12.410j/8.287j Problem Set #1
Due 18 September 2015 at 1:05pm

Relevant Reading:
- Chromey Textbook Chapter 1;
- Observational Astronomy Quick Start Guide (handout)
- Elliot Notes "Fundamentals" (online)

1. The faintest objects that can be seen with the unaided eye on a dark, clear night have a visual magnitude (m_V) of about +6. How many photons per second would enter the pupil of your eye from such an object within a 1000 Angstrom bandwidth? (Assume: the diameter of your pupil is 8 mm and neglect extinction by the earth's atmosphere.)

The next set of questions uses the data from the in-class lab demonstration. You have discovered a new, fast pulsar and want to find its approximate period. You will analyze these data and present your solution in the format of a lab report. See sample lab report format after question 8.

2. Display the image `pulsar-105.fit`. In this class we will typically use ds9/saoimage, but you may choose any FITS viewer on the webpage (http://fits.gsfc.nasa.gov/fits_viewer.html) or any other that you may know. Adjust the view so that the entire image is visible at once, and adjust the display scaling so that both the source and background variation are visible at the same time ("zscale" in ds9). Screen capture this image display annotate it to indicate which object is the pulsar.

3. Open image `pulsar-105.fit`, and calculate the following quantities:
   a. Average background. In addition to the **value**, indicate which **region** you have chosen to use as your background (x,y)=(....) to (....) as well as region **shape** (rectangular, circular) and **method** (offset, annular)
   b. Total signal in star + background (include your chosen region and region shape)
   c. Star-only signal: scale the average background by the number of pixels in your star + background region and subtract this from the total.
   d. Which software did you use?

4. Series photometry: following the procedure in #3, determine the star-only signal in images 101-200. Use the same positioning as you used for #3, you will not need to recenter for each image. Provide a list of the values as a list of {file#, value} as well as a plot of signal vs. file#. The plot should have axes that are labeled.

5. Convert your answer to #4 (series photometry) to apparent magnitudes. You will need to convert your raw signal values to instrumental magnitudes and then apply the zero point offset. Instrumental magnitude is defined as:
   $$m_I = -2.5 \log_{10}(F)$$
   where F is the measured flux or signal. The apparent magnitude m is then:
   $$m = m_I + K$$
   where K is the zero point. You may use K=+22 as an approximate value for the zero point. In actual data analysis, you would determine this value from your observations of standard

stars. The symbols used here are consistent with those used in Chromey chapter 1. Provide a list of {file#, apparent magnitude value}.

If you had trouble completing #3 or #4, you may use the following list of values for your input raw signal levels. (Note that this supplied list is not the answer to #4; these are intentionally different values.) Clearly indicate whether you are using your own measurements or these supplied values.

```
{10, 11, 10, 11, 196, 15, 14, 12, 11, 194, 13, 8, 13, 15, 193,
7, 14, 5, 15, 190, 11, 10, 8, 7, 194, 6, 6, 8, 13, 191, 13, 8,
6, 10, 197, 6, 12, 5, 8, 200, 11, 8, 15, 5, 193, 11, 13, 15,
5}
```

6. Plot light curve vs. file number. Remember that brighter values should be plotted higher on the y axis.

7. What is the approximate change in brightness (in magnitudes) between when the pulsar is on and when it is off?

8. Signal-to-noise ratio: your series photometry values (#4 or the supplied values given in #5) should show a variety of signal levels when the "pulsar" is ON. This happens because varying fractions of the ON time are being recorded. There is also a ceiling value that occurs when the entire ON time is within the exposure interval. For ease of this problem, assume that any values that are within 98% of the maximum value in the list are measurements of the full ON value. Select and plot these values. Calculate the mean and standard deviation of the selected values. The signal-to-noise ratio of the full ON value is then the mean divided by the standard deviation.

Sample Lab Report Format

Use your results from Q2-8 to fill in the sections of the lab report. Items in square brackets [like this] are comments and should not be included in your report.

[Title] Pulsar Candidate Period Determination

by [your name here]

Introduction

Pulsars are rapidly rotating neutron stars that emit focussed beams of radiation. When these beams align with the Earth, a periodic signal is observed, some with periods as short as one milli-second. Determination of the period and light curve shape helps to determine the interior structure of the pulsar.

Data

In class on [date] we obtained observations of a pulsar candidate. We used [instrument] with [optics]. The exposure time used was [xx] seconds and the read time between exposures was [xx] seconds. The exposure sequence was comprised of [xx] individual frames, lasting approximately [xx] seconds.

[Insert image from Q#2 here. Label appropriately.]

I performed aperture photometry on this data set using [describe software, aperture shape, aperture sizes] [Insert answers to Q#3 here.] [Insert plot and results table from Q#4 here.]

Analysis

The light curve in magnitudes is shown in Fig. xx [Insert plot from Q#5 and Q#6 here.] The maximum observed changed in brightness is [xx] mag [from Q#7], although the brightness change varies between [xx] and [xx] mag. If this variation is due to photon noise within the data, the signal-to-noise ratio of these data is [xx][from Q#8].

[Discussion--you would normally have a discussion section as well, but since these are fake data, we will skip it here.]