Investigating Mode Switching in PSR J1909-3744

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Abstract

This research project is focused on the millisecond pulsar PSR J1909-3744, the most precisely timed pulsar in pulsar timing array (PTA) experiments. Recently, the pulsar showed a change in its average emission, switching from a strong to a weak emission mode, during an exceptionally bright scintillation event. Past observations indicate that the weak emission mode arrives 9.26 ± 3.94 μs earlier than the strong emission mode (Miles et al. 2022). Additionally, they provided a new value of jitter noise (8.20 ± 0.14 ns per hour) for this pulsar. These findings have implications for improving pulsar timing models, which are crucial for enhancing the sensitivity of gravitational wave background searches, as well as the overall impact of similar timing improvements on PTA pulsars. The goal of this research project is to examine the pulsar's average emission and single pulses and extract the respective arrival times to search for indicators of emission mode changes. The applied methods include the extraction of single pulse arrival times using algorithms resulting from the pulsar software package PSRCHIVE and the calculation of phases of occurrence, intensity, fluences, pulse shapes, and equivalent pulse widths using existing Python scripts.

Introduction

Pulsars are rapidly rotating neutron stars that emit beams of radio waves detectable on Earth as periodic pulses. Among these, PSR J1909–3744 is notable for its exceptional timing stability, making it a prime candidate for studying subtle variations in pulse behavior. These variations in pulse behavior is referred as "mode switching", this is important for PSR J1909-3744, because it is the most precisely timed pulsar. Since recent data shows that there is irregularity in PSR J1909-3744 pulse behavior, it has become of great interest to better understand this phenomenon and to see how it will impact the precision of timing models. This project will analyze data from PSR J1909-3744 to investigate for mode switching and its impact on pulse stability

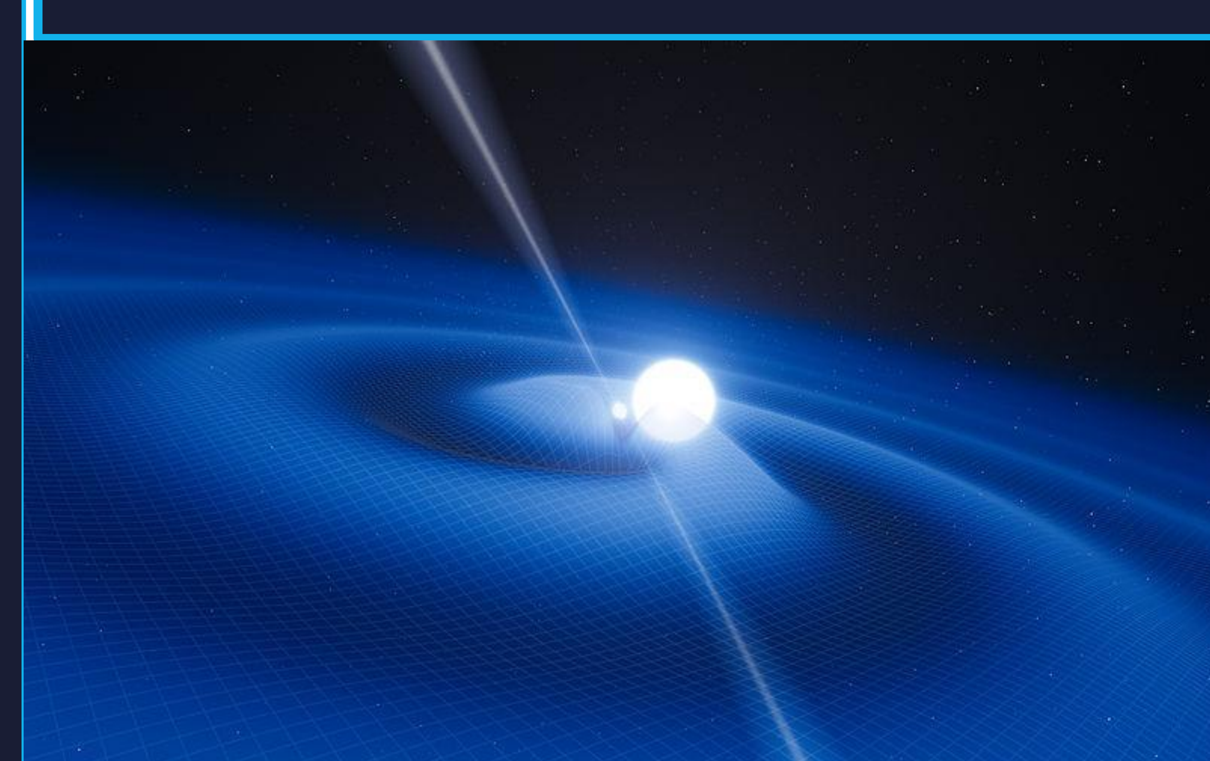
Methodology

- ❖The Examination of the average emission and single pulses from that pulsar using already existing software packages DSPSR and PSRCHIVE.
- ❖The extraction of single pulses arrival times will be done using algorithms resulting from the pulsar software package PSRCHIVE and existing Python scripts written by the PI.
- ❖The calculation of phases of occurrence, intensity, fluences, pulse shapes, equivalent pulse widths will be carried out with already existing Python scripts. The student will be tasked to develop their own corresponding scripts after an initial training period.
- ❖The extracted single pulses will be examined with regards to their polarimetry. The PI developed parts of the scripts already and the student will be actively involved in the development

Results

Since I have only been given the knowledge that I'd be able to do this project, the following are results I expect to get

- ❑ **Detect variations in PSR J1909-3744's signal pulses, including changes in**
  - ➢ **Intensity**
  - ➢ **Pulse Shape**
  - ➢ **Fluence and equivalent pulse width**
  - ➢ **Degree of polarization**
- ❑ **Identify transitions between distinct emission states**
- ❑ **Determine if the mode changes occur stochastically**
- ❑ **Assess how mode switching affects**
  - ➢ **Pulse arrival time consistency**
  - ➢ **Overall timing precision of the pulsar**
- ❑ **Contribute to a better understanding of pulsar emission mechanisms and their role in high-precision timing experiments like NANOGrav**



Conclusions

This project aims to investigate mode switching in PSR J1909–3744, the most precisely timed recycled pulsar known. By analyzing its single-pulse emission, we hope to identify patterns in pulse behavior that indicate transitions between emission modes. Understanding these changes is essential for improving pulsar timing precision and refining models used in gravitational wave detection. This research will contribute to a deeper understanding of pulsar magnetospheres and help assess how pulse variability impacts long-term timing stability in millisecond pulsars

References

- ❑**Miles, M. T., Desvignes, G., Kramer, M., et al. (2023).** ***Mode changing in J1909–3744: the most precisely timed pulsar*****.** ***Monthly Notices of the Royal Astronomical Society*****, 518(2), 2184–2194.**

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