PARAMETERS OF THE MAGNETIC FIELD IN THE LOCAL GALACTIC ARM DERIVED FROM LOW FREQUENCY ABSORPTION MEASUREMENTS IN THE IONIZED GAS

Eugene A. ABRAMENKOV and Valery V. KRYMKIN
Institute of Radio Astronomy
Academy of Sciences of the Ukrainian SSR
Kharkov, USSR

ABSTRACT. Parameters of the interstellar magnetic field – the strength ratio of the regular and the isotropic component and the orientation of the regular component – have been derived in the Local Galactic arm over a scale $\leq$ 1000 pc in the direction of the Galactic anticentre. The results have been obtained by an independent method involving analysis of the Galactic longitude dependences of the volume density of the low frequency Galactic background. An estimate of the ratio of the arm and interarm magnetic field strengths has been made.

1. Introduction

Almost all experimental estimates of the interstellar magnetic field parameters are derived by the laborious polarization measurements. In our work we present the results obtained by a nontraditional method based on the analysis of the volume density distribution of the nonthermal background (η) in the Galactic disk. The dependence of this value on the strength and the structure of the magnetic field $\eta \sim H_{\perp}^{(\gamma+1)/2}$ allows the estimation of the field parameters. The volume density of the background was obtained from low frequency observations of extended HII regions. They are optically thick at long radio waves and absorb effectively the Galactic and metagalactic background. Therefore only the foreground is registered. Hence with the distances to the nebulae known the volume density of the foreground emission in the directions of the HII regions is easily determined (below this value is given in Kelvin·parsec^{-1}). The data processing was described by Krymkin (1978a,b).

2. Measurements

The measurements were carried out at decametric wavelengths with the radio telescope UTR-2 (Observatory of the Institute of Radio Astronomy) at five frequencies ranging from 12.6 to 25 MHz with a spatial resolution of about 0°.5 at 25 MHz. The telescope has the best technical character-

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istics at long decametric waves (Braude et al., 1978). The brightness distribution has been obtained in the directions of HII regions at Galactic longitudes from 80° to 210°. The HII regions observed nearly exhaust the list of objects having an angular size of ≥ 1° that are accessible for the UTR-2. The results necessary for the further analysis are presented in the Table below (we also use the data by Caswell (1976) and Tokarev (1987)). l and L are Galactic longitudes and distances to the HII regions, respectively.

The volume density of the Galactic background at 25 MHz

HII region	l (°)	L (pc)	η (K.pc^{-1})
Cyg X*	80	1800	16±6.5
Sh 117	85	1040	18.5±2
119	87	870	19±2.5
171**	118	790	22.5±5.5
190	135	2200	10.5±0.5
202	141	1000	25±2
220	161	490	26±3
229	172	650	30±4
236	174	3000	7.2±1
264	195	500	25±2
273	203	710	21±4
275	206	1500	12±1
277	207	500	20±3
276	209	500	13±2
280	209	1500	11.5±1
282	210	1500	12.5±1
284	212	5200	3.7±0.5

From: *Tokarev (1987); **Caswell (1976). The data have been recalculated for 25 MHz with a temperature spectral index 2.4.

3. Results

a) Magnetic field parameters in the Local arm

The selection of HII regions with the distance of ≤ 1000 pc from the Table above makes it possible to analyze the Local Galactic arm. We also suppose more distant nebulae in Cyg X and Sh 117 to belong to the Local arm since they are seen along the axis of the arm.

Longitude dependence of the volume density η_{25} shows the anisotropy in the Local arm (see Fig. 1). We connect this fact with the anisotropy of the interstellar magnetic field. Our data seem to be in agreement with the field model consisting of the regular (directed) component and the isotropic component. The curve in Figure 1 is fitted to the measured points by the least-squares method in accordance with the model given. The following three parameters characterize the curve: the regular and

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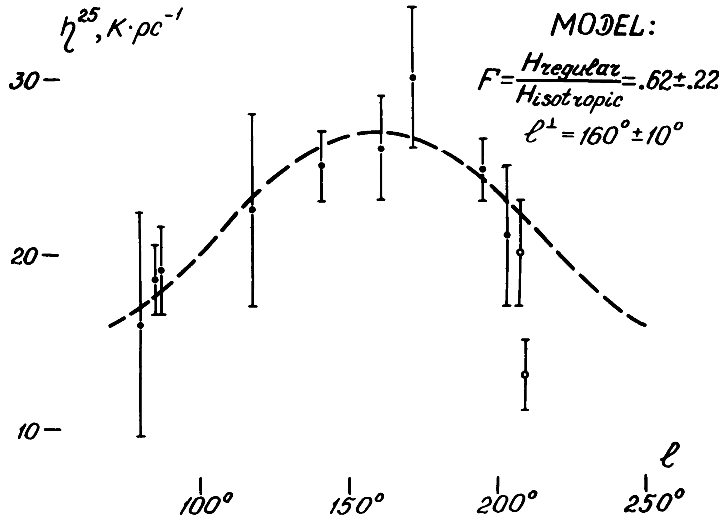

Figure 1. The longitude dependence of the volume density of the Galactic background in the Local arm at 25 MHz. The approximating dashed curve corresponds to the model of the magnetic field consisting of the regular and isotropic components. $l_{\perp}$ is orthogonal to the regular component of the field.

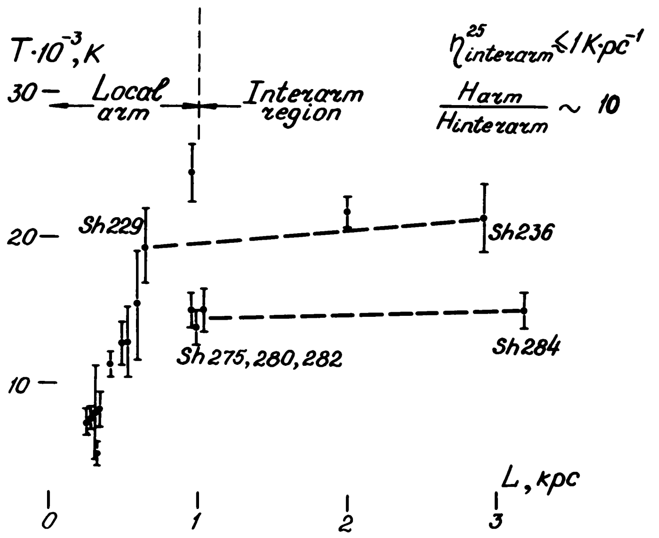

Figure 2. The distance dependence of the brightness temperature of the background on the line of sight "observer - HII region" at 25 MHz in the direction l = 160°.

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isotropic magnetic field component strength ratio (F = 0.62±0.22); the direction which is orthogonal to the regular component ($l_\perp$ = 160°±10°); the volume density of the Galactic background in the direction of $l_\perp$ ($\eta_\perp$= 27±3 K.pc^{-1} at 25 MHz). These data characterize the magnetic field and the nonthermal background over a scale of ≤ 1000 pc in the direction of the Galactic anticentre. We did not take into account the values in the directions of Sh 276 and 277 (the two right hand circles in Fig. 1) because of the remoteness of the nebulae from the Galactic plane (z ~ 120 ... 150 pc). So the density of the background in the directions of Sh 276, 277 is not typical for the Galactic disk in these longitudes.

Our field parameters are in good agreement with the independent results obtained at optical and high radio frequencies.

b) Magnetic field in the interarm region

The analysis of the dependence of the background brightness temperature generated between the observer and the HII regions (η_{25}.L - see Table) on the distances to the nebulae (L) enables us to estimate the volume density of the background in the interarm region. The dependence projected in the direction l = 160° is derived from the Table data and presented in Figure 2. The essential weakening of the nonthermal emission from the Local arm for l ≥ 200° and the absence of the Perseus arm for l ≥ 170° might be supposed from Figure 2 which corresponds to the data by Avedisova (1985). Hence from the comparison of the data concerning HII regions situated at essentially different distances from the Sun but in the same direction (Sh 229 and Sh 236; Sh 275, 280, 282 and Sh 284) the estimate of the density of the background in the interarm region have been derived: ≤ 1 K.pc^{-1} at 25 MHz (the result is in agreement with the assumption by Caswell (1976)). So the magnetic field strength in the interarm region is approximately one tenth as compared with the arm strength if the density of the cosmic rays is the same throughout the Galaxy disk (Berezinski et al., 1984).

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VERSCHUUR: I am impressed that you can observe at these low frequencies. Do you not suffer severely from interference produced by shortwave radio transmissions?

ABRAMENKOV: Yes, this is a problem, and not only this hinders our observations. The other reasons are the confusion with strong radio sources and the ionosphere. The decametric observations are very laborious. Our measurements were carried out during 10 years. We dropped out nearly 70% of our observations.

HELOU: How good is the assumption that the density of cosmic ray electrons is the same in the arms as in the interarm regions? After all, cosmic rays are supposed to be accelerated in the arms and then diffuse out.

ABRAMENKOV: The assumption is in some works (for example, Berezinski et al. (1984) and the references in this work). But if the assumption is wrong (if the electron density in the interarm region is smaller), then our strength ratio of the arm and interarm field (~10) will be the upper limit.

MOUSCHOVIAS: Perhaps I did not understand your conclusion that $B_{arm}/B_{interarm} = 10$. Doesn't this imply a contrast in synchrotron emissivity between the arm and interarm region of about 100? And, is that consistent with observations?

ABRAMENKOV: Our conclusion implies a contrast in emissivity arm/interarm ~ 27 (not 100, since the temperature spectral index at decametric waves is smaller than at short waves). This is inconsistent, for example, with the observational conclusion by Caswell (1976) that the arm/interarm contrast is ~10.