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Scintillation optics of pulsar binaries and microstructure in the local ionized interstellar medium

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Interstellar scintillation (ISS) caused by scattering from electron density microstructure ($\ll$1 AU) provides unequaled spatial resolving power for a number of applications in astronomy. These include studies of the interstellar medium on scales as small as 100 km and constraints on emission structure in the magnetospheres of compact objects on similar scales. An important tool for these efforts is the dynamic spectrum (DS) $I(\nu, t)$, the intensity vs. radio frequency ν and time t, often extending over bandwidths of 100 MHz to 1 GHz, and time spans of hour(s), respectively. The temporal dependence of the DS results from motions of the source, the Earth, and the scattering medium that transports the line-of-sight through the diffraction pattern. The underlying velocities include orbital motions of the Earth and the pulsar if it has orbital companion(s).

In ref. [1], a beautiful analysis of multi-epoch the DS of two binary millisecond pulsars has localized scattering structures along the lines of sight and constrained the orbital orientation for one object (J0613−0200). The characteristic ISS time scale in the DS varies from epoch to epoch due to orbital motions. For both pulsars, the Earth's orbital speed $\sim$30 km s^{-1} is large enough to produce measurable changes of the DS with season. The contribution of the scattering region's velocity to these temporal changes depends on its distance from the Earth. Model fitting yields scattering region distances of $\sim$320 and 260 pc with about 10% and 30% errors, respectively. Compared with dust extinction within 500 pc of the Sun [2], these distances correspond to locations just beyond the walls of the "Local Bubble", a region surrounding the Sun that is driven by supernovae and stellar winds [3]. The velocities of the interstellar medium (ISM) scattering regions $\lesssim$ 20 km s^{-1} are similar to the expansion speed of the Bubble and to the Sun's peculiar velocity in the Galaxy (when projection effects are taken into account) and the underlying scattered images of the two pulsars are elliptical, in one case very highly so, indicative of anisotropic scattering.

These results illustrate the power of the ISS observations for probing interstellar density microstructure, most likely turbulent in nature, and its context with respect to Galactic processes that sculpt the ISM. Going forward, the application of these techniques using multi-epoch data can be expected for a large number of lines of sight, allowing a more detailed picture of the local ISM. Many pulsars are monitored at high cadence for other applications (e.g., detection of long wavelength gravitational waves) and scintillation analyses will be a valuable byproduct, as demonstrated in ref. [1], especially as more sensitive telescopes and better spectrometers are deployed.

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