MANCHESTER 1824
The University of Manchester

LOFAR

Transient Key science project meeting 2014

GMRT High Resolution southern sky (GHRSS) Survey for MSPs and transients

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GHRSS Team

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- Duncan Lorimer

- Paul Ray

- Scott Ransom

- Jayanta Roy
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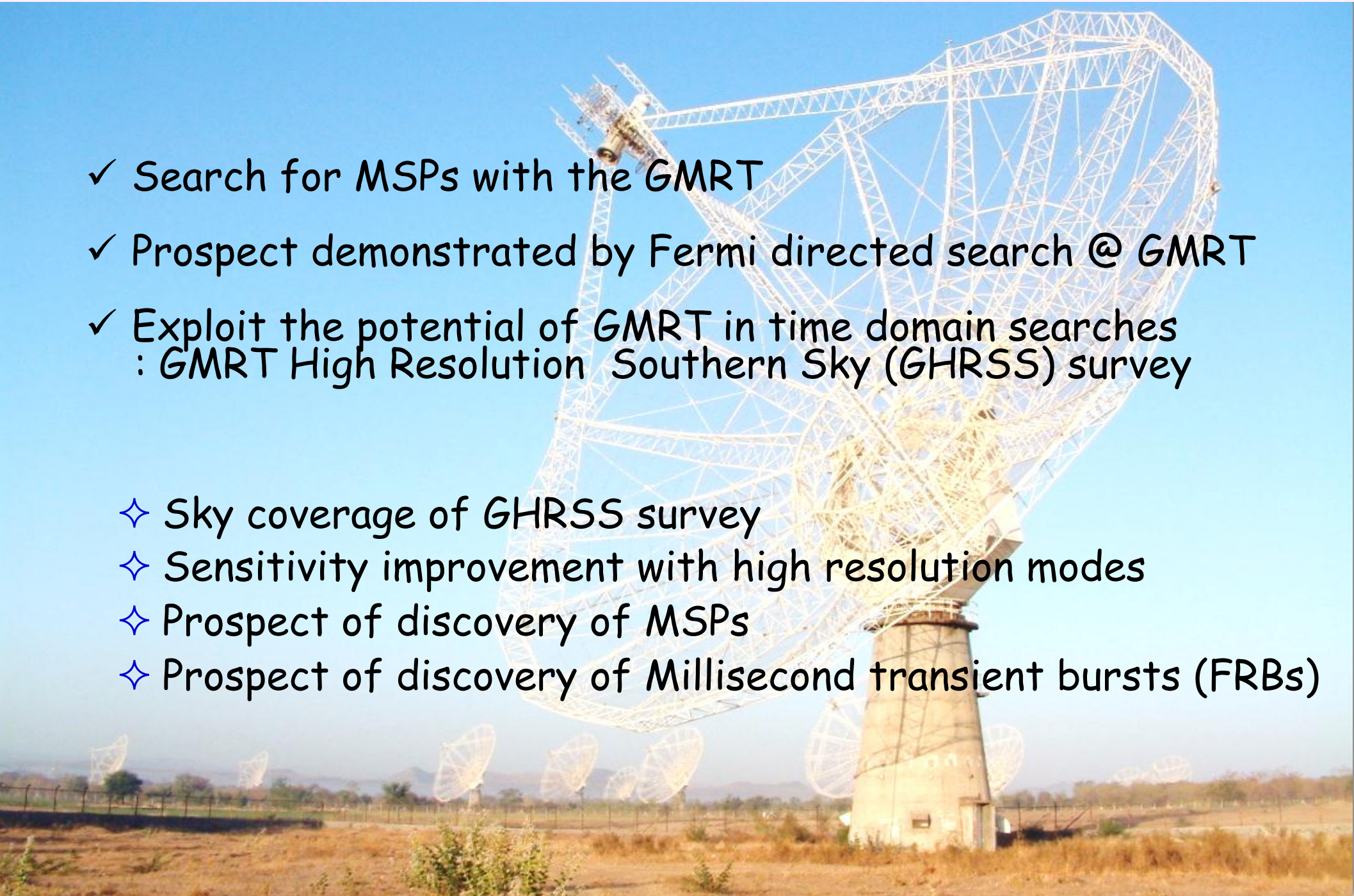
Plan of the talk



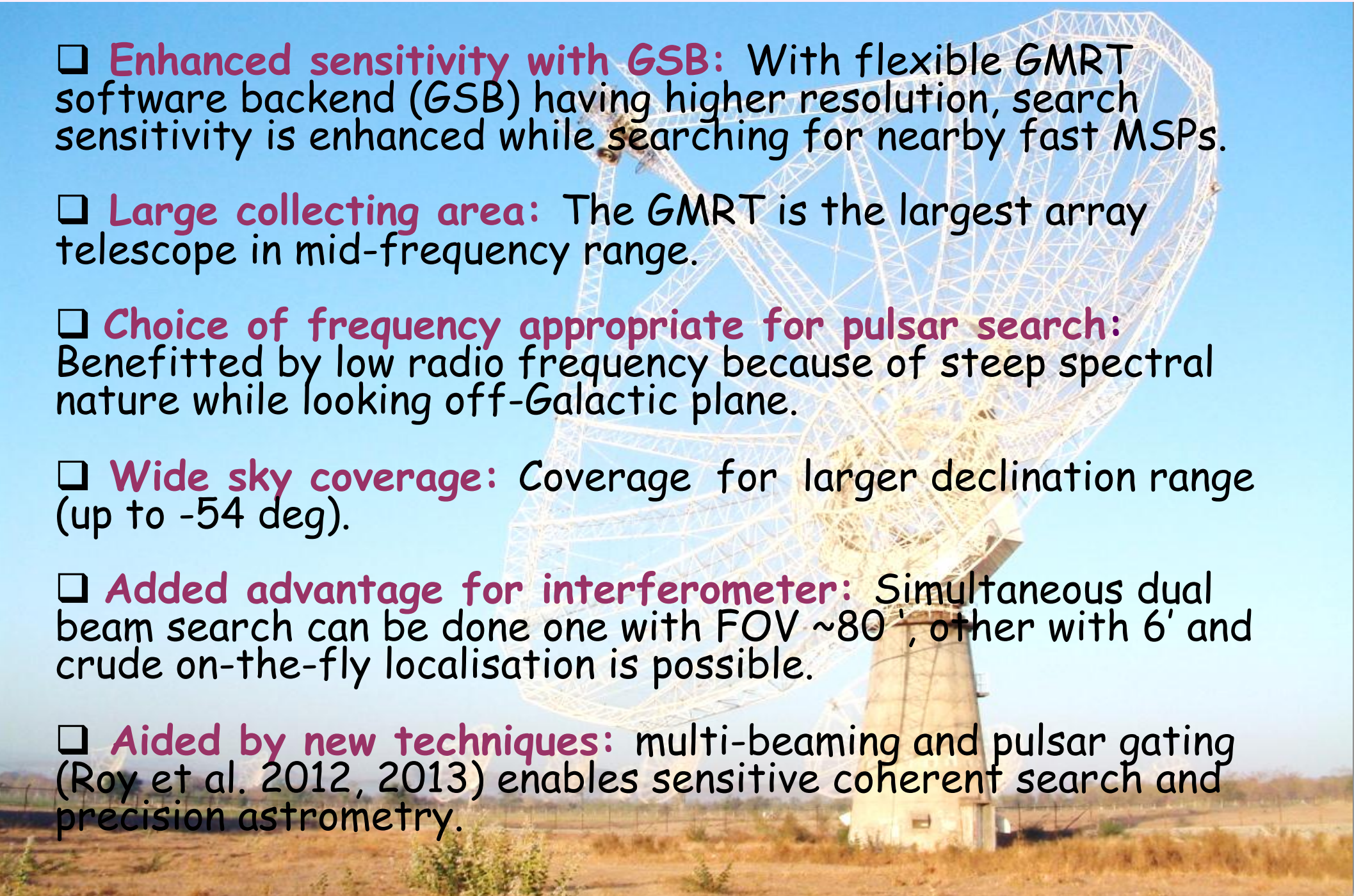
- ✓ Search for MSPs with the GMRT
- ✓ Prospect demonstrated by Fermi directed search @ GMRT
- ✓ Exploit the potential of GMRT in time domain searches
  : GMRT High Resolution Southern Sky (GHRSS) survey

  - ✧ Sky coverage of GHRSS survey
  - ✧ Sensitivity improvement with high resolution modes
  - ✧ Prospect of discovery of MSPs
  - ✧ Prospect of discovery of Millisecond transient bursts (FRBs)

MSP searches

- 61 % increase in Galactic MSP population in last 4 years
- New population is biased towards shorter period (median P~3.2 ms) and tighter orbits (median P_b~ 1.9 days) with larger binary fraction (83 %)
- Contributing new MSPs to Pulsar Timing Array (PTA) to increase the sensitivity towards the detection of Gravitational Waves (GWs)
- Possible discovery of exotic systems like NS-NS binary, massive NS-WD binaries or NS-BH binaries provide laboratories to test theories of gravity.

Why search for pulsation with GMRT ?



- **Enhanced sensitivity with GSB:** With flexible GMRT software backend (GSB) having higher resolution, search sensitivity is enhanced while searching for nearby fast MSPs.

- **Large collecting area:** The GMRT is the largest array telescope in mid-frequency range.

- **Choice of frequency appropriate for pulsar search:** Benefitted by low radio frequency because of steep spectral nature while looking off-Galactic plane.

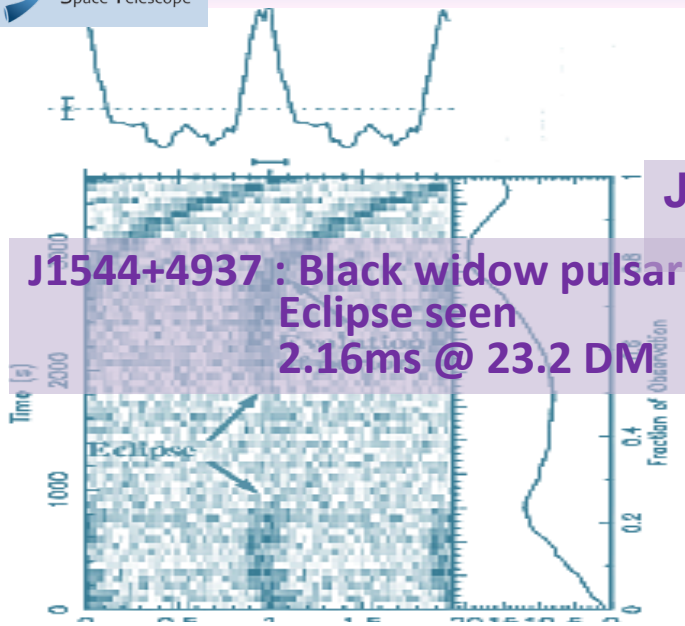
- **Wide sky coverage:** Coverage for larger declination range (up to -54 deg).

- **Added advantage for interferometer:** Simultaneous dual beam search can be done one with FOV ~80 ', other with 6' and crude on-the-fly localisation is possible.

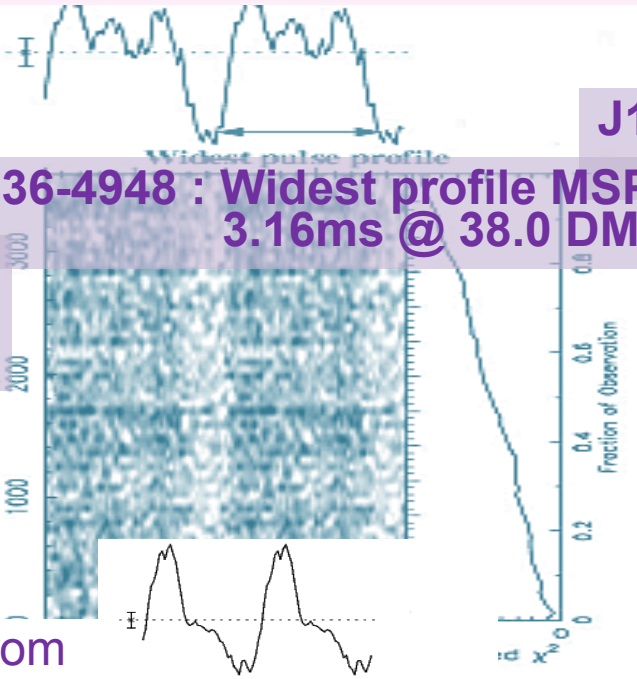
- **Aided by new techniques:** multi-beaming and pulsar gating (Roy et al. 2012, 2013) enables sensitive coherent search and precision astrometry.

Eight MSPs discovered at GMRT from 2011-2014

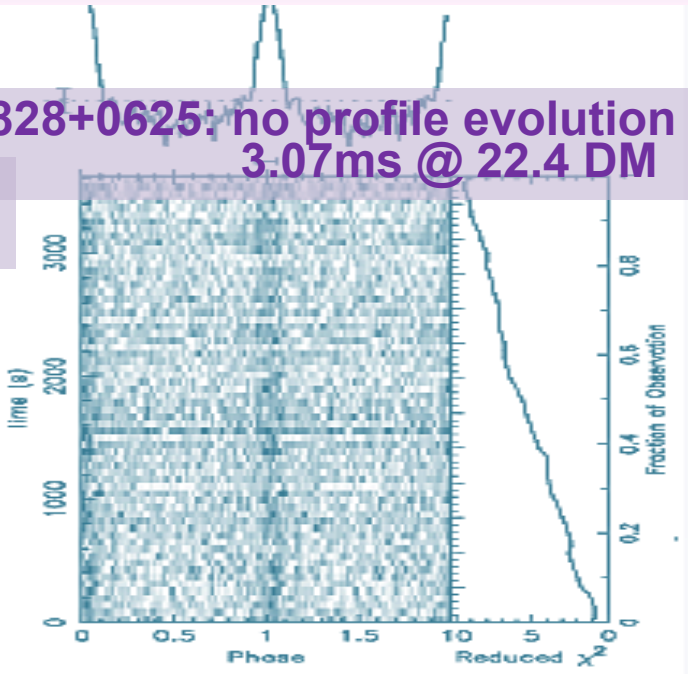
Fermi Gamma-ray Space Telescope



J1544+4937 : Black widow pulsar
Eclipse seen
2.16ms @ 23.2 DM



J1536-4948 : Widest profile MSP
3.16ms @ 38.0 DM

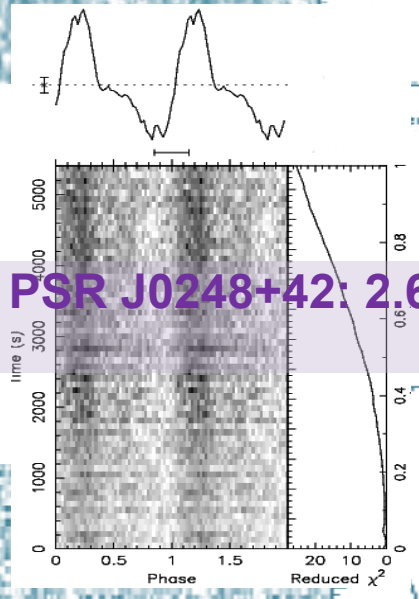


J1828+0625: no profile evolution
3.07ms @ 22.4 DM

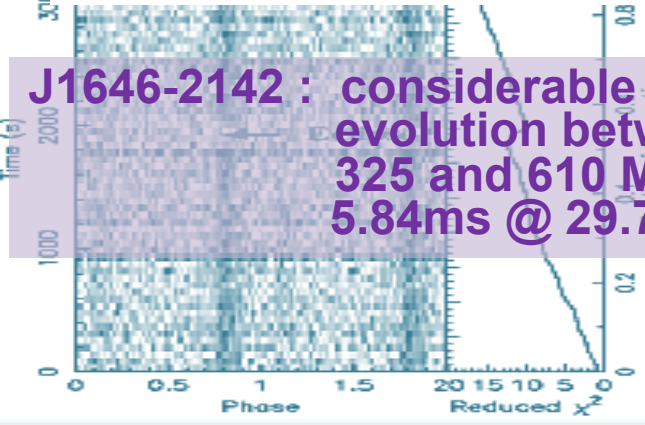
2 of the MSPs discovered are from internal 18 month and 3 year catalog of weak γ -ray sources

2 are serendipitous discoveries of in-beam pulsars

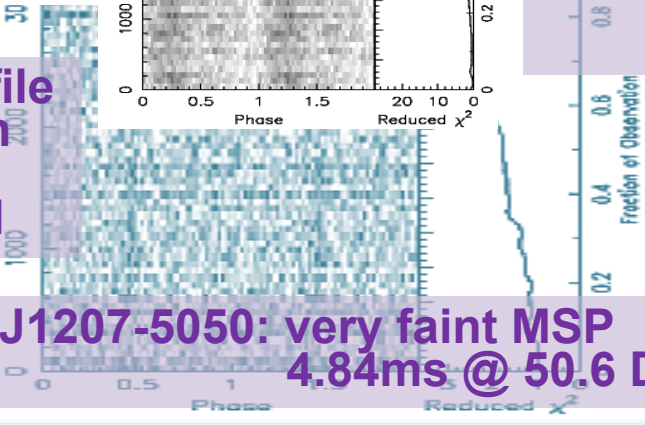
1MSP per 25 Hour of observations



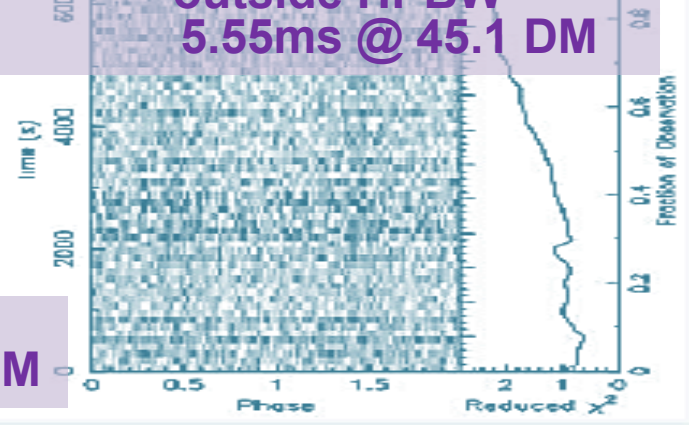
PSR J0248+42: 2.6 ms @ 48.2 DM



J1646-2142 : considerable profile evolution between 325 and 610 MHz
5.84ms @ 29.7 DM



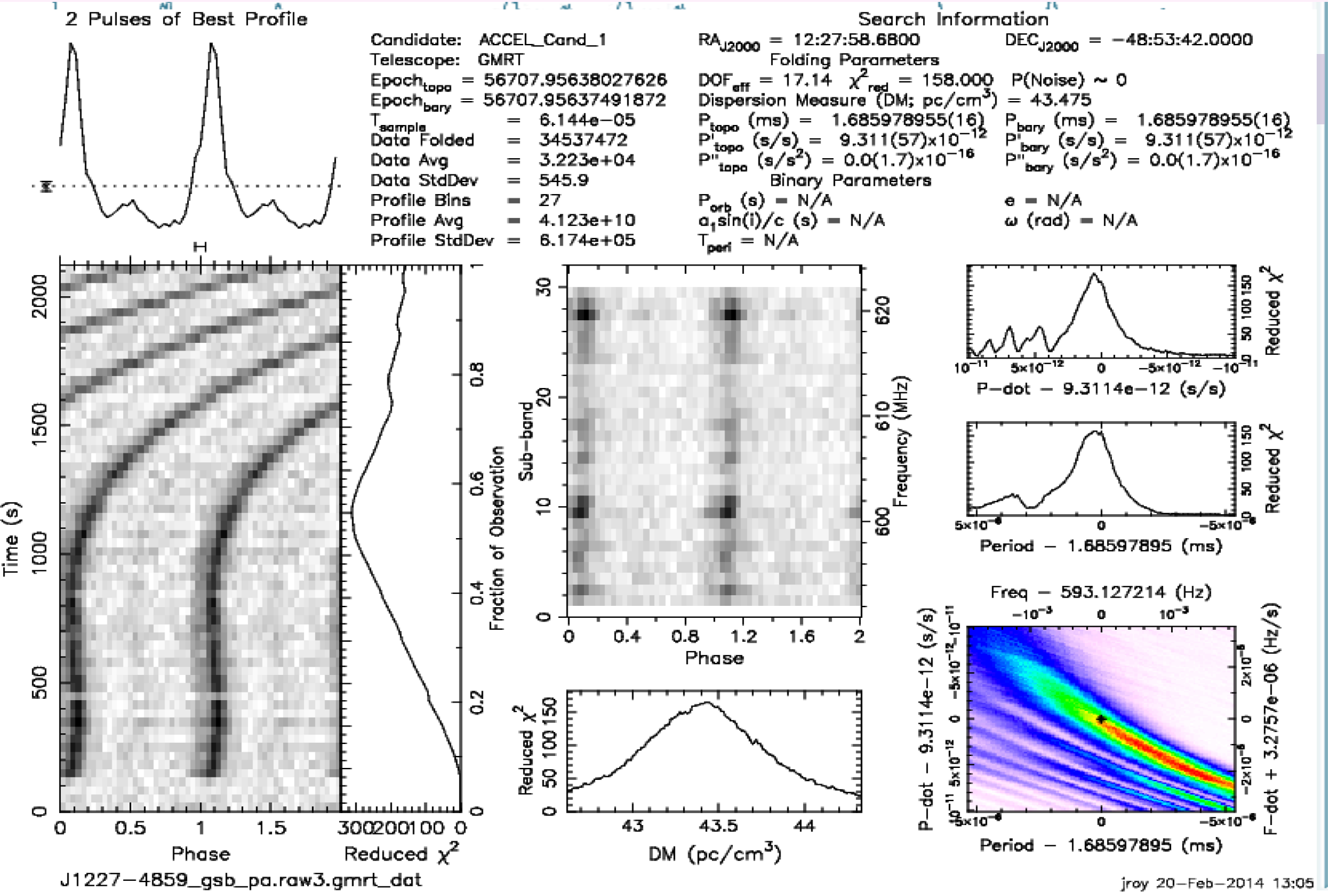
J1207-5050: very faint MSP
4.84ms @ 50.6 DM



J1120-3618: In-beam binary MSP outside HPBW
5.55ms @ 45.1 DM

Eight MSPs discovered at GMRT from 2011-2014

PSR J1257-4853 :LMXB-radio pulsar transition object



Future of MSP search at the GMRT: GMRT High Resolution Southern Sky (GHRSS) Survey

Motivated by the success of Fermi-directed searches we started the GMRT High Resolution Southern Sky (GHRSS) survey at 322 MHz which will be the most sensitive survey for MSPs and transients in GBNCC complementary sky.

Collaborating Institutes : UoM, NCRA, WVU, NRL, NRAO

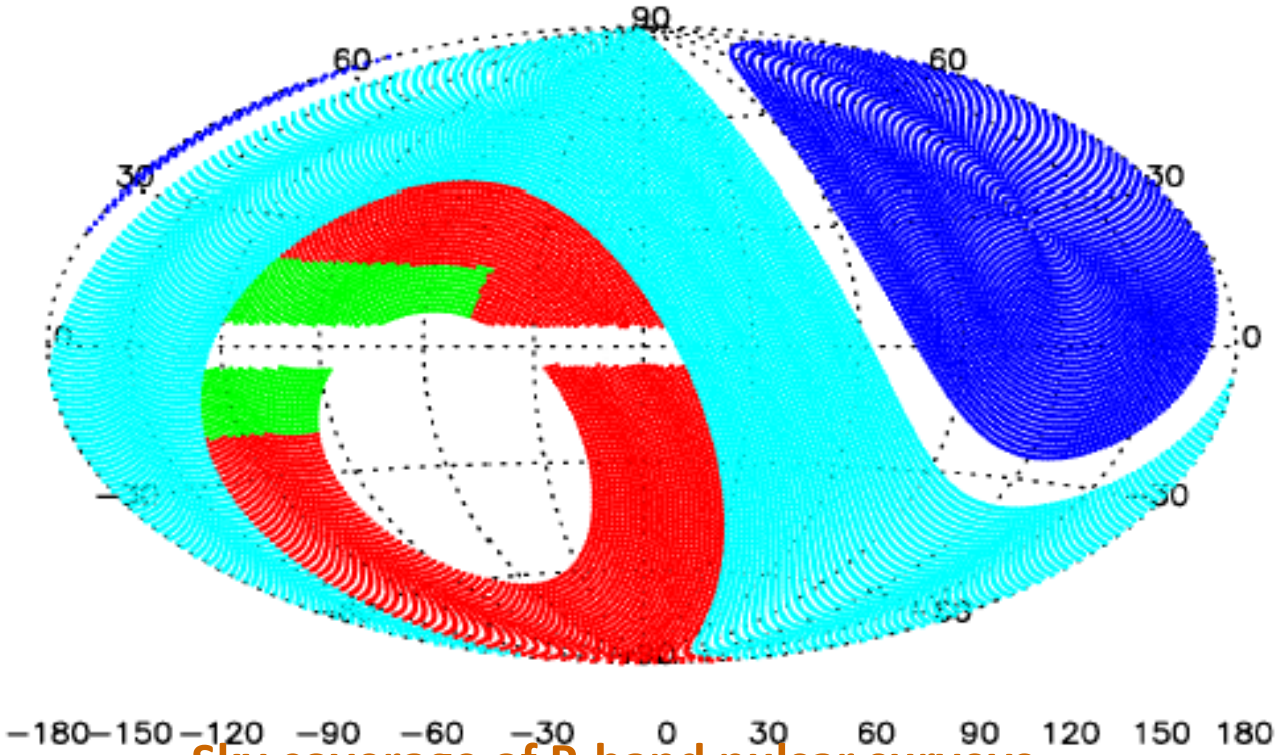
GHRSS survey will exploit the potential of GMRT in blind searches

GMRT High Resolution Southern Sky (GHRSS) Survey

GHRSS SKY COVERAGE

GHRSS survey will be scanning a portion of sky -20 to -54 degrees with priority to declination -40 to -54 i.e. declination complementary to other ongoing low-frequency surveys at GBT and LOFAR

:This portion of sky is not surveyed at frequencies less than 1.4 GHz for last two decade



Sky coverage of P-band pulsar surveys

GBT drift scan (cyan); GBNCC (blue);

GHRSS (red,green)

GMRT High Resolution Southern Sky (GHRSS) Survey

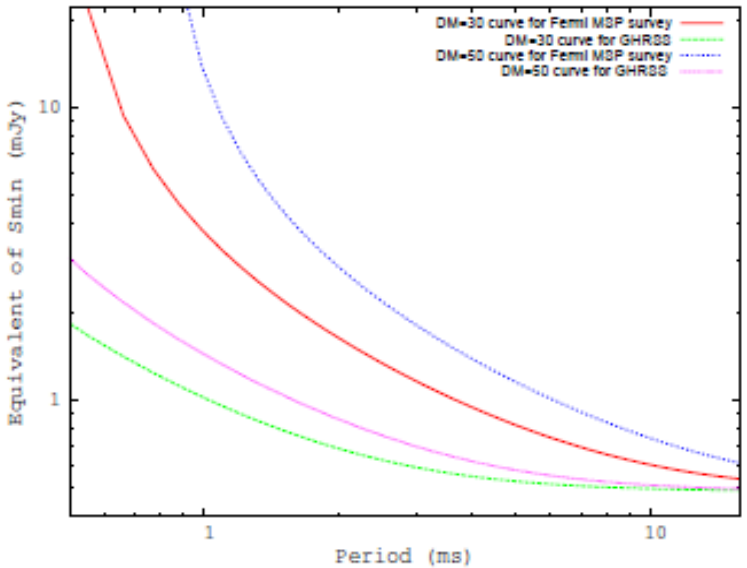
GHRSS SENSITIVITY

- Development of new high resolution survey modes in the GSB using optimally weighted incoherent array
  - 1024 x 32.5 kHz filterbank sampled @ 30 μs
  - 2048 x 16.2 kHz filterbank sampled @ 61 μs

- Survey sensitivity ~ 0.5 mJy

Using radiometer equation for 15m of observing at 322 MHz for 5sigma detection with 10% duty cycle, GMRT incoherent array gain of 2.5 K/Jy for 32 MHz bandwidth.

Sensitivity similar to GBNCC but in complementary sky



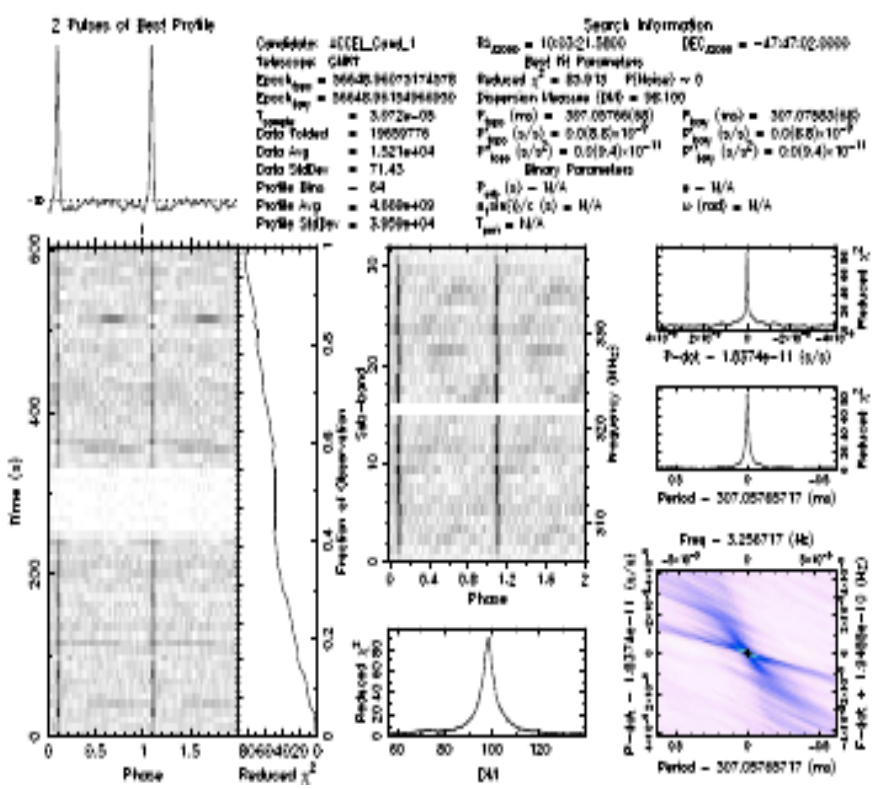
3x sensitivity improvement with respect to the Fermi MSP survey mode, while searching for 2 ms MSP @ DM of 50

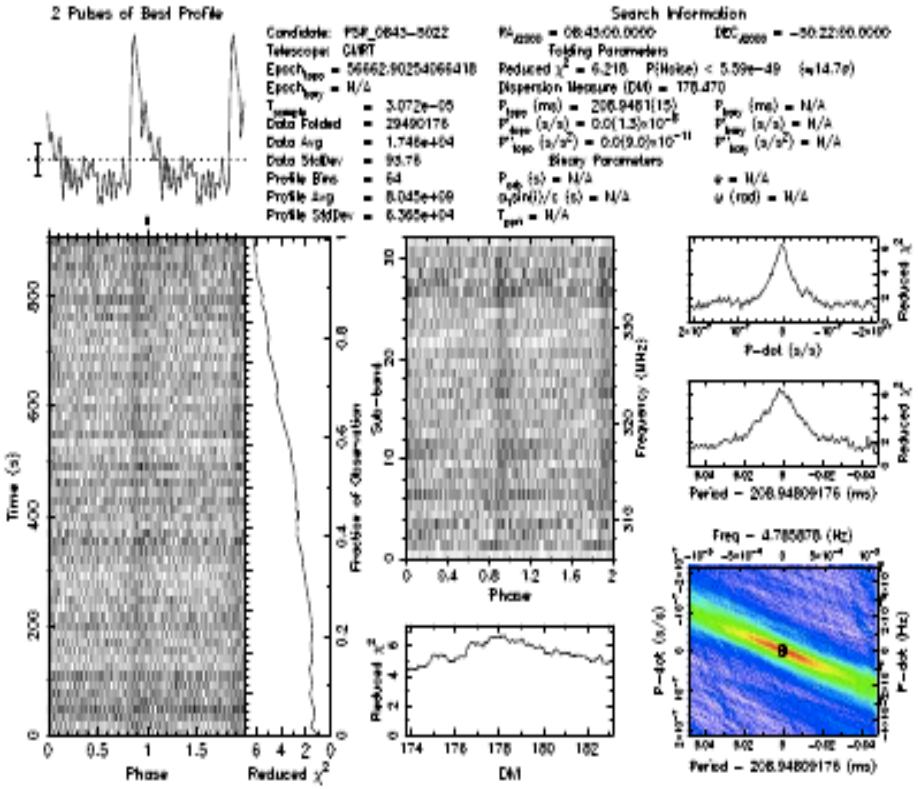
Optimal weighting of antennas and efficient RFI mitigation (zeroDM filtering)

GHRSS SENSITIVITY :LIMITS ACHIEVED FROM SURVEY OBSERVATIONS

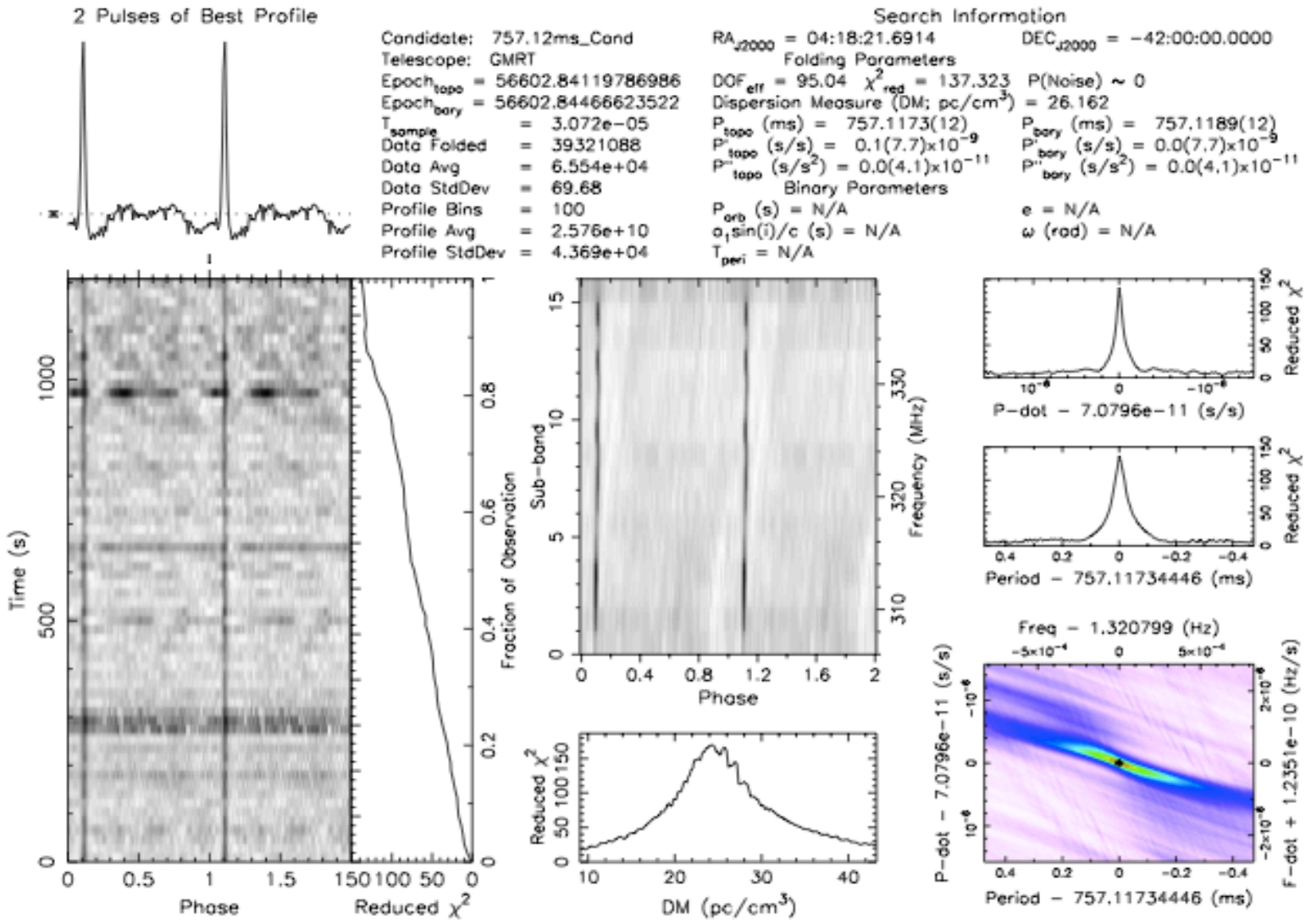
High resolution survey modes are successfully validated in our survey observations

Re-detection of in-beam known pulsars demonstrate that targeted sensitivity improvement is achieved





GHRSS DISCOVERY : 1 NORMAL PULSAR



Larger parameter space resulting in many promising fast pulsar candidates :

LOTASS machine learning is getting implemented for GHRSS

Comparison of parameter space of GHRSS and other off-galactic plane surveys

Table 1: Parameters for major existing surveys and the GHRSS survey

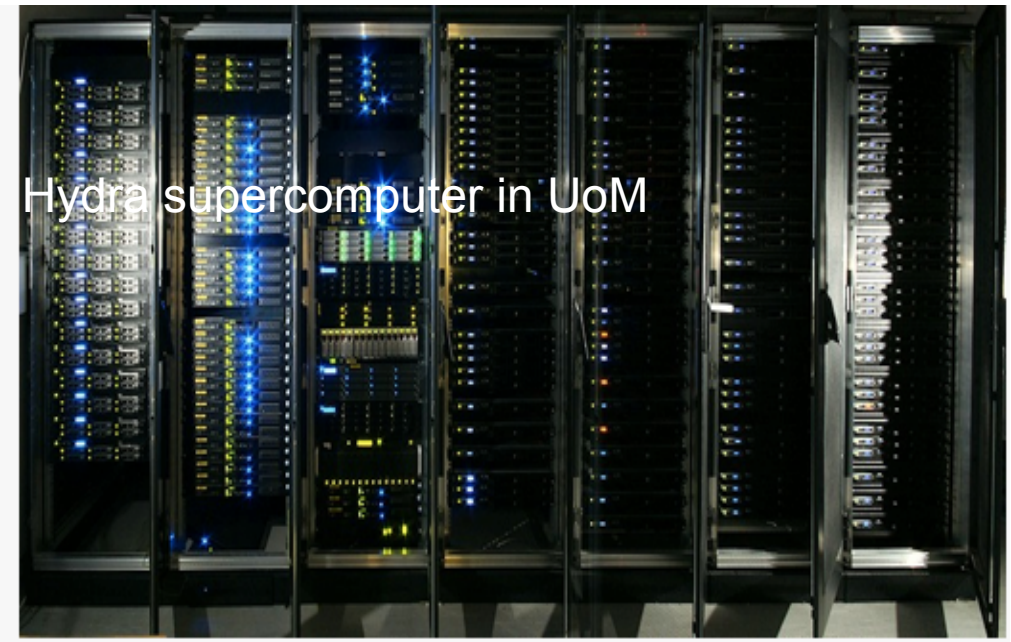
Survey name – Telescope	Frequency of search (MHz)	Sky coverage	Discovery	Sensitivity (mJy)
HTRU – Parkes	1352	south of dec +10 deg	131 PSR, 27 MSP	2.2
HTRU–N – Effelsberg	1360	$\|b\|$ >15 deg, dec>-20 deg	12 PSR	1.9
GBNCC – GBT	350	dec> 38 deg	64 PSR, 9 MSP	0.6
GBTdriftscan – GBT	350	-21 deg<dec<26 deg	26 PSR, 7 MSP	0.9
GHRSS – GMRT	322	-20 deg<dec<-54 deg	45 PSR	0.5 0.2

SURVEY PARAMETERS FOR THE GHRSS SURVEY

Table 2: Survey parameters for GHRSS

Survey	Mid Galactic latitude	High Galactic latitude
Galactic region	$5< \|b\| <20$ deg	$\|b\| >20$ deg
Declination	$-40 < dec < -54$	$-40 < dec < -54$
Integration time	20m	12m
Sampling time	60μs	30μs
Bandwidth	32 MHz	32 MHz
Number of channels	2048	1024
Frequency Resolution	15.625 kHz	31.25 kHz
Number of pointing	682	911
Sky coverage	1212 sq deg	1620 sq deg
Data/pointing	76 GB	45 GB
Total data	50 TB	40 TB

Analysis



We are analysing the data in

1. NCRA cluster: with 512 core (32 nodes each with dual 8 cores) with 10 TFLOPS compute capacity are getting used for periodicity search

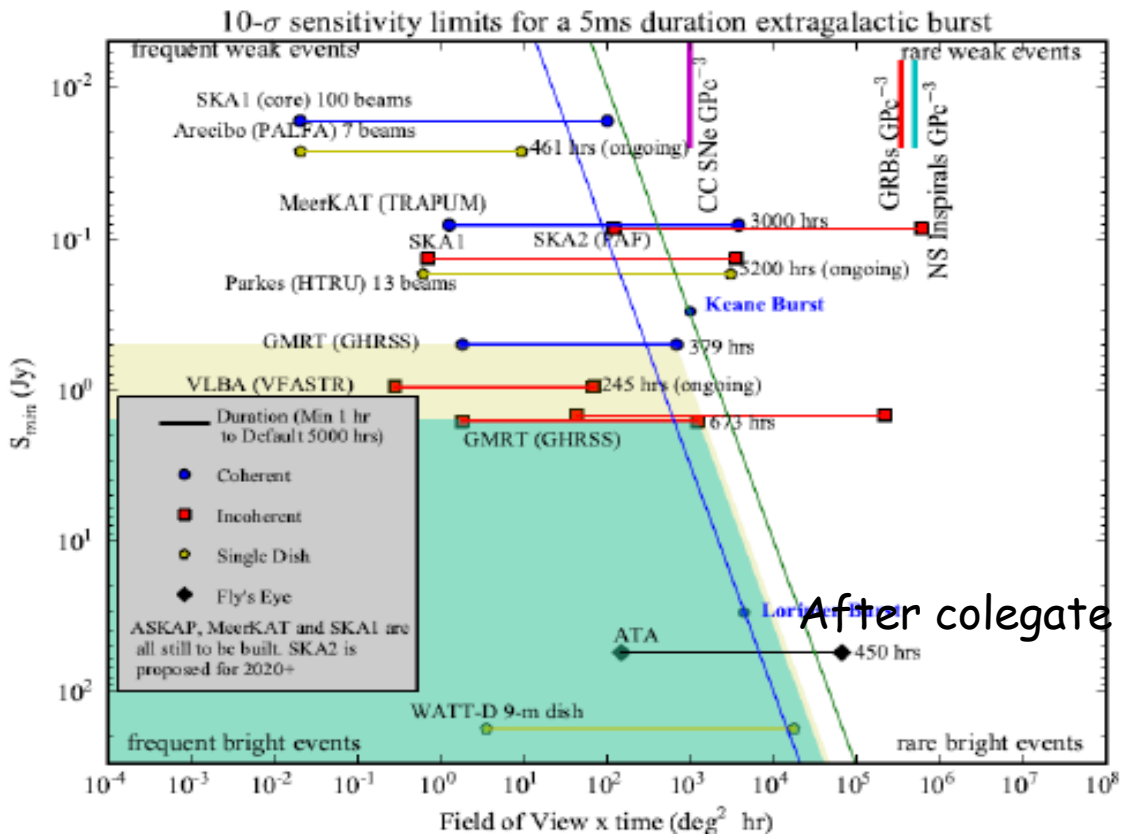
2. Hydra supercomputer : with 1456 core (182 node each with 2 quad cores) with 30 TFLOPS compute capability are getting used for single pulse search

3. GPU based Peasoup pipeline : Acceleration search (+/- 250 m/s^2) using GTX 780TI

Search for extragalactic Fast Radio Bursts (FRBs)

- Eight millisecond extragalactic bursts are found at inferred redshift of 0.1 – 0.9
- Opportunity to probe ionised IGM through plasma propagation effects

- 1.6 Jy for 10 sigma detection of 5ms burst
- Single pulse search upto DM of 2000 pc cm^-3
- The GHRSS survey promises to find 10 new FRBs in 500 hours (based on Parkes rate)
- Simultaneous localisation of such cataclysmic events using GMRT interferometer

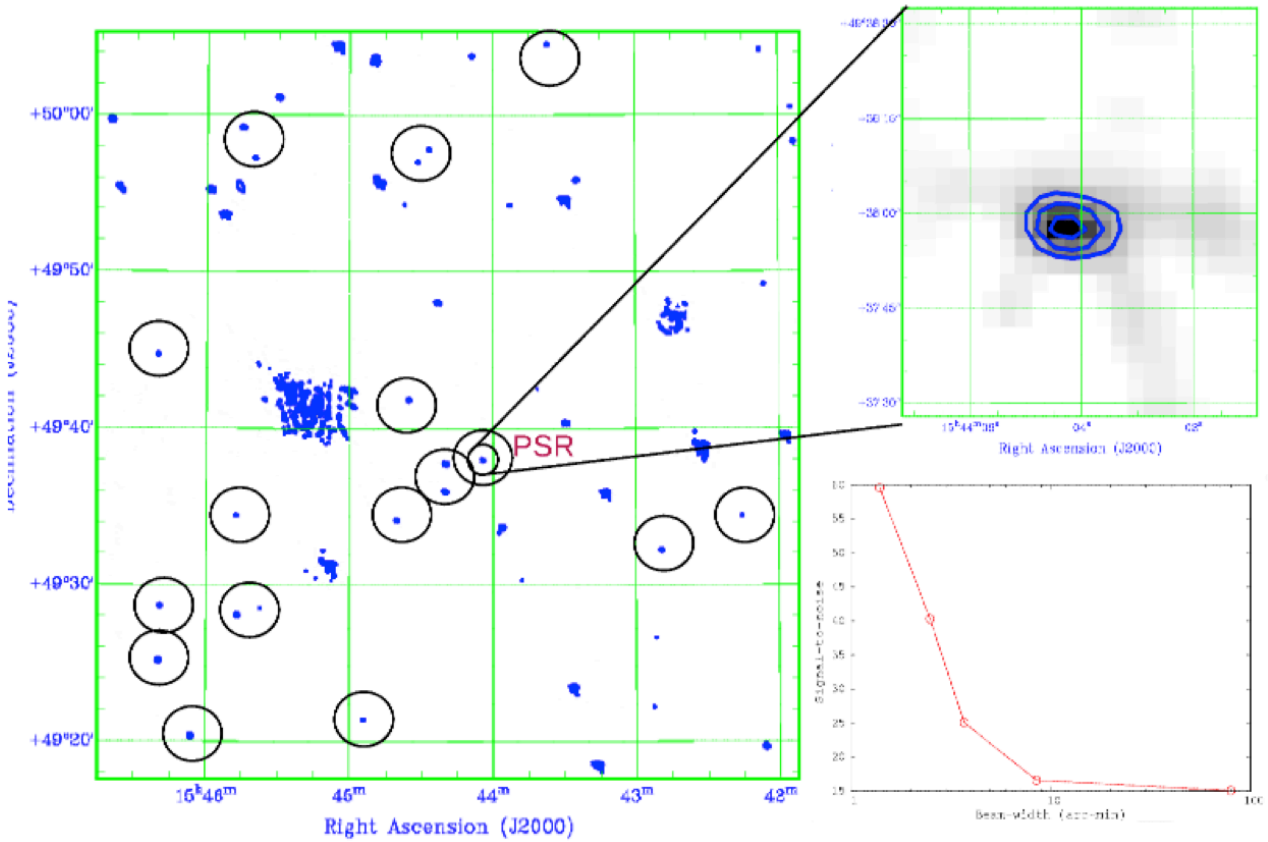


After colegate

Localisation for extragalactic Fast Radio Bursts (FRBs)

The time domain detection will be imaged form the simultaneously taken imaging data

- On-the-fly localisation allows study of origin of the event; identification with host galaxy, enabling determination of IGM baryon content; any association of GW signal



Roy et al. 2012

GMRT interferometric array

GMRT software backend

Thank you

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GHRSS a SKA pre cursor survey

- Being the present largest array telescope at meter wavelengths GMRT is prototype of SKA in many ways and provide excellent test bed to develop new Techniques and test those
- Optimised search techniques, efficient beamforming and simultaneous localisation in the image plane will provide vital input to SKA pulsar search

EVEN MORE IMPROVEMENT OF SENSITIVITY IN GHRSS SURVEY WITH MULI-PIXEL SEARCH IN THE RAWDATA : A TECHNIQUE DECIDED TO BE APPLIED FOR SKA PULSAR SEARCH

For part of the GHRSS survey we plan to use the baseband recording facility of the GMRT Software Backend followed by Multi-pixel coherent beamformation (Roy et al. 2012)

- Pixelisation of the full FoV while scanning extreme southern sky of the GMRT →Factor of two reduction in required number of beams (~ 300)

WIDE-FIELD MULTI-PIXEL GHRSS SURVEY : A SKA PRE CURSOR SURVEY

- 3x improved search sensitivity with 20x of real-time compute cost
- Survey sensitivity of 0.2 mJy for 10m pointing for 5σ detection in P-band
- @ 10% cost of the SKA-mid multibeam pulsar search (~ 2222 beams)