MULTI-NARROWBAND FILTER SHOOTOUT

By Jim Thompson, P.Eng

Introduction

For those who have had the opportunity to use astronomical filters, you are probably already aware of the benefits they can provide to your observing or imaging. The ability of a filter to block light pollution and improve contrast depends on how narrow its pass bands are, with narrower bands generally being better.

Over the past couple of years, there seems to have been an ongoing interest from manufacturers in producing the "ultimate filter" – a sort of filter arms race if you will. In an effort to tap into the one-shot colour (OSC) camera user market, and to reject as much light pollution as possible, filter manufacturers are striving to make multi-narrowband (i.e. dual-band, tri-band, or quad-band) filters with narrower and narrower pass bands.

While better performing filters sounds good for us amateurs, there is a cost … literally! Narrower pass bands invariably mean more expensive filters. So, the question then is: "Are fancy filters with super narrow pass bands worth the cost?"

Method

The objective of this article is to compare a number of multi-narrowband filters based on their performance, as determined by: their actual spectral responses and images captured using the same equipment.

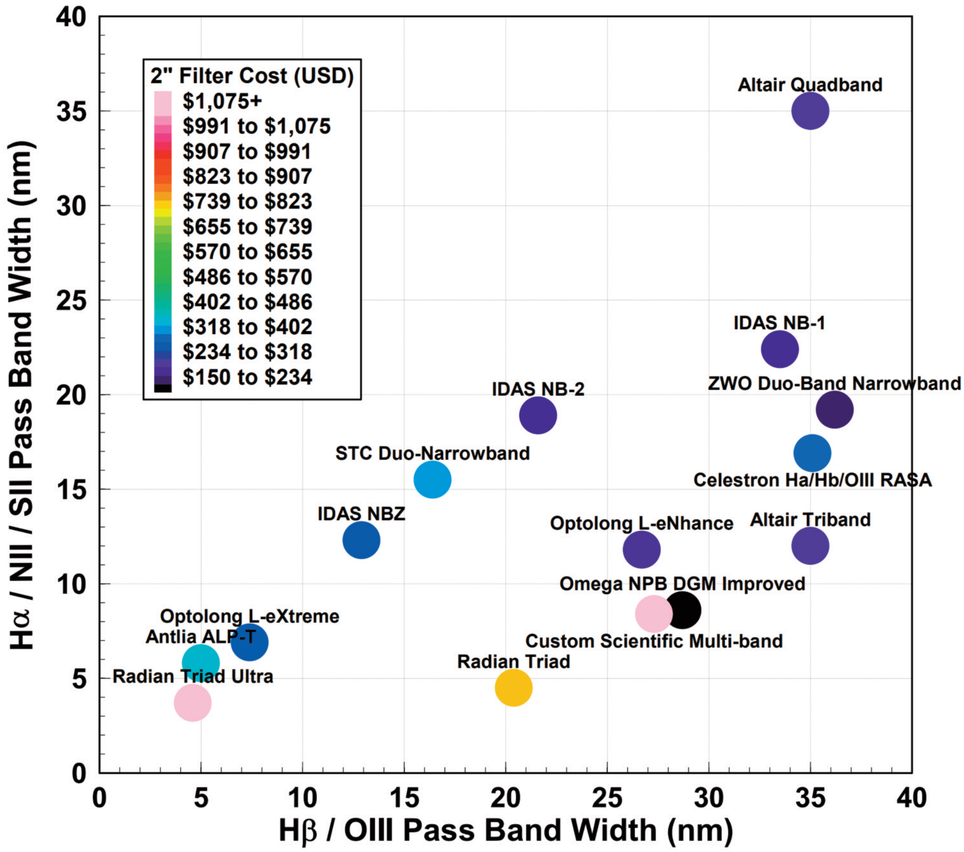

Figure 1 - Commercially Available Multi-Narrowband Filters by Bandwidth & Cost

Spectral transmissivity data, from near-UV to near-IR, was measured using an Ocean Optics USB4000 spectrometer over a range of filter angles. Image data was collected using a ZWO ASI-533MC Pro OSC camera, and a William Optics FLT98 triplet apochromatic refractor with f-ratio f/6.3.

The image data was collected from my backyard in central Ottawa, Canada where the naked eye limiting magnitude (NELM) due to light pollution is +2.9 on average (Bortle 9+).

Two common Winter deepsky targets were used for all the images: the Orion Nebula (M42) with the neighbouring Running Man Nebula (NGC1977), and the Flame Nebula (NGC2024) with nearby Horsehead Nebula (B33).

In terms of what filters to compare,

I had many to choose from. My definition of "multi-narrowband" is any filter with more than one pass band with a width of 35nm or narrower. There are now no less than fifteen different models of multi-narrowband filter available on the market. **Figure 1** presents all the offerings, at least those I am aware of, in terms of their band widths and cost.

For this article I chose to compare the top four filters based on performance: IDAS NBZ, Optolong L-eXtreme, Antlia ALP-T, and Radian Triad Ultra. You can find test results for many of the other filters in Figure 1 in some of my past ATT articles.

Results – Spectrum Measurements

The spectral transmissivity for each filter was measured for a range of filter angles relative to the light path. **Figure 2** presents a plot of the resulting spectral transmissivity data for the case of the filter perpendicular to the light path.

The O-IIIb pass bands for all the filters tested appear to be well centered on the desired wavelength of 500.7nm. The Hα pass band for the Triad Ultra is well centered on the desired wavelength of 656.3nm. For the NBZ and ALP-T their bands are shifted slightly up in wavelength, which is advantageous when the filter is used on fast optics. This shift is by design for the NBZ filter, but I don't know if the same is true for the ALP-T.

The L-eXtreme's Hα pass band is shifted slightly down in wavelength, making it more sensitive to fast optics. Also noted from the measured spectrum data for the Triad Ultra filter was that its S-II pass band is well centered in wavelength, and its Hβ pass band is shifted significantly down in wavelength (not optimal).

The impact of angle on each filter's transmission for some important nebula emission wavelengths is shown in **Figure 3**. As expected, filters with wide pass bands were less sensitive to angle than filters with narrow pass bands, with the most sensitive filter to angle being the Radian Triad Ultra.

As mentioned earlier, my sample of the Antlia ALP-T has a small shift of its Hα pass band which gives it a slight advantage over the L-eXtreme and Triad Ultra in that band. The L-eXtreme has a dual peak response in its O-III pass band, giving it the advantage over the ALP-T and Triad Ultra in that band. The NBZ in comparison has superior transmissivity versus angle to all the filters in both bands.

Figure 3 also has black vertical lines

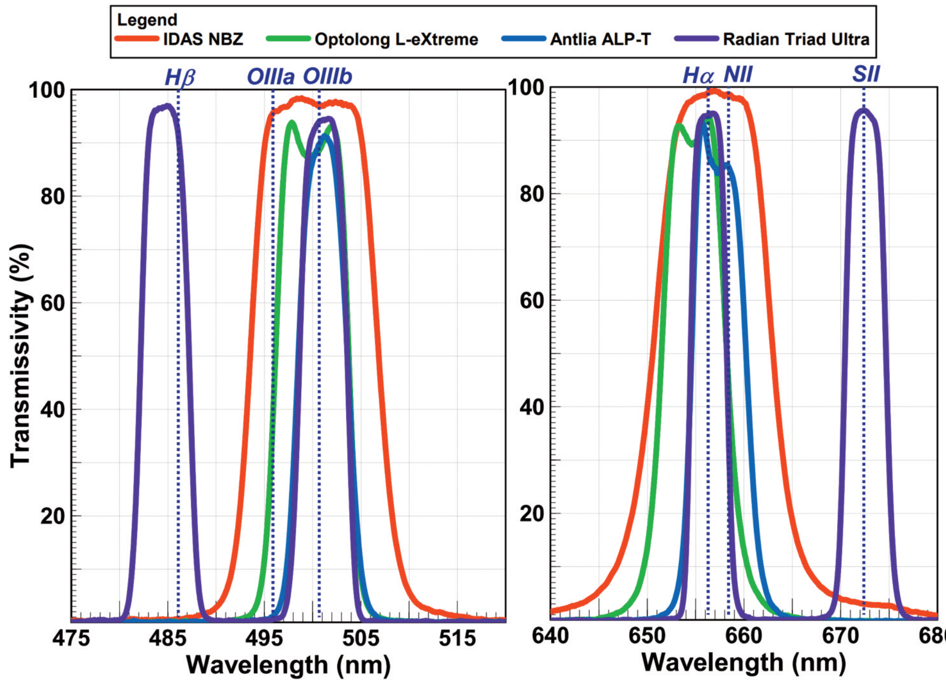

Figure 2 - Measured Spectral Response of Tested Filters

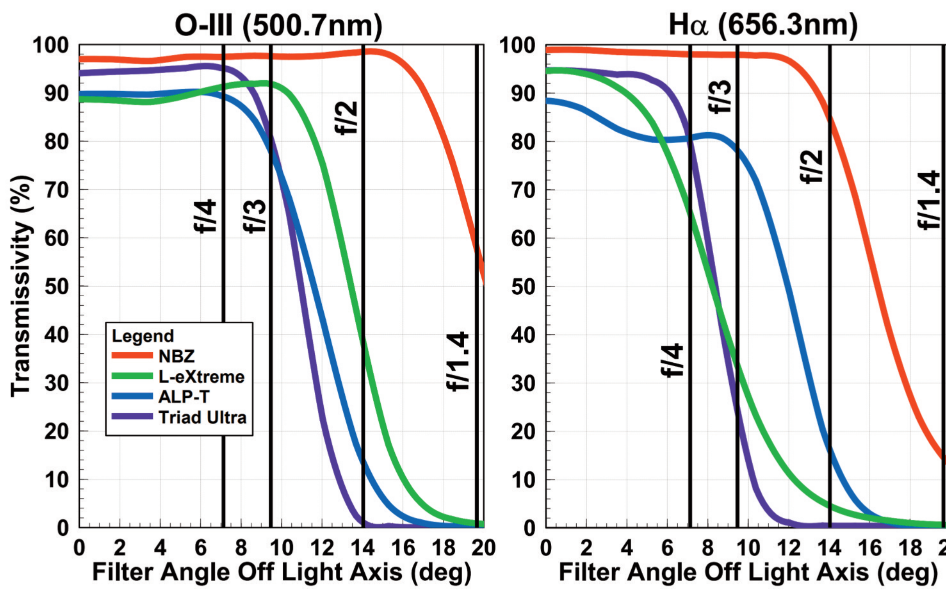

Figure 3 - Measured Impact of Angle on Filter Response

corresponding to different optics f-ratios. These lines are positioned at the angle values corresponding to light coming from the outer edge of the scope's aperture for the noted f-ratio. The net performance of a filter on any particular speed of optics is an area weighted average of the filter's performance, for light angles from perpendicular out to the angle at the outer edge of the aperture.

Net filter spectra for a selection of telescope f-ratios have been calculated using my spectrometer data, and they are available upon request along with a lot of other useful filter statistics such as peak transmission rates and pass band widths.

Knowing the measured spectral response of the sample filters also allowed me to predict the theoretical relative performance of each filter on different kinds of deepsky object. To do this I used the method I developed back in 2012 which uses the spectral response of the filter and sensor combined with the spectral emission from the deepsky object and background sky to estimate the apparent luminance observed.

To help visualize the results of this analysis I have plotted the predicted % increase in contrast for each filter versus the filter's % luminous transmissivity (%LT), a measure of generally how much light is getting through the filter.

Figure 4 shows the resulting plot corresponding to filter performance when using a colour CMOS camera under heavily light polluted skies complete with local LED street lights (i.e. my backyard). Note that these are theoretical predictions of the increase in visible contrast between the object and the background. The absolute values of my predictions may not reflect what a user will experience with their own setup, but the predicted relative performance of one filter to another should be representative.

In general the desired performance for a filter is high contrast increase with high %LT, so the higher and more to the right a filter's performance is in the plot the better. Each filter's performance is plotted as a short line to show how the performance is predicted to change depending on the f-ratio of the telescope you are using the filter with. Slow f-ratio optics are at the right-most end of the line, f/3 is roughly in the middle of the line, and f/2 is at the left-most end of

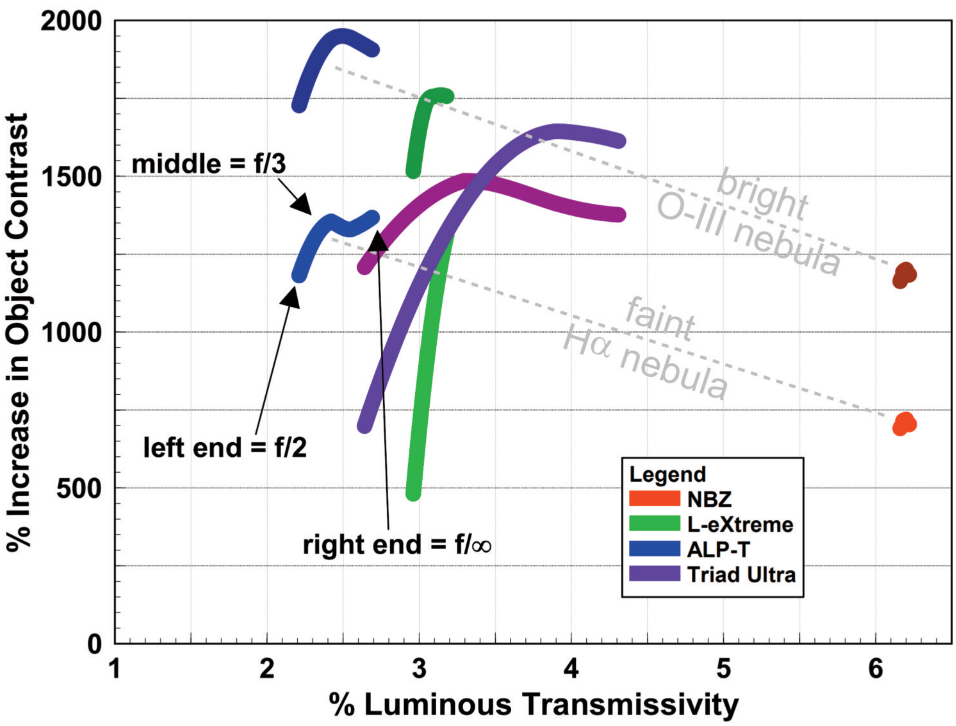

Figure 4 - Predicted Filter Performance – Back Illuminated Colour CMOS, LP w/LED (NELM+2.9)

the line.

I have plotted predicted filter performance for two different types of deepsky object: bright O-III rich nebulae (eg. M27) along the top of the graph, and dim Hα rich nebulae (eg. NGC7000) across the bottom of the graph.

As expected, the predictions suggest that the narrower the filter's pass band (and thus lower %LT), the larger the contrast increase on emission-type nebulae. The NBZ is predicted to deliver a consistent increase in contrast, one that does not change significantly down to an f-ratio of f/2. This is consistent with the measured angle sensitivity data presented in Figure 3.

The L-eXtreme and ALP-T are predicted to deliver a higher increase in contrast than the NBZ, but they are also more sensitive to f-ratio. The L-eXtreme is predicted to be especially sensitive to f-ratio on Hα rich objects.

The Triad Ultra is predicted to be much more sensitive to f-ratio than any of the other filters tested. On slow optics it is predicted to deliver the best performance on Hα targets, but performance not much different than the NBZ on O-III targets. The superior performance on Hydrogen-rich objects is likely due to its narrow pass band at Hβ, something none of the other filters under test have. Nonetheless on average the Triad Ultra is not predicted to perform significantly different than the other tested filters. On emission nebulae it could be argued that the ALP-T has a slight edge in overall object contrast, depending on the particular object you are imaging and the nature of your optics. Another thing to note from Figure 4 is the trade-off between contrast increase and exposure time. For example: the ALP-T filter is predicted to provide a 60% contrast increase over that of the NBZ (1905% vs. 1201%), but at the cost of ~2.3x the exposure (%LT of 2.7 vs. 6.2). In practice this increase in required exposure may be realized by using longer sub-exposures, or by stacking a larger number of subs to achieve a particular signal-to-noise ratio (SNR), or a combination of both.

Results - Imaging

All image data was captured on the same night within a two-hour time window. The camera colour channel gains were adjusted at the start of the imaging session to give a white balanced image with a reference UV/IR cut filter on, and then left fixed for the duration of the data collection with each of the other filters. Data was collected by generating a live stack in Sharpcap of five minutes total duration, which was then saved as a 16bit FITS file.

The exposure time per frame was adjusted for each filter to achieve an image of generally the same level of overall exposure. This was determined qualitatively by observing the extent of image saturation around the core of M42. There were no histogram adjustments made to the live stacks within Sharpcap; black point and white point were left at their default positions, and the gamma slider was positioned in the middle.

For the visual comparison of the images in this article, I chose to work with the full colour images. I first aligned the colour channel histograms for each image in Fitswork v4.47, a free FITS editing software. This was done by adjusting the black point on each colour

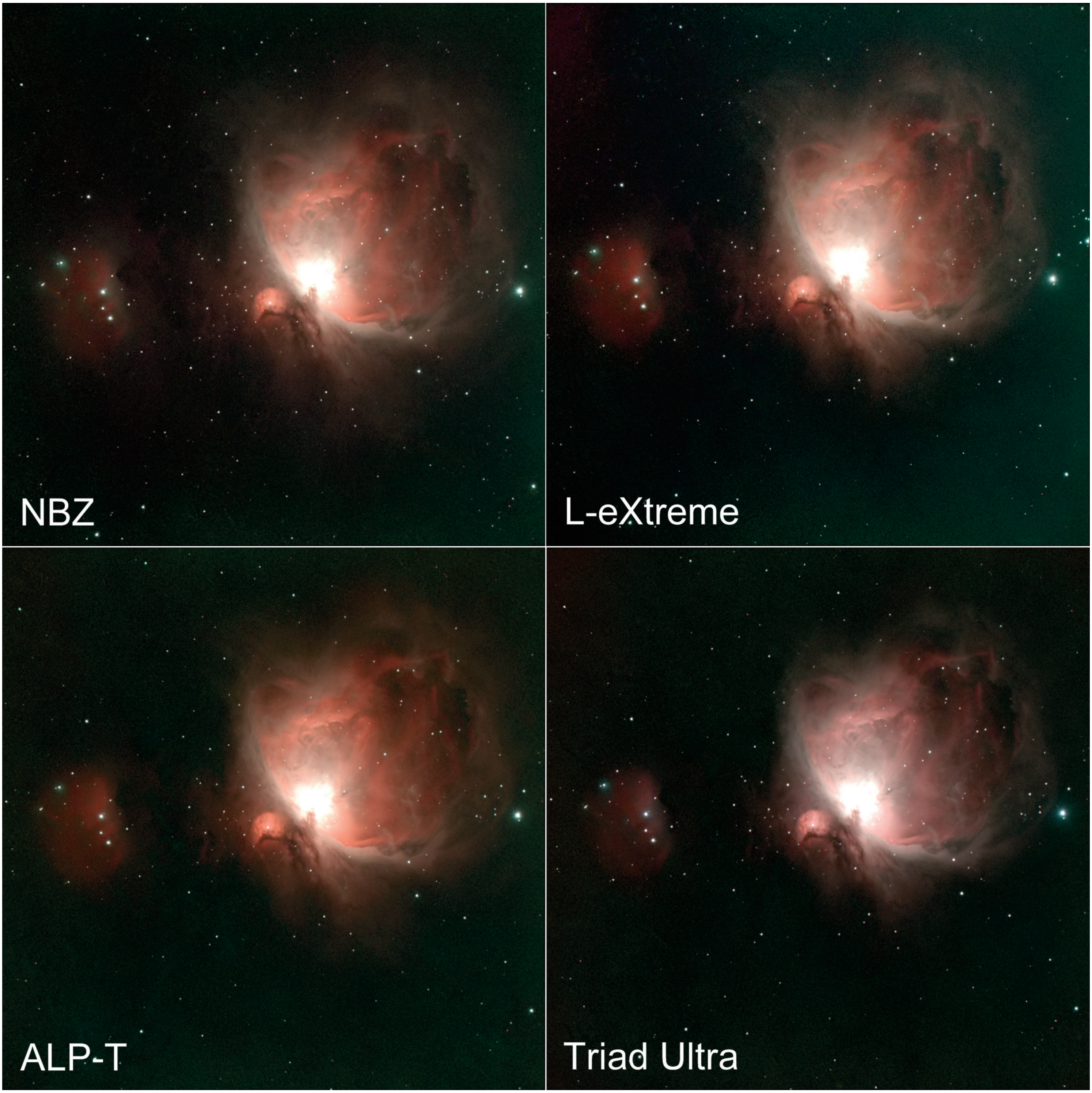

Figure 5 - Image Comparison: M42, Full Colour

channel's histogram until the histogram peaks were all aligned with each other. I then applied the same amount of luminance channel histogram stretching to each image. The resulting images are presented in Figures 5 and 6. A more thorough comparison of each individual colour channel was also performed, the results of which are available upon request.

Observations & Conclusions:

In my opinion, the trend in contrast improvement predicted by my spectral analysis was reflected in the images that

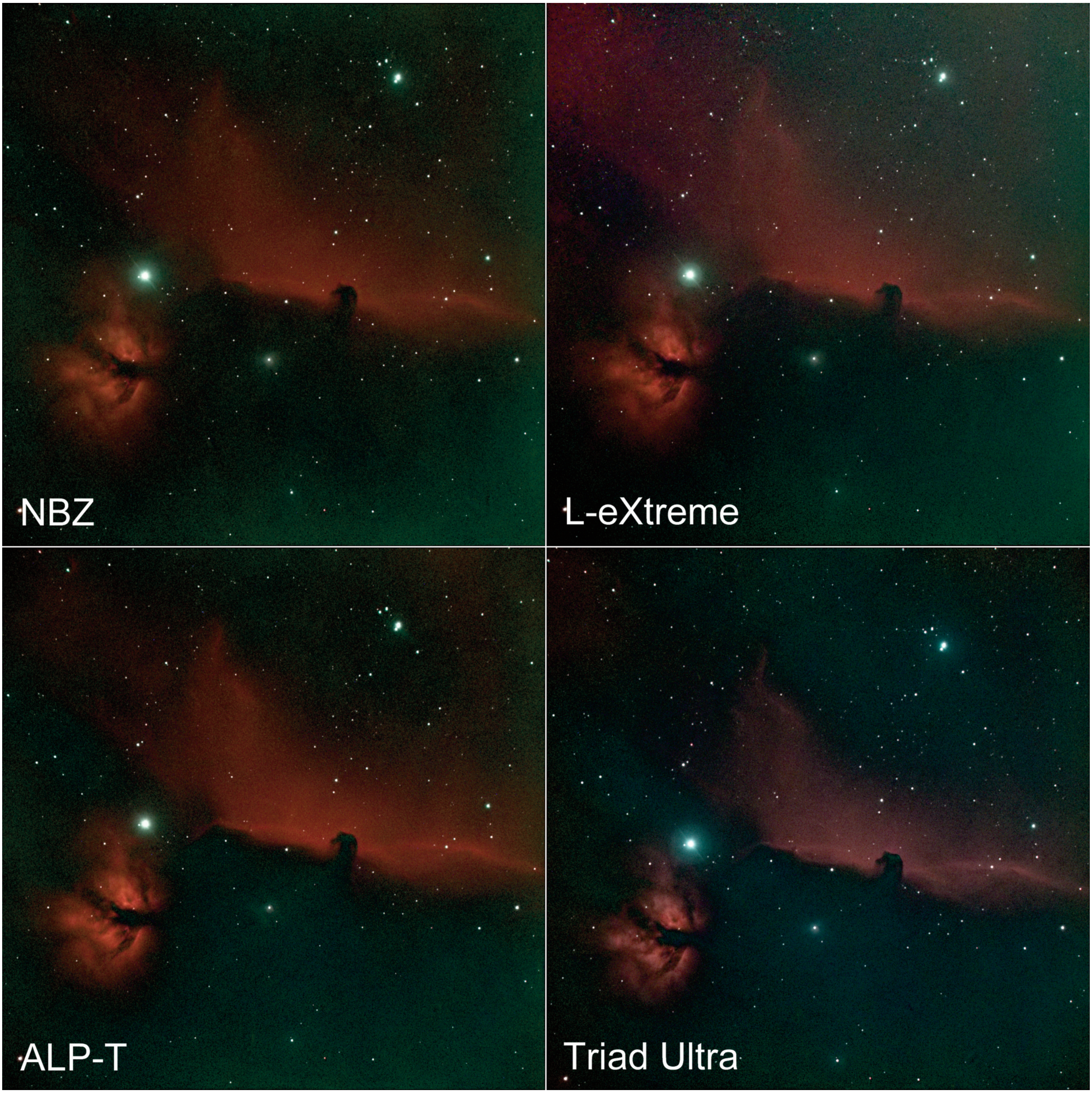

Figure 6 - Image Comparison: Flame Nebula, Full Colour

were recorded. The observations I made from the collected images were as follows.

1 - The NBZ and L-eXtreme had measured spectra that closely matched with that marketed by their manufacturers, with the NBZ being almost exactly the same. The ALP-T and Triad Ultra had measured spectra that varied from that marketed by their manufacturers; the ALP-T having a below spec Hα pass band, the Triad Ultra having a below spec O-III pass band. Although my measurements are a single sample, my results do hint at a level of risk asso-

ciated with consistency between manufacturing batches.

2 - On moderate to slow optics (> f/3), the ALP-T delivered the highest contrast of the filters tested. The NBZ filter delivered the most consistent contrast increase across a broad range of optics speeds.

3 - Many of the filters tested showed halos around bright stars, especially around the bright star Alnitak in Flame Nebula images. The halo is quite prominent with the L-eXtreme, and Triad Ultra, but is more subdued with the NBZ. The halo is all but gone when using the ALP-T. I believe the halo is due to a reflection between the camera and the filter. I did not explore the effect of varying the distance between camera and filter on the extent of the visible halo.

4 -The difference in contrast that can be observed in my images when comparing one filter to another is small. It can be perceived that the ALP-T shows more detail than the L-eXtreme, and the L-eXtreme more detail than the NBZ, but the differences are subtle. Perhaps the differences would be more evident if I used a longer total exposure time.

5 - My predictions of contrast improvement (Figure 4) suggest that there isn't a significant difference in net performance between the L-eXtreme and the Triad Ultra; the Triad Ultra is better on Hα but not as good on O-III. This prediction was in my opinion born out by my image data; the contrast and detail observed in the images collected using these two filters on average was not significantly different.

6 - The colour saturation in the images captured using the Triad Ultra was less than that produced using the other filters. This may be a result of the Triad Ultra's pass band at Hβ letting in more light pollution from the blue part of the spectrum, for example from LED streetlights. It may also be that the cyan coloured Hβ emissions passed by the filter tend to wash out the red coloured Hα and green coloured O-III emissions.

7 - The relative cost of the tested filters seems reasonable, with the exception of the Triad Ultra. The incremental cost increase moving from NBZ to L-eXtreme, and L-eXtreme to ALP-T is accompanied by a corresponding increase in contrast. The Triad Ultra however, not demonstrating significantly different performance than the other three filters tested, did not justify to me its high cost.

If you have any questions, please feel free to contact me: Jim Thompson topjimmy@rogers.com. ATT