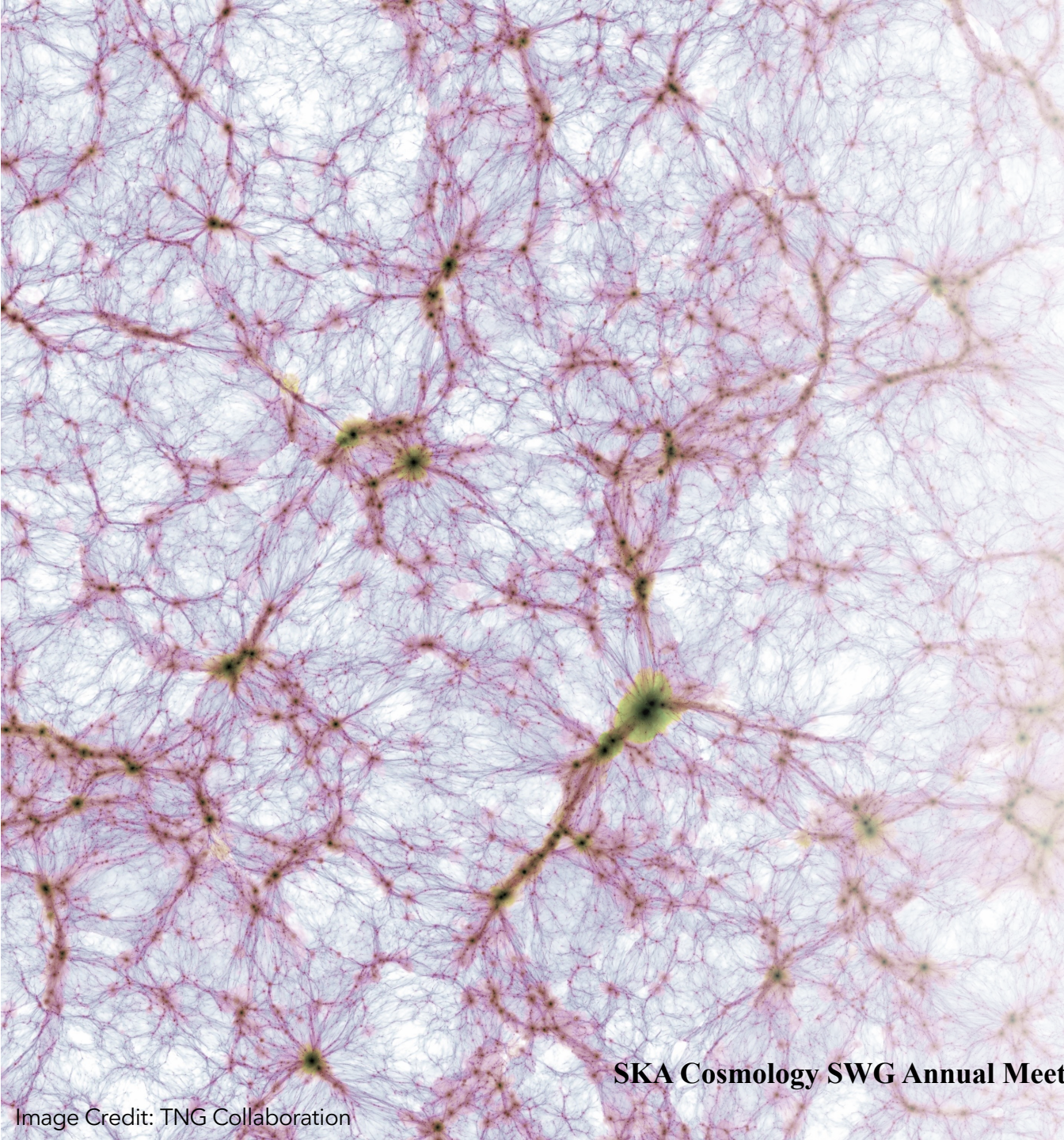


HI Intensity Mapping with the MIGHTEE Survey

Aishrila Mazumder

with Laura Wolz, Mario Santos, Zhaoting Chen, Sourabh Paul, et al.

SKA Cosmology SWG Annual Meeting, January 16, 2024

MANCHESTER 1824

The University of Manchester

Image Credit: TNG Collaboration

Outline

- Cosmology with HI Intensity Mapping
- Intensity Mapping with Interferometers
- HI IM with MIGHTEE survey

Cosmology with HI Intensity Mapping

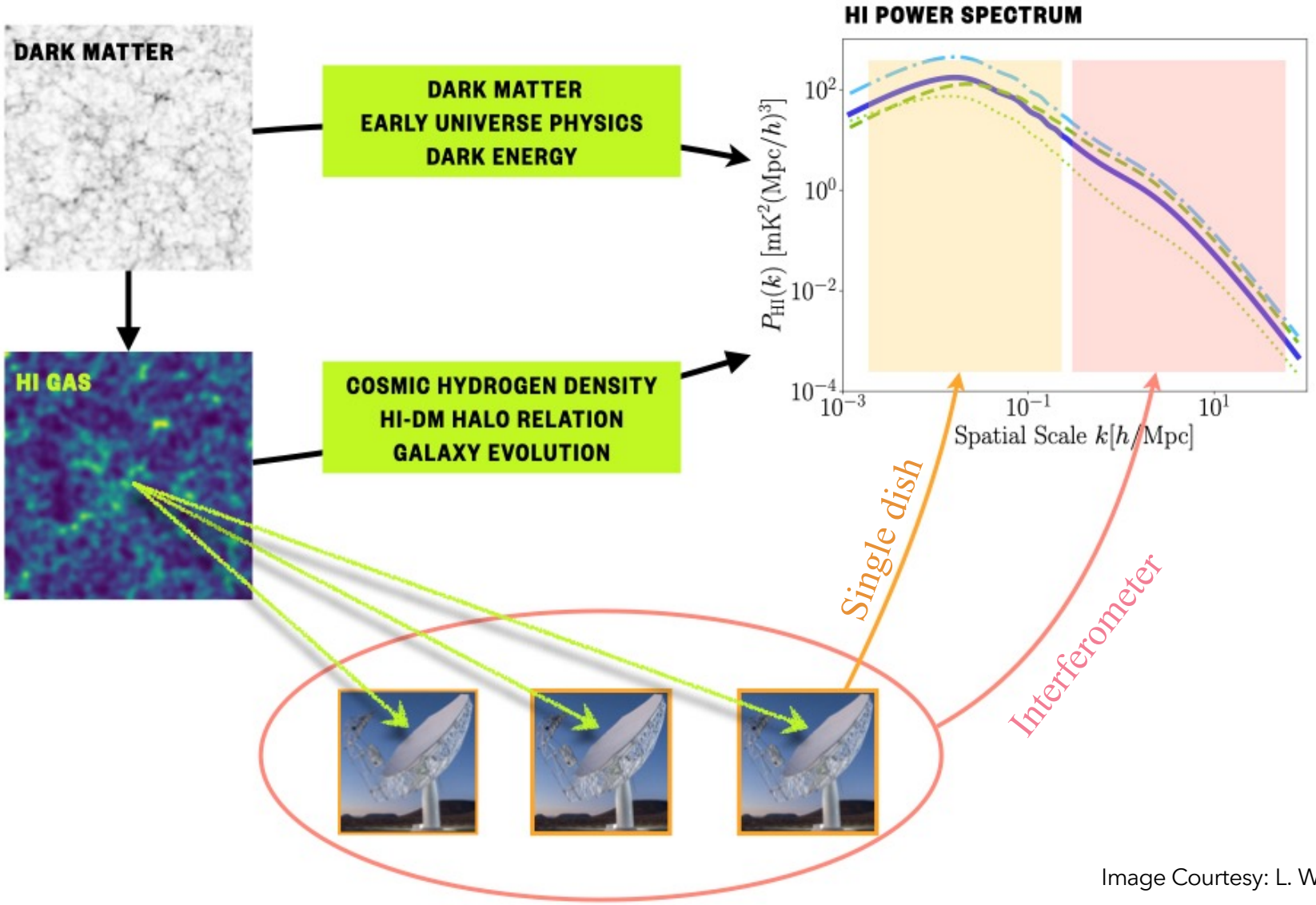
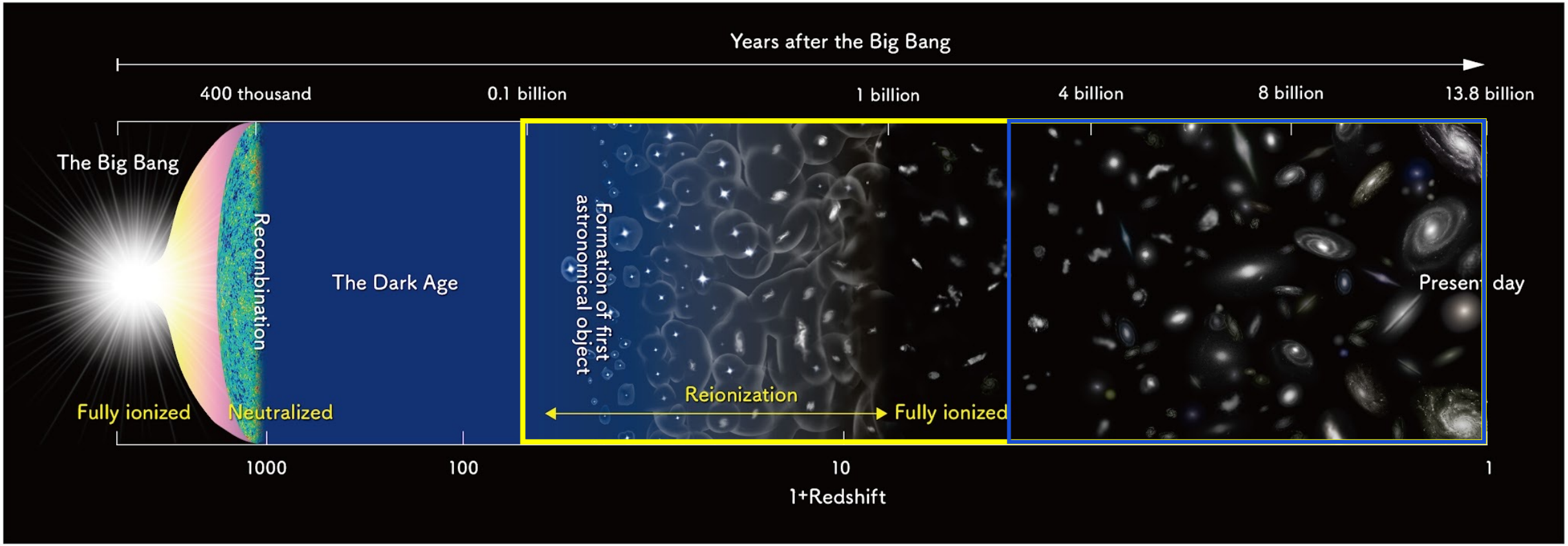


Image Courtesy: L. Wolz

Cosmology with HI



Detecting the HI Signal using Interferometer

- Delay transform: V(u,v,ν) to V(u,v,τ)
- Foregrounds pose one of the major obstructions in detection of the cosmological 21-cm signal - orders of magnitude higher than HI
- "Foreground wedge" & "EoR window" - foregrounds in low $k_\parallel$ modes combined with the chromaticity of the instrument confined to a "wedge"
- Noise dominated "window" outside the wedge for detecting HI signal
- Interaction of foregrounds with systematics – leakage into window

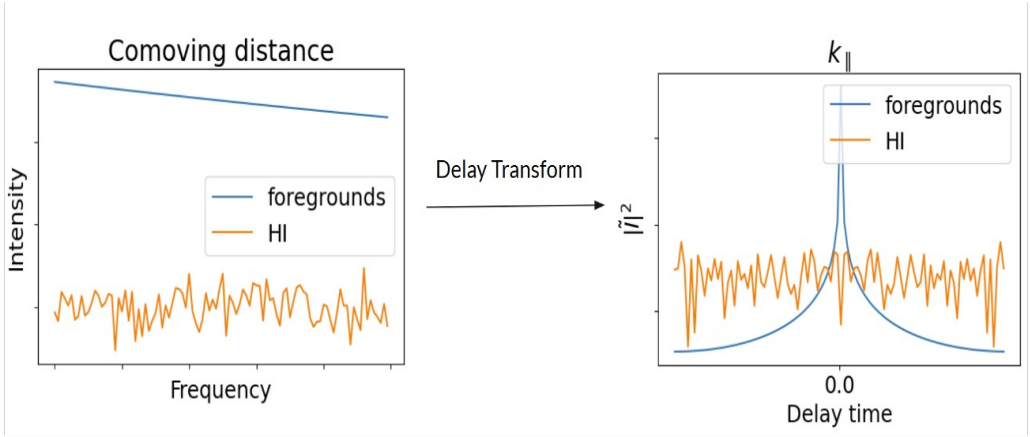
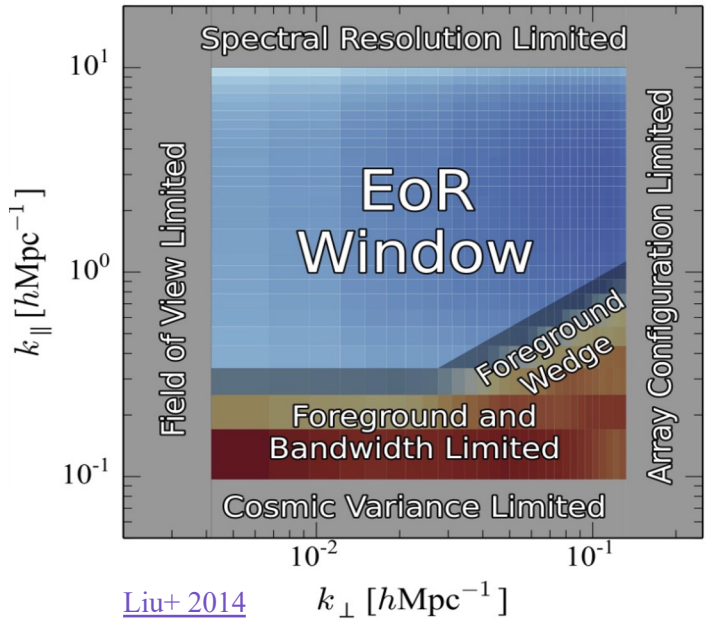


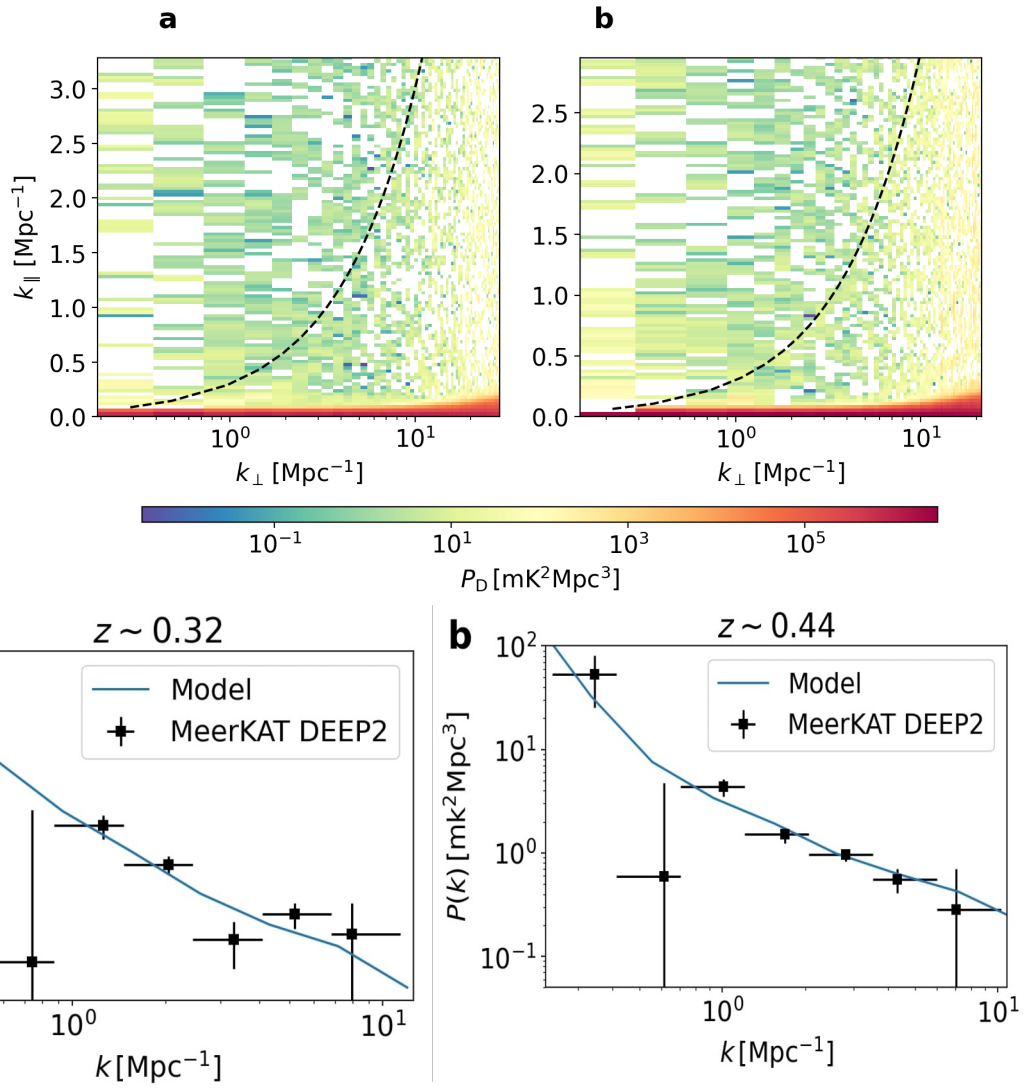
Image Courtesy: Z. Chen



Liu+ 2014

Low z Intensity Mapping: The DEEP2 Detection

- MeerKAT L-band observation with a single pointing in DEEP2 region for 96 hours (Mauch+ 2020)
- Long integration – high SNR & target has minimal bright source contamination
- The detection of the IM was recently reported with this data for the DEEP2 field (Paul+ 2023)
- Two clean sub-bands selected in the L-band
- Redshifts 0.32 and 0.44
- Foreground avoidance – conservative cut-off using the beam horizon limit



Paul+ 2023

MIGHTEE

- HI Intensity Mapping observations – single pointing with deep observations or shallow wide area multi-pointing
- MIGHTEE : ~20 square degree over well-known extragalactic deep field
- Total observing time of 1000 hours – autocorrelation with excellent signal-to-noise
- COSMOS field: 15 pointings at 32k channel resolution & total ~ 94 hr on source (6.25 hr/pointing)
- Small clean sub-band 962.55-1008.42MHz centred at z~0.44 used for this

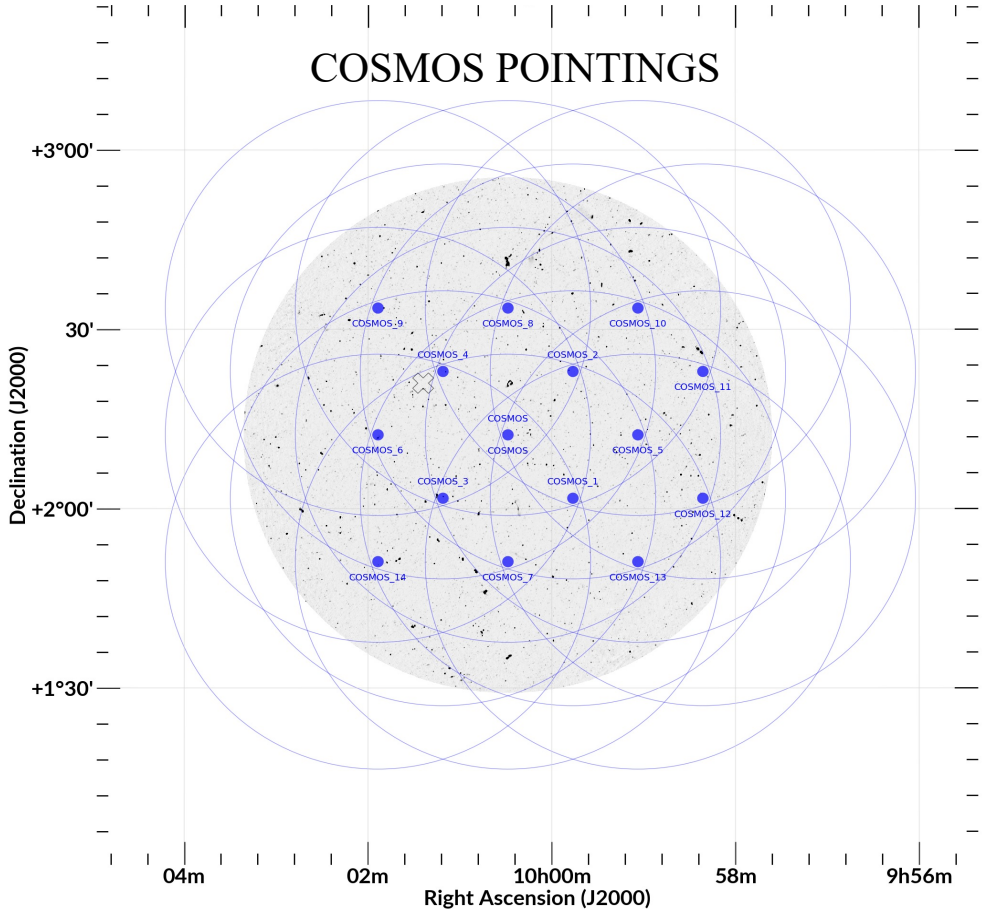
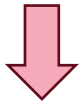


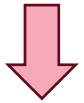
Image Courtesy: MIGHTEE Collaboration

Visibilities to Auto Power Spectrum

Real visibilities : severely systematics limited, leakage into measurement window

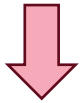


Visibilities are checked for the cleanest part of the band



Gridded visibilities – alternative tracks grouped into together – reduces noise bias

Delay transform the gridded visibilities to calculate the 3D power

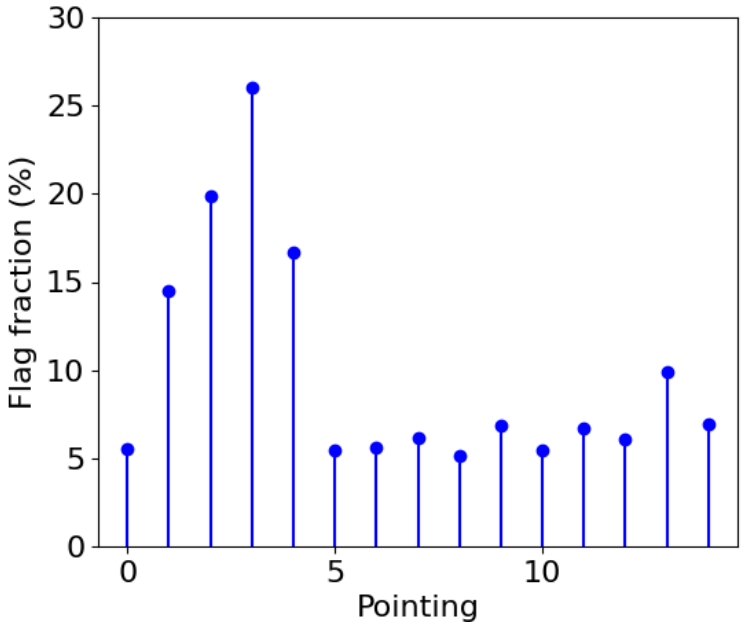


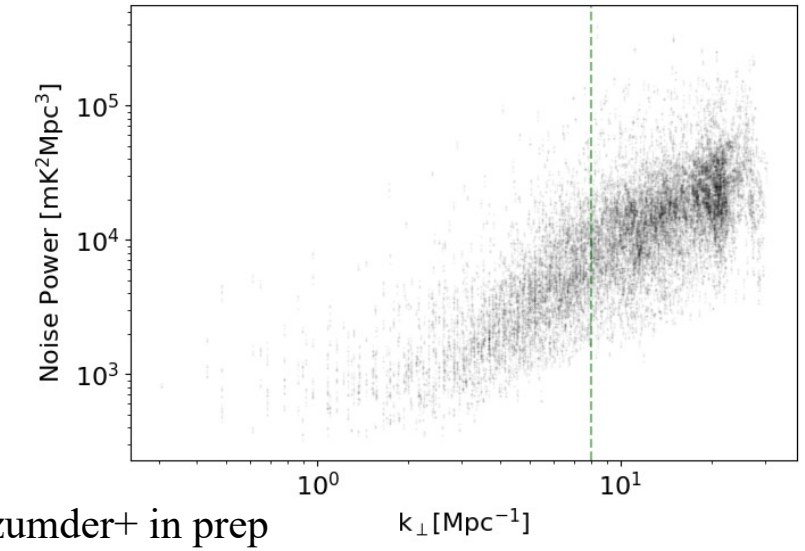
Cross correlate odd and even scans to calculate the spherical power spectrum

Incoherently average the pointing together for the final power spectrum

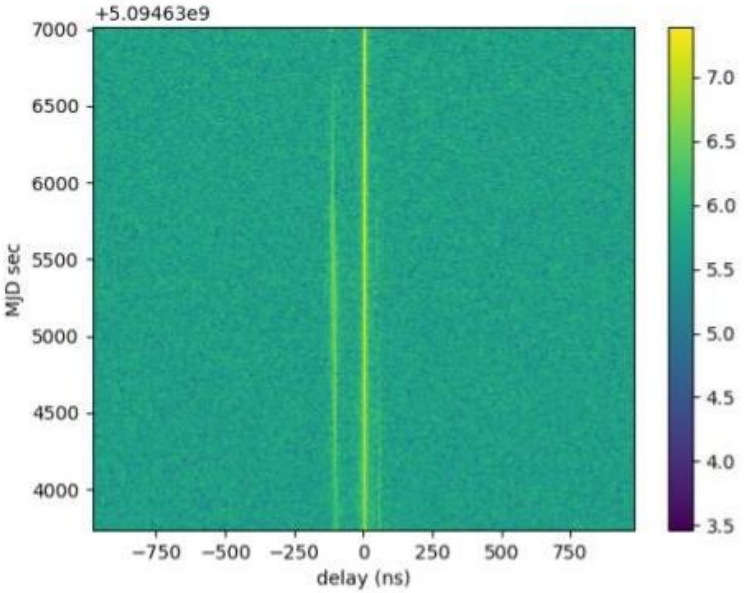
Data Assessment

- Amount of data flagged reasonable
- Flagging more than 15% for pointing observed in 2021- indicative of deteriorating RFI environment?
- Systematics in data seen delay transforming visibilities
- Observation tracks per pointing smaller than DEEP2 – sufficient SNR not present for long baselines



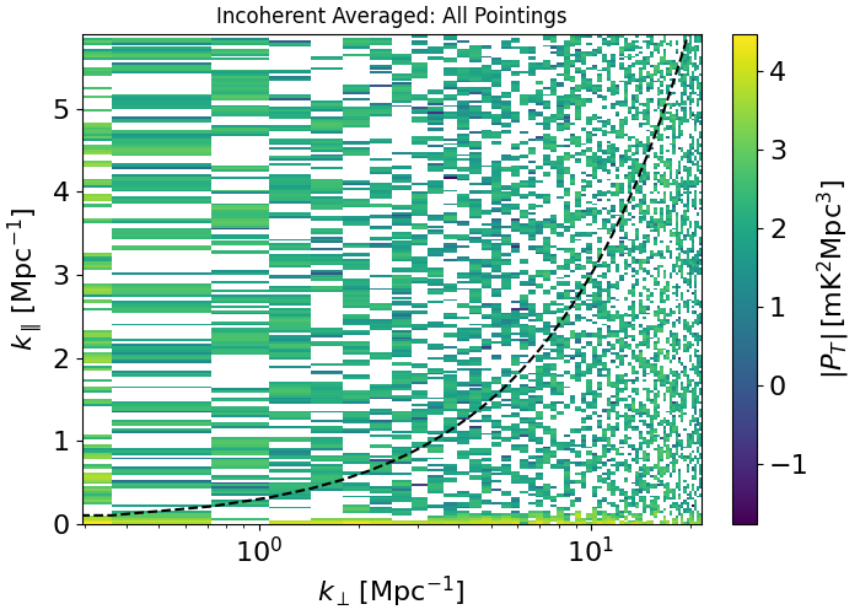


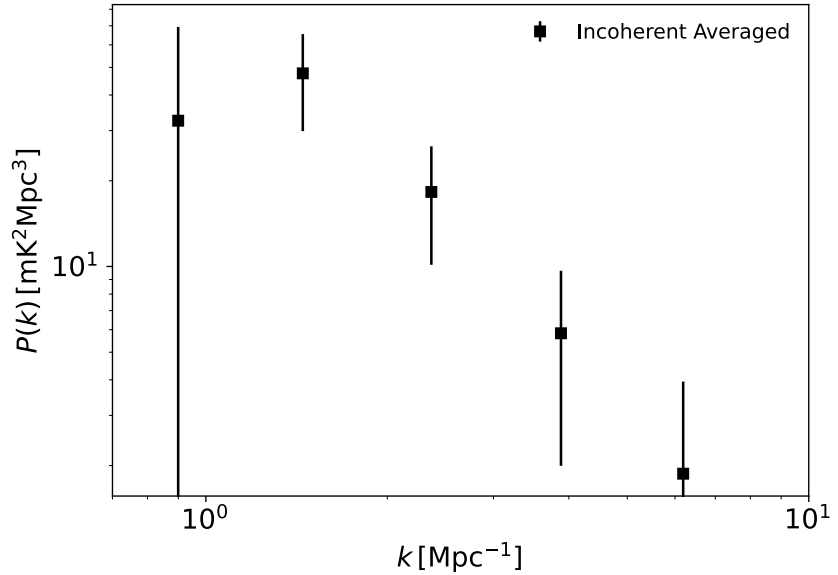
Mazumder+ in prep



Power Spectrum Estimation

- Each pointing has slightly different phase centre – visibilities sample slightly different sky
- MIGHTEE-COSMOS fields arranged in a close pack mosaic-significant areas overlap – coherent averaging not easy
- Alternatively, averaging in power spectrum i.e. incoherent average
- Average 3D power spectrum of each pointing weighted by the noise variance and bin in cylindrical/spherical bins
- Region beyond the horizon selected ($k_{\parallel} \gtrsim 0.3\ k_{\perp}$) for foreground avoidance
- Signal to noise for each k-bin ~2
- Detection not yet possible with the partial MIGHTEE data used





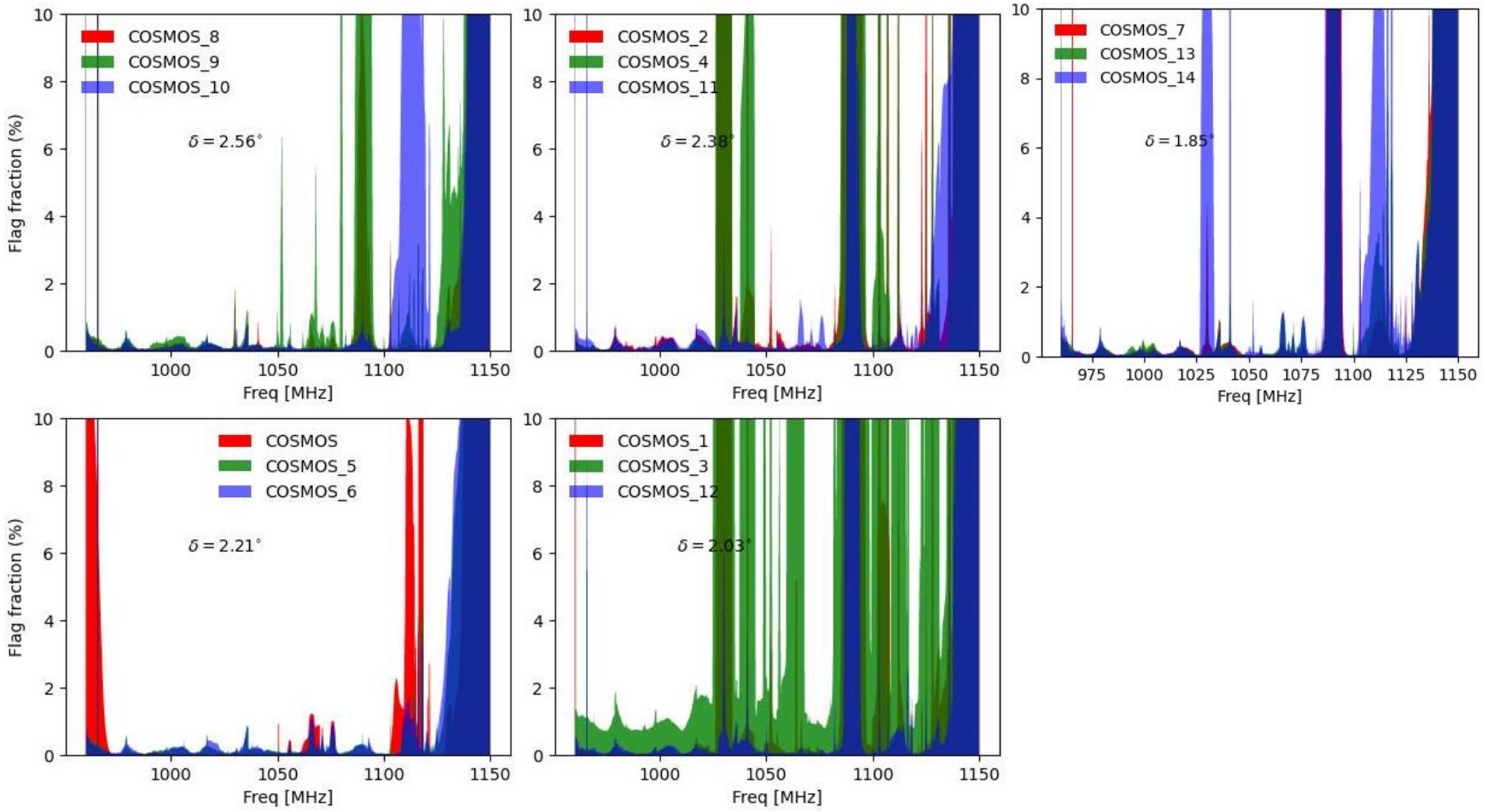
Mazumder+ in prep

Summary

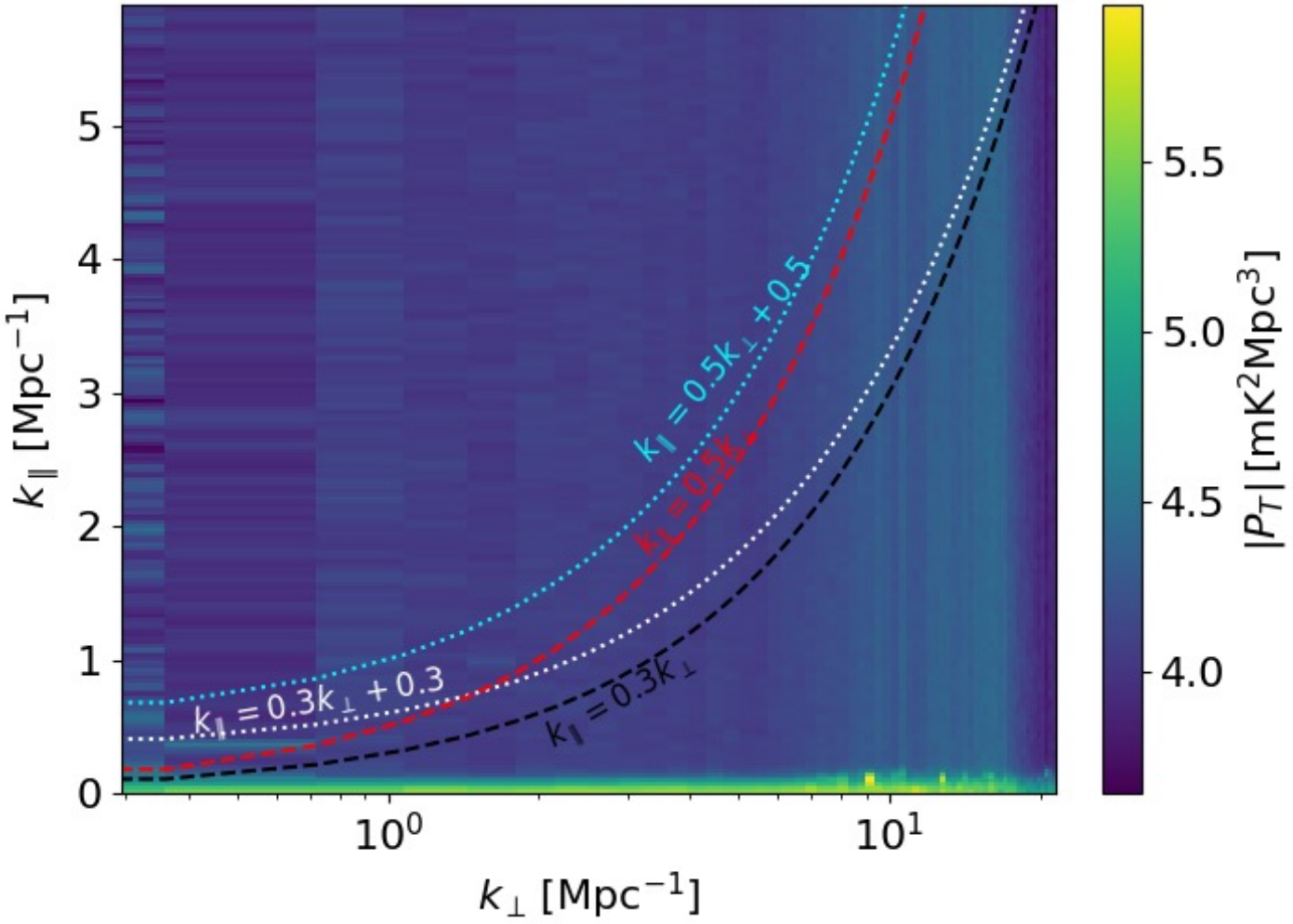
- HI Intensity Mapping using interferometers can probe the “quasi-linear” scales to provide important cosmological constraints
- Power spectrum at z~0.32 and 0.44 detected using deep observation of the DEEP2 field
- Full MIGHTEE observations for ~1000 hours over ~ 20 square degree- ideal for HI intensity mapping
- Partial data for only 96 hours of the COSMOS field used for this work
- Contribution from residual systematics and smaller amount of data per pointing deter high significance detection
- Upper limit can be set on the HI power at z ~ 0.44 between $0.5 < k < 10$ using MIGHTEE-COSMOS
- Incorporating more data from other field to be done

Thank You !!

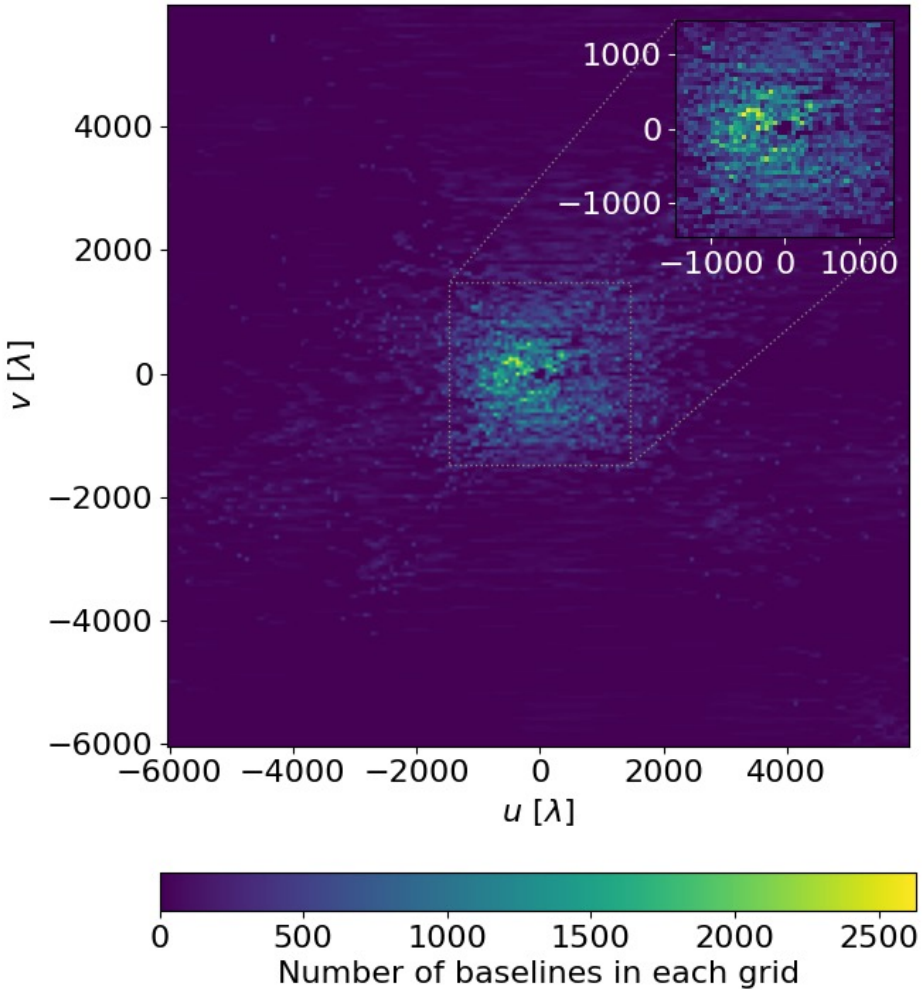
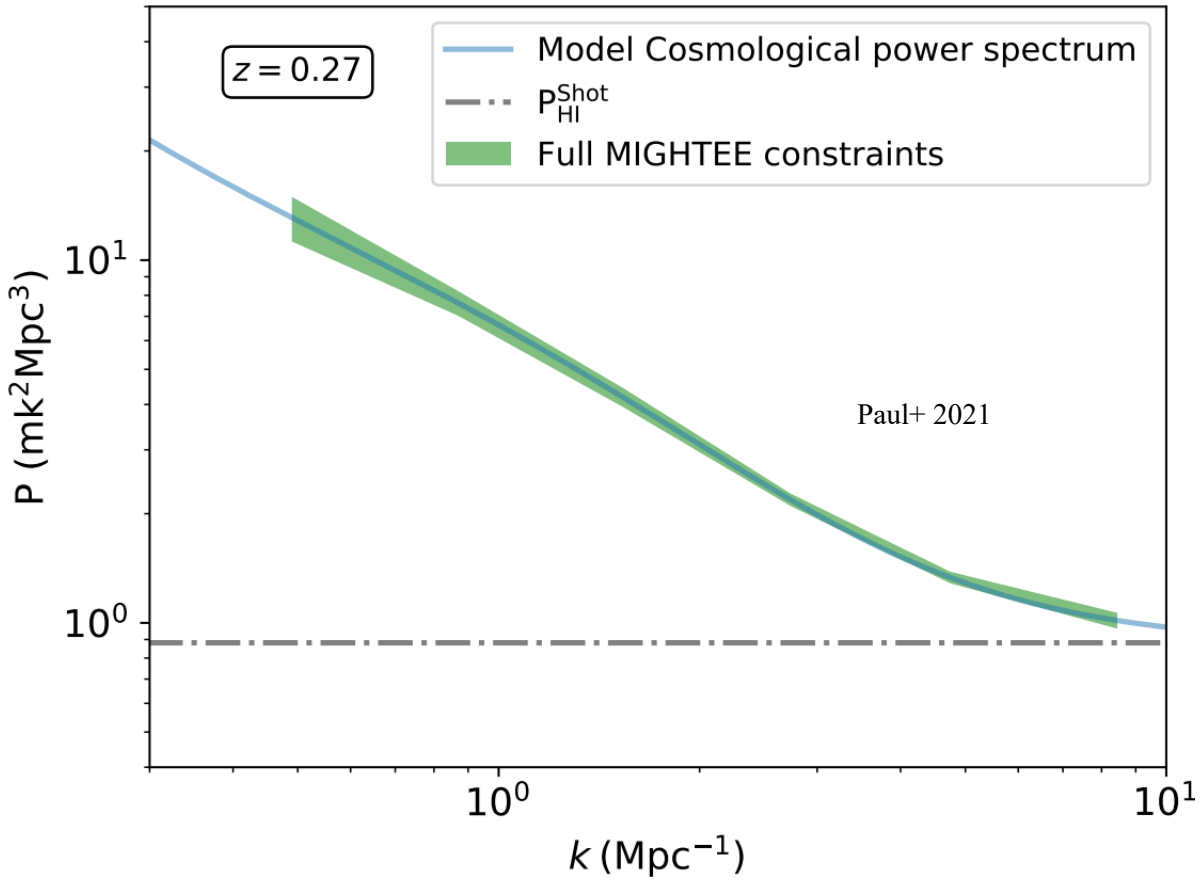
Backup Slide: Flagging Fraction



Backup Slide: Cylindrical auto power



Backup Slide :UV Grids



Backup Slide : Full MIGHTEE constraints