

PULSARS

ERIRA 2025

Team Members

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- Haygen Warren



Credit: Cambridge University Lucky Imaging Group

Goals

With the 40 ft. telescope:

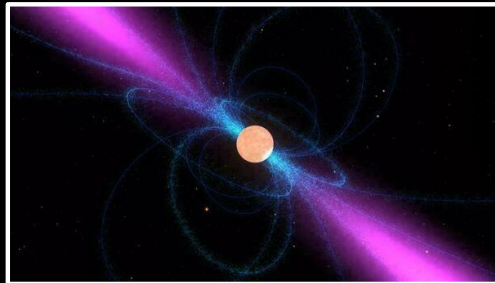
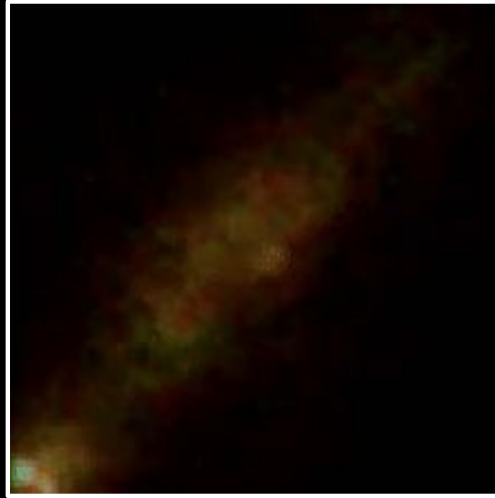
1. Determine the periodogram and period of pulsar PSR B0329+54.
2. Determine the pulse profile of PSR B0392+54 and sonify it.
3. Determine if PSR B0329+54's emission is polarized and hence non-thermal.
4. Attempt to detect and sonify other pulsars with the 40 ft.

With the 20 meter:

1. Detect and sonify as many pulsars as possible.

What is a Pulsar??

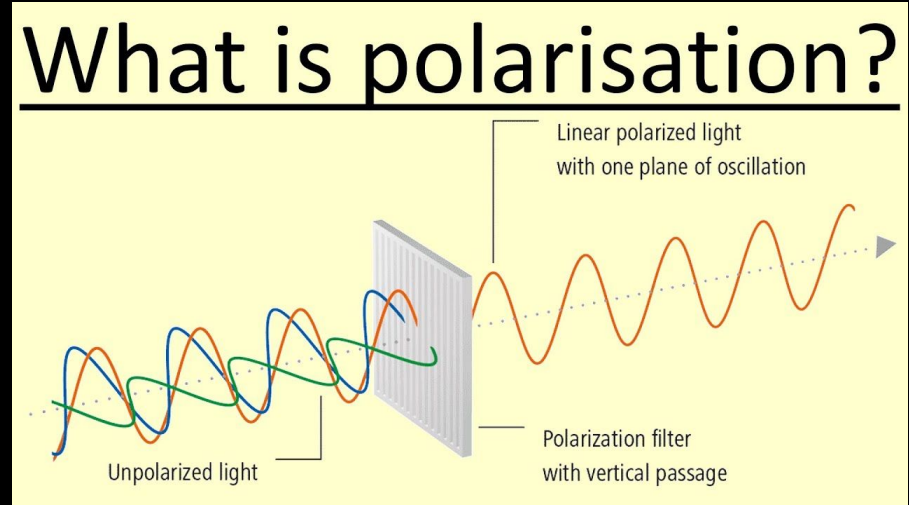
- A pulsar is a highly magnetized and rotating neutron star that is left in the wake of a supernova produced by an exploding high-mass star.
- Due to the intense nature of pulsars, massive beams of radiation are emitted at their magnetic poles.
- When pulsars are tilted such that these beams are pointed toward Earth, the star's rotation makes the beams appear as bright "pulses." The superdense, rapidly rotating core of neutron stars



- The range of pulsar rotational velocities varies wildly, with some pulsars having multi-second rotational periods while others complete one rotation in milliseconds.
- These rotational speeds make pulsars great cosmic clocks, with pulsar timing arrays and upcoming space missions (i.e., LISA) using them to detect low-frequency gravitational waves.

What is polarization?

- The phenomenon in which waves (light, magnetism, etc) move in specific directions
- Most sources emit unpolarized waves, as they emit waves in all kinds of directions
- Pulsars are, by nature, polarized.
- Synchrotron Radiation travels along the magnetic field lines of a pulsar, and due to its extreme speed the rads are moving away from the pulsar, rather than around it, launching the radiation in beams



Detecting Pulsars

40 ft. telescope:

- For each observation, the 40 ft. collected radio data for three to four minutes.
- After observations were completed, the data was opened in the Skynet plotting tool in the "Pulsar" setting.
- Data was run through a periodogram to determine if a pulse had been detected.
- If a pulse was detected, the period data was folded to highlight the pulsar's pulse.
- From this folded period, a sonification of the pulse was produced.

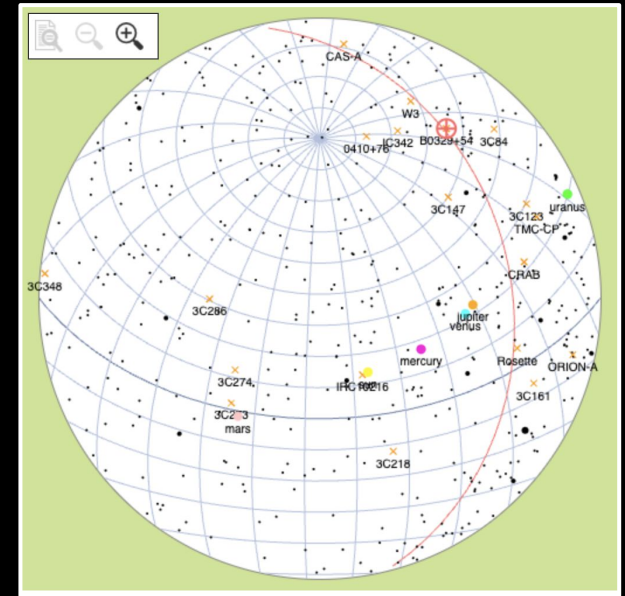
20m telescope:

- In Skynet, begin a new radio observation with the 20m telescope.
- Enter the pulsar's name, observation duration, track type, and integration time.
- Skynet's Pulsar Mode was used for a few observations.
- After observations, data was downloaded from Skynet and opened in the Skynet plotting tool.
- Create a periodogram, folded period, and sonification.

Our Main Target:

PSR B0329+54

- The brightest pulsar visible to the 40 ft. during ERIRIA 2025 (yay us!!!)
- Located approximately 5,300 light-years away from Earth in the constellation Camelopardalis.
- Rotational period of 0.714 seconds.

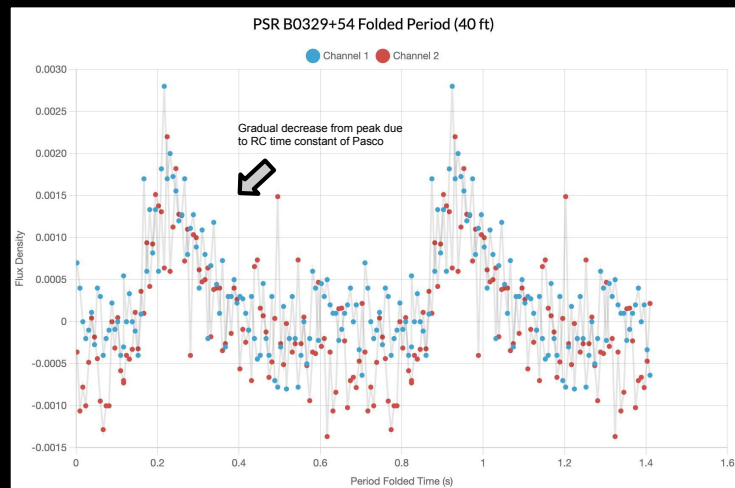
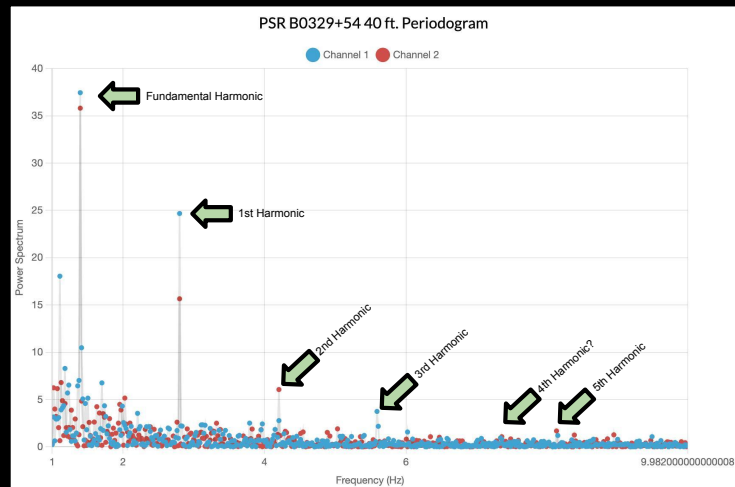


Credit: Skynet

40 ft. Observations of PSR B0329+54

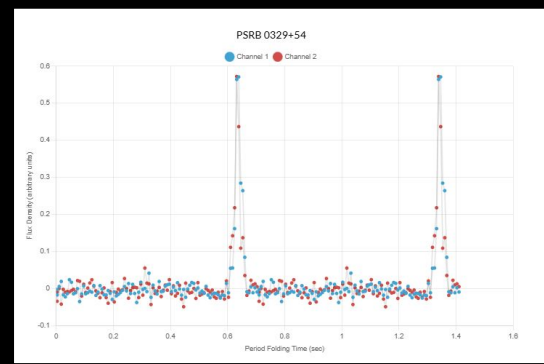
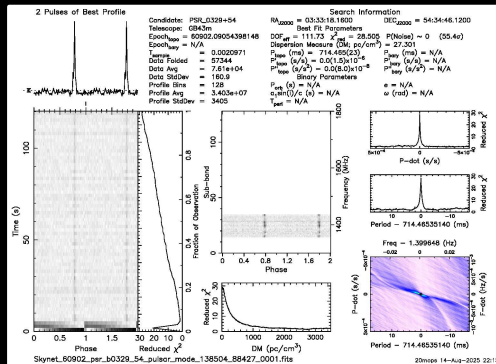
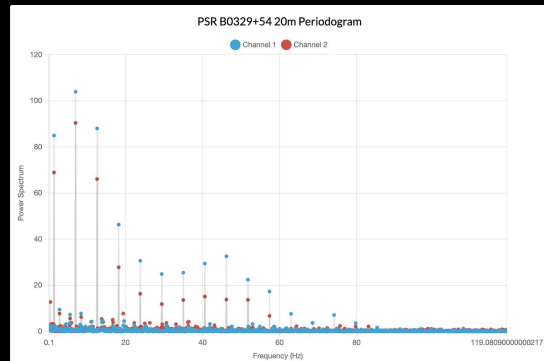
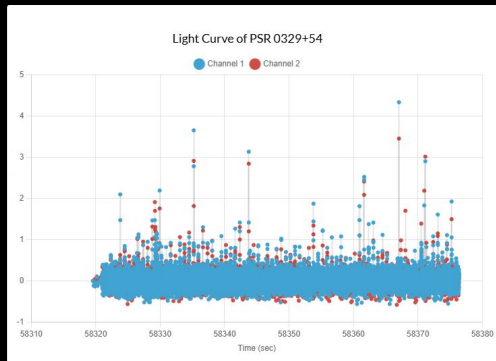
- This week we regularly observed PSR B0329+54 using the 40-ft. telescope.
- This pulsar is easier to observe due to its slow pulse period (0.7 seconds) and relative brightness in the radio spectrum.
- Early in the week, the 40 ft.'s observations were noisy and absent of any distinct pulse.
- Thursday, we obtained intense pulses with the assistance of Jonathan's Pasco ScienceWorkshop750 analog-to-digital converter.
- In the data, four (and possibly five!) harmonics were observed, with the folded period highlighting the pulsar's distinct pulse.
- Emission is polarized!

Listen to the pulses! →



Skynet Observations of PSR B0329+54

- In addition to the 40-ft. observations, we submitted several observations of pulsars on the 20m . We even submitted a 20m of PSR B0329+54
- After receiving our data from Skynet, data was opened and analyzed with the Skynet plotting tool.
- The harmonics seen on the periodogram from the 40 ft. data are also present in the Skynet data, though there are significantly more due to the 20m's size.
- Pulsar mode observations also highlight strong pulses.



Additional Skynet Observations



PSR B1133+16

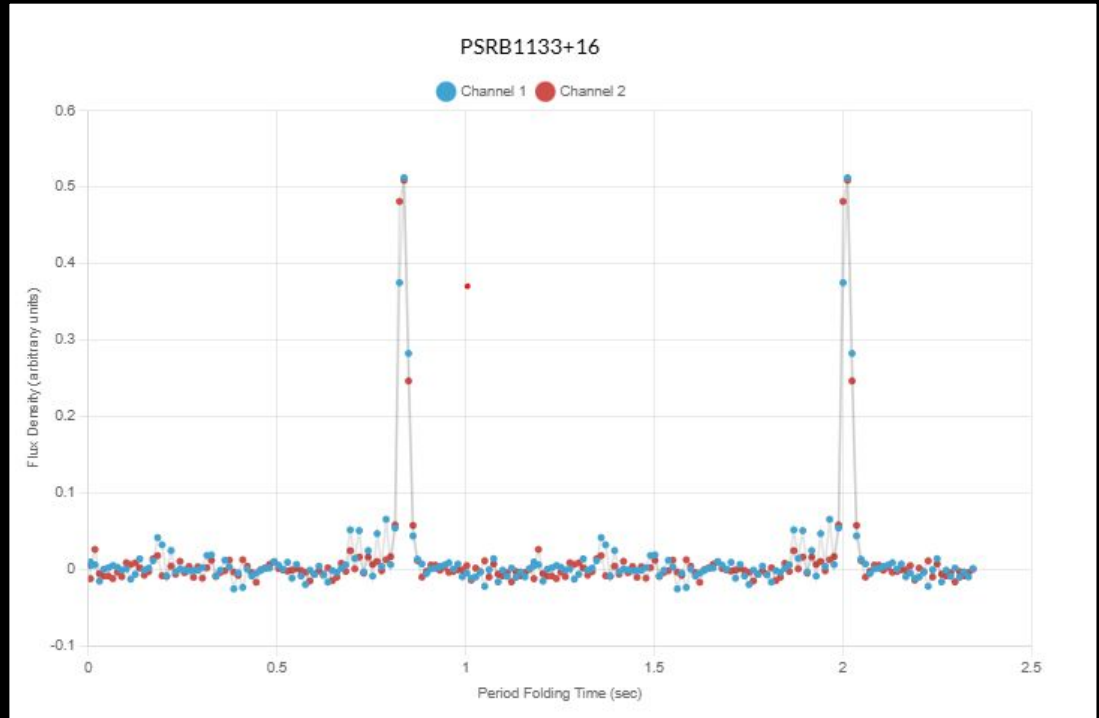
Actual Period: ≈ 1.18880

Measured Period: 1.1872

Distance: $\sim 1,141$ light-years

Sonification

:

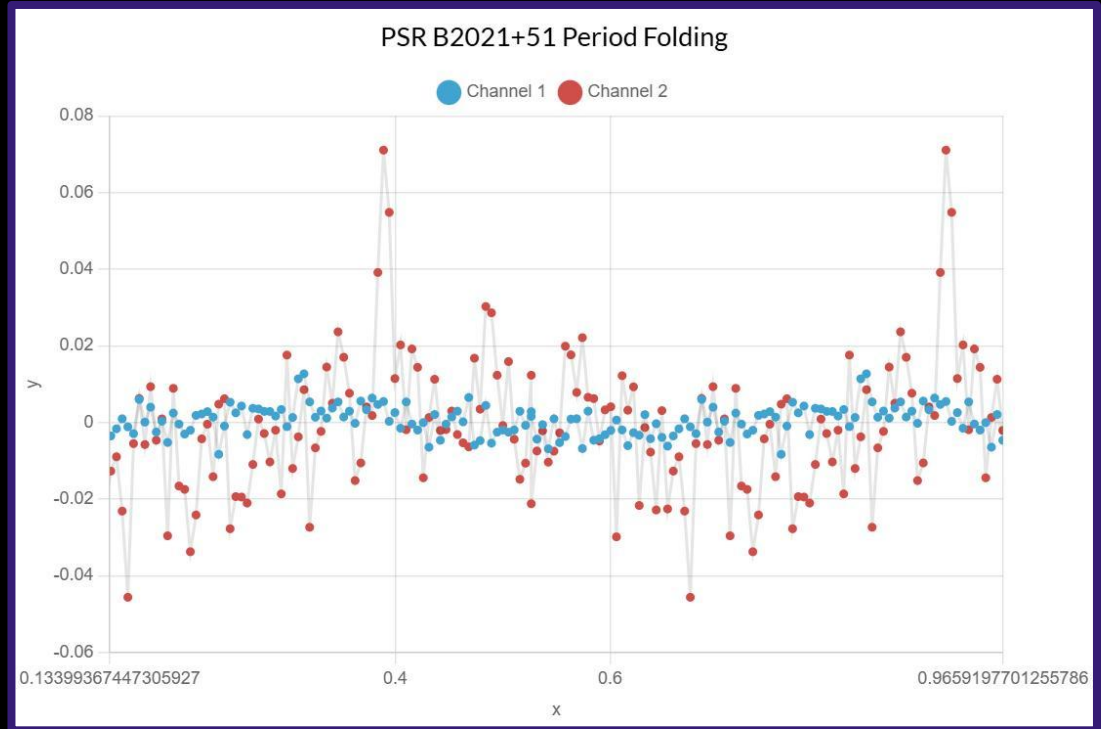


PSR B2021+51

- Actual Period: ≈ 0.529
- Measured Period: 0.529131
- Distance: $\sim 6,979.7$ light-years

Sonification

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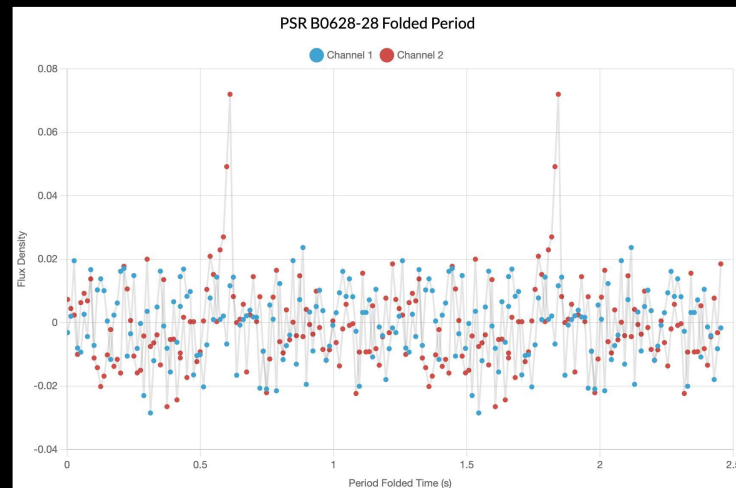
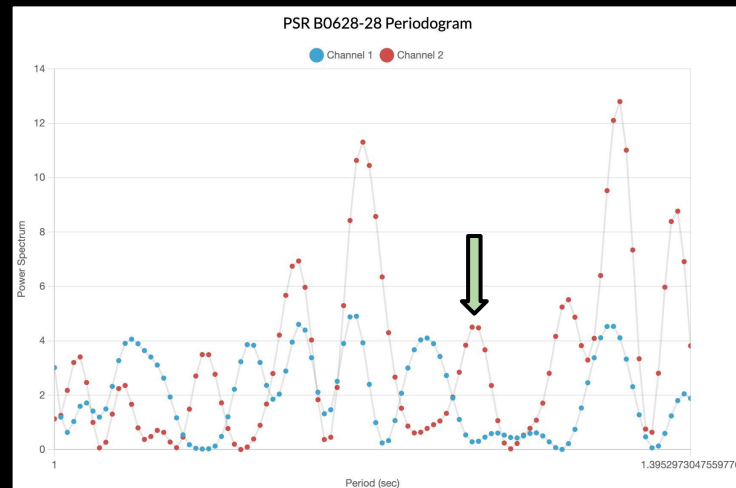


PSR B0628-28

- Actual period: 1.2444 seconds
- Measured period: 1.2445 seconds
- Distance: ~6,979.7 light-years

Sonification

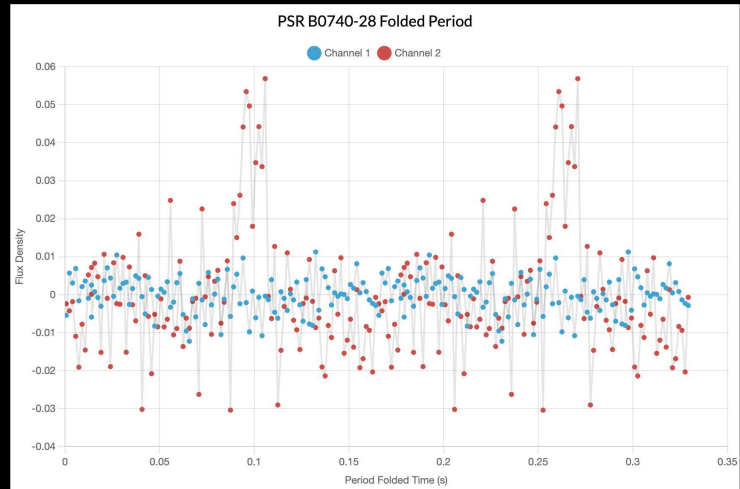
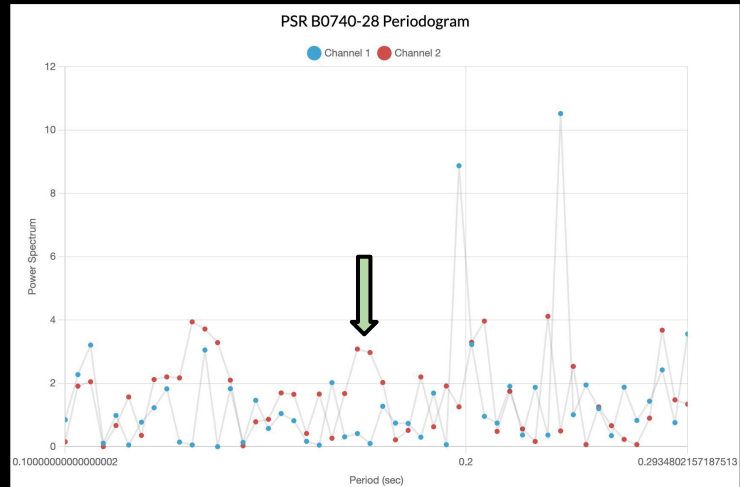
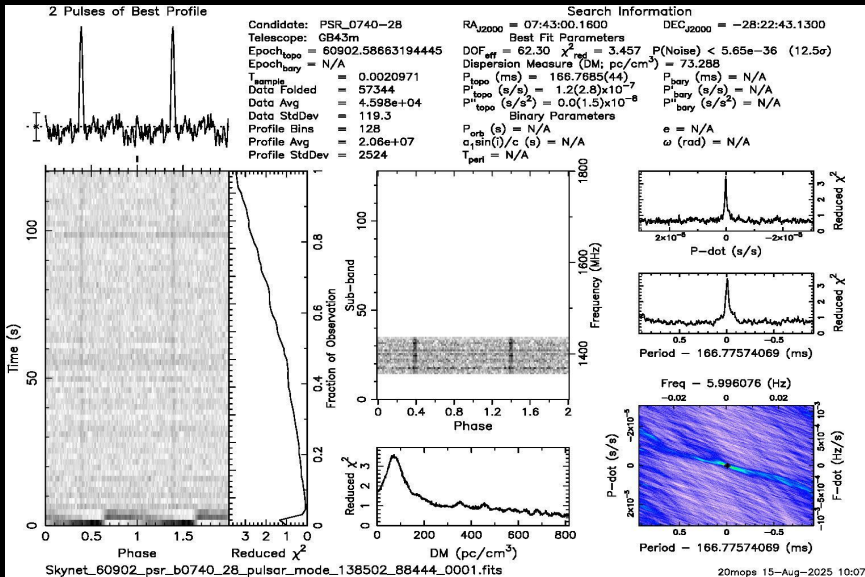
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PSR B0740-28

- Actual Period: 0.1667 seconds
- Measured Period: 0.1668 seconds
- Distance: ~6,198 light-years

Sonification

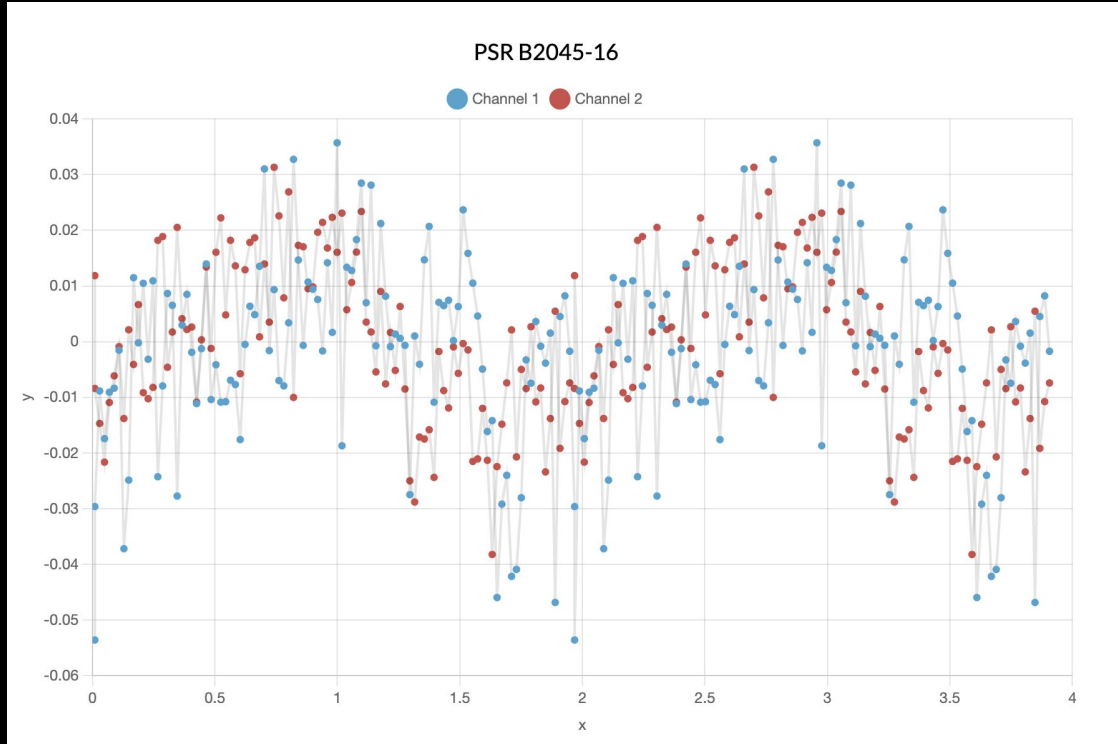


PSR B2045-16

- Actual period: 1.961 seconds
- Measured period: 1.9780 seconds
- Distance: ~3,100 light-years

Sonification

:



The Pulsar Graveyard

While the 40 ft. and 20m telescopes provided great data for some pulsars, the pulses from other observable pulsars were not able to be identified.

The lack of observable data could be due to:

- Pulsar position in the sky (below horizon)
- Low signal-to-noise ratios
- Insufficient data collection area
- Poor time resolution

Unobservable pulsars:

PSR B0833-45

PSR B2021+51

PSR B0736-40

PSR B0835-41

PSR B1641-45

PSR B1933+16

PSR B1749-28

Thanks!

Questions?



Credit: NASA/CXC/PSU/ Pavlov et al.