Lab 8
Data Analysis I: Optical/Infrared

Log into your department Unix account and start X Windows using the "startx" command. Download the data for this lab and associate homework assignment, and save in the "data" subdirectory. For this lab, you will use the J image of B59-CONTROL. Then, start and initialize **IDL**, and start **PhotVis**:

```
cd ~/data
idl

IDL>  decompose, retain=2
IDL>  window,0
IDL>  astrolib
```

Load the J image into PhotVis, and adjust the grayscale of the image such that you can see even the faint stars above the background. If you zoom into a region that is ~1/16th of the total field, and click the left mouse button, you will be able to place a small square on a region absent of any detectable sources. (If the grayscale is not properly set and you do not zoom in sufficiently, it is difficult to determine whether sources are present within the square region.) The noise level of the background is represented by the standard deviation of the pixel values, which is displayed in the upper right of the PhotVis window. Record the noise values for three separate square regions in the table included in Question 1 of the homework assignment. For now, use three significant figures for these separate noise values.

Compute the mean (n) and standard deviation (σ_n) of the J noise values. The error in the mean (Δn) may be calculated by: $\Delta n = \sigma_n / \sqrt{N}$, where N is the number of measurements ($N = 3$, in this case). The error in the mean should only be cited with one significant digit, and, in turn, that digit represents the least significant position in the mean. Thus, with the appropriate number of significant digits, record the adopted noise and its error in the table. Compute the intensity threshold that will be used for source detection in this lab: $50 \times n$. To the nearest 0.5 pixel, estimate the FWHM of objects in the J image, and record this estimate in the table. Use the intensity threshold and FWHM in the PhotVis source extraction procedure to detect objects.

As a reminder, 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.

Record the number of objects detected. Using the left mouse button, you may visually inspect each object to determine whether it is a real or spurious object. If you believe the object to be spurious (e.g., its intensity profile has a FWHM that is significantly less than that of real objects), then you may double-click the right mouse button to reject the object. Real objects are identified by green squares, while rejected objects are identified by red squares. Record the number of objects that you rejected. Finally, determine the number of real objects detected in the J image by subtracting the number of rejected objects from the original number of detected objects.

Now, you will proceed to obtain aperture photometry for these objects. Under the **Configuration** menu, open the **Aperture Photometry** window. This window allows you to set the aperture radius (in pixels), the inner and outer radii (in pixels) of the sky annulus, the number of photons per ADU, and the magnitude zero point. Set the aperture radius to be the nearest integer to 3/2 of the FWHM estimate. Set the other parameters to:

Inner Sky Radius: 20	Photons per ADU: 1.00000
Outer Sky Radius: 30	Magnitude Zero Point: 25.0000

After pressing <RETURN> in every box of the **Aperture Photometry** window to ensure that all parameters have been entered properly, the aperture photometry may be saved by selecting the **Save Photometry Results** option under the **File** menu. By convention, these PhotVis data (PV_DAT) files should be saved with *.pvd* extensions (e.g., B59-CONTROL_J.pvd) to distinguish them from normal IDL-save files. At this point, to safeguard from the loss of your work, save the current IDL session by selecting the **Save Current Session** option under the **File** menu. By convention, these IDL-save files should be saved with .*idl* extensions (e.g., B59-CONTROL_J.idl).

The saved PV_DAT files that contain the aperture photometry may be read into IDL by using the *restore* procedure. For example, to read in a PV_DAT file named "B59-CONTROL_J.pvd", the following command may be issued:

IDL> restore, "B59-CONTROL_J.pvd"

After issuing the command, the 12-column array *pv_dat* is available with the following columns:

Column 0: x-pixel position (RA position, in decimal degrees, if transformed)
Column 1: y-pixel position (Dec. position, in decimal degrees, if transformed)
Column 2: "roundness"
Column 3: "shape"
Column 4: aperture radius, in pixels
Column 5: inner sky annulus radius, in pixels
Column 6: outer sky annulus radius, in pixels
Column 7: aperture instrumental magnitude
Column 8: aperture instrumental magnitude error
Column 9: sky (or background), in ADU
Column 10: sky (or background) error, in ADU
Column 11: "user status"

You may see the values in these columns by making your IDL window large and printing the *pv_dat* array:

IDL> print, pv_dat

Each row represents a single detected object. You may see the dimensions of *pv_dat* by:

IDL> help, pv_dat

You should find that *pv_dat* has the same number of rows as the number of real objects recorded in the table in Question 1 of the homework assignment. **If you do not, please see the instructor!**

Note that the coordinates of the objects (Columns 0-1) extracted by PhotVis are given as pixel positions (x, y) on the image. While these positions are helpful for identifying the objects on the image itself, they are not helpful for identifying these objects on other images. The pixel positions must be transformed to WCS coordinates (RA, Dec). There are several methods for doing this coordinate transformation in IDL. The simplest method for the PhotVis results is to make use of the procedure *wcs_pvd*:

IDL> wcs_pvd

When prompted, enter the PhotVis data (PV_DAT) file, the image (FITS) file, and the output (WCS PV_DAT) file that will include WCS positions instead of pixel positions. By convention, you may choose to distinguish the WCS PV_DAT file by adding "*_wcs"* to the root name before the extension (e.g., B59-CONTROL_J_wcs.pvd). The *pv_dat* array saved in the WCS PV_DAT file has the same format as the previous *pv_dat* array, except the first two columns contain the WCS positions (RA, Dec) of the objects instead of the pixel positions (x, y). You may verify, by inspection, that the first two columns have changed by:

```
IDL>  restore, "B59-CONTROL_J_wcs.pvd"
IDL>  print,  pv_dat
```

At this point, you have instrumental J photometry for all detected objects, but this photometry needs to be transformed to a standard system. To see the distribution of instrumental J magnitudes, plot a histogram of these magnitudes:

```
IDL>  restore, "B59-CONTROL_J_wcs.pvd"
IDL>  ncols = n_elements ( pv_dat(*,0) )
IDL>  nrows = n_elements ( pv_dat(0,*) )
IDL>  J_inst_mags = fltarr(nrows)
IDL>  J_inst_mags(*) = pv_dat (7, *)
IDL>  hist_J_inst_mags = histogram ( J_inst_mags, binsize = 0.5, locations = bins_J_inst_mags, /nan)
IDL>  plot,  bins_J_inst_mags, hist_J_inst_mags, psym = 10
```

Revise the *plot* statement to appropriately label the axes, save the plot as a PostScript file, and print it. **Turn in this printed copy at the end of the lab.**

Similar to the manner in which you saved the instrumental J magnitudes into an array (J_inst_mags) above, you may save the RA and Dec positions of these objects in (**double precision**!) arrays as follows:

```
IDL>  ra_J = dblarr(nrows)
IDL>  dec_J = dblarr(nrows)
IDL>  ra_J(*) = pv_dat (0, *)
IDL>  dec_J(*) = pv_dat (1, *)
```

For the purposes of this lab, you will transform the instrumental J magnitudes into the standard 2MASS photometric system using the single "standard star," identified as 2MASS 17104567-2715064, which has the following coordinates:

RA(standard star) = 17h 10m 45.68s = 257.69032 deg
Dec (standard star) = -27° 15′ 06.5″ = -27.25180 deg

Find this star in your list of detected J objects. While you could scan through the WCS positions (RA, Dec) of the objects, such inspection would require a great deal of time and effort, especially for a long list of objects. Instead, you should use IDL to create an array of the distance between each detected J object and the standard star:

```
IDL>  ra_standard = 257.69032d0
IDL>  dec_standard = -27.25180d0
IDL>  delta_ra = ( ra_J (*)– ra_standard )*cos( dec_standard*!pi/180.)
IDL>  delta_dec = dec_J(*) – dec_standard
IDL>  distances = 3600. * sqrt ( delta_ra(*)^2 + delta_dec(*)^2 )
```

You can then use the IDL *min* procedure to find which observed J object is nearest to the catalogued coordinates of the standard star:

```
IDL>  mindist = min( distances, minind )
```

Be sure to read the IDL help page for *min* to understand the statement above. The distance, in arcseconds, between the standard star coordinates and coordinates of the nearest observed J object is given by *mindist*. If this distance is less than or equal to 1 arcsecond (a typical "tolerance" for optical and near-infrared observations), then we may assume that this observed J object corresponds to the standard star. So, verify that the distance to the nearest observed object qualifies:

IDL> print, mindist

If it does not, please see the instructor! If it does, then the index associated with the observed object assumed to be the standard star is *minind*. Thus, you may print the observed RA and Dec of the standard star and its instrumental J magnitude:

IDL> print, ra_J(minind), dec_J(minind), J_inst_mags(minind)

Record these values, as well as the value of *mindist*, in the table in Question 2 of the homework assignment. **For the purposes of this lab, assume that the observed coordinates are known to within 0.00001 deg and the instrumental magnitude is known to within 0.01 mag.**

Use the Gator search engine (recall the notes and assignment for Lecture 2) to determine the catalogued ("accepted") 2MASS J magnitude and error for the standard star, and record them in the table with the appropriate number of significant digits. **While the 2MASS J magnitude error typically will include several non-zero digits, the magnitude error should be considered to have only one significant digit. In turn, the position of this significant digit determines which digits in the 2MASS J magnitude are significant.** Calculate the J magnitude zero point offset:

Zero Point Offset = 2MASS Magnitude – Instrumental Magnitude

and record this zero point in the table, with the appropriate number of significant digits. With the zero point offset known, the instrumental magnitudes may be transformed to the standard 2MASS photometric system by:

Transformed Magnitude = Instrumental Magnitude + Zero Point Offset

From the array of instrumental J magnitudes (J_inst_mags) and the J zero point offset, create an array of transformed J magnitudes (J_trans_mags). Similar to the previous histogram plot you created, construct a histogram of these transformed J magnitudes, except use a logarithmic scale for the y-axis. (On such a plot, you will need to set the lower limit of the y-axis to be 0.1 instead of 0.) Appropriately label the axes, save as a PostScript file, and print the plot. **Turn in this printed copy at the end of the lab.**