Cosmic background with model of cloudy interstellar medium

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Introduction

Non-thermal radio background contains information about the distribution of relativistic electrons and magnetic fields in the Galaxy as well as about isotropic radiation from integrated extra-galactic radio sources. As the observing wavelength increases, the intersellar medium (ISM), in which synchrotron emission is generated and through which it propagates, begins to influence the parameter of the observed radio background.

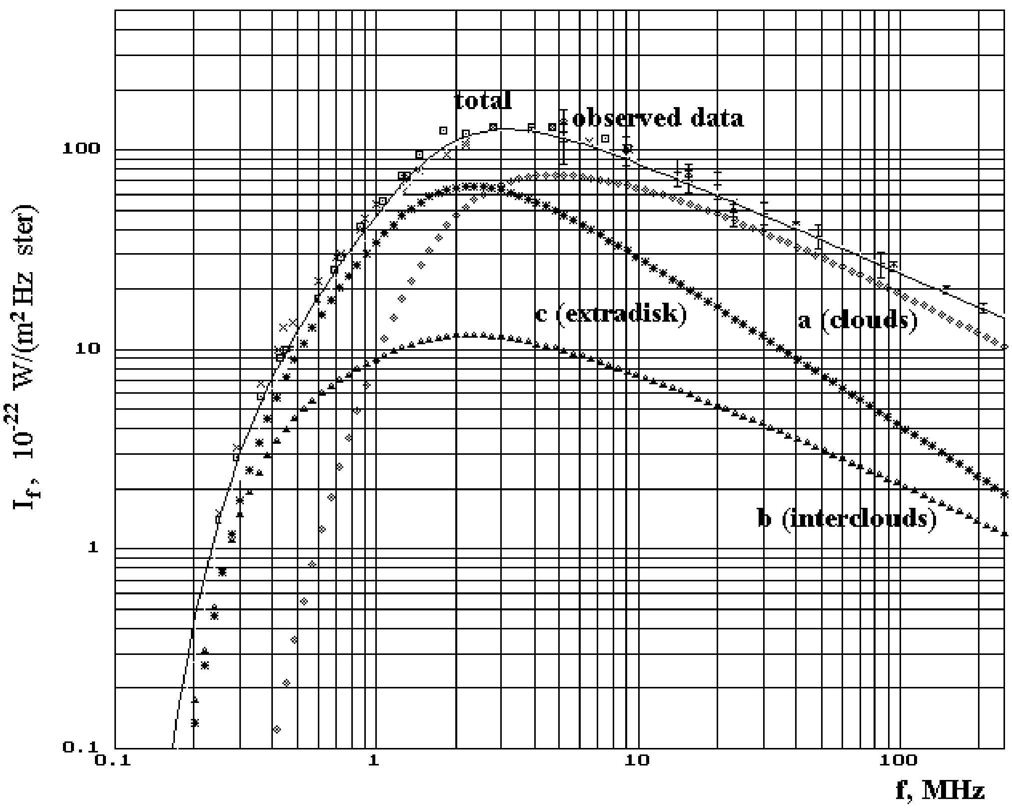

Figure 1: Averaged spectrum of the cosmic background $I(f)$ in frequency range 0.25 - 200 MHz for the Galactic poles. Vertical axis is intensity in units 10^{-22} W/m^2 Hz Ster. Horizontal axis is frequency in MHz. Diamonds are RAE 2 measurements, vertical bars are ground based measurements. The solid line is sum of the a, b, c background component (see text). The dashed plots are the spectra of the separate components.

In analysis of the averaged spectrum $I(f)$ of low-frequency cosmic background it is usually assumed that the galactic synchrotron radiation sources are uniformly mixed with ionized gas in disk with thickness of 1 kpc. The spectral maximum near 3 MHz (see Fig. 1) is associated with free-free absorption, and depression below 0.6 MHz is associated with the Razin-Tsytovich effect in an ISM (Kaplan and Pikelner, 1979). Inherent contradictions of this approach for the frequency range below 1 MHz have been recently shown (Fleishman and Tokarev, 1995; Korsakov et al., 1997).

Now it is well known both from observations and theoretical predictions that ISM is characterized by strong variations of the thermal gas electron densities in clouds and in the intercloud medium. First interpretation of the cosmic noise background spectrum at broad band frequency range 0.25 – 200 MHz with a model of the cloudy interstellar medium (ISM) is presented here.

Model description

The new interpretation of $I(f)$ was done with a model of the diffuse ISM described as a set of ionized H clouds which type was discovered by Reynolds (1990) (electron concentration of 0.15 cm^{-3}, temperature of 6000 K, filling factor of 20%). For usual value 6 mkG of interstellar magnetic field the Razin cut-off frequency in the clouds would be near the frequency of the observed $I(f)$ maximum. The spectrum $I(f)$ was considered as a result of three components : a) sinchrotron radiation from cosmic ray electrons in the clouds; b) the same type of radiation from the interclouds medium; c)the radiation from the sources located outside absorption gaseous disk of the Galaxy. It was used that the effective optical depth of cloudy ISM increases against of frequency fall more slow than it is predicted by an inverse power law (Tokarev, 1972) (Fig. 2).

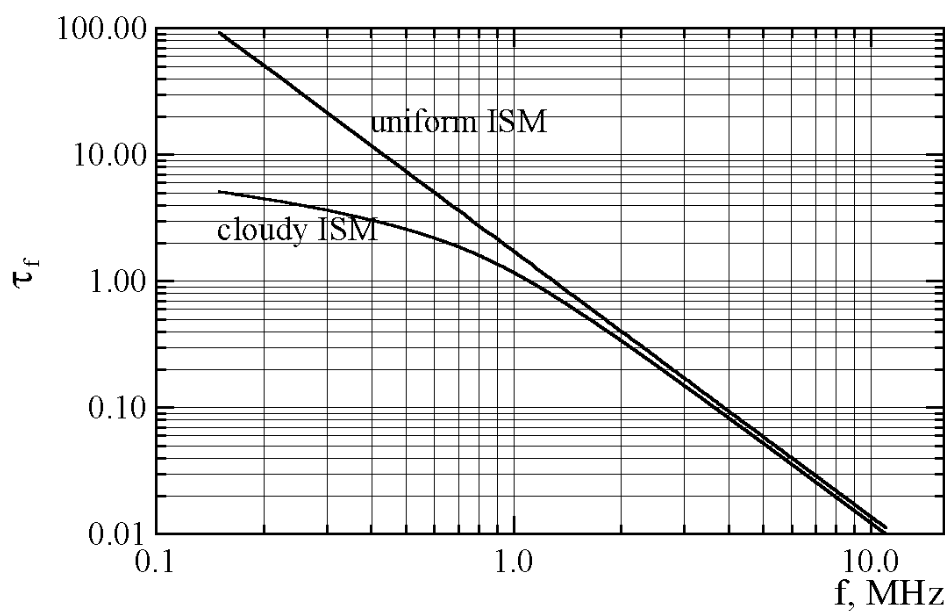

Figure 2: Optical depth $\tau(f)$ of the galactic disk for the pole direction versus frequency. The solid line is the dependance for considered model of cloudy ISM . The dashed line is one for uniform medium. Here was used Ellis (1982) estimation $\tau(f = 2.1\text{MHz}) = 0.41$.

It was taken into account also that the sharp depression of $I(f)$ at $f \leq 0.6$ MHz caused by the absorption in a local interstellar cloud (Korsakov et al, 1997).

Results

Low-resolution background observations at long wavelengths have been done by many authors using a variety of instruments. Only data obtained with identical angular resolution have been used here. Measurements at RAE-2 spacecraft at frequency range from 0.25 to 9 MHz (resolution of ~ 100 deg) have been combined with ground-based observations from 5.2 to 200 MHz with dipole antennae. Synthesized background spectra $I(f)$ for regions of the Galactic poles at the frequency range 0.25 – 200 MHz is presented in Fig. 1. The best fit procedure was used to separate total radiation into the components described above.

Spectral index of disk components was taken to be about 0.5 in accordance with galactic spectrum investigations; spectral index of extra-disk component was taken to be about equal to the average spectral index (~ 0.8) observed for surveys of extra-galactic discrete sources.

Conclusion

The following conclusions can be made:
– observed $I(f)$ maximum near 3 MHz is not only due to free-free absorption in the Galactic gaseous disk but also due to suppression of the Galaxy synchrotron emission in ambient plasma of the clouds;
– the volume synchrotron emissivity in the clouds must be at about 10 - 20 times longer than out of clouds;
– brightness of extra-disk component is about 1.5 time larger than expected value of extra-galactic background, it could indicate the presence of weak radio halo of the Galaxy with spectral index ~ 0.8; the extra-disk spectrum hasn't a remarkable low frequency turnover outside the galactic absorption gas at least up to 1 MHz.

The observations of angular variations of cosmic background brightness at $f \leq 0.6$ MHz would be very useful to give a more precise definition of the parameters involved.

These results are valuable for the study of spatial variations of interstellar magnetic field and the propagation of cosmic ray electrons in cloudy ISM, as well as the analysis of low-frequency extra-galactic radiation.

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