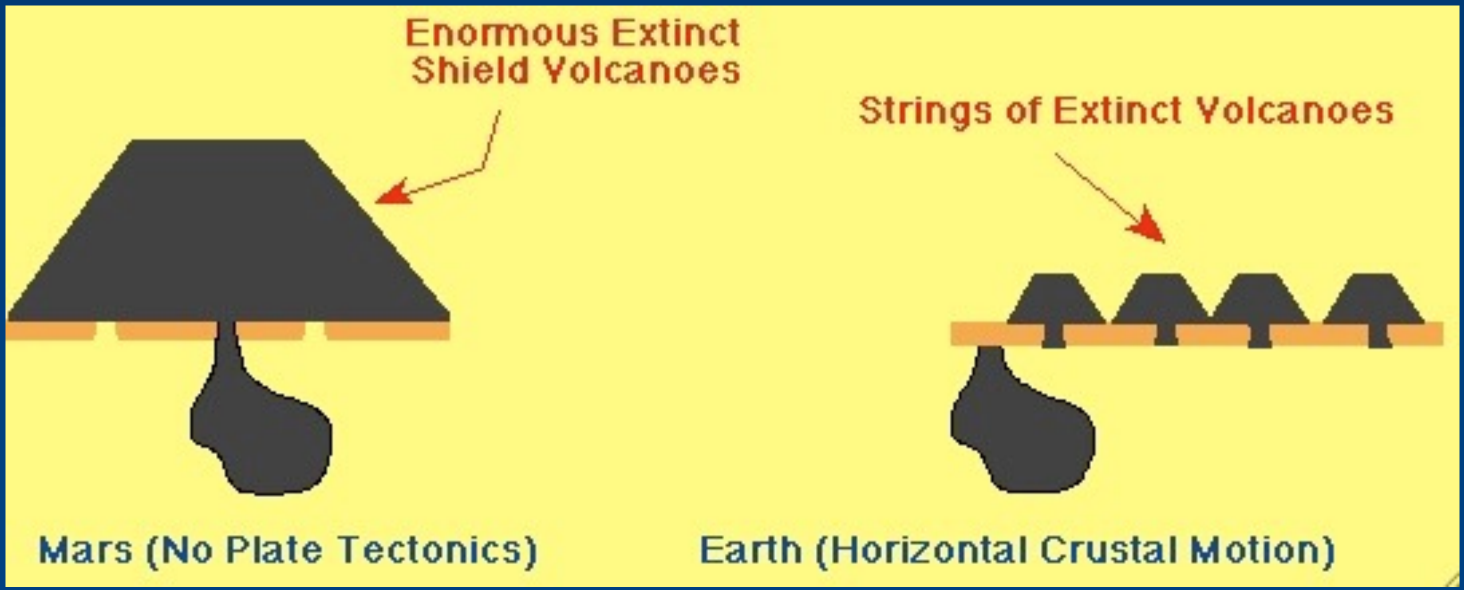
- One idea: <u>more</u> active volcanism keeps crust thin, continually covers up craters. Rock may even be soft due to surface heat. Easy to break through ("flake tectonics").

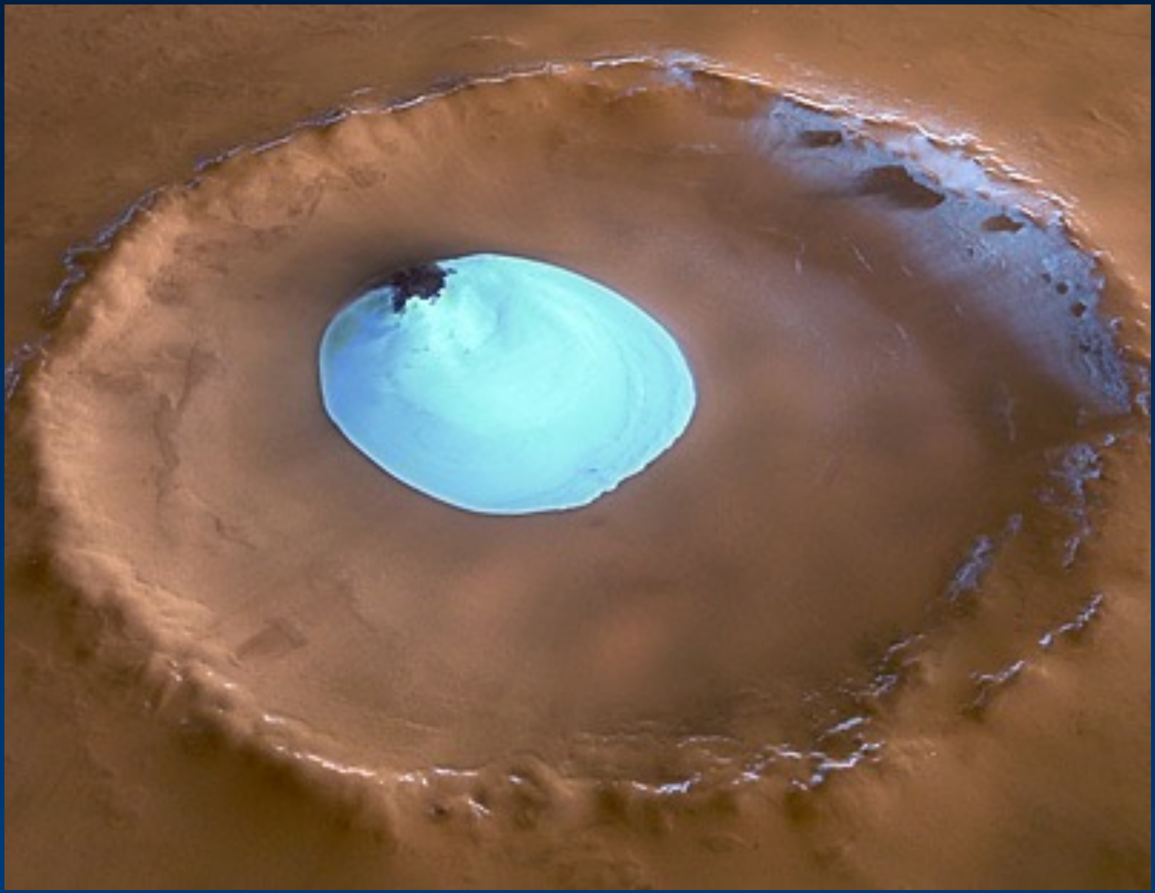


Mars: plate tectonics?

Current thinking NO, or if so only briefly.

- Absence of plate tectonics (or brief period due to shorter cooling time)
- Crust is thick and solid
- Lower surface gravity (0.38 of Earth's) helps volcanoes to grow high





Residual water ice in crater (Mars Express).

Interiors of planets

- Which planets are geologically active and why (Venus, Earth, Mars)
- Their main interior features (e.g. which have liquid cores, what the differences are)
- Jupiter has an extraordinary magnetic field (and implications for Io)

The planets - general

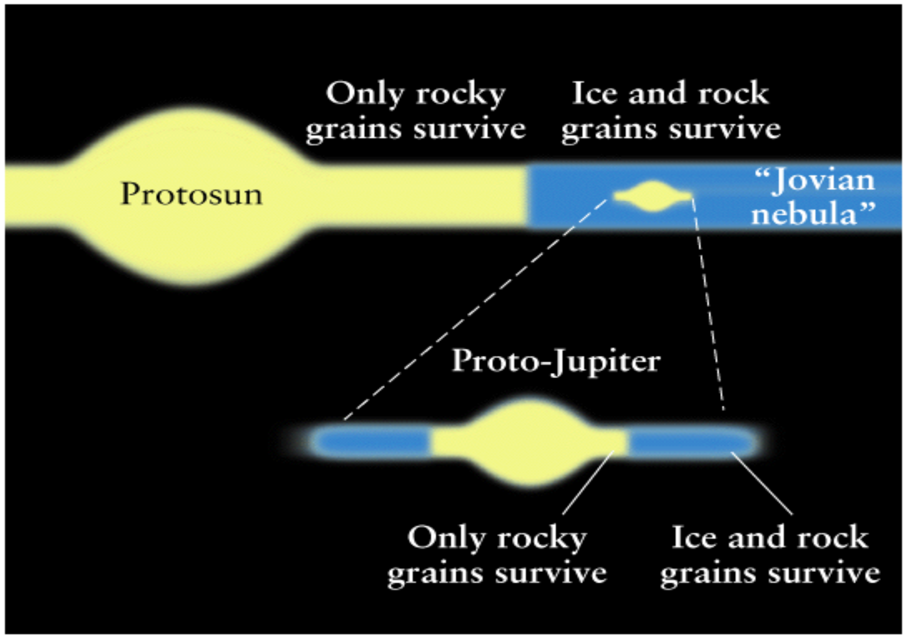
- Know the unique properties/features and why. Examples
  - Mercurys 3:2 spin-orbit coupling (tidal effect, elliptic orbit)
  - Venus retrograde (and slow) rotation (collision or tidal effect), hard to understand from solar nebula formation
  - Mars has volcanoes and rift valleys, evidence for water
  - Saturns rings, what keeps them stable (gravitational resonances and shepherd satellites)
  - Mercurys surface cratered like the Moon but flatter (stronger gravitation)
  - Neptune discovered by prediction
  - Tilt of Uranus

Moons

- Saturn: 1 giant moon, Titan, size of a planet. Low density $\Rightarrow$ ice and rock. Only satellite in the solar system with its own atmosphere.
- Mars has two captured asteroid Moons, Phobos & Deimos
- Neptune's Triton (retrograde)
- That some moons are in the rings, that others are captured asteroids (why)

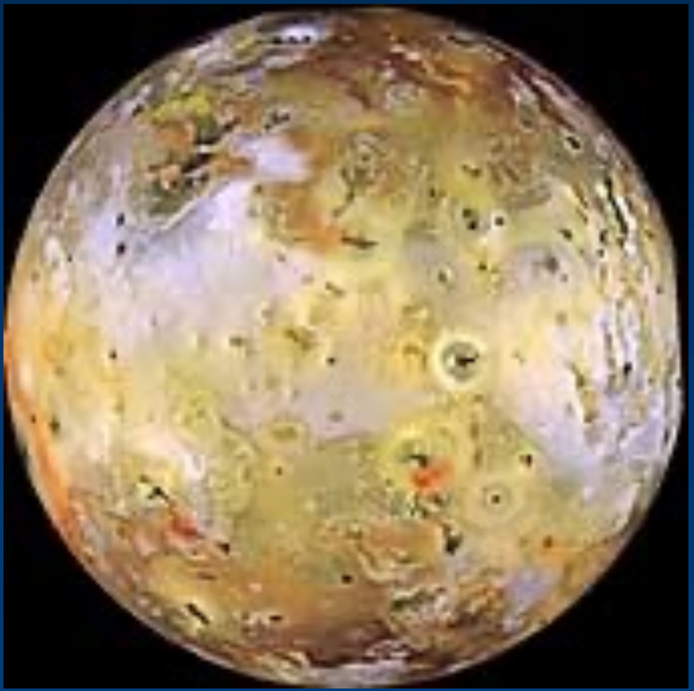
The Galilean satellites

- Io, Europa, Ganymede & Callisto
- Large satellites in orbits around Jupiter
- Synchronous rotation, with orbital resonance
- Densities gives two different types:
  - Io, Europa: primarily rocky material.
  - Ganymede, Callisto: roughly equal parts rock and water ice.

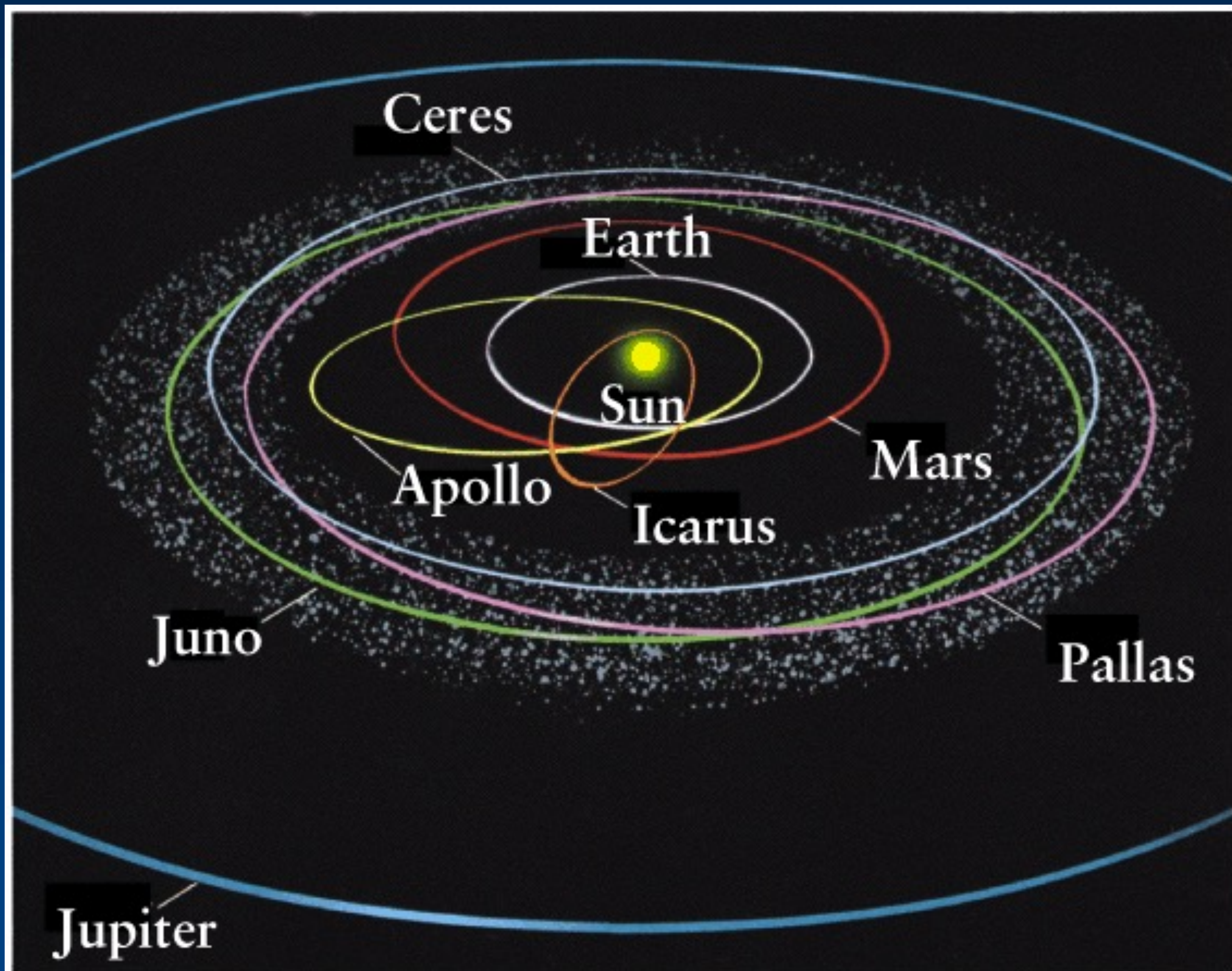


Io - innermost moon

- Hot and molten interior
- Feels a strong tidal pull from Jupiter, plus an additional tug from Europa every 2 orbits.
- Heats the interior, melting silicates & sulfur => active volcanoes
- Largest volcanoes in the solar system. Active eruptions & pools of molten sulfur
- Magnetic field due to Jupiter



Most asteroids reside in Asteroid Belt, 1.5 AU wide between Mars and Jupiter (why: Jupiter's gravity).



Terminology

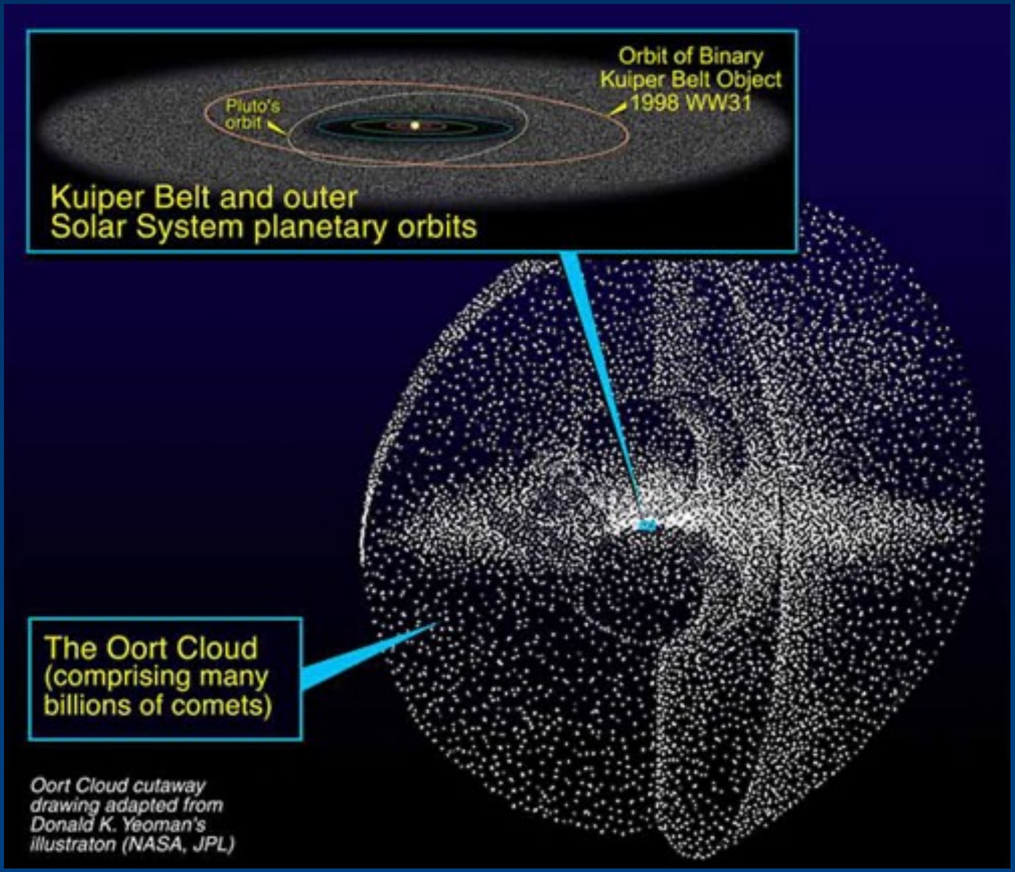
- Meteoroid - part of asteroid on collision course with Earth.
- Meteor - while still in atmosphere burning up, typical ones are the size of peas.
- Meteorite – meteor that survives to hit surface of Earth.
- Comet orbits are very different from asteroids or planets. They are highly elliptical and have random orientations (not necessarily in ecliptic).
- Sporadic vs meteor showers

Origin of comets

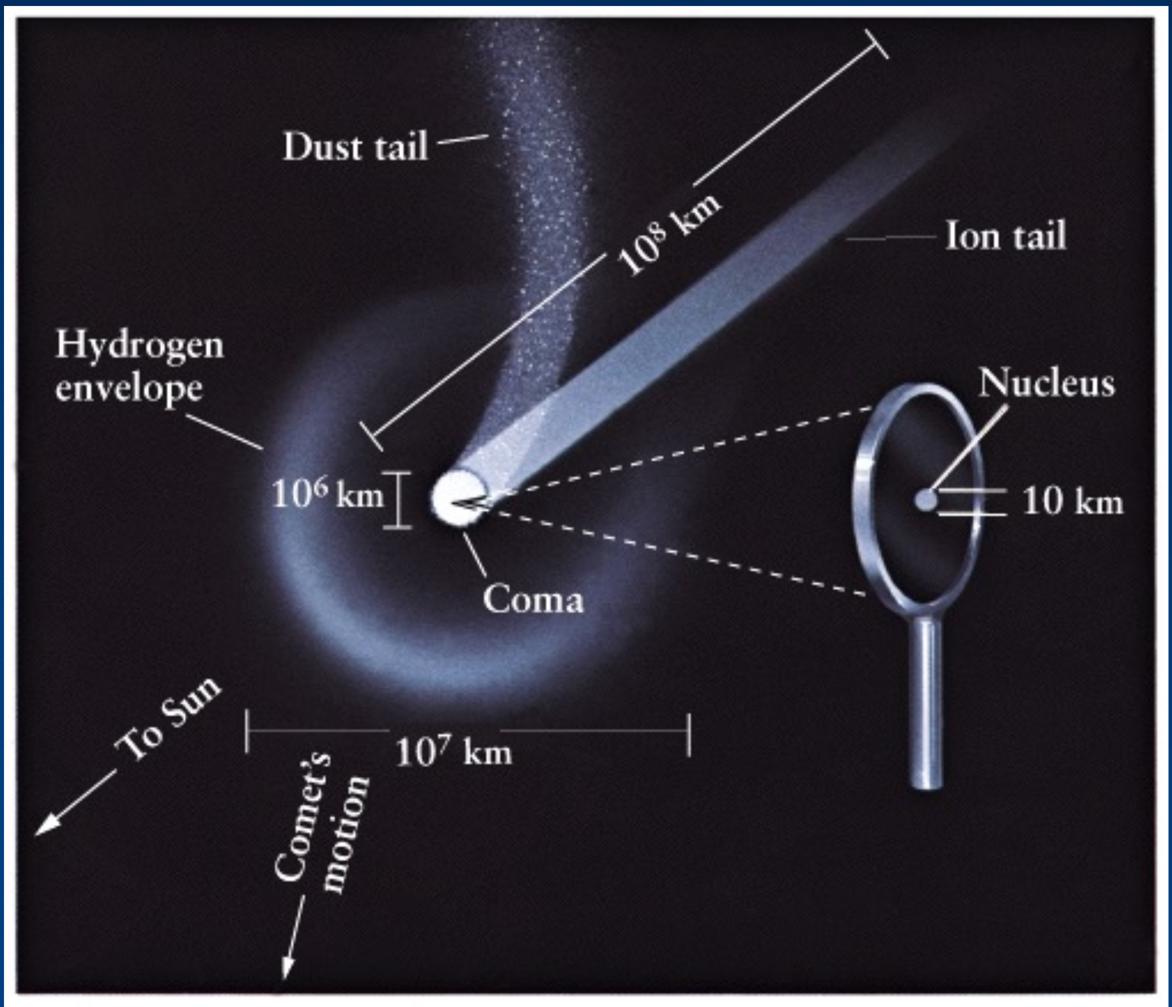
- Short period: Kuiper Belt (30-500AU)
  - Knocked into inner parts by passing stars, into smaller orbits by Jupiter's gravity
- Long-period: from the Oort cloud
  - Occasional disturbances by passing stars, giant molecular clouds

The Oort cloud

- Spherical cloud surrounding the planetary system up to 3 lyrs away
- The edge of the Sun's physical, gravitational and dynamical influence
- Trillions of icy objects relics of primordial nebula



Comet compositions are different from asteroids. "Dirty snowballs" – ices and small rocky particles.



"Physical" part: nucleus, 99% of the mass

Visible parts:

coma - low ρ gas/dust cloud

dust tail - whitish

ion tail - bluish (CO+ emission).

Hydrogen envelope from H_2O dissociated by solar UV.