The primordial Universe and 21cm

Roy @ 70

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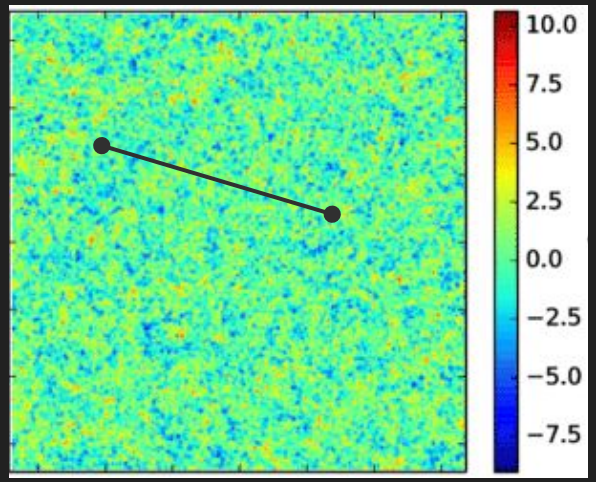
Cape Town 11/03/2025

It was a warm summer evening in Greece circa 2019 AD…

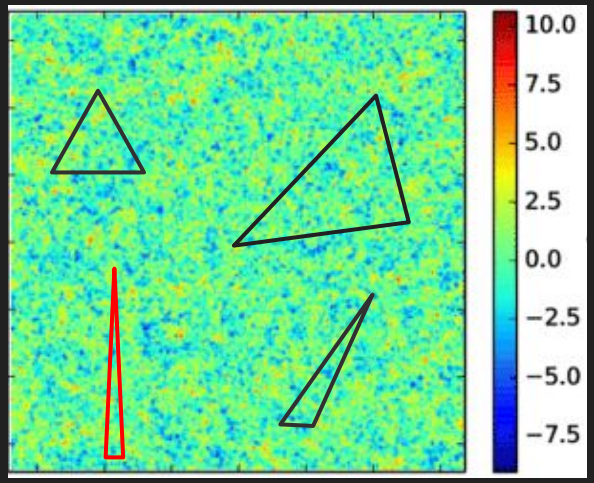
Statistics of the primordial perturbations

Standard inflation ~ Gaussian



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

More complex models ~ non Gaussian

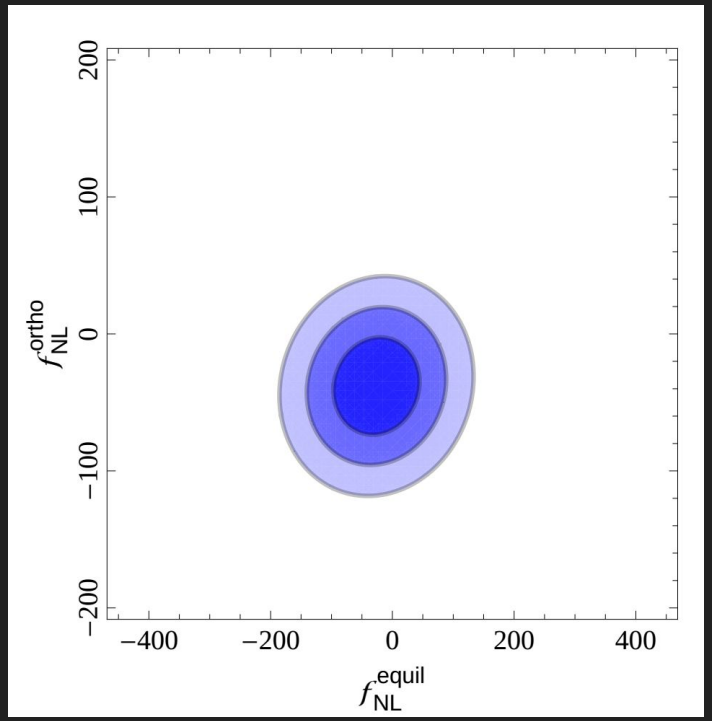


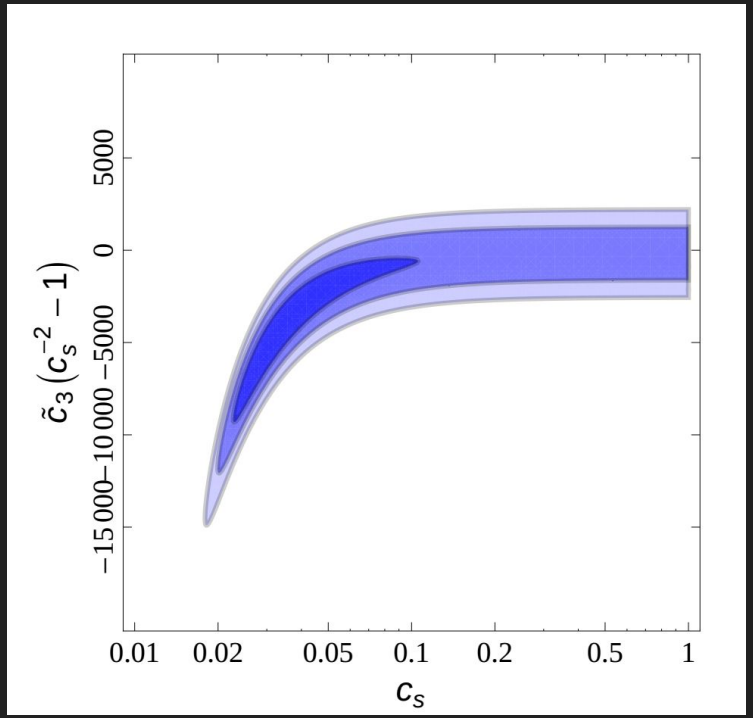
$\langle \zeta(k_1)\zeta(k_2)\zeta(k_3) \rangle = \delta(k_1+k_2+k_3) B_\zeta(k_1,k_2,k_3)$

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

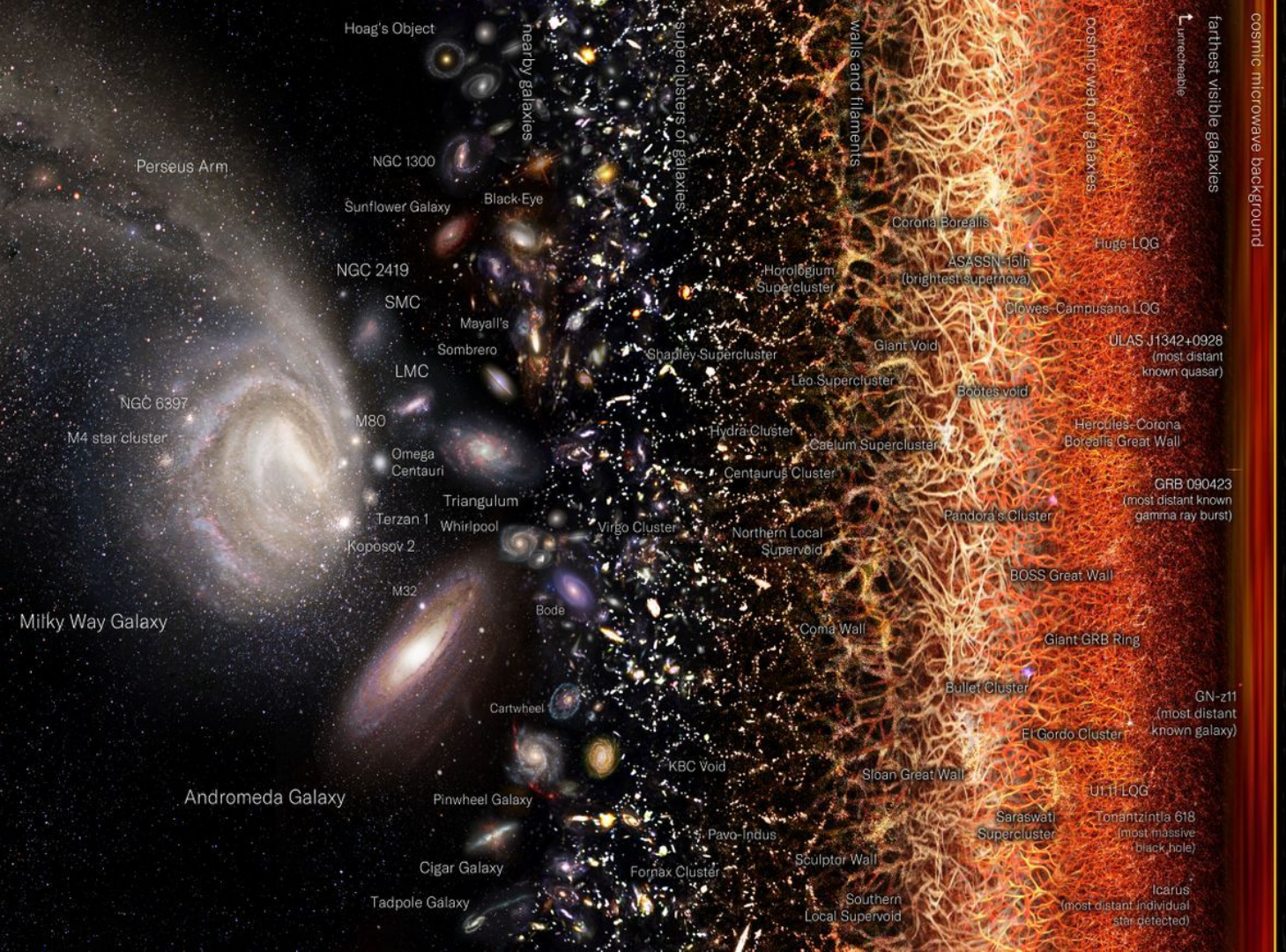
$f_{NL}=0$ → Gaussian **$f_{NL}\neq 0$ → non-Gaussian**

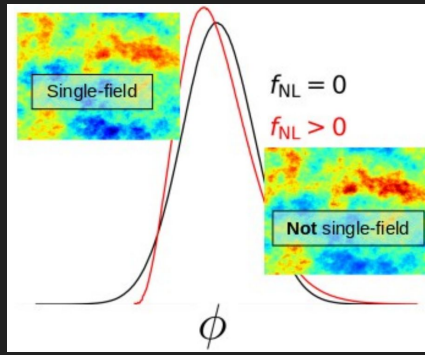
f_{NL} to inflationary parameters





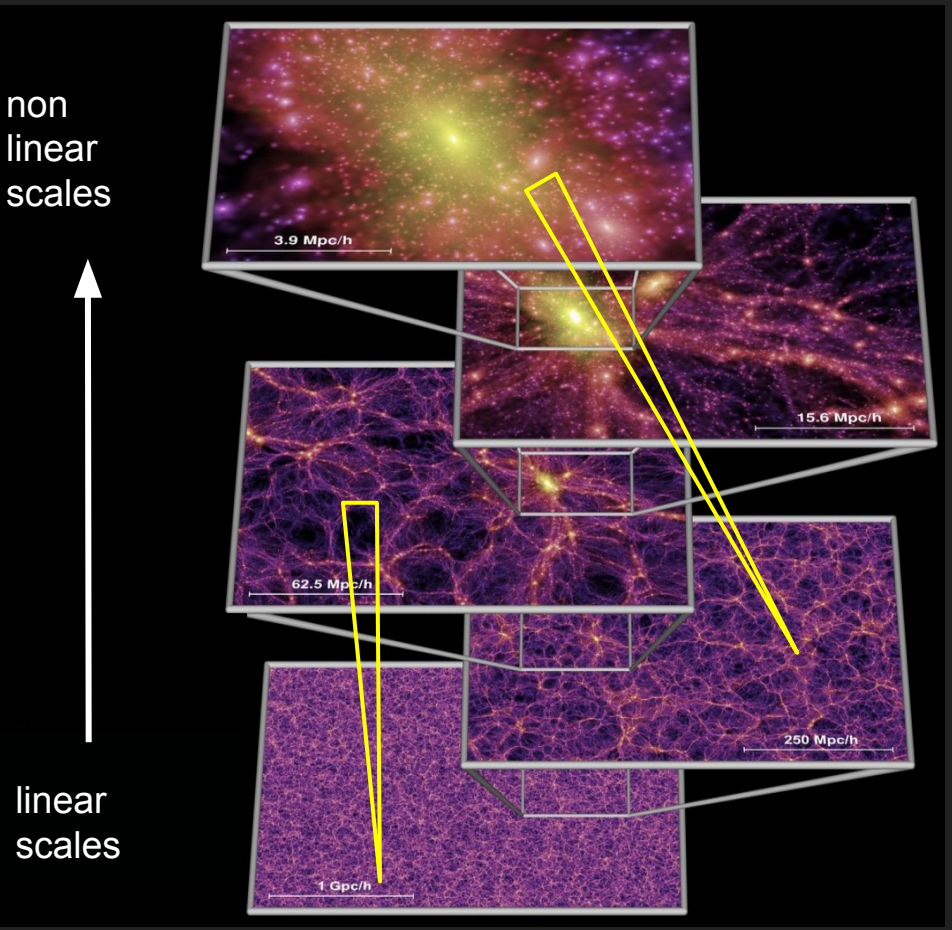
Planck et al 2018

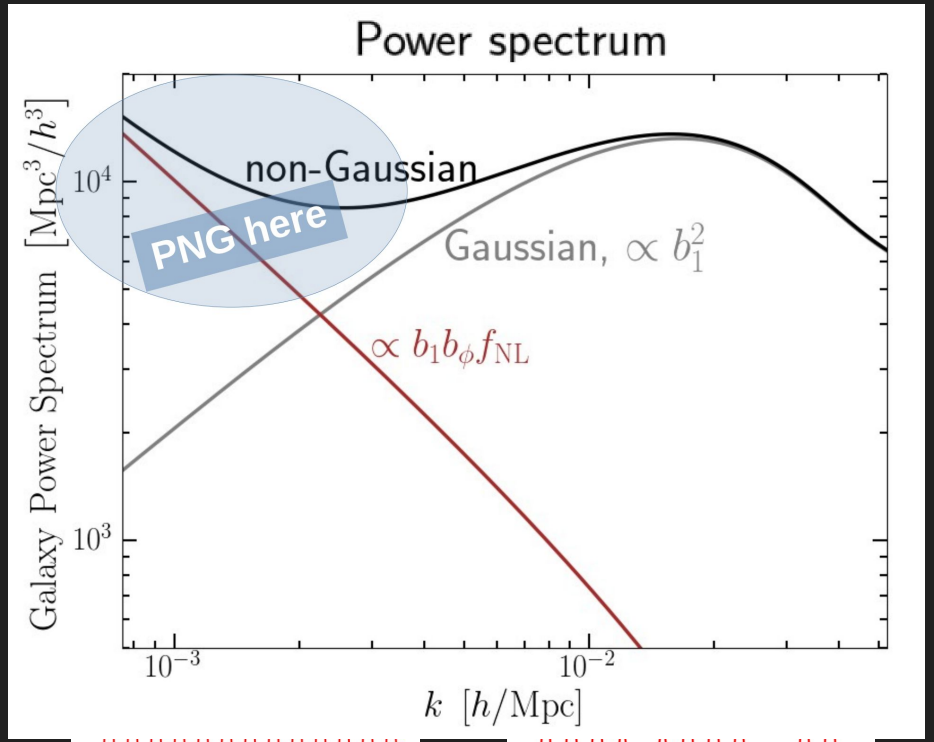


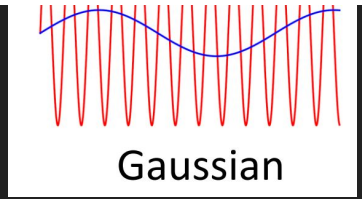


$$B_{obs} = B_{prim} + B_{late}$$

The effect of PNG on LSS







The effect of LSS on PNG

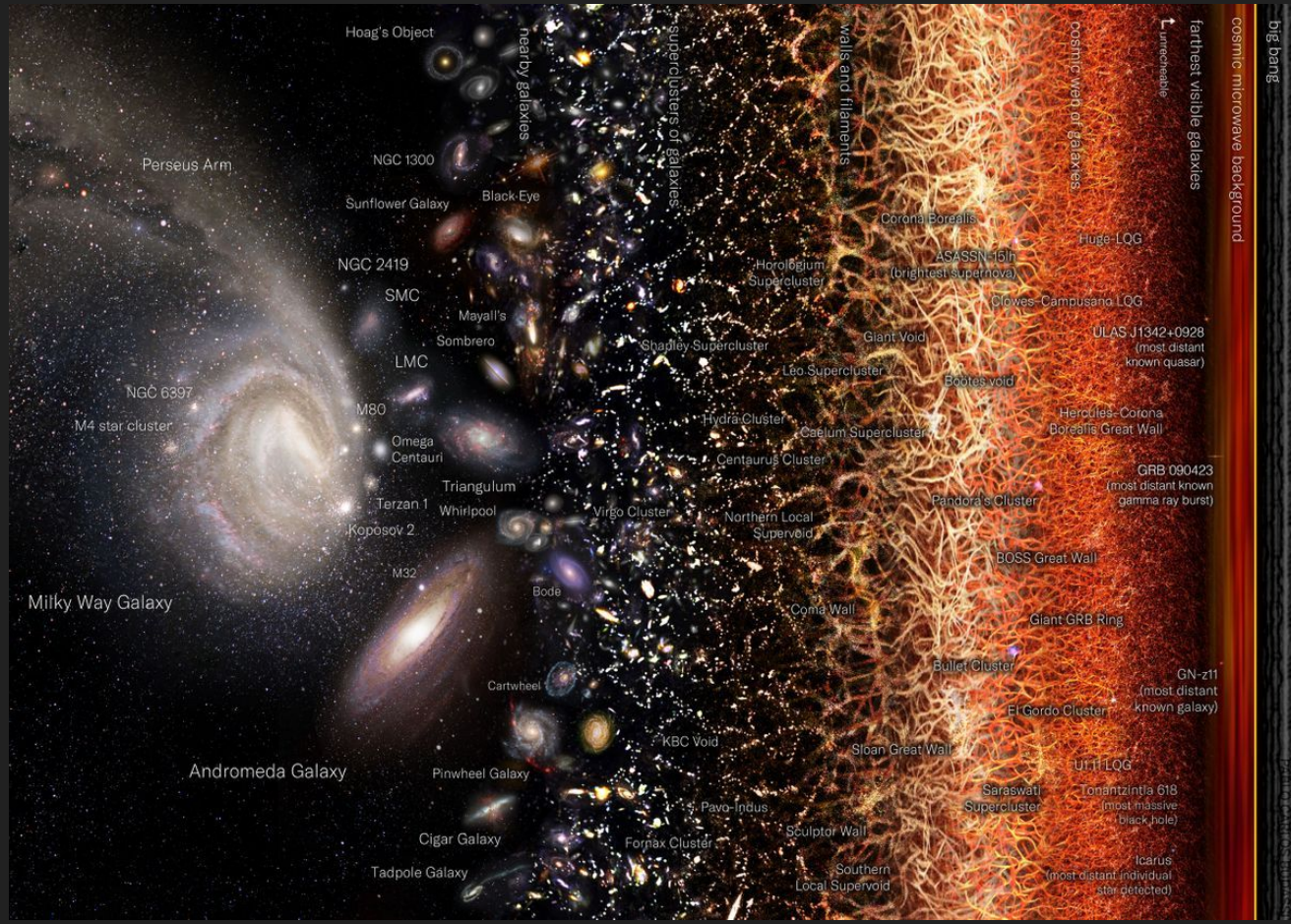
$B_{obs} = B_{prim} + B_{late}$

$B_{prim} << B_{late}$

Signal regime: From large to small scales

Problems:

- Shot noise regime kills the rich intermediate scale signal in low density surveys.
- Modelling these scales is tricky….linear model it is then….



Current constraints from LSS surveys

BOSS CMASS+LOWZ

Bispectrum constraints on Primordial non-Gaussianities with the eBOSS DR16 quasars

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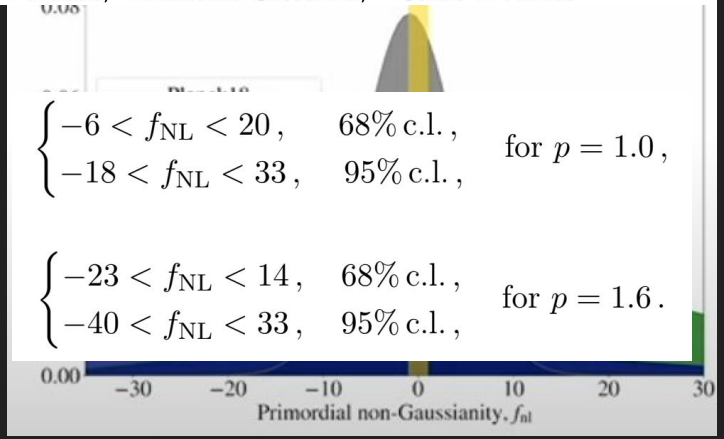
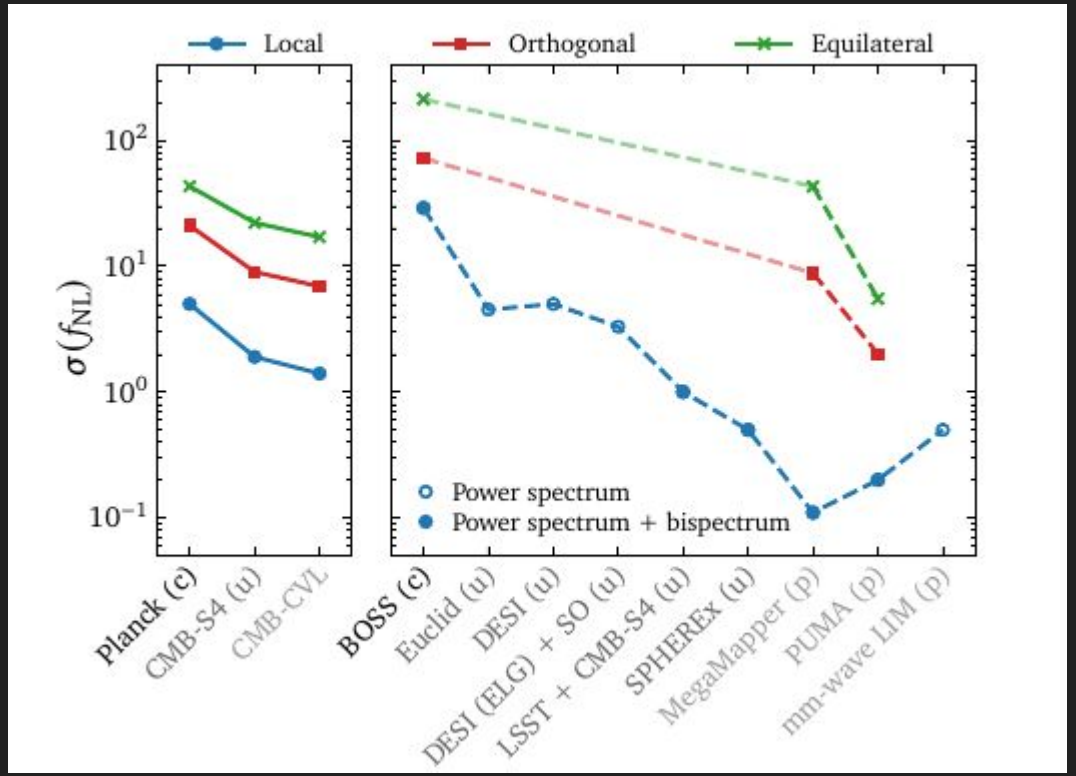
$$\begin{cases} -6 < f_{\rm NL} < 20\,, & 68\%\,\text{c.l.}\,, \\ -18 < f_{\rm NL} < 33\,, & 95\%\,\text{c.l.}\,, \end{cases} \quad \text{for } p = 1.0\,,$$

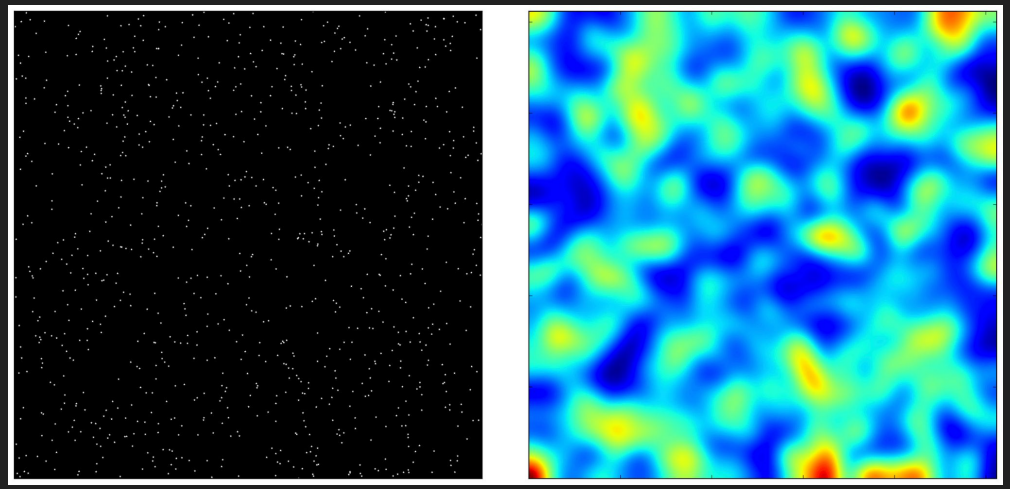
$$\begin{cases} -23 < f_{\rm NL} < 14\,, & 68\%\,\text{c.l.}\,, \\ -40 < f_{\rm NL} < 33\,, & 95\%\,\text{c.l.}\,, \end{cases} \quad \text{for } p = 1.6\,.$$



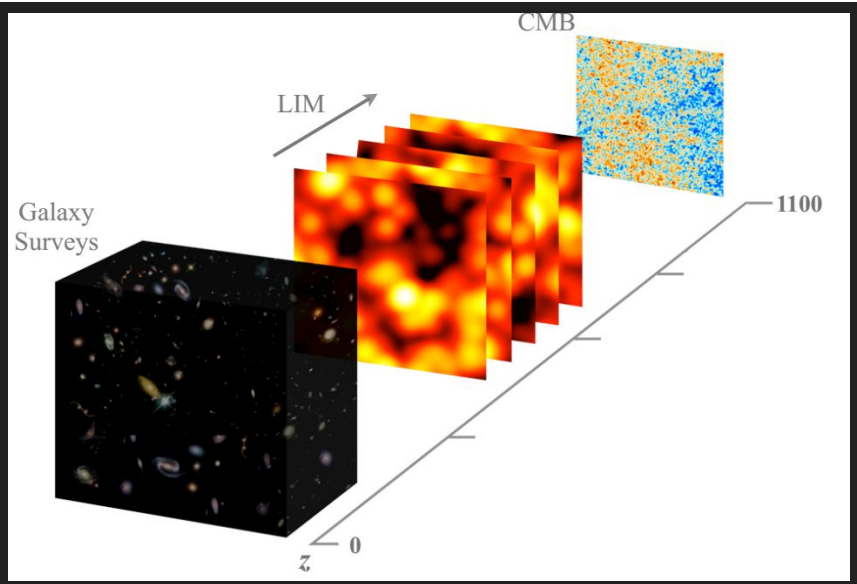


Achucarro et al 2022

21cm intensity mapping



- A different way to trace the Universe's large-scale structure is by detecting the 21cm emission from cosmic neutral hydrogen using the intensity mapping technique.
- Main idea: carry out a low angular-resolution survey where the emission from many unresolved galaxies and HI blobs is measured.



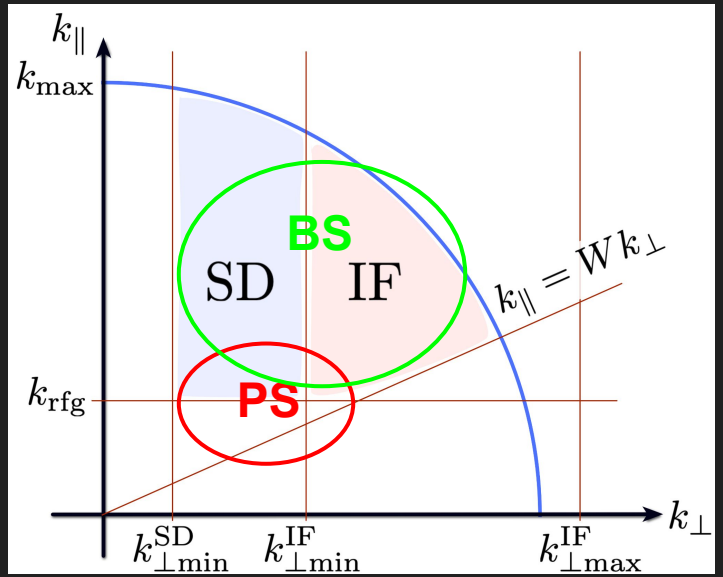
- 1) Very large sky area

  2) It is spectroscopic in nature

  3) high redshift range (z=0-30)

  4) Each pixel in the map contains many galaxies. i.e. larger detectable signal.

21cm Intensity Mapping and PNG

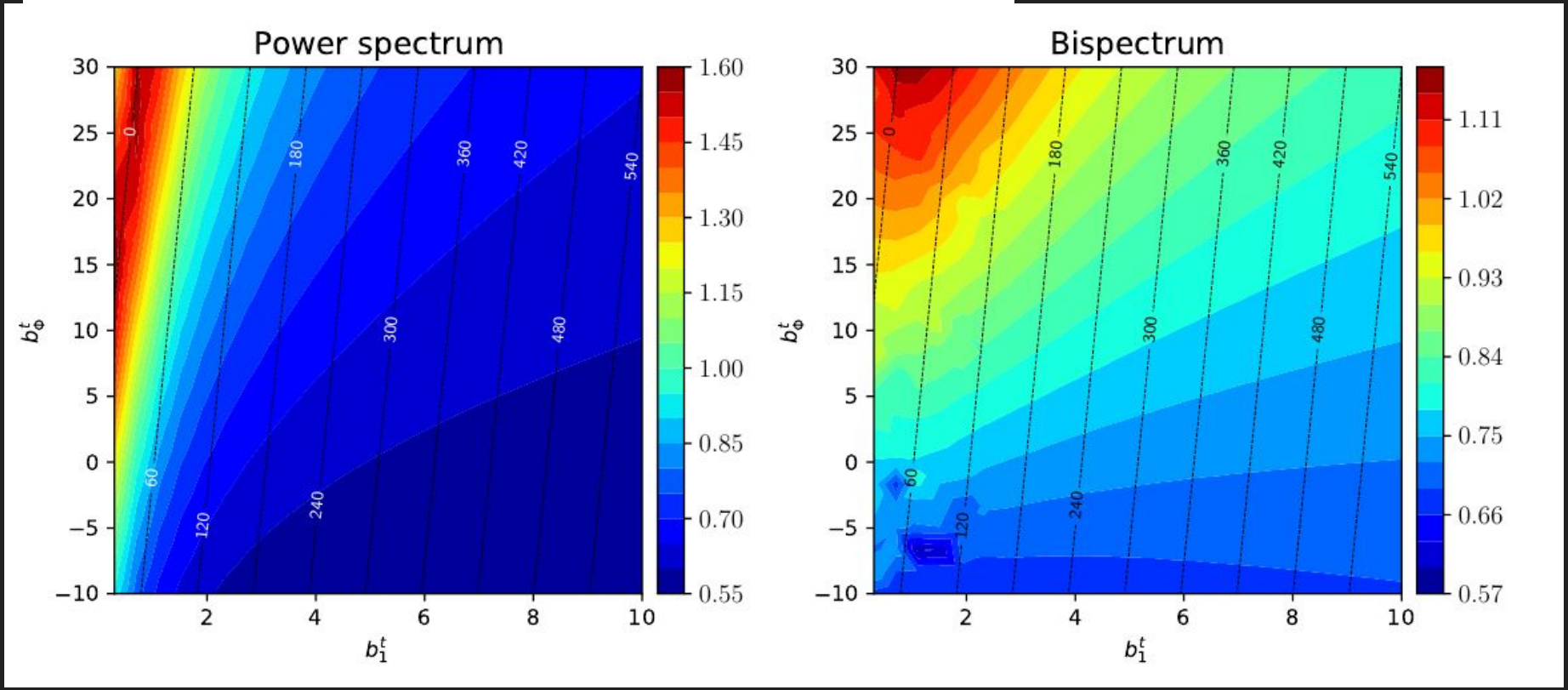


	CHIME		HIRAX		PUMA Full	
$k_{\parallel,min}$ [h/Mpc]	0.01	0.05	0.01	0.05	0.01	0.05
P(loc)	31.9	105.5	25.8	101.3	2.52	8.42
B(loc)	72.7	457.7	10.2	71.5	0.91	3.63
P+B(loc)	28.4	101.7	9.3	47.9	0.84	3.05

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)

Improve PNG constraints with multi-tracer

arXiv:2305.04028

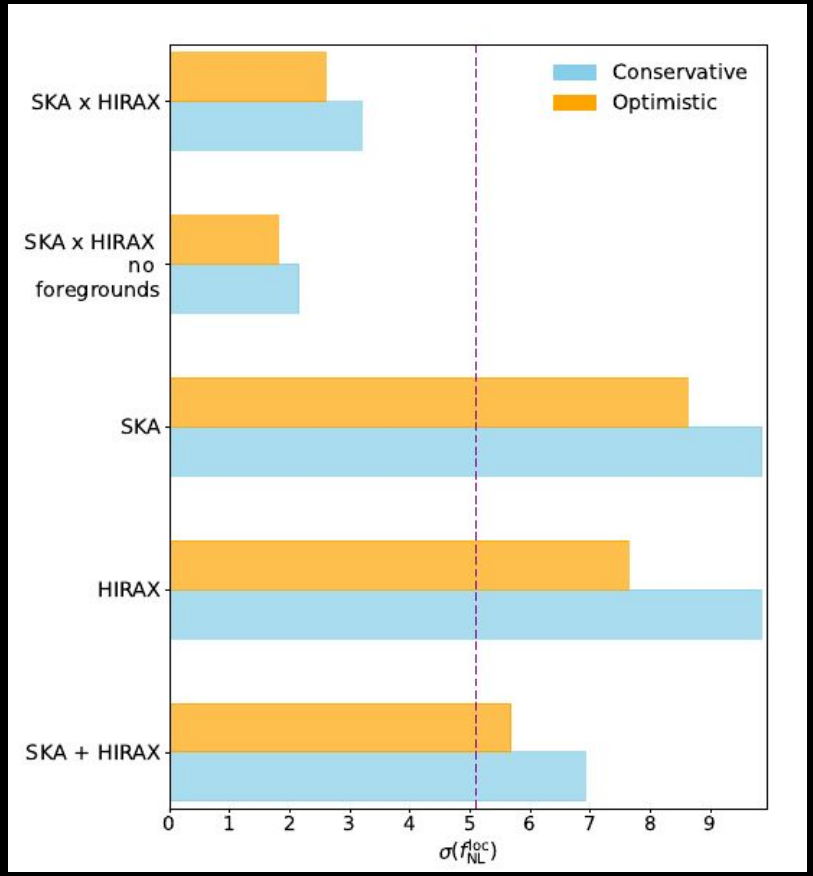


The 21cm bimodal bispectrum

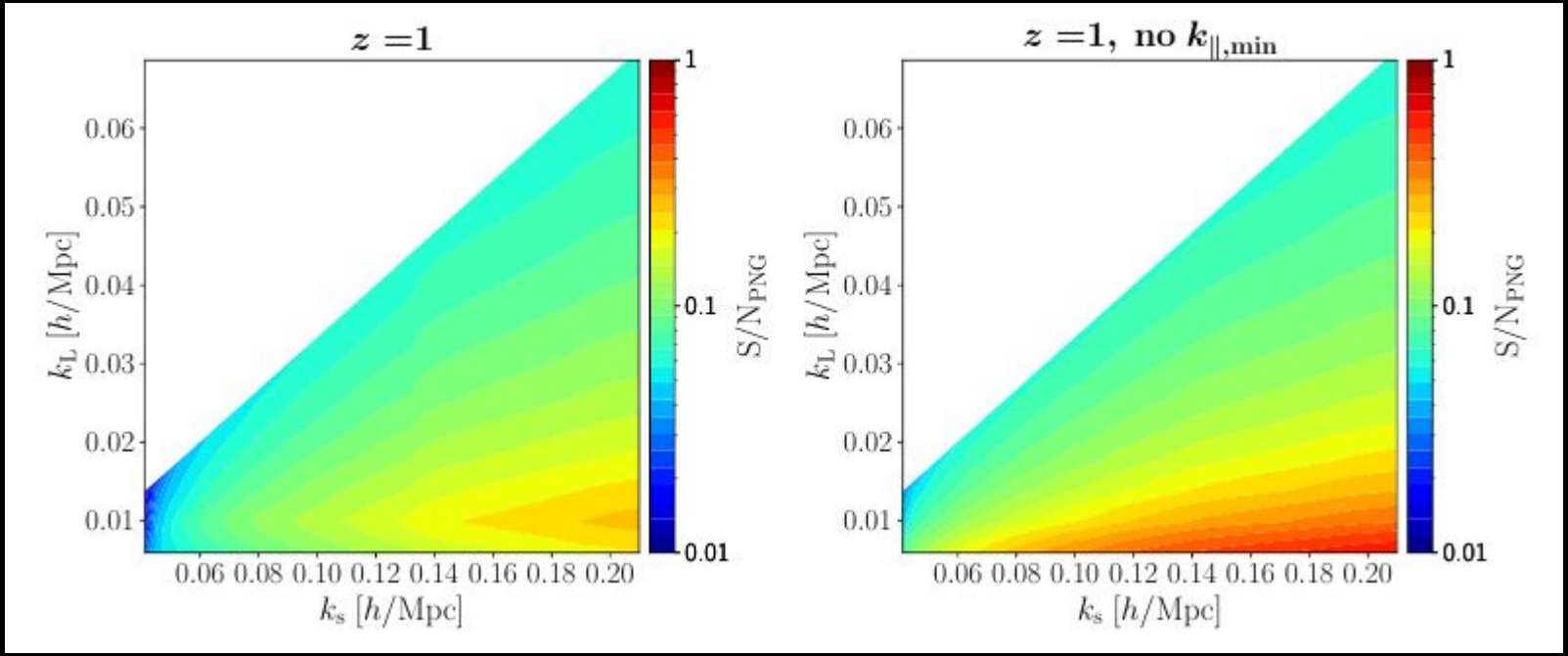
$$\langle \delta^{\mathrm{IF}}(\boldsymbol{k}_1)\, \delta^{\mathrm{IF}}(\boldsymbol{k}_2)\, \delta^{\mathrm{SD}}(\boldsymbol{k}_3) \rangle = (2\,\pi)^3\, \delta_{\mathrm{D}}(\boldsymbol{k}_{123})\, B^{\mathrm{SD}\times\mathrm{IF}}(\boldsymbol{k}_1, \boldsymbol{k}_2, \boldsymbol{k}_3)$$

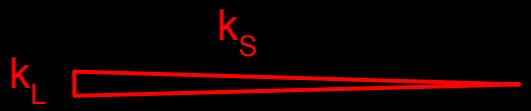
Fisher matrix bispectrum forecasts:

- SKA and HIRAX
- area=15,000 deg^2 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





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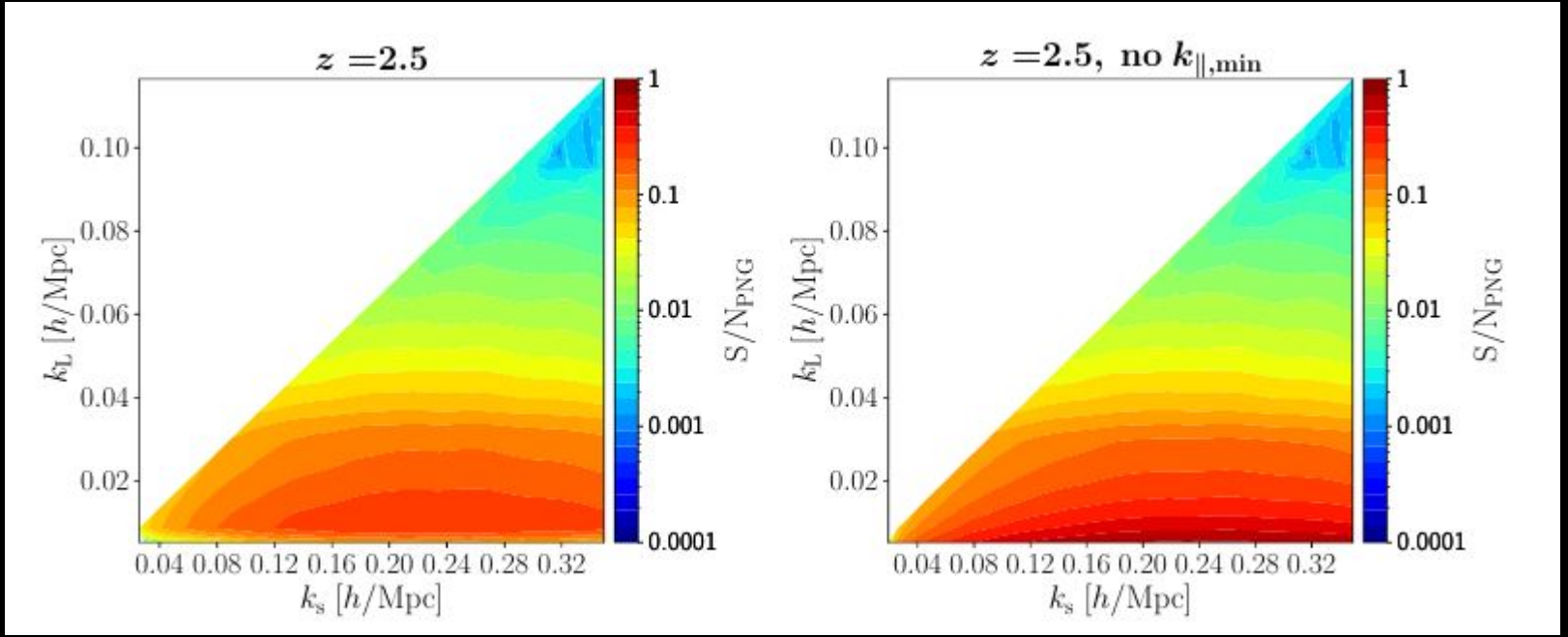
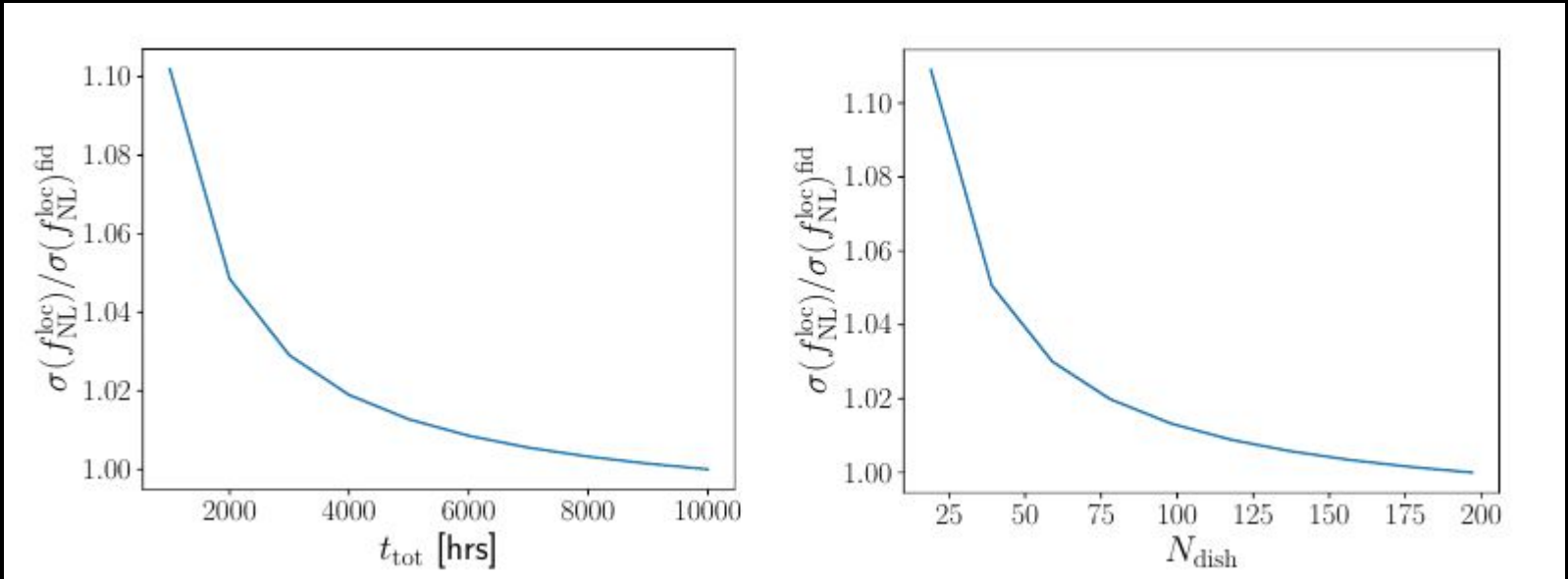
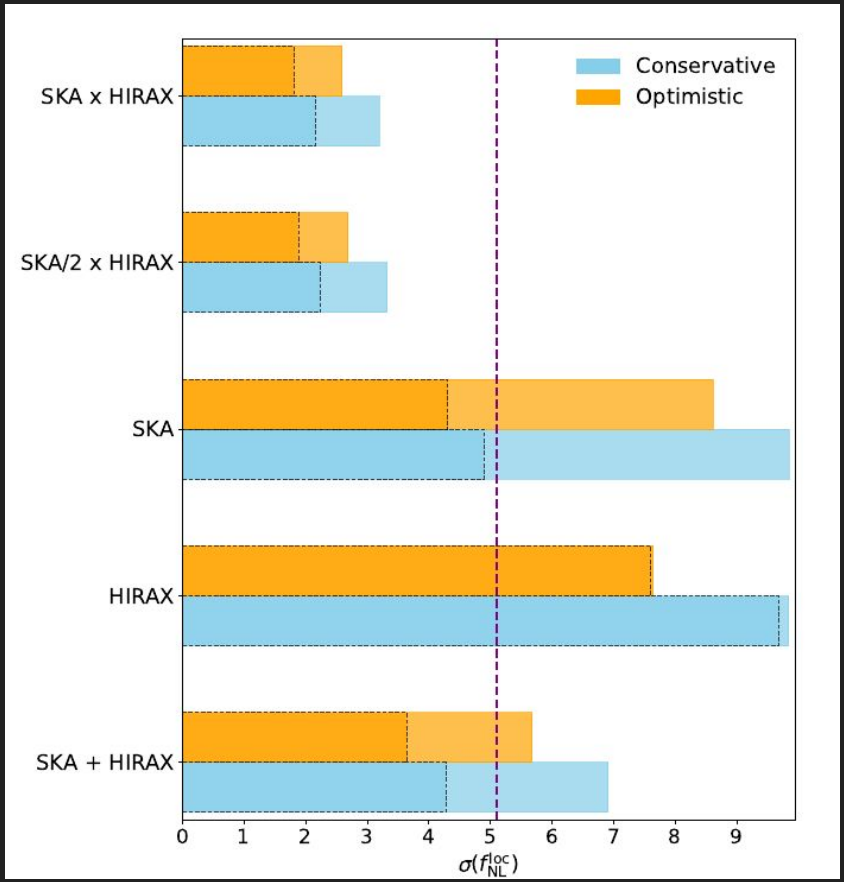
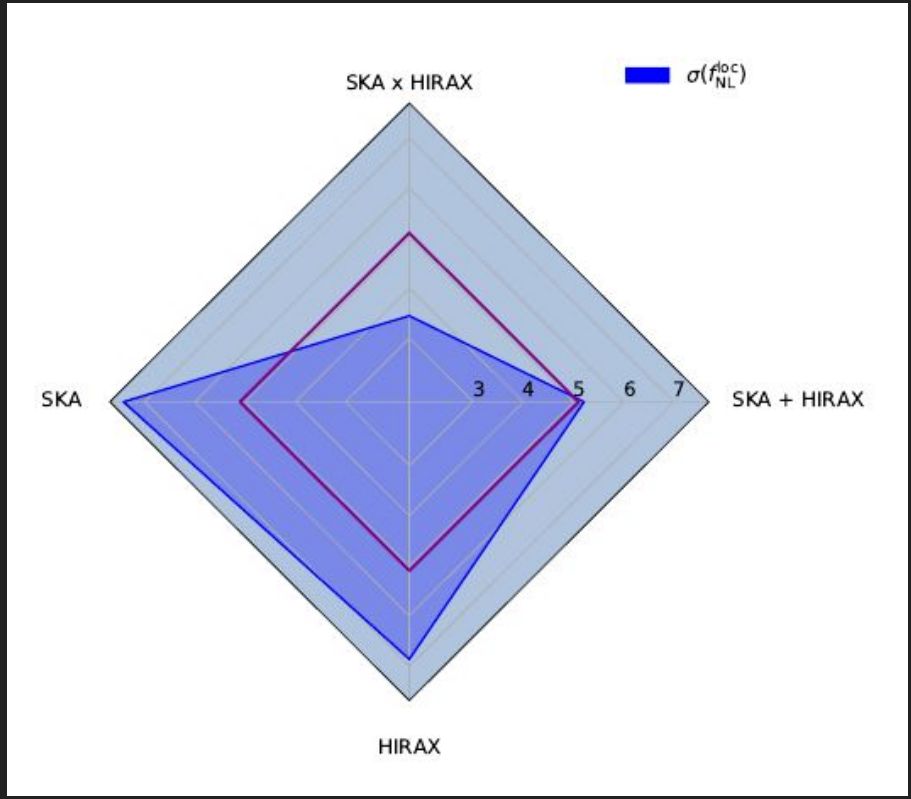


The effect of the SD survey




Conservative
Optimistic
SKA x HIRAX
SKA/2 x HIRAX
SKA
HIRAX
SKA + HIRAX
0
1
2
3
4
5
6
7
8
9
$\sigma(f_{\rm NL}^{\rm loc})$


$\sigma(f_{\rm NL}^{\rm loc})$
SKA x HIRAX
SKA
SKA + HIRAX
HIRAX
3
4
5
6
7


100