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:

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

   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 $\mu > 1$.

   (a) Show that the mean of the Poisson distribution is μ. [1]

   (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 $\mu = 30$. 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 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) For what exposure times does the read noise dominate over the dark current? (Assume the camera is operated at 0°C.)

4. For the following, use "your" science frame from Tutorial 4.

   (a) Open the header to find out the gain.

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

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

(b) Re-do the flat-fielding step; this time, normalize the masterflat (e.g. by its mode) before you divide the science frame by it. The pixel values in the masterflat should thus vary around 1.0 . Discuss why normalizing the masterflat is helpful (you may want to complete the following steps before you think about this question).

(c) Open the image in ds9 and identify the star at (300.236734, +22.658612). Draw a circular region around it that encompasses all the light from the star. Double-click on the region, and in the pop-up frame select "Analysis" and then "Statistics", which will show you the number of counts within that region.

(d) Draw an "Annulus" Region around the star (avoiding light from any objects), and measure the standard deviation of the background.

(e) Repeat these steps for the star at (300.237300, +22.846978), which has a magnitude of $R = 7.50$. Given this information, what is the magnitude of "your" star? What is the uncertainty?

(f) Compare your measurement to those of your labmates (performed on the other science images). Are they statistically consistent?