Stars and Galaxies

Observational Techniques Homework Set 3

1) Using the reflection grating equation of a spectrograph, calculate the difference in angle for light reflected from a grating for two wavelengths of 550 nm and 560 nm. Assume the grating is used in the first order, the angle of incidence is 45°, and the ruling density is 1000 lines / mm. [2 marks]

2) The resolution of a spectrograph, R, is given by:

$$R = \frac{n\rho\lambda W}{\chi D_{\mathrm{T}}},$$

where n is the diffraction order, ρ is the ruling density of the grating, λ is the wavelength, W is the size of the grating, χ is the angular size of the target star and D_{T} is the size of the telescope.

Which three parameters can the designer change to improve this resolution for that particular telescope? [1 marks]

Assuming diffraction limited performance of both telescopes, how will the resolution of a particular spectrograph change if it is moved from a 4 m to 8 m telescope? [1 mark]

3). Can the human eye detect a single photon? [6 marks]

[Hint: The figure below shows a schematic of the human eye (*Left*), and a highly magnified image of the retina (*Right*). The human eye comprises a lens which has a diameter of 9 mm which has a focal length of 1.7cm, and detects radiation betwen 390 nm and 700 nm, but is most sensitive at $\lambda = 550$ nm (which unsurprisingly is where the Sun spectrum also peaks). 10% of the photons that are incident at the front of the eye make it to the retina (i.e. the eye has an efficiency of 10%).

The "detector" for the human eye is the retina, which comprises a grid of cells which detect light and dark (the rods), and colour (the cones). The rods have much more sensitivity than the cones (which is why it is hard to see colour in low-light). Each rod cell has a diameter of 2.0μm.

Other things you might want to think about to answer the question: What is the refresh rate of your television? What is the magnitude of the faintest star that a human eye can see on a dark site? Note also that the flux density of a 0-magnitude star is $f_0 = 3.9 \times 10^{-8}\,\mathrm{W\,m^{-2}\,\mu m^{-1}}$.]