The MeerKLASS survey: updates

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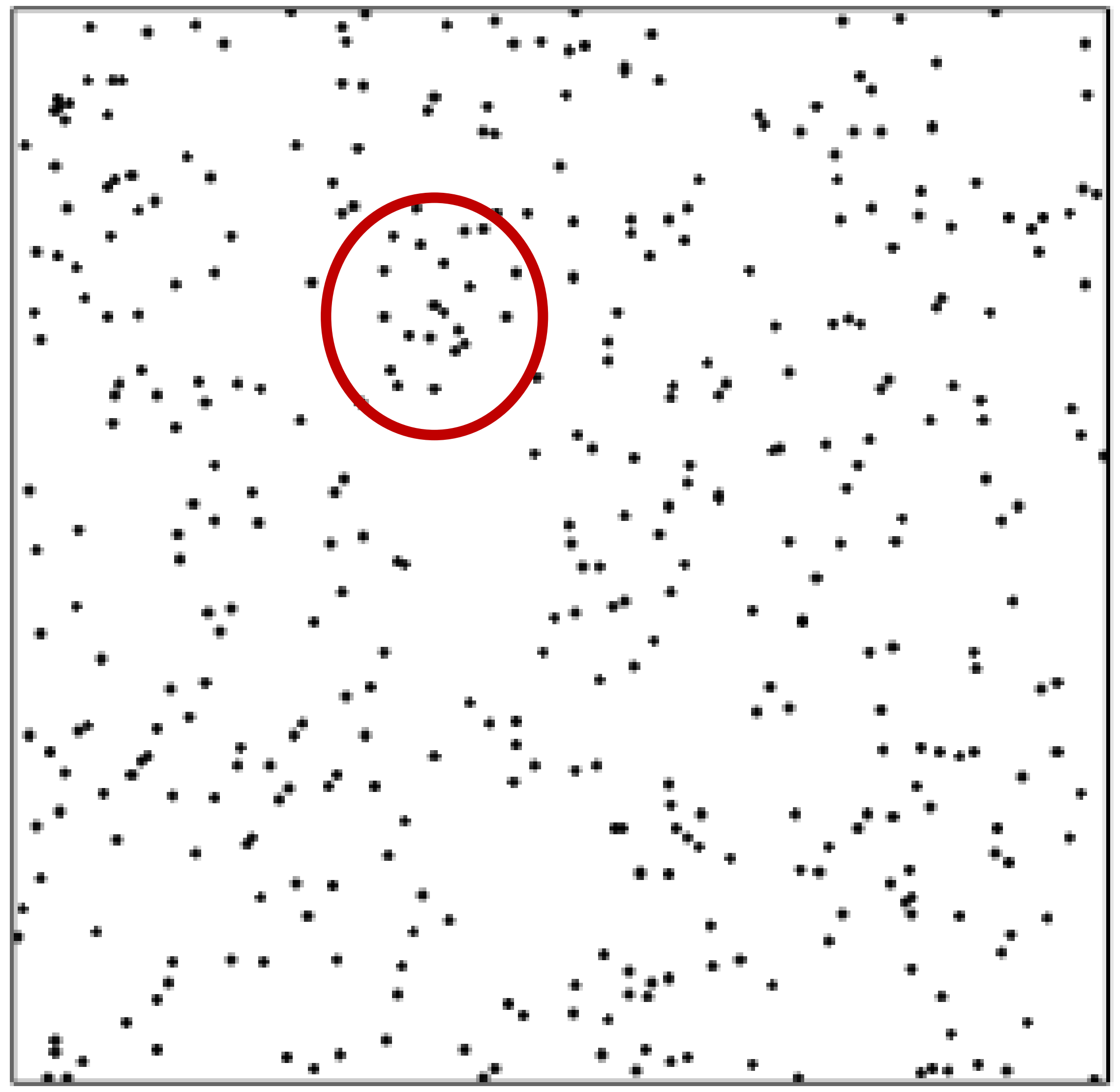
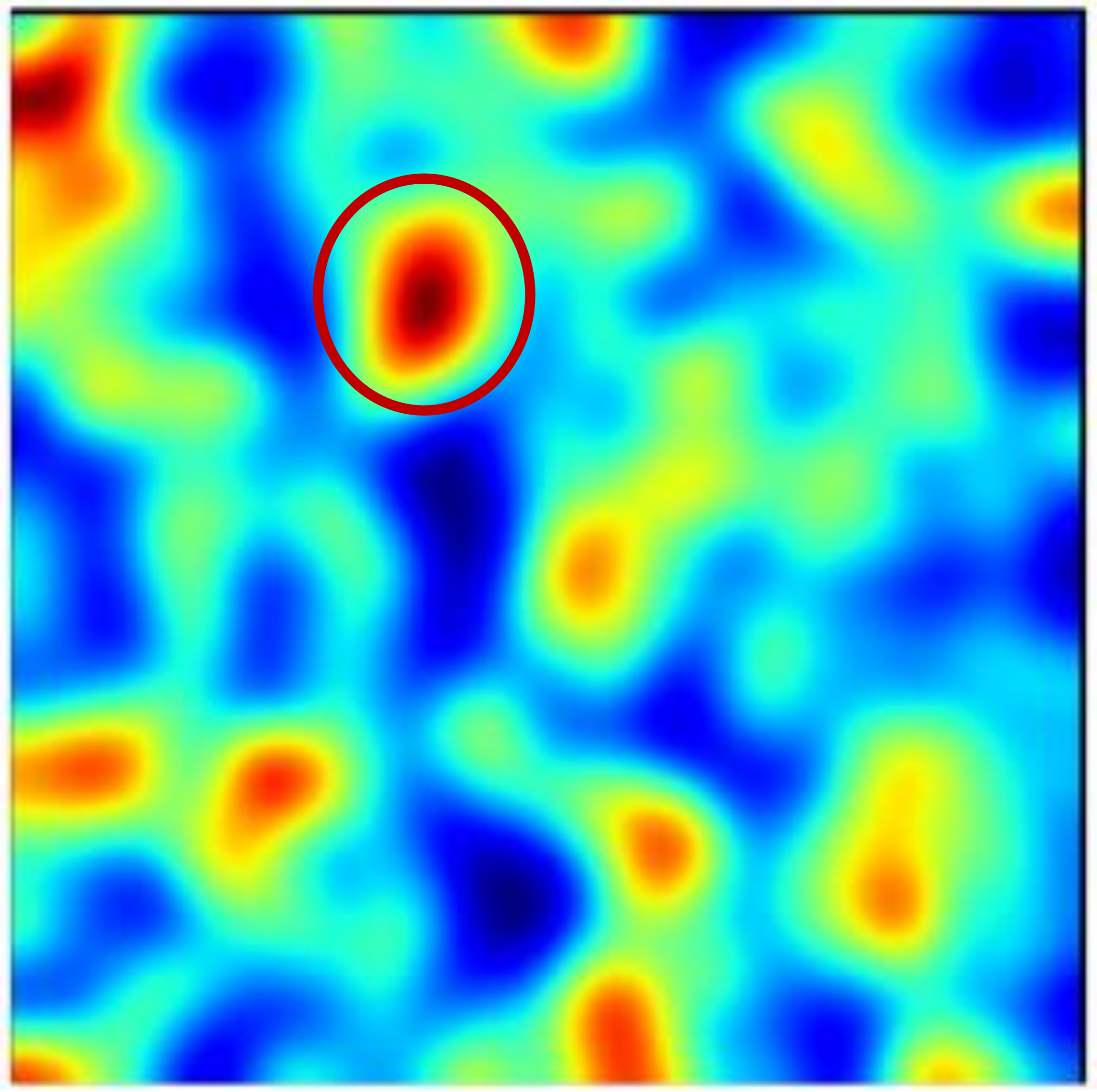
HI/21cm intensity mapping?

- Detecting galaxies and getting their redshift is very time consuming (even more for the HI line)
- Cosmology only needs large scales (> 10 Mpc)
- HI is a good tracer of dark matter
- Use radio telescopes to make maps of intensity at each frequency/redshift -> high survey speeds

Note: only way to probe the IGM HI



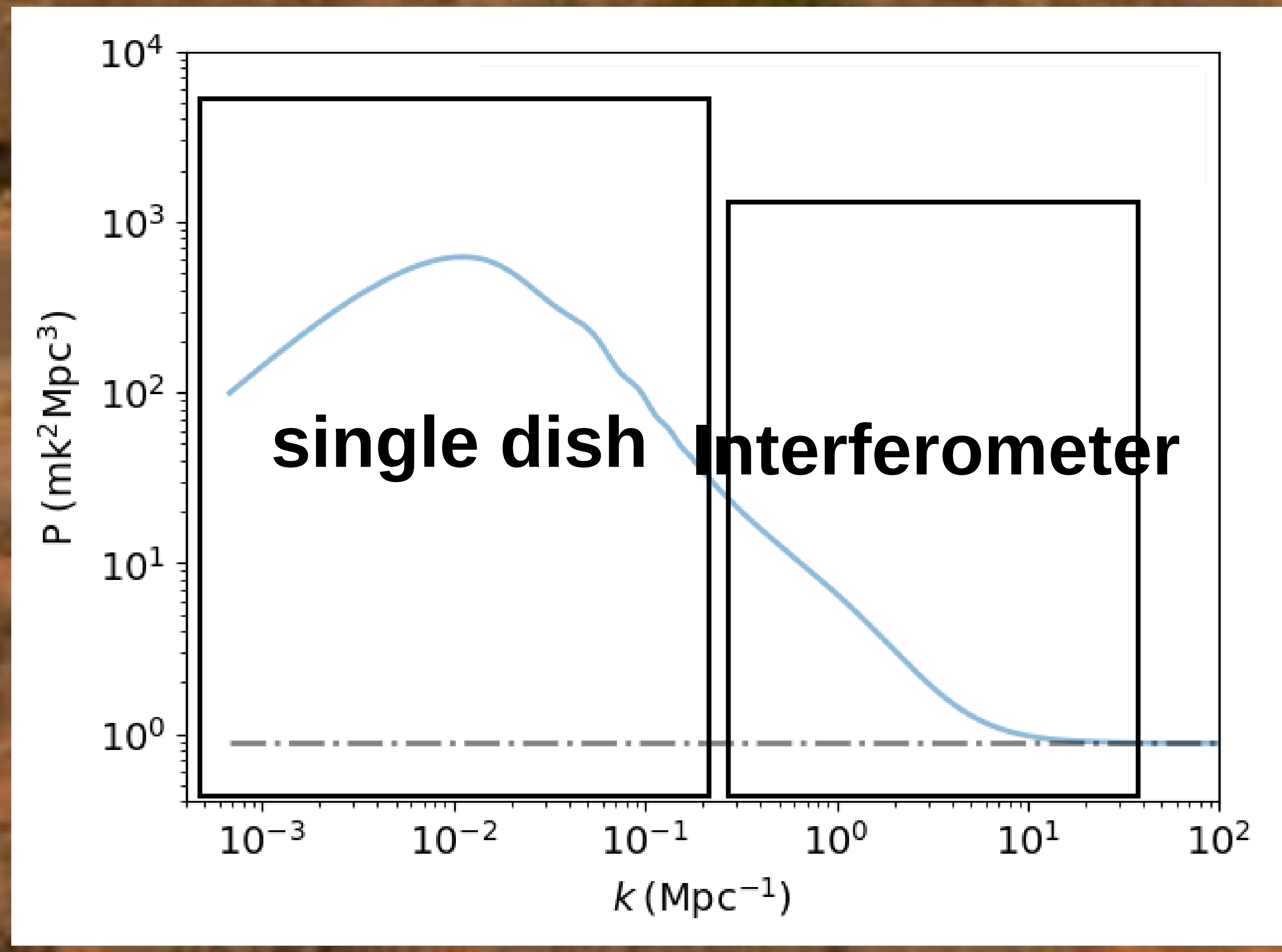
galaxies



Intensity map

MeerKAT?

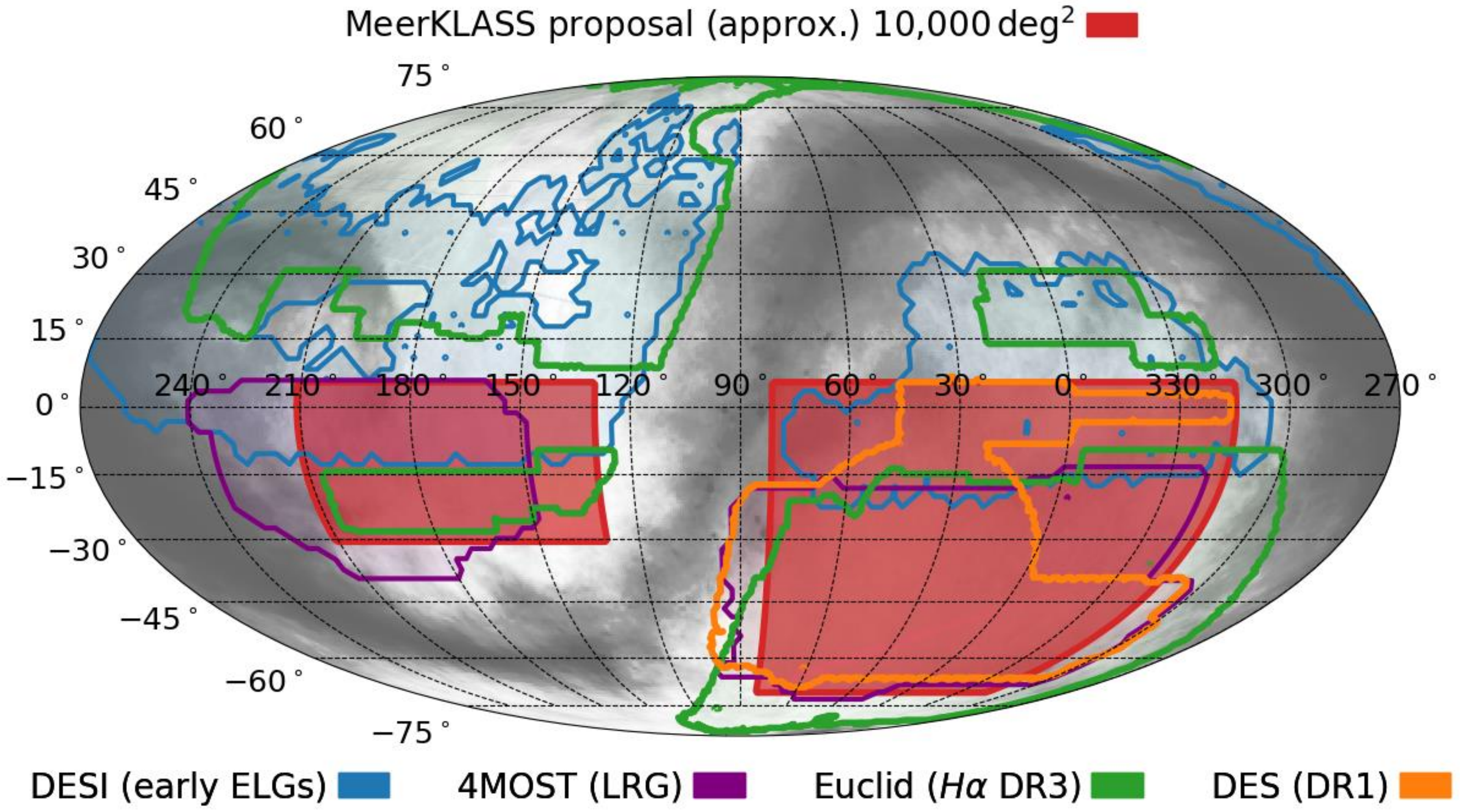
- South Africa
- 64, 13.5 m dishes – 2018
- Maximum baseline: 8 Km - soon ~ 20 Km
- Frequencies: 580 MHz – 3500 MHz (0 < z < 1.5)
- Part of SKA1-MID in the future



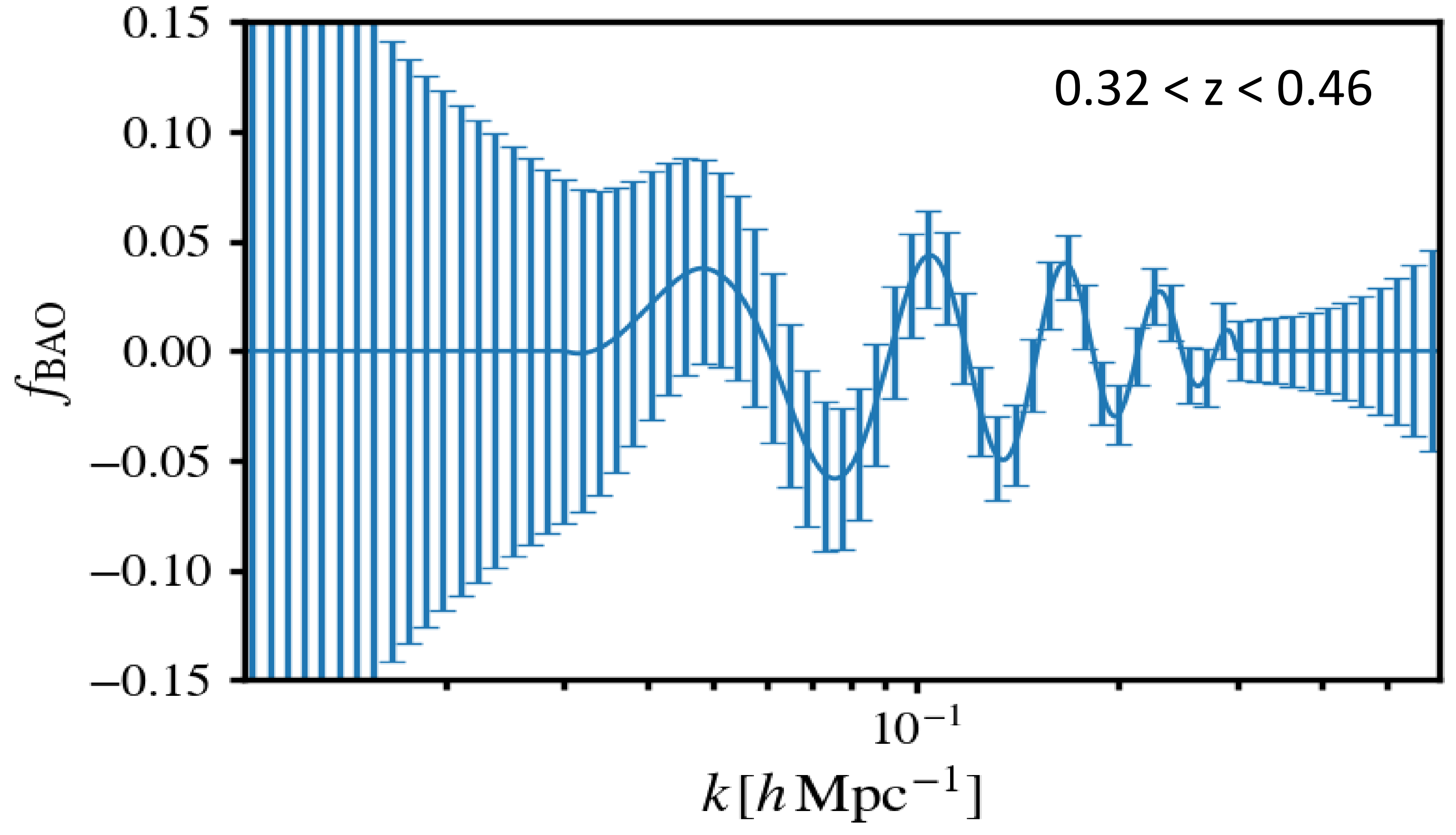
The present: an SKA cosmology survey precursor with MeerKAT

- ***MeerKLASS: MeerKAT Large Area Synoptic Survey*** (> 50 members - Santos et al., arXiv:1709.06099)
- Aim: Cosmology (HI intensity mapping) but commensal with lots of other science
- Use single dish data for cosmology and interferometer data for a continuum galaxy survey

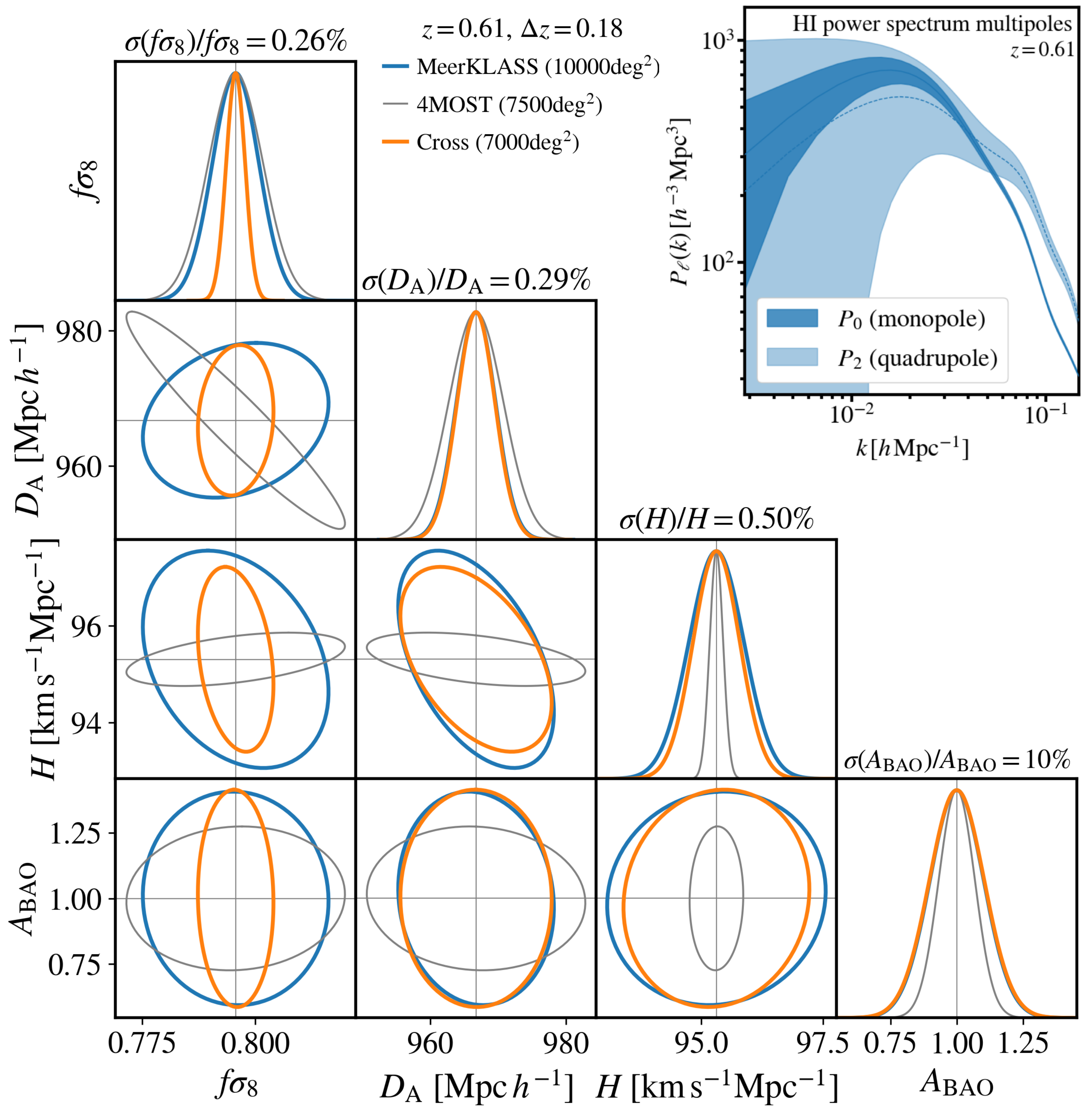
- **L-band:**
  - 900-1670 MHz (z<0.58)
  - ~ 100 hours observed
  - MeerKLASS+ proposal submitted: 2,000 h over 5,000 deg2 (continuum: 9 uJy rms, 5’’)
- **UHF band:**
  - 580 MHz-1015 MHz (0.40 < z < 1.45)
  - ~ 120 hours observed
  - Project “approved”: 2,500 hours over 10,000 deg^2 (continuum: 25 uJy rms, 13’’)



MeerKLASS: Cosmology



- Measurement of Baryon Acoustic Oscillations (BAO), Hubble rate and redshift space distortions
- Measure the HI content of the Universe at 0.4 < z < 1.4 (UHF-band)
- **Cross-correlations with galaxy surveys -> large improvements on the errors**
- Constraints of primordial non-Gaussianity (f_{NL}) by measuring large scale correlations and multi-tracers (Fonseca et al., arXiv1611.01322): $f_{NL} < 2$

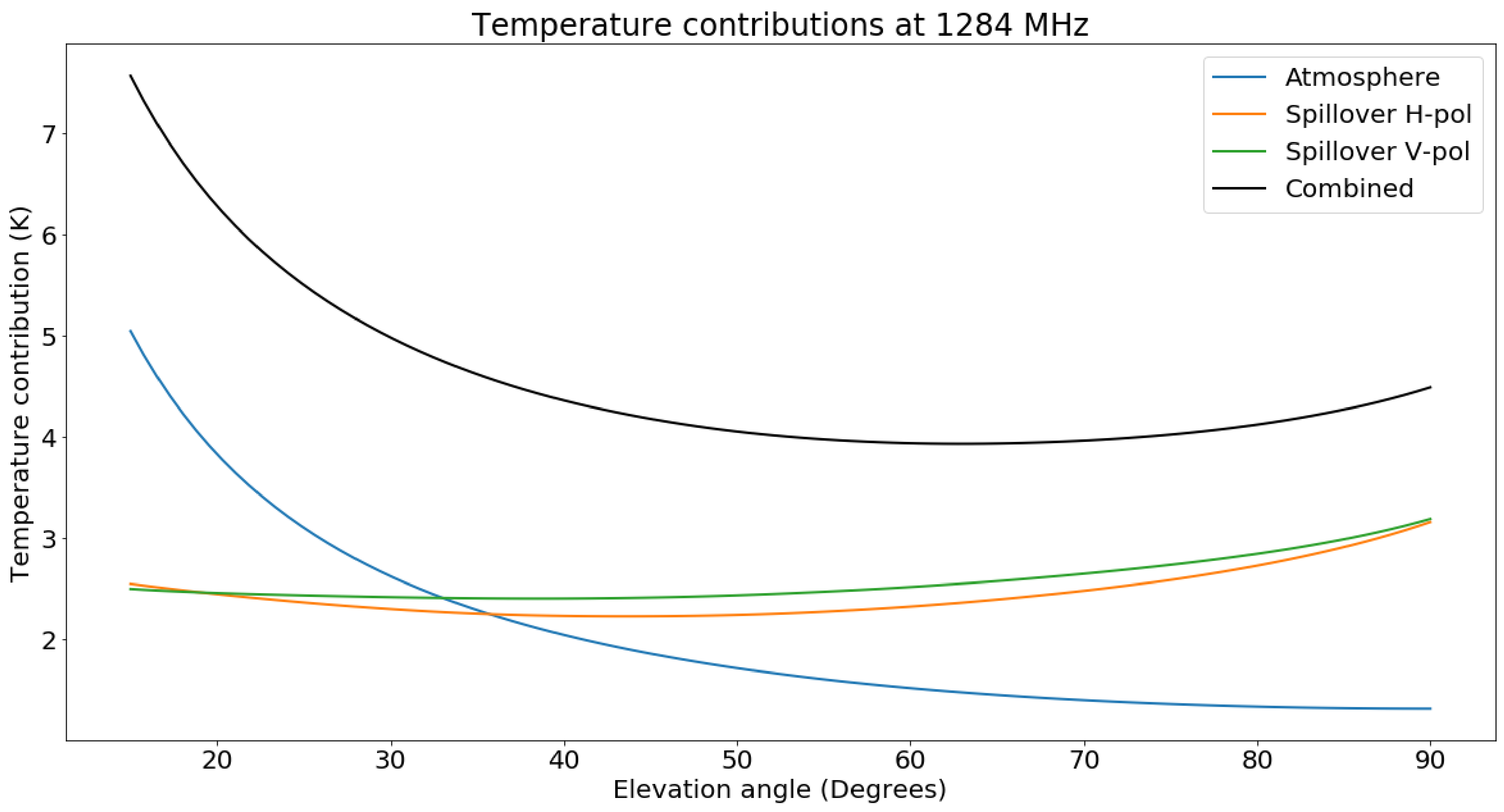


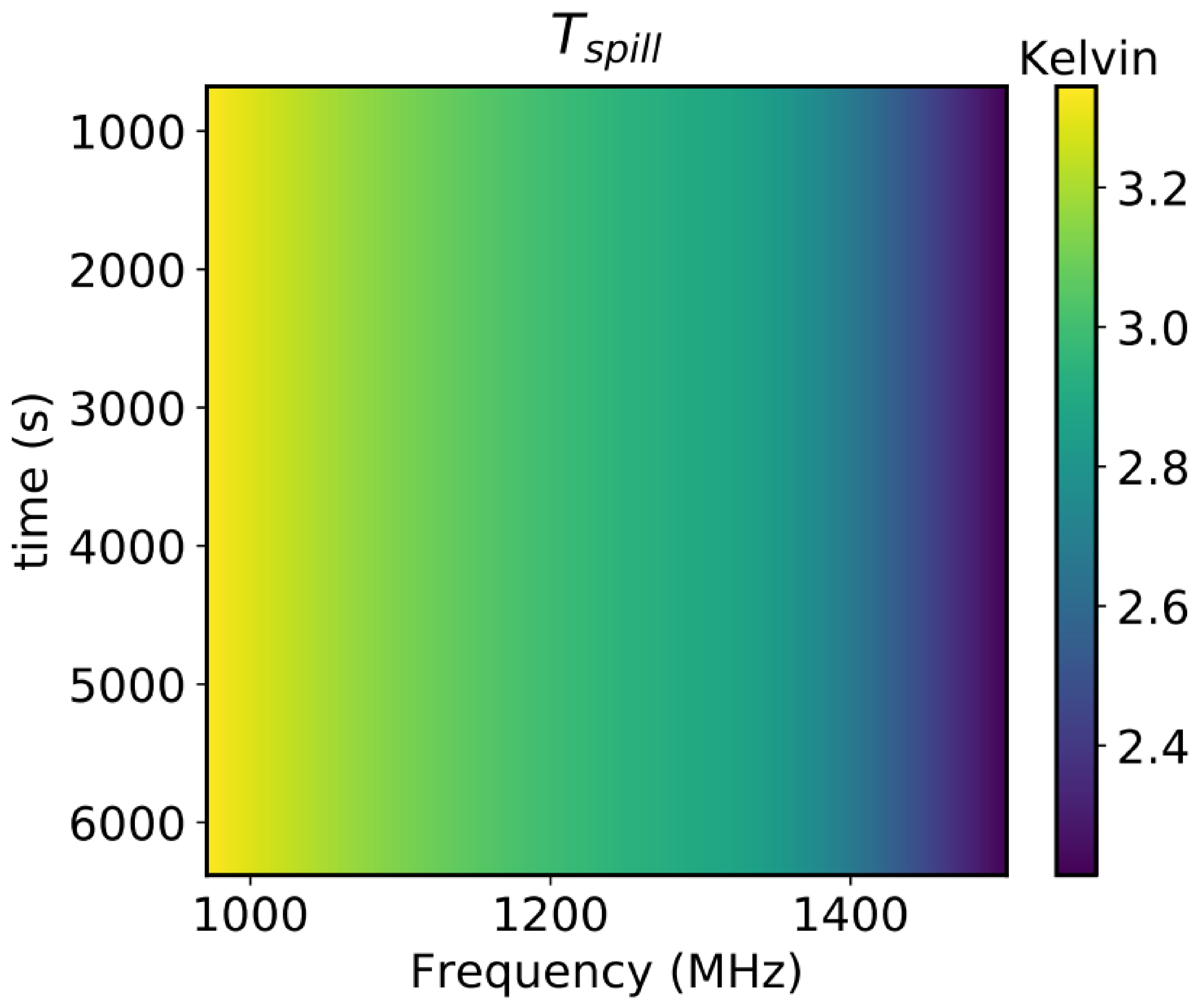
Steve Cunnington

MeerKAT: 1,300 hours. 60 dishes

Issues: ground "pickup"

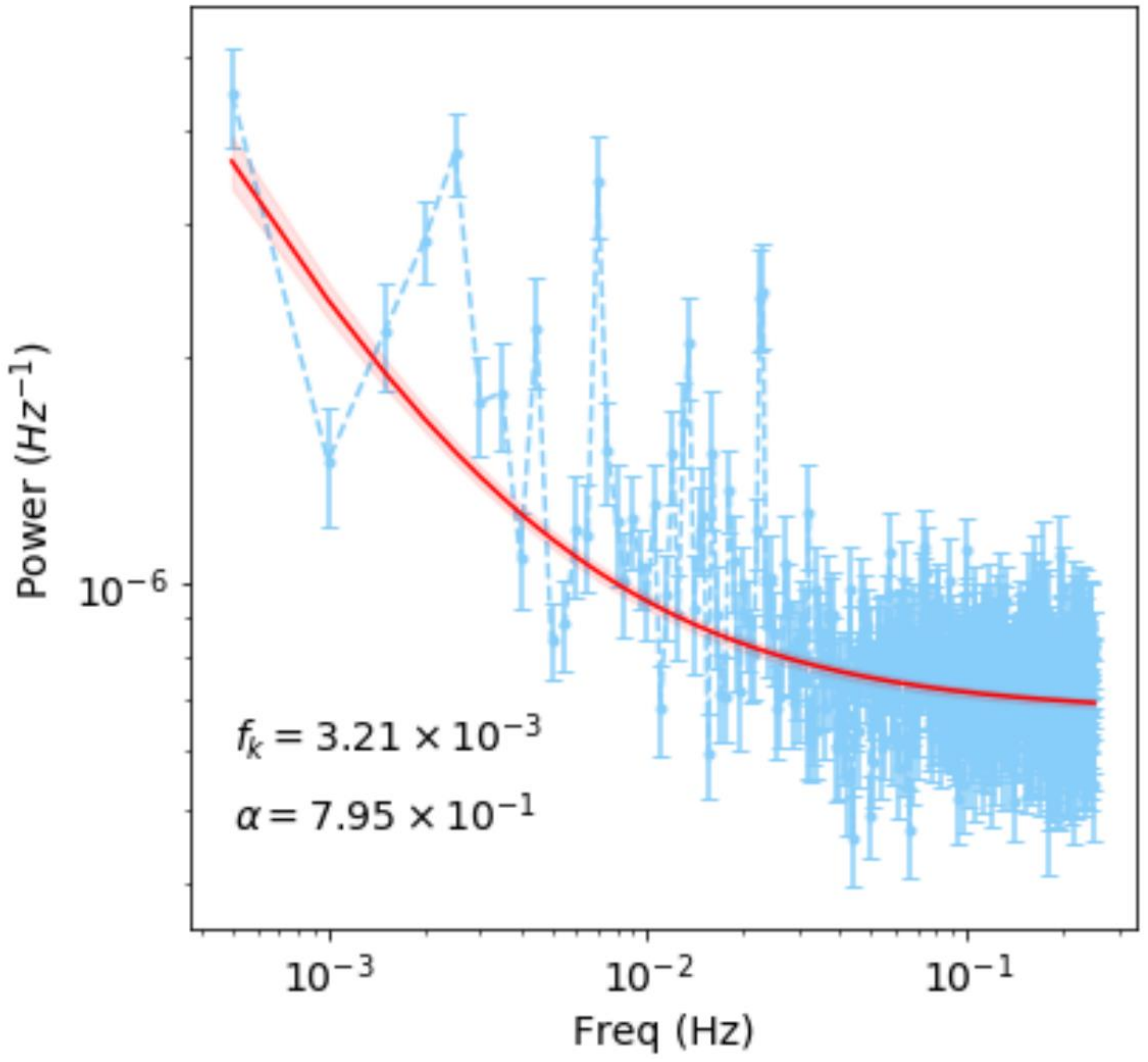
- Ground is "hot" -> observe at constant (high) elevation to avoid fluctuations

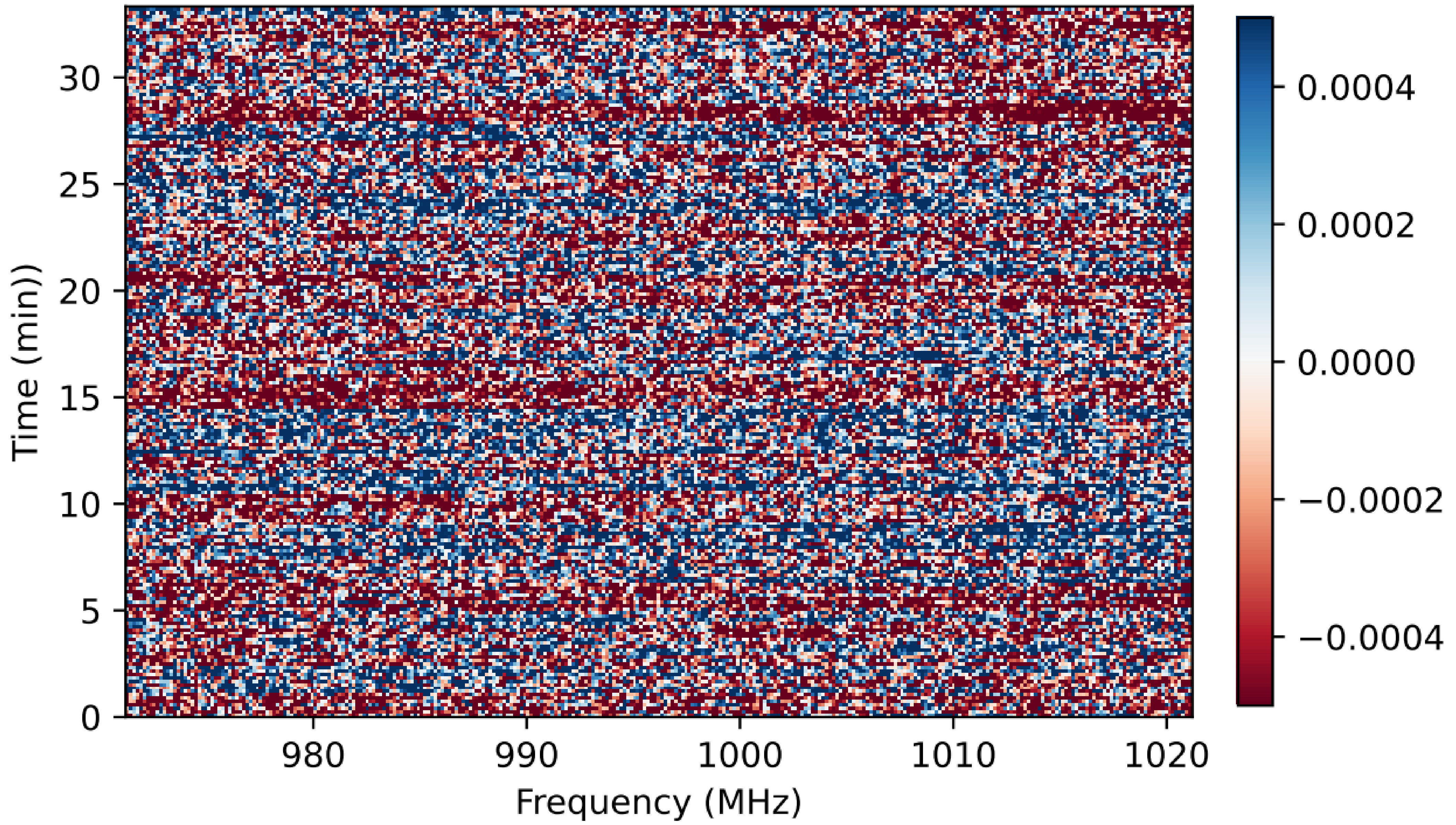




Issues: correlated noise/gain fluctuations

- Gain fluctuates in time -> generates correlated noise in time even after calibration
- Need to scan the sky fast

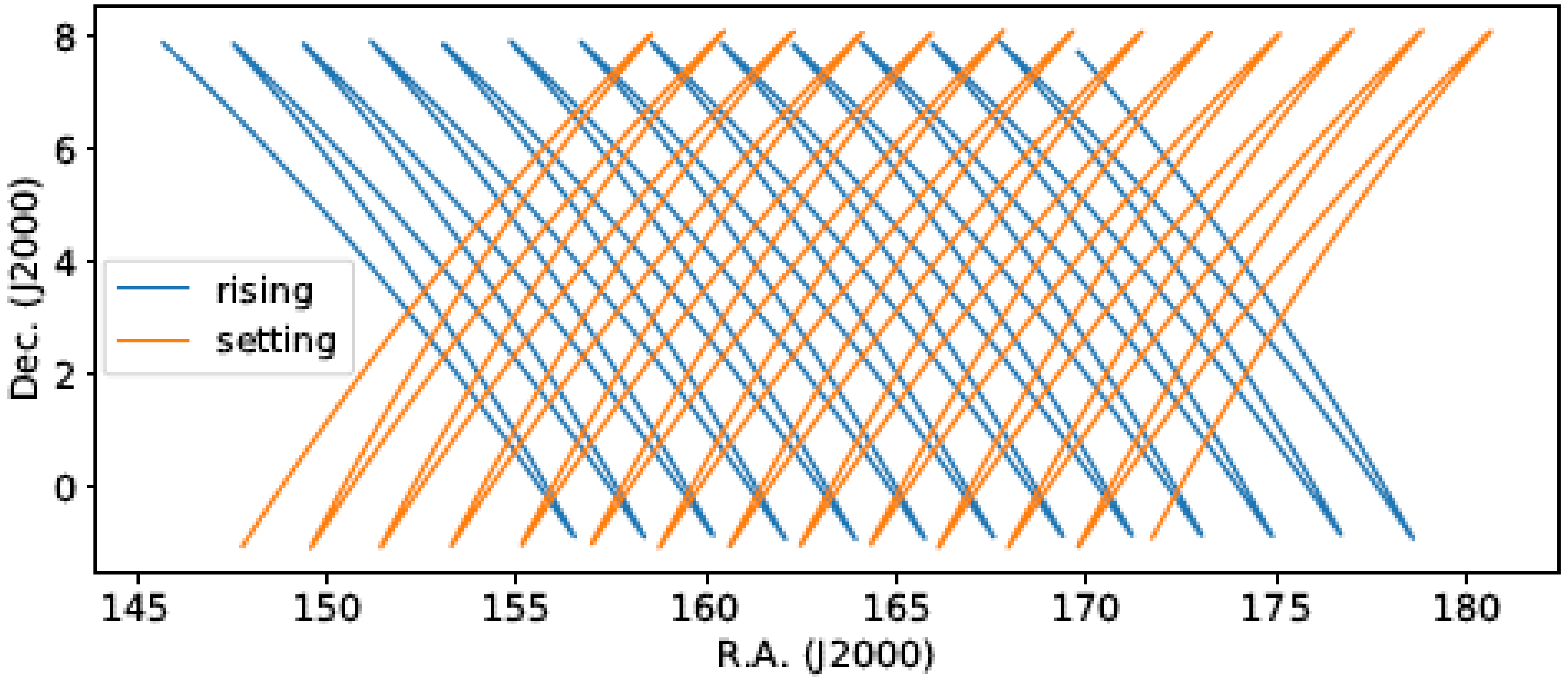


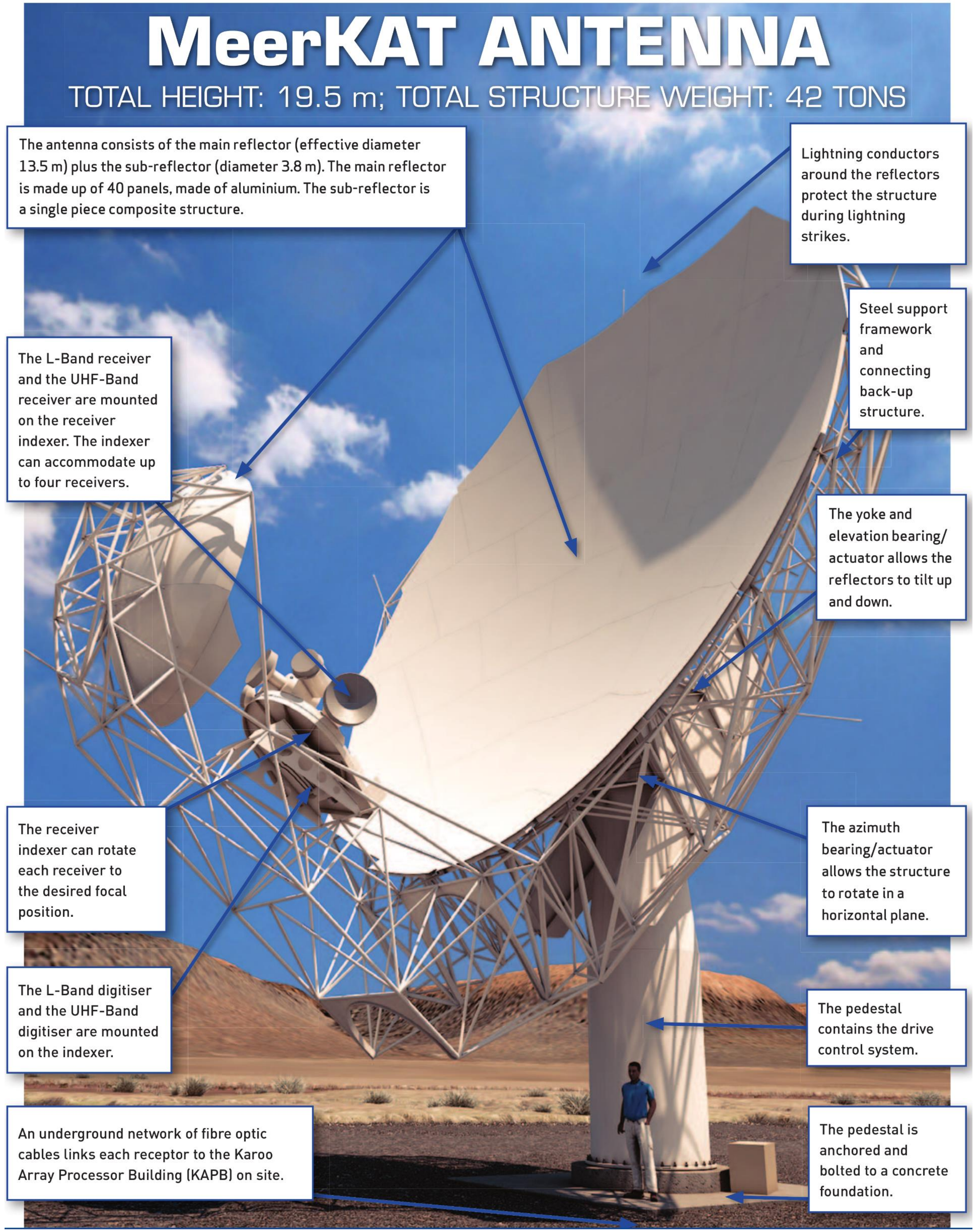


M. Irfan, et al., MNRAS 2023

Observation strategy:

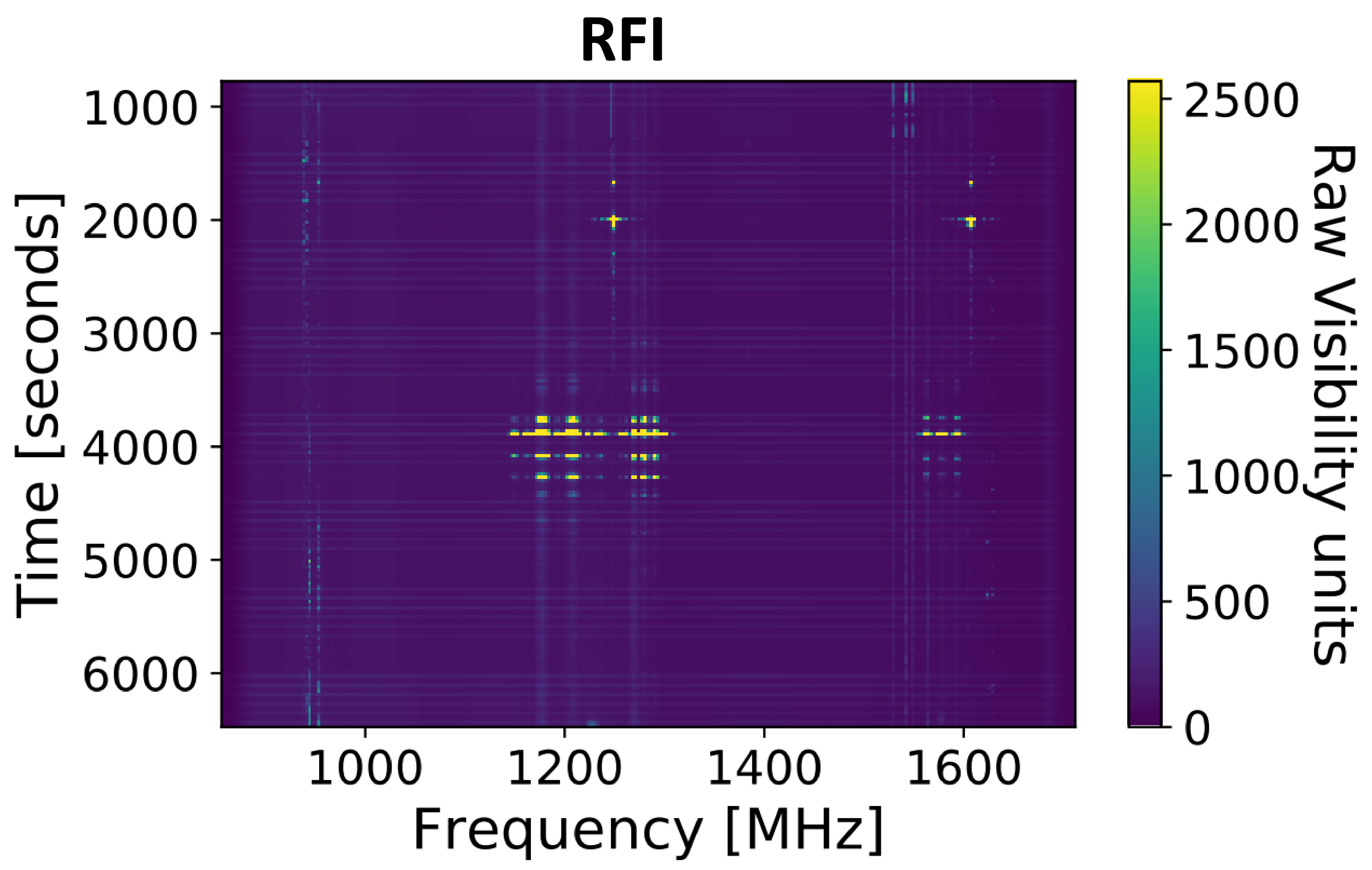
- Scan at constant elevation
- Inject noise diodes every 20 sec for ~ 0.6 sec
- Azimuth speed: 5 arcmin/sec
- ~ 200 sec per scan line, 1.5 hours per block
- Patches ~ 200 deg2
- Resolution: 2 sec/0.2 MHz



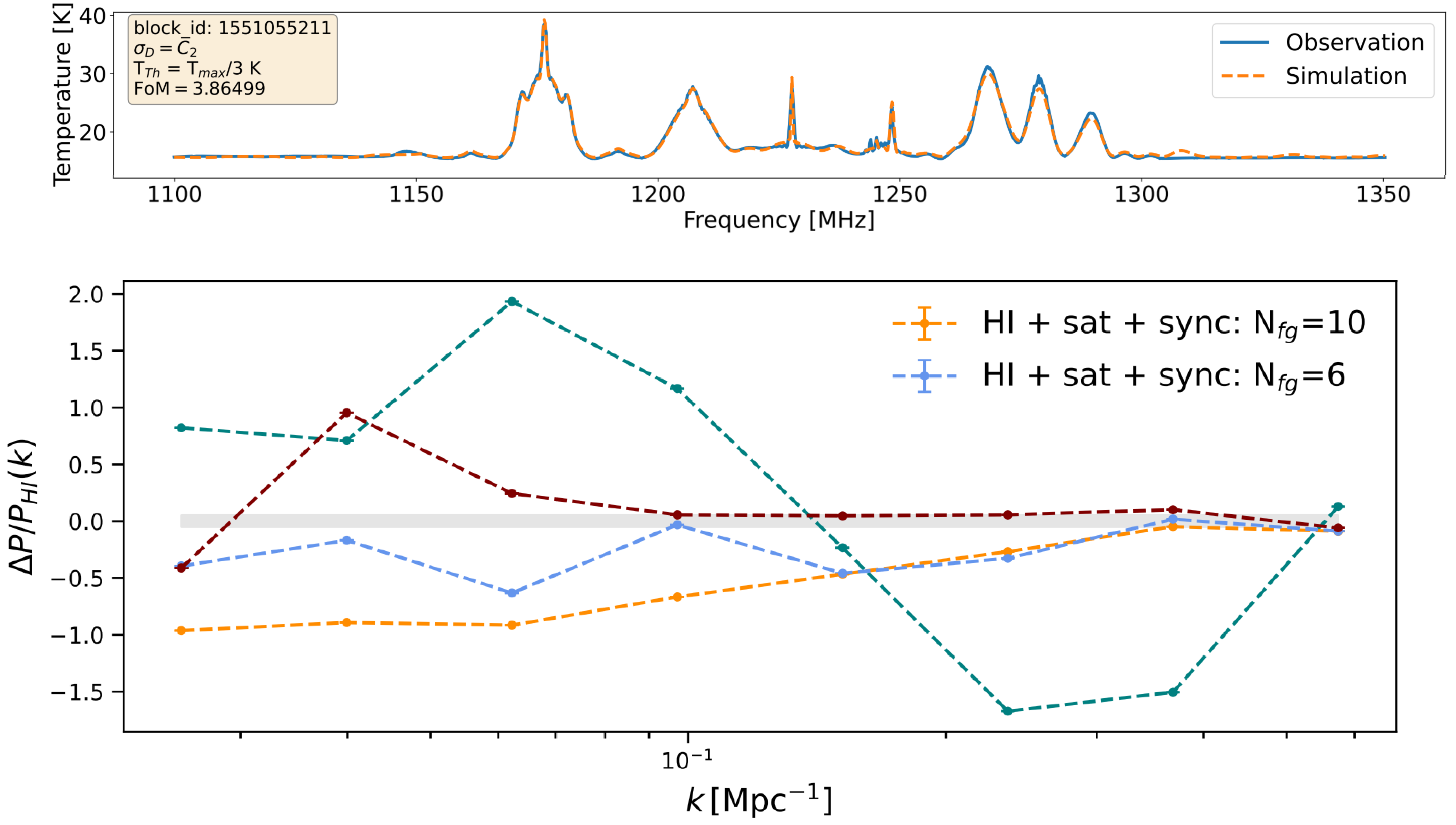


Issues: radio frequency interference (RFI)

- Satellites, cell phone towers, radio stations, etc
- Needs to be flagged or smaller than the signal (hard to “clean”)
- Large data loss
- Non-linearities in the instrument



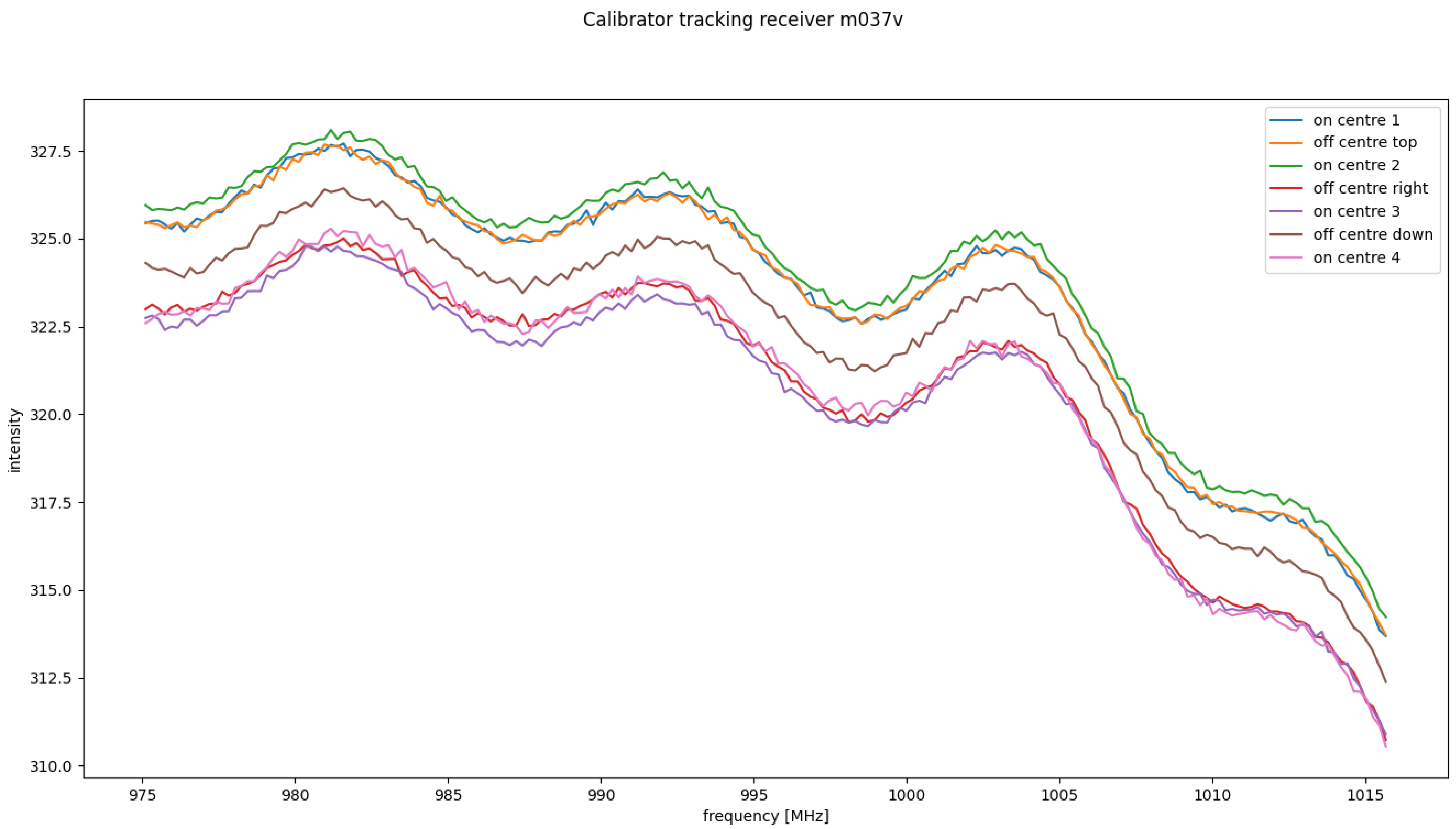
Satellite simulations



Brandon Engelbrecht, et al., to be submitted

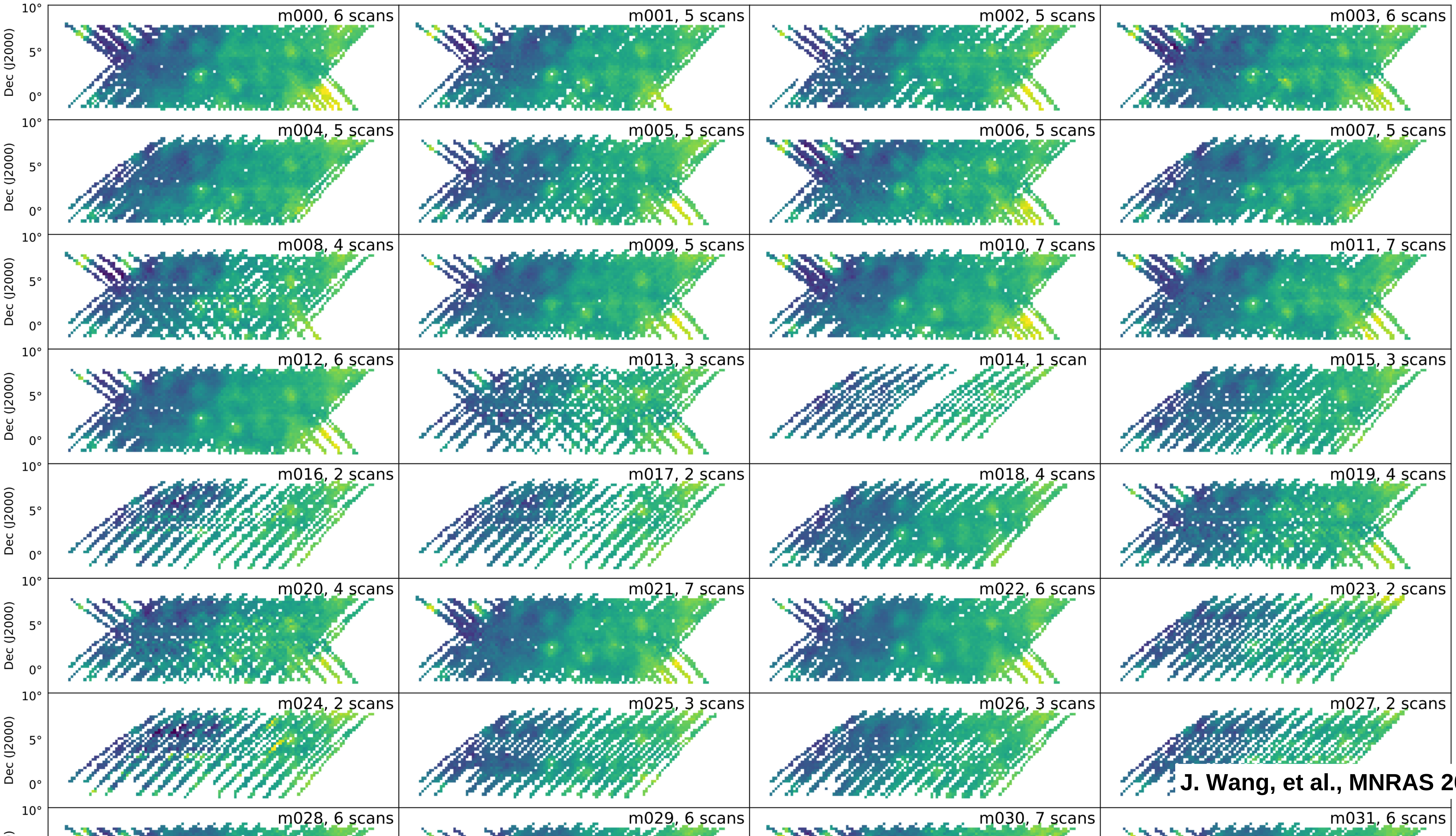
Other issues

- Calibration – how well do we know the sky? How constant is the ground pickup and receiver temperature? How to parameterise the instrument?
- Standing waves – see talk by Keith Grainge
- Foreground cleaning – see talk by Isabella Carucci
- Optimal estimators – see talk by Steve Cunnington
- Massive parameter fitting? (see talk by Phil Bull)



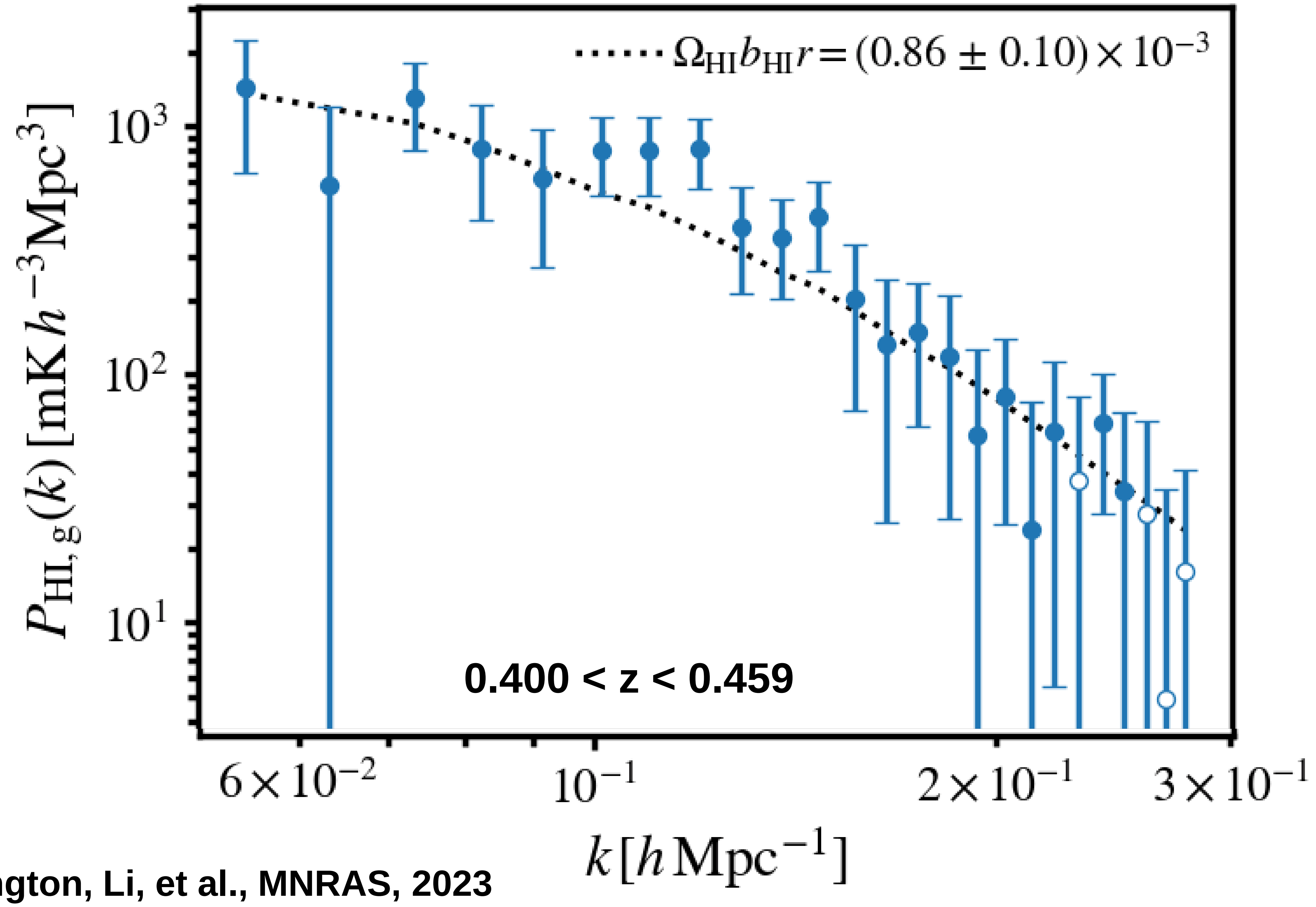
Looking for fluctuations ~ $1/10^5$

Temperature maps at 1023 MHz – we can cross-correlate between dishes

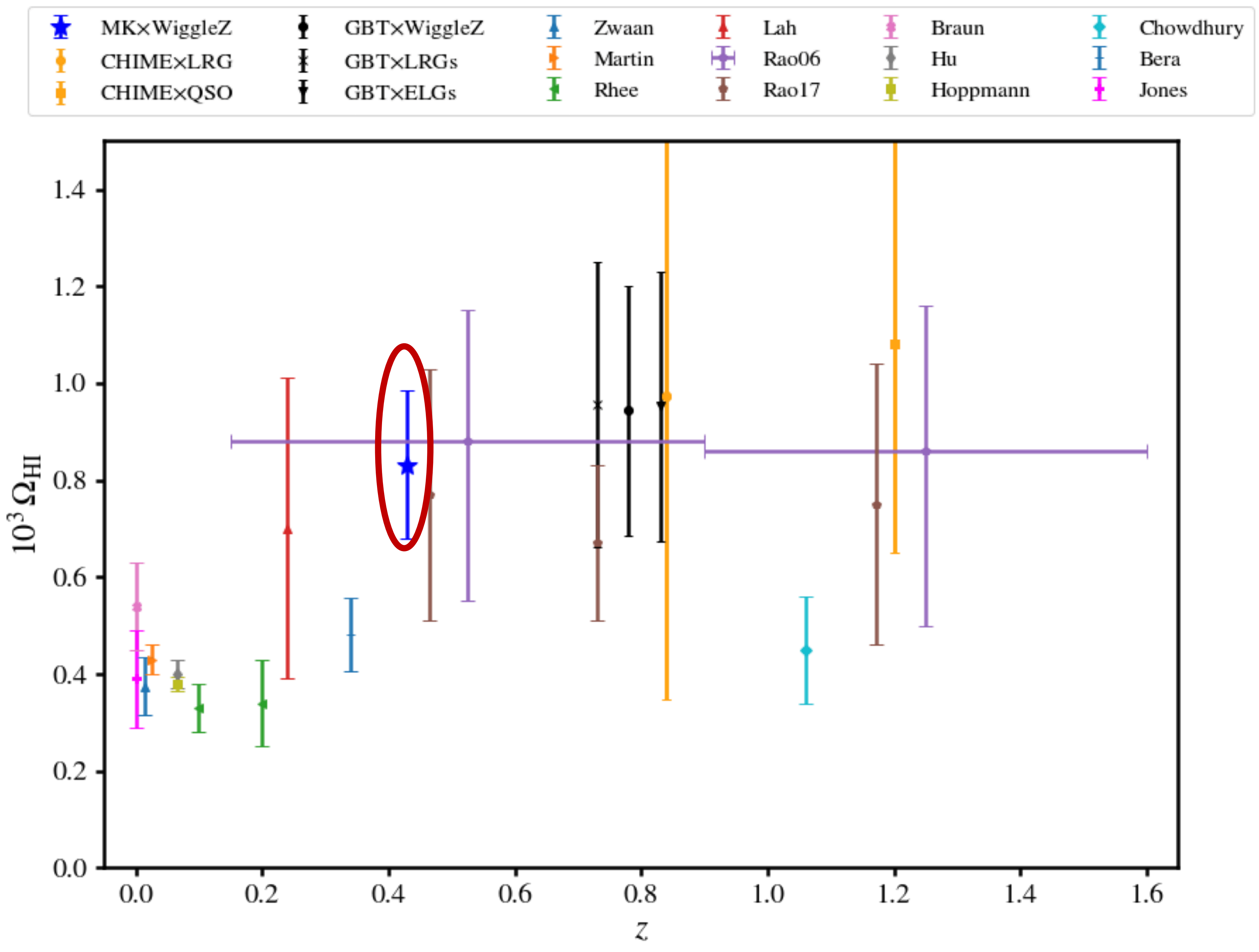


J. Wang, et al., MNRAS 2021

Cosmological results with MeerKAT: Detection of the cross-correlation power spectrum with WiggleZ galaxies

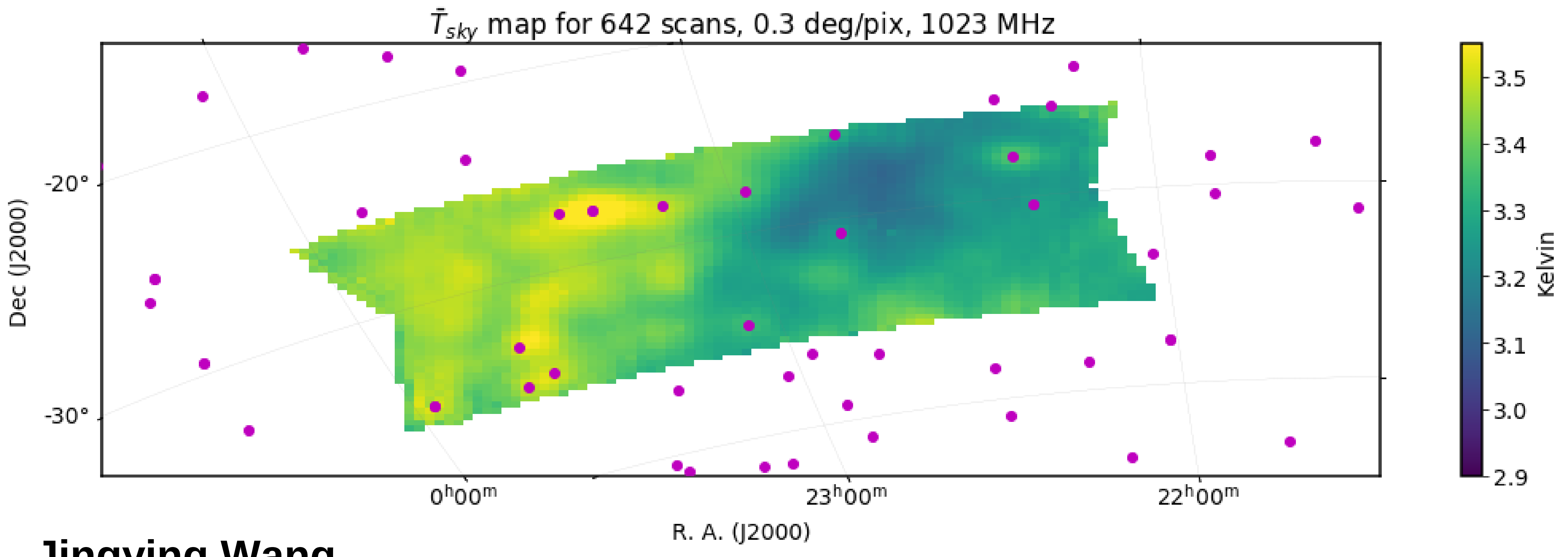


Cunnington, Li, et al., MNRAS, 2023

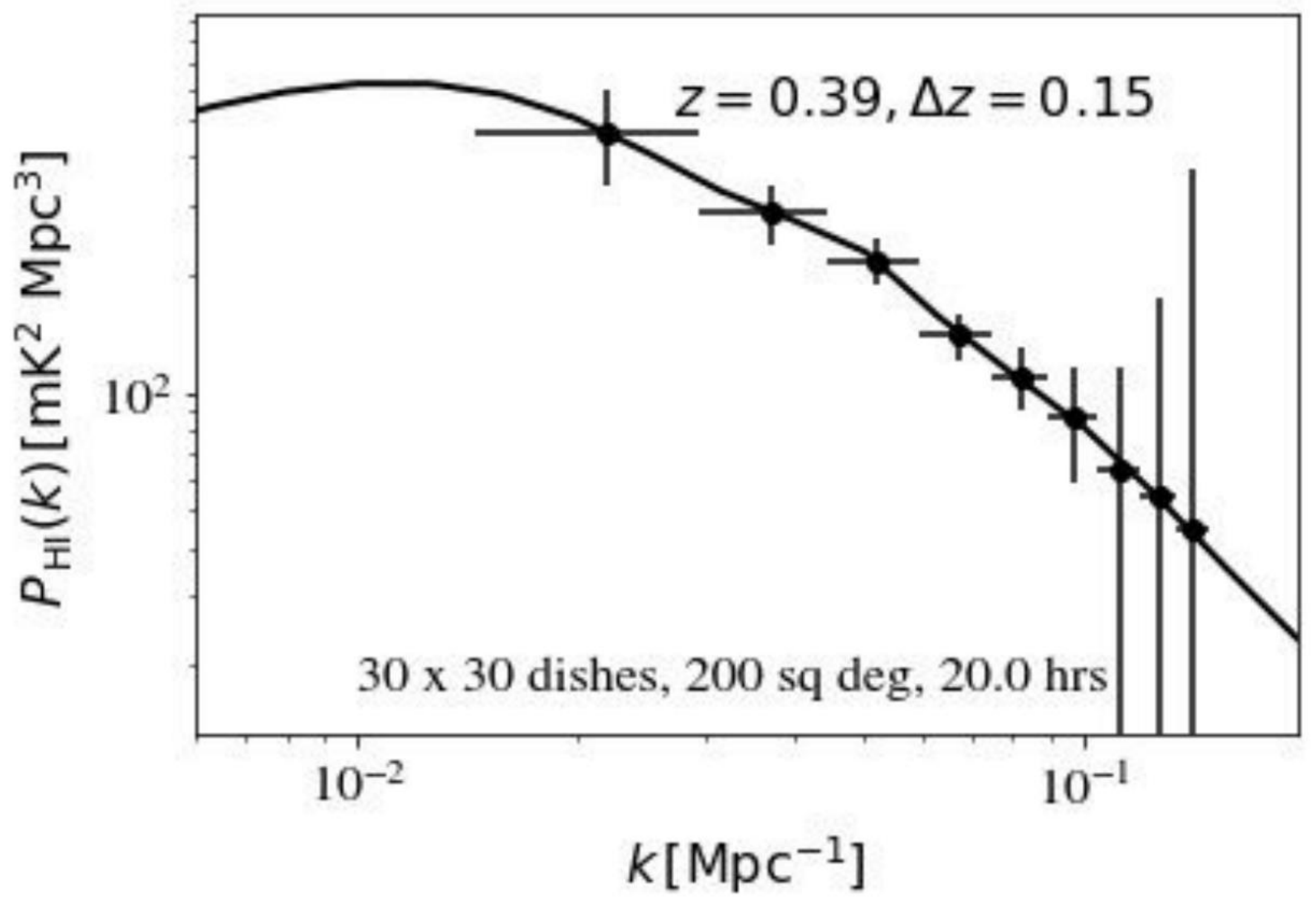


Ongoing analysis

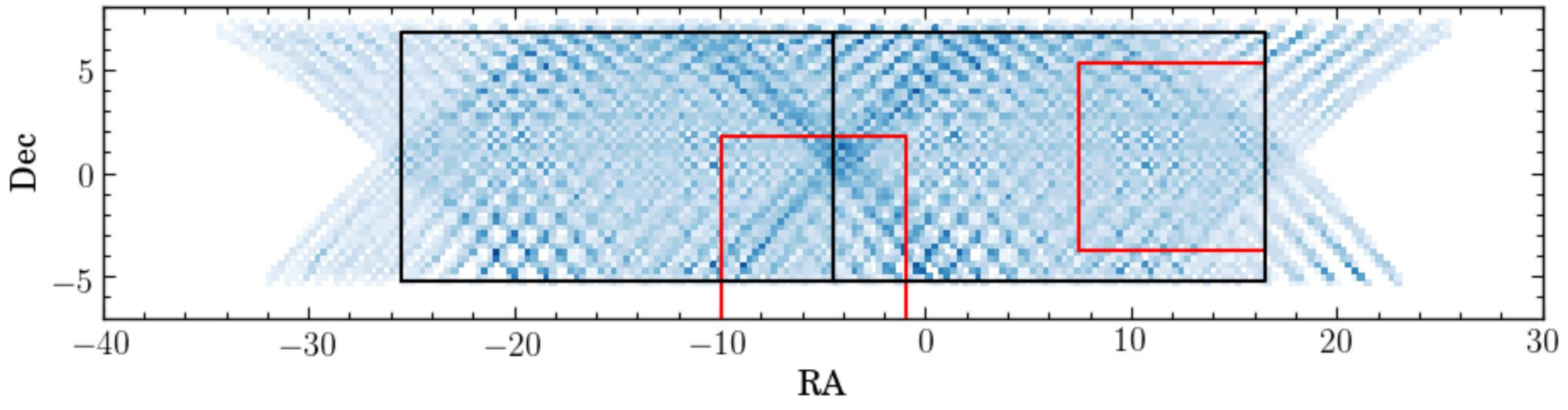
- 80 hours of L band data at lower declination – see talk by Matilde Squarotti

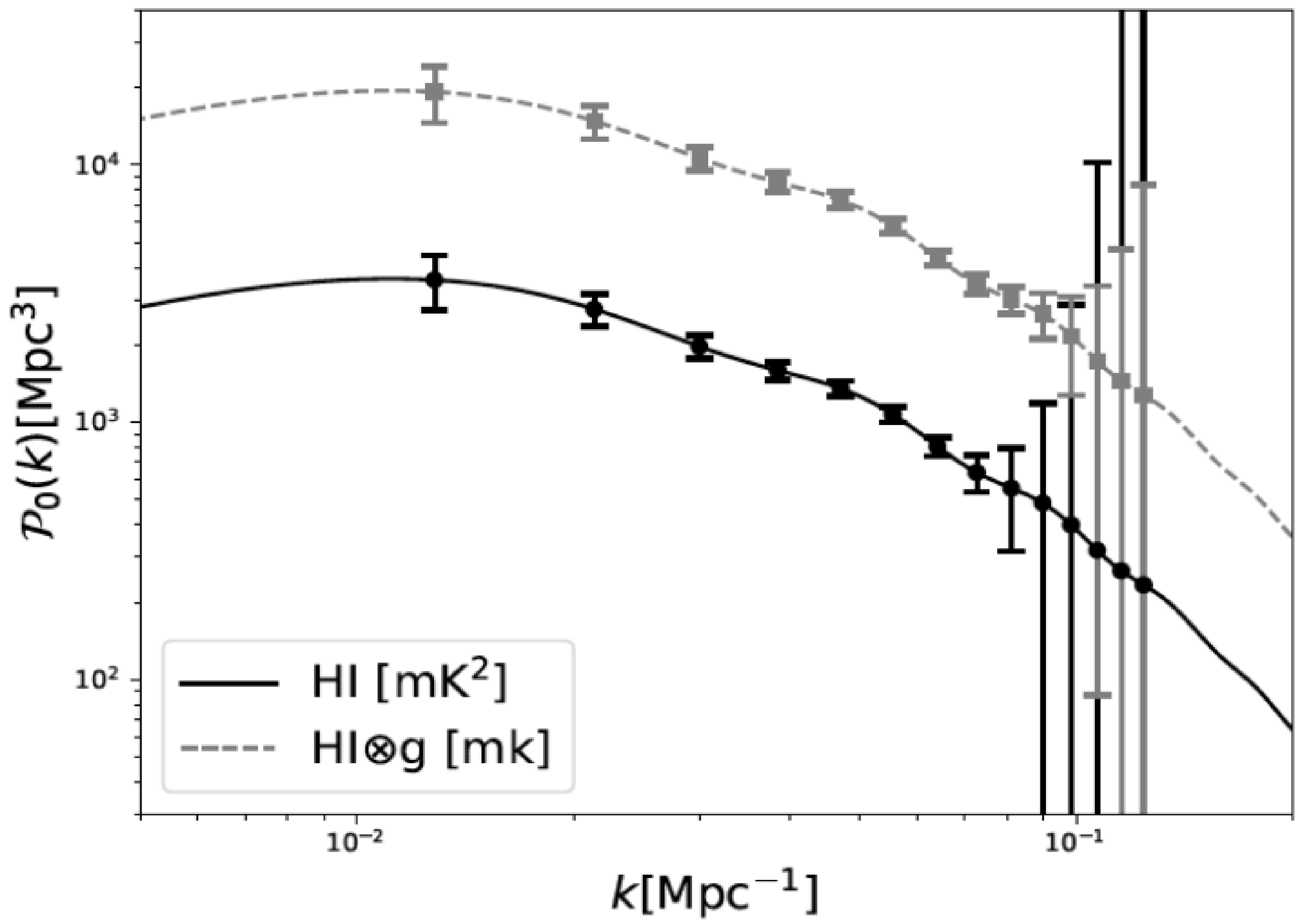


Jingying Wang



- 120 hours of UHF band data

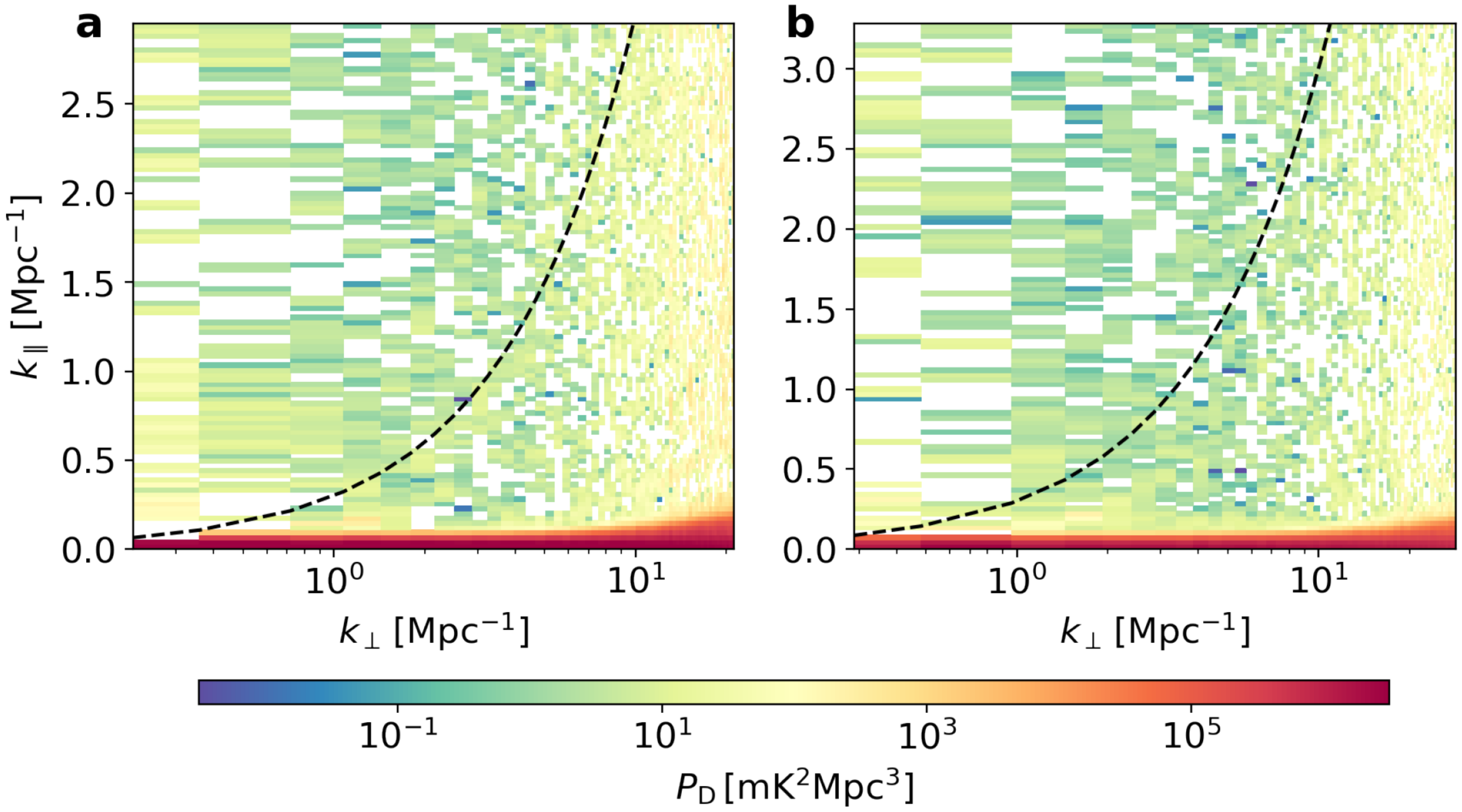




HI IM using the MeerKAT interferometer?

- HI intensity mapping can also measure quasi-linear cosmological scales (k ~ 1 Mpc^{-1} and above)

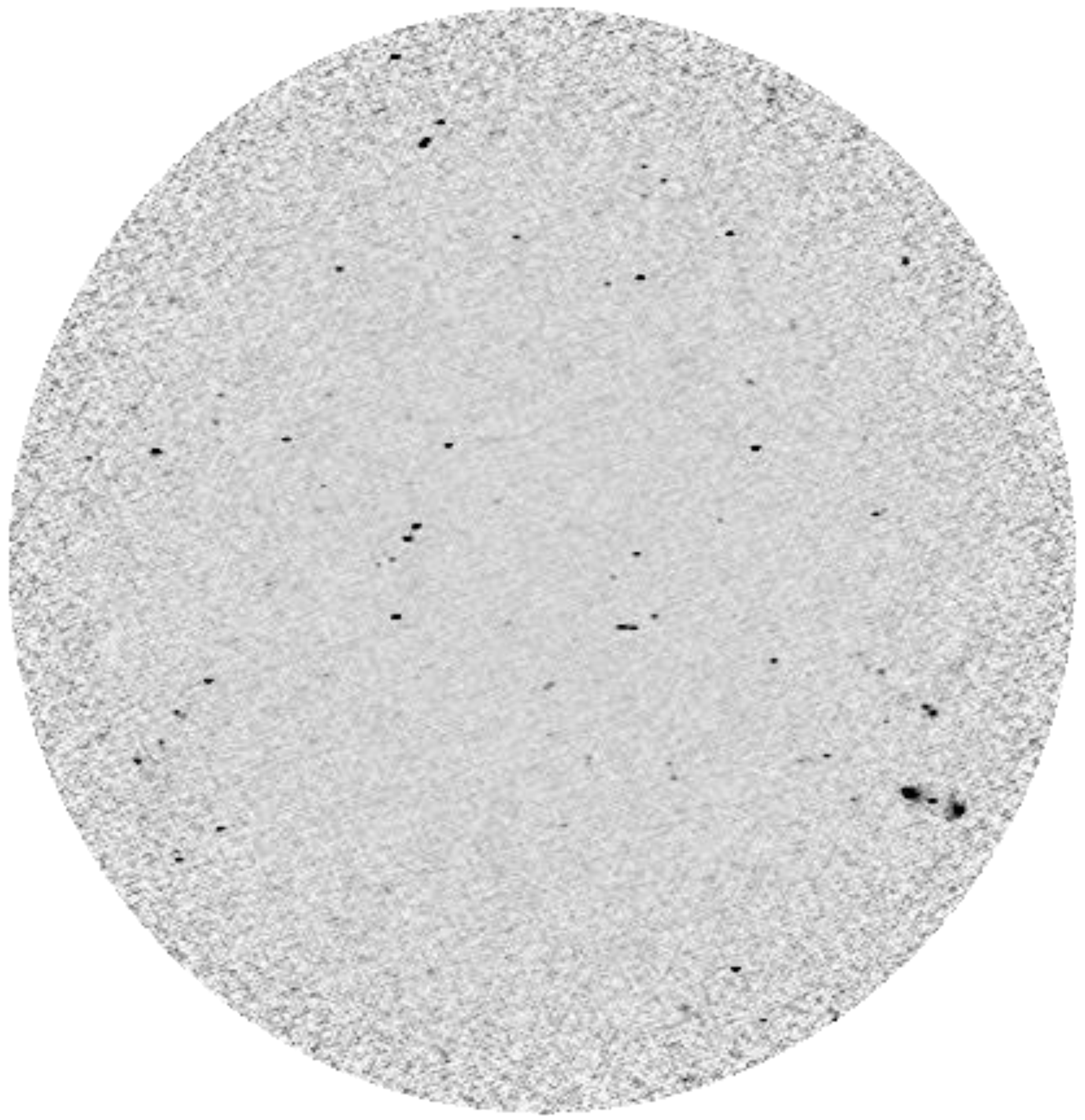
- Great way to test the halo model and compare to HI simulations!



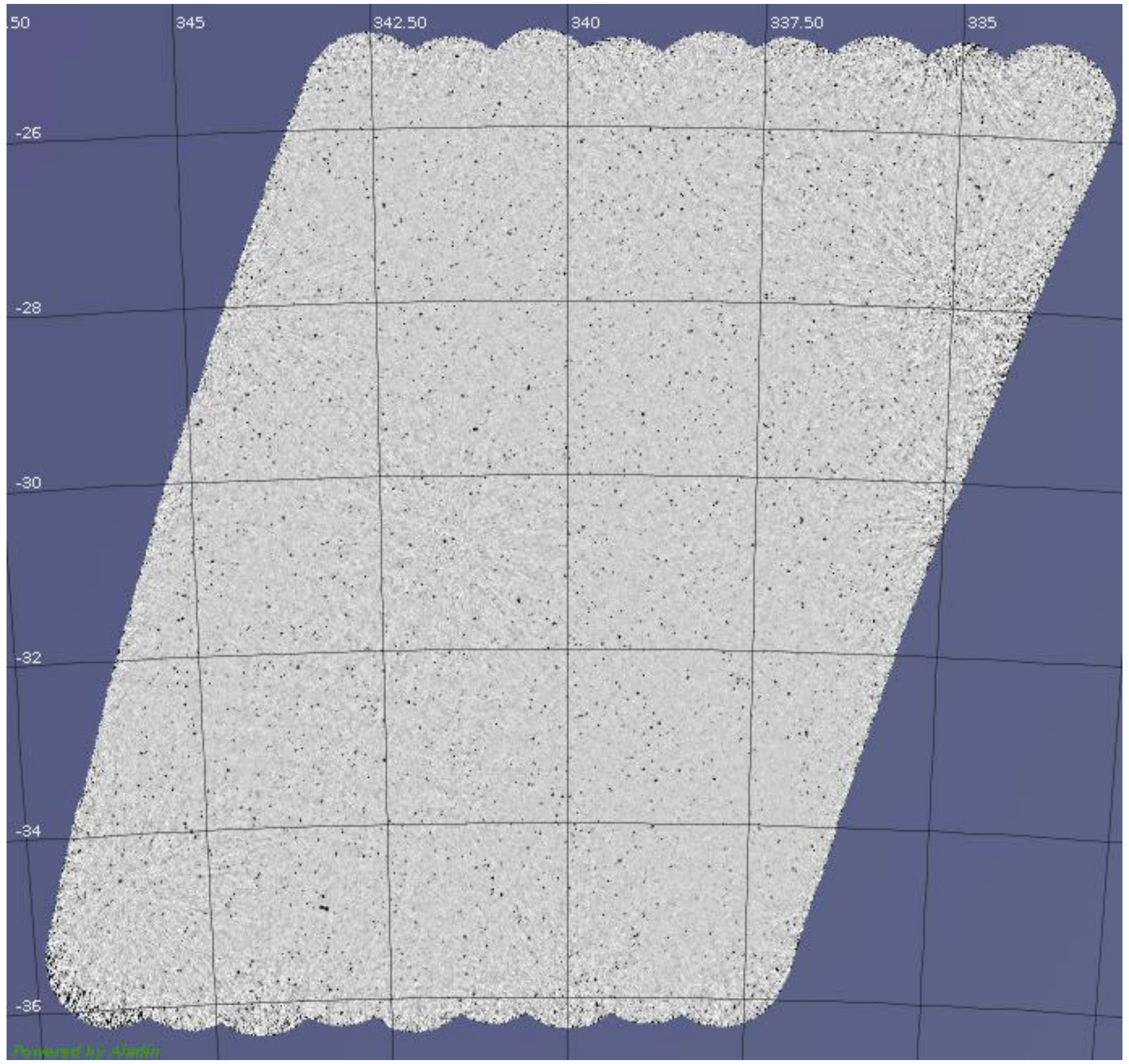
Direct detection of the HI signal - See talk by Zhaoting Chen

Continuum survey with the same data?

- Need On-The-Fly (OTF) calibration/imaging technique to deal with constant dish movement
- Ongoing pipeline development using L band data
- UHF observations include full calibration for interferometer



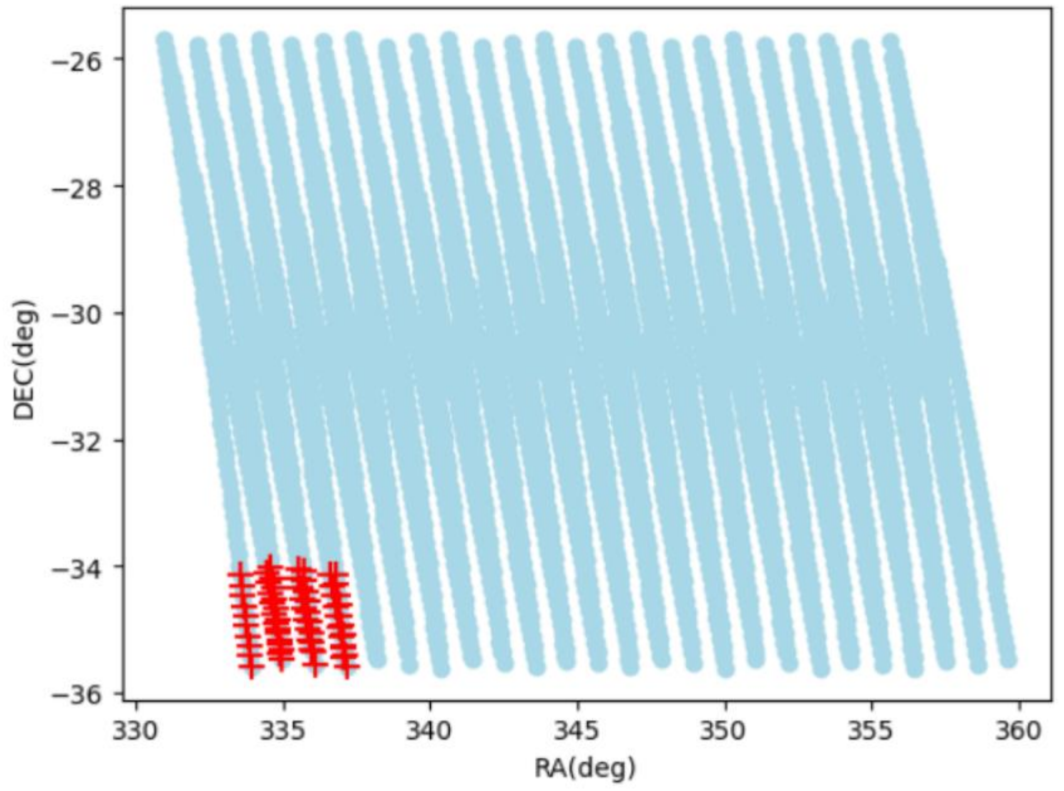
1 snapshot (2 sec)

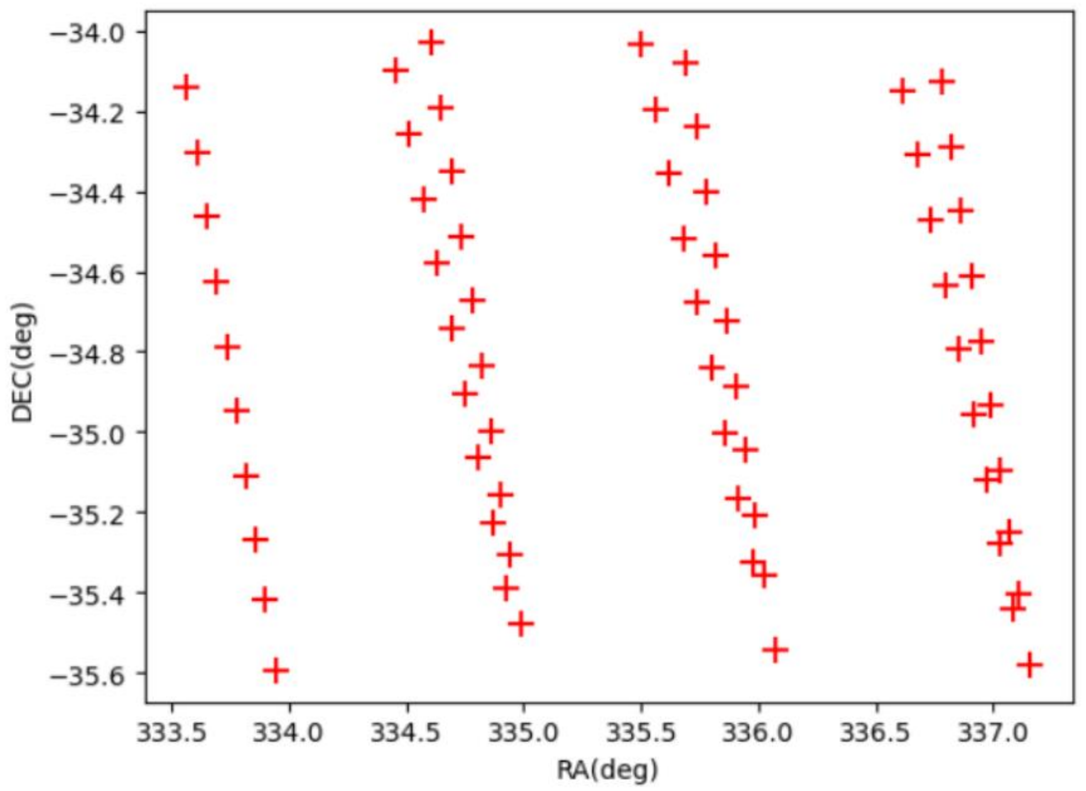


18 scan lines

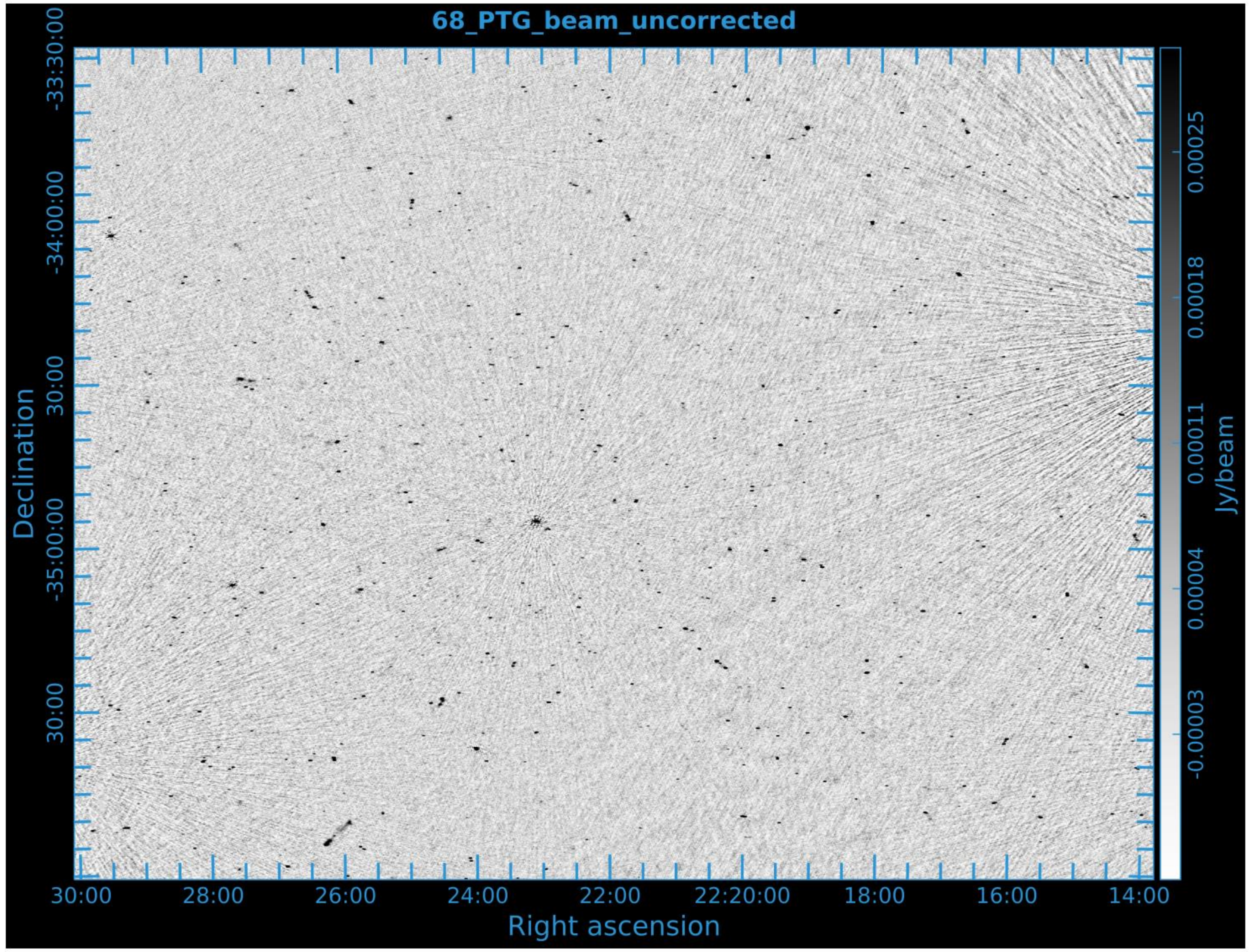
Daniel Hernandez, Kristof Rozgonyi, Joe Mohr

Continuum survey with the same data?





- Mosaic using DDFacet
- Preliminary!
- Suman Chatterjee, Cyril Tasse, Oleg Smirnov



~ 140 uJy rms

~~Summary~~ Recruitment pitch

- HI intensity mapping with MeerKAT/SKA in single dish mode will deliver state of the art cosmological constraints: BAO in HI – dark energy, RSDs – modified gravity, primordial non-Gaussianity…
- Multi-wavelength cross correlations adds more than the sum of the parts
- We have HI IM detections using the MeerKAT single dishes in cross with optical galaxies and auto detections with the interferometer
- Ongoing observations and data processing – new observations starting in January!
- Ongoing data processing for continuum imaging
- Lots of interesting challenges and cool results ahead – be part of it – join us!