Narrow band filters

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1 Filters characteristics

The three most important parameters in a narrow band filter are the FWHM (or bandpass), the maximum transmittance and the out-of-band blocking. To understand each of these characteristics is important in order to adequately select the narrow band filter. Let's to explain each of them.

FWHM or bandpass

The technical term of **Full-Width at Half-Maximum** or FWHM is a simple measure of the width of a distribution. In astrophotography is used to describe a measurement of the width of an object in a picture, when that object does not have sharp edges. In the case of the image of a star in an astronomical photo, has a profile which is closer to a Gaussian curve, given mathematically by

$$f(x) = \exp(\frac{-x^2}{2\sigma^2}) \tag{1}$$

The above equation can be represented graphically as in figure 1

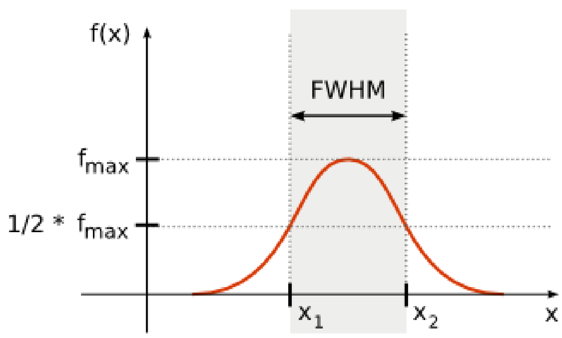

Figure 1: Representation of the FWHM of a gaussian distribution

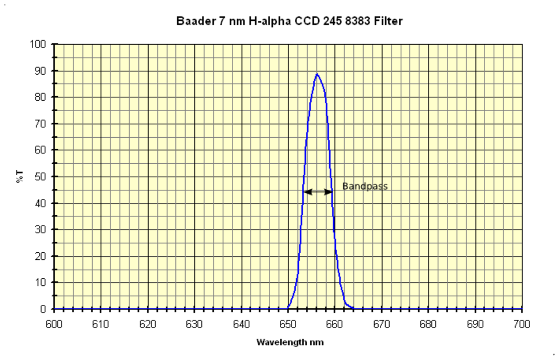

Figure 2: Representation of the bandpass of a filter

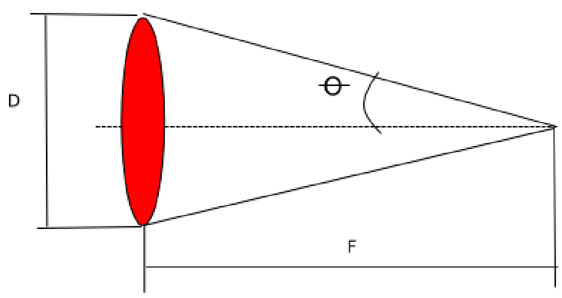

Figure 3: Cone light angle of incidence

In a filter, the FWHM or the bandpass can be defined as the width measured at the half maximum transmission.Bandwidth describes the size of a spectral segment. A bandwidth of 10nm indicates a range of 10nm of radiation. It is measured in [nm] and as can be observed is a band around the wavelenght of pass (see figure 2).

The bandpas of a narrowband filter is a function of the light incidence angle. This angle can be easily evaluated from the focal radio of the scope by means of simple trigonometrics relationships. In the fig 3, the cone of light is shown. It is the result of the light entering the scope and focussing at a point. The angle produced by the light cone can be calculated as:

$$\theta = \tan^{-1} \frac{D}{2F} \tag{2}$$

where D is the scope diameter (apperture) and F is the focal length. If the focal ratio is $f = F/D$, thus the above equation can be expressed as:

$$\theta = \tan^{-1} \frac{1}{2f} \tag{3}$$

The bandpass in narrowband filters is a function of the incident light angle. The combination of a steep light cone and wide field angles limits the use of narrowband filtes to slower systems[1]. In this situation, the bandpass wavelenght of the filter shifts with increasing angle toward shorter wavelenghts. Thus, it can affects/reduces the efficiency of the filter.

The following formula can be used to determine the wavelength shift of a filter in collimated light with incident angles up to 15 degrees:

$$\lambda_\theta = \lambda_0[1 - (\frac{N_e}{N_f})^2 \sin^2\theta]^{\frac{1}{2}} \tag{4}$$

where λ_θ is the wavelength at the incident angle, λ_0 is the wavelength at normal incidence, N_e is the refractive index of the external medium, N_f is the refractive index of the filter and θ is the incidence angle.

For fast telescopes (faster than f/4), filters narrower than $13nm$ will be degraded. For slower systems a narrower filter is recommended as it enhances the effect of the filter.

1.1 Maximum transmittance

The ratio of the radiant power transmitted through a material to the incident radiant power. Transmittance is usually expressed as a percent. A filter with a 50% transmittance (at a specific wavelength) will absorb half of the light incident on it and allow half of it to pass through it. The higher transmittance of the filter at the pass wavelength (e.g. at 656.3nm for the case of an $H\alpha$ filter), the better efficiency obtained.

1.2 Out-of-band blocking

The out-of-band blocking is the attenuation of the incidence radiation at wavelenght different than the pass wavelenght. It is important for a filter all the unwanted radiation, at all the wavelength other than the pass one at which transmittance should be maintained at a maximum.A good out-of-band blocking can allow to achieve very high signal to noise ratio (SNR) and high contrast, even with a bright moon nearby or under light polluted skies.

2 How to select the filter

There are a lot of variety of filters for the different pass wavelength ($H\alpha$, [OIII], [SII]) in the market at different prices. The most known: Astrodon, Astronomik, Baader, etc. Manufacturers also offer different bandpass (6nm, 7nm, 10nm, 13nm, etc.). Thus, it can be a difficult decision for which filter to select. There

[1] Slower systems is referred to system with focal ratios equal or greater than f/4

is not a unique answer, because it depends of your optical system and of course (maybe the most important) your budget. At the same bandpass, the higher transmittance the better. At the same transmittance, the narrower the bandpass the better. In both cases, SNR increase.

Another think to take into account if you plan to buy not only the $H\alpha$ filter but also the [SII] and [OIII] filters is that they should be parfocal, i.e. they all focus at the same point. This should eliminate the need for refocusing when you change of filter.

3 How to detect the halos source

An usual problem when taking photos with filters (not always is the only cause of halos) is that sometimes appear non-desired halos around stars. These halos depend on the configuration used, but also they can be due to a bad performace of the antireflection coating on the optical elements near the image. This condition is worst for fast systems. The dominant factor in these systems is the steep incidence angles. At high angles coatings have increased reflection. With more reflected light enanating from the optical surfaces, halos will appear. In fast systems even with high anti-reflection coatings images will have halos. It is the limits of the physics. These conditions exist in all systems but are more pronounced in fast systems.

The most important thing is to know which surface is the cause of these halos at the CCD. Hereafter we'll try to comment some useful steps to find what cause them. For more information [1].

- First step if your taking photos with different filters (says RGB or Ha [OIII] [SII]) is to detect if the halos are reproduced in the different images taken with different filters. This is important because if halos are produced by the three filters, then they are not dependent of the filter bandpass. In this case a good hypothesis is that there are reflections.
- Secondly, we will calculate the halo size on the CCD. First measure the number of pixels that are contained in the halo diameter. To do this strech the histogram until the halo can be observed in the image. The halo size is:

$$Halo\,diameter\,at\,the\,CCD = diameter\,in\,pixels \cdot pixel\,size \qquad (5)$$

  where the pixel size is in mm. If the photo has been taken in binning, says 2x2, then you have to multiply the pixel size by 2.
- We will find the source of the reflection. To do this, we must find how far away from the CCD is the source of this reflection. In a simmilar manner as you calculate the focal distance of your scope from the focal ratio and the diameter, you can calculate the distance from the CCD where the reflection is produced.

$$Reflectance\,distance = f \cdot halo\,diameter \tag{6}$$

In figure 4 each halo diameter is caused by a different reflection, between the entrance window and the filter, between the entrance window and the chip, due to entrance window thickness. In all cases, **each reflection distance is twice the distance between the surfaces that cause the reflection.** In the figure it is not represented the cover of the chip that can also cause a reflection.

References

[1] http://www.astrodon.com/documentation/documentation.cfm?DocID=3

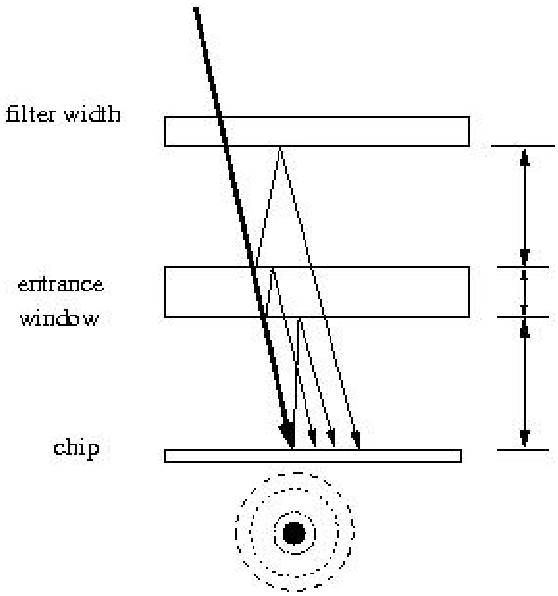

Figure 4: Diagram of the different surfaces from the filter to the CCD chip