

Image Photometry

How to measure brightness on an astronomical image

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Background:

Stars are not all the same apparent brightness. We quantify brightness as “magnitudes” with lower numbers representing brighter objects. This is a non-linear scale relative to the actual number of photons arriving per second on a given surface. It is actually logarithmic, like most of human senses. That is, *addition* of magnitudes is the same as *multiplication* of photon flux.

Magnitude difference = 5 steps → brightness ratio = 100 times

The scale of magnitudes has been agreed upon by reference to a specific set of standard stars which have been measured by many astronomers many times. All we need to do is find a few stars of known apparent magnitude on a photo, then measure differentials from them for the stars we are interested in which appear on that photo. One of the really nice features of CCD technology is that the brightness recorded is nearly linear with photon flux. Photometry is the precise measurement of the brightness of a star image.

Method:

1. Start, All Programs, AIP4WinV2. (Astronomical Image Processing for Windows) by Richard Berry and Jim Burnell. Open your image.

First we want to check to see that none of the stars we are interested in have saturated the CCD chip (been overexposed). If you measure a star with a saturated image, it will give useless information. You will have to pick another image. We can check easily by selecting Measure, Star Image Tool. Click on the brightest star you are interested in. Look in the dialog box for the Peak Pixel Value. Saturation sets in about 65500. At that number or above, discard the image.

2. For accurate results we need to subtract from the recorded image the dark current (due to the camera itself). This dark current is a function of the camera's thermal temperature and the image's exposure time and binning scale.

Read the properties of the image from Edit, FITS Header.

X binning _____

Y binning _____

Exposure Time _____

CCD Temperature _____

Close the Editor without making any changes.

Multiple similar dark frames have been averaged and named by their binning scale, exposure time and temperature in degrees Celsius. For example, “3x3dark2sec-10ave6” means 3x3 binning, 2 second exposure, T = -10 C, six such frames were averaged to make this Master Dark Frame.

From the top menu bar choose Calibrate, Setup, Basic.

Click Select Dark Frames, then choose from the hard drive or from a CD the dark frame which most closely matches the properties of the image you are working on. The radio button by Select Dark Frames should change from red to green.

Click Average Combine, Process Dark Frames, and then its button should also change to green. Close. From the top menu bar choose Calibrate, Manual Calibration, Subtract Dark from Image.

3. From the top menu choose Measure, Photometry, Single Star.

Use scroll bars to find the section of the calibrated image you are interested in. Sometimes you can locate it better using Zoom to 50% in the Image Display Control panel on the left.

If you cannot see details on the image, then click to adjust the minimum pixel value and the maximum pixel value until it is easy for you to see details. Usually this is not necessary. Note that this will not change the intensity values (brightness or magnitude) which the computer will measure.

Move the dialog box for Single Star Photometry to the side of the screen, off the image as much as possible.

4. Click the Settings tab. Check to see that the radii are at 6.0, 9.0, and 15.0 pixels. These are the Star Aperture, Sky Annulus Inside, and Sky Annulus Outside. They can be changed later if needed.

5. Now you are ready to measure how bright a star is on this image.

Click the result tab.

Click on one star image. A little bull's eye will jump to center itself on the star you have chosen.

The program will display the measurements of this star in the dialog box.

In your data table write down the Raw Instrumental Magnitude and its uncertainty. For example, $17.267 \pm .006$. We want to choose at least five stars of known magnitude, and then the one star of unknown magnitude we are interested in.

6. To measure the brightness of the next star on your list, click on it.

Proceed as in step 5.

7. When you have finished measuring all the stars of interest, close the program and do not save the measurement log.

8. These raw values of magnitude should be entered into a spreadsheet to be calibrated properly.

Plot the stars' known magnitude (from The Sky or other reputable source) vs. their raw instrumental magnitude from AIP4WIN. Have Excel generate a linear trendline with its equation and R squared value displayed. Examine the fit for outliers and decide if you want to exclude any points and tweak the trendline. Use this equation to calculate the magnitude of your star of interest from its raw instrumental magnitude.

Record this value and its date and time in your log.