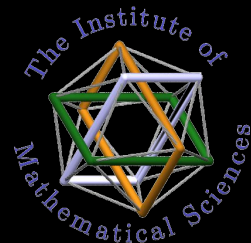


# The role of Indian Pulsar Timing Array in the global hunt for nanoHz gravitational waves

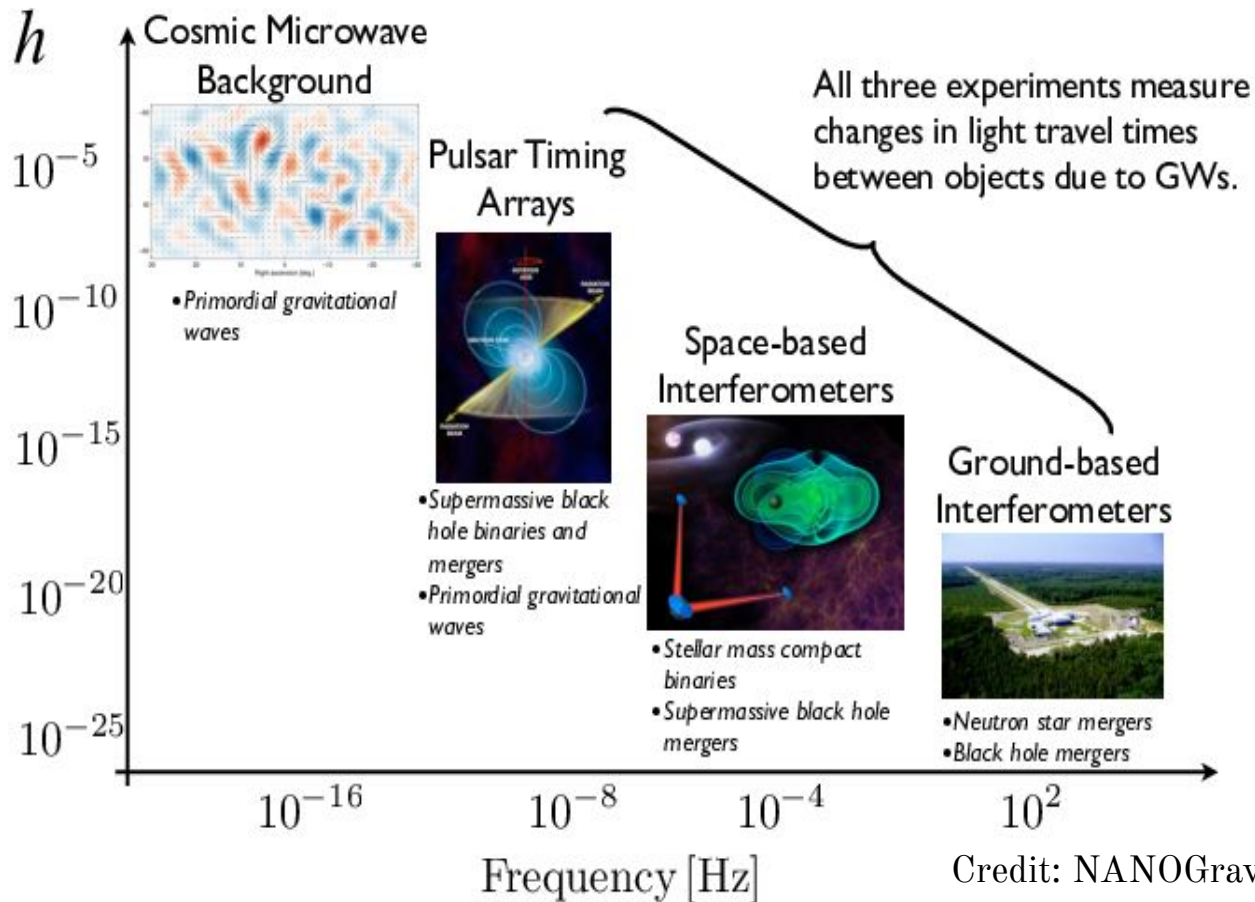
—  
Pratik Tarafdar

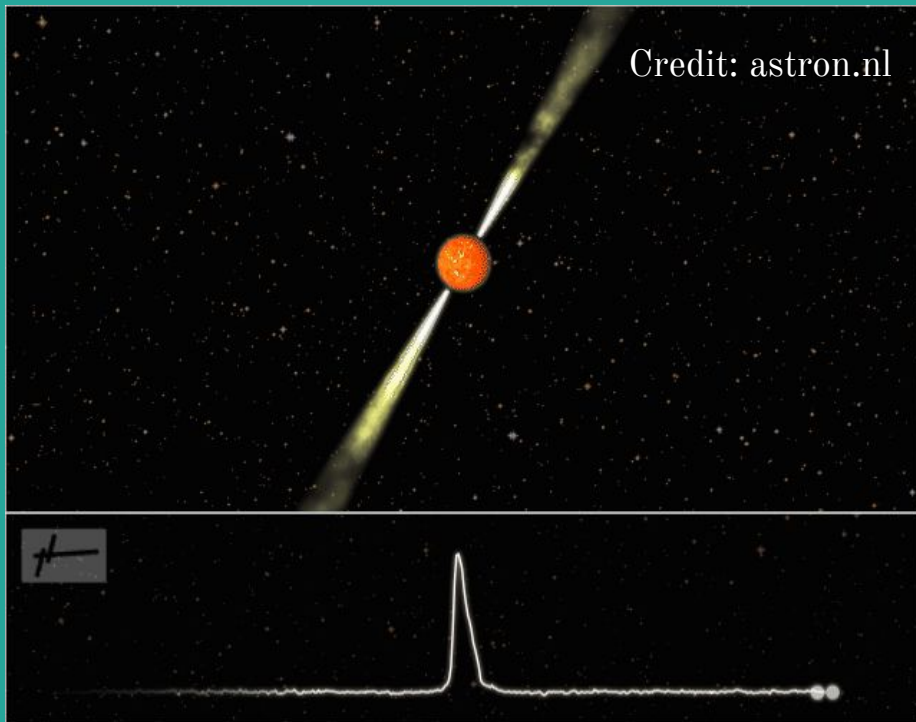
Institute of Mathematical Sciences

On behalf of the InPTA collaboration

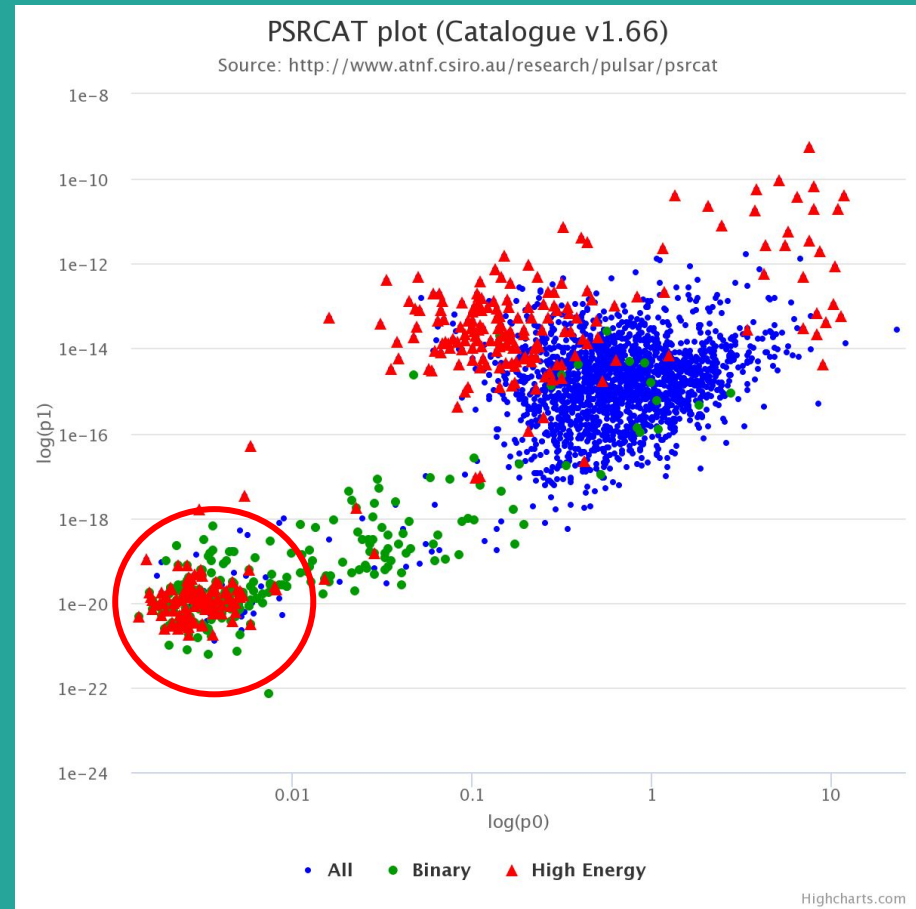


# The spectrum of gravitational wave astronomy





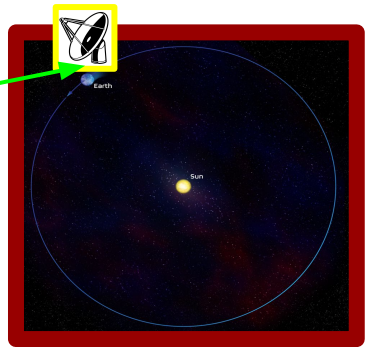
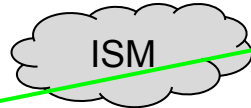
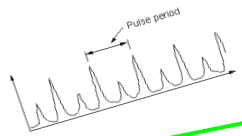
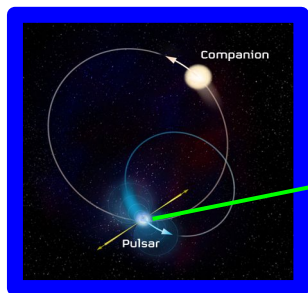
- ★ Millisecond Pulsars (MSPs) -  $P \sim 10^{-3}$  sec
- ★ Spun-up 'recycled' pulsars - usually binaries
- ★ Extremely stable rotators - high precision celestial clocks



ATNF Pulsar Catalogue v1.66  
Manchester, D. et. al. AJ (2005)

$$t_{\text{obs}} = t_{\text{em}} + \Delta_{\text{Binary}} + \Delta_{\text{DM}} + \Delta_{\text{SolarSystem}} + t_{\text{clock}} + \Delta_{\text{GW}} + \dots$$

(Hobbs et.al. 2006)



Credit: P. Freire

Image credit: Abhimanyu Susobhanan

Clocks (mostly binary pulsars) are moving (Pulsar ephemeris corrections)

Planets in the SS are moving (SS ephemeris corrections)



Observer (Earth) is moving  
 Revolution (SSB correction) +  
 Rotation (local clock corrections)

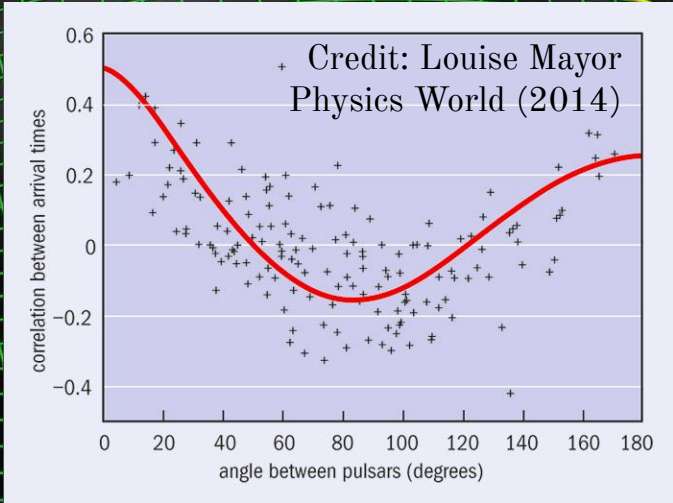
**Moving clock runs slow**



○●○ Dispersive delays + scattering delays

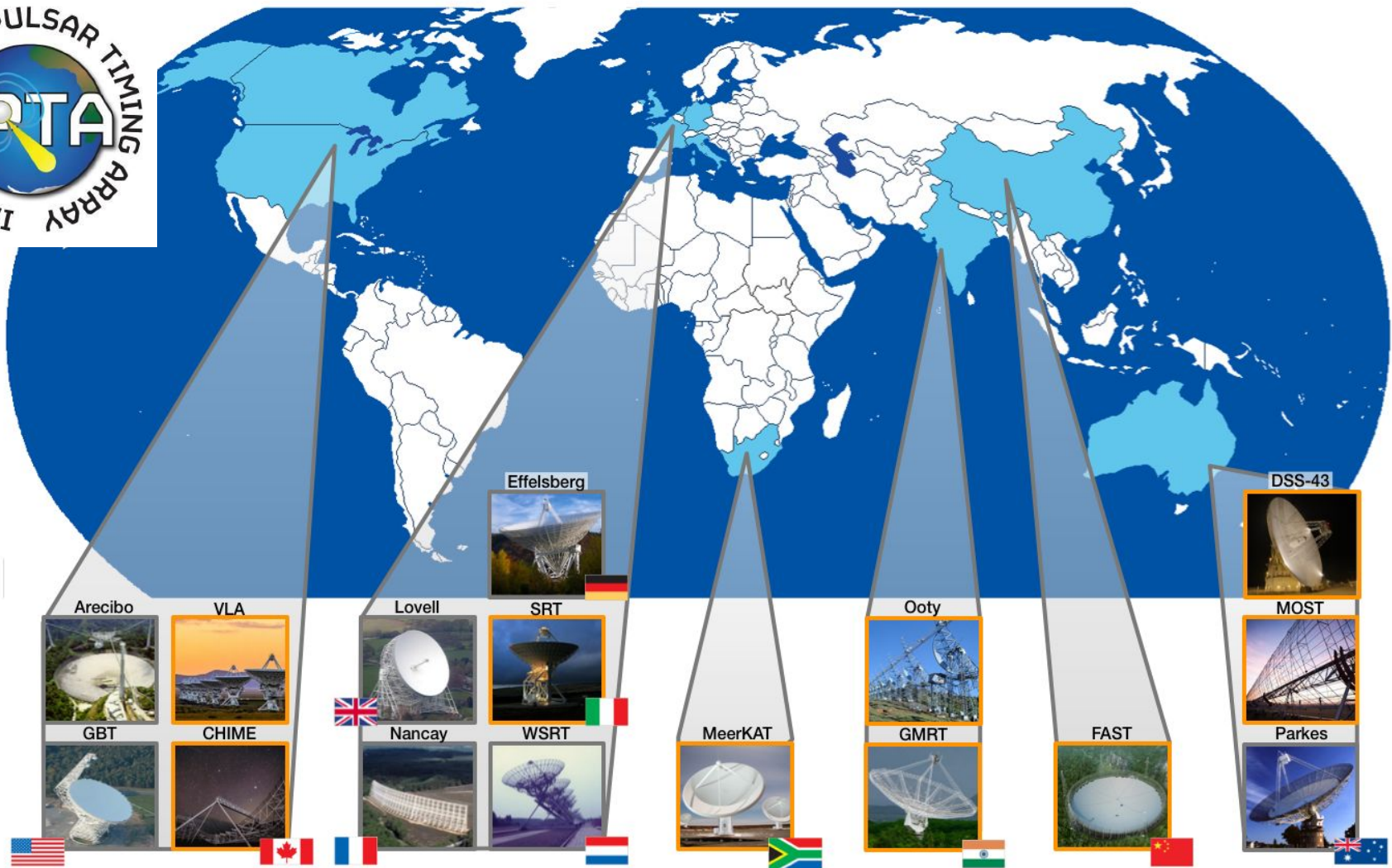
# An array of ultra-stable clocks for detection of low frequency (nanoHz) GWs

To A precision  $\sim \text{sub-}\mu\text{s}$



Credit: NANOGrav







# InPTA

Indian Pulsar Timing Array

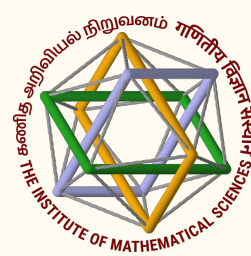
**International Pulsar Timing Array**

NANOGrav + EPTA + PPTA + InPTA

## Unique strength of uGMRT

High sensitivity at low frequencies  
Ideal for studying FD effects  
(like ISM noise)

- ★ The Indian Pulsar Timing Array Experiment since 2015
- ★ Legacy data from ORT & GMRT
- ★ Presently observing 14 IPTA pulsars with the uGMRT
- ★ Cadence  $\sim$  10 days
- ★ Plans of extension to more pulsars in future



**Indian instrumentation – Global participation !**



# Faculty Members



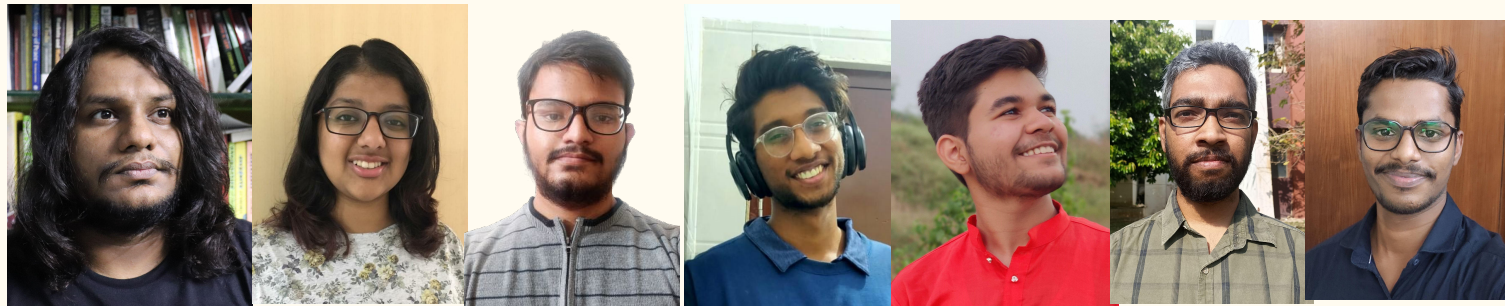
# Postdoctoral Fellows



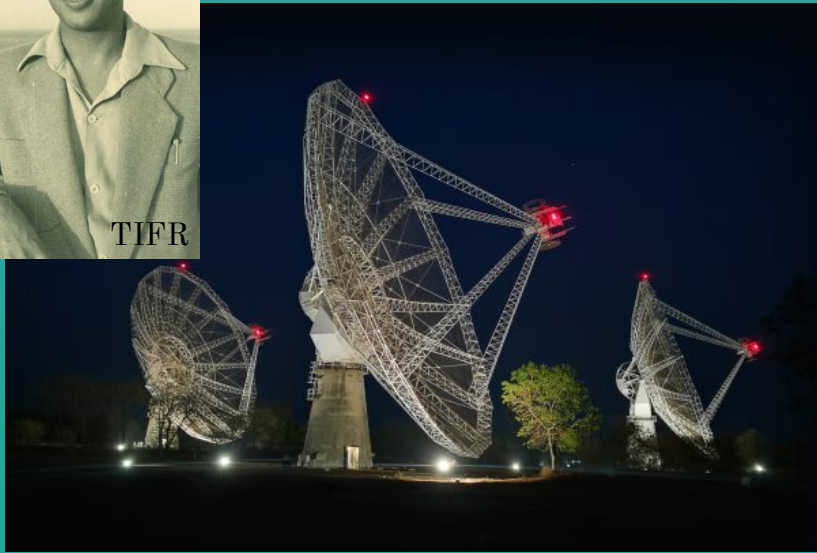
## Ph.D. Students



## Undergraduate Students



# The upgraded Giant Metrewave Radio Telescope (uGMRT)



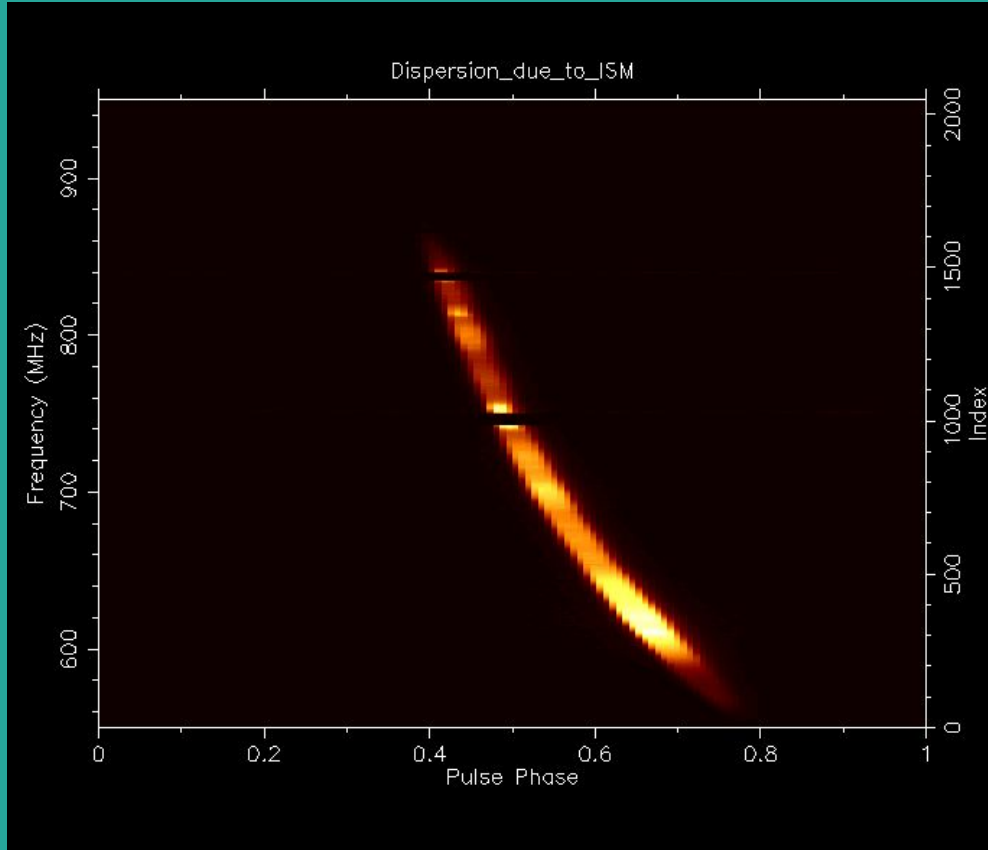
- Located at Khodad near Pune, operated by NCRA-TIFR
- Interferometric array - 30 antennae (parabolic reflector, 45 m diameter each)  
14 in central square, 16 distributed in Y-shaped arms
- Simultaneous multi-band observations across 4 bands (frequency range - 30 MHz to 1.5 GHz)
- Better receivers, higher instantaneous bandwidth, upgraded servo, frontend and digital backends

Gupta, Y. et. al. Current Science (2017)

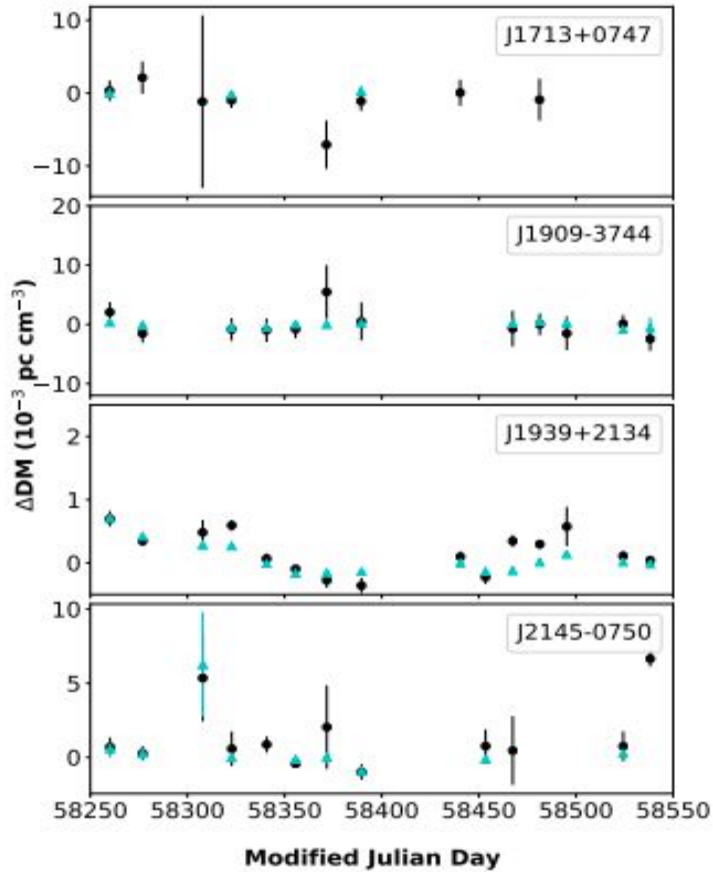
High precision DMs

—

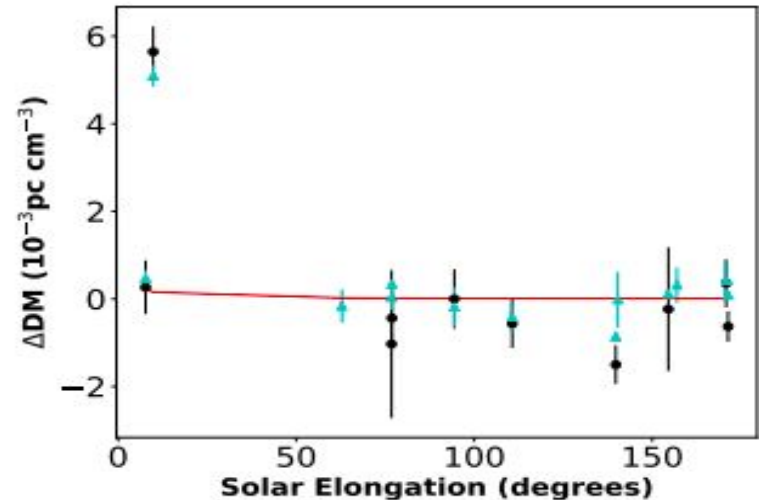
# ISM Propagation Effect I - Dispersion



- Electron rich plasma - frequency-dependent refractive index
- Velocity of arriving signal depends on its frequency
- Low frequency arrives late
- Dedispersion required
- Needs precise DM estimation

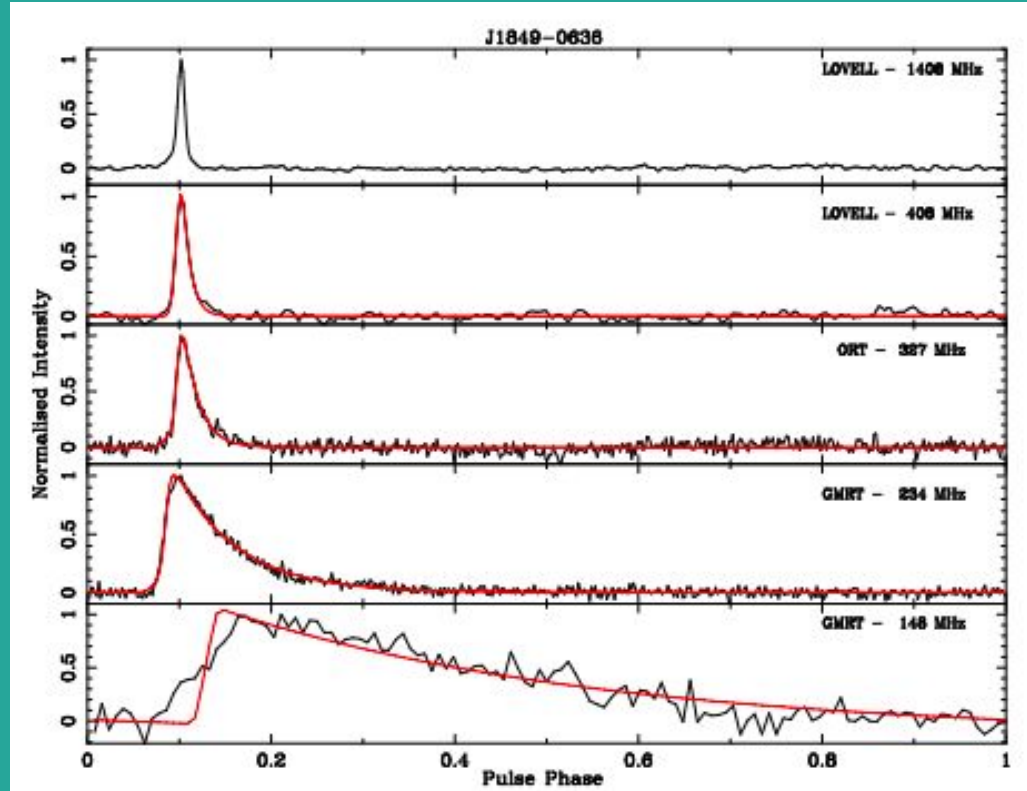
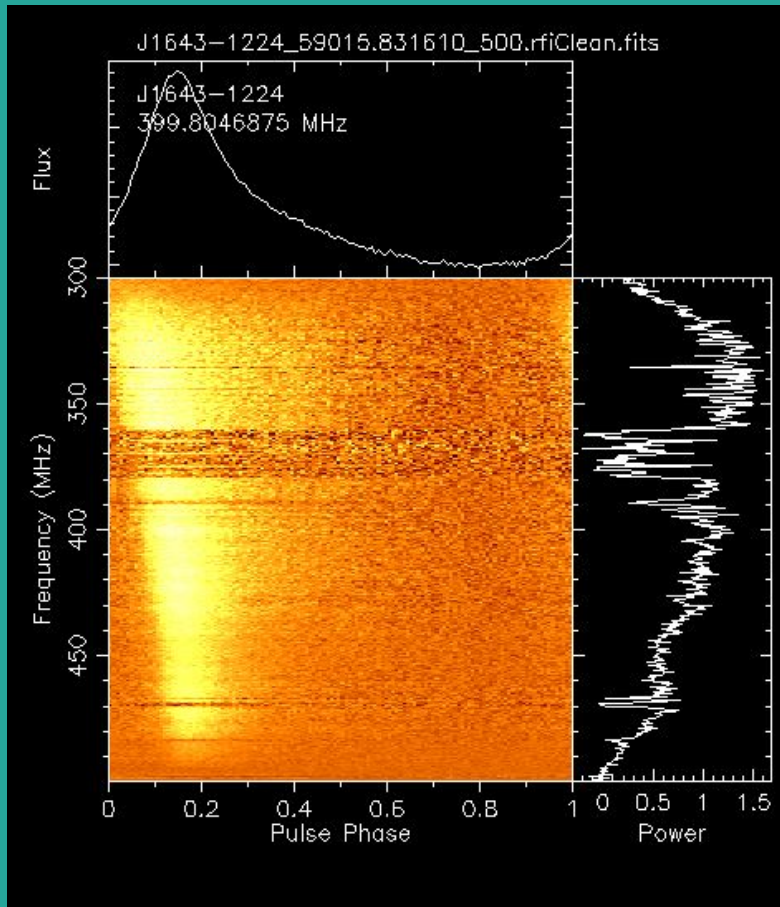


- DM estimation with unprecedented precision at low frequencies
- Precision measurement led to the first signature of CME event in pulsar astronomy data

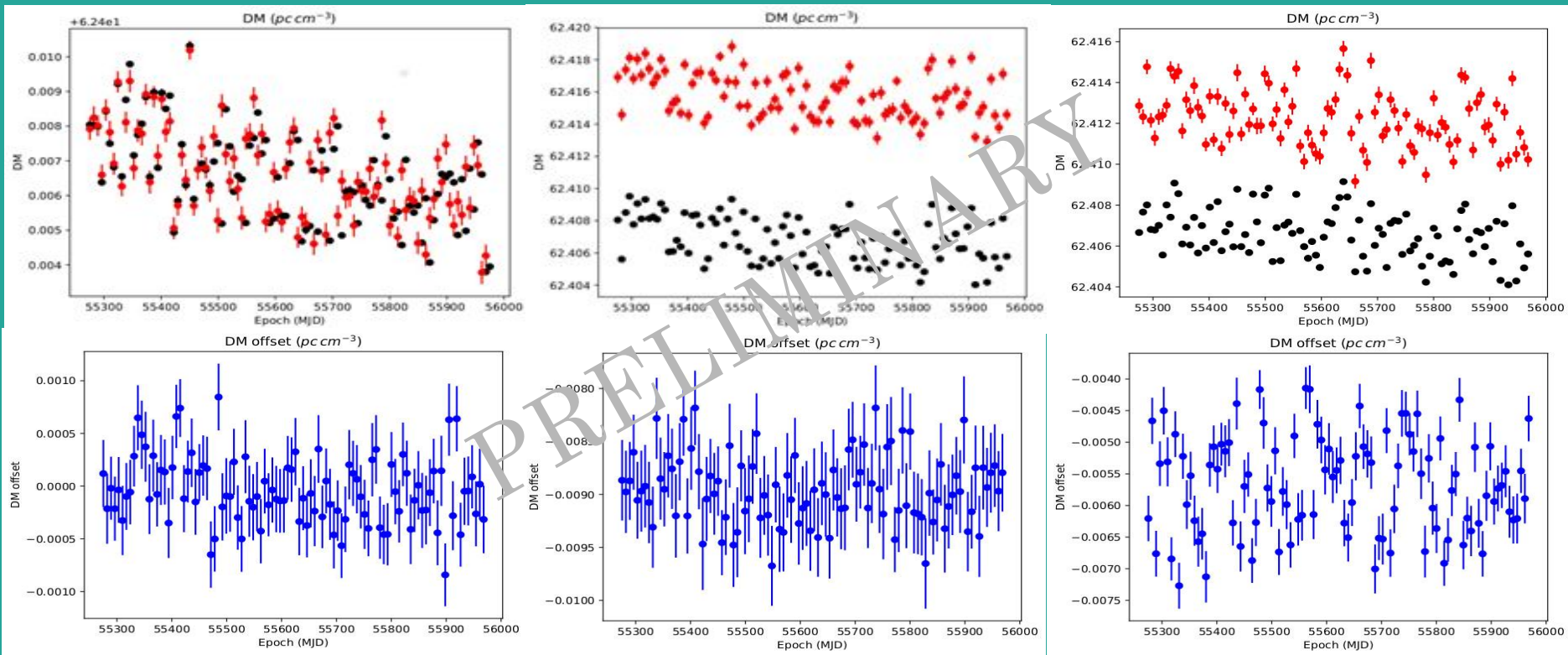


## ISM Propagation Effect II - Scatter Broadening

- Turbulence effect
- Multi-path propagation through ISM



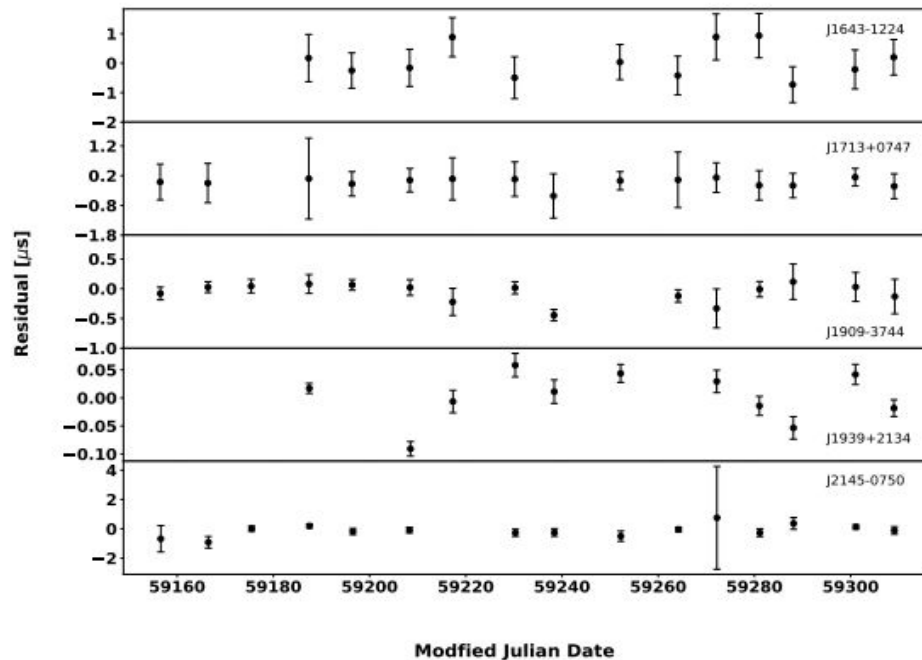
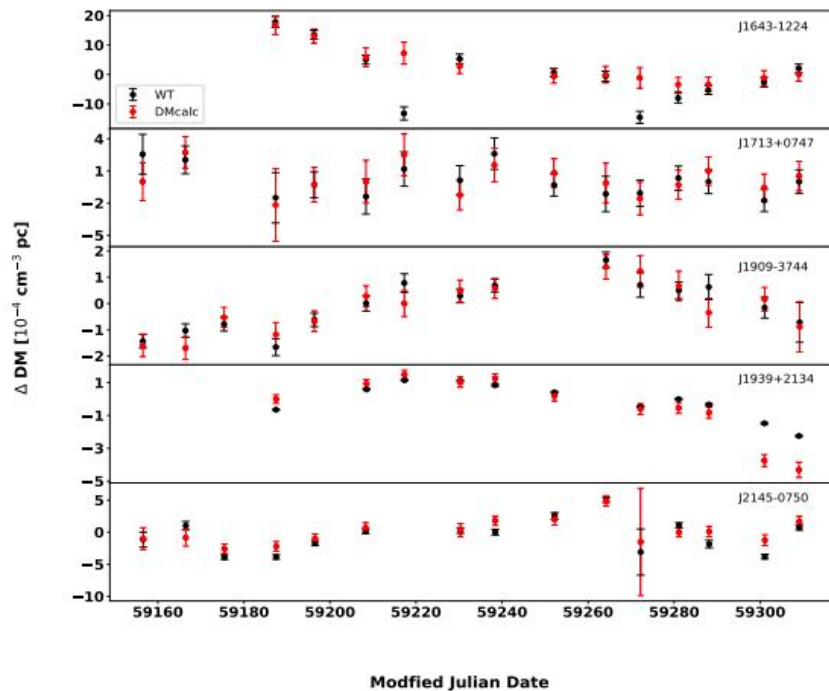
- Simulated DM and pulse profile to generate fake data
- Simulations with scatter broadening show systematic offset in DMs





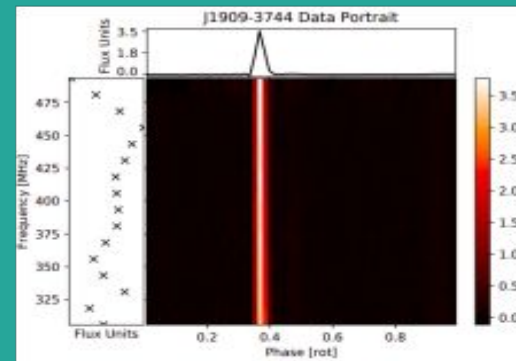
# Wideband timing using uGMRT





- ❖ Very high precision DM and ToA measurements at low frequencies
- ❖ Frequency resolved templates take care of frequency dependent profile evolution

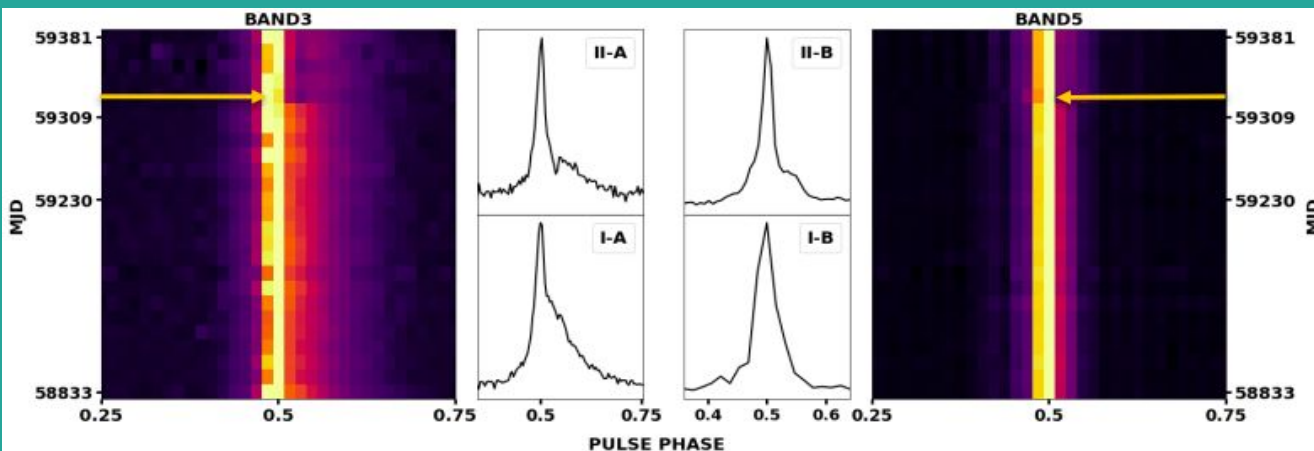
**Nobleson K. et. al. (arXiv:2112.06908)**



# Recent profile change in PSR J1713+0747

➤ uGMRT observed the change at low frequencies

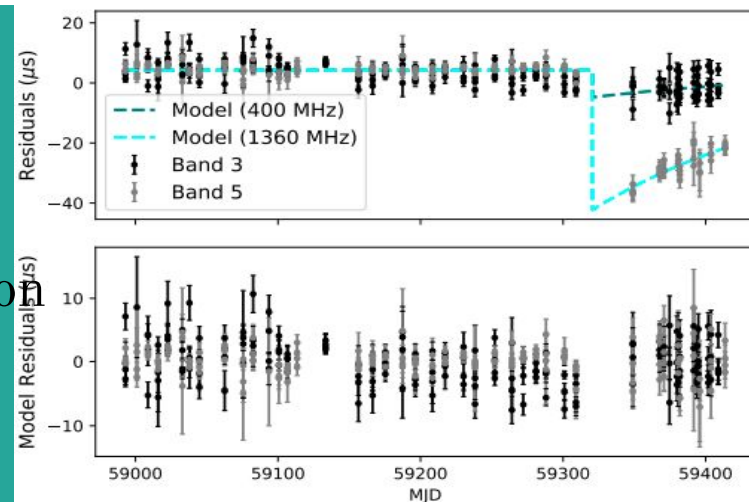
➤ Timing residuals affected in both higher and lower frequency bands



**Singha, J. et. al. MNRAS Lett. (2021)**

- ➔ Nature of FD being studied
- ➔ Extraction of ISM effects to reveal the reason behind profile change

**Tarafdar, P. et. al. (in prep)**



# Coming up

- ★ InPTA Data Release 1 - High precision DMs, ToAs spanning over 3.5 yrs.
- ★ Effects of scatter broadening on DM measurements at low frequencies
- ★ Frequency dependence of decorrelation bandwidths
- ★ High precision DM measurements to characterise solar eruptive events
- ★ Detailed wideband analysis of InPTA pulsars
- ★ Investigation of the PSR J1713+0747 profile change event
- ★ Closer study of suspected mode changing MSPs.
- ★ SPTNA and GW analysis - InPTA Data Release 2
- ★ **Combination of data with other PTAs towards IPTA DR3 (Detection?)**

**We are online !**

**<http://inpta.iitr.ac.in>**