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Probing inflationary consistency relation with galaxy surveys

YAMAUCHI, Daisuke
(RESCEU, U. Tokyo)

DY and K. Takahashi(Kumamoto), in progress

In this talk I focus on SKA as a representative galaxy survey, but…

I don’t consider 21cm-line survey (SKA-LOW) but radio continuum survey (SKA-MID)!

A critical test of primordial Universe

- One of the most powerful tests of inflation

  → *Primordial non-Gaussianity*

  = Possible departures from a purely Gaussian distribution of primordial density fluctuations

- Hint about a mechanism for generating primordial fluctuations
- More generally key to understanding the extreme high-energy physics

$f_{NL}, \tau_{NL}, g_{NL}, \cdots$

- Primordial bispectrum (3-pt. fn.)

$$\langle \Phi(\boldsymbol{k}_1)\Phi(\boldsymbol{k}_2)\Phi(\boldsymbol{k}_3)\rangle = (2\pi)^3 B_\Phi(\boldsymbol{k}_1,\boldsymbol{k}_2,\boldsymbol{k}_3)\, \delta^3(\boldsymbol{k}_1+\boldsymbol{k}_2+\boldsymbol{k}_3)$$

(amplitude) × (shape dependent fn)

f_{NL}

- Primordial trispectrum (4-pt. fn.)

$$\langle \Phi(\boldsymbol{k}_1)\Phi(\boldsymbol{k}_2)\Phi(\boldsymbol{k}_3)\Phi(\boldsymbol{k}_4)\rangle = (2\pi)^3 T_\Phi(\boldsymbol{k}_1,\boldsymbol{k}_2,\boldsymbol{k}_3)\, \delta^3(\boldsymbol{k}_1+\boldsymbol{k}_2+\boldsymbol{k}_3+\boldsymbol{k}_4)$$

(amplitude) × (shape dependent fn)

τ_{NL}, g_{NL}

Current constraints from CMB

- (local-form) bispectrum

f_{NL} = 0.8+-5.0 (68%CL) [Planck 2015]

- (local-form) trispectrum

g_{NL} = (-9.0+-7.7) × 10^4 (68%CL)

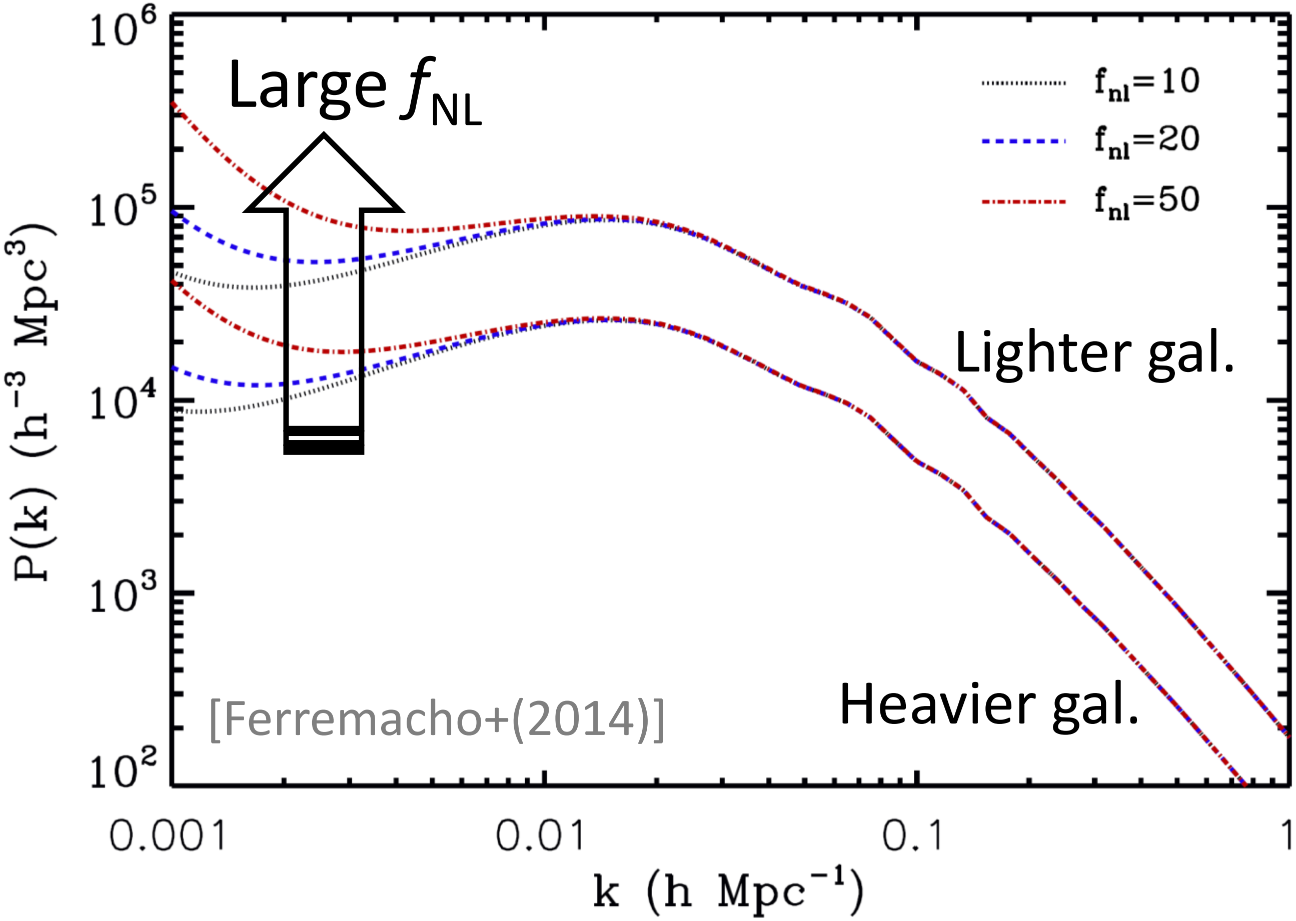
[Planck 2015]

τ_{NL} < 2800 (95%CL) [Planck 2013]

Almost all models are still consistent, though model parameters are severely constrained.

PNG in large-scale structure

$$P_{\rm gal} = [b_{\rm L}(M,z) + f_{\rm NL}\beta_{\rm f}(M,z)/k^2 D_+(z)]^2\, P_\delta$$



PNG consistency relation

All inflationary models predict that (if $f_{NL} \neq 0$) the trispectrum must necessarily exist with

$$\boxed{\tau_{NL} \geqq ((6/5) f_{NL})^2}$$

[Suyama+Yamaguchi (2010)], [Sugiyama+Komatsu+Futamase(2011)]

Confirmation of the consistency relation leads to strong suggestion for the inflationary models.

It should be the target in future experiments!

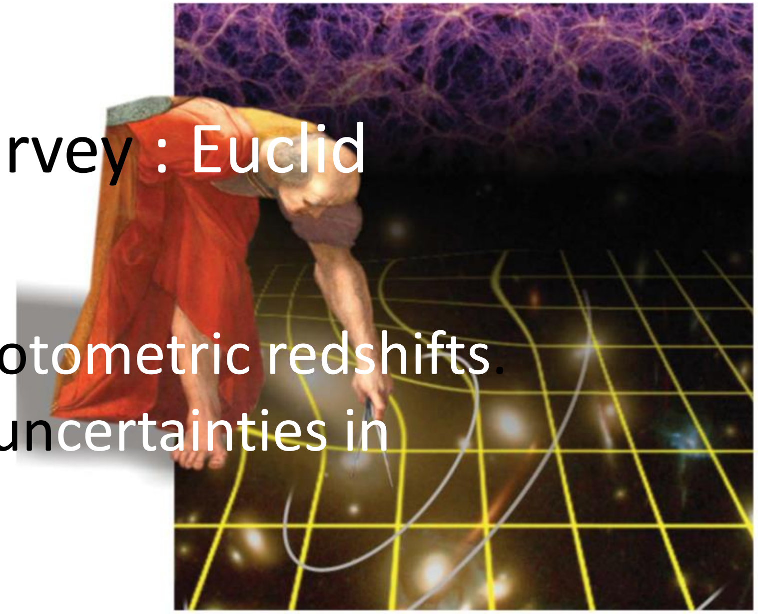
Main message

Q: What is the required survey level needed to test the consistency relation for future galaxy surveys?

ANSWER

With multitracer technique, the combination of SKA continuum and Euclid photometric surveys can reach the consistency relation with $f_{NL}>3$ (though for a single survey it is still hard to confirm).

Survey design

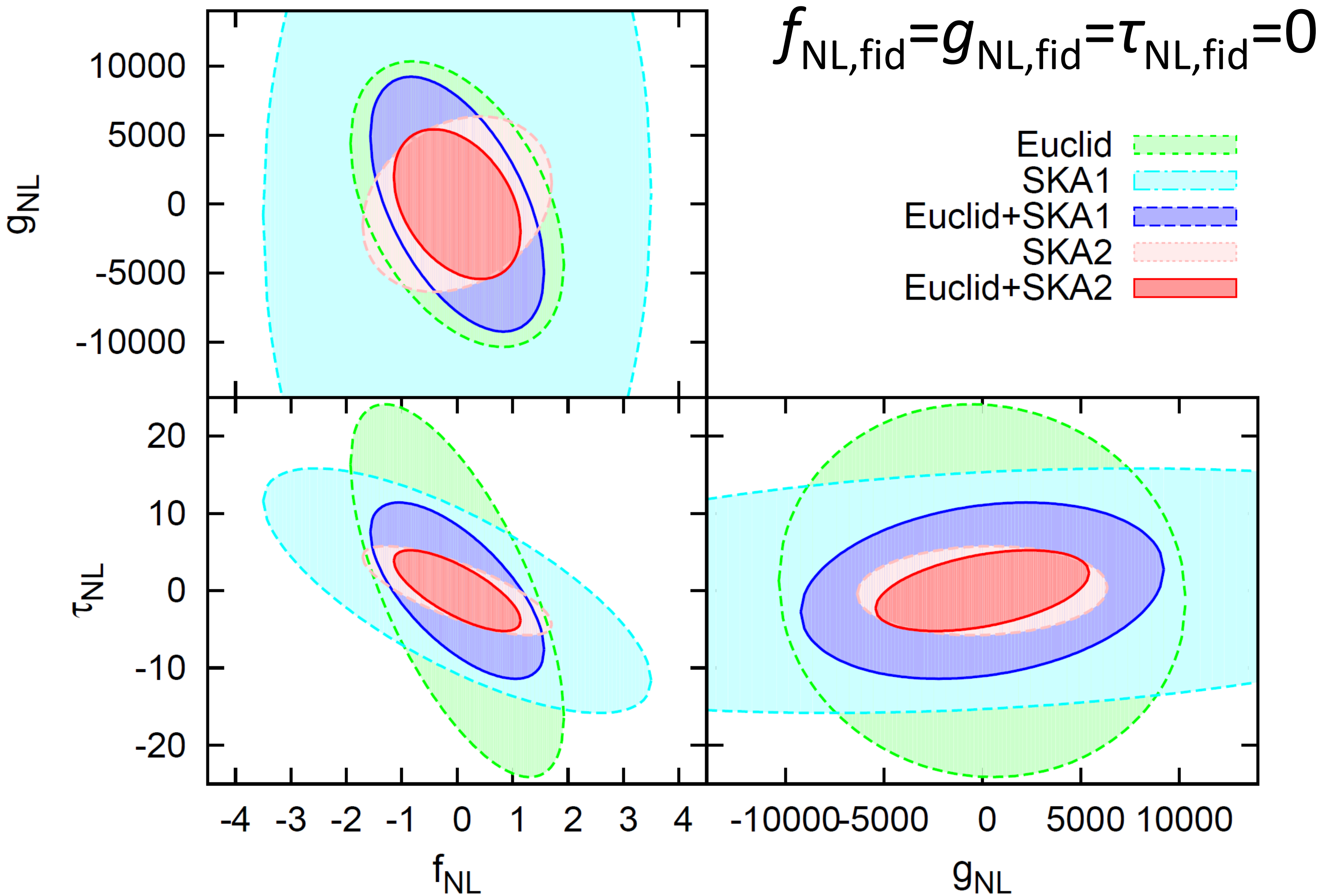


- Optical/infrared photometric survey : Euclid
  - Covers 15,000 [deg^2] out to z~2.7.
  - Provides redshift information via photometric redshifts.
  - 14 nuisance parameters to include uncertainties in mass inference from data

- Radio continuum survey : SKA phase-1/2 (SKA MID)
  - Covers 30,000 [deg^2] out to z~5.
  - The redshift information is not available.
  - Halo mass can be estimated from the galaxy type.
  - 8 nuisance parameter for mass inference

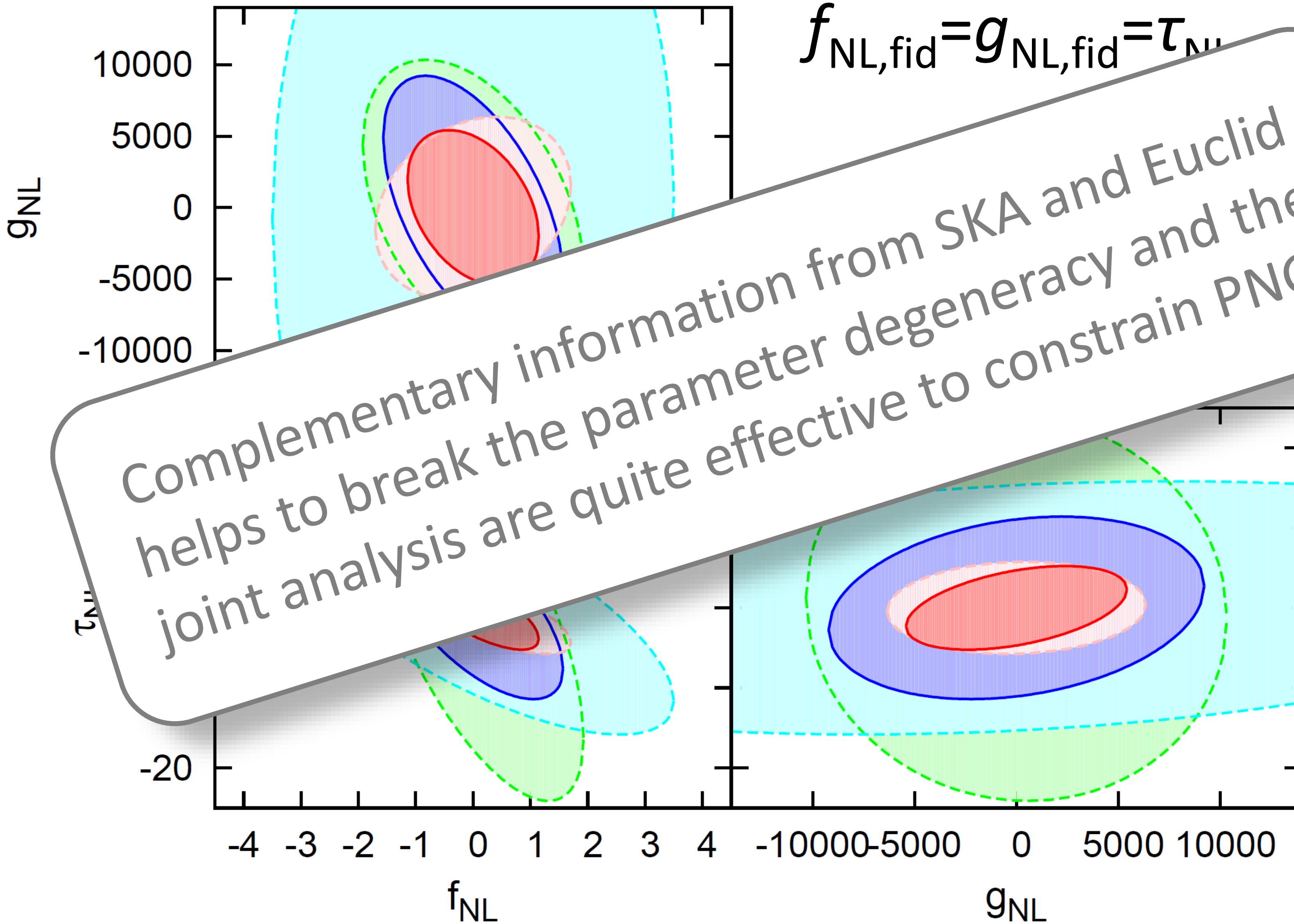
- SKA+Euclid : 9,000 [deg^2]

Expected 1σ contour



Expected 1σ contour

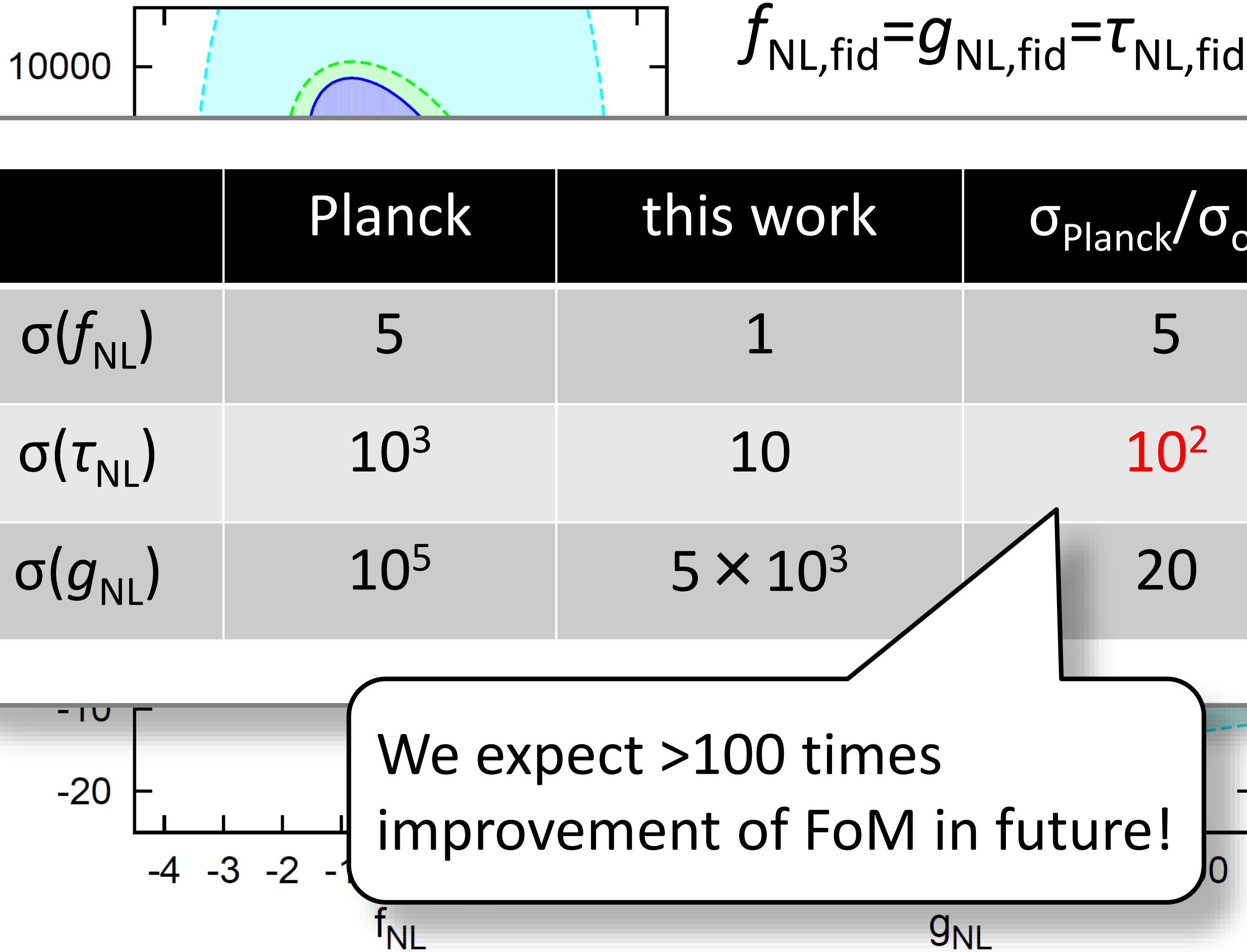
$f_{\mathrm{NL,fid}}=g_{\mathrm{NL,fid}}=\tau_{\mathrm{NL}}$ … $=0$



Complementary information from SKA and Euclid helps to break the parameter degeneracy and the joint analysis are quite effective to constrain PNG.

Expected 1σ contour

$f_{\mathrm{NL,fid}} = g_{\mathrm{NL,fid}} = \tau_{\mathrm{NL,fid}} = 0$

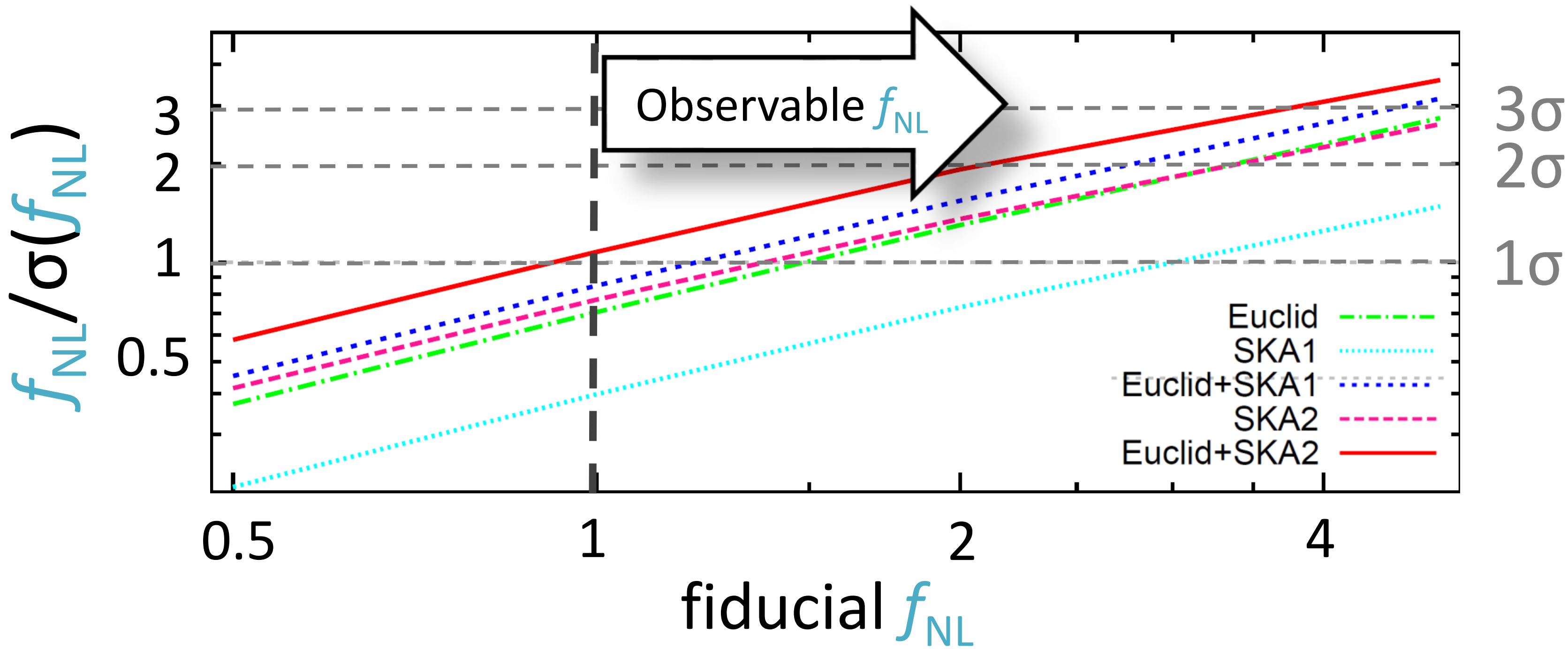


	Planck	this work	$\sigma_{\mathrm{Planck}}/\sigma_{\mathrm{ours}}$
$\sigma(f_{\mathrm{NL}})$	5	1	5
$\sigma(\tau_{\mathrm{NL}})$	10^3	10	10^2
$\sigma(g_{\mathrm{NL}})$	10^5	5×10^3	20

We expect >100 times improvement of FoM in future!

(simplest scenario $\tau_{NL}=((6/5)f_{NL})^2$)

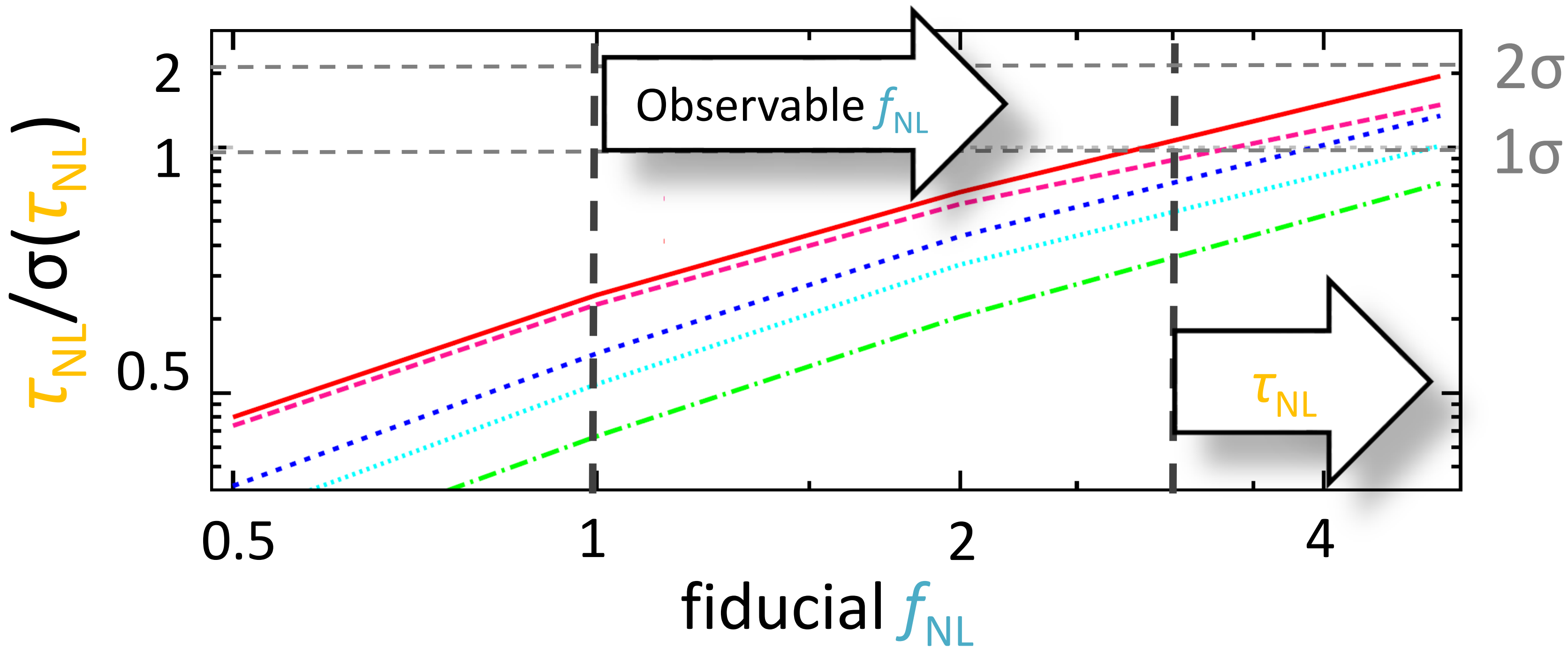
Statistical significance for f_{NL}



For a relatively larger value of f_{NL}(>1), Euclid and SKA2 can detect f_{NL} at the >1σ level.

(simplest scenario $\tau_{NL}=((6/5)f_{NL})^2$)

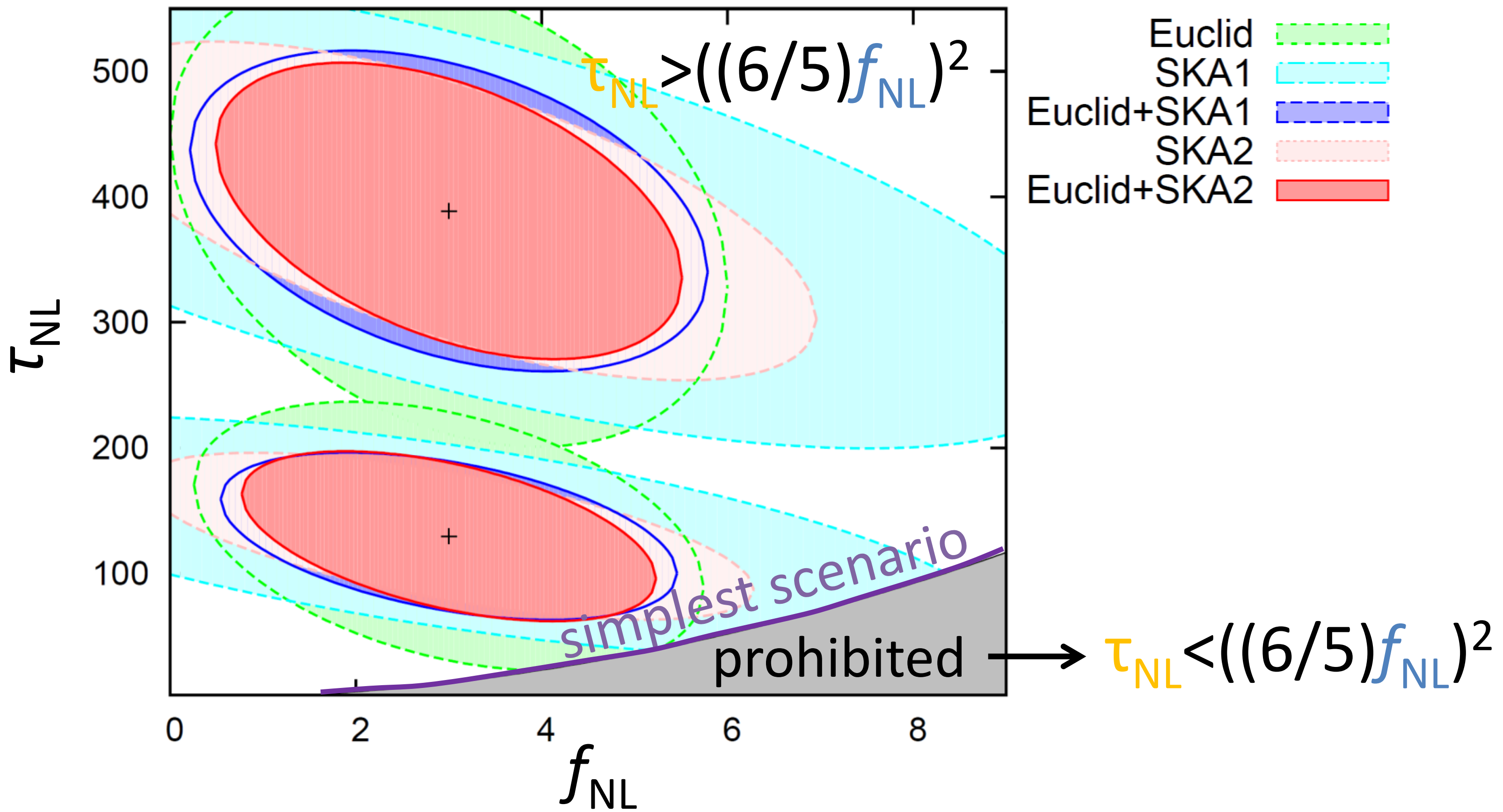
Then, for τNL



For $f_{NL}<3$, the confirmation at >1σ level is rather challenging for a single survey.

However,... **Combining SKA and Euclid can reach it !**

Extension to general situation



It is easier to confirm the consistency and SKA+Euclid has a power to distinguish from the simplest scenario.

Summary

Q: What is the required survey level needed to test the consistency relation for future galaxy surveys?

ANSWER

With multitracer technique, the combination of SKA continuum and Euclid photometric surveys can reach the consistency relation with f_{NL}>3 (though for a single survey it is still hard to confirm).