The Expanded Giant Metrewave Radio Telescope

Narendra Nath Patra

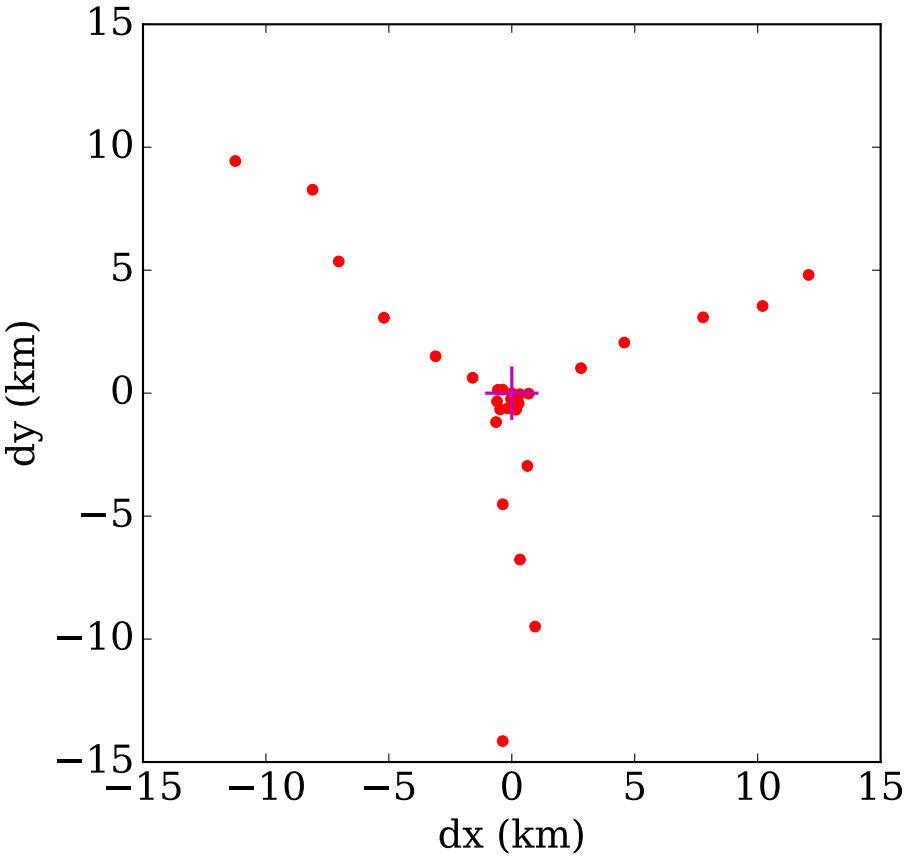
National Centre for Radio Astrophysics
Tata Institute of Fundamental Research

Nissim Kanekar
Jayaram N. Chengalur
Rohit Sharma
Mattieu deVilliers

Overview

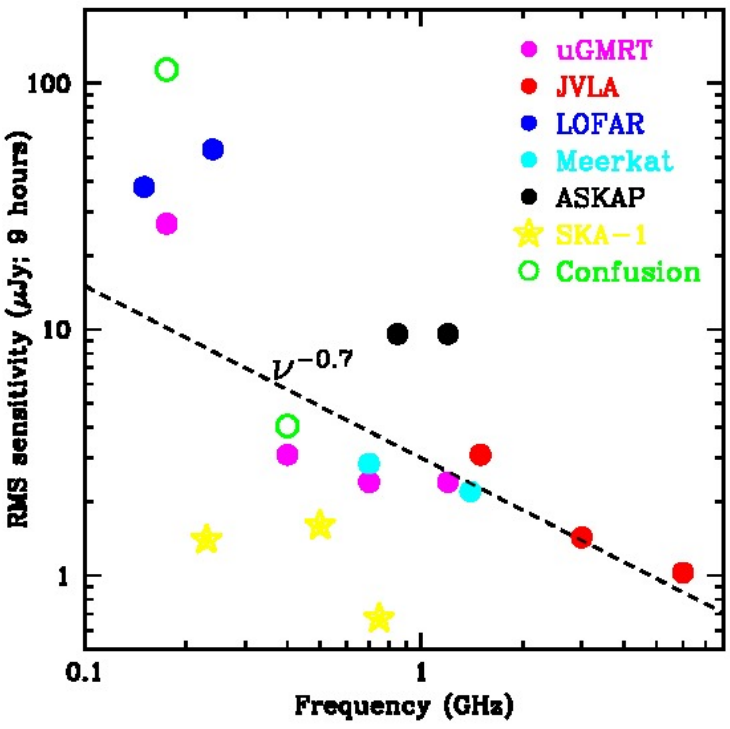
- The Giant Metrewave Radio Telescope today
- Scientific motivation for expansion
- Possible expansions strategies
  - Short baseline
  - Long baselines
  - Focal plane array
- Detecting HI-21cm line from cosmological distances
  - Using GMRT
  - Using GMRT with FPA
  - Using eGMRT without FPA
  - Using eGMRT with FPA
- Summary

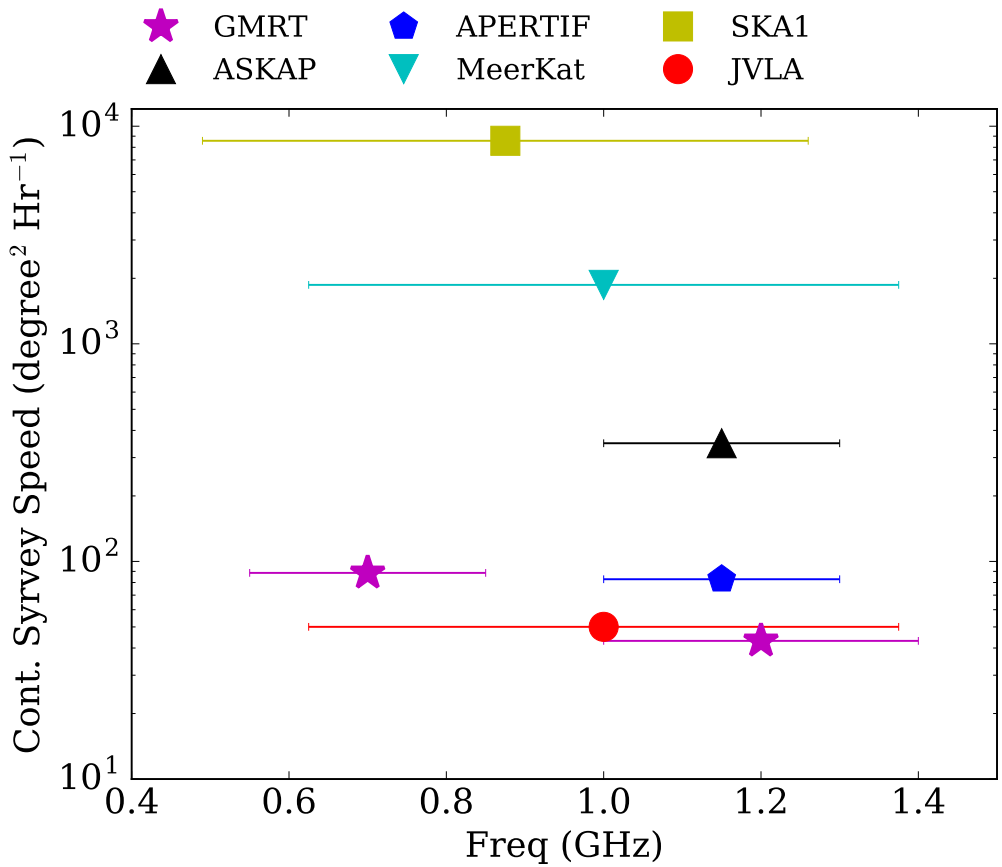
The GMRT today



- Thirty 45-m dishes.
- Max. baseline $\sim$ 25 km.
- Min. baseline $\sim$ 60 m.
- 14 antennas in a compact array.
- 16 antennas in ‘Y’ array.
- Freq: $\sim$ 125 MHz $-$ 1450 MHz.
- BW: 400 MHz, 16384 channels.
- Single pixel feeds.

Continuum Sensitivity and Survey Speed





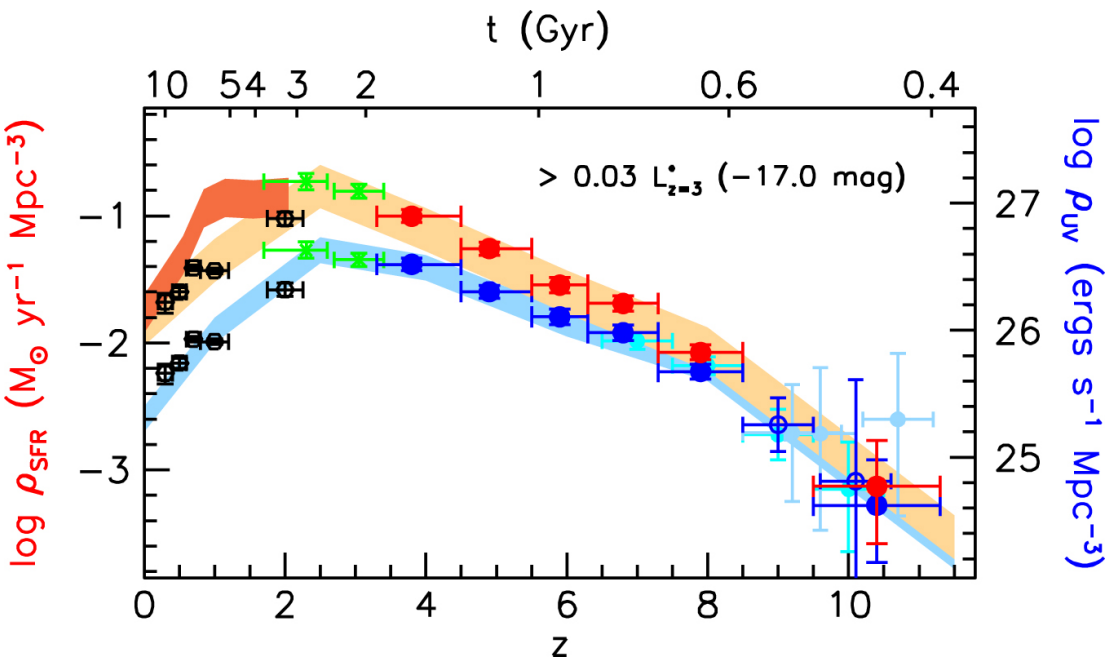
- Survey speed is defined as the area on the sky over which a target sensitivity (100 μJy) can be achieved in one hour observation. e.g. (Gupta et al. 2008)
- Continuum sensitivity calculated for 9 Hr observation.

Possible Expansion Routes

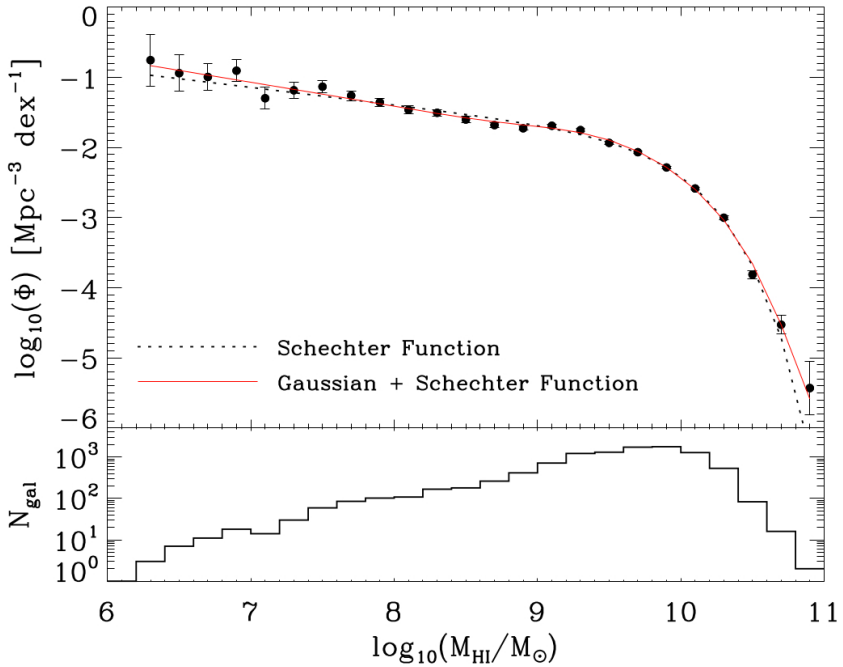
- Installing antennas at $\sim$ 50 km baselines
  - Currently confusion noise at 400 MHz $\sim$ 5 μJy
  - With $\sim$ 50 km baselines confusion noise $\sim$ 0.2 μJy

  (Condon et al. 2012)
- Increasing the number of short baselines
  - To image complex galactic fields with high fidelity
  - Improve HI-21cm sensitivity
- Focal plane array
  - Increase the speed of continuum, line and pulsar surveys
- Gaussian beam over a wide range of baselines
  - 0.5 km $\rightarrow$ 1.8 km $\rightarrow$ 5 km $\rightarrow$ 50 km

Detecting HI-21cm emission at $0.1 \lesssim z \lesssim 1.5$



(Bouwens et al. 2014)



Martin et al. (2010)

- Individual HI-21cm detections to probe the nature and evolution of gas in galaxies.
- Trace evolution of HI mass function as a function of z.
- Estimate cosmological gas mass density Ω_{HI} at high z.
- HI in emission detected from highest $z \sim 0.376$

(Fernandez et al. 2016)

Method used to calculate HI detection rate - I

- Straw-man model for eGMRT
  - 30 new antennas at baselines $\lesssim$ 5 km
  - FPA feeds with 30 beams on the sky
  - BW: 300 MHz, Velocity resolution: 300 km/s
  - Observing frequencies
    - 1000 - 1300 MHz ($0.1 \leq z \leq 0.4$)
    - 550 - 850 MHz ($0.7 \leq z \leq 1.5$)

1. GMRT + FPA
2. eGMRT
3. eGMRT + FPA

Method used to calculate HI detection rate - II

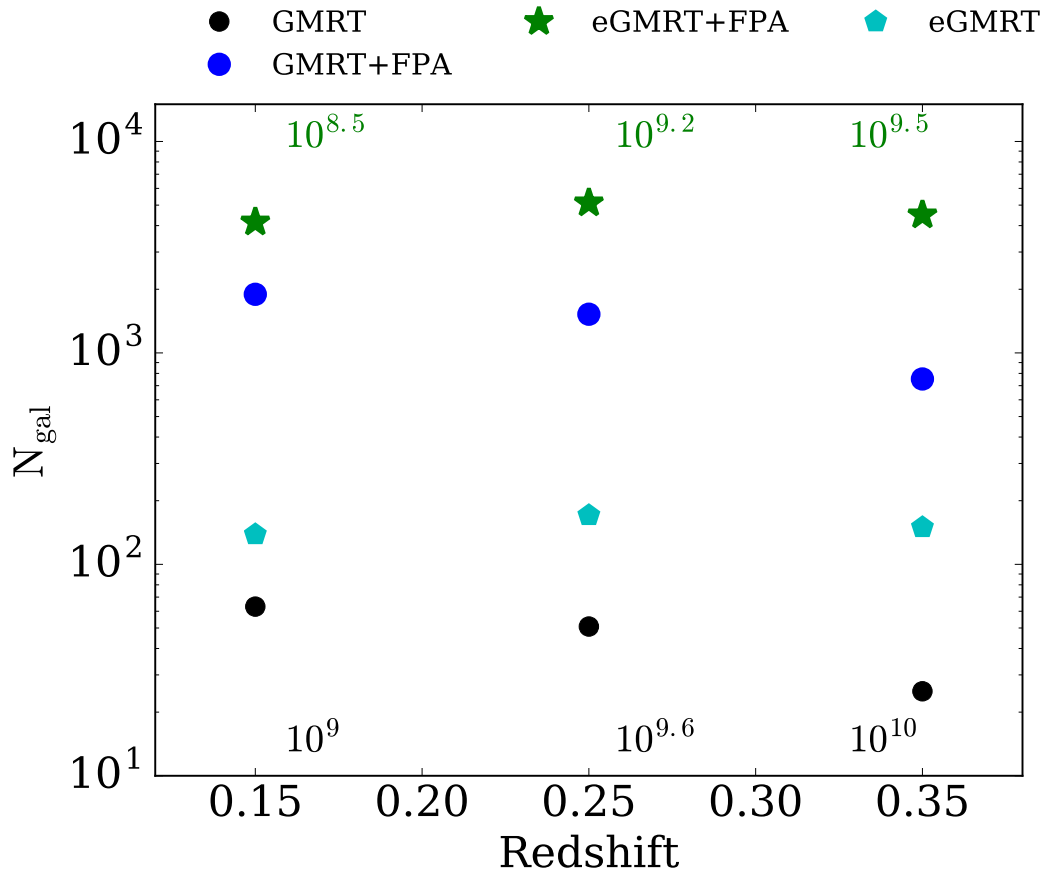
Assumptions:

- Used an unchanging HI mass function of $z \sim 0$ (from ALFALFA survey) up to $z \sim 0.4$ (Martin et al. 2010)
- For higher z calculations, we used luminosity function of optically selected star forming galaxies (DEEP2 survey) Willmer et al. (2006)
- We assumed a local $M_{HI}/L_B \sim 0.3$

At every HI mass bin, size of a galaxy was calculated using Mass-size relation and optimum baselines were selected to cover the angular extent of the galaxy.

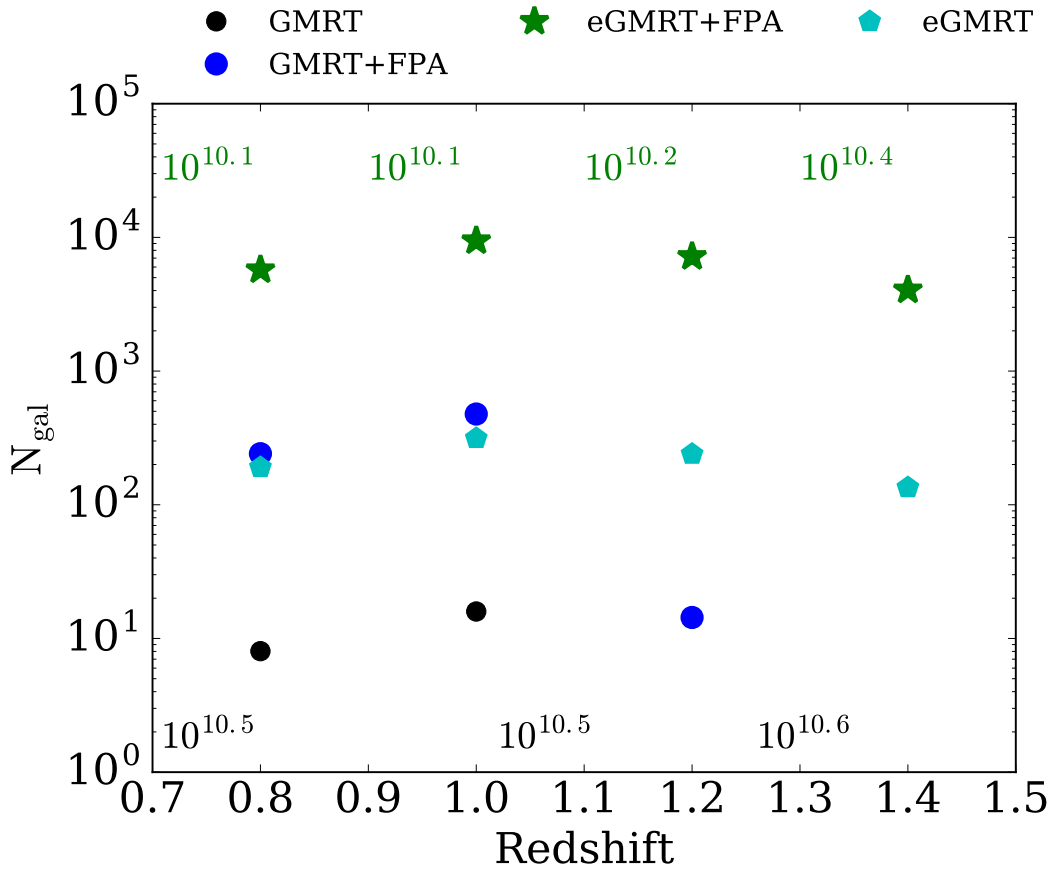
Wang et al. (2016)

HI detection rate at $z \sim 0.1 - 0.4$



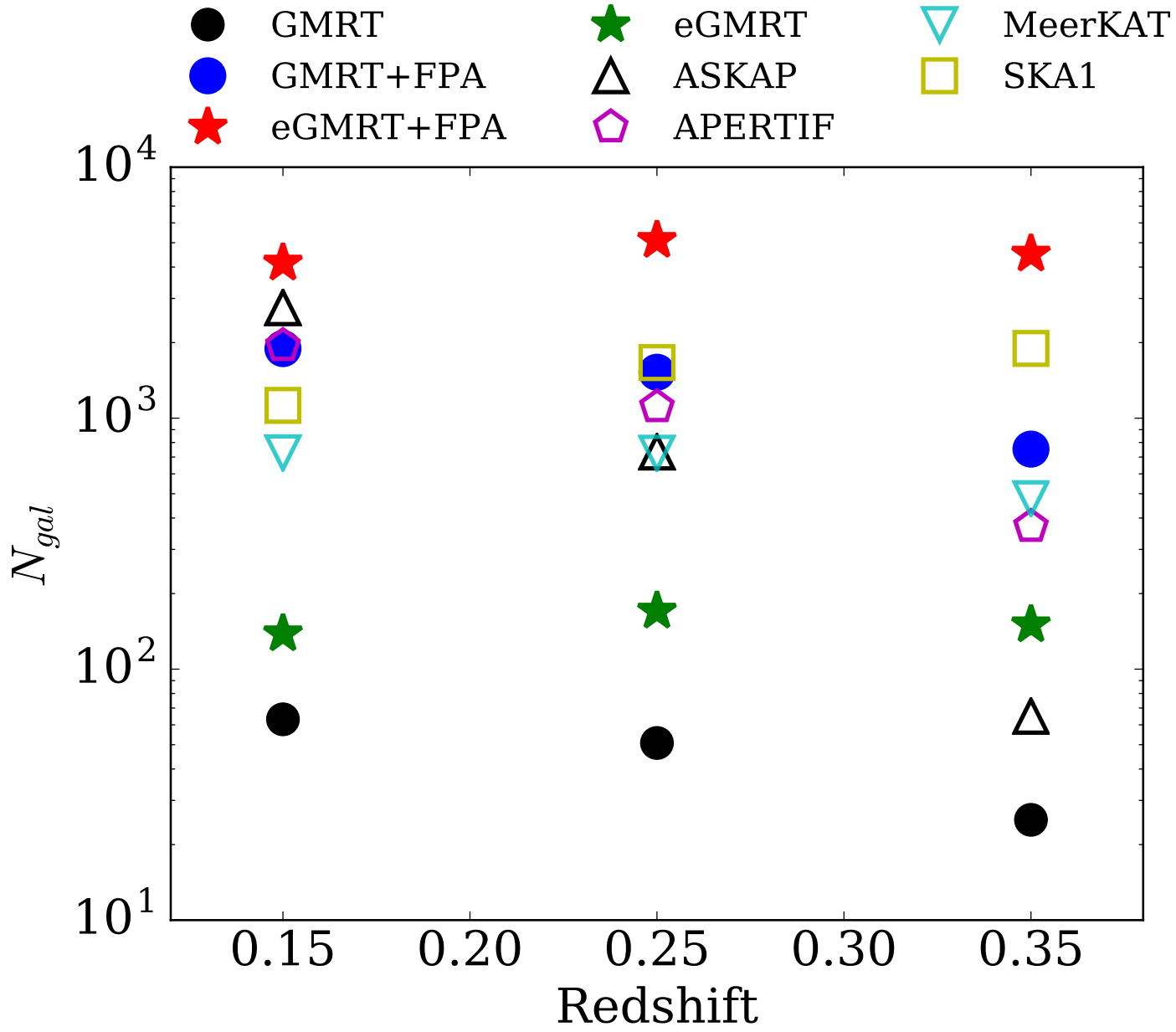
- Local HI mass function, 200 Hrs of integration
- HI detection limits GMRT: ($\mathbf{10^9}$, $\mathbf{10^{9.6}}$, $\mathbf{10^{10}M_\odot}$)
- HI detection limits eGMRT: ($\mathbf{10^{8.5}}$, $\mathbf{10^{9.2}}$, $\mathbf{10^{9.5}M_\odot}$)
- Knee of the HI mass function $\sim \mathbf{10^{9.9}}$ $\mathbf{M_\odot}$

HIdetection rate at $z \sim 0.7 - 1.5$

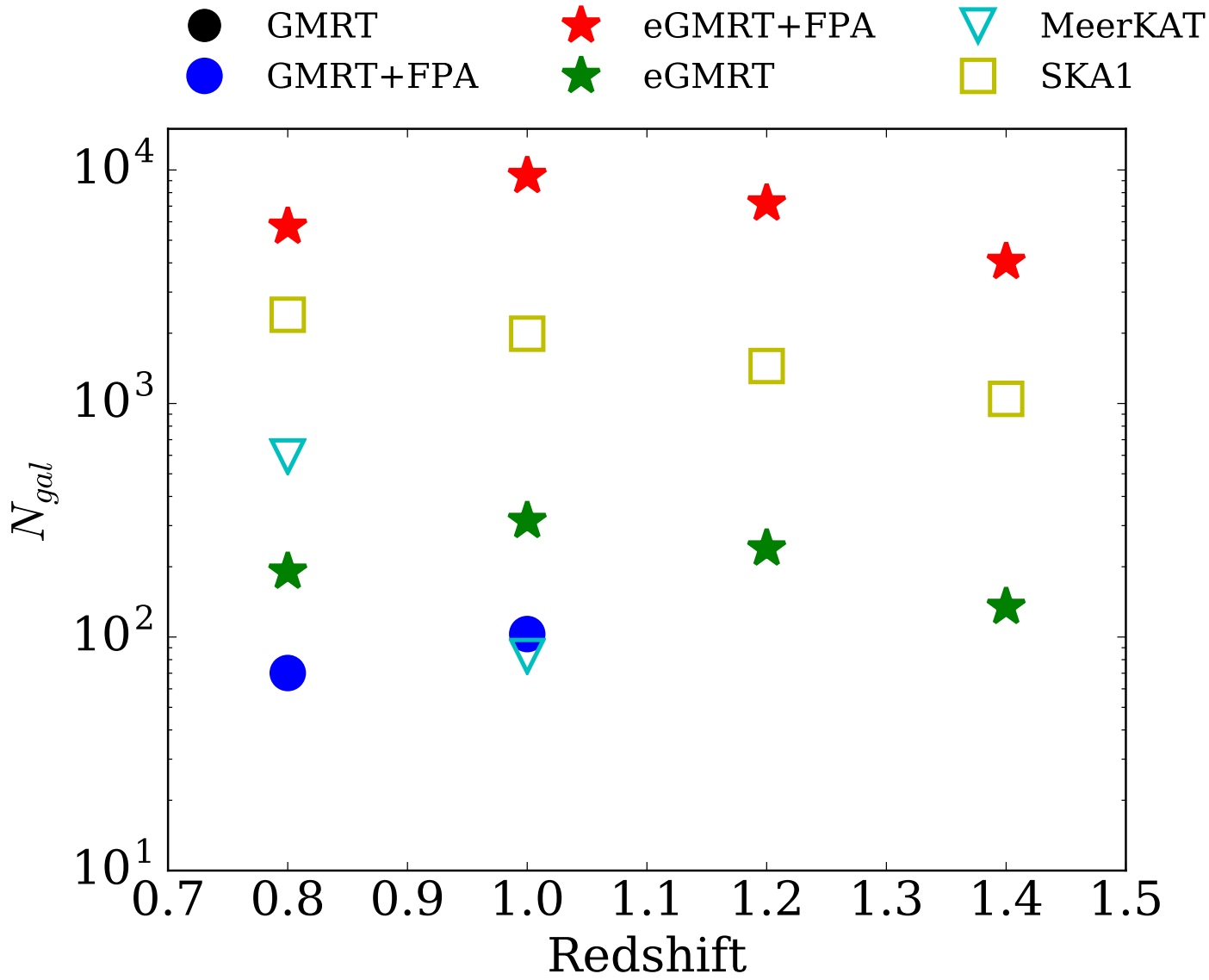


- Luminosity function, 1000 Hrs of integration
- HI detection limits GMRT: ($\mathbf{10^{10.5}}$, $\mathbf{10^{10.5}}$, $\mathbf{10^{10.6}M_\odot}$)
- eGMRT: ($\mathbf{10^{10.1}}$, $\mathbf{10^{10.1}}$, $\mathbf{10^{10.2}}$, $\mathbf{10^{10.4}M_\odot}$)
- Knee of the HI mass function $\sim \mathbf{10^{10.3}}$ $\mathbf{M_\odot}$

Comparison with other facilities ($z \sim 0.1 - 0.4$)



Comparison with other facilities ($z \sim 0.7 - 1.5$)



Summary

- Possible expansions of the GMRT
  - Long baselines $\sim$ 50 km : reduce confusion noise
  - Short baselines : improve UV coverage
  - Focal Plane Array : increase survey speed
- Used straw-man eGMRT model with 30 new antennas and/or FPAs to estimate the HI-21cm emission detections at $z \lesssim 1.5$
- $0.1 \leq z \leq 0.4$ (200 Hrs) and $0.7 \leq z \leq 1.5$ (1000 Hrs)
- eGMRT : $\sim$ few hundred, $\sim$ few hundred
- GMRT+FPA : $\sim$ few thousand, $\sim$ few hundred
- eGMRT+FPA : ~ 15000, $\gtrsim 20000$
- In terms of HI detections in an HI-21cm survey at $z \lesssim 1.5$, eGMRT will outperform any existing or planned telescope.