Exercises Astronomical Observing Techniques, Set 7

Exercise 1

a) A star is imaged using a CCD with a read out noise (RON) of $7e^-$, assuming that 1 photon corresponds to 1 e^-. The CCD has a pixel size of 0.25 arcsec and a quantum efficiency of 80%. The flux from the star, integrated over the entrance aperture, is 1 photon s^{-1}, the background flux is 100 photons $arcsec^{-2}$ s^{-1}. The seeing is 0.5 arcsec: you may assume that all the light detected from the star falls within a circle of $0.5''$ in diameter. Determine the exposure time needed to reach a signal to noise ratio (SNR) of 5 for the star.

b) Explain why a low RON is important if we want to achieve a high SNR with a short exposure time. State also why this is less of an issue for long exposure times.

Exercise 2

The bandgap of an intrinsic silicon photo-conductor is 1.11 eV.

a) Calculate the cut-off wavelength in μm.

b) How can you limit the bandpass of a detector system on the high energy (blue) side?

Exercise 3

Now we consider a single-pixel Si:As BIB detector, which is illuminated by a constant photon stream of 1,000,000 photons/s.

a) What is the resulting photo-current in Ampere that we would measure when we apply the right bias voltage? For simplicity we assume that the photo-conductive gain G = 0.5 and that the quantum efficiency is only reduced by reflection from the surface. (The refractive index of Si is 3.4 and the reflectivity is generally calculated by $R = ((n_0 - n_1)/(n_0 + n_1))^2$ for two materials with refractive indices n_0 and n_1). Is a pre-amplifier necessary?

b) For this detector we calculate now the main noise components at T=300K. What are the G-R noise-current if we assume an integration time of 1 second, and the Johnson noise-current if we assume a read-out time of 10millisecond, a resistance of R=1 GΩ and an operating temperature of 30K?

c) What is the dominant noise component and how could the performance be improved?