

Neutral hydrogen intensity mapping on Mpc scales with MeerKAT interferometer

Sourabh Paul

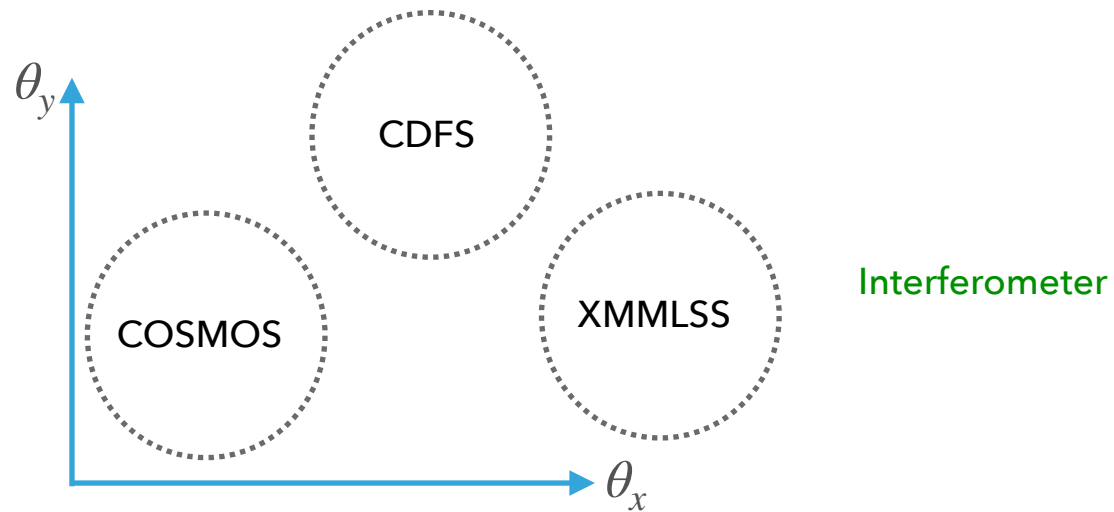
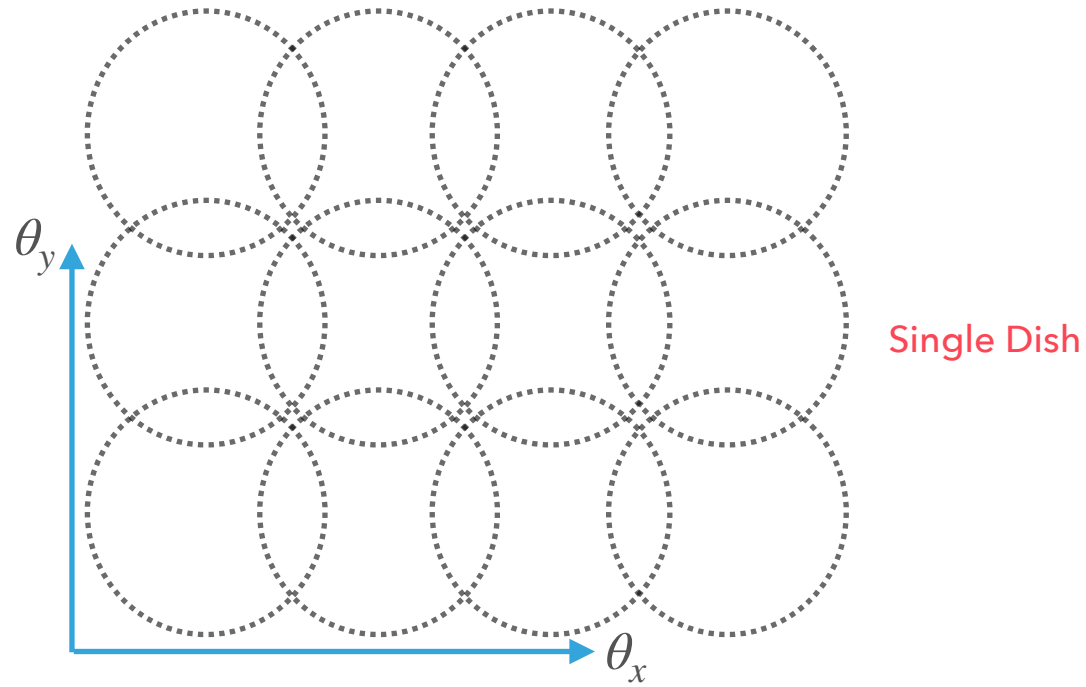
Jodrell Bank Centre for Astrophysics

The University of Manchester

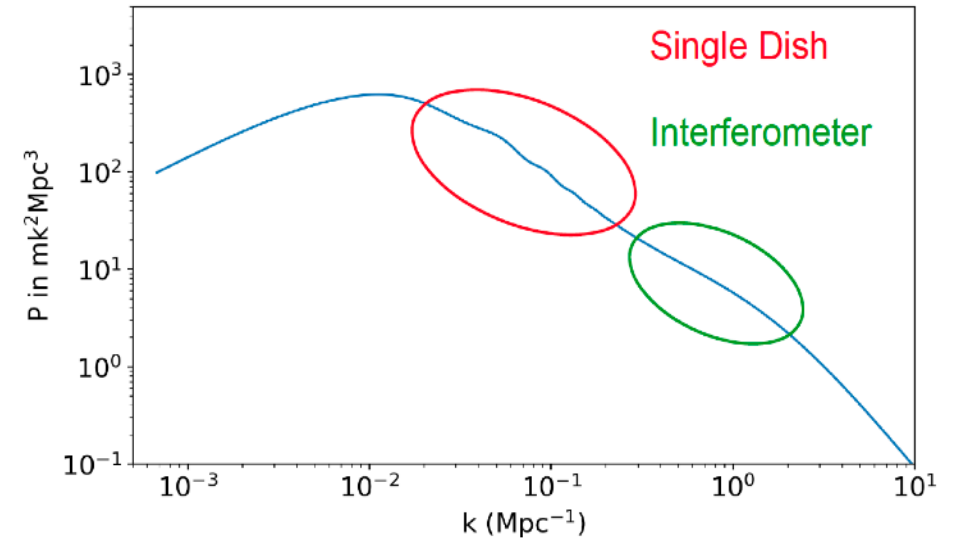
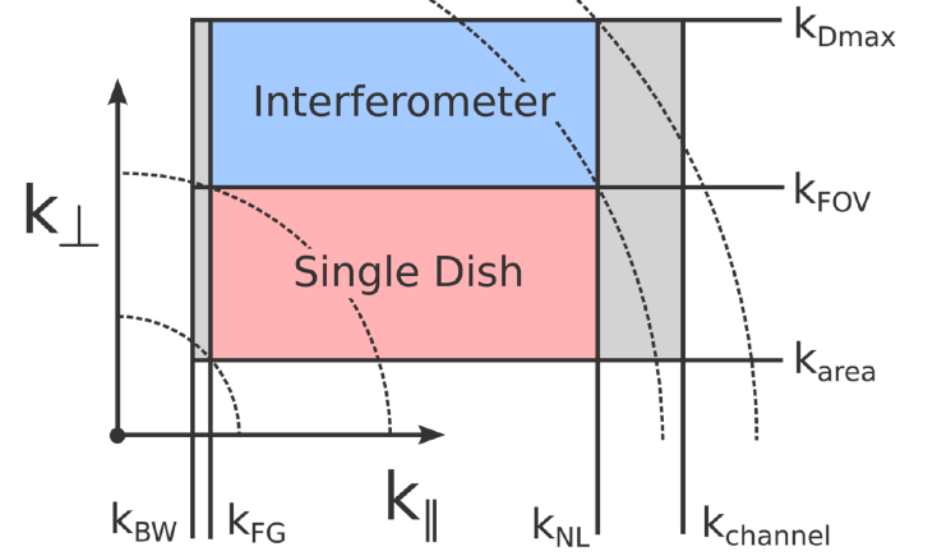
Cosmology in the Alps 2024



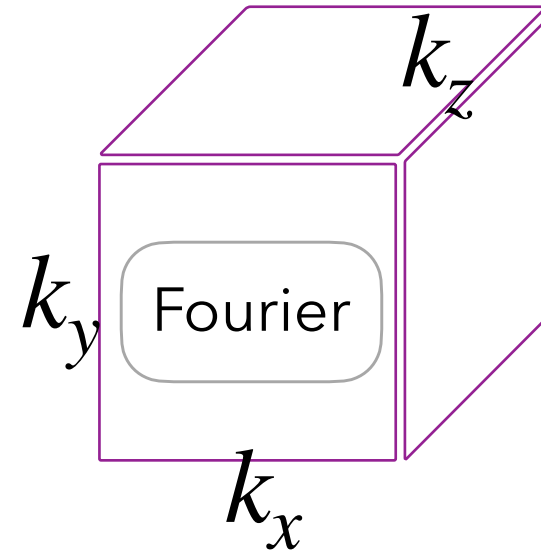
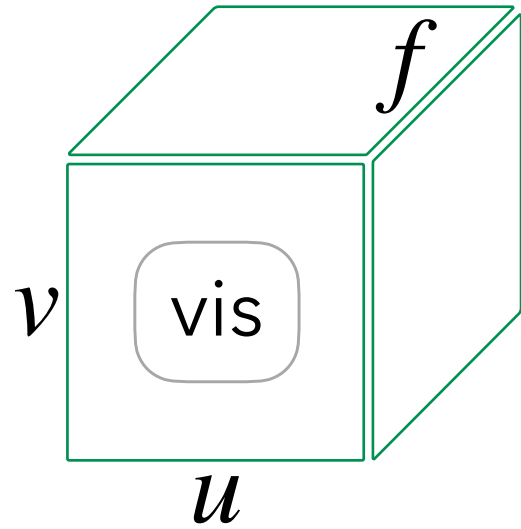
Single Dish & Interferometric IM (MeerKAT)



(Bull et al. 2015)



Power Spectrum from visibility data

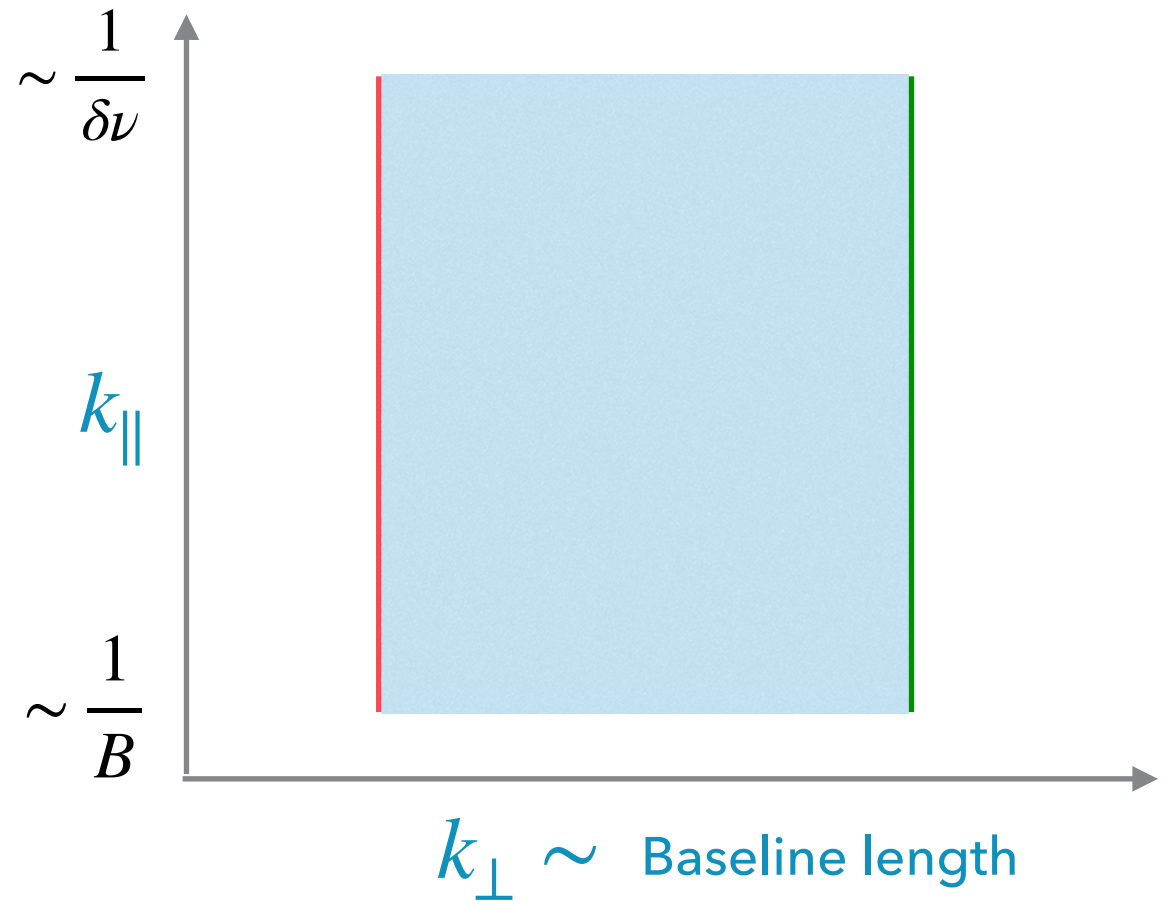
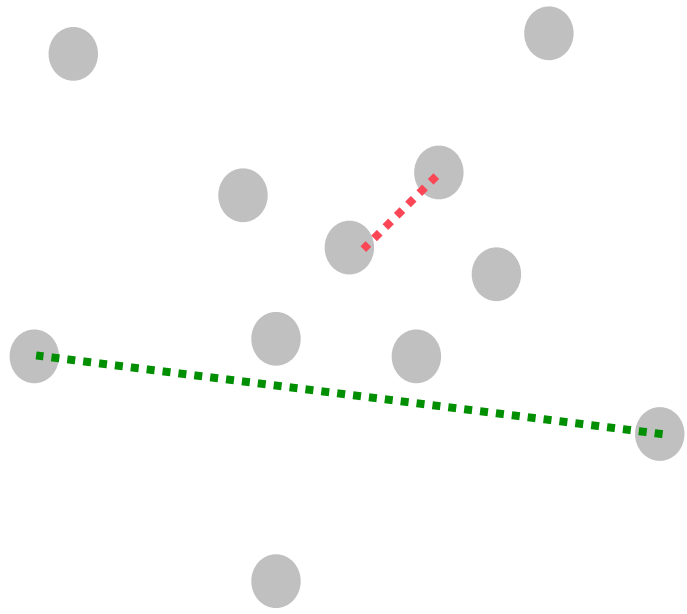


$$k_x = \frac{2\pi}{R}u; \quad k_y = \frac{2\pi}{R}v; \quad k_{\parallel} = \frac{2\pi\nu_{21}H_0E(z)}{c(1+z)^2}\tau$$

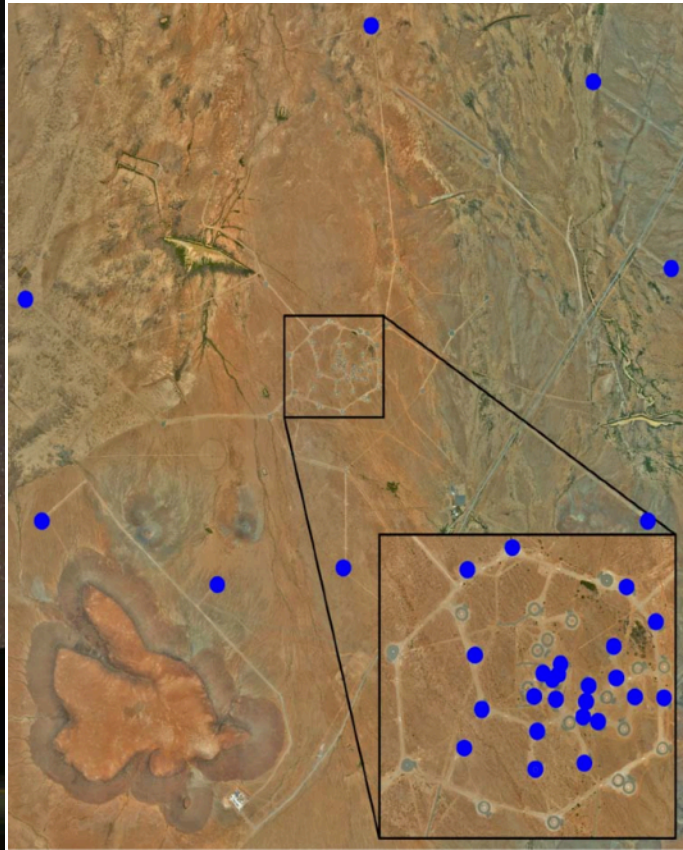
Delay PS

$$P(k_{\perp}, k_{\parallel}) \equiv \frac{A_e}{\lambda^2 B} \frac{R^2 \Delta R}{B} |V(u, v, \tau)|^2 \left(\frac{\lambda^2}{2k_B} \right)^2$$

Power Spectrum from visibility data



MeerKAT Radio telescope



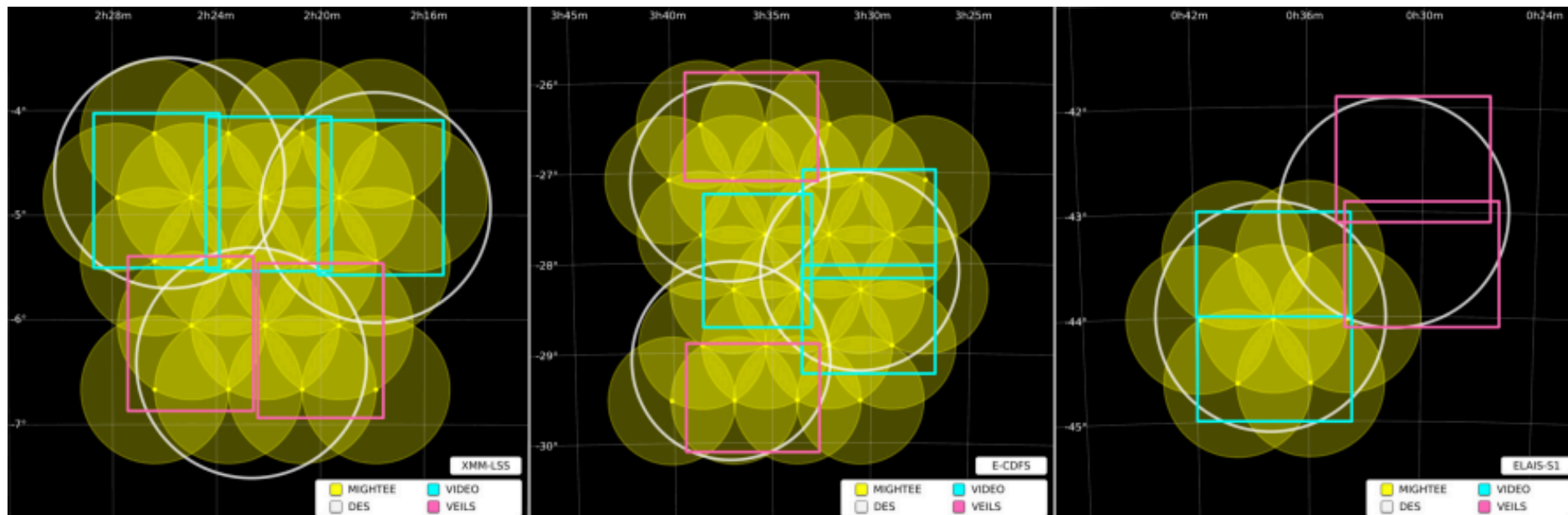
- MeerKAT, precursor to SKA, managed by SARAO. Located in the Karoo region, South Africa.
- 64 dish antennas of 13.5 meter diameter.
- Central core region of 1km houses 48 antennas, other 16 antennas are distributed upto a radius of 4km from the center.
- Dense core facilitates higher sensitivity at low k_{\perp} modes.
- L-band range: 856 ~ 1712 MHz.
- UHF-band range: 544 ~ 1087 MHz.



MIGHTEE

(MeerKAT International GHz Tiered Extragalactic Exploration)

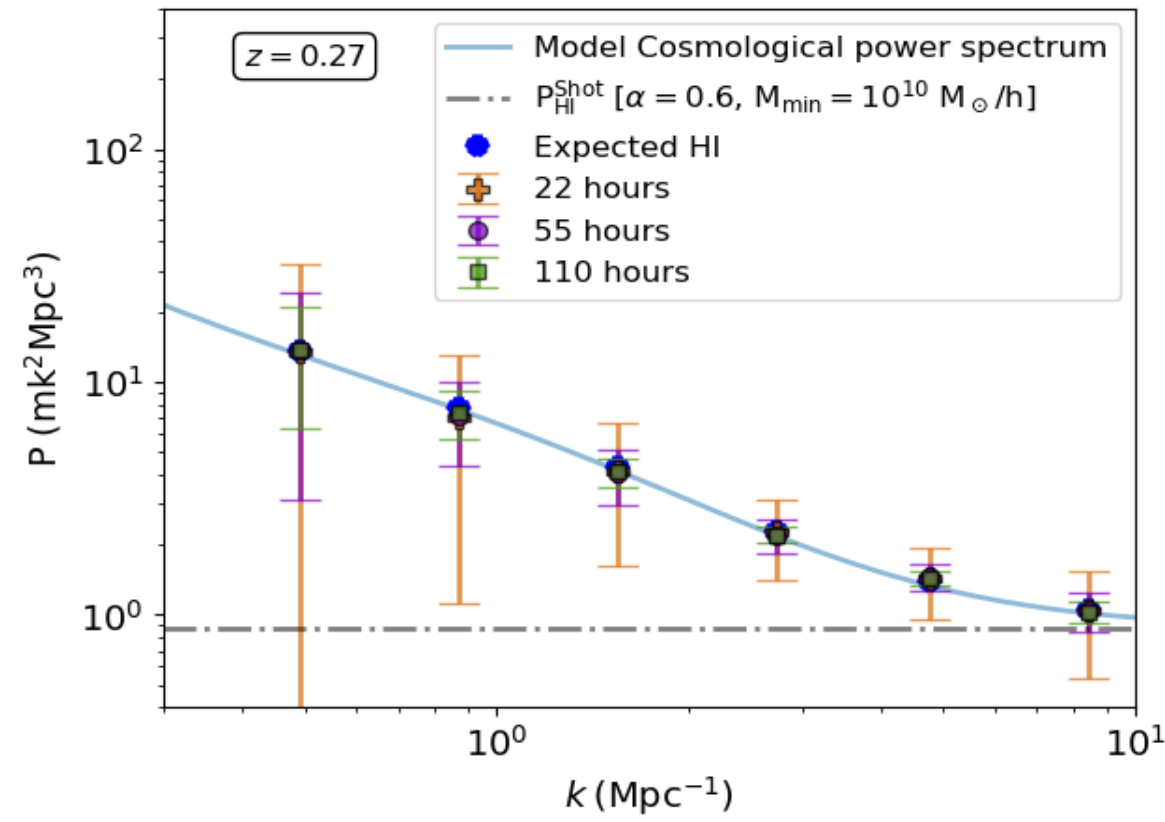
- 20 square deg sky area, L and UHF bands
- COSMOS, CDFS, XMMLSS, ELAIS-S1, ~ few thousand hours



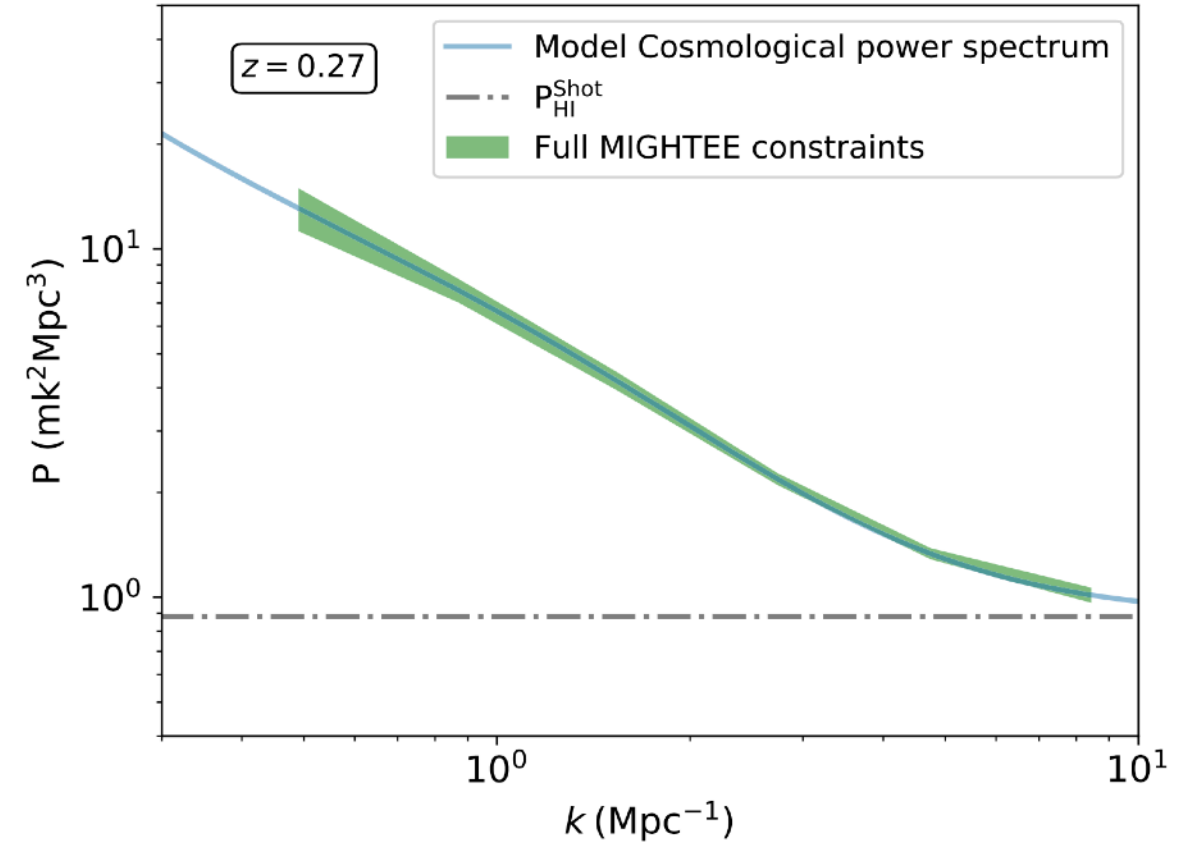
XMMLSS

CDFS

ELAIS-S1



Expected constraints on HI PS with MIGHTEE (COSMOS)



Full MIGHTEE (COSMOS, CDFS, XMM-LSS, ELAIS-S1)
20 square degrees, ~ 1000 hrs observation time

HI intensity mapping with the MIGHTEE survey: power spectrum estimates
Paul, Santos et al., 2021, MNRAS, 505, 2, 2039

Long integration time, avoid bright foreground sources

Data used ~ 96 hrs (9 observing sessions, > 58 antennas)

J2000 $\alpha = 04^{\text{h}}13^{\text{m}}26.4^{\text{s}}$, $\delta = -80^{\circ}0'0''$

Time resolution: 8s

Frequency resolution: 0.209MHz

Calibration: processMeerKAT + selfcals

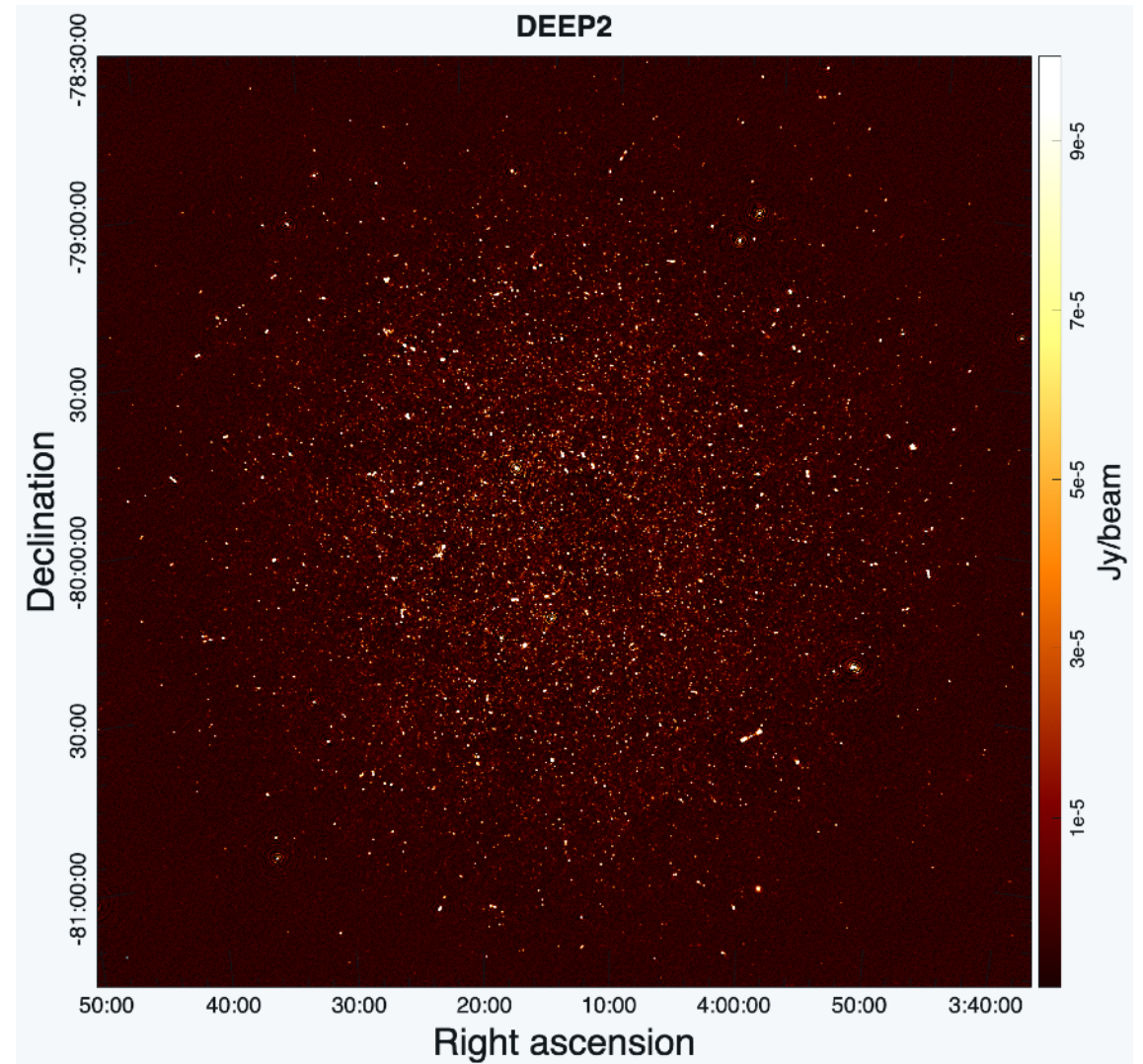
Bandwidth: 950 \sim 1170 MHz

RMS: 3 μ Jy/beam

Target scan duration: 15 mins

Two sub-bands: 1078 MHz ($z \sim 0.32$)

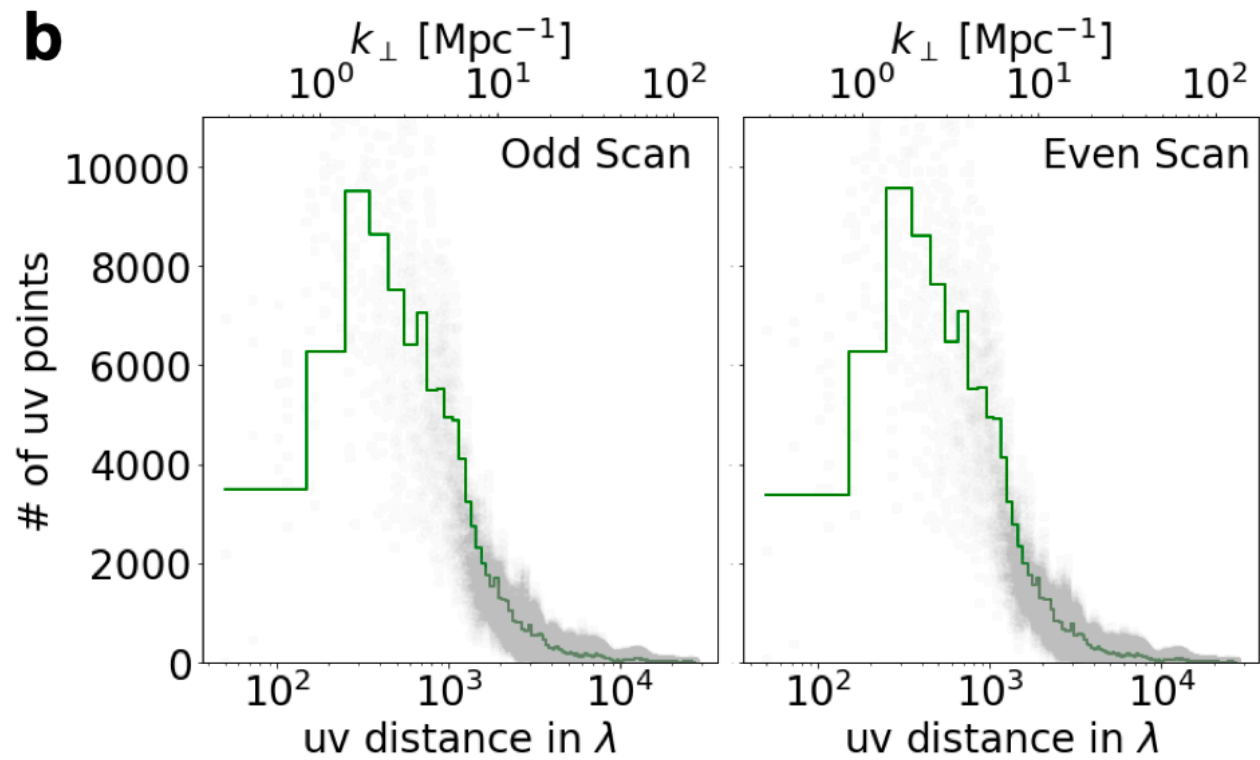
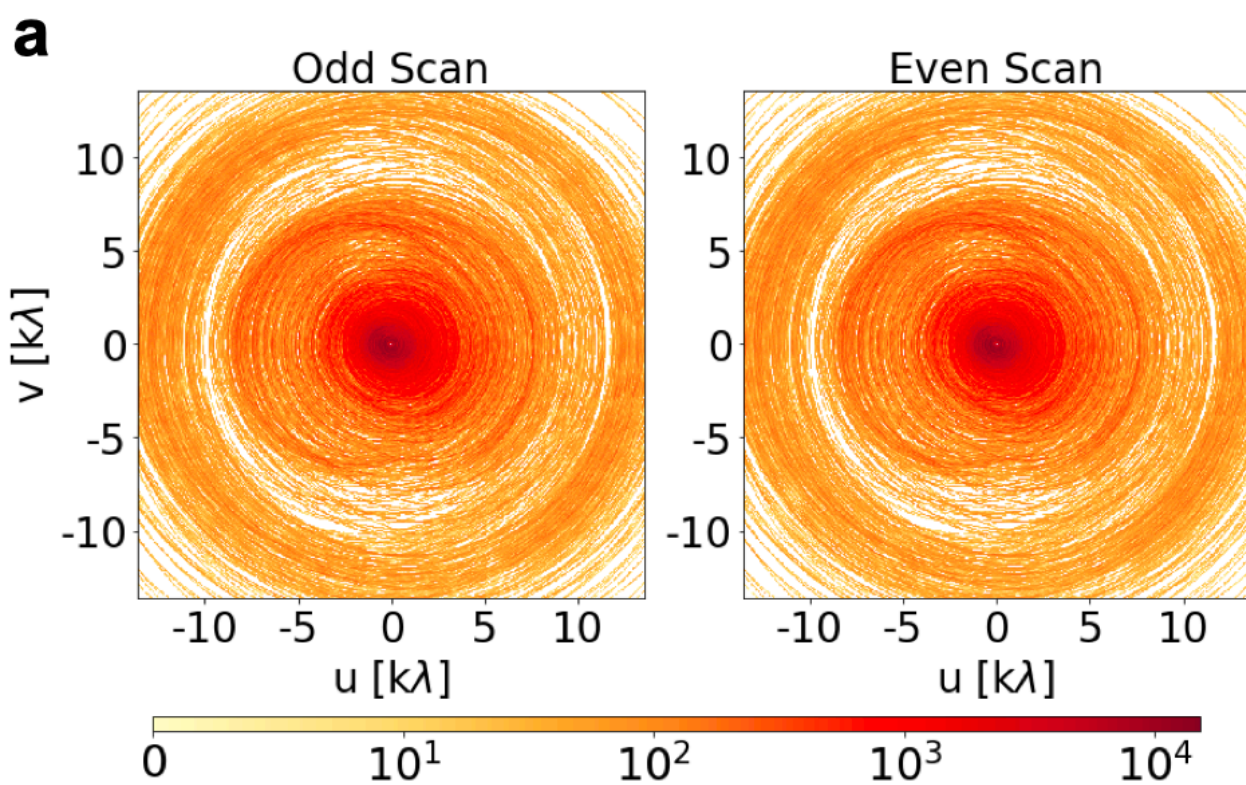
(46 MHz) 986 MHz ($z \sim 0.44$)



A first detection of neutral hydrogen intensity mapping on Mpc scales at $z \sim 0.32$ and $z \sim 0.44$

Paul, Santos et al., arXiv:2301.11943

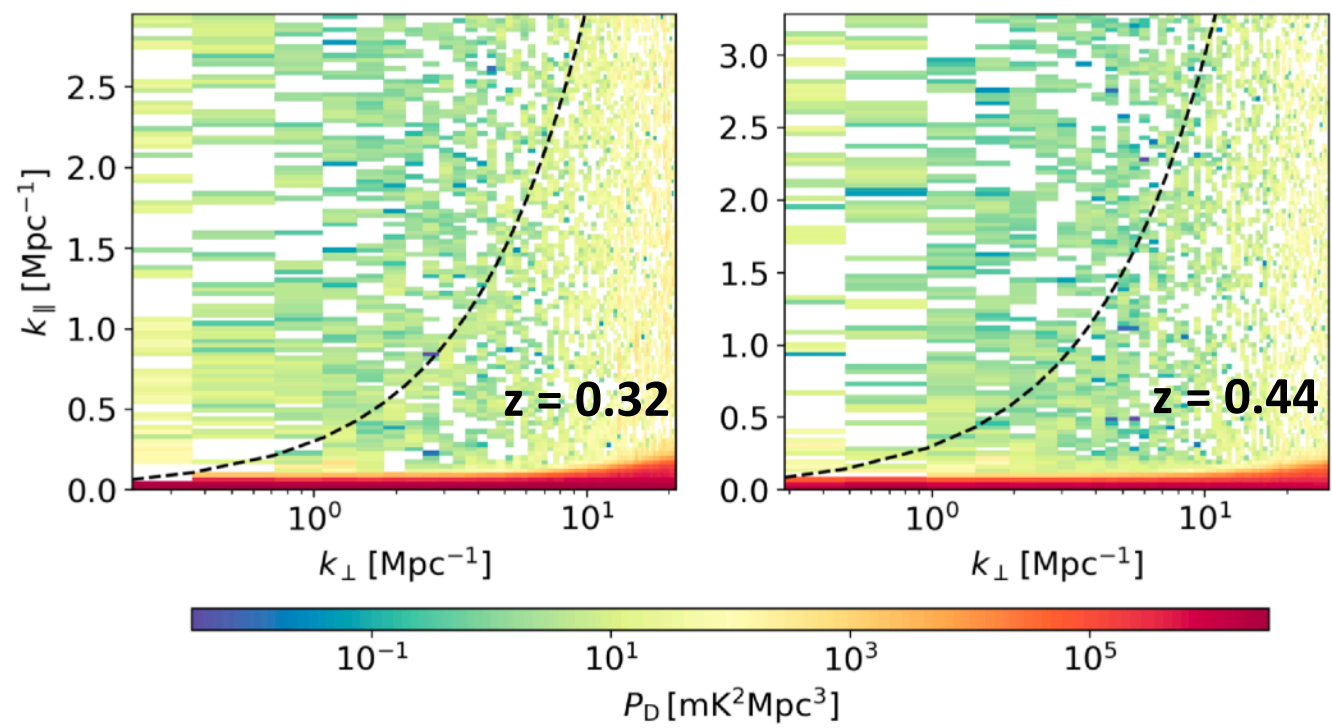
Power spectrum (odd scans vis x even scans vis)



A first detection of neutral hydrogen intensity mapping on Mpc scales at $z \sim 0.32$ and $z \sim 0.44$

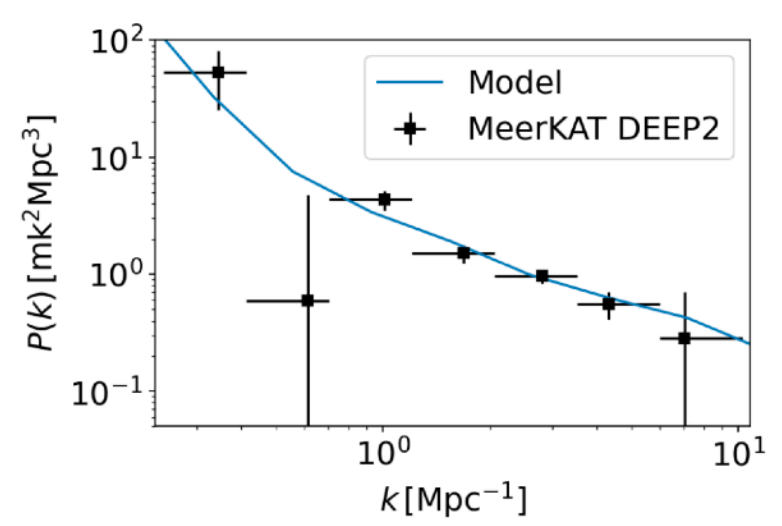
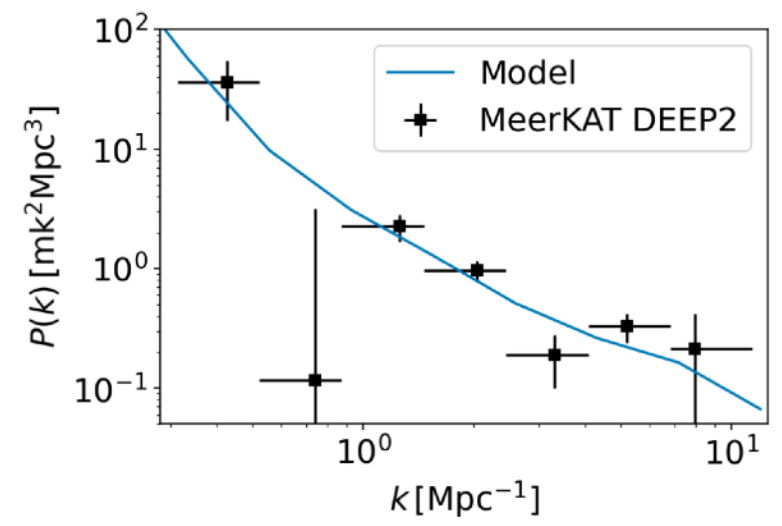
Paul, Santos et al., arXiv:2301.11943

First detection of auto power spectrum

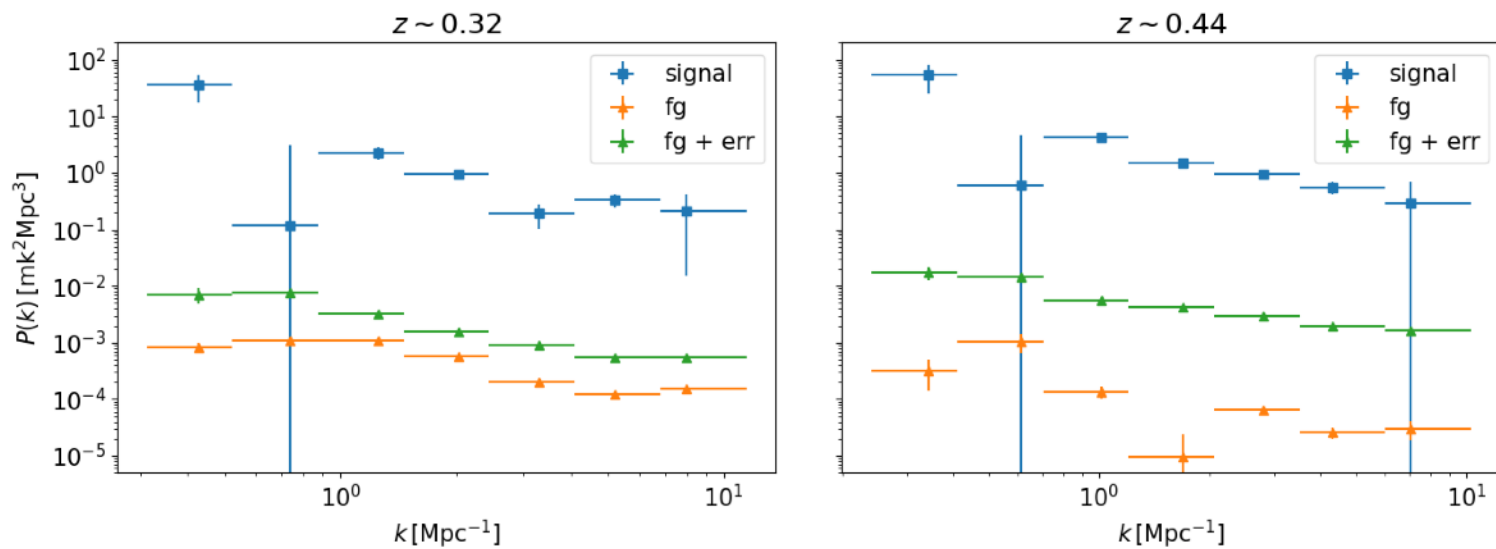
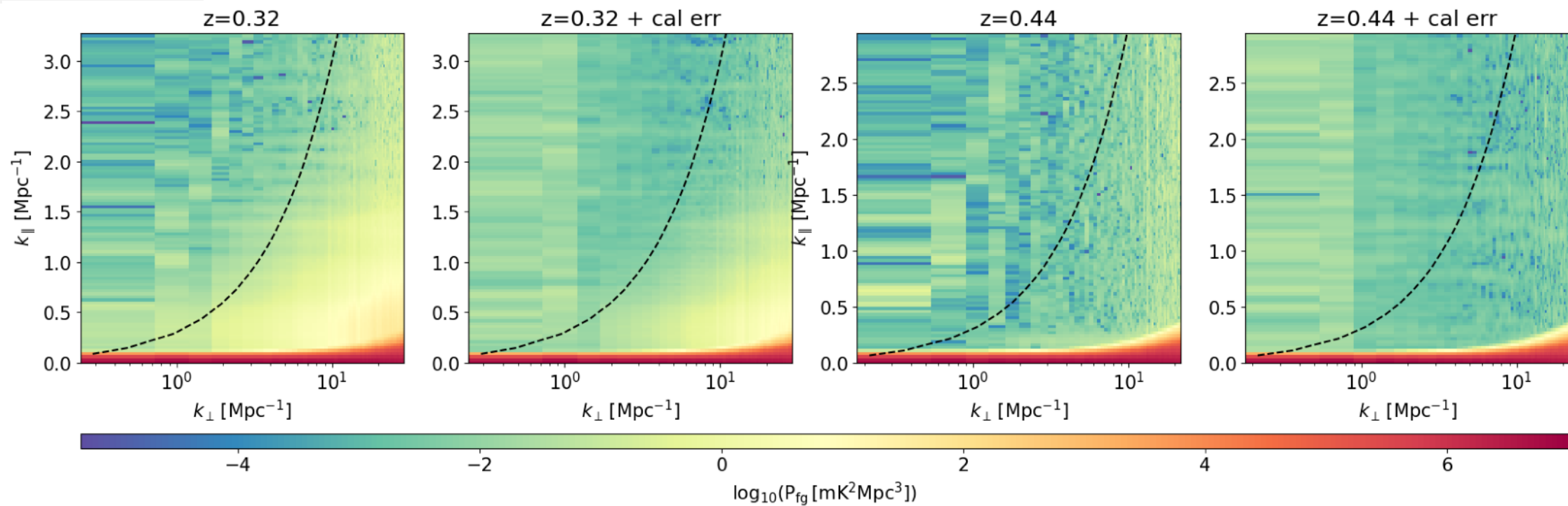


A first detection of neutral hydrogen intensity mapping on Mpc scales at $z \sim 0.32$ and $z \sim 0.44$

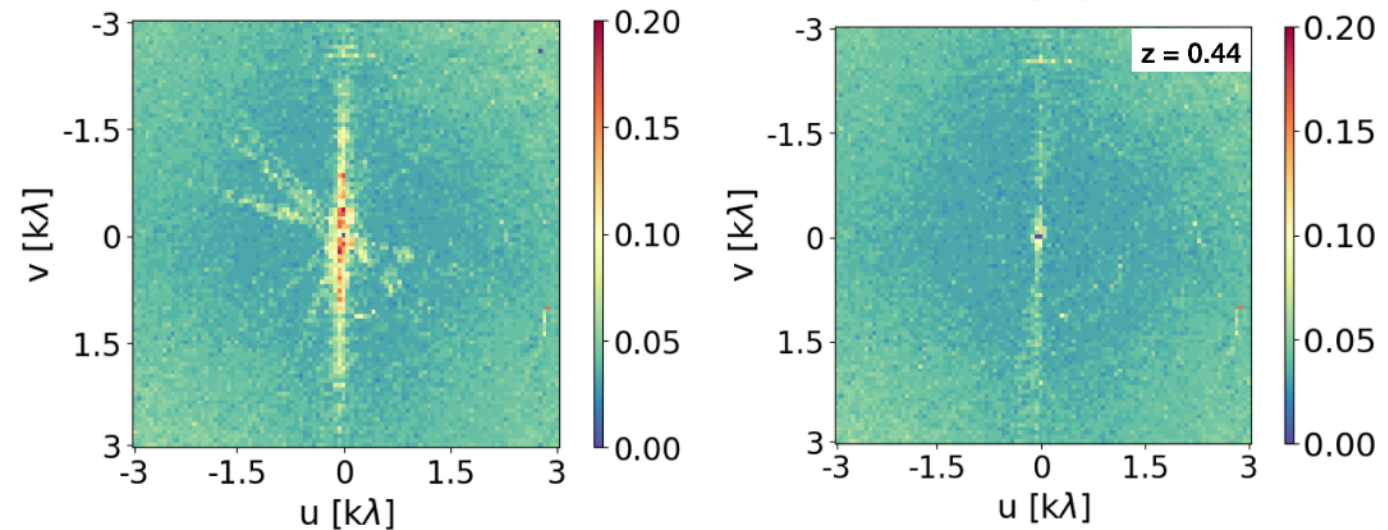
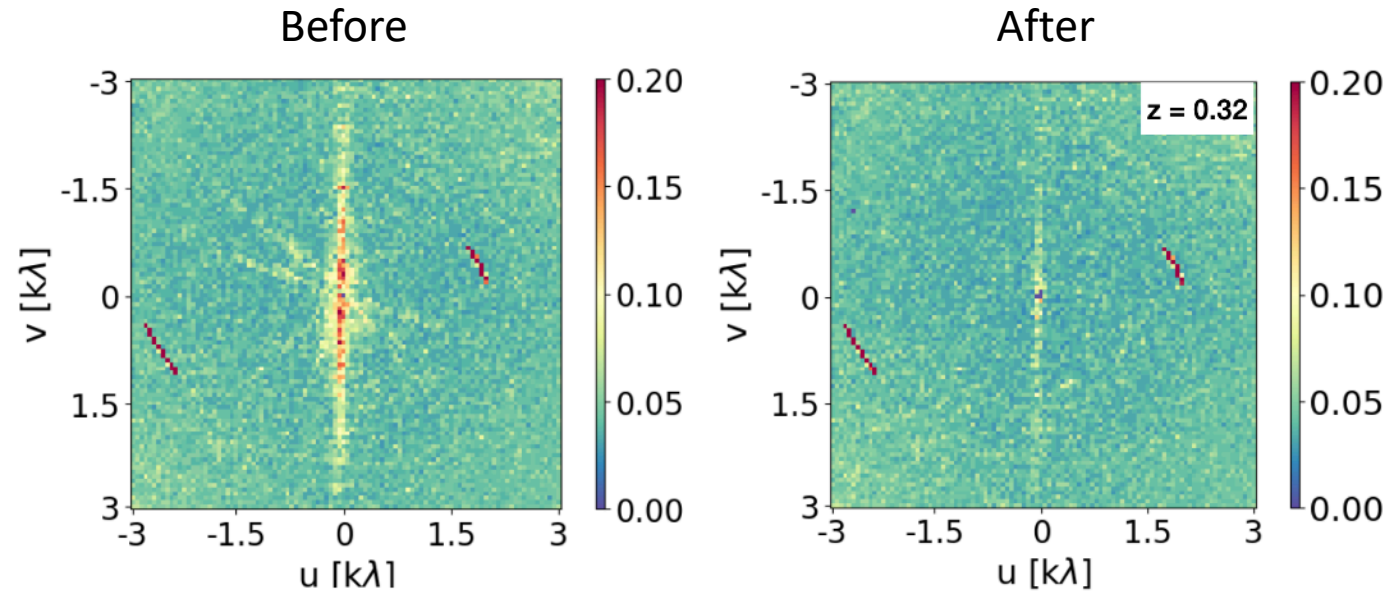
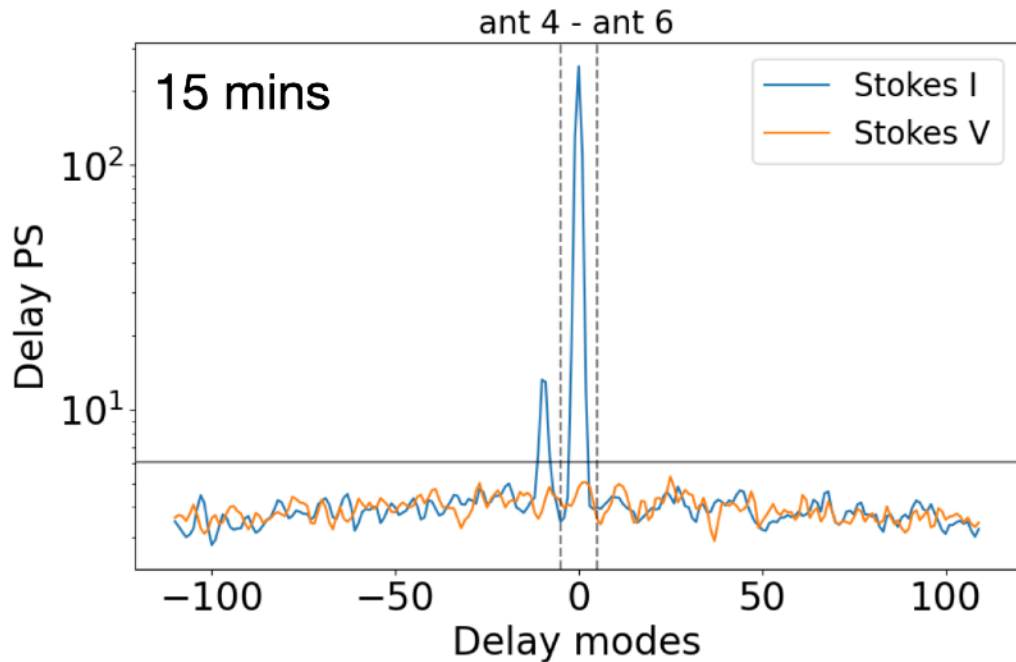
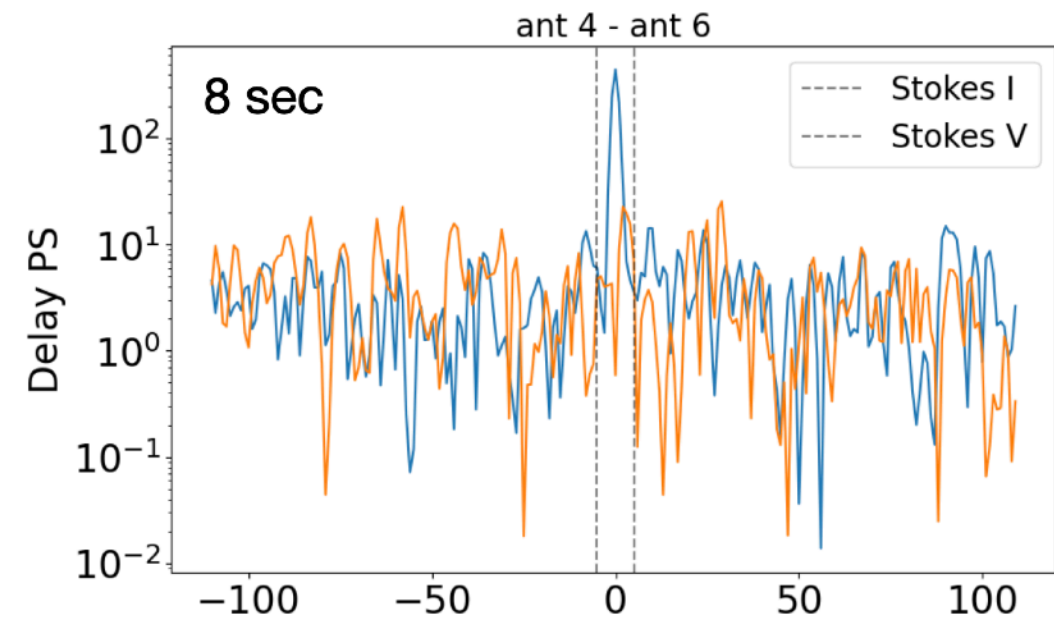
Paul, Santos et al.



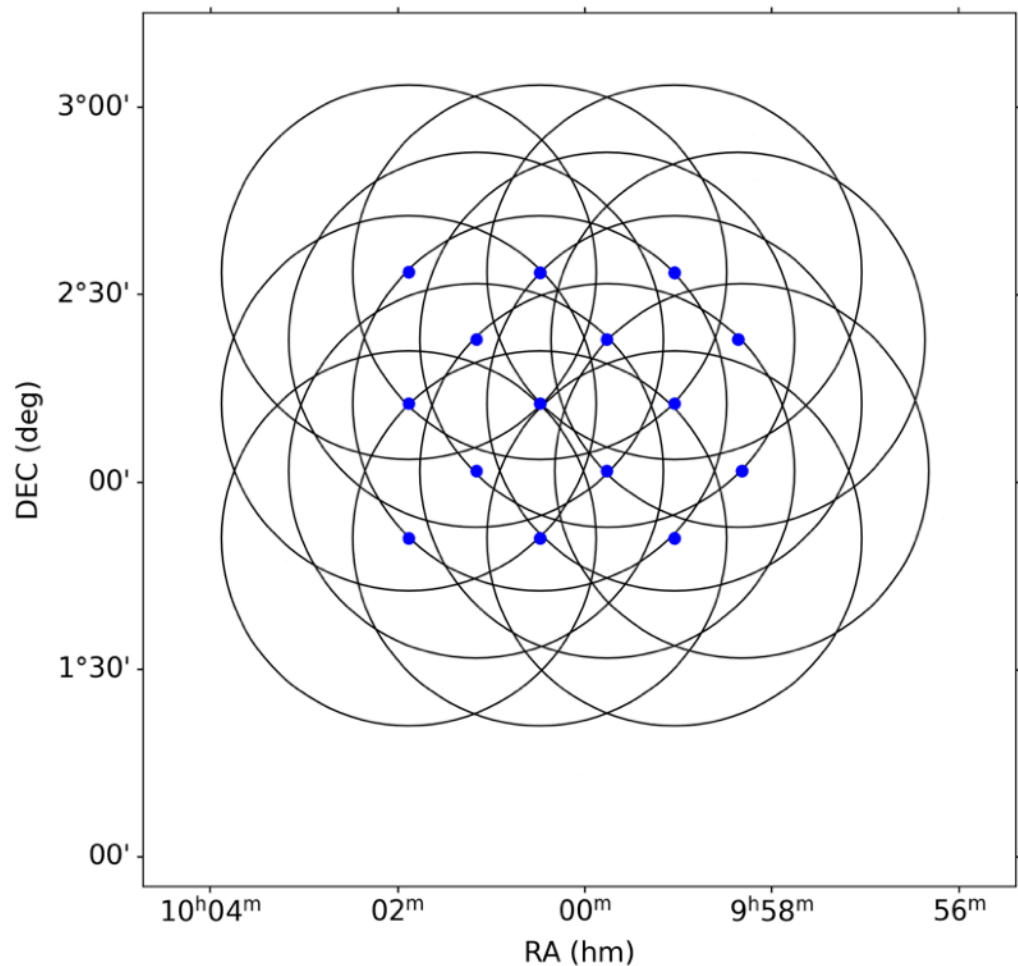
Foreground scatter



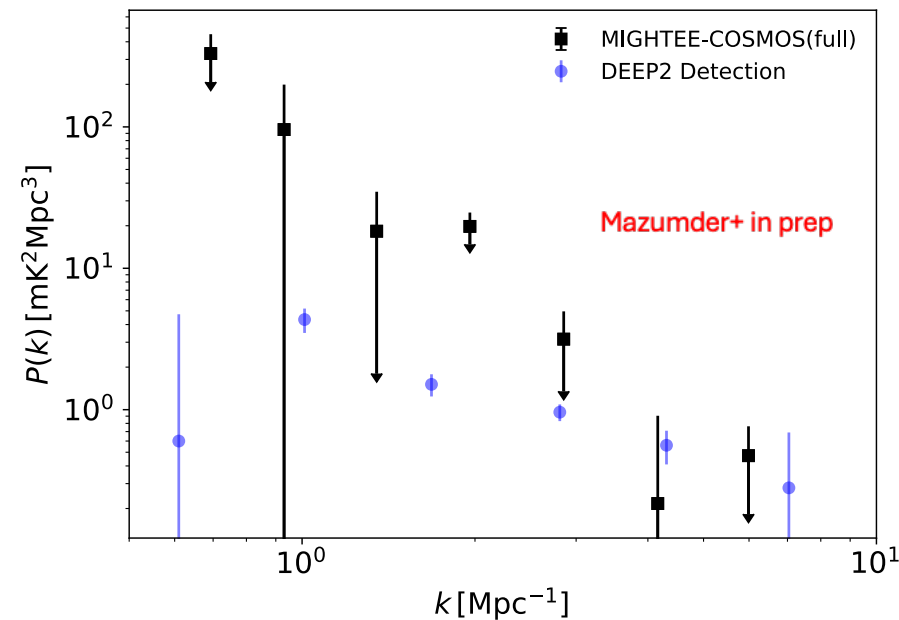
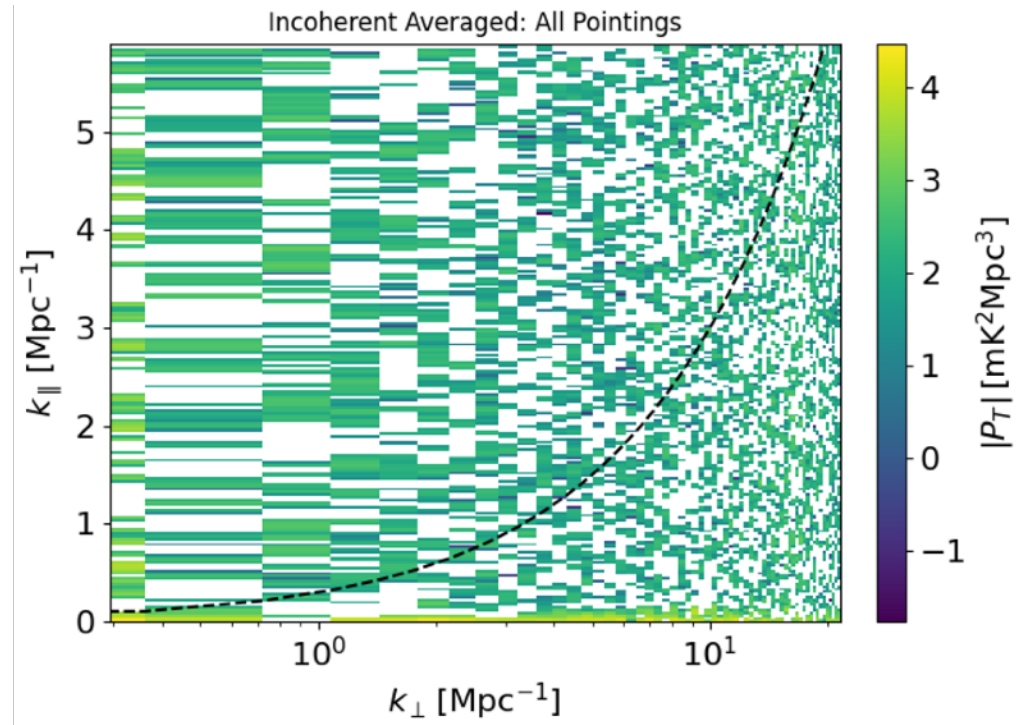
Low-level broadband RFI Flagging



Intensity mapping with MIGHTEE survey



COSMOS pointings



Aishrila Mazumder

Summary

- 21cm Intensity mapping research is at the forefront of cosmology, with the potential to provide new insights into the large-scale structure of the Universe.
- MeerKAT offers a distinctive approach to Intensity Mapping by leveraging both single-dish and interferometric capabilities.
- First detection in auto-correlation with MeerKAT interferometer—significant step towards precision cosmology with intensity mapping with new generation of radio telescopes and upcoming SKA.
- Many challenges are yet to overcome, detection are still limited to small scales.

