Observations of Linear Polarization of Background Galactic Radio Emission in Selected Directions at 8.3 GHz

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Abstract. Polarization observations of the Galactic radio emission at 8.3 GHz were made by the 32-m Medicina (Italy) radio telescope in four pixels (HPBW=4.'8). A method of tracking around the upper culmination was used in order to use the rotation of the parallactic angle for detecting the weak linearly polarized Galactic radio emission against the background of relatively strong and variable spurious and instrumental polarization. The well known source 3C 286 was used as calibrator. As a result the brightness temperatures of linearly polarized component of the Galactic radio emission and positions angles were measured for all pixels. Comparison was made for the pixels in the first Galactic quadrant with Duncan et al. 2695 MHz polarization measurements and as a result spectral indexes and rotation measures were determined.

1. INTRODUCTION

By now the linearly polarized component of the Galactic diffuse synchrotron radio emission has been partly investigated at frequencies of meter (e.g. [1]) and decimeter (e.g. [2,3]) wavebands up to 2.695 GHz [4]. Current estimates of the Galactic polarized contributions to the microwave region are obtained by extrapolating available low frequency data and are affected by uncertainties because of Faraday depolarization and the use of spectral indexes from low frequencies. To study the spectrum and the angular distribution of the Galactic polarization at centimeter wavelengths new observations are urgently needed [5]. A knowledge of the polarized radio emission spectral index for high enough frequencies to avoid Faraday depolarization would be useful also for the separation of the synchrotron and free-free components of the total microwave Galactic diffuse radio emission. Besides that, higher frequency polarization observations will bring information on the interstellar magnetic fields at larger distances. To make a first step before observations of more extended areas of the Galactic plane we have observed four pixels at 8.3 GHz by the 32-m Medicina (Italy) radio telescope (HPBW=4.'8). The centers of these pixels are the points with Galactic coordinates l=141º09', b=7º53'; l=145º20', b=4º00'; l=61º36', b=3º43' and l=65º38', b=3º43'. The first point (α_{1950}=57º.0, δ_{1950}=64º.0) is a well known calibrator for polarization measurements (e.g. [2,6]). The 3rd and the 4th points are in the longitude and latitude ranges examined by Duncan et al. [4] at 2.695 GHz. The areas with a radius ~5 HPBW around each of these 4 points are free of discrete sources with flux densities higher than 30-40 mJy at 6 cm and free of Galactic supernova remnants.

As a result we have obtained values of brightness temperature of the linearly polarized component of the Galactic radio emission and position angle at 8.3 GHz for all four pixels.

This paper is organized as follows. In section 2 our observations are described. In section 3 we describe the data reduction. Results and discussion are given in section 4. In section 5 conclusions are formulated.

2. OBSERVATIONS

Observations were made in December 2000 and March-April 2001 at the Medicina (Italy) radio observatory by a 32-m radio telescope. A method of tracking the selected point on the sky around its upper culmination was used.

Observations of a point in the second Galactic quadrant consist of an hour angle (t) interval tracking between the point's East elongation and the West one. Observations of a point in the first Galactic quadrant consist of an hour angle interval tracking between the minimum and the maximum value of the equatorial parallactic angle $q(t)$ of the point. We used a correlation polarimeter to measure Stokes parameters I, Q and U. Some of the telescope and observing parameters are listed in Table 1. The characteristics of 3C286 were taken from [7,8].

TABLE 1. Polarimeter data, telescope parameters and assumed calibrator 3C286 values

Centre frequency (MHz)	Receiver bandwidth (MHz)	Beamwidth (HPBW)	Q,U RMS noise (mK $s^{1/2}$)	3C286 assumed flux density (Jy)	3C286 degree of polarization (%)	3C286 position angle
8300	80	4'.8	10	(5.0 ± 0.1)	(11.8 ± 0.2)	34º.0 ± 1º.5

For each point several observations were made. Calibration source 3C286 was observed daily during observations. One observation of 3C286 consists of an hour angle interval tracking between the minimum and the maximum value of the equatorial parallactic angle of the source using the "on-off" technique. Fig. 1 shows an example of such observation of the Stokes parameters Q and U. The 3C286 observations were used for calibrating both the brightness temperature and the position angle of the linearly polarized Galactic radio emission. Instrumental linear polarization was also measured from 3C286 observations. Values of the radio telescope Müller matrix elements as M_{21}=−1.8% (conversion $I \rightarrow Q$) and M_{31}=1.7% (conversion $I \rightarrow U$) were measured.

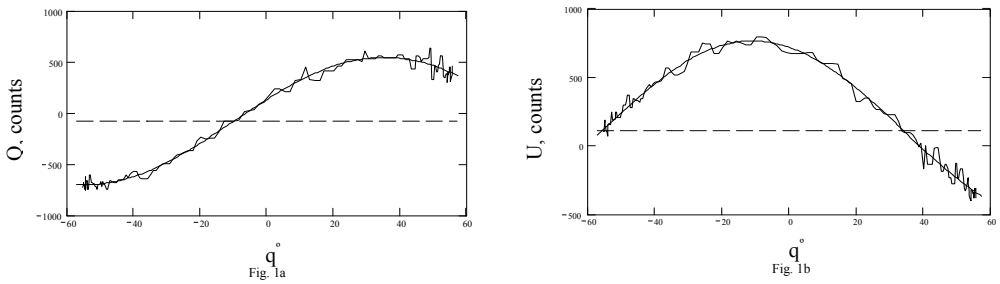

FIGURE 1. The observation of 3C286 made in Dec 3rd, 2000: a) Measured values of the Stokes parameter Q as a function of the parallactic angle q and the best fit sinusoid are shown. The horizontal dashed line shows the value of the instrumental polarization. b) The same for the Stokes parameter U.

Measured values of the Stokes parameters Q, U of an incoming radio emission are the sums of the true very weak signals of the Galactic linearly polarized radio emission Q_g, U_g, spurious Q_s, U_s and instrumental Q_i, U_i polarization: $Q= Q_g+Q_s+Q_i$, $U= U_g+U_s+U_i$. The main source of spurious polarization is a partly linearly polarized ground radio emission received by the side lobes of the radio telescope. It depends mainly on the elevation angle h and the time and it is vertically polarized. During the observation $h=h(t)$, so that spurious polarization depends only on time in fact. Besides that, the total ground radio emission converts into Q_i, U_i via instrumental polarization. Contributions from the atmosphere radio emission and the CMBR into Q_i, U_i are much smaller than the contribution of the ground radio emission. The method of tracking gives the possibility to use specific time dependence of Q_g, U_g due to the rotation of parallactic angle for detecting the weak linearly polarized Galactic radio emission against the background of relatively strong and variable spurious and instrumental polarization.

3. DATA REDUCTION

The data reduction procedure is as follows. In order to take into account a bulk of spurious and instrumental polarization effects, the measured values Q, U are fitted to a polynomial of degree 2 as a function of the parallactic angle q. It is convenient to use q as argument instead of the time because around culmination the ratio q to t is

approximately constant. Fig. 2 shows an example of observation (Dec 2nd, 2000) of the point with coordinates l=145º20', b=4º00' and the approximation of Q, U by a polynomial of degree 2.

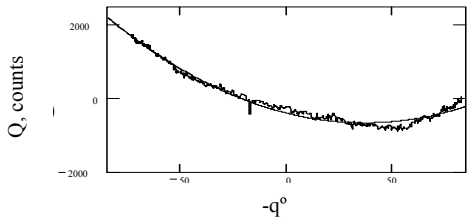

Fig. 2a

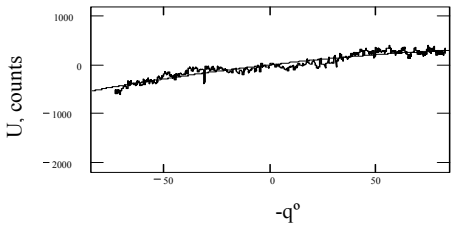

Fig. 2b

FIGURE 2. Results of fitting the measured values of Q, U by a polynomial of degree 2 for observations of the point with coordinates l=145º 20', b=4º 00' made in the Dec 2nd, 2000: a) Stokes parameter Q, b) Stokes parameter U.

After that, the best fit polinomials $Q_2(q)$, $U_2(q)$ are subtracted from the observed Stokes parameters to obtain $Q_r = Q - Q_2$, $U_r = U - U_2$. The values Q_r, U_r consist of the true signals, Q_g, U_g,, and fluctuations of spurious and instrumental polarization. Finally $Q_r(q)$ is fitted to $Q_g(q)$ and $U_r(q)$ is fitted to $U_g(q)$, where

$$\begin{aligned} Q_g(q) &= Q_0 cos(2q) + U_0 sin(2q) \\ U_g(q) &= -Q_0 sin(2q) + U_0 cos(2q) \end{aligned} \qquad (1)$$

in order to obtain the values of Q_0 and U_0. Fig. 3 shows the results of these fits for the same observations of Fig. 2. For each observation two values of Q_0 and two values of U_0 are obtained. Q_0 and U_0 values were averaged over N observations to obtain the mean values Q_{0m} and U_{0m}, they were calibrated and the values of the polarized brightness

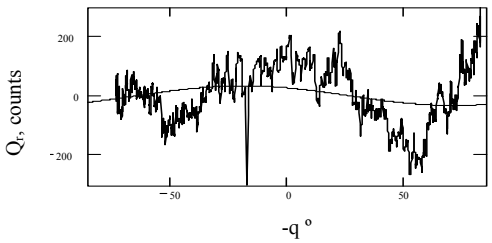

Fig 3a

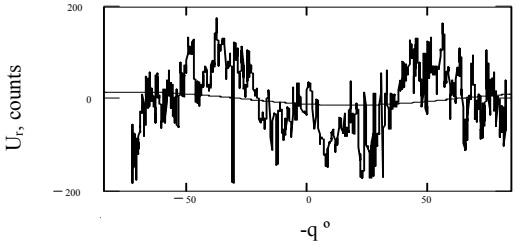

Fig 3b

FIGURE 3. Results of the fits of Q_r and U_r to Q_g and U_g, respectively, for the same observations of Fig. 2: a) Stokes parameter Q_r, b) Stokes parameter U_r.

temperature $T_b^p=(Q_{0m}^2 + U_{0m}^2)^{1/2}$ and of the position angle χ, obtained from formulae $\tan(2\chi)=U_{0m}/Q_{0m}$, were calculated for each pixel.

4. RESULTS AND DISCUSSION

Table 2 shows the values of polarized brightness temperature and position angle we obtained. It is of interest to compare polarization characteristics of the 3rd and 4th pixels with 2695 MHz polarization data [4] obtained with similar angular resolution (map resolution (HPBW) is 5.'1 in [4]). Table 3 shows the values of T_b^p and the Galactic position angle χ_g for the 3rd and 4th pixels at 2695 MHz [4] and 8300 MHz (this paper). Values of temperature spectral index of linearly polarized radio emission β_p ($T_b^p \propto \nu^{-\beta p}$) and rotation measures RM were calculated by

comparing 2695 MHz and 8300 MHz data (see also Tab. 3). One can see that in the 3rd pixel *RM* is positive and in the 4th it is rather positive too. This is in agreement with the sign of rotation measures of extragalactic radio sources and distant pulsars and also with values for the positive low latitudes of the first Galactic quadrant [9].

TABLE 2. Results of brightness temperature and position angle measurements at 8300 MHz of the linearly polarized component of the Galactic radio emission for four pixels. *N* is the number of observations.

Galactic longitude	Galactic latitude	Polarized brightness temperature, mK	Galactic position angle	*N*
141º09'	7º53'	3.3 ± 1.2	143º ± 11º	7
145º20'	4º00'	4.4 ± 1.9	126º ± 11º	4
61º36'	3º43'	1.4 ± 0.8	99º ± 7º	6
65º38'	3º43'	2.7 ± 1.2	86º ± 13º	5

TABLE 3. The values of polarized brightness temperature and position angle at 2695 MHz [4] and 8300 MHz for the 3rd and 4th pixels and values of polarization brightness temperature spectral index β_p and rotation measure *RM*.

l	b	T_b^p (2695 MHz) mK	T_b^p(8300 MHz) mK	χ_g (2695 MHz)	χ_g (8300 MHz)	β_p (2695-8300 MHz)	*RM* rad m^{-2}
61º36'	3º43'	37.4 ± 7.3	1.4 ± 0.8	132º.9 ± 7º.2	99º ± 7º	2.91 ± 0.53	53.3±15.8
65º38'	3º43'	39.1 ± 7.3	2.7 ± 1.2	92º.7 ± 6º.9	86º ± 13º	2.37 ± 0.43	10.5±23.2

5. CONCLUSION

As a first step before future observations of more extended areas of the Galactic plane, polarization observations of the pixels in the first Galactic quadrant and two pixels in the second quadrant were made at 8.3 GHz. The main difficulty of these observations is the detection of a very weak true signal against the background of much stronger and variable spurious ground polarization. Rotation of the parallactic angle during the tracking of an observed pixel (space filtering), repeating observations and averaging were used for the detection of the signal. Values of polarized brightness temperature and position angle were obtained for all four pixel. By comparison with Effelsberg 2695 MHz brightness polarized temperatures and position angles, obtained with nearly the same angular resolution, values of temperature polarization spectral index of linearly polarized radio emission β_p(2695-8300 MHz) and rotation measures were determined for two pixels from the first Galactic quadrant. Both the absolute values and the sign of our *RM*s are in an agreement with the configuration of the magnetic field inside the Solar circle of the Galaxy revealed by extragalactic source and pulsar polarization observations.

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