ASTR 306/406 - HW #2

1. Plate Scale and CCDs (15 points; courtesy Paul Harding)

I want to get photometry for stars in the globular cluster M13 (which has an angular diameter of about 10 arcmin) using the prime focus camera on a new telescope at Kitt Peak (where typical seeing is about 1 arcsec). When I turn up for my observing run, I am asked what CCD I wish to use. I don't want to let on that I have not read the observers manual, so a quick look at the telescope tells me the distance from the primary mirror to the focal plane is 40 feet. I also want to make sure that the whole globular cluster fits in the field of view. The choice is between a CCD A, which has 3000x3000 pixels with each pixel 9x9 microns, and CCD B which has 2048x2048 pixels with each pixel 24x24 microns. Which CCD would you pick and why?

2. Filters (15 points for ASTR 306; 25 points for ASTR 406)

The file http://burro.case.edu/Academics/Astr306/HW/HW2/kp1422.dat contains a filter tracing (transmission percentage as a function of wavelength in Angstroms) for one of the Kitt Peak R band filters. From this tracing, calculate the filter's central wavelength and the width of the "equivalent square filter." Plot the filter transmission function and overplot the transmission function for the equivalent square filter.

Helpful tip: the file has some transmission values < 0, which are obviously unphysical and you will want to set to zero. An easy way to zero out negative values in a numpy array is to say x[x<0]=0.

ASTR406: If an object has a spectrum given by $f_\lambda = f_0(\lambda/5450\text{Å})^n$, where $f_0 = 3.63 \times 10^{-13}$ erg/s/cm^2/Å. For this filter, and for the equivalent square filter, calculate its R band magnitude (m_R) in the STMAG system for $n = -2$ (a blue spectrum) and $n = +2$ (a red spectrum). Comment on the differences between the numbers for the two filters with the different values of n — that is, why do you get different values depending on whether you use the real filter tracing or the equivalent square filter, and why do the differences depend on the spectrum of the object?

3. Charge Transfer Efficiency (10 points)

Charge Transfer Efficiency (CTE) describes the fraction of electrons successfully moved during a single pixel shift during CCD readout. That is, a CTE of 0.99 means that 1 out of every 100 electrons is left behind during a shift. If you have a 4096x4096 pixel CCD and want to make sure that at least 99% of the electrons held in each pixel are moved successfully into the serial readout register (meaning they don't get left behind in a trailing pixel), how good does the CTE need to be for your CCD?

4. Gaussian Profiles (15 points)

Astronomers often use a Gaussian model to approximate the radial profile of a star on an image: $I(r) = I_0 e^{-r^2/2\sigma^2}$. We also characterize the seeing quality in terms of the "full width at half max" (FWHM) of the profile.

Work out the relationship between FWHM and σ for a Gaussian profile. If the seeing is 1.2″ FWHM, what is the value for σ (in arcsec)?

Work out an analytic expression for the total enclosed light as a function of radius (also known as a "curve of growth"). That is, given sigma (or FWHM), what fraction of the total light from a star do you expect inside a circular aperture of radius r? What is the radius which contains half the light? 80% of the light (a common "spec" by which optical designs are rated)? 90% of the light? 99% of the light? If you measure a seeing value of 1.2″ FWHM, make a plot of enclosed light as a function of radius for a star (hint: it should go from 0% at r=0 to 100% at r=big).

Finally, express your curve of growth in terms of an "aperture correction" in magnitudes. By an aperture correction we mean if you measure the magnitude of a star using an aperture of radius r, what correction do you apply to turn that "aperture magnitude" into the true total apparent magnitude of the star?

5. Sky Background (15 points)

You are doing photometry of stars using circular apertures. The typical seeing is not great, about 1.5 arcsec FWHM, and the night sky has a surface brightness of μ_R = 20.8 mag/arcsec^2. Plot the fraction of total light in the aperture that comes from a star of magnitude m_R=15 as a function of aperture radius, with aperture radii going from $r = 0 - 5$ arcsec. Overplot similar curves for stars of magnitude m_R=16, 17, and 18. Why would using big apertures be good for doing photometry? Why would they be bad?

6. AB magnitudes (ASTR 406 only; 15 points)

In the AB magnitude system, in any filter the magnitude zeropoints are given by $m_{AB} = -2.5\log(f_\nu) - 48.6$. From this, calculate the flux zeropoint in Janskys (Jy); this is, what is the flux in Jy for an $m_{AB} = 0$ star?

In the Vega system, magnitudes are referenced to the brightness of Vega is each filter, so each filter has a different zeropoint (the mean flux density of Vega in that filter). For example, in Johnson B the zeropoint is 4260 Jy, and in Johnson V the zeropoint is 3640 Jy. If a solar-type star has $B - V = 0.65$ in the Vega system, what is its $B - V$ color in the AB system?

If a star has an R band AB magnitude of $m_{R,AB} = 12.5$ and lies at a distance of 2.3 kpc, what is its total R band luminosity (in erg/s)? (Assume no dust extinction!)