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Research Note

Polarization maps for the dark clouds B 227 and L 121

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Abstract. Optical linear polarization measurements for stars in the regions of the molecular clouds B 227 and L 121 are presented. The magnetic field geometry in the clouds as indicated by the polarization maps is discussed in relation to their morphology. In the outer parts of B 227 the field is more or less parallel to the long axis of the cloud while in L 121 it appears to be parallel to the short axis. The wavelength dependence of polarization for two stars in the region of B 227 is found to be anomalous.

Key words: polarization – interstellar medium – molecular clouds – magnetic fields

1. Introduction

Measurements of polarization of light from stars that are either embedded within or behind a cloud can be used to map the geometry (projected on to the plane of the sky) of the magnetic field in the cloud, assuming that the polarization is caused by non-spherical dust grains in the cloud aligned by the cloud magnetic field due to the Davis–Greenstein mechanism (e.g. Vrba et al. 1976; Goodman et al. 1990). The polarization vectors have the same direction as the projected magnetic field for this grain-alignment mechanism. A study of the polarization maps of dark (average extinction through the cloud $\gtrsim 1$ mag.) interstellar clouds in relation with their other properties, like the morphology (e.g. flattening), the direction of rotation and alignment of any bipolar outflows that may be present in the cloud, can help us understand better the role of the magnetic field in determining the structure and dynamics of these objects.

In this paper we present the results of polarization measurements for stars in the regions of the dark clouds Barnard 227 (B 227) and Lynds 121 (L 121). B 227 is the same as L 1570 in Lynd's catalogue (Lynds 1962). L 121 is a high-latitude molecular cloud (MBM 142; Magnani et al. 1985).

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2. Observations

Optical linear polarization measurements were made with the 1-m telescope at the Vainu Bappu Observatory, Kavalur, on the nights of 1991 February 18 and March 18 (B 227), and May 19-20 (L 121). A fast star-and-sky chopping polarimeter (Jain & Srinivasulu 1991) with an unfiltered dry ice-cooled EMI 9658R photomultiplier tube was used for the measurements. For two stars in the region of B 227 multiband (B, V, R, I) measurements were also made by using the Fernie (1974) combinations of Schott colour glass filters. The mean instrumental polarization, determined by observing several of the unpolarized standards in Serkowski (1974), was found to be 0.10% and has been subtracted from the measurements of the programme stars. The zero of the polarization position angles was determined by observing the polarized standards of Hsu & Breger (1982). An aperture of 15″ was used for all the observations. Typical integration time for the programme stars was $\sim$10–12 min.

3. Results

The results of our measurements for stars in the regions of B 227 and L 121 are listed in Tables 1 and 2 respectively. The dark cloud regions observed are shown in Figs. 1 and 2 reproduced from the Palomar Observatory Sky Survey (POSS) prints. The stars observed have been numbered in increasing order of right ascension. For programme stars that could be identified with stars in the SAO catalogue we give the SAO numbers in column 1 of the Tables 1 and 2. The other columns give the polarization P (in percent), the position angle θ (in degrees) and the standard errors ε_P and ε_θ associated with P and θ. The position angle θ is measured from north increasing eastward. In Figs. 1 and 2, centered

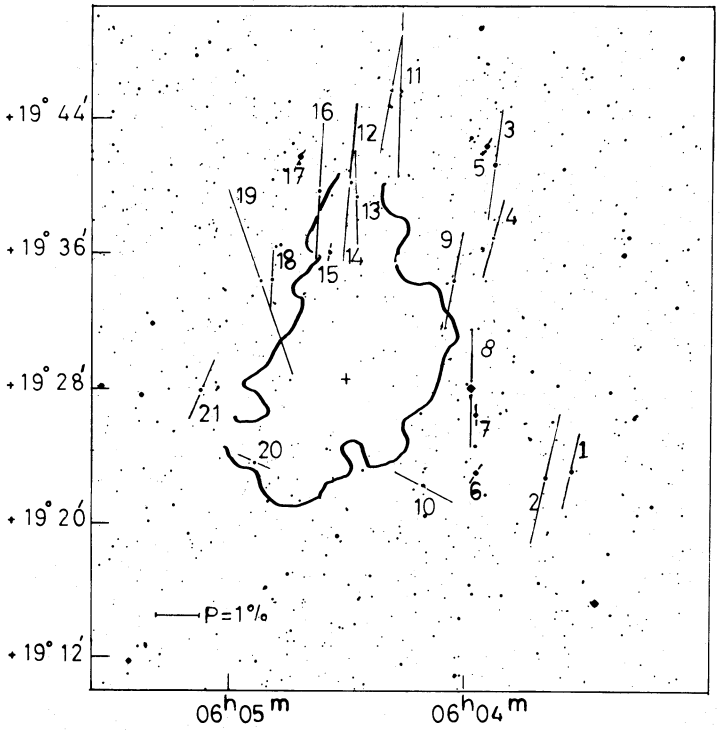

Fig. 1. Polarization map for the region of B 227. The solid curve shows the outermost contour of the CO map from Arquilla & Goldsmith (1985) and "+" marks the position of the CO emission peak

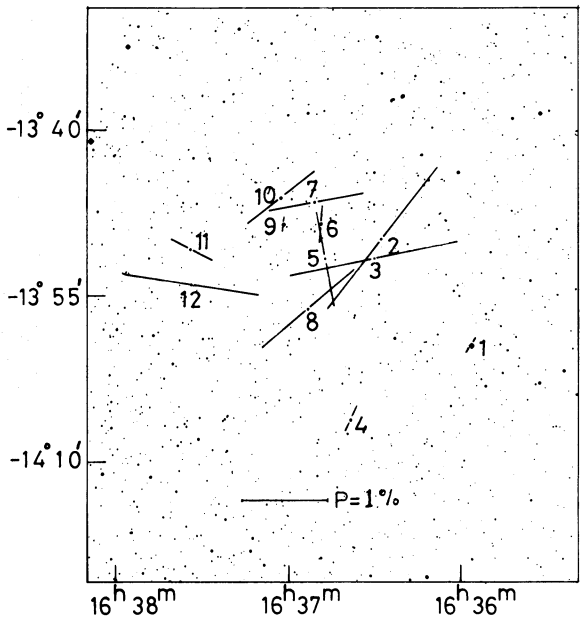

Fig. 2. Polarization map for the region of L 121

on the stars observed, the polarization vectors have been drawn. The length of the polarization vector is proportional to the percentage polarization P and it is oriented in the direction indicated by θ. Also shown in Fig. 1 is the outermost contour of the CO map of B 227 adapted from Fig. 1e in Arquilla & Goldsmith (1985). The contour corresponds to the ^{13}CO column density of $5\ 10^{14}\ \mathrm{cm}^{-2}$.

4. Discussion

The polarization maps shown in Figs. 1 and 2 represent the geometry of the magnetic field, projected on to the plane of the sky, in the regions of the clouds observed. We now discuss the results obtained for the individual clouds.

(i) B 227. This is a compact, elongated cloud (galactic co-ordinates: $l=190\overset{\circ}{.}63$, $b=-0.84\,^{\circ}$) whose major axis has a position angle 165° and has two infrared point sources in the IRAS Point Source Catalogue (IRAS 06047+1923 and 06048+1934) associated with it (Clemens & Barvainis 1988). Figure 1 shows that most of the stars observed lie close to or outside the CO contour. However, it should be noted that molecular clouds have atomic envelopes that are much larger in angular sizes. Our observations are thus limited to the lower opacity outer parts of the cloud where stars brighter than ~13 mag (a limit imposed by the telescope size and the instrument) can be seen projected. The polarization vectors for most of the stars in Fig. 1 are nearly parallel to the long axis of the cloud. Position angles for only two stars (numbered 10 and 20) out of a total of twenty one observed show polarization position angles that deviate significantly from the mean value. Excluding stars 10 and 20 the mean of the values for the position angles is $\langle\theta\rangle=171^{\circ}$ and the standard deviation $\sigma_{\theta}=12^{\circ}$. This value for $\langle\theta\rangle$ is nearly the same as the position angle (165°) of the long axis of the cloud. The mean value of the percentage polarization $\langle P\rangle$ for the 19 stars is 2.1, while the values of P for stars 10 and 20 are 1.5 and 0.91 respectively. These two stars with lower values of P and position angles very different from the mean value for the rest of the stars may be foreground to the cloud. We have no information on the distances to the stars observed. The distance to the cloud may be ~400–600 pc (Bok & McCarthy 1974; Arquilla & Goldsmith 1985). The nearest field star in the neighbourhood of B 227 at a distance similar to that of the cloud for which polarization measurements are available is HD 40862. For this star (at an angular distance ~4° from B227) Mathewson & Ford (1970) give: distance modulus $\Delta m=8.9$, $P=1.09\%$, $\theta=164^{\circ}$, while for two other nearby stars in this direction (HD 41753: $\alpha=6^{\mathrm{h}}04^{\mathrm{m}}\overset{\mathrm{m}}{.}8$, $\delta=14^{\circ}47'$ $\Delta m=5.9$; HD 42560: $\alpha=6^{\mathrm{h}}09^{\mathrm{m}}\overset{\mathrm{m}}{.}1$, $\delta=14\,^{\circ}13'$, $\Delta m=6.1$) they found $P=0.14\%$, $\theta=25^{\circ}$ and $P=0.12\%$, $\theta=35^{\circ}$. This suggests that foreground stars in the region of B 227 may be characterized by $P\lesssim 1\%$ and their θ values could show

Table 1. Polarization measurements of stars in the region of B 227. O – No filter

Star No. (SAO No.)	Filter	P (%)	ε_p (%)	θ (°)	ε_θ (°)
1 (SAO 95230)	O	1.85	0.08	167	1
2	O	3.13	0.16	168	1
3	O	2.67	0.13	172	1
	V	2.62	0.39	155	4
	R	3.01	0.21	166	2
	I	1.68	0.60	176	10
4	O	1.91	0.63	165	9
5	O	0.37	0.07	154	6
6 (SAO 95238)	O	0.54	0.06	149	3
7	O	0.46	0.10	1	6
8 (SAO 95239)	O	2.78	0.05	179	1
	B	3.78	0.39	176	3
	V	3.12	0.12	179	1
	R	2.80	0.07	174	1
	I	2.27	0.20	179	3
9	O	2.31	0.16	169	2
10	O	1.50	0.37	62	7
11	O	4.03	0.50	179	4
12	O	3.04	0.87	170	8
13	O	2.21	0.29	1	4
14	O	3.67	0.21	175	2
15	O	0.40	0.13	170	9
16	O	3.24	0.13	177	1
17	O	0.28	0.06	152	6
18	O	1.44	0.19	178	4
19	O	4.57	0.93	19	6
20	O	0.91	0.43	66	13
21	O	1.53	0.18	157	3

Table 2. Polarization measurements of stars in the region of L 121

Star No. (SAO No.)	P (%)	ε_p (%)	θ (°)	ε_θ (°)
1 (SAO 160022)	0.08	0.06	148	19
2	2.15	2.05	143	27
3	2.02	0.67	102	9
4	0.28	0.19	156	20
5	1.15	0.48	11	12
6	0.37	0.18	176	14
7	1.13	0.28	101	7
8	1.42	0.66	131	13
9	0.11	0.11	175	52
10	0.99	0.12	129	3
11	0.54	0.60	63	52
12	1.58	0.38	81	7

a very large dispersion. The dust in the cloud B 227 introduces additional polarization in the light of stars behind it at a level of ~1% to ~3% with a position angle ~171°. Similarity of the position angle $\langle\theta\rangle = 171°$ with $\theta = 164°$ for the nearby field star HD 40862 indicates that the magnetic field in the outer parts of the cloud has the same direction as the local interstellar magnetic field.

For two stars (3 and 8) in the region of B 227 polarization measurements in more than two wavelength bands are given in Table 1. Star 3 was measured in the *V*, *R* and *I* bands, while star 8 in *B*, *V*, *R* and *I*. It can be seen that for these stars the percentage polarization P varies with wavelength λ (effective wavelengths in μm for the *B*, *V*, *R*, *I* bands are 0.44, 0.55, 0.70, 0.90 respectively) while position angle θ does not show any significant variation. The wavelength λ_{max} at which the linear polarization is maximum (P_{max}) is a measure of the average grain size of the dust grains causing the polarization (e.g. McMillan 1978) and can be estimated for stars 3 and 8 by using the data in Table 1. A fit to the empirical law: $\ln(P_{max}/P_\lambda) = K \ln^2(\lambda_{max}/\lambda)$ (Serkowski et al. 1975) gives $\lambda_{max} = 0.65$ μm with $P_{max} = 3.11\%$ and $K = 5.8$ for star 3 and $\lambda_{max} = 0.46$ μm with $P_{max} = 3.40\%$ and $K = 0.78$ for star 8. Compared with $\lambda_{max} = 0.545$ μm and $K = 1.15$ for the mean interstellar medium (Serkowski et al. 1975) the values found here are anomalous. Values of λ_{max} larger than the mean interstellar value are not uncommon for dark cloud regions. For example, values for λ_{max} in the range from ~0.63 to ~1.1 μm have been found for stars in the region of the dark cloud B 5 (Bhatt 1986) and attributed to grain growth by accretion of condensable heavy elements from the gas in the cloud. $\lambda_{max} = 0.65$ μm for star 3 in B 227 may be similarly explained. However, star 8 has $\lambda_{max} = 0.46$ μm, a value smaller than the interstellar mean. This star (SAO 95239) is likely to be a foreground star as it is the brightest star in our sample. In the SAO catalogue it is listed as a star with spectral type G 5 and $m_v = 8.4$. For a main sequence star its distance would be only ~40 pc. But then the linear polarization observed for this star would be too large to be of interstellar origin and must be intrinsic.

(ii) L 121. This is a high galactic latitude molecular cloud with galactic coordinates: $l = 3\overset{\circ}{.}58$, $b = 21\overset{\circ}{.}03$. *It is elliptical in shape with the long axis at a position angle* 45°, and has an infrared point source IRAS 16371−1353 associated with its core (Clemens & Barvainis 1988). The polarization map (Fig. 2) and the distribution of the position angles show that the magnetic field geometry in the cloud is not uniform. For two stars (9 and 11) with relatively low values of polarization the errors in the position angle measurements are large. Excluding these two stars, the mean value of the position angle is $\langle\theta\rangle = 136°$ with standard deviation $\sigma_\theta = 33°$. The direction defined by the mean position angle $\langle\theta\rangle$ makes an angle $\simeq 90°$ with the long axis of the cloud, although the dispersion in the position angles is large. Thus the magnetic field in the cloud is more likely to be parallel to the short axis of the elongated cloud than to its long axis.

5. Conclusions

We have presented the results of linear polarization measurements for stars in the regions of the dark clouds B 227 and L 121. The polarization maps for these clouds indicate that:

(i) The magnetic field in B 227 is more or less unidirectional and nearly parallel to the long axis of the cloud, and has the same direction as the local interstellar magnetic field.

(ii) In L 121 the magnetic field appears to be less ordered. The statistics of observed polarization position angles, although rather poor, suggests that the mean field may be parallel to the short axis of this cloud.

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References

Arquilla R., Goldsmith P.F., 1985, ApJ 297, 436
Bhatt H.C., 1986, MNRAS 222, 383
Bok B.J., McCarthy C.C., 1974, AJ 79, 42
Clemens D.P., Barvainis R., 1988, ApJS 68, 257
Fernie J.D., 1974, PASP 86, 837
Goodman A.A., Bastien P., Myers P.C., Ménard F., 1990, ApJ 359, 363
Hsu J.C., Breger M., 1982, ApJ 262, 732
Jain S.K., Srinivasulu G., 1991, Opt. Eng. 30, 1415
Lynds B.T., 1962, ApJS 7, 1
Magnani L., Biltz L., Mundy L., 1985, ApJ 295, 402
Mathewson D.S., Ford V.L., 1970, Mem. R. Astron. Soc. 74, 139
McMillan R.S., 1978, ApJ 225, 880
Serkowski K., 1974, in: Gehrels T. (ed.) Planets, Stars and Nebulae Studied with Photopolarimetry. The University of Arizona Press, Tucson, Arizona, USA.
Serkowski K., Mathewson D.S., Ford V.L., 1975, ApJ 196, 261
Vrba F.J., Strom S.E., Strom K.M., 1976, AJ 81, 958