How to find pulsar?
--with examples

K. J. Lee
Max-Planck Institute for Radio astronomy
kjlee@mpifr-bonn.mpg.de

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Outline

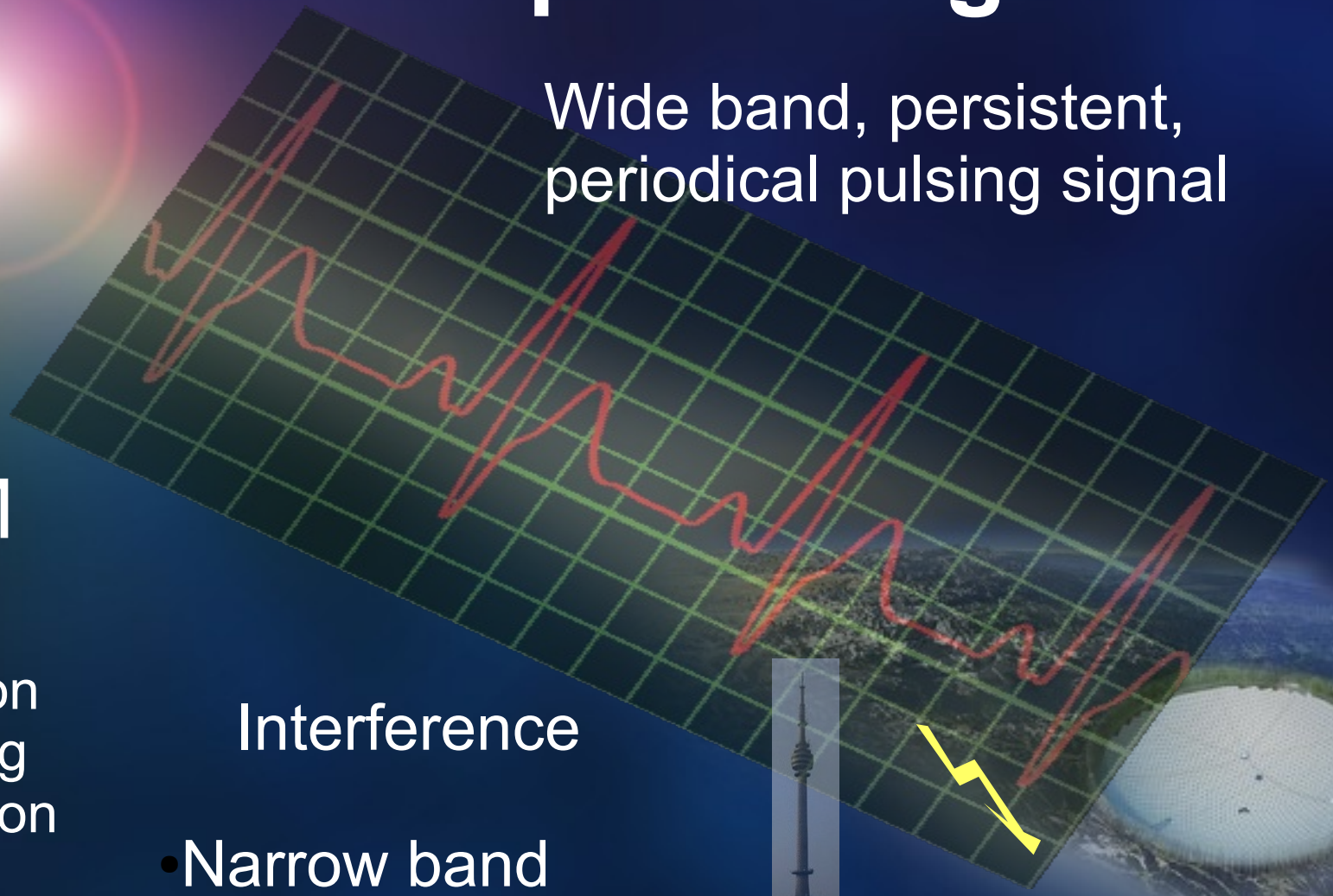
- Find pulsar candidates
- Identify pulsar candidates
- Confirm pulsar candidates

Software aspects of the lecture is based on the related software manual, see

http://www.cv.nrao.edu/~sransom/presto/
http://sigproc.sourceforge.net/
http://dspsr.sourceforge.net/manuals/dspsr/
http://psrchive.sourceforge.net/

A general picture of pulsar signal

Wide band, persistent, periodical pulsing signal



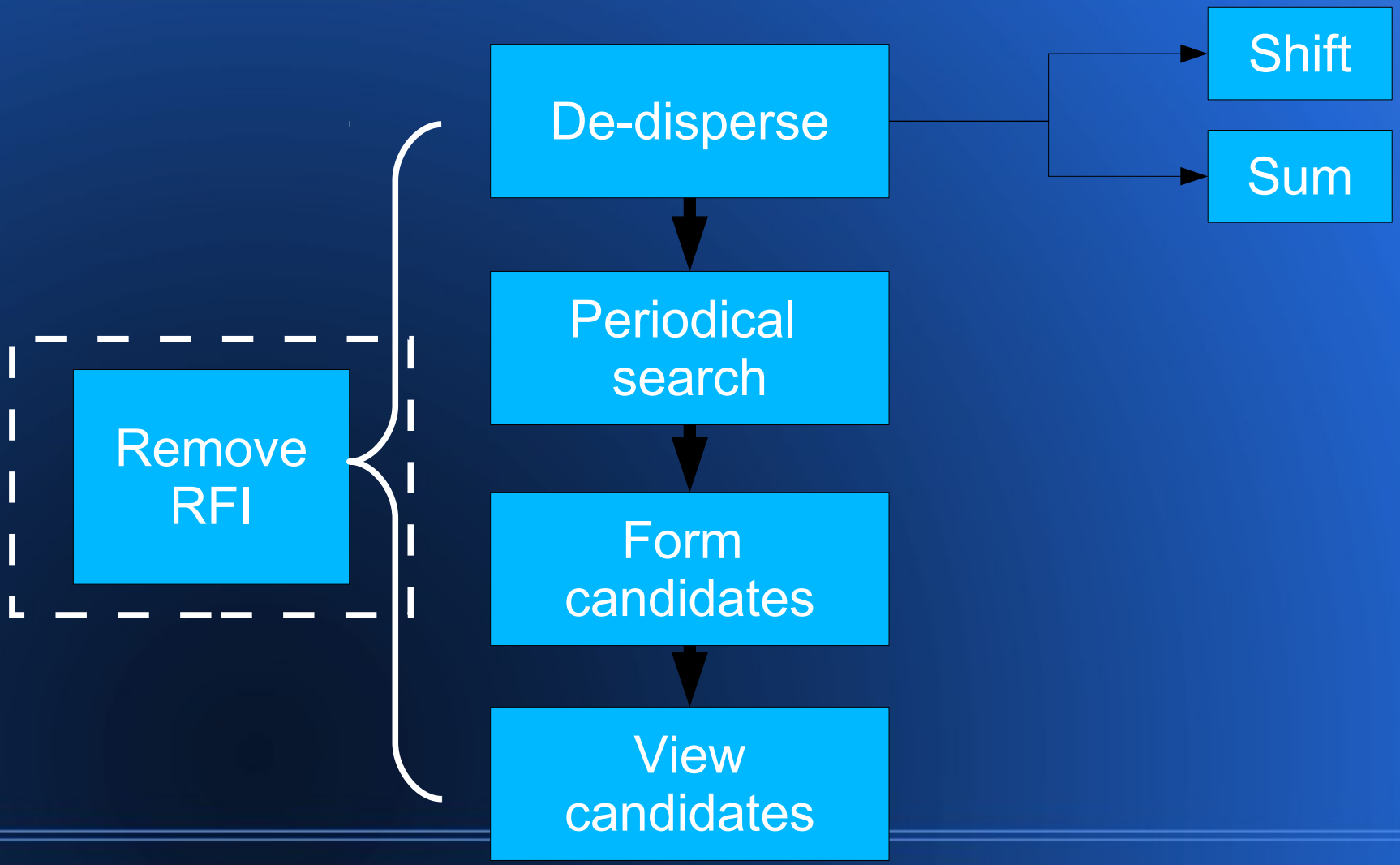
ISM

- Dispersion
- Scattering
- Scintillation

Interference

- Narrow band
- Can be short duration
- Sin/cos/square/chirp...

Search solitary pulsars



Mitigate RFI

- RFI is one of the bottlenecks for pulsar searching. It limits the survey depth as well as increase the work-load of identifying candidates. **It is critical to mitigate RFI at all stages of pulsar searching!**
- e.g. In band, peak radio flux of 1 cell phone at 10 km away from telescope is 1e9 (十亿倍) times of that of the most bright pulsar!

Common method of RFI mitigation

- Time domain methods
  - Usually implemented together with the backend
  - Higher order statistics
  - Spatial filtering
- Radio-frequency domain methods
  - Frequency filtering
- Fluctuation spectrum domain methods
  - Birdie lists, candidate filtering
- Other methods
  - Compare multi-beam obs, 0-DM method, likelihood filter

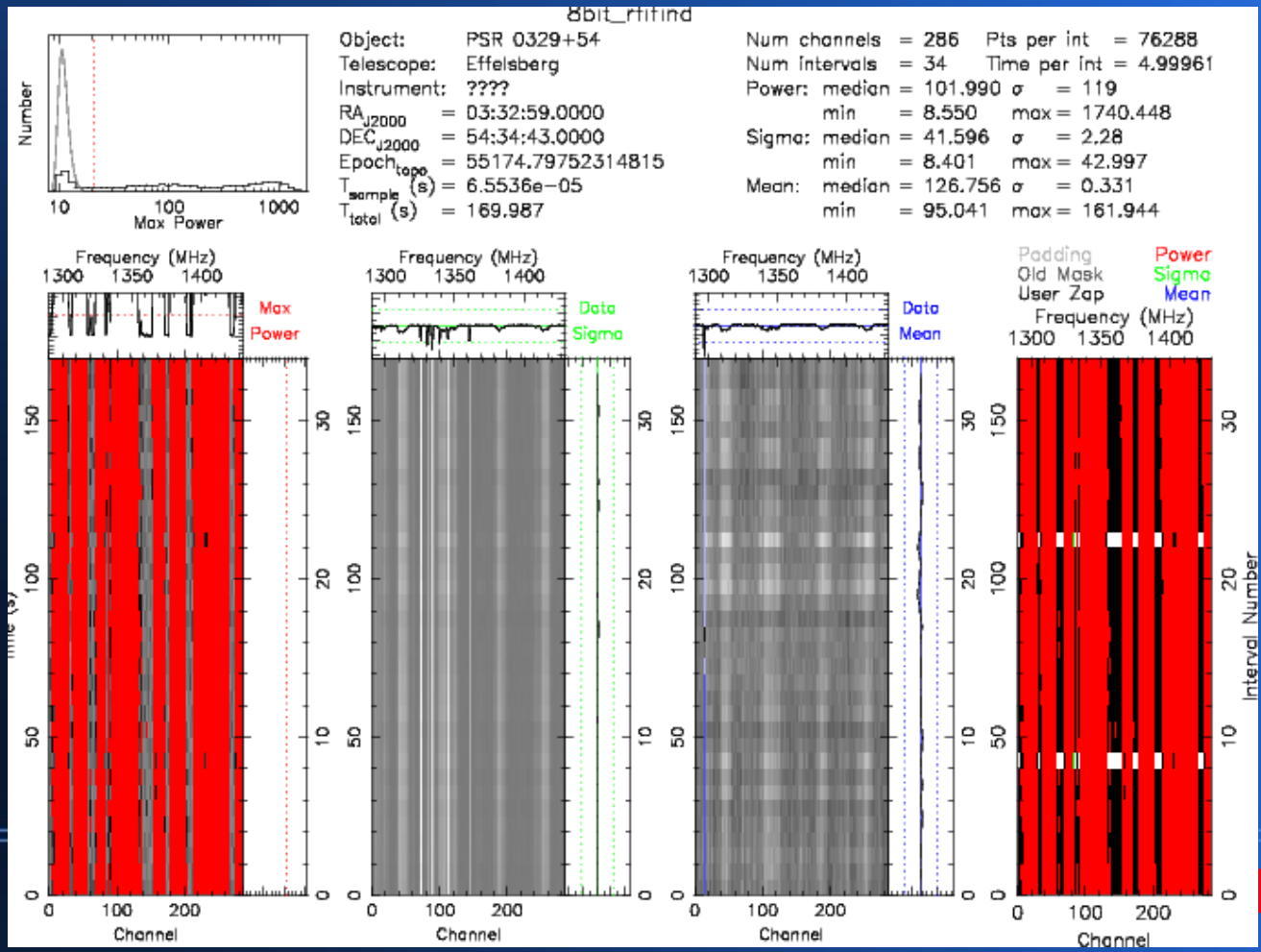
Example

```
rfifind -time 5 -o 8bit 8bit.fil
```

```
  Ten most significant birdies:
#  Sigma     Period(ms)      Freq(Hz)        Number
-------------------------------------------------
1  27.91     357.115         2.80022         28315
2  27.43     178.558         5.60044         26574
3  25.98     238.077         4.20033         27164
4  25.88     119.038         8.40065         27288
5  23.78     59.5192         16.8013         25303
6  23.42     714.23          1.40011         27337
7  23.36     181.804         5.50043         24942
8  23.28     370.342         2.70021         26448
9  23.13     59.8756         16.7013         23846
10 22.87     120.473         8.30065         25915
```

Masked too much data

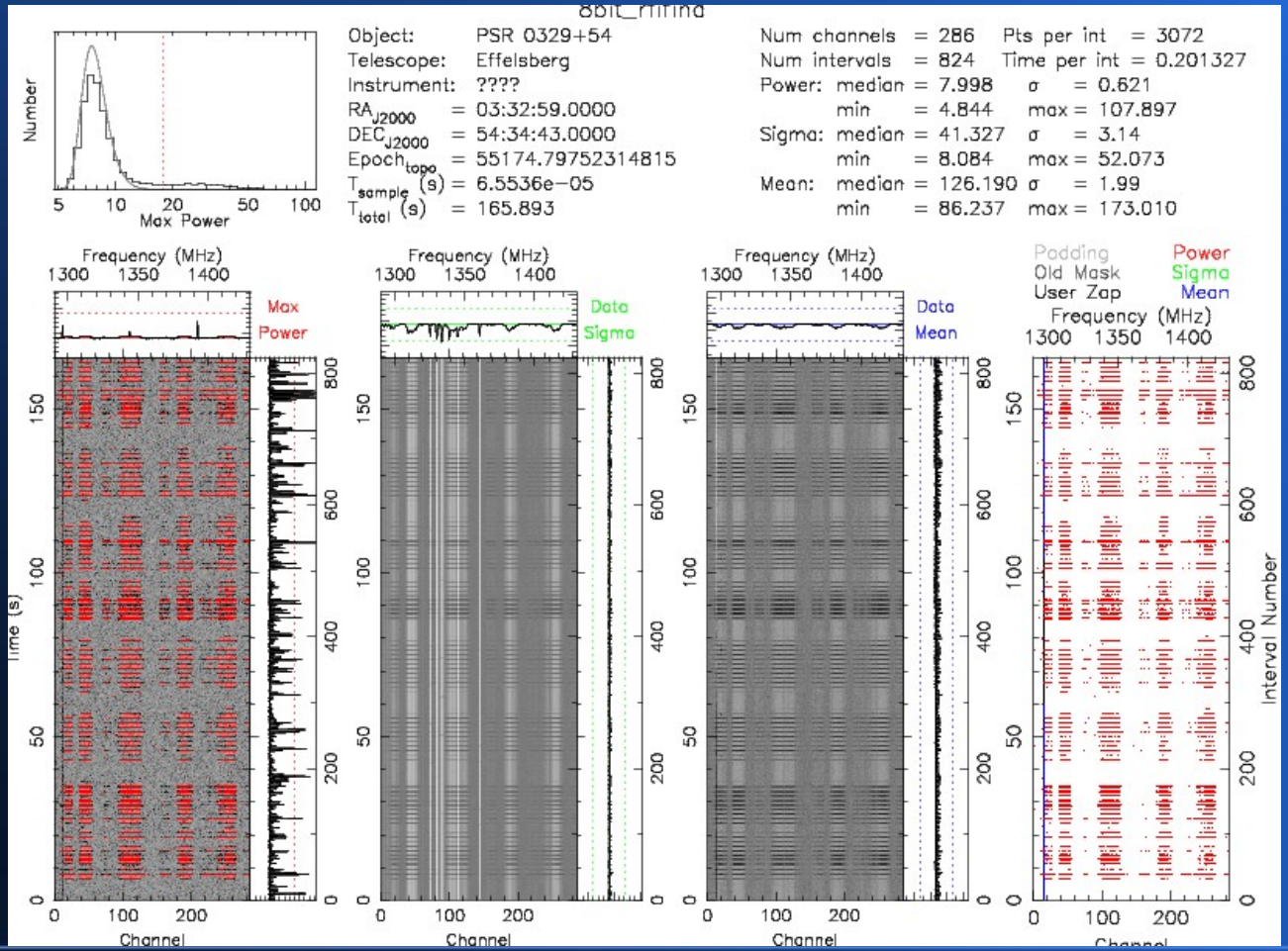
```
Total number of intervals in the data:  22594

  Number of padded intervals:        0  ( 0.000%)
  Number of  good  intervals:     4367  (19.328%)
  Number of  bad   intervals:    18227  (80.672%)
```



Example

Mask less

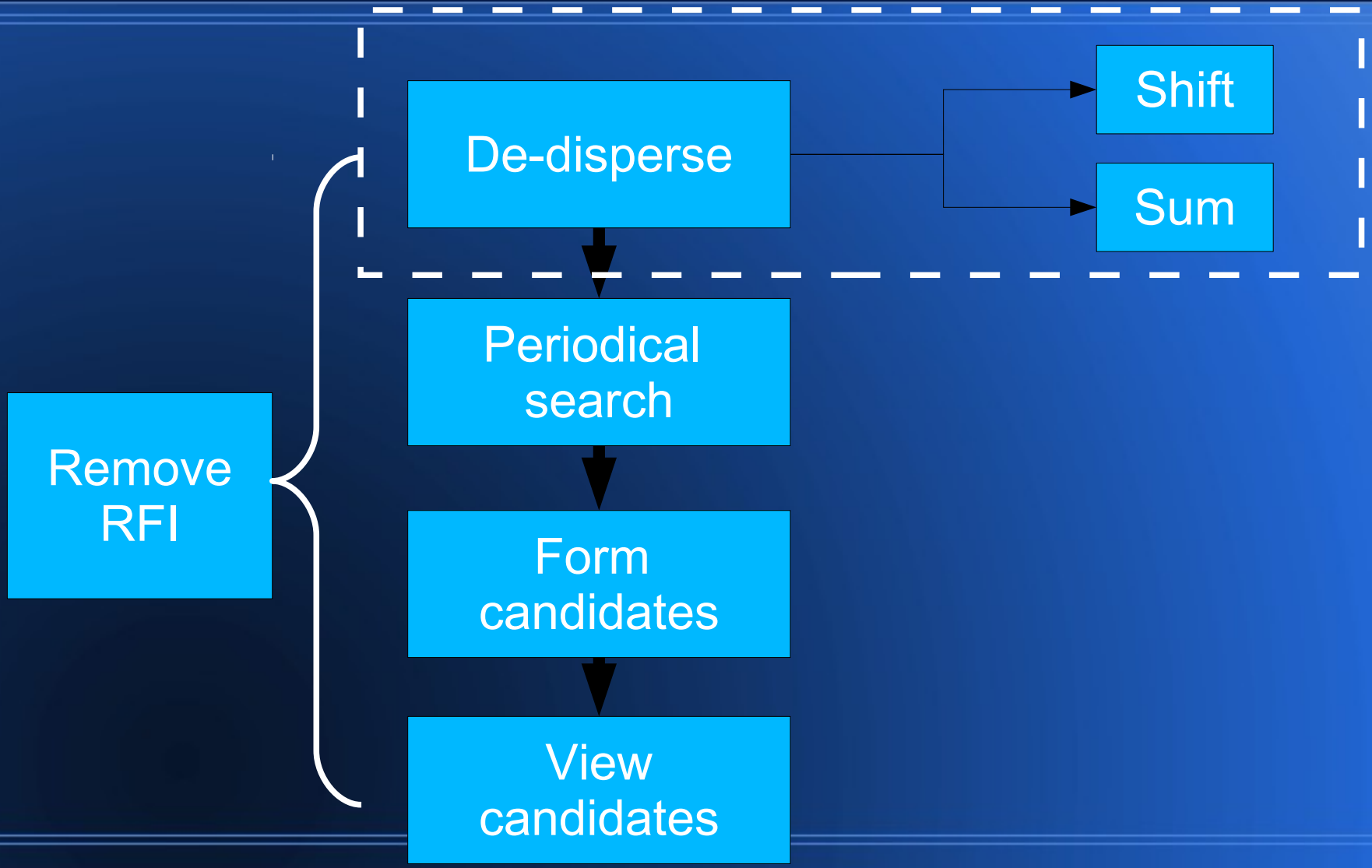
With -time 0.2



- 10%~20% is a usual number

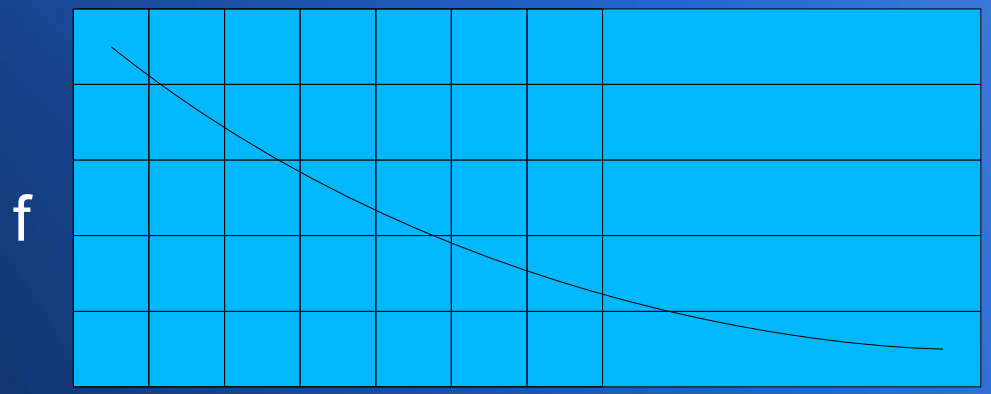
Example

Search solitary pulsars



Make a De-dispersing plan

- Keep sensitivity under the computational constraints!



- Max DM= DM enough to smear the subband
- Min DM=shift one bin the edge
- DD plan is sensitive to data taking scheme!
- Optimal template method

Softwares

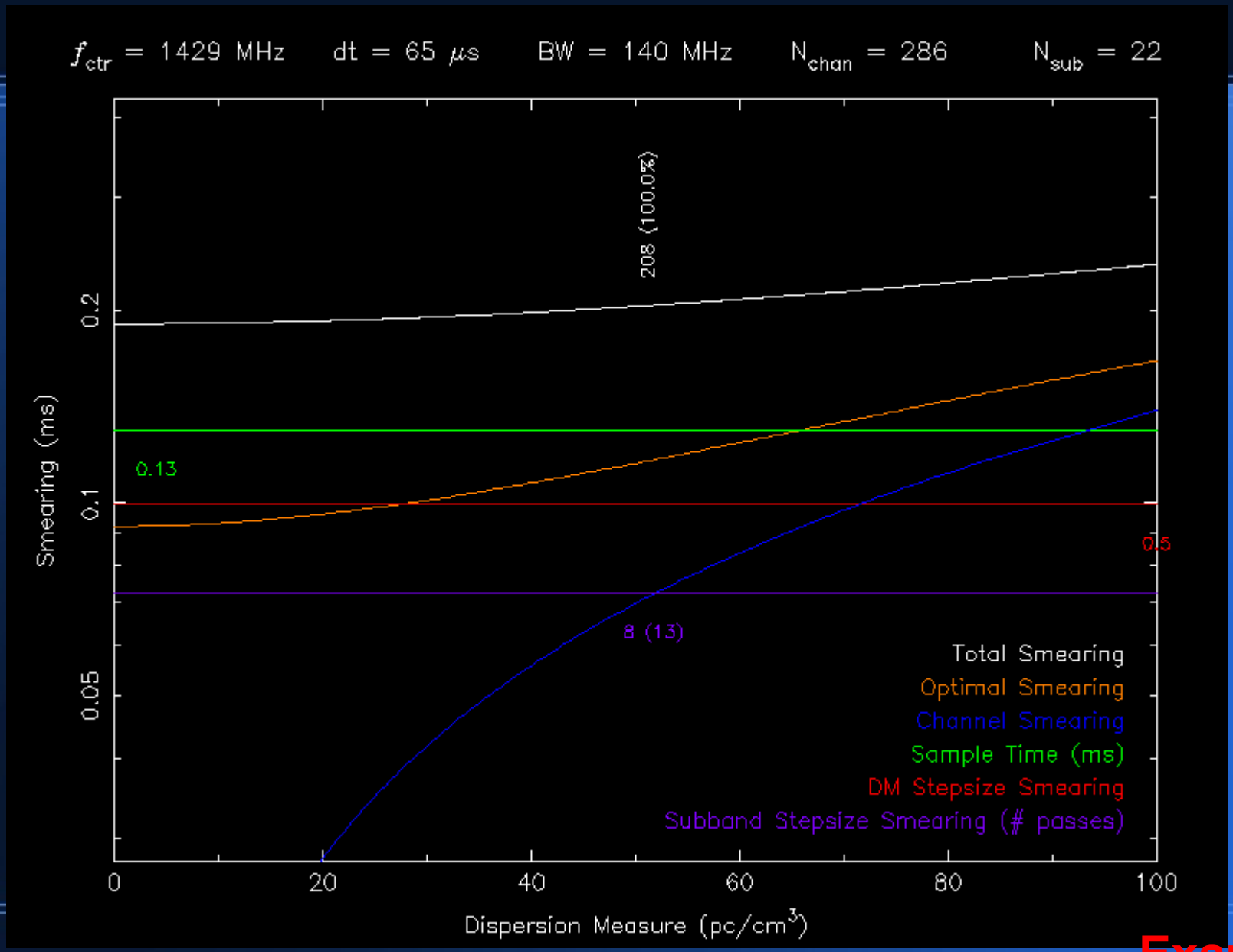
- Code dedicated to the architecture can be much faster than the generic code!
  - Sigproc
    - Dedisperse
  - Psrchive-DSPSR
    - dspsr
  - Presto
    - Prepdat, prepsubband
  - Dedicated program
    - Dedisperseall
    - Many other

Make De-dispersion plan

DM nchan bandwidth sampling-time frequency subband time resolution

```
random@AlphaX:~/work/pulsarsch/dat_tst$ DDplan.py -d 100 -n 286 -b 140 -t 0.000065 -f 1429 -s 22 -r 0.2

Minimum total smearing     : 0.0919 ms
------------------------------------------
Minimum channel smearing   : 6.96e-06 ms
Minimum smearing across BW : 0.00199 ms
Minimum sample time        : 0.065 ms

Setting the new 'best' resolution to : 0.2 ms
   Note: ok_smearing > dt (i.e. data is higher resolution than needed)
         New dt is 2 x 0.065 ms = 0.13 ms
Best guess for optimal initial dDM is 0.653

  Low DM    High DM     dDM  DownSamp  dsubDM   #DMs  DMs/call  calls  WorkFract
    0.000    104.000    0.50        2    8.00     208        16     13     1
```

Example


f_{ctr} = 1429 MHz
dt = 65 μs
BW = 140 MHz
N_{chan} = 286
N_{sub} = 22
208 (100.0%)
0.13
0.5
8 (13)
Smearing (ms)
0.2
0.1
0.05
0
20
40
60
80
100
Dispersion Measure (pc/cm^3)
Total Smearing
Optimal Smearing
Channel Smearing
Sample Time (ms)
DM Stepsize Smearing
Subband Stepsize Smearing (# passes)

Example

De-disperse

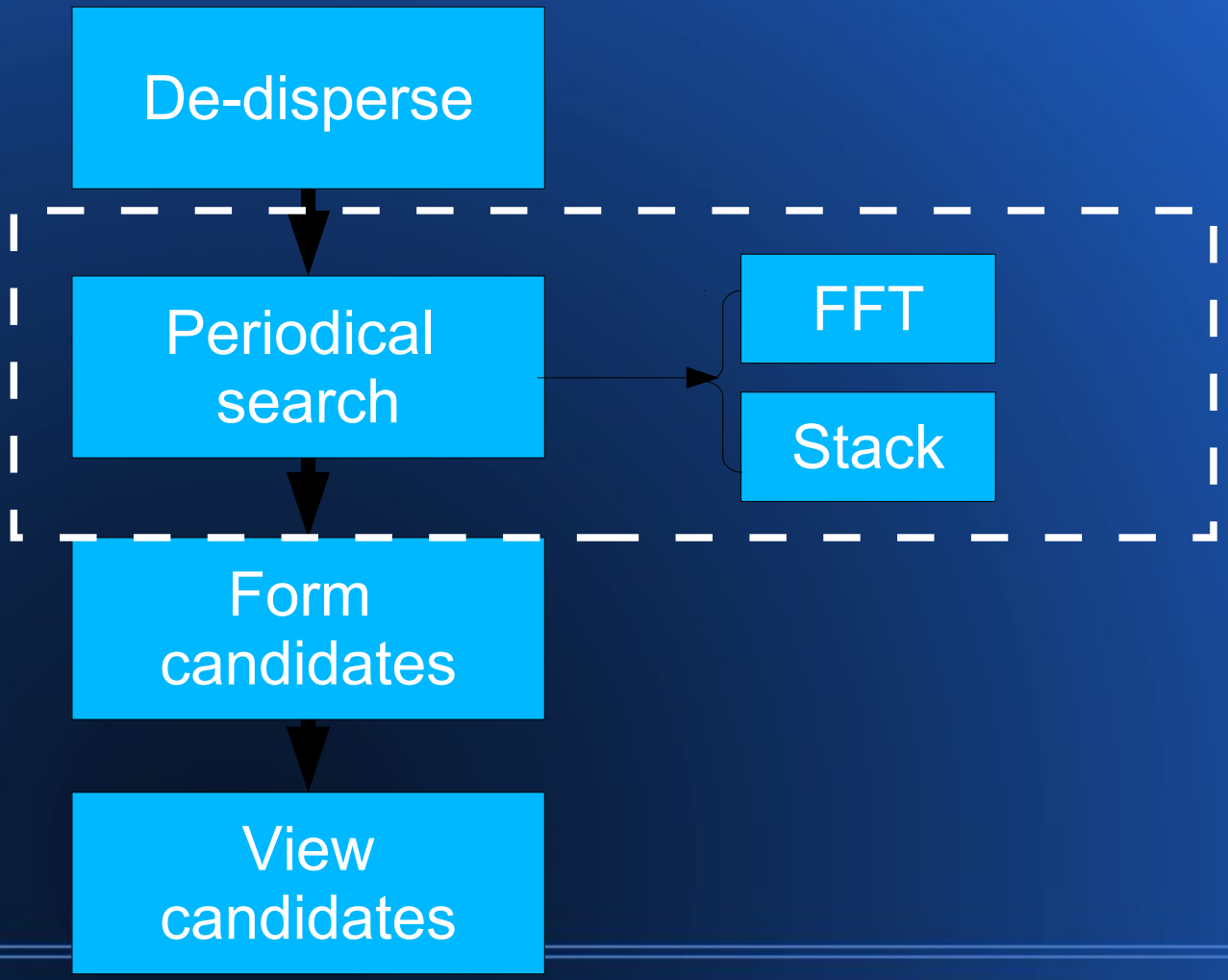
**prepsubband -nsub 22 -lodm 0.0 -dmstep 10.0 -numdms 3 **
-zerodm -downsamp 2 -mask 8bit_rfifind.mask -o 8bit 8bit.fil

```
-rw-rw-r-- 1 random random 1.1K  8月 13 21:14 8bit_DM20.00.inf
-rw-rw-r-- 1 random random 4.9M  8月 13 21:14 8bit_DM20.00.dat
-rw-rw-r-- 1 random random 1.1K  8月 13 21:14 8bit_DM10.00.inf
-rw-rw-r-- 1 random random 4.9M  8月 13 21:14 8bit_DM10.00.dat
-rw-rw-r-- 1 random random 1.1K  8月 13 21:14 8bit_DM0.00.inf
-rw-rw-r-- 1 random random 4.9M  8月 13 21:14 8bit_DM0.00.dat
```

RFI mask is used here!
Dd plan tell how to chose these parameters.

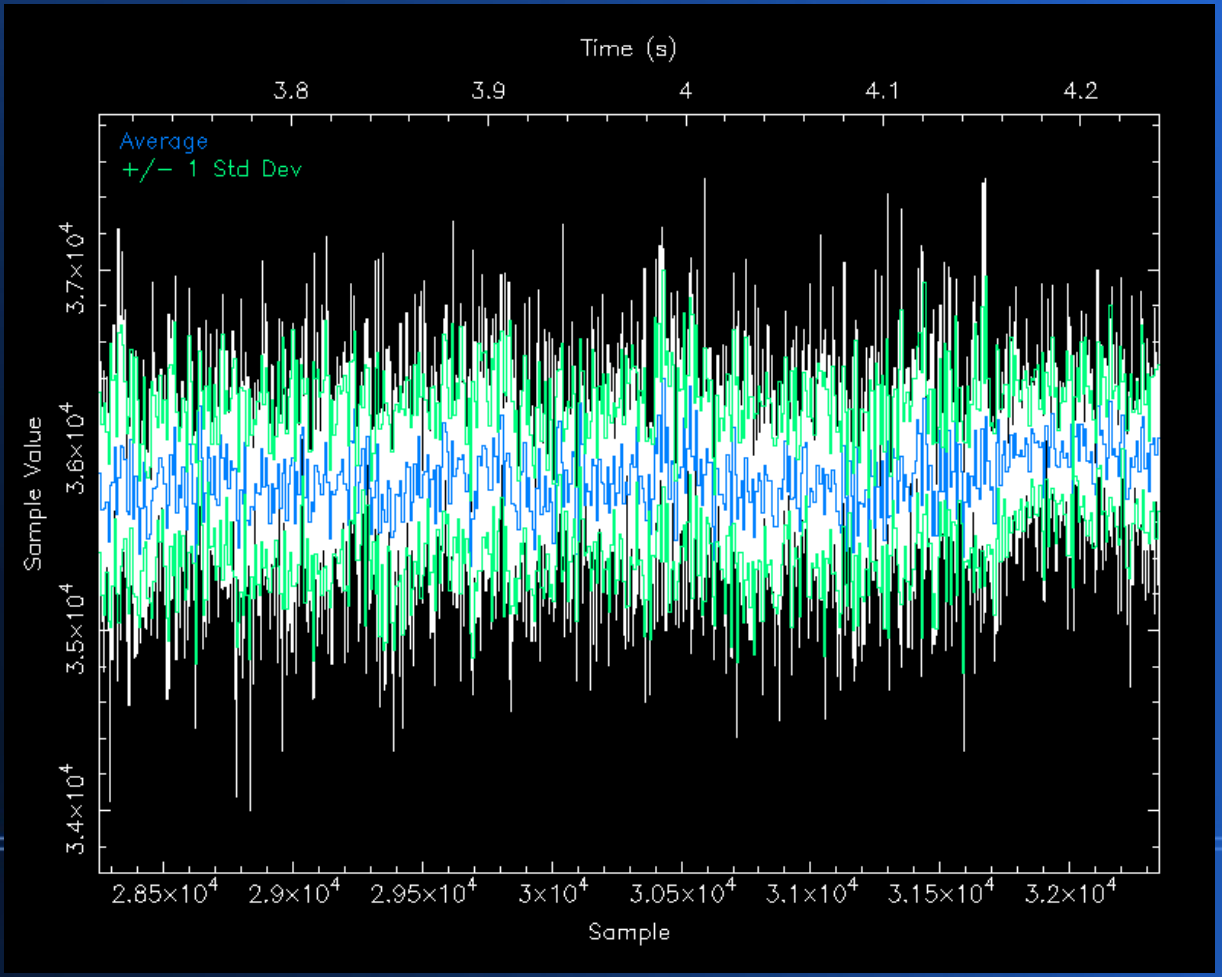
Example

Search solitary pulsars

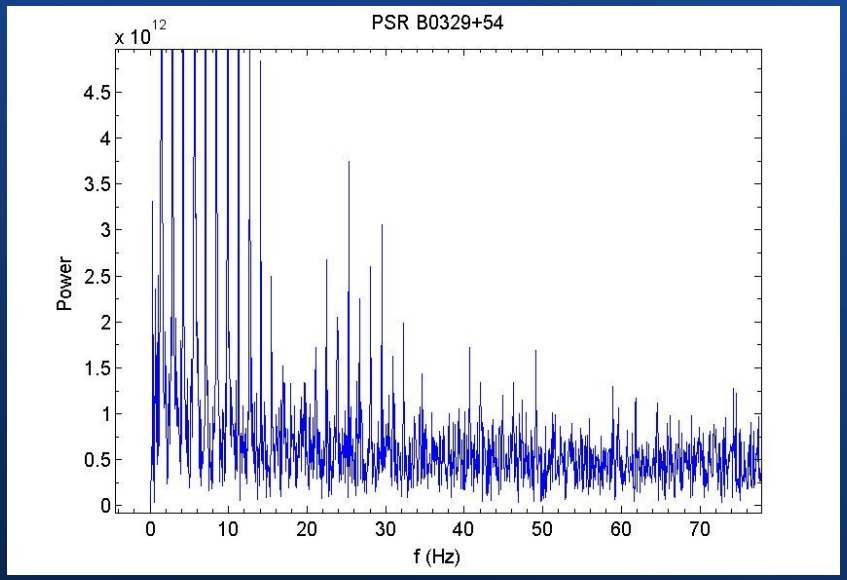


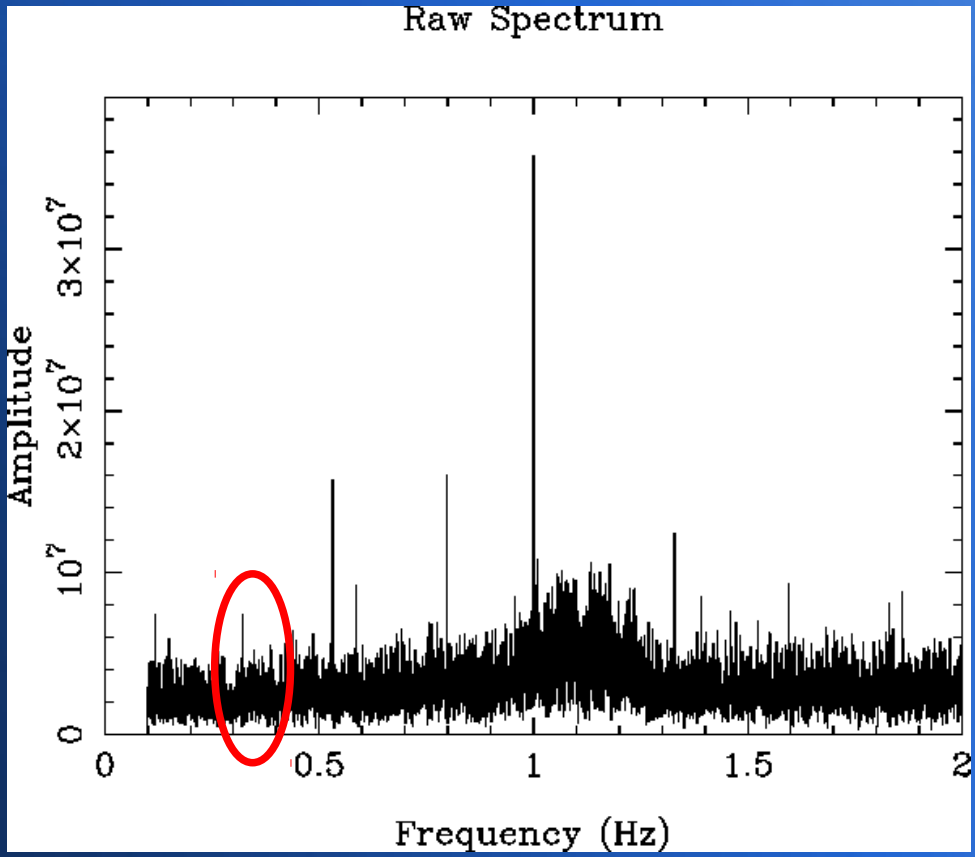
Why search pulses with FFT

Most of the time, in the raw de-dispersed data, there is no way to see the single pulses!



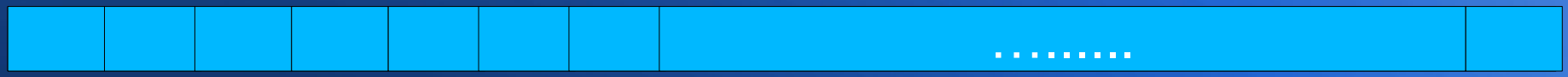
FFT





Test data from Effelsberg

FFT / Stack II

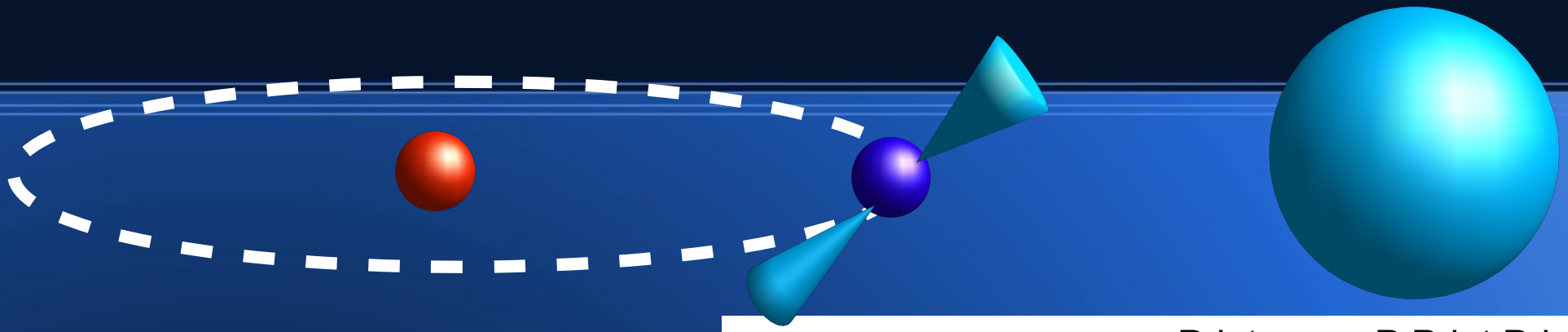


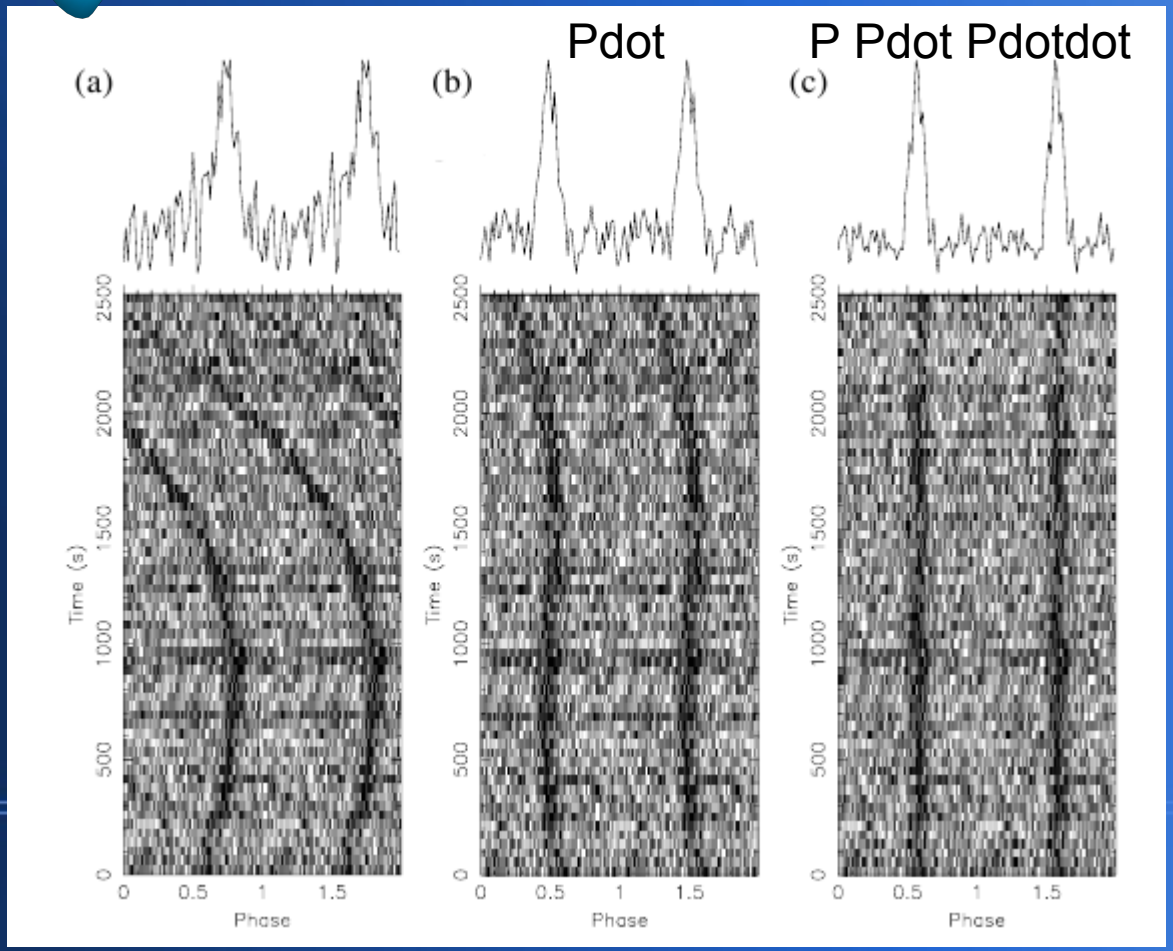
- For any element perform FFT
- Sum the power spectral (incoherently)

N ln(N) V.S. N ln(N/M)
SNR (power)~ T V.S. T/sqrt(M)

N~5E7 for 1 hour observation

Search for binaries





Hessel 06

Current binary search techniques

- Time domain

$$T(t)=T0\ (1+v(t)/c);$$

$$v(t)=v0+a\ t+\ b\ t^2$$

- Frequency domain

Above formula in frequency space

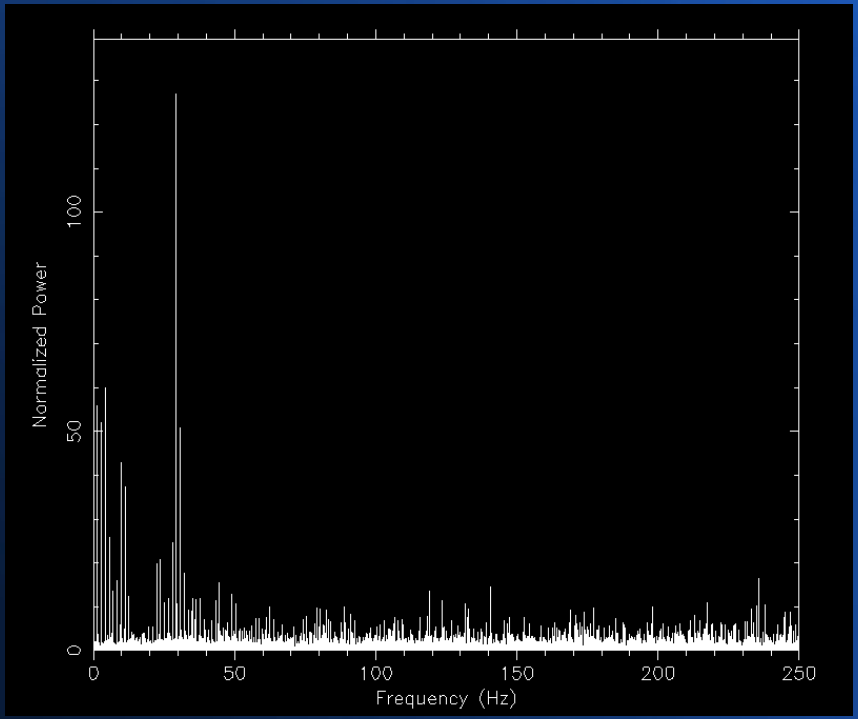
- Incoherent

Softwares

- Sigproc
  - Seek
- Presto
  - Realfft, accelsearch

Check the 0-DM spectrum

prepdata -nobary -o 8bit_dm0 -dm 0.0 -mask 8bit_rfifind.mask -numout 500000 8bit.fil
realfft 8bit_dm0.dat
explorefft bit_dm0.fft



Example

Find the peaks

accelsearch -numharm 4 -zmax 0 8bit_dm0.dat

```
Searched the following approx numbers of independent points:
  1 harmonic:      249967
  2 harmonics:     124983
  4 harmonics:      62491

Timing summary:
    CPU time: 2.080 sec (User: 2.080 sec, System: 0.000 sec)
  Total time: 2.100 sec

Final candidates in binary format are in '8bit_dm0_ACCEL_0.cand'.
Final Candidates in a text format are in '8bit_dm0_ACCEL_0'.
```

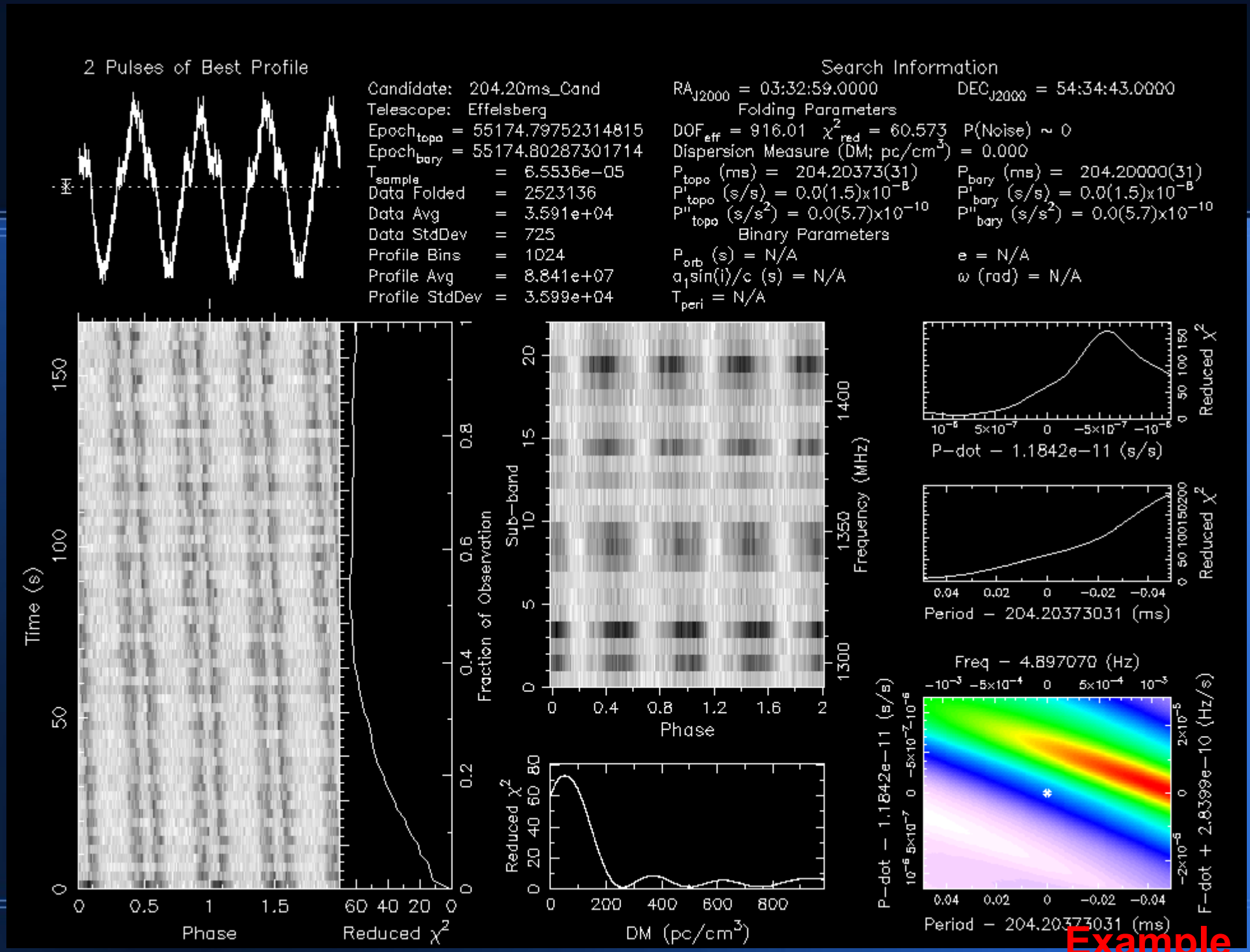
Example

RFIs

Cand	Sigma	Summed Power	Coherent Power	Num Harm	Period (ms)	Frequency (Hz)	FFT 'r' (bin)	Freq Deriv (Hz/s)	FFT 'z' (bins)	Accel (m/s^2)	Notes
1	15.01	140.38	1313.53	4	714(2)	1.400(4)	45.88(13)	0.0000(5)	0.00(50)	0.0(1.0)x10^5	PSR B0329+54
2	9.42	69.56	33.89	4	204.2(2)	4.898(4)	160.50(13)	0.0000(5)	0.00(50)	0.0(2.9)x10^4	
3	8.14	57.60	31.15	4	39.701(6)	25.188(4)	825.38(13)	0.0000(5)	0.00(50)	0.0(5.5)x10^3	18th H B0329+54
4	7.85	55.16	5.64	4	35.729(5)	27.988(4)	917.13(13)	0.0000(5)	0.00(50)	0.0(5.0)x10^3	20th H B0329+54
5	6.68	37.61	38.35	1	32.48(2)	30.79(2)	1009.00(50)	0.000(2)	0.0(2.0)	0.0(1.8)x10^4	22nd H B0329+54
6	6.39	38.69	36.18	2	42.04(1)	23.788(8)	779.50(25)	0.0000(9)	0.0(1.0)	0.0(1.2)x10^4	17th H B0329+54
7	6.22	42.73	1.84	4	37.610(5)	26.588(4)	871.25(13)	0.0000(5)	0.00(50)	0.0(5.3)x10^3	19th H B0329+54
8	4.76	33.77	8.74	4	27.484(3)	36.385(4)	1192.25(13)	0.0000(5)	0.00(50)	0.0(3.8)x10^3	26th H B0329+54
9	4.23	23.78	35.35	1	31.07(1)	32.18(2)	1054.50(50)	0.000(2)	0.0(2.0)	0.0(1.7)x10^4	23rd H B0329+54

Cand	Harm	Sigma	Power / Loc Pow	Raw Power	FFT 'r' (bin)	Pred 'r' (bin)	FFT 'z' (bins)	Pred 'z' (bins)	Phase (rad)	Centroid (0-1)	Purity <p> = 1	Notes
1	1	7.97	34.8(8.3)	17.9	45.875(57)	45.88	0.02(39)	0.00	6.17(12)	0.362(35)	1.153(47)	PSR B0329+54
	2	12.90	87(13)	28.5	91.750(37)	91.75	0.05(25)	0.00	6.036(76)	0.425(22)	1.138(30)	2nd H B0329+54
	3	16.48	140(17)	43.8	137.625(34)	137.62	0.07(26)	0.00	5.854(60)	0.510(17)	0.984(27)	3rd H B0329+54
	4	12.81	85(13)	56.8	183.500(45)	183.50	0.10(37)	0.00	5.787(76)	0.503(22)	0.936(37)	4th H B0329+54
2	1	0.14	0.8(1.3)	0.436	160.53(46)	160.50	-0.1(3.7)	0.00	2.67(79)	0.31(23)	0.95(37)	
	2	9.82	51(10)	62.4	321.052(52)	321.00	-0.17(39)	0.00	5.421(99)	0.500(28)	1.038(42)	7th H B0329+54
	3	0.00	0.41(90)	0.157	481.58(35)	481.50	-0.3(1.6)	0.00	5.8(1.1)	0.65(32)	1.74(28)	
	4	4.85	14.3(5.3)	9.24	642.10(14)	642.00	-0.3(1.6)	0.00	2.09(19)	0.537(54)	0.72(12)	14th H B0329+54
3	1	10.33	57(11)	36.6	825.415(55)	825.38	0.23(45)	0.00	2.166(94)	0.530(27)	0.947(44)	18th H B0329+54
	2	4.15	11.0(4.7)	10.8	1650.83(13)	1650.75	0.5(1.1)	0.00	6.05(21)	0.408(62)	0.89(11)	36th H B0329+54
	3	3.00	6.6(3.6)	6.21	2476.25(20)	2476.12	0.7(2.1)	0.00	3.00(28)	0.406(79)	0.75(16)	
	4	1.91	3.6(2.7)	3.76	3301.66(27)	3301.50	0.9(2.8)	0.00	1.05(37)	0.39(11)	0.76(22)	
4	1	7.75	33.0(8.1)	40.3	917.196(73)	917.12	0.55(61)	0.00	2.09(12)	0.516(36)	0.925(60)	20th H B0329+54

Example


2 Pulses of Best Profile
Candidate: 204.20ms_Cand
Telescope: Effelsberg
Epoch_topo = 55174.79752314815
Epoch_bary = 55174.80287301714
T_sample = 6.5536e-05
Data Folded = 2523136
Data Avg = 3.591e+04
Data StdDev = 725
Profile Bins = 1024
Profile Avg = 8.841e+07
Profile StdDev = 3.599e+04
Search Information
RA_J2000 = 03:32:59.0000
DEC_J2000 = 54:34:43.0000
Folding Parameters
DOF_eff = 916.01 χ²_red = 60.573 P(Noise) ~ 0
Dispersion Measure (DM; pc/cm³) = 0.000
P_topo (ms) = 204.20373(31)
P_bary (ms) = 204.20000(31)
P'_topo (s/s) = 0.0(1.5)x10⁻⁸
P'_bary (s/s) = 0.0(1.5)x10⁻⁸
P''_topo (s/s²) = 0.0(5.7)x10⁻¹⁰
P''_bary (s/s²) = 0.0(5.7)x10⁻¹⁰
Binary Parameters
P_orb (s) = N/A
e = N/A
a₁sin(i)/c (s) = N/A
ω (rad) = N/A
T_peri = N/A
Time (s)
Phase
Reduced χ²
Fraction of Observation
Sub-band
Frequency (MHz)
DM (pc/cm³)
P-dot = 1.1842e-11 (s/s)
Period = 204.20373031 (ms)
Freq = 4.897070 (Hz)
F-dot = 2.8399e-10 (Hz/s)
Example

Create RFI list

- Width is the number of harmonic to zap
- If zap width increase as harmonic counts, grow =1
- To zap celestial source (a known pulsar), bary =1

```
# Freq   width harm grow barycentering
4.898    0.001 4    0    0
~
~
~
```

makezaplist.py birds.birds

```
random@AlphaX:~/work/pulsarsch/dat_tst$ more birds.zaplist
# This file created automatically with makebirds.py
# Lines beginning with '#' are comments
# Lines beginning with 'B' are barycentric freqs (i.e. PSR freqs)
#                 Freq                  Width
# --------------------  --------------------
                 4.898                  0.001
                 9.796                  0.001
                14.694                  0.001
                19.592                  0.001
```

Example

Example

realfft 8bit_DM*.00.dat

```
-rw-rw-r-- 1 random random 1.1K  8月 13 21:21 8bit_DM20.00.inf
-rw-rw-r-- 1 random random 4.0M  8月 13 21:21 8bit_DM20.00.dat
-rw-rw-r-- 1 random random 1.1K  8月 13 21:21 8bit_DM10.00.inf
-rw-rw-r-- 1 random random 4.0M  8月 13 21:21 8bit_DM10.00.dat
-rw-rw-r-- 1 random random 1.1K  8月 13 21:21 8bit_DM0.00.inf
-rw-rw-r-- 1 random random 4.0M  8月 13 21:21 8bit_DM0.00.dat
-rw-rw-r-- 1 random random 4.0M  8月 13 21:23 8bit_DM20.00.fft
-rw-rw-r-- 1 random random 4.0M  8月 13 21:23 8bit_DM10.00.fft
-rw-rw-r-- 1 random random 4.0M  8月 13 21:23 8bit_DM0.00.fft
```

zapbirds -zap -zapfile birds.zaplist 8bit_DM10.00.fft

accelsearch -numharm 4 -zmax 0 8bit_DM20.00.dat

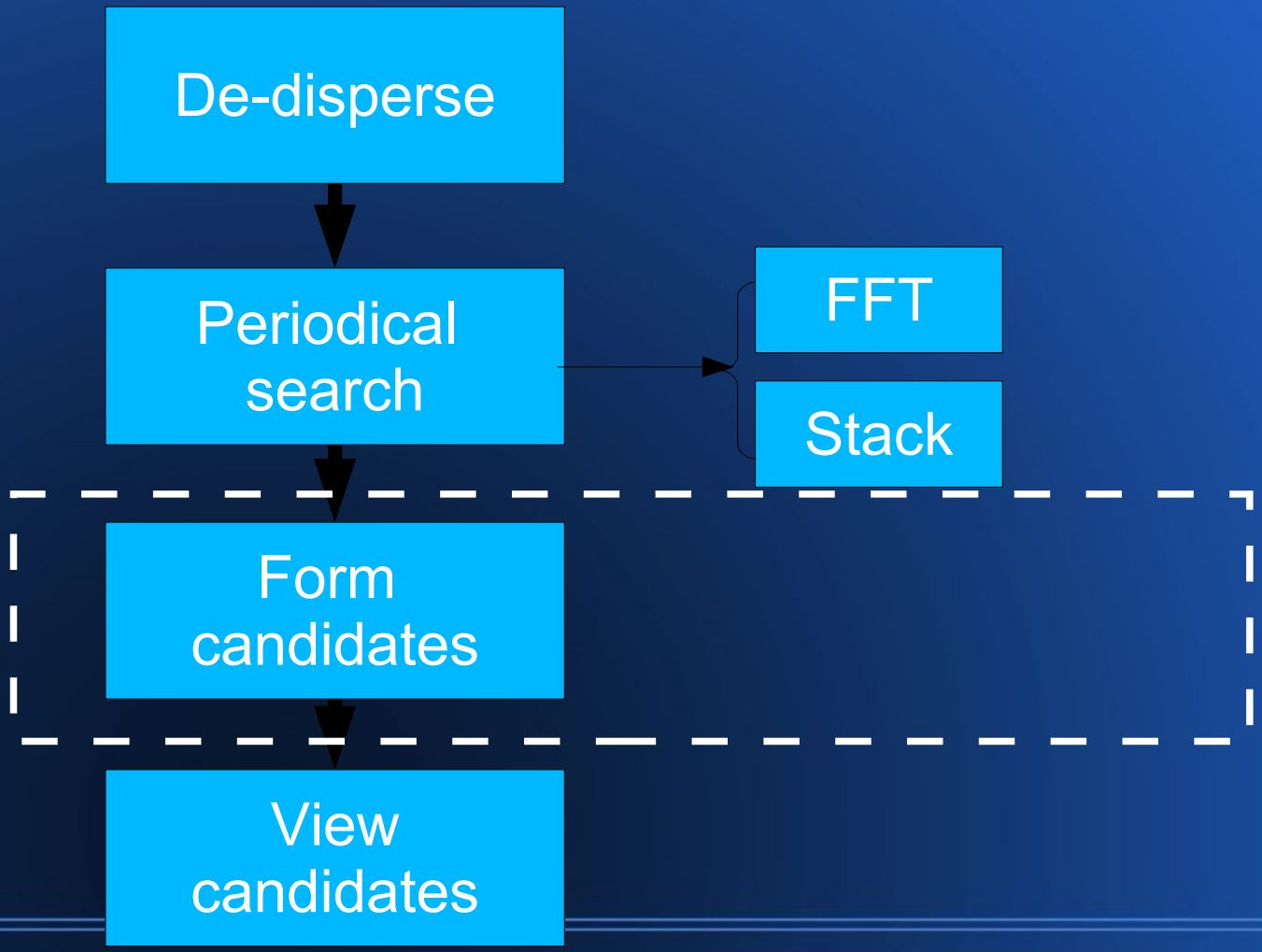
```
-rw-rw-r-- 1 random random 1.8K  8月 13 21:31 8bit_DM0.00_ACCEL_0.cand
-rw-rw-r-- 1 random random  18K  8月 13 21:31 8bit_DM0.00_ACCEL_0
-rw-rw-r-- 1 random random 1.6K  8月 13 21:31 8bit_DM10.00_ACCEL_0.cand
-rw-rw-r-- 1 random random  16K  8月 13 21:31 8bit_DM10.00_ACCEL_0
-rw-rw-r-- 1 random random 2.1K  8月 13 21:31 8bit_DM20.00_ACCEL_0.cand
-rw-rw-r-- 1 random random  22K  8月 13 21:31 8bit_DM20.00_ACCEL_0
```

Candidate lists

Cand	Sigma	Summed Power	Coherent Power	Num Harm	Period (ms)	Frequency (Hz)	FFT 'r' (bin)	Freq Deriv (Hz/s)	FFT 'z' (bins)	Accel (m/s^2)	Notes
1	43.81	994.86	7486.98	4	714.4(5)	1.3997(9)	192.38(13)	0.00000(3)	0.00(50)	0.0(5.7)x10^3	PSR B0329+54
2	25.30	351.72	424.07	4	158.80(2)	6.2973(9)	865.50(13)	0.00000(3)	0.00(50)	0.0(1.3)x10^3	
3	23.05	296.81	1023.96	4	42.030(2)	23.7924(9)	3270.00(13)	0.00000(3)	0.00(50)	0.0(3.3)x10^2	17th H B0329+54
4	18.71	204.83	690.69	4	37.607(1)	26.5909(9)	3654.63(13)	0.00000(3)	0.00(50)	0.0(3.0)x10^2	19th H B0329+54
5	17.76	187.30	346.94	4	35.726(1)	27.9906(9)	3847.00(13)	0.00000(3)	0.00(50)	0.0(2.8)x10^2	20th H B0329+54
6	17.46	181.89	216.44	4	129.92(2)	7.6971(9)	1057.88(13)	0.00000(3)	0.00(50)	0.0(1.0)x10^3	
7	17.41	180.86	3.99	4	31.0667(9)	32.1888(9)	4424.00(13)	0.00000(3)	0.00(50)	0.0(2.5)x10^2	23rd H B0329+54
8	17.39	180.55	117.49	4	204.14(4)	4.8985(9)	673.25(13)	0.00000(3)	0.00(50)	0.0(1.6)x10^3	
9	16.64	167.62	36.19	4	27.4816(7)	36.3880(9)	5001.13(13)	0.00000(3)	0.00(50)	0.0(2.2)x10^2	26th H B0329+54
10	15.79	153.50	18.17	4	29.7721(8)	33.5885(9)	4616.38(13)	0.00000(3)	0.00(50)	0.0(2.4)x10^2	24th H B0329+54
11	11.15	82.37	113.12	2	19.3114(7)	51.783(2)	7117.00(25)	0.00000(5)	0.0(1.0)	0.0(3.1)x10^2	37th H B0329+54
12	10.18	78.17	213.01	4	13.4815(2)	74.1757(9)	10194.63(13)	0.00000(3)	0.00(50)	0.0(1.1)x10^2	H 53 of Cand 1
13	9.57	71.85	123.69	4	61.244(3)	16.3282(9)	2244.13(13)	0.00000(3)	0.00(50)	0.0(4.9)x10^2	
14	8.19	58.87	43.94	4	38.277(1)	26.1252(9)	3590.63(13)	0.00000(3)	0.00(50)	0.0(3.0)x10^2	
15	7.99	57.08	55.26	4	85.739(7)	11.6634(9)	1603.00(13)	0.00000(3)	0.00(50)	0.0(6.8)x10^2	
16	7.86	56.03	28.73	4	38.973(1)	25.6587(9)	3526.50(13)	0.00000(3)	0.00(50)	0.0(3.1)x10^2	
17	7.35	51.83	40.00	4	24.6389(6)	40.5862(9)	5578.13(13)	0.00000(3)	0.00(50)	0.0(2.0)x10^2	29th H B0329+54
18	5.73	40.23	62.78	4	17.4271(3)	57.3818(9)	7886.50(13)	0.00000(3)	0.00(50)	0.0(1.4)x10^2	H 41 of Cand 1
19	5.56	39.20	86.09	4	43.746(2)	22.8592(9)	3141.75(13)	0.00000(3)	0.00(50)	0.0(3.5)x10^2	
20	5.47	30.76	30.50	1	10.0636(4)	99.368(4)	13657.00(50)	0.0000(1)	0.0(2.0)	0.0(3.2)x10^2	
21	4.96	35.65	89.48	4	16.6167(3)	60.1804(9)	8271.13(13)	0.00000(3)	0.00(50)	0.0(1.3)x10^2	H 43 of Cand 1
22	4.81	34.85	26.71	4	23.0486(5)	43.3865(9)	5963.00(13)	0.00000(3)	0.00(50)	0.0(1.8)x10^2	31st H B0329+54
23	4.66	26.50	26.91	1	6.9372(2)	144.151(4)	19812.00(50)	0.0000(1)	0.0(2.0)	0.0(2.2)x10^2	

Example

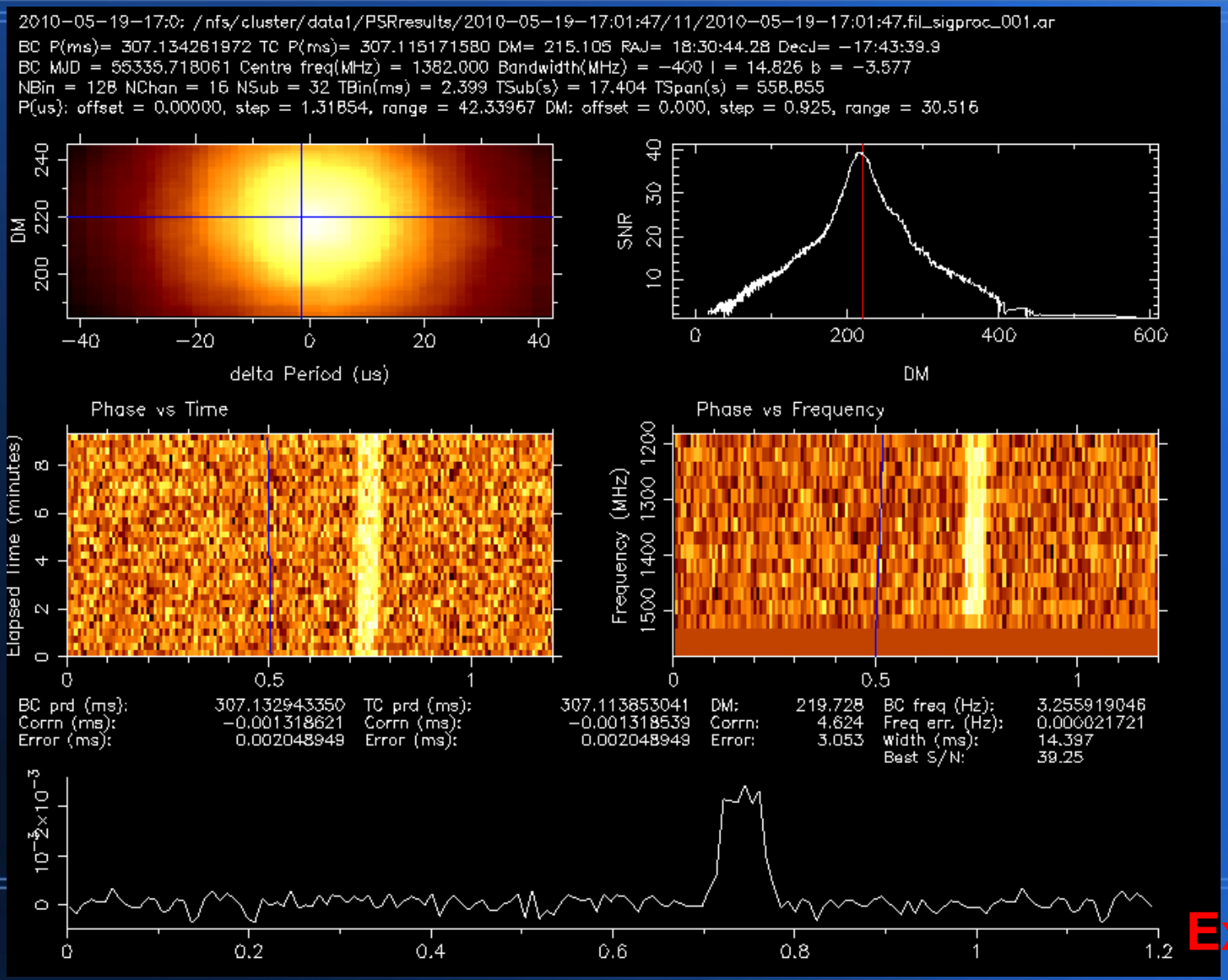
Search solitary pulsars



Form the candidates

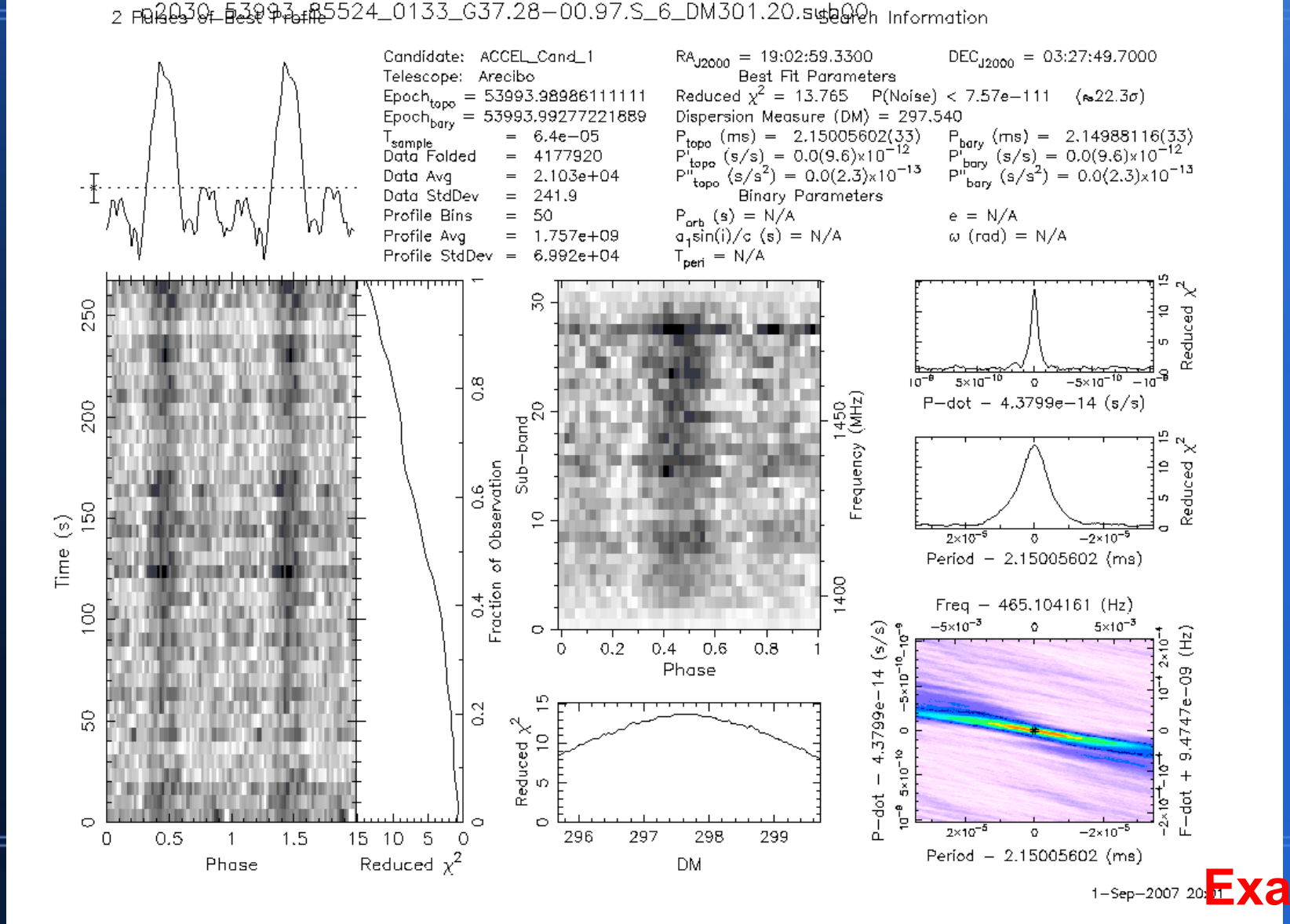
- De-disperse
- Fold
  - The fold is used to avoid spectral leakage. A local search are usually performed to further improve SNR.
- Software
  - Prepfold, pdmp etc...

How the pulsar candidates look like?---PDMP



Example

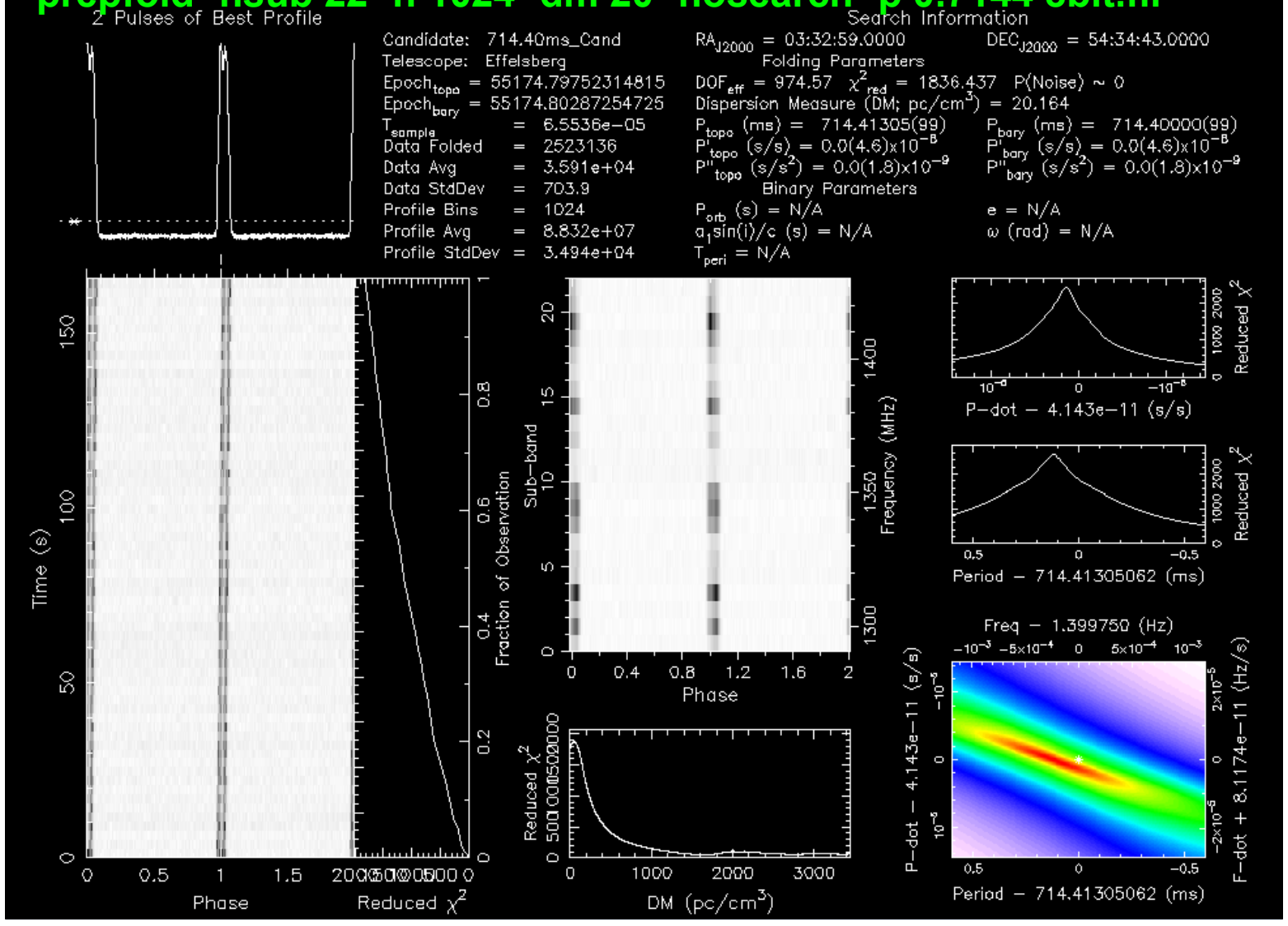
Presto



Example

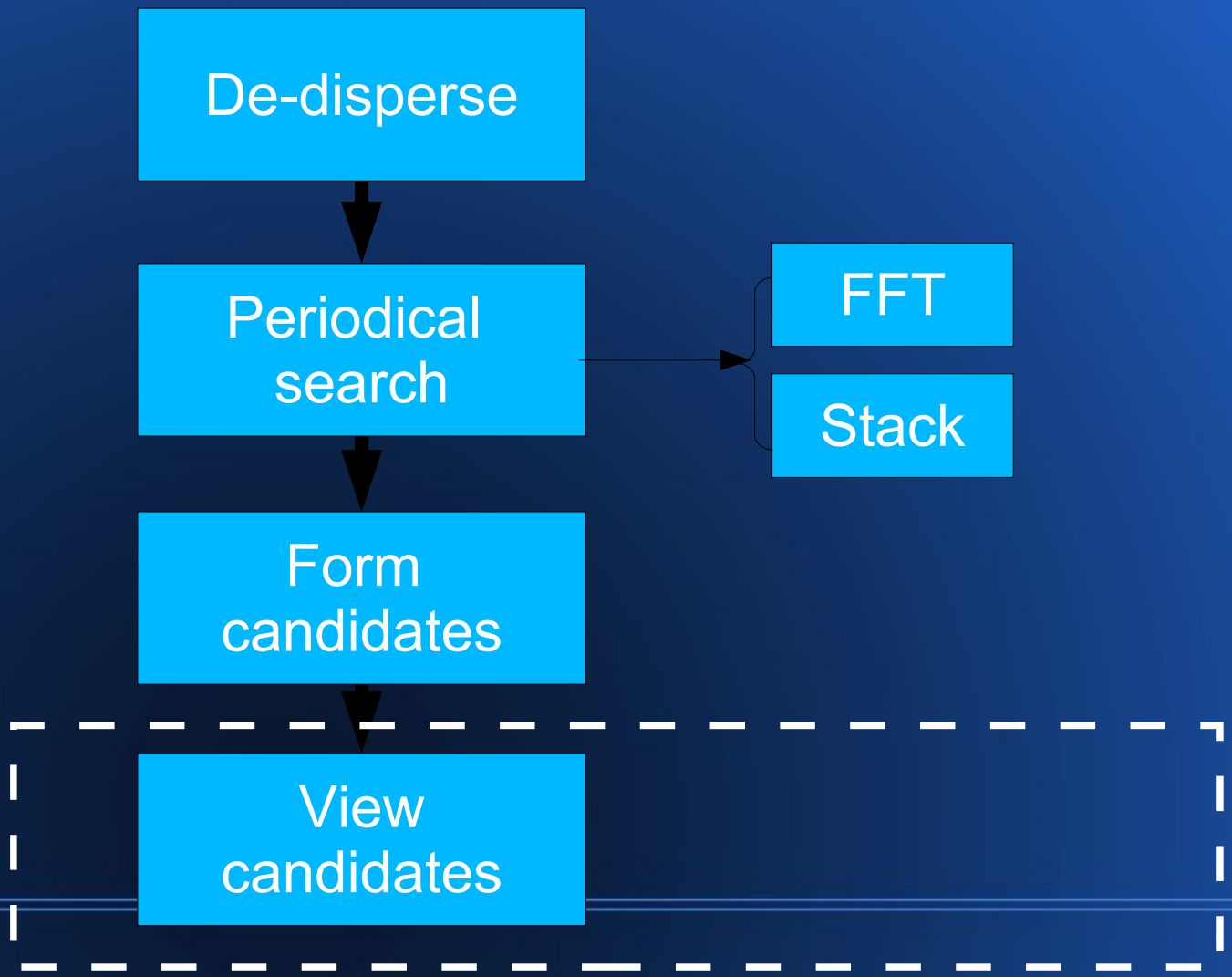
Cand	Sigma	Summed Power	Coherent Power	Num Harm	Period (ms)	Frequency (Hz)	FFT 'r' (bin)	Freq Deriv (Hz/s)	FFT 'z' (bins)	Accel (m/s^2)	Notes
1	43.81	994.86	7486.98	4	714.4(5)	1.3997(9)	192.38(13)	0.00000(3)	0.00(50)	0.0(5.7)x10^3	PSR B0329+54
2	25.30	351.72	424.07	4	158.80(2)	6.2973(9)	865.50(13)	0.00000(3)	0.00(50)	0.0(1.3)x10^3	
3	23.05	296.81	1023.96	4	42.030(2)	23.7924(9)	3270.00(13)	0.00000(3)	0.00(50)	0.0(3.3)x10^2	17th H B0329+54
4	18.71	204.83	690.69	4	37.607(1)	26.5909(9)	3654.63(13)	0.00000(3)	0.00(50)	0.0(3.0)x10^2	19th H B0329+54
5	17.76	187.30	346.94	4	35.726(1)	27.9906(9)	3847.00(13)	0.00000(3)	0.00(50)	0.0(2.8)x10^2	20th H B0329+54
6	17.46	181.89	216.44	4							
7	17.41	180.86	3.99	4							
8	17.39	180.55	117.49	4							
9	16.64	167.62	36.19	4							
10	15.79	153.50	18.17	4							
11	11.15	82.37	113.12	2							
12	10.18	78.17	213.01	4							
13	9.57	71.85	123.69	4							
14	8.19	58.87	43.94	4							
15	7.99	57.08	55.26	4							
16	7.86	56.03	28.73	4							
17	7.35	51.83	40.00	4							
18	5.73	40.23	62.78	4							
19	5.56	39.20	86.09	4							
20	5.47	30.76	30.50	1							
21	4.96	35.65	89.48	4							
22	4.81	34.85	26.71	4							
23	4.66	26.50	26.91	1							

prepfold -nsub 22 -n 1024 -dm 20 -nosearch -p 0.7144 8bit.fil



Example

Search solitary pulsars



Candidate identification and confirmation

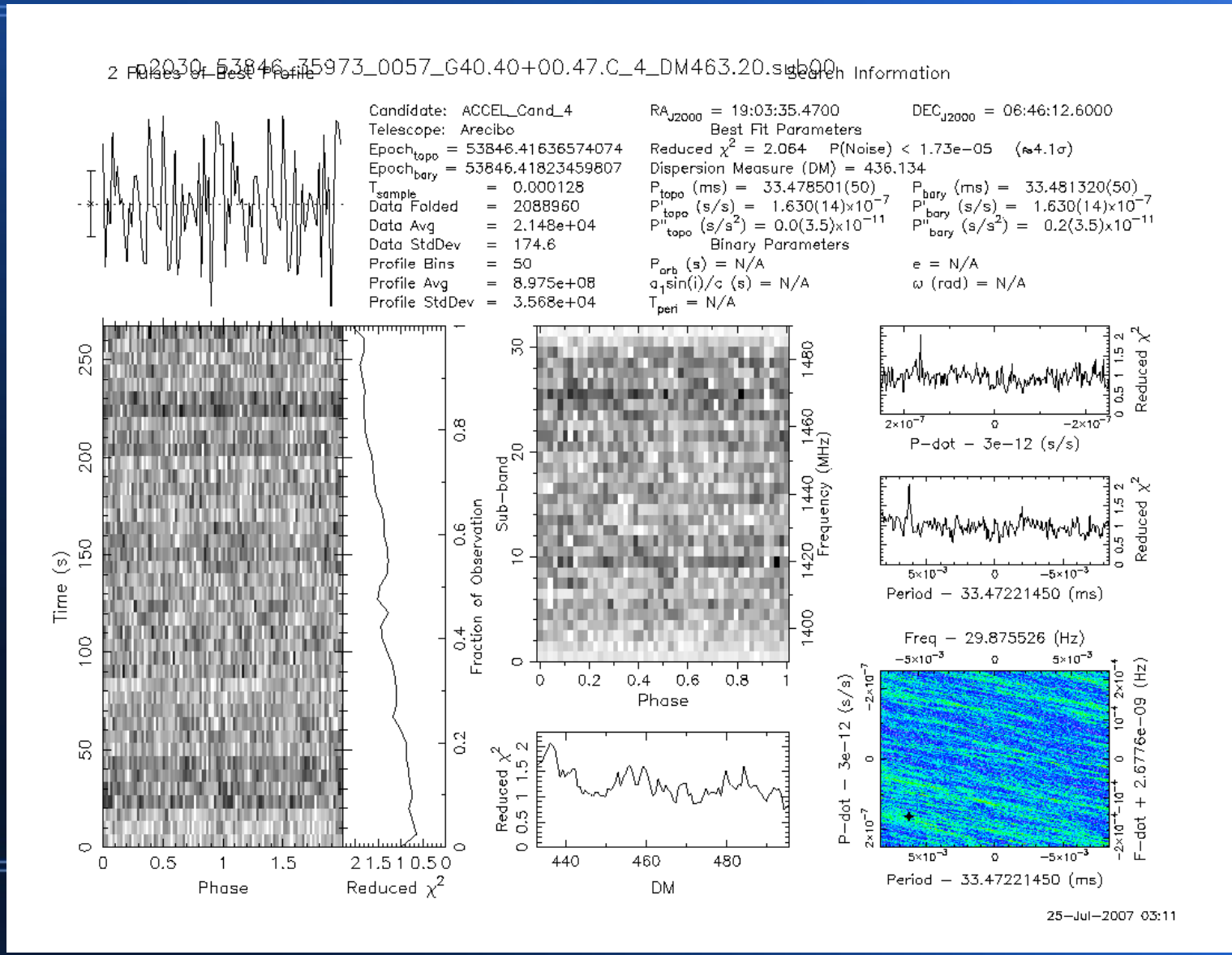
Astronomers are busy.

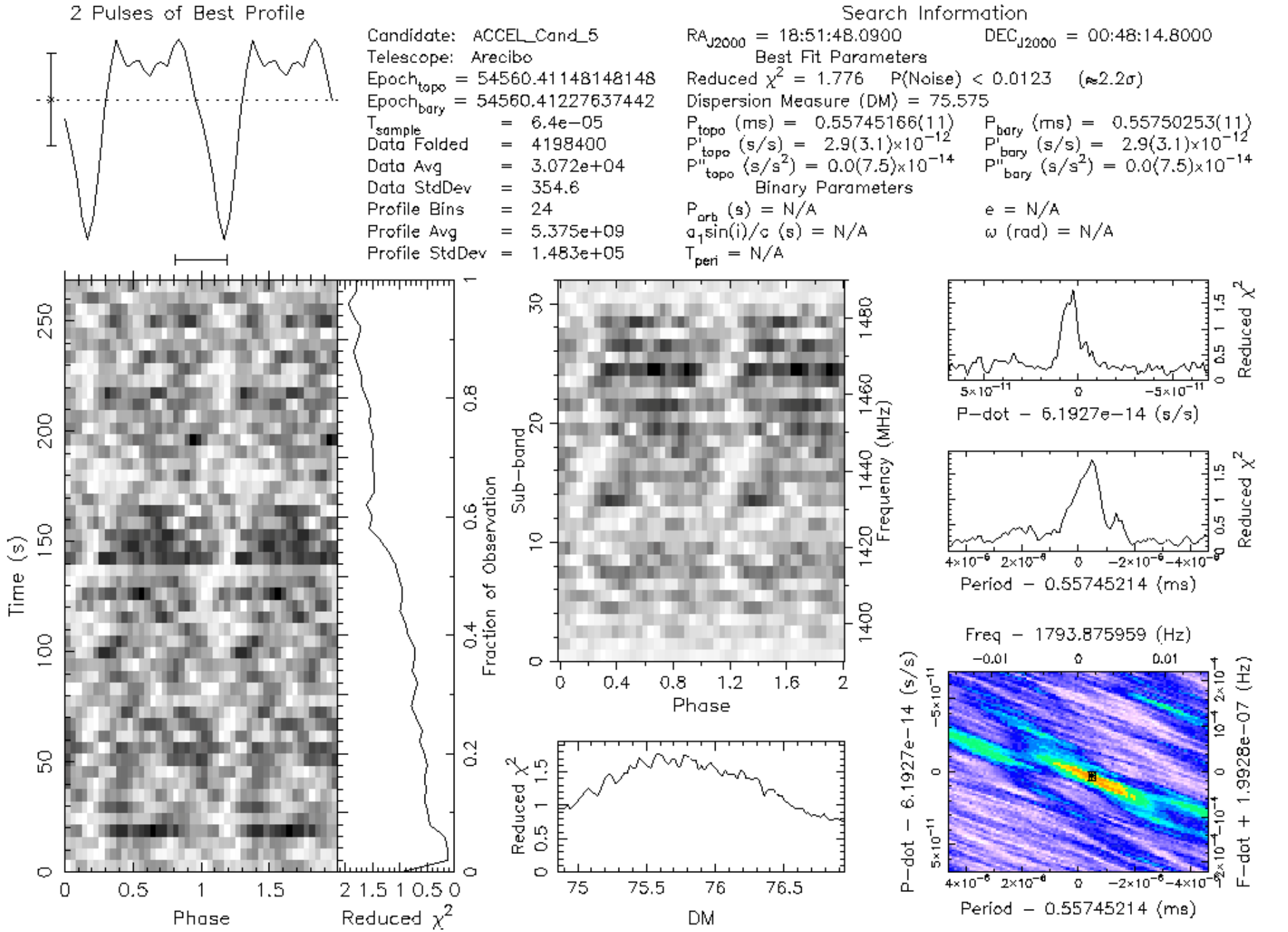
- Past experience show that pulsar search agrees with Moor's law. (indication for computational cost limitation)
- At certain stage, we can not keep up looking all the candidates (e.g. PMPS has ~ 1e7 candidates, which take about 342 day x 8 hr x 3600 s to view all)
- Every 18 month 2 times better computer
- In future large scale survey, we need to face ~a few time 1e9 candidates. We will be limited by candidate viewing processes possibly, NOT computer!

How to evaluate a candidates?

- Is the pulse profile be good?
- Is signal broad band?
- Is signal persistent?
- Is DM trustful?
- Is period be good natural number?

A few example of bad candidates

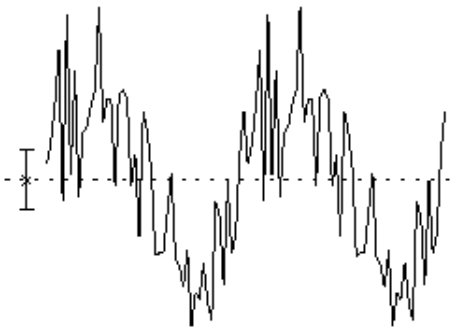



2 Pulses of Best Profile
Candidate: ACCEL_Cand_5
Telescope: Arecibo
Epoch_topo = 54560.41148148148
Epoch_bary = 54560.41227637442
T_sample = 6.4e-05
Data Folded = 4198400
Data Avg = 3.072e+04
Data StdDev = 354.6
Profile Bins = 24
Profile Avg = 5.375e+09
Profile StdDev = 1.483e+05
Search Information
RA_J2000 = 18:51:48.0900
DEC_J2000 = 00:48:14.8000
Best Fit Parameters
Reduced χ^2 = 1.776 P(Noise) < 0.0123 (≈2.2σ)
Dispersion Measure (DM) = 75.575
P_topo (ms) = 0.55745166(11)
P_bary (ms) = 0.55750253(11)
P'_topo (s/s) = 2.9(3.1)×10^-12
P'_bary (s/s) = 2.9(3.1)×10^-12
P''_topo (s/s^2) = 0.0(7.5)×10^-14
P''_bary (s/s^2) = 0.0(7.5)×10^-14
Binary Parameters
P_orb (s) = N/A
e = N/A
a_1sin(i)/c (s) = N/A
ω (rad) = N/A
T_peri = N/A
Time (s)
Phase
Reduced χ^2
Fraction of Observation
Sub-band
Frequency (MHz)
Phase
Reduced χ^2
DM
P-dot = 6.1927e-14 (s/s)
Reduced χ^2
Period = 0.55745214 (ms)
Reduced χ^2
Freq = 1793.875959 (Hz)
P-dot = 6.1927e-14 (s/s)
F-dot = 1.9928e-07 (Hz)
Period = 0.55745214 (ms)
p2030_54560_35552_0028_G33.65+00.30.S_6_DM75.60.sub00
20-Sep-2009 07:29

2 Pulses of Best Profile

P2030_53755_54695_0090_G36.72−01.38.N_2_DM3.60.sub00

Search Information



Candidate: ACCEL_Cand_4
Telescope: Arecibo
$Epoch_{topo}$ = 53755.63304398148
$Epoch_{bary}$ = 53755.62878471635
T_{sample} = 6.4e−05
Data Folded = 4177920
Data Avg = 2.028e+04
Data StdDev = 236.4
Profile Bins = 50
Profile Avg = 1.694e+09
Profile StdDev = 6.833e+04

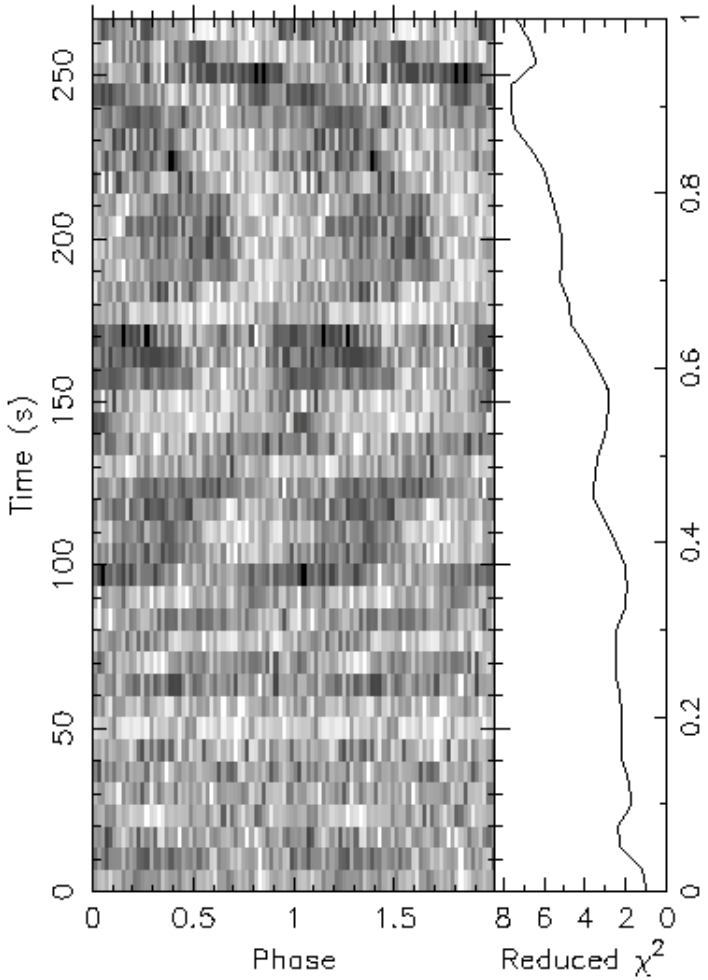
RA_{J2000} = 19:02:51.3500 DEC_{J2000} = 02:48:24.0000

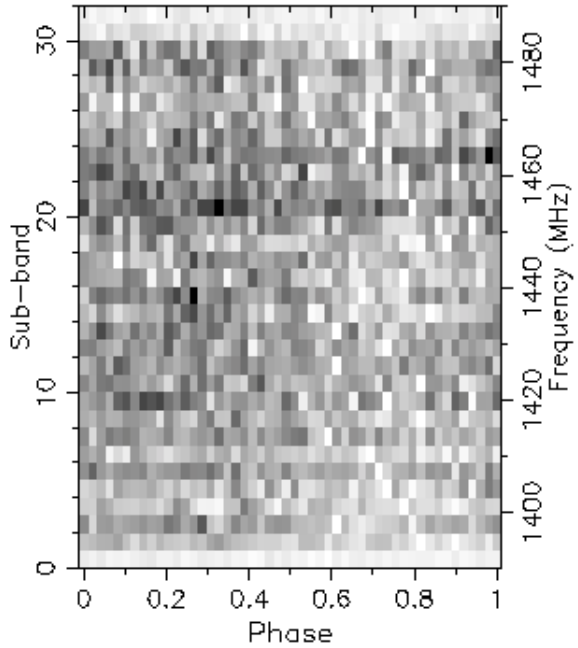
Best Fit Parameters

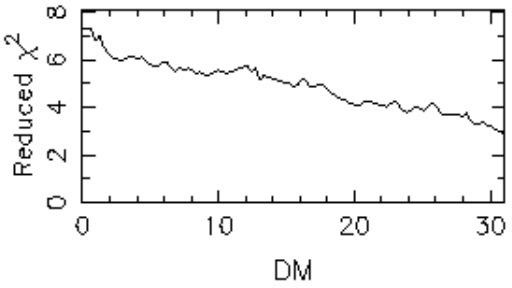
Reduced χ^2 = 7.347 P(Noise) < 6.07e−49 (≈14.7σ)
Dispersion Measure (DM) = 0.620
P_{topo} (ms) = 16.648621(13) P_{bary} (ms) = 16.648955(13)
P'_{topo} (s/s) = 4.775(37)×10^{-8} P'_{bary} (s/s) = 4.775(37)×10^{-8}
P''_{topo} (s/s^2) = 0.0(9.0)×10^{-12} P''_{bary} (s/s^2) = 0.3(9.0)×10^{-12}

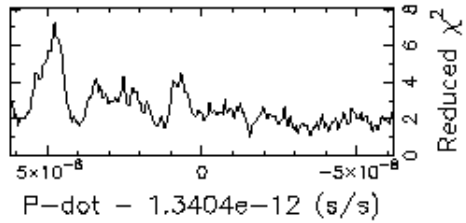
Binary Parameters

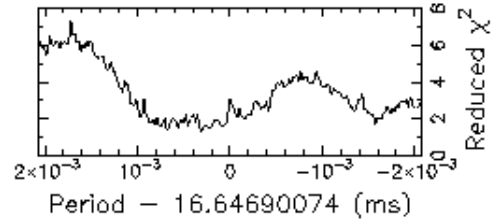
P_{orb} (s) = N/A e = N/A
$a_1 \sin(i)/c$ (s) = N/A ω (rad) = N/A
T_{peri} = N/A

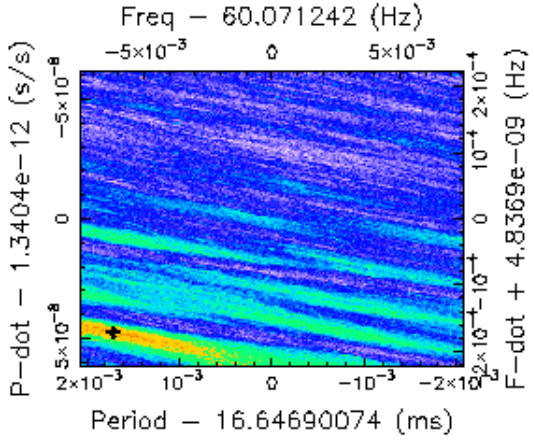




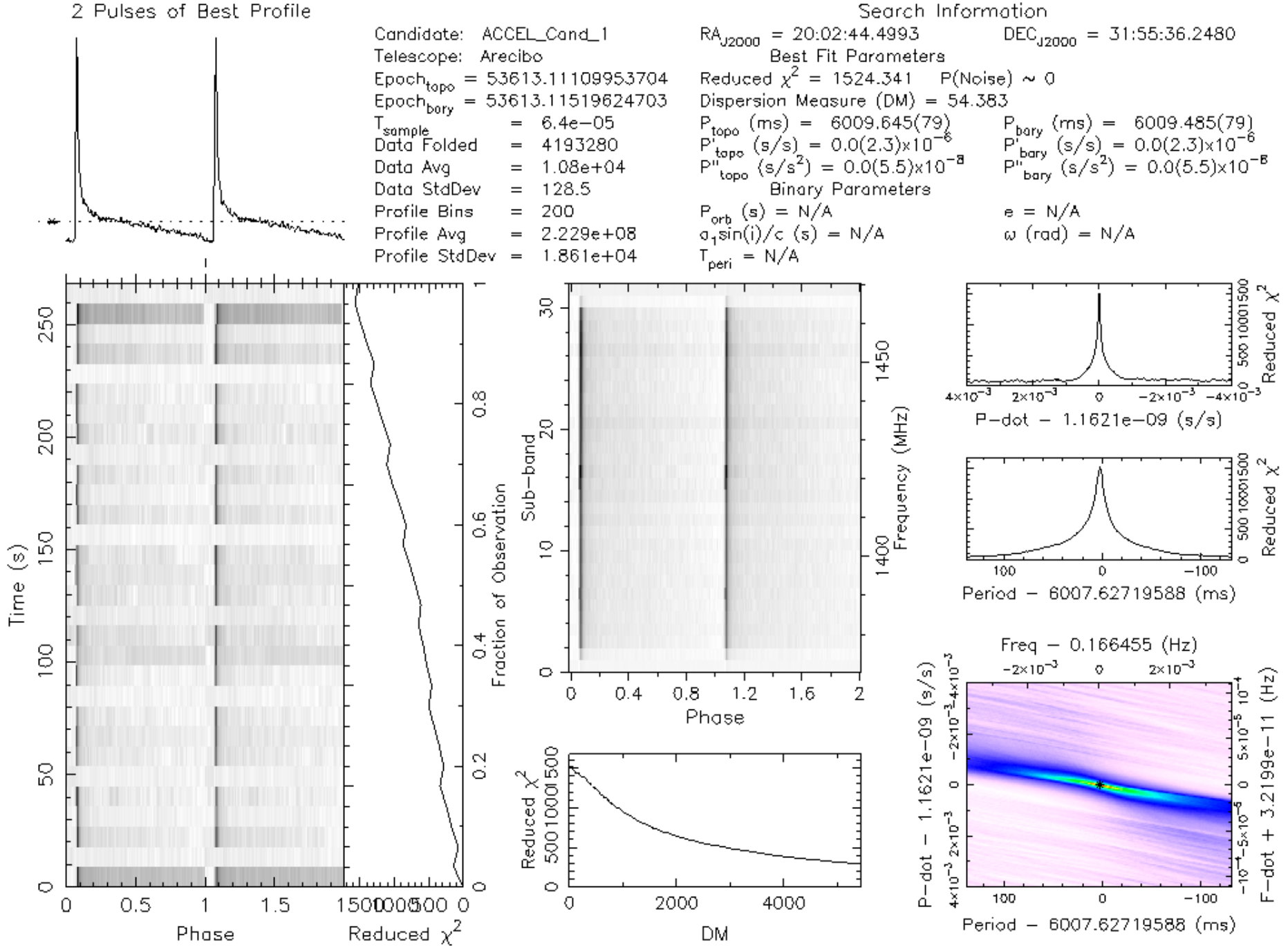








10−Mar−2009 12:39


2 Pulses of Best Profile
Candidate: ACCEL_Cand_1
Telescope: Arecibo
Epoch_topo = 53613.11109953704
Epoch_bary = 53613.11519624703
T_sample = 6.4e-05
Data Folded = 4193280
Data Avg = 1.08e+04
Data StdDev = 128.5
Profile Bins = 200
Profile Avg = 2.229e+08
Profile StdDev = 1.861e+04
Search Information
RA_J2000 = 20:02:44.4993
DEC_J2000 = 31:55:36.2480
Best Fit Parameters
Reduced χ^2 = 1524.341
P(Noise) ~ 0
Dispersion Measure (DM) = 54.383
P_topo (ms) = 6009.645(79)
P'_topo (s/s) = 0.0(2.3)x10^-6
P''_topo (s/s^2) = 0.0(5.5)x10^-8
P_bary (ms) = 6009.485(79)
P'_bary (s/s) = 0.0(2.3)x10^-6
P''_bary (s/s^2) = 0.0(5.5)x10^-8
Binary Parameters
P_orb (s) = N/A
a_1sin(i)/c (s) = N/A
T_peri = N/A
e = N/A
ω (rad) = N/A
Time (s)
Phase
Reduced χ^2
Fraction of Observation
Sub-band
Frequency (MHz)
DM
P-dot = 1.1621e-09 (s/s)
Period = 6007.62719588 (ms)
Freq = 0.166455 (Hz)
P-dot = 1.1621e-09 (s/s)
F-dot = 3.2199e-11 (Hz)
p2030_53613_09599_0015_G69.03+00.44.N_2.fil
18-Aug-2010 17:10

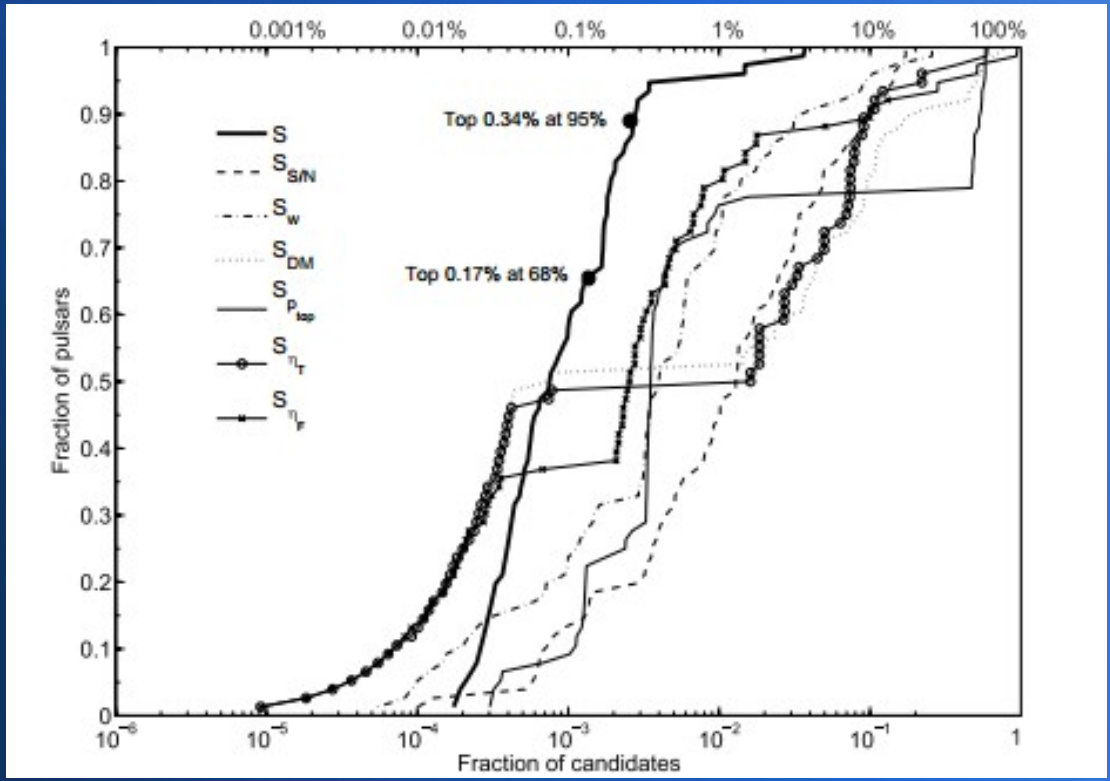
Computer based algorithms for candidate identification

- Simple selection rule
  - Pulsar viewers (Arccviewer, Dirtyplot etc) (Several PhD thesis)
- Naive Bayesian classifier
  - PEACE (Lee 2009, Lee et al., 2013)
- Neural network
  - Eatough et al. 09, Zhu et al. inpreparing

PEACE: Pulsar Evaluation Algorithm for Candidate Extraction

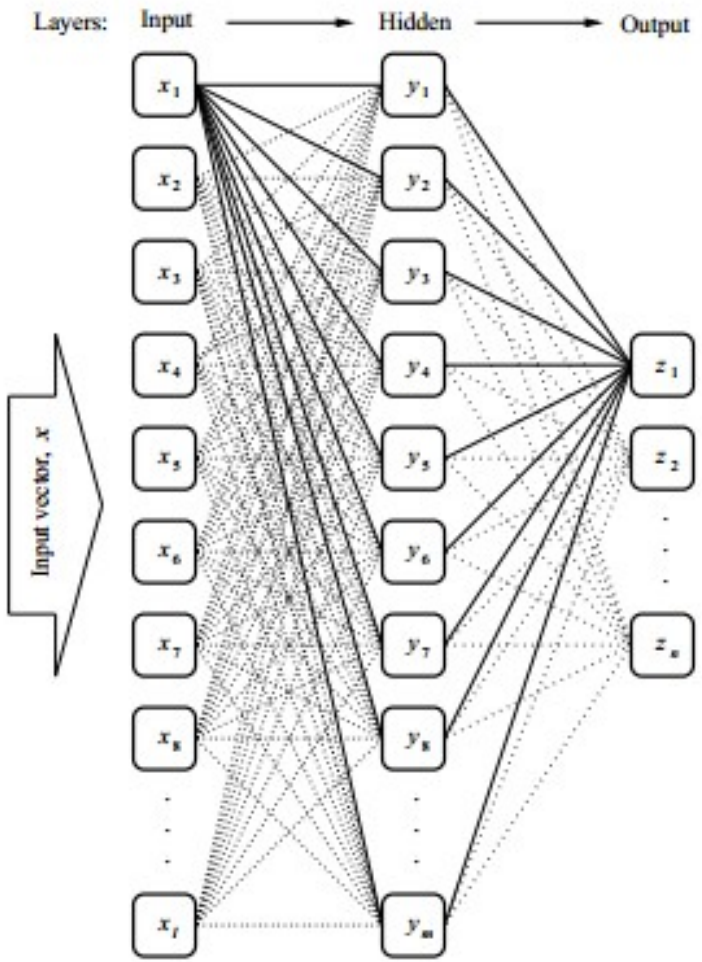
APCS

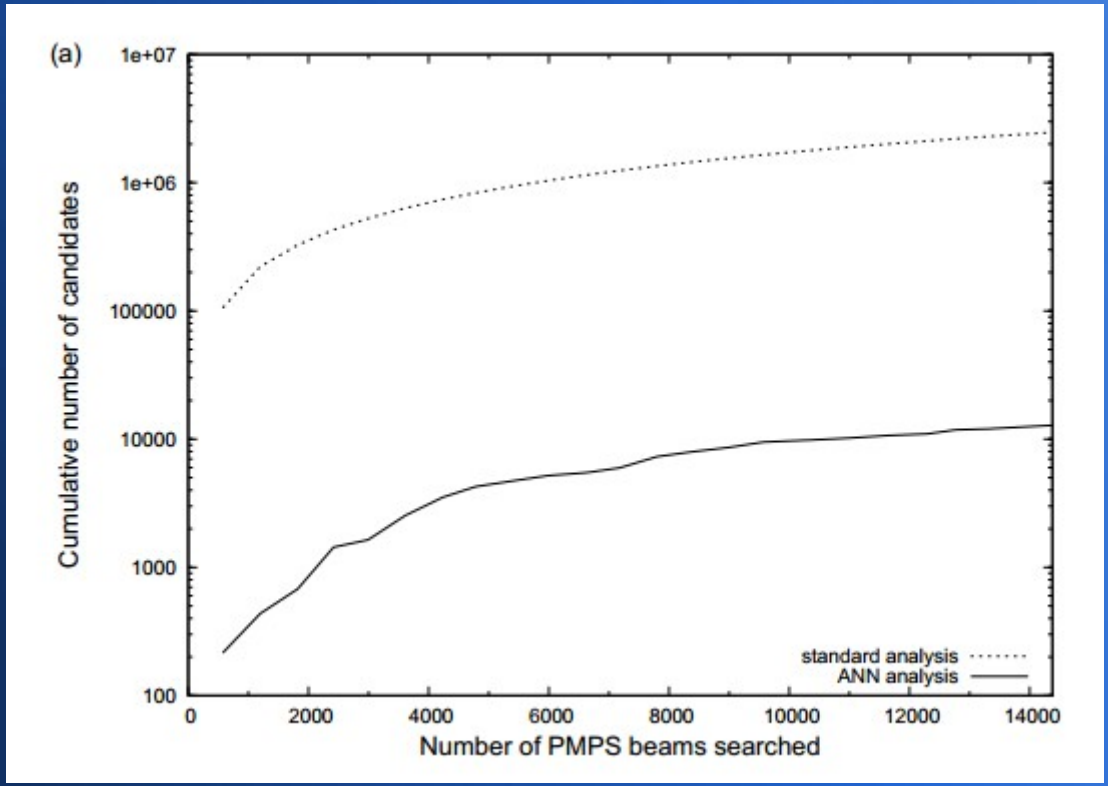
- Pulse Profile
- Persistent
- Bandwidth
- DM qual.
- Period
- Final score



Lee et al. 2013

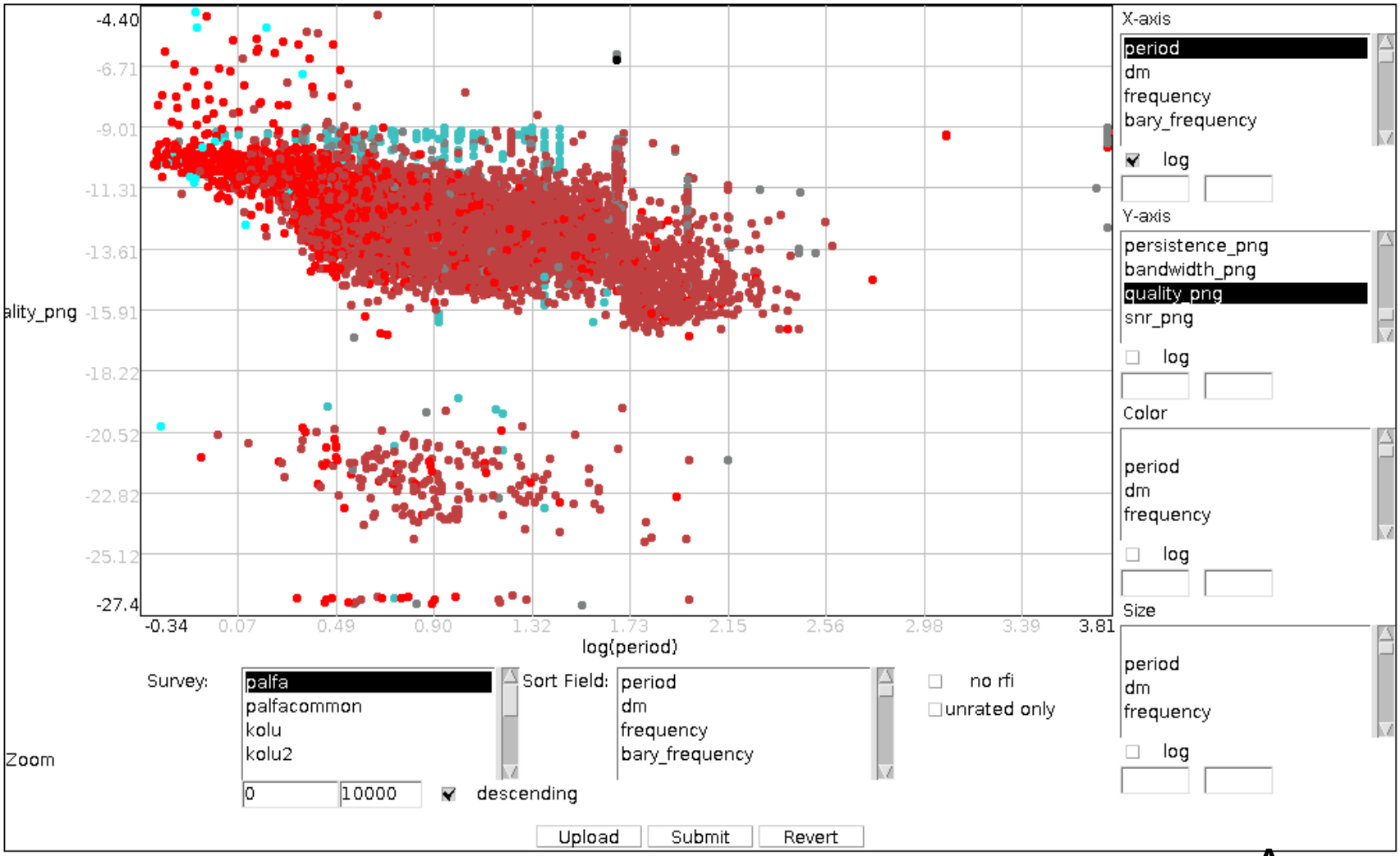
Neural network





Eatough et al. 09

Graphical tools to identify candidates



Arcc viewer

PEACE

```
random@AlphaX:~/work/pulsarsch/dat_tst$ ~/work/autopsr/bin/autos2.exe -ostd -color -f 8bit_714.40ms_Cand.pfd
8bit_714.40ms_Cand.pfd     179.61822868     0.15326063     0.14046060     1.00000000     1.00000000     1.00000000     1.00000000
   20.16394705     0.87634284     1265.05018972          0.71441305     -0.78300660     -2.76439535     -2.76439535
```

```
random@AlphaX:~/work/pulsarsch/dat_tst$ ~/work/autopsr/bin/autos2.exe -ostd -color -f 8bit_204.20ms_Cand.pfd
8bit_204.20ms_Cand.pfd     31.51972545     0.59717765     0.71004247     0.84375000     0.87500000     0.77272727     0.86363636
   0.00000000     0.79010663     1747.68983850          0.20420373     -10.68460260     -5.98291260     -5.98291260
```

Example

What to do next before one can start to do the science?

- Check if it is a known pulsar (ATNF catalog is not complete!)
- Try several times to confirm the source
- Do a griding to refine the source position
- Radiometer to get the flux
- Polarization, scattering, profile evolution etc...
- Start one or two dense observing to determine the system, binary or solitary
- Regular timing, if it is interesting.

Thanks!

If you have any further questions, please contact

kjlee007@gmail.com

Most of the lecture is based on the related software manual, see

http://www.cv.nrao.edu/~sransom/presto/

http://sigproc.sourceforge.net/
http://dspsr.sourceforge.net/manuals/dspsr/

http://psrchive.sourceforge.net/