

Hot Big Bang "Universe expanded from an initial
1950s... 60s hot, dense state..." ↑

"...to its current cooler & lower
density state, & that expansion
is continuing today."

Had a beginning

↖ what about the future?

expansion rate = Hubble constant is a key quantity:

- age
- prospects for future expansion

originally: only initial exp. of Big Bang solved
by gravity → dynamic problem is simple

$$H_0, g_0, \Omega$$

new 1990s onward:

- Ω has contributions well beyond that from baryons (Dark Matter)
- g is negative - the expansion is accelerating (Dark Energy)

Cold Dark Matter

now we say that the favored type of Hot Big Bang model is Λ CDM
↑
dark energy

Matter / particles

proton, neutron + electron
↳ leptons

$$m_p \approx m_n \approx 2000 m_e$$

"baryonic matter"
'regular' stuff
tech: made of 3 quarks

neutrinos also leptons
interactions via weak force

≈ massless
(but not quite)

travel at close to/
exactly C

photons bosons

massless, $v = c$

dark matter

???
(not baryonic,
not anything
that interacts w/
electric force)

massive,
not very fast
(so "cold")

↑
stuff tends to
cluster → hot stuff
tends to spread out

At first let's keep this only in the back of
our minds : focus on regular matter (baryons)
; its gravitational & light emitting/abs. properties
; think of light only as a form of energy
that carries information to us

SI/mks units generally
but special units when convenient

$$c = 3.00 \times 10^8 \text{ m/s}$$

$$G = 6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2}$$

electron Volts for energy

$$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$$

keV, MeV, GcV

via $E = mc^2$

particle rest masses can be expressed
in energy units

{ can verify rest mass of electron is
given in Table 23.1 given the mass in kg given
in Table A.1 in the appendix

distances are vast \rightarrow

$$1 \text{ light year} \Rightarrow d = \frac{ct}{t} = \frac{ct}{1 \text{ yr}} = 9.46 \times 10^{15} \text{ m}$$

$$1 \text{ parsec (pc)} = 3.26 \text{ ly} = 3.09 \times 10^{16} \text{ m}$$

kpc, Mpc

The Galaxy traditionally has been the unit - the "atom" -
of cosmology

galaxy is test particle : *HDF
 \rightarrow they are luminous;
can be seen from far away image

Milky Way diameter $\sim 50 \text{ kpc}$

$$\sim 1 \text{ pc between stars} \quad \text{nw: } \pi \cdot 25 \text{ kpc}^2 \cdot 0.5 \text{ kpc} \sim 10^{11} \text{ to } 10^{12}$$

We'll start w/ the basic observations that support the hot BB picture — ; along the way, develop a theoretical framework for describing the behavior of the Universe, quantitatively

∅. Olber's paradox

- uniform, infinite, Euclidean Universe would have a bright night sky

easier way to see this

Galaxies?

density of galaxies = η_*
(stars per cubic pc)



$$\text{vol. shell} = 4\pi r^2 dr$$

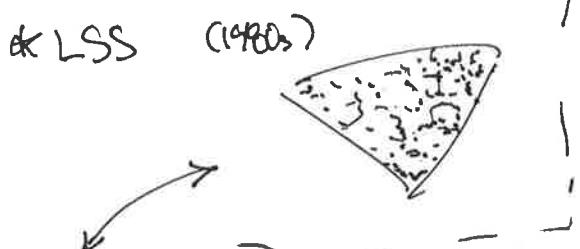
$$\text{stars in shell} = \eta_* 4\pi r^2 dr$$

$$L_{\text{from shell}} = L_* \eta_* 4\pi r^2 dr$$

is our sky representative?
 L_* , η_* should be galaxies?
our sky is bright

$F_{\text{you see, contr. from each shell}} = \frac{L_{\text{shell}}}{4\pi r^2} = \frac{L_* \eta_* 4\pi r^2 dr}{4\pi r^2}$

$$F_{\text{shell}} = L_* \eta_* dr$$



Cosmological Principle ↳ , in principle we can measure F_{tot} , calculate t_{alb} , $\therefore C = \frac{F_{\text{tot}}}{t_{\text{alb}}} \quad t_{\text{alb}} = \frac{F_{\text{tot}}}{C} \sim 10^7 - 10^8 s$

* the night sky is very dark \Rightarrow Univ. is young

1. Hubble Law: Galaxies show a redshift proportional to distance

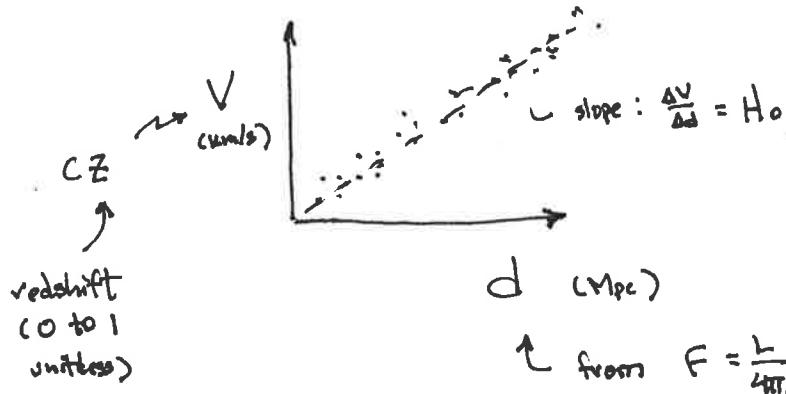
p.484 § 20.5

empirically the redshift of
i. distance to a galaxy
is correlated

hallmark of uniform expansion

$$v \text{ (km/s)} \quad d \text{ (Mpc)}$$

$$v = H_0 d$$



$$H_0 = 70 \pm 5 \text{ km/s/Mpc}$$

↑ from $F = \frac{L}{4\pi d^2}$, assume we can't

$$\frac{\Delta \lambda}{\lambda} = \frac{v}{c} \equiv z$$

