Lab 11 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 "_____".

1. **XRT spectrum plotting and fitting**

   (a) As usual, source the headas setup file

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

   (b) Go to the XRT GRB Burst Analyser `http://www.swift.ac.uk/burst_analyser/`, find the spectrum page for GRB 171020A, and download the time-average spectrum by one of the following methods:

   i. Using the wget command by typing

   ```
   wget http://www.swift.ac.uk/xrt_spectra/00780845/interval0.tar.gz
   ```

   ii. Clicking the link "Download spectral files for Time-averaged spectrum", which will download a zip file to your current machine (usually in the "download" folder). If you are using your own laptop, you will need to upload the tar file to the lab machine by using the scp command like this:

   ```
   scp interval0.tar.gz <your_user_name>@ursa.astro.umd.edu:<destination_directory>
   ```

   (c) untar and unzip the file by typing

   ```
   tar -zxvf interval0.tar.gz
   ```

   You should see the following files:

   - interval0pc.pi: spectrum of the source and background. This is the main file to be used in Xspec.
   - interval0pcsource.pi: the unbinned source spectrum of the source (i.e. the GRB)
   - interval0pcback.pi: spectrum of the background
   - interval0pc.arf and interval0pc.rmf: XRT instrumental response files
   - the "models" folder: contain *.xcm file, which contains the model used by the automatic fit that is displayed on the website.

   The word "pc" in the filename indicates that this spectrum is made with data in the "photon counting" mode.

   More instruction of the data product can be found at

   `http://www.swift.ac.uk/xrt_spectra/docs.php#products`

   (d) Open Xspec by typing

   ```
   xspec
   ```

   (e) Load the main spectrum file

   ```
   data interval0pc.pi
   ```

   You can see that Xspec also automatically loaded the relevant background spectrum and instrumental response files.

   (f) Ignore bad data by typing

   ```
   ignore bad
   ```

(g) Plot data

```
cpd /xs
plot data
```

(h) Set x-axis to energy

```
setplot energy
plot
```

(i) Model fitting. Becuase the XRT observations usually have very low photon counts. The χ^2 statatistic is no longer valid. Therefore, you need to first change the default χ^2 statistics to the "C-stat" statistic by typing.

```
statistic cstat
```

After the appropriate statistic is selected, you can load to model. The "*.xcm" in the "models" directory is the model used by the automatic fit. You can load this model by typing

```
@models/interval0pc.xcm
```

Xspec will load and execute the command lines in interval0pc.xcm.

(j) Now the model is loaded, fit data by typing

```
fit
```

(You may need to type yes to continue fitting iterations until a solution is found.)

(k) plot your data again with the fitted model in log scale

```
plot ldata
```

You can see that a lot of data have large error bars because many bins only have very small number of photons. This is a property of XRT measurements. The number of source photons is small, but the number of background photons is also small.

(l) To make the plot prettier, you can re-bin the energy bins using the following command:

```
setplot rebin 3 5
plot
```

This means that the plot is now rebinned so that each new bin has either at least 3 sigma detection, or contains 5 original bins. This is just to make the plot prettier, and has nothing to do with the fitting.

(m) Question:

What is the best-fitted value for the host (intrinsic) hydrogen density N_H? _____.

What is the best-fitted value for the photon index? _____.

(n) Once the fitting is done, you can also find the uncertainty (the error bar) of each model parameter by using the error command.

For example, the photon index is the 7th parameter in the loaded model. You can find the uncertainty range of the photon index by typing

```
error 7
```

You will see the uncertainty range (i.e., the confidence range) show up after the command.

(o) Questions:

What is the lower limit of the intrinsic N_H? _____.

What is the upper limit of the intrinsic N_H? _____.

(p) Saving the plot to a file. You can save the plot to a file by typing

```
setplot command cpd XRT_test.gif/gif
plot ldata delchi
```

After you exit Xspec, the plot will be saved to the file named `XRT_test.gif`.

2. **Automation**

As seen in the exercise above, you can put all the xspec command in a file end with "xcm", and Xspec can execute these commands by calling this file. In fact, you can have Xspec execute the "*.xcm" file in the regular terminal environment (or in a shell script) by using the following command:

```
xspec - test.xcm
```

where "test.xcm" is the xcm file that contain the Xspec commands (you can name the xcm file whatever you would like, it just needs to end in "xcm").

Now let's try this by doing the following questions.

(a) Copy the spectrum `sw00769177000b_test.pha` and response file `sw00769177000b_test.rsp` you made in the previous lab to the current directory.

(b) Open an file named `test_<yourname>.xcm`.

(c) Type in the Xspec commends in the `test.xcm` file that will do the following:

i. Load the pha file.
ii. Load the response file.
iii. Ignore energy range that are outside of 15-150 keV.
iv. Load the simple power-law model.
v. Type in your initial guess. In the xcm file, you need to type in the number of your initial guess, you can use the default value given by Xspec (you can see the default values when typing "model powerlaw" in Xspec).
vi. Fit the data with the simple power-law model (use the command "fit 100" to make sure you have enough fitting iterations).
vii. Find the error range of the photon index.
viii. Open a gif file to save the plot to a file named `lab11_yourname.gif`.
ix. Plot data in log space and the residual (the "delchi" command).
x. Type the command "exit" to exit Xspec.

(d) Run the test.xcm file in the terminal (that is, not by opening Xspec).

(e) Copy your xcm file and the figure to the instructor's directory:
`/n/ursa/A288C/alien/lab11_student_results`

3. **Exercise of writing an automated script for spectral fits**
(Optional; do this exercise if have time. This code can be very useful for your project if you are doing spectral study.)

The following file from the BAT GRB catalog shows the time interval of the Bayesian blocks found for GRB170419B:

`https://swift.gsfc.nasa.gov/results/batgrbcat/GRB170419B/data_product/remake_spec/spec_time_resolved/bb_spec_times.txt`

The first and the last intervals are the background intervals before and after the burst, while the three intervals in between are the intervals of Bayesian blocks for this GRB. That is, these intervals are the sub-structure of this burst.

Write a shell script to

(a) Get the data from the BAT GRB catalog website.

(b) Create the spectrum for the second interval in `bb_spec_times.txt`.

(c) Fit the spectrum with a simple power-law model.

Once this shell script works, change the time interval to fit spectra of the 3rd and 4th intervals in `bb_spec_times.txt`.

What is the photon index of the first interval? _____.

What is the photon index of the second interval? _____.

What is the photon index of the third interval? _____.

Does the spectrum become softer or harder over time? _____.