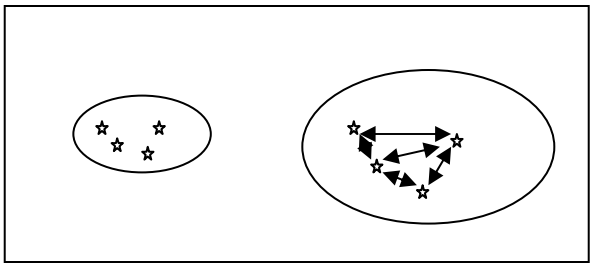
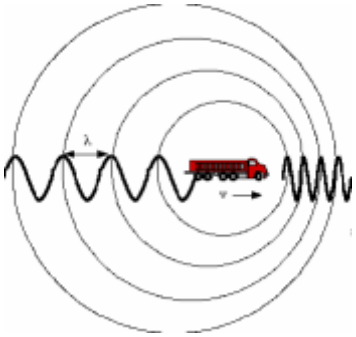
Creation of the universe

- The Big Bang theory (coined in the late 1940s by Fred Hoyle)

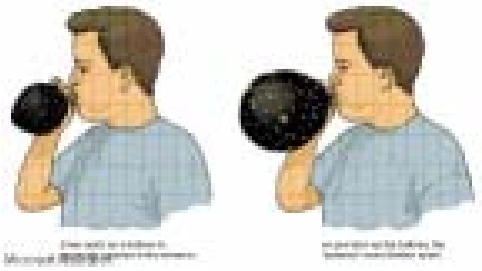
Observation: the universe is expanding, most stars red shifted.





Doppler Effect

(balloon model = space expanding)



Big Bang Time Line

- Big Bang = **creation** of ALL *matter (H, He), space & time*
- Began as a "singularity" ~13.7 billion years ago
  Point with no size, ∞ density
- Nothing known before Planck time (10^{-43} sec)
  - Before this laws of physics don't apply
- Temp = 10^{32}K
- Universe expands, cools, condenses
  - 10^{-12} sec – protons & neutrons form at
  - 10^{-2} sec – electrons form at
  - ~ 3 minutes – ***H & He*** nuclei (10^{9} K)
  - 300,000 years – Full atoms (w/ electrons)
    - Becomes transparent to light
    - Cosmic Microwave Bkgrnd (2.7K) COBE satellite
  - 10^{9} years (T=20K) galaxies begin to form, then stars & planets

:. Universe is NOT infinite
- What we can see is limited by speed of light and age of universe
- There is no "outside" or edge
(analog: earth's surface has no edges but finite)

Big Questions

- What caused it? Where did it come from?
- Why is it inhomogeneous?
- Is the Universe open or closed or "flat"?
    - Open = Will expand forever (heat death) or
    - Closed = Will slow, contract, collapse (Big Crunch)
    - Flat = expansion = gravity, will slow, stop and stay
- Analogy – throw a base ball
    - Open = flies into space (> escape velocity)
    - Closed = fall back to earth (< escape velocity)
    - Flat = go into orbit (= escape velocity)

Early matter *(H, He)* condensed into stars & galaxies.

Stars "burn" by **fusion** (H -> He ... Fe) [657 million tons/sec]

- Have finite life times, use up "fuel" (sun will last ~ 5 by more)
    - if small (white dwarf) may explode as nova & collapse
    - if large (> 8 solar masses) explode as supernovas
    (fission: only way to create elements heavier then Fe)
    "We are stardust..."
    - Nebula = cloud of gas and dust

- Solar system is 2^{nd} or 3^{rd} generation system

- Formed by dust and gas from:
    - original big bang
    - exploded starts (novas)

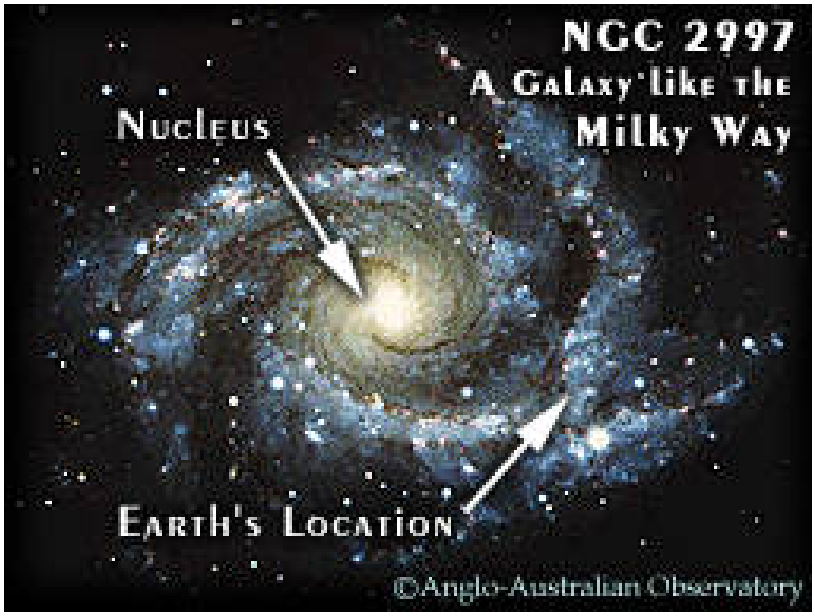
The Scale of the Universe

Universe contains ~20 * 10^9 galaxies

"Local Group" = 3 large + 37 dwarf (elliptical) galaxies within 5x10^6 ly

Our galaxy is the "Milky Way"

- ~100 billion stars
- 100,000 ly across (9*10^{16} km) (1 ly = 3*10^5 km/sec)
- rotates once in 230 million years (1 mill. km/hr)



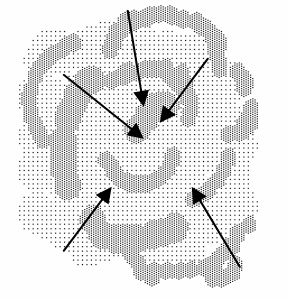
Scientific Notation

Scientific notation is a convenient way to write large or small numbers and do calculations with them. It also quickly conveys two properties of a measurement that are useful to scientists—significant figures and order of magnitude.

Examples

- An electron's mass is about **0.00000 00000 00000 00000 00000 00000 91093 826** kg. In scientific notation, this is written **9.1093826×10^{-31} kg.**
- The Earth's mass is about **5,973,600,000,000,000,000,000,000** kg. In scientific notation, this is written **5.9736×10^{24} kg**.

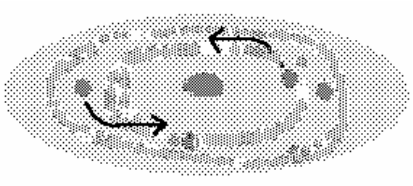
Creation of the solar system - The Nebular Hypothesis
(Kant & LaPlace ~1798)



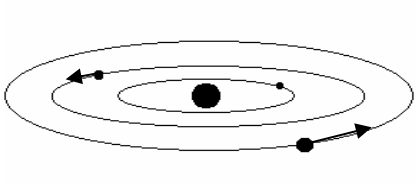
1) dust and gas condense by gravitational attraction, possibly driven by nearby novas.

2) cloud (nebula) continues to collapse due to gravity

3) cloud begins to spin
(conservation of *angular momentum*)



4) cloud flattens into disk, segregates into rings (like a pizza crust),
- all orbit/revolve in same direction
- all lie on **ecliptic plane**



5) rings condense into planets

6) sun reaches critical mass and fusion begins (99.9% of mass)

7) excess gas and dust "blown out" by solar wind

This model explains why:

- All planets and satellites (moons) orbit ccw (viewed from the north)
- All planets revolve ccw (viewed from the north)
[except Venus which has "tipped" over on it's axis]

Gravity = an intrinsic property of all matter that causes mutual attraction between objects with mass.

The force of gravity (F) depends on the mass of the objects (m_1 & m_2) considered and their distance (r).

$$F = G\frac{m_1 m_2}{r^2}$$

F is the magnitude of the gravitational force between the two point masses
G is the gravitational constant
m_1 is the mass of the first point mass
m_2 is the mass of the second point mass
r is the distance between the two point masses

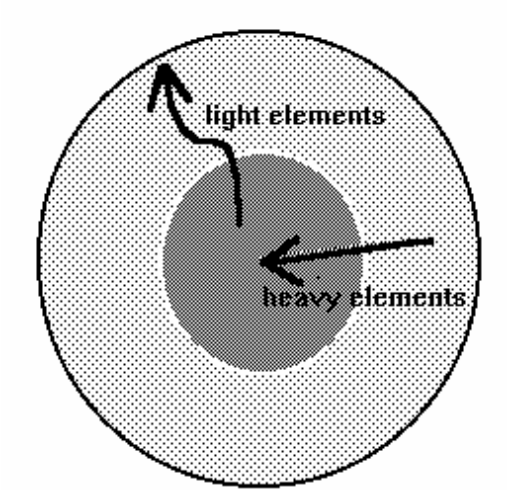
The constant G is approximately equal to 6.67×10^{-11} N m^2 kg^{-2}.

Formation of Earth (~4.6 billion years ago)

1) Earth forms by **accretion** (condensation) like a snowball
   a. Craters have been erased by erosion and tectonics
   b. Can still be seen on Moon, Mercury, etc.

2) After ~100 million years Earth heats up to melting due to:
   a) impact energy
   b) gravitational compression
   c) **radioactive decay** (U, Th, K) (keeps earth hot)
   Lord Kelvin incorrectly estimated age of earth at 20-40 million years when radioactive decay was not taken into account

3) Earth **differentiates (= density layers)** (examples: oil & vinegar dressing)



- Heavy Fe & Ni to core

- Intermediate "mafic" minerals to mantle

- Light silicates to crust

- Lightest gases to atmosphere & seas (outgassing)

<u>Outgassing ("Big Burp")</u>- H_2, CO_2, H_2O, N_2, CO, HCl
(current rate at volcanic vents ~1/4 needed :. must have been greater)

- Light gases escaped to space (H, He)

- Reactive gases combined to make compounds (O)

- Water (H_2O) condensed into oceans (with Na and Cl, :. always salty)
  (comet hypothesis says water came from comets - doubtful)

- Original atmosphere was N_2, CO_2

- Plant life (algae) later consumes CO_2 and produces O_2 (~3-3.5bya)
  (i.e. current atm. was "polluted" by plants)