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ON A POSSIBLE JET OF OUR GALAXY

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Abstract. We assume a large-scale feature of the Galactic background, the North Polar Spur (NPS), being a jet of the Milky Way galaxy. The suggested interpretation explains the visible circular structure of NPS. The jet may be enveloped by an extended cocoon of a jet-long diameter. The hypothesis is supported by analysis of the physical parameters of NPS.

Key words: radio continuum: ISM – galaxies: jets – North Polar Spur

1. INTRODUCTION

Jets are typical features of radio sources, especially, of weak radio galaxies (Bridle & Perley 1984). They often have an extended envelope – cocoon. We assume that the large-scale feature of the Galactic radio background, the North Polar Spur (NPS), is a jet of our Galaxy. The non-thermal radio emission of this feature proves our assumption. As all the background maps show, the NPS is a strip of strong radio emission between the Galactic longitudes $\ell = 15$–$45°$originating from the Galaxy disk. It is nearly perpendicular to the Galactic plane and extends up to $b = 85°$ (see, e.g., Tkachenko 1972; Antonov 1973). It is of interest that the NPS has a very narrow neck near the Galactic plane (Haslam et al. 1964).

2. NPS PARAMETERS SUPPORTING THE JET HYPOTHESIS

With the NPS angular dimension of about 30°, the jet diameter should be $d \approx 1.7$ kpc, the Sun-to-jet distance $R \approx 8$ kpc. The existence of a cocoon with diameter about 15 kpc enveloping the jet can be assumed also. The suggested interpretation explains well the visible circular structure of the spur. The Galaxy jet is enveloped by an extended cocoon of a jet-long diameter. Thus, the observed edge of the jet envelope may be at a near distance of the order of 100 pc.

The observations show that the jets of weak radio galaxies are most often S-shaped or bent, just as they emerge from the galactic disk. That may be due to the effect of the dynamical pressure of the revolving gas disk (Bridle & Perley 1984).

The galactic background at 10 MHz was mapped in 1972 by A. V. Antonov and A. P. Tkachenko-Miroshnichenko (Tkachenko 1972; Antonov 1973) with a specially designed antenna at the Grakovo Radio Observatory, Kharkiv region using 48 turnstile vibrators, the resolution being 16.5°. It was determined that the average flux density at the NPS region is about 10^6 Jy at 10 MHz. This flux value corresponds to the NPS average brightness temperature $\sim 3.5 \cdot 10^5$ K. Using radio isophotes from the above survey at 10 MHz and the survey with the same resolution ($\sim$17°) at 200 MHz (Droege & Priester 1956) we obtained an average spectral index along the NPS central longitude ($\ell = 30°$) $<\alpha_{10-200}> = 0.55 \pm 0.07$, that is close to the spectral indices of jets in galaxies and quasars.

We also used the high resolution data with the following results. At higher frequencies (240–820 MHz range) the NPS spectral index is 0.65±0.02 (Berkhuijsen 1971). For the 22 MHz to 408 MHz frequencies the average NPS spectral index is $<\alpha_{22-408}> = 0.51 \pm 0.05$ (Roger et al. 1999).

The NPS radio emission is highly polarized, that points to the synchrotron mechanism of radiation, e.g., the polarization p reaches 70% at 1411 MHz (Berkhuijsen 1971). It is accepted that for the power spectrum of relativistic electrons ($N \sim E^{-\gamma}$) the following relation is valid (Ginzburg 1987):

$$p = \frac{\gamma + 1}{\gamma + \frac{7}{3}}, \tag{1}$$

$\gamma = 2.11$ at $p = 0.7$, i.e., the corresponding spectral index $\alpha = 0.56$. This estimation is close to the above NPS average spectral index.

Using the condition of energy equipartition between the relativistic particles and the magnetic field (Ginzburg 1987) and our NPS data for 10 MHz, the NPS magnetic field strength can be obtained:

$$B = \left[48kA(\gamma, \nu) \frac{S_\nu}{R\varphi^3} \right]^{2/7}, \tag{2}$$

where $k = 100$ (proton to electron energy ratio); $A(\gamma, \nu)$ is the tabular function (Ginzburg 1987); S_ν is the flux density at the frequency ν; R is the jet distance; $\varphi = \frac{d}{R}$ is the jet angular dimension; d is the jet diameter.

For $d = 1.7$ kpc and $R = 8$ kpc the NPS magnetic field strength is $B \approx 10^{-5}$ G and it is close to the magnetic field strength of jets in other galaxies. For the obtained B the corresponding synchrotron decay time t of relativistic electrons in the decametric range ($\nu = 10$ MHz) equals $t = 1.4 \times 10^8$ years, that coincides with the characteristic activity time of galaxies and quasars (Miroshnichenko 2000; Martini & Weinberg 2001). The t is estimated from the expression (Kardashev 1962):

$$\nu = 340 B^{-3} t^{-2}, \tag{3}$$

where ν is in MHz, B is in 10^{-6} G and t is in 10^9 years.

Let us consider another way of estimation the NPS magnetic field strength using X-ray data. It is known that the NPS vicinity reveals soft X-ray radiation, especially, at $E \approx 260$ eV (Bunner et al. 1972). Relativistic electrons, producing the synchrotron radio emission, may scatter photons of the microwave background, thus increasing the microwave photon energies to the X-ray energies (inverse Compton-effect). Under this assumption for the characteristic energy of the NPS X-ray photons $<E> = 260$ eV and for the frequency of synchrotron radiation of relativistic electrons $\nu = 10$ MHz, the magnetic field strength B can be found from the relation (Felten & Morrison 1966):

$$< E >= 0.9 \cdot 10^2 \frac{T}{B} \nu, \tag{4}$$

where $T = 2.7$ K, E is in eV, B is in 10^{-6} G and ν is in MHz. The estimated $B \approx 10^{-5}$ G from (4) agrees well with the above B estimated from (2).

To examine the jet fine structure we used the known radio isophotes of NPS at $\nu = 240$ MHz (Haslam et al. 1964), which had been obtained with resolution $\sim 1°$ in the latitude range $b = 10$–$40°$. These data revealed four compact domains of strong radiation along the NPS central longitude ($\ell = 30°$). Probably, these compact domains correspond to the jet knots. The NPS fine structure was also examined with the maps from Haslam et al. (1982) and Roger et al. (1999).

Jets of weak radio galaxies are most often bilateral, revealing both a jet and a counterjet (Bridle & Perley 1984). It is of interest that the background spur in the Galactic southern hemisphere at $\ell \approx 0°$ (map at $\nu = 10$ MHz from Cane & Erickson 2001) can be supposed to be a counterjet for NPS. This southern spur originates near the Galaxy plane at the Galactic longitude $\ell = 0°$ and extends to high southern latitudes.

3. CONCLUSION

Our hypothesis about the NPS being a Galaxy jet with an envelope simply explains the observed features of the NPS. In future studies of the probable Galaxy jet some special observations of NPS with sufficiently high resolution, in particular the polarization measurements in a wide frequency range, are required.

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