# PHY517 / AST443: Observational Techniques

## Homework 3

1. Complete the homework assignments in Tutorial 4.

2. The Poisson distribution describes the probability to observe $x$ events during a certain measurement interval, given a mean rate $\mu$:

$$P_{\mathrm{P}}(x|\mu) = \frac{\mu^x}{x!} e^{-\mu}$$

Note that $x$ has to be a positive integer. Examples of where the Poisson distribution applies are counting experiments. In optical astronomy, we often *count* the number of electrons registered in the CCD due to incoming photons from a celestial object. The Poisson distribution is asymmetric for low rates $\mu \lesssim 10$, and becomes the Gaussian distribution for high rates $\mu \gg 1$.

   (a) Show that the mean of the Poisson distribution is $\mu$. [1]

   (b) Show that the variance of the Poisson distribution is $\mu$.

   (c) Plot (on a single panel) the Poisson distribution for rates of $\mu = 1, 2, 4, 10$.

   (d) For $\mu = 30$, plot the Poisson distribution, as well as a Gaussian distribution of mean $\mu = 30$. What do you need to set the standard deviation of the Gaussian to?

   (e) You measured $N = 10,000$ electrons from a star. What is the uncertainty on this measurement?

3. For the following, consider the CCD sensor in our STL-1001E camera. When necessary, look up the relevant properties on its spec sheet.

   (a) How many pixels would you expect to fall outside the $1\sigma$ interval for a random Gaussian process? How many for the $2\sigma$, $3\sigma$, $4\sigma$, $5\sigma$ intervals? You can look up the corresponding integrals of the normal distribution at `https://en.wikipedia.org/wiki/68%E2%80%9395%E2%80%9399.7_rule`.

   (b) The read noise of the camera is fixed - it is not a counting process, and thus does not depend on exposure time or number of counts. It quantifies the standard deviation of a roughly Gaussian distribution of pixel values around the bias level in the absence of any signal. For the following, assume the camera is operated at 0°C.

[1] Hint: the following series identity is useful for Exercise (1):

$$\sum_{k=0}^{\infty} \frac{\lambda^k}{k!} = e^{\lambda}$$

i. How large does the background sky level need to be (in counts per pixel), so that statistical noise from the background sky dominates over the read noise?

ii. If there were no background sky, at what exposure time does noise from the dark current start to dominate over the read noise?