Multi-Narrowband Astronomical Filters

by Jim Thompson, P.Eng
Test Report - February 28th, 2020

Introduction:

Of all the things that can impact our personal enjoyment of astronomy, besides the weather, light pollution is perhaps the most prevalent. Every year the night-time background light levels around populated areas continue to grow. However, light pollution (LP) filters are working hard to claw back some of what we have lost. Commercially available for decades, the performance of these filters continues to improve, and their costs have come down considerably in recent years. I have invested significant time and money into evaluating LP filters, through both testing and analysis. From all my research of LP filters it has become clear that the narrower the pass band of a filter, the better it is for light pollution rejection. This reality has culminated in the creation of what is perhaps the penultimate LP filter: the multi-narrowband filter. More commonly referred to as duo-band, tri-band, or quad-band, these filters are designed to very precisely pass some combination of the main wavelengths of light associated with emission nebulae (Hβ, O-III, Hα, N-II, and S-II) while blocking everything else. Figure 1 shows the spectral response of an example of this relatively new filter type.

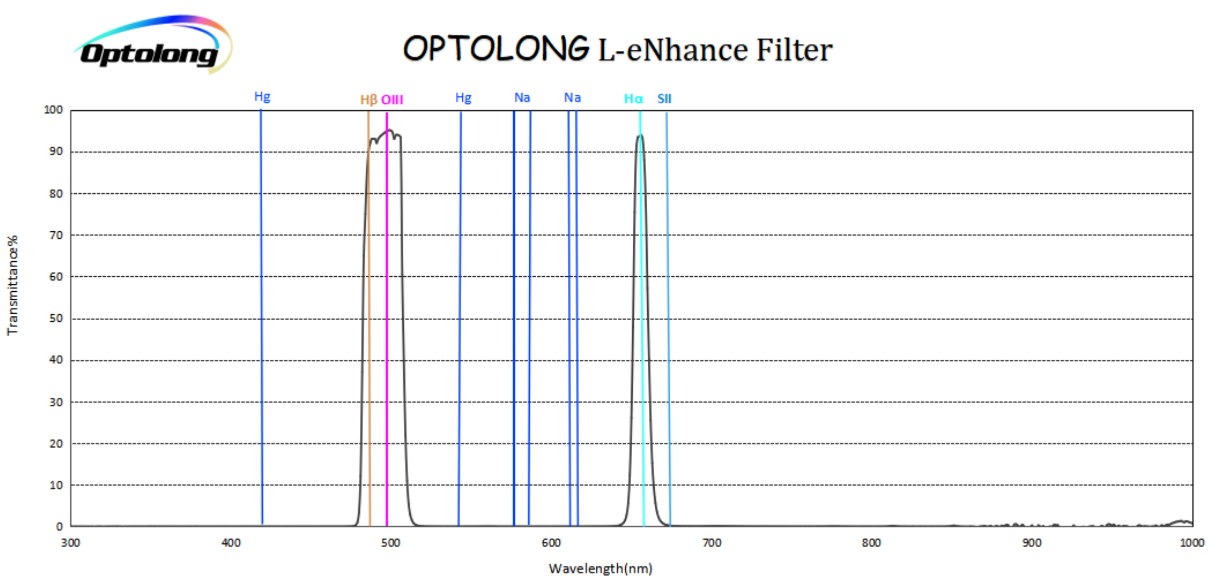


Figure 1 Spectral Response of Example Multi-Narrowband Filter

Background:

I have a keen interest in multi-narrowband filters, not only because of my long-time general interest in astronomical filters, but also because I believe I may have played a role in their development. My involvement with multi-narrowband filters starts back in March 2011 when I placed an order for a custom built UV/IR blocking filter from Omega Optical, a prominent filter manufacturer located in Vermont, USA. The filter I had them build for me was narrower than a normal UV/IR cut, with cut-off wavelengths carefully selected to block light below Hβ and above Hα. My plan was to stack this custom filter with a commercially available LP filter, in my case a Meade brand O-III filter, to achieve the end result of a dual narrowband filter. After working through some trial and error with Omega, they delivered what I now call the Blue and Deep Red Blocker (BDRB) later that year. The spectral response of the BDRB is compared to a typical UV/IR cut filter in Figure 2.

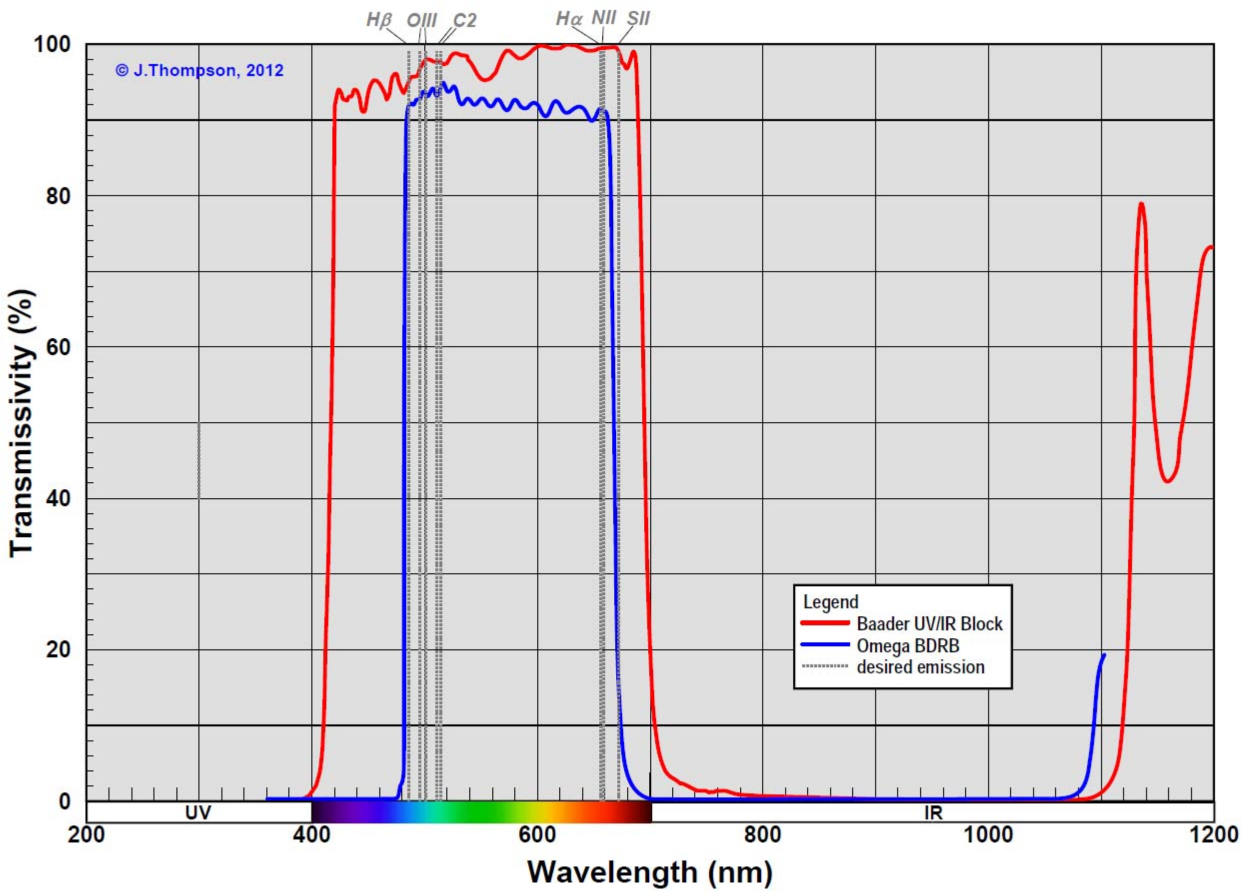


Figure 2 Spectral Response Comparison Between BDRB & Typical UV/IR Cut Filters

I tested the BDRB filter extensively over the course of the next year, using a one-shot colour astrovideo camera (Mallincam Xtreme) for all of my observations. My test results confirmed what theory suggested: the narrower the band pass, the better the image contrast. I was so excited by the positive results of my testing that I shared a summary report with Omega Optical in August 2012. This story might have ended there except that in November 2014, while casually browsing the Omega Optical store on eBay, I noticed that Omega had a new filter for sale: the Hydrogen & Oxygen Nebula LPF Improved NPB DGM. This filter was the first multi-narrowband filter available commercially, and was essentially an improved version of what I presented to Omega back in 2012. I contacted Omega immediately after my discovery, and expressed my concerns over them having used my idea to generate a new product. As a show of good faith Omega sent me a free 2" sample of the new filter, which I proceeded to test and author a test report on. A copy of the test report is available at the link below:

http://karmalimbo.com/aro/reports/Test%20Report%20-%20Omega%20Improved%20NPB%20DGM.pdf

At this point the story goes fairly quiet. Omega sold small quantities of the Improved NPB DGM filter over the following years, sufficient numbers though to keep the item in their online inventory. It wasn't until September 2017 that the tale picks up again, this time with the announcement by Oceanside Photo & Telescope (OPT) of a new revolutionary filter they had developed called the Radian Triad filter. OPT focused on promoting the Triad as a high performance filter that allowed for multi-narrowband imaging using a one-shot colour (OSC) camera. It took about a year, but eventually OPT's idea for marketing this filter to OSC imagers paid off. There are now many users of multi-narrowband filters, and versions of the filter type are available from several different original equipment manufacturers (OEMs). Table 1 below provides a summary of the timeline for the development of the multi-narrowband filter. If you were to ask each of the different OEMs where the idea for their multi-narrowband filter came from I am sure they'd say they came up with it themselves. Nonetheless I can't help but think that it was my interaction with Omega Optical that started the ball rolling.

Date	Activity	Date	Activity
Mar. 2011	Jim T. orders custom UV/IR cut filter from Omega Optical, to stack with LP filter and make dual narrowband filter	Fall 2018	OPT Radian Triad and other multi-narrowband filters start to become popular with OSC astrophotographers
Fall 2011	Jim T. begins testing custom Omega filter, the BDRB	Dec. 2018	Astro Hutech releases IDAS-NB1 filter
Aug. 2012	Jim T. updates Omega Optical with results of BDRB testing	Jan. 2019	OPT releases Radian Quad Band filter
Fall 2014	Omega Optical releases the first commercially available multi-narrowband filter	Mar. 2019	Optolong releases L-eNhance filter
Sep. 2017	OPT announces new product, the Radian Triad filter	Aug. 2019	Astro Hutech releases IDAS-NB2 and NB3 filters
Jan. 2018	STC release Astro Duo-Narrowband filter	Nov. 2019	ZWO releases Duo Band filter

Table 1 Timeline of Multi-Narrowband Filter Development

Objective:

As indicated in Table 1, there are now at least six different OEMs selling various versions of the multi-narrowband filter. The retail prices of these offerings vary widely, which made me pose the question: "Which of these filters provides the best value?" That is the objective of the testing summarized in this report, to test samples of the available multi-narrowband filters and compare them to each other in terms of performance and cost. The filters under test are summarized in Table 2, along with what it cost me to acquire a sample of each filter. Because I am located in Canada, the shipping and customs charges tend to add a significant amount to the landed cost. In addition to the seven filters listed in Table 2, I also tested two other multi-narrowband filter configurations to use as bench marks:

- Astronomik UHC + Baader UV/IR cut
- Meade O-III + Omega BDRB

The UHC stacked with a UV/IR cut is a filter combination that many amateurs can easily achieve using their existing gear. The Meade O-III plus Omega BDRB is the original filter combination that started it all (*maybe*).

Retailer/Brand	Filter Name	Size	Retail Price [USD]	Shipping [USD]	Customs [USD]	Landed Cost [USD]
Astro Hutech	IDAS NB1	2"	$239.00 **	$10.00	$38.38	$287.38
Astro Hutech	IDAS NB2	2"	$219.00			
Astro Hutech	IDAS NB3	2"	$219.00			
Omega Optical (eBay seller: bjomejag)	Hyd' & Oxy' Nebula LPF Improved (2019)	1.25"	$99.50	$10.00	$20.25	$129.75
Omega Optical (eBay seller: bjomejag)	Hyd' & Oxy' Nebula LPF Improved (2014)	2"	$0.00*	$32.00	$0.00	$32.00
Optolong Optics	L-eNhance	1.25"	$179.00			
Optolong Optics	L-eNhance	2"	$229.00	$10.50	$37.08	$276.58
Radian Telescopes (OPT)	Triad Tri-Band Narrowband	1.25"	$375.00	$18.47	$52.43	$445.90
Radian Telescopes (OPT)	Triad Tri-Band Narrowband	2"	$775.00			
Radian Telescopes (OPT)	Triad Ultra Quad-Band Narrowband	1.25"	$975.00			
Radian Telescopes (OPT)	Triad Ultra Quad-Band Narrowband	2"	$1,075.00			
Sense-tech Innovation Company (STC)	Astro Duo-Narrowband	1.25"	$280.00	$33.00	$17.10	$330.10
Sense-tech Innovation Company (STC)	Astro Duo-Narrowband	2"	$348.00			
Suzhou ZWO Co. Ltd.	Duo-Band Narrowband	1.25"	$99.00			
Suzhou ZWO Co. Ltd.	Duo-Band Narrowband	2"	$179.00	$10.50	$28.64	$218.14

* Free sample since I gave Omega the idea for this filter 2 years prior.
** Since I made my purchase the retail price has been reduced to $219USD.

Table 2 Summary of Available Multi-narrowband Filters c/w Cost

Method:

The testing began with a thorough visual inspection, followed by 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 one of two cameras: ZWO ASI-294MC Pro (OSC), or Mallincam Skyraider DS432M-TEC (monochrome).

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 with each camera were collected on different evenings, the colour images on October 8th, 2019, and the monochrome images on

October 12th, 2019. The ZWO brand filter was released after these images were collected, so images with that filter were collected of a different target on a much later date of February 21st, 2020.

Results - Visual Inspection:
Figure 3 presents the appearance of the seven sample filters relative to each other. Photographs of each sample filter with their respective packaging can be found in Appendix A. The first thing I noticed was that the extent of the packaging varies considerably between the different filters. Both of my samples from Omega arrived in a fabric envelope that was taped to my receipt, which was shipped inside a simple padded mailer. At the other end of the spectrum are the OPT and STC filters which came inside plastic cases that were in turn packaged inside decorative boxes, packed inside protective outer boxes for shipping. The other samples were mostly what you would expect, with the filter contained in a plastic case shipped in a small cardboard box.

Figure 3 Photo of Sample Filters Used In Test

The next thing I noted was the differences in the filter cell designs. Both Optolong and STC use much lower profile cells, reportedly to save weight and space. In my opinion the smaller cell is simply to reduce manufacturing costs, and does not provide any practical advantage. While switching between filters during my testing I found the shorter cells harder to handle. The STC filter was the worst as I found the machining and finish of the filter left it slippery (I dropped it on the ground once when swapping it with another filter). Another thing I noted was that the thickness of the retaining rings varied widely between the different filter brands. In the case of the Optolong and ZWO brand filters the retaining ring thickness was such that there were no female threads showing. I find this a bit of a nuisance since it means that you can't put the filter in the middle of your optical train, you have to put it on the end. I often place filters right at the camera, followed by the focal reducer or nosepiece, but was not able to do that with the Optolong and ZWO brand filters.

Based on visual inspection it appears that all of the filters use physical vapour deposition (PVD) coatings on the exterior surfaces of the glass substrate, and not a coated substrate sandwiched between two clear glass windows like in the 80's and 90's. This is good as it means that all of the filters should be reasonably durable and easy to maintain. I disassembled all the sample filters to see if the glass media had darkened edges, a small detail but one that shows the company has an underlying understanding of what it takes to make quality optics. The darkening of the edges on optics helps to reduce scattering of light within the glass media, improving contrast. I found the following filters had darkened edges: ZWO, Optolong, OPT, and STC; and the following did not: Omega, and Astro Hutech. Regarding attention to detail however I was surprised to find that the OPT filter arrived with very noticeable dirt on the glass, and with the glass loose in its cell. I found out later, when I disassembled the OPT filter, that part of the reason for the looseness was that the filter glass is cut about 1mm too small in diameter and so is able to move significantly in the cell unless it is pressed down tightly by the retaining ring. All the other filter samples, even the frugally packaged Omega ones, arrived clean and tight in their cells.

In addition to the observations noted above, the STC brand filter presented some additional curious features. For one thing it was packaged with a small microfiber cloth for cleaning the filter, and a print out of this particular filter's quality inspection report including a spectral response plot, both very nice additions. Coincidently filters from Omega normally come with measured spectral response data as well as part of the shipping paperwork. In contrast to the nice additions, however, the STC filter comes in an impractically large case, much larger than needed. Also, the silk-screened labelling on the side of the filter cell is so darn small (<1mm tall) I found it impossible to read without a magnifying glass! Now why would they do that? I also discovered when I disassembled the filter that they used extremely thin glass, on the order of 0.5mm thick. Knowing this fact I am worried this filter will be very easy to break … I was evidently very lucky the filter fell onto the grass when I dropped it. All the other filters use thicknesses that are more typical, between 1 and 3mm.

Results – Spectrometer Measurements:

For me, one of the big questions to be answered by this test was: "Does the filter deliver what the manufacturer says it does?" In my many investigations of astronomical filters I have found numerous occurrences of marketing material not being entirely accurate. That is probably the main reason I purchased my spectrometer, so that I could determine who the trustworthy manufacturers are. The individual spectral transmissivity measurement plots for each filter can be found in Appendix B. Included in each plot is an inset of the manufacturer reported spectral response. Based on my spectrometer measurements, it would appear that all of the filter performances are well characterised by their corresponding marketing material, with the exception of the OPT and STC filters. The spectral response plot provided by OPT for the Triad filter shows in-band responses that are essentially at 100%, but that is very clearly not the case. Similarly the STC Duo-Narrowband filter marketing material shows a single peak at >90% transmissivity centered on 500.7nm for the O-III pass band, but in reality the filter has a double peak in that pass band, with a transmissivity closer to 80%.

The other big question that can be answered by the spectrometer measurements is: "How do the performances of the filters compare with each other?" Figures 4 and 5 present a comparison of spectral transmissivity between all the filters measured, for the bands around O-III and Hα respectively.

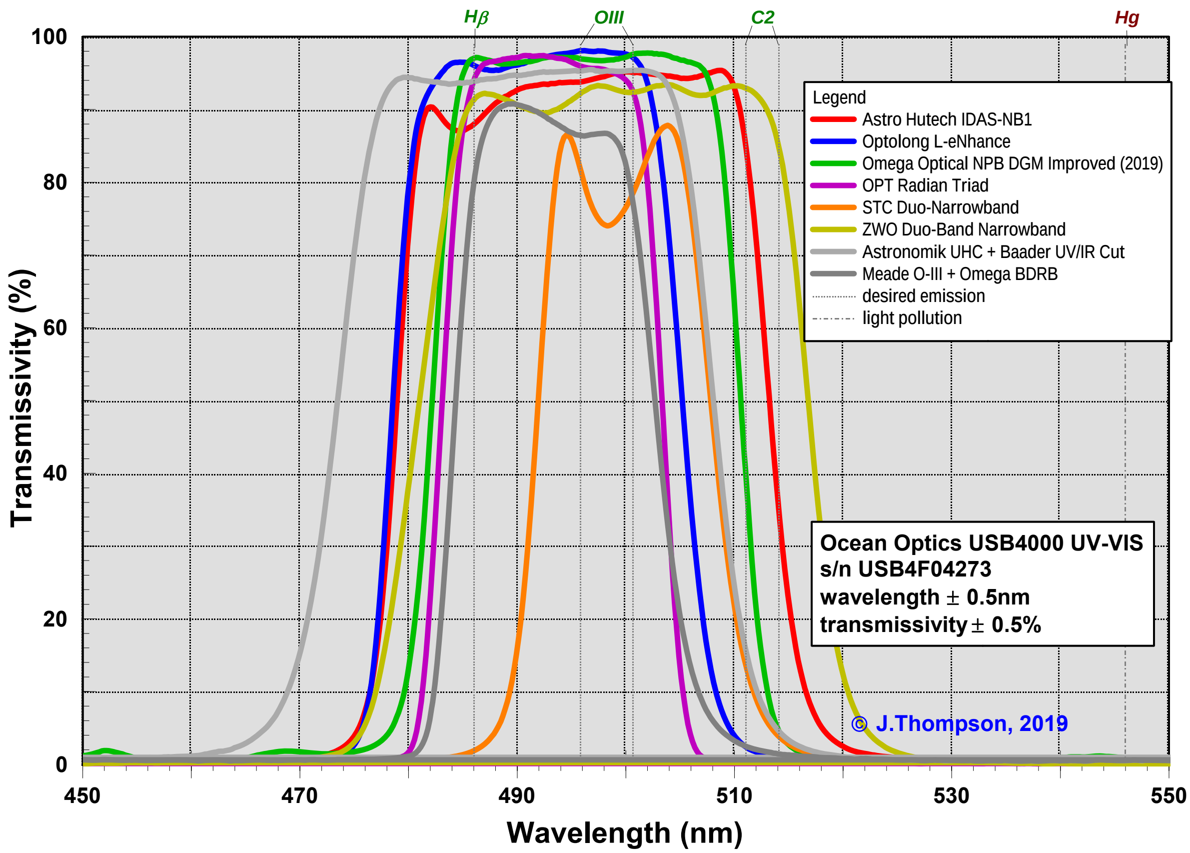


Figure 4 Measured Spectral Response Comparison – O-III Pass Band

The measurements show a fair amount of variation in the pass band definition of each filter. These filters would all seem to have been made with slightly different recipes, and are not direct copies of one another. The principle performance characteristics for each filter have been calculated from the measured data, and are summarized in Table 3. Of the multi-narrowband filters tested, the Astro Hutech and ZWO versions are expected to be the weakest performers. They have wider pass bands than the other filters so they are not expected to provide as good an increase in contrast as the others. I should note that Astro Hutech also has an NB2 and NB3 model filter with narrower pass bands that are expected to provide higher contrast levels similar to the other filters in this test. The OPT Triad, having the narrowest pass bands, is expected to deliver the best increase in contrast, however the narrowness and band position around Hα suggests that this filter is also more sensitive to focal ratio than the others. This is something that I will discuss in more detail later in this report. The Omega and Optolong filters, although not as narrow as the OPT Triad, are expected to be very good performers as well. The STC filter is hard to judge by looking at the spectral response plots, but I suspect it will provide performance similar to the Omega and Optolong brand filters.

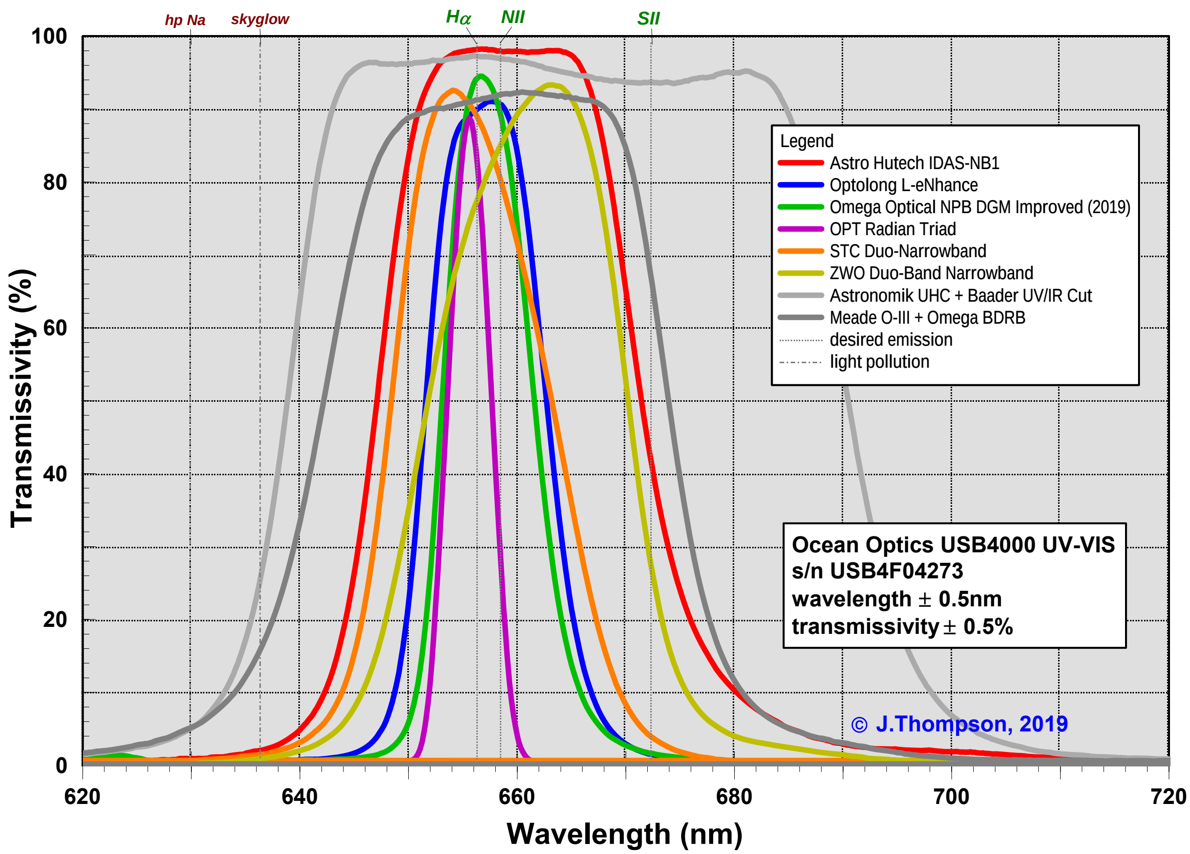


Figure 5 Measured Spectral Response Comparison – Hα Pass Band

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)	
Astro Hutech IDAS-NB1	34.5nm	88.2%	93.8%	95.0%	24.7nm	98.2%	98.0%	40.9%	OD 2.4
Optolong L-eNhance	26.7nm	95.9%	98.1%	97.0%	11.8nm	90.1%	90.7%	1.5%	OD 2.5
Omega Optical NPB DGM Improved	28.7nm	97.1%	96.9%	97.6%	8.6nm	94.3%	90.0%	1.6%	OD 2.3
OPT Radian Triad	20.4nm	94.7%	95.9%	92.1%	4.5nm	81.7%	29.1%	0.2%	OD 2.9
STC Duo-Narrowband	16.4nm	2.0%	80.9%	78.8%	15.5nm	88.7%	80.0%	3.8%	OD 2.4
ZWO Duo-Band Narrowband	36.2nm	91.6%	92.3%	92.4%	19.2nm	77.8%	84.9%	26.5%	OD 3.0
Astronomik UHC + Baader UV/IR Cut	35.2nm	93.9%	95.3%	95.3%	51.9nm	97.2%	96.9%	93.7%	OD 2.2
Meade O-III + Omega BDRB	18.9nm	81.7%	86.4%	76.4%	32.6nm	91.3%	92.0%	66.0%	OD 2.2

Table 3 Measured Filter Performance Summary

Knowing the measured spectral response of the sample filters also allowed me to predict the 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 6 shows a sample of the resulting plot, specifically the plot corresponding to filter performance when using a monochrome CMOS camera under heavily light polluted skies complete with local LED street lights. Plots for the other cases, CMOS under a dark sky and the comparable two plots for a human observer, can be found in Appendix C.

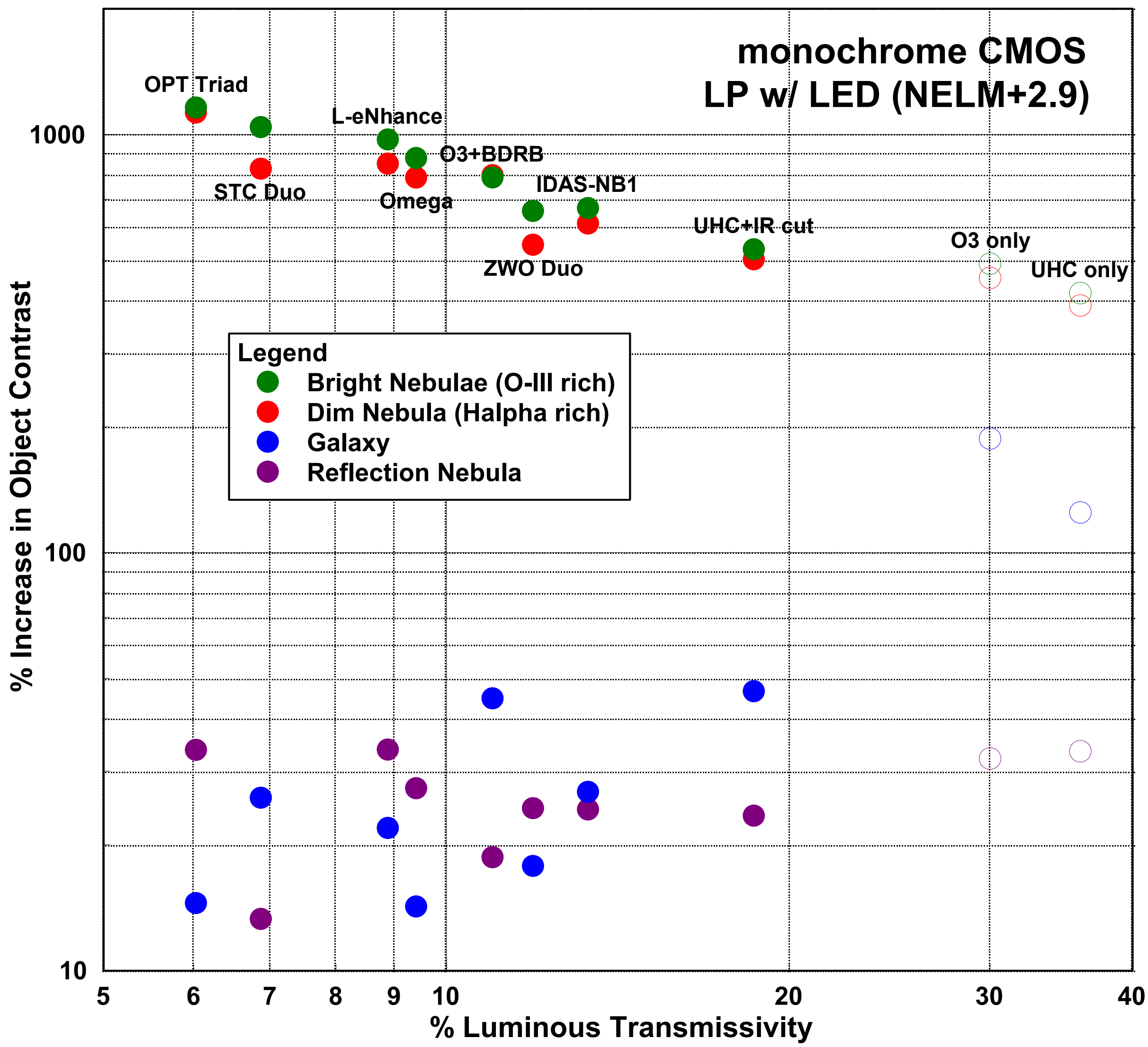


Figure 6 Predicted Filter Performance: Monochrome CMOS, LP w/LED (NELM+2.9)

For emission type nebulae, there is an obvious trend to the data: as the pass band gets 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 attenuates with decreasing %LT. The average expected increase in contrast is also significantly less for broadband targets than for emission nebulae. For comparison I have included in the plot the case of the Astronomik UHC and Meade O-III filters without an IR blocking filter added since previous studies have shown these filters to be good performers on galaxies when observed with a camera.

In terms of how each multi-narrowband filter is predicted to perform relative to the others, the results are consistent with what was surmised from looking at the measured spectral response data. The OPT Triad filter is predicted to provide the best increase in contrast compared with no filter. The ZWO and IDAS NB1 are predicted to improve contrast the least, and the other three are predicted to have similar reasonably good performance. Another interesting observation from the predicted performance plots is that when used visually on faint nebulae, ie. those that emit mostly Hα and Hβ only, the STC Duo-Narrowband filter performs much more poorly than the other multi-narrowband offerings. This is because the STC filter passes virtually no Hβ, but the other brands do.

Results – Imaging:
Figure 7 and 8 are examples of the monochrome and colour images respectively that were collected using the different multi-narrowband filters. The rest of the collected images can be found in Appendix D and E. The target used for all the images was the Eastern Veil nebula (NGC6992) as it has prominent emissions from both O-III and Hα, and it was well placed overhead at the time the images were captured. The exception is the colour image collected using the ZWO Duo-Band filter, which I did not received until late November 2019. The sample image I captured using that filter is of NGC2244, the Rosette Nebula, captured in February 2020.

Let's look first at the monochrome images. These images are as captured, but with levels adjusted post-capture so that the histograms of each image are comparable to each other. My initial impression was that all the filters tested provided a similar large increase in contrast versus no filter. Looking more closely at each image there are subtle differences in the extent of faint nebulosity that is visible. These subtle differences are consistent with the measured spectral response data. For example the clearest presentation of faint nebulosity details is provided when using the OPT Triad filter, followed closely behind by the Optolong, Omega, and STC brand filters. The IDAS filter showed a good increase in contrast, but not quite as good as the other filters. Based on the other observations made during my testing, I would expect an image captured using the ZWO filter to be very similar to that captured with the IDAS filter.

Next let's look at the colour images. These images are as captured from the camera, with no post-processing. The camera white balance (WB) settings were left at default so that the full effect of the filter on WB can be seen clearly. The most obvious observation is that all of the multi-narrowband filters impart a strong green cast to the image. This is to be expected on a OSC camera since the typical Bayer matrix on the sensor has two green pixels for every red or blue pixel, and most of the light passed by the filter is centered around the green part of the spectrum.

Figure 7 Sample Image – Monochrome (DS432M), IDAS NB1 filter, levels adjusted post-capture

To investigate the WB issue further, I present the histograms from each image for each of the filters in Figure 9. The histograms clearly illustrate the disparity between the different colour channels in the images. There are a couple of implications resulting from the WB disparity:

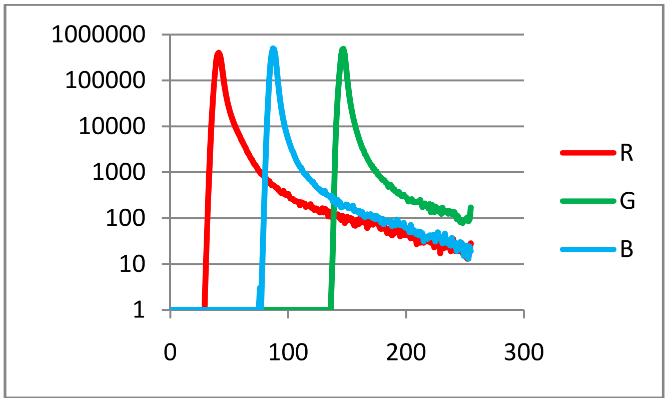
1. The effective exposure on each colour channel is not the same, making image data collection less straight forward than using a monochrome camera and a set of narrowband filters. Table 4 summarizes the effective exposure of the RED and BLUE channels relative to GREEN for each filter, as measured from the histogram data. Using a multi-narrowband filter and an OSC camera one will need to be careful to pick an exposure time that does not saturate the green channel, yet provides sufficient signal on the red channel. The difference in channel exposure also means that the number of sub-exposures needed to achieve the desired signal-to-noise ratio (SNR) should be based on the SNR of the red channel subs and not the overall sub-image SNR which is dominated by the green channel.

Figure 8 Sample Image – Colour (ASI294MC Pro), IDAS NB1 filter, as captured by camera

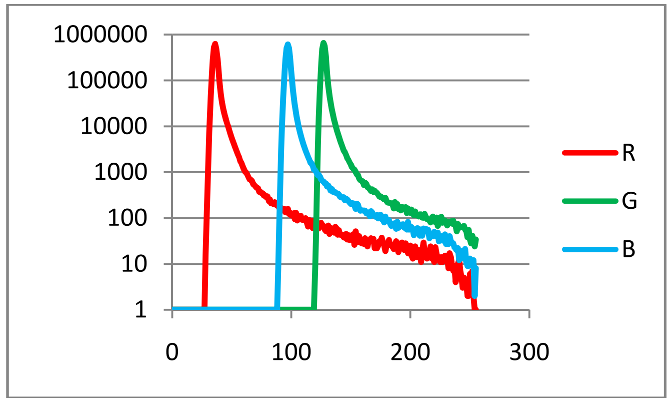
Filter	Exposure (Relative to Green)	
	Red	Blue
Astro Hutech IDAS-NB1	0.30	0.60
Optolong L-eNhance	0.29	0.76
Omega Optical NPB DGM Improved	0.22	0.68
OPT Radian Triad	0.24	0.76
STC Duo-Narrowband	0.48	0.57
ZWO Duo-Band Narrowband	0.21	0.49
Meade O-III + Omega BDRB	0.72	0.52

Table 4 Relative Colour Channel Exposure

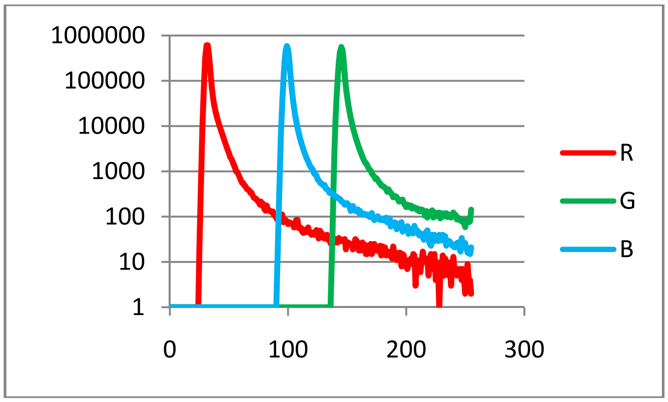
2. Use of a global post-processing method for correcting WB is challenging. Achieving the desired WB on the deepsky object and the background sky/stars simultaneously is difficult. Figure 10 shows the processed version of Figure 8, where a LEVELS tool has been used to individually adjust each colour channel's histogram so that their peaks and widths roughly align with each other. Corrected images for all the filters can be found in Appendix F. This method gives a reasonably good WB, but when you compare the result of this correction method on the images from each filter you can see there are differences that result, and in some cases a general tint remains in the image. The corrected OPT Triad image is a good example of this, showing a definite cyan hue in the background and stars. The relative prominence of each emission type also varies significantly, some filters emphasizing O-III more than Halpha, some emphasizing Halpha more, and some providing more of a balance between the two.



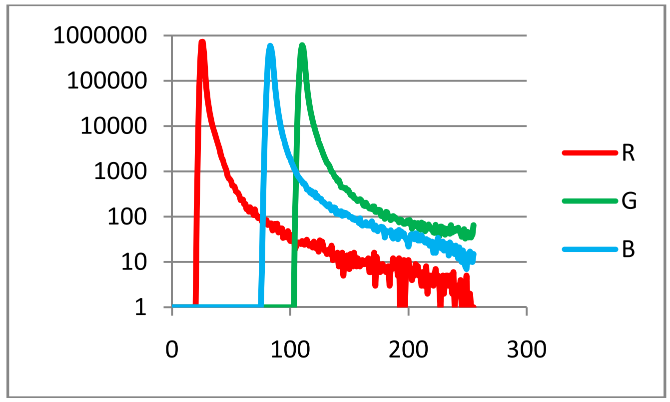
Astro Hutech IDAS-NB1



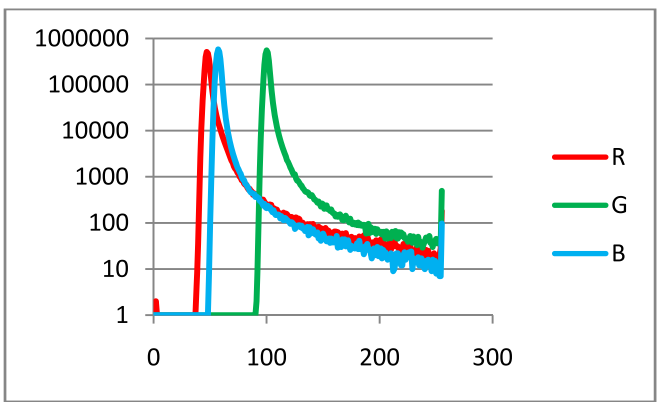
Optolong L-eNhance



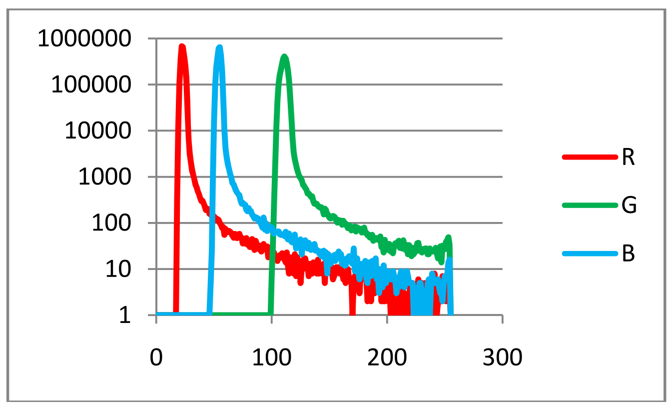
Omega H&O Nebula LPF Improved



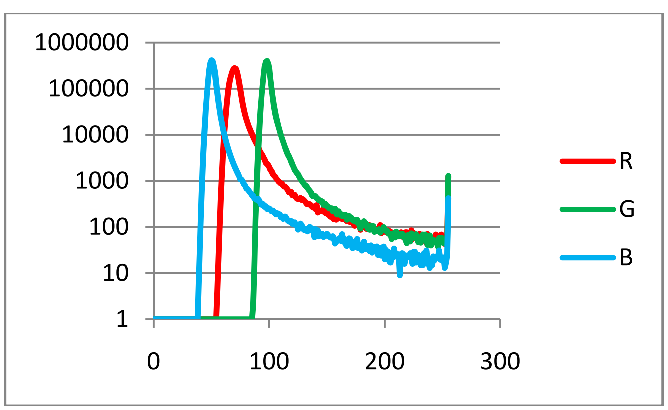
OPT Radian Triad



STC Astro Duo-Narrowband



ZWO Duo-Band Narrowband



Meade O-III + Omega BDRB

Figure 9 Histograms From Each Filter's Sample Colour Images

Figure 10 Sample Image – Colour (ASI294MC Pro), IDAS NB1 filter, WB using LEVELS

The WB has a very large impact on the end result, and so requires a significant amount of attention from the user of multi-narrowband filters if they expect to get results they are satisfied with. For the astrophotographer who is using a normal image processing work flow, the WB is perhaps not an issue they aren't already used to dealing with. For users who are applying the filter to a camera for "live" observing (Electronically Assisted Astronomy, Video Astronomy, Near Real-time Imaging, etc.), it is more of a challenge to achieve the desired WB as the software tools available are not as elaborate as for image post processing. My recommendation is that if your software of choice has the function, use the LEVELS tool on each channel individually so you can set the black point and white point on each colour channel separately. Just using a gain adjustment on each channel does not give the same result, tending to spread the red channel data out over a wide part of the histogram, giving odd colour blotchiness and clipping of data at the dark end of the histogram. For the visual observer, the WB issue is not really an issue at all since humans can't see colour very well when their eyes are dark adapted. Stars will however have a very obvious blue-green colour when using a multi-narrowband filter visually.

Results - Angle Sensitivity:
The narrowness of a filter's pass bands will have an impact on how it performs on fast f-ratio telescopes. This is because the faster the f-ratio of your optics, the bigger the angle off of perpendicular the light passing through the filter will be. Making the light pass through the filter at an angle effectively increases the thickness of the many layers that make up the filter, thus changing the optical properties of the filter. To quantify this effect I re-measured the spectrum

of each filter using my spectrometer, but propped one end of the filter up using a range of spacer blocks in order to achieve a known filter angle relative to the incoming light. Figure 11 shows an example of how the angle of the light affects the resulting filter response spectrum. The behaviour demonstrated in Figure 11 is typical; as the angle increases, the pass bands shift to the left and peak transmissivity reduces. I have summarized the measured impact of filter angle into plots showing how the transmission of each wavelength of interest changes with angle. The resulting plots are shown in Figure 12. Included in the plots are lines denoting the angle corresponding to optics with f-ratios of 4, 3, and 2.

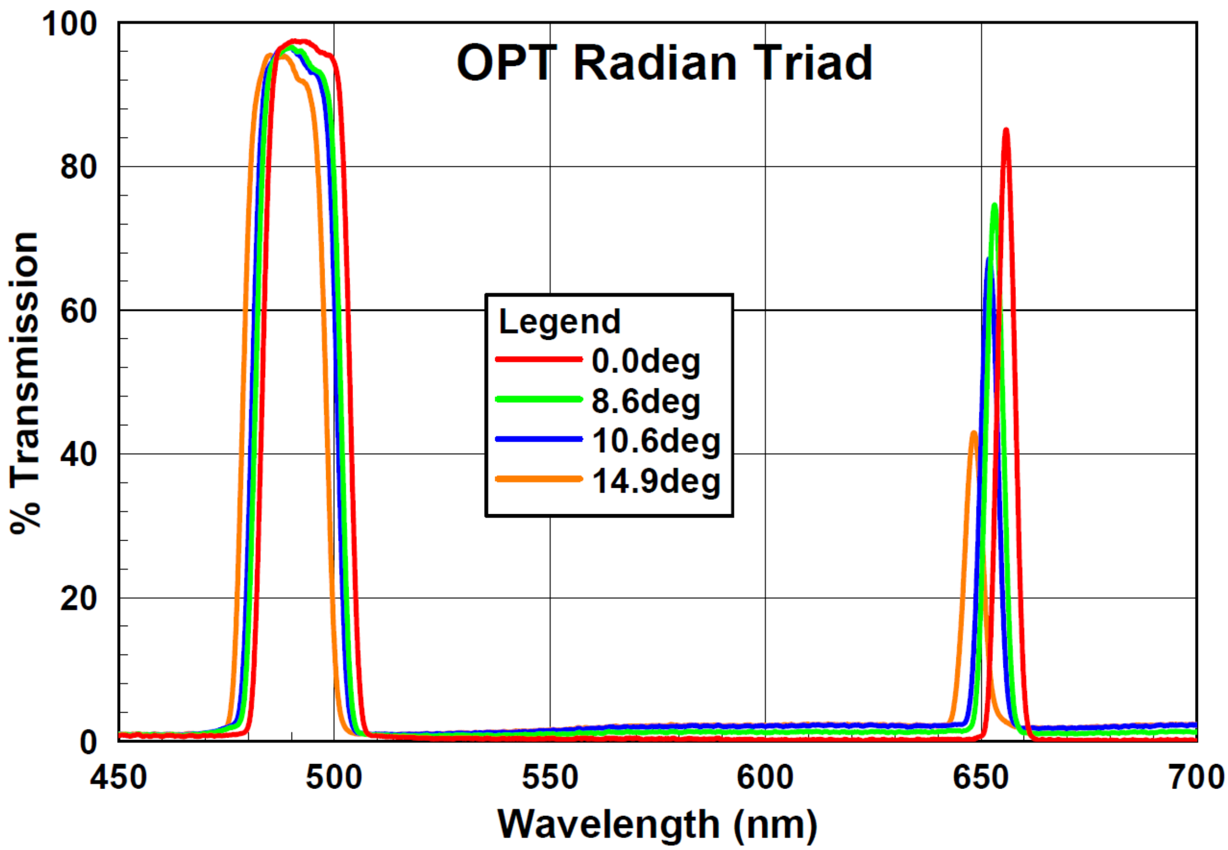


Figure 11 Impact of Filter Angle On Spectral Response – OPT Radian Triad

I find the results presented in Figure 12 to be rather interesting as they have opened my eyes up to the fact that there is more involved in picking the best filter than just which one has the narrowest pass bands. The optics with which the filter will be used plays a large role in how effective the filters are. When looking at the plots, probably the two most important lines to pay attention to are the dark blue and orange lines, those for O-IIIb and Halpha respectively. These two wavelengths are the strongest emission sources we see coming from nebulae. The two filters I identified earlier as producing the lowest increase in contrast, the IDAS NB-1 and ZWO Duo-Band, are also the two filters providing the least sensitivity to f-ratio. Conversely the filter identified as providing the largest improvement in contrast, the OPT Radian Triad, is also the one with the largest sensitivity to f-ratio.

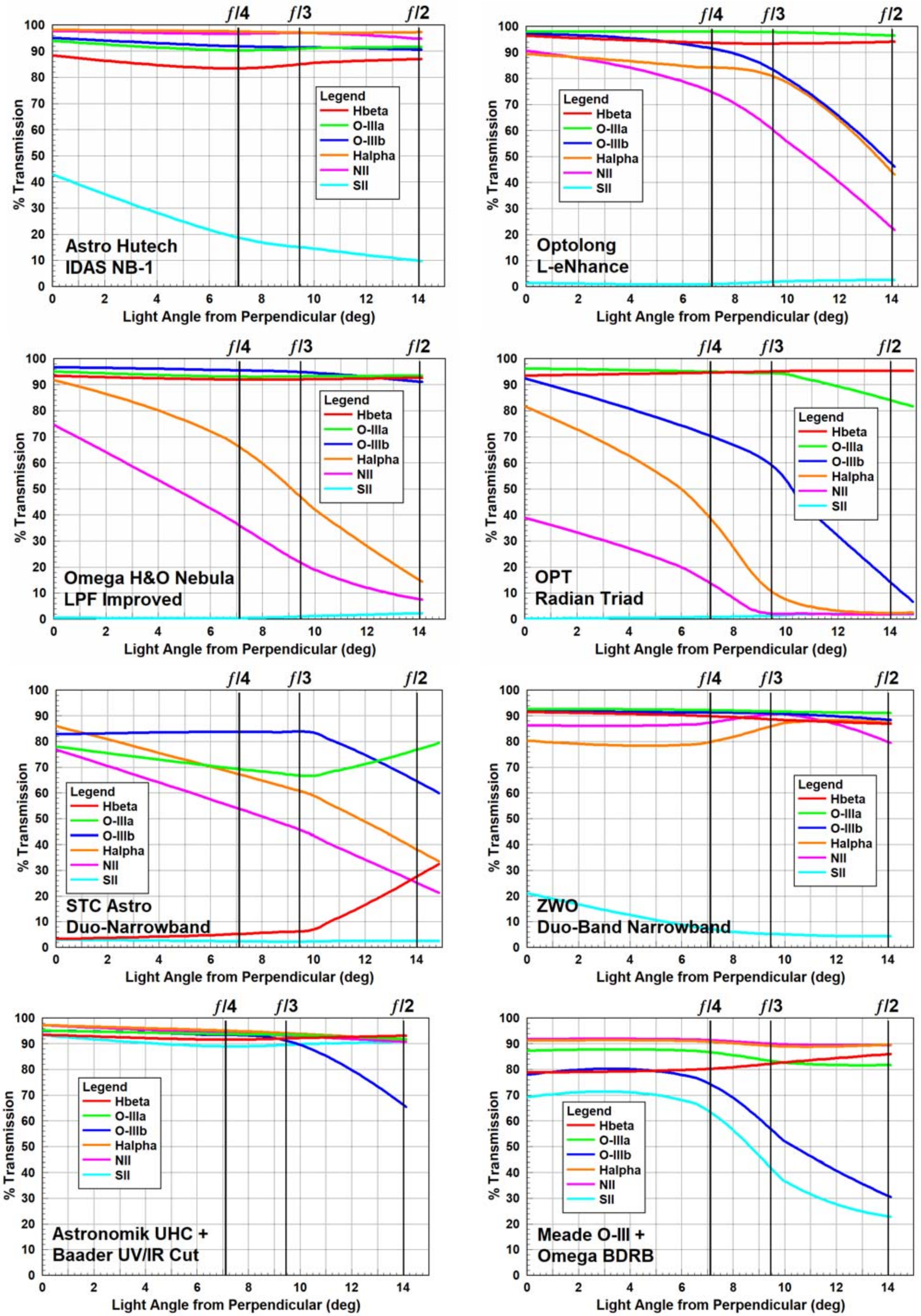


Figure 12 Summary of Angle Impact On Filter Transmission

Some may wonder how exactly a filter's sensitivity to f-ratio will manifest itself, whether the filter is being used visually or with a camera. Light travelling down the center of the scope's aperture is passing through the filter at nearly right angles, so in that part of the view the filter performance is as we'd expect. Light travelling down the scope at the edges of the aperture is passing through the filter at an angle, shifting the filter performance as shown in Figure 11 and 12. The end result is a view that looks like it is suffering from vignetting, bright in the center and dark on the edges. This vignetting can only be partly compensated for using a flat frame. Some of the vignetting is due to the filter's overall transmission being lower at higher angles; this part can be corrected for using a flat frame. The other part of the vignetting is due to the shift in the pass bands affecting how much of the target nebula emission is getting through the filter; this part can't be corrected for with a flat frame ... unless one can somehow take a flat frame where the light source has the same emission spectrum as a nebula.

Conclusions:

This test report summarizes what is probably the most thorough testing and analysis I've ever done on any sort of filter. My extra effort stems from a heightened interest in the multi-narrowband class of filters, with which I share a personal history. The conclusions of my testing are as follows:

1. All of the filters tested demonstrated an increase in contrast when used to observe emission type nebulae. The extent to which each filter improved contrast was dependant on how narrow their pass band widths are. The OPT Radian Triad showed the largest increase in contrast, while the IDAS NB-1 and ZWO Duo-Band showed the smallest increase in contrast.
2. Most of the filters showed sensitivity to f-ratio. The IDAS NB-1 and ZWO Duo-Band showed almost no sensitivity to f-ratio due to their wider pass bands. All the other filters showed sensitivity varying with the width of their pass bands, the narrower the band the more sensitive it was. The Optolong and STC filters are probably okay for use with f/3 or slower systems, the Omega filter down to f/4, and the OPT will work best on systems slower than f/5.
3. Most of the filters tested had measured spectral transmissivities consistent with that reported by their manufacturers. The exceptions to this were the OPT Radian Triad and STC Duo Narrowband, both of which had measured spectral responses very different from that reported by their manufacturers.
4. All of the filters tested showed a large impact on white balance. The green channel is strongly favoured by these filters, resulting in a strong bias in colour towards green. The relative widths of the O-III and Halpha pass bands plays a role in how emissions at these wavelengths appear in the final white balanced image. The disparity between colour channels also results in a need to carefully consider exposure time (so don't over expose green channel) and number of sub-exposures (to get desired SNR on red channel).
5. The OPT Radian Triad filter arrived with the glass media dirty and loose in its housing. This was unique to OPT as all the other filter samples arrived clean and secure.

6. The STC Duo Narrowband filter is made from extremely thin glass. I am worried that this filter will be easily broken if dropped, or if exposed to rapid temperature changes.
7. Based on quality and performance, I am unable to justify the cost of the OPT Radian Triad or STC Duo Narrowband filters. The Astro Hutech, Omega, Optolong, and ZWO brand filters provide a much better value for money.
8. The Omega brand filter is the cheapest available option, and it delivers very good performance. I would like to say it is my favourite of the filters tested, also because of the history we share, but to be honest I think the Optolong brand filter has an edge over the Omega filter due to its better f-ratio sensitivity.

I apologise for the length of this test report. I felt it was important to be as complete as possible. If you have any questions, please feel free to contact me.

Cheers!

Jim Thompson
top-jimmy@rogers.com

Appendix A

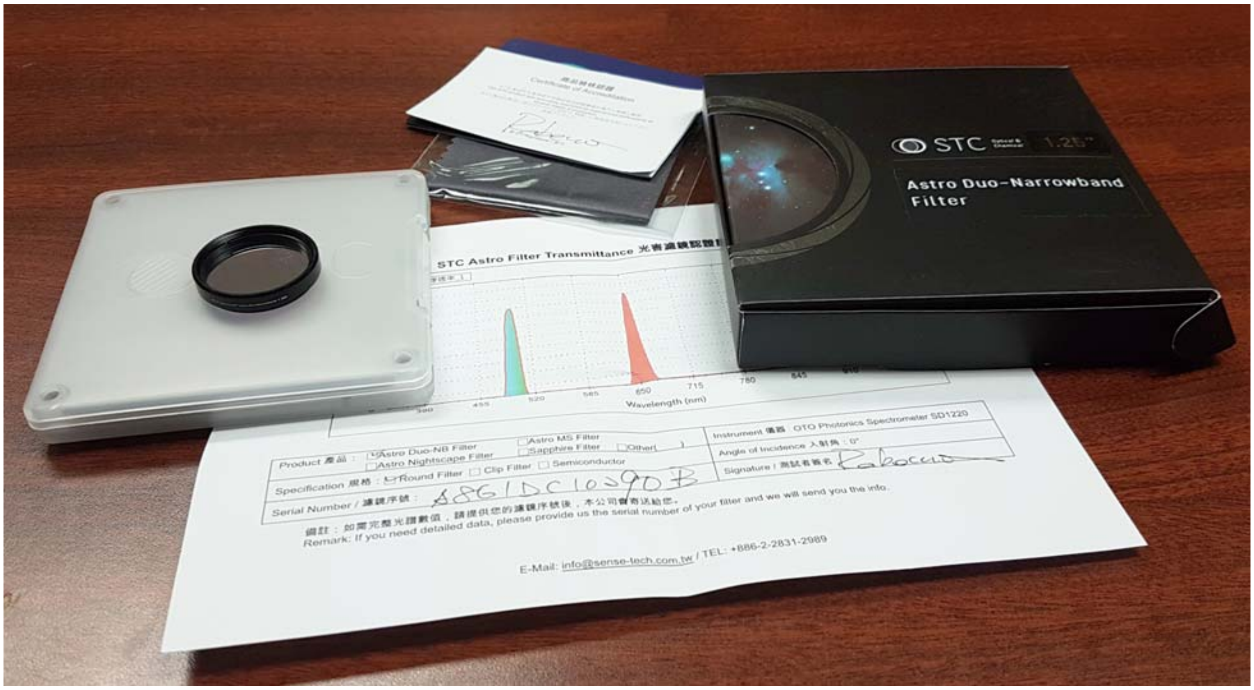
Filter & Packaging Images

Astro Hutech: IDAS NB1

Optolong: L-eNhance


Omega Optical: Hydrogen & Oxygen Nebula LPF Improved (NPB DGM)

Oceanside Photo & Telescope: Radian Triad

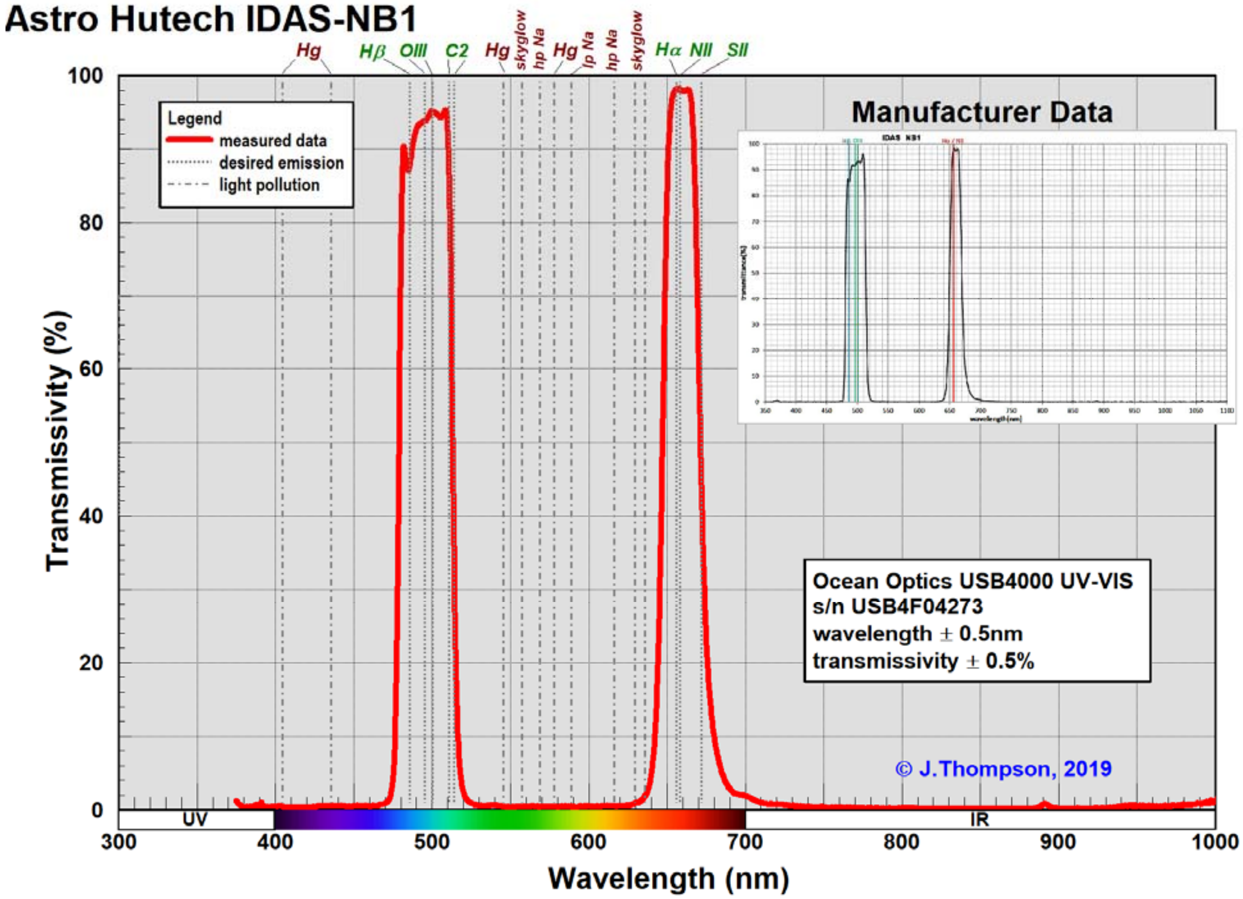


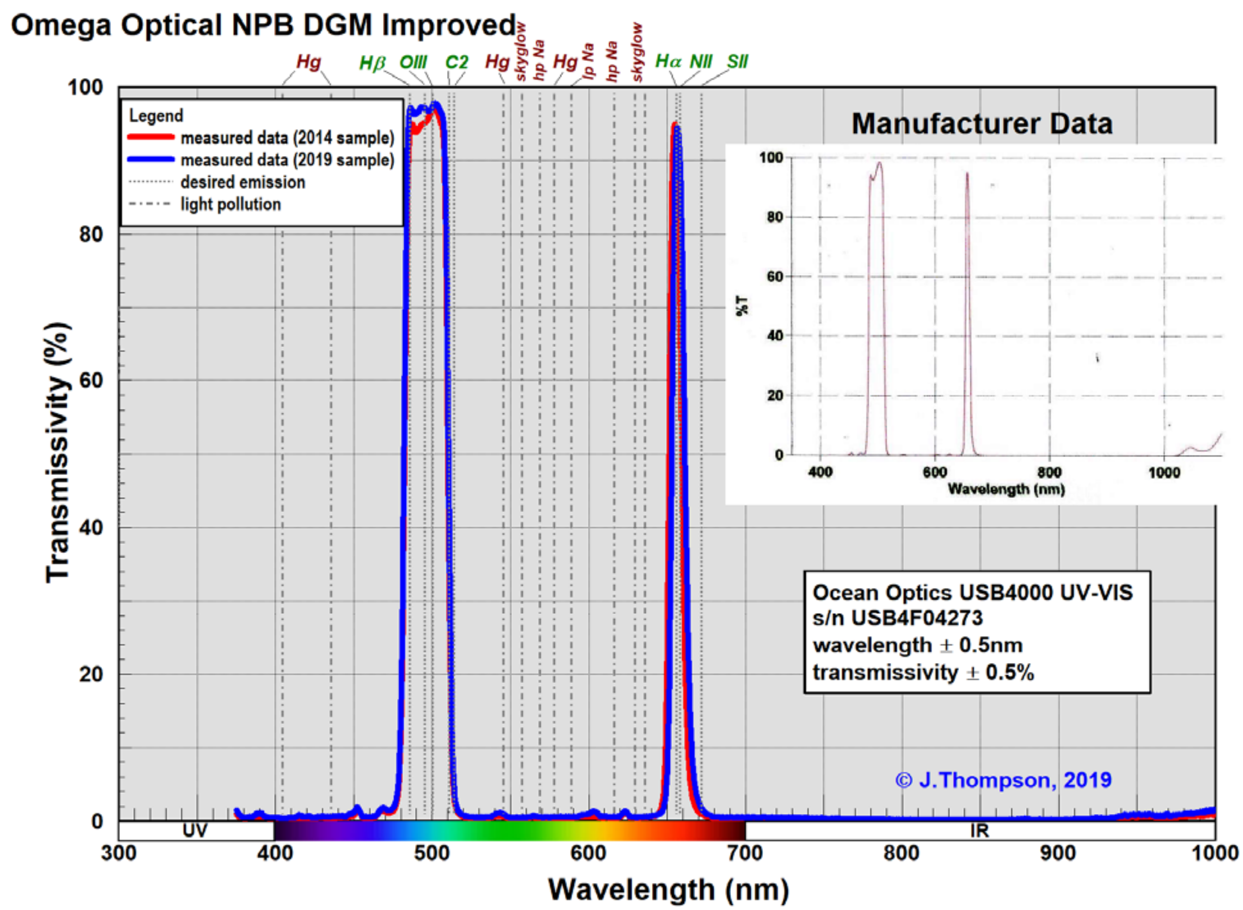
Sense-tech Innovation Company: Astro Duo-Narrowband

ZWO: Duo-Band Narrowband

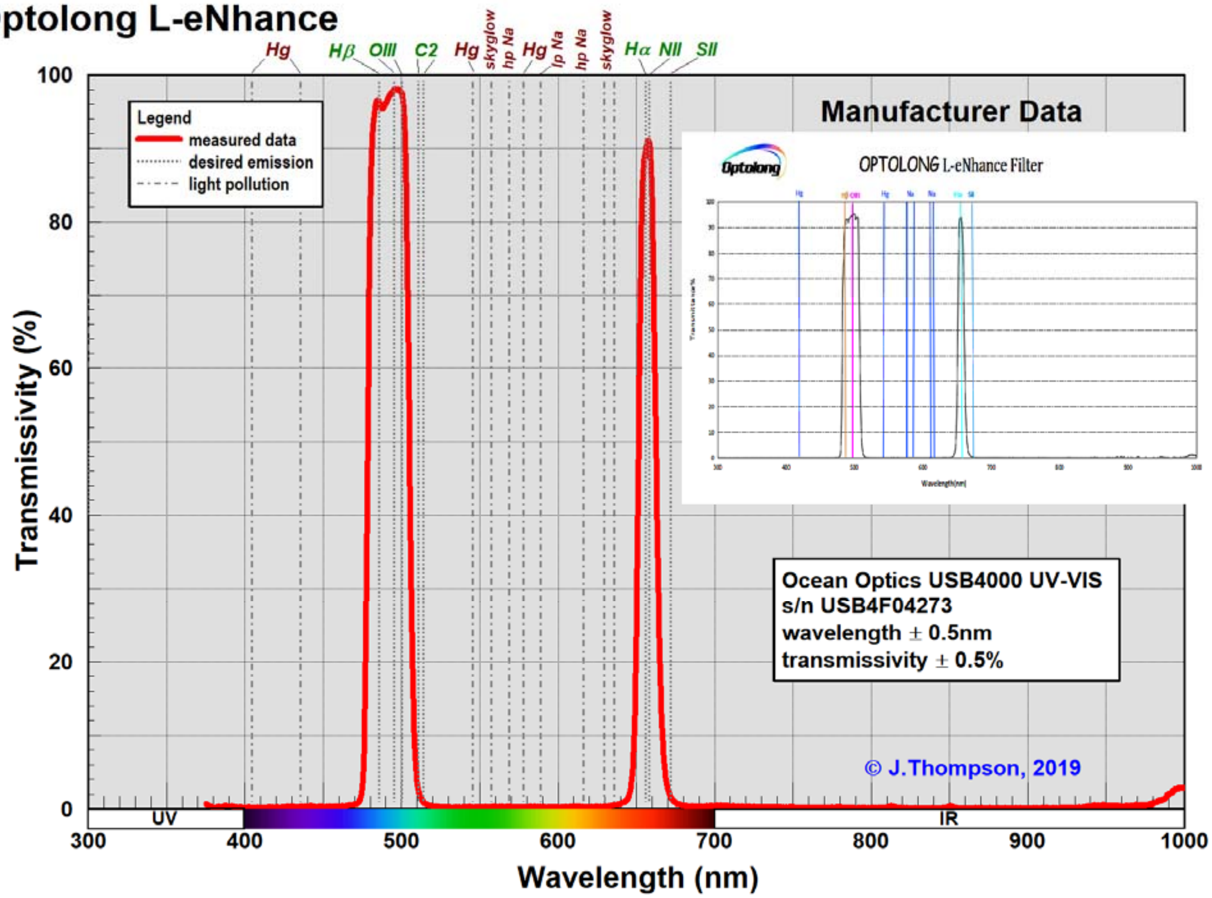
Appendix B

Measured Filter Spectral Transmissivity

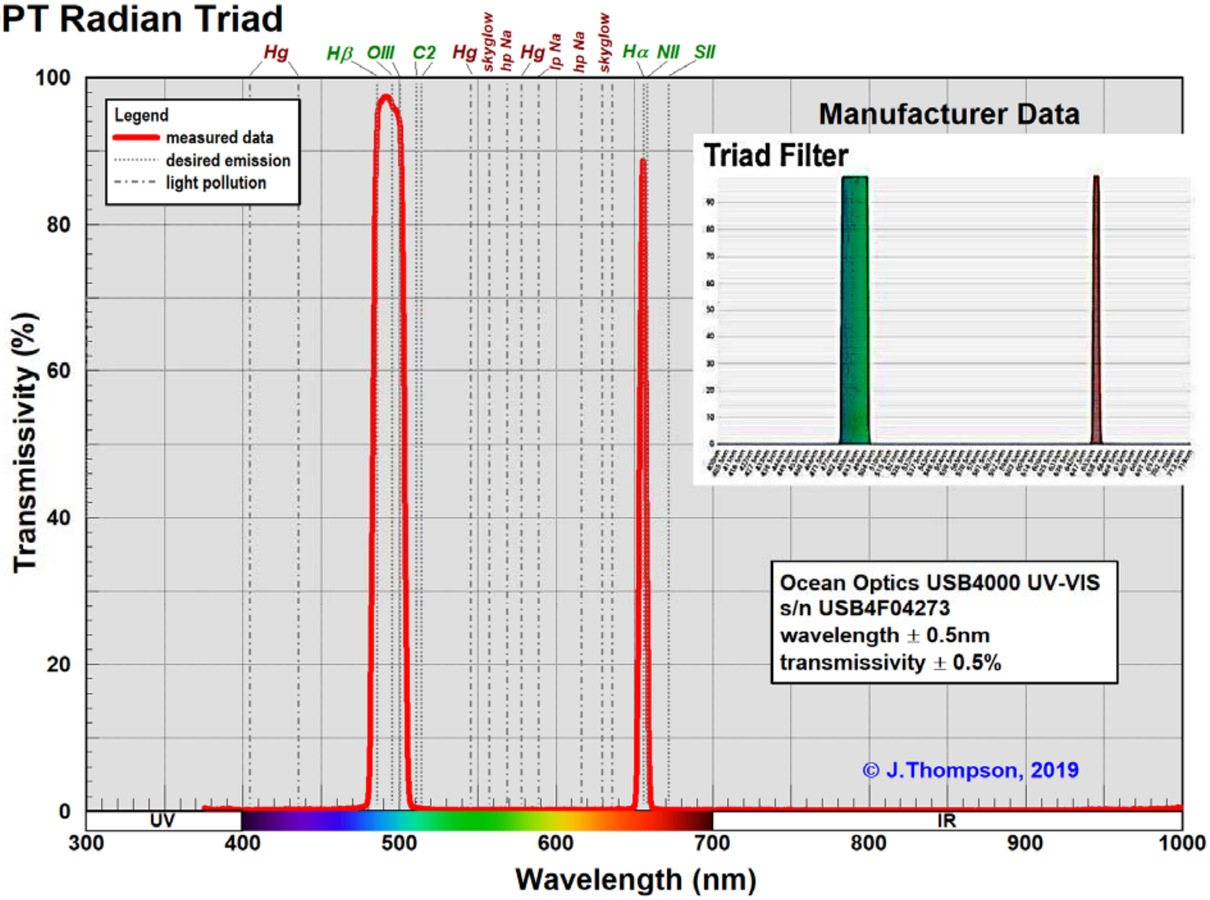

Astro Hutech IDAS-NB1
Hg
Hβ
OIII
C2
Hg
skyglow
hp Na
Hg
lp Na
hp Na
skyglow
Hα
NII
SII
Legend
measured data
desired emission
light pollution
Manufacturer Data
Ocean Optics USB4000 UV-VIS
s/n USB4F04273
wavelength ± 0.5nm
transmissivity ± 0.5%
© J.Thompson, 2019
Transmissivity (%)
Wavelength (nm)
UV
IR


Omega Optical NPB DGM Improved
Hg
Hβ
OIII
C2
Hg
skyglow
hp Na
Hg
lp Na
hp Na
skyglow
Hα
NII
SII
Legend
measured data (2014 sample)
measured data (2019 sample)
desired emission
light pollution
Manufacturer Data
%T
Wavelength (nm)
Ocean Optics USB4000 UV-VIS
s/n USB4F04273
wavelength ± 0.5nm
transmissivity ± 0.5%
© J.Thompson, 2019
Transmissivity (%)
Wavelength (nm)
UV
IR

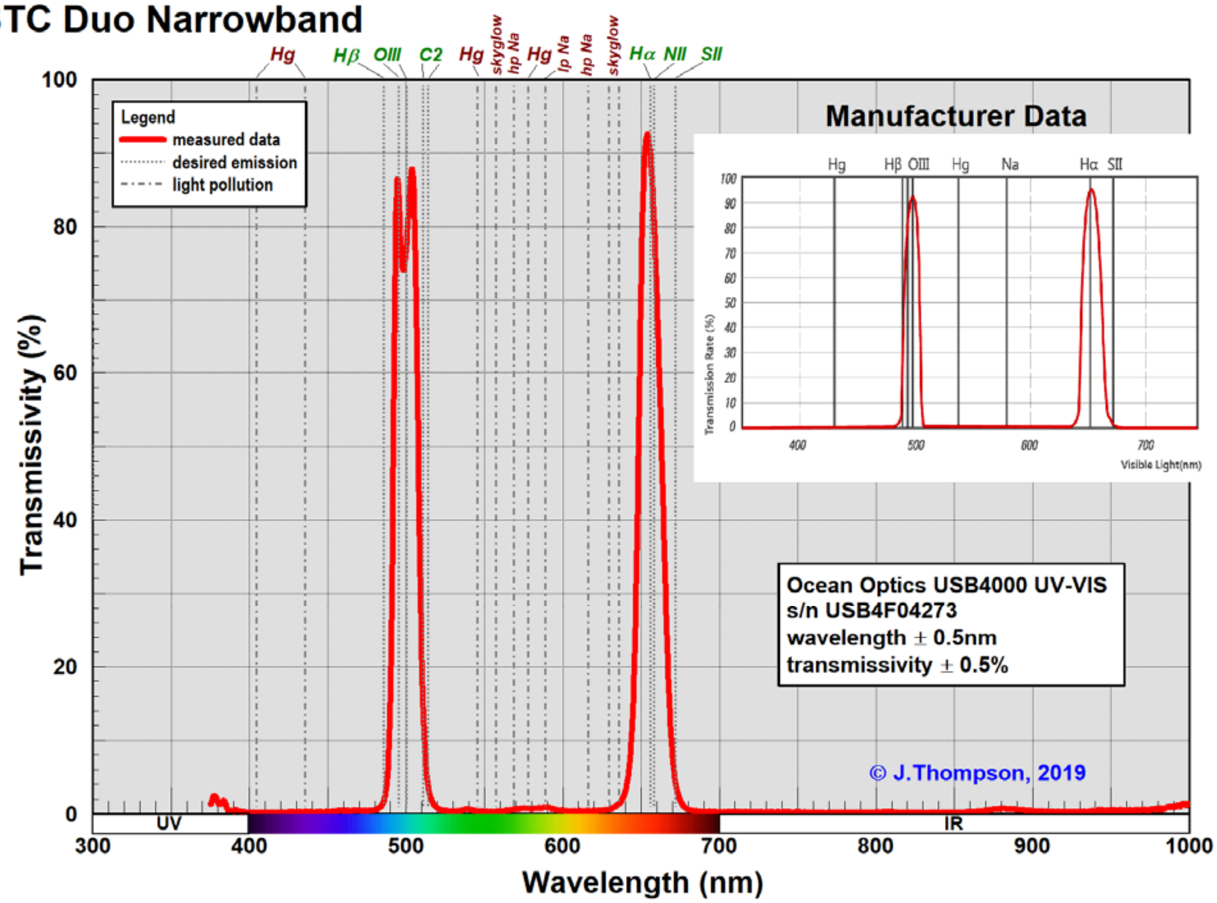
Optolong L-eNhance



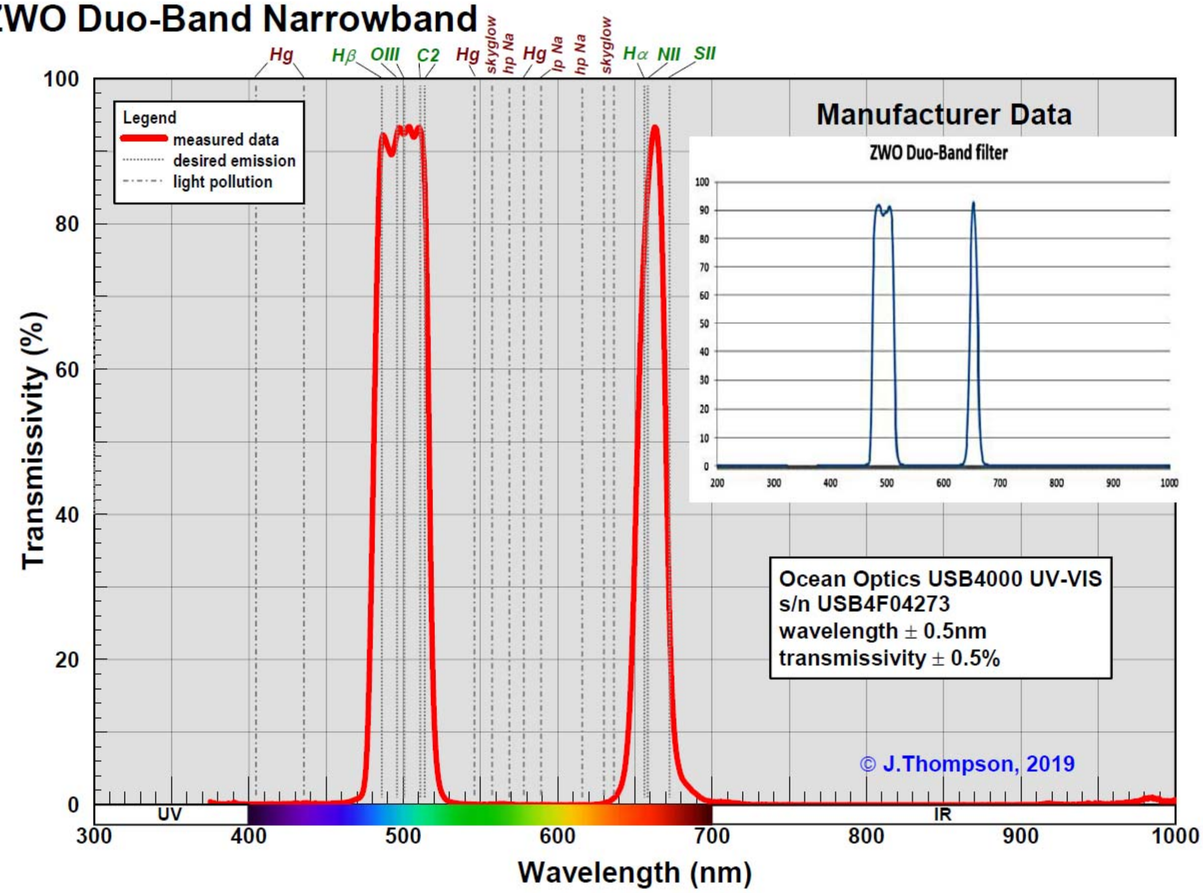
OPT Radian Triad



STC Duo Narrowband

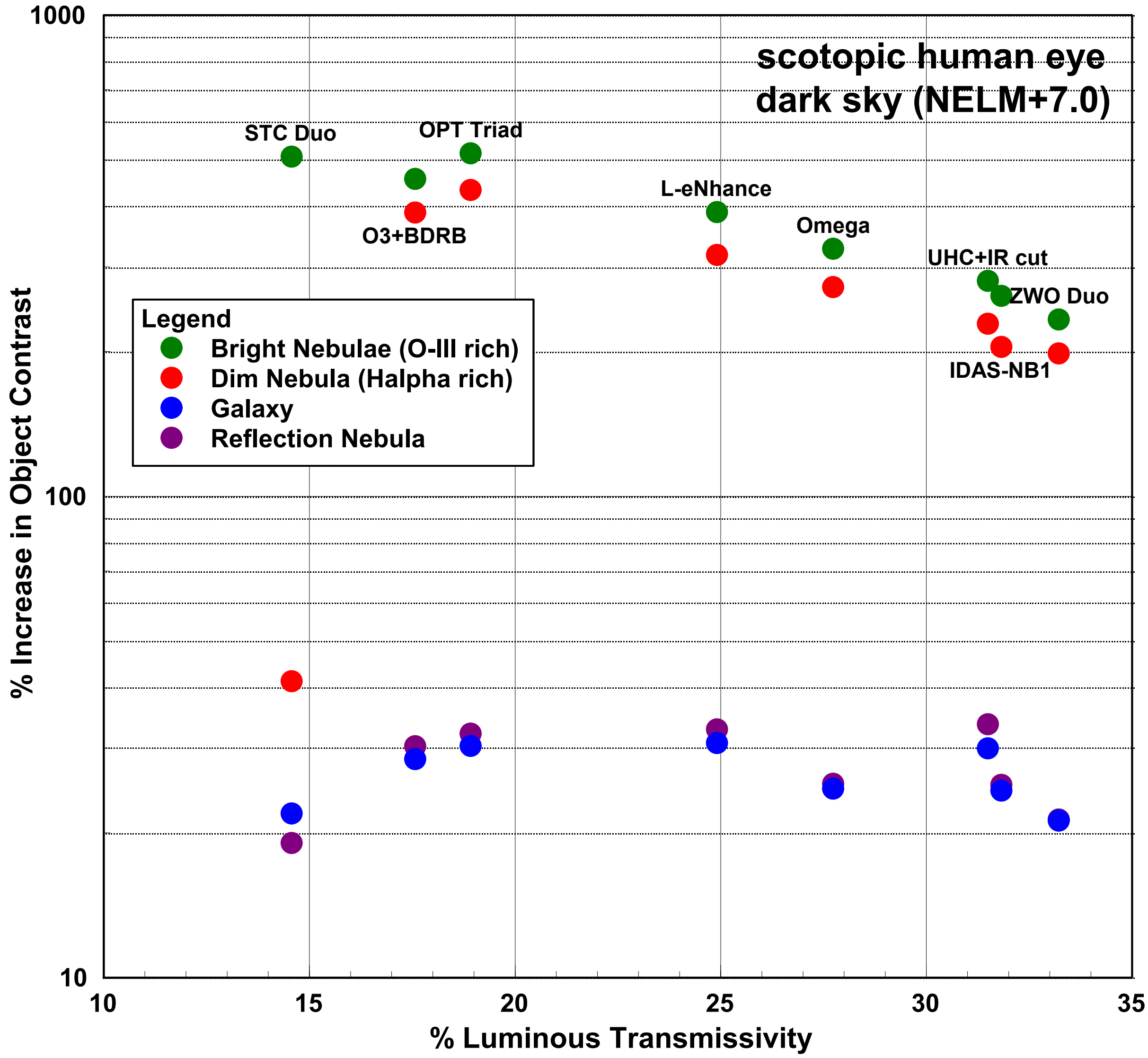


ZWO Duo-Band Narrowband

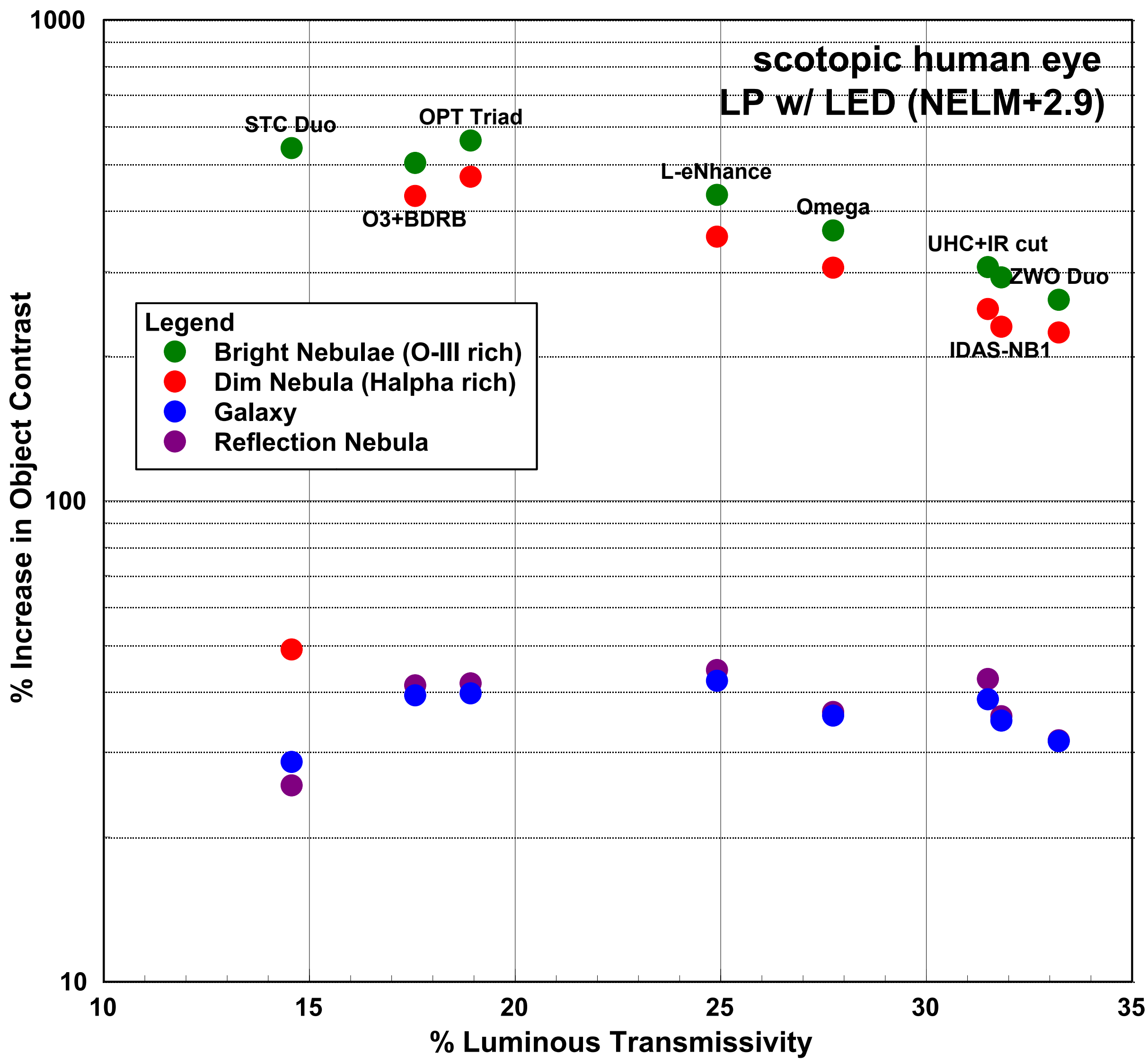


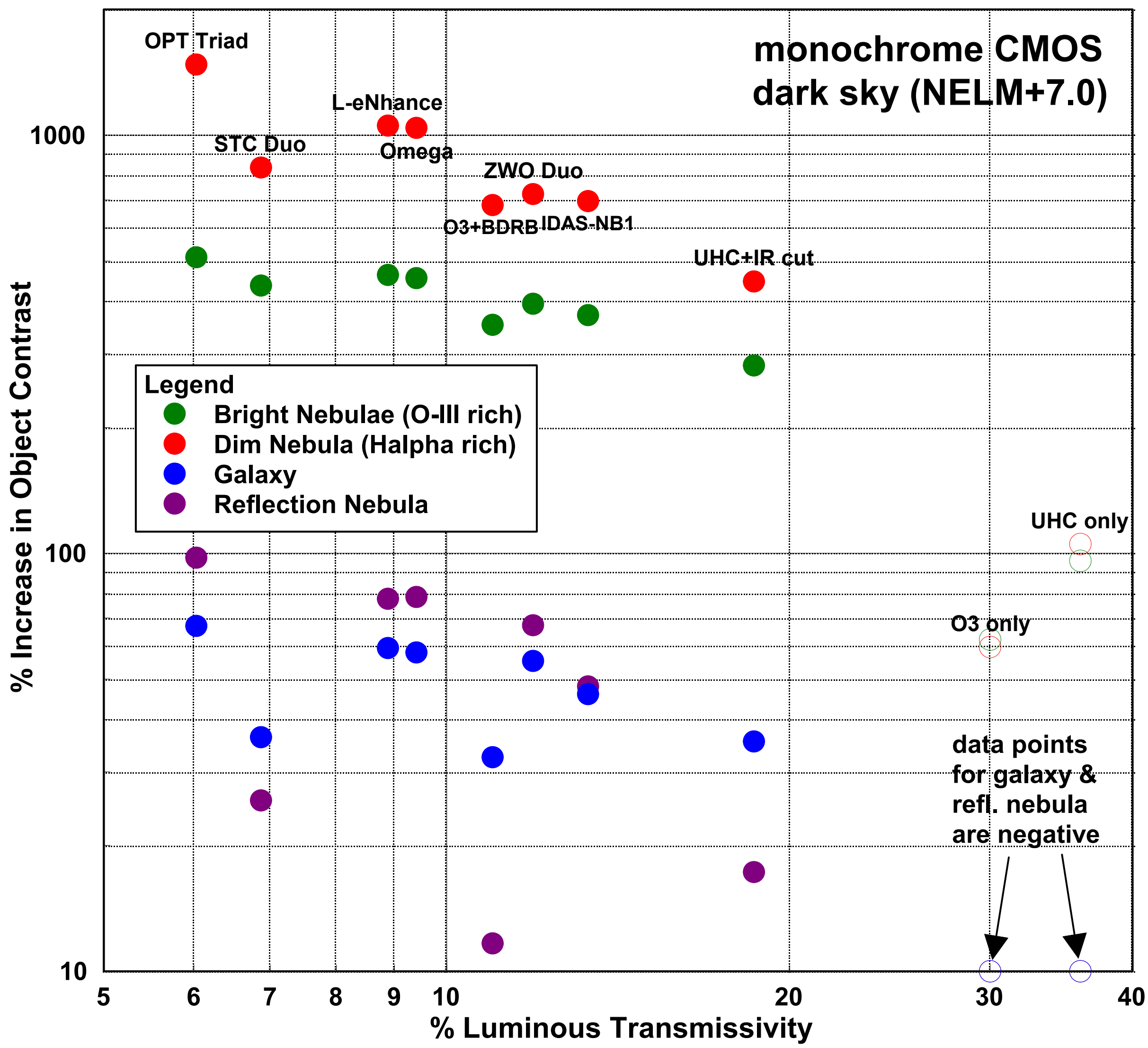
Appendix C

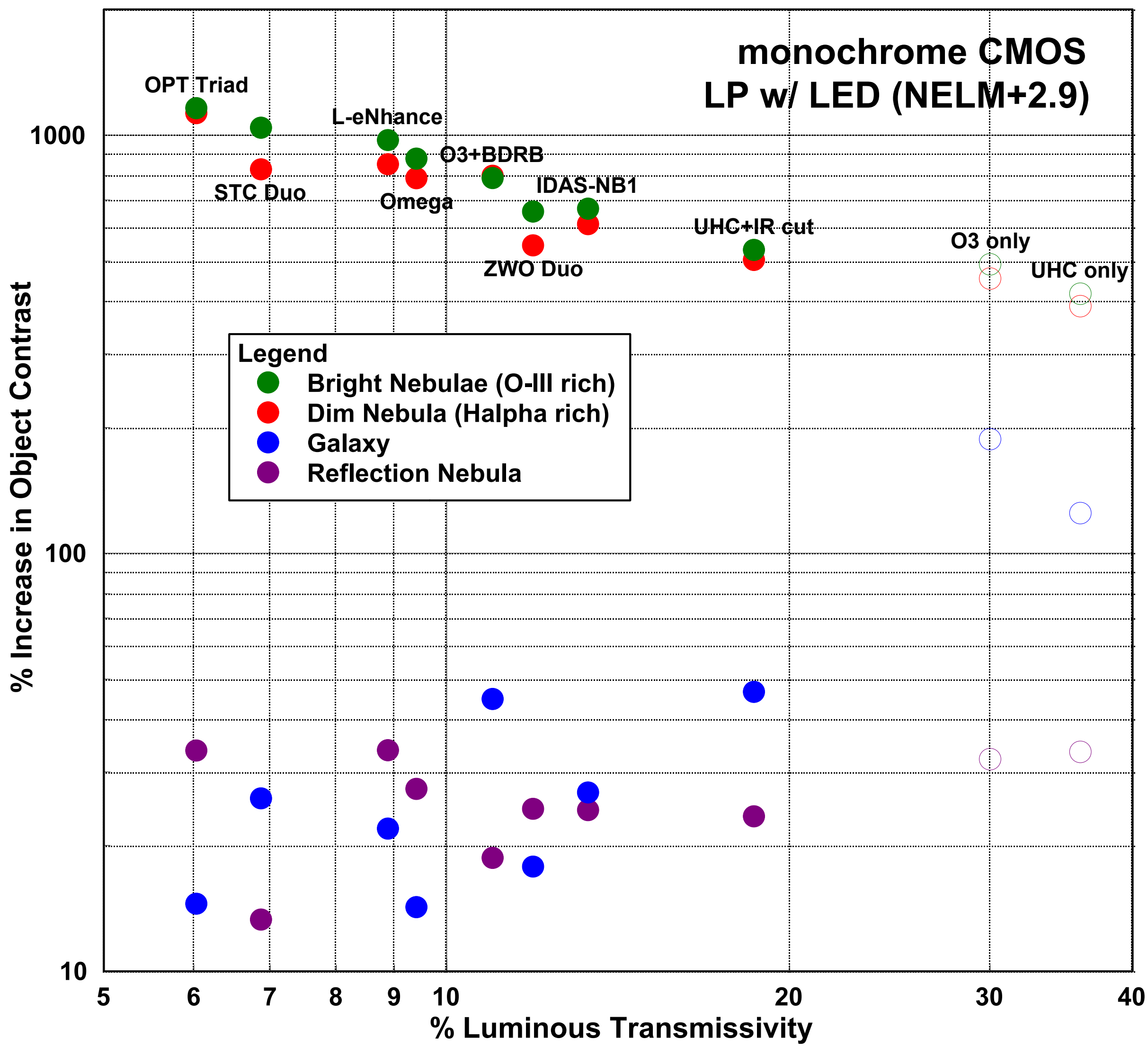
Predicted Filter Performance



scotopic human eye
dark sky (NELM+7.0)
STC Duo
OPT Triad
O3+BDRB
L-eNhance
Omega
UHC+IR cut
ZWO Duo
IDAS-NB1
Legend
Bright Nebulae (O-III rich)
Dim Nebula (Halpha rich)
Galaxy
Reflection Nebula
% Increase in Object Contrast
% Luminous Transmissivity
1000
100
10
10
15
20
25
30
35


scotopic human eye
LP w/ LED (NELM+2.9)
STC Duo
OPT Triad
O3+BDRB
L-eNhance
Omega
UHC+IR cut
ZWO Duo
IDAS-NB1
Legend
Bright Nebulae (O-III rich)
Dim Nebula (Halpha rich)
Galaxy
Reflection Nebula
% Increase in Object Contrast
% Luminous Transmissivity
1000
100
10
10
15
20
25
30
35


monochrome CMOS
dark sky (NELM+7.0)
OPT Triad
L-eNhance
STC Duo
Omega
ZWO Duo
O3+BDRB
IDAS-NB1
UHC+IR cut
Legend
Bright Nebulae (O-III rich)
Dim Nebula (Halpha rich)
Galaxy
Reflection Nebula
UHC only
O3 only
data points
for galaxy &
refl. nebula
are negative
% Increase in Object Contrast
10
100
1000
5
6
7
8
9
10
20
30
40
% Luminous Transmissivity


monochrome CMOS
LP w/ LED (NELM+2.9)
OPT Triad
L-eNhance
O3+BDRB
STC Duo
Omega
IDAS-NB1
UHC+IR cut
ZWO Duo
O3 only
UHC only
Legend
Bright Nebulae (O-III rich)
Dim Nebula (Halpha rich)
Galaxy
Reflection Nebula
% Increase in Object Contrast
1000
100
10
5
6
7
8
9
10
20
30
40
% Luminous Transmissivity

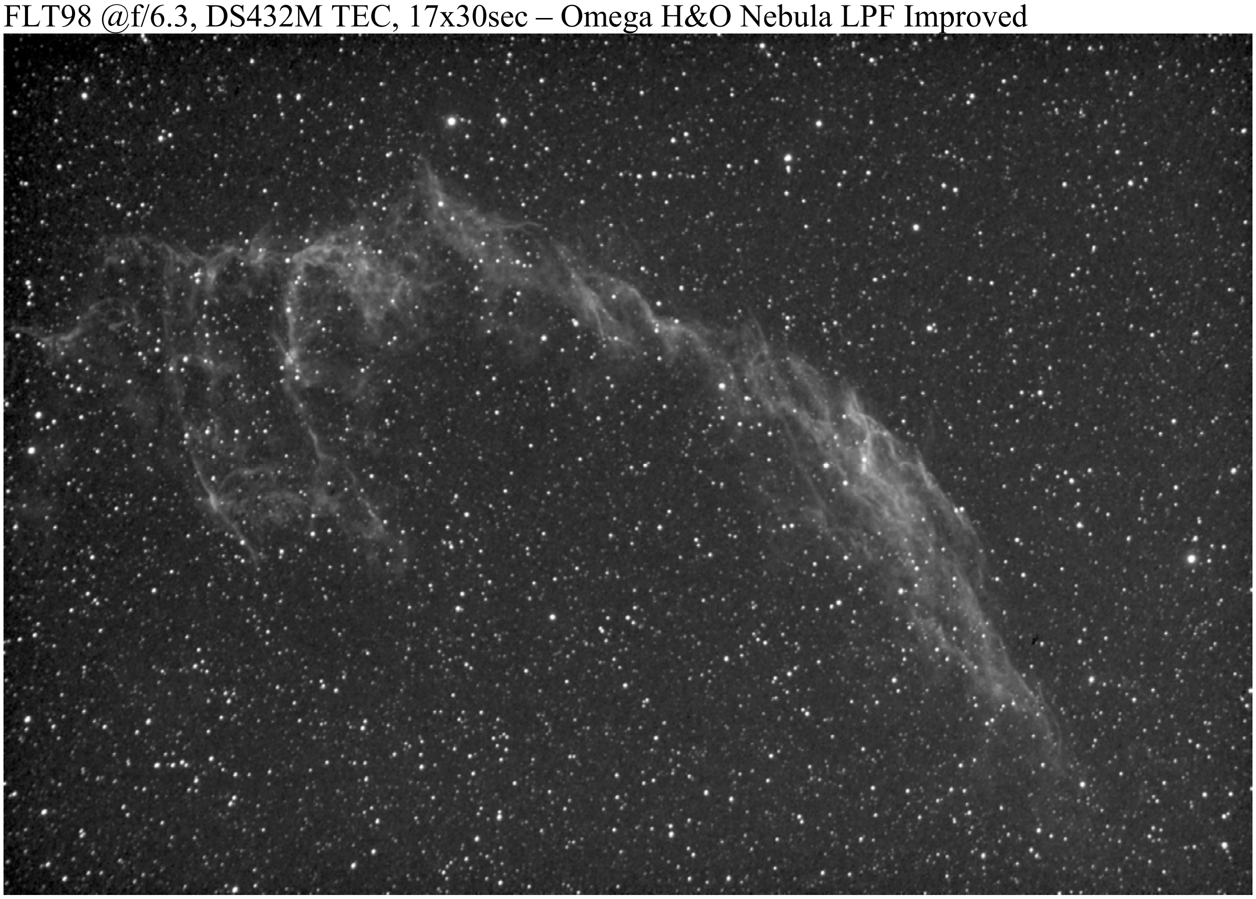
Appendix D

Sample Monochrome Images
Levels Adjusted


FLT98 @f/6.3, DS432M TEC, 17x30sec – IDAS NB1

FLT98 @f/6.3, DS432M TEC, 17x30sec – Optolong L-eNhance

FLT98 @f/6.3, DS432M TEC, 17x30sec – Omega H&O Nebula LPF Improved



FLT98 @f/6.3, DS432M TEC, 17x30sec – Meade O-III + Omega BDRB

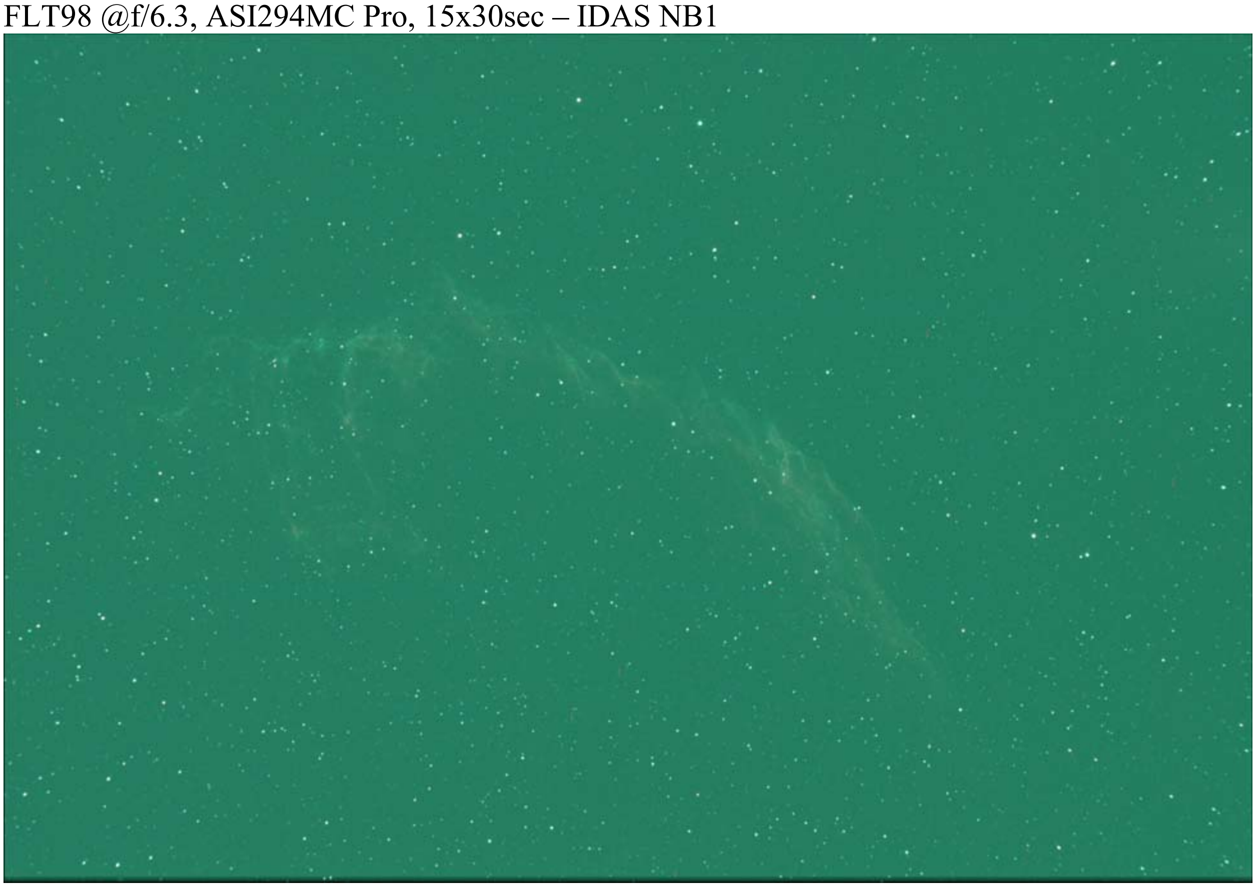
FLT98 @f/6.3, DS432M TEC, 17x30sec – OPT Radian Triad

FLT98 @f/6.3, DS432M TEC, 17x30sec – STC Astro Duo-Narrowband

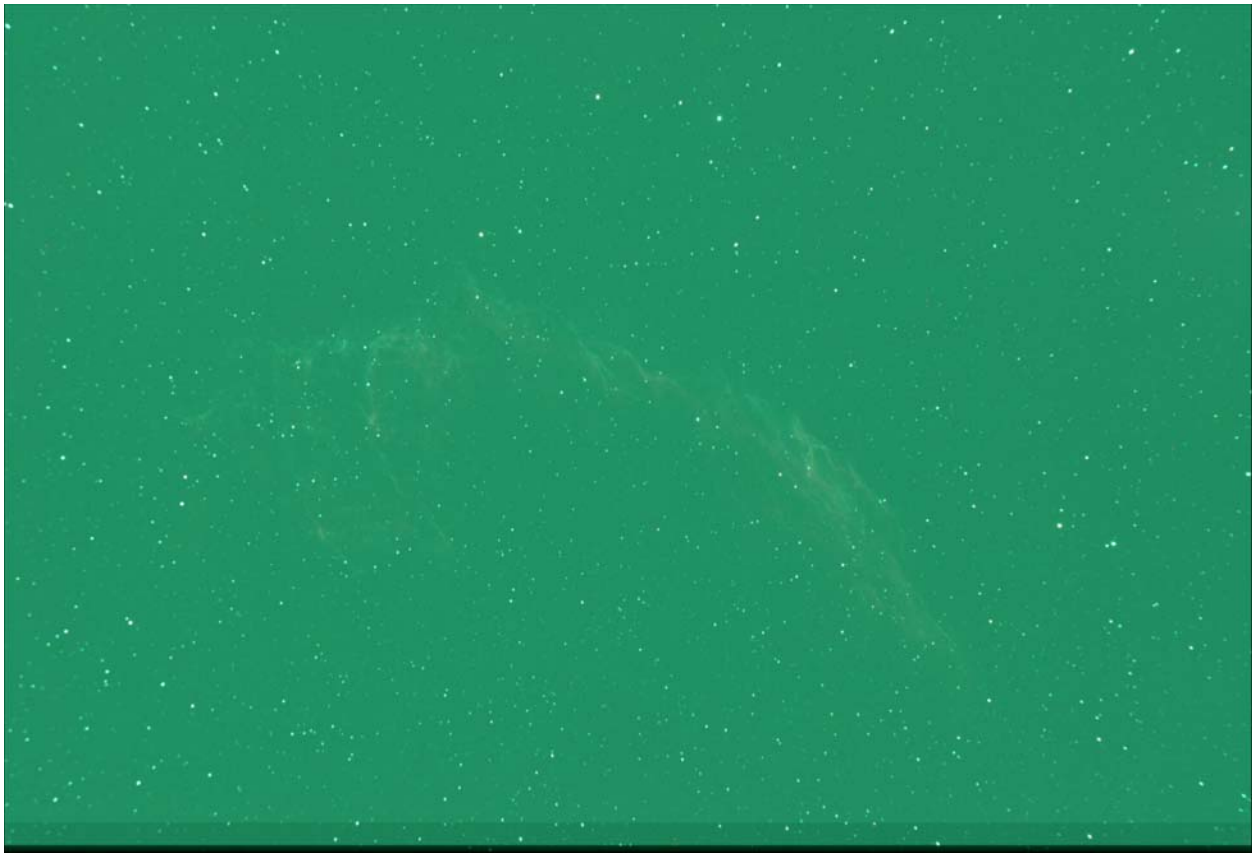
Appendix E

Sample One-Shot-Colour Images
As Recorded

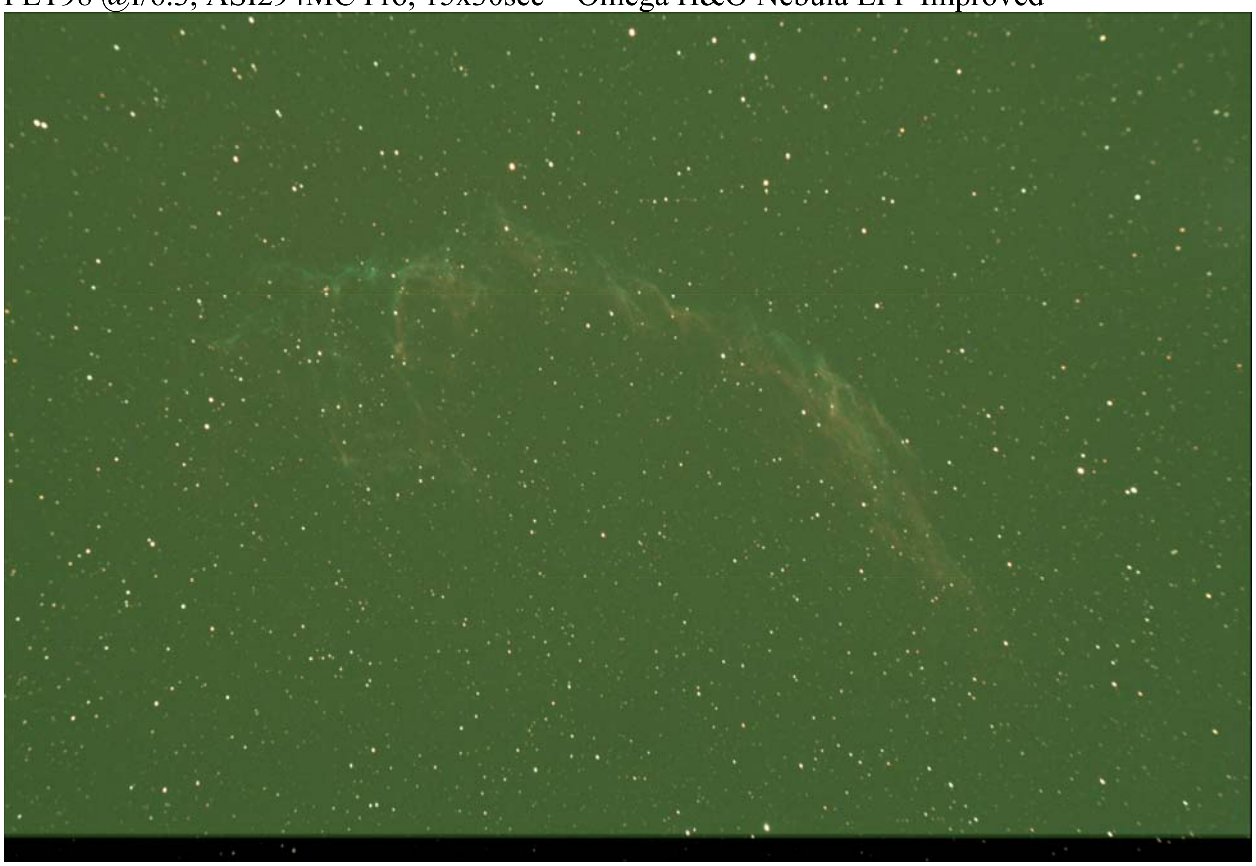
FLT98 @f/6.3, ASI294MC Pro, 15x30sec – IDAS NB1



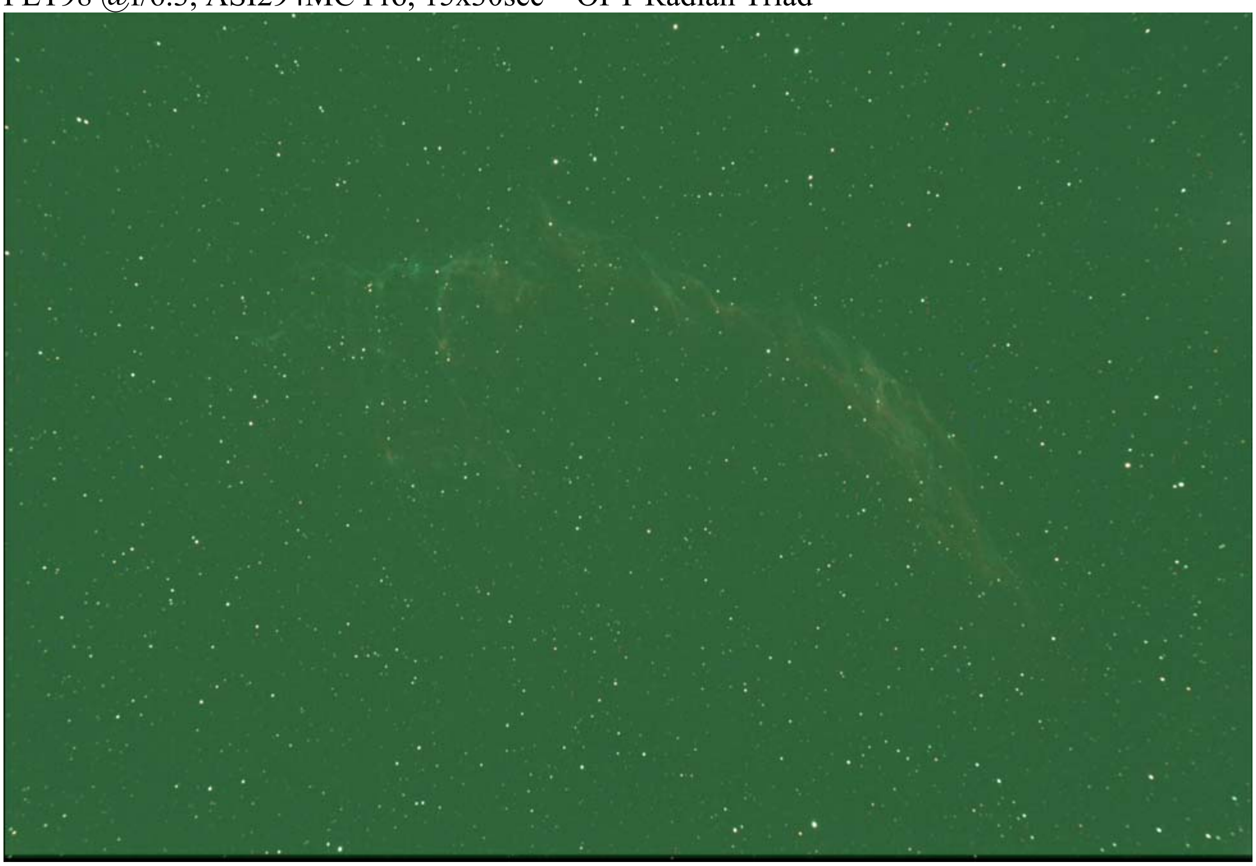
FLT98 @f/6.3, ASI294MC Pro, 15x30sec – Optolong L-eNhance



FLT98 @f/6.3, ASI294MC Pro, 15x30sec – Omega H&O Nebula LPF Improved



FLT98 @f/6.3, ASI294MC Pro, 15x30sec – Meade O-III + Omega BDRB

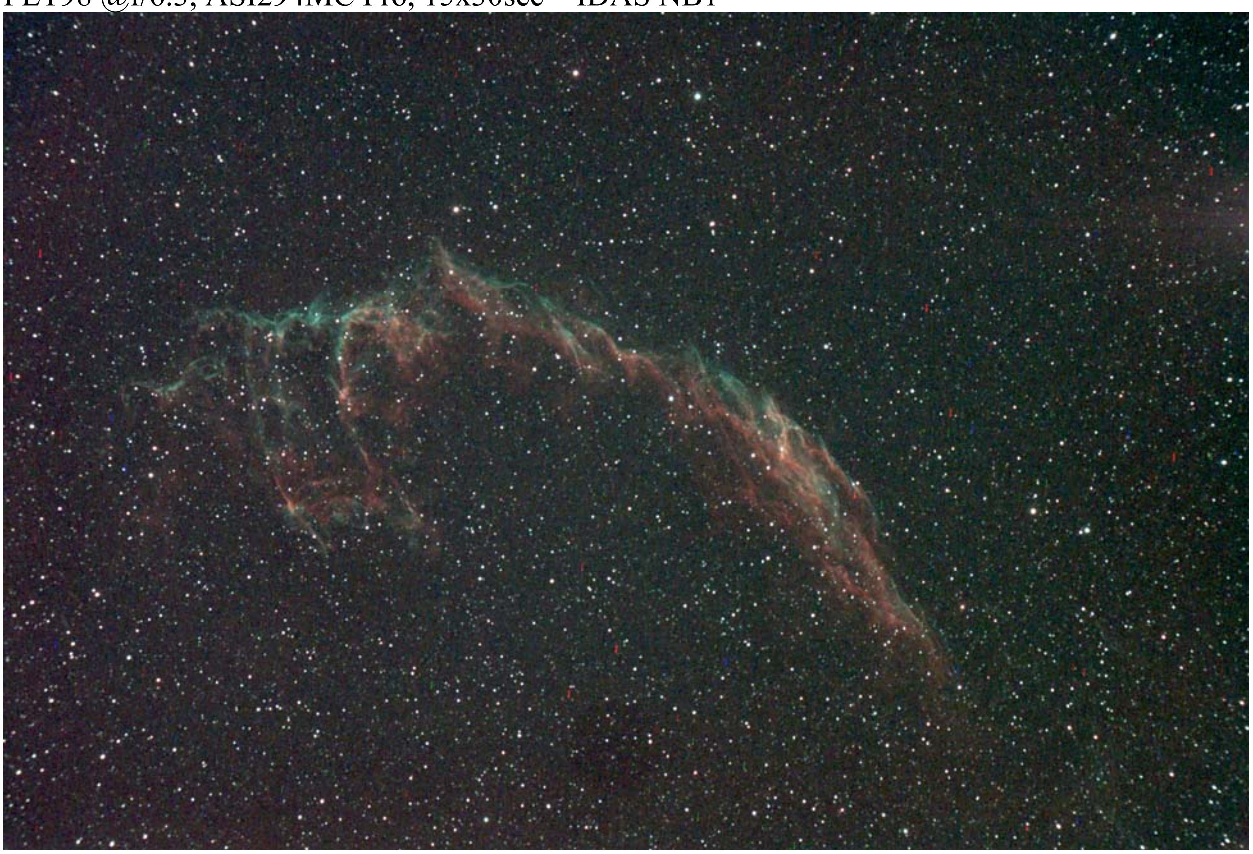

FLT98 @f/6.3, ASI294MC Pro, 15x30sec – OPT Radian Triad

FLT98 @f/6.3, ASI294MC Pro, 15x30sec – STC Astro Duo-Narrowband

FLT98 @f/5, ASI294MC Pro, 30x10sec – ZWO Duo-Band Narrowband

Appendix F

Sample One-Shot-Colour Images
WB & Level Adjusted

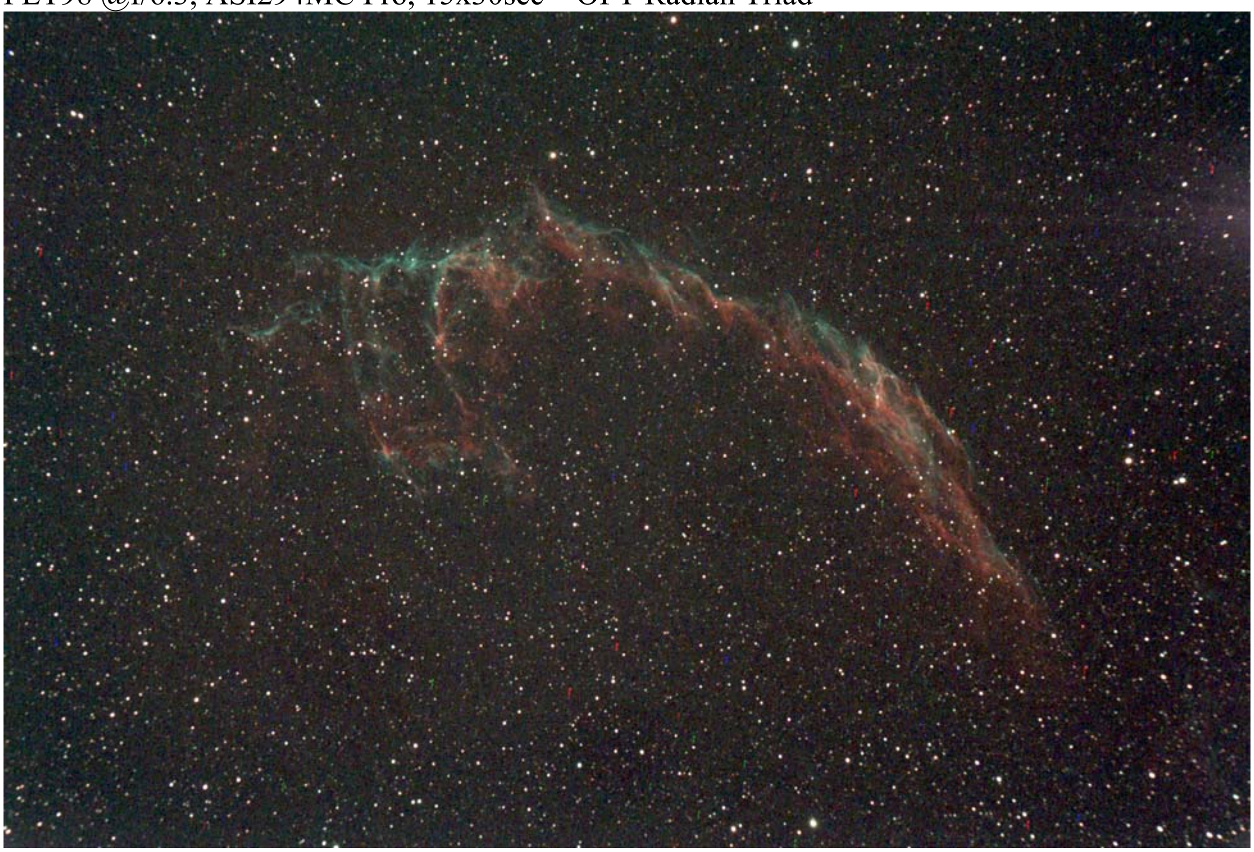

FLT98 @f/6.3, ASI294MC Pro, 15x30sec – IDAS NB1


FLT98 @f/6.3, ASI294MC Pro, 15x30sec – Optolong L-eNhance

FLT98 @f/6.3, ASI294MC Pro, 15x30sec – Omega H&O Nebula LPF Improved

FLT98 @f/6.3, ASI294MC Pro, 15x30sec – Meade O-III + Omega BDRB


FLT98 @f/6.3, ASI294MC Pro, 15x30sec – OPT Radian Triad


FLT98 @f/6.3, ASI294MC Pro, 15x30sec – STC Astro Duo-Narrowband

FLT98 @f/5, ASI294MC Pro, 30x10sec – ZWO Duo-Band Narrowband
(n.b. darkness in lower right corner is due to tree branch in FOV)