Data Reduction Using the HEASARC Archive and Ftools

- Open Netscape
- Go to HEASARC web page by typing `http://heasarc.gsfc.nasa.gov`
- W3Browse

  On the bottom of the page there are two rows of six locations within HEASARC to which you can go. The top left option is the *W3Browse* location where you can search for observations of various objects.

  - Click on it.
  - Select the *Basic* option.
- Search for a specific object
  - From the *Active Mission Archives* section select *ROSAT* by clicking on the gray button to its left.
  - In the box at the top labeled *Object Name or Coordinates* enter `GK PER`.
  - Click on *Submit Query*.
- Selecting an observation
  - Select the second observation whose instrument is the PSPCB.
  - Slightly below the table of observations there is a box, entitled *Categories of data products*, containing different types of data collected in each observation. Click

on the gray *Submit* button below. You may receive a security warning message from Netscape, to continue just click on *Continue Submission*.

  - This page shows all the possible data that can be examined from the observation you chose. At the end of each line the filename of the data you wish to retrieve is printed in the form of *file.Z*. Select the *Basic Science Events* file by clicking on the gray button on its left.
  - Scroll down the page and click on *Retrieve Data Products*

- Downloading TAR files
  - The screen that appears should list the file you chose. Click on *Download TAR file* which appears right below.
  - The window that appears contains four sections: *Filter, Directories, Files, Selection*. Make sure that **your** directory apears in the *Selection* box. If it does not then you must enter the `/temp` directory you created to store your files.

    If you had to re-enter your directory then when you finished typing click on *Cancel*, then Click on *Download TAR file* again. This time the correct directory should appear in the *Selection* box.
  - Click on *OK*

    Netscape will copy the files you have selected into your directory in the form of a *w3browse-#.tar* file. It is a compressed file and cannot be used until it is opened up properly.

- Un-tar your *w3browse-#.tar* by typing:

  `tar -vxf` *w3browse-#.tar*

  This command produced a subdirectory chain in your directory called *rp300217n00/* where youre files are located.

- Organizing and uncompressing the files in your directory

  - You will find the files you downloaded from HEASARC in their new subdirectory by typing:

    `cd` *rp300217n00/*

  - Then type `ls` to list the files.

    rp300217n00_bas.fits.Z should appear.

    Notice the file ends with *.Z* . This means it is comrpessed further and still cannot be used.

  - Uncompress the files by typing:

    `uncompress *.Z`

    The * is a wildcard character so that your command above says "uncompress **anything** in this directory that ends with *.Z*".

    Then type `ls`. The *.Z* should have disappeared from the filename making the file usable.

  - Remove the *w3browse-#.tar* file now that you have what you need. Type:

    `rm ../`*w3browse-#.tar*

- To see the important information about this observation open up one of the files in the emacs editor. Type:

  `emacs rp300217n00_bas.fits &`

The file that comes up contains information such as the date and time of this observation, the telescope and instrument that collected the data, the location of the object as well as its name.

Close emacs.

- Reading the data into Xselect
  - The program you are using to process and analyze the data from HEASARC, *ftools* contains a package (i.e. subprogram) named *xselect* which contains all the commands you will need to look at the images from your data, and examine lightcurves and power spectra.
  - To use *xselect* you must execute its commands. At the prompt type:

    `xselect`
  - You will be asked to enter a session (so that when you are done you can save all your work into that session or continue where you left off).

    Call your session `session1`.
  - Notice the information that appears on the screen is specific for *ASCA* - a different satellite. We want to analyze *ROSAT* data and we need to tell *xselect* to do so. Type:

    `read events`
  - You will be asked in which directory do the event files exist. If you called up *xselect* from the directory where youre *ROSAT* files exist then enter `./` (which means *this* directory).

- Then enter the name of your file: `rp300217n00_bas.fits`
- Type `yes` to reset the mission.

  Now *xselect* is configured. Notice the important notes that follow on your screen.

Notes: XSELECT set up for	ROSAT	
Keywords for time and pha are	TIME	PI
Units of time are	s	
Default timing binsize =	16.000	

  This data and that which follows describes how the program is now configured to handle your data. For example, it tells that the units of time in any process will be in seconds. It also prints the directory where your data is located. Finally, the programs outputs the information about your object, *GK PER*, its position in the sky, the livetime (how long the detector was taking data on this object), and the date of observation.

• A few Commands

xselect has some general commands that you will be using to create images, light curves, and power spectra. Here are some of the commands (and their descriptions) that you will be using the most.

- *Read event*, which you have already used in the previous section, enters data into the program. If you wish to enter a new set of data, you can do it with this command

- *Filter* commands do no work. They merely enter filters selecting a particular region or time interval that will be applied to the next run of the *extract* command.
- *Extract* command produces a product file such as an image, a pectrum, or a lightcurve.
- *Clear* command is used to clear any changes you have made to data and restores it to the way it was originally.
- Another useful command is *show data* which you can type at any time and you will receive an output of your working directory and the names of the files you are using.
- Similar to the *ls* command, to list all the files in your current directory you can type `list workdirectory` or `list datadirectory`.

• Image analysis

- To look at *GK PER* you need to command *xselect* to show it to you. At the prompt type:
  `extract image < Enter >`
  Once again *xselect* prints out information on the screen. The important facts are the *seconds* and the *counts* that provide a countrate for the image. This is important because a high countrate means the object was giving off photons at a high rate and will be bright. A very low countrate implies a faint or no image (just noise).
- The image has been extracted from the data and you must now use an imaging tool to look at it. Type `saoimage` to call up the imaging tool. A new window should pop up with your data displayed upon it.

SAOIMAGE

You should take some time to familiarize yourself with this tool. You can change the features of your display by selecting a "button" from the top row. If you click on *Scale*, for example, you have a choice, on the seconds row, of viewing your image in a variety of brightness scales. Notice the grayscale legend at the bottom. A linear scaling would let the brightest thing in your image be the color of the extreme right, the least bright thing in your image be the color of the extreme left, and the values in between would be evenly spaced along the grayscale legend. A square root display would let the square root of the maximum and minimum brightness values be displayed as the leftmost and rightmost grayscale values. Try the logarithmic scaling to see what it does.

You can also change the color schemes by clicking on *Color*. The button *cmap* will add more choices to your display options. You can invert the grayscale legend by clicking on *invert*. To return to the color options click on *cmap* again.

You can mark your object of choice with a *cursor* and define a region to later observe.

* The object we are examining is GK PER. It is located at the bottom left of the display. If you want to center your object click on *Pan* and then click on the object. It should move to the center. Then click on *Cursor*.
* Select a circle shaped cursor. With your mouse

button choose a circle size that places your object comfortably inside. The left mouse button puts the center of your shape in place, and clicking down on both mouse buttons allows you to drag out the radius of the shape to any size you wish. Make your circle just big enough to enclose the star. Then type `s` on the keyboard to "save" the region.

  * Click on the button labeled *region* (the rest of the buttons should change) and select *write*. On the line that appears type `src.reg` which saves the region surrounding your object for later use.

  Continue to play with SAOimage until you feel comfotable using it.

- To look at the data inside your selected region only, return to the window where *xselect* is running and type:

  `filter region src.reg < Enter >`

  When you apply the filter command to an image it is as if you are placing an opaque screen with a hole in it over the data. The hole int he screen is the region you selected.

- Next you must type `extract events` to select only the data contained in your region. In other words you are choosing only the points that show through the hole in the screen. The rest are ignored. The output of this command should show a *Grand Total* of 112910 counts with a much smaller number (around 3 or 4 thousand) of *Good* counts and the rest are *Bad: Region* counts. This tells you you have excluded all the points not in your selected region.

– Now type `clear region`

  This removes the filter from your image since you pulled out the events you wanted and no longer need the filter.

– Now you must extract the image from those points you selected by typing:

  `extract image`

– Call up SAOimage again to display your new image. (You may close your old SAOimage window by clicking on *etc* and then on *QUIT* or leave it up for comparison with your new display.)

– Getting a Filtered Image

  The following is a list of the commands you just used with no comment so that you may refer to it quickly beginning after `read events`:

  `extract image`

  `saoimage` (select a region with the cursor)

  `filter region src.reg`

  `extract events`

  `clear region`

  `extract image`

  `saoimage` (To see the final image)

  You may now proceed to manipulate the image of *GK PER*

– Binning up pixels.

  The image you originally displayed (before the filtering) is made up of 1024×1024 pixels. When you chose the region you simply selected a particular set of pixels to be displayed. Sometimes, however, it is helpful to group pixels together into one block to get a smoother appearence of the data. This technique is called block-averaging. If you tell *xselect* to take every 8 pixels and replace them with 1 pixel whose grayscale value is the average of those eight, you have binned up your image into 128 × 128 pixels. To see this type:

`set xybinsize < Enter >`

– You will be asked for a rebinning factor (this would be the value 8 mentioned above) select `8` to see a 128 × 128 pixel image.

  Then continue to process the image by commanding:

  `extract image < Return >` and `saoimage < Return >`

  You should see your region selected image in a binned up fashion. The pixels should now be larger sized squares.

– Try to rebin with different values such as 32.To do this you simply need to type:

  `set xybinsize` and input the binning you desire.

  `extract image`

  `saoimage`

  The default xybinsize is 15; this means the first image you looked at had an xybinsize of 15. When you are done exploring this function, set it back to 15.

– Smoothing images.

  Smoothing images often allows you to concentrate on the general features of the image and not worry about individual pixels.

Type: `smooth image`

You will be asked for a smoothing method. Your options are *Boxcar, Gaussian,* or *Lorentzian.* Choose the `Gaussian` method by typing it at the prompt. You will be asked for a sigma for image smoothing. The default is 1.5 you may accept that value to see what happens.

Again display your result with `saoimage`.

  - Notice your object is now smoothed. Try different color schemes on the smoothed data and pan in on it so you can see it clearer. Notice the top left part of the image is now bright and there is a dark "hole" in the middle. The value 1.5 is the σ in a gaussian curve which you are applying to the image, a larger σ means a smoother image.
  - An image will be smoothed differently depending on the binning factor of the image. You can explore different possibilities by following these steps:

    `set xybinsize` and input the binning you desire.

    `extract image`

    `smooth image < Enter >` then choose `Gaussian` with a σ of 2 or any value you wish to explore.

    Then view it with `saoimage < Enter >`.

    Try a σ of 3 or 4 to see what happens when you smooth too much!

- Examining lightcurves
  - You will now use the *extract* command to make a lightcurve of your observation.

```
extract curve
```

– Next you must set a program device upon which your lightcurve can be plotted.

  `set device /XW`

  and now plot it `plot curve`

– You will notice that all of your data is in the center of the plot and a curve or spectrum is hard to make out. Also, notice that at the top of your plot you are told that the binsize is 16.000s. This means that the total livetime has been divided by 16s and plotted accordingly.

  Notice on your *Xselect* screen that the prompt has changed from *session1:ROSAT-PSPC*> to *PLT*>. This means you are in an *interactive* mode with the plot window and commands you give the screen will be received by the plot window.

  The most important command is *exit*; type it if things get really crazy. In this case you can clear events and start the lightcurve extraction all over.

– One useful thing you can do is reset the x and y axes to zoom into some interesting part of the lightcurve.

  `rescale x 4e5 6e5`

  This displays the datapoints across the entire screen. You can zoom in even more by typing `rescale x 4.8e5 5.5e5`

  Type `exit` to return to *xselect* now.

– It is useful to define a region of interest from your image and extract the events from that region. Since you already extracted the lightcurve you can define a time interval through which you can filter the data.

Type: `filter time cursor < Enter >`

Again you will be in the *PLT*> mode. The first thing to do is to enter `quit` as you are told to do on the screen. Then in the plot itself click to the right of the curve (around x=5.5e5) and to the left (around x=4.8e5). A horizontal line should have connected your clicks.

Then type `x` *in* the plot window to exit this mode. NOTE: You can get tangled up very quickly while in this mode. Do not attempt to try the other commands that appear unless you have plenty of time and motivation! The instructions above will be sufficient for your purposes.

- Type `show status < Enter >` to see that file of the time selections was added to the filters. It also shows what you have done so far under *PRODUCTS*.

- Type `extract curve < Enter >` since now there has been a filter applied to it.

  And `plot curve < Enter >`.

- You now have a light curve. You can rescale this curve as you did before. Typing `rescale` with no argument will return the original curve.

- Finally, you might want to make a hardcopy (printout) of your lightcurve. to create a postscript file that can be printed, type at the *PLT*> prompt:

  `Hardcopy /PS`. this will make a ps file in your main directory that you can later print out.

- Extracting an Energy Spectrum from the Lightcurve

  - To further analyze the light curve you extracted, it is useful to make a energy spectrum, which tells you the intensity of the radiation as a function of energy. By looking at the shape of this energy spectrum, we can tell a lot about the nature of the processes that give rise to the x-rays that we see.

    Type `extract spectrum < Enter >`

    Followed by `plot spetrum < Enter >`.

    You will get a plot of COUNTS vs. CHANNEL

- When you are done using Xselect you may type `exit` at the prompt and save the session so that all the images, curves and spectra remain in your directory as independant files. You are now able to take these data and manupilate them to produce power spectra, as well as fit the spectral data to learn more about the properties of this star!