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The Puppis OB III association: polarization measurements

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Abstract. Optical linear polarization measurements of association members and field stars in the region of the Puppis OB III association are presented. The association members are found to have larger values of polarization than the field stars.In the direction of the association there are two regions of polarizing interstellar medium with magnetic fields that are nearly at right angles to each other. The observed ratio of polarization to reddening for stars in this direction is about a factor of 3 smaller than the mean interstellar value indicating either a very poor efficiency of dust grain alignment, or a magnetic field configuration that is predominantly longitudinal.

Key words: stellar associations: Puppis OB III – polarization – dust, extinction

1. Introduction

From a study of the early-type stars in the region of the long-period cepheid RS Puppis, Westerlund (1963) suggested the existence of an OB association (Puppis OB III) in this direction (l = 254°, b = 0°) at a distance of about 1700 pc. The age of the association was estimated to be 4.10^6 yrs. It is situated in a volume of space that is rich in dust as well as gas. The association has an angular diameter of about 5 degrees and contains the emission nebulae Gum 10 = RCW 19 and Gum 11 = RCW 20 = NGC 2579 (Gum 1955; Rodgers, Campbell & Whiteoak 1960). In a wide latitude CO survey of the third galactic quadrant, May et.al. (1988) identified a molecular cloud feature at l = 254°, v= 35 km s^{-1} to be associated with Puppis OB III and the HII region RCW 19. The kinematic distance of this molecular cloud is 3.3 kpc.

Westerlund (1963) gave a list of 31 OB type stars brighter than $V = 11.7 mag$ within about 3 degrees from RS Puppis. From the colour - magnitude diagram for these stars, it was suggested that 23 of them are members of an OB association and the rest were assumed to be field stars. In this paper we present the results of optical linear polarization measurements of all the 31 stars in the list of Westerlund (1963). The association members are found to have higher values of polarization when compared with the field stars. We produce a polarization map for this region and study the relationship between the degree of polarization and reddening for stars in the direction of the OB association.

2. Observations

Polarization measurements were made on several nights between 1990 and 1993 with a fast star and sky chopping polarimeter (Jain & Srinivasulu 1991) at the Cassegrain focus of the 102 cm telescope at the Vainu Bappu Observatory, Kavalur, of the Indian Institute of Astrophysics. The instrumental polarization was determined by observing unpolarized reference stars from Serkowski (1974) and its average value was found to be ∼0.1%. It was subtracted vectorially from the measured polarization of the programme stars. The zero of the polarization position angle was determined by observing the polarized standard stars (Hsu & Breger 1982). The measurements were made in the $R(\lambda_{eff} = 0.70\mu m)$ filter.

3. Results

The results of our observations are presented in Table 1. For the identification of the programme stars we follow the numbering system in Table II of Westerlund (1963). The polarization position angles (of the electric vector) are measured from the celestial north pole increasing towards east in the equatorial coordinate system, and from the Galactic north pole in the direction of increasing galactic longitude in the galactic coordinate system. For stars numbered 13 and 22 the observed polarization is smaller than the probable error of the measurement and therefore the polarization position angle can not be determined. The entries in Table 1 are as follows:

Column1 : Programme star identification number
Column2 : Date of observation
Column3 : Degree of polarization
Column4 : Probable error in the degree of polarization
Column5 : Polarization position angle in equatorial frame
Column6 : Polarization position angle in galactic frame
Column7 : Probable error in the position angle
Column8 : Remark about membership of the association

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Table 1. Polarization measurements for stars in the region of the Puppis OB III association

Star No.	Date	p(%)	ϵ_p(%)	θ_{eq}(°)	θ_{gal}(°)	ϵ_θ(°)	Remark[†]
1	25 Jan 92	1.26	0.13	23	146	3	*
2	27 Jan 92	0.61	0.17	126	70	8	*
3	27 Jan 93	1.43	0.24	157	101	5	*
4	27 Jan 93	0.61	0.28	157	101	13	*
5	28 Mar 92	4.38	2.74	110	55	18	*
6	27 Jan 92	0.83	0.18	170	114	6	*
7	31 Dec 92	1.02	0.26	101	45	7	*
8	05 Feb 90	0.48	0.05	103	47	3	*
9	31 Dec 92	0.73	0.27	111	55	10	*
10	25 Jan 92	0.61	0.10	143	87	5	?
11	30 Mar 92	0.45	0.09	34	158	6	
12	07 Dec 91	0.73	0.18	94	38	7	*
13	25 Jan 92	0.08	0.14				
14	05 Feb 90	1.01	0.05	106	50	2	*
15	27 Jan 93	2.21	0.22	110	54	3	*
16	07 Dec 91	0.77	0.11	142	86	4	*
17	04 Feb 90	1.56	0.13	134	78	2	*
18	05 Feb 90	2.49	0.08	100	44	1	*
19	08 Dec 91	0.77	0.14	102	47	5	*
20	25 Jan 92	0.19	0.04	138	81	6	*
21	25 Jan 92	0.10	0.09	20	144	25	
22	25 Jan 92	0.05	0.10				
23	28 Mar 92	0.16	0.09	162	106	17	
24	25 Jan 92	0.09	0.04	44	168	12	
25	30 Mar 92	0.40	0.07	45	169	5	
26	25 Jan 92	0.24	0.07	155	99	8	*
27	31 Dec 92	0.62	0.41	159	103	19	*
28	30 Mar 92	1.06	0.21	36	161	6	*
29	27 Mar 92	0.83	0.22	117	62	8	*
30	27 Feb 93	1.72	0.14	120	65	2	*
31	25 Jan 92	1.13	0.10	136	80	3	*

[†] *An asterisk in this column indicates that the star was considered to be an association member by Westerlund (1963), and star 10 (marked ?) a possible member. The rest are field stars.*

For 8 of our programme stars (8,14,16,17,26,28,30 and 31) earlier polarization measurements (though in a different wave-band B, $\lambda_{eff} = 0.44 \mu m$) were made in a survey of southern early type stars by Klare & Neckel (1977). Our R band measurements generally agree with these fairly well in position angle; and are positively correlated for the degree of polarization. Because the wave-bands are different, an exact match is not expected.

4. Discussion

The observed polarization for the programme stars ranges from a negligibly small value of 0.05 % for star 22 to a value as large as $\sim 4\%$ for star 5. The polarization position angle also shows a large dispersion when all the stars are considered together. However, when the association members and field stars are considered separately the two groups of stars can be distinguished by their polarization behaviour. The association members (including star 10 that was considered a possible member by Westerlund (1963)) are characterized by a moderately high value of polarization. These stars have an average value of polarization $< p >= 1.14\%$ with a standard deviation σ_p = 0.89%. The average position angle $< \theta_{gal} >= 63°$ with a standard deviation σ_θ = 35°. Only 3 stars (numbered 8, 20 and 26) of the 24 have polarization $\lesssim 0.5\%$ but their position angles are similar to the other member stars. In contrast, the field stars have polarization values all $< 0.5\%$ with $< p >= 0.19\%$; σ_p = 0.16% and $< \theta_{gal} >= 149°$; σ_θ = 23°. This large standard deviation in the position angles is due to only one star (number 23). If star 23 is not included then the average position angle for field stars is 160° with σ_θ = 12°. Thus the association members and the field stars form two distinct groups. The histograms of the observed degree of polarization and position angles presented in Figs. 1 and 2 show this separation very clearly. The histograms are double peaked with the member stars and the field stars predominantly occupying the high polarization (with position angles in the range $\sim 50 - 100°$) and the low polarization (with position angles in the range $\sim 140 - 170°$) bins respectively.

The double peaked histograms discussed above indicate that in the direction of the Puppis OB III association there are perhaps

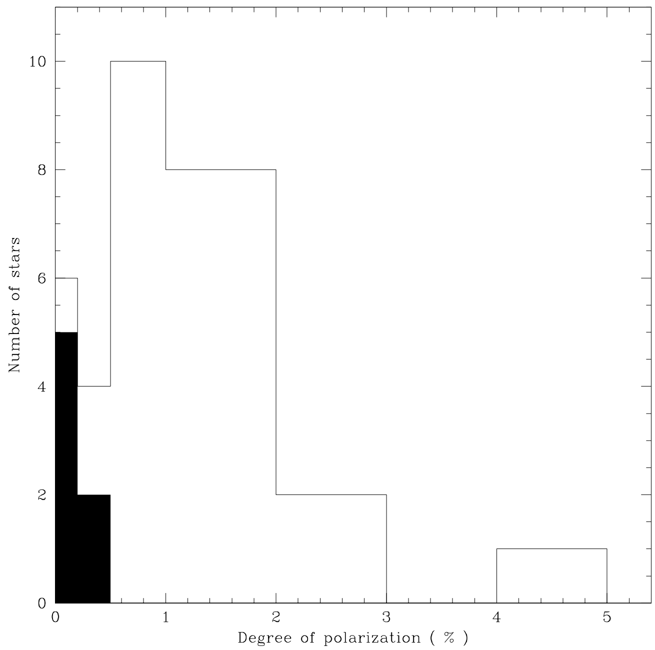

Fig. 1. Histogram of the degree of polarization measured for stars in the region of Puppis OB III association. The shaded area corresponds to the field stars.

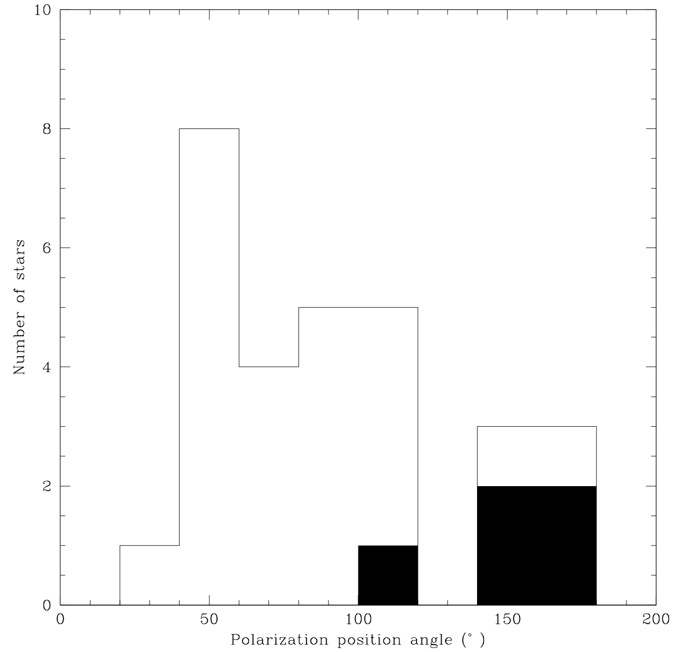

Fig. 2. Histogram of the polarization position angle (θ_{gal}) measured for stars in the region of Puppis OB III association. The shaded area corresponds to the field stars.

two distinct regions of obscuring interstellar matter. If the observed polarization is caused by dust grains aligned by the Davis - Greenstien mechanism, then the two regions of the interstellar medium are threaded by magnetic fields that are oriented (in the plane of the sky) very differently. The nearby field stars are polarized by a relatively thin region of obscuring matter with a magnetic field oriented at $\theta_{gal} \sim 160 \pm 12°$ and a thicker region (perhaps local to the OB association) with the magnetic field oriented at $\theta_{gal} \sim 63 \pm 35°$. The two field directions are almost perpendicular to each other. A polarization map (which also represents the geometry of the projected magnetic field in the region) is presented in Fig. 3, with the polarization vectors of lengths proportional to the degree of polarization measured and the direction parallel to the electric vector. The Galactic equator is also drawn for reference.

A plot of the observed polarization against the distance could give information on the location of the polarizing medium. However, the distances to individual stars are not well determined. The distance modulii $(m - M)$ that can be determined from the photometry for these stars given in Westerlund (1963) indicate that the field stars are all within $\sim 1kpc$. The association members must all be nearly at the same distance. However, we compute formal distance modulii (which can have considerable scatter) from the data given in Westerlund (1963). In Fig. 4 we plot the degree of polarization measured against the formal distance modulus for the programme stars as well as 14 additional stars within an angular radius of 3° around the star RS Pup for which measurements are available in the catalogue of polarization measurements by Mathewson, Ford, Klare, Neckel & Krautter (1978) available in the *Simbad* data base. It is evident from Fig. 4 that the degree of polarization jumps up at around $m - M = 11.5$. This implies the existence of a polarizing medium at $\sim 2kpc$, perhaps a system of dust clouds including RCW 19, 20 and the CO cloud detected by May et al (1988) related to the Puppis OB III association itself.

As expected for interstellar polarization the oberved degree of polarization shows a positive correlation with the reddening for these stars. Fig. 5 shows a plot of the degree of polarization measured by us against the colour excess E_{B-V} for the stars given in Westerlund (1963). There is much scatter, but larger values of polarization are generally observed for stars with larger values of reddening. For interstellar polarization a similar plot (Serkowski et al 1975) of polarization in the V band against E_{B-V} is well bounded on the polarization axis by a line $P_V/E_{B-V} = 9.0\% mag^{-1}$. In Fig. 5 also the points are bounded on the polarization axis. However, polarization measurements in the present work were made in the R band. For normal interstellar polarization, the wavelength dependence of polarization is well represented by the Serkowski law (Serkowski 1973): $\ln(P_\lambda/P_{max}) = -1.15 \ln^2(\lambda_{max}/\lambda)$, with $\lambda_{max} = 0.55\mu m$ corresponding to the V band. For interstellar polarization, the Serkowski law gives $P_R = 0.94 P_V$, and the line $P_R/E_{B-V} = 8.42\% mag^{-1}$ (drawn in Fig. 5 as a solid line) is expected to bound the points in the P versus $E(B-V)$ plot. However, the observed points in Fig. 5 are well bounded by the line $P_R/E_{B-V} = 2.83\% mag^{-1}$ drawn in the figure as a dotted line. Thus the average polarization to extinction ratio is 3 times *smaller* than the normal interstellar value. This may indicate a poor grain alignment efficiency in the direction of the Puppis OB III association. Alternatively, the low

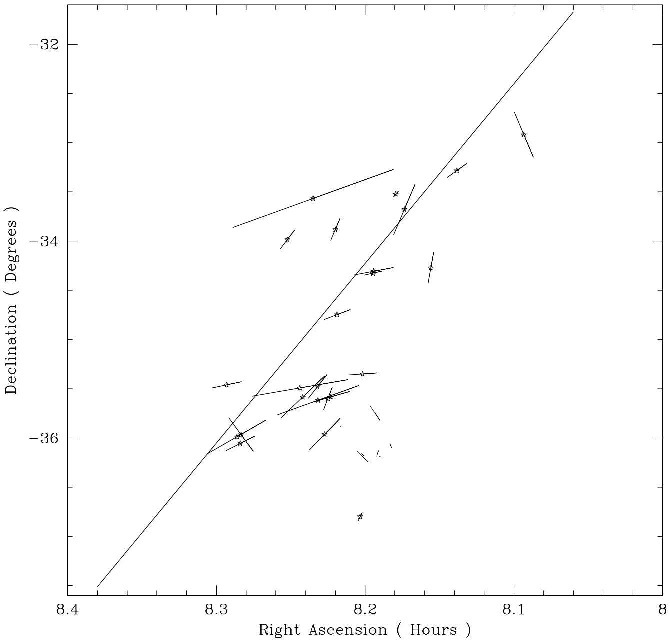

Fig. 3. Polarization map for the region of the Puppis OB III association. The Galactic equator is drawn as a solid line. The association member stars are distinguished from the field stars by the asterisks

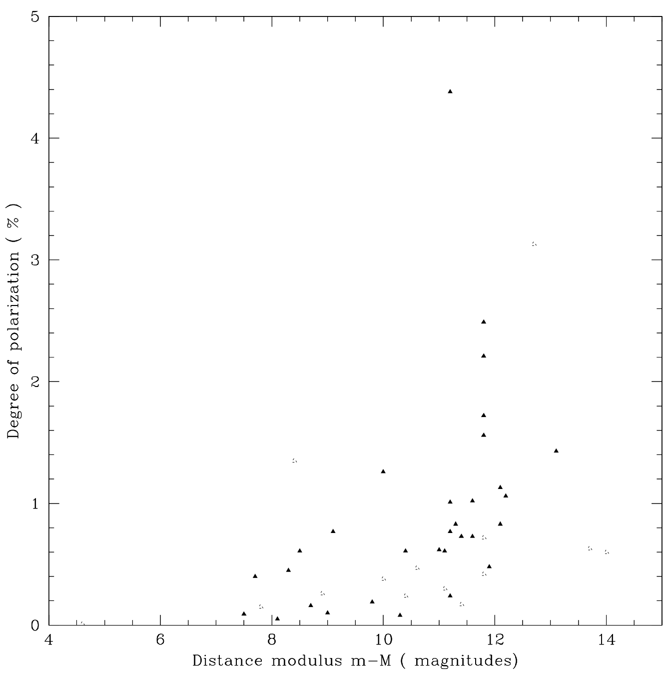

Fig. 4. Plot of the degree of polarization against the distance modulus for stars in the region of the Puppis OB III association.The filled triangles represent stars measured in this work, while the open triangles are used for stars from the *Simbad* data base

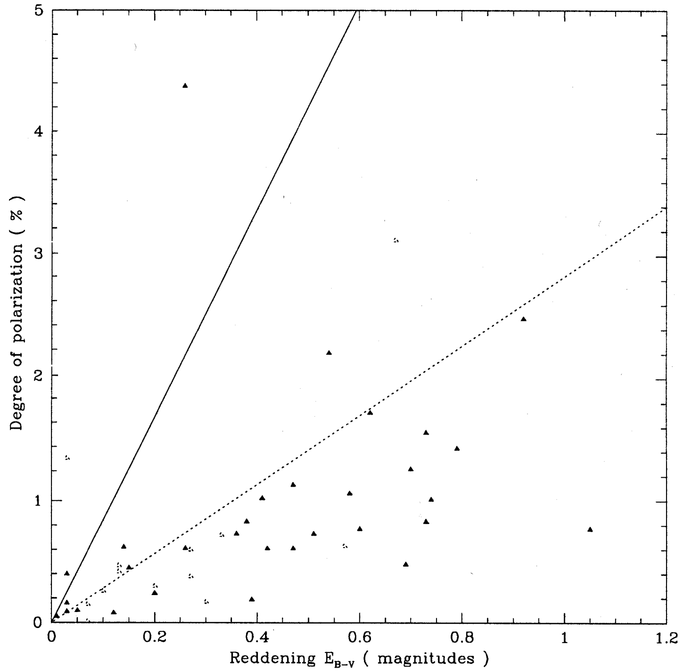

Fig. 5. Plot of the degree of polarization against the reddening for stars in the region of the Puppis OB III association. The dotted line P_R/E_{B-V} = 2.83 bounds the observed points on the polarization axis, while the solid line corresponds to that expected for normal interstellar polarization. The filled triangles represent stars measured in this work, while open triangles are used for stars from the *Simbad* data base

value of the polarization/reddening ratio could be a result of the magnetic field configuartion being predominantly longitudinal. At the galactic longitude (l = 254°) of the Puppis OB III association, this situation could arise if the magnetic field is parallel to the galactic spiral arm in that region. However, as seen in Fig. 5, the nearby field stars for which the projected magnetic field is nearly perpendicular to the galactic plane, also show low polarization /reddening ratio.

5. Conclusions

In this paper we have presented the results of optical linear polarization measurements of stars in the region of the Puppis OB III association. It is found that the association members can be distinguished from the field stars on the basis of their polarization characteristics. The association members are characterized by a relatively large degree of polarization (average $\sim 1\%$) at position angles (in the galactic frame) around 63° compared with the low values (average $\sim 0.2\%$) of polarization at position angles around $\sim$ 160° for the field stars.

In the direction of Puppis OB III association there are two discrete regions of polarizing interstellar matter threaded by magnetic fields oriented quite differently. In a low density region, causing only small amount of polarization in field stars in the solar neighbourhood (within $\sim 1kpc$) the field is oriented at large angles ($\sim$ 70°) to the Galactic plane, while a system of more dense clouds at a distance of $\sim 2kpc$ and probably related to the OB association itself, with the magnetic field more nearly parallel to the Galactic plane causes relatively larger polarization in the association member stars.

The ratio of polarization to reddening in the direction of the association is ~ 3 times smaller than the mean interstellar value. This indicates either a very poor efficiency of dust grain alignment, or a magnetic field configuration that is predominantly longitudinal in this region.

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