Radio Polarization and Geometry of PSR J1119–6127

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Abstract

Using 1400-MHz archival data from the Parkes radio telescope, we present radio polarization characteristics for PSR J1119–6127, a very young pulsar notable for its large magnetic field. We discuss the polarization features of PSR J1119–6127 and consider the pulsar in the context of a recent theoretical model of pulsar spin-down; this spin-down model can in principle be tested with polarization and timing data from this pulsar. Constraints on the pulsar's emission geometry obtained from a rotating vector model fitted to the available position angle data are not sufficient to test the spin-down model, but additional data may allow a significant test in the future.

Features of the Polarization Profile

- High linear polarization: Similar to linear polarization found in PSR J1513–5098 (B1509–58), which has comparable age, magnetic field, and rotational period (Crawford et al. 2001b).

- Constraints on model parameters and $\beta$ are shown in Figure 3.

- A model of pulsar spin-down

Testing a Model of Pulsar Spin-Down

- Treats the pulsar and its inner magnetosphere as a single perfectly conducting sphere rotating in a vacuum.
- Predicts first and second braking indices and $n$ and $m$ given the pulsar's period, period derivative, and magnetic inclination angle $\alpha$.
- No free parameters; highly falsifiable.

- So far applied with some success to the Crab pulsar, PSR B0534+25, and PSR J1515–5098.

- The clean polarization profile and measurable braking index of PSR J1119–6127 make it a candidate for testing the model.

Testing the Model Observationally:

- Despite the good fit of the RV model to the polarization data, it can only be constrained to $\alpha < 140^\circ$ at the 3σ level (see Figure 3).

- No significant difference found in agreement with the model.

Prospects For a Future Test:

- 12 hr of observation time with a similar system could produce a 3σ constraint on the model.

- Improvements in the measurement of $\alpha$ through further timing observations could also contribute to such a test (see Figure 4).

Conclusions

- The polarization profile of PSR J1119–6127 exhibits a high degree of linear polarization, consistent with trends for other young, energetic pulsars.

- Polarization data indicates that the pulse leads the symmetry axis, supporting interpretation of the pulse profile as a partial conal beam.

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References


Observations and Results

- Observations taken 1 January and 19 January 1999 with the Parkes radio telescope; total integration time 48 min.
- Center frequency 1366 MHz; bandwidth 126 MHz.
- Position angle was corrected for Faraday rotation.

PSR J1119–6127

- discovered August 1997 in the Parkes Multibeam Pulsar Survey
- Inferred surface magnetic field is very large: $4.4 \times 10^{10}$ G
- One of the youngest known pulsars: $\tau = 0.8 \times 10^4$ yr

Right Ascension, $\alpha$ (J2000) $11^h 19^m 14.0^s$ Declination, $\delta$ (J2000) $-61^\circ 25' 40"$ Galactic Longitude, $\ell$ 292$^\circ$ Galactic Latitude, $b$ $-54^\circ$

- Period, $P$ 0.08 ms
- Spectral luminosity, $S_\nu$ $2.3 \times 10^{30}$ erg s$^{-1}$
- Braking index, $n$ 2.91 ± 0.08
- Dispersion Measures, DM 700 ± 2 pc cm$^{-3}$ (Cami lo et al. 2000)

Introduction

Pulsar polarimetry is one of the keys to understanding the process and geometry of radio emission from pulsars. In the rotating-vector (RV) model of polarization (Rudak & Esseen 1999), the polarization of radio emission is linked to the emission geometry so that as the pulsar rotates, the axis of linear polarization is aligned with the projected direction on the sky of the pulsar's magnetic dipole axis. The pulsar's emission geometry itself may be described by two angles, each measured from the pulsar's angular momentum vector: the magnetic inclination angle $\alpha$ is the angle between the spin axis and the magnetic dipole axis, and the angle $\beta$ measures the minimum separation between the magnetic dipole axis and an observer's line of sight (Everett & Weisberg 2001). Given this geometric description, the RV model defines the linear polarization position angle (PA) $\phi$ as a function of pulse phase $\phi$ according to:

$$\phi = \phi_0 + \alpha + \beta$$

where $\phi_0 = \phi_1 \alpha + \phi_2 \beta$. With sufficient coverage over pulse phase, a fit to RV model parameters $\phi_0$, $\phi_1$, $\phi_2$, and $\beta$ may be performed. Since $\phi_0$ is the phase corresponding to the center of the magnetic pole, it fixes the geometry not only of the pulsar itself, but of the pulsar's region of radio emissions, which can be at various positions relative to the pulsar's magnetic axis. Emission at the magnetic axis is not always present, and emission may not be symmetrical about the axis, in some cases giving rise to one or more pulses that lead or trail the beam center (Lyne & Manchester 1988).