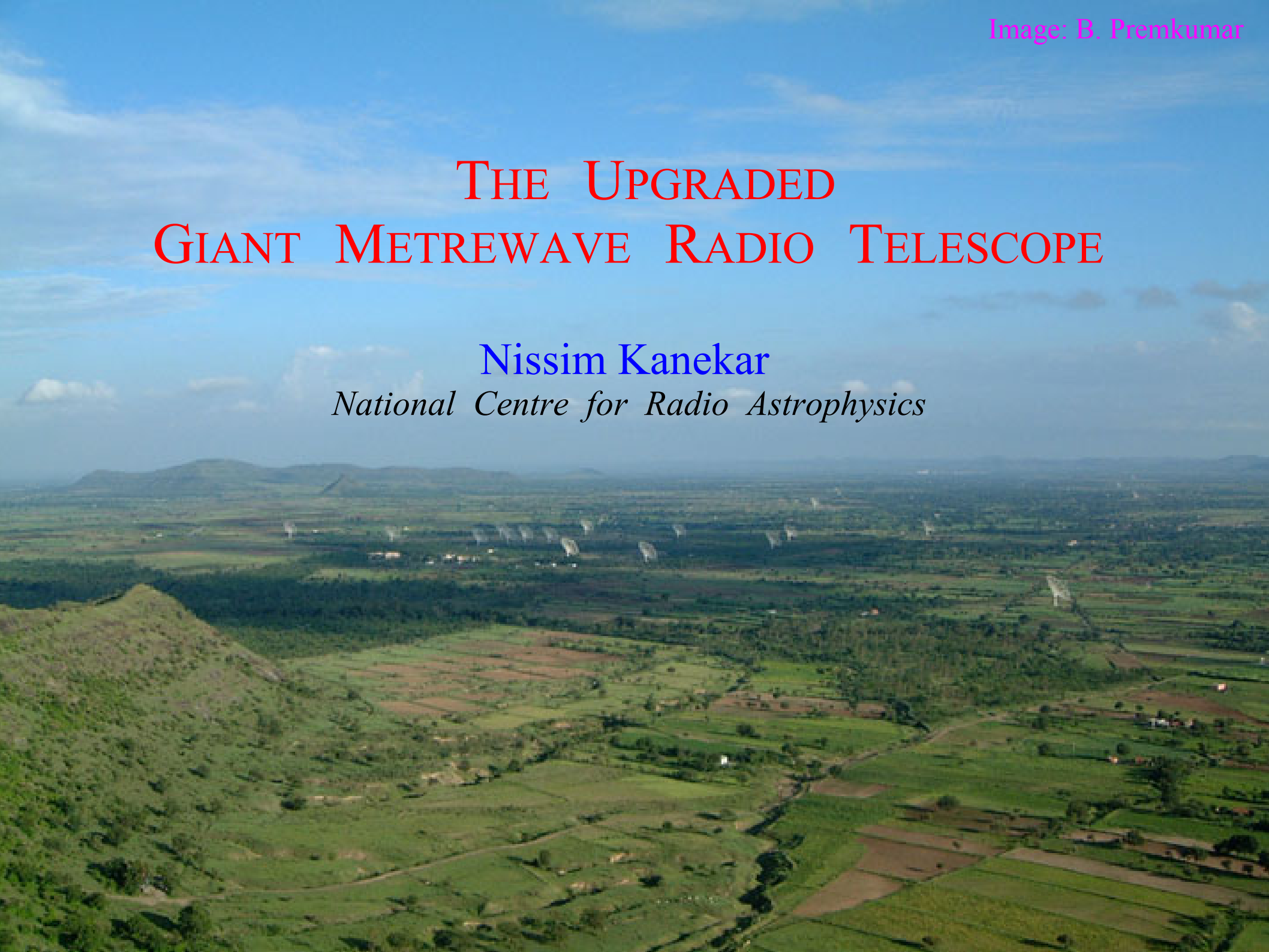


THE UPGRADED GIANT METREWAVE RADIO TELESCOPE

Nissim Kanekar
National Centre for Radio Astrophysics

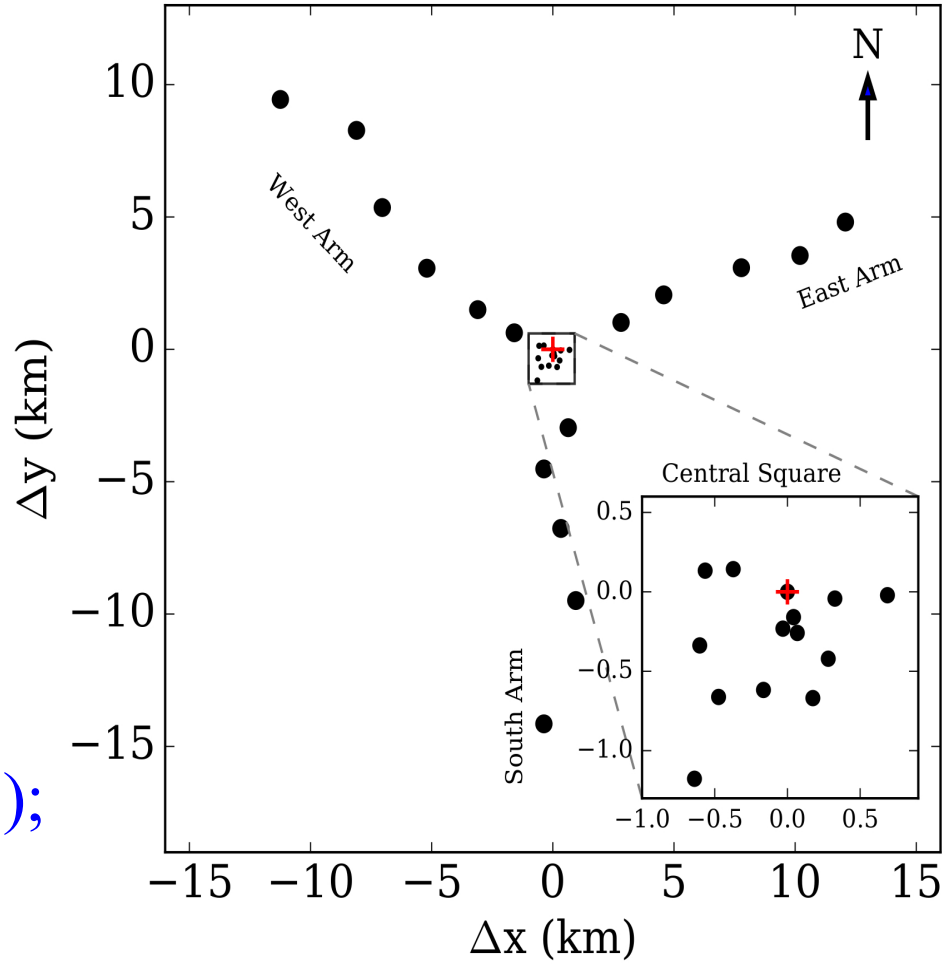
OUTLINE

- The Giant Metrewave Radio Telescope (GMRT).
- The upgraded GMRT.
- The new receivers: Sensitivity.
- The GMRT Wideband Backend (GWB).
- Early results: Continuum imaging, spectral lines, RFI mitigation.
- Summary.

THE ORIGINAL GMRT

(Swarup et al. 1991, Curr. Sci.)

- 30 mesh antennas; 45m diameter.
- 14 dishes in a ~1 km central square.
  16 dishes along the arms of a "Y".
  435 baselines: ~ 75 m – 25 km.
- 5 frequency bands: 130 – 170 MHz;
  225 – 245 MHz; 300 – 350 MHz;
  580 – 660 MHz; 1000 – 1450 MHz.
- GMRT Software Backend (2010 – …);
  32 MHz BW, 128 – 512 channels.

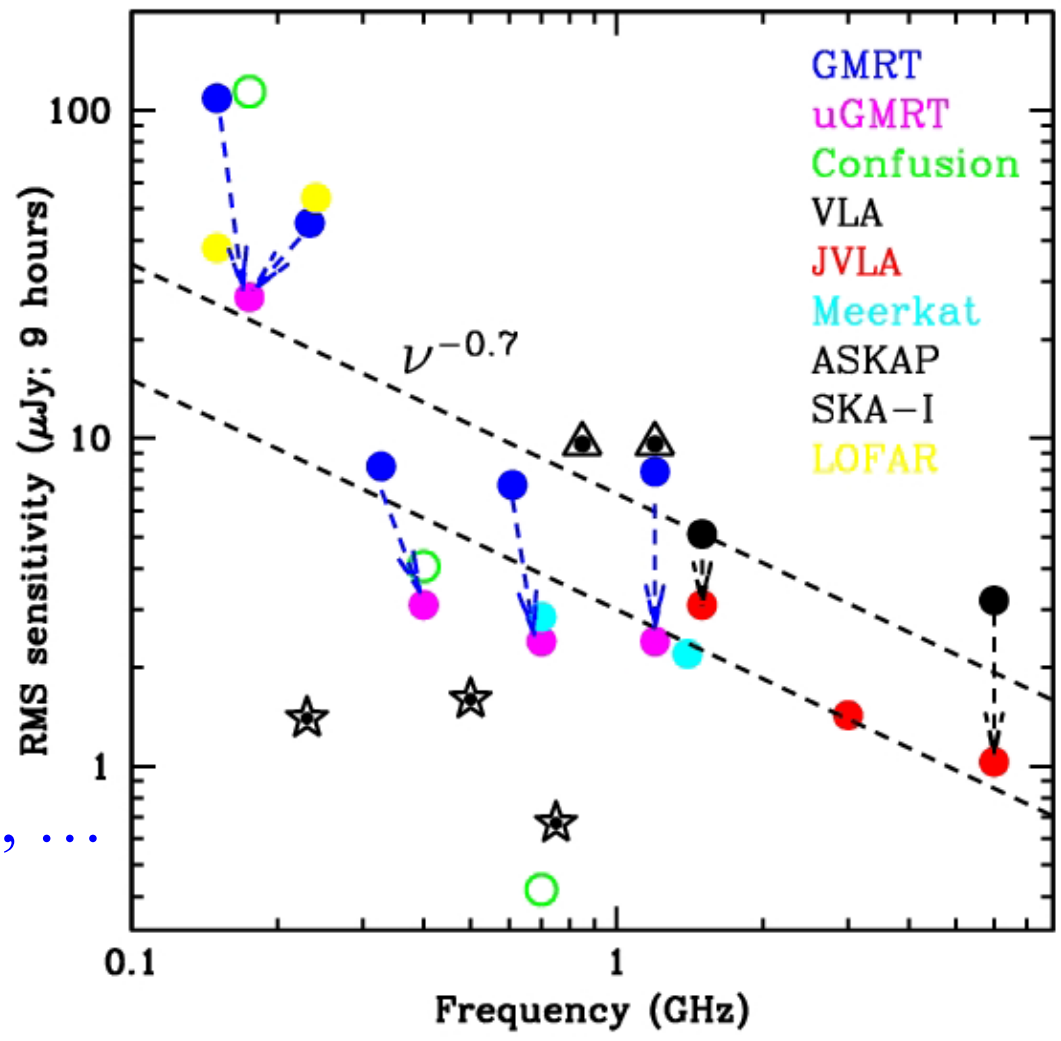


- ~ 50% "international" PI's since 2002; proposals on Jan. 15, July 15.

THE UPGRADED GMRT

(Gupta et al. 2017, Curr. Sci.)

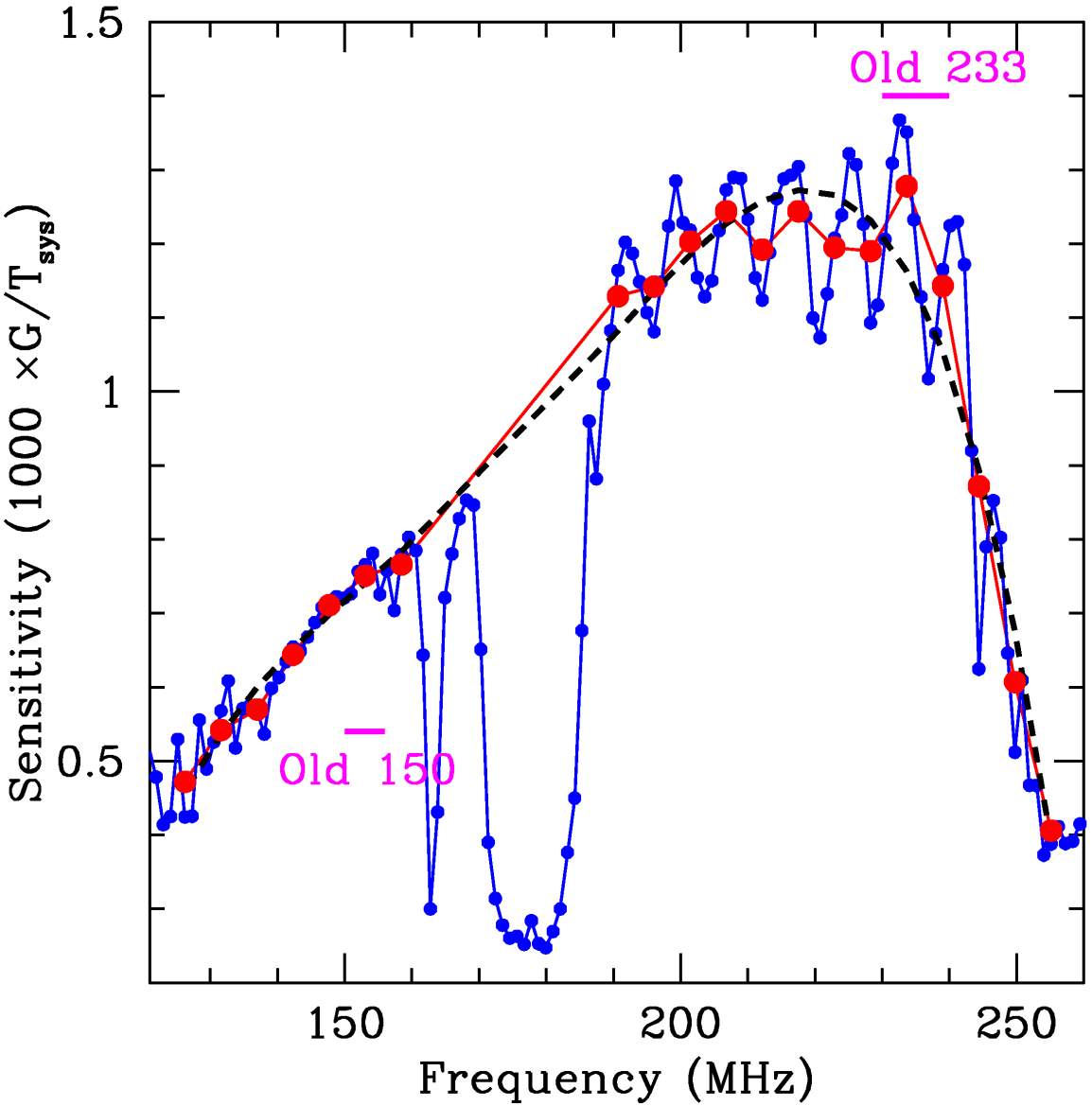
- Proposed ~ 2007; begun ~ 2010.
- New wide-band receivers:
  125 – 250 MHz; 250 – 500 MHz;
  550 – 850 MHz; 1.0 – 1.5 GHz.
- GMRT Wideband Backend:
  400 MHz BW, 16384 channels.
- New, cleaner signal path, new algorithms to excise RFI, new servo & antenna control system, …
- Continuum, pulsar sensitivity better by a factor of ~ 3!



- Uniform* frequency coverage ⇨ Great HI 21cm redshift coverage!
- Correlator, signal path, all receivers done: Observations under way!

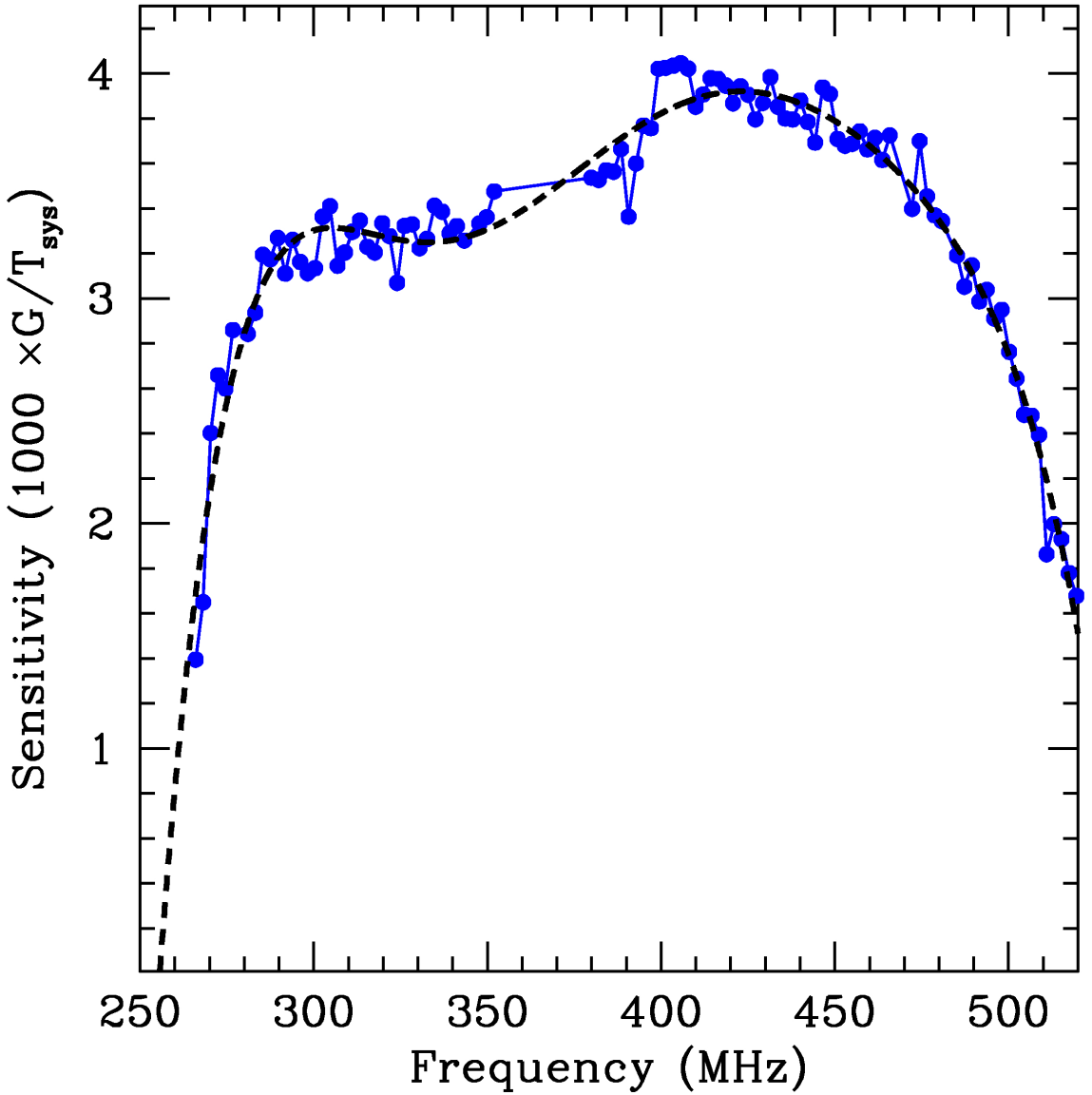
THE UPGRADED GMRT: THE NEW RECEIVERS

- "Band-2": 125 – 250 MHz.
  Notch filter at ~ 165 – 185 MHz to zap a strong TV station.



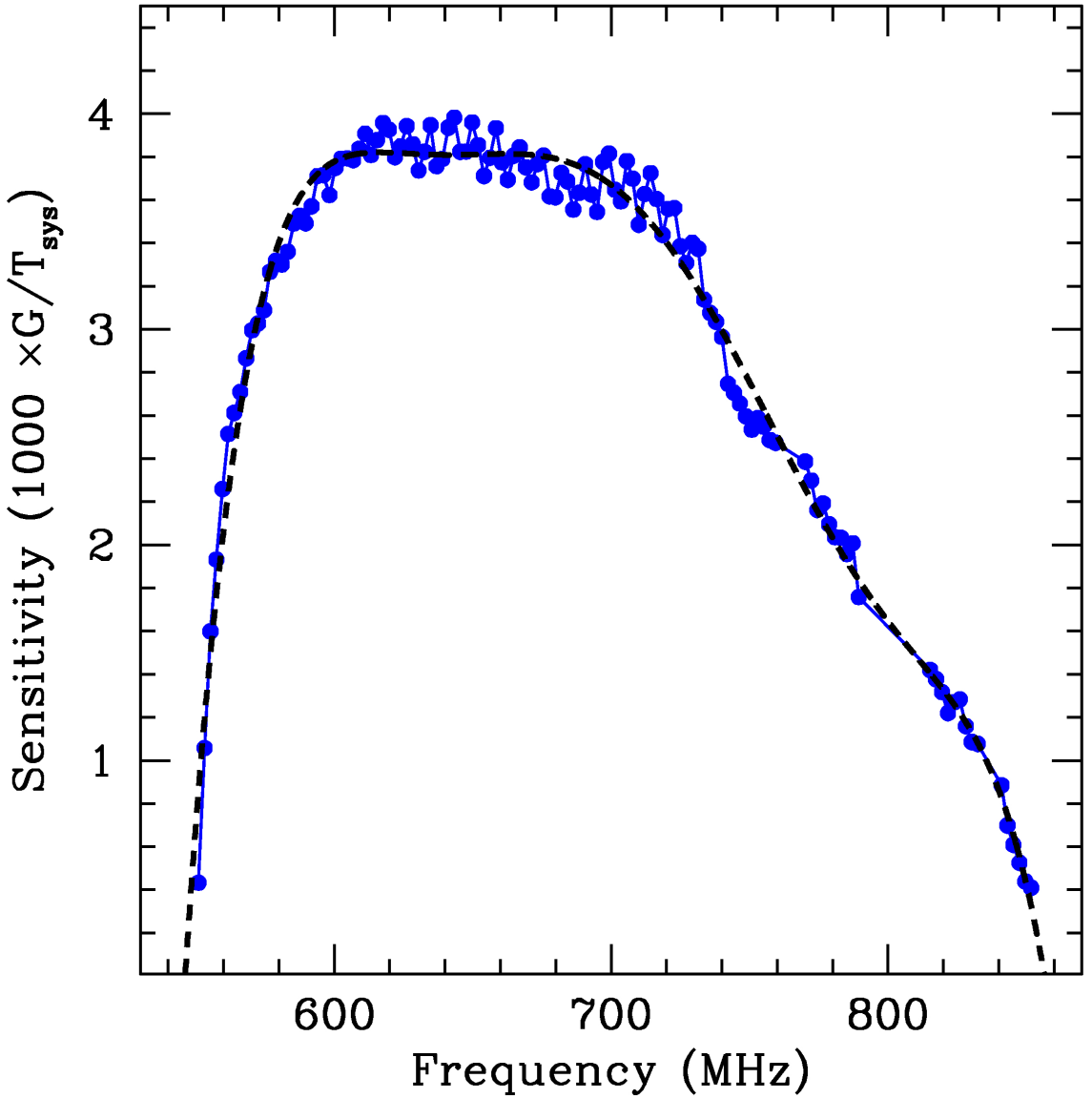
THE UPGRADED GMRT: THE NEW RECEIVERS

- "Band-3": 250 – 500 MHz. MUOS satellites at 360 – 380 MHz. RFI below 275 MHz. Digital TV (upto 11 PM): ~ 480 – 490 MHz.



The Upgraded GMRT: The New Receivers

- "Band-4": 550 – 850 MHz. Remarkably clean band!
  Better sensitivity than that of the old 610/233 MHz receivers.
  Cut-off at ~ 850 MHz, to avoid cellular transmissions.

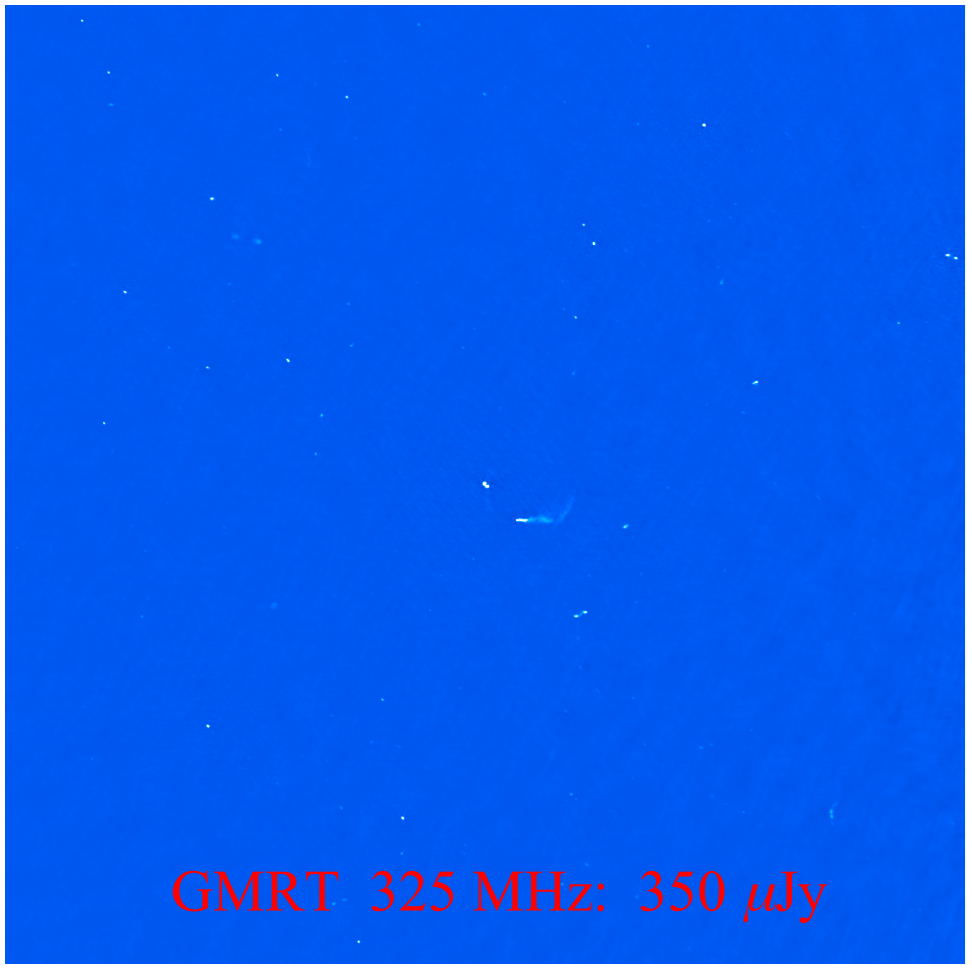


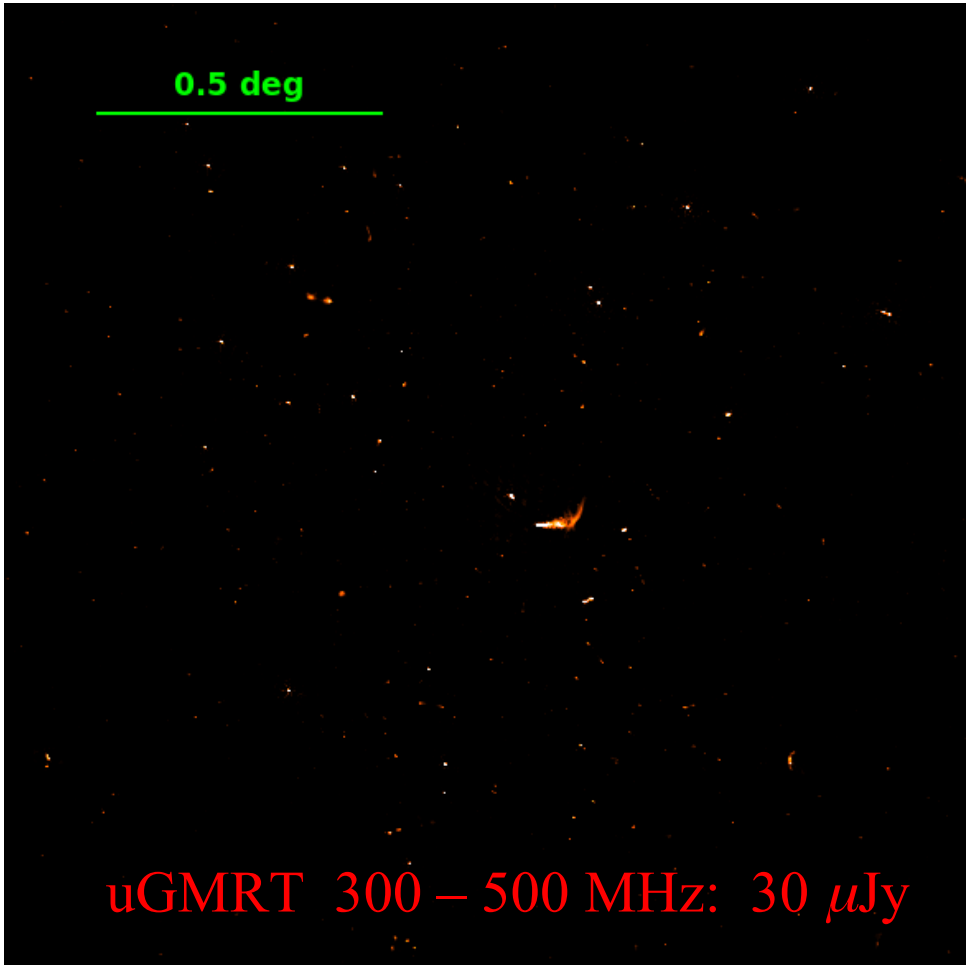
The GMRT Wideband Backend (GWB)

- Optical fibre system brings 50 – 2000 MHz RF band from antennas.
- Analog Backend system: Converts to 0 – 400 MHz baseband.
- "Hybrid correlator": Analog-to-digital conversion followed by packetization on FPGA's, and a CPU – GPU correlator.
  Dual Tesla K40 GPU's on each of sixteen T630 nodes.
- 100, 200 and 400 MHz input bandwidths; 2,048 – 16,384 channels.
  Narrow-band modes: 100 MHz – 0.39 MHz, in steps of 2.
  Pulsar and beamformer modes; full polarization.
- 8-bit correlator for bandwidths $\leqslant$ 200 MHz; 4-bit for 400 MHz.
- Online RFI mitigation tools now being developed on FPGA's.
  Plan to port to GPU's soon.
- Parallel signal path for the old GMRT Software Backend (GSB).

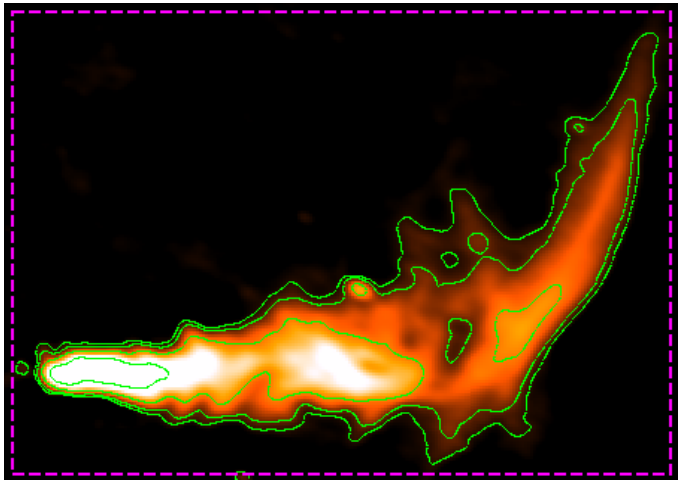
EARLY RESULTS: CONTINUUM IMAGING

(Dharam Vir Lal)



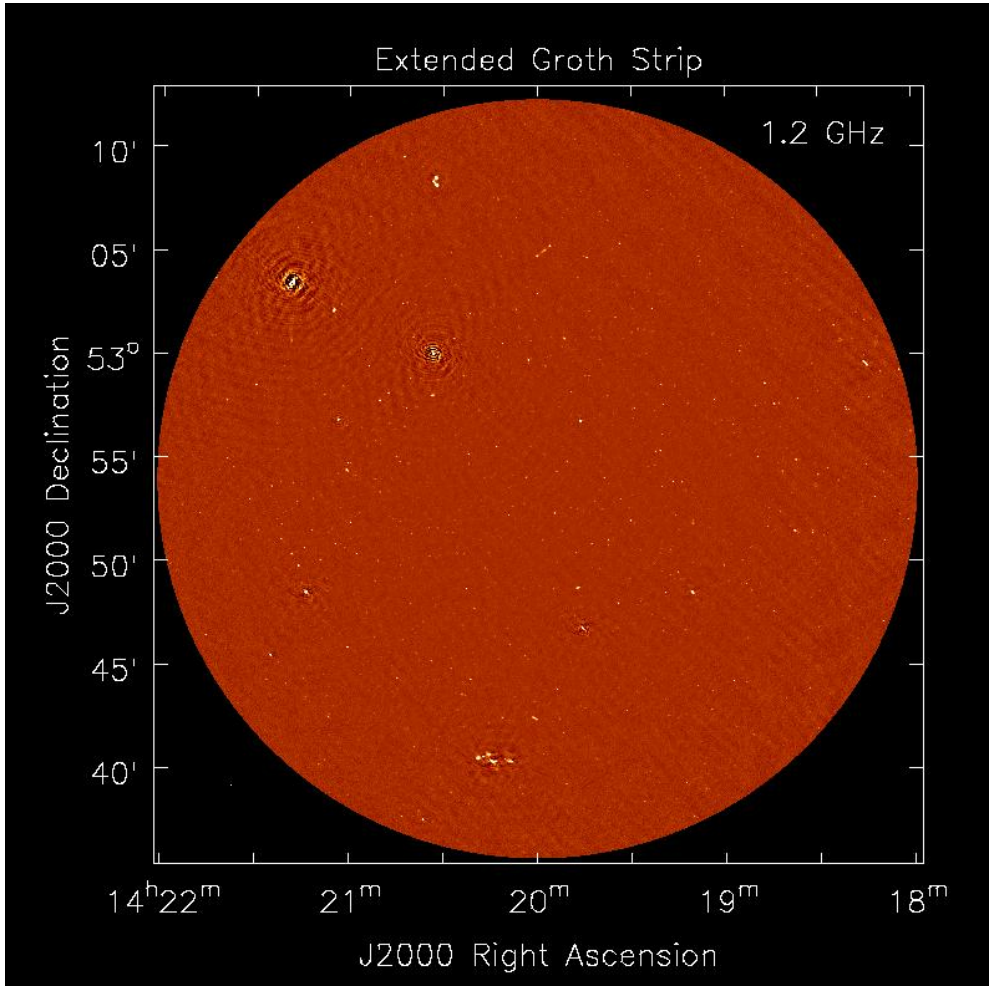


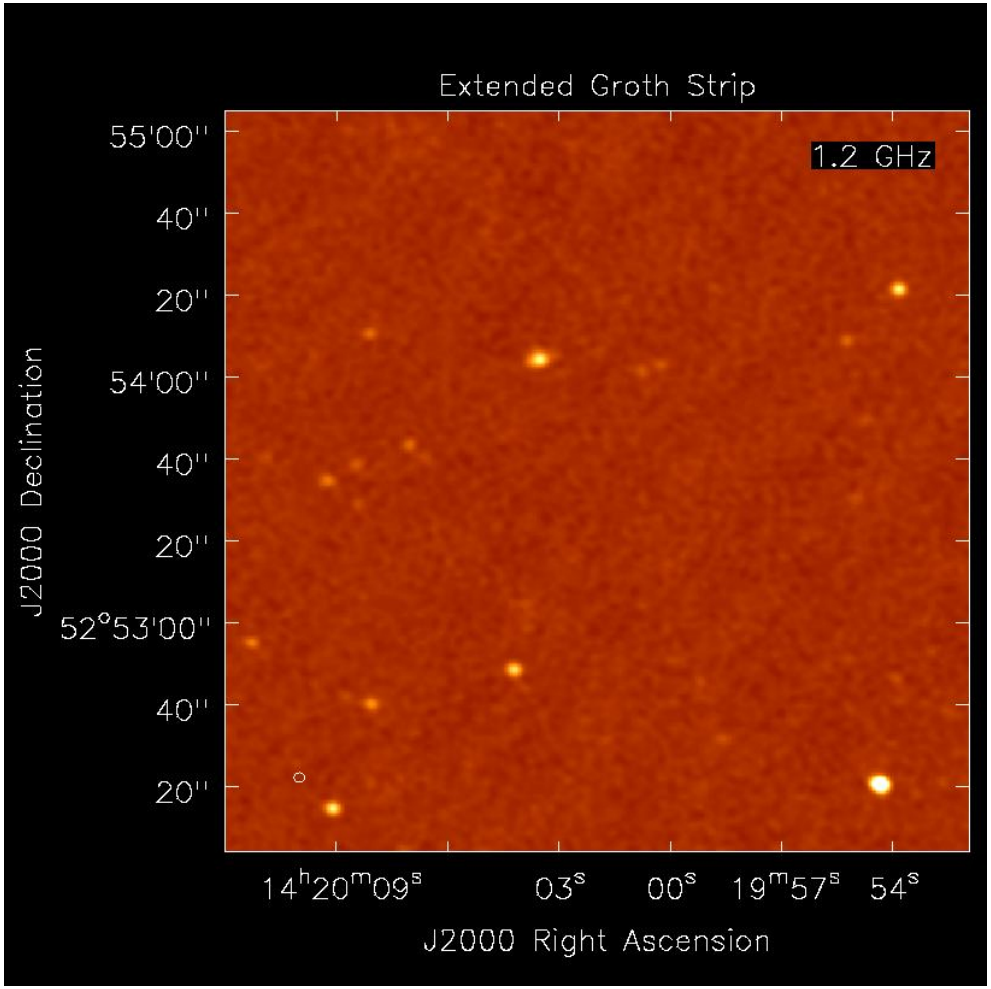
- 10 times lower RMS noise in uGMRT image with similar observing times!
- Detected 30 radio galaxies in the Coma cluster, 2 for the first time!



EARLY RESULTS: CONTINUUM IMAGING

(Apurba Bera, NK, Chengalur)

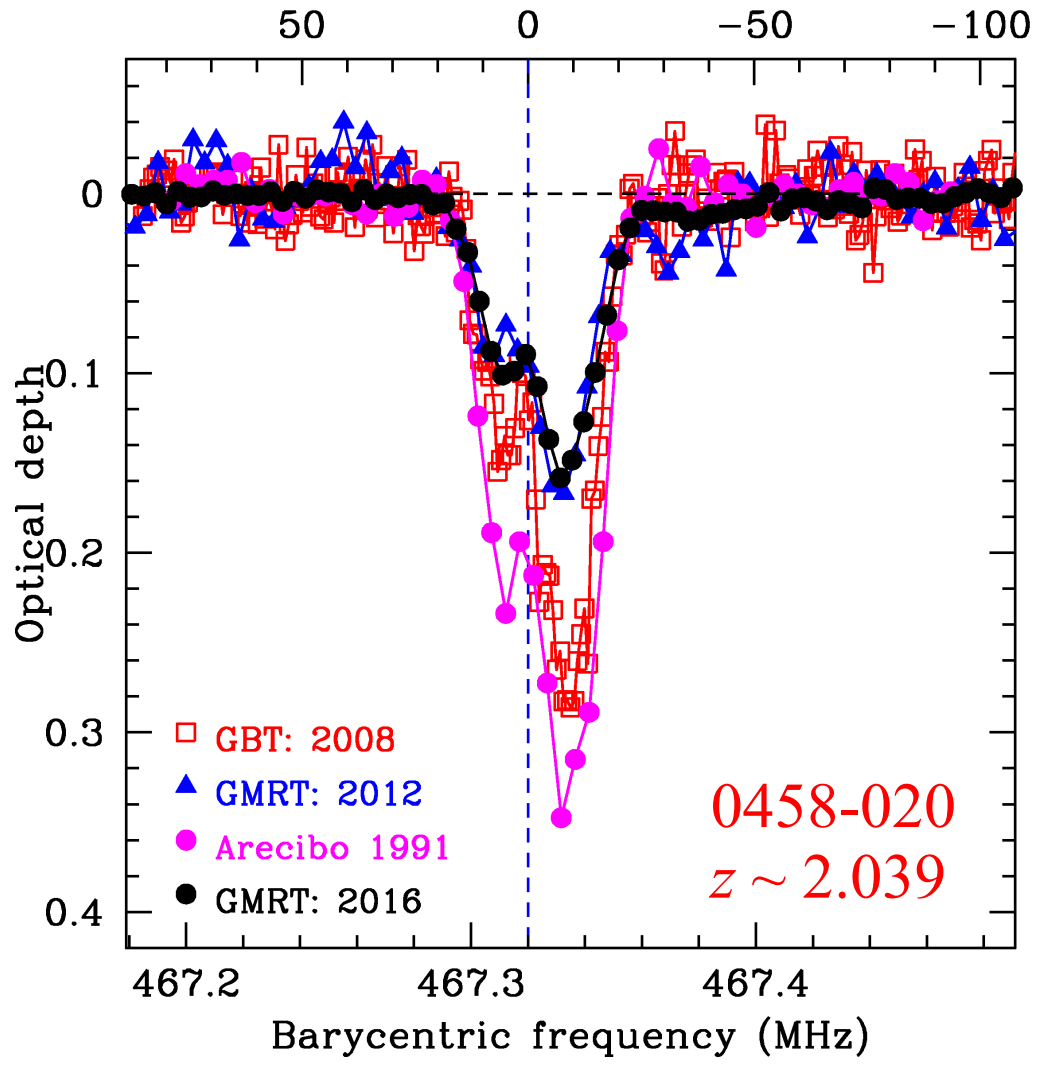


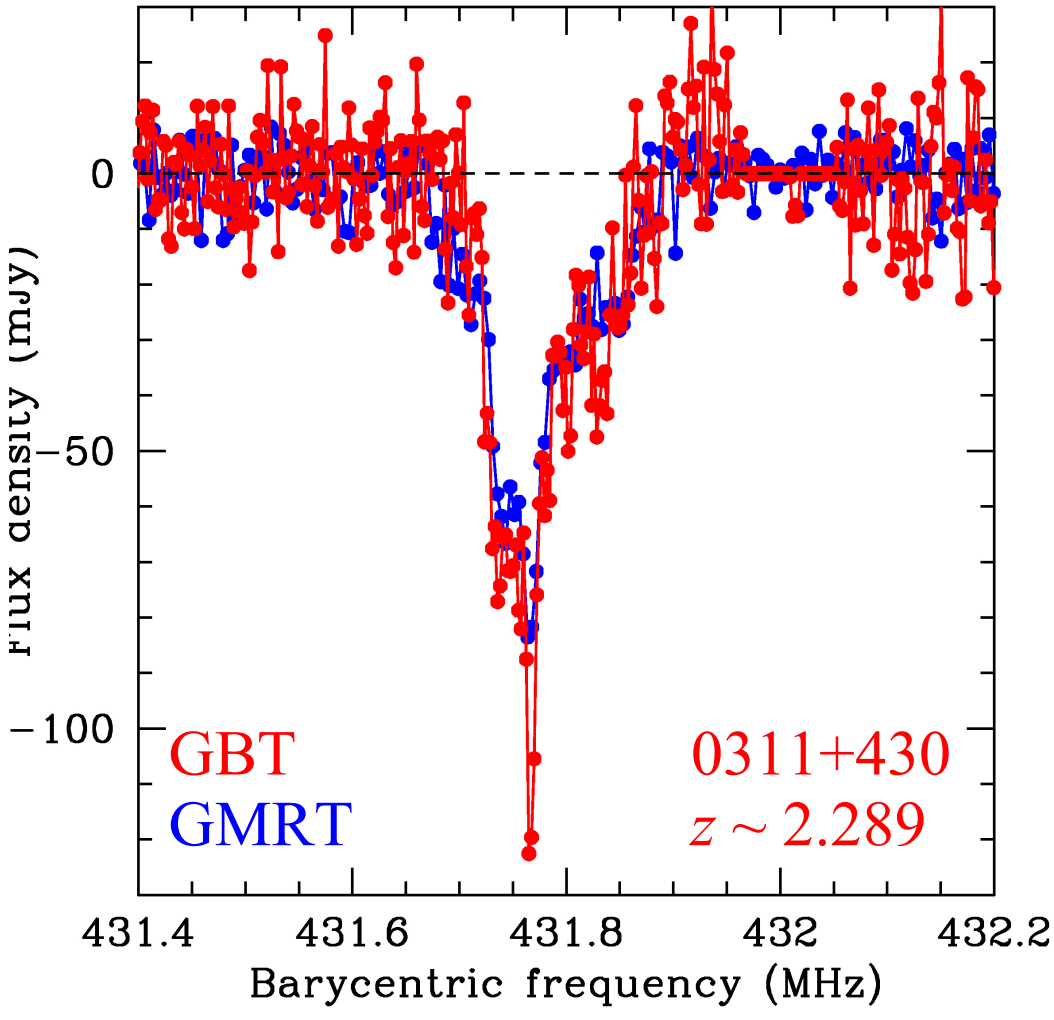


- 1000 – 1400 MHz search for redshifted HI 21cm & radio continuum emission from star-forming galaxies in the Extended Groth Strip.

- ~ 100 hours of data processed so far; RMS noise ~2.7 μJy!

Spectral Lines: 250 – 500 MHz

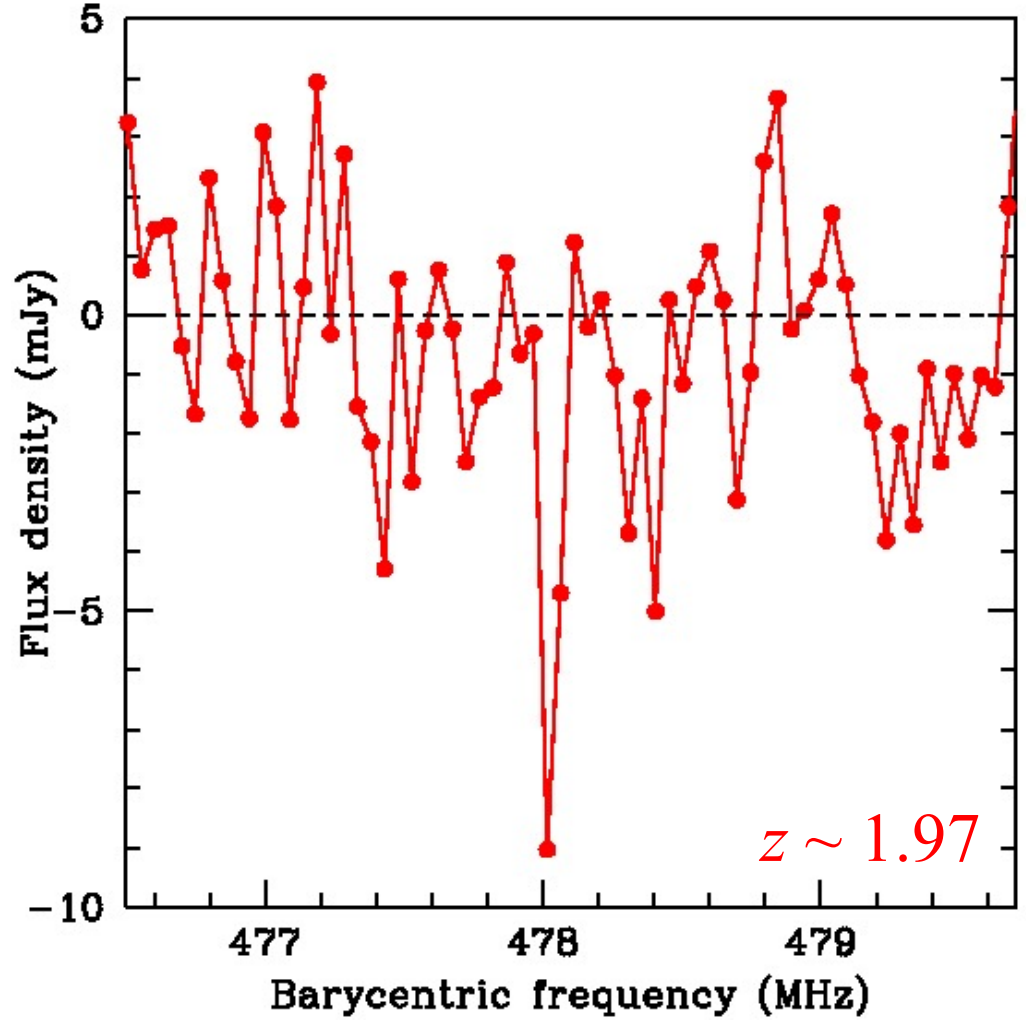


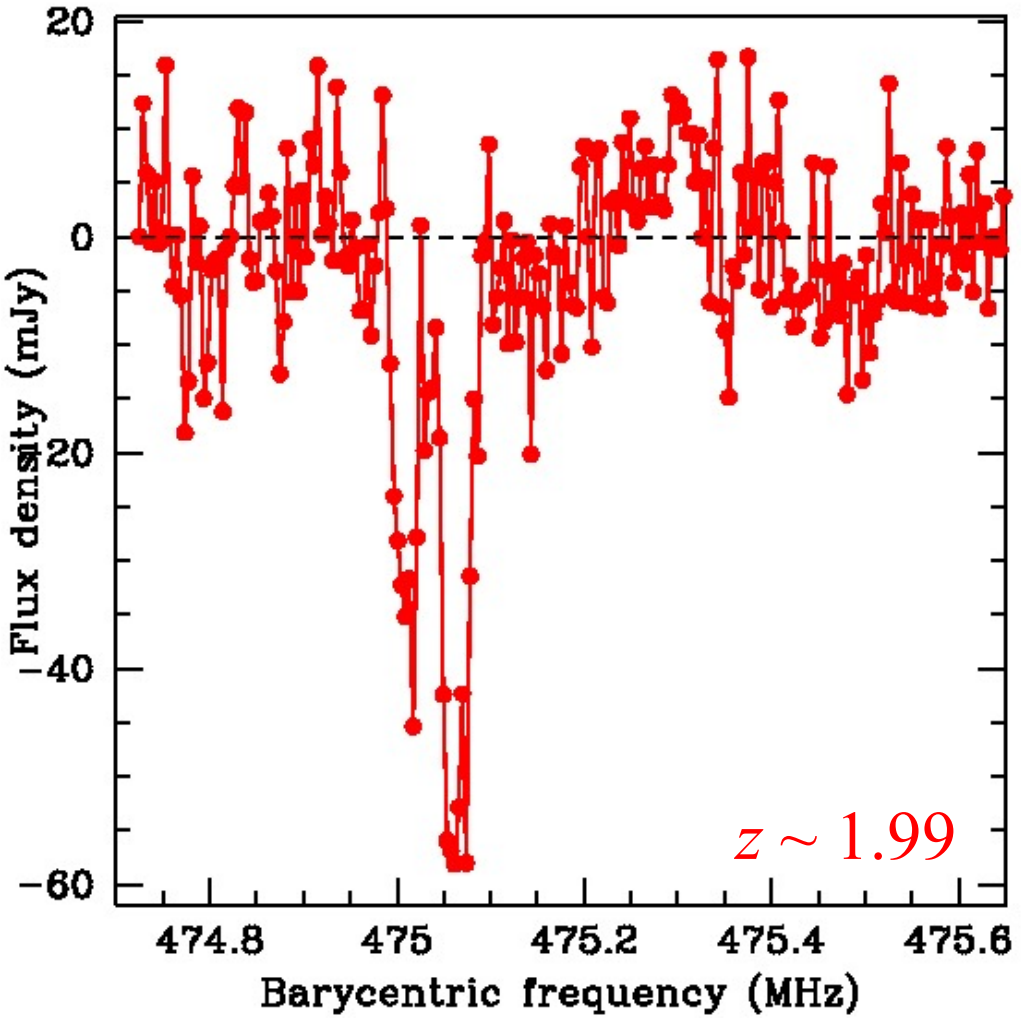


(Wolfe et al. 1985, ApJ; York et al. 2007, MNRAS)

- Re-detections of all known HI 21cm absorbers at $z \sim 1.9 - 2.7$: Curious evidence for variability in two sources so far.

SPECTRAL LINES: 250 – 500 MHz

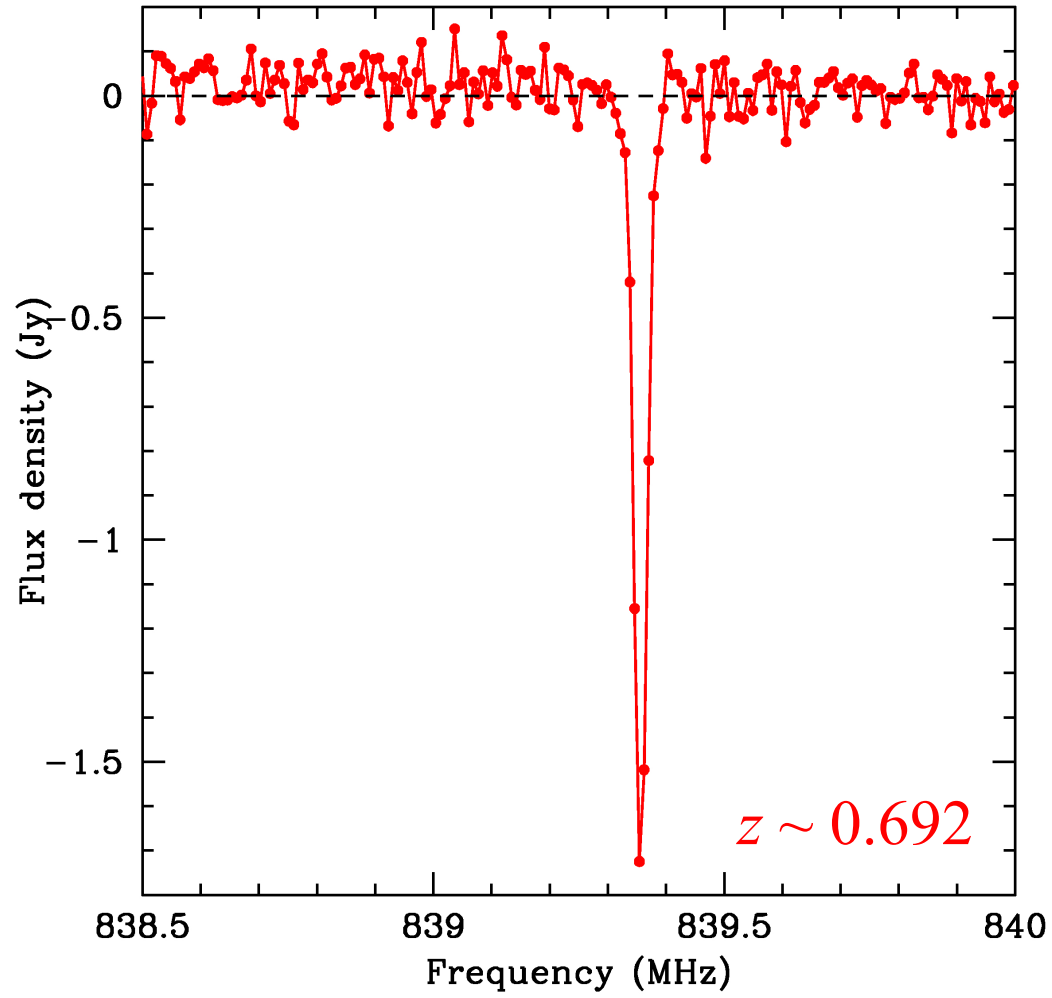


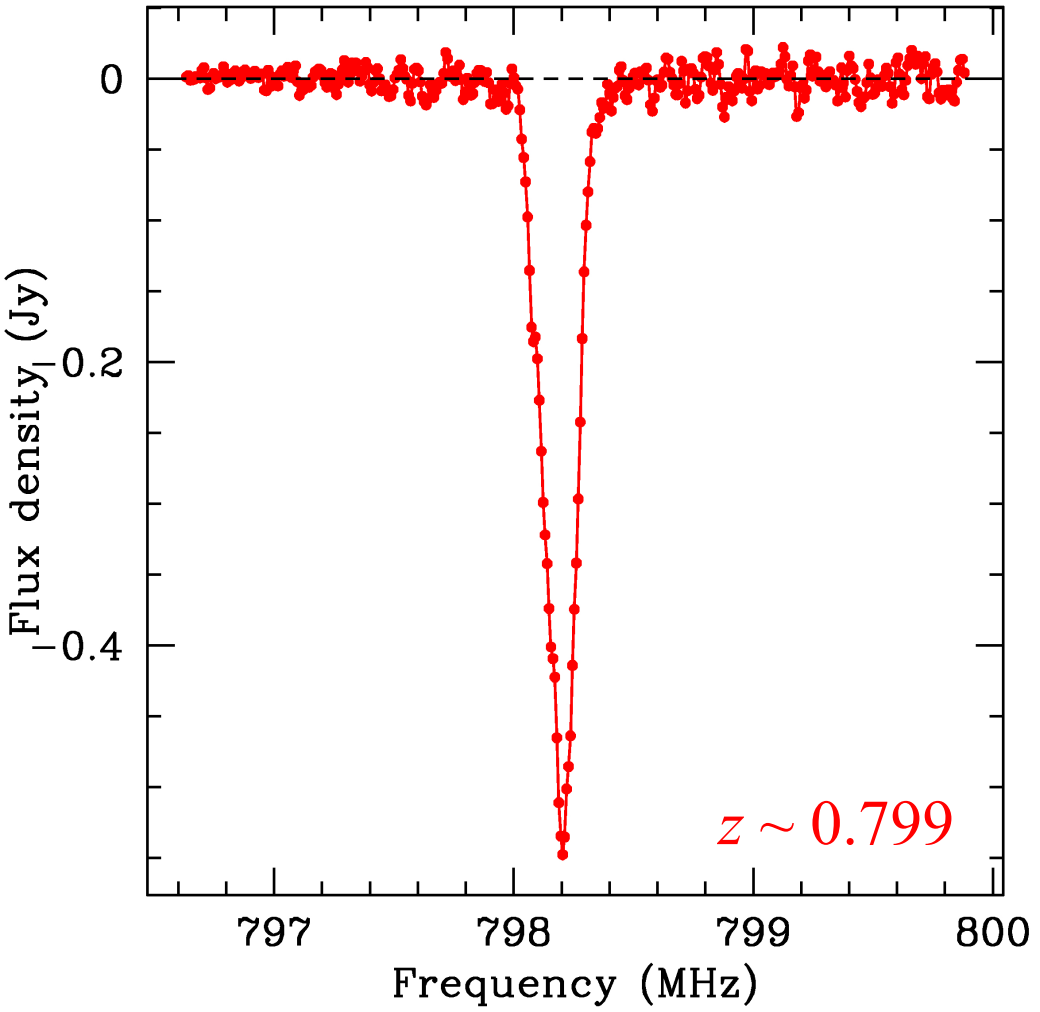


(NK 2014, ApJL)

- New detections of redshifted HI 21cm absorption in DLAs at $z \sim 2$!

SPECTRAL LINES: 550 – 850 MHz



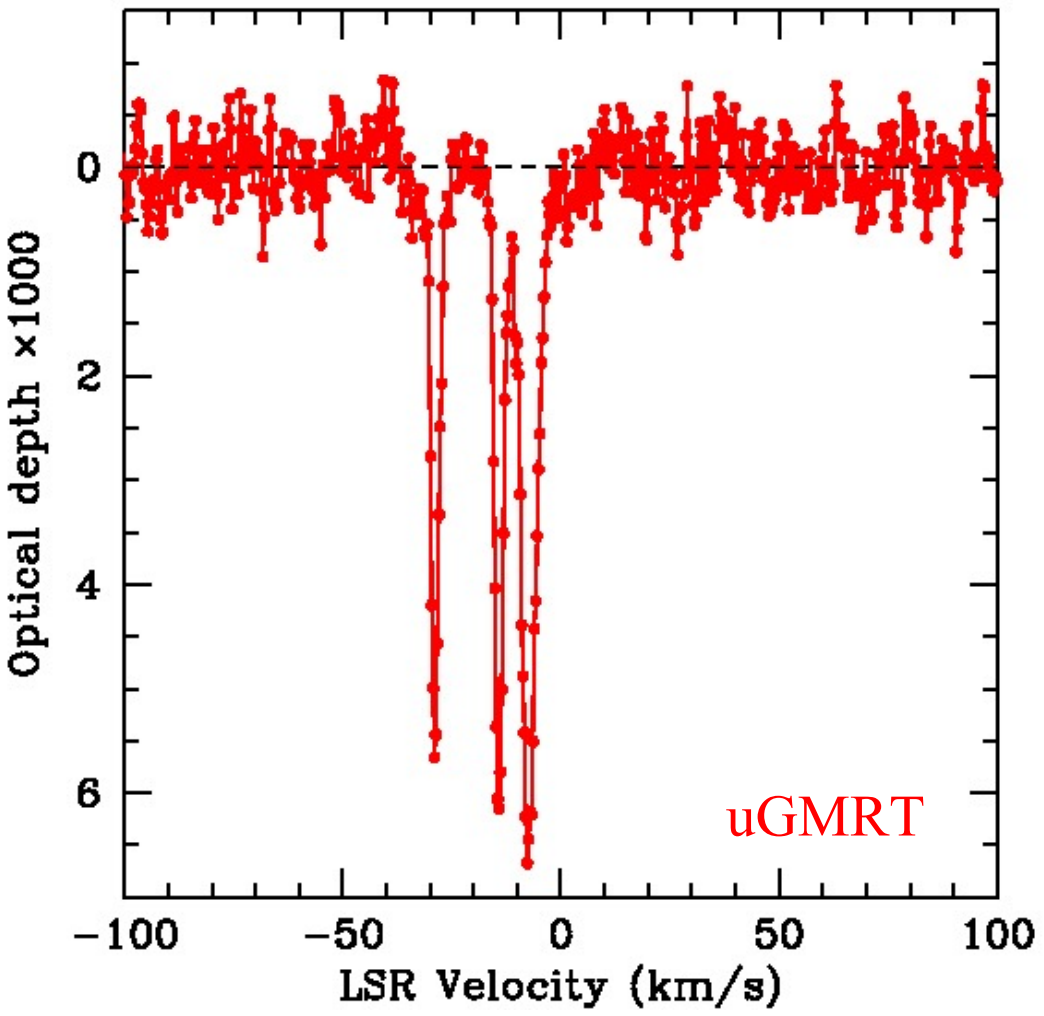


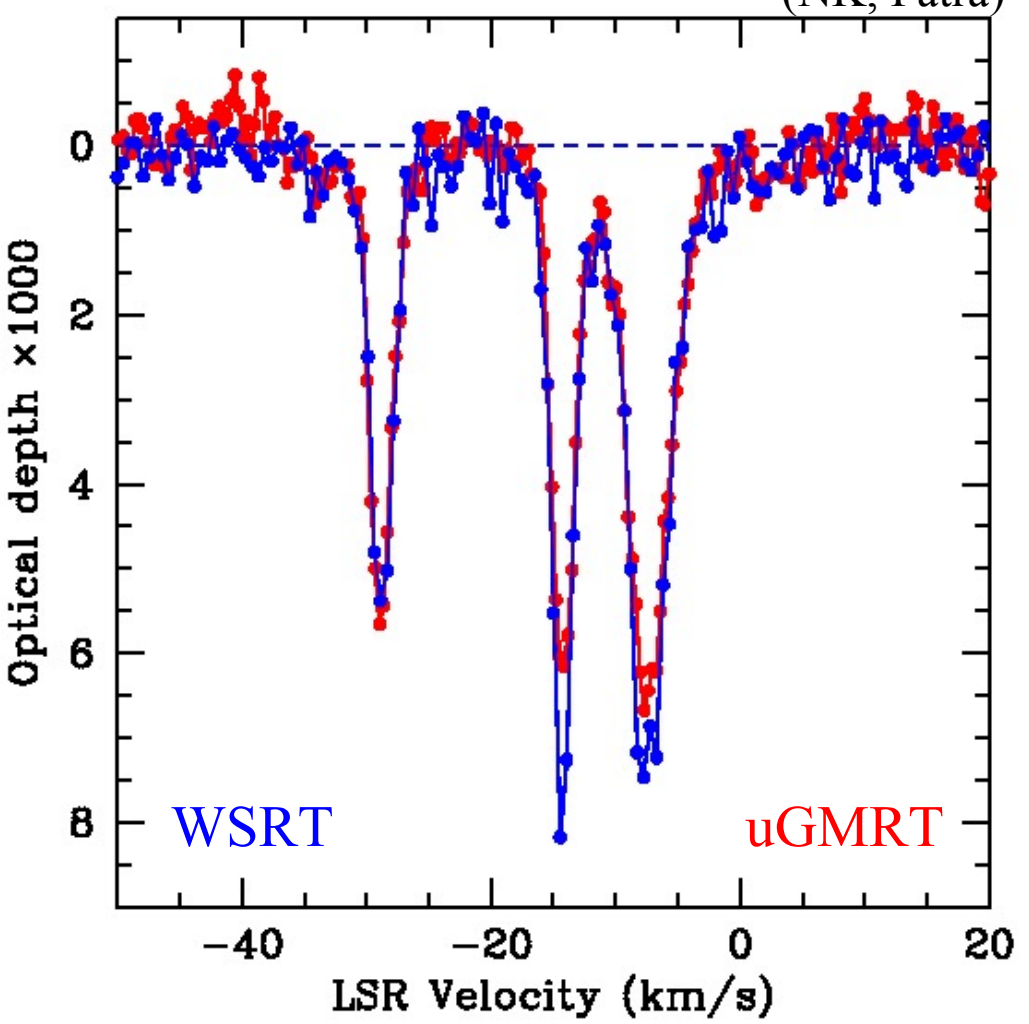
(Brown & Roberts 1973, ApJ; Darling et al. 2004, ApJL)

- Re-detections of known HI 21cm absorbers at $z \sim 0.7$, with 4 antennas and the new Band–4 receivers!

SPECTRAL LINES: FREQUENCY SWITCHING

(NK, Patra)





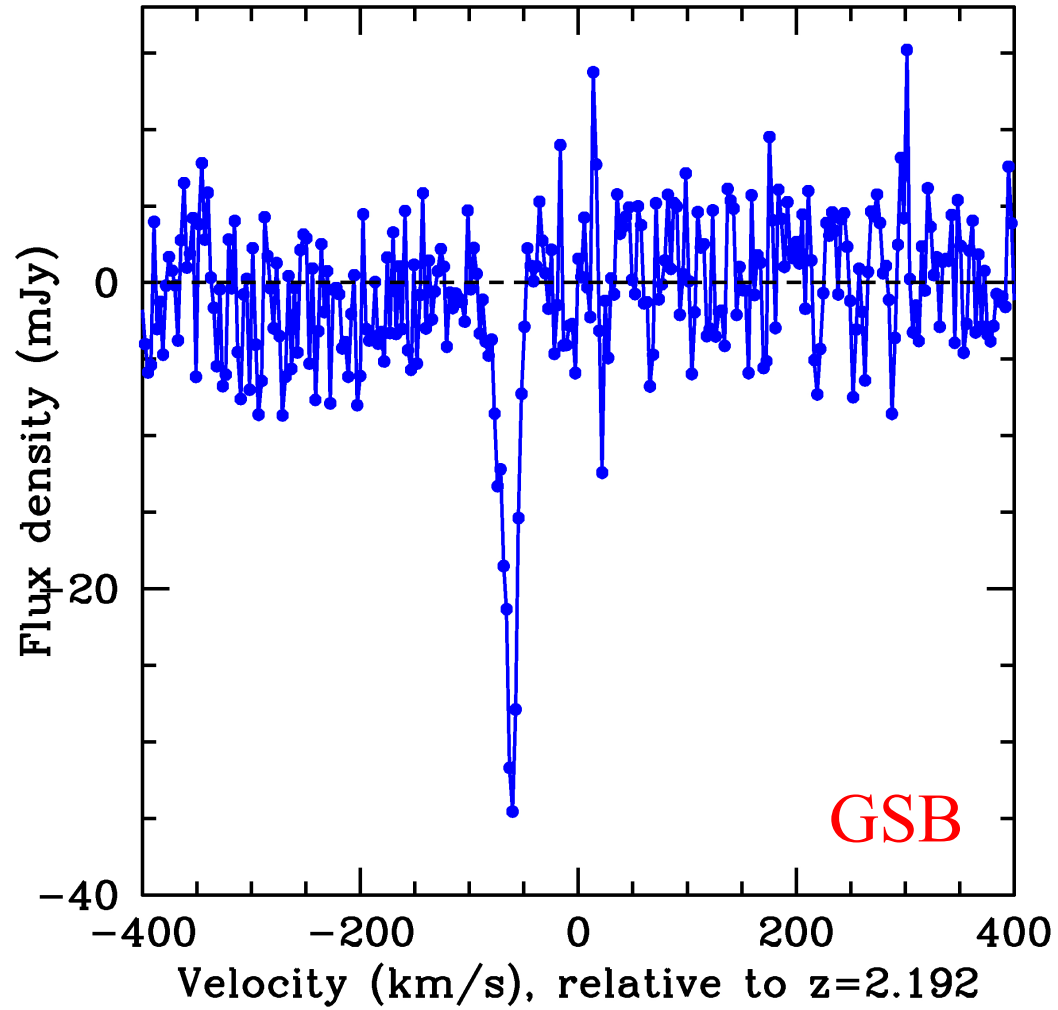
- First high-spectral resolution (0.3 km/s) uGMRT HI 21cm spectrum! Sensitivity in 5-hour observing run similar to that of the best-ever Galactic HI 21cm spectrum (using WSRT for ~ 24 hours!).

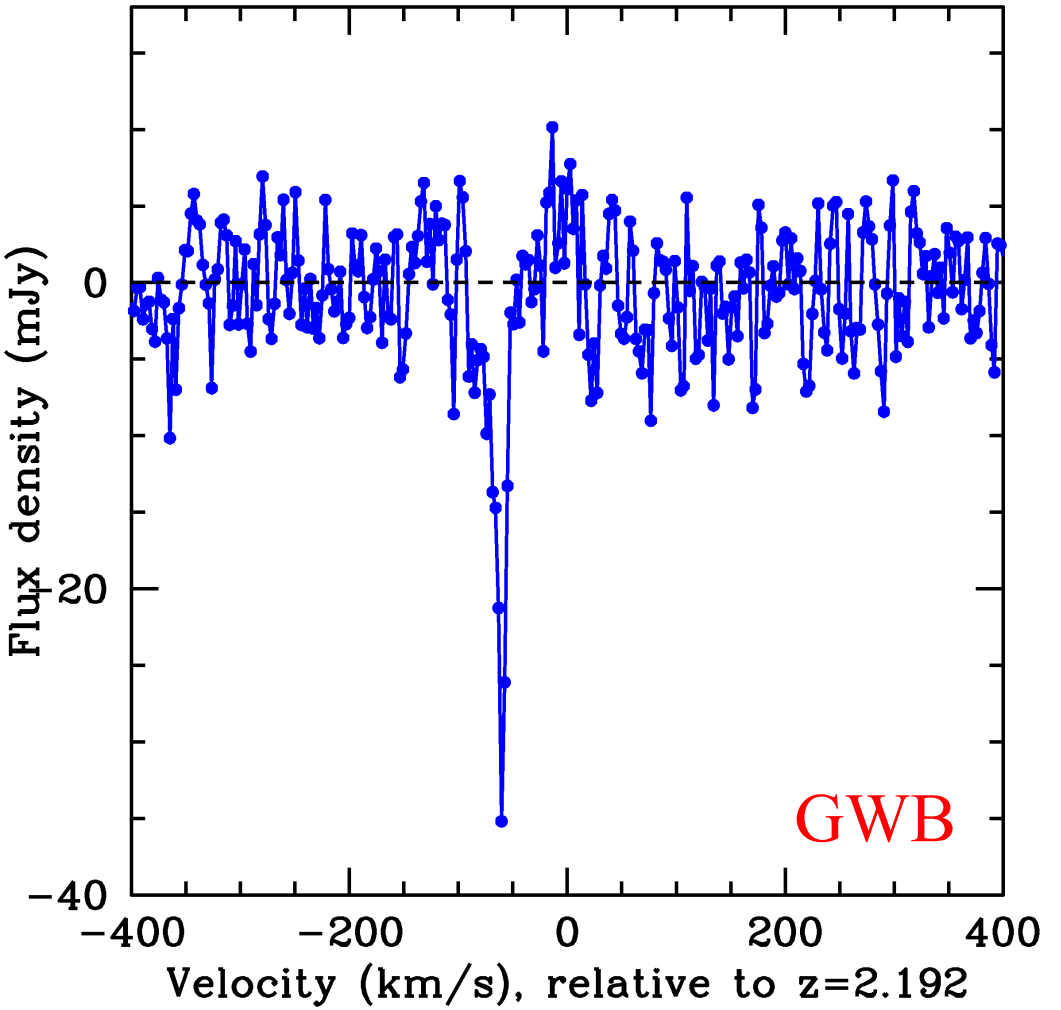
(Braun & NK 2005, A&A-Lett.)

- Clear changes in line profile: Small-scale structure in the cloud!

SPECTRAL LINES: ONLINE RFI MITIGATION

(Muley, Buch, NK)





- RFI spikes replaced by noise before correlation in the GWB data. No RFI mitigation in the *simultaneous* GSB data (daytime run).
- RMS noise in GWB spectrum 20% lower than in GSB spectrum.

SUMMARY

- The upgraded GMRT: New receivers at 125 – 250 MHz, 250 – 500 MHz, 550 – 850 MHz, and upgraded receivers at 1000 – 1450 MHz.
- New correlator, with bandwidth $\leqslant$ 400 MHz, and 16,384 channels.
- New correlator algorithms: Better data processing, RFI mitigation.
- Great uGMRT frequency coverage, and "benign" RFI environment ⇨ Superb instrument for spectral line studies, especially HI 21cm!
- Large uGMRT bandwidths, new algorithms, sensitivity ⇨ Deepest low-frequency images of deep fields!
- Challenges: Large data volumes; new algorithms for wide bands.
- Open for proposals since 2018. "Official" release in 2019!
- The Metrewavelength Sky – II: uGMRT conference in March 2019; See http://www.ncra.tifr.res.in/mwsky2 .