ASTR 400B In Class Lab 10

April 17, 2018

In this lab you will build on the CosmologicalTools program that you completed last class to create new functions that return the various distance measures used in observational cosmology.

1 Question 1: Look Back Time

1.1 Part A

- Complete the function "LookBackTime" that takes as inputs the desired redshift and returns the corresponding time (Gyr ago)
- Numerically integrate

$$t_L = \int_0^z \frac{dz'}{(1+z')H(z')} \tag{1}$$

- The scipy function simps is really useful for numerical integrations. At the start of the program I have imported this module: **from scipy.integrate import simps**

  To use it, I have already defined an array with redshifts, spaced in intervals of 0.001
  zrange = np.arange(zo, ze, 1e-3)

  Where zo is the redshift of the observer (it's us, so zo= 0). And ze is the redshift of the emitter.

- Next define the integrand and simps lets you integrate. **simps(y(x), x)**

1.2 Part B

1. What is the age of the universe in the benchmark cosmology? Use a large z value to estimate this.
2. What is the age in the Einstein De Sitter cosmology (where $\Omega_m = 1$ and all other density parameters are 0) ?
3. Which cosmology results in the youngest age?

1.3 Part C

Complete the plot template for Look Back Time as a function of z for both the benchmark and Einstein De Sitter cosmologies. You will need loop over the "LookBackTime" function from z = (0, 15). Follow the instructions in the template.

2 Question 2: Comoving Distance

2.1 Part A

Using similar techniques, complete the function "ComovingDistance" that takes as input the redshift and returns the Comoving Distance D_C by numerically integrating the following:

$$D_C = c\int_0^z \frac{dz'}{H(z)} \tag{2}$$

2.2 Part B

1. What is the size of the observable universe in the Benchmark cosmology today? (use a large redshift)
2. What is the size in the Einstein De Sitter cosmology? Which is smaller?

3 Question 3: Luminosity Distance

3.1 Part A

Complete the function "LuminosityDistance" that takes as input the desired redshift and returns $D_L = D_C(1+z)$).

3.2 Part B

Consider a Type 1A Supernova (absolute magnitude M = =19.3 ± 0.3) that goes off at an unknown redshift. We measure an apparent magnitude m = 25.1.

1. What is the inferred Luminosity Distance (D_{LSne}) ?

$$m - M = 5Log(D_{LSne}/\mathrm{Mpc}) + 25 \qquad D_{LSne} = 10^{((m-M)/5-5)} \tag{3}$$

2. Using the function "LuminosityDistance", what redshift most closely returns the inferred D_{LSne}?
3. Using the function "ComovingDistance", what is the proper distance from an observer on earth to the supernova?

4 Question 4: Angular Diameter Distance

4.1 Part A

Complete the function "AngularDiameterDistance", which takes as input the desired redshift and return $D_A = D_C/(1+z)$.

4.2 Part B

Complete the function "Separation", which takes as input the desired redshift and angle (assumed to be in arcsec) between two galaxies and returns their physical separation.

$$\theta = \frac{D_{\mathrm{sep}}}{D_A} \tag{4}$$

4.3 Part C

Consider two galaxies that are located at an average redshift of 1.0 and separated by an angle of 1". What is their physical separation in kpc ?

5 Question 5: Plotting all the distance measures

Follow the instructions in the template to complete a plot of all 3 distance measures on the same scale. Are they different at all redshifts? Why do they diverge?