

## Nearby pulsars B0950+08 and B1919+21

RadioAstron detected a space-Earth interferometric response of individual radio pulses from the pulsar B0950+08 in one of its first experiments. The observations took place on 25 January 2012, in the 92-cm wavelength band, at a maximum distance to the space radio telescope of 300,000 km. The projected interferometer baseline was 220,000 km, providing a record angular resolution of 1/1000 of arcsecond at this wavelength. The space-ground arms of the interferometer were formed by the largest radio telescopes on Earth, at Arecibo (USA), Westerbork (Netherlands) and Effelsberg (Germany).

From data processing and analysis by the original method of structure functions, the observations produced information on the distribution of interstellar plasma. The modulation index of scintillation was found to be about 40%. Theoretical work has shown that such a modulation can be caused by plasma along the line of sight, in the form of two scattering layers and a “cosmic prism.” This “prism” is a quite sharp transverse gradient in the plasma distribution. It deflects radio emission from the pulsar by 1.1 to 4.4 milliarcseconds. The far scattering layer is most likely on the outer boundary of the Local Bubble (a region of low-density gas in neighborhood of the solar system) at a distance of 26 to 170 pc. The near scattering layer is ionized gas at the border of a local molecular cloud, at a distance of 4.4 to 16.4 pc. The spectrum of turbulent density fluctuations in both layers follows a power-law with index  $\gamma = 3.00 \pm 0.08$ . This is significantly different from the Kolmogorov spectrum, with  $\gamma = 11/3$ .

These results could be obtained by Space VLBI observations only, because the Fresnel zone of the observed refraction is greater than the diameter of the Earth. The results of this study are published in the *Astrophysical Journal* (T.V. Smirnova, V.I. Shishov, M.V. Popov, C.R. Gwinn et al., 2014, *ApJ*, 786, 115): <http://dx.doi.org/10.1088/0004-637X/786/2/115>.

Similar results were obtained recently for another nearby pulsar, B1919+21. The interstellar scintillation of PSR B1919+21 is also defined by two screens of plasma inhomogeneities. Two components of scintillation consist of strong diffractive scintillation from a screen located at a distance of 300 pc, and weak scintillation at the layer at a distance 0.7 pc from the Earth. Angular refraction by a cosmic prism located on the distance of 1.7 pc defines the frequency structure of the scintillation. The refractive angle of this prism is 110 mas. The cosmic interferometer resulting from scattering resolves the scattering disk, with size of  $\theta_{diff} \approx 1.5$  mas.

## Scattering disc substructure in the pulsar B0329+54

The high angular resolution offered by the RadioAstron space-ground interferometer provided the possibility to measure the size of the scattering disk and to estimate the position of the effective scattering screen for the pulsar B0329+54, at an observing frequency of 324 MHz. Observations were conducted in two separate periods: in November 2012 and in January 2014. Observations were supported by the Green Bank Telescope (USA), the Westerbork Synthesis Radio Telescope (the Netherlands), and the 64-m radio telescope at Kalyazin (Russia). The

space-ground baseline projections varied from 60,000 to 235,000 kilometers during the November 2012 session, and from 15,000 to 120,000 kilometers in January 2014.

Notable visibility amplitudes were detected even at the longest baseline projections of more than 200,000 km, with a values of about 5%, at a  $20\text{-}\sigma$  significance level. The visibility function at the longest space-ground baselines in the delay domain consists of many isolated unresolved spikes. The overall spread of such spikes corresponds to a temporal broadening with a full-width at half-maximum of about  $7.5 \mu\text{s}$ . The fine structure of the visibility function in delay is consistent with an amplitude-modulated noise model, and so supports a theoretical picture of randomly scattered rays.

At short space-ground baselines, the distribution of peaks contains a strong central peak. The amplitude of a central peak decreases with the baseline, providing a direct measurement of the size of the scattering disk. This size was found to be 4.6 mas. By comparison of temporal and angular broadening we estimated a distance to the effective scattering screen, and found that it is located nearly halfway to the pulsar. Figure 1 shows the evolution of visibility structure with increasing baseline projection: at short baselines there is a central peak and an extended component; the amplitude of the central peak decreases with the increasing baseline; and only the extended component is present at the longest baselines.

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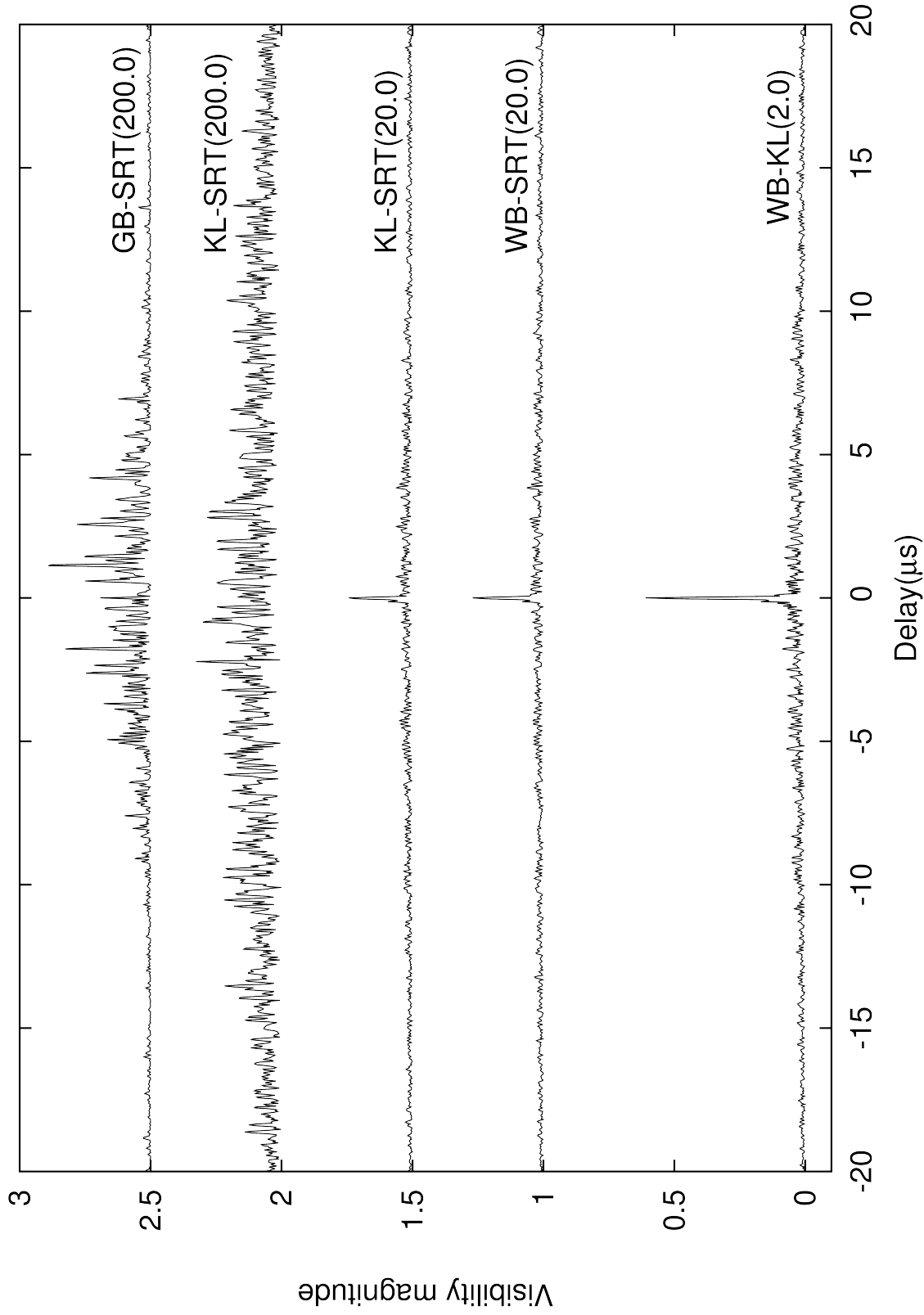


Figure 1: Examples of fine structure in the magnitude of visibility as a function of delay. Letters near each curve designate combinations of radio telescopes, and figures in brackets indicate baseline projections in  $M\lambda$ . The upper two curves are shown with the Y-scale amplified by a factor of 5.