

Astro 121, Spring 2014
Week 6 (February 27)

Topic: Photometry

Break: Catherine (the following week, Eric, for the midterm)

Topics: This week, we'll take on photometry, or the quantitative measurement of starlight.

Reading:

As always, you don't have to read all of these sources; but all have the potential to be helpful, so you should use them as resources as needed. Definitely read the Chromey material, and then use others as needed.

- Chromey, *To Measure the Sky*, Ch. 9 (skim earlier parts, concentrate on Sec. 9.5), and Ch. 10 through Section 10.4. I find most of the discussion in Chapter 9 a little too abstract for my taste, but the discussion in Sec. 9.5 is important.
- *Handbook of CCD Astronomy*, Howell. Chapter 5 through Sec. 5.4.
- *The Handbook of Astronomical Image Processing*, Berry and Burnell. Chapter 8.
- Notes on photometry by Steve Majewski at the University of Virginia, http://www.astro.virginia.edu/class/majewski/astr313/lectures/photometry/photometry_mags.html There are four pages on photometry; this first one should be mostly review, so you can skim it quickly, then follow the links at the bottom of the page to subsequent pages.

Problems

1. You observe the unusual stellar object BU Boo with a photon-counting photometer through a V filter on two nights, together with the sky and a nearby standard star ($V = 10.3$). The total counts in each integration, and the total integration time in seconds were:

	Night 1		Night 2	
	Counts	Time	Counts	Time
BU Boo + Sky	1600	100	1800	200
Sky	900	100	800	200
Standard + Sky	110000	10	100000	10

Calculate the V magnitude of BU Boo on the two nights, the magnitude difference, and its uncertainty. What is the probability that BU Boo is variable? (You may find it useful to set up a spreadsheet to do some of these calculations – then it's easy to tweak your procedure without redoing everything.)

2. The shape of stellar images on a given CCD frame is set by a combination of the atmospheric conditions at the time of observation and the optical properties of the telescope and camera. This shape is called the *point spread function*, or PSF, of the image. The PSF is typically fairly well-fit by a Gaussian, and in a given image each star has the same PSF (i.e. same σ in the Gaussian) but with different peak amplitudes for stars of different brightness. Show mathematically that a

circular aperture of any fixed radius will encompass the same *percentage* of the total light from stars of different brightnesses in a given image. This fact is critical for allowing us to do aperture photometry.

3. Chromey, problem 9.7 (about the exposure time necessary for a given S/N under different conditions).
4. Chromey, problem 10.5 (about two stars of the same V mag, observed with a CCD).
5. Chromey problem 10.7 (about Johnson and SDSS filters).
6. This week in seminar we encountered a puzzle, in that no one came up with a value for the CCD gain that was really close at all to the manufacturer's spec. I trust that you all checked your calculations, so I suspect that the problem lies in the data you were using. So, please do it again. (This is part of science! And a part that we maybe don't practice in classes quite as much as we ought to. If something doesn't work the first time, you try to figure out what went wrong, and try it again.) This time, you don't need to turn in as detailed a writeup of what you did, but *do* write enough explanation so I can see what you've done, and which data you used. Three things I think you should try that are different from what you did before:
 - a. Use two flats that have about the same amount of signal in them. You don't need to take new flats. Just poke around in /tel_data – there is a *lot* of data there. In the subdirectories for most nights, you will find a directory named AutoFlat, and within that, some flats. Use imstat to find two with about the same amount of signal, taken in the r', i', or R filter.
 - b. Don't use the whole flat image for your statistics – just the central part, which doesn't have as much of the edge falloff. See last week's assignment for some notes on how to tell IRAF to only pay attention to a subset of an image.
 - c. Plot histograms of your images (or image subsections). Make sure that they look at least approximately Gaussian. (Remember, a Poisson distribution with a large mean will approach a Gaussian.) Use imhist rather than imexam – it gives you more control. (To get the best look at the histograms to judge their shape, you probably want to use a linear rather than logarithmic y axis, and to restrict the x axis range if there are just a few outlying pixels that are stretching the range out.)

OK? Keep at your analysis until you get a gain greater than one, and talk to me if you're stuck.

Data analysis:

To give you some direct experience with photometry, we'll do some photometric measurements of our own with the van de Kamp telescope.

For this assignment we'll do some time-series photometry (e.g. of an eclipsing binary, an RR Lyrae variable star, or extrasolar planet) in a single filter. Another sort of target would be OK, too, but talk to me about it first. I think an RR Lyrae would be one of your best choices, due to the relatively short period and relatively large amplitude. With our telescope, differential photometry of any star that is 13th magnitude or brighter (in V or R) will have no problem detecting variations of 0.1 mag or less quite easily, and can go to 10x smaller amplitudes with careful analysis.

Some resources for finding targets:

- You can go to VizieR and search for catalogues of eclipsing binaries or RR Lyraes. Then you can narrow down by RA/Dec, period (shorter is probably better – shoot for a period less than a day if it's an RR Lyrae, or try to observe an eclipse if it's an eclipsing binary), etc.
- I have put together a tool that lists upcoming extrasolar planet transits, at <http://astro.swarthmore.edu/transits.cgi>. There you can see when there are upcoming transits. Note that these are much smaller-depth events than a typical eclipsing binary, and thus harder to detect. You may want to stick with an easier target for your first attempt... But if you do choose this, go for a transit depth of at least 10 milli-magnitudes (i.e. 0.010 mag).

After break, you will do a more formal writeup of this project. For this coming seminar (February 27), I would like you to turn in the following:

- What target(s) you observed;
- What filter(s) you used, and why;
- The coordinates of the target(s).
- A finding chart, i.e. an image of the field that is roughly 30' x 30'.
- A light curve (magnitude or flux vs. time) for your target.
- An explanation of how you did the photometry (aperture size, sky annulus, comparison stars, etc.). I'm not looking for a detailed cookbook of software-related commands here, but rather a summary of the relevant parameters that governed what magnitudes actually came out. One way to look at it is that you should give enough information that someone could reproduce your results if they were using the your images but *different* software. In general, that's what you need to strive for in scientific research writing – what information is necessary for someone to reproduce your results?