The Giant Metrewave Radio Telescope (GMRT)

Ishwara Chandra C. H.

(with inputs from several colleagues)

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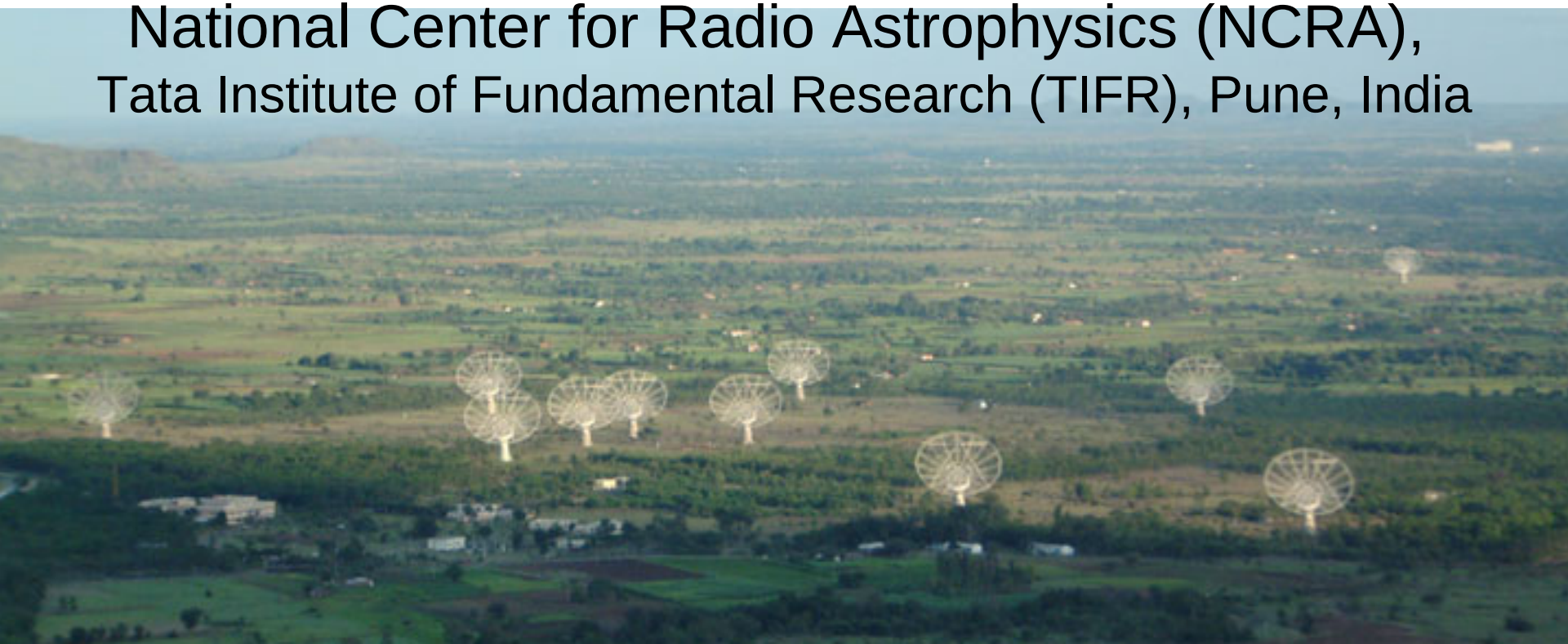


GMRT in Media

IEEE Milestones for GMRT (news)

American Physical Society video on GMRT

Vigyan Prasar video on GMRT

Several other videos on youtube on GMRT

Many press releases related to GMRT

Giant Metre-wave Radio Telescope (GMRT)

GMRT consists of 30 antennas, each of 45 meter diameter, spread over 25 km area, at Khodad, 90 km off Pune city.

It is the world's largest radio telescope at metre-waves.

Novel antenna concept (SMART)
Frequency of operation 150 to 1430 MHz
Fully Designed and fabricated in India

GMRT is run by

National Center for Radio Astrophysics

of the

Tata Institute of Fundamental Research

URL: http://www.ncra.tifr.res.in

The GMRT Antenna

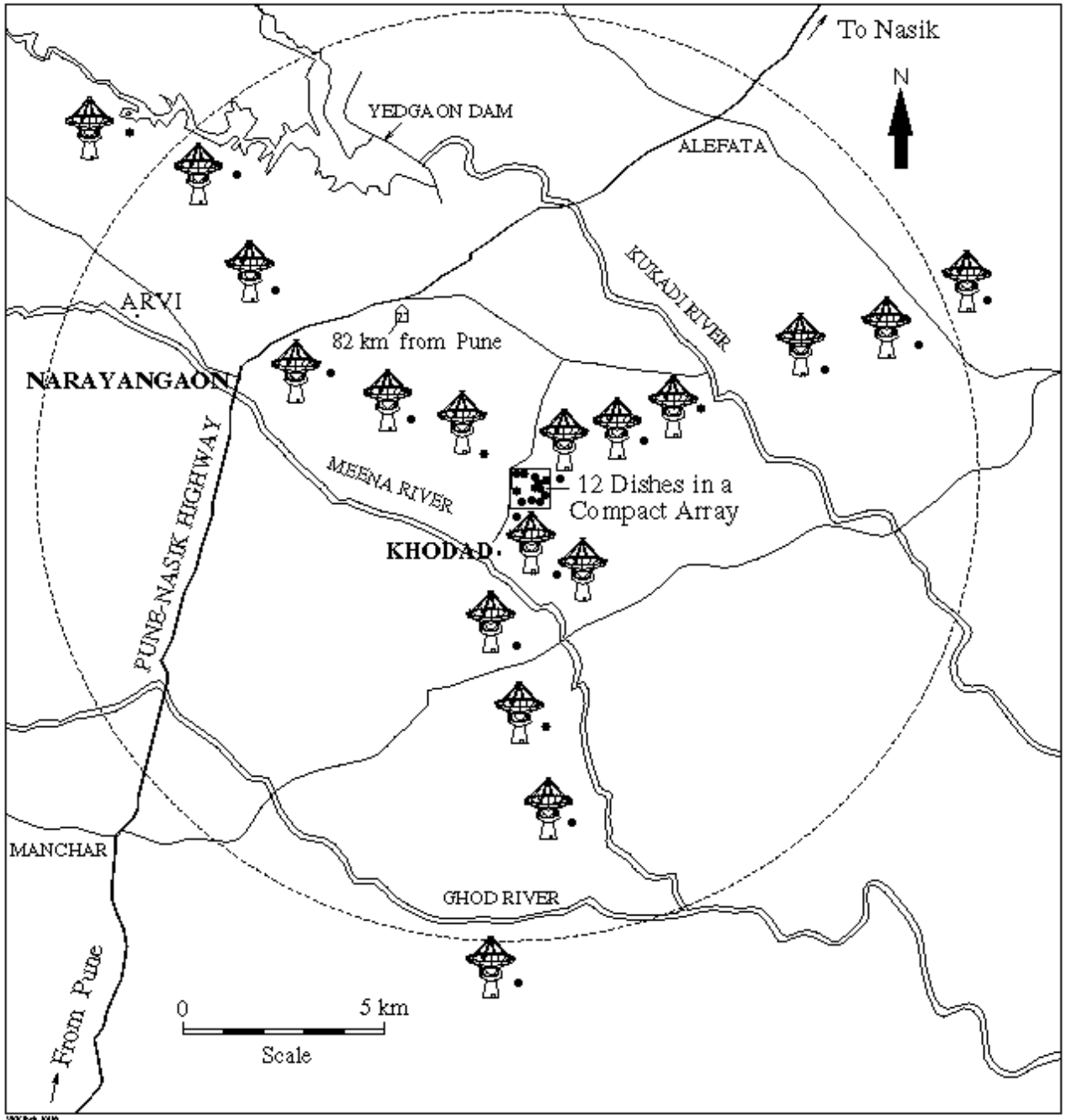
Diameter: 45 meter

7% solidity with 0.38 mm dia ss wires to form a surface with wire-grid

Mesh panel supported by ss rope trusses attached to tubular parabolic frame: SMART concept to form the parabola : PATENTED

The “see – through” Antenna

LOCATIONS OF GMRT ANTENNAS (30 dishes)



The *original* GMRT : An Overview

- 30 dishes, 45 m diameter each
  - 12 dishes in a central 1 km x 1 km region (central square)
  - remaining along 3 arms of Y-shaped array
  - baselines : ~ 200 m (shortest);
    ~ 30 km (longest)

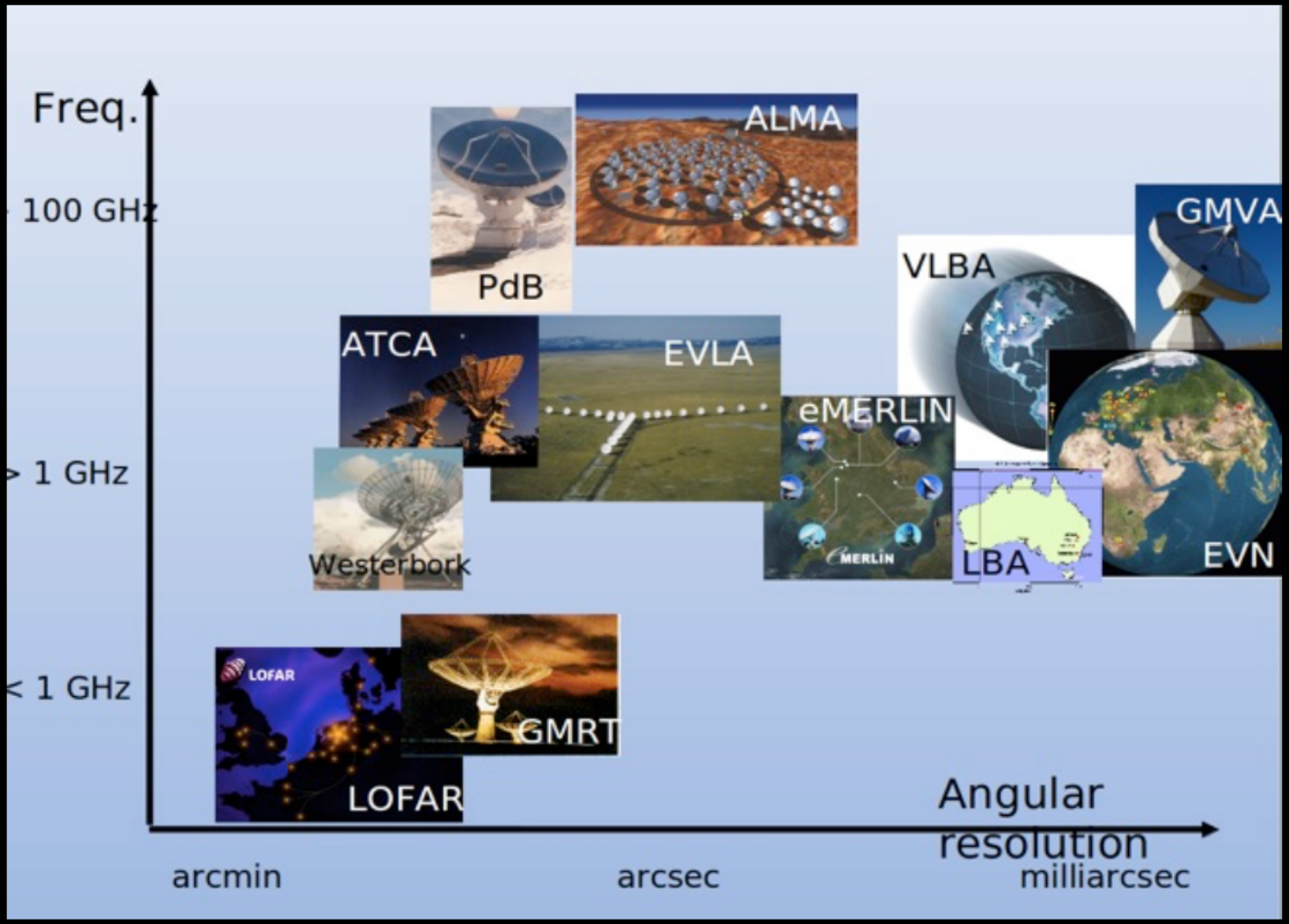
- Frequency range (of original GMRT) :
  - 130-170 MHz
  - 225-245 MHz
  - 300-360 MHz
  - 580-660 MHz
  - 1000-1450 MHz
  - max instantaneous BW = 32 MHz

- Effective collecting area (2-3% of SKA) :
  - 30,000 sq m at lower frequencies
  - 20,000 sq m at highest frequencies

- Supports 2 modes of operation :
  - Interferometry, aperture synthesis
  - Array mode (incoherent & coherent)

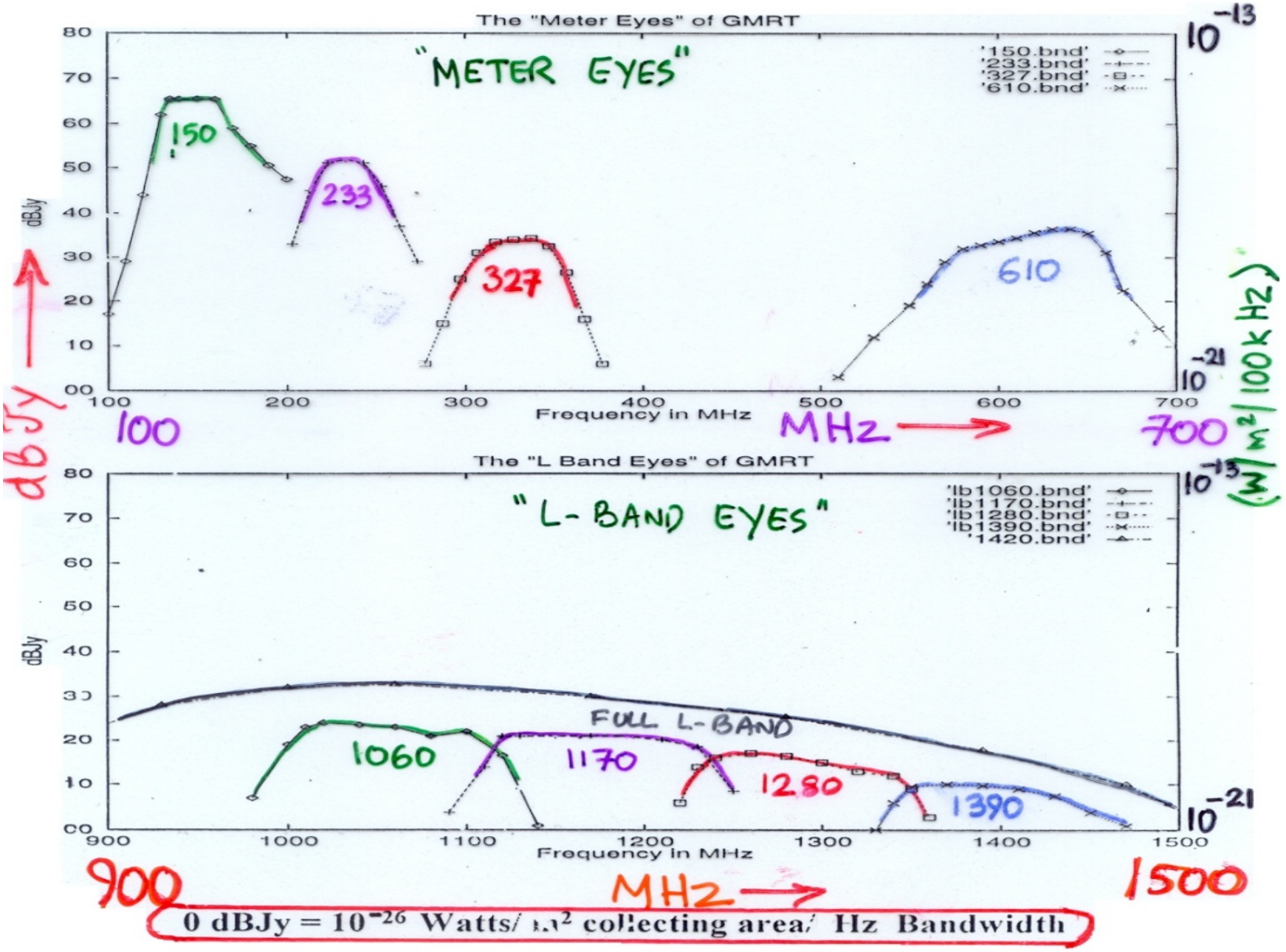
Some synthesis Radio Telescopes (cm & m waves)

Synthesis Radio Telescope	Location	No. of Antennas	Synth. Aperture.	Freq. Range
VLA	USA	27 x 25 m	33 km	1.4 GHz – 44 GHz (74 MHz & 327 MHz)
WSRT	Netherlands	14 x 25 m	3 km	327 MHz – 8000 MHz
AT	Australia	6 x 25 m	6 km	1.4 GHz – 44 GHz
GMRT	**India**	**30 x 45 m**	**25 km**	**130 MHz – 1450 MHz**
MERLIN	UK	6 x 25 m +1 x 76 m	400 km	408 MHz – 5000 MHz



Credit: T. Savolainen

Observing bands of Legacy GMRT



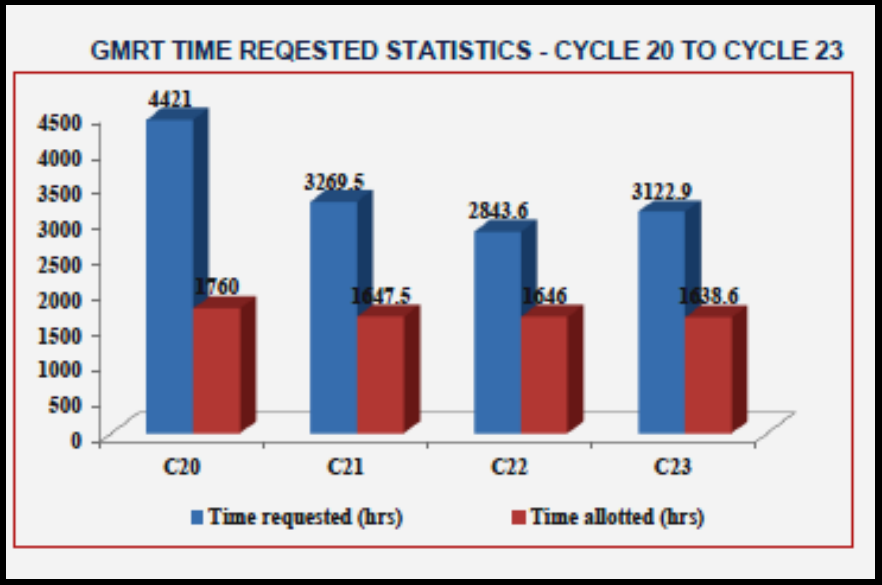
Inauguration of the legacy GMRT

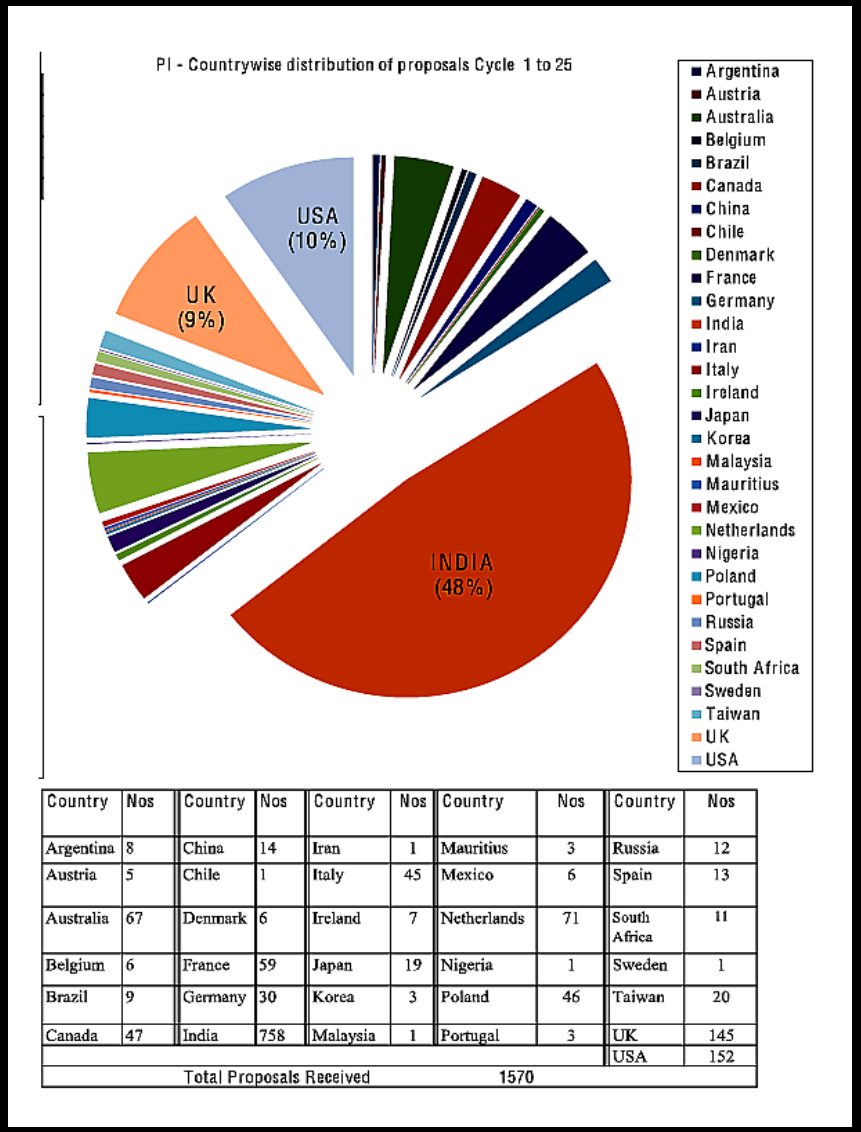
- The GMRT was built during the 1990s
- It was made available to the global scientific community from early 2002

Dedication of the GMRT : October 4, 2001

GMRT : Usage Statistics

- GMRT sees users from all over the world : distribution of Indian vs Foreign users is close to 50:50
- The GMRT is oversubscribed by a factor of 2 or more





Country	Nos	Country	Nos	Country	Nos	Country	Nos	Country	Nos
Argentina	8	China	14	Iran	1	Mauritius	3	Russia	12
Austria	5	Chile	1	Italy	45	Mexico	6	Spain	13
Australia	67	Denmark	6	Ireland	7	Netherlands	71	South Africa	11
Belgium	6	France	59	Japan	19	Nigeria	1	Sweden	1
Brazil	9	Germany	30	Korea	3	Poland	46	Taiwan	20
Canada	47	India	758	Malaysia	1	Portugal	3	UK	145
								USA	152
Total Proposals Received						1570			

Next Generation: The uGMRT

GMRT has been working well on the global stage; upgrade planned keeping in mind global efforts such as the SKA.

The main features of the upgraded GMRT (uGMRT) are:

Band 5 (1000 – 1450 MHz) : existing wide-band feed + improved dynamic range receivers with appropriate RFI filters

Band 4 (550 – 850 MHz) : new feed with matching receiver

Band 3 (250 – 500 MHz) : new feed + matching receiver

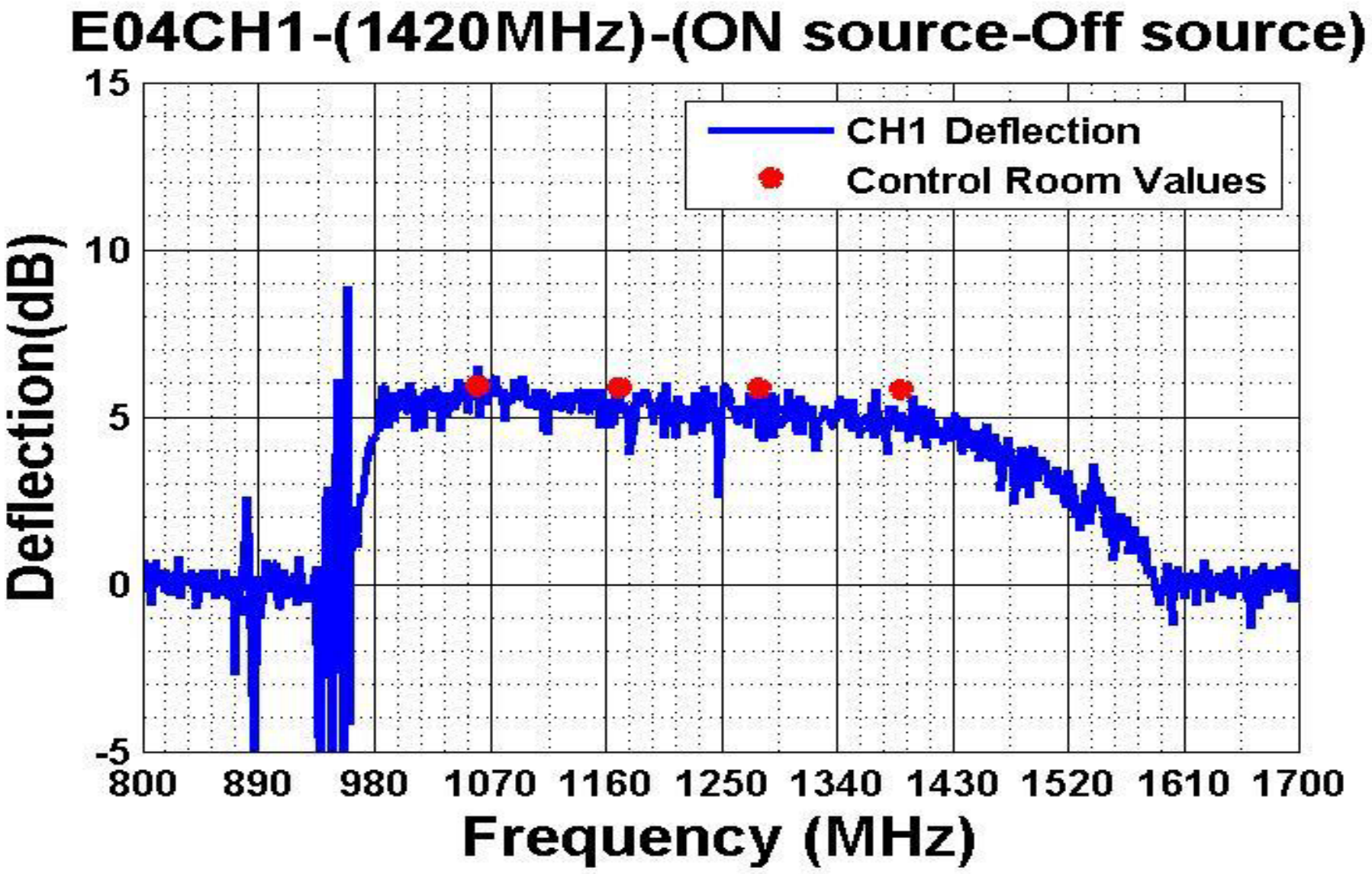
Band 2 (120 – 250 MHz) : modified Kildal feed + receiver

Band 1 (30 – 80 MHz) : on hold at present.

Digital backend: upto 400 MHz, 32K channels, 0.5s int, full stokes

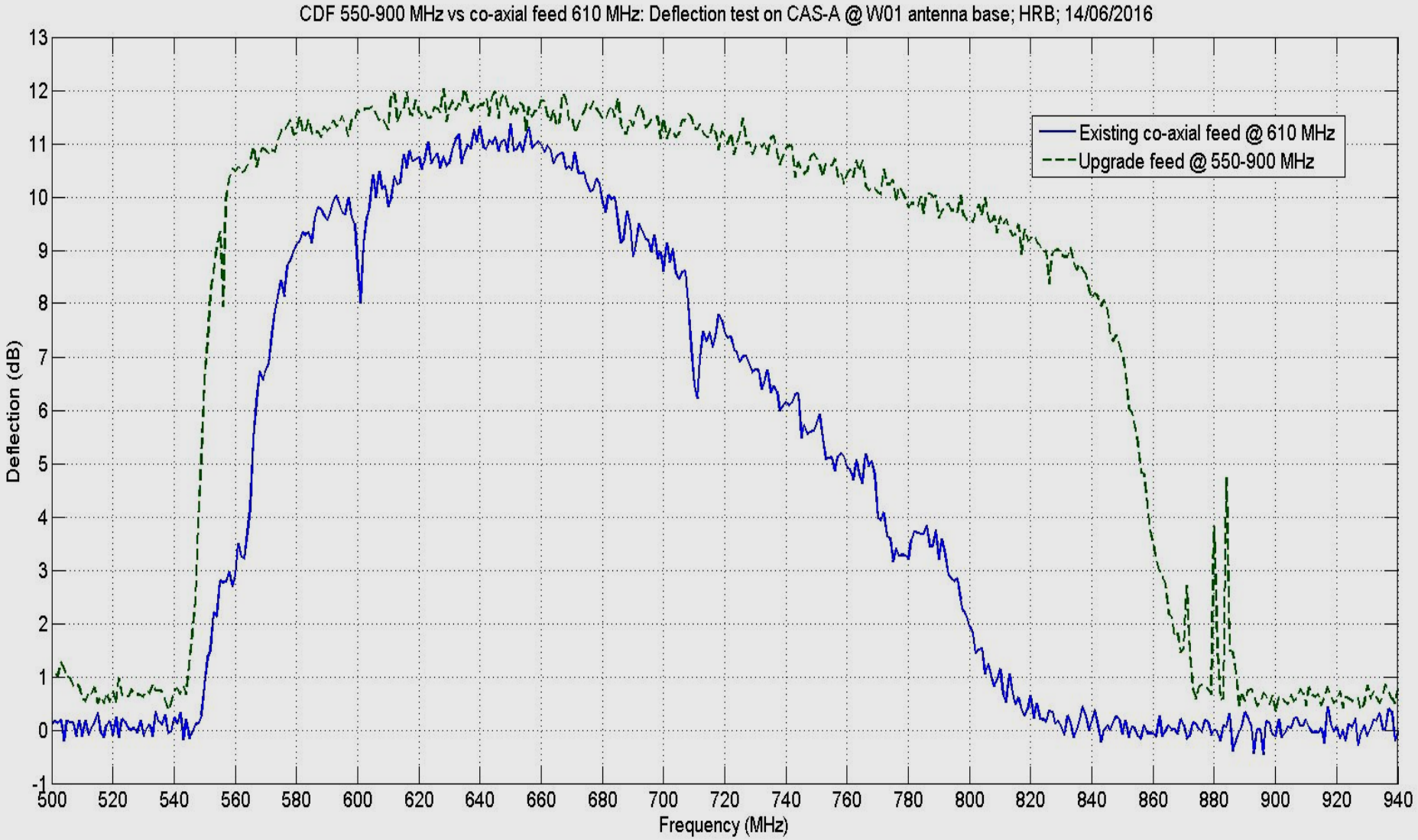
New Control and Monitor systems, servo, FPS etc.

uGMRT band-5 (L-band)

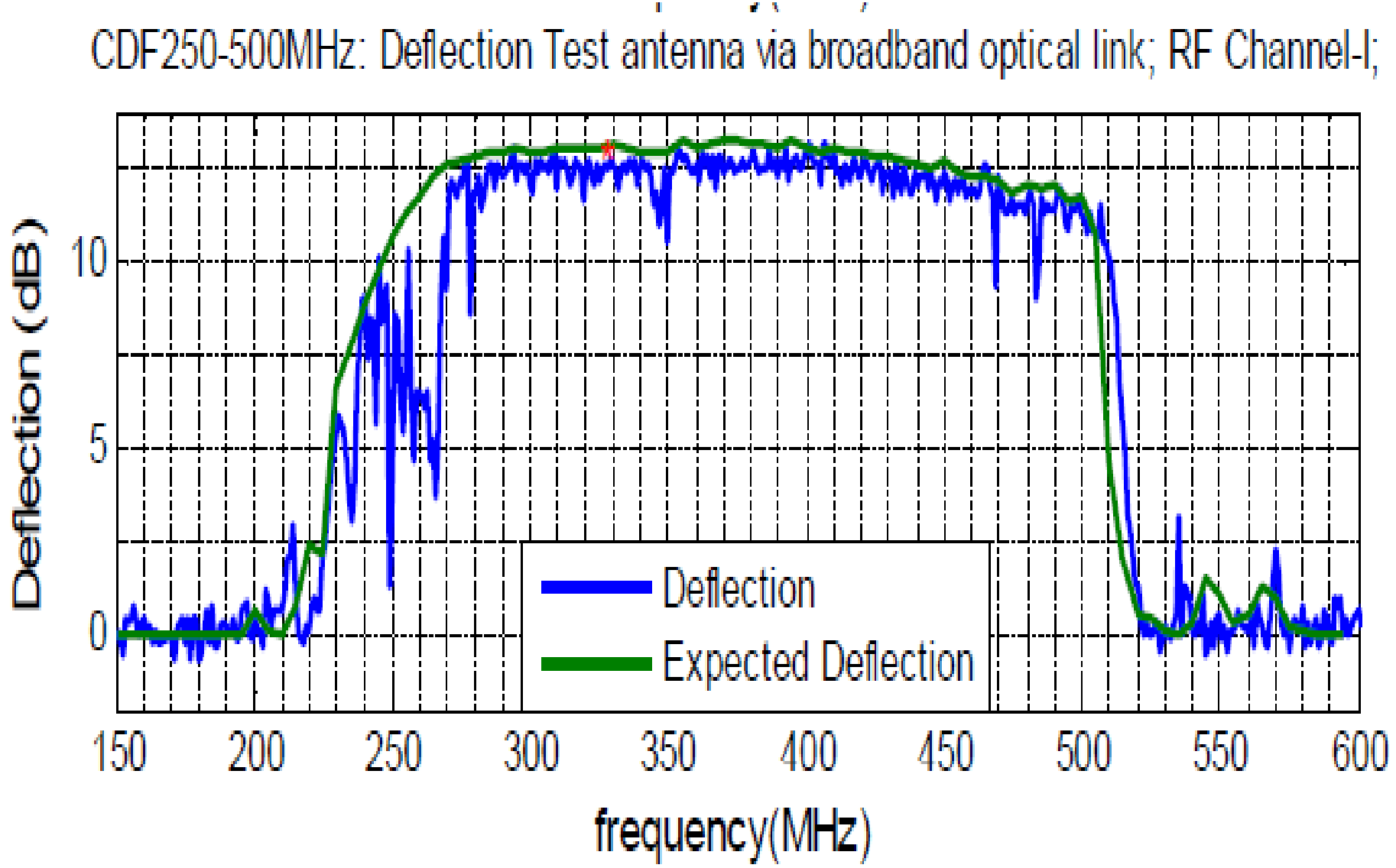


uGMRT band-4 (550 – 850 MHz)

Better than narrow band 610 MHz feed, relatively clean

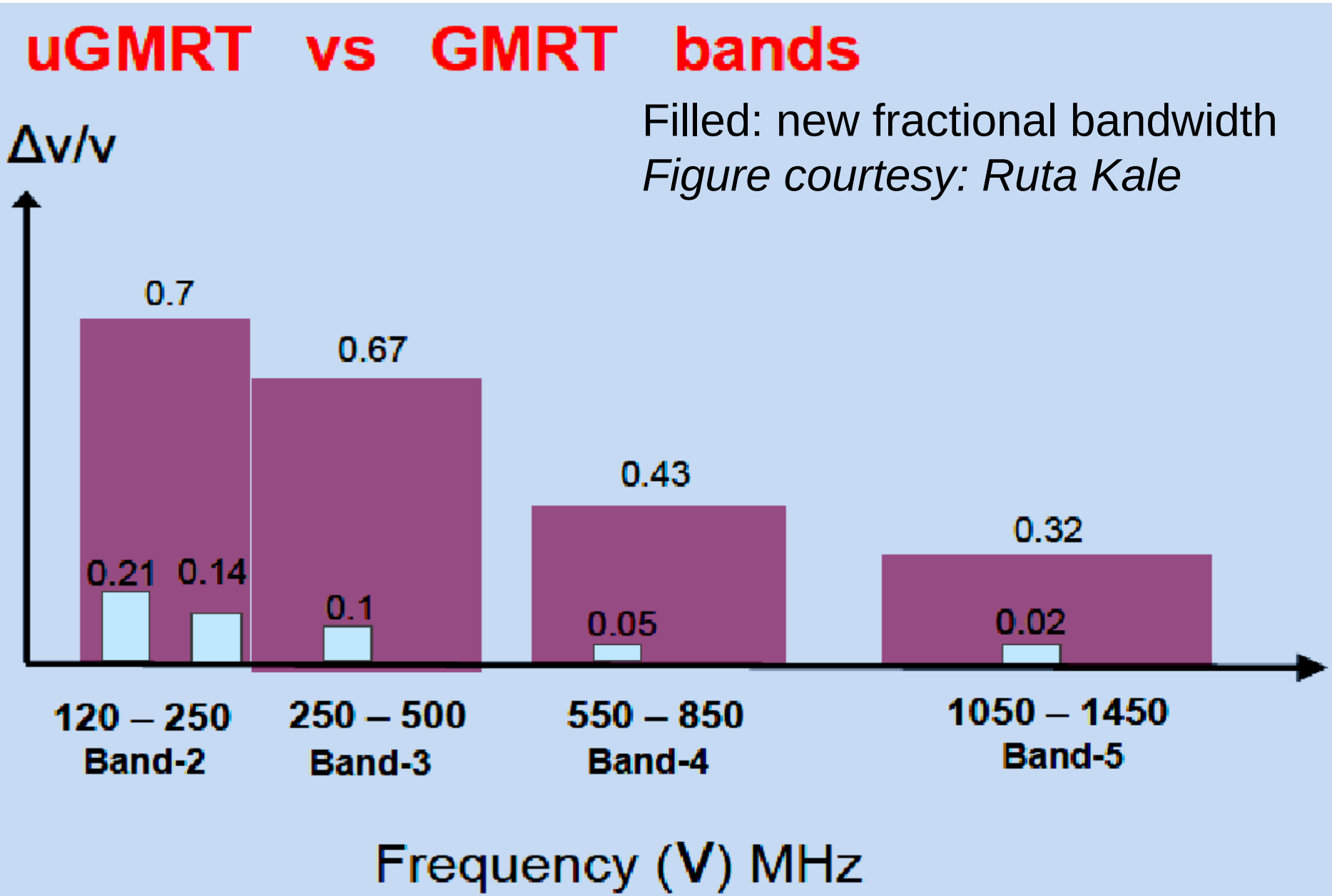


uGMRT band-3 (250 – 500 MHz)



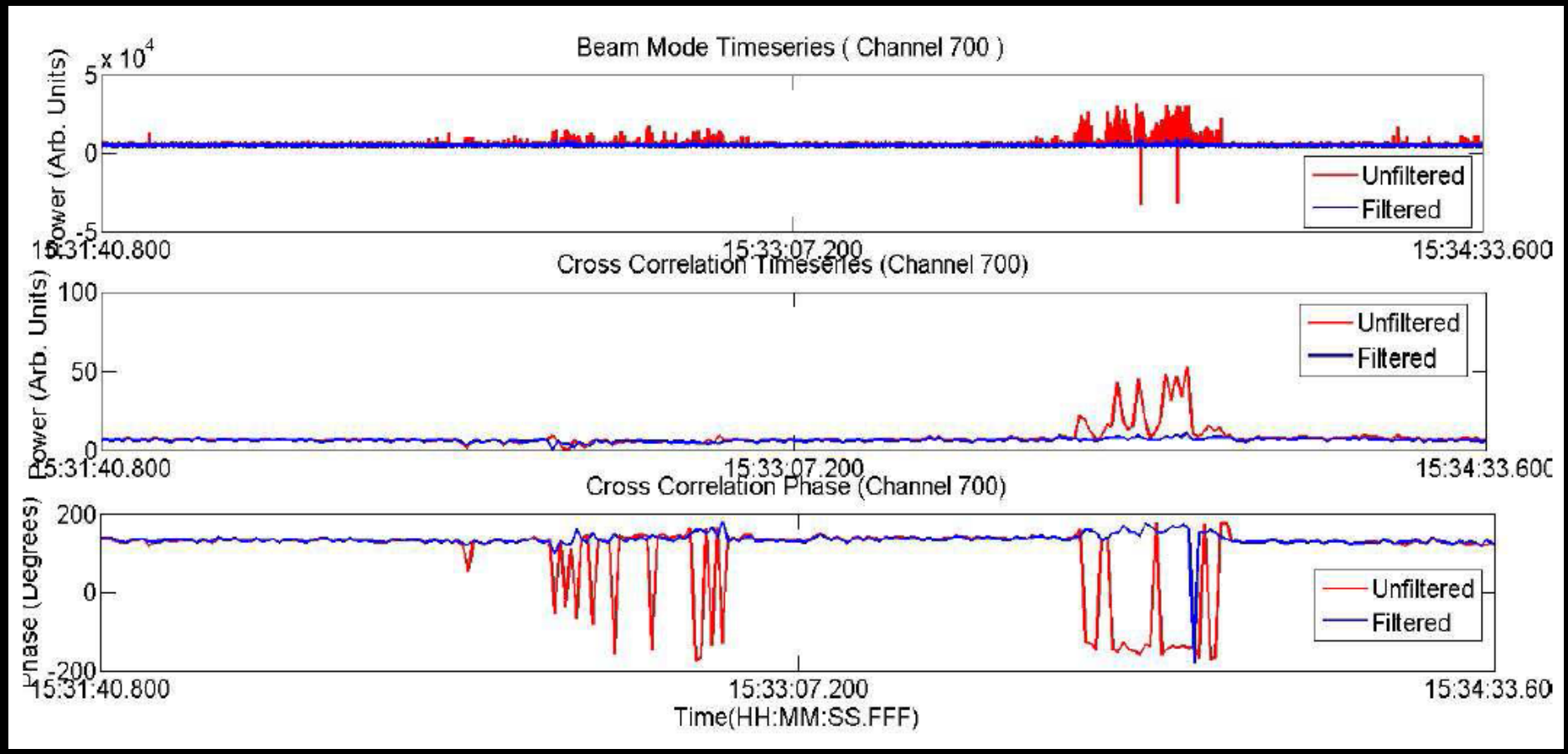
Need to watch out for growing menace of RFI.

Upgraded GMRT– SKA Pathfinder!



Real-time RFI Detection & Filtering

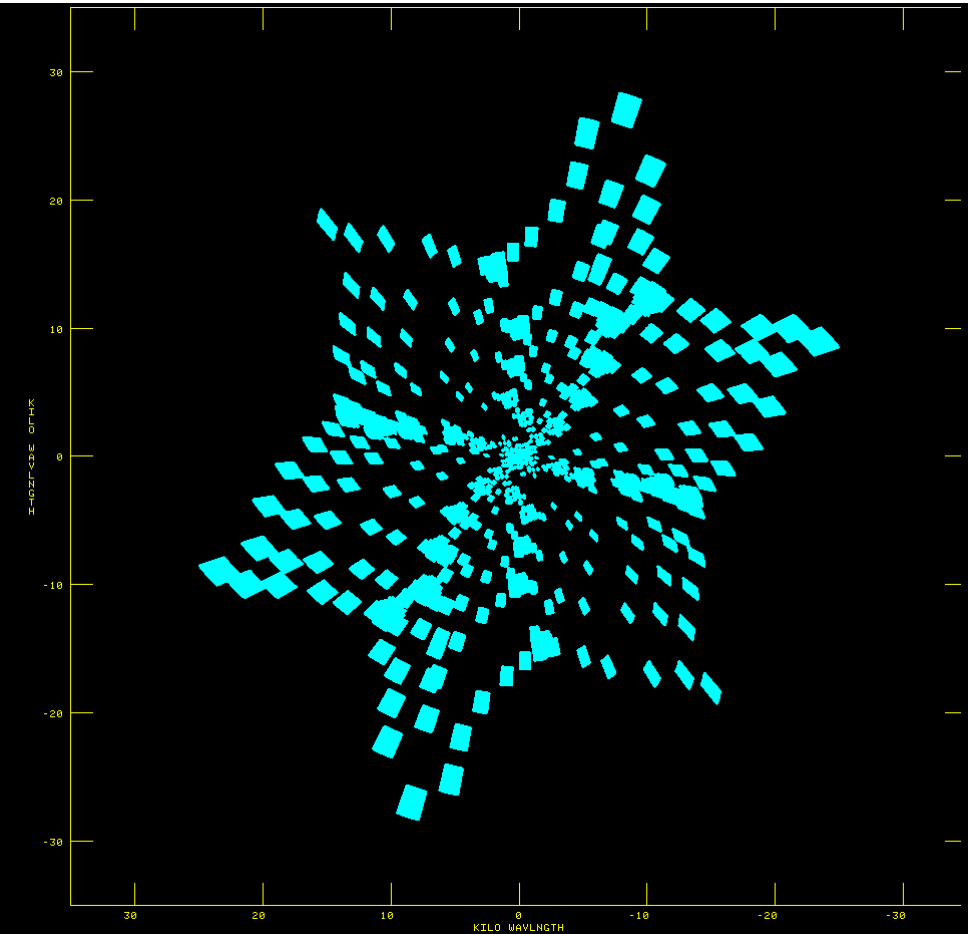
Ruta Kale and team

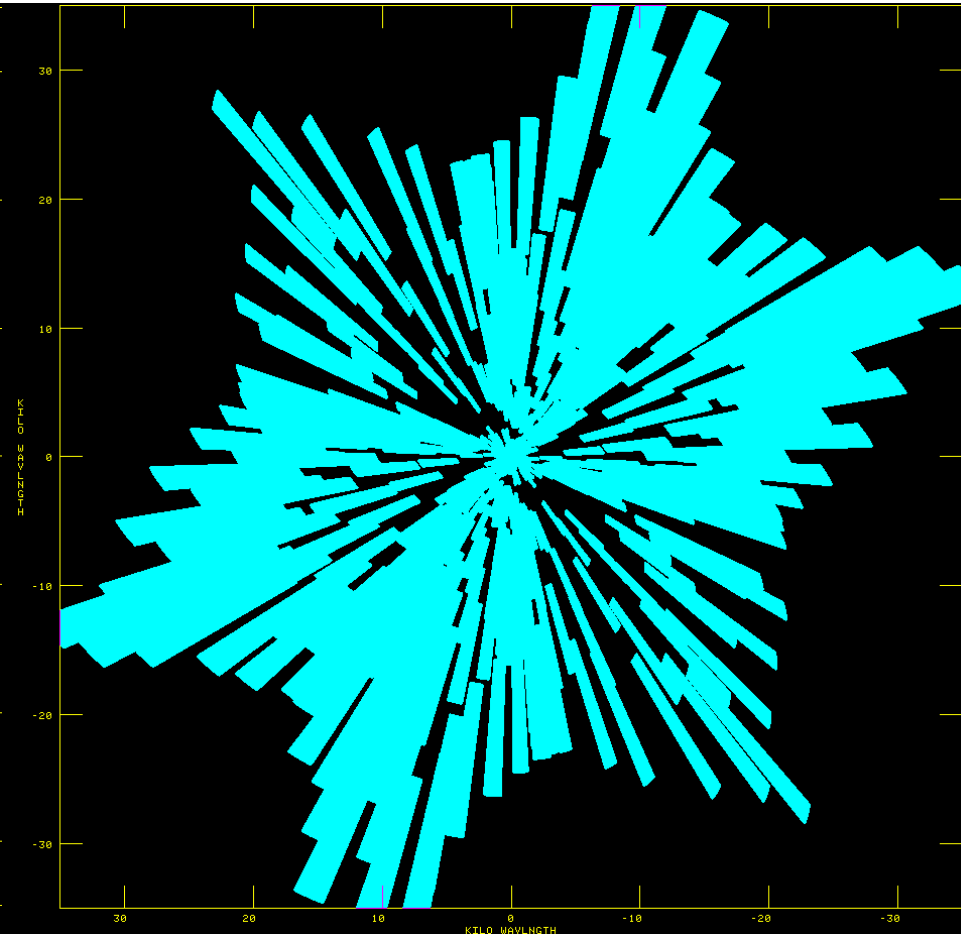


Improved UV-Coverage

Excellent UV coverage due to large fractional bandwidth

30mins, legacy system vs upgraded, band-3 (250-500MHz)

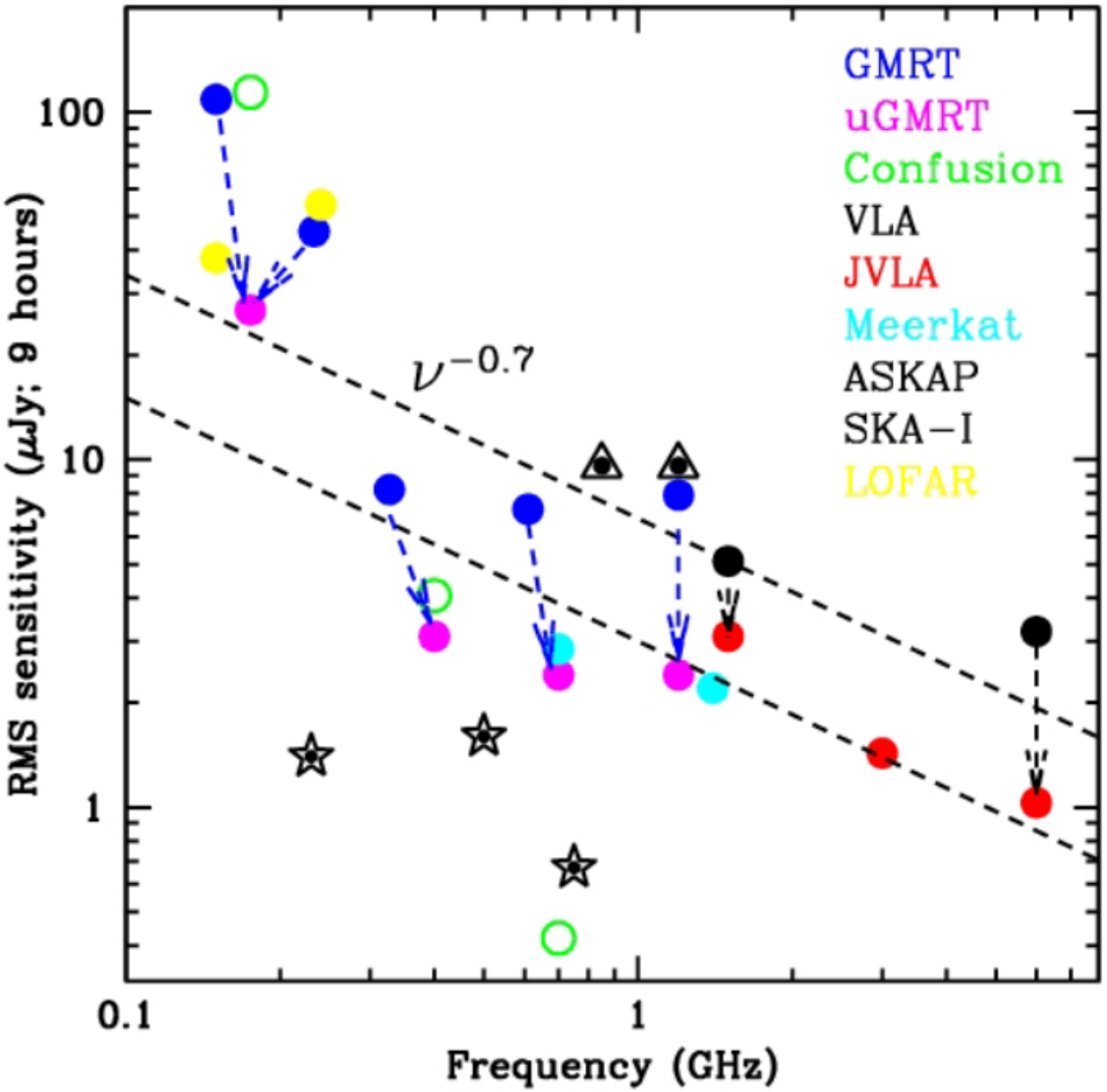




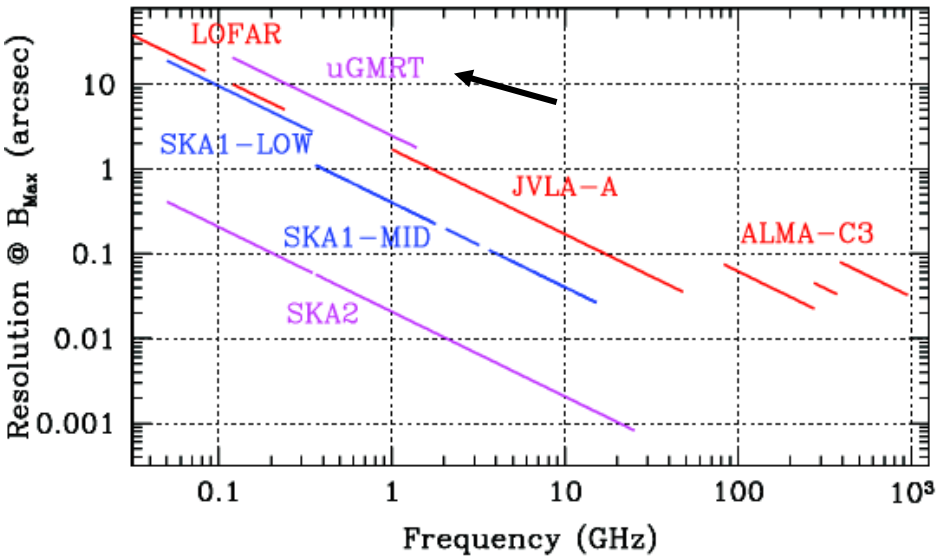
uGMRT: Expected Performance

Expected sensitivity performance of the upgraded GMRT compared to other major facilities in the world, present and projected (*courtesy : Nissim Kanekar, NCRA*)

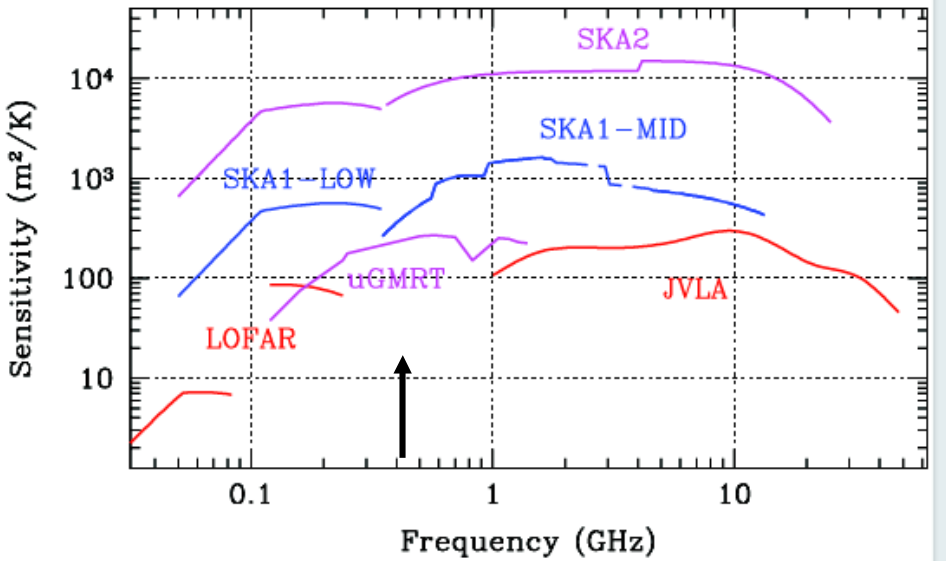
Only SKA-I will do better than uGMRT at centimeter and metre wavelengths

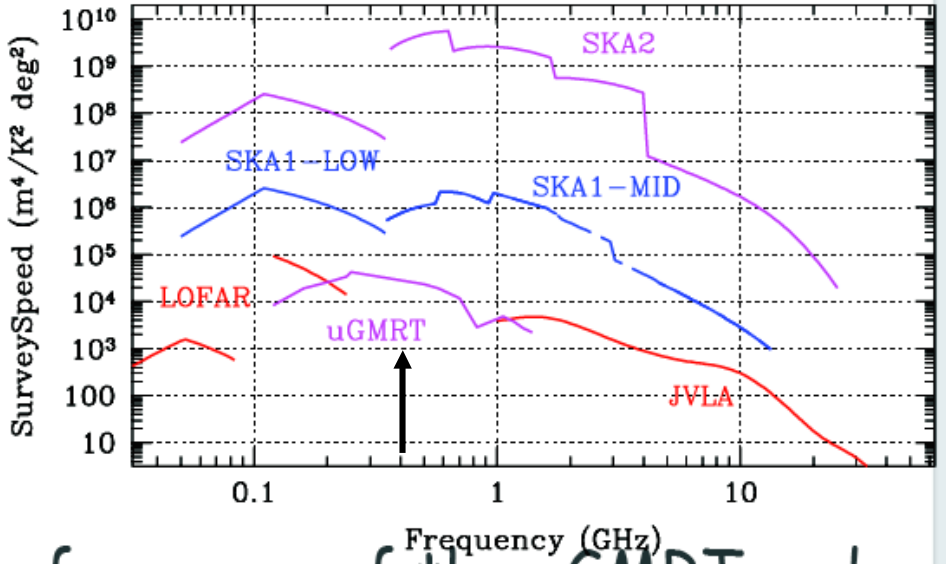


The uGMRT vs SKA, JVLA, LOFAR



Credits: R. Braun



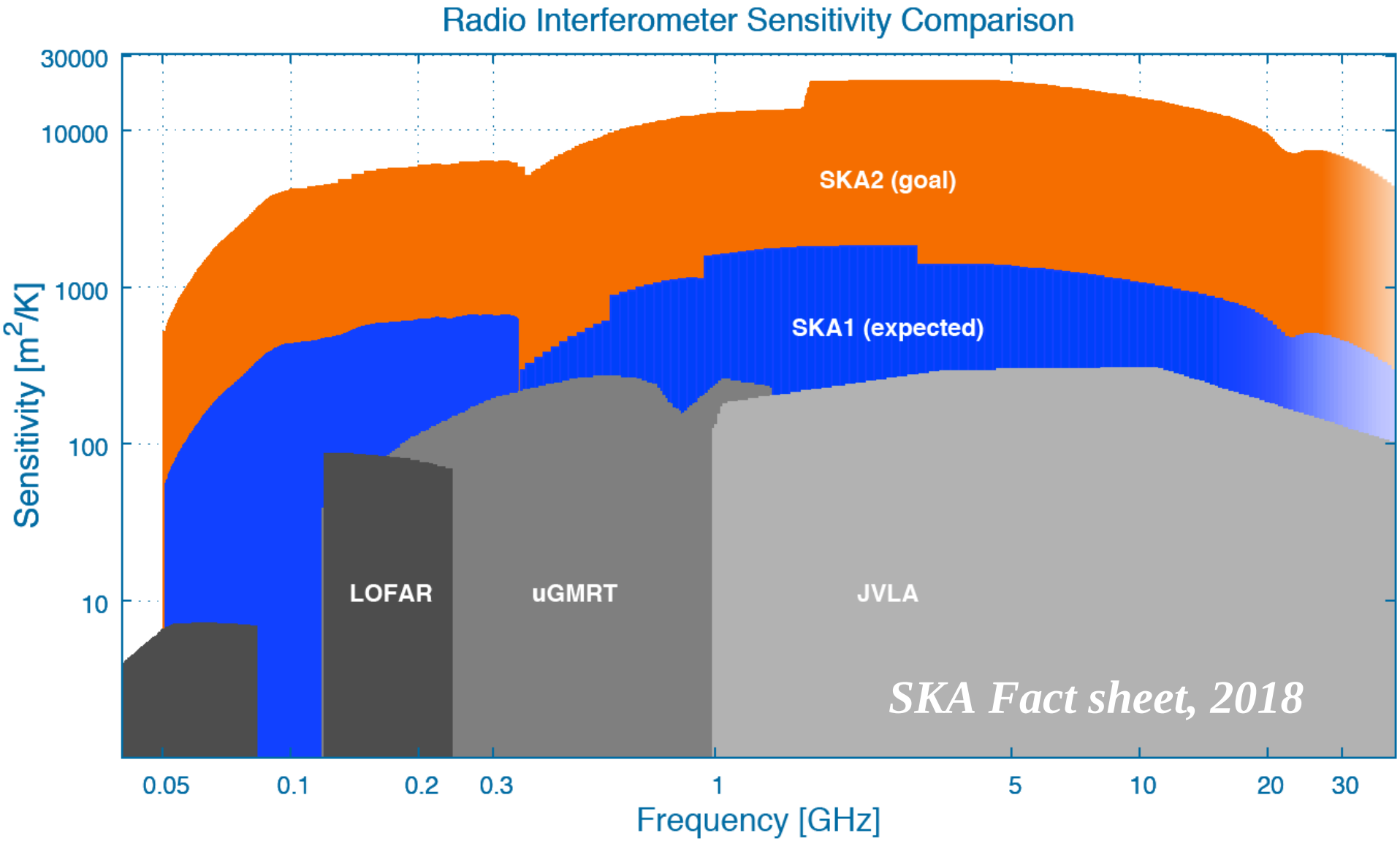


The uGMRT nicely fills the frequency gap between LOFAR and JVLA

Only SKA-I will do better than uGMRT at cm wavelengths

Expected sensitivity performance of the uGMRT and ...

The uGMRT vs SKA, JVLA, LOFAR



Challenges on the Road to uGMRT

The main challenges that we have encountered have been :

Technological : design of the wideband receiver systems was a major challenge

Operational : keeping the existing GMRT working for our regular users while upgrading simultaneously took some effort

Taking care of Radio Frequency Interference (RFI) generated by the technology advancement remains biggest challenge !

Containing self generated RFI

Mitigating RFI from external sources :

(i) broadband impulsive (ii) spectral line

GMRT : Range of Science

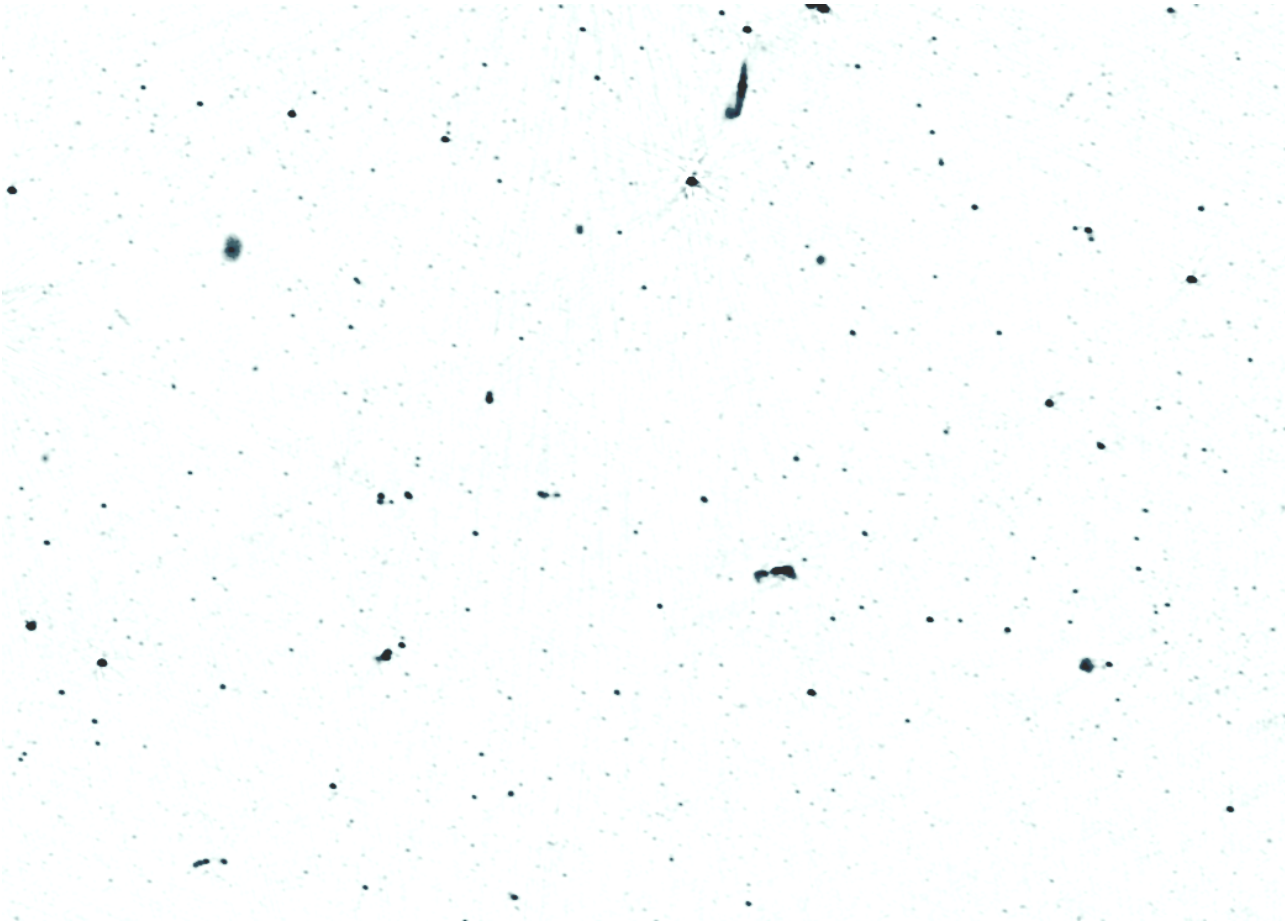
The GMRT is a powerful instrument to probe several astrophysical objects and phenomena :

- The Sun, extrasolar planets
- Pulsars : rapidly rotating neutron stars
- Other Galactic objects like : supernova remnants, microquasars etc
- Other explosive events like Gamma Ray Bursts
- Ionized and neutral Hydrogen gas clouds (in our Galaxy and other galaxies)
- Radio properties of different kinds of galaxies; galaxy clusters
- Radio galaxies at large distances in the Universe
- Cosmology and the Epoch of Reionization
- All sky surveys such as the 150 MHz TGSS

…and many interesting new results have been produced

Deep field imaging with the uGMRT : XMM-LSS at Band-3 (300-500 MHz)

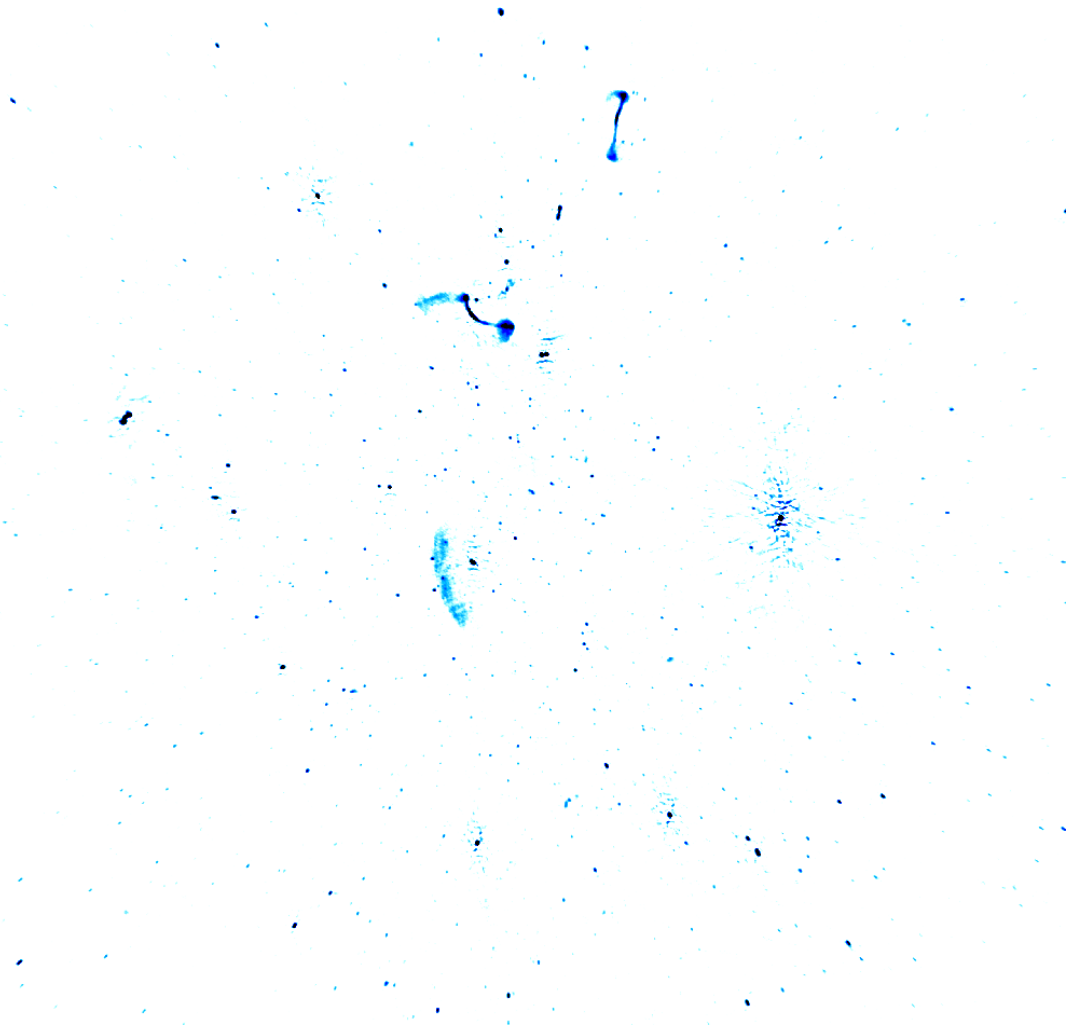
- Deepest ever (most sensitive) image made at 400 MHz by any telescope !
- 200 MHz BW
- 20 hrs on-source time
- 6.7”x5.8” resolution
- 14 microJy / beam noise
- Over 1600 sources per sq deg !



Ishwara-Chandra & collaborators

Deep imaging with the uGMRT : Abell 521 at Band-4 (550-850 MHz)

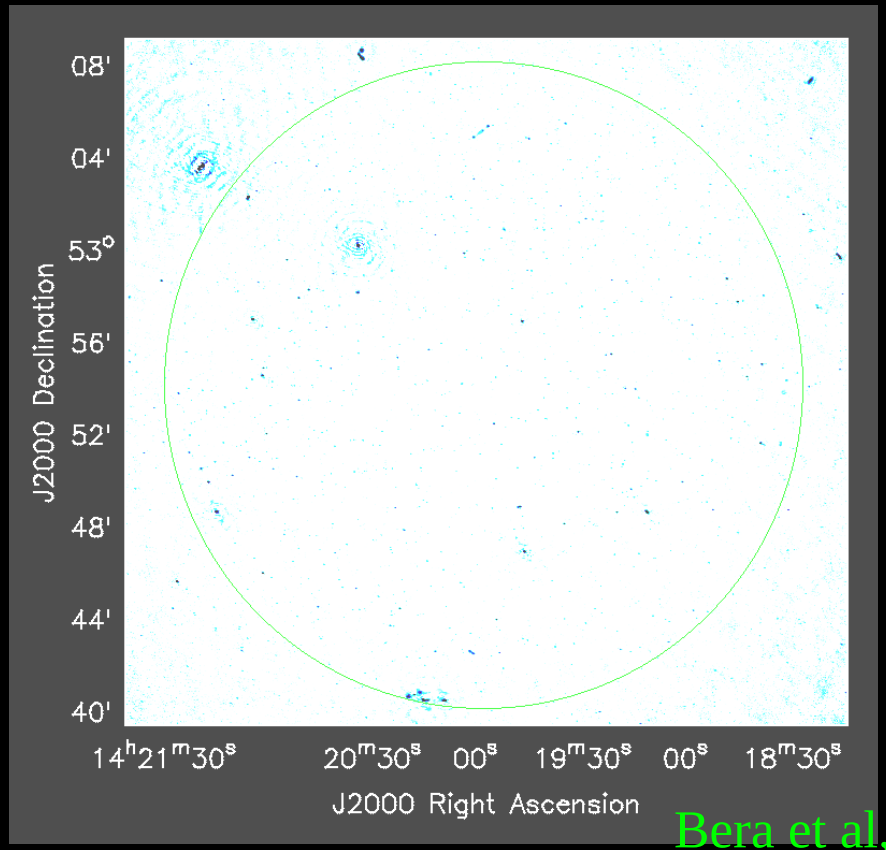
- Deep image at Band-4
- 10 microJy / beam noise !
- Arc like shock relic
- Faint central radio halo
- Radio lobes of some of the galaxies – new detections

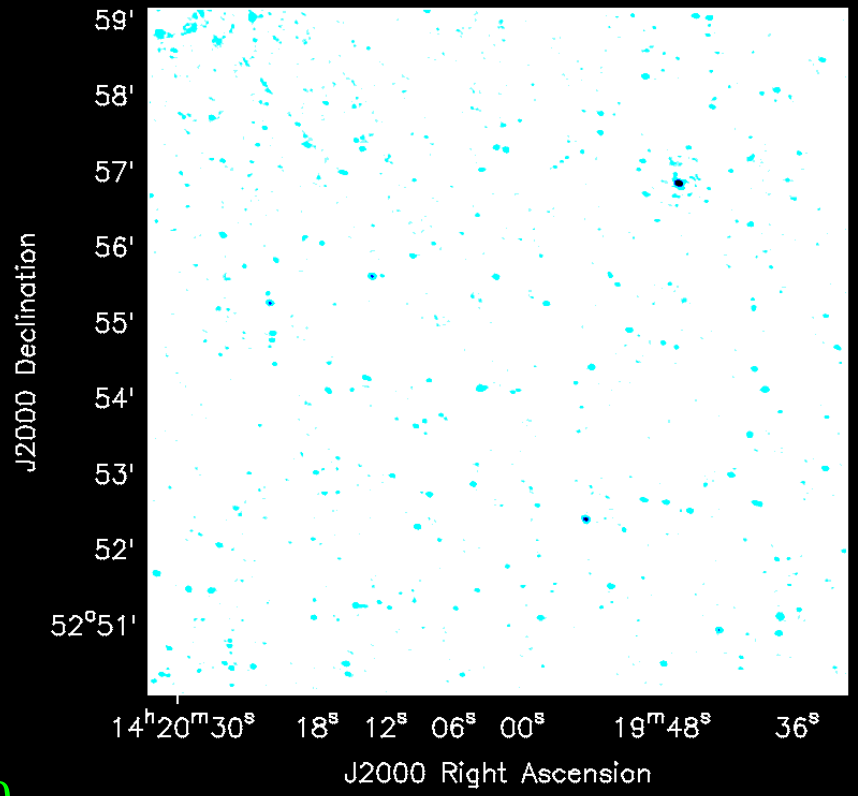


Kale & collaborators, 2019

Deep fields with the GMRT : Best image at Band-5 (1000-1460 MHz)

- Recent result from L-band (1000 – 1460 MHz) study of the Extended Groth Strip (EGS) field with the uGMRT
- Reached noise level of 2.3 microJy in ~ 110 hrs of on source observing
- Deepest image of the EGS ! deepest image with the uGMRT so far !!
- 2nd deepest image at L-band EVER (only JVLA has one deeper) !!!





Bera et al, 2019.

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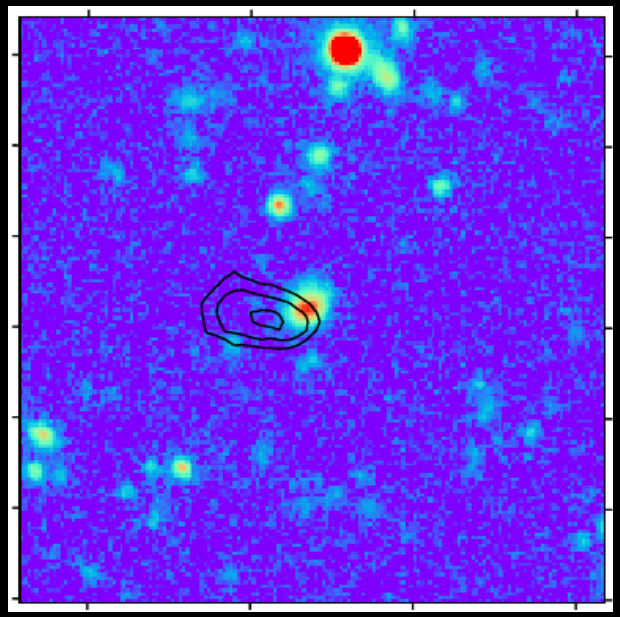
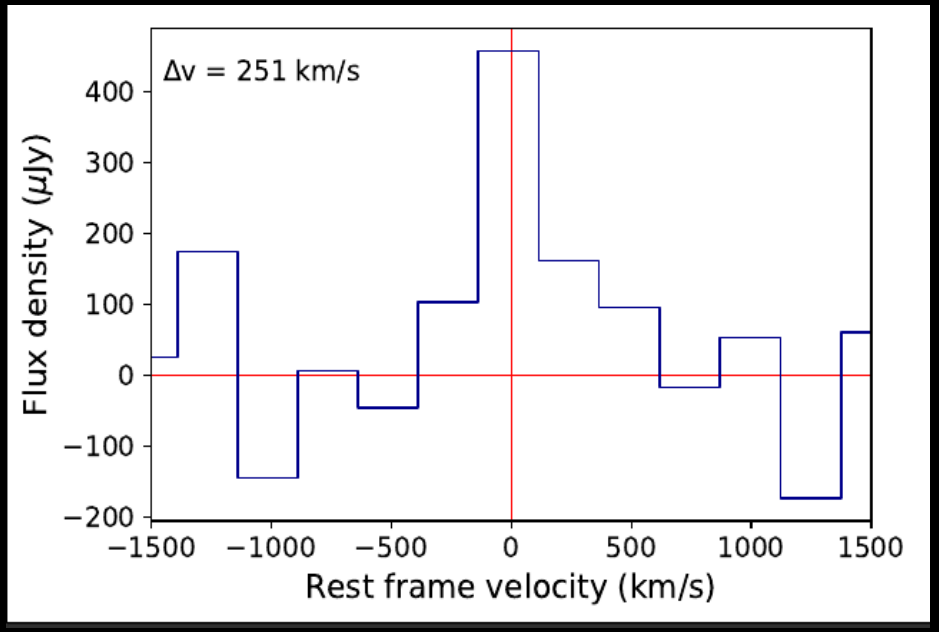
- Deepest image of the EGS ! deepest image with the uGMRT so far !!
- 2nd deepest radio image at L-band EVER (only the JVLA has one deeper) !!!
- Discovery of 2 galaxies in HI in emission at redshifts of 0.324 and 0.387 – latter is THE highest redshift for detection of HI emission to date !





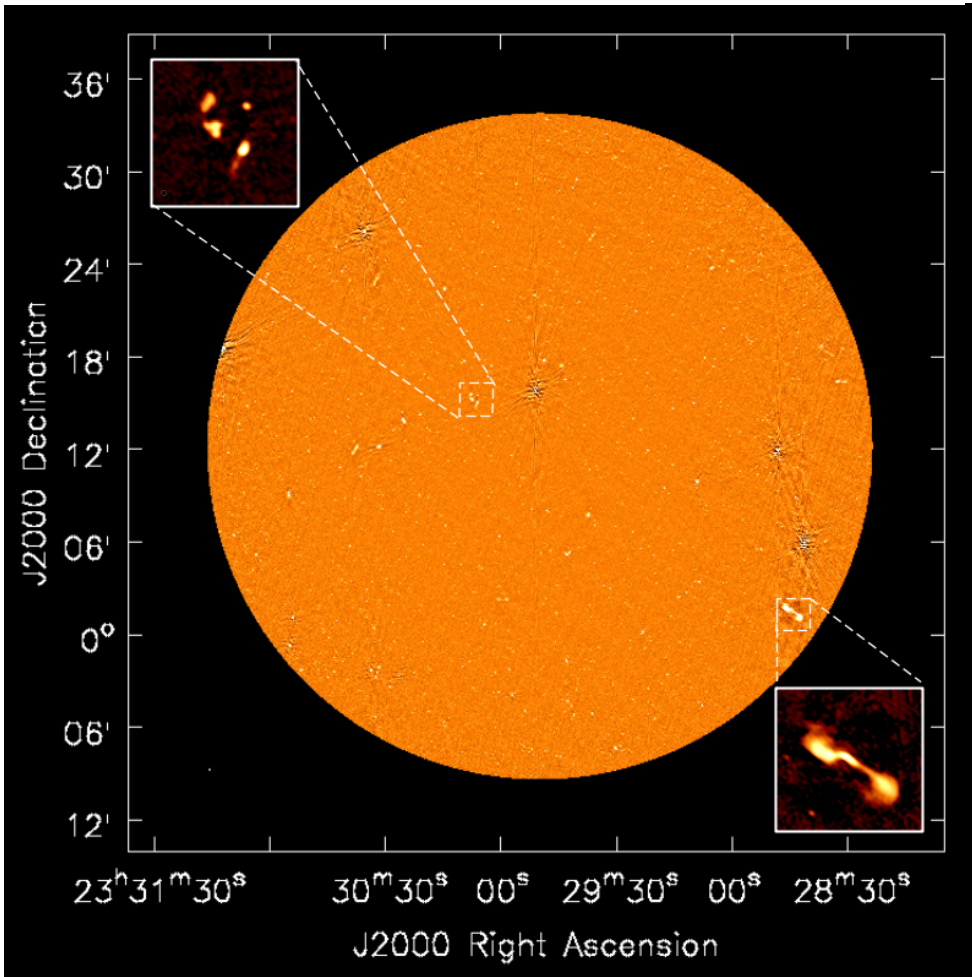
Bera et al, 2019

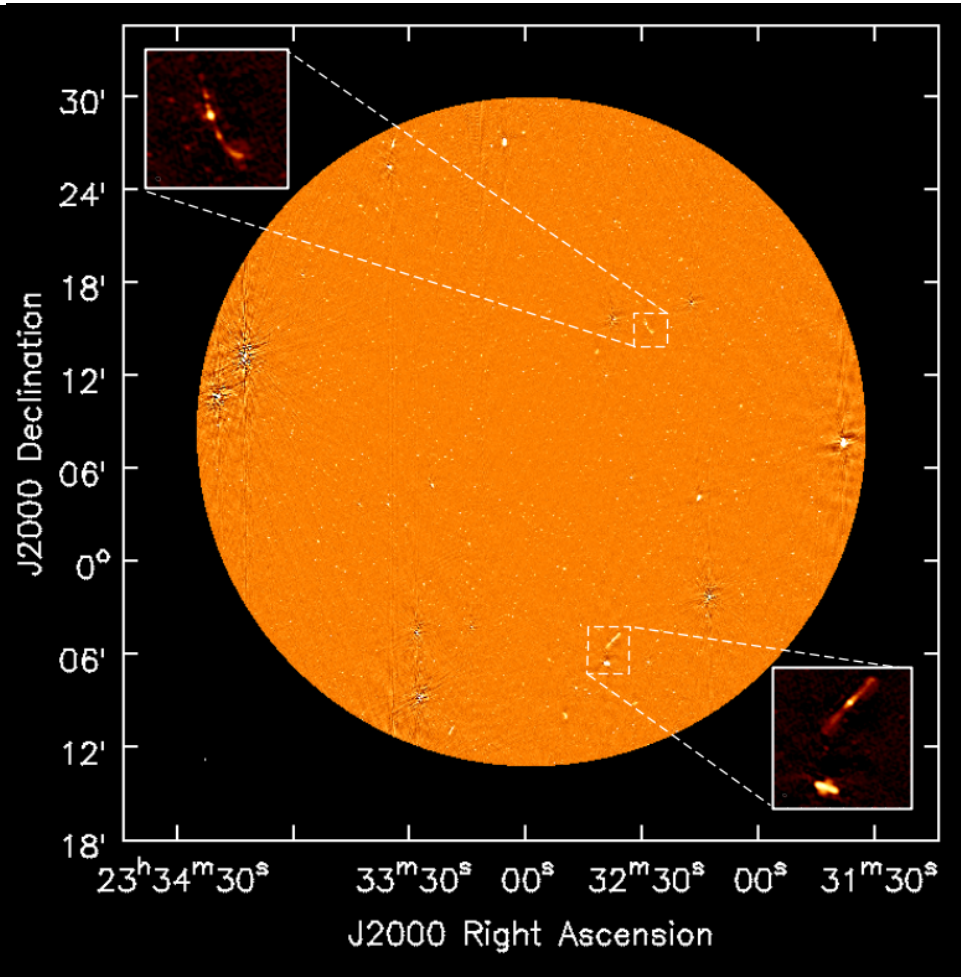
Deepest image of the DEEP2 fields at band-4 (550–850 MHz) with uGMRT

Chowdhury et al.. (2020, Nature) and Chowdhury (2021, ApJL ; Ph. D Thesis)

Field 32; rms = 6.4 μJy/Bm

Field 33; rms = 5.4 μJy/Bm

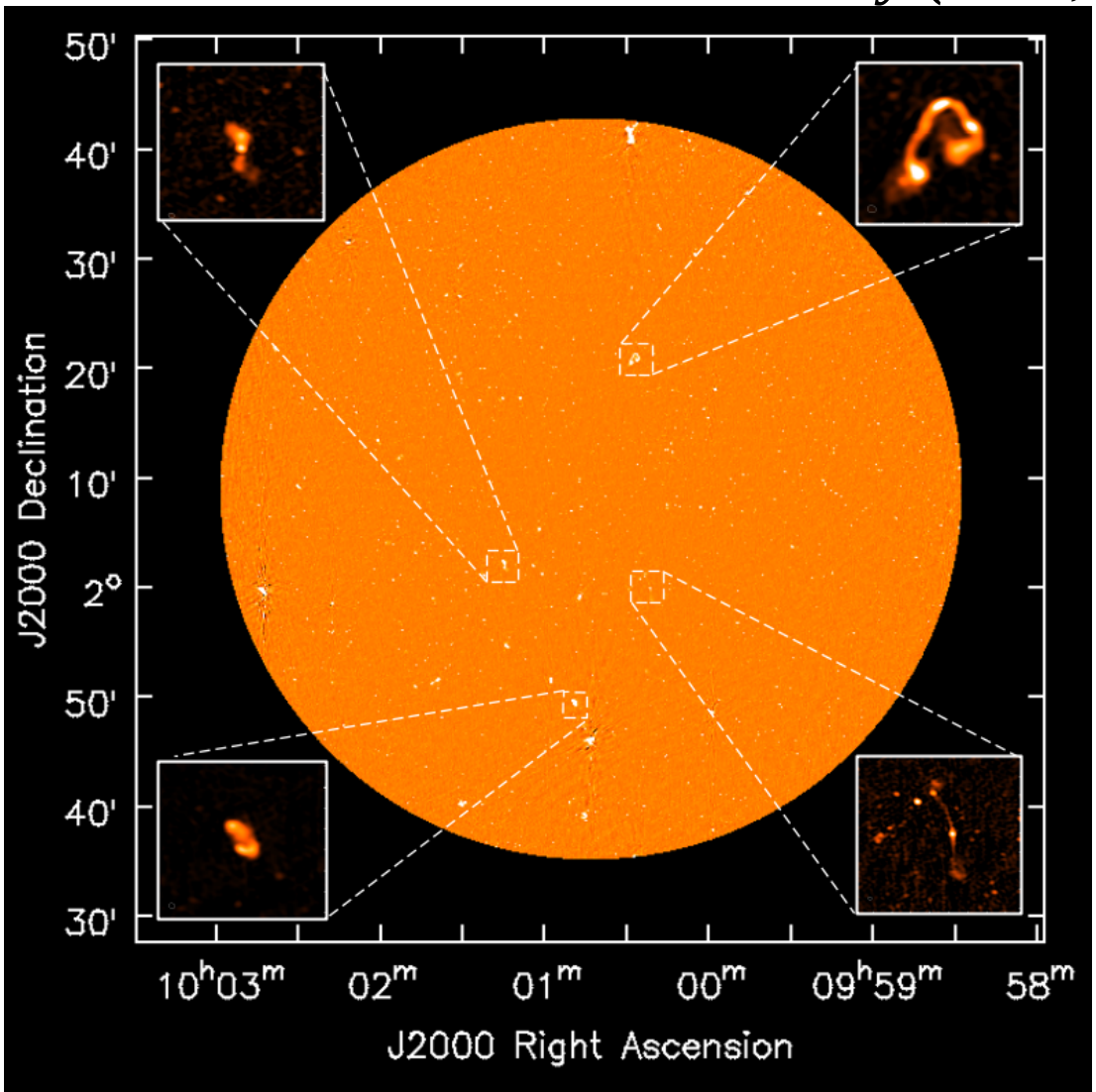




COSMOS field in band-3 (250-500 MHz)

Deepest image of the COSMOS field ; rms ~ 10 microJy/beam

Chowdhury (2021, Ph. D Thesis)



GW170817 : neutron star merger event with the uGMRT

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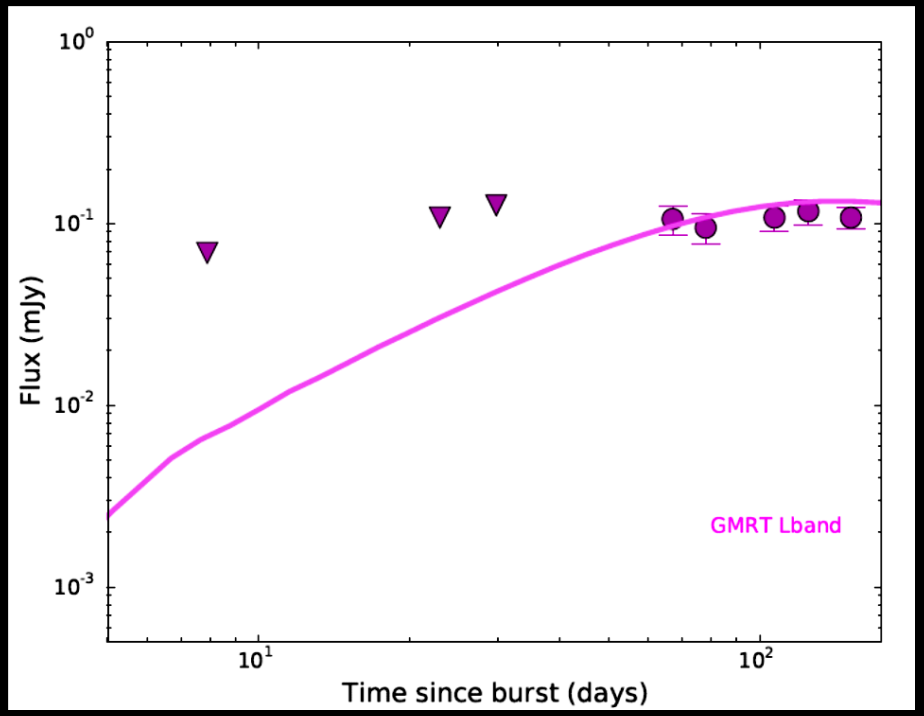
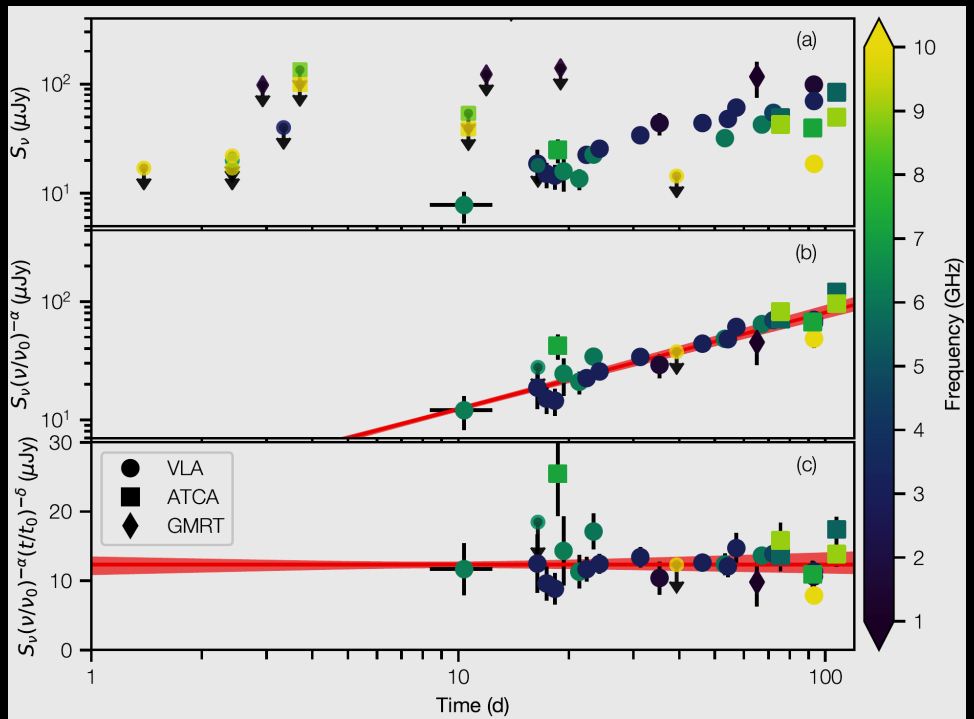
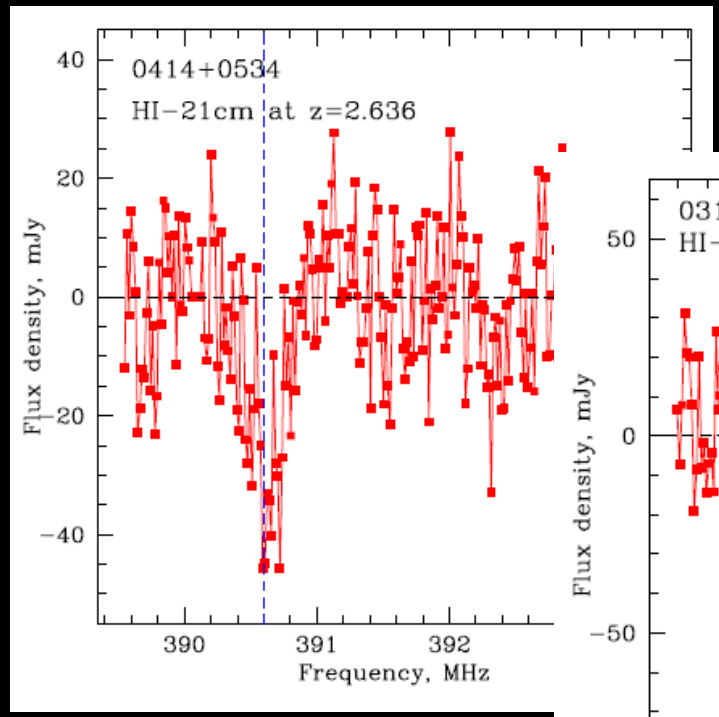


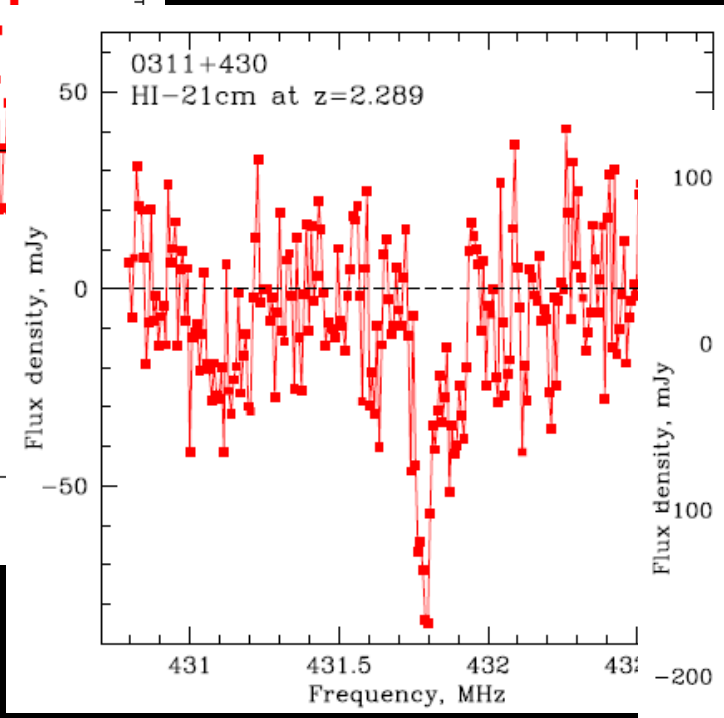
Resmi et al 2018

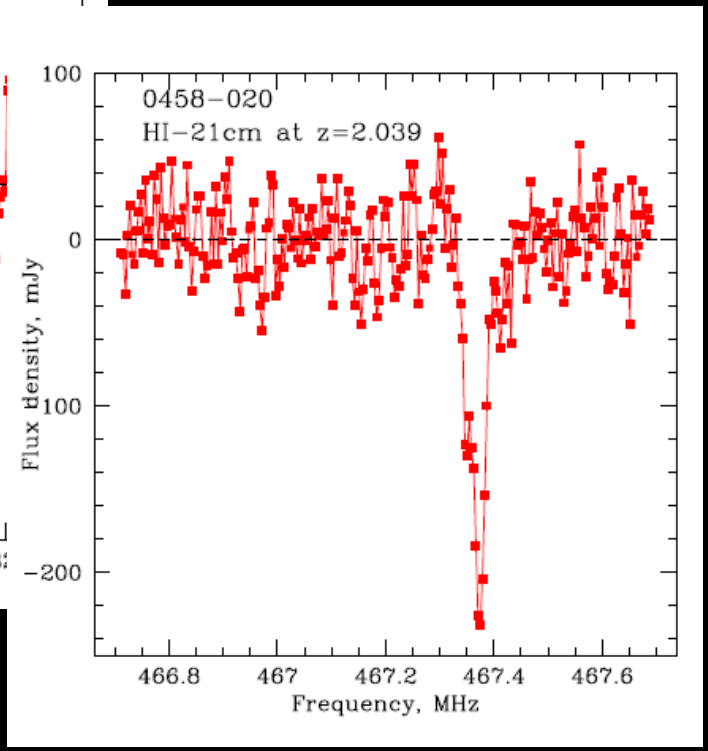


Hallinan et al 2017

Upgraded GMRT : opening new windows – Band 3 (250-500 MHz)

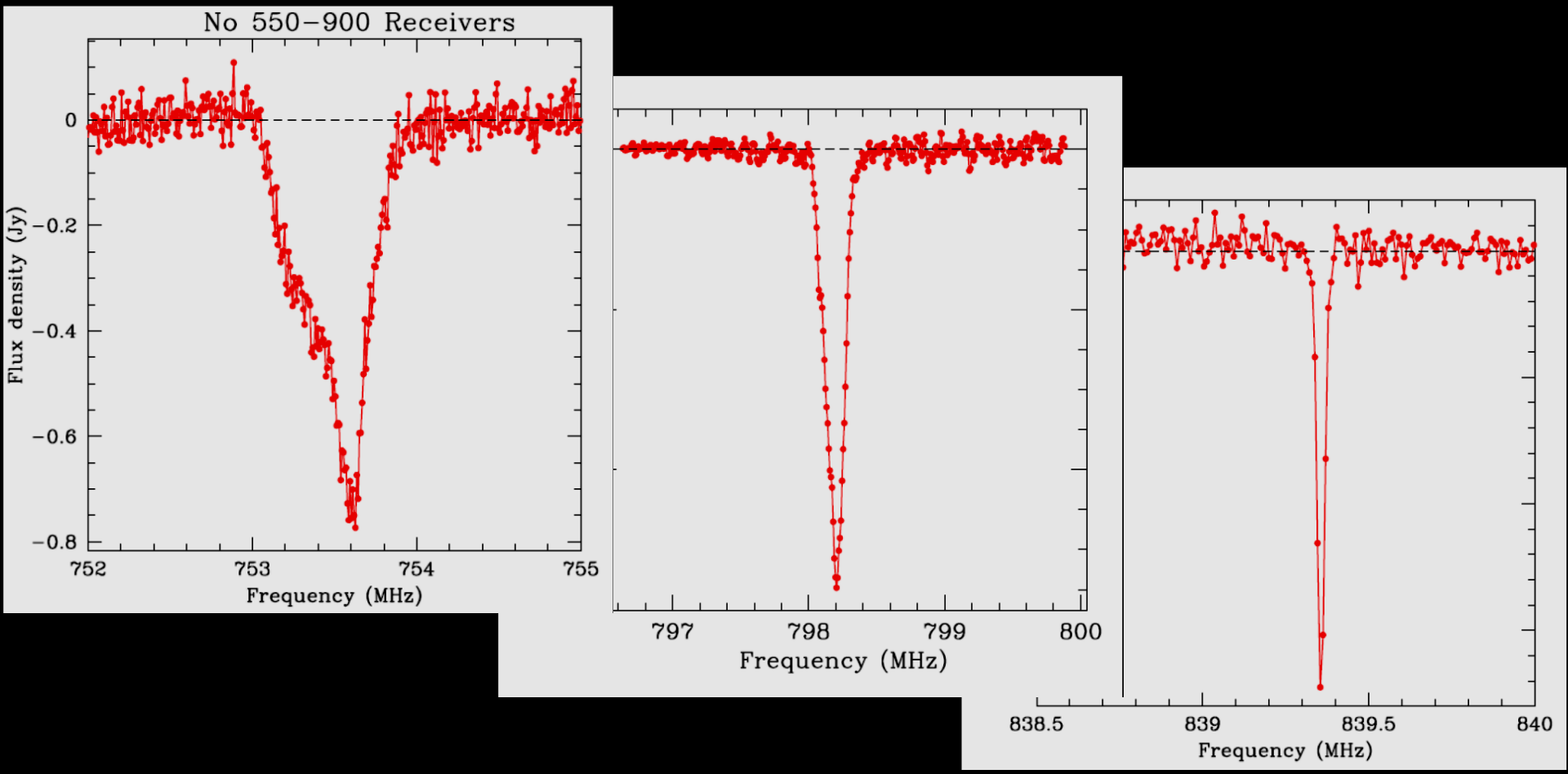






First light results : spectral lines from different sources, at different parts of the 250-500 MHz band (Nissim Kanekar)

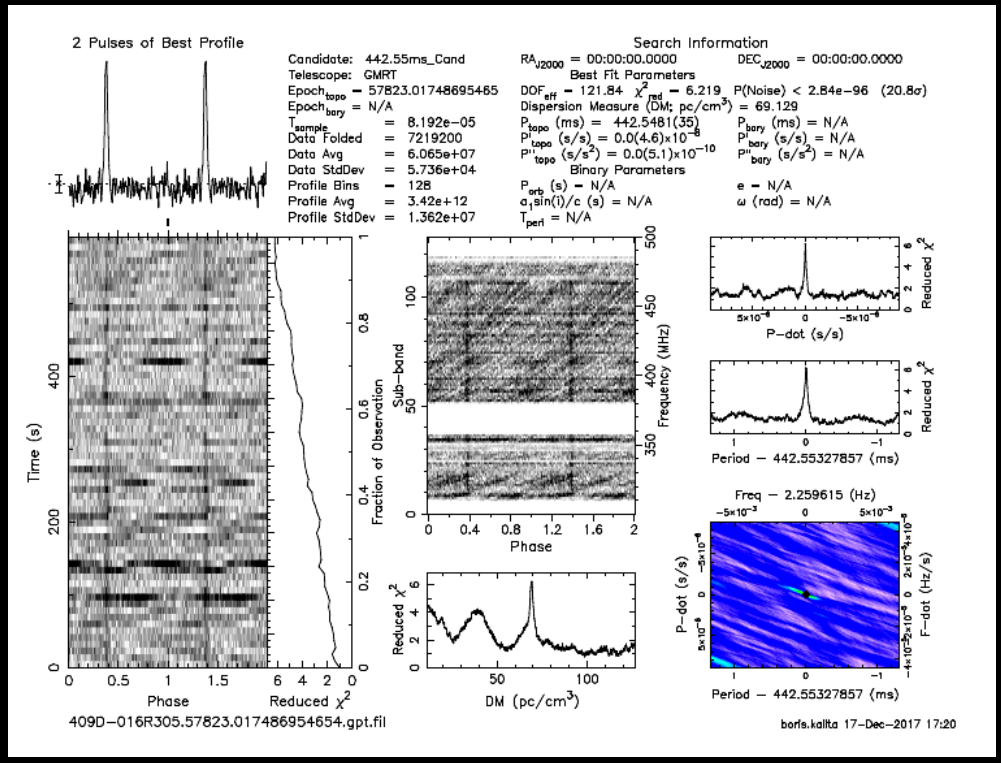
Upgraded GMRT : opening new windows – Band 4 (550-850 MHz)



First light results : spectral lines from different sources, at different parts of the 550-900 MHz band (Nissim Kanekar)

Finding new pulsars with the uGMRT

- uGMRT has significant potential for discoveries of new pulsars (0.5 mJy in 10 mins in incoherent array mode) and transients
- Some of the ongoing / planned pulsar searches are :
  - GHRSS : legacy GMRT + upgraded GMRT
  - uGMRT survey for pulsars (Pugmarks)
  - Targeted search in selected globular clusters
  - Targeted search in TGSS steep spectrum sources



Pugmarks survey team, 2017

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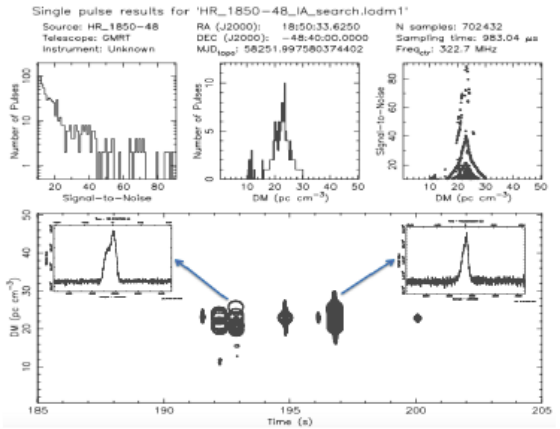
1st RRAT discovered with the GMRT



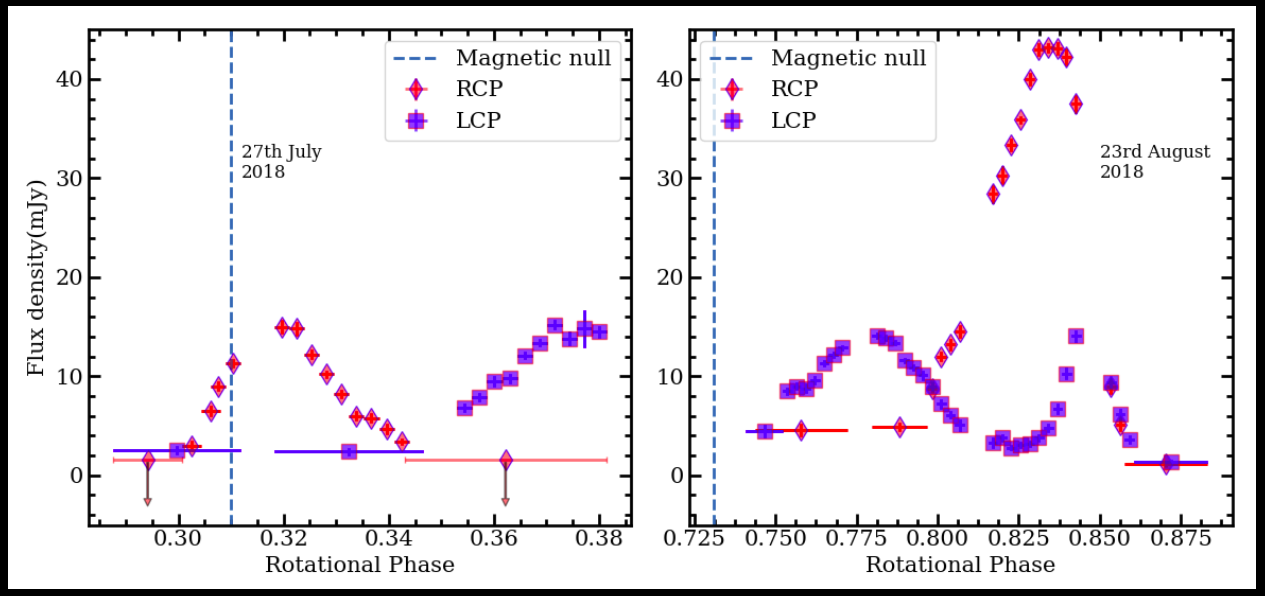
Credit : GHRSS team

J1850-48 at DM of 23 pc cm^{-3} and period of 327 ms is a RRAT discovered from the GHRSS survey

7 pulses (< 10 ms wide) see over 10-mins. The strongest pulse is at ~ 3 Jy

One of the nearby RRAT @ 0.8 kpc

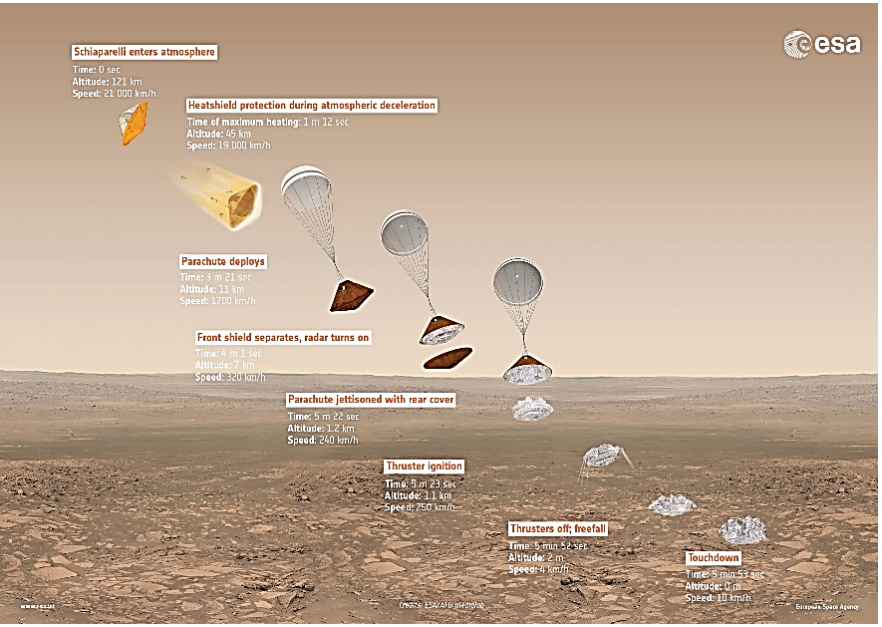
Magnetic stars with the uGMRT



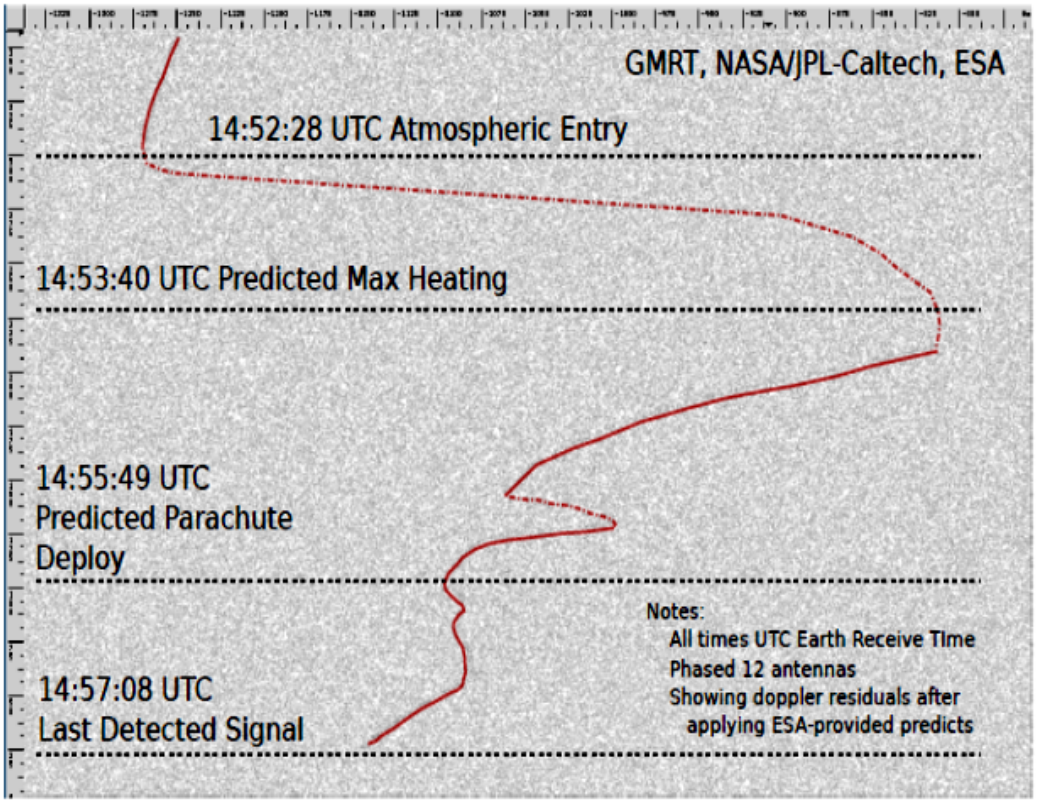
Das & Chandra 2017 onwards

“Fringe” benefits with the uGMRT : Tracking Space Probes !

Tracked Schiaparelli Lander module of ExoMars through last 8 minutes



ExoMars/Schiaparelli/EDM
Entry, Descent, Landing (EDL)
Detection at GMRT, India
2016-10-19



14:57:50 : Predicted Backshell & Parachute Jetison
(This exposes +6 dBiC antenna), Thrusters On
14:58:20 : Predicted Thursters Off & Touchdown

Square Kilometre Array (SKA)

SKA is next generation radio telescope, with collecting area of 1 million square meters, spread over a few thousand kms – first phase (10%) expected ~ 2020

India is also part of SKA, NCRA is the nodal institute

Telescope Manager, the brain and nerve of the array is lead by NCRA in collaboration with Industries..

Upgraded GMRT is SKA-Pathfinder.

(talk on SKA on 17th March)

Concluding Remarks

The uGMRT is an open facility for international users

uGMRT is nicely placed between LOFAR and JVLA in frequency and sensitivity space

uGMRT is producing several new results

Stay tuned for GMRT visit on 18th....