

Basic CCD Image Processing

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What exactly *is* a CCD?

We're glad you asked. To make a connection that doubtless many of you have already made, the CCD is basically a digital camera. In fact, the digital cameras you can buy in the mall have CCDs as their detectors. Astronomical CCDs are designed to be more sensitive to low light levels but the idea is the same: the chip is divided into pixels and light falling onto each pixel is converted into an electronic signal. This signal is typically expressed in "counts". The resulting image is output in one of a few typical formats and can be manipulated by any number of image processing programs.

Contributions to signal

The number of counts recorded will come from a number of sources. Ideally, the *target object* will contribute the majority of the signal, and is of course the signal we're most interested in. The *sky* will unavoidably contribute signal, depending upon the light pollution conditions and proximity to (and phase of) the Moon among other things. As mentioned in Handout 8, signal unrelated to photons is also present in your images: *read noise* which occurs even in zero-second exposures with no incident light and *dark current* which is inherent in the electronics of the instrument, building up with time even with no incident light. Differences in sensitivity across a chip leads to *flat-field* effects.

Again, as mentioned in Handout 8 it is important to take calibration frames to help make the most of your images though in this class it won't be necessary to take the kinds of calibration data necessary for astronomical research. We can get away with just dark frames for our purposes. The dark frames will be subtracted from the object frames, which will also take care of the read noise.

Aside: Can you think of a way to take care of the sky counts? Would you still need dark frames?

Color Tables and S t r e t c h e s

OK. Now you've got your image. How best to display it to bring out the details?

Let's assume we have an image where the peak intensity is 10,000 counts, and we have a display where zero counts shows up as black, 10,000 shows up as white. Most image processing software defaults to a linear mode where 5,000 counts would show up half as bright as 10,000 but twice as bright as 2,500. This set of display parameters (black level, white level, function between them) is informally called the *stretch*. What if you have a very faint object that only has 1000 counts? Or what if you're looking at Jupiter and interested in the atmospheric features, all of which fall between 7,000 and 8,000 counts? As may be obvious, you can change the stretch. Most commonly, the white or black levels are changed to maximize contrast-in the first example you'd set the white level low, perhaps to only 2,500 or 3,000 counts to make the faint object appear brighter. In the second, you'd set the black level quite high, maybe 5,000 or 6,000 counts. A general rule of thumb (which you may have deduced) is to set the black level a bit below the faintest level you want to see and the white level a bit above the brightest level you want to see. In some software you can change from a linear to a log (for example) stretch. What would that do? A square root stretch? An exponential stretch?

Note! CCDOPS uses a black level and range rather than a black level and a white level. As you can see, the two are exactly equivalent (e.g. use black level of 5,000 and range of 1,000 for the Jupiter example).

There is no hard and fast rule about what levels should be set where, however. Particularly in 12.409, the main point is to get images that look good to you! And since the original data doesn't get affected (**check to make sure this is true in the program you're using!**), you can always keep tweaking!

The use of black for faint and white for bright is ultimately an arbitrary one. Many display programs will allow you to *invert* the image, making faint objects white and bright ones black. This simulates what you would see in a photo negative, which is the imaging medium most astronomers used up until the 1980s. Some astronomical software will allow setting blue through red or yellow, or user-defined color schemes. These are called *color tables* (or occasionally *lookup tables*). For our purposes here, we assume a standard black-to-white color table, but since looking cool is the name of the game, your mileage may vary.

Saving your work

There are 3 different file formats that the software we'll be using can handle. One is "SBIG", which is the native format created by the camera and specific to it. The second is the more familiar TIFF format, and the third is FITS format, commonly used in astronomical research.

For these purposes, you should save your work in the SBIG format. That is the only kind of data that can be read by CCDOPS (though it can write in others). Saving in compressed format will save a lot of space and has no negative effects, so we suggest you save your work compressed.

Some specifics

Much of the following comes from the CCDOPS manual (Version 4.0) by the Santa Barbara Instrument Group. There are copies of the manual around the classroom and in PDF format on the computers in the same folder as the CCDOPS application. It's useful to get more details of the software and menus.

To load an image that you have previously taken, use the Open command. Easy! The first thing that comes up is a window containing header information: file name, date and time the image was taken, exposure time, etc. Click it to make it go away, and the image appears in a new window, with another new window labeled "Contrast." If you need the header information again, click "Parameters" in the Display menu.

There are a few ways to set the stretch: you can enter values for the background ("back") and range ("Range") and hit return, you can click on the arrows which update in real-time (the buttons with two arrows move the numbers twice as quickly), or you can let the computer decide by clicking *Auto*. Other things you can do in this window are invert the image so that black represents brighter pixels, smooth the image, and change the magnification of the image. Play with the settings to get a feel for what things do-- there should be a sample image or two available if you haven't taken your own yet.

Crosshairs

To activate a set of crosshairs, pick *Show Crosshairs* under the Display menu. Now when you move the crosshairs over the image you get the X and Y value for the point (measured from upper left), the value in counts for the pixel the crosshair is directly over, the average value for a box centered under the crosshair (the initial size is 5 x 5 pixels, but that's changeable through a menu at the bottom of the window), and the RMS (root mean square) variation of the pixels in the box. We're not going to worry about the other entries in the window, though you should at least be able to recognize the words!

Coadds

Sometimes it is necessary to take relatively short exposures due to sky brightness conditions or to keep an object from saturating. If your target is too faint (or the contrast too low on bright objects) to show up well in short exposures, the typical approach is to take several exposures and *coadd* them. In order to coadd images, use the crosshairs tool to determine their relative offsets (and write them down-- the computer doesn't keep this information) and then use the *Co-add* command in the Utility menu. You can also use

this command in order to average a number of frames without registering them (dark frames for instance). Unfortunately, you'll have to do the coadding 2 images at a time. Better would be to use *Average Images*, also in the Utility menu, which lets you average many objects at once.

Dark Subtraction

If you are going to take a large number of frames with the same exposure times, it is best to turn off auto dark subtraction and do it post facto. Auto-subtracting images will take over twice as long as doing it manually. Take a dark frame of the relevant exposure time first, then after your object frames have been taken use the *Dark Subtract* command under the Utility menu.

Other commands

The Utility menu has a number of other commands of greater-or-lesser importance for 12.409. *Smooth* has the effect of replacing every pixel with a weighted sum of itself and its neighboring pixels. *Sharpen* could also be used to, well, sharpen the image. Both of these functions can be done with varying strengths. Neither one would be used in research-quality data, but since we don't have that problem here, feel free to mess with them to see what they do! The same goes for the other commands in the Utility menu. Just make sure you know what you're saving when you save it, and keep backup copies of images!