Astronomy 400B In Class Lab 9

April 17, 2018

In this lab you will create a code that returns the Hubble Parameter and the Density Parameters as a function of redshift.

1. Update your clone of the Class Github Repo (git pull)
2. Under InClassLabs/InClassLab9 you should find a template jupyter notebook and script called 'CosmologicalTools_Template'.
3. Open the template file. You will find the benchmark Planck 2015 cosmology already defined.
4. A class called "CosmologicalTools" has been created for you.
5. Each instance of the class is initialized using the given cosmology.

1 Question 1

1.1 Part A

The first function of the class is called "HubbleParameterZ". From class:

$$H(z)^2 = H_o^2\left[\Omega_{m,o}(1+z)^3 + \Omega_{rad,o}(1+z)^4 + \Omega_{\Lambda,o} + \Omega_K(1+z)^2\right] \quad (1)$$

Complete the function to return H(z).

1.2 Part B

Check your code to make sure it returns the correct Hubble Parameter at z=0 of 67.81 km/s/Mpc

1.3 Part C

Determine the Hubble Parameter at z = 1 in the benchmark cosmology

1.4 Part D

The Einstein De Sitter cosmology refers to a time when normal matter dominated the energy budget. $\Omega_m = 1$ and all other density parameters are negligible (set to 0).

1. Determine the Hubble Parameter at z=1 in the Einstein De Sitter Cosmology
2. Is the recession velocity of a galaxies at a given distance expected to be larger or smaller than in the benchmark cosmology at z=1?

2 Question 2

2.1 Part A

From class:

$$\Omega_m(z) = \Omega_{m0}(1+z)^3\left(\frac{H_o}{H(z)}\right)^2 \qquad \Omega_{rad}(z) = \Omega_{rad0}(1+z)^4\left(\frac{H_o}{H(z)}\right)^2 \qquad \Omega_\Lambda(z) = \Omega_{\Lambda 0}\left(\frac{H_o}{H(z)}\right)^2 \tag{2}$$

Complete the corresponding functions in the class

2.2 Part B

Plot Ω_m(z), Ω_{rad}(z) and Ω_Λ(z) as a function of **(z+1)**. An array of redshifts has already been defined (zrange), starting from the future (zmin = -0.9) to the past (zmax = 10^5).

2.3 Part C

1. At what redshift does radiation dominate? This epoch is referred to as matter-radiation equality.
2. At what redshift does dark energy dominate?