Data Generation

For Pulsar Detection using Deep Learning

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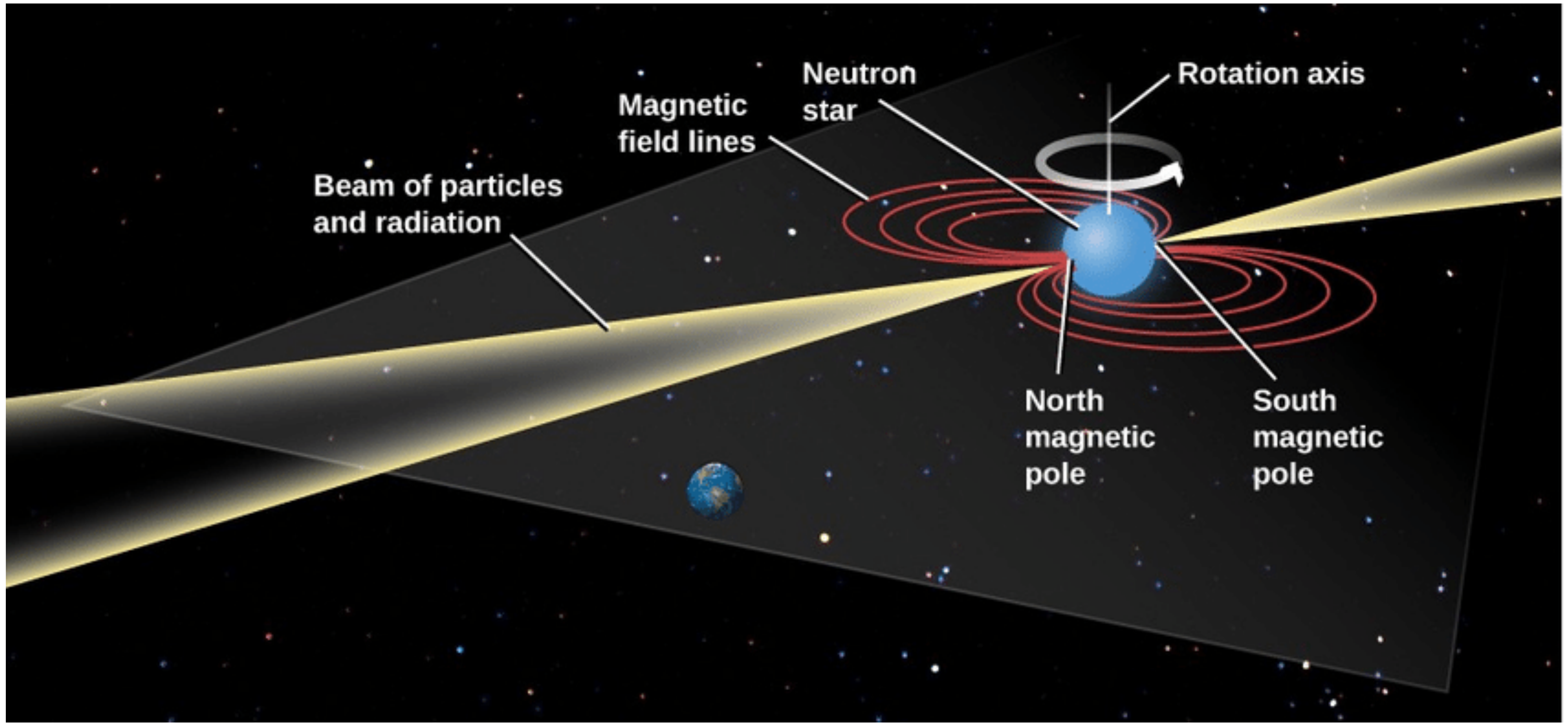
What are pulsars ?

- Pulsars are highly-magnetised, rotating neutron stars that emit beams of electromagnetic radiation.
- When looked at sky in wavelengths other than visible range. Astronomers discovered spots that flicker overtime, these points seem to emitextremely regular oscillations i.e they are pulsating hence called pulsars.



Why study Pulsars ?

Very strong magnetic fields

- One billion to one quadrillion times that of Earth's
- Reason for radiation beaming from magnetic poles of pulsar
- Provides insights into the behavior of matter in extreme magnetic conditions.

Very precise Clocks

- Extremely stable periods
- Tick of pulsar is time it takes for it to spin around once
- Can predict with very high precision when any given pulse should arrive at Earth.

Very high spin

- Lighthouses on Earth certainly don't spin this fast!
- Spin anywhere from once every few seconds to as many as hundreds of times in a single second!
- Like a light house, but instead of visible light pulsar creates radio waves.

Tool for studying universe

- Natural probes to map the distribution of mass within our galaxy.
- TOA of pulse gets effected if there are disturbances.
- Astronomers can model all of these effects to bring prediction back in line with observations

Observation of pulsars

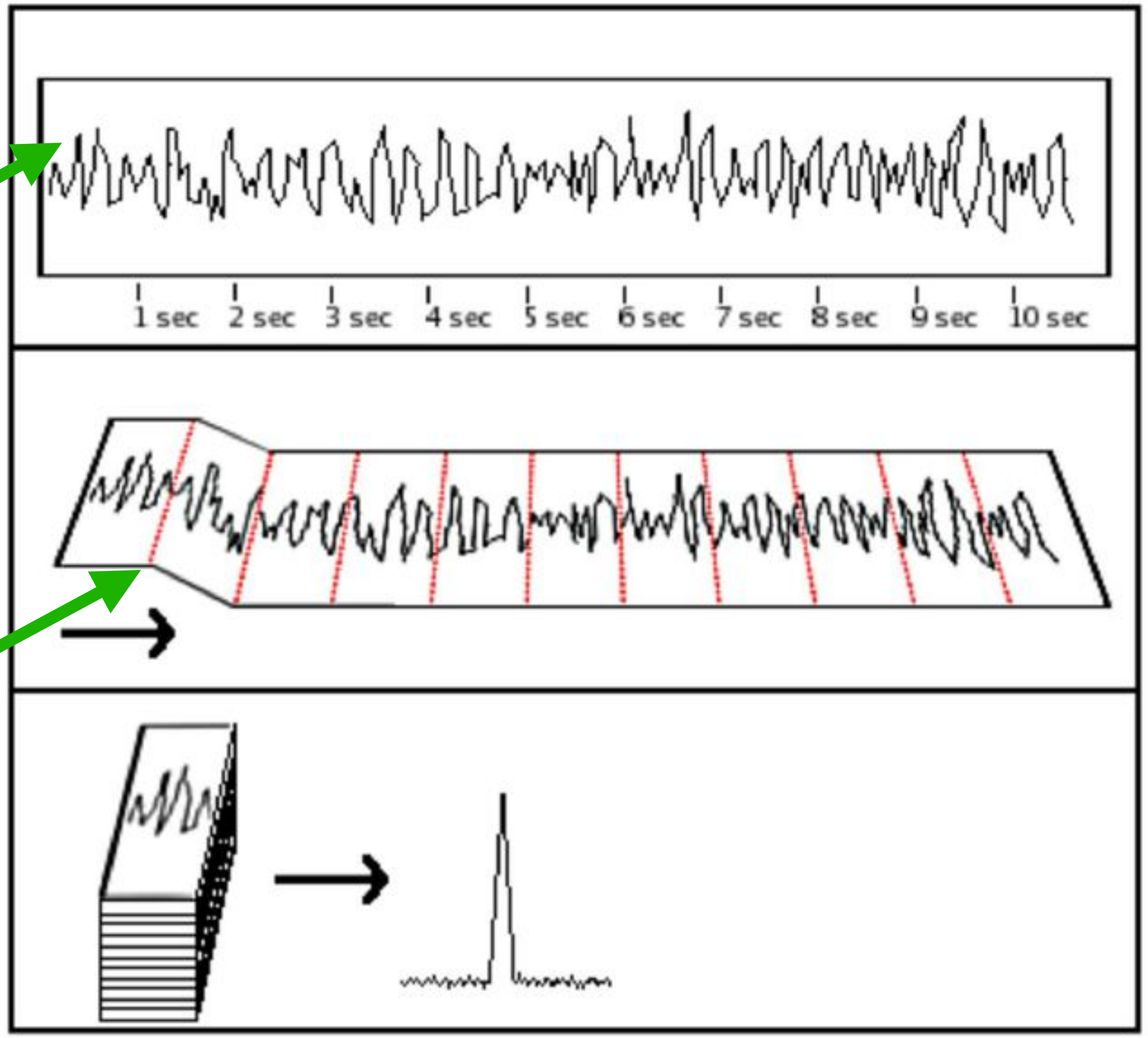
- It must be easy to observe pulsars right! Point a radio telescope at sky and boom!
- No, that’s not the case.
- Pulsar signals are very weak. Single pulse is not even strong and gets swamped by background noise.
- Most of technology we use emit radio waves.
- It’s just trying to see stars during the day.

How pulsar data is created ?

Folding - Astronomers combine many pulses together in order to build up a detectable signal.

Mark that indicates strength of our signal detected by telescope, higher the mark stronger the signal

Mark representing one period of pulsar



Record of how strong signal is during course of observation.

Can't tell if there is any pulsar in here. It looks like noise.

If we know the spin period, we can fold the pulsar signal to raise above the noise.

Just like this. But we don't know spin period for new pulsars.

Fourier transform

- We can use the Fourier transform tool to identify periodic signals in our data. This mathematical operation transforms the data from signal vs. time form to signal vs. frequency form, where the frequency is related to time as frequency = 1/time.
- I Fourier transform a set of pulsar data to look for signals in the frequency domain. If I find one, I can go back and fold the data in the time domain to see if it's from a real pulsar.
- For example, if I see a signal at 100 Hz in the Fourier transformed data, I would fold the data at a spin period of 0.01 seconds. This is a more efficient way of searching for pulsars than doing blind folds.
- I have outlined the process of detecting a pulsar signal in the Fourier transformed data set. Computer programs are very effective at identifying potential signals, but we need a human touch to separate true pulsars from the impostors.

Radio Frequency Interference (RFI)

- Pulsars emit radio waves, which are collected by telescopes, but they compete with other sources of radio waves, like car radios, satellite TV, cell phones, wireless Internet, power lines, and even spark plugs. Cosmic sources, like the Sun, also emit radio waves.
- The sources of radio waves in our society get in the way, and make some observations almost impossible. For this reason, astronomers refer to these man-made sources of radio waves as Radio Frequency Interference, or RFI. RFI is similar to light pollution.
- RFI can look like a pulsar signal in Fourier transformed data, due to the repeating signal of pulsars and man-made RFI.
- For example, the AC power in our homes gives off RFI at 60 Hz. We can tell a computer to ignore this frequency, but other sources of RFI may not be as easy to handle.

Introducing PRESTO

- **The software package PRESTO is used by pulsar astronomers to take raw data and search for periodic signals.**
- **It does so by conducting thousands of guesses. When a promising signal shows up, the program prepfold can be used to fold the data at the period of the candidate.**
- **The output file generated is called a “pulsar candidate” and is of format “.pfd”.**
- **We need to break down each element of the plot and analyse its importance, so that you can look at the plot and determine if it shows a true pulsar.**

PRESTO Pipeline

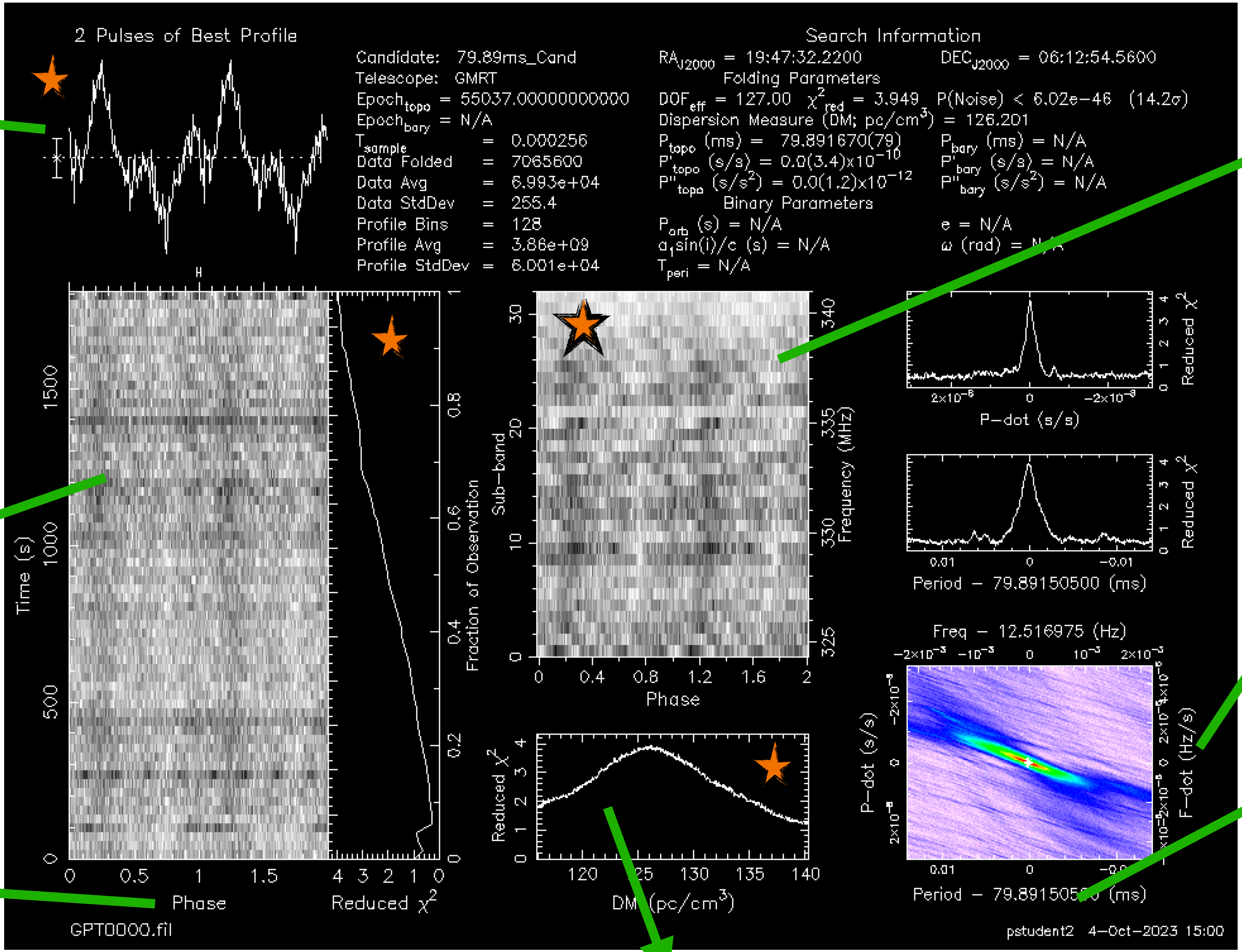
One of the 18,352 candidates generated

Summed Pulse Profile: The total sum of the entire data folded at the best period.

The dark grey parts here correspond to the pulse. We've broken the data into small pieces and stacked them on top of each other.

We can see pulsar is constant approximately over all the time and you can also see other data in here that corresponds to RFI which has not yet been removed from the data.

Pulse phase means one rotation of pulsars going from 0 to 1. Here, it goes to 2 because we are showing two pulses.



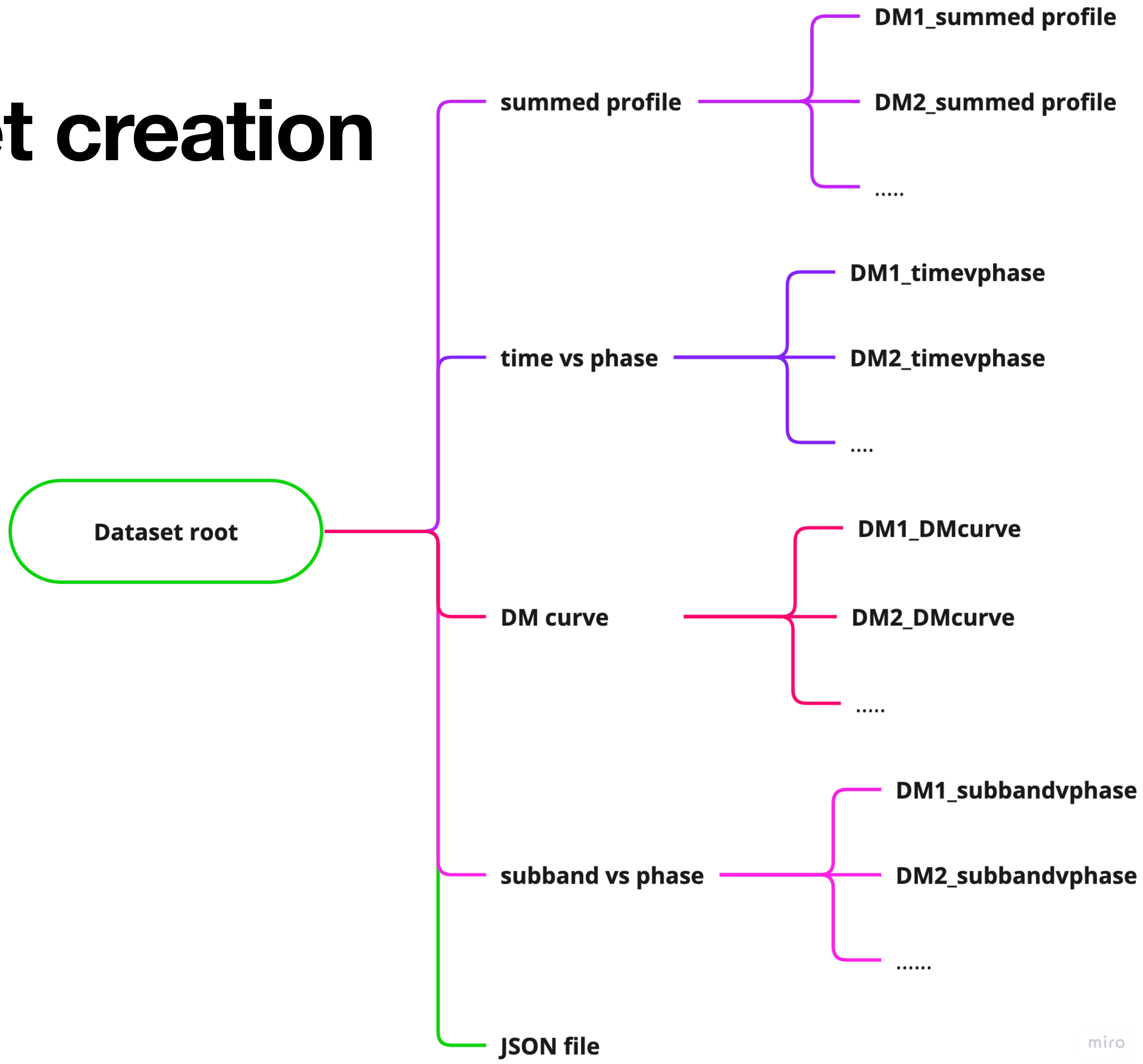
Still pulse phase but as a function of frequency. We've broken the data into multiple frequency bands and we show if we use correct DM the pulsar signal is straight.

Best change of period

Best period. It may be that we don't get exactly the right period from our Fourier analysis. So, we search around that period to see if we can further improve the value or it may be that the period is slightly changing as a function of time especially if the system is in a binary.

You can think of Khi^2 is like signal to noise. It sharply peaks at best value for the DM and that's the DM we used for all the other analysis

Dataset creation



Thesis Timeline

Thank you