Initial Pulsar Data Reduction

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Before we begin ...

Please download the following files using wget

http://ipta.phys.wvu.edu/files/student-week-2018/B1907+10.fil

http://ipta.phys.wvu.edu/files/student-week-2018/new_pulsar.fil

These will be used for the activity later on

Data Formats

- Pulsar data is usually in the time-frequency format.
- In addition, one may have four Stokes' parameters instead of just total intensity.
- Although each telescope back-end may have its own way of writing the data, we have two types of data formats: filterbank and psrfits.
- Both the formats are basically time-frequency arrays but their headers and the way they are read and treated differs.

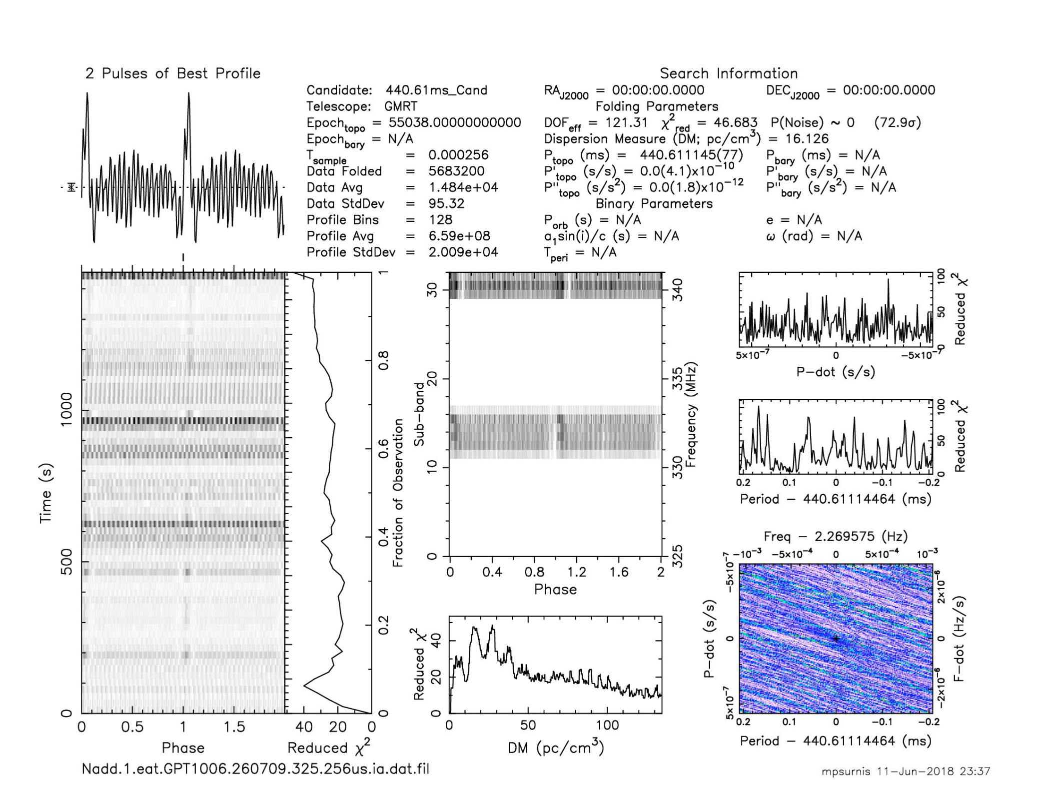
Metadata

- Contained in the header.
- Information about the source, the telescope and the back-end settings.
- Without this, the rest is basically junk!

Data Reduction

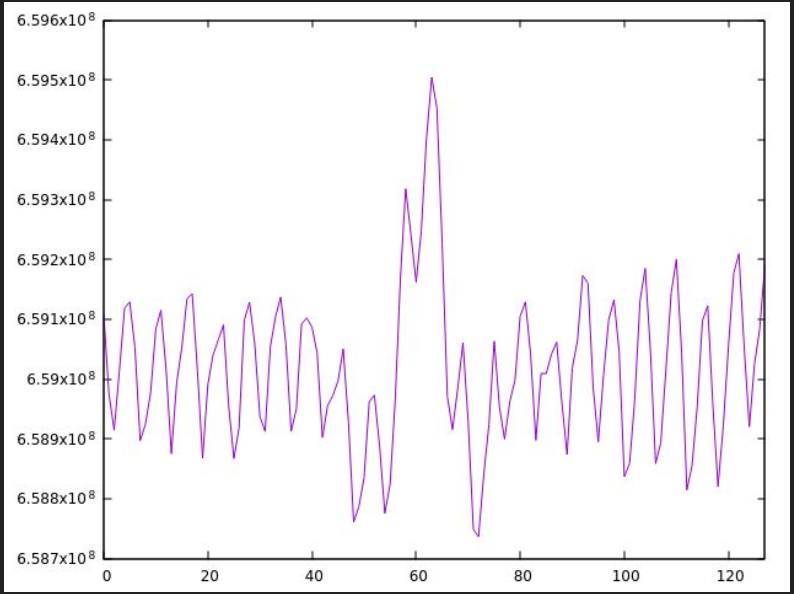
- There are many ways data reduction can be done.
- We have software packages like sigproc, presto, dspsr, psrchive etc.
- Data visualization is of foremost importance!
- It always starts with looking for and dealing with radio frequency interference (RFI).

A Nice (or Not so Nice) Example



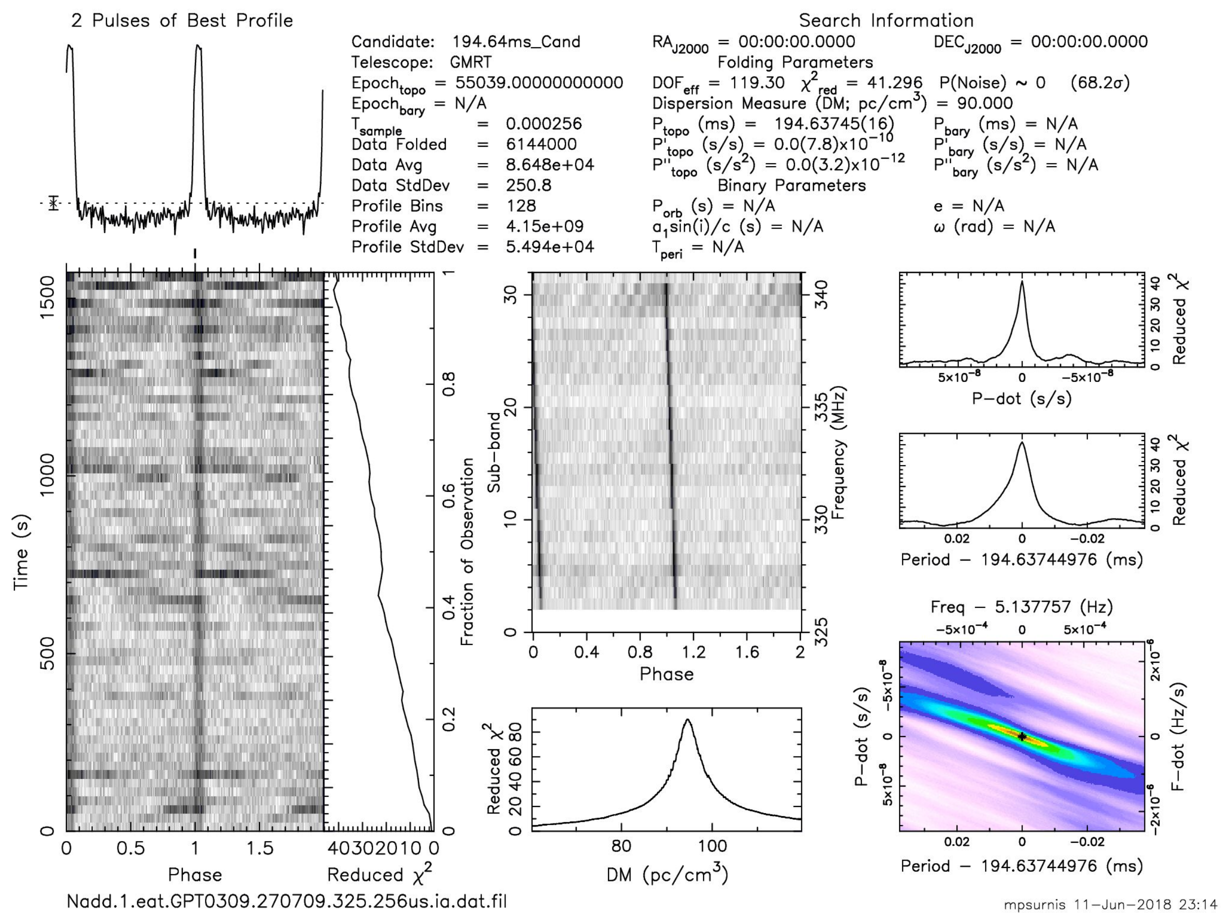
PSR B1944+17

P ~ 440 ms



Determining the DM of the pulsar

- DM is the integrated free electron density along the line of sight.
- It is a proxy for the distance of the pulsar.
- It provides an opportunity to study the interstellar medium (ISM).
- If gone wrong, it may hinder the determination of a good timing solution.



PSR B1915+13

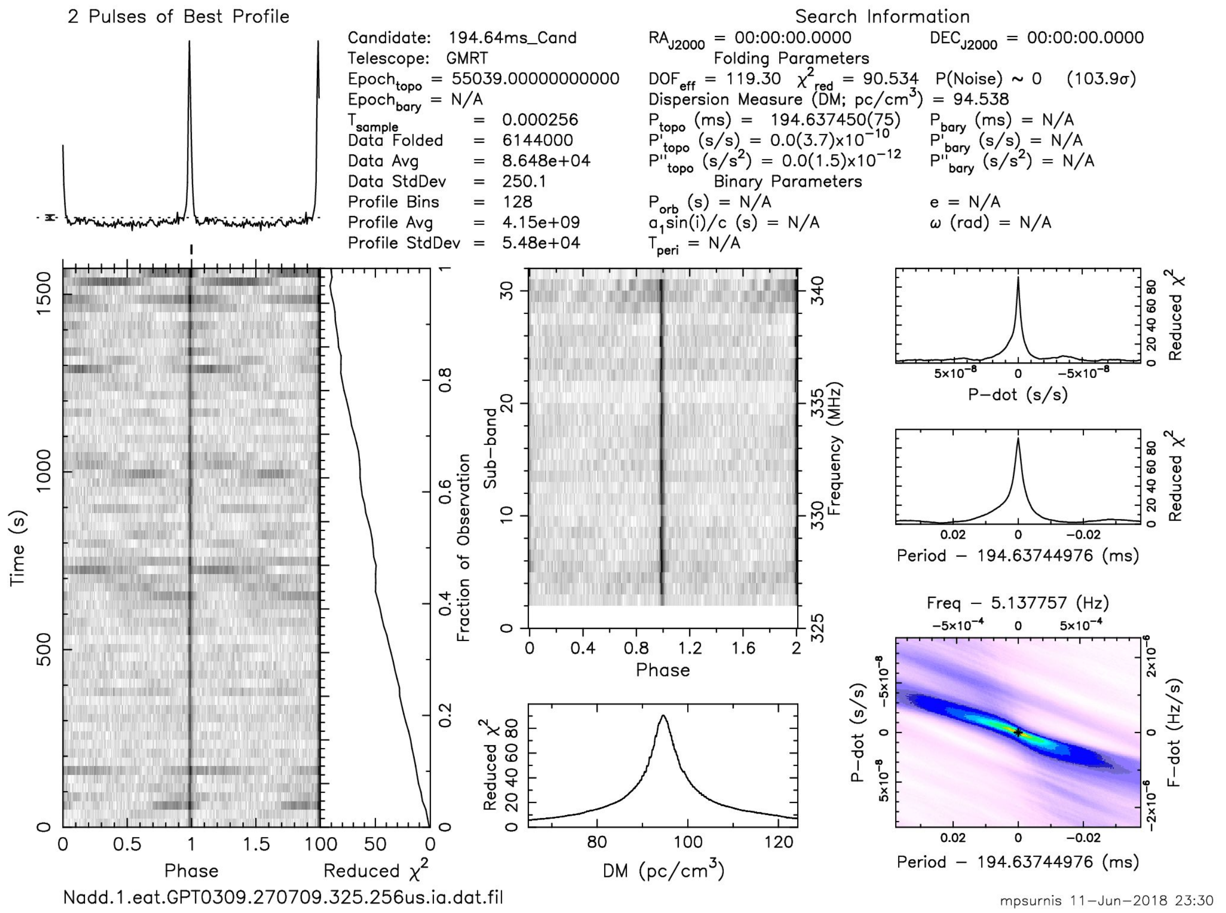
Data de-dispersed at the wrong DM.

Notice the broadening in the pulse shape.

- Based on the slope of the pulse in the frequency sub-band plot, one can estimate the DM offset.
- The delay due to DM in ms is given by

$$\text{Delta } T = 4.15 \times 10^6 \times (f1^{-2} - f2^{-2}) \times DM$$

- Where f1 and f2 are in MHz and the DM is in pc/cc
- Once correct DM is obtained, the time-frequency data can be de-dispersed to get the time series



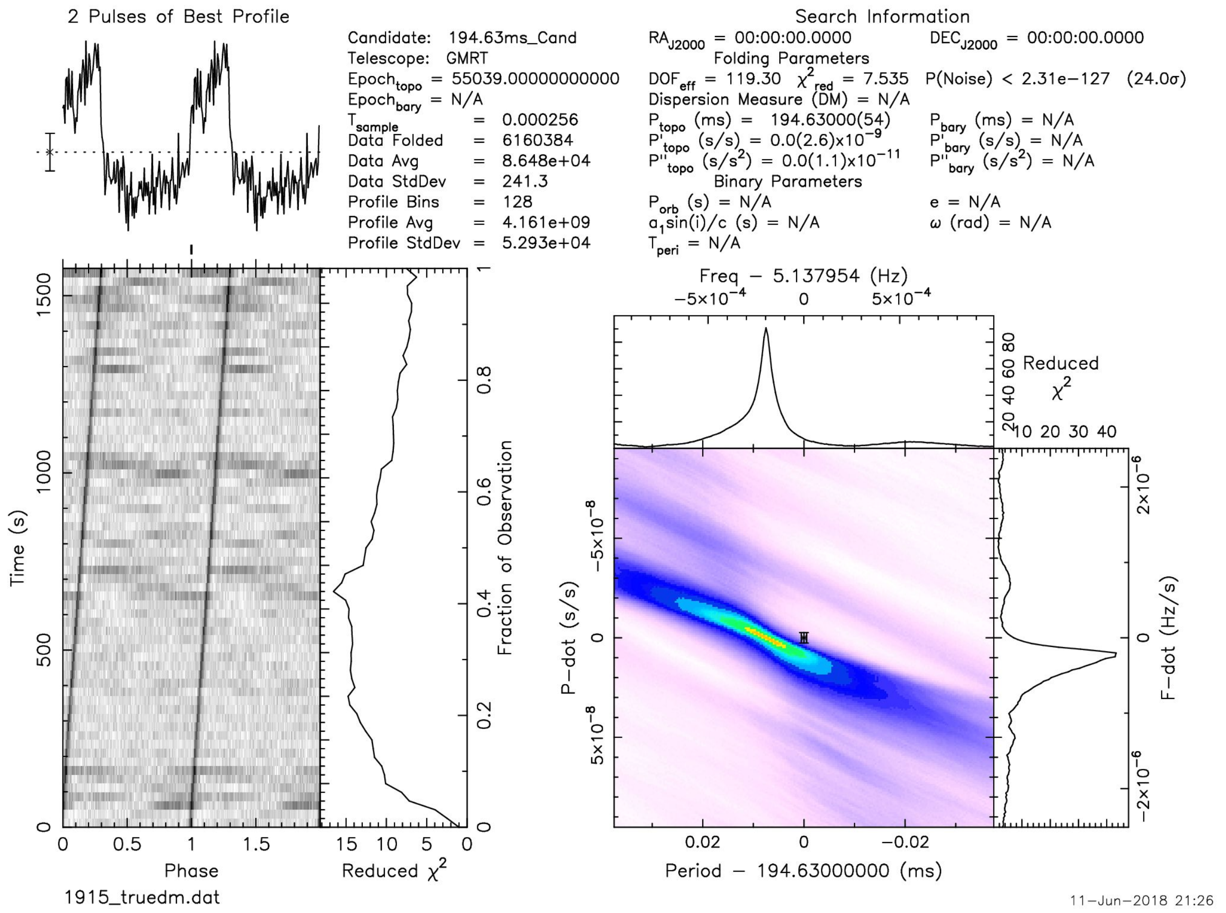
PSR B1915+13
Data de-dispersed at the correct DM.

Notice the sharp pulse shape and increase in S/N.

Determining the Period of the Pulsar

- Fold the time series modulo the best known period.
- Produce a time sub-integration plot.
- Estimate the period offset from the accumulated error across the observing length.
- If the error in period is dP, error across the observation is dT with P and T being the period and observing length respectively, the period error is given by

$$dP = dT\ (P / T)$$

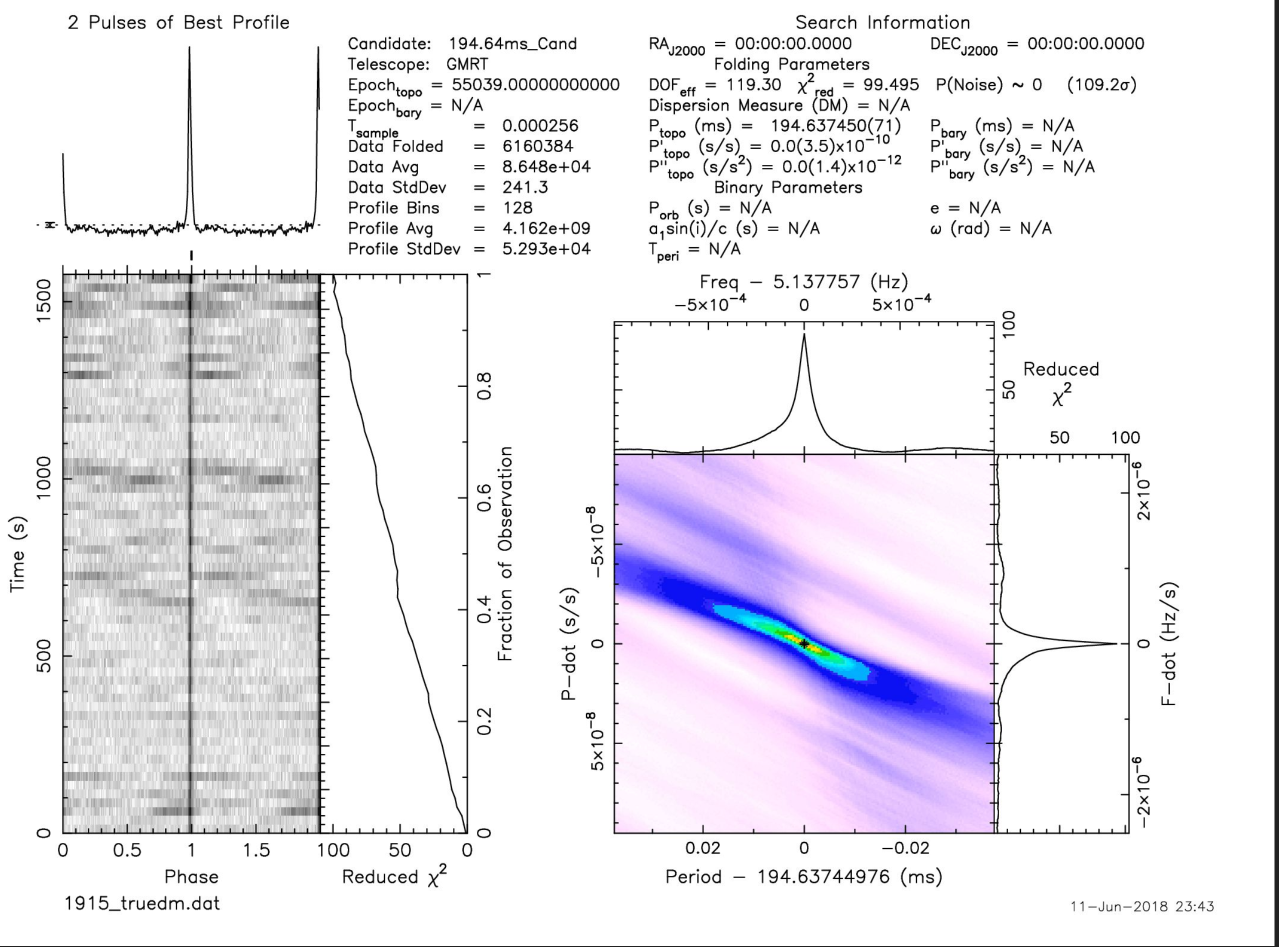


PSR B1915+13

Time series folded at the wrong period.

Notice the pulse shape broadening.

The period error is about a few microseconds!



PSR B1915+13

Time series folded at the correct period.

Notice the sharp pulse and increase in S/N.

Using the Profile S/N to Estimate the True Period

- Profile signal-to-noise ratio (S/N and not SNR. SNR is supernova remnant!) is defined as the ratio of the mean signal intensity to the rms in the OFF-pulse region.
- To determine the profile S/N, use the following steps:

1. Calculate the baseline mean and subtract from the profile.
2. Calculate the rms in the OFF-pulse region.
3. Calculate the equivalent width of a top-hat pulse with the same area as the pulse.
4. Use Equation 3 from the activity sheet to estimate profile S/N.

- Set-up a trial period grid, calculate profile S/N at each trial period.
- The trial period yielding the maximum S/N is the true period of the pulsar.

Closing Remarks ...

These steps are usually important during the initial timing observations where a precise timing solution is not available.

As the accuracy of the timing solution improves, the timing solution itself can be extended to get an accurate prediction of the topocentric period.

Precise measurement of the DM however, requires closely spaced or simultaneous multi-frequency observations.

In case of DM variations, one needs to keep doing multi-frequency observations in order to correct for the errors introduced in the timing residuals.

Closing Remarks ...

- Even after getting very precise timing solution, having at least a customary look at the data is advisable.
- This helps in catching interesting events like nulling, mode changing, extreme scattering events, chromatic DM events.
- The longer you observe a pulsar, the more aspects of its personality are revealed!
- As an example, the first intermittent pulsar, PSR B1931+24, was realized to be intermittent around 1999 whereas it was discovered in a survey carried out in 1985!