Tutorial18 - Astronomical Imaging

Open a new jupyter notebook and call it "`Tutorial_18_{your identikey}`". In the first cell of your notebook, please type your name and the name of this tutorial. '

```
In [ ]: import matplotlib.pyplot as plt
        import numpy as np
        %matplotlib inline
```

1 think+code: astronomical images

The data you'll be using in this tutorial are stored in two FITS files. Use the following commands to load those files into 2D numpy arrays. We'll talk more later about the details of using the `astropy` package for reading and writing FITS images.

```
In [ ]: from astropy.io import fits

        # set the directory where the files are located
        path = '/home/jdarling/astr2600/'

        # we'll cover the [0].data at the end later
        img1 = fits.open(path+'stars1.fits')[0].data
        img2 = fits.open(path+'stars2.fits')[0].data
```

The variables `img1` and `img2` are 256x256 images of the same patch of sky taken 30 minutes apart. Each pixel is 0.4 arcseconds on a side. Let's `imshow` those two images. To make more of the faint stars show up, we'll show the logarithm of the intensity values, instead of the linear values themselves.

```
In [ ]: for image in [img1, img2]:
            plt.imshow(np.log(image), cmap='gray')
            plt.colorbar()
            plt.show()
```

Notice anything different about them? *Spoiler alert:* there is an asteroid in these images, but it's going to be hard to see!

2 think+pair+code: find the asteroid

Respond to the following in as many code cells as you like. Work with your neighbor(s) to discuss the procedure and results.

If the asteroid is moving at velocity v_a perpendicular to the line of sight and is at a distance of D from Earth, then the apparent shift in its position on the sky over the time interval Δt is

$$\tan\theta \approx \theta(\text{radians}) \approx \frac{v_a(\text{m/s})\Delta t(\text{s})}{D(\text{m})}$$

Assume the asteroid is at a distance of 1 AU $\simeq 1.5\times10^{11}$ m. Recall that there are 206,265 arcseconds in one radian.

Your task is to determine the asteroid's velocity through space based on the shift in its position between two images.

- Visually identify the asteroid in the field. Think about how might you efficiently do this. Remember that the images are simply arrays of numbers and that you want to find what has *changed* between the two images.
- Determine the starting and ending position of the asteroid in approximate pixel coordinates (row and column). You can do this visually, or if you want, use code to identify the centers.
- Compute the separation between the start and end point, first in pixels, then converted to an angle on the sky (θ).
- Finally, use the angular separation along with the distance to the asteroid and time between exposures to find the asteroid's velocity. Quote this in km/s. Does your number make sense?

When finished, save your notebook and upload it to D2L in the "Tutorial 18" folder.