IDAS Filter Comparison

by Jim Thompson, P.Eng
Test Report – November 9th, 2021

Introduction:
There are many specialised astro-gear suppliers out there in the market, so many in fact that it is easy for some of them to operate "under the radar". One such company, well respected as a specialist in their field, is IDAS. This Japanese company is a division of the high-tech firm ICAS Enterprises. IDAS has a number of products and services for the astrophotographer such as DSLR IR cut filter mods, but what is of most interest to me personally is the fact that they also produce a large assortment of light pollution blocking filters. Through their distributors, like Astro Hutech, IDAS maintains a close relationship with their customer base, putting them in a unique position where they can respond quickly to customer feedback. They have made many innovations in the area of astronomical filters. For example: IDAS was the first company to produce a high quality multiband or "notch" filter for use in astrophotography, the LPS-P1. They are also one of the few companies that manufacture astronomical filters in large sizes suitable for attaching to the front of a DSLR camera lens. Today IDAS continues to push the envelope and deliver innovative products to meet their customers' needs.

I've been an IDAS customer since April 2010, when I purchased one of my first astronomical filters: a 2" LPS-P2. Since then I have purchased a number of other high quality filters from them, including most recently the NBX filter. Upon recent reflection I realised that IDAS now has quite a large assortment of filters available, causing me to ask the question: how do all those filters perform relative to each other? That is the question that I have set out to answer with the testing presented in this report.

Figure 1 IDAS's Assortment of LP Filters

Objective:

As indicated below in Table 1, IDAS has a large variety of astronomical filters available. The table includes some filters that are identified as "discontinued". These filters are either no longer available from IDAS or they are only available in limited quantities from local resellers. Often these older filter models can be found on used equipment sites, which is why I have included them in this test report. The filters for which I have samples for testing are also indicated in the table. IDAS also sells a variety of narrowband and other specialty filters, but I have chosen to limit my comparison to the light pollution (LP) filters that pass multiple nebula emission wavelengths since they are of the most interest to one-shot colour (OSC) camera users. Included in the list are two new filters, the NBZ and NBZ-UHS. The NBZ is IDAS's response to users of their relatively new NBX filter who found that it produced halos around bright stars. The filter was completely redesigned to give the same performance as the NBX but with greatly reduced halos. IDAS's North American distributor, Astro Hutech, has offered a trade-in program so that NBX users don't have to pay for a new filter to get the improved performance. The NBZ-UHS is the newest filter, which is further optimized for optics faster than f/2.8.

Filter Family	Filter Name	Retail Price [USD]**			Sample Tested
		28mm (1.25")	48mm (2")	Other sizes	
Light Pollution Suppression (LPS)	P1 (discontinued)	n/a	n/a	n/a	No
	P2 (discontinued)	n/a	$189	52mm $159	Yes
	P3	n/a	$199	52mm $199	Yes
	D1 (discontinued)	n/a	$169	52mm $169*	No
	D2 (discontinued)	n/a	$189	52mm $189	Yes
	D3	n/a	$189	various $179 - $209	No
	V3 (discontinued)	n/a	n/a	n/a	No
	V4 (discontinued)	n/a	n/a	n/a	No
Nebula Contrast Booster (NB)	NB1	n/a	$199	52mm $199	Yes
	NB2***	n/a	$149	52mm $149	Yes
	NB3***	n/a	$149	52mm $149	Yes
	NBX (discontinued)	n/a	$299	52mm $299	Yes
	NBZ	n/a	$299	various $299 - $329	Yes
	NBZ UHS	n/a	$249	52mm $259	No
Night Glow Suppression (NGS)	NGS1 (discontinued)	n/a	$189	52mm $189	No
Electronically Assisted Observing (EAO)	EAO1	$179	n/a	T2 $189	Yes
Halpha Enhanced UV/IR Blocking	HEUIBII	n/a	$189	52mm $189	No

* Sizes up to 82mm available

** Prices quoted from astrohutech.store

*** Sale on at time of this writing, get NB2+NB3 together for $219

Table 1 Summary of IDAS LP Filters

The objective of the testing summarized in this report is to evaluate samples of the filters listed above and compare them to each other in terms of their relative performance. 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 qualitatively by visually comparing images captured using each filter and a OSC camera.

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. Filter spectrums were measured for a range of filter angles relative to the light path, from 0° (perpendicular) to 20° off-axis. Additional information about my spectrometer setup is provided in Appendix D.

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, 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 the various filters under test were collected on a single evening to minimize the variation between images due to sky conditions. A common deepsky target was used for all the images, the Orion Nebula (M42) and the neighbouring Running Man Nebula (NGC1977), which was well placed in the southern sky for the duration of the image captures. These two deepsky targets are a good proxy for many different types of objects, presenting a variety of emissions (i.e. O-III, H-alpha, reflection nebula, & dark nebula).

Results – Spectrum Measurements:
Using the test method mentioned above and described in detail in Appendix D, the spectral transmissivity for each filter was measured. Filters in the IDAS catalog for which no sample was available use an alternative source for the spectral transmissivity data. I was able to source some measurement data from amateur astronomer André Knöfel (https://www.astroamateur.de/filter/), and the rest from the plots of IDAS data on the Astro Hutech website. Figures 2 to 6 present plots of the resulting spectral transmissivity data. The source of each curve's data is noted in the legend on each plot.

With the transmissivity data in hand, it was then 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 2, 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, so two representative values have been provided: one for the dark adapted human eye, and one for a modern back illuminated monochrome CMOS sensor. Note that all the filter performance values in Table 2 assume parallel light passing through the filter at a 0° angle (i.e. filter is installed normally in a telescope with a slow focal ratio). The exception is the performance for the NBZ-UHS (Ultra High Speed) filter which is presented for a light cone corresponding to f/2.8 optics. The NBZ-UHS filter is designed to be used only with fast optics, telescopes such as the RASA and SCT's with Hyperstar having f-ratios between f/1.4 and f/2.8.

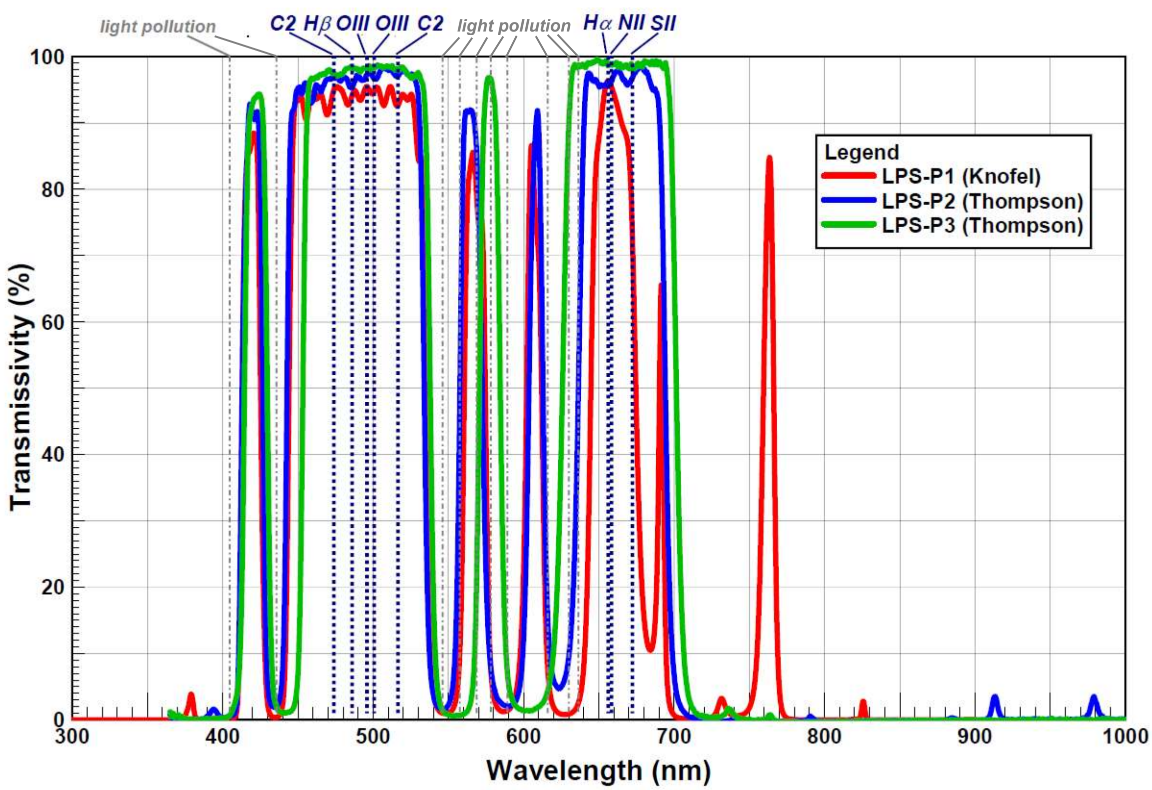

Figure 2 Measured Spectral Response of IDAS Filters – Light Pollution Suppression P-Series

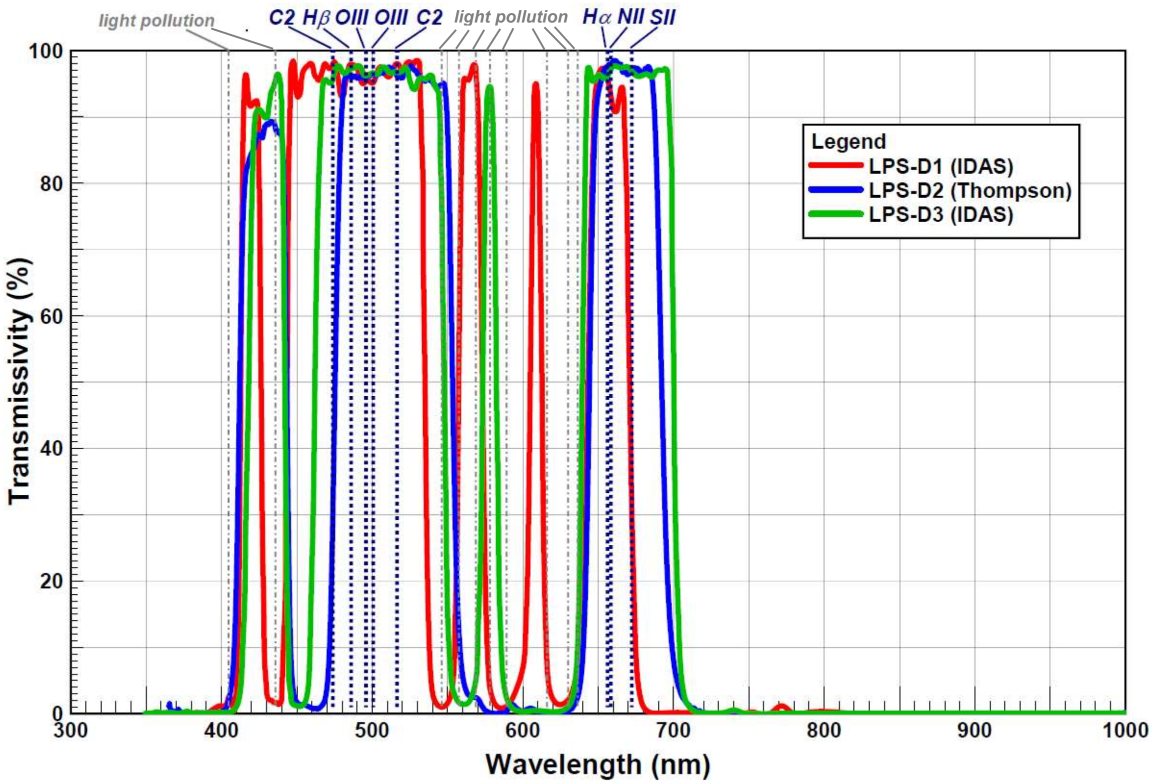

Figure 3 Measured Spectral Response of IDAS Filters – Light Pollution Suppression D-Series

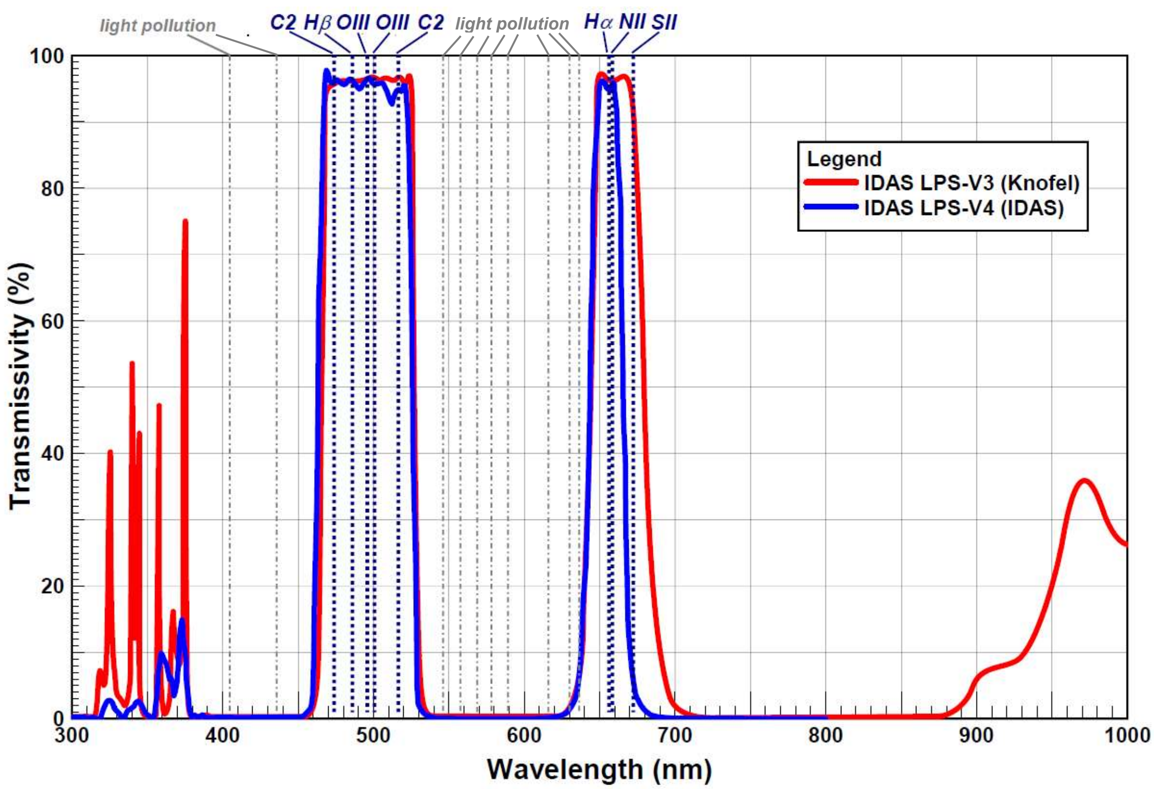

Figure 4 Measured Spectral Response of IDAS Filters – Light Pollution Suppression V-Series

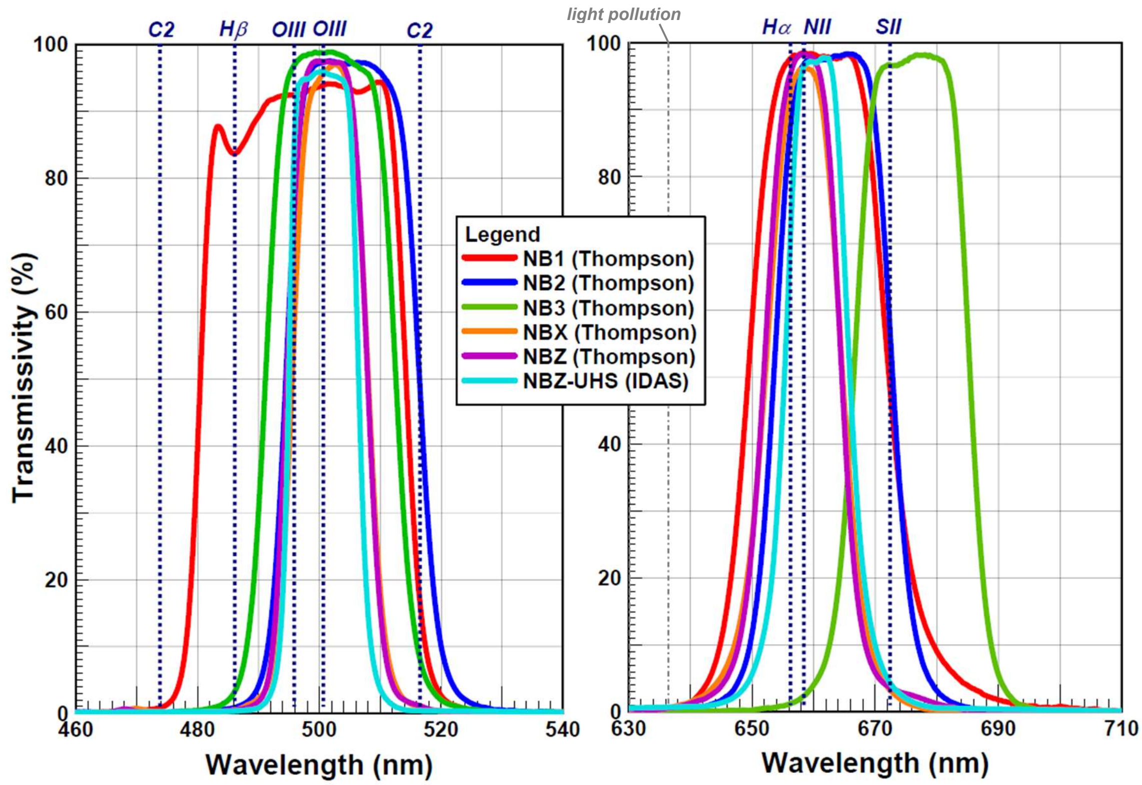

Figure 5 Measured Spectral Response of IDAS Filters – Nebula Booster Series

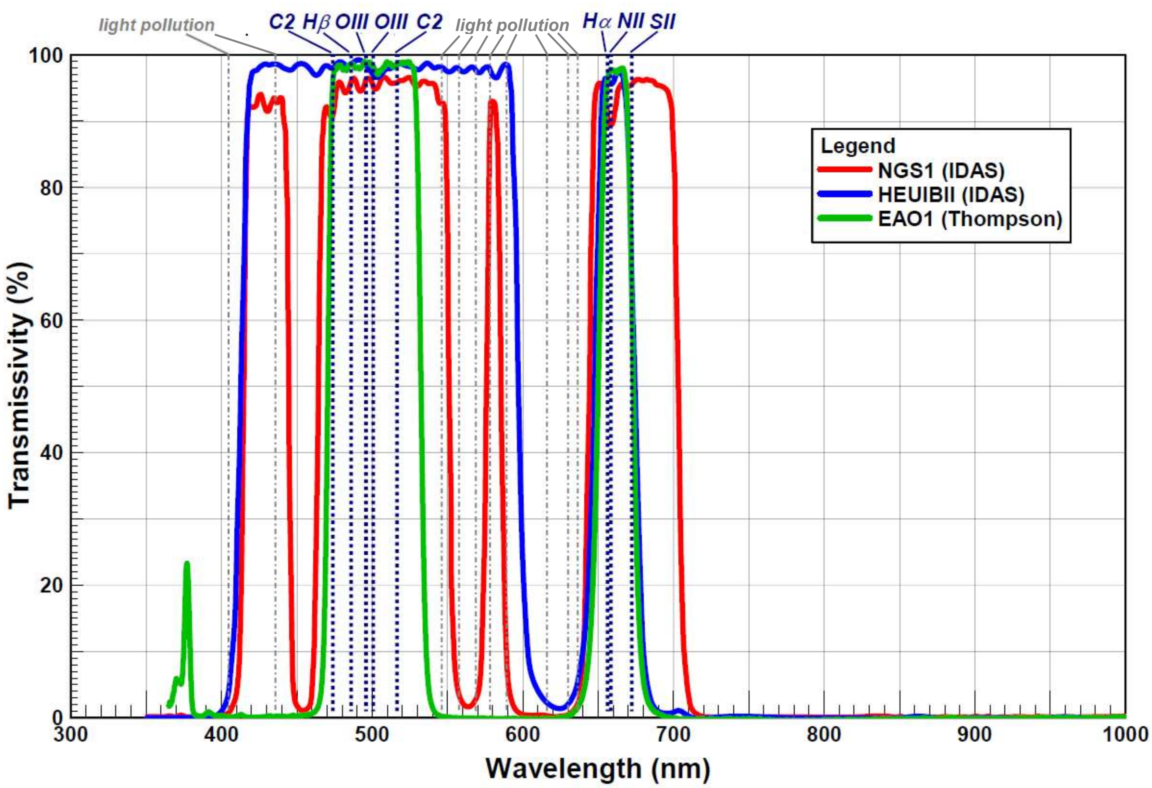

Figure 6 Measured Spectral Response of IDAS Filters – Other

Filter	Spectral Data Source	%LT		Hbeta/O-III Pass Band						Halpha Pass Band			
		Scotopic Human Eye	Back Illum. CMOS**	FWHM	C2 (473.8)	Hbeta (486.1)	O-IIIA (495.9)	O-IIIB (500.7)	C2 (516.5)	FWHM	Halpha (656.3)	N-II (658.4)	S-II (672.4)
LPS-P1	Knöfel	73.7%	34.9%	91nm	94.9%	94.2%	95.5%	94.8%	92.7%	30nm	96.2%	95.4%	72.3%
LPS-P2	Thompson	76.9%	40.5%	91nm	96.8%	95.3%	97.2%	96.8%	97.1%	57nm	95.8%	96.3%	96.8%
LPS-P3	Thompson	74.3%	41.1%	84nm	97.5%	98.1%	98.3%	98.4%	98.1%	75nm	98.7%	98.8%	98.2%
LPS-D1	IDAS	77.8%	35.0%	92nm	97.8%	97.9%	95.4%	95.2%	98.0%	28nm	95.9%	93.4%	30.4%
LPS-D2	Thompson	69.6%	33.3%	78nm	28.0%	96.1%	96.1%	96.7%	96.2%	48nm	97.5%	97.7%	96.8%
LPS-D3	IDAS	76.8%	38.6%	86nm	95.7%	97.3%	96.2%	96.6%	96.8%	61nm	96.1%	97.3%	96.8%
LPS-V3	Knöfel	54.8%	23.6%	62nm	95.7%	96.1%	96.5%	96.6%	96.7%	36nm	96.2%	96.1%	91.1%
LPS-V4	IDAS	54.1%	20.1%	63nm	96.0%	96.1%	96.4%	95.7%	94.9%	22nm	94.9%	95.5%	5.7%
NB1	Thompson	30.4%	12.5%	33.6nm	0.8%	83.6%	92.4%	93.9%	16.9%	22.5nm	97.7%	98.6%	48.9%
NB2-PM	Thompson	23.0%	16.1%	21.6nm	0.2%	0.8%	76.3%	97.3%	49.4%	18.9nm	87.8%	96.7%	57.8%
NB3-PM	Thompson	21.6%	15.3%	21.0nm	0.2%	3.3%	96.9%	98.6%	8.3%	18.5nm	1.2%	2.4%	96.7%
NBX	Thompson	13.5%	6.1%	12.2nm	0.0%	0.5%	59.0%	95.5%	0.9%	12.4nm	92.6%	96.1%	3.3%
NBZ	Thompson	14.4%	6.4%	12.9nm	0.2%	0.5%	76.2%	97.4%	1.1%	12.3nm	95.4%	98.1%	3.7%
NBZ-UHS*	IDAS	13.2%	5.8%	11.6nm	0.1%	0.3%	92.7%	95.8%	0.4%	10.9nm	90.4%	97.1%	3.3%
NGS1	IDAS	77.4%	39.1%	87nm	90.8%	96.0%	96.3%	95.2%	95.8%	59nm	90.4%	89.4%	95.5%
EAO1	Thompson	56.4%	19.9%	61nm	95.2%	98.6%	98.9%	98.3%	98.7%	23nm	96.3%	97.8%	63.4%
HEUIBII	IDAS	97.3%	47.4%	184nm	98.0%	98.7%	98.6%	97.1%	98.5%	27nm	96.1%	95.6%	66.4%

* evaluated for f/2.8 light cone; ** calculated assuming spectral QE curve for IMX174M with no UV/IR blocking filter

Table 2 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 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 in learning more about this method, you can read about it at the link below. Appendix A presents the reference spectrums I used for the various deepsky object types.

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 %LT. Figure 7 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). Additional plots for different levels of light pollution and for dark adapted human eyes are provided in Appendix B. Note that these are theoretical predictions of the increase in visible contrast between the object and the background. The absolute values of my predictions may not reflect what a user will experience with their own setup, but the predicted relative performance of one filter to another should be representative. In general the desired performance for a filter is high contrast increase with high %LT, so the higher and more to the right a filter's performance is in the plot the better.

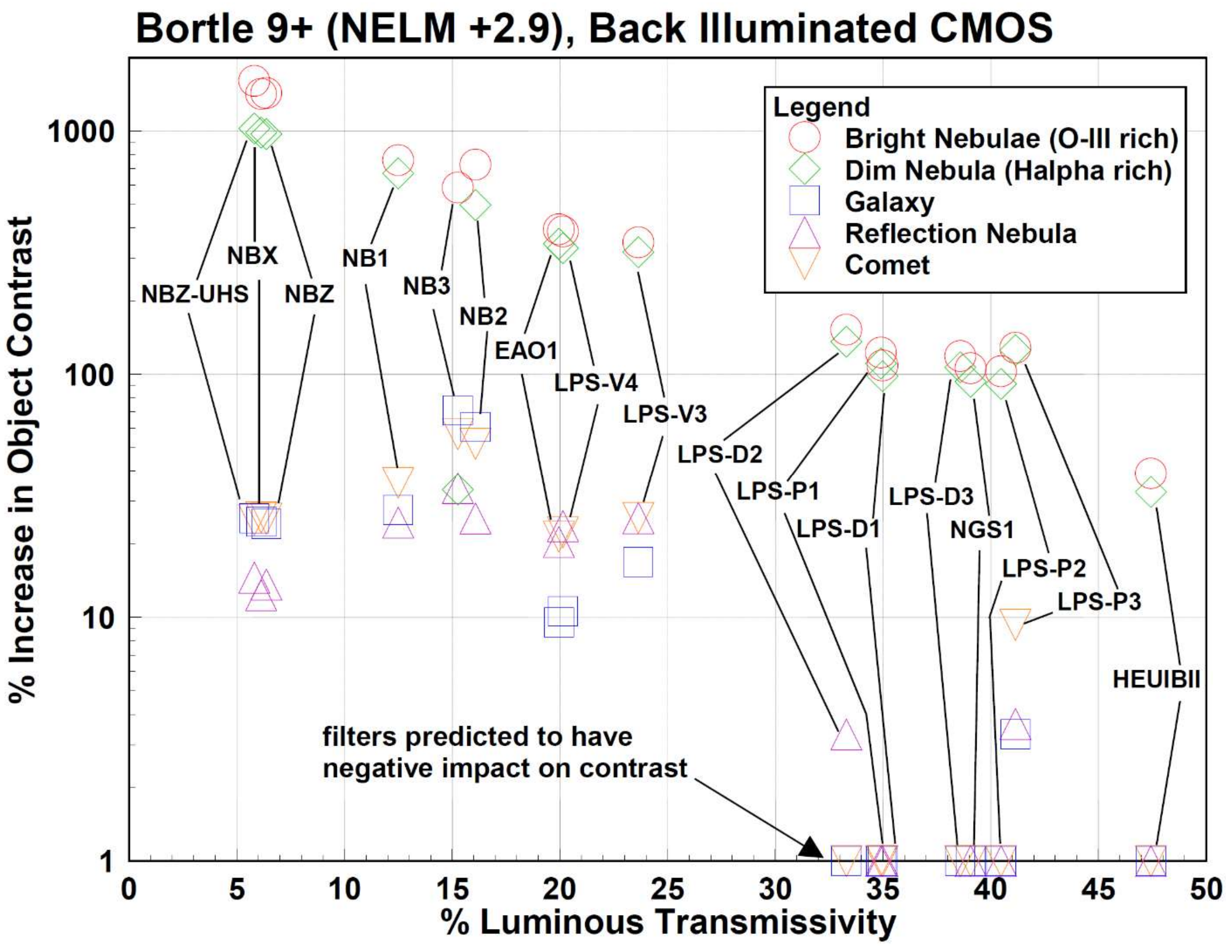

Figure 7 Predicted Filter Performance: Back Illuminated CMOS, LP w/LED (NELM+2.9)

There are a number of interesting things to note from Figure 7 and the plots in Appendix B. First, regardless of light pollution level or sensor type, the contrast increase when observing emission type nebulae is highest for the filters with the narrowest pass bands. Thus the nebula booster (NB) family of filters consistently provide the largest increase in contrast on emission nebulae. The cost for maximizing the increase in contrast is an increase in required exposure time, or in the case of a visual observer a larger aperture telescope. For the other types of objects considered, the increase in contrast that is possible using a filter is more modest. It is arguable whether or not an observer would even be able to notice an increase in contrast of 10 to 20%. When imaging in heavy light pollution conditions, a number of filters are predicted to actually reduce contrast. This effect is related to how object emission in the UV and IR part of the spectrum plays a role in its contrast with the background. Object emissions at these wavelengths are important when there is a lot of man-made light pollution, but become less so as the light pollution level decreases.

Results – Angle Sensitivity:

Another important characteristic that can be determined using the filter spectrum measurements is sensitivity to filter angle. All of the filters considered in this test report are interference type, i.e. they achieve their filter properties via a series of multiple thin layers of refractory material applied to the filter's glass substrate. The thickness of these layers has a direct effect on the filter's response. Thus if light passes through the filter at an angle, the thickness of the layers is effectively increased and thus the filter's spectrum is changed. For the filters I had available to me for test, I measured spectral transmissivity data for each at a range of angles to the light path. The results have been plotted in Figure 8 in terms of O-III and Hα transmission versus angle.

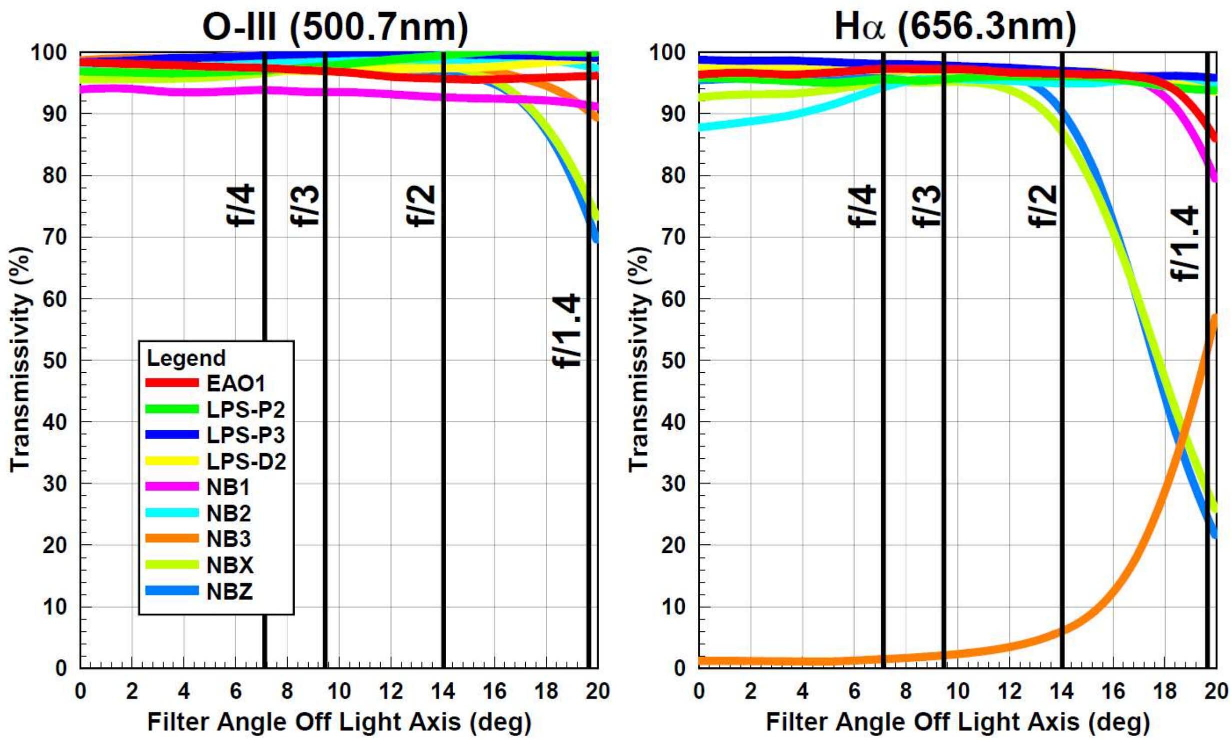

Figure 8 Impact of Light Angle On Filter Performance

Included on the plots in Figure 8 are vertical lines corresponding to the angle at which light passes through the filter from the outer edge of the optics aperture for various focal ratios – the faster the focal ratio the larger the angle. The net transmissivity of a filter is the area weighted average of the values in Figure 8, from the center of the telescope primary where the light angle is perpendicular (0° on graph), out to the edge of the primary where the light angle is at its maximum. All of the IDAS filters tested were measured to have very low sensitivity to angle. The NBX and NBZ filters that were tested have the narrowest pass bands of the filters considered in this report, but they also show practically no degradation in performance for f-ratios down to f/2, consistent with the claims from the manufacturer. For f-ratios faster than f/2 the performance of the NBX/NBZ filter does start to degrade, which is why IDAS recently released the NBZ-UHS which is further optimized for very fast optics.

Results - Imaging:

All image data was collected on the same night: January 23rd, 2021. The night was clear with average transparency and below average seeing. There was a waxing gibbous Moon out (three days past 1st quarter), positioned approximately 30° away from where my telescope was aimed. As described above in the Method section, image data was captured with each filter using a OSC camera on a 98mm refractor. The telescope was configured at its native f-ratio of f/6.3. The camera colour channel gains were adjusted to give a white balanced image with no filter, and then left fixed for the duration of the data collection with each of the filters. Data was collected by generating a live stack in Sharpcap of five minutes total duration, which was then saved as a 16bit FITS file. Gain was fixed at 400, and binning at 2x2, but exposure time per frame was adjusted for each filter in order to achieve an image of generally the same level of overall exposure. This was determined qualitatively by observing the extent of image saturation around the core of M42. I did not use any calibration frames during my data collection, so no dark or flat frames have been applied. There was also no histogram adjustment made to the live stacks; black point and white point were left at their default positions, and the gamma slider was positioned in the middle. The raw captured images can be found in Appendix C. Note that the images captured using the NB-2 and NB-3 filters were made with a UV/IR cut filter added (Baader Planetarium brand), as recommended by IDAS.

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. This information can be used to help astrophotographers determine how each filter will impact their exposure time relative to no filter. For interest sake I have included the %LT values that were calculated from each filter's spectral transmissivity data in Table 4. The calculated value of %LT aligns well with my measurement of relative exposure for all the filters except the NB-2 and NB-3. The discrepancy for those two filters is because of the UV/IR cut filter that was added to those filters during the image data capture.

Filter	Sub-Exposure Time [s]	Measured Exposure (Relative To No Filter)				%LT*
		R	G	B	L	
EAO-1	5	11.7%	26.8%	22.6%	22.0%	19.9%
LPS-D2	4	17.7%	39.7%	38.9%	34.0%	33.3%
LPS-P2	4	28.6%	41.2%	53.0%	41.0%	40.5%
LPS-P3	4	31.3%	42.3%	42.4%	39.6%	41.1%
NB-1	7	8.3%	13.5%	12.1%	11.9%	12.5%
NB-2**	7	9.5%	13.0%	10.7%	11.5%	16.1%
NB-3**	10	7.5%	11.5%	10.3%	10.2%	15.3%
NBX	9	5.6%	6.6%	6.1%	6.2%	6.1%
NBZ	9	5.6%	6.9%	6.3%	6.4%	6.4%

* Calculated for back illuminated CMOS sensor

** As per IDAS recommendations, a UV/IR cut filter was added for images captured using these filters

Table 3 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 first aligning the colour channel histograms for each image in Fitswork v4.47, a free FITS editing software. This was done by adjusting the black point on each colour channel's histogram until the histogram peaks were all aligned with each other. I then applied the same amount of luminance channel histogram stretching to each image: 3% clipping black point, 0.1% clipping white point, and midpoint at 1.8. The resulting images are presented in Figures 9 and 10.

Starting with Figure 9, the differences between the images are quite subtle. If I had used much longer total exposure times and stretched the images more, the differences would be more obvious. Nonetheless, some observations can be made from the images. Of the images shown in Figure 9, the EAO-1 filter provides the biggest increase in contrast of the emission nebula, followed by the LPS-D2 and LPS-P3. This increase in contrast is most visible through the faint nebulosity in the lower right corner of the images. This observation is consistent with the predictions made earlier. All the filters result in a subtle improvement in the visibility of the blue reflection part of the Running Man nebula, found in the upper section of the images, with the LPS-P3 providing the largest increase in contrast. There was also a decrease in the brightness and number of stars visible in the images from all filters. This is primarily due to the built-in UV/IR blocking present on all the IDAS filters.

Next, looking at Figure 10 we can see that the NB filters provide a significantly larger increase in the contrast of the emission nebula, as predicted. The largest contrast increase was observed when using the NBX/NBZ filter, as this filter has the narrowest pass bands of all the filters tested. However, as a result of the blocking of the blue part of the spectrum the NBX/NBZ also present the most subdued view of the reflection nebula component. Filters in the NB family with a wide enough O-III pass band to also pass Hβ seem to still provide visibility of the reflection nebula. As with the filters presented in Figure 9, so too do these filters subdue stars, with the NBX/NBZ producing the faintest stars. Lastly, another seeming benefit of the NB filter family is an enhancement in the saturation of colour. Comparing the images in Figure 9 with those in Figure 10 it is evident that as the pass bands get progressively narrower, the intensity of the colours in the image increase.

The NB-3, with its strong O-III band but no Hα band has a peculiar colour. The intent of this filter is to use it with the NB-2 to capture narrowband data with a OSC camera that can later be combined to produce an image in the Hubble palette, i.e. SII = red, Hα = green, and O-III = blue. I have attempted to do this with the image data I collected, a first for me. The result can be seen in Figure 11. Clearly a better result would have been possible if I had collected more than five minutes of image data. Nonetheless the application of the NB-2 and NB-3 filters for this purpose has been demonstrated as possible.

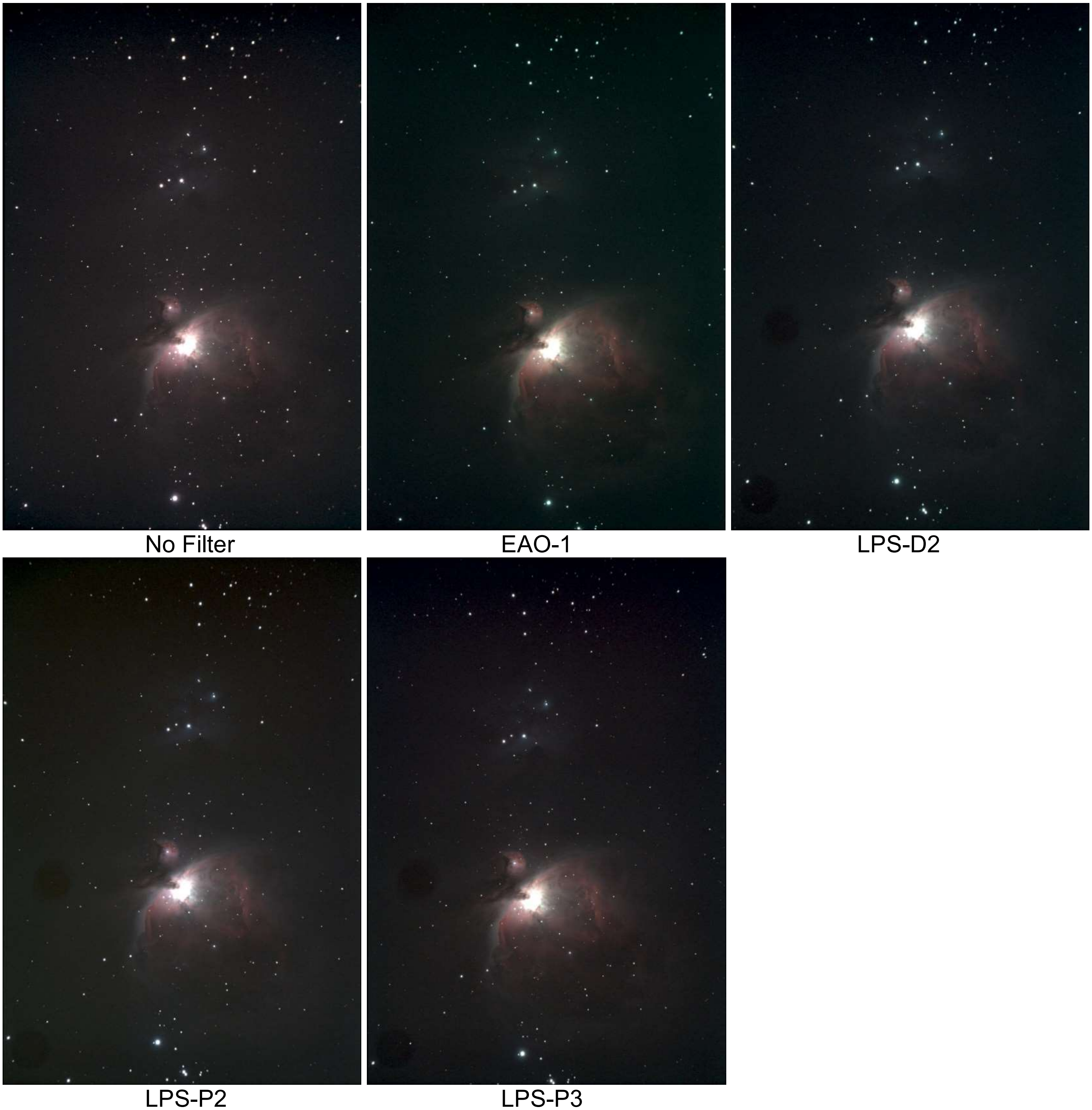

Figure 9 Image Captures Group 1 – White Balance & Histogram Stretch Applied

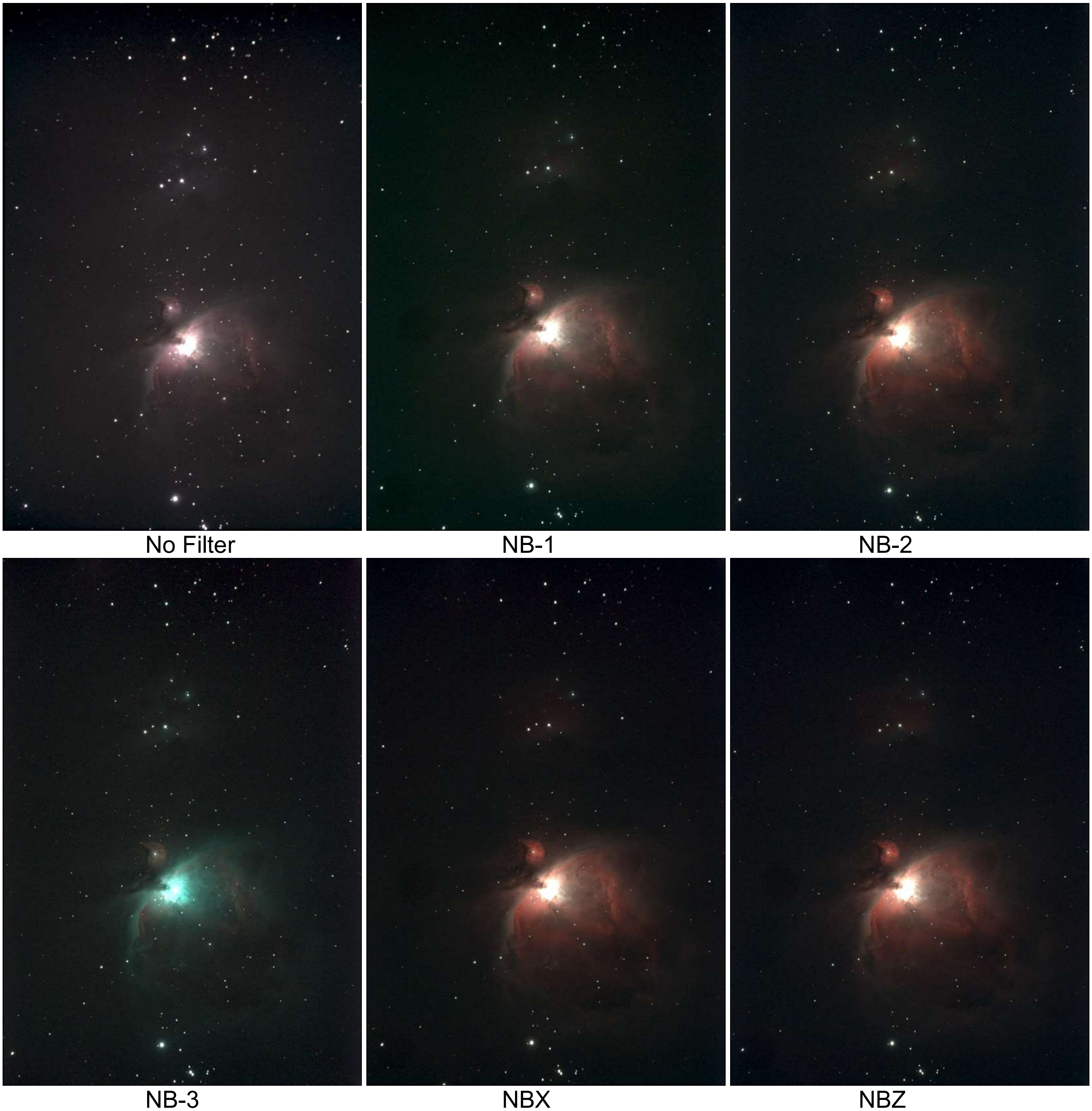

Figure 10 Image Captures Group 2 – White Balance & Histogram Stretch Applied

Figure 11 My Attempt To Combine NB-2 & NB-3 Data Into Hubble Palette Image

Results: White Balancing

There are many happy users in the amateur astronomy community of the LPS family of filters. Some of them may argue that my findings regarding the amount of light pollution reduction this family of filters provides (i.e. a relatively small reduction) is not consistent with their own observations. The reason for this apparent inconsistency is that filters not only affect image contrast, they also affect white balance. Consider the image sequence below in Figure 12, where I have simulated the impact of light pollution on the appearance of a simple colour pattern (a). The orangish-brown tone that results from adding light pollution (b) to the picture causes an unnatural looking colour balance (c), as well as a reduction in perceived colour saturation and contrast. White balancing the light polluted image after the fact (d) is not able to return the image to its original appearance because the process of white balancing has affected the image data for the colour bars as well as the light pollution; contrast and saturation are still subdued, and neutral tones have a slight colour cast. I used my Canon M3 mirrorless camera to take a photo of the light polluted image on my computer monitor, both without (e) and with (f) an LPS-P2 filter added. The image with the LPS-P2 applied (f) is very similar to the white balanced image (d) except with better colour saturation, illustrating the colour correction capability of this family of filters. This is an important effect since at the end of the day the objective is to produce an image that the astrophotographer feels has a pleasing appearance.

Thus, just like the NB family of filters are well suited to their role of improving the contrast of emission nebulae while under light polluted conditions, the LPS family of filters have their own role to play helping to correct the colour cast in images of all deepsky object types caused by light pollution.

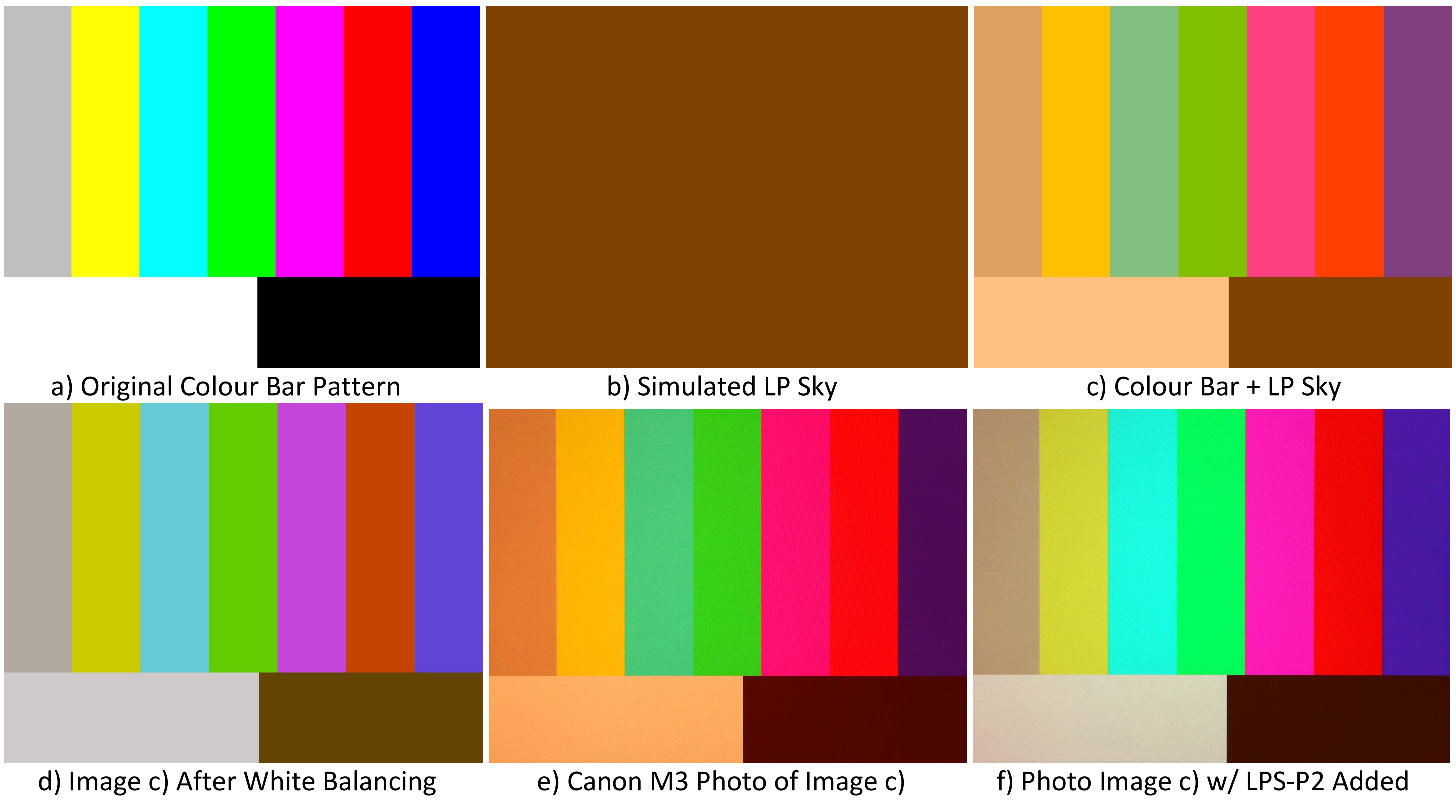

Figure 12 Images Simulating Effect of Light Pollution & LPS Filters on White Balance

Conclusions:

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

1. In my opinion IDAS delivers filter products of a high quality. All the filters I have purchased or been provided samples of have had a consistently high build quality. The measured performance of all tested filters is consistent with that quoted by the manufacturer. IDAS has also demonstrated a willingness to incorporate observations from their users into the development of better performing future products.
2. There are principally two main families into which almost all of IDAS' filter products can be sorted: nebula contrast enhancement, and colour correction. Filters falling into the nebula contrast enhancement category include: all NB series filters, LPS-V3 & V4, and EAO-1. Filters falling into the colour correction category include: all LPS-P series, all LPS-D series, NGS-1, and HEUIBII.
3. The purpose of the nebula contrast enhancement family of filters is to increase the contrast between deepsky object and background sky when observing emission type nebulae. This

is accomplished by blocking all wavelengths of light except those coming from the emission nebula. These filters are effective at increasing contrast under all levels of light pollution. The highest increase in contrast comes from the filters in this family with the narrowest pass bands, the NBX/NBZ/NBZ-UHS. The increase in contrast of emission nebulae comes at the expense of longer exposure times and a reduction in the visibility of blue-rich features such as reflection nebulae or young blue stars in galaxy spiral arms.

4. The purpose of the colour correction family of filters is to improve the white balance of deepsky images taken in light polluted conditions. This is accomplished by strategically blocking sections of the spectrum that are rich in light pollution, while leaving sections of the spectrum required to deliver a properly white balanced image. This family of filters does improve the contrast of emission nebulae, but only to a small extent relative to what can be achieved using a filter from the nebula contrast enhancement family. The colour correction capability of these filters is not affected by the type of deepsky object, they can be used effectively on any object type. Effectiveness is predicted to be best under light to moderate LP conditions.
5. All the filters tested were shown to have a low sensitivity to angle and therefore f-ratio. The narrowest filters tested, the NBX and NBZ, where sensitive to angle but only at angles greater than 14° or an f-ratio of f/2.

Acknowledgements:
This test report would not be possible without the generous help I received from a number of people. I would like to thank Ted Ishikawa at Astro Hutech for supplying me with complimentary samples of the IDAS filters. I would also like to thank the engineers at IDAS who helped me to trouble shoot and characterize the error of my spectrometer setup. Finally I would like to thank amateur astronomer André Knöfel for his online library of measured filter spectrums, which I have referred to on numerous occasions.

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

Cheers!

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top-jimmy@rogers.com

Appendix A
Reference Deepsky Object Spectra

To perform my prediction of filter impact on object contrast, I have assumed a representative spectrum for a list of typical objects. These spectra are taken from open source materials available online, and in most cases are simplified from the available data, or made up of a combination of multiple data sources. The spectra for the objects used in my analysis are presented in Figure B-1 below.

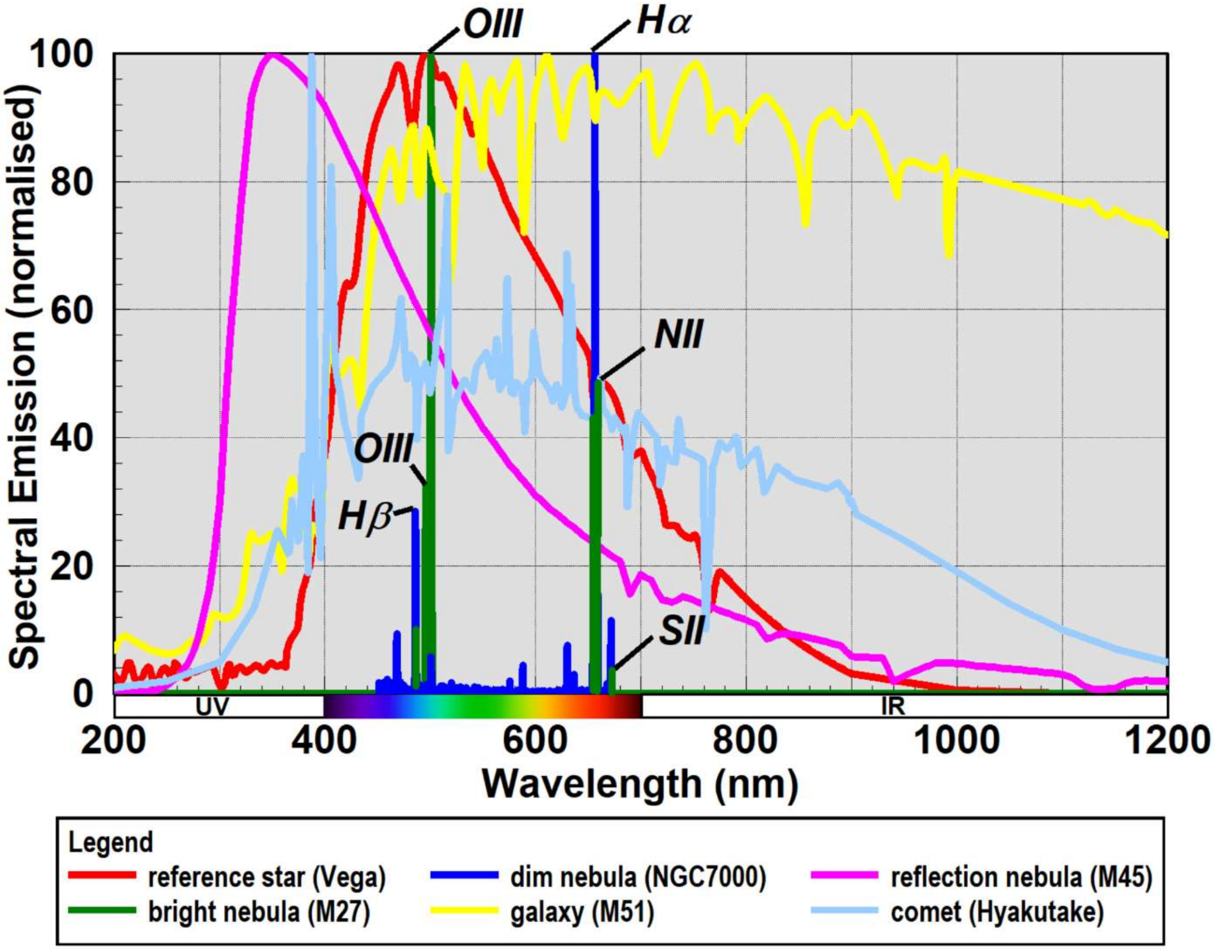
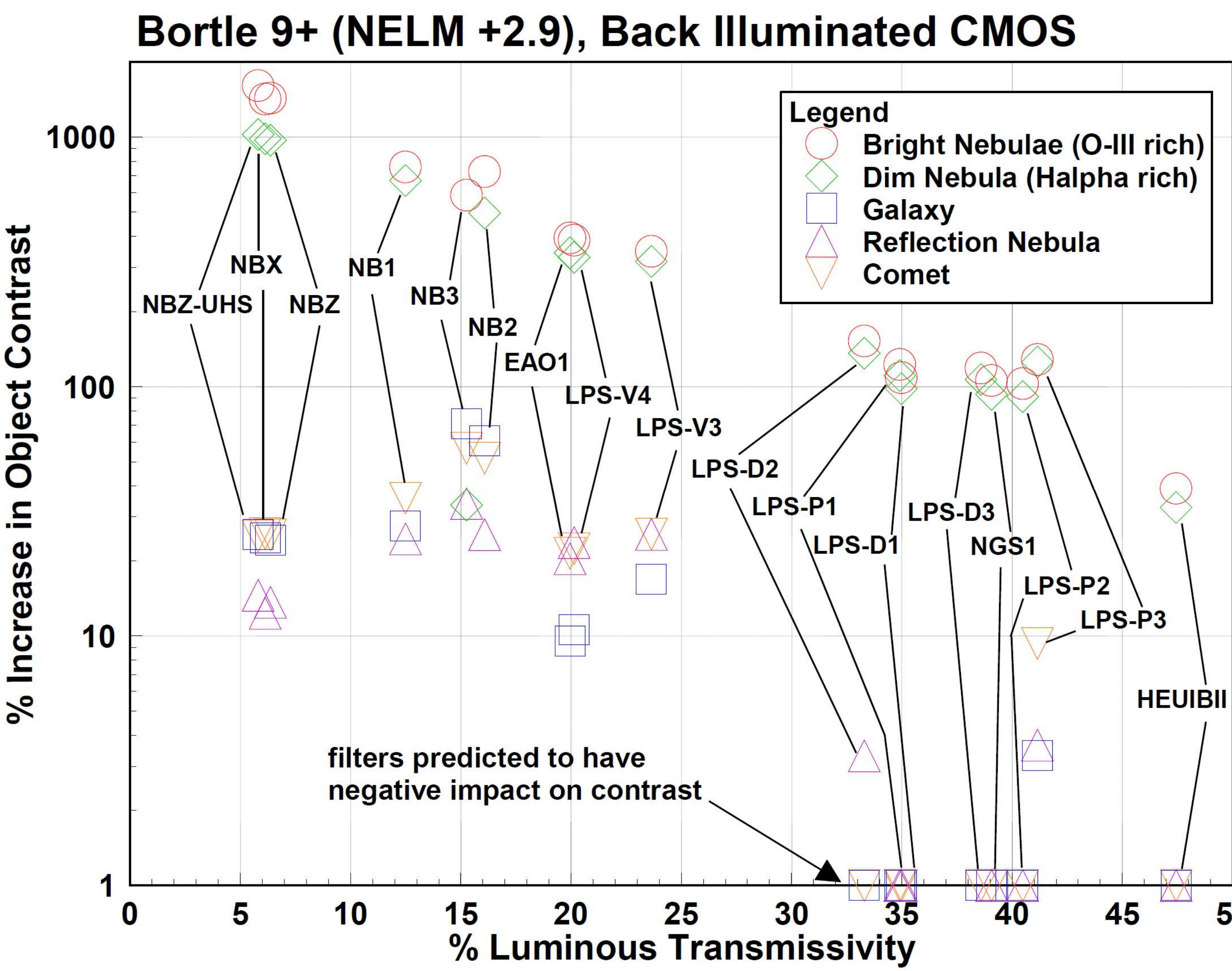
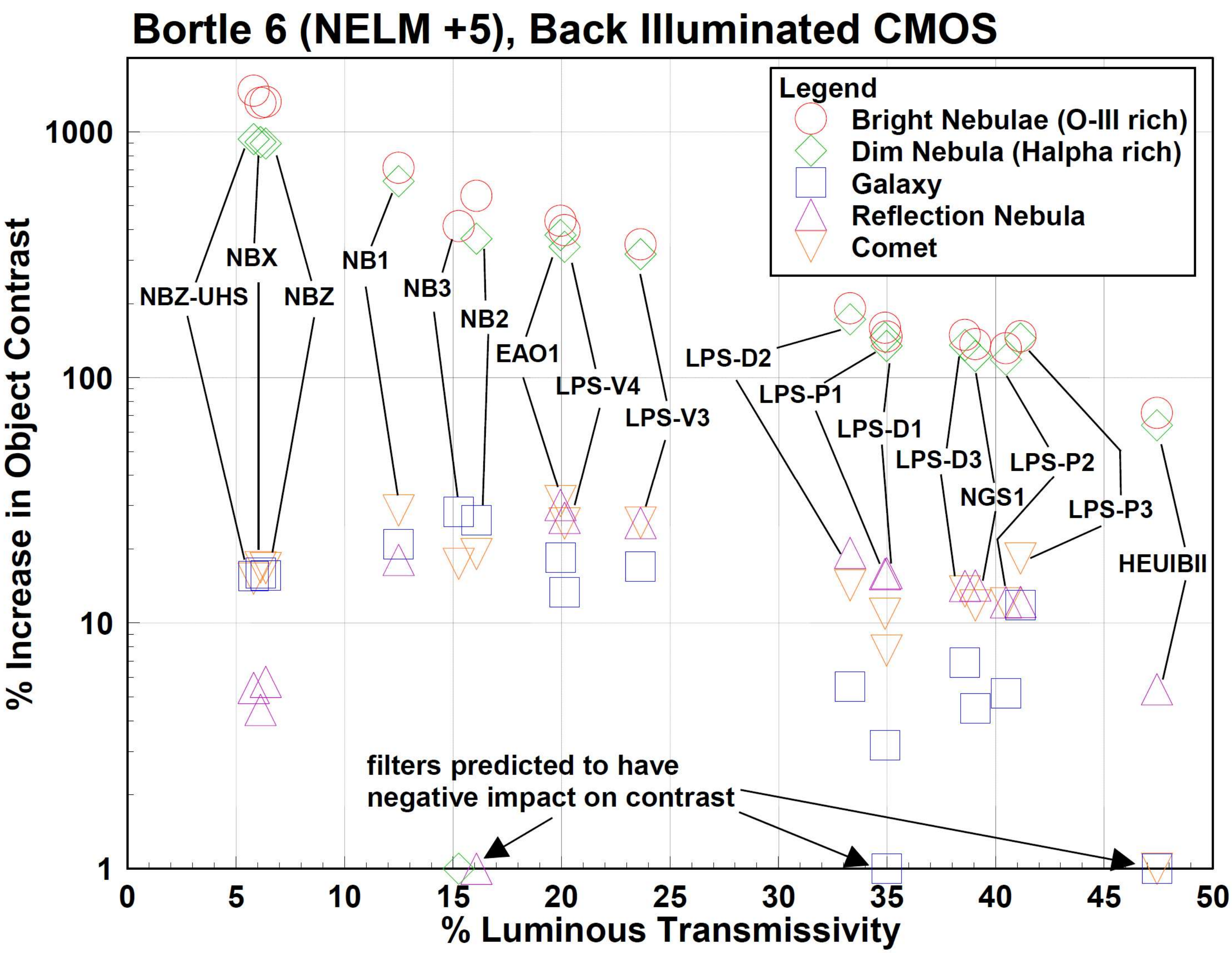
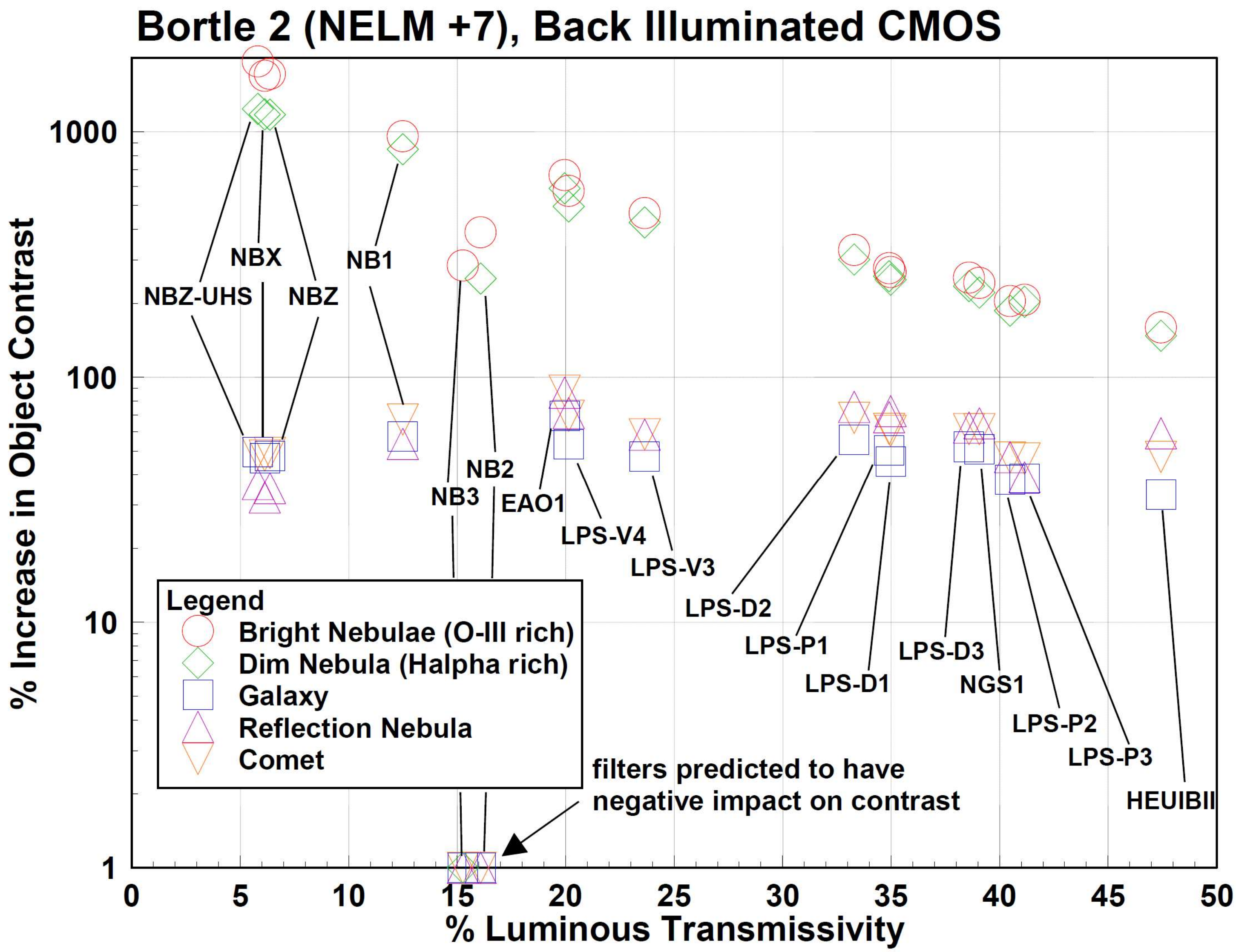


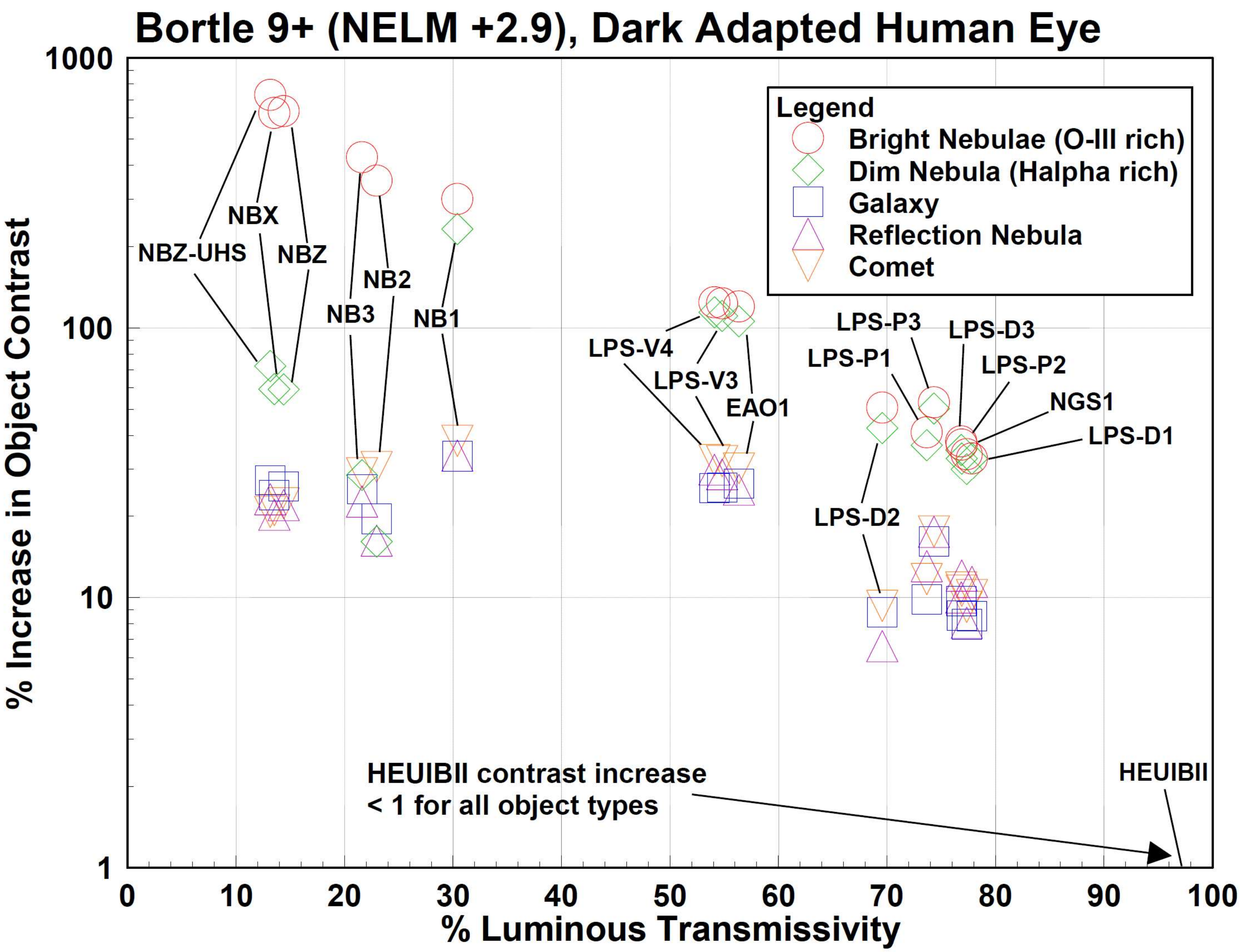
Figure A-1 Reference Observing Target Spectra

Appendix B
Filter Performance Prediction Plots

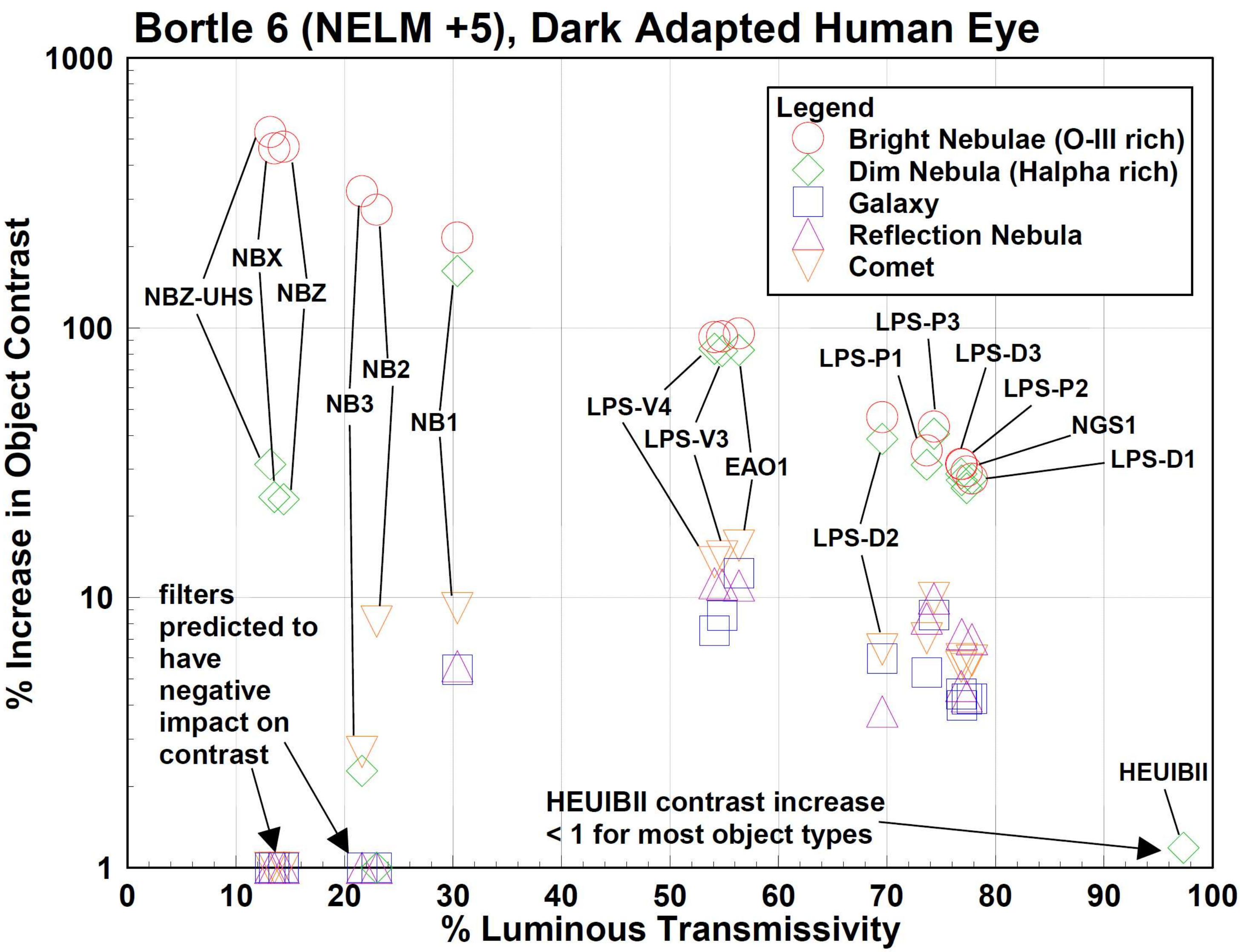



Bortle 6 (NELM +5), Back Illuminated CMOS
Legend
Bright Nebulae (O-III rich)
Dim Nebula (Halpha rich)
Galaxy
Reflection Nebula
Comet
% Increase in Object Contrast
% Luminous Transmissivity
1000
100
10
1
0
5
10
15
20
25
30
35
40
45
50
NBZ-UHS
NBX
NBZ
NB1
NB3
NB2
EAO1
LPS-V4
LPS-V3
LPS-D2
LPS-P1
LPS-D1
LPS-D3
NGS1
LPS-P2
LPS-P3
HEUIBII
filters predicted to have
negative impact on contrast

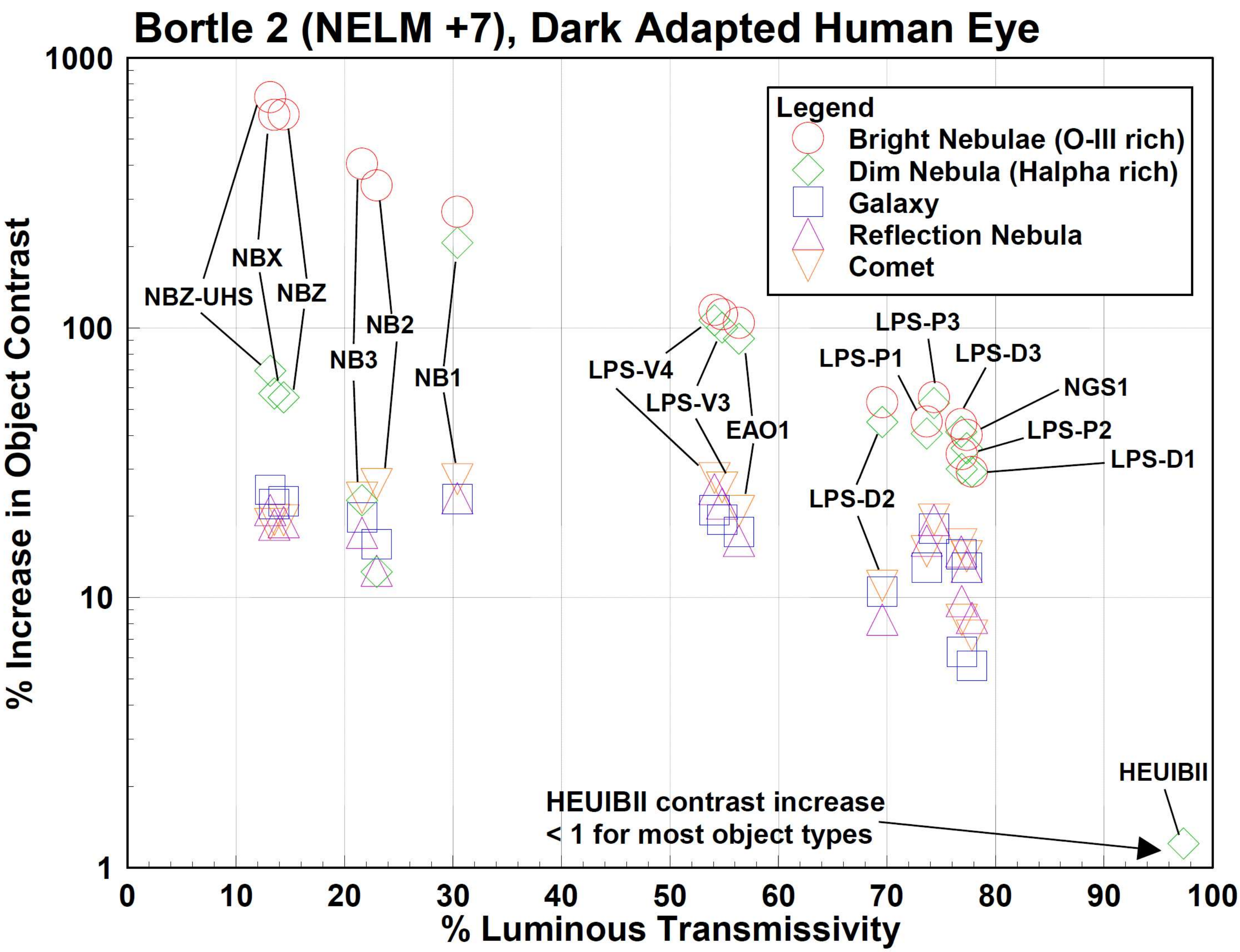

Bortle 2 (NELM +7), Back Illuminated CMOS
% Increase in Object Contrast
% Luminous Transmissivity
1000
100
10
1
0
5
10
15
20
25
30
35
40
45
50
NBZ-UHS
NBX
NBZ
NB1
NB3
NB2
EAO1
LPS-V4
LPS-V3
LPS-D2
LPS-P1
LPS-D1
LPS-D3
NGS1
LPS-P2
LPS-P3
HEUIBII
Legend
Bright Nebulae (O-III rich)
Dim Nebula (Halpha rich)
Galaxy
Reflection Nebula
Comet
filters predicted to have
negative impact on contrast



Bortle 9+ (NELM +2.9), Dark Adapted Human Eye
Legend
Bright Nebulae (O-III rich)
Dim Nebula (Halpha rich)
Galaxy
Reflection Nebula
Comet
% Increase in Object Contrast
% Luminous Transmissivity
1000
100
10
1
0
10
20
30
40
50
60
70
80
90
100
NBZ-UHS
NBX
NBZ
NB2
NB3
NB1
LPS-V4
LPS-V3
EAO1
LPS-P3
LPS-D3
LPS-P1
LPS-P2
NGS1
LPS-D1
LPS-D2
HEUIBII contrast increase
< 1 for all object types
HEUIBII



Bortle 6 (NELM +5), Dark Adapted Human Eye
1000
100
10
1
% Increase in Object Contrast
0
10
20
30
40
50
60
70
80
90
100
% Luminous Transmissivity
Legend
Bright Nebulae (O-III rich)
Dim Nebula (Halpha rich)
Galaxy
Reflection Nebula
Comet
NBX
NBZ-UHS
NBZ
NB2
NB3
NB1
LPS-V4
LPS-V3
EAO1
LPS-P3
LPS-P1
LPS-D3
LPS-P2
NGS1
LPS-D1
LPS-D2
filters predicted to have negative impact on contrast
HEUIBII
HEUIBII contrast increase < 1 for most object types


Bortle 2 (NELM +7), Dark Adapted Human Eye
% Increase in Object Contrast
% Luminous Transmissivity
1000
100
10
1
0
10
20
30
40
50
60
70
80
90
100
Legend
Bright Nebulae (O-III rich)
Dim Nebula (Halpha rich)
Galaxy
Reflection Nebula
Comet
NBX
NBZ-UHS
NBZ
NB2
NB3
NB1
LPS-V4
LPS-V3
EAO1
LPS-P3
LPS-P1
LPS-D3
NGS1
LPS-P2
LPS-D1
LPS-D2
HEUIBII
HEUIBII contrast increase
< 1 for most object types

Appendix C
Raw Image Captures

No Filter

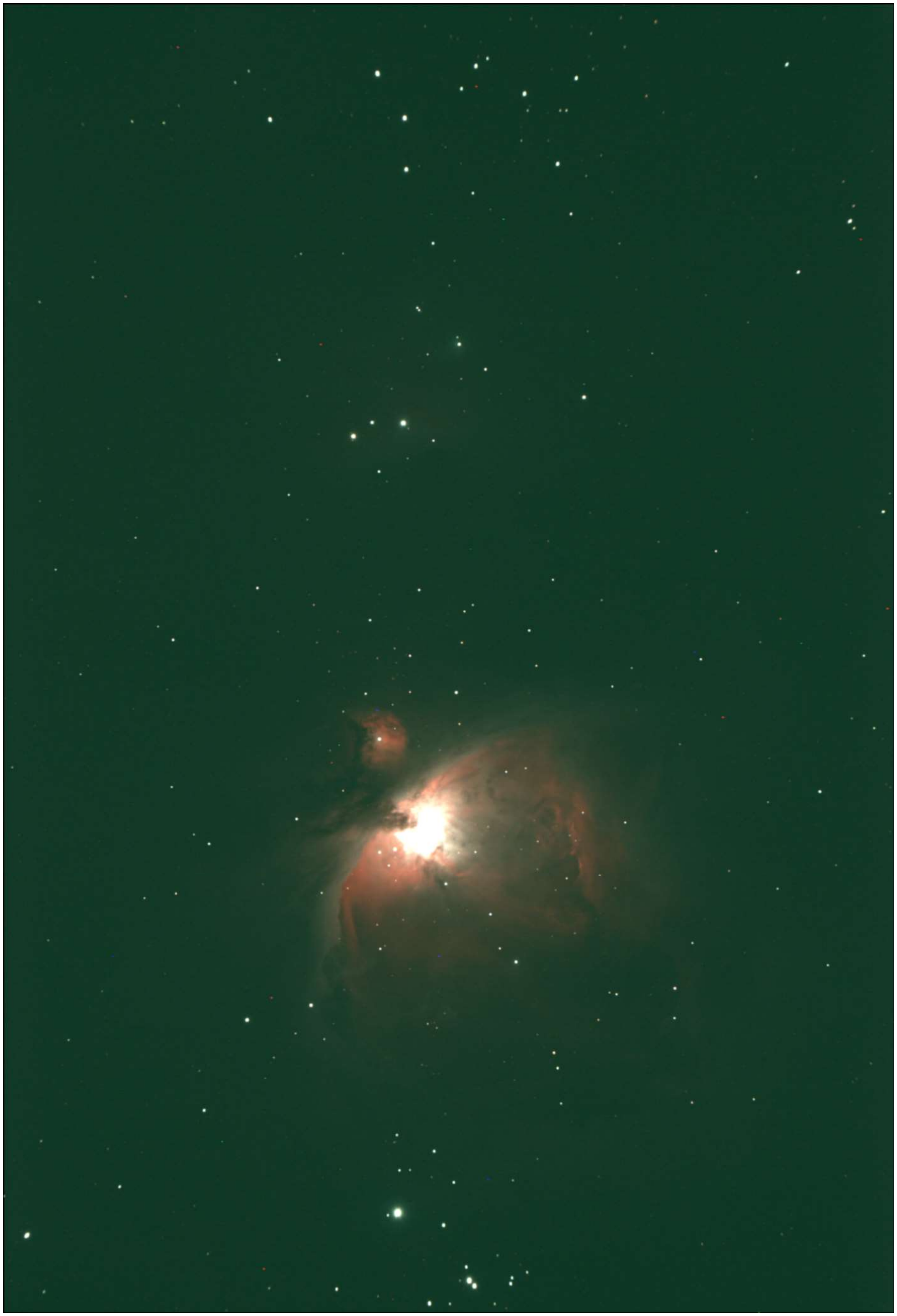
EAO-1

LPS-D2

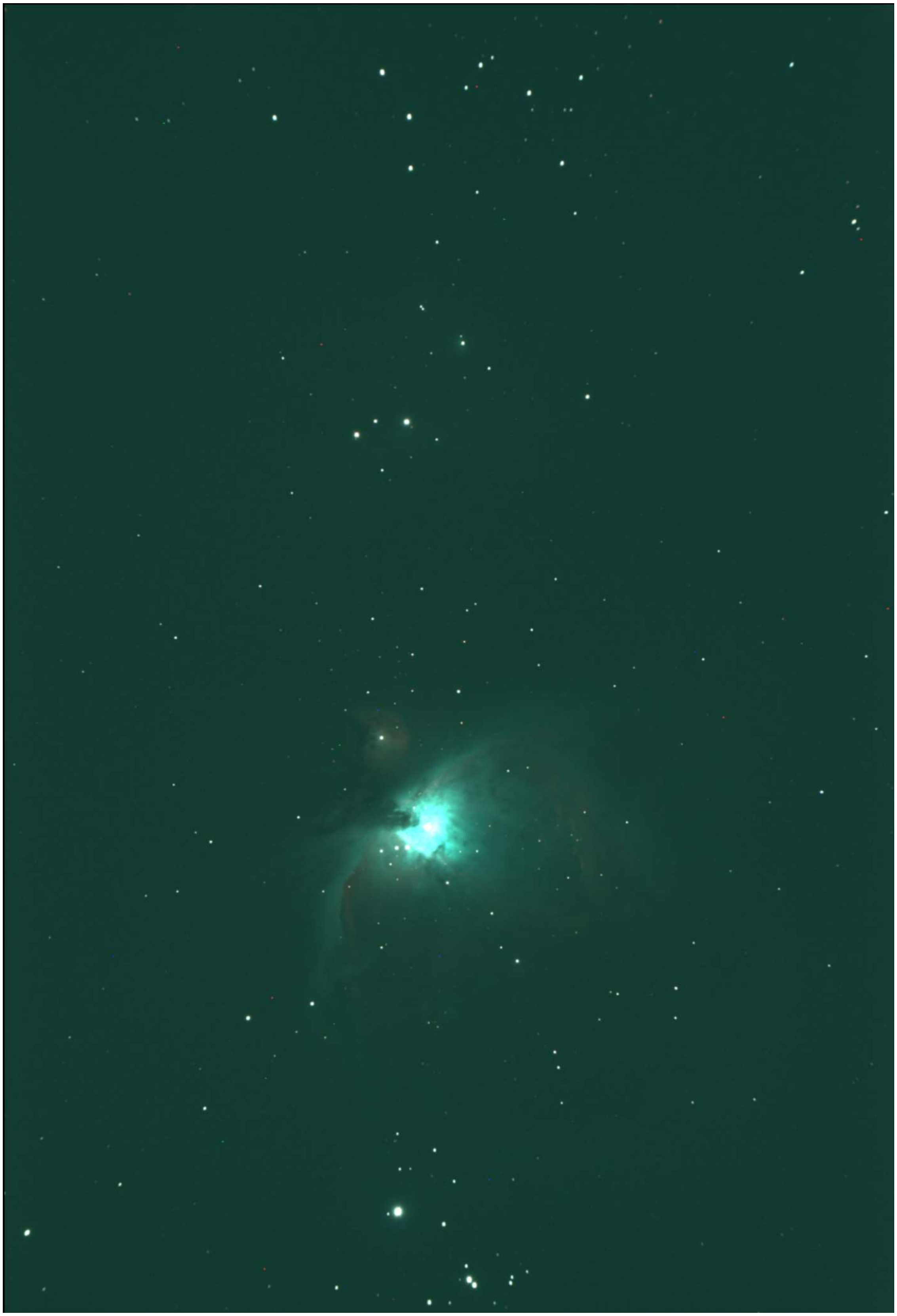
LPS-P2

LPS-P3

NB-1

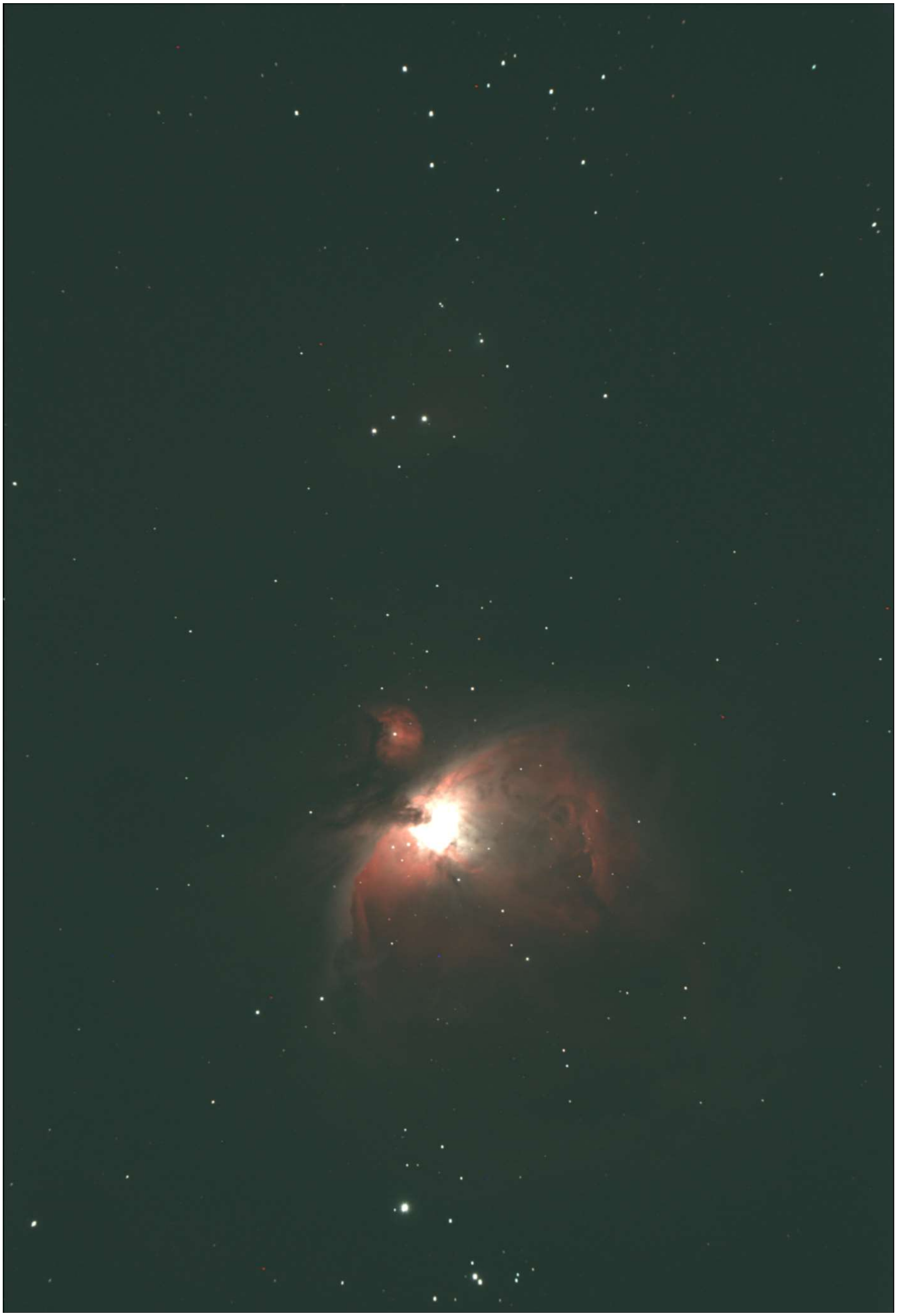


NB-2



NB-3

NBX



NBZ

Appendix D
Spectrometer Setup

As mentioned briefly in the body of this test report, I perform all my filter spectrum measurements from my basement workshop. A photo of my typical test setup is shown in Figure D-1.

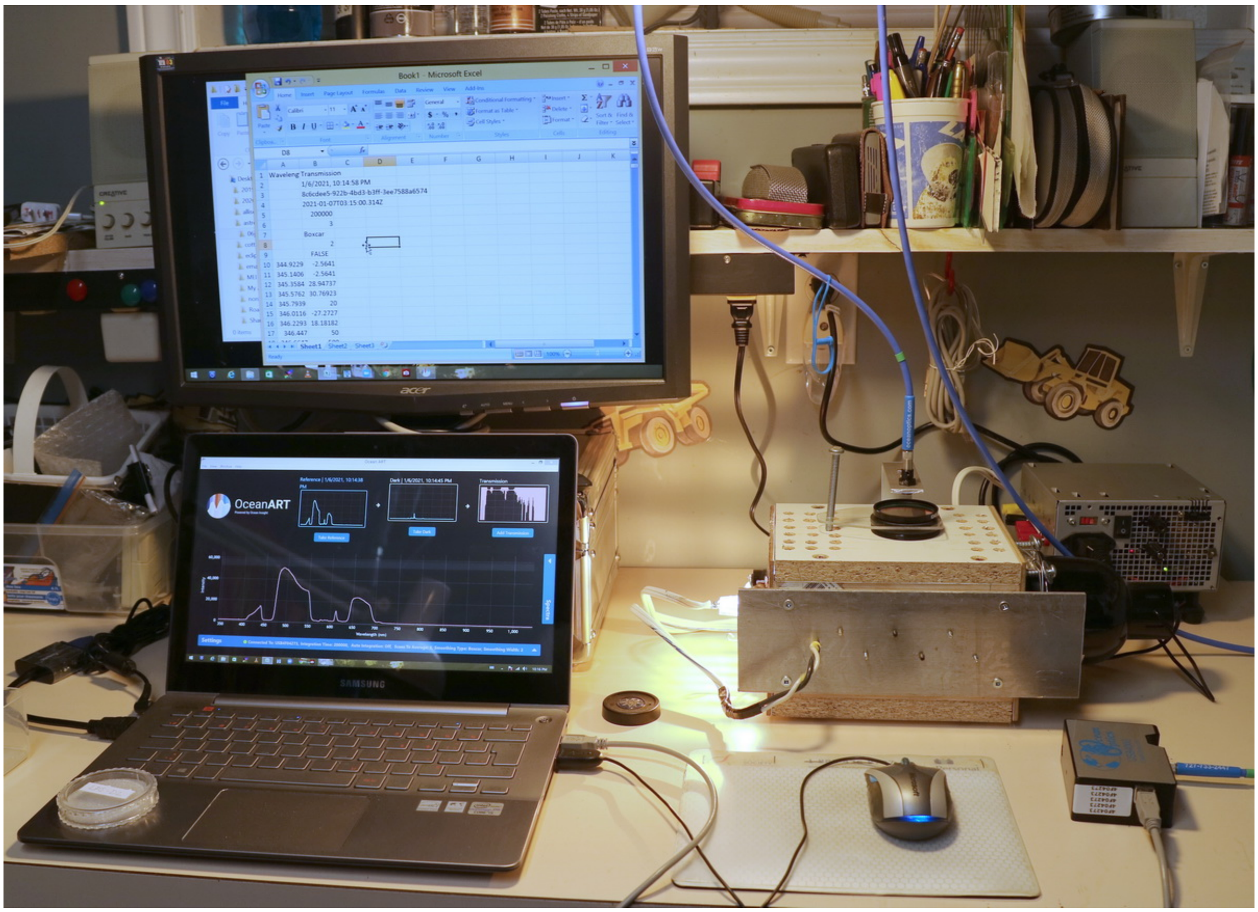


Figure D-1   Typical Setup for Filter Spectrum Measurement

Figure D-2 shows a more detailed view of the filter spectrum measurement setup, complete with labels of the main components. The central component of my filter spectrum measurement setup is an Ocean Optics (now called Ocean Insight) USB4000 UV-VIS-NIR spectrometer. A schematic view of the device is provided in Figure D-3. This is a compact and easy to use device that connects to your computer via a standard USB interface. I use the basic free OEM software "Ocean ART" to collect my measurements. The general appearance of the software interface is shown in Figure D-4. The USB4000 model that I own can provide spectrum data from 345 to 1040nm, with a wavelength step size of 0.16nm. The unit was factory calibrated, as well as in-situ calibration performed by myself using an Ocean Optics HG-1 calibration reference.

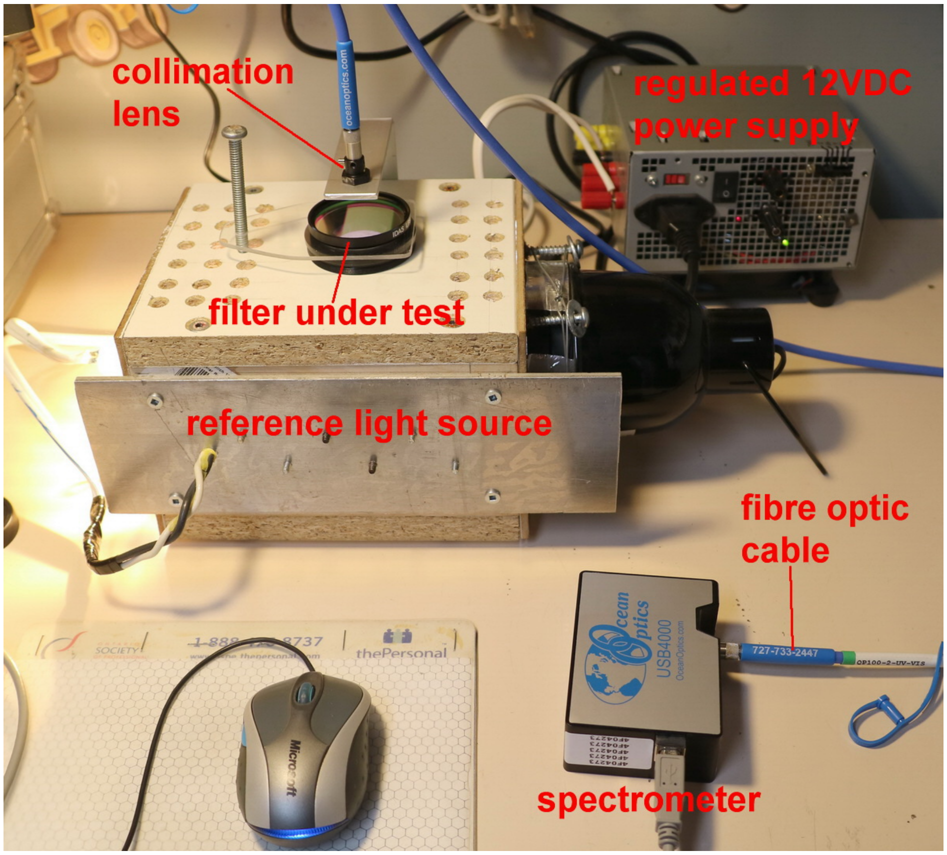
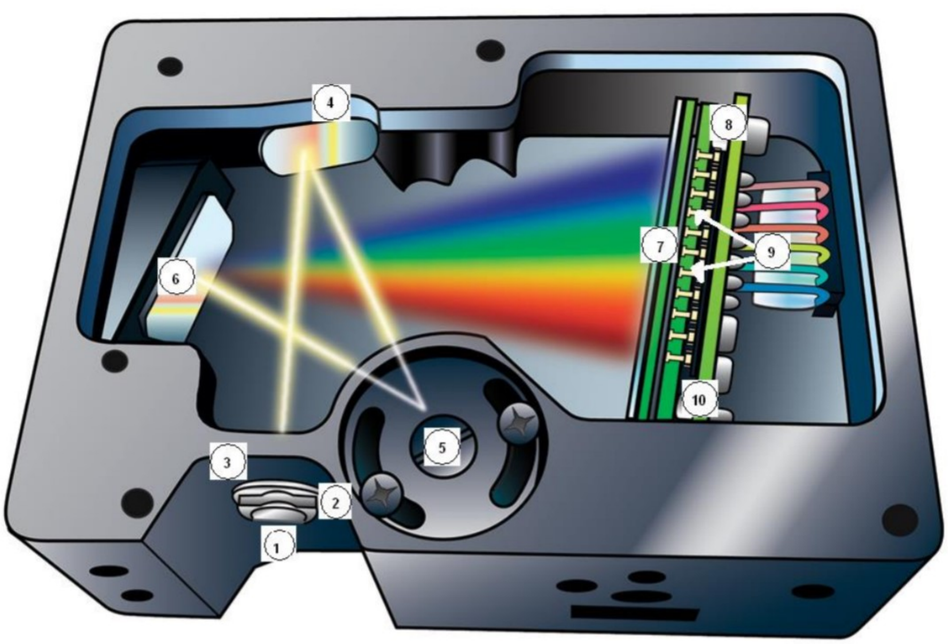


Figure D-2 Close-Up View of Filter Spectrum Measurement Setup



(1. SMA905 connector, 2. slit, 3. filter, 4. collimating mirror, 5. grating, 6. focusing mirror, 7. L4 detector collecting lens, 8. detector, 9. OFLV filters, 10. UV4 detector upgrade)

Figure D-3 Schematic View of USB4000 Spectrometer

Figure D-4 Sample View of Spectrometer Software

The Spectrometer connects optically to the filter test rig via a 1m long fibre optic cable. On the measurement end of the cable is a collimation lens to help focus the measurement on only the light rays passing through the filter at 90° (perpendicular). The filter sits on a machined platform that is set to be perpendicular to the collimation lens within 1/4°. When measurements are to be made at filter angles other than 90°, the filter sits on an acrylic panel that can have its angle adjusted using a ¼"-20 machine screw. A detailed view of this angle jig is provided in Figure D-5.

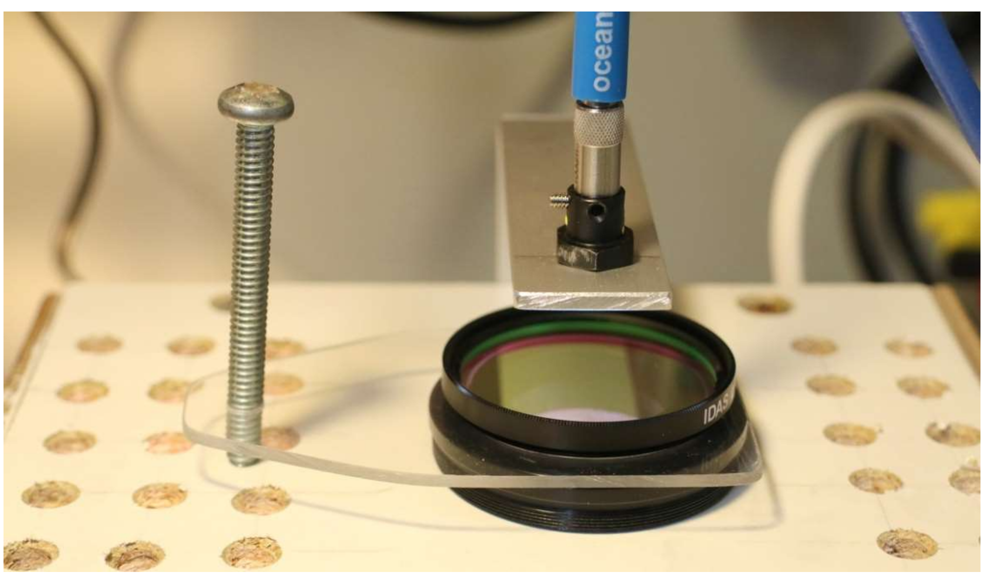


Figure D-5 Detail View of Filter Angle Jig

The other main component of my test setup is the reference light source. Finding a commercially available broad flat spectrum light source that was reasonably priced was not possible. After a lot of trial and error I managed to build my own using three different light sources: a 4700K halogen spot light combined with an IR blocking and blue coloured filter, an incandescent spot heat bulb combined with a 950nm high pass filter, and an array of high output UV LED's. These three light sources are mounted onto a wooden enclosure that is painted flat white on the interior. Figure D-6 is an image of the reference light source.

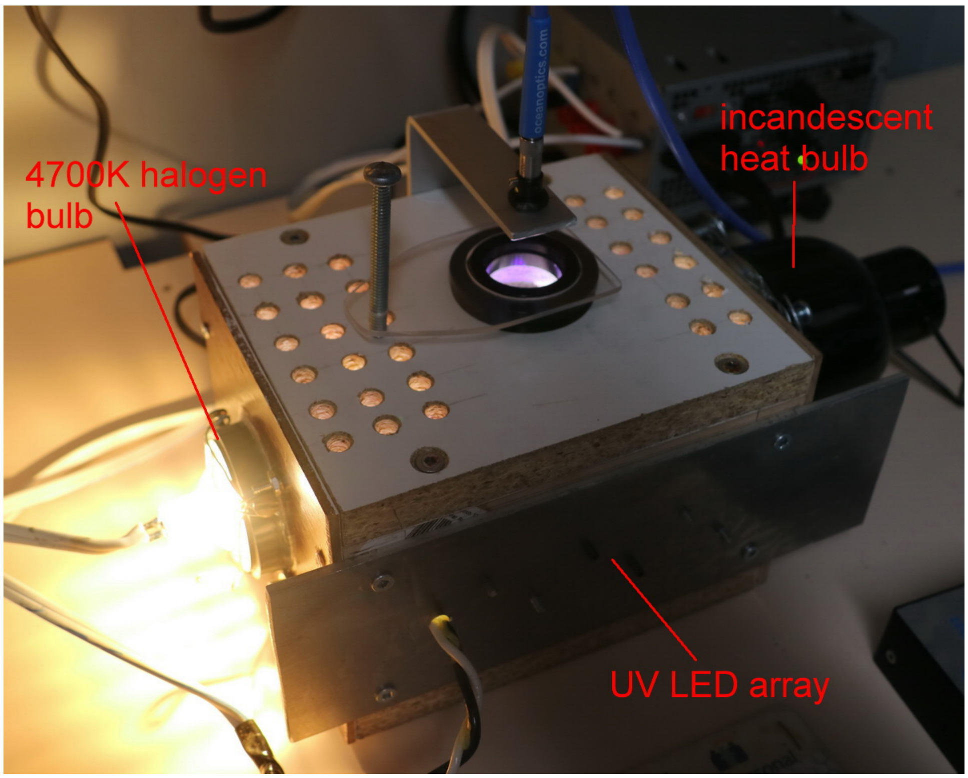


Figure D-6 Self-Built Broad Spectrum Light Source

As you can see, the reference light is not fancy to look at, but in my opinion performs sufficiently well for my purposes. Figure D-7 is a plot of the emission spectrum from each of the three light sources, as well as the resulting spectrum of all three sources together.

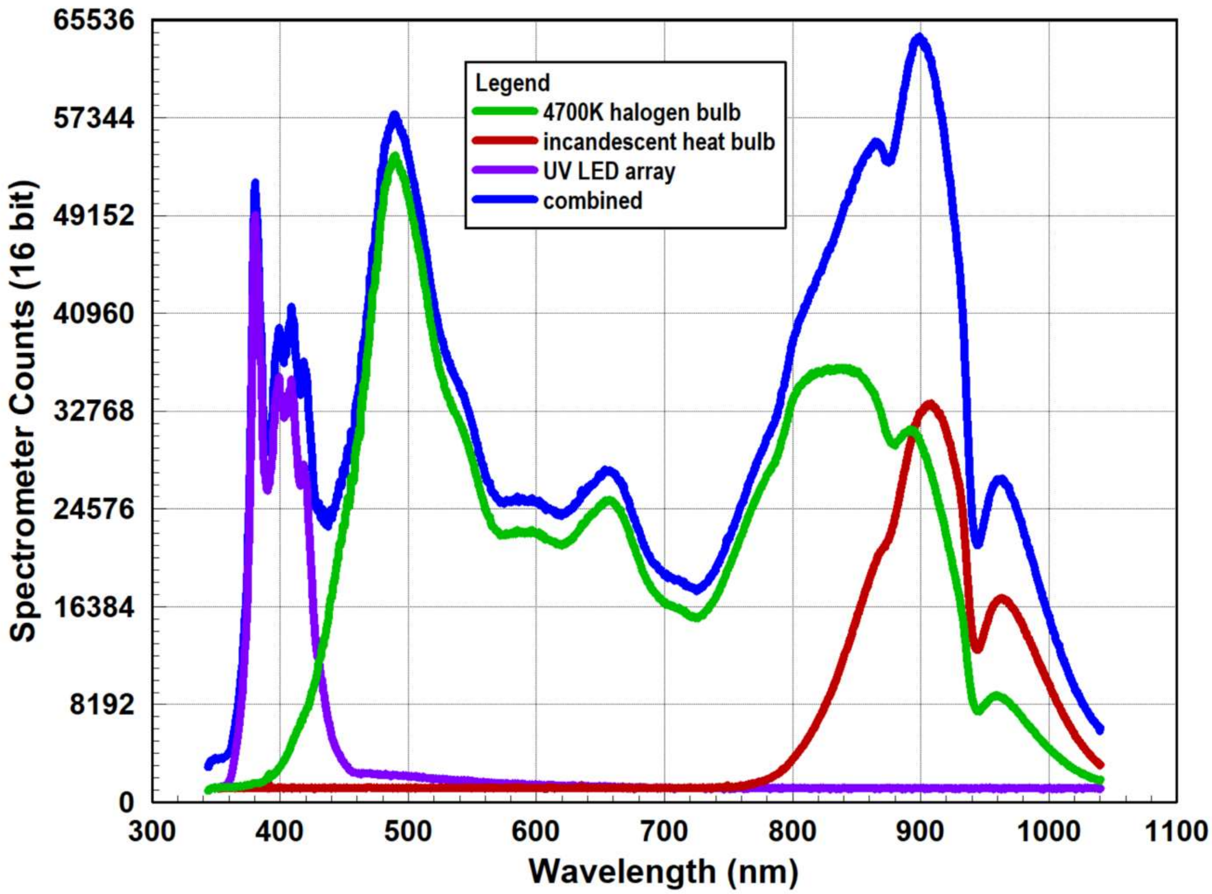


Figure D-7 Reference Light Source Emission Spectra

I have been fortunate to work recently with the engineers at IDAS as they have assisted me in characterizing the accuracy of my filter spectrum measurement apparatus. IDAS provided me a filter sample for which they had a detailed spectrum measurement, made using an Agilent Cary 5000 spectrometer. I was able to compare IDAS' spectrum measurement to mine in order to quantify the errors in my system. From the comparison it is evident that there is a small amount of band shift in my measurements as a result of the geometry of my measurement setup (see Figure D-8). Without a lens to collimate the source light before it passes through the filter, the result is a measurement that is an average of a small range of incident angles, as illustrated in Figure D-9. Table D-1 summarizes the magnitude of the band shift error associated with my measurement setup. These values will be accounted for in all my reported test results going forward.

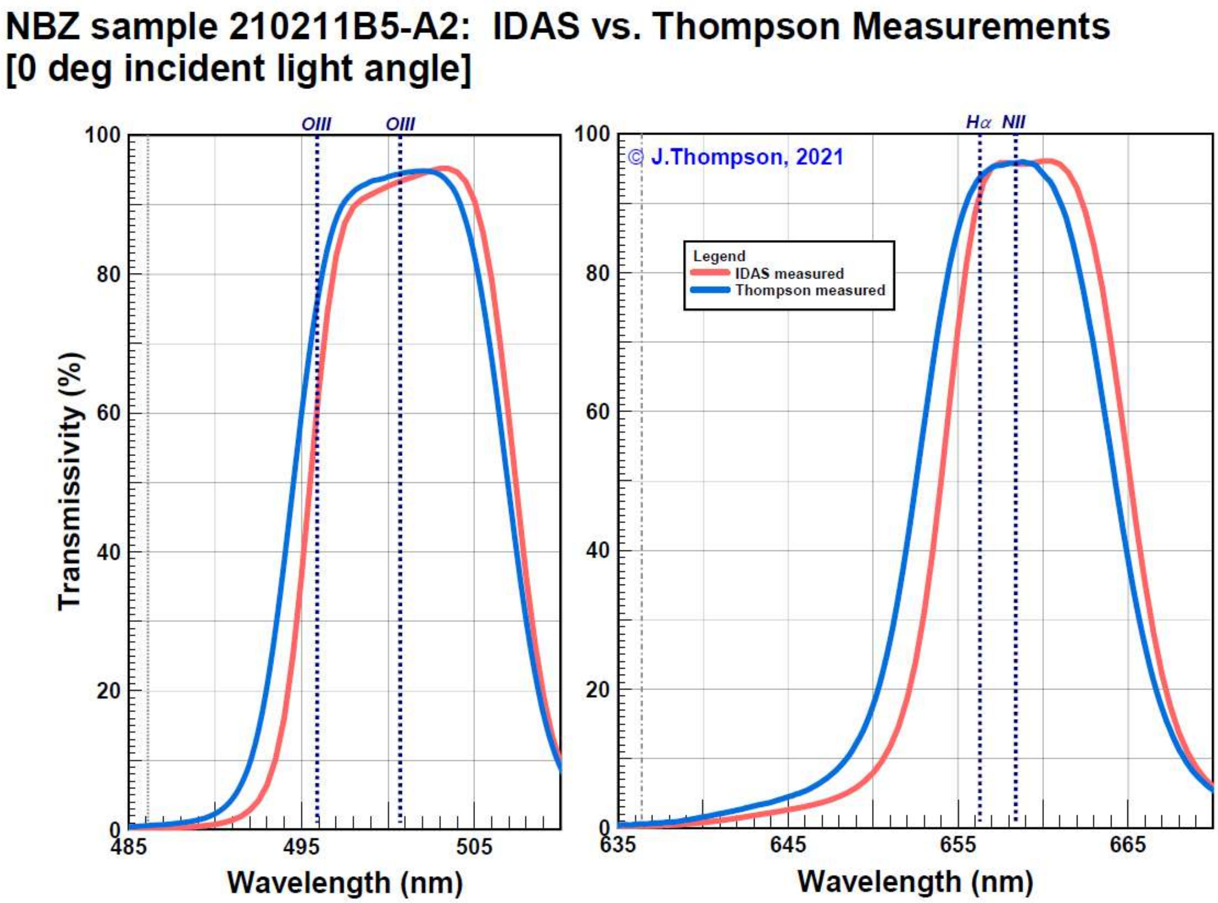


Figure D-8 Comparison Between IDAS & Thompson Filter Spectrum Measurements

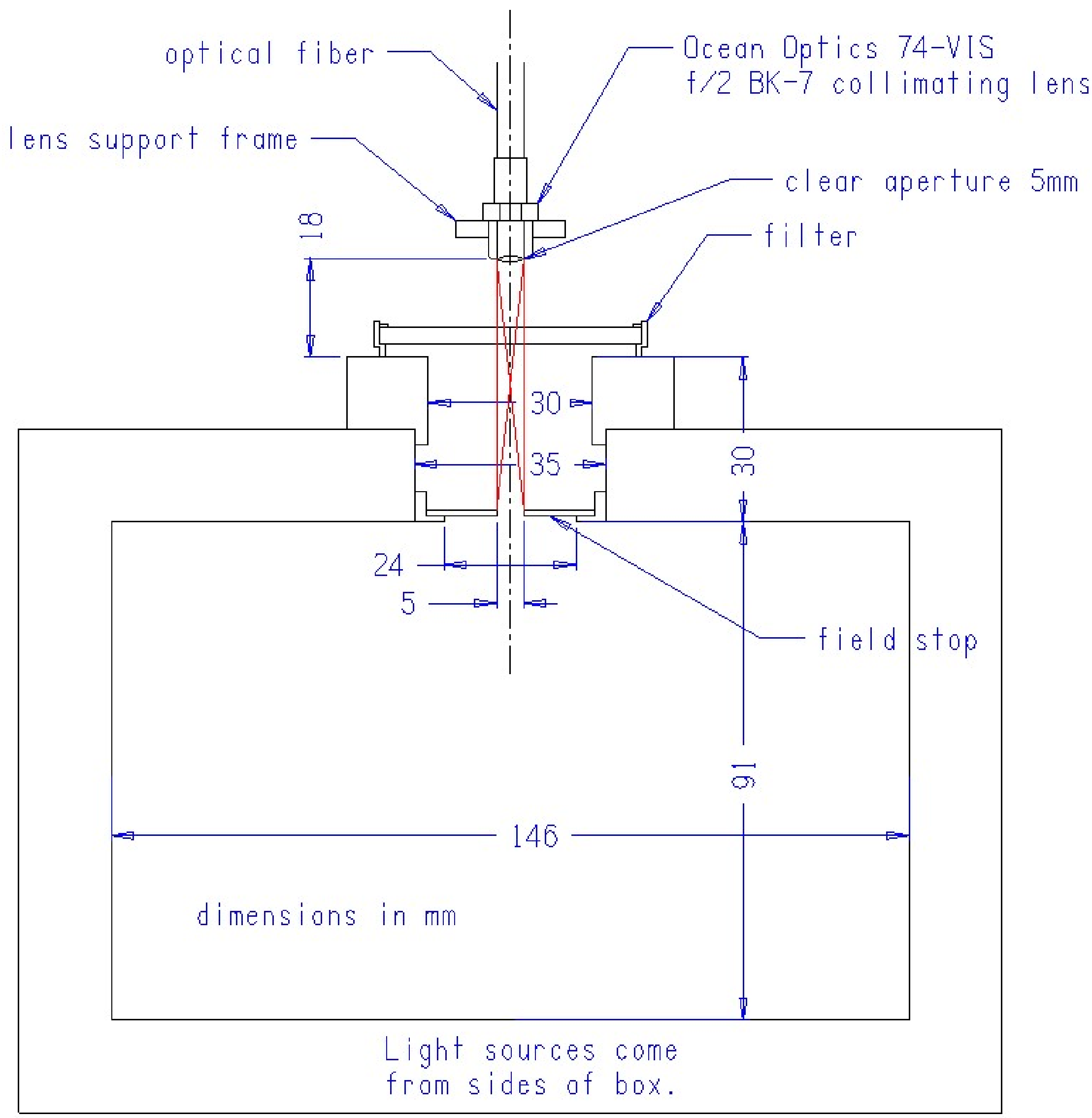


Figure D-9 Detailed Dimensions of Thompson Spectrum Measurement Apparatus

Measurement Source	O-III band		H-alpha band		
	CWL	FWHM	CWL	FWHM	
IDAS	501.45	12.10	659.58	11.34	
Thompson	500.73	12.65	658.40	11.96	
	-0.72	*0.55*	*-1.18*	*0.62*	*delta (nm)*

Table D-1 Summary of Thompson Spectrum Measurement Apparatus Band Shift Error