Optolong L-eXtreme Filter Comparison

by Jim Thompson, P.Eng
Test Report – August 25th, 2020

Introduction:

The light pollution filter market continues to grow, with new offerings being released every couple of months. One of the latest filters to be released is the new L-eXtreme filter from the Chinese company Yulong Optics Co. Ltd. under their Optolong brand. I have a fair amount of experience with Optolong brand filters, all of which started in 2015 with a request directly from Optolong for me to test some of their filters for them*. I was impressed by Optolong's filters then and I am still impressed today. Because of my history of testing Optolong filters I have a library of their products available to which I can compare any new offerings. This is exactly what I have summarized in this report: a comparison between the new L-eXtreme filter and Optolong's other filter models. Figure 1 shows the spectral response of the new L-eXtreme filter that was released in North America just this past June. The filter is a refinement of their popular L-eNhance filter, having even narrower pass bands around O-III and Hα.

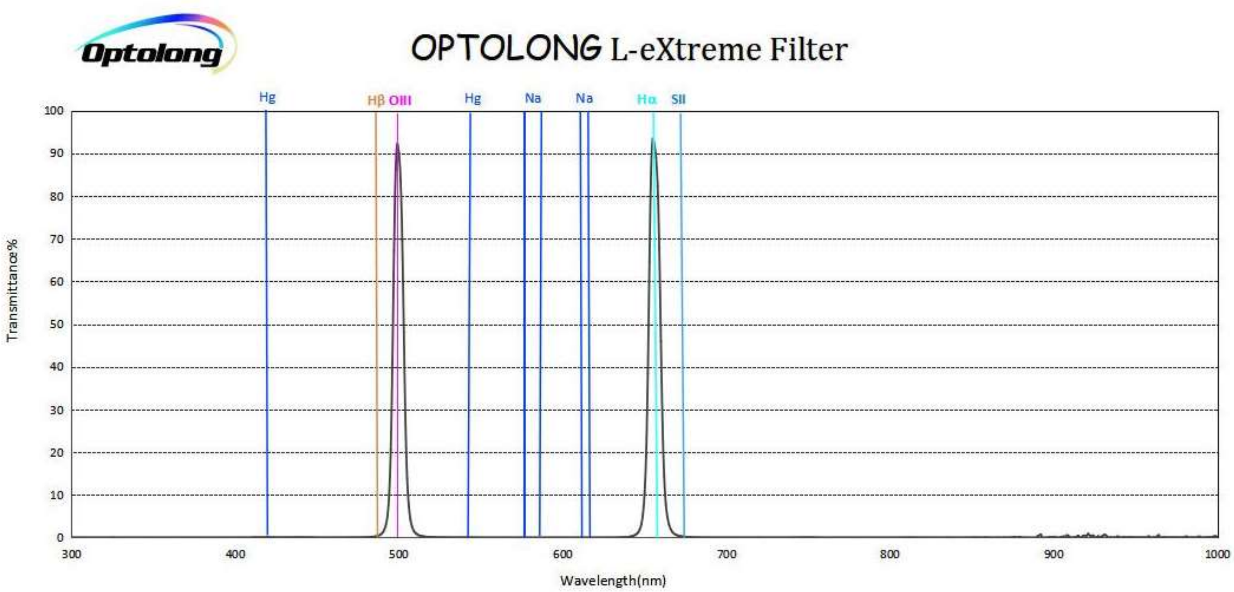

Figure 1 Spectral Response of the New L-eXtreme Filter

* *You can read the test report here:*
http://karmalimbo.com/aro/reports/Optolong_preliminary%20filter%20test%20report_26Aug2015.pdf

Objective:

As indicated below in Table 1, Optolong has a large variety of filters available. The table lists only the filters that I have on-hand for my testing. Optolong also sells a variety of narrowband filters (O-III, Hβ, Hα, SII, etc.), as well as some specialty filters. I have chosen to limit my comparison to the filters that pass multiple nebula emission wavelengths since they are of the most interest to one-shot colour (OSC) users. The retail prices of these offerings vary widely, which raises the question: "Is the cost of a filter justified by its performance?" That is the objective of the testing summarized in this report, to test samples of the filters listed and compare them to each other in terms of relative performance. Of special interest is the L-eXtreme filter, and whether its performance is better than the other filter models by a large enough margin to justify its cost.

Filter Name	Retail Price [USD]**	
	1.25"	2"
L-Pro	$149	$199
CLS (non-CCD)	$55	$85
UHC	$55	$85
UHC + IR cut	$55 + $44	$85 + $65
L-eNhance	$179	$229
L-eXtreme	$239	$309

** Prices quoted from AgenaAstro.com

Table 1 Summary of Optolong Filters Considered During Test

Method:
Testing consisted of data collection in the following manner:

- Spectral transmissivity data, from near-UV to near-IR, measured using an Ocean Optics USB4000 spectrometer; and
- Image data, collected using a William Optics FLT98 triplet apochromatic refractor and a ZWO ASI-294MC Pro OSC camera.

The spectrometer data was collected in my basement workshop with the USB4000 and a broad spectrum light source. To collect the data I recorded two back-to-back scans from each filter and calculated the average. In the event that the data varied by more than 0.1% between back-to-back scans, I rejected the data set and repeated the whole measurement again.

The image data was collected from my backyard in central Ottawa where the naked eye limiting magnitude (NELM) due to light pollution is +2.9 on average, which translates to Bortle 9+. I don't have a filter wheel, so to switch filter configurations I had to remove the camera from the focuser, and swap the filter manually. Each time I changed filters I would refocus on a conveniently located bright star using a Bahtinov mask. Images were collected on a single evening, August 12th, 2020. A single deepsky target was used, the Eastern Veil Nebula (NGC6992/95), which was located near the zenith for the duration of the image captures.

Results – Spectrum Measurements:
Figures 2 and 3 present plots of the measured spectral responses for each of the filters under test. The CLS, L-Pro, and UHC filters all have relatively wide pass bands around Hβ/O-III and Hα. The L-eNhance and L-eXtreme filters on the other hand have significantly narrower pass bands, with the L-eXtreme having the narrowest pass bands of all the Optolong filters tested. From the measured spectral response data I extracted the filter characteristics summarized in Table 2.

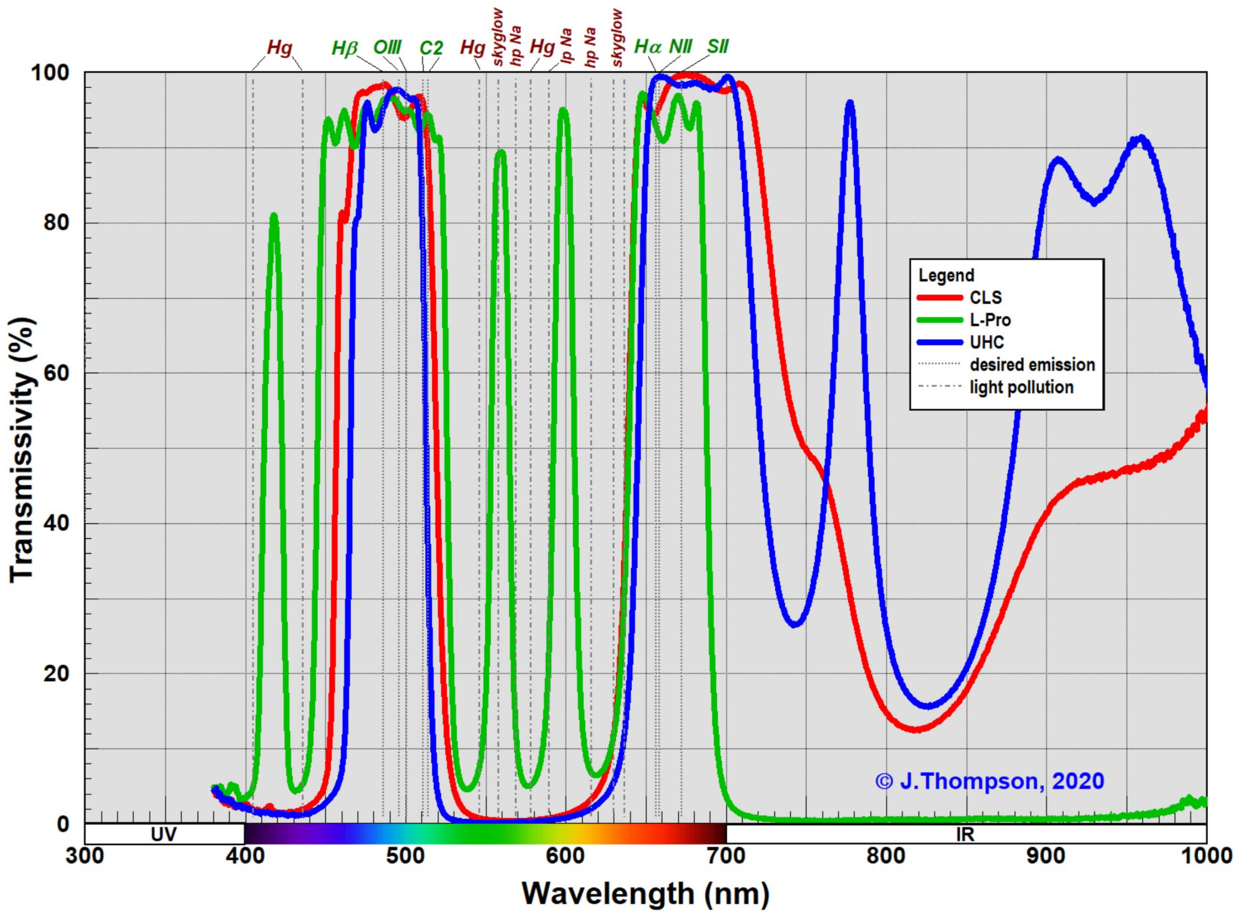

Figure 2 Measured Spectral Response of Optolong Filters – 1

Filter	Hbeta/O-III Pass Band				Halpha Pass Band				Mean Off-Band Blocking
	FWHM	Hbeta (486.1)	O-IIIA (495.9)	O-IIIB (500.7)	FWHM	Halpha (656.3)	N-II (658.4)	S-II (672.4)	
L-Pro	81.2nm	96.4%	95.6%	94.9%	49.4nm	92.7%	91.5%	95.8%	OD 1.3
CLS (non-CCD)	62.8nm	98.4%	94.5%	94.1%	110.7nm	94.7%	95.6%	99.8%	OD 2.2
UHC	47.5nm	95.4%	97.6%	96.8%	77.1nm	99.3%	99.6%	98.4%	OD 2.4
UHC + IR Cut	47.1nm	93.2%	95.7%	94.1%	63.3nm	98.3%	98.6%	98.1%	OD 2.5
L-eNhance	26.7nm	95.9%	98.1%	97.0%	11.8nm	90.1%	90.7%	1.5%	OD 2.5
L-eXtreme	8.1nm	0.3%	60.7%	89.9%	7.8nm	79.5%	42.8%	0.1%	OD 2.8

Table 2 Measured Filter Performance Summary

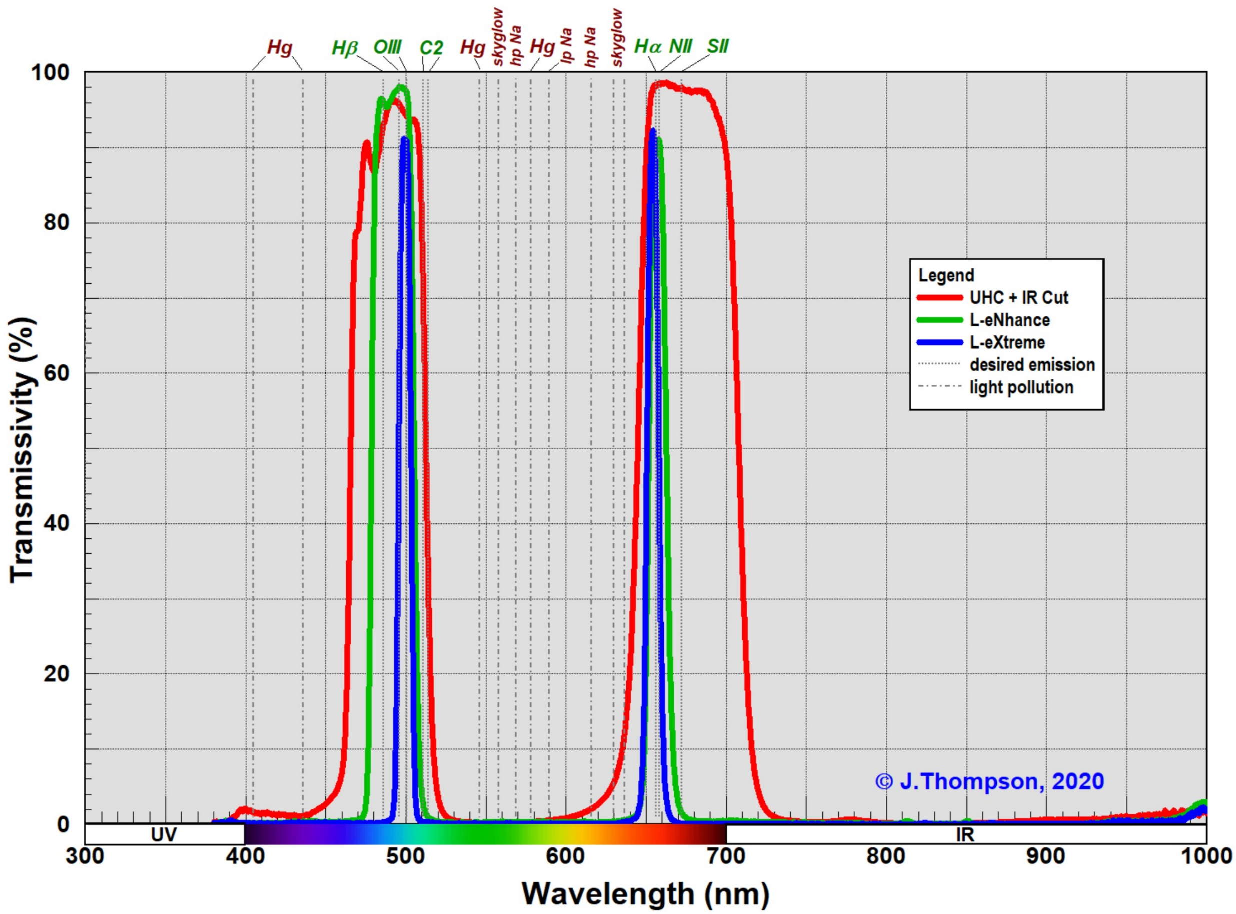

Figure 3 Measured Spectral Response of Optolong Filters - 2

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, under different sky conditions. 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. If interested you can read more about the method at the following link:

http://karmalimbo.com/aro/reports/paper_MethodForEvaluatingFilters-part1.pdf

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). %LT is a measure of how much light gets through the filter in the wave band being observed, which varies depending on whether the observer is a human or a camera. Figure 4 shows the resulting plot corresponding to filter performance when using a monochrome CMOS camera under heavily light polluted skies complete with local LED street lights (i.e. my backyard).

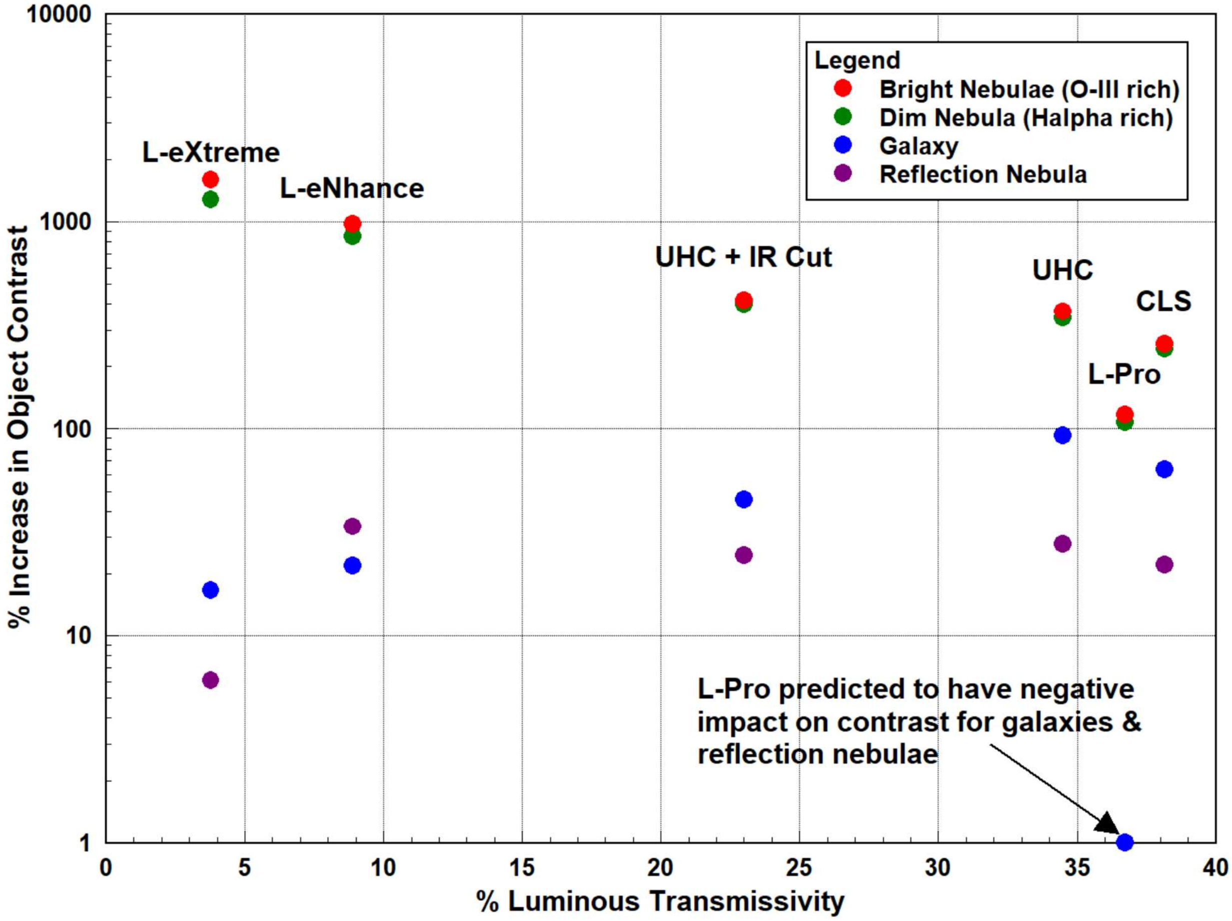

Figure 4 Predicted Filter Performance: Monochrome CMOS, LP w/LED (NELM+2.9)

For emission type nebulae, there is an obvious trend to the predictions: as the pass bands get narrower (ie. %LT is lower), the contrast increase gets larger. For broadband targets like galaxies and reflection nebulae there does not seem to be any sort of trend with %LT; if anything the contrast increase reduces with decreasing %LT. The average expected increase in contrast is also significantly less for broadband targets than for emission nebulae. The values plotted in Figure 4 are also provided below in Table 3 for reference. Note that these are theoretical values, and may not reflect what a user will experience with their setup. The relative performance of one filter to another should however be representative.

Filter	%LT	Bright Nebulae (O-III rich)	Dim Nebulae (Hα rich)	Galaxy	Reflection Nebulae
L-Pro	36.7	116.9	108.1	-8.4	-0.8
CLS	38.1	255.8	242.5	63.8	22.0
UHC	34.5	368.7	345.2	92.6	27.8
UHC + IR Cut	23.0	417.8	396.8	45.4	24.6
L-eNhance	8.9	973.1	851.8	21.9	33.8
L-eXtreme	3.8	1596.2	1279.8	16.6	6.1

Table 3 Predicted Filter Performance : Monochrome CMOS, LP w/LED (NELM+2.9) - % Increase In Object Contrast

Results – Imaging:
The images collected using the different filters under test are presented below in Figures 5 to 11. Included is a reference image taken with no filter at all. All seven images were taken using the same total exposure time of 5 minutes, but the sub-exposure time was varied as required to avoid clipping of the histogram. All other camera settings (white balance, gain, binning) were left unchanged between the different filter configurations. The no-filter image was captured using 5 second sub-exposures as that was the longest I could go without saturating the image with light pollution. For the image captures using the L-Pro, CLS, and UHC filters, I was able to use sub-exposure times of 10 seconds. These filters removed some of the contribution to the scene brightness resulting from the light pollution, thus allowing for a longer exposure time without saturating the image. For the image captures made using the L-eNhance and L-eXtreme filters, I had to use sub-exposure times of 30 seconds in order to not clip the image at the dark end of the histogram. These two filters removed so much of the light pollution that the resulting signal was too low below 30 seconds exposure to not clip data, especially in the case of the red channel. Using the histograms from my raw captured images, combined with the sub-exposure times, I pulled out the impact of each filter on relative exposure for each colour channel. The results are summarized in Table 4.

Filter	Sub-Exposure (s)	Exposure Relative To No Filter				%LT*
		R	G	B	RGGB Avg	
None	5	100%	100%	100%	100%	100%
L-Pro	10	33.2%	40.3%	49.4%	40.8%	36.7%
CLS	10	22.7%	25.4%	34.9%	27.1%	38.1%
UHC	10	20.0%	21.2%	27.9%	22.6%	34.5%
UHC + IR Cut	10	13.5%	17.7%	24.0%	18.2%	23.0%
L-eNhance	30	4.4%	8.7%	10.3%	8.0%	8.9%
L-eXtreme	30	3.6%	4.4%	5.3%	4.4%	3.8%

* For generic monochrome CMOS camera

Table 4 Measured Relative Exposure By Colour Channel

One of the challenges of this test was applying white balancing and levels adjustments to all the collected images in a way that was repeatable, and that did not diminish or over-emphasize the performance of one filter relative to another. I accomplished this by separating each raw image into its three colour channels, and doing some initial analysis of each channel's histogram. Using the histogram data from the image with the maximum contrast, the L-eXtreme image, I set black point, mid point, and white point values to apply to all the images so that the end result was the same amount of histogram stretching as well as a matching white balance. I accomplished this using the freeware software AstroImageJ, working from 16-bit per channel FITS files captured directly out of Sharpcap. The resulting output images are what is presented in Figures 5 to 11.

Figure 5 No Filter – White Balancing + Levels Adjustment Applied

Figure 6 L-Pro – White Balancing + Levels Adjustment Applied

Figure 7 CLS (non-CCD) – White Balancing + Levels Adjustment Applied

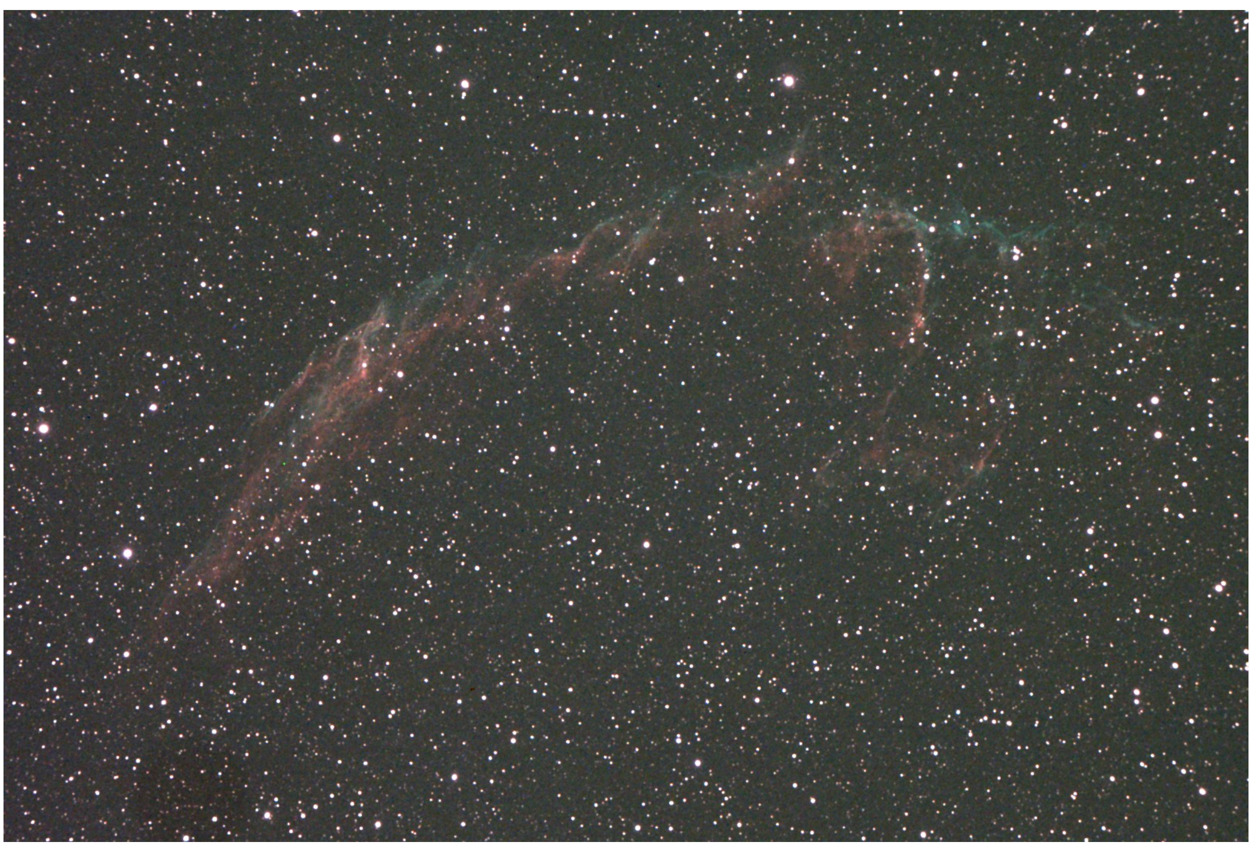

Figure 8 UHC – White Balancing + Levels Adjustment Applied

Figure 9 UHC + IR Cut – White Balancing + Levels Adjustment Applied

Figure 10 L-eNhance – White Balancing + Levels Adjustment Applied

Figure 11 L-eXtreme – White Balancing + Levels Adjustment Applied

The adjusted images confirm visually the filter performance predictions presented in Figure 4. Using the L-Pro, CLS, or UHC filter all resulted in a noticeable improvement in the contrast of the nebula. As predicted, the UHC provides a slightly better contrast than the CLS, which in turn provides a slightly better contrast than the L-Pro filter. One interesting observation was that the L-Pro filter image had a non-uniform colour cast that is not observed with the other filters. This may be related to the non-uniform appearance of my L-Pro filter sample's coatings that I observed originally back in 2015 when I first tested these filters. Adding the IR Cut filter to the UHC does not increase the contrast of the nebula significantly, however it does greatly reduce the brightness of stars in the image, making the nebula easier to see. Using the L-eNhance filter resulted in a large improvement in the nebula's contrast compared with the first four filter configurations. One peculiarity of the L-eNhance image however is that the image still has a turquoise hew after being white balanced in the same way as the other filters' images. I don't know if this is a specific issue when using the filter with the ASI294 camera, but I have heard reports of similar issues with white balancing this filter on other cameras. Finally, using the L-eXtreme filter resulted in another significant increase in image contrast over the L-eNhance filter. The visibility of stars was also greatly reduced, making the nebula easier to see. I also noted that the white balance was much better than with the L-eNhance filter. I have since used the L-eXtreme filter for some live EAA observing, and can confirm that this new filter is much easier to get a nice white balance than the L-eNhance filter.

Results - Angle Sensitivity:
The final thing I confirmed from my testing was how sensitive each filter's performance is to the f-ratio of one's optics. I did not bother measuring the angle sensitivity for the L-Pro, CLS, and UHC filters because their pass bands are so wide – too wide really to be affected in any significant way by f-ratio. I did however measure the spectrum of the L-eNhance and L-eXtreme filters for a range of f-ratios. The results are summarized in Figure 12.

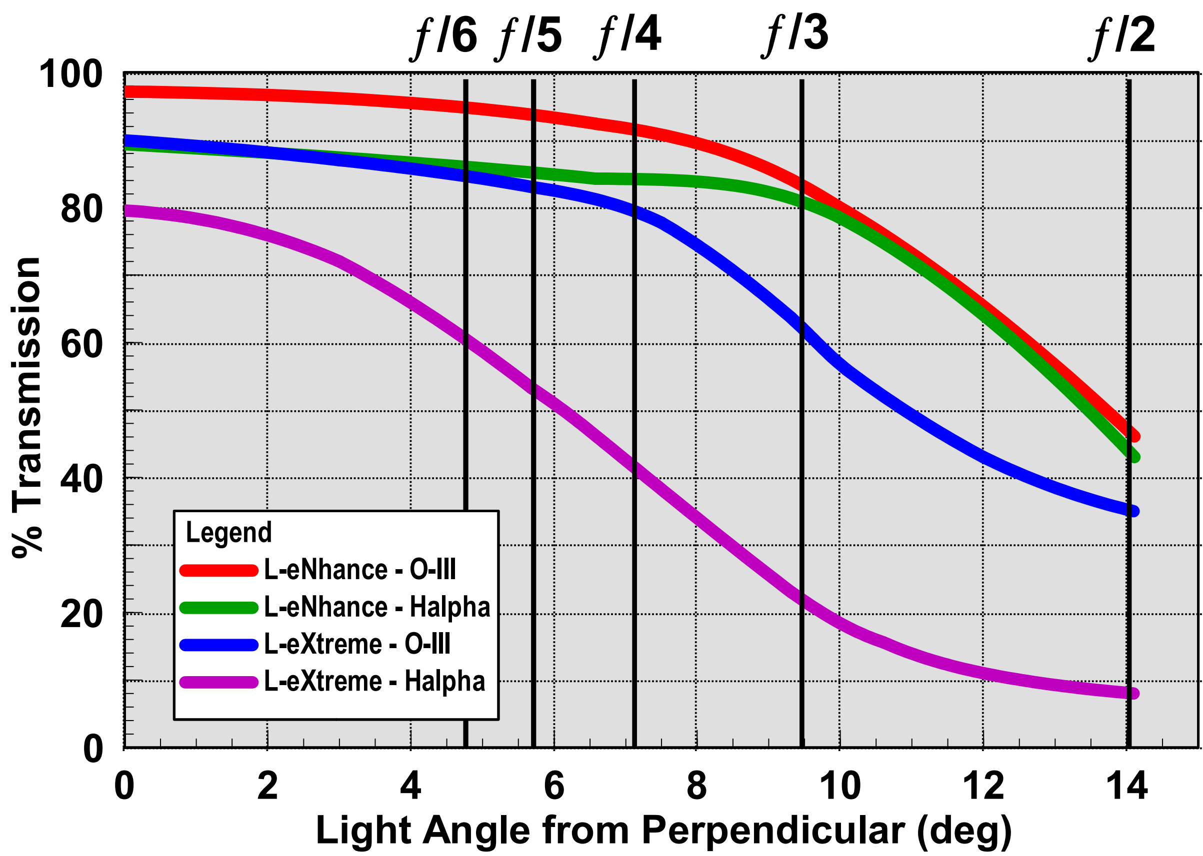

Figure 12 Impact of Angle On Filter Performance

As expected, the narrower pass bands of the L-eXtreme filter make it more susceptible to losses in performance with progressively faster optics. The images I collected were captured at f/6.3, so some of the effects of f-ratio should have been apparent. Since the object I was observing did not fill the field of view (FOV), the images presented above are cropped and so don't really show any noticeable gradient in performance from center to edge using the L-eXtreme filter. On an object that fills the FOV the impact would be more visible. Even with the supposed reduction in performance due to f-ratio, the L-eXtreme filter still produced an image of superior contrast compared to all the other filters tested.

Conclusions:
The data collected during this test confirms yet again that a filter with narrow pass bands produces an image with superior contrast on emission-type nebulae. Some other more specific conclusions drawn from this test are:

- When compared to other available filters with the same %LT, the Optolong L-Pro filter provides inferior performance under light polluted skies. This observation is true for all filters of this type (i.e. Multi-band), regardless of brand.
- In terms of cost per performance the Optolong UHC filter provides a very good value. The filter performs very similar to the Astronomik UHC but at a fraction of the cost.
- There is a significant improvement in contrast on emission-type nebulae resulting from the use of the Optolong L-eNhance filter. There is however an issue with white balancing that was not encountered with the other filter models.
- Of the six filter configurations tested, the Optolong L-eXtreme filter provided the largest increase in contrast. The increase in contrast relative to the L-eNhance filter was observed to be significant. The filter was also easier to use than the L-eNhance due to it being easier to white balance.

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

Cheers!

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