# Lab 5
# Statistics, Source Detection, and Noise at High Energies

Log into your department unix account and start X Windows using the "startx" command.

Open a browser and download the zipped and tarred data file ("lecture5-data.tar.gz") for this lab, found in the "Data" link under the "Materials" section on the course webpage. When you click on the "Data" link , the browser will prompt you for direction on how to download. Select the option to save to disk. It should save the file, by default, into your home directory. Move the file into your data directory, unzip and untar the file:

```
mv  lecture5-data.tar.gz  ~/data
cd ~/data
gunzip  lecture5-data.tar.gz
tar  xvf  lecture5-data.tar
```

There should be five new FITS image files, and two new ds9 region files. One of these, **cdfn_hbs.fits**, is the adaptively smoothed *Chandra* Deep Field-North hard X-ray band image downloaded from http://www.astro.psu.edu/~niel/hdf/hdf-chandra.html.

Open this FITS image in ds9, and adjust the zoom, color, and scale to your liking. Load the regions files called **back_box.reg**, and **source_box.reg**. The FITS image files called **cdfn_back_img.fits** and **cdfn_source_img.fits** are subimages of **cdfn_hbs.fits** corresponding to these regions, and are the subject of the remainder of the lab. Additional files, **cdfn_source_img_binned.fits** and **cdfn_back_img_binned.fits** were created by binning these by a factor of 8 so that the counts from a source will lie in a single pixel (more or less). These will be needed for the homework assignment.

Now that you are orientated, start up IDL and -- as in the previous lab -- open an IDL plotting window, start the IDL Help interface, and load the astrolib library:

```
IDL>  window,0
IDL>  ?
IDL>  astrolib
```

First, we will examine the background file. Read the **cdfn_back_img.fits** into IDL and calculate the mean pixel value. The number of pixels in the image is equal to the number of elements in the image array, and can be computed within IDL.

```
IDL>  image_back = readfits("cdfn_back_img.fits",bkghdr)
IDL>  print, mean(image_back)
IDL>  print, n_elements(image_back)
```

*Enter the mean intensity, and the number of pixels, in the table in question 1 of the homework assignment.*

A primary distinction between these X-ray images and the K-band images we looked at last week, is their sparseness. For this reason the distribution of pixel values more nearly follows a Poisson, rather than Gaussian, distribution (since this is not a completely source-free region, this is only approximate). We will examine this by constructing pixel value histograms as we did last week, using a logarithmic scale due to the exponential drop-off in the number of pixels with number of counts.

```
IDL>  hist_back=histogram(image_back, binsize=1, locations=bins_back, /nan)
```

```
IDL>  plot, bins_back, hist_back, psym=10,xrange=[0,10],/ylog
```

In order to make some sense of this, and for purposes of comparison with the statistics in the source region, construct a normalized histogram of the fraction of pixels with different numbers of counts:

```
IDL> hist_back_norm=hist_back/65536.0
IDL> plot, bins_back, hist_back_norm, psym=10,xrange=[0,10],/ylog
```

The factor of 65536.0 is equivalent to n_elements(image_back) that was previously calculated, but expressed as a *floating-point*, rather than an i*nteger*, constant. This conversion can be done within IDL using the *float* function.

*Estimate the fractions of background pixels with more than 0 counts, and with more than 4 counts, and enter these in the table in question 1 of the homework assignment*. Open up a web browser and navigate to http://www.wolframalpha.com/entities/calculators/Poisson_distribution_CDF_formula/nu/4p/an/.
Use the calculator to derive the expected fractions for a pure Poisson distribution (the intensity corresponds to the mean; set the right endpoint equal to some large, but not too large, value).

Construct conventional and normalized histograms for the source image in the same manner. Using the IDL *oplot* command, plot the normalized source-image histogram on the same plot as the normalized background-image histogram using a distinct linestyle. Label the axes, and produce a hardcopy to be *turned in at the end of the lab* ***or*** *with the homework assignment***.** Recall, this can be done along the following lines:

```
IDL>  set_plot, 'ps'
IDL>  device, filename='histogram_compare.ps', /landscape
…
<plotting commands here>
IDL>  device, /close
IDL>  set_plot, 'x'
```

[*in a separate terminal*] gv 'histogram_compare.ps' &

*Estimate the fractions of source pixels with more than 0 counts, and with more than 4 counts, and enter these in the table in question 1 of the homework assignment*. Calculate the expected fractions for a pure Poisson distribution.