TransientX: A New High Performance Transient Search Software

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Background

Key Science:

- Pulsar Searching
- Pulsar Timing
- FRB Searching
- ……

FAST

SKA

Huge Data:

- FAST: ~PB/day
- SKA: ~EB/day

We need better softwares!

Background

GPU:
- ~1 RMB per GFLOPS
- High performance

CPU:
- ~40 RMB per GFLOPS
- Easy to program

FPGA:
- ~10 RMB per GFLOPS
- Low power consumption

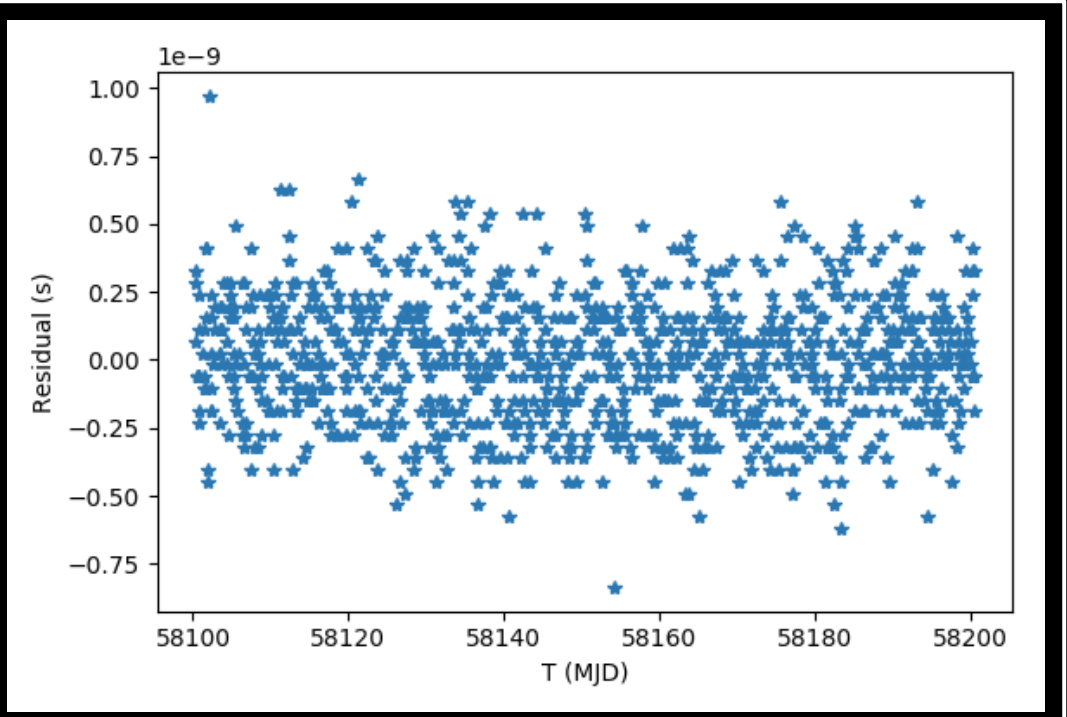
Plan and Current Status

	TransientX	PulsarX	TimingX	BasebandX
Function	transient search	pulsar search	high precision Timing	baseband record coherent dedisperse real-time folding
Language	C++ & Python	C++	Python (current)	C++
Compute platform	CPU (current)	CPU (current) GPU (future)	CPU	FPGA & CPU & GPU

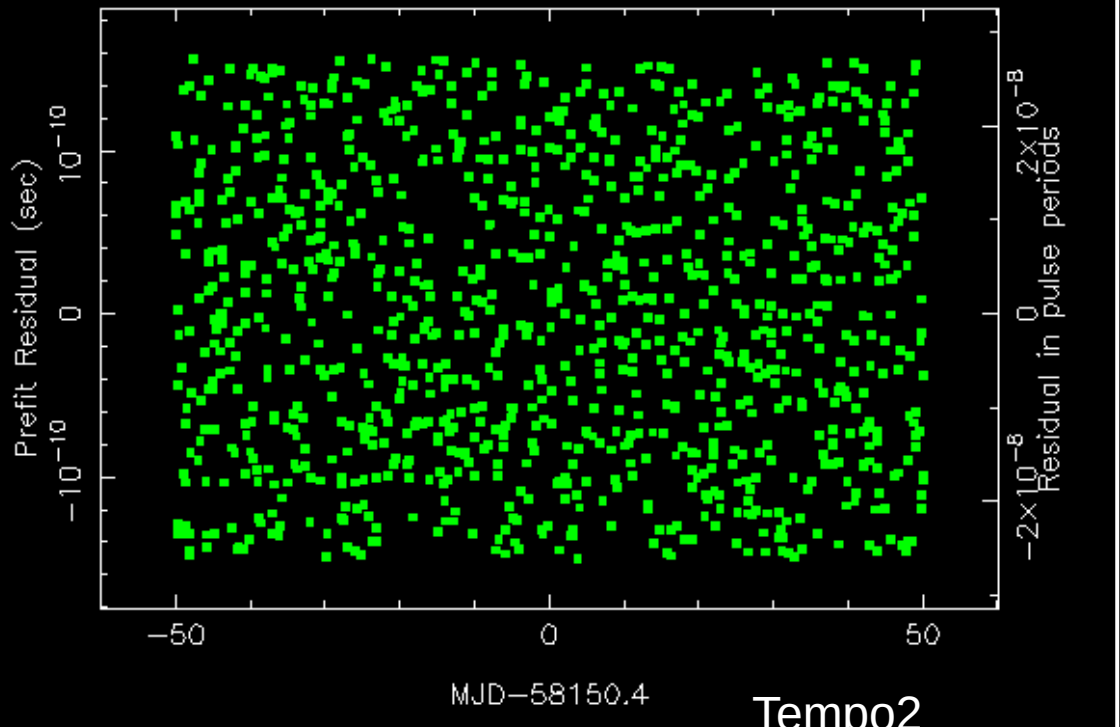
TimingX

< 1 ns !!!

PSRJ	J0437-4715
RAJ	04:37:15.7865145
DECJ	-47:15:08.46158
F0	173.68794630603231663
F1	-1.7283139464042999791e-15
PEPOCH	51194.000124816837459
POSEPOCH	51194.000124816837459
DMEPOCH	51194
DM	2.6469001231221270132
PMRA	121.43799811707980448
PMDEC	-71.437998892339688341
PX	7.1900000000000000001
SINI	0.6788
BINARY	T2
PB	5.741046089016054484
T0	51194.624024826511153
A1	3.3666916222012191204
OM	1.2
ECC	1.9186e-05
PBDOT	3.6400000000000000732
OMDOT	0.0159999997519168371 64
M2	0.2360000000000000001
START	50640.92811624134664
FINISH	52088.897138692392559
TZRMJD	51204.64389248407203
TZRFRQ	1413.3999780849536031
TZRSITE	7
CLK	TT(TAI)
EPHEM	DE405
CORRECT_TROPOSPHERE	0
UNITS	TCB

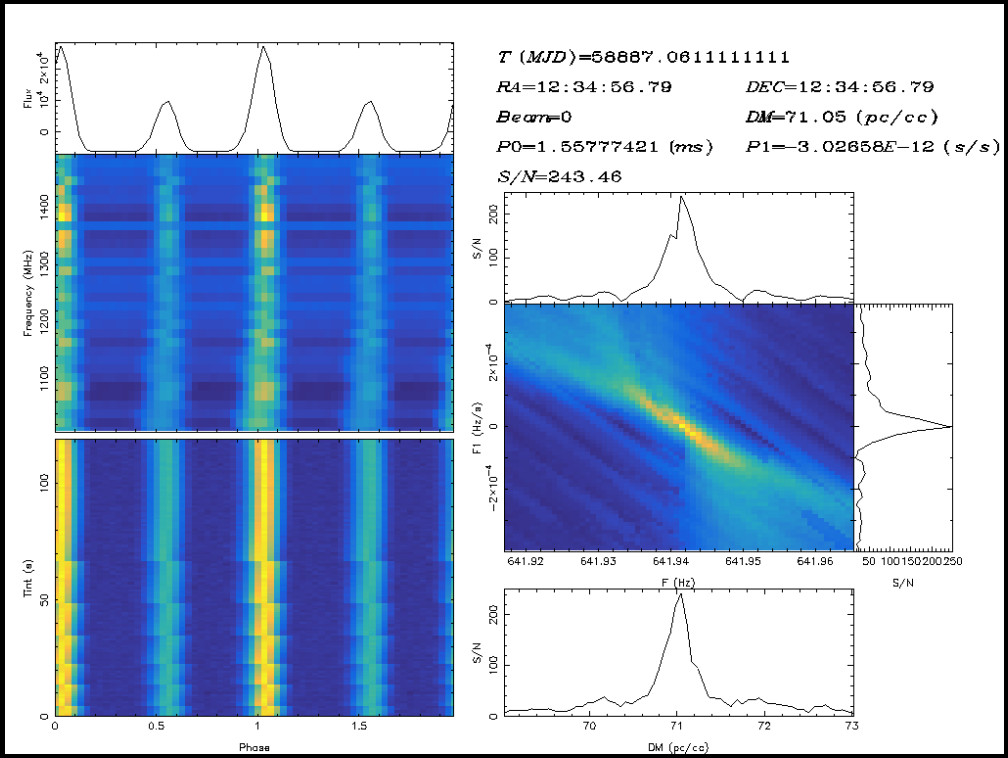


TimingX



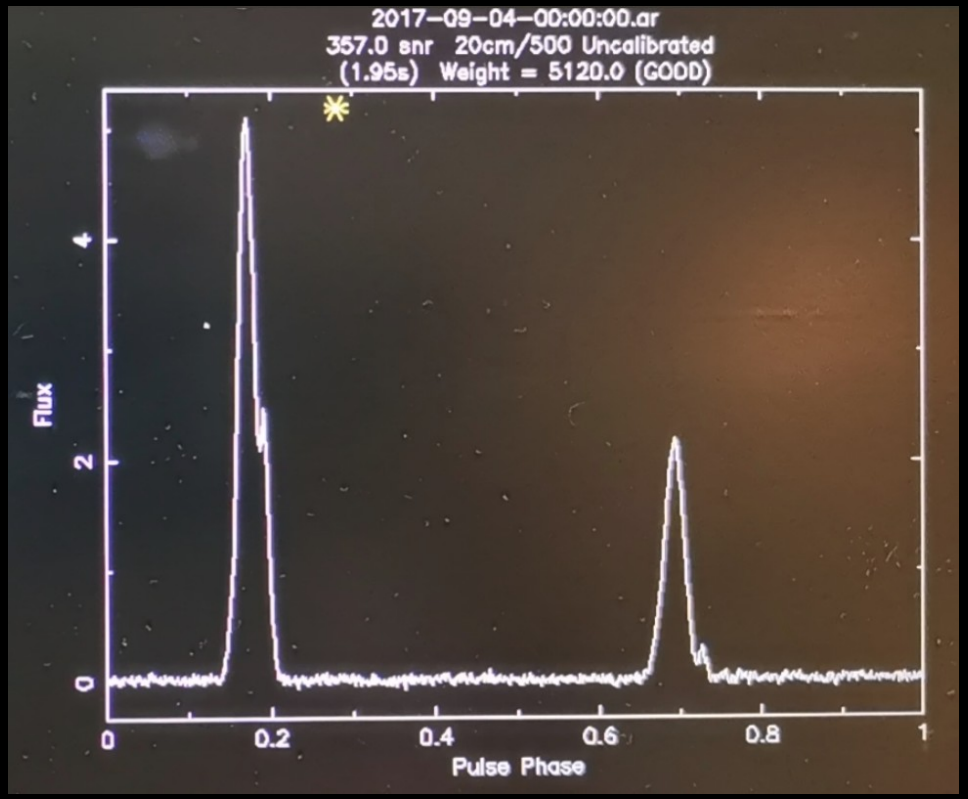
Tempo2

PulsarX



- Still under development
- GPU is needed !

BasebandX



- Coherent dedispersion and fold in real-time on a single compute node !!!
- Fold speed ~10 times faster than dspsr!

TransientX

RFI mitigation

- Zap
- Zero-DM filter (Eatough et al. 2009)
- Zero-DM mathed filter (Men et al. 2019)
- Intensity mask
- ….

Dedispersion

- Subband dedispersion

Pulse Detection

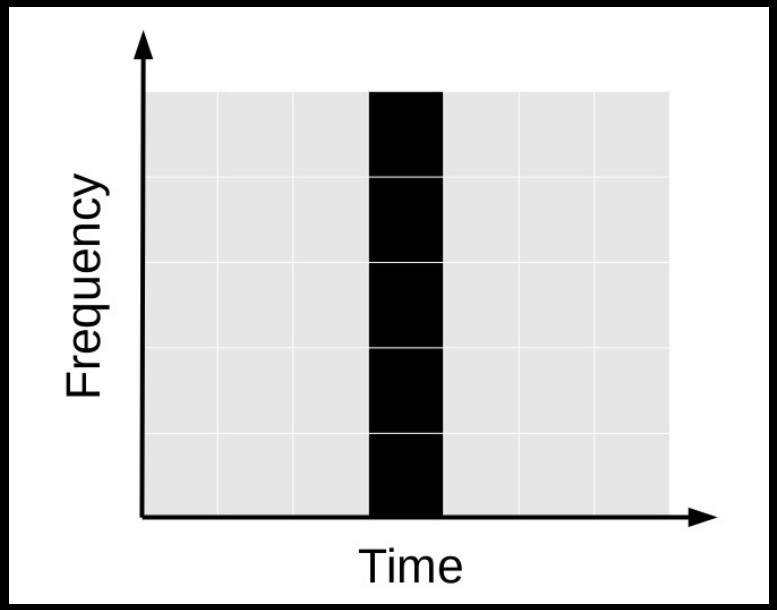
- Matched filter

Clustering

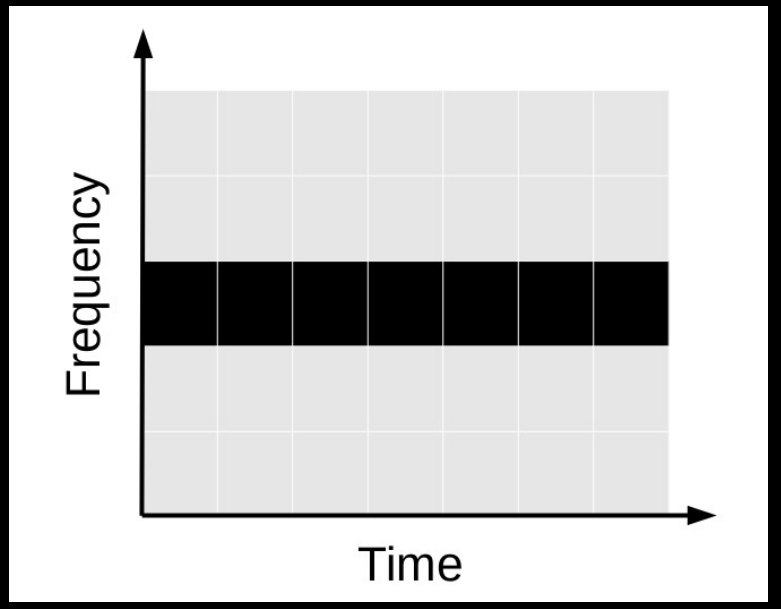
- Density-based spatial clustering of applications with noise (DBSCAN)

Candidate Plot

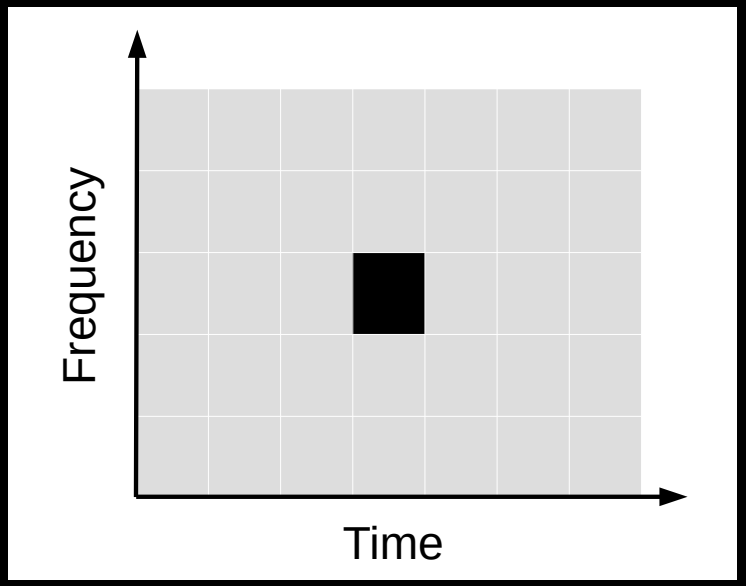
RFI mitigation



Zero-dm filter &
Zero-dm matched filter

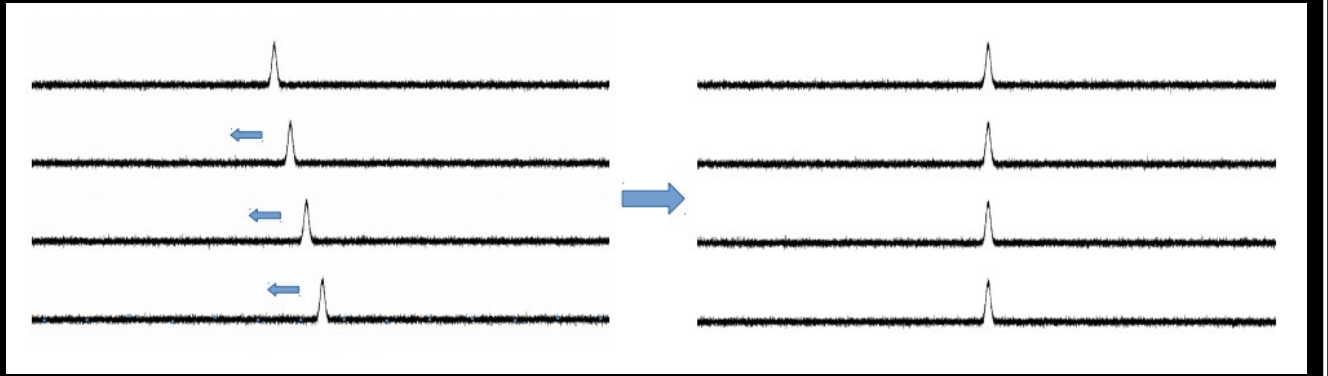


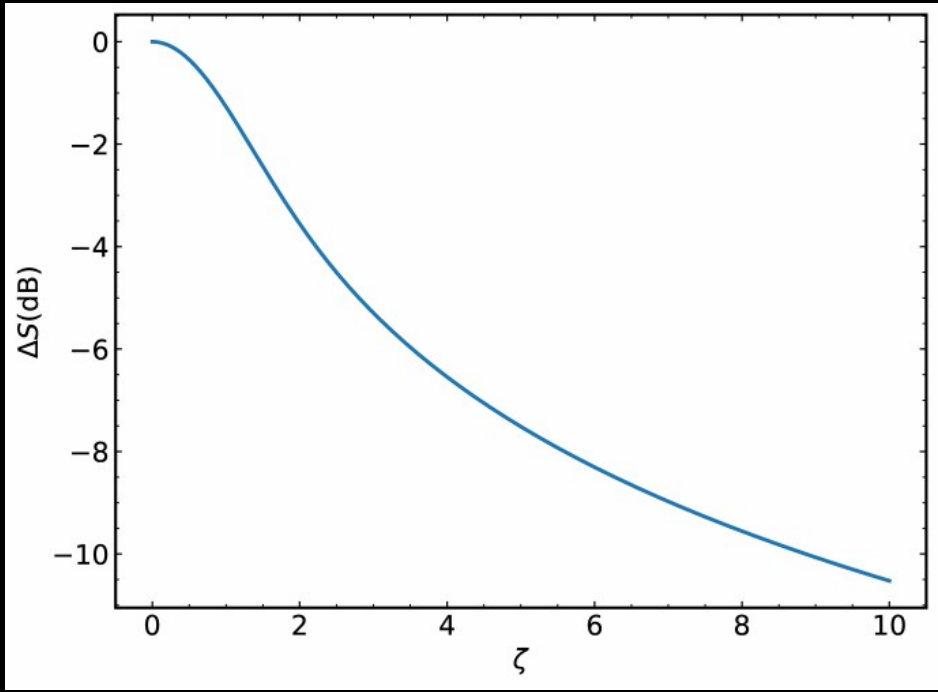
Zap



Intensity mask

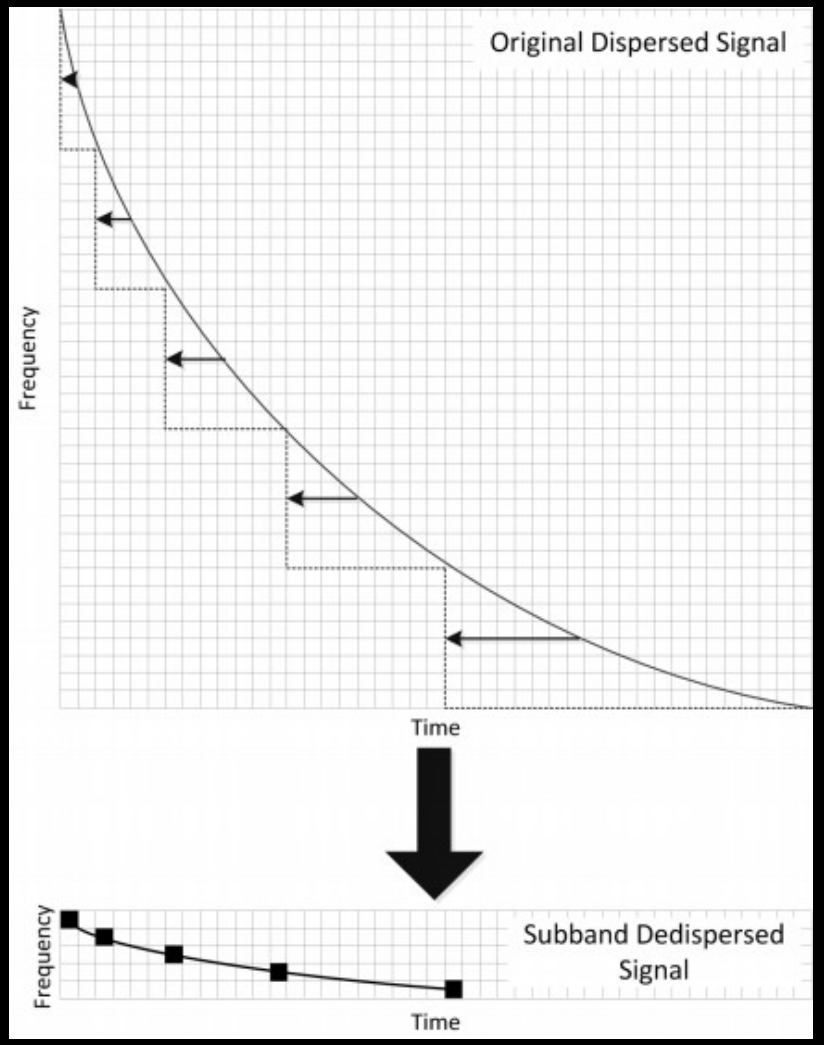
Dedispersion





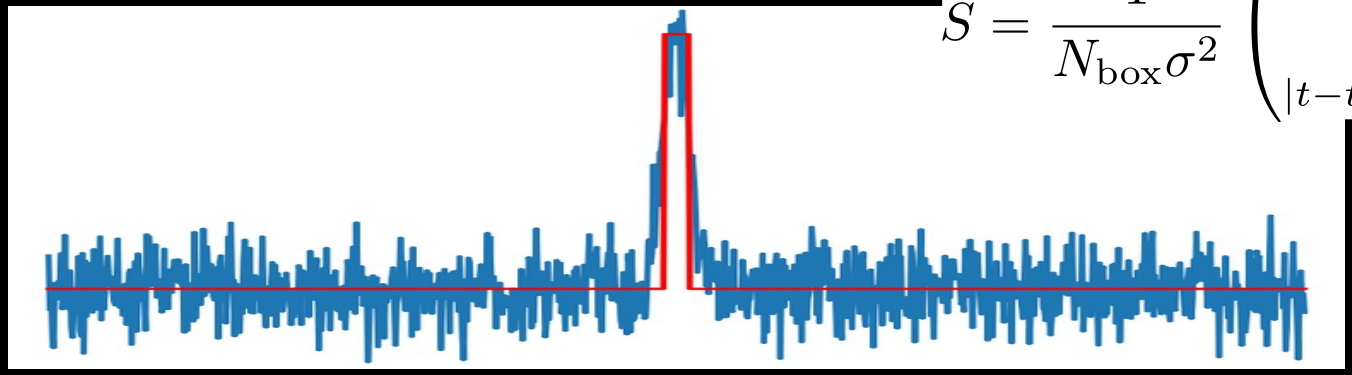
$$\frac{\mathrm{SNR}}{\mathrm{SNR}_0} = \frac{\sqrt{\pi}}{2}\zeta^{-1}\mathrm{erf}\zeta$$

$$\zeta = 6.91 \times 10^{-3}\delta\mathrm{DM}\frac{\Delta\nu_{\mathrm{MHz}}}{W_{\mathrm{ms}}\nu^3_{\mathrm{GHz}}}$$



Magro et al.2011

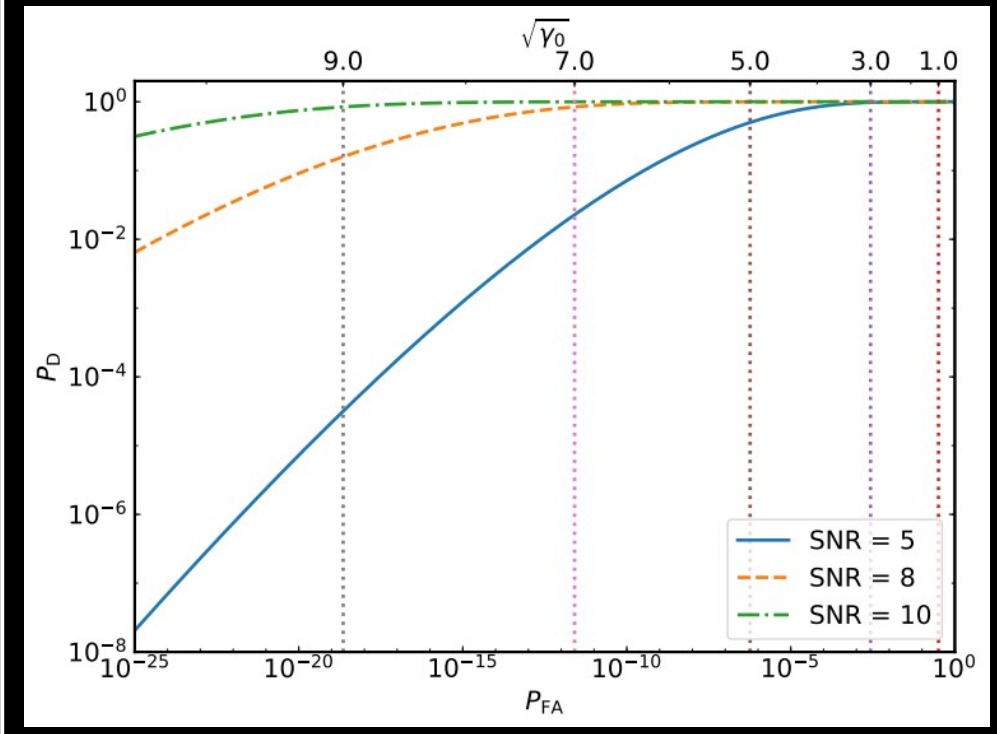
Matched filter

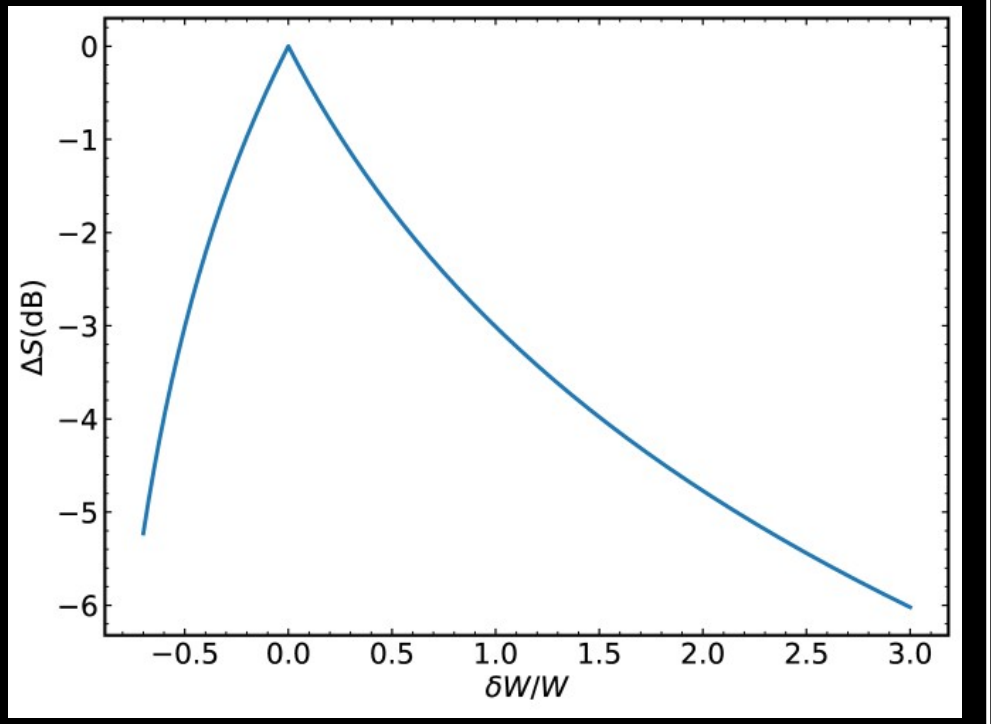


$$S = \frac{1}{N_{\mathrm{box}}\sigma^2}\left(\sum_{|t-t_0|\le W/2} s(t)\right)^2$$

$$\frac{\mathrm{SNR}}{\mathrm{SNR}_0} = \begin{cases} \frac{W}{W+\delta W}, & \text{for } \delta W \ge 0, \\ \frac{W+\delta W}{W}, & \text{for } \delta W < 0. \end{cases}$$

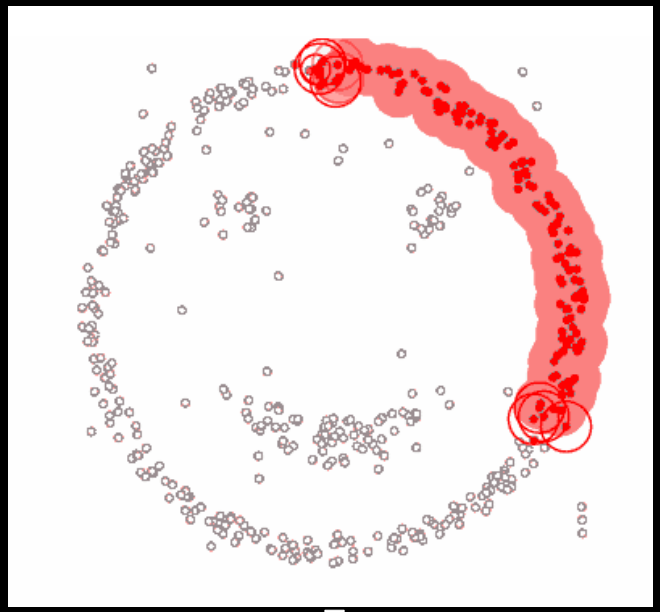
ROC curve





Clustering

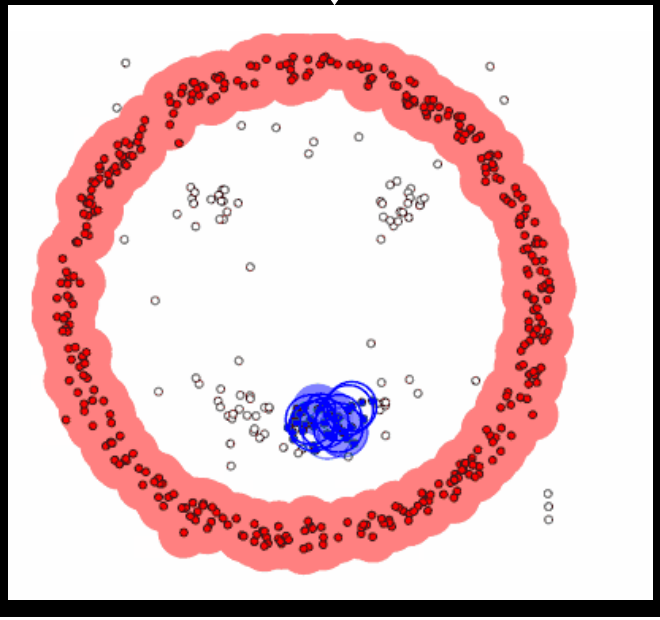
Density-based spatial clustering of applications with noise (DBSCAN)

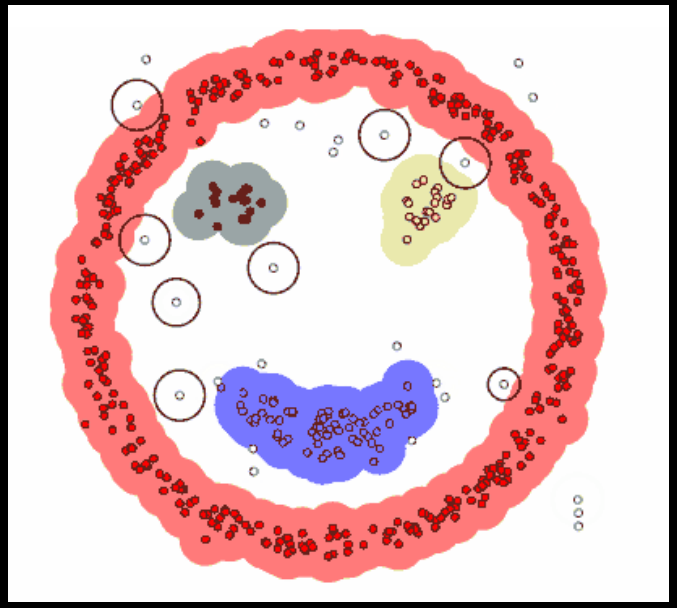


S(DM, width, time)

Compress width

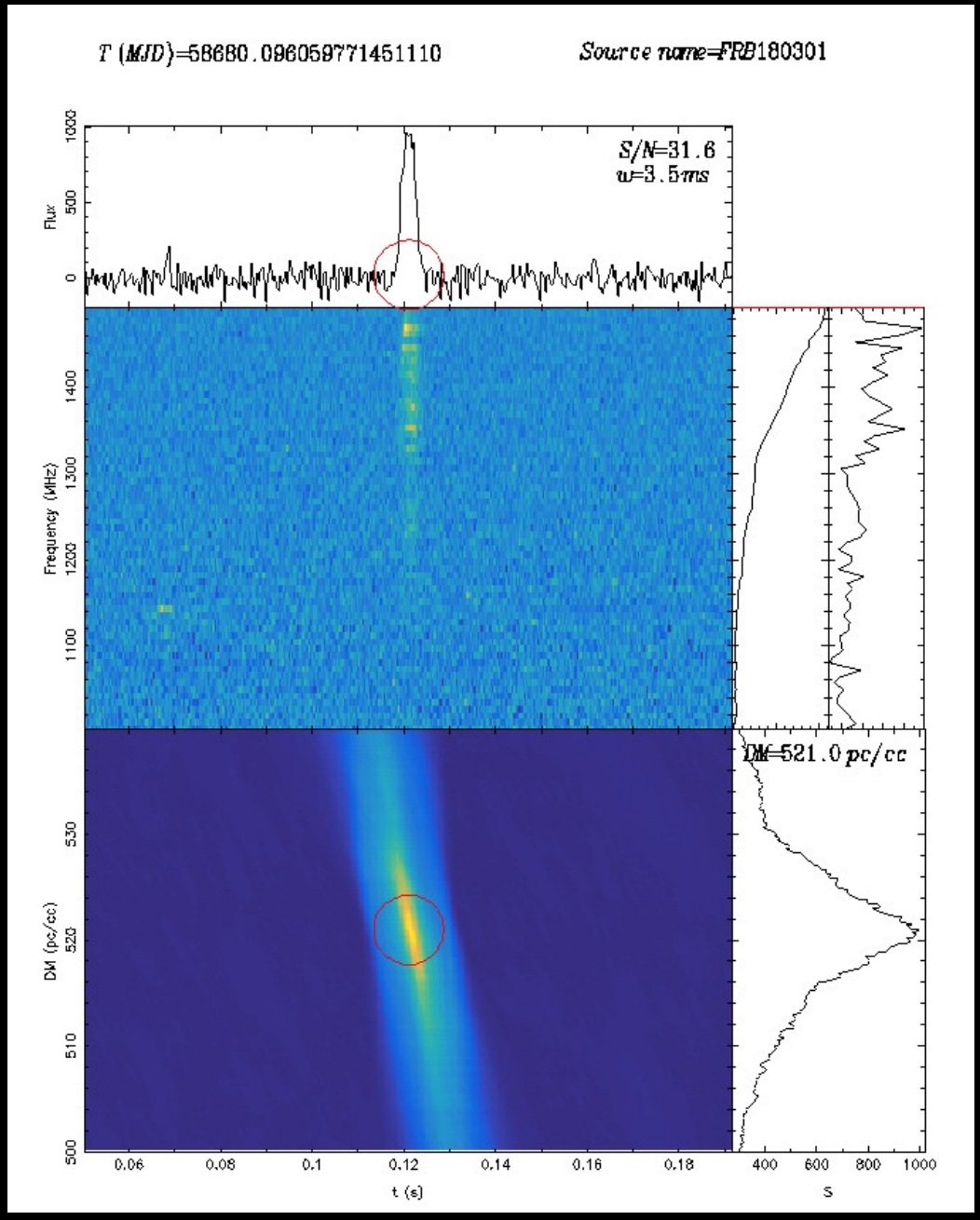
S(DM, time)





Candidate Plot

Pass the test of fast data!
Catch all bursts successfully!



Benchmark

very very very fast!!!

- Statistical optimal
- DM ->13000 pc/cc, Width ->100 ms real-time search using single cpu core!!!
- ~10 times faster than BEAR
- ~400 times faster than Heimdall !!!

- Better algorithm
- Better software design
- Better software optimization

Summary

- Start to develop our own softwares and the results are pretty good!
- TransientX: can be more perfect
- PulsarX: explore new algorithm, CPU -> GPU
- BasebandX: a low cost baseband backend (<200,000 RMB vs GUPPI(NRAO) 2000,000RMB)
- TimingX: can add more functions

Thank you!

The future must be better!