

COMBINING BROADBAND AND NARROWBAND IMAGERY

By Stephen J. Maas

Emission and planetary nebulae are some of the most beautiful deep-sky objects sought out by astro-imagers, but their successful capture is often challenging. The surface brightness of many of these objects is low, often requiring long exposures to bring out their details. Unfortunately, long exposures can result in stars in the field surrounding the nebula appearing overexposed and bloated. Is there a way to have both bright, detailed nebulae and compact, natural-looking stars?

A possible solution comes from the way emission and planetary nebulae produce their light. High-intensity radiation from nearby stars, or collisions with the interstellar medium, cause a nebula's gases to glow. This light is emitted at specific wavelengths. For example, ionized hydrogen can emit light at 656.3 nm (H-alpha) or 486.1 nm (H-beta), while ionized oxygen can emit light at 500.7 nm (O III). These emissions give nebulae their characteristic colors.

Monochrome digital cameras equipped with the appropriate narrow-bandpass filters can capture the specific colors of nebulae. Long exposures using narrowband filters can record the detail of nebulae without overexposing the surrounding stars. Stars generally emit light in a nearly continuous spectrum, so imaging them with narrowband filters records only a small portion of their light. But, for this same reason, you generally can't combine narrowband images of stars and get them to come out in their correct colors.

So, how about a hybrid approach? Suppose you collected long exposures in the appropriate narrow bands to show the details of the nebula, but also shorter exposures in the standard broad bands (red, green, and blue) to produce sharp stars in their correct colors. If you could then combine them properly, the resulting hybrid image would display a bright, detailed nebula and sharp, point-like stars.

This has been attempted by many astro-imagers. The devil is in how you combine the various broadband and narrowband images.

Often a degree of subjectivity is employed so that the resulting image "looks good." But what looks good to one person may not look good to another. Is there an objective method for combining these images that can produce a "true color" rendition of an object?

But first, what do I mean by a "true color" image? To me, a true color image is one that shows the object in the colors you would see if your eyes were sensitive enough to adequately respond to the levels of light emitted by the object. The Orion Nebula (M42) looks like a grayish wisp in a small telescope not because that is its true color, but because your eyes aren't sensitive enough to properly respond to it. Were your eyes more sensitive, the nebula would blaze with the red and pink colors that we know it has.

To illustrate the procedure, I'll use the example of the Dumbbell Nebula (M27). In 2015, I acquired 16-bit broadband (red, green, and blue) and narrowband (H-alpha, H-beta, and O III) imagery of it using a QSI 583 monochrome camera on an Orion EON 120 mm refractor. To capture the star field, I used broadband exposures of 1.5 minutes. To capture the nebula, I used narrowband exposures of 15 minutes.

I used standard image processing to align the individual images, apply dark and flat images, and correct for atmospheric extinction. The individual images were then stacked to produce "master" red, green, blue, H-alpha, H-beta, and O III images.

The first step in the hybridization process

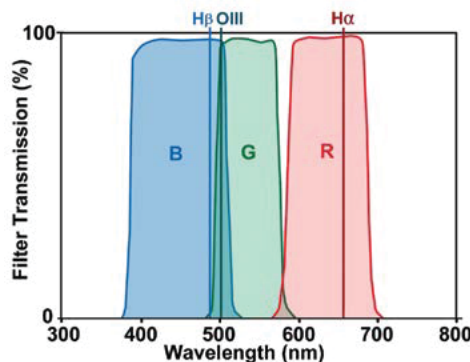


Figure 1. Bandpass characteristics of typical broadband and narrowband astronomical filters

is to remove the stars from the master narrowband images. I used Straton (zipproth.de/Straton), an inexpensive standalone package that generally does a good job. The results are master narrowband images that only contain the nebula.

Before we start combining images, let's look at the spectral characteristics of broadband and narrowband images. Figure 1 shows the spectral bandpass characteristics for the filters I used in the example. Where the narrowband filters lie with respect to the broadband filters will determine how we combine the images produced with them. The H-alpha filter lies entirely within the red broadband filter's bandpass, so images produced with those two filters should be combined. The O III filter lies within the green broadband filter's bandpass, and thus images produced with those two filters belong together. But it also lies in a portion of the blue broadband filter's bandpass. This mixture of blue and green produces the "teal" color characteristic of many planetary nebulas. So, we must combine the blue broadband image with not only the H-beta narrowband image but also the O III narrowband image. We can do this by adding the H-beta and O III narrowband images using image processing software to produce a single H-beta + O III image.

Now we have three pairs of images (Figure 2). The red broadband image goes with the H-alpha narrowband image, the green broadband image goes with the O III narrowband image, and the blue broadband image goes with the H-beta + O III narrowband image.

Before we combine the images, there's one thing we need to do. We usually assume that "empty space" is black, but some of the light that we capture with our images doesn't come from space but actually comes from atmospheric sources, primarily light pollution and airglow. This is often referred to as "skylight" and it can affect the color balance of our imagery. Using image processing software, I collected digital number (DN) values for pixels in the "empty spaces" between stars in the images. This is indicative of the skylight

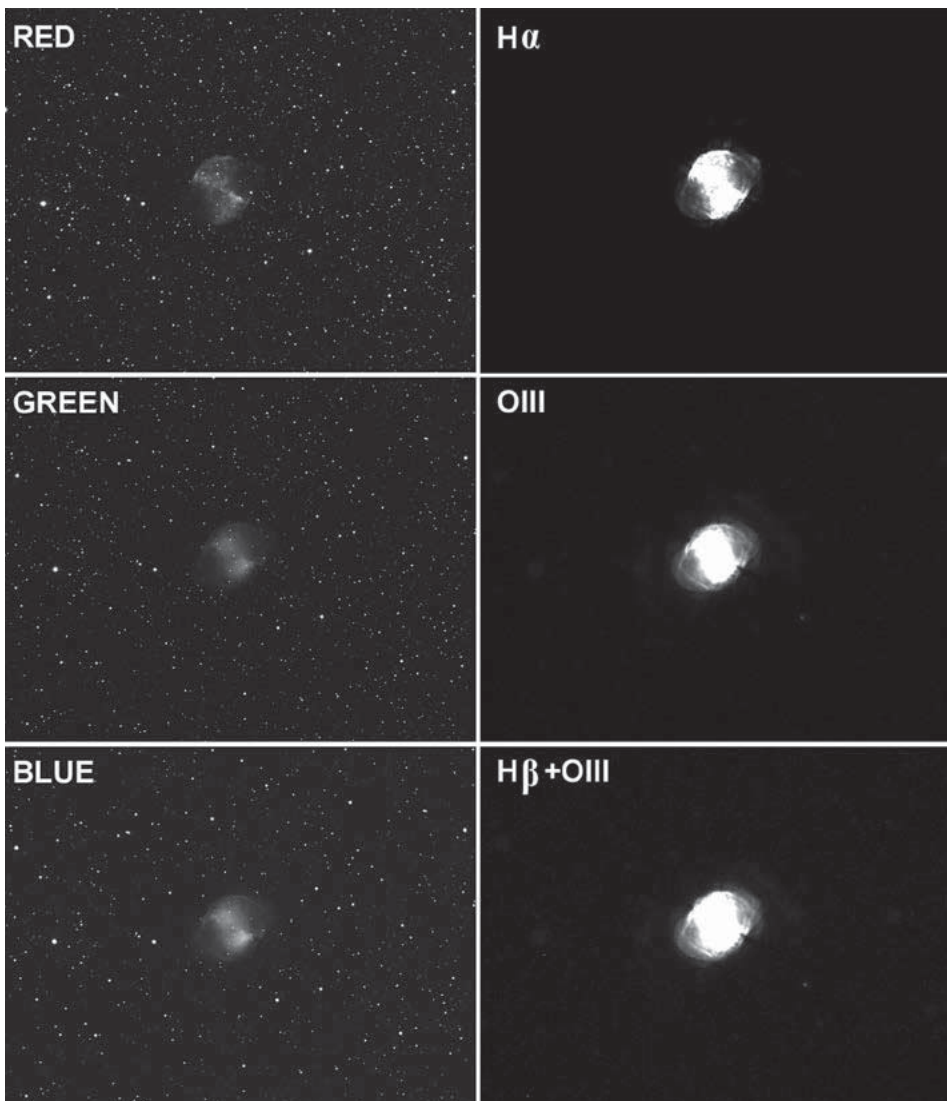


Figure 2. Master broadband and narrowband images



Figure 3. "True color" image of M27 resulting from this procedure

brightness. Objects in the image also contain the effects of skylight, but it's easier to quantify this effect by looking at the "empty" portions of the imagery. Averages are listed below for the images in Figure 2. Note that the average value for the H-beta + O III image is about twice the values for the other images. In adding the H-beta and O III images, we also added their skylight values.

RED	381
GREEN	356
BLUE	376
H-ALPHA	313
O III	343
H-BETA + O III	653

The easiest way to fix this problem is to normalize the skylight brightness among the images. We can do this separately for the broadband images and the narrowband images. To normalize the broadband images, I first noted that the green image had the lowest DN value (356). Using AIP4Win (willbell.com/aip4win/aip.htm), I subtracted 25 DN from each pixel in the red image and 20 DN from each pixel in the blue image. This resulted in each broadband image having approximately the same skylight brightness. For the narrowband images, the H-alpha image had the lowest average skylight brightness (313). I subtracted 30 DN from each pixel in the O III image and 340 DN from each pixel in the H-beta + O III image. This normalized the skylight brightness among the narrowband images. This process not only corrects the color balance of the "empty" portions of the images but also the color balance of the objects in the image.

We're now ready to combine

images. Instead of simply adding images, we'll use the "maximize" function found in many image processing software packages. I used MaxIm DL (diffractionlimited.com/product/maxim-dl). This function looks at each pixel location in two images and determines which has the greater DN value; it then writes this value into the corresponding pixel location of a new image. Since the narrowband images don't contain stars, the stars for the new image will come from pixels in the broadband images. And since the nebula is brighter in the narrowband images than in the broadband images, the nebula for the new image will come from pixels in the narrowband images. Exactly what we wanted!

We now have "hybrid" red, green, and blue



Figure 4. "True color" image of NGC 2174 resulting from this procedure

images created from our pairs of broad-band and narrowband images. These can be combined to produce the final color composite image. Since this was a 16-bit image, I had to do some contrast-stretching using Photoshop

to convert it to an 8-bit version that could be saved as a JPG image.

Figure 3 (previous page) shows the results. In this image, the stars display a natural range of colors without strongly saturated

cores or bloating. The nebula is bright yet still shows a lot of detail. Most importantly, the nebula's colors are realistically rendered, from the soft teal of the O III emissions from the nebula's interior to the intense red of the H-alpha emissions along the nebula's shock fronts.

Figure 4 shows another example, NGC 2174, the Monkey Head Nebula. This is an H II star-forming region. As such, most of its light is due to ionized hydrogen and, in contrast to planetary nebulae, little is due to ionized oxygen. Thus, the nebula glows in the reds of hydrogen emissions.

Keep in mind that this approach is totally objective. All the information used in it came from the images themselves. Prior to contrast stretching of the final result, there was no subjective "fidgeting" with the images to produce a desired appearance. While this approach might not appeal to those who want a more artistically creative result, it does a good job of rendering realistic views of what many astronomical objects actually might look like. ✨

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