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Strömgren-Hβ photometry and optical polarization study of young open clusters

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Abstract. We combine stellar physical parameters derived from Strömgren-Hβ photometry with estimates of the total-to-selective extinction based on multi-wavelength polarimetry to study several young open clusters. This approach provides a more detailed stellar distribution of complex and heavily reddened regions. Our initial sample includes M 29, NGC 1502 and NGC 457.

1. Introduction

Homogeneous estimates of the basic parameters of stellar clusters yield useful information about the structure and chemical evolution of our Galaxy. Despite extensive studies, the distance determinations of many Galactic open clusters still need improvement. In addition, the main-sequence isochrone fitting that is often used to infer the clusters' age could be biased by assuming either an average value of the total-to-selective extinction ratio or solar metallicity. This is especially important for young objects located in star-forming fields of high and often differential extinction.

In our study we combine intermediate-band *uvbyβ* photometry with multi-wavelength polarization measurements of O and B-type stars in young Galactic clusters. This is expected to remove inconsistencies in extinction and distance determination, especially when the derived parameters are based on small samples of stars from the high-mass end of the main sequence. We use the wavelength of maximum polarization to calculate the total-to-selective extinction ratio for each star. Further, we combine these estimates with *uvbyβ* photometry to obtain improved individual stellar distances. This approach should result in a more detailed stellar distribution of the studied regions and provides more constraints on the derivation of the interstellar absorption and clusters' distance and age.

We have applied this approach to three young Galactic clusters with controversial distance estimates. NGC 457 is relatively young, but not associated with any prominent nebulosity, and appears isolated from the nearby Cassiopeia-Perseus star-forming complex. NGC 1502 is moderately reddened, located near the periphery of the Cam OB1 association. The almost vertical main sequence of this cluster leads to somehow varying distance determinations. There is also an indication of a lower value of the total-to-selective extinction for this region than the Galactic average. The situation is similar with the third cluster included in our study, NGC 6913 (M 29), located toward the Great Cygnus Rift within the boundaries of the Cyg OB1 association.

2. Observations, analysis and results

Polarimetric observations were obtained using the 0.5 m, $f/13.5$ Cassegrain telescope at the Virginia Military Institute (VMI) Observatory located at McKethan Park in Lexington, VA. The design and operation of the polarimeter, as well as a description of the data reduction procedure and mathematics of polarization, can be found in Topasna et al. (2013). A nonlinear fit of the multi-wavelength polarization measurements to the Serkowski equation $p(\lambda)/p_{max} = exp[-K \ln^2(\lambda_{max}/\lambda)]$ was used to determine p_{max} and λ_{max}, the maximum degree of polarization and the wavelength at which it occurs, respectively. The polarization measurements also provide the direction of the polarization vectors on the sky, which trace the Galactic magnetic field. Our results show that the measured polarization is fairly uniform for each cluster and the V-band polarization vectors are generally aligned in the direction of the Galactic plane at the location of the clusters.

The $uvby\beta$ data that we utilize come from current homogenized catalogs (Hauck & Mermilliod 1998; Paunzen 2015) and new homogenizations that we performed of existing photometry, or are based on new data obtained with the 0.9-m WIYN (Wisconsin Indiana Yale National Optical Astronomy Observatory) telescope. The $uvby\beta$ system is very resourceful in providing physical stellar parameters (Strömgren 1966). We apply the calibrations by Crawford (1978) and (Balona & Shobbrook 1984) to infer the individual color excesses and absolute magnitudes for all stars with available data in the fields of the studied clusters.

2.1. NGC 457

Polarization measurements of cluster's members yield a total-to-selective extinction ratio $R = 3.05 \pm 0.17$ for the field of NGC 457. Using this value and existing UBV and $uvby$ photometries (Pesch 1959; Fitzsimmons 1993) we obtain color excess $E(B-V) = 0.500$ mag and a distance of 2.75 ± 0.49 kpc. Assuming a slightly sub-solar metallicity we find an age of 15.8 Myr (Topasna et al. 2017).

2.2. M 29 (NGC 6913)

Based on observations performed with the 0.9-m WIYN telescope, we obtain new $uvby\beta$ photometry of about 50 stars in the field of this cluster (Kaltcheva et al. 2017). The polarization measurements of several probable cluster members provide a (still preliminary) estimate of the total-to-selective extinction ratio of 2.85 ± 0.23. M 29 is located in a low-extinction area, highly contaminated by cluster nonmembers.

2.3. NGC 1502

The study of NGC 1502 is based on a new homogenization of existing $uvby\beta$ data and on polarization measurements of most of the brightest cluster members, and results in an average $R = 2.83 \pm 0.14$ (Topasna et al., in preparation). Using B-type stars representing the main sequence of the cluster, we calculate a photometric distance of 1.1 ± 0.1 kpc and, assuming a solar metallicity, an age of 5 Myr.

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