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 μ:

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

   Note that x has to be a positive integer.

   (a) Show that the mean of the Poisson distribution is μ.

   (b) Show that the variance of the Poisson distribution is μ.

   (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 $\mu = 30$. Motivate your choice of standard deviation when plotting the Gaussian.

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 1σ interval for a random Gaussian process? How many for the 2σ, 3σ, 4σ, 5σ 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) Calculate the probability to have 0 pixels outside the 5σ range. Also calculate the probability for 1 pixels, and for 2 pixels.

   (c) **Bonus points:** Use the `scipy.stats.norm` package[1] for the calculation in part (a).

4. Again consider the STL-1001E camera, operated at 0°C. For what exposure times does the read noise dominate over the dark current?

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

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

[1] https://docs.scipy.org/doc/scipy/reference/generated/scipy.stats.norm.html