Crab Pulsar

Dominik Szablonski and Nicholas Smith

December 2, 2025

What is a Pulsar?

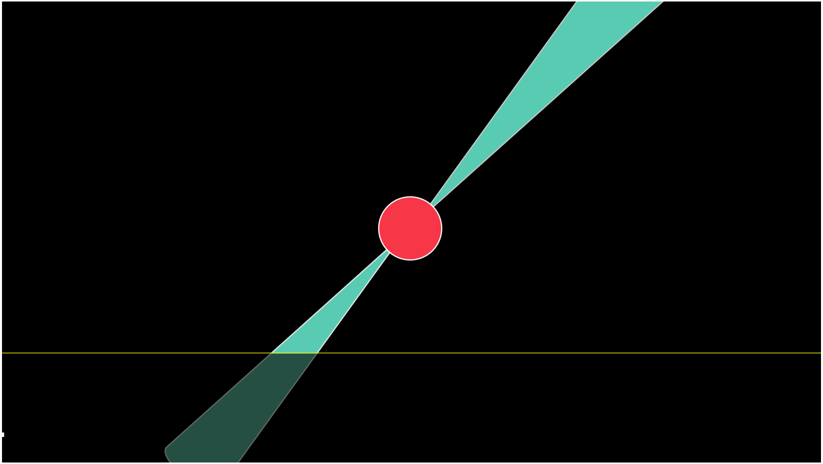


Figure 1:
https://lilith.fisica.ufmg.br/~dsoares/extn/ogs/ogs-psr.htm

Aims and Goals of the Experiment

1. Measure dispersion measures (DMs) of multiple pulsars and find their distance from the earth.
2. Measure the period and identify pulsars by Fourier analysis of their data.
3. Measure the period of the Crab Pulsar a period of time using pulsar timing techniques to find its period derivative, and hence estimate its surface magnetic field and age.

Dispersion Measures

- Pulsar beams ”spread out” as they travel through the intergalactic medium.
    - Higher frequency signals arrive before low frequency ones.
- The delay caused due to dispersion is,

$$\Delta\tau = \tag{1}$$

where

$$DM = \tag{2}$$

Dispersion Measures

- Pulse broadening decreases amplitude
    - No pulse broadening, maximum amplitude.
- Generate DM values and fit the data to a $-x^2$ graph to find DM
    - In reality, data is Lorentzian but interval of fitting chosen so that the first order Taylor expansion would be a valid choice.
- This method is limited in that it produces high error, but can identify a sensible DM for noisy data.

Searching for Pulsars via Fourier Analysis

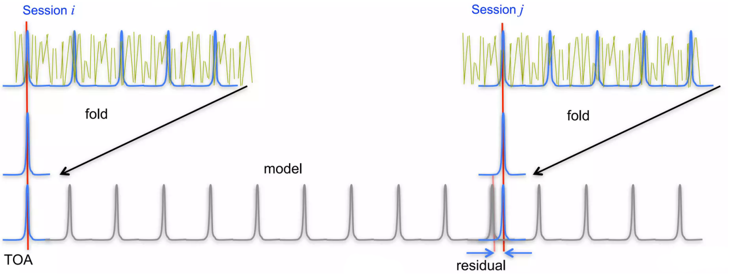
- A Fourier transform takes a function as input in some basis, i.e., time, and outputs a new function which describes the extent to which frequencies are present in data.
- Discrete Fourier transforms exist alongside algorithms for performing them on computers, known as fast Fourier transforms (FFTs). This algorithm is defined by,

$$X_k = \sum_{m=0}^{n-1} x_m e^{-\frac{i2\pi km}{n}}, \quad k = 0, \ldots, n-1 \tag{3}$$

- Feeding de-dispersed pulsar data into a real-FFT (RFFT), we can identify pulsar signals and their harmonics to determine the period.
  - If a signal has N harmonics corresponding to an initial f_i and final f_f frequency, the frequency of the pulsar is,

$$f = \frac{f_f - f_i}{N}. \tag{4}$$

Pulsar Timing



- If our pulsar's model period P is a perfect, each pulse measured at a time t will correspond to a number N of periods,

$$\frac{P}{t} = N. \tag{5}$$