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RESEARCH OF THE LOCAL INTERSTELLAR MEDIUM AND GALACTIC MAGNETIC FIELD BY MULTI-FREQUENCY POLARIMETRY OF SYNCHROTRON RADIO EMISSION

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Results of the polarimetric measurements are presented of the diffuse Galactic radio emission at meter and decimeter wavelengths in a number of directions and regions of the sky. Spectra of brightness temperature of the linear polarized component, rotation measure map and the local structure of the Galactic magnetic field are discussed.

Introduction

The interstellar medium extending up to distances of a few hundred parsecs from the Sun (the local interstellar medium) is a subject of numerous experimental and theoretical studies (see [1] and references therein). The maximum distance from which the linearly polarized component of the diffuse Galactic radio emission comes to us (the polarization horizon) was estimated on the basis of the results of our polarimetric measurements in the area of the sky around $l = 144°$, $b = 8°$ [2–6] at 102, 210 and 290 MHz. For this estimation we used the data on the brightness temperature T_b^p of the diffuse Galactic radio emission linearly polarized component [2–6] and the interstellar medium synchrotron emissivity [7]. The distances turned out to be equal, respectively, to 10, 40 and 275 pc [2–6], i.e. they correspond to the local interstellar medium. There is very little information on the interstellar magnetic field at such distances from the Sun. This explains the substantial interest for special polarimetric studies of the diffuse Galactic radio emission at decimetre and metre wavebands aiming at getting information on the local interstellar medium and magnetic field.

Observations

Multi-frequency polarimetric observations of the diffuse Galactic radio emission in select directions of the sky are among basic observations carried out at the NIRFI Radio Astronomy Observatory "Staraya Pustyn'" near Nizhny Novgorod. In recent years multi-frequency polarimetric observations in five select directions were carried out at "Staraya Pustyn'" in the band of 151.5÷1250 MHz. These observations were made by the tracking method using fully steerable radio telescopes with parabolic reflectors of 10 and 14 m in diameter and modulation radio polarimeters[1].

[1] The method, calibration, data reduction and the radio telescopes are described in more detail in [2–6].

The table below shows the coordinates of the directions, the band and a number of frequencies, and type of the T_b^p spectrum[2]. We traditionally use here the "old" definition of T_b^p according to the following relation between polarization intensity I_p and T_b^p: $I_p = kT_b^p\nu^2/c^2$, where k is the Boltzmann constant, c is the speed of light, ν is the frequency ($I_p = 2kT_b^p\nu^2/c^2$ according to the "new" definition of T_b^p [9]).

More extended areas in Loop III and Loop I were also observed [10–12]. In particular, the rotation measure (RM) map was obtained for the area of high linear polarization with Galactic coordinates ($130° < l < 155°$, $-10° < b < 40°$) by the results of our multi-frequency measurements of the position angle of the linear polarization plane taking into account the Faraday rotation in the ionosphere (see below).

Discussion

Let us discuss the results of polarimetric measurements in the selected directions and the area of high linear polarization. The analysis has shown that there are two basic types of the T_b^p spectrum in the band studied: the power spectrum (with or without the maximum) and the oscillating spectrum. Figures 1 and 2 show, respectively, the T_b^p spectra of the North Celestial Pole region and the region of minimum radio brightness [13]. Both spectra are satisfactorily fitted by a power law ($T_b^p \propto \nu^{-\beta_p}$).

The temperature spectral index β of the minimum radio brightness region total Galactic radio emission is equal to 2.43 ± 0.02 in the band $17.5 \div 1420$ MHz [13]. The degree of linear polarization is approximately proportional to λ^{-1} that testifies to the presence of a large number of "polarization" cells within the main antenna beam.

Another type of spectrum is revealed by the polarimetric observations of the regions in Loop III and Loop I. Figures 3 and 4 show, respectively, the T_b^p spectra of regions $\alpha_{1950} = 4^{\mathrm{h}}30^{\mathrm{m}}$, $\delta_{1950} = 61°$

[2]We also used results of polarimetric observations at 1407 MHz [8].

Region, frequency band of the observations (MHz), and number of frequencies	North Celestial Pole, 151.5 ÷ 1407, 14	Region of high meter wavelengths polarization, 151.5 ÷ 1407, 26	Region of minimum radio brightness, 238 ÷ 1407, 4	North Galactic Pole, 238 ÷ 1407, 5	North Polar Spur, 238 ÷ 1407, 6
$\alpha_{1950}, \delta_{1950}$ l, b	$\delta_{1950} = 90°$ $123°, 27°24'$	$4^h30^m, 61°$ $146°47', 9°03'$	$9^h40^m, 35°$ $190°10', 49°15'$	$12^h49^m, 27°24'$ $b = 90°$	$14^h28^m, 14°$ $7°51', 63°20'$
Type of the T_b^p spectrum	Power (in the band 200 ÷ 1407 MHz): $T_b^p(\mathrm{K}) = (1.95 \pm 0.05) \cdot \left(\frac{\nu}{300}\right)^{-1.87\pm0.05}$	Oscillating. The spectrum is fitted by a uniform synchrotron slab spectrum [2, 3, 5, 6]	Power (in the band 238 ÷ 1407 MHz): $T_b^p(\mathrm{K}) = (1.03 \pm 0.10) \cdot \left(\frac{\nu}{300}\right)^{-1.55\pm0.34}$	Power (in the band 290 ÷ 1407 MHz): $T_b^p(\mathrm{K}) = (2.34 \pm 0.72) \cdot \left(\frac{\nu}{300}\right)^{-1.82\pm0.72}$	Oscillating or power with maximum near 408 MHz

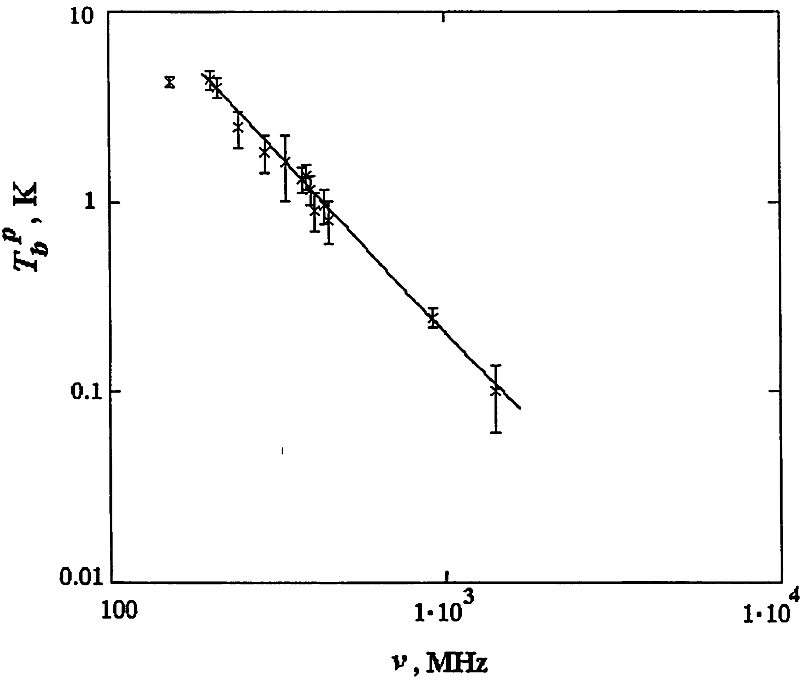

Figure 1: Spectrum of the polarization brightness temperature of the North Celestial Pole region and its approximation by a power spectrum with $\beta_p = 1.87 \pm 0.05$ in the band $200 \div 1407$ MHz

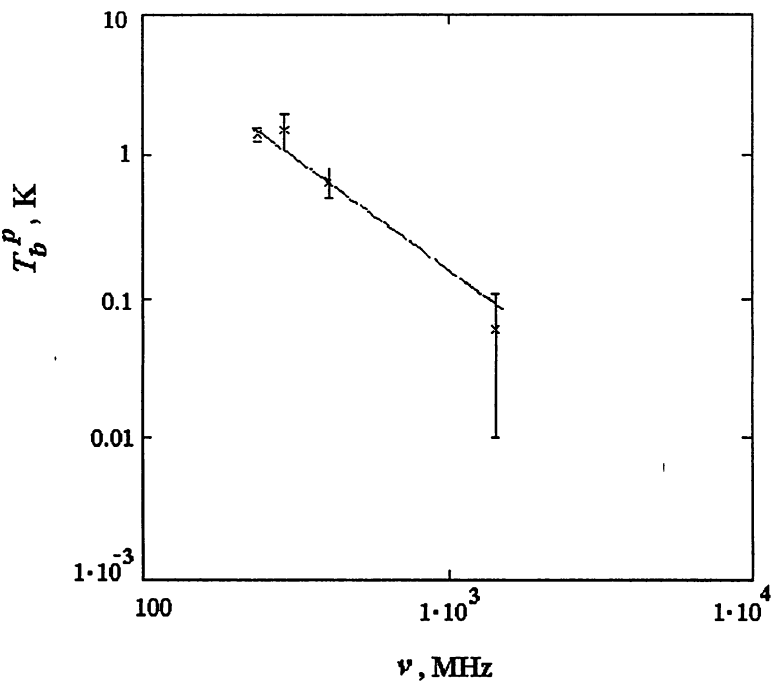

Figure 2: Spectrum of the polarization brightness temperature of the region of minimum radio brightness and its approximation by a power law with $\beta_p = 1.55 \pm 0.34$ in the band $238 \div 1407$ MHz

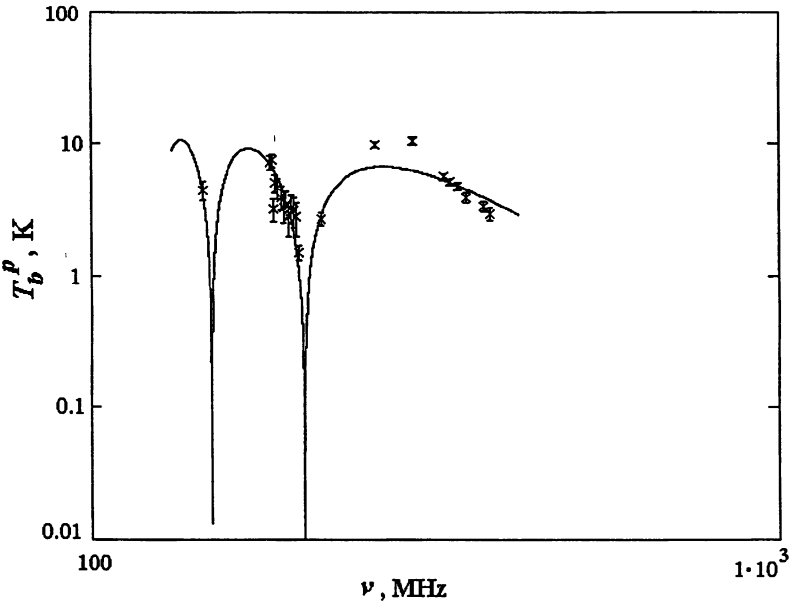

Figure 3: T_b^p spectrum of the region $\alpha_{1950} = 4^{\rm h}30^{\rm m}$, $\delta_{1950} = 61°$ in the band $151.5 \div 448$ MHz and its approximation by a uniform synchrotron slab spectrum with $RM = 0.86$ rad/m^2 and $\beta = 2.6$

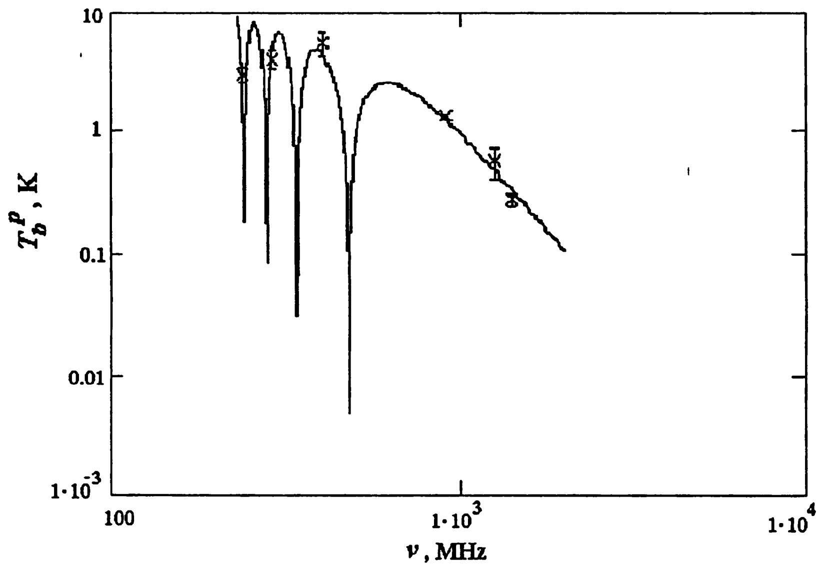

Figure 4: T_b^p spectrum of the region $\alpha_{1950} = 14^h 28^m$, $\delta_{1950} = 14°$ in the band $238 \div 1407$ MHz and its approximation by a uniform synchrotron slab spectrum with $RM = 4.06$ rad/m^2 and $\beta = 3.3$

and $\alpha_{1950} = 14^h28^m$, $\delta_{1950} = 14°$ [14]. It is clear from Figure 3 that the spectrum is non-monotone.

There is a maximum near 300 MHz and a deep minimum near 220 MHz. The simplest interpretation of this spectrum involves a homogeneous synchrotron slab model [2, 3] taking into account bandwidth depolarization [5, 6]. Formula (5) from [6] was used to fit the observed spectrum (see Figure 3).

As to the NPS region (Figure 4), an interpretation of its T_b^p spectrum by the same model seems to be the most probable because of high ordering of the magnetic field in the NPS upper part (see [12] and references in it)[3]. The model predicts the least wavelength minimum at 482 MHz [14].

Figure 5 shows the *RM* map of the area of high linear polarization with Galactic coordinates ($130° < l < 155°$, $-10° < b < 40°$). It is seen that this map testifies to the fact that the structure of the magnetic field in the region has a loop character.

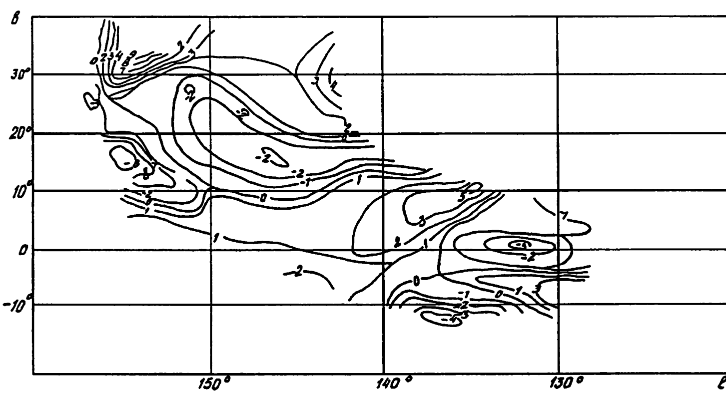

Figure 5: The *RM* map of the area with Galactic coordinates $130° < l < 155°$, $-10° < b < 40°$

[3]Figures 2, 3 and 4 in [15] should be respectively replaced by Figures 2, 3 and 4 of this paper.

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