ETH zürich Cosmology Research Group

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Generation of 21 cm Emission Maps based on a Halo Model Approach

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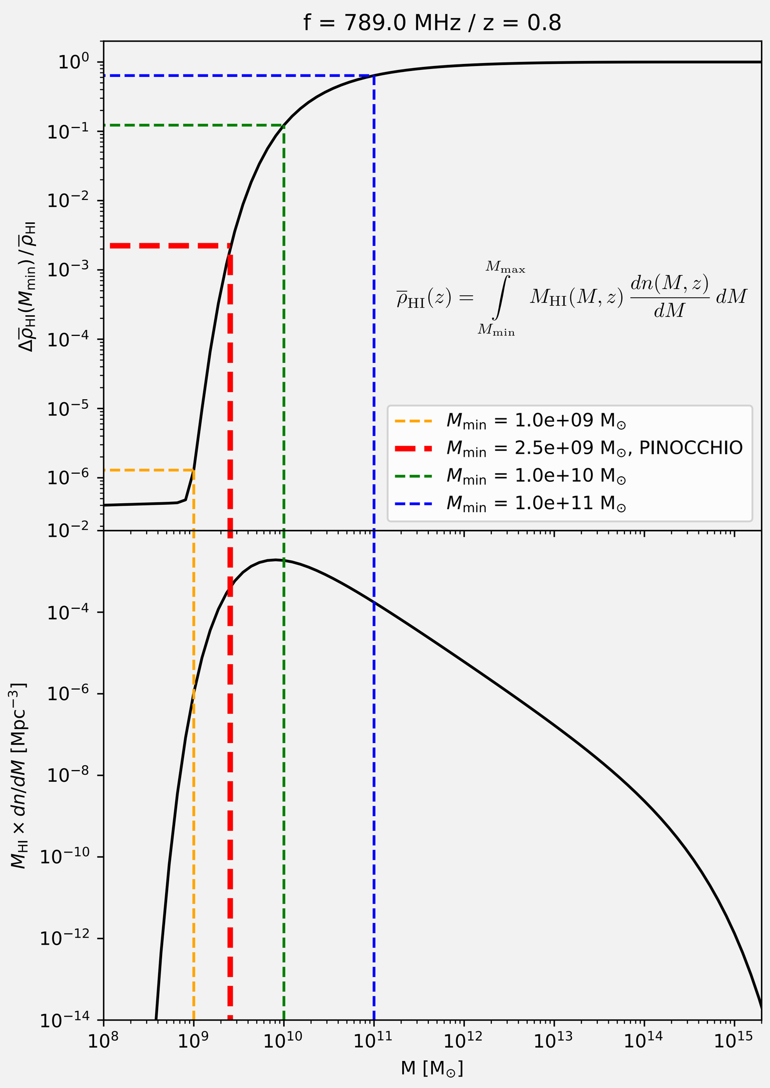
1 Overview

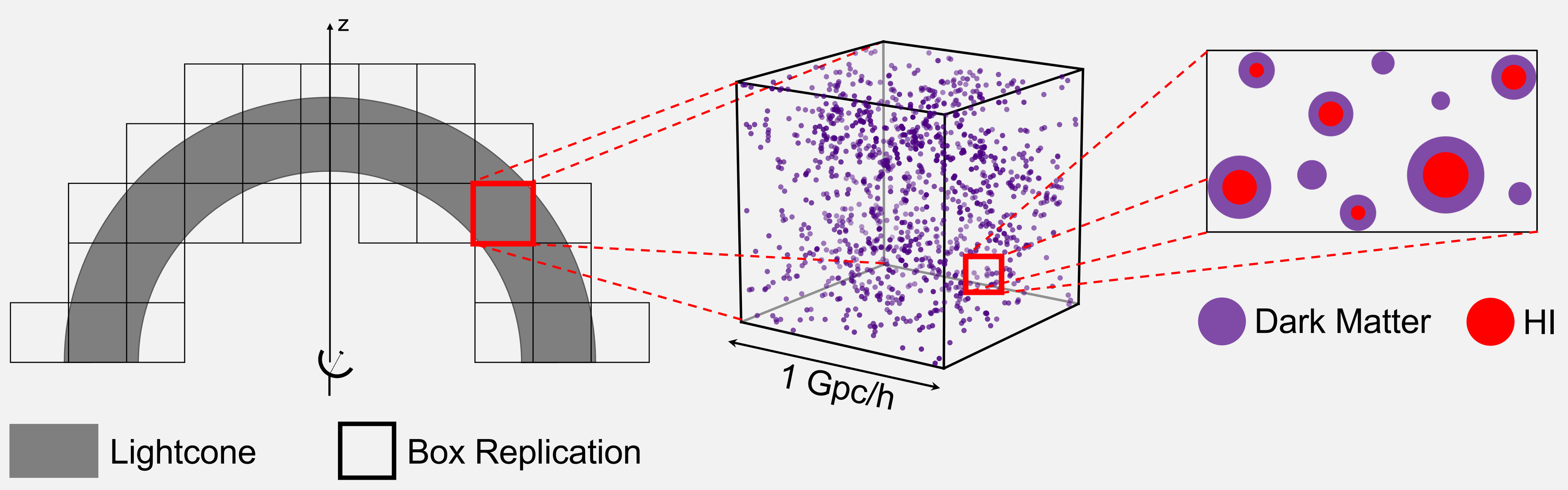
The nature of 21 cm intensity mapping demands large-volume simulations with a high halo mass resolution. Employing the approximate but fast `PINOCCHIO` [1] code, we generate the past light cone of dark matter halos in the frequency range from 700 – 800 MHz, which lies well in the observed frequencies of HIRAX [2]. Subsequently, the halos are populated with neutral hydrogen (HI) according to an HI-Halo mass relation [3]. From that maps with a specific width in the radial direction can be generated. To validate the quality of the maps, they are compared to predictions of a dark matter- and HI-halo model that we implemented in `PyCosmo` [4], a Python-based framework for theoretical cosmological predictions.

2 PINOCCHIO Simulation

`PINOCCHIO` is used to simulate a box with a side length of 1 Gpc/h and 8000^3 particles, which is then replicated to cover the entire light cone over the frequency range from 700 – 800 MHz (0.77 < z < 1.03). The smallest simulated halos have masses of $2.5 \times 10^9\ M_\odot$, resulting in a relative loss of <0.6% of HI mass over the simulated frequency range.

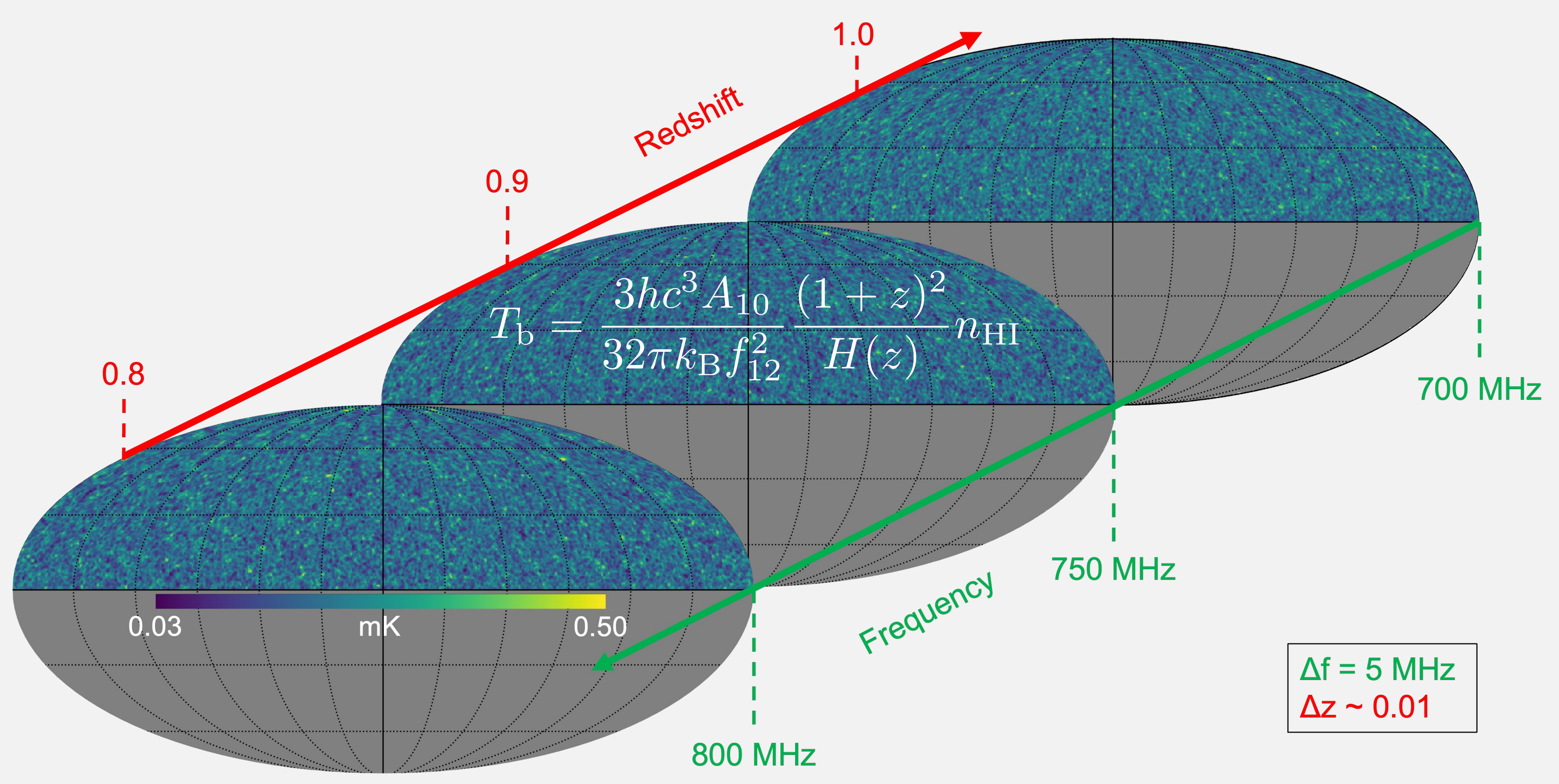
There is more HI in large dark matter halos, but there are many more small halos, making their contribution to the total HI content not negligible.





3 HI Brightness Temperature Maps

To resolve the structure along the line of sight, the light cone is sliced into 20 maps with a width of 5 MHz. The HI mass of each halo is converted into the HI brightness temperature [5], as this is the actual observed signal. The signal is then averaged within voxels according to the 3D positions of the halos. `HEALPix` [6] is used for pixelation, with *NSIDE* set to 512.

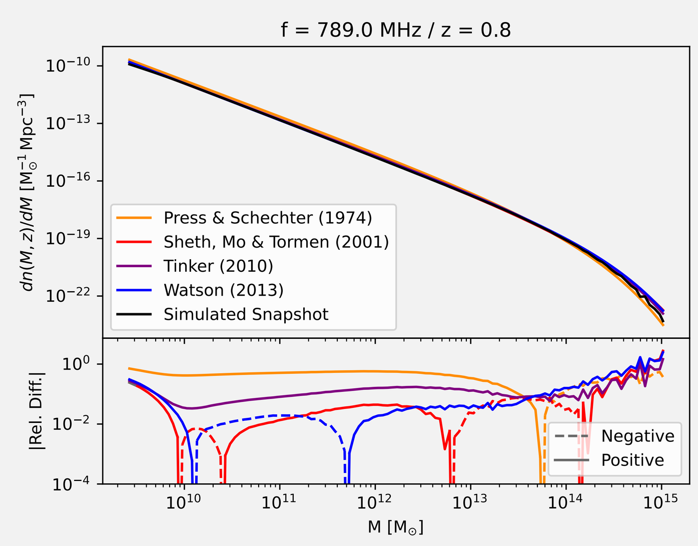


4 Statistical Comparison with PyCosmo

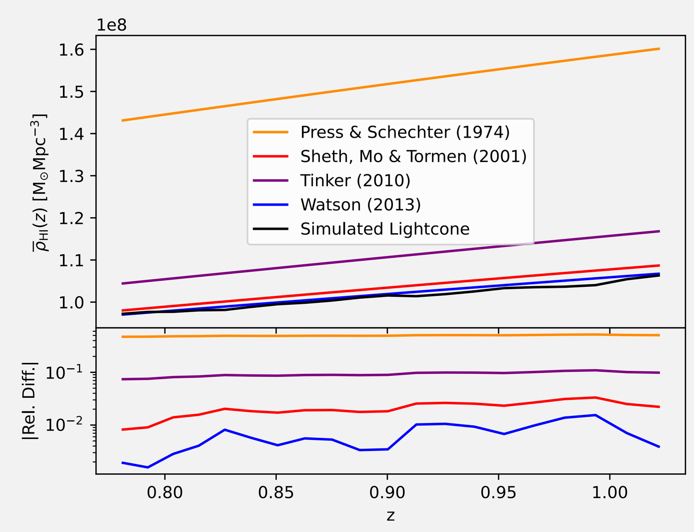
Since the simulations are based on the distribution of dark matter halos, a flexible dark matter- and HI-halo model has been implemented to `PyCosmo`. The halo model assumes that all matter in the universe resides in halos and allows to predict statistical properties of the simulations.

`PyCosmo` offers four options for the dark matter halo mass function, which can be compared to results of the simulated mass function and HI mass density:

Mass Function

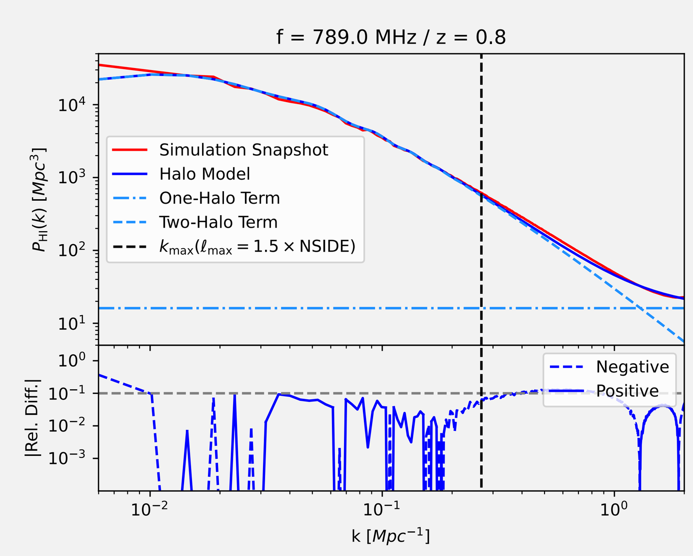


HI Mass Density

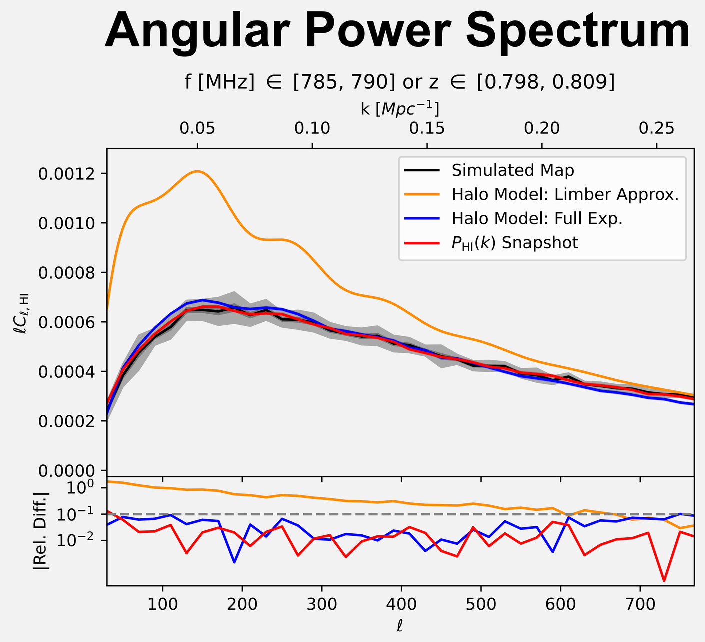


The best agreement to simulation for the mass function and HI mass density is found for the mass function by Watson et al. [7]. Therefore, the clustering properties in terms of the following 3D power spectrum and angular power spectrum are calculated using that one:

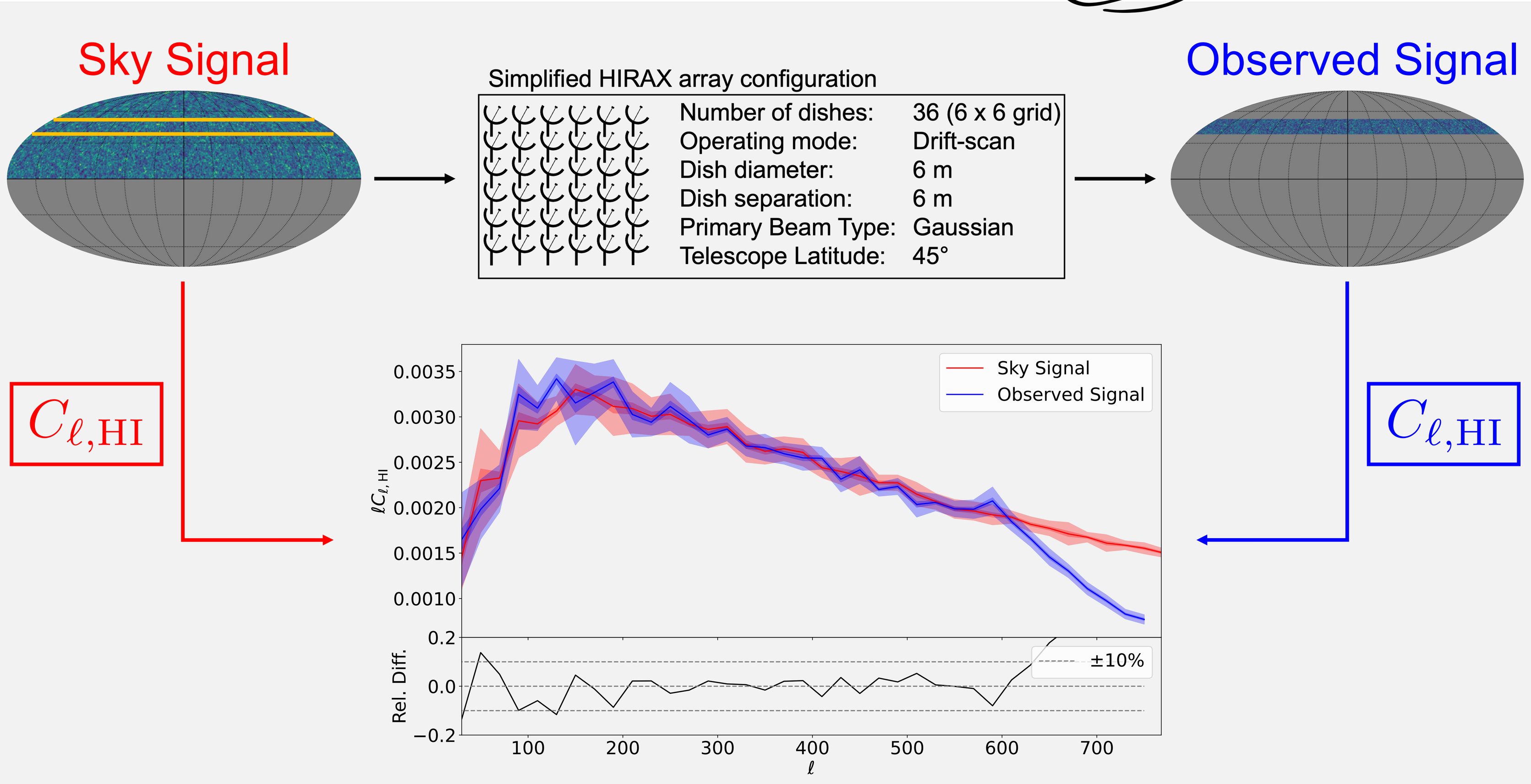
3D Power Spectrum



Angular Power Spectrum



5 Application of the Maps to HIRAX



References

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[6] K. M. Gorski et al. (2005), *Astrophys. J.*, **622** 759
[7] W. A. Watson et al. (2013), *MNRAS*, **433** 1230 – 1245

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