Probing Primordial non-Gaussianity with the Multi-tracer Technique

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Constraining primordial non-Gaussianity by combining next-generation galaxy and 21 cm intensity mapping surveys

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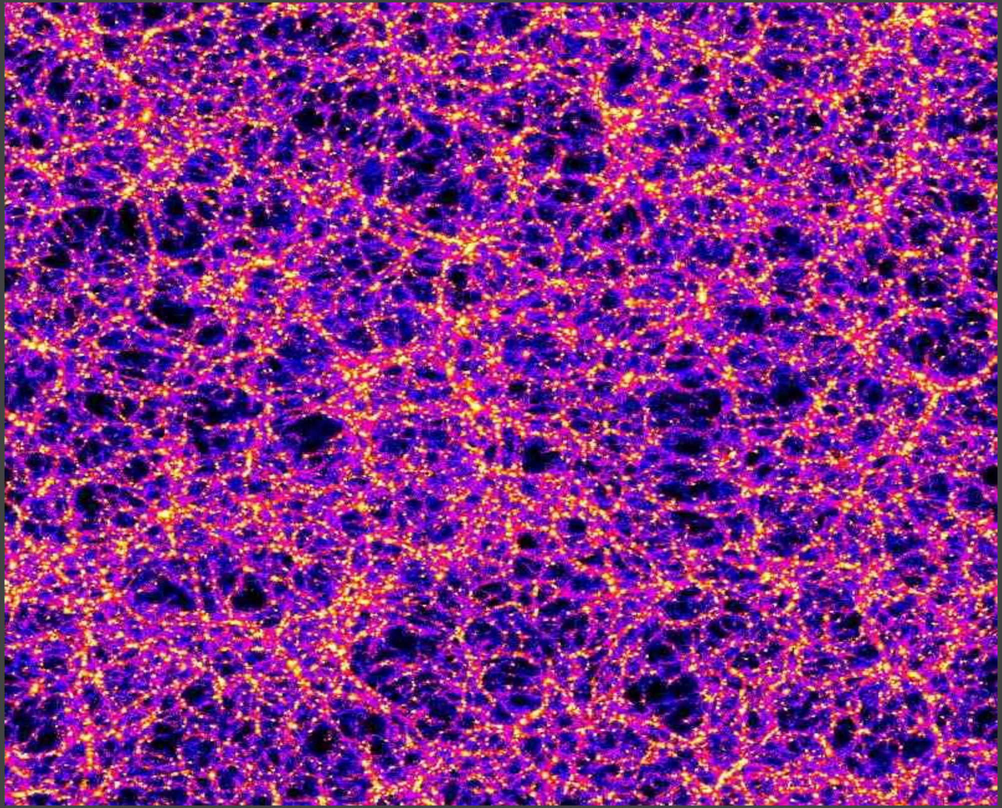
LARGE-SCALE STRUCTURE

- Tells us about the evolution of the universe and the physics of dark components.

- Help us to understand the physics that drive the growth of the cosmic structures.

- Observations on large scale structure can be use to search primordial non- gaussian signal.

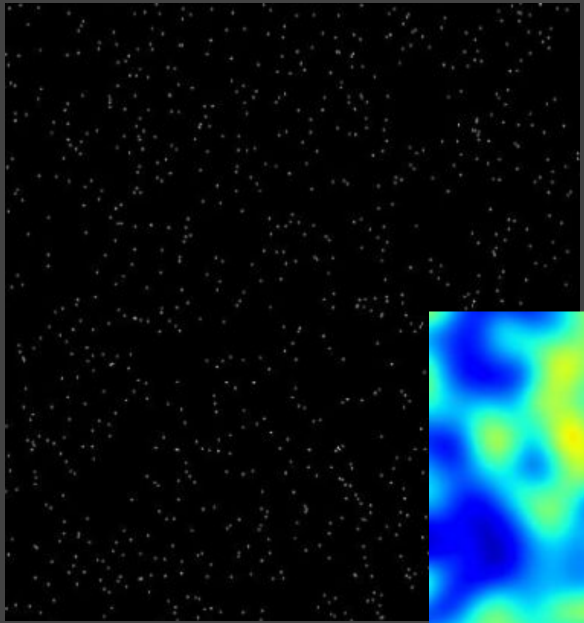
- We use Galaxy Surveys to trace it.



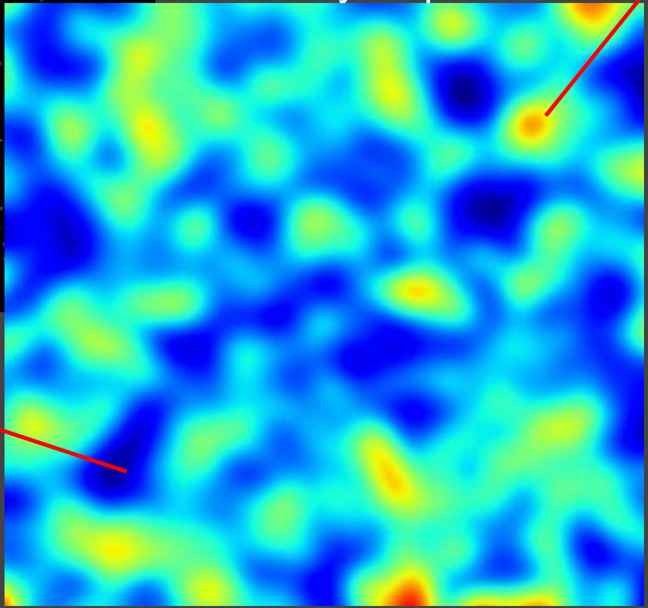
STRUCTURE REFLECTS THE DENSITY PATTERNS OF THE EARLY UNIVERSE

INTENSITY MAPPING

Galaxies



HI intensity Map



Francisco Villaescusa-Navarro

Higher Intensity
More HI present
More matter present

Low Intensity
HI present
More matter present

➢ Very large areas of the sky can be surveyed very efficiently.

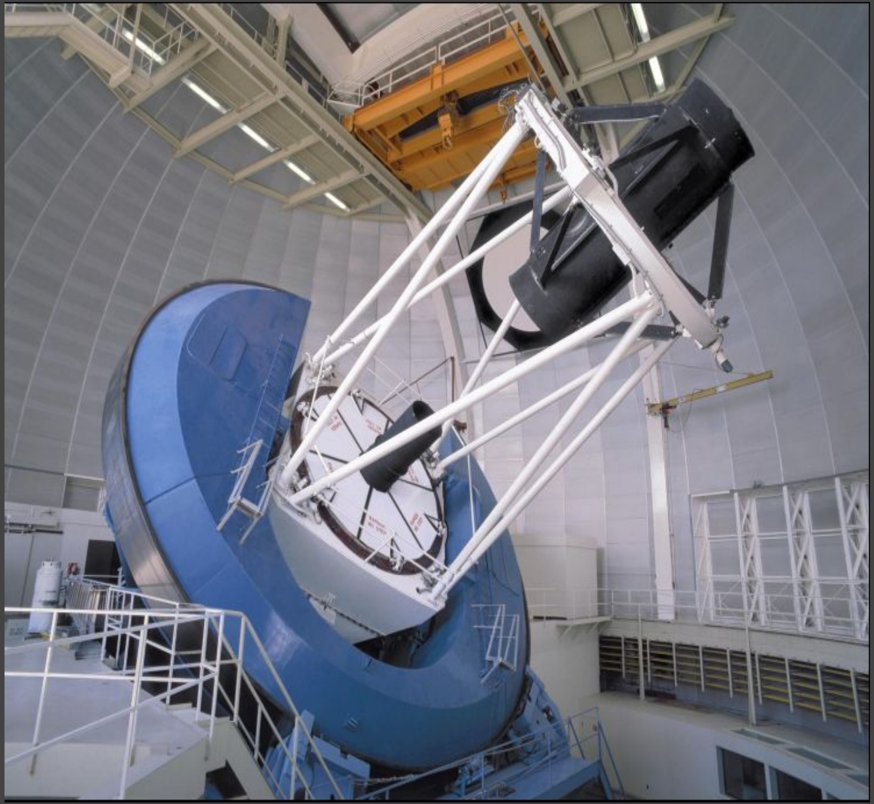
➢ Can use HI to map the 3D Large-Scale-Structures of the Universe.

➢ It is not essential to resolve individual galaxies for cosmology.

MAPPING THE 3D MATTER DISTRIBUTION

SKAO Telescope

DESI Telescope



PROBING THE PRIMORDIAL UNIVERSE

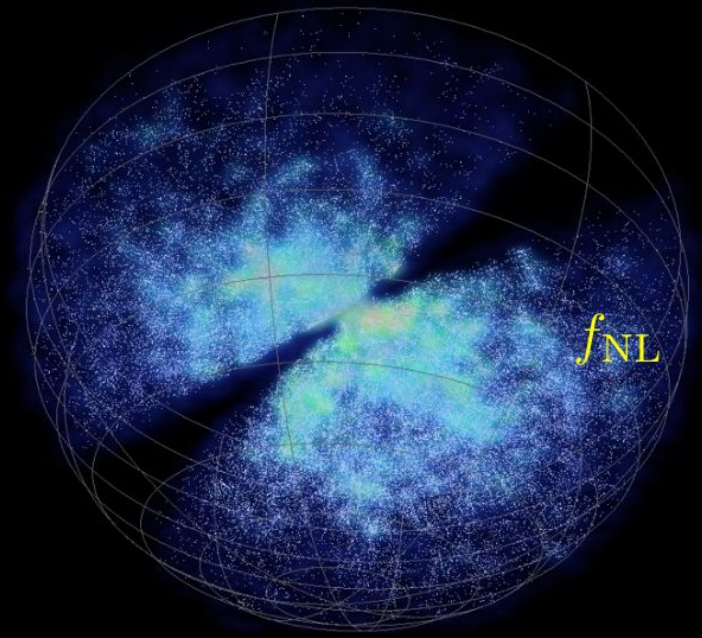
Quantum fluctuations seed the growth of large-scale structure and PNG leaves a trace in the CMB and galaxy surveys

- On ultra-large scales the perturbations remain linear and the PNG signal is uncontaminated.

- The galaxy power spectrum carries a fossil signal on ultra-large scales from the primordial Universe.

The Current (**local PNG parameter**) fNL constraint from Planck:

- fNL = - 0.9 ± 5.1



PROBING THE PRIMORDIAL UNIVERSE

- PNG affects the galaxy power spectrum on ultra-large scales via the bias of galaxies.

$$\delta_A(z, \boldsymbol{k}) = b(z)\delta_m(z, \boldsymbol{k})$$

- The non-Gaussian galaxy bias,

$$\hat{b}(z, k) = b(z) + \Delta b(z, k)$$

Need ultra-large volume surveys to constrain fNL.

where $$\Delta b(z, k) \propto f_{\rm NL} \frac{\mathcal{H}^2}{k^2}$$

NOISE MODELLING

- Consider two different surveys, **DESI-like BGS, ELG** and **SKAO-like, band (1&2)** HI intensity mapping.
- The total signal received from observed HI Power Spectrum and from observed galaxy Power Spectrum is given as,

For Galaxy Surveys

$$\tilde{P}_{gg} = P_{gg} + P_{gg}^{\mathrm{shot}}$$

Shot-Noise

Single survey galaxy power spectrum

For HI IM Surveys

$$\tilde{P}_{HH} = P_{HH} + P_{HH}^{\mathrm{thermal}}$$

Thermal noise

Single survey HI power spectrum

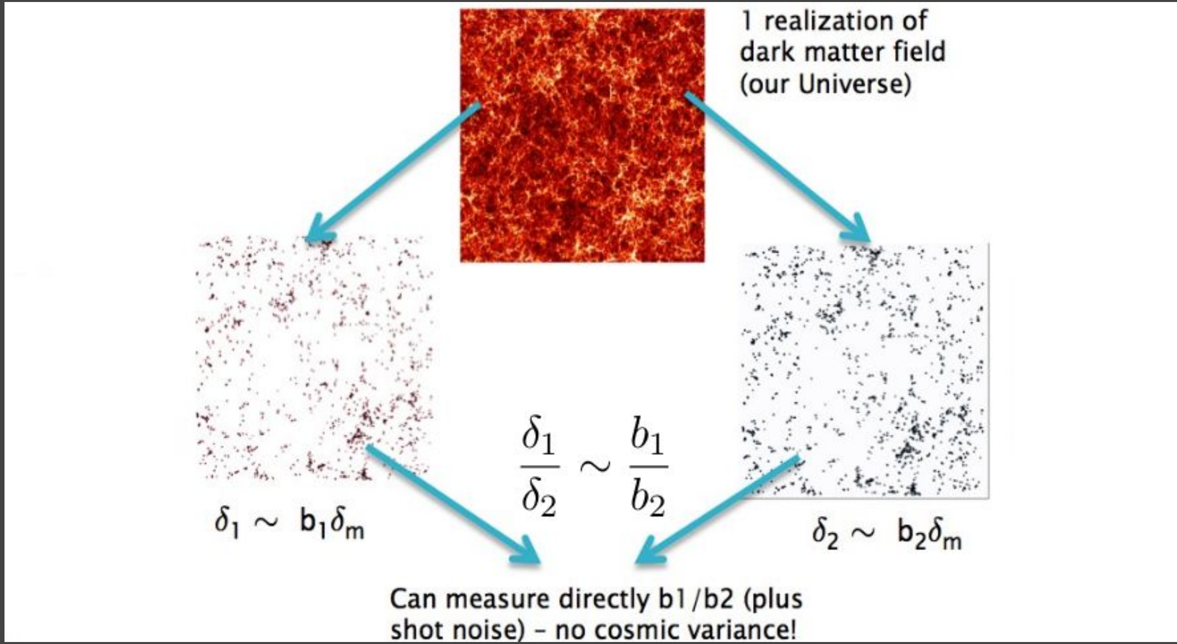
For HI cross GS

$$\tilde{P}_{gH} = P_{gH} \quad \text{with} \quad P_{gH}^{\mathrm{shot}} \approx 0$$

FOURIER POWER SPECTRUM

➔ The single tracer power spectrum is affected by cosmic variance on ultra-large scales.

➔ The multi-tracer method uses two different tracers of the dark matter distribution to beat down cosmic variance.



FISHER FORECAST

$$\boldsymbol{P} = \left(P_{\rm gg}\,,\, P_{\rm gH}\,,\, P_{HH}\right)$$

$$\vartheta_\alpha = \left(\sigma_{8,0},\, n_s,\, f_{\rm NL},\, b_{\rm g0},\, b_{H0}\right)$$

$$\mathrm{Cov}(\boldsymbol{P},\boldsymbol{P}) = \frac{k_{\rm f}^3}{4\pi k^2 \Delta k}\,\frac{2}{\Delta\mu}\begin{pmatrix} \tilde{P}_{\rm gg}^2 & \tilde{P}_{\rm gg}\tilde{P}_{\rm gH} & \tilde{P}_{\rm gH}^2 \\ \tilde{P}_{\rm gg}\tilde{P}_{\rm gH} & \frac{1}{2}\left[\tilde{P}_{\rm gg}\tilde{P}_{HH} + \tilde{P}_{\rm gH}^2\right] & \tilde{P}_{HH}\tilde{P}_{\rm gH} \\ \tilde{P}_{\rm gH}^2 & \tilde{P}_{HH}\tilde{P}_{\rm gH} & \tilde{P}_{HH}^2 \end{pmatrix}$$

$$F_{\alpha\beta} = \sum_{\mu=-1}^{+1}\sum_{k=k_{\rm min}}^{k_{\rm max}} \partial_\alpha \boldsymbol{P}\cdot \mathrm{Cov}(\boldsymbol{P},\boldsymbol{P})^{-1}\cdot \partial_\beta\, \boldsymbol{P}^{\rm T}$$

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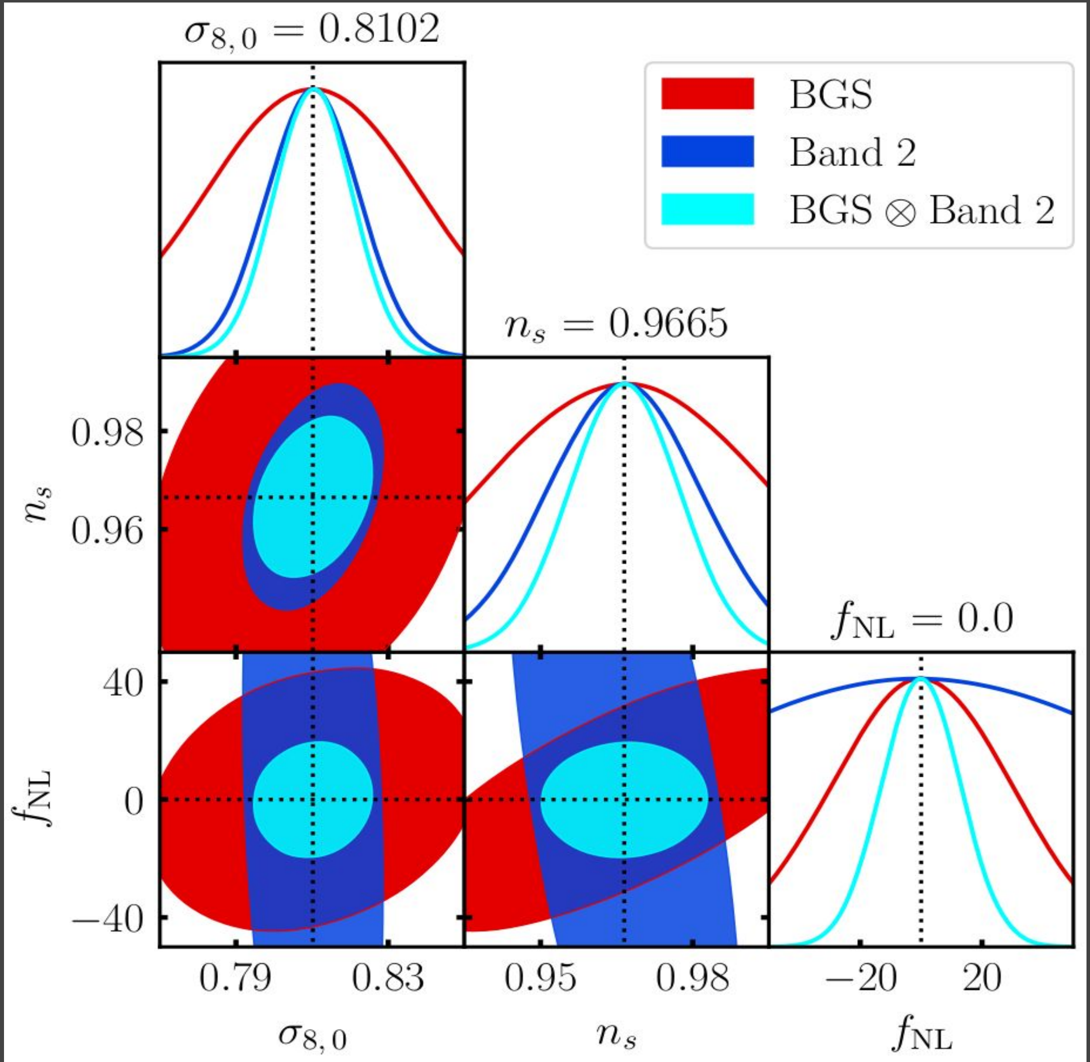
SURVEY SPECIFICATIONS

Survey	Sample	$\Omega_{\rm sky}$ $[10^3\,{\rm deg}^2]$	$t_{\rm tot}$ $[10^3\,{\rm hr}]$	redshift range
g (DESI-like)	BGS	14	-	0.00–0.50
	ELG	14	-	0.60–1.70
H (SKAO-like)	Band 2	20	10	0.10–0.58
	Band 1	20	10	0.35–3.05
$g \times H$ (low z)	BGS × Band 2	10	5	0.10–0.50
$g \times H$ (high z)	ELG × Band 1	10	5	0.60–1.70

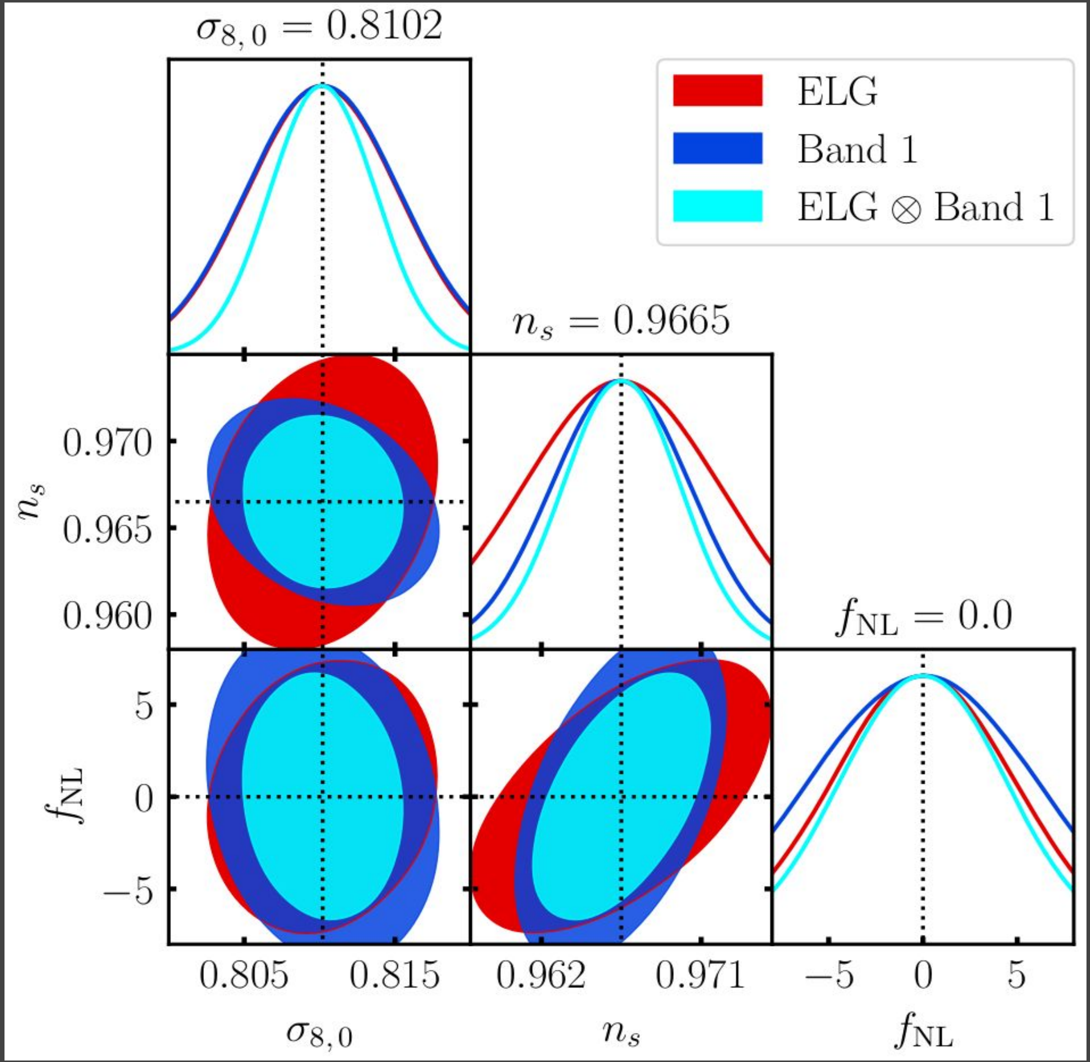
RESULTS OBTAINED



- ➢ We use the fiducial values, σ(8,0) = 0.8102, n_s = 0.9665 and fNL = 0.0
- ➢ We use Planck 2018 best-fit values, to other cosmological parameters.

1-σ CONTOURS OF THE LOW-REDSHIFT SURVEYS

MORE RESULTS



1-σ CONTOURS OF THE HIGH-REDSHIFT SURVEYS

RESULTS SUMMARY

Survey	$\sigma(f_{\rm NL})$
BGS	29.4
ELG	4.9
Band 2	95.7 (66.9)
Band 1	6.1 (1.9)
BGS $\otimes$ Band 2	13.0 (3.2)
ELG $\otimes$ Band 1	4.4 (1.8)
BGS $\otimes$ Band 2 + ELG $\otimes$ Band 1	4.0 (1.5)

CONCLUSIONS

- We see an improvement on fNL, for the multi-tracer power spectrum of the high redshift surveys.
- The low-redshift surveys gives weak constraints on fNL.

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