Testing the Player-One Pro Dual-Band Filter

by Jim Thompson, P.Eng
Test Report – October 12th, 2023

Introduction:
The marketplace for high performance narrowband filters grows every day. New filter models continue to be released by existing original equipment manufacturers (OEMs), but also new OEMs are making their way onto the scene. One such new imaging equipment manufacturer is the Chinese company Player One Astronomy. They have introduced an extensive line of solar system and deepsky object imaging cameras, but also a broad selection of imaging filters. Of particular interest to one-shot colour (OSC) camera owners is their Anti-Halo PRO Dual-Band Ha+OIII filter, which has 3nm wide pass bands. This test report compares this new Player One filter to other multi-narrowband filters in the same class.

Objective:
The objective of this test report is to evaluate the performance of the new Player One Dual-Band filter, comparing it to the other two 3nm filters on the market, the Optolong L-uLtimate and Askar Colour Magic Duo-Narrowband (see Figure 1). Thus, the list of filters considered in this test report is as follows (quoted price for 2" version):

- Optolong L-uLtimate – $389USD
- Player One Astronomy Anti-Halo PRO Dual-Band Ha+OIII – $499USD
- Askar Colour Magic Duo-Narrowband – $539USD

Figure 1 Photo of Filters Under Test

My samples for each of these filters were provided courtesy of each of the respective OEMs in exchange for my providing an independent and unbiased evaluation of their performance. The Optolong and Askar filters have been previously tested and reported on by me, but have new imaging data collected for them as part of this comparison test. Filter performance was evaluated based on the increase in contrast between the observed object and the background, which is a measurable quantity. It was evaluated quantitatively using the measured filter spectra combined with the spectra of several common deepsky objects, and by direct measurement from images captured using each filter and a OSC camera. The spectrometer and image data was also used to evaluate the signal-to-noise ratio (SNR) achieved using each filter.

Method:
Testing consisted of data collection from the following sources:

- Spectral transmissivity data, from near-UV to near-IR, measured using an Ocean Optics USB4000 spectrometer; and
- Image data, collected using two different setups:
  - Askar FMA230 apochromatic refractor (f/4.6) with ZWO ASI533MC Pro; and
  - William Optics FLT98 apochromatic refractor (f/6.3) with ZWO ASI585MC.

The spectrometer data was collected in my basement workshop with the 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.

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+). I switched filter configurations using a ZWO 2” filter drawer. Each time I changed filters I refocused on a conveniently located bright star using a Bahtinov mask. Images of three different targets were captured as follows:

1. August 16th, Veil Nebula (NGC6960/6995), using FMA230 + ASI533
2. August 28th, star Deneb (1.25 mag, 8500K), using FLT98 + ASI585
3. August 28th, Dumbbell Nebula (M27), using FLT98 + ASI585

The purpose of selecting different deepsky objects was to use the filters on targets with varying amounts of H-α and O-III emission. The bright star Deneb was selected to evaluate filter generated halos. The waxing gibbous Moon was in the sky for the August 28th tests but was far enough away in the sky (>45°) to not affect testing.

Results –Spectrum Measurements:
Using the test method mentioned above 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 Optolong and Askar filters have their O-III pass band center wavelengths (CWL) well positioned over 500.7nm, while the Player One filter is shifted ~1nm to the left. The Askar filter’s H-α pass band CWL is well centered on 656.3nm, but the Player One filter is shifted again ~1nm left, and the Optolong filter ~1nm right. A CWL shift left will make the filter more sensitive to angle, and a shift to the right makes the filter less sensitive. In terms of bandwidth the Player One and

Optolong filters are consistent with their design specifications. The Askar filter however was measured to have significantly wider pass bands than the other two filters, well outside its design spec. Peak transmissivity values in each band are comparable between the three filters, being >85% for O-III and >90% for H-α.

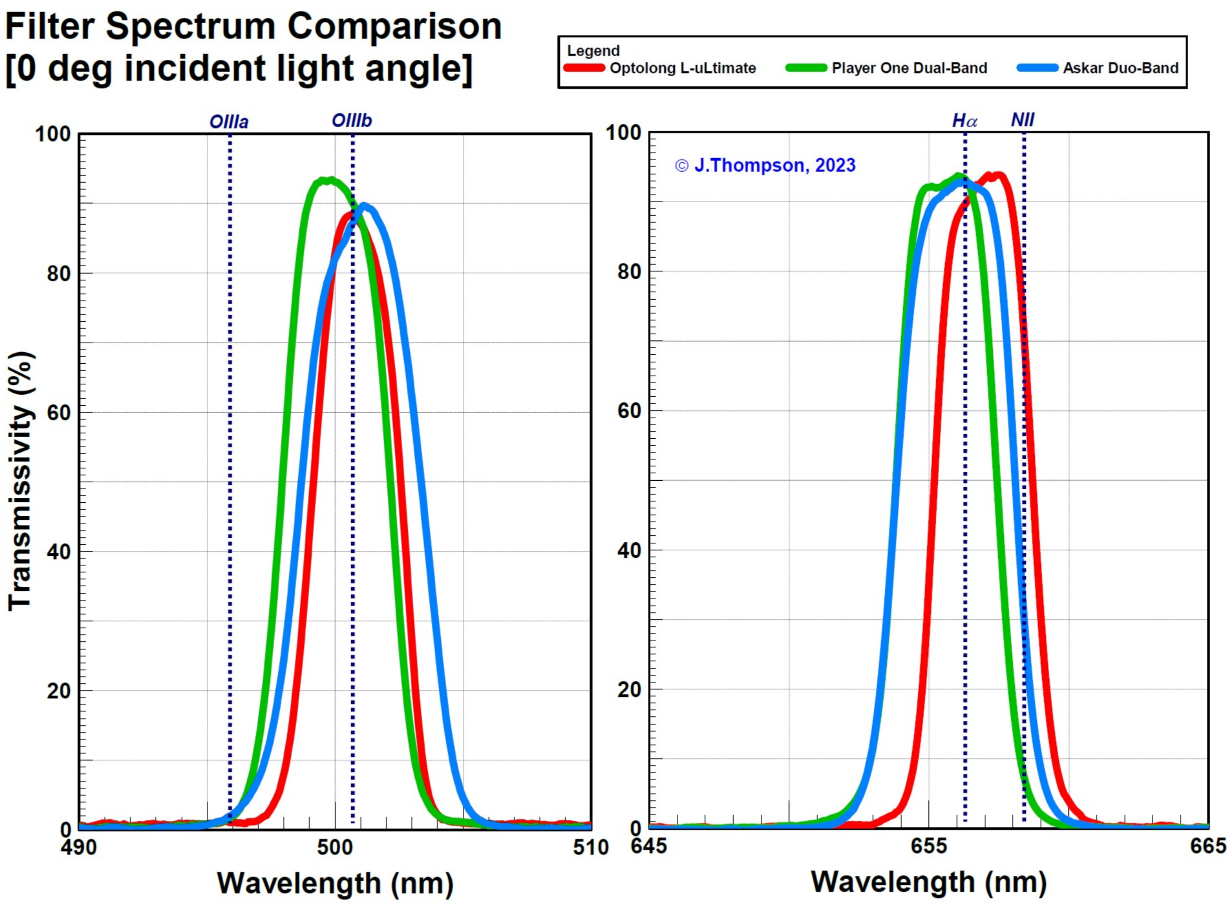


Figure 2 Measured Spectral Response of Tested Filters –Filter Perpendicular to Light Path

The impact of angle on each filter's respective emission band transmission is shown in Figure 3 for the O-III and H-α bands. A significant amount of angle sensitivity variation was observed in the O-III band, but all three filters respond pretty much identically in the H-α band.

Figure 3 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: for an f/2 scope the light from the outer edge of the optics is passing through the filter at a 14° angle. The net performance of a filter on any particular speed of optics is an area weighted average of the filter's performance, from the center of the optics (perpendicular light path) out to the edge of the aperture (max light path angle).

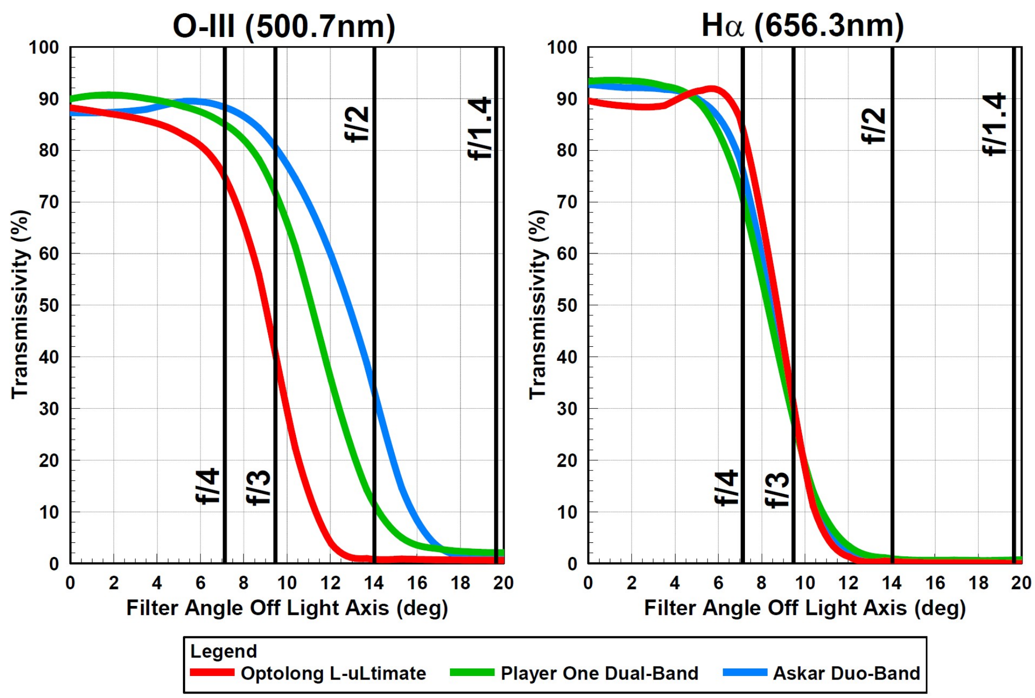


Figure 3 Measured Impact of Angle on Filter Response

Using the measured filter spectra at each angle I have calculated a net filter spectrum for a selection of telescope f-ratios. The area averaging process is illustrated in Figure 4. Essentially the aperture of the scope is divided into rings defined by the angles at which I have measured filter data. The percentage each ring is of the total primary optical area is the weighting applied to that particular spectrum in the average. Figures 5 through 8 present the resulting net spectra for the different speeds of telescope. The shift in filter response between that shown in Figure 2 and for the f/6.3 telescope (Figure 5) is almost zero, but is very significant for the f/2 scope (Figure 8). The effects of filter band shift are worse on RASA and Hyperstar scopes due to the large central obstruction which results in a larger percentage of the light having to pass through the filter at an angle.

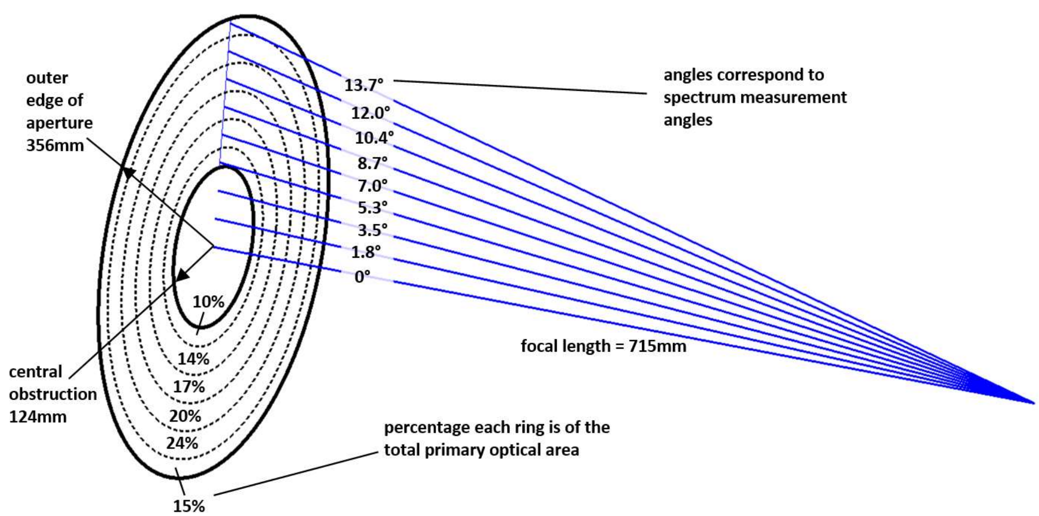


Figure 4 Illustration of Area Weighted Average Filter Response Calculation – C14 Hyperstar

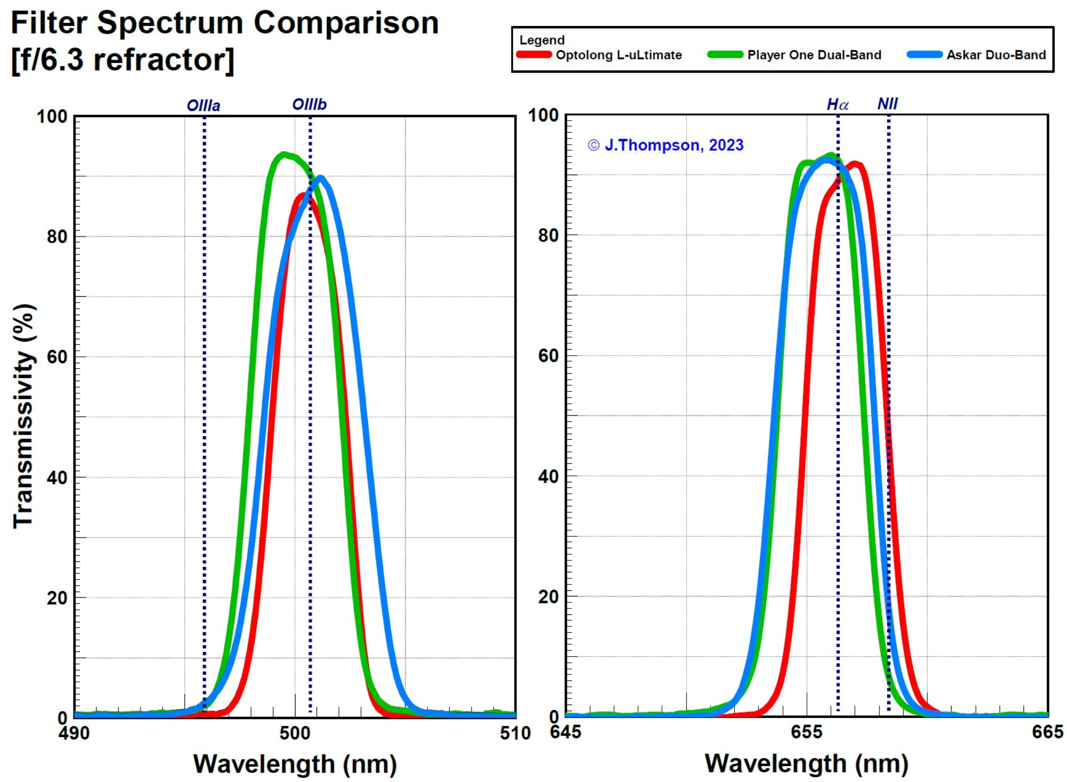


Figure 5 Net Spectral Response of Tested Filters – f/6.3 Refractor Area Weighted Average

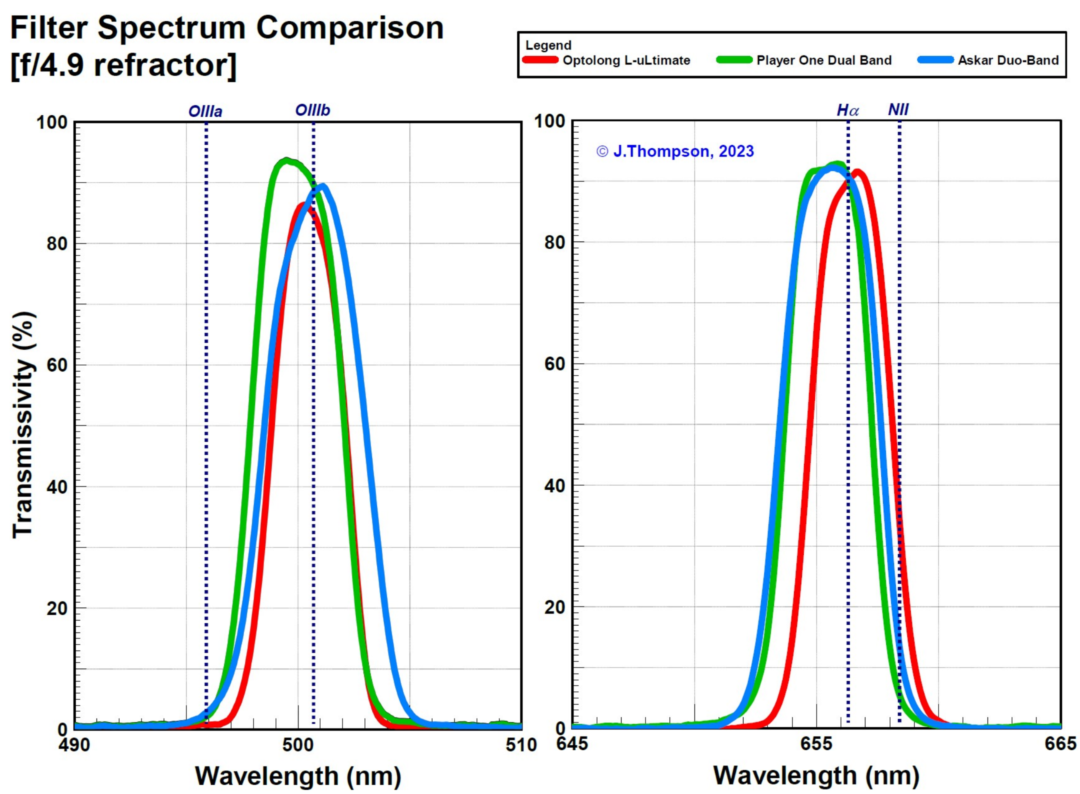


Figure 6 Net Spectral Response of Tested Filters – f/4.9 Refractor Area Weighted Average

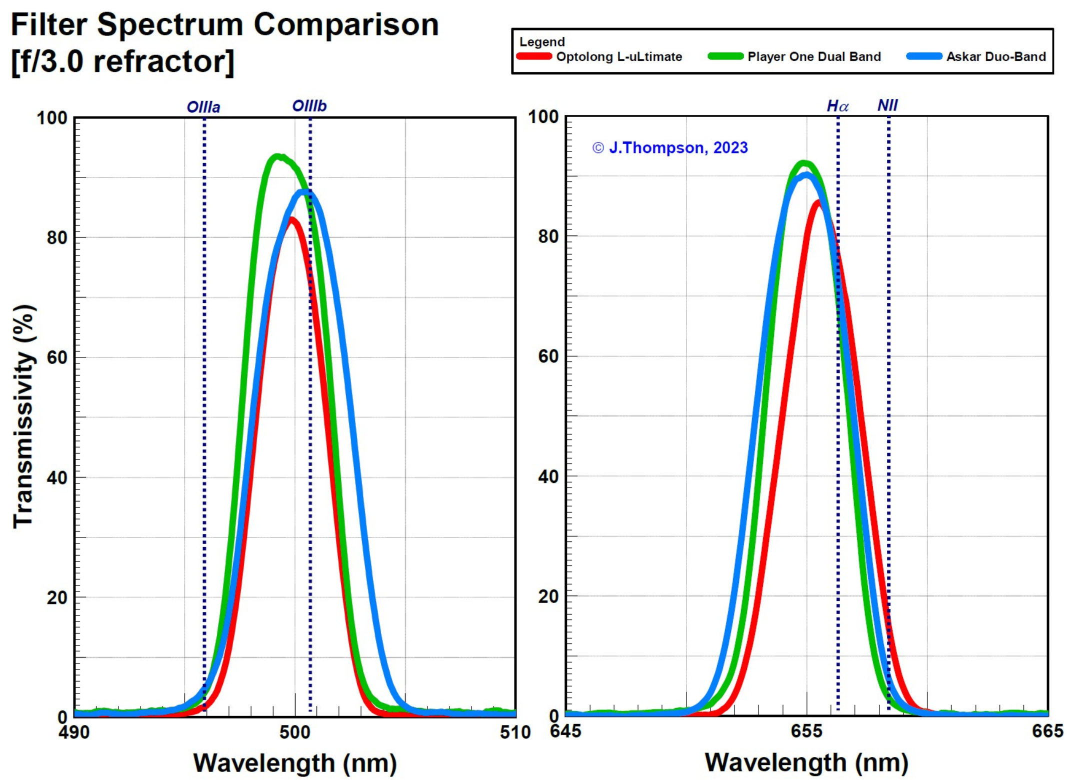


Figure 7 Net Spectral Response of Tested Filters – f/3.0 Refractor Area Weighted Average

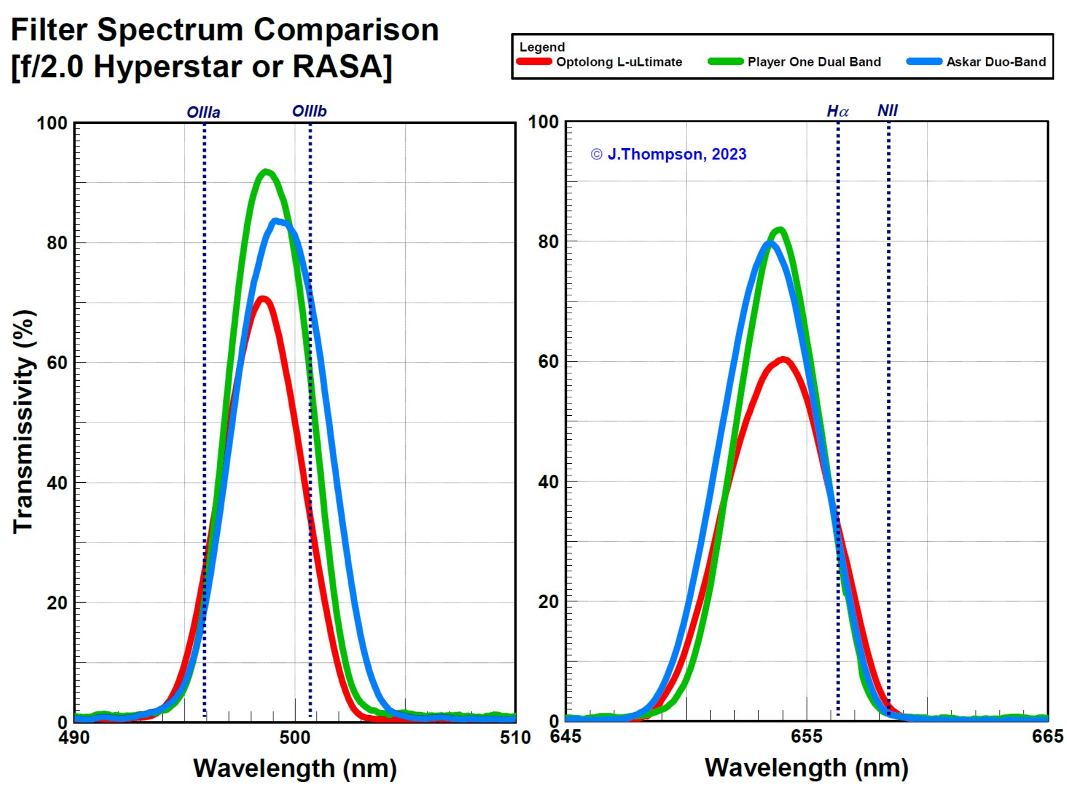


Figure 8 Net Spectral Response of Tested Filters – f/2 C14 w/Hyperstar Area Weighted Average

With the net filter spectra in hand, it was possible to extract overall performance related statistics for each filter, such as transmission values at key wavelengths of interest and pass band widths. These filter statistics are provided in Table 1, including a calculated value for percent Luminous Transmissivity (%LT), a single number that describes generally how much light is getting through the filter. The calculated value of %LT depends on the spectral response of the detector, which in this case is assumed to be a modern back illuminated CMOS sensor. I have included transmission measurements in the table for a range of telescope f-ratios, from f/∞ (perfectly parallel & perpendicular light) down to f/2. Also included in the table are the filter statistics quoted by the manufacturers.

Filter	Scope Optics	%LT*	Hbeta/O-III Pass Band				Halpha Pass Band			
			FWHM	Hbeta (486.1)	O-IIIA (495.9)	O-IIIB (500.7)	FWHM	Halpha (656.3)	N-II (658.4)	S-II (672.4)
Optolong L-uLtimate	*manuf.*	-	*3nm ± ?*	-	-	*90%*	*3nm ± ?*	*88%*	-	-
	f/∞	1.52%	3.4nm	0%	1.0%	88.2%	3.3nm	89.6%	71.2%	0%
	f/6.3**	-	-	0%	0.6%	86.0%	-	88.8%	45.9%	0%
	f/4.9**	-	-	0%	0.7%	84.8%	-	89.9%	34.2%	0%
	f/3.0**	1.56%	3.4nm	0%	1.6%	73.2%	3.5nm	76.5%	14.8%	0%
	f/2***	-	-	0%	24.5%	34.1%	-	32.5%	2.5%	0%
Player One Astronomy Anti-Halo PRO Dual-Band Ha+OIII	*manuf.*	-	*3.2nm ±0.5*	-	-	*>85%*	*3.7nm ±0.5*	*>85%*	-	-
	f/∞	1.87%	3.9nm	0%	1.5%	89.9%	3.2nm	93.2%	7.5%	0%
	f/6.3	-	-	0%	1.9%	90.1%	-	92.5%	6.7%	0%
	f/4.9	-	-	0%	2.0%	89.4%	-	90.9%	5.5%	0%
	f/3.0	1.90%	3.9nm	0%	4.0%	84.7%	3.2nm	70.4%	3.1%	0%
	f/2	-	-	0%	20.0%	57.1%	-	30.0%	1.2%	0%
Askar Colour Magic 3nm Duo-Narrowband	*manuf.*	-	*3nm ± ?*	-	-	*85%*	*3nm ± ?*	*88%*	-	-
	f/∞	1.99%	4.7nm	0%	1.9%	87.2%	4.1nm	92.7%	30.4%	0%
	f/6.3	-	-	0%	2.3%	87.8%	-	91.7%	17.9%	0%
	f/4.9	-	-	0%	2.7%	88.4%	-	90.8%	13.4%	0%
	f/3.0	1.97%	4.6nm	0%	4.6%	87.2%	4.1nm	72.8%	6.2%	0%
	f/2	-	-	0%	18.5%	70.8%	-	30.8%	1.3%	0%

* calculated assuming spectral QE curve for IMX174M with no UV/IR blocking filter; ** refractor; *** C14 w/Hyperstar

Table 1 Measured Filter Performance Summary

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. To do this I used the method I developed back in 2012 which applies the spectral response of the filter and sensor combined with the spectral emission from the deepsky object and background light polluted sky to estimate the apparent luminance observed. To help visualize the results of this analysis I have plotted the predicted % increase in contrast (vs. no filter) for each filter versus the filter's %LT. Figure 9 shows the resulting plot corresponding to filter performance when using a OSC CMOS camera under heavily light polluted skies, Bortle 9+ (i.e. same as 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 and 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 line to show how the performance is predicted to change depending on the f-ratio of the telescope you are using the filter with. Performance with slow f-ratio optics is at the top end of the line, and performance at f/3 is at bottom end. I have plotted predicted filter performance for two different types of nebulae: bright O-III rich like M27 the Dumbbell Nebula (dashed line w/ triangle data markers), and faint H-α rich like NGC7000 the North American Nebula (solid line w/ circle data markers).

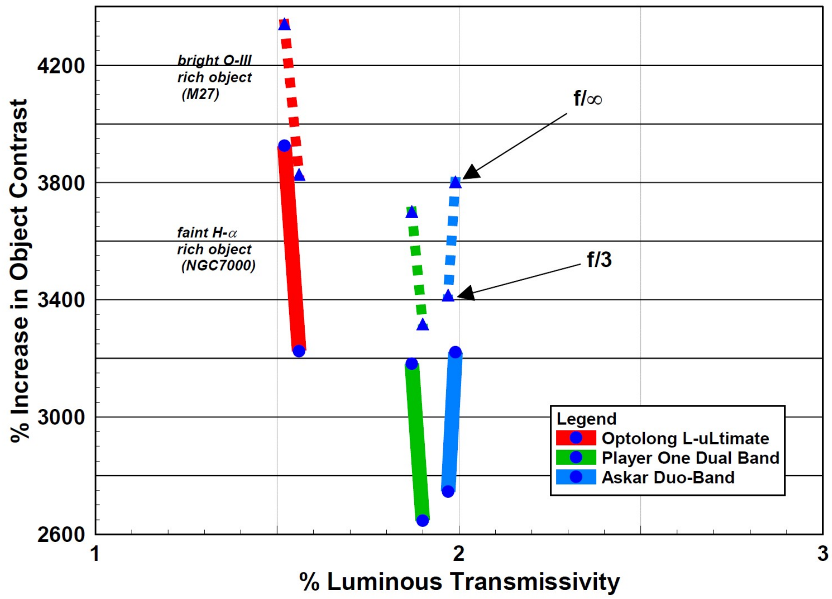


Figure 9 Predicted Filter Performance - Contrast: Back Illuminated OSC CMOS, Bortle 9+ Sky

The Player One and Askar filters are predicted to perform the same in terms of contrast increase, with the Optolong filter predicted to perform roughly 15% better than the other two filters. Also calculated using my prediction method is the image SNR, as shown in Figure 10. The predicted SNR values are normalized so that the SNR with no filter equals 1.0. Based on my prediction, the three filters all perform roughly the same in terms of image SNR.

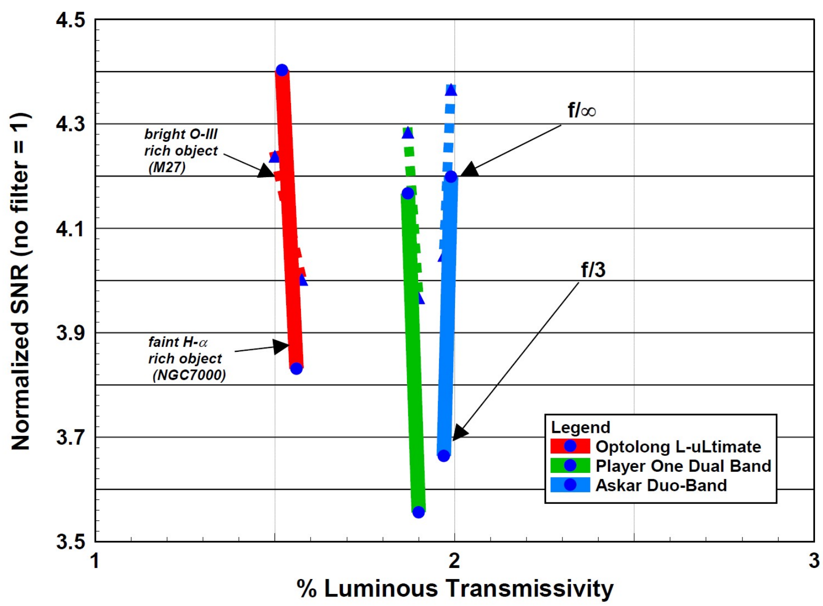


Figure 10 Predicted Filter Performance - SNR: Back Illuminated OSC CMOS, Bortle 9+ Sky

Results - Imaging:
All image collection on a particular night was done within a one-hour time window. This process was repeated three times, each on a different target as described above. Images were generated by live stacking in Sharpcap, with enough sub's captured in each case to generate a stack with 10 minutes total exposure. Imaging results are provided below. All the images had their histograms adjusted in exactly the same way using Fitswork v4.47, a free FITS editing software, so that they provide as fair a visual comparison as possible. Adjustments were made primarily for white balancing, but a small amount of non-linear stretch was also applied to enhance the visibility of the nebulosity.

Images from the first imaging session are shown in Figures 11 to 14. They have had an additional processing step applied, the removal of stars using the free software StarNet. This was done to make faint nebulosity easier to see and compare between the images. Images from all three filters look very similar to each other. The Optolong filter has H-α emissions that are subtly more bright or vibrant, which is consistent with the contrast predictions made from the spectrometer measurements. Otherwise, the images are all practically the same.

The second imaging session focused on star halos, as shown in Figure 15. The Optolong filter very clearly had a halo around the bright star Deneb, where the other two filters had no discernable halo. This observation is consistent with what I was expecting. The Askar and Player One filters both advertise off-band blocking of OD5 or better, but the Optolong filter only advertises OD4. Another noted difference is that the Optolong filter uses 2mm thick glass, while the other two filters both use 1.85mm thick glass. Based on my own investigations into what filter properties affect halo generation, filters with higher off-band blocking and/or thinner glass will have less prominent halos.

The third imaging session results are presented in Figure 16. During this session there was a more obvious difference in the appearance of the images, with the Optolong filter producing an image that is stronger in H-α, the Player One filter producing an image stronger in O-III, and the Askar filter producing an image in between the other two in appearance. The differences are however still relatively small and one could easily achieve the same end result after some post processing.

All the filters tested delivered images with good contrast and detail from my Bortle 9+ backyard, as seen by comparing the three images taken with filters to the "no filter" image in Figure 14 and also included in Figure 16. However to extract a quantitative assessment of imaging performance required the application of image analysis software. Using the raw 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 in Figures 11 through 16. 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. The particular areas used are illustrated in Figure 17 (red box for nebulosity, blue box for background), with these same areas used for all the images from the various filters. Measurements of luminance average and standard deviation were taken from the original unedited FITS files in each colour channel. Contrast increase was calculated from the measured luminance values using the following equations:

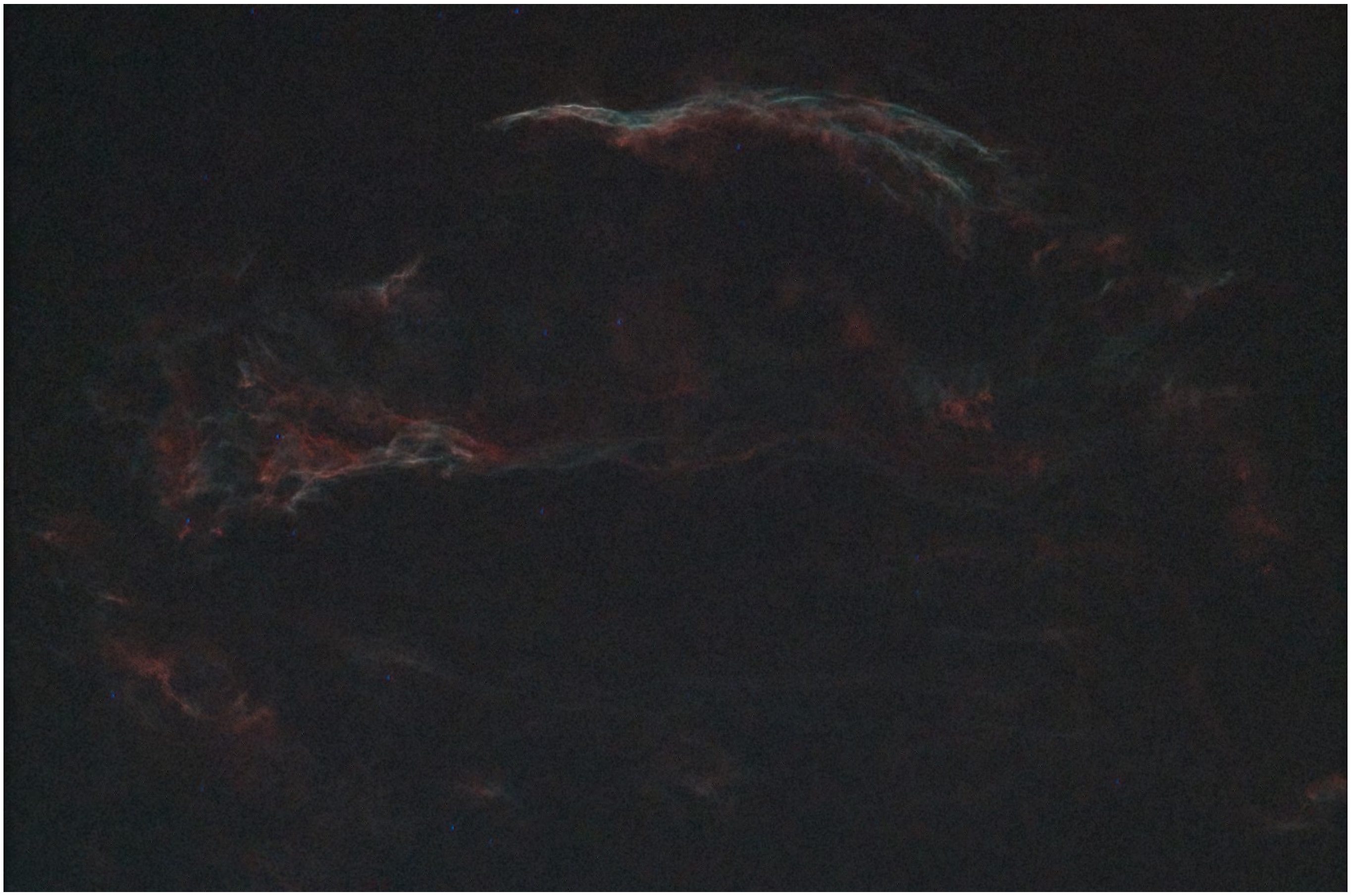


Figure 11 Aug. 16th Imaging Results – Optolong L-uLtimate (10x60s)

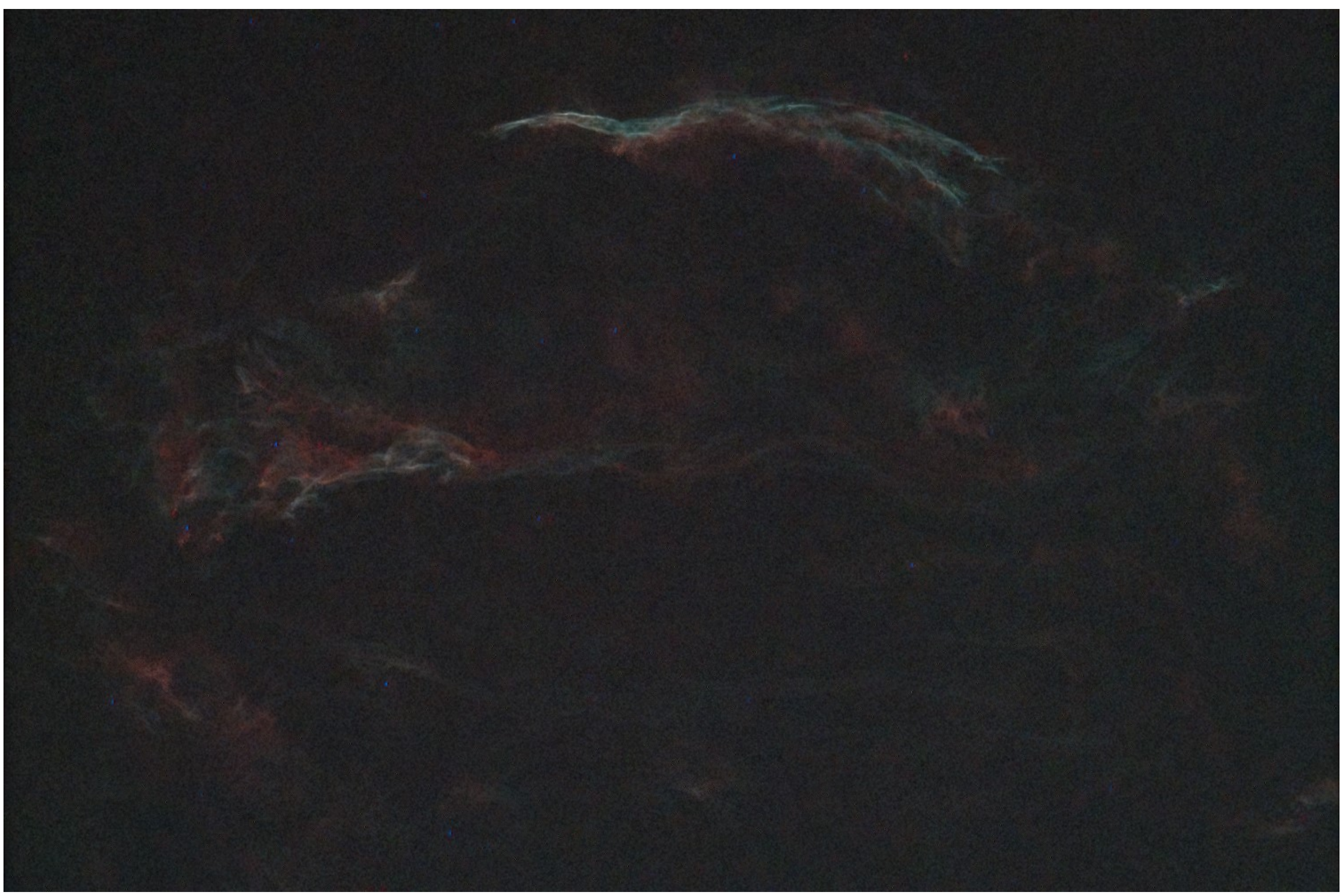


Figure 12 Aug. 16th Imaging Results – Player One Dual Band (10x60s)

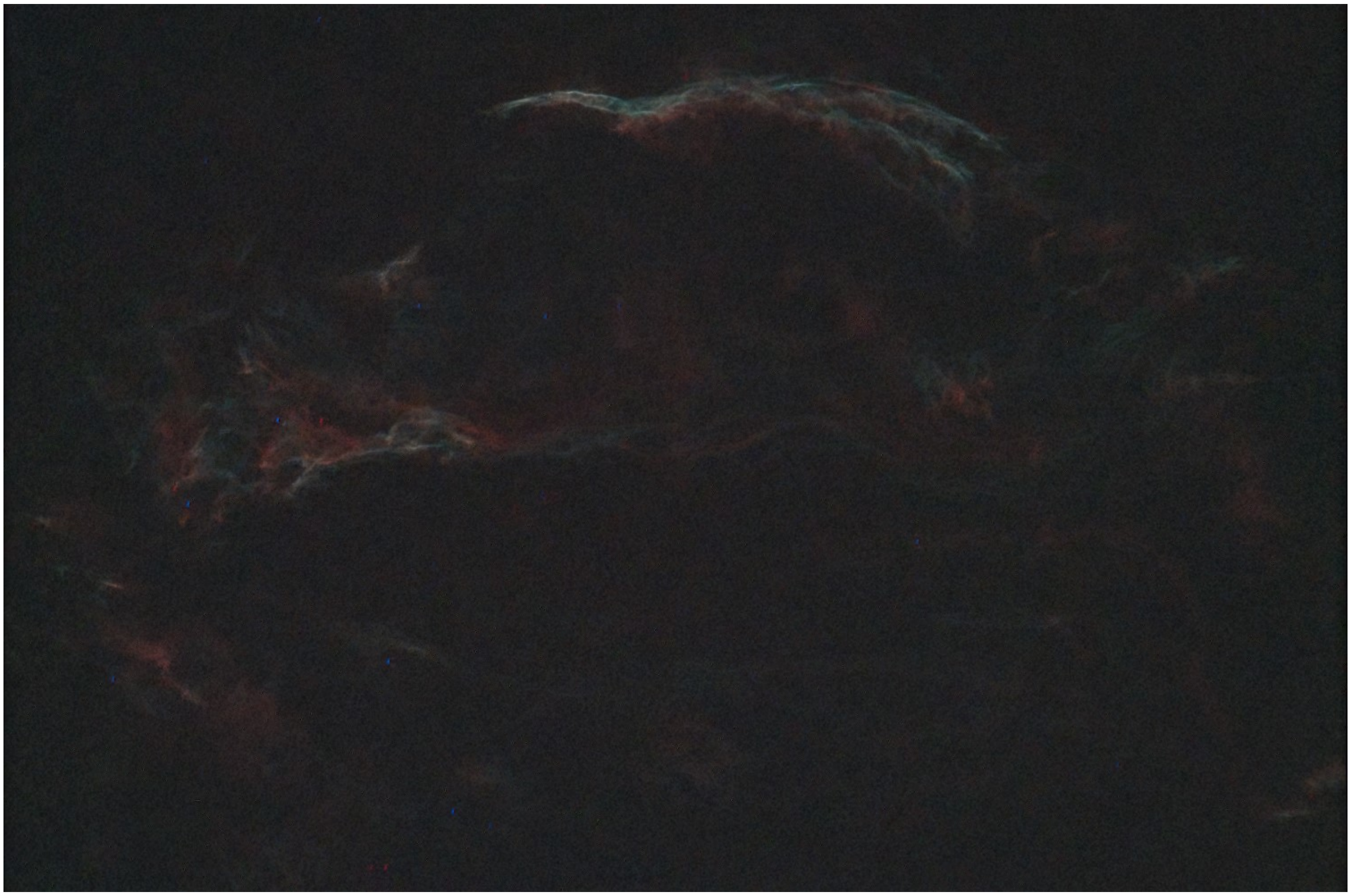


Figure 13 Aug. 16th Imaging Results – Askar Duo-Band (10x60s)

Figure 14 Aug. 16th Imaging Results – No Filter (210x3s)

Optolong L-uLtimate (3 x 30s)

Player One Dual Band (3 x 30s)

Askar Duo-Band (3 x 30s)

Figure 15 Aug. 28th Imaging Results – Star Deneb

Optolong L-uLtimate (20 x 30s)

Player One Dual Band (20 x 30s)

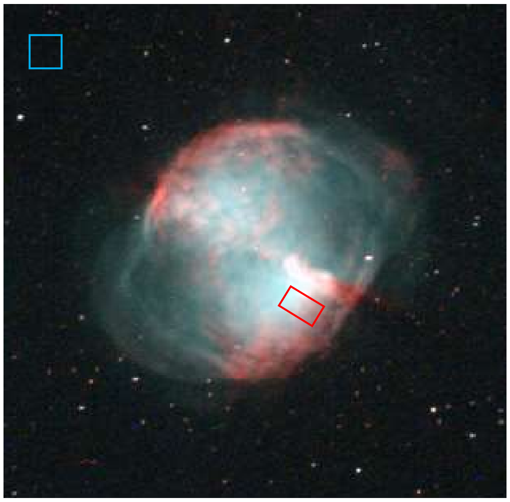
Askar Duo-Band (20 x 30s)

No Filter (100 x 1.5s)

Figure 16 Aug. 28th Imaging Results – M27 Dumbbell Nebula

Measured Contrast = [measured nebula luminance – measured background luminance] ÷ measured background luminance

% Contrast Increase = [contrast w/filter – contrast w/out filter] ÷ contrast w/out filter x100



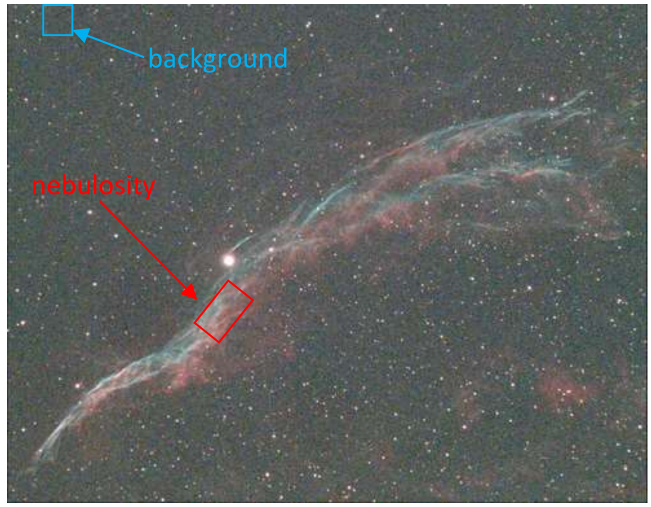


Figure 17 Areas Used for Image Analyses

The resulting contrast increase measurements are plotted in Figure 18, 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 assumed in the prediction calculations.

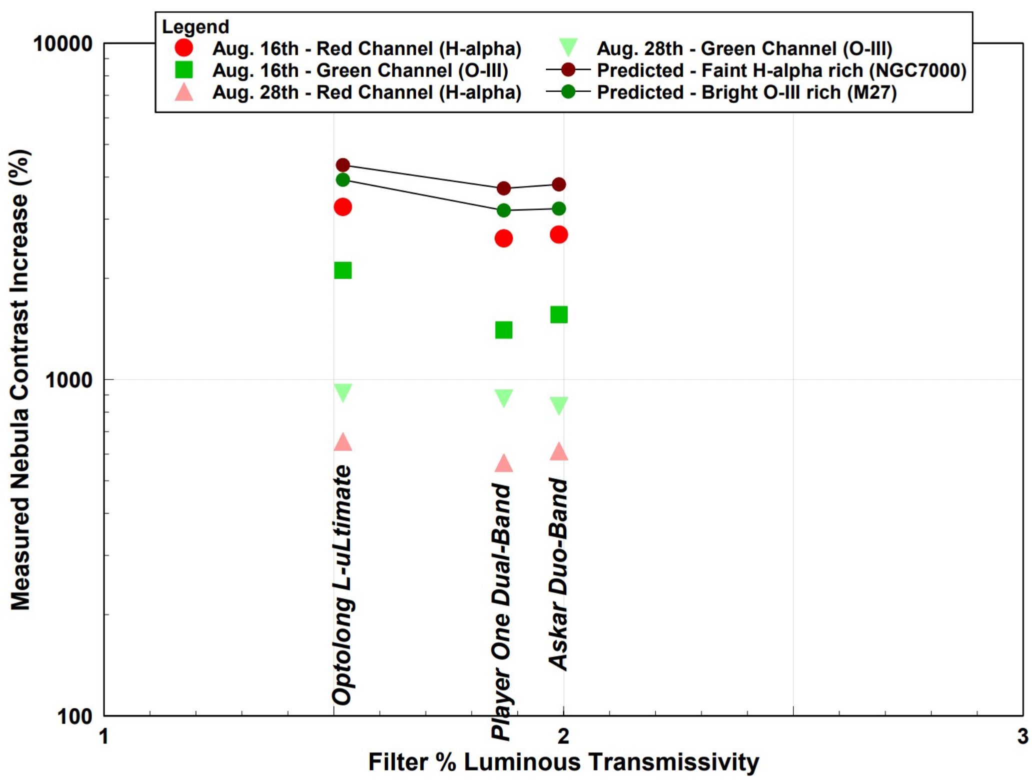


Figure 18 Measured Nebula Contrast Increase vs. Predicted

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 using the following equation:

SNR = (measured nebula luminance – measured background luminance) ÷ measured nebula σ

The SNR measurement results, from the 10 minute stacked images collected during the 3rd imaging session are shown in Figure 19. Only SNR measurements from the M27 images were used as there was not a sufficiently large area in the Veil Nebula images with a uniform nebula emission for use in the measurement – the magnitude of the noise in the image is masked by the naturally occurring variations in the nebulosity. The measured SNR values are not quite as expected in that the image collected using the Optolong filter had a significantly better SNR than using the other two filters, where it was expected from the predictions to be roughly the same. In my opinion more image data is required to confirm this observation.

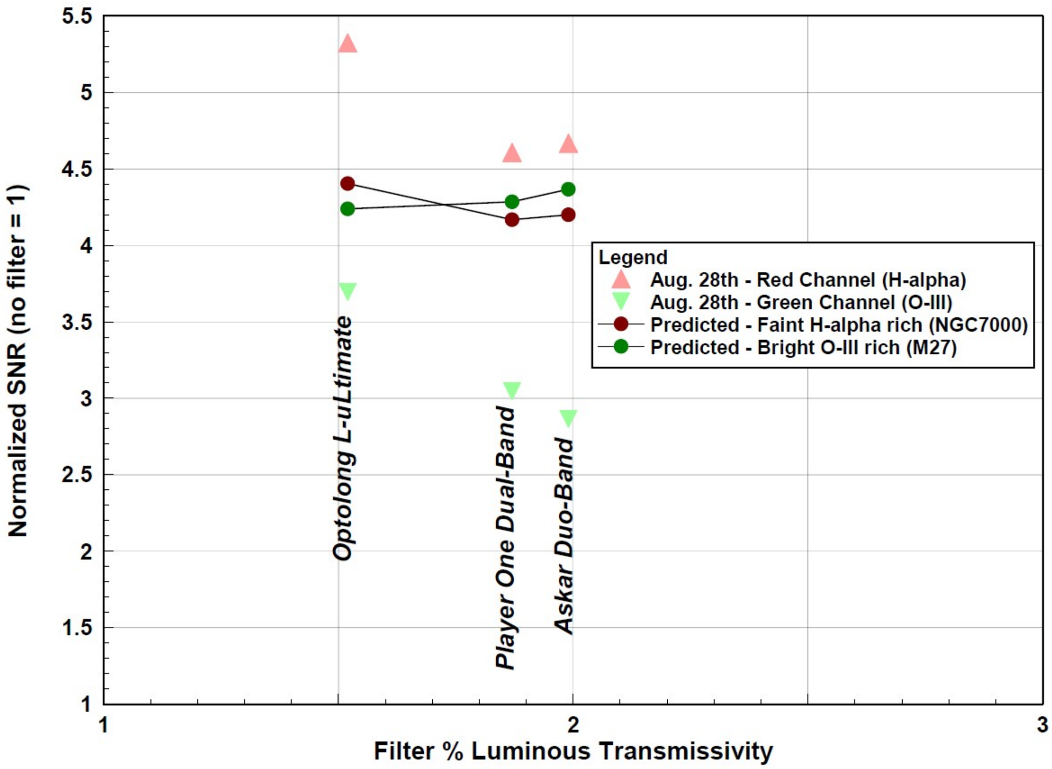


Figure 19 Measured Nebula SNR vs. Predicted

Finally, the measurement of luminance from the images allowed me to calculate the impact of each filter on exposure time. Figure 20 plots the %LT of each filter, as calculated from the spectrometer data, against the exposure (i.e. overall brightness) of the recorded images from each session divided by sub-exposure time. The black diagonal line in the plot represents perfect correlation; the closer the measured points are to this line the better an estimate of relative exposure the calculated %LT is. Based on the results, %LT is well correlated with the actual measured relative exposure time.

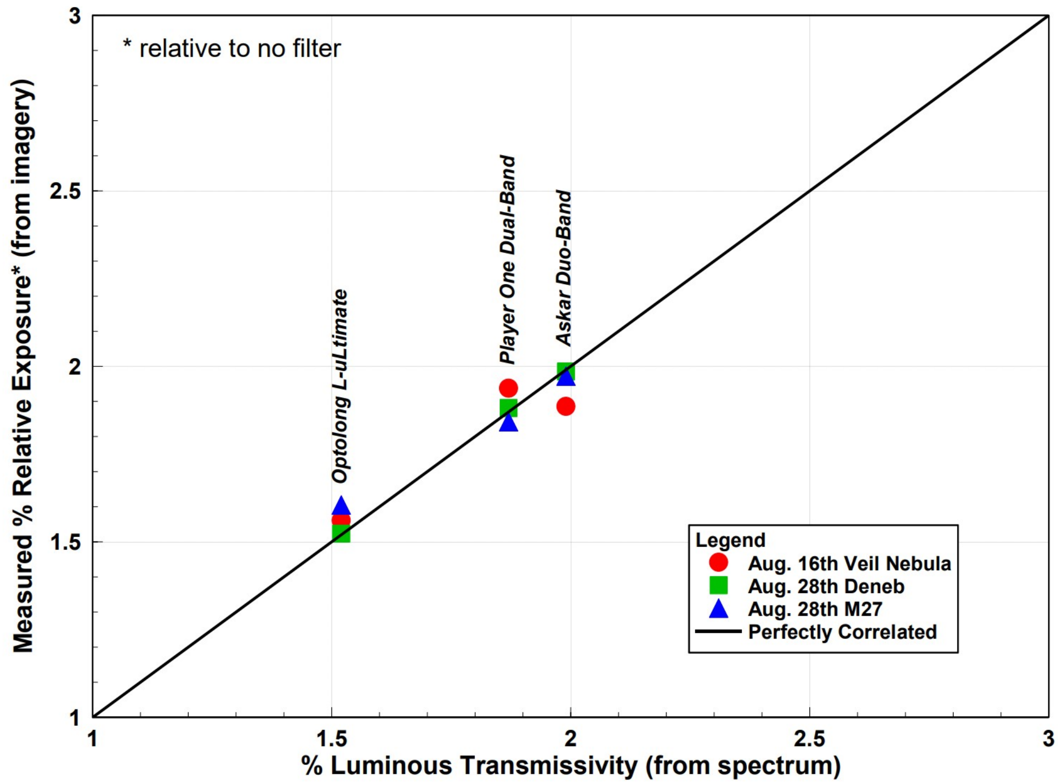


Figure 20 Measured Relative Exposure vs. %LT

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

1. Within my ability to measure, the Player One filter has properties that are fully consistent with the manufacturer's specifications.
2. All three filters demonstrated a high level of performance, permitting the capture of images with high levels of contrast and SNR from my highly light polluted location. The Player One filter delivered less contrast and SNR than the Optolong filter due to it having slightly wider pass bands, however the differences between images due to filter performance are of a small magnitude and are easily accommodated during post processing – the same high quality image result is achievable using any of the filters tested.
3. Both the Player One and Askar filters showed no discernable halos around bright stars. The Optolong filter did produce halos, but only around the hottest and brightest of stars. In the majority of images captured during this test and subsequent imaging sessions there were no discernable halos produced by any of the filters (see Figure 21).
4. In terms of price-for-performance, a useful figure of merit to use is purchase price per unit SNR. The value of that parameter for each filter tested is as follows: Optolong $88, Player One $124, and Askar $134. Thus, the filter giving the best value is the Optolong filter, followed second by the Player One filter. One can surmise that the delta cost of

having a filter with no halos, even on bright stars, is the difference in pricing between the Optolong and Player One filters.

5. The similarities in measured properties and performance between the Player One and Askar filters leads me to believe that these two filters are made by the same OEM. Even the plastic cases that they are shipped in are identical.

Optolong L-uLtimate *Player One Dual-Band* *Askar Duo-Band*

Figure 21 Aug. 16th Imaging Results – Close-up on 52 Cygni (Mag +4.2, 4677K)

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

Cheers!

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