Giant Metrewave Radio Telescope upgrades

Dharam Vir Lal, NCRA (TIFR)

With due thanks to
NCRA-colleagues
Scientists, engineers and support personnel at NCRA-GMRT

SPARCS-2015, 1 July 2015

GMRT: Science objectives

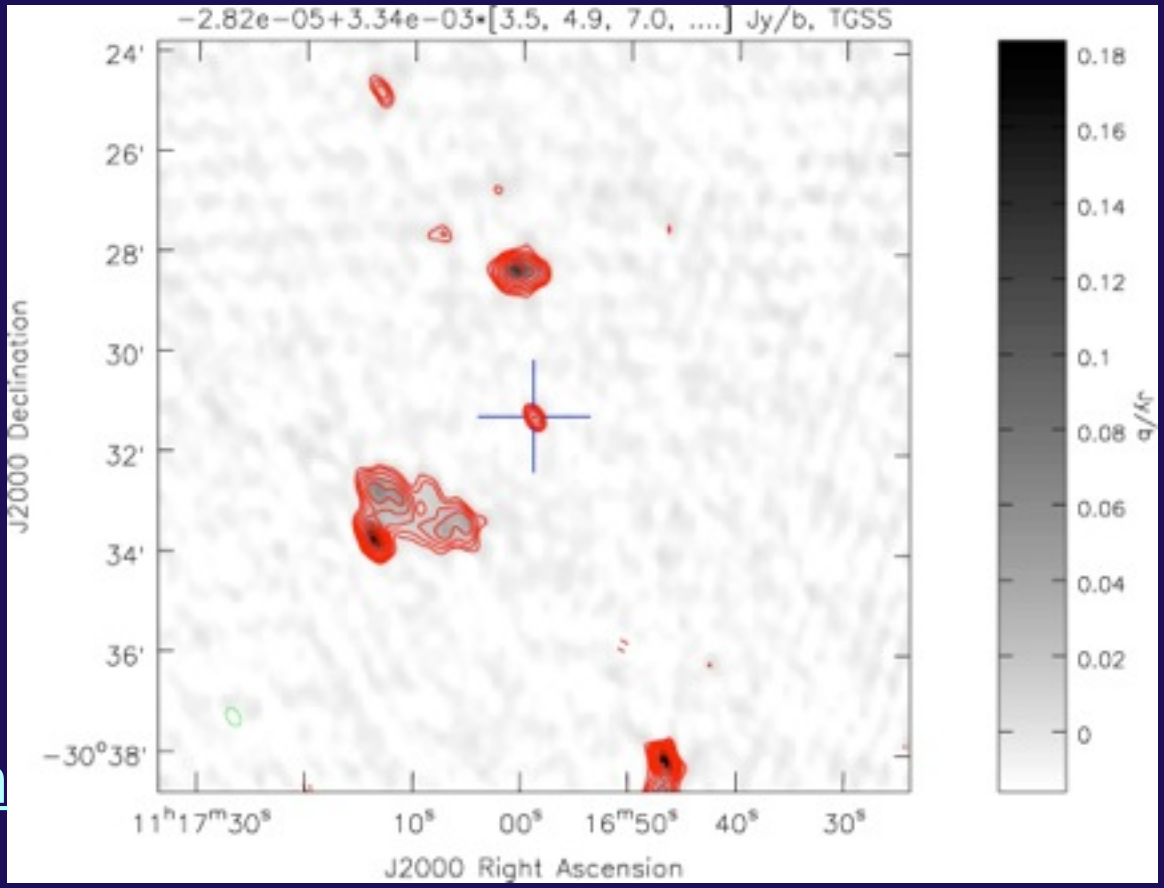
- Solar system objects — **P.K. Manoharan, D. Oberoi**
- Pulsars: rapidly rotating NSs — **Y. Gupta, B.C. Joshi, D. Mitra, S. Konar, B. Bhattacharyya, C.H. Ishwara-Chandra, J. Roy**
- Transients — **P. Chandra, C.H. Ishwara-Chandra**
  - Ex. SNRs, GRBs, etc.
- centre of the Galaxy — **S. Roy, J.N. Chengalur, N. Kanekar**
- Molecular gas, and HI — **J.N. Chengalur, N. Kanekar, N.G. Kantharia, S. Sirothia, C.H. Ishwara-Chandra, V.R. Marthi**
- Galaxies — **T.R. Chowdhury**
  - normal / active galaxies — **D.J. Saikia, N.G. Kantharia, R. Kale., S. Sirothia, C.H. Ishwara-Chandra, S. Roy, JNC, NK, DVL**
- Clusters / Groups of galaxies — **Y. Gupta, S. Sirothia, Y. Wadadekar…**
- Deep-fields / EoR — **S. Sirothia, N.G. Kantharia, C.H. Ishwara-Chandra, Gopal-Krishna**
- All-sky survey

TIFR-GMRT Sky Survey

TIFR-GMRT Sky Survey

- Team: Sirothia, Kantharia, Ishwara-Chandra, Gopal-Krishna
- @150 MHz
- metre-wavelength counterpart of cm-wavelngth NVSS survey
  - 20”
  - (5x better than NVSS)
- 2,000,000 sources!

http://tgss.ncra.tifr.res.in



Deep field: Lockman hole

Lockman Hole:

Image: 18.7′ x 7.5′

- 4.3″ x 4.3″; 6 μJy
- 7.1″ x 6.5″; 15 μJ

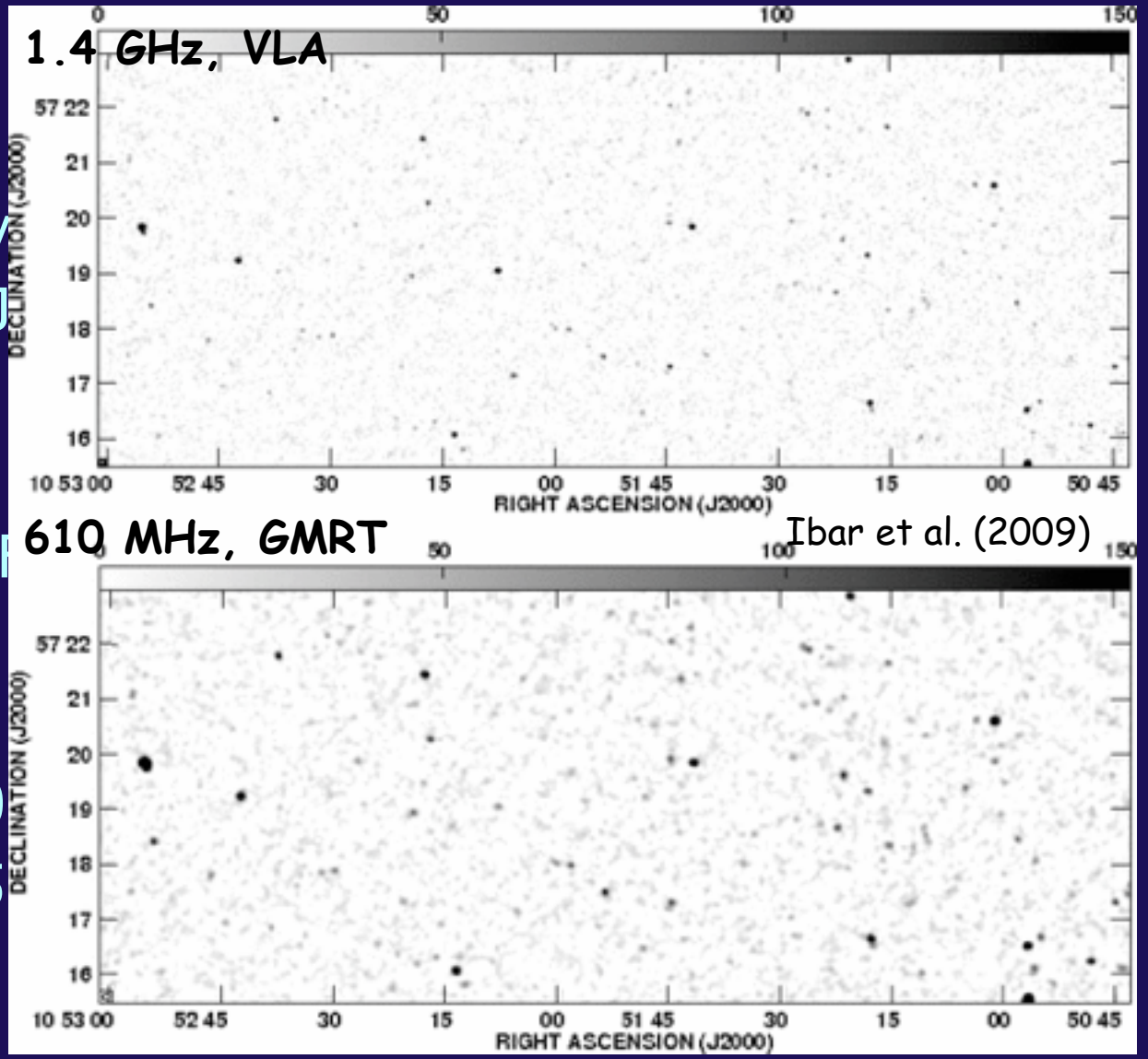
lll′ly

Spitzer extra-galactic F

- 5″; ~27 μJy

ELIAS N1 FLS-field

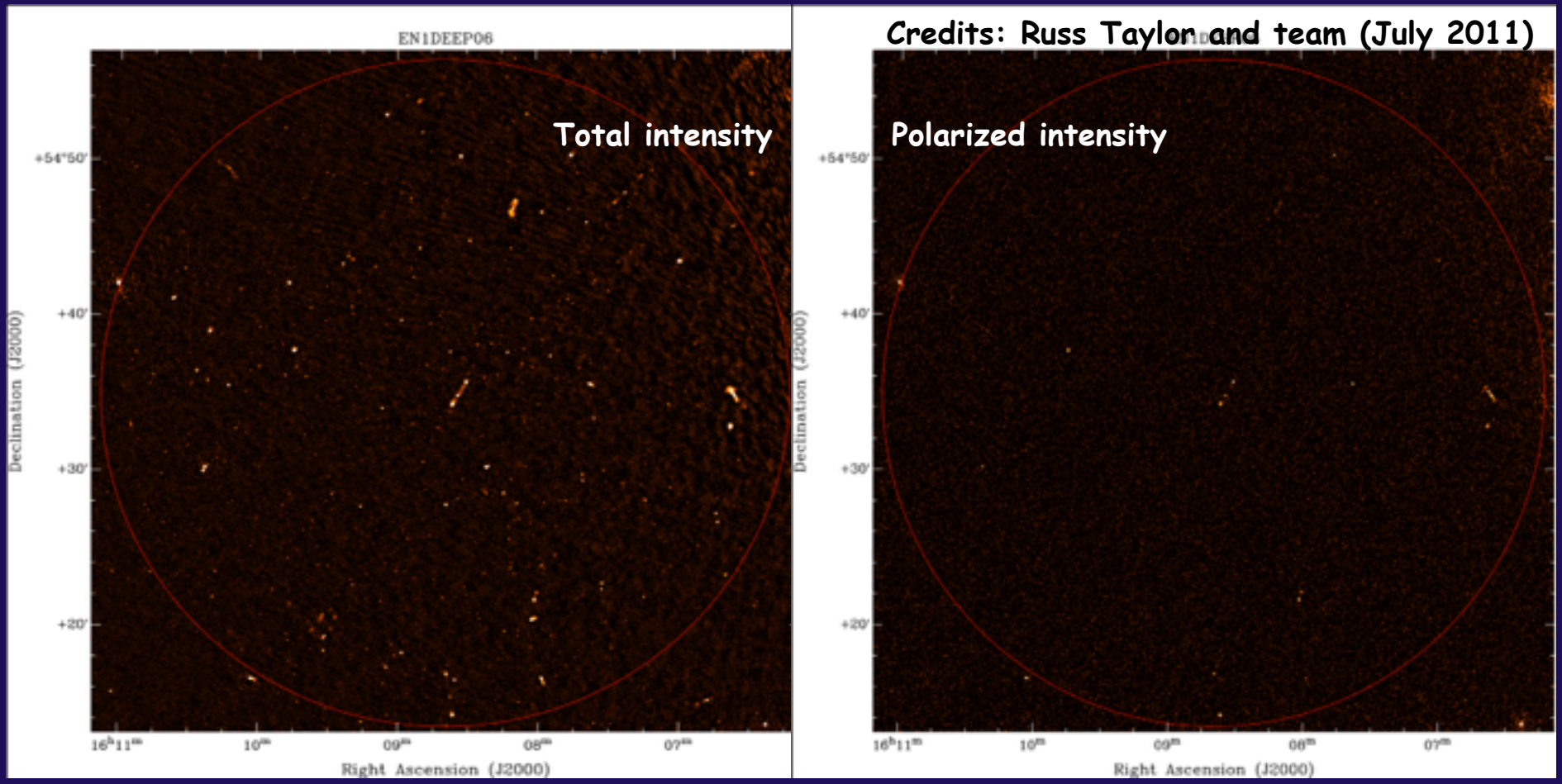
- ~27 μJy @610
- ~40 μJy @325



Radio Polarization: ELIAS N1

ELIAS-N1-DEEP06 (15 μJy in 30 hr at 610 MHz)

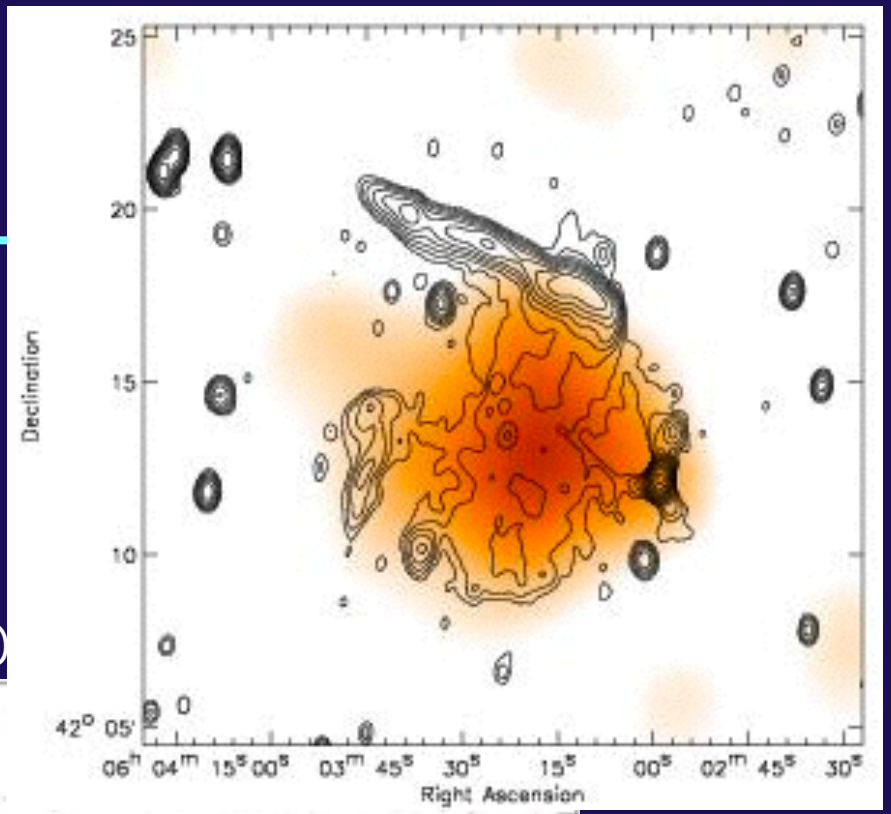
- GMRT deep polarization image

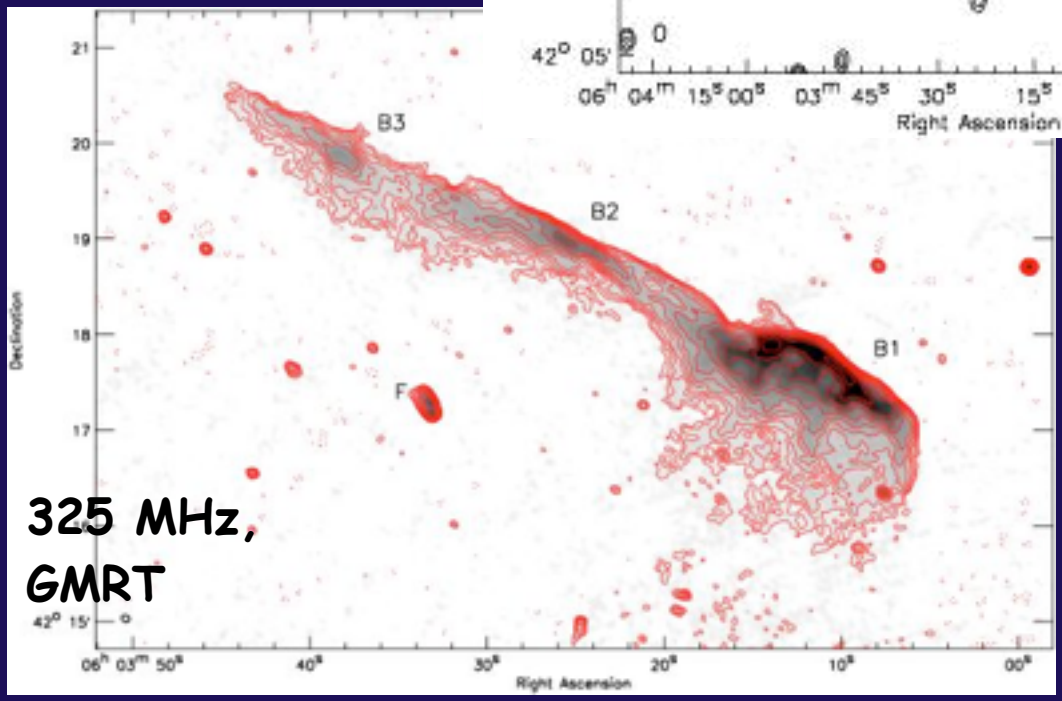


Tooth-brush relic

- Evidence for a coherent linear 2 Mpc scale shock wave in massive merging galaxy cluster

van Weeren et al. (2012)

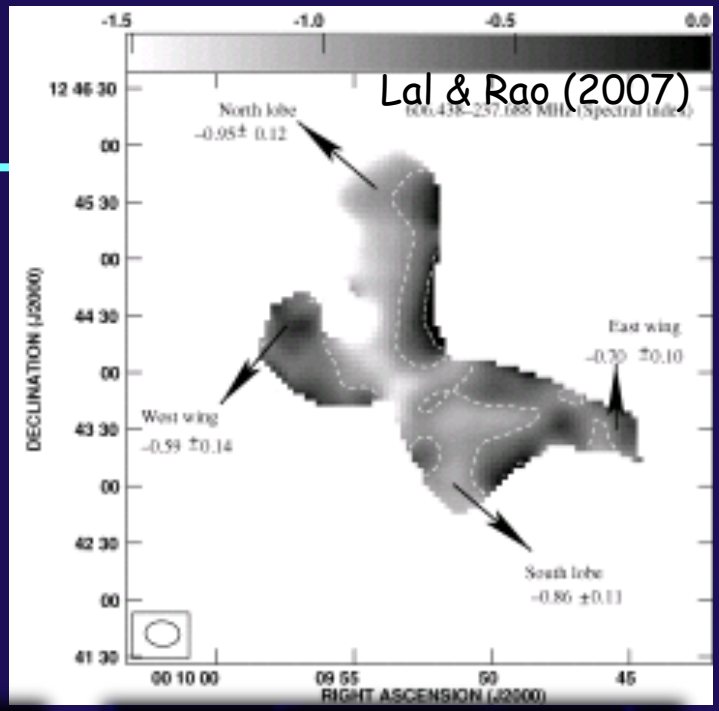


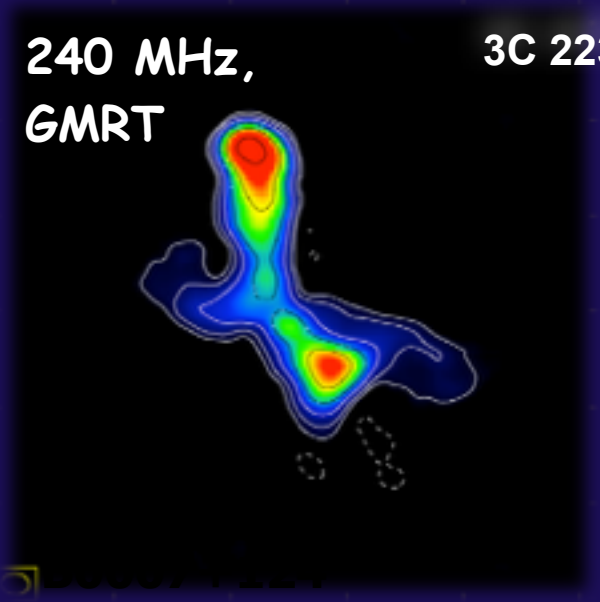


Unusual spectrum?

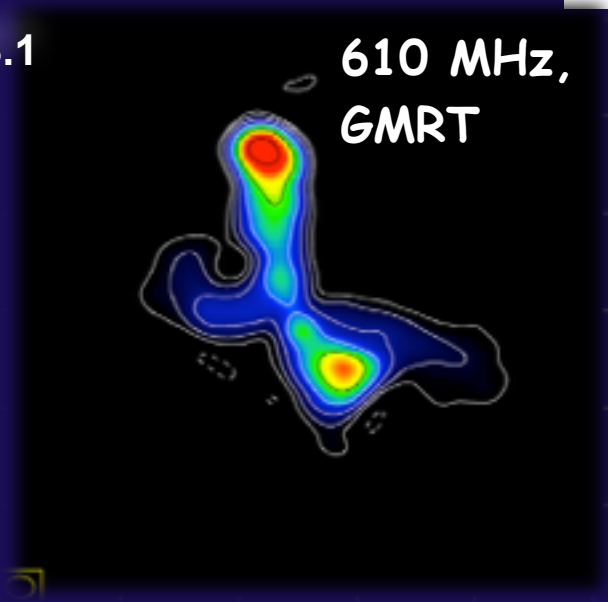
It is not true that the low surface brightness features always have steeper spectral indices.

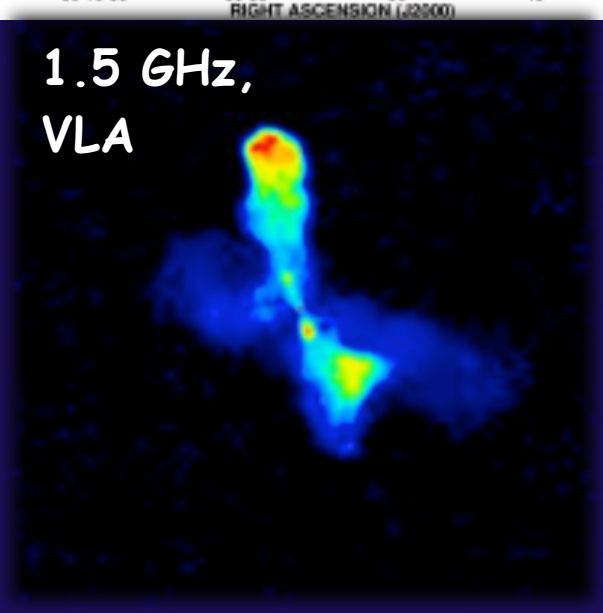
ATLAS of DRAGNs: Leahy et al. 1993; Lal & Rao 2007





3C 223.1





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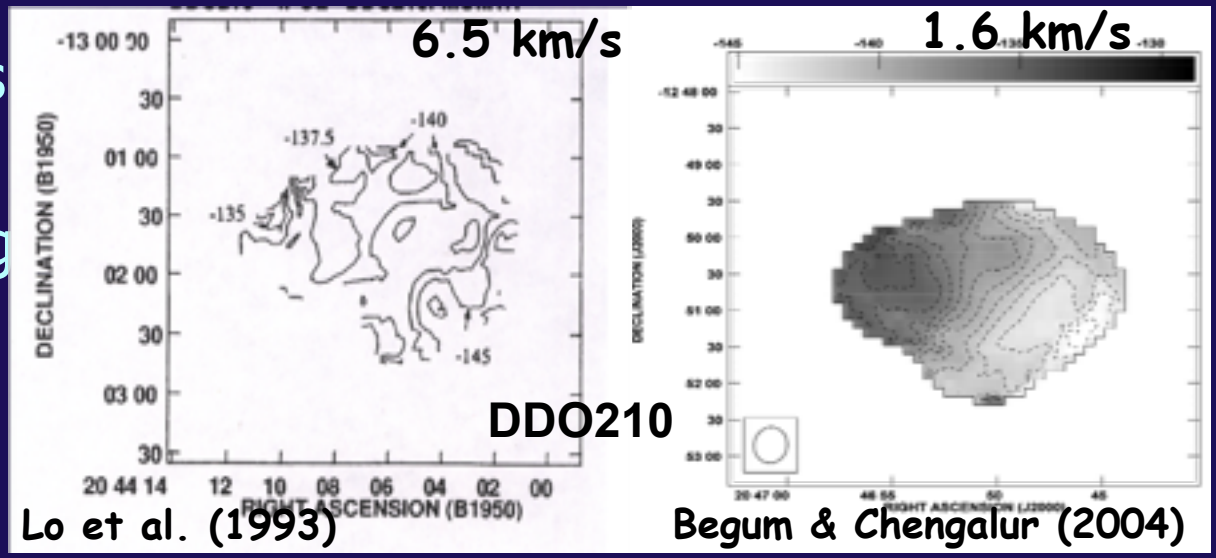
- Pulsars: rapidly rotating NSs
- Transients
  - Ex. SNRs, GRBs, etc.
- centre of the Galaxy
- Molecular gas, and HI
- Galaxies
  - normal / active galaxies
- Clusters / Groups of galaxies
- Deep-fields / EoR
- All-sky survey

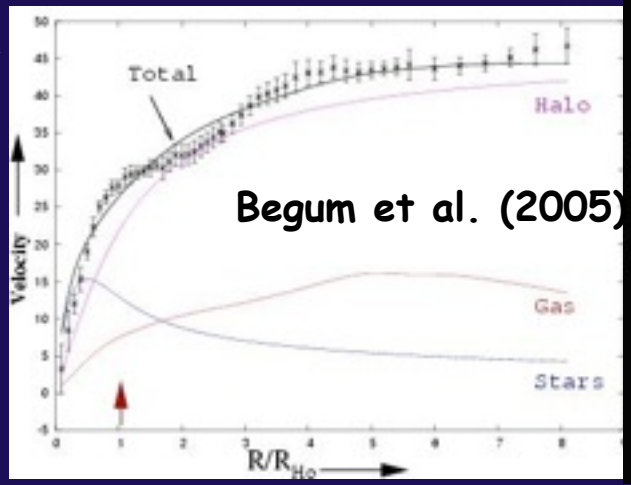
J.N. Chengalur, N. Kanekar, N.G. Kantharia, S. Sirothia, C.H. Ishwara-Chandra, V.R. Marthi T.R. Choudhury, A. Banerjee, Datta-Kanan, P. Dutta

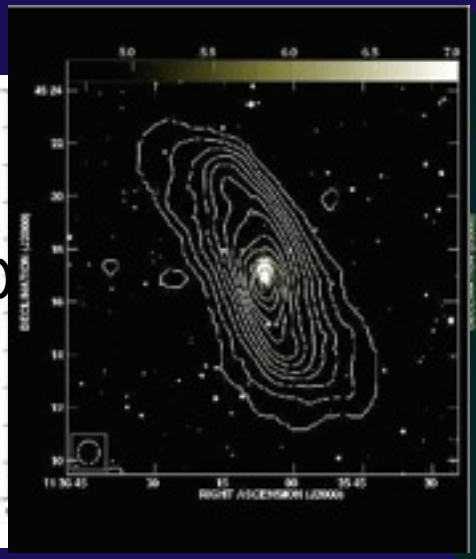
GMRT: Dwarf galaxies

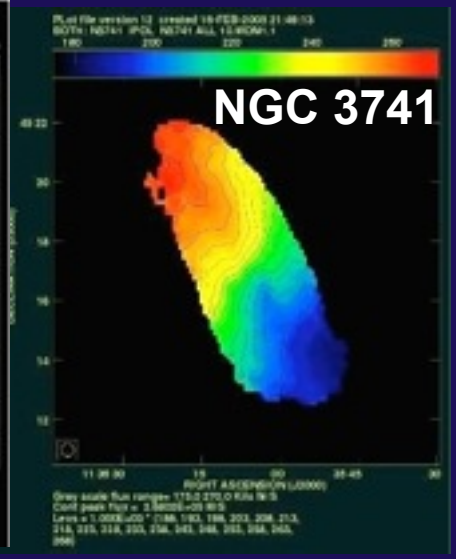
HI from Dwarf galaxies

- High-vel. resolution crucial for measuring HI gradients
- DDO210
- NGC 3741
  - most extended HI disk





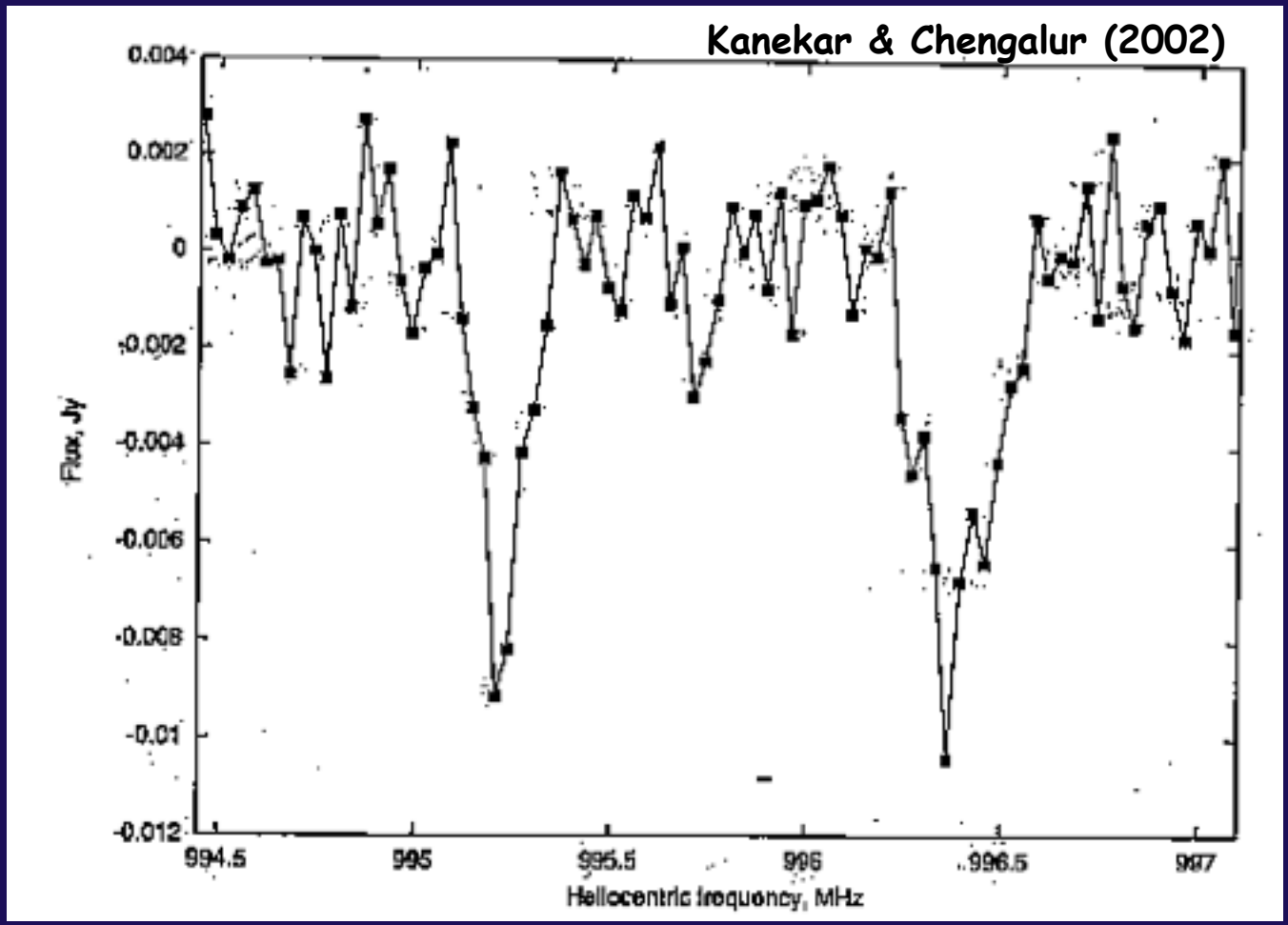




Molecular gas at intermediate-z

B1504+377

- OH line
  - 1665 and 1667 MHz
  - z = 0.67345
- N_{OH} and H_{HCO+}
  - OH is a good tracer of H_2 at cosmological distances



Variation of fundamental constants

VOLUME 91, NUMBER 24 PHYSICAL REVIEW LETTERS week ending 12 DECEMBER 2003

Constraining the Variation of Fundamental Constants using 18 cm OH Lines

Jayaram N. Chengalur*
NCRA/TIFR, P.O. Bag 3, Ganeshkhind, Pune 411007, India

Nissim Kanekar†
Kapteyn Institute, Groningen University, The Netherlands

(Received 2 June 2003; revised manuscript received 17 July 2003; published 10 December 2003)

We describe a new technique to estimate variations in the fundamental constants using 18 cm OH absorption lines, with the advantage that all lines arise in the same species, allowing a clean comparison between the measured redshifts. In conjunction with one additional transition, it is possible to simultaneously measure changes in α, g_p, and $y \equiv m_e/m_p$. We use the 1665 and 1667 MHz line redshifts in conjunction with those of HI 21 cm and mm-wave molecular absorption in a gravitational lens at $z \sim 0.68$ to constrain changes in the three parameters over the redshift range $0 < z \lesssim 0.68$. While the constraints are relatively weak ($\lesssim 1$ part in 10^3), this is the first simultaneous constraint on the variation of all three parameters. Either one (or more) of α, g_p, and y must vary with cosmological time or there must be systematic velocity offsets between the OH, HCO^+, and HI absorbing clouds.

DOI: 10.1103/PhysRevLett.91.241302 PACS numbers: 98.80.Es, 06.20.Jr, 33.20.Bx, 98.58.–w

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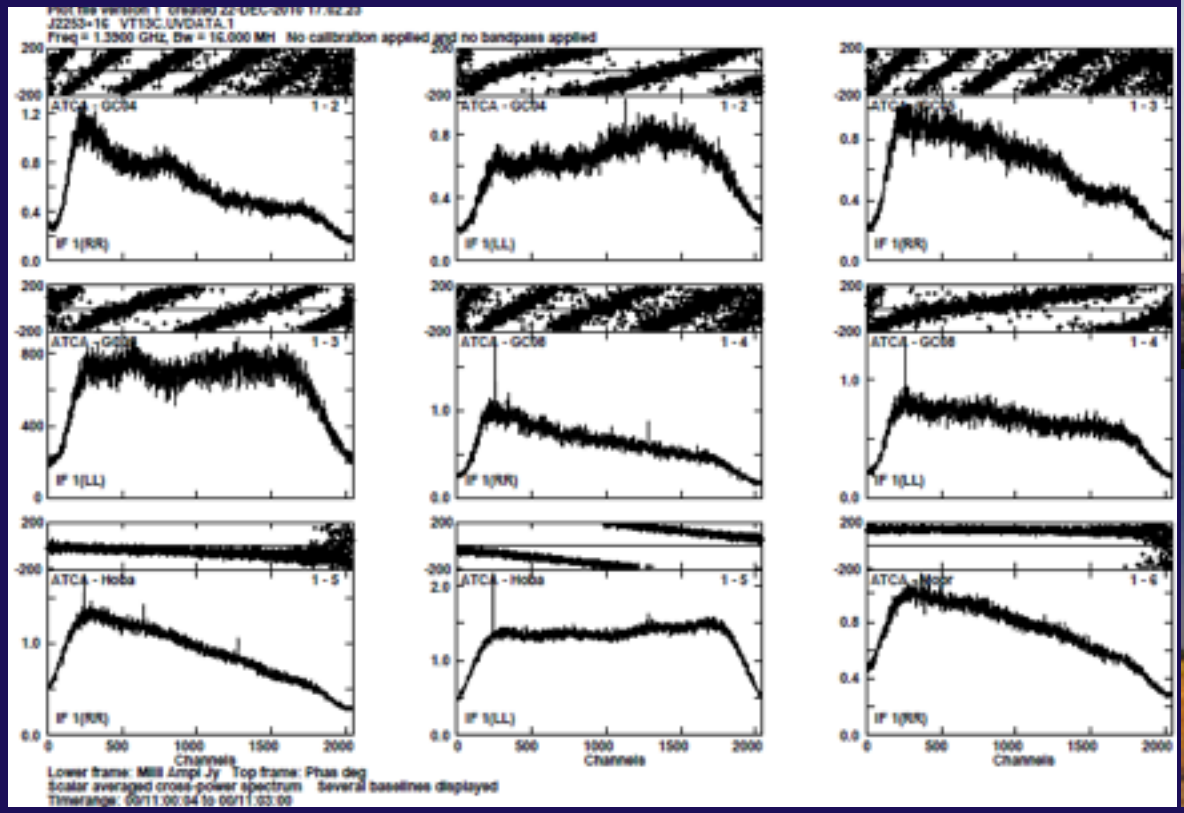
GMRT: results from Pulsar studies

- Pulsar discoveries
  - NGC1851A (Freire et al. 2004),
  - J1833-1034 in G21.5-0.9 (Gupta et al. 2005), etc.
- Pulsar timings
  - J1833-1034 (Roy et al. 2011)
- Pulsars polarization
  - Mitra et al. (2007, 2009), Johnston et al. (2008)
- Simultaneous multi-frequency observations
  - Kramer et al. (2003), Bhat et al. (2007), etc.
- Single pulse studies
  - Bhattacharyya et al. (2007, 2010), Backus et al. (2011), Gajjar et al...
- Off-pulse emission from Pulsar
  - Basu et al. (2012)

GMRT: VLBI station

15Dec2010: GMRT(4) + ATCA + MOPRA

- 3C 454.3, 1390 MHz, 16 MHz (BW)



GMRT: Looking ahead

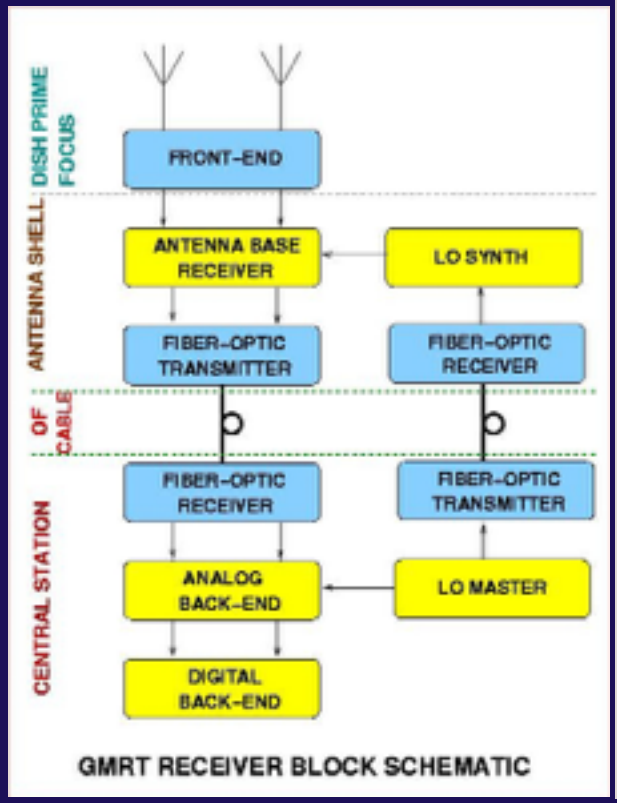
A **major upgrade** is underway at the **GMRT**, with focus on

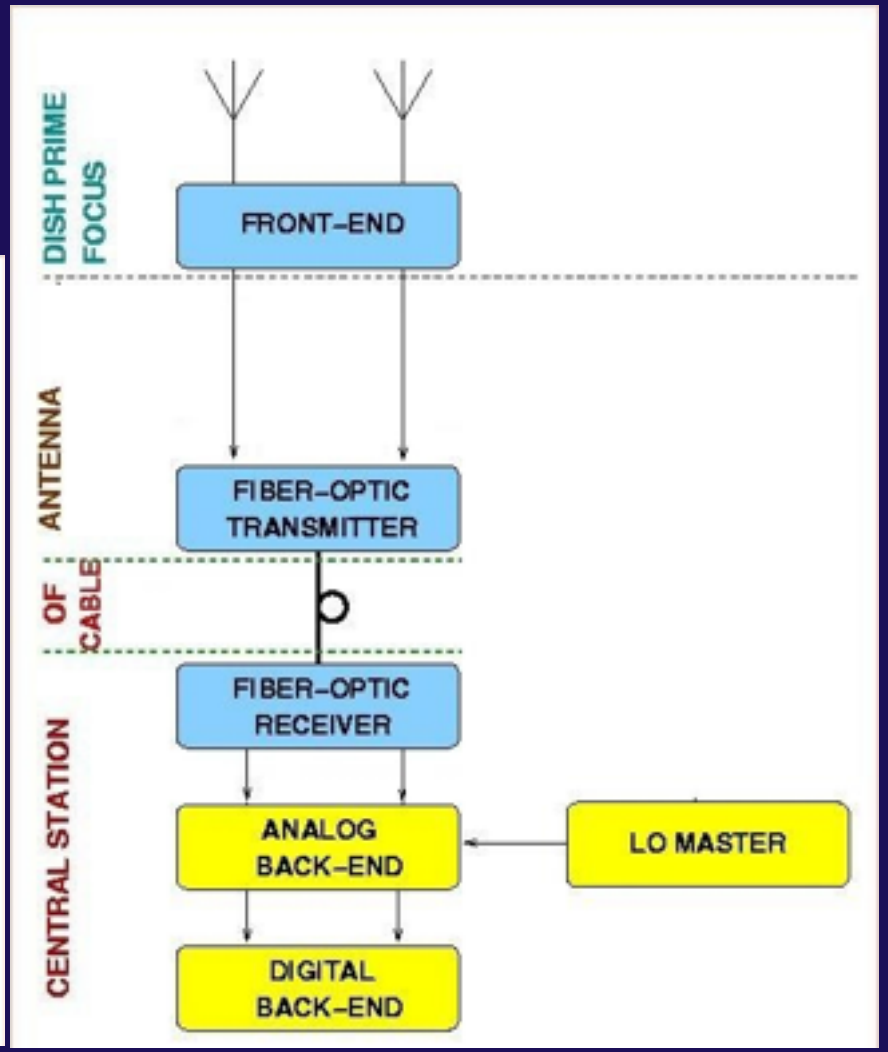
- (nearly) seamless frequency coverage from
  - ~30 MHz to 1500 MHz,
  - design of completely new 'feeds' and 'receiver' system
- Improved G/T_{sys},
  - i.e., use of better tech. receivers and reduce T_{sys}
- Increased instantaneous bandwidth to 400 MHz
  - from present 32 MHz using new digital 'backend' receiver
- Revamp Servo-system for the Antennas
- Modern and more versatile 'control and monitor' system
- Matching improvements in off-line computing facilities and other infrastructure

uGMRT: Overview

A relatively simplified electronics

Several improvements @dish-focus, optical-fibre system, backend, etc.





uGMRT: Overview of Rx system

Broad-band feeds + FE (in octaves) :

- 130 – 260 MHz (replacing 150)
- 250 – 500 MHz (replacing 325)
- 550 – 900 MHz (replacing 610)
- 1000 – 1450 MHz (updating L-band)

Modified optical fibre system to cater to wideband (50 - 2000 MHz) dual pol RF signals (while allowing existing IF signals).

Analog backend system to translate RF signals to 0 - 400 MHz baseband.

Digital backend system process 400 MHz BW for interferometric and beam modes.

(+ improvements @dish-focus, optical-fibre system, backend…)

uGMRT: (wideband) feeds

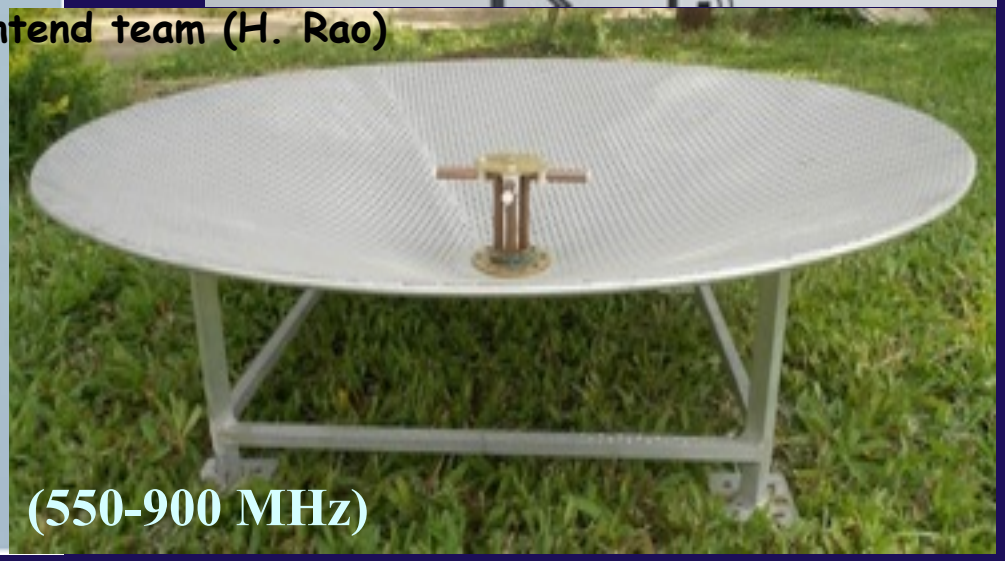
Cone-dipole design

550-900 MHz

250-500 MHz

Dual-ring feed (130-260 MHz)

Credits: frontend team (H. Rao)



uGMRT: optical-fibre

New optical fibre system

Credits: OF team (S. Sureshkumar)

uGMRT: analog baseband

New analog baseband system

Credits: backend team (B. Ajith Kumar)

uGMRT: GWB

16-station
dual pol'n
200/400 MHz BW
2048 channels

16 ADC cards
8 FPGA boards
16 compute nodes
t_{int} = 0.67 s

Credits: backend team (B. Ajith Kumar)

uGMRT: current status

Proposed configuration of feeds + receivers (current status):

1000 – 1450 MHz: existing feed + improved dynamic range Rx with appropriate RFI filters.

(completed on 30 antennas; work ongoing to have 5-7 spares.)

550 – 900 MHz: prototype feeds (cone-dipole); prototypes for

(a) matching receiver systems tested and ready;

(b) final set of sub-band filters ready, and

(c) RFI rejection filters are ready.

250 – 500 MHz: cone-dipole feed + Rx (mass production + installation)

15 antennas with new feed, 10 antennas with new FE box (ver1),

8 antennas with new Common-box (ver1).

Prototype of (final ver3) FE box now cleared for mass production.

Common-box (ver2) under development

(including temperature + power monitoring and new MCM interface).

125 – 250 MHz: modified Kildal ring feed: prototype version tested on single antenna and found to give good results for 130-240 MHz; prototype FE box also tested; system now installed on 3 antennas and under tests before finalisation; filter scheme is almost finalised.

30 – 80 MHz: prototype system (in collaboration with RRI, Bangalore) installed & tested on 4 antennas a few years ago; awaiting final decision for mass production.

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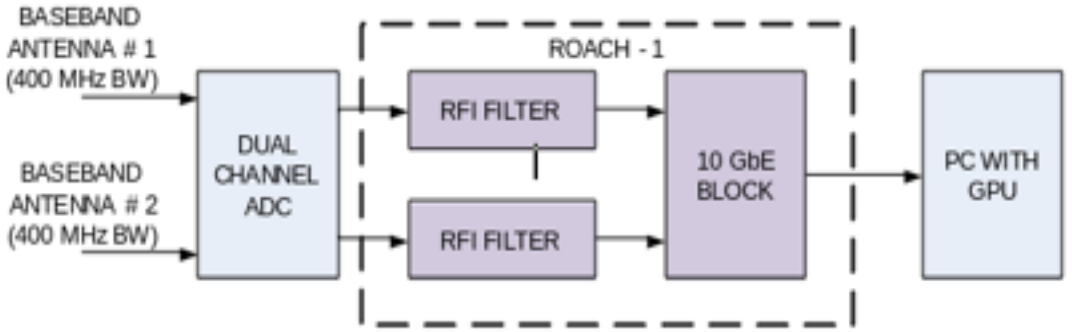
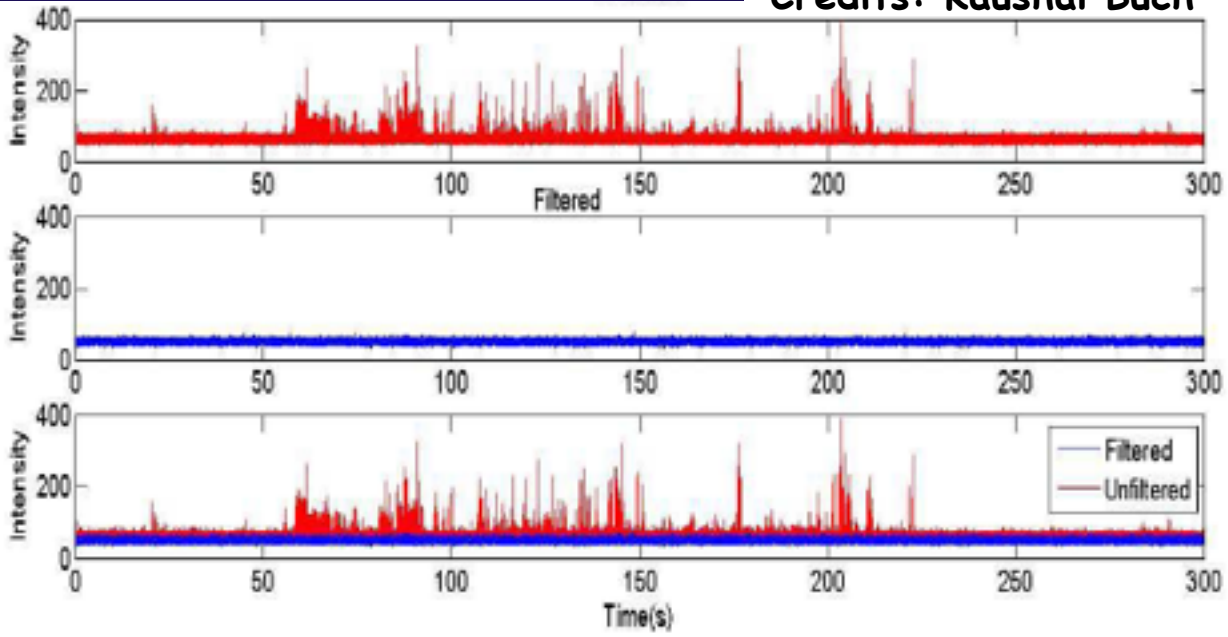
uGMRT: RFI detection & filtering

Braodband RFI
(using MAD)
filtering at ADC output



Credits: Kaushal Buch



Time series of a spectral channel showing filtering at 3σ threshold computed in continuous mode – replacement with zero

FPGA
implementation

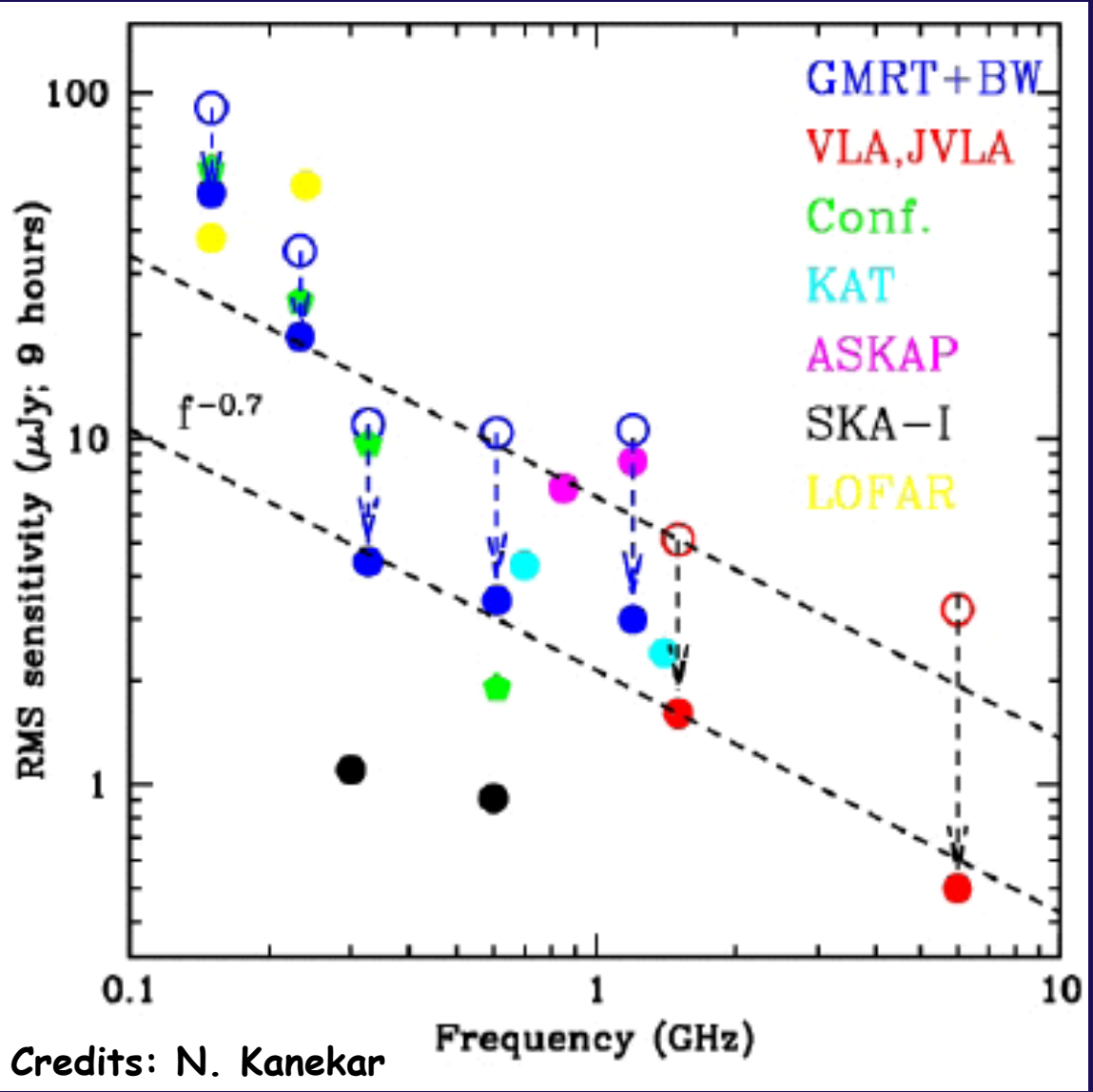
GMRT: more upgrades

A **major upgrade**

- Antenna surface
- BLDC
- Mechanical
  - HLP, gearbox, etc.
- M-&-C system
- Servo control computer
- Electrical system
  - (RFI friendly) UPS
- Workshop machinery
- …

“upgraded”-GMRT

- **Expected performance** of “upgraded”-GMRT and comparison of it’s sensitivity with other major facilities in the world.

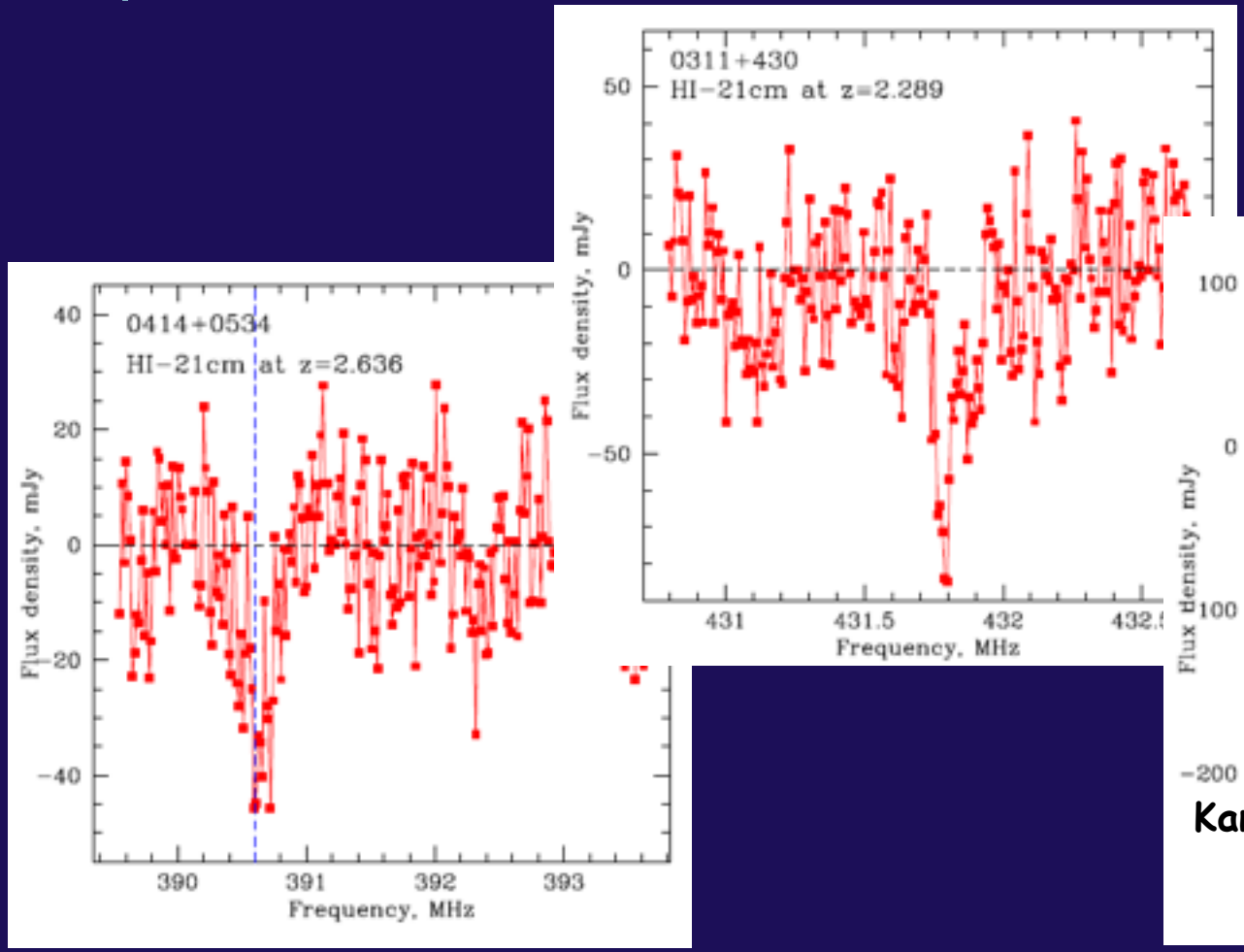


The upgrade of Giant Metrewave Radio Telescope is happening at a full pace! Of course there are a loads of (system) tests that are happening and many more needs to be performed.

uGMRT: Opening new window

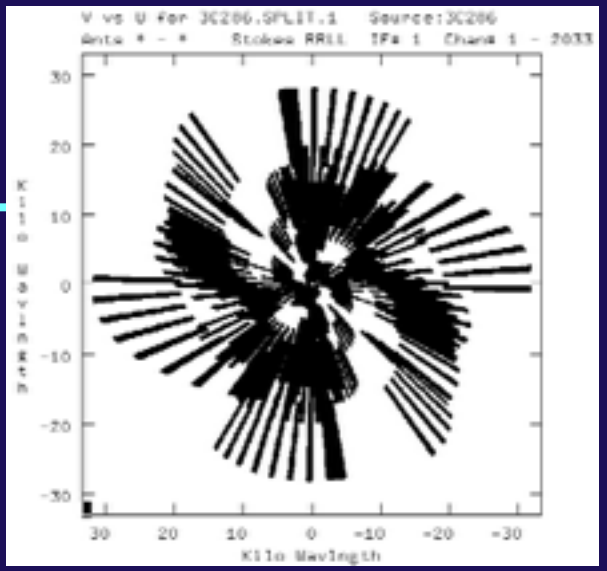
- Detection of spectral lines from different sources at different parts of the 250-500 MHz band

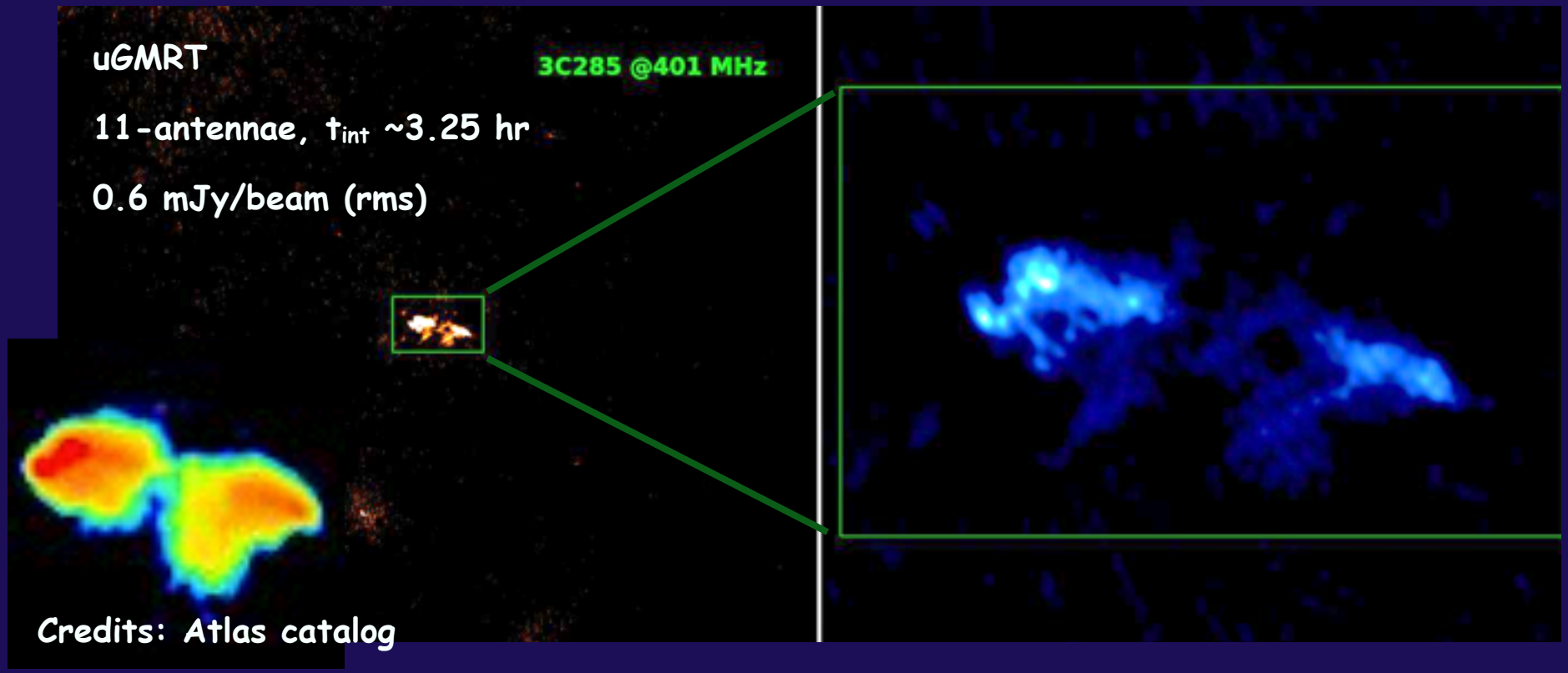
Credits: N. Kanekar



uGMRT: First results I

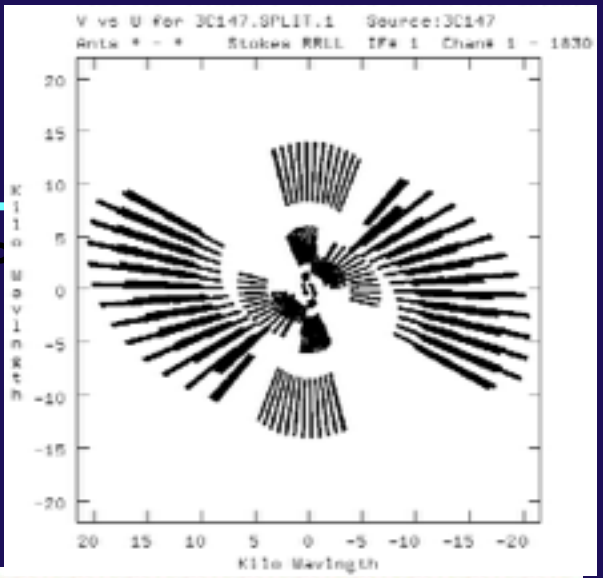
- Imaging an extended radio galaxy, 3C285
  - 300-500 MHz (~195 MHz bandwidth)

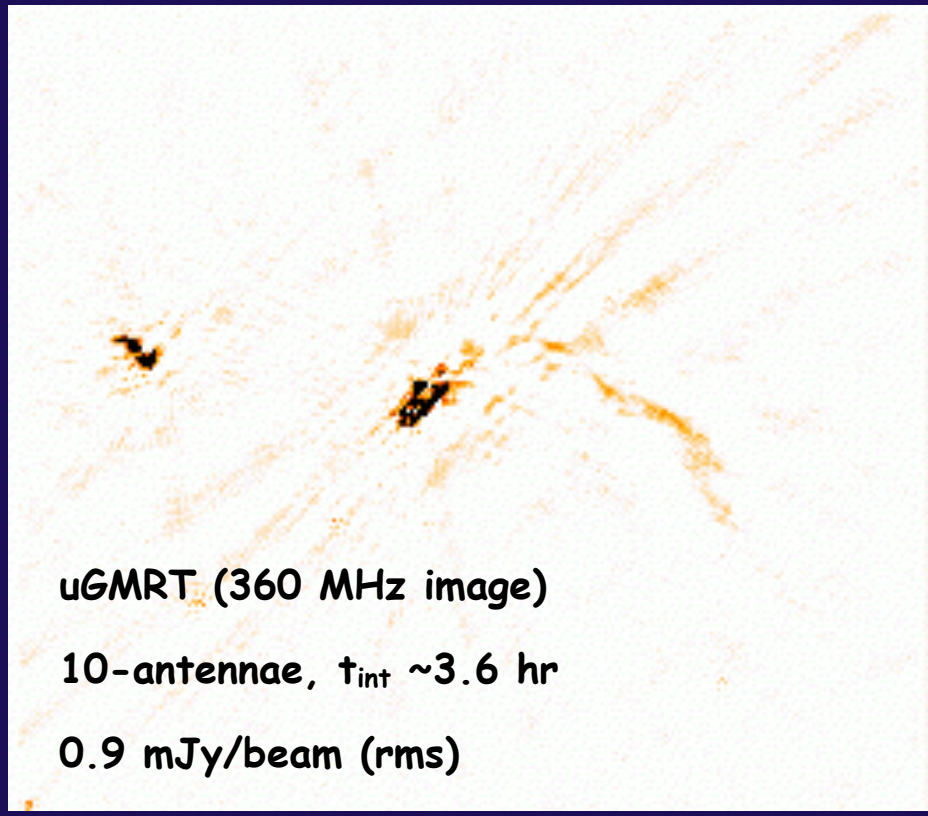




uGMRT: First results II

- Imaging an extended radio galaxy, 3C129
  - 250-450 MHz (~180 MHz bandwidth)

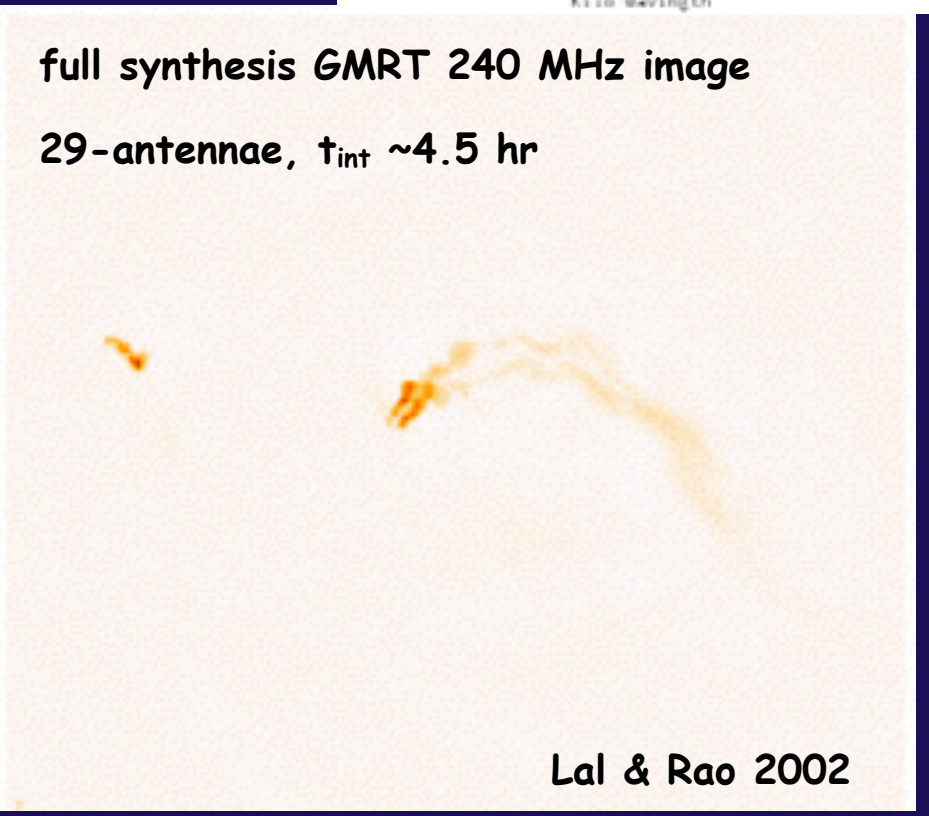




uGMRT (360 MHz image)

10-antennae, t_{int} ~3.6 hr

0.9 mJy/beam (rms)



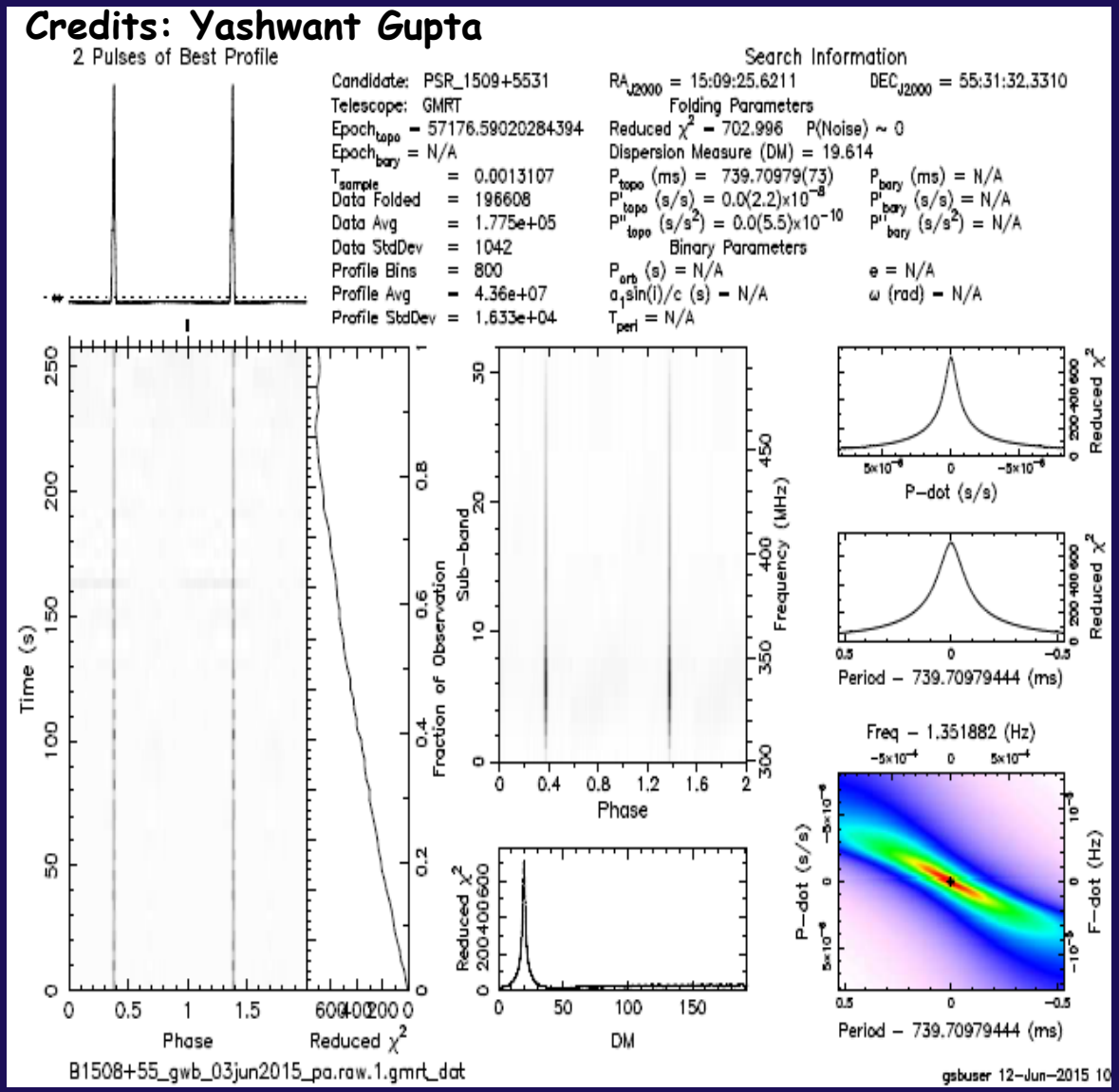
full synthesis GMRT 240 MHz image

29-antennae, t_{int} ~4.5 hr

Lal & Rao 2002

uGMRT: First results (BF/Pulsar)

- PSR B1508+55
  - 300-500 MHz band
  - (200 MHz BW)
  - 8 antennas
  - Phased Array mode



uGMRT: where do we stand?

The proposal is to have a uGMRT phase-II release with the following features:

1. **30 antennas with broadband L-band FE (completed)**
2. **30 antennas with broadband OF link (soon to be completed)**
3. **16 antennas with broadband 250-500 feed (with final ver. FE boxes)**
4. **30 antennas with GAB Analog Backend (completed)**
   - **(i) Switchable gain +/-8 dB with 0.5 dB step**
   - **(ii) Variable bandwidth 100, 200, 400 MHz**
   - **(iii) LO selection at 0.5 MHz step**
5. **16 antenna 400 MHz (up to 16k-ch) backend with following modes:**
   - **(i) total intensity interferometry**
   - **(ii) full polar interferometry**
   - **(iii) total intensity IA and PA beams**
   - **(iv) full polar PA beam**
   - **(v) spectral zoom modes**

uGMRT: where do… + users

The proposal is to have a uGMRT phase-II release with the following features:

6. **16 antennas with BLDC system (soon to be completed)**
7. **16 antennas with PC104 system installed (complete)**
8. **2 antennas with upgraded reflecting surface (one antenna!)**
9. **8 antennas with UPS, with final electrical wiring (for two antennas)**

The phase-II will be released (for users within **NCRA**) from **15 Sep 2015**, followed by a release for **GTAC** users, starting in **Apr 2016**.

(There will be more improvement of the specifications listed above, for sure!)

The Giant Metrewave Radio Telescope is a powerful instrument to probe several astrophysical objects and the upgraded GMRT will make several orders of improvement.

Thank you all for your attention!