Multiwavelength Timing Study of the Millisecond Pulsar PSR J1713+0747

Project level: MSc / Advanced Honours

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Background

Millisecond pulsars are among the most stable natural clocks known in the Universe. Pulsar Timing Arrays (PTAs) use long-term observations of these pulsars to search for ultra-low-frequency gravitational waves produced by supermassive black hole binaries and other cosmological sources.

Most PTA experiments currently rely on radio observations, where pulse arrival times can be measured with extremely high precision. However, radio signals are affected by propagation through the interstellar medium, introducing effects such as dispersion and scattering that can influence pulsar timing measurements over long timescales.

Gamma-ray pulsar timing provides a complementary approach because high-energy photons are unaffected by interstellar plasma propagation effects. Observations from the *Fermi* Large Area Telescope therefore offer an independent way to study pulsar rotational stability and pulse profile behaviour.

Recent timing irregularities and residual variations observed in the PTA pulsar PSR J1713+0747 have further motivated investigations into possible long-term profile variability and multiwavelength timing behaviour.

This project aims to explore how pulsar timing behaviour compares between radio and gamma-ray observations and whether long-term pulse profile variability or dispersion measure variations may influence timing performance.

Project statement

In this project, the student will investigate the millisecond pulsar PSR J1713+0747 using archival radio and gamma-ray observations obtained from Pulsar Timing Array (PTA) experiments and the *Fermi* Large Area Telescope (LAT). The primary aim is to explore how pulsar timing behaviour differs across radio and gamma-ray wavebands and whether long-term pulse profile variability or dispersion measure (DM) variations may contribute to observed timing irregularities.

The student will begin by learning the fundamentals of pulsar timing and pulse profile formation in both radio and gamma-ray observations. Using publicly available datasets, the student will analyse long-term observations of PSR J1713+0747 and generate integrated pulse profiles over different observing epochs.

A major component of the project will involve studying whether the pulse profile shape remains stable over long timescales or exhibits measurable variations. Such profile changes can influence pulse time-of-arrival (ToA) estimation and may contribute to timing residual structures observed in PTA datasets.

The student will also generate gamma-ray pulse profiles and estimate gamma-ray ToAs using *Fermi*-LAT data products. These gamma-ray timing measurements will then be compared with radio timing behaviour in order to investigate similarities and differences between the two wavebands.

In addition, the project will explore whether long-term dispersion measure variations in the interstellar medium can influence the observed timing properties and whether gamma-ray timing, which is unaffected by plasma dispersion effects, can provide an independent probe of pulsar rotational stability.

The project will involve:

- analysing archival radio and gamma-ray pulsar observations,
- generating and comparing pulse profiles across different observing epochs,
- investigating possible long-term profile variability,
- generating gamma-ray pulse times-of-arrival (ToAs),
- comparing radio and gamma-ray timing behaviour,
- studying whether dispersion measure variations influence the observed timing properties,
- and exploring how gamma-ray timing may complement future PTA observations.

The project will primarily involve pulsar timing analysis, gamma-ray astronomy, statistical analysis, and scientific programming in Python using publicly available observational datasets and standard pulsar timing software tools.

Scientific Scope of the Project

This project combines several active areas of modern astrophysics:

- pulsars and neutron stars,
- gamma-ray astrophysics,
- gravitational-wave astronomy,
- pulsar timing arrays,
- multiwavelength astronomy,
- and computational data analysis.

Students will work with real astronomical datasets and modern timing analysis techniques used in current international pulsar timing and gravitational-wave detection experiments.

Recommended skills and interests

The project is suitable for students interested in:

- pulsars and compact objects,
- high-energy astrophysics,
- gravitational-wave astronomy,
- radio astronomy,
- computational astrophysics,
- and scientific programming.

The analysis will primarily be carried out using Python and Linux-based scientific tools. Prior programming experience is helpful but not mandatory, as training will be provided during the project.

Students will gain experience in:

- pulsar timing techniques,
- gamma-ray data analysis,
- radio astronomical data analysis,
- scientific visualization,
- and modern computational research workflows used in astrophysics.