Department of Physics and Astronomy
University of Iowa
29:137 Astronomical Laboratory
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Lab 5: Advanced CCD Photometry and Imagery
Supplement: Methods of Photometry in Maxim DL

1 Introduction

The program *Maxim DL* provides a number of techniques for doing photometry. The techniques described below should be useful in Lab projects #5 and #6. The formulas for computing magnitudes from the raw counts (or ADU units) are given in the appendix.

2 Setting the Aperture

For the measurements described in Sections 3 and 4 below, it is necessary to set the aperture in Maxim DL. Here is how to do it.

1. Pick the cross hairs radio button, which is called the "Information Window", and click on it.

2. The numbers displayed in the window of particular interest to us are "Pixel", "Maximum", "Average", and "Magnitude", and "Bgd Average".

3. The aperture consists of a circular region, of radius R_1 pixels, in which the counts due to the stars are measured, and an exterior annulus, of inner and outer radii R_2 and R_3, $R_2, R_3, > R_1$ in which the background counts are measured so that they may be subtracted from the star measurement.

4. To set the aperture, *right click* on the aperture, and subsequently choose the values for aperture radius (R_1), gap width ($R_2 - R_1$), and annulus thickness ($R_3 - R_2$). The choices for these dependent on the specific application. You want R_1 to be large enough to include all the counts from the brightest star (usually the calibrator) you are measuring. You

want the outer annulus to be close to the star you are measuring, but not so close that it is picking up some of the stellar photons. To get the ball rolling, in a test I did, I picked 8, 2, and 4 for aperture radius, gap width, and annulus thickness.

5. You're ready to roll.

3 Magnitudes within an Image

The simplest case is measuring relative magnitudes within a single CCD image from a Celestron 8 or the Rigel telescope. This will give the true, apparent magnitude if the magnitude of a calibrator star within the image is known. The method to be employed here is described on p78 of the 29:50 manual (given in "Textbooks" on this web page).

First set the aperture as described in Section 2. Then you are ready to "train" the system to measure magnitudes. Do the following.

1. In the Information Window, click on the "calibrate" radio button. It gives you choices for "exposure", "intensity", and "magnitude".
2. Click "set from fits" for the exposure.
3. Click "extract from image" intensity.
4. Type in the correct number for magnitude. What is the "correct number"? If you know the magnitude of a calibrator star in the image, input that. If (as is more commonly the case) you don't know the magnitudes of any of the stars in the field, you can type in a plausible value, given the telescope and the exposure time. The magnitude itself will be meaningless, but *relative magnitudes* between this star and all others will be correct. This is perfectly good for doing light curves of variable objects such as variable stars and asteroids.
5. Move the cursor to the calibrator star and click on it. You have just trained Maxim DL to equate the total number of raw counts on the calibrator star to a specific magnitude.
6. You can now move the aperture to any star in the field and it will give you the magnitude of that star. Neat!

4 Magnitudes Relative to a Bright Calibrator Star

The more common situation is use of a bright standard star (like Vega) in one exposure, and measurement of much fainter stars in longer exposures. The formulas in the Appendix treat this situation, and this is what we worked with in Lab #2. In this case, we need to work with raw counts Q_1 AND Q_2. Let either of these raw counts be called Q_*. If $\bar{Q}$ is the "average" from the Information Window, and B is the Bgd average from the Information Window, then

$$Q_* = \bar{Q} - B \tag{1}$$

The justification for this formula is as follows. The total "charge" or number of counts within the circular aperture ($r \leq R_1$) is

$$Q_{tot} = Q_* + NB \tag{2}$$

where N is the number of pixels in the circular aperture. The average in the Information Window is

$$\bar{Q} = \frac{Q_{tot}}{N} = \frac{Q_* + NB}{N} \tag{3}$$

so

$$Q_* = N\bar{Q} - NB = N(\bar{Q} - B) \tag{4}$$

Since in measuring magnitudes we are taking ratios of the signals for two stars, the number of pixels cancels from the numerator and denominator, as long as we use the same aperture for both stars.

When measuring magnitudes using a calibrator star on one CCD image (with signal Q_{*1}), and unknown star on another image (with signal Q_{*2}), substitute equation (4) for each star into equation (7) below.

5 Magnitudes from Slices in the Image

The final method to be discussed is that initially used in Lab #2. This consists of analysing a "slice", or measurement of intensity of radiation versus position along a line on the sky. In the case of the images we are using, this amounts to a measurement of raw counts as a function of pixel number along this line. This method readily shows the background which must be subtracted. A disadvantage is that the measurement of the peak is very noise-sensitive. At any rate, to do a measurement this way, follow these steps.

1. Locate the star you want to measure.
2. Click on the “Line Profile” radio button. It will generate a window with a plot on it.
3. Select the option of “line” in the window. This line is more flexible than the “horizonal line” option, which runs across the whole image.
4. Choose the starting point of the line segment by clicking on the desired point on the sky, then dragging the cursor across the star to another black sky reference point. When you release the cursor, it defines the line segment.
5. Look at the plot, which shows a roughly Gaussian profile centered on the star.
6. When you move the cursor to the line segment, a little hand appears, which allows you to move your line segment around to make it optimum.
7. To get better results, make a slice in the horizontal and vertical directions, and average the results.

When analysing the data in this way, the background-corrected stellar charge Q_* is given by

$$Q_* = Q_{max} - B \tag{5}$$

where Q_{max} is the peak in the Gaussian profile through the star, and B is the average baseline value.

To get a good idea of the error in your measurements, try the techniques in Sections 4 and 5 and calculate the difference.

6 Appendix: Measuring Stellar Magnitudes

The model we use for the response of the camera to a star is as follows. Let Q be the raw count on a pixel of the CCD. Then

$$Q = AFt \tag{6}$$

where F is the flux of radiation from the star (Watts/m^2), t is the time of integration or exposure, and A is the coefficient describing the instrumental response. Given fluxes F_1 and F_2 from two stars, the difference in their magnitudes is then

$$m_1 - m_2 = 2.50 \log \left(\frac{F_2}{F_1} \right) \tag{7}$$

So if we have observations of two stars, characterized by measureables Q_1 and t_1 and Q_2 and t_2, respectively, the difference in magnitudes is

$$m_1 - m_2 = 2.50 \log \left(\frac{Q_2 t_1}{Q_1 t_2} \right) \tag{8}$$

Obviously, the camera must be unsaturated for these equations to be valid. In addition, there is a noise floor that must be corrected for. Even in the total absence of light, the pixels will develop a charge. This must be corrected for. In standard operation, the camera takes a dark frame and subtracts it. However, at least as a check that this has been done properly, you need to measure the background far from any star and determine the background that needs to be subtracted from the raw measurement to yield a value of Q that is used in the above formula.