Cosmological detections from HI intensity mapping using the SKAO pathfinder MeerKAT

NOW ON arXiv: 2206.01579 !

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Cosmology from Home 2022

MeerKAT telescope Karoo Desert, South Africa

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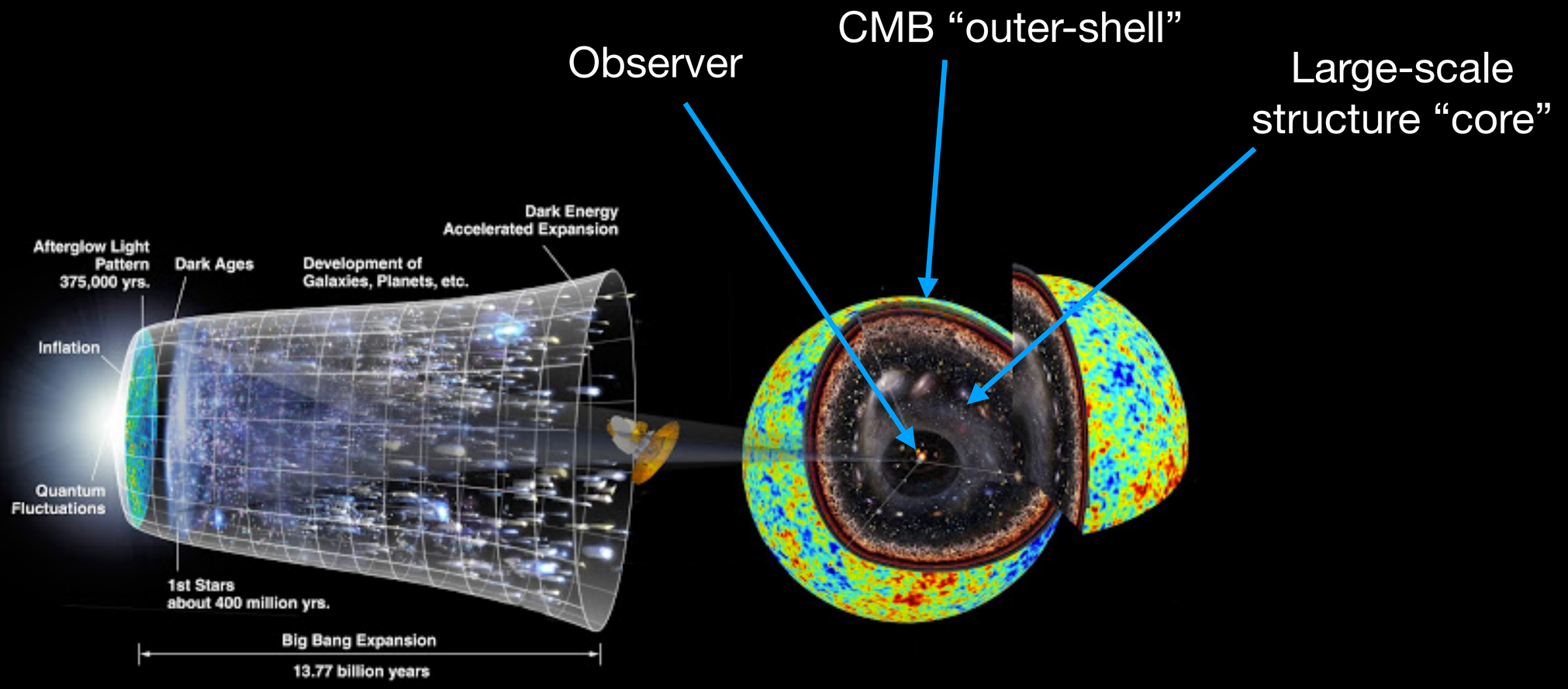
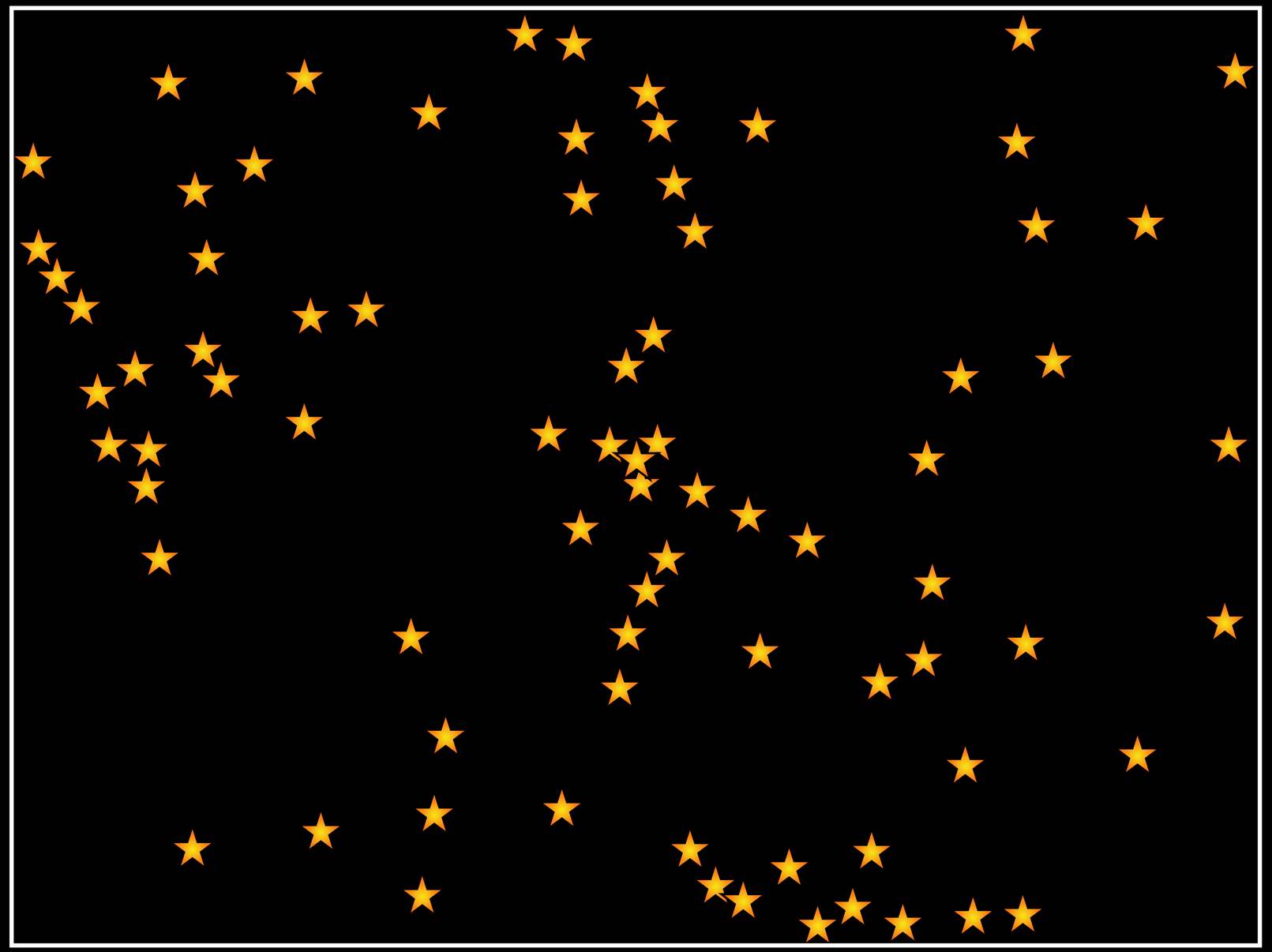
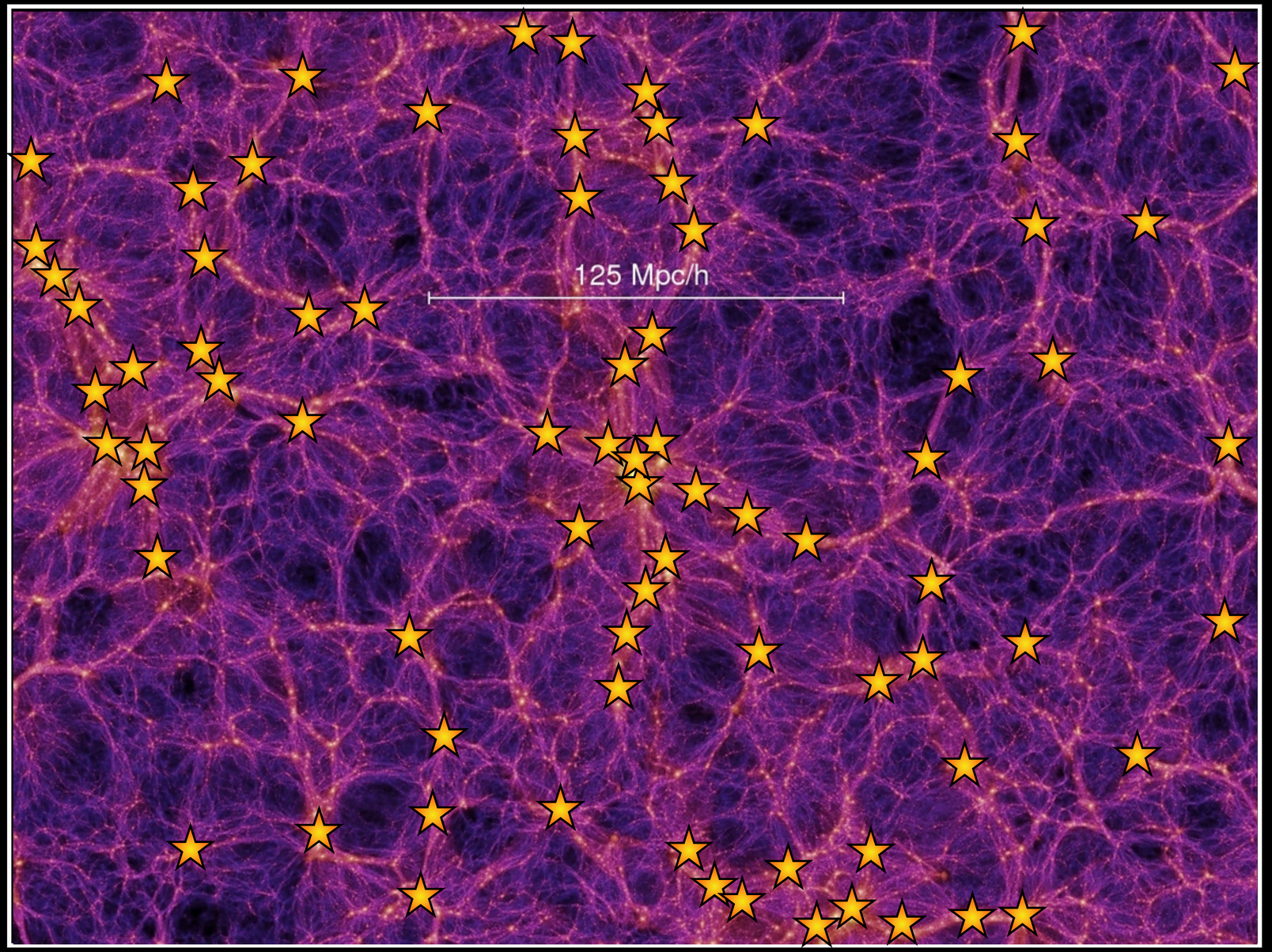
Why study large-scale cosmic structure?



Probing large-scale cosmic structure



Probing large-scale cosmic structure

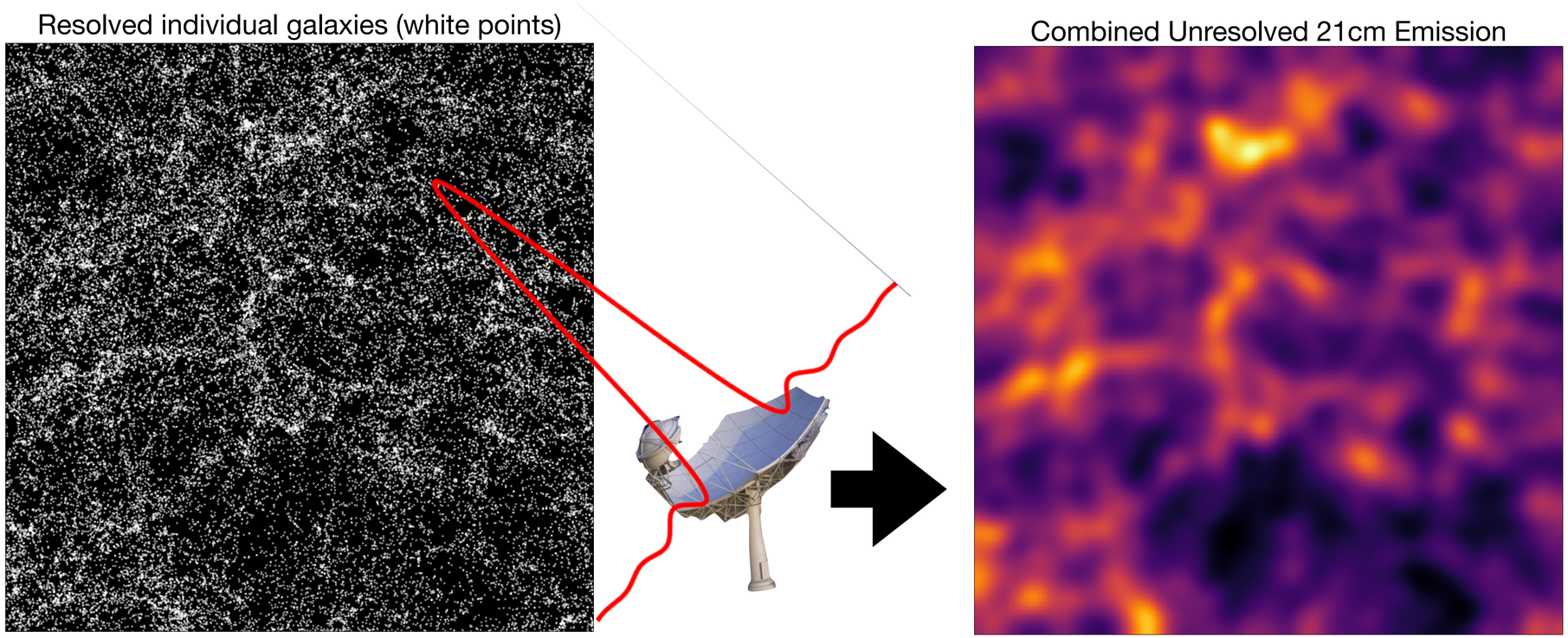


The Millennium
Simulation Project

Other ways to map large-scale structure?

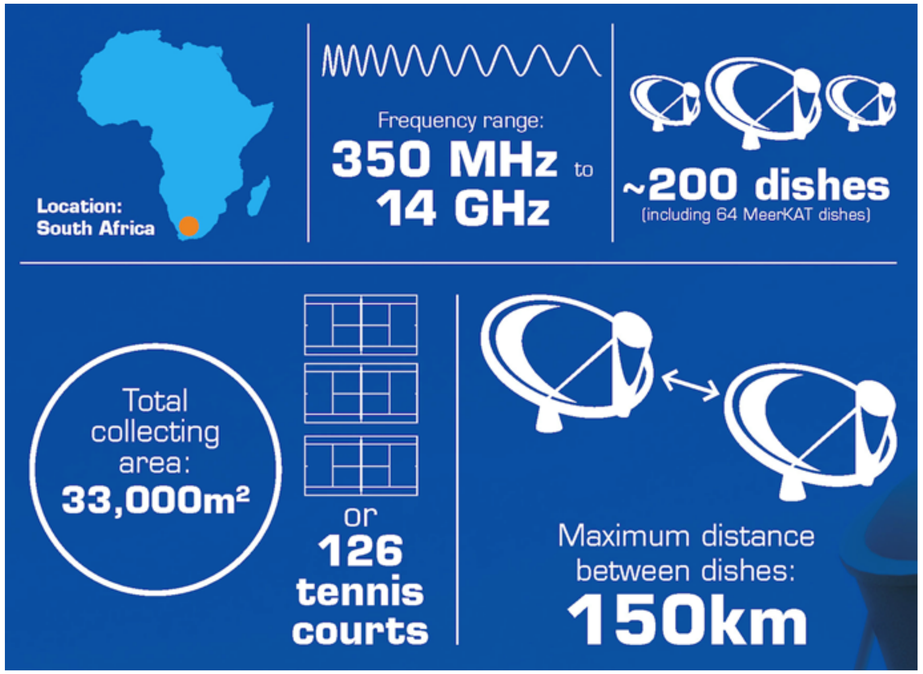
- Record the combined and unresolved emission from all sources?

This is known as … **intensity mapping**



“SKA Observatory”

SKA1 - MID (South Africa)

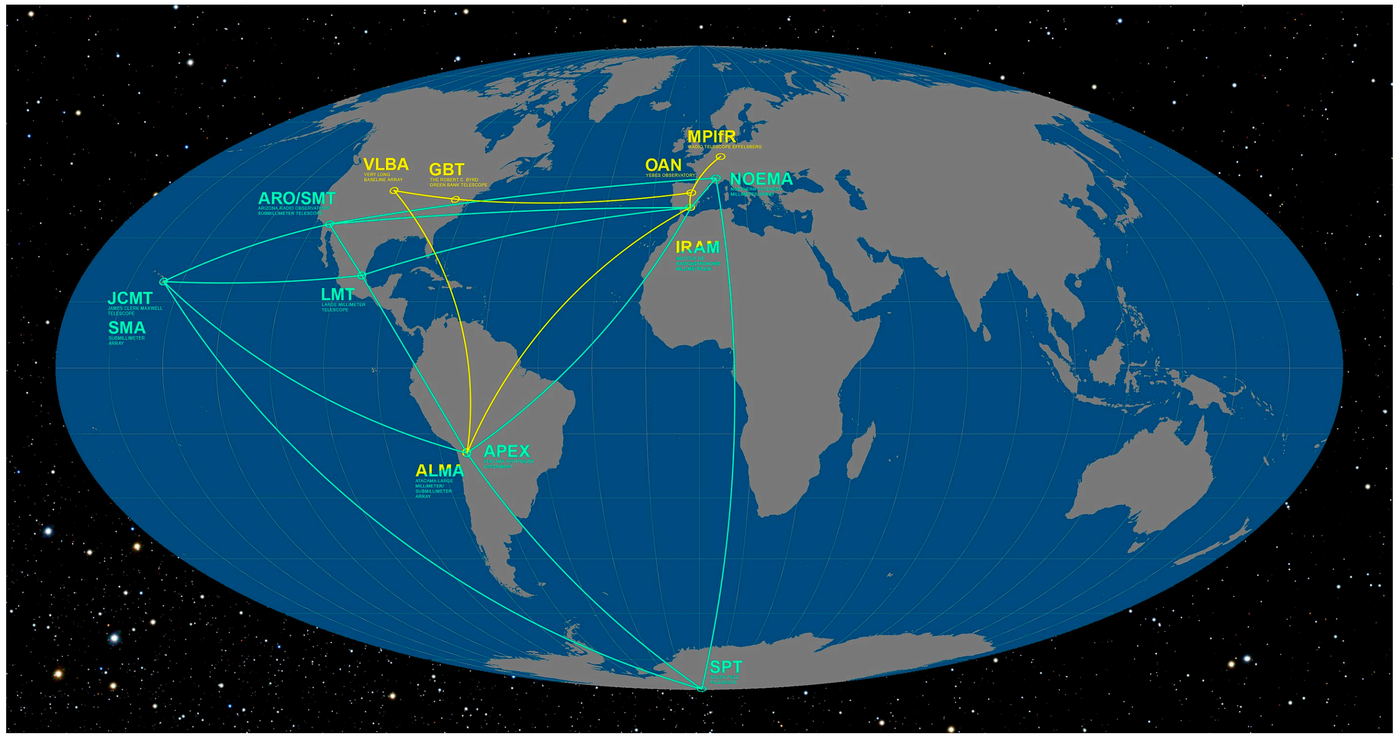


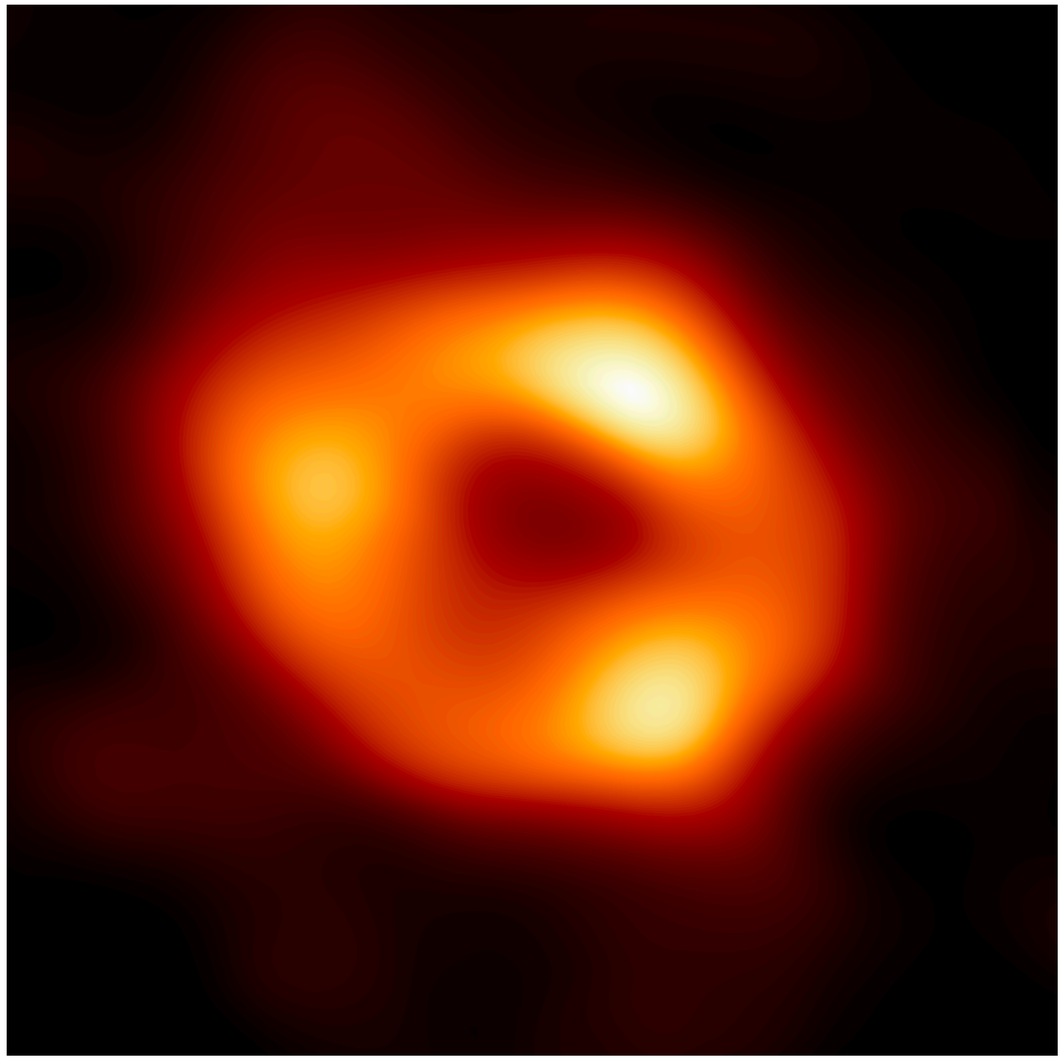
Redshift range: $0 < z < 3$

SKAO Pathfinder: MeerKAT

- 64 dishes
- Will become part of SKA-MID
- $0.2 < z < 0.58$ (L-band)
- $0.4 < z < 1.45$ (UHF-band)
- ~4000 sq.deg surveys

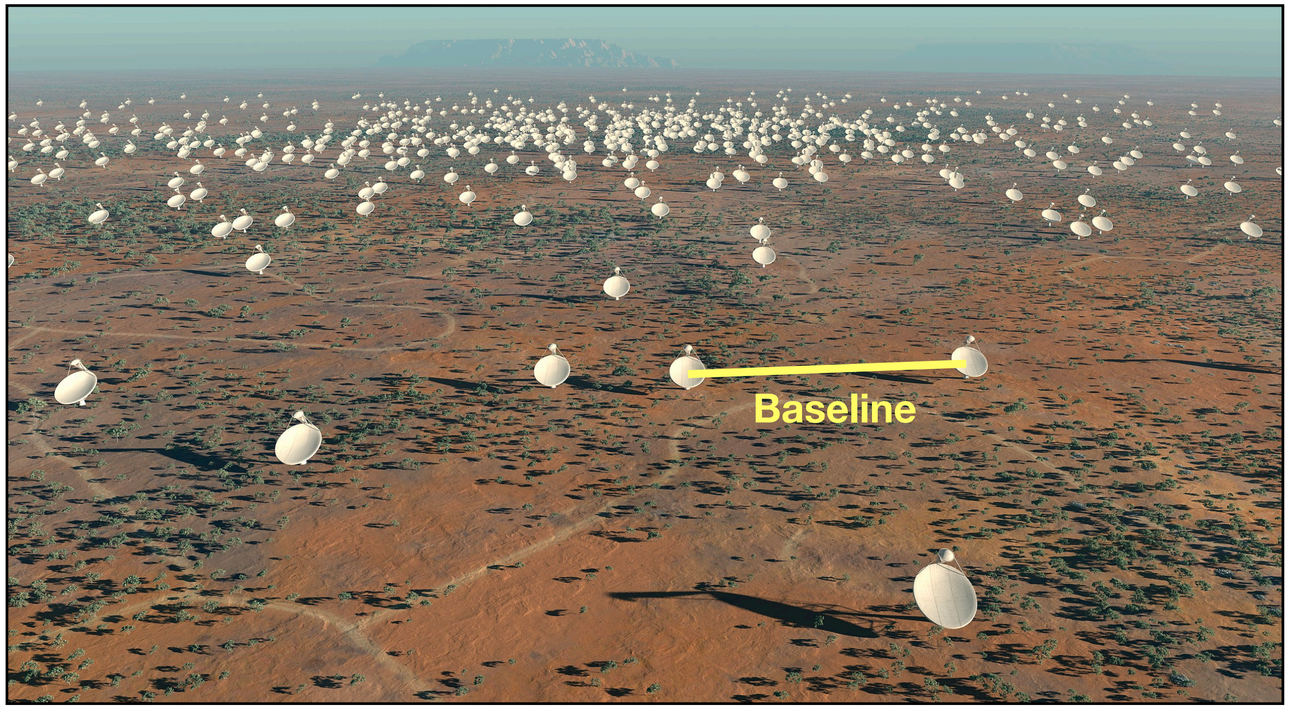
Interferometers: multiple-dish arrays acting as one telescope





Black hole imaged by the Event Horizon Telescope

Interferometer has limitations for large-scale cosmology



www.skatelescope.org/

Using SKAO as an **interferometer** means the largest scales we can probe are limited by how small the baselines are i.e. how *tightly-packed* the dishes are

Advantages achieved by using “single-dish mode”:

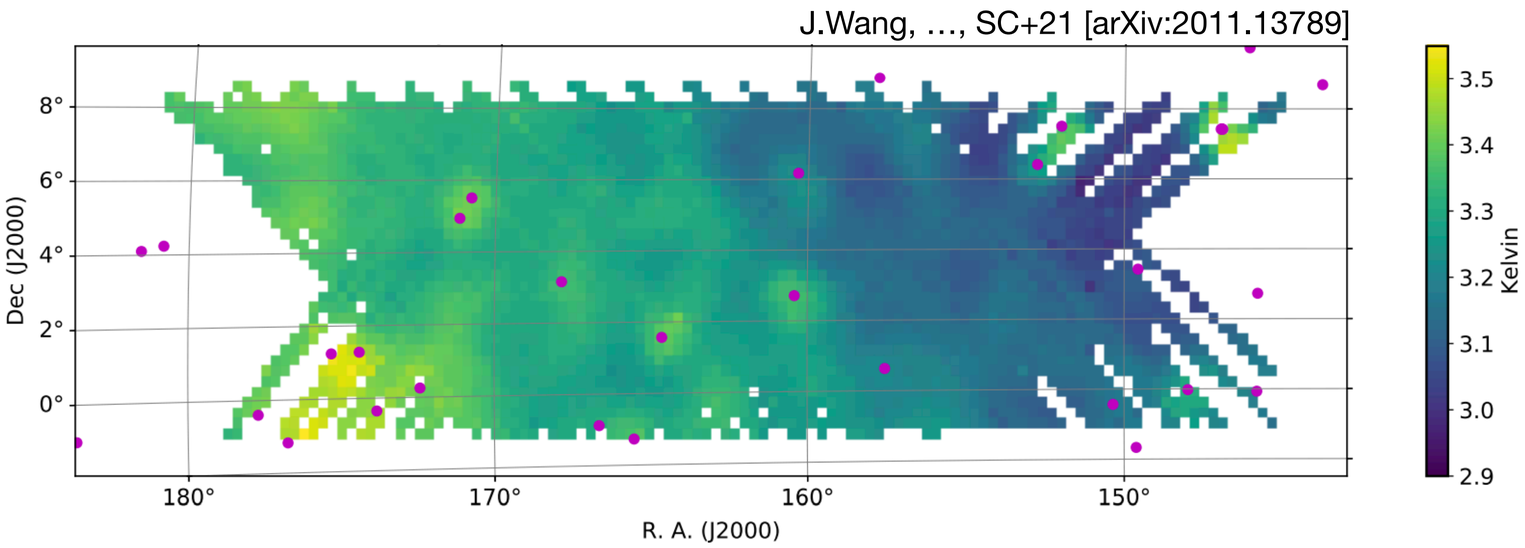
☑ Largest cosmological scales become accessible

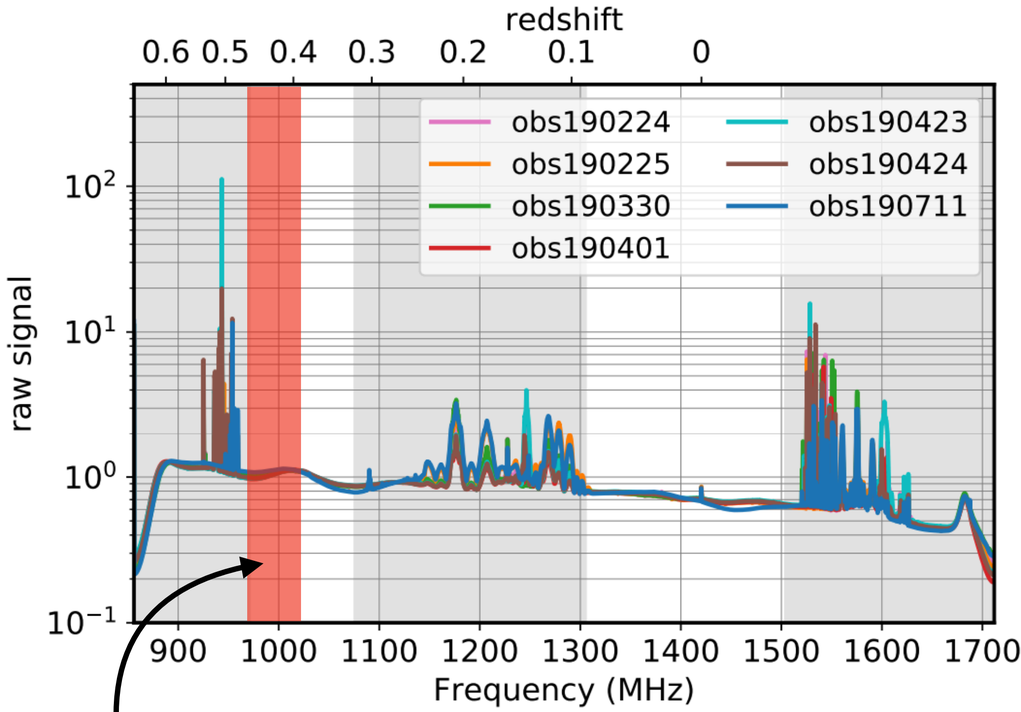
☑ Increases observation time by a factor of N_{dish}

Conducting single-dish intensity mapping observations with MeerKAT

Pilot survey data:

- 10.5 hours of data from six nights of observations
- Overlapping with the WiggleZ11hr field (~200 deg^2)



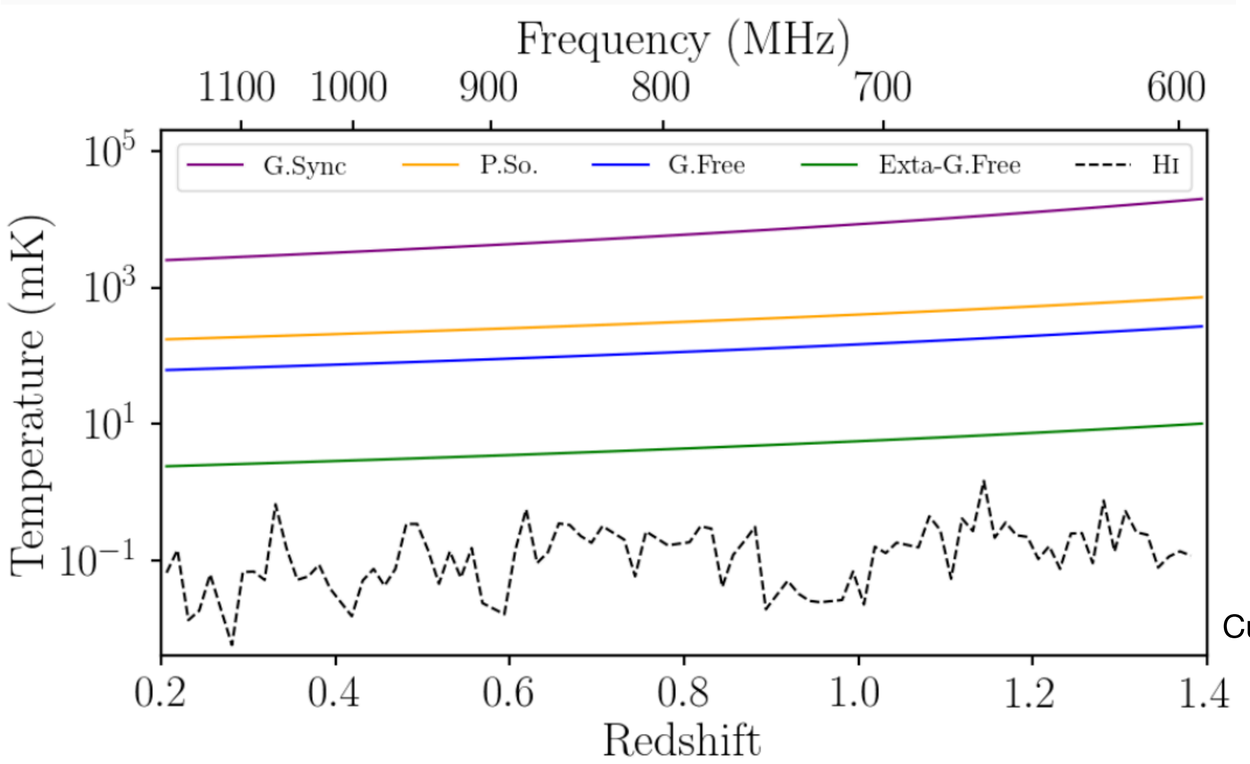


Channels used for analysis

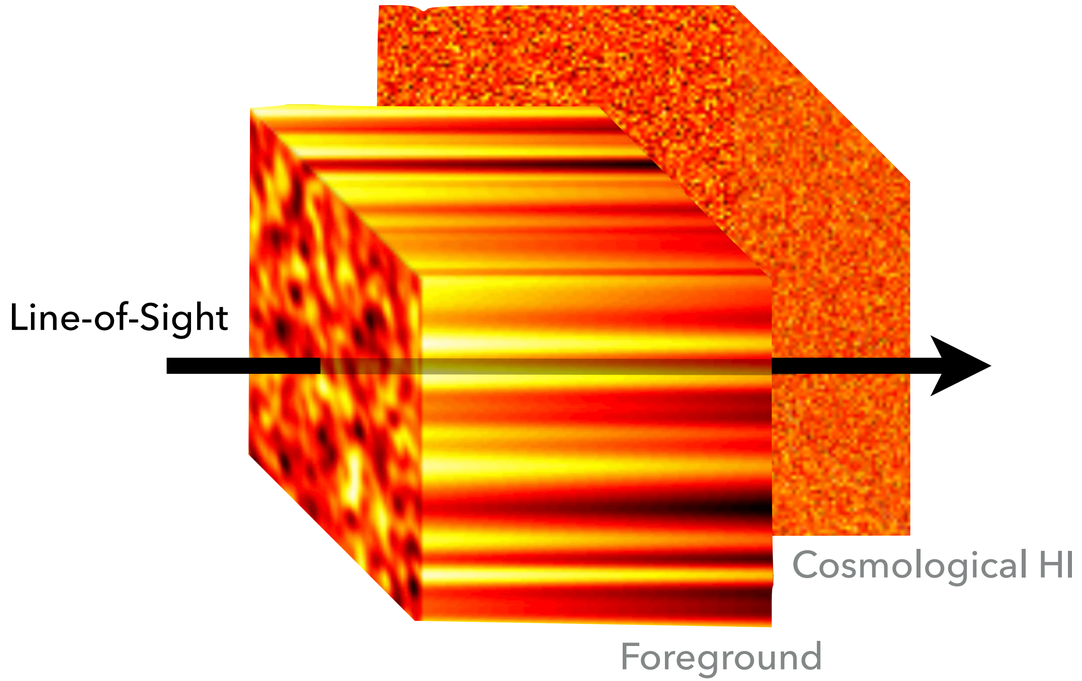
199 frequency channels at 973.2 – 1014.6 MHz.
- A further 32 within this range are also removed due to their dominant contributions

Foreground cleaning MeerKAT HI intensity maps

Idealised simulation demo:



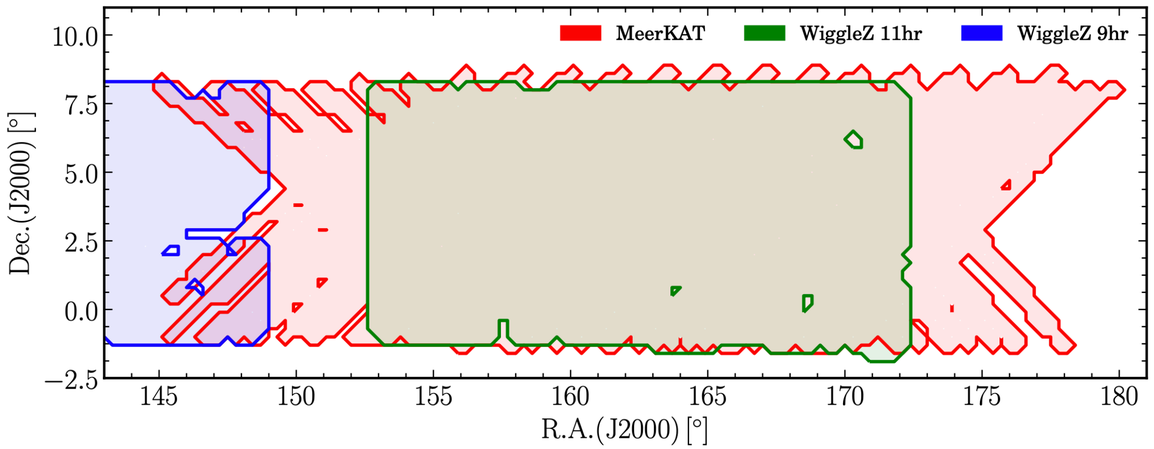
Cunnington+19 [arXiv:1904.01479]



- We utilise smooth foreground spectra to distinguish them from cosmological signal

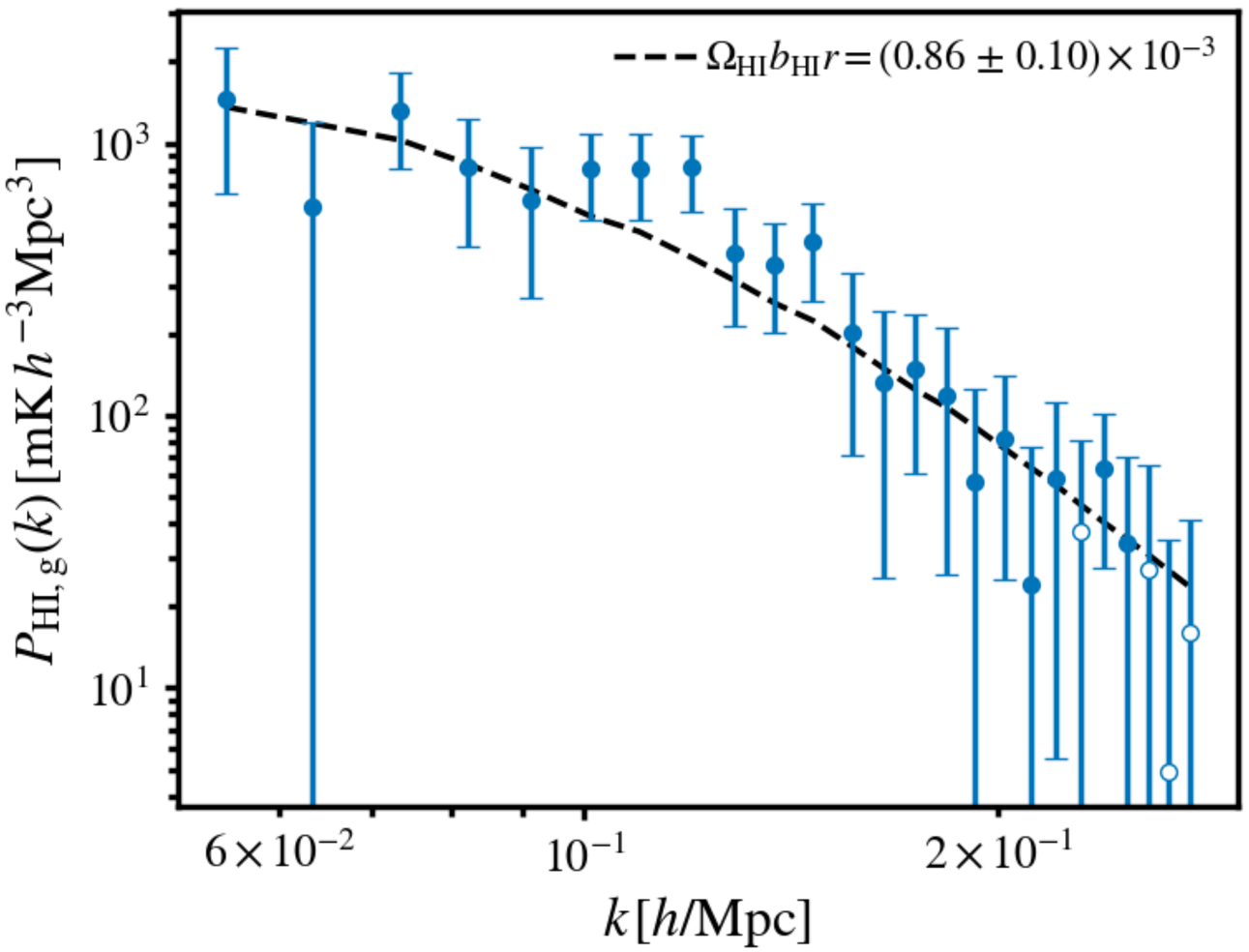
Cosmological detection with MeerKAT pilot intensity mapping survey in cross-correlation with WiggleZ galaxies

J.Wang, …, SC+21 [arXiv:2011.13789]

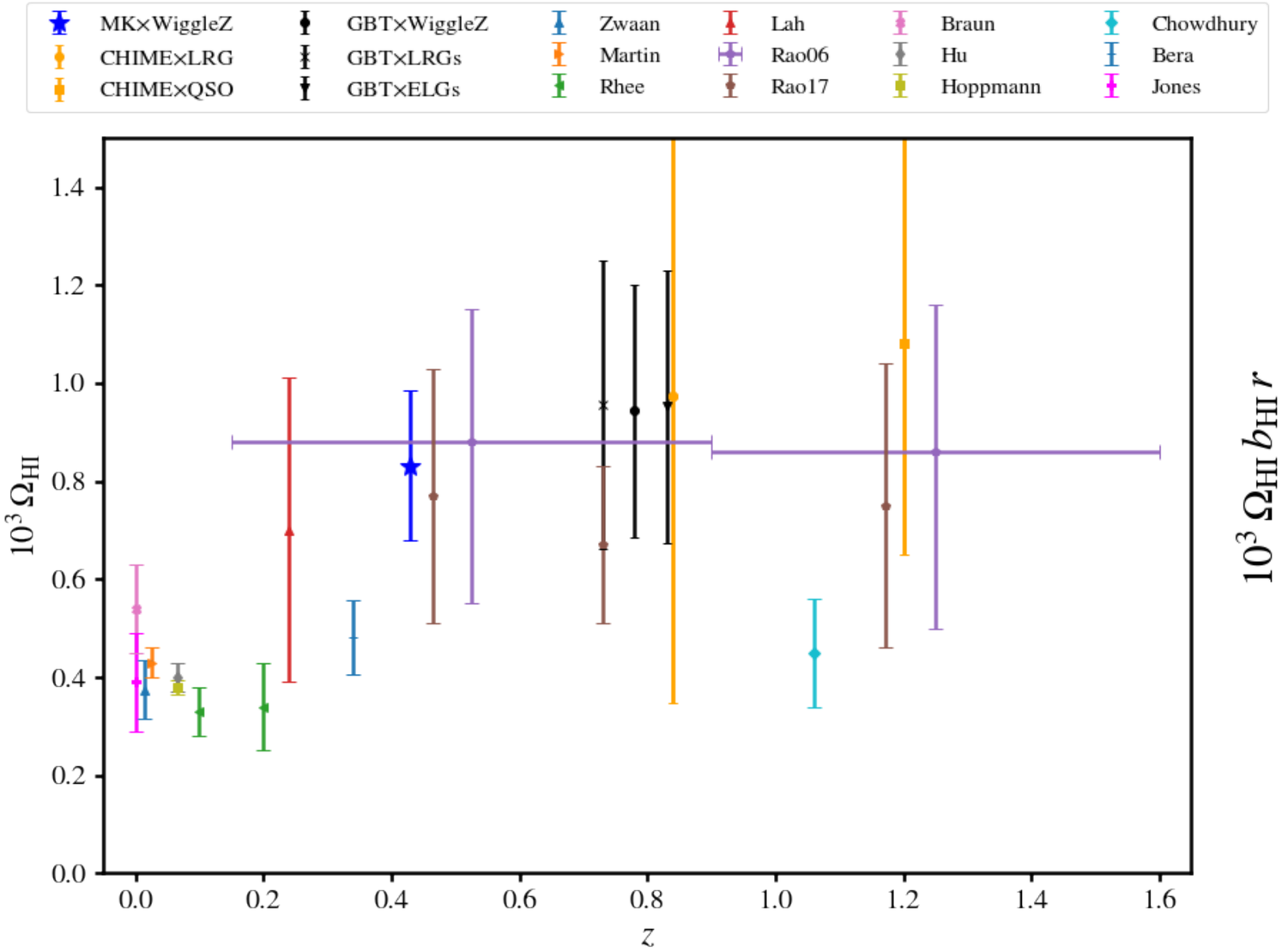


- Positive correlation (7.7σ) between galaxy survey and array of dishes in single-dish mode
- The first detection of its kind
- Important milestone for doing LSS cosmology with SKA intensity mapping

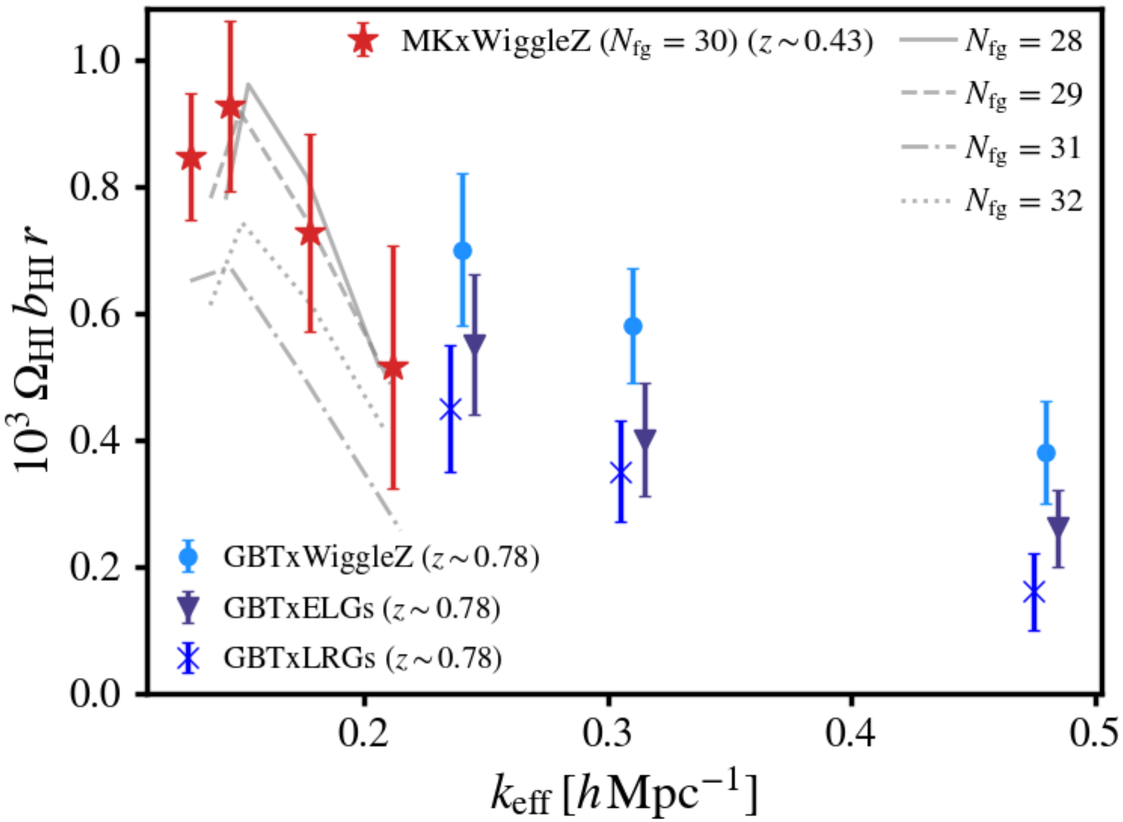
S.Cunnington+22 [arXiv:2206.01579]



Constraining the HI abundance



$$\Omega_{\rm HI} b_{\rm HI} r = [0.86 \pm 0.10\,({\rm stat}) \pm 0.12\,({\rm sys})] \times 10^{-3}$$



S.Cunnington+22 [arXiv:2206.01579]

What next for MeerKAT & SKAO intensity mapping?

Future observations

- ☑ Overlapping data with KiDS survey to explore HI IM x photo-z galaxies
- ☐ ~500 sq.deg field in MeerKAT's UHF band ($0.40 < z < 1.45$) to explore higher redshift probes (proposal submitted)
- ☐ ~4000 sq.deg survey is ultimate aim for MeerKLASS (MeerKAT Large Area Sky Survey)
  - ➡ L-band or UHF ?

Science goals

- ☑ Achieve detection with array in single-dish mode
- ☐ HI auto correlation
- ☐ Redshift-space distortions in HI - detecting a quadrupole
- ☐ Bispectrum? Could reveal systematics
- ☐ BAO in HI
- ☐ Detecting the power spectrum turnover
- ☐ Constraints on f_{NL}

In summary….

- HI intensity mapping will observe unprecedented volumes to probe large scale structure
- Identified as a key science goal for the SKA
- The SKAO's pathfinder MeerKAT is now conducting intensity mapping
- Detected a 7.7σ correlation with overlapping WiggleZ galaxies
- Larger survey data with MeerKAT is arriving fast - more science to done!

S.Cunnington+22 [arXiv:2206.01579]