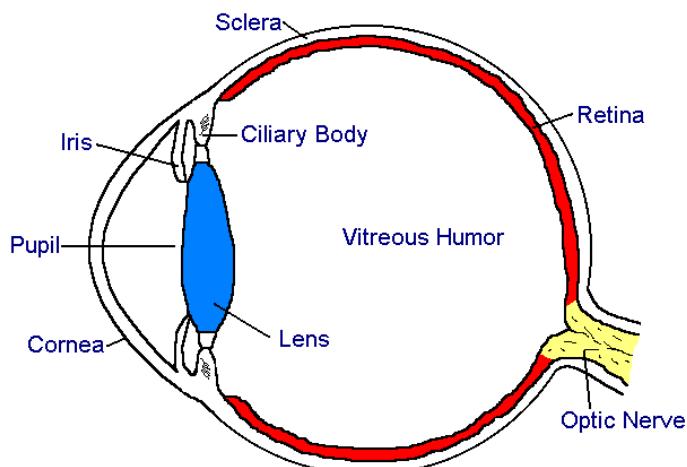


## ASTRONOMICAL FILTERS PART 1: An Introduction

I have recently been finding my way back into amateur astronomy after having been away from it for two decades. Most of those 20 years has been spent pursuing a career in Aerospace Engineering, which has changed my perspective of astronomy as a hobby from what it was as a teenager. Choices of equipment and how to use it are now more based on methodical research and testing than on random trial and error. This is especially true in my efforts to figure out what to do about filters.

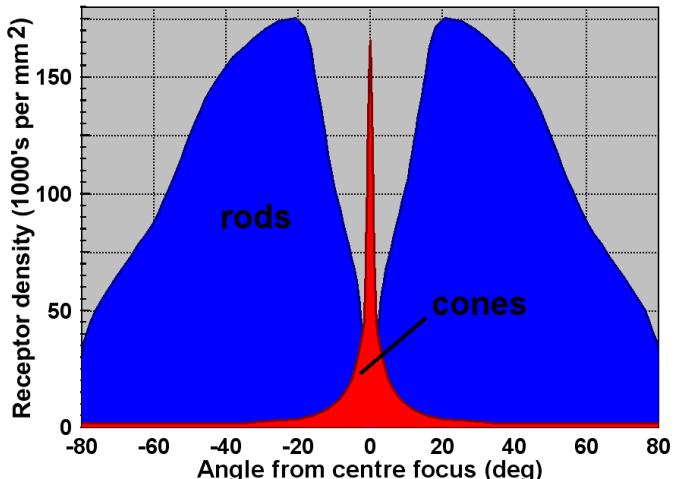
There are many books and websites out there that will describe some aspect of using astronomical filters. In my attempt to understand what filters are best to have in my own accessory case and why, I have had to gather small bits of information from many different places. Most sources compare a couple filters to each other, and only a very small number of sources site real measured data instead of personal opinions and general impressions. No single website or book compares all the available filters to each other, or tries to explain why one is better than the other. In this multi-part article I present the information about astronomical filters that I have compiled, or discovered for myself through observations and experimentation.

To keep things simple, let's start by talking strictly about filters for visual astronomy. That is after all why filters were created in the first place. I'll discuss the use of filters in video astronomy later. A good place to begin then is with the human eye.



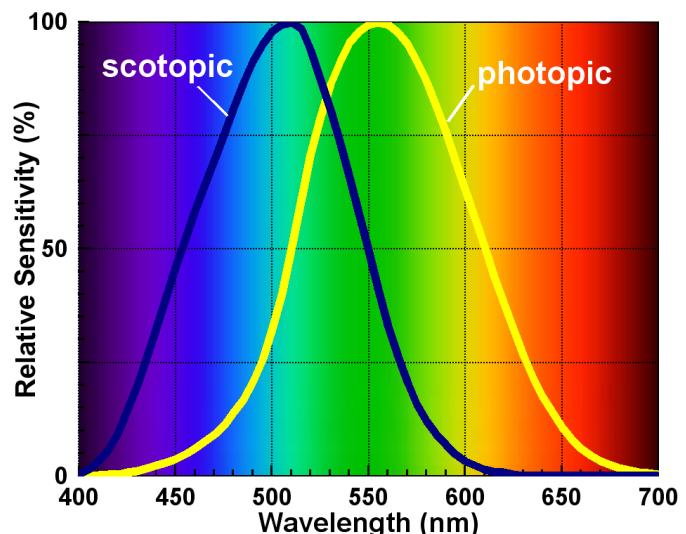
**Figure 1. The Human Eye:** The retina contains two types of receptors, rods & cones. Each has different sensitivity to light as well as colour.

The retina, the part of our eye that converts light into nerve impulses, is covered in two types of receptors: the high resolution colour sensing cones, and the monochrome but more light sensitive rods. Cones are located in a very narrow area at our central focus, and the rods are located over a broad region on either side of the central focus, with a peak density around 20° off center. It is this peak rod density location that makes using “averted vision” affective for seeing faint objects.

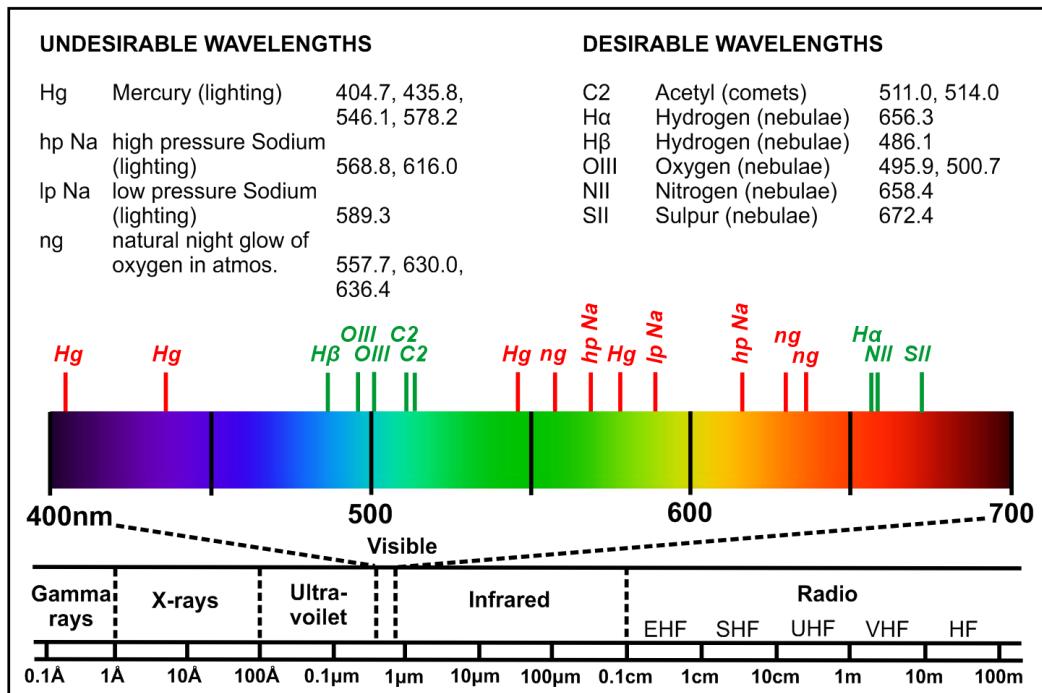


**Figure 2. Rod & Cone Density:** Colour sensitive cones are located primarily in a narrow region around our central focus. The more light sensitive rods are broadly distributed on either side, with a peak density around 20° off centre.

One fascinating feature of our vision system is its ability to automatically change what receptors are used depending on the lighting conditions. In bright light our brain uses data primarily from the cone receptors, while in low light our brain uses the more sensitive rod receptors. As it happens, the sensitivity of the rods and cones to different colours or “wavelengths” of light is different. As a result of this, our ability to see different colours changes depending on whether our eyes are light adapted (photopic) or dark adapted (scotopic). This is an important point since the state of our eyes’ light adaptation will affect how the filters discussed later will work.



**Figure 3. Human Eye Spectral Sensitivity:** Our eyes have a different sensitivity to colours depending on whether they are light (photopic) or dark (scotopic) adapted.



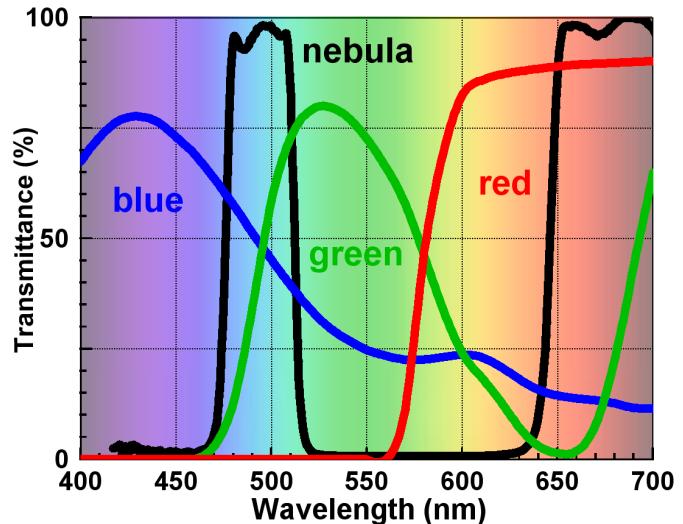
**Figure 4. The Electromagnetic Spectrum:** Amateur astronomy takes place mostly in the visible portion of the electromagnetic spectrum. Within that band there are a number of key wavelengths associated with desirable light sources like hydrogen and oxygen in nebulae, and undesirable sources like mercury and sodium in man-made lighting.

Human vision is generally assumed to be within a narrow band of the electromagnetic spectrum, wavelengths from 400 to 700nm. Of the objects we want to observe, the Sun, Moon, planets, stars, clusters, galaxies, and reflection nebulae all emit a broad spectrum of light, a continuous distribution across the whole visual band. Objects such as emission nebulae, planetary nebulae, and supernova remnants all emit in very narrow and well defined bands. This is a result of the light being emitted by discrete gases such as hydrogen and oxygen that have been energized with ultraviolet radiation from nearby stars. There are also undesirable light emissions in the sky that obscure the dimmer objects we wish to observe. This “light pollution” also tends to be mostly in discrete bands defined by the element in the lighting fixture that is generating the light. Mercury (Hg) and sodium (Na) are the two most commonly used in outdoor lighting as the colour of their light is well placed near the wavelength where our light adapted eyes are most sensitive, around 560nm. Luckily the discrete nature of light pollution makes it possible to selectively filter them out, as we will discuss later.

Filters can improve what we see by removing what we don't want to see from the view. For example a light pollution filter improves the view of faint deep-sky objects by removing the wavelengths of light from man-made outdoor lighting. Another example is how the contrast of Mars' blue and red features is improved by using a filter that blocks green light. Regardless of the filter type, they all work by blocking some

combination of wavelengths of light. Knowing what wavelengths of light are being blocked by a filter and by how much, we can determine how effective the filter might be for a specific application. This type of information is normally presented in the form of a “spectral transmissivity” graph. Such a plot shows the fraction of incoming light that passes through the filter at each wavelength. For example, in the figure below, the blue filter passes a large amount of the incoming light at short wavelengths (purples & blues) but blocks light at longer wavelengths (oranges & reds). The end result is the filter makes objects look

more bluish. By plotting different filters together on the same graph, it is very easy to see how each filter's performance compares to the other.



**Figure 5. Example Spectral Transmissivity Graph:** The ability of different wavelengths of light to pass through a filter is often presented using this type of spectral transmissivity graph. A response of 100% means all the light at that wavelength is able to pass through the filter. The bandwidth of a filter is defined as the wavelength width at the point where the transmittance is  $\frac{1}{2}$  the filter's maximum. Similarly the cut-off wavelength of a filter is the wavelength where the transmittance is  $\frac{1}{2}$  the maximum.

The complete picture of what a filter is doing requires us to consider both the filter's spectral transmissivity and the spectral sensitivity of our eyes together. To help boil down and compare this combined response for the various filters

## ASTRONOMICAL FILTERS PART 1: An Introduction

there is a useful parameter called “Luminous Transmissivity” or LT for short, expressed normally as a percentage. This fancy term is simply the amount of light passed by the filter averaged over the whole visible band, weighted by the spectral eye sensitivity at each corresponding wavelength. The result is that filters that pass colours near the same wavelength as our eyes’ peak sensitivity (510nm at night, 560nm during day) will have a large value of %LT. From what I have found, the %LT values quoted by filter manufacturers are always that corresponding to the light adapted eye. In the remaining parts of this article, I have calculated both the photopic and scotopic %LT, since in all likelihood we will be using these filters in the dark too!



**Figure 6. Example Of Astronomical Filters Available Today:**  
There are a large variety of planetary and deep-sky filters available today, ranging in price from \$5 up to several hundred.

Filters for astronomical use are relatively easy to use. They consist of a flat clear glass element coated with something that gives it the desired properties. This piece of glass is then held in some sort of aluminum or plastic housing. Visual astronomical filters typically come in two sizes, 2" (48mm thread) and 1.25" (28mm thread), corresponding to the two popular sizes of eyepiece available today. The filter housing has a male thread allowing it to be attached to the bottom of your eyepiece or diagonal, and normally has a corresponding female thread on the other side allowing you to stack multiple filters. Filter types can be separated into two broad categories: planetary and deep-sky. Planetary filters are essentially colour filters, identical to those used in terrestrial photography. They use coatings that selectively absorb different wavelengths of light in order to get the desired colour. Deep-sky filters are also called band pass or interference filters. They use many thin layers of coatings with different optical properties to setup destructive interference amongst the different wavelengths, thus attenuating the undesirable wavelengths. The remaining parts of this article will discuss each of these two filter types in more detail, as well as how they can be applied to both visual and video astronomy.

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