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Insights into Pulsar Magnetospheres Using FAST Single Pulses

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Pulsars are highly magnetized rotating compact objects that emit pulse-like periodic signals. Various emission processes take place in the magnetized plasma around the compact star, the pulsar magnetosphere. The magnetospheres around compact stars are natural plasma laboratories with extreme physical conditions, and could serve as a probe into particle physics. They also seem to play a crucial role in generating fast radio bursts (FRBs).

Since the discovery of pulsar, much effort has been made on understanding the abundant phenomena in pulsar radiation, but we are still not clear about some basic questions like "what is the true particle number density distribution in a pulsar magnetosphere". There are often several mechanisms put forward for one single phenomenon (like the circular polarization in radio pulsar emission), and need to be clarified through detailed analysis on observation data.

Five-hundred-meter Aperture Spherical radio Telescope (FAST) has given us chance to study more pulsars of their radiation in individual pulse periods, which are usually called single pulses. Single pulses could reveal more information of the pulsar magnetosphere, especially with the polarization properties, which is closely related to the propagation effects.

We would like to introduce one or two pieces of our work that aim to relate pulsar single pulse behaviors to processes in the pulsar magnetosphere. One interesting example[1] is that we found that in the emission of pulsar B1919+21, the polarization position angle of single pulses could rotate rapidly along the pulse phase (see the ψ panel in Figure 1). Such polarization position angle changes are too large to be explained by the magnetic field configuration, thus should be induced by propagation effects. We attribute this polarization pattern to monotonically change of phase lag between normal wave modes along the pulse phase. Some simple phenomenological modeling could roughly reproduce the observation (see the right plot in Figure 1). We estimate the phase lag in the pulsar magnetosphere in the paper, and it raises more questions which may be associated with magnetospheric parameters.

We may also include part of our more recent work on investigating the mechanisms that shaping the single pulse circular polarization.

References

[1] S. S. Cao *et al.* Astrophysical Journal 983:43 (2025)

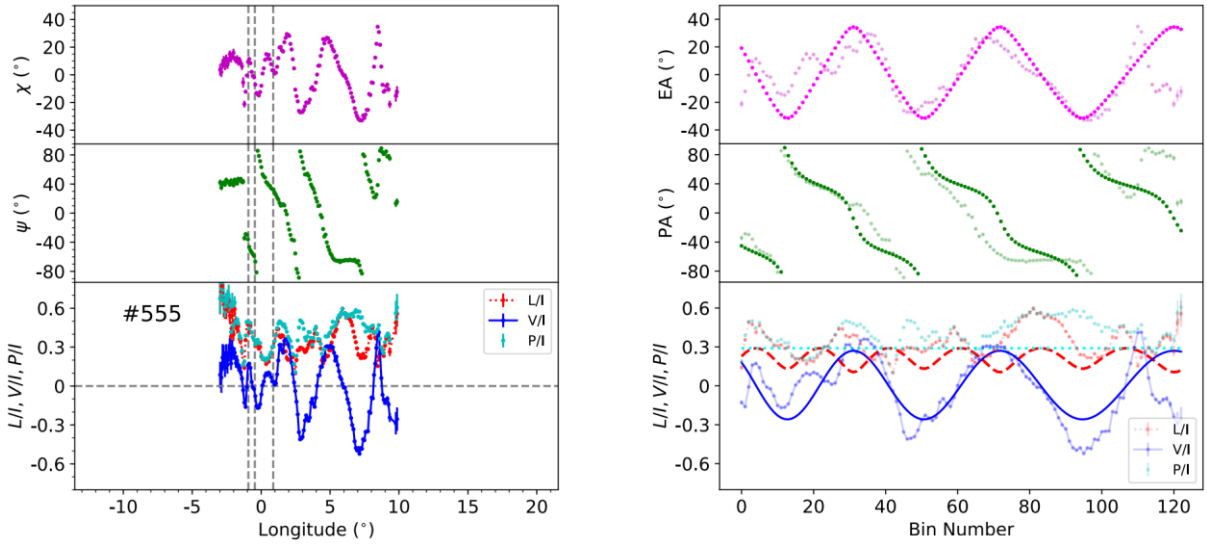

Figure 1. Phenomena and modeling of the polarization of one single pulse of PSR B1919+21. Left: linear (red), circular (blue), total (cyan) polarization degrees drawn from FAST data, as well as the polarization angle (PA, ψ) and the ellipticity angle (EA, χ). Right: Comparison of the data (pale dots) and the modeling result (darker dots).