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Ionospheric scintillations in observations of pulsars with the LOFAR telescope

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Pulsars are extremely dense neutron stars that are leftovers from the evolution of massive stars. Thanks to the LOFAR radio telescope [1], we can observe the specific emission of these objects in the frequency range available for this instrument (30-90 and 110-240MHz). Previous studies have demonstrated the influence of the ionosphere on the flux of the pulsar signal [2]. We would like to present new tools of LOFAR pulsar data analysis and how utilize them in ionosphere diagnostics.

The characteristics of the pulsar signal allow for the determination of changes in the relative flux over time, divided into a selected frequency range and into channels, which is known as the so-called dynamic spectrum. As we cannot determine absolute fluxes from observations of individual LOFAR stations, dynamic spectra are constructed based on instantaneous S/N (signal to noise) values. Comparative analysis of such a signal with the results of TEC measurements carried out by GNSS services and analysis of variability allow for determining the dynamics of changes in the direction of the observed source. To determine the dynamics of changes in the signal received by the LOFAR station, the PSI – pulsar scintillation index calculation, based on S4 index described in [3] is used according to the rule:

$$PSI = \sqrt{\frac{\langle S/N^2 \rangle - \langle S/N \rangle^2}{\langle S/N \rangle^2}} \quad (1)$$

Where "S/N" is the Signal to Noise value, and $\langle\, \rangle$ is the temporal averaging.

Preliminary data (see example in Fig. 1) show the presence of quasi-periodic changes, which gives hope for the possibility of further analyzes related to TID structures and increase knowledge on spatiotemporal disturbances of the ionospheric plasma.

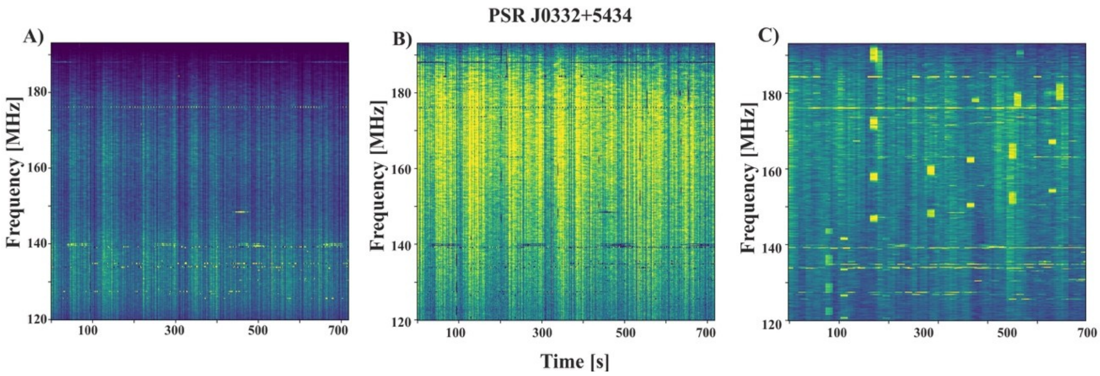

Figure 1. A) The dynamic spectrum of pulsar PSR J0332+54 observed in September 22nd, 2018, based on relative flux and **B)** on S/N value measured, and **C)** PSI index calculated with (1).

1. M. P. van Haarlem et al., "LOFAR: The LOw-Frequency ARray," *A&A*, **556** ,2013, A2 DOI: https://doi.org/10.1051/0004-6361/201220873
2. L.P. Błaszkiewicz et al., "Finding the Ionospheric Fluctuations Reflection in the Pulsar Signals' Characteristics Observed with LOFAR". *Sensors*. 2021; 21(1):51. DOI: https://doi.org/10.3390/s21010051.
3. P. Flisek et al., "Towards the possibility to combine LOFAR and GNSS measurements to sense ionospheric irregularities", *J. Space Weather Space Clim*. **Vol. 13**, 2023, DOI: https://doi.org/10.1051/swsc/2023021