

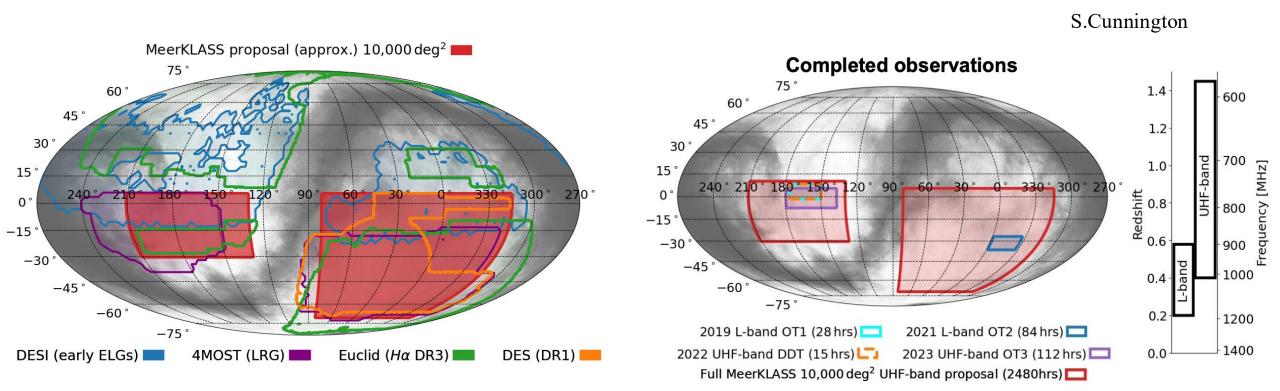
Medium-and ultra-deep HI surveys with SKA

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Sep. 30, 2025

MeerKLASS: MeerKAT Large Area Synoptic Survey

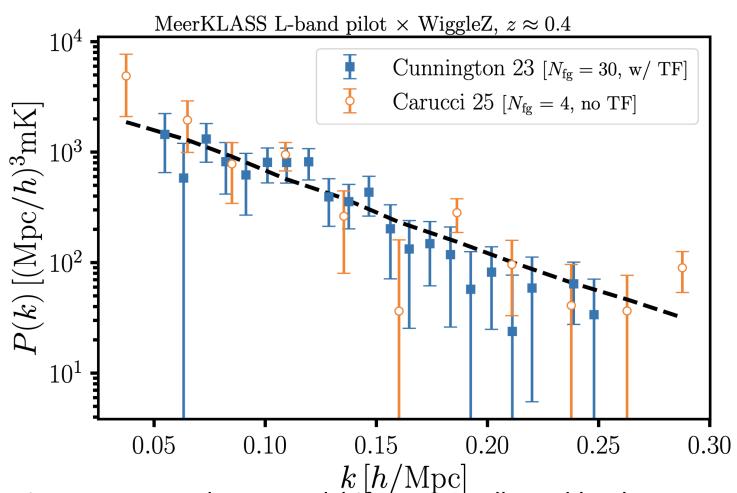
- ➤ Aim: Cosmology (HI intensity mapping) but commensal with lots of other science (continuum survey)
- \triangleright Covering L-band (900-1670MHz, z<0.57) and UHF band (580-1015MHz, z ~ 0.4-1.45)
- > Focus on sky patches with multi-wavelength data for cross-correlation
- ➤ Goal: 2,500 hours over 10,000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





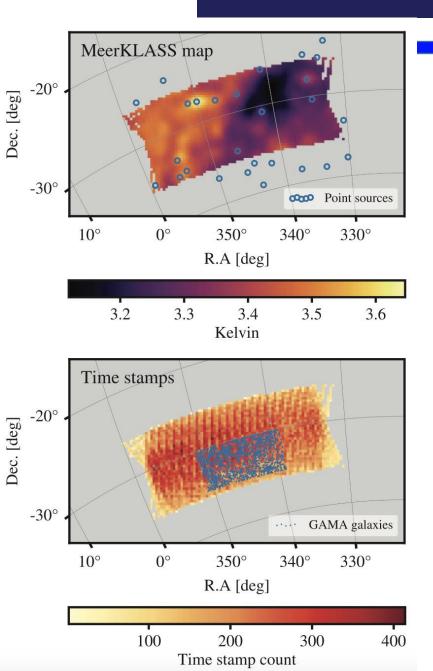
MeerKLASS studies

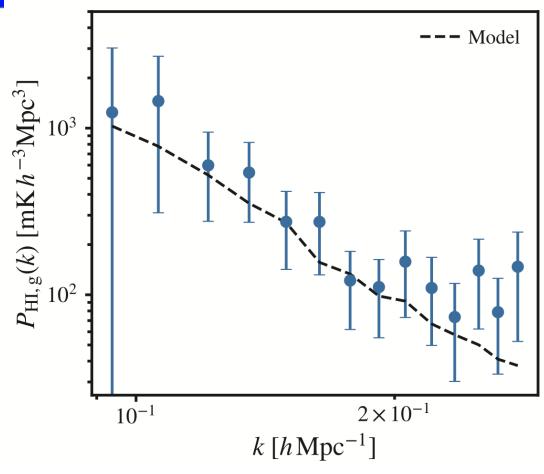




 $k \, [h/{\rm Mpc}]$ Carucci 25 100 deg2 at redshift $z\approx 0.4$ collected by the MeerKAT, with a combined 10.5-hour observation

MeerKLASS studies





MeerKLASS Collaboration 2025

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 < v < 1023 MHz)



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

4A2 2029	AA* 2031	Cycle 0 2032		Cycle 1 2033			Cycle 2 2034			Cycle 3 2035		
cience 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		4 subarrays		16 subarrays			Full drift scanning capabilities					
non-sidereal tracking		Drift scanning capped at a few mins			Drift scanning capped at a few mins		Wide area scanning					
Calibrated, averaged and gridded visibilities, image cubes	Full BW (up to 5 GHz) 8 hour max observations, up to	Limited support for PLDP generation tests Limited joint	eration tests processed independently (i.e no	Fast imaging Transient buffer triggered by fast	Source finding (& associated image cutouts)	Multiple pointings Autocorrelation processed processed data products	processed data	Fast imaging Improved source finding (& associated image cutouts)		processed data n	Improved PSS machine learning fo improved triggering	
(excluding SKA008) Full BW (800 MHz), FoV Single pointing	16 images (either in time i.e. 30min, or pointings)	deconvolution Limited support for	joint deconvolution) Use of SKA008 possible for appropriate projects	imaging (limited by buffer latency, perhaps less than 10 seconds)	Limited PLDP generation Joint deconvolution	joint deconvolution) Use of SKA008 possible for appropriate projects	Autocorrelation processed data products	imaging (limited by buffer latency, perhaps less than 10 seconds)	Full PLDP generation Joint deconvolution		Autocorrelation processed data products	Fast imaging Transient buffer
40 channel max 4h max observations	Zoom resolution (up to 0.21 kHz)	PLDP generation tests Limited joint deconvolution	50h max integration	Improved PSS machine learning for improved triggering	Source finding (& associated image	50h max integration	products	Improved PSS machine learning for	Improved source finding (& associated image cutouts)		products	triggered by fast imaging (limited by buffer latency, perhaps less than
Raw, calibrated, averaged and gridded visibilities, mage cubes	Continuum subtraction 4 hour max observations, up to 8 images (either in time i.e. 30min, or	Transient buffer - triggered by PSS observations	16k channel max Multiple pointings processed independently (i.e no joint deconvolution)	, 33 3	cutouts) 64k channel max Joint deconvolution Limited PLDP	16k channel max Multiple pointings processed independently		improved triggering	64k channel max Joint deconvolution Full PLDP generation			seconds)
excluding SKA008) Single pointing Full FoV, 4k channel	PSS 200 beams fully processed VLBI 4 beams PST 8 beams, full processing		Use of SKA008 possible for appropriate projects	5	generation Transient buffer -	Use of SKA008 possible for appropriate projects 12h max integration PSS full basic capability			Transient buffer triggered by PSS observations		Т	elescope mode
max output, up to full BW Early continuum subtraction			12h max integration PSS full basic capability		triggered by PSS observations							atory Data Products and their capabilitie
mplementation 4h max observations	,		VLBI full basic capability			VLBI full basic capability PST full 16 beam						Continuum
ST at least one eam, full processing			PST full 16 beam capability			capability						pectral Beamformed
PSS beams, fully rocessed VLBI beam											Т	ransient

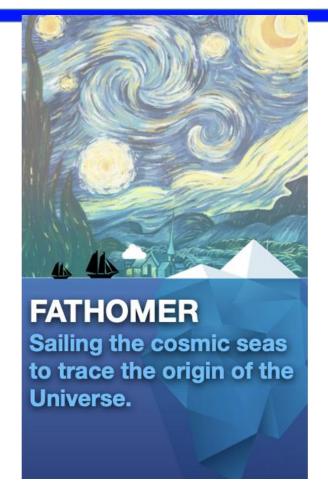
Ska-mid



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





Data preparation Main pipeline Raw FITS files Drift scan TOD Noise diode off Apply g_{ν} RFI flagging Maps calibrated TOD Feed01 Feed02 Feed19 RFI flagged Noise diode on Map-making RFI flagging HDF5 files 1050-1150 MHz Convert format 1150-1250 MHz Bandpass & 1250-1450 MHz temporal drift calibration Zero-centered Apply g_t Coordinate file **Calibration** Noise diode Baseline 3C286 TOD Flux calibration Calibrated TOD spectrum pipeline subtraction Frequency 1323.07 - 1399.87 MHz

FAst neuTral HydrOgen intensity Mapping ExpeRiment

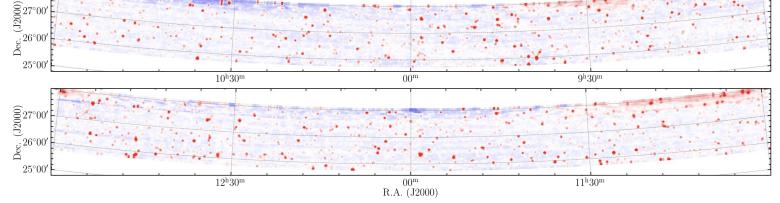
(FATHOMER 宇宙溯源人) Li Y.C., Wang Y.G. et al.

2023, ApJ, 954, 139. liyichao@mail.neu.edu.cn



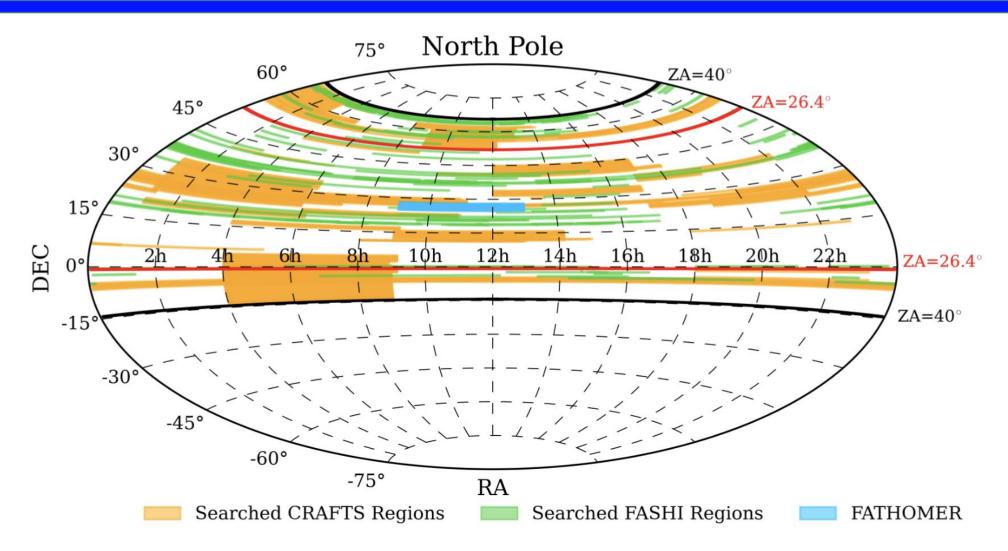




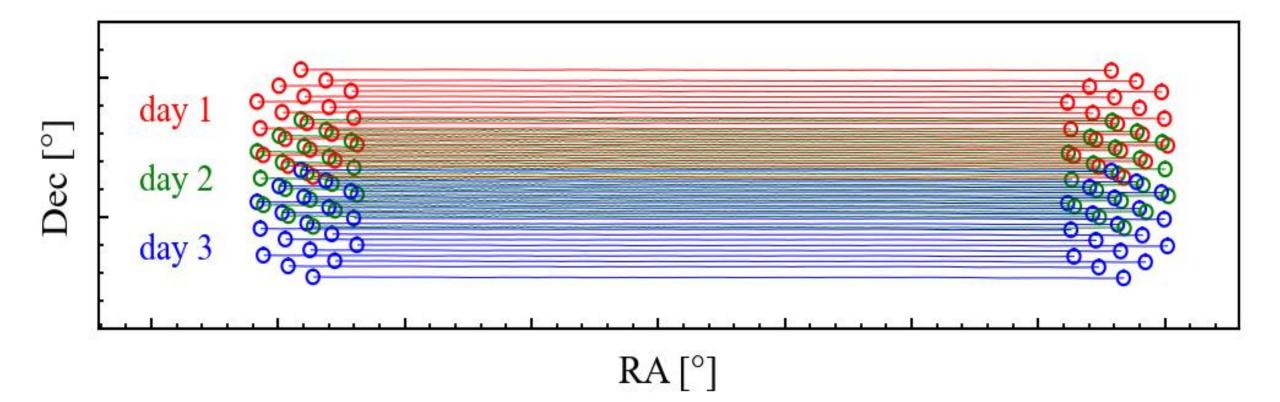


Li, Wang et al. 2023, ApJ, 954, 139







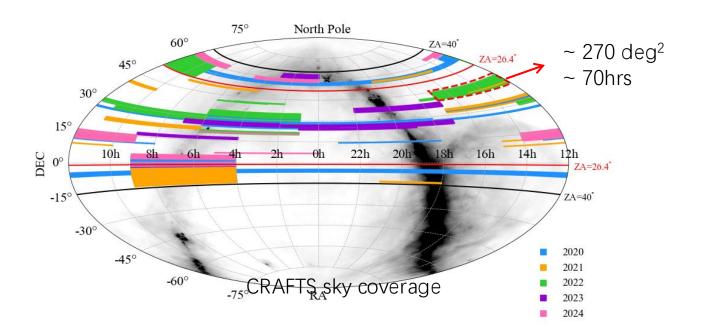


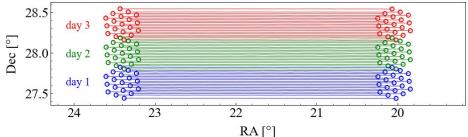
FAST large scale surveys

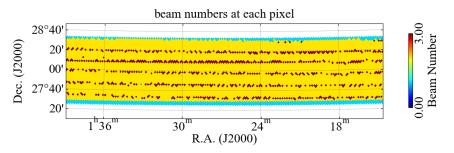




- CRAFTS (The Commensal Radio Astronomy FAST Survey)
- calibration mode: high-cadence noise(~ 1 K) injection mode: $T_{inj} \sim 196.608 \mu s$



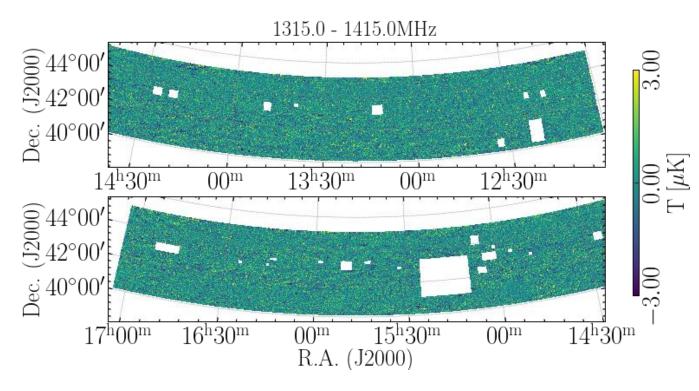




drift scan with L-band 19-beam receiver

power spectrum estimation





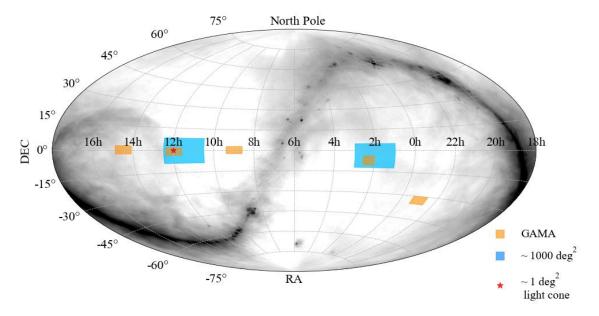
 10^{2} $\frac{1}{10^{2}}$ $\frac{1}{10^{2}}$

30 foreground modes removed map

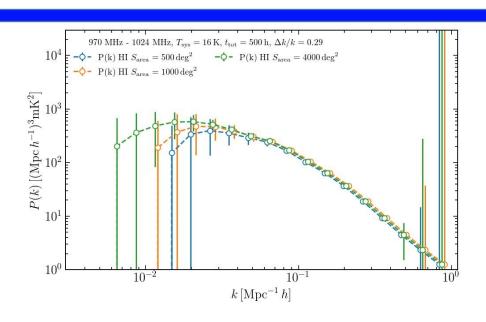
HI x SDSS power spectrum



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

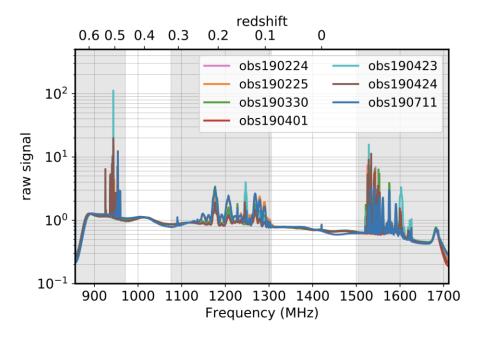


500hours, OTF

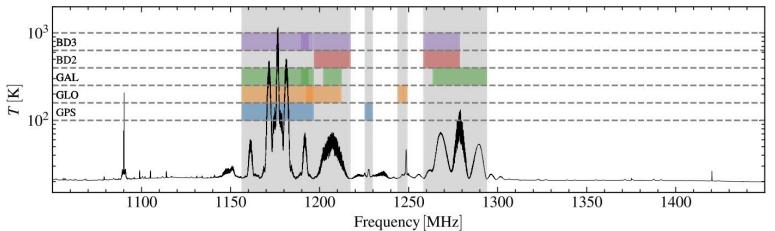


Telescope	Band	Frequency Range (MHz)	Available Bandwidth (MHz)	Notes (MHz)	
SKA1-Low	N/A	50 - 350	300	(1)	
SKA1-Mid	1	350 - 1050	700	(1)	
	2	950 - 1760	810	(1)	
	3	1650 - 3050	1400	(2)	
	4	2800 - 5180	2380	(2)	
	5a	4600 - 8500	3900	(1)	
	5b	8300 - 15400	2 x 2500	(1)	





Wang Jingying et al. 2021 MeerKAT



Li et al. 2023

FAST

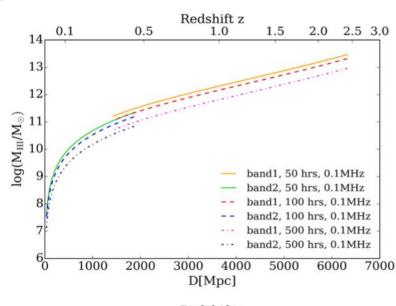


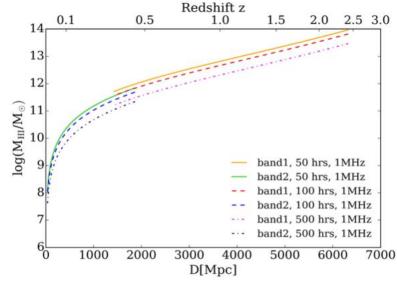


- > HI ultra-deep survey
- 1 deg² region (100 hours)

Related sciences:

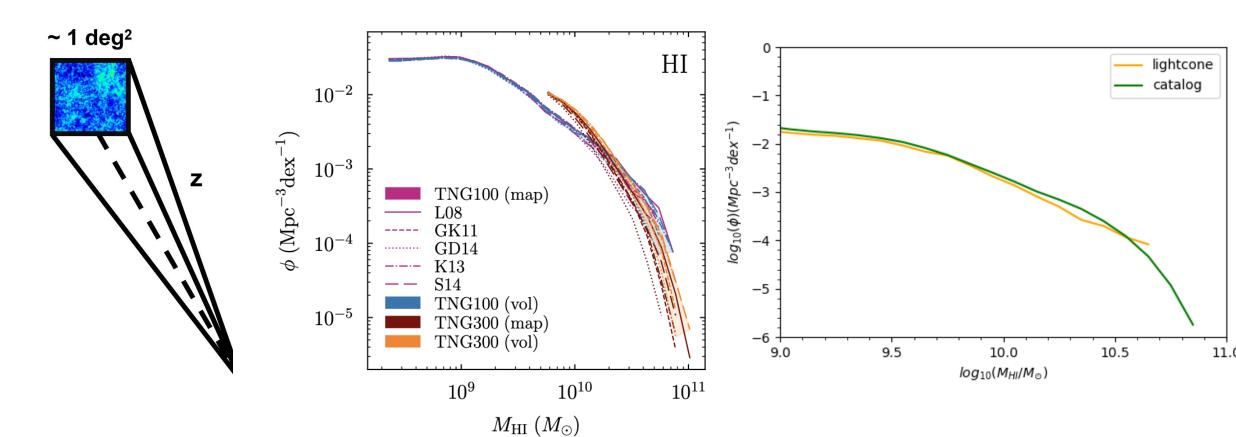
- 1. HI mass function at the low mass end, high redshift, 2d power-spectrum with the Interferometry
- 2. One-dimensional power spectrum of HI
- 3. Dependence of HI galaxy on the environments
- 4. Evolution of Ω_{HI} with redshift
- 5. Redshift distortion on the small-scale
- 6. Other sciences





Light-cone





TNG300, length ~ 600 Mpc, the radius is 15Mpc 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.