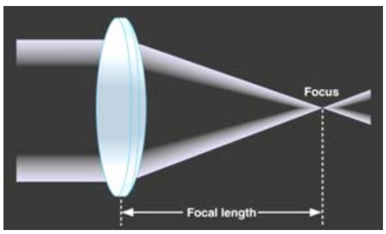
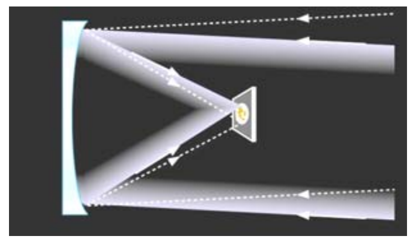
Telescopes [5]

Galileo's telescopes: ~1" in diameter x 24-30" long

- Magnify images ➔ see details
- Gather light over large surface area ➔ see fainter objects.



Using a lens (refractor) [Fig.5.2]



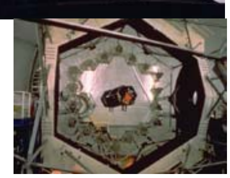
Using a mirror (relector) [Fig. 5.3]

Some large ground-based optical telescopes

Lick 36" Refractor 1888

Mt. Palomar 200" Reflector 1948

Twin Keck 10m (400") reflectors Mauna Kea, 1993



Light-gathering power

$\propto$ (mirror area)

$\propto$ (mirror diameter)^2

Technological advances

- Lenses ➔ mirrors
- Thick mirrors ➔ thin mirrors
  passive ➔ active support
- Now working on designs for 30m diameter telescopes.

Europe's Very Large Telescope (Four 8m telescopes)

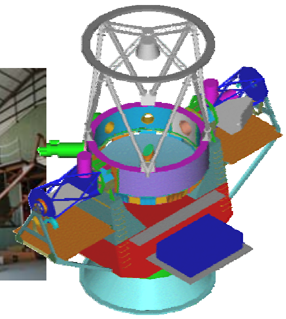
Mirror for Gemini 8m Telescope

SOAR: MSU's New 4m Telescope

Superb image quality.
Superb site in Chile.
⇒ Highly competitive for optical/infrared observations.

SOAR on
Cerro Pachón, Chile

Start operations in 2004



An International Partnership

- MSU
- University of North Carolina
- National Optical Astronomy Observatories
- Brazil

SOAR mirror casting

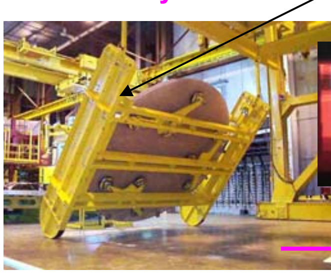
Corning Glass Works

Hex Layout

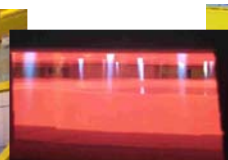
Seal Fire

Sealed Plano

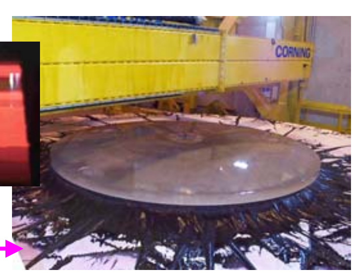
SOAR Turnover Fixture



Handling For Plano Grind



Sag Fire



Blank Ready for R2 Grind

Just finished polishing the mirror!

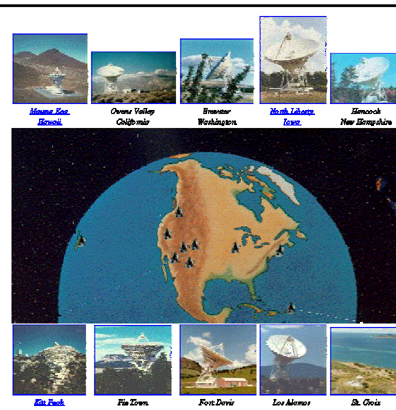
by B.F.Goodrich, in Danbury, CT

Radio telescopes

$$\text{Angular resolution} = \frac{\text{wavelength}}{\text{mirror diameter}}$$

- Radio wavelengths are large ➔ need large mirror diameter to see small-angle details.

- Arecibo, Puerto Rico….
  - **1000 ft. diameter, but same angular resolution as 0.01 ft optical telescope.**

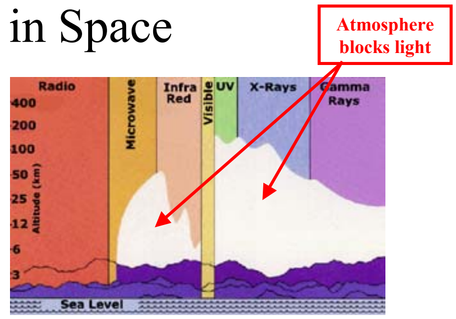


Array of smaller telescopes simulates a huge aperture.

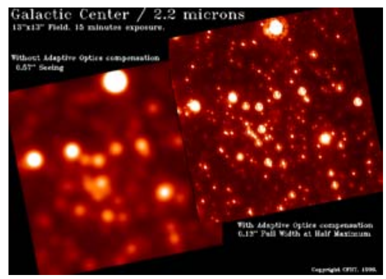
Radio galaxy Cygnus A

Telescopes in Space

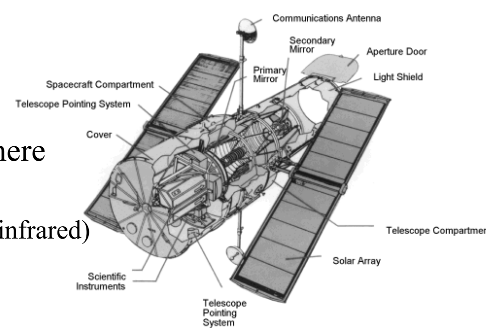
- Atmosphere blocks light at many wavelengths



- Atmospheric turbulence smears out images.



Hubble Space Telescope



- 2.4m diameter mirror
- Ultraviolet/optical/infrared
- Above (most of) Earth's atmosphere
  - High angular resolution
  - Light not blocked in ultraviolet (or infrared)
  - Low earth orbit
    - 600 km (370 mile) altitude
    - 95 min orbits
    - Earth blocks view half of each orbit
    - But can be reached by shuttle to install new instruments
- Launched in 1990
- To be replaced by JWST in ~2008

Don't write these all down!

Exploring the Solar System

Information explosion in ~ 1970's, due to *spaceflight*.

Great source of Solar System info:
Nine Planets website
www.seds.org/billa/tnp/
www.seds.org/billa/tnp/

Partial list of missions

Moon:
1. Luna 3 (1959)
2. Ranger (1964-65)
3. Luna 9 lander (1966)
4. Apollo moonwalks (1968-1972)

Venus
5. Mariner 2 (1962)
6. Venera 7 lander (1970)
7. Venera 15,16 orbiters (1983)
8. Magellan orbiter (1991-93)

Mars
9. Mariner 4 (1964)
10. Mariner 9 orbiter (1971)
11. Viking 1,2 landers (1976-80)
12. Pathfinder rover (1997)

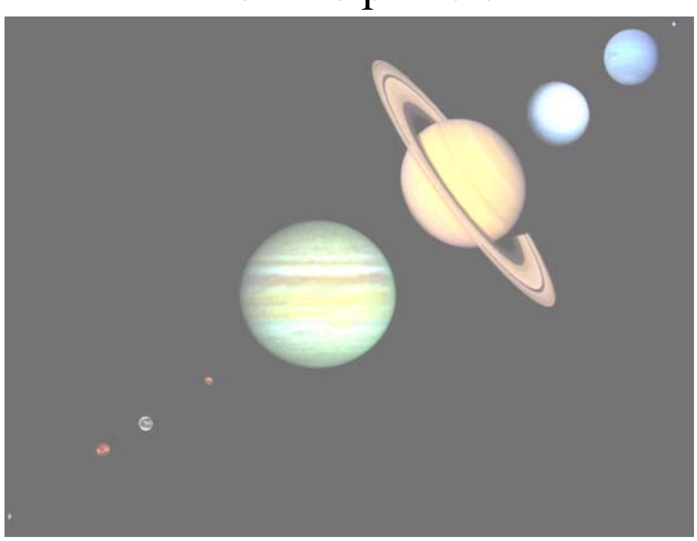
Outer planets
13. Pioneer 10 (1973)
14. Pioneer 11 (1974)
15. Voyager 1 (1979-1980)
16. Voyager 2 (1979-1989)
17. Galileo orbiter/probe (1995)
18. Cassini orbiter/probe (2002-2004)

Contents of Solar System

- Sun
- 9 planets
- Moons
- Asteroids
  - rocky mini-planets
  - up to a few 10's of km dia.
  - mostly in orbits bewteen Mars and Jupiter
- Comets
  - icy
  - spend most of time at fringes of Solar System.
- Dust (==> meteorites)

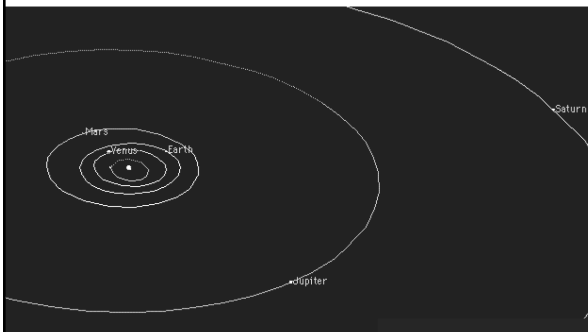
Object	% Total Mass
Sun	99.8
Jupiter	0.1
Comets	0.05
All other planets	0.04
Satellites & rings	0.00005
Asteroids	0.000002
Cosmic dust	0.0000001

The nine planets

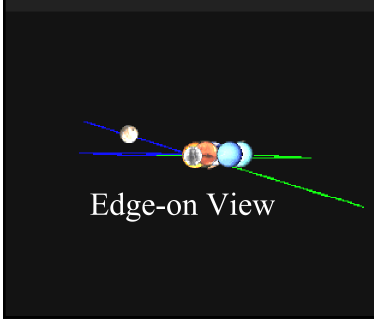


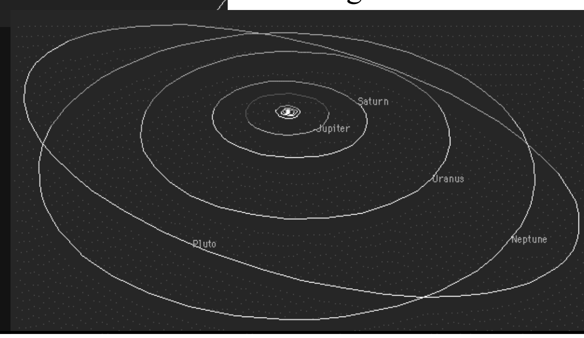
Mercury Venus Earth Mars Jupiter Saturn Uranus Neptune Pluto

The orbits of the planets



- Planets all go around Sun in same direction
- Except for Pluto,they are in nearly circular orbits in thin plane.
- These views look down on that plane at 45º angle.



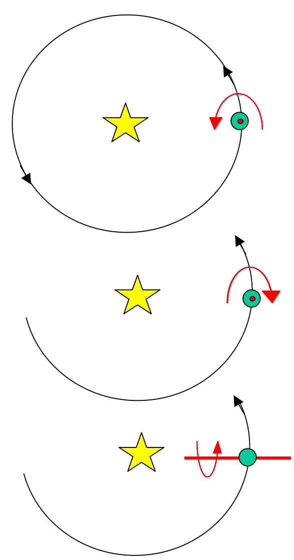


The rotation of the planets

- same sense as orbital motion

except:

- Venus (retrograde, very slowly)
- Uranus, Pluto (tipped on side)

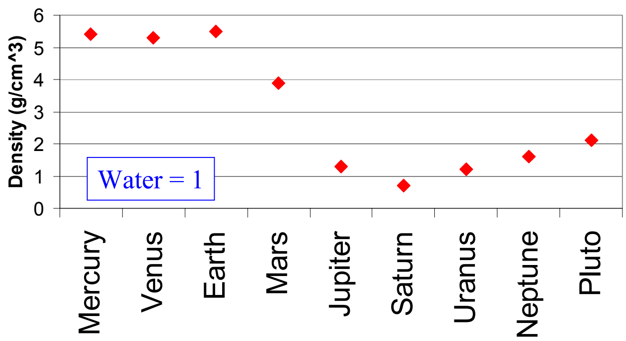


Two distinct types of planets

- Terrestial planets
  - small, rocky, made of heavy elements: silicon, oxygen, iron, etc.
- Giant (Jovian) planets
  - large, primarily gas, ice & liquid: hydrogen & helium.

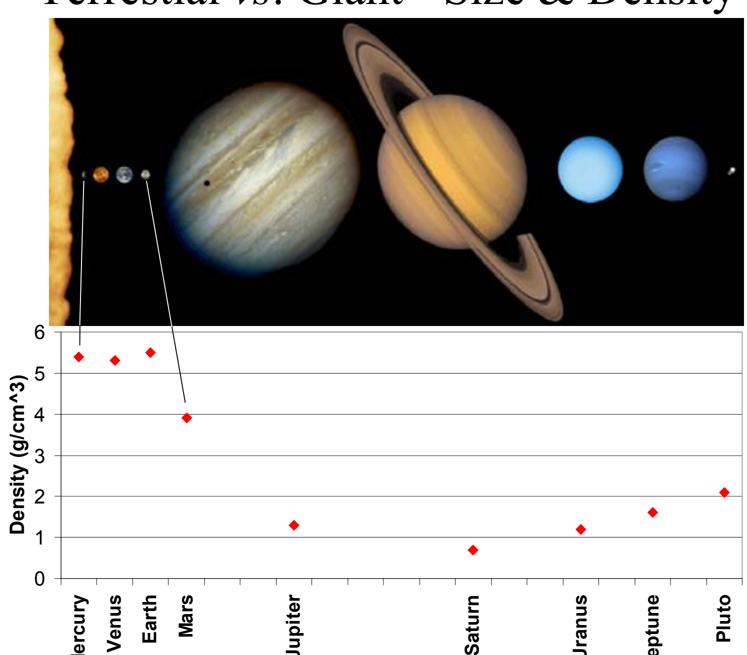
Same as the Sun

- and then there's Pluto…



Planet	Density g/cm^3
Mercury	5.4
Venus	5.3
Earth	5.5
Mars	3.9
Jupiter	1.3
Saturn	0.7
Uranus	1.2
Neptune	1.6
Pluto	2.1

Terrestial *vs*. Giant - Size & Density



Differentiation

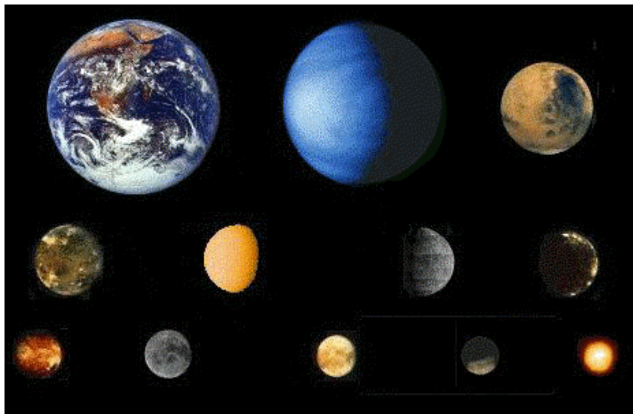
- Heavy stuff sinks to center of planets
- Giant planets
  - total mass, density →small solid cores
    - (~10x mass of Earth).
- Terrestrial planets
  - cores contain iron, nickel, etc.
  - lighter silicates make up crust.
  - This separation must have occurred when planets were hot & liquid.

Moons & Rings

Planet	Known Moons	Rings?
Mercury	0	
Venus	0	
Earth	1	
Mars	2	
Jupiter	16	Yes
Saturn	19	Yes
Uranus	18	Yes
Neptune	8	Yes
Pluto	1	

Some planets and moons
shown in correct relative sizes

Earth Venus Mars

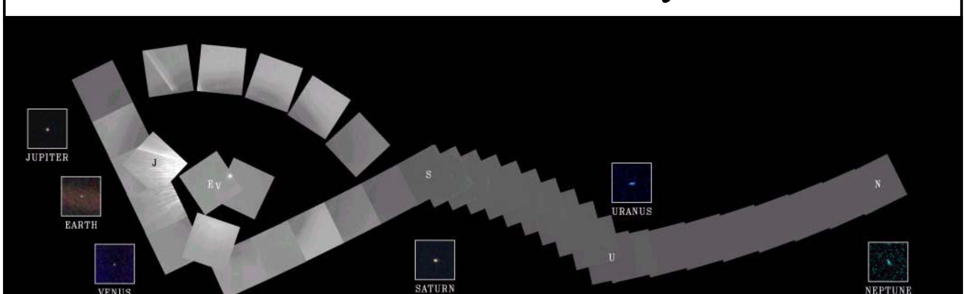


Ganymede Titan Mercury Callisto
Io Moon Europa Triton Pluto

Planets: orbit around Sun

Moons: orbit around planets

A look back at the Solar System

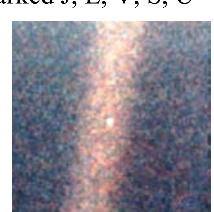


The view back from Voyager 1, on its way out of the Solar System.

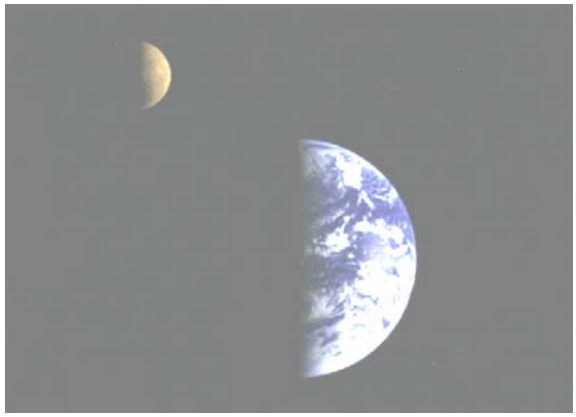
Mosaic of images taken at a distance of 40 au (4 billion miles) from the Sun. The Sun is blocked out to make the planets visible. The points marked J, E, V, S, U and N are at the actual locations of the planets. The little boxes show blow-ups of each planet image … the planets are all just little dots.

Note how the planets are in a plane.

EARTH



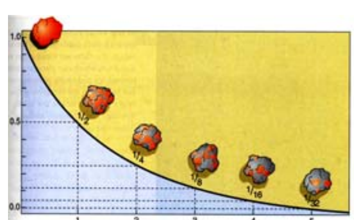
The Earth as a Planet



Material from:
  Chapter 7: whole chapter.
  Chapter 3: fast skim over sect. 3.2, 3.5, 3.6, 3.7 + box on page 73

Age dating from radioactive rocks [6.3]

- Radioactive decay
  - unstable atomic nucleus splits into smaller nuclei (different elements)
    - Example: Uranium-238 ➔ Lead-206 + 4 x Helium-4
- *Half-life*
  - Time for 1/2 of radioactive nuclei to decay

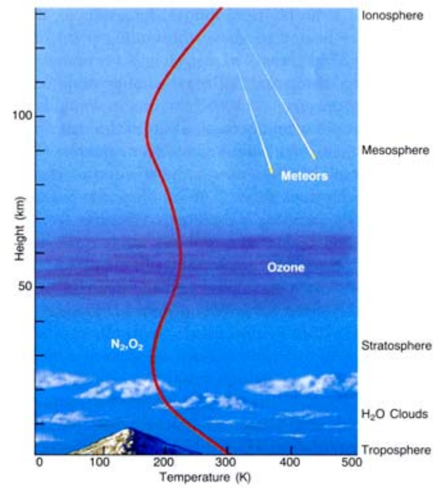


[Fig 6.11]

- Minerals form with radioactive elements
  - decays produce "daughter" nuclei that shouldn't be in pure mineral.
  - Ratio of daughter/parent nuclei shows age since mineral was formed.
- This shows age of Earth, Moon = 4.5 billion years.

The Earth's Atmosphere

- Weighs 13.6 pounds per square inch
  - 10^{-6} of total mass of Earth.
- 78% nitrogen, 21% oxygen, + argon, H_2O, CO_2, etc.
- Ozone (O_3) is critical for life
  - blocks Sun's ultraviolet radiation
  - *Ozone hole*: over Antarctica, where ozone destroyed by man-made pollutants.
- Where did it come from?
  - Formed with rest of Earth?
  - Released from interior?
  - Dumped onto us by comets?



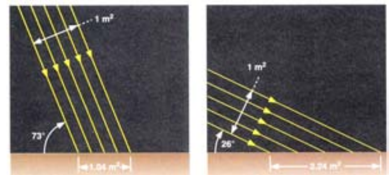
[Fig 7.11]

Life [7.4]

- Started in CO_2 atmosphere, roughly 4 billion yrs ago.
- Life initially only in sea… converted CO_2 to oxygen through *photosynthesis*.
- The released oxygen was swallowed up in interactions with surface material until ~ 2 billion yrs ago.
- After 2 billion yrs ago, oxygen able to build up in atmosphere.
  - + geological activity buried much of the free carbon.
- Atmosphere then converted to today's mix:
  78% nitrogen, 21% oxygen, 1% everything else.
- Free oxygen ➔ ozone
  ➔ protection from ultraviolet light➔ land animals

Seasons [3.2]

- Heating of Earth's surface determined by *flux* of sunlight.
  - Flux = incident electromagnetic energy per square meter per second.
  - Think of incoming raindrops.

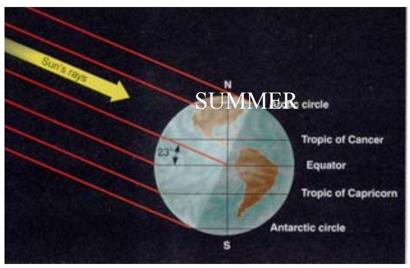


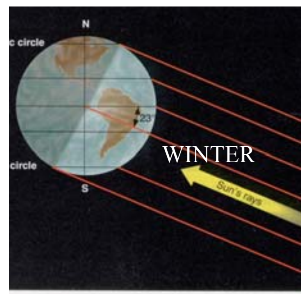
- Earth's orbit nearly round

  … not a factor.
- But tilt of Earth's axis

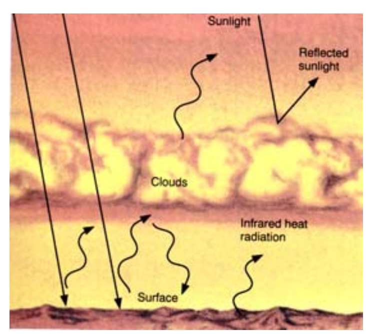
  + conservation of angular momentum

  ==> much higher flux in one half of year than in other.





Global Warming



[Fig 7.14]

- Greenhouse Effect
  - Incoming sunlight passes through atmosphere.
  - Absorbed by ground.
  - Re-emitted as infra-red radiation.
  - CO_2 gas causes atmosphere to be opaque to infra-red light.
  - Infrared light is trapped, so heats surface.
- The Problem
  - Human activity causing huge rise in CO_2, other gases.
  - So temperature is going up.
  - What will the consequences be????

Lots of scientific debate about the details….

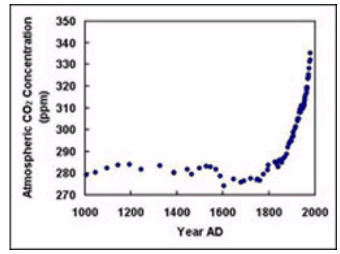
Is the CO_2 increase really causing the temperature increase?

• Man-made greenhouse effect is clearly driving up the temperatures.
• But other gasses have bigger effect per molecule than does CO_2.

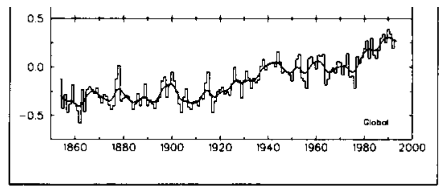
How hot will it get?

• Predictions uncertain - very complicated interactions between atmosphere and ground.
• 3° C (5° F) increase by 2030 is typical prediction.

For more info:
www.ems.psu.edu/info/explore/GlobalWarming.html Penn State web site



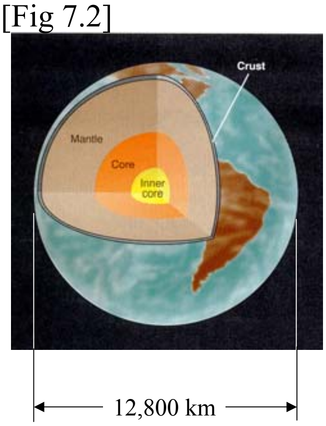
CO_2 concentration, from Antarctic ice cores.



Hemispheric and mean global temperature trends, 1854 to the present

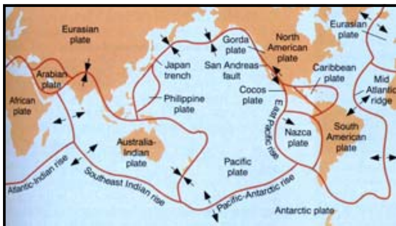
The Interior of the Earth

[Fig 7.2]



- Crust
  - ~6 km thick under oceans.
  - 20-70 km thick under continents.
  - Rocks composed of silicon, oxygen, etc.
  - 0.3% of mass.
- Mantle
  - Slowly flowing semi-solid rock.
- Core
  - 7000 km diameter.
  - Metallic (iron, nickel, sulfur)
  - Outer core is liquid.
  - Inner core probably solid.

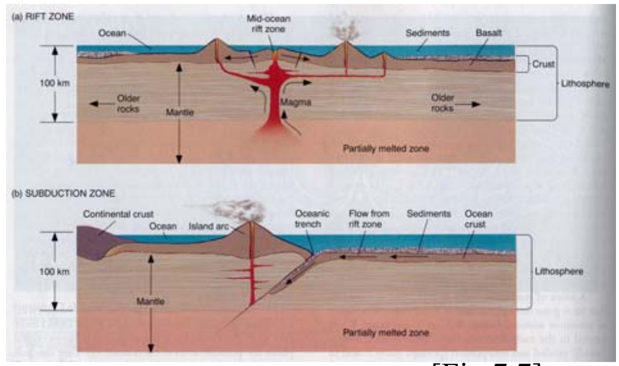
Plate Tectonics



- Crust split into huge *plates* drifting around on top of the mantle.
- Driven by *convection* (same as bubbles in boiling water).

- Plates pushed apart in *rift* zones
  - mid ocean
  - also Red Sea + Great Rift Valley).

- Plates bash together in *subduction* zones.
  - e.g. "Rim of Fire" around Pacific Ocean.



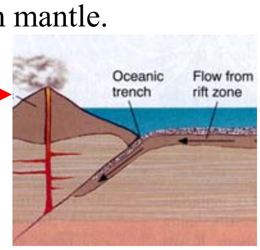
[Fig 7.7]

- Also *fault zones*, where one plate slides alongside another.

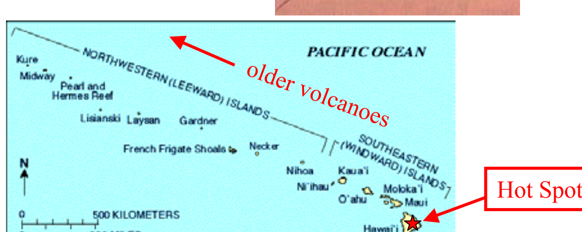
Geological Activity on Earth

- Plate collisions ➔ big-time wrinkling….
  … *mountain building* (*e.g.* Himalayas, Andes)

- Volcanoes.
  - *Magma* (molten rock) forced upwards from mantle.
  - Along mid-ocean ridges (rift zones).
  - Around subduction zones (Rim of Fire) ➔



- Hawaiian Island chain:
  - Crust drifts past hot spot.
  - Unusual.

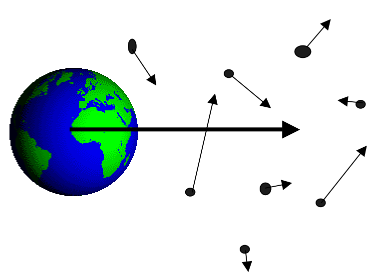


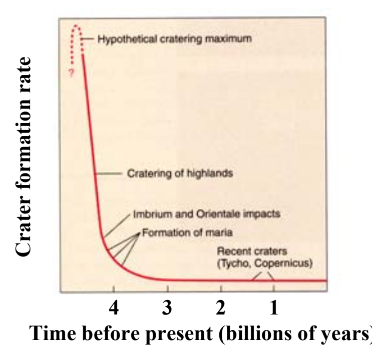
Geological Activity elsewhere in the Solar System [6.3]

- Buckling and twisting of crust
  - Mountain building
  - Volcanoes
- Caused by hot interiors
- Presently occurring on
  - Earth
  - Venus
  - Mars
  - Several moons of the giant planets
- Formerly occurred on Moon, Mercury (lava flows)

How can we tell when this happened?

Impact Craters

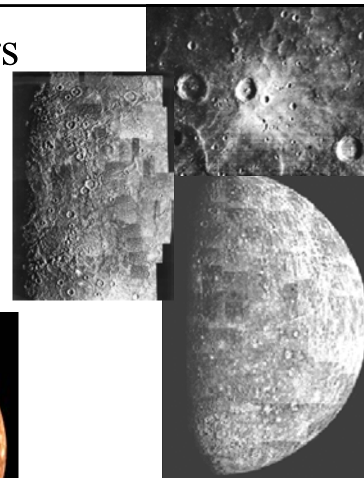




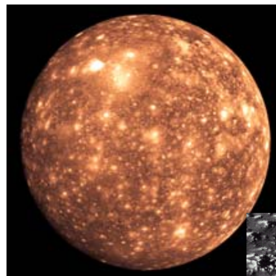
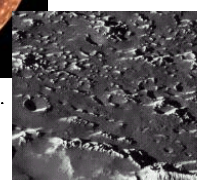
- Earth, moon or other large body runs into lots of small stuff
- Requires intersecting orbits between the two bodies.
- Used to be lots more small bodies on intersecting orbits
  - We have already smashed into most of them.

Impact Craters


The Earth's Moon

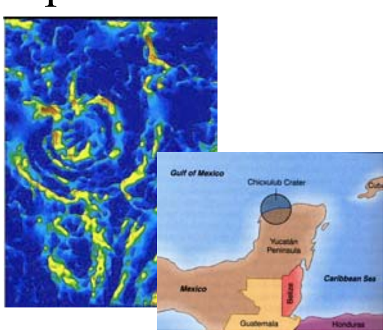


Mercury

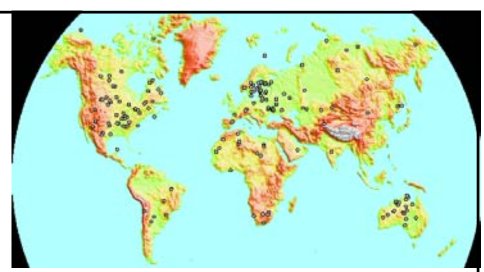
Callisto --- a moon of Jupiter.

Impact Craters on Earth

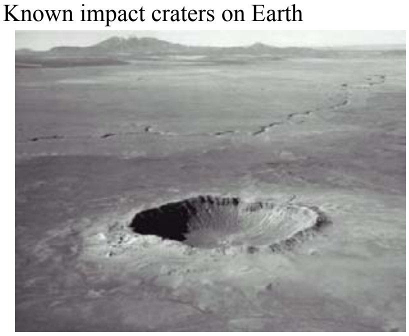


Chicxulub Crater, Yucatan
Gravity gradient map
170 km diameter
65×10^6 years old.
Wiped out dinosaurs. Mass extinctions.

> Closest impact crater: Calvin, MI
> 8.5 km dia.
> 450×10^6 years old
> NO PICTURE AVAILABLE



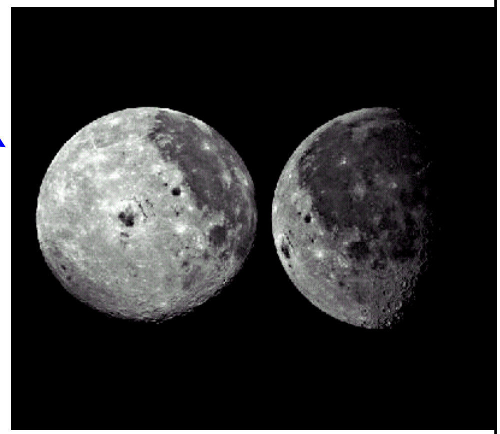
Known impact craters on Earth



Barringer Meteor Crater, Arizona.
1.2 km diameter, 49,000 years old.
Made by 100,000 ton iron-nickel meteorite with diameter of ~50 meters.

Impact Craters as Clocks

The Moon:
Two types of surfaces…
heavily cratered highlands
and smooth maria.



- Constant rain of meteors continuously makes craters
- Geologic activity

  ==> lava flows

  ==> covers over craters
- So number of craters per unit area proportional to time span since surface was last covered.