URSI-RCRS 2024, ARIES/GEHU, Bhimtal, India, 22 - 25 October, 2024

In-situ measurements of scintillation and scatter broadening: the case of XTE J1810-197

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Abstract

Radio waves propagating through the ionized interstellar medium (IISM) undergo many effects such as dispersion, scatter broadening and scintillation. Of these, scatter broadening and scintillation are multipath propagation effects. Scatter broadening arises from the arrival of delayed copies of the electric field from an infinitesimally small range of angles about the line of sight, whereas scintillation is the result of interference of these waves. Scatter broadening leads to scintillation, and these phenomena allow us to probe the inhomogeneities in the IISM and quantify it. It is believed that the inhomogeneities in the IISM have their genesis in turbulence. Since pulsars are compact objects, they function as the best probes of the inner scale of IISM turbulence. The theory of Kolmogorov turbulence predicts a power law dependence on frequency for the scatter broadening timescale, with an index of 4.4. There is some evidence for departure from this index at high dispersion measures (DM) from a small sample of multifrequency scatter broadening studies. Besides, due to the inverse relationship $C_1 = 2\pi\tau_{sc}\Delta\nu_d$, the scintillation bandwidth $\Delta\nu_d$ is inferred for highly scattered lines of sight and vice versa, implicitly assuming Kolmogorov turbulence, which may not always be valid.

We have measured both τ_{sc} as well as the $\Delta\nu_d$ independently, allowing us to measure C_1 in-situ and without assumptions, for the magnetar XTE J1810-197, which is at 2.5 kpc and has a DM=178.85 pc cm^{-3}. Our fine measurement of $\Delta\nu_d$=160 Hz along with τ_{sc}= 1 ms rule out at 2σ a homogeneous medium with a square-law index for the power spectrum, while poorly constraining three other scenarios, including Kolmogorov thin and thick screens. The wide bandwidths of the GMRT receivers as well as the excellent capabilities of the digital back-end make this possible. Some of the challenges encountered in this research could be alleviated by observing a sample of pulsars, thus obtaining a fully empirical measurement of the turbulence parameter C_1 for multiple sightlines up to different distances.

Keywords: Scintillation, Scatter broadening, Ionised Interstellar Medium, Turbulence.