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Broadband observations of pulsar profiles and frequency dependent DMs

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Abstract. The aim of our project is to search for ways to best extract information on pulsar profiles and the interstellar medium (ISM), using the wide frequency bands that are typical of radio telescopes today. Pulsar profiles typically show a strong dependence on frequency. This depends both on the intrinsic radio emission mechanism, and the interaction of the radio waves with the ISM that lies between the pulsars and our detectors on Earth, due mostly to the effects of dispersion and scattering. In this work, we make use of radio pulsar beam models from the existing literature, to generate simulated pulse profiles, observed across various bands (centre frequencies and bandwidths), for each beam model. For all the chosen geometric parameters of the pulsar beam, observed in any frequency band, the simulated profiles manifest a relative shift in phase in their observed components, as a result of the intrinsic profile evolution. This relative shift in phase could be interpreted as an additional component to the ISM induced dispersion measure (DM). This additional DM component due to profile evolution is frequency dependent. We discuss the systematics introduced to pulsar data due to this effect.

Keywords. pulsars: general

1. Introduction

Broadband emission from pulsars can be observed across broad frequency bands, to increase the measured signal-to-noise ratio of integrated pulse profiles. This also allows the deduction of ISM related parameters from low frequencies (where propagation effects are more severe) to apply to high frequencies (where pulse profiles have narrow features that can be used for arrival time (TOA) determination. Propagation effects through the ISM, mainly dispersion and scattering, can delay the profile arrival time at a given frequency. Intrinsic radius-to-frequency mapping, i.e. the frequency dependent emission heights in pulsar magnetospheres, introduce additional frequency dependent delays, due to the shape of the magnetic field lines. In this work, we attempt to quantify the additional delays due to intrinsic profile evolution in broadband data and compare the delays for different centre frequencies and fractional bandwidths. From this, we can find statistical biases of DM measurements across different frequency bands.

2. Simulations and Results

We assume emission from the polar cap region in the magnetosphere. For the purpose of our study, we adopt two pulsar beam models, the hollow cone beam by Backer (1976) and the conal-patchy beam model by Karastergiou & Johnston (2007) - see fig. 1. Both models use the same form of radius-to-frequency mapping and emission from the last open

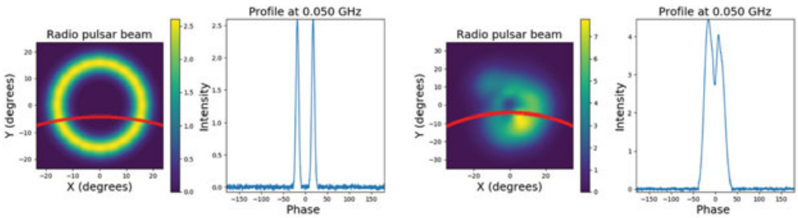

Figure 1. The hollow cone beam with the line-of-sight (LOS) profile (left) and conal patchy beam with the corresponding LOS cut (right). The LOS cut is represented with the curved line across the beams. Both the beams are at 50 MHz.

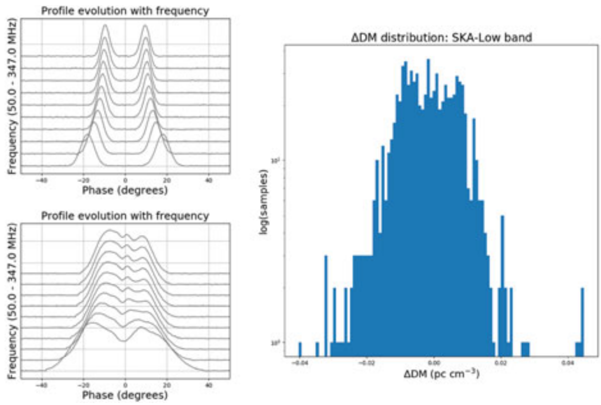

Figure 2. Left: Simulated pulse profiles at 50 - 350 MHz from the hollow cone beam (up) and the conal-patchy beam (down). Right: An example of the 1000 δDM distribution for the 50 - 350 MHz band using the conal-patcy beam model.

field lines. For a pulse period of 1 s, we randomly sample the geometry (inclination angle α and impact parameter β) and simulate 1000 pulsars with profiles in 10, evenly spaced channels for a number of different frequency bands. Fig. 2 shows example simulated average profiles in the 50 - 350 MHz band.

Components in the profiles in Fig. 2 display a relative phase shift which introduce a small δDM on the measured ISM induced DMs, a geometric effect that is due to profile evolution. To find this δDM we conduct a brute-force search over a range and select the best δDM as the one that maximises the peak signal to noise ratio. The histogram on the right of Fig, 2 shows the distribution of δDMs for the 50 - 350 MHz band.

3. Implications

Due to profile evolution with frequency and for a given pulsar, the DM measured within each of the simulated bands will be different. This implies that a single DM measured at low frequencies may not be straight forwardly usable at high frequencies. We also find that small delays at high frequencies correspond to larger DM discrepancies. We can statistically test the validity of our emission model assumptions by attempting to obtain such distributions observationally.

References

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