HI Intensity Mapping on Small Scales

Aishrila Mazumder

Jodrell Bank Centre for Astrophysics, University of Manchester
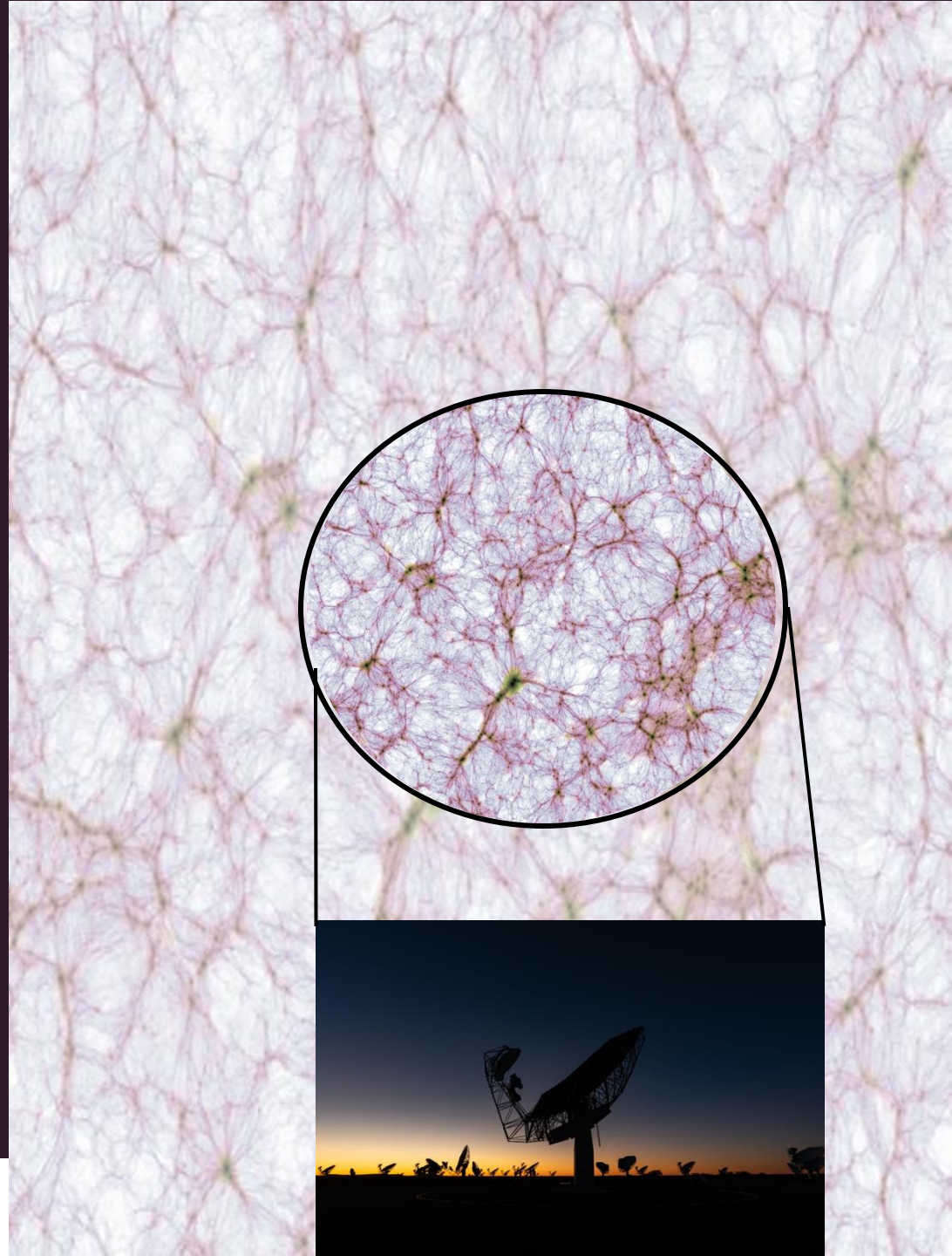
SKA Cosmology SWG, Nice

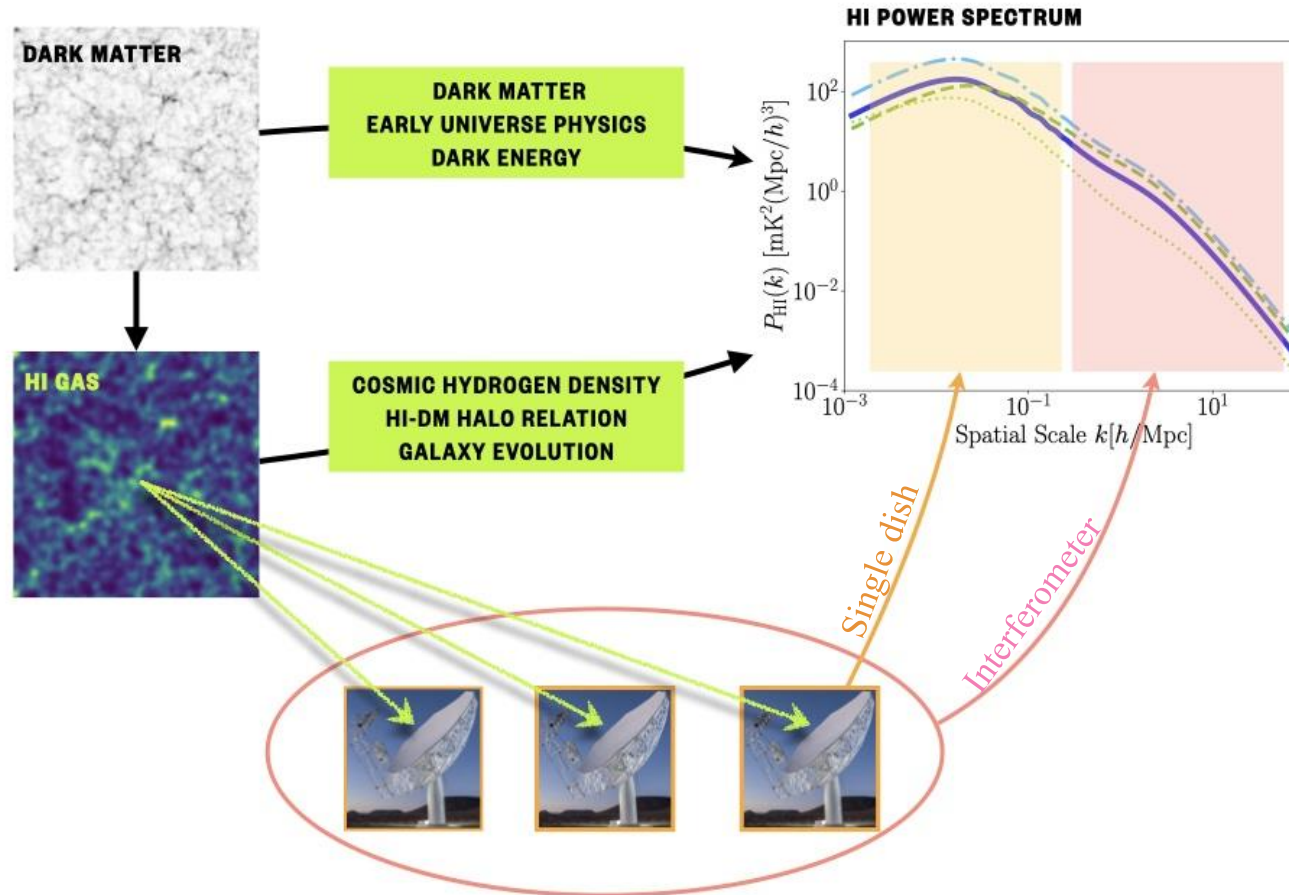The University of Manchester

Cosmology with HI Intensity Mapping

Courtesy: Laura Wolz

Cosmology with HI Intensity Mapping

Courtesy: Laura Wolz
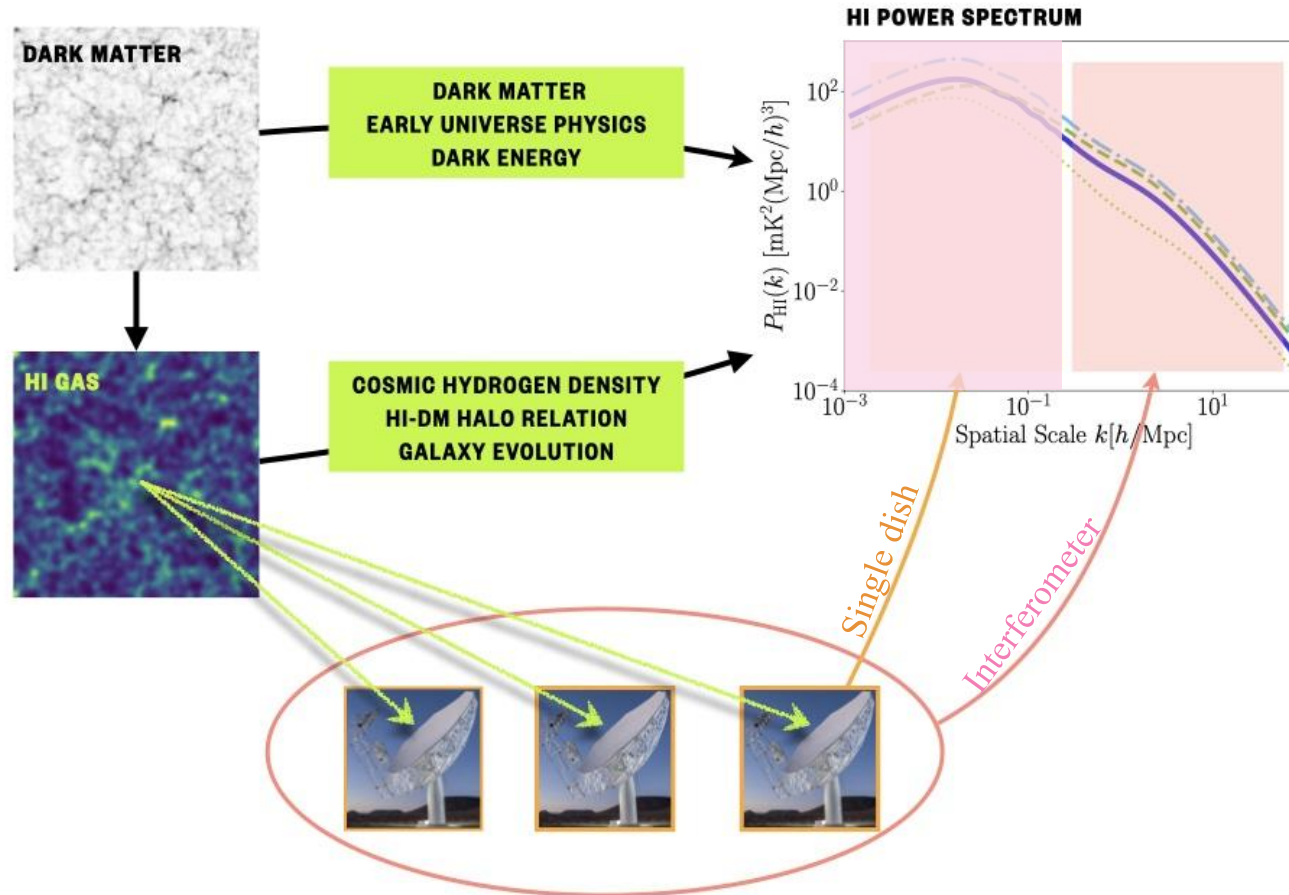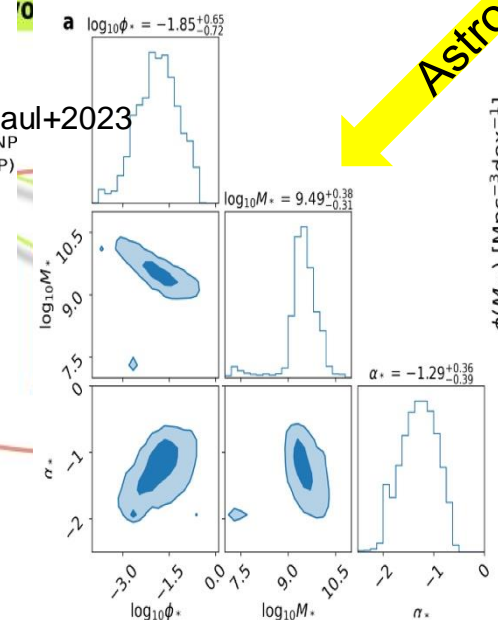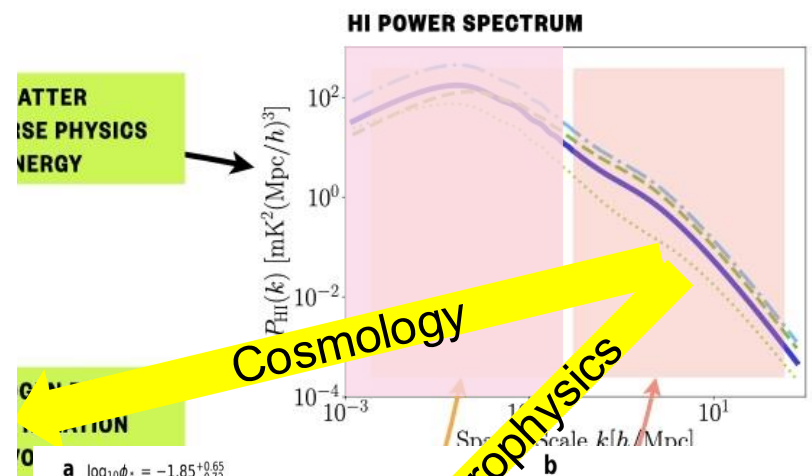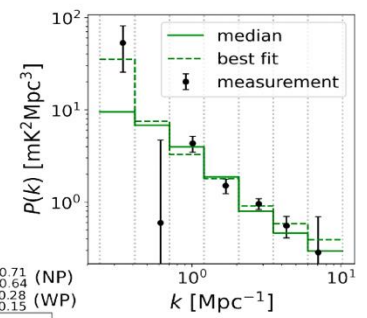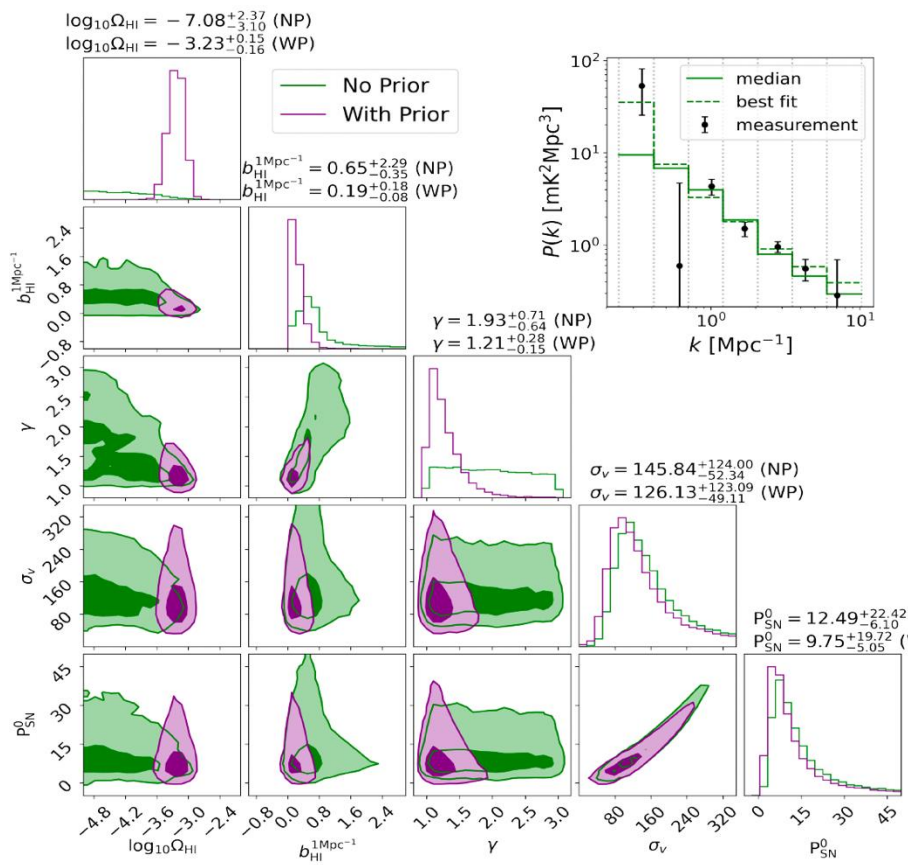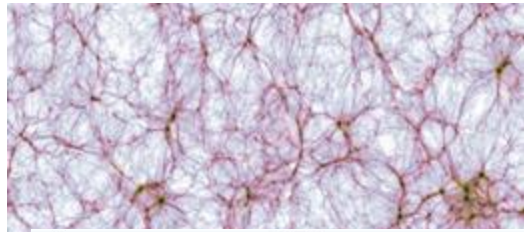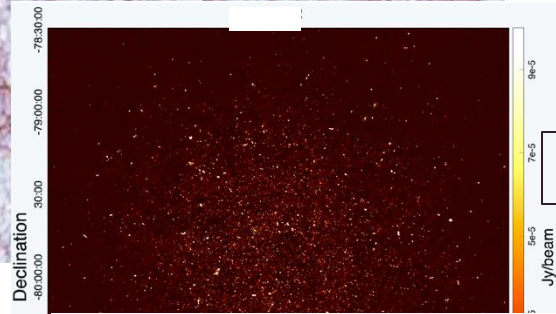
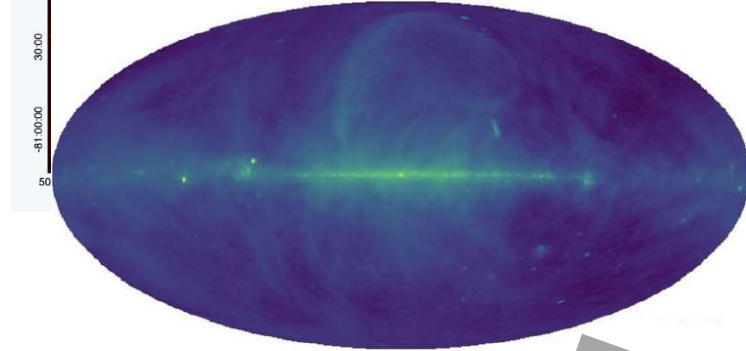# Cosmology with HI Intensity Mapping

Paul+2023
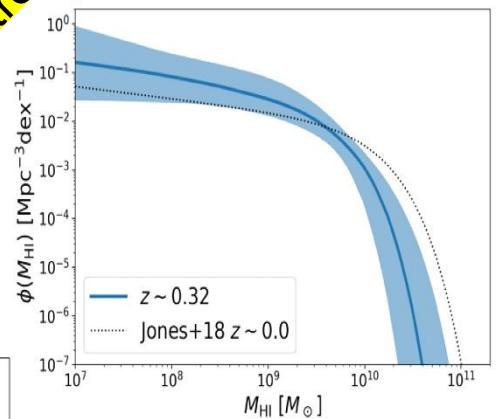
Primer on Intensity Mapping with Interferometers

HI

Extragalactic foregrounds

Galactic foregrounds

Visibility
(sky + instrument)

FT along **f**

Delay
(sky + instrument)
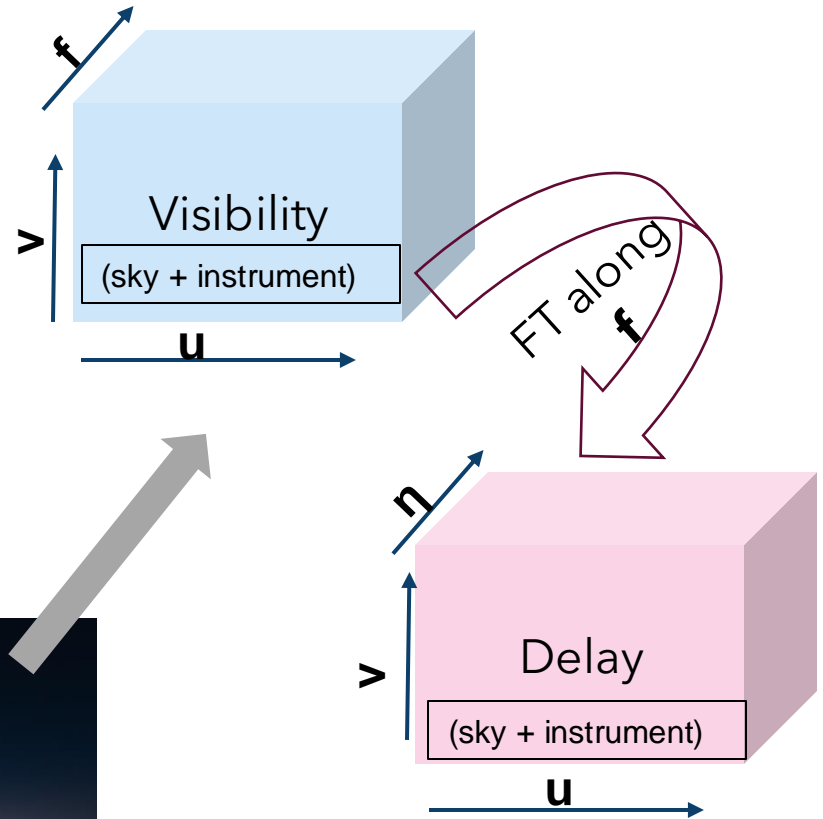
Primer on Intensity Mapping with Interferometers
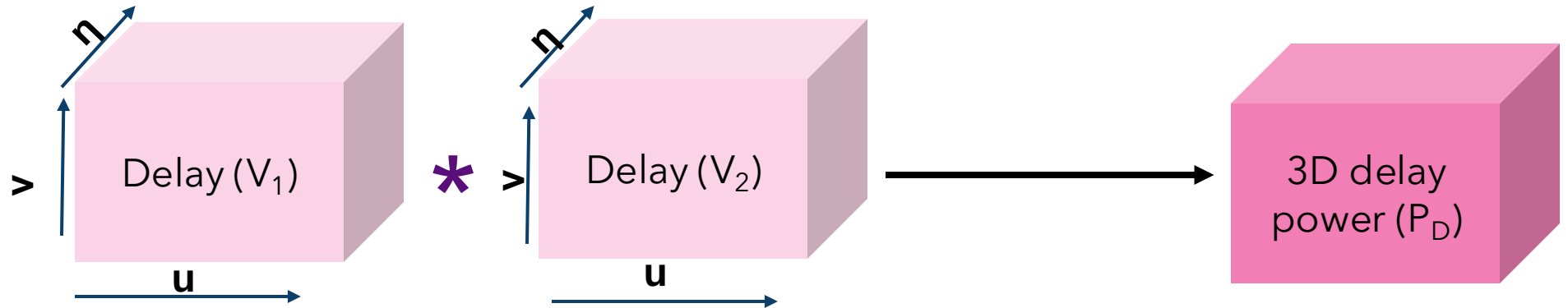
$$P_{\mathrm{D}}(\boldsymbol{k}_\perp, k_\parallel) \equiv \frac{x^2 y}{\Omega_{\mathrm{ps}} B} \left(\frac{\lambda^2}{2 k_B} \right)^2 \mathrm{Re}\{\tilde{V}_1(\boldsymbol{b}, \tau) \tilde{V}_2^*(\boldsymbol{b}, \tau)\}$$

Foreground Avoidance

- Foregrounds orders of magnitude brighter

- Foregrounds are spectrally smooth

- Foregrounds in low $k_\parallel$ modes combined with the chromaticity of the instrument confined to "Foreground wedge"

- Noise dominated "window" outside the wedge for detecting HI signal

- Interaction with systematics –> contamination in the window
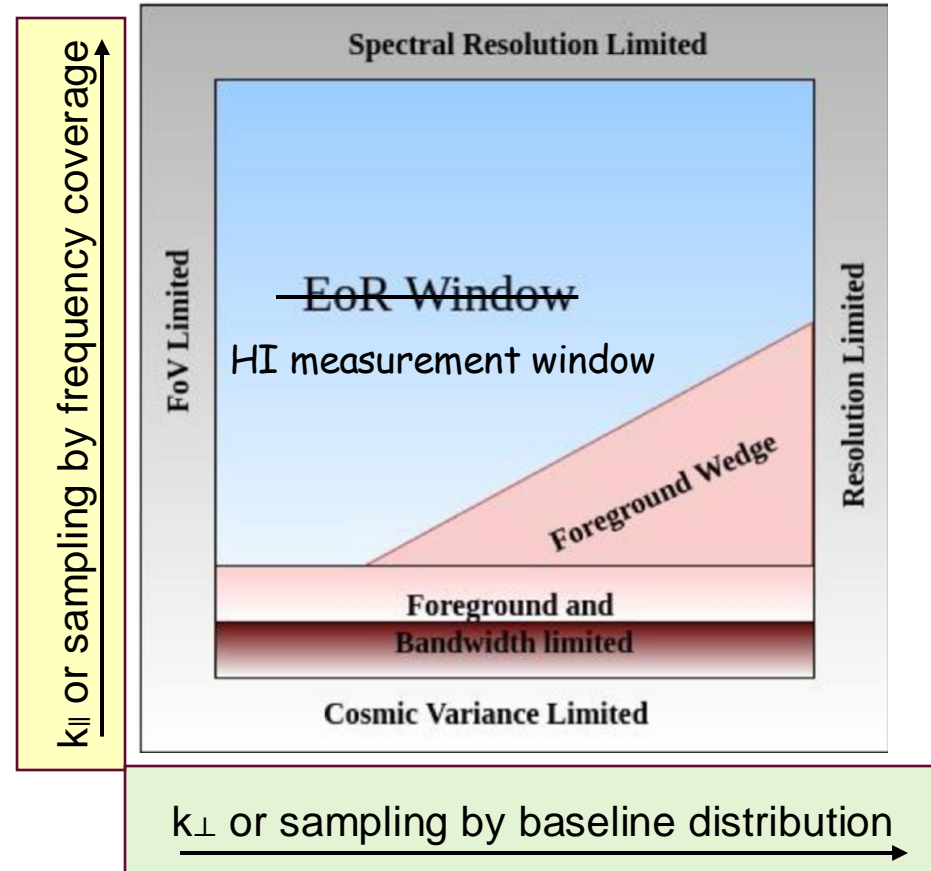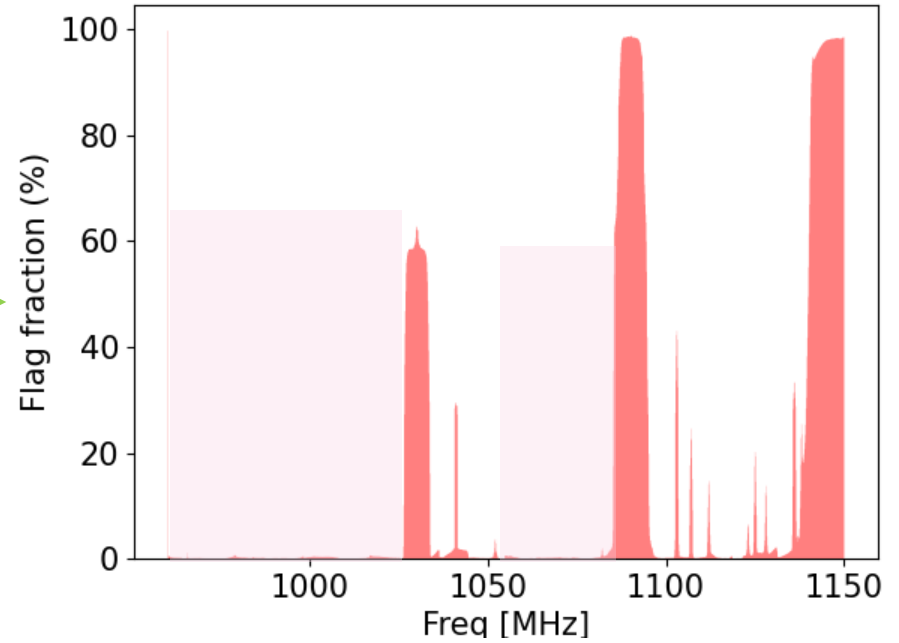

Mazunder+2023

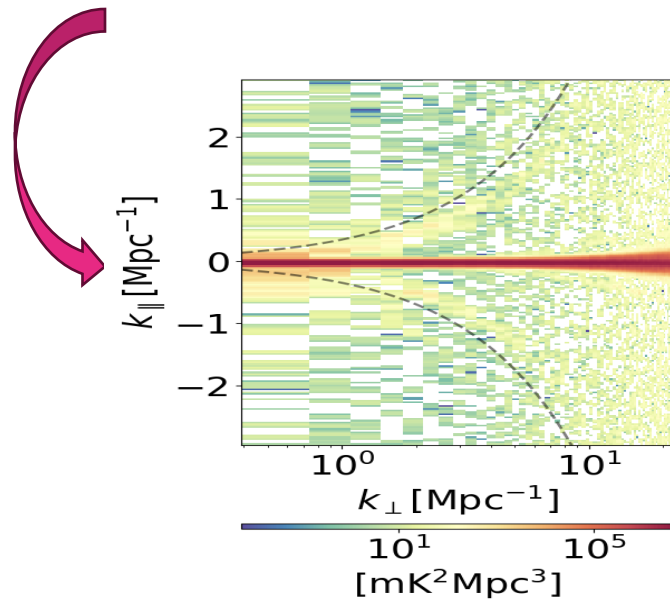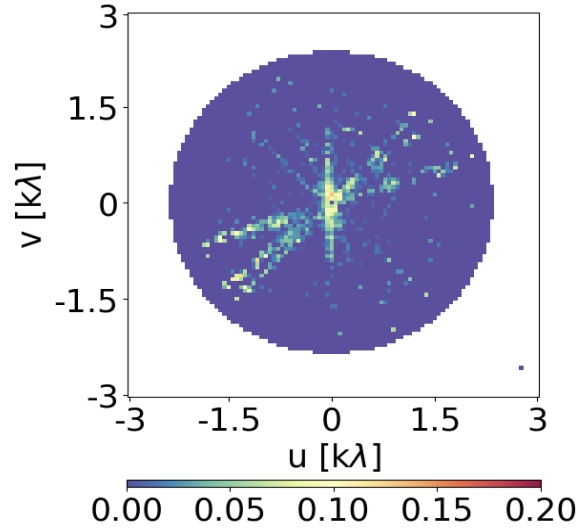# Low Redshifts with MeerKAT: Contamination Detectives
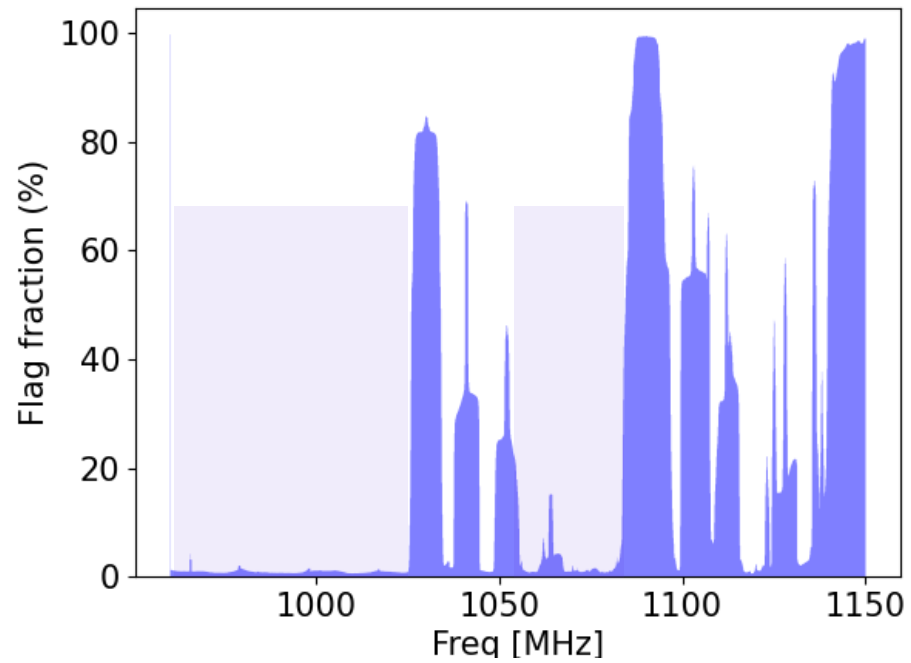
Low Redshifts with MeerKAT: Contamination Detectives
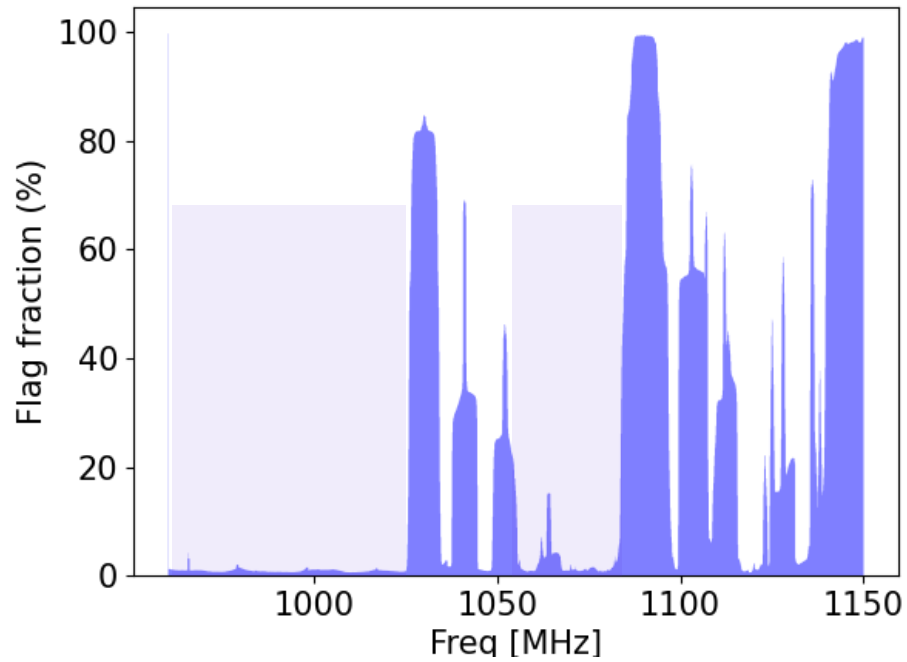
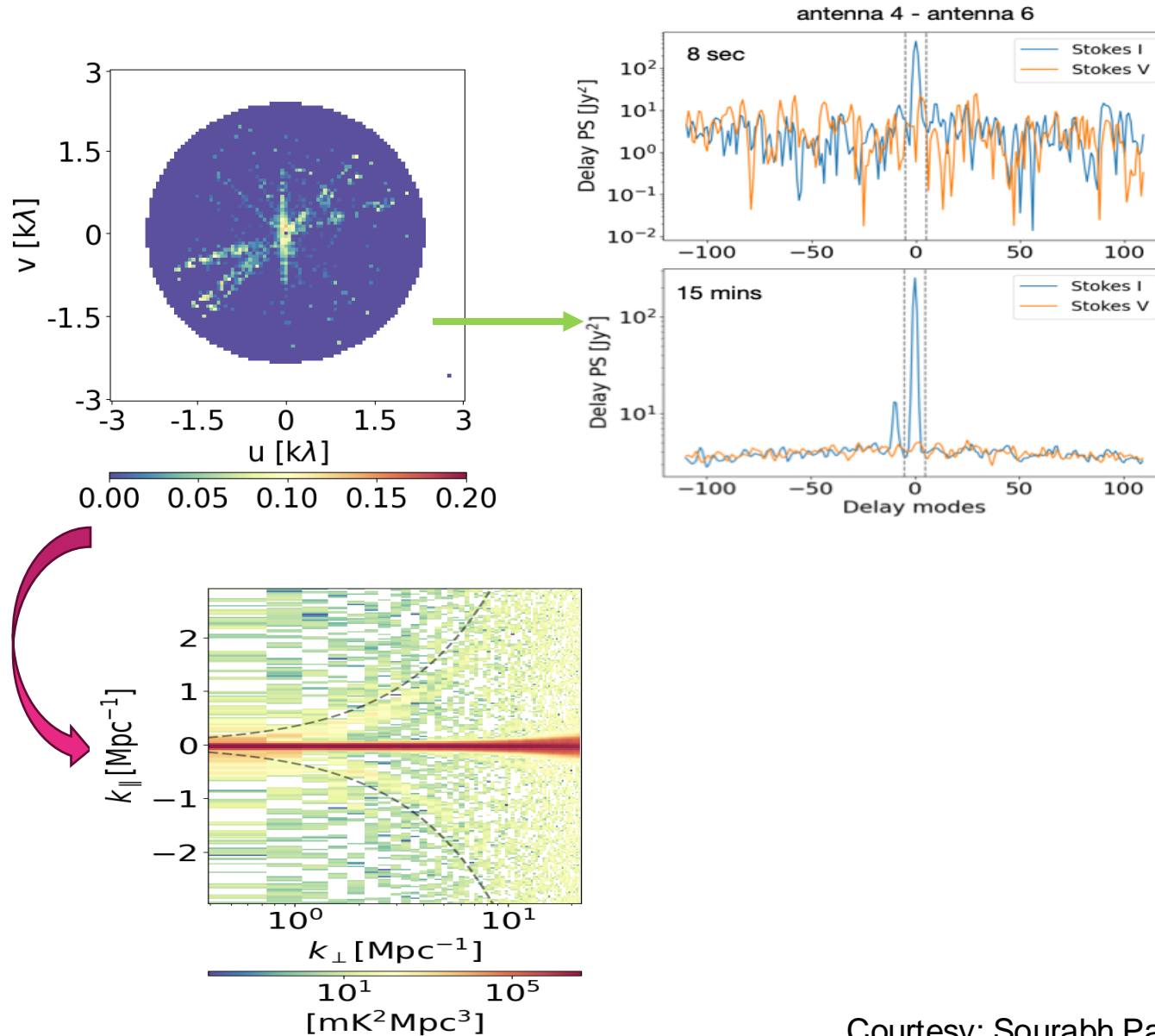Remove baselines > fixed flagging %

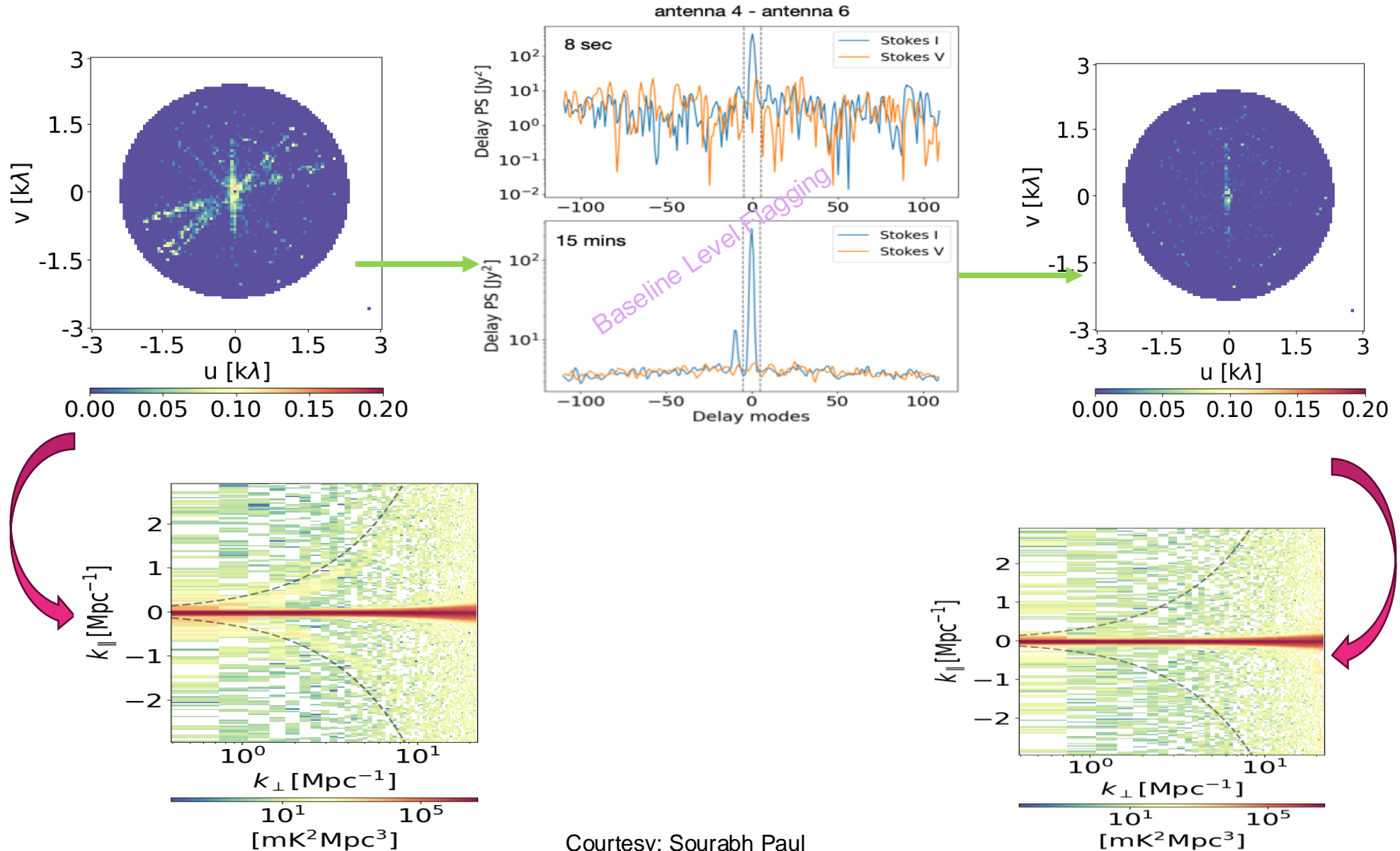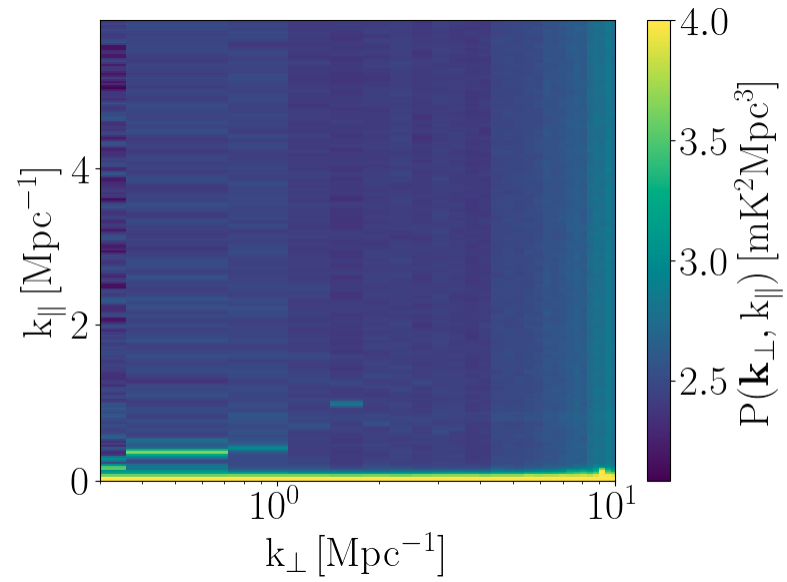# Low Redshifts with MeerKAT: Contamination Detectives

Courtesy: Sourabh Paul

Low Redshifts with MeerKAT: Contamination Detectives

Courtesy: Sourabh Paul

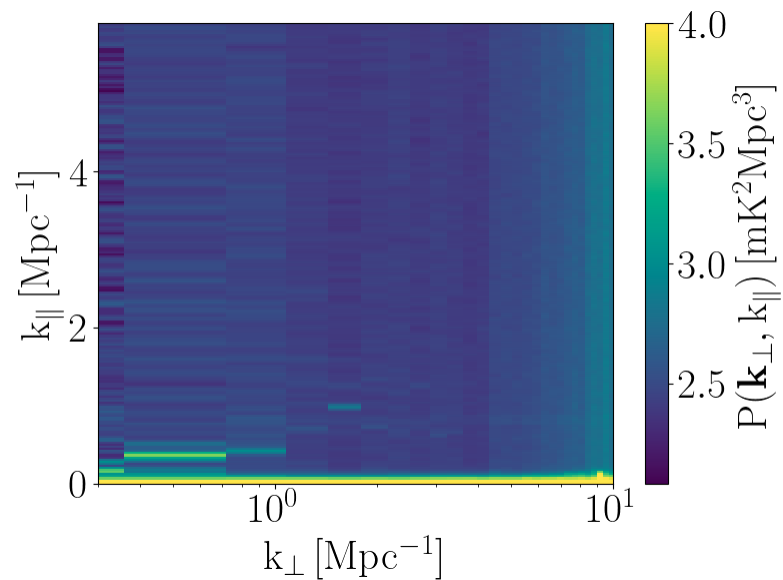# Low Redshifts with MeerKAT: Contamination Detectives
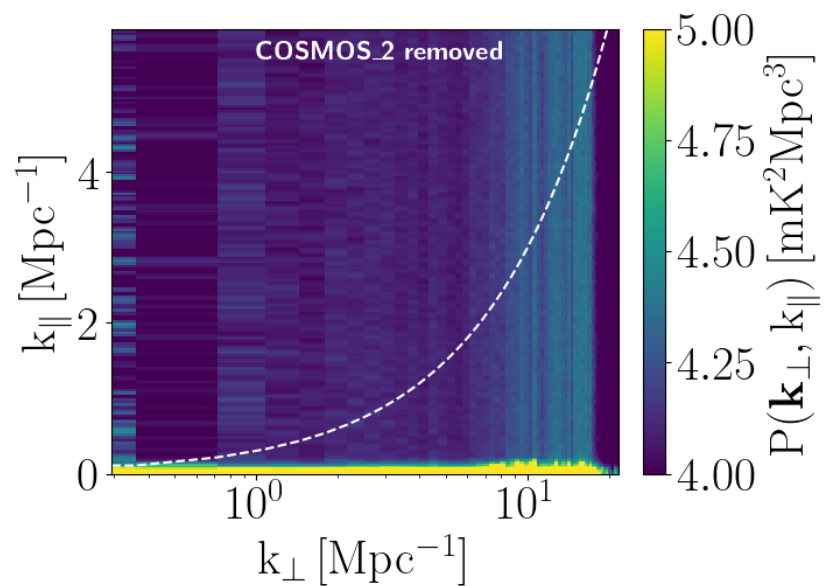

Courtesy: Sourabh Paul

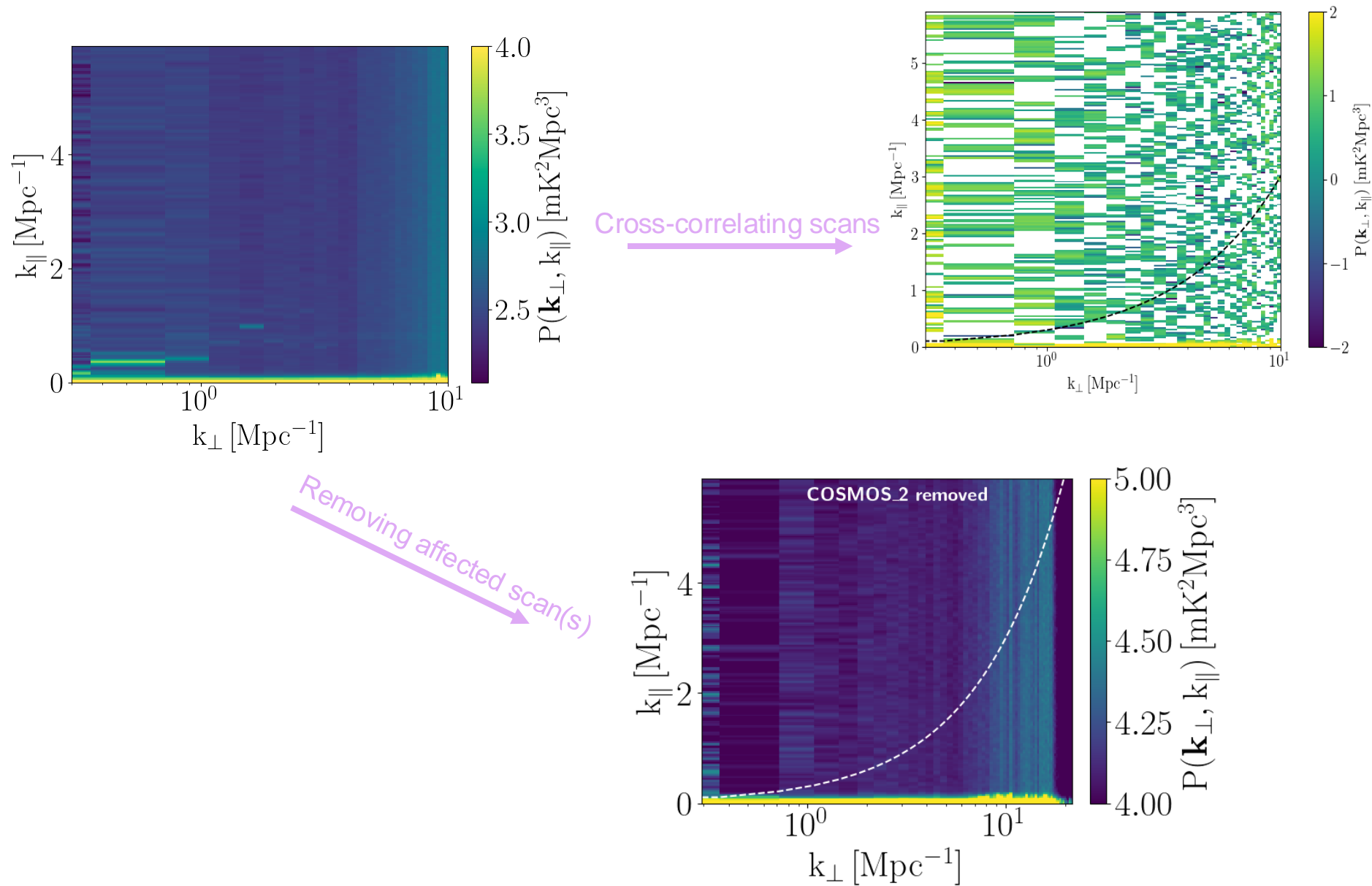# Low Redshifts with MeerKAT: Contamination Detectives

# Low Redshifts with MeerKAT: Contamination Detectives

Removing affected scan(s)

Low Redshifts with MeerKAT: Contamination Detectives

Cross-correlating scans

Removing affected scan(s)

COSMOS_2 removed

Low Redshifts with MeerKAT: Power Spectrum Estimates

- L-band observation ($0 \lesssim z \lesssim 0.5$) with a single pointing in DEEP2 region

- Single pointing- averaged coherently in visibilities

- Detection at z~0.32 and z~0.44 at 8.0σ and 11.5σ respectively (Paul+2023)

- MIGHTEE observations ($0 \lesssim z \lesssim 0.5$) over ~4 square degree in COSMOS field

- Multiple pointings- averaged incoherently in power spectrum (noise equivalent 25 hours)

- Best 2σ upper limit at k~1.96 Mpc^{-1} of 10 mK^2 Mpc^3 (Mazumder+, submitted)
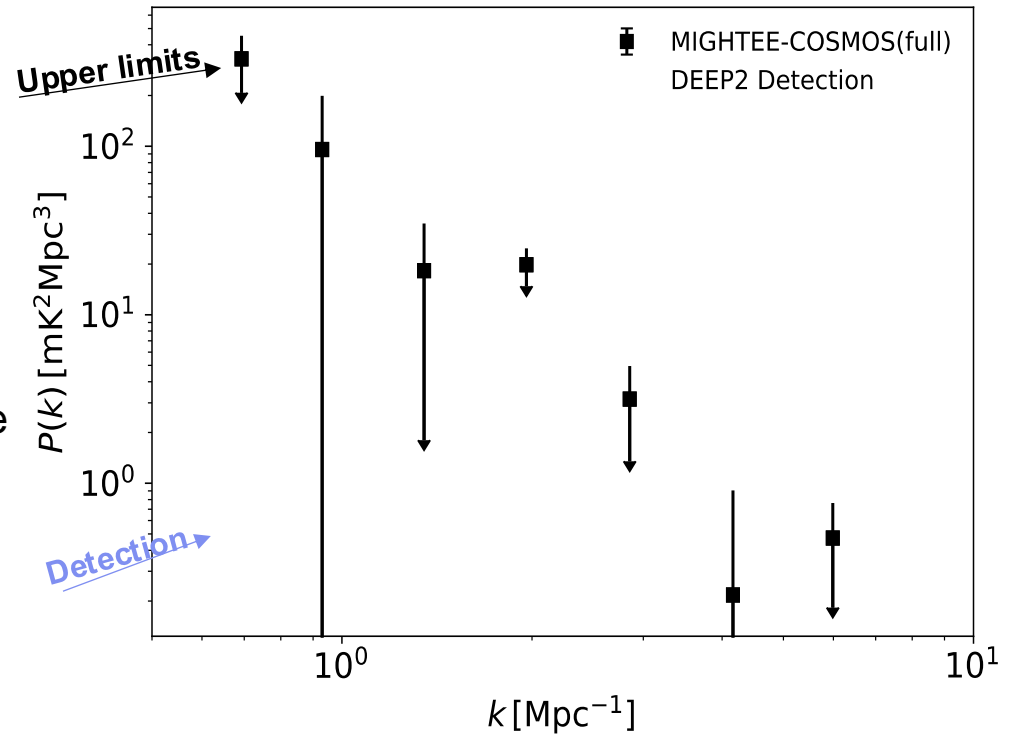
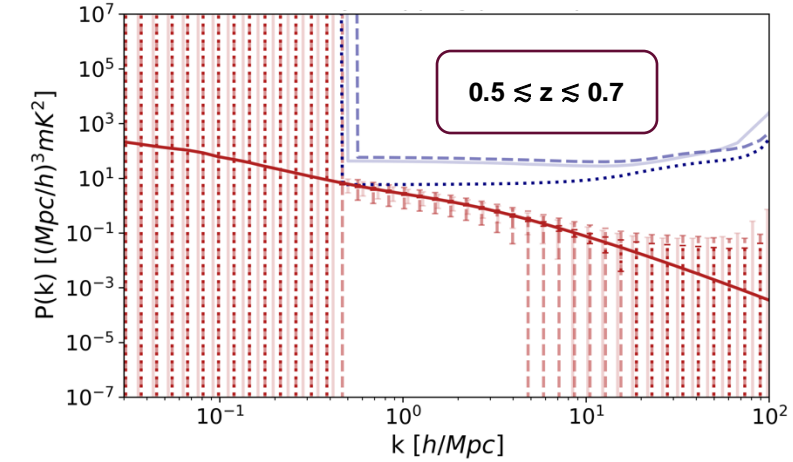# Towards SKAO: Predictions with Precursors

- Several completed and on-going surveys with precursors/pathfinders

- Large survey areas (and observing tines)

- Overlapping optical surveys present

- Auto & cross-correlation feasible at scales $\gtrsim 0.1$ h Mpc^{-1}

Paul+2021

Mazumder+ (in prep)
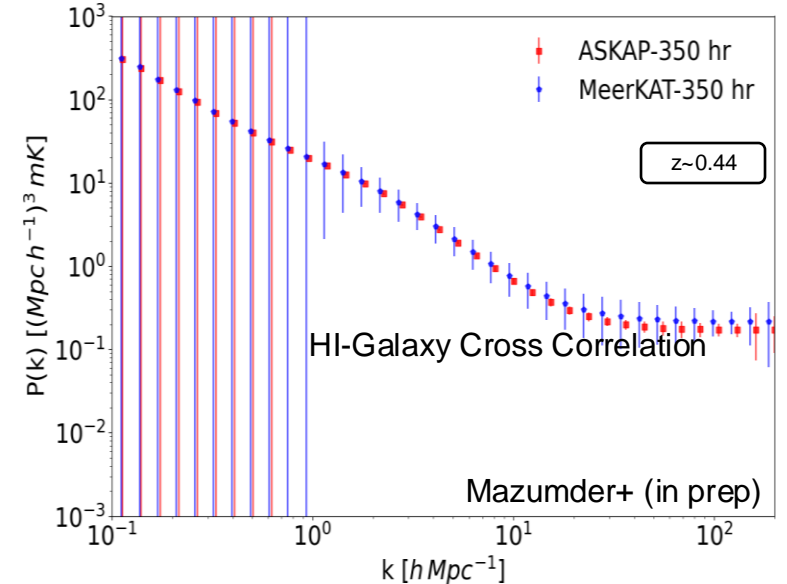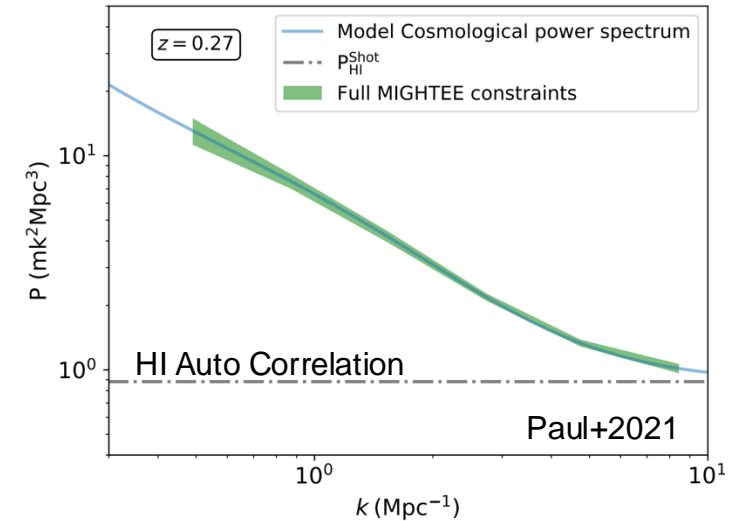
Predictions for Intensity Mapping with SKAO
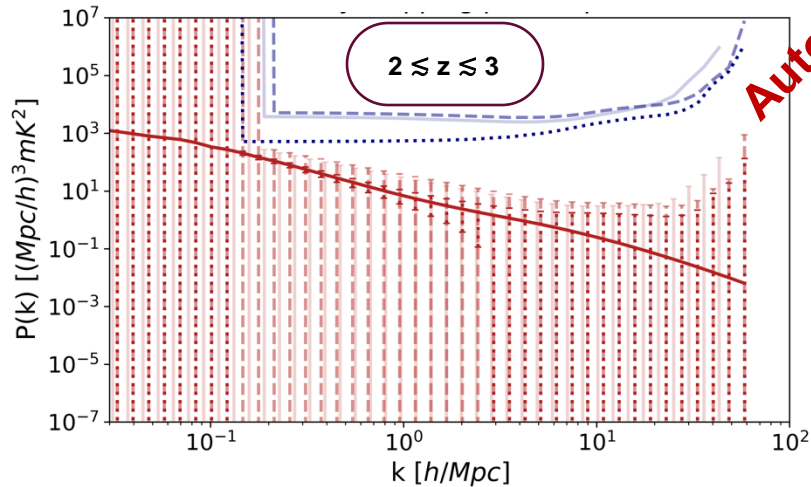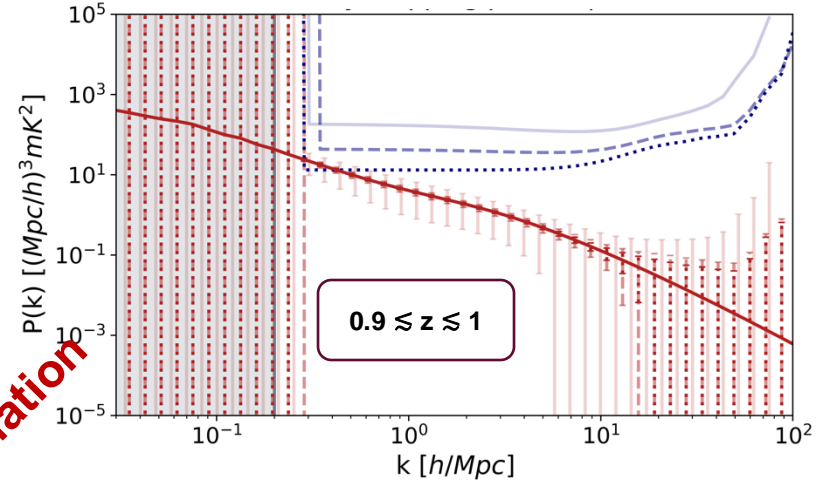
1000 hours observation,
15 square degree,
SKA-Mid

Courtesy: Alex Walls

Predictions for Intensity Mapping with SKAO

Courtesy: Alex Walls

Summary

- HI IM using interferometers probes k scales $\gtrsim 0.1$ Mpc^{-1}

- MeerKAT sensitivity making detection possible at z < 0.5

- Foregrounds and systematics constitute major issues - mitigation techniques actively being researched

- Power spectrum detection with deep observations coherent averaging works well

- Upper limits with shallow(er) multi-pointing observations – incoherent averaging also works!

- Forecasts with AA* and AA4 configurations for both auto and cross-correlations are promising for "reasonable" survey areas and times

- HI Intensity Mapping (& HI galaxy) Science Chapter(s)?

Thank You!