Pulsar Astrophysics the Next Fifty Years
Proceedings IAU Symposium No. 337, 2017
P. Weltevrede, B.B.P. Perera, L.L. Preston
& S. Sanidas, eds.

doi:10.1017/S1743921317008390

Wide band simultaneous multi-frequency single pulse study of PSR J1822−2256 with upgraded GMRT

Bhal Chandra Joshi[1], Arun Naidu[2], Vishal Gajjar[3] and Geoffrey A. E. Wright[4]

[1]National Centre for Radio Astrophysics (TIFR), Postbag No 3, Ganeshkhind, Pune INDIA
email: bcj@ncra.tifr.res.in

[2]Mcgill Space Institute, McGill University, Montreal Canada

[3]Space Science Laboratory, University of California, Berkeley USA

[4]Jodrell Bank Centre for Astrophysics, University of Manchester UK

Abstract. We present simultaneous multi-frequency observations of PSR J1822−2256 for the first time, utilizing the unique capabilities of upgraded Giant Meterwave Radio Telescope (uGMRT). No emission is detected in about 10 % of pulses. At least two drift modes and a possibly third rare mode, occur for 66, 21 and 2 % pulses respectively ($P_3 \sim 17$, 7.5 and 5 P_0 respectively). The three drift modes and the nulls occur concurrently from 250 to 1500 MHz. Modal average profiles are distinct with their widths increasing with drift rate. These sub-pulse drift related profile mode-changes can provide independent probes of beam geometry and polar gap physics.

Keywords. pulsars: individual : PSR J1822−2256, radiation mechanisms: general

1. Introduction

While the sub-pulse drift is believed to be related to polar gap potential (Leeuwen & Timokhin 2012), relativistic plasma outflow appears to be diminished during pulse nulls, if OFF duration of intermittent pulsars is considered as an extreme form of nulling (Gajjar *et al.* 2012; Lyne *et al.* 2010; Timokhin 2010). Both these phenomena occur concurrently over a wide band of frequencies (Gajjar *et al.* 2014; Naidu *et al.* 2017a). In some pulsars, changes in sub-pulse drift organizes the average emission in distinct profile modes (Wright & Fowler 1981; Vivekanand & Joshi 1997). Unlike sub-pulse drift (P_3) and nulls, these profile modes are dependent on the observing frequency and the beam geometry. Thus, deep simultaneous multi-frequency studies of pulsars with distinct drift rates can provide independent probes of geometry and polar gap physics. PSR J1822−2256 is a 1.8 sec pulsar, with a single component profile at 610 and 1400 MHz, developing a leading component at 325 MHz. Three distinct drift rates and pulse nulling were reported at 610 MHz (Naidu *et al.* 2017a). Here, we present recent observations of this interesting pulsar for the first time using the new unique capabilities of upgraded Giant Meterwave Radio Telescope (uGMRT).

2. Simultaneous multi-frequency observations with uGMRT

GMRT has recently been upgraded with installation of wide-band feeds covering 250−500 MHz, 550−950 MHz and 1100−1500 MHz (Band 3, 4 and 5 respectively) and 400 MHz wide-band digital backend providing 4 phased array beams (Gupta *et al.* 2017).

These upgrades make uGMRT a unique instrument providing a seamless frequency coverage from 250 − 1500 MHz with high sensitivity, making it an ideal instrument for our study. PSR J1822−2256 was observed in July 2017 using the uGMRT in a multi-beam mode, employing Band 3, 4 and 5 with 400 MHz bandwidth. The pulse sequences, aligned using time-stamps derived from an atomic clock, were obtained after folding dedispersed data to 512 bins across the period using TEMPO2 predictors (See Gajjar *et al.* 2014 for details of analysis).

We present for the first time a detailed study of single pulse behaviour of PSR J1822−2256 using the unique wide-band capabilities of uGMRT. PSR J1822−2256 shows prominent nulls, occurring concurrently from 250 to 1500 MHz with a nulling fraction of 10.1 ± 1.4 %. Three drift modes were identified, using both visual examination and short time fluctuation spectra (STFS), with P_3 of 17, 7 and 5 P_0 (Mode A, B and C respectively), occurring for 66, 21 and 2 % of pulses respectively. The drift mode switches simultaneously across all observing bands. Mode C is very rare and represents chaotic occurrence of sub-pulses. Average profiles for each mode, formed from mode separated pulses using STFS analysis are distinctly different with a leading component becoming more prominent for Mode B as compared to Mode A. The width of Mode B profile is also larger than Mode A. The presence of multiple profile modes, associated with changes in sub-pulse drift, reported here for the first time, makes this pulsar as the sixth such pulsar, similar to PSRs B0031−07, J1727−2739, B1918+19, B2303+30, B2319+60 (Joshi 2013; Rankin *et al.* 2013; Wen *et al.* 2016).

3. Discussions

The multiple drift modes in PSR J1822−2256 can be interpreted in a manner similar to the mode-changes of PSR B1918+19 , which was modeled as a carousel of 12 "sparks" circulating at a fixed speed, where the modes are observed as first-order aliases with each mode change corresponding to a loss of a single spark (Rankin *et al.* 2013). Applying this model to PSR J1822−2256, we assume 12 sparks initially observed under aliasing to drift at $P_3 \sim 17\ P_0$ with a constant circulation time of $12{\times}17/16\ P_0 = 12.8\ P_0$, not radically different from the value predicted by Ruderman & Sutherland (1975)'s original model (5.2 P_0). Then, when one spark is lost its P_3 changes to $17{\times}12/(17{+}11) = 7.3\ P_0$, as observed. We note also that the sub-pulse spacing increases (i.e. the profile width) as would be expected by this model. Finally, a further loss of a spark predicts a P_3 of 4.6 P_0 for Mode C, close to the estimated value.

References

Gajjar, V., Joshi, B. C., & Kramer, M. 2012, *MNRAS*, 424, 1197
Gajjar, V., Joshi, B. C., Kramer, M., Karuppusamy, R., & Smits, R. 2014, *ApJ*, 797,18
Gupta, Y. *et al.* 2017, *Current Science*, 113, 707
Joshi, B. C. 2013, *Proc. IAU Symp.*, 291, 414
van Leeuwen, J. & Timokhin, A. N. 2012, *ApJ*, 752, 155
Lyne, A., Hobbs, G., Kramer, M., Stairs, I., & Stappers, B. 2010, *Science*, 329, 408
Naidu, A., Joshi, B. C., Manoharan, P. K., & Krishnakumar, M. 2017, *A&A* 604, A45
Rankin., J., Wright, G. & Brown, A. 2013, *MNRAS*, 433, 445
Ruderman, M. A. & Sutherland, P. G. 1975, *ApJ*, 196, 51
Timokhin, A. N. 2010, *MNRAS*, 408, L41
Vivekanand, M. & Joshi, B. C. 1997, *ApJ*, 477, 431
Wen, Z. G. *et al.* 2016, *A&A* 592, A127
Wright, G. A. & Fowler, L. A. 1981, *A&A*, 101, 356

https://doi.org/10.1017/S1743921317008390 Published online by Cambridge University Press