

Squeezing information from radio surveys to probe the primordial Universe

Dionysis Karagiannis
with Roy Maartens, Shun Saito, José Fonseca,
Stefano Camera, Chris Clarkson

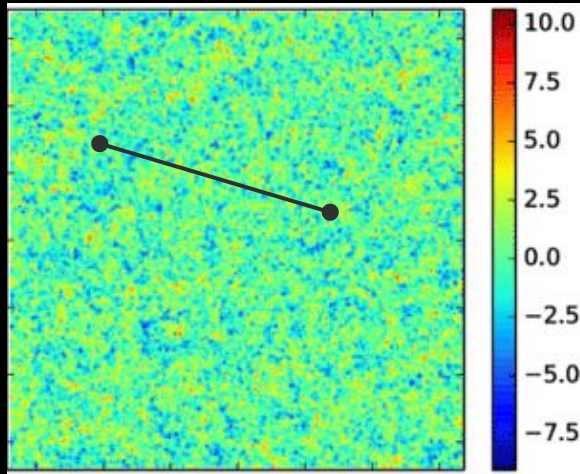
arxiv: 2406.00117

SKA Cosmology SWG meeting
9 November 2024



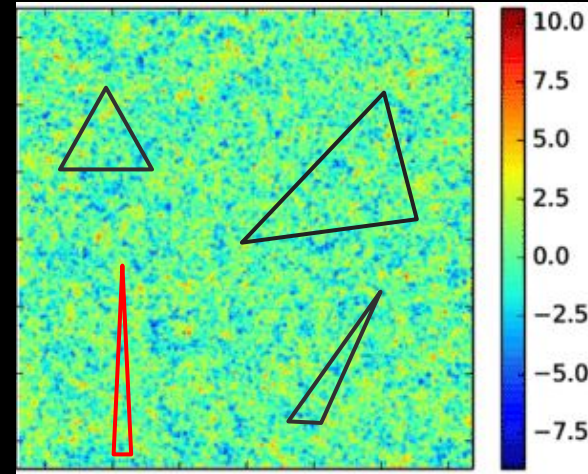
Statistics of the primordial perturbations

Standard inflation ~ Gaussian



$$\langle \zeta(k)\zeta(k') \rangle = \delta(k+k')P_\zeta(k)$$

More complex models ~ non Gaussian



$$\langle \zeta(k_1)\zeta(k_2)\zeta(k_3) \rangle = \delta(k_1+k_2+k_3)B_\zeta(k_1,k_2,k_3)$$

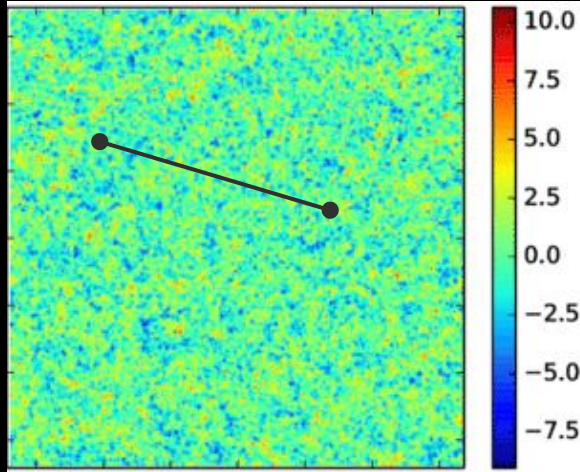
$$B_\zeta(k_1,k_2,k_3) = \mathbf{f}_{\text{NL}} * F(\text{triangle shape})$$

$\mathbf{f}_{\text{NL}} = 0 \rightarrow$ Gaussian

$\mathbf{f}_{\text{NL}} \neq 0 \rightarrow$ non-Gaussian

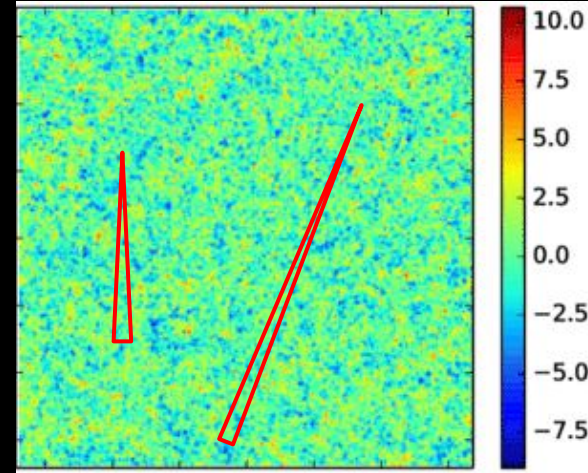
Statistics of the primordial perturbations

Standard inflation ~ Gaussian

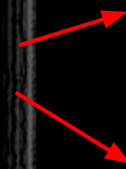
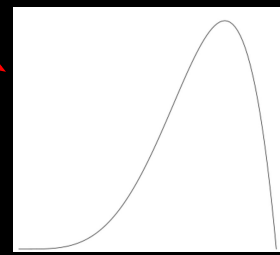
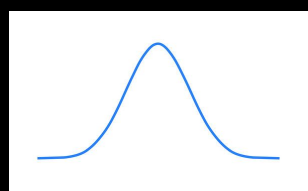
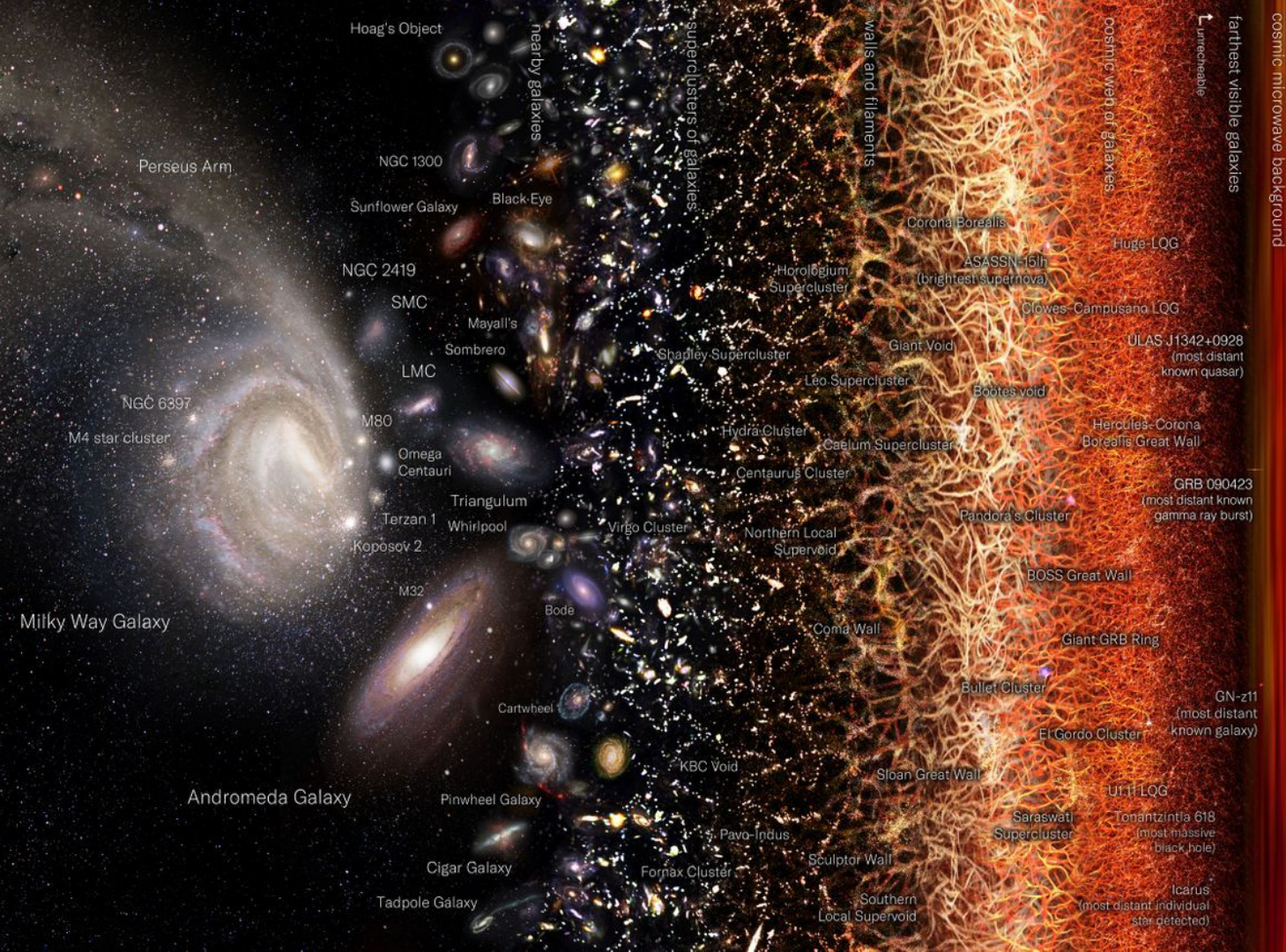


$$\langle \zeta(k)\zeta(k') \rangle = \delta(k+k')P_{\zeta}(k)$$

More complex models ~ non Gaussian



Local type PNG:
maximal value on squeezed triangles ($k_1 \sim k_2 \gg k_3$)



$$B_{\text{obs}} = B_{\text{prim}} + B_{\text{late}}$$

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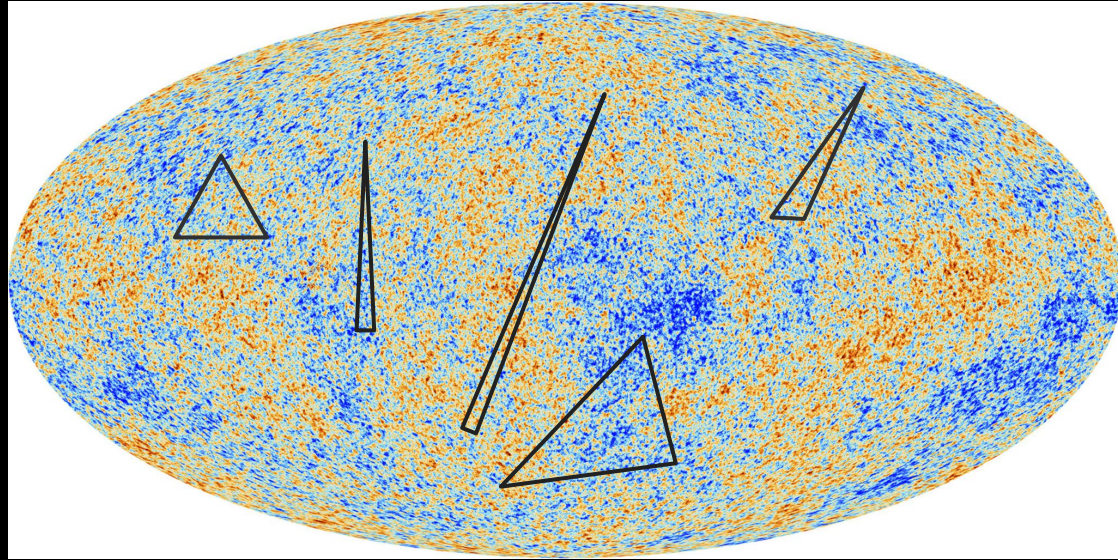
PNG from CMB

$$B_{\text{obs}} \sim B_{\text{prim}}$$

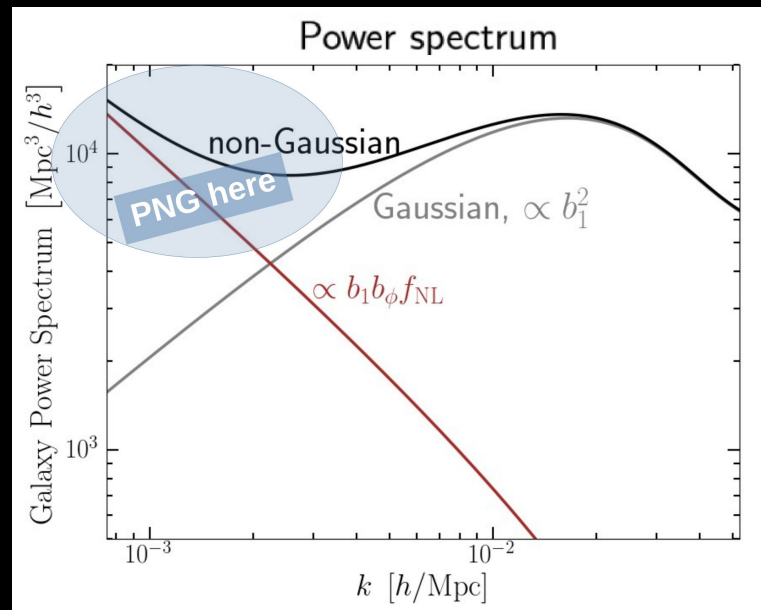
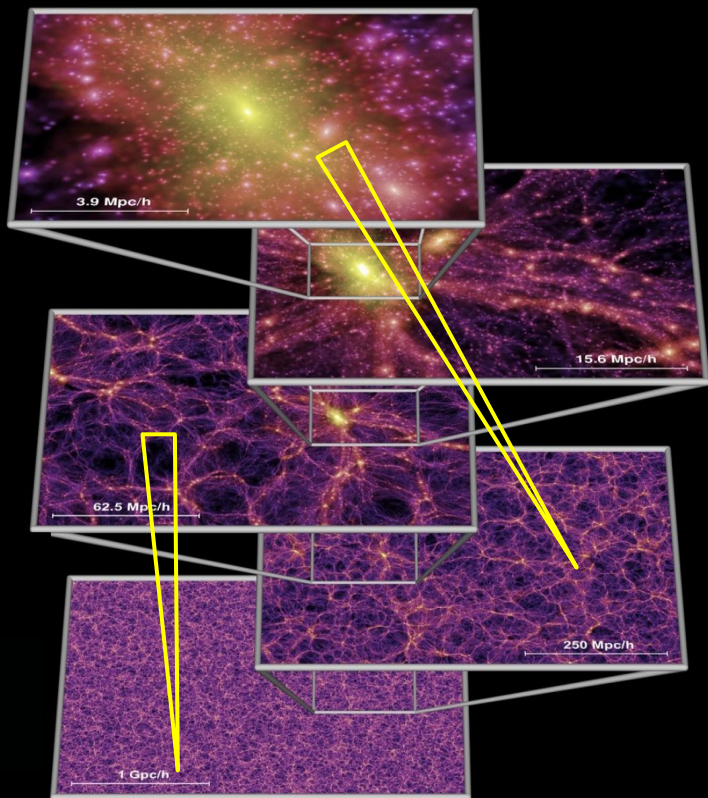
Planck collaboration 2018:

$$f_{\text{NL}}^{\text{local}} = -0.9 \pm 5.1$$

Signal regime: Large scales



LSS and PNG

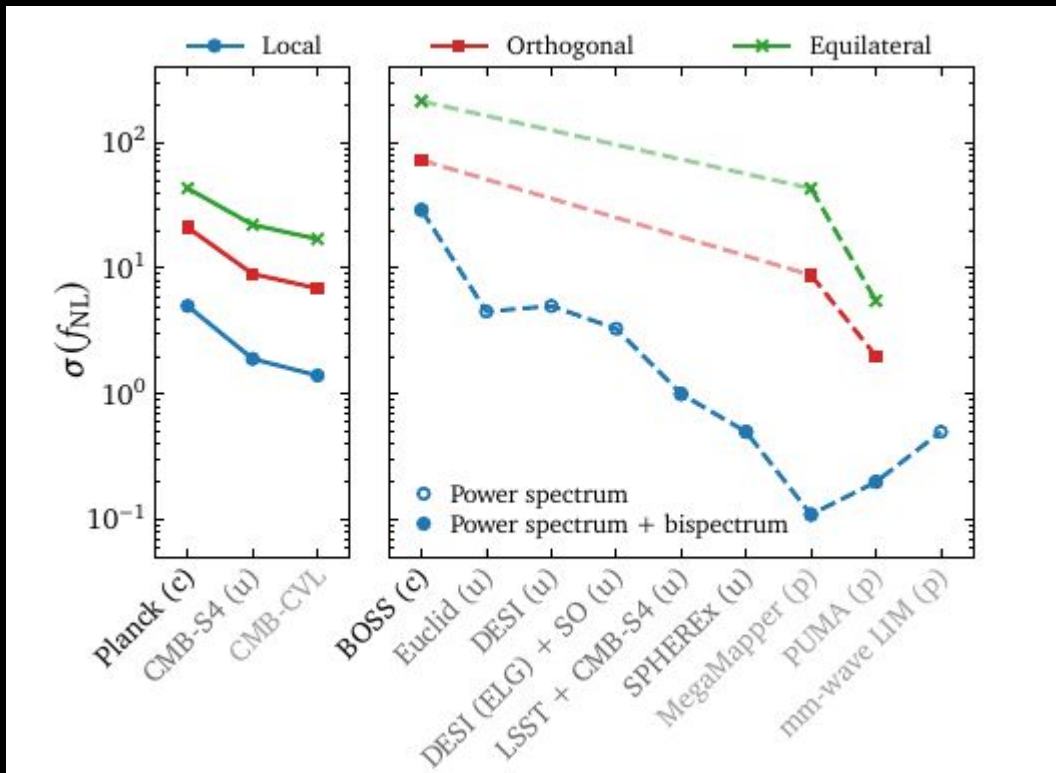
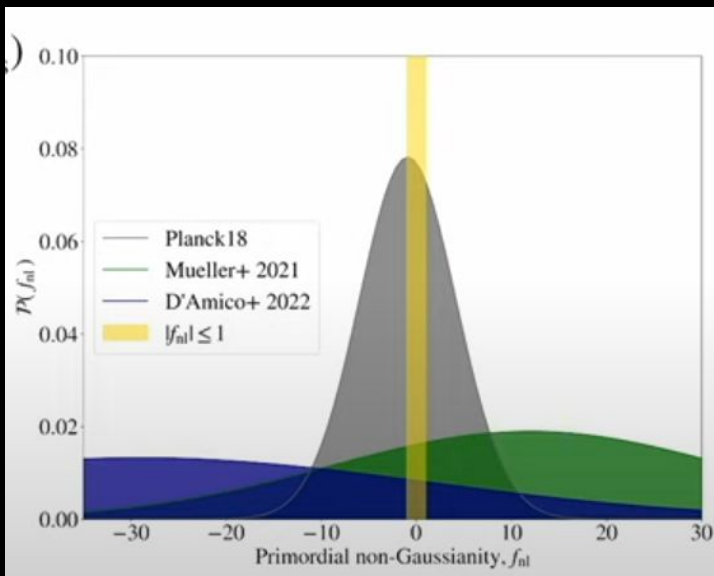


Signal regime: Large scales

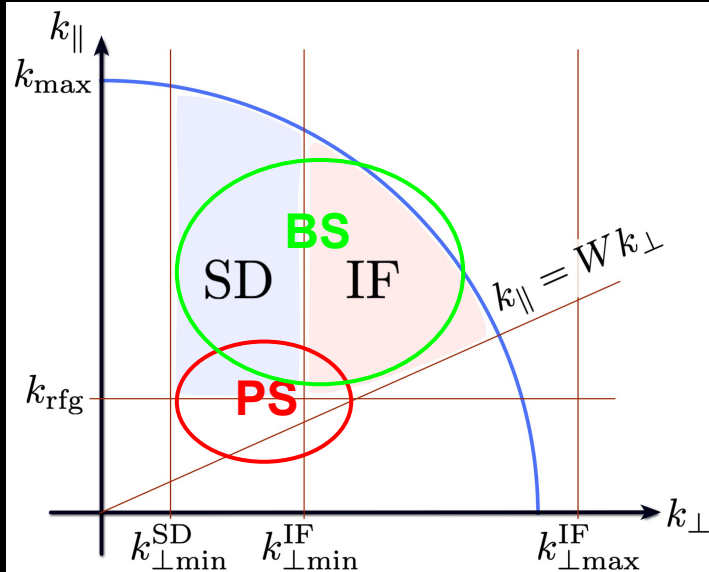
Problem: Systematic-prone region and cosmic variance (MT can solve this)!

Current constraints from LSS surveys

BOSS CMASS+LOWZ
($0.1 < z < 0.8$):



HI IM and PNG



	CHIME		HIRAX		PUMA Full	
$k_{\parallel, min}$ [h/Mpc]	0.01	0.05	0.01	0.05	0.01	0.05
P(loc)	31.9	105.5	25.8	101.3	2.52	8.42
B(loc)	72.7	457.7	10.2	71.5	0.91	3.63
P+B(loc)	28.4	101.7	9.3	47.9	0.84	3.05

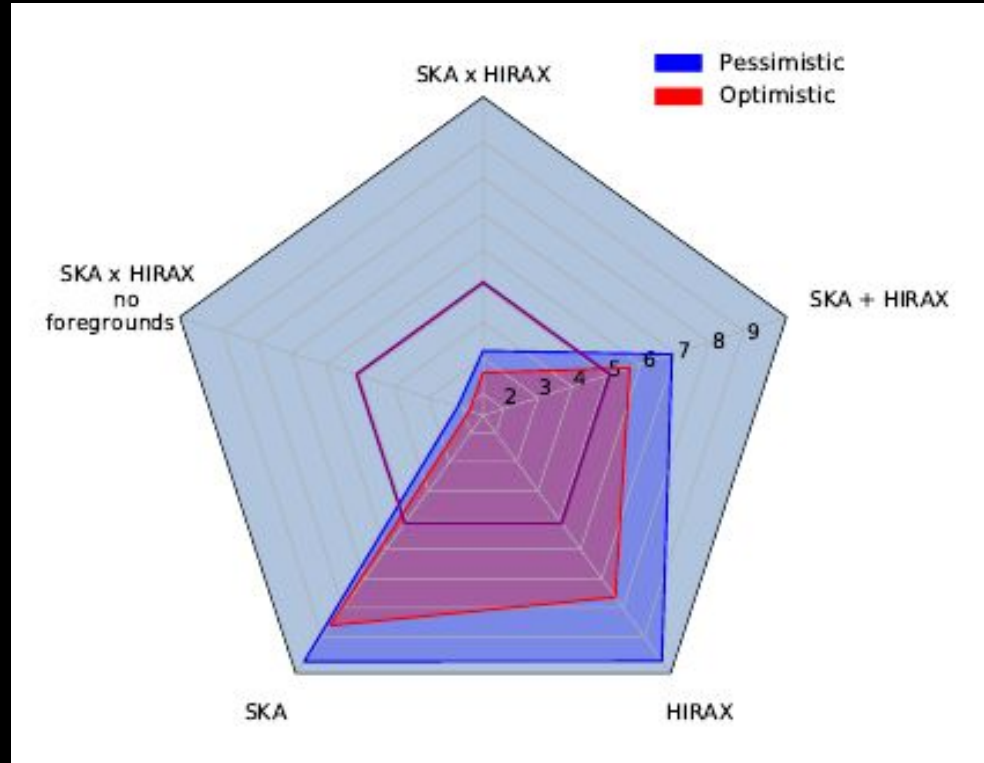
PNG cases	MEERKAT (SD)		SKA-MID (SD)		PUMA (SD)	HIRAX (SD)	SKA1-LOW (IF)	SKA2-LOW (IF)
	L-BAND	UHF	BAND 1	BAND 2				
Local	77 (105)	15 (22)	8 (12)	33 (52)	3 (6)	10 (17)	18 (19)	0.7 (0.8)

The 21cm bimodal bispectrum

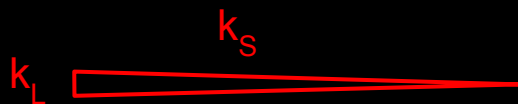
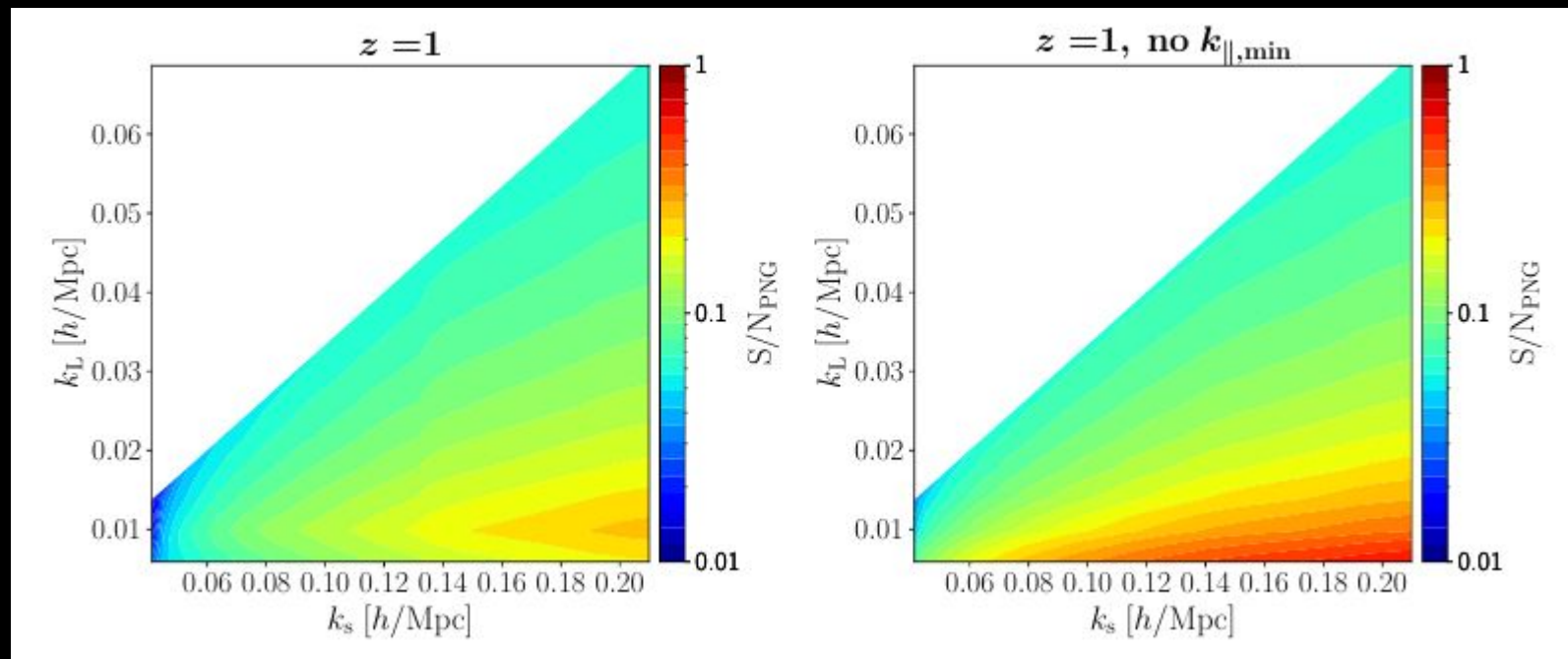
$$\langle \delta^{\text{IF}}(\mathbf{k}_1) \delta^{\text{IF}}(\mathbf{k}_2) \delta^{\text{SD}}(\mathbf{k}_3) \rangle = (2\pi)^3 \delta_{\text{D}}(\mathbf{k}_{123}) B^{\text{SD} \times \text{IF}}(\mathbf{k}_1, \mathbf{k}_2, \mathbf{k}_3)$$

Fisher matrix bispectrum forecasts:

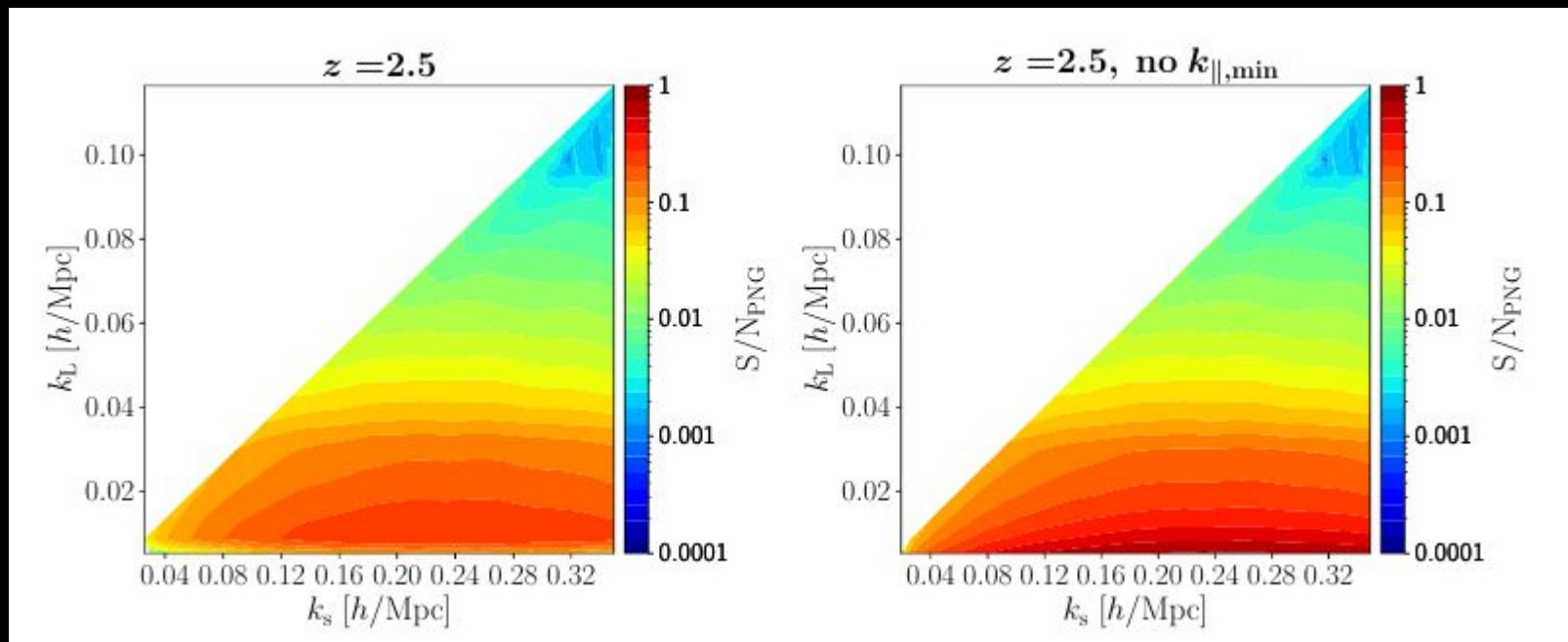
- ❖ SKA and HIRAX
- ❖ area=15,000 deg² 0.8<z<2.5
- ❖ Stay up to linear scales
- ❖ Use only a subset of triangles (the squeezed triangles).
- ❖ Analytic bispectrum covariance.
- ❖ Avoid contaminated regions.



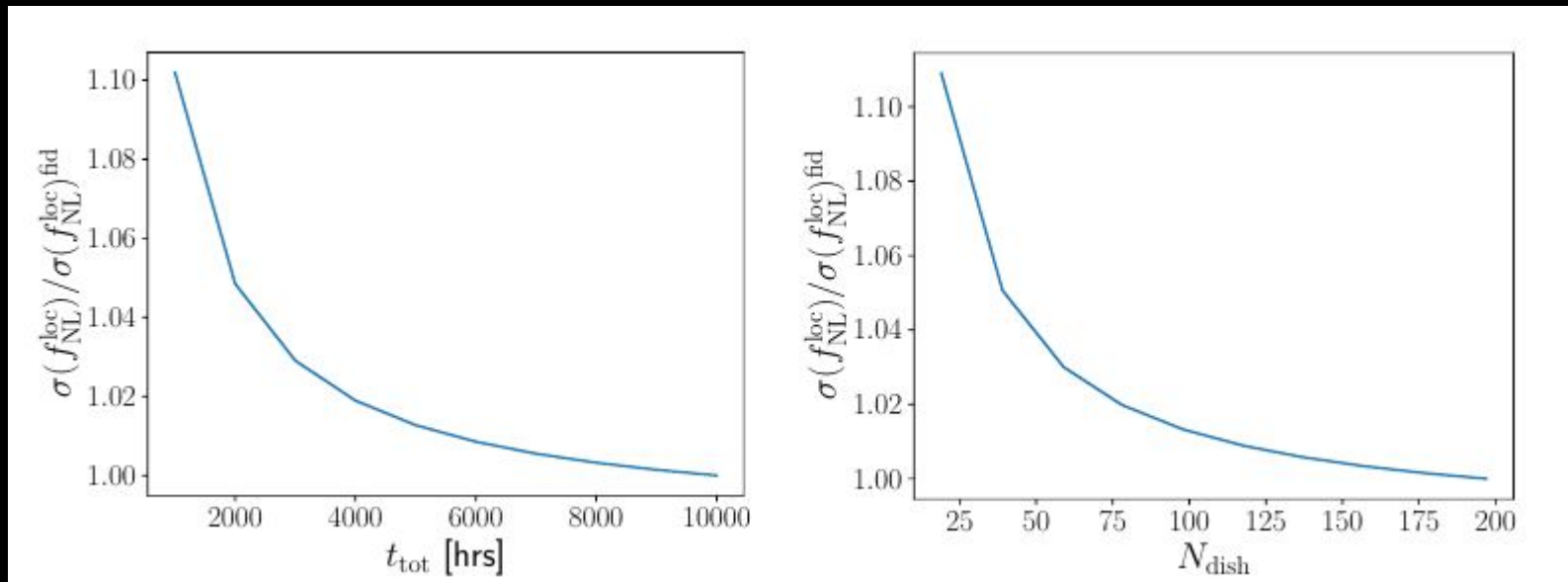
The effect of foregrounds



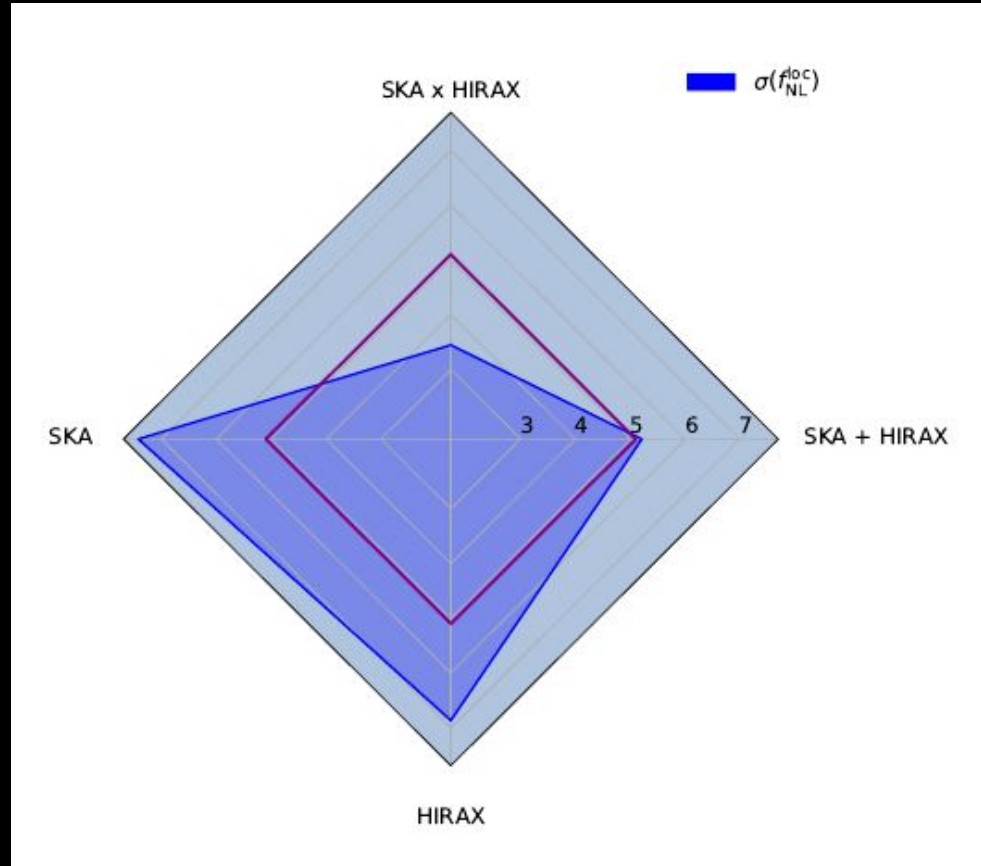
The effect of foregrounds



The effect of the SD survey



Is this limited only to squeezed configurations?



Main points

- This method offers a new way to exploit to the fullest the PNG information within the the HI IM dataset.
- Non correlated noise and reduced window convolution complexity.
- Competitive constraints on local PNG from HI IM, while avoiding contaminated regions.
- Could achieve $\sigma(f_{\text{NL}}) < 1$ and improve significantly over current Stage 4 surveys.
- Significant improvement from SD-IF synergy compared to SD and IF.