

Medium-and ultra-deep HI surveys with SKA

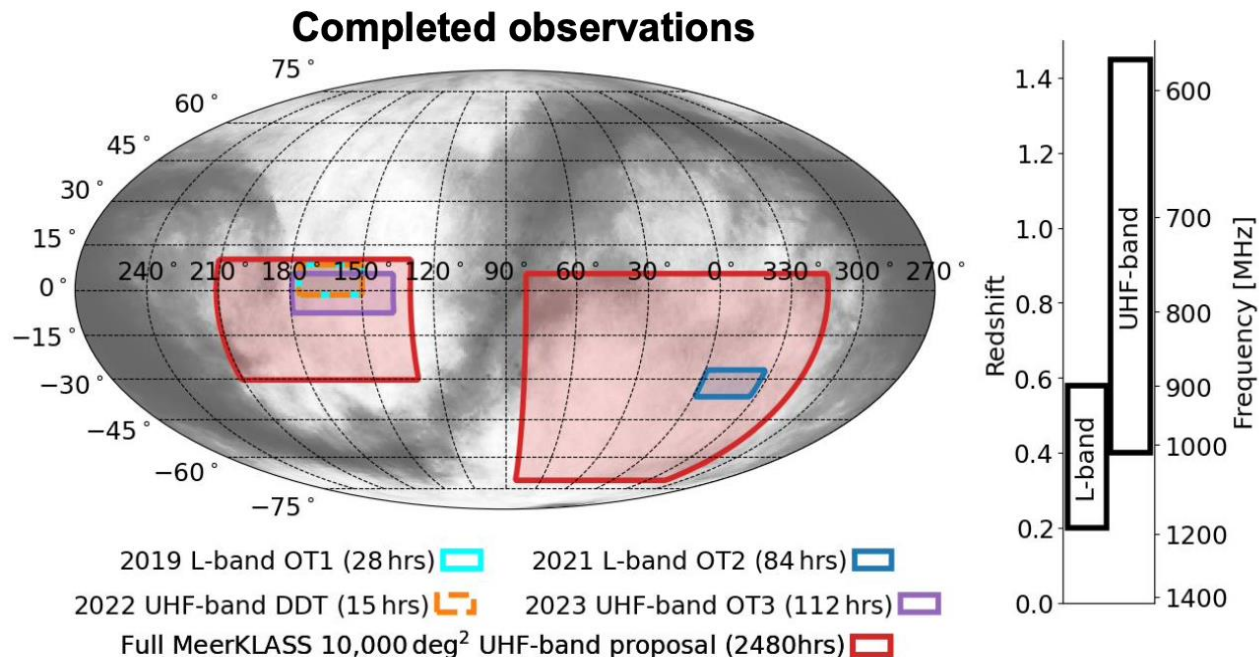
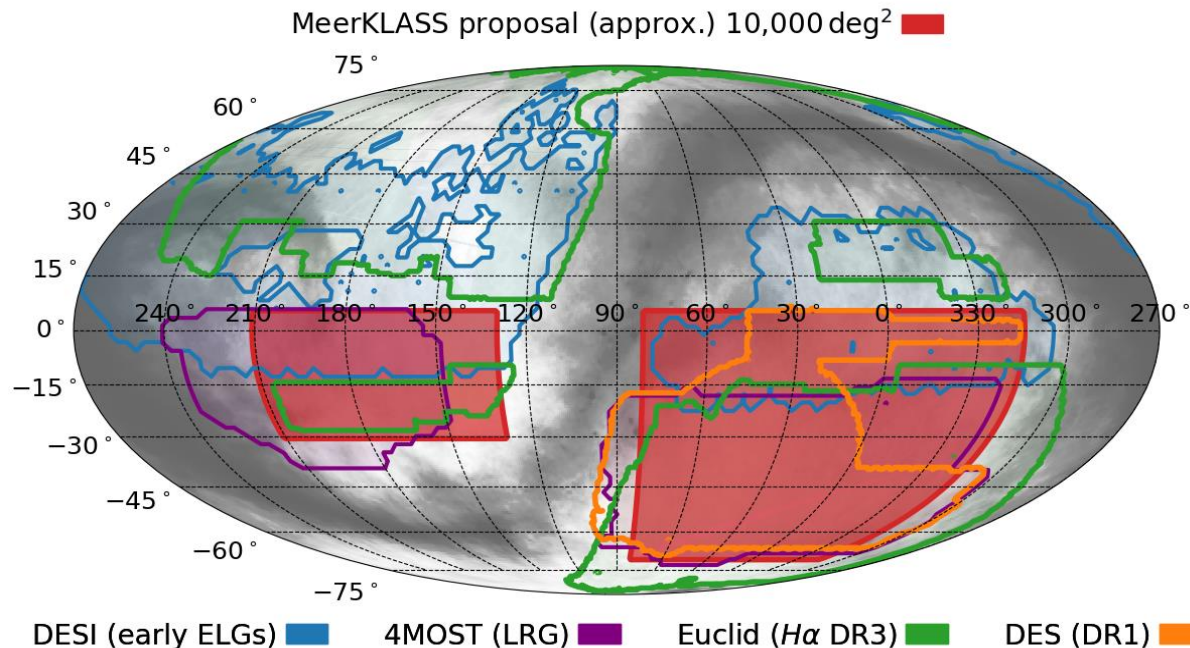
Yougang Wang

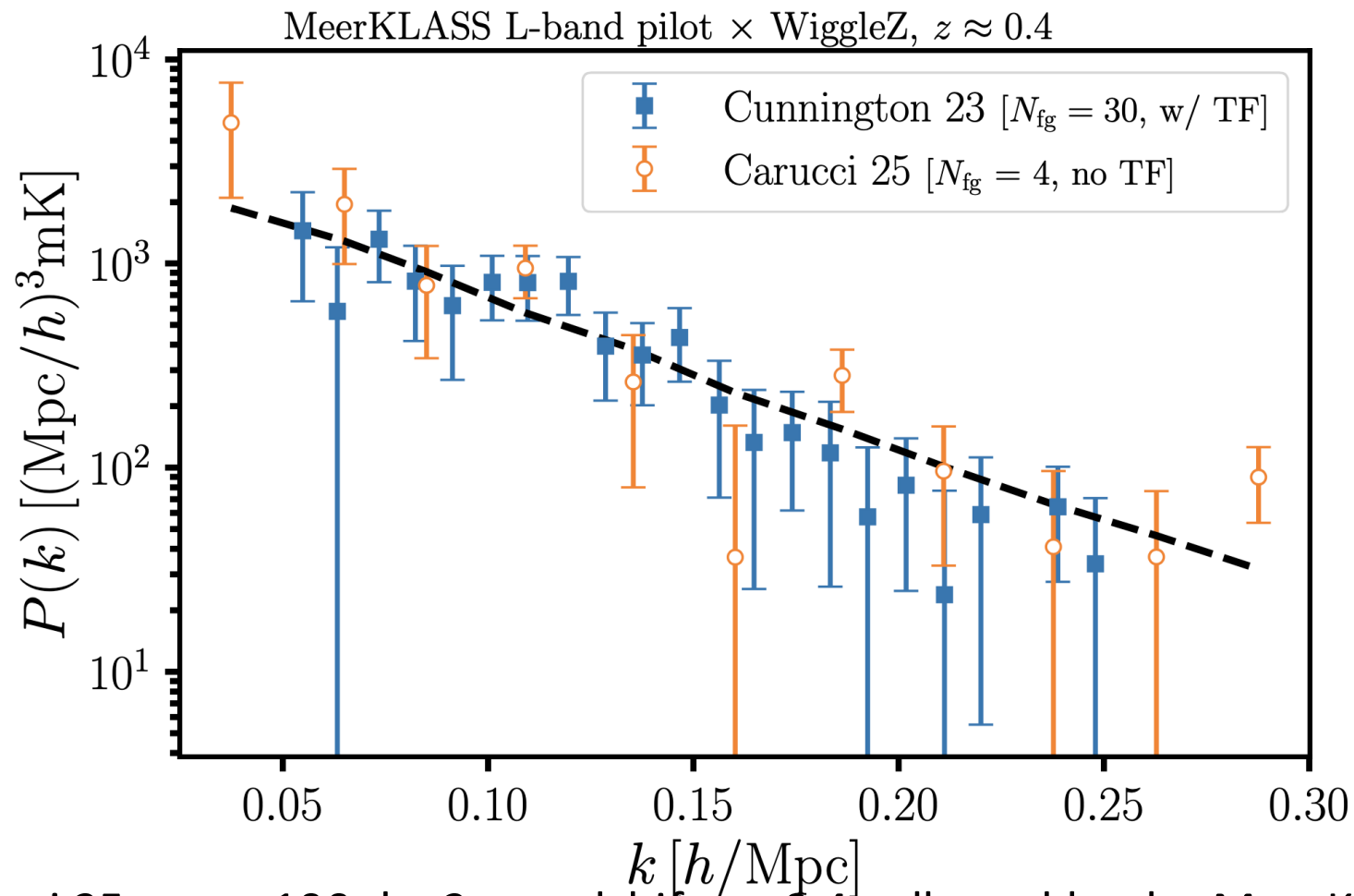
Sep. 30, 2025

MeerKLASS: MeerKAT Large Area Synoptic Survey

- Aim: Cosmology (HI intensity mapping) but commensal with lots of other science (continuum survey)
- Covering L-band (900-1670MHz, $z < 0.57$) and UHF band (580-1015MHz, $z \sim 0.4-1.45$)
- Focus on sky patches with multi-wavelength data for cross-correlation
- Goal: 2,500 hours over 10,000 deg² within next 4 years
- The leading radio Cosmology survey in preparation towards SKA1-MID
- International collaboration

S.Cunnington

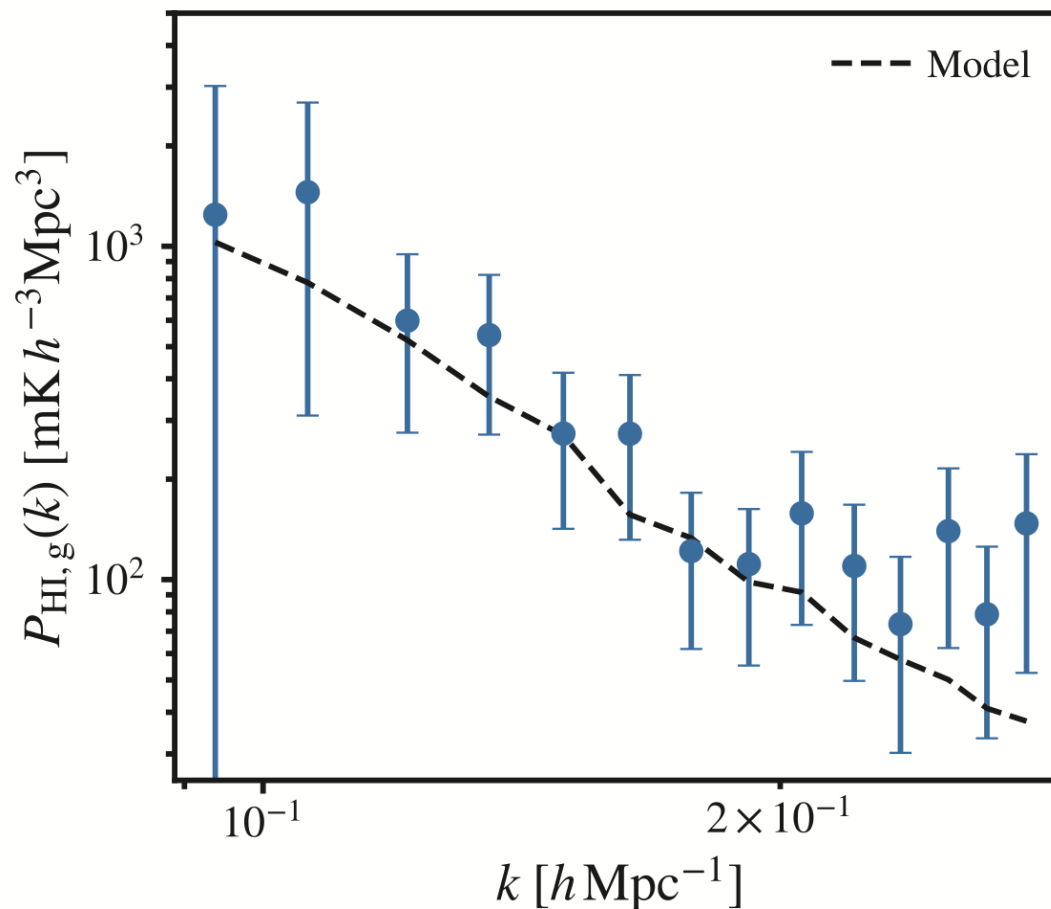
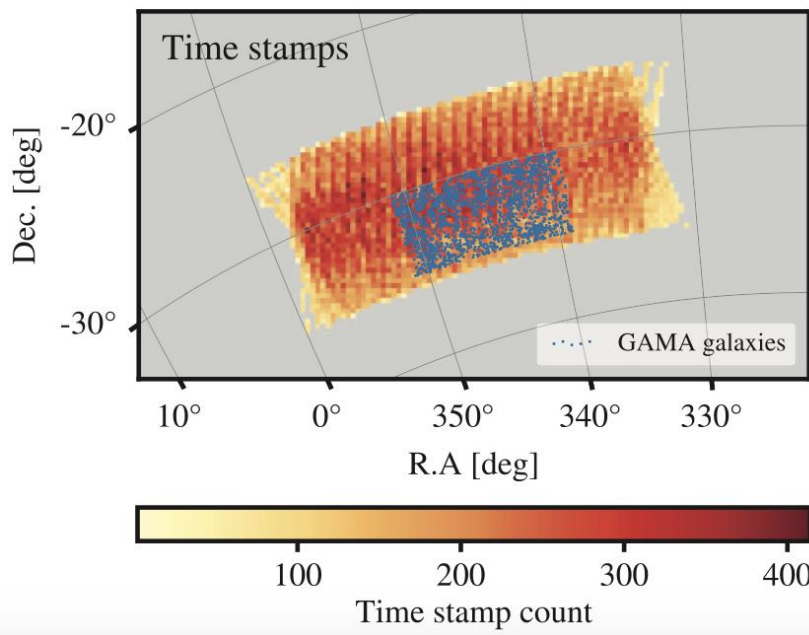
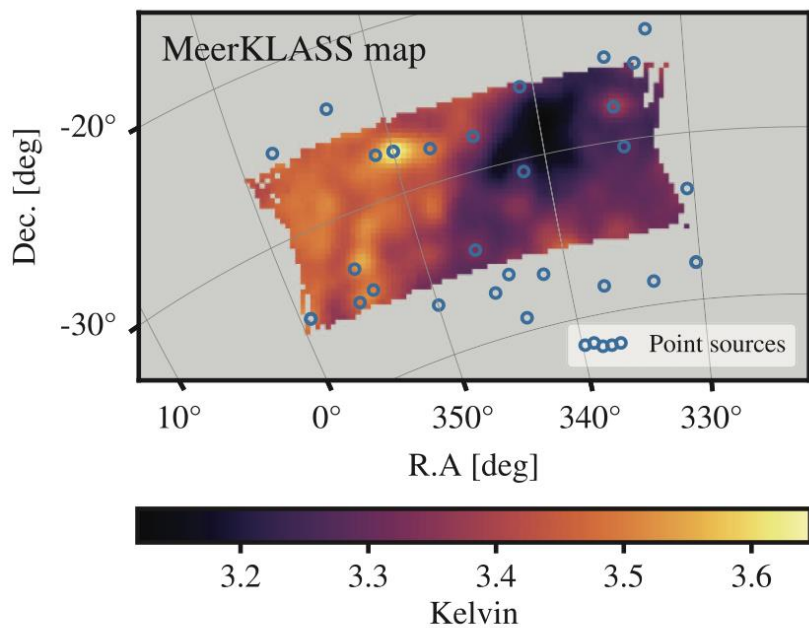




Carucci 25

100 deg² at redshift $z \approx 0.4$ collected by the MeerKAT, with a combined 10.5-hour observation

MeerKLASS studies



41 repeated scans
over 236 deg²,

62 h of observation
for each of the 64
dishes before
flagging.

$0.39 < z < 0.46$
(971 MHz < ν <
1023 MHz)

MeerKLASS Collaboration 2025

SKA-Mid: Delivery of observing modes and ODPs to the astronomy community

AA2 2029	AA* 2031	Cycle 0 2032		Cycle 1 2033			Cycle 2 2034			Cycle 3 2035		
Science Verification (SV)	SV	SV	Shared risk	SV	Shared risk	Standard ops	SV	Shared risk	Standard ops	SV	Shared risk	Standard ops
Single subarray Both sidereal and non-sidereal tracking		4 subarrays Drift scanning capped at a few mins		16 subarrays Drift scanning capped at a few mins			Full drift scanning capabilities Wide area scanning					
Calibrated, averaged and gridded visibilities, image cubes (excluding SKA008) Full BW (800 MHz), FoV Single pointing 40 channel max 4h max observations	Full BW (up to 5 GHz) 8 hour max observations, up to 16 images (either in time i.e. 30min, or pointings) Zoom resolution (up to 0.21 kHz) 4 hour max observations, up to 8 images (either in time i.e. 30min, or pointings) Continuum subtraction PSS 200 beams fully processed VLBI 4 beams PST 8 beams, full processing	Limited support for PLDP generation tests Limited joint deconvolution Limited support for PLDP generation tests Limited joint deconvolution Transient buffer - triggered by PSS observations	Multiple pointings processed independently (i.e no joint deconvolution) Use of SKA008 possible for appropriate projects 50h max integration 16k channel max Multiple pointings processed independently (i.e no joint deconvolution) Use of SKA008 possible for appropriate projects 12h max integration PSS full basic capability VLBI full basic capability PST full 16 beam capability	Fast imaging Transient buffer triggered by fast imaging (limited by buffer latency, perhaps less than 10 seconds) Improved PSS machine learning for improved triggering	Source finding (& associated image cutouts) Limited PLDP generation Joint deconvolution Source finding (& associated image cutouts) 64k channel max Joint deconvolution Limited PLDP generation Transient buffer - triggered by PSS observations	Multiple pointings processed independently (i.e no joint deconvolution) Use of SKA008 possible for appropriate projects 50h max integration 16k channel max Multiple pointings processed independently Use of SKA008 possible for appropriate projects 12h max integration PSS full basic capability VLBI full basic capability PST full 16 beam capability	Autocorrelation processed data products Autocorrelation processed data products	Fast imaging Transient buffer triggered by fast imaging (limited by buffer latency, perhaps less than 10 seconds) Improved PSS machine learning for improved triggering	Improved source finding (& associated image cutouts) Full PLDP generation Joint deconvolution Improved source finding (& associated image cutouts) 64k channel max Joint deconvolution Full PLDP generation Transient buffer triggered by PSS observations	Autocorrelation processed data products Autocorrelation processed data products	Improved PSS machine learning for improved triggering Fast imaging Transient buffer triggered by fast imaging (limited by buffer latency, perhaps less than 10 seconds)	

Telescope mode

Observatory Data Products (ODPs) and their capabilities

ContinuumSpectralBeamformedTransient

Telescope mode

Observatory Data Products (ODPs) and their capabilities

- Continuum
- Spectral
- Beamformed
- Transient

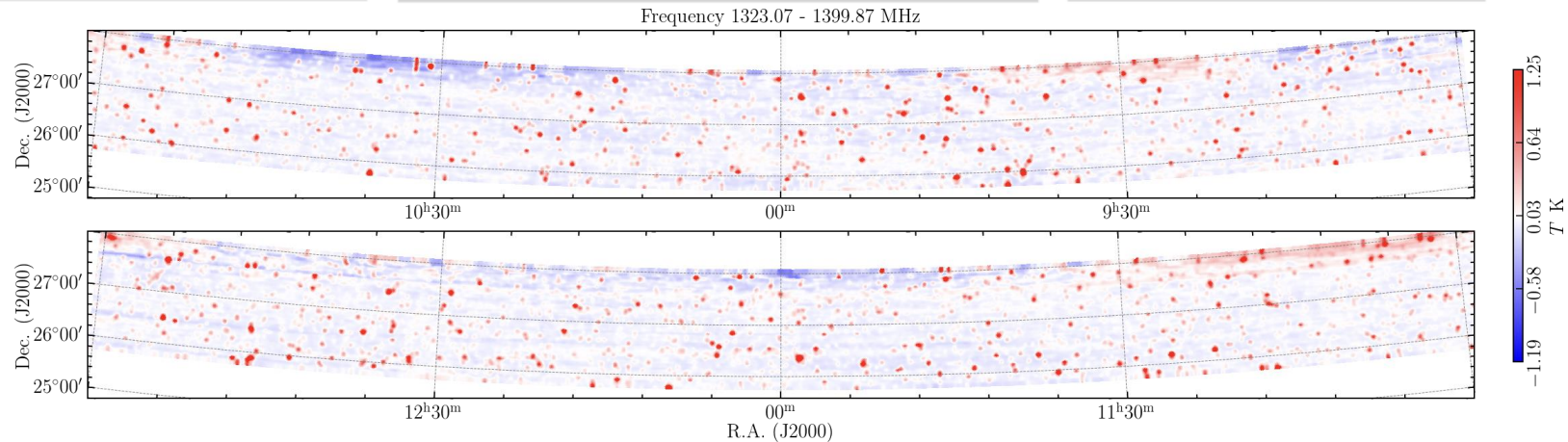
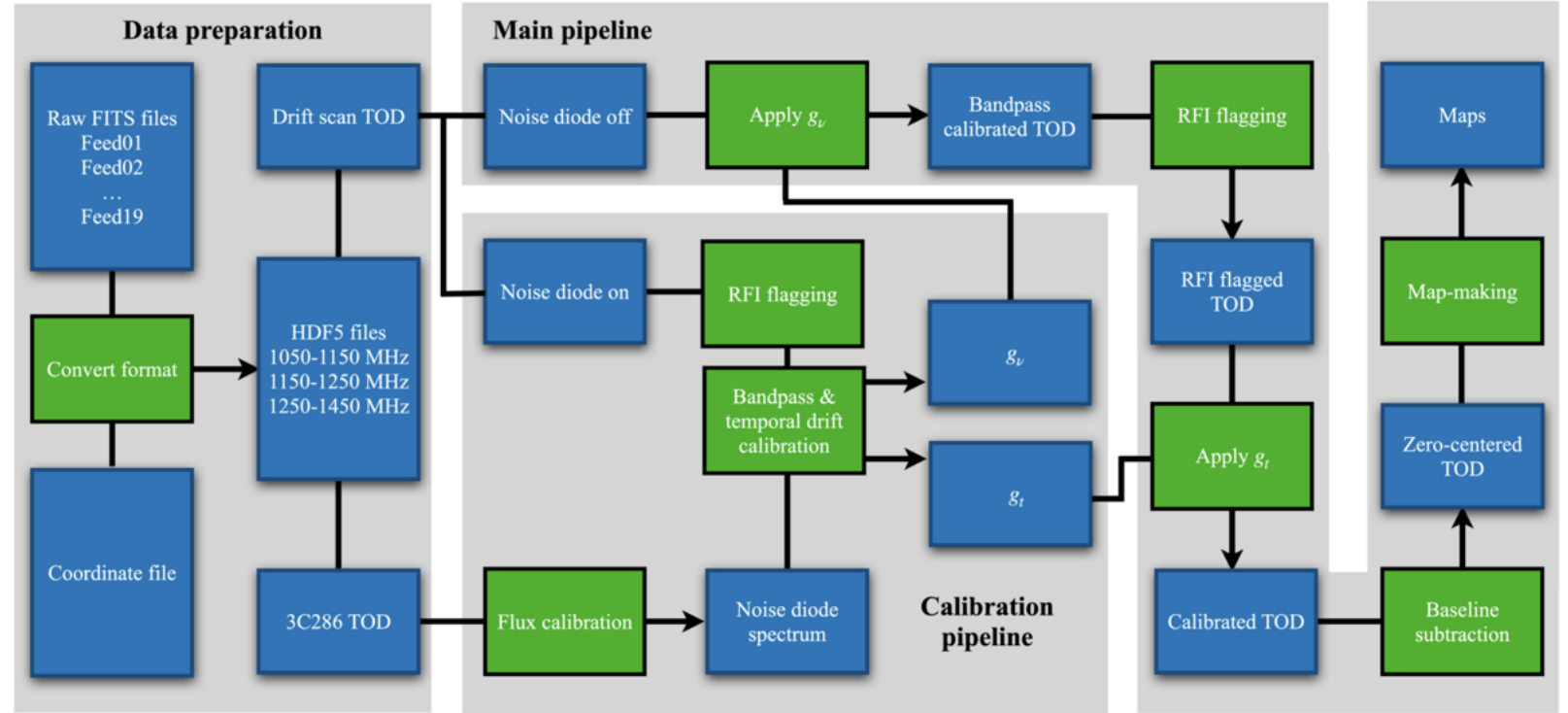
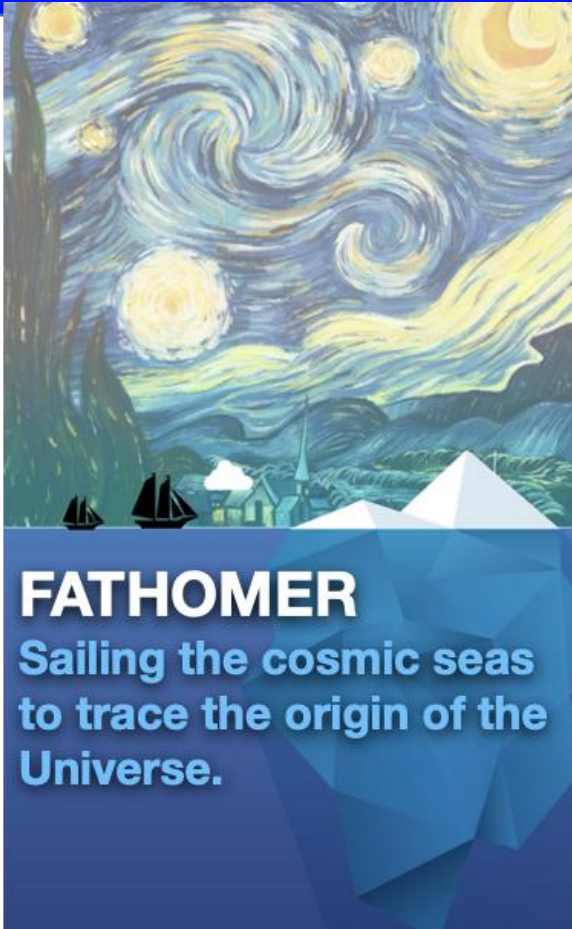


Ska-mid



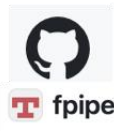
Subarray configuration	Number ska Antennas	Number of meerkat Antennas
AA0.5	4	0
AA1	8	0
AA2	64	0
AA*/AA4(13.5-m only)	0	64
AA*	80	64
AA4	133	64

FATHOMERS

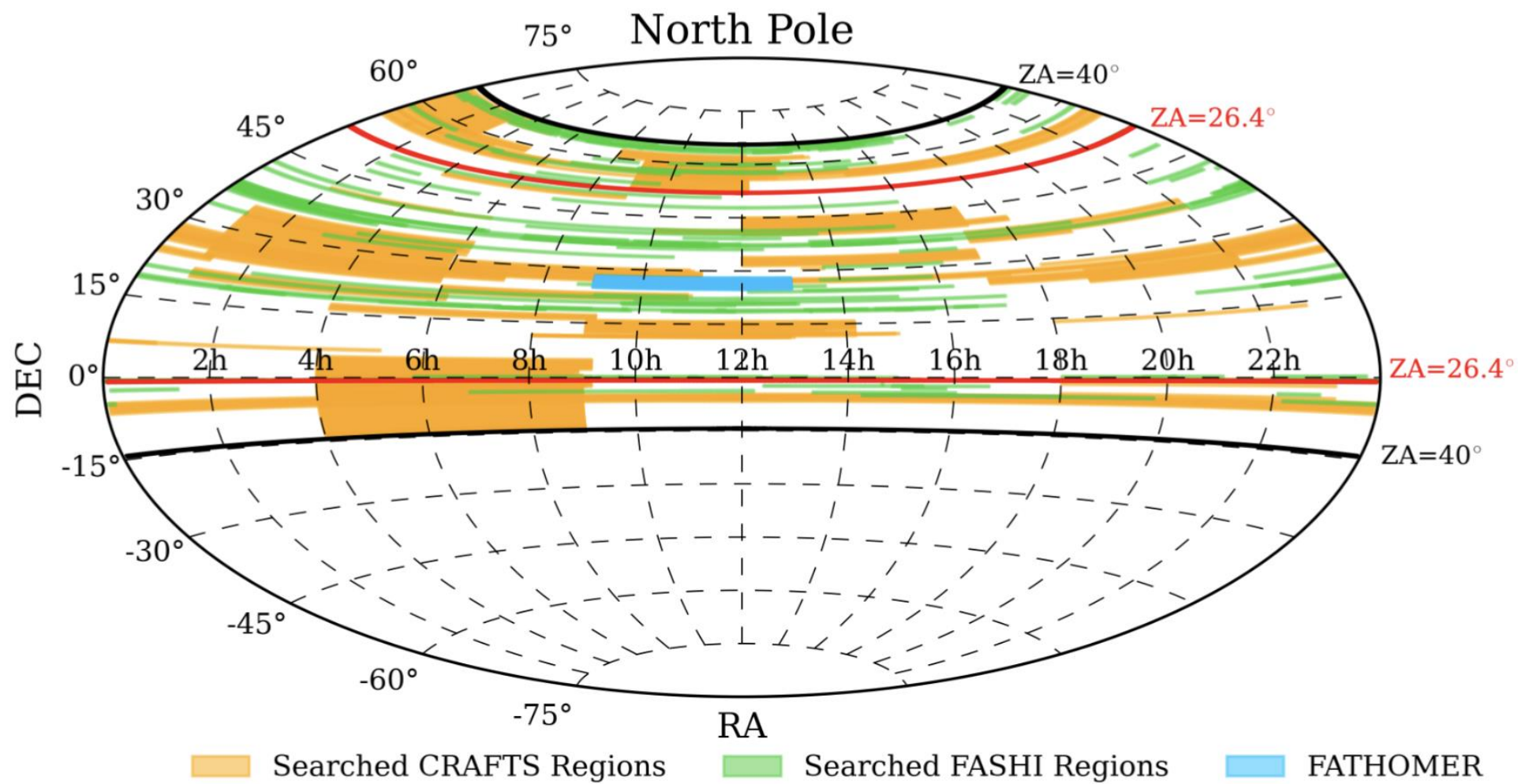


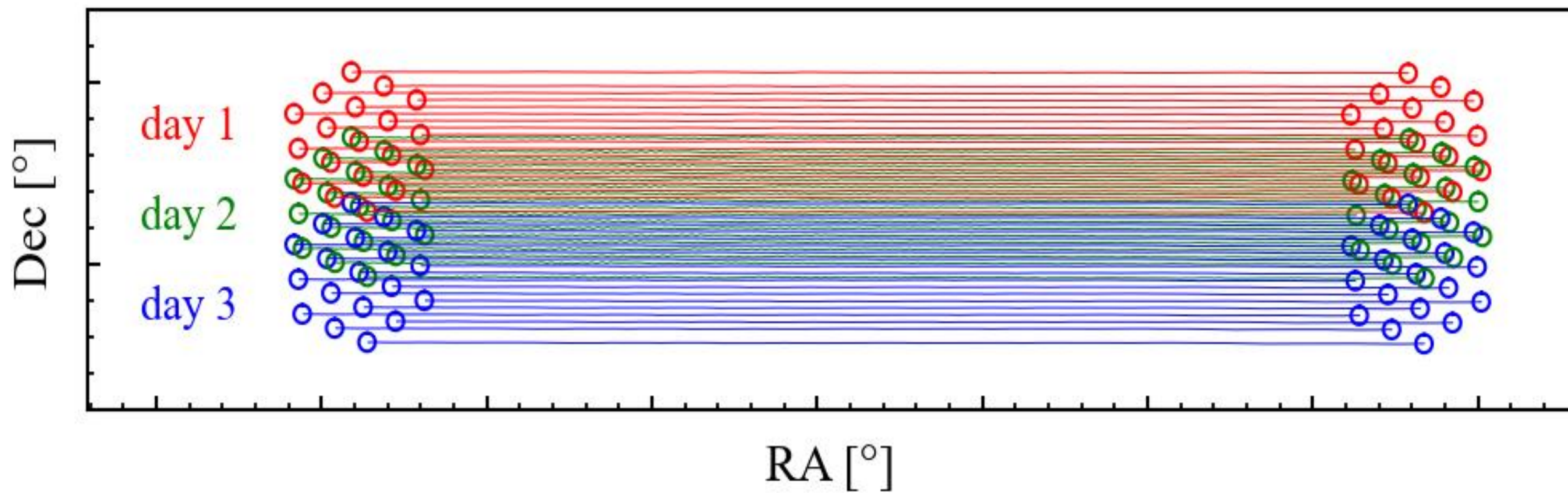
FAst neuTral HydrOgen intensity Mapping ExpeRiment
(FATHOMER 宇宙溯源人)

Li Y.C., Wang Y.G. et al.
2023, ApJ, 954, 139.
liyichao@mail.neu.edu.cn



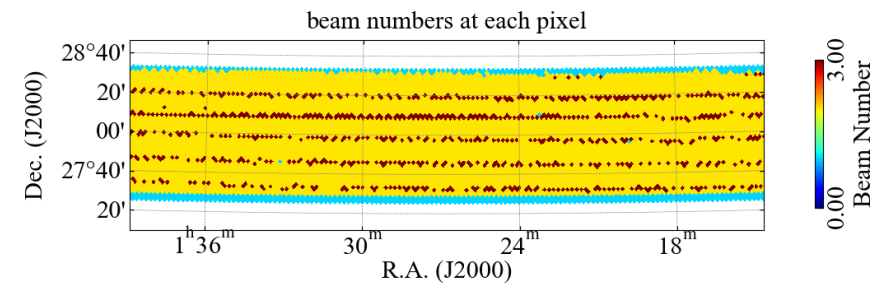
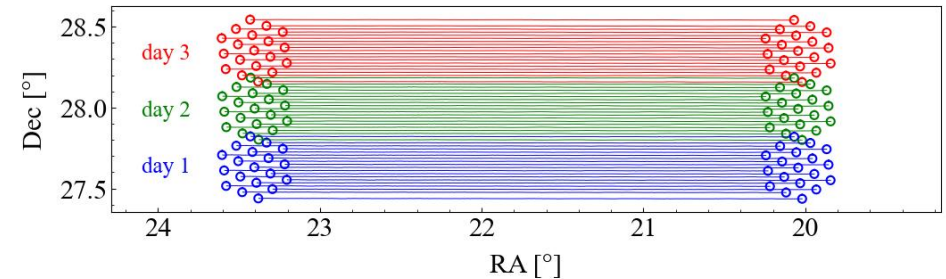
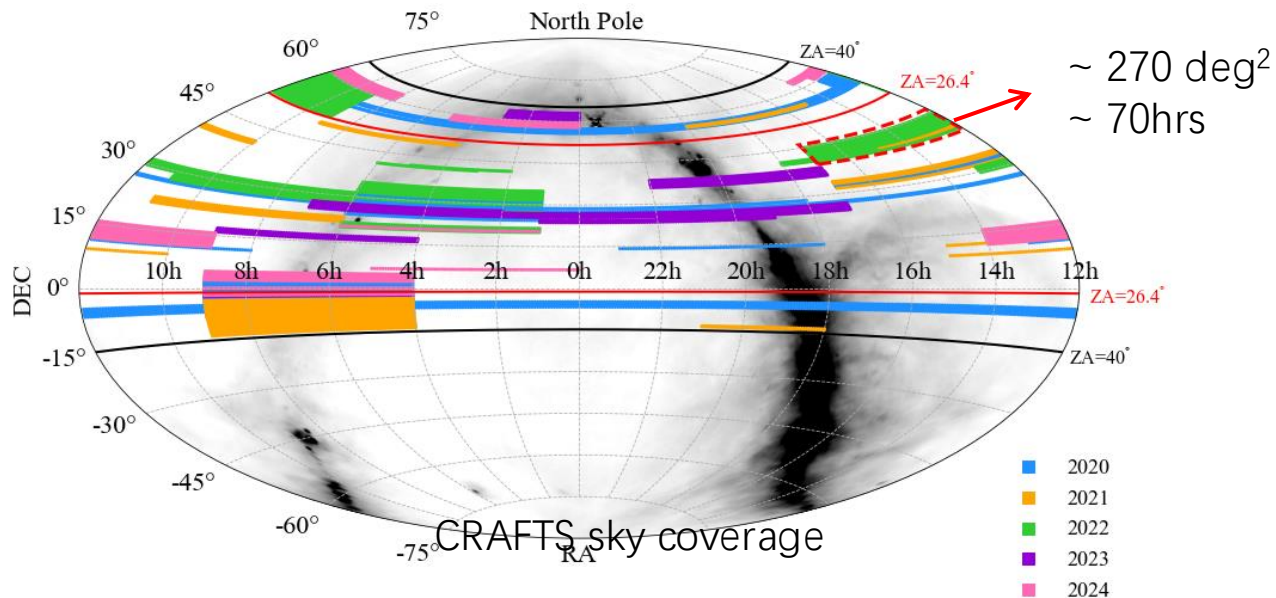
Li, Wang et al. 2023, ApJ, 954, 139





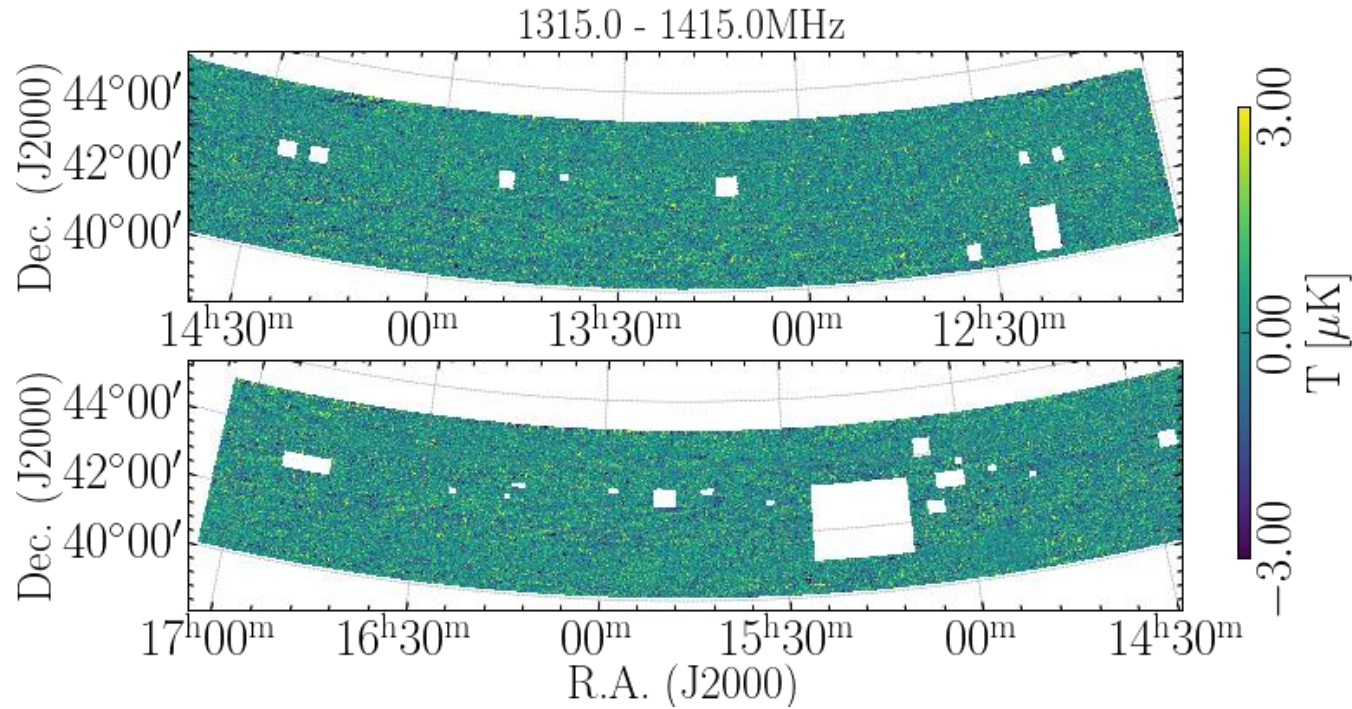
FAST large scale surveys

- **CRAFTS** (The **C**ommensal **R**adio **A**stronomy **F**AST **S**urvey)
- calibration mode: high-cadence noise($\sim 1\text{K}$) injection mode: $T_{\text{inj}} \sim 196.608\mu\text{s}$

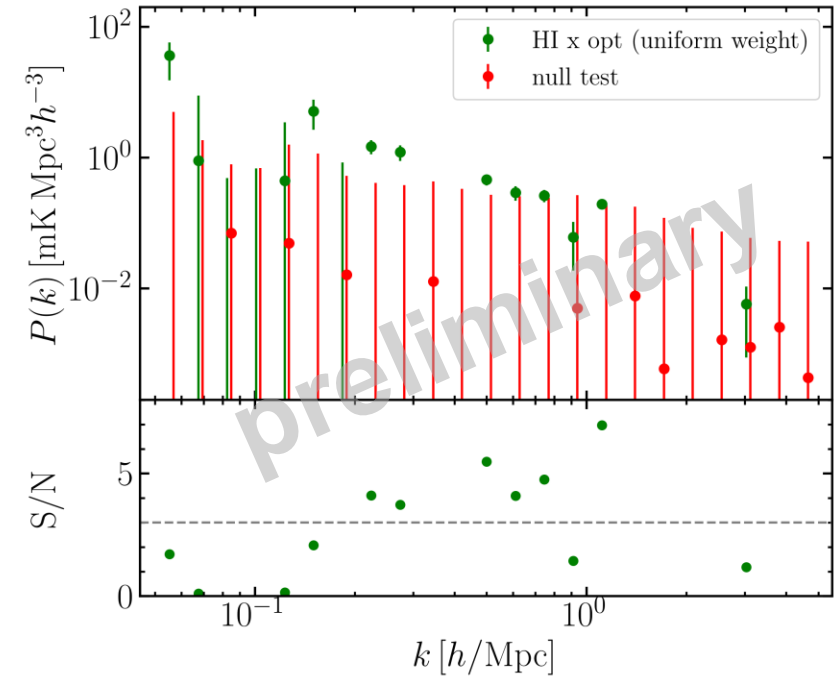


drift scan with L-band 19-beam receiver

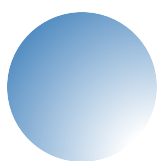
power spectrum estimation



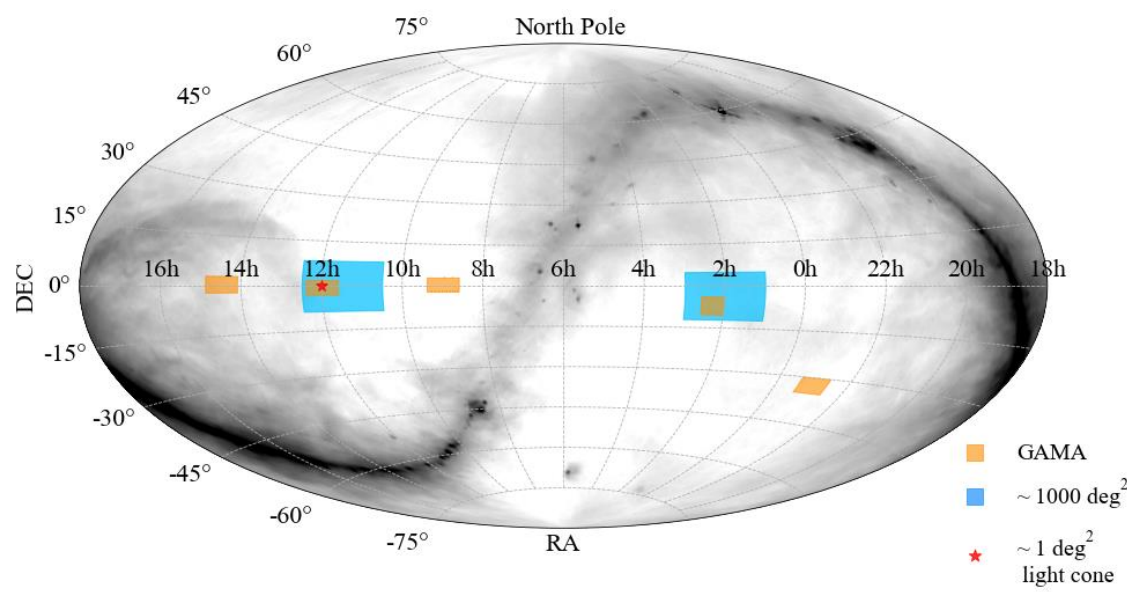
30 foreground modes removed map



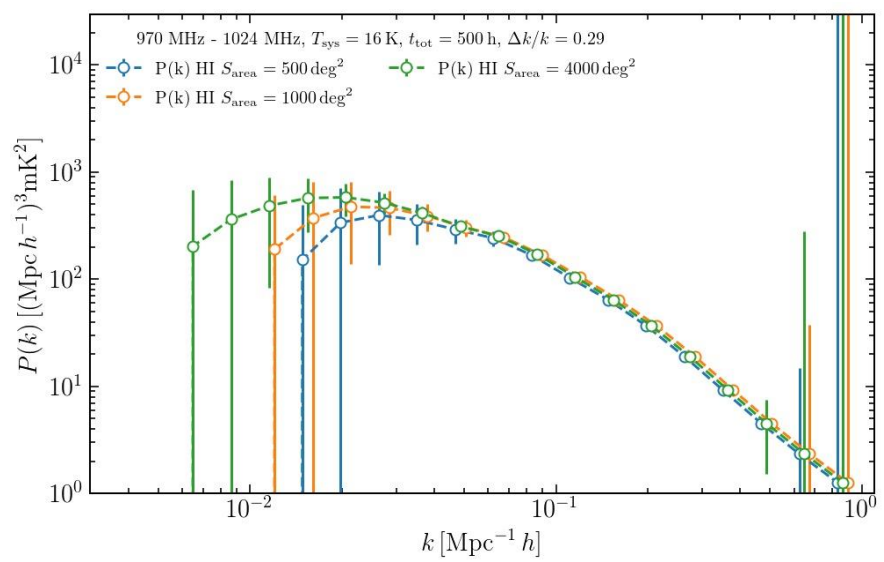
HI x SDSS power spectrum



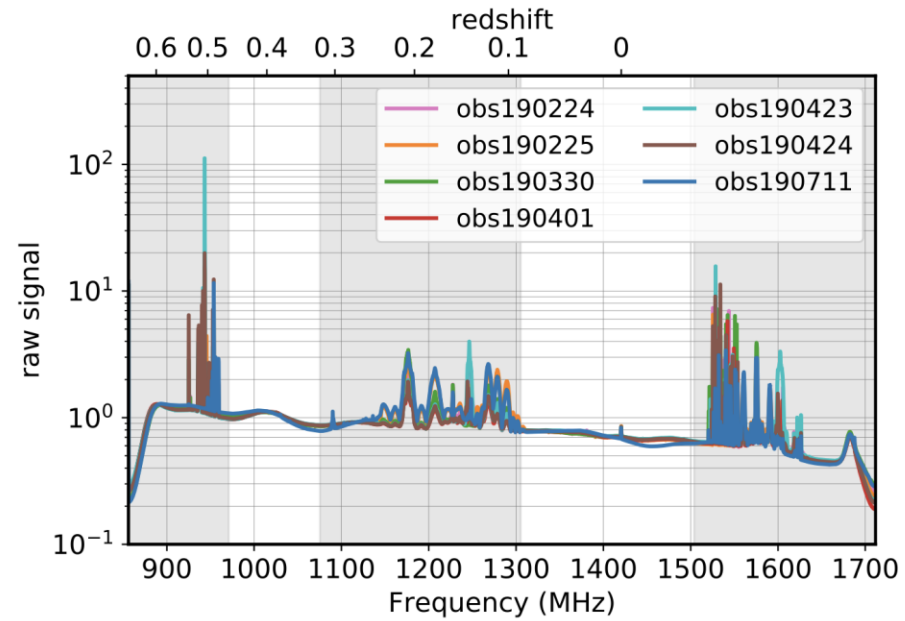
- **HI medium-deep survey**
- **1000 deg², overlaped with FAST.**
 - **For the first step, forced on ~1130MHz for the second step, moving to the high redshift**



500hours, OTF

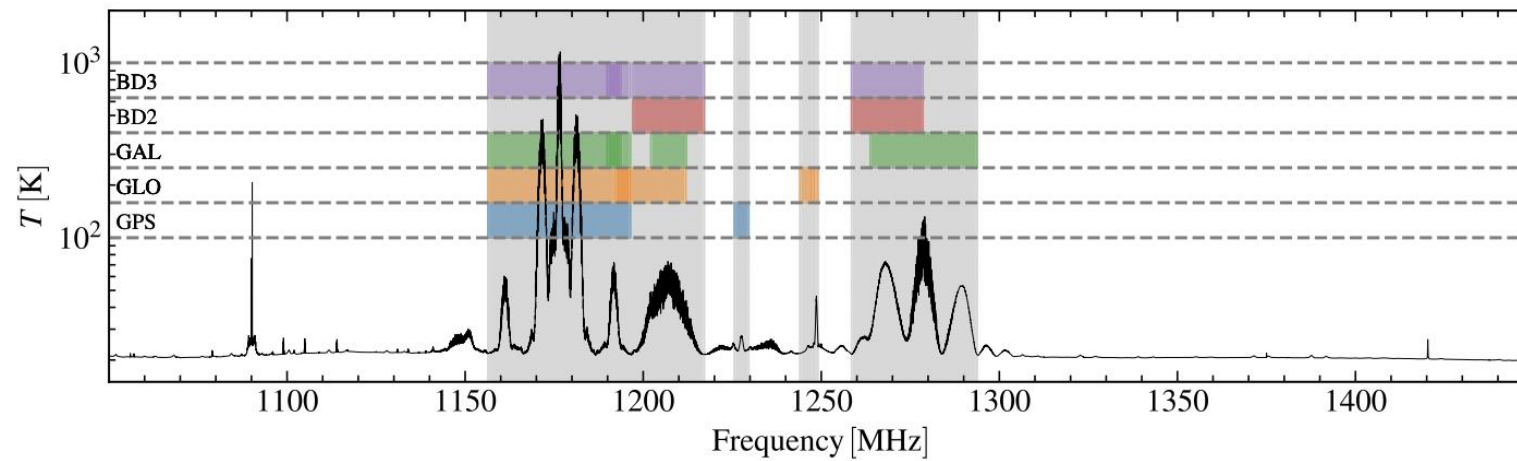


Telescope	Band	Frequency Range (MHz)	Available Bandwidth (MHz)	Notes (MHz)
SKA1-Low	N/A	50 - 350	300	(1)
SKA1-Mid	1	350 - 1050	700	(1)
	2	950 - 1760	810	(1)
	3	1650 - 3050	1400	(2)
	4	2800 - 5180	2380	(2)
	5a	4600 - 8500	3900	(1)
	5b	8300 - 15400	2 x 2500	(1)



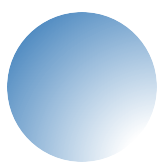
Wang Jingying et al. 2021

MeerKAT



Li et al. 2023

FAST

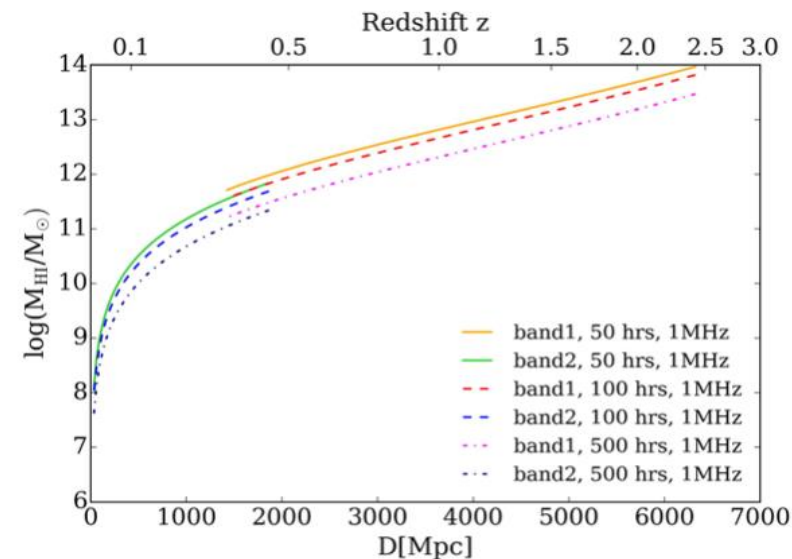
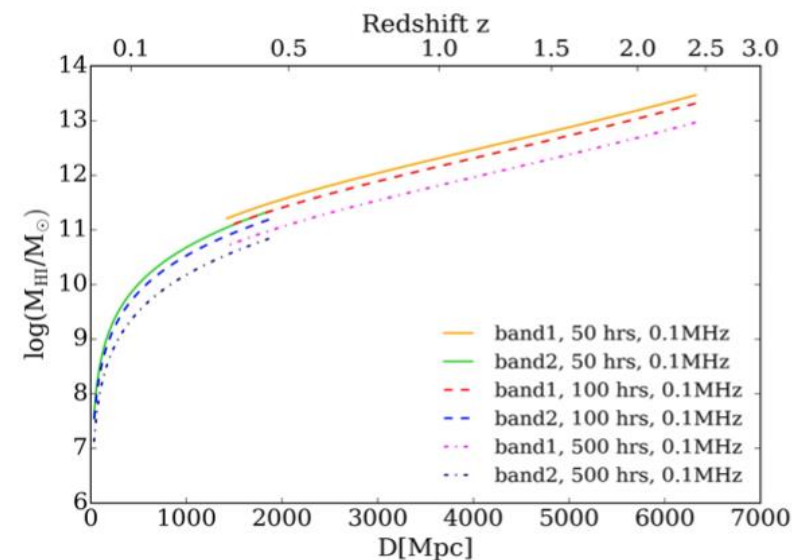


➤ HI ultra-deep survey

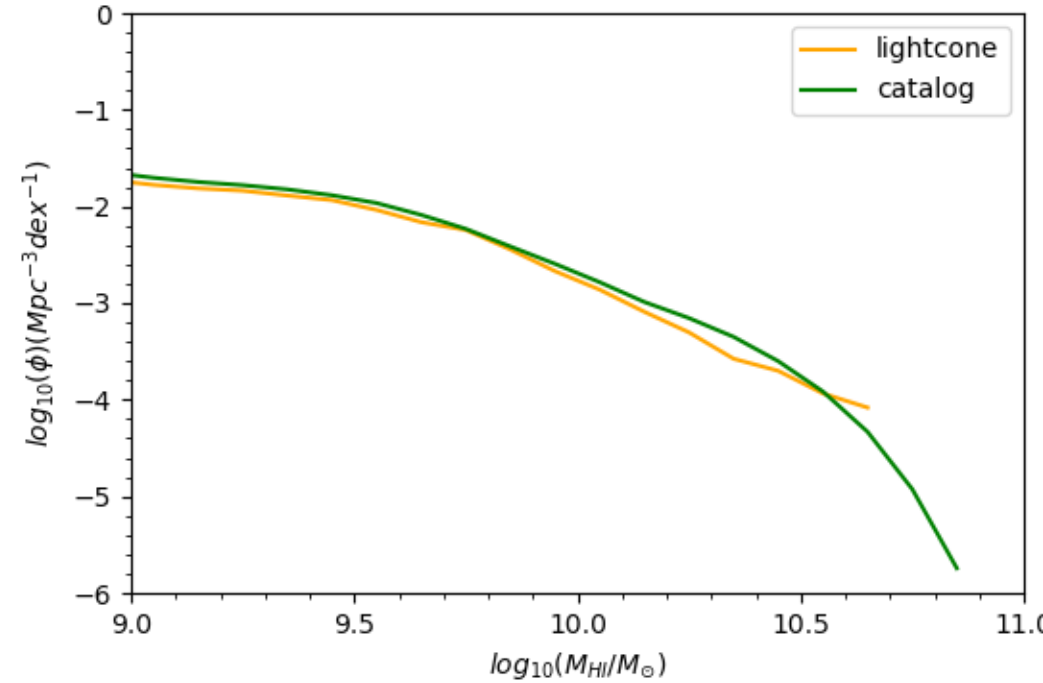
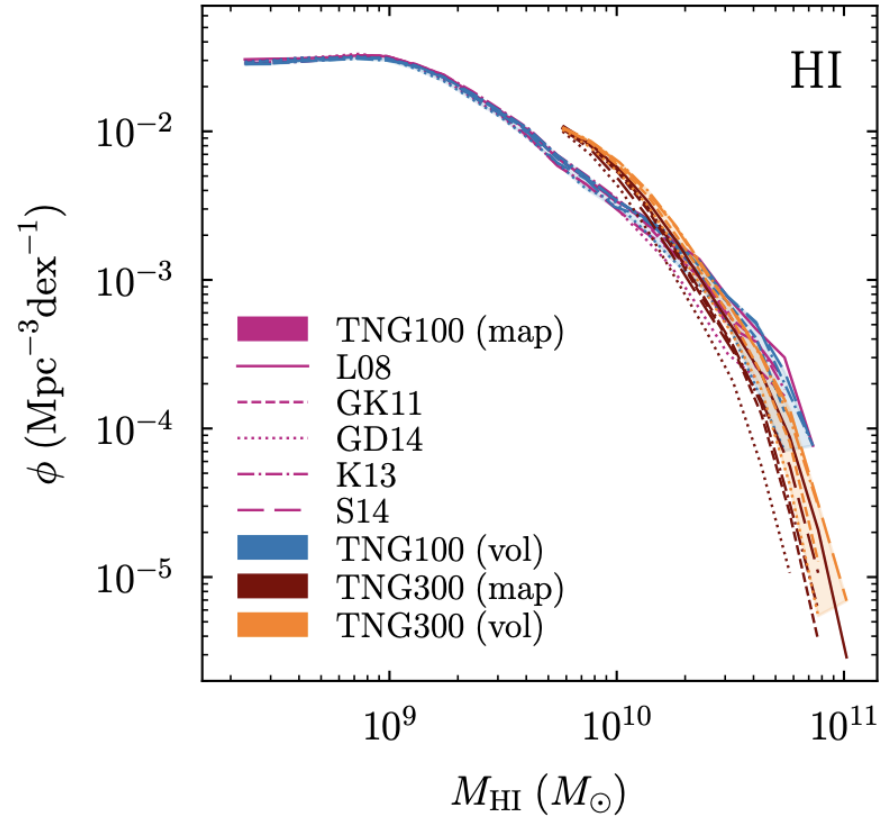
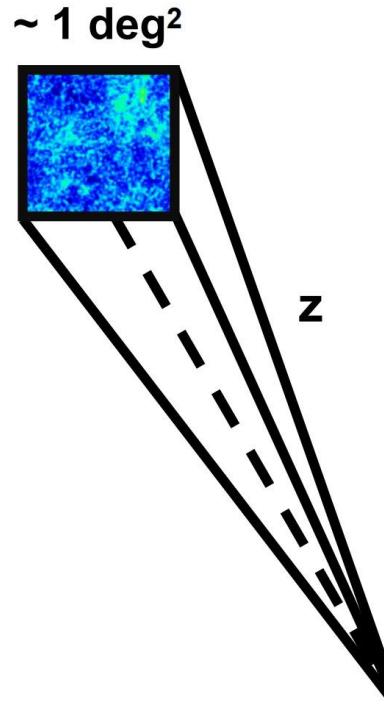
- 1 deg² region (100 hours)

Related sciences:

1. HI mass function at the low mass end, high redshift, 2d power-spectrum with the Interferometry
2. One-dimensional power spectrum of HI
3. Dependence of HI galaxy on the environments
4. Evolution of Ω_{HI} with redshift
5. Redshift distortion on the small-scale
6. Other sciences



Light-cone



TNG300, length $\sim 600 \text{ Mpc}$, the radius is 15 Mpc at $z=0.5$

Next step



- To add the systematical error to the light-cone
- To apply the observation time of MeerKAT in 2026
- For the CRAFTS survey in FAST, we will make sure the PS for the cross-correlation, even for the auto-correlation
- For the FATHOMER survey, we have obtained 60 hours for the observations this year.