High Linear Pulsar Polarization using Effelsberg Ultra-Broad Band

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Pulsar Magnetospheres

The position polarization angle (PPA) of most pulsars can be described by the Rotating Vector Model (RVM), enabling the estimation of the angle between the spin and magnetic axes (α) as well as the angle between the magnetic axis and our line of sight (β).

However, challenges arising from propagation effects in the magnetosphere, causing disturbances in the PPA, restrict our ability in constraining α and β, and, hence, our understanding of how these angles evolve over time and across different frequencies.

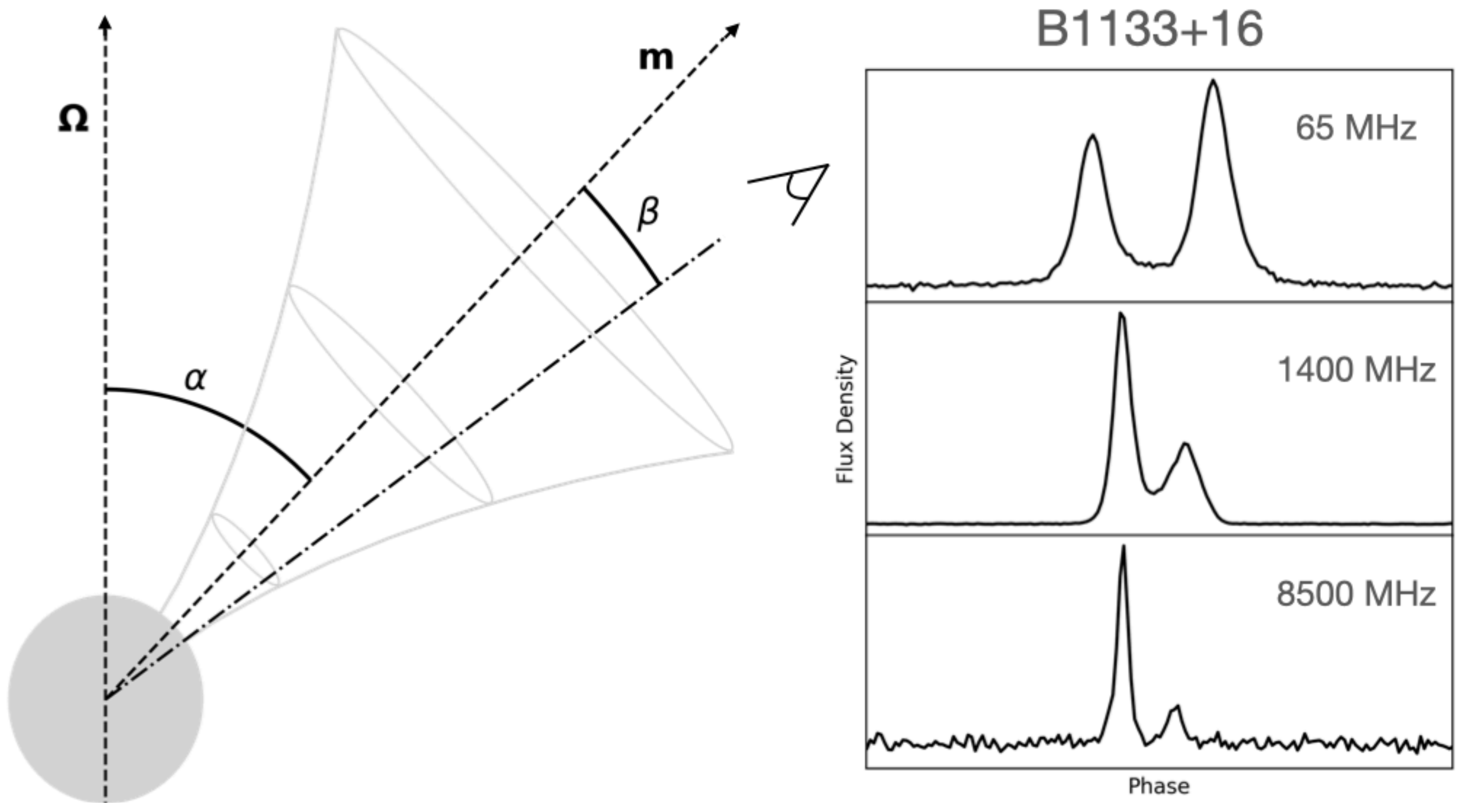


Figure 1: Illustration of a neutron star beam angles α and β, in addition to the broadening of the pulsar beam at different emission heights. The right graphs show the pulse profile at different frequencies. Data from LOFAR and Effelsberg.

Testing the Rotating Vector Model

We have studied the RVM fitting to better constrain the angle α by using simulations of the Stokes parameters including orthogonal jumps. The addition of weights on the edge of the PA swing helps in determining the geometry parameters.

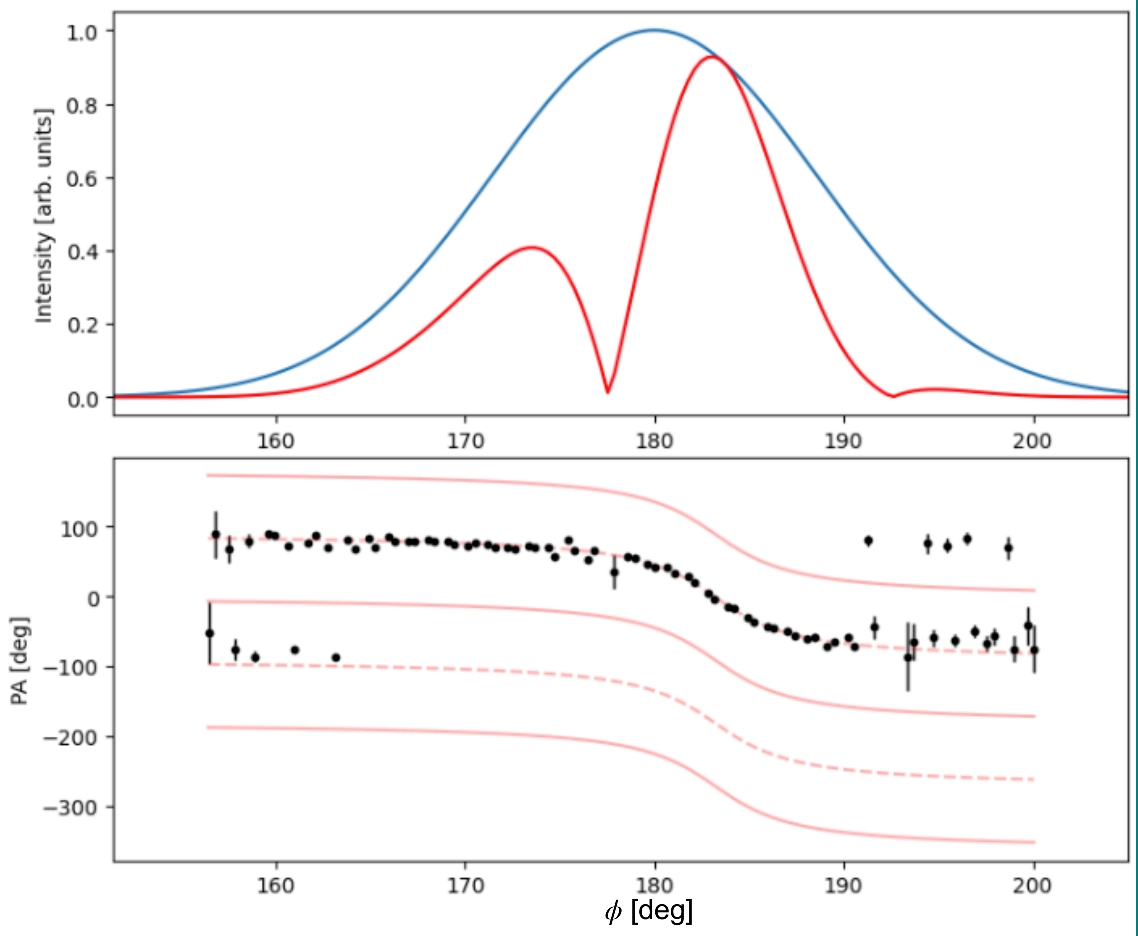


Figure 2: Example of simulated data of $\alpha = 92.9^\circ$ and $\beta = 3.1^\circ$. The top panel shows the total intensity, linear polarization (red line) and circular polarization (blue line). The bottom panel shows the PA swing.

The performance of any fitting method that uses PPA can be tested with the simulated data and check if the original distribution of α and β can be recovered.

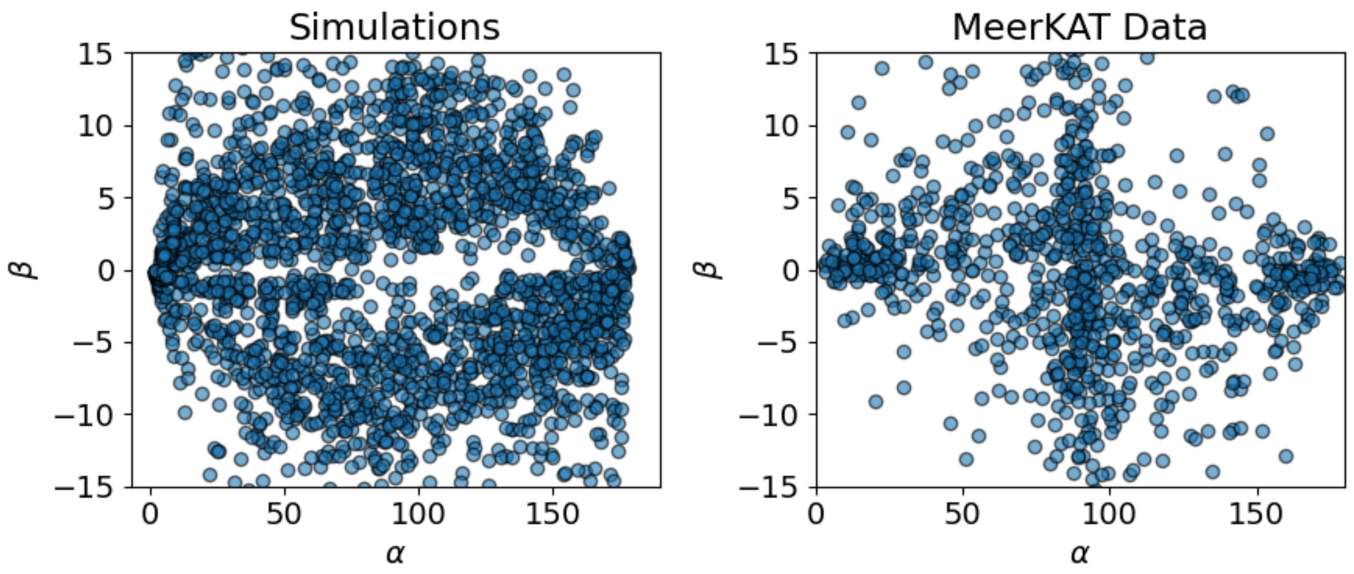


Figure 3: Comparison of the fit results ftom simulations (left panel) and fit results from MeerKAT Data (right panel).

Ultra Broad Band Effelsberg

The Effelsberg Radio Telescope's Ultra Broad Band (UBB) receiver covers a frequency range from 1.3 GHz to 6 GHz, offering a unique opportunity to comprehend the PPAs at higher-frequency regimes better as well as to a larger sample of pulsars.

The single pulse emission will also be used to investigate other phenomenon like subpulse drifting, nulling and emission mode changing, their polarization dependence, and provide important constraints on the origin of the outflowing plasma in pulsars.

UBB will give an unprecedented frequency coverage which will permit to study propagation effects in much detail.

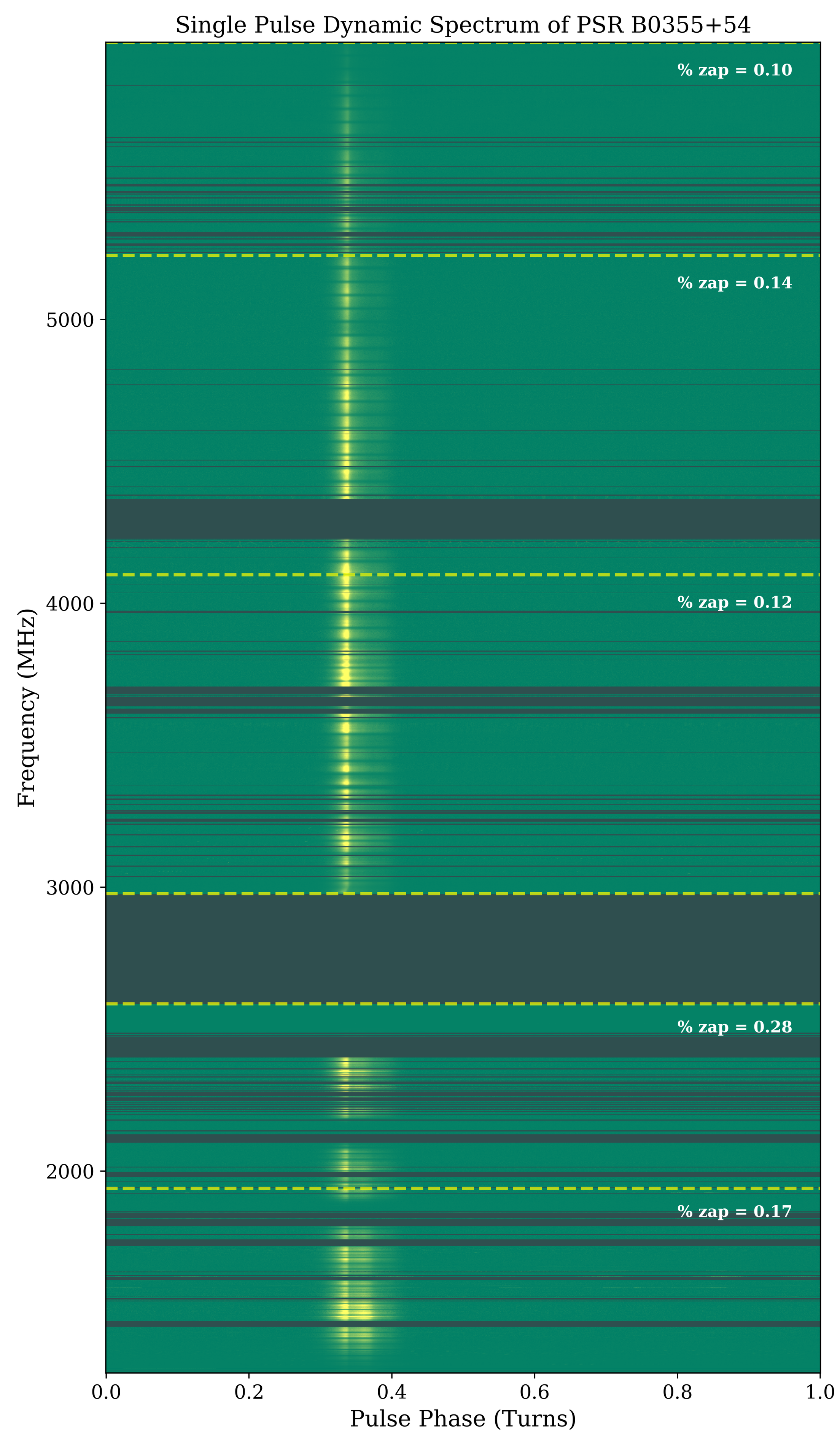
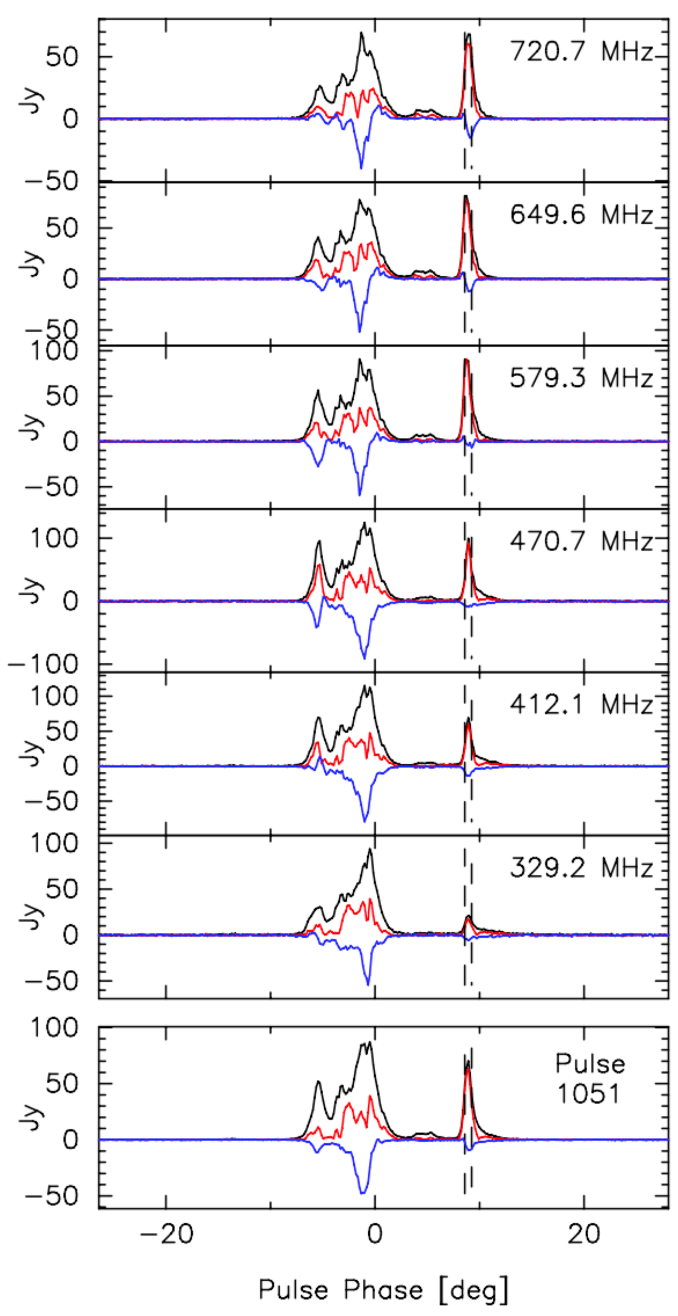


Figure 4: Pulse profile of B0355+54 across UBB frequency range. Courtesy Sanket Bangar.

Coherent Radio Emission



The origin of the radio emission remains a mystery. The RVM nature of the PPA suggests position angle of the projected electric vector closely follows the diverging magnetic field lines as the pulsar rotates across the observer's line of sight. This gives some new insight in the emission mechanism and the propagation effects at play.

Figure 3: The figure has been obtained from [3]. Highly polarized time samples of PSR B0329+54 from GMRT. The polarized feature is seen between 300-750MHz within a narrow longitude range.

Highly Polarized Signal

RVM-like PPA tracks can be recovered from pulsars that were previously thought to be too disturbed.

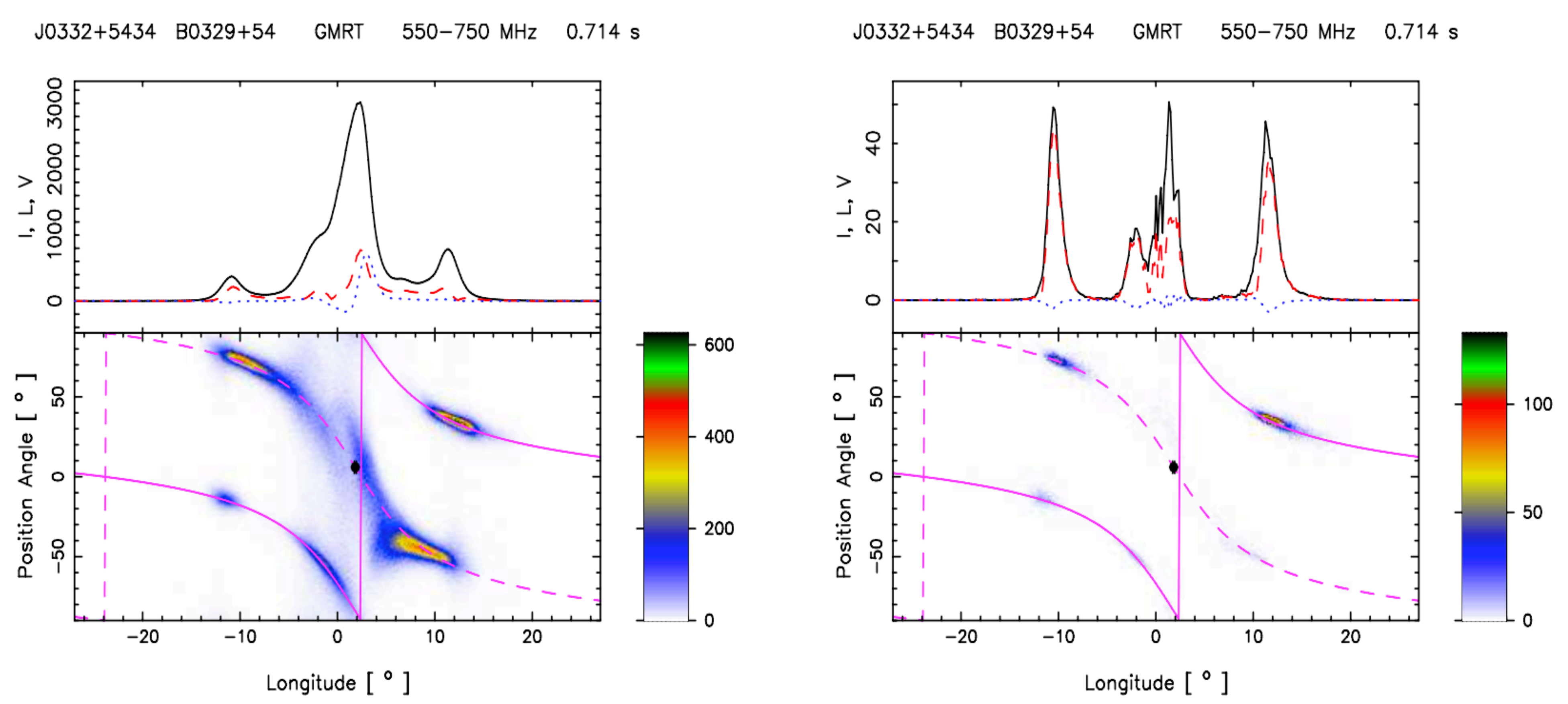


Figure 4: The left panel shows the average profile (top window) of PSR B0329+54 at 600 MHz using GMRT, and the single pulse PPA distribution (bottom window). The two orthogonal RVM fits (solid and dotted curves) to the PPA are also shown in the figure. The right panel shows the equivalent plots for the highly polarized time samples with linear polarization fraction above 90%. The PPA scatter is significantly reduced and they lie on the RVM tracks. Both plots are reproduced from [4].

References

[1] V. Radhakrishnan and D. J. Cooke, 1969. AL, Vol. 3, p.225.

[2] Johnston et al. 2024. MNRAS 530, Issue 4, pp.4839-4849.

[3] Mitra et al. 2024. ApJ, Volume 974, Issue 2, id.254, 12 pp.

[4] Mitra et al. 2024. Universe, Volume 10, Issue 6, id.248.