Astronomy 210

Section 1– MWF 1500-1550

134 Astronomy Building

This Class (Lecture 19):

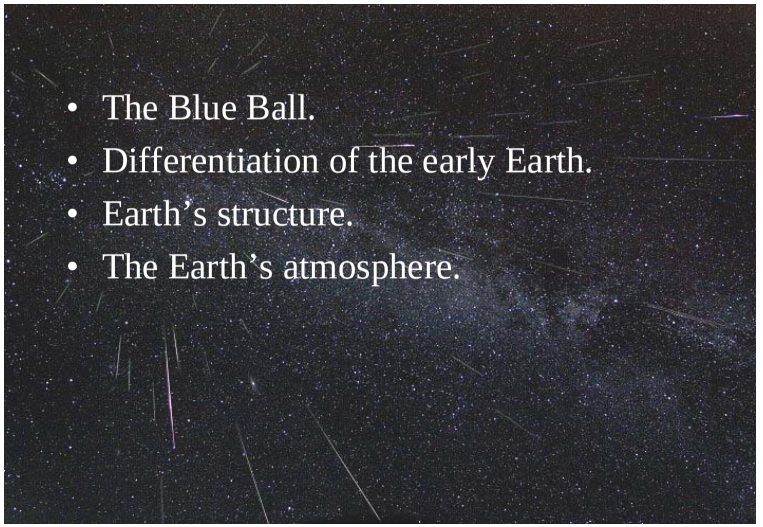
The Earth

Night Observations!

Next Class:

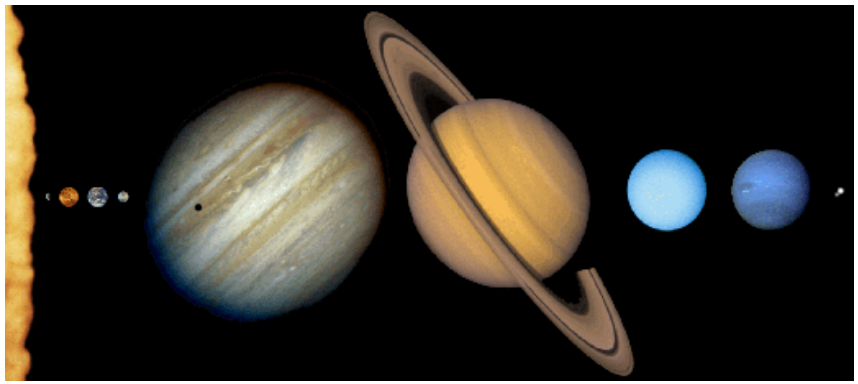
The Earth-Moon System

Outline



- The Blue Ball.
- Differentiation of the early Earth.
- Earth's structure.
- The Earth's atmosphere.

The Solar System is Ours!



The Earth – Fast Facts

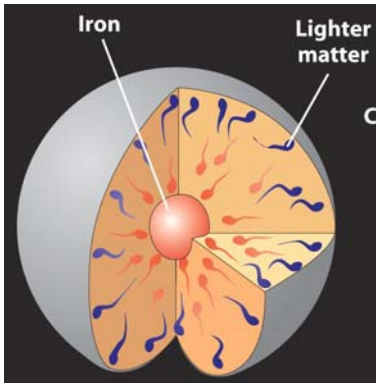
Radius	6378 km
Surface gravity	9.8 m/s^2
Mass	6.0×10^{24} kg
Avg. Density	5500 kg/m^3
Distance from Sun	1.5×10^8 km
Year	365.2422 days
Solar day	1 day

The Earth – Fast Facts

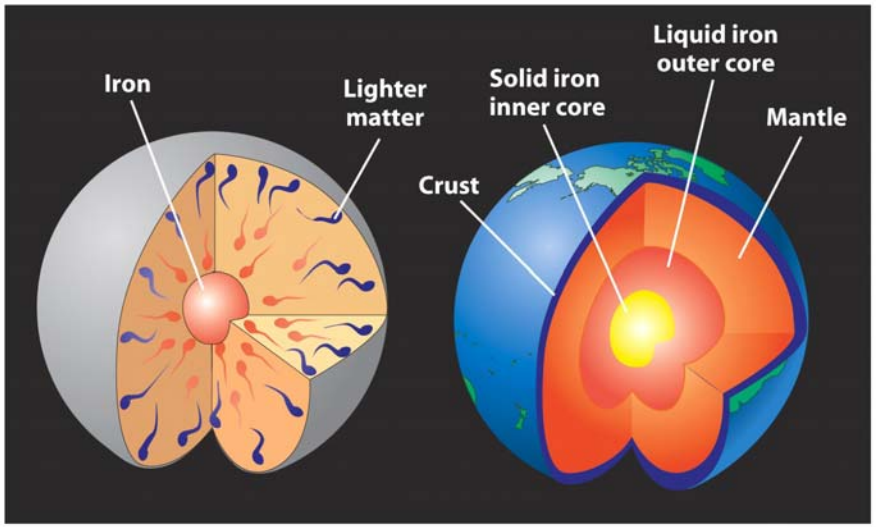
Easily get the Mass from $g=GM/R^2$
Then the average density is
$\rho=3/4\pi M/R^3 = 5500$ kg/m^3
This is between rock and iron, so some of each.

Differentiation

- Average density of Earth is 5.5 g/cm^3
- Average density on the surface is 3 g/cm^3
- So, something heavy must be inside
- When the Earth formed it was molten
  - Heavy materials (e.g. iron, nickel, gold) sank
  - Lighter materials (e.g. silicon, oxygen) floated to the top

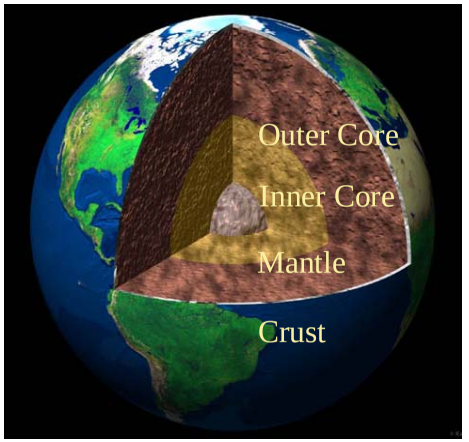


Planetary Differentiation



Structure

- Luckily, not all of the iron sank to the center, else we would be still in the Stone Age.
- Core is made of 2 parts– inner core and the outer core.
- Temperature increases as you go deeper. From around 290 K on surface to nearly 5000 K at center.
  - Heated by radioactive decay
- The deeper you go, more pressure from mass of Earth.
- Mass of the core = 1/3 Earth's mass and nearly half the radius.

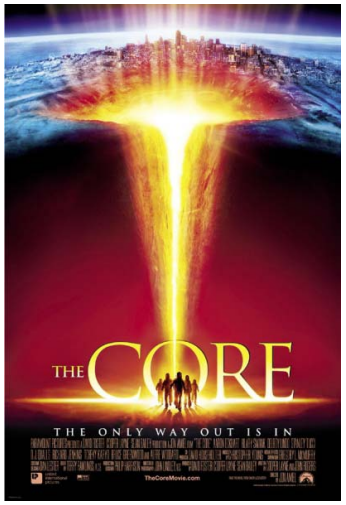


Inner Core

- Reaches very high temperatures– 5000 K (Close to the temperature at the surface of the Sun)!
- But still the high pressure makes the inner core remains a solid
  - Solid inner core – 1200 km radius
- Mostly made of iron (Fe) and nickel (Ni)
- Information about the inner core comes from the study of earthquakes, meteorites and the Earth's magnetic field.
- Might be rotating faster than the rest of the planet.

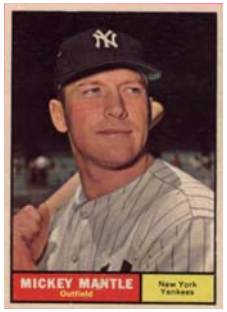
Outer Core

- The liquid layer of the Earth, high pressure but not enough to solidify
  - Liquid outer core – 2200 km radius
- Mostly Fe and Ni.
- Made of very hot molten liquid that floats and flows around the solid inner core– creates the Earth's magnetic field.



The Mantle

- Largest layer of the Earth
  - To a depth of 2900 km
  - Temperature increases with depth
  - Made of heavy silicates
- Parts of the mantle are hot enough to have an oozing, plastic flow
  - Sort of like Silly Putty
  - Currents in the mantle cause plate tectonics
  - Hot spots in the mantle can become plumes of magma (e.g., the Hawaiian Islands)



http://www.martyspsagradedcards.com/61mm.jpg

The Crust

- Outside layer of the Earth (includes oceans) that floats on top
  - About 50 km thick
  - Coldest layer – rocks are rigid
- Mostly silicate rocks
  - Made of lighter elements like silicon, oxygen, and aluminum
- Oxygen and water are abundant
- Excellent insulator
  - Keeps the Earth's geothermal heat inside!

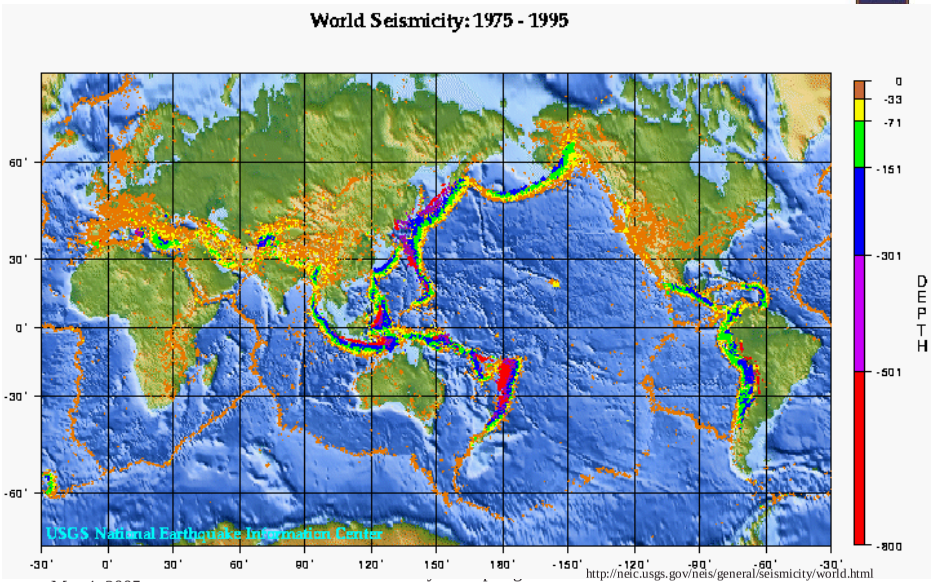
Earth's Surface

- 70% of the Earth's surface is covered with water
  - Ocean basins
  - Sea floors are young, none more than 200 million years old
- 30% is dry land – Continents
  - Mixture of young rocks and old rocks
  - Up to 4.2 billion years old

Geologically Active Surface

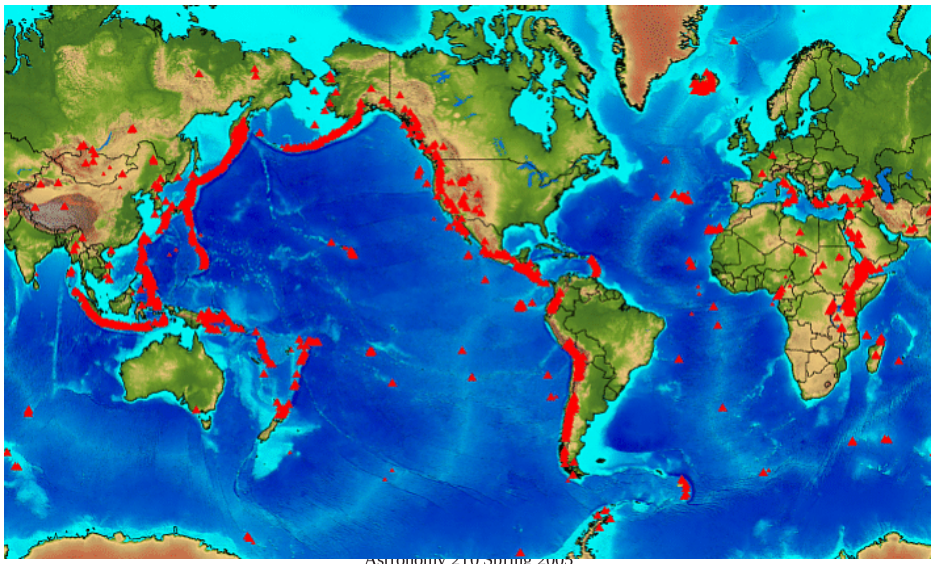
- The young rocks on the Earth's surface indicate it is geologically active
- Where do these rocks come from?
  - Volcanoes
  - Rift valleys
  - Oceanic ridges
- Air, water erode rocks
- **The surface is constantly changing**

Earthquake Activity



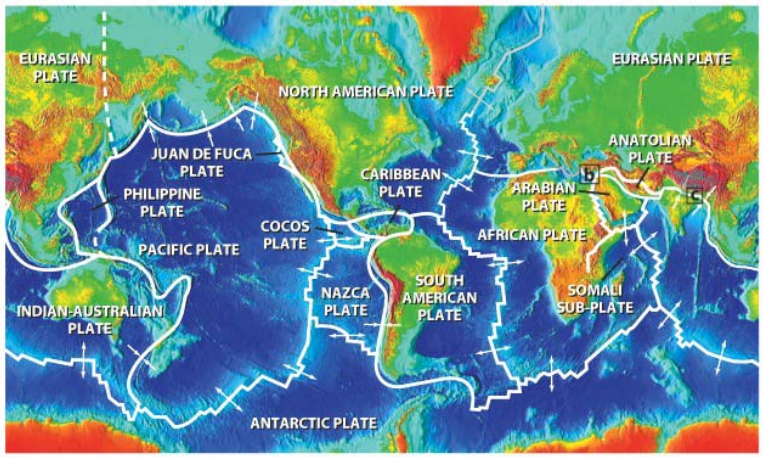
http://neic.usgs.gov/neis/general/seismicity/world.html

Volcanoes



http://www.volcano.si.edu/world/location.cfm

Plate Tectonics

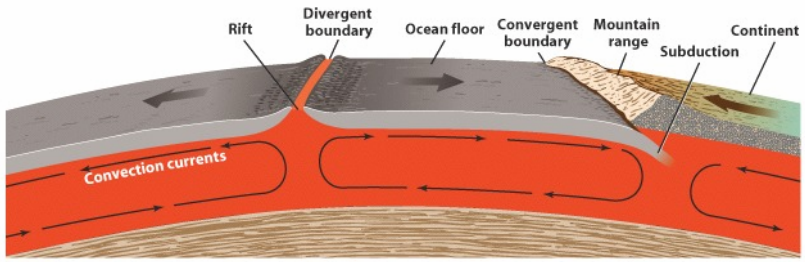


- The Earth's surface is broken up into about a dozen "plates"
- Plates "float" on denser rock below

Continental Drift

- You might think that South America and Africa "fit" like a jigsaw puzzle
- This gave rise to the idea of *continental drift*
- In the 1950s, the discovery of underwater mountain ridges confirmed the idea
- The seafloor between the North America and Europe/Africa is spreading at 3cm per year!

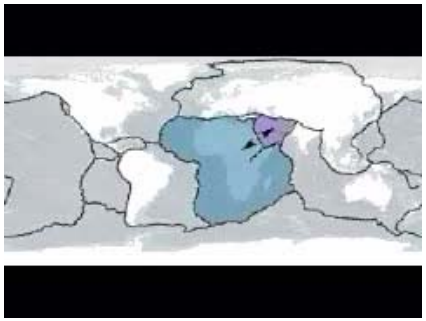
How Plate Tectonics Works



- Currents in the denser rock squeeze, pull, break, and stretch the Earth's surface
  - Stresses build up between the plates
    - Released in the form of **earthquakes**
  - Breaks in the plates allow magma to flow up
    - Creates **volcanoes**

Moving Earth

Plate Tectonics in Action



Seafloor Spreading

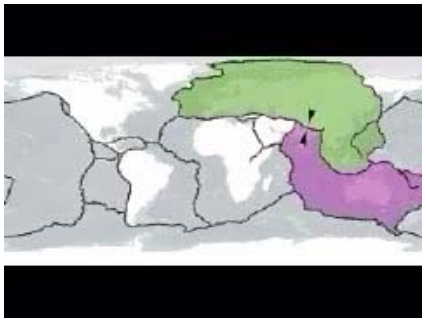
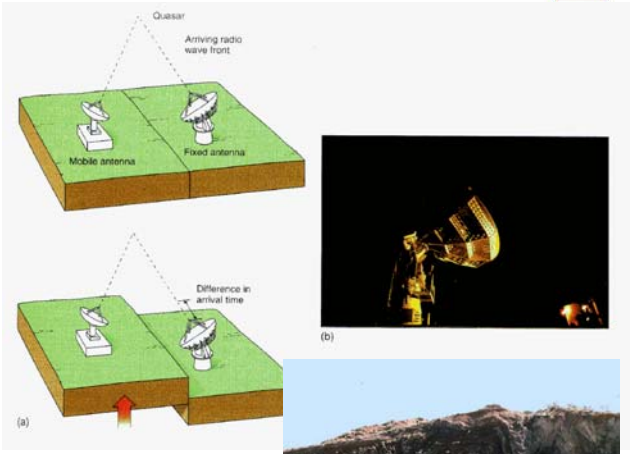


Plate Subduction

Pudding Proof



http://www.earth.northwestern.edu/people/seth/107/Platemotion/vlbi.htm
http://kids.earth.nasa.gov/archive/pangaea/SLR.JPG
http://www.earth.northwestern.edu/people/seth/107/Intro/safpalmdale.html
http://kids.earth.nasa.gov/archive/pangaea/evidence.html

Plate Tectonics in Action

Seafloor Spreading

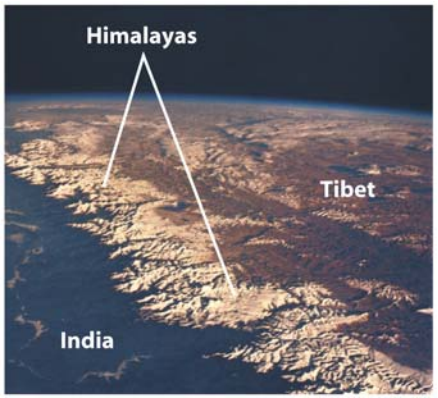


Plate Subduction

Recycling Bio-elements

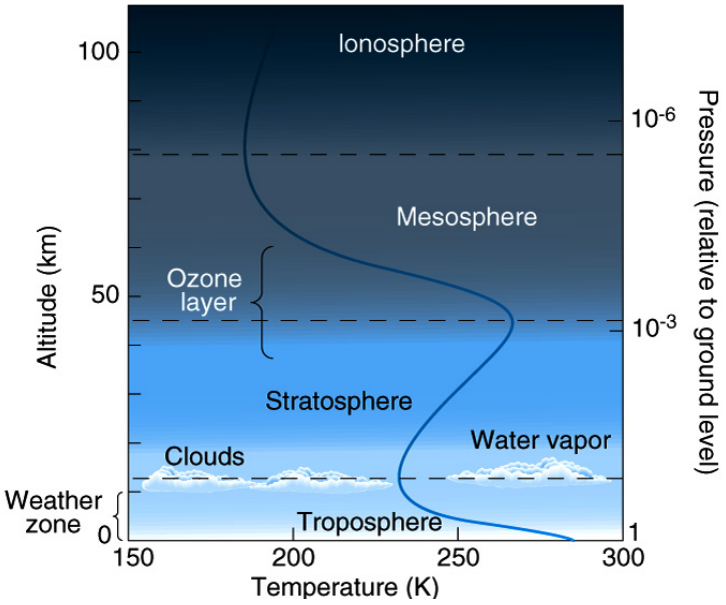
- From gravity and radioactivity, the core stays hot.
- This allows a persisting circulation of bioelements through continental drift— melting of the crust and re-release through volcanoes.
- Otherwise, certain elements might get locked into sediment layers– e.g. early sea life.
- Maybe planets being formed now, with less supernovae, would not have enough radioactivity to support continental drifts and volcanoes. (Idea of Peter Ward and Donald Brownlee.)

http://www.pahala-hawaii.com/j-page/image/activevolcanoe.jpg

Earth's Atmosphere

- Earth's atmosphere is a mixture of gases
  - Nitrogen (N_2) 77%
  - Oxygen (O_2) 21%
  - Argon Gas (Ar) 1%
  - Water Vapor (H_2O) 1%
  - Carbon Dioxide (CO_2) 0.033%
  - Trace gases (Helium, Neon, Ozone, Methane, etc.)

Layers of the Atmosphere



Roles of the Gases

- Nitrogen is relatively *inert* (chemically inactive)
- Oxygen is used by animals to *oxidize* (chemically burn) food for energy production
- Water vapor and carbon dioxide are *greenhouse gases*
  - Act as an insulating blanket
  - Earth is 35 K warmer than it would be otherwise

Layers of the Atmosphere

- Troposphere - lowest layer, 0-11 km
  - 85% of the air
  - Weather occurs here
  - Temperature drops with altitude
- Stratosphere - 11-50 km
  - Temperature goes up with altitude
  - Ozone layer at the top
- Mesosphere - 50-80 km
  - Temperature again drops with altitude
- Ionosphere - 80+ km
  - Temperature climbs, up to 1000 K at 200 km

Ozone Layer

- Ozone is O_3
  - Three oxygen atoms bound together
  - Created by sunlight
- Absorbs solar ultraviolet light
  - Protects life on the surface from harmful UV rays
- Very low density
  - If at the same density as near the surface only a few mm thick
- Human-made chemicals deplete the ozone layer

Origins of Our Atmosphere

- This is the Earth's 3rd atmosphere
- First was from formation
  - Hydrogen and helium
  - Escaped to space
- Second was from volcanoes
  - Carbon dioxide and water, some nitrogen
  - 100 times thicker than our atmosphere today!

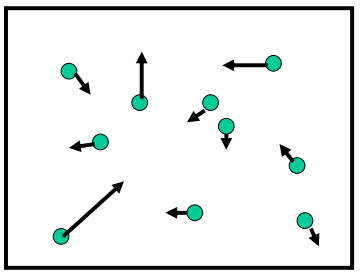
What Happened to the CO_2?

- Water
  - Precipitated out of the air, into the oceans
  - CO_2 dissolved into the oceans
- Life
  - Converted CO_2 in the water into shells
  - Now trapped in seafloor sediments
  - Photosynthetic organisms converted CO_2 into O_2
- What remained was N_2, O_2, and H_2O

Pressurized

Collisions with the walls of the box transfer momentum (change velocity) that implies a change in acceleration, which means a force. That force can be interpreted as pressure. For an ideal gas:

$$PV = NkT$$



$$\text{note}: \rho = M/V = mN/V$$

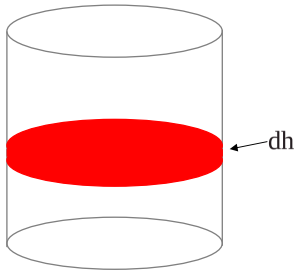
$$\text{so}: P = \rho\, kT/m$$

Earth's Atmosphere

- Think about the column of air above you.
- Consider a slab in that column with a constant temperature (isothermal)

Mass of slab: $dM = \rho dV = \rho A dh$

Force on slab: $F_w = -gdM = -g\rho A dh$



A downward force, but it doesn't fall? Why? The atmosphere has mass, so why isn't it all pooled around our feet?

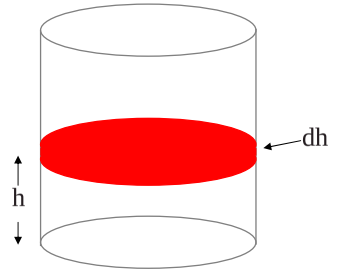
The Pressure is on

- There is a difference in pressure.
  - On bottom P(h) and on top P(h+dh)

$$F_p = \Delta P \times A = [P(h+dh) - P(h)]A$$

$$= A\frac{dP}{dh}dh$$

$$= A\frac{kT}{m}\frac{d\rho}{dh}dh$$



- If the atmosphere is in hydrostatic equilibrium the downward force of gravity is countered by the upward force of pressure.

Density Dentist

- If we are in hydrostatic equilibrium then
  - $F_w = F_p$

$$-g\rho A dh = AkT\frac{d\rho}{dh}dh$$

$$\frac{d\rho}{\rho} = -mg\frac{dh}{kT}$$

Atmospheric density is exponentially decreasing with height!