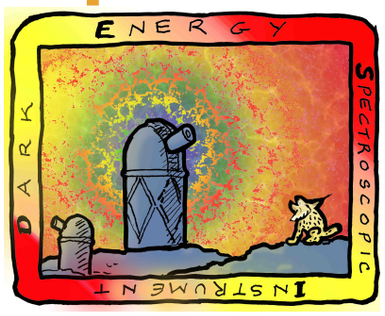
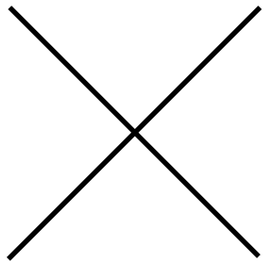
HIR4

Mock 21 cm maps for cross-correlations with optical surveys





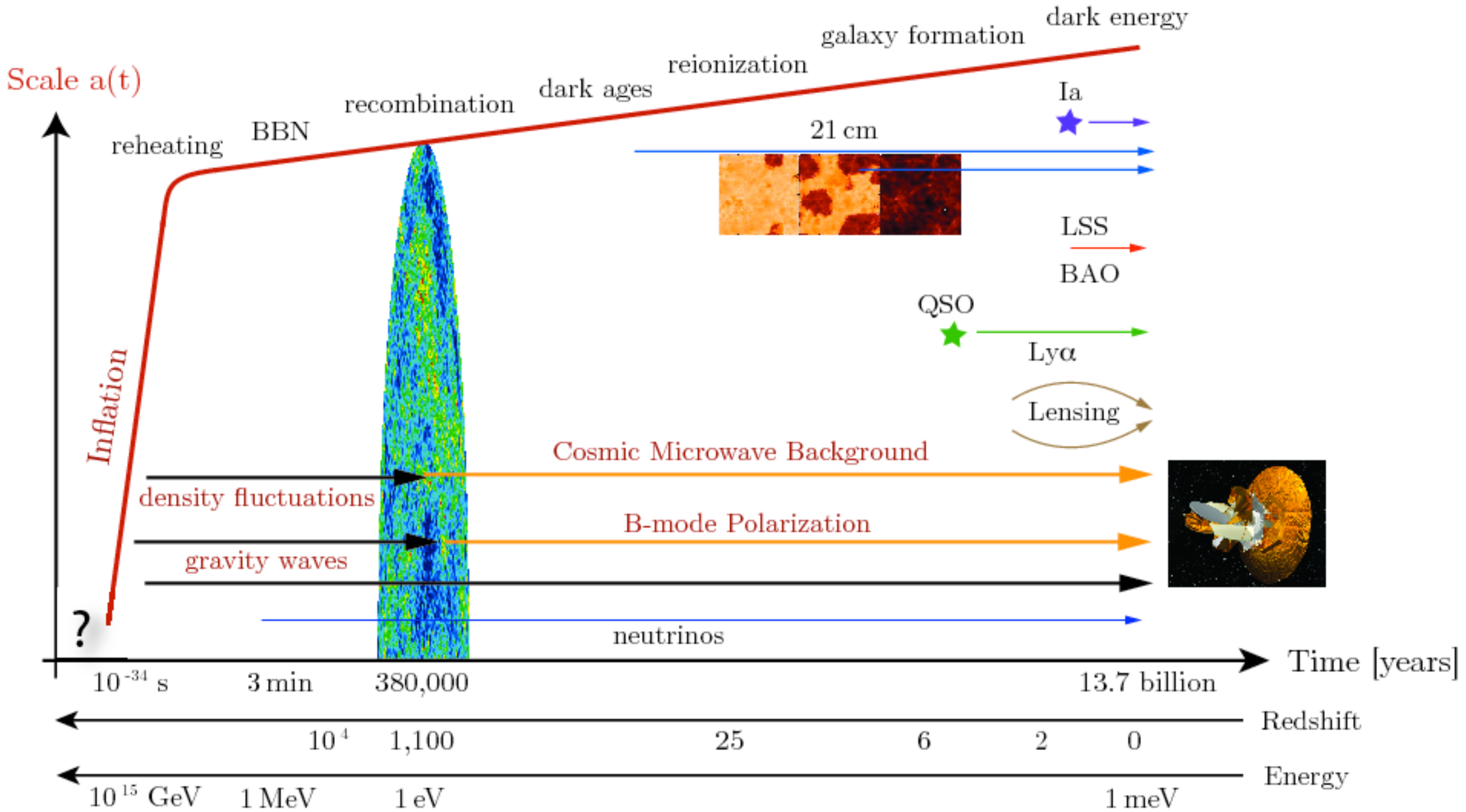
Jacobo Asorey (아소레이, 자코보)
with K. Ahn, D. Parkinson, F. Shi, Y-S. Song and L. Zhang

KASI 한국천문연구원
Korea Astronomy & Space Science Institute

CosKASI
Cosmology Group at
Korea Astronomy and Space Science Institute

CosKASI Conference 2019, Seogwipo, Jeju-do, Korea, 23 April 2019

Expansion, Growth and Cross-correlations



D. Baumann, 2009, arXiv:0907.5424

Radio Surveys

HI galaxy

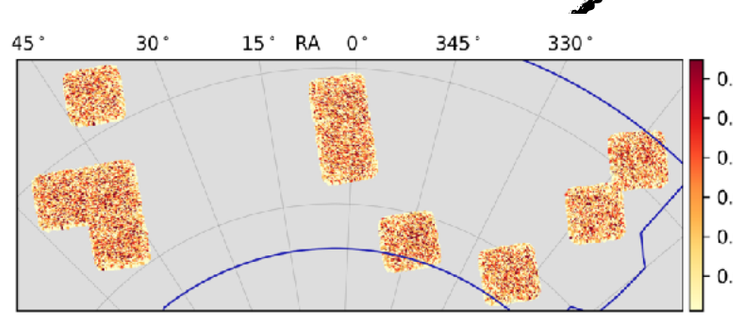
(like spectroscopic surveys)

[e.g., HIPASS, ALFALFA]

Continuum galaxy

(like photometric) surveys)

[e.g., EMU]

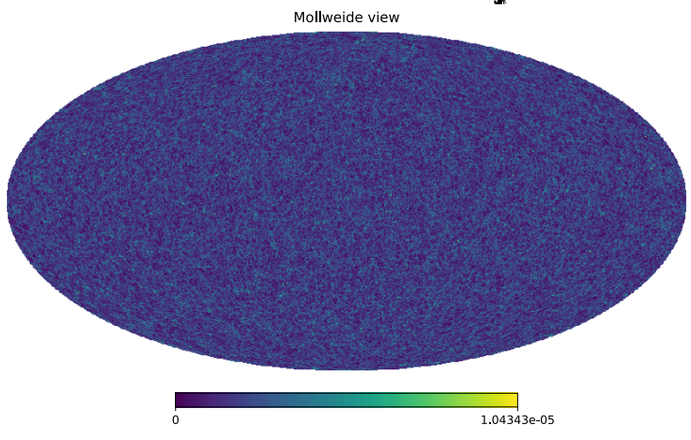


ASKAP-EMU

HI intensity mapping

(like 3D CMB)

[e.g., CHIME, TIANLAI]



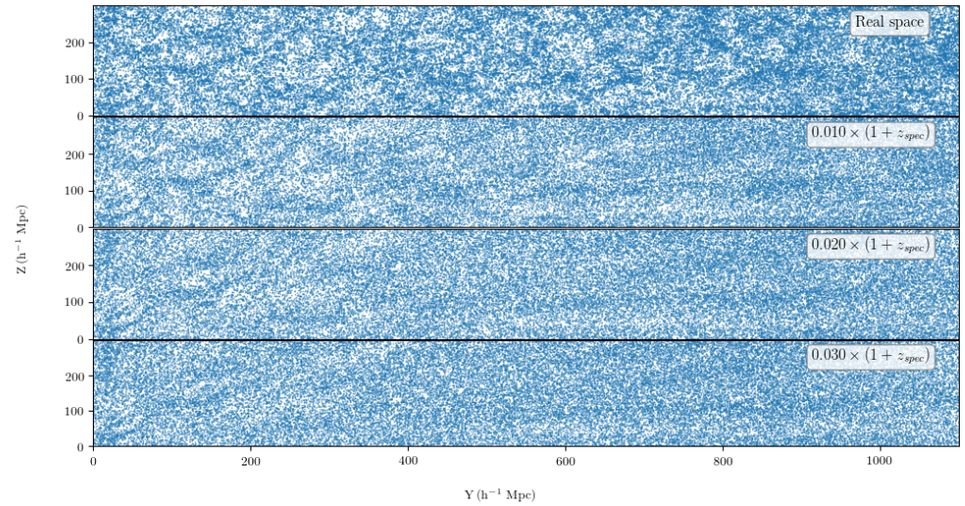
HI intensity mapping

- **Neutral hydrogen** is another **tracer** of matter.

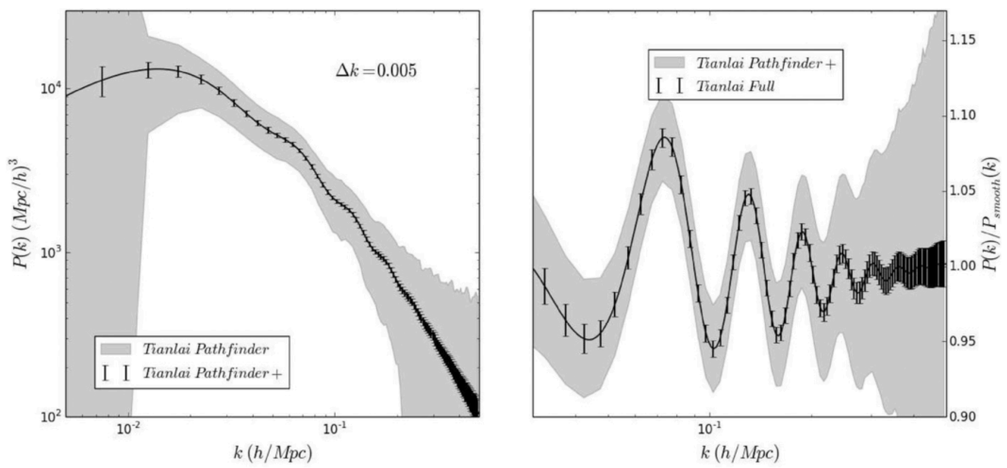
- Intensity mapping produces 3D maps of Large Scale Structure with lower angular resolution.

- Multi-tracer cross-correlation with optical surveys alleviate systematics. Main systematic: **Radio foregrounds**

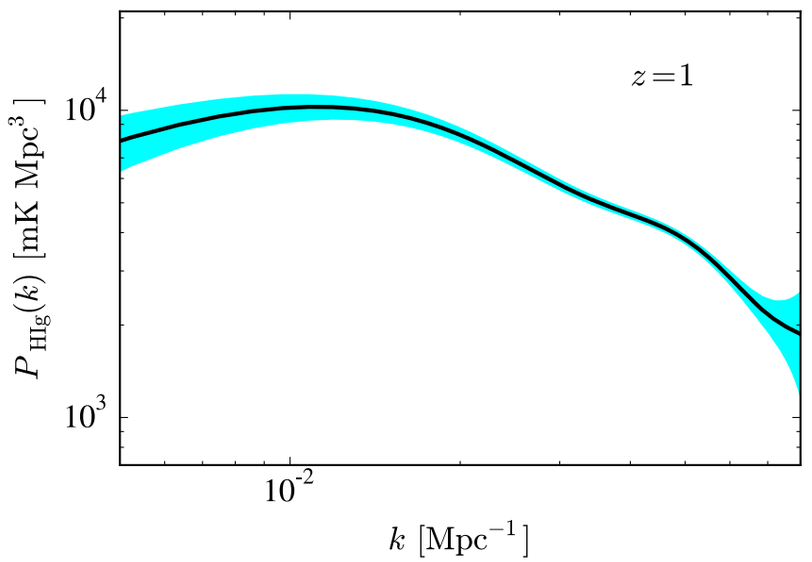
- In the near future, **DESI** will overlap with surveys such as CHIME and **Tianlai** and in the future partially with SKA.



Sridhar & Song, 2019



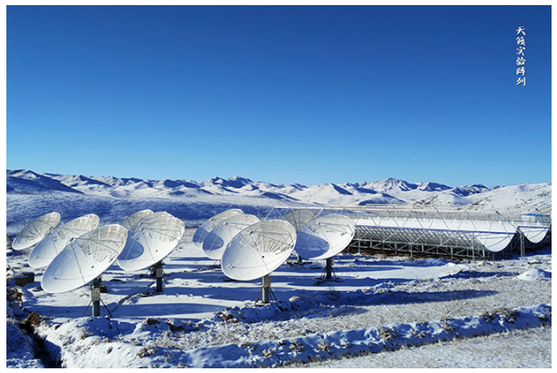
Xu, Wang & Chen, 2015



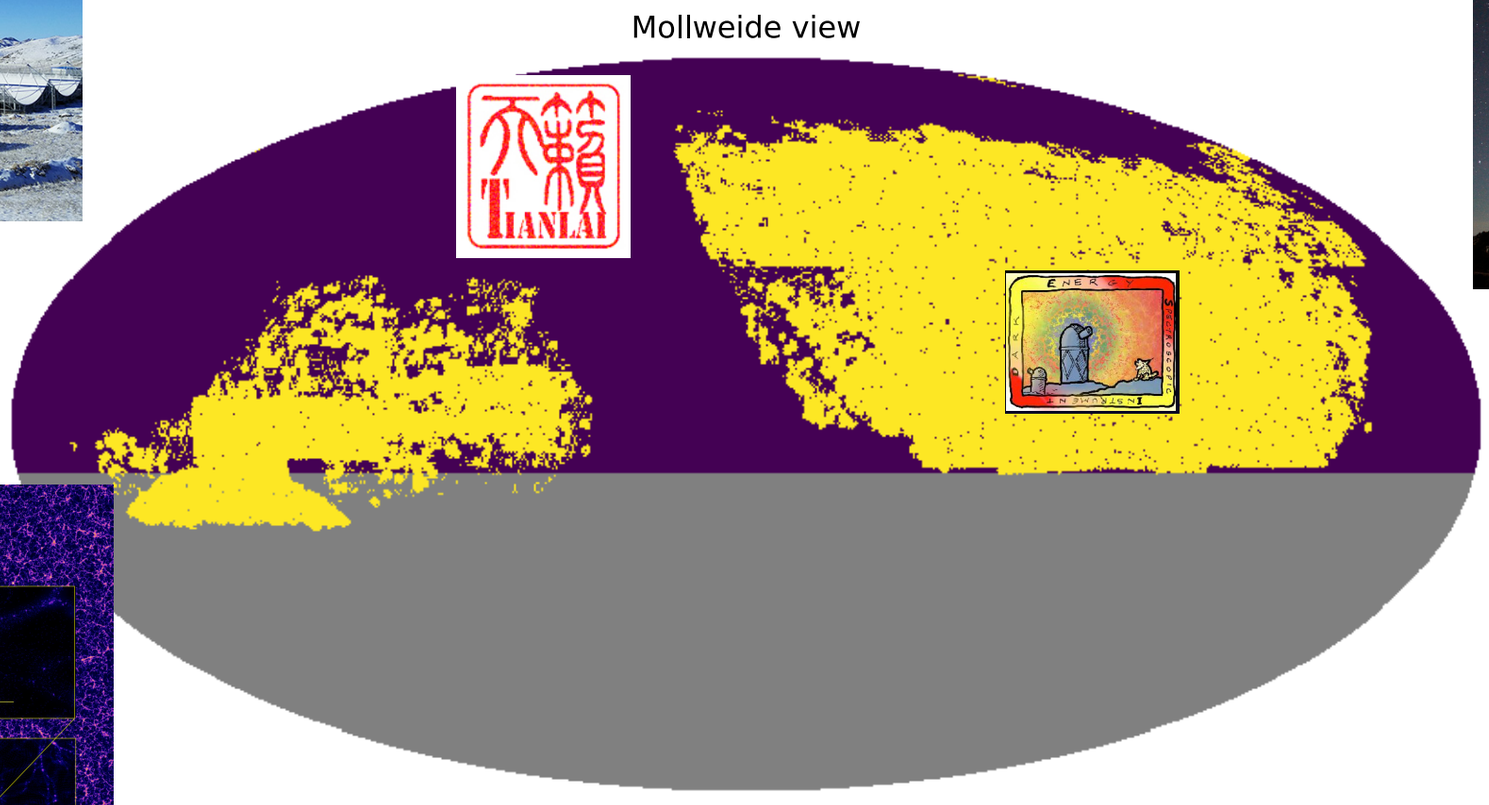
SKA Red Book 2018

H1R4: Tianlai x DESI opportunity window

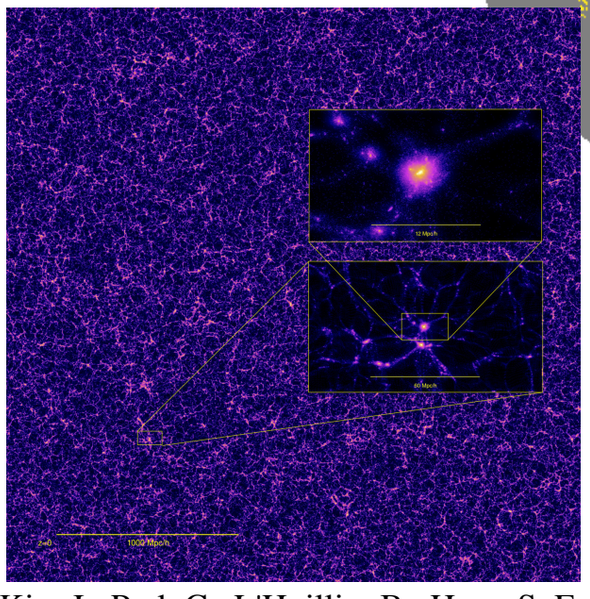
- TIANLAI Pathfinder:
  - 3 (15x40m) cylinders
  - 16 (6m) dishes
  - 700-800MHz
  - $0.775 < z < 1.03$
- DESI survey:
  - 5000 fibre multi-object @ 4m Mayall
  - Footprint of 14000 sq. degs:
    - 35 million ELGs
    - 4 million LRGs
    - 2.4 million QSOs



Credit: NAOC



Credit: R. Lafever



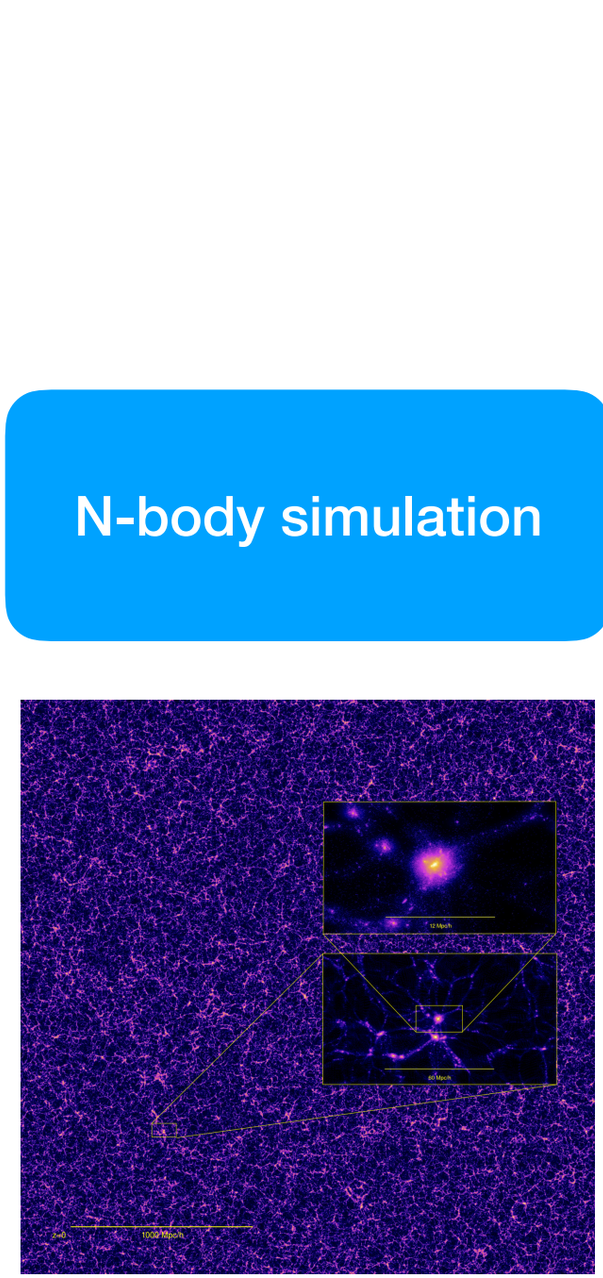
Kim J., Park C., L'Huillier B., Hong S. E. 2015

Start with simulations!!

Great overlap for cross-correlation!

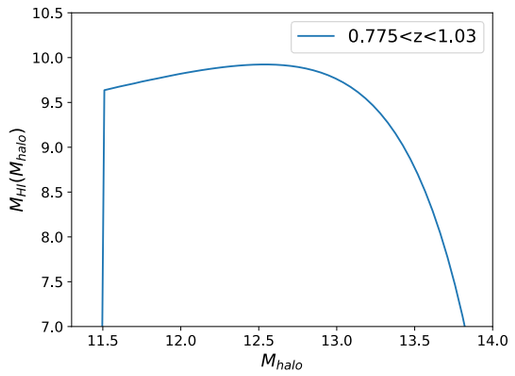
‘Painting’ neutral hydrogen in the Halo canvas I

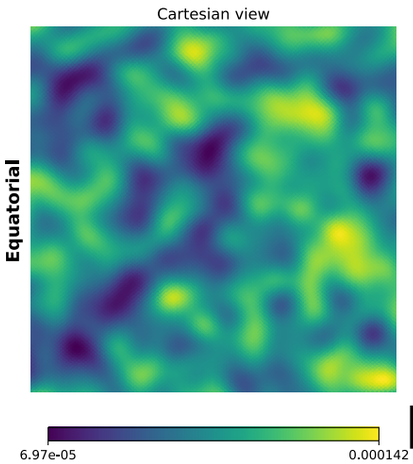
- We start with halo catalogue from **HR4 simulation** (Kim J et al.).

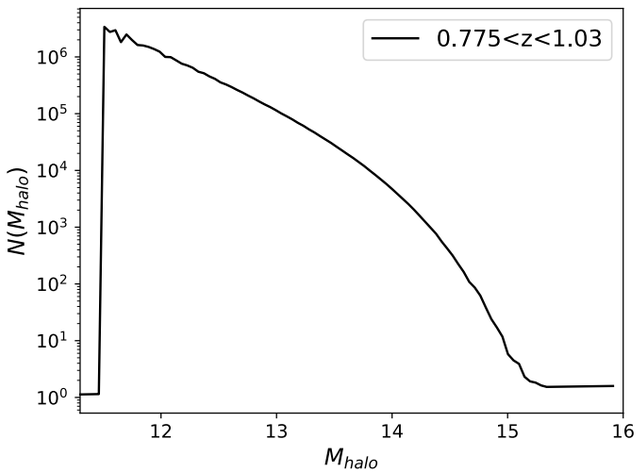


Kim J., Park C., L'Huillier B., Hong S. E. 2015

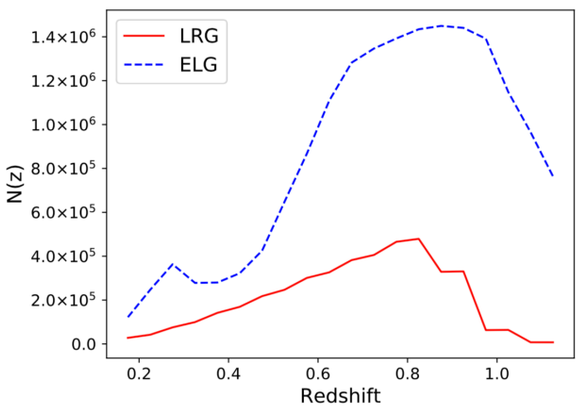
N-body simulation → Halo catalogue → HI halos → HI brightness T

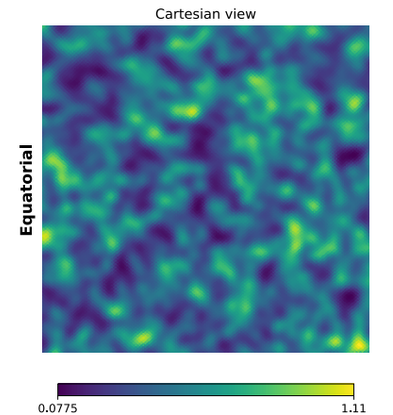




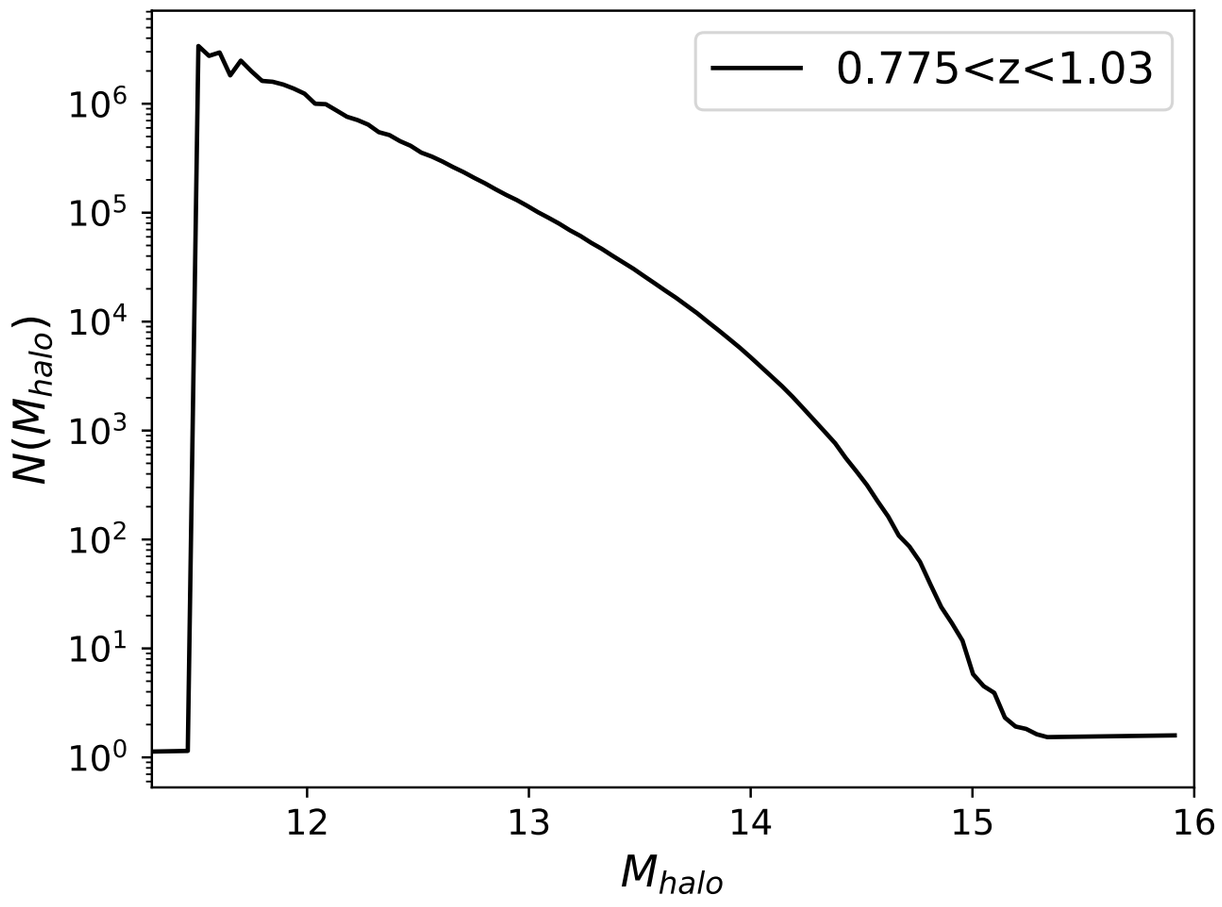


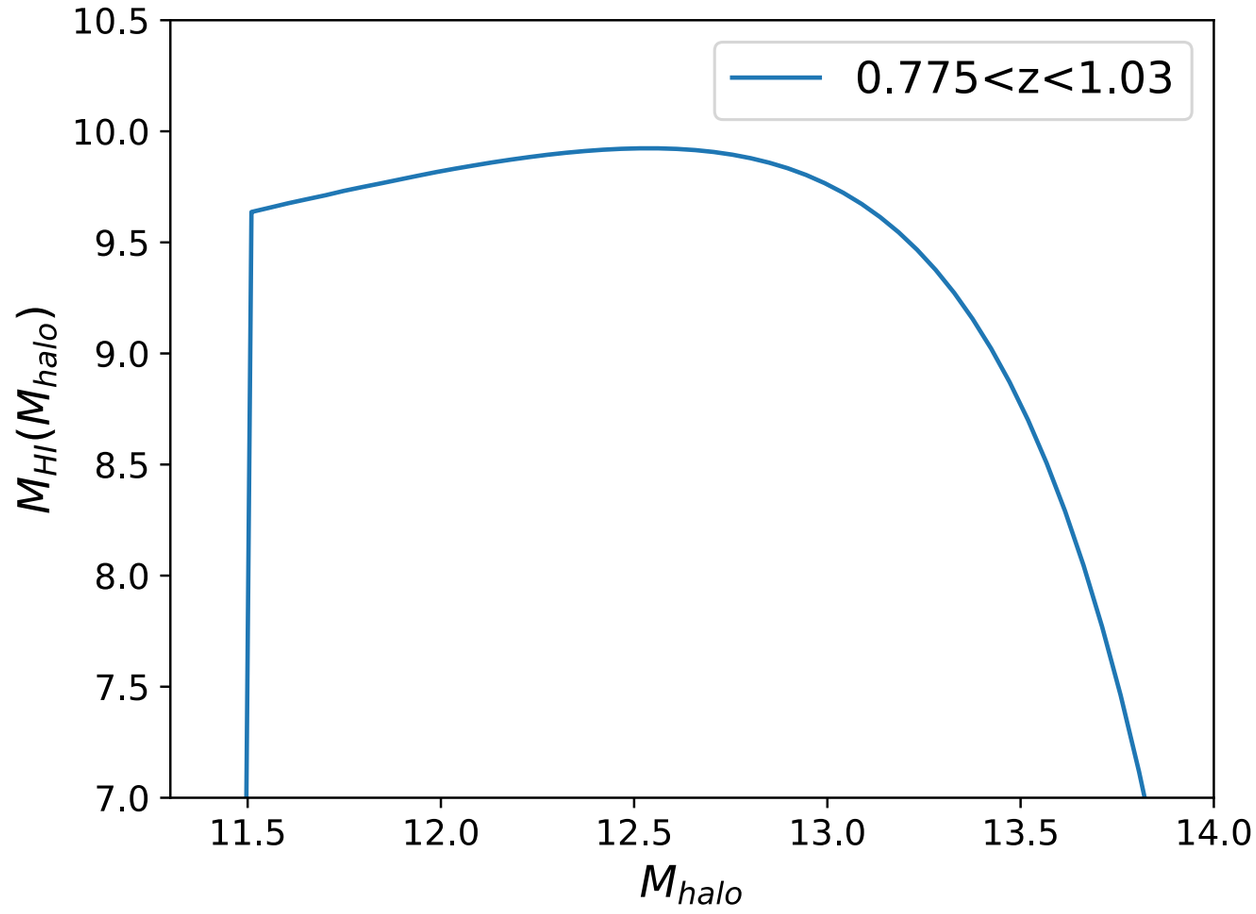
Halo catalogue → ELG halos → ELG density





Populate HR4 with Hydrogen



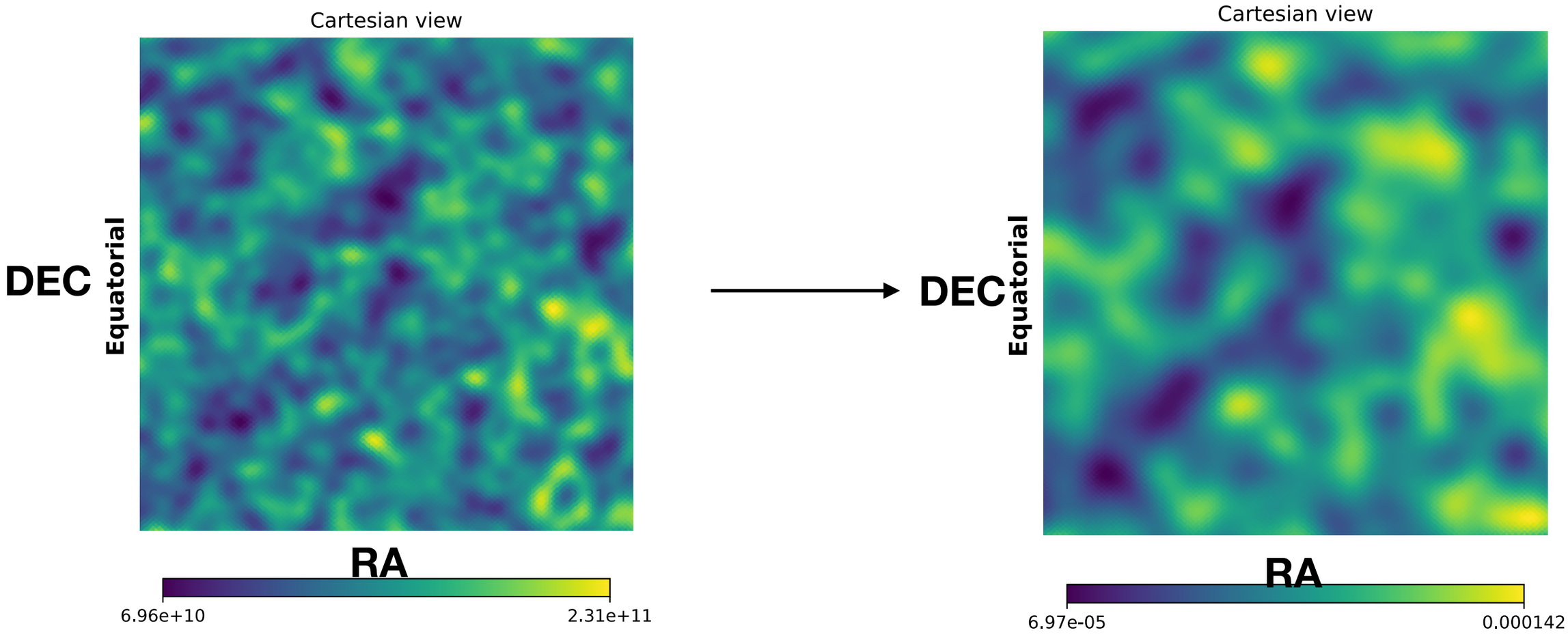


$$M_{HI}(M_h) = f_{HI} f_c M_h \left(\frac{M_h}{10^1 1 M_\odot}\right)^\beta \exp\left[-\left(\frac{v_{vc0}}{\sigma_v(M_h)}\right)^3\right] \exp\left[-\left(\frac{\sigma_v(M_h)}{v_{c1}}\right)^3\right]$$

H. Padmanabhan & A. Refregier (2017), MNRAS, 464, 4008

‘Painting’ neutral hydrogen in the Halo canvas II

- Given a neutral hydrogen density in a frequency bin, we assign a brightness temperature to a given pixel in the sky.



$$T_{21} = \frac{3h_P c^3 A_{12}}{32\pi m_h} \frac{(1+z)^2}{H(z)} \rho_{HI}$$

P. Bull & P. G. Ferreira, P. Patel, M. Santos (2015), ApJ, 803, 21

Adding the foregrounds: Global Sky Model

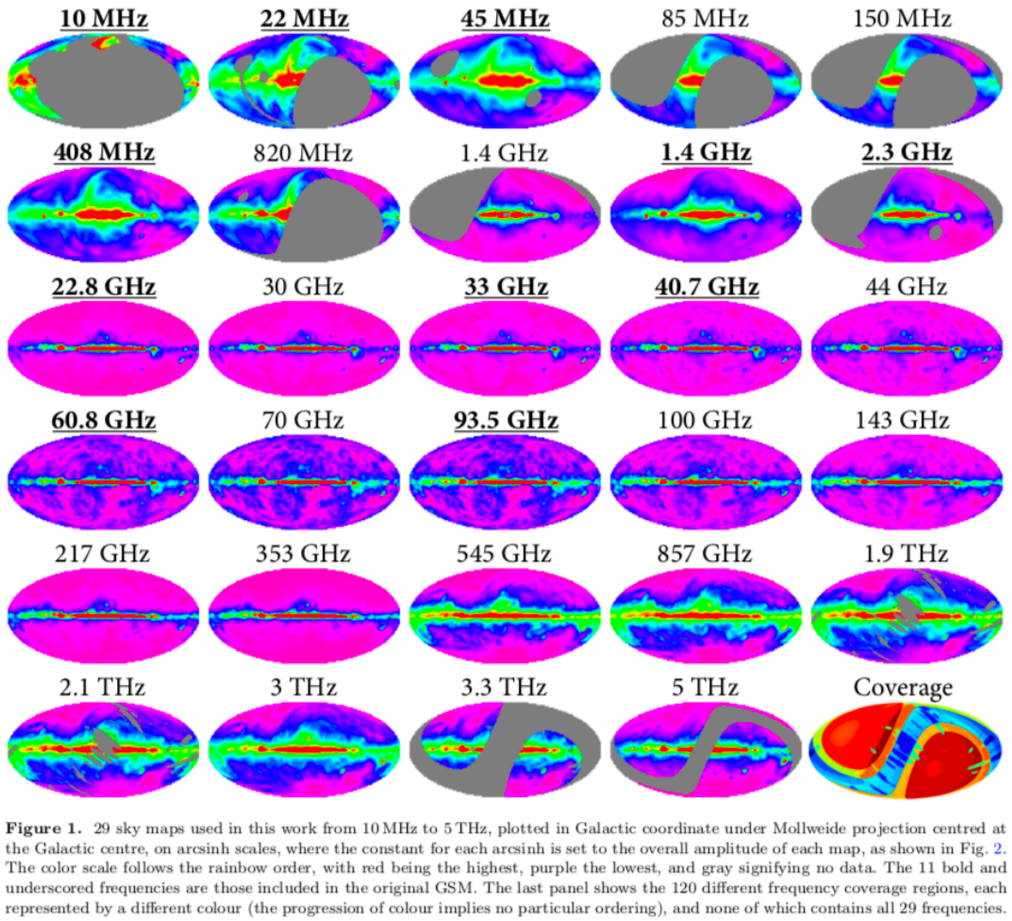
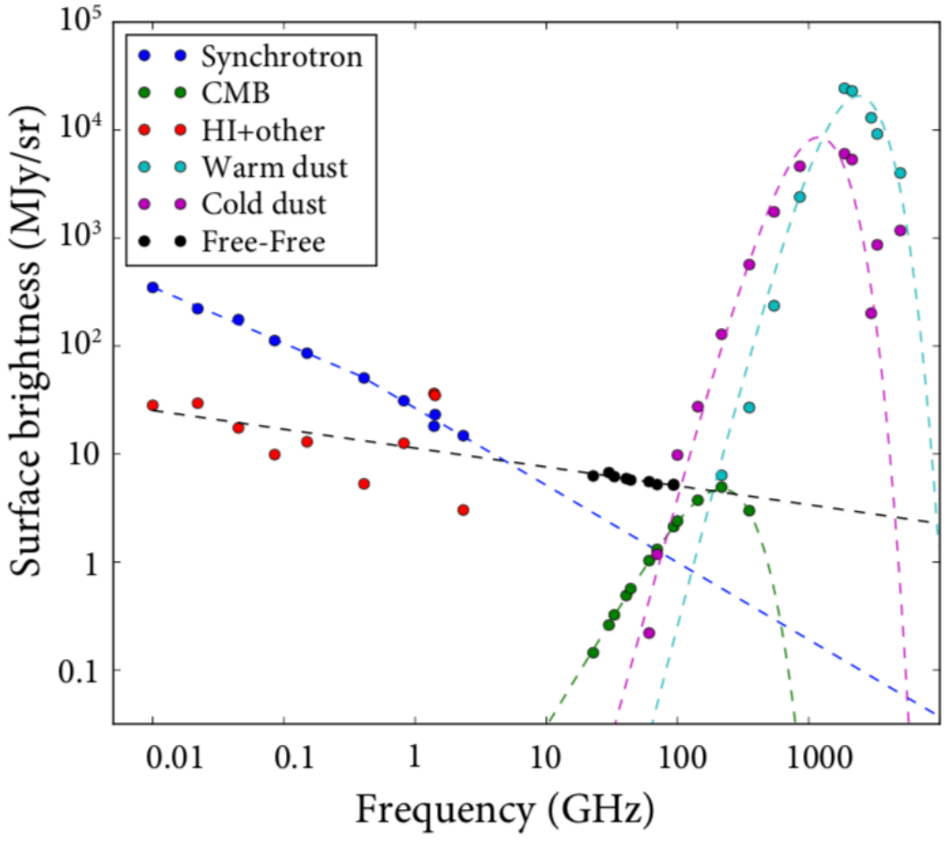


Figure 1. 29 sky maps used in this work from 10 MHz to 5 THz, plotted in Galactic coordinate under Mollweide projection centred at the Galactic centre, on arcsinh scales, where the constant for each arcsinh is set to the overall amplitude of each map, as shown in Fig. 2. The color scale follows the rainbow order, with red being the highest, purple the lowest, and gray signifying no data. The 11 bold and underscored frequencies are those included in the original GSM. The last panel shows the 120 different frequency coverage regions, each represented by a different colour (the progression of colour implies no particular ordering), and none of which contains all 29 frequencies.

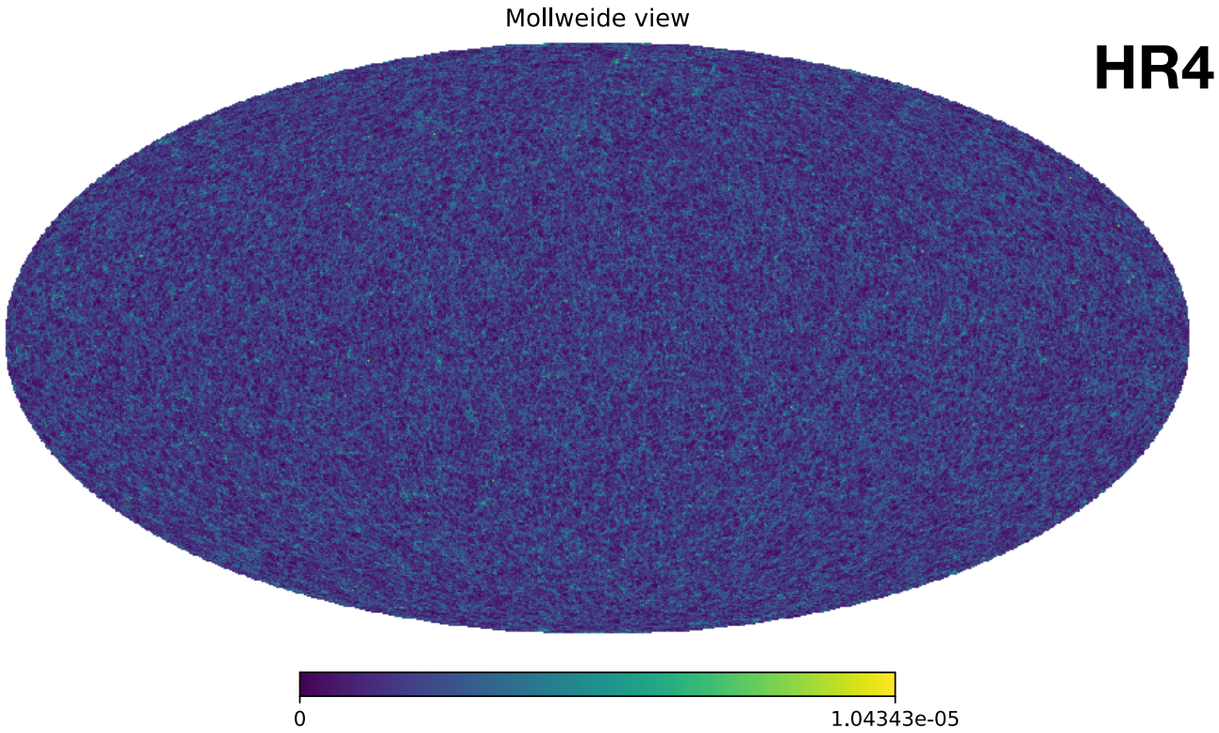


- We add the foreground at a given frequency by using the PCA solution from GSM.

A. de Oliveira-Costa et al. (2008), MNRAS, 388, 247

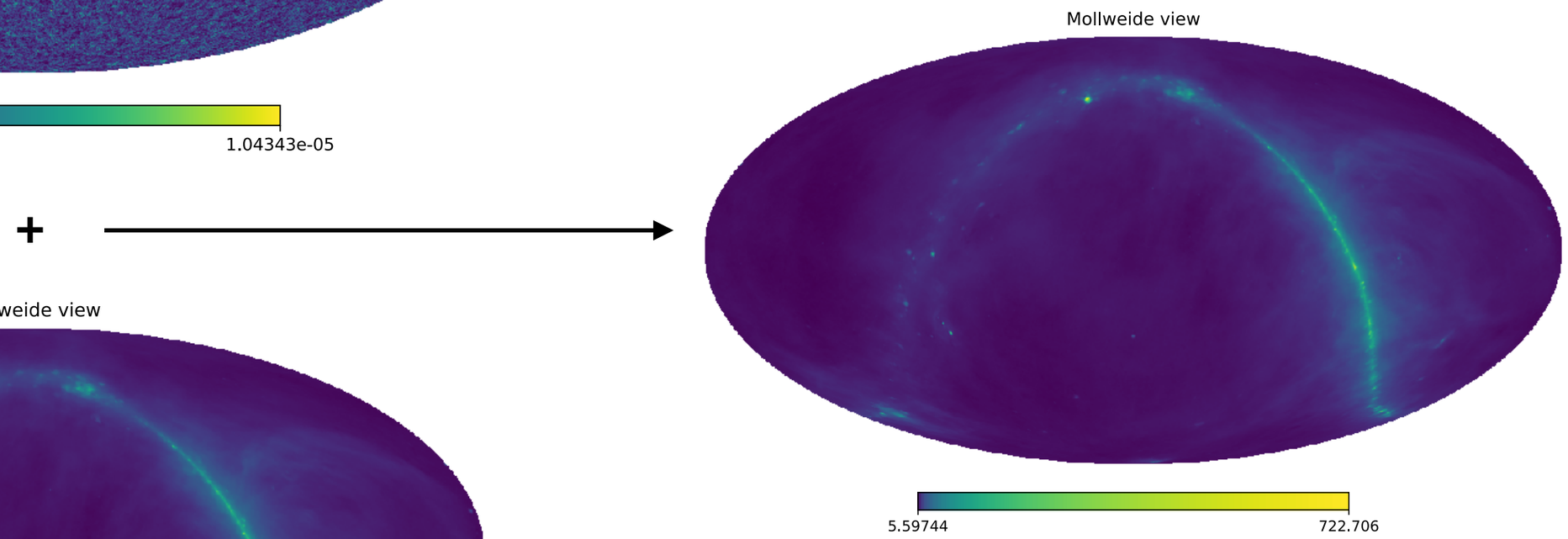
H. Zheng et al. (2017), MNRAS, 464, 3486

Hydrogen brightness maps

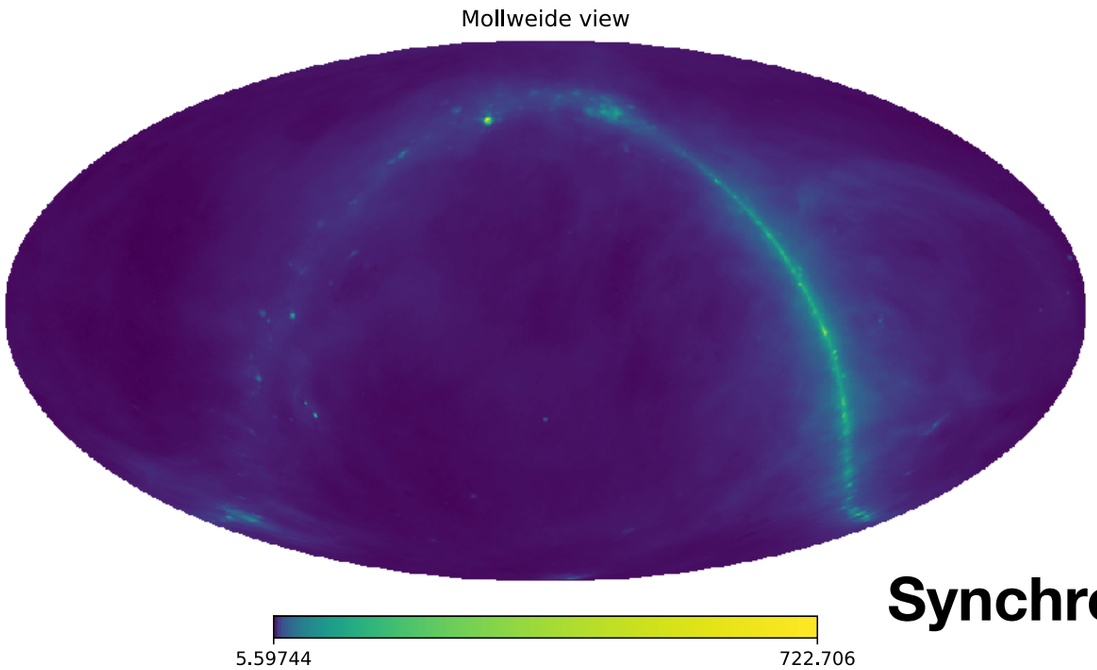


HR4 21cm f=795 MHz

Healpix Nside=256 (0.23 deg)

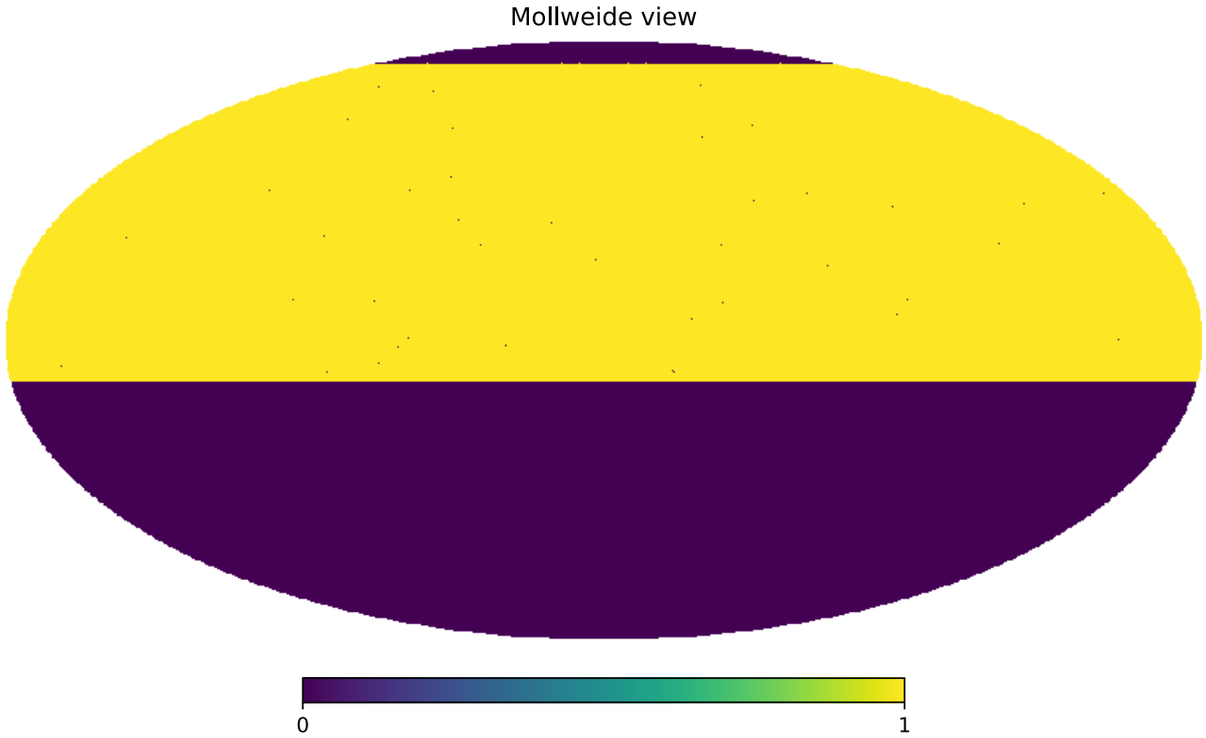


+

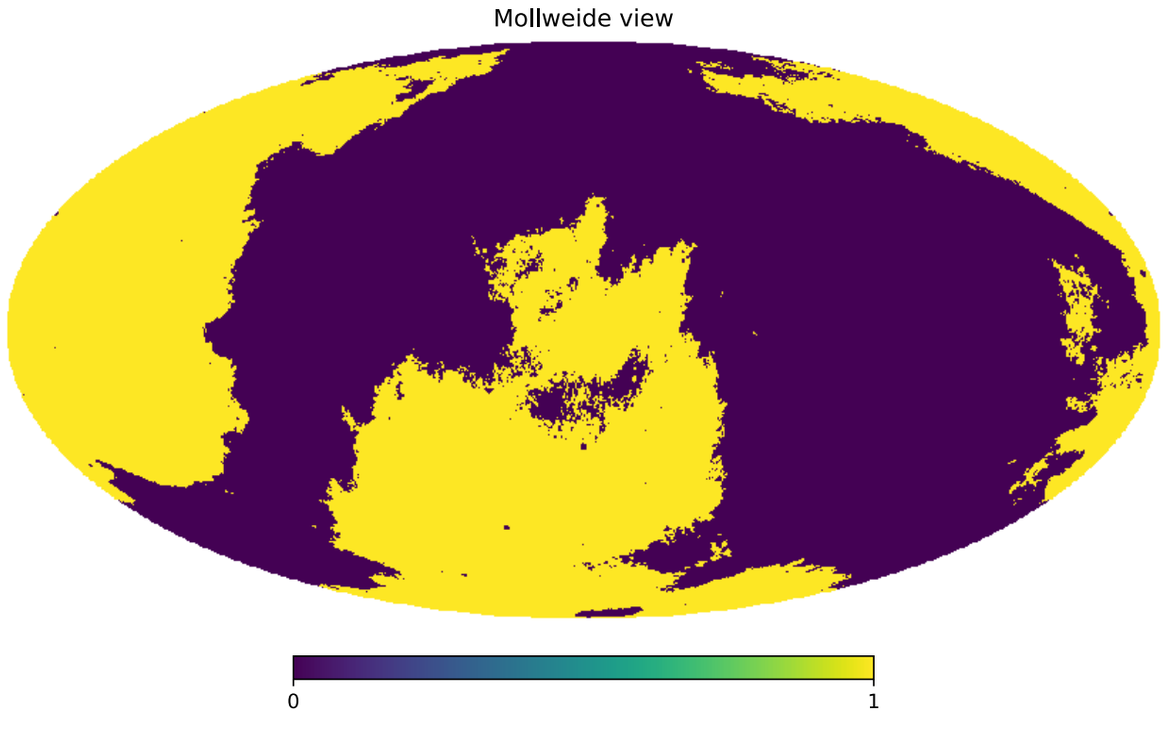


Foreground f=795 MHz
Synchrotron, CMB, HI, Warm & Cold Dust, Free-free
Global Sky model: 1605.04920

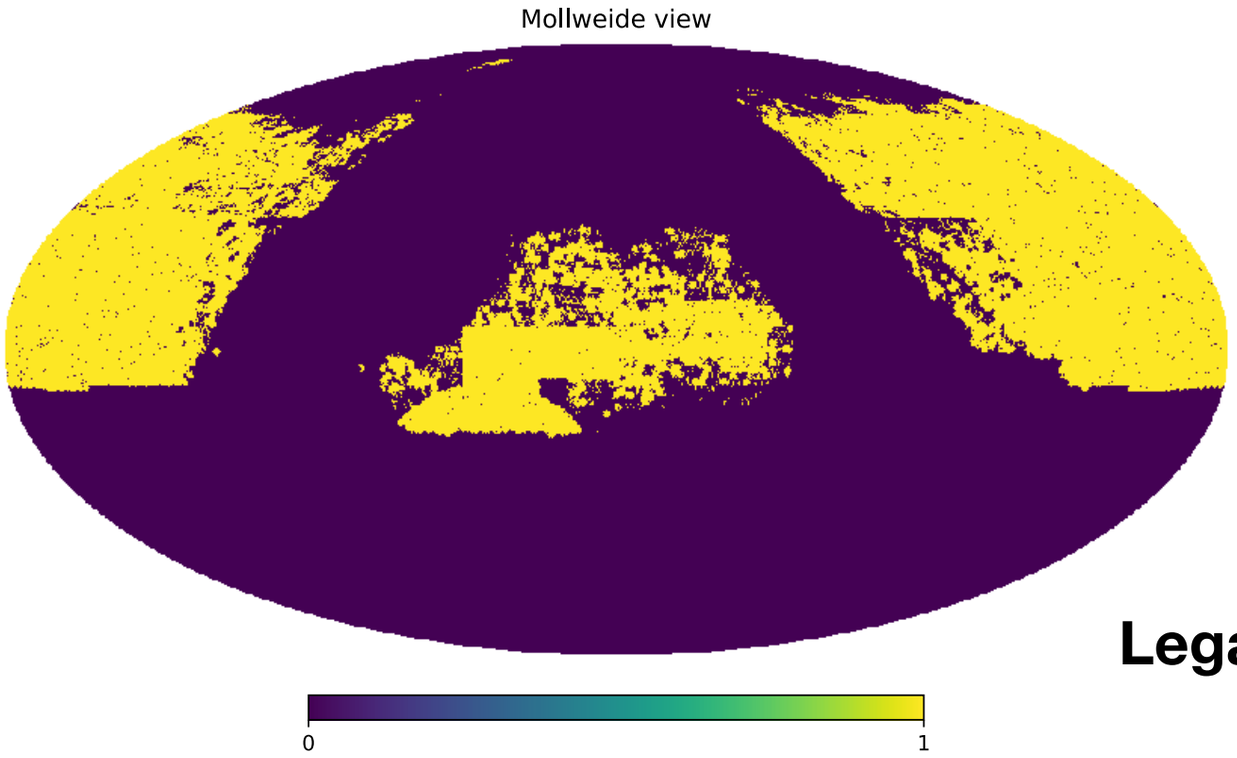
Masking the MW and DESI



Mock ‘ELG’ mask



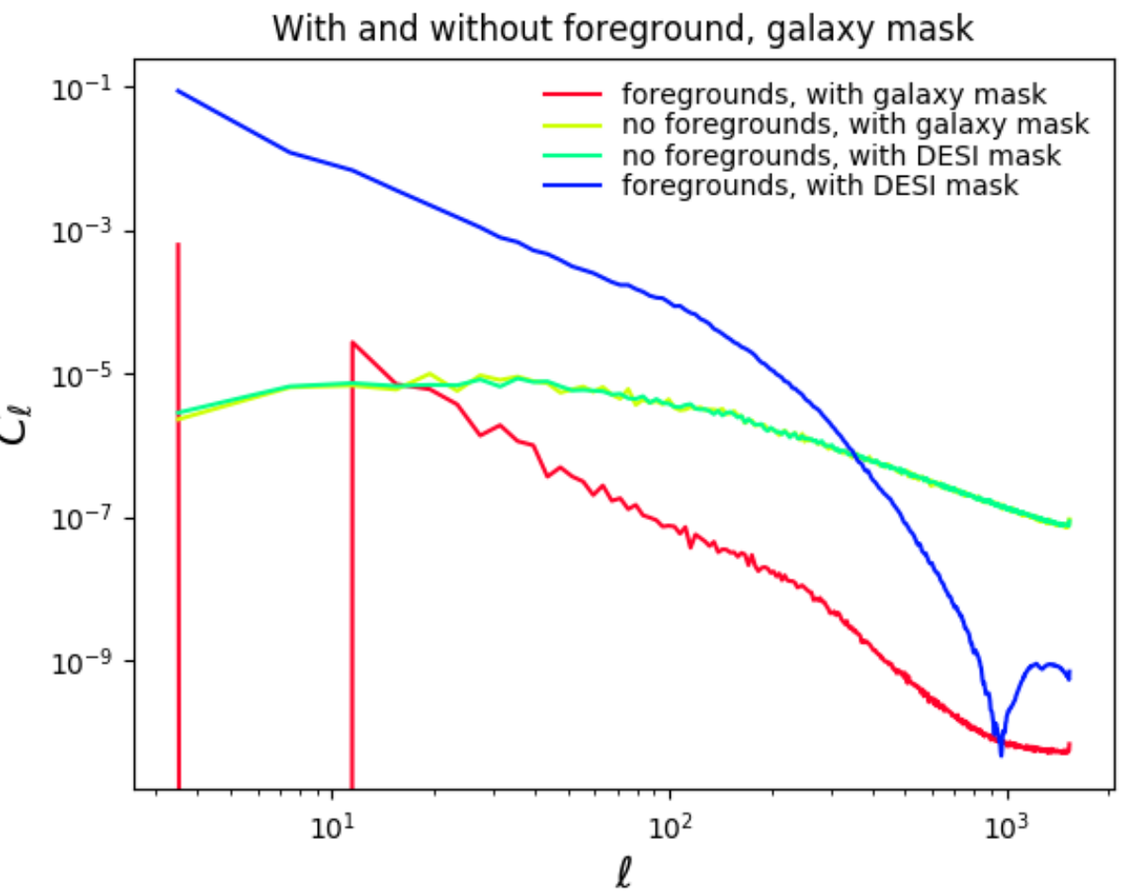
Foreground cut 8K



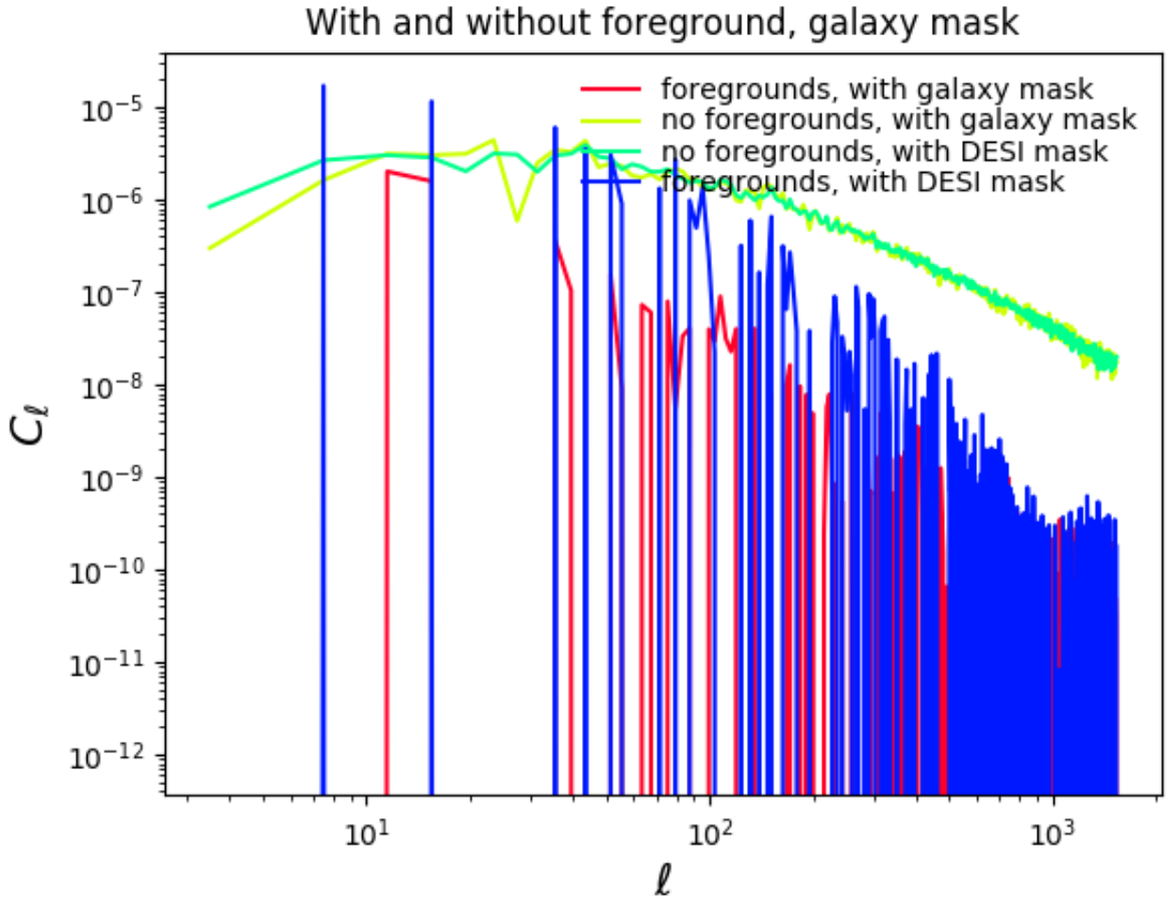
Legacy Surveys mask

Angular Power Spectra (APS)

Auto-correlations of 21cm



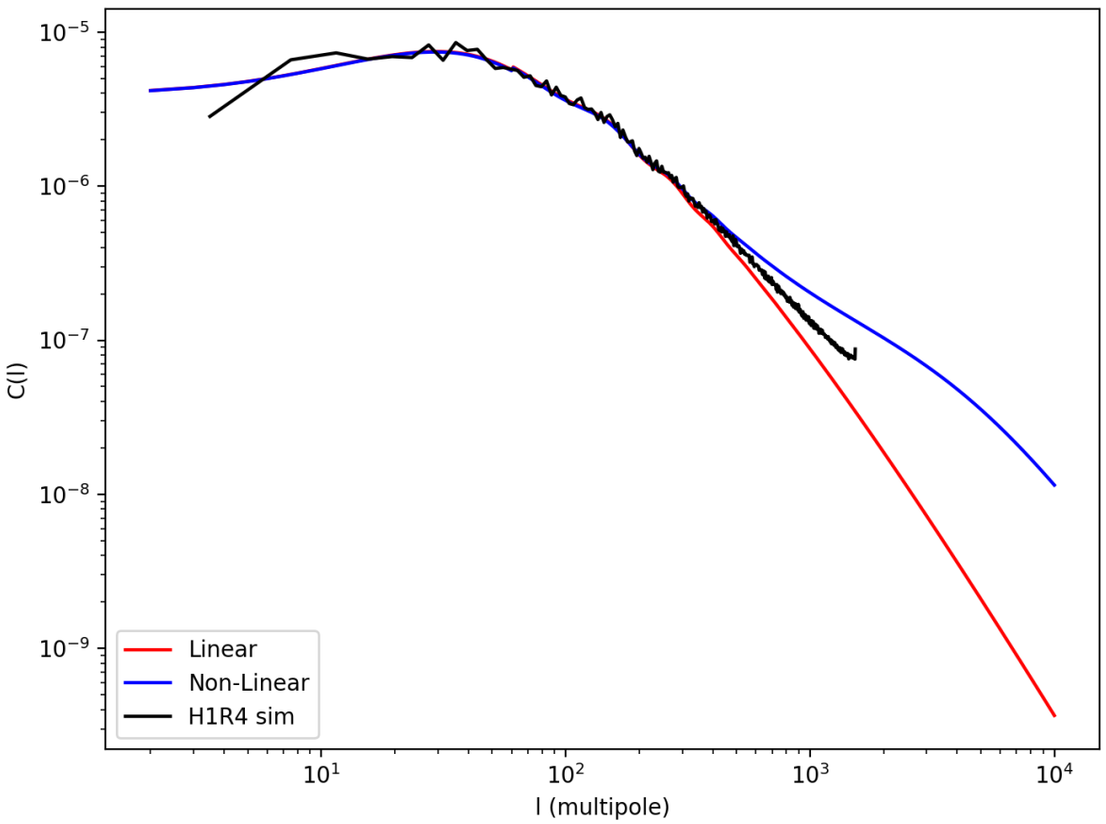
Cross-correlations of 21cm x ELG

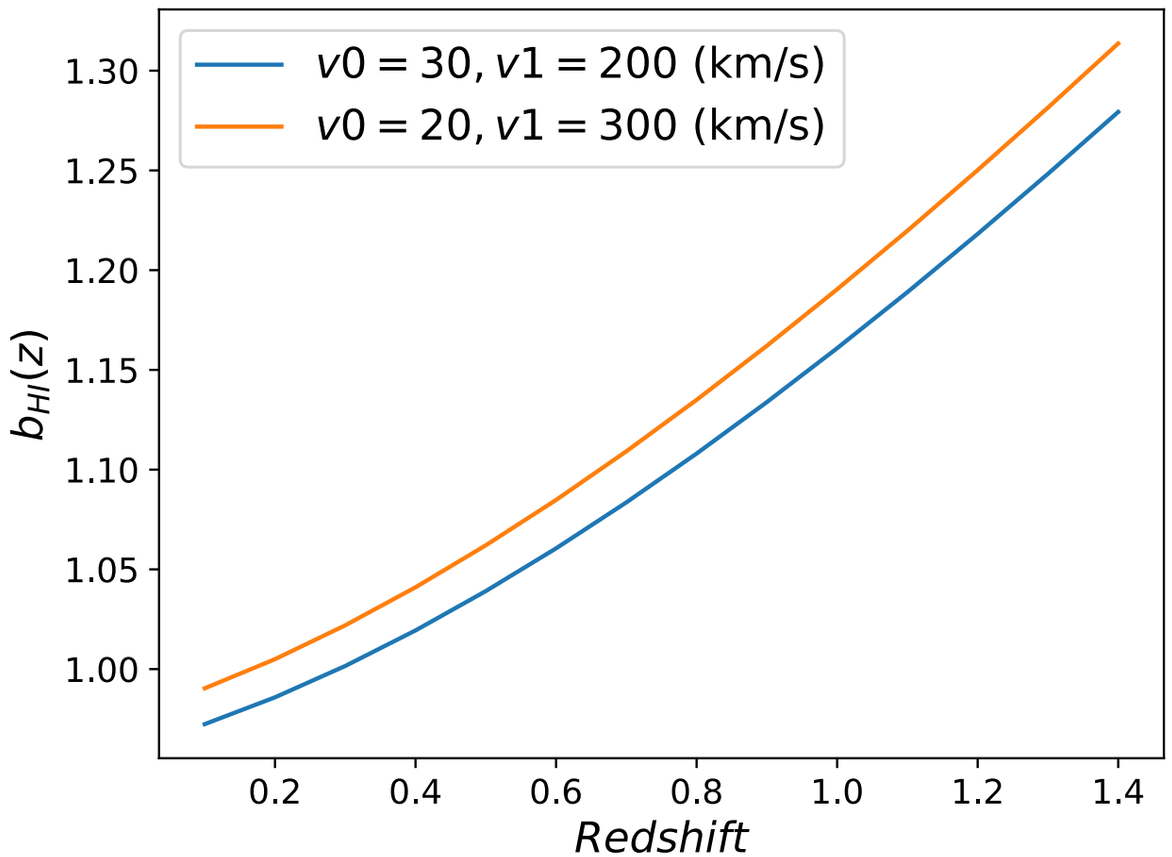


Credit: D. Parkinson

Measured using Namaster code (arXiv:1809.09603)

Theoretical comparison





Credit: D. Parkinson

- We recover the expected bias in the linear scales. Preliminary different foreground removal techniques (PCA, polynomial, FastICA) look promising.

Conclusions / Work in Progress

- We have created a **full-sky mock 21cm intensity mapping** maps using HR4 N-body simulation.

- Foreground removal and foreground understanding either for continuum surveys and for intensity mapping (10^7 factor difference). Receiver noise impact on foreground removal.

- **CosKASI participates of both TIANLAI and DESI**, opening the opportunity to cross-correlate both surveys and implication for future surveys such as SKA. Potential case for TIANLAI x DECALS (photo-z) cross-correlations.

- **Friday at 14:00: discussion** session about 21cm Intensity mapping

감사합니다!

¡Gracias!

Thank you!