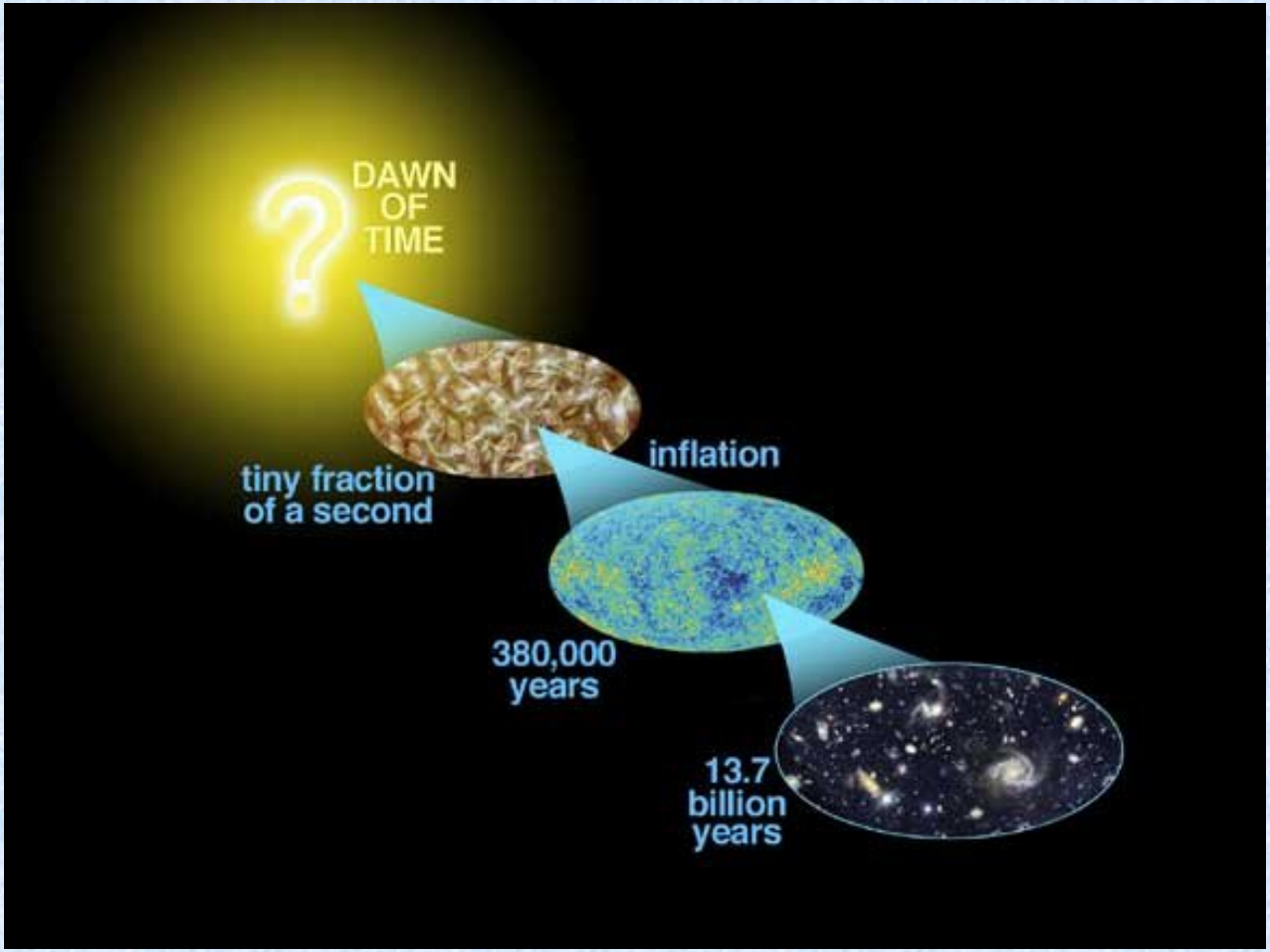
Physics 133: Extragalactic Astronomy ad Cosmology



Lecture 8; February 3 2014

Previously:

- Matter + Curvature + Λ
  - Big Bounce or various scenarios
- Radiation + Matter
  - Good for the early universe
- The current best guess. Concordance cosmology or "benchmark model"

Outline:

- Measuring cosmological parameters:
  - Intro. A brief history and notation
  - Proper distance
  - Luminosity distance
  - Angular Diameter Distance
  - Cosmological dimming and the Tolman Test
  - Cosmic volume
- A good reference for some of today's stuff:
  - xxx.lanl.gov/abs/astro-ph/9905116

Kinematics and Mass

$$a(t) = a(t_0) + \left(\frac{da}{dt}\right)_{t=t_0}(t-t_0) + \frac{1}{2}\left(\frac{d^2a}{dt^2}\right)_{t=t_0}(t-t_0)^2 + O(t^3)$$

$$a(t) \sim 1 + H_0(t-t_0) - \frac{1}{2}q_0 H_0^2 (t-t_0)^2$$

$$q_0 \equiv -\left(\frac{\ddot{a}a}{\dot{a}^2}\right)_{t=t_0}$$

$$q_0 = \frac{1}{2}\sum_w \Omega_{w,0}(1+3w)$$

$$q_0 = \Omega_{r,0} + \frac{1}{2}\Omega_{m,0} - \Omega_{\Lambda,0}$$

The kinematics of the universe measure its content!

A search for two numbers…

In the good old days with no Λ, H0 and q0 were enough….

Seriously… how do we measure the kinematics of the Universe?

- What's the relation between redshift and proper distance, locally?
- Hubble's law
  - [Blackboard]
- This allows us to measure one parameter… maybe
- But proper distance is hard to measure…
- Proper distance and cosmological parameters
  - [Blackboard]

More convenient distances. Luminosity distance

- We can measure Flux
- If we know the luminosity, we have a distance!
  - $F=L/4\pi\,(d_l)^2$
- But what distance is this?
- [Blackboard]

Standard candle

More convenient distances. Angular size distance

- We can measure angles
- If we know the size of an object, we have a distance!
  - $\theta = L/d_a$
- But what distance is this?
- [Blackboard]

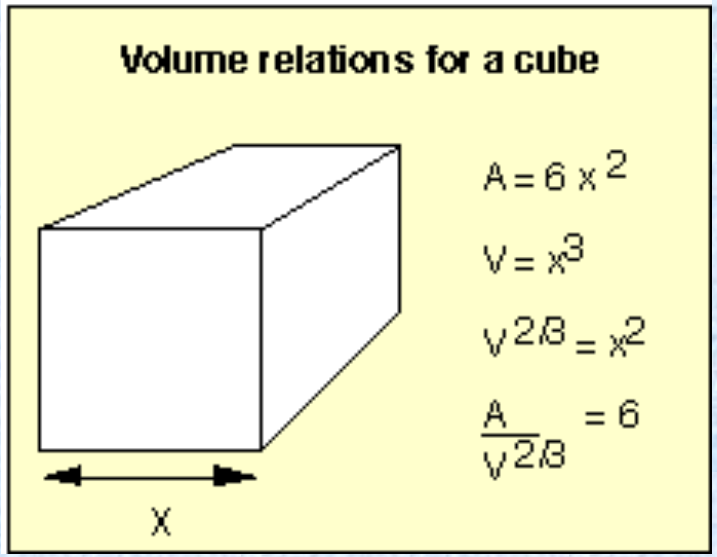
"Standard rods"

Cosmological dimming and the Tolman Test

- An test of the expansion was proposed by Tolman.
- How does surface brightness depend on distance in a Euclidean static universe?
- How about in the expanding universe?
- [Black board]

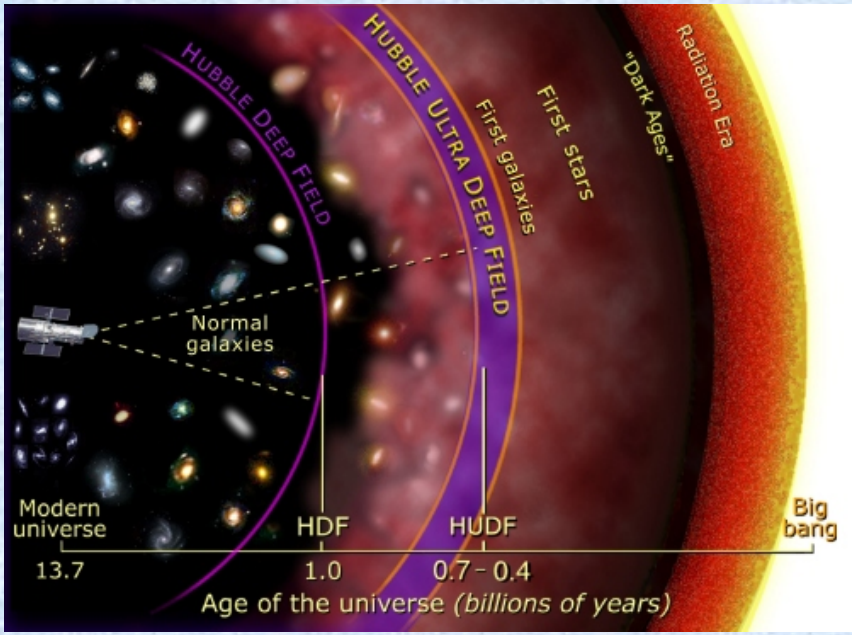
What else? Cosmic volume

- Suppose we knew the abundance of something
- Counting the number of objects per unit redshift and solid angle we can determine the cosmic volume!
- [Black board]



What else? Cosmic time

- Suppose we had a clock
- For example?
- Measuring time as a function of redshift gives us the cosmological parameters
- [Black board]



Summary:

- Measuring kinematics of the universe determines cosmological parameters.
- Proper distance depends on redshift via the Hubble constant, to first order
- Higher order terms of the kinematics are needed to obtain other cosmological parameters
- Proper distance is not appropriate. We need stuff we can measure.
  - Luminosity distance ~ Proper distance (1+z) for a "flat" universe
  - Angular-diameter distance
  - Evolution of volume

The End

Wednesday is midterm!