Hopefully by now, you've plotted up your spectrum of an M8.5 star and found its methane spectral index. (Hint: we don't expect M stars to have methane absorption at all – they are simply too hot for methane molecules to form in their atmospheres. What sort of methane spectral index does that imply?) Now you are ready to measure the methane spectral index for the companion brown dwarf, straight from the data.

1) The sky is very bright at ~1.6 um, where these data were taken. To try to remove this, the star and brown dwarf was moved to different parts of the detector during the observation (i.e. each of the 4 slices in the data cube). If we median over the data cube to create one final median image we can use this to subtract off the sky background. This requires a little bit of python wizardry. You'll want to do something like this:

```
f1_bgnd = np.median(f1.reshape((4,-1)), axis=1)
f1 = f1 - f1_bgnd[:,np.newaxis,np.newaxis]
```

(the first line takes the median along the correct axis, the second line subtracts it from the original image.)

2) After you've found the position of the primary star in each of the frames (hint: try changing the stretch in ds9 to really zoom in on the best position), you'll need to calculate the flux in an aperture around that position. You can use the r_theta function that is defined in the first cell to do so.

if you do:

```
r, t = r_theta(im, x, y)
```

this will return:

-- a 2d array r with the radial distance for each point in your image array relative to point x, y

-- a 2d array t with the angle theta for each point in your image array relative to point x, y

Like with the wavelengths in your spectrum, you can define a Boolean mask from this array to get only the flux in an aperture of your choice.

```
mask = (r < ap)
```

Then:

```
flux_star = np.sum(im*mask)
```

3) You can do something similar for the brown dwarf if you know its position as well. Its separation and position angle is given in the notebook, so with some basic trigonometry you can figure out its separation in x and y coordinates from the star. Remember that for astronomical images, north points up and east to the left. Angles are defined starting north and going east – i.e. anticlockwise from the y-axis. The

easiest way to check if you have the positions correct is to do the trigonometry and then see if the brown dwarf companion is where you expect it to be in the image!

4) To plot the images in python, here is some useful syntax:

```
f, axarr = plt.subplots(2, 2)
for x,y,axx,i in zip(f1_x, f1_y, axarr.flat, np.arange(4)):
   axx.imshow(box(f1[i,:,:], x, y, 20), vmin=0., vmax=1000.)
```

5) The last part of the notebook asks you to plot MSI for a variety of objects – you can get the relevant spectra from the same website as before. The final part of the notebook should be fairly similar to plotting the spectrum in the very first part of the notebook.