Lab 8
The Proper Motion of Barnard's Star

1 Introduction

The *proper motion* of an astronomical source is the component of its motion along the plane of the sky. In constrast, motion towards or away from us is called *radial velocity*, usually measured by the Doppler effect. Detecting an object's proper motion is straightforward. You determine its position, wait a few months or years, and then determine its position again to see how far the object has moved. We usually report an object's proper motion as an angular velocity in arcsec per year, rather than reporting a physical speed, because for the latter one needs to know the distance to the object. As you know, it is often difficult to obtain distance information precisely.

Astronomical sources are so far away that their proper motions are extremely small, usually being measured in milliarcseconds per year. (Proper motions can be larger of course for sources within the solar system.) Ideally, proper motion is measured by waiting an extremely long time between position measurements. The longer the time baseline between measurements, the farther the object will have moved, making it easier to measure the displacement with high accuracy. But in practice it's often not feasible to wait years or decades. Your career will pass by, while you wait. Instead, one must try to measure the position of an object as precisely as possible at two epochs separated by only a few months.

You took images at the Nickel telescope of Barnard's Star, the star with the highest proper motion in the entire night sky. Your goals for this lab are simple:

- Measure the proper motion of Barnard's Star.
- Estimate the uncertainty on your result.

1.1 Schedule

You have *one* week to complete this lab. Reports are due Tuesday, December 4^{th} at the end of that class. This is the last lab of the semester.

2 Data

Our class took severeal images of Barnard's Star, the best being from November 11^{th}. To provide you with a long time baseline, we asked Berkeley astronomer, Dr. Weidong Li, to obtain Nickel images of Barnard's Star before the semester started (!) on the night of August

5^{th}. Barnard's Star is the brightest star in all of the various images. We have images in both V and I bands.

The relevant files have been collected together in the directory `/home/ay120/ucolick/promo_lab` on the `ugastro` cluster. As usual, there is a file called `logsheet.txt` describing the various files in that directory. Note that Weidong's images are inverted vertically from our images. Compensate for this in whatever way you see fit.

3 Preparation

Unsurprisingly, Barnard's Star is a very well-characterized celestial source. Look up its proper motion. (Hint: the SIMBAD database contains this information, split up into motion in the RA and DEC directions.) Given our time baseline, what angular distance do you expected Barnard's Star to have moved from our first set of observations to the second? The angular size of an individual pixel on the Nickel Direct Imaging Camera is 0.368 arcsec/pixel. How many pixels do you expect Barnard's star to have moved between our two epochs of observations?

4 Analysis

Measure the proper motion of Barnard's Star, using any technique you wish, using some or all of the data we have provided. For example, you may measure the x and y positions of Barnard's star and a handful of reference stars. The reference stars in the images taken in August and November will be displaced by a nearly constant amount, Δx and Δy, due to different pointing of the telescope. Since each ref star should yield the same value of Δx and Δy, the scatter (σ) in their Δ's tells you the uncertainty in the measurements. Barnard's star will have a different Δx and Δy than the reference stars, due to its proper motion.

Describe your technique to the usual level of detail found in scientific papers, *i.e.*, so that someone reading your report could reproduce your work. Explain why your chosen technique will measure the motion of the star despite possible instrumental changes (such as a shift in the position of the CCD or quality of focus) over the course of several months. Report your answer (and uncertainty) in the customary units of milliarcseconds per year. Compare your result to the known proper motion of Barnard's Star.

(If you're feeling adventurous, feel free to look through the other logsheets in the `ucolick` directory for more data that may be helpful to you.)

5 Extra Credit

The astronomer Peter Van de Kamp reported in 1969 that Barnard's star has a Jupiter-mass planet with 1.6 times the mass of Jupiter with an orbital period, P=24 years. For extra credit, calculate the angular displacement (in milliarcsec) of the star caused by its motion about the common center of mass with this supposed planet. The distance to Barnard's star is 1.82 pc (5.95 light years), and the mass of Barnard's star is 0.3 solar masses. (You might use kepler's 3rd law to determine the samimajor axis of the orbit of the planet, which in turn implies the angular displacement of the star caused by the planet.)