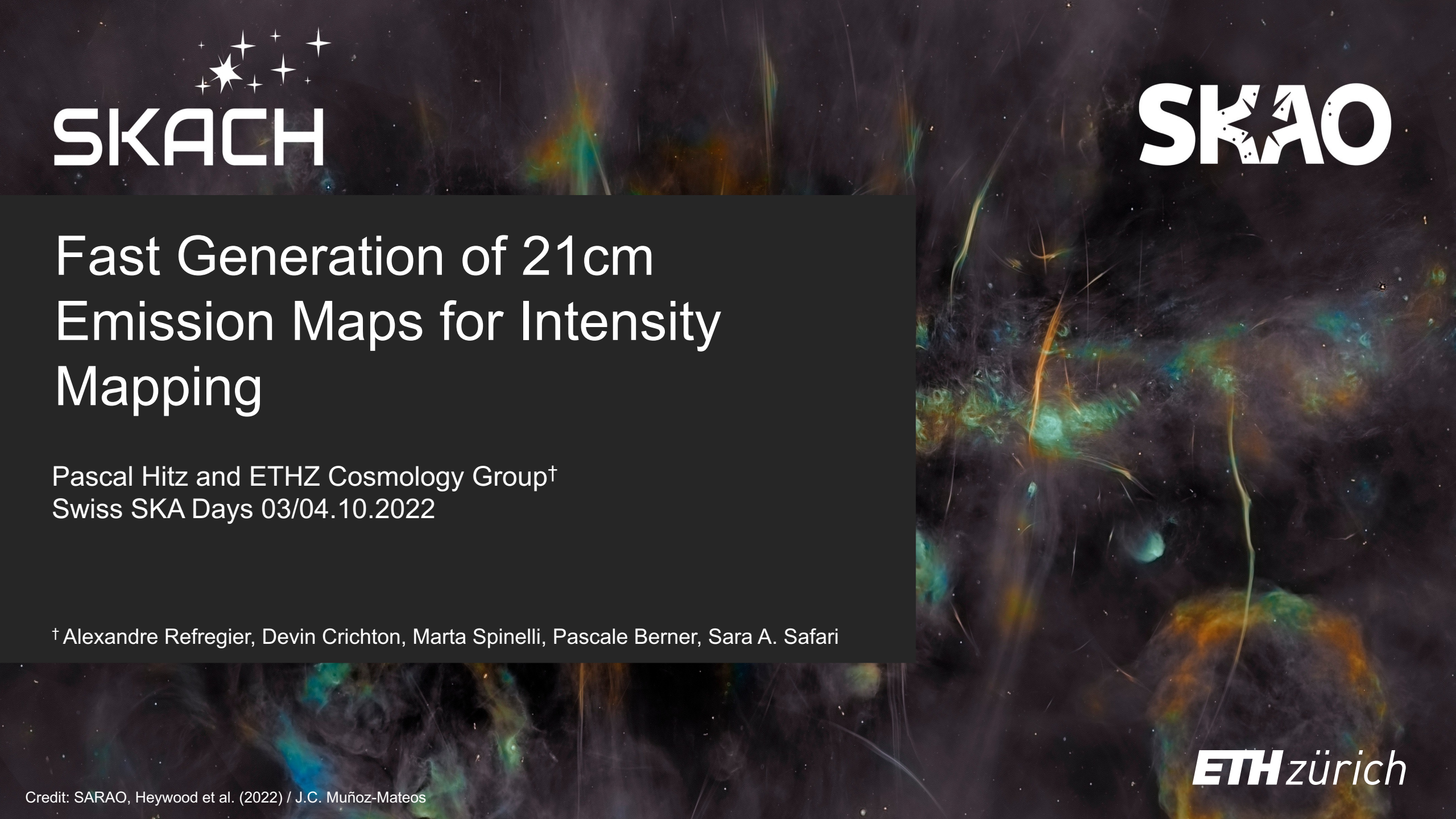


Fast Generation of 21cm Emission Maps for Intensity Mapping

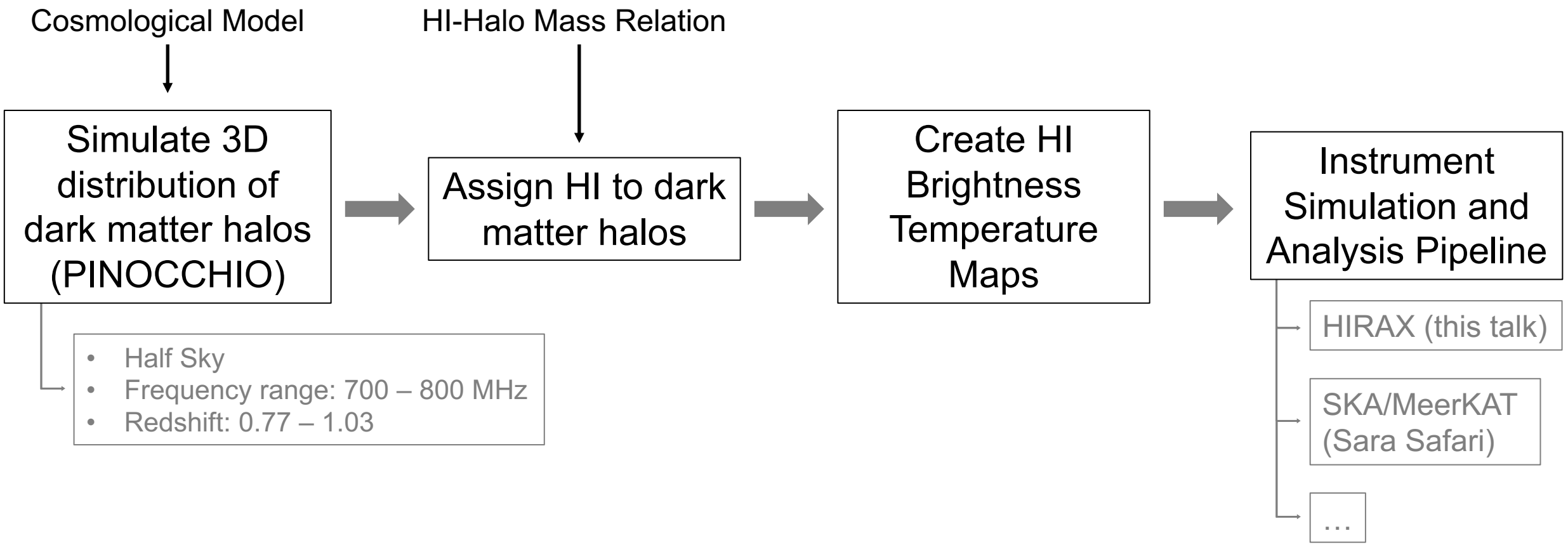
Pascal Hitz and ETHZ Cosmology Group†
Swiss SKA Days 03/04.10.2022

† Alexandre Refregier, Devin Crichton, Marta Spinelli, Pascale Berner, Sara A. Safari

Credit: SARAO, Heywood et al. (2022) / J.C. Muñoz-Mateos

Overview

- Fast and large volume simulations of neutral hydrogen (HI) distribution
- Test instrument simulation and analysis pipeline to measure the HI emission

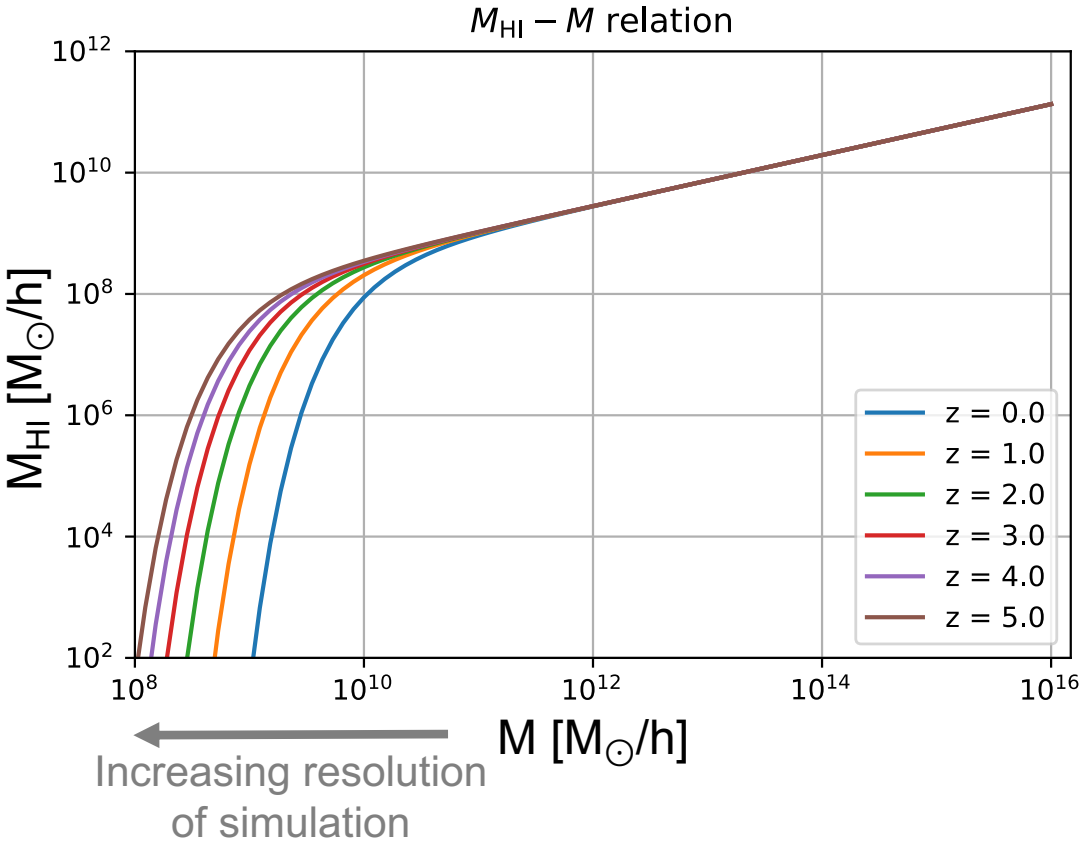


Halo Model for Cosmological HI

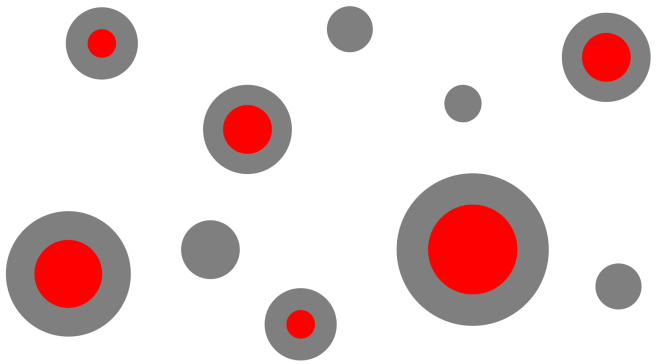
HI-halo mass relation fitted to observations:

$$M_{\mathrm{HI}}(M,z) = \alpha f_{\mathrm{H,c}} M \left(\frac{M}{10^{11} h^{-1}\mathrm{M}_\odot}\right)^{\beta} \exp\left[-\left(\frac{v_{\mathrm{c},0}}{v_{\mathrm{c}}(M,z)}\right)^{3}\right]$$

Padmanabhan et al. 2017



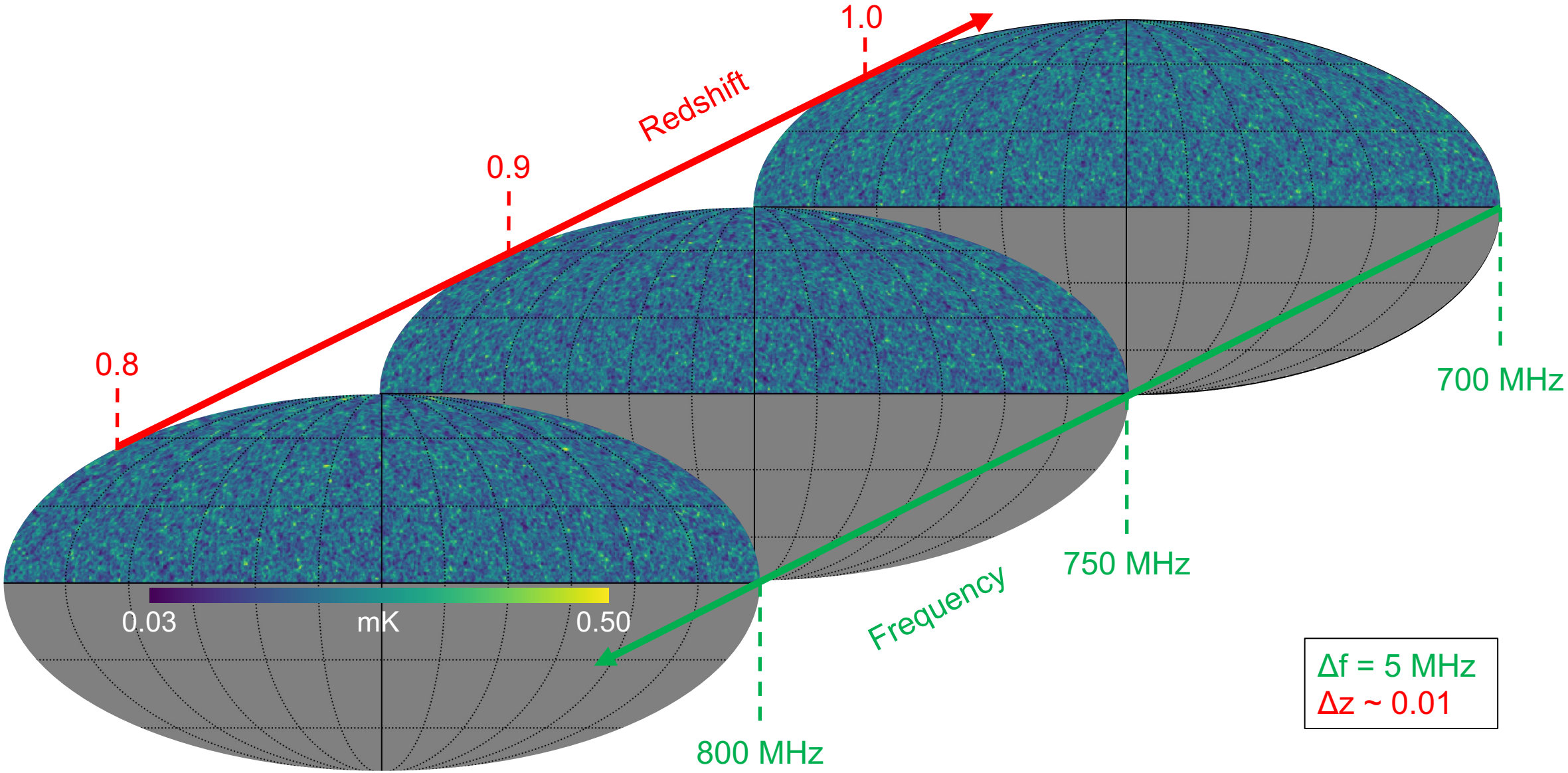
Dark Matter
Neutral Hydrogen



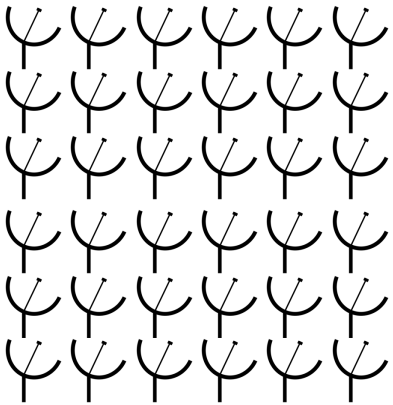
- More massive halos contain more HI
- Many more small halos than large ones

➔ Do not neglect small halos.

Brightness Temperature Maps



Instrument Simulation and Analysis Pipeline



Number of dishes:	36 (6 x 6 grid)
Operating mode:	Drift-scan
Dish diameter:	6 m
Dish separation:	6 m
Primary Beam Type:	Gaussian
Telescope Latitude:	45°

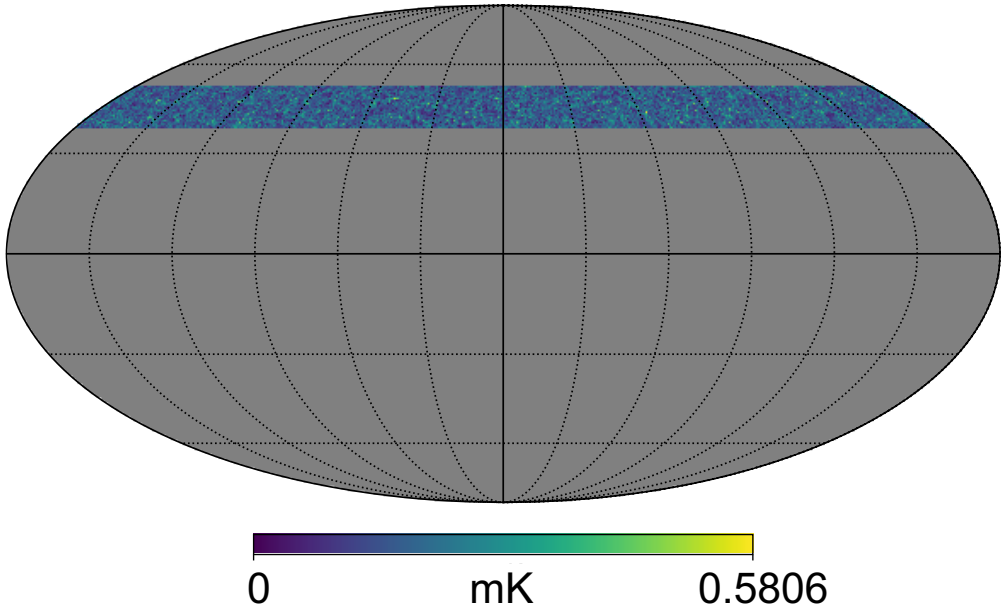
Simplified HIRAX array configuration

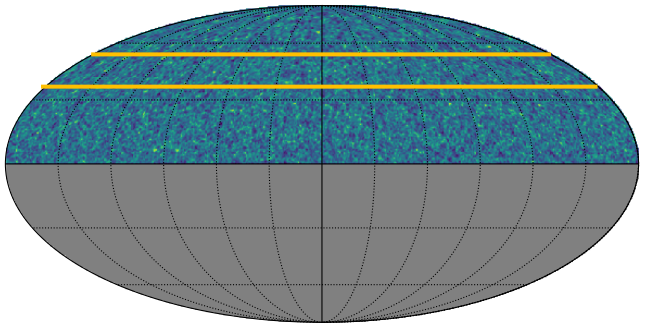
Construct instrument model

Generate synthetic data: Visibilities

Map Making

Recovered Map





Angular Power Spectrum

Angular Power Spectrum

ETH zürich

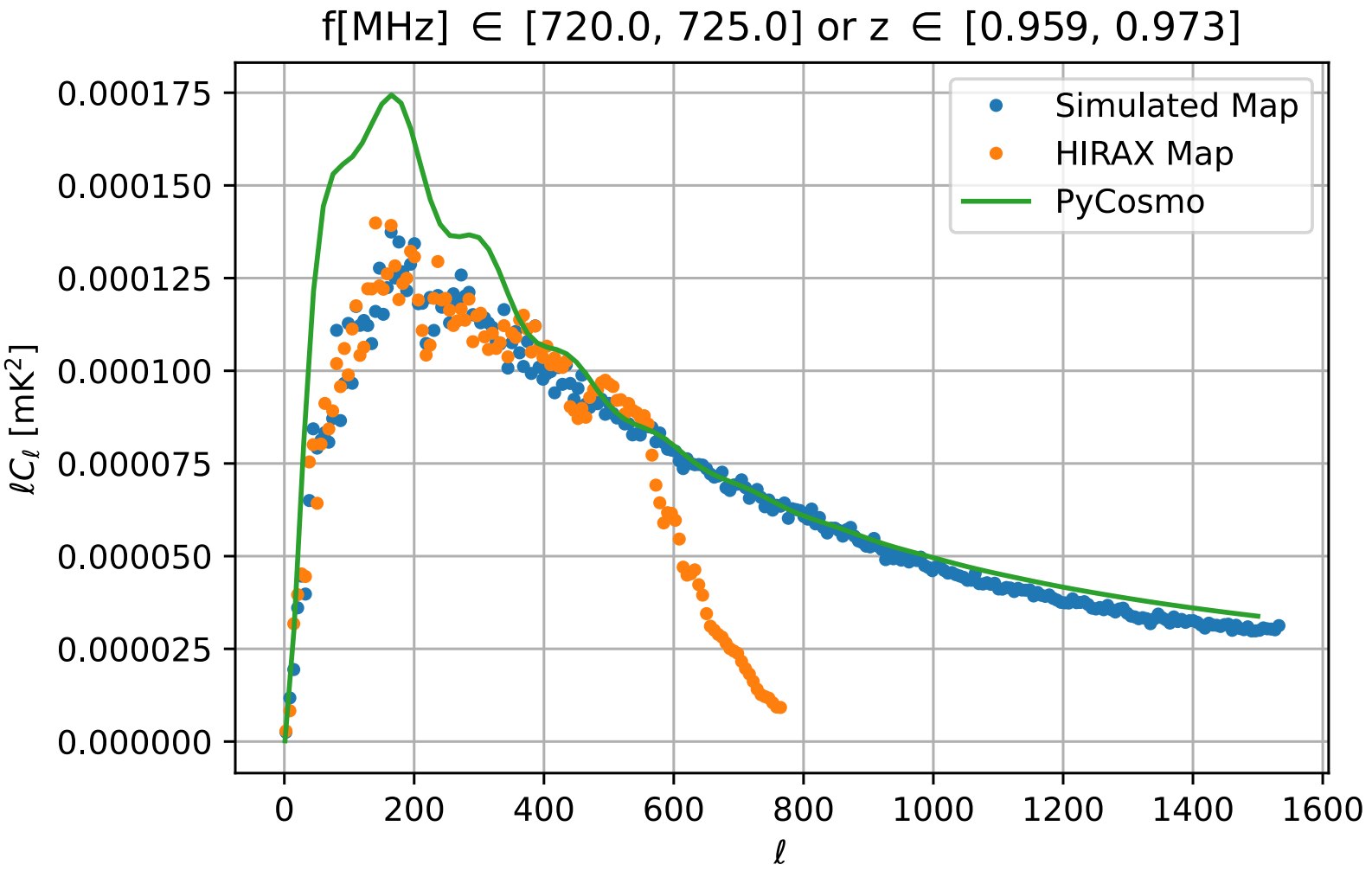
HI Angular Power Spectrum

- Simulated Map:
  Input sky model
- HIRAX Map:
  Output map of analysis pipeline
- PyCosmo:
  Theoretical prediction
  Refregier et al. 2017

Summary:

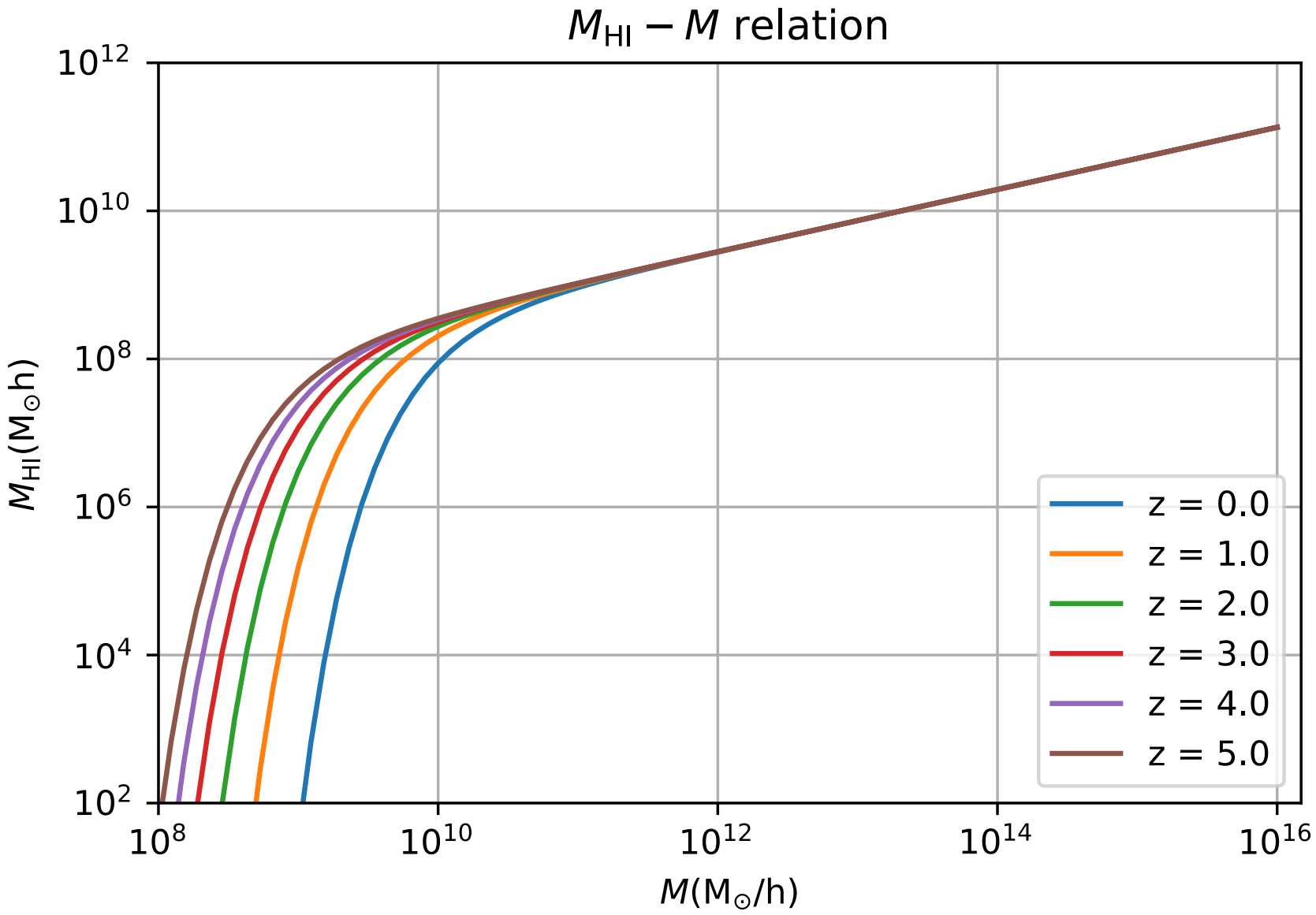
- Simulation pipeline of HI maps for intensity mapping
- Apply it to HIRAX and SKA
- Current developments:
  - Increasing resolution
  - Extend theoretical predictions
  - Vary HI-Halo mass relation
  - Consider foregrounds and noise

Hitz et al. 2022 (in prep.)

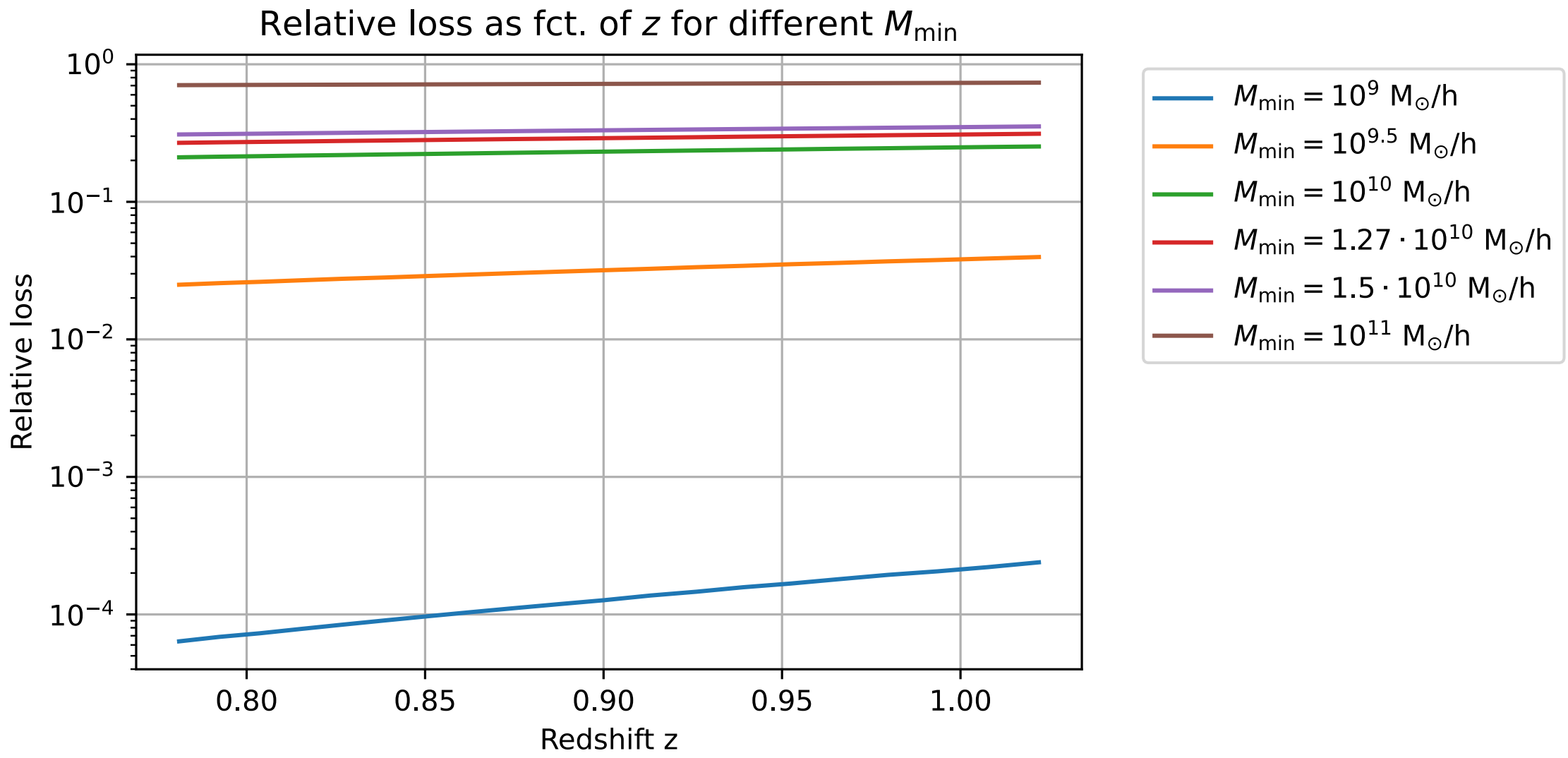


Backup Slides

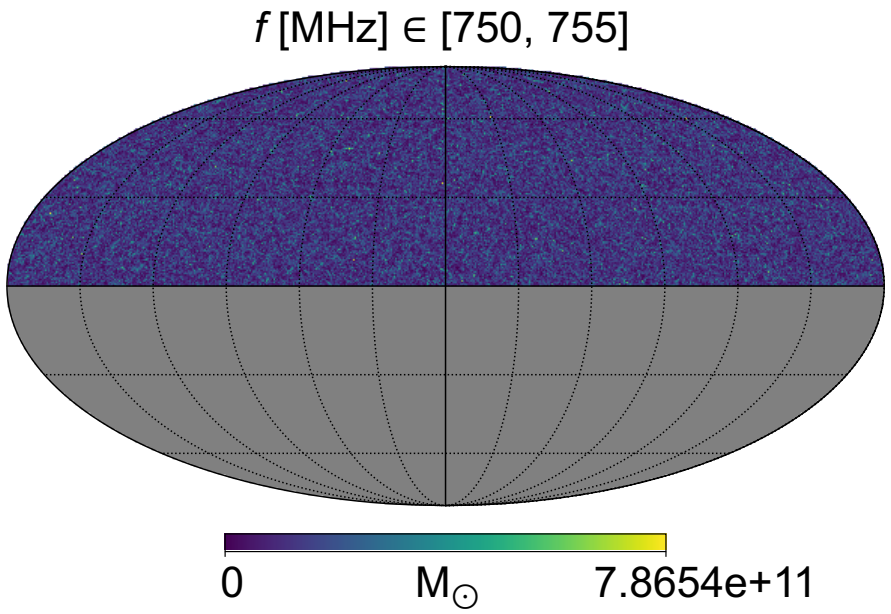
Halo Model for Cosmological HI



Relative Loss of Total HI Mass

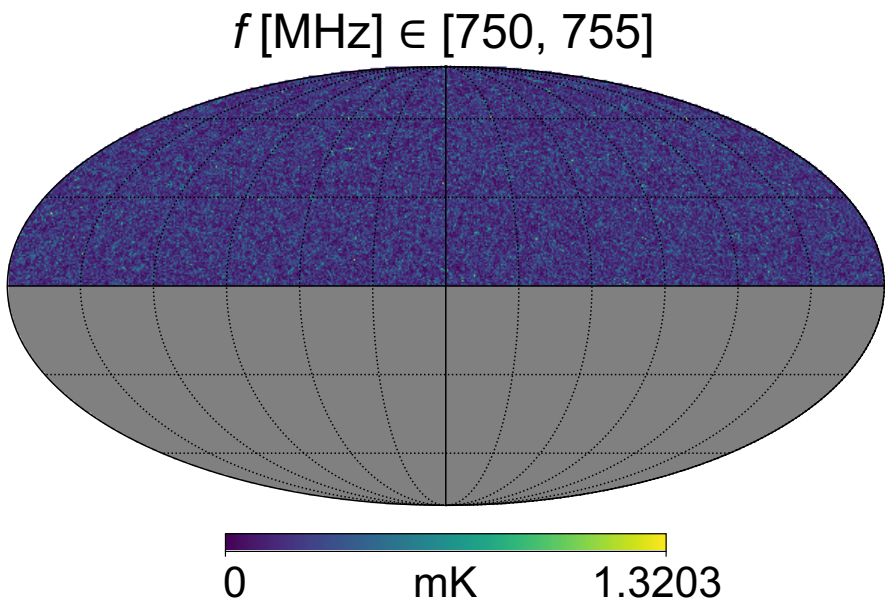


Brightness Temperature Maps



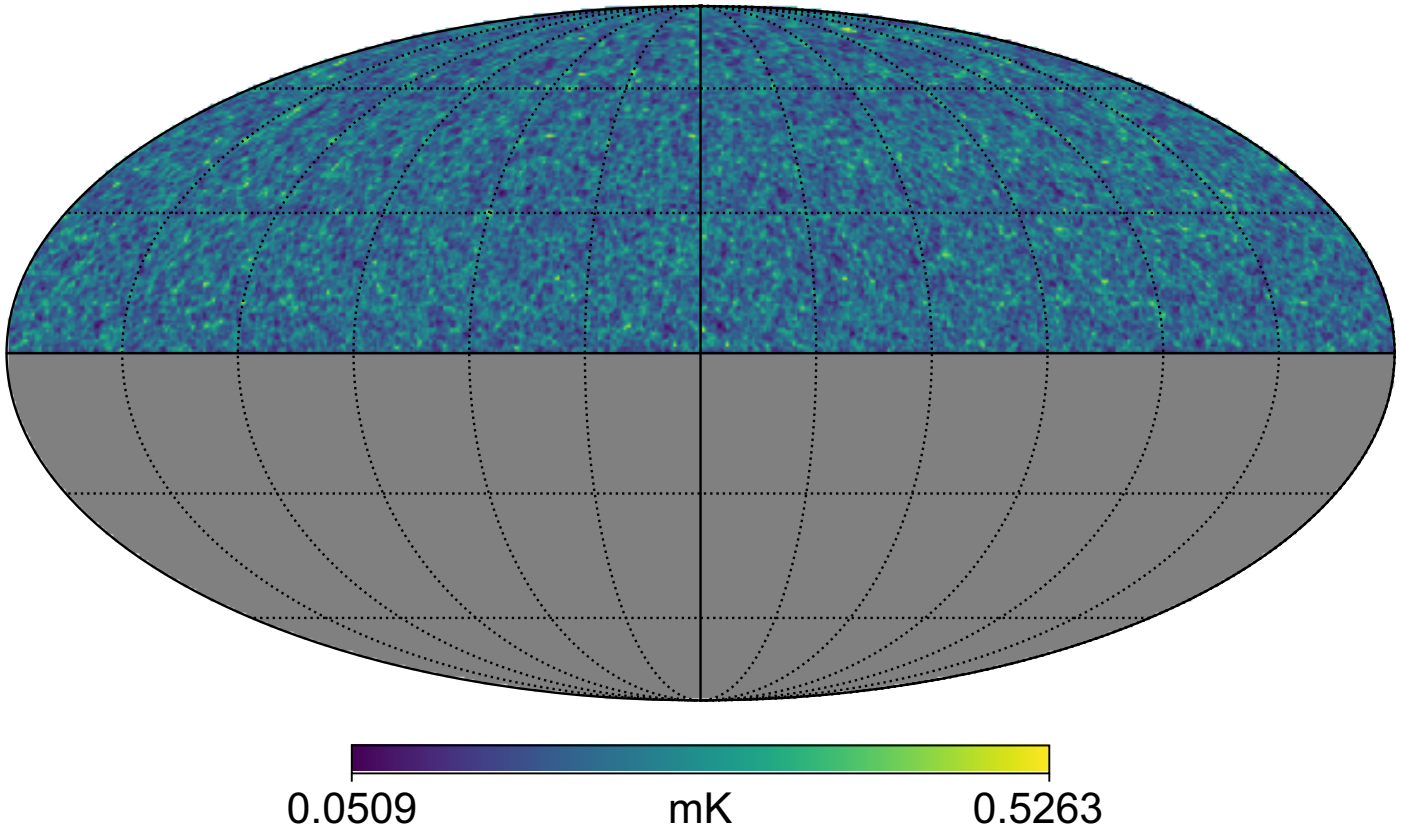
$$T_{\mathrm{b}} = \frac{3hc^3 A_{10}}{32\pi k_{\mathrm{B}} f_{12}^2} \frac{(1+z)^2}{H(z)} n_{\mathrm{HI}}$$

Bull et al. 2015

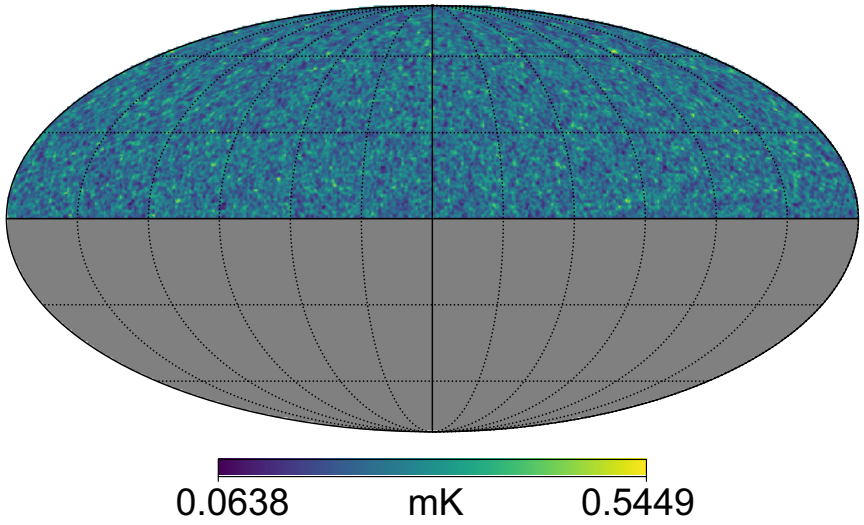


Brightness Temperature Maps

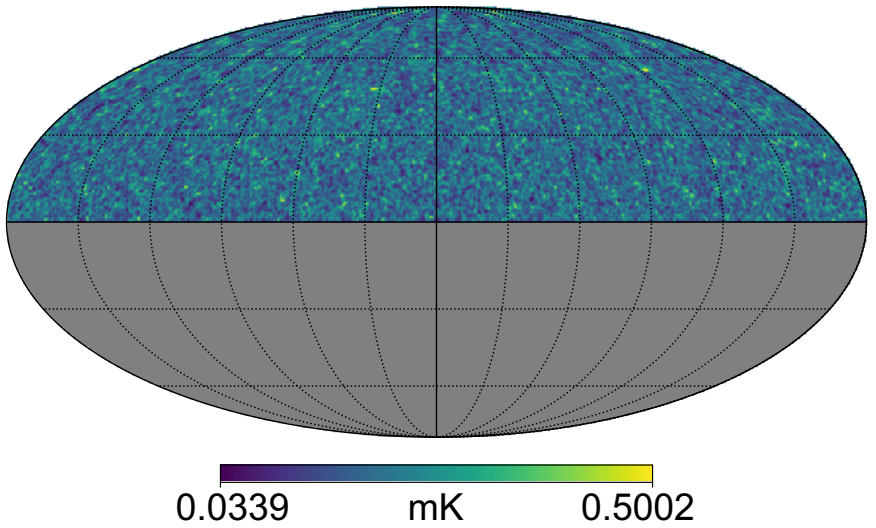
f[MHz] ∈ [750, 755]



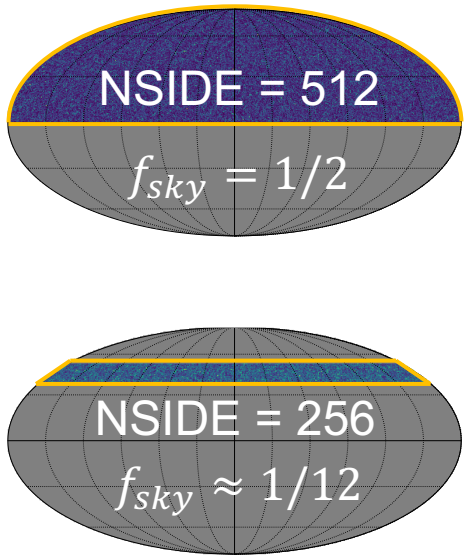
f[MHz] ∈ [700, 705]

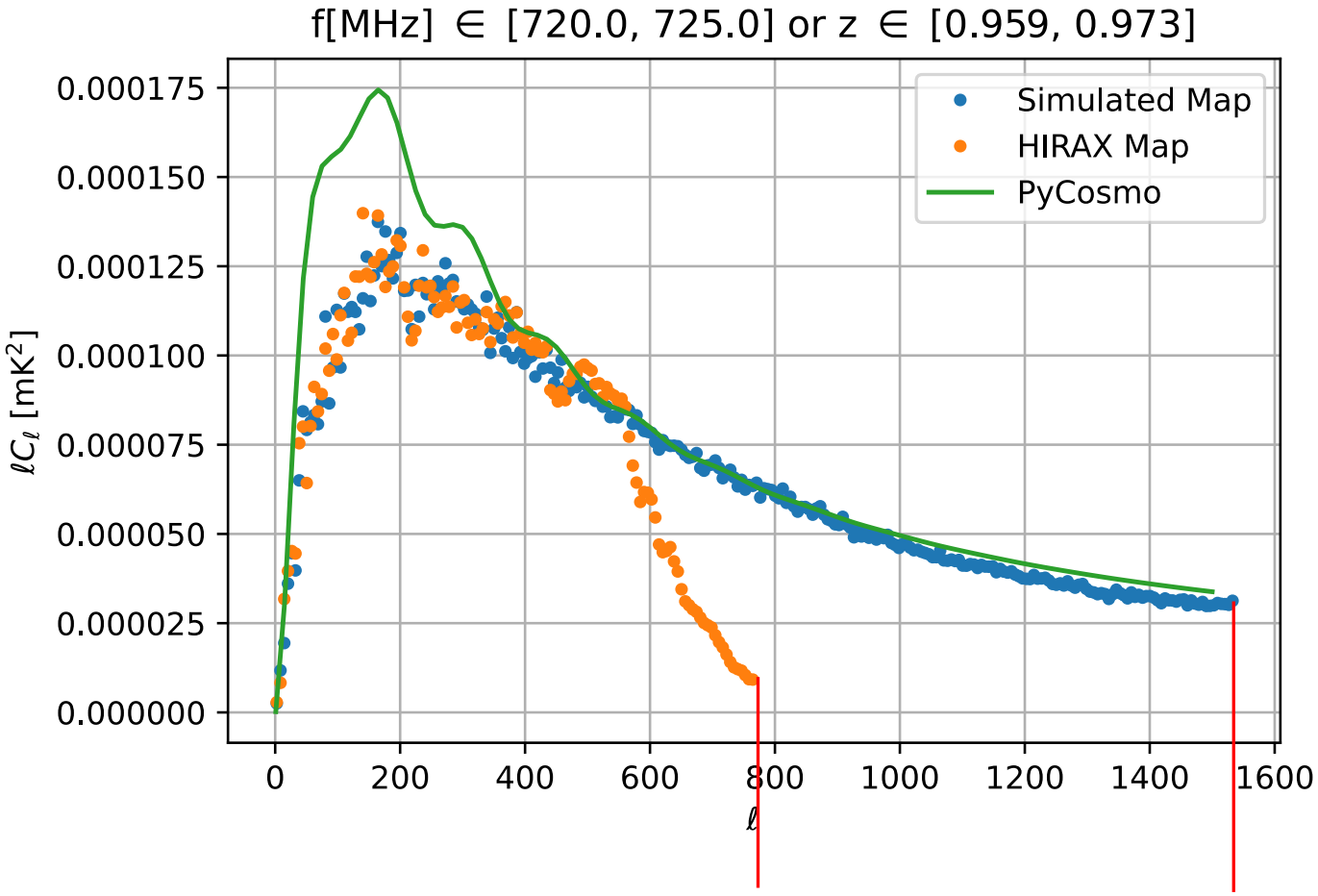


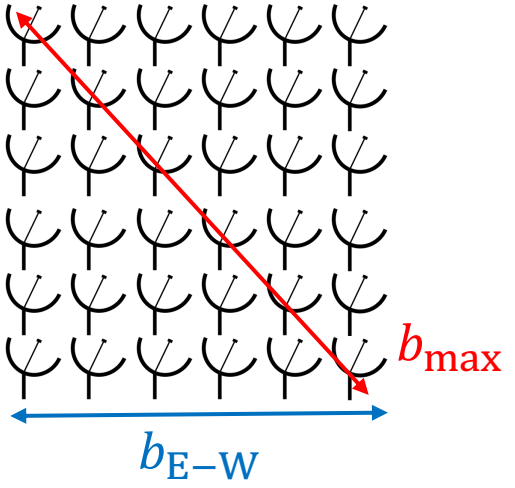
f[MHz] ∈ [795, 800]



HI Angular Power Spectrum







$$\ell \sim \frac{2\pi}{\lambda} b$$

$$\ell_{max}(720\ \text{MHz}) \sim 640$$

$$\ell_{E-W}(720\ \text{MHz}) \sim 450$$