5.0 GHz TMRT observations of 71 pulsars and Q parameter research

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Outline

Background

- Integrated profiles help us investigate pulsar radio emission geometry, stable structure and the magnetic field properties
- Characteristics of the frequency dependence of integrated pulsar profiles
  - Steep intensity spectral index $\alpha \sim -1.8$ ($S_\nu \propto \nu^\alpha$)
  - Steeper spectrum of central components
  - Diverse frequency dependence of component separation
  - The polarization level decreases with increasing frequency
- 159 pulsars have been observed (4.0 $\sim$ 5.0 GHz)
- More high-frequency observations to understand the pulsar radio emission

Observation

- Using the Shanghai Tian Ma Radio Telescope (TMRT)
- A sample of 71 pulsars having $S_{1.4GHz} \gtrsim 4.0$ mJy
- 2015 May (MJD 57155) $\sim$ 2017 December (MJD 58114)
- The central frequency: 5.12-4.92-4.82 GHz
- 1 GHz bandwidth; 512 channels; 1024 phase bins; 30s subintegration time
- ATNF pulsar catalogue & PSRCHIVE programs

Results

- For 28 pulsars, the flux densities were calibrated using 3C48, 3C123, 3C196 and/or 3C295; For the other 43 pulsars, flux densities were estimated using SEFD
- There are 20 where there are no previously published 5.0 GHz profiles; for 19 pulsars, these profiles have a much better signal-to-noise ratio (S/N) than previous observations
- 3 Pulsar profiles (PSRs J0538+2817, J0742-2822 and J1825-0935) with mode changing at 5.0 GHz
- Spectra of 27 pulsars

Discussion

- Correlations of spectral index versus pulsar parameters

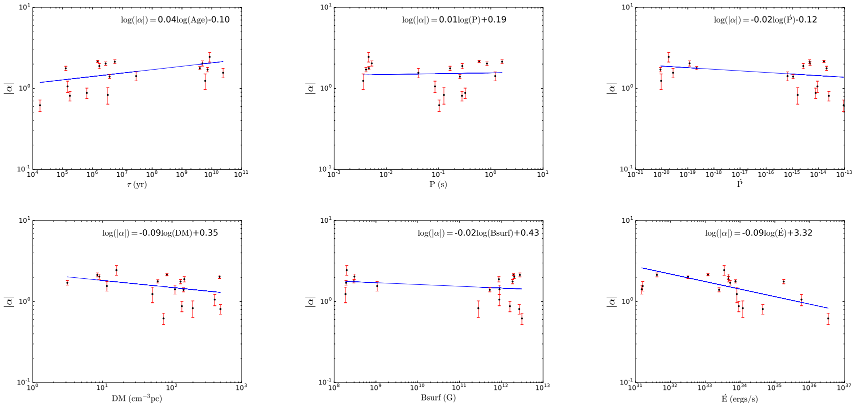


Figure: The correlations of spectral index versus τ, P, $\dot{P}$, the DM, B and $\dot{E}$. The blue line is a weighted power-law fit and the red bars are the uncertainties in spectral index.

Discussion

- Pulsar profiles with interpulse emission

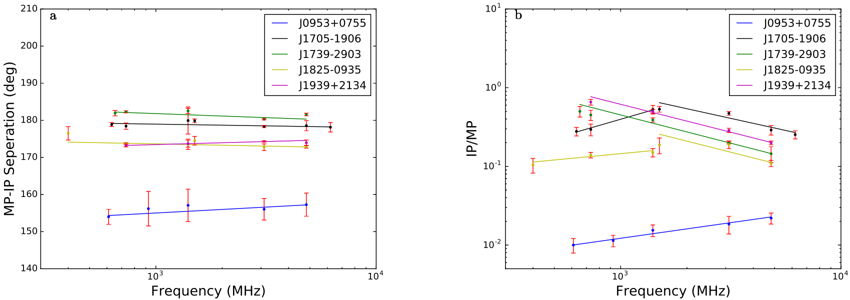


Figure: Left: IP separation from MP at different frequencies is shown for five pulsars. Right: Ratio of the peak flux of the IP to the peak flux of the MP is shown for all five pulsars. Errors marked by red bar are the uncertainty of several measurements. A weighted power-law fit line has been drawn for each pulsar.

Discussion

- Frequency dependence of profile width

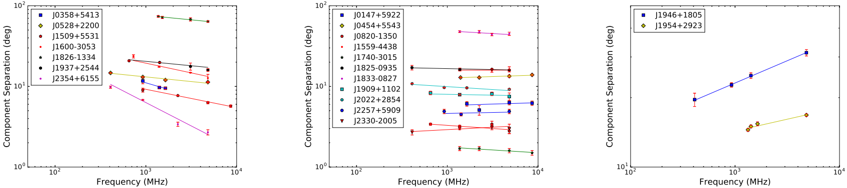


Figure: Separation of profile outermost components as a function of frequency for 20 pulsars. The lines are the weighted fitted power law for each pulsar.

Discussion

- Period dependence of width of core components
  - 6 pulsars with inter-pulse were analyzed by Rankin (1990) and found the relation between core width and period around 1 GHz:

$$W_{50}^{c,1.0} = 2^{\circ}45P^{-1/2}/sin\alpha_B \tag{1}$$

  - Maciesiak et. al (2012) confirmed that the same lower bound for W_{50} and W_{10} at 1.0 GHz existed in a wider populsation of 1450 pulsars and the lower bound is valid for both core and cone components.
  - The average ratio of 5.0 GHz width to 1.0 GHz width for multiple-component profile is about 0.95, so we adopt a scale factor for the 5.0 GHz intrinsic core widths of $2^{\circ}32$:

$$W_{50}^{c,5.0} = 2^{\circ}32P^{-1/2}/sin\alpha_B. \tag{2}$$

Discussion

- Period dependence of width of core components:

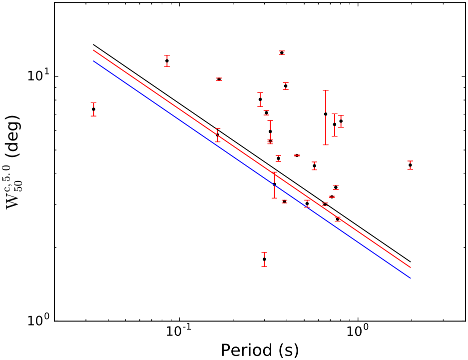


Figure: Observed core-component half-power widths at 5.0 GHz plotted against pulse period. Three lower-bound relations are shown: that from 1.0 GHz observations (black line), 8.6 GHz observations (blue line) and the 5.0 GHz data (red line).

Discussion

- Period dependence of width of core components

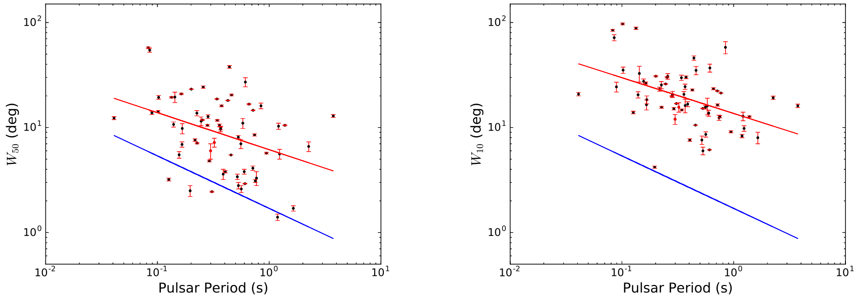


Figure: The 50 and 10 percent widths versus P around 5.0 GHz The red lines are the power-law fits with the slopes of -0.35 for W_{50} and -0.34 for W_{10}, respectively. The blue lines in both figures are the W_{50} and W_{10} as a function of pulsar period at 5.0 GHz according to Equation 2, respectively.

Recent Work: Research of Q parameter

- Simple model of radio beam
  - Geometry of pulsar emission beam & Rotating-vector model

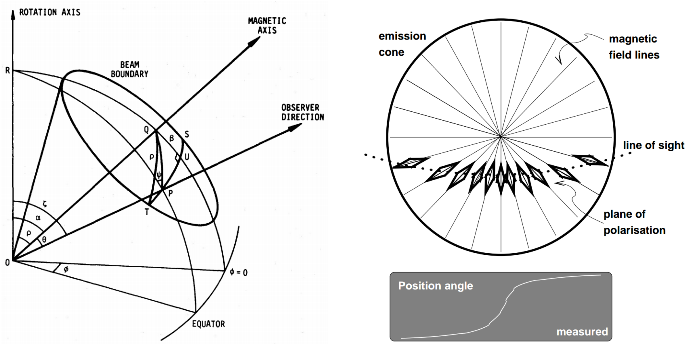


Figure: α: the inclination angle; β: the impact parameter; ρ: the radius of the emission cone; ψ: the position angle; ϕ: the longitude, defined to be zero on the magnetic meridian; $2\Delta\phi$: the total pulse width in longitude

Recent Work: Research of Q parameter

RVM model Radhakrishnan & Cooke (1969)

$$tan(\Delta\psi) = \frac{sin\alpha sin(\Delta\phi)}{sin(\alpha+\beta)cos\alpha - cos(\alpha+\beta)sin\alpha cos(\Delta\phi)} \quad (3)$$

$$(\frac{d\psi}{d\phi})_{max} = \frac{sin\alpha}{sin\beta} \quad (4)$$

Beam geometry Gil et.al. 1984

$$sin^2(\frac{\rho}{2}) = sin^2(\frac{\Delta\phi}{2})sin\alpha sin\zeta + sin^2(\frac{\beta}{2}) \quad (5)$$

Recent Work: Research of Q parameter

- Q parameter

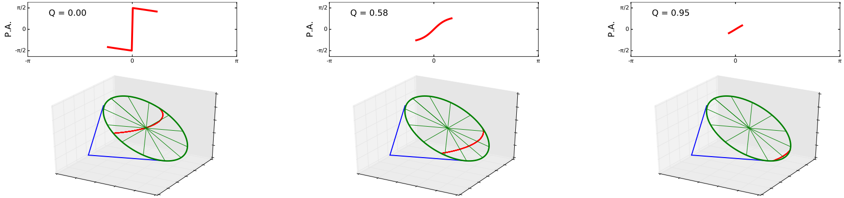
Wu et.al. 1986

$$Q = \frac{\beta}{\rho} \tag{6}$$

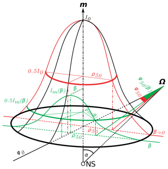
- Q indicates where the line-of-sight sweeps over the emission cone
- The value of Q almost equals a constant for every value of α. For any α we can get a β by Equation 4 and then get the ρ using Equation 5, then we can get Q.

Recent Work: Research of Q parameter

- We simulated the Q using Equation 3∼6:

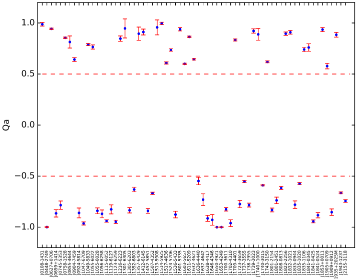


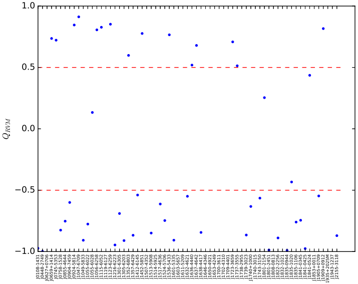
Find that position angle ψ is linear with the increasing Q. Maciesiak & Gil 2011 assumed that the radiation intensity on the pulsar beam centred on the magnetic axis **m** is gaussian-shaped distribution. According to the simulation and gaussian-shaped distribution we select the sample in Johnston & Kerr (2018) to study Q parameter.



Recent Work: Research of Q parameter

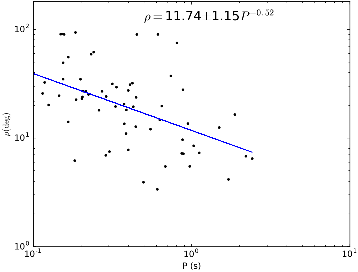
- Sample: Polarization observations for 600 pulsars by Johnston & Kerr (2018); Single: 173 (103); Double: 126; Multiple: 85
- Q parameters of 103 single peak profiles with simple linear polarization position angle swing curve are caculated using our method and the RVM model. Q ∈[| 0.5 |,| 1.0 |] means the radio emission region is away from the center.





Recent Work: Research of Q parameter

- ρ-P relation: Using different method we get the similar indices ($\sim$ 0.5) and coefficients of power-law, which is larger than the one from Rankin 1990.



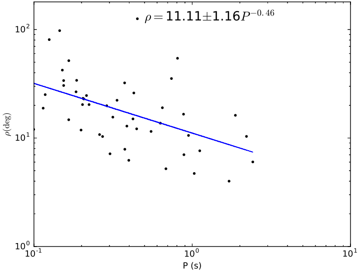


Figure: Correlation of ρ with Period obtained by Q method and RVM model

Summary

- 20 no previously published profiles at 5.0 GHz;
- 19 profiles with much better signal-to-noise ratio (S/N) than previous observations
- 3 Profiles with mode changing at 5.0 GHz
- The correlations of sepctral index versus τ and $\dot{E}$ is stronger than other parameters
- Independence of seperation between IP and MP; different behaviors of Ratio of the peak flux of IP to the peak flux of MP.
- Three different behaviors of the separation between the outmost leading and trailing components with frequency
- The relation between core width and period: $Wc50 = 2^{\circ}32 * P^{-0.5}$
- Q of 103 single peak profiles means the line-of-sight sweeps over the emission region where is away from core.
- We get the similar ρ - P relation with two different methods

Thank you!

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