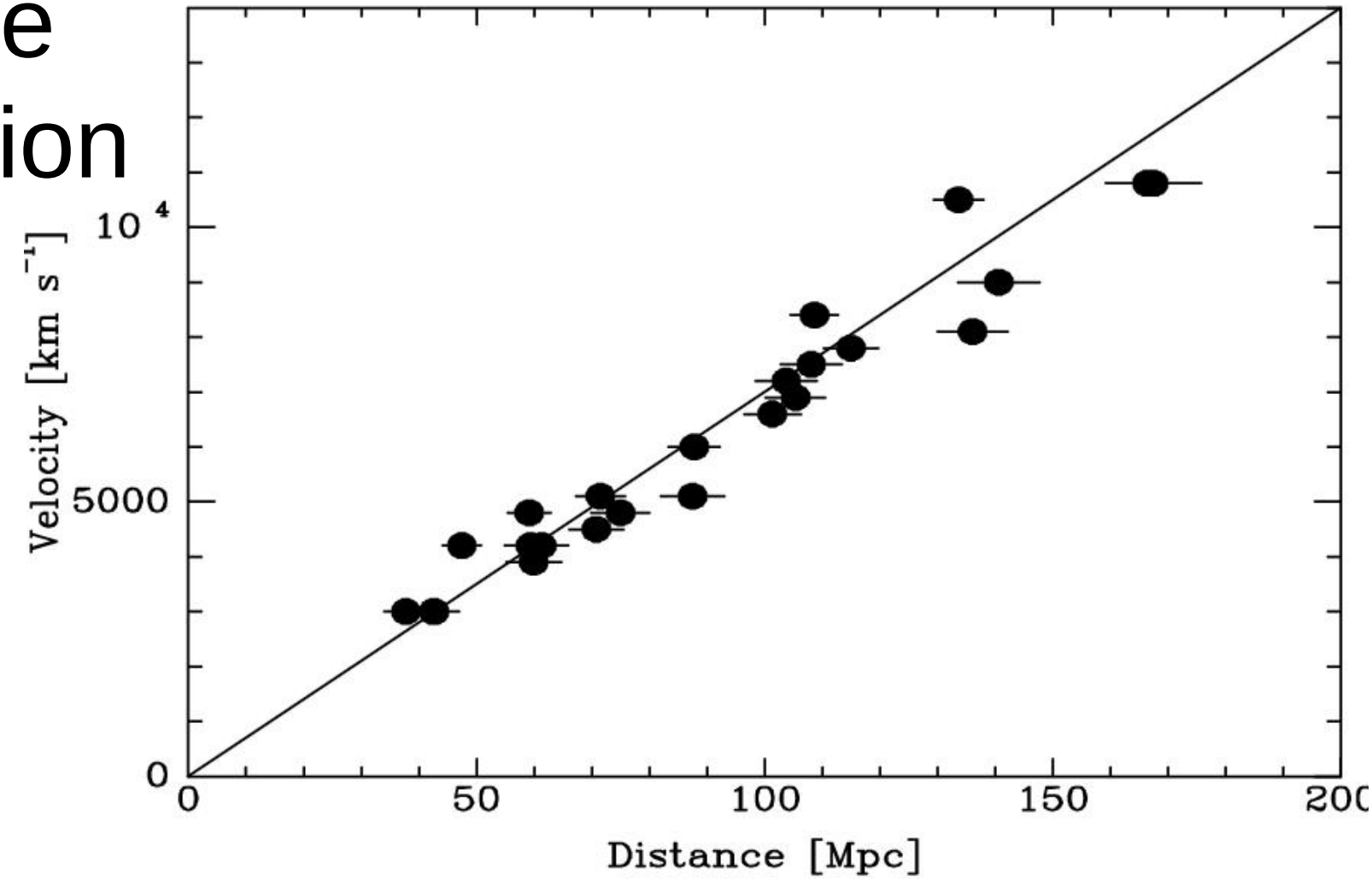
Outline

- Go over problem 7.1
- Hubble expansion
- Cosmic clocks

Hubble Expansion

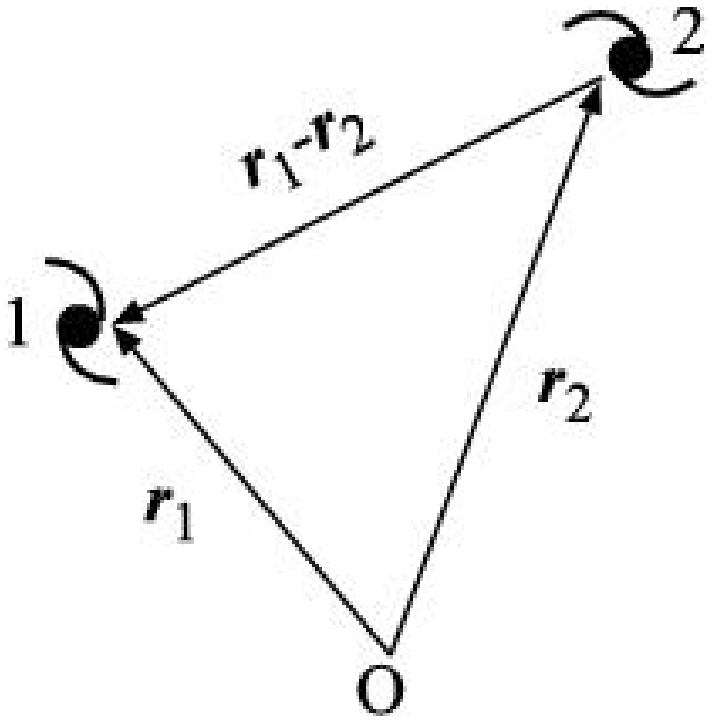


- Galaxies are moving away with speed, v, proportional to distance, D,

$$v = H_0 D$$

- H_0 = 70 km/s/Mpc = Hubble "constant" – not actually a constant.

Hubble Expansion



- Expansion appears the same to all observers – work out on board.
- Implies no center to expansion.
- Work out age of universe on board.

Cosmic Clocks

- It is useful to check cosmological age estimates using the ages of physical objects in the universe.
- These provide only lower bounds on the age of the universe

- White dwarf cooling
  - white dwarfs start at roughly the same temperature
  - coolest white dwarfs require ~ 10 Gyr to cool
- Ages of globular clusters
  - construct HR diagrams for old clusters
  - oldest are 10-15 Gyr
- Ratios of radioactive elements

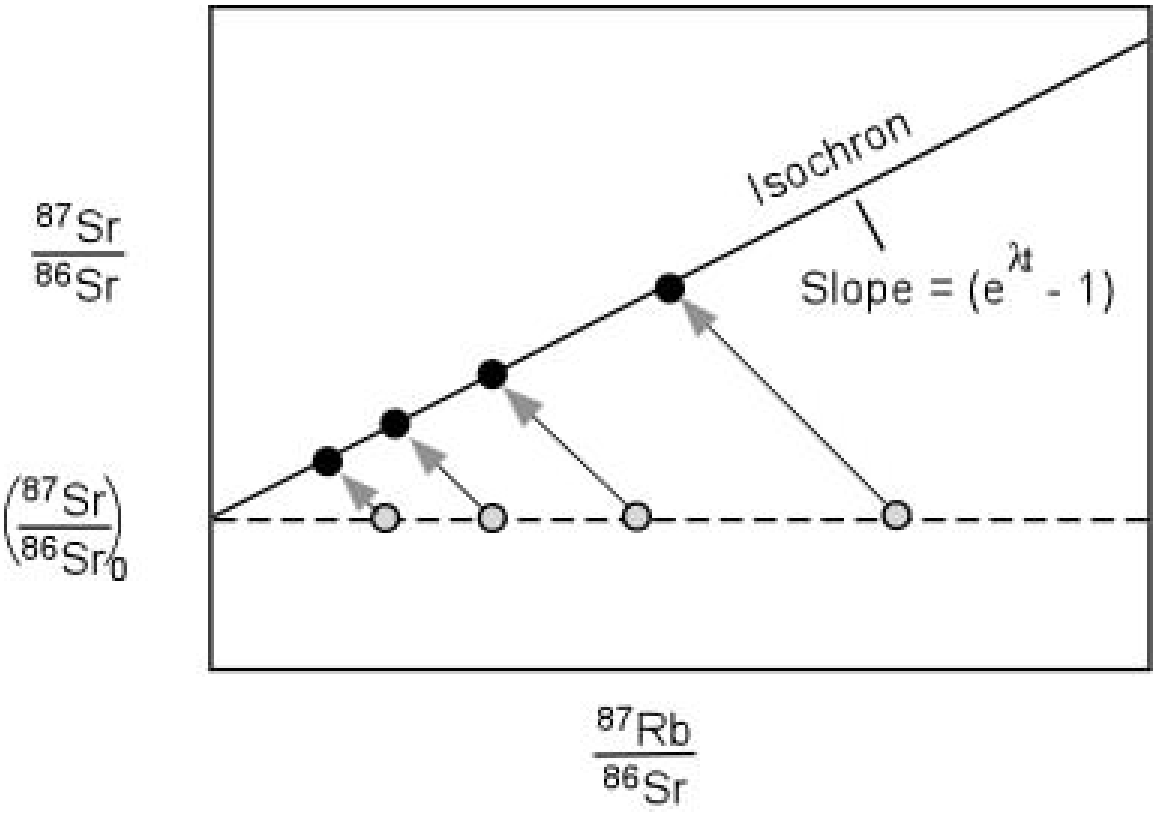
Radiometric Dating

- Need some object that produces two isotopes of a radioactive element in a known or calculable ratio.
- Each isotope decays with its own half life.
- Measure current ratio of isotopes. Can calculate age of object from known half lives and known initial ratio.
- Work out on board.
- Best to pick isotopes with half life ~ age of object

Radiometric Dating

- ^{235}U and ^{238}U
  - made in supernova, ratio ~ 1.2
  - current ratio on Earth, gives age of Earth or solar nebula
- ^{12}C and ^{14}C
  - found in fossils of organic matter
  - ^{12}C is stable ($1/\tau = 0$)
  - ^{14}C is made via cosmic ray interactions in atmosphere
  - assume initial ratio set by current atmospheric ratio

Isochron Plot



- ^{87}Rb decays to ^{87}Sr, ^{86}Sr is stable
- ^{87}Sr and ^{86}Sr are chemically identical, so $^{87}Sr/^{86}Sr$ = constant within rock
- $^{87}Rb/^{86}Sr$ can vary from place to place
- as ^{87}Rb decays, ^{87}Sr builds up → $^{87}Sr/^{86}Sr$ increases, $^{87}Rb/^{86}Sr$ decreases
- work out formula for slope

Homework

For next class: problem 7.2

- Why are there radial lines of galaxies in the position-redshift diagram below?