Advantages of using the CBB filter for small aperture, exoplanet differential photometry

The CBB is a clear filter with blue blocking at ~ 480 nm. All frequencies longer than this are allowed to pass. The CBB was first suggested for exoplanet differential photometry by Dr. Joshua Pepper of Lehigh University. The CBB is particularly appropriate for this use because differential photometry requires a wider FOV and therefore a smaller aperature (~<1m). Much of the superior performance of the CBB filter can be attributed to its large throughput which is a priority in smaller telescopes. Dr. Bruce Gary analyzed the capabilities of the CBB filter as compared to other filters for exoplanet observations using small telescopes. The results presented in this section sumarize the results of Dr. Gary's work.

The flux throughput of the CBB compared to other filters is shown below.

Filter Throughput at airmass 1.2

Filter	Throughput
CLR	100%
CBB	92%
NIR	37%
B	6%
V	19%
R	36%
I	22%
g'	26%
r'	48%
i'	48%
z'	9%

As will be demonstrated, in most situations the greater the filter throughput the better the precision of exoplanet LC measurements.

To quantize the comparison of the CBB with alternative filters, Dr. Gary analyzed the LC RMS departure from best model fit. From this, Dr. Gary assigned a "figure of merit" (f_m) that endeavors to predict the RMS quality of exoplanet LCs using various filters. The filters used in the study were: CBB, NIR, V, Rc and i'. The exposure times were set in such a way as to provide a similar total flux (and SNR) for the target star for each filter. The figure of merit is prortional to "information rate" (proportional to the inverse square-root of the predicted RMS of a model light curve).

$$f_m = \frac{c}{\sqrt{RMS}}$$

The constant was chosen so that the V-band filter produced a figure of merit equal to one.

Findings: The resulting Figure of Merit was found to generally correlate with filter throughput, and in general, the CBB filter was found to be superior in most cases for telescopes ~< 1m. However, for brighter stars the i' filter outperformed. Three example stars of different magnitues were analyzed and the results are shown below.

Target star V-mag = 13.3:

Figure of Merit: CBB 6.27, NIR 1.67, VIS 1.00, RED 2.93, i' 1.26

In other words, when the CBB filter is used, a specific level of precision can be achieved 6.3 times faster than if the V-band filter were used.

Target star V-mag = 11.7:

Figure of Merit: CBB 8.10, NIR 5.45, VIS 1.00, RED 5.10, I' 4.65

Target star V-mag = 10.2:

Figure of Merit: CBB 6.16, NIR 6.83, VIS 1.00, RED 5.37, i' 8.14

Although a clear filter passes a higher flux than the CBB, a clear filter should be avoided for exoplanet light curve observations because it proviedes different effective atmospheric extinction values for red and blue stars (0.132 and 0.191 mmag/airmass), whereas with a CBB filter the two extinction coefficients are almost the same (0.116 and 0.124 mmag/airmass). Therefore the extinction difference between red and blue stars is 59 mmag/airmass for a clear filter and only 8 mmag/airmass for a CBB filter. That is a 7-fold improvement, which means there should be a 7-fold reduction in the size of the "air mass curvature" systematic error component when using a CBB filter instead of a clear filter. The reduction in flux for the CBB in comparison to a clear filter however is only 8%.

A fuller analysis of the CBB filter in comparison to other filters for use in exoplanet differential astronomy can be found here:

http://brucegary.net/AXA/FilterChoice/APPENDIX%20H%20v9918.htm

Ed Mullen
Dr. Bruce Gary