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Research Note

Interstellar polarization at high galactic latitudes from distant stars

II. Evidence for depolarization starting at $Z \approx 600$ pc

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Abstract. We have measured linear polarization for 20 distant high latitude A and F stars, as a first step to extend our previous study (Berdyugin et al. 1995: Paper I) of the North Galactic polar cap to distances larger than 600 pc. The results give tentative evidence for depolarization starting to be seen around $Z \approx 500$ pc, possibly indicating that there is a significant change in the magnetic field direction. Depolarization requires that there is still light-polarizing dust in the Z range 500–1000 pc and the lower limit to extinction inferred in Paper I ($A_B > 0.11$ mag) must be increased by a yet undetermined amount.

Key words: polarization – dust, extinction – solar neighbourhood

1. Introduction

In our previous paper (Berdyugin et al. 1996, or Paper I) we extended measurements of interstellar polarization at high galactic latitudes ($b > 70$ deg) up to $Z \approx 600$ pc. The main aim of this programme is to investigate the distance dependence of linear polarization and plane of vibration all over the northern galactic polar region, in order to obtain information on the amount of interstellar extinction and on the structure of the Galactic magnetic field and dust distribution in this important general direction.

The principal instruments applied to this effort are the 1.25 m and 2.56 m telescopes at CAO (Crimea) and NOT (La Palma), respectively, both having the five-colour Piirola photopolarimeter. When the electronic interface and control programme of the NOT photopolarimeter were recently modernized and the instrument was taken in use after a couple of years' rest, we had the opportunity to make observations related to our programme during the commissioning run on 1–4 April 1996. For these measurements we had selected a sample of distant A and F stars, mostly with $Z > 600$ pc, in order to explore whether the trends reported in Paper I continue at such large distances.

It was the main result of Paper I that the interstellar polarization increases at least up to $Z \approx 600$ pc. This happens roughly similarly in the different zones defined in Paper I (A, B, C) on the basis of the preferred directions of plane of vibration. In the present Note we report on the NOT measurements of 20 distant stars, as a first step towards still larger distances.

2. Sample and observations

The stars for the present observations were selected from the catalogue of Hill et al. (1982). Most of them are more distant than 600 pc and fainter than 10.8 mag, and of spectral type A and F. See Table 1 for relevant data for the stars that we could measure during the nights 1–3 April 1996 that were suitable for observations. In order to determine the instrumental polarization, we observed the nonpolarized stars HD65583 and HD144287 and the highly polarized HD161056. The instrumental polarizations were determined to be less than 0.02 percent, and therefore negligible for our purposes.

The average integration time for one star was about 45–60 min, and the size of error was about 0.02–0.04 percent. The data were reduced using the method developed by Piirola (1975).

The results of our observations are shown in Table 1 where the columns refer to: (1) BD, or SS2 number, (2) V – magnitude, (3) reddening $E(b-y)$, (4) polarization (%) and its error, (5) equatorial position angle Θ of the plane of vibration and its error, (6) the galactic position angle Θ', (7) galactic longitude, (8) galactic latitude, (9) distance. The data in columns 3 and 7–9 are from Hill et al. (1982). SS2 number, used by Hill et al., refers to Table 2 of the SS survey (Slettebak & Stock 1959).

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Table 1.

BD, SS2	Mag.	$E(b-y)$	$P(\%)$	Θ	Θ'	l	b	Distance
27.2063	11.10	0.008	0.104±0.030	12±8	108	212.83	76.68	723
28.2061	10.89	0.016	0.136±0.030	29±6	121	207.95	77.58	450
74	11.39	−0.007	0.063±0.035	-	-	167.46	77.07	765
90	10.99	−0.028	0.100±0.032	23±9	58	152.31	74.52	800
119	11.27	−0.007	0.072±0.045	-	-	209.66	82.64	507
19.2574	10.83	0.043	0.440±0.042	78±3	48	270.60	80.30	507
20.2729	11.12	0.029	0.177±0.024	90±3	57	268.81	81.37	435
30.2290	11.45	0.017	0.084±0.039	33±12	93	180.96	85.26	582
31.2384	11.02	−0.007	0.168±0.034	19±6	67	168.87	84.83	737
36.2292	11.01	−0.016	0.100±0.025	31±7	49	138.99	80.85	625
214	11.16	−0.017	0.103±0.027	159±7	161	124.32	75.36	748
218	10.92	−0.003	0.026±0.024	-	-	297.60	87.59	771
29.2413	10.96	−0.011	0.183±0.025	47±4	146	46.38	81.49	791
23.2604	11.12	−0.001	0.175±0.044	59±6	124	13.96	77.33	687
23.2403	11.56	−0.018	0.086±0.032	96±10	27	227.99	76.73	968
60	11.44	−0.010	0.120±0.034	169±7	43	170.01	75.92	834
25.2478	10.65	0.005	0.227±0.044	18±6	128	228.79	81.76	780
12.2516	10.14	0.011	0.133±0.026	68±5	66	300.39	75.03	743
30.2431	10.07	0.010	0.091±0.034	71±10	170	47.89	79.42	1328
41.2375	10.74	−0.013	0.228±0.033	53±4	31	104.13	75.63	720

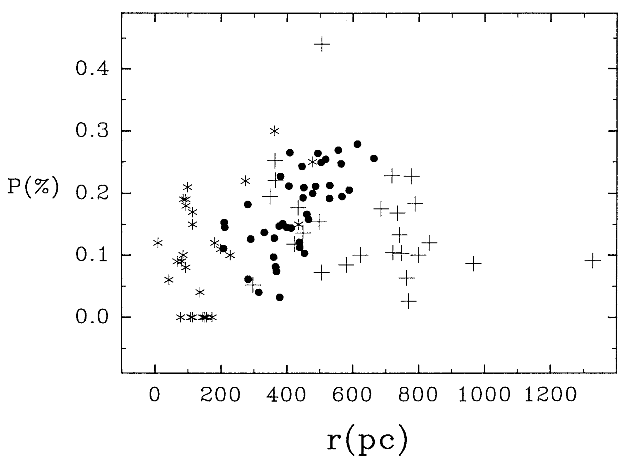

Fig. 1. Linear polarization P vs. distance r. Observations at NOT have been indicated as crosses. Asterisks and filled circles come from Tuorla and Crimea, respectively (Paper I)

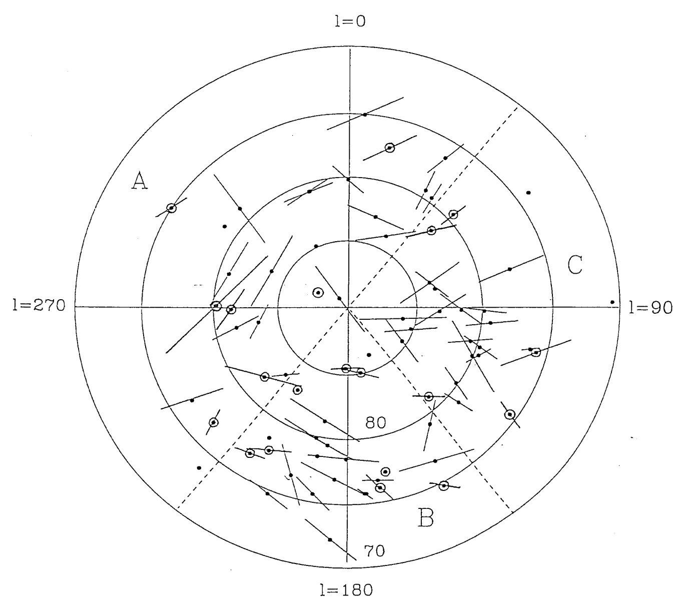

Fig. 2. Distribution of the new stars around the NGP, measured at NOT, together with those from Paper I. The length of the bars give the amount of polarization. The directions give the direction of the plane of vibration. The dots are stars with very small or no polarization. Zones A, B, and C were defined in Paper I. The new stars are indicated by the encircled dots

3. Behaviour of degree and angle of polarization in different zones

It is well known that the maximum degree of interstellar polarization may occur at different wavelengths, apparently depending on the properties of the dust particles causing the polarization (e.g. Clayton & Mathis 1988). In Fig. 1 we show for the new data the dependence of the *maximum* polarization (chosen from the bands B,V,R) as a function of distance r. In this diagram we have also indicated separately the older measurements in Tuorla (asteriks) and the measurements in Crimea (dots) from Paper I. The measurements at NOT, both the few old ones (in V band) and the present ones have been shown as crosses.

It is interesting that, while there is first an increasing trend in polarization, the NOT observations suggest that above $Z \approx$ 600 pc the polarizations start to drop. The reality of this effect is also supported by Fig. 2 where the polarization directions have been plotted on the map around the NGP. Clearly, the polarization vectors of the new, more distant measurements (identified by open circles), well agree with the results in Paper I. Figure 3 shows the polarization degrees against distance in the zones A, B, and C. In every zone there is a clear impression that polarizations start to decrease above $Z \approx$ 500–600 pc.

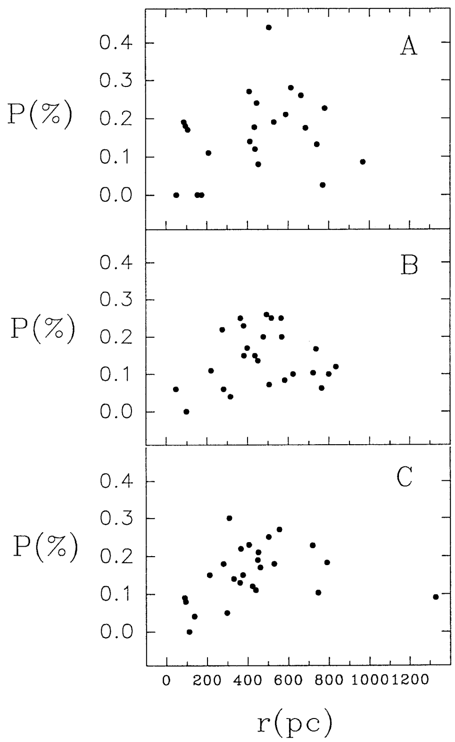

Fig. 3. P. vs. distance for the new and Paper I stars together in the different zones

One star of our sample, BD+19.2574, has an exceptionally large value of observed polarization. We have carefully inspected this case and conclude for several reasons that its polarization quite probably has an interstellar origin. BD+19.2574 is not listed as variable, and the direction of the plane of vibration for this star is well aligned with the directions for five nearby stars in the sky. The wavelength dependence of its polarization has an interstellar appearance with the maximum in the V band. It is also noteworthy that this star has the largest reddening $E(b-y)$ in our sample, and it is situated in zone A where in general the polarizations rise steeply and which also includes the cloud complex of Markkanen (Paper I).

4. Discussion and concluding remarks

In principle, one might expect three different types of behaviour for the polarization after an initial increase with distance: I. The increase may continue, if both dust and homogeneous magnetic field extend to large Z distances. II. There may be a flattening and subsequent horizontal run in the distance-polarization diagram, if above some Z there is no more polarizing dust. III. The polarization may start to decrease after some Z, i.e. depolarization occurs if the magnetic field and polarizing dust particles change there direction by more than 45 deg.

All these three alternatives provide interesting information on the dust and magnetic field distributions. Especially it should be noted that the quite contrary trends I and III both require that there is light-polarizing dust at large distances. If the depolarization is completed before the light reaches the observer, the remaining foreground dust polarizes the light, and we may add to the behaviour the case III′: Polarization decreases beyond some Z, but then keeps non-zero. The polarization angle reflects in this case the foreground magnetic field.

The new observations give preliminary support to depolarization starting around $Z \approx 500$–600 pc. In principle, it is also possible that at large distances one preferably selects stars in the directions of "windows" with little dust and, hence, little polarization. There is slight evidence that the new distant stars are found close to the borders of the zones A, B, and C. However, we are not yet inclined to believe that the smaller values of polarization could be due to this Holmberg-Fesenko selection effect. This is because the NOT sample was especially selected to have faint apparent magnitudes and the extinctions in question are not large ($<$ 0.2–0.3 mag). Naturally, more data are necessarily needed in order to see in more detail the polarization behaviour in all the zones and to decide whether selection effects are deforming the distance-polarization diagram. Even with the present data we wish to point out the following interesting features.

The fact that the polarization angles for the distant stars agree with those of the closer ones, is actually expected from an incomplete depolarization (case III′ above). This explanation, if true, also implies that the foreground dust is rather diffusely distributed, because practically every line of sight shows the angle agreement (we do not see the direction of the more distant magnetic field as one would expect if some lines of sight avoid the foreground dust).

Depolarization would need a drastic change in the magnetic field direction around $Z \approx 500$ pc. Perhaps this is somehow related to the fact that in zone A the magnetic field is about perpendicular to that in B and C.

Depolarization requires dust, hence the minimum value of $A_{\rm B} \geq 0.11$ mag from Paper I should be increased by some amount, probably at least by 50 percent.

A good analysis of all these questions will require more data that we intend to gather for several tens of new faint stars within our continuing programme at the NOT tescope.

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