PHY517 / AST443: Observational Techniques

Homework 4

1. 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. 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 $\mu \gg 1$. μ is both the mean and the variance of the Poisson distribution.

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

   (b) 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, so that the two distributions have the same variance?

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

2. 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) 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.

      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?

3. Photometry

   (a) Complete Tutorial 5. Submit a screenshot of the image in ds9, with the object catalog overlaid, a `Compass` region to show the North and East directions, and a scale bar (`Line` region).

(b) Compare the flux measurement of the star at (300.236734, +22.658612) between SExtractor and HW4. Comment on any discrepancies.

(c) *Bonus:* Fix any mistakes in the "by-hand" flux measurements that you may have found by comparing with SExtractor. Then, calculate the uncertainty on the number of photons that were measured. Does it agree with the one from SExtractor?

(d) Calculate the uncertainty on the magnitude measurement.