Lab 10
Data Analysis III: Optical/Infrared

Log into your department Unix account and start X Windows using the "startx" command. For this lab, you will use the WCS-transformed PhotVis data (WCS PV_DAT) files you obtained in Lab 8 (i.e., B59-CONTROL._J_wcs.pvd, B59-CONTROL_H_wcs.pvd, B59-CONTROL_K_wcs.pvd). Start and initialize **IDL**:

```
cd ~/data
idl

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

At the moment, you have three separate photometry tables for the JHK images. In order to obtain the photometry at all three bands for each source, you would need to search for the source in each table. For convenience, such tables are usually "bandmerged." Sources with positions consistent to within a tolerance (often ≤ 1´´ for optical and infrared observations) in two bands are considered detections of the same source. While you could write an IDL procedure to do your own bandmerging of sources across the JHK bands, the *wcs_photmatch* procedure has been written to bandmerge the WCS PVD_DAT files created by PhotVis. To bandmerge your results for B59-CONTROL, using a tolerance of 1´´, use the following statement:

```
IDL> merge = wcs_photmatch(tol=1. ,  bands=['J', 'H', 'K'], /write)
```

The procedure will then ask you for the filenames of the PVD_DAT files for each band. Be sure to provide the WCS PVD_DAT files — the files with (RA, Dec) positions — and not the PVD_DAT files with (x, y) pixel positions. In this case, you would provide the following files: B59-CONTROL_J_wcs.pvd, B59-CONTROL_H_wcs.pvd, B59-CONTROL_K_wcs.pvd. Save the output table as B59-CONTROL_JHK.tbl in your "data" subdirectory.

Inspect the output table. You will find that the first row labels each of the 12 columns:

Column 0: RA position, in decimal degrees, of source in J image
Column 1: Dec. position, in decimal degrees, of source in J image
Column 2: RA position, in decimal degrees, of source in H image
Column 3: Dec. position, in decimal degrees, of source in H image
Column 4: RA position, in decimal degrees, of source in K image
Column 5: Dec. position, in decimal degrees, of source in K image
Column 6: Instrumental J magnitude of source
Column 7: Instrumental H magnitude of source
Column 8: Instrumental K magnitude of source
Column 9: Instrumental J magnitude error of source
Column 10: Instrumental H magnitude error of source
Column 11: Instrumental K magnitude error of source

For your tables, the J, H, K magnitude errors have not been calibrated, and we will ignore them in the lab. Since we have focused on well detected sources, the instrumental magnitude errors should be limited to 0.01-0.05 mag, depending on the magnitude, with brighter sources having the smaller errors.

Ultimately, non-detected sources and problematic photometry will need to be removed in order to generate scientific plots. For the bandmerged table created by the *wcs_photmatch* procedure, such sources are "flagged" with specific values. Sources that were detected in at least one band, but not detected in a another band, are listed with RA=0.0000000 and Dec.=0.0000000 in the non-detected band. Furthermore, these sources are listed with an instrumental magnitude and error of -100.00000 and 10.000000, respectively, in the non-detected band. Finally, if a source was detected in a band, but determination of the photometry was problematic (e.g., the source is too close to the image edge), then the RA and Dec. have legitimate values but the instrumental magnitude and error are listed with values greater than 99.999 and 9.99, respectively.

Read the bandmerged table into IDL arrays using the *readcol* procedure included in the astrolib library:

```
IDL>  readcol, 'B59-CONTROL_JHK.tbl', ra_J, dec_J, ra_H, dec_H, ra_K, dec_K  $
IDL>  ,J_inst_mags, H_inst_mags, K_inst_mags, format='D,D,D,D,D,D,F,F,F', skipline=1
```

You now have double-precision arrays with RA and Dec. values for the sources detected in each of the images, and floating-precision arrays with values derived for the instrumental magnitudes.

Now, exercise your IDL skills by obtaining the indices (or, rows) for sources detected in all three JHK images and that have legitimate photometry in all those bands:

```
IDL>  indsJHK=where( (J_inst_mags  ge  0.)  and  (J_inst_mags  le  99.)  $
IDL>  and  (H_inst_mags  ge  0.)  and  (H_inst_mags  le  99.)  $
IDL>  and  (K_inst_mags  ge  0.)  and  (K_inst_mags  le  99.)  , nJHK)
```

The indices of these sources are saved in the array *indsJHK*, and the number of such sources is given by *nJHK*.

Next, write an IDL procedure, saved with filename "myregions.pro", to input RA and Dec. arrays and construct a **ds9 regions** file. The procedure should appear as follows:

```
pro  myregions, raARRAY,  decARRAY

nsources = n_elements(raARRAY)

openw, 1, "radec.tbl"
for  i = 0, nsources-1  do  begin
        printf, 1, raARRAY(i), decARRAY(i)
endfor
close, 1

make_regions, "radec.tbl",  inds=[0,1]
spawn, "mv  regions.reg  myregions.reg"

end
```

This *myregions* procedure creates a file listing the RA and Dec. of sources in Columns 0 and 1, respectively, and then makes use of the *make_regions* procedure that creates a ds9 regions file from such a file. Your ds9 regions file will be saved as "myregions.reg". Compile and run your *myregions* procedure, inputting arrays of RA and Dec. values for only sources detected with legitimate photometry in all JHK images:

```
IDL>  .run  myregions
IDL>  raARRAY = ra_J(indsJHK)
IDL>  decARRAY = dec_J(indsJHK)
IDL>  myregions, raARRAY, decARRAY
```

You should now be able to see that the regions file “myregions.reg” has been saved. Open this file in a text editor to view its contents and format.

Now, let’s visually display which sources were detected with legitimate photometry in all JHK images. Open the J image of B59-CONTROL in **ds9**. Adjust the grayscale of the image appropriately to make faint sources visible. Load the regions file by selecting the **Load Regions** option from the **Regions** menu. Once you select the “myregions.reg” file, you should see the sources identified with green circles. Maximize the display by making the ds9 window large, and then display the full image by selecting the **Zoom to Fit Frame** option from the **Zoom** menu. Save this image by selecting the **Save Image** option from the **File** menu. **Email this image to the instructors before leaving the lab today.**

Finally, referring to the plotting statements used in Lab 4, plot the (J-H) colors as a function of (H-K) colors for only the sources detected with legitimate photometry in all JHK images. This plot is known as a color-color diagram. Normally, this diagram will include transformed colors, but you should use instrumental colors, for the purpose of this lab. When creating this diagram, please:

- Plot (J-H) on the y-axis and (H-K) on the x-axis.
- Label the axes appropriately.
- Force the axes to plot the same ranges of values without excluding any of the data. For example, if you find that the (J-H) colors range from 0.90 mag to 2.20 mag and (H-K) colors range from -0.30 mag to 0.35 mag, then you might choose each axis to span from -0.50 mag to 2.50 mag.
- Use filled circles as symbols. These symbols may be defined with the following statement:

  ```
  usersym, cos(findgen(40)*2.*!pi/39.), sin(findgen(40)*2.*!pi/39.), /fill
  ```

  prior to the plot statement, and then setting psym=8 in the plot statement.

Save this diagram as a PostScript file, using portrait orientation instead of landscape, by embedding your plot statements as follows:

```
IDL>  set_plot, ‘ps’
IDL>  device, filename=’color-color-B59-CONTROL.ps’, /portrait

IDL> [your plot statements]

IDL>  device, /close
IDL>  set_plot, ‘x’
```

At the end of lab, turn in a printed copy of this plot.