

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

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**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

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## 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  $10.1 \pm 1.4$  %. 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.

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