Lab 10 Worksheet

You are required to hand this worksheet in at the end of the lab.

Name:_____ User Name:_____

- The places you need to put your answer in this worksheet are marked by "_____".

Use the data of GRB170823A to do the following questions. You should have already downloaded the data during the lab last week.

To download the data again, you can use the following wget command to download the data folder `00769177000/` and result folder `00769177000-results/` for GRB170823A from the BAT GRB catalog website `https://swift.gsfc.nasa.gov/results/batgrbcat/`:

wget -nH –cut-dirs=4 -r -l3 -c -N -np -R 'index*' -R '*gif' -erobots=off –retr-symlinks `https://swift.gsfc.nasa.gov/results/batgrbcat/GRB170823A/data_product/00769177000/`

wget -nH –cut-dirs=4 -r -l3 -c -N -np -R 'index*' -R '*gif' -erobots=off –retr-symlinks `https://swift.gsfc.nasa.gov/results/batgrbcat/GRB170823A/data_product/00769177000-results/`

(If it takes too long to download, copy the folders from `/n/ursa/A288C/alien/lab09_test`.)

Use these data to do the following questions:

1. **BAT spectrum plotting and fitting**

   (a) As usual, source the headas setup file

   ```
   source ~/headas_caldb_setup.sh
   ```

   (b) Go to the spectrum directory

   ```
   cd 00769177000-results/pha
   ```

   (c) Open xspec by typing

   ```
   xspec
   ```

   (d) Load the spectrum data

   ```
   data sw00769177000b_total.pha
   ```

   (e) Load the instrumental response file

   ```
   resp sw00769177000b_preslew.rsp
   ```

   (f) Open the plotting device

   ```
   cpd /xs
   ```

   (g) Plot spectrum

   ```
   plot data
   ```

   (h) You see that there are a lot of data around zero. This is because the BAT is mostly sensitive to energy range from $\sim 13-150$ keV. Therefore, let's focus on the BAT energy range and ignore energies outside of this range by typing

   ```
   ignore **-13.0 150.0-**
   ```

   Remember to type the ".0" after the number (that is, including the first decimal place). Without the decimal digit, Xspec will assume these numbers refer to the energy channel instead of the energy in keV.

(i) Plot your data again

```
plot data
```

You should see that now we only include data from $13 - 150$ keV.

(j) The x-axis of the plot is labelled as "channel", which is the energy channel in the spectrum file. Let's change the x-axis to energy so it has more physical meaning by typing

```
setplot energy
```

(k) You can also plot it in log scale by typing

```
plot ldata
```

(l) Now let's fit the spectrum with a simple power-law model. First, load the simple power-law model by typing

```
model powerlaw
```

As we have seen in class, the power-law model has the following functional form

$$f(E) = K \times E^{-\alpha} \tag{1}$$

Where K is the normalization factor and has the unit of [photon cm^{-2} s^{-1} and α is the power-law index (a.k.a. photon index, PhoIndex).

The two variable parameters in this function are K and α, and you should see that Xspec asks you to enter your initial guess of these two parameters with some default numbers listed. Just hit enter to use the default values.

Once the initial values are entered, you should see that Xspect lists the initial calculation of the χ^2 numbers and other relevant values.

(m) Now let's do the model fitting to find the best-fit parameters that gives the smallest χ^2 by typing

```
fit
```

Sometime you might see Xspec asking you

"Number of trials exceeded: continue fitting?"

Type yes to continue fitting.

Alternatively, you can type "fit 100" to go through 100 iterations.

(n) You should see the final fit from Xspec shown on the screen.

What is the best-fit power-law index? _____.

What is the normalization factor? _____.

What is the degree of freedom in this fit? _____.

What is the reduced χ^2? _____.

(o) Plot the data with the fitted model by typing

```
plot data
```

You can also add a panel to plot the residuals between the data and the model (that is, to show how good your fit is in comparison to the data) by typing

```
plot data delchi
```

(p) From the webpage of this burst in the BAT GRB catalog, find the reported photon index for the T_{100} spectrum.

The photon index found on the webpage is _____.

You will note that there is a difference in minus sign, this is because the BAT GRB catalog use the definition of E^{α} for the simple power-law model, while Xspec adopts the definition of $E^{-\alpha}$.

2. **Create your own spectrum**

(a) Similar to the light curves your created in the previous lab, you can also use "batbinevt" to easily create your own spectrum with a specific interval. First, go to the directory of the `00769177000-results` folder.

(b) Now let's create a spectrum for the largest pulse of this burst, from T0+20 s to T0+22 s by using the following command:

```
batbinevt infile='00769177000-results/events/sw00769177000b_all.evt'
outfile='sw00769177000b_test.pha'
outtype=PHA timedel=0 timebinalg=u energybins='CALDB:80'
detmask='00769177000-results/auxil/sw00769177000b_qmap.fits'
ecol=ENERGY weighted=YES outunits='RATE' tstart=XXX tstop=XXX
clobber=yes
```

Remeber to (1) fill in the XXX with the corresponding time of T0+20 s and T0+22 s, and (2) remove the line break. If you have problem with things copied from the pdf file, you can go to the "process.log" and modify from the command that makes the pha file (those line that includes "outtype=PHA").

The option of "energybins=CALDB:80" will create a spectrum with the standard 80 energy channels. You can also create a spectrum with specific energy bands by modifying this option. For example, to create a spectrum with only 10 energy bins (same width in log space) by setting

energybins='13.00-17.75,17.75-22.50,22.50-28.52,28.52-36.15,36.15-45.83,45.83-58.09,58.09-73.64,73.64-93.35,93.35-118.33,118.33-150.0'

(c) Update some spectral keywords by typing

```
batupdatephakw infile=sw00769177000b_test.pha
auxfile=00769177000-results/auxil/sw00769177000b_all.evaux
```

Again, this should be one line without space.

(d) Update systematic error by typing

```
batphasyserr infile=sw00769177000b_test.pha syserrfile=CALDB
```

(e) Create the corresponding instrumental response file by typing

```
batdrmgen infile=sw00769177000b_test.pha outfile=sw00769177000b_test.rsp
chatter=2 hkfile=NONE clobber=yes
```

(f) Fit this spectrum with a simple power-law model.

What is the best-fit power-law index? _____.

What is the normalization factor? _____.

What is the degree of freedom in this fit? _____.

What is the reduced χ^2? _____.

(g) Plot the data with the fitted model by typing

```
plot data
```

You can also add a panel to plot the residuals between the data and the model (that is, to show how good your fit is in comparison to the data) by typing

```
plot data delchi
```