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Research Note

Interstellar polarization at high galactic latitudes from distant stars

V. First results for the South Galactic Pole

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Abstract. We present the first results of our interstellar polarization programme for the South Galactic Pole ($b < -70°$). The new observations (43 stars) combined with previously published data show that there is a substantial interstellar polarization in this area of the sky. Starting at a distance of 300 pc, we have found stars with $P > 0.3\%$ including one for which $P \approx 0.6\%$. These measurements lead to the conclusion that there is a significant amount of interstellar dust at high south galactic latitudes. Futhermore, there is a remarkable alignment seen over the South Polar Cap: for most stars the directions of polarization vectors are aligned with the longitude $l \approx 80°$, close to the expected direction of the global magnetic field. In this respect the SGP seems to differ strongly from its northern counterpart.

Key words. polarization – dust, extinction – solar neighbourhood

1. Introduction

The present paper continues our programme on the interstellar polarization at high galactic latitudes (by Berdyugin et al. 1995; Paper I, Berdyugin & Teerikorpi 1997; Paper II, Berdyugin et al. 2000; Paper III, and Berdyugin et al. 2001; Paper IV).

The aim of our investigation is to measure interstellar polarization in the North Galactic Pole (NGP, $b > 70°$) and in the South Galactic Pole (SGP, $b < -70°$) from observations of stars at intermediate (100–300 pc) and large ($d > 300$ pc) distances. The data are applied to determine the amount of interstellar extinction and the structure of the Galactic magnetic field in these areas, which are important in many ways for the study of our Galaxy and for extragalactic research. Papers I–IV were concerned with the NGP region, and we now discuss our first results obtained for the SGP zone.

2. Extinction and dust at high galactic latitudes

Our programme was inspired by the long-standing question about the exact amount of interstellar extinction at the Galactic Polar Caps. Different methods, such as those based on photometry, galaxy counts, H I measures etc., often give controversial or inconclusive results (see Paper I for details). Stellar reddenings obtained by use of multicolor photometry usually imply very low, even negligible, extinction which assumes that these areas are essentially free of dust. However, as Appenzeller (1975) already pointed out, despite that, "the stars at both galactic poles are known to be appreciably polarized". The older polarization measurements were restricted to distances closer than 200 pc, dealing with stars near the galactic plane. Our observations made with the NOT for the NGP have extended the distance scale well beyond 300 pc, showing that there is a substantial amount of dust even at much larger Z.

Stellar reddenings are influenced by a Malmquist-like bias (Teerikorpi 1990) and could be influenced by the uncertanties in the calibration of intrinsic stellar magnitudes and colours (see, for example, McFadzean et al. 1982). Polarization measurements are free from these effects and they can provide an estimate of the lower limit of extinction by utilizing the well-known Serkowski's law: $P \leq 3.0A_V$, (Serkowski et al. 1975). It is also interesting that Appenzeller (1968), on the basis of his rather scarce data, concluded that there is a difference in the directions of the magnetic fields in the NGP and the SGP. We intend to check this proposition in our polarization programme.

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Table 1. Polarization of stars in the area of the South Galactic Pole

Star	P	$\sigma_{\rm P}$	$\theta°$	σ_θ	d(pc)	l	b	Sp
HD 5867	0.38(V)	0.05	125	3	365	159.67	−86.81	G8IV
HD 6001	0.57(V)	0.05	128	3	290	165.85	−86.78	F5V
HD 5766	0.16(B)	0.02	133	2	333	150.00	−86.15	F5/F6V
HD 4339	0.14(B)	0.02	135	5	272	110.20	−83.95	F2V
HD 4273	0.19(B)	0.03	123	4	333	113.98	−79.99	K1III
HD 2066	0.07(R)	0.01	139	6	338	86.27	−79.40	K3III
HD 9435	0.07(B)	0.02	125	6	347	176.37	−77.98	F6V
BD-16.115	0.16(V)	0.03	129	4	318	110.43	−77.94	K5
BD-18.38	0.18(B)	0.02	142	2	340	82.18	−77.69	G0
HD 995	0.19(B)	0.02	145	3	309	78.89	−77.09	B4V
HD 3256	0.16(B)	0.03	145	5	306	105.62	−77.07	A1V
HD 2693	0.17(V)	0.05	137	8	317	99.76	−77.04	K0III
HD 730	0.23(B)	0.03	146	3	298	75.80	−77.03	K0IV
HD 5202	0.20(V)	0.04	127	6	355	125.34	−76.78	G8III/IV
BD-16.45	0.17(B)	0.02	138	2	296	87.21	−76.56	G0
HD 6969	0.16(V)	0.03	138	6	437	142.38	−76.42	K0III/IV
HD 6426	0.19(B)	0.04	122	6	306	136.99	−76.26	K0III
HD 10558	0.06(B)	0.02	124	8	326	182.06	−75.94	G6IV
HD 9158	0.17(B)	0.05	147	8	415	163.01	−75.51	K4III
HD 6442	0.15(V)	0.02	117	4	312	135.97	−74.94	F0V
HD 2213	0.33(B)	0.02	135	1	313	98.41	−74.90	F0V
HD 8445	0.17(V)	0.02	129	4	316	154.07	−74.82	F6IV
BD-17.306	0.13(B)	0.02	131	4	285	174.89	−74.20	F5
HD 11132	0.11(B)	0.02	140	5	345	181.46	−73.87	F6V
HD 666	0.16(B)	0.04	134	8	444	85.34	−73.74	K1/K2III
HD 3127	0.17(B)	0.03	137	5	408	107.92	−73.66	K0
HD 3400	0.24(V)	0.05	149	5	313	110.14	−73.64	G5
HD 9930	0.16(V)	0.02	126	3	500	164.89	−73.44	A1V
HD 1036	0.30(V)	0.04	134	4	331	90.24	−73.24	K0IV
HD 10584	0.12(B)	0.04	145	9	337	169.07	−72.56	K4III
HD 11080	0.08(R)	0.02	133	6	362	172.91	−71.84	K5III
HD 2335	0.33(B)	0.04	141	3	312	103.40	−71.82	G5
HD 2305	0.24(B)	0.04	126	5	382	104.97	−71.48	G5
HD 2658	0.17(B)	0.02	140	3	329	106.23	−71.41	A2
HD 10174	0.21(B)	0.03	128	4	304	161.93	−71.19	G8III
HD 225088	0.32(B)	0.04	142	3	296	83.98	−71.08	K1III
HD 1833	0.22(V)	0.05	136	6	417	100.87	−70.86	G5
HD 4781	0.19(R)	0.03	139	5	316	121.66	−70.72	K0
HD 12628	0.00(R)	0.03			333	185.40	−70.54	A7V
HD 8877	0.21(B)	0.04	146	5	313	150.13	−70.24	K0
HD 11389	0.10(V)	0.03	108	9	408	171.29	−70.22	K4III
HD 12065	0.08(V)	0.02	150	7	334	177.74	−70.17	G8III/IV
HD 13459	0.14(R)	0.02	169	4	370	194.00	−70.12	K2III

2.1. Extinction estimates for the SGP area

Early photometric investigations made by Knude (1977), Albrecht & Maitzen (1980) and Nicolet (1982) give $E(b-y) \approx 0.02-0.04$, $(E(B-V) = 1.35 \times E(b-y))$. The later measurements by McFadzean et al. (1982), which were based on a larger star sample and better photometric calibration, gave a much smaller, essentially zero value: $E(b-y) = -0.004 \pm 0.003$. Fong et al. (1987), using deep galaxy counts, H I measures and IRAS fluxes, have found an average variation in $E(B-V)$ over the SGP of only about 0.002–0.005 mag, except in one particular small area where $E(B-V)$ variation had a peak about of 0.02 mag. Eggen (1995) from his photometry of stars within 10° radius around the South Galactic Pole has derived the average reddening $E(b-y) \approx 0.04$. Appenzeller (1975) using polarization data available at the time, estimated $E(B-V) \approx 0.03$.

3. New polarization measurements

New polarization measurements were obtained during September-October 2000, with the 2.6 m Nordic Optical Telescope (NOT, 33 stars) and 60 cm Kungliga Vetenskapsakademien telescope (KVA, 10 stars), both equipped with identical copies of the $UBVRI$ photopolarimeter (Korhonen et al. 1984; Piirola 1988). The observation techniques and data reduction procedure are described in detail in Papers I and II. Polarization data are given in Table 1. The table entries are as follows.

Column 1: Star identification. HD or BD number.
Column 2: P, the polarization percentage. The passband is given in brackets.
Column 3: σ_P, the error of the polarization.
Column 4: θ, the position vector of polarization measured in the equatorial coordinate frame.
Column 5: σ_θ, the error of position angle measurement.
Column 6: d(pc), star distance, in parsecs. All distance estimates were obtained from HIPPARCOS (Perryman et al. 1997).
Column 7 and 8: Galactic longitude and latitude, (l^{II}, b^{II}).
Column 9: Sp, the spectral type.

Our choice of stars for the first observational run was dictated by their visibility at La Palma at this time of the year. For this reason the new polarization data are restricted to the sector $60° < l < 180°$. The distance range for our sample was intentionally chosen as 300–500 pc, as we were interested to see how large the polarization is at higher Z, where the old measurements are very scarce. In the future we plan to complement our investigation with stars located in the remaining area of the SGP, probing also closer ($d < 300$ pc) and larger ($d > 500$ pc) distances.

4. Interstellar polarization in the SGP area

The first polarization measurements of the stars in the SGP were published by Appenzeller (1968) who produced for the first time the polarization map of the area restricted by $45° < l < 195°$ and $-70° < b < -80°$. As he found, directions of the magnetic field lines in the SGP and NGP are different. Data on interstellar polarization in the SGP can be also found in Mathewson & Ford (1970) and Korhonen & Reiz (1986). All these measurements concern mostly bright and close ($d < 300$ pc) stars. It seems that these data have never been combined for a comprehensive analysis. We used the old measurements and our new data to produce a polarization vs. distance diagram and a new polarization map for the SGP area. Selecting the stars from the mentioned publications, we have applied the accuracy criterium which has been used in our previous papers: only the data with $P > 2\sigma_P$ are taken. Under this restriction the error in the derived direction angle of polarization is $\leq 14°$. We also assume that if P and σ_P are both <0.05 then $P = 0.0$.

4.1. Polarization vs. distance

Figure 1 shows the polarization vs. distance dependence for the SGP, which includes all available data. One can see an obvious trend of polarization increase with the distance even up to 300 pc. In fact, there is only one star at distance >300 pc with $P \approx 0.0$. Most stars from our sample are significantly polarized ($P > 0.1$), some stars have $P > 0.3$ and there is a star - HD 6001 with $P \approx 0.6$. One can see from the figure that the amount of dust in the line-of-sight definitely increases with distance up to at least 400 pc. It is interesting to note that HD 6001 and HD 5867 (with $P = 0.38$) are both located in the area where Fong et al. (1987) found a peak in the 100 μm flux and their polarization vectors are co-aligned within 3°. Note also the sharp upper envelope for the data points. It is tempting to speculate that it gives the limiting case of Serkowski's law, implying that in these directions the magnetic field lines and dust grains are especially well aligned.

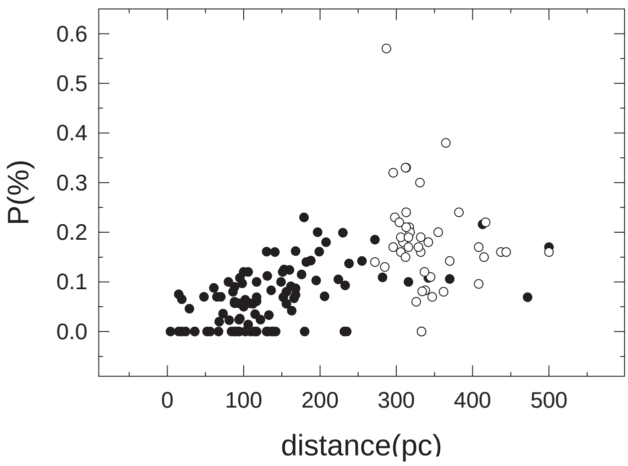

Fig. 1. Polarization vs. distance dependence in the SGP area. The new data are plotted with open circles

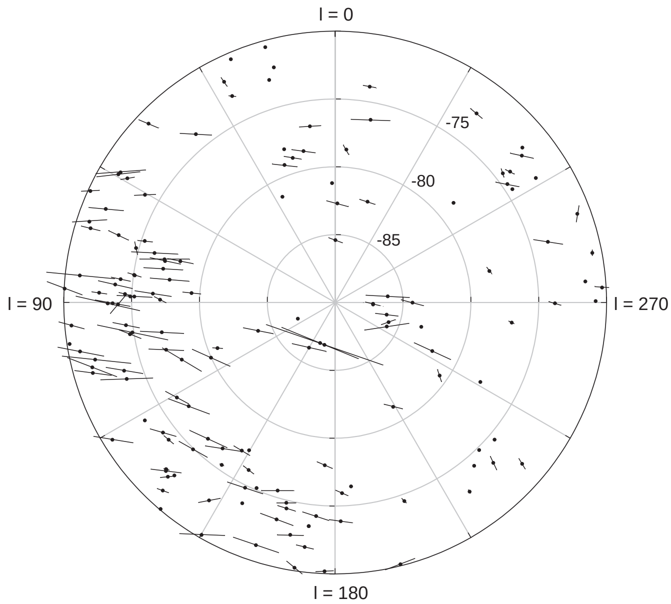

Fig. 2. Polarizations of the stars around the SGP. The length of the bar gives the amount of polarization, its direction gives the direction of the polarization plane

4.2. Polarization map

Figure 2 shows the new map of interstellar polarization around the SGP. Obviously, this map still suffers from undersampling in the area outside of $60° < l < 180°$.

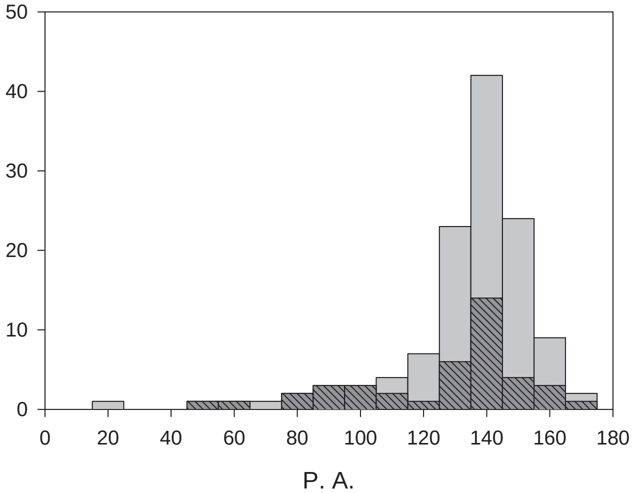

Fig. 3. Distribution of the equatorial position angle of polarization of stars around the SGP. Histogram for the stars outside the area $60° < l < 180°$ is shown by shaded bars. The maximum at 140° corresponds to the direction of 83° in the galactic coordinate frame

Nevertheless, the most distinctive feature of the map is the preferred direction of the polarization vectors: most of them are aligned with longitude $l \approx 80°$. Figure 3 shows the distributions of the polarization vectors by their orientation over the whole SGP area and ouside of the $60° < l < 180°$ sector. Both histograms have a maximum at 140°, which in the galactic coordinate frame corresponds to $l = 83°$. Therefore, the galactic magnetic field lines in the studied area have quite similar and regular directions. This is not the case for the NGP, where we have found several distinctly different field orientations (Paper III). Of course, the detailed structure of the magnetic field lines in the SGP zone is yet to be determined, as the largest part of this area is still poorly studied.

5. Conclusions

Our first results on interstellar polarization in the SGP area, although preliminary, allow us to draw the following important conclusions: 1) there are substantial amounts of dust in this part of the sky even at distances beyond 300 pc. At the distance of 400 pc the upper envelope of the interstellar polarization approaches 0.4% which implies a lower limit for $E(B-V) \geq 0.045$ mag. In the area around $l \approx 165°, b \approx 86°$ polarization reaches a peak of 0.6%, or $E(B-V) \geq 0.066$ mag. 2) Another remarkable feature is the alignment of polarization vectors in the area $60° < l < 180°$. A signature of this alignment also can be seen outside this sector, over the remaining part of the SGP zone. We can conclude that magnetic field lines in the South Polar Cap seem to have a strongly uniform pattern – they are directed with $l \approx 80°$, which is close to the expected direction of the global galactic magnetic field. In this respect the SGP differs strongly from its northern counterpart, where only a weak hint of this direction can be seen (Paper III).

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References

Albrecht, R., & Maitzen, H. M. 1980, A&AS, 42, 29
Appenzeller, I. 1968, ApJ, 151, 907
Appenzeller, I. 1975, A&A, 38, 313
Berdyugin, A., Snåre, M.-O., & Teerikorpi, P. 1995, A&A, 294, 568, Paper I
Berdyugin, A., & Teerikorpi, P. 1997, A&A, 318, 37, Paper II
Berdyugin, A., Teerikorpi, P., & Haikala, L. 2000, A&A, 358, 717, Paper III
Berdyugin, A., Teerikorpi, P., Haikala, L., et al. 2001, A&A, submitted, Paper IV
Eggen, Olin, J. 1995, AJ, 109, 229
Fong, R., Jones, L. R., Shanks, T., et al. 1987, MNRAS, 224, 1059
Knude, J. 1977, Astrophys. Lett., 18, 115
Korhonen, T., Piirola, V., & Reiz, A. 1984, ESO Messenger, No. 38
Korhonen, T., & Reiz, A. 1986, A&AS, 64, 487
Mathewson, D. S., & Ford, V. L. 1970, Mem. R. Astron. Soc., 74, 139
McFadzean, A. D., Hilditch, R. W., & Hill, G. 1982, MNRAS, 205, 525
Nicolet, B. 1982, A&AS, 47, 199
Perryman, M. A. C., Lindegren, L., Kovalevsky, J., et al. 1997, A&A, 323, L49
Piirola, V. 1988, in Polarized Radiation of Circumstellar Origin, ed. G. V. Coyne, et al. (Tucson, Univ. of Arizona Press), 735
Serkowsi, K., Mathewson, D. S., & Ford, V. L. 1975, ApJ, 196, 261
Teerikorpi, P. 1990, A&A, 235, 362