Introduction to pulsar timing

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Pulsars

- Pulsars are sources of quasi-regular “pulses” that are broadband and sum to a mean pulsar profile that (to the eye) looks largely identical.

By timing average pulses, we can learn about:

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- How fast pulsars spin
- How they slow down
- How they have starquakes (glitches)
- The interstellar medium
- Any orbits they are part of

Pulsar data is usually folded into “psrchive-compliant” archives on disk

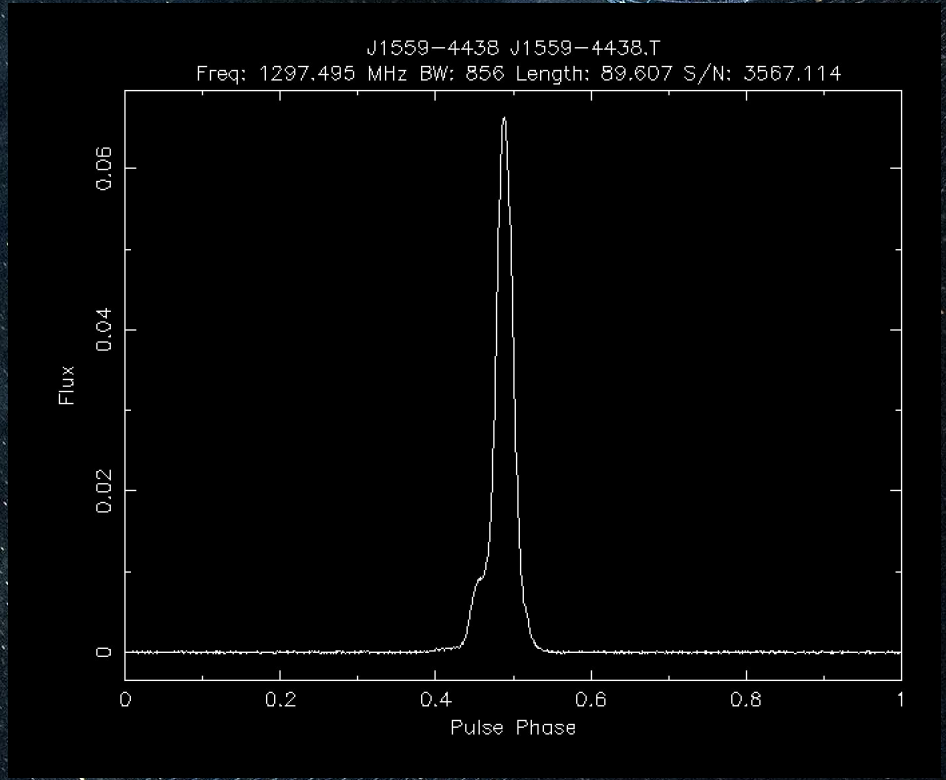
An archive is a collection of pulsar profiles, each of which contains information about the pulsar’s intensity as a function of pulse “phase”, usually in 1024 = 2^10 bins

> cd MeerKAT_Tutorial

> pav -DFTp -r 0.5 J1559-4438.T

pav = “pulsar archive viewer”

This can be seen at https://dev.pulsars.org.au



Some unix

> cd blah

Change to the directory “blah”

> ls

List all of the files

> ls *.ar

Show all of the files ending in “.ar”

> ls -l

Show a long list of all the files

```
[mbailes@farnarkle1 MeerKAT_tutorial]$ ls -l
total 7262
drwxr-sr-x 2 mbailes oz002   33280 Sep 16 21:04 J1141-6545
-rw-r--r-- 1 mbailes oz002 8481600 Sep 16 20:26 J1559-4438.T
drwxr-sr-x 2 mbailes oz002   57856 Sep 16 20:59 MSPs
[mbailes@farnarkle1 MeerKAT_tutorial]$
```

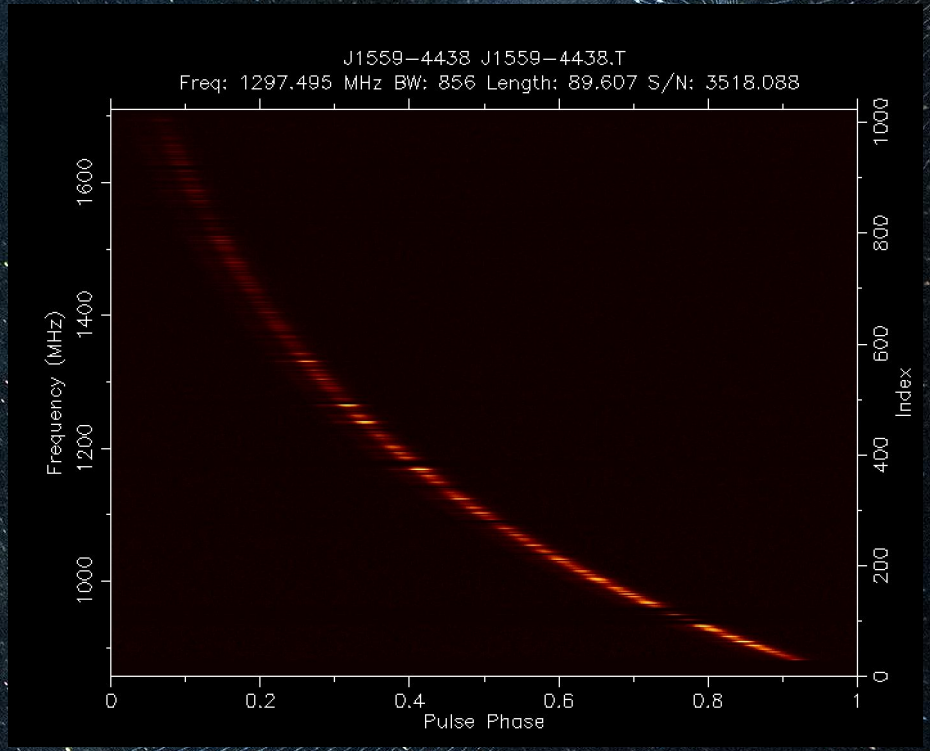
Here there is a file call J1559-4438.T
and two “directories” (think folders)

J1559-4438.T is actually many profiles in one file

See the effect of free electrons in the Universe by doing:

> pav -Gp J1559-4438.T -r 0.7

> this pulsar has a spin period of 257 ms and a dispersion constant of 56.1 pc/cc.



Dispersion Measure is proportional to the integrated free electron column density between us and the pulsar

The time delay $t_2 - t_1$ between two observing frequencies ν_1 and ν_2 is:

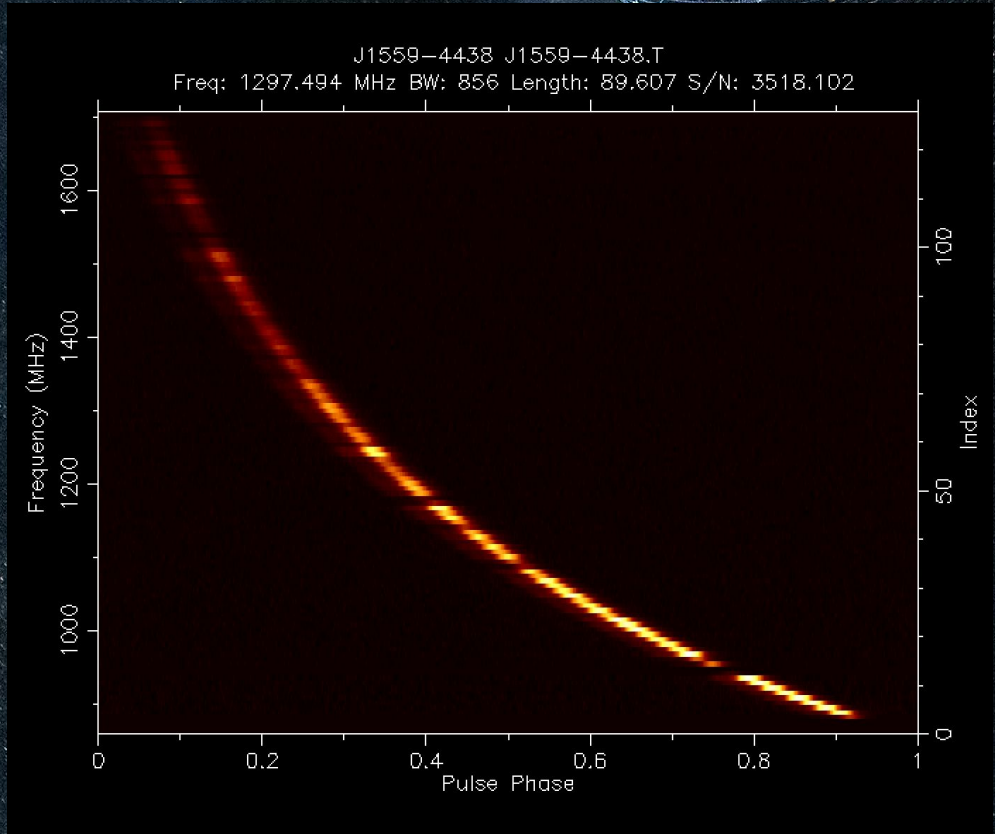
$$t_2 - t_1 = 4.15 \text{ ms } DM \left[\left(\nu_1 / \text{GHz} \right)^{-2} - \left(\nu_2 / \text{GHz} \right)^{-2} \right]$$

Scrunching the data to “reduce” it

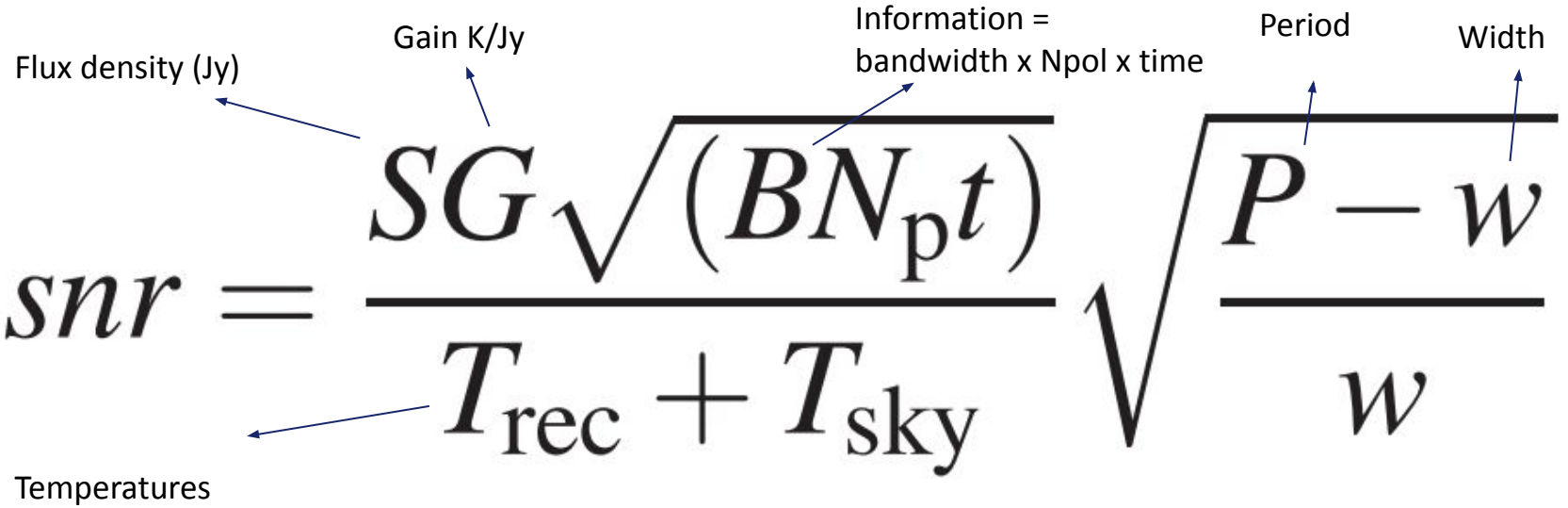
We can reduce the number of profiles by “scrunching” either in time or frequency

To plot fewer profiles we can add “-f 8” to the “flags” given to pav

Eg > pav -f 8 -Gp J1559-4438.T -r 0.7



What Signal-to-noise will I get?
Incentive to scrunch in pol, time frequency - but less points!



vap = give me information about archive

> vap -c “NAME FREQ BW NSUB NPOL NCHAN” J1559-4438.T

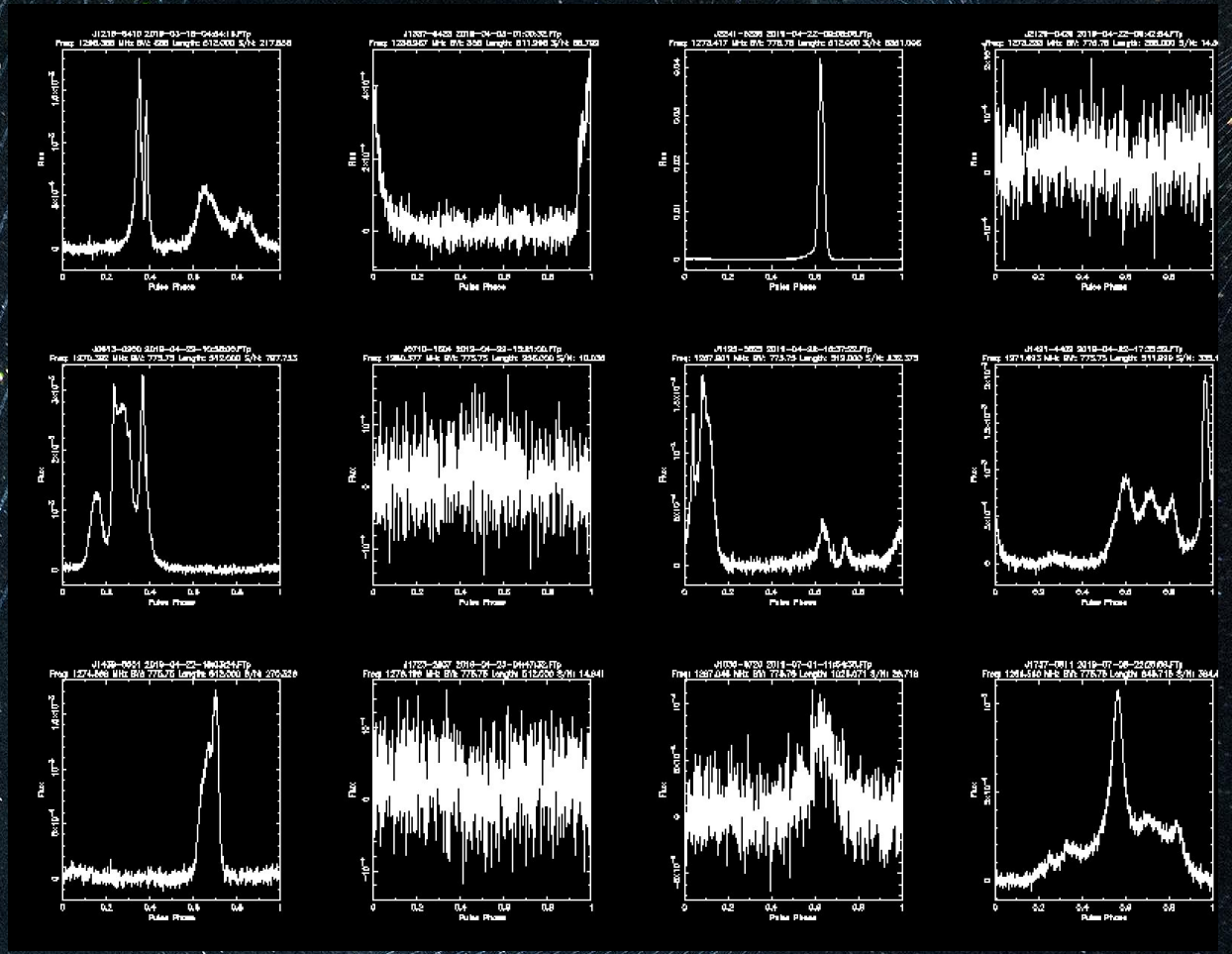
> vap -h for everything

```
[mbailes@farnarkle1 MeerKAT_tutorial]$ vap -c "NAME FREQ BW NSUB NPOL NCHAN" J1559-4438.T
filename    NAME    FREQ    BW    NSUB    NPOL    NCHAN
J1559-4438.T    J1559-4438    1283.582    856.000    1    4    1024
```

Plot lots of profiles

> cd MSPs

> pav -N 4,3 *.FTp



Generate “arrival times” or ToA’s by comparing to an average profile

Step 1. Form average profile

Step 2. Use “pat” to generate arrival times from your data

Step 3. Create a timing model “.par” file

Step 4. Use tempo2 to fit a model to the data

What about binary pulsars?

> cd ../J1141-6545

> tempo2 -gr plk -f playground.par withpn.tim

Vorb = 2 x pi x a sin(i) x c / Pb

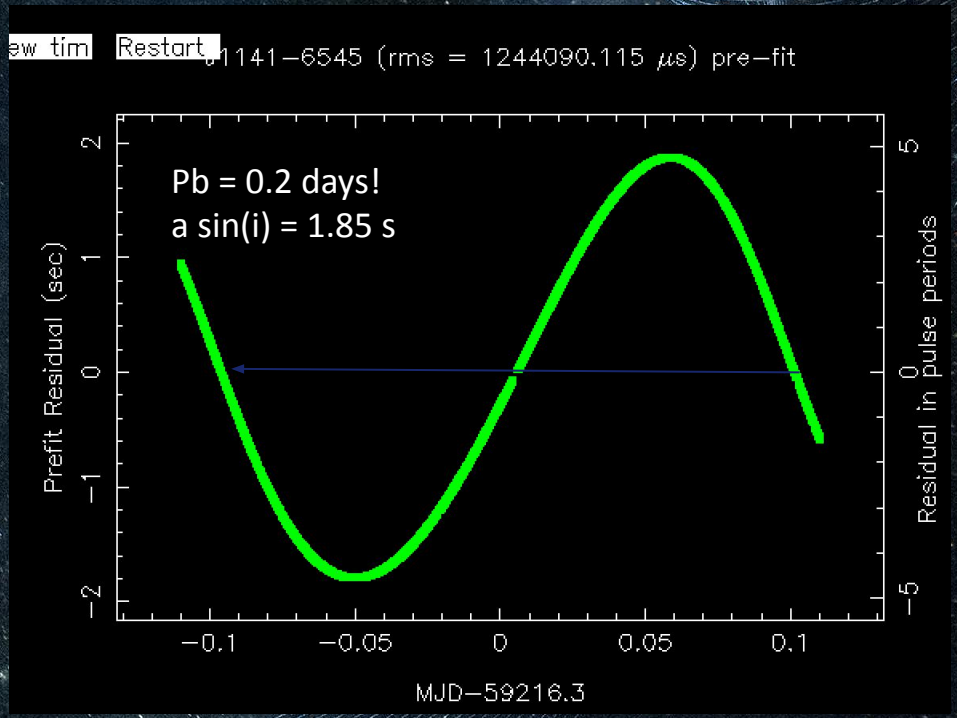
= 2 x 3.141 x 1.85 x 3e8 / (0.2x24x3600)

= 201 km/s!

(companion = 1.3 x faster)

Mutual speed = 464 km/s = 0.15% c!!

White dwarf @ 1 Mo + 1.3 Mo pulsar



This system is only just bigger than the Sun

Advance of periastron = 5.33 deg/year

90 degree phase shift in ~17 years

Orbit shrinking due to GW emission

Few mm/orbit