Observational Astronomy

Problems Set 4: Solutions

1. What is the expected value of the Fried parameter at a wavelength of 5500 Å 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?
   Solution:
   From Lecture 4, slide 181: Full Width Half Maximum of the point spread function due to atmospheric turbulence (the seeing) is given by $\beta = 0.98\ \lambda / r_0$.
   Then r_0 = 18.5 cm for 5500 Å and 53.9 cm for 1.6 microns.

2. Which has a greater energy flux, 10 photons cm^{-2} s^{-1} at 10 Å or 10^5 photons cm^{-2} s^{-1} at 5000 Å?
   Answer: 10^5 photons cm^{-2} s^{-1} at 5000 Å is larger ($3.97\times10^{-7} > 1.99\times10^{-7}$ erg cm^{-2} s^{-1})

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%, the sky has a brightness of 20 magnitudes per square arcsec, and the seeing is 1 arcsec . Estimate the exposure time required to detect the star at a signal-to-noise ratio of 20.
   Solution:
   From Lecture 10, slide 412:
   $N_{star} = \eta\ \varepsilon_{atm}\ \varepsilon_{tel}\ \varepsilon_{filt}\ \varepsilon_{win}\ \varepsilon_{geom}\ \phi\ \Delta\lambda\ A\ t$
   $\eta=0.8$
   $\varepsilon_{atm}\ \varepsilon_{tel}\ \varepsilon_{filt}\ \varepsilon_{win} = 0.6$
   $\Delta\lambda=1500\times10^{-8}$ cm
   $A=\pi R^2=138544$ cm^2
   The WHT telescope is of a Ritchey Chretien Cassegrain system, it has a secondary mirror with the diameter 1.0 m. Then from Lecture 10, slide 411,
   $\varepsilon_{geom}=0.94$
   $\phi=F/h\nu=F\lambda/hc= F_0\lambda/hc\times2.512^{-m}=7.18\times10^{-7}$photons s^{-1} cm^{-2} $Å^{-1}$
   N_{star} = 67 photons s^{-1}
   N_{sky} = 425 photons s^{-1} from square arcsec

   $$\frac{S}{N} = \frac{N_{star}t}{\sqrt{N_{star}t+2N_{sky}t}}$$ → t=82 sec (if $\varepsilon_{geom}=1$, then t=76 sec)

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(λ) in the V band is 0.15 mag $airmass^{-1}$.
   Answer: Lecture 11, Slide 444: 13% absorbed at the zenith and 29% at the airmass of 2.5.

5. In making differential observations, explain why you should know the colors of the variable and comparison stars.
   Short answer (but you had to elaborate it!): There is a colour term in the accurate formula, caused by the variation in spectral profile of the stars and the filter response over the passband (Slides 447-448, Lecture 11).

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 Å and 5889.977 Å. How many lines must the grating have to achieve this resolution in second order?

   Answer: $R = \lambda / \delta\lambda = nN$ (Lecture 12, slide 475) → $R \approx 988$ and $N = 494$