

Observational Astrophysics and Data Analysis

Problems: Set 3

1. What is the expected value of the Fried parameter at a wavelength of 550 nm if the observed seeing is 0.6 arcsec? What is the corresponding value of r_0 at 1.6 microns in the infrared assuming Kolmogorov turbulence? For a 10m telescope, how many sub-apertures does this imply for infrared observations?
2. Which has a greater energy flux, $10 \text{ photons cm}^{-2} \text{ s}^{-1}$ at 10 \AA or $10^5 \text{ photons cm}^{-2} \text{ s}^{-1}$ at 5000 \AA ?
3. A star has a measured I-band magnitude of 22.0. How many photons per second are detected from this star by the William Herschel Telescope on La Palma (4.2 m diameter), assuming that the telescope and imaging optics have a throughput of 60%, the detector has a quantum efficiency of 80%, and the sky has a brightness of 20 magnitudes per square arcsecond. You can use the following information, for Vega, which has an I-band magnitude of $m_I = 0.0$:

Filter	λ_{eff} (nm)	$\Delta\lambda$ (nm)	F ($\text{W m}^{-2} \text{ nm}^{-1}$)
I	800	240	0.83×10^{-11}

(Advanced)

Estimate the exposure time required to detect the star at a signal-to-noise ratio of 20.

This star is unlikely to be “saturated” on a modern CCD detector, fortunately.

What is the saturation limit (in electrons) of a modern CCD’s 16-bit analogue-to-digital (A-to-D) converter with gain = 4? What happens to your images when saturation is reached?

Suppose that the noise in your measurements is entirely Poissonian. What would the signal-to-noise ratio be at 40% of the full-well level of such a 16-bit CCD with gain = 4? Assume full linearity and that we are signal limited.

4. What fraction of the photons in the V band of a bright star would be absorbed by the atmosphere if one were to observe the star at an airmass of 2.5, and at the zenith (airmass = 1)? Assume that the atmospheric extinction $k(\lambda)$ in the V band is $0.15 \text{ mag airmass}^{-1}$.
5. In making differential observations, explain why you should know the colors of the variable and comparison stars.
6. Find the resolving power of a grating needed to separate the sodium spectral lines D_1 and D_2 , which are at 5895.944 \AA and 5889.977 \AA . How many lines must the grating have to achieve this resolution in second order?