Origin of Pulsar Pulse Fine Structure

O.M Ulyanov[a], A.A. Seredkina[a], A.I. Shevtsova[a]

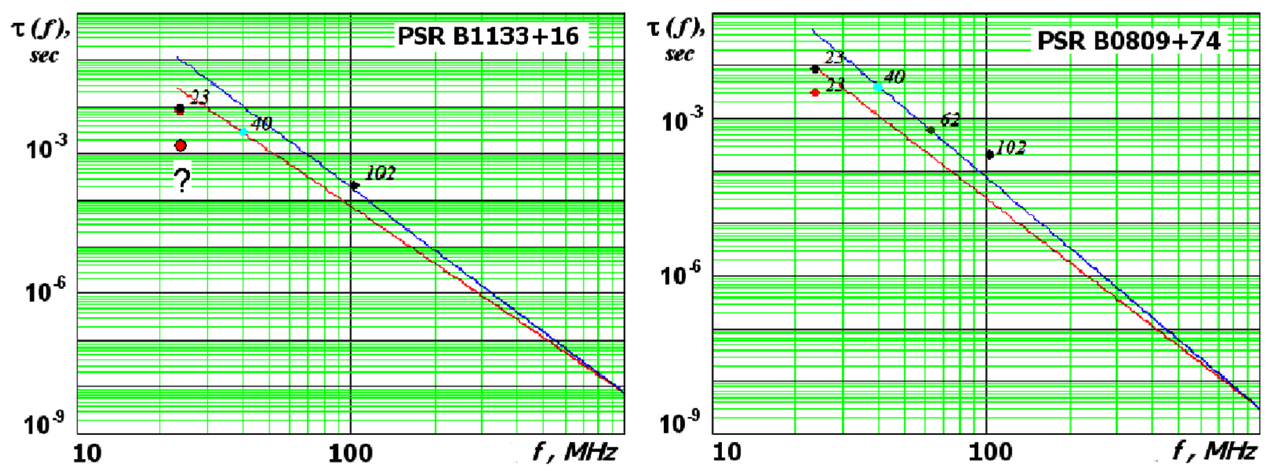
IAU Symposium 291
Neutron Stars and Pulsars: Challenges and Opportunities after 80 years

[a] *Department of Astrophysics, Institute of Radio Astronomy of NAS of Ukraine Krasnoznamennaya str. 4, Kharkov 61002, Ukraine;* e-mail: oulyanov@rian.kharkov.ua; seredkina.a@gmail.com; alice.shevtsova@gmail.com

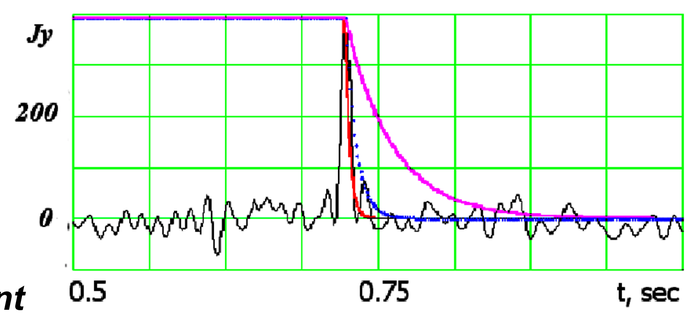
ABSTRACT

Despite the fact that the micro structure of pulsar radio emission was discovered more than 40 years ago still there is no generally accepted model of an origin of this phenomenon. We consider a conception of a fine structure of pulsar radio emission that covers different time scales from nanoseconds in the centimeter wave range to milliseconds in the decameter wave range. We propose a new model of the fine structure formation that is considered as a result of the propagation of the radio pulses through the interstellar medium and subsequent processing of received signal in a lab frame. Using numerical simulation methods we examine this model in which we present pulsar radio emission as a periodic sequence of short pulses generated at different frequencies. We consider three main factors: influence of cold plasma, scattering by density inhomogeneities of free electrons and time dispersion delay. The scattering was taken into account using the thin phase screen model with variable time scattering constant. Also we assumed a presence of at least two sources of additive white noise in the propagation channel. The modeled signals were studied by spectral and correlation analysis. Our simulation shows that at the receiver and it is possible to detect a fine structure, while the original pulses should be scattered in to TS at low frequencies. Registration of the fine structure will be possible for small-scale electron density inhomogeneities on the line of sight. The shortage of the scattering measure at low frequencies will be detected in this case. The characteristic width of the fine structure is increasing with decreasing of the signal frequency. The low level plateau which is located near the main pulse window should be detected with more high probability at low frequencies. The results of this numerical simulation are in qualitative agreement with the real pulsar observation data.

Problem of a Shortage of the Scattering Measure in the Decameter Range



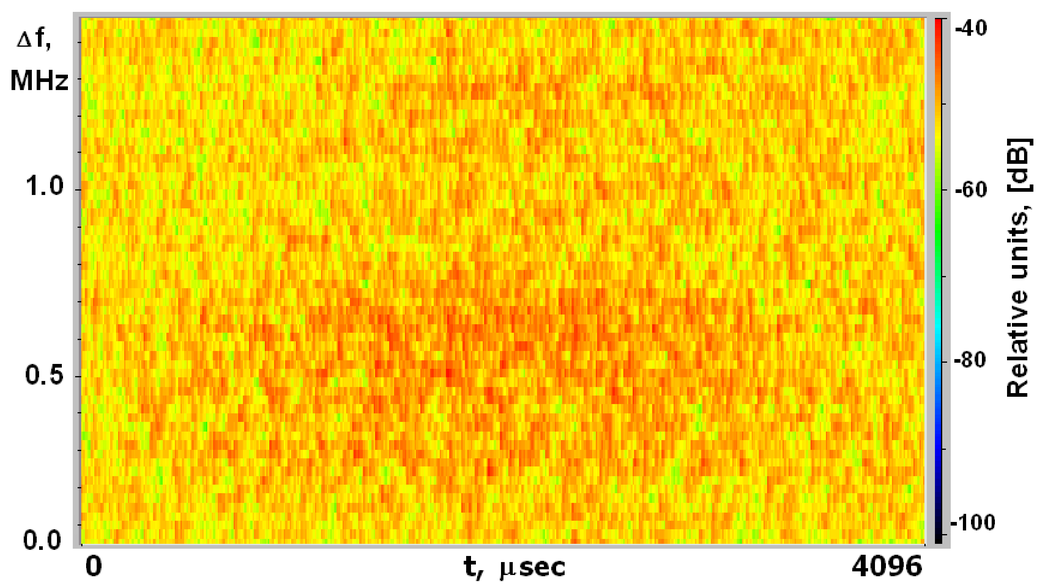
The Shortage of the Scattering Measure is Registered at Law Frequencies (Decameter Range) for Anomalous Pulses



Scattering measure: $SM = \int_0^L C_n^2 dl$

where C_n^2 ***is the structural constant***

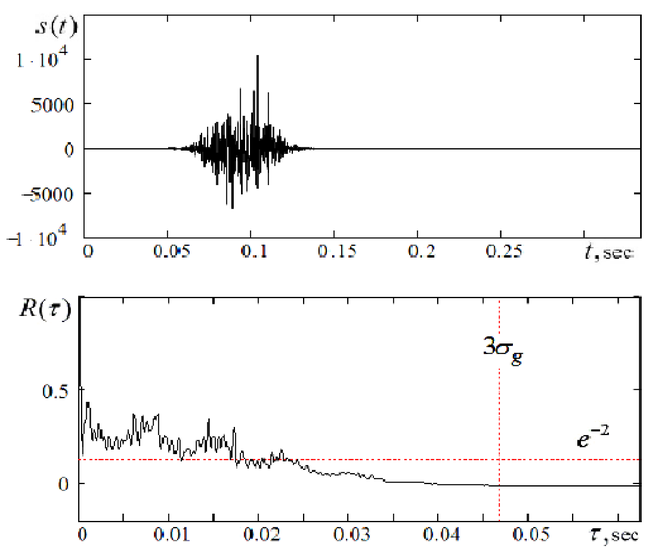
Dynamic Spectrum of the Single Pulse PSR B0809+74 at 23.7 MHz with Short-Scale of the Fine Structure

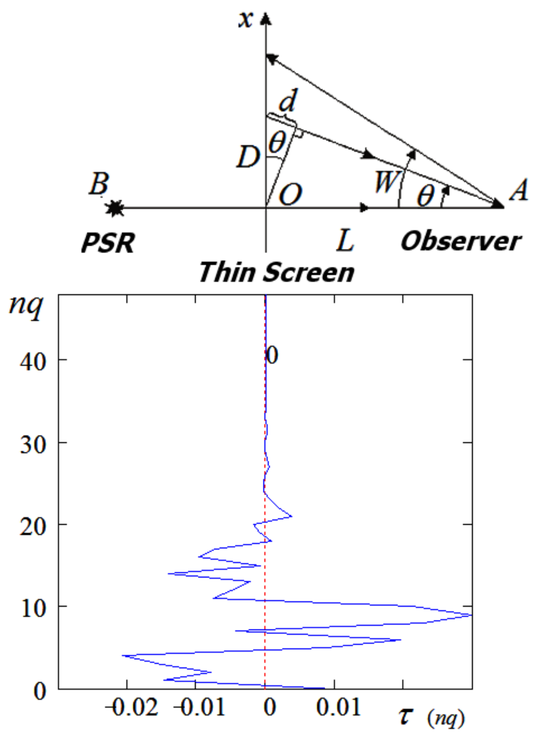


Fc = 23.7 MHz; ΔF = 1.538 MHz; Δτ = 40 us

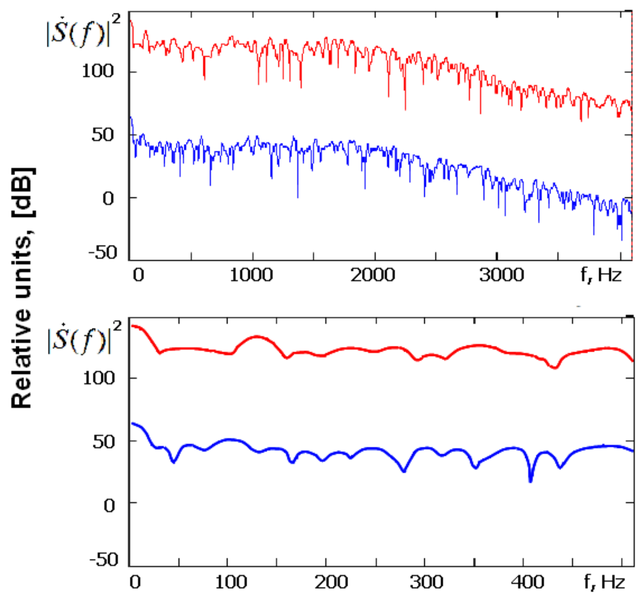
Simulation Study:

Pulse with Fine Structure and its ACF

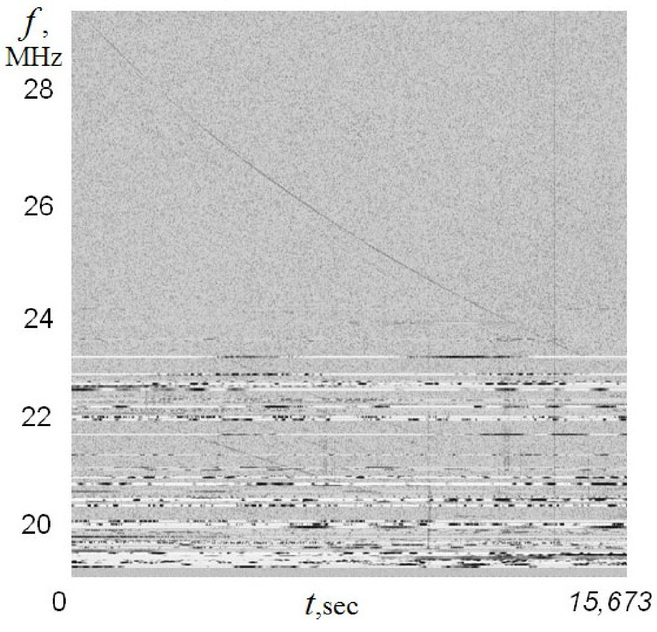




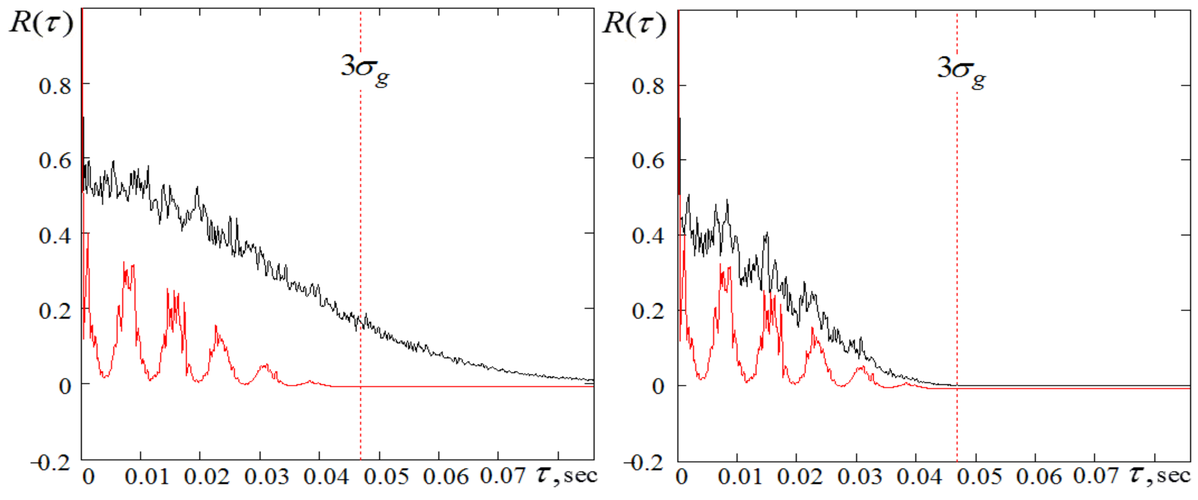
Spectrum of the Single Pulse before (red lines) and after (blue lines) of the Thin Screen (f = 20 MHz)



Dynamic Spectrum of the Single Pulse PSR B0809+74 at 23.7 MHz with Short-Scale in the Wide Band of UTR-2



Input (red lines) and Output (blue lines) ACFs of the Single Pulses with Fine Structure. Large-Scale and Short-Scale Inhomogeneities are given at the Left and Right Sides Respectively



CONCLUSIONS :

1) The presence or absence of the fine structure in the low frequency range is explained by a reaction of radio waves on the propagation in a plasma environment, which is located on the view axis.
2) The fine structure is smoothed out more strongly by scattering at the large-scale spatial inhomogeneities of the electron density.
3) The characteristic width of the recorded fine structure depends on frequency and increases with decreasing of radiation frequency.
4) The low-level plateau appears near the main pulse window with decreasing of frequency.