Higher Order Statistics for Neutral Hydrogen Intensity Mapping

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Summary

Physical background and Motivations

HI Intensity Mapping and State of the Art

Utility of Higher Order Statistics

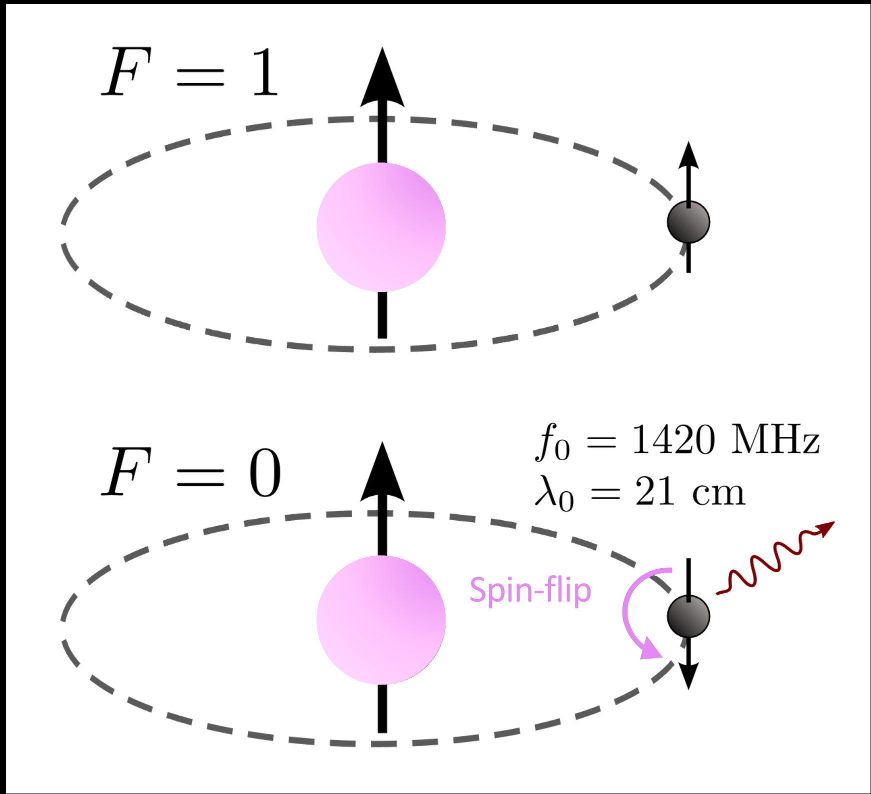
C_ℓ vs starlet $\ell 1$-norm for Cosmological Parameter Inference

Prospective

Physical background

- Hydrogen: most abundant element in the Universe.
- After reionization, HI is located inside galaxies.

$\Longrightarrow$ **biased tracer** of the underlying **matter distribution** of the Universe.



HI hyperfine transition

Why using 21cm line ?

Benefits:

- Can be **measured from earth** (penetrates the atmosphere).
- thermal noise in HI surveys is less important than shot noise in galaxy surveys $\Longrightarrow$ HI analysis is **more constraining than galaxies.**

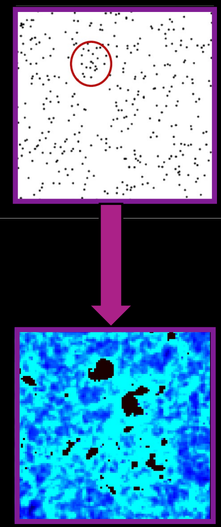
Uses:

- Reconstruct **DM density fields.**
- **Map 3D Large Scale Structures** of the Universe.
- Complementary measurement to optical surveys to **constrain cosmological parameters.**

What is Intensity Mapping?

- Measurement of redshift and intensity of HI over the **whole sky.**
- Treats HI signal as a **diffuse background.**
- Large cosmological volume.
- Less costly, less time consuming.
- High spectral resolution $\Longrightarrow$ **high redshift resolution.**
- Individual galaxy detection not needed for LSS study.

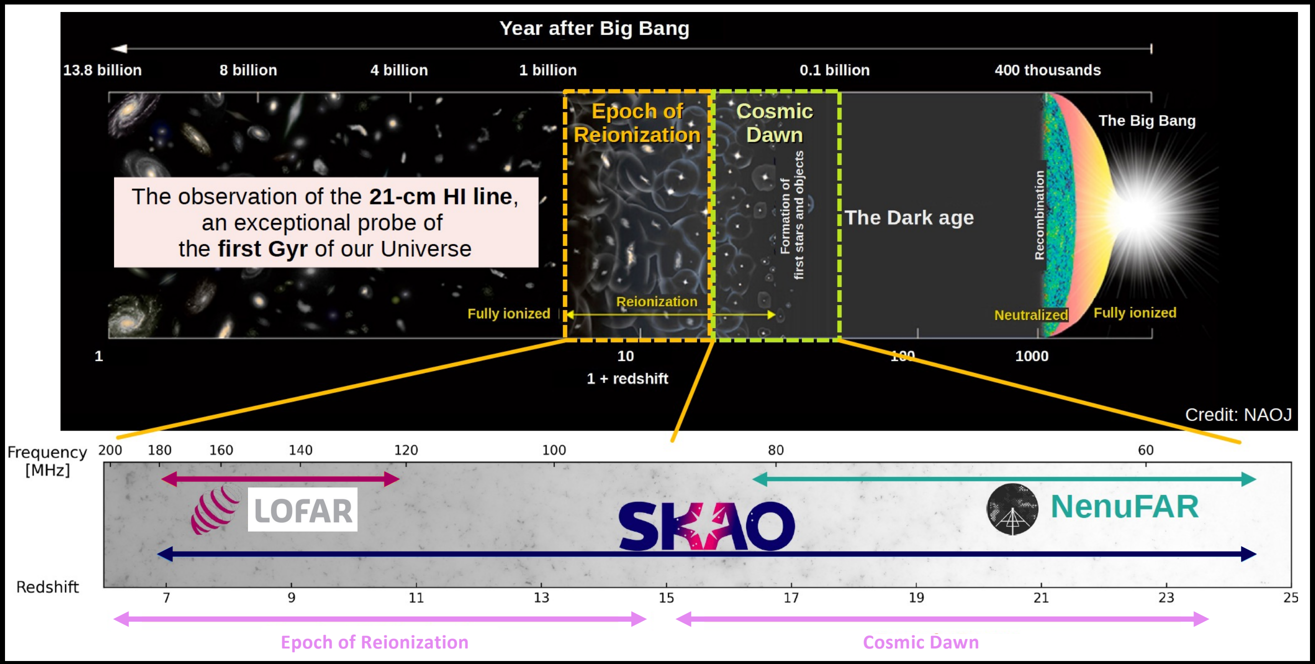
Galaxy distribution



Intensity map

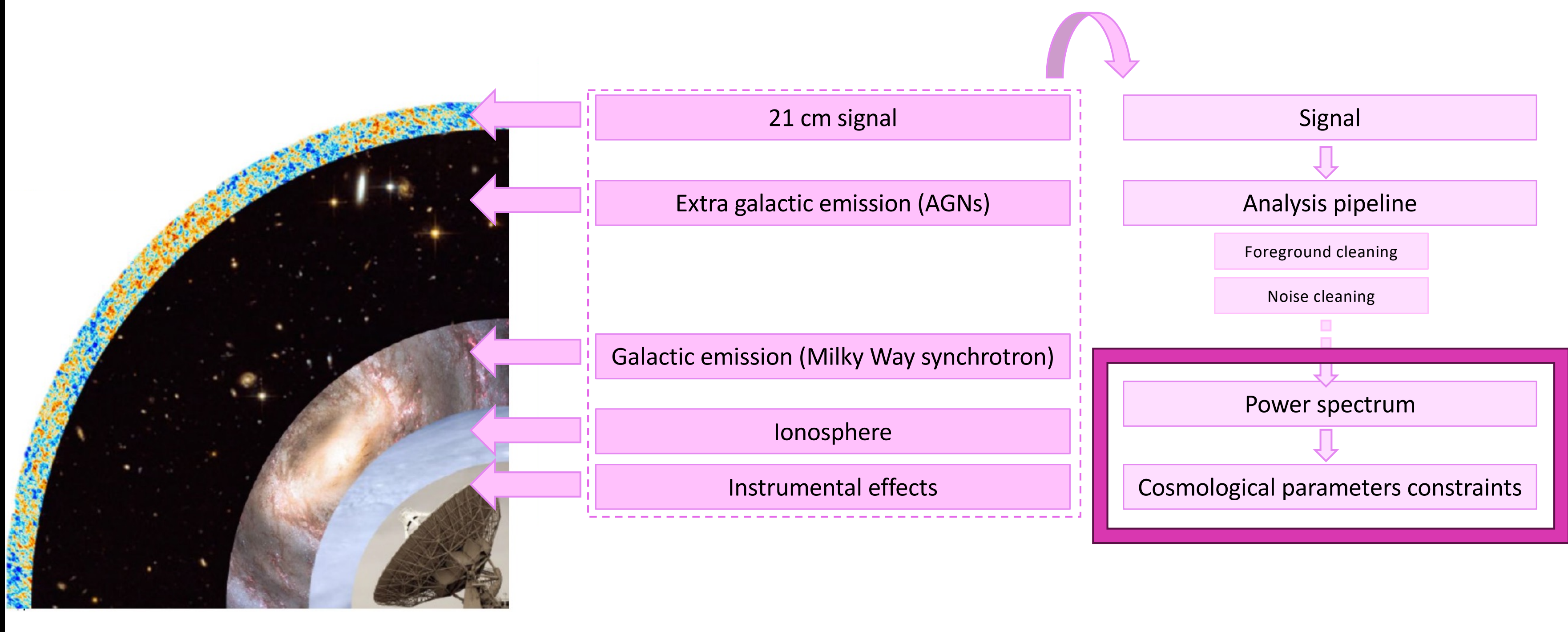
State of the Art for HI IM

- For now detection by **cross-correlation between galaxy and 21 cm.**
- **Not yet possible** to obtain a measurement of the **21cm auto-Power Spectrum.**

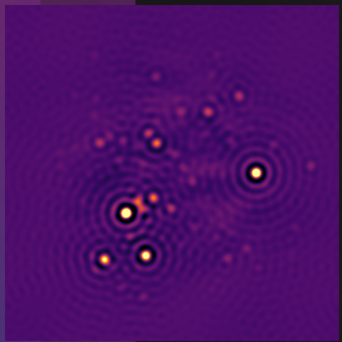


Measurements scheme

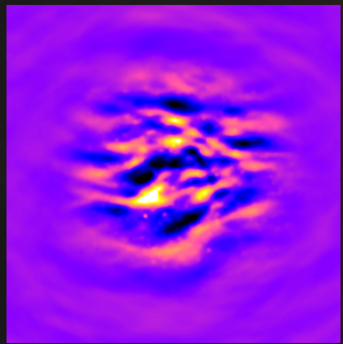
Credits: :Marta Spinelli



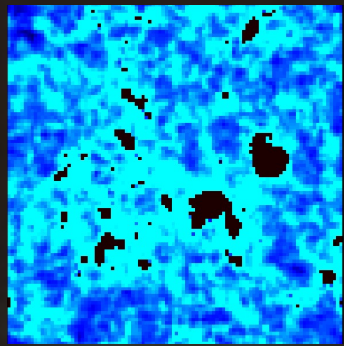
From observations to cosmological information



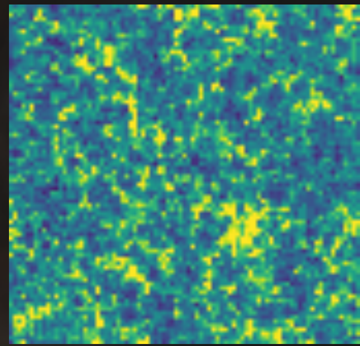
1 Signal with bright sources



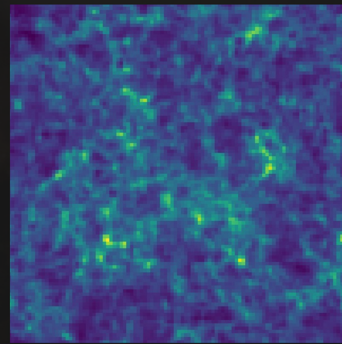
2 Signal without bright sources



3 Brightness temperature map



4 HI density field



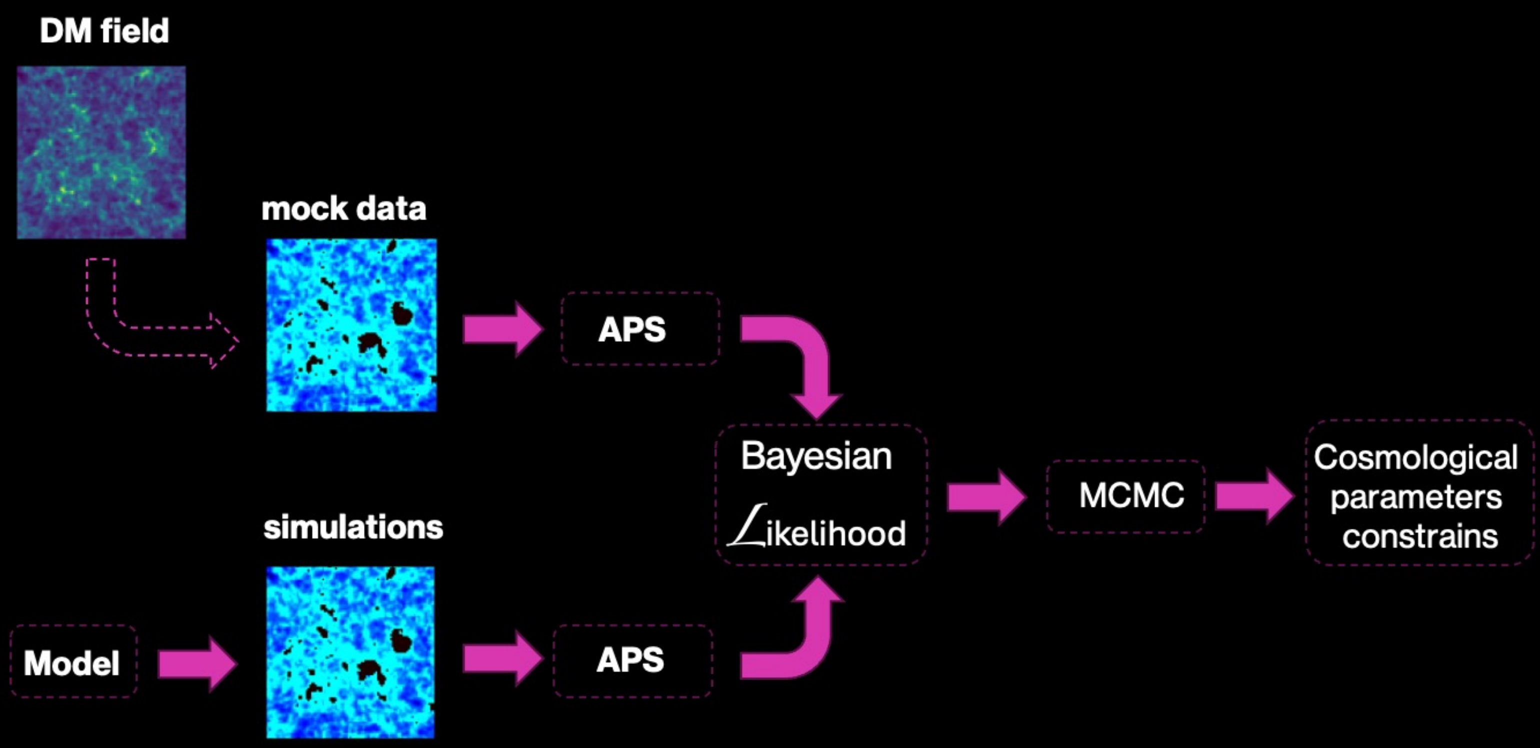
5 Underlying dark matter distribution

Limitations of the power spectrum

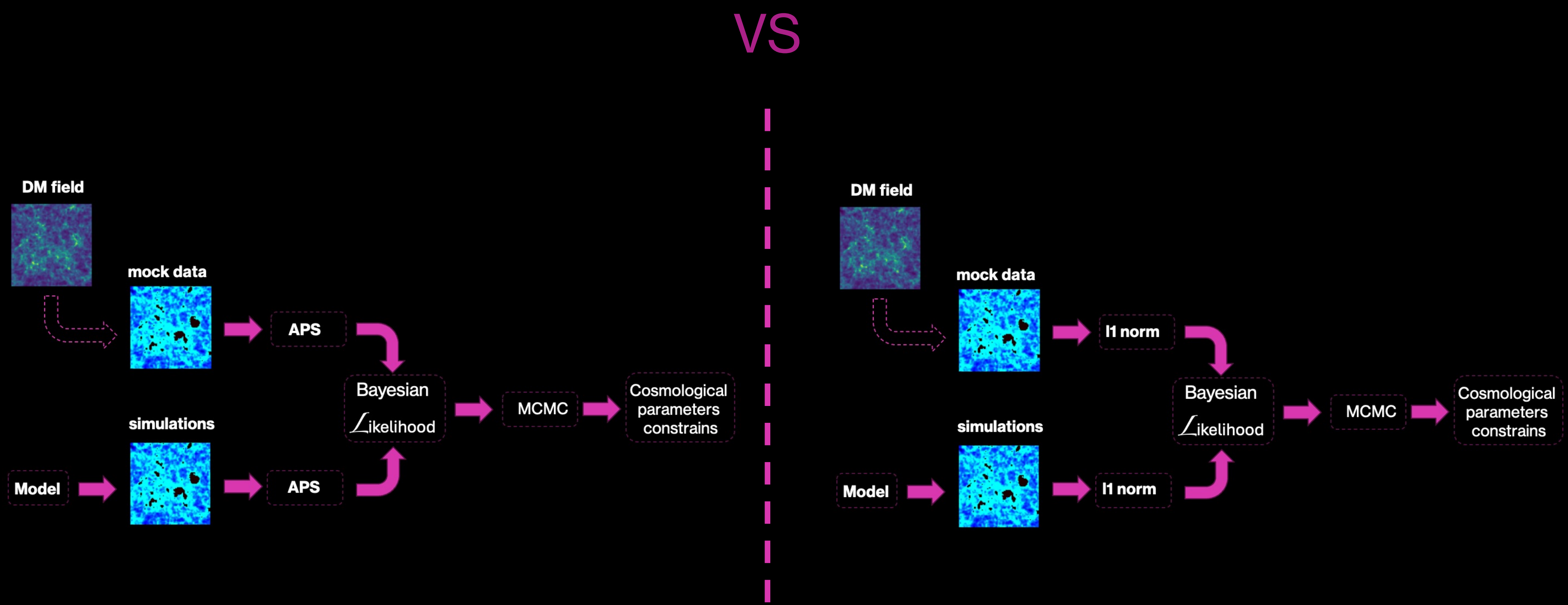
- **Gaussian Assumption**:
  - The power spectrum is most effective for Gaussian random fields.
- **Non-Gaussian Features**:
  - The universe exhibits non-Gaussian features due to non-linear growth of structures and primordial non-Gaussianities.
- **Loss of Information**:
  - Higher order interactions and complex structures are not captured by the power spectrum.
  - Important information about the morphology and connectivity of cosmic structures is lost.

Make use of Higher order statistics which are sensitive to the non-Gausianities.

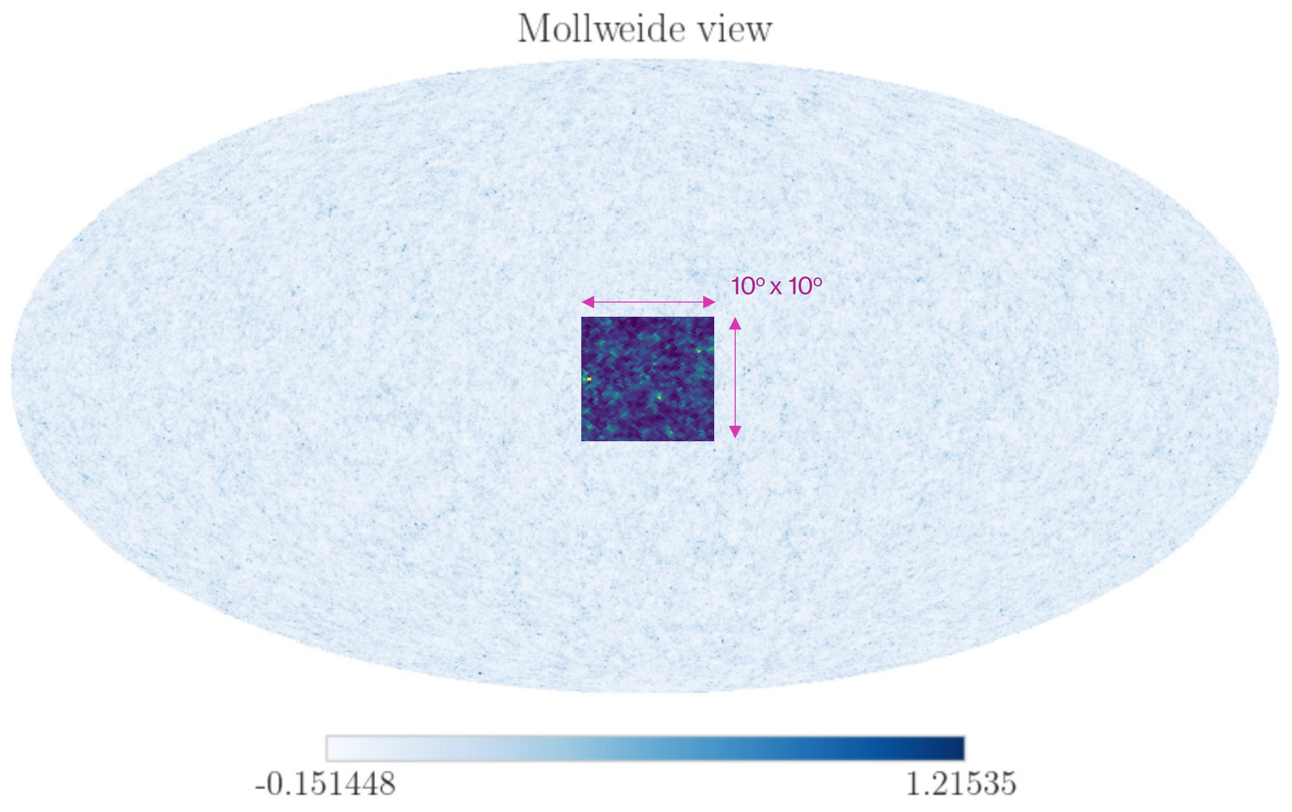
Bayesian cosmological parameter inference



Bayesian cosmological parameter inference



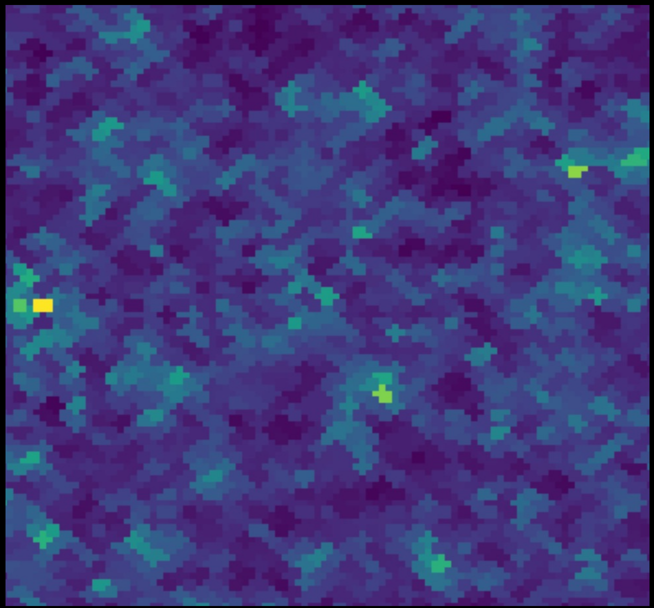
GLASS for HI IM simulations



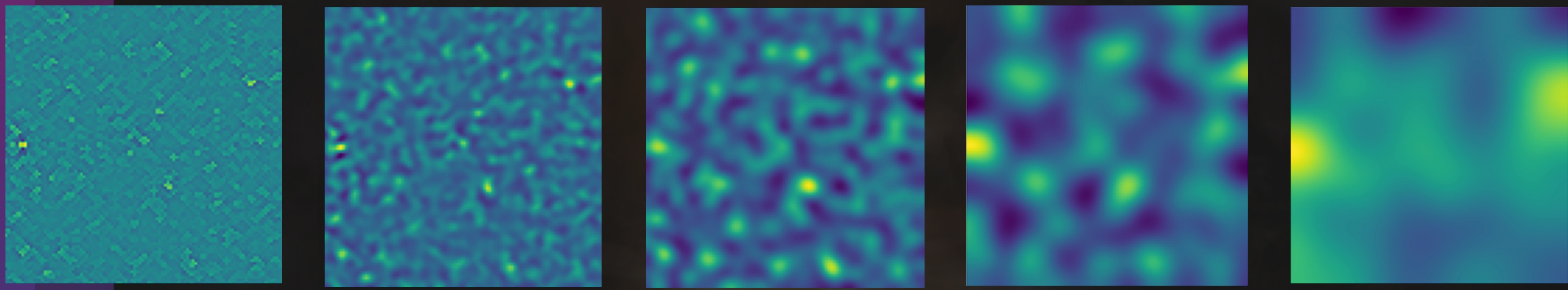
No noise

HI bias painted on the Galaxy clustering distribution

GLASS for HI IM simulations

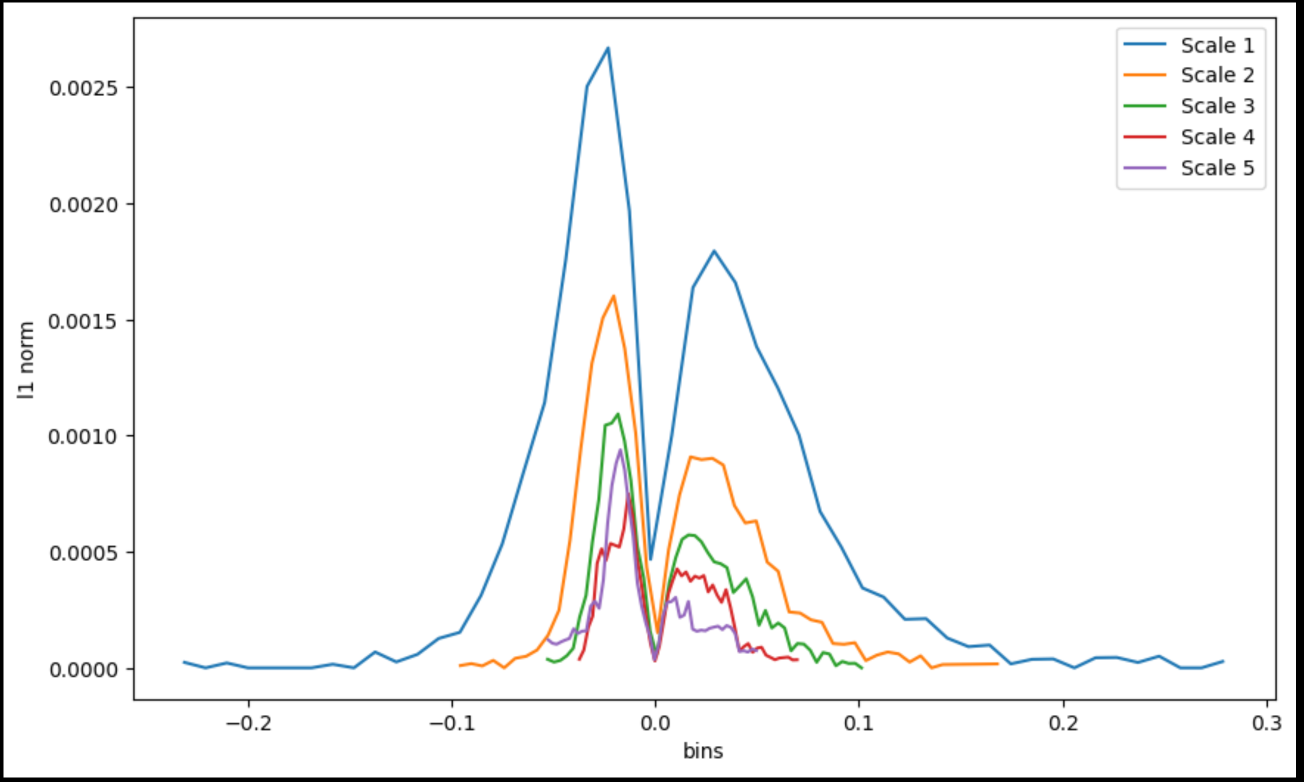


Starlet transform decomposition for a multiscale representation



1st Scale | 2nd Scale | 3rd Scale | 4th Scale | 5th Scale

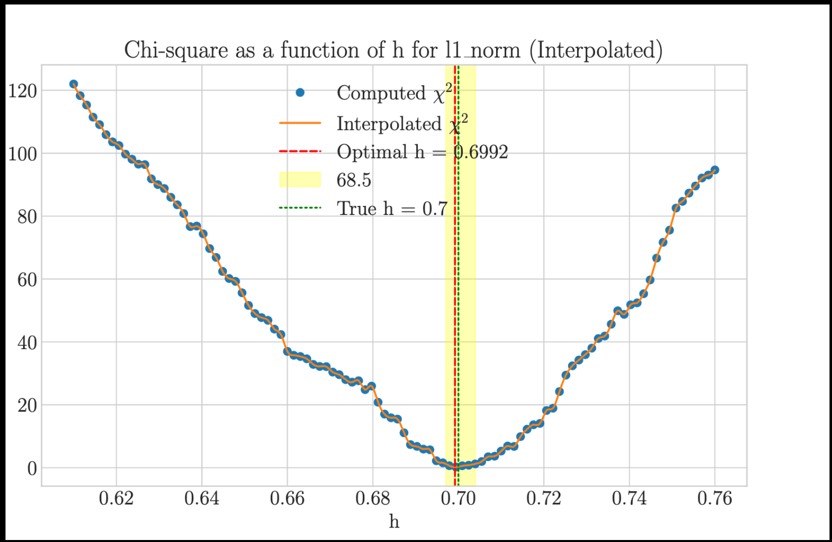
ℓ1-norm

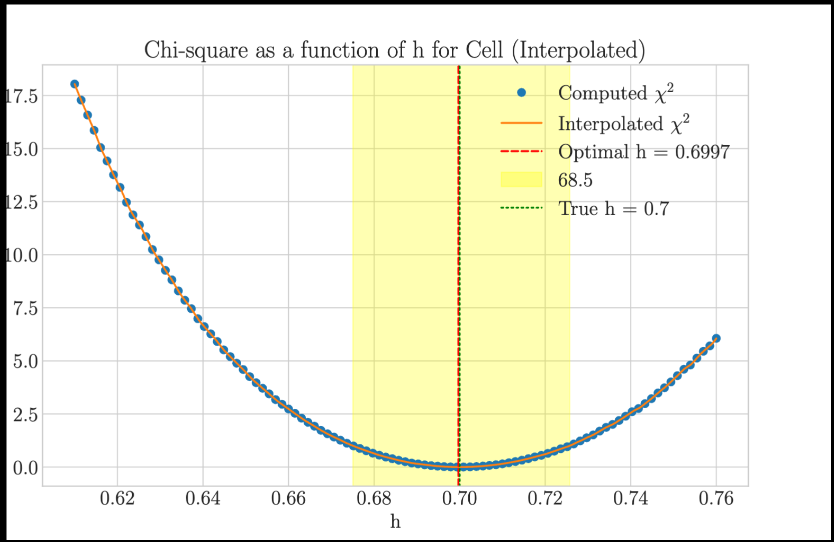


Scale 1
Scale 2
Scale 3
Scale 4
Scale 5
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
l1 norm
−0.2
−0.1
0.0
0.1
0.2
0.3
bins

Preliminary tests of the chi square with GLASS square maps

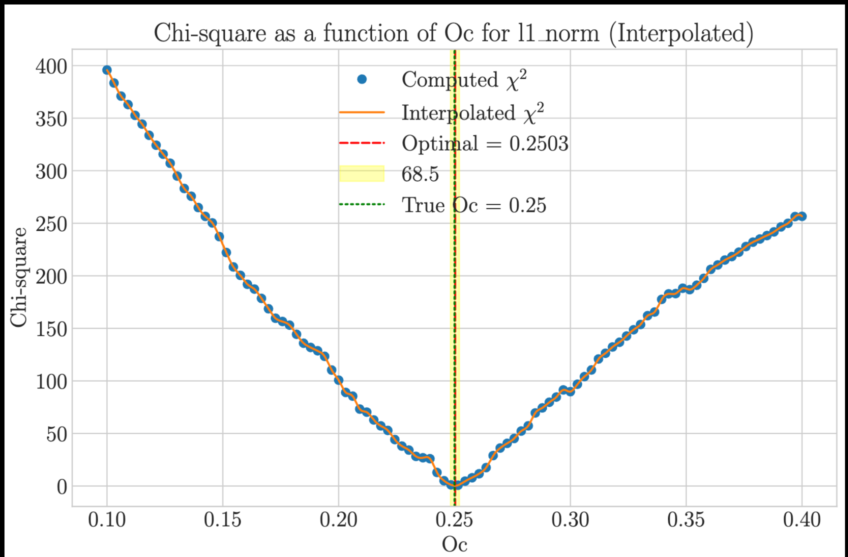
- For the Hubble parameter

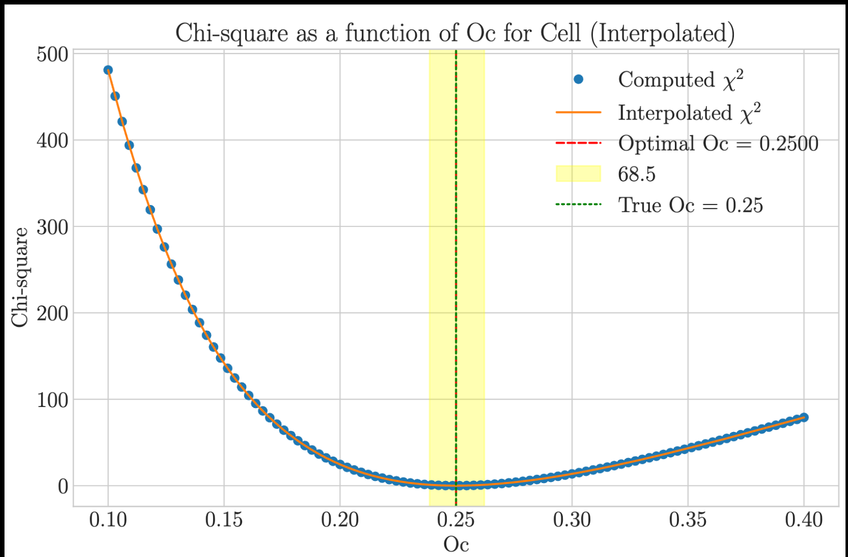




Preliminary tests of the chi square with GLASS square maps

- For the Ω_m

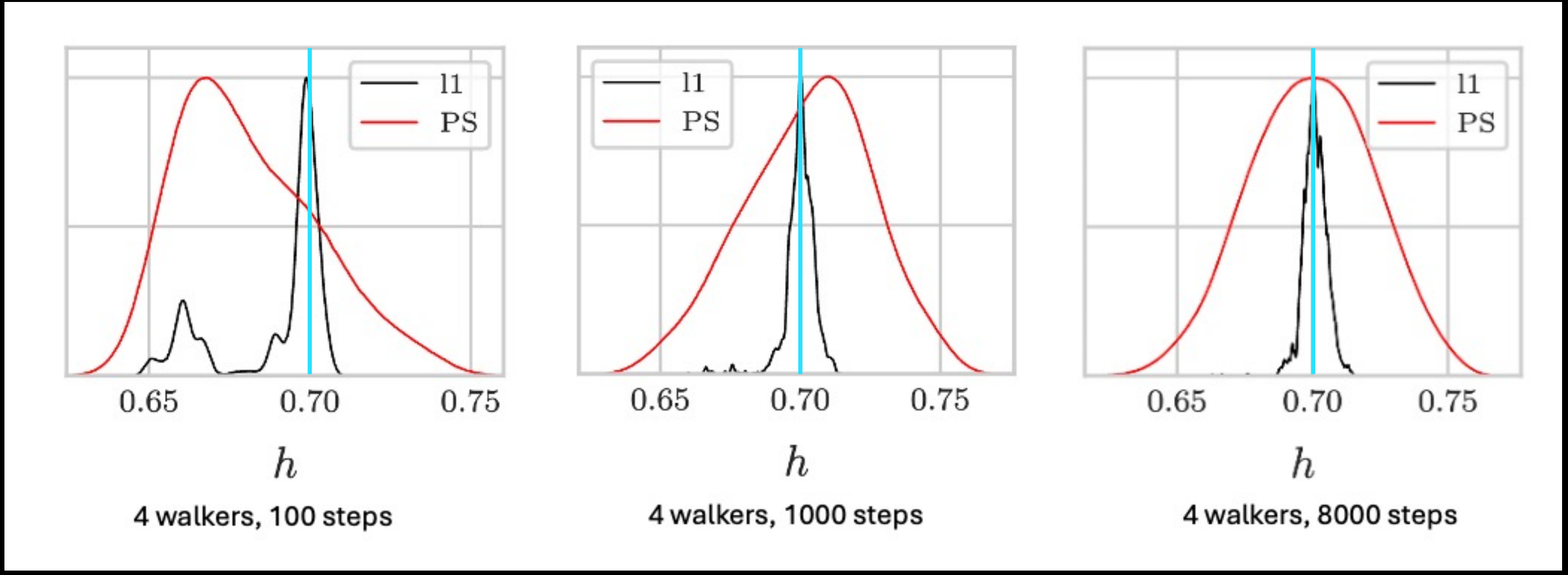




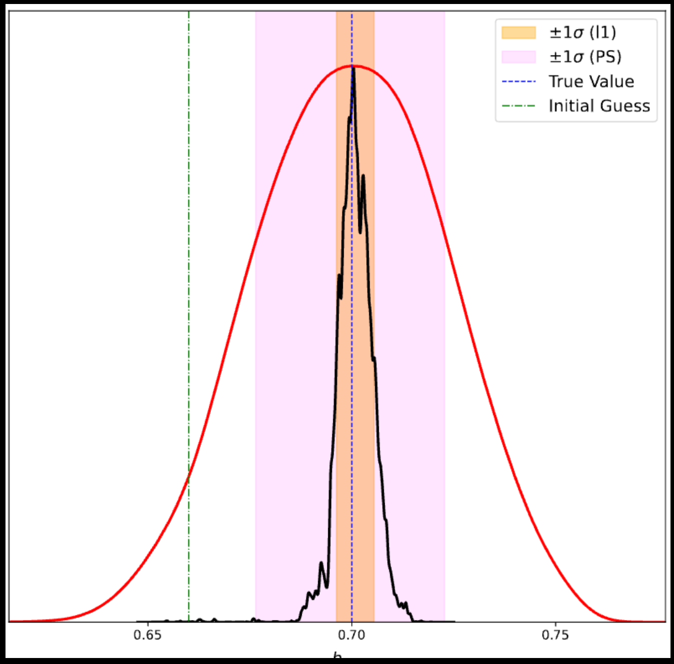
MCMC for Hubble parameter h

No burn in removed

True value h=0.7

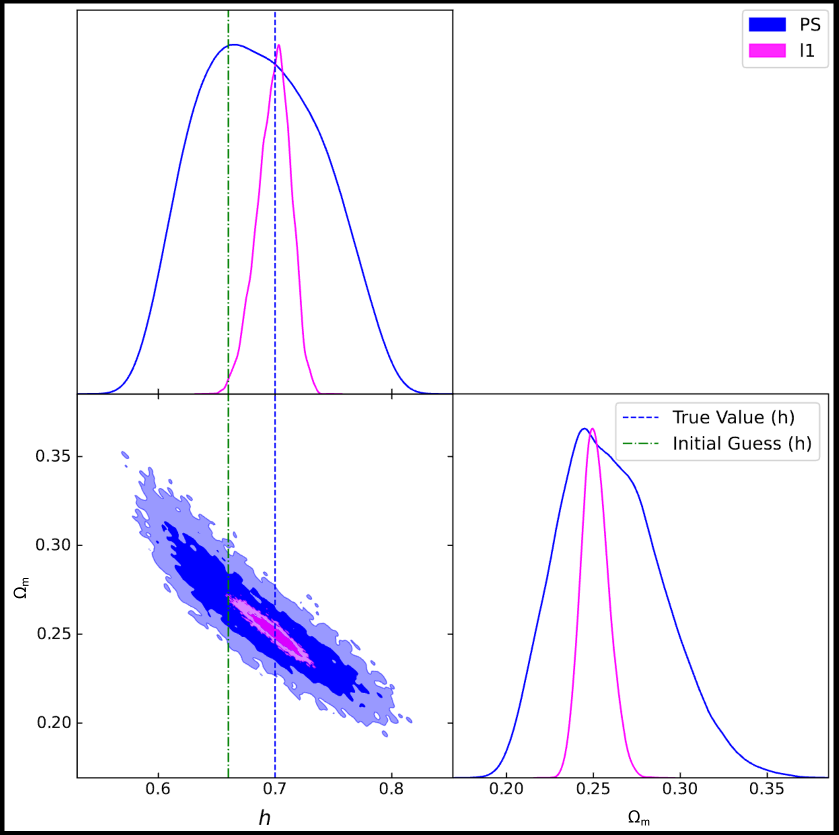


Constraining power of the l1-norm VS APS



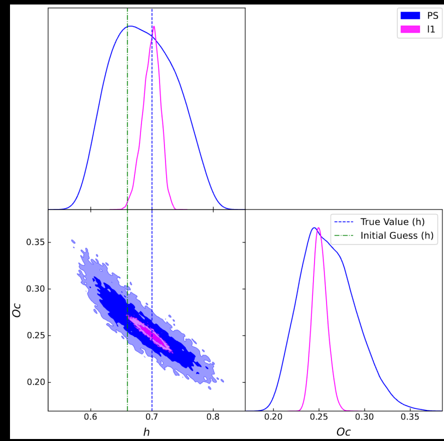
Constrains improved by a factor 5

2 parameters MCMC



8000 steps, 40% discard

Next steps



- Constrain more parameter As, σ_8..
- Use N-body simulations instead of lognormal.