Fast Radio Bursts (and fast transients) with the GMRT

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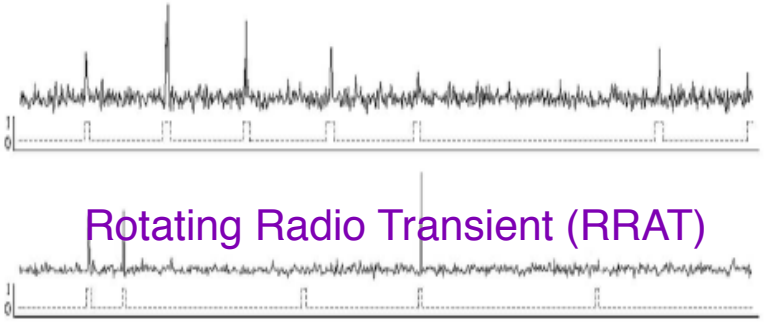
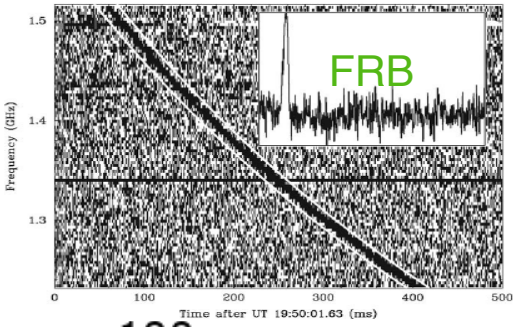
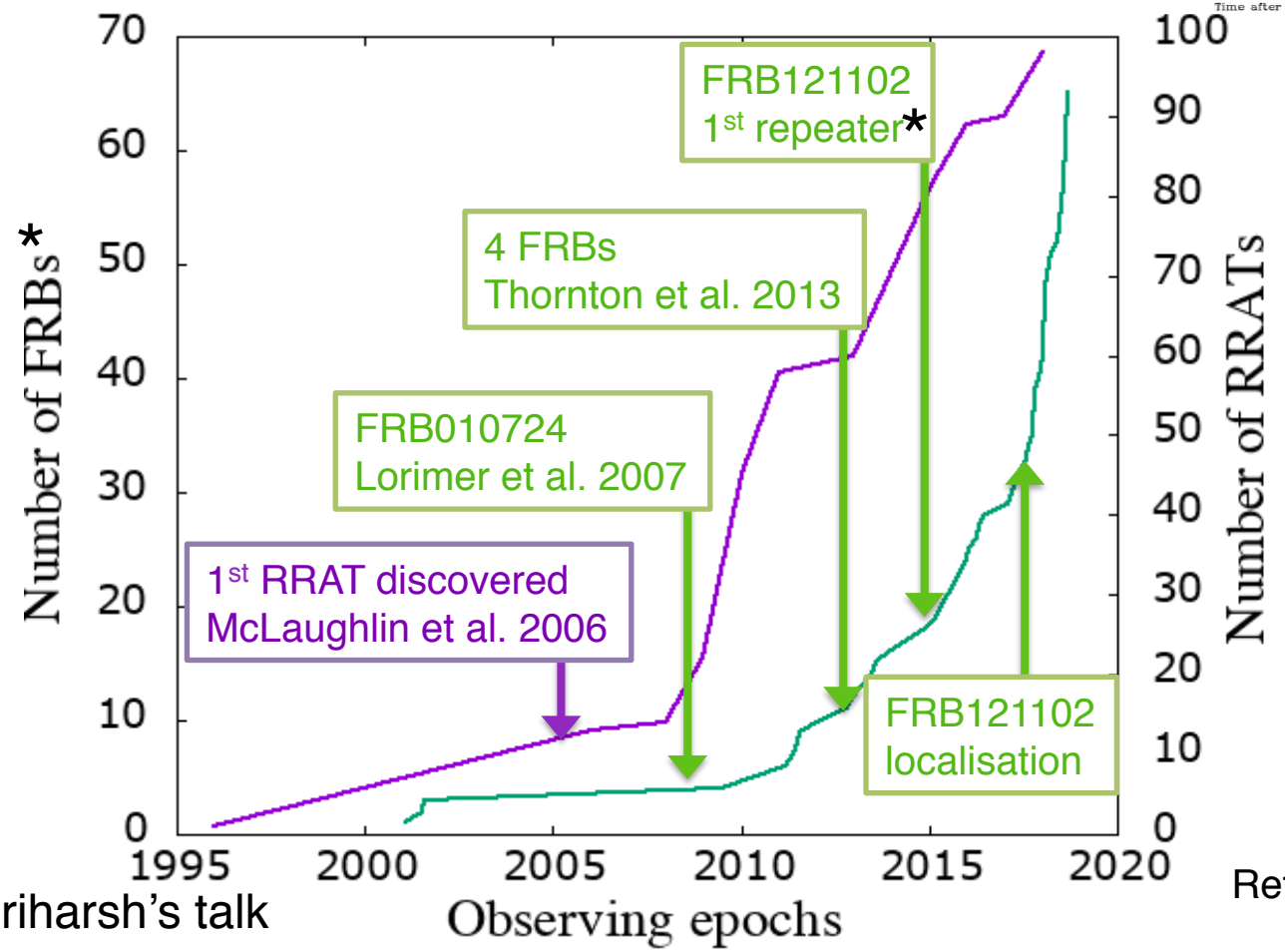
Fast Transients: FRBs and RRATs



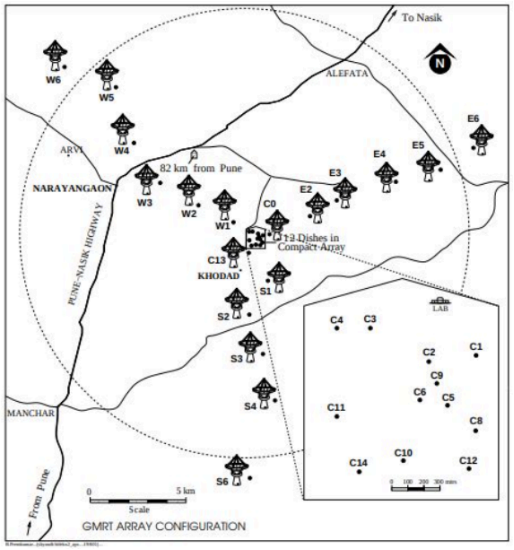




* Refer to Shriharsh's talk

Ref: psrcat, frbcat

GMRT with upgrades



A radio interferometer with fully steerable dishes of 45 metres diameter, operating over 120-250, 250-500, 550-850 and 1060-1460 MHz bands having good G/T_{sys}

Array located at 80 km north to Pune consisting of 30 antennas over 25 km maximum baseline

An increase of instantaneous bandwidth from 32 to 200/400 MHz makes GMRT an excellent instrument for time-domain studies of Pulsars/FRBs (with simultaneous imaging)

Refer to Yashwant's talk on the uGMRT

A CPU-GPU cluster with 10 Tflops

Why Fast Transients with the GMRT?

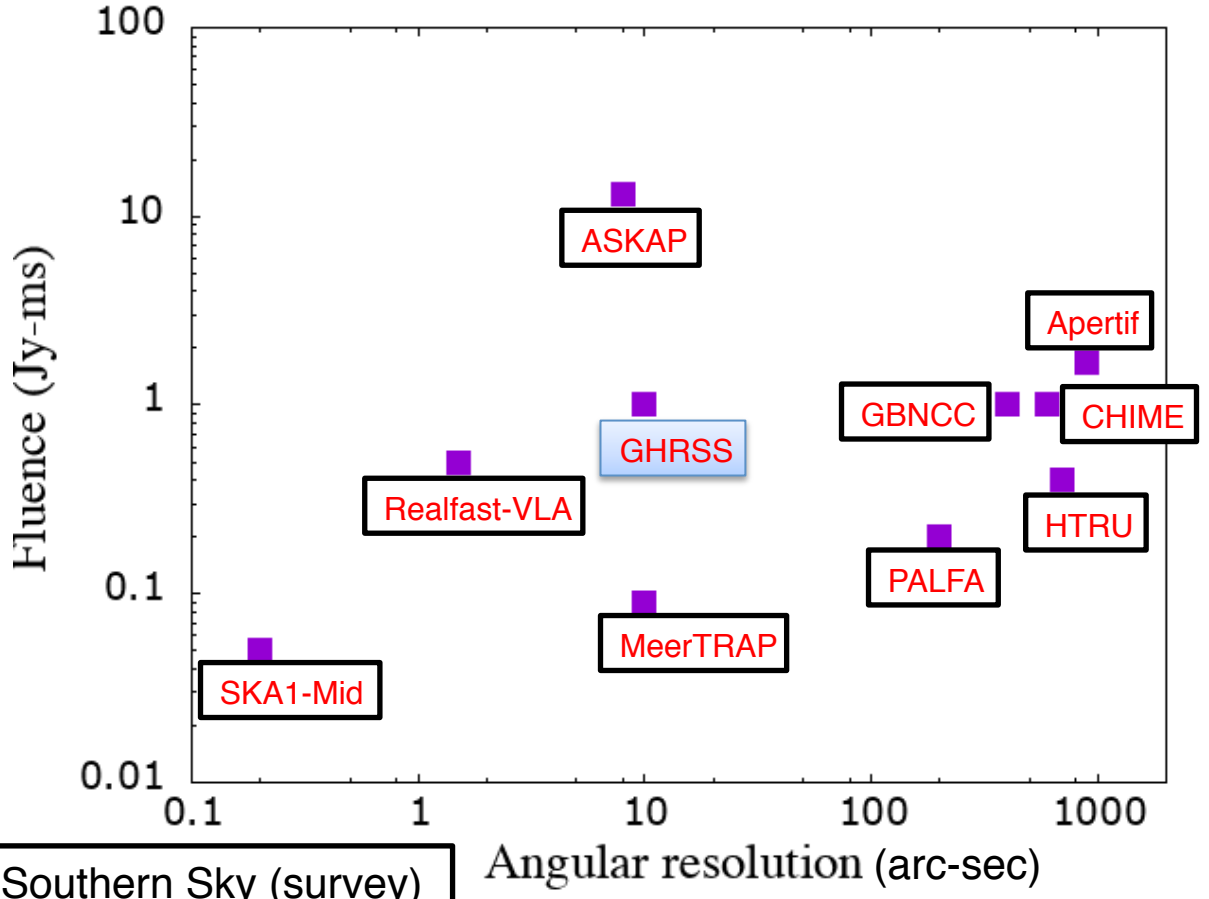
- Interferometric detection

➢ FRBs with extreme luminosity and intrinsic short period suggest extreme events

➢ GMRT is only one of very few facilities (e.g. MeerTRAP, ASKAP) can give detection and arc-sec localisation

➢ Localise at extragalactic distance
→ probe IGM, identify host

➢ Triggering multi-wavelength follow-up rapidly after the burst



GHRSS: GMRT High Resolution Southern Sky (survey)

Why Fast Transients with the GMRT?

- Lower frequency

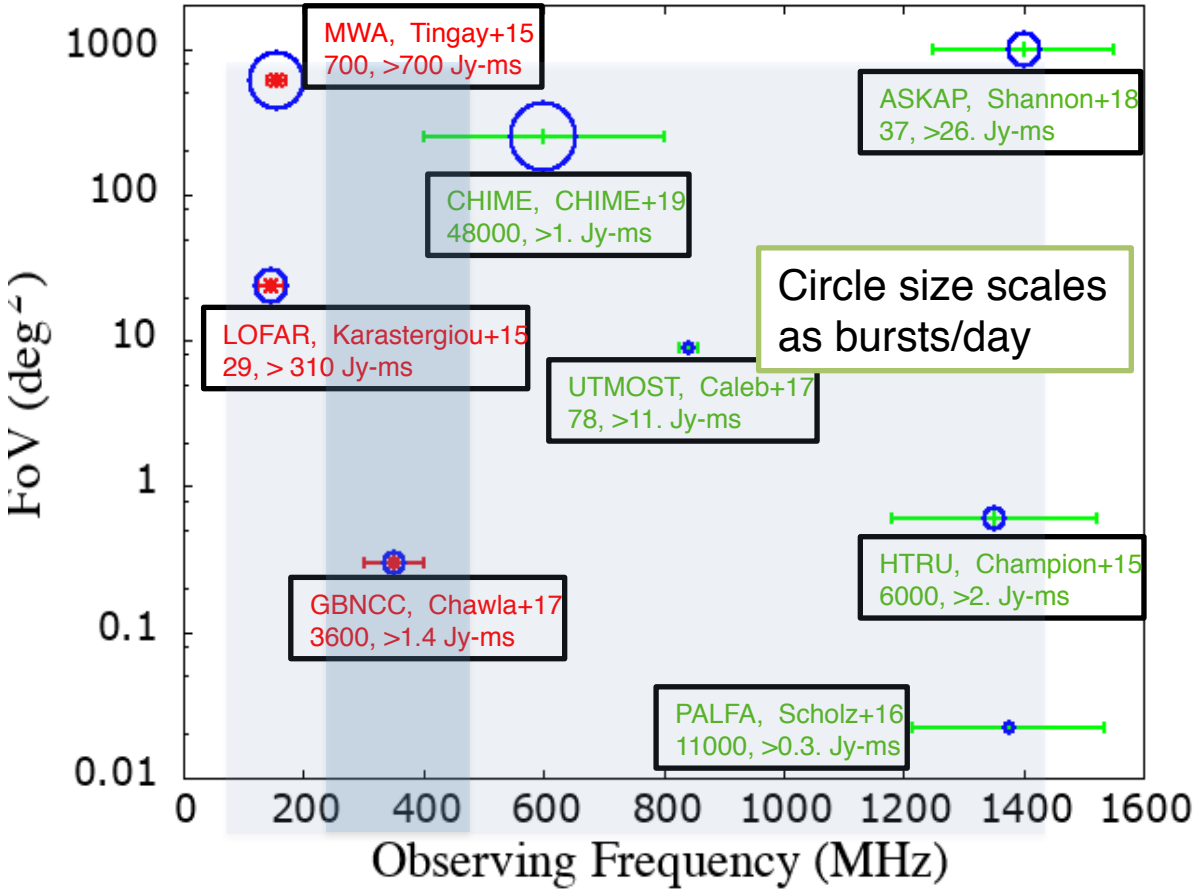
➢ FRBs are detected over 400 MHz to 8 GHz

➢ After CHIME detection, GMRT is more important to find spectral cut-off, spectral-index, scattering

➢ More sensitive than previous GBNCC (with GBT) survey

→ can probe different luminosity distribution

→ can give rate variation to see which of the above effects are dominant



Fast Transients with GHRSS survey

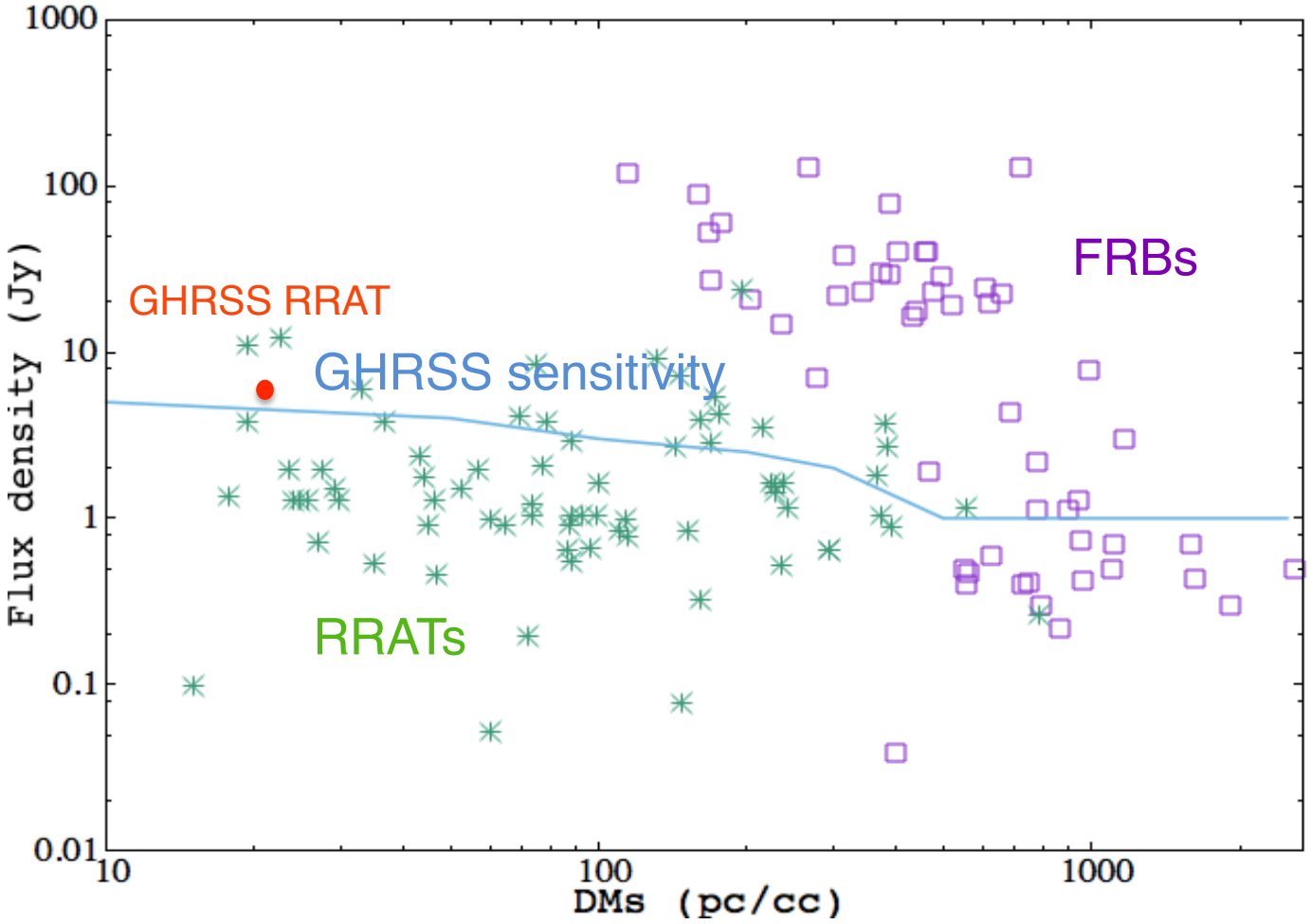
GMRT High Resolution Southern Sky (GHRSS) survey

Survey team: Bhattacharyya, Roy, Stappers, Keith, McLaughlin, Ray, Ransom, Chengalur, Lyne, Sally, Mateusz, Sanjay

- Periodic sky: 18 pulsars (Refer to Bhaswati's talk)
- Bursting sky: 1 RRAT

- **Survey specifications**
  - All-sky survey at 300-500 MHz for Declination $< 0^0$ and |Gbl| $> 3^0$
  - FoV of 1.4 deg^2
  - 10σ Fluence of 1 Jy-ms (60% of FRBs and 80% of RRATs)
  - Imaging localisation at 10σ for 10 Jy events
- **Processing**
  - Searching for 1 ms burst up to dispersion measure (DM) of 2000 pc cm^{-3}
  - CPU processing using 192 processors: 4 hours per survey pointing
  - Trigger time ~ about a week after the survey observations

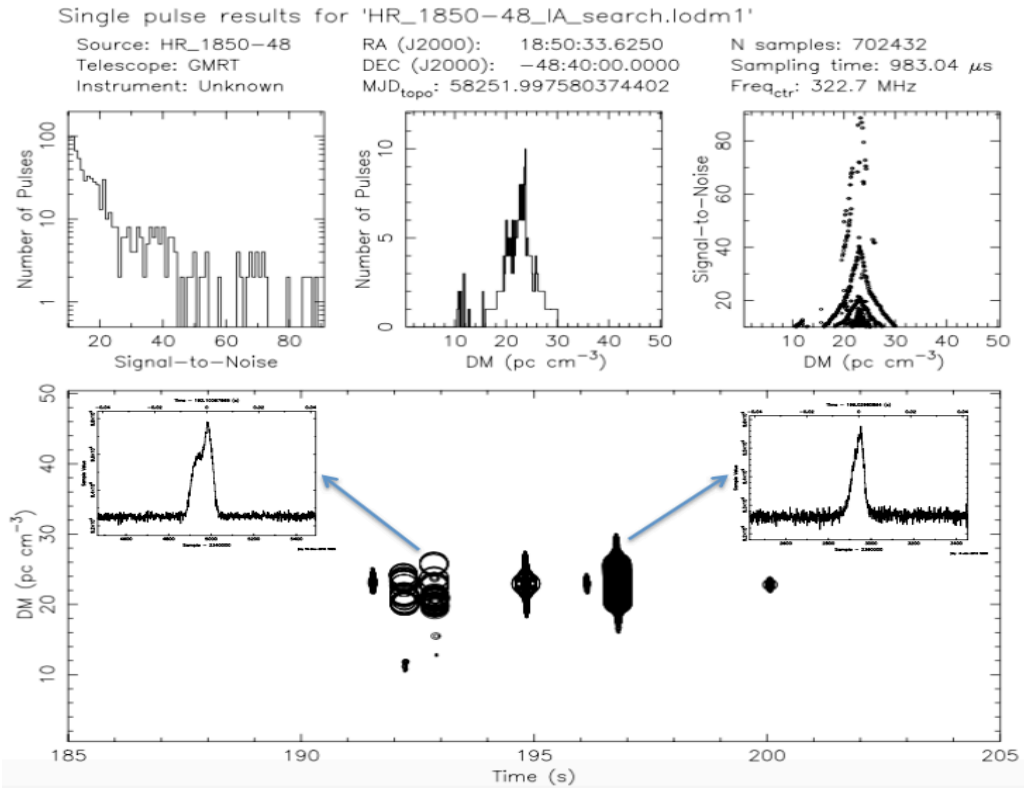
Fast Transients sensitivity with GHRSS

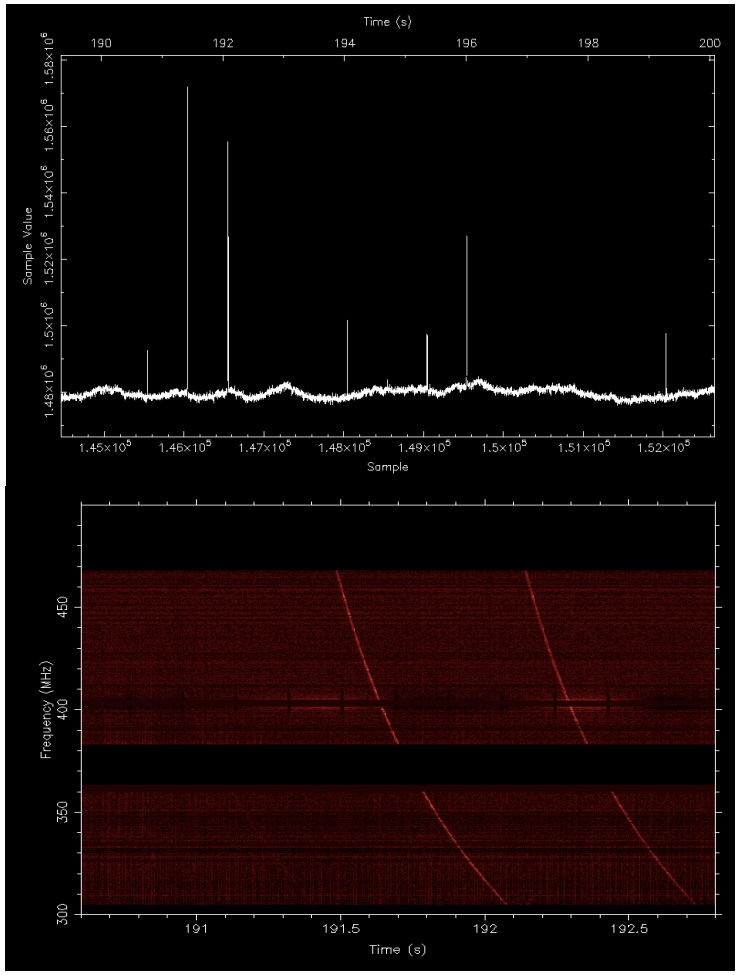


- RFI limiting the sensitivity at lower DMs (DM < 500 pc cm^{-3})

GHRSS sensitivity at 10σ threshold for 1 ms pulse-width

RRAT discovered with the GHRSS





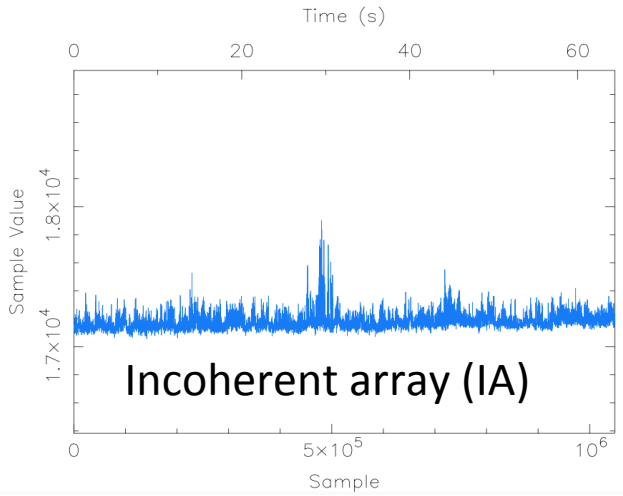
- J1850-48 at DM of 23 pc cm^{-3}, period of 327 ms
- 7 pulses (< 10 ms wide) see over 10-mins.
- The strongest pulse is at ~ 3 Jy
- One of the nearby RRAT @ 0.8 kpc

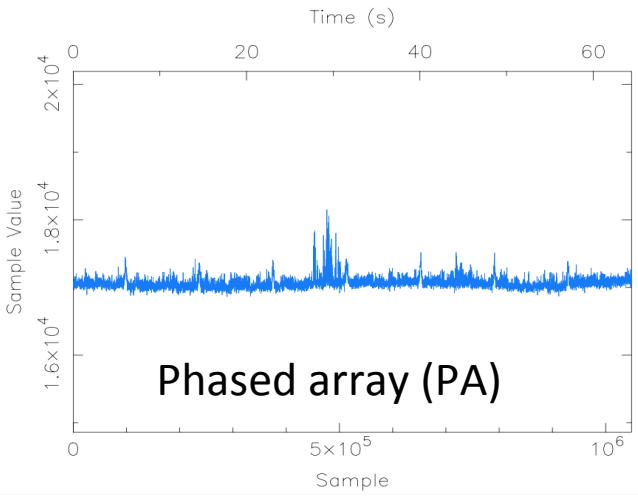
1st RRAT discovered with the GMRT

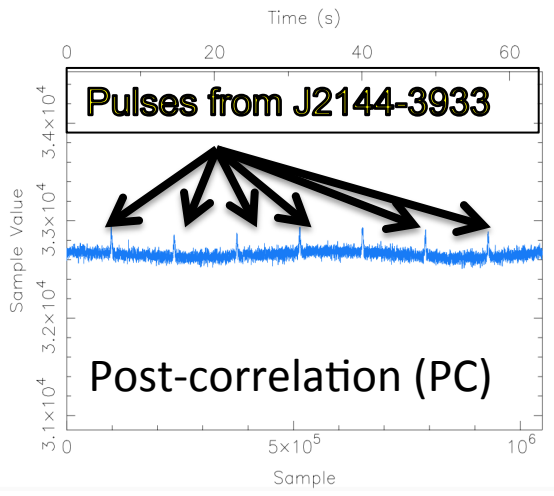
Sensitivity enhancement in time-domain search

Post-correlation beamformer for the GMRT (Roy, Chengalur, Pen, ApJ, 2018)

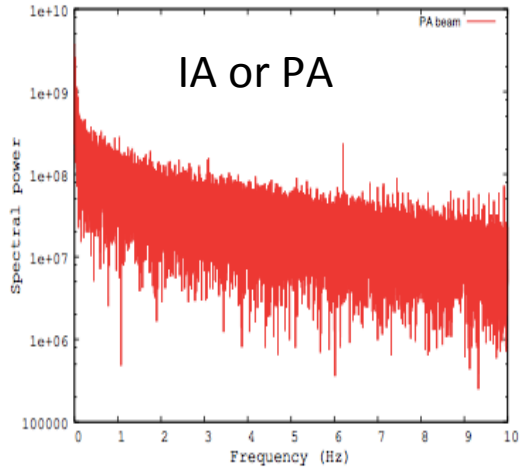
- Remove RFIs to a large extent compared to conventional beamformer currently in place at the GMRT
- Significantly reduce red-noise to improve sensitivity towards pulsed signal in Fourier domain
- 2-5 times of current time-domain sensitivity of the GMRT
- Further mitigation of red-noise with short baseline flagging

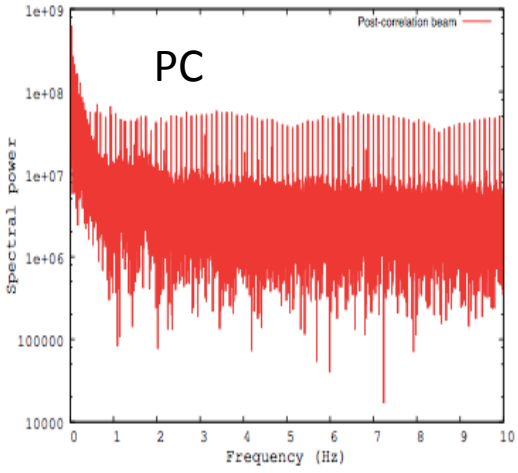


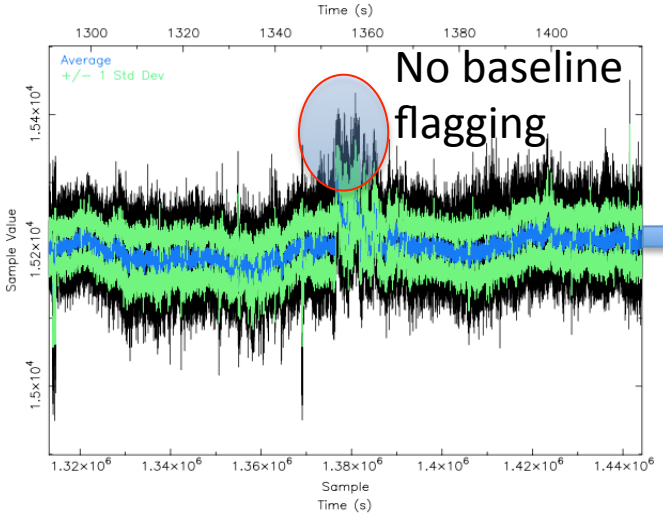


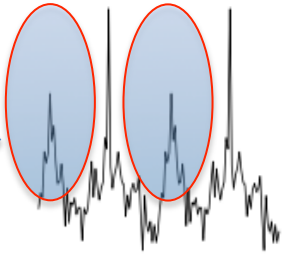


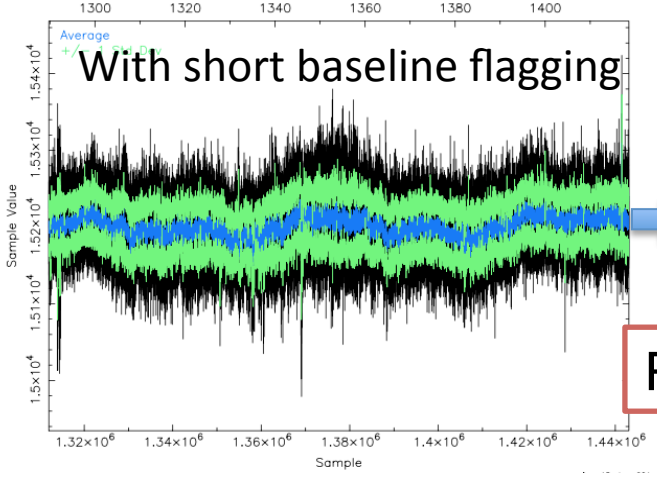
Red-noise reduction in power spectra

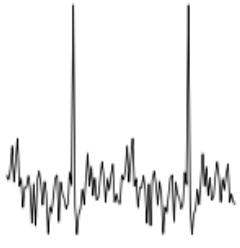


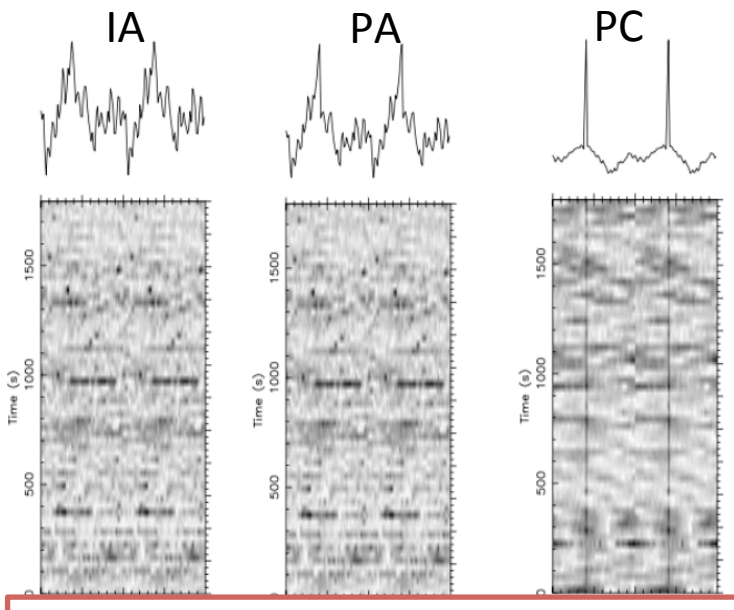








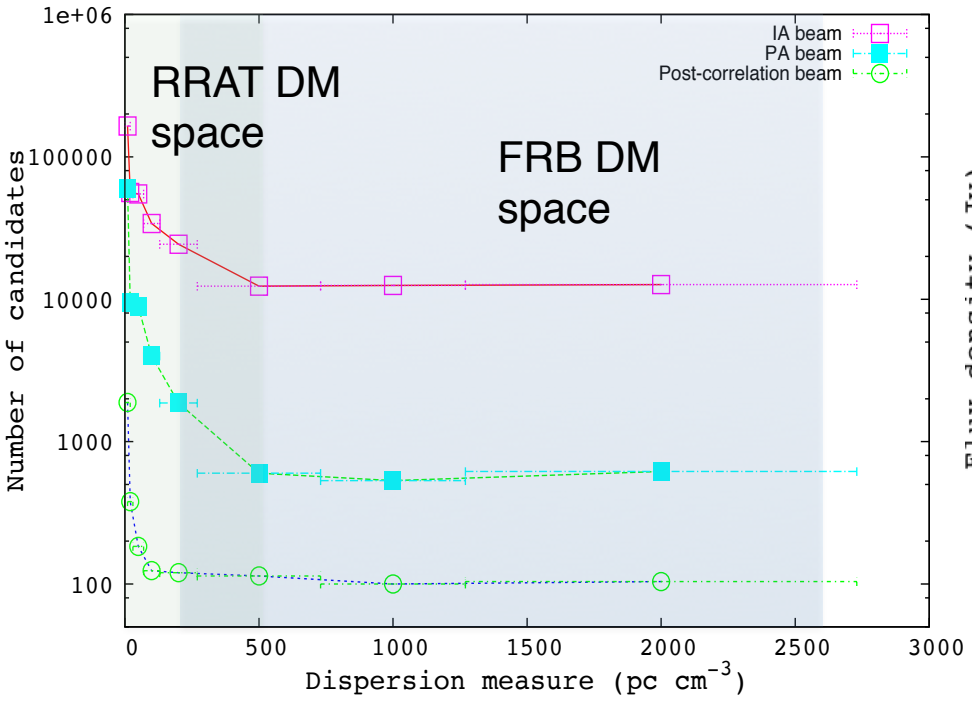


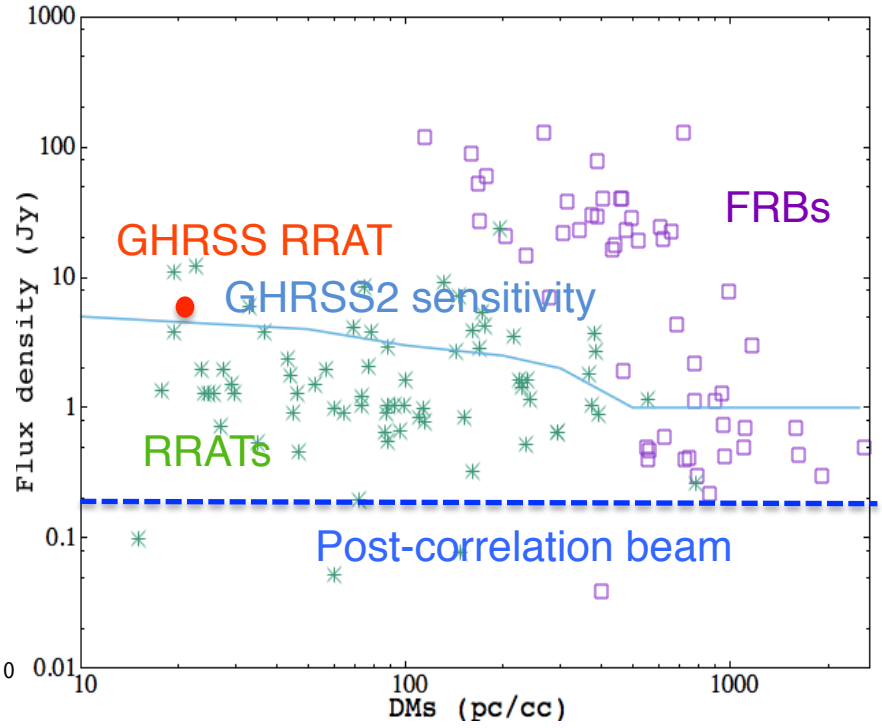


5-6 times improvement in S/N

RFI removal from < 4% baseline flagging

Reduction in number of false triggers

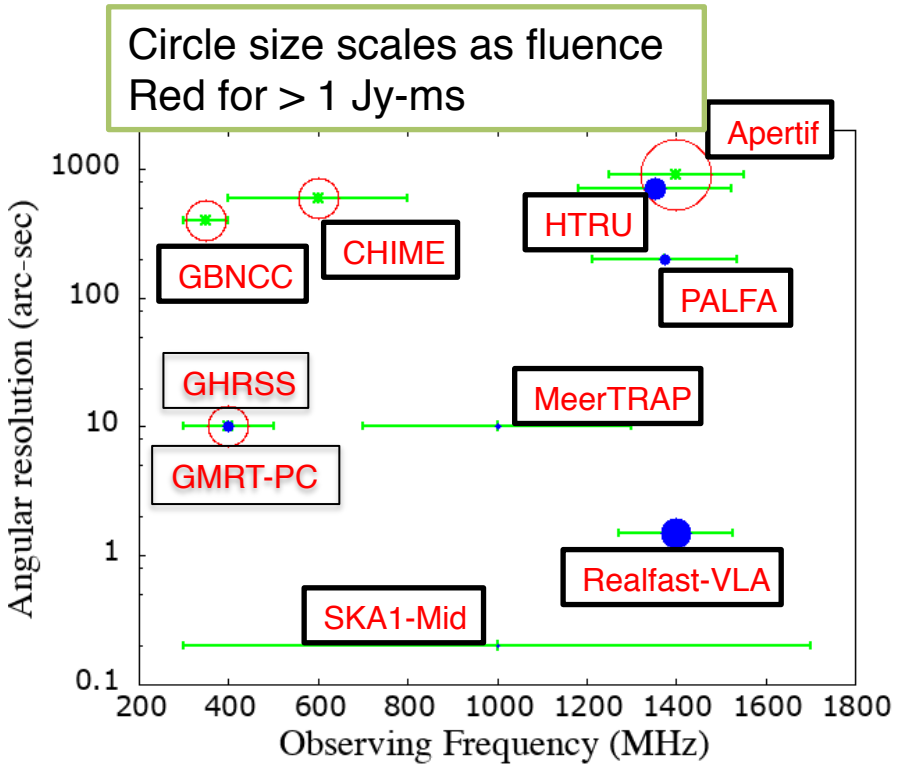




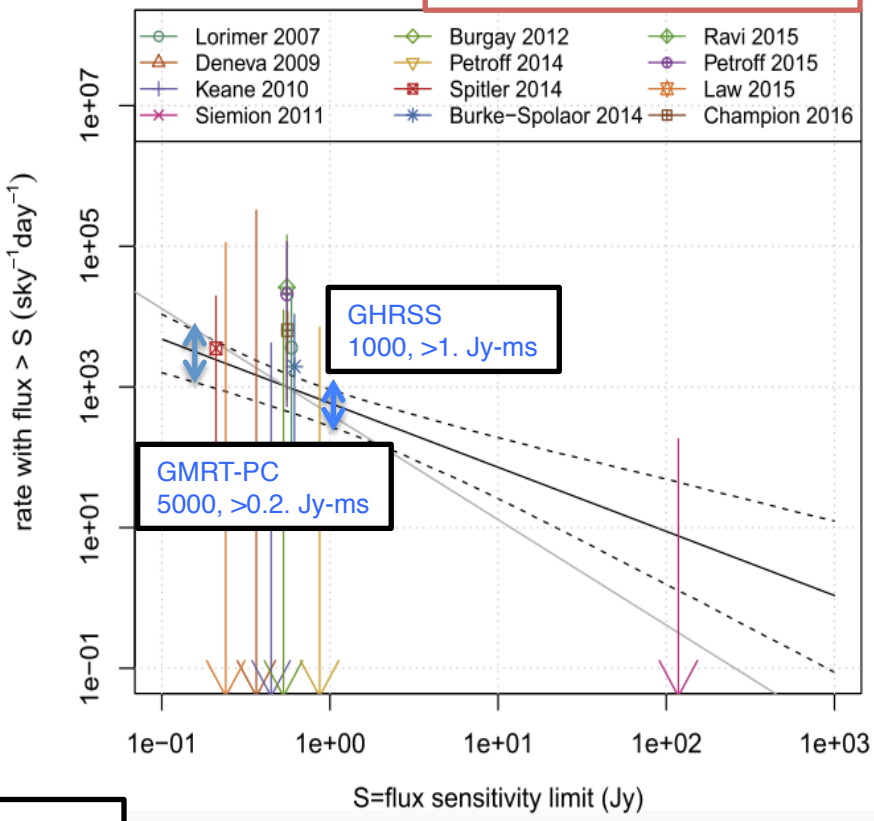
- 2-orders of magnitude reduction in number of triggers for PC compared to IA
- 5-times reduction in number of triggers for PC compared to PA
- Significantly improved sensitivity to detect event below DM < 500 pc cm^{-3}

Survey Sensitivity and detection rate

- GHRSS with incoherent mode can detect 50 bursts/year
- GMRT-PC with coherent mode can detect 4 bursts/year @ 5x lower flux values



Lawrence et al. 17



GMRT-PC is one of the pre-SKA era developments can give best of resolution and fluence

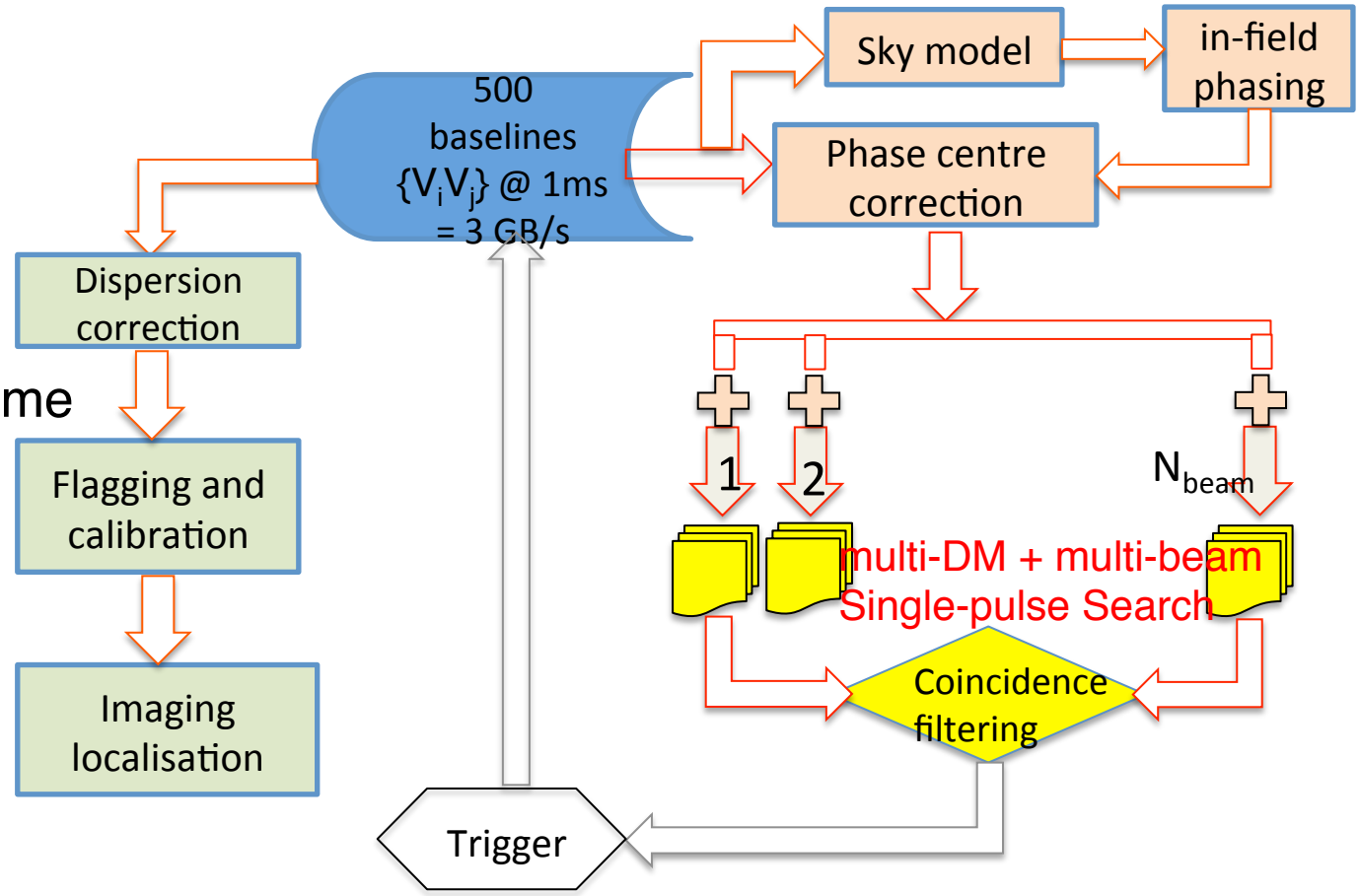
Detection rates for surveys with varied sensitivities

Real-time FRB search with multiple PC beams

- A 128-beams real-time FRB detection system (proposal under review)
  - Real-time detection of transients using 128 PC beams
  - Sensitivity of 0.1 Jy (cover all FRBs and RRATs)

- Capability of capturing full DM-sweep up DM of 2000 pc cm^{-3} at 400 MHz (~ 50 sec)

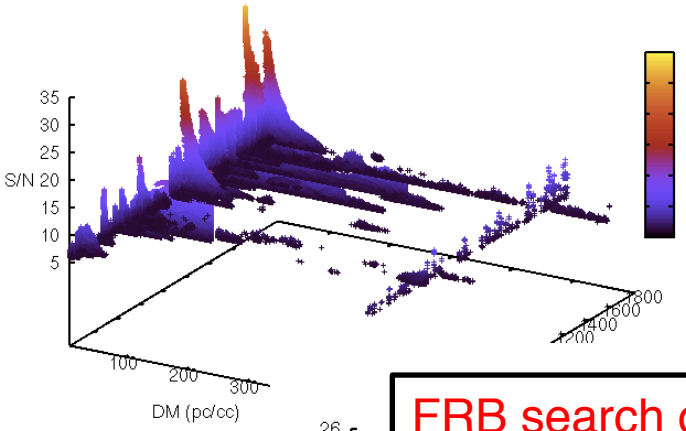
- Quasi-realtime imaging using the dumped visibilities (based on real-time trigger)



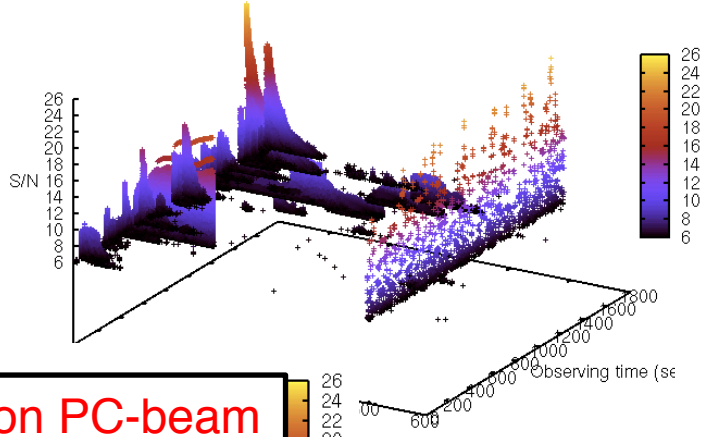
Real-time FRB search pipeline

- A GPU-based FRB detection pipeline for the GMRT (using AstroAccelerate credit: Wes et al.)
- 5 GMRT beams can be processed in real-time for DM up to 2000 pc cm^{-3}
- 25 Volta GPUs for the full proposed system of 128-beams

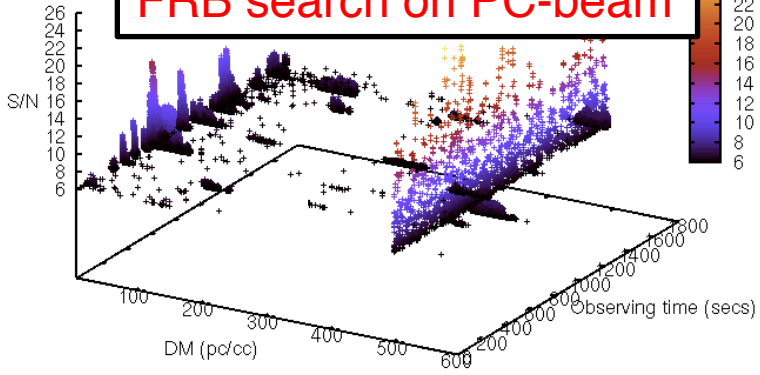
FRB search on IA-beam



FRB search on PA-beam



FRB search on PC-beam



Prototyping system

Summary

- GMRT offers a good trade off between resolution and sensitivity for FRB search
- GHRSS survey currently exploring bursting sky with the GMRT
- GHRSS can extend the low-frequency limit of FRB detection
- Post-correlation beam provides much cleaner view of the bursting sky reducing the false triggers
- Development of FRB search with post-correlation beam pushes the GMRT flux limit by many-folds allowing to probe different luminosity distribution


Thank you