ASTR 288C
Homework 7

Due: 3:30pm, Oct. 23, 2017

- **In your home directory, create a directory on the ursa machine called** `homework7_yourname`. **Put all your codes in this directory.**.
- **Name your code in this format: question1.py, question2.py...etc, where the 1 and 2 refer to the question number.**
- **The instructor will test run your code in order to grade it.**
- **In all your code, write brief comments to describe each command/step in your code (similar to the comments in the example codes). This will be part of your grade.**
- **Email the full path of your homework directory to the instructor before the deadline.**

1. [**10 points**] Download the 1-channel, 1-s binned light curve of GRB170711A (i.e., FITS file `sw00761622000b_1chan_1s.lc`) from the BAT GRB catalog website. Plot the GRB light curve directly from FITS file for this burst with error bars on the y-axis. Plot the light curve in time range of from T0-50 s to T0+50 s, which T0 is the BAT trigger time. Your x-axis needs to be the time relative to the T0 (that is, seconds before/after T0). You can choose whichever line styles (or no line), marker style, and color that make the plot look better/clearer for you.

   Clearly label the x and y axis of what you are plotting, including the units if applicable.

2. [**10 points**] In cosmology, the lookback time is the time between the age of the Universe now and the time when the photon were emitted from a distant object. The relation between lookback time t_L and redshift z is described by the following equation:

$$t_L = \frac{1}{\mathrm{H}_0} \int_0^z \frac{1}{(1+z)\sqrt{\Omega_M (1+z)^3 + \Omega_\Lambda}}, \tag{1}$$

   where H_0 is the Hubble constant at $z = 0$, and the value is

$$\mathrm{H}_0 = 70.5 \text{ km s}^{-1} \text{ Mpc}^{-1} = 2.2845 \times 10^{-18} \text{ s}^{-1} = 0.072 \text{ Gyr}^{-1}. \tag{2}$$

   $\Omega_M = 0.274$ and $\Omega_\Lambda = 0.726$ are the fraction of dark matter and dark energy, respectively. These values are based on measurements from WMAP (Spergel et al. 2007).

   Write a python code to do the following (these are all in one code):

- **[6 points]** Calculate the lookback time **in unit of Gyr** at the following redshifts: 0.1, 0.5, 1.0, 2.0, 5.0, 10.0. Print out the redshift and the corresponding lookback time to the screen.
- **[4 points]** Plot the redshift in x-axis and lookback time (in unit of Gyr) in y-axis for these redshift in a scatter plot (i.e., a dot for each data point, without any lines connecting the data points). Clearly label the x and y axis of what you are plotting, including the units if applicable. Show the plot on the screen.

  Note: If your code didn't calculate the lookback time successfully, just put lookback time equal to [1, 2, 3, 4, 5, 6] for the 6 redshift points.

3. **[15 points]** The luminosity L and flux F are related by the well-known equation,

$$L = 4\pi D_L^2 \; F \tag{3}$$

In cosmology, the distance measurement is more complex due to the expansion of the Universe. Thus, we need to use the so-called "luminosity distance (D_L)" to convert flux to luminosity. The luminosity distance at a specific distance is defined as the following,

$$D_L(z) = \frac{\mathrm{C}}{\mathrm{H}_0}(1+z)\int_0^z \frac{1}{\sqrt{\Omega_M(1+z)^3+\Omega_\Lambda}}, \tag{4}$$

where C is the speed of light, and H_0, Ω_M, and Ω_Λ are the cosmological parameters as defined in question 2.

Write a code to find the corresponding luminosity for the 15-150 keV flux of GRB090423. Specifically, your code need to include the following steps (these are all in one code):

- **[2 points]** Find the redshift of GRB090423 from this file `https://swift.gsfc.nasa.gov/results/batgrbcat/summary_cflux/summary_general_info/GRBlist_redshift_BAT.txt`.
- **[2 points]** Find the 15-150 keV flux of GRB090423 from this file `https://swift.gsfc.nasa.gov/results/batgrbcat/summary_cflux/summary_T100/summary_cutpow_energy_flux.txt`.
- **[6 points]** Calculate the luminosity distance D_L by integrating eq. 4 from redshift $z = 0$ to the redshift of GRB090423.

- **[3 points]** Calculate the luminosity of GRB090423[1].
- **[2 points]** Have your code print out the redshift, the 15-150 keV flux, the luminosity distance, and the corresponding luminosity to the screen, with clear description of which is which, and the unit associated with the value (if applicable).

4. **[10 points]** Plot the histogram of $\log_{10}\mathrm{T}_{90}$ for all the BAT-detected GRBs from this file `https://swift.gsfc.nasa.gov/results/batgrbcat/summary_cflux/summary_general_info/summary_general.txt`. Set the bin size of the plot to be 0.2 (in $\log_{10}\mathrm{T}_{90}$), and set the bins to cover the range from $\log_{10}\mathrm{T}_{90} = -3.0$ to $\log_{10}\mathrm{T}_{90} = 3.0$. Clearly label the x and y axis of what you are plotting, including the units if applicable. Save your plot as `T90.png`.

5. **[5 points]** Use the GRB table `https://swift.gsfc.nasa.gov/results/batgrbcat/summary_cflux/summary_general_info/summary_general.txt` and make a 2-d array called `GRB_info` that contains GRB name and T_{90} for all the BAT-detected GRBs.

   Specifically, this will be an array that looks like this:

   [[GRBname_1,T90_1], [GRBname_2, T90_2], [GRBname_3, T90_3]....]

   Print out the GRB name and the T_{90} of the last element in the array (i.e., the first GRB and its T_{90}) to the screen.

[1] Note that because photon loses its energy due to the redshifting effect from the expansion of the Universe, the luminosity calculated from eq. 3 is the luminosity of the "rest-frame" energy band that corresponds to the observed 15-150 keV.