ON THE NECESSITY OF GROUND-BASED SPECTROPHOTOMETRY OF STANDARD STARS FOR CALIBRATION OF THE GAIA BP/RP SPECTRA

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V. Straižys[1], K. Zdanavičius[1] and R. Lazauskaitė[1,2]

[1] *Institute of Theoretical Physics and Astronomy, Vilnius University, Goštauto 12, Vilnius, LT-01108, Lithuania*

[2] *Department of Theoretical Physics, Vilnius Pedagogical University, Studentų 39, Vilnius, LT-08106, Lithuania*

Abstract. The effect of contamination in the low-dispersion *Gaia* BP and RP spectra is demonstrated for main-sequence stars of various temperatures. The contamination corrections depend on the physical parameters of stars and create difficulties in applying traditional methods for photometric classification of stars. Additionally, the *Gaia* spectra exhibit a series of fictional interstellar extinction laws depending on the intrinsic spectral energy distribution of the star and the value of its interstellar extinction. All these classification problems would be facilitated if the ground-based spectral energy distributions of stars of various temperatures, gravities, metallicities, peculiarity types and interstellar reddenings were available.

1. INTRODUCTION

As was shown by Straižys et al. (2006a,b; hereafter Paper I), the *Gaia* BP and RP spectra will be affected by energy redistribution, arising from broad wings of the star image profiles. As a result, each pixel in the spectrum, in addition to the "local" photons, will contain "alien" photons with wavelengths corresponding to other pixels. Since the wings of stellar images in the focal plane are quite large, a considerable part of the photons from the yellow-red spectrum will fall on the ultraviolet and blue pixels and vice versa. This energy redistribution (or contamination by the "alien" photons) can be characterized by the ratio of "local-to-alien" photon numbers or the corresponding fluxes of energy. The amount of contamination depends on the wavelength, on the star physical parameters ($T_{\rm eff}$, $\log g$, [Fe/H], peculiarity) and on its interstellar reddening.

2. CONTAMINATION EFFECT FOR STARS OF DIFFERENT TYPES

In Figures 1–7 we compare the original and the contaminated spectra simulated by A. G. A. Brown using the mean spectral energy distribution curves of main-sequence stars of spectral types O8, A0, F0, G0, K0, M0 and M4 from Straižys & Sviderskienė (1972), with some corrections in the ultraviolet (Straižys

1996). Before simulation, the energy distribution curves were transformed to the photon number scale. Each figure contains both BP and RP spectra normalized to 1.0 at maximum. The black curves include only the pixel-size integration, these spectra represent the measurements with a "perfect" instrument. The red curves additionally include all the smearing effects related to the image profile. It is evident that the inclusion of the PSF smearing leads to a considerable photon redistribution effect.

The contamination values are the largest in the wavelength ranges where either the intensity of the "local" photons or the sensitivity of CCD (or both) are low. This happens in the wings of the BP and RP response functions, where the sensitivity falls down, or in the short wavelengths for cool and heavily reddened stars, where the intensity of the source radiation is low. Figures 1–7 exhibit the largest contamination effect in the ultraviolet and violet ranges which increases and extends the covered spectral range with decreasing star temperature. In Paper I we demonstrated that for M-type giants and supergiants the contamination at 350 nm is ≥ 2 mag and at 400 nm it is ≥ 0.6 mag.

3. CONTAMINATION EFFECT FOR REDDENED STARS

The contamination effect distorts not only the intrinsic spectral energy distributions but also the interstellar extinction law, i.e., the dependence of monochromatic interstellar extinction on the wavelength. The presence of red and yellow photons in the violet and ultraviolet spectral ranges leads to an apparent decrease of common interstellar extinction. This decrease depends on the amount of the low energy photons added, i.e., on the intrinsic spectral energy distribution (defined by the temperature, gravity, etc.) as well as on the value of interstellar extinction.

We have determined the fictional extinction laws from the *Gaia* spectra of reddened model stars simulated by Vallenari (2006) using the standard interstellar extinction law of Cardelli et al. (1989). Figure 8 shows how the apparent interstellar extinction law changes with the star temperature. Figures 9 and 10 show the dependence of the law on the interstellar extinction A_V for stars of the temperatures 25 000 K and 4000 K. The quantity

$$\tau(\lambda) = I(\lambda)/I_0(\lambda)$$

characterizes the transmittance of light by a unit quantity of interstellar matter, which is defined as giving the extinction $A_V = 1.0$. All the transmittance curves are normalized at 650 nm, where BP and RP spectra overlap.

Figure 8 shows that the largest deviations from the normal interstellar extinction law (Cardelli et al.) happen at the wavelengths shorter than 400 nm. However, for the stars cooler than the Sun this deviation starts to appear already in the green spectral range. In the red and infrared ranges the deviation is in the opposite direction since there the spectra are contaminated by photons of higher energy, and this increases the apparent extinction.

The dependence of the apparent extinction law on gravities and on metallicities of stars is much smaller. However, the effect should be taken into account in classification of reddened stars.

4. DISCUSSION AND CONCLUSIONS

The *Gaia* BP and RP spectra may be used for the determination of physical parameters of stars either by applying traditional photometric quantities (color indices, color excesses, interstellar reddening-free Q-parameters) or the new methods, such as the neural networks or the pattern recognitions. The *Gaia* spectra may be considered as a multicolor photometric system formed by several tens of passbands. However, the traditional methods may be applied only after taking into account the decontamination corrections. For their determination we need sufficient number of standard stars of different temperatures, luminosities, metallicities and peculiarities. Decontamination corrections may be determined most precisely by comparing orbital spectra with simulated spectra of the same stars, based on their spectral energy distribution curves. Standard stars are also essential for the calibration and verification of "non-traditional" methods of classification.

The dependence of the apparent interstellar extinction law on physical parameters of stars and on the value of the extinction itself creates an additional difficulty in determining the decontamination corrections and in classification of reddened stars. Therefore it would be important to include into the set of spectrophotometric standards some stars of various spectral types affected by different amounts of interstellar extinction. For this aim O-type stars and supergiants of various spectral classes with different interstellar reddening may be used. Pre-launch investigation of the quality of images (PSF function) and the contamination effect is essential.

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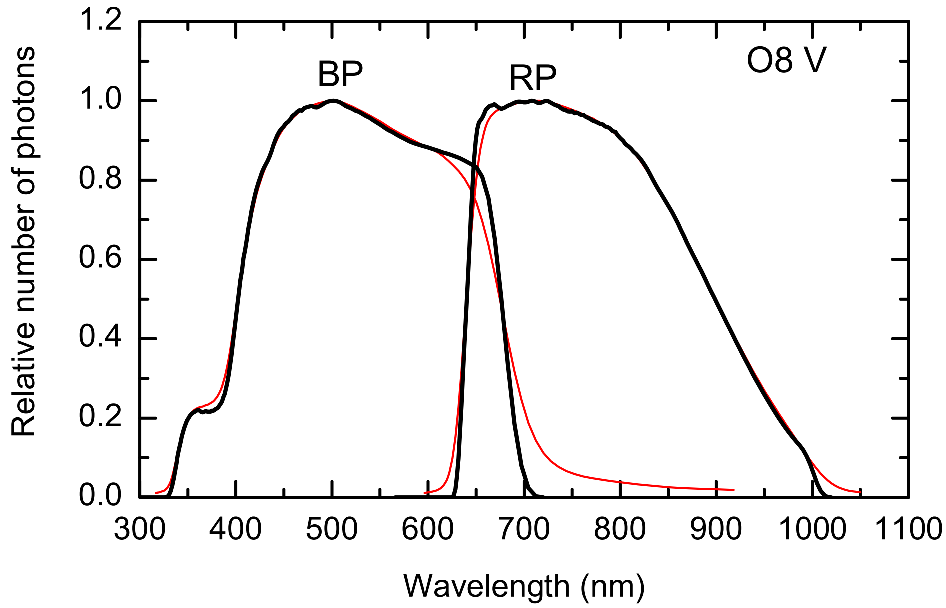

Fig. 1. The *Gaia* BP and RP spectra for O8 V type star without (black line) and with (red line) the PSF smearing.

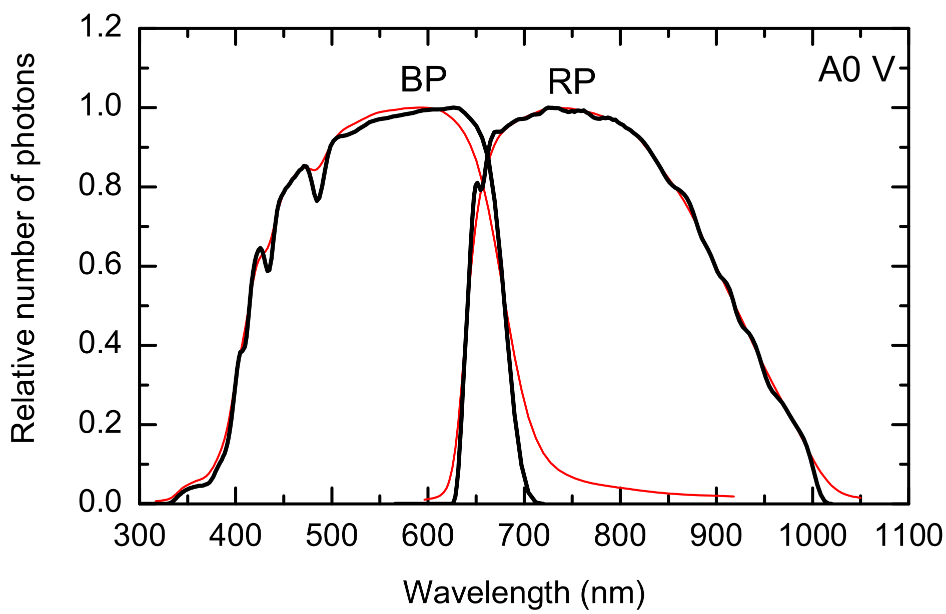

Fig. 2. The same as in Figure 1 but for A0 V type star.

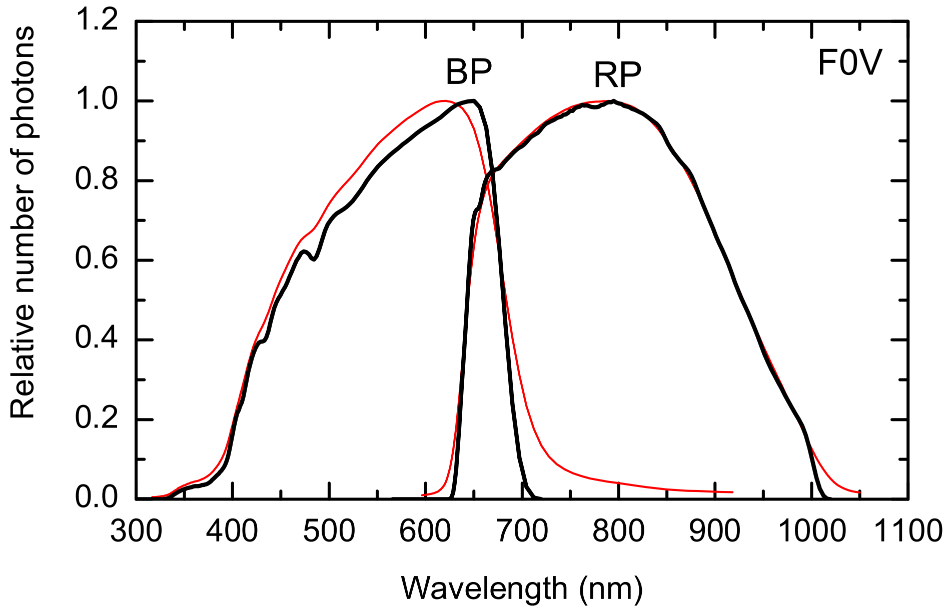

Fig. 3. The same as in Figure 1 but for F0 V type star.

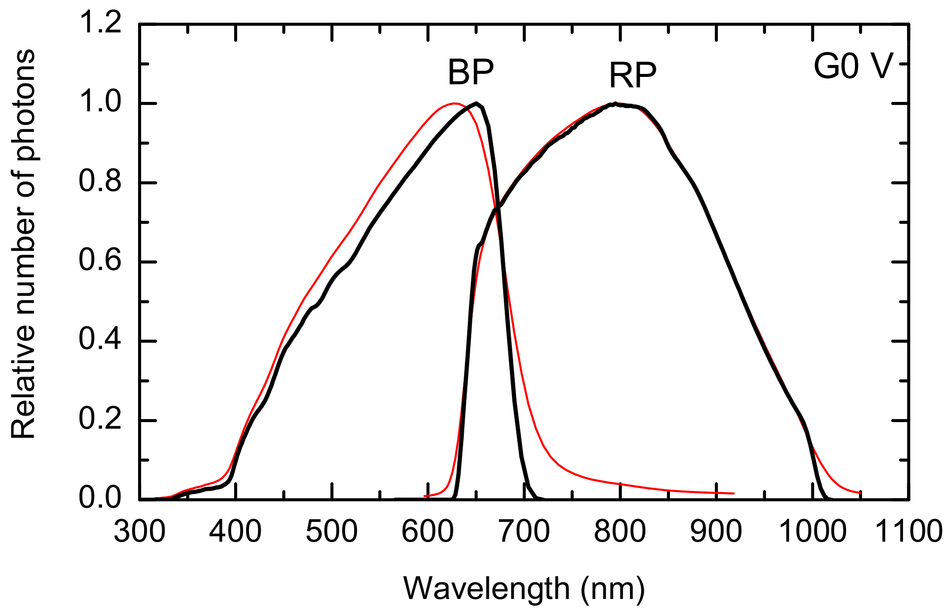

Fig. 4. The same as in Figure 1 but for G0 V type star.

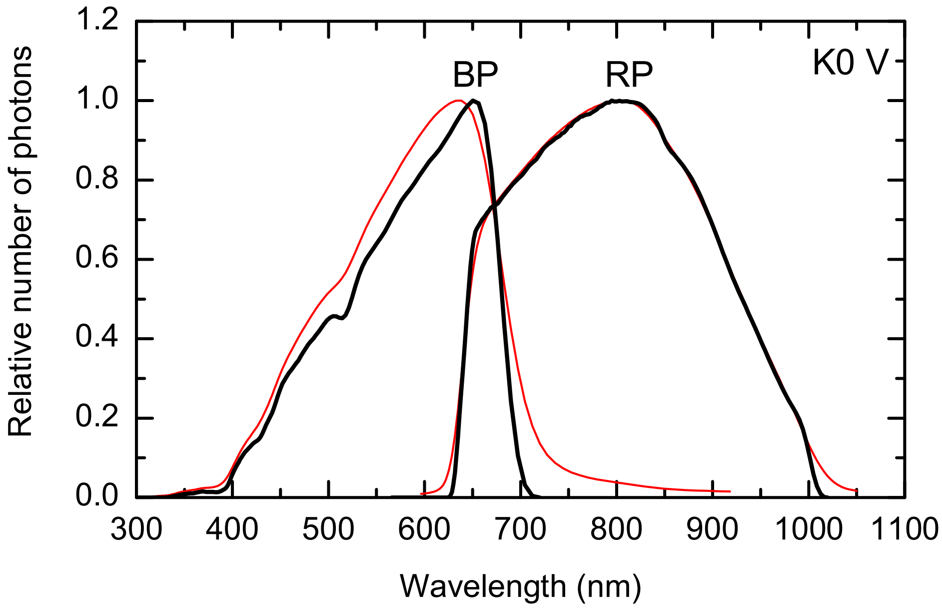

Fig. 5. The same as in Figure 1 but for K0 V type star.

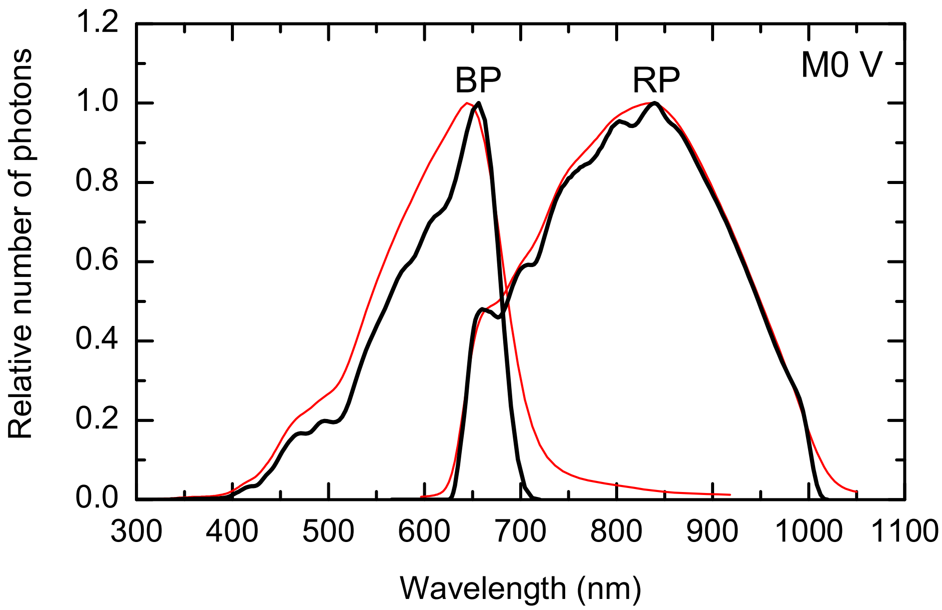

Fig. 6. The same as in Figure 1 but for M0 V type star.

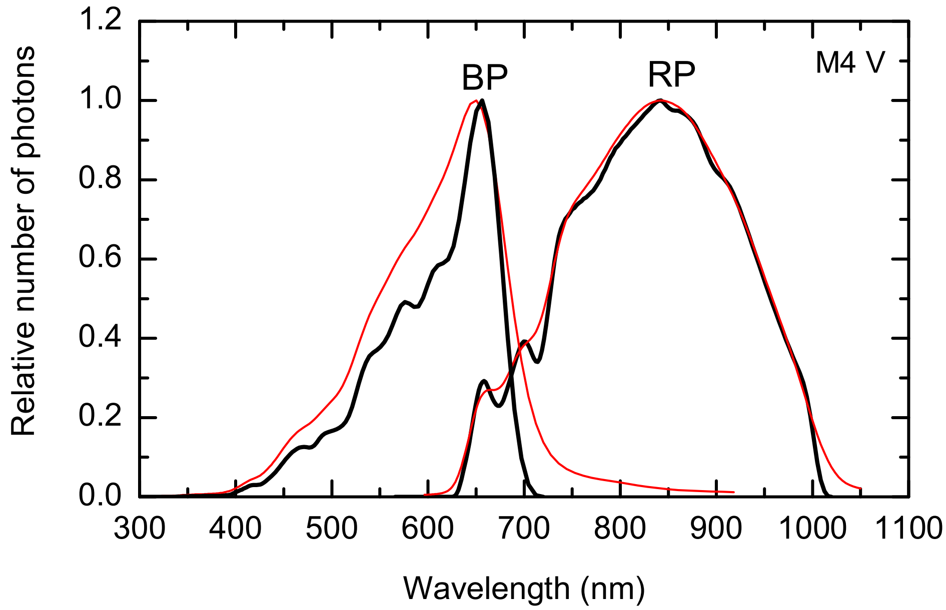

Fig. 7. The same as in Figure 1 but for M4 V type star.

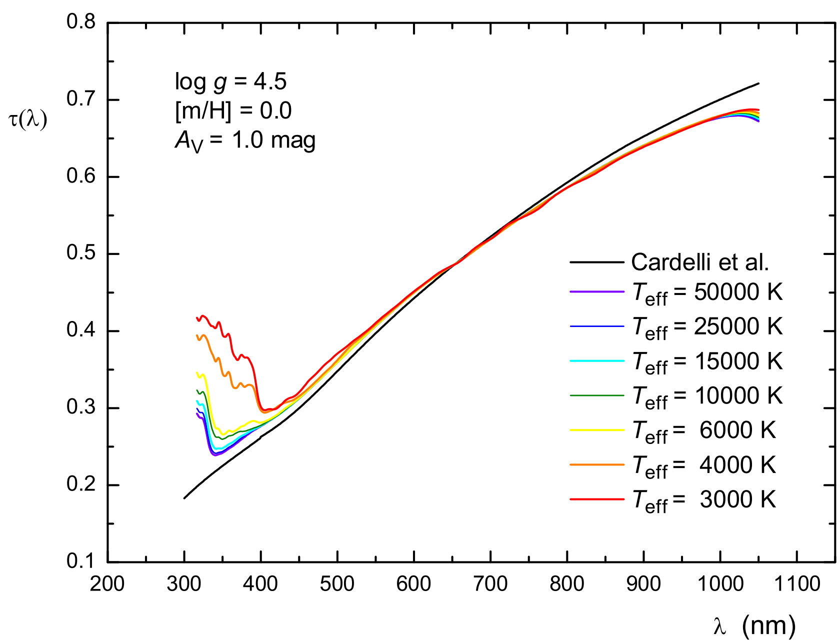

Fig. 8. The *Gaia* apparent interstellar extinction laws for different effective temperatures.

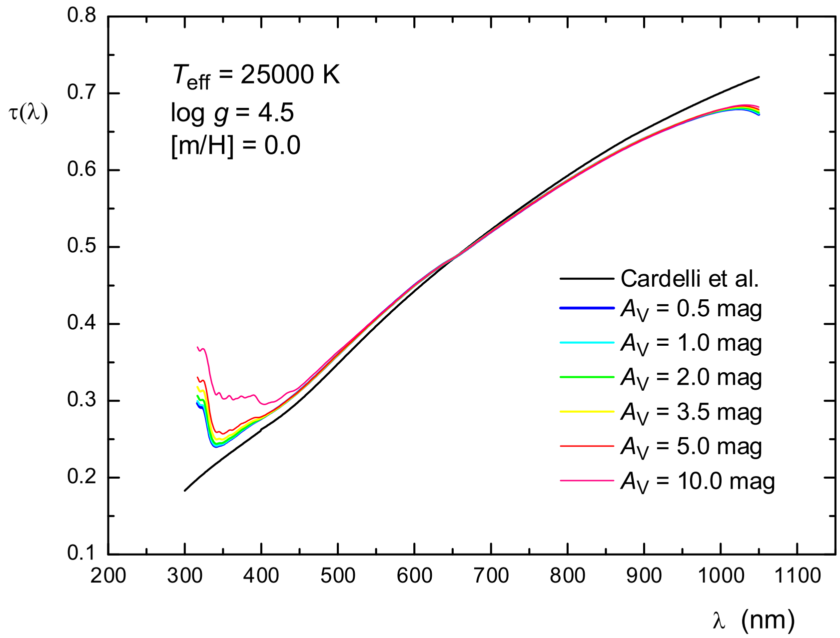

Fig. 9. The *Gaia* apparent interstellar extinction laws for $T_{\rm eff}$ = 25 000 K and different A_V values.

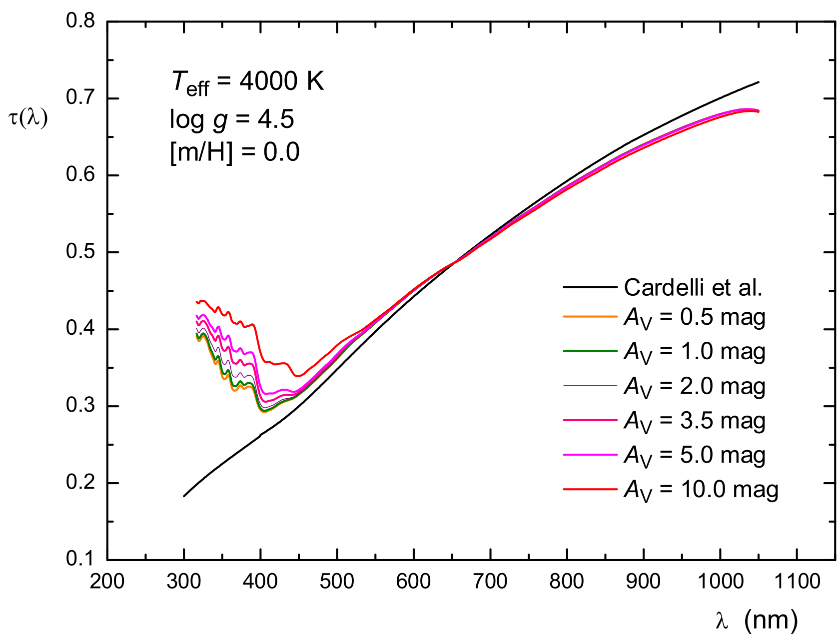

Fig. 10. The *Gaia* apparent interstellar extinction laws for $T_{\rm eff}$ = 4000 K and different A_V values.