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Interstellar polarisation towards a region around B5

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Abstract. Interstellar polarization was known to give information on the direction of galactic magnetic fields. Nowadays, the Gaia parallaxes and various photometric surveys allow the wavelength dependence of this polarization to provide even more information about the magnetic fields and dust grains. We consider the region of the interstellar medium towards the Bok globule Bernard 5 (B5, $l \approx 161°$, $b \approx -17°$). We performed a spectroscopic study of stars in this region at 0.7-m telescope of the Abastumani observatory. We carried out $UBVRI$ polarimetric observations of some of our stars at 1.25-m and 2.6-m CrAO telescopes and determined the parameters of the dependence of polarization on wavelength. Using stellar photometry and parallaxes available from recent sky surveys, we have estimated the visual extinction towards the observed stars. By analyzing the relationship between the parameters of the interstellar polarization and extinction for stars located at different distances and at different angular distances from the B5 globule, the structure and properties of the interstellar medium in the region under consideration are discussed.

Keywords: interstellar dust; polarisation; magnetic fields

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1 Introduction

Interstellar polarization is a phenomenon associated with two components of the interstellar medium (ISM)—cosmic dust and galactic magnetic fields—that are widely studied today. Although the phenomenon was independently discovered by Hall, Hiltner and Dombrovsky about 75 years ago, observational data on it is still quite scarce, especially with respect to its wavelength dependence. Nowadays, polarization changes near star-forming regions are of particular interest. Such data become more informative due to stellar photometry and parallax measurements that are now available.

2 Observations

We spectroscopically observed the stars surrounding the B5 globule at the Abastumani Astrophysical Observatory in 1990. Based on this data, we carried out a MK spectral classification of almost 50 bright stars.

A comparison between our results and other data is presented in Fig. 1. We find general agreement in the data, but some details should be noted. The standard work of Cannon and Pickering for HD/HDE stars agrees well with our results, with the exception of the A–F stars. More recent studies, collected in the well-known Skiff catalog, better correspond to our data. Note that our classes of A stars are on average two subclasses earlier than in other works, as shown by the dashed line in Fig. 1.

We also carried out the multi-wavelength polarimetric observations of about 20 of our stars at the Crimean Astrophysical Observatory (at the ZTSh in the $UBVR$ bands and at the AZT-11 in the $UBVRI$ ones) in the 1990s.

Our data on the wavelength dependence of the polarization degree $P(\lambda)$ were approximated by the Serkowski curve. Our fitting was performed using the Levenberg–Marquardt method. For most stars we did not have good enough data to estimate all three parameters of the curve ($P_{\max}$, $\lambda_{\max}$, K) and used the mean relation $K = 1.7\,\lambda_{\max}$ to rule out the curve width parameter K.

3 Photometric spectral classification

Today, one can derive the visual extinction A_V to the stars in different ways. For some reasons, we have selected our own method. We did not fix the parallax and resulting spectral type of our stars, but considered both as free parameters.

To determine the spectral type Sp, distance d and visual extinction A_V, we varird them to find a minimum of the residual between calculated X_n^{calc} and observed X_n^{obs}

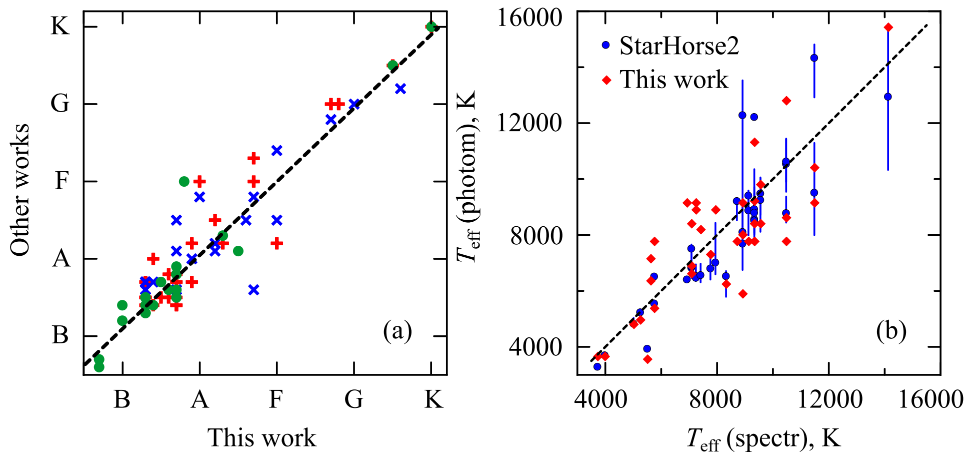

Fig. 1. A comparison of the spectral classification made in this and other works (a): (red) pluses correspond to HD/HDE, (blue) crosses of LAMOST DR7, and (green) circles for some mean classes from the Skiff catalog. A comparison of $T_{\rm eff}$ (b) derived from StarHorse2 (blue circles) and our (red rhombus) photometric classification and from spectral studies.

(with uncertainty σ_{X_n}) stellar magnitudes for $N_{\rm obs}$ bands:

$$\bar{\chi}^2 = \frac{1}{N_{\rm obs} - 3} \sum_{n=1}^{N_{\rm obs}} \left(\frac{X_n^{\rm calc}({\rm Sp}, A_V, d) - X_n^{\rm obs}}{\sigma_{X_n}} \right)^2 . \tag{1}$$

To calculate the stellar magnitude in an X band, we used the stellar absolute visual magnitudes, the mean intrinsic colours, and the mean galactic extinction curve as follows: $X^{\rm calc}({\rm Sp}, A_V, d) = M_V({\rm Sp}) - (V - X)_0({\rm Sp}) + A_X(A_V) + 5\log(d/10)$.

We applied this classification procedure to the photometric and astrometric data available for our stars. The results of our approach were compared to the data from StarHorse2 (Anders et al. 2022). We found that the results were generally consistent, and hence our approach applied to original photometric data (more accurate than in the surveys) can be useful.

We have also compared the values of $T_{\rm eff}$ obtained from spectral and photometric classifications and noticed a larger scatter in the regions of A5–G0 stars and earlier than B9 (see Fig. 1).

4 Discussion

We use our results to consider the relations between the extinction (A_V) and polarisation ($P_{\rm max}$, $\lambda_{\rm max}$, θ) parameters and the distance d to the stars (mostly located at $d = 70$–700 pc).

We deduce that there is no significant contribution of the Perseus molecular cloud complex ($d \sim 300$ pc) assumed in some works. So, we deal mostly with the only dust layer which is related to the Taurus molecular cloud complex (TMC, $d \approx 150$ pc). We find that in this layer $A_V = 0.6$–1.4 mag, $P_{\rm max} = 0.9 \pm 0.4\%$ changes randomly, while the position angle $\theta = 55° \pm 15°$ remains almost the same with an increase of d. Wavelength of the maximum polarization is also nearly constant $\lambda_{\rm max} = 0.53 \pm 0.04$ μm. We have compared the results with the estimates of these parameters made in other works that considered close parts of the TMC and found a reasonable agreement.

We have also confronted the obtained relation of the polarizing efficiency $P_{\rm max}/A_V$ on $\lambda_{\rm max}$ with theoretical analysis of Voshchinnikov et al. (2016). We find that in the considered part of the TMC the dust is typical of the diffuse interstellar medium, but the magnetic field is tilted more than 45 degrees to the plane of the sky. The low polarization efficiency we achieved cannot be explained by an overestimating of A_V, since this effect can increase $P_{\rm max}/A_V$ less than by 1.3 times.

5 Summary

We present the results of our spectroscopic and $UBVRI$ polarimetric observations of about 40 stars in a vicinity of the B5 globule. We have also performed photometric spectral classification of the stars to estimate A_V and compared its results with the data of the spectral study and other photometric classifications (like StarHorse2).

We find that for the majority of our stars interstellar extinction and polarization are formed in a dust layer related to the Taurus molecular cloud complex at $d \approx 150$ pc. Our results allow us to evaluate the parameters of this layer: $A_V = 1.0 \pm 0.4$ mag, $P_{\rm max} = 0.9 \pm 0.4\%$, $\lambda_{\rm max} = 0.53 \pm 0.04$ μm, $\theta = 55° \pm 15°$. They are in a reasonable agreement with the estimates made by other authors for close fields.

We have compared the derived correlation of the polarizing efficiency $P_{\rm max}/A_V$ and the maximum polarization wavelength $\lambda_{\rm max}$ with theoretical dependencies and suggested that the magnetic field in the layer makes an angle less than 45° with l.o.s. In more detail the results will be described by Krayani & Il'in (2024).

References

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