# TESTING THE ULTRA-NARROW-BAND FILTERS

By Jim Thompson, P.Eng

## Introduction

Multi-narrowband filters, i.e. filters with two to four narrow pass bands located at key nebula emission wavelengths like Oxygen-III (O-III) or Hydrogen Alpha (H-α), have really come of age in the last couple of years. When paired with a one-shot colour (OSC) camera, these filters have opened the door to amateurs imaging objects never thought possible before from urban observing sites.

The growing popularity of multi-narrowband filters has fuelled a filter "arms race", with several companies vying for the position of "best performing filter". Six months ago the narrowest pass bands one could buy in a multi-narrowband filter was 5nm (the Antlia ALP-T), but now there are filters on the market with pass bands only 3nm wide including the Optolong L-uLtimate and the Askar Colour Magic Duo-Narrowband.

I had an opportunity to test these new ultra-narrow filters and compare them to existing multi-narrowband filters to see what sort of performance increase one can hope to realize using filters as narrow as 3nm. This article is an excerpt from a more complete test report, which is available from the author upon request.

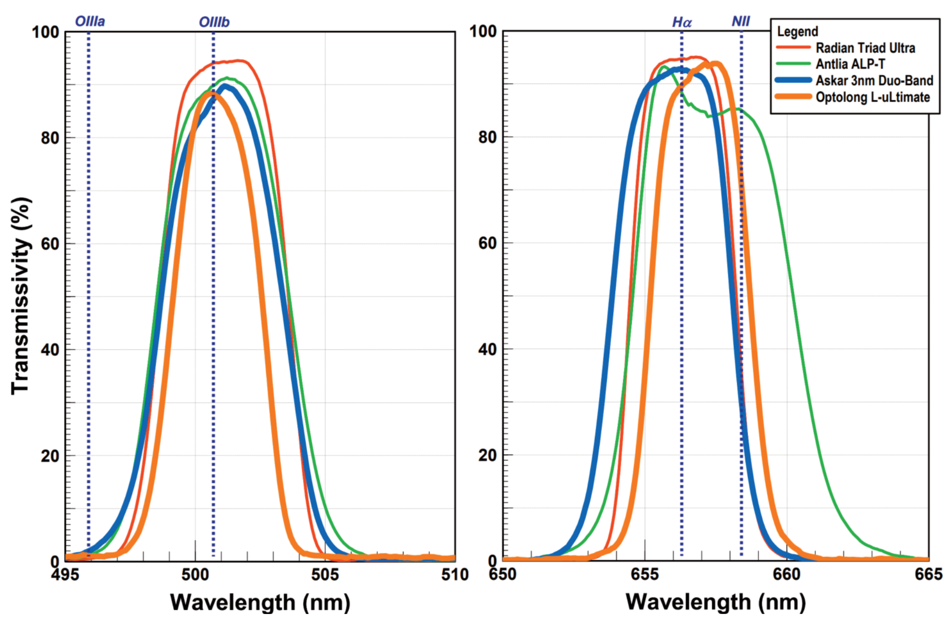


**Figure 1: Measured Spectral Response of Tested Filters – Filter Perpendicular to Light Path**

## Method

The objective of my test was primarily to evaluate the performance of the Optolong L-uLtimate filter, comparing it to other multi-narrowband filters already on the market. It was a lucky happenstance that a sample of the Askar filter came into my possession at the same time, allowing me to evaluate it as well.

The list of filters considered in my comparison is as follows (prices for 2" version):

- Radian Triad Ultra – 5nm/4nm/4nm/4nm bands, $1075USD
- Antlia ALP-T – 5nm/5nm bands, $380USD
- Askar Colour Magic Duo-Narrowband – 3nm/3nm bands, $539USD
- Optolong L-uLtimate – 3nm/3nm bands, $389USD

If theory is born out in the test results, there should be an observable improvement in deepsky object contrast as I move down

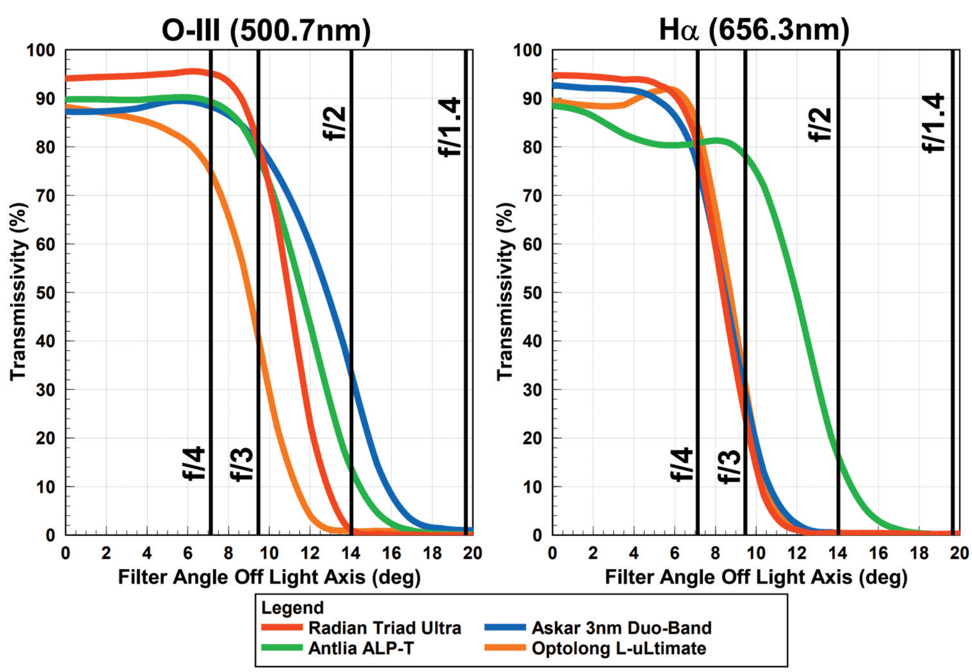


Figure 2: Measured Impact of Angle on Filter Response

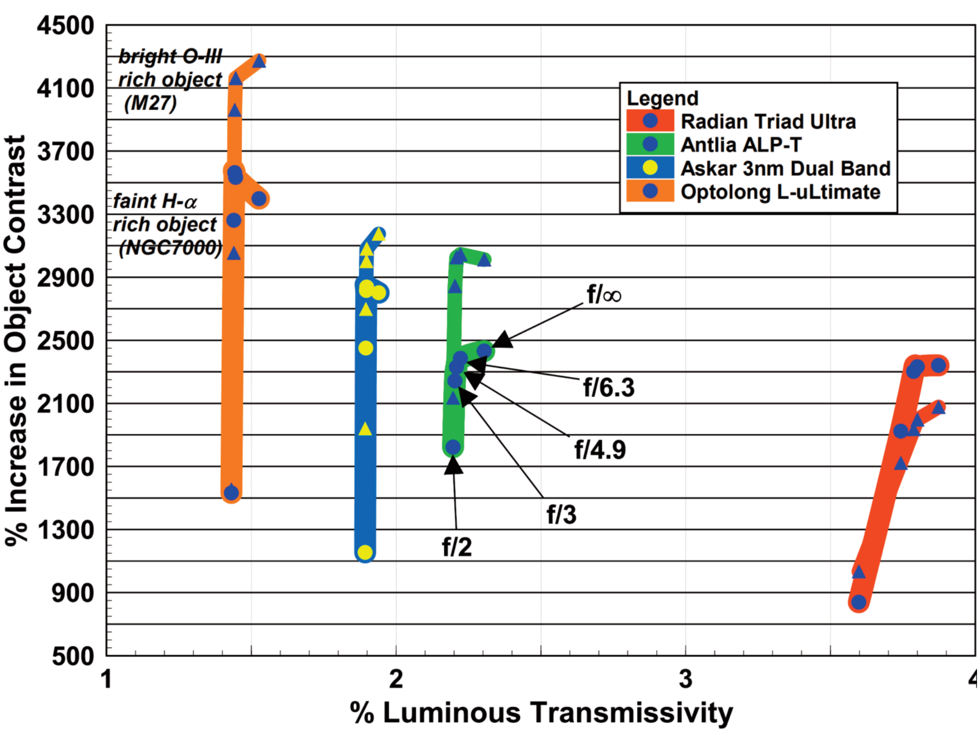


Figure 3: Predicted Filter Performance: Back Illuminated OSC CMOS, Bortle 9+ Sky

the list of filters since they have progressively narrower pass bands. Filter performance was evaluated during this test based on the increase in contrast between the observed object and the background, which is a measurable quantity. It was evaluated computationally using the measured filter spectra, and by direct measurement from images captured using each filter and a one-shot colour (OSC) camera. The image data was also used to evaluate the signal-to-noise ratio (SNR) achieved using each filter.

The spectrometer data was collected in my basement workshop with an Ocean Insight USB4000 and a broad spectrum light source. Filter spectrums were measured for a range of filter angles relative to the light path, from 0° (perpendicular) to 20° off-axis. The spectrometer was recently upgraded, replacing the entrance slit and diffraction grating, to give a wavelength resolution of 0.5nm.

Image data was collected using a ZWO ASI533MC Pro OSC camera, and one of three different telescopes: Mallincam VRC-10” Ritchey-Chretien + Astrophysics 0.67x focal reducer (f/6.5), William Optics FLT98 triplet apochromatic refractor (f/6.3), or Askar FMA230 quad apochromatic refractor (f/4.5). Images were all 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+).

Images of four different deepsky objects were captured, each on a different evening as follows: entire Veil Nebula (Cygnus Loop) on September 8th using FMA230; M27 Dumbbell Nebula on September 29th using VRC10, NGC6960 Western Veil Nebula on October 18th using FLT98; and M42 Orion Nebula on October 22nd using FLT98.

The purpose of selecting different deepsky objects was to use the filters on targets with varying amounts of H-α and O-III emission. Note that the sample of the Askar filter did not arrive until the beginning of October, so image data was collected with that filter only during the last two imaging sessions.

## Results – Spectrum Measurements

**Figure 1** presents a plot of the measured spectral transmissivity data for the case of the filter perpendicular to the light path. Both of the 3nm filters have their O-III pass band center wavelengths (CWL) well positioned over 500.7nm.

The Askar filter’s H-α pass band CWL is well centered on 656.3nm, but the L-uLtimate filter’s H-α band CWL is shifted


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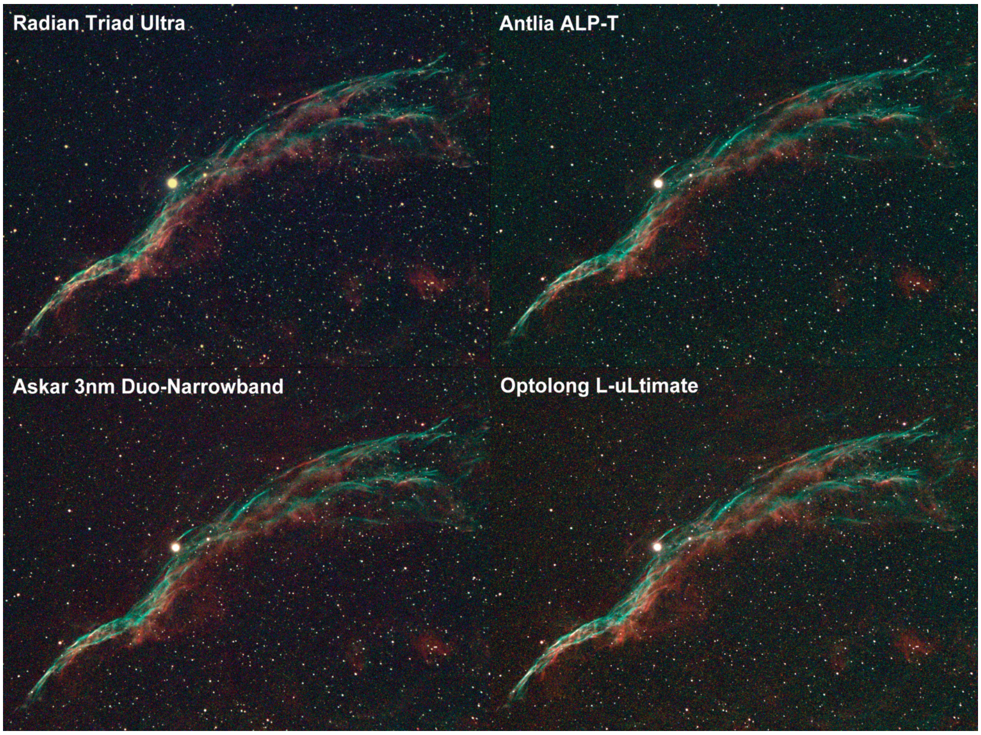


**Figure 4: Imaging Results – NGC6960 Western Veil Nebula, RGB**

slightly to the right which should improve performance at faster f-ratios. Although advertised to have the same full width half maximum (FWHM) band width, the Askar filter was measured to have significantly wider pass bands than the L-uLtimate filter.

FWHM values of 4.7 and 4.1nm were measured for the Askar filter's O-III and H-α bands respectively, while the corresponding values for the L-uLtimate were measured to be 3.4 and 3.3nm. Peak transmissivity values in each band are comparable between the two 3nm filters. Discussion of the results for the other filters under test has already been presented in my August 2022 ATT article: "Multi-Narrowband Filter Shootout".

The impact of angle on each filter's respective emission band transmission is shown in **Figure 2** for the O-III and H-α bands. In general, filters with wider pass bands were less sensitive to angle than filters with narrow pass bands. There can be, however, a significant amount of variation found due to the combination of FWHM and CWL - filters that have their bands shifted to the left perform more poorly than those with bands shifted to the right. As a result of this, the Askar filter has lower sensitivity to angle for the O-III band than the L-uLtimate, but worse sensitivity to angle for the H-α band.

Note that Figure 2 also has black vertical lines representing 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. For example - light from the outer edge of an f/2 scope's optics passes through the filter at a 14° angle. The net performance of a filter on any particular speed of optics is equal to the area weighted average of the filter's performance over the whole aperture, from the center of the optics (perpendicular light path) out to the edge of the aperture (max light path angle).

Knowing the measured spectral response of the sample filters also allowed me to predict the theoretical relative performance of each filter when imaging an emission nebula. **Figure 3** shows a plot of predicted contrast increase when using a OSC CMOS camera under heavily light polluted skies. Note that these are theoretical predictions and the absolute values may not reflect what a user will experience with their own setup, however the relative performance of one filter to another should be representative.

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 top right-most end of the line, f/3 is roughly in the middle of the line, and f/2 is at the bottom left-most end of the line. I have plotted predicted filter performance for two different types of nebulae: bright O-III rich like M27 the Dumbbell Nebula (thinner line w/ triangle data markers); and faint H-α rich like NGC7000 the North American Nebula (thicker line w/ circle data markers).

As expected, the predictions suggest that the narrower the filter's pass bands (and thus lower %LT), the larger the contrast increase. The exception being the Triad Ultra's performance on faint H-α rich nebula, which is predicted to be comparable to that of the 5nm wide ALP-T, presumably because of the presence of a pass band at H-β that adds to the total nebula emission passed by the filter.

The Askar filter, with its pass bands measured at wider than 3nm, is predicted to perform more similar to the ALP-T than the L-uLtimate. The L-uLtimate filter has the narrowest pass bands and therefore is predicted to deliver the largest increase in contrast. The sensitivity of each filter to f-ratio is also evident in the length of each line on the plot, with filters having the narrowest pass bands predicted to be the most sensitive to f-ratio.

Another thing to note from Figure 3 is the trade-off between contrast increase and exposure time compared with the other filters under test. For example: the L-uLtimate

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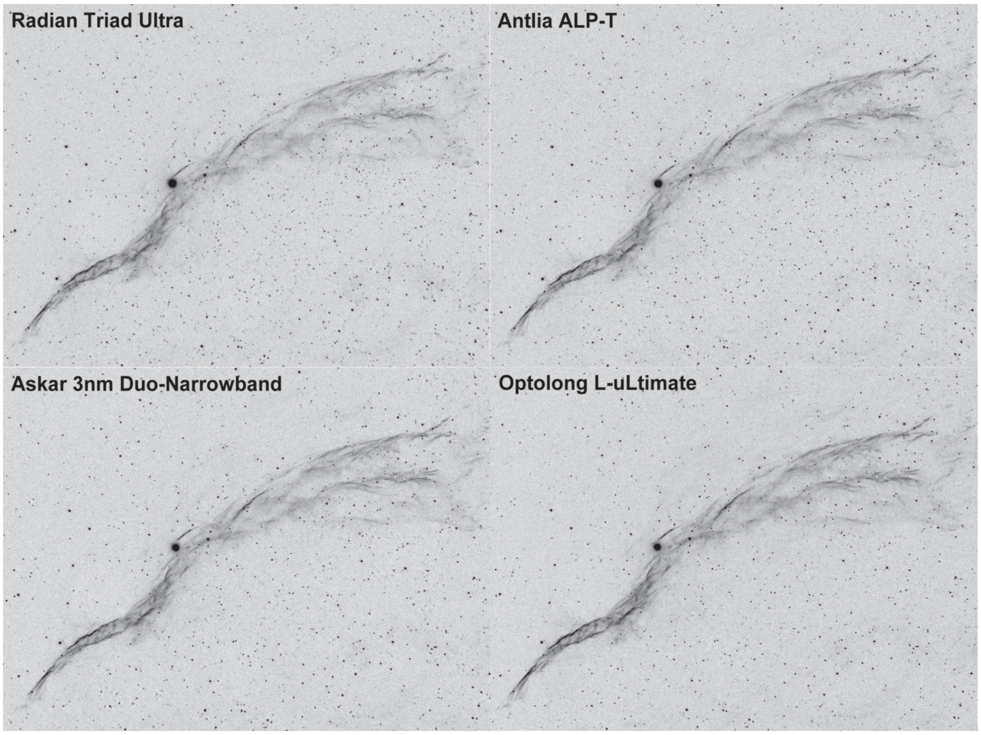


**Figure 5: Imaging Results – NGC6960 Western Veil Nebula, Green Channel**

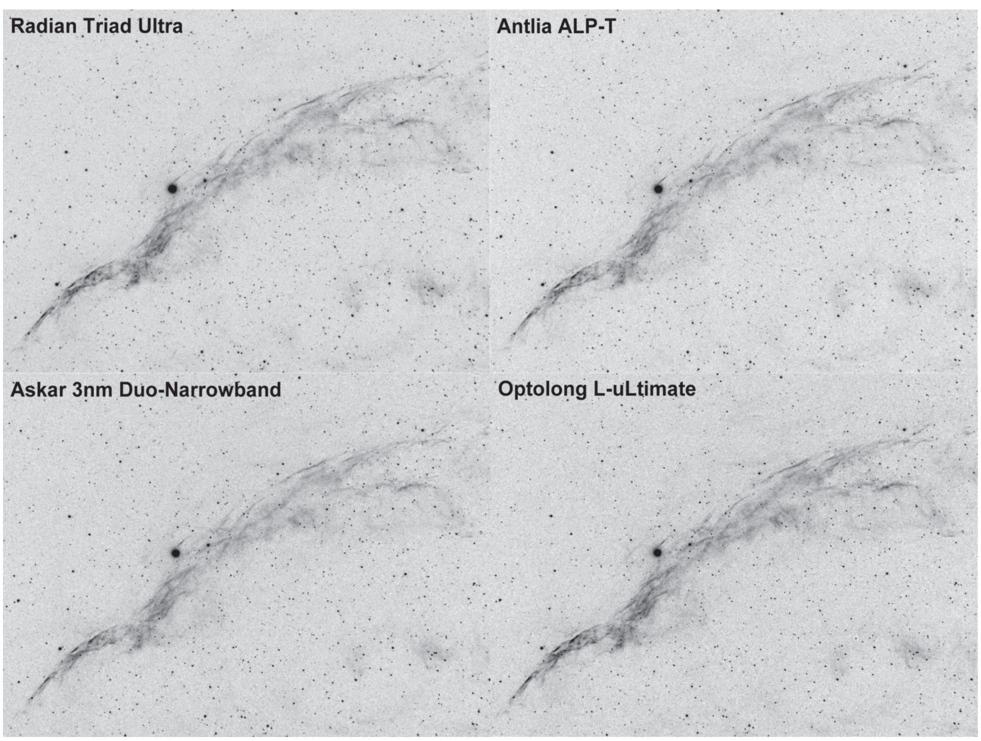


**Figure 6: Imaging Results – NGC6960 Western Veil Nebula, Red Channel**

filter is predicted to provide a contrast increase that is 52% larger than the Triad Ultra on faint H-α nebulae (3533% vs. 2332% @ f/6.3), but at the cost of 2.6x the exposure time (%LT of 1.45% vs. 3.80%). Before purchasing one of these new 3nm filters, it is important for the user to understand what the impact will be on the way they collect their image data.

## Results - Imaging

Although images were collected on four separate occasions during this test, only images from Oct. 18th are presented here. Images from the other three nights can be found in the full test report. The images were generated by live stacking 60 second sub-exposures in Sharpcap to create an image with five minutes total exposure. The resulting colour images are provided in **Figure 4**.

All the images had their histograms adjusted in exactly the same way using Fitswork v4.47, so that they provide as fair a visual comparison as possible. To further assist with the visual comparison, the green and red colour channels are compared separately in **Figures 5 and 6**. The green channel focuses relative filter performance on O-III emissions, and the red channel on H-α emissions.

In general, the differences visible between filters on the same target are very subtle. Only after close examination is it possible to identify features that are more prominent in one filter's image than another's. All the filters tested delivered images with good contrast and detail from my Bortle 9+ backyard. To be able to extract more quantitative observations it was required to do some image analysis using software tools.

Using the captured image data I was able to directly measure the contrast increase delivered by each filter, putting a number to what was already observed qualitatively from the images. This was accomplished by using AstroImageJ to measure the average luminance from two common areas in the images: a dark background area, and a bright nebulous area.

Measurements of luminance average and standard deviation were taken from the original un-edited FITS files in each colour channel, and the contrast increase calculated. The resulting contrast increase measurements from all the imaging sessions are plotted in **Figure 7**, along with the corresponding prediction for each filter. The absolute value of the measurements are consistently below the predictions, however the relative performance of one filter to the other matches the prediction very well. There are a number of reasons why the magnitude of the measurements might not match the predictions, the most important reason being the sky conditions during the imaging sessions (i.e. transparency) were likely worse than the ideal value assumed in the prediction calculations.

The measurements of luminance from the images also allowed me to evaluate signal-to-noise ratio (SNR). When I extracted the average luminance values from each image in AstroImageJ, I also recorded the standard deviation (σ). This allowed me to calculate the SNR achieved by each filter, as well as a cost effectiveness value in $USD per unit SNR. The SNR measurement results corresponding to the images presented in Figure 5 are shown in **Figure 8**. As one would hope, there was a gradual increase in the SNR of the nebula observed as the filter FWHM was decreased, with the L-uLtimate filter delivering the best SNR of the filters tested.

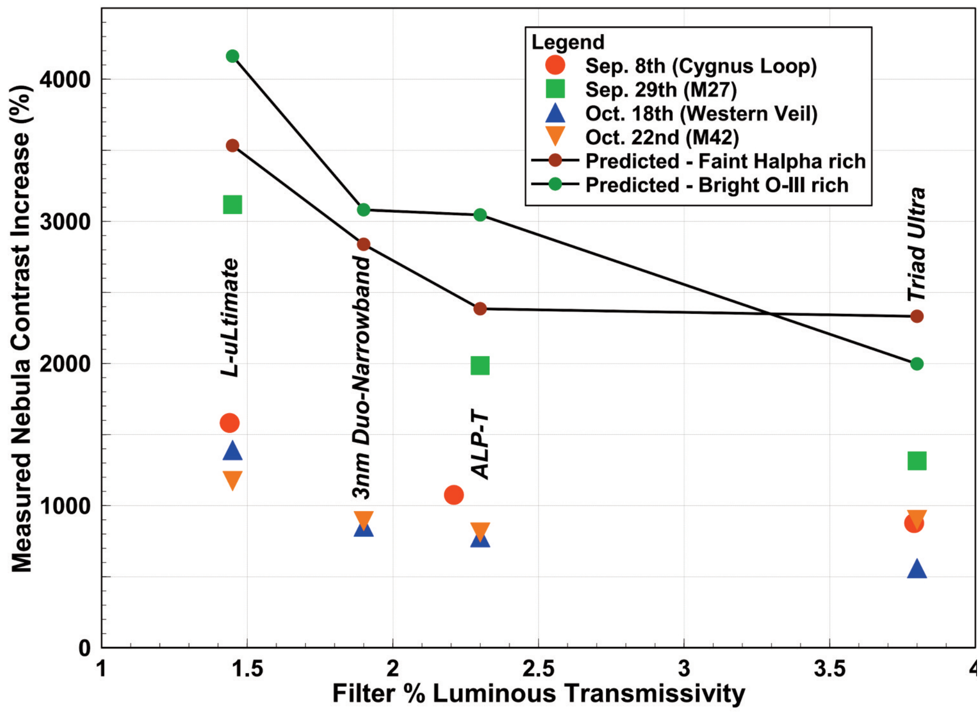


**Figure 7: Measured Nebula Contrast Increase vs. Predicted**

| Filter | %LT @ f/6.3 | SNR (5x60s) | $USD/ SNR |
|---|---|---|---|
| No Filter | 100% | 0.40 | - |
| Radian Triad Ultra | 3.80% | 2.65 | $406 |
| Antlia ALP-T | 2.22% | 2.77 | $137 |
| Askar Colour Magic 3nm Duo-Narrowband | 1.90% | 3.02 | $178 |
| Optolong L-uLtimate | 1.45% | 3.61 | $108 |

**Figure 8: Measured Nebula SNR, Oct. 18th Imaging Session**

## Star Halos

A performance parameter that I have not devoted much attention to in the past, but that has been brought to my attention as an important detail to astrophotographers, is the extent to which a filter displays halos around bright stars.

My investigation of this topic has spun-off an entirely new and rather elaborate test program, the results of which I will report on soon. In the meantime I can report that around most stars the Optolong filter displayed little or no halos, the exception being young hot blue stars for which the L-uLtimate did display subdued halos. The Askar filter on the other hand displayed virtually no halos on any stars, regardless of how hot they were.

## Conclusions

Based on the results of the testing described above, I have made the following conclusions:

1. Of the two 3nm filters tested, only the L-uLtimate had measured properties that were fully consistent with the manufacturer's specifications. The Askar filter was measured to have peak transmission values consistent with specifications, but the FWHM for the filter's two pass bands were measured to be significantly wider than spec.
2. The L-uLtimate filter, having the narrowest pass bands of the filters tested, delivered the largest increase in nebula contrast. This was demonstrated both by analysis (spectrums) and by test (imaging).
3. To realize the full advantage of the narrower filters requires the use of longer sub-exposure times. The extent to which the filter affects sub-exposure time is proportional to the %LT values calculated for each filter from their measured spectrums.
4. In terms of cost-performance benefit, the L-uLtimate filter has the best $USD per unit SNR at $108. The Triad Ultra and Askar filters are not priced competitively relative to the other filters having a $USD per unit SNR of $406 and $178 respectively.
5. The L-uLtimate filter produces very subdued but still visible halos around hot bright stars. The Askar filter does not seem to produce any discernable halos around stars.

If you have any questions, please feel free to contact me. ATT