Science (highlights) from Giant Metrewave Radio Telescope

Dharam Vir Lal, NCRA (TIFR)

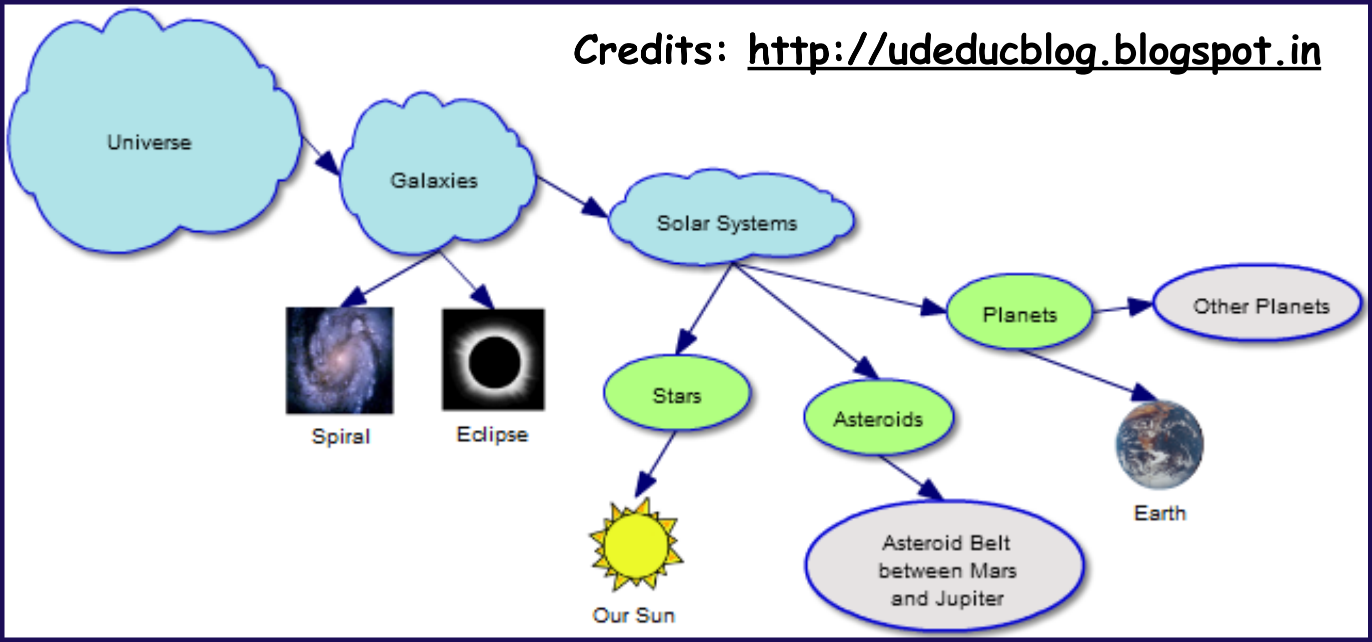
With due thanks to

Scientists, engineers and support personnel at NCRA-GMRT
S. Bhatnagar (NRAO), A.P. Rao (NCRA, India)
R.P. Kraft, W.R. Forman, C. Jones, P.E.J. Nulsen (CfA-SAO, USA)
M.J. Hardcastle (UH, UK)

GMRT Observatory, 24 August 2013

Plan

- Topic / Object
  - Why study?
    - List of experts (group) from NCRA
  - A flavor of some result
- Topic II / Object II
  - ...
- Topic ...
- STOP!



GMRT: Science objectives

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

B. Bhattacharyya: Pulsars (Mon, 26 Aug, 16:15 hrs)

N. G. Kantharia: Galactic radio sky (Mon, 19 Aug, 9:45 hrs)

C.H. Ishwara-Chandra: Extra-galactic radio sky (Mon, 19 Aug, 11:45 hrs)

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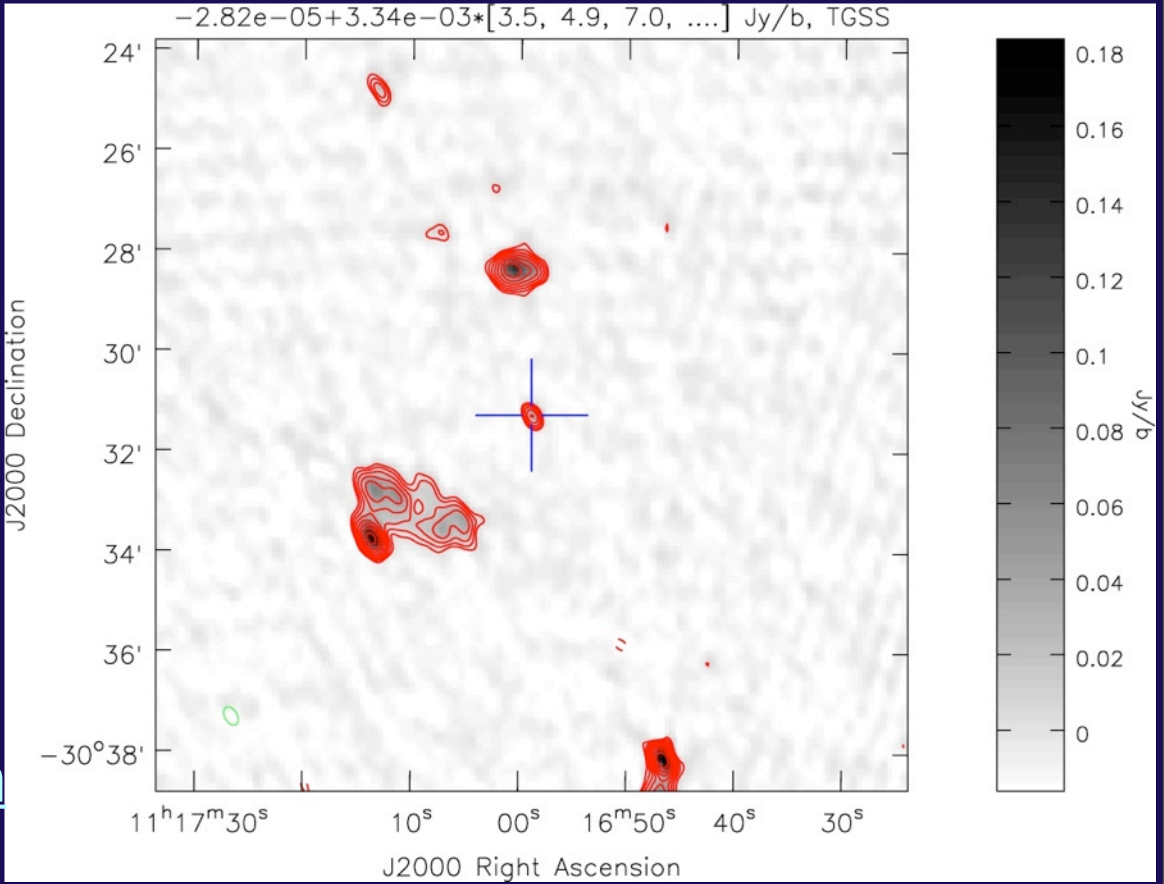
S. Sirothia, N.G. Kantharia, C.H. Ishwara-Chandra, Gopal-Krishna

TIFR-GMRT Sky Survey

TIFR-GMRT Sky Survey

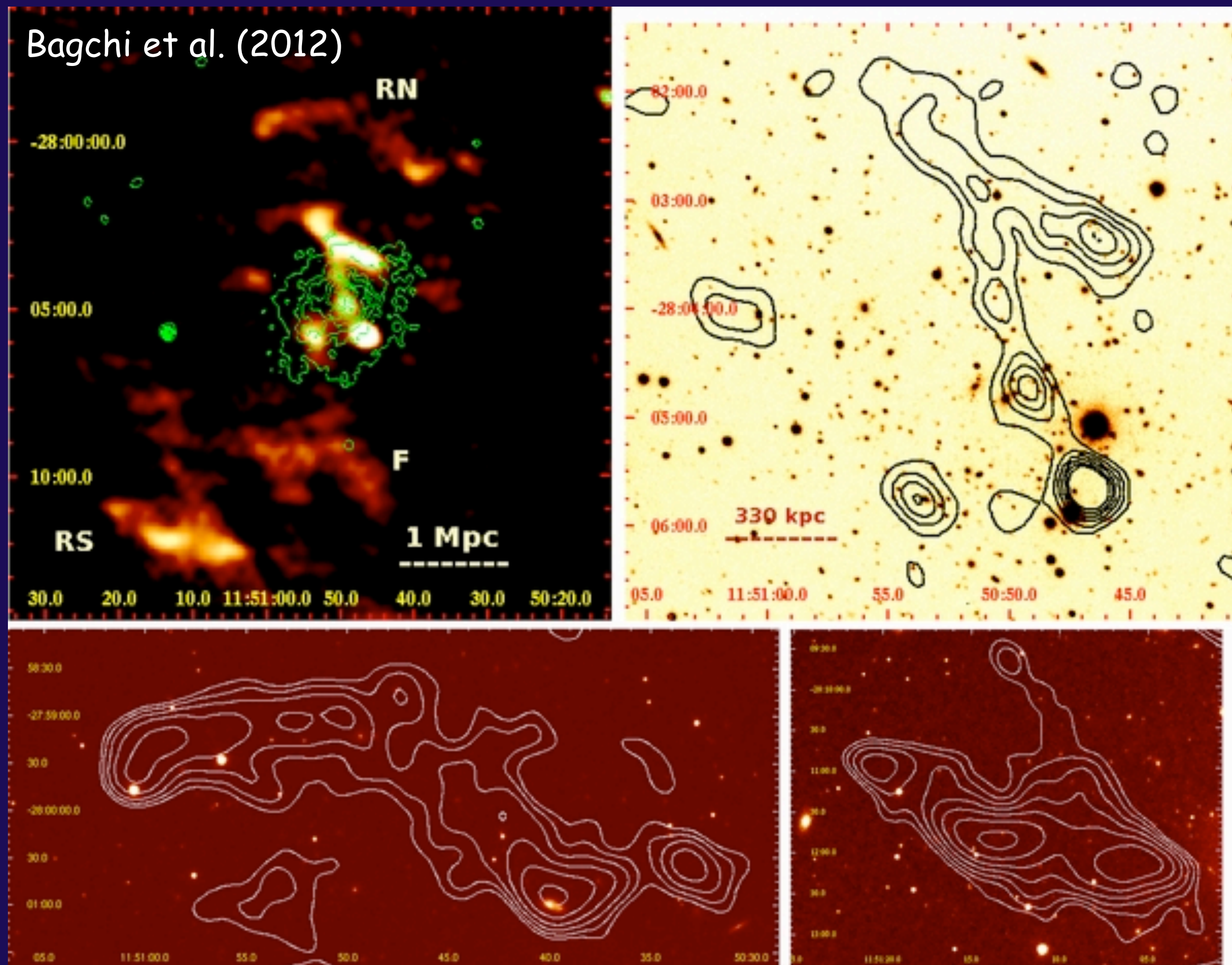
- Team: Sirothia, Kantharia, Ishwara-Chandra, Gopal-Krishna
- @150 MHz
- metre-wavelength counterpart of cm-wavelngth NVSS survey
  - 20”
  - (5x better than NVSS)
- 2,000,000 sources!

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



TGSS: An example result

- TGSS: Discovery of Giant double radio **relic** source in Planck-SZ-cluster



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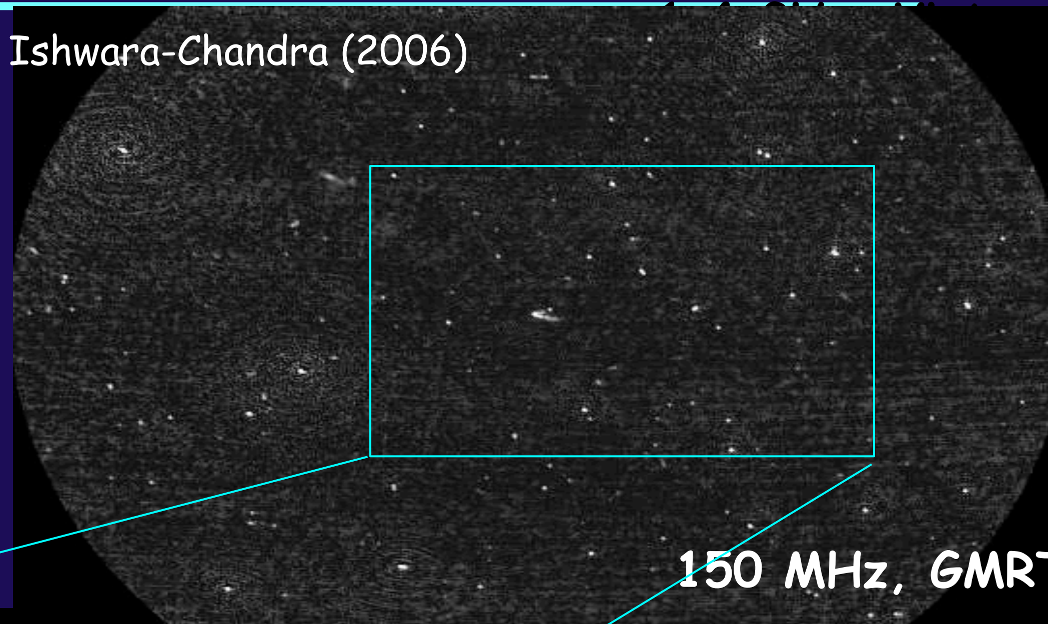
Y. Gupta, S. Sirothia, Y. Wadadekar, Ishwara-Chandra, ...

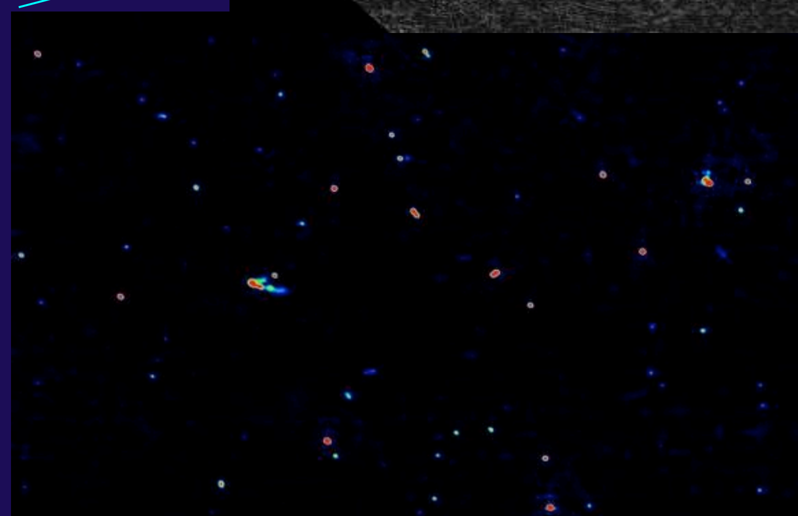
Deep field: A764 @150 MHz

Abell 764 field

Image: 3 deg FoV

- 23″ x 19″
  - ~2 mJy
- WENSS-NVSS OR GMRT-NVSS, latter is superior by a factor ~2



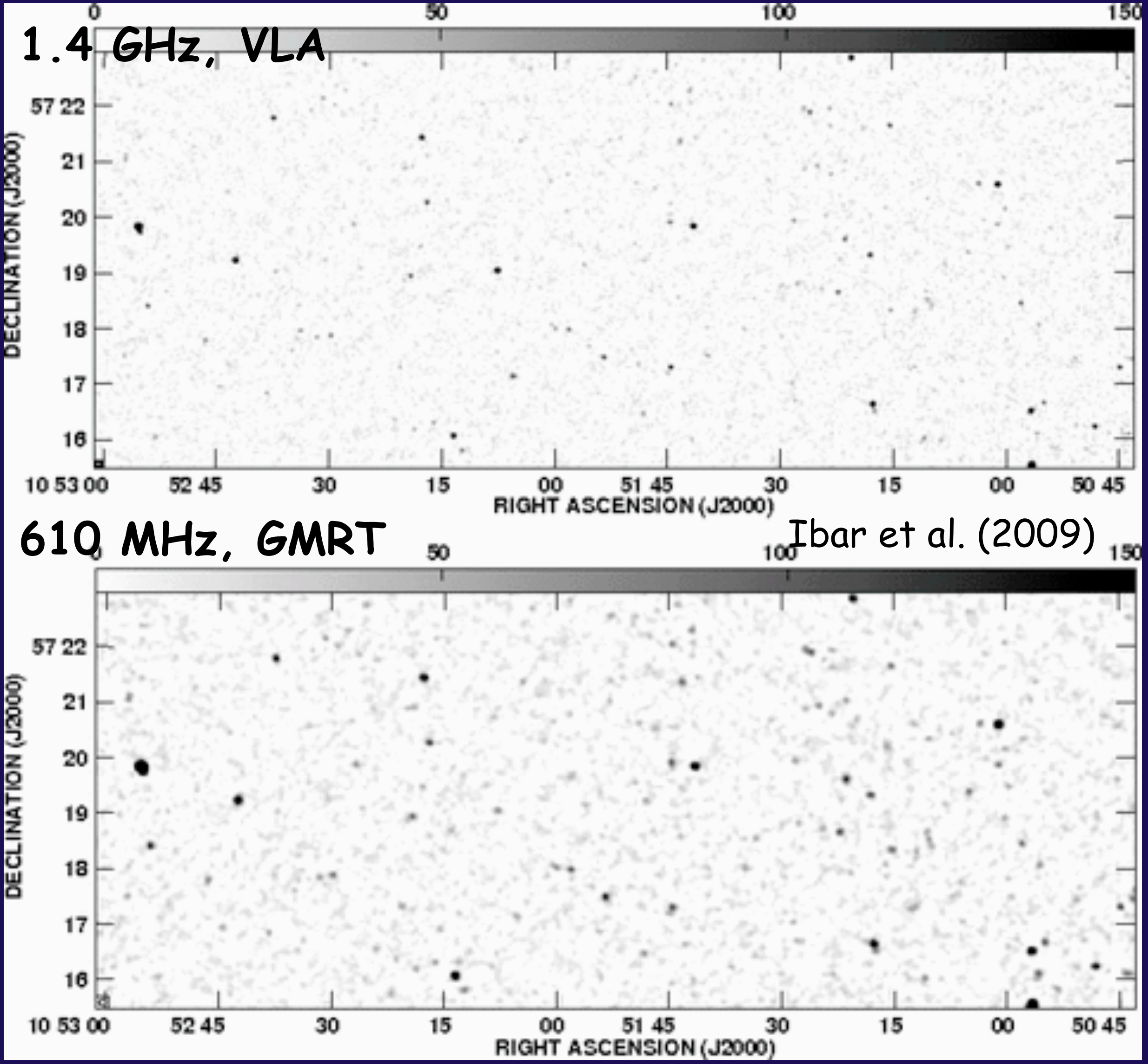


Deep field: Lockman hole

Lockman Hole:

Image: 18.7′ x 7.5′

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



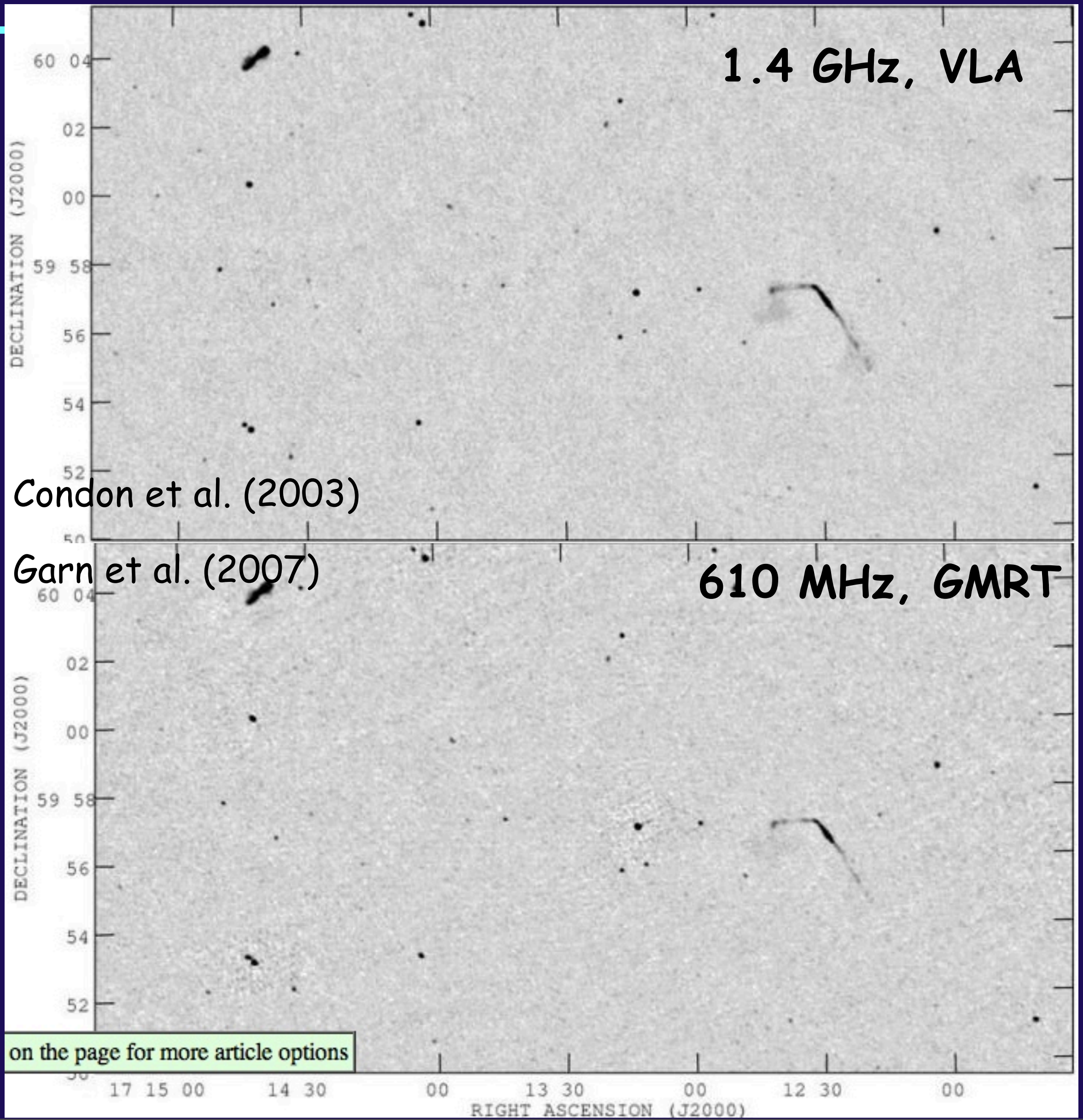
Deep field: ELIAS FLS field

Spitzer extra-galactic FLS-field

3944 sources!

Image: 18.7′ x 7.5′

- ~5″
  - ~45 μJy
- 5.8″ x 4.7″
  - ~27 μJy

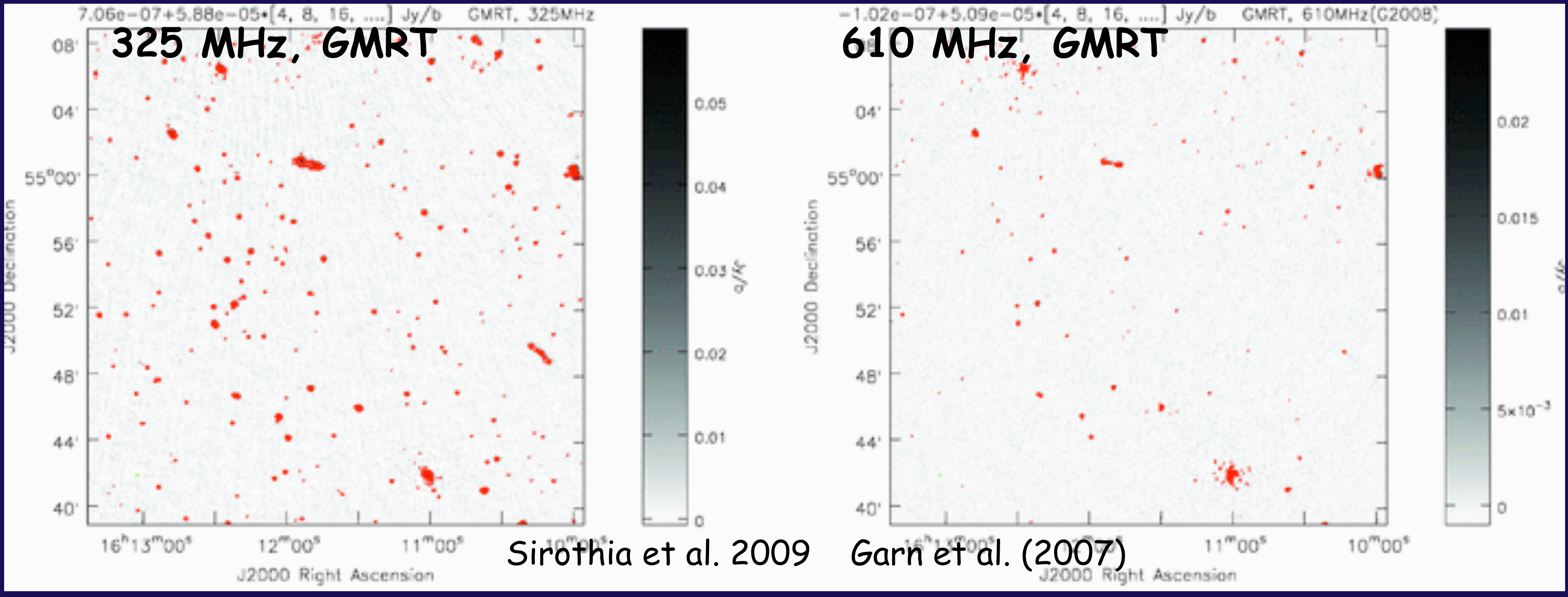


Deep field: ELIAS N1 field

ELIAS N1 FLS-field - 1286 sources (above 270 muJy)!

Image: 30’ x 30’

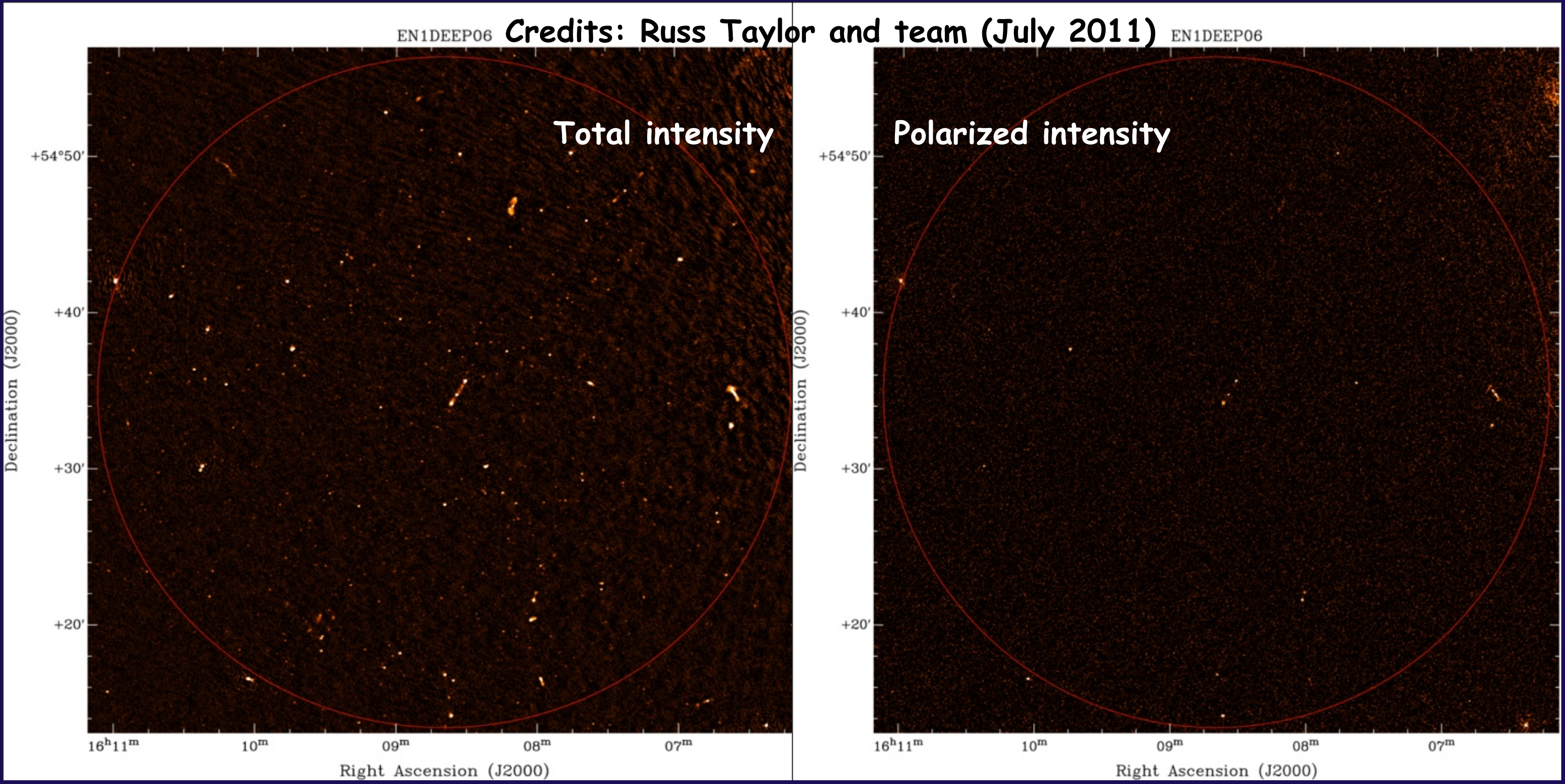
- ~27 µJy at 610 MHz
- ~40 µJy at 325 MHz



Radio Polarization: ELIAS N1

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

- GMRT deep polarization image



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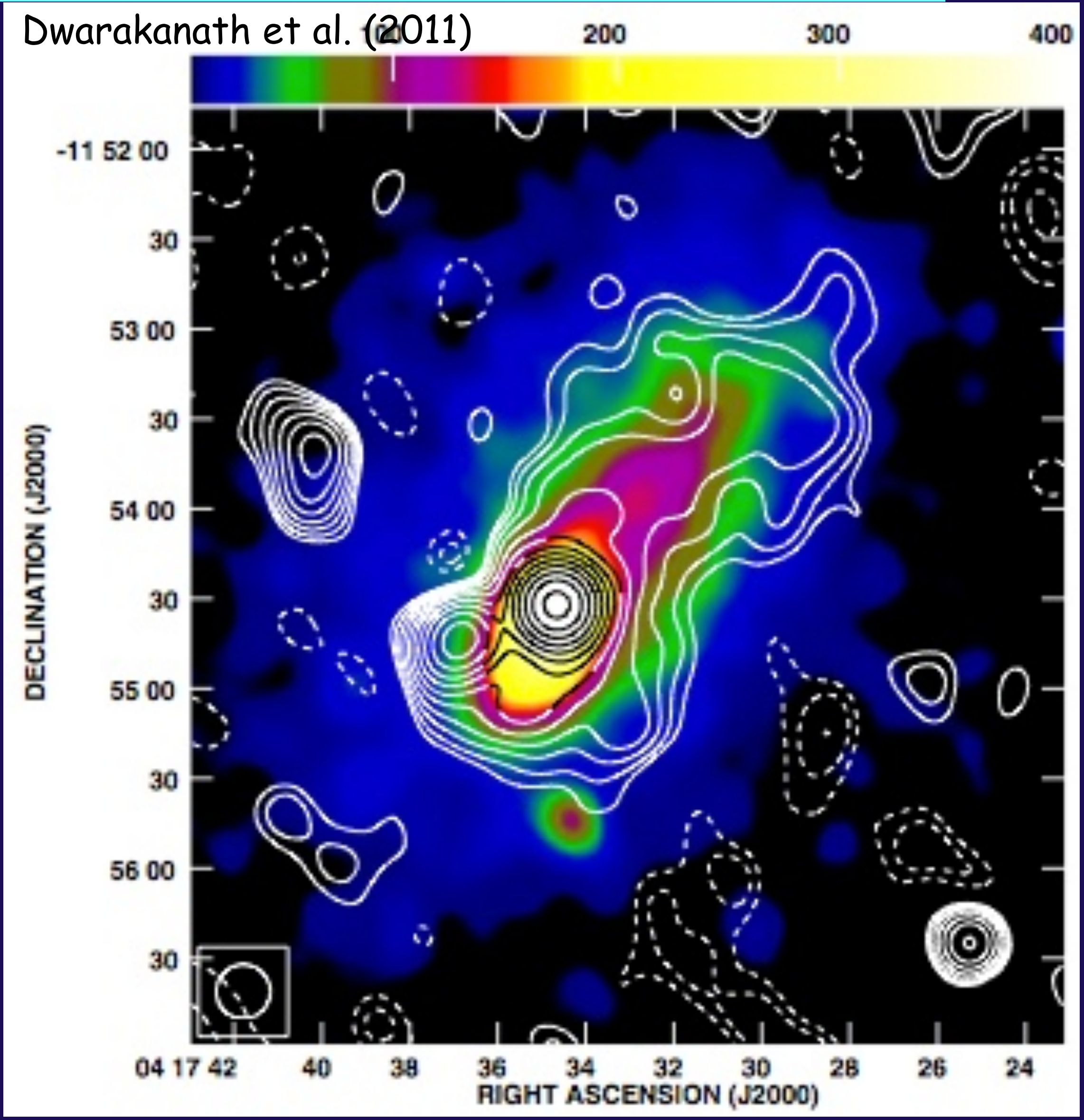
D.J. Saikia, N.G. Kantharia, S. Sirothia, C.H. Ishwara-Chandra, S. Roy, A. Basu, JNC, NK, DVL

Giant radio halo

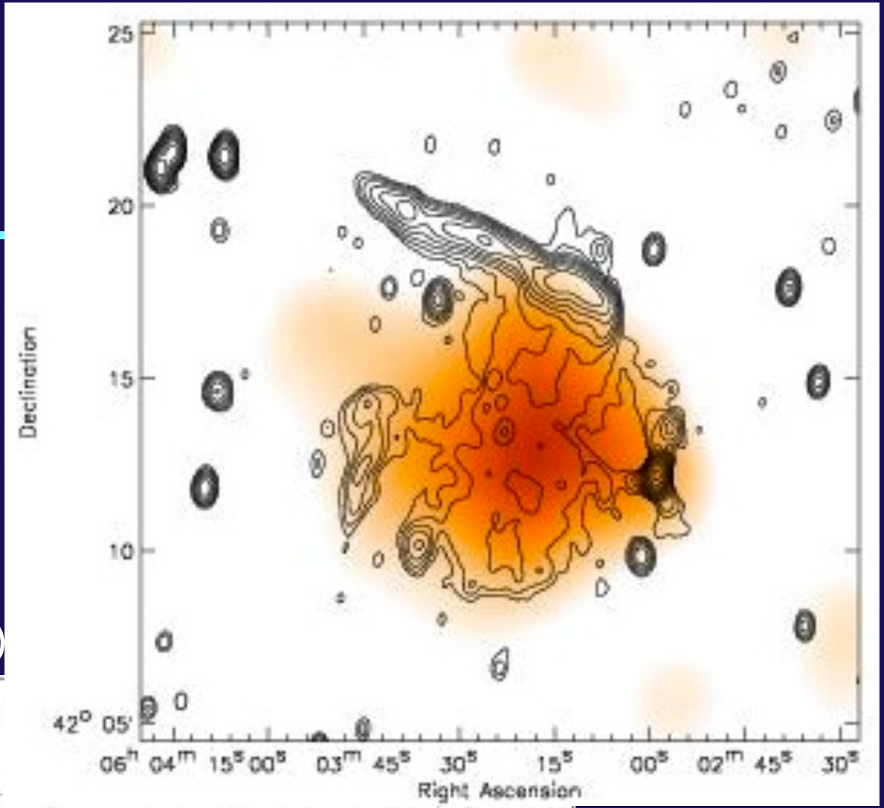
- Discovery of giant relic radio halo in a massive merger cluster at z = 0.443

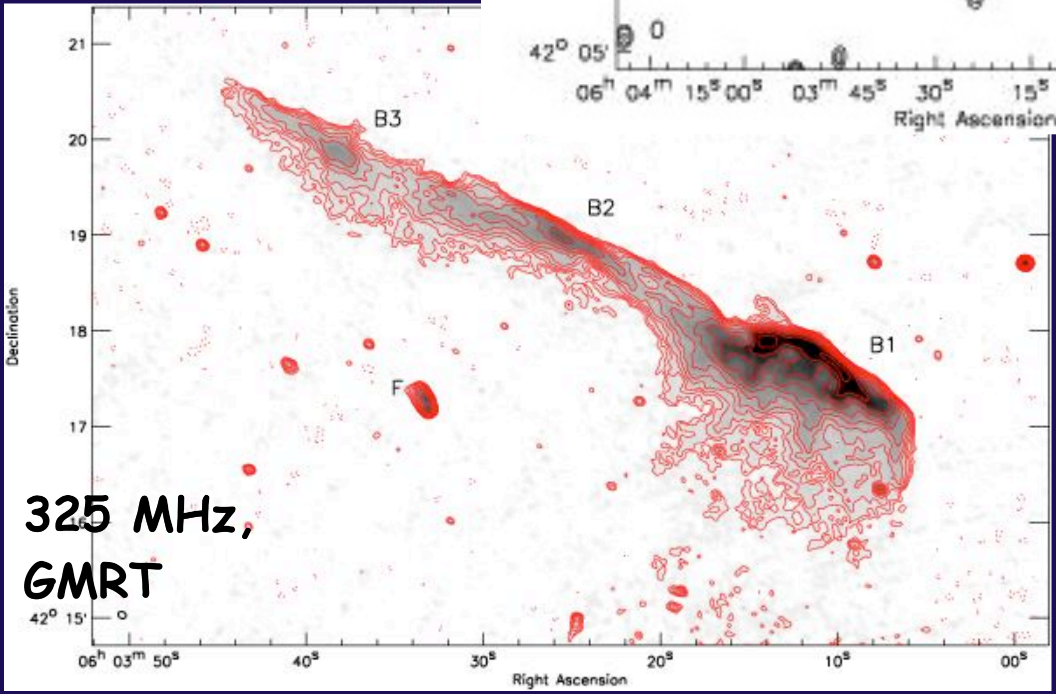


Tooth-brush relic

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

van Weeren et al. (2012)





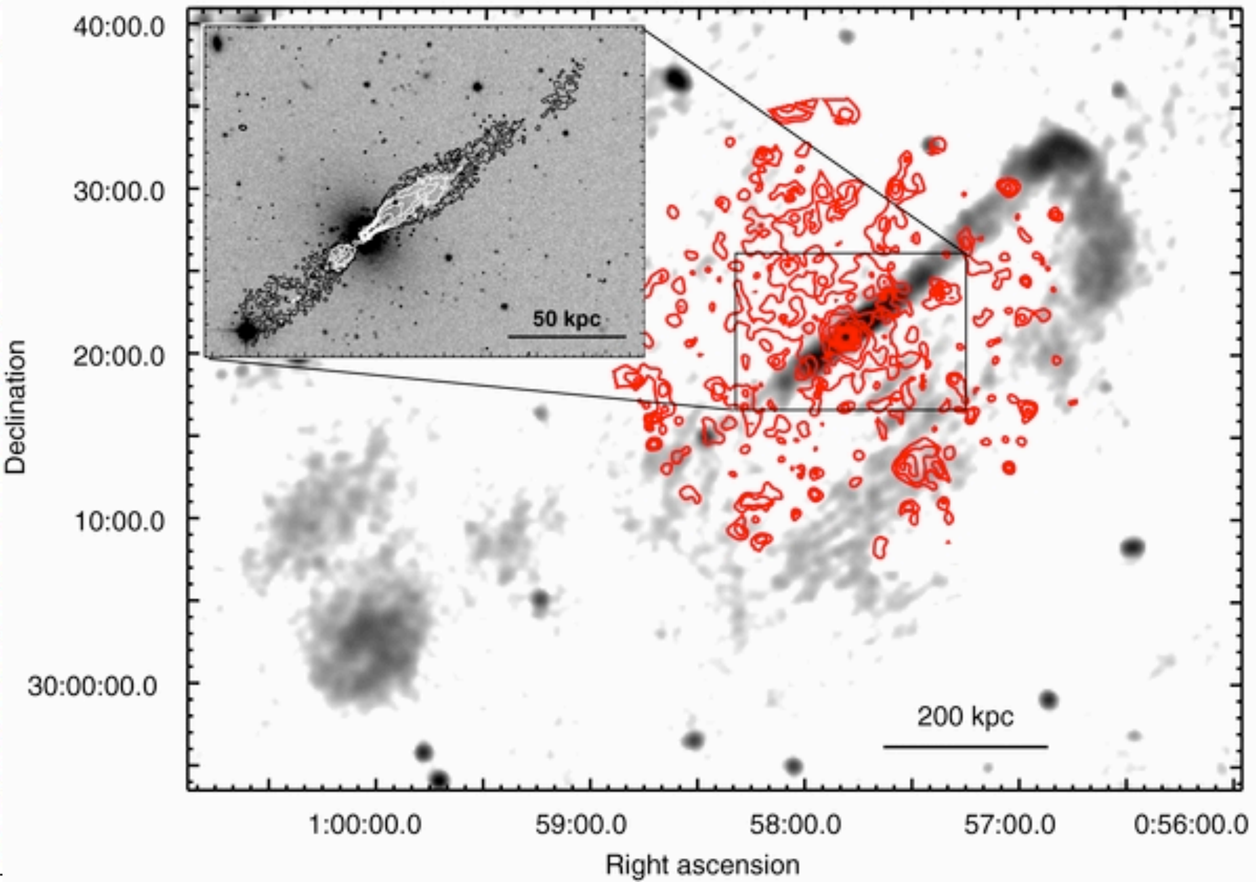
GMRT study of galaxy groups

The List of Galaxy Groups

Group Name	R.A.$_{J2000}$ (h m s)	Decl.$_{J2000}$ (°,′,″)	z
UGC 408	00 39 18.6	+03 19 52	0.0147
NGC 315	00 57 48.9	+30 21 09	0.0165
NGC 383	01 07 25.0	+21 24 45	0.0170
NGC 507	01 23 40.0	+33 15 20	0.0165
NGC 741	01 56 21.0	+05 37 44	0.0185
HCG 15	02 07 37.5	+02 10 50	0.0228
NGC 1407	03 40 11.9	−18 34 39	0.0059
NGC 1587	04 30 39.9	+00 39 43	0.0123
MKW 2	10 30 10.7	−03 09 48	0.0368
NGC 3411	10 50 26.1	−12 50 42	0.0153
NGC 4636	12 42 50.4	+02 41 24	0.0031
HCG 62	12 53 05.8	−09 12 16	0.0137
NGC 5044	13 15 24.0	−16 23 06	0.0090
NGC 5813	15 01 11.2	+01 42 07	0.0066
NGC 5846	15 06 29.3	+01 36 20	0.0057
AWM 4	16 04 57.0	+23 55 14	0.0318
NGC 6269	16 58 02.4	+27 51 42	0.0348
NGC 7626 (NGC 7619)[d]	23 20 42.3	+08 13 02	0.0114

Giacintucci et al. (2012)

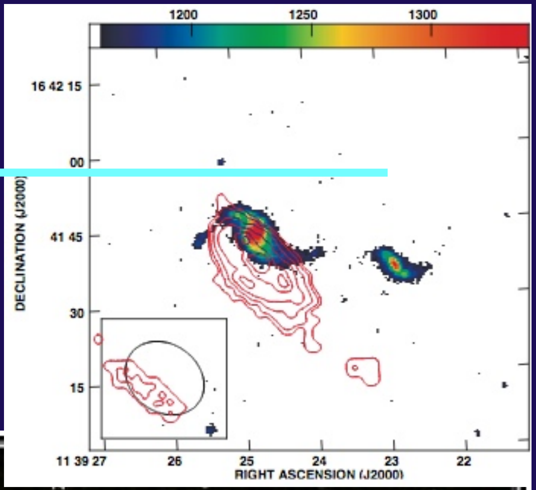
Venturi et al. (2013), ...

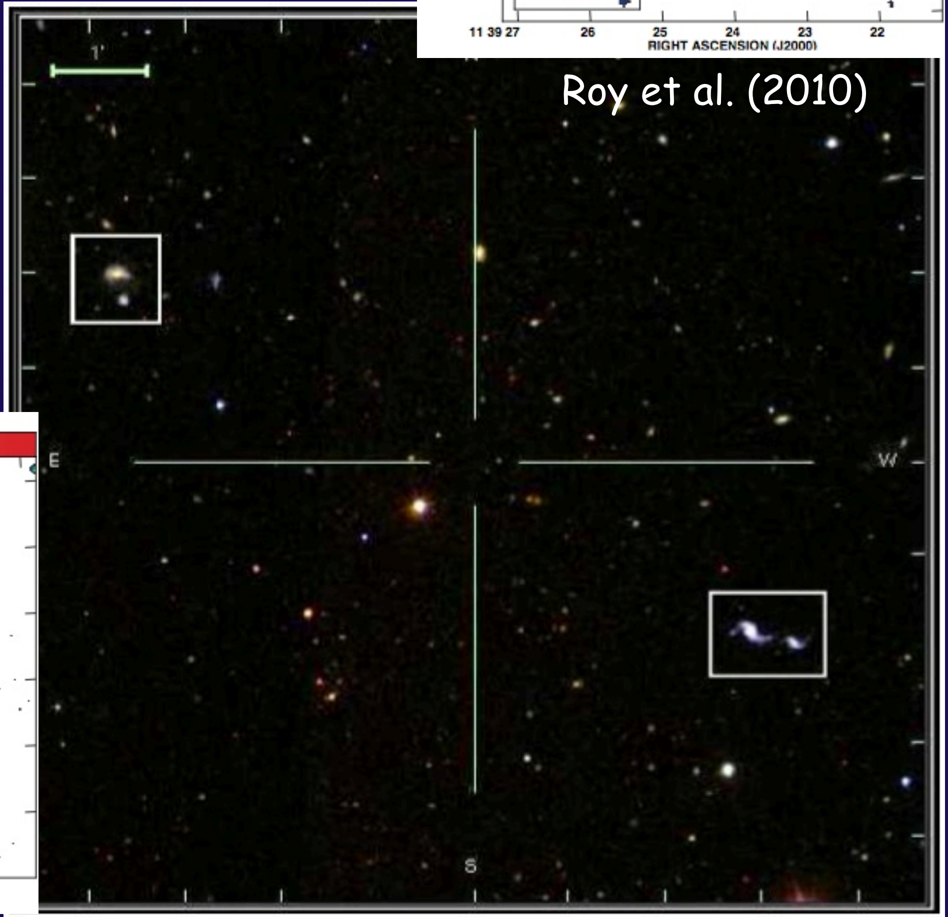


GMRT: A new group?

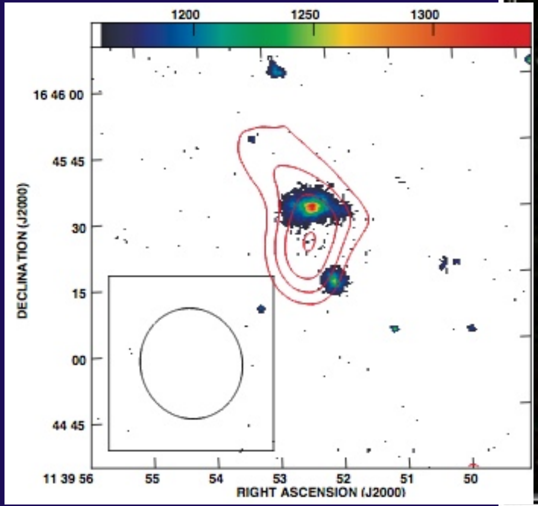
- Curious case of J113924.74+164144.0
- z = 0.0693 (D_L = 305 Mpc)
- HI emission is extended, offset from opt.-position
  - possible interaction

all these form a loose-group!





Roy et al. (2010)



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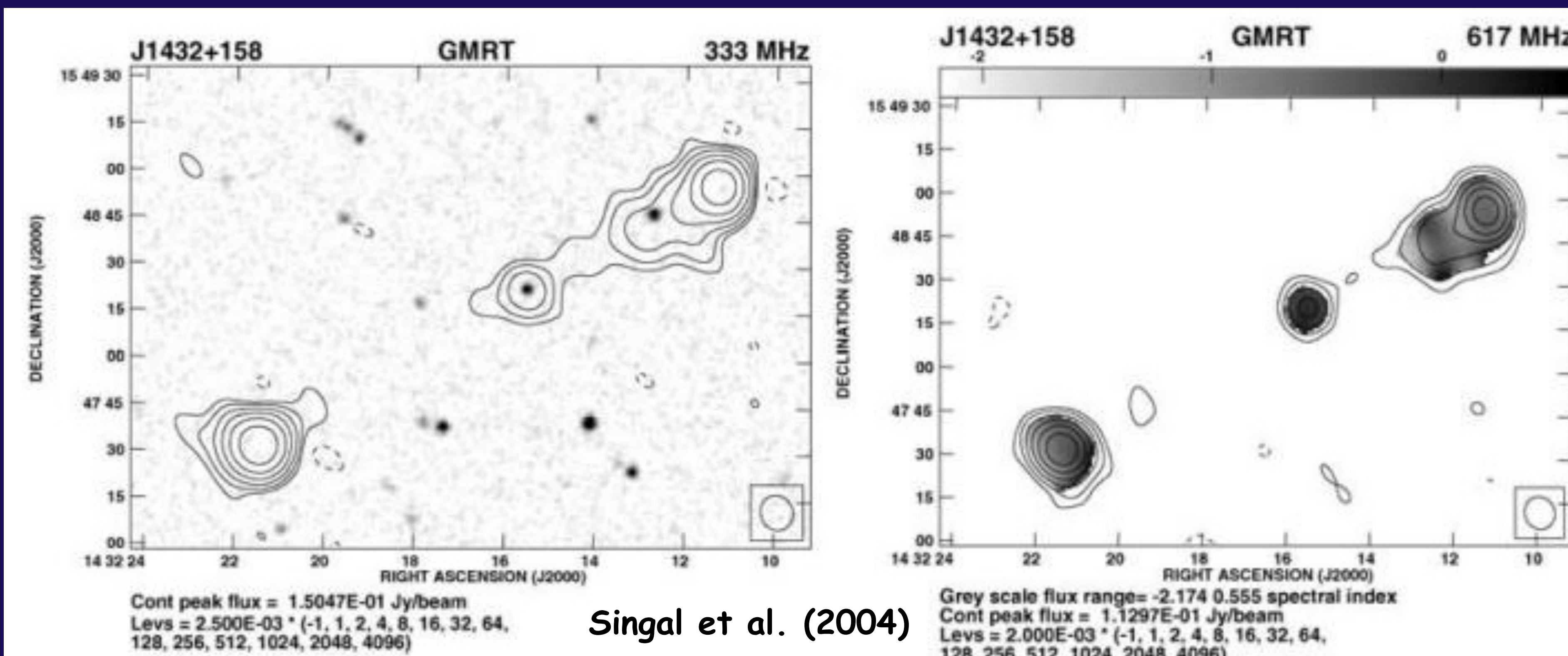
D.J. Saikia, N.G. Kantharia, GK, S. Sirothia, C.H. Ishwara-Chandra, S. Roy, A. Basu, JNC, NK, DVL

Most distant, giant quasar

J1432+158 (z = 1.005)

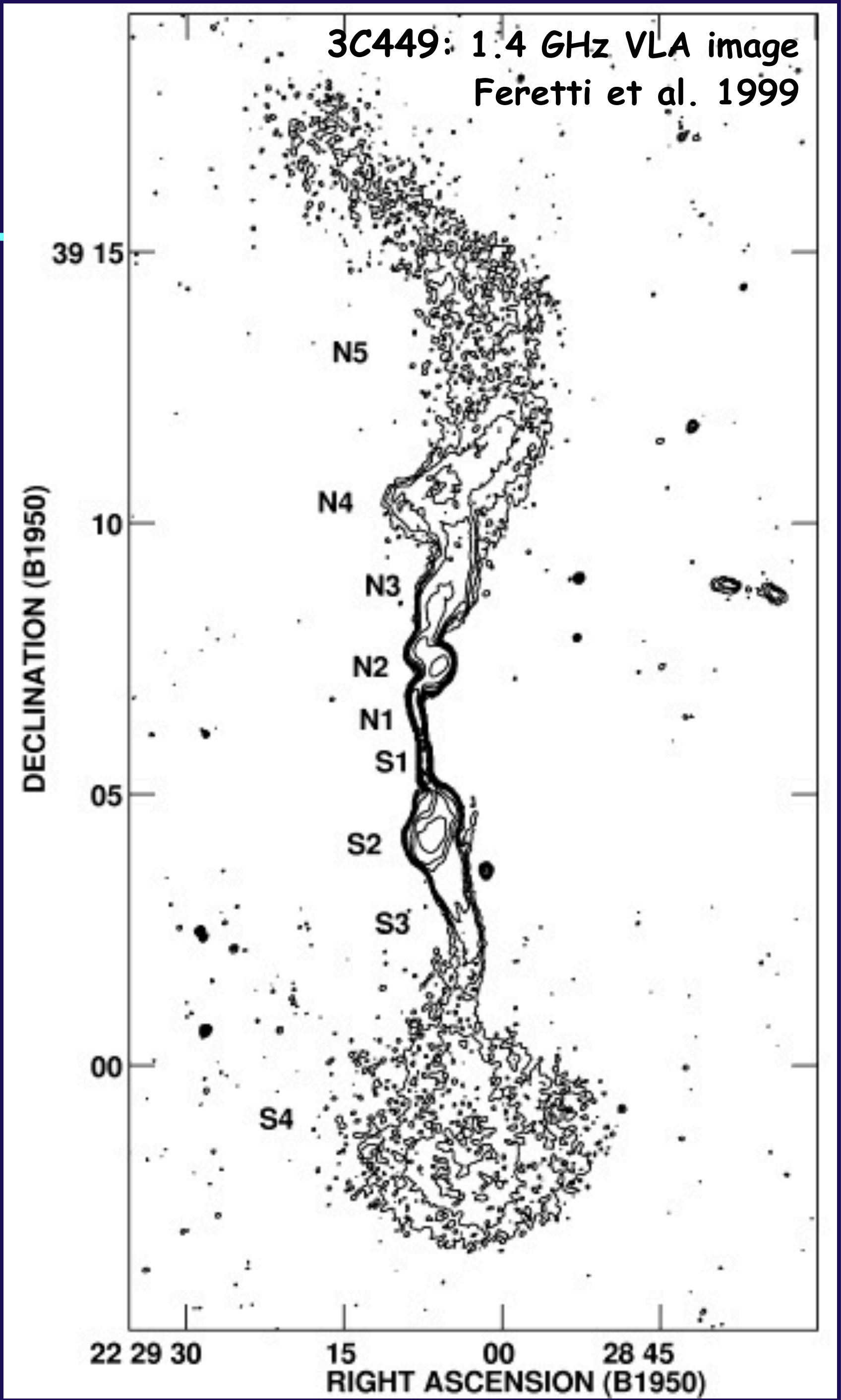
- giant radio quasar
- ~168″ = 1.35 Mpc



Singal et al. (2004)

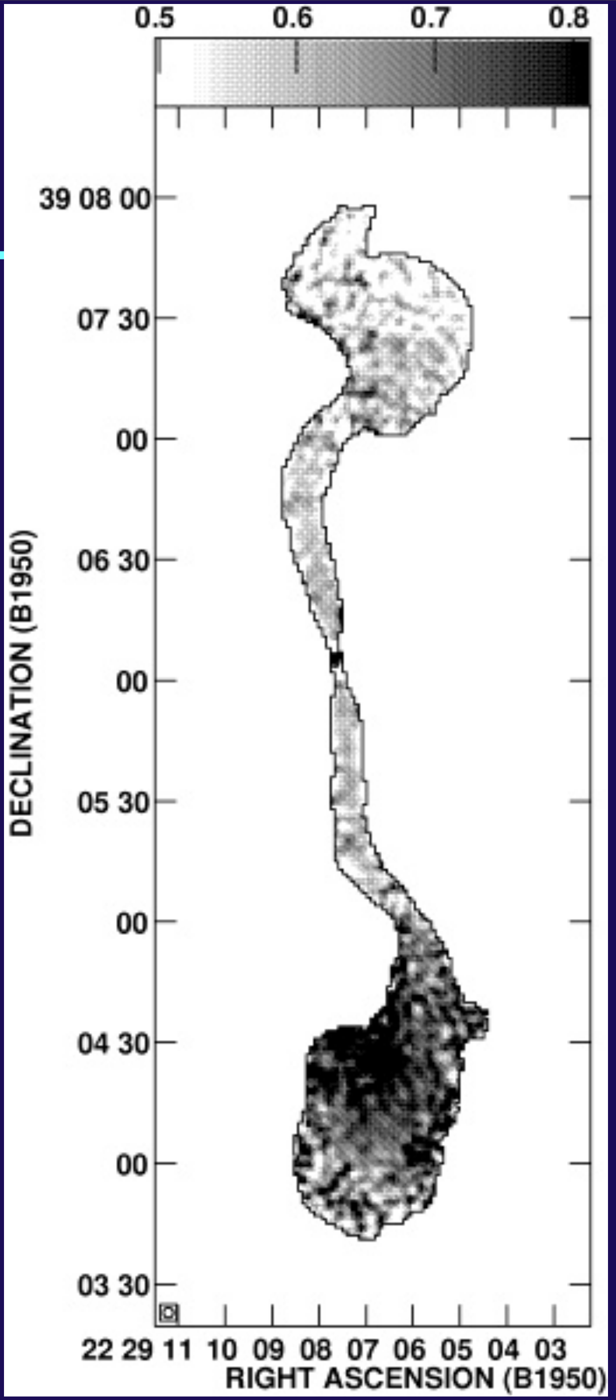
Morphology

- FR I
- radio morphology on several spatial scales
- remarkably straight jet,
  - 50” from nucleus
- mirror symmetry of the jets and lobes
- diffuse lobes and are in relaxed appearance



Spectral index

- Jet shows steepening with distance
- sheath has a steeper spectral-index than jet

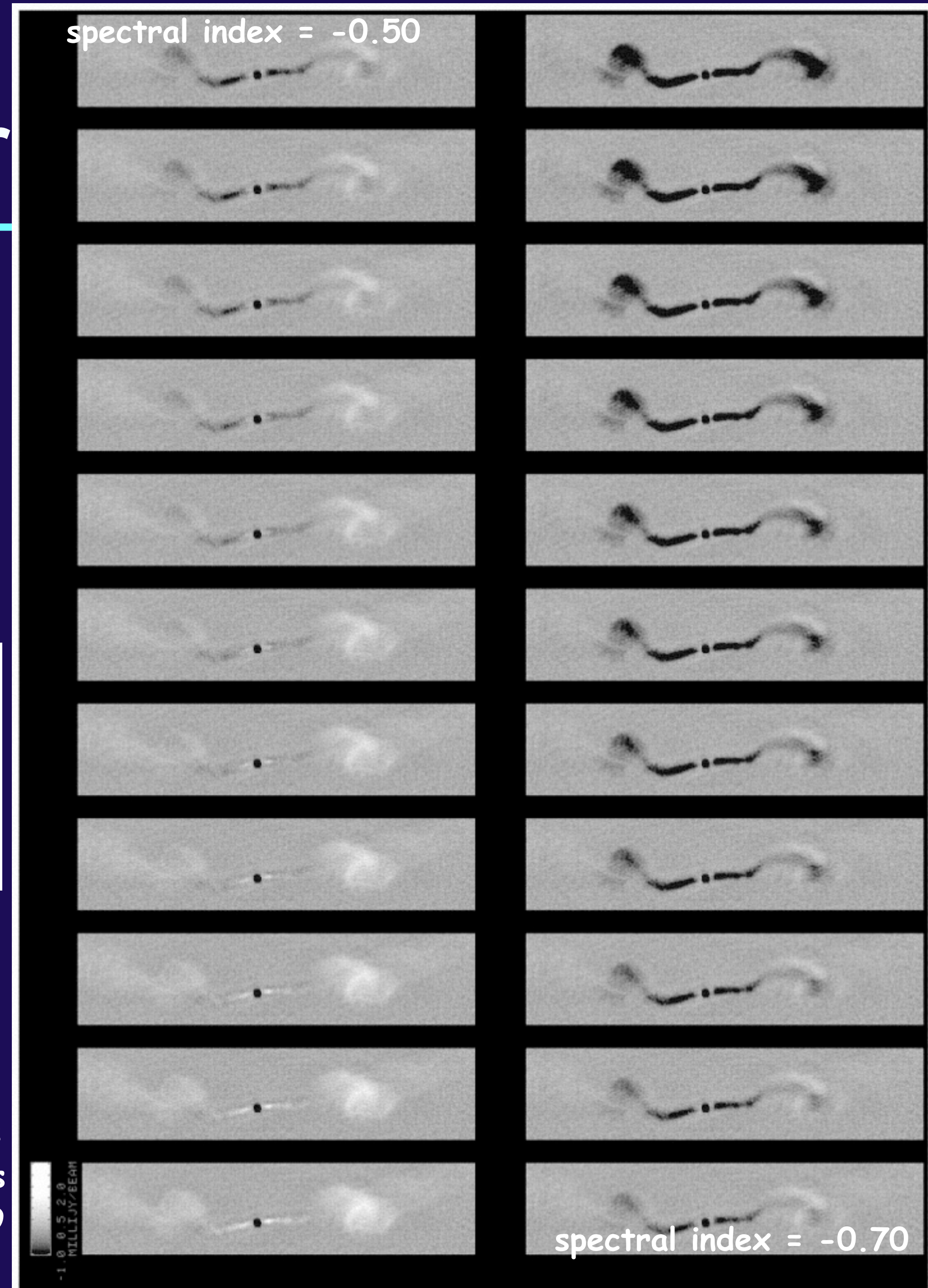


3C449: 5.0 and 8.4 GHz spectral index image
Feretti et al. 1999

Spectral tomogr

- Jet shows steepening with distance
- sheath has a steeper spectral-index than jet

$$I_{\mathrm{tom}}(\alpha_t) \equiv I_{20} - \left(\frac{\nu_{20}}{\nu_6}\right)^{\alpha_t} I_6$$



3C449:
5.0 & 8.4 GHz spectral index tomography images
Katz-Stone et al. 1999

Role of GMRT...

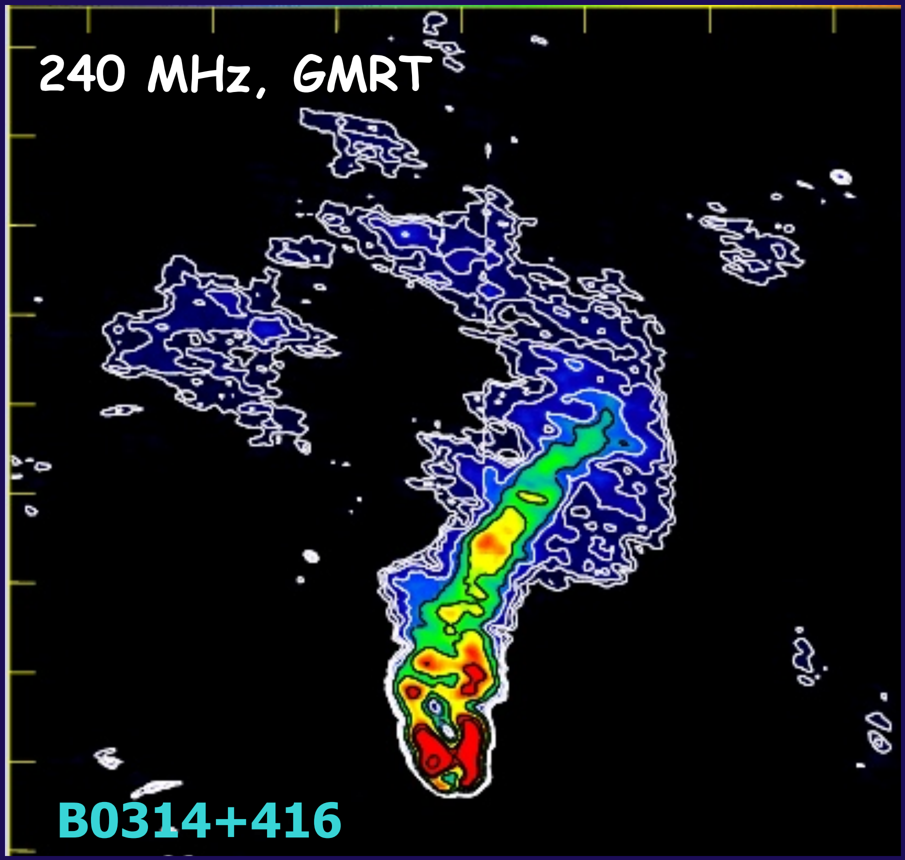
Expectation:

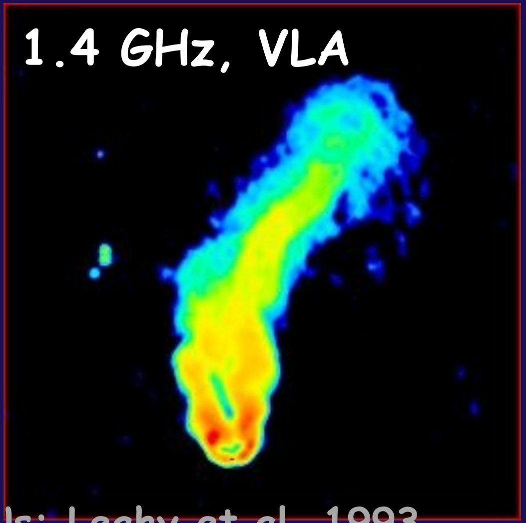
- as the radio emitting plasma flows away from hot-spots in radio galaxies, it ages;
- therefore one expects the low frequency observations to show diffuse emission surrounding radio galaxy.

The prime motivation is to test this!

Radio sources in clusters

The radio sources in cluster environments show presence of steep spectrum diffuse emission at low radio frequencies as against at high radio frequencies.

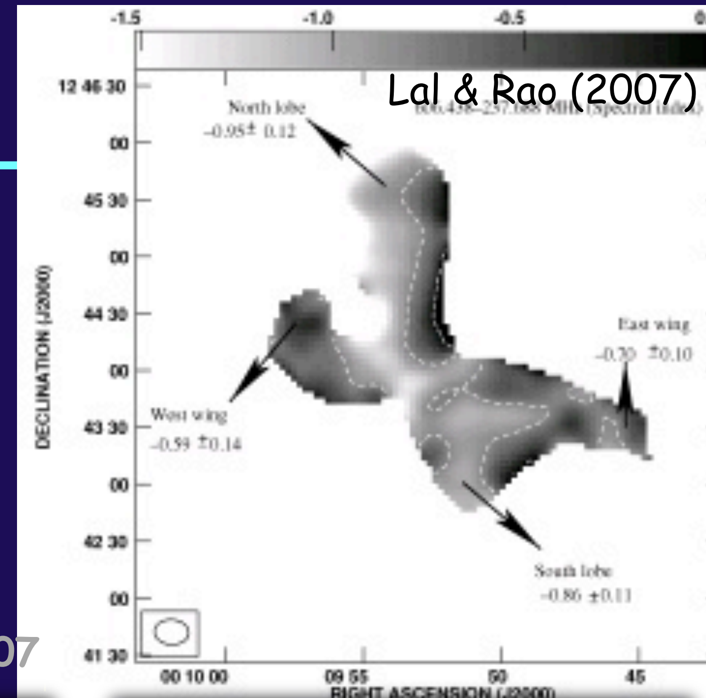




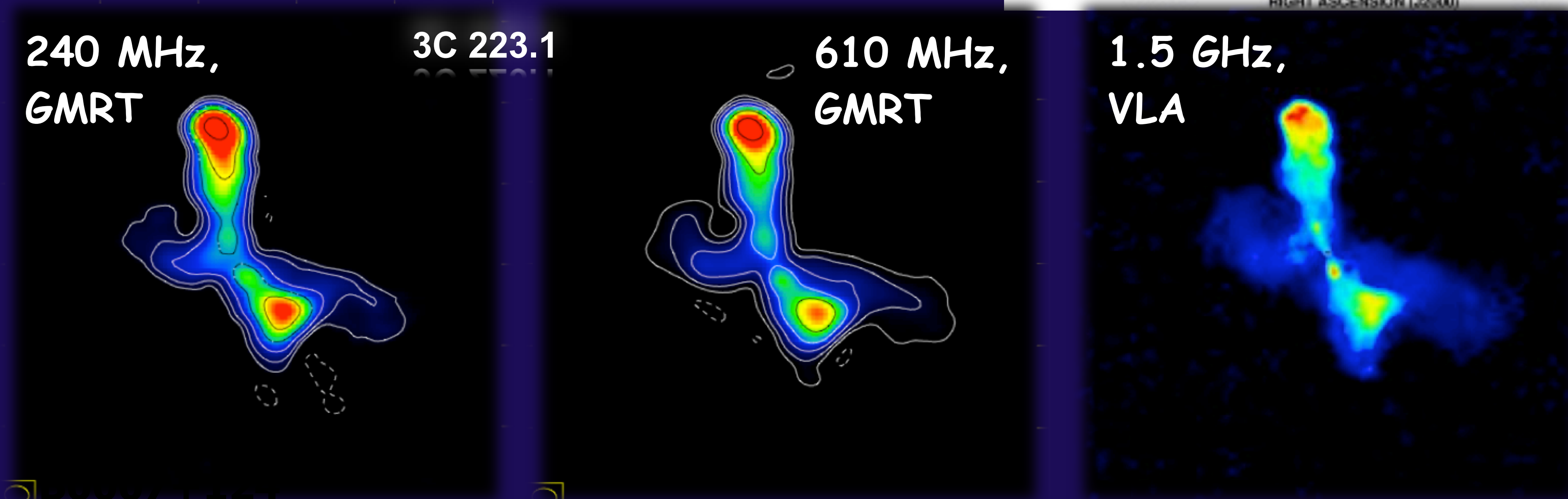
ATLAS of DRAGNs: Leahy et al. 1993

Unusual spectrum?

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



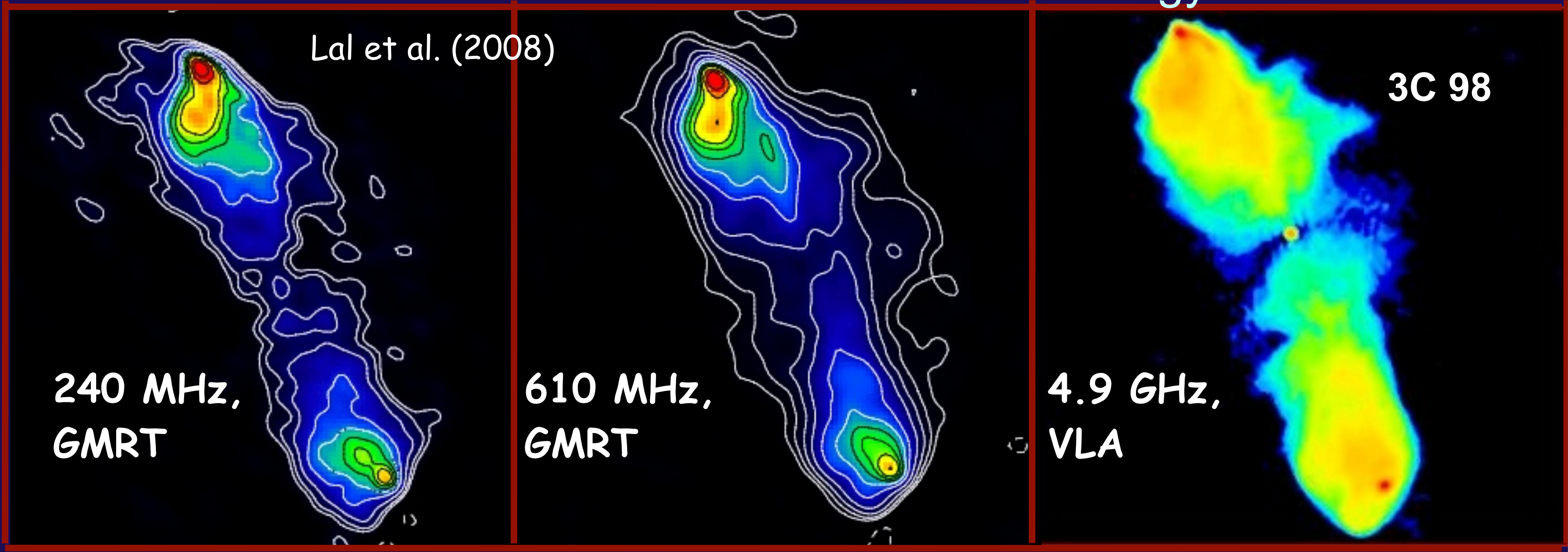
ATLAS of DRAGNs: Leahy et al. 1993 and Lal & Rao 2007



Field radio galaxies

Remarkably similar radio morphologies at a large range of radio frequencies (Blundell 2008; Lal & Rao 2007, 2008).

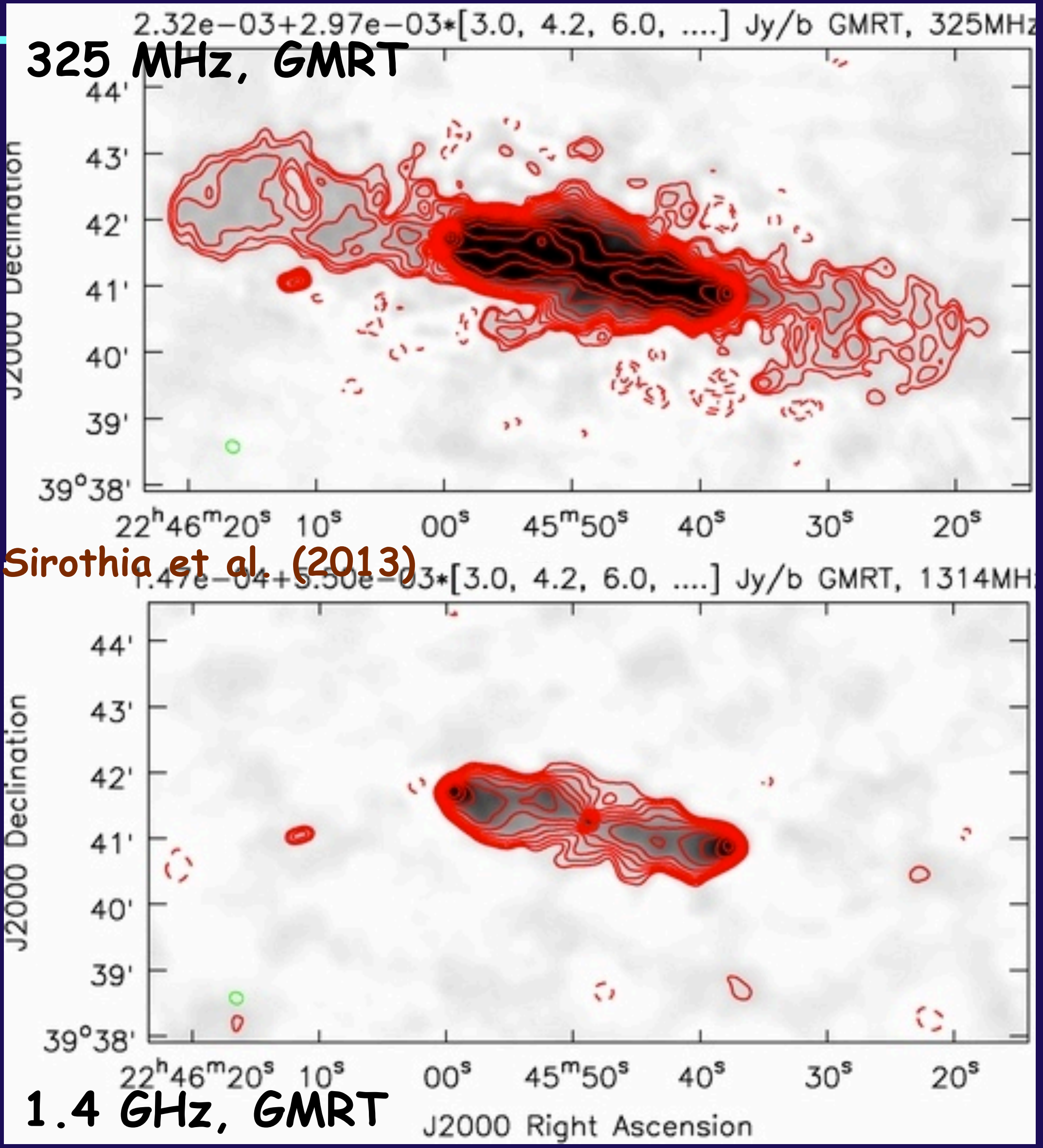
Synchrotron emitting electrons of all energies permeate the lobe in the same way, despite the fact that high energetic electrons have shorter radiative lifetimes than the low energy ones!



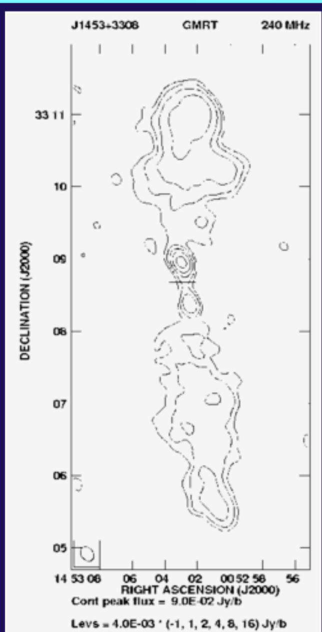
Giant fossil lobe in 3C452

Expectation:

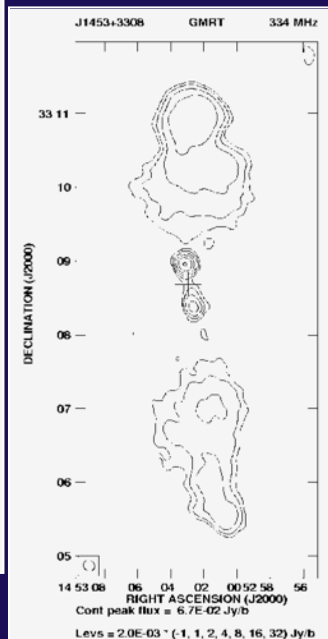
- as the radio emitting plasma flows away from hot-spots in radio galaxies, it ages forming fossil radio lobes
- recurrent activity (at multiple epochs) may be more common than thought so far



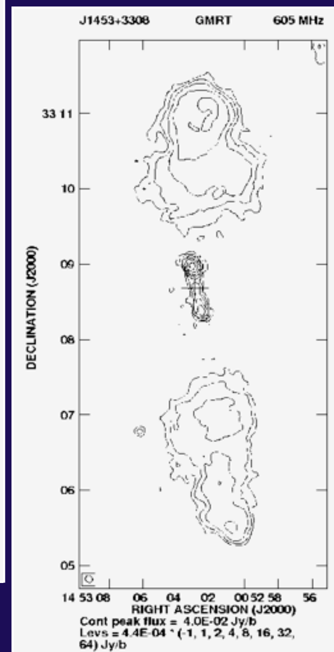
DDRG: J1453+330



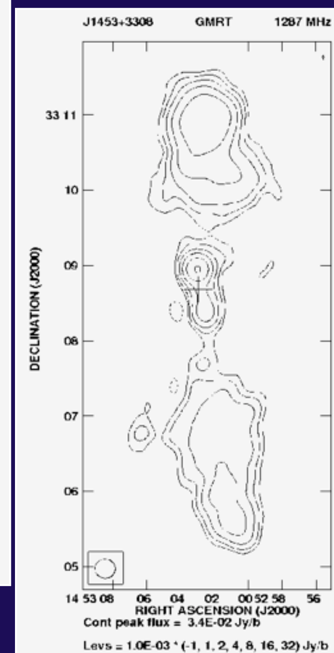
235 MHz, GMRT



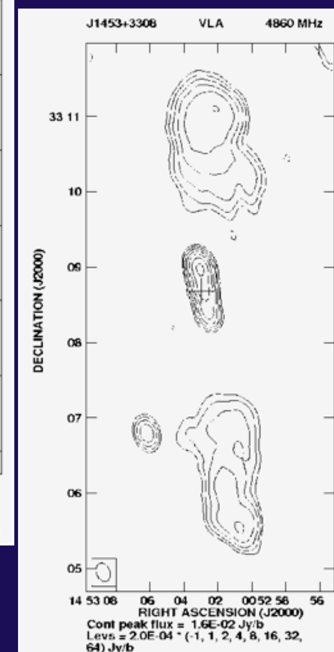
330 MHz, GMRT



610 MHz, GMRT



1420 MHz, GMRT



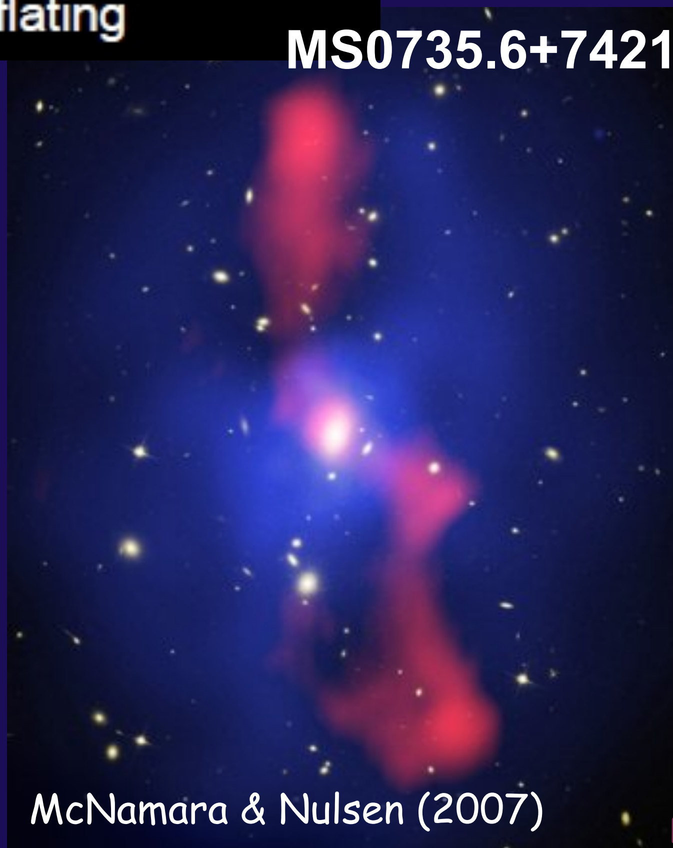
5.0 GHz, VLA

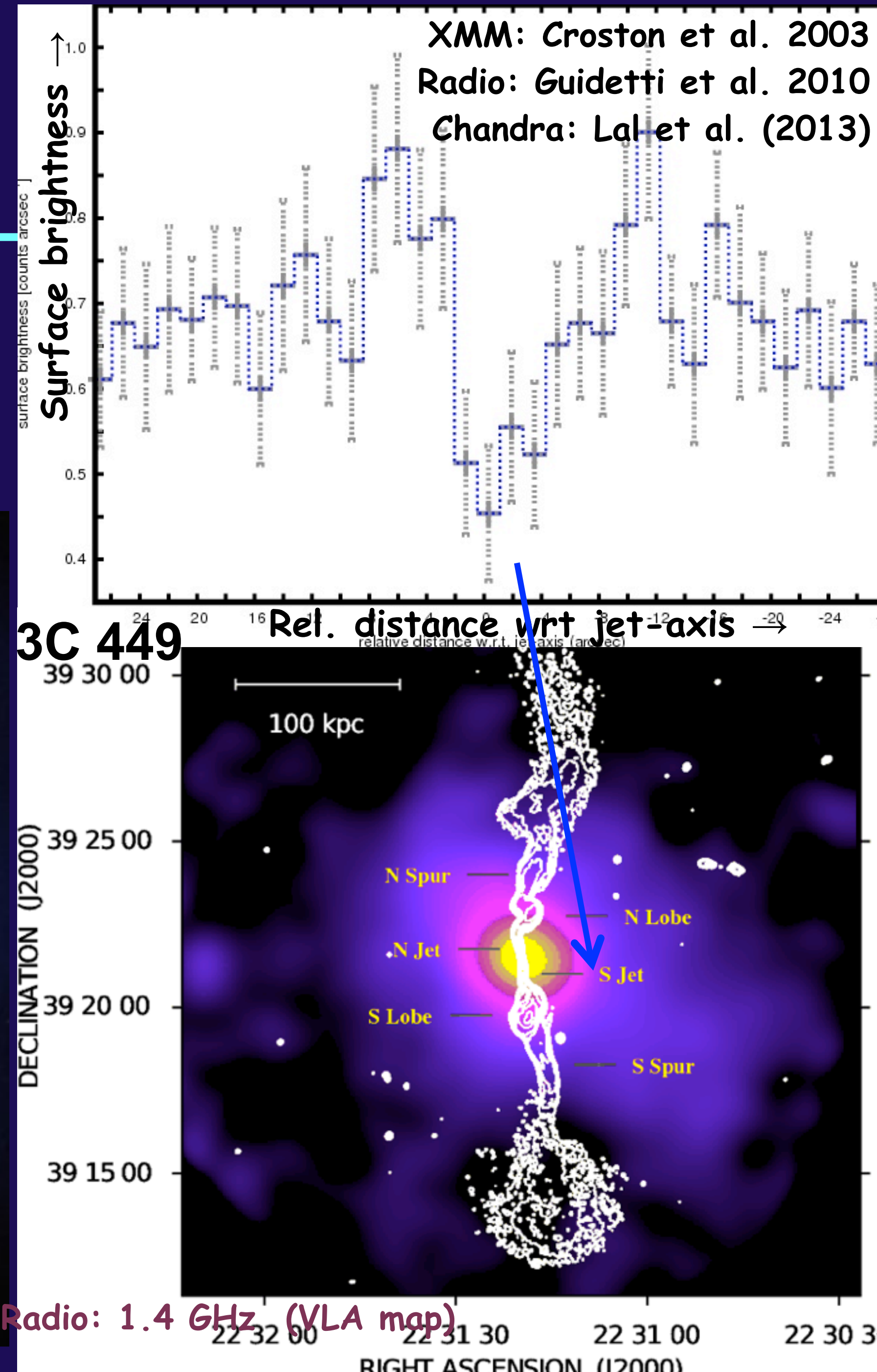
Konar et al. 2006

X-ray + radio

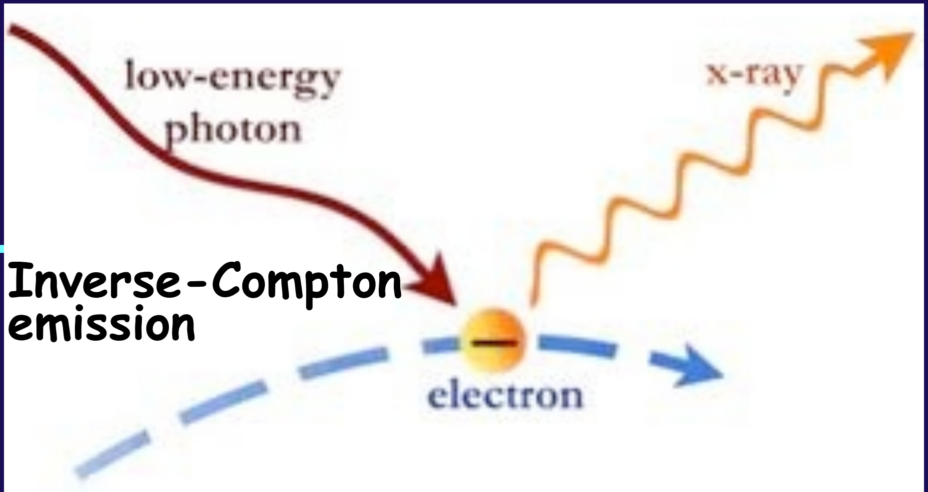
$$H = E + pV = \frac{\gamma}{\gamma - 1} pV$$

thermal energy — work for inflating





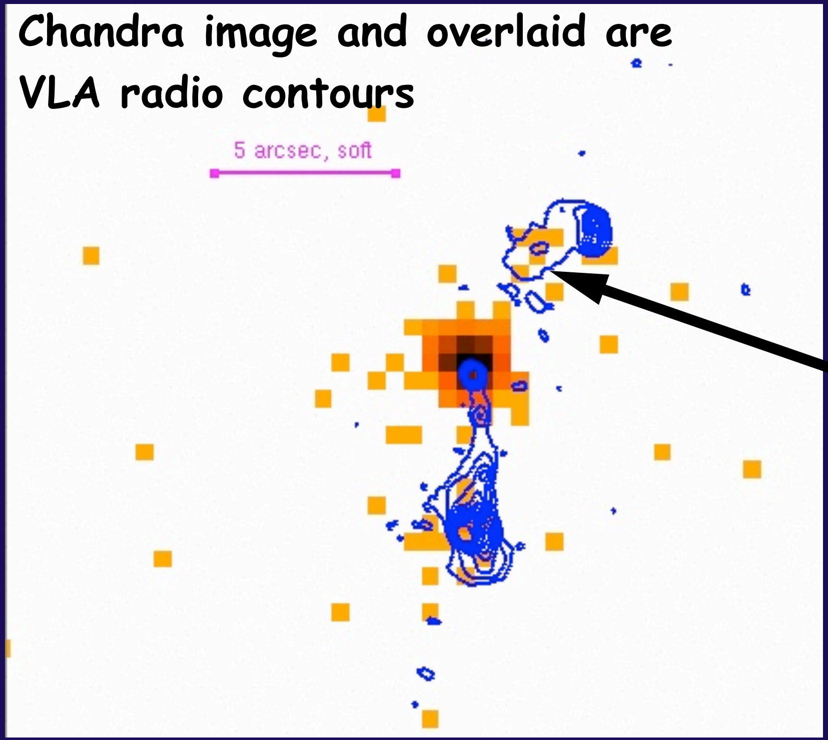
IC-CMB

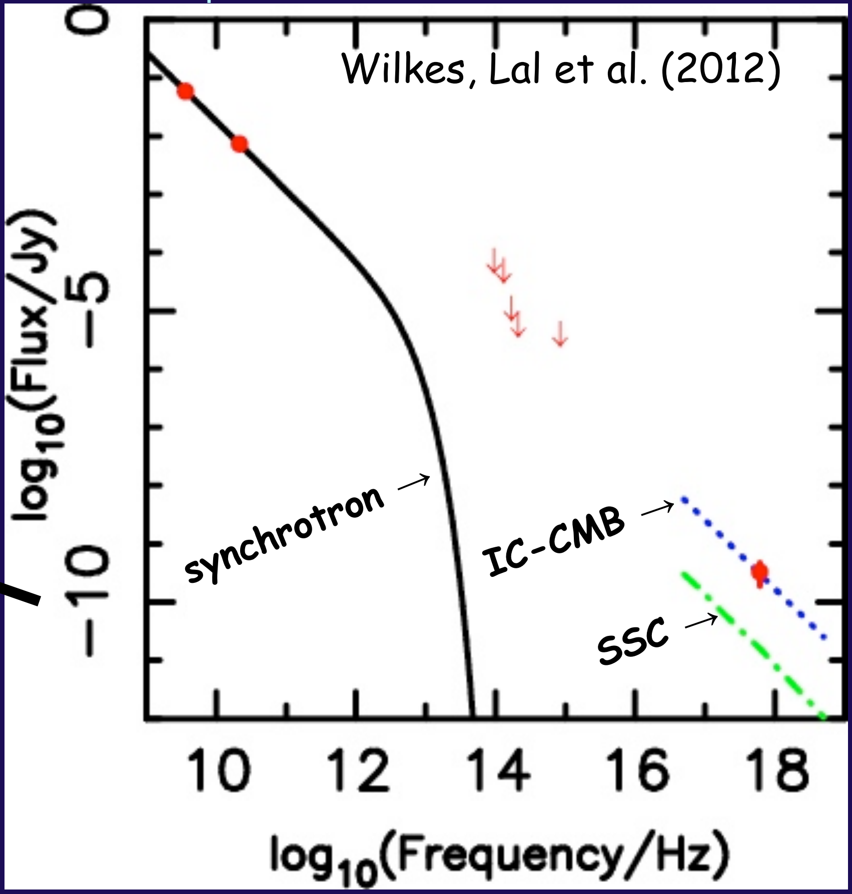


- **IC:**
  - a rel. e^- collides with an existing photon and scatters it to high energies;
    - energy of the photon α γ^2
      - if it is one of the radio photon, then γ of 10^4
      - and if CMB, then γ of 10^3 are required.
  - Energy radiated in scattered photon (= IC) α $n_e \times n_{ph}$
  - Power radiated by collection of e^{-}s depends on n_e, B
- **Equipartition:**
  - energy densities in the rel. e^{-}s and magnetic fields are equal,
  - energy density in synchrotron emitting plasma = sum of these

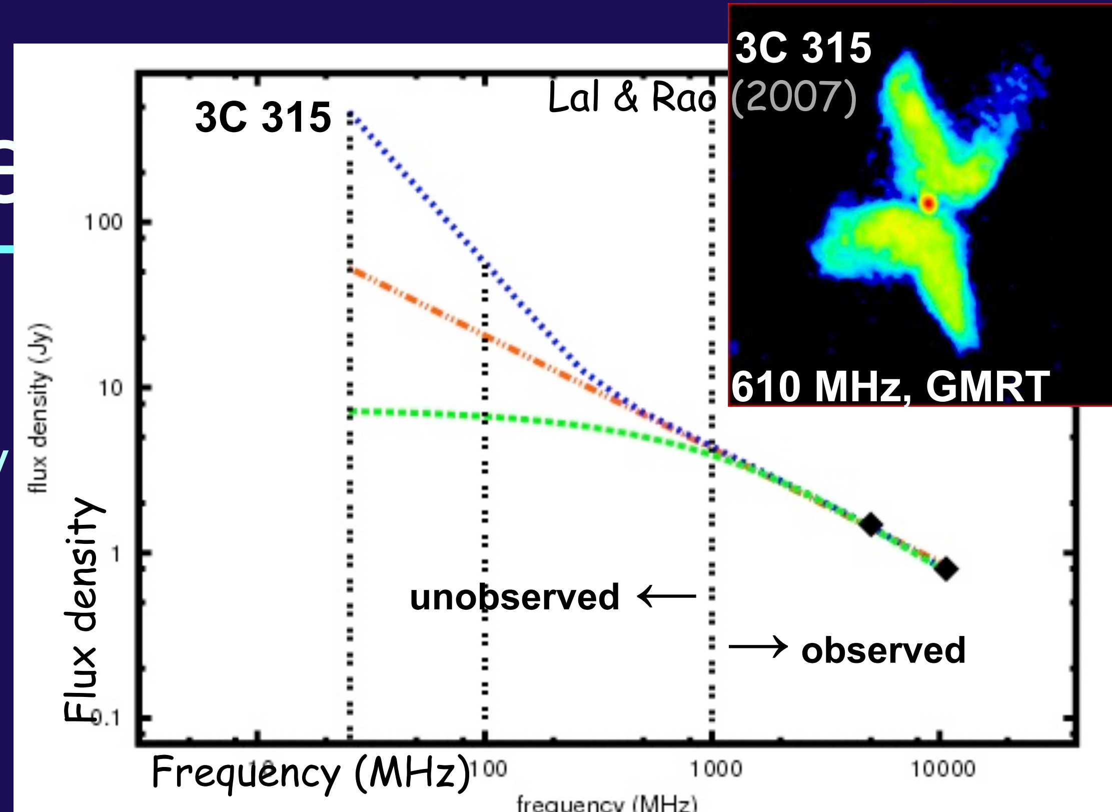
3C 270.1 (z = 1.5324): lobe emission

- X-ray emission from the radio lobes:
  - Spectral indices consistent with predicted inverse-Compton
  - Measured flux (within a factor of 0.11 off B_{eq}) is predicted via inverse-Compton scattering of CMB.
  - Magnetic field strengths ~3.2 nT.





Role of low-fre

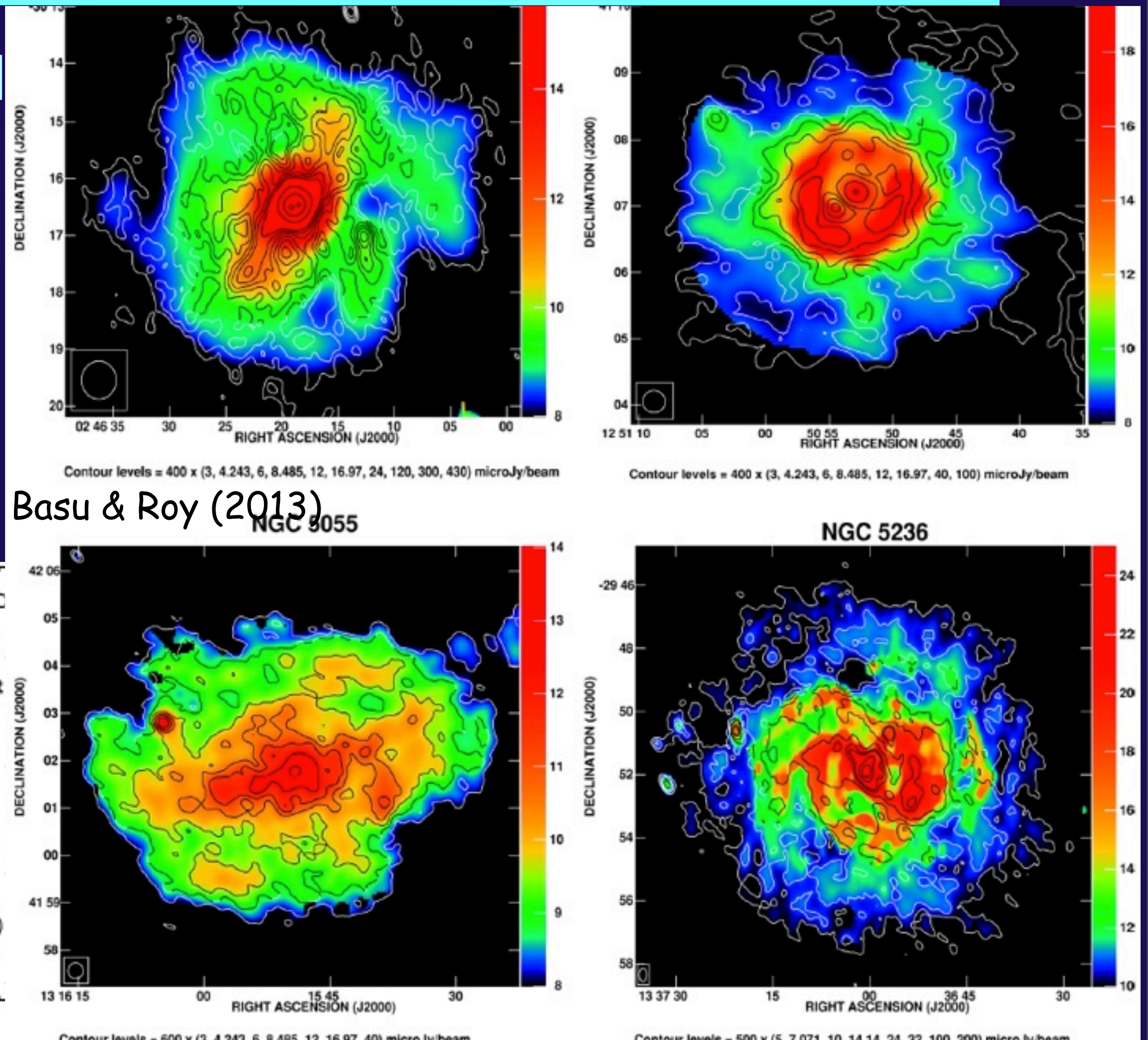


- IC:
  - low frequency sensitivity and resolution will help in accurately characterizing the radio spectrum over a wide range of frequencies;
  - with current instruments one has to extrapolate down to these energies from the observable radio region).
  - radio-source properties depend strongly on assumed spectrum below ~300 MHz, i.e., α_{low} and γ_{low} (Harris 2004).
  - Assumptions

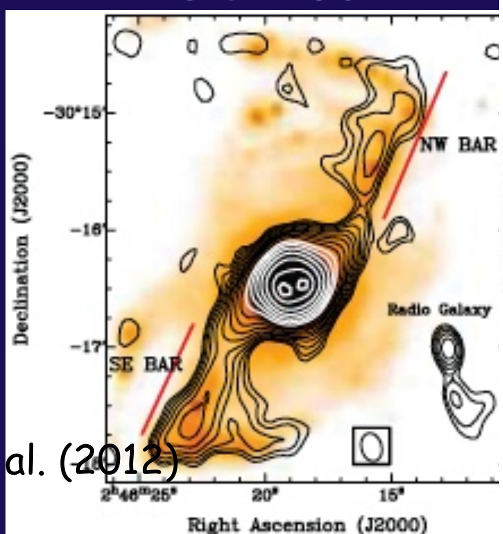
    (have assumed simplistic model for the radio spectrum)
    - e.g., cut-off frequency, adiabatic expansion, etc.

GMRT: **B**-field in normal galaxies

- Equipartition **B**-field in normal galaxies
- field is strongest in centres (~25 μG), becomes weaker in outer-parts (10 μG)
- Bar in NGC 1097



Basu & Roy (2013)



Basu et al. (2012)

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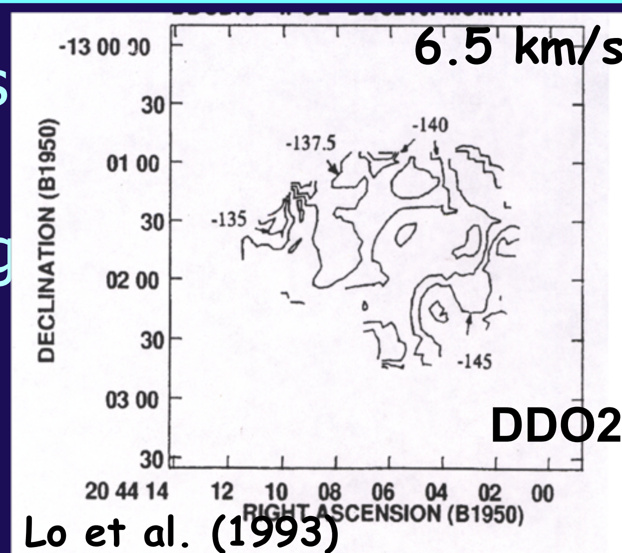
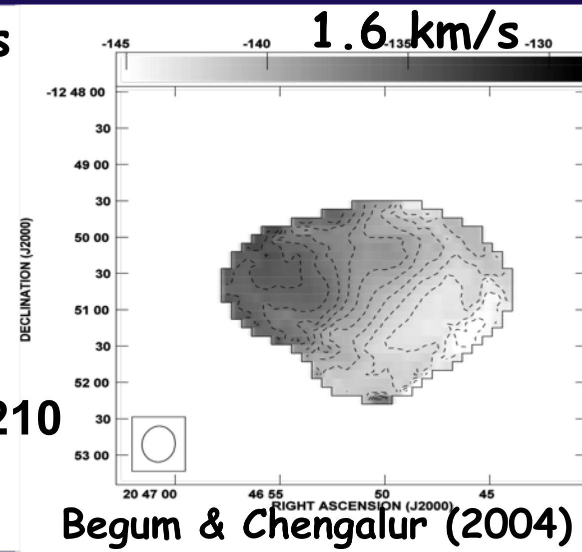
J.N. Chengalur, N. Kanekar, N.G. Kantharia, S. Sirothia, C.H. Ishwara-Chandra, V.R. Marthi T.R. Choudhury, A. Banerjee, Datta-Kanan, P. Dutta

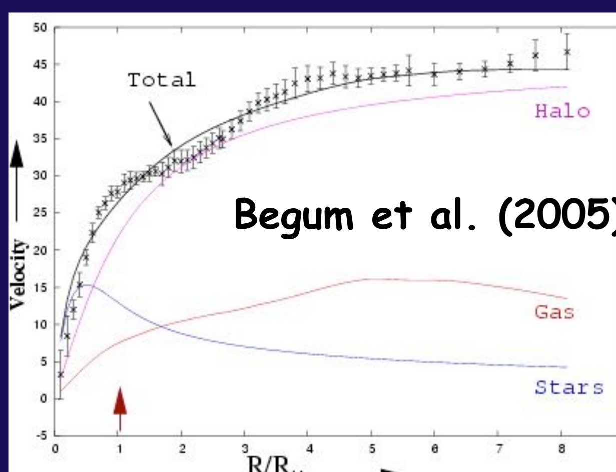
GMRT: Dwarf galaxies

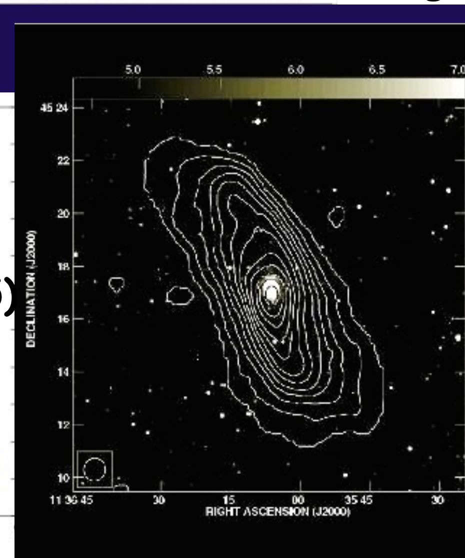
HI from Dwarf galaxies

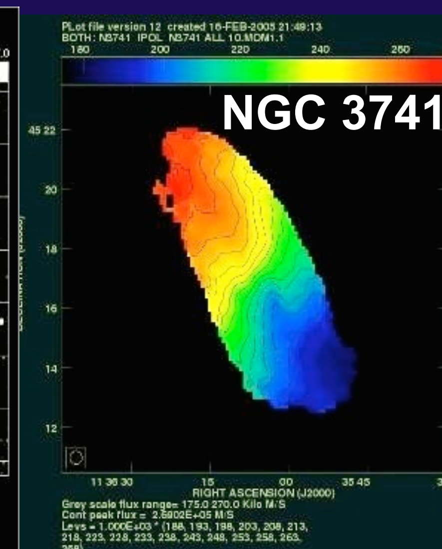
- High-vel. resolution crucial for measuring HI gradients
- DDO210
- NGC 3741
  - most extended HI disk







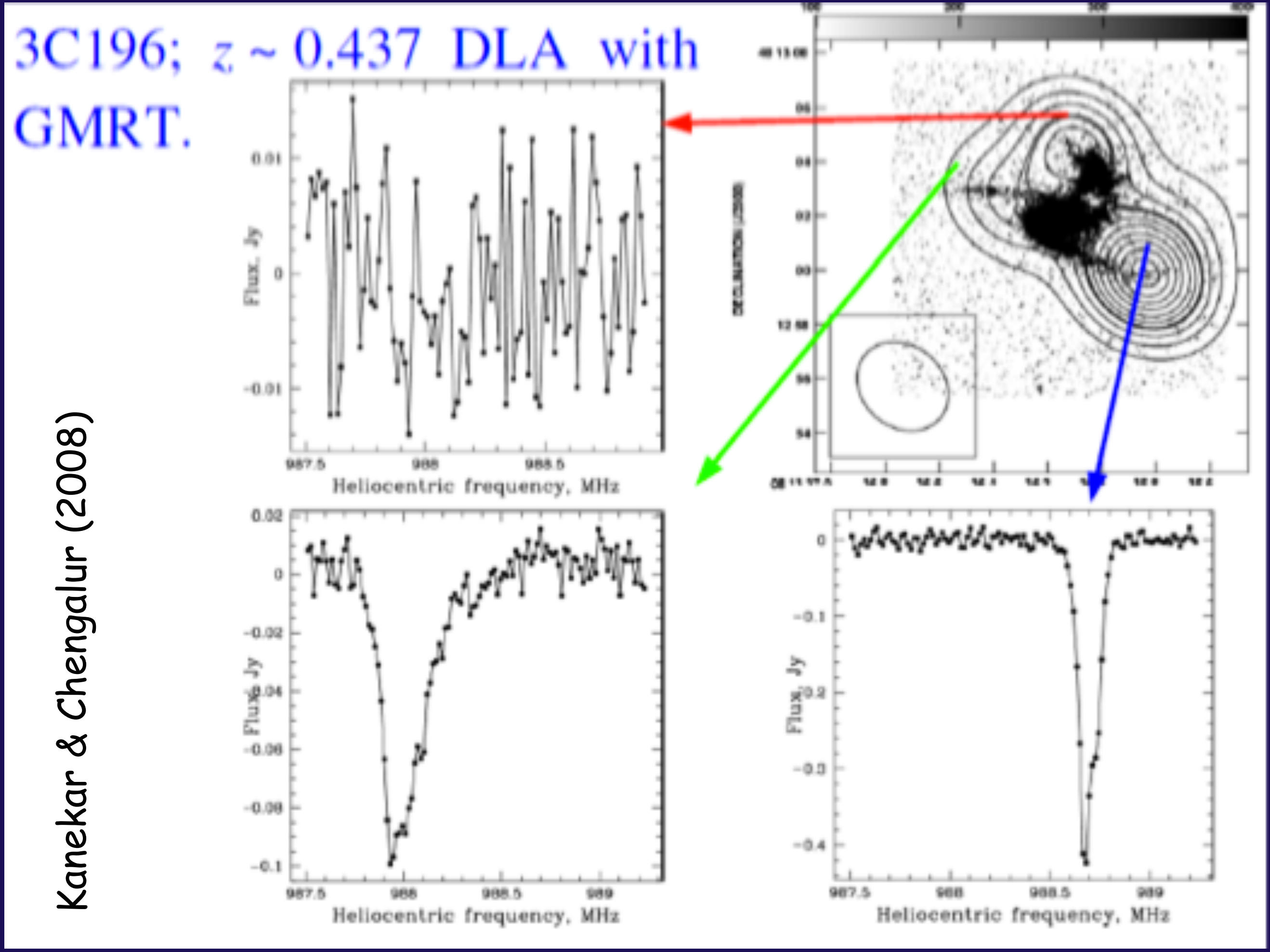




DLAs with GMRT

Damped Lyman alpha absorption system: 3C196

- $z = 0.437$

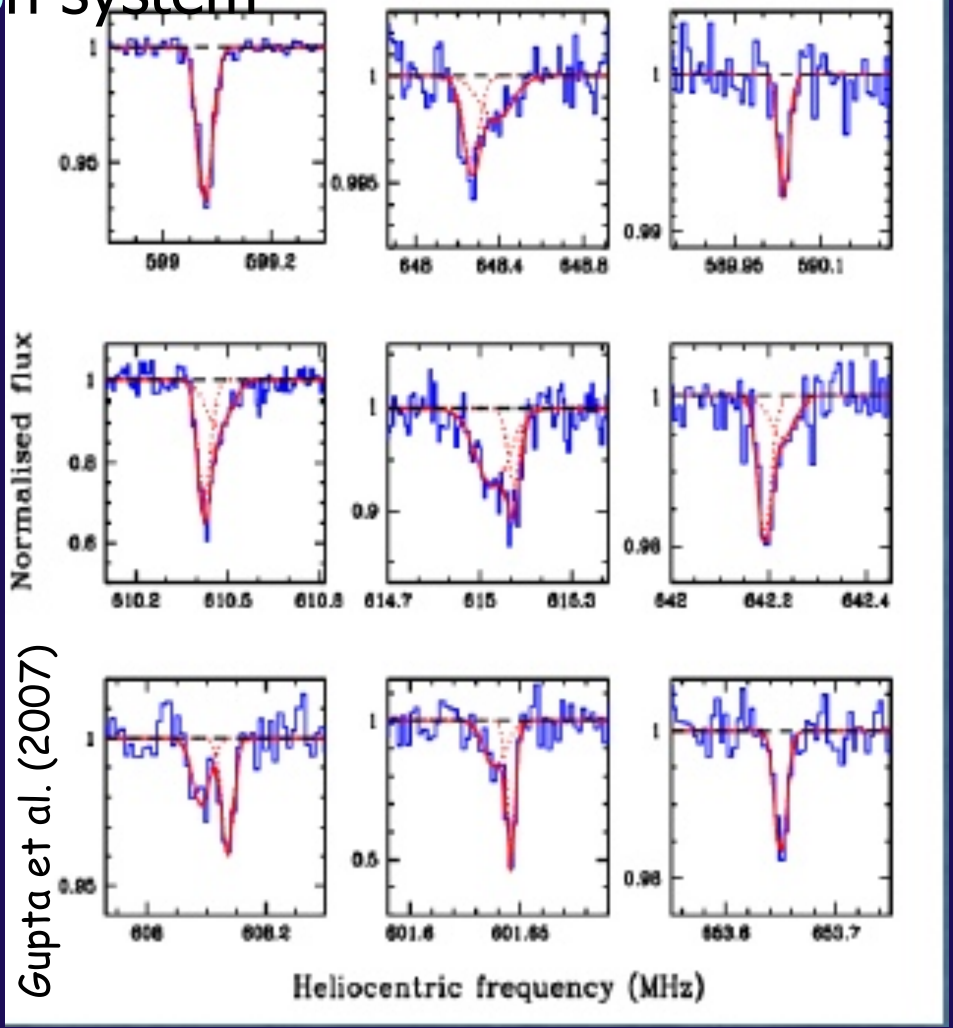


Kanekar & Chengalur (2008)

DLAs with GMRT (& more!)

Damped Lyman alpha absorption system

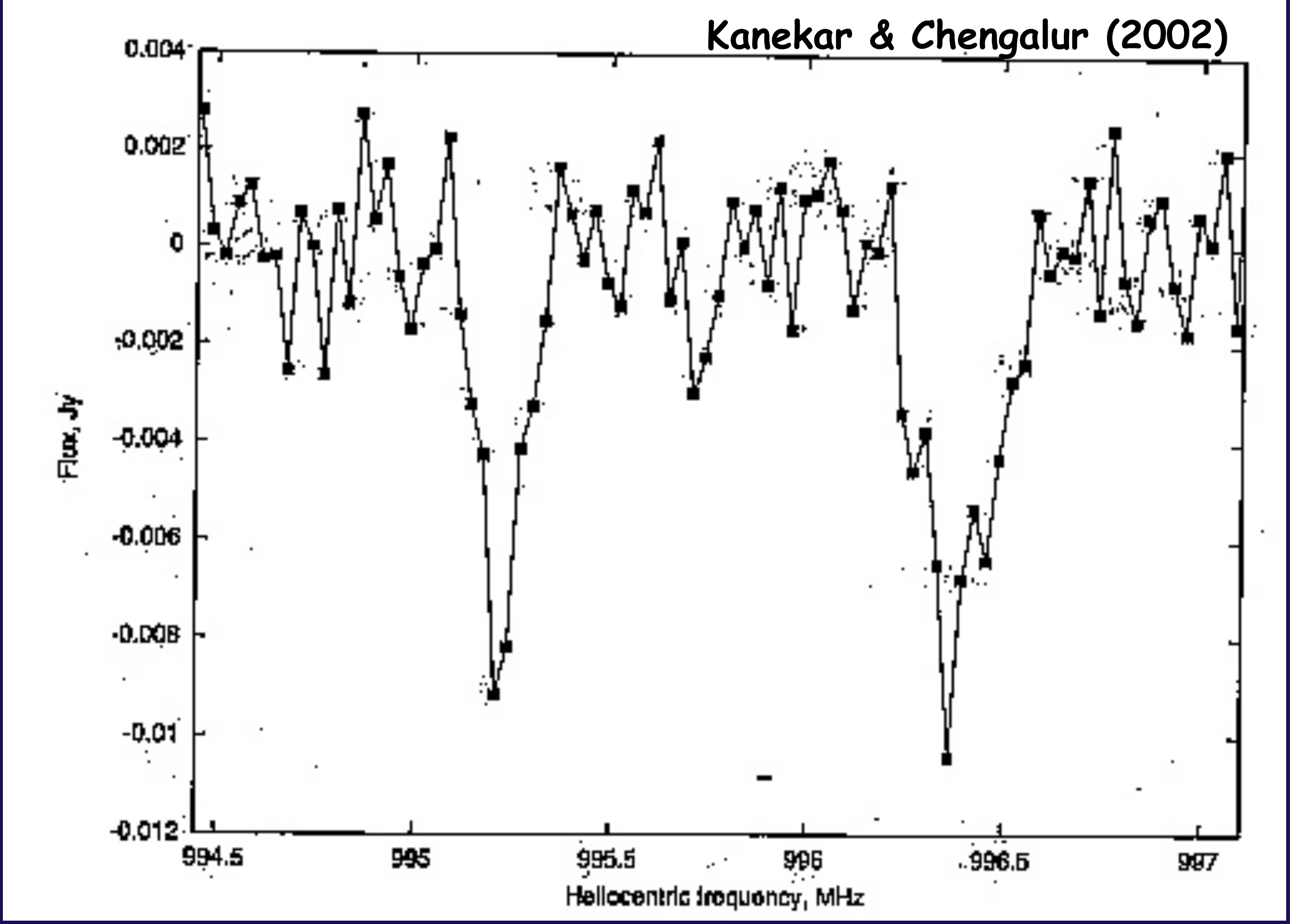
- several new DLAs have been discovered using GMRT
- 9 new detections in 400 hr survey with the GMRT at 610 MHz



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

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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

A Search for 55 MHz OH line

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

Mon. Not. R. Astron. Soc. **407,** 258–262 (2010) doi:10.1111/j.1365-2966.2010.16889.x

A search for the 55-MHz OH line

Visweshwar Ram Marthi★ and Jayaram N. Chengalur★

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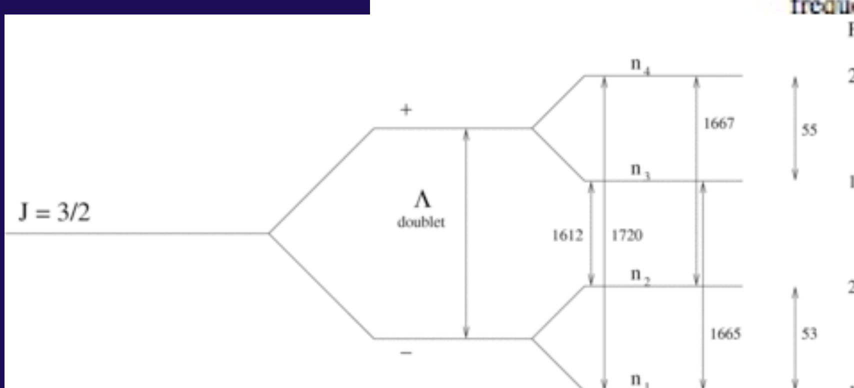
Accepted 2010 April 21. Received 2010 April 21; in original form 2010 March 17

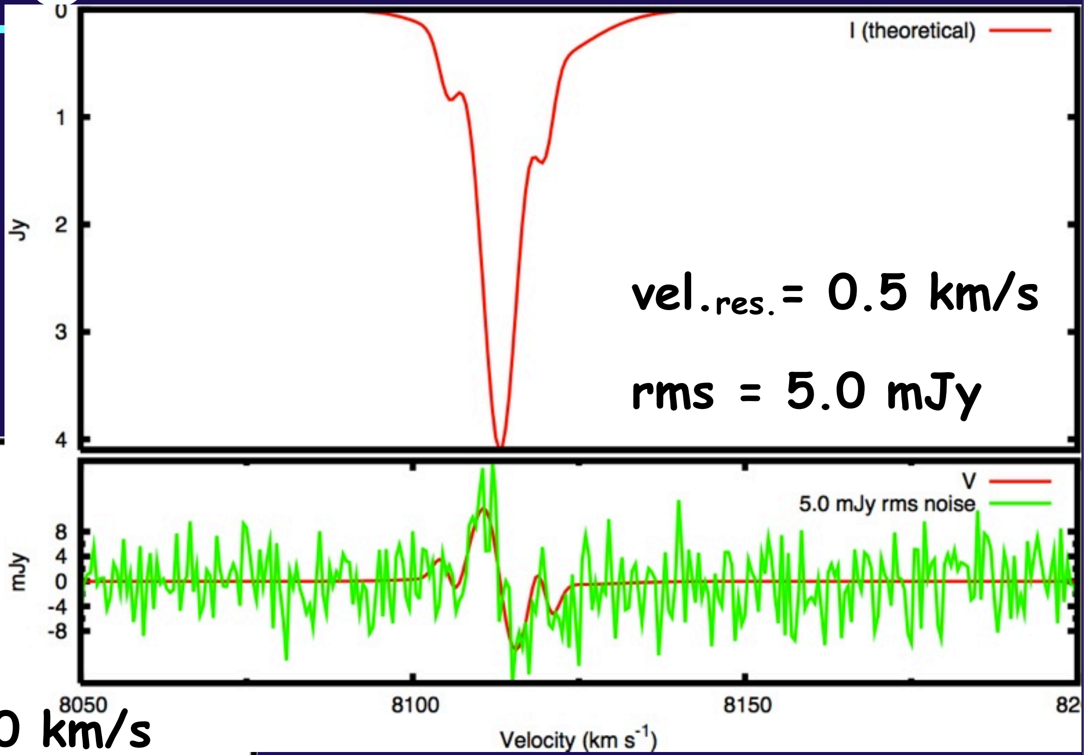
ABSTRACT

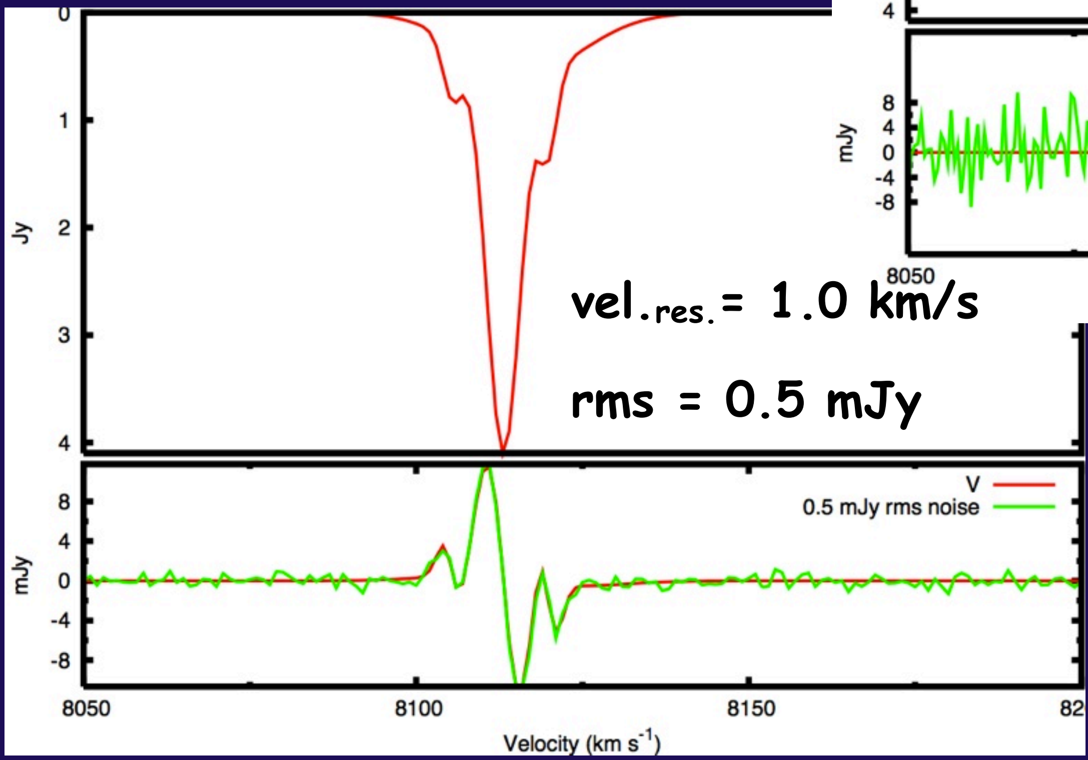
The OH molecule, found abundantly in the Milky Way, has four transitions at the ground-state rotational level ($J = 3/2$) at cm wavelengths. These are E1 transitions between the F^+ and F^- hyperfine levels of the Λ doublet of the $^2\Pi_{\frac{3}{2}}$, $J = 3/2$ state. There are also forbidden M1 transitions between the hyperfine levels within each of the doublet states, occurring at frequencies of 53.171 and 55.128 MHz. These are extremely weak and hence difficult to
. However, there is a possibility that the level populations giving rise to these lines are
·d under special conditions, in which case it may be possible to detect them through their
emission. We describe the observational diagnostics for determining when the hyperfine
are inverted and identify a region around W44 where these conditions are satisfied. A
·elocity-resolution search for these hyperfine OH lines using the low-frequency feeds on
ntennas of the Giant Metrewave Radio Telescope (GMRT) and the new GMRT Software
nd was performed on a target surrounding W44. We place a 3σ upper limit of ~17.3 Jy
m s^{-1} velocity resolution) for the 55-MHz line from this region. This corresponds to an
limit of 3×10^5 for the amplification of the Galactic synchrotron emission providing the
round.



Zeeman splitting of HI

- Perseus A / NGC 1275
  - Stokes I (red)
  - Stokes V (green)
  - t_{int} = ?





Credits: Roy & Chengalur

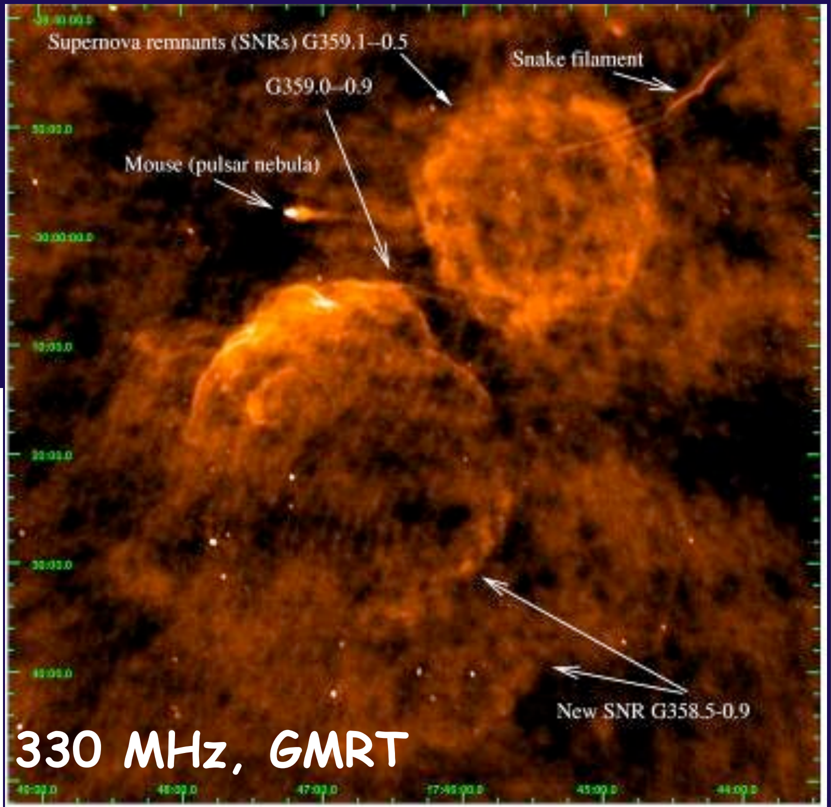
GMRT: Science objectives

- Solar system objects
- 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

S. Roy, J.N. Chengalur, N. Kanekar

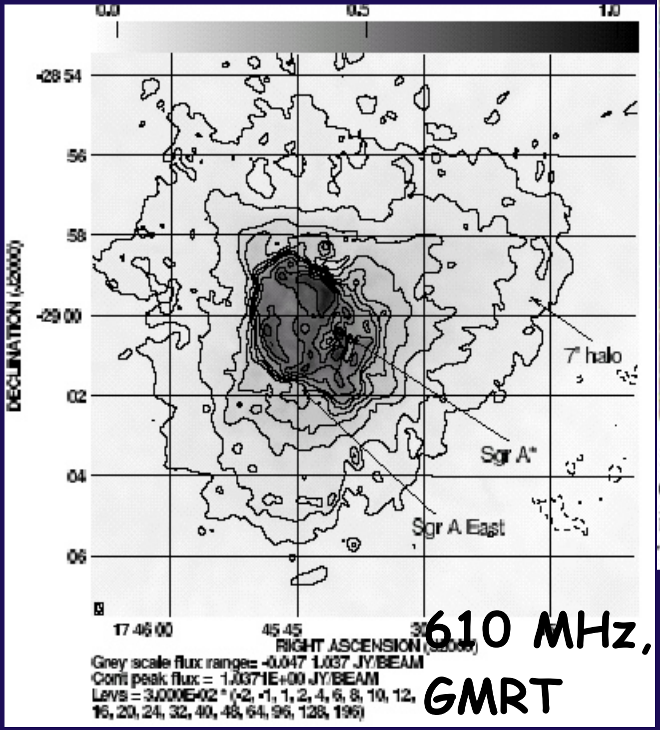
GC region: Sgr A*

- First detection of Sgr A* (BH candidate) at 610 MHz
  - it lies in front of Sgr A west HII region



330 MHz image of the field G358.8–01 located about 1 degree south of the Galactic Centre. The resolution is ~14" and the rms noise ~1 mJy/beam. This is the highest sensitivity image of the region and is made from GMRT data. The map is used to confirm a faint barrel shaped SNR shown near the bottom.

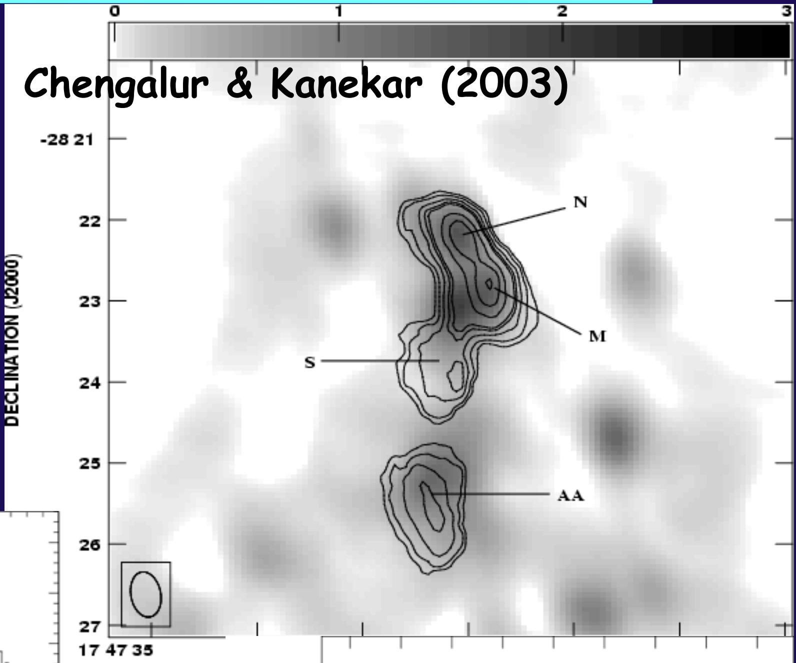
Roy & Bhatnagar (2007)

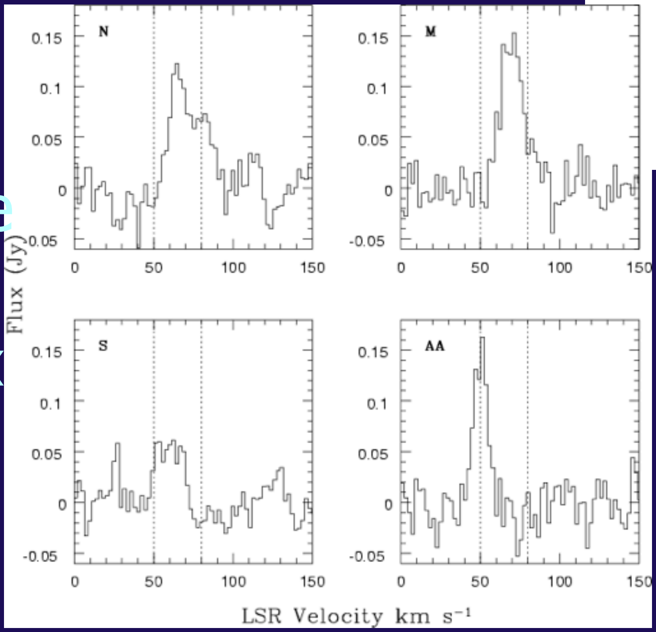


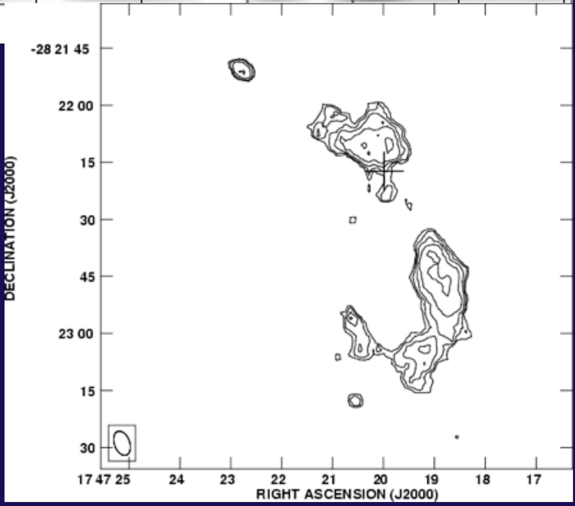
Roy & Rao (2004)

GC region: Acetaldehyde

- Complex organic molecules (Acetone, Methyl-formate, Acetic-acid) are concentrated in very small core, whereas Acetaldehyde is spread over larger region!
- rotational transition of CH_3CHO in the molecular cloud complex Sgr B2







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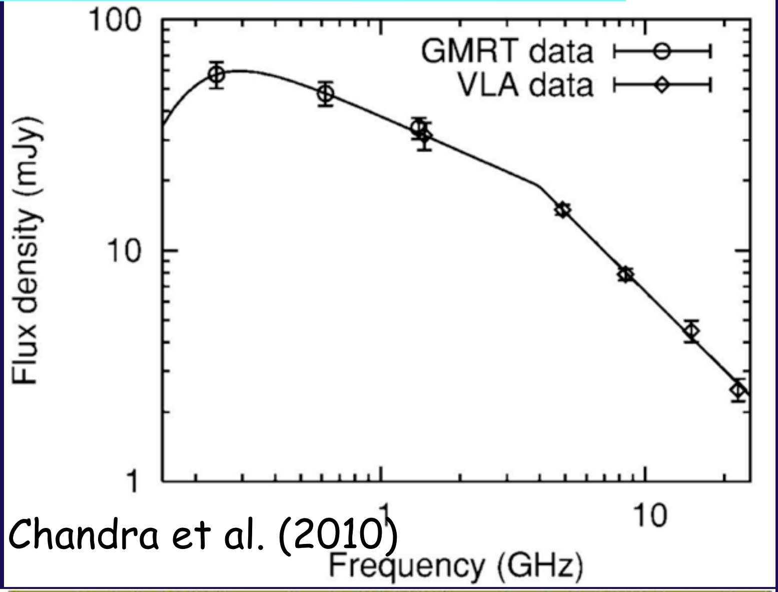
- All-sky survey

P. Chandra, C.H. Ishwara-Chandra

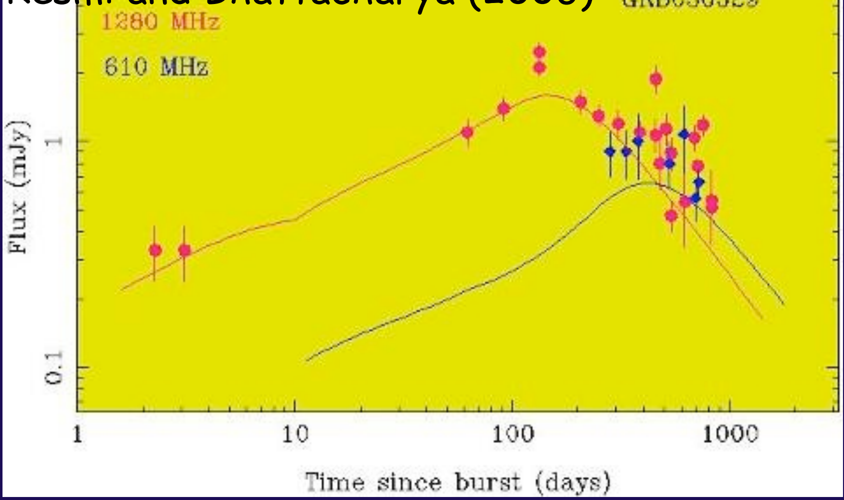
GMRT: Transient sources

- 1993J: GMRT + VLA observations
  - establish a break in the spectrum => direct estimation of **B**-field
- GRB030329: GMRT data at 1280 and 610 MHz
  - "refreshed-jet" model of after-glow
  - jet becomes sub-relativistic ~2 months after the burst
  - one of the first source with longest ever follow-up and using lowest radio frequency!



Chandra et al. (2010)

Resmi and Bhattacharya (2006)



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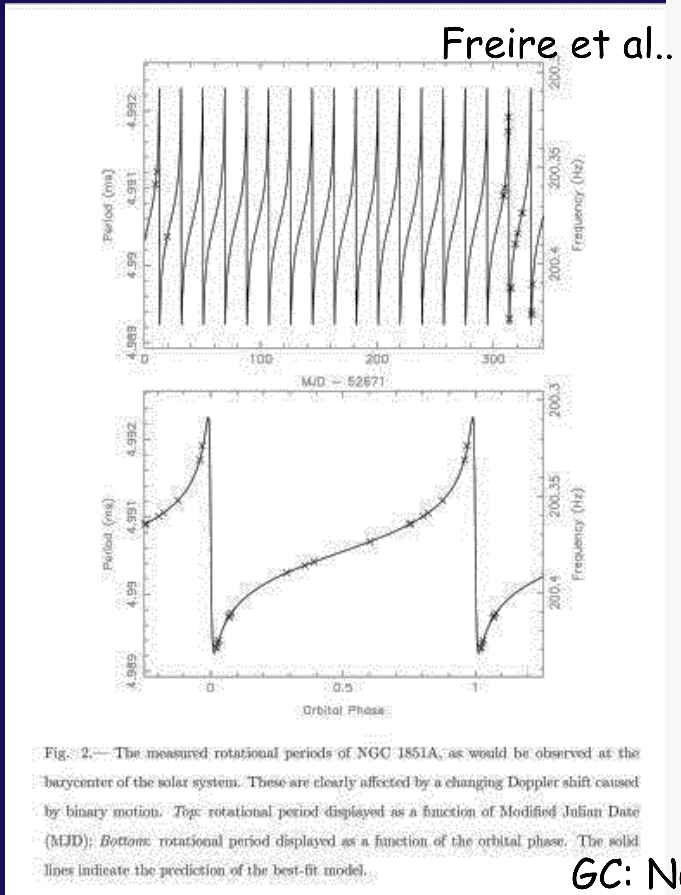
Y. Gupta, B.C. Joshi, D. Mitra, S. Konar, B. Bhattacharyya, C.H. Ishwara-Chandra, J. Roy

GMRT: results from Pulsar studies

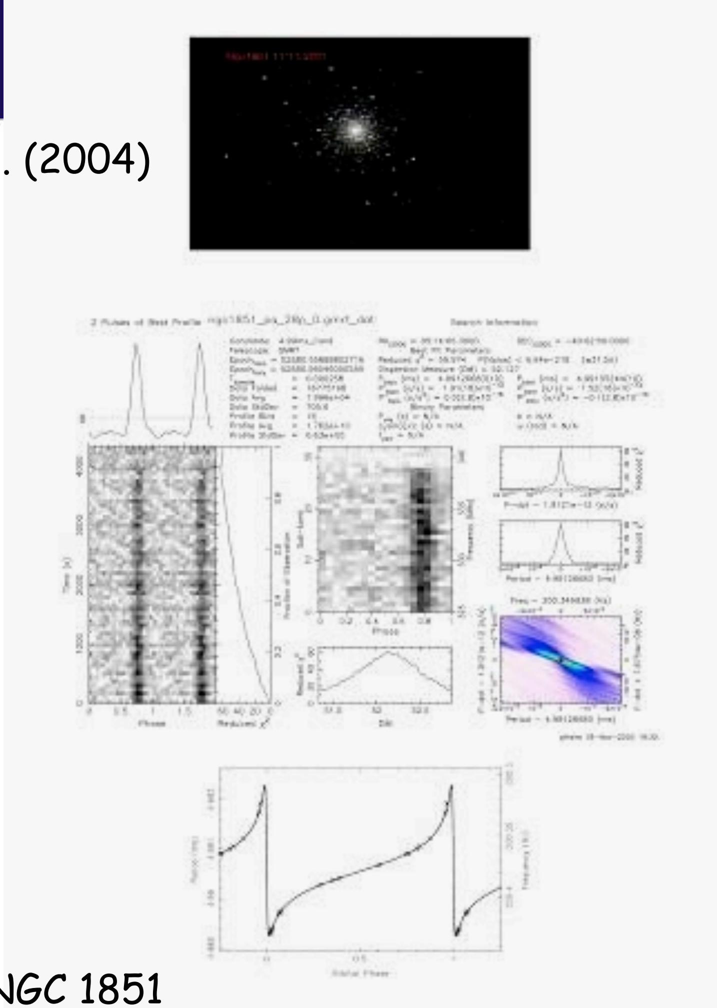
- Pulsar discoveries
  - NGC1851A (Freire et al. 2004),
  - J1833-1034 in G21.5-0.9 (Gupta et al. 2005), etc.
- Pulsar timings
  - J1833-1034 (Roy et al. 2011)
- Pulsars polarization
  - Mitra et al. (2007, 2009), Johnston et al. (2008)
- Simultaneous multi-frequency observations
  - Kramer et al. (2003), 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: eccentric Pulsar

- Discovery of first “new” binary msp in Globular cluster
- Very interesting variation of period with epoch
- binary pulsar
- very eccentric orbit
  - e = 0.89



Freire et al.. (2004)



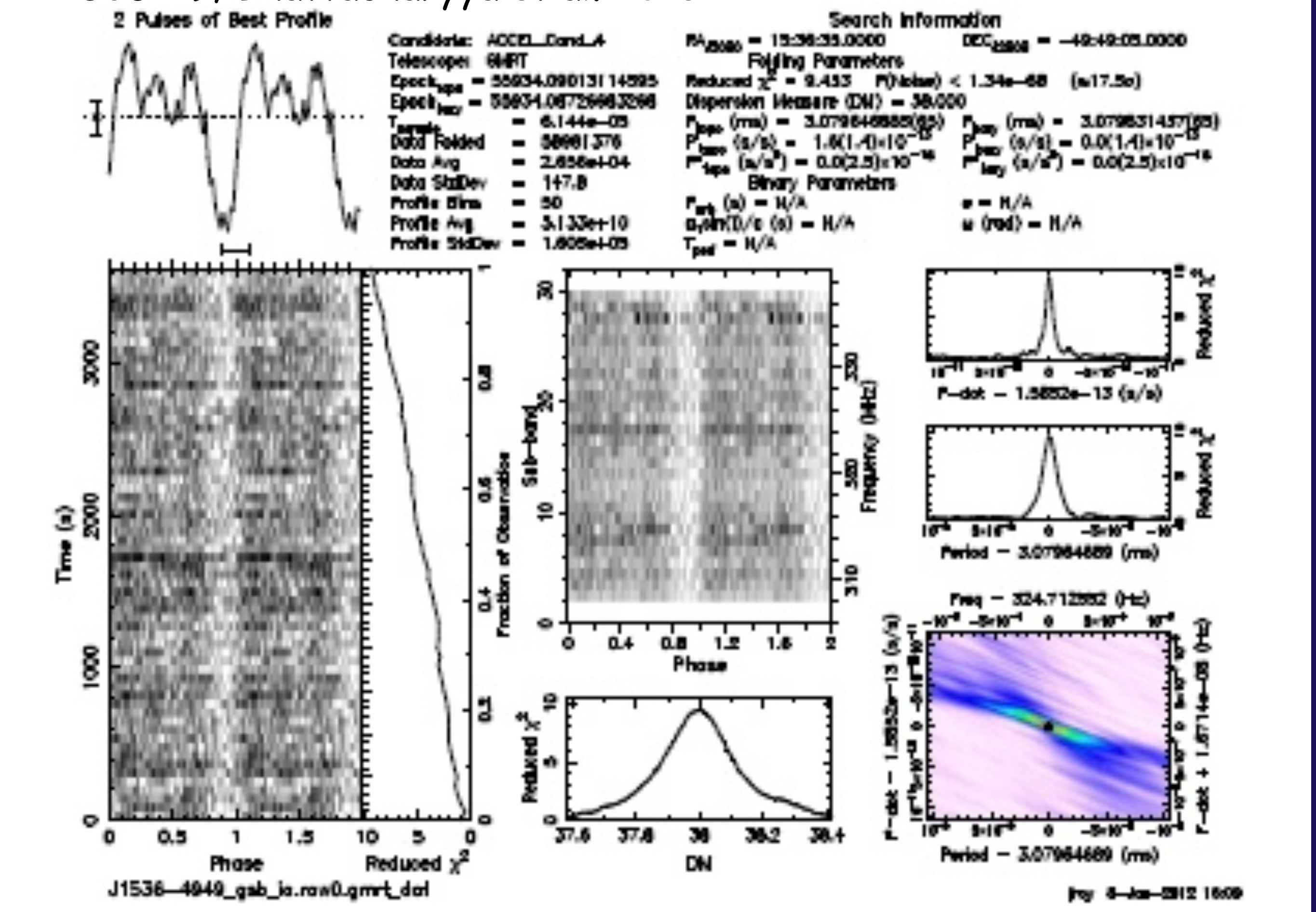
GC: NGC 1851

GMRT: *Fermi* LAT Pulsar

- Discovery of 7 new MSPs in last ~2 yr
- Follow-up search of Fermi LAT sources
- of these 7,
  - black-widow
  - isolated MSP
  - wide-profile
  - etc.

Bhattacharyya, Roy, Gupta, Bhattacharya

1536-49; Bhattacharyya et al. 2013



GMRT: *Fermi* LAT Pulsar (& more)

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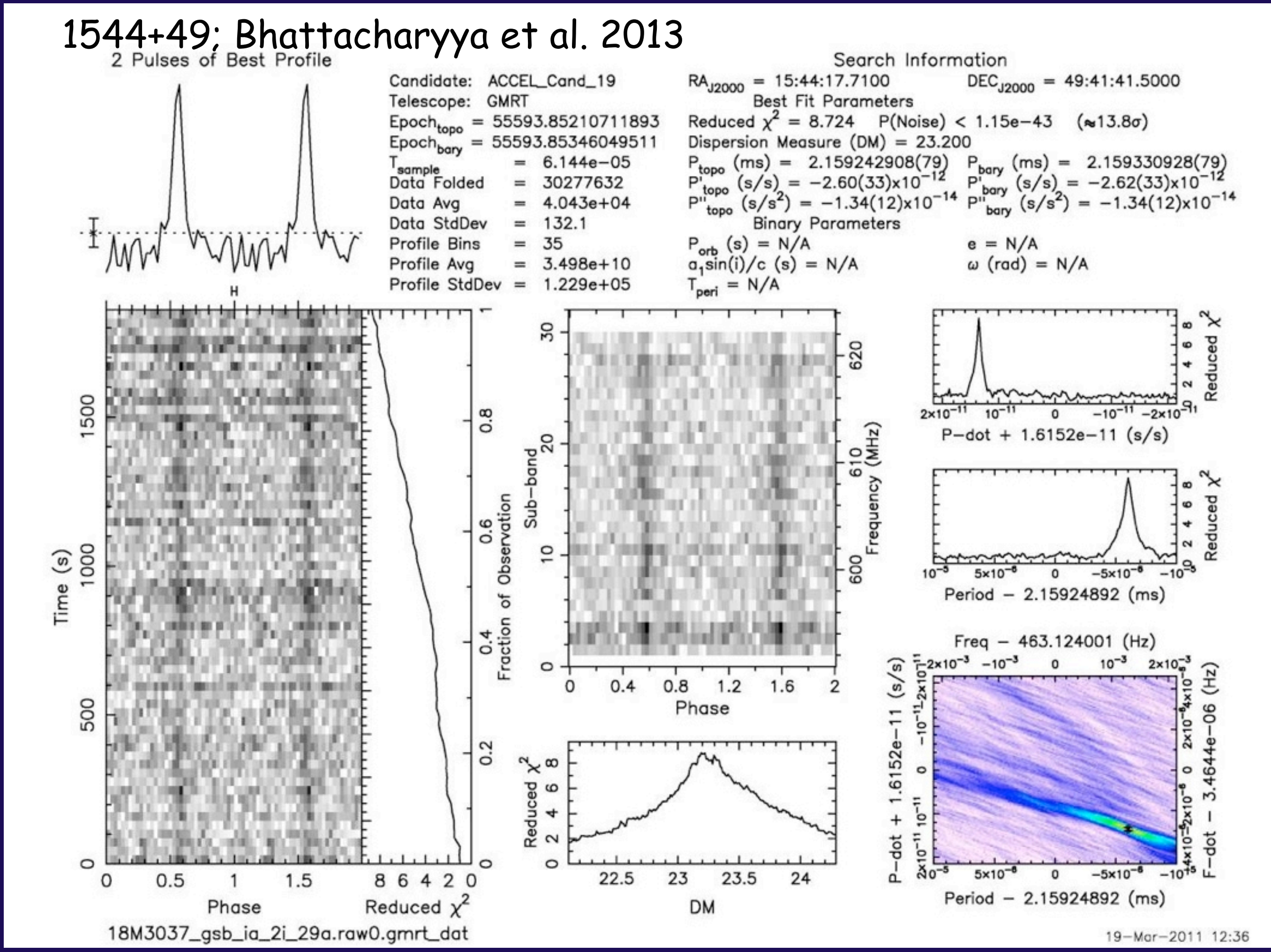
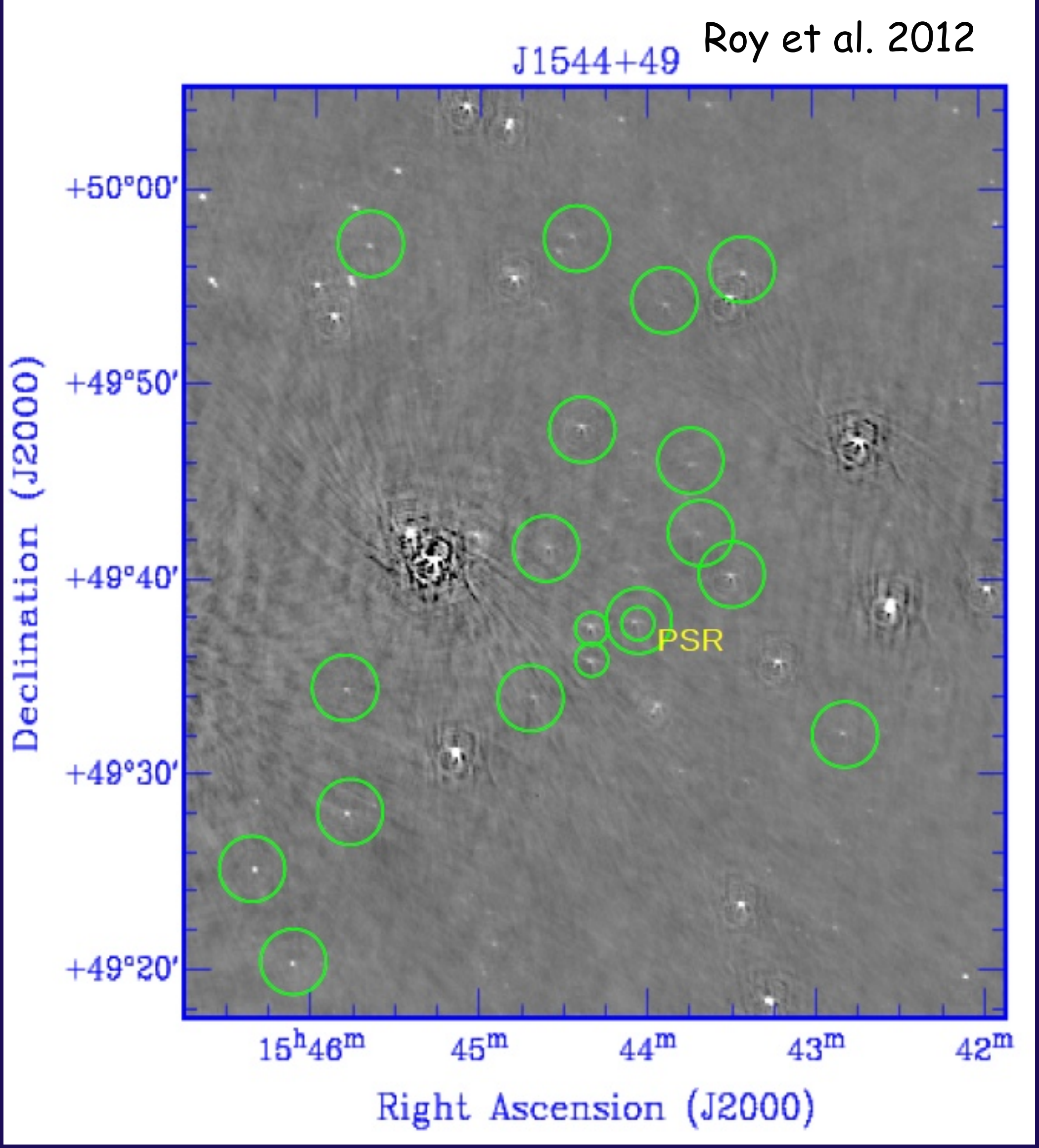
Bhattacharyya, Roy, Gupta, Bhattacharya



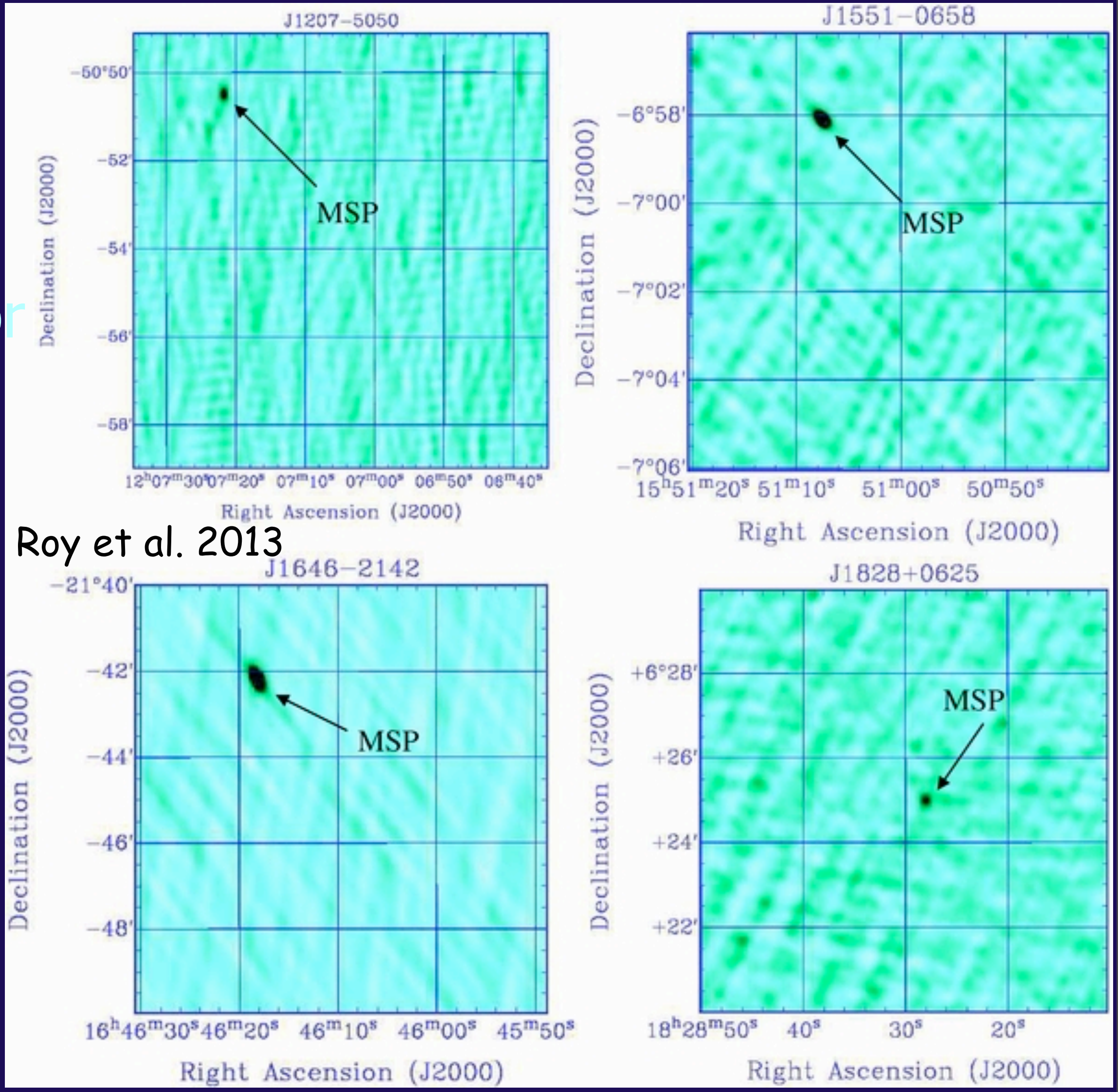
GMRT: Localising *Fermi* Pulsar

- Localising Fermi LAT Pulsars...
  - make a quick image of FoV
  - record raw voltages,
  - making multiple phased array beams at different possible locations,
  - and hunt for the pulsar
- unique capability of GMRT!



GMRT: Localising *Fermi* Pulsar

- Localising Fermi LAT Pulsars...
  - Even better!
  - use GATED-correlator
  - perform on-pulse minus off-pulse
  - and make a map
- yet another unique capability of GMRT!

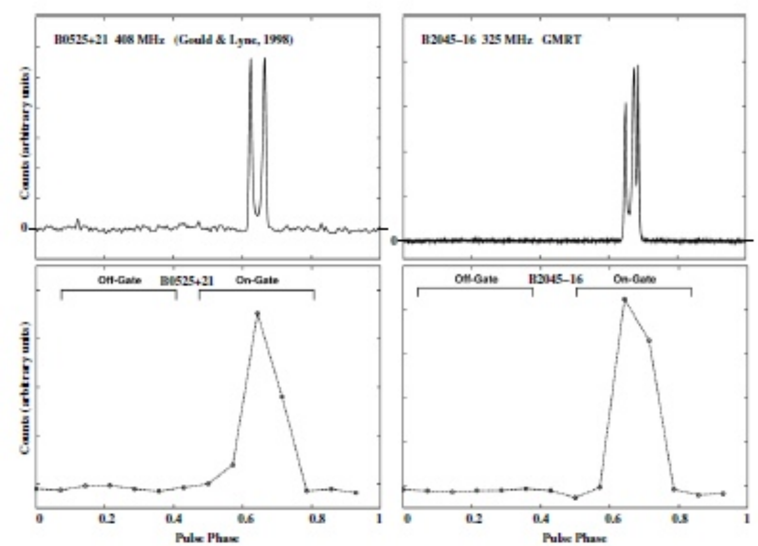


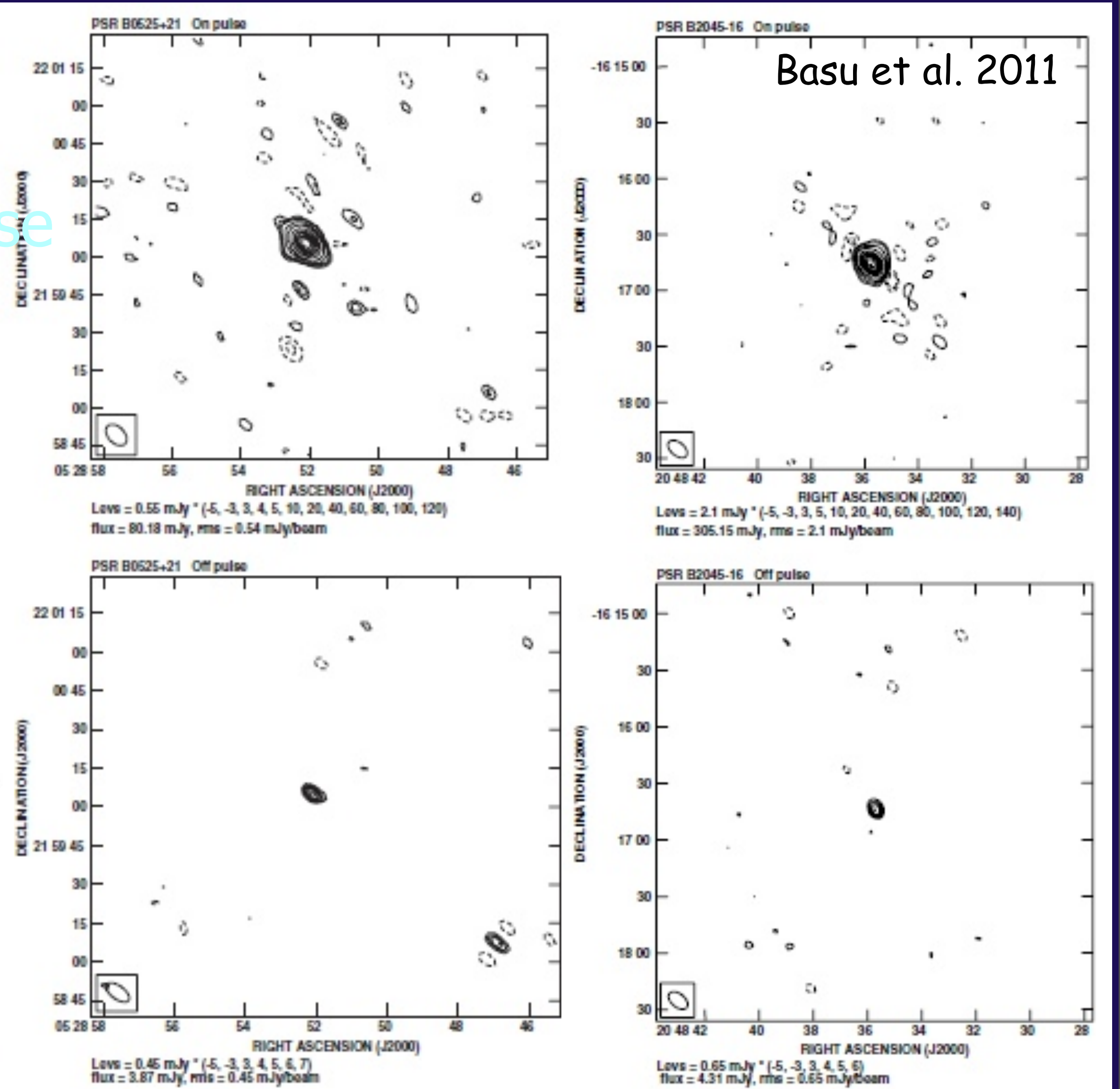
Roy et al. 2013

GMRT: off-pulse emssion

Off-pulse emission?

- use GATED-correlator make images of on-pulse and off-pulse regions
- again due to unique capability of GMRT!

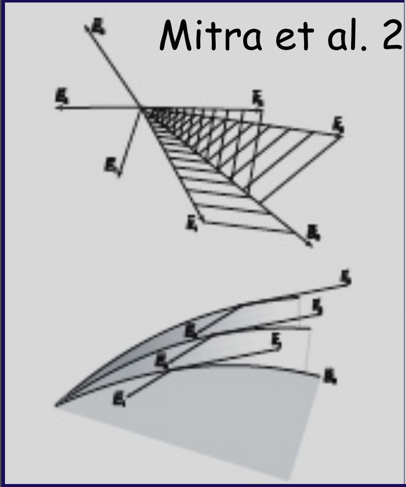




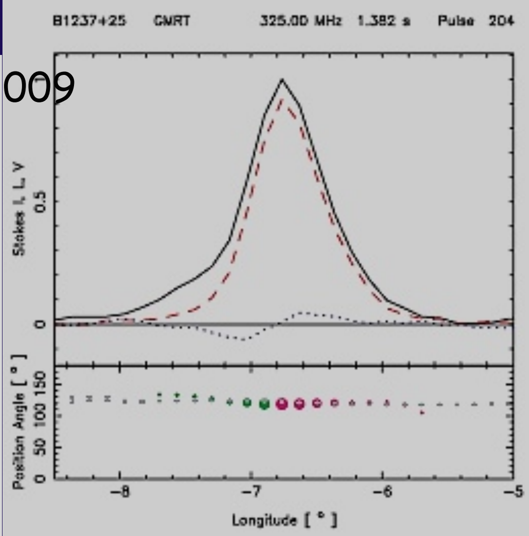
GMRT: decoding emission nature

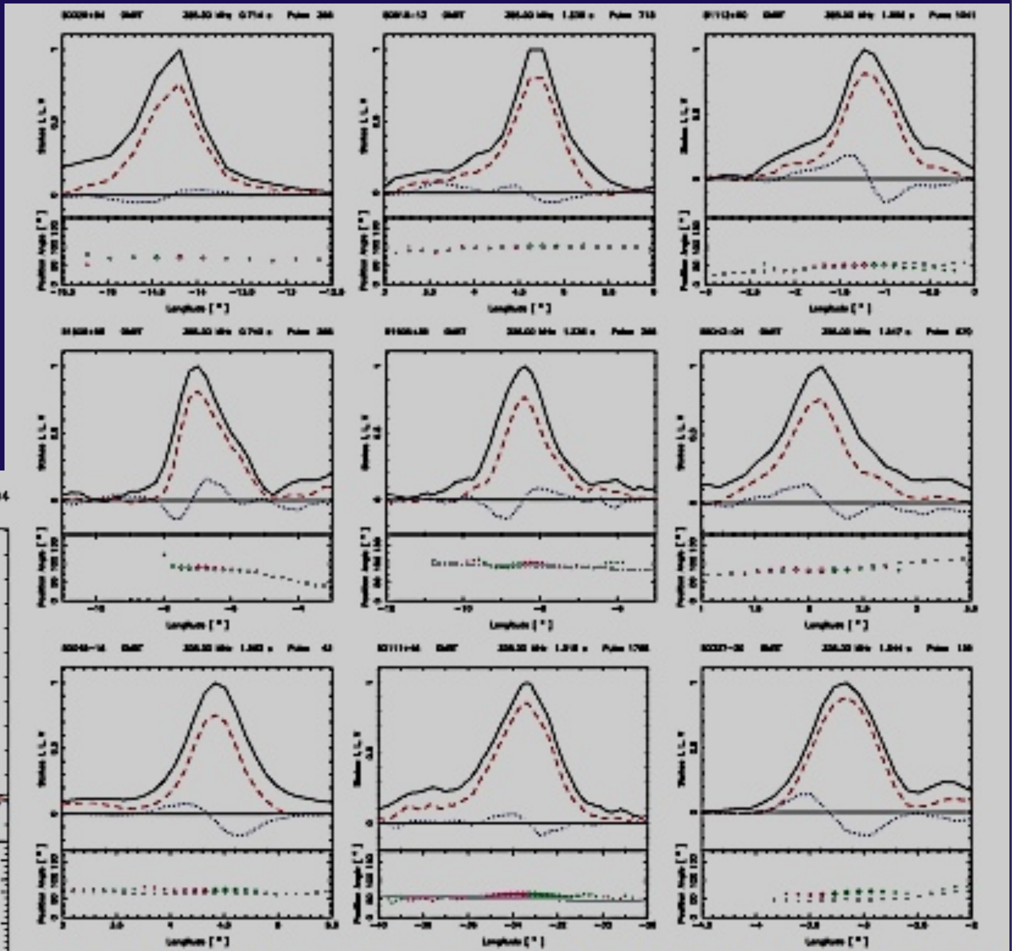
Unravelling the nature of coherent emission from Pulsar

- extraordinary-waves are excited by maser or **coherent curvature radiation**?
- high-quality single-pulse polarimetry - a capability of GMRT!



Mitra et al. 2009



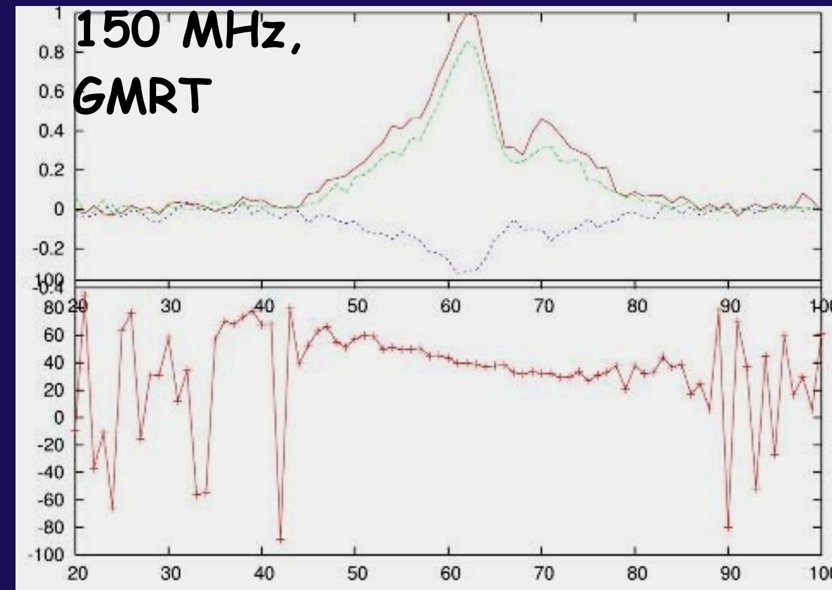


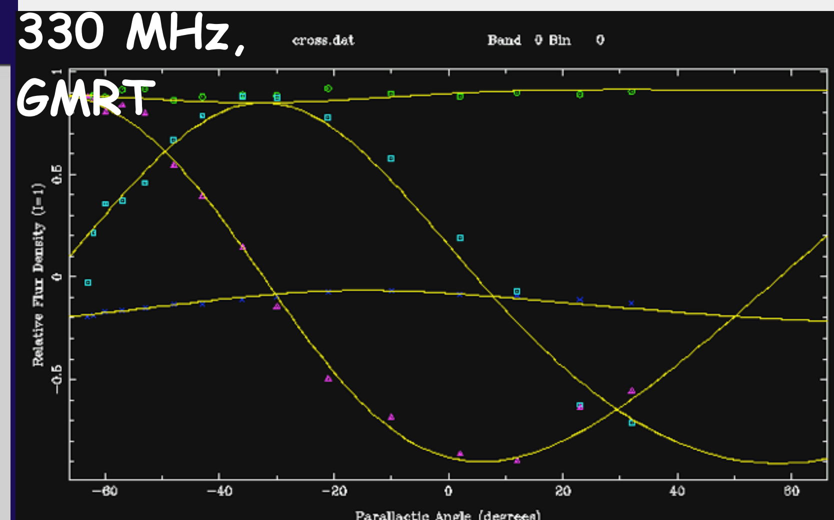
gure 2. Same as in Figure 1. The subpulses are from pulsars PSRs B0329+54, B0818−13, B1112+50, B1508+55, B1905+39, B2043−04, B2045−16, B2111+46, d B2327−20 (the order is from left to right and top to bottom).

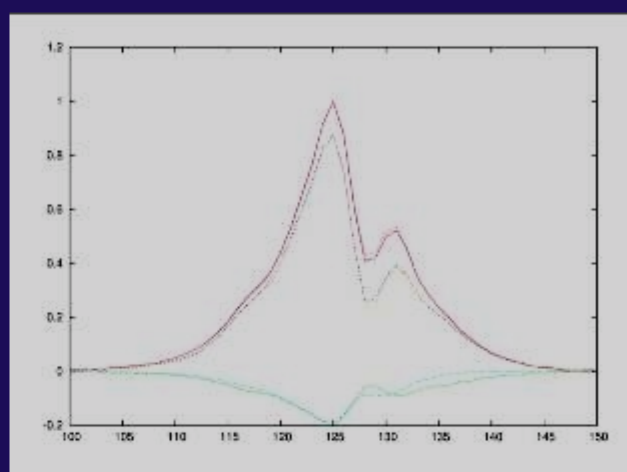
GMRT: Pulsar polarization

phased-array mode for polarization observations

- key! understand the instrumental polarization
  - now possible using GMRT at several frequencies...





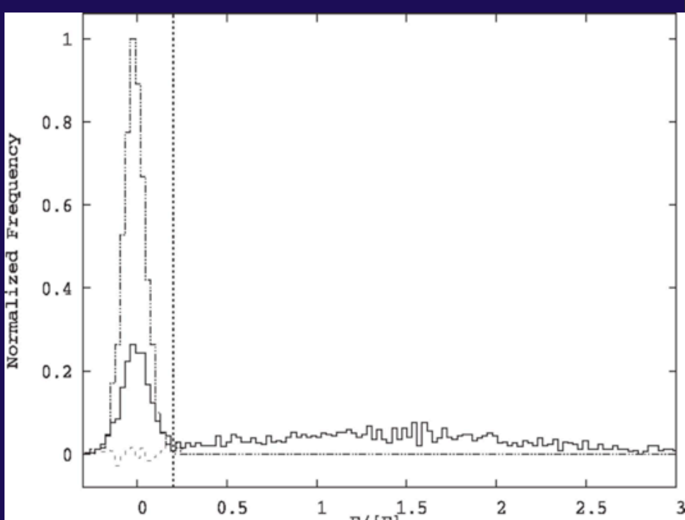


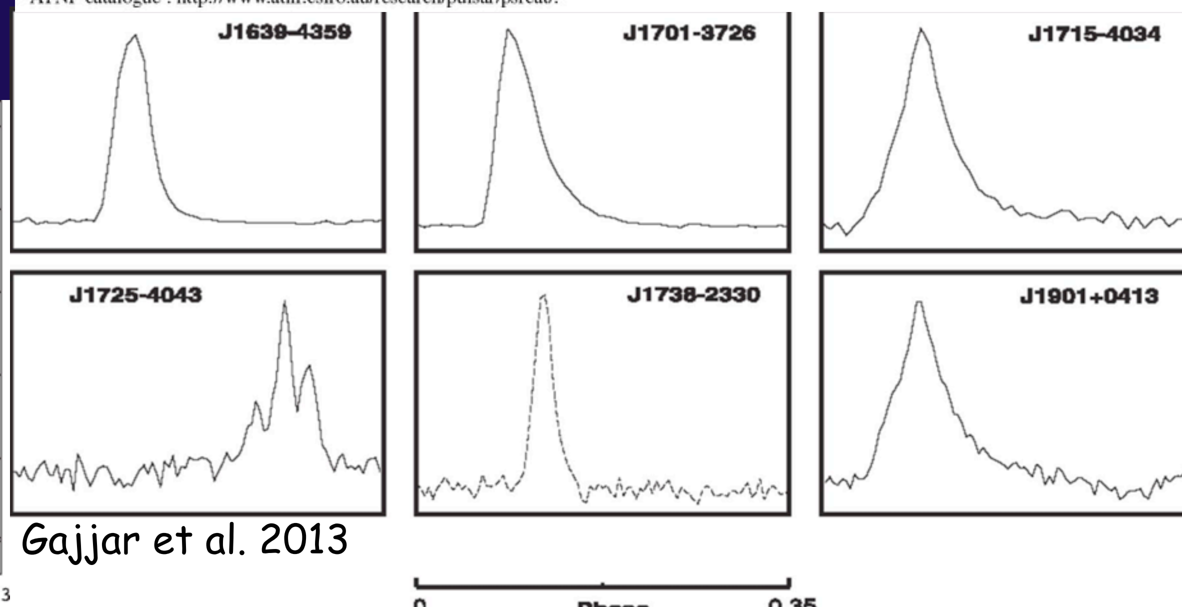
GMRT: Nulling Pulsars

- Nulling Pulsars statistics
  - parameters
  - pulse profiles
  - on-pulse and off-pulse energies
  - etc.

J2000 Name	B1950 Name	Period (s)	DM (pc cm^{-3})	S1400 (mJy)	Obtained NF (per cent)	Known NF (per cent)	η –	Number of Runs –	N (subintegration) –
J0814+7429	B0809+74	1.292241	06.1	10.0	1.0(0.4)	1.42(0.02) [1]	172.0(0.5)	246	13 766 (1)
J0820−1350	B0818−13	1.238130	40.9	7.0	0.9(1.8)	1.01(0.01) [1]	4.2(0.2)	114	3341 (1)
J0837−4135	B0835−41	0.751624	147.2	16.0	1.7(1.2)	≤1.2 [2]	15.7(0.2)	148	3335 (1)
J1115+5030	B1112+50	1.656439	9.2	3.0	64(6)	60(5) [3]	44.7(0.2)	1270	2634 (1)
J1639−4359	–	0.587559	258.9	0.92	≤0.1	–	–	–	13 034 (1)
J1701−3726	–	2.454609	303.4	2.9	19(6)	≥14 [5]	6.4(0.2)	–	2464 (1)
J1715−4034	–	2.072153	254.0	1.60	≥6	–	–	–	1591 (16)
J1725−4043	–	1.465071	203.0	0.34	≤70	–	–	–	2481 (24)
J1738−2330	–	1.978847	99.3	0.48	≥69	–	5.3(0.3)	–	2178 (5)
J1901+0413	–	2.663080	352.0	1.10	≤6	–	–	–	2605 (1)
J2022+2854	B2020+28	0.343402	24.6	38	0.2(1.6)	≤ 3 [3]	2.5(0.2)	–	8039 (1)
J2022+5154	B2021+51	0.529196	22.6	27.0	1.4(0.7)	≤5 [3]	2.6(0.2)	24	1326 (1)
J2037+1942	B2034+19	2.074377	36.0	–	≥26	44(4) [4]	6.4(0.1)	672	1618 (3)
J2113+4644	B2111+46	1.014685	141.3	19.0	21(4)	12.5(2.5) [3]	14.9(0.3)	290	6208 (1)
J2321+6024	B2319+60	2.256488	94.6	12.0	29(1)	25(5) [3]	115.8(0.4)	450	1795 (1)

[a] ATNF catalogue : http://www.atnf.csiro.au/research/pulsar/psrcat/.





Gajjar et al. 2013

GMRT: Science objectives

P.K. Manoharan, D. Oberoi, VCD

- Solar system objects
- 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

GMRT: Sun

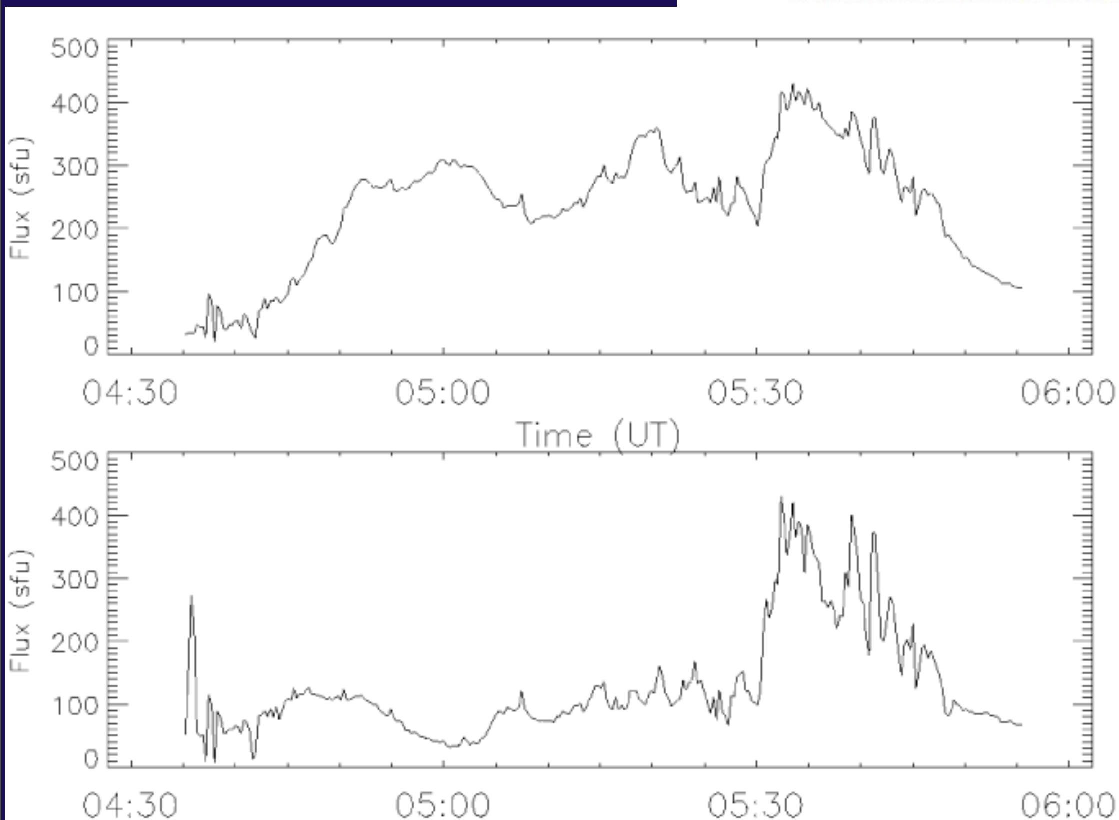
- Sun
  - CMEs, etc.

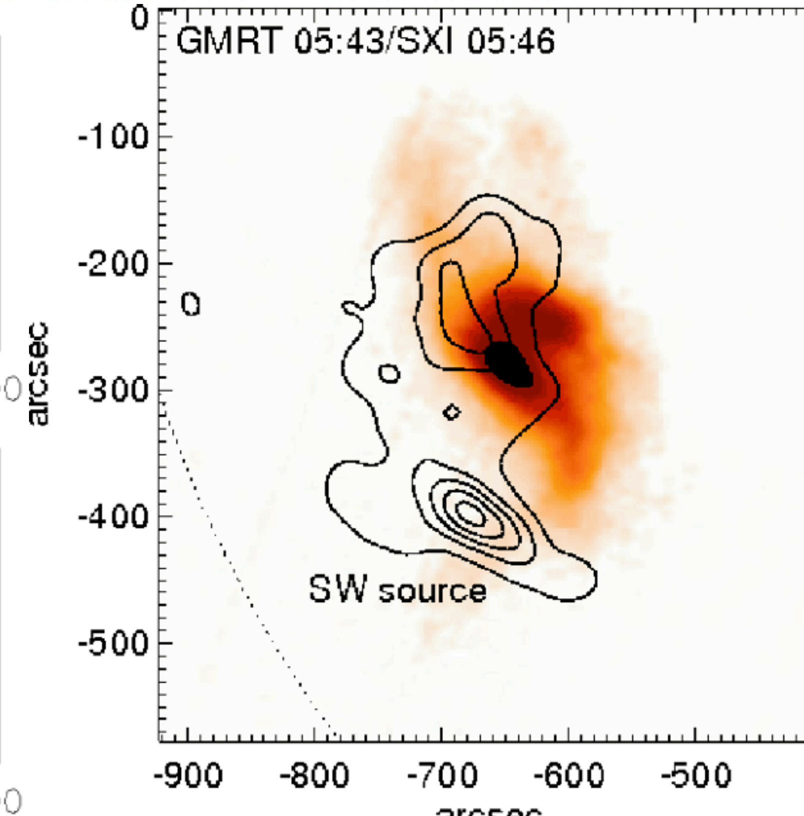
A&A 468, 1099–1102 (2007)
DOI: 10.1051/0004-6361:20077341

Astronomy & Astrophysics

Electron acceleration in a post-flare decimetric continuum source
(Research Note)

P. Subramanian[1], S. M. White[2], M. Karlický[3], R. Sych[4], H. S. Sawant[5], and S. Ananthakrishnan[6]





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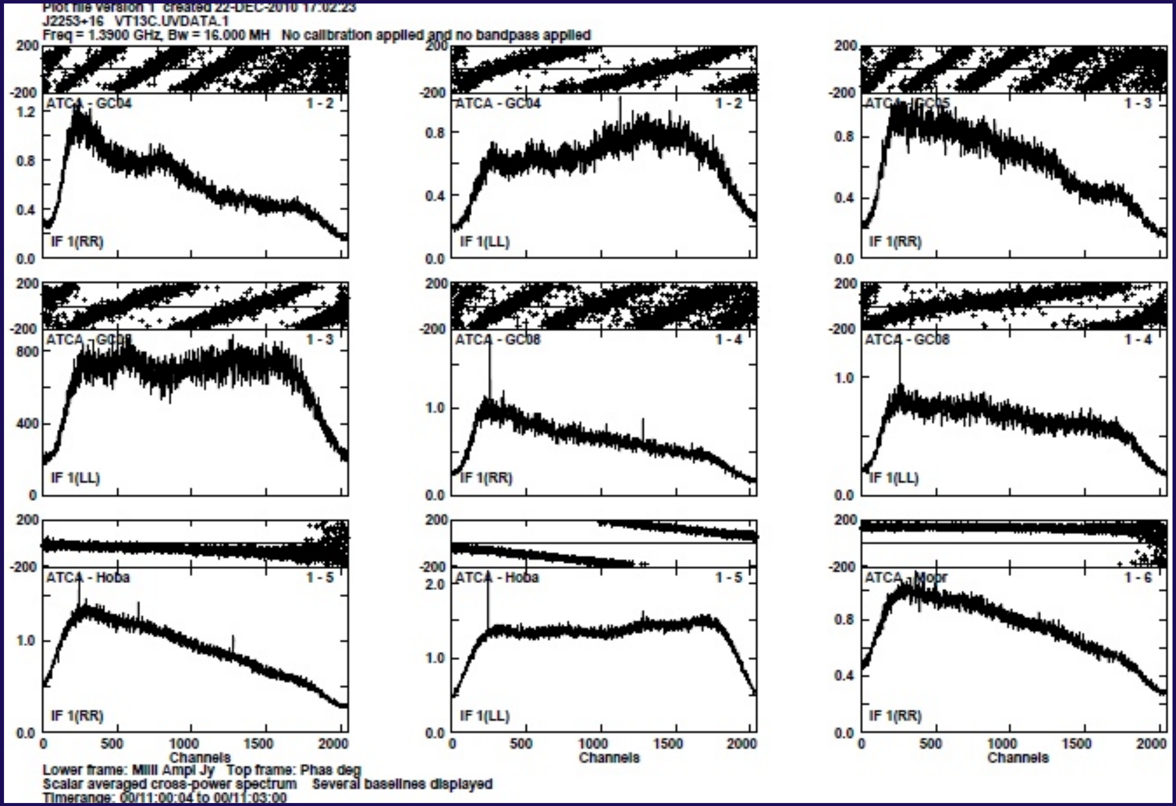
GMRT: VLBI station

15Dec2010: GMRT(4) + ATCA + MOPRA

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



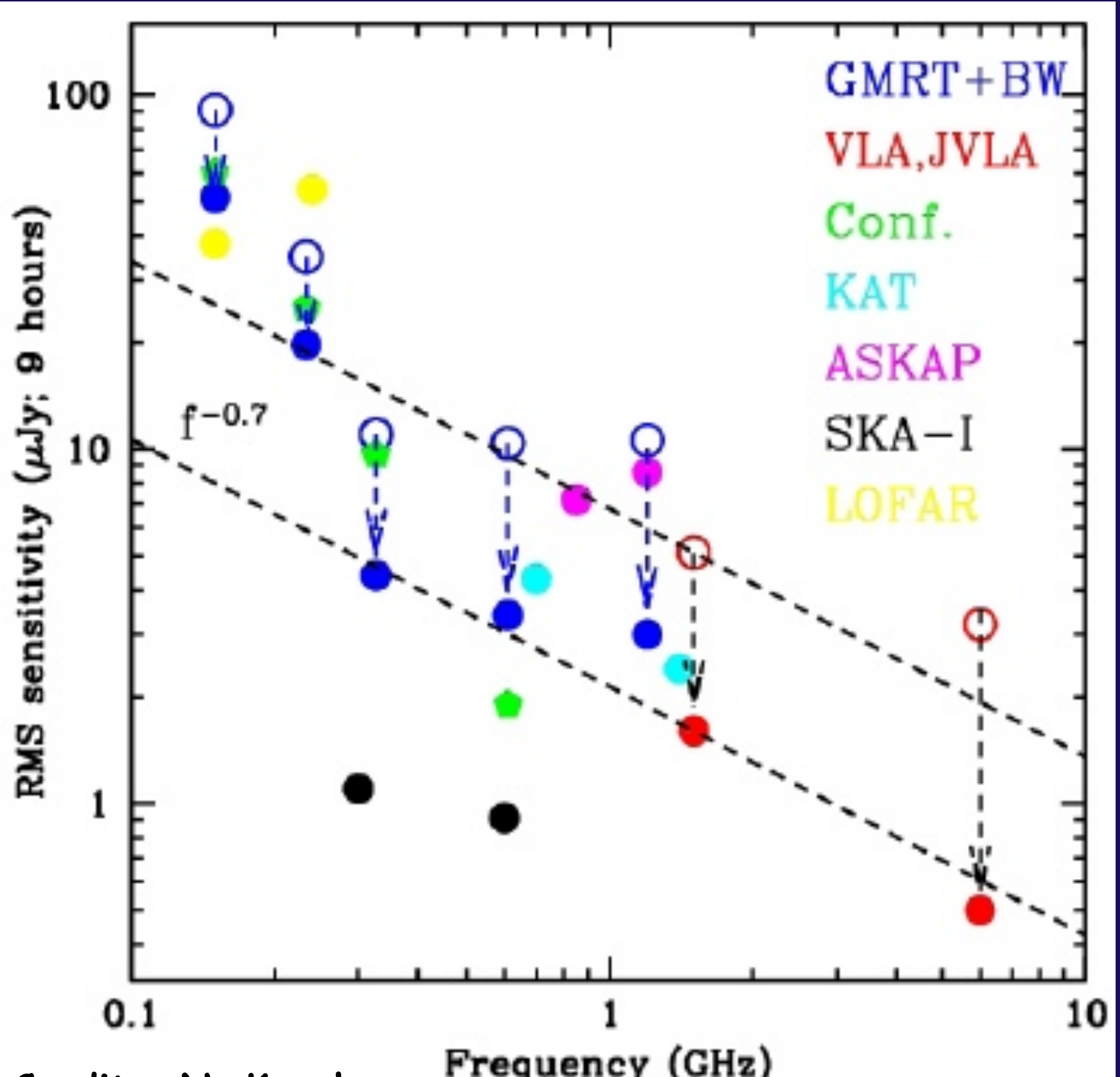
GMRT: Looking ahead

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 'back-end' 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

GMRT: “upgraded”-GMRT

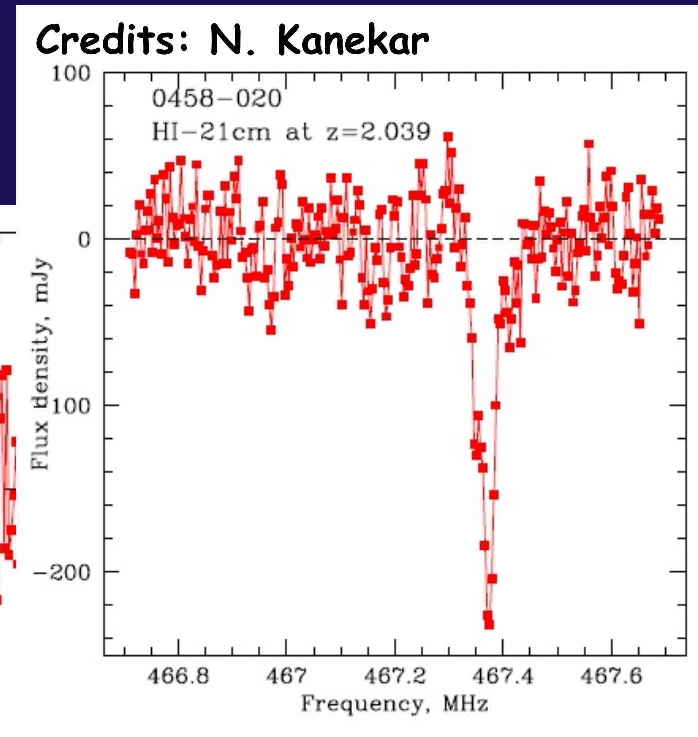
- Expected performance of “upgraded”-GMRT and comparison of it’s sensitivity with other major facilities in the world.

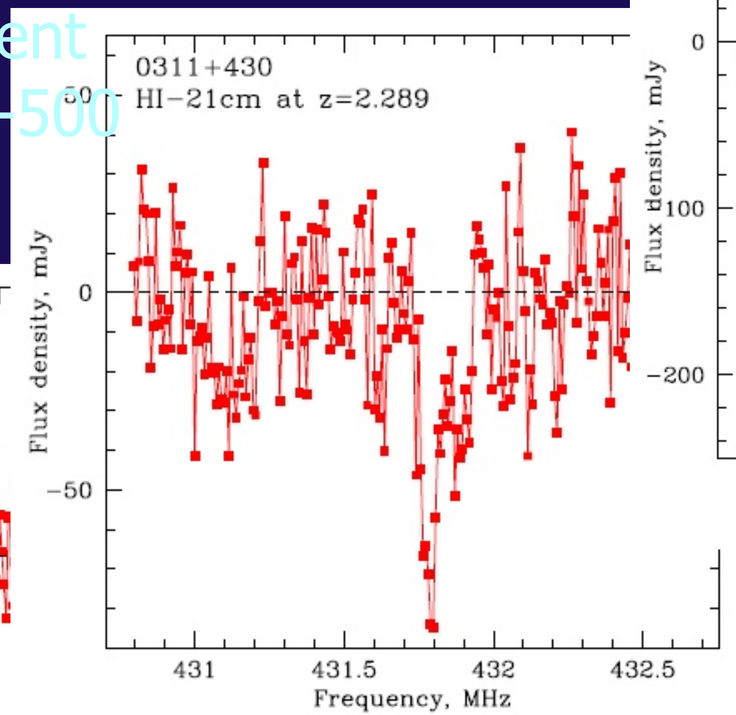


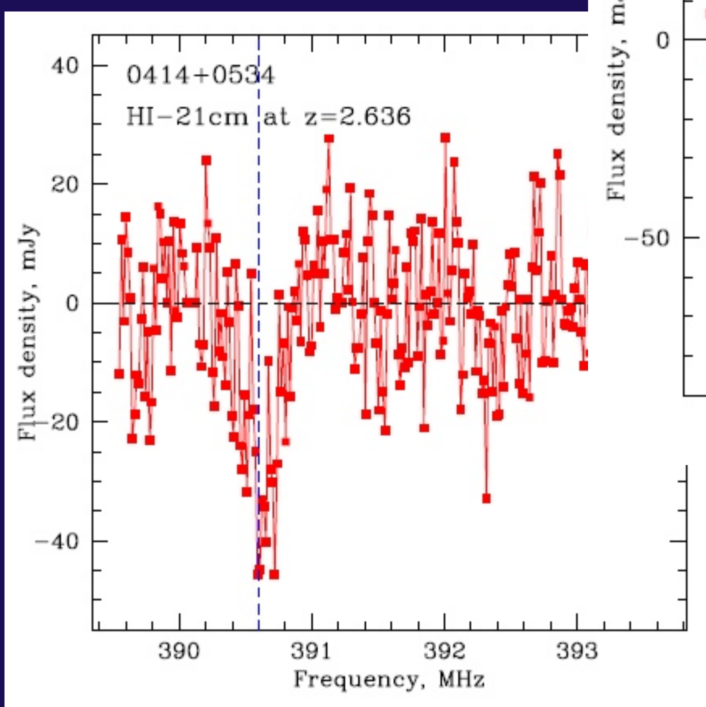
Credits: N. Kanekar

“upgraded”-GMRT: First results

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







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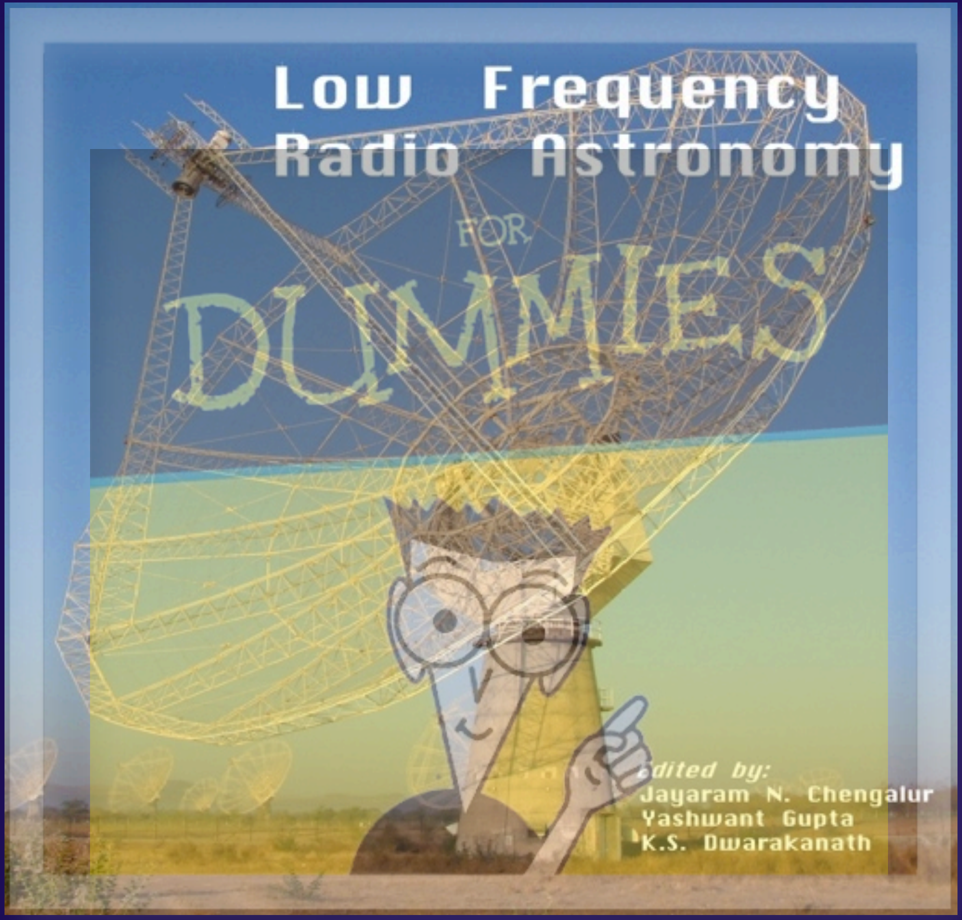

P. Chandra: From an idea to an observing proposal (Tue, 27 Aug, 16:45 hrs)

The Giant Metrewave Radio Telescope is a powerful instrument to probe several astrophysical objects

Thank you all for your attention!

GMRT Observatory, 24 August 2013

GMRT: Science objectives

- Solar system objects — **P.K. Manoharan, D. Oberoi, VCD**
- 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. Choudhury, A. Banerjee, Datta-Kanan, P. Dutta**
  - normal / active galaxies
- Clusters / Groups of galaxies — **D.J. Saikia, N.G. Kantharia, S. Sirothia, C.H. Ishwara-Chandra, S. Roy, A. Basu, JNC, NK, DVL**
- Deep-fields / EoR — **Y. Gupta, S. Sirothia, Y. Wadadekar…**
- All-sky surveys — **S. Sirothia, N.G. Kantharia, C.H. Ishwara-Chandra, Gopal-Krishna**