

Polarimetric Approach towards Membership Probability

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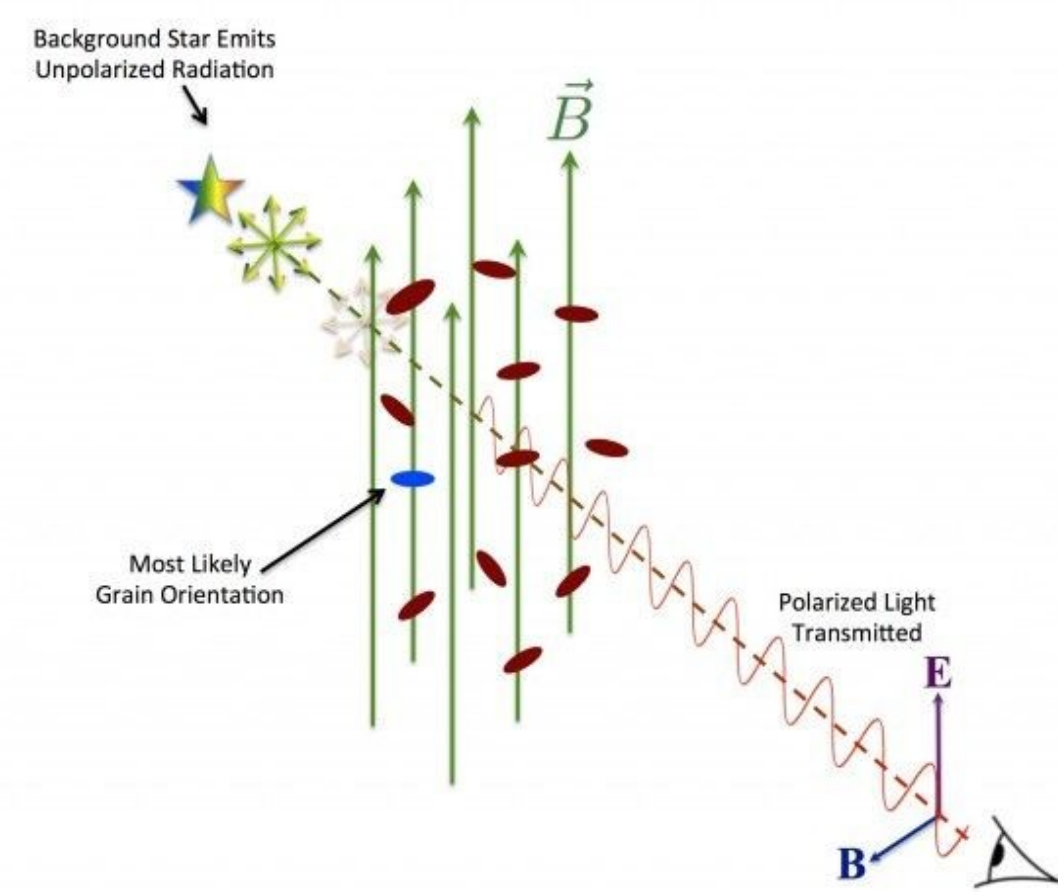
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1. Introduction

The polarization of a star depends on the column density of dust grains that lie in front of the star. The aligned asymmetric dust grains present in front of the star cause the dichroic extinction of the starlight, and hence, the light gets linearly polarized (as shown in Figure 1).



Cluster parameters	NGC 2345
R.A. (J2000)	07 ^h 08 ^m 18 ^s
Dec. (J2000)	-13°11'56"
Longitude (degree)	226.58
Latitude (degree)	-2.31
Age (Myr)	55-79
Distance (kpc)	2.2-3.0
Reddening [E(B - V)] (mag)	0.59-0.68
Core radius (arcmin)	4
Cluster radius (arcmin)	7
References	Kharchenko et al. (2005, 2013); Cantat-Gaudin et al. (2018, 2020)

Figure 1: Diagram for the most likely grain alignment in the interstellar medium and the process of polarized light (<http://bgandersson.net>).

Table 1: The basic parameters of open star cluster NGC 2345.

As the star clusters are formed from the same molecular cloud, the member stars of the cluster are found at similar distances. So, the member stars are expected to have more or less similar values of linear polarization. This principle is being used to extract the cluster membership (Medhi & Tamura 2013).

The polarimetric technique is being used for the estimation of the membership probability of proper motion member stars for the cluster NGC 2345. The basic parameters of the cluster are given in Table 1.

2. Instrument and Observations

- Polarimetric observations using the Aries IMaging POLarimeter (AIMPOL), mounted as a bank-end instrument at 104 cm telescope at ARIES.

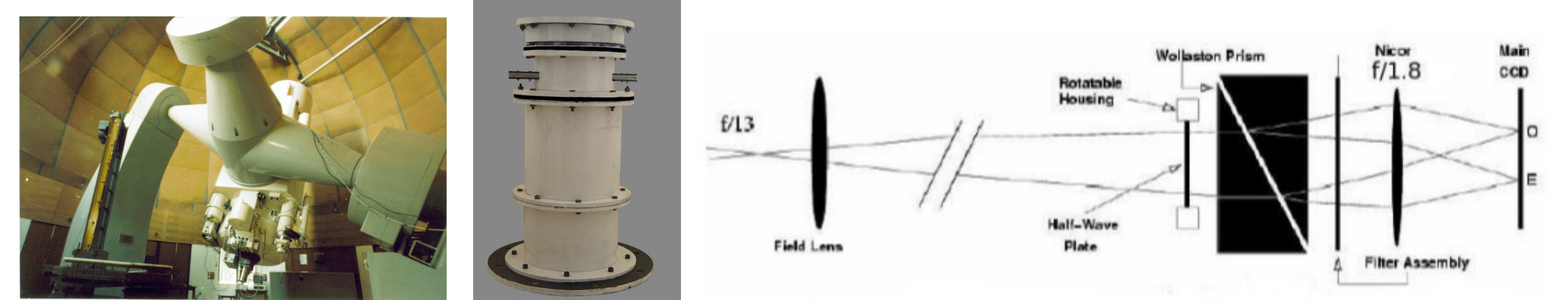


Figure 2: 104-cm Sampurnanand telescope (left), Aries polarimeter (middle), and optical layout of AIMPOL (right, Rautela et al. 2004).

Detector:	Array	Pixel size	Active field of view	Read noise	Gain
	1k X 1k	24μ x 24μ	8 arcmin in diameter	7.0 e ⁻	11.98 e ⁻ /ADU

- In four filters (B, V, R, and I) and at four positions of the half-wave plate (0°, 22°.5, 45°, 67°.5) along with the polarized and unpolarized standard star.
- Details about observations and data reduction methods are described in Rautela et al. (2004), Singh et al. (2020, 2022).

The proper motion cluster membership information for polarimetric observed stars in the cluster is taken from Cantat-Gaudin et al. (2018). We have considered only those stars as members of the cluster which have a membership probability (MP) ≥ 50 %.

3. Results

Distribution of polarization and position angle:

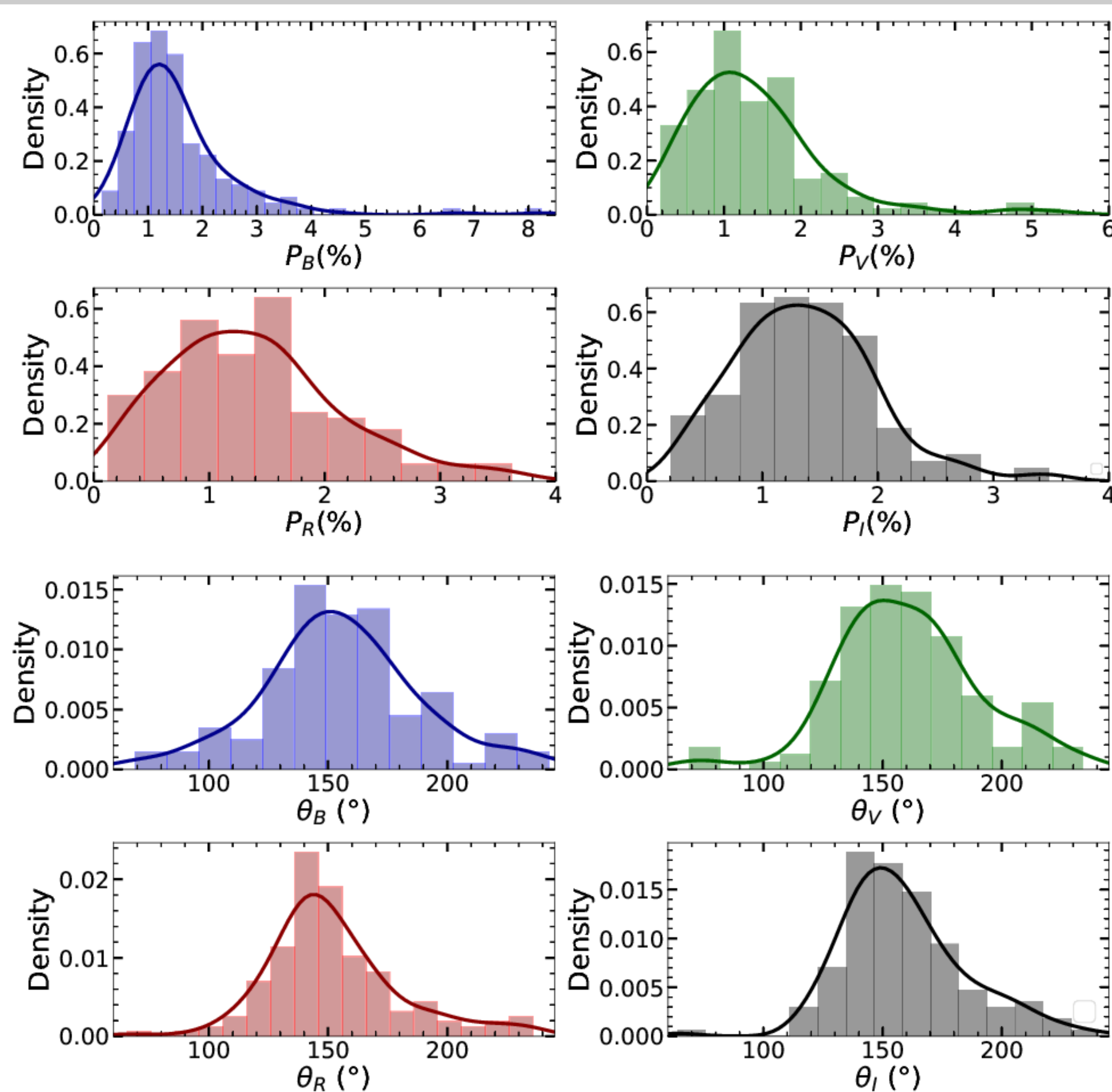
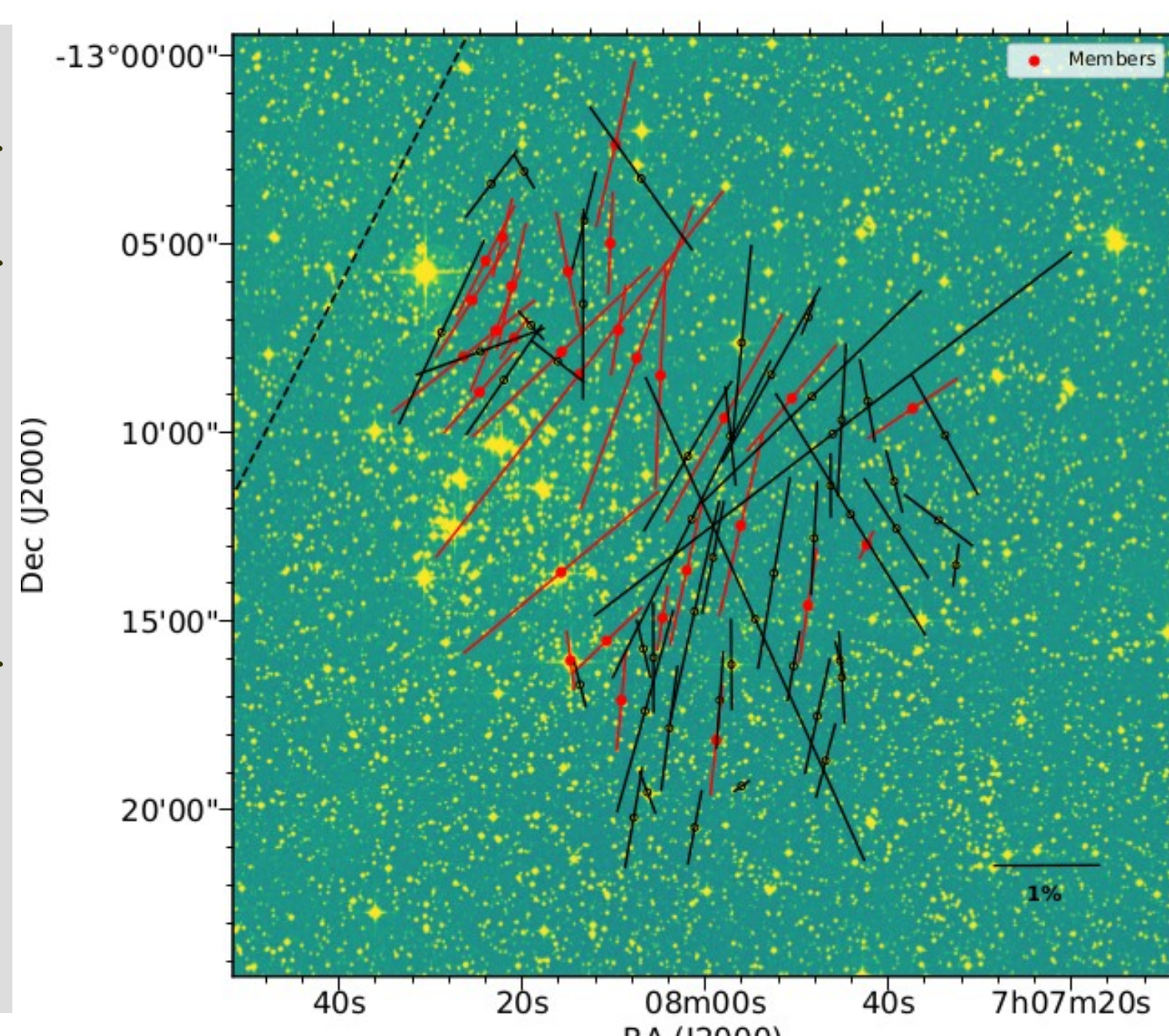


Figure 3: The distribution of the degree of polarization and polarization angle.

Sky projection of polarization vectors:

Figure 4: The V-band polarization vectors are overplotted on the 25' x 25' Digitized Sky Survey image of the cluster NGC 2345. The length of the vectors shows the degree of polarization and their tilt denotes the position angle. The reference length for 1% polarization is shown at the bottom right. The dotted line denotes the orientation of the projection of the Galactic Parallel (GP). The parallelism of polarization vectors with the GP indicates that dust grains are aligned with the Galactic magnetic field in the region of the cluster NGC 2345.



References:

- Cantat-Gaudin T., Jordi C., Vallenari A., et al. 2018, A&A, 618, A93
 Cantat-Gaudin T., Anders F., 2020, A&A, 633, A99
 Kharchenko N. V., Piskunov A. E., Roeser S., Schilbach E., Scholz R. D., 2005, A&A, 438, 3, 1163
 Kharchenko N. V., Piskunov A. E., Schilbach E., Roeser S., Scholz R. D., 2013, A&A, 558, A53
 Medhi B. J., Tamura M., 2013, MNRAS, 430, 1334
 Rautela B. S., Joshi G. C., Pandey J. C., 2004, Bull. Astron. Soc. India, 32, 159
 Sampedro L., Dias W. S., Alfaro E. J., Monteiro H., Molino A., 2017, MNRAS, 470, 4, 3937
 Singh S., Pandey J. C., Yadav R. K. S., Medhi B. J., 2020, AJ, 159, 99
 Singh S., Pandey J. C., Hoang T., 2022, MNRAS, 513, 4, 4899

Methodology for MP estimation:

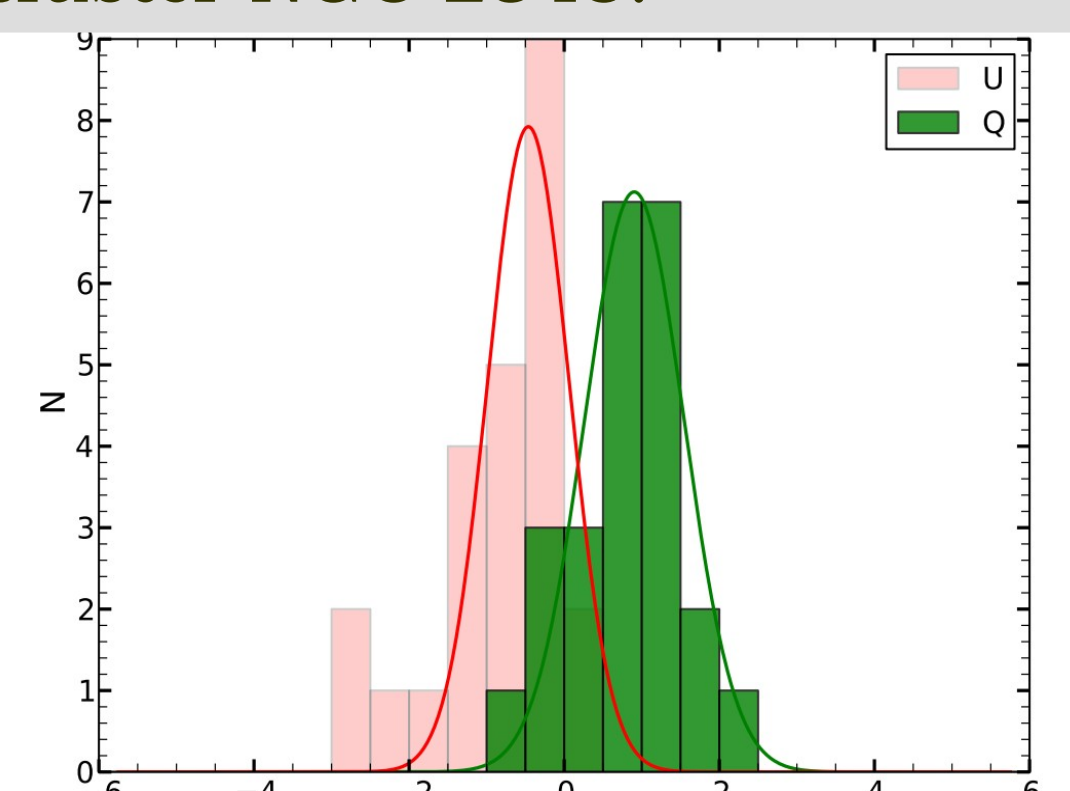
- As the cluster is best represented by its members, hence we have chosen stars with very high MP to represent the cluster, i.e. we have taken stars with mp > 90% to take as the cluster Stokes parameters.

- The mean value of Stokes parameters ($Q = P \cos 2\theta$, $U = P \sin 2\theta$) for the cluster is extracted by fitting the Gaussian curve to their distributions.

- The average deviation of the Stokes vectors Q and U of an individual star from the mean values of $Q_{cluster}$ and $U_{cluster}$ are calculated.
- Percentage scaling/calibration is performed using the full ranges of Stokes vectors.

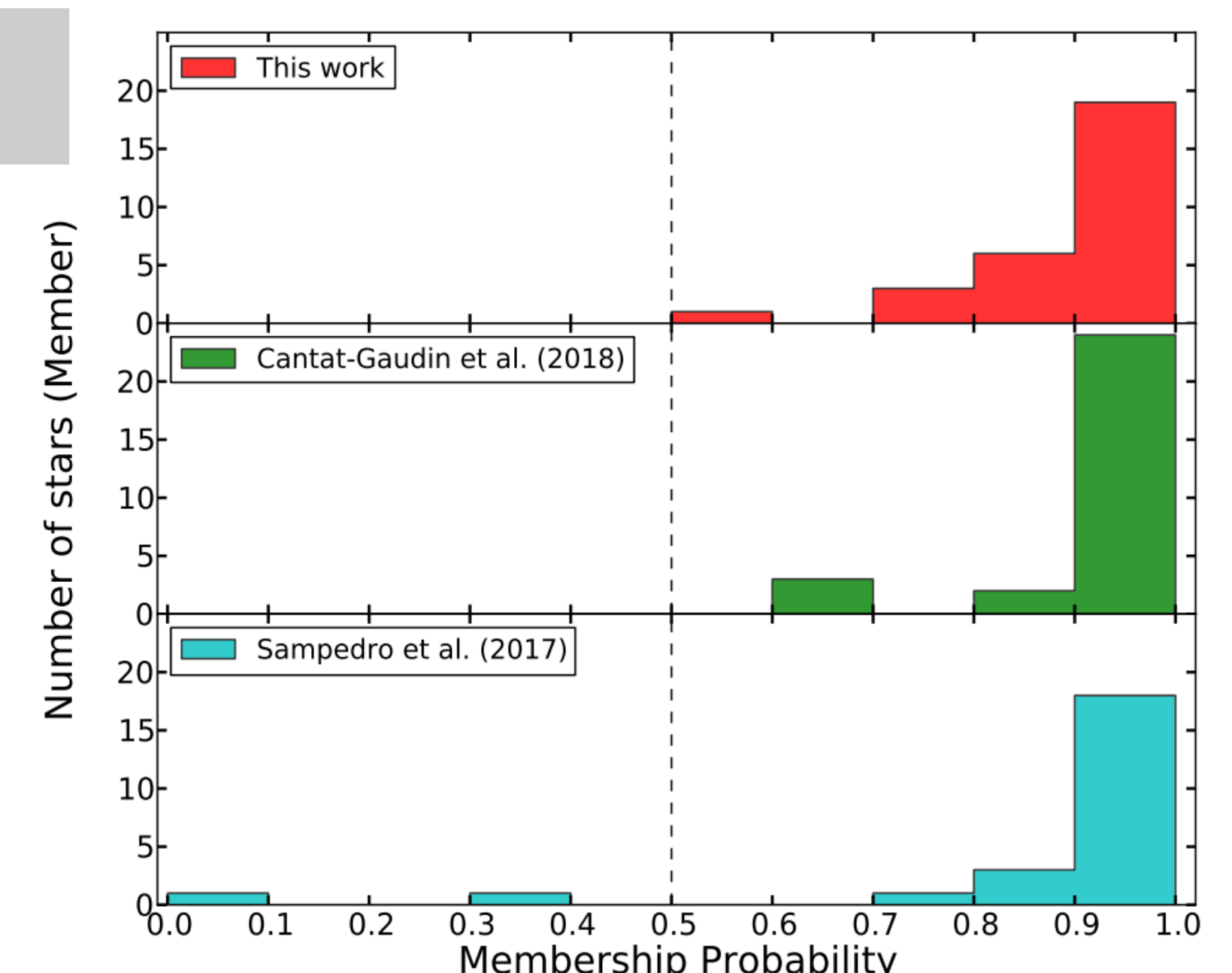
Hence, to estimate any individual star's cluster membership probability we compare the average deviation of the Stokes vectors with these ranges.

Figure 5: The distribution of Stokes parameters for members with MP > 90%. $Q_{mean_cluster} = 0.7636$, $U_{mean_cluster} = -0.8093$, for cluster NGC 2345.



Results of MP:

Figure 6: The MP's of members extracted using the polarimetric technique are compared with MP's from proper motion studies of those stars in previous studies [Cantat-Gaudin et al. (2018, in green) and Sampedro et al. (2017, in cyan color)].



4. Summary

- Using the polarimetric observations in the region of cluster NGC 2345, we found a single distribution of the degree of polarization and position angles in all four bands.
- The majority of polarization vectors are found nearly parallel to the direction of the Galactic parallel indicating the alignment of dust grains possibly with the Galactic magnetic field.
- We have calculated the membership probability of members of cluster NGC 2345 using the polarimetric technique and we found a good correlation between our results and previously estimated probabilities of members. Yet, there are some drawbacks to this technique because stars that have a component of intrinsic polarization may also show scattered distribution. The cluster with differential reddening may also influence the polarization and hence values of Stokes parameters.