# Postprint of the Study on Pulse Nulling and Subpulse Drifting Characteristics of the Long-Period Pulsar J1840−0840

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## Abstract

This study investigates dual-frequency observations of the long-period pulsar J1840-0840 based on the Giant Metrewave Radio Telescope in India and the Effelsberg 100 m radio telescope in Germany, systematically revealing its complex emission behavior. The average pulse profile of this pulsar exhibits two significantly separated emission components, and the evolution of the average profile with frequency is consistent with the theoretical expectations of the classical radius-frequency relationship, indicating that the radio emission height of the pulsar systematically decreases as the observation frequency increases. Single-pulse analysis reveals that the pulsar possesses significant pulse nulling and subpulse drifting characteristics. The nulling fractions at 625 MHz and 1358 MHz are $32.63\% \pm 10.46\%$ and $28.36\% \pm 7.35\%$, respectively. The occurrence rates of the pulse burst state and nulling state exhibit exponential decay characteristics as the duration increases. Furthermore, PSR J1840-0840 exhibits quasi-periodic nulling phenomena, with two modulation periods at 625 MHz, namely: $(50.57 \pm 9.03)$ and $(21.33 \pm 3.91)$ times the rotation period, while at 1358 MHz there is only one modulation period of $(31.37 \pm 11.90)$ times the rotation period. By modeling each drift band, the evolution relationships of the phase interval between drift bands, the drift period, and the drift rate over time were obtained, and the results show that the subpulse drifting parameters have significant frequency dependence.

## Full Text

# Study of Pulse Nulling and Subpulse Drifting Characteristics of the Long-Period Pulsar J1840−0840

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### Abstract

This study presents a systematic investigation into the complex emission behavior of the long-period pulsar J1840−0840, based on dual-frequency observations conducted with the Giant Metrewave Radio Telescope (GMRT) in India and the Effelsberg 100 m Radio Telescope in Germany. The mean pulse profile of this pulsar exhibits two significantly separated emission components. The frequency evolution of the average profile is consistent with the theoretical predictions of the classical radius-frequency relation, indicating that the radio emission height of the pulsar systematically decreases with increasing observation frequency. Single-pulse analysis reveals significant pulse nulling and subpulse drifting characteristics. The nulling fractions at 625 MHz and 1358 MHz are $32.63\% \pm 10.46\%$ and $28.36\% \pm 7.35\%$, respectively. The occurrence rates of both pulse burst and nulling states exhibit an exponential decay with increasing duration. Additionally, PSR J1840−0840 shows quasi-periodic nulling behavior, with two modulation periods at 625 MHz ($50.57 \pm 9.03$ and $21.33 \pm 3.91$ times the spin period) and one modulation period at 1358 MHz ($31.37 \pm 11.90$ times the spin period). By modeling each drifting band, we derived the temporal evolution of phase separation, drift period, and drift rate, revealing a significant frequency dependence of the subpulse drifting parameters.

**Keywords:** pulsars: individual: PSR J1840−0840, radio lines: stars, methods: data analysis

## 1. Introduction

Pulsars serve as natural laboratories for exploring physics under extreme conditions. These rapidly rotating, highly magnetized neutron stars provide a unique environment for studying matter at densities exceeding those of atomic nuclei.

The stability of radio pulses originates from the ultra-strong magnetic fields ($10^8$-$10^{15}$ G) and rapid rotation, creating a stable magnetospheric structure. While integrated pulse profiles exhibit statistical stability, individual pulses demonstrate complex radiative variations, including pulse nulling [?], mode switching [?], and subpulse drifting [?]. These phenomena reveal the complexity of dynamical processes within the magnetosphere, such as non-steady acceleration of relativistic particles in the polar cap.

PSR J1840−0840 is an isolated pulsar with an extremely long rotation period $P = 5.31$ s and a period derivative $\dot{P} = 2.37 \times 10^{-14}$, suggesting an advanced stage of evolution with a characteristic age of $\tau_c = 3.55 \times 10^6$ yr. Previous studies preliminarily identified nulling and drifting in this source [?], but limited data sensitivity and a lack of multi-frequency analysis have left gaps in our understanding. This study utilizes high-sensitivity dual-frequency data from the GMRT (625 MHz) and Effelsberg (1358 MHz) to systematically analyze these behaviors.

## 2. Observations and Data Analysis

The GMRT observations were conducted at 625 MHz with a 32 MHz bandwidth divided into 512 channels. The Effelsberg observations used the 21 cm 7-beam receiver at a center frequency of 1358.438 MHz with a 250 MHz bandwidth. Data were processed using DSPSR [?] and PSRCHIVE [?] software. RFI mitigation was performed using statistical analysis and non-Gaussian feature detection. After incoherent dedispersion and folding using a dispersion measure of 272.00 pc $cm^{-3}$, we obtained 1,260 pulses from GMRT and 2,697 pulses from Effelsberg.

## 3. Integrated Pulse Profile

The average pulse profile reflects the geometric features of the radio emission region. We modeled the profiles using a multi-Gaussian decomposition:

$$I(\phi) = \sum_{i=1}^{n} A_i \exp\left[-4\ln 2\left(\frac{\phi - \phi_i}{W_i}\right)^2\right]$$

[Figure 1: see original paper] The profile exhibits two distinct components. At 625 MHz, the peak-to-peak separation is 8.78°, which reduces to 6.58° at 1358 MHz. This frequency-dependent contraction is consistent with radius-to-frequency mapping, where higher-frequency emission originates from lower altitudes. The $W_{50}$ width decreased from 16.84° at low frequency to 12.57° at high frequency, a broadening rate of 33.97%.

## 4. Single-Pulse Analysis

[Figure 2: see original paper] illustrates the single-pulse sequences. Both datasets clearly show subpulse drifting and quasi-periodic nulling.

### 4.1 Pulse Nulling

Using energy integration and Gaussian Mixture Modeling [?], we determined nulling fractions ($NF$) of $32.63\% \pm 10.46\%$ at 625 MHz and $28.36\% \pm 7.35\%$ at 1358 MHz. The consistency of $NF$ across bands supports the hypothesis of global magnetospheric scale perturbations. [Figure 3: see original paper] The durations of nulling and burst states follow an exponential decay: For the burst state: $N = 10^{2.43\pm0.05} \times e^{-t/(5.60\pm0.35)}$ For the nulling state: $N = 10^{2.54\pm0.04} \times e^{-t/(4.45\pm0.21)}$ [Figure 4: see original paper] Discrete Fourier Transforms (DFT) of the nulling sequences revealed quasi-periodicities. At 625 MHz, peaks were found at $50.57\pm9.03$ and $21.33\pm3.91$ periods. At 1358 MHz, a single modulation period of $31.37 \pm 11.90$ periods was observed.

### 4.2 Subpulse Drifting

Subpulse drifting was modeled using an exponential decay function for the drift rate [?]:

$$D = \Delta D e^{-n/\tau} + D_\infty$$

$$\phi_{sub} = \tau \Delta D(1 - e^{-n/\tau}) + D_\infty n + (\phi_0 + kP_2)$$

The drift period $P_3$ was measured at $18.2 \pm 0.5P$ (GMRT) and $18.5 \pm 0.8P$ (Effelsberg), showing no significant frequency dependence. However, the longitudinal spacing $P_2$ showed frequency evolution, with $10.18^\circ$ at low frequencies and narrower intervals at high frequencies.

## 5. Discussion and Conclusion

This study confirms that PSR J1840−0840 exhibits complex, frequency-dependent emission. The contraction of the pulse profile at higher frequencies follows the radius-frequency relationship. The broadband nature of the nulling suggests global magnetospheric transitions. The subpulse drifting, while diffuse, shows stable $P_3$ values across frequencies, consistent with the carousel model where drifting is governed by the polar cap potential. Future high-sensitivity polarization observations with FAST will further constrain the 3D emission geometry and relativistic particle acceleration mechanisms in this long-period pulsar.

*Note: Figure translations are in progress. See original paper for figures.*

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