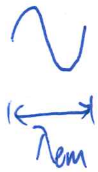
AST 353 Astrophysics 01-21-2016

Quick Intro. to Cosmology

- Redshift

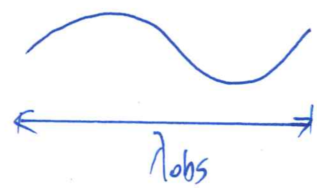
A galaxy far, far away →

The galaxy emitted a photon with wavelength λ_{em}



It traveled a long way

to us today

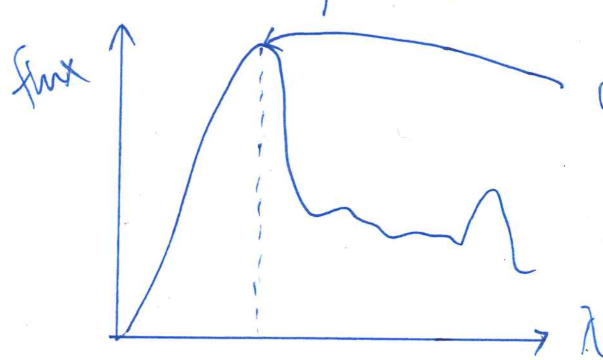


the observed wavelength.

Definition: $\lambda_{obs} \equiv \lambda_{em}(1+z)$

Empirically, how do we measure z?

we consider spectra, which look something like

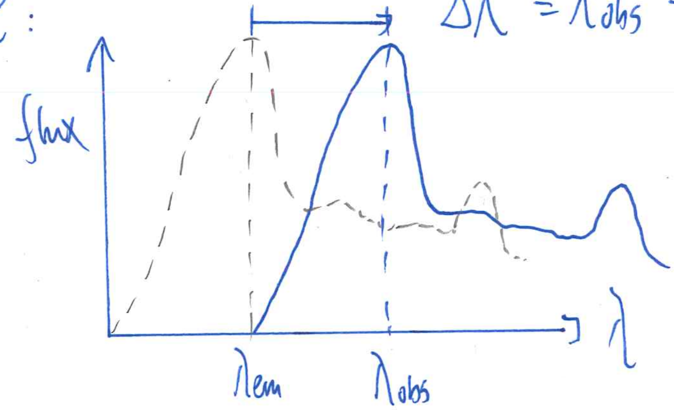


we focus on this Lyman-α line, for example

$\lambda_\alpha = 121.6\,nm = 1216\,Å$

observationally, we don't see the same spectrum, but a redshifted version of it:

$\Delta\lambda = \lambda_{obs} - \lambda_{em}$



$$\frac{\Delta\lambda}{\lambda_{em}} = \frac{\lambda_{obs} - \lambda_{em}}{\lambda_{em}} = \frac{\lambda_{obs}}{\lambda_{em}} - 1$$

$$= z$$ (using the above definition)

People thought such redshift was due to the peculiar velocity of the galaxy; modern interpretation is the expansion of space itself!!

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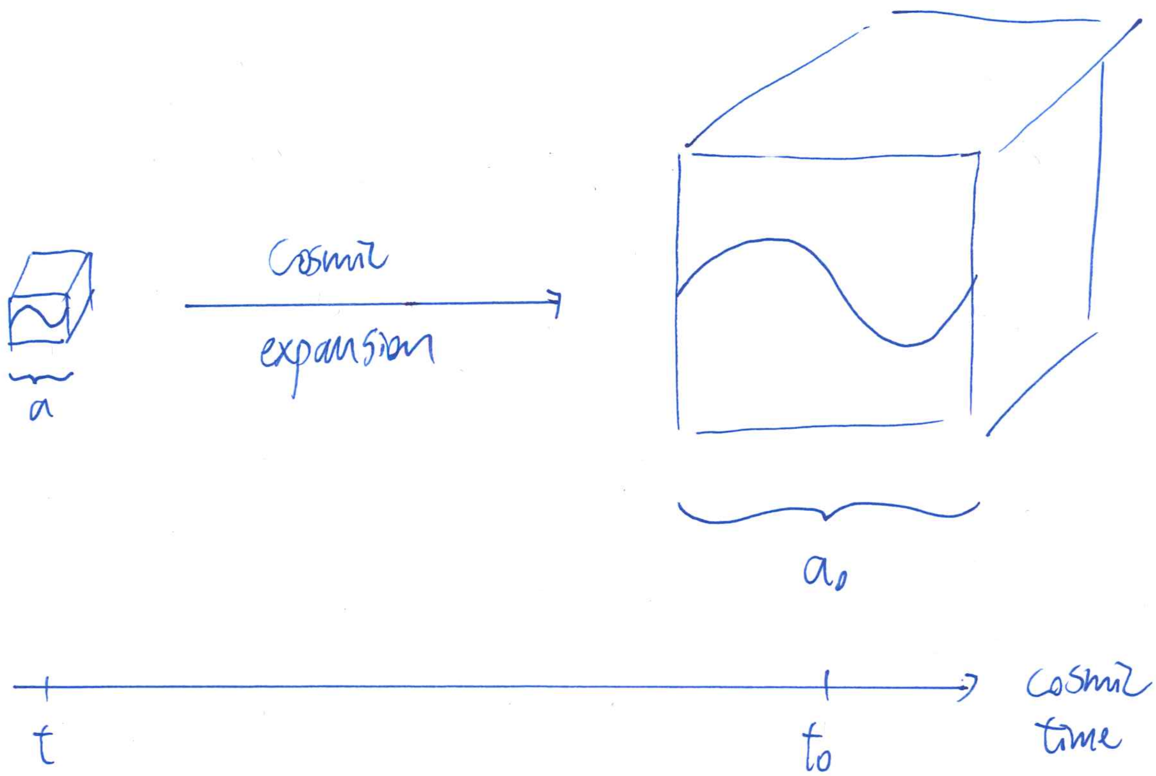
Let's say we create a box with side of the photon wavelength, and label it as 'a'.
The expansion of space will stretch the wavelength to a larger value we observe today, 'a_0'.



a = cosmic "scale factor"

$$\frac{a_0}{a} = \frac{\lambda_{obs}}{\lambda_{em}} = 1 + z$$

For convenience, a_0 = scale factor at present = 1

$$\boxed{\frac{1}{a} = 1 + z}$$

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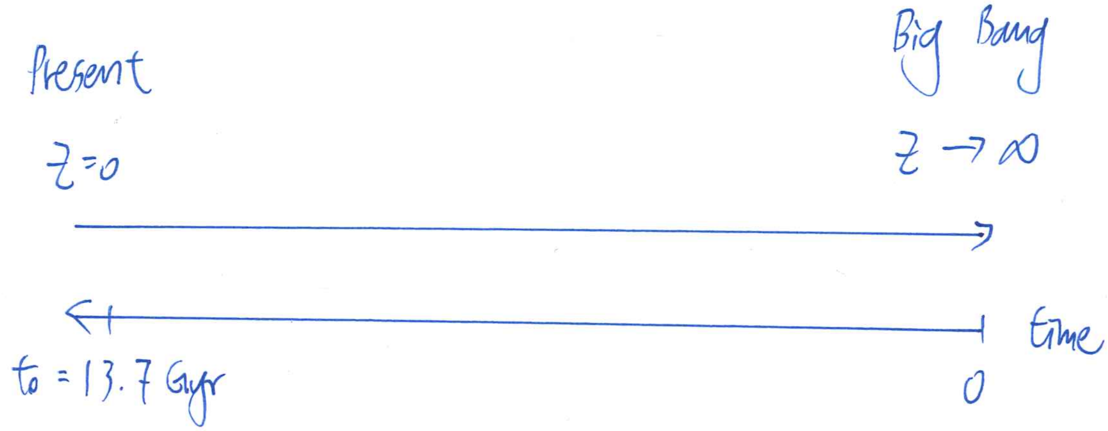
$$\boxed{\frac{1}{a} = 1 + z}$$

Note: Redshift (observable) is a measure of cosmic size, at different moments in time.



t_0 = age of universe today

$= t_H$ = Hubble time $= 13.7$ Gyr.

<u>Big Question</u>: How does the size of universe depend on time?

$$a = a(t) = a(z) = ??$$

We will go into further details on this question when we consider the "equation of motion" of the universe, the Friedmann models.

Now let's look at two more concepts!

- Comoving Distances / Sizes / coordinates.

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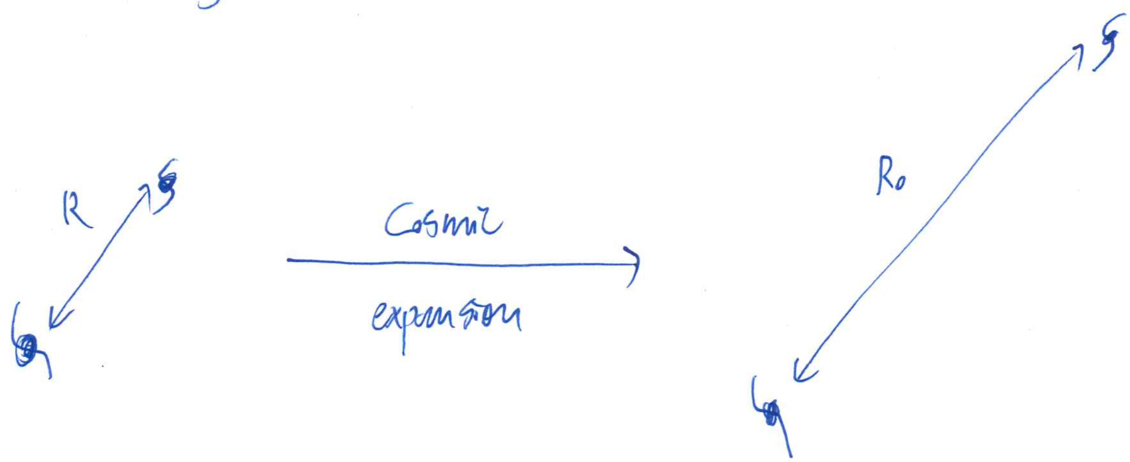
Note: a is a dimensionless number

Question: what if we want to describe sizes WITH dimensions?

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

Now consider a pair of galaxies separated by distance R, cosmic expansion will similarly stretch it into a bigger distance today, R_0.



let

$$R \equiv \underbrace{a}_{\text{Time-dependence all goes in here!}} \cdot \underbrace{R_0}_{\text{constant in time}}$$

Hubble Law.

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$$R = a \cdot R_0$$

taking time derivative,

$$V = \dot{R} = \dot{a} R_0$$

$$\Rightarrow \quad \frac{V}{R} = \frac{\dot{R}}{R} = \frac{\dot{a} \cdot \cancel{R_0}}{a \cdot \cancel{R_0}} = \frac{\dot{a}}{a} = H(t) = \text{A function only depends on time.}$$

$$\boxed{V = H(t) \cdot R}$$

Present day $\boxed{V_0 = H_0 \cdot R_0}$ } Hubble Law

Note: units of H_0

$$H_0 = \frac{\text{velocity}}{\text{distance}} = \frac{km\,s^{-1}}{Mpc}$$

$$\Rightarrow \quad t_0 \sim \frac{1}{H_0}$$