

When I first became involved with astronomical filters, my interest was solely for visual observing. I live in a large city where light pollution is a real problem, so I was hungry to find a way of seeing more from my backyard than simply the Moon and planets. Using LP filters did help significantly to increase the range of objects I could observe from inside the city, but still the list of possible targets was very short. To be honest my interest in observing, at least on any sort of regular basis from my home, was beginning to wane.

Then, in November 2010, I was introduced to a new way of observing that blows away the limitations of traditional visual observing...video astronomy. It was on the fairly new but quickly growing live video streaming site NightSkiesNetwork.com that I was introduced to observing using a specially designed video camera instead of an eyepiece. I was amazed at the views that were possible, and the remoteness of the objects that could be viewed, all from a light polluted backyard. Three main things make video astronomy so appealing: full colour images in near real-time, a sensor that has a wider spectral response and much higher absolute sensitivity than the human eye, and high performance video processing circuitry to manipulate and optimize the image live. I purchased my MallinCam (MC) Xtreme in January 2011, and have loved it ever since.

video camera is able to view dim objects that would normally not be possible from inside a city. By effectively applying the right LP filter however, the views that can be achieved are simply stunning.

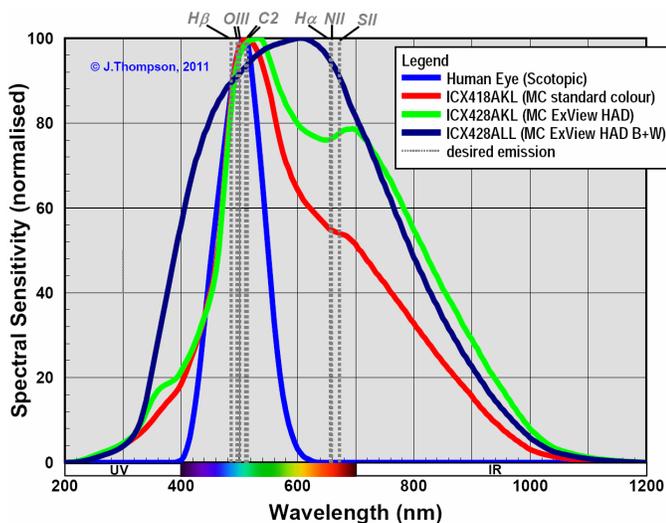


Figure 1. Spectral Sensitivity Comparison: CCDs used for video astronomy & imaging in general are much more sensitive than our eye, especially at the red end of the spectrum.

Video astronomy is a combination of live observing and imaging, and as a result it is able to take advantage of the best aspects of both fields, including the use of filters. No longer limited to viewing objects in the narrow cyan-green band that our eyes can see at night, video astronomy opens the door to using filters normally used for CCD imaging. The most notable changes over eyepiece observing is being able to see hydrogen alpha emissions from nebulae, and being able to see near-infrared emissions from galaxies. Unfortunately, astro-video cameras are also more sensitive to the main wavelengths for light pollution as well. Without using filters, an astro-

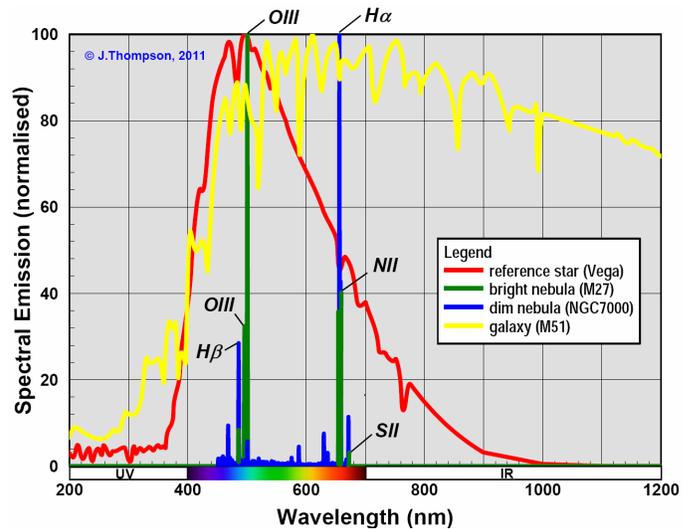


Figure 2. Typical DSO Spectrums: Using video astronomy the observer is able to see things never before possible with just the naked eye.

Being now able to use filters meant originally for imaging adds to the problem of choosing the right filter. I had to add four new filter categories in order to capture these new additions: H-alpha Group A & B, IR Cut, and IR Pass. The first three new categories are all interference type filters like the other LP filters, but the IR Pass is an absorption type; essentially a colour filter. I have not included extremely narrowband filters in my list such as NII and SII filters since the length of the integration time required to use them makes them not practical for live observing. To compare the performance of filters when used on an astro-video camera I have used the same methodology as I used for visual observing (see my preceding article). I used the same telescope setup, same background light pollution cases, and same three DSOs. The detector selected for the analysis was the Sony ICX418AKL, the same CCD used in the standard MallinCam Xtreme. The only difference in my analysis was the unit of measure used to evaluate each filter's performance. SNR was not a good measure of performance since the video processing circuitry in the camera is able to adjust the contrast and brightness (and thus SNR) on-the-fly. Instead I chose to use the max predicted difference in RGB level between the DSO and the background. Assuming a 24-bit digital colour system, the maximum contrast in a video image is achieved when the DSO is at the saturation limit (RGB=255) and the background is black (RGB=0). Using the same 2% rule from my previous article, the minimum Δ RGB level for detection of the DSO is 5. The predicted Δ RGB level is calculated using the following equation:

$$\Delta\text{RGB} = 255 * (1 - (\text{Luminance}_{\text{sky}} / \text{Luminance}_{\text{sky}+\text{DSO}})) * C$$

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The constant 'C' was used to calibrate my predicted ΔRGB against what I have measured in the past using my Mallincam.

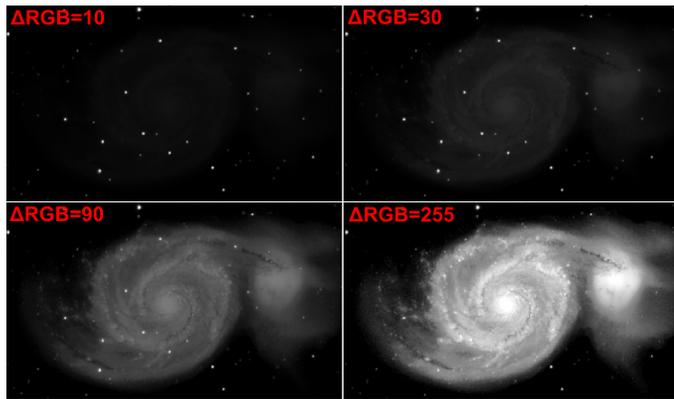


Figure 3. Comparison of Different ARGB Levels: In this simulated image, the relative appearance of different ARGB levels is illustrated.

As with the visual analysis, I began with one representative from each of my filter categories:

- Multi Band: IDAS LPS-P2
- Extra Wide Band: DGM GCE
- Wide Band: Lumicon Deepsky
- Medium Band: Astronomik UHC
- Narrow Band: Meade Narrowband
- O-III: Astronomik O-III
- H-beta: Astronomik H-beta
- H-alpha: Astronomik H-alpha 6nm
- Special: Canadian Telescope Moon&Sky Glow
- IR Pass: generic 680nm high-pass

I did not include IR Cut filters as a separate category, but instead evaluated all the other filters with and without an idealized IR Cut; a filter with 100% transmission between 400 and 700nm, and 0% transmission everywhere else. I plotted the predicted ΔRGB values for a MAG +3.5 (LP), +2.3 (Moon), and +2 (LP + Moon) sky, with and without filters.

On bright nebulae, light pollution filters were found to be very effective at increasing ΔRGB in the image when there was no Moon out. When the Moon is out, the effectiveness of the filters was greatly reduced. This is consistent with what I have observed using my MC. Medium and Narrow band filters perform reasonably well, with the OIII filter being slightly better again. The Halpha filter provided the best level of ΔRGB , being almost equivalent to the no-filter case under dark skies. In all cases, adding the IR Cut filter to the LP filter improved the ΔRGB slightly, with the biggest

improvement showing up on Medium Band, Narrow Band, OIII, and Hbeta filters.

When applied to dim nebulae, LP filters help somewhat, but not enough to bring the ΔRGB level significantly above the detection limit for my telescope setup. The exception is the Halpha filter, which increased the ΔRGB to a level several times more than what would be achievable with no filter under dark skies. Amazing! Even with the Moon up, the Halpha filter increased the ΔRGB level above the detection limit. Applying an IR Cut filter did improve filter performance slightly, as was observed for bright nebulae.

When LP filters were used on the galaxy, there was a small improvement in ΔRGB . The Medium Band, Narrow Band, and Hbeta filters provided the best improvement out of the LP filters tried. More interesting was the large improvement in ΔRGB realized by using the IR Pass filter. This filter was able to produce ΔRGB levels twice that predicted for the LP filters. For all filters, adding an IR Cut resulted in a significant drop in ΔRGB , the opposite of what was found when viewing nebulae.

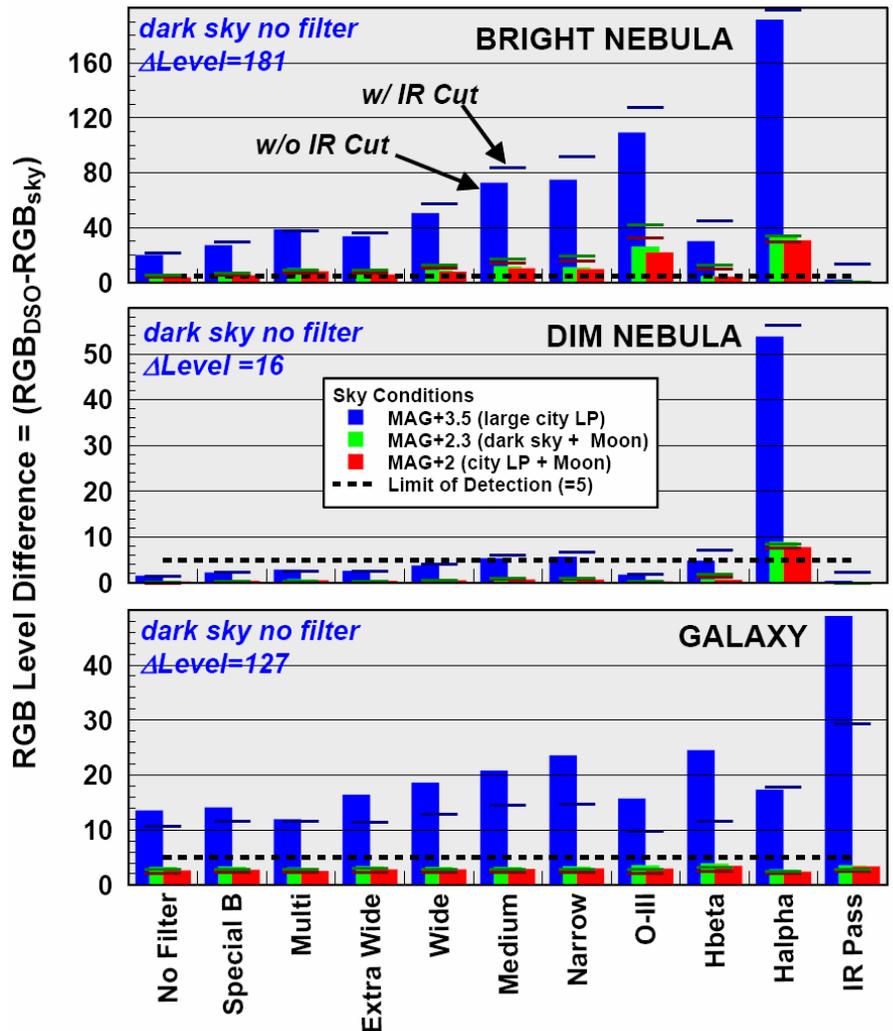


Figure 4. Filter Video Performance By Category: A representative filter from each category has been plotted above for a range of LP levels and DSOs.

I have had an opportunity to test many of the filters in this short list using my MC. I have observed much the same filter performance as predicted by my analysis. The only exception is that my analysis predicts that even with LP filters, galaxies are not detectable with my telescope setup when the Moon is up. In practice I have found that galaxies are detectable when the Moon is out, albeit at a much decreased ΔRGB , and their view is improved with the use of an LP filter. This observation varies depending on the surface brightness of the particular galaxy, ie. low surface brightness galaxies are indeed not visible with my setup when the Moon is out. The consistency between my predictions and actual observations gave me confidence to proceed with analyzing the rest of the filters in my library.

a good improvement in image contrast at a much decreased integration time over Halpha and O-III filters.

Dim nebulae benefit from LP filters much like bright nebulae do. The performance of O-III filters is reduced to the point of being useless on this type of target, but Hbeta filters step up to fill the roll. Again Halpha filters are the best performers for contrast over Hbeta and Narrow Band filters, at the cost of longer integration times. When the Moon is up, it would appear that Halpha filters are the best bet on dim nebulae.

The performance of LP filters on galaxies was the most scattered plot of them all. The response of LP filters in the NIR band seems to play a large part in how well each filter performs. Of the conventional multiband LP filters, Medium

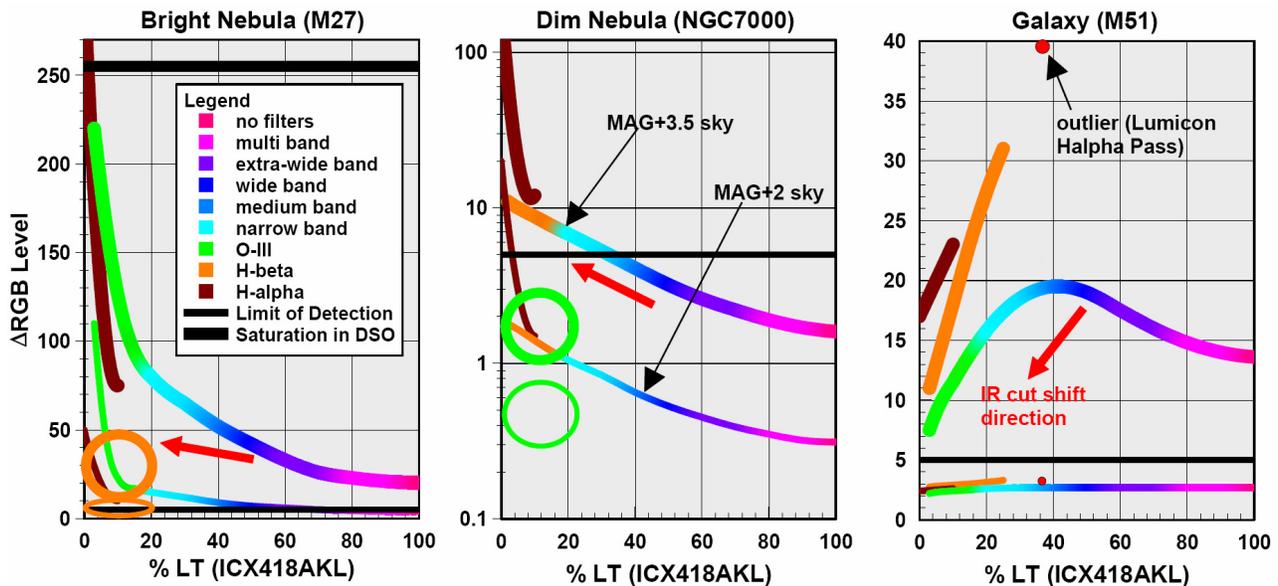


Figure 5. All Deep-Sky Filters Compared: These plots are a simplified view of predicted performance for all interference type filters for which I have data.

As in the preceding article, I plotted the predicted ΔRGB for each filter versus its Luminous Transmissivity (%LT). Doing so revealed some very definite trends in filter performance. Figure 5 shows a simplified version of the results, identifying the general trend in performance for the different filter categories. In reality there was a large amount of scatter in the results. The scatter is due to the fact that most LP filters, being designed for visual use, do not all pass Halpha and Near Infrared to the same extent. Some filters are clearly superior due to them including good Halpha and NIR responses in their design. The plots in Figure 5 also show the shift in filter performance when an IR cut filter is added; up and left on nebulae, down and left on galaxies.

On bright nebulae, Halpha and O-III filters appear to provide by far the best contrast. With no Moon, narrowband Halpha filters edge out O-III slightly, to the point of getting saturation in the nebula image when the integration is maximized. When the Moon is out, O-III filters seem to edge out Halpha. Narrow and Medium Band LP filters also provide

Band filters seem to perform the best. I was surprised at how well Hbeta filters were predicted to perform. This result prompted me to include an Hbeta filter in a recent test with my MC, the result being my prediction seems to be true.

Before you run out and get an Hbeta filter, I should point out another more interesting discovery; high pass filters, specifically reds and infrareds. In Figure 5 an outlier has been marked, the Lumicon Halpha Pass filter. This filter is essentially a dark red high pass filter. The performance of this filter on galaxies encouraged me to include colour filters in my analysis, including infrared high pass filters. The simplified plot of colour filter performance is shown in Figure 6. I have left out lines for filter groups that did not improve the ΔRGB by a significant amount. On bright nebulae there was some improvement realized from the blue and green filters, but not enough to make them competitive with traditional LP filters. On dim nebulae there is an improvement predicted using red and the shorter wavelength infrared pass filters, especially when combined with an IR cut filter. This is not surprising since this filter combo essentially makes a broad band Halpha filter. The really interesting result was the performance of red and infrared filters on galaxies. Infrared pass filters are clearly superior to LP filters, with peak contrast occurring for an IR

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pass filter with a cut-off wavelength around 800nm. If you don't mind black-and-white images (you'll have to put your Saturation = 0), IR Pass filters may be the way to go on galaxies. Note that if you want to see H α regions in some of the closer galaxies, you'll have to select the appropriate high pass filter (ie. filter that does not cut off 656nm).

pronounced since this more complex design does a better job of focusing all the wavelengths of light. On a Schmidt-Cassegrain design, the improvement is just barely noticeable since the only refraction that occurs is in the corrector plate. I do not know from experience, but I assume that the benefit realized from using an IR Cut filter on a Newtonian telescope

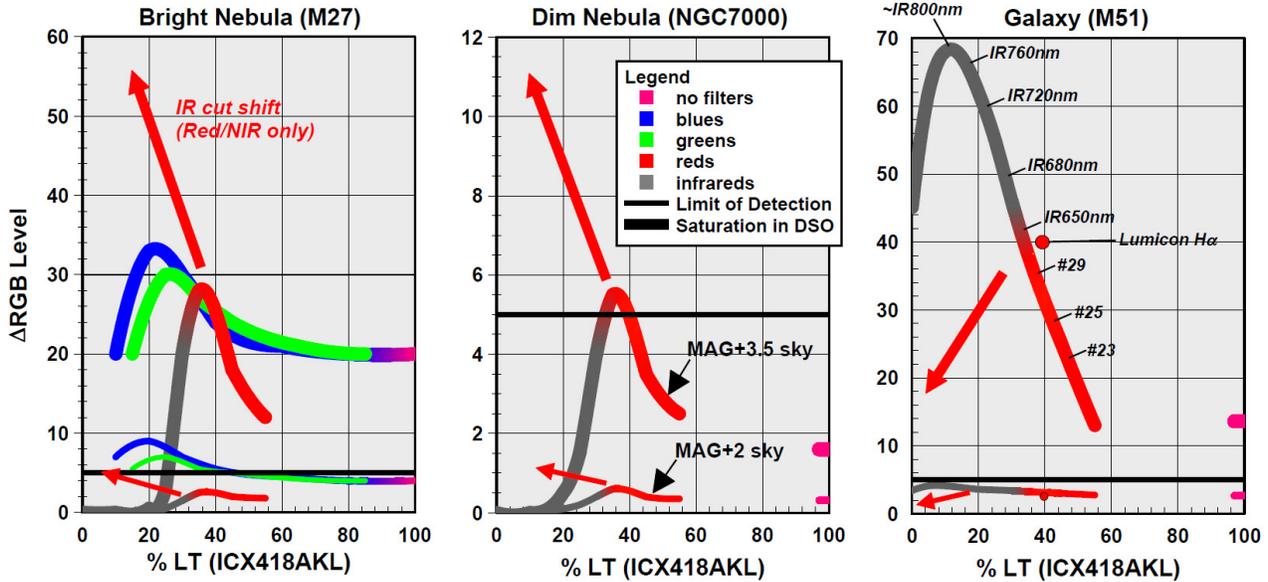


Figure 6. Colour Filters Compared: These plots are a simplified view of the predicted performance of colour filters. Only colour groups that showed a significant improvement in ΔRGB are shown.

It appears that IR Cut filters are beneficial when observing nebulae, but not galaxies. For galaxy observing you want your camera to see all the IR it can. IR Cut filters were not originally designed for reducing infrared LP, they were made for improving image quality in astrophotography. Refracting type telescopes and lenses are designed to focus all the colours of the visible spectrum to a single point in space. Early lens designs are not perfect at focusing all the wavelengths of light, resulting in a visible blue-red halo around bright objects called chromatic aberration. These early lens designs are still used today in achromatic camera lenses and telescopes because they are easy and inexpensive to make. When people began using this type of lens for astrophotography they found that their H α sensitive films (and more recently DSLR and CCD detectors) produced slightly out-of-focus images and bloated stars. The cause was the contribution of infrared light to the image, which the lens is not designed to focus at the same point as the visual light. The simple answer to this problem was to add an IR Cut filter. Ultraviolet light results in a similar blurriness to the image, so most IR Cut filters block UV as well.

The additional sharpness and reduction in star bloat achieved by using an IR Cut filter in astrophotography can also be realized in video astronomy. In my experience, the improvement in image sharpness and reduction in star bloat is quite significant when using an achromatic scope or lens. With an apochromatic lens the improvement is less

would be only that provided by the reduction in infrared light pollution.

It was mentioned in one of my earlier articles that interference type filters are sensitive to the angle at which the light passes through the filter. As the angle increases, the response of the filter widens and shifts down in wavelength. I've tested this behaviour using a very short focal length lens, and have found that as long as you stay slower than f/2 (scope-filter-camera) or a field of view < 30° (filter-lens-camera), you should be fine.

The final thing to discuss is %LT. This filter characteristic defines the percentage of the total incoming light that is getting to the camera detector. In all cases, the filters that provide the best image contrast are also the ones with the smallest %LT. Thus if you plan to use these top performing filters, you must be prepared to deal with the large increases in integration time. If you plan to use filters with %LT less than 10, you will need to consider guiding of your telescope or at least using an equatorial mount.

Based on the results of my analysis, LP filters can dramatically improve the images produced by astro-video cameras. A good all round performer seems to be a Medium Band filter with good H α and Infrared response. I recommend starting there, and after you have played with that filter for a while and know what it can achieve, you can branch out into more specialized filters. I also recommend having an IR Cut filter, certainly to improve the view with refractors, but also just for an extra boost to your views of nebulae.

For questions or access to more details of my results, contact me at: karmalimbo@yahoo.ca, or visit my website at: <http://karmalimbo.com/aro>