*The Universe at Low Radio Frequencies*
*IAU Symposium, Vol. 199, 2002*
*A. Pramesh Rao, G. Swarup and Gopal-Krishna, eds.*

# Low Frequency Observations of Millisecond Pulsars

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**Abstract.** We present results of the first low frequency measurements of integrated profiles and flux densities of a large set of millisecond pulsars at 102 MHz. Combining our observations with data at higher frequencies, borrowed from literature we performed the comparative analysis of the frequency dependence of profile width and spectra of millisecond and normal pulsars, searching for similarities and differences between their properties. Millisecond pulsars are differ to "normal" ones in much weaker frequency dependence of the width of integrated profile and the absence of the low- frequency turn-over in pulsar spectra.

## 1. Introduction

Millisecond pulsars (MSP) are a special population of pulsars, which distinguished from 'normal' ones by period, its derivative, magnetic field, age and evolutionary history. Therefore one may expect that the radio emission characteristic of MSP will be different to 'normal' pulsars.

Most known studies of MSP concentrate on high radio frequencies, while lower radio frequencies are of special interest. Low-frequency part of the spectra of normal pulsars yield as a typical features the low frequency turn-over (Sieber 1973; Bruck et al. 1978; Izvekova et al 1981). The frequency of a spectra turn-over depend on pulsar period as $\nu_{max}(MHz) = 120P(sec)^{-0.36}$ (Malofeev 1996). For periods $P \geq 50$ ms the frequency of maximum of spectra $\nu_{max} \geq 350$ MHz. Therefore, one expect that at low frequency all millisecond pulsars will be in the turn-over region of spectra. The profile's width-to-frequency dependence of normal pulsars is most pronounced at the low frequencies. Is the same for MSPs too?

There were only few data on MSPs at low frequency. Kuzmin et al. (1990) and Kuzmin & Losovsky (1996) have performed observations of MSPs PSR B1855+09 and J2145-0705 at lowest frequency 102 MHz and reported no evidence of a low frequency turn-over. Kuzmin & Losovsky (1996) detect also that the width of the integrated profile of PSR J2157-0705 is nearly independent of frequency contrary to normal pulsars.

We performed the low frequency measurements of integrated profiles and flux densities of a large set of millisecond pulsars at 102 MHz. Combining our observations with data at higher frequencies, borrowed from literature we made the comparative analysis of the frequency dependence of profile width

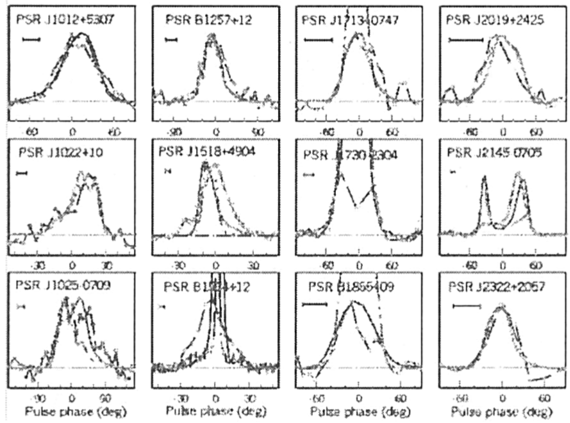


Figure 1. Profiles of millisecond pulsars. Details see in the text.

and spectra of millisecond and normal pulsars, searching for similarities and differences between their properties.

## 2. Observations and Data Reduction

The observations were performed at 102 MHz between 1996 and 1999 with the giant (72000 m2) phase-array radio telescope of the Pushchino Radio Astronomy Observatory. Linear polarization was received. All observations were time referenced to the Observatory rubidium master clock, with in turn was monitored against National Time Standard. Several session were added together to increase the signal to noise ratio and to reduce the influence of a polarization and scintillation of pulsar radio emission

At low frequencies the observed integrated profiles of the majority of short period pulsars are distorted for interstellar scattering. For reducing these distortions we used descattering compensation method (Kuzmin & Izvekova 1993). The short summary of this method one can find in Kuzmin & Losovsky paper "Low frequency Profiles of the Crab Pulsar" in this issue.

## 3. A Width of Pulse Profile Frequency Dependence

The frequency dependence of the integrated profiles of the MSPs is shown in Fig.1 by superposition of profiles at 0.1 GHz (dash-hollow-dot line), $\approx 0.4$ GHz (solid line) and $\approx 1.4$ GHz (dash-double-filled-dot line). Bars in the left top corner indicate a dispersion broadening at 102 MHz. High frequency profiles are smoothed out to obtain the same dispersion broadening equal to that observed at 102 MHz. For pulsars PSR B1534+12, J1713+0747, J1730-2304 and B1855+09 the high frequency profiles are shown in magnified scale.

The profile width of MSPs near the zero level remains nearly constant with frequency. This is in contrast with what is known for 'normal' pulsars where typically the pulse profile narrows significantly at the same frequency range.

https://doi.org/10.1017/S0074180900169426 Published online by Cambridge University Press

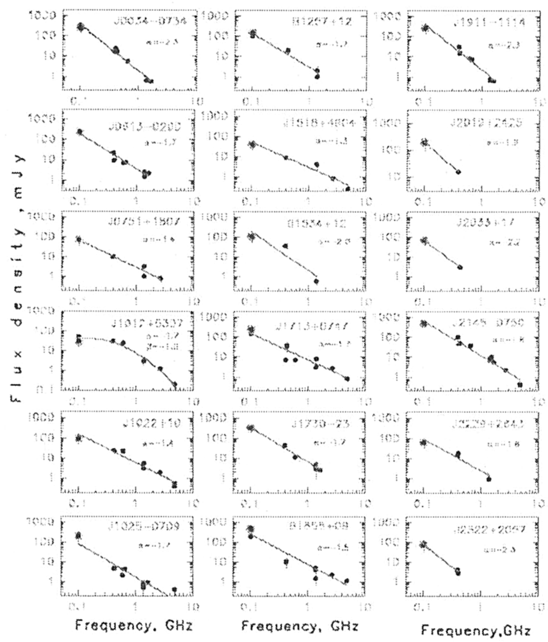


Figure 2. Spectra of millisecond pulsars. Details see in the text.

The quantitative analysis of the profile width-to-frequency dependence (at 0.1 level) as a power-low regression $W_{10}(\nu) \propto \nu^{\beta}$ confirm this qualitative visual examination. The mean values of power index of MSPs $\bar{\beta} = -0.02$ is significantly smaller then $\bar{\beta} = -0.17$ of 'normal' pulsars.

More detailes on this subject one can find in Kuzmin & Losovsky (1999).

## 4. Millisecond Pulsars Flux Densities and Spectra

Measurements of MSP flux densities $F_{PSR}$ were performed by reference to discrete sources with known flux densities using the signal to noise ratio $F_{PSR} = F_{Ref}(S/N)_{PSR}/(S/N)_{Ref} = \delta F \times (S/N)_{PSR}$, where $\delta F = F_{Ref}/(S/N)_{Ref}$. Here $F_{PSR}$ and $F_{Ref}$ are the flux densities of measured pulsar and reference source, $(S/N)_{PSR}$ and $(S/N)_{Ref}$ are their signal to noise ratios, $\delta F$ is the radio telescope sensitivity. The radio telescope sensitivity was derived from measurements of 70 reference discrete sources.

Results are presented in Fig.2 as the spectra of 18 millisecond pulsars. The circled points denote our measurements, the filled points indicate published data. The solid line represent the regression $F \propto \nu^{\alpha}$ , where $\alpha$ is a spectral index. For pulsar PSR J1012+5307 the spectrum was fitted by power low with a quadratic term as $\log F = c + \alpha \log \nu + \beta \log \nu^2$.

Spectra of millisecond pulsars are very different from those of normal ones that they have no low-frequency turn-over typical to normal pulsars.

More detailes on this subject one can find in Kuzmin & Losovsky (2000).

## 5. Discussion

Both, a weak frequency dependence of the width of integrated profiles and no low-frequency turn-over in pulsar spectra may be interpreted with the hypothesis that the geometry (topology) of the radio emission region of millisecond pulsars differs from that of normal pulsars.

We suggest that either the magnetic field configuration in MSP pulsar deviates from that of a pure dipole (the divergence of the magnetic field lines in the emission region of MSP pulsars is much less than in normal ones) or (and) the radio emission region is compressed.

## 6. Summary

Millisecond pulsars are differ to "normal" ones in much weaker frequency dependence of the width of integrated profile and no low- frequency turn-over in pulsar spectra.

We suggest that the geometry (topology) of the radio emission region of millisecond pulsars differs from that of normal pulsars (multipole magnetic field or compact emission region).

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