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Interstellar polarization at high galactic latitudes from distant stars

VI. Extended polarization map and connection with the local spiral structure

A. Berdyugin and P. Teerikorpi

Tuorla Observatory, 21500 Piikkiö, Finland
e-mail: andrei@astro.utu.fi; pekkatee@astro.utu.fi

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Abstract. We present new interstellar polarization measurements for 116 stars at high galactic latitudes. Our data show that Markkanen's cloud – the main polarization structure seen in the North Galactic Pole area ($b > 75°$) extends further towards lower latitudes. Especially, we have found a new dust formation in the area $35° < l < 45°$, $57° < b < 63°$. Interstellar polarization in this part of the sky peaks at 0.7%, which gives a lower limit to the extinction $A_V > 0\overset{\mathrm{m}}{.}23$. Polarization vectors in this cloud are very well aligned along the direction of $l = 50°$. On the IRAS 100 micron map this dust structure shows up as a bright emission area. We discuss the new polarization map extending from circumpolar to lower latitudes and point out features which suggest that Markkanen's cloud may be a part of the dust lane in the inner edge of the local spiral or spur.

Key words. polarization – ISM: dust, extinction – Galaxy: structure – Galaxy: general

1. Introduction

The present paper continues our study of the interstellar polarization at high galactic latitudes (Papers I–V: Berdyugin et al. 1995; Berdyugin & Teerikorpi 1997; Berdyugin et al. 2000; Berdyugin et al. 2001; Berdyugin & Teerikorpi 2001). We use the interstellar polarization data from observations of stars at intermediate and large distances ($d > 300$ pc) for the determination of the amount of interstellar extinction and the structure of the Galactic magnetic field in the areas of the North (NGP) and South (SGP) Galactic Poles.

In his early polarimetric study of the NGP area Markkanen (1979) found a dust complex extending over the North Galactic Cap down to latitude $b = 80°$ with an extinction $A_V \geq 0\overset{\mathrm{m}}{.}1$ at a distance of about 100–200 pc. This dust structure elongates roughly parallel to $l = 50°$. Our Paper III showed that this cloud extends to lower latitudes ($b \leq 75°$) in both directions, i.e. towards the first and third quadrants. Interstellar polarization inside the cloud peaks at 0.4% and the polarization vectors are well aligned in the direction $l \approx 50°$. This part of the IRAS 100 micron map this part shows bright filaments elongated in the same direction as the polarization vectors and Markkanen's cloud itself.

The infrared emission extends far beyond $b = 70°$ towards the first and third quadrants. In order to see how these features correlate with interstellar polarization we made polarimetric measurements of stars with distances 100–400 pc in the sector $10° < l < 50°$ down to $b = 55°$. We also measured polarization for about 15 stars located in the third quadrant, between $b = 70°$ and $75°$.

2. Observations

The new observations were carried out on La Palma in May–July 2001 with the NOT (38 stars) and KVA (78 stars) telescopes both equipped with identical *UBVRI* photo-polarimeters (Piirola 1988; Korhonen et al. 1984). In addition, we have included in our analysis older data for $b < 70°$ published by Korhonen & Reiz (1986) and by Mathewson & Ford (1970). The details of our observation techniques, the data reduction method, and the accuracy criteria, which we apply to polarization data, can be found in Papers I, II, and III. Choosing the stars for our observations, we took only those for which sufficiently accurate parallaxes ($\pi > 2\sigma_\pi$) are available from HIPPARCOS (Perryman et al. 1997). Our new measurements are given in Table 1[1]. The description of the table entries follows.

Column 1: Star identification. We give the BD (*Bonner Durchmusterung*) number.

Send offprint requests to: A. Berdyugin,
e-mail: andrei@astro.utu.fi

[1] Table 1 is only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via
http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/384/1050

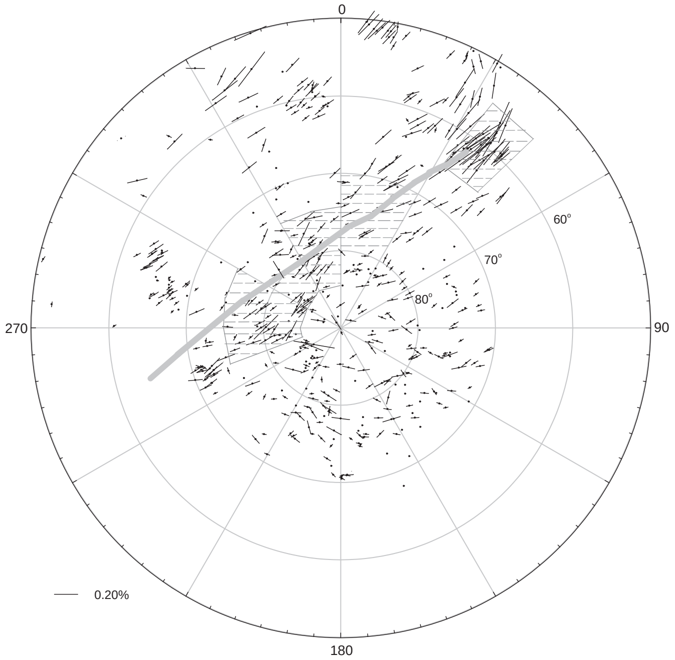

Fig. 1. Polarizations of the stars around the NGP. The length of the bar gives the amount of polarization, its direction is the direction of the polarization plane. The shaded areas show the approximate location of Markkanen's cloud and the new cloud found in the first quadrant. The expected run of the inner spiral edge, as seen from spiral tracers, is also shown (see the text).

Column 2: P, the polarization percentage. The number in brackets gives the source of data: (1)- from the KVA 60 cm telescope; (2)- from the NOT 2.56 m telescope.

Column 3: σ_P, the error of polarization.

Column 4: θ, the position angle of polarization vector measured in the equatorial coordinate frame.

Column 5: σ_θ, the error of position angle.

Column 6: $d(pc)$, the distance of the star, in parsecs.

Columns 7–8: Galactic longitude and latitude, (l, b).

Column 9: Sp, the spectral type, when available.

2.1. The new polarization map

Figure 1 shows a new large polarization map of the north Galactic sky down to $b = 50°$. There are no polarization data available for the area $60° < l < 270°$, $b < 70°$. Even in the remaining part of the map, the sky below $b = 70°$ is still undersampled. However, the sector of our prime interest, located at $0° < l < 60°$ is well covered by polarization data.

The IRAS 100 micron map of the same part of the sky is shown in Fig. 2. Comparing the two figures one can see that the infrared emission region extending over the first quadrant along $l \approx 30°$ shows up on the polarization map as a region of enhanced polarization. The most remarkable feature in this sector is the relatively small area located at $35° < l < 45°$, $57° < b < 63°$ where the interstellar polarization is significantly higher than around it. Among the 24 stars in this part of the sky 12 have polarizations above 0.4% and 4 above 0.6%. Polarization vectors of all these stars are remarkably well co-aligned, in the direction parallel to $l = 50°$.

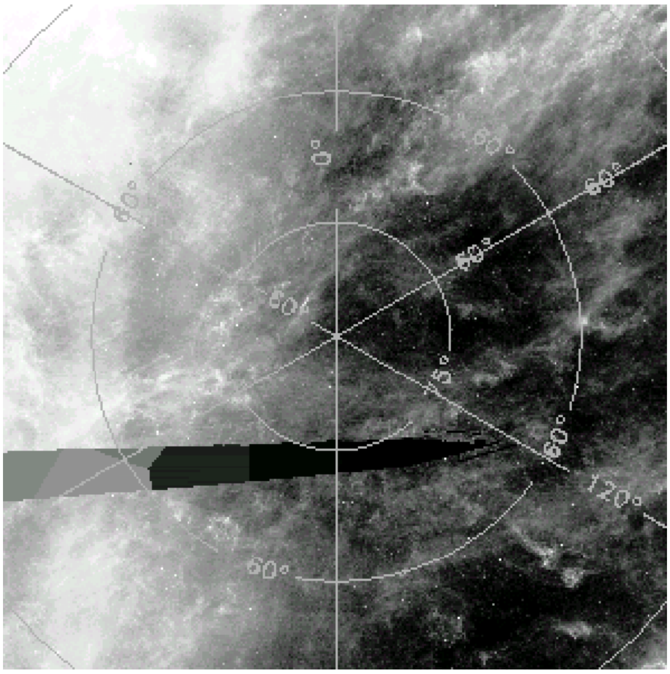

Fig. 2. The IRAS 100 micron map of the NGP area down to $b = 60°$. Data taken from Wheelock et al. (1991).

Figure 3 shows the P vs. distance dependence for the area around this cloud, but inside the sector $0° < l < 60°$, where polarization vectors are also aligned parallel to $l \approx 50°$. It is seen that in the outside area the polarization grows with distance slowly, reaching $P \approx 0.5\%$ at about 250 pc. The median curve, calculated by binning the polarization within 50 pc (up to the distance of 200 pc) and within 100 pc (after the distance of 200 pc) is also shown.

Figure 4 shows the dependence of polarization vs. distance for the newly found low-latitude cloud. As seen from the figure, beyond 100 pc all stars are substantially polarized ($P \geq 0.2\%$). At a distance of about 250 pc the polarization approaches 0.7% which gives a lower limit for extinction the $A_V \geq 0\overset{m}{.}23$. The median line from Fig. 3 is also shown for comparison.

This remarkable polarization alignment is actually seen over the whole high latitude sky between $0° < l < 60°$, $240° < l < 360°$; $50° < b < 90°$. The rest of the NGP area ($60° < l < 240°$) apparently does not show such alignment pattern.

2.2. The extension for Markkanen's cloud

One can see now that Markkanen's cloud is a central part of an elongated dust complex which spreads over the NGP area in the direction of the first quadrant down to $b = 50°$. Available polarization data show that in the opposite direction it continues down to $b = 70°$ at least and probably still further according to the IRAS map. Besides the diffuse dust, this complex also includes more dense dust

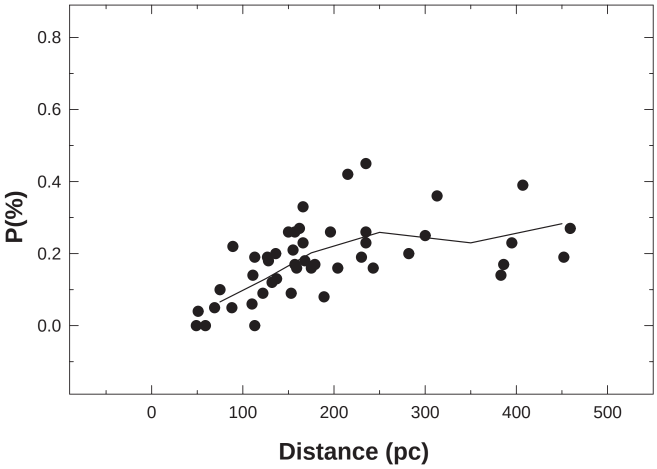

Fig. 3. Polarization vs. distance dependence for the stars in the region around the lower-latitude cloud. The median line calculated by binning the distances is also shown.

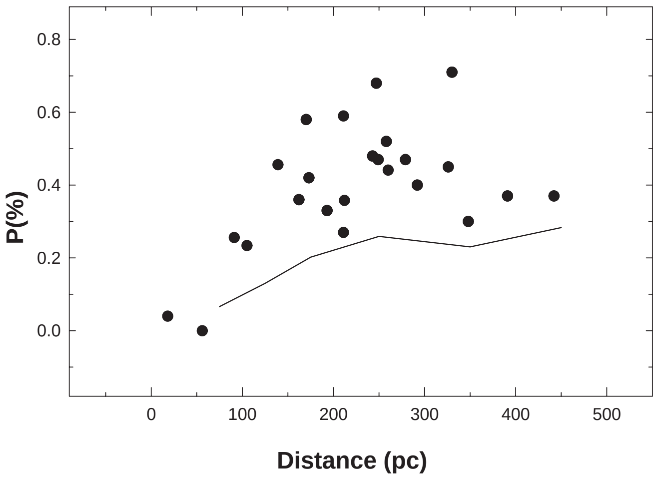

Fig. 4. Polarization vs. distance dependence for the stars in the region of the newly found lower-latitude cloud. The median line from Fig. 3 is also shown for comparison.

formations, one of which we have found recently. On the IRAS 100 micron map this dust complex is seen as an extended band of bright emission filaments which spreads along direction $l = 50°$.

3. Connection with the local spiral structure

A clear picture is still lacking both for the global and local (within 1−2 kpc from the Sun) spiral structure of the Milky Way. Various young, luminous spiral tracers (HII regions, long-period cepheids, OB stars etc.) do reveal local bits of spiral arms: the inner Sagittarius arm, its edge starting at about 1 kpc from the Sun, the outer Perseus arm, and between them the local Orion-Cygnus arm. However, it is often regarded that the strip of tracers close to the Sun is not a genuine large spiral, but perhaps a bridge between Perseus and Sagittarius ("Orion spur"). Its pitch angle of 30° argues against a true spiral, as "a major spiral arm with such an angle of inclination seems not even geometrically possible for the Milky way" (Yuan 1970). On the other hand, Chernin (1999) notes that even the main spirals are often made of rectilinear "rows"of star-forming regions, so that locally the pitch angle could be 30 degrees. Berdnikov & Chernin (1999) suggest that such a rectilinear part exists in the Sagittarius arm.

Thus one might add to the two alternatives (the Orion arm is a true spiral, or it is just a bridge) the possibility that we are seeing the rectilinear part of a true spiral. Locally it is difficult to find clues in favour some of these variants, as the bridges in other galaxies (e.g. M 51, see Mathewson et al. 1972) often display features typical for the spiral arms themselves: dust lanes and synchrotron radio emission due to enchanced magnetic field.

We plot on the polar diagram, how the inner edge of a spiral, h in height, would be seen if the Sun lies at a distance Δx from the edge which has a pitch angle θ. Our polarization studies suggest that the cloud complex is at a typical height $h \approx 200$ pc. If the cloud defines the very local edge, then $\Delta x \approx 35$ pc would put the cloud at $b \approx 80$ deg, as observed. Thus Fig. 1 shows the expected run of the spiral edge for the pitch angle $\theta = 35°$. This appears to reproduce rather well what is observed. In the maps made from different classes of spiral tracers, the Sun persistently lies inside but close (a few tens of parsecs) to the inner edge of the strip (see Humphreys 1976).

In galaxies narrow dust lanes mark the inner edge of the spiral arms. The elongated dust complex extending over the NGP could be a local part of such structure. The Lick galaxy counts show a clear "hole" in that part of the sky as well (Fig. 3 in Teerikorpi & Haarala 1987). Futhermore, the regular component of the galactic magnetic field is stronger in the interarm regions (see Han & Qiao 1994; Indrani & Deshpande 1998). Therefore, the optical interstellar polarization is enchanced there and polarization vectors are well aligned. Figure 1 shows that as one moves from the interarm area across the inner edge into the spiral (in direction of $l = 150°$), polarization decreases and becomes less regular, probably due to the less regular magnetic field in this region.

4. Wavelength dependence of interstellar polarization in the lower latitude cloud

There are 9 stars in the area $35° < l < 45°$, $57° < b < 63°$ for which the accuracy of the measured polarization in all $UBVRI$ bands is high enough for a study of the wavelength dependence of polarization. We found that it follows the Serkowski law (Serkowski et al. 1975) quite well. The maximum wavelength of the polarization $\lambda_{\max}$ for these stars is within a range 0.49μ–0.59μ and the average value is 0.53μ. We conclude, therefore, that optical properties and physical conditions of interstellar dust in this part of the sky do not differ from those in galactic diffuse interstellar medium, where $\lambda_{\max} \simeq 0.55\mu$.

5. Conclusions

Our new polarization observations show that Markkanen's cloud actually is a part of a large elongated dust complex. This complex consists of diffuse dust and compact dust formations, and it may belong to a dust lane marking the inner edge of the local spiral. Polarization observations reveal that in this dust complex the magnetic field is quite regular and directed parallel to the edge of the local spiral. Markkanen's cloud makes a border between two different regions: 1) in the IRAS 100 micron map it divides the bright diffuse emission from the darker area; 2) on the polarization map it separates the area of the enchanced, regular interstellar polarization from small and irregular one; 3) on the soft X-ray map (Paper III), the deep shadow of Markkanen's cloud also separates two regions of different structure.

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References

Berdnikov, L. N., & Chernin, A. D. 1999 Astron. Lett., 25, 591
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., Hanski, M., Knude, J., & Markkanen, T. 2001, A&A, 372, 276 (Paper IV)
Berdyugin, A., & Teerikorpi, P. 2001, A&A, 368, 635 (Paper V)
Chernin, A. D. 1999, MNRAS, 308, 321
Han, J. L., & Qiao, G. J. 1994, A&A, 288, 759
Indrani, C., & Deshpande, A. A. 1998, New Astron., 4, 33
Humphreys, R. M. 1976, PASP, 88, 647
Korhonen, T., & Reiz, A. 1986, A&AS, 64, 487
Korhonen, T., Piirola, V., & Reiz, A. 1984, ESO Messenger, No 38
Markkanen, T. 1979, A&A, 74, 201
Mathewson, D. S., & Ford, V. L. 1970, MNRAS, 74, 139
Mathewson, D. S., Kruit van der, P. C., & Brouw, W. N. 1972, A&A, 17, 468
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
Serkowski, K., Mathewson, D. S., & Ford, V. L. 1975, ApJ, 196, 261
Teerikorpi, P., & Haarala, S. 1987, A&ASS, 137, 397
Wheelock, S. L., Gautier, T. N., Chilleri, J., et al. 1991, IRAS Sky Survey
Yuan, C. 1970, in Galactic Astronomy, ed. H.-Y Chiu, & A. Muriel (Gordon and Breach, New York), 2, 233