HIR4: Cosmology from a simulated neutral hydrogen full sky using Horizon Run 4

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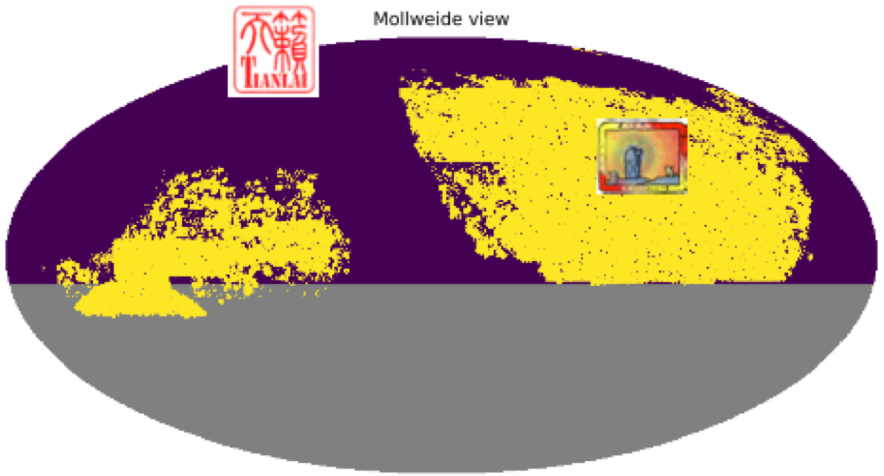
The distribution of cosmological neutral hydrogen will provide a new window into the large-scale structure of the Universe with the next generation of radio telescopes and surveys. In this paper, we simulate future surveys, focusing on the Tianlai pathfinder, of neutral hydrogen using the Horizon Run 4 (HR4) cosmological N-body simulation. We generate **HI intensity maps from the HR4 halo catalogue**, and combine with foreground radio emission maps from the Global Sky Model, to create accurate simulations over the entire sky. We simulate the HI sky for the frequency range 700-800 MHz, matching the sensitivity of the Tianlai pathfinder. We test the accuracy of the fastICA, PCA and log-polynomial fitting foreground removal methods to recover the input cosmological angular power spectrum and measure the parameters. We show the effect of survey noise levels and beam sizes on the recovered the cosmological constraints. We find that while the reconstruction removes power from the cosmological 21cm distribution on large-scales, we can correct for this and **recover the input parameters in the noise-free case**. However, the effect of noise and beam size of the **Tianlai pathfinder** prevents accurate recovery of the cosmological parameters when using only intensity mapping information.

Context of the research**: Opening new Windows for cosmological large-scale structure**

- Radio observations will allow us to access bigger volumes of matter clustering. Crucial to understand evolution of the Universe between early and late time expansion history and solve tensions.
- Great overlap between the 21cm survey experiment Tianlai (China) and optical survey the Dark Energy Spectroscopic Instrument (DESI, USA).
- Tianlai pathfinder currenty using frequencies between 700 and 800 MHz (redshift ~ 0.78-1.03)

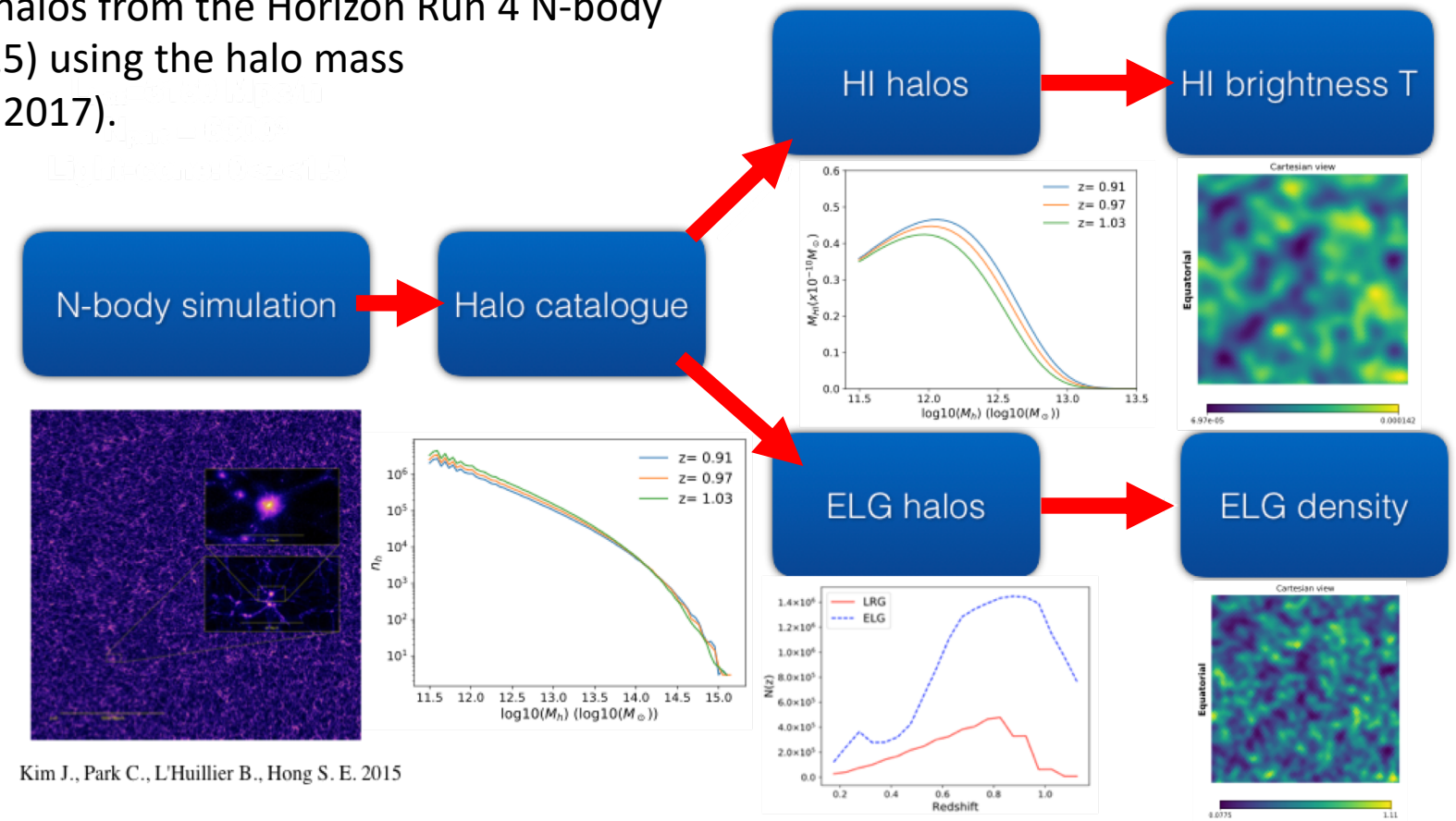


Tianlai (blue/dark) and DESI (yellow/light) footprints

Tianlai Telescope. Credit: NAOC

Methodology: **Painting neutral Hydrogen in the halo canvas**

- We populate Dark Matter halos from the Horizon Run 4 N-body simulation (Kim J. et al., 2015) using the halo mass (Padmanabhan & Refregier, 2017).



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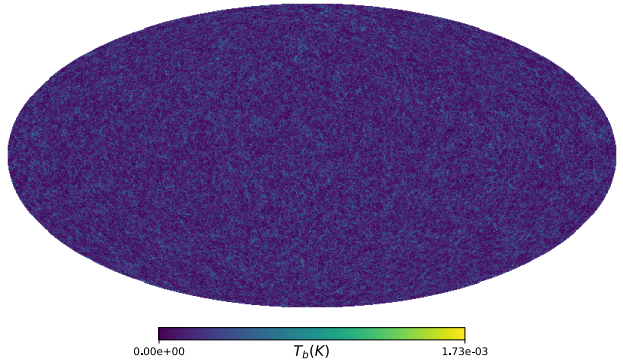
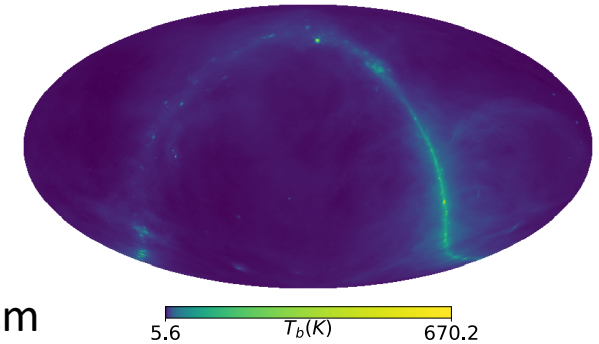
Results: **Full Sky maps of 21cm**

- We add foregrounds to the full sky simulated maps using the foreground model based on data: Global Sky Model (Zheng et al., 2017)
- Foreground removal: Independent Component Analysis (ICA) & Principal Component Analysis (PCA) & log-polynomial fitting.

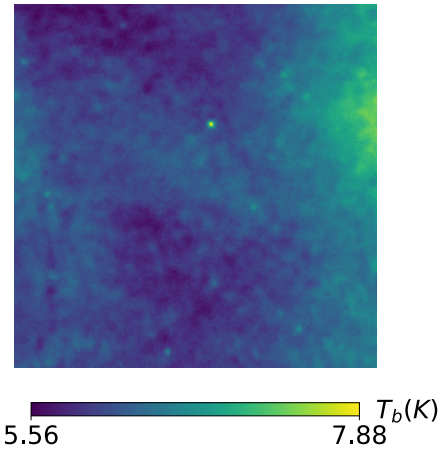
Cosmological 21cm



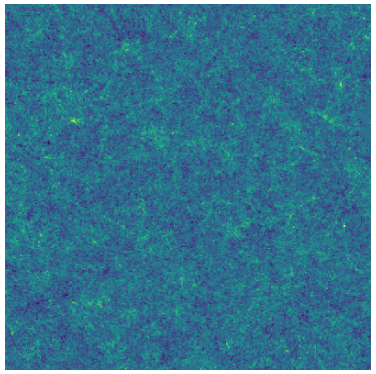
21cm + foreground



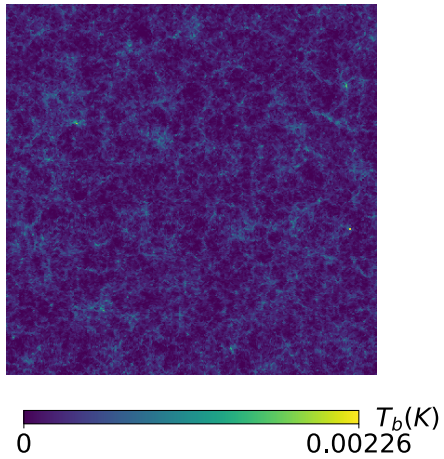
21cm + foreground



Foreground removal



Cosmological 21cm



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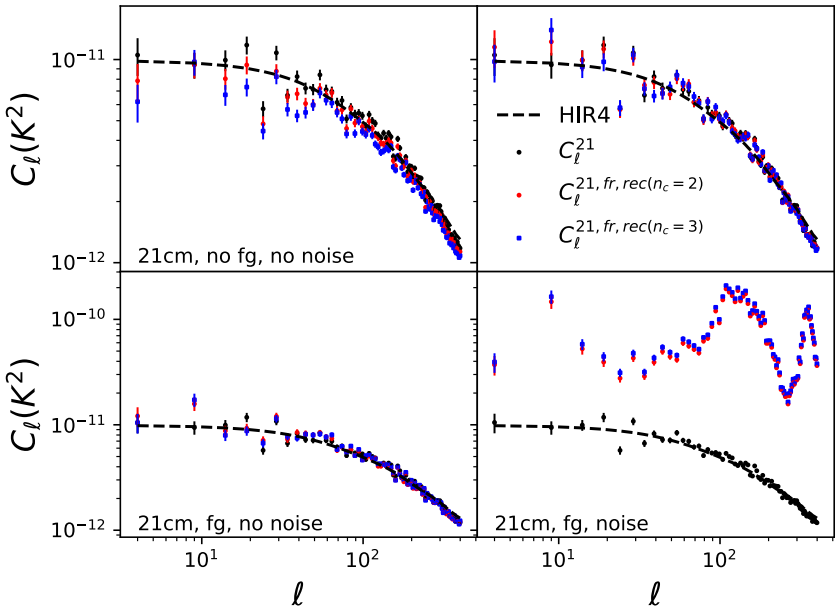
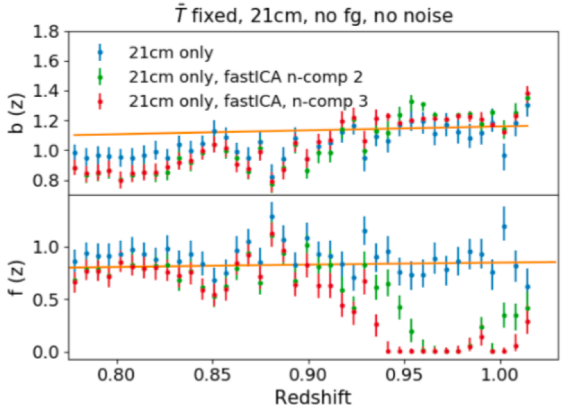
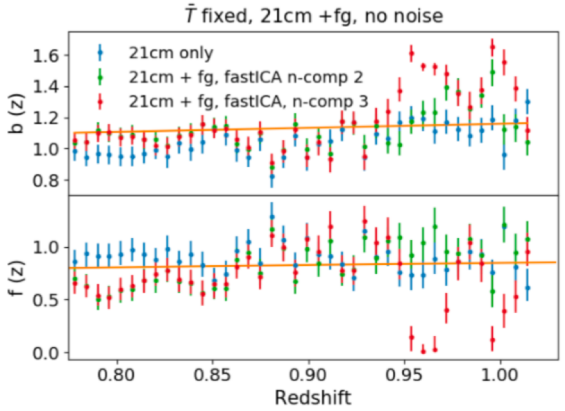
Results: **Cosmological parameters with auto and cross-correlations**

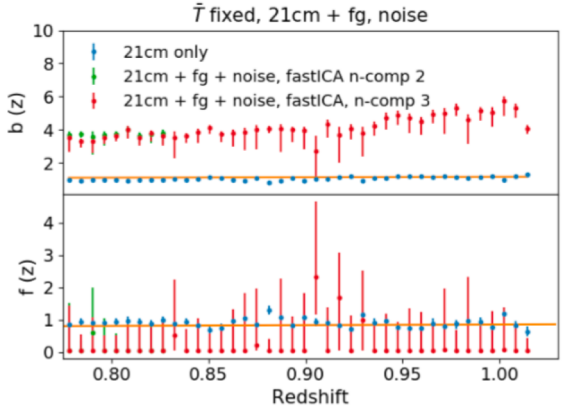
- We measure the angular clustering of 21cm maps with foregrounds and with noise.
- We can recover input cosmology when removing foregrounds.
- We cannot recover the input cosmology when including instrument noise for Tianlai pathfinder.

Angular power spectra & foreground removal









Cosmological Fits to Galaxy bias and linear growth of structure rate. Simulation input theory with solid lines.

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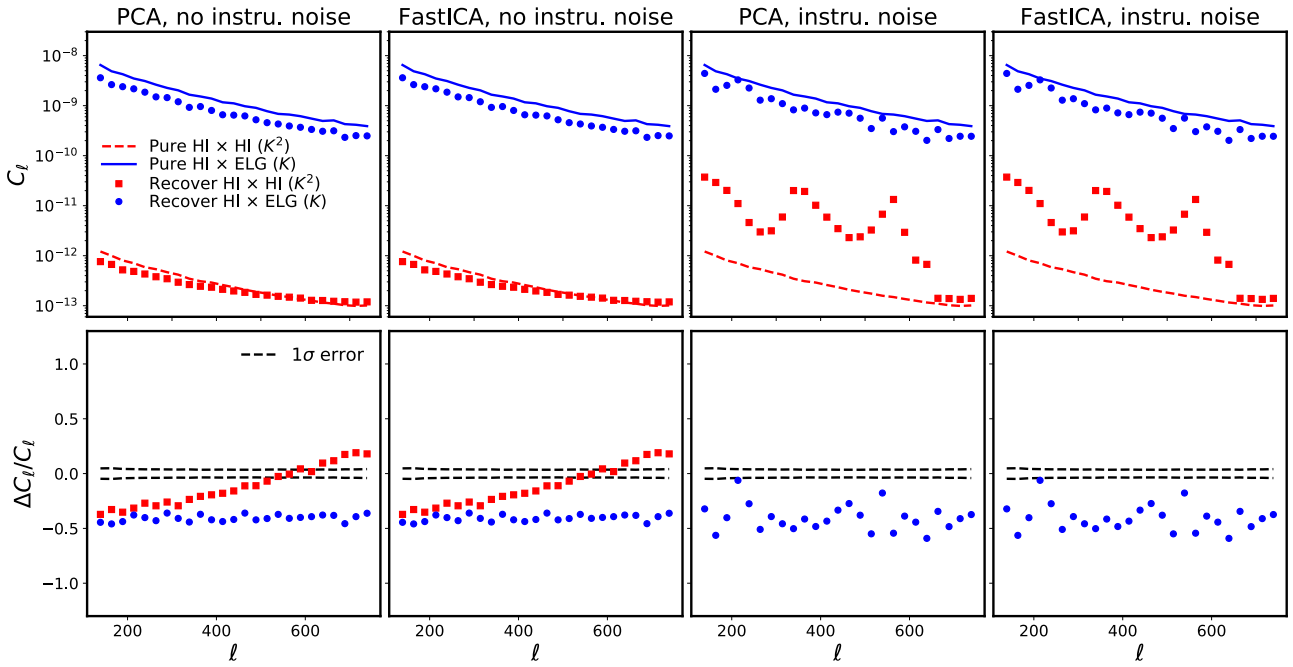
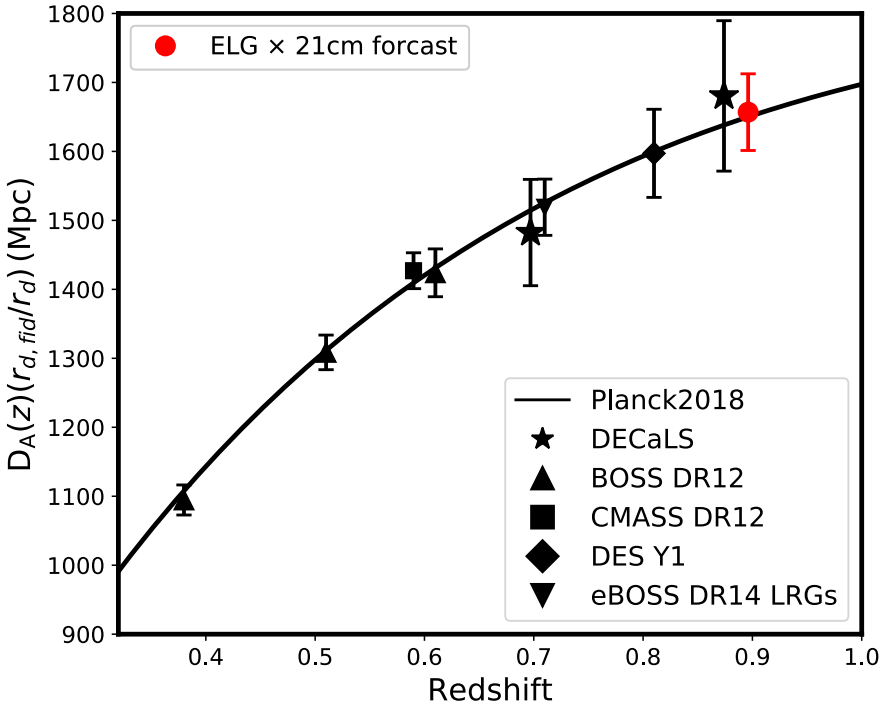
Impact/Conclusions: **Forecast for Tianlai Pathfinder**

- Instead of using auto-correlations **->** Use cross-correlations with optical data. Different systematics
- Prospects for Tianlai distance estimation as good as with optical surveys and at higher redshift.
- New observational window to Cosmology with radio telescopes.





F. Shi, Y-S. Song, J. A, D. Parkinson, K. Ahn, J. Kim, J. Yao, L. Zheng. S. Fuo, arXiv: 2006.01407 (2020)