Processing Techniques and Philosophy by Debra Ceravolo

How we perceive color

- Achieving realistic color in astronomical imaging is never an easy task to accomplish. There is no true or perfect color of an image that everyone can agree on. Color has always been and always will be subjective. There are several reasons for this. Each person sees color slightly differently due to their unique genes that make up their individual nature. Color is picked up by the cones sensors in our eyes which only work in strong light conditions for example during daylight. But our brains also process the color, even boosts it in areas that we are not as sensitive to such as blue. In fact, a lot of image processing is going on within our brains and everyone is slightly different.
- Visual stargazers using a telescope to observe details of a nebula or galaxy don't see the color at all because there is not enough light to activate the cones in their eyes. In low light level conditions, another kind of sensor in our eyes becomes activated - the rods, which see only in black and white but give us great detail in what we can see at night. These sensors are located off-center of our eyes and so one need to use averted vision to see the faint details of astronomical objects rather than looking directly at them. If an object is bright like the Orion Nebula, some of the cones may become activated and we can see faint color but we are not very sensitive at all in the red and hence using a red flashlight or red computer monitor while observing does not activate the cones and ruin our night vision.
- CCD camera systems usually try to replicate the colors seen by the human eye. The CCD chips are very sensitive in the red particularly near the hydrogen alpha wavelength as most nebula and objects are strongly emitting Hα. RGB filters are used to better match the chip's sensitivities to what we perceive visually but our eyes are not very sensitive in the Hα region of the visual spectrum so it is pointless to try to replicate an astronomical image according to what our eyes see. As an image processor, we want to bring out the details of what is really there and translate that into an image that is as close to a natural representation of color as possible.

True color and color balancing

- So achieving a color balanced image is more closely related to balancing the RGB channels rather than mimicking what the human eye sees, especially at night. There are a few ways to do this and probably the most accurate is the technique of using a G2V star as a white balance reference for each filter. A G2V star is any star that has a spectral class similar to the Sun which is white. The quantum efficiency of the camera and the filters as well as the elevation of the star in the sky should all be factored in. Don Goldman of Astrodon Filters has an excellent tutorial on balancing color using G2V stars. http://www.astrodon.com/Orphan/g2v_tutorial/

Color Mapping:

- To have a balanced color in an image, three layers need to be color mapped together. Traditionally the three colors would be red, green and blue (RGB). This is commonly referred to as the subtractive color theory and this is how human eyes see color and how our computer monitors display color. All three colors together create white.
- Color mapping is a software technique commonly used to give a monochrome image its color value. This is how the Hubble Palette is achieved. The SII is mapped as red, Ha is mapped as green and OIII is mapped as blue. Many imagers have experimented with color mapping using different values to achieve a pleasant looking pretty picture but this is far from natural looking color images. In fact, false color narrowband imaging is so popular, that many people have become so used to seeing these astronomical images that they believe they are the true colors of the universe.

Narrowband filters

- Using narrowband filters is a huge asset to astronomical imaging. By filtering out specific wavelengths being emitted within an object, much detail can be captured that is otherwise overwhelmed by the broader band of the RGB filters. Narrowband filters also cut through light pollution as well as the Moon's glare. The challenge is to implement this detail and still maintain true color and a natural look to your images.
- Narrowband filters can be used on their own without the RGB filters and this approach has become very popular. The Hubble Space Telescope imagers were the first to use the technique of color mapping the three most popular narrowband filters; hydrogen alpha, sulfur (SII) and oxygen (OIII). This false color technique brings out interesting details due to the contrast in the colors and is often scientifically useful for gaining new information into the inner workings of the object.
- There are a couple of ways that are popular to achieving a natural look using narrowband filters. The most wildly known and used is a technique first taught by Rob Gendler. That is blending narrowband images into a broadband color channel such as Ha into the red channel using Photoshop. OIII can also be blended into the blue and green channels this way. OIII has a wavelength roughly between the blue and green wavelengths of the visual spectrum, so this blending technique is closer to the true values as opposed to the Hubble Palette.
- Another way to achieve natural looking color with narrowband images is to Make Ha red which it is, OIII as blue and green which is it is. Then layering SII on top, neutralizing the background.

- One way to achieve natural looking narrowband images is to colorize the RGB as red, green and blue and then add the narrowband in according to their true wavelength emitted and recorded in the CCD camera. To learn more about this technique developed by Debra Ceravolo, see the article written in Sky and Telescope's December 2011 issue.