A590 – Problem Set #1

Due: September 9, 2004

Please work on this problem set by yourself. It will be used as part of your grade.

1) Suppose a filter with a square-wave (box-car) profile is centered at νᵣ with width ∆ν. You mistakenly choose a frequency

\[ \nu_o = \nu_r + \xi \Delta \nu \]

as the effective wavelength of your filter where \( \xi \) is the fractional amount you are off compared to the bandpass. Assume source fluxes have the form:

\[ f_\nu = f_r (\nu/\nu_r)^\alpha \]

Initial photometric calibration is done assume \( \alpha = -1 \) for all sources. Let us call this flux \( f_o \) at wavelength \( \nu_o \).

a) Derive expressions for the actual flux in terms \( f_o \) for sources that have \( \alpha = 0, 1, \) and 2.

Simplify your expressions assuming \( \Delta \nu / \nu_r \ll 1 \).

b) What happens as \( \xi \) gets larger?

c) What happens as \( \xi \) goes to zero?

2) The signal-to-noise ratio for many optical and infrared imaging systems can be written as

\[ S/N = \frac{N_s t}{\sqrt{N_s t + pN_B t + pR_N^2}} \]

where \( N_s \) is the number of photons per second detected from the source (over the area integrated), \( N_B \) is the number of background photons detected per pixel, \( p \) is the number of pixels used to extract the source, and \( R_N \) is the read noise of the device, and \( t \) is the integration time. This expression is valid because photon noise follows Poisson statistics in this regime and the noises add in quadrature.

Let us look at the Wide-field Infrared Camera (WIRC) located at Palomar. WIRC images to 0.2487 arcsec/pix, has a read noise of ~ 12 electrons, and has a gain of 5.467 e-/DN. The background at Ks is approximately 400 DN/sec/pix and the response is about 11 DN/sec for a 20th magnitude star.

It is found that WIRC achieves S/N = 5 on a Ks = 20.6 source in 3600 seconds using a 2 arcseconds diameter aperture to extract the source

a) Suppose you wish to observe a galaxy that is 2 x 1 arcminutes across. What integrated Ks magnitude must the galaxy have to achieve S/N = 10 in one hour?

b) For the same size galaxy, what Ks magnitude yields S/N = 10 in 4 hours?
3) Assume that the apparent bolometric magnitude of the Sun is -26.82.
   a) Determine the zero point (luminosity at zero magnitude) of the bolometric magnitude scale.

4) Suppose a galaxy has an episode of star formation started $10^9$ years ago and has been proceeding at a rate of $2\, M_{\text{Sun}}/\text{yr}$ since then.
   a) What population of stars would be present today, e.g. $dn(m)/dm$ vs. $m$?
   b) Estimate the total accumulated mass in stars.
   c) Estimate the current luminosity of the galaxy.

Assume that only stars with $M > 0.5\, M_{\text{Sun}}$ are produced. Be sure to state any assumptions you make in solving the problem.