Spectral response of RINGSS

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1 Introduction

This document is a study of the spectral response of the RINGSS instrument based on the ZWO ASI290M camera and Celestron Nexstar 5SE 5-inch telescope. The idea is to compare fluxes recorded from stars of different colors, find the empirical dependence of flux on color, and compare it to the expected fluxes computed from the instrumental response curve. In this way, we check that the curve matches reality.

Stars of different colors were pointed on January 11, 2021. The optics contained a yellow glass filter with approximate cutoff of 470 nm. On March 21, 2021, the experiment was repeated, this time using the Thorlabs FES0750 filter that cuts wavelengths longer than 750 nm and shorter than 500 nm. This filter has a parasitic transmission at 400–430 nm that can be blocked by the yellow glass filter FG455 from Thorlabs (455nm cutoff). This filter was installed on May 24, and the experiment was repeated again. In the following we focus on this latest data set pertinent to the final RINGSS instrument.

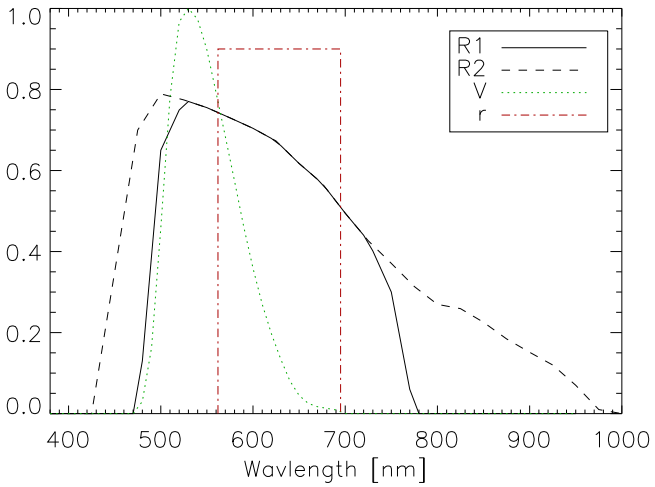

Figure 1: Response of the RINGSS camera with the interference and yellow filters `qedata3.txt` (R1, full line) and with the yellow-filter only (R2, dashed line). The reaction curves of the V and SDSS r' bands are plotted in green and red for reference.

The filter transmission multiplied by the QE of the camera is listed in the text files `quedata.txt` and `qedata3.txt` for the two configurations tested (Fig. 1).

2 Analysis

The data cubes recorded on May 24 were processed by the IDL pipeline version 5. The resulting data structure produced by `allcubes5.pro` contains the total flux in electrons F per the 1-ms exposure time and the HR number of the observed star. The response is analyzed using `ptmresp5.pro`. The fluxes are converted into the instrumental magnitudes M as

$$M = -2.5 \log_{10} F + 12, \tag{1}$$

where the offset 12 is added only for convenience.

The code `getbsc.pro` reads the bright-star catalog downloaded from the Vizier service (catalog V/50) as a —-separated text file. The selected data are saved in the IDL structure `bsc`. This structure is retrieved and the catalog magnitudes V and colors $B - V$ are found from the HR numbers of the observed stars.

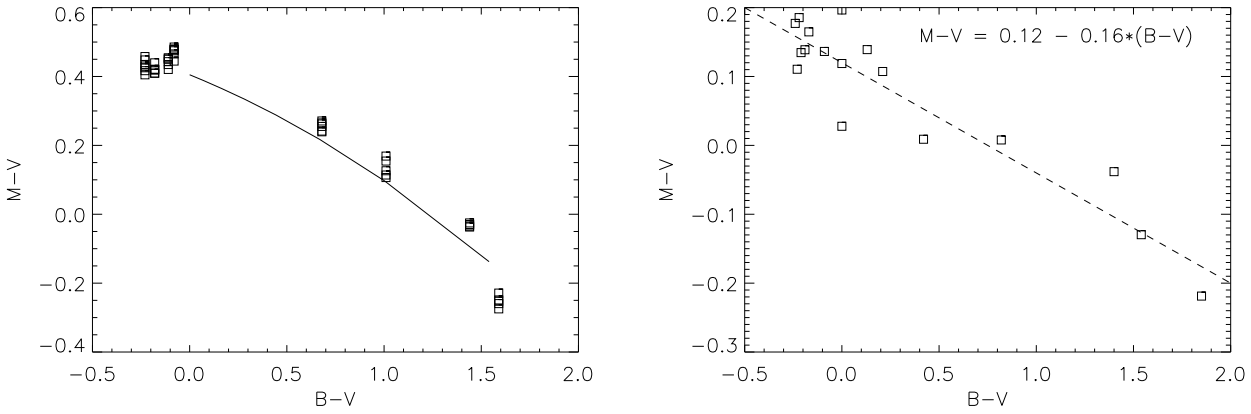

Figure 2: **Left:** difference between instrumental and catalog magnitudes vs. $B - V$ color (squares) and the theoretical curve (full line) on May 24. **Right:** a similar plot for the data of May 21, with a shallower slope and a smaller intercept.

Figure 2 compares the difference $\Delta = M - V$ to the colors of the observed stars. For red stars (large $B - V$), this difference is negative, meaning that we get more photons compared to the blue stars (spectral type A0, $B - V = 0$). This is expected from the response curves in Fig. 1. The linear regression has a slope of -0.33 and the intercept of $+0.40$. The rms scatter around this line is 0.07 mag. In this plot, stars at airmass above 1.6 are excluded, as well as one strong outlier (wrong HR number?).

The code `photometry.pro` computes the M, V, and B magnitudes for black-body spectra with temperatures from 3000 to 10,000 K (it uses `blackbody.pro`). The reaction curves of the standard filters are taken from the Table 2 of Bessell, M. 1990, PASP, 110, 1181 and read from the file `BVR.txt`. All magnitudes are equal for stars of A0 type (10,000 K). A plot similar to the one in Fig. 1 is constructed ($B - V$ ranges from 0 to 1.5) and a slope is found by a linear regression. The resulting slope is -0.35, similar to the observed one. The theoretical curve, offset by $+0.4$ mag, is also plotted in Fig. 1. One notes that the relation is not exactly linear.

A similar analysis of the data taken on March 21 (with the interference filter but without the blocking filter) has a linear-regression slope of -0.16 and the constant of 0.12. This indicates that

the blue leak of the interference filter is substantial. The flux reduction caused by the yellow filter is $10^{0.4(0.40-0.12)} = 1.29$ times. It is larger than deduced from the vendor's filter response curve. Apparently, the blue transmission of the interference filter is not well defined because it is meant to work in the red only.

This analysis was also made for the data taken on January 11, 2021 taken with the yellow filter. The theoretical slope of -0.50 coincided nicely with the measured slope of -0.50. The telescope and camera were the same, only the filters changed. The fitted regression was $\Delta = 0.11 - 0.50(B - V)$ and the rms scatter was 0.03 mag.