

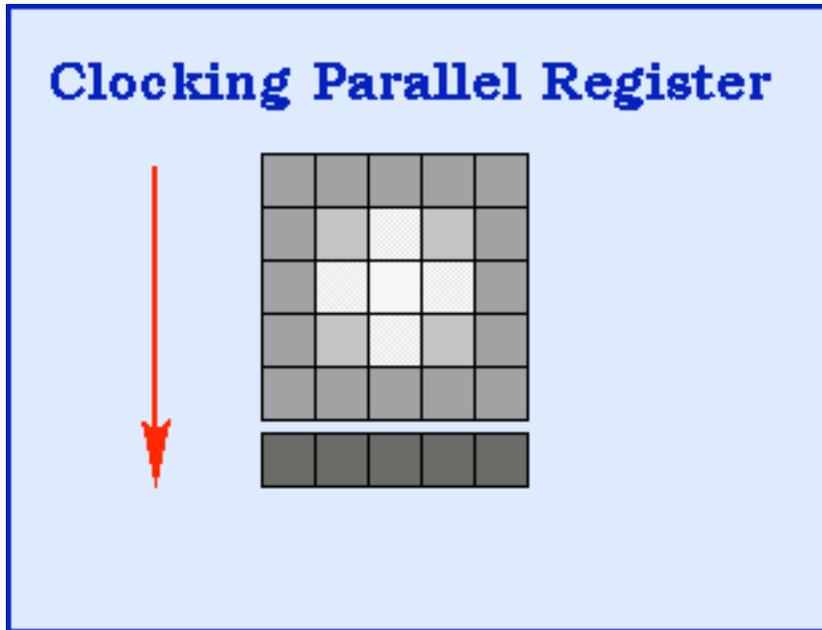
CCD Basics: Astronomical Imaging (ver 5/22/07)

I. What is a CCD?

Virtually all the astronomical images you see are produced by CCD (which stands for charged coupled device) detectors. Only a few years ago this technology was still only common in science labs, but today everyone has experience with digital cameras, as well as other forms of CCDs. Terms such as “pixels” are heard more frequently: a CCD, or digital camera, produces an “image” composed of megapixels (millions of pixels). In astronomy, CCD's replaced photography by the mid 1980's because of the tremendous advantages they offered. A photographic image can record about 5% of the light that reaches the film; modern CCDs can record up to 90% of the light. Photographs must be carefully developed in darkrooms, where the result can be very dependent on the temperature and strength of the chemical developers, and copies are always inferior to the original. The digital image from a CCD is completely reproducible. A CCD image is also what we refer to as linear: doubling the exposure time exactly doubles the intensity of the image – something that is only approximately true with photographic film. And while your digital camera unobtrusively produces color images that you can manipulate with software programs, astronomers appreciate the characteristics of CCD that make it possible to record an image through different filters and then analyze the separate images.

But what are those pixels? A CCD is sort of a reusable piece of film. It is composed of picture elements, or pixels. When the camera takes an exposure, these pixels collect light which is converted to an electric charge when it hits the surface. We describe light as either a wave or a particle: here we treat light as a particle known as a photon. You can think of each pixel as a little bucket open to the rain of photons. At the conclusion of the exposure, the electric charge is read out in a sort of bucket brigade. See the animation at astro.swarthmore.edu/astro121/readout.gif. At the output, the charge is converted to a number representing the number of light photons in each pixel. These numbers are saved in a computer and manipulated to produce the final image.

Fig. 1: Reading out a ccd.



III. How Does a CCD produce color images?

In the previous discussion of the ccd you may have noticed that there was no discussion of the color of the image. The number associated with each pixel read out represents all the light photons that fall into the “bucket”: red, green, blue, etc. So to make a color image, several additional steps involving filters are necessary. A filter is simply a plate than permits only light of a specific wavelength range to pass through. (Think of a piece of colored cellophane.) Astronomers put a filter in front of the ccd and take an image. Then the image is repeated with another filter, and often with a third filter.

The image produced in this way are each assigned an appropriate color by the computer for that filter and combined to produce the final image (Fig. 2)

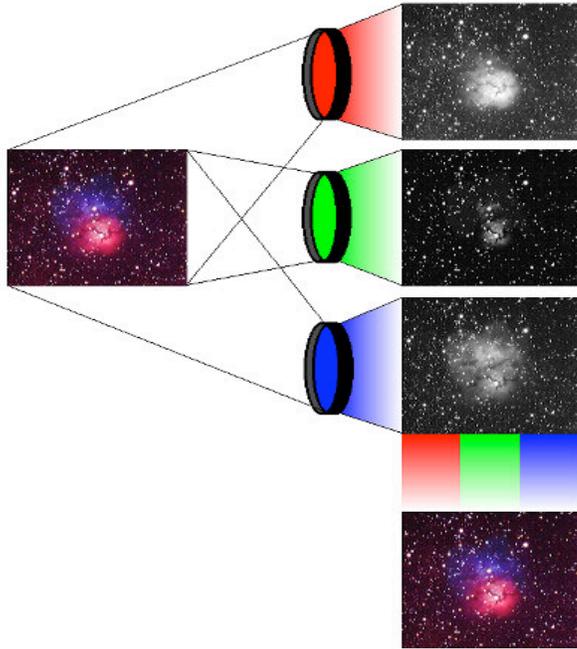


Fig. 2 Combining images to produce a color image

III. Manipulating Images

If you haven't already, download ImageJ and install it on your computer. Also download the three images of M16 from the web page.

1. Open an image. Using your ImageJ software, open the files for the object M16. Start with M16_Halpha, which was taken through a filter that allowed only red light produced by hydrogen gas. This image was taken through a hydrogen alpha filter with the 0.9M telescope at Kitt Peak (you can take a virtual tour at: www.noao.edu/outreach/kptour/).
2. Adjust the image. Select the following item from the ImageJ menu pulldown bar: "Image", >"Adjust", >"Brightness/Contrast." A new sub-window ("B&C") will appear on your screen and you can use the various slider bars to adjust the appearance of the image. Note that a histogram is displayed at the top of the "B&C" window. The associated solid line shows the range of pixel values currently being displayed by the shades of gray in your image. Play with the minimum and maximum sliders until you see the maximum amount of detail on the image. The image should now be displayed with good contrast. You could also just check the box marked "auto"
3. Now you are ready to explore the image. Try magnifying it with the magnifier icon on the toolbar. What do you find when you get to a magnification of about 800? . In the image, zoom in using the magnifying glass. Use the "hand" for

- panning around the image. Note that as you move the pointer from pixel to pixel you can read the position in x,y and also the counts for the pixel. Describe the appearance of a bright star compared with a faint star. How do the counts vary across the stellar image? What is the diameter of each star in pixels? If you draw a box around a star with the drawing tool, under “analyze, plot profile” you will get a profile of the star you examined.
4. Open the image M16_V.fits This was taken with a filter that transmits visual red light. Astronomers refer to this filter as “V”. To learn more about this, look at: <http://astro.unl.edu/naap/blackbody/blackbody.html> Under simulators, click on “blackbody simulator” which shows how a body of a given temperature emits light at different wavelengths Click on the filters option tab. This shows 4 filters: U,B,V and R superimposed on the blackbody curve.
 5. Next, open the image M16_B.fits. With three images, you can try combining them much as was done with the Sombrero galaxy. Under Image > color > RGB merge assign colors to each filter. You might try red for the H alpha, green for V and blue for B. Click “Keep source image” Click ok

This is only a taste of what sorts of image manipulation can be done. For more about how astronomers measure ccd images, continue exploring the open cluster project and the nova project.