Line Intensity Mapping in GLASS

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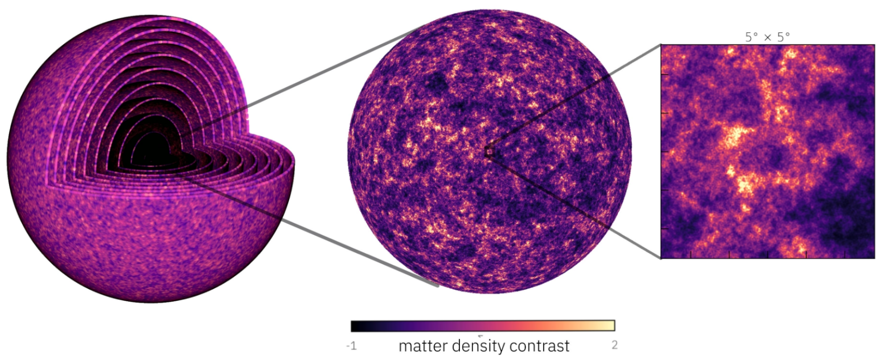
What is GLASS?

GLASS (Generator for Large-Scale Structure) is a novel code developed for the simulation of galaxy surveys in a cosmological context [3]. GLASS iteratively constructs a light cone populated with matter, galaxies, and weak gravitational lensing signals, organized as a sequence of nested spherical shells.



The simulated data produced by GLASS achieve percent-level precision in the two-point statistics of galaxy clustering and weak lensing, making it a powerful tool for validation and inference in cosmology [4, 5]. Key features of GLASS:

- A new technique for generating transformations of Gaussian and lognormal fields with high precision.
- Iterative integration along the line of sight to obtain weak lensing fields.
- Flexible galaxy modeling.

How it works?

The simulation assumes a standard ΛCDM cosmology. Space is discretized into nested spherical shells, each defined by increasing redshift values:

$$0 = z_0 < z_1 < z_2 < z_3 \ldots \tag{1}$$

For each shell i, a radial weight function $W_i(z)$ is defined as:

$$W_i(z) = \begin{cases} 1 & \text{if } z_{i-1} \leq z < z_i, \\ 0 & \text{otherwise.} \end{cases} \tag{2}$$

This weight function is used to project the matter density contrast δ onto the unit sphere, effectively averaging the matter distribution within each shell.

HI Temperature in GLASS

To extend the capabilities of GLASS to include **Line Intensity Mapping** of the 21 cm emission line of neutral hydrogen (HI), we incorporate the mean temperature as reported in Battye et al. (2013)[1]:

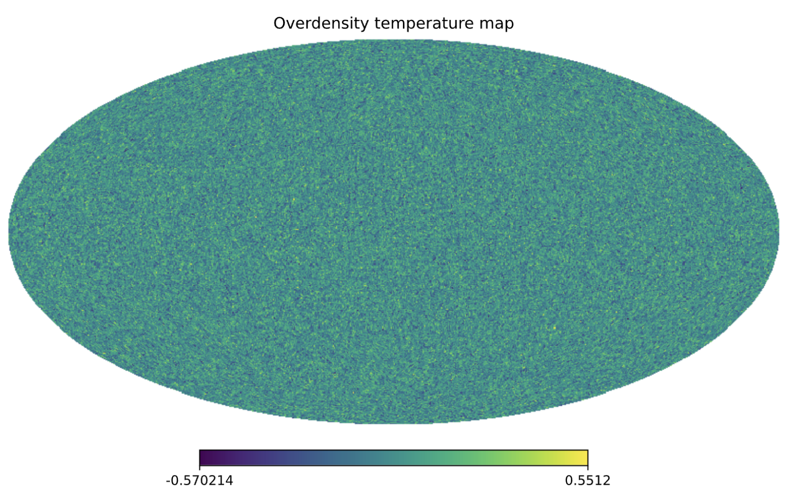
$$\bar{T}_{HI}(z) = 180\,\frac{(1+z)^2}{E(z)}\,\Omega_{HI}(z)\,h \tag{3}$$

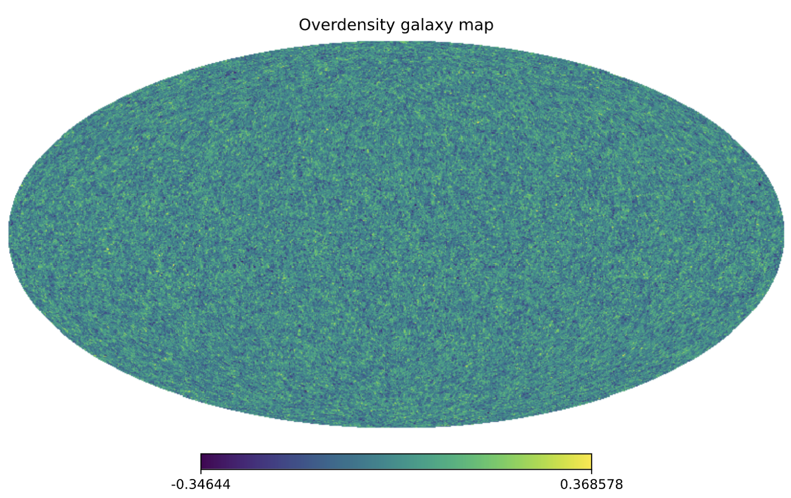
where $\Omega_{HI}(z)$ is the present-day density parameter of neutral hydrogen, while $E(z) = H(z)/H_0$.

Temperature maps

As a first step, we generated full-sky maps of the brightness temperature overdensity.

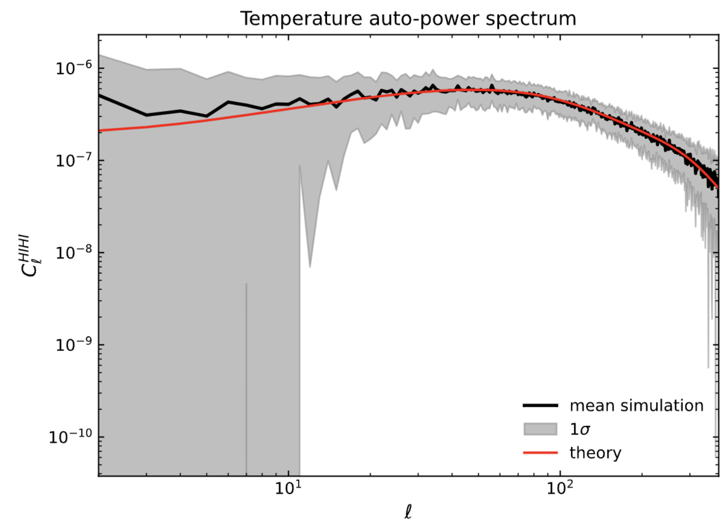
$$\delta(z) = \frac{T_{HI}(z) - \bar{T}_{HI}}{\bar{T}_{HI}} \equiv \frac{\delta T_{HI}(z)}{\bar{T}_{HI}} \tag{4}$$





Auto-power spectrum

The angular power spectrum C_ℓ is then computed from these maps using the **anafast** routine from HEALPix, and compared to theoretical predictions obtained with **CAMB**.



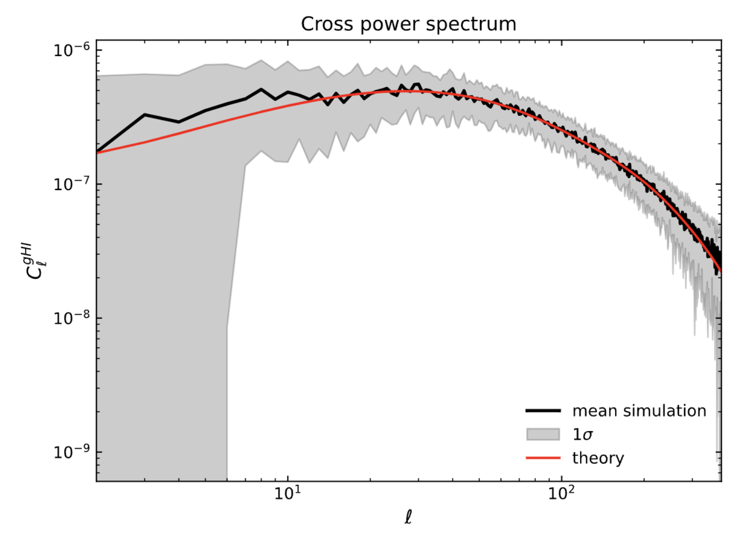
The angular power spectrum quantifies the variance of the harmonic coefficients as a function of scale, and is defined as:

$$C_\ell^{\mathrm{HI,HI}} \equiv \frac{1}{2\ell+1} \sum_{m=-\ell}^{\ell} \left\langle \left| a_{\ell m}^{\mathrm{HI}} \right|^2 \right\rangle \tag{5}$$

where $a_{\ell m}^{\mathrm{HI}}$ are the spherical harmonic coefficients (multipole moments) of the 21 cm temperature overdensity field.

Cross power spectrum

Galaxy clustering serves as a fundamental tool for studying the large-scale structure of the Universe. Similarly, the 21 cm emission line of neutral hydrogen (HI) offers complementary insights. In this context, a key observable is the **cross-power spectrum** between galaxy clustering and HI temperature fluctuations.



The cross-spectrum is defined as:

$$C_\ell^{g,HI} \equiv \frac{1}{2\ell+1} \sum_{m=-\ell}^{\ell} \left\langle a_{\ell m}^{g}\,(a_{\ell m}^{HI})^* \right\rangle \tag{6}$$

Here, $a_{\ell m}^{g}$ are the spherical harmonic coefficients of the galaxy overdensity map, and the cross-spectrum captures correlated structures between the two tracers of large-scale structure.

Next goals

These preliminary results will be further refined by separately analyzing the auto- and cross-power spectra within five equally spaced redshift bins. In addition, we plan to extend the analysis to more realistic observational scenarios by incorporating real survey data distributions, such as those expected from **MeerKLASS** [2].

References

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[2] Mário G Santos, Philip Bull, Stefano Camera, Song Chen, José Fonseca, Ian Heywood, Matt Hilton, Matt Jarvis, Gyula IG Józsa, Kenda Knowles, et al. A large sky survey with meerkat. *POS PROCEEDINGS OF SCIENCE*, 2016.

[3] Nicolas Tessore, Arthur Loureiro, Benjamin Joachimi, Maximilian von Wietersheim-Kramsta, and Niall Jeffrey. Glass: Generator for large scale structure. *arXiv preprint arXiv:2302.01942*, 2023.

[4] Maximilian von Wietersheim-Kramsta, Kiyam Lin, Nicolas Tessore, Benjamin Joachimi, Arthur Loureiro, Robert Reischke, and Angus H Wright. Kids-sbi: Simulation-based inference analysis of kids-1000 cosmic shear. *Astronomy & Astrophysics*, 694:A223, 2025.

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