Stars and Galaxies

Observational Techniques Workshop 3

1) What are the four main components of a spectrograph?

2) State the resolving power, R, in terms of wavelength. An astronomical slit spectrograph has a resolving power of $R = 7000$. What is the smallest wavelength difference that can be discerned at a wavelength of 700 nm?

3) The spectrum of a nearby star peaks at a wavelength of 3000 Å. It has a parallax of 379 milliarcseconds and a V-band magnitude of $V = -1.5$. Sketch a HR diagram and place the star on it. What type of star is it? [The Sun has a V-band absolute magnitude of 4.8]

4) Write down the reflection grating equation of a spectrograph, and define the symbols. The sodium D line is a doublet of wavelengths 589.0 nm and 589.6 nm. A grating produces a first order spectrum where these two lines are diffracted at angles of 42.69° and 42.78° (with respect to the grating normal). Calculate the ruling density of the grating (in units of lines mm^{-1}).

5) The two Keck telescopes are each 10 m across and separated by 85 meters. What is the maximum distance from Earth that an extra-solar planet will be resolved if observed with *(i)* a single telescope; *(ii)* both telescopes when used as an interferometer? Assume the extra-solar planet is located 1 AU from the star ($1\,\mathrm{AU} = 1.50 \times 10^{11}$ m).

6) (i) Write down two properties of a star or galaxy that can be measured with a spectrograph.

(ii) The resolving power, R, of a slit spectrograph that employs a diffraction grating is given by $R = m\rho\lambda W/(\chi D_T)$. Define all the terms in this expression for R.

(iii) For a spectrograph equipped with a reflection grating of length 10.4 cm with input angle $\alpha = 20°$ and output angle $\beta = 15°$, find the spectrograph's resolving power if used on an 8-m telescope with a slit width of 0.5 arcsec.

(iv) Calculate the spectral resolution at a wavelength of 500 nm if the telescope is put in space.

7) [from 2013 June Exam]

An astronomical slit spectrograph has a resolving power of $R = 7000$. What is the smallest wavelength difference that can be discerned at a wavelength of 700 nm? [3 marks]

The same spectrograph is used to observe an active galaxy nuclear emission line with flux 1×10^{-20} W m^{-2}. What is the total power that reaches the spectrograph detector when it is used on a telescope with a 6-m diameter mirror? You may assume that the telescope and spectrograph combination have 100% quantum efficiency. [4 marks]

If the emission line is just contained within a single pixel on the spectrograph CCD detector, what is the signal-noise ratio (S/N) of the measurement of the emission line strength in a $t = 1000$ s exposure if the sky flux is 10 times higher than the total emission line flux? You may assume that the dark noise is negligible and that the read-out noise is ±5 electrons per pixel. [6 marks]

Is the S/N of the observation approximately sky-noise or read-out noise limited? [2 marks]

If the slit width doubles what is the new resolving power, R, of the spectrograph? [2 marks]

What is the new S/N of the measured emission line strength? [3 marks]