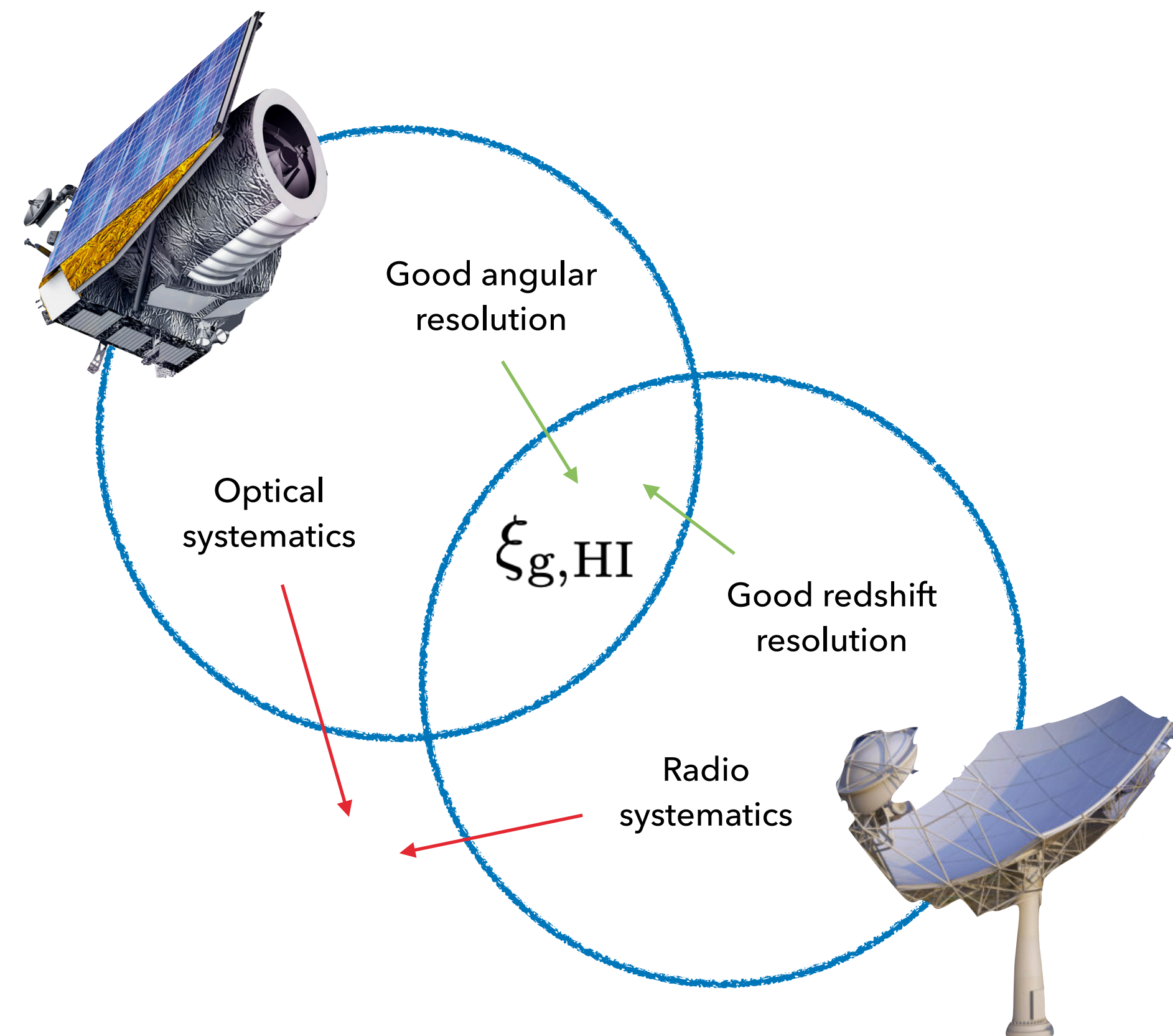


Science with 21cm intensity mapping cross-correlations

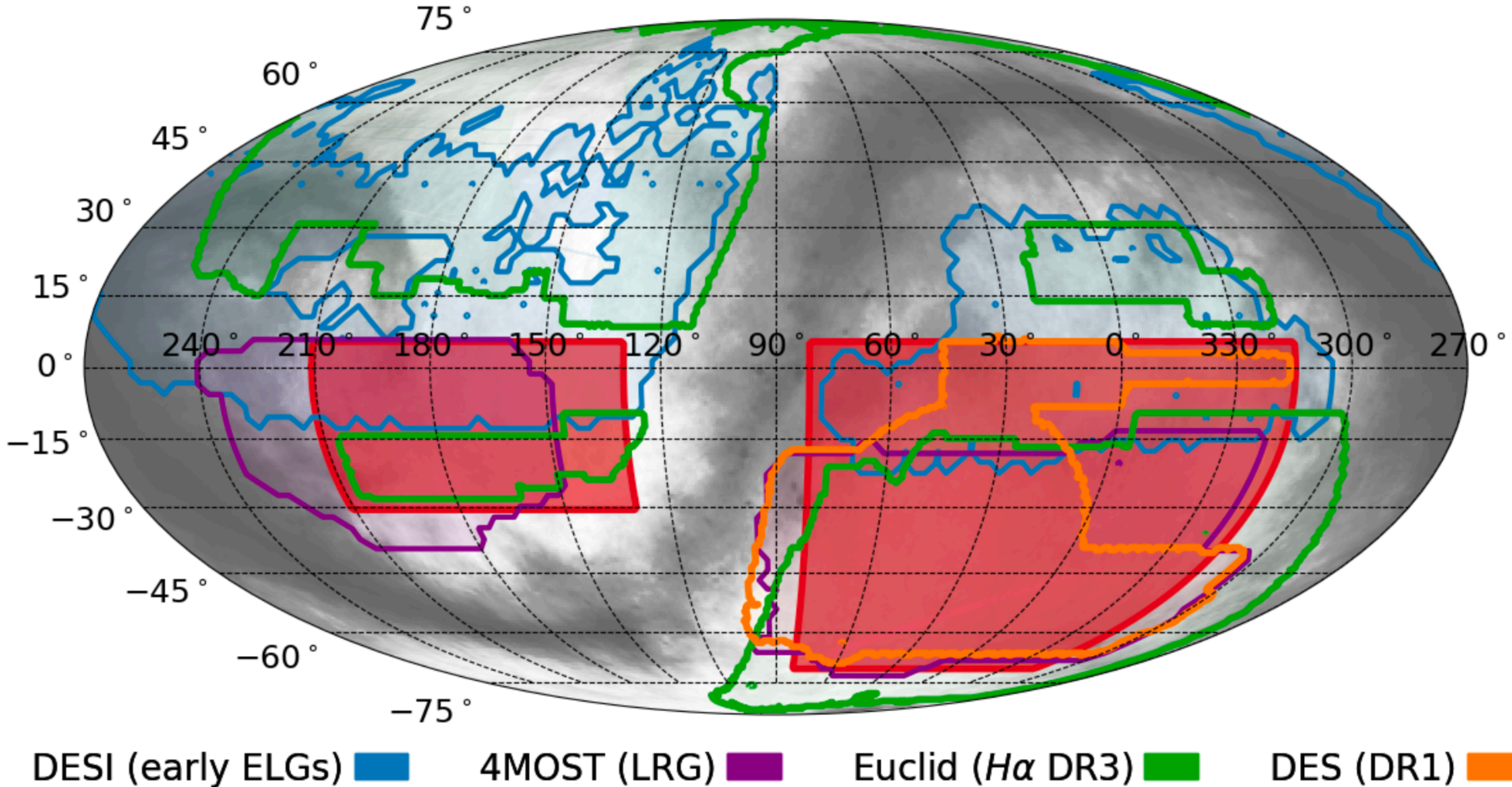
Steve Cunnington

Jodrell Bank Centre for Astrophysics - The University of Manchester

21 cm Cosmology Workshop 2024
& Tianlai Collaboration Meeting
23rd July 2024



Optical surveys will soon cover most of the sky



SKAO pathfinder: MeerKAT



- ▶ 64 dishes to merge with full SKA-MID
- ▶ $0.2 < z < 0.58$ (L-band)
- ▶ $0.4 < z < 1.45$ (UHF-band)



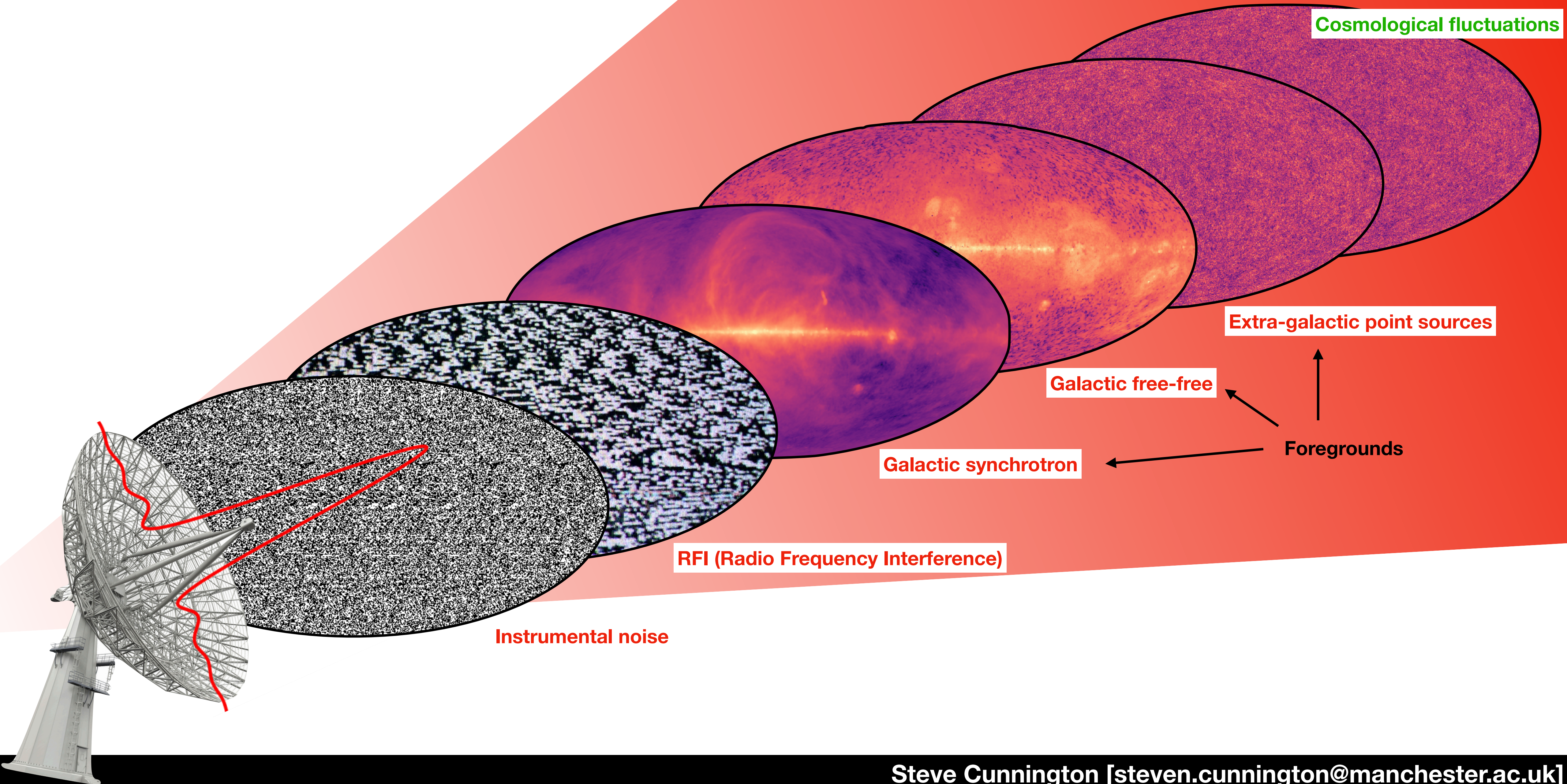
MeerKLASS

(MeerKAT Large Area Synoptic Survey)

- rely on single-dish mode observations (not interferometer)

- ▶ Several pilot surveys already complete
- ▶ 10,000 deg² survey **commencing now/early 2024**

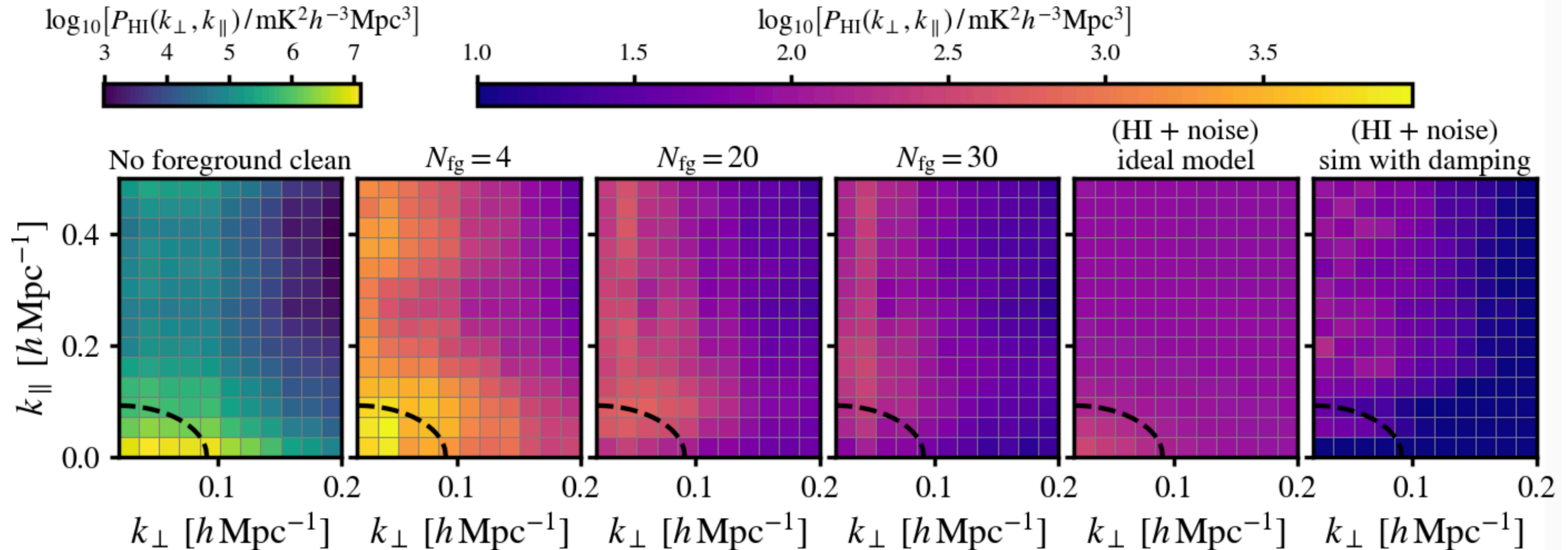
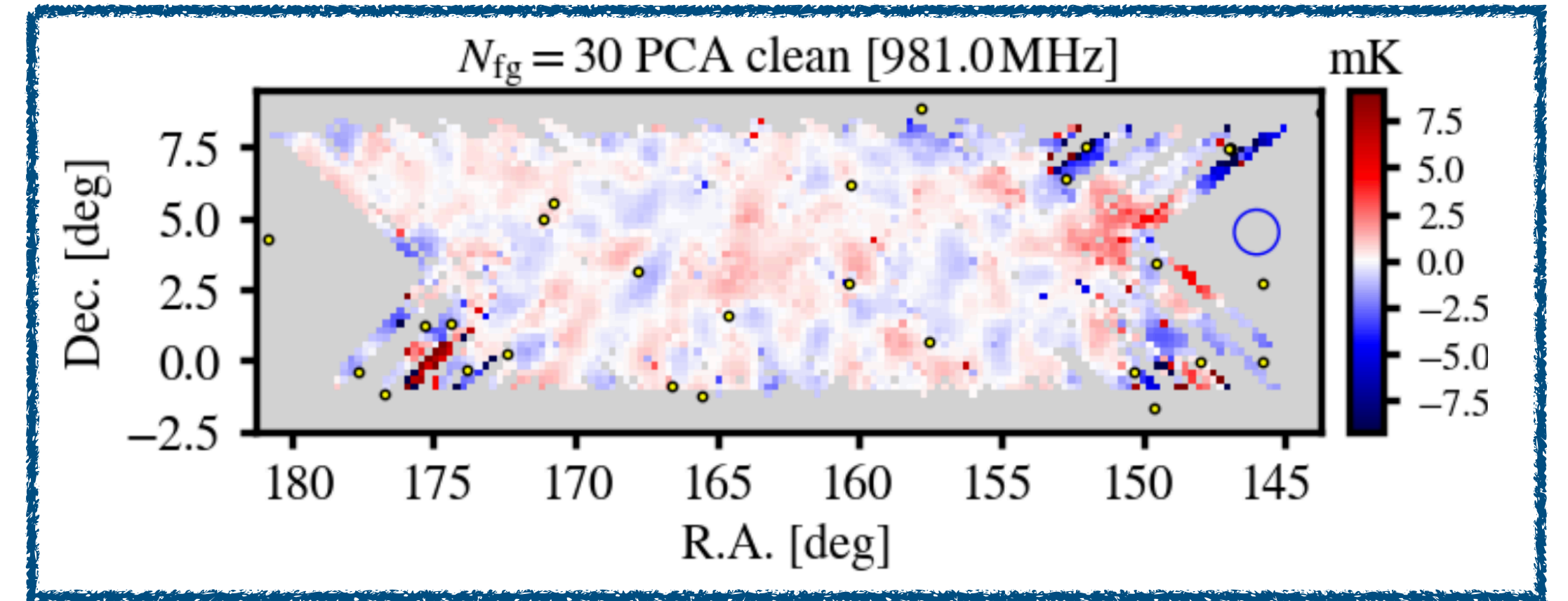
Challenges for 21cm intensity mapping



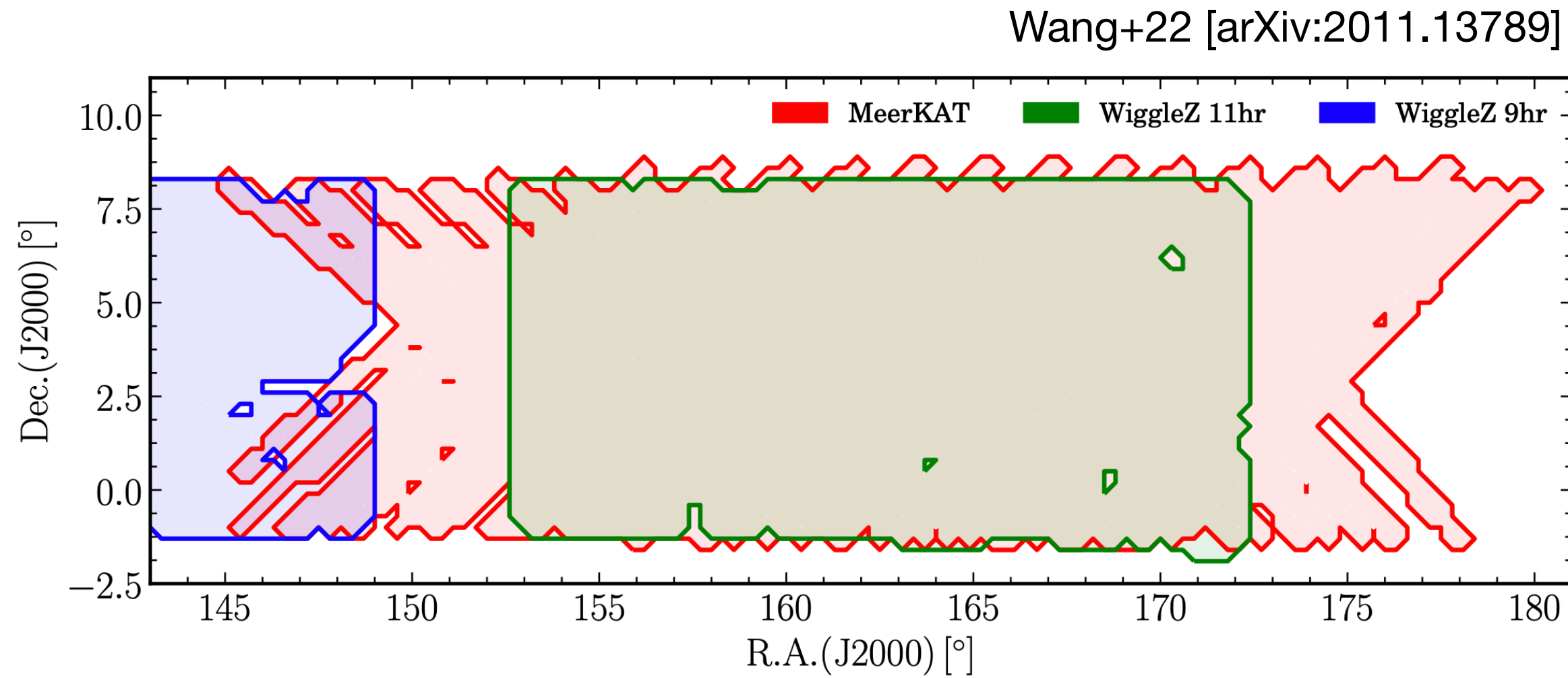
21cm auto-correlations and systematic bias

Results from MeerKLASS pilot survey

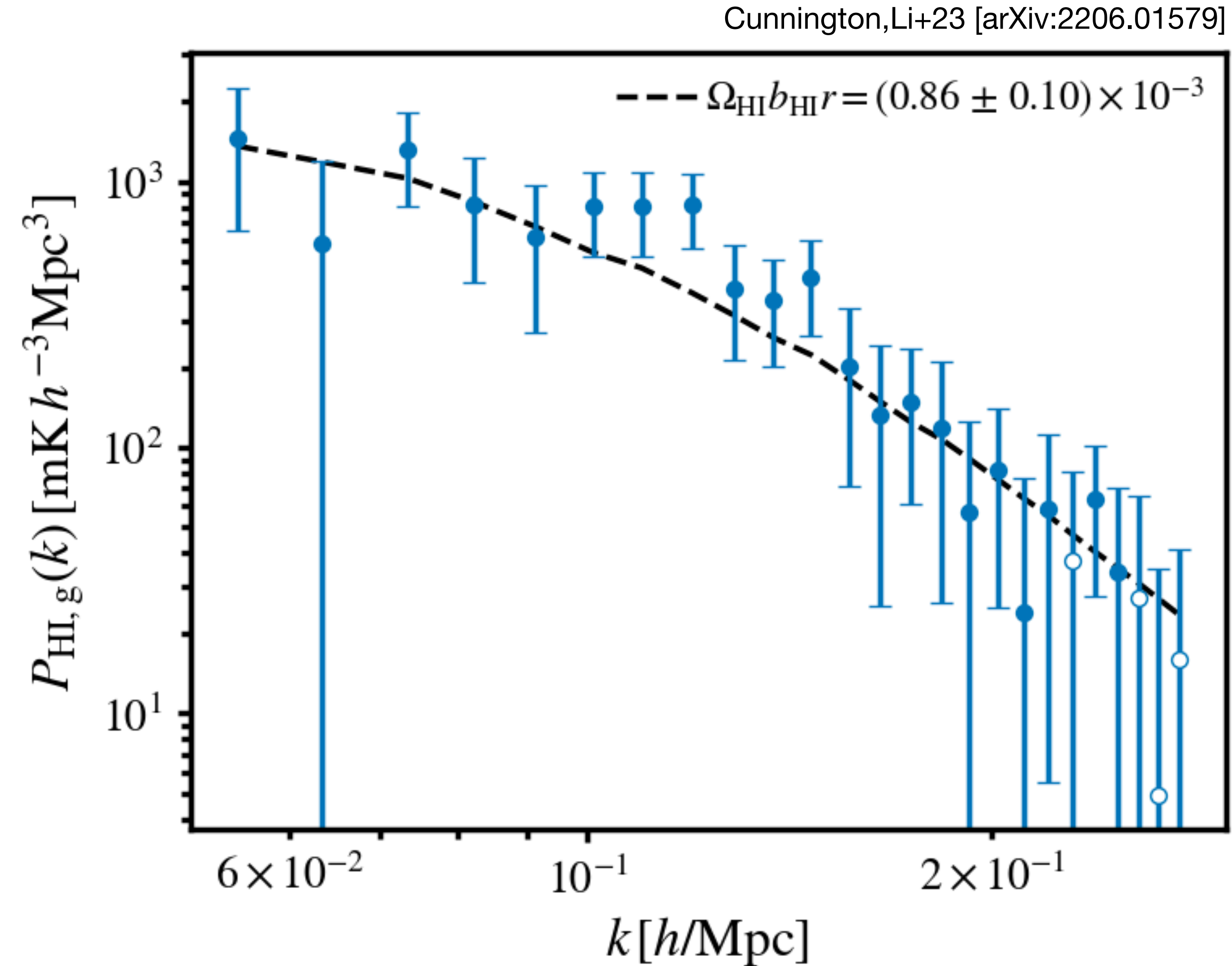
Cunnington, Li+23 [arXiv:2206.01579]



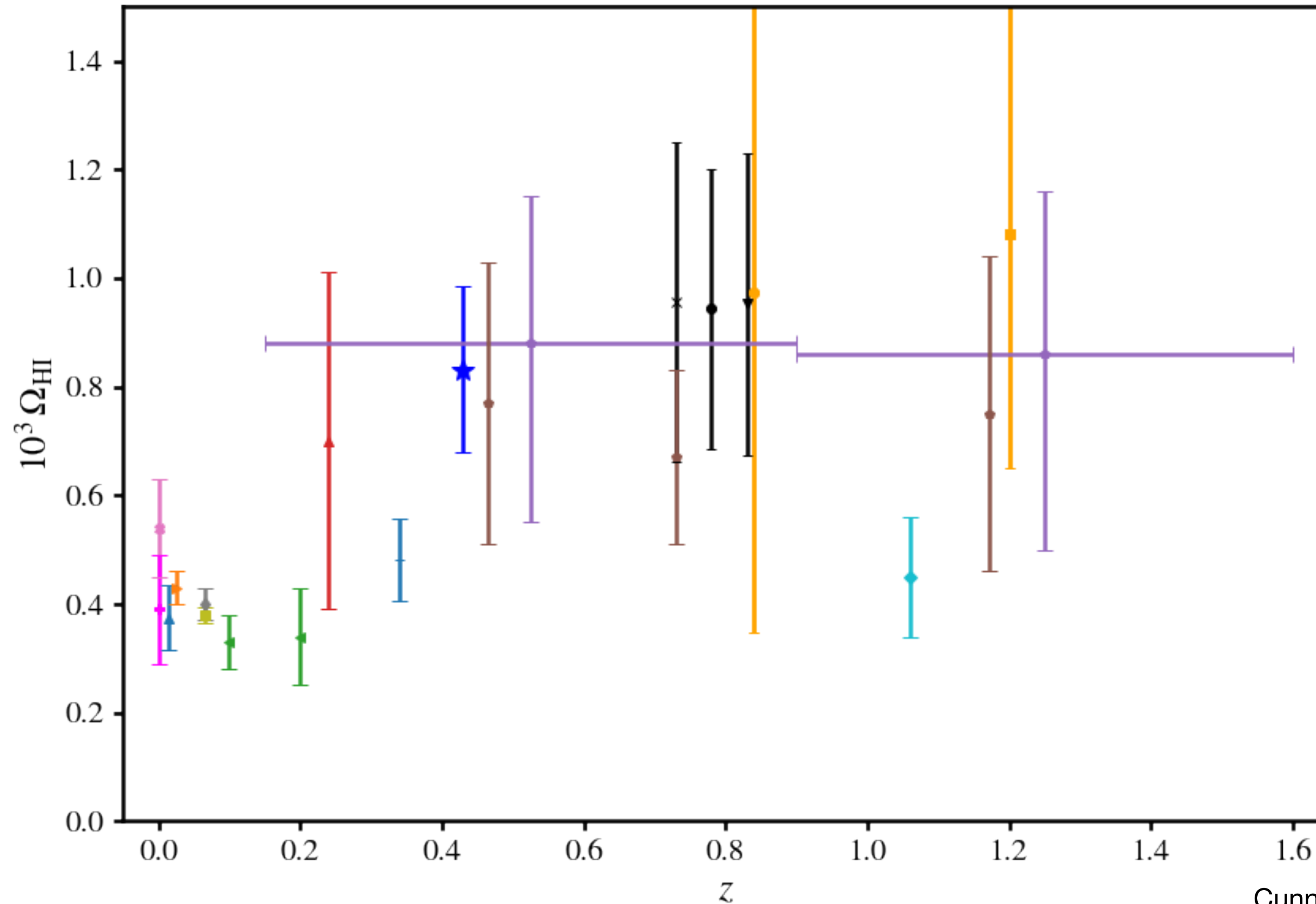
Can instead make a detection with *cross-correlations*



- Positive correlation (7.7σ) between galaxy survey and array of dishes in single-dish mode
- The first detection of its kind
- Important milestone for doing LSS cosmology with SKA intensity mapping

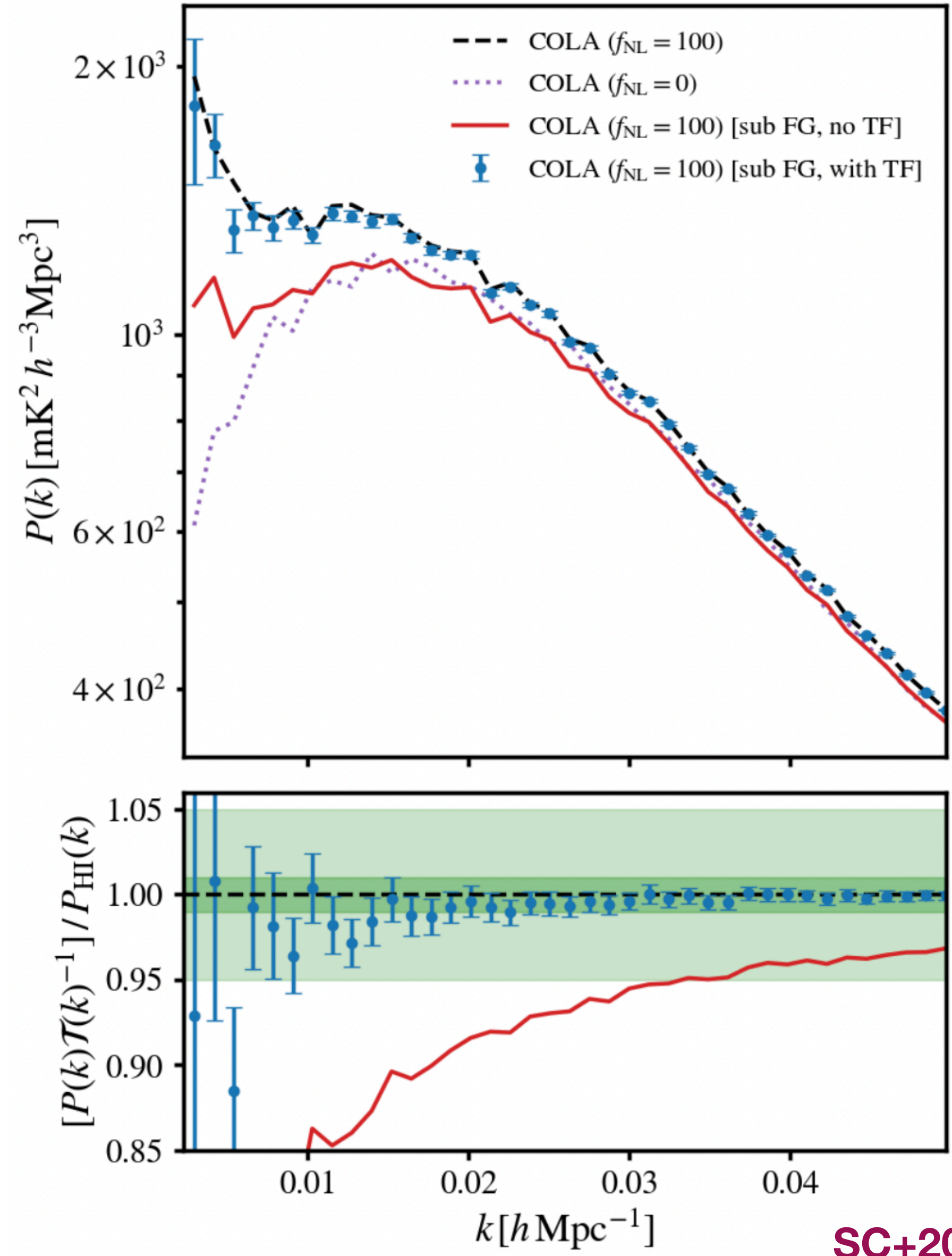


Constraining the HI abundance



Cunnington, Li+23 [arXiv:2206.01579]

Overcoming challenges

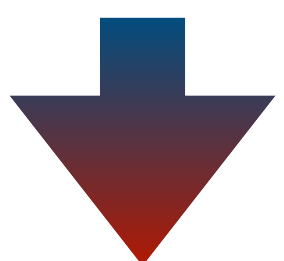


Reconstructing signal loss from foreground cleaning

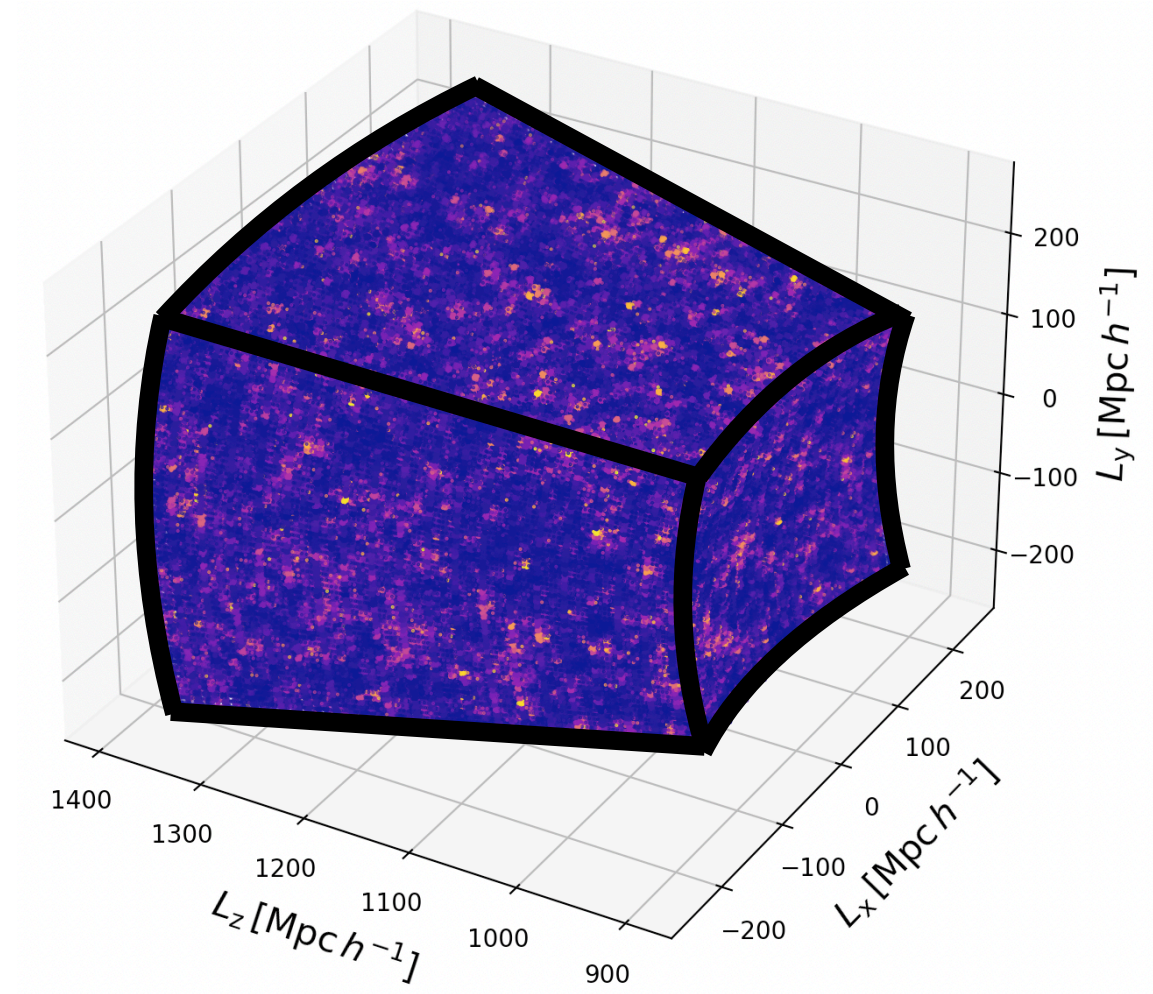


SC+2023 [arXiv:2302.07034]

Observations on the sky

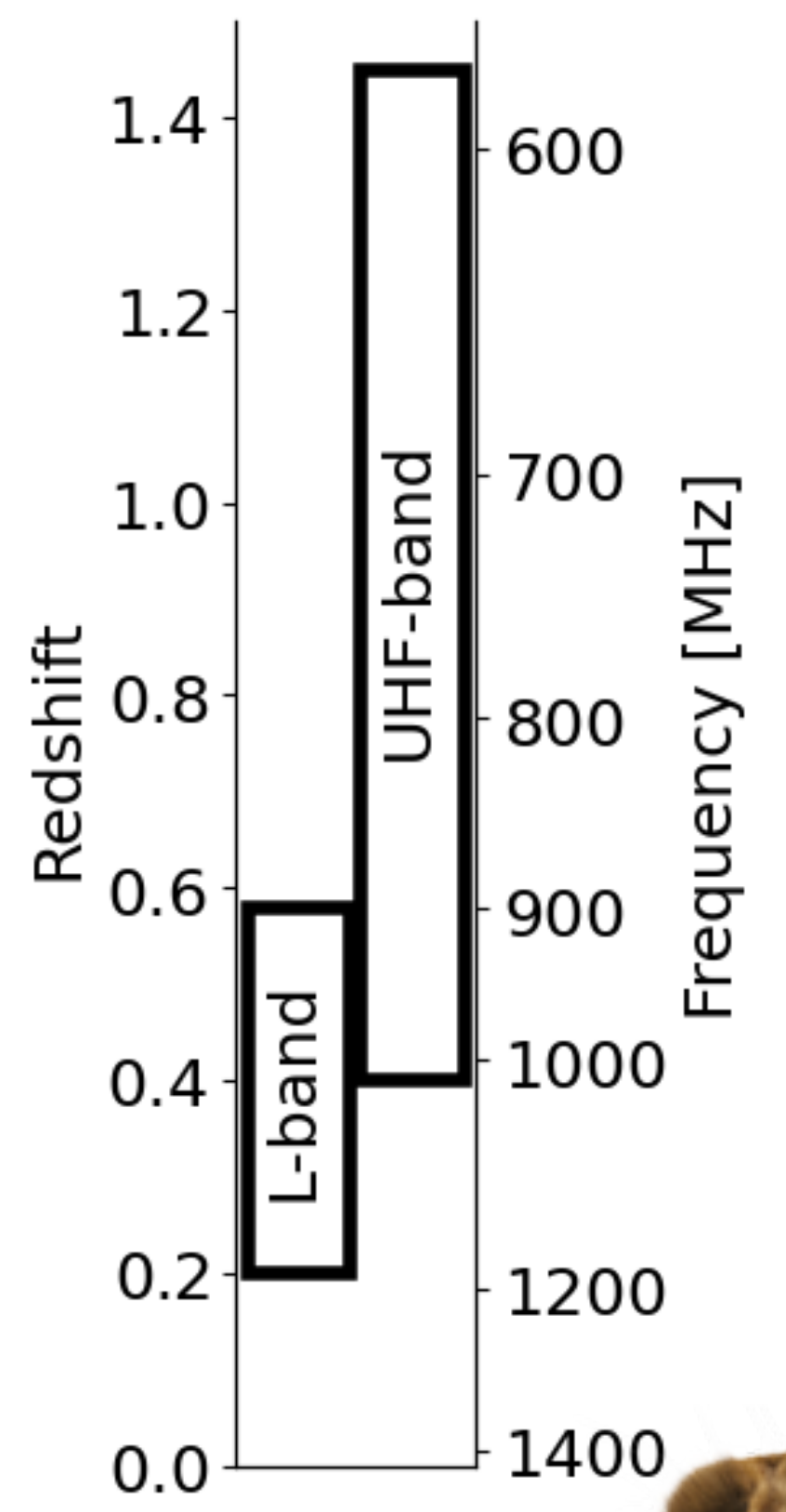
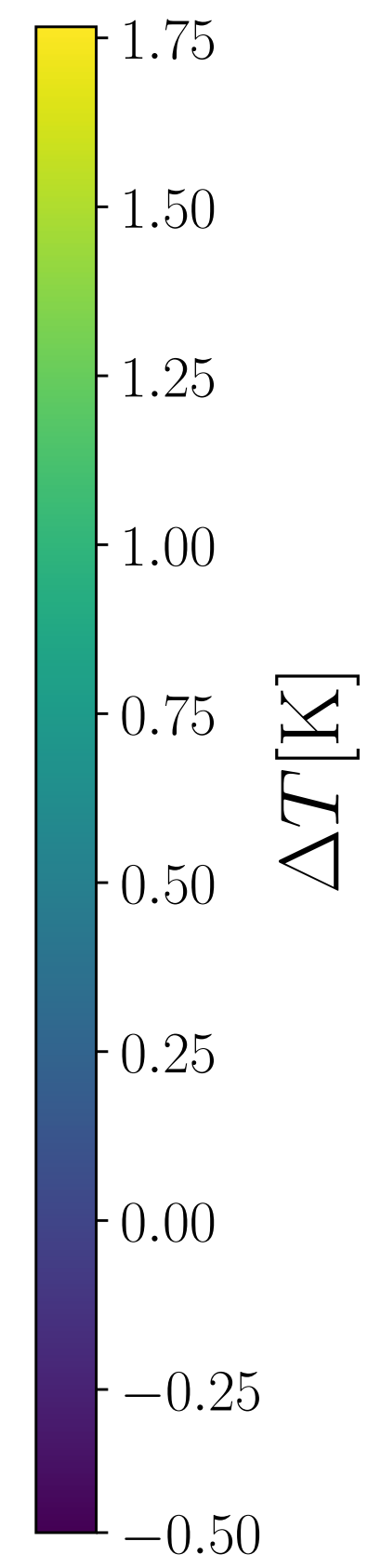
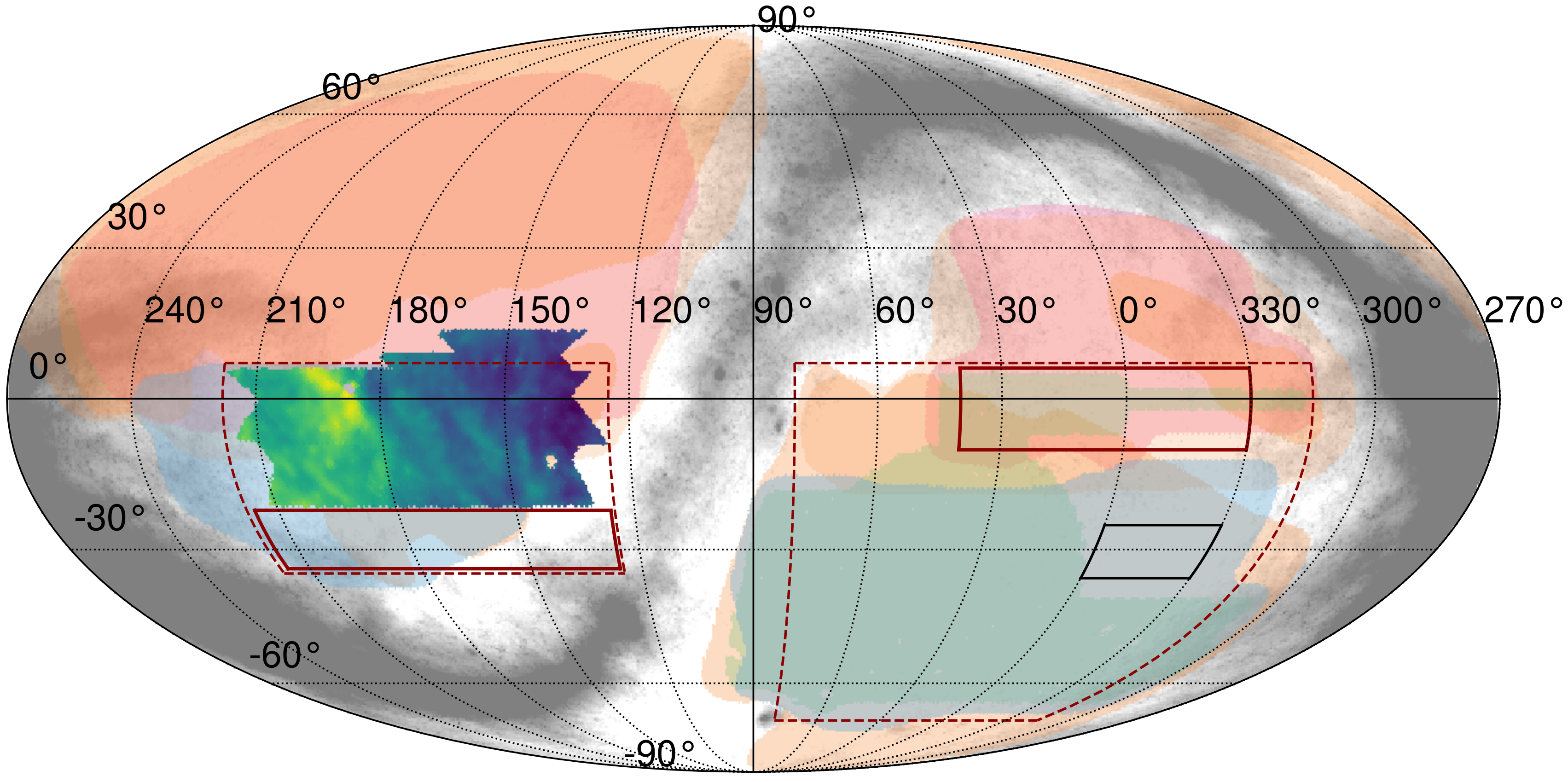


Analysis in Cartesian space



SC & Laura Wolz 2023 [arXiv:2312.07289]

What the future holds... MeerKLASS (MeerKAT Large Area Synoptic Survey)



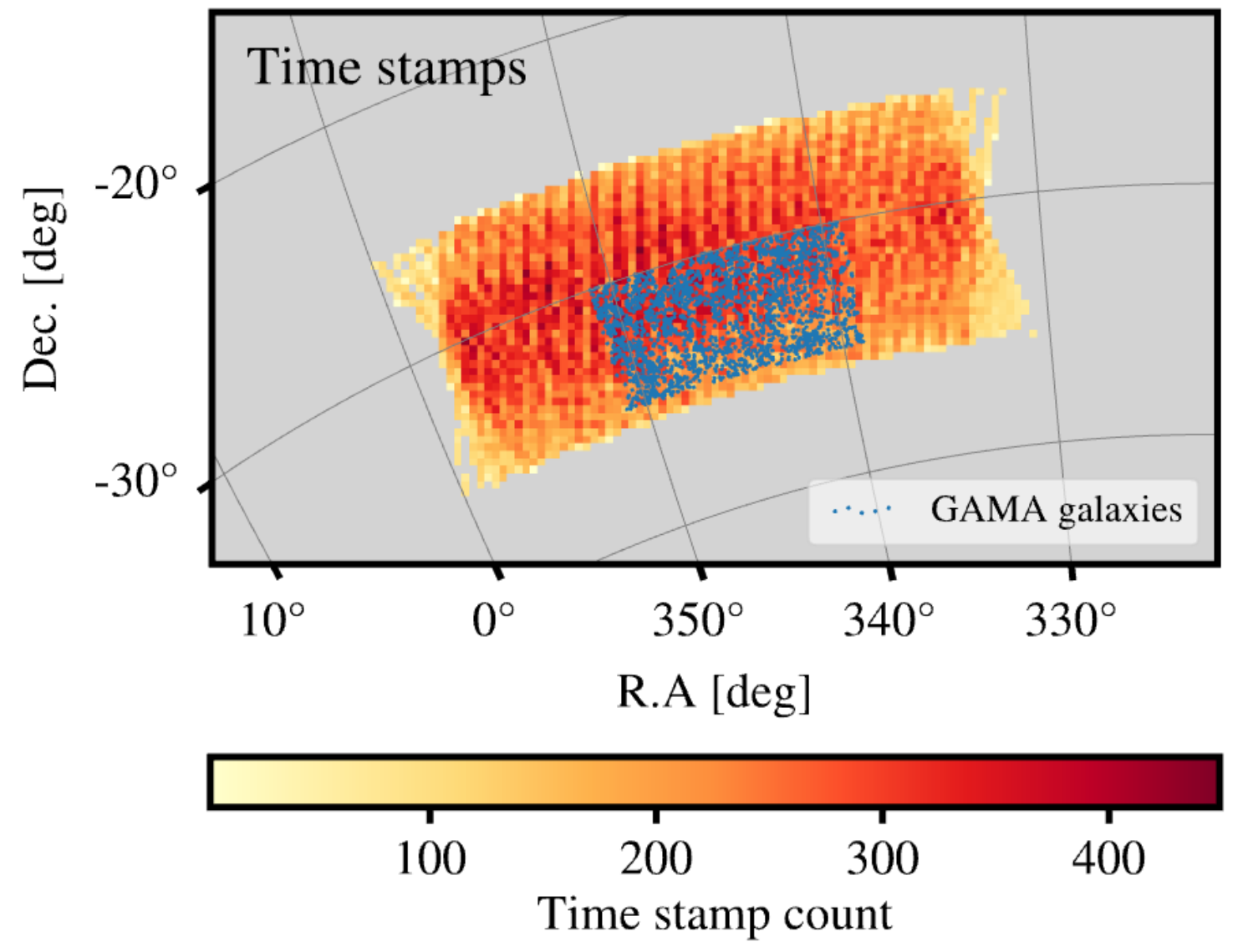
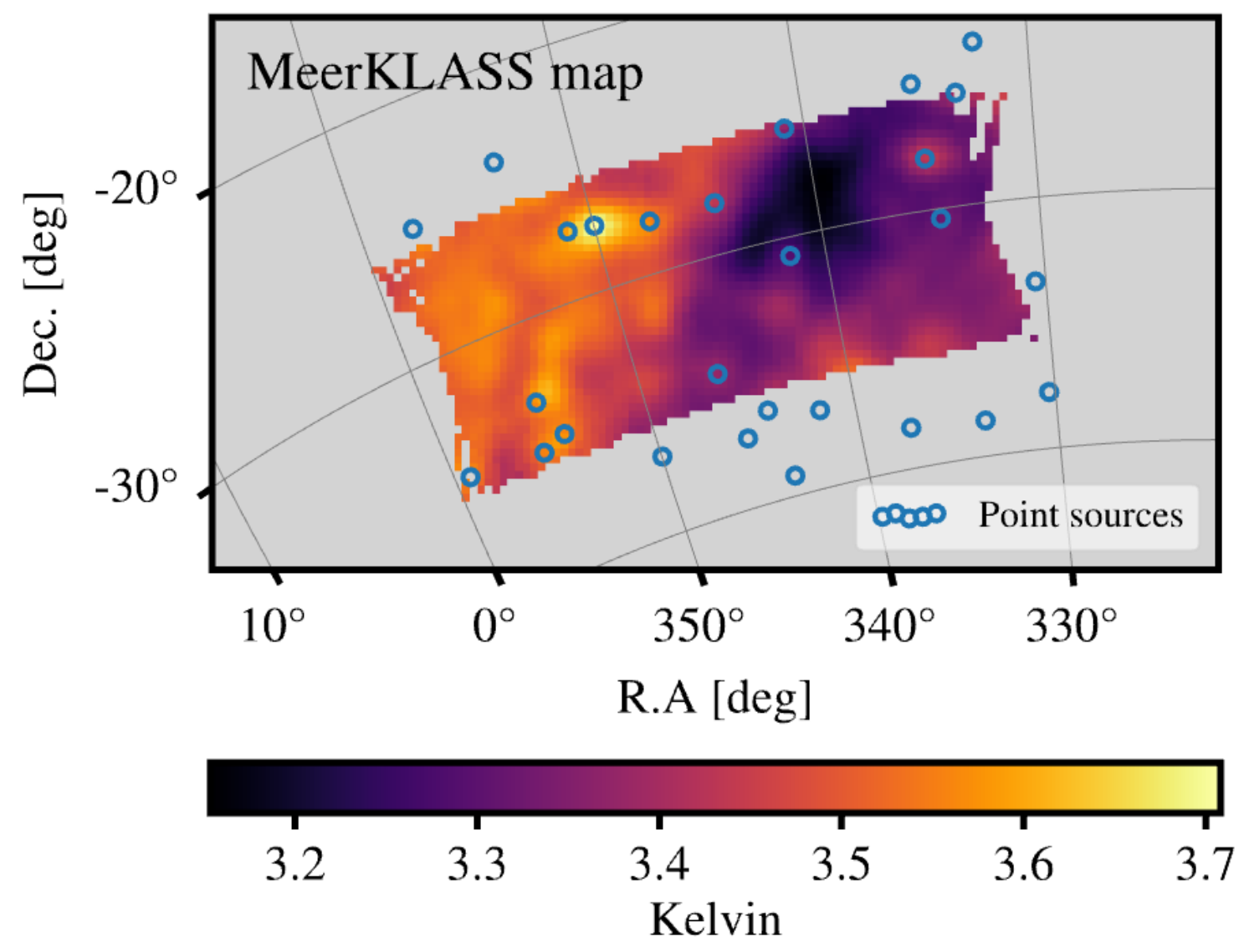
- SDSS
- Euclid
- 4MOST
- MeerKLASS 2024-2025
- DES
- DESI
- L-band deep field
- MeerKLASS 2023-2028

Credit: Marta Spinelli & MeerKLASS Collab.

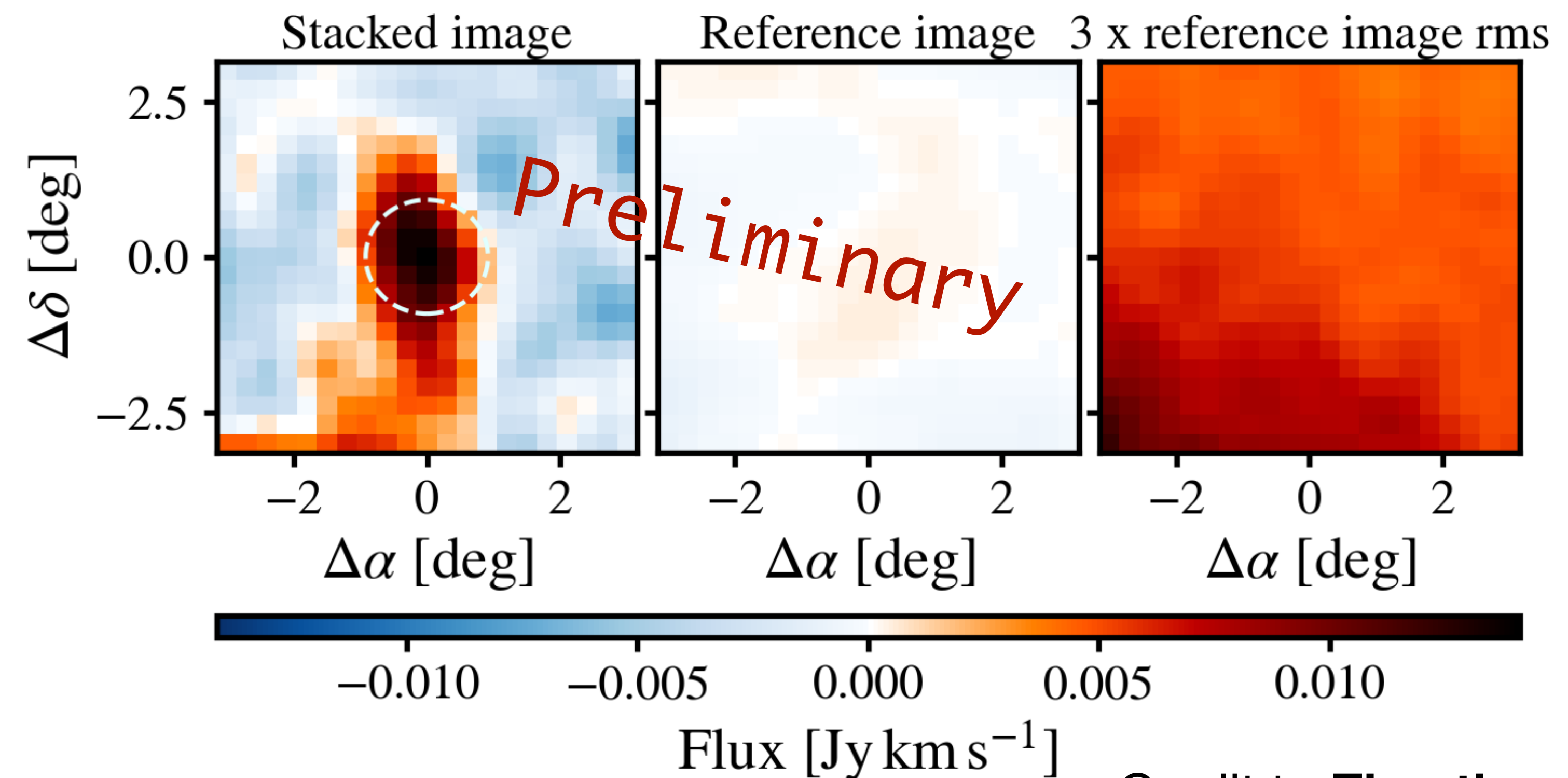


almost not

Preliminary results from MeerKLASS deep-field



Cross-correlation with small field of GAMA galaxies



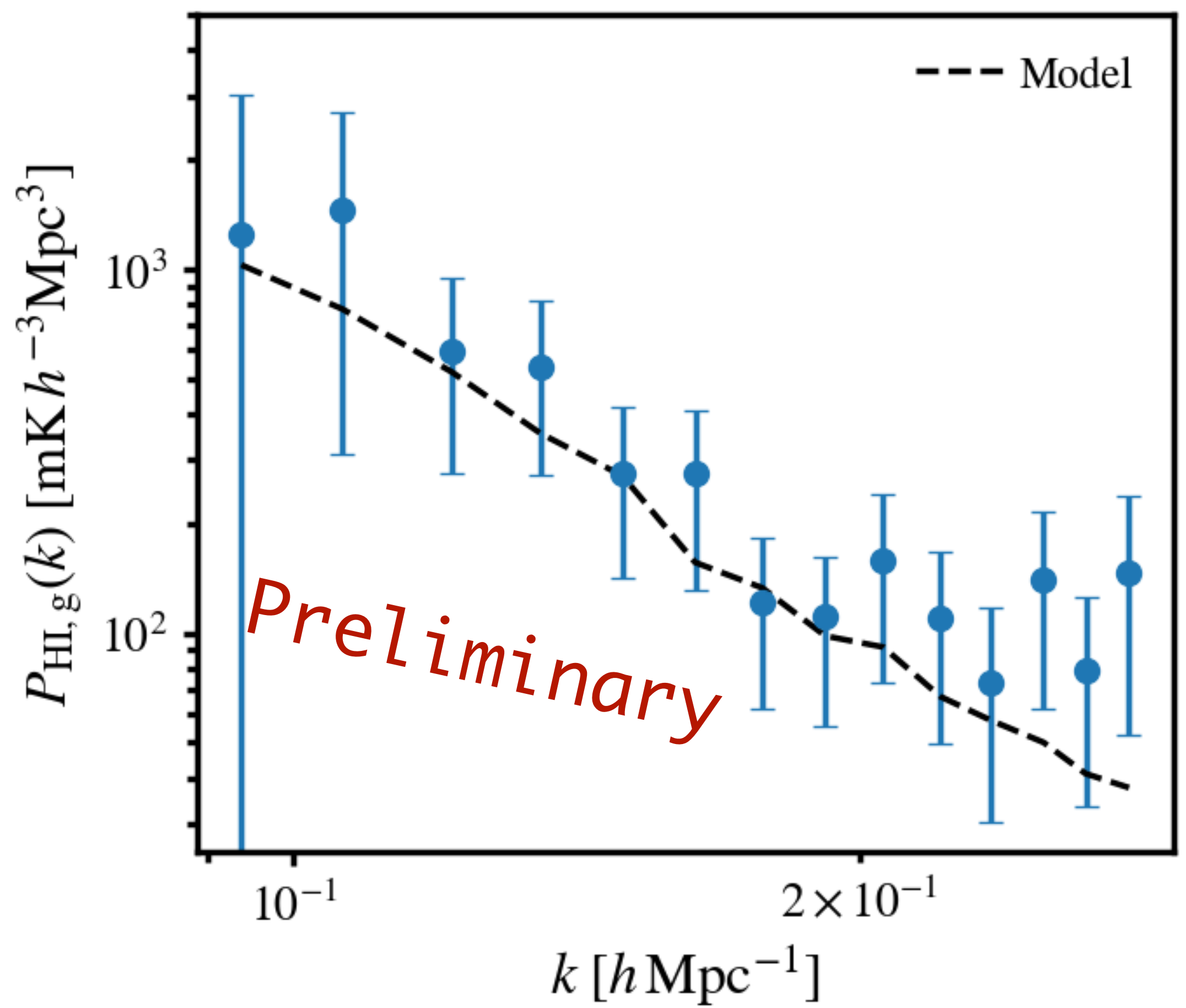
Credit to **Zhaoting Chen**
(aiding in release of **meerpower** pipeline)

arXiv:2407.?????? (next week 🤞🤞🤞)

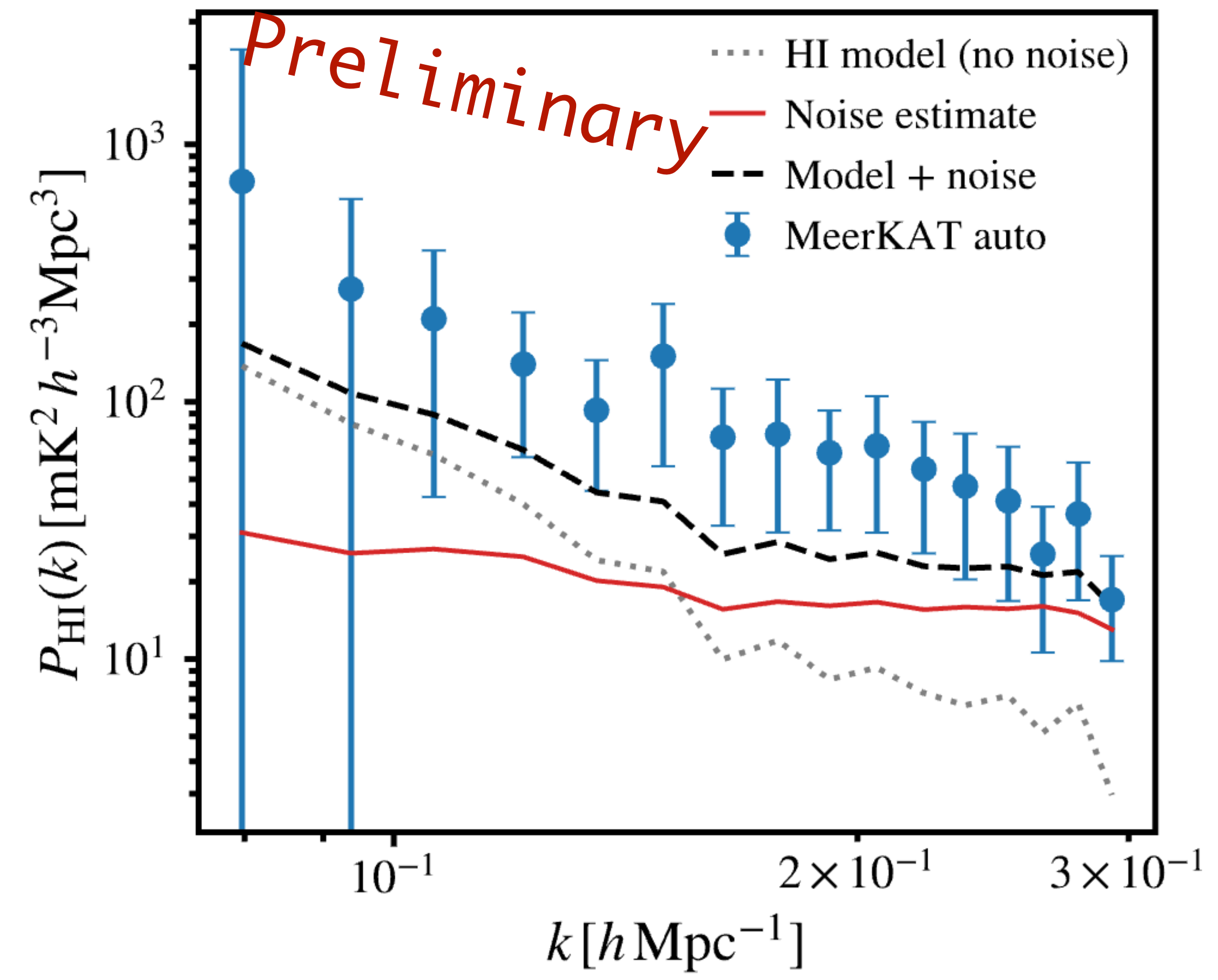
almost not

Preliminary results from MeerKLASS deep-field

Cross-correlation with GAMA galaxies



HI auto power spectrum "lowest upper-limit" ...

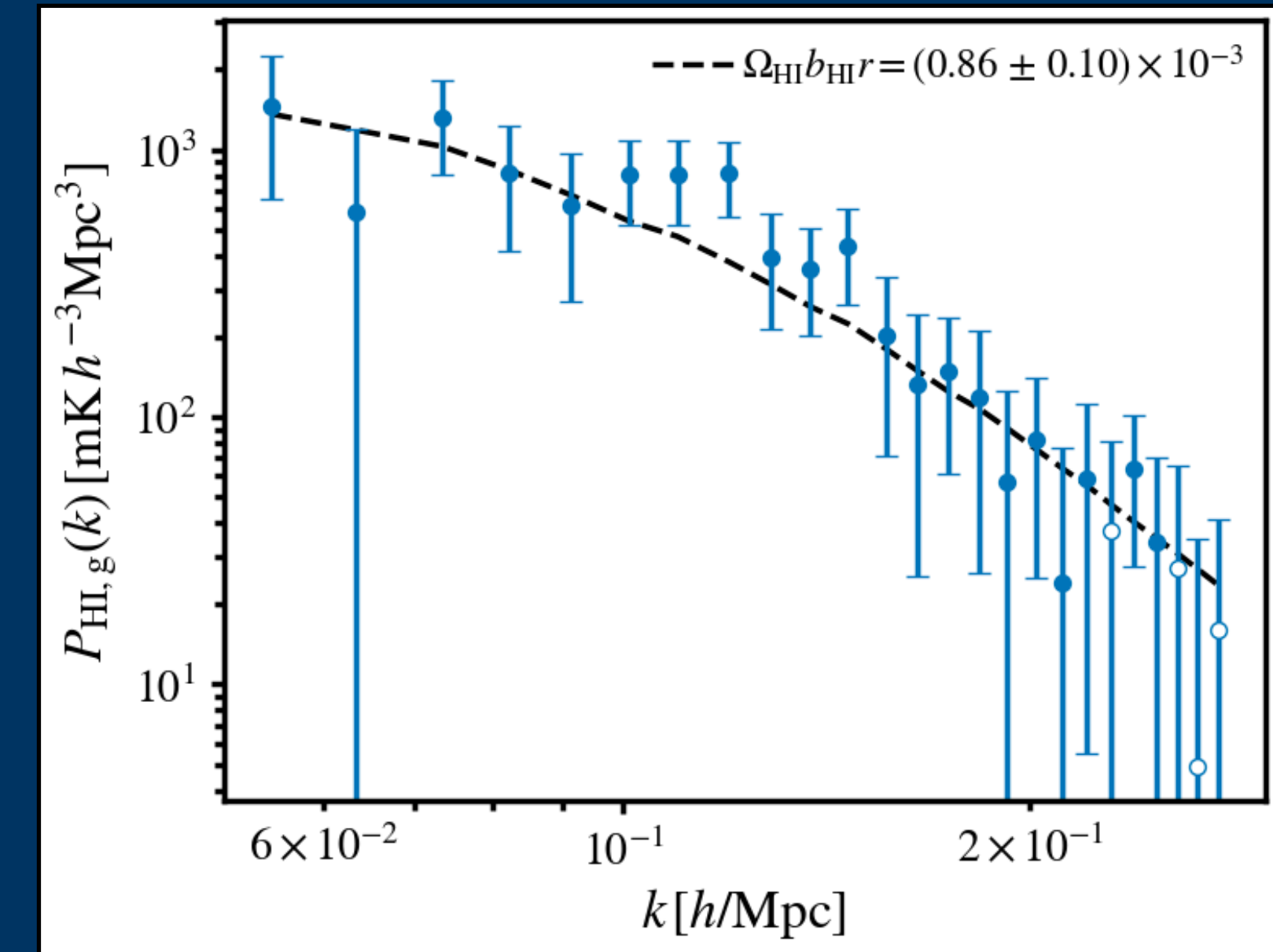
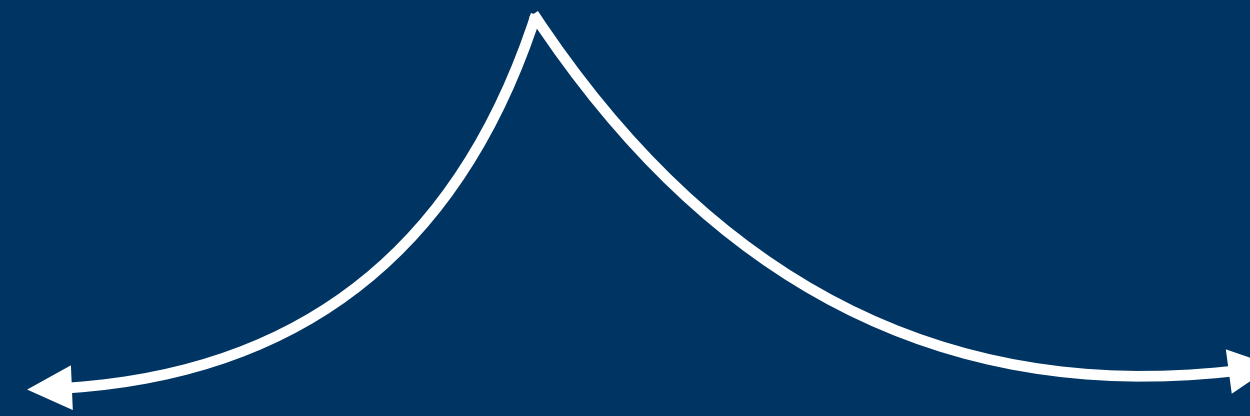
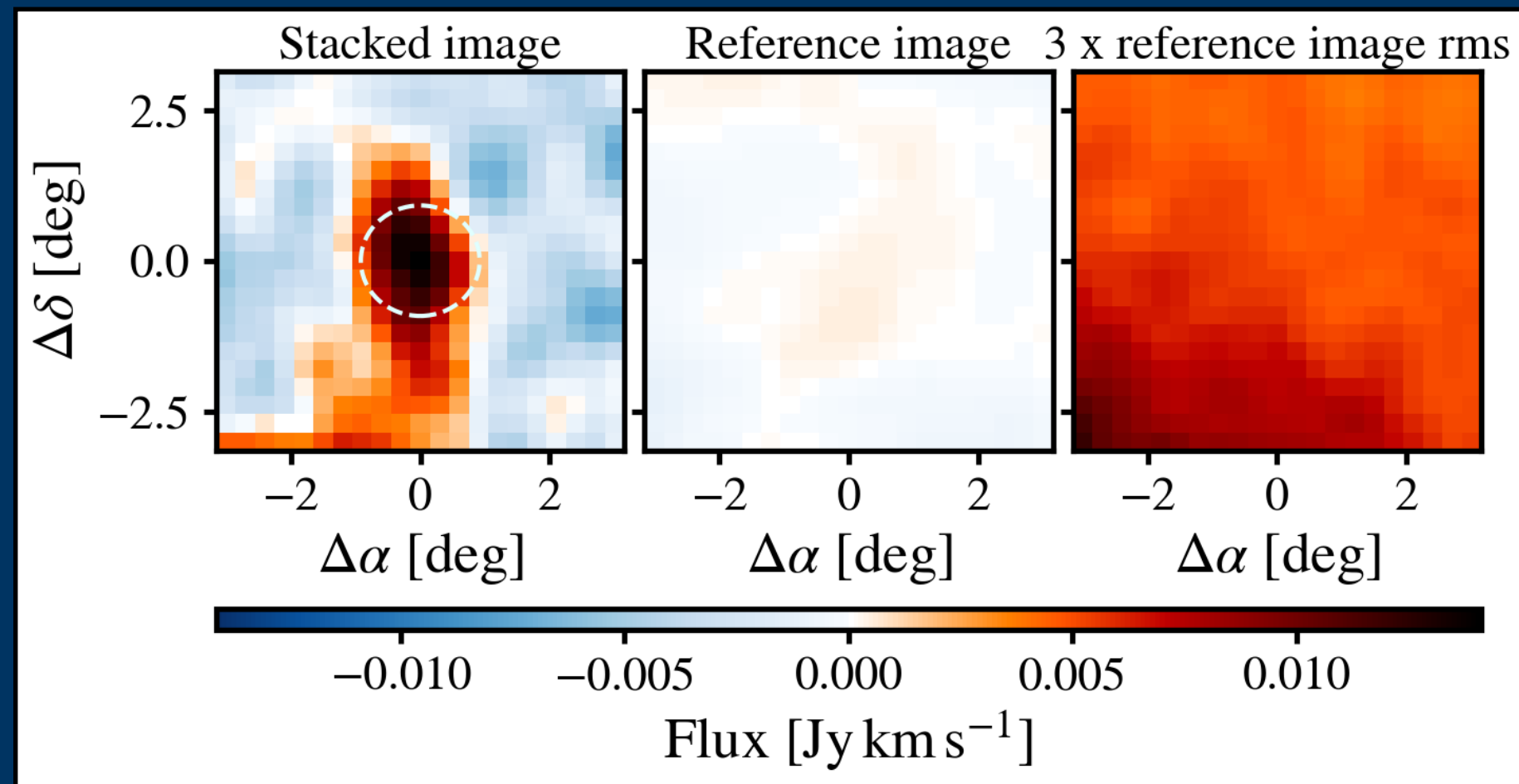


arXiv:2407.?????? (next week 🙌🙌🙌)

In Summary...

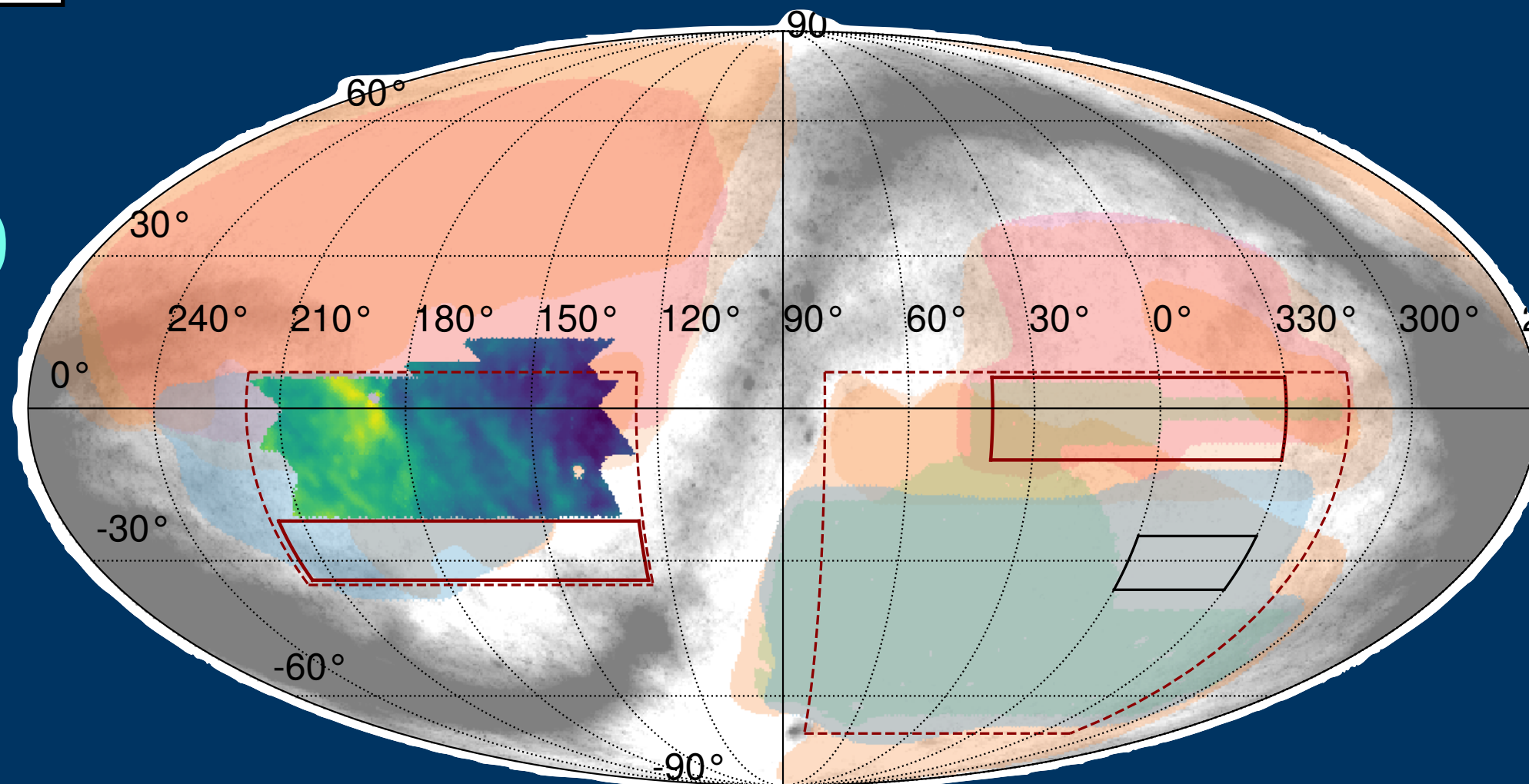
- Cross-correlations provide a method for **bypassing and understanding systematics**

- Pilot surveys with **MeerKLASS** have demonstrated this making consistent detections of using cross-correlation



[arXiv:2206.01579]

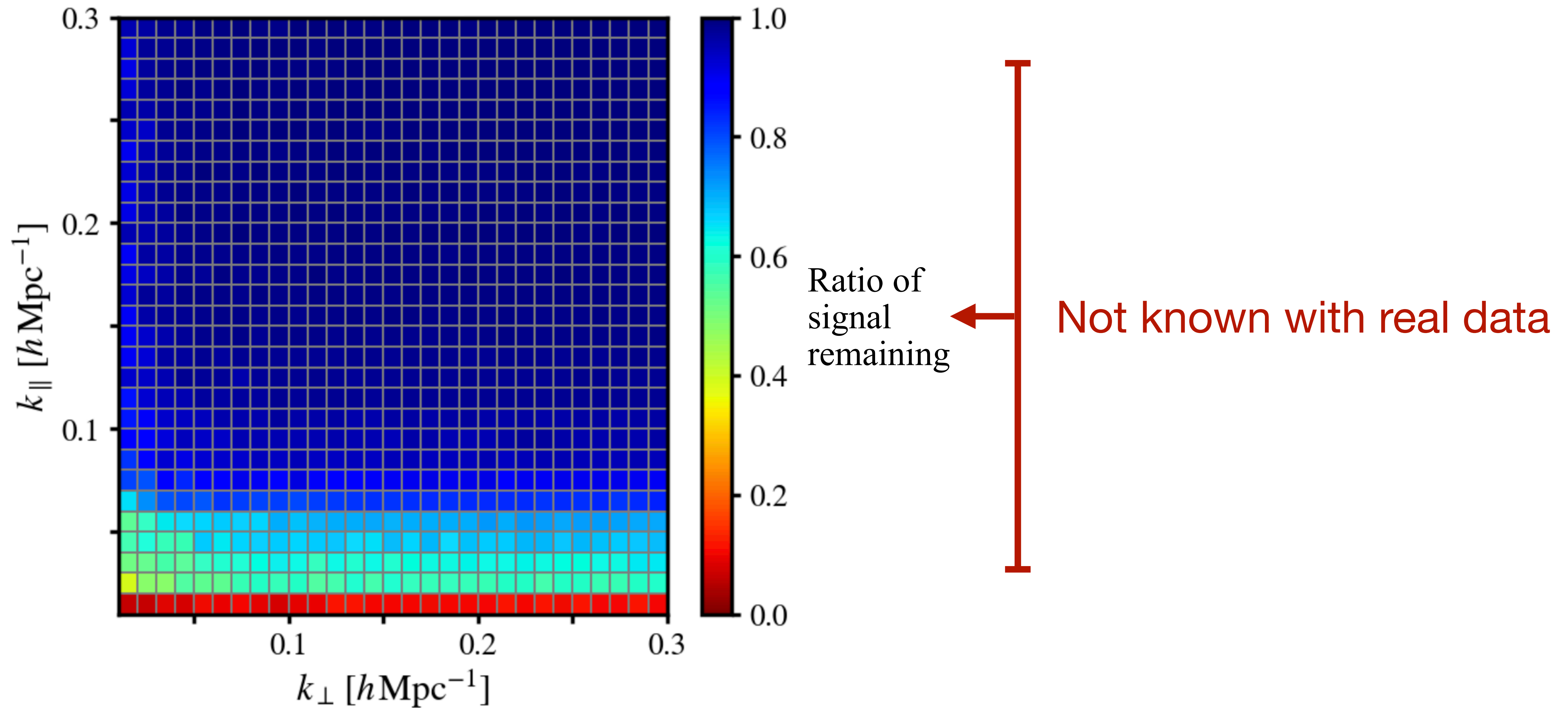
- Observations for a **10,000 deg²** ($0.4 < z < 1.4$) MeerKLASS survey are now underway...



谢谢
Thank you!

Backup slides

How much (HI) signal is lost in foreground cleaning?



Testing signal loss reconstruction with simulations

Constructing a foreground cleaning transfer function for signal reconstruction:

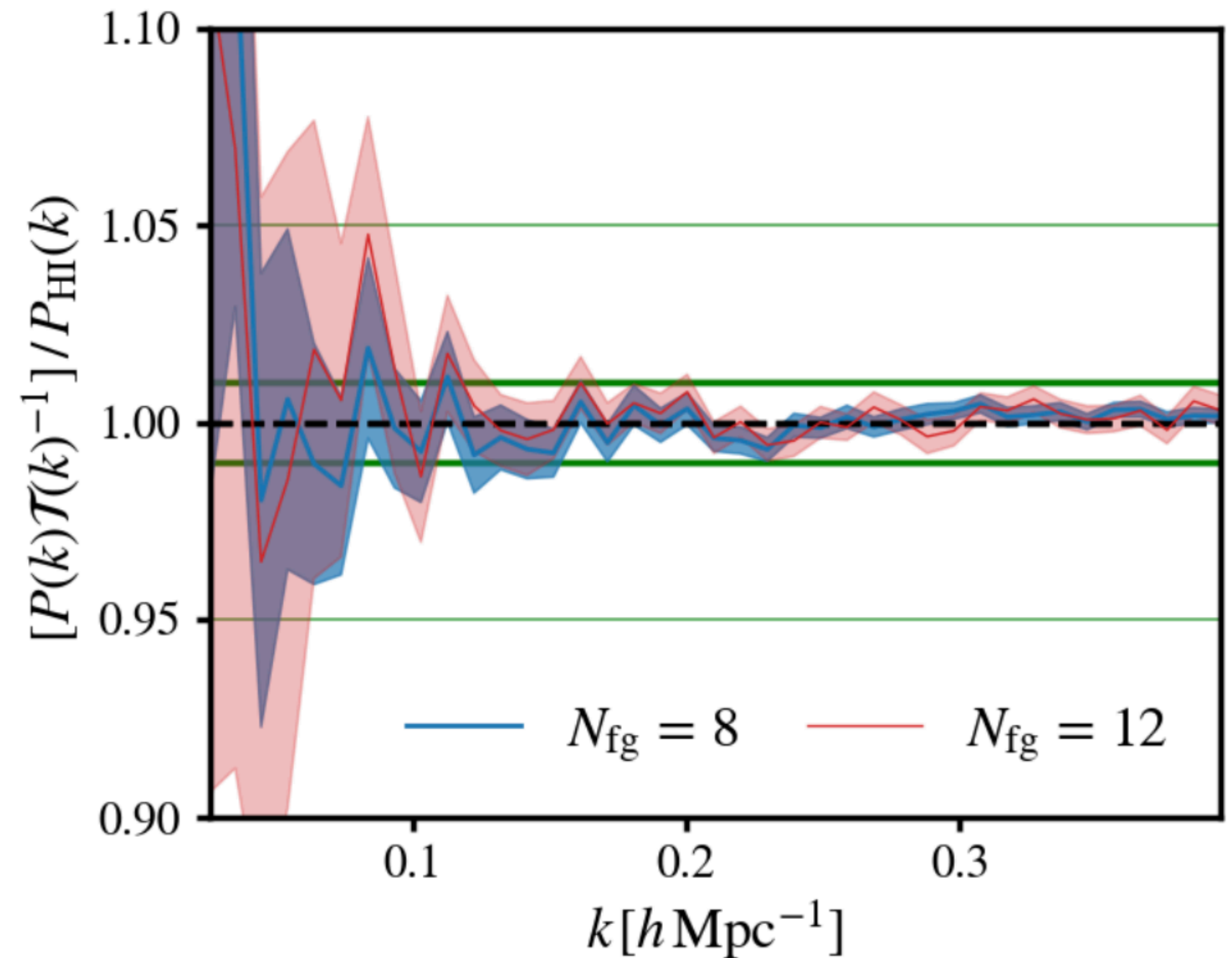
Inject mocks into real observational data and clean:

$$\mathbf{X}_{\text{clean}}^m = \mathbf{X}_{f+s+m} - \mathbf{U}_{f+s+m} \mathbf{S} \mathbf{U}_{f+s+m}^T \mathbf{X}_{f+s+m}$$

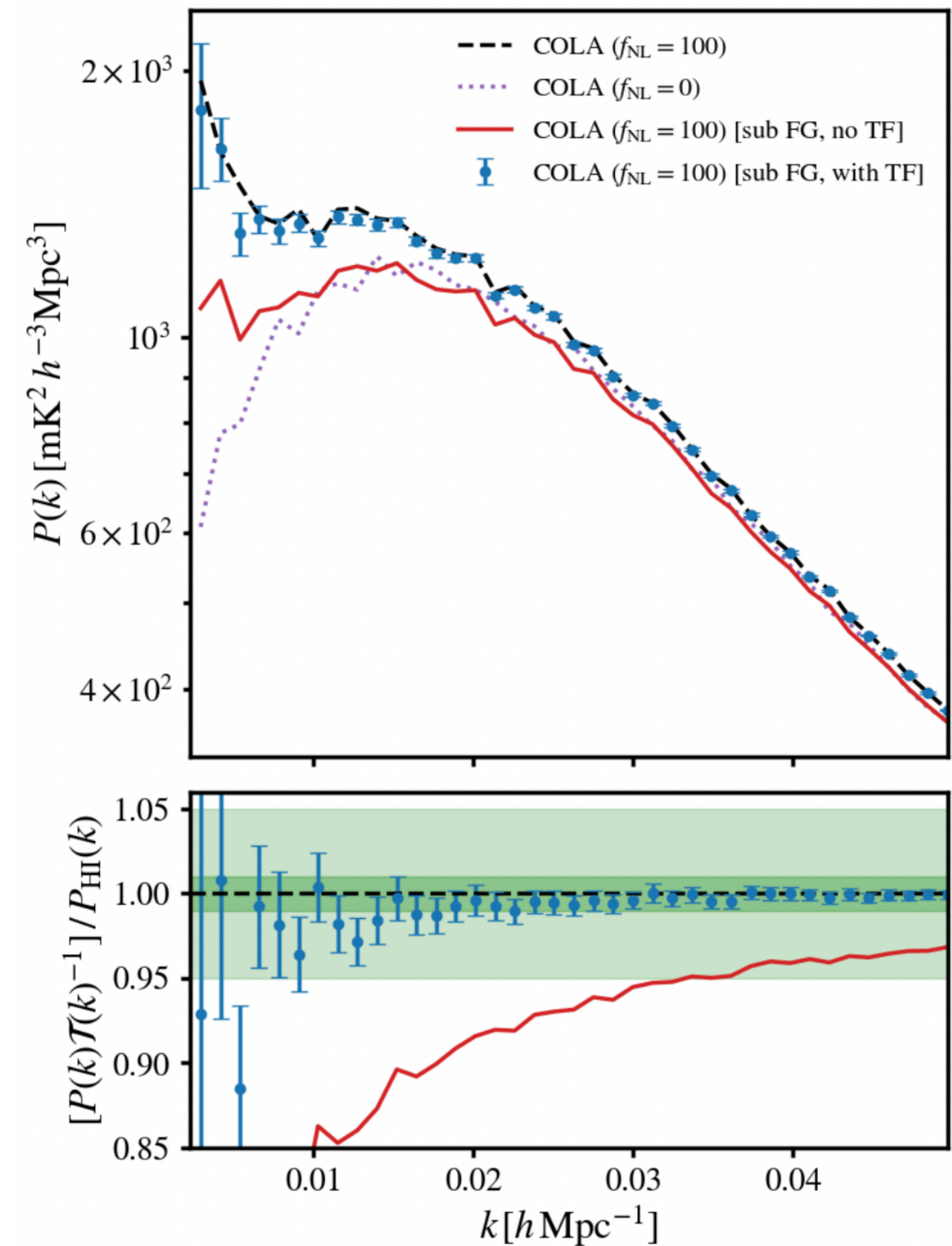
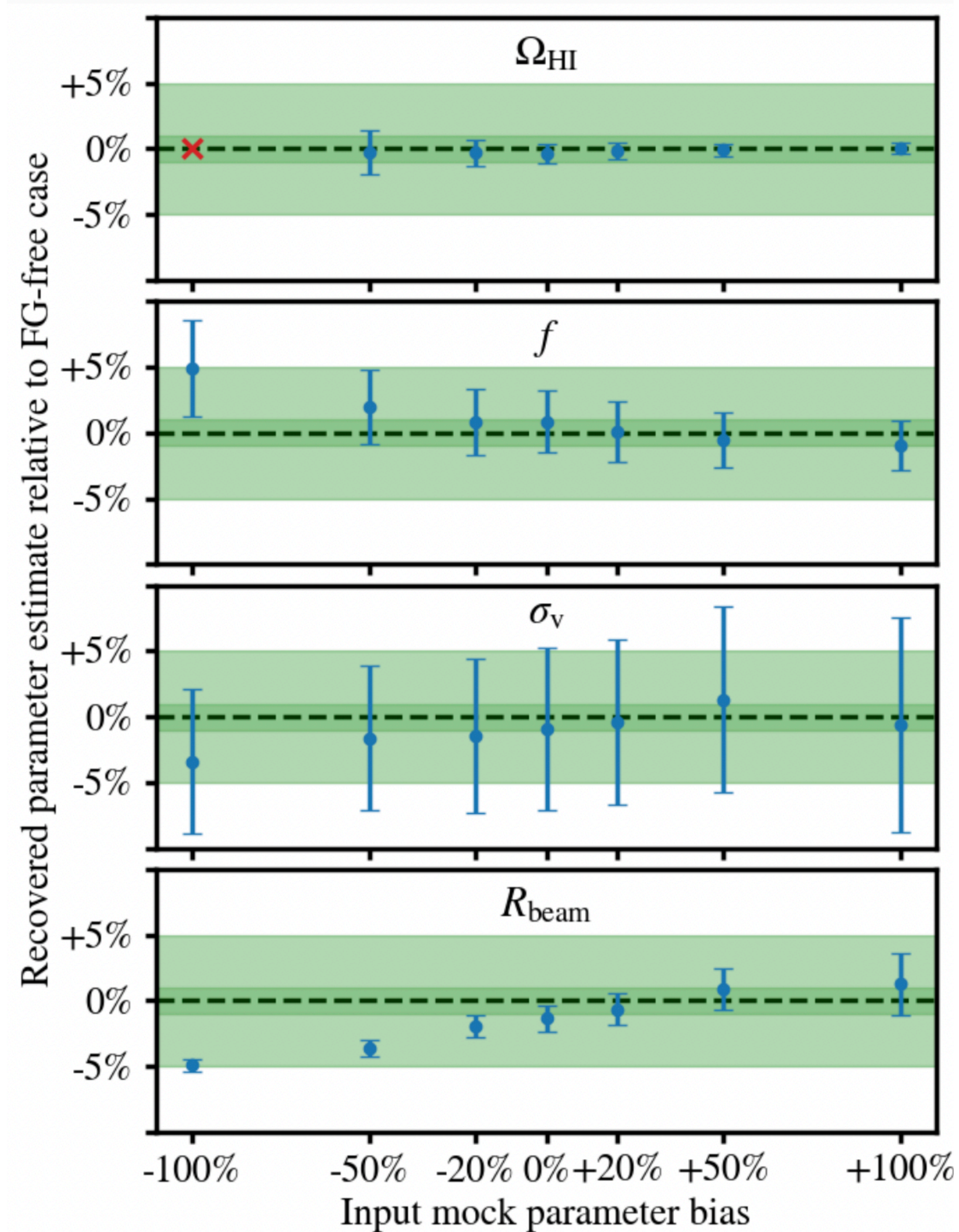
“Cleaned” mock Uncleaned (original) mock

$$\mathcal{T}(k) = \left\langle \frac{\mathcal{P}(\mathbf{X}_{\text{clean}}^m, \mathbf{X}_m)}{\mathcal{P}(\mathbf{X}_m, \mathbf{X}_m)} \right\rangle$$

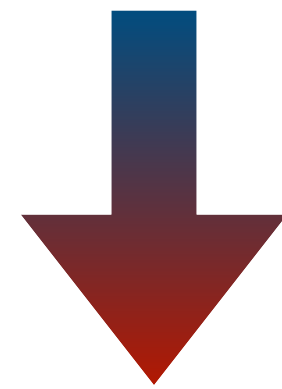
$$P_{\text{corrected}}(k) = P_{\text{cleaned}}(k) / \mathcal{T}(k)$$



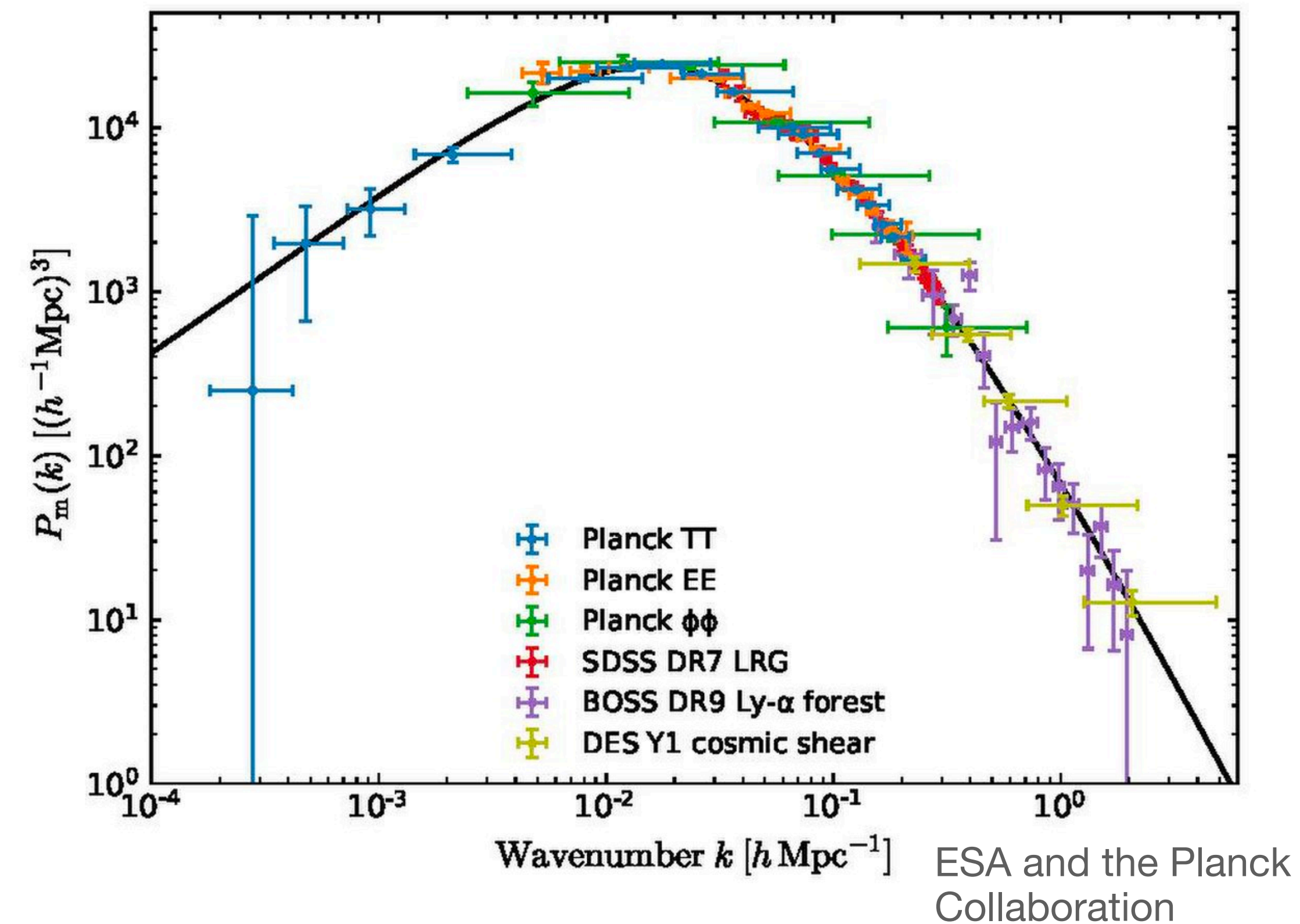
Foreground cleaning signal loss reconstruction for precision cosmology



Observations on the sky

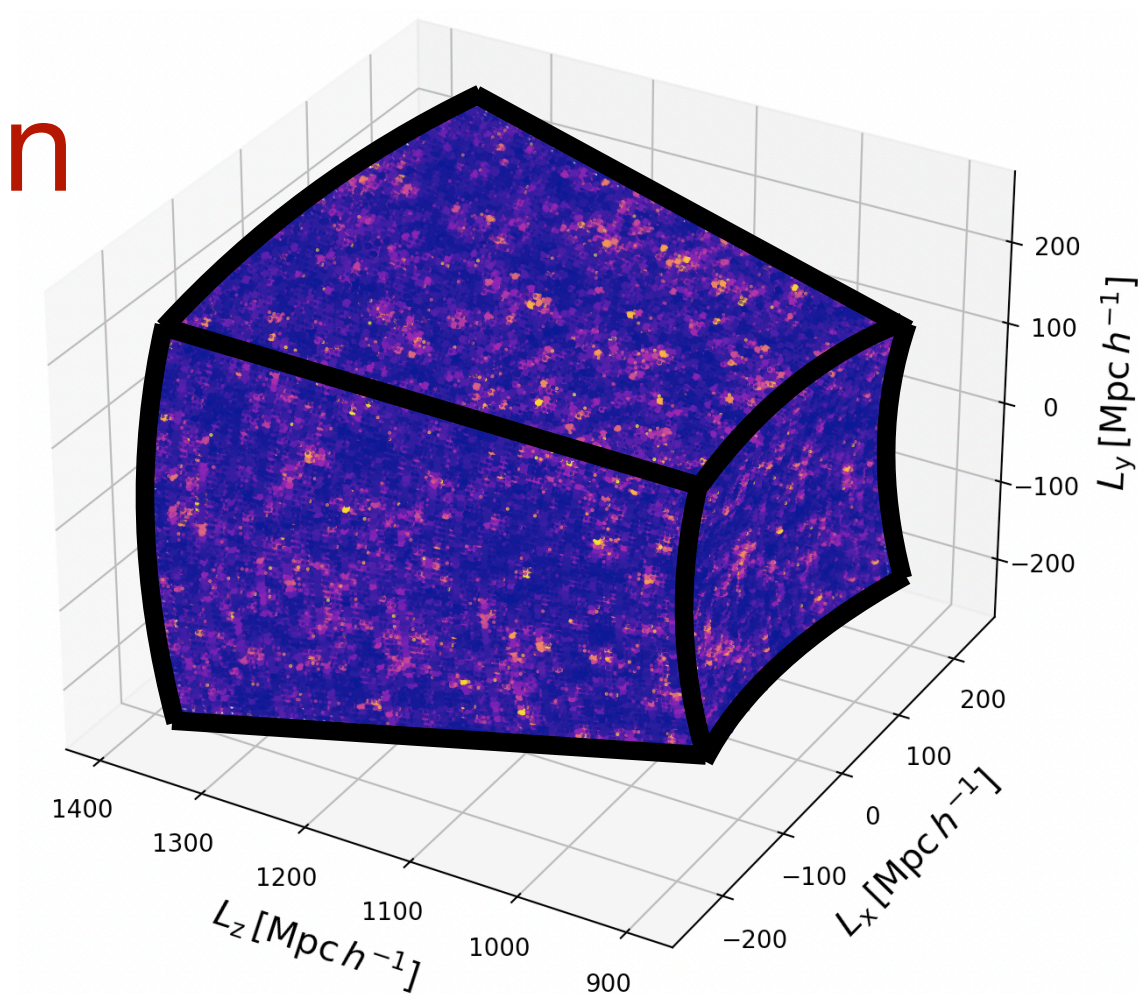


Analysis in Cartesian space

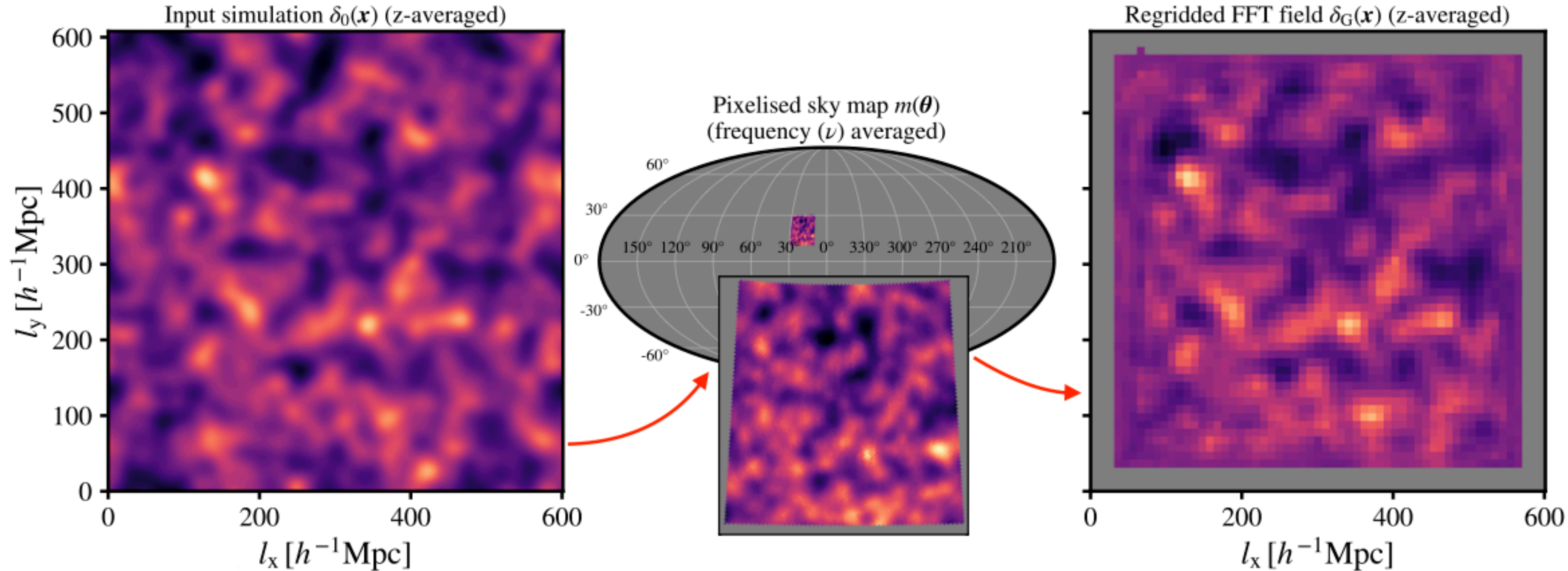


3D **Fourier-space** clustering analysis require observations in **Cartesian comoving** (Mpc/h) space

➔ Require transformation of voxel intensities

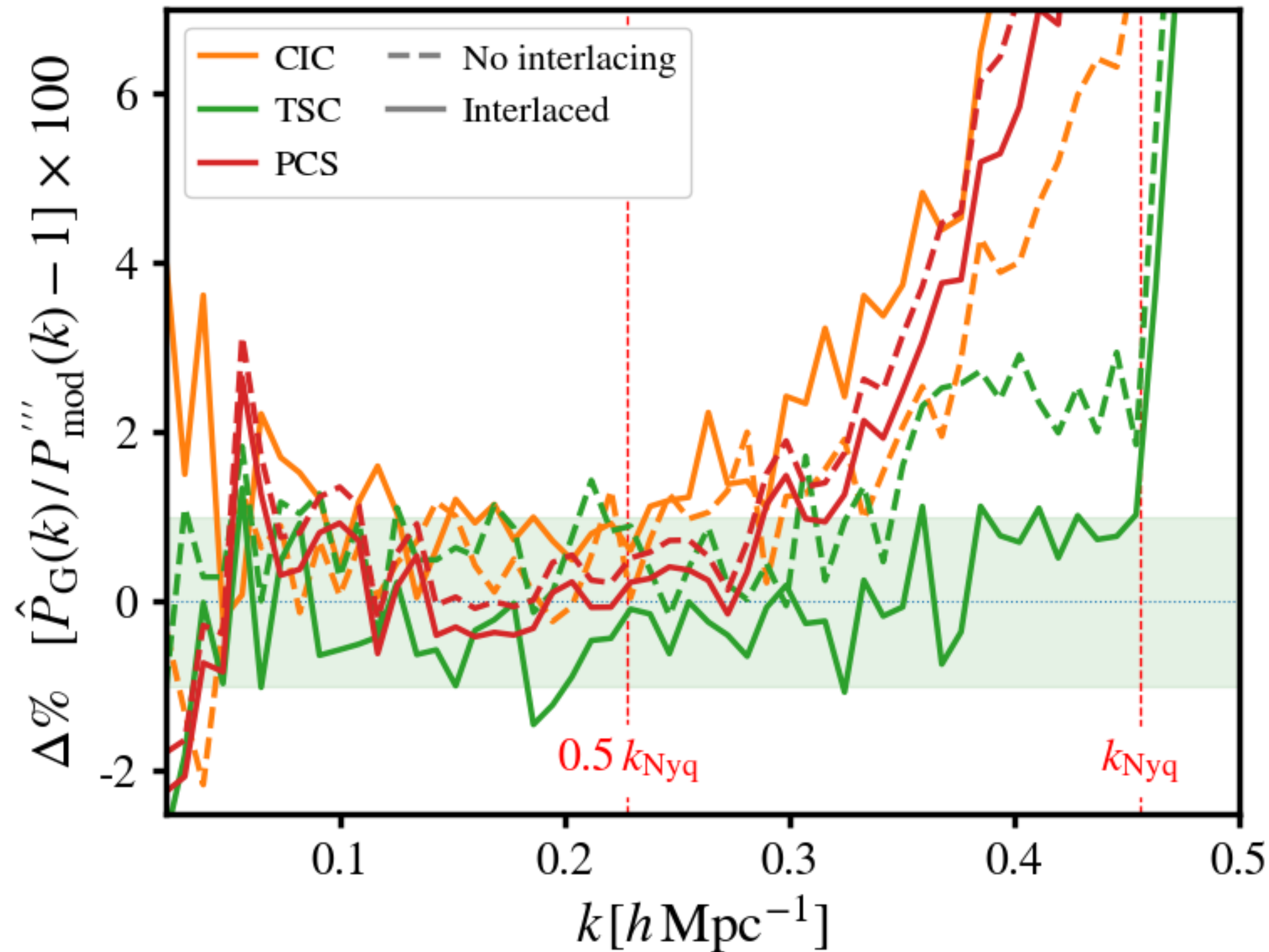


Testing regridding pipeline with simulations



→ <https://github.com/stevecunnington/gridimp>

Mitigating regridding effects with modelling and higher-order *mass* assignment



Results include:

- modelling power damping from HEALPix pixelisation
- modelling power damping from frequency channels
- higher-order mass-assignment to test suppression of **aliasing**