Lab 4
Statistics, Source Detection, and Noise in the Optical/Infrared

Log into your department unix account and start X Windows using the “startx” command. In a terminal, change directories to the data subdirectory of your home directory, and then start **IDL**:

```
cd ~/data
idl
```

Once IDL has been started, also open an IDL plotting window and start the IDL Help interface:

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

This interface may be used to search for standard IDL procedures, their descriptions, and the syntax for using them. For example, within the **Search** box, type “mean” and click the “Search” button. Much like an index, the interface will return different pages discussing “mean.” Find the IDL procedure that may be used to determine the mean pixel value of an array or image. Likewise, find the IDL procedures that may be used to determine the median and standard deviation of the pixel values of an array or image.

IDL procedures that have been developed specifically for astronomy are not standard IDL procedures. Thus, the IDL Help interface cannot be used to search these astronomy-specific procedures. One of the largest, most widely used IDL astronomy libraries is *astrolib*, distributed by NASA Goddard Space Flight Center. Load this library:

```
IDL>  astrolib
```

To access a list of the *astrolib* procedures, open the following file:

```
~/idl_libs/astrolib/contents.txt
```

in a text editor. This file also includes a brief description of the function of each procedure. For more details about a procedure, including the syntax for using it, you must refer to the procedure itself. The *astrolib* procedures are found in the following directory:

```
~/idl_libs/astrolib/pro
```

Just as you could read a FITS image file into **ds9**, you may also read them into IDL using the astrolib procedure readfits. Read in the K-band image for B35A that was previously saved in your data directory, and determine the mean pixel value in the image using the following IDL statements:

```
IDL>  image_B35A_K = readfits(“B35A_K.fits”, hdr_B35A_K)
IDL>  mean_B35A_K = mean(image_B35A_K)
IDL>  print, mean_B35A_K
```

Note that, instead of first saving the mean as named variable and then printing it, you may simply print it:

```
IDL>  print, mean(image_B35A_K)
```

Now, determine the median and standard deviation of the pixel values in the image. **Record these "Full Image Statistics" in the table in Question 1 of the homework assignment.**

Let's now use the standard IDL procedure *histogram* to construct a histogram of the pixel values in the image. As an example, for a bin size of 0.3 ADU, the IDL statement would be:

```
IDL>  hist_B35A_K = histogram(image_B35A_K, binsize=0.3, locations=bins_B35A_K, /nan)
```

This statement saves the locations of the bin centers in named variable *bins_B35A_K* and the histogram values as *hist_B35A_K*. You may view the resulting histogram by using the *plot* procedure, with *psym* set to 10:

```
IDL>  plot, bins_B35A_K, hist_B35A_K, psym=10
```

Alternatively, you may save the plot by creating a PostScript (ps) file. The details concerning the creation of such files may be complicated, and are beyond the scope of this lab. But, you may create a PostScript file, with filename "histogram_B35A_K.ps", by using *set_plot* and *device* statements before and after the *plot* statement as follows:

```
IDL>  set_plot, 'ps'
IDL>  device, filename='histogram_B35A_K.ps', /landscape

IDL>  plot, bins_B35A_K, hist_B35A_K, psym=10

IDL>  device, /close
IDL>  set_plot, 'x'
```

You may then view this file using **gv** in a terminal separate from that running IDL:

```
gv  histogram_B35A_K.ps  &
```

You should choose a bin size that provides at least a few bins on either side of the distribution peak, without creating a "noisy" distribution by setting the bin size too small. Remake the histogram with different bin sizes until you achieve a smooth and well sampled distribution around the peak. Also, using the IDL Help interface, scan the documentation for *plot* to determine how to change the range of the x- and y- axes and how to label these axes. Save your final histogram as a PostScript file and print it. Based on the histogram, estimate the mode of the distribution and record it on the printed copy. **Turn in this printed copy at the end of the lab.**

Now, start the PhotVis interface:

```
IDL>  photvis
```

Load the image by selecting the **Open FITS Image** option under the **File** menu, and browse for the B35A_K.fits image. After the image has been loaded, adjust the grayscale by changing the **Min** and **Max** values on the PhotVis interface. **Note that whenever any value in a PhotVis box has been changed, this change must be followed by a <RETURN> while the cursor is active in that box in order for the change to take effect.** The grayscale should be set such that you can see the background level and faint sources barely above the background level. You will find that zooming in on different regions of the image (using the zoom buttons and dragging the display box found to the right of these buttons) will help you to set the grayscale appropriately.

Under the **Info** menu, you will find the **FITS Header** and **Statistics** options. The former option displays the header, similar to the ds9 capability. The latter option displays the basic statistics of the image pixel values.

The mean, median, and standard deviation returned by PhotVis should be the same as those you previously found and recorded in Question 1 of the homework assignment.

Moving the cursor into the main PhotVis image display and clicking the left mouse button causes a box to appear. This box may be moved to isolate different regions of the image. The "Local Statistics" for pixel values in that box are shown in the upper right of the PhotVis interface. Place a box in the upper left (northeastern; NE) quadrant of the image, in a region free of sources, and **record the local mean, median, and standard deviation in the table in Question 1 of the homework assignment**. Similarly, repeat for regions in the upper right (NW), lower left (SE), and lower right (SW) quadrants. **Record these local statistics in the table in Question 1 of the homework assignment.** Are these statistics consistent with those found for the full, entire image? Based on the local statistics and the full image statistics, settle on single values (to the nearest 0.1 ADU) to adopt for the median and standard deviation. The adopted value for the standard deviation will be used later in the source detection routine.

Next, zoom in on a region with at least three well isolated, non-saturated sources. Place the cursor over the center of one of these sources and click the left mouse button. Profiles of the pixel values along that row and along that column will appear in the black window located in the lower right of the PhotVis interface. Use these profiles to estimate the FWHM (in pixels) of this source. **Record this FWHM estimate as well as the Column and Row numbers in the table in Question 2 of the homework assignment. Repeat for the two other isolated sources, and record.** From these three separate FWHM estimates, settle on a FWHM estimate (to the nearest 0.1 pixel). This adopted FWHM will be used for the source detection routine.

Configure the automatic source detection by selecting the **Object Detection** option under the **Configuration** menu. A **PhotVis Config: Object Detection** window will appear. Change the **FWHM** value to be appropriate for your image, and then <RETURN>. Choice of the **Intensity Threshold** (above the local background) may be expressed in terms of the **Standard Deviation** by:

Intensity Threshold = N x (Standard Deviation)

For this lab, choose a threshold that is 50 times the standard deviation, or **N** = 50. **Again, always remember that whenever any value in a PhotVis box has been changed, this change must be followed by a <RETURN> while the cursor is active in that box in order for the change to take effect.** Do not change any of the other object detection parameters. Initiate the automatic detection by selecting the **AutoDetect Active**. How many objects were detected (*and accepted*) by the PhotVis **AutoDetect** routine? This number is displayed in the upper right of the PhotVis interface. **Record this number in the table in Question 3 of the homework assignment.**

Zoom in near the center of the lower left (SE) quadrant of the image, displaying a field that is about 1/16 of the area of the full image. Within this sub-region, sources that were detected above the intensity threshold and accepted as real sources are identified by green squares. Sources that were detected above the threshold, but rejected by other criteria, are identified by red squares. You may examine each source in detail by placing the cursor over that source and clicking the right mouse button. In this way, "judge" for yourself whether each detection that was accepted (green square) by the AutoDetect routine represents a *real* or *anomalous* source. **Record the number of anomalous detections in this sub-region in the table in Question 3 of the homework assignment. Also, record in that table the total number of detections that were accepted (green squares) by the AutoDetect routine.**

Finally, save the PhotVis session by selecting the **Save Current Session** option under the **File** menu. Use a filename with extension ".idl" (e.g., PhotVis_B35A_K.idl). This PhotVis session may be loaded anytime by starting IDL and PhotVis, and selecting the **Load Current Session** option under the **File** menu.