

Astronomical Filters on Skynet Telescopes

Or...how astronomers use filters.

by Dr. Rich Kron, University of Chicago

Measuring physical properties of stars

Astronomers use filters to measure properties of astronomical objects, a good example being the temperature of a star. Cooler stars look redder, and hotter stars look bluer. By quantifying how red or blue a star looks, we can relate this measurement to its temperature, which can then give us some insight into other properties like its mass and age.

What filters do and how they are used

Filters are colored glass disks that are placed, one at a time, in front of the CCD detector inside the camera that is mounted at the focus of the telescope. A filter lets only some range of wavelengths of light through, and blocks other wavelengths. For example, a filter that looks blue when looking through it lets short wavelengths through. When this filter is placed in front of a CCD, the image is recorded in blue light (short wavelengths).

How color is quantified

Things that look blue shine with more energy at shorter (bluer) wavelengths compared to longer (redder) wavelengths, and vice versa. By taking images through both a blue and a red filter, the bluer (hotter) stars will appear relatively bright in the image taken with the blue filter, and the redder (cooler) stars will appear relatively bright through the red filter. Without using filters, we would have no way of knowing which was which.

We quantify the color of a star (or asteroid or planet or galaxy) by dividing the amount of light passing through one filter by the amount passing through another filter. These numbers are called "colors" and can be calculated from any pair of filters. An important application is the Hertzsprung-Russell (or color-magnitude) diagram, which often uses a color like B-V on the x-axis.

Photometric systems - general

The brightness, or "counts," that results from the measurement of a star in an image depends on many factors besides which filter is used: the exposure time, the size of the telescope, the transparency of the atmosphere, the manufacturer of the CCD camera, and so on. All of these factors are accounted for by relating, or calibrating, the brightness you measure for a star to the brightness for the same star as expressed on a photometric system. A photometric system is defined by measurements of particular stars (called standard stars) through specified filters that are meant to be copied and used by other people with other telescopes and cameras.

Photometric systems - Skynet

There are two primary photometric systems used by Skynet: a system with filters represented by upper-case letters UBVRI, and a system with filters represented by lower-case letters ugriz (primes on these letters are not necessary). The former is the Johnson-Morgan-Cousins system and the latter is the Sloan Digital Sky Survey (SDSS) system. The Johnson-Morgan UBV system was established in the 1950's and has been used extensively for measurements of brighter stars. The SDSS is more recent and surveyed much fainter stars. The APASS survey is intermediate in brightness and includes a hybrid set of filters: BV and gri. If you use any of the filters UBVRI or ugriz, your image can be used by other researchers because the numbers can be calibrated. For this reason, we recommend that you use these filters by default.

With more filters, more things can be measured

Many other things can be done with measurements of colors. For example, if a star is behind a cloud of interstellar dust, it will look redder, so the color of the star informs us about the amount of interstellar dust along the line-of-sight (an effect called "reddening"). Different colors measure the combination of temperature of the star and amount of dust differently, which can be separated by using three or more filters as opposed to just two filters. Similarly, the chemical composition of a star affects how it shines, a feature that can also be measured with colors. With four or more filters, we can measure temperature, reddening, and chemical composition, all at the same time!

Measuring nebulae

Some astronomical objects like nebulae (planetary nebulae, H II regions, and supernova remnants) shine the same way a neon sign does, putting most of the energy into a number of "lines" that can be sampled with narrow-band filters, namely filters that transmit only a small range of wavelengths. These filters are named after the line that is sampled, e.g. H α , OIII, SII. A gas cloud can be ionized by the ultraviolet radiation given off by a neighboring hot star. When this happens, the gas glows at the wavelengths of the atoms or ions involved. By measuring the amount of light in these lines by taking pictures through the narrow-band filters, we get information about which and how many atoms and ions are emitting, how far away from the hot star the atoms and ions are, and how much ultraviolet light the star is radiating. The narrow-band filters are designed for these kinds of investigations.

Detecting faint variable sources

In some cases you may be looking for a very faint source that is moving or rapidly changing in brightness. In this case, you may want to prioritize detection as opposed to calibration, and the best choice for filters would be one of the "high throughput" or "maximum light" filters.