BATTLE OF THE QUADS!

By Jim Thompson, P.Eng

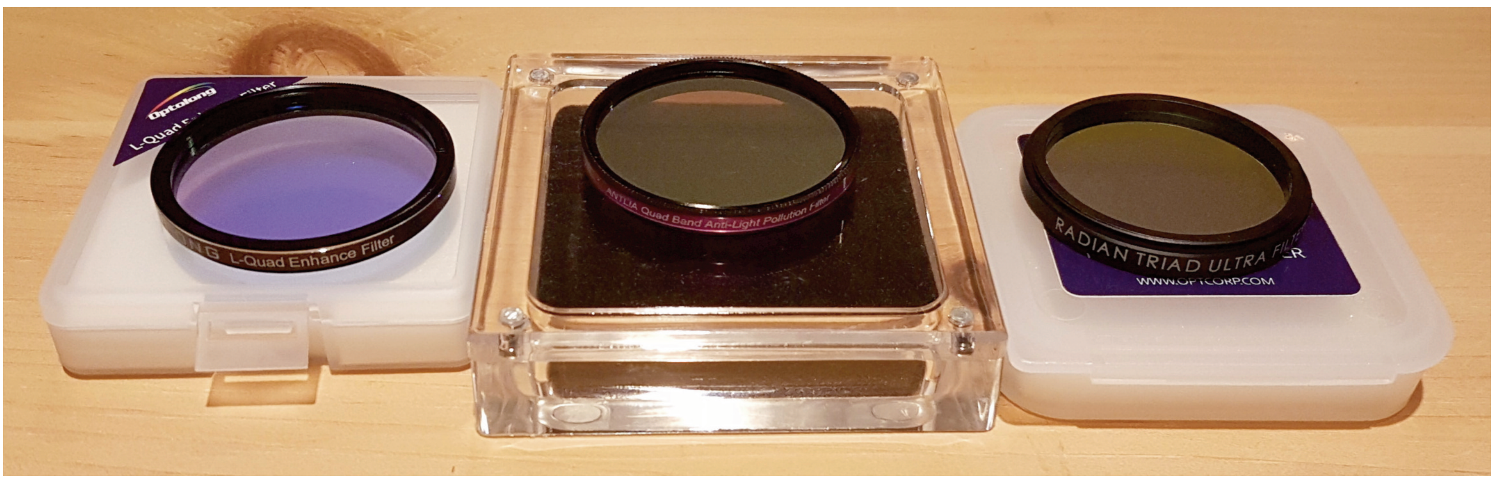

Figure 1: "Quad" Filter Samples Used in Comparison

Amateur astronomers today live in "interesting times," but I don't mean to say we are cursed, quite the opposite. Never have there been so many choices of high quality astronomy equipments at affordable prices than now.

Included in this long list of high performance astro-gear are optical filters for improving our view of the night sky. These filters go by many names: anti-light pollution, nebula contrast booster, narrowband, dual-band, or even tri-band. The focus of this article is on what is perhaps the ultimate in filter naming conventions: the "quad-band". There are four filters on the market bearing that moniker, their names and 2" version retail prices (prices as of the writing of this article) being as follows:

- Optolong L-Quad Enhance Filter (L-QEF), $199USD
- Antlia Quadband Anti-Light Pollution (Quad ALP), $198USD
- Altair QuadBand V2 (Quad V2), $170USD
- Radian Triad Ultra Quadband (Quad Ultra), $1075USD (discontinued)

With the unfortunate closing of Oceanside Photo and Telescope (OPT) this year, the Radian Triad is no longer available new, but it can be found for sale from time-to-time on used equipment sites.

Through transmission spectra measurements, theoretical contrast increase predictions, and real deepsky target imaging I have compared these four different quad filters. As shown in **Figure 1**, I have physical samples of all but the Altair filter. For it I used the manufacturer supplied spectrum in my predictions, and the IDAS NB-1 filter as a proxy during my imaging sessions

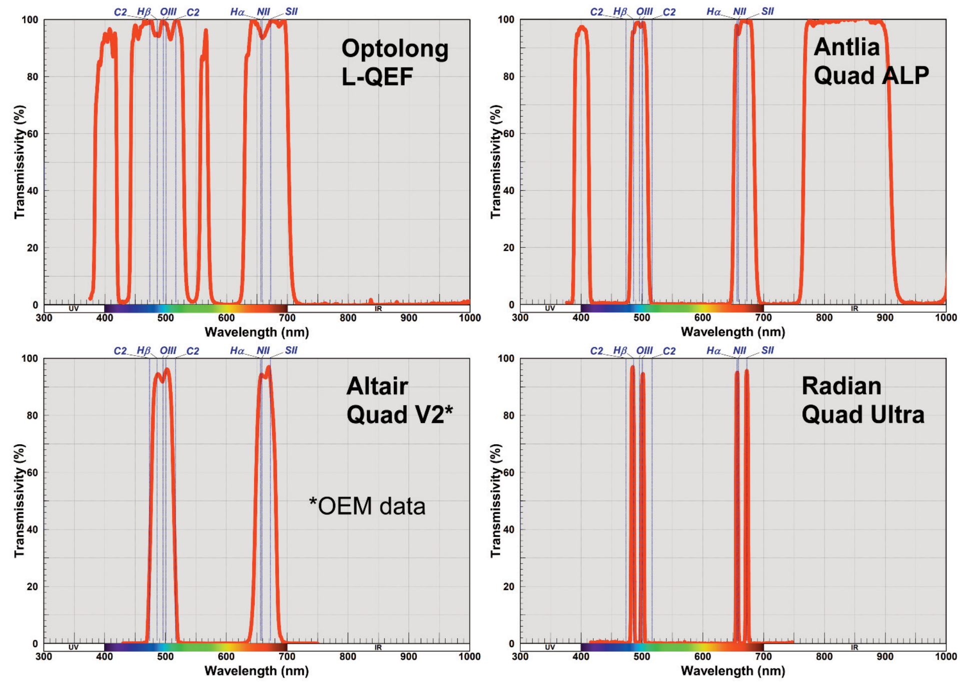

Figure 2:Measured Spectral Response of Tested Filters

as that filter has almost the same spectrum as the Altair filter. Although these four filters all share the "quad" designation in their names, they each fill a rather different niche in the amateur astronomy market, as will be explained in more detail in this article.

Filter Spectra

For the three filters that I have samples of, I used my Ocean Insight USB4000 spectrometer to measure their spectra, from 0° (perpendicular) to 20° off-axis. As mentioned earlier, the Altair filter's spectrum was extracted from the available marketing material on the OEM's website.

Figure 2 compares the measured spectra for the four filters for the case of the filter perpendicular to the light beam. The L-QEF is what I consider to be a "multi-broadband" filter as three of its four pass bands are well over 40nm in width. The Quad ALP and Quad V2 filters just barely fit into my definition of a "multi-narrowband" filter, with pass bands of around 30 to 35nm width. The Quad Ultra filter is squarely in the multi-narrowband category, with all four pass bands being in the 3 to 4nm width range. Each filter's pass band widths have implications regarding how effective they will be at blocking light pollution (LP), with narrower pass bands blocking more LP.

Pass band width also has implications regarding how sensitive the filter is to telescope f-ratio, with wide pass bands being less sensitive than narrow. **Figure 3** illustrates this behaviour, showing how each filter's transmission of H-α and O-III varies with the filter's angle to the light beam. Note that the response of the IDAS NB-1 is shown here as a proxy for the Quad V2. The L-QEF, Quad ALP and Quad V2 all have pass bands that are wide enough to provide consistent performance at f-ratios as fast as f/1.4. The Quad Ultra on the other hand, with its very narrow pass bands, delivers consistent performance only down to around f/3.5.

Predicted Performance

Having each filter's transmission spectrum I was able to calculate a prediction of how each filter will perform on different types of deepsky target, specifically: H-α rich emission nebulae, broad spectrum galaxies, and reflection nebulae. This prediction was made for a range of LP levels, from a Naked Eye Limiting Magnitude (NELM) of +2.9 (Bortle 9+) down to a NELM of +7.0 (Bortle 2).

The predicted increase in object contrast relative to no filter is presented in **Figure 4**. Also included is a prediction of a typical UV/IR cut filter's per-

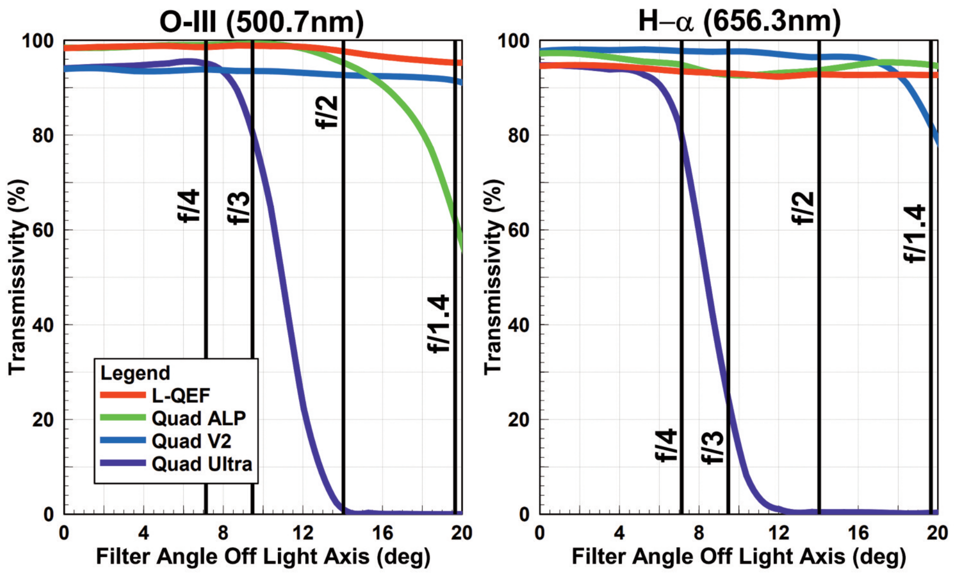

Figure 3: Measured Filter Performance Summary

formance for comparison since this is often the default filter used by many astrophotographers. Each graph has a green and black line plotted to represent performance on a one-shot colour (OSC) and monochrome camera respectively. Note that negative values of % Contrast Increase means that adding the filter on that object type for that particular LP level results in a reduction in contrast versus no filter.

On emission nebulae, all four Quads are predicted to increase contrast, the extent of the increase varying with the filter band width. The L-QEF has the widest pass bands and therefore the lowest contrast increase, around 100% under heavy LP. The Quad Ultra filter has the narrowest pass bands, and thus the largest contrast increase at around 2000%. On galaxies only the Quad ALP is predicted to deliver a significant increase in contrast when under heavy LP. The other filters are predicted to deliver a negligible or negative increase in contrast under heavy LP.

This situation flips around NELM +5 to +6, at which point the Quad ALP's contrast increase is below that of the other three filters. A similar behaviour is predicted on reflection nebulae, with the Quad ALP delivering the best contrast increase under heavy LP, but then flipping so that the other three filters are superior for NELM better than +4.

Worth noting here is that delivering the largest contrast increase is not enough to make a filter your best choice. For example, even though the Quad V2 and Quad Ultra are predicted to deliver superior contrast on reflection nebulae under dark skies, those two filters require significantly longer exposure times than the L-QEF, so the contrast improvement may not be worth it from a practical stand point.

The % Luminous Transmissivity (%LT), a general measure of how much light is getting through a filter, has been calculated for the tested filters as follows: L-QEF 33%, Quad ALP 35%, Quad V2 13%, and Quad Ultra 4%. These values of %LT are calculated for a modern back-illuminated CMOS sensor. The UV/IR Cut filter included in Figure 4 has a %LT of 53%.

Another measure of a filter's performance is how it impacts image signal-to-noise ratio (SNR). By reducing the signal contribution due to LP, a filter has the potential to improve SNR and thus reduce the time required to acquire image data. **Figure 5** presents the predicted SNR of a single image frame assuming a fixed sub-exposure time.

The SNR values are calculated relative to no filter having a value of 1.0. Thus a value greater than one means the filter improves SNR, and a value below one means it makes the SNR worse. On emission nebulae all of the filters considered improve SNR, with the extent again varying with filter pass band width – narrower bands give a better SNR.

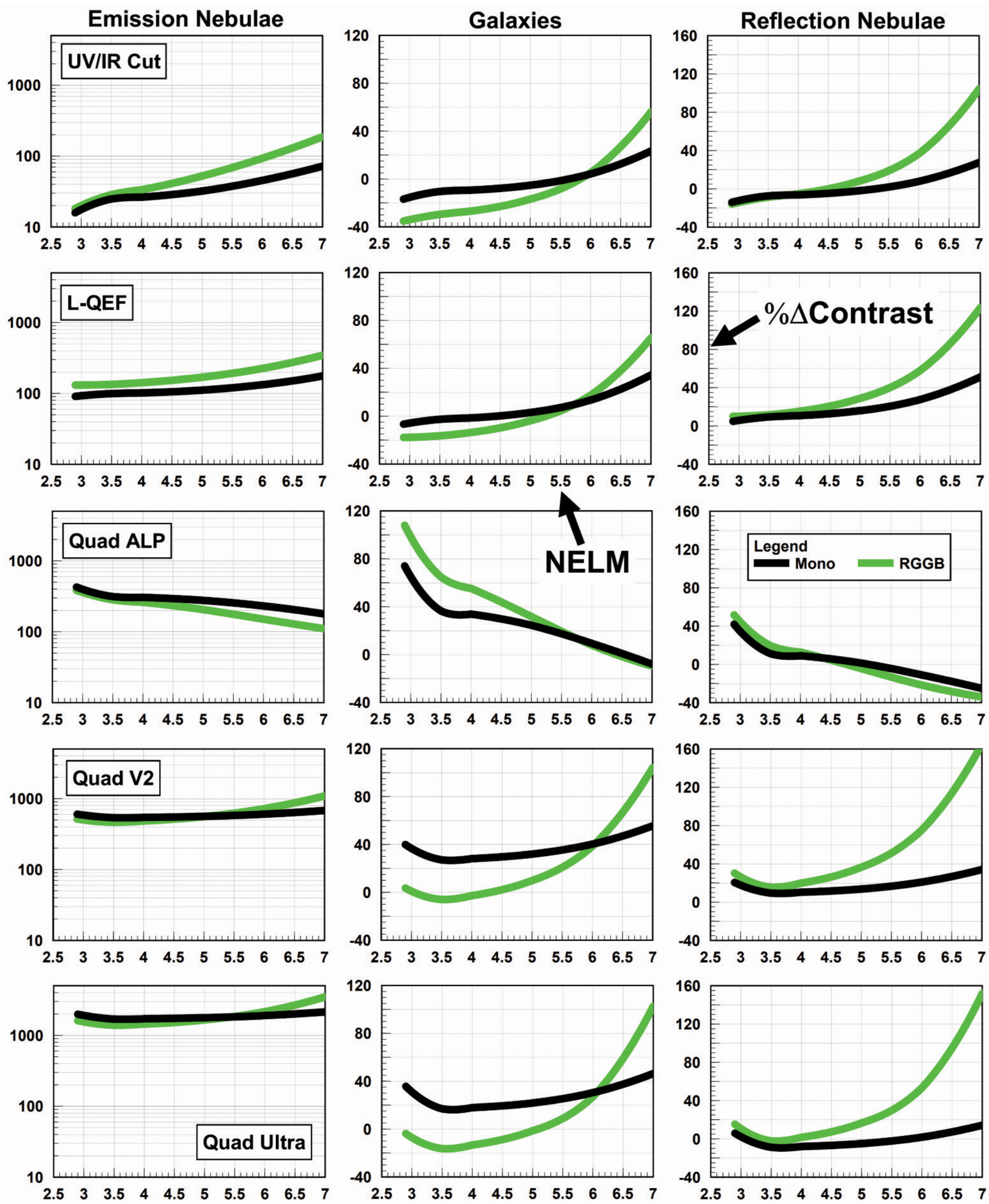

Figure 4: Predicted Filter Performance – Contrast Increase

On galaxies, none of the filters improve SNR, with the reduction in SNR being worse the lower the filter's %LT. Under heavy LP the Quad ALP presents a bit of an exception, as with a OSC camera it delivers the lowest reduction in SNR of the quad filters down to a NELM of +6, after which the L-QEF is the better of the quads.

SNR values below one are also predicted for all the quad filters on reflection nebulae. In this case there are no exceptions; the least reduction in SNR is achieved with the filter having the largest %LT. The implication of a reduction in SNR versus the no filter

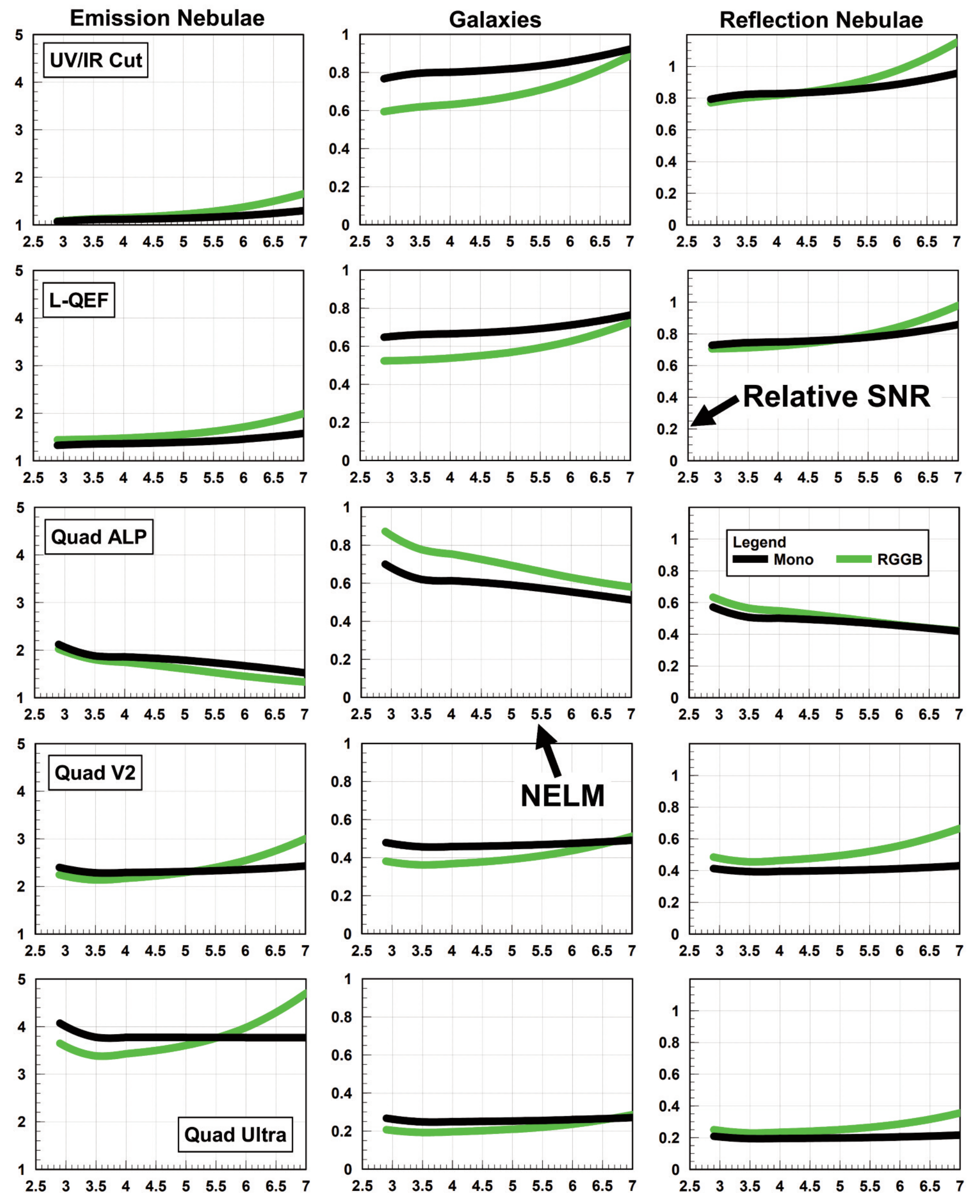

Figure 5: Predicted Filter Performance – Relative SNR

case is that longer exposure times will be required to achieve the desired final image SNR. This increase in exposure time, both sub-exposure and total integrated, may be worth it if the filter is able to deliver an increase in contrast.

Imaging Results

Image data was collected using a ZWO ASI533MC Pro OSC camera, and William Optics FLT98 triplet apochromatic refractor (f/6.3). mages were all collected from my backyard in central Ottawa, Canada where the NELM due to light pollution is +2.9 on average.

Images of four different deepsky object were captured, all on the night of November 20th as follows: IC410 Tadpole Nebula, M33 Triangulum Galaxy, M45 Pleiades Cluster, and M42 Orion Nebula. The images were generated by live stacking enough frames in SharpCap to produce a ten minute total exposure. Sub-exposure time was varied according to filter %LT so that overall frame exposure was similar between filters.

The resulting colour images are provided in **Figures 6 to 9**. All the images have had their histograms adjusted in exactly the same way using Fitswork v4.47, so that they provide as fair a visual comparison as possible. GraXpert was also used to remove any gradients that may have been present in the images. Recall that I have used the IDAS NB-1 filter as a proxy for the Quad V2 since they have very similar transmission spectra.

On the emission nebula IC410 the differences visible between filters is rather obvious. There is a clear increase in object contrast with reducing pass band width. On the galaxy M33 there are a couple of observations that can be made from the images.

First, object contrast is only better for the Quad ALP filter, an observation that is consistent with predictions. Second, the colour balance of the galaxy varies noticeably between filters. The L-QEF produced a slightly bluish galaxy, the Quad ALP slightly purplish, the Quad V2 greenish, and the Quad Ultra something entirely different.

With the Quad Ultra filter the H-α emissions in the galaxy are highlighted, to the point that almost none of the galaxy's stars are visible, making for a very odd ghostly-looking image. On M45 the variation in white balance is perhaps even more pronounced with the reflection nebula taking on a definite colour cast. Also evident from the M45 images are each filter's propensity for halos around bright stars. The L-QEF showed no halos, but the Quad ALP (moderate) and Quad Ultra (significant) do. The NB-1 filter I used as a proxy for the Quad V2 displayed the worst halos, a known problem with this filter. Altair has indicated that the off-band blocking of their Quad V2 filter is OD5 in the visual band, so I would expect halos generated by the actual filter to be negligible.

The last object imaged, M42, is a complex target. It displays a broad range of dynamic range and multiple types of emission; H-α, O-III, and reflection. NGC1977, the Running Man Nebula, is also nearby, further adding to the complexity of the composition. The filter behaviours observed on the other three objects can be observed rolled into this one image. Emission nebula and the faint dark dusty nebulosity around the periphery of M42 has progressively better contrast as the filter pass band width decreases. The contrast of reflection nebula components is better for the Quad ALP and Quad V2 filters. The L-QEF also seems to perform better for this complex scene than it did with each object type separately.

To help interpret the imaging results I have made measurements of contrast increase for each filter on each object type. These measured results are compared to the predictions in **Figure 10**.

The magnitude of my predictions differ from my measurements, however the trend in performance of one filter relative to another aligns well between prediction and measurement. The offset in magnitude can be explained by differences in sky conditions and the object brightness from what was assumed in my predictions.

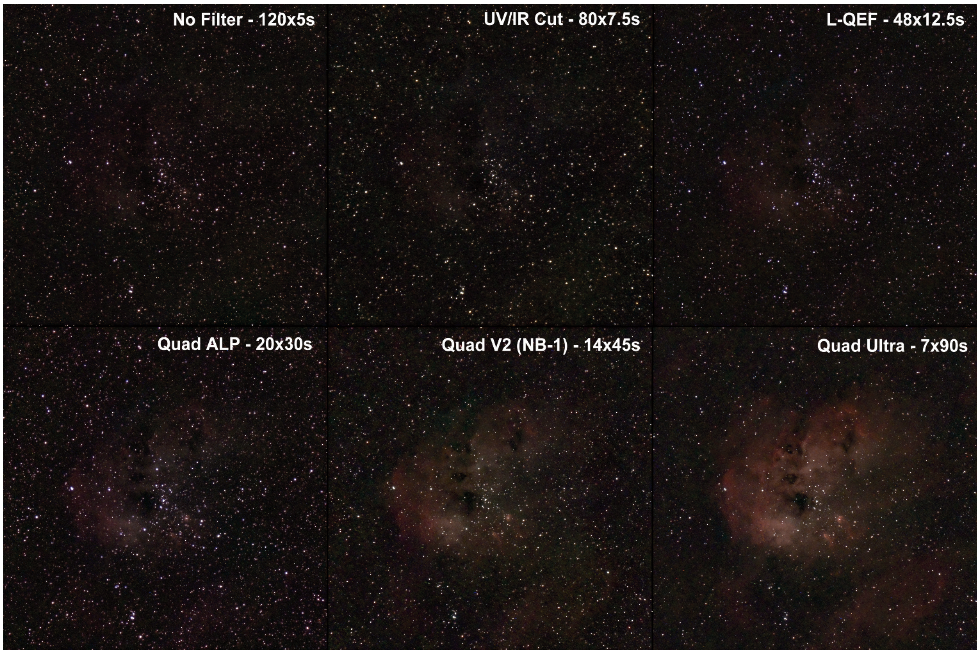

Figure 6: Imaging Results – IC410 Tadpoles Nebula

Figure 7: Imaging Results – M33 Triangulum Galaxy

Conclusions

Some readers are probably waiting for me to choose the winner in the "Battle of the Quads". They will be disappointed then to hear me say that they are all winners! By comparing spectra, predicted contrast increase, and imaging results, it is fairly clear to me that these four quad filters are

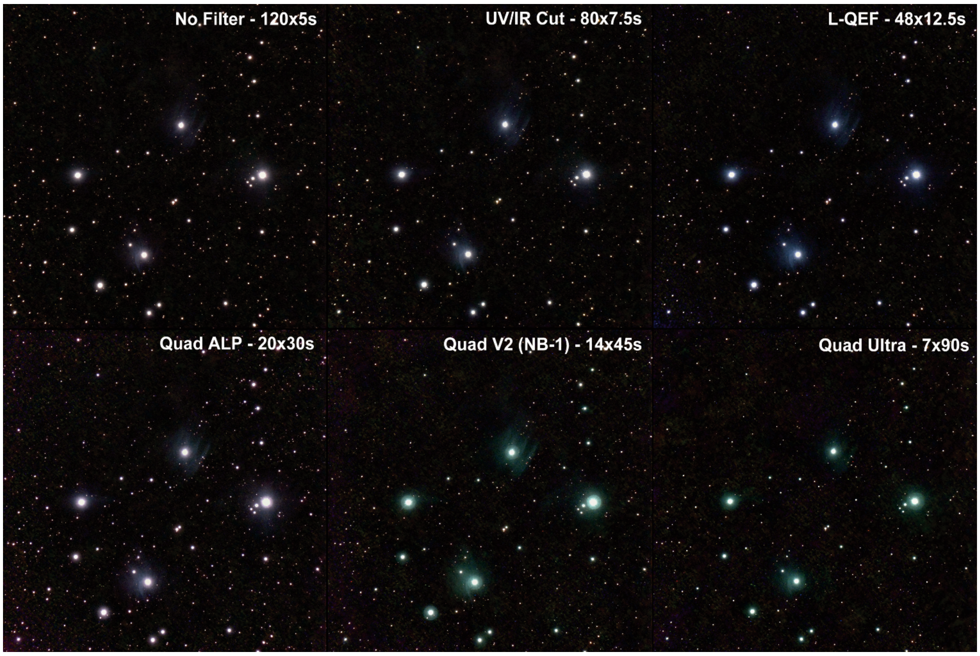

Figure 8: Imaging Results – M45 Pleiades Cluster

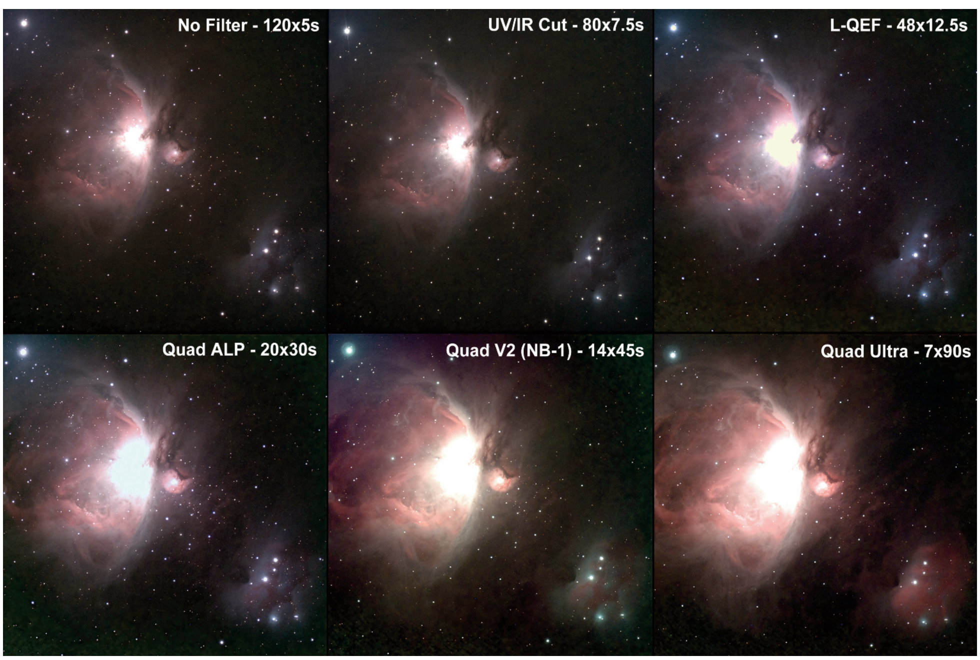

Figure 9: Imaging Results – M42 The Orion Nebula

designed for different applications. In my opinion, those applications are as follows:

Optolong L-QEF: This filter's broad pass bands mean it does not block much LP, but for the same reason it does not block much light from broad spectrum targets either. This makes it useful to astrophotographers looking to darken the background in their images when shooting any object type from a moderately dark sky (Bortle 6 or better). More noticeable than the contrast increase it provides is the colour correction, favouring the blue channel to improve the white balance in images with mild LP that can have an orangish-brown cast.

Antlia Quad ALP: This is the closest I have yet seen a filter come to being the perfect all-purpose filter for heavy LP. It does not deliver the best possible contrast increase on any single object type (except maybe reflection nebulae), but it does deliver a good amount of contrast increase on all object types. It is well suited to people doing Electronically Assisted Astronomy (EAA). The benefits of using the Quad ALP quickly diminish as the LP level goes down, so it is probably best suited for use in skies worse than Bortle 6.

Altair Quad V2: This filter is a strong performer on emission nebulae and reflection nebulae, but has a neutral to negative impact on galaxies when imaging under light polluted skies. It is best suited for imaging nebulae of all types, but over a much broader range of LP than the Quad ALP. It is effective from Bortle 9 down to Bortle 2. It's pass bands are wide enough to be used for visual observing as well.

Radian Quad Ultra: This quad has the narrowest pass bands of the filters considered in this comparison, making it ideally suited to imaging emission nebulae. The trade-off of achieving very high contrast increase and SNR on emission nebulae is that it performs poorly on all other object types. This filter is effective from Bortle 9+ down to Bortle 2.

So ends the Battle of the Quads. If you have any questions, please feel free to contact me at topjimmy@rogers.com. ATT

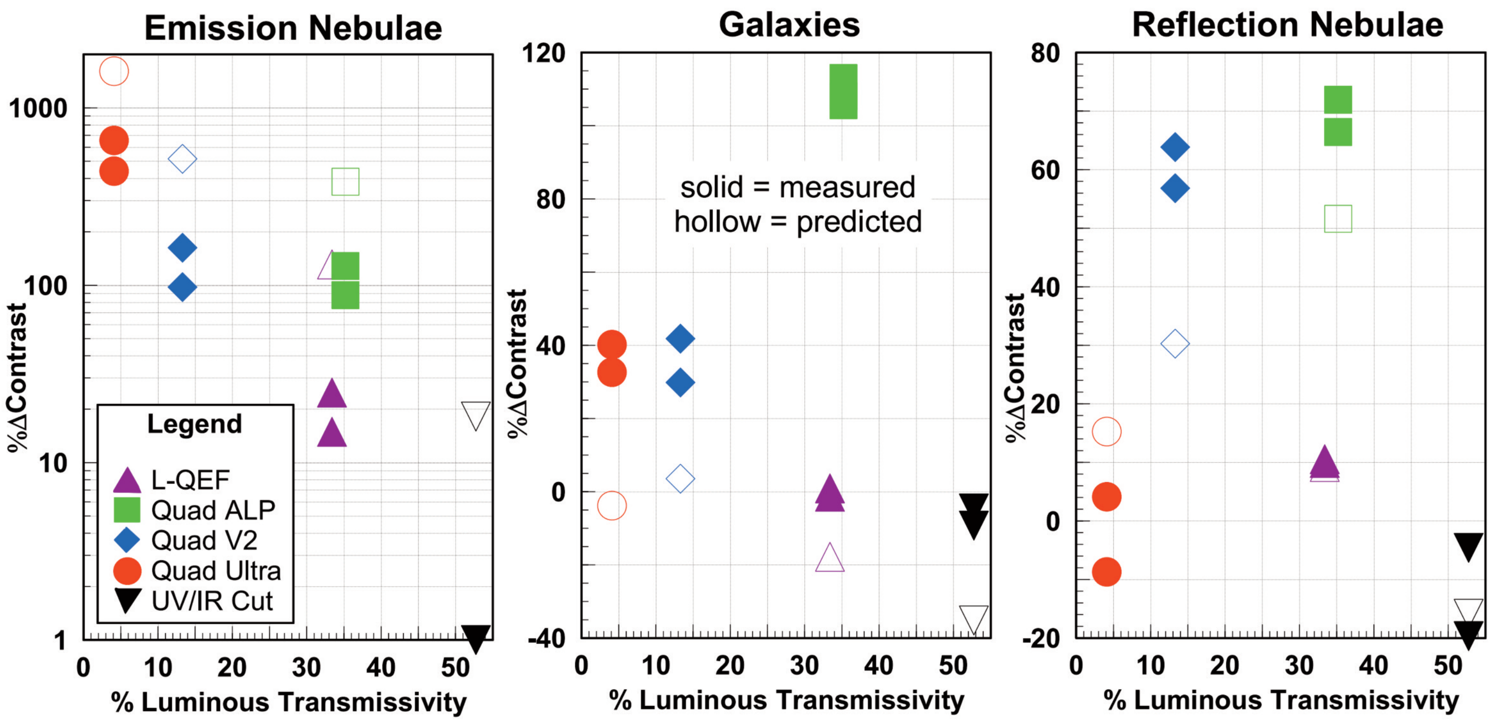

Figure 10: Measured Contrast Increase