IPTA Student Week Tutorial on PSRCHIVE

IPTA Student Week 2026:

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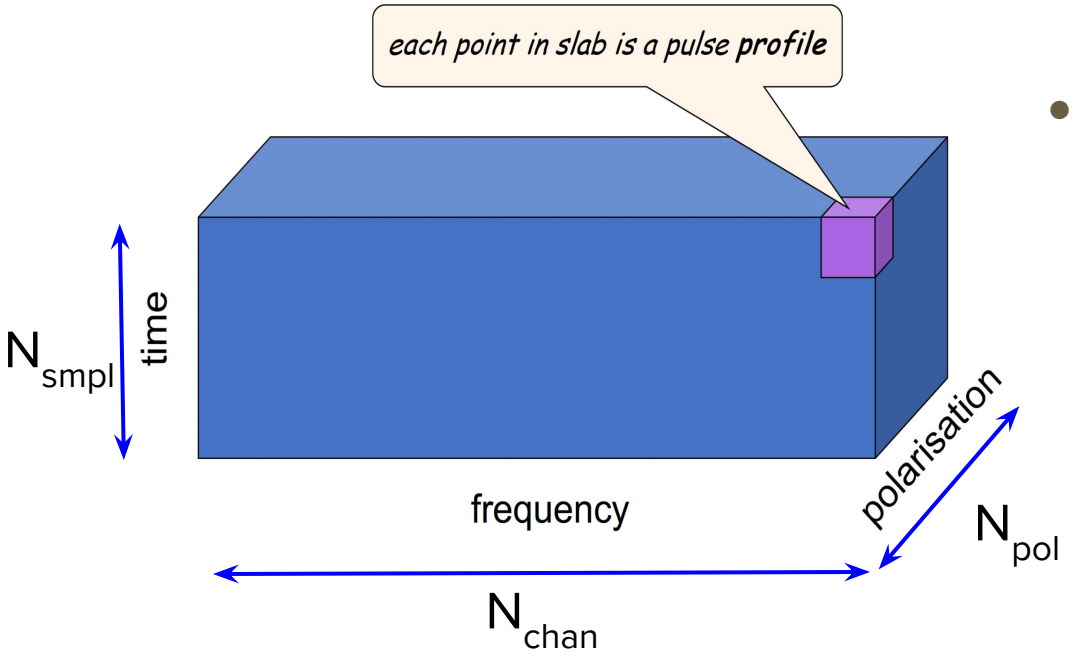
Pulsar Data Format

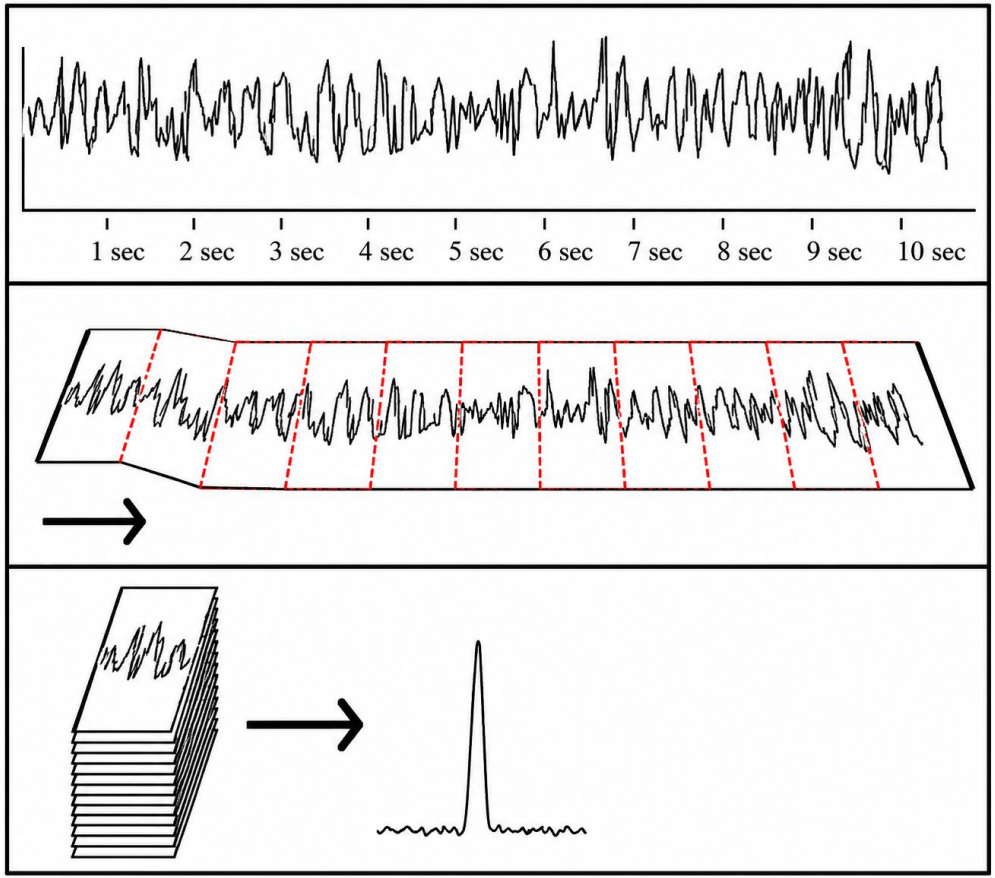


- The binary raw data file stores **Npol** polarization products in **Nchan** channels for every time sample as **16-bit integers**.
  - Npol = 1 : Total intensity
  - Npol = 4 : Stokes I,Q,U,V

Data Volume (Bytes) = $N_{chan} * N_{smpl} * N_{pol} * (N_{bits} / 8)$

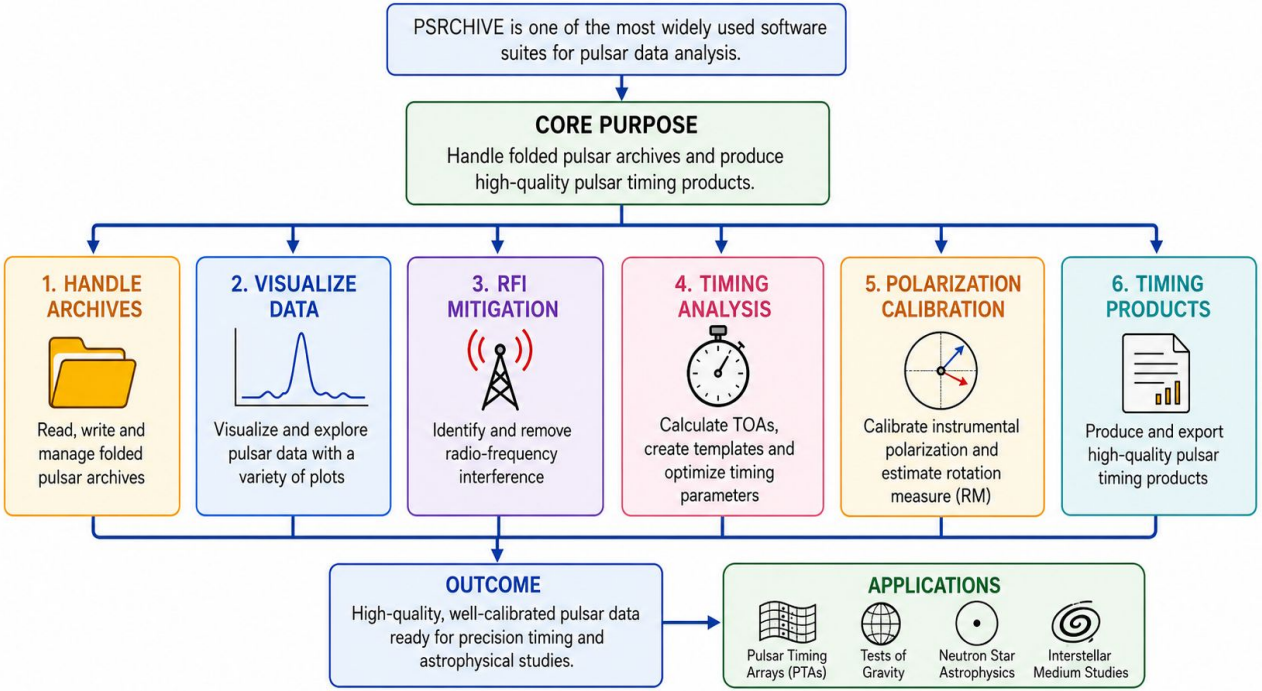
Folding using dspsr

Folding - Add large number of pulses in phase to improve signal to noise ratio.



Credit: Lynch, Ryan S. 2022, "Searching for and Identifying Pulsars"

What Can PSRCHIVE Do?



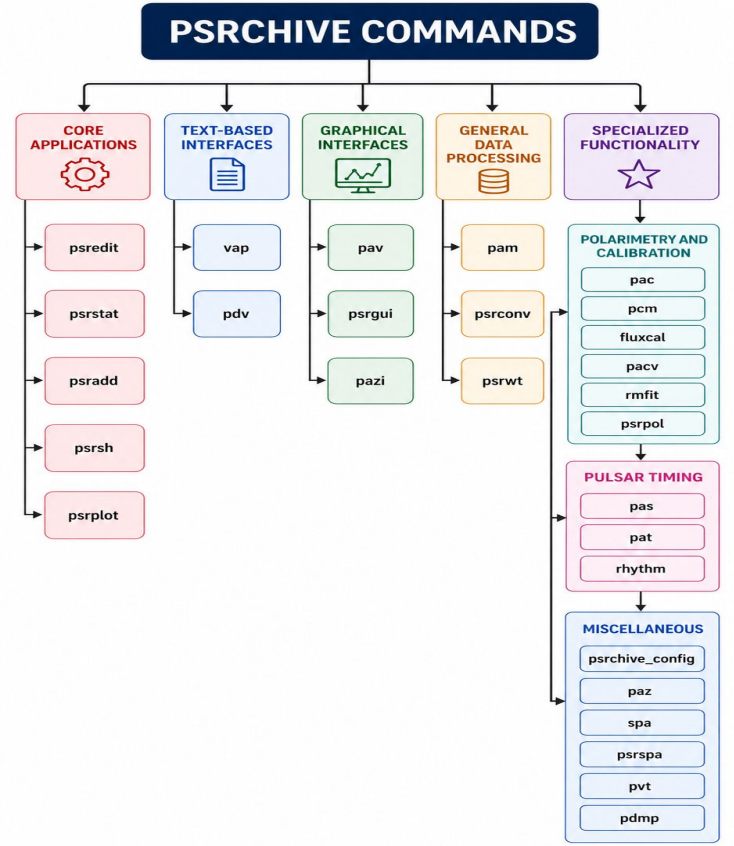
- An open-source pulsar data analysis suite
- A C++ library with Python bindings
- Integrated with UNIX command-line workflows
- Widely used in PTA and pulsar timing experiments

PSRCHIVE primarily operates on

- *PSRFITS*
- *EPN*
- *PRESTO folded archives*

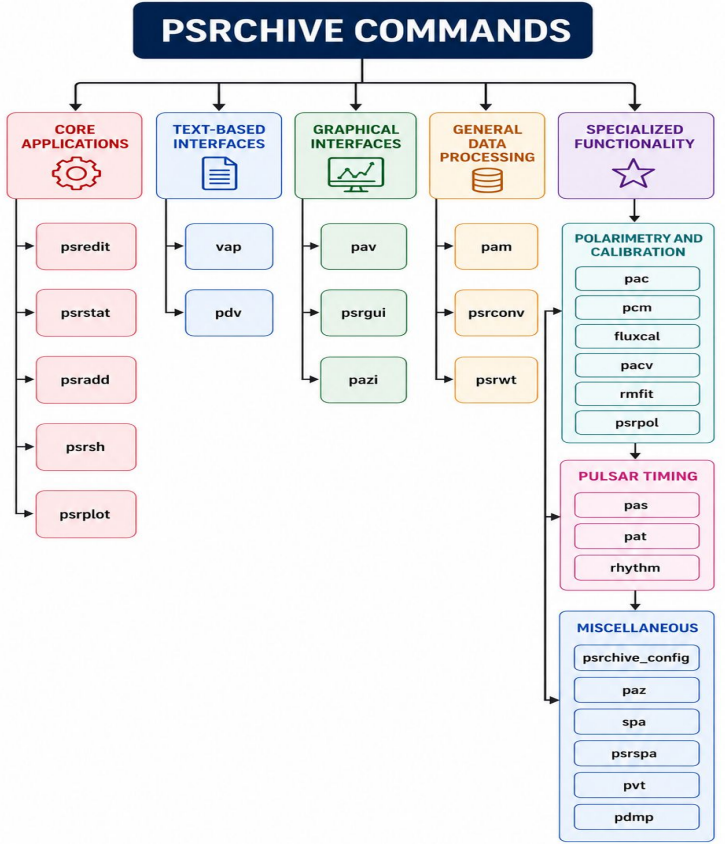
PSRCHIVE Commands and Functional Categories

Command	Purpose
psredit	Query/edit metadata
psrstat	Query attributes and statistics
vap	Output tables of parameters and derived values
psrplot	Generate publication-quality plots
pav	Produce a wider variety of plots
pam	Command line general purpose data reduction

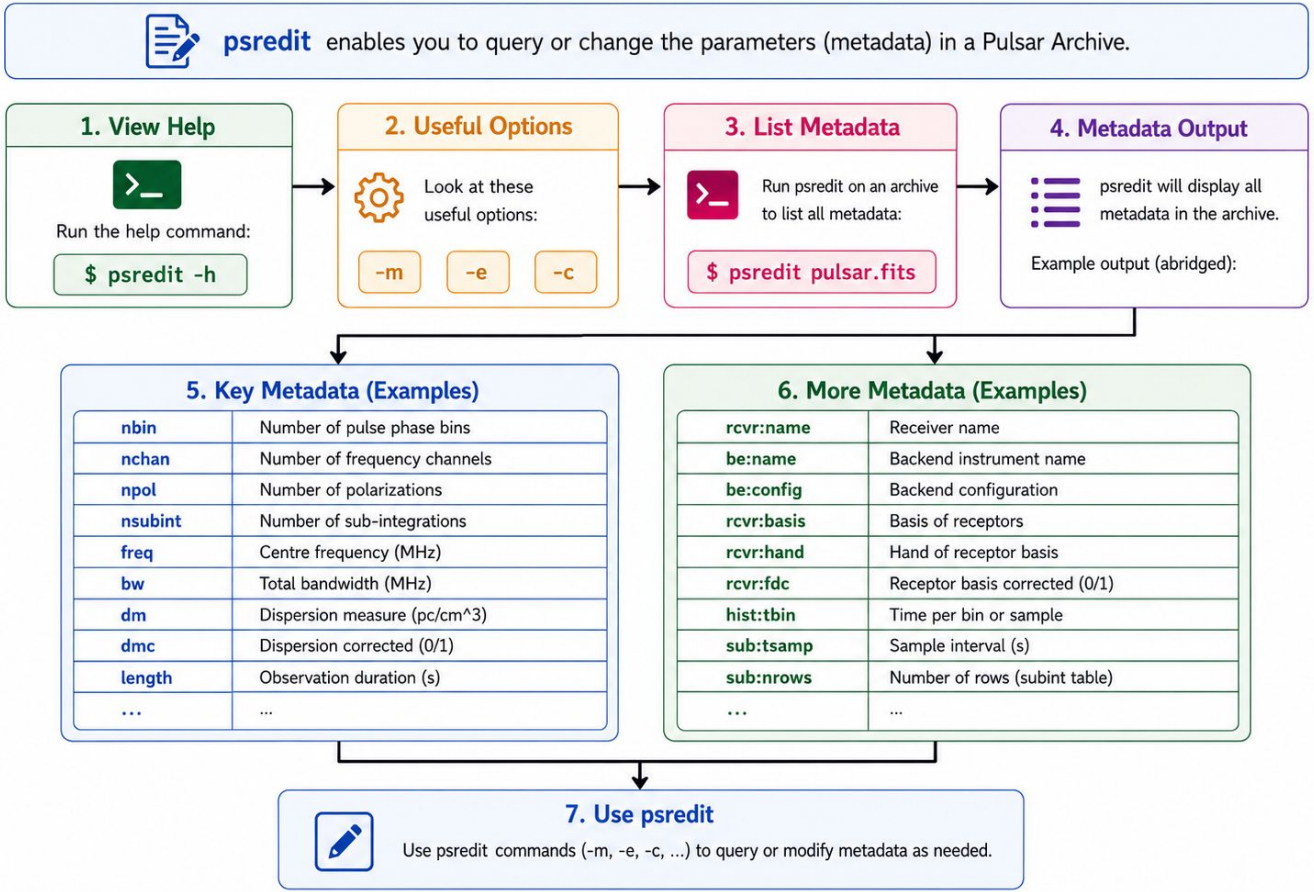


PSRCHIVE Commands and Functional Categories

Command	Purpose
paz	RFI mitigation
psradd	Combine data in various way
pat	Produce time of arrival estimates
pas	Generate template profiles (standards)
pdmp	Find optimal period and dispersion measure
rmfit	Estimate the Faraday rotation measure



Inspecting Pulsar Archives: Pulsar Archive Editor, psredit



Inspecting Pulsar Archives: Pulsar Archive Editor, psredit

- **Viewing Metadata**

```
psredit pular.ar
```

```
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psredit pular.ar
itoa_code no alias found for unknown
file            Name of the file                        pular.ar
nbin            Number of pulse phase bins              2048
nchan           Number of frequency channels            128
npol            Number of polarizations                 1
nsubint         Number of sub-integrations              265
type            Observation type                        Pulsar
site            Telescope name                          GMRT
name            Source name                             J2145-0750
coord           Source coordinates                      21:45:50.454-07:50:18.59
freq            Centre frequency (MHz)                  399.21875
bw              Bandwidth (MHz)                         -200
dm              Dispersion measure (pc/cm^3)            8.99752998352051
rm              Rotation measure (rad/m^2)              0
dmc             Dispersion corrected                    0
rmc             Faraday Rotation corrected              0
polc            Polarization calibrated                 0
scale           Data units                              FluxDensity
state           Data state                              Intensity
length          Observation duration (s)                2640.06270976
int*:@          int:help for attribute list
ext:obs_mode    Observation Mode                        PSR
ext:obsfreq     Centre frequency                        399.21875
ext:obsbw       Bandwidth                               -200
ext:obsnchan    Number of channels                      128
ext:hdrver      Header Version                          6.2
ext:date        File Creation Date                      2023-03-20T22:56:14
ext:coord_md    Coordinate mode                         J2000
ext:equinox     Coordinate equinox                      2000
ext:trk_mode    Tracking mode                           UNSET
ext:bpa         Beam position angle                     0
ext:bmaj        Beam major axis                         0
ext:bmin        Beam minor axis                         0
ext:stt_date    Start UT date                           UNSETTUNSE
ext:stt_time    Start UT
ext:stt_imjd    Start MJD                               60014
ext:stt_smjd    Start second                            15225
ext:stt_offs    Start fractional second                 0.724512240998592
ext:stt_lst     Start LST                               0
ext:stt_crd1    Start coord 1                           00:00:00.000
ext:stt_crd2    Start coord 2                           +00:00:00.000
ext:stp_crd1    Stop coord 1                            UNSET
ext:stp_crd2    Stop coord 2                            UNSET
ext:ra          Right ascension                         21:45:50.454
```

Inspecting Pulsar Archives: Pulsar Archive Editor, psredit

- **Extracting Specific Parameters**

```
psredit -c freq pular.ar
```

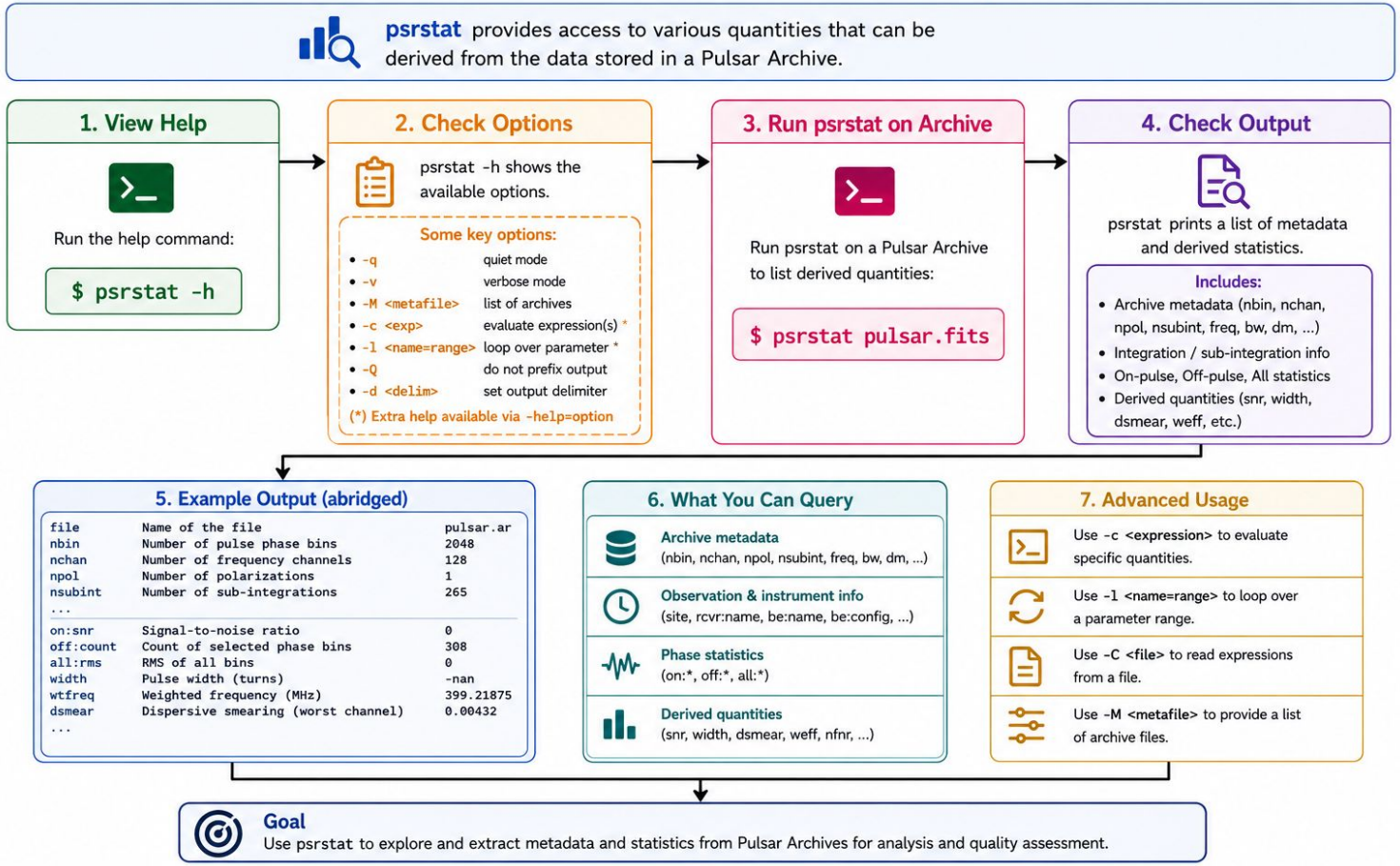
```
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psredit -c freq pular.ar
itoa_code no alias found for unknown
pular.ar freq=399.21875
```

- **Extracting Specific Parameters**

```
psredit -c dm=10.4 -e newdm pular.ar
```

```
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psredit -c dm pular.ar
itoa_code no alias found for unknown
pular.ar dm=8.99752998352051
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psredit -c dm=10.4 -e newdm pular.ar
itoa_code no alias found for unknown
pular.ar
Unloading pular.newdm ... done
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psredit -c dm pular.newdm
itoa_code no alias found for unknown
pular.newdm dm=10.4
```

Inspecting Pulsar Archives: psrstat



Inspecting Pulsar Archives: psrstat

- SNR of the time and frequency scrunched profile

```
psrstat -c snr -j TF pulsar.ar
```

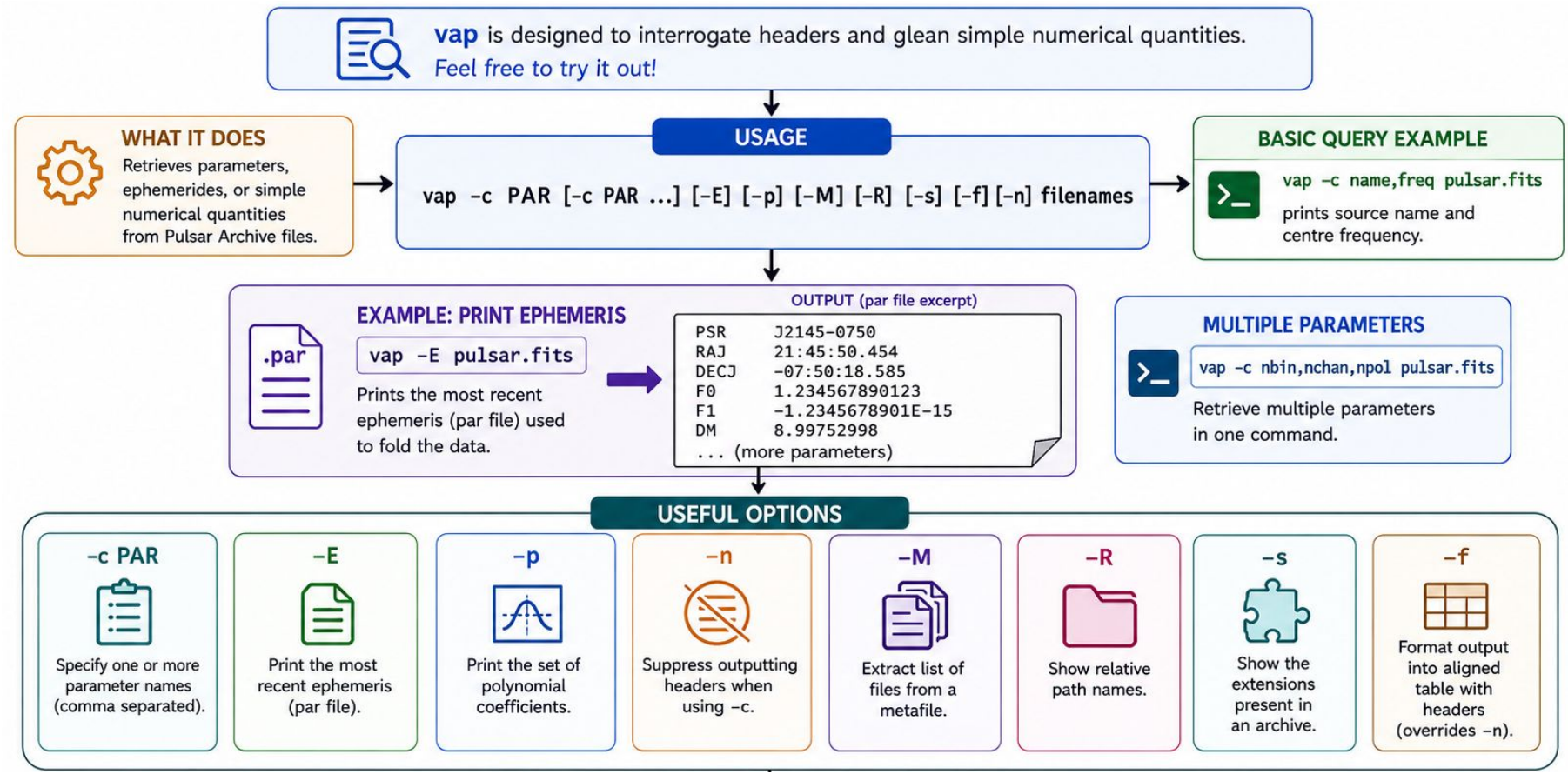
```
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psrstat -c snr -j TF pulsar.ar
itoa_code no alias found for unknown
pulsar.ar snr=944.031188964844
```

- pdmp method to calculate the SNR

```
psrstat -c "snr=pdmp" -c snr -j TF pulsar.ar
```

```
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psrstat -c "snr=pdmp" -c snr -j TF pulsar.ar
itoa_code no alias found for unknown
pulsar.ar snr=926.361206054688
```

Inspecting Pulsar Archives: vap



Inspecting Pulsar Archives: vap

- **Viewing parameters using vap**

```
vap -c nchan,nsub,nbin,length pulsar.ar
```

```
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ vap -c nchan,nsub,nbin,length pulsar.ar
filename   nchan   nsub   nbin   length
itoa_code no alias found for unknown
pulsar.ar   128   265   2048   2640.063
```

- **Viewing the Folding Ephemeris**

```
vap -E pulsar.ar
```

Inspecting Pulsar Archives: vap

```
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ vap -E pulsar.ar

itoa_code no alias found for unknown
PSRJ           J2145-0750
RAJ             21:45:50.4535432            0.00000658329205692095
DECJ           -07:50:18.58484              0.00027072792512247781
F0             62.295887797420199029        0.00000000000144545151
F1             -1.1563551169321617895e-16    9.4909581393480609126e-21
PEPOCH         59000
POSEPOCH       59000
DMEPOCH 59150
DM 8.99753
PMRA           -9.5829939502220306199       0.02538155917840002884
PMDEC          -8.8717993656713608893       0.06926494255067648653
PX             1.5346509610735751529        0.09528401532682594099
BINARY         ELL1
PB             6.83890261542634449          0.00000000003190189756
A1             10.164108024319806264        0.00000008025281329441
PBDOT          1.2740878501840923706e-13    2.8300251478235610462e-14
XDOT           7.5171540742475576178e-15    4.8784761068738545289e-16
TASC           53558.375983405215582        0.00000000941538588326
EPS1           -6.8707864931387065228e-06    0.00000000939429549871
EPS2           -1.8054550416325962692e-05    0.00000000991414871823
EPHVER         5
NE_SW 0
CLK            TT(BIPM2019)
MODE 1
UNITS          TCB
TIMEEPH        IF99
DILATEFREQ     Y
PLANET_SHAPIRO Y
T2CMETHOD      IAU2000B
CORRECT_TROPOSPHERE  Y
EPHEM          DE440
```

Inspecting Pulsar Archives: psrplot

The Pulsar Archive Plotter, **psrplot**, is a highly configurable plotting program that may be used to create customized plots of pulsar data.

1. List Available Plots

To see all available plot types:

```
psrplot -P
```

2. Choose a Plot Type

Select one or more plot types using the `-p` option.

```
psrplot -p <plot> file.ar
```

3. Preprocess the Archive (optional)

Use `-j` to preprocess the archive before plotting (see table below).

```
psrplot -j TFDp -p <plot> file.ar
```

4. Output the Plot

Use `-D` to choose the output device (e.g., screen, PNG, PDF, etc.).

```
psrplot -p <plot> -D output.png/png file.ar
```

5. Example

Dedisperse and scrunch in time, frequency and polarisation, then make a frequency vs phase plot and save as PNG.

```
psrplot -j TFDp -p freq -D freq_plot.png pulsar.ar
```

Available Plot Types (psrplot -P)

Plot	Key	Description
flux	[D]	Single plot of flux
stokes	[s]	Stokes parameters
Scyl	[S]	Stokes; vector in cylindrical
Scyl+	[E]	Stokes; vector in cylindrical+
Ssph	[m]	Stokes; vector in spherical
Sfluct	[U]	Stokes; fluctuation power spectra
Sflph	[u]	Stokes; fluctuation phase spectra
freq	[G]	Phase vs. frequency image of flux
freq+	[F]	freq + integrated profile and spectrum
time	[Y]	Phase vs. time image of flux
pa	[o]	Orientation (Position) angle
ell	[e]	Ellipticity angle
p3d	[P]	Stokes vector in Poincare space
pahist	[h]	Phase-resolved position angle histogram
pahist+	[H]	Phase-resolved PA histogram and total profile
psd	[b]	Pulsed power spectrum

Plot	Key	Description
2bit	[2]	Two-bit distribution
cal	[C]	Calibrator Spectrum
calm	[M]	Calibrator model information
calp	[p]	Calibrator parameter
line	[R]	Line phase subints
dspec	[j]	Dynamic S/N spectrum
dstat	[d]	Dynamic statistic spectrum
offdspec	[r]	Dynamic baseline spectrum
dcal	[l]	Calibrator dynamic spectrum
dweight	[w]	Weights dynamic spectrum
snrspec	[n]	S/N ratio
calphvf	[X]	Calibrator phase vs frequency plot
bandpass	[B]	Display original bandpass
chweight	[c]	Display Channel Weights
bpcw	[J]	Plot off-pulse bandpass and channel weights
digstats	[K]	Digitiser Statistics
digcnts	[A]	Digitiser Counts histogram
fourth	[4]	4x4 covariance of Stokes parameters
cross	[x]	1-D cross covariances between Stokes parameters
alt	[a]	Greyscale of auxiliary profiles

Preprocessing with -j (psrsh commands)

Code	Meaning
T	Time scrunch to one subint
F	Frequency scrunch to one channel
p	Polarisation scrunch to total intensity
D	Dedisperse (but not fscrunch)
S	Transform to Stokes parameters

Examples:

- `TFDp` → dedisperse and time, frequency and polarisation scrunch
- `TFD` → dedisperse, time and frequency scrunch

Output with -D (Device)

- `-D /x` → display on screen (X window)
- `-D output.png/png` → save as PNG
- `-D output.pdf/pdf` → save as PDF
- `-D output.ps/cps` → save as PostScript

Use `-g WxH` to set size, `-N XxY` for panels, `-r` for aspect ratio, `-w` for width (cm).

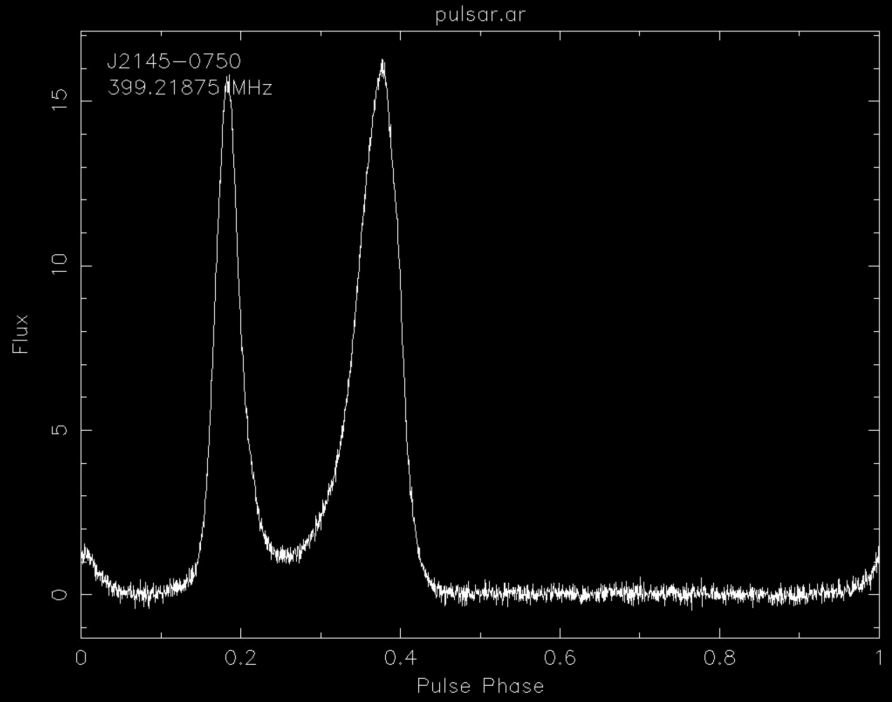
Other Useful Options

- `-x` disable default preprocessing
- `-S` stack plots
- `-O` overlay plots
- `-F` overlay plots from multiple files
- `-l name=<range>` loop over parameter range
- `-C plot / -A plot` help for options specific to a plot

Inspecting Pulsar Archives: psrplot

- **Pulse profile**

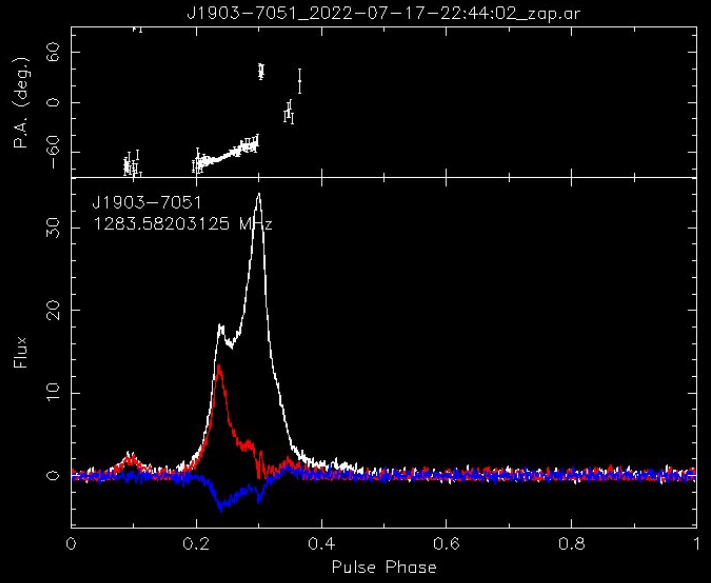
```
psrplot -p flux -j FTD pulsar.ar -D /xs
```



Inspecting Pulsar Archives: psrplot

- **Polarisation (Stokes) profile**

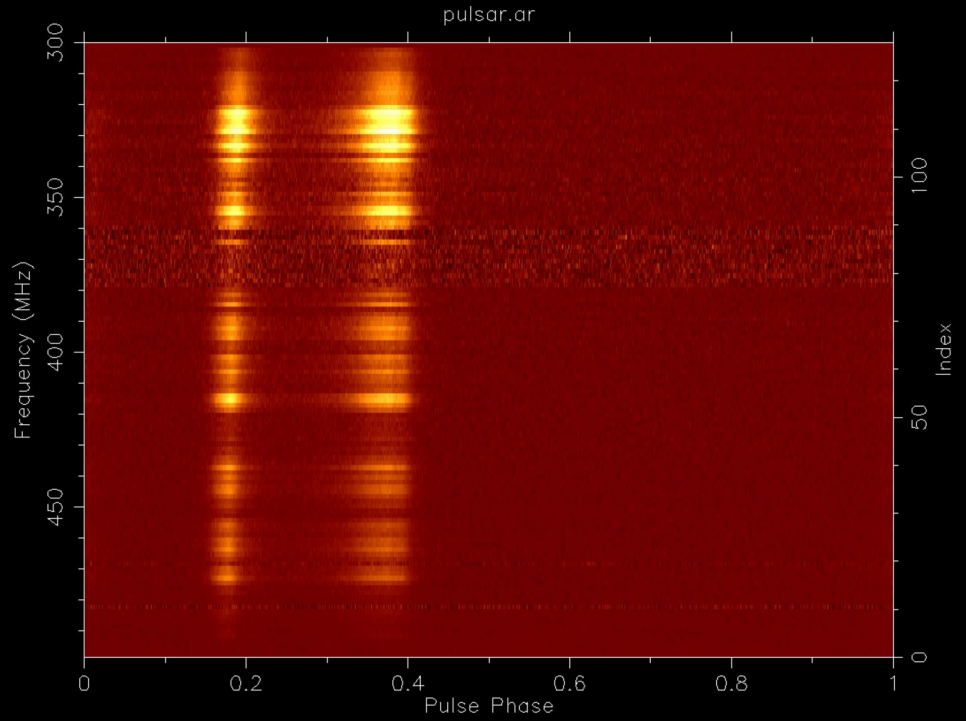
```
psrplot -p Scyl -j FTD pJ1903-7051_2022-07-17-22:44:02_zap.ar -D /xs
```



Inspecting Pulsar Archives: psrplot

- **Phase vs. Frequency**

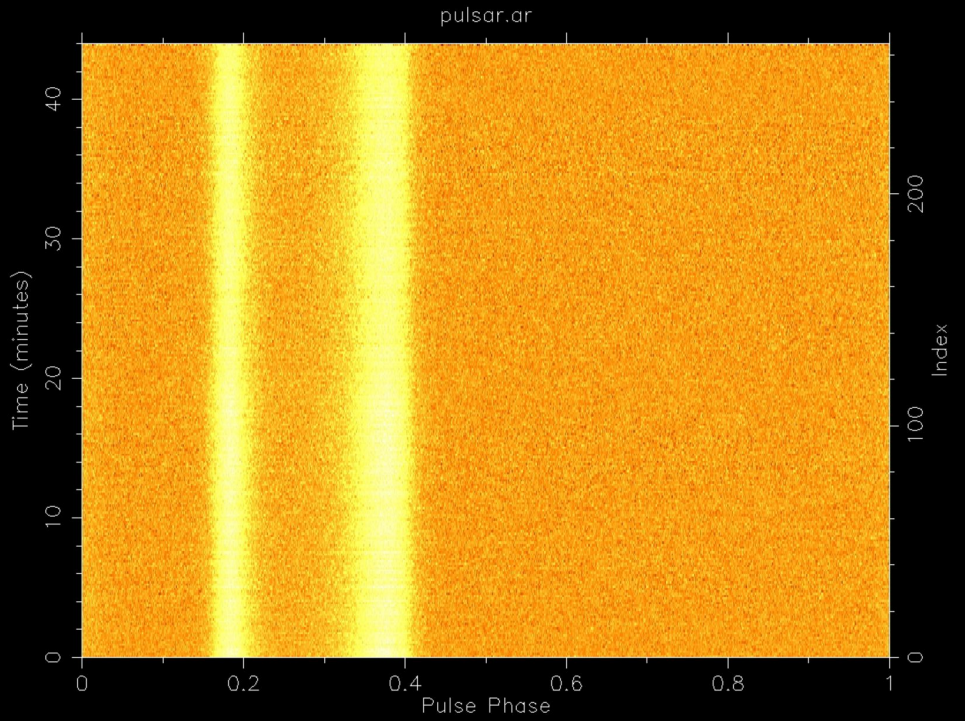
```
psrplot -p freq -j TD pulsar.ar -D /xs
```



Inspecting Pulsar Archives: psrplot

- **Phase vs. Time**

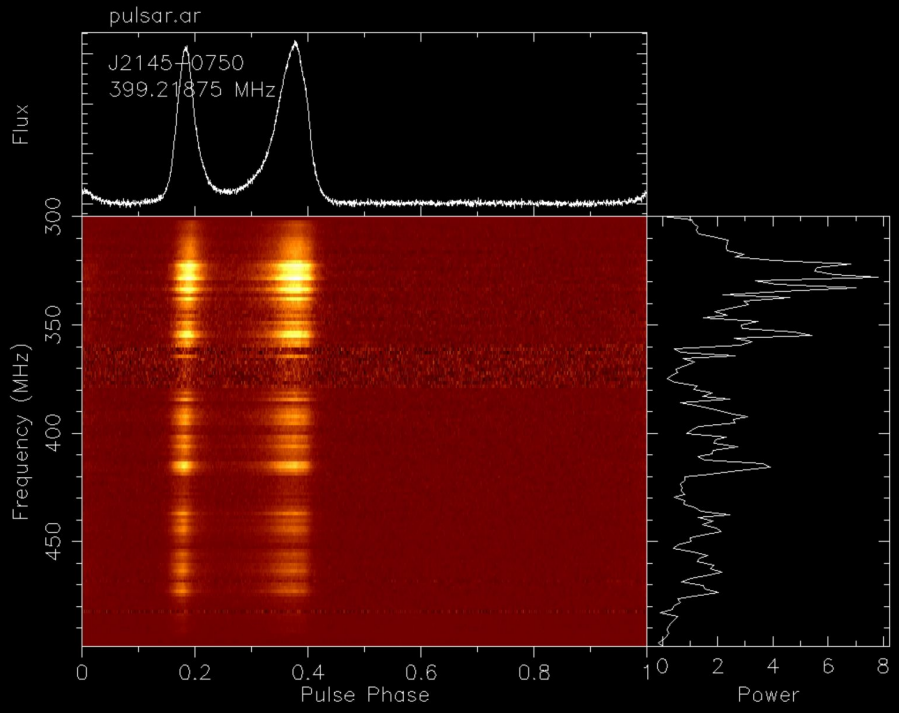
```
psrplot -p time -j FD pulsar.ar -D /xs
```



Inspecting Pulsar Archives: psrplot

- **Flux vs. Phase vs. Frequency**

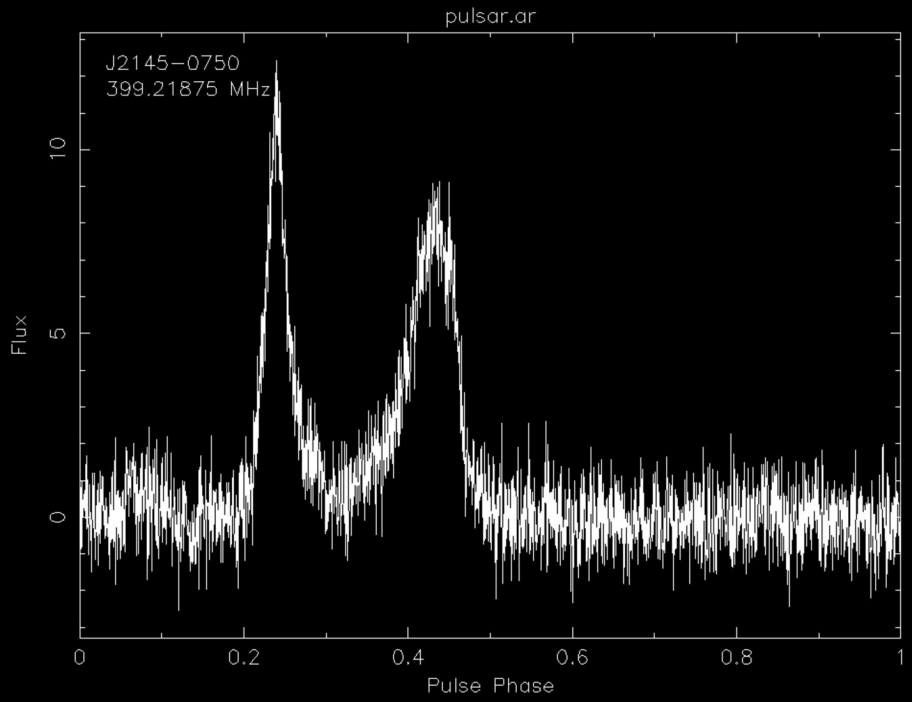
```
psrplot -p freq+ -j TD pulsar.ar -D /xs
```



Inspecting Pulsar Archives: psrplot

- **t-scrunched profile of a particular chanel**

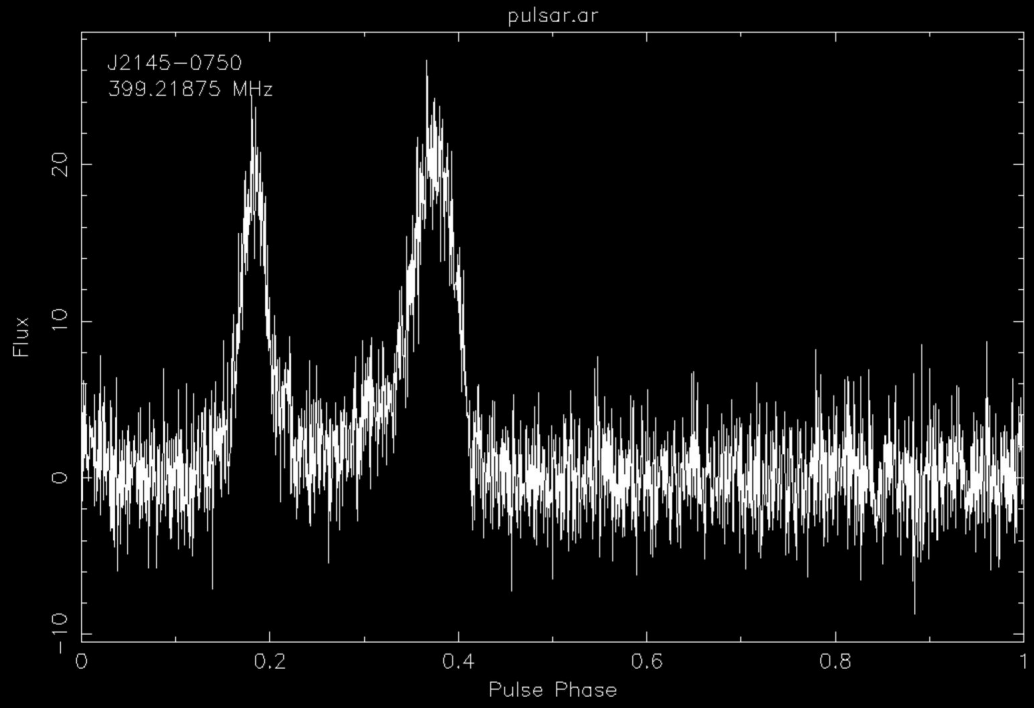
```
psrplot -p flux -c chan=20 -j T pulsar.ar -D /xs
```



Inspecting Pulsar Archives: psrplot

- **Plot the f-scrunched profile of a particular subint**

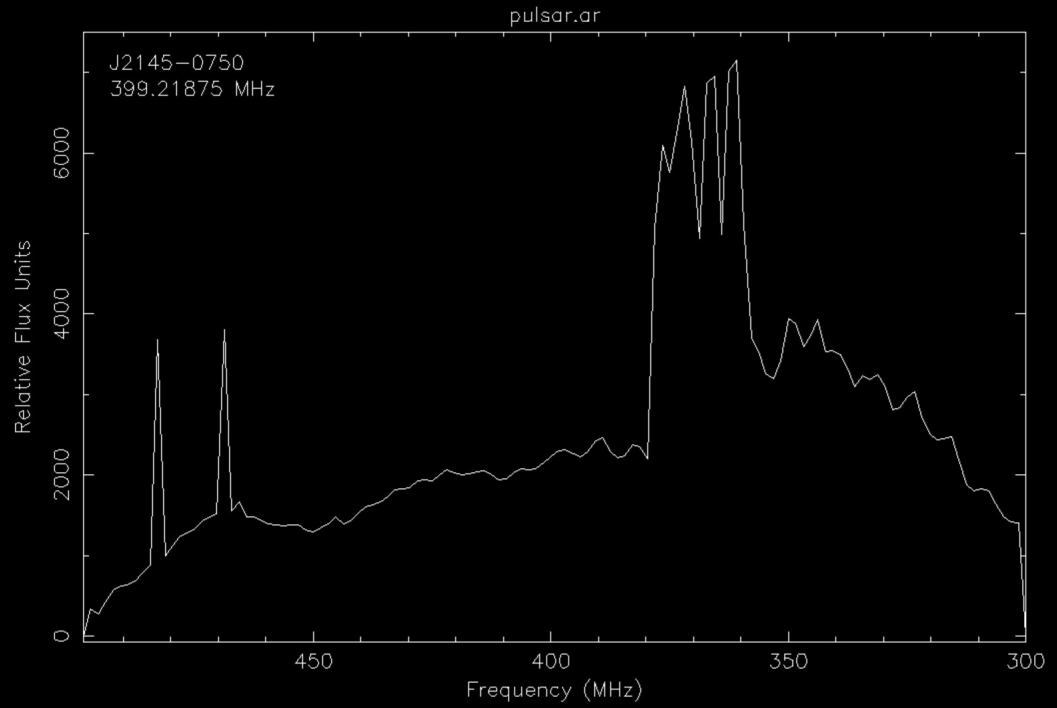
```
psrplot -p flux -c subint=100 -j F pulsar.ar -D /xs
```



Inspecting Pulsar Archives: psrplot

- **Cleaned bandpass**

```
psrplot -p b -jT pulsar.ar -D /xs
```



Inspecting Pulsar Archives: paz

paz is a psrchive command that can do some automated and manual RFI removal.
You can use it manually or as a part of other commands.

1. Purpose

Detect and remove (zap) Radio Frequency Interference (RFI) from pulsar archives.

2. Basic Usage

```
paz [options] filename[s]
```

3. Typical Workflow

- Preprocess (optional)
- Zap RFI (manual or automatic)
- Modify or save cleaned archive
- Inspect with `psrplot/psrstat`

4. Example

```
paz -j F -r -d -o 5 -m pulsar.ar
```

Frequency scrunch, auto zap (median diff + mean offset), remove negative dropouts < 5σ, overwrite file.

5. Output Control

`-m`	overwrite original file
`-e ext`	write with new extension
`-O path`	write to new directory

Command Syntax

```
paz [options] filename[s]
```

Other common options

`-h`	help	`-v`	verbose	`-V`	very verbose
`-q`	quiet	`-M`	metafile	`-config file`	

Manual Zapping Options

`-I`	Zero weight the intersection of -[wW] and -[zZk]
`-k file`	Zero weight channels listed in kill file
`-B "a b"`	Zap phase bins between a and b (inclusive)
`-z "a b c ..."`	Zero weight these channels
`-Z "a b"`	Zero weight channels between a and b (inclusive)
`-f "a b c ..."`	Zero weight channels with these frequencies (MHz)
`-F "a b"`	Zero weight frequency range a to b (MHz, inclusive)
`-x "a b c ..."`	Delete all subints except these
`-X "a b"`	Delete all subints except a to b (inclusive)
`-E percent`	Zero weight this % of each band edge
`-s "a b c ..."`	Delete these sub-integrations
`-S "a b"`	Delete subints between a and b (inclusive)
`-w "a b c ..."`	Zero weight these sub-integrations
`-W "a b"`	Zero weight subints between a and b (inclusive)
`-p "p i"`	Interpolate over every p-th phase bin, start at i
`-poln 0/1`	Delete the specified polarization (0 or 1)

Automatic Zapping Algorithms

`-r`	Zap channels using median smoothed difference
`-R size`	Set the size of the median smoothing window
`-l subint`	Mow the lawn of the specified subint
`-L`	Mow the lawn of all subints
`-d`	Zero weight channels using mean offset rejection
`-C cutoff [std]`	Zero weight channels based on S/N
`-P stdfile`	Use this standard profile
`-o cutoff`	Zero weight subints with negative dropouts (< cutoff σ)
`-8`	Fix ATNF WBCORR 8-bin problem (see also -p)
`-b`	Remove variable baseline

Kill File Format (-k)

A simple list of channel numbers, separated by white space.

Cutoff S/N (-C)

The cutoff S/N value is arbitrary. Experiment to find the best value for your data.

Tips

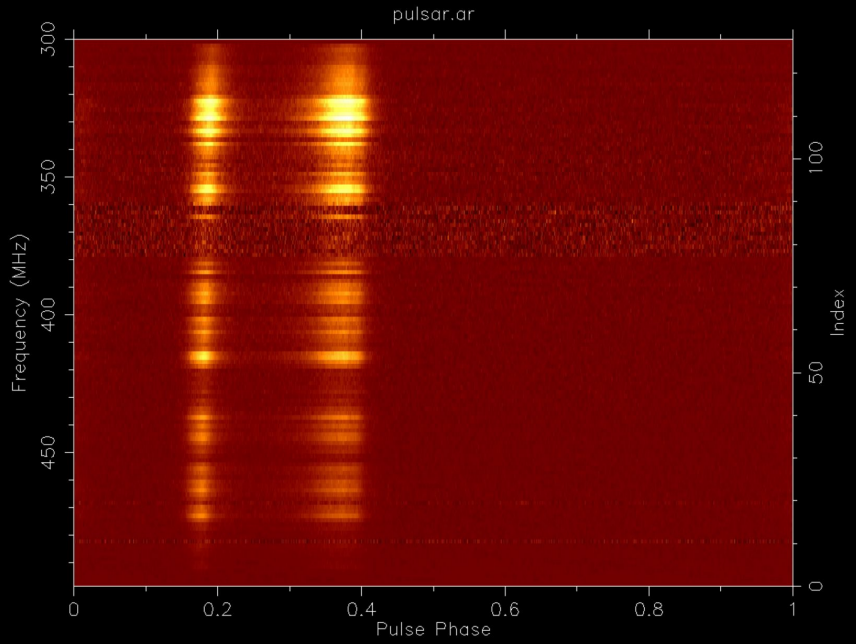
- Combine manual and automatic options as needed.
- Inspect results with `psrplot` and `psrstat`.
- Use `-m` to overwrite, or `-e`/`-O` to save new files.

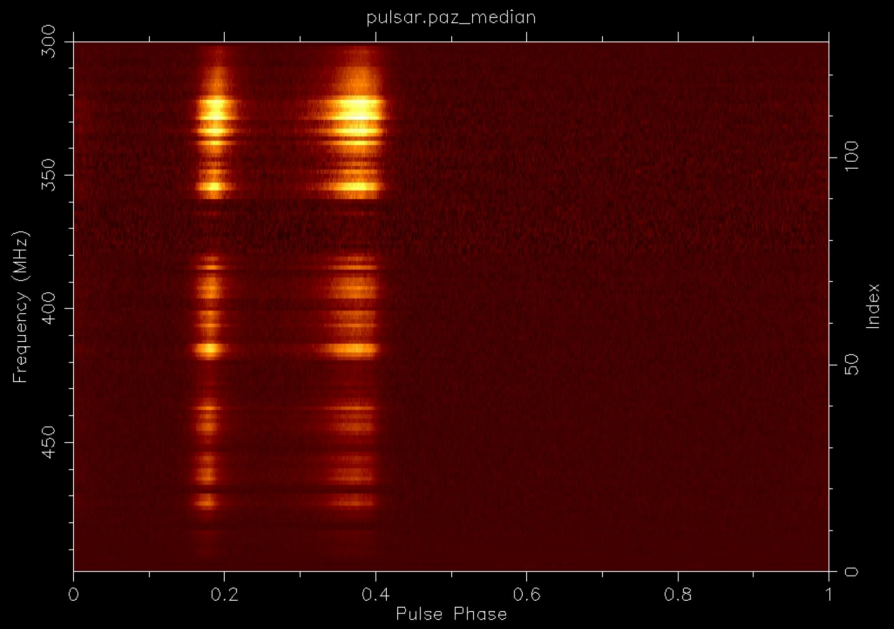
Inspecting Pulsar Archives: paz

- **Automatic Channel Zapping**

```
paz -r -e paz_median pulsar.ar
```

```
psrplot -p freq -j TD pulsar.paz_median -D /xs
```

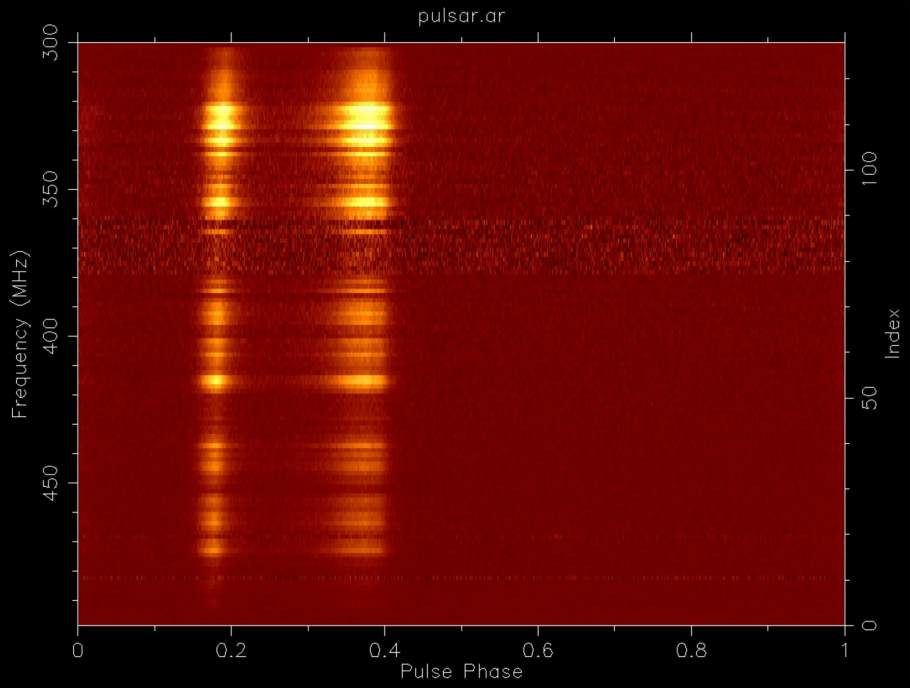


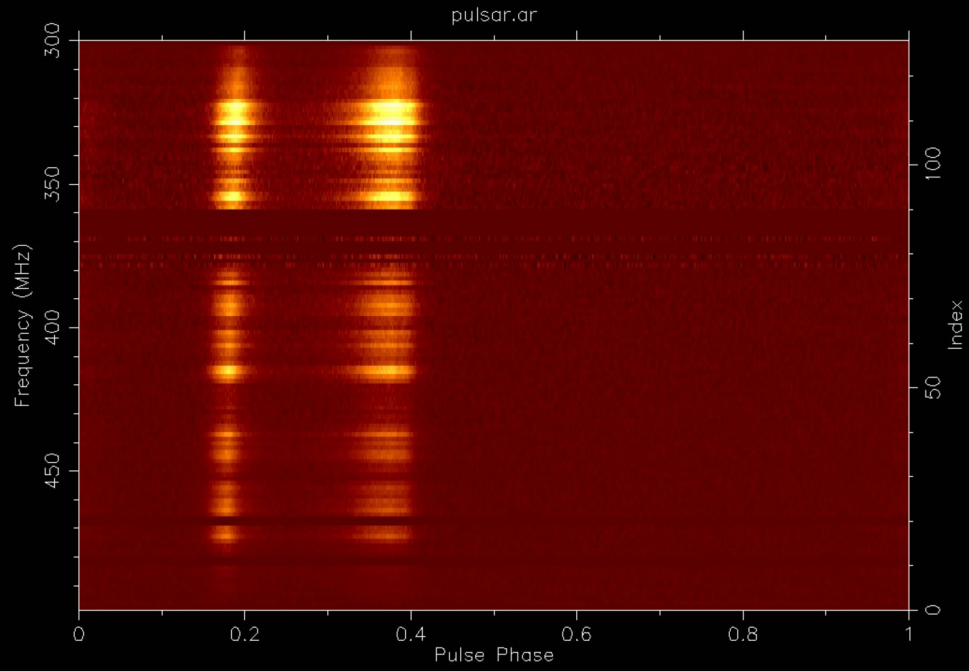


Inspecting Pulsar Archives: paz

- **Automatic Channel Zapping**

```
psrplot -p freq -j TD,"zap median" pulsar.ar -D /xs
```





Inspecting Pulsar Archives: pam

The Pulsar Archive Manipulator, **pam**, is designed to do the dirty work of messing around with archives on disk, processing them, compressing them, tweaking them... As such it is one of the most dangerous of the PSRCHIVE applications.

1. Get Help

View all options and usage information.

```
pam -h
```

2. Choose Output

- `-m` → modify original file
- `-e ext` → write to new file with extension ext

3. Choose Operations

Select one or more options below to manipulate the archive.

4. Run pam

Combine options as needed and run on your archive(s).

```
pam [options] file.ar
```

5. Output

pam writes the modified archive according to `-m` or `-e`/`-u` options.

Key Options You Can Try

A. Basic Processing Options

`-T`	Time scrunch to one subint
`-F`	Frequency scrunch to one channel
`-p`	Polarisation scrunch to total intensity
`-D`	Dedisperse (but not fscrunch)
`--DD`	Dededisperse (undo -D)
`-I`	Transform to Invariant Interval
`-S`	Transform to Stokes parameters
`--SS`	Transform to coherence parameters (undo -S)
`-x "a b"`	Extract subints in inclusive range a to b

B. Scrunch / Resample Options (integer arguments)

`-t n`	Time scrunch by factor *n*
`-f n`	Frequency scrunch by factor *n*
`-b n`	Bin scrunch by factor *n*
`--setnsub n`	Time scrunch to *n* subints
`--settsub t`	Time scrunch to subint length t (s)
`--setnchn n`	Frequency scrunch to *n* channels
`--setnbin n`	Bin scrunch to *n* bins
`--binphsperi`	Binary phase (periastron order)
`--binphsasc`	Binary phase (asc node order)
`--binlngperi`	Binary longitude (periastron order)
`--binlngasc`	Binary longitude (asc node order)

C. Numerical / Calibration Options (floating point arguments)

`-d DM`	Alter header DM
`-R RM`	Correct ISM Faraday rotation
`--RM RM`	Install new RM (no correction)
`--aux_rm RMi`	Correct absolute aux RM
`-s duty`	Smear with duty cycle
`-r turns`	Rotate profiles by turns
`-w weight`	Reset profile weights
`--mult fac`	Multiply amplitudes by fac
`--period P`	Install a new folding period

Other Useful Groups

E. Manual Zapping (RFI)

Options such as `-z`, `-Z`, `-f`, `-F`, `-k`, `-w`, `-W`, `-x`, `-X`, `-E`, etc. to zero weight or delete channels / subints / phase bins.

(See `pam -h` for full list under "Manual zapping options".)

F. Automatic Zapping Algorithms

Options such as `-r`, `-d`, `-C`, `-o`, `-8`, `-b`, `-L` etc. for automated RFI removal using median filtering, mean offset rejection, S/N thresholding, baseline cleaning, etc.

(See `pam -h` for full list under "Automatic zapping algorithms".)

G. Output Control

`-m`	overwrite original file
`-e ext`	write new files with extension ext
`-u path`	write files to this location
`-a archive`	specify archive class to create

D. Archive Parameter Overrides

`--receiver file`	Install Receiver from text file
`-L`	Set feed basis to Linear
`-C`	Set feed basis to Circular
`-E ephfile`	Install new ephemeris and update model
`--ephver ver`	Ephem type for -E (tempo or tempo2)
`-B`	Flip the sideband sense
`--flip freq`	Flip the band about frequency
`--reverse_freqs`	Reverse ordering of freq channels and update BW flag
`-o freq`	Change frequency labels (centre frequency)
`--type type`	Change observation type (Pulsar, PolnCal, FluxCalOn, FluxCalOff, Calibrator)
`--inst inst`	Change instrument name
`--site site`	Set telescope site (tempo 1-letter code)
`--name name`	Change source name
`--update_dm`	Replace header DM with value from input ephemeris

Inspecting Pulsar Archives: pam

- **Frequency Scrunching**

```
pam --setnchn 64 -e nscrunched pulsar.ar
```

```
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psredit -c nchan pulsar.ar
itoa_code no alias found for unknown
pulsar.ar nchan=128
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ pam --setnchn 64 -e nscrunched pulsar.ar
itoa_code no alias found for unknown
pulsar.nscrunched written to disk
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psredit -c nchan pulsar.nscrunched
itoa_code no alias found for unknown
pulsar.nscrunched nchan=64
```

- **Time Scrunching**

```
pam --setnsub 1 -e nsubint pulsar.ar
```

```
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psredit -c nsubint pulsar.ar
itoa_code no alias found for unknown
pulsar.ar nsubint=265
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ pam --setnsub 1 -e nsubint pulsar.ar
itoa_code no alias found for unknown
pulsar.nsubint written to disk
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psredit -c nsubint pulsar.nsubint
itoa_code no alias found for unknown
pulsar.nsubint nsubint=1
```

Inspecting Pulsar Archives: pam

- **Update DM using Ephemeris file**

```
pam -m -E pulsar.par -e parupdated --update_dm pulsar.ar
```

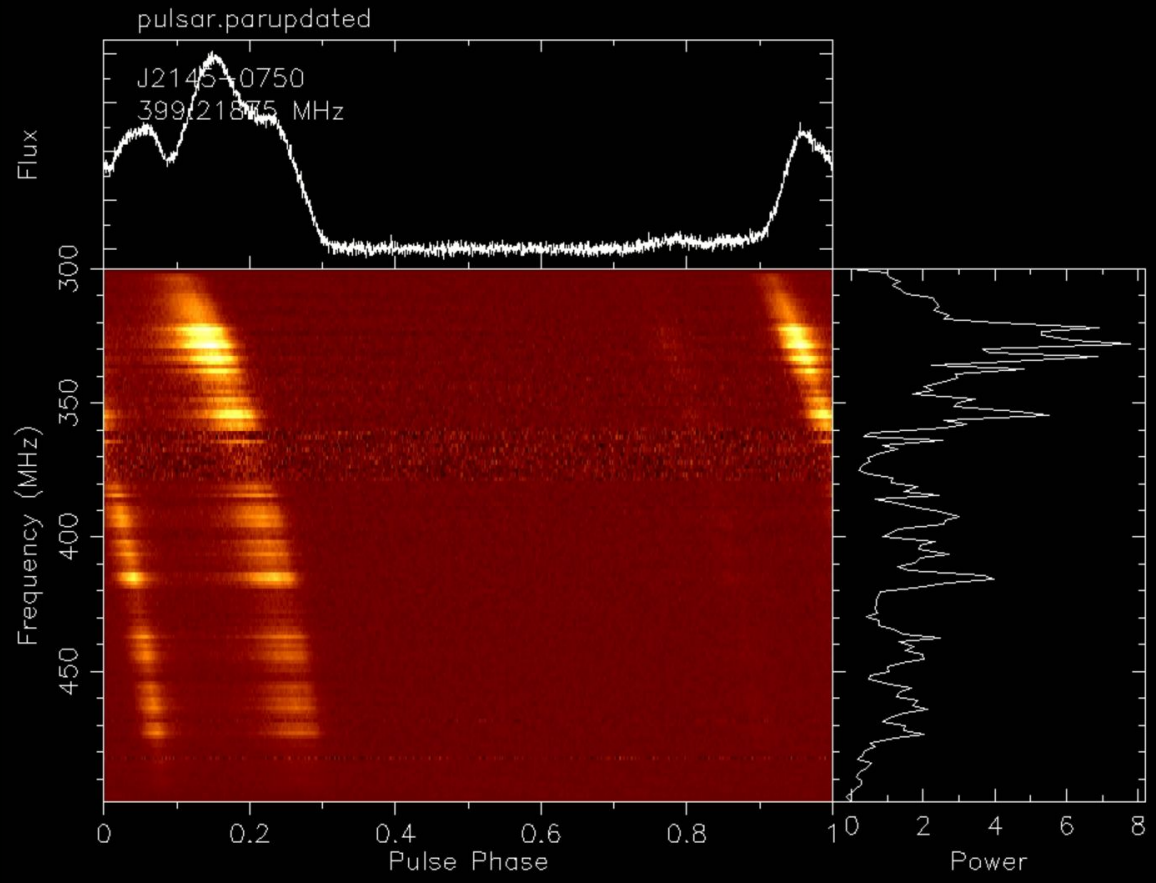
```
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psredit -c dm pulsar.ar
itoa_code no alias found for unknown
pulsar.ar dm=8.99752998352051
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ pam -m -E pulsar.par -e parupdated --update_dm pulsar.ar
itoa_code no alias found for unknown
pulsar.parupdated written to disk
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psredit -c dm pulsar.parupdated
itoa_code no alias found for unknown
pulsar.parupdated dm=9.1
```

- **De-disperse with the header dms**

```
pam -m -D pulsar.parupdated
```

```
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ pam -m -D pulsar.parupdated
itoa_code no alias found for unknown
pulsar.parupdated written to disk
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ psredit -c dmc pulsar.parupdated
itoa_code no alias found for unknown
pulsar.parupdated dmc=1
```

Inspecting Pulsar Archives: pam



Inspecting Pulsar Archives: psradd

psradd combines two or more pulsar archives into a single archive.
It can append data in time, frequency, or both, with many options to control preprocessing, output, and automatic handling.

1. PURPOSE

- Combine multiple archives
- Append data in time and/or frequency
- Handle gaps, align phase, and automate combining

2. BASIC USAGE

```
psradd [options] file1.ar file2.ar ...
```

3. COMMON EXAMPLES

- Combine all .ar files:

```
psradd -o combined.ar *.ar
```

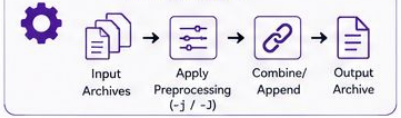
- Frequency append:

```
psradd -R -o wideband.ar *.ar
```

- Auto add (unload when S/N > 50):

```
psradd -S 50 -o out.ar *.ar
```

4. WORKFLOW



COMMAND SYNTAX

```
psradd [options] filename[s]
```

A. PREPROCESSING OPTIONS

`-j commands`	Execute psrchive (psrsh) commands
`-J script`	Execute psrchive script file

B. OUTPUT OPTIONS

`-e ext`	Write files with new extension
`-O path`	Write files to new directory
`-o fname`	Output result to 'fname'

C. GENERAL OPTIONS

`-E f.eph`	Load & install new ephemeris
`-T`	Tscrunch result after each new file
`-tsub sec`	Tscrunch subints to this length after each new file
`-R`	Append data in the frequency direction
`-m domain`	Patch missing sub-integrations (domain = time or phase)
`-n`	Patch missing frequency channels
`-inplace file`	Append archives to the specified file
`-P`	Phase align archive with total before adding
`-L`	Log results in <source>.log
`-t`	Test mode: make no changes to file system

D. RESTRICTIONS / FILTERING OPTIONS

`-F`	Force append against all conventional wisdom
`-r freq`	Add archives only with this centre frequency
`-z`	Only add archives that have integration length > 0
`-Z time`	Only add archives that are time (+/- 0.5) seconds long
`-ip`	Do not apply model, ignore phase alignment

E. AUTO ADD OPTIONS

Automatically tscrunch and unload when...

`-C turns`	... CAL phase changes by >= turns
`-D sec`	... next archive is from different 'sec' division of MJD
`-G sec`	... time to next archive > 'sec' sec
`-g sec`	... time spanned exceeds 'sec' sec
`-I sec`	... integration length exceeds 'sec' sec
`-S s/n`	... signal-to-noise ratio exceeds 's/n'
`-exp condition`	... "condition" is true
`-autoT`	Disable tscrunch before unloading

Note: AUTO ADD options are incompatible with -o and -T

QUICK REFERENCE (BY FUNCTION)

Combine / Append
- `-R` : append in frequency
- (default) : append in time

Handle Gaps
- `-m time|phase` : patch missing subints
- `-n` : patch missing frequency channels

Control Output
- `-o fname` : write to file
- `-e ext` : new extension
- `-O path` : write to directory

Alignment & Quality
- `-P` : phase align before adding
- `-ip` : ignore model / no alignment

Selection / Filtering
- `-r freq` : match by centre frequency
- `-z` : integration length > 0
- `-Z time` : match by integration time

Automation
- `-C, -D, -G, -g, -I, -S, -exp, -autoT` control when to unload and start a new output archive

Inspecting Pulsar Archives: psradd

- **Combining Multiple Observations**

```
psradd -o combined.ar *. ar
```

- **Frequency Integration**

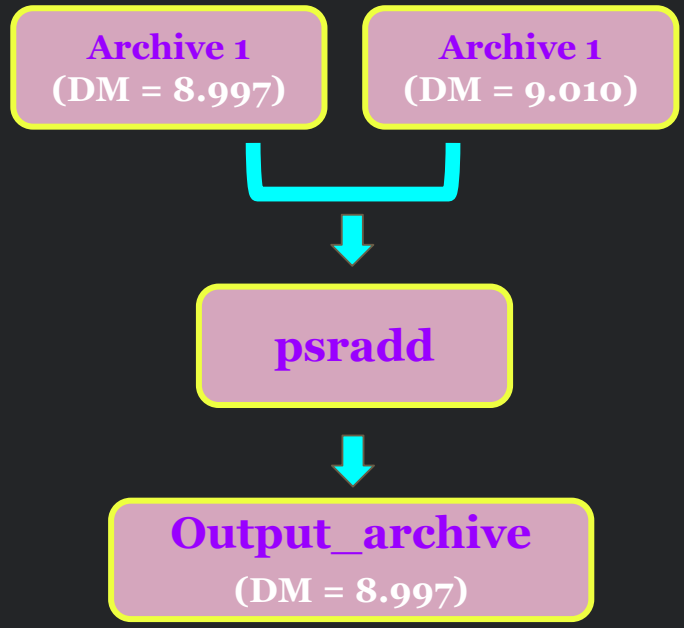
```
psradd -F -o combined_freq.ar *. ar
```

- **Time Scrunch During Combination**

```
psradd -T -o tscrunched.ar *. ar
```

- **Phase Align Before Addition**

```
psradd -P -o aligned.ar *. ar
```



Always verify that all archives use a consistent DM before combining.

Inspecting Pulsar Archives: pdmp

pdmp searches a range of barycentric period and DM (dispersion measure) to find the combination that gives the highest signal-to-noise (S/N) ratio.

When to use?

- Phase–vs–Time plot shows a slope → Period may be wrong
- Phase–vs–Freq plot shows a sweep → DM may be wrong

1. WORKFLOW

1. Input
Provide one or more pulsar archive file(s).

```
pdmp [options] file1 [file2 ...]
```

2. Search Space
Search over ranges of Period and DM (and optional acceleration).

Compute S/N for each trial combination.

3. Find Best
Locate the period & DM that maximize S/N.

Optionally save results to files.

4. Visualize
Inspect DM–vs–Period (PDM) map and contours to verify the optimum.

5. Output
Take the best values and refold / continue timing analysis.

BASIC COMMAND

```
pdmp [options] file1 [file2 ...]
Example: pdmp -do 0 -dr 10 -po 0 -pr 50 test.ar
```

A. PERIOD SEARCH OPTIONS (μs)

`-po <offset>`	Period offset (μs)	[default = 0]
`-pr <half-range>`	Period half-range (μs)	[default = natural]
`-ps <step>`	Period step (μs)	[default = natural]

B. DM SEARCH OPTIONS (pc/cm³)

`-do <offset>`	DM offset (pc/cm³)	[default = 0]
`-dr <half-range>`	DM half-range (pc/cm³)	[default = natural]
`-ds <step>`	DM step (pc/cm³)	[default = natural]
`-eph-coord`	Use tempo parameter (not header) coordinates	

C. ACCELERATION SEARCH OPTIONS

`-ao <offset>`	Acceleration offset
`-ar <half-range>`	Acceleration half-range
`-as <step>`	Acceleration step
`-af`	Save S/N vs acceleration to `accel.dat`

D. PREPROCESS / SPEED OPTIONS

`-j`	Combine multiple archives
`-mc <max chan>`	Partially scrunch frequency channels (<= max)
`-ms <max subint>`	Partially scrunch subintegrations (<= max)
`-mb <max bin>`	Partially scrunch phase bins (<= max)

E. STANDARD PROFILE & OUTPUT FILES

`-s <profile file>`	Use this standard profile for comparison
`-b <bestfilename>`	Output from best S/N vs DM
`-bf`	Output best period/freq/DM/width/NS
`-output-pdm-s/n`	Save S/N map (dP–dDM) to `pdmp_snr.dat`
`-o`	Use own (self-generated) standard profile

F. SELECTION & CONTROL OPTIONS

`-f , --force`	Force computation without prompting
`-ip`	Do not apply model / ignore phase alignment
`-z`	Only add archives with integration length > 0
`-Z <time>`	Only add archives with time = value ± 0.5 s
`-inplace <file>`	Append archives to the specified file
`-P`	Phase align archive with total before adding
`-R`	Append data in the frequency direction
`-m <time|phase>`	Patch missing sub-integrations in domain
`-n`	Patch missing frequency channels
`-T`	Tscrunch result after each new file added
`-tsub <sec>`	Tscrunch subints to this length after each
`-L`	Log results in <source>.log
`-t`	Test mode (no changes to file system)

G. PLOTTING OPTIONS

`-g <dev>` Manually specify plot device

`-k <min level> <max level>` Show DM–vs–Period plot only

If both = 0, pdmp auto-determines levels

`-con <clevel1> <cstep> <nc>` Draw contour map over PDM plot

- clevel1 = first contour level
- cstep = step between contours
- nc = number of contours

`-c <index>` Colormap for PGIMAG–style plots

```
0: Greyscale (default)
1: Inverse Greyscale
2: Heat (default)
3: Cold
4: Plasma
5: Forest
6: Alien Glow
7: Cubehelix
```

H. UTILITY / INFO OPTIONS

`-h`	Show most useful help
`--help`	Show complete list of options
`-v`	Verbose output
`-S`	Silent mode (less text output)
`-G`	Debug mode (tell all SCINT SNRs)
`-o`	Use own standard profile (Scint)

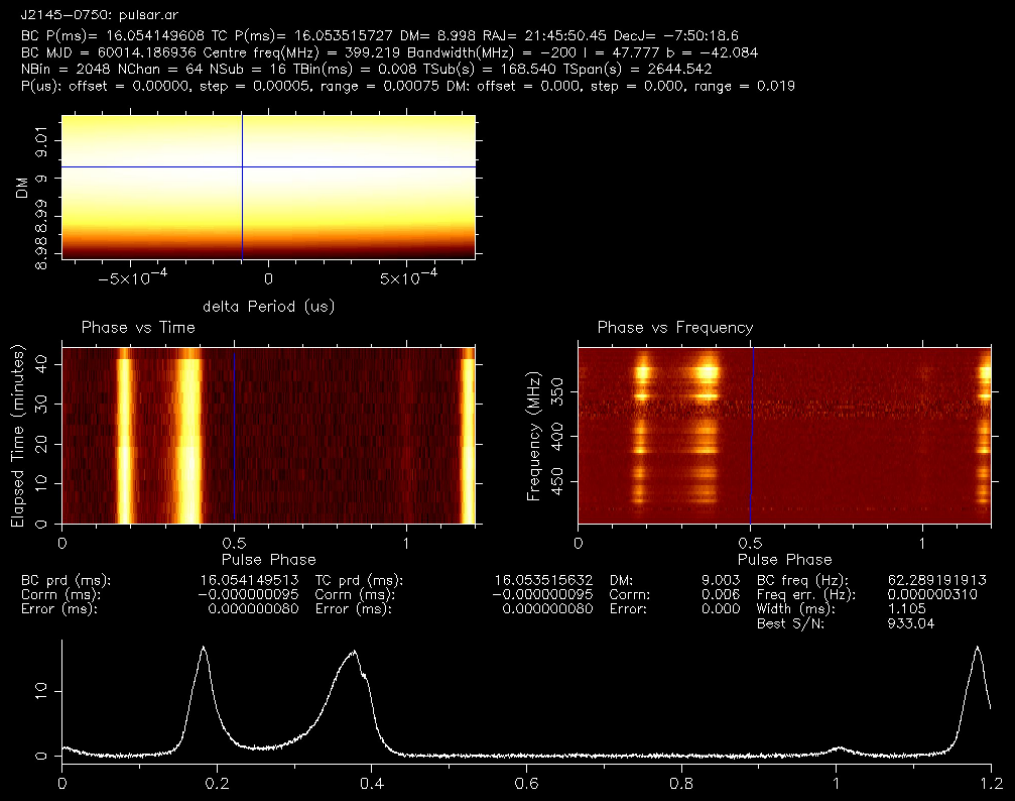
Inspecting Pulsar Archives: pdmp

- **Dispersion Measure Optimization**

```
pdmp -mc 64 -ms 16 pulsar.ar
```

This searches for:

- *Optimal DM*
- *Best folding period*



Inspecting Pulsar Archives: pdmp

- **Dispersion Measure Optimization**

```
pdmp -mc 64 -ms 16 -g /NULL pulsar.ar
```

```
[PSRSOFT-IMAGE] root@08e5f3270e3d:/Data/debabrata/IPTA_tutorial/working_space$ pdmp -mc 64 -ms 16 -g /NULL pulsar.ar
itoa_code no alias found for unknown

Working on archive J2145-0750: pulsar.ar
Searching for optimum DM and Period...
 DM: 258   P1: 0   P0: 32
100%

Best S/N = 933.04
BC MJD = 60014.186936
BC Period (ms) = 16.05414961  TC Period (ms) =  16.05351573  DM =    8.9975
Best BC Period (ms) = 16.05414951  Correction (ms) = -9.51714901e-08  Error (ms) = 8.000264804e-08
Best TC Period (ms) = 16.05351563  Correction (ms) = -9.516773503e-08  Error (ms) = 8.000264804e-08
Best DM =    9.0032  Correction = 0.005664  Error = 0.000458
Best BC Frequency (Hz) = 62.28919191  Error (Hz) = 3.104057486e-07
Pulse width (bins) = 141
Best Pdot =   0 s/s
Best Accn =   0 m/s

pdmp took 58.67 seconds
```

Inspecting Pulsar Archives: pdmp

- **Dispersion Measure Optimization**

```
pdmp -g /NULL pulsar.ar
```

```
[PSRSOFT-IMAGE] root@0413bc4ffcf9:/Data/debabrata/IPTA_tutorial/working_space$ pdmp -g /NULL pulsar.ar
itoa_code no alias found for unknown

Working on archive J2145-0750: pulsar.ar
Searching for optimum DM and Period...
 DM: 514   P1: 0   P0: 619
100%

Best S/N = 934.13
BC MJD = 60014.186936
BC Period (ms) = 16.05414922  TC Period (ms) =  16.05351534  DM =    8.9975
Best BC Period (ms) = 16.05414917  Correction (ms) = -4.766680104e-08  Error (ms) = 7.176568429e-08
Best TC Period (ms) = 16.05351529  Correction (ms) = -4.766491912e-08  Error (ms) = 7.176568429e-08
Best DM =    9.0028  Correction = 0.005237  Error = 0.0004544
Best BC Frequency (Hz) = 62.28919324  Error (Hz) = 2.784468071e-07
Pulse width (bins) = 141
Best Pdot =   0 s/s
Best Accn =   0 m/s
FREQSCINTER RATIO TEST FAIL: RATIO 10.0906
TIMEFREQSCINTER RATIO TEST FAIL: RATIO 10.0212
TIMEFREQSCINTER RATIO TEST FAIL: RATIO 10.0263
TIMEFREQSCINTER RATIO TEST FAIL: RATIO 10.1302
TIMEFREQSCINTER RATIO TEST FAIL: RATIO 10.1534
TIMEFREQSCINTER RATIO TEST FAIL: RATIO 10.1702
TIMEFREQSCINTER RATIO TEST FAIL: RATIO 10.3549
TIMEFREQSCINTER RATIO TEST FAIL: RATIO 10.5159
TIMEFREQSCINTER RATIO TEST FAIL: RATIO 10.5571
TIMEFREQSCINTER RATIO TEST FAIL: RATIO 12.2105

pdmp took 2710.75 seconds
```

Inspecting Pulsar Archives: pat

pat is used to determine the **time of arrival (TOA)** of each integrated profile in a pulsar archive by matching it with a standard (template) profile.

1. WORKFLOW

1. Input Archive(s)
Provide one or more pulsar archive file(s).

```
pat [options] file.ar
```

2. Preprocess
Scrunch, dedisperse, or apply other preprocessing as needed.

3. Fit Profiles
Match each integrated profile with a standard (template) profile using a chosen algorithm.

4. Compute TOA
Determine phase shift (TOA) and uncertainty for each subintegration.

5. Output TOAs
Write TOAs in desired format for timing analysis (e.g., tempo2).

COMMAND SYNTAX

```
pat [options] filenames
```

Example: `pat -F -s template.ar -f "tempo2 IPTA" obs.ar`

A. PREPROCESSING OPTIONS

`-F`	Frequency scrunch before fitting
`-T`	Time scrunch before fitting
`-j job1[,jobN]`	Preprocessing job(s)
`-J jobs`	Multiple jobs in 'jobs' file
`-d`	Discard profiles with zero weight
`-x`	Disable default preprocessing

B. FITTING OPTIONS

`-a stdfiles`	Automatically select standard from group
`-D`	Denoise standard
`-e cfg1[,cfgN]`	Estimator configuration option(s)
`-E cfg`	Estimator configuration in 'cfg' file
`-g datafile`	Gaussian model fitting
`-s stdfile`	Location of standard profile
`-S period`	Zap harmonics due to periodic spikes (implies SIS)

C. MATRIX TEMPLATE MATCHING OPTIONS

`-c`	Choose the maximum harmonic
`-n harmonics`	Use up to the specified number of harmonics
`-p`	Enable matrix template matching
`-P`	Do not fscrunch the standard

D. ALGORITHM SELECTION (-A name)

Select shift algorithm [default: PGS]

`PGS`	= Fourier phase gradient (default)
`GIS`	= Gaussian interpolation
`PIS`	= Parabolic interpolation
`ZPS`	= Zero pad interpolation
`SIS`	= Sinc interpolation of cross-correlation function
`FDM`	= Fourier domain with Markov chain Monte Carlo
`COF`	= Centre of Flux
`RVM`	= Rotating Vector Model magnetic meridian

`-m filename`	Load a component model (output by paas)

E. OUTPUT OPTIONS

`-f "fmt <flags>"`	Select output format [default: parkes] Available formats: parkes, tempo2, itoa, princeton For tempo2, <flags> include: `i` = display instrument `r` = display receiver `IPTA` = all IPTA-format flags
`-G char`	Format/flag separator char [default: space]
`-C "<options>"`	Select vap-like options to be displayed
`-C "<subint> <chan>"`	Print subint and/or channel
`-X "text"`	Extra TOA-line text to add (for tempo2)
`-r`	Print reference phase and dt
`-R`	Print only the phase shift and error in turns
`-u`	Print as pat-like format: smjd + dt
`-b`	Output profile residuals

F. PLOTTING OPTIONS (if compiled with pgplot)

`-K`	Specify plot device
`-t`	Plot template, profile and difference

Inspecting Pulsar Archives: pat

❑ Generating TOAs

```
pat -j"F 16" -A FDM:mcmc=1 -f tempo2 -P -X '-sys GM_GWB_500_200_b1'
-s pulsar.std pulsar.T.ar > pulsar.B3.tim
```

```
[PSRSOFT-IMAGE] root@08e5f3270e3d:/Data/debabrata/IPTA_tutorial/working_space/tim_files$ pat -j"F 16" -A FDM:mcmc=1 -f tempo2 -P -X '-sys GM_GWB_500_200_b1' -s pulsar.std
pulsar.T.ar > pulsar.B3.tim
itoa_code no alias found for unknown
itoa_code no alias found for unknown
[PSRSOFT-IMAGE] root@08e5f3270e3d:/Data/debabrata/IPTA_tutorial/working_space/tim_files$ more pulsar.B3.tim
FORMAT 1
pulsar.T.ar 399.218750 60014.191492709671064   0.651  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709671961   0.443  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709670916   0.466  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709676504   0.763  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709665656   0.687  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709660622   1.143  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709679933   1.494  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709674986   0.660  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709673132   0.650  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709671022   0.634  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709674502   0.972  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709670119   0.507  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709672617   0.658  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709670812   0.722  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709672969   0.370  gmrt  -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709682327   1.272  gmrt  -sys GM_GWB_500_200_b1
```

Inspecting Pulsar Archives: pat

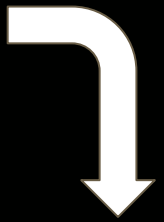
❑ Generating TOAs

```
pat -j"F 16" -A FDM:mcmc=1 -f tempo2 -P -X '-sys GM_GWB_500_200_b1'
-C "chan rcvr snr length subint" -s pulsar.std pulsar.T.ar >
pulsar.B3.v1.tim
```

```
[PSRSOFT-IMAGE] root@6191194ca0b5:/Data/debabrata/IPTA_tutorial/working_space/tim_files$ pat -j"F 16" -A FDM:mcmc=1 -f tempo2 -P -X '-sys GM_GWB_500_200_b1' -C "chan rcvr
snr length subint" -s pulsar.std pulsar.T.ar > pulsar.B3.v1.tim
itoa_code no alias found for unknown
itoa_code no alias found for unknown
[PSRSOFT-IMAGE] root@6191194ca0b5:/Data/debabrata/IPTA_tutorial/working_space/tim_files$ more pulsar.B3.v1.tim
FORMAT 1
pulsar.T.ar 399.218750 60014.191492709671064   0.651  gmrt  -chan 0 -rcvr uGMRT_B3 -snr 471.62 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709671961   0.443  gmrt  -chan 1 -rcvr uGMRT_B3 -snr 816.6 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709670916   0.466  gmrt  -chan 2 -rcvr uGMRT_B3 -snr 871.53 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709676504   0.763  gmrt  -chan 3 -rcvr uGMRT_B3 -snr 395.55 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709665656   0.687  gmrt  -chan 4 -rcvr uGMRT_B3 -snr 360.04 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709660622   1.143  gmrt  -chan 5 -rcvr uGMRT_B3 -snr 65.816 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709679933   1.494  gmrt  -chan 6 -rcvr uGMRT_B3 -snr 144.9 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709674986   0.660  gmrt  -chan 7 -rcvr uGMRT_B3 -snr 490.4 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709673132   0.650  gmrt  -chan 8 -rcvr uGMRT_B3 -snr 487.44 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709671022   0.634  gmrt  -chan 9 -rcvr uGMRT_B3 -snr 533.1 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709674502   0.972  gmrt  -chan 10 -rcvr uGMRT_B3 -snr 252.54 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709670119   0.507  gmrt  -chan 11 -rcvr uGMRT_B3 -snr 648.71 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709672617   0.658  gmrt  -chan 12 -rcvr uGMRT_B3 -snr 466.73 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709670812   0.722  gmrt  -chan 13 -rcvr uGMRT_B3 -snr 427.81 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709672969   0.370  gmrt  -chan 14 -rcvr uGMRT_B3 -snr 118.17 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
pulsar.T.ar 399.218750 60014.191492709682327   1.272  gmrt  -chan 15 -rcvr uGMRT_B3 -snr 133.02 -length 2640.06270976 -subint 0 -sys GM_GWB_500_200_b1
```

Inspecting Pulsar Archives: PSRCHIVE python interface

```
import psrchive
import numpy as np
import matplotlib.pyplot as plt

# ================================================
# Input Archive
# ================================================

filename = "pulsar.ar"

# ================================================
# Load Archive
# ================================================
ar = psrchive.Archive_load(filename)

# ================================================
# Standard PSRCHIVE Processing
# (similar to psrplot -p flux)
# ================================================
ar.dedisperse()
ar.tscrunch()
ar.fscrunch()
ar.pscrunch()
ar.remove_baseline()
```



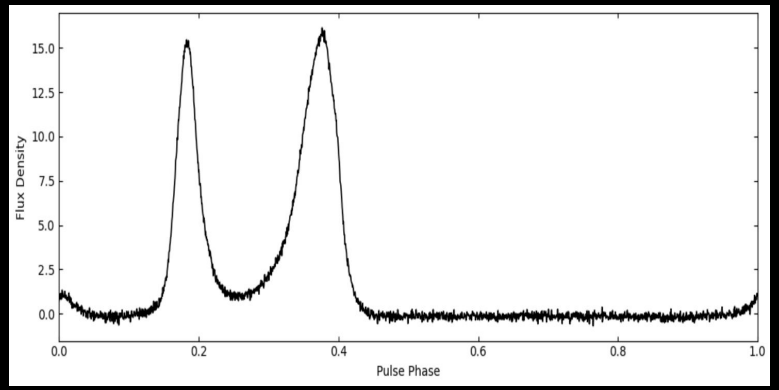
```
psrplot -p flux -j FTD pulsar.ar -D /xs
```

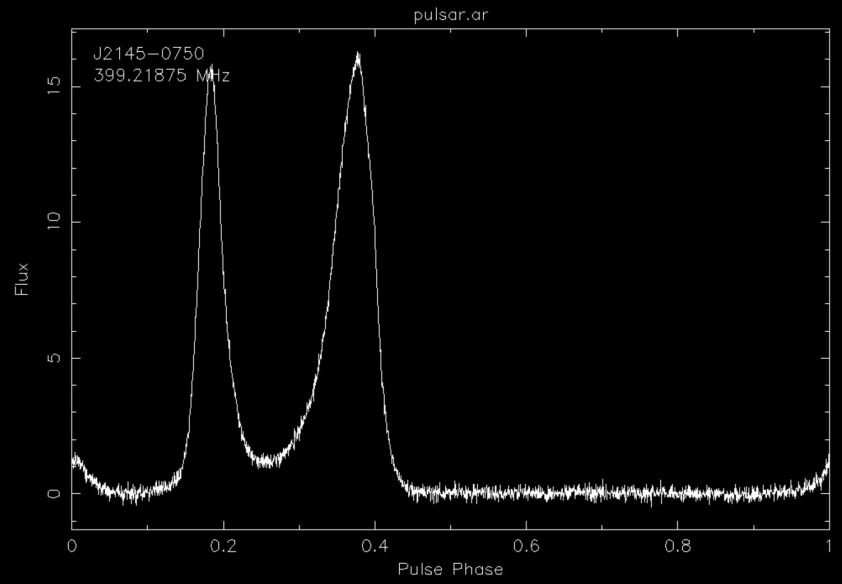
Inspecting Pulsar Archives: PSRCHIVE python interface

```
# ================================================
# Extract Profile
#
# Data dimensions:
# [subint, pol, chan, bin]
#
# After tscrunch+fscrunch+pscrunch:
# [1,1,1,nbin]
# ================================================
profile = ar.get_data()[0, 0, 0, :]

# ================================================
# Remove residual offset
# ================================================
profile = profile - np.median(profile)

# ================================================
# Pulse Phase Axis
# ================================================
nbin = len(profile)
phase = np.linspace(0, 1, nbin, endpoint=False)
```

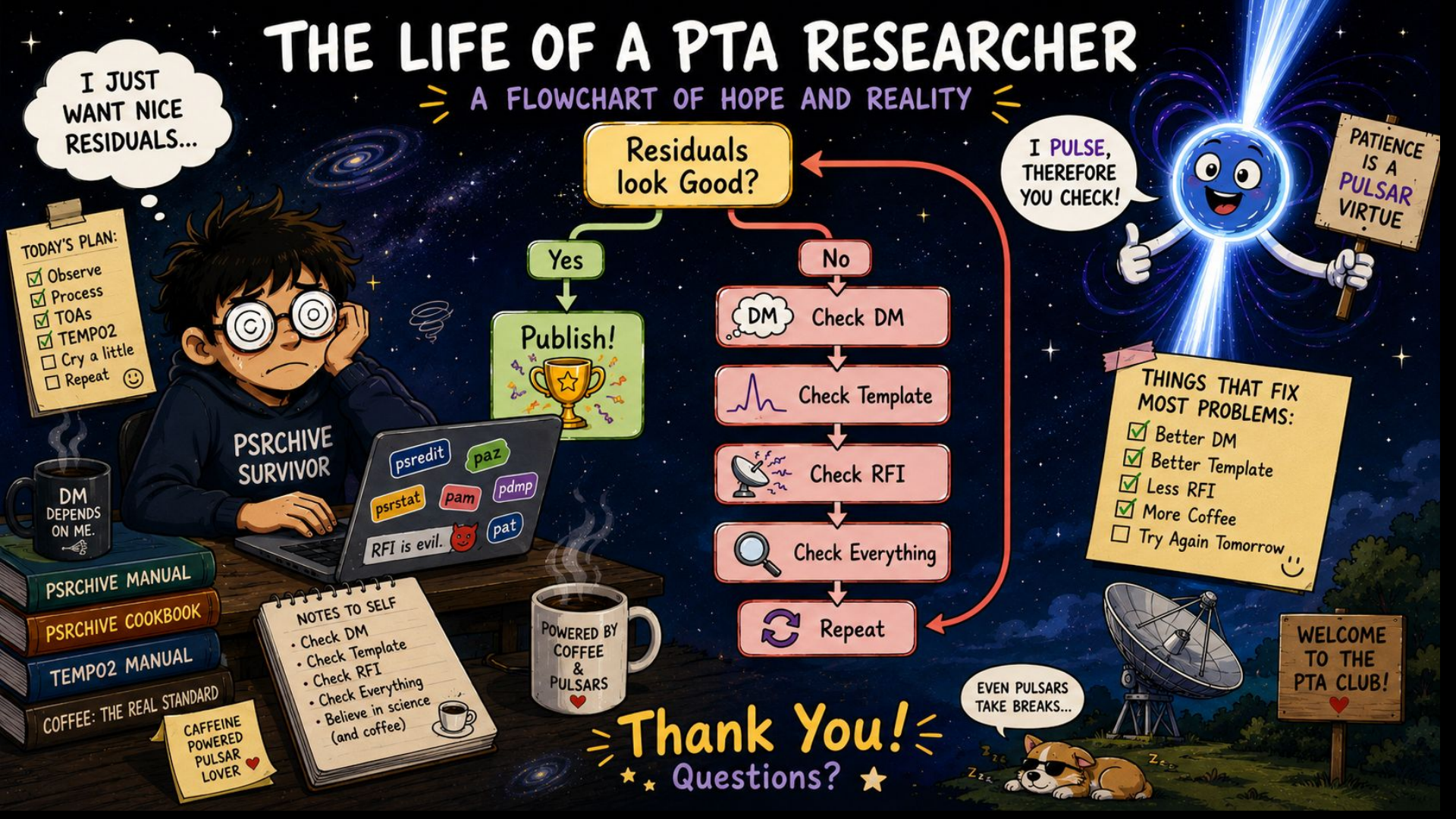
Inspecting Pulsar Archives: PSRCHIVE python interface

```
# ==========================================
# Plot
# ==========================================
plt.figure(figsize=(10,4))
plt.plot(phase, profile, color='black', linewidth=1.2)
plt.xlim(0,1)
plt.xlabel('Pulse Phase')
plt.ylabel('Flux Density')
plt.tick_params(direction='in', top=True, right=True)
plt.tight_layout()
plt.show()
```





Using psrplot


THE LIFE OF A PTA RESEARCHER
A FLOWCHART OF HOPE AND REALITY
I JUST WANT NICE RESIDUALS...
TODAY'S PLAN:
Observe
Process
TOAs
TEMPO2
Cry a little
Repeat
PSRCHIVE SURVIVOR
psredit
paz
psrstat
pam
pdmp
RFI is evil.
pat
DM DEPENDS ON ME.
PSRCHIVE MANUAL
PSRCHIVE COOKBOOK
TEMPO2 MANUAL
COFFEE: THE REAL STANDARD
CAFFEINE POWERED PULSAR LOVER
NOTES TO SELF
• Check DM
• Check Template
• Check RFI
• Check Everything
• Believe in science (and coffee)
POWERED BY COFFEE & PULSARS
Residuals look Good?
Yes
Publish!
No
DM Check DM
Check Template
Check RFI
Check Everything
Repeat
I PULSE, THEREFORE YOU CHECK!
PATIENCE IS A PULSAR VIRTUE
THINGS THAT FIX MOST PROBLEMS:
Better DM
Better Template
Less RFI
More Coffee
Try Again Tomorrow
WELCOME TO THE PTA CLUB!
EVEN PULSARS TAKE BREAKS...
Thank You!
Questions?