HIR4

Mock 21 cm maps for cross-correlations with optical surveys

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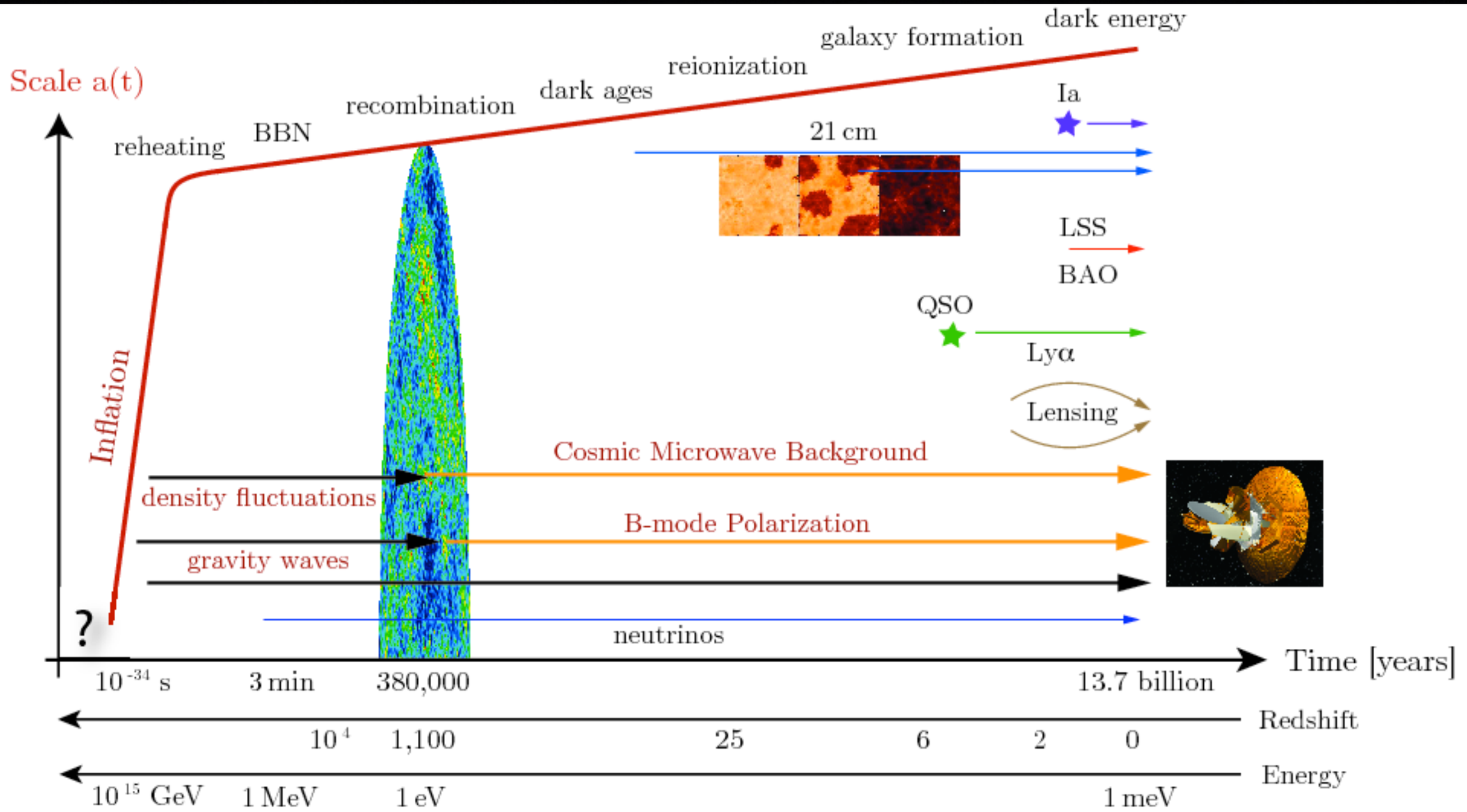


D. Baumann, 2009, arXiv:0907.5424

Radio Surveys

- HI galaxy (like spectroscopic surveys) [e.g., HIPASS, ALFALFA]
  - Measures RA, Dec and redshift - Functions like an optical galaxy redshift survey
  - Can also measured peculiar velocities through Tully-Fisher relation (e.g. WALLABY & TAIPAN)
- Continuum galaxy (like photometric surveys) [e.g., EMU]
  - Measures RA, Dec, but not redshifts - Projected tomographic bins
  - Cross-correlate with CMB and low-z sample for ISW and lensing magnification
- HI intensity mapping (like 3D CMB) [e.g., MeerKLASS, CHIME, Tianlai]
  - Measures RA, Dec, z, but no galaxies - low resolution in angular space
  - Can still use it like a spectroscopic survey (BAO & RSD)

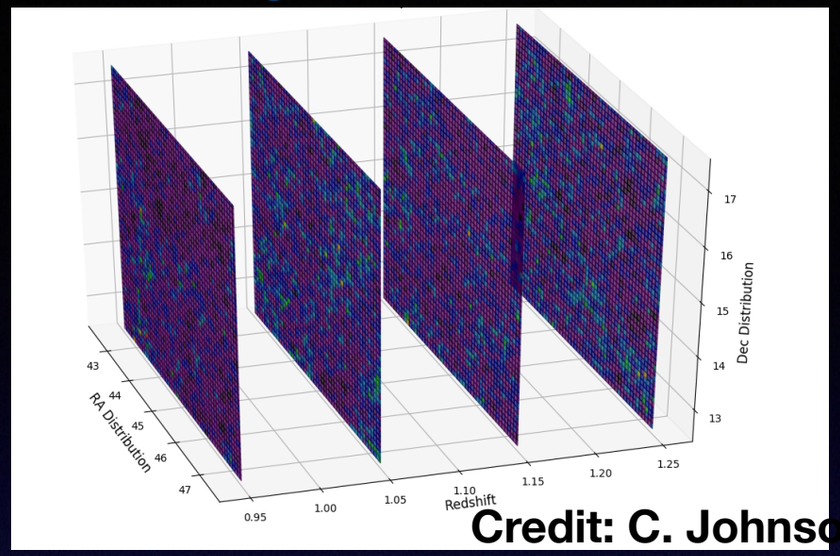
HI intensity mapping

- Neutral hydrogen also tracer of matter.

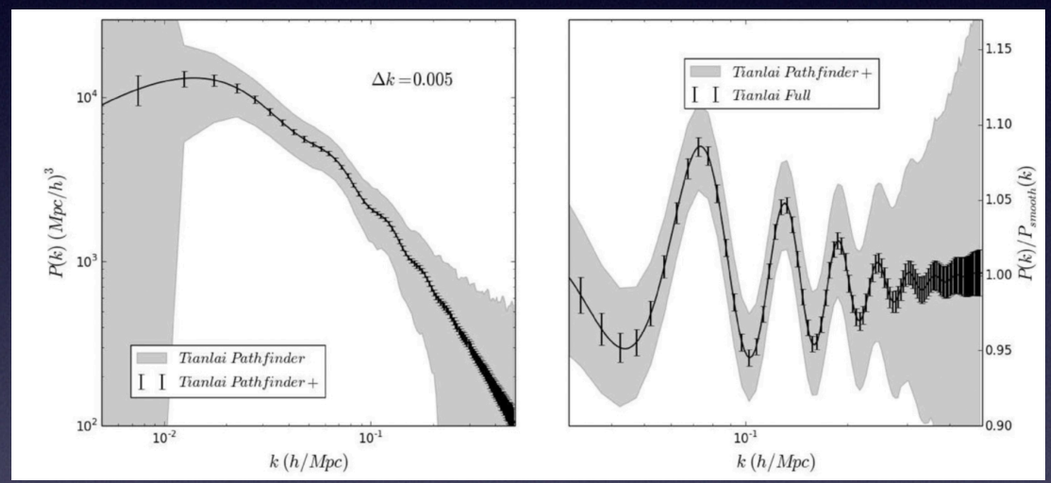
- Intensity mapping produces 3D maps of Large Scale Structure with lower angular resolution.

- Multi-tracer cross-correlation with optical surveys alleviate systematics.

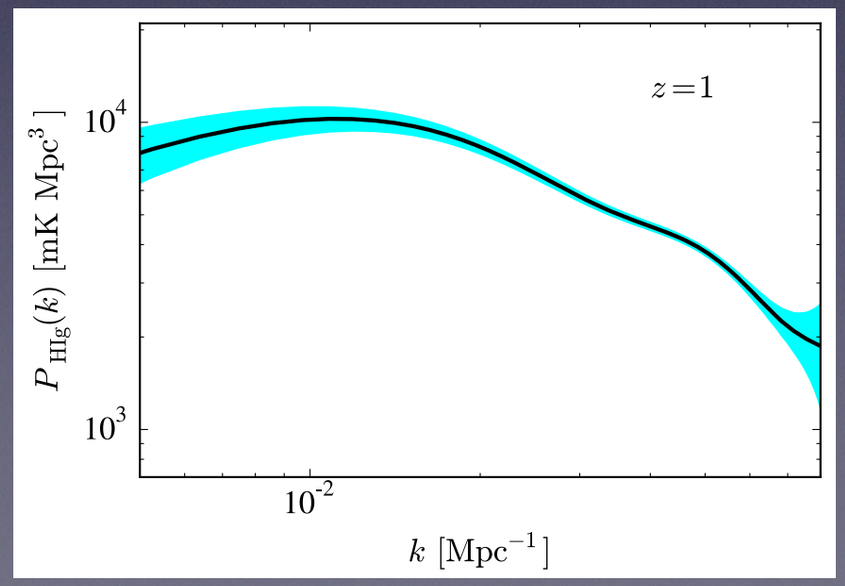
- In the near future, DESI will have overlap with surveys such as CHIME and Tianlai and in the future some with SKA.



Credit: C. Johnson

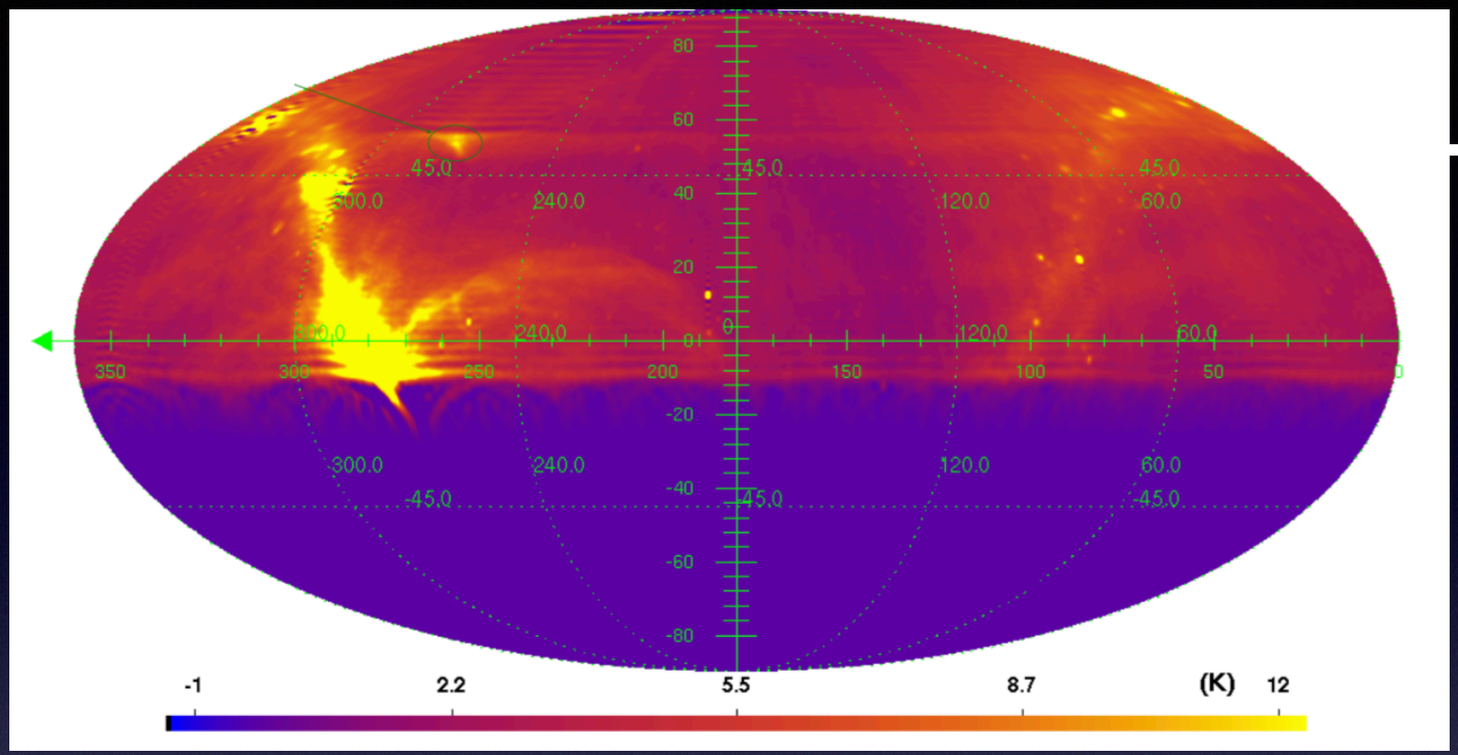


Xu, Wang & Chen, 2015

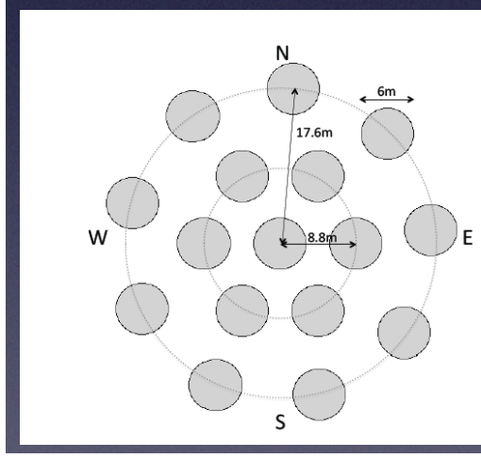


SKA Red Book 2018

Tianlai



- Pathfinder:
  - 3 (15x40m) cylinders
  - 16 (6m) dishes
  - 700-800MHz
  - 0.775 < z < 1.03



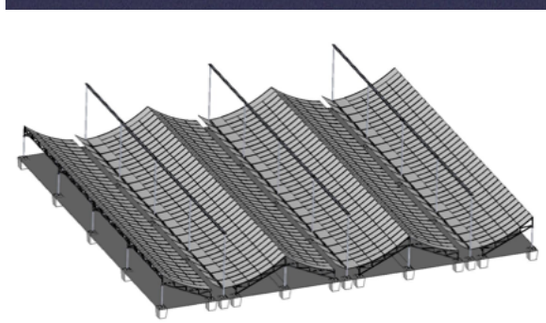
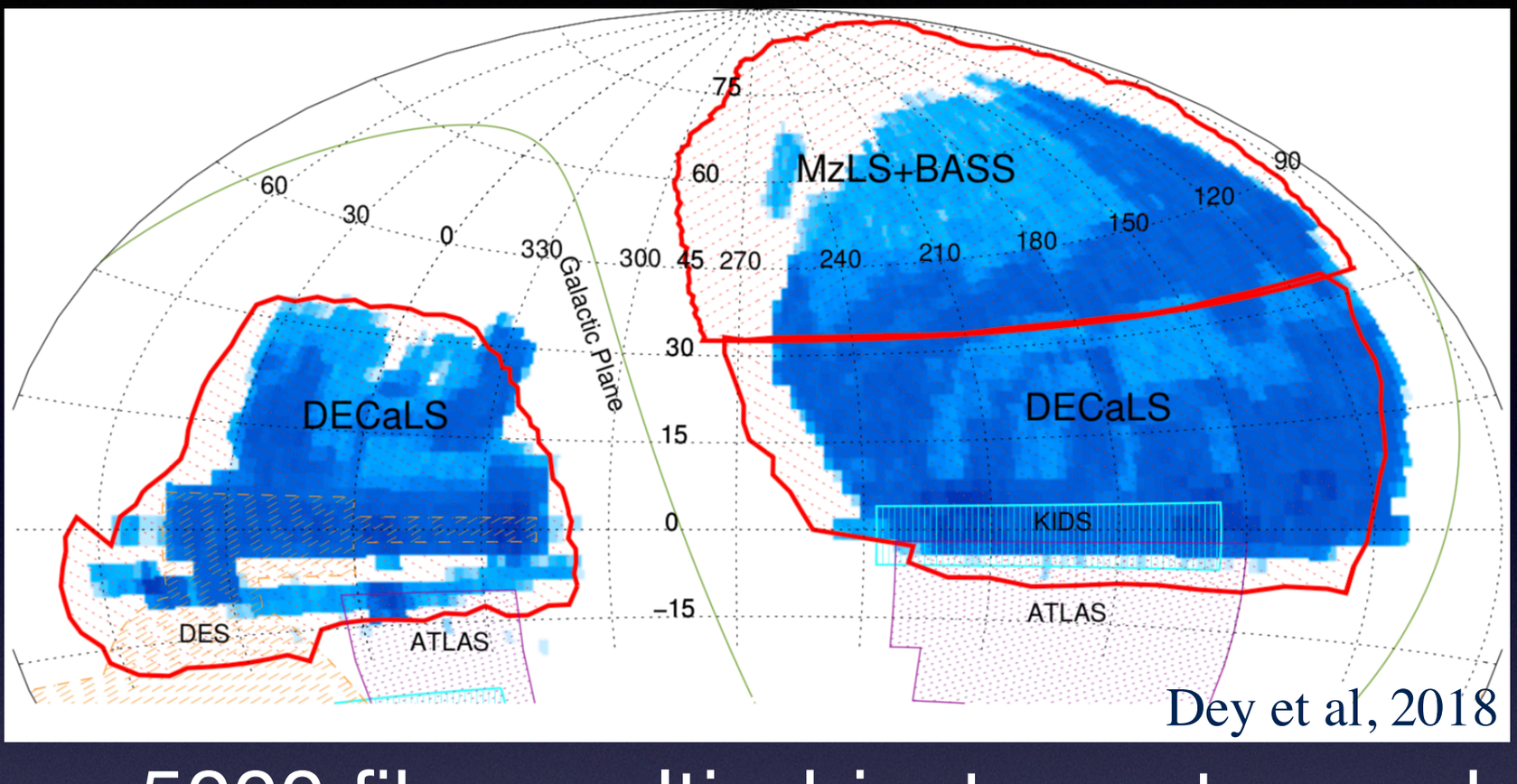


Table 1
The Experiment Parameters for Tianlai

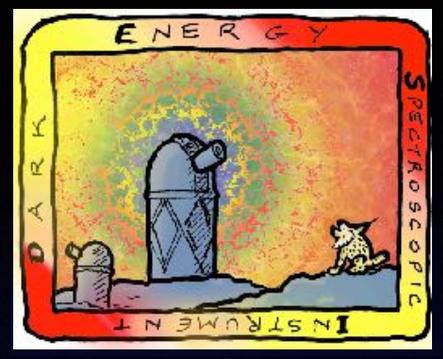
	Cylinders	Width	Length	Dual Pol. Units/Cylinder	Frequency
Pathfinder	3	15 m	40 m	32	700–800 MHz
Pathfinder+	3	15 m	40 m	72	700–800 MHz
Full scale	8	15 m	120 m	256	400–1420 MHz

Credit: X. Chen, L. Zhang

Dark Energy Spectroscopic Instrument



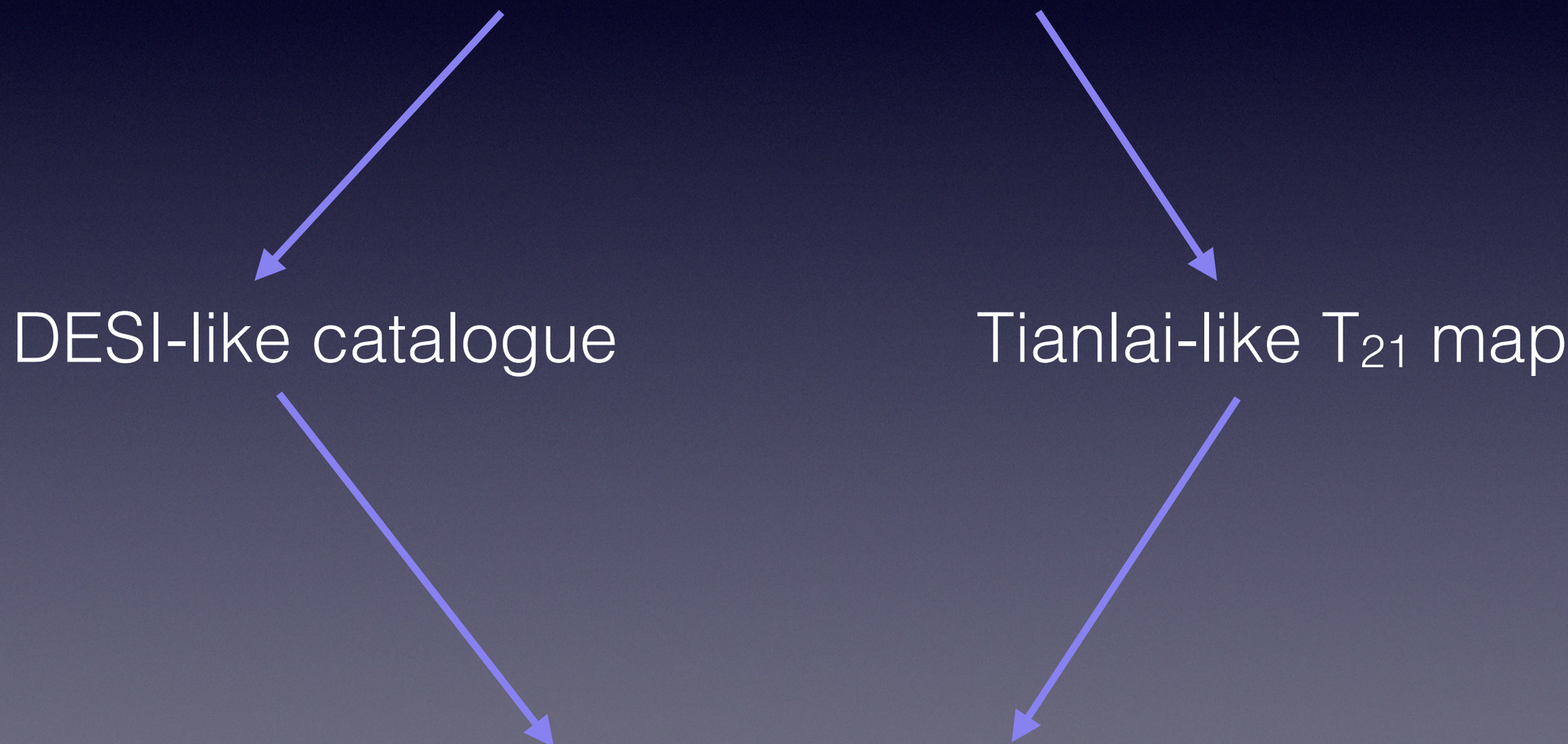
Dey et al, 2018



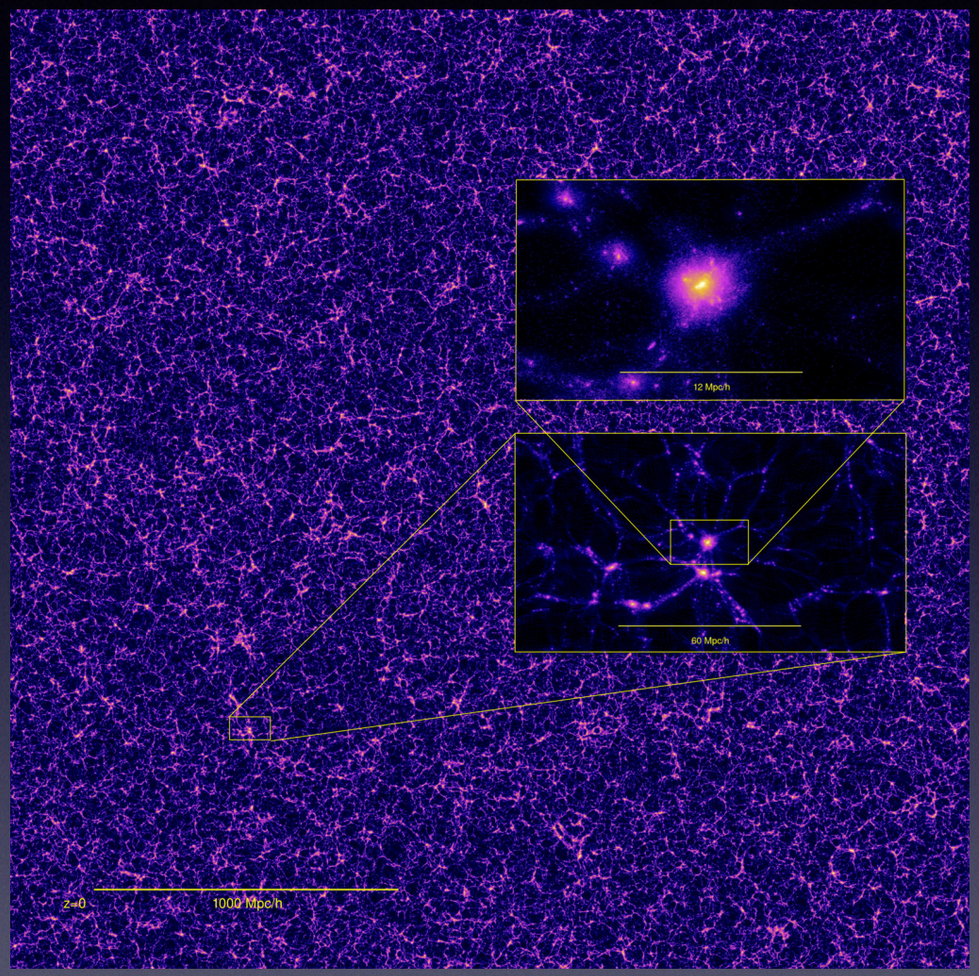
- 5000 fibre multi-object spectrograph at 4m Mayall telescope.
- 35 million galaxies in 14000 sq. degs.
  - 35 million ELGs
  - 4 million LRGs
  - 2.4 million QSOs
- Main goals are BAO and RSD but also great opportunities for cross-correlations.

Plan

N-body sim
(e.g. Horizon Run 4)

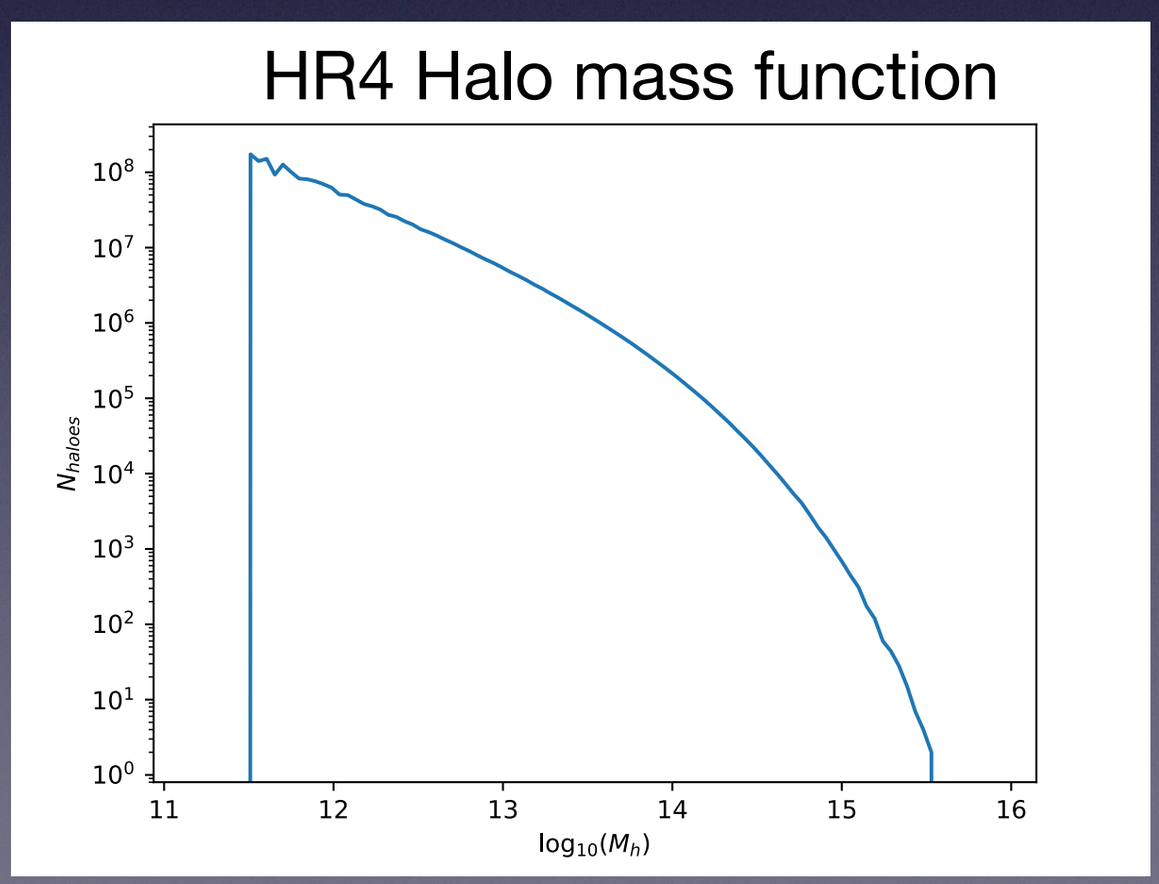


N-body simulation: Horizon Run 4

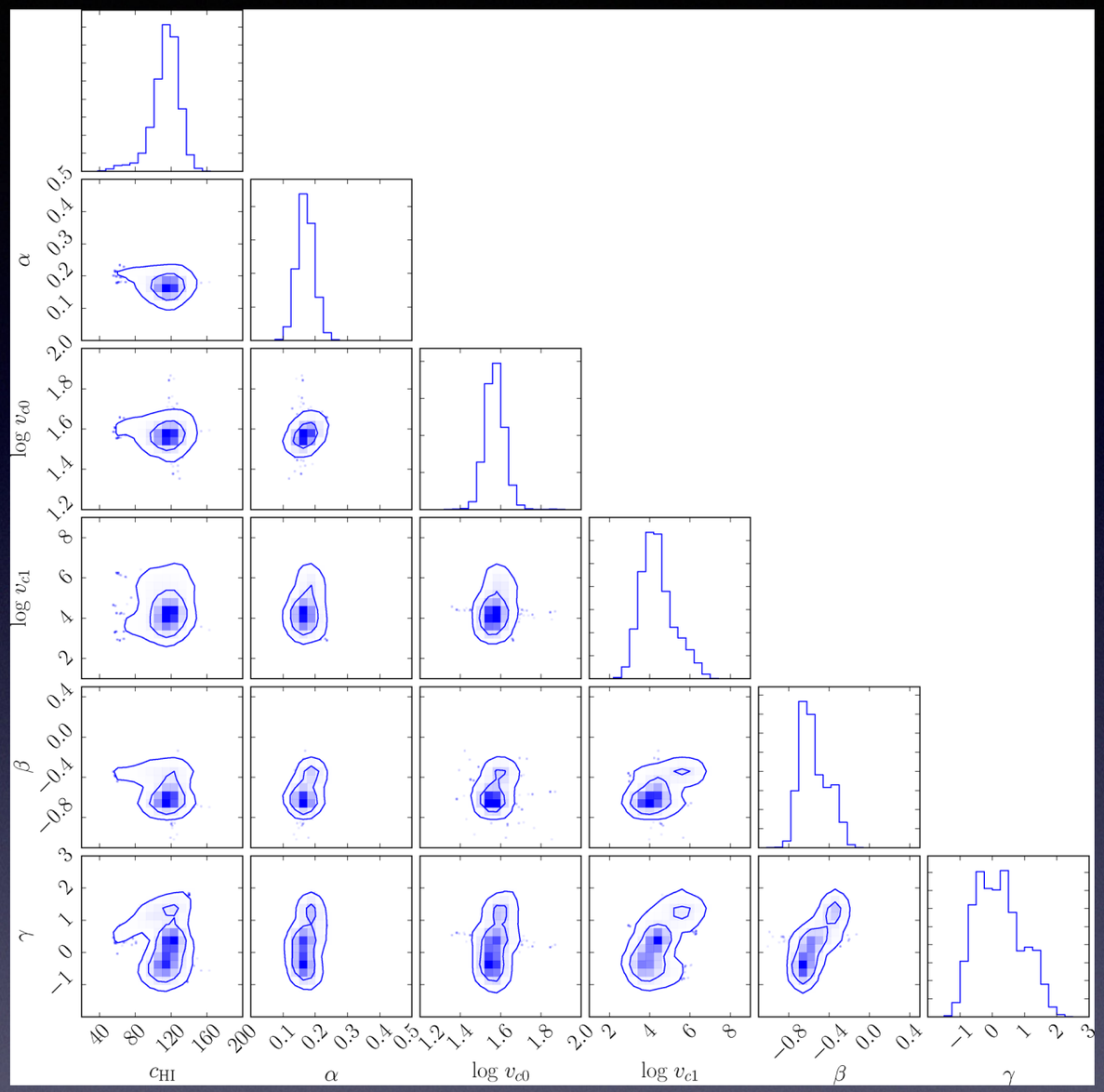


- LCDM N-body simulation
- Box size: 3150 h^{-1}Mpc
- $N_{particles}$: 6300^3
- Lightcone to z=1.5
- Mp = 9×10^9 $M_\odot h^{-1}$

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



Halo model for neutral hydrogen

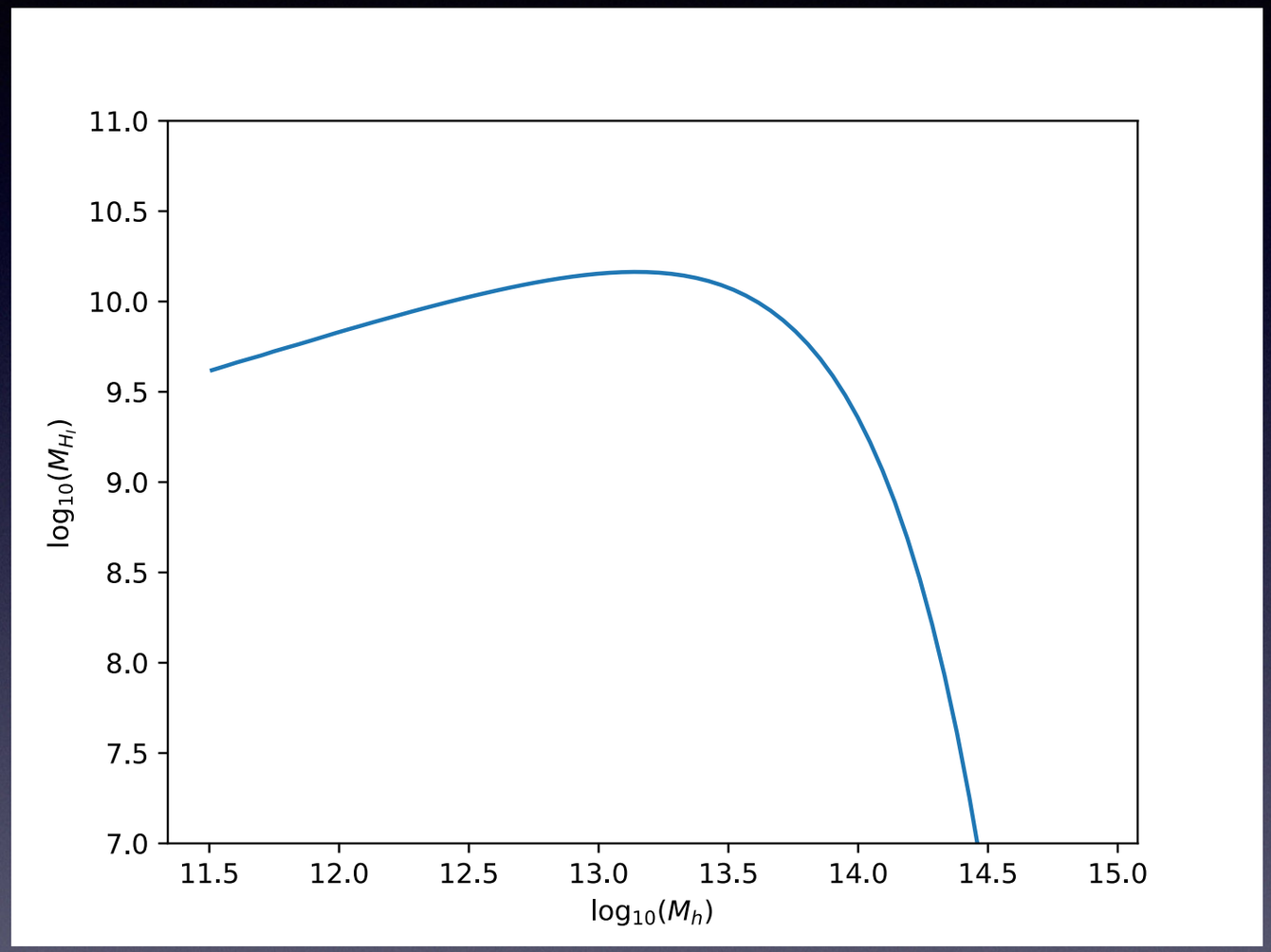


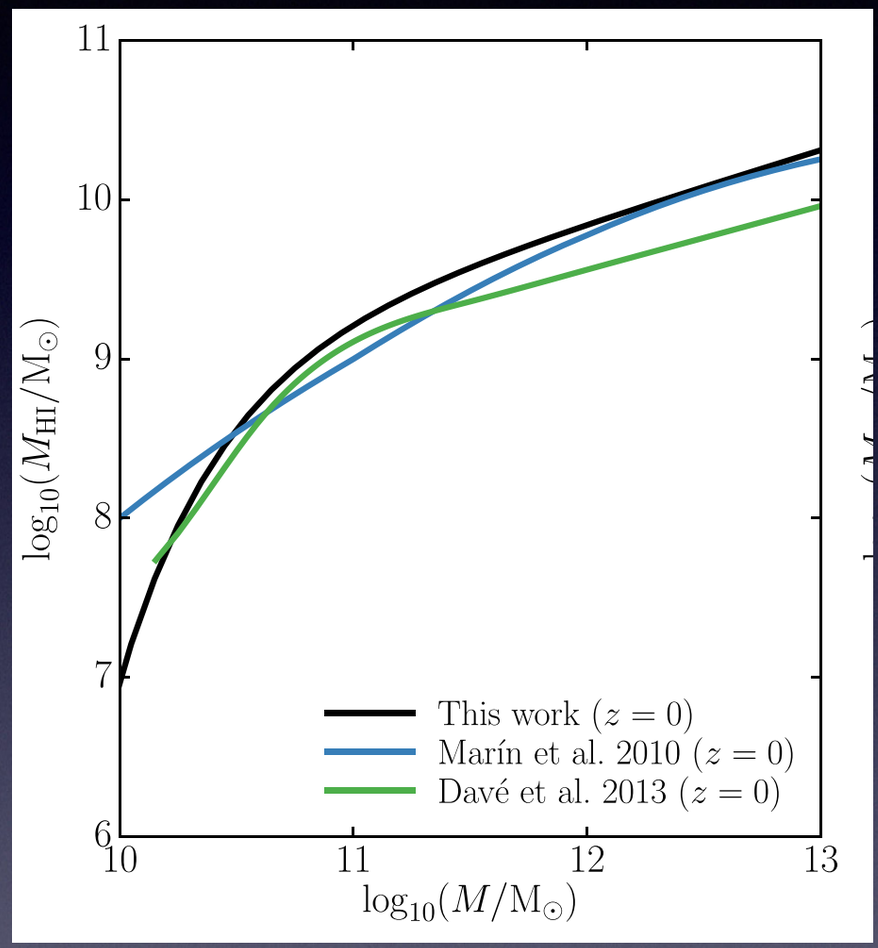
- Halo model with best fit parameters from low, intermediate and high redshift neutral hydrogen probes.

$$M_{HI}(M_h) = f_{HI} f_c M_h \left(\frac{M_h}{10^11 M_\odot}\right)^\beta \exp\left[-\left(\frac{v_{vc0}}{\sigma_v(M_h)}\right)^3\right] \exp\left[-\left(\frac{\sigma_v(M_h)}{v_{c1}}\right)^3\right]$$

Padmanabhan H., Refregier A., 2017

Neutral hydrogen mass function

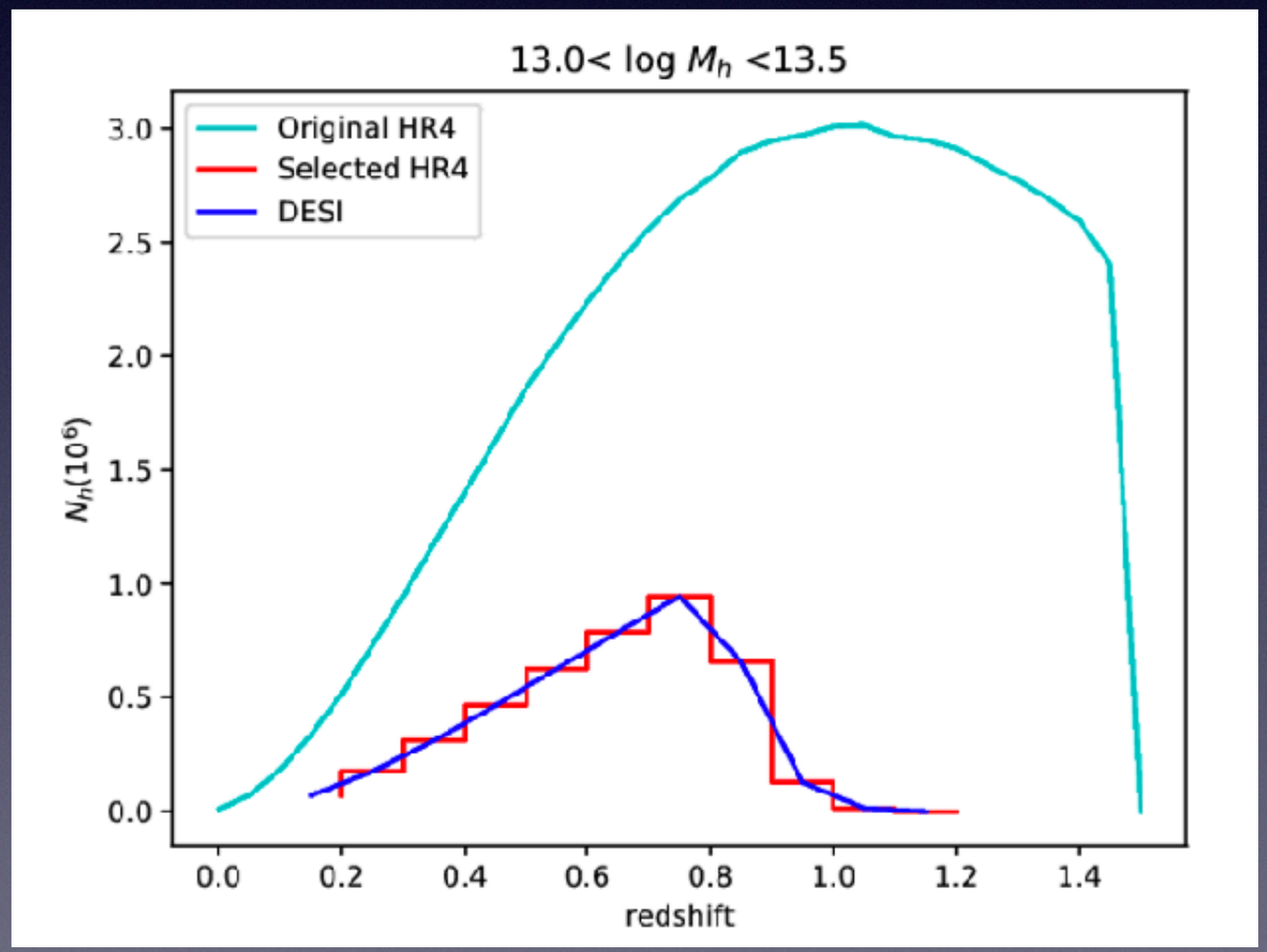


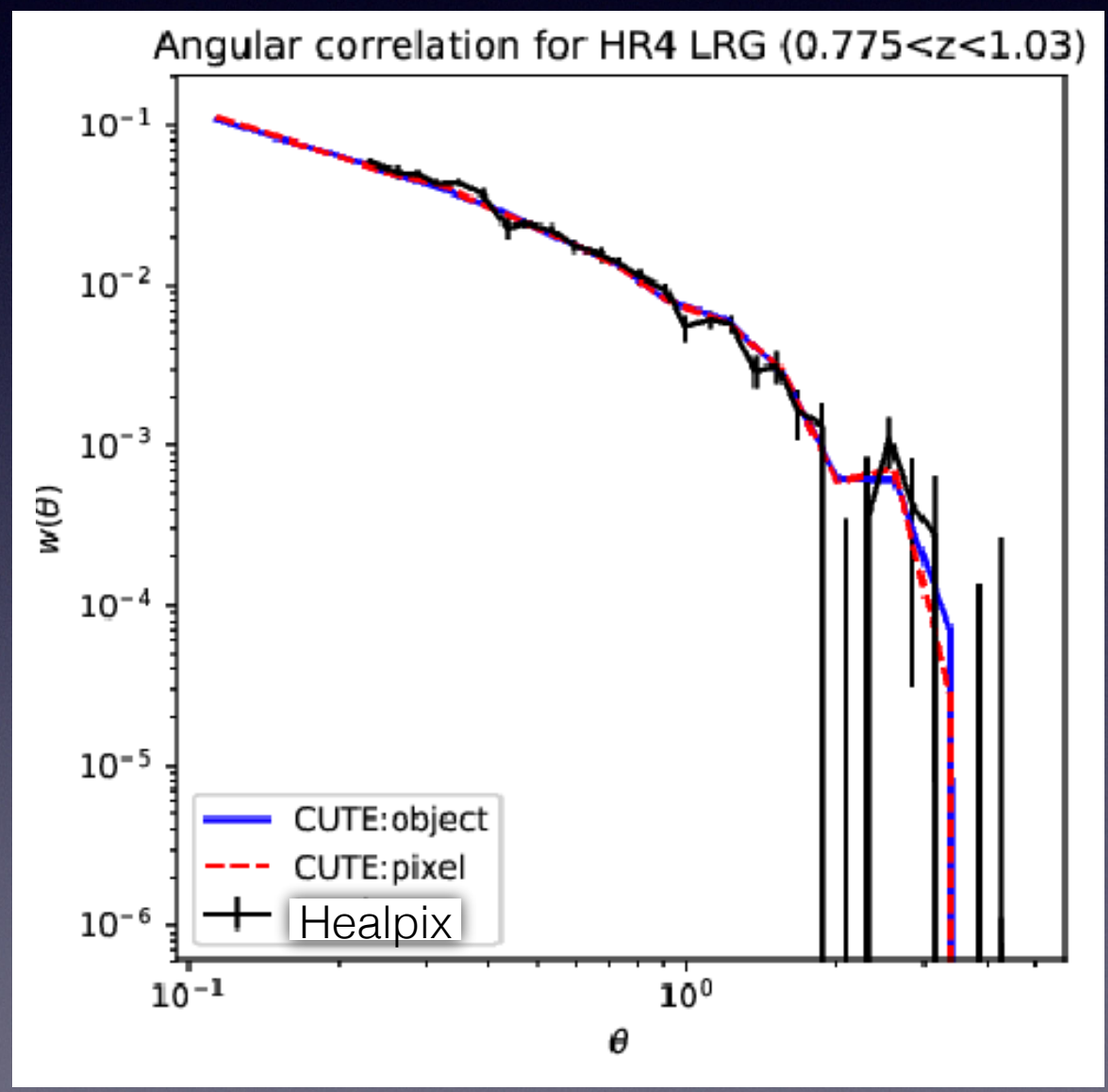


Padmanabhan H., Refregier A., 2017

Mock halo ‘galaxy’ catalogues

- ‘LRG sample’: 13<log Mh<13.5
- ‘ELG sample’: 12<log Mh<13





Credit: F. Shi

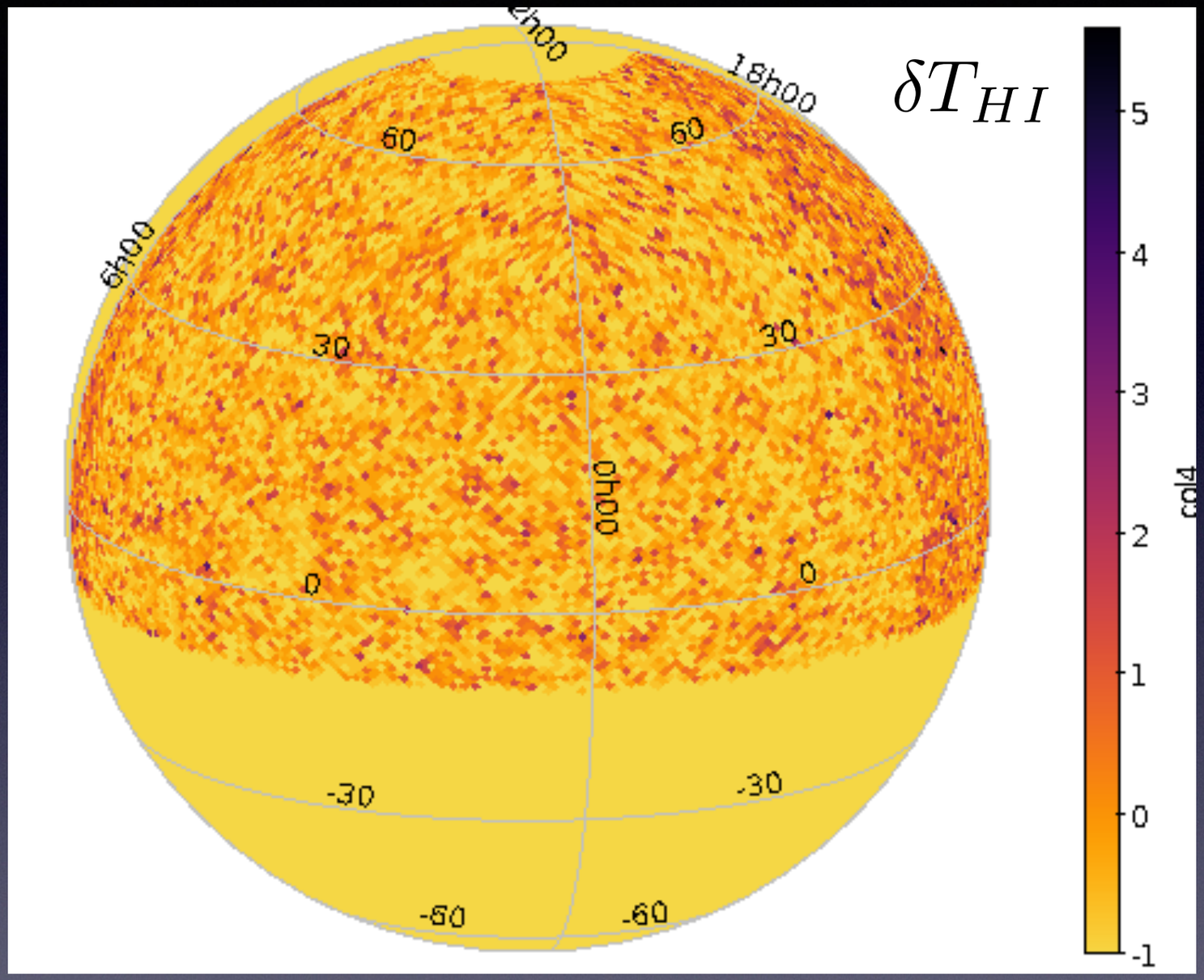
Intensity mapping maps

Example:
f1 = 700 MHz
f2 = 800 MHz

Nz = 50, dz = 0.005

Nside = 512

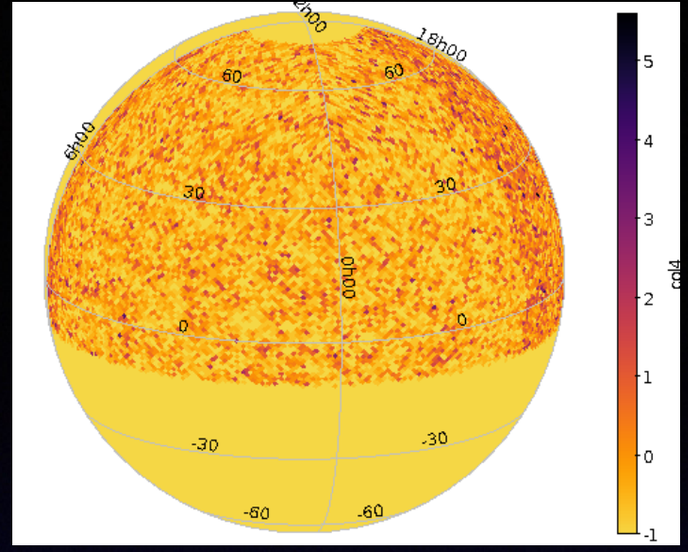
Total redshift range:
0.775 < z < 1.03



- **Ongoing verification and creation of maps for:**
  - **different angular resolutions (e.g. Tianlai)**
  - **different redshift resolution (e.g. DECaLS x Tianlai pathfinder)**

Foregrounds

- Intensity mapping extremely sensitive to foregrounds (especially in auto-correlations.
- Plan: simulate foregrounds from noise power spectra (e.g. CORA, ForGet)
- Foreground removal (Wolz et al. 2013



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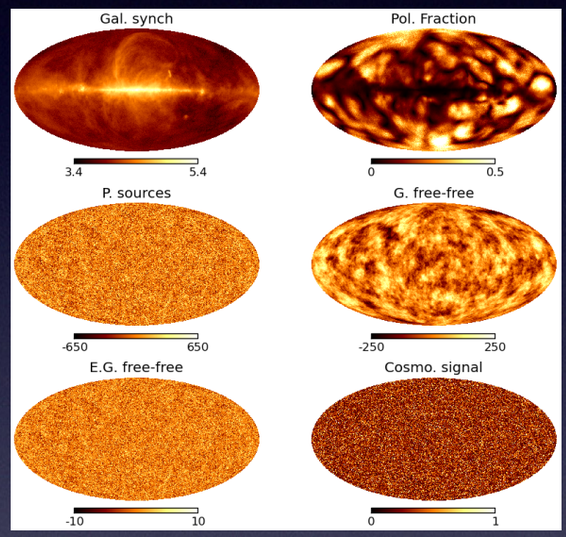
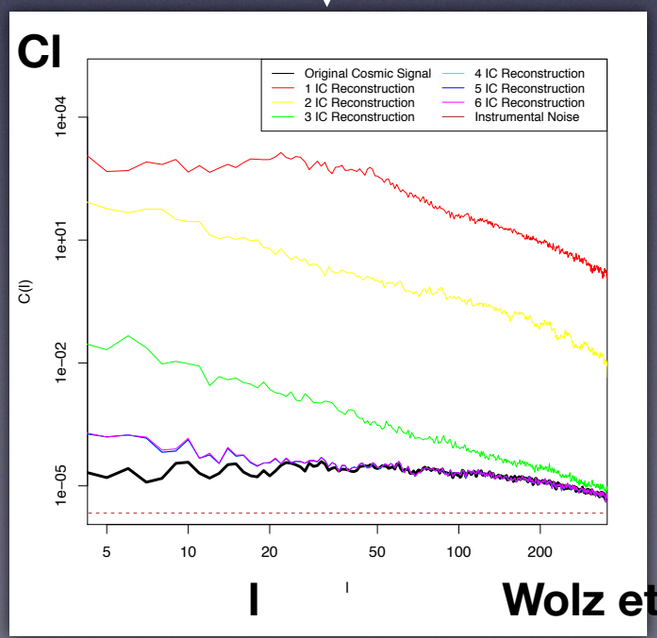
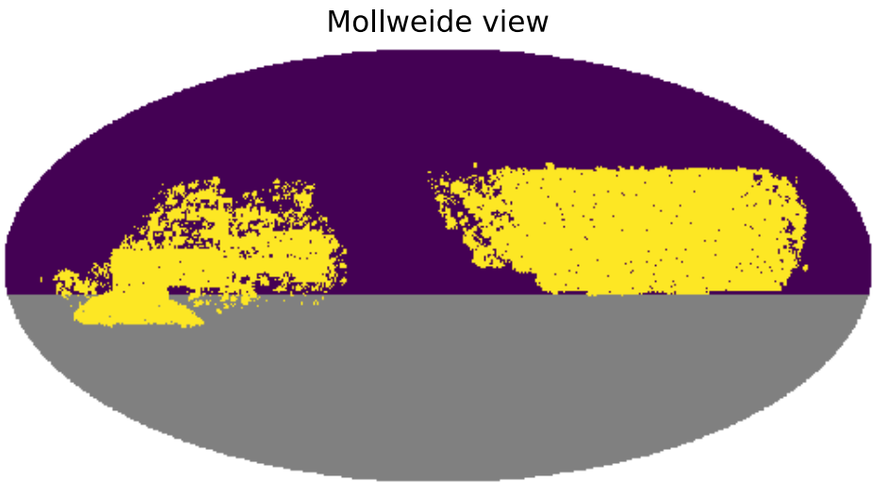


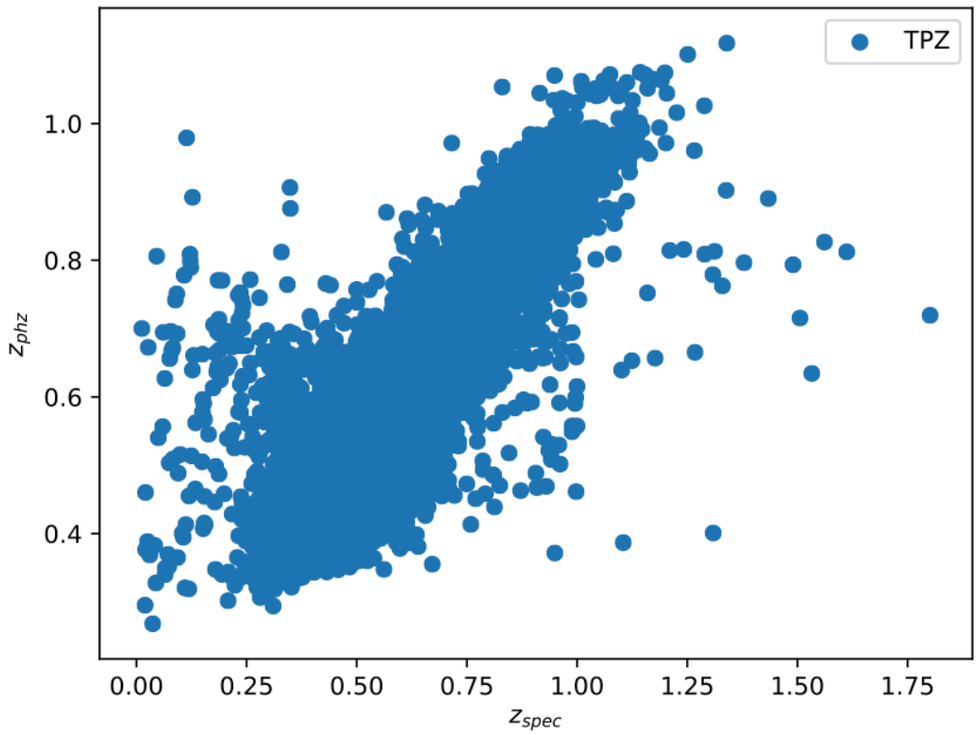
Alonso et al. 2014



Wolz et al, 2013

Cross-correlation with photo-z catalogues





- **Tianlai and DECaLS overlap so possibility of cross-correlation between them.**
- **Caveats: radio foregrounds at large scales and photo-z at small scales**

Summary

- Intensity mapping is a promising probe for the future years.

- Cross-correlations between optical surveys and intensity mapping surveys can help us deal with the foregrounds and also understand galaxy evolution.

- Tianlai and DESI will overlap opening a great opportunity for this cross-correlations.

- Ongoing creation of mock intensity maps to study the DESI x Tianlai case (and also DECaLS x Tianlai).

감사합니다

Thank you!

Ongoing & Future

- Halo catalogue with hydrogen masses **done**
- LRG and ELG subsamples **done**
- Check of angular correlations codes **done**
- First intensity mapping maps **done**
- Measuring auto and cross-correlations for LRG and ELG mocks **ongoing**
- Creation of foreground maps **ongoing**
- Cross-correlations between DECaLS and TIANLAI pathfinder data **ongoing**
- Develop simulations and test 3D case (including 3D foregrounds