Direct Imagining Exercise

Download the tar file using the Dropbox link I've shared with you. There you will find two papers describing the Angular Differential Imagining (ADI) the Locally Optimized Combination of Images (LOCI) methods. Both are standard methods for point-source function (PSF) subtraction to achieve high-contrast exoplanet detection with adaptive optics enabled cameras. Read both papers.

For this exercise you will be using a dataset obtained at Keck with the NIRC2 camera. The data consist of images of the HR8799 planetary system. Your goal is to locate at least 3 planets. Specific tasks are outlined below.

So that you may focus on the ADI and/or LOCI steps, the images have already been calibrated (e.g., flat fielding, dark subtraction and bad pixel corrections) and registered (i.e. the center of the star is located at the same pixel (x,y) location in each image). These are standard steps performed in basic imaging data reduction. Locating the center of a star in a saturated image (due to the exposure time and the brightness of the star) can be very challenging. Also, for your convenience, the rotation angle of each image (relative to North) has been extracted from the image headers and stored in a single file. East and west are flipped when looking up at the sky and, in this case, increasing angle is to the west.

The data files are:

- center_im.fits : contains an array of size (1224 x 1224 x 94). So, 94 images, each image has 1224 x 1224 pixels (spatial elements).
- median_unsat.fits : array (60 x 60), an image of the star, unsaturated.
- rotnth.fits : array with 94 elements. Each value is the image rotation angle, relative to north.

In IDL, you can read the files as follows:

```
IDL> rotnth = readfits('rotnth.fits')
IDL> im = readfits('center_im.fits')
IDL> unsat = readfits('median_unsat.fits')
```

To put North up in the image im(*,*,k), you can do, for example:

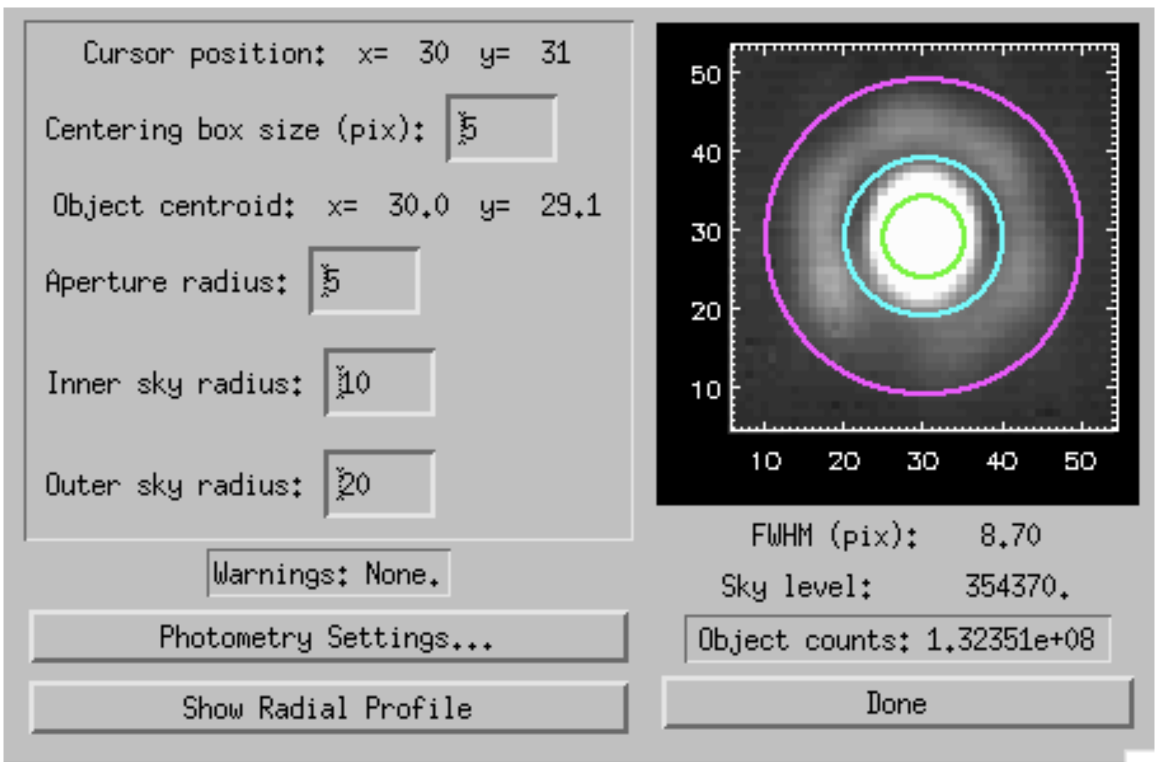
```
IDL> derot = rot(im(*,*,k),rotnth(k),1.,1224./2.,1224./2.,/piv,cub=-0.5)
```

Part 1: Derotate all images and stack them (using median). How many planets can you find? Estimate the contrast in the resulting median-combined image by injecting "fake planets" into each individual image and determine the minimum detectable brightness as a function of separation. Define "detectable" as signal-to-noise of 5, where the "noise" is measured at the same radial distance. You can either using Gaussians or the unsaturated stellar image (appropriately scaled) to represent the PSF of the fake planets.

Part 2: Implement ADI following the procedures in Marois et al. (2008).

Part 3: Estimate the contrast in final ADI processed image by again injecting fake planets into each individual image. How does this compare to what you found in step 1? Repeat this step with random 5-pixel offsets in the image centers. How are the planets affected by centering errors?

Note: You can use atv in IDL and the imexam tool to do basic photometry and to determine the centroids. A window that looks the follow will pop up. Note: the default aperture radii for the "sky" landed on the first Airy ring so increase them to avoid this. DS9 has similar functionality.



Part 4: Calculate the separations and planet/star brightness for each planet you. For this you will need the median_unsat.fits image. Use the same aperture size to calculate the counts for star and planet. For pixel scale see:

http://www2.keck.hawaii.edu/inst/nirc2/genspecs.html
(We are using the narrow camera)

Part 5: Devise a scheme for estimating the errors on both position and brightness of your planets.

Part 6: Try implementing LOCI using Lafreniere et al. (2007) and determine how the contrast improves. Can you find HR8799 e?