RADIAN TRIAD & TRIAD ULTRA PERFORMANCE VS. F-RATIO

By Jim Thompson

Editor's Note: Because of the number of graphs and schematics included with this article, several are provided at the end of the article.

Introduction

Over the past couple of years there has been a growing interest in a new family of filters that I refer to as multi-narrowband. These filters offer excellent light pollution rejection, and a large increase in contrast on emission nebulae in multiple wavebands at the same time.

These filters are characterised by multiple narrow pass bands at the main wavelengths of interest emitted by nebulae: hydrogen-β (486.1nm), oxygen-III (495.9 & 500.7nm), hydrogen-α (656.3nm), nitrogen-II (658.4nm), and sulphur-II (672.4nm).

Many astrophotography (AP) and electronically assisted astronomy (EAA) users have achieved excellent results using multi-narrowband filters. However, one concern that users continue to have over these filters is how they perform when used with fast f-ratio optics.

Theory tells us that as the telescope's f-ratio decreases, an interference-type filter's pass bands will slowly shift down in wavelength. For a narrow pass band filter this is a concern because if the scope is fast enough, the filter's center wavelength (CWL) can shift completely off the desired nebula emission.

One of the early entries in this new filter category came from Oceanside Photo & Telescope (OPT). Today they sell two different models of multi-narrowband filter, the Radian Triad and Radian Triad Ultra. Response curves for these two filters, as provided by the OEM, are shown in **Figures 1 and 2**.

The marketing material on the OPTCorp website indicates that the Triad Ultra is "usable on telescopes up to f/2 speed". The objective of this test report is to determine if this statement is correct. Although the behavior of filters on fast f-ratio optics is common to all brands, I have selected the two OPTCorp filters to use as the example in this test report.

Method

To evaluate how the two Radian brand filters' performance changes with scope f-ratio, my preferred method is to measure each filter's spectral response for a range of light angles relative to the filter. This is possible for the Radian Triad since I purchased a sample filter a

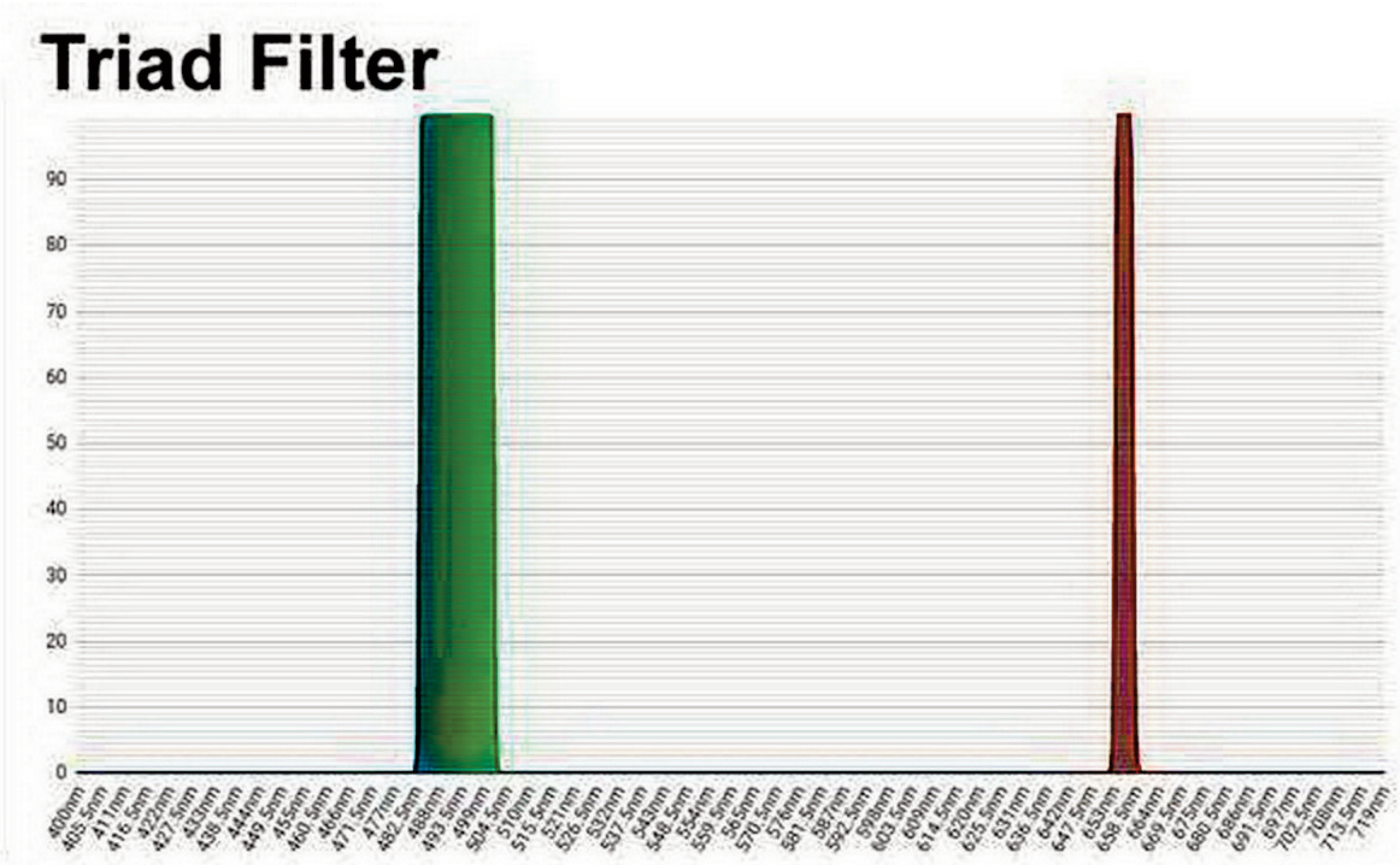

Figure 1 - OPT Radian Triad Spectral Response (courtesy OPTCorp)

year ago as part of a broader multi-narrowband filter comparison test I did.

Unfortunately I do not have a sample of a Radian Triad Ultra filter. I asked OPTCorp if I could borrow a sample, but they declined, which was not that much of a surprise considering the list price for the 2" version is $1075 USD.

With no sample filter, my only alternative was to construct a theoretical spectral response from the data available on the OPTCorp website and use the measurements from the Triad filter to estimate how the Triad Ultra's pass

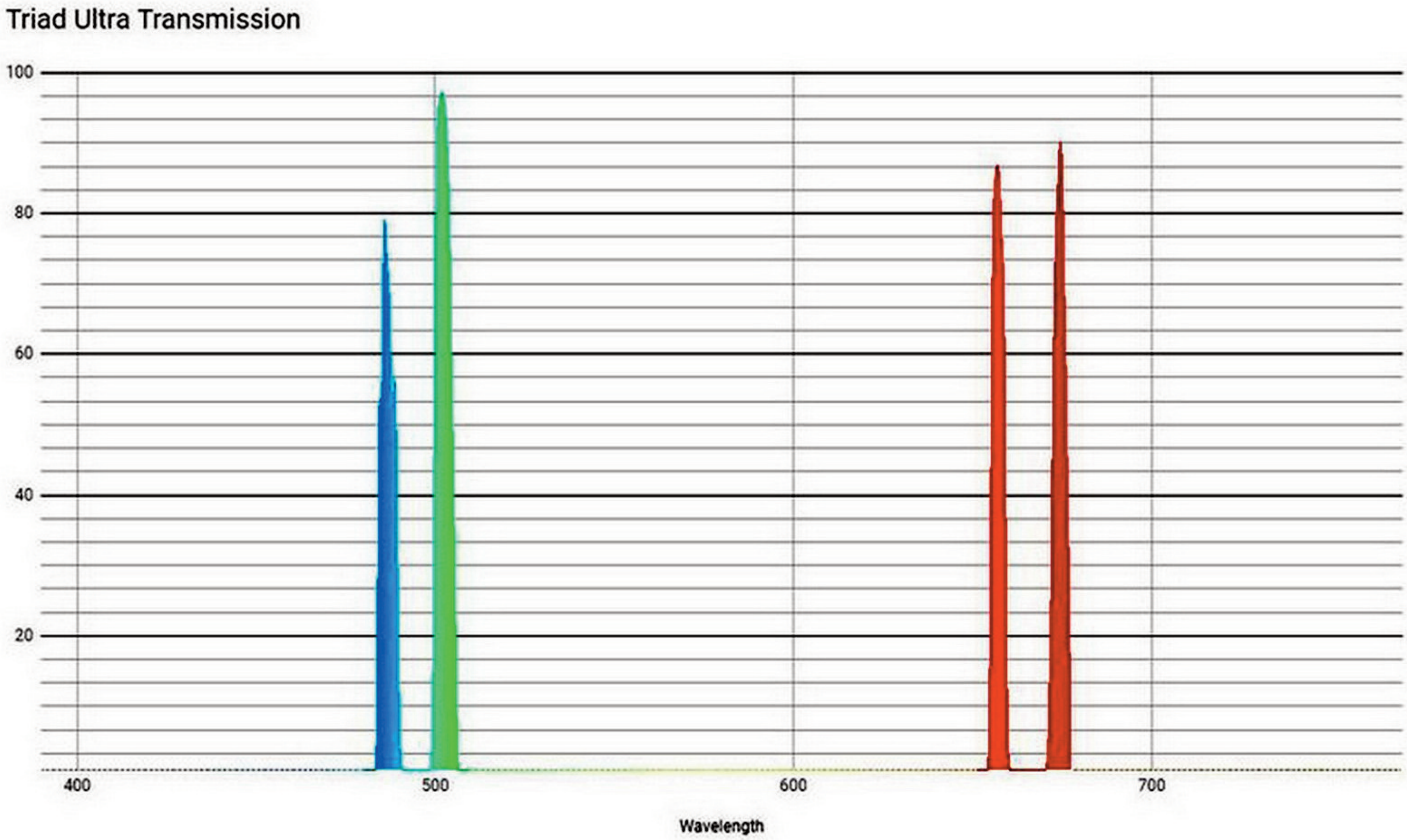

Figure 2 - OPT Radian Triad Ultra Spectral Response (courtesy OPTCorp)

bands shift with f-ratio.

The spectrometer data was collected in my basement workshop with an Ocean Optics USB4000 near-UV to near-IR spectrometer, and a broad-spectrum light source that I built. To adjust the angle of the filter I built a jig that uses a ¼"-20 screw to tip the filter up on one side (**see Figure 3**). This allowed me to finely adjust the filter angle in a repeatable way. Spectrum measurements were made in 1.7° increments (two turns of the screw), from 0° to 15.5°.

Results – Radian Triad

Figures 4 and 5 present the spectrometer measurements around the filter's O-III and H-alpha pass bands respectively. The impact of changing filter angle relative to the light path is very evident. The effect appears to be more dramatic at longer wavelengths (i.e. for H-alpha).

From the measured spectrum data I extracted the key characteristics of each pass band: CWL, full width half maximum (FWHM) band width, and peak luminous transmissivity (%LT). To more clearly see how angle affects each of these parameters, I have plotted measured data relative to the 0° filter angle case. The result is plotted in **Figures 6 to 8**.

To put these results into perspective, consider that the light angle at the edge of an f/4 light cone is 7.1°, and at the edge of an f/2 light cone is 14.0°. The curve fits I applied are quadratics for CWL Shift and Peak %LT Scale Factor, and linear for FWHM Shift. I used these curve fits for predicting the performance shift of a theoretical Triad Ultra filter, as will be discussed later in this report.

The net effect of the changes to the filter's performance with angle is a reduction in the transmission of the desired wavelengths for observing deep sky objects, more specifically emission type nebulae. **Figure 9** presents the measured shift in Radian Triad transmission at the main nebula emission wavelengths.

The filter's pass band at H-beta/O-III is relatively wide at 20nm, and so the transmission of nebula wavelengths within this pass band remain high for a wide range of angles. The wider band allows the wavelengths we want to stay in the filter's pass band longer as it shifts down. In contrast the pass band at H-alpha is only 4.5nm wide, and so it does

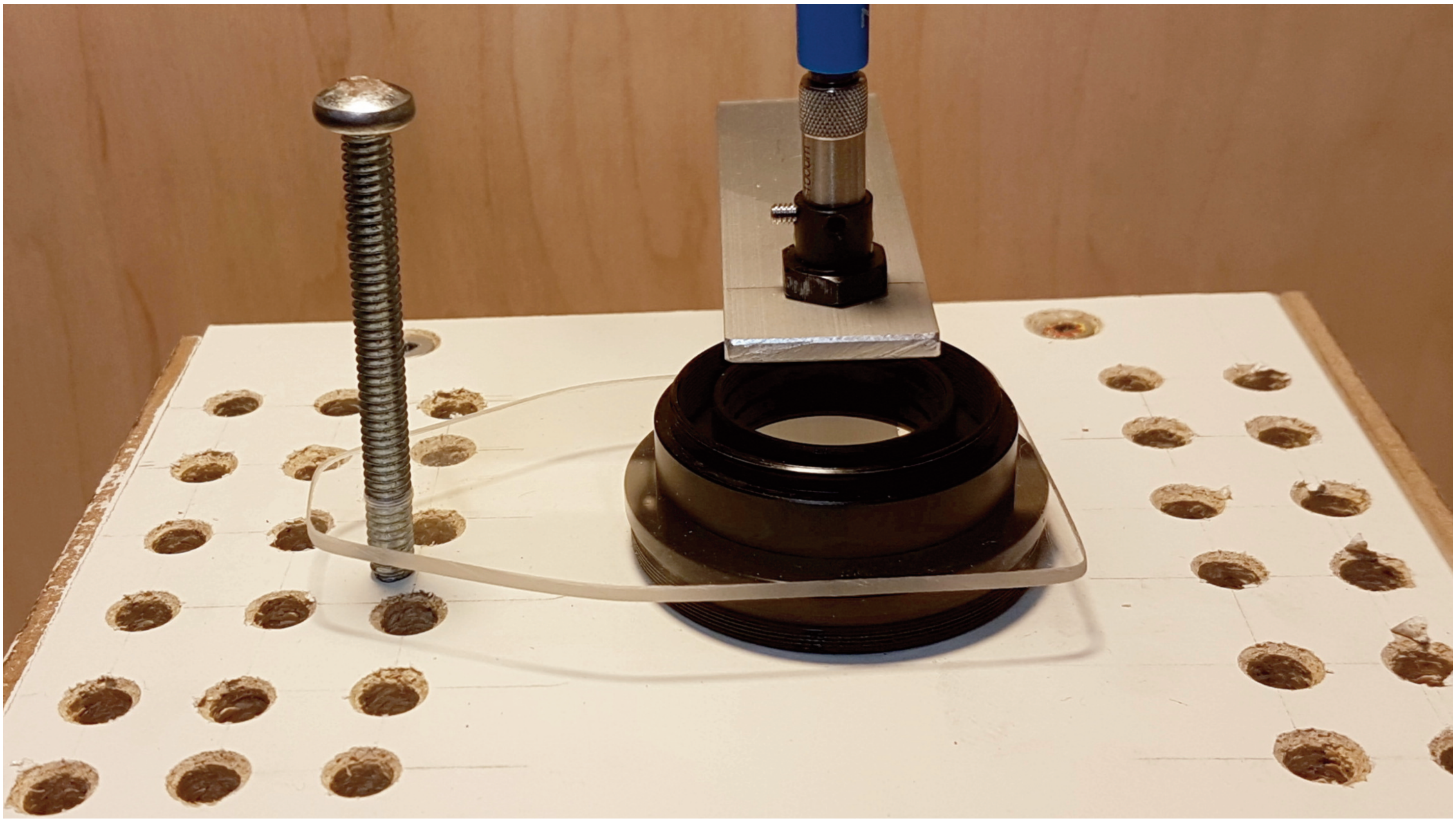

Figure 3 - Photo of Filter Angle Jig

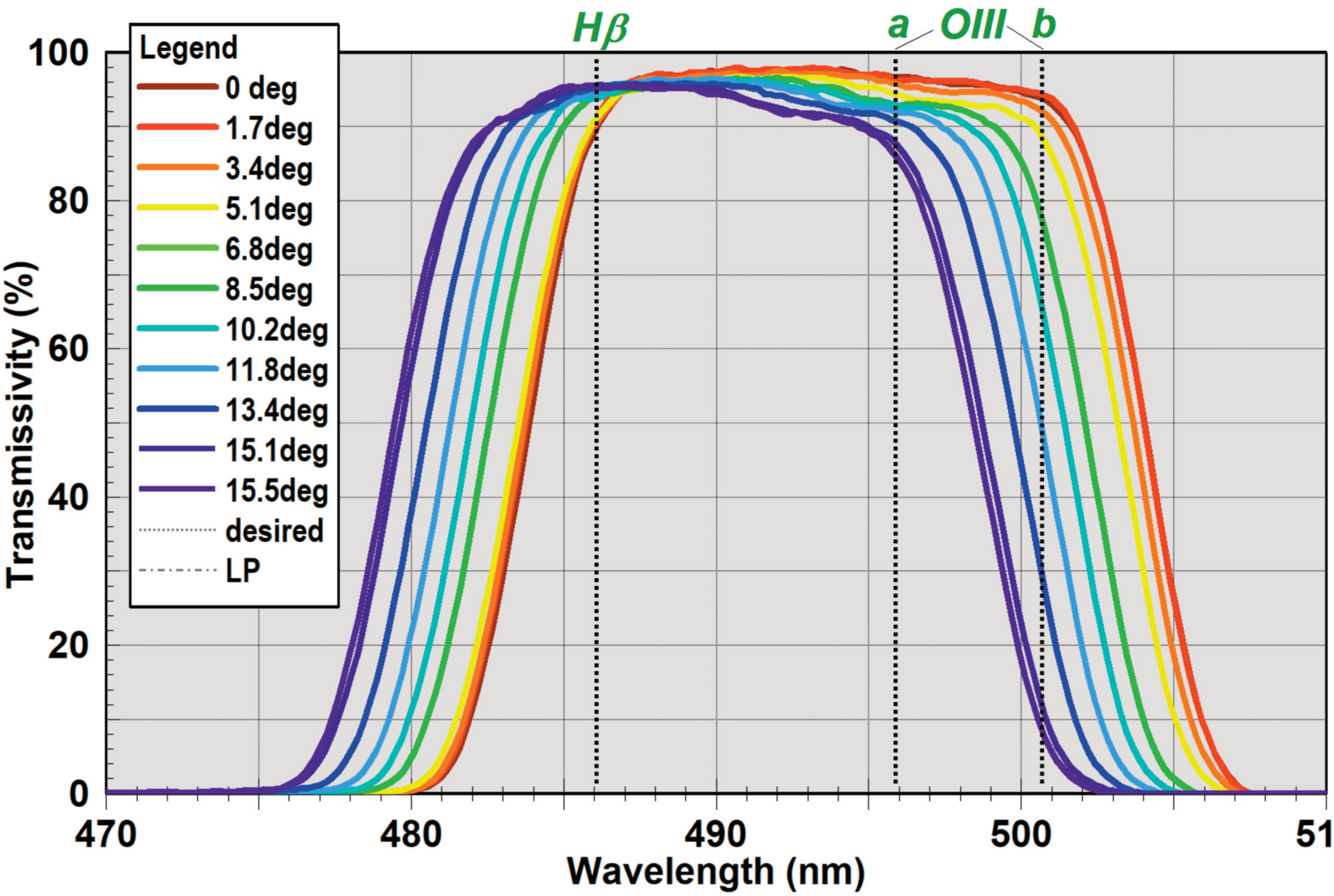

Figure - 4 Measured Radian Triad Spectral Response vs Angle – O-III Pass Band

not take much of an angle to move the filter's pass band past our desired wavelengths.

Anecdotally I have heard from a couple of users that have confirmed in practice this filter behavior when using it on an f/2 telescope. The relative exposure of H-alpha in their images is significantly less than the O-III.

Results – Radian Triad Ultra

As I mentioned earlier in this report, I do not have access to a sample Triad Ultra filter. What I have to work with is the filter performance numbers provided on the OPTCorp website. Table 1 summarizes these filter performance numbers.

From this information I have constructed a theoretical model of the Triad Ultra's spectral response. This theoretical response is plotted in **Figure 10**. Using this theoretical spectral response, and the angle impact values measured from the Triad filter (Figures 6 to 8), I have calculated a prediction of how the Triad Ultra filter performs at different angles.

To do this I have assumed that the H-alpha and S-II bands behave like the H-alpha band on the Triad filter, and that the H-beta and O-III bands behave like the O-III band on the Triad filter. The results of this calculation are presented in **Figure 11**.

Since all four of the Triad Ultra's pass bands are narrow, the transmission of each wavelength of interest is strongly affected by the filter angle. For angles of 14º or larger (i.e. f/2 or faster), the filter is predicted to have zero transmission at any of the wavelengths it was designed for. By coincidence, at a 14º angle the O-IIIb band has shifted far enough that it is now well centered on O-IIIa at 495.9nm.

Discussion

So, what do my results mean? The initial impression that most people get

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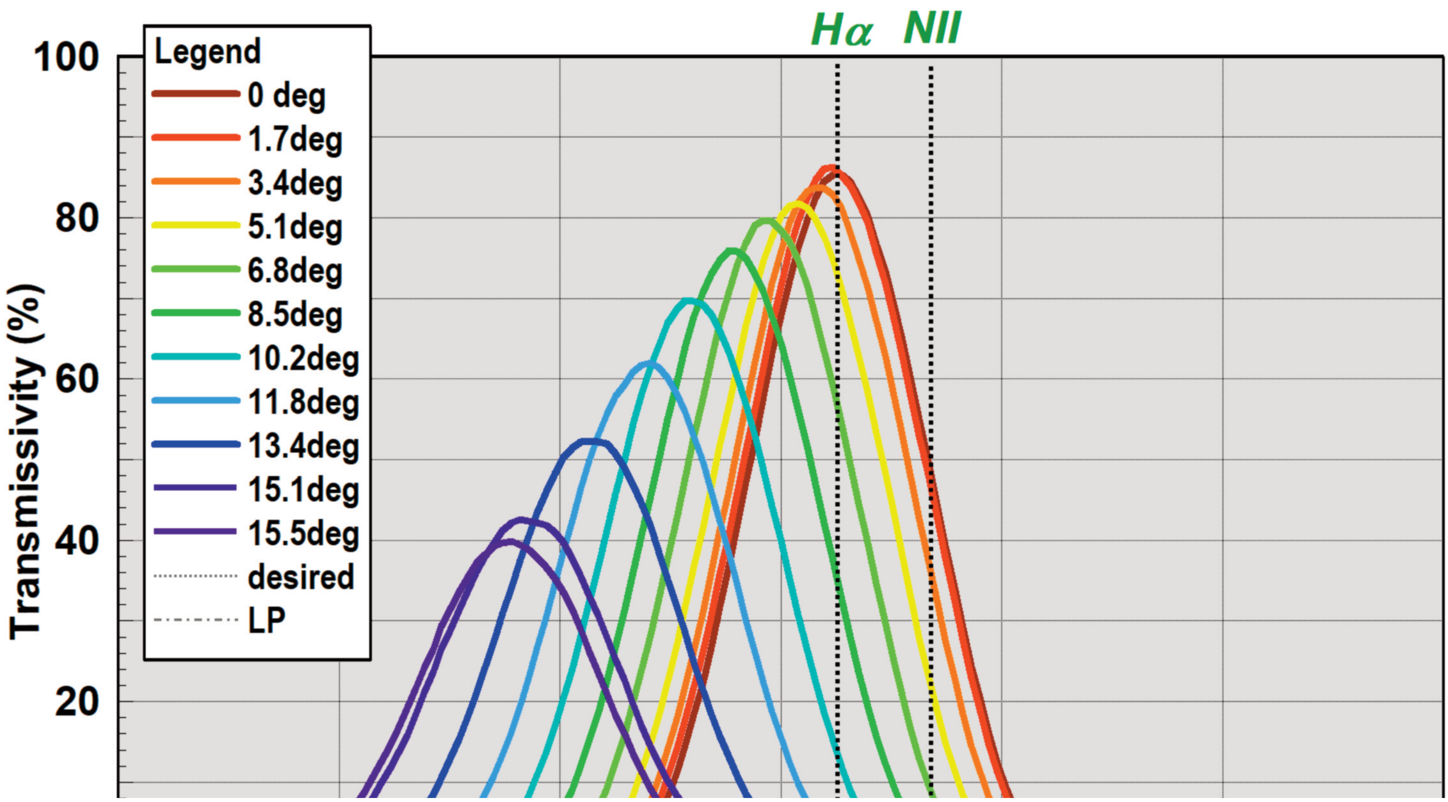

Figure 5 Measured Radian Triad Spectral Response vs Angle – Halpha Pass Band

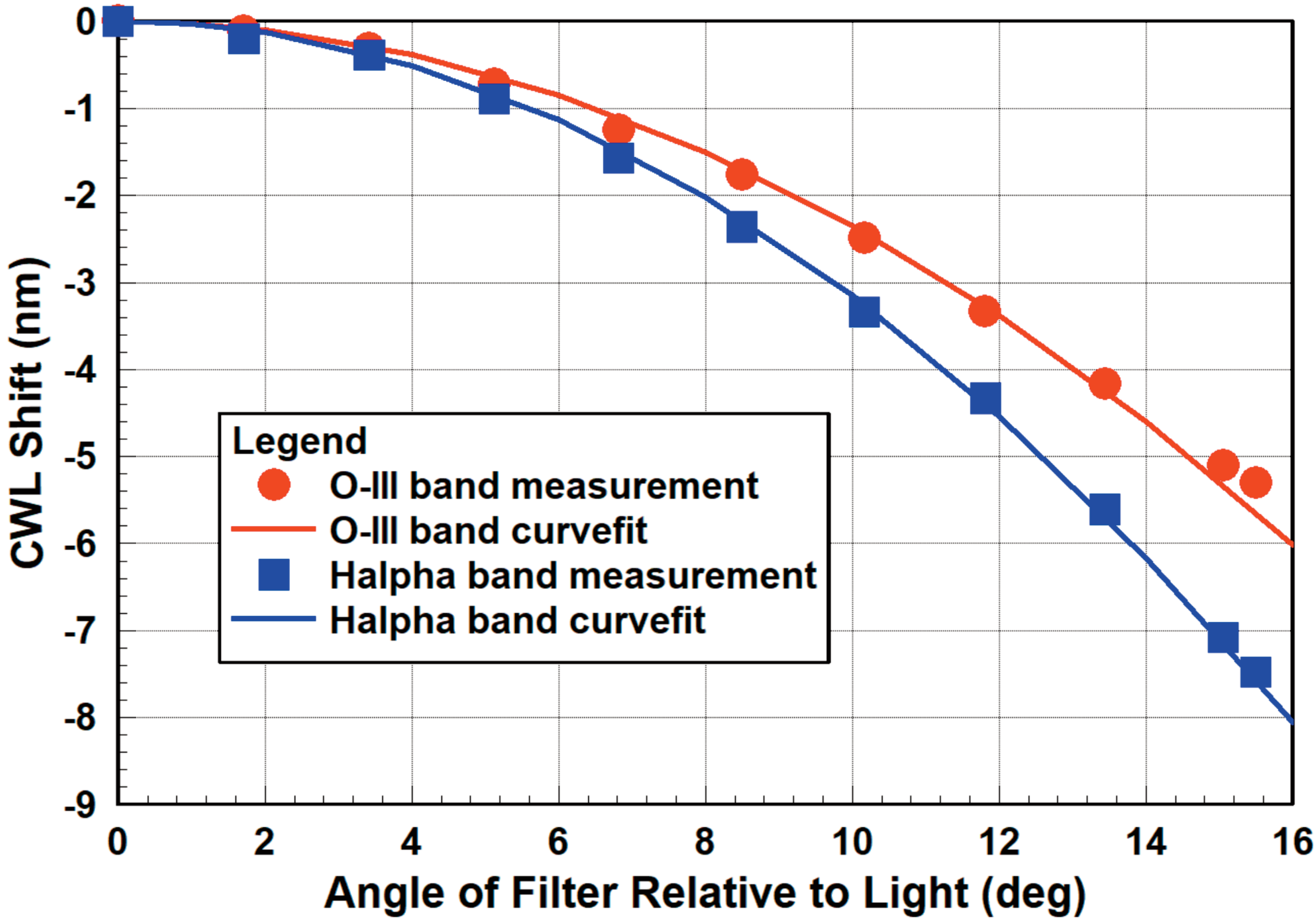

Figure 6 - Measured Radian Triad CWL Shift vs Angle

from Figures 9 and 11 is that these two filters, and perhaps multi-narrowband filters in general, can't be used with fast f-ratio optics.

The plots clearly show that the transmission of our desired nebula emission wavelengths trends to zero at f-ratios as fast as f/2. So how is it then that many AP and EAA users have had good success using multi-narrowband filters on their fast scopes?

The missing piece of the puzzle is that all of the light from the telescope does not pass through the filter at the same angle. Referring to the RASA telescope schematic in **Figure 12**, the light from the primary mirror approaches the focus point in the shape of a cone. The overall angle of the cone is defined by the f-ratio of the telescope, i.e. focal length / aperture. Light from the center of the mirror passes through the filter at an angle closer to perpendicular than the light from the edge of the mirror does. Thus, the transmission of the filter varies across the aperture of the telescope, acting like an aperture mask.

It is possible to estimate what the net affect of the filter is on the telescope's effective aperture. I have elected to show an example of this calculation using my predicted angle response for O-IIIb and H-alpha from the Triad Ultra (Figure 11). I have chosen this filter since it has the narrowest pass bands of any of the currently available multi-narrowband filters, and therefore my calculations will be a "worst case". I have calculated an effective f-ratio for a number of different telescopes, the results for which are plotted in **Figures 13 and 14**.

My calculations show that when the Triad Ultra is used with telescopes that are at f/4 or slower, the difference between the f-ratio of the telescope and the effective f-ratio with the filter

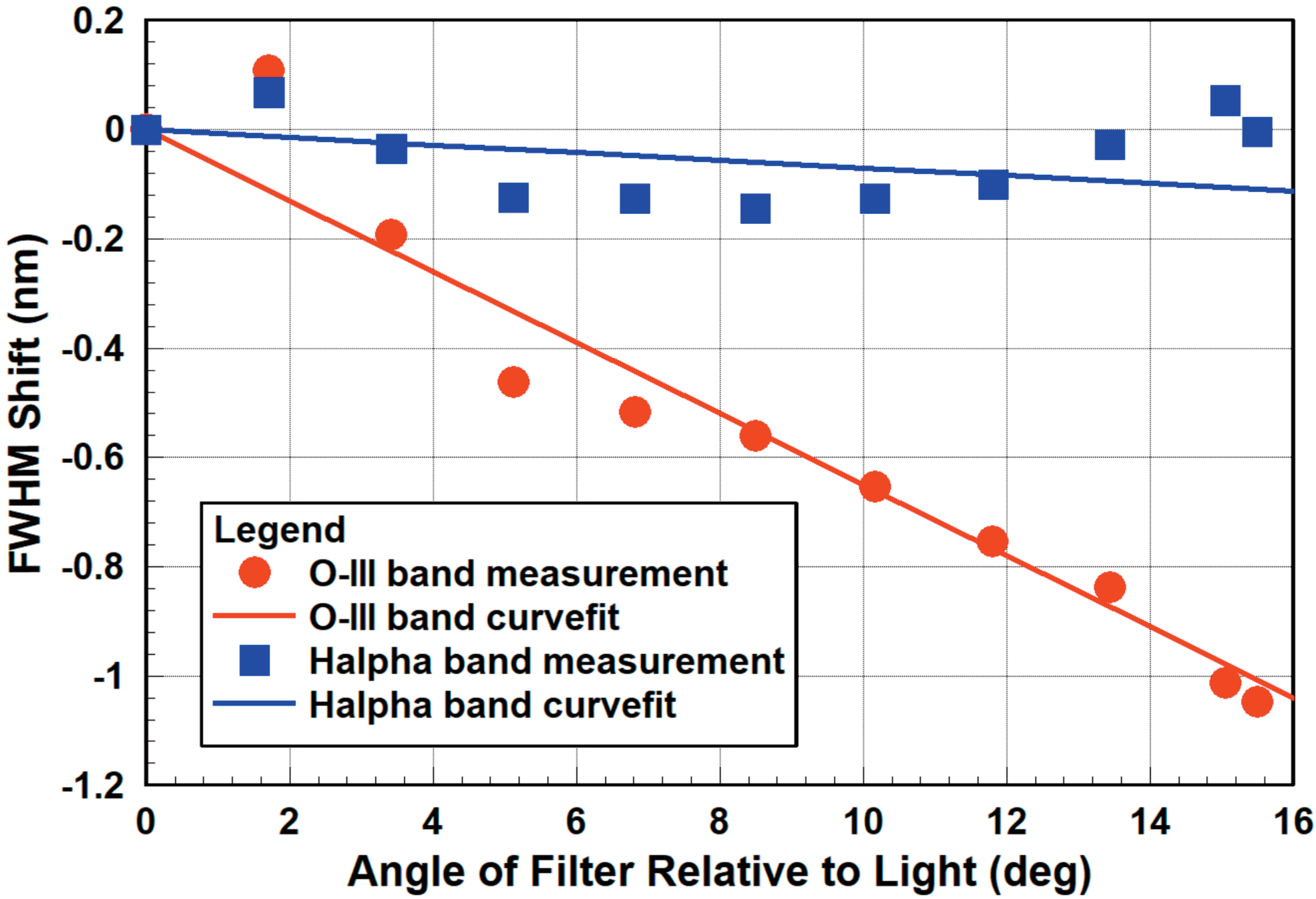

Figure 7 - Measured Radian Triad FWHM Shift vs Angle

is fairly small. This is because the majority of the primary mirror, or objective lens as the case may be, is directing light through the filter at an angle that is not far from perpendicular, and thus does not result in much band shift.

The small difference between the scope f-ratio and the effective f-ratio we do see is mostly due to the filter pass bands having peak transmission values less than 100%. As the scope f-ratio drops below f/4 however, the effective f-ratio quickly increases. This is especially so for Hyperstar and RASA telescope designs. Telescopes with central obstructions are more impacted by multi-narrowband filters because there is no percentage of the scope's aperture where the light is coming from the center of the mirror, it is all coming from an area outside of the central obstruction. This pushes the average angle of the light passing through the filter to a higher value than you would get with a refractor. The effect seems to be worst for the 8" RASA, which has a larger central obstruction relative to its aperture than all the other scopes considered.

Another thing to note from Figures 13 and 14 is that the impact of the filter on effective f-ratio is not as strong for the O-III band as it is for H-alpha. This prediction is based on the measurement of CWL Shift and Peak %LT Scale Factor from the Radian Triad filter. The pass bands at long wavelengths seem to be affected more strongly by filter angle, and so that is reflected in the effective f-ratio calculation. This behaviour of multi-narrowband filters has been observed by some users as a disparity in the relative exposure of O-III nebula features (brighter) and H-alpha features (dimmer). This can be corrected in post processing, but needs to be taken into account when setting exposure times to collect light frames.

These results raise an interesting

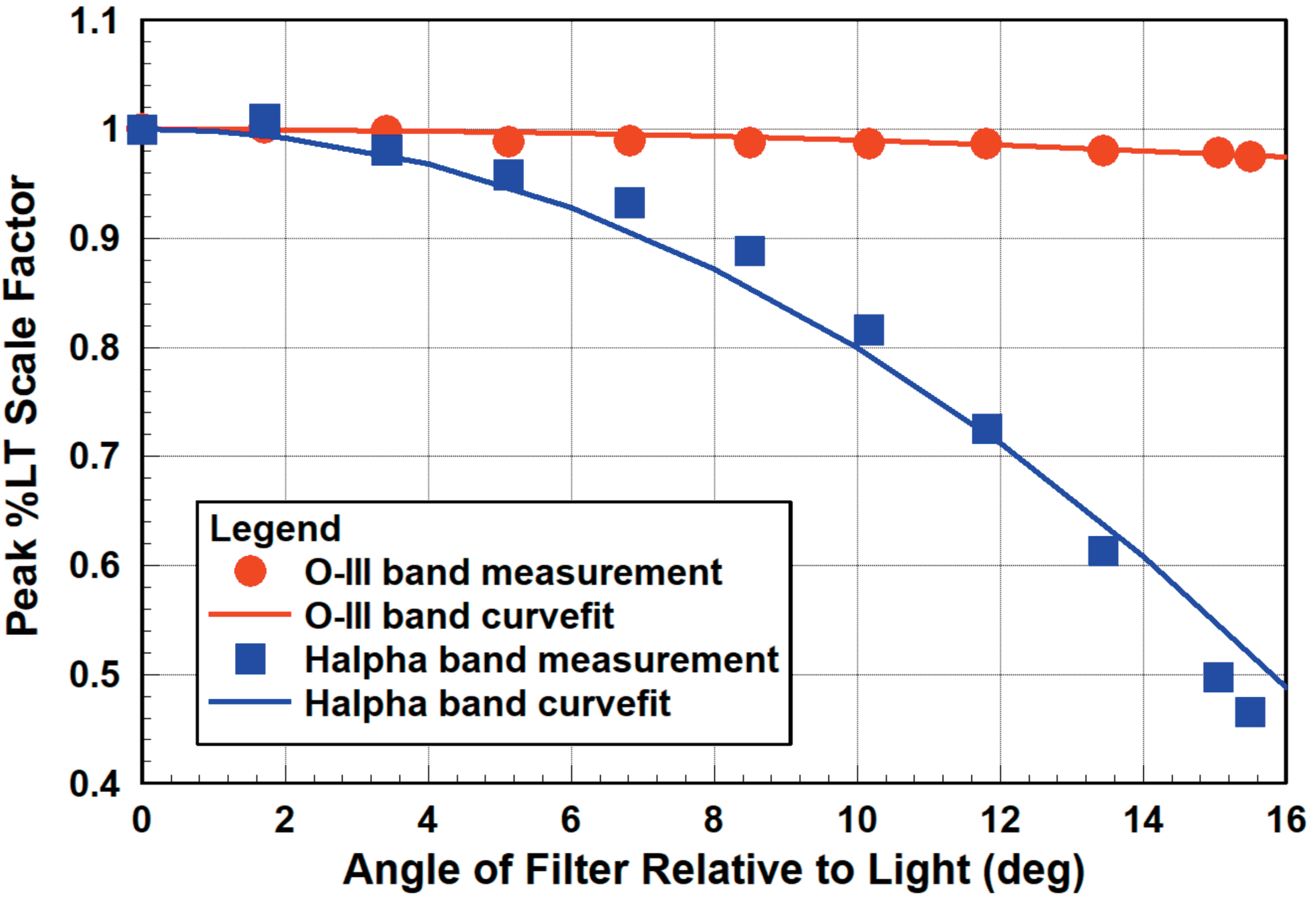

Figure 8 - Measured Radian Triad Peak %LT Scale Factor vs Angle

question as to whether an f/2 telescope is the best choice to use with the Radian Triad Ultra filter. Instead of using it with an 8” RASA for example, you could achieve the same field of view (FOV) with the same exposure time and better balance between O-III and H-alpha if you used the filter with a 67mm f/5.9 refractor. This same question exists for the other brands and models of multi-narrowband filter as well, but to a lesser extent depending on how wide their pass bands are. The wider the pass band, the smaller the impact on effective f-ratio. This behaviour extends to more traditional single band pass filters as well.

Conclusions

In this test report I have presented the results of measuring how f-ratio affects the performance of multi-narrowband filters using a widely used filter example: the Radian Triad sold by OPTCorp. The measurements show that when light passes through the filter at an angle corresponding to an f-ratio of f/2 (14° from perpendicular), the filter’s pass band CWL shifted down in wavelength by as much as 6.2nm, and its peak band transmission dropped by as much as a factor of 0.6.

When the angle sensitivity of the Radian Triad filter is applied to the theoretical spectral response of the Radian Triad Ultra filter, my calculations show that filter transmission at the key nebula emission wavelengths trends to zero at a filter angle corresponding to f/2. The net effect of the band shift observed from using multi-narrowband filters on fast f-ratio optics is a significant increase in the optics’ effective f-ratio (i.e. an effective decrease in aperture).

Therefore, it is possible to use multi-narrowband filters with fast optics such as an SCT with Hyperstar or a Celestron RASA, but because of the filter’s impact on scope effective f-ratio, it may be a better choice to use the filter with a refractor of the same focal length.

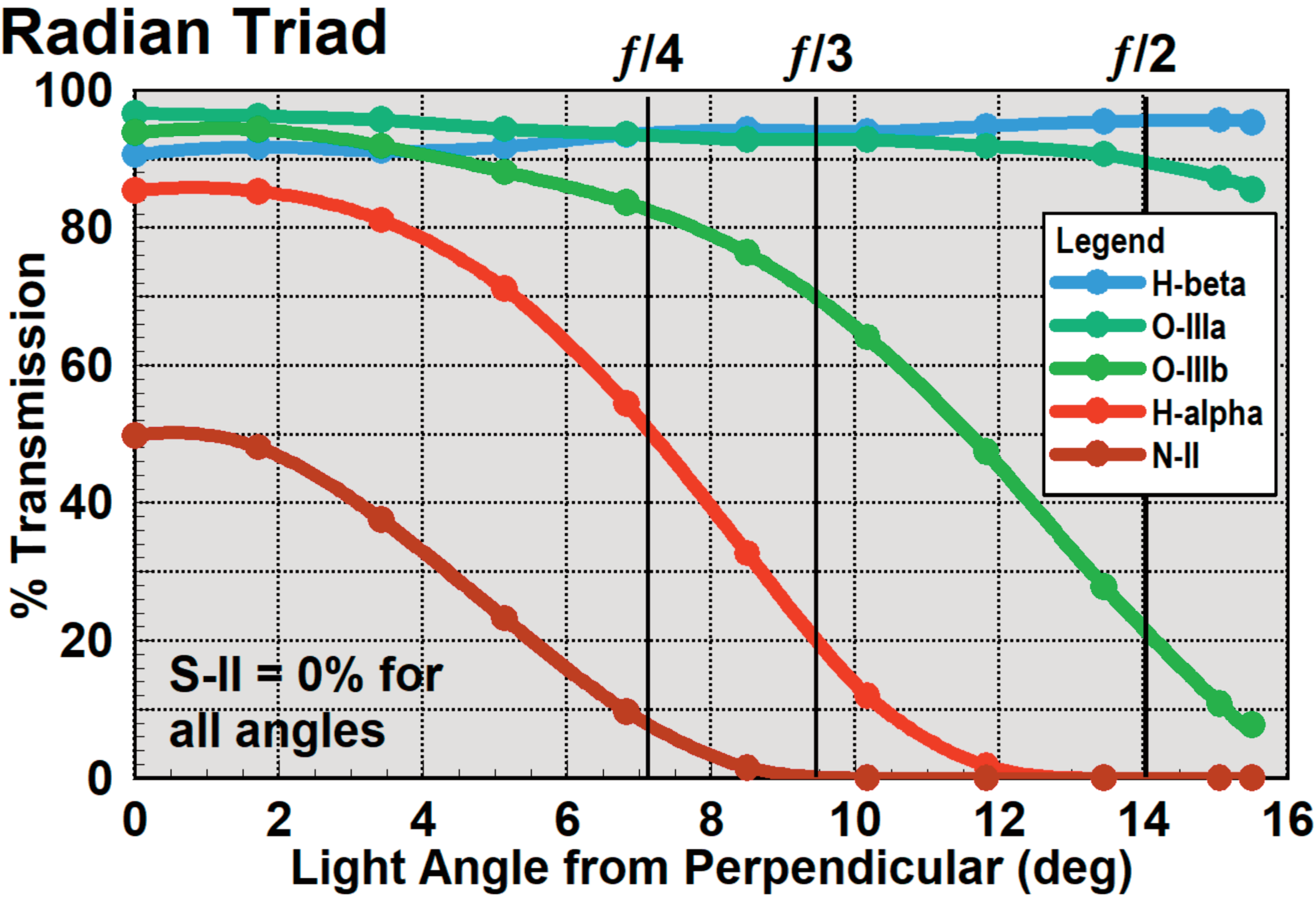

Figure 9 - Measured Radian Triad Nebula Wavelength Transmission vs Angle

Band	H-β	O-IIIb	H-α	S-II
CWL (nm)	486.1	500.7	656.3	672.4
FWHM (nm)	5	4	4	4
Peak LT (%)	79	97	87	90

Table 1 - OEM Provided Radian Triad Ultra Properties

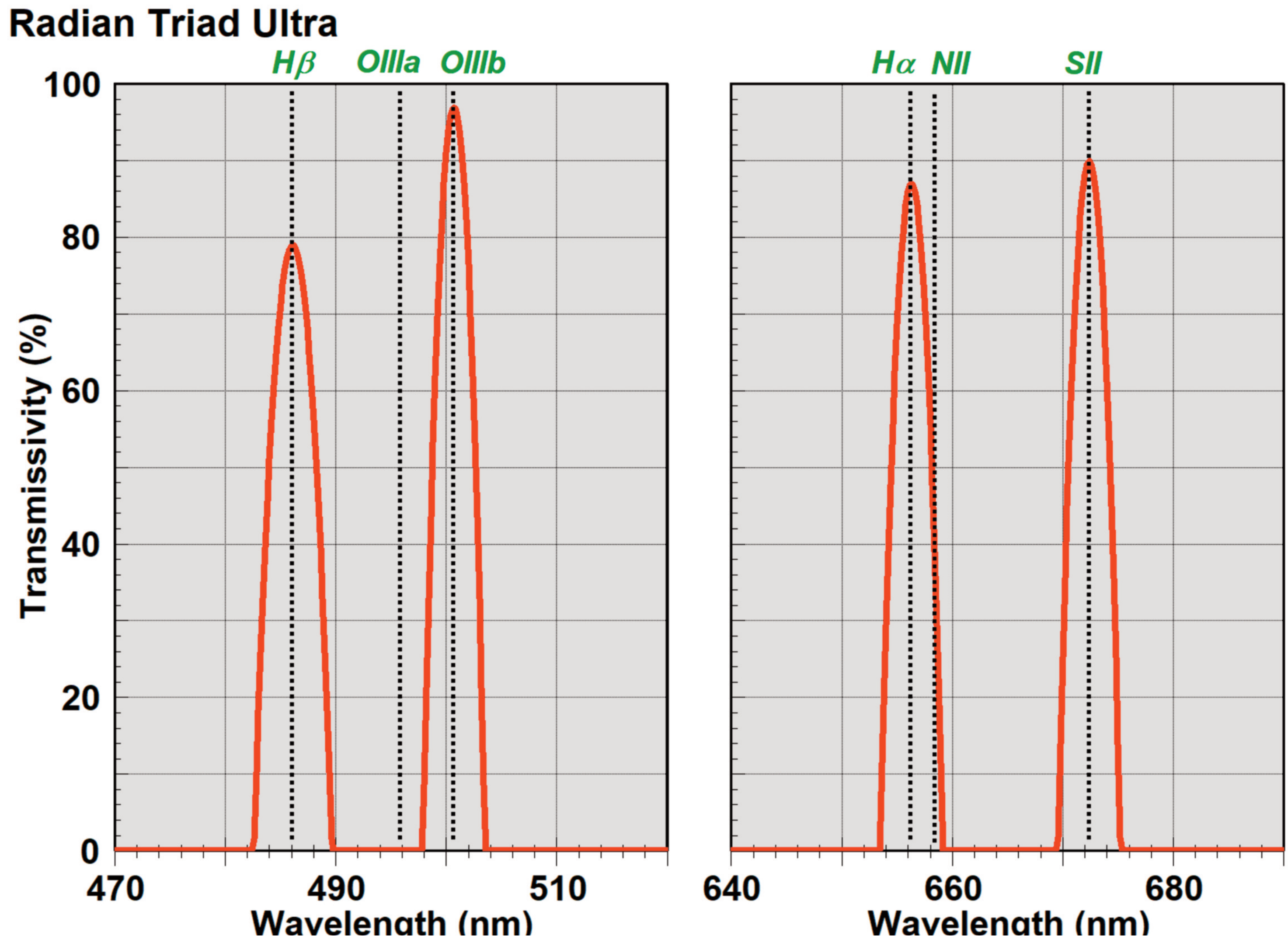

Figure 10 - Theoretical Radian Triad Ultra Spectral Transmissivity

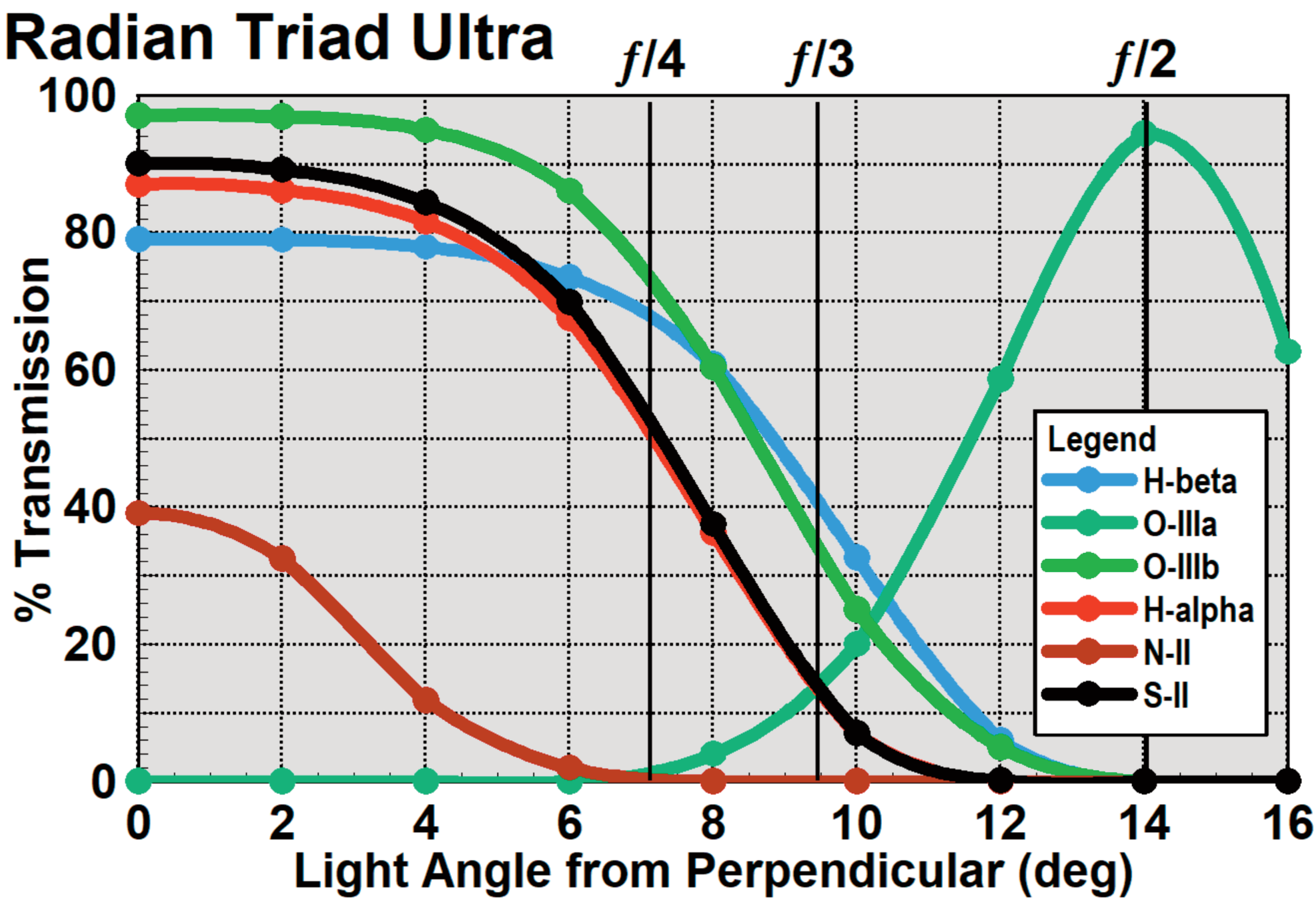

Figure 11 - Theoretical Radian Triad Ultra Nebula Wavelength Transmission vs Angle

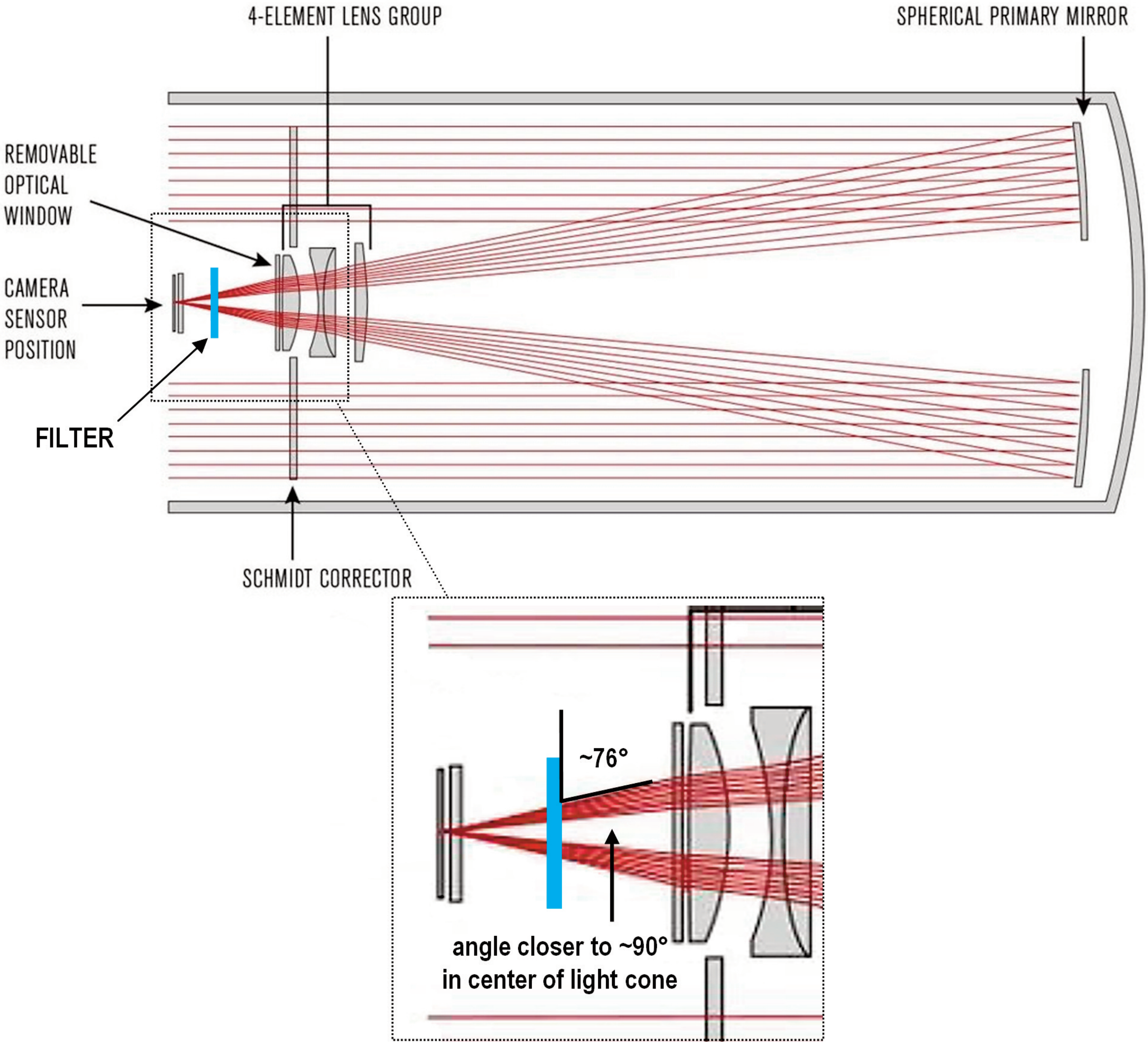

Figure 12 - Schematic of Light Path Inside Celestron RASA Telescope (courtesy Celestron)

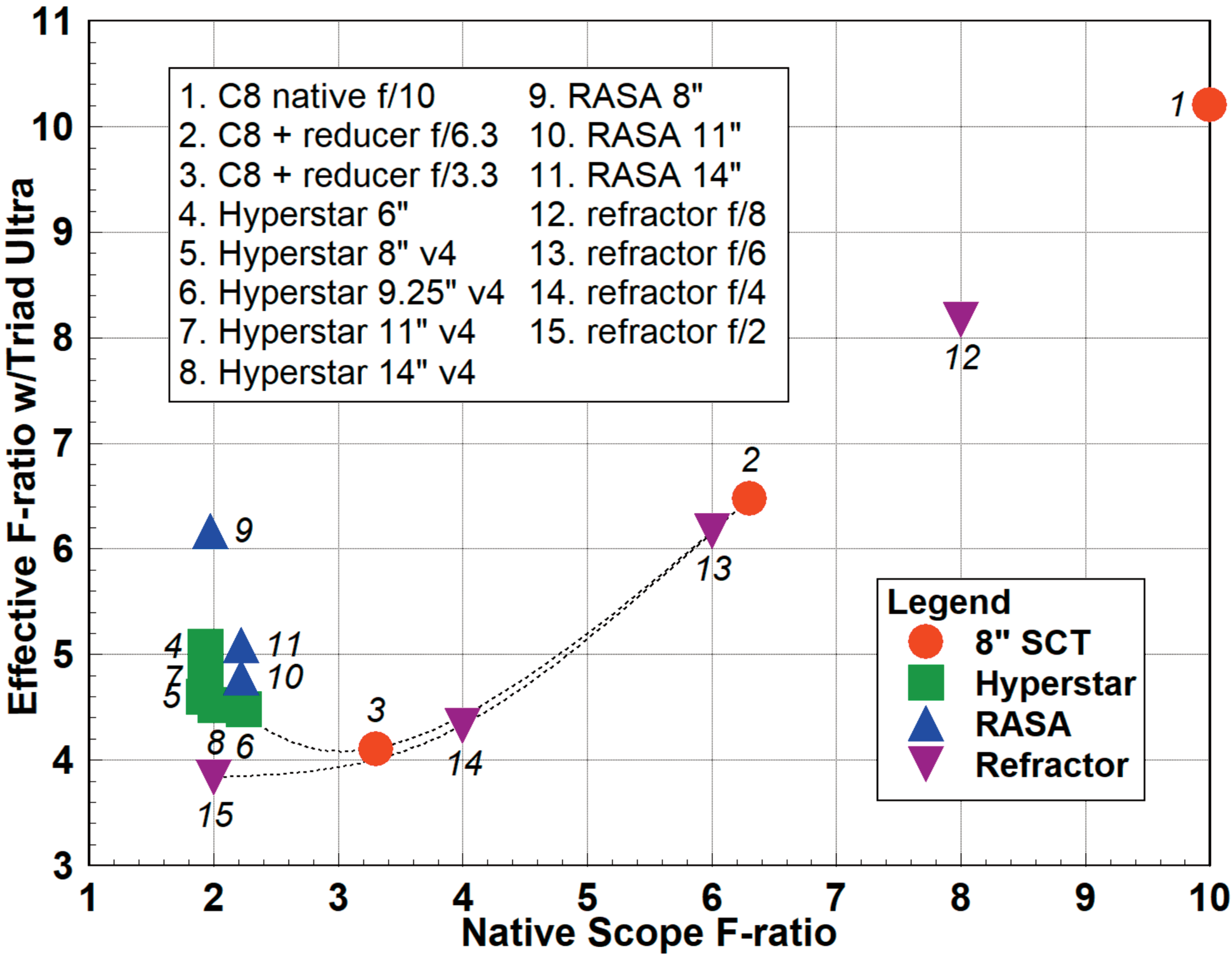

Figure 13 - Prediction of Triad Ultra Filter Impact on Scope Effective F-ratio – O-IIIb Band

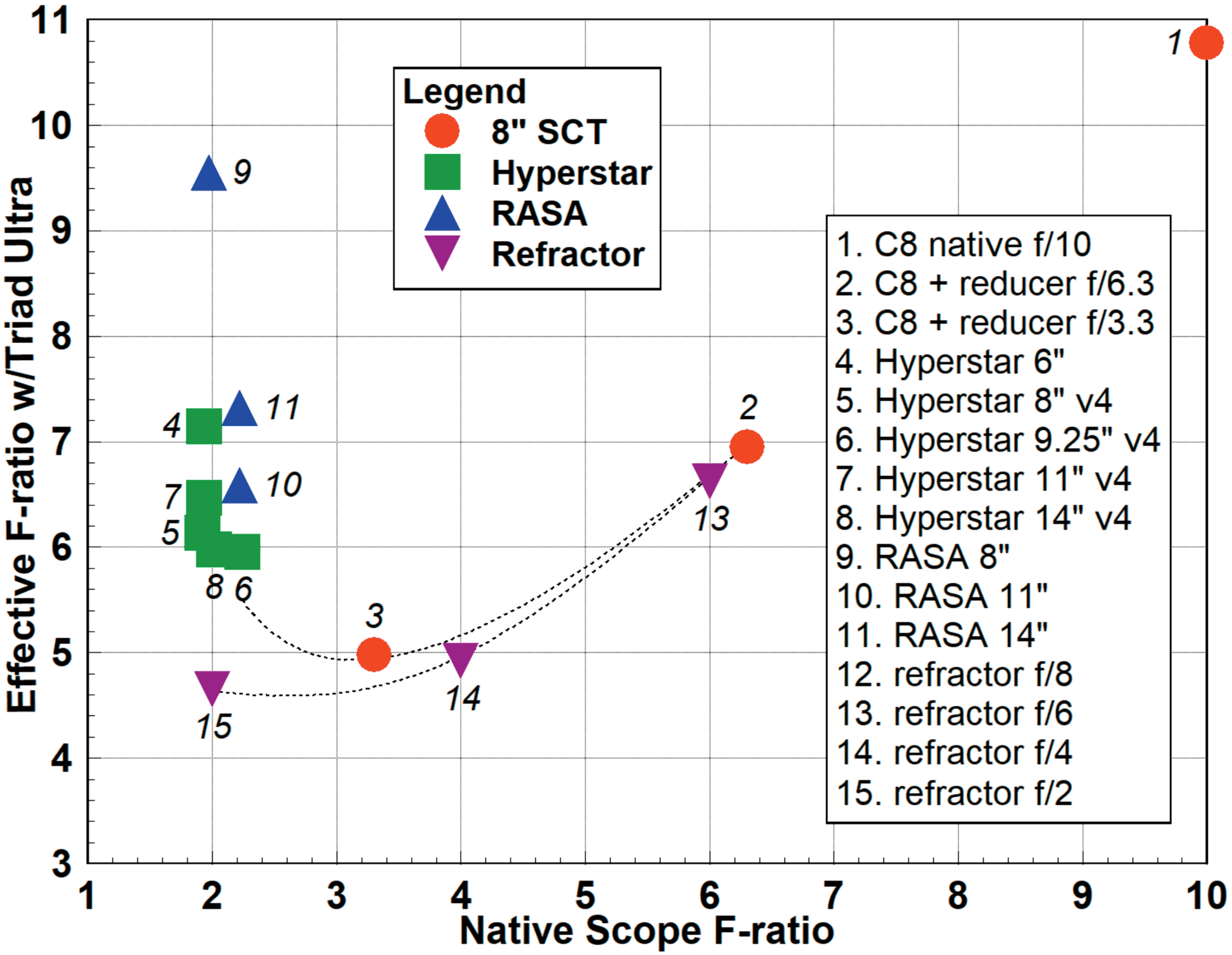

Figure 14 - Prediction of Triad Ultra Filter Impact on Scope Effective F-ratio – H-alpha Band