Stars and Galaxies

Observational Techniques Workshop 2

Warm-up Question 1

1) A star with V-band magnitude of $V = 23$ mag is measured with a CCD mounted on a 4-m telescope to give S / N = 10 in a certain exposure time in 1 arcsec FWHM seeing. Assume throughout that all observations are sky noise limited.

(a) What would the S/N have been for a $V = 25.5$ mag star under the same conditions?

(b) If the sky brightness had doubled due to moonlight, what S / N would result?

(c) If the seeing had been 0.5 arcsec FWHM what S / N would have been measured?

(d) What S / N for the star would have been measured by the same CCD mounted on an 8-m telescope in the same conditions and with the same exposure time?

(e) If the 4-m and 8-m telescopes were observing from above the atmosphere, by what factor would the 4-m telescope's exposure have to be increased relative to the 8-m exposure to ensure the same S / N?

Long Question #1 from June 2010

2) Determine the diffraction limit performance in arcseconds for a 1 meter diameter telescope operating at 20μm. [3 marks]

What is the diffraction limit for a 10 m telescope operating at the same wavelength? [1 mark]

The two telescopes are equipped with imaging cameras at 20μm with a square field of field of 20 arcminutes across.

For the two telescopes, determine the exposure time required to detect a source at a signal to noise ratio of 5 that has a magnitude of 24.0 at 20μm, assuming that the sky background is 20.0 mag per square arcsecond, the seeing is 0.5 arcseconds, the zeropoint for the 1m telescope is 15.5 mag and for the 10 m is 20.5 mag. [Hint: ensure that you take the diffraction limit of the images into account when determining the background contribution. Also the dark current and read noise contributions to the background are negligible.] [7 marks]

Long Question #2 from June 2012

Write down the major sources of statistical error in a CCD measurement of a star magnitude. [4 marks]

Which errors are usually governed by Poisson statistics and which are governed by Gaussian statistics? [2 marks]

For Poisson noise, if a process produces an average of N counts what will be the standard deviation? [1 mark]

Write down the general equation for the signal-to-noise (S/N) of a star's flux, f, measured using a CCD detector in a set exposure time, t. Include all the above four sources of noise. [2 marks]

ATLAS is a new CCD imaging survey aiming to reach the same depth as the previous SDSS survey. Both survey telescopes and instruments are identical except that the ATLAS CCD pixels are two times smaller in each of their linear dimensions. Relative to SDSS, what ATLAS exposure time will be required to reach the same S/N as SDSS in a passband where the observations are purely read-out noise limited? Assume that the star flux is completely contained in just one pixel for SDSS and 4 pixels for ATLAS. [4 marks]

In another passband, the sky noise is more significant relative to the readout noise. The readout noise is ± 2.5 ADU for both SDSS and ATLAS CCDs and the sky background is 50 ADU in an SDSS pixel in a set exposure time. If the star flux is now assumed small compared to the sky background, how much fainter a star magnitude can be observed to the same S/N limit in the same exposure time? Assume the same observing conditions for ATLAS and SDSS, a gain of 2 electrons/ADU and zero dark current for both ATLAS and SDSS CCDs and that the star flux is completely contained in one SDSS pixel and 4 ATLAS pixels. [6 marks]