# How To Get Started in CCD Photometry

## Photometry is Simple!

You've had your CCD camera for several months and have taken the requisite images of every Messier object visible from your site. Now you are ready to move on to something else, and you have heard that CCDs are good for photometry. You have heard right -- photometry is easy to do and remarkably accurate with a CCD.

The required hardware is a telescope and a CCD camera. If you have a filter wheel and filters, so much the better, but they are not essential. Your image processing program needs to have a photometry function: point to a star and return a magnitude for that star. You should find out if that is a sky-subtracted magnitude (the program uses an annulus around the star image to find a sky value, and subtracts it from the star aperture), or whether you will need to point at a blank section of the image to find the sky reading that needs to be subtracted from the star magnitude.

## What Should I Observe?

The easiest method of photometry is called differential photometry, where you measure a program star with respect to other constant stars in the same image. This method can be used even if there are thick clouds in the sky. Since all objects are seen simultaneously, any clouds that affect one object affects all the others equally.

I would suggest picking a field where you have a brightish variable star along with 2-3 equally bright comparison stars. What is bright for your telescope may not be bright for a smaller telescope, so let me give you three possible fields that are visible during summer mornings for northern observers:

| Name | RA (B1950) | DEC | Magrange | Epoch | Period | Type |
|---|---|---|---|---|---|---|
| V836 Cyg | 21:19:21 | 35:31:25 | 8.59-9.30B | 26547.522 | 0.653411090 | BetLyr |
| SW Lac | 22:51:22 | 37:40:20 | 10.2-11.23B | 43459.748 | 0.3207216 | W UMa |
| RR Lyr | 19:23:52 | 42:41:12 | 7.2-8.6B | 38241.460 | 0.5668054 | RRLyr |

The epoch is the Julian date of the minimum or maximum of light variation, and the period is in days. You may need to position the variable somewhere other than the field center in order to pick up a couple of good comparison stars.

## How Do I Observe?

I recommend picking a field where the variable and comparison stars reach about 1/2 full A/D range in about 10 seconds (your drive will track for 10 seconds, right?). Half-fullrange is almost always safe with any CCD system. When in doubt, use this exposure level on any new field. Then just sit on that field, taking a frame every few minutes. Record the clock time (like UT) of each exposure. The variables I gave in the previous section are all short period, so after an hour or so you would see an obvious change in the variable's brightness.

The next day (or during the night if you feel ambitious), measure the brightness of the variable and at least two comparison stars. form the magnitude differences (variable - 0.5*(comp1 + comp2)) and (comp1 - comp2). The (comp1 + comp2) term will average out variations in each of the comparison stars and give you better results. The (comp1 - comp2) term gives you an indication of the quality of the photometry.

If your photometry program does not do an automatic sky subtraction, you will need to point to a blank area in your image to obtain a sky reading, and then subtract it from each of your star magnitudes before performing the magnitude differencing.

Finally, take the differential photometry for your variable and plot it versus the clock time of your exposure. You should see a cyclic variation with a period equal to the period given in the table above.

## Do I Need Flats and Darks?

For simple photometry, non-flatfielded images will give you 0.05mag or so accuracy, certainly good enough to see the variability. You can check your internal accuracy by looking at the magnitude difference between two comparison stars. This should scatter around some constant value, and the amount of scatter is an indication of how well you can do photometry.

Likewise, dark subtraction is often useful in improving the accuracy. It removes the additive components of the pixel reading before you apply corrections such as flatfielding. However, as long as you use exposure times of a few tens of seconds, you should not need to dark subtract for the kind of photometry I am discussing here.

## How Can I Improve My Photometry?

Use flatfielding on your images. A flatfield removes the pixel-to-pixel variation in the sensitivity of the CCD. You will hear many ways to take a flatfield, and everyone has their opinion as to which is best. My feeling is sky flats work the best for most portable systems where you can't conveniently bring a flatfield screen along, and it is a toss-up for permanent installations as to whether you use sky flats or dome flats. There are some fine details as to how to get the most uniform flats, but let's not worry about them for now.

For sky flats, you have a 20-minute window sometime after sunset or before sunrise when the sky is just the right brightness. Try to have your telescope focussed. Point your telescope at the zenith and turn off the clock drive. Expose so that the sky reaches about 1/2 full well (usually about 1/2 range on your A/D converter). Any star will trail, which lessens its effect on the final flat. The best sky region for such 'trailed flats' is a blank one, but I take several flats and use the one that has the fewest star trails (or else average several together). That is all there is to getting a reasonable flat! Your image processing program or the manual that came with your camera should tell you how to subtract dark current and flatfield your images, so I won't discuss those techniques here.

Your image processing program may not have a very good photometry routine, so another way of improving your photometry is to ask around for some suggestions about a better reduction program. A list of photometry programs was posted to the AAVSO and VSNET discussion groups, and that is a good starting point.

Be sure to expose your variable star images so that the variable and its comparison stars are well-exposed (not too bright, and not too faint). This is usually around half-well.

You can use filtered images for your photometry, and get some information regarding how blue or red your variable is, and whether it changes color during the cyclic variation. I recommend the Johnson-Cousins BVRI system, but any filter set will do.

There are more ideas about improving your photometry in the accompanying article "Tricks for High-Precision CCD Photometry." Some of the information in that article gets pretty technical, so experiment with the simpler photometric techniques described here before moving on to handling the more complex issues.

Bottom line: photometry is simple and fun! As you gain experience, you may want to make your results more scientifically interesting by adding a filter wheel and contacting a professional astronomer to see what projects he/she might have for you to get involved. The professionals who like to work with amateurs can usually be found lurking on the discussion groups.

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