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A Rare Non-drifting State in the Subpulse Drifting Pulsar PSR J1059–5742

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Abstract

We report single-pulse observations of PSR J1059–5742 carried out with the 64-m Parkes radio telescope. Single-pulse analysis of the observations identifies three distinct emission states: a dominant subpulse-drifting state, a rare brighter non-drifting state, and short nulls. Our study show that 96.2% of the pulsar’s radio radiation is in the drifting state. In the drifting state, subpulses drift toward earlier longitudes, with drift periods of $P_3 = 5.7 \pm 0.5P$ and $P_2 = 5.6 \pm 0.7^\circ$. In the observations, we detect two rare non-drifting state events. The two non-drifting-state events persist for 107 and 108 rotation periods respectively. These two events accounted for 3.8% of the total observing time. Compared with single pulses in the drifting state, those in the non-drifting state are brighter, and the peak of the average pulse profile for the non-drifting state leads that of the drifting state by about 2° in spin longitude. This implies that changes may have occurred in the polar-cap discharge process or the magnetospheric configuration. Examination of the energies of all detected single-pulses revealed that the pulsar may have a nulling fraction of $13 \pm 1\%$, and pulse nulling occurs only within the drifting state. The occasional cessation of drifting in PSR J1059–5742 may thus reveal a mode change of the polar-cap discharge.

Keywords: pulsar: individual: J1059–5742

1 Introduction

Rotation-powered pulsars are believed to produce their coherent radio emission in the polar-cap regions of the magnetosphere. In the classic inner-gap model of Ruderman & Sutherland (Ruderman and Sutherland, 1975), the strong potential difference above the polar cap cannot be maintained in a steady state; instead, the gap undergoes repeated breakdowns in which bursts of electron–positron pair production, the “sparks”,

are ignited. Driven by the $E \times B$ drift and by the magnetic-field curvature, the sparks circulate across the cap and leave a characteristic imprint on the emitted radiation pattern. The resulting subpulse emission is naturally described by the carousel model, in which n sparks are arranged around the magnetic axis and rotate with a characteristic period P_4 ; the line of sight sweeps through the successive sparks once per rotation, giving rise to the subpulses observed within the

pulse window and, when the carousel rotates, to the drifting of those subpulses.

The drift phenomenon is closely tied to the pulsar’s energy and evolutionary stage. [Basu et al \(2016\)](#) showed, from a survey of 123 pulsars, that the drift period anticorrelates with the spin-down energy-loss rate, $P_3 \propto \dot{E}^{-0.6}$, and that phase-modulated drifting is confined to pulsars of intermediate and low $\dot{E}$, in support of the partially screened gap (PSG) model ([Gil and Sendyk, 2000a](#)). [Song et al \(2023\)](#) further found that P_3 follows a V-shaped locus as a function of characteristic age, and introduced the parameter $\xi = (P/1\text{ s})^{-1.7} (\dot{P}/10^{-15})$, which separates young, aliased drifters ($\xi \gtrsim 0.8$) from old, unaliased ones.

Two related phenomena complicate the emission of many pulsars. Nulling is the temporary cessation of the pulsed emission, or its reduction below the detection threshold of the telescope, lasting from a few to many pulse periods ([Backer, 1970b](#); [Ritchings, 1976](#)), and is quantified by the nulling fraction (NF). Mode changing is the abrupt switching between two or more quasi-stable emission states with distinct average profile shapes ([Backer, 1970b](#); [Wang et al, 2007](#)). From a large Parkes sample, [Wang et al \(2007\)](#) concluded that nulling and mode changing are different manifestations of a single underlying phenomenon, and that both become more common among older pulsars. Mode changes are frequently accompanied by variations of the spin-down rate, pointing to a magnetospheric rather than a surface origin ([Lyne et al, 2010](#)). High-sensitivity observations have recently revealed a rich phenomenology of such switching, including periodic mode changing ([Yan et al, 2020](#)), changes in the subpulse-drifting state ([Xu et al, 2024](#); [Szary et al, 2022](#)), and bi-drifting ([Szary et al, 2020](#); [Shang et al, 2022](#)).

PSR J1059–5742 (B1056–57) was discovered in the second Molonglo pulsar survey ([Manchester et al, 1978](#)). It has a rotation period of $P = 1.185\text{ s}$ and a period derivative of $\dot{P} = 4.31 \times 10^{-15}$ ([Keith et al, 2024](#)), which imply a characteristic age of $\tau_c = 4.36\text{ Myr}$, a surface dipolar magnetic field of $B_s = 2.29 \times 10^{12}\text{ G}$, and a spin-down energy-loss rate of $\dot{E} = 1.02 \times 10^{32}\text{ erg s}^{-1}$. Its dispersion measure of $\text{DM} = 108.57\text{ pc cm}^{-3}$ corresponds to a distance of roughly 1.6 kpc , estimated using a free electron density model ([Yao et al, 2017](#)). In this paper, we present a single-pulse study

of PSR J1059–5742 using observations from the Ultra-Wideband Low-Noise (UWL) receiver of the Parkes 64-m radio telescope, revealing its peculiar single-pulse behaviour. The paper is organized as follows. Section 2 describes the observations and data reduction. Section 3 presents our analysis and results, including nulling, subpulse drifting, and a rare non-drifting state. Section 4 provides a discussion and conclusions.

2 Observations and Data Processing

PSR J1059–5742 was observed with the 64-m Parkes radio telescope on 2018 December 27 (MJD 58479), using the UWL receiver system and the PDFB4 backend. The observation was made at a center frequency of 1369 MHz with a bandwidth of 256 MHz, split into 512 frequency channels of 0.5 MHz each. The data were recorded in search mode with a sampling time of $256\text{ }\mu\text{s}$, and the observation lasted about 2 hours, during which 5681 single pulses were recorded.

The single pulses were de-dispersed and folded into 512 phase bins per pulse period using the *DSPSR* software package ([van Straten and Bailes, 2011](#)), with the rotational ephemeris taken from the Australia Telescope National Facility (ATNF) pulsar catalogue ([Manchester et al, 2005](#)); the single-pulse integrations were written in the *PSR-FITS* format ([Hotan et al, 2004](#)). Strong narrow-band radio-frequency RFI were removed from the affected frequency channels, respectively, using the *PSRCHIVE* software system ([Hotan et al, 2004](#)). The fluctuation-spectral analysis of the single pulses was performed using the PSRSALSA software package ([Weltevrede, 2016](#)).

3 Results and Analysis

3.1 Single-pulse Energy Distribution and Nulling

The single-pulse stack provides a direct view of the peculiar phenomena of the single pulses, such as subpulse drifting. Figure 1 shows the single-pulse stack of PSR J1059–5742, in which each row displays the intensity of one single pulse as a function of pulse longitude, and the right-hand panel shows the relative energy of each pulse. Throughout most of the observation the subpulses exhibit

subpulse drifting, moving regularly towards earlier pulse longitudes and forming inclined drift bands, for example near pulse 2800. The drifting pattern is occasionally interrupted by short nulls, during which the pulsed emission disappears for one or two pulse periods; near pulse 3045, for instance, the pulse energy drops to zero, as can be seen in the right-hand panel. Moreover, the single pulses sometimes enter a distinct non-drifting state, in which the pulse phase is stationary, the energy is higher, and the profile is wider, so that the drift bands are replaced by a broad emission.

To determine the energy distribution of the pulsar, we defined the energy of each single pulse as the sum of the intensities in the phase bins of the emission window, which was taken as the longitude range over which the mean pulse profile exceeds 10% of its peak intensity. Following [Bhattacharyya et al \(2010\)](#), we adopted 3σ as the threshold for distinguishing the null and burst pulses, where $\sigma = \sqrt{N_{\text{on}}} \sigma_{\text{off}}$, with N_{on} the number of on-pulse phase bins and σ_{off} the rms noise measured in an off-pulse window of the same duration. A pulse whose on-pulse energy fell below this threshold was classified as a null pulse, and otherwise as a burst pulse.

The energy distribution of all single pulses is displayed in Figure 2. The on-pulse distribution does not show a clear bimodal structure, mainly because the null pulses of this pulsar are relatively few; nevertheless, a distinct population of single pulses with energies near zero is clearly visible. Using the method described above, we successfully separated the null and burst pulses and computed the nulling fraction (NF), defined as the ratio of the number of null pulses to the total number of pulses. We find $\text{NF} = 13 \pm 1\%$.

Figure 3 shows the average profiles of the burst and null pulses. The burst profile shows a broad, asymmetric single component, with a steeper trailing edge, which may result from the retardation effect ([Phillips, 1992](#)). The null profile, in contrast, is flat and fluctuates only at the level of the off-pulse noise, with no significant emission, confirming that the pulsar’s radiation is completely switched off during the nulls. It is also possible that the emission is too weak, falling below the detection threshold of the present observations; more sensitive telescopes would be required to test this.

The duration distributions of the burst and null states are presented in Figure 4. The durations of the two states are strongly asymmetric: the nulls are short and sharply concentrated between one and two pulse periods, the longest lasting about six periods, whereas the bursts persist for tens of pulse periods and can exceed one hundred periods. This indicates that once the pulsar enters the burst state, it is able to sustain steady emission over long intervals.

We further find that the nulls occur only in the drifting state; no nulls were identified within the two non-drifting segments, as detailed in Section 3.3. We caution, however, that only two non-drifting events were detected in this observation, so this correlation rests on a small sample and awaits confirmation from more observations.

3.2 Subpulse Drifting

To quantify the subpulse drifting, we performed a fluctuation-spectral analysis of the single pulses using the PSRSALSA software package ([Weltevrede, 2016](#)), which computes the longitude-resolved fluctuation spectrum (LRFS) ([Backer, 1970a](#)) and the two-dimensional fluctuation spectrum (2DFS) ([Edwards and Stappers, 2002](#)). In the LRFS, the fluctuation power is measured as a function of pulse longitude and fluctuation frequency; a drift feature appears as a band of enhanced power at a characteristic frequency, from which the drift period P_3 is directly obtained. The 2DFS further separates the modulation into amplitude- and phase-modulation components; for drifting subpulses it shows a phase-modulation signature, from which the P_2 value can be obtained.

The LRFS (top) and 2DFS (bottom) of the entire observation are shown in Figure 5. In the LRFS, a prominent drift feature is present within the radiation window at a fluctuation frequency of about $0.18 P/P_3$. A Gaussian function was fitted to the peak of this feature, yielding $P_3 = 5.7 \pm 0.5P$, where P is the pulsar spin period. Interestingly, the fluctuation frequency increases slightly with pulse longitude, from about 0.16 near the leading edge to about 0.19 near the trailing edge, which corresponds to P_3 decreasing from about $6.3P$ to about $5.3P$. This merits confirmation with longer-duration observations.

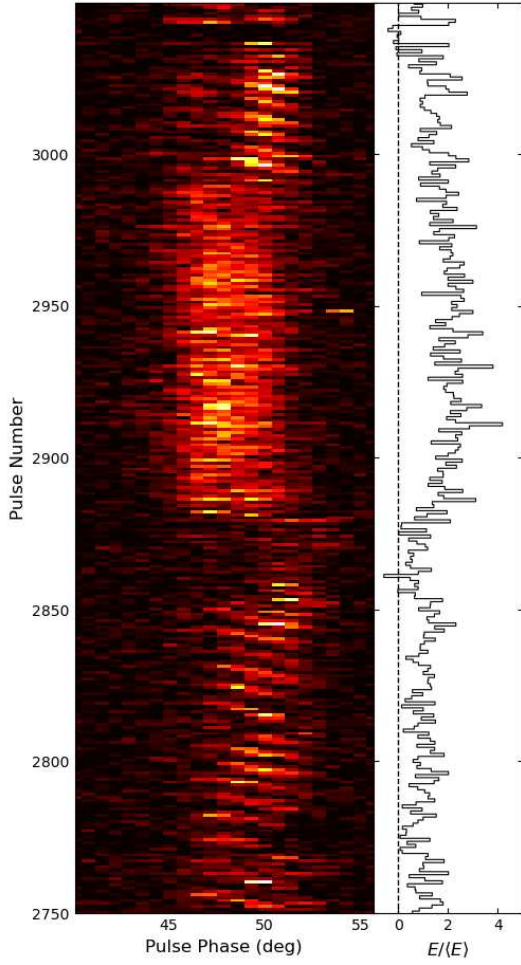


Fig. 1 Single-pulse stack of PSR J1059–5742. Each row shows the intensity of one single pulse as a function of pulse longitude, and the right-hand panel shows the relative energy of each pulse. The three subpulse states are clearly visible: the drifting state (e.g., pulses 2750–2850), the non-drifting state (e.g., pulses 2890–2990), and the null state (e.g., at pulse 3045).

The 2DFS simultaneously provides the drift period P_3 and the subpulse phase spacing P_2 , and its phase-modulation signature confirms that the subpulses move regularly in pulse longitude rather than undergoing a simple amplitude modulation. We measure a subpulse phase spacing of $P_2 = 5.6 \pm 0.7^\circ$. As can be clearly seen in Figure 1, the subpulses drift towards earlier pulse longitudes, i.e., negative drifting, at a rate of $D = P_2/P_3 = 0.98 \pm 0.15^\circ$ per pulse period.

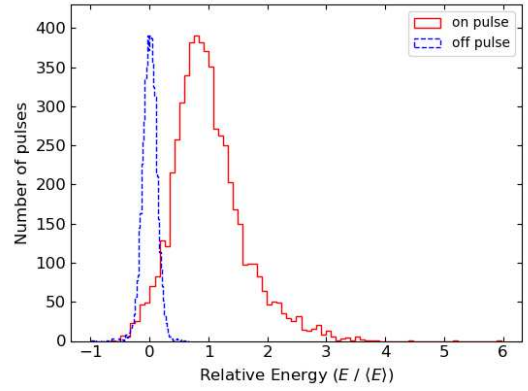


Fig. 2 Energy distribution of the single pulses. The on-pulse (red solid) and off-pulse (blue dashed) energy distributions are compared. The on-pulse distribution does not show a clear bimodal structure, but a fraction of the single pulses have energies near zero, indicating the presence of null pulses.

The drift parameters of PSR J1059–5742 appear to be stationary between epochs. Song et al (2023) independently reported $P_3 = 5.6 \pm 0.2$ P and a subpulse phase spacing of about 5.6° for this pulsar from their MeerKAT observations,

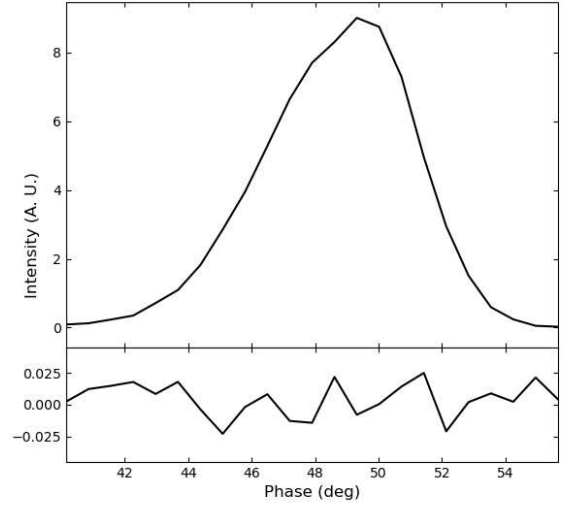


Fig. 3 Average profiles of the burst (top) and null (bottom) pulses. The burst profile shows a broad, asymmetric single component with a steeper trailing edge. The null profile shows no significant radiation component and fluctuates only at the level of the off-pulse noise, confirming that the emission is completely switched off during the nulls.

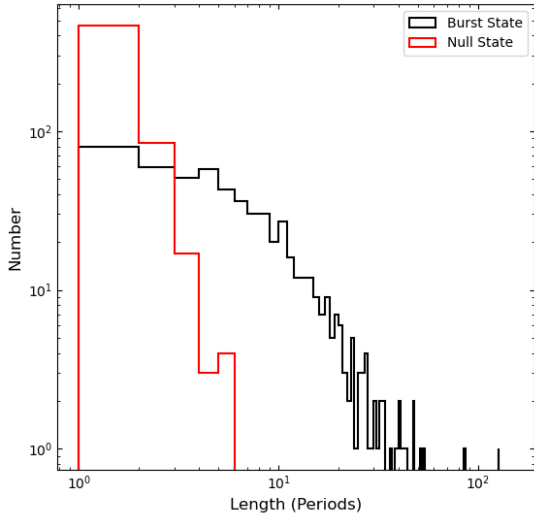


Fig. 4 Duration distributions of the burst and null states. The null-state durations are sharply concentrated between one and two pulse periods, the longest lasting about six periods, whereas the burst-state durations extend to more than one hundred periods.

consistent with our values within the uncertainties. The agreement between the two independent observations indicates that the subpulse-drifting behaviour of this pulsar is stable and confirms that the P_3 feature detected here is genuine.

3.3 Non-drifting State and Mode Changing

To identify the non-drifting state and determine its occurrence rate, we divided the single pulses into sub-integrations of five consecutive pulses. Following Mahajan et al (2018), we classified each sub-integration using a mode metric $\Delta\chi_i^2$,

$$\Delta\chi_i^2 = \sum_j \frac{[p_i(j) - p_d(j)]^2 - [p_i(j) - p_{nd}(j)]^2}{\lambda(j)^2}, \quad (1)$$

where $p_i(j)$ is the profile of the i -th sub-integration, $p_d(j)$ and $p_{nd}(j)$ are the average profiles of the drifting and non-drifting states, $\lambda(j)$ is the standard deviation of the entire data set at phase bin j , and the sum runs over the phase bins of the emission window. The two templates were selected visually from the drifting and non-drifting

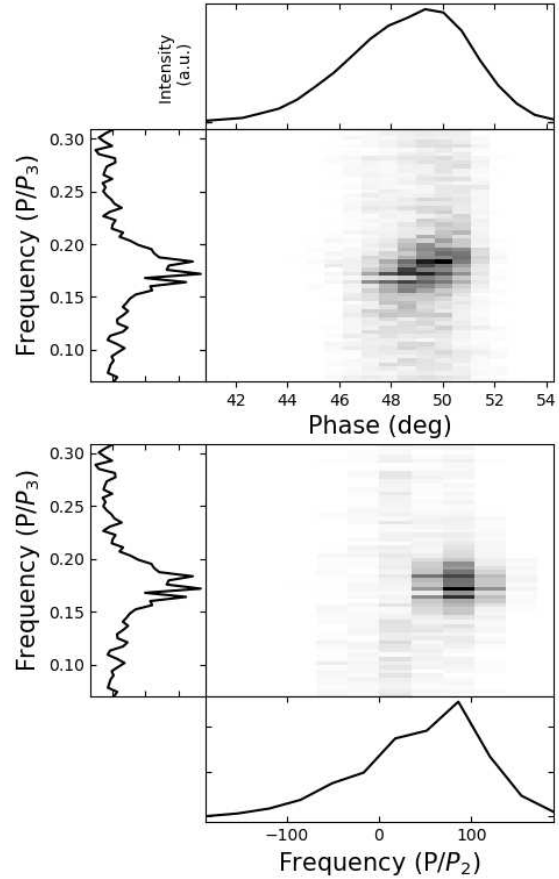


Fig. 5 LRFS (top) and 2DFS (bottom) of PSR J1059–5742 for the full observation. A prominent drift feature appears in the LRFS at a fluctuation frequency of about $0.18 P/P_3$, giving $P_3 = 5.7 \pm 0.5 P$, and the 2DFS yields a subpulse phase spacing of $P_2 = 5.6 \pm 0.7^\circ$.

segments within the sub-integration window 350–650, which contains both non-drifting episodes. The distribution of $\Delta\chi^2$ was fitted with two Gaussian functions, and their intersection was adopted as the threshold separating the two states: sub-integrations with $\Delta\chi^2$ above the threshold were classified as non-drifting, and those below as drifting. A non-drifting episode was assigned only when at least three consecutive sub-integrations exceeded the threshold, and each candidate was further verified at the single-pulse level.

Figure 6 shows the mode sequence of PSR J1059–5742 for 300 sub-integrations, each being the average of five consecutive single pulses. The drifting state dominates, appearing as a relatively uniform background, with the five-pulse

256 averaging smoothing out the subpulse drifting;
 257 the two non-drifting episodes stand out as two
 258 bright and phase-stationary blocks, located at
 259 sub-integrations $\sim 420\text{--}440$ and $\sim 580\text{--}600$. These
 260 two episodes are the only non-drifting events
 261 detected in the entire observation. Applying the
 262 classification to the entire observation, we find
 263 that the pulsar was in the drifting state for 96.2%
 264 of the time and in the non-drifting state for
 265 3.8% of the time. The two non-drifting events
 266 lasted approximately 108 and 107 pulse periods,
 267 respectively.

268 The distribution of $\Delta\chi^2$ for the 300 sub-
 269 integrations shown in Figure 6 is displayed in
 270 Figure 7. The distribution is clearly bimodal:
 271 the broad dominant component at negative val-
 272 ues corresponds to the drifting state, and the
 273 low-amplitude component at positive values cor-
 274 responds to the non-drifting state, which is con-
 275 centrated within the two episodes. The two Gaus-
 276 sian functions fitted to the distribution and the
 277 adopted threshold are also shown.

278 Using the above classification, we separated
 279 the single pulses into the drifting and non-drifting
 280 states and obtained their average profiles, which
 281 are shown in Figure 8 together with the over-
 282 all mean profile of the entire observation; the
 283 black dashed line shows the overall mean pro-
 284 file, the blue solid line the drifting state, and the
 285 red solid line the non-drifting state. The overall
 286 mean profile is nearly identical to the drifting-
 287 state profile, consistent with the dominance of
 288 the drifting state. The non-drifting profile dif-
 289 fers in two respects. First, its peak occurs at a
 290 phase of $\sim 47.3^\circ$, about 2° earlier than the drifting-
 291 state peak at $\sim 49.4^\circ$. Second, the non-drifting
 292 profile is closer to a symmetric single Gaussian
 293 and slightly narrower: its widths at 50% and 10%
 294 of the peak intensity are $W_{50} = 4.9 \pm 0.7^\circ$ and
 295 $W_{10} = 9.2 \pm 0.7^\circ$, compared with $W_{50} = 5.5 \pm 0.7^\circ$
 296 and $W_{10} = 9.9 \pm 0.7^\circ$ for the drifting state. Both
 297 sets of widths were measured on the average pro-
 298 files at 50% and 10% of the peak intensity, and the
 299 uncertainties were estimated following Kijak and
 300 Gil (1997). The pulsar therefore switches abruptly
 301 between the drifting state, which dominates the
 302 observation, and a rare, brighter, phase-stationary
 303 non-drifting state, with the two states differing in
 304 brightness, profile shape, peak phase, and width.

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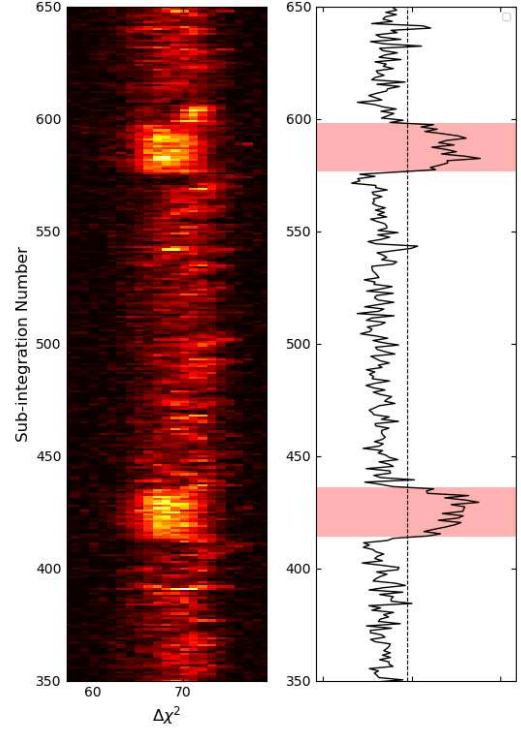


Fig. 6 Mode sequence of PSR J1059–5742 for 300 sub-integrations, where each sub-integration is the average of five consecutive single pulses. Left: intensity as a function of pulse longitude and sub-integration number; the two non-drifting episodes appear as bright and phase-stationary blocks. Right: the mode metric $\Delta\chi^2$ of each sub-integration, with the dashed line marking the threshold; the pink-shaded regions mark the two non-drifting episodes.

4 Discussion

PSR J1059–5742 was observed with the 64-m Parkes radio telescope on 2018 December 27 using the UWL receiver at a center frequency of 1369 MHz. Our single-pulse analysis of 5681 pulses reveals that the pulsar exhibits three distinct emission states: a dominant subpulse-drifting state, a rare, brighter, phase-stationary non-drifting state, and short nulls that occur exclusively within the drifting state. Here we discuss the possible physical origins of these states and their implications for the carousel structure of the polar cap discharge.

The short nulls of PSR J1059–5742, lasting only one or two pulse periods and occurring exclusively within the drifting state, find a natural explanation in the rotating-carousel picture (Ruderman and Sutherland, 1975). The measured

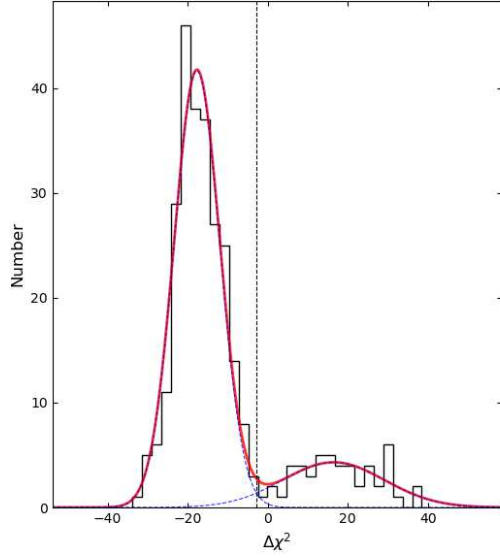


Fig. 7 Distribution of the mode metric $\Delta\chi^2$ for the 300 sub-integrations shown in Figure 6. The distribution is fitted with the sum of two Gaussian functions: the red solid line shows the fit, and the blue dashed line shows one of the individual Gaussian components. The intersection of the two components, marked by the vertical dashed line, is adopted as the threshold separating the drifting and non-drifting states.

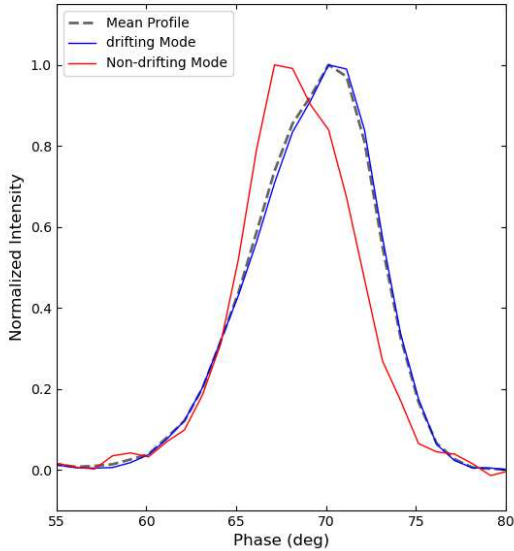


Fig. 8 Normalized average pulse profiles of the drifting state (blue solid line), the non-drifting state (red solid line), and the entire observation (black dashed line).

subpulse spacing $P_2 \approx 5.6^\circ$ implies a number of sparks $n = 360^\circ/P_2 \approx 64$, so that the emission window, whose width $W_{10} \approx 9.9^\circ$ spans roughly two subpulse spacings, samples one or two sparks at any instant. A null then corresponds to the line of sight passing through a gap between adjacent sparks, i.e., a pseudo-null (Basu et al, 2017), or to the temporary extinction of one of the sampled sparks, in which case part of the rotating sub-beam system is missing (Rankin and Wright, 2008) and the pulsed emission disappears for one or two rotation periods. Such short, isolated nulls are distinct from the prolonged nulls lasting tens or hundreds of periods seen in a substantial fraction of nulling pulsars (Basu et al, 2017; Ritchings, 1976; Wang et al, 2007), which are more readily attributed to a global reconfiguration of the magnetosphere (Wang et al, 2007); nulls of different durations may indeed have different physical origins (Cordes, 2013). The confinement of the nulls to the drifting state is consistent with this picture, in which the drift pattern and the nulls may share the same spark configuration.

The dominant drifting state is well described by the rotating-carousel model, in which a number of discrete sparks, uniformly spaced in magnetic azimuth, circulate around the magnetic axis, and the line of sight samples them once per rotation period (Ruderman and Sutherland, 1975; Gil and Sendyk, 2000b). Because the emission is sampled only once per rotation period, the observed modulation period is generally an alias of a faster intrinsic periodicity (Rankin et al, 2013; McSweeney et al, 2019); the observed $P_3 \simeq 5.7P$, which exceeds the Nyquist limit of $2P$, is therefore likely to be the aliased value (Song et al, 2023). The number of sparks is anchored by the measured subpulse spacing, $n = 360^\circ/P_2 \approx 64 \pm 8$. Following the brute-force search of carousel solutions described by Janagal et al (2022), the observed P_3 and P_2 are found to be reproduced with $n \approx 66$ sparks under first-order aliasing ($k = 1$). Under this assumption, the observed period P_3 , the intrinsic period P'_3 , and the carousel circulation period P_4 are related by

$$P_3 = \frac{P_4}{|n - kP_4|}, \quad P'_3 = \frac{P_4}{n}, \quad (2)$$

where n is the number of sparks. With $n = 66$ and $P_3 = 5.7 P$, the first relation yields $P_4 \approx 80 P$ and

$P'_3 = P_4/n \approx 1.2$ P. The intrinsic period of 1.2 P, shorter than the Nyquist limit of 2 P, confirms that the observed $P_3 = 5.7$ P is indeed the aliased value.

Whether the drift of PSR J1059–5742 is aliased can be assessed with the criterion of Song et al (2023), $\xi = (P/1\text{ s})^{-1.7}(\dot{P}/10^{-15}) = 3.2$, which places the pulsar on the young, aliased side of their V-shaped P_3 evolution (the turning point is at $\xi \simeq 0.8$), consistent with our inference of $P'_3 \approx 1.2$ P < 2 P. The carousel period predicted by the vacuum gap model of Ruderman and Sutherland (1975) is

$$P_4 = 5.7 (P/1\text{ s})^{-3/2} (\dot{P}/10^{-15})^{1/2}, \quad (3)$$

For PSR J1059–5742 this yields $P_4 \approx 9.2$ P, so the inferred carousel period of $P_4 \approx 80$ P is about nine times longer than the vacuum-gap prediction. A slowly rotating carousel requires a partially screened gap (PSG), in which a steady flow of ions from the stellar surface partially screens the accelerating electric field by a screening factor η , reducing the $\mathbf{E} \times \mathbf{B}$ drift velocity of the sparks (Gil et al, 2003; Basu et al, 2016). This is consistent with the anti-correlation between P_3 and $\dot{E}$ found for the phase-modulated drifting population by Basu et al (2016): with $\dot{E} = 1.02 \times 10^{32}$ erg s⁻¹, PSR J1059–5742 lies within that population, and its P_3 follows the trend of the correlation. We emphasize that the carousel parameters quoted here rest on the assumption of first-order aliasing; higher-order aliasing cannot be entirely excluded but would imply an even faster intrinsic carousel (Janagal et al, 2022).

The rare non-drifting state, in which the pulsar becomes brighter, phase-stationary, and loses its subpulse structure, cannot be attributed to a simple change of the carousel parameters. The abrupt transition between the two states resembles the mode changes observed in many pulsars. For example, the periodic mode changing of PSR J1048–5832 (Yan et al, 2020) and the mode switching of PSR J1326–6700 (Wen et al, 2020) have been attributed to quasi-stable reconfigurations of the polar-cap discharge. The disappearance of the drift and the increase in brightness all indicate that the emission region sampled by the line of sight differs between the two states, consistent with a change in the polar-cap discharge structure rather than a purely geometric effect.

Moreover, the non-drifting profile peaks about 2° earlier than the drifting profile and is slightly narrower. In the absence of polarimetric information we cannot determine whether this shift reflects a change in the emission height or in the magnetic azimuth sampled by the line of sight. For PSR J1326–6700, a phase shift of the abnormal mode was interpreted as a change in the emission altitude, with the abnormal mode arising at a higher altitude than the normal mode (Wen et al, 2020). By analogy, if the two states of PSR J1059–5742 arise from the same magnetic field lines, the non-drifting emission would come from a higher altitude than the drifting emission. A single-epoch, single-frequency observation cannot fully distinguish these possibilities. Polarimetric observations, which measure the position-angle swing and the aberration/retardation signature, would directly constrain the emission height and further clarify the physical origin of the mode change.

To summarize, our single-pulse analysis of PSR J1059–5742 reveals three distinct emission states and supports the following conclusions:

1. The pulsar is in a drifting state for 96.2% of the observation, with $P_3 = 5.7 \pm 0.5$ P, $P_2 = 5.6 \pm 0.7^\circ$, and a negative drift rate $D = 0.98 \pm 0.15^\circ$ per period.
2. The drifting state is described by the rotating-carousel model with $n \approx 66$ sparks and a carousel period $P_4 \approx 80$ P under first-order aliasing; the intrinsic drift period is $P'_3 \approx 1.2$ P.
3. A rare, brighter, phase-stationary non-drifting state (3.8% of the time, two episodes of ~ 108 and 107 pulse periods) is attributed to a change in the polar-cap discharge structure; polarimetric observations are required to further constrain its origin.
4. Nulls occur only in the drifting state, with a nulling fraction of $13 \pm 1\%$ and durations of one to two pulse periods, consistent with the line of sight passing through gaps between the carousel sparks.

These observations establish PSR J1059–5742 as a clean example of a carousel-driven drifting pulsar in which the occasional cessation of drifting reveals a mode change of the polar-cap discharge. We note, however, that the present conclusions are based on a single epoch; multi-epoch observations

with polarimetry would verify the stability of the drift parameters.

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Materials availability. Not applicable.

Code availability. Not applicable.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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