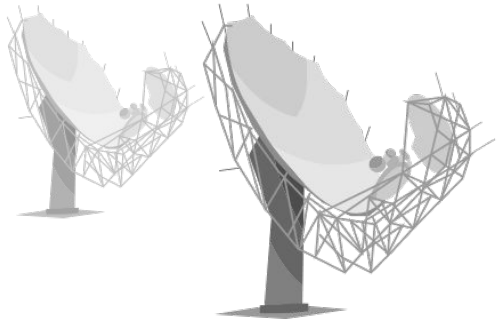
21cm Intensity Mapping: opportunities and challenges on the road to the SKA Observatory

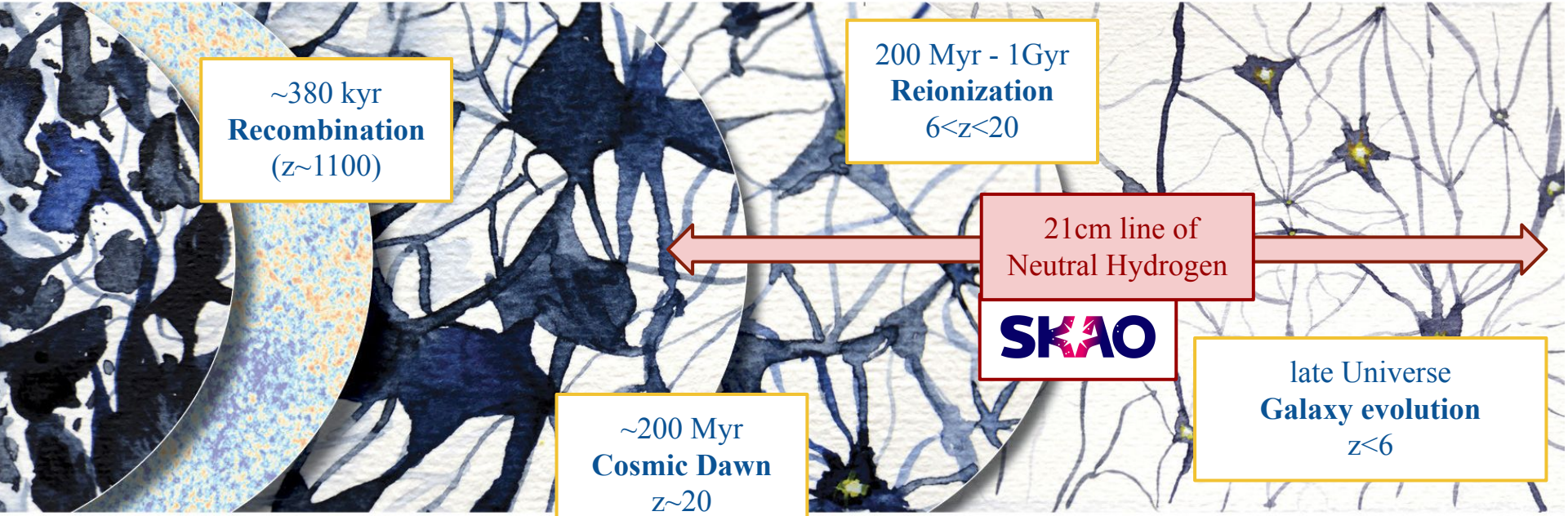


Marta Spinelli

ETH zürich

IPA

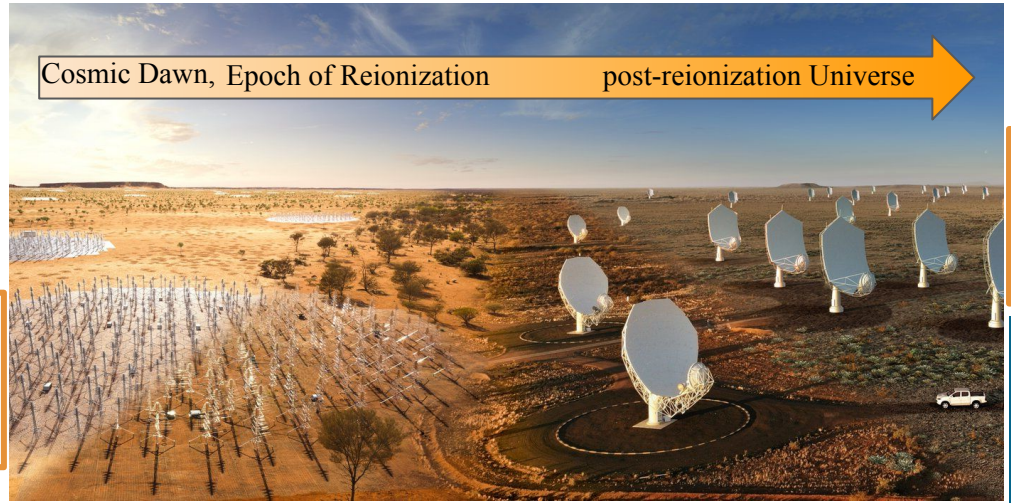
Hydrogen through cosmic time



credit: ESA

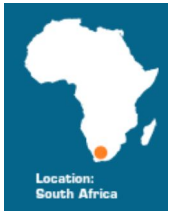
21cm Cosmology

- signal *redshifted* due to the expansion of the Universe to **Radio Frequencies**
- **SKA Observatory**: cover **all the relevant frequencies** with unprecedented sensitivity



SKA-LOW
50 MHz - 350 MHz
30>z>3

SKA-MID
350 MHz - 13.5 GHz
3>z>0



credit: skatelescope.org

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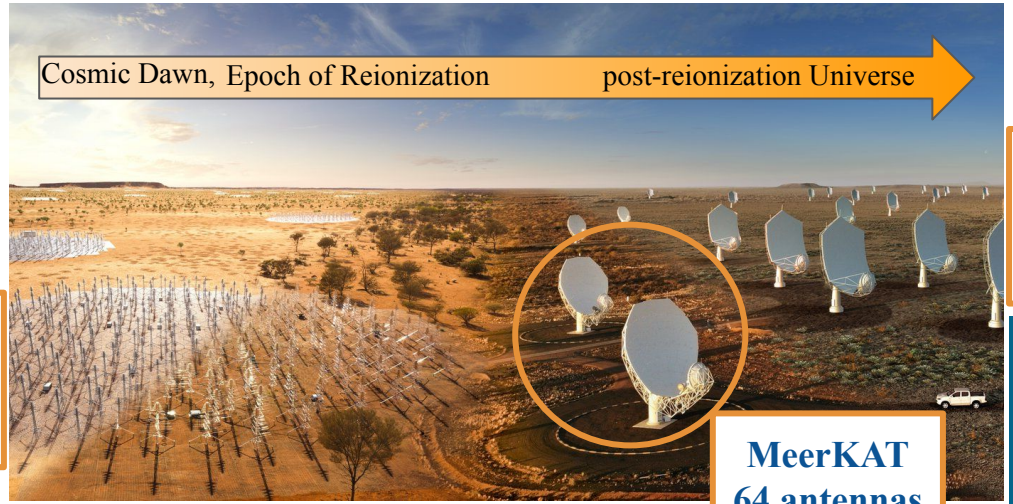

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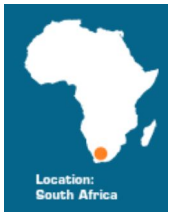

MeerKAT
64 antennas
1.5>z>0

Cosmology Science Working Group

chairs: S. Camera and **MS**

HI galaxies De Lucia	**Intensity Mapping** Wang, Wolz
Continuum Hale, Parkinson	**Weak lensing** Brown, Harrison

e.g. SKA Red Book (2020)

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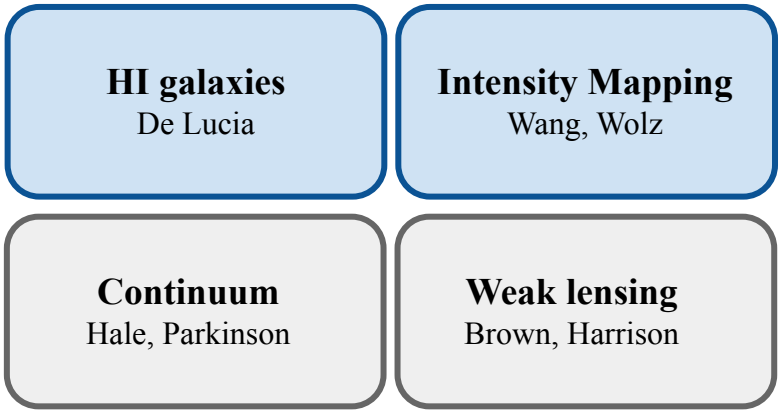

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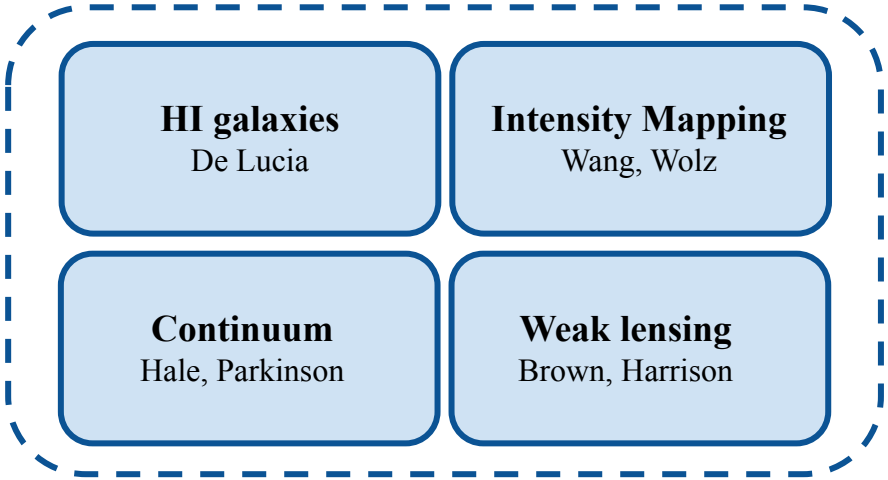

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Simulations Coordination
Carucci, Cunnington, MS

Sinergies
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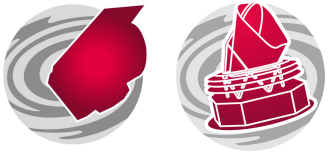

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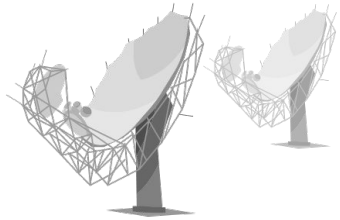

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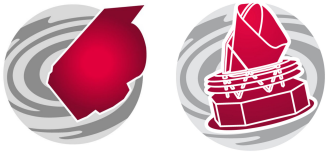
Precursor data
MeerKAT,
SuperCLASS (VLA)
ASKAP



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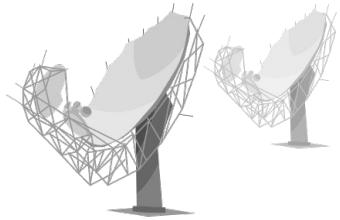

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Cosmology SWG annual meeting
Manchester,
17-19 Jan 2023

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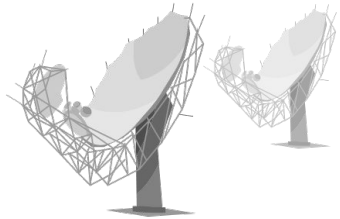

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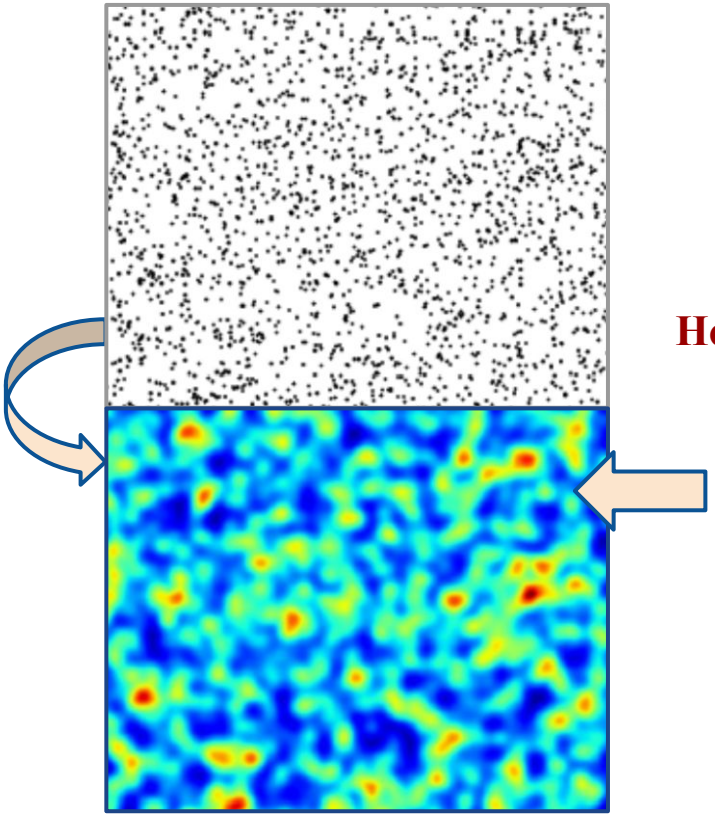
Intensity Mapping

credit: A. Pourtsidou



The distribution of **neutral Hydrogen** is a biased tracer of the **matter clustering** *similar to galaxy surveys*

In cosmology, **large scales** are fundamental

How can we efficiently observe cosmological volumes?

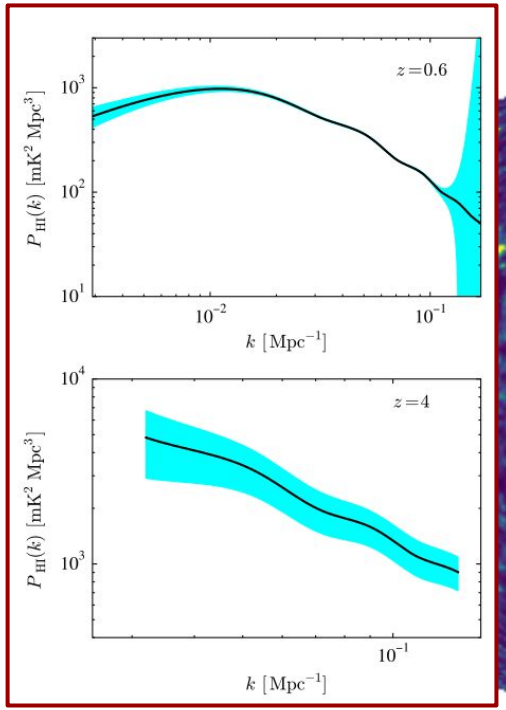
Intensity Mapping: total intensity of the 21cm emission line in a **large pixel** (low spatial resolution)

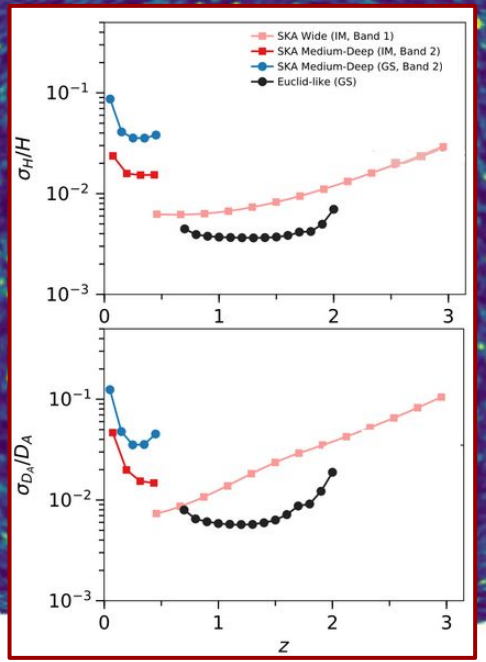
different frequencies, different z
high spectral resolution (tomography)

Key cosmological probe

Key cosmological probe

SKA Red Book (2020)





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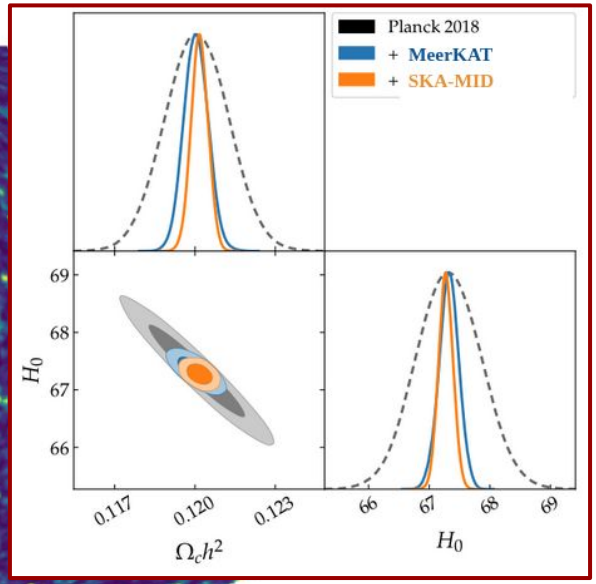
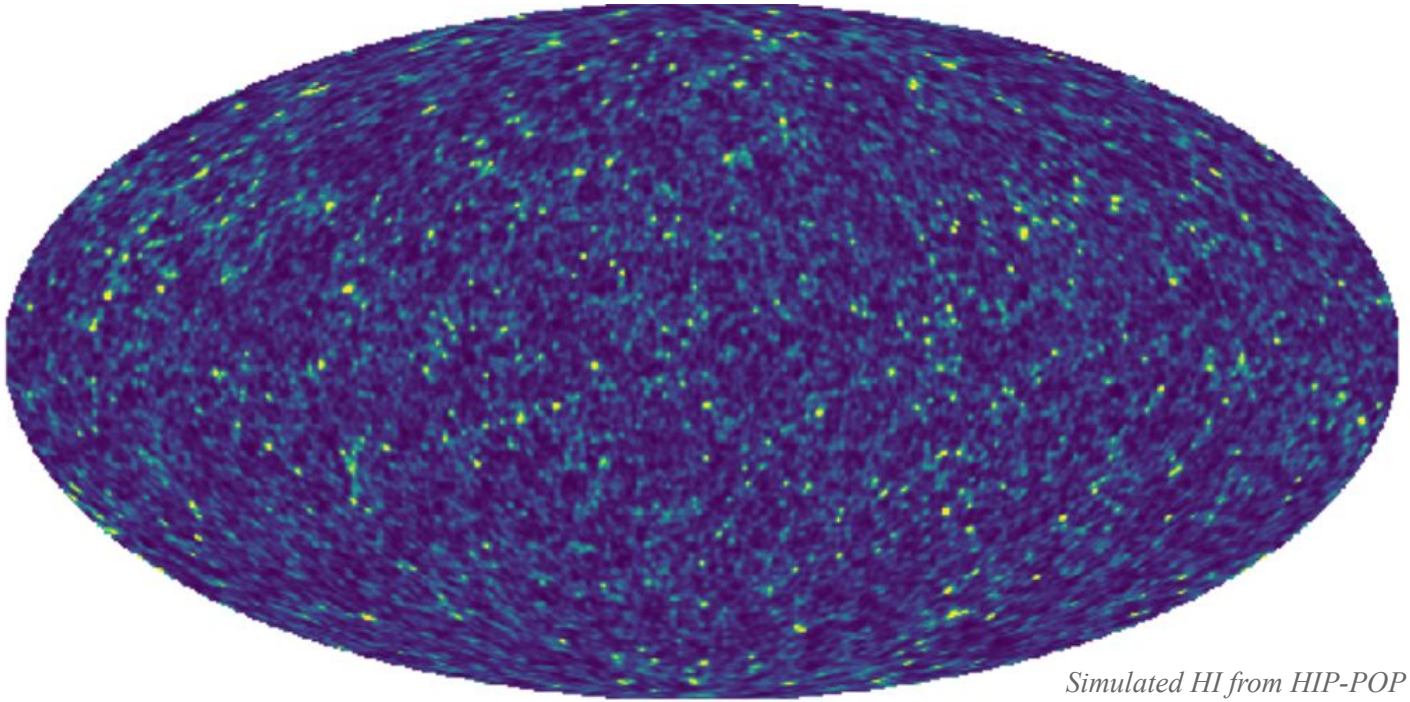


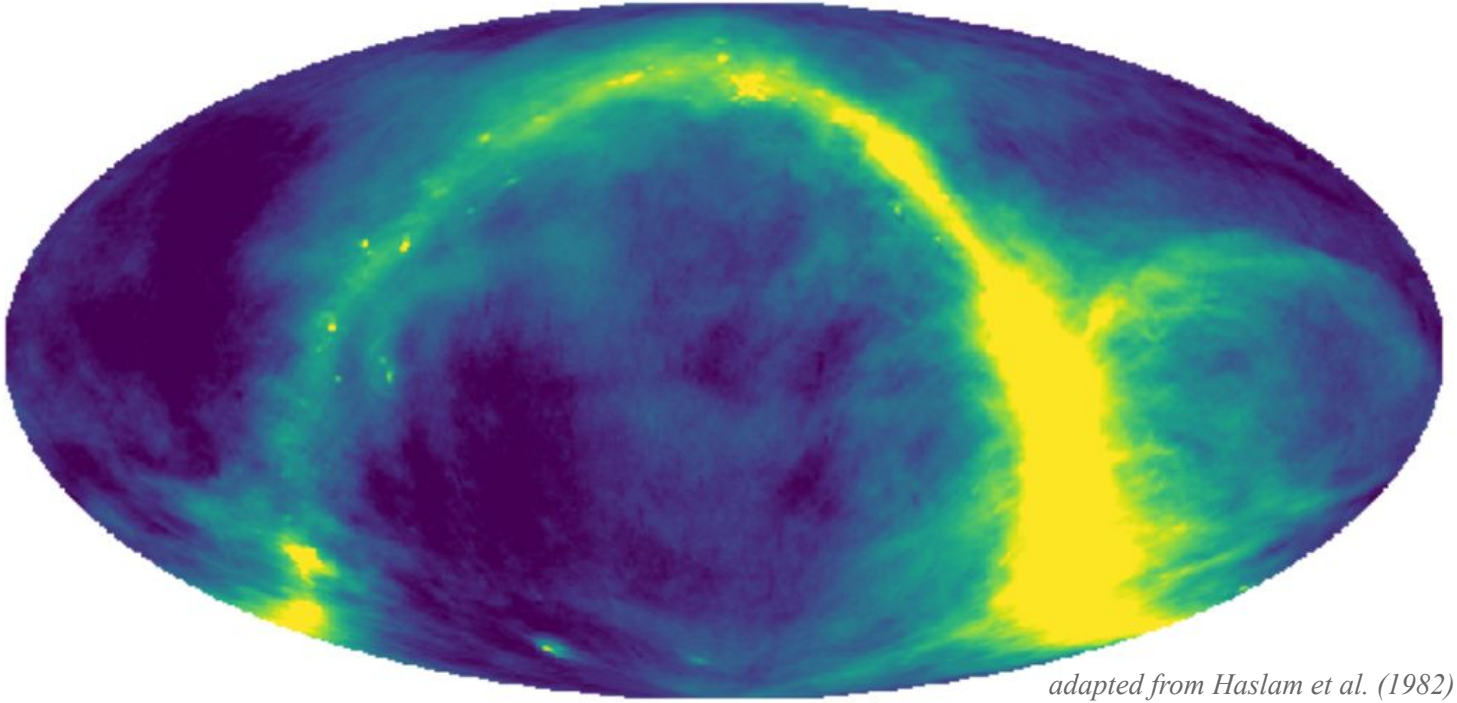
Berti et al. 2022

Key cosmological probe



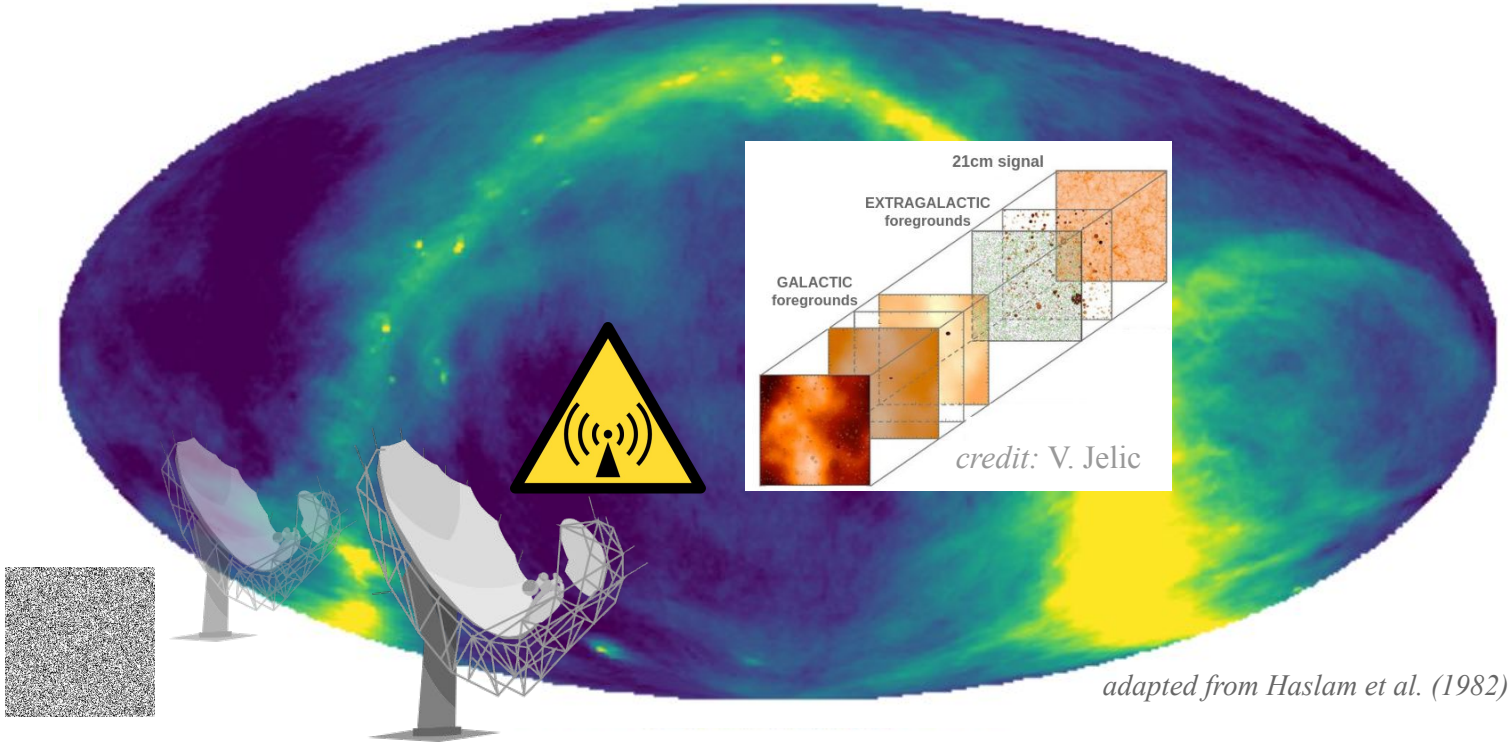
Simulated HI from HIP-POP
MS et al. 2022

The challenge of foregrounds



adapted from Haslam et al. (1982)

The challenge of foregrounds



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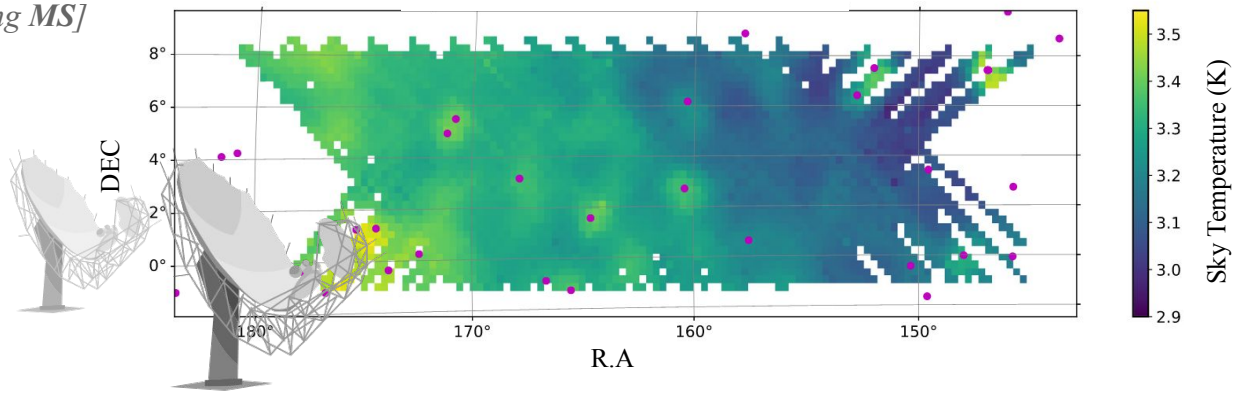
MeerKAT observations

*Wang et al. 2021 [including **MS**]*

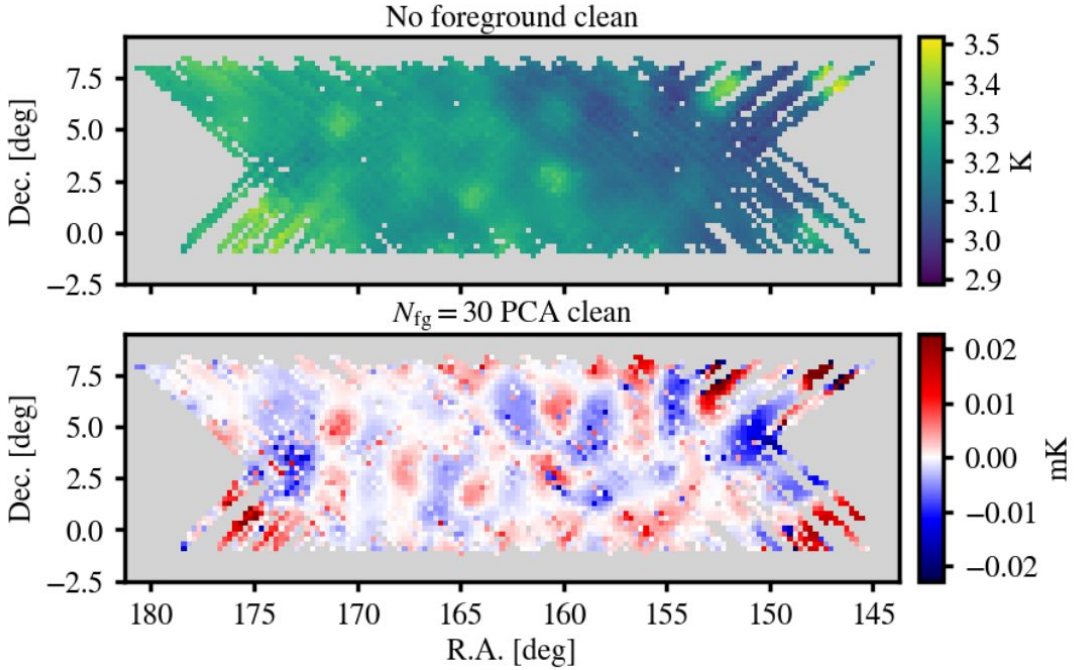


MeerKLASS: 64 MeerKAT antennas used in **single-dish mode**

- PI: Mario Santos (UWC) *Santos et al. 2015,2017*
- first successful calibration of **intensity mapping data from MeerKAT**
- 10.5 hour of data (1.5h x 7 scans) after RFI flaggling
- L-band: 850-1700 MHz (4096 channels) but using only 199 around ~1 GHz

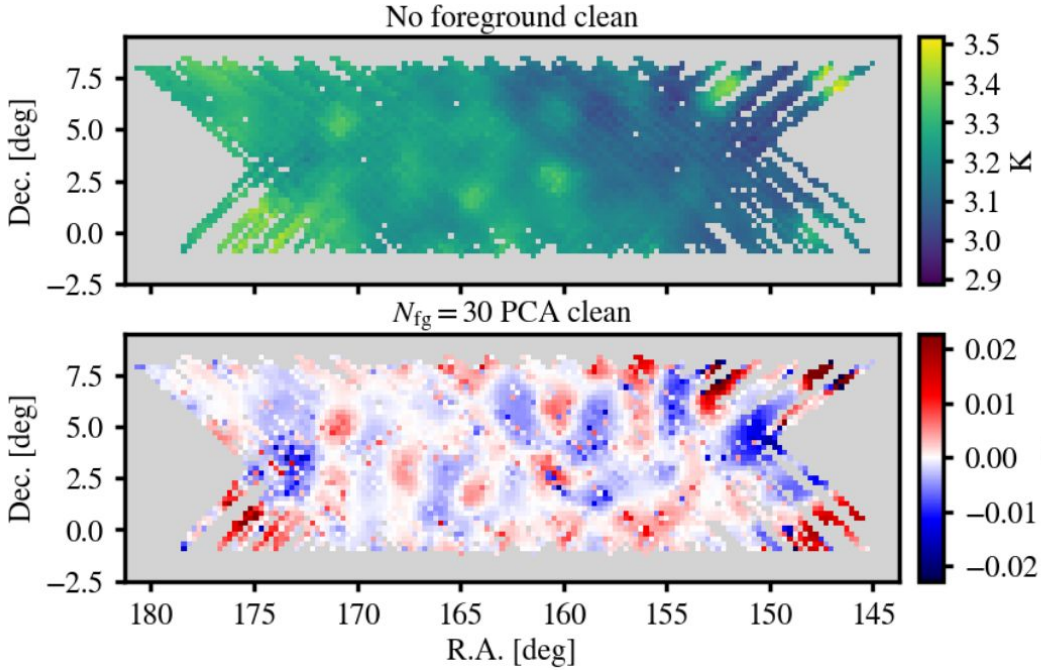
- new L band data under analysis (41 x 1.5 h)
- UHF band available (could go to higher redshift)
- improving RFI flagging and calibration

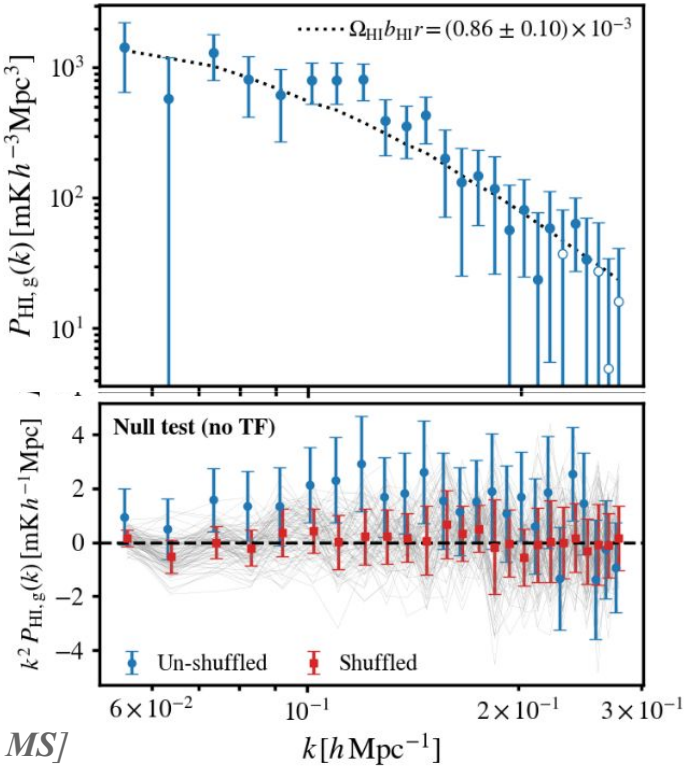
MeerKLASS results



*Cunnington et al. 2022 [including **MS**]*

MeerKLASS results





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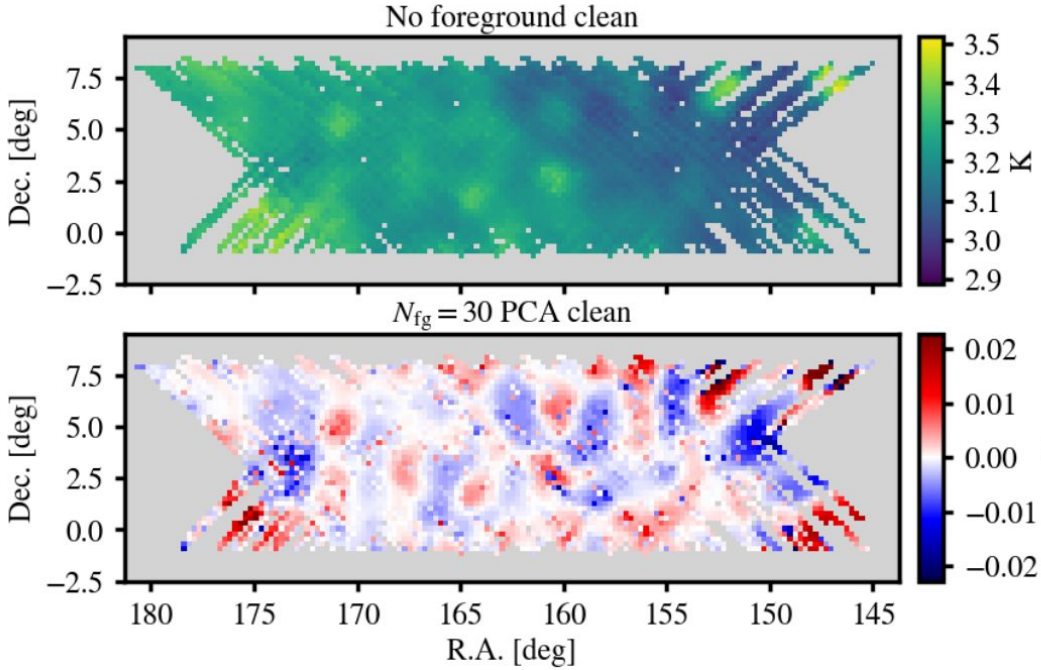
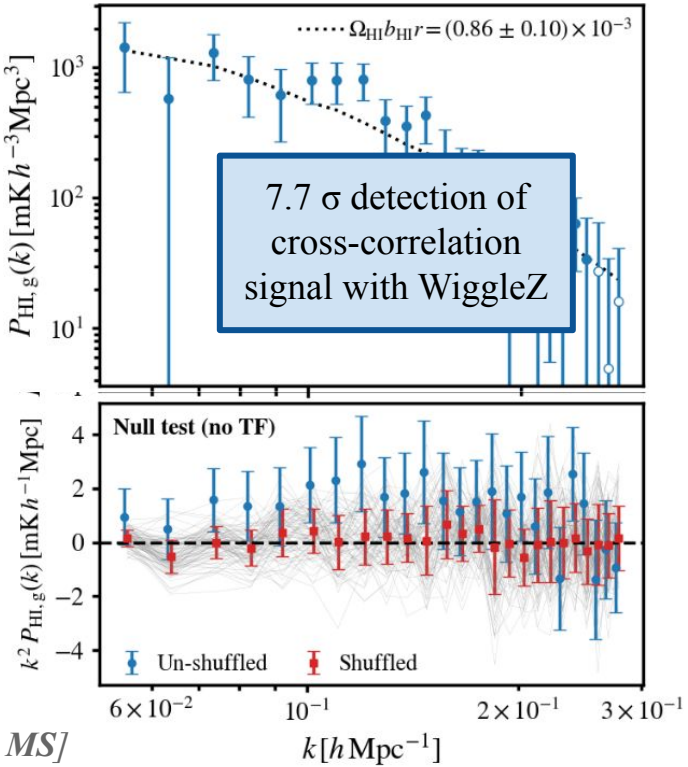




*Cunnington et al. 2022 [including **MS**]*

Foreground subtraction challenge

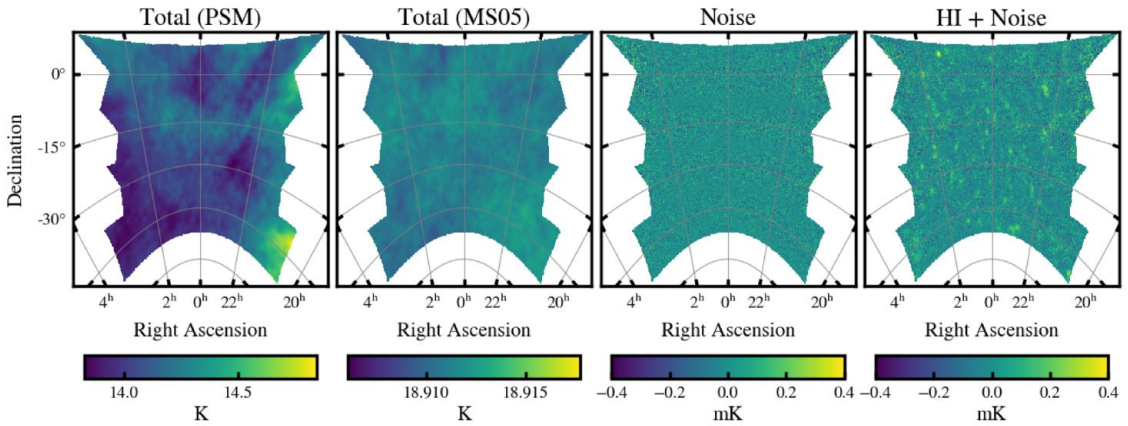
MS et al. 2022

(subset of) **SKA IM Focus Group**

Project setup:

- various foreground models and realistic HI maps: fast halo catalogues + painted HI
- **instrumental modeling MeerKAT-like and SKAO-like**
- 9 different foreground removal methods (PCA, FastICA, …)

Blind challenge to discover weaknesses and strengths of the various methods



given IM data now, would your favorite method extract the cosmological signal?

Towards the SKA Observatory

from a 21cm Intensity Mapping perspective

Data:

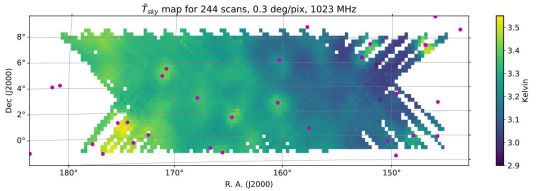
Keep working with pathfinder data (MeerKLASS) to understand the instrument and improve the pipelines

Simulations:

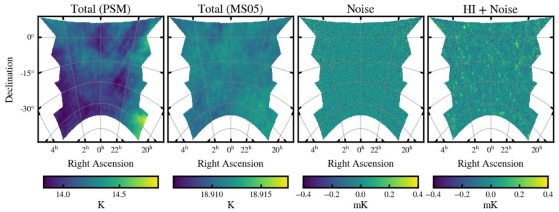
Improve and refine end-to-end simulations

Final aim:

A 21cm **(auto) power spectrum detection** validated with realistic simulations



Wang et al. 2021



***MS** et al. 2022*