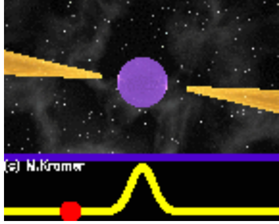


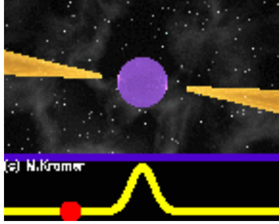
Pulsar Studies with the Shanghai TianMa Radio Telescope

Speaker： Zhen Yan*

Shanghai Astronomical Observatory, CAS

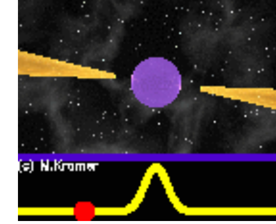
*On behalf of the Shanghai TianMa Radio Telescope Team

*Thanks to cooperators from XAO/NAOC/YNAO/PKU/GZU/HKU…



Outline

- Introduction to Shanghai TianMa Radio Telescope
  - The history of TRMT
  - Receivers of TMRT
  - The pulsar backend of TMRT
- Some pulsar observation results
  - Pulsar timing
  - Multi-frequency observation
  - FRB hunting
  - Pulsar astrometry with VLBA
- How to apply for TMRT observation time
- Conclusion

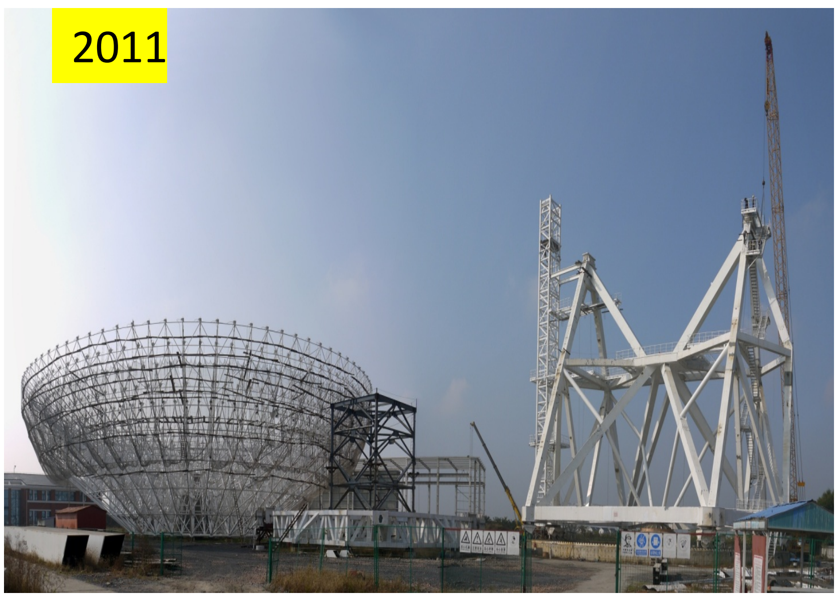


Introduction to Shanghai TianMa radio telescope

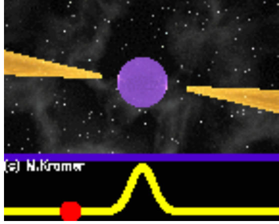
- Newly built 65-m in diameter fully steerable radio telescope located in Song-Jiang district of Shanghai city;
- It is called Tianma Radio Telescope (TMRT), because it is near the small mountain named TianMa;
- Phase of the SH-65m project
  - Funded in 2008;
  - Started manufacturing in 2009;
  - 1st phase was finished in July 2013, four low frequency receivers (L, S, C, X) have been installed.
  - Have been expanded to Q-band (43GHz) in 2017 using active surface system to make sure its efficiency

天马望远镜
Tian Ma Telescope

2008-2009
2010-2013
2014-2017



Comparison TMRT with others of the same architecture



Frequency: 1.25-50.0 GHz, eight receivers; four low frequency receivers which are suitable for normal pulsar observations.

		GBT	Effelsberg	Parkes	Lovell	Tianma
L	Freq-R	1.15-1.73	1.27-1.45, 1.59-1.73	1.2-1.8	1.25-1.50, 1.55-1.73	1.25-1.75
	SEFD	10	20,19	31	36,65	31
S	Freq-R	1.73-2.6	2.20-2.30	2.2-2.5	-----	2.2-2.4
	SEFD	12	300	25	-----	≥31
C	Freq-R	3.95-5.85	5.75-6.75	4.5-5.1	6.0-7.0	4.0-8.0
	SEFD	10	25	61	80	28
X	Freq-R	8.00-10.1	7.9-9.0	8,1-8.7	-----	8.2-9.0
	SEFD	15	18	170	-----	≥38

Note: **System Equivalent Flux Density** (SEFD): $SEFD = \frac{2k_B T_{sys}}{A_e}$

DIBAS-The Digital Backend System for Tianma

- Combination of GUPPI (pulsar system) and Vegas (spectra line system) of NRAO
- In comparison with GUPPI, DIBAS is an **updated system**. Maximum bandwidth that GUPPI can support is 800MHz (both coherent & incoherent de-dispersion).

Coherent:
- Both the inter- and intra-channel dispersion effects can be eliminated.
- Dense computation
- Accomplished with 8 GPU computers
- Maximum bandwidth supported : 800MHz

Coherent de-dispersion search

Incoherent de-dispersi

DIBAS for TM

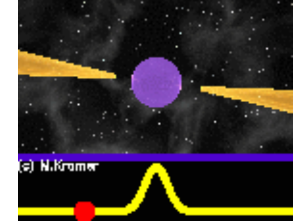
Coherent de-dispersion online folding

Incoherent de-dispersion onli folding

As DIBAS is an updated system from NRAO, we have to spent a lot of time on testing!

Incoherent:
- Dispersion effect in sub-band can not be eliminated;
- Maximum sub-channel number: 8192
- Maximum bandwidth supported : 6000MHz (2000MHz/Roach)

(GTX-580 GPU)



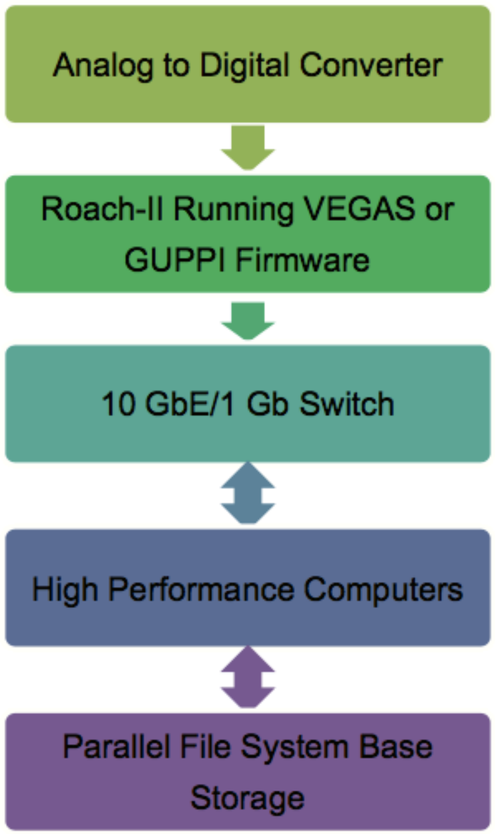


Figure 1. The block diagram of the DIBAS

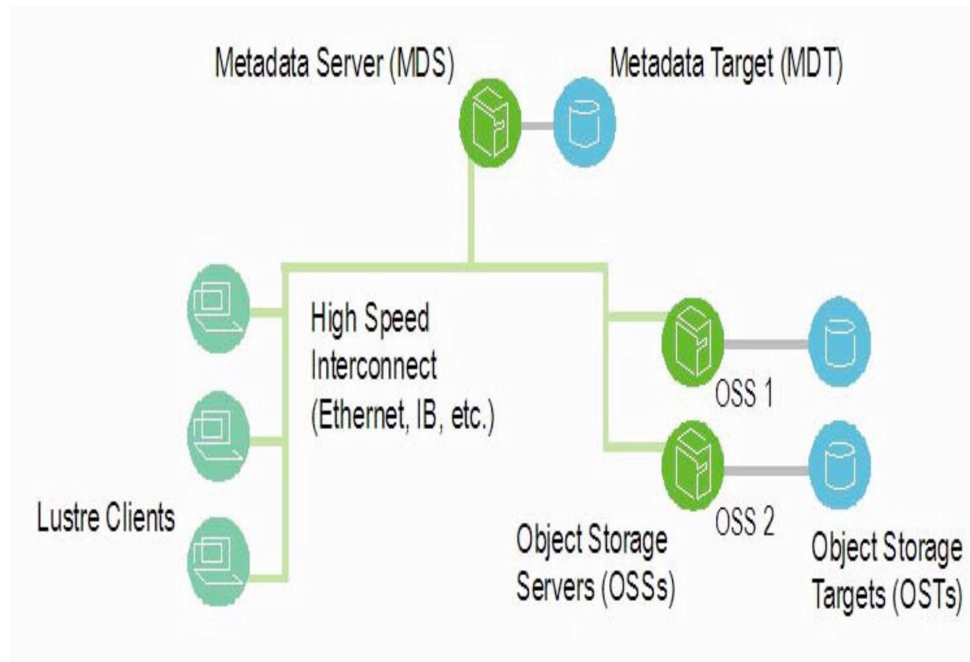
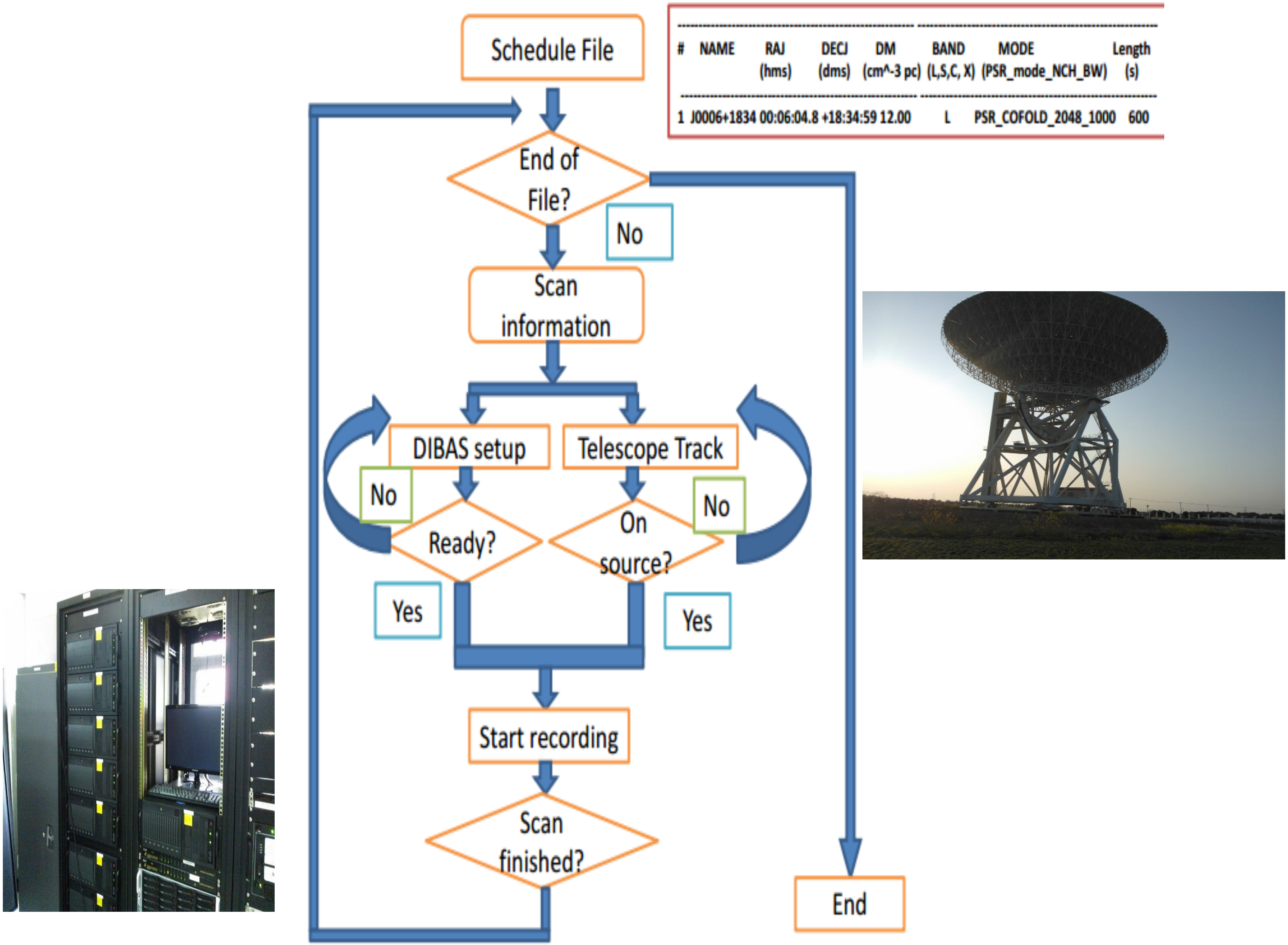


Fig.Lustre File System

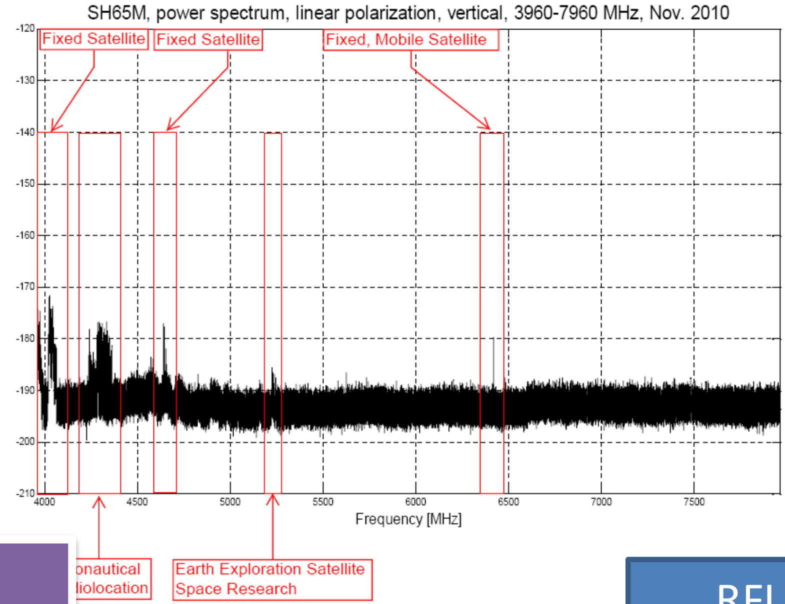
- Maximum data recording speed: 300MB/s (per thread)
- Highest time resolution: 40.96μs


Schedule File
NAME RAJ (hms) DECJ (dms) DM (cm^-3 pc) BAND (L,S,C, X) MODE (PSR_mode_NCH_BW) Length (s)
1 J0006+1834 00:06:04.8 +18:34:59 12.00 L PSR_COFOLD_2048_1000 600
End of File?
No
Scan information
DIBAS setup
Telescope Track
No
Ready?
On source?
No
Yes
Yes
Start recording
Scan finished?
End

An example of schedule file

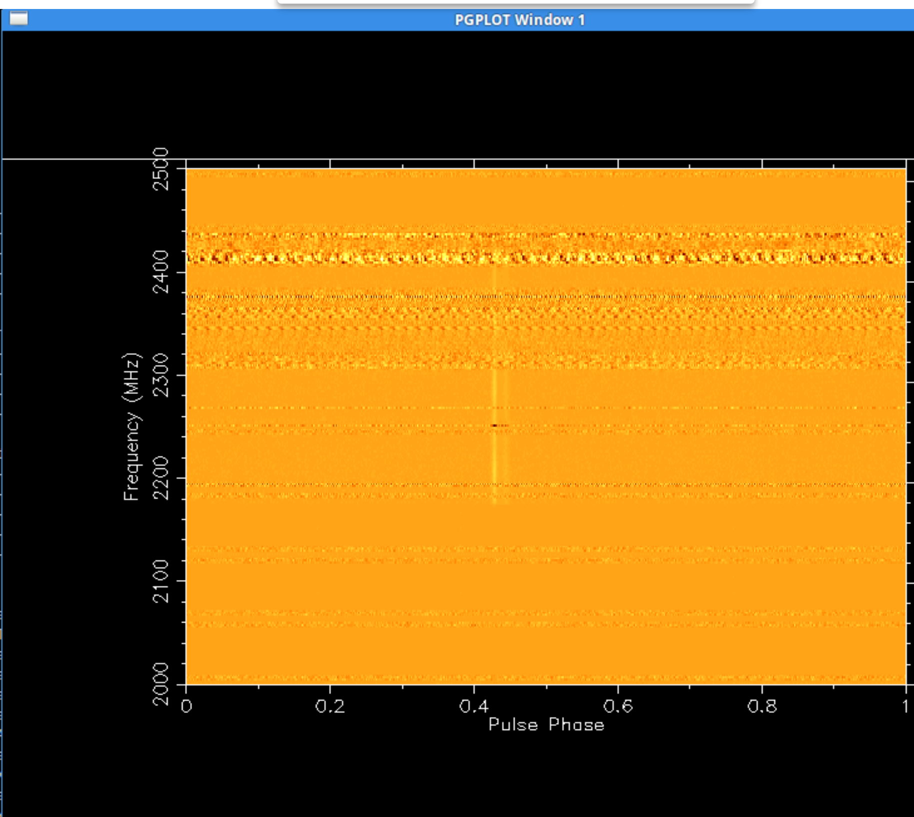
```
 TITLE: Pulsar observation
PROJECT-ID: PSR-TMP001-YZ-02-18

#PI-INFORMATION:
####################################
PI-NAME: ********
PI-EMAIL: ********
PI-TELEPHONE: ********
PI-INSITITUTE: SHAO
PI-ADRESS: NO.80 NanDan Road, Shanghai
####################################

#OBSERVER-INFORMATION (input by the Observer)
####################################
OBS-NAME: ********
OBS-EMAIL: ********
OBS-TELEPHONE: ********
####################################

#TIME OF OBSERVATION (Year-Month-Day)
OBS-TIME: 2017-02-18(BJ-08:30:00)


#POLARIZATION INFORMATION (Only needed by the pulsar searching mode, "FULL" or "IONLY").
POLARIZATION: IONLY


SOURCE-TABLE:
##############################################################################################################
#   NAME          RAJ           DECJ           DM              MODE              BAND      T-INT     LENGTH
#                (hms)         (dms)        (cm^-3 pc)  (PSR_MODE_NCH_NBIN)    (L,S,C,X)    (s)       (s)
##############################################################################################################
 1     B1742-30     17:45:56.3     -30:40:23.5     88.37    PSR_INFOLD_512_1024    C   40.96e-6     600
 2     B2319+60     23:21:55.2     +60:24:30.7     94.59       PSR_INSRCH_512_*    C  140.96e-6    1800
```

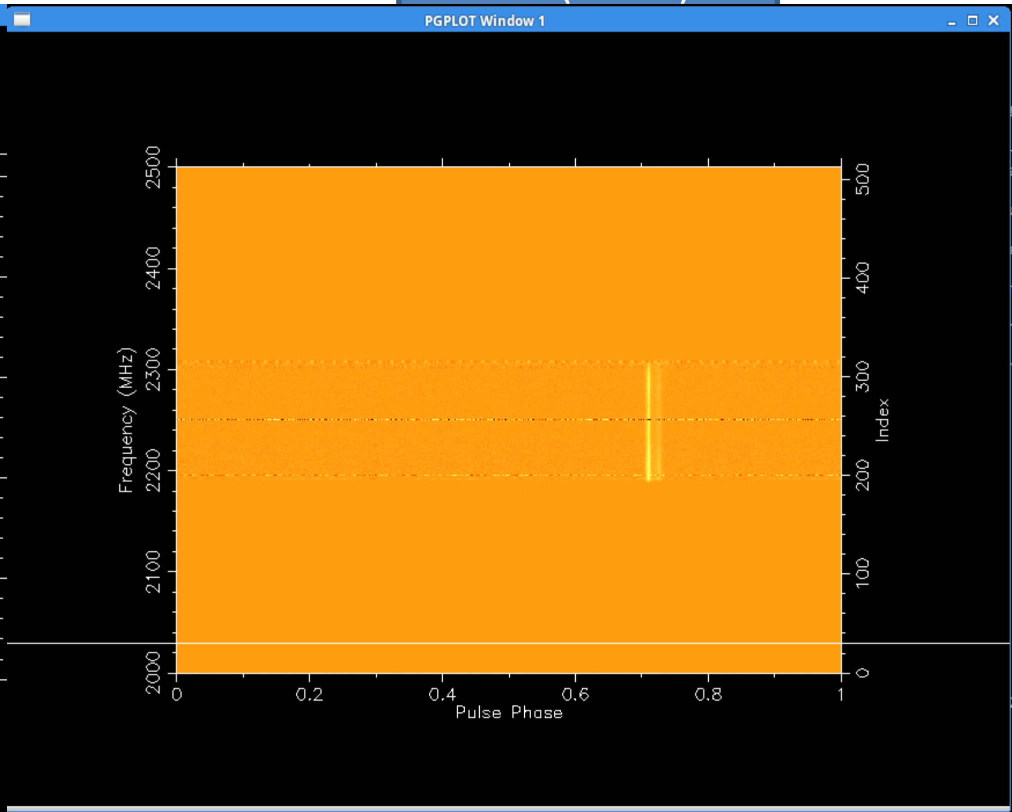
FTP Download



RFI (Before!)

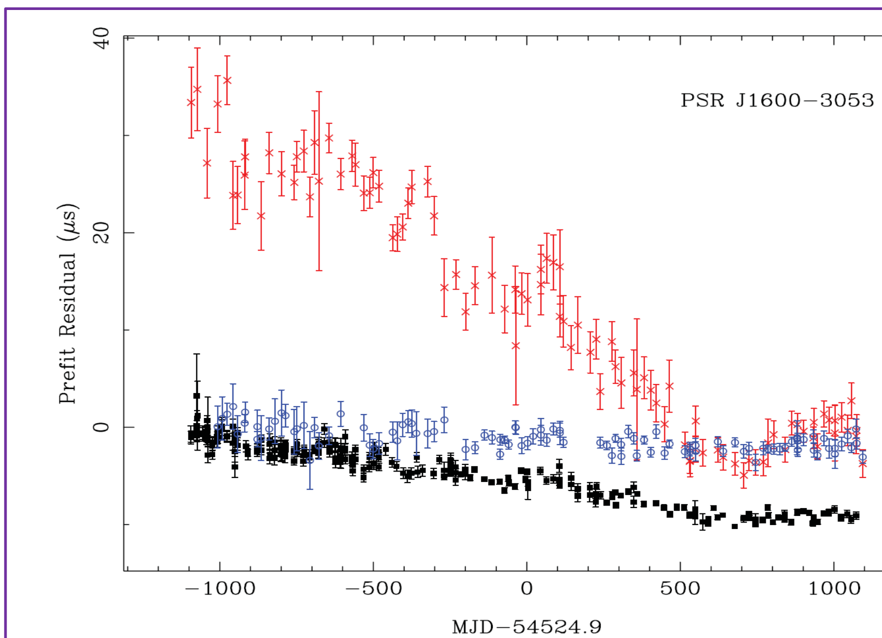
RFI (Now!)

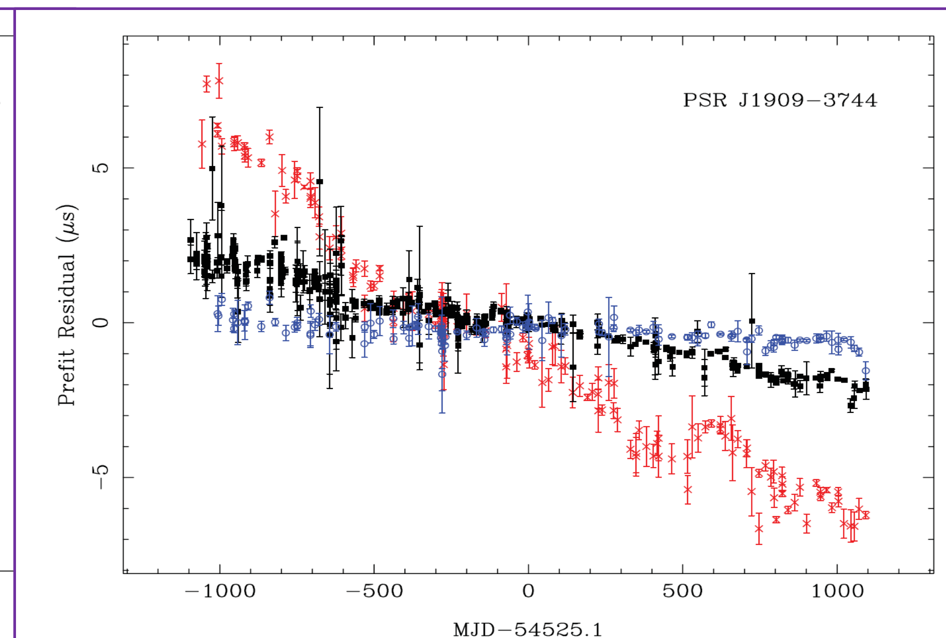




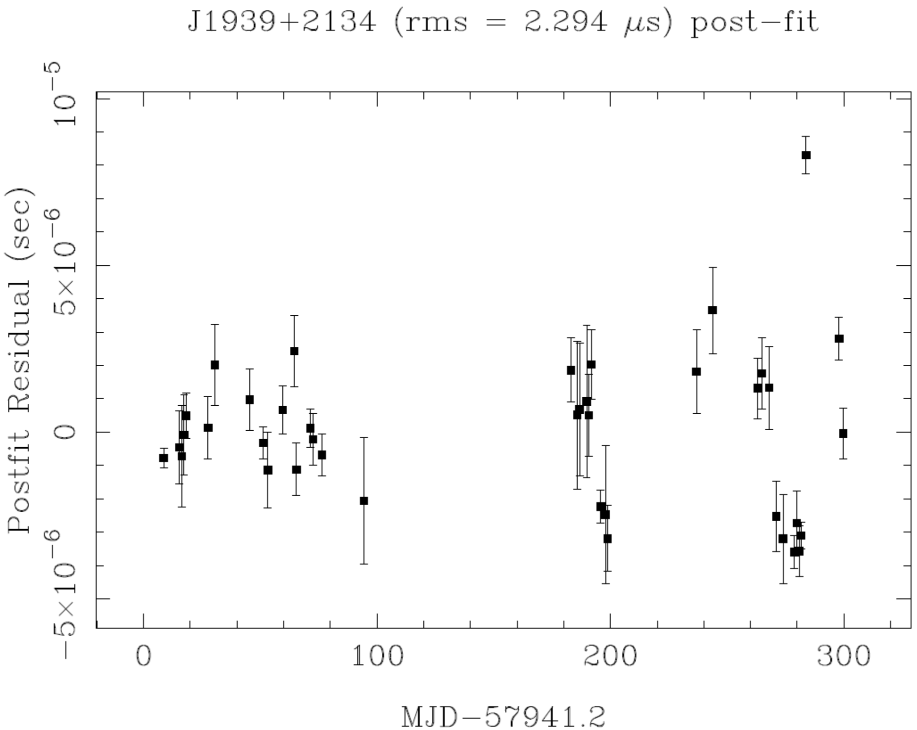
- RFI removing making it is possible to monitor the timing properties of 350 pulsars at 2.3 GHz;
- S1400 of some pulsars less than 1mJy
- Less DM effects compared with L-band (or lower frequencies)

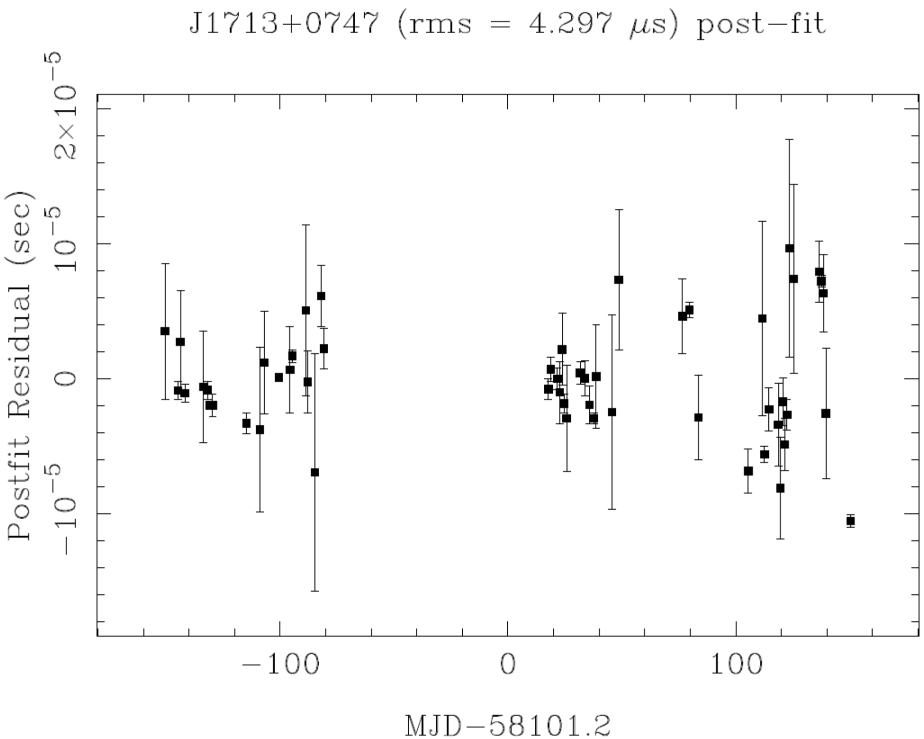
> - Parkes pulsar timing：
> - Red:700MHz；
> - Black： 1400 MHz；
> - Blue： 3.1 GHz (Lowest RMS; Most stable)





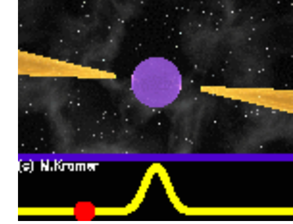
Timing results of some pulsars





Some glitch phenomena are detected.

See Jie Liu's talk for more information



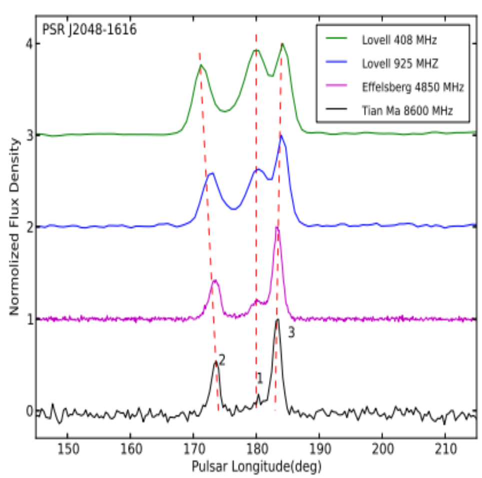
Multi-frequency observation of integrated pulsar profile and its radiation mechanism

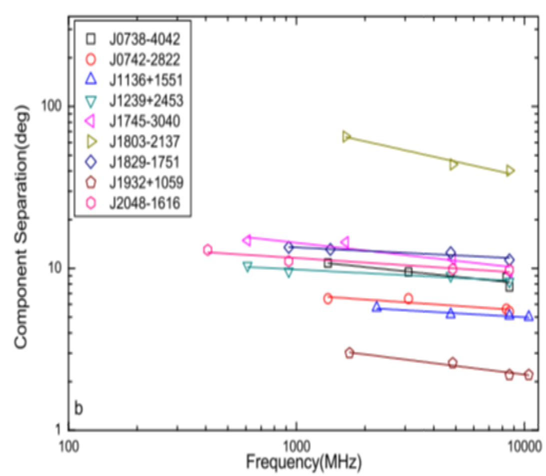
☐ 26 integrated pulse Profiles

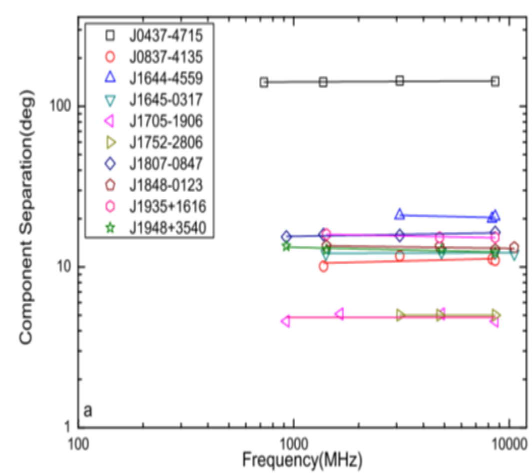
- The quality of 26 profiles are comparable with the previous from Effelsberg or Parkes.
- Mean flux densities of these pulsars are estimated and the calibrated pulse profiles are provided.
- 11 profiles of this sample are obtained for the first time at 8.6 GHz.

☐ Relationship between the component separation of 19 integrated pulse profiles and frequency

- firstly, the separation in 9 pulsar profiles decrease with the increasing of frequency, which is roughly agreement with radius-to-frequency mapping (RFM);
- secondly, the separation in 10 pulsar profiles are nearly constant, which seems not in accordance with RFM, and could be due to the presence of the smallest separation.







See Rushuang Zhao's talk for more information

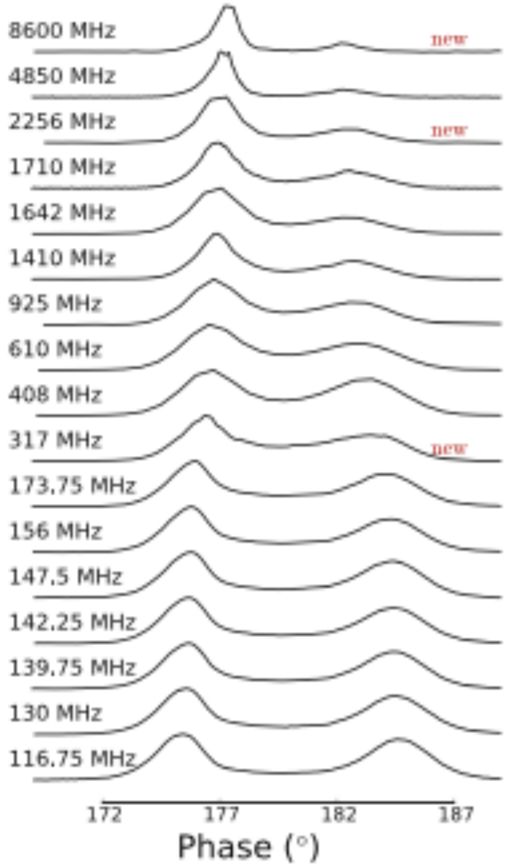
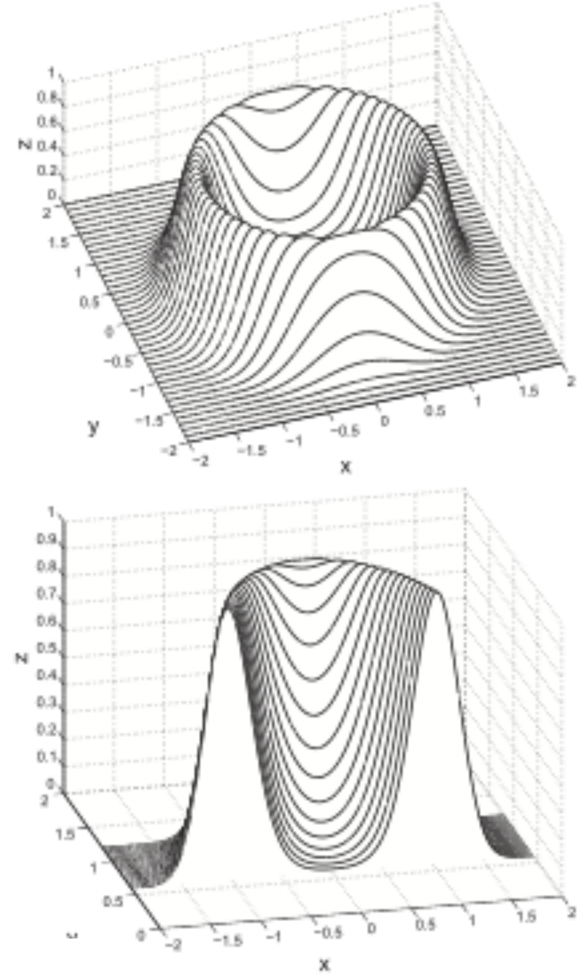


Figure 1. Multi-frequency profile of PSR B1133+16. All profiles have been normalized by their maximum flux densities and are aligned at phase ϕ_0, which was obtained by fitting the profile to Equation (6).



adiation conal component; bottom: cut-out section. The height ity of the radiation beam. The curves show sections along the ., pulse profiles. The bridge component is clearly seen.

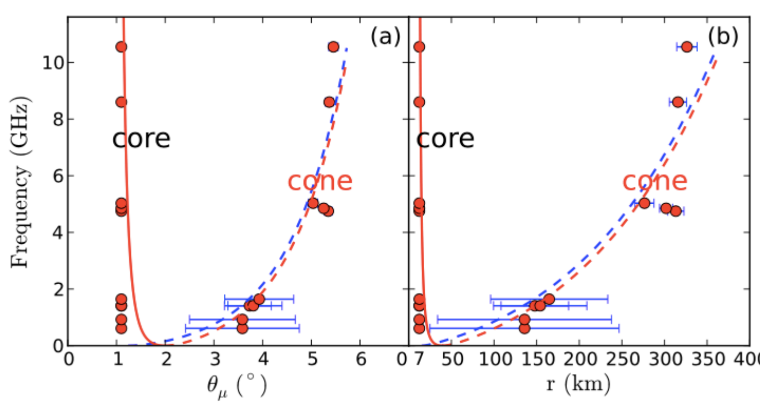
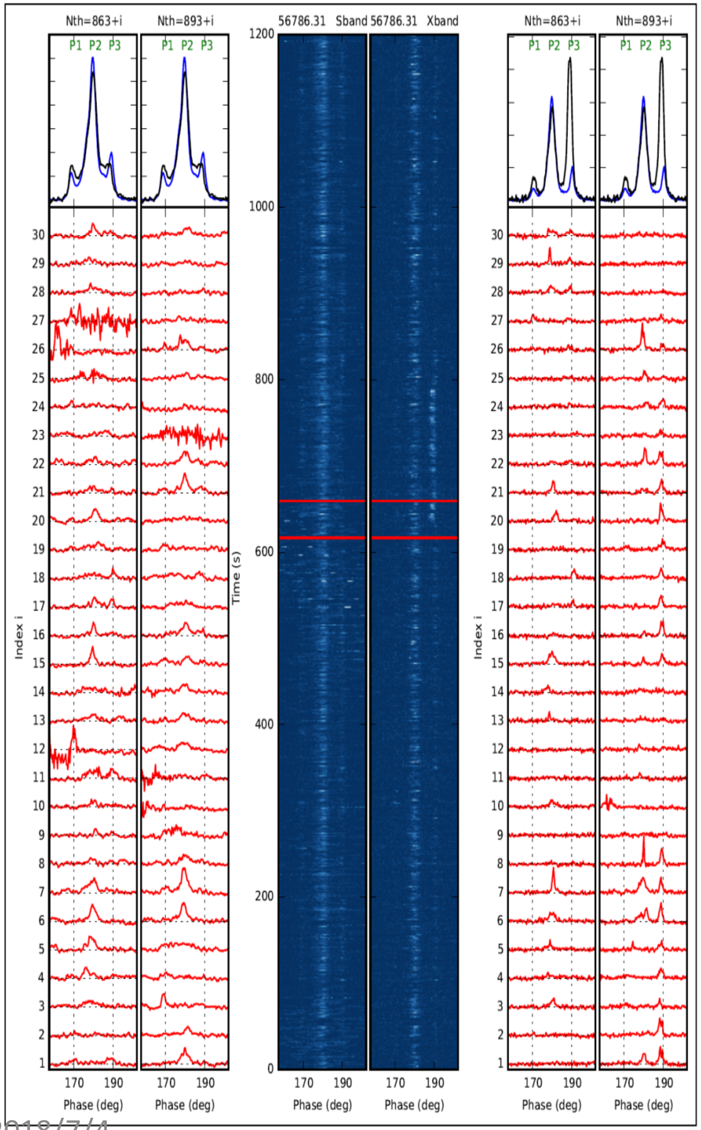


Figure 6. As for Fig. 5, but for PSR B1642−03 with $\gamma_0 = 1.6 \times 10^3$ and $k = -0.02$. The fitting curves are plotted with solid curves for the core component and dashed curves for the cone component.

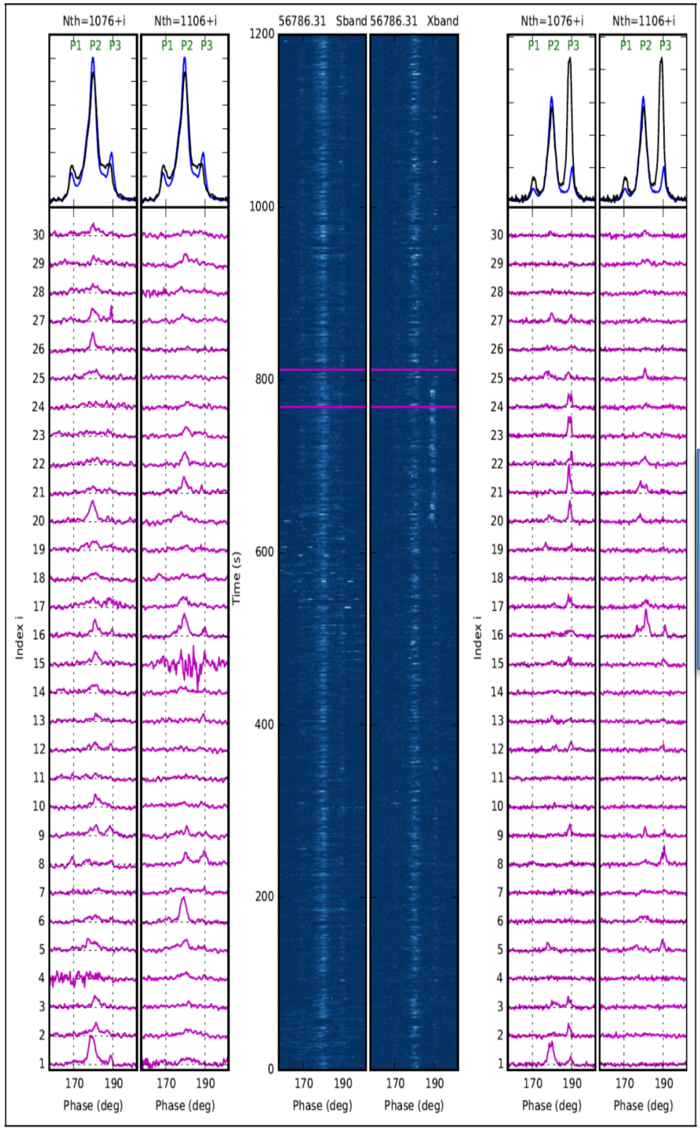
J.G. Lu et al., ApJ, 2016

L.H. Shang et al., MNRAS, 2017

Dual-frequency mode change studies at single-pulse level



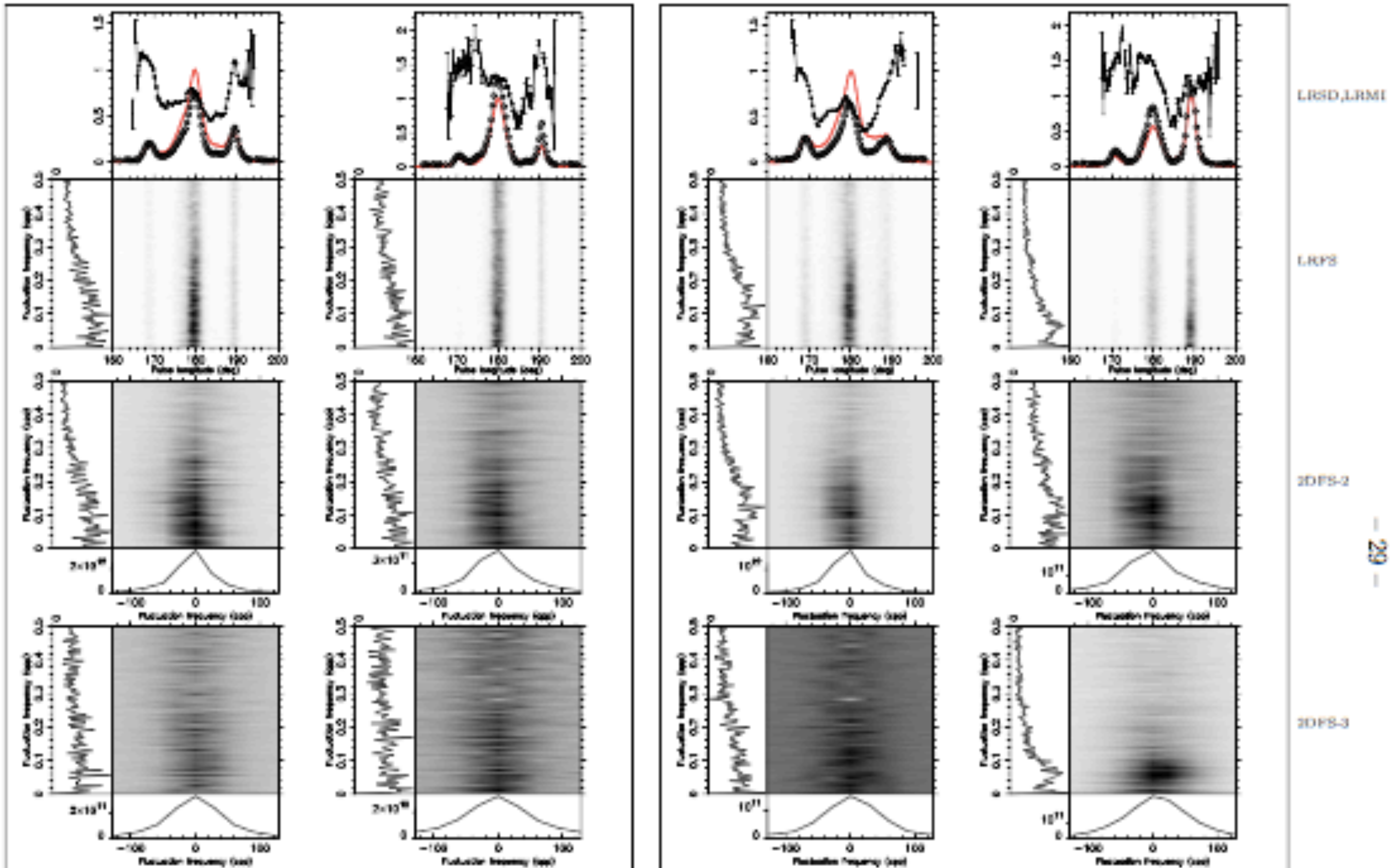
(a) Normal to abnormal mode



(b) Abnormal to normal mode

- B0329+54
- S/X−band

Different drifting properties on different mode and frequency

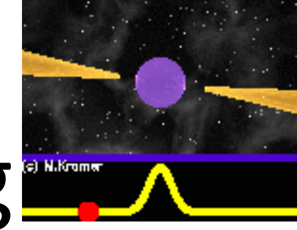


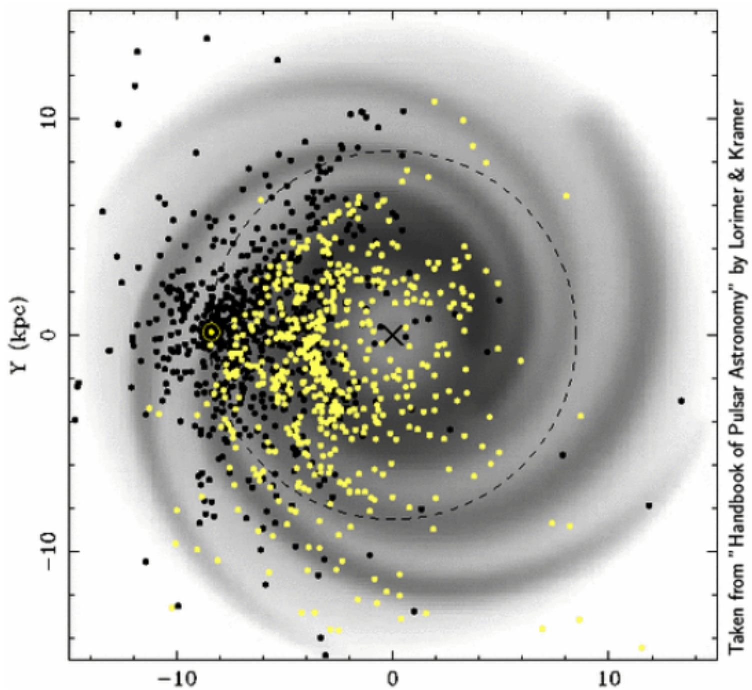
(a) Normal mode (Left: 13 cm; Right: 3 cm) (b) Abnormal mode (Left: 13 cm; Right: 3 cm)

Fig. 7.— Subpulse drifting analysis results for (a) normal mode and (b) abnormal mode observations at both 13 cm and 3 cm for PSR B0329+54 on MJD 56785.20 ($N=16$). The top row shows the longitude-resolved rms fluctuation and modulation index, along with the relevant integrated profile (in red). The second row gives the longitude resolve fluctuation spectrum along with the integrated spectra on the left side of each plot. The third and fourth rows give the two-dimensional fluctuation spectra for C2 and C3 respectively, with the integrated spectra to the left and below.

Zhen Yan et al., ApJ, 2018

High Frequency Pulsar Hunting

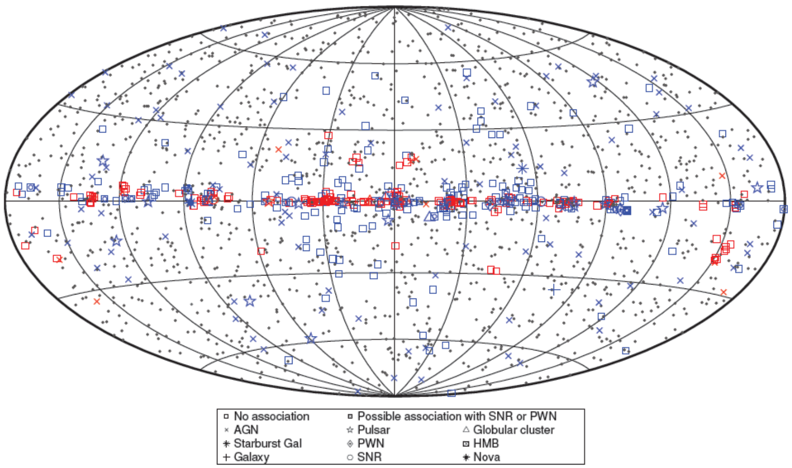




Yellow ： discovered by 1.4GHz survey
Black ： discovered by 430MHz survey

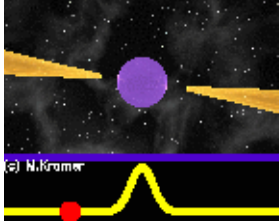
- Low frequency is blocked by thick plasma around the Galactic center
- lower galactic noise background, as the galactic noise is steeper power law
- weaker dispersion effect, as the dispersion delay is in proportion with the square of observation frequency
- weaker scattering, as the width of scattering broadening is in proportion of 4^{th} power of observation frequency;
- weaker scintillation

Unassociated γ-ray point sources

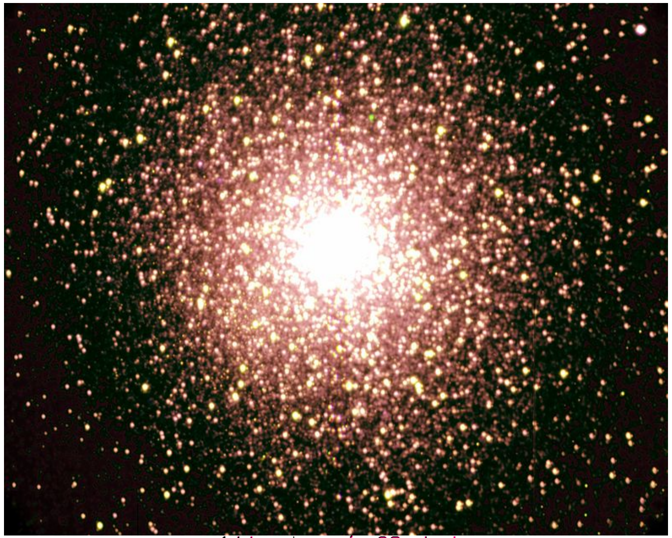


1873 sources, including 1062 associated with blazars and other AGNs, 11 GCs, 5 binaries, 576 «unassociated».

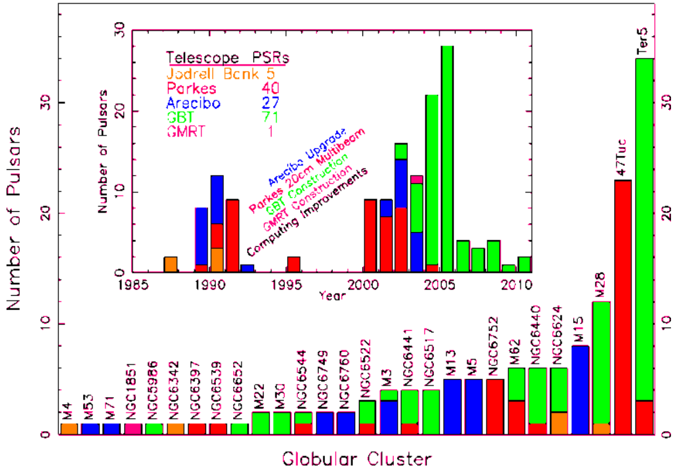
- GBT search 27 bright γ-ray unassociated source, 3 new pulsar discovered（all of them are binary）!
- ~200 pulsars have been discovered in Globular clusters by now. Most of these pulsars are recycled pulsars (P<50ms)

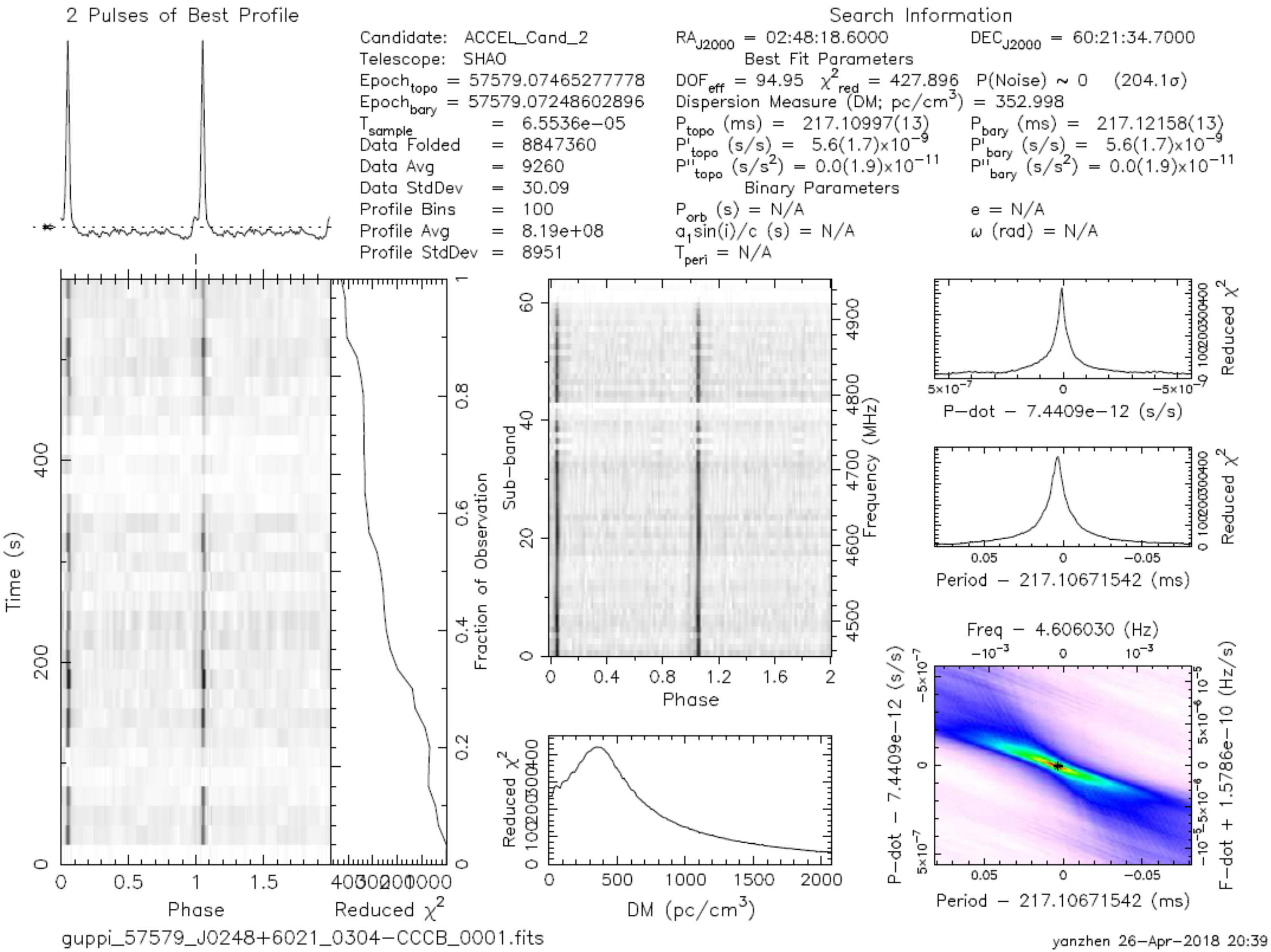


Globular clusters

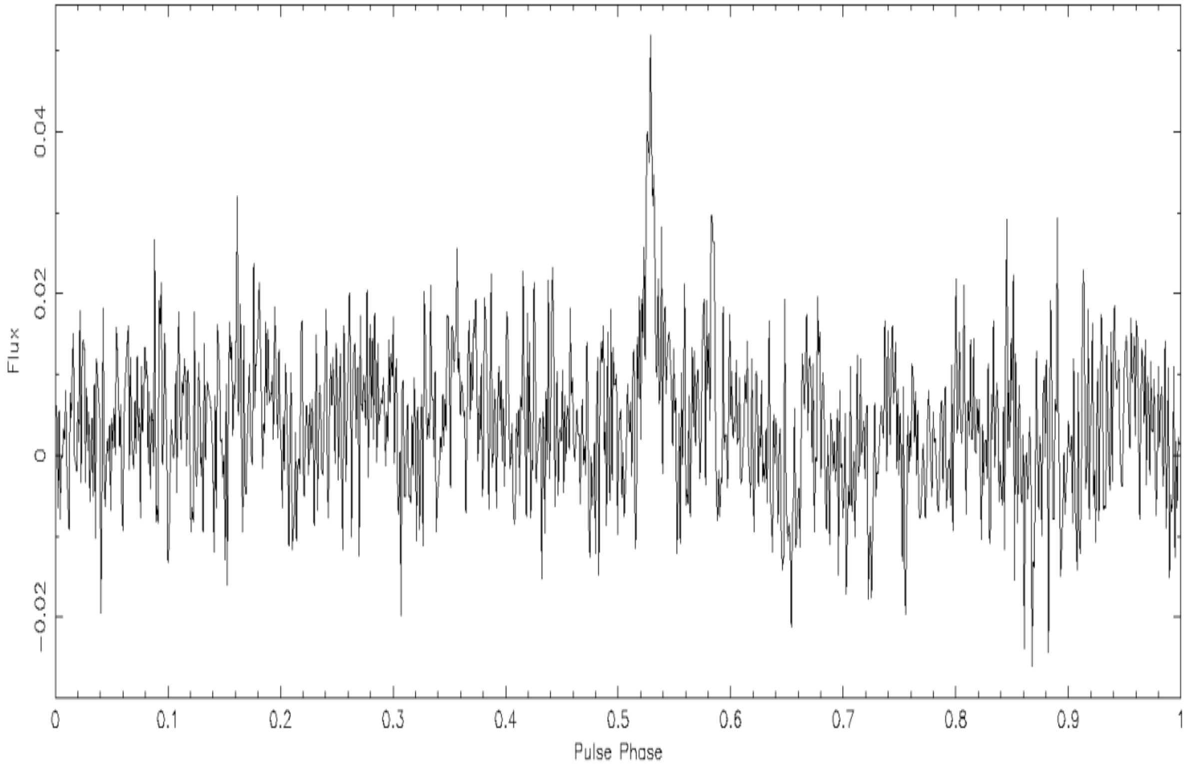


144 pulsars in 28 clusters



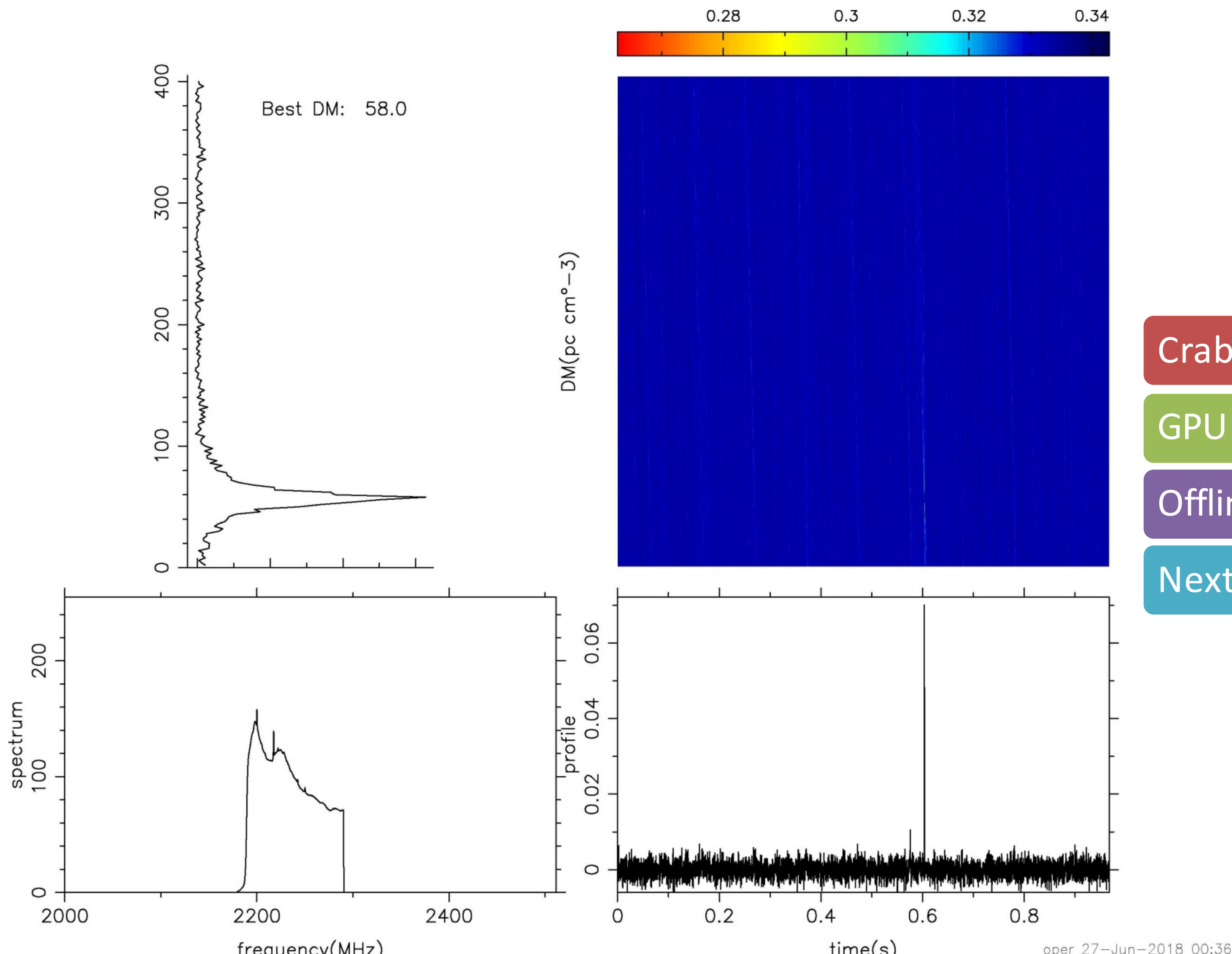

2 Pulses of Best Profile
Search Information
Candidate: ACCEL_Cand_2
Telescope: SHAO
Epoch_topo = 57579.07465277778
Epoch_bary = 57579.07248602896
T_sample = 6.5536e-05
Data Folded = 8847360
Data Avg = 9260
Data StdDev = 30.09
Profile Bins = 100
Profile Avg = 8.19e+08
Profile StdDev = 8951
RA_J2000 = 02:48:18.6000
DEC_J2000 = 60:21:34.7000
Best Fit Parameters
DOF_eff = 94.95 χ²_red = 427.896 P(Noise) ~ 0 (204.1σ)
Dispersion Measure (DM; pc/cm³) = 352.998
P_topo (ms) = 217.10997(13)
P_bary (ms) = 217.12158(13)
P'_topo (s/s) = 5.6(1.7)x10⁻⁹
P'_bary (s/s) = 5.6(1.7)x10⁻⁹
P''_topo (s/s²) = 0.0(1.9)x10⁻¹¹
P''_bary (s/s²) = 0.0(1.9)x10⁻¹¹
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 χ²
Fraction of Observation
Sub-band
Frequency (MHz)
DM (pc/cm³)
P-dot − 7.4409e-12 (s/s)
Period − 217.10671542 (ms)
Freq − 4.606030 (Hz)
F-dot + 1.5786e-10 (Hz/s)
guppi_57579_J0248+6021_0304−CCCB_0001.fits
yanzhen 26−Apr−2018 20:39

FAST pulsar candidate observation



- FAST: J1945+1211
- Discovered: 0.5GHz
- Observation: 2017-10-12
- Frequency: 2.25 GHz
- Length: 1 hour
- Flux: 0.2 mJy

FRB hunting system



Crab giant pulse

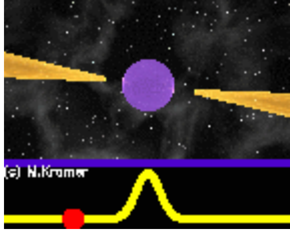
GPU dedispersion;

Offline: T/Tobs=1;

Next step: Online

Wu-Yajun, Yan-Zhen, et al

Challenges face for pulsar studies with VLBI



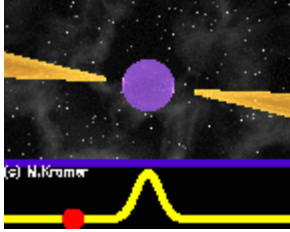
Faint, narrow pulse

- Average flux 0.8mJy (statistics on 908 pulsars)
- Duty cycle of most of pulsars less than 10%
- Pulsar gating in correlation (Booting SNR 3-6 times)
- Pulsar binning (More advanced gating)

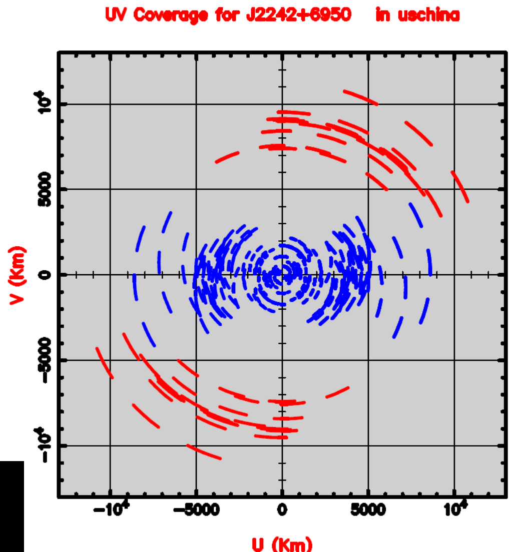
Power-law spectra

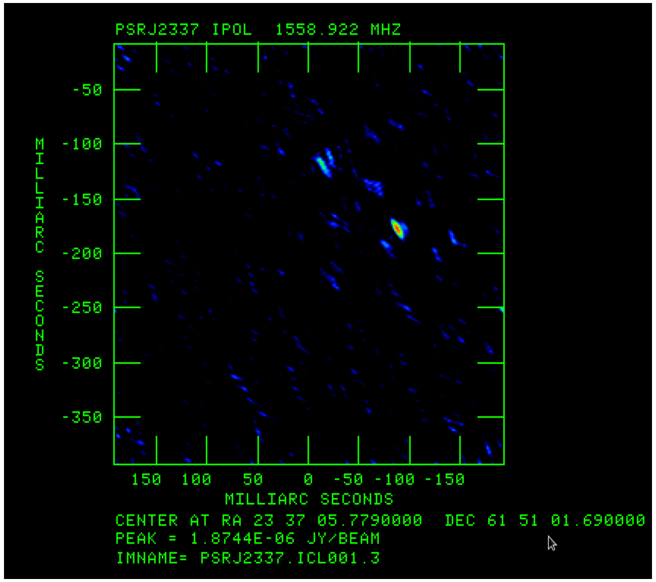
- Power-law spectra(~-1.6), most observations at L-band
- Affected by ionosphere heavily
- Phase referenced (in-beam, nodding), GPS correction

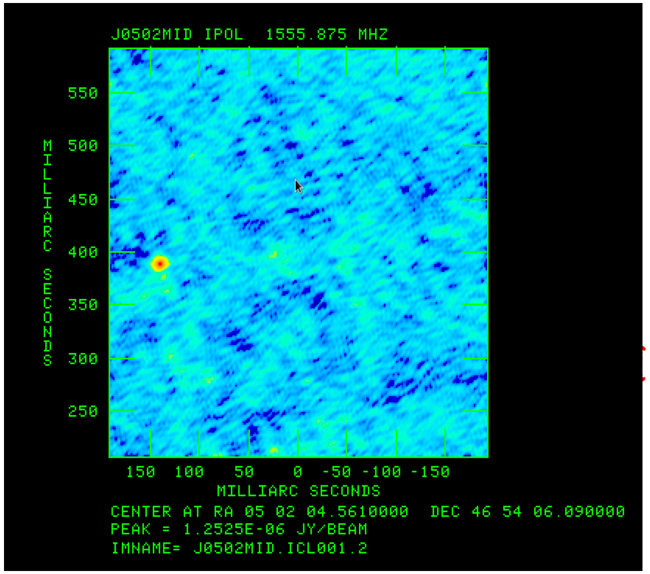
Pulsar Astrometry with VLBA plus TMRT

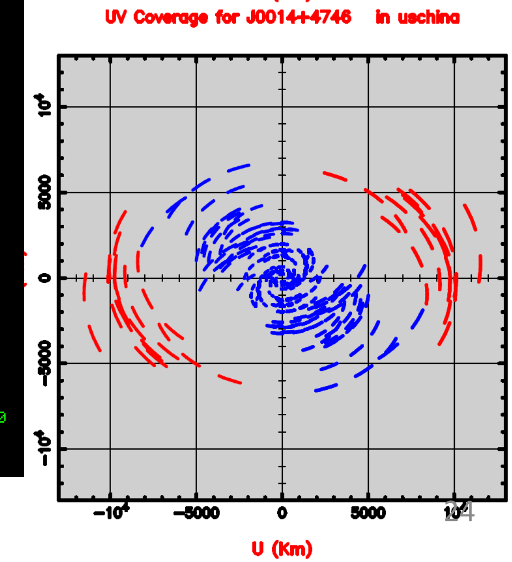


- For pulsars located at high declination (DEC>*45 deg), the resolution in right ascension (RA) will* be affected because of the limited length of projected baseline along East-West direction of VLBA .
- The partition of some Chinese antennas will lengthen the baseline twice times in East-West direction and make the UV-coverage of observation of source much better.
- Pathfinder observations on 2 high latitude pulsars are proposed by us. Highest data rate 2Gbps (previously 512 MHz) was used in our observation. Accuracy ~3 time higher than previous observation.









Some other projects

- Radio radiation from X-ray binaries: Wenfei Yu et al.
- Cooperated Crab observation with HXMT: Jiguang Lu et al.
- Try to detect Gravitational wave of 10^{-7}~10^{-6} Hz through daily timing observation of PSR J1713+0747: Shenghua Yu et al.
- Follow-up FAST pulsar monitoring: Zhichen Pan et al.
- ……

How to apply the observation time

Call for proposals of TianMa 65 meter telescope

2017-10-25 | 编辑： | 【大 中 小】【打印】【关闭】

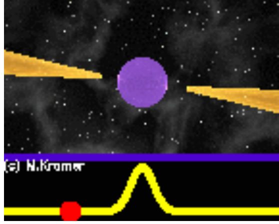
Dear Colleagues,

We wish to draw your attention to call for proposals of spectroscopic and pulsar observations with TianMa 65m telescope. With the hard work of technical staffs at TianMa 65m telescope, we now have 5 receivers fully tested for observations as L (1.25-1.75GHz), S (2.2-2.4 GHz)/X (8.2-9.0 GHz), C (4-8GHz), and Ku (12.0-18.2GHz) bands. The typical system temperatures of these receivers are from 40 to 80K depending on weather conditions for Ku and about 30 K for the other four receivers, while the main beam efficiency below 18 GHz is about 60%. K (18-26.5 GHz) and Q (35-50 GHz) band dual beam receivers are also on the telescope with limited capabilities. We will accept proposals using L, S/X, C, and Ku band receivers, as well as K and Q band receivers as shared-risking project. The DIBAS backend can provide 29 modes of different frequency resolutions, from 0.022 kHz to 1464.8 kHz. For more detailed information of the receivers and backend, please download dibas spectral line mode: dibas-spectral_line_mode

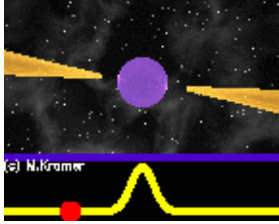
For each proposal, please include a cover letter and the main text part. The cover letter should have an abstract, information of PI and Co-Is (Name, Institute, email, etc.), and time requests (LST ranges, receivers, backend setups), while the main text part should include Scientific Justification and Technical Justification. The proposals should be in English with one page of cover letter and the main text should be less than 3 pages including figures, tables and references.

The deadline will be Dec 1st, 2017, 17:00 (Beijing time) and this call for proposals will cover the observing period from Feb 1st, 2018 to Jul 30th, 2018. The maxim requested time for each proposal should be less than 100 hours for using L, S/X, C, Ku receivers, while it should be less than 15 hours for K or Q band receivers. In this call for proposal, the PI's institute should be within China. Please send the pdf file to tac-65m@shao.ac.cn before the deadline. If you have any technical questions, please send email to

Conclusions



- Pulsar will be one of important scientific targets of TMRT
- Some pulsar observations with TMRT have been done. And good results have been obtained.
- TMRT can play an important role in the fields of pulsar research, such as pulsar searching, giant pulse, RRAT, pulsar timing, astrometry plus VLBA et al.
- Looking forward your cooperation!



Thank you!