Constraints on primordial non-Gaussianity from galaxy-CMB lensing cross correlation

Yoshitaka Takeuchi (Nagoya U.) in collaborate with K. Ichiki (Nagoya U.) & T. Matsubara (KMI, Nagoya U.)

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Ref : Takeuchi, Ichiki & Matsubara, Phys.Rev.D 82, 023517 (2010) / E-mail : yositaka@a.phys.nagoya-u.ac.jp

1. Introduction

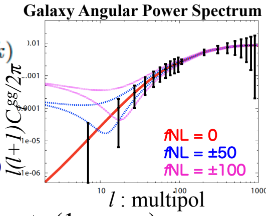
• The primordial non-Gaussianity (NG) affects the clustering of dark matter halo through **the scale-dependent bias.**

Gaussianity → non-Gaussianity

$$P_h(k) = b_0^G P_m(k) \Rightarrow [b_0^G + \Delta b(z,k)]^2 P_m(k)$$

$$\Delta b(z,k) = \frac{3(b_0^G - p) f_{\rm NL} \Omega_m H_0^2 \delta_c}{D(z) k^2 T(k) c^2}$$

(Dale et al. 2008, Slosar et al. 2008)



• Recent results : Observations & Forecasts (1σ error)

Observations : (Xia et al. 2010)

$f_{\rm NL} = 53 \pm 25$ & $f_{\rm NL} = 47 \pm 21$: from NVSS & SDSS DR6 QSOs data

Forecasts : (Cunha et al. 2010)

$\Delta f_{\rm NL} \sim 1\text{-}5$: cluster counts for DES-like survey

• On the next generation CMB experiments, CMB lensing will be a powerful tool to explore the large scale structure, which can get matter distribution **without uncertainty of bias**.

• Cross correlation between galaxy & CMB lensing can be break some degeneracy between NG and bias.

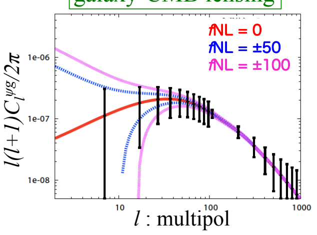
• We estimate the effect of galaxy-CMB lensing cross-correlation for the constraint of NG. We also estimate the effect of comic shear (weak lensing) survey for the constraints.

2. Cross-correlation angular power spectrum

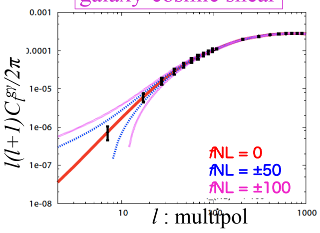
• The cross correlations between the CMB and the galaxy (e.g. ISW-galaxy) are well known as providing additional information other than their respective autocorrelation.

• We introduce the cross correlation between **CMB lensing**, **galaxy angular distribution** and **cosmic shear** to estimate errors in constraining cosmological parameters.

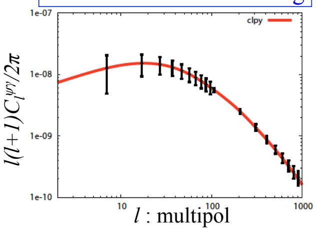
galaxy-CMB lensing



galaxy-cosmic shear



cosmic shear-CMB lensing



survey parameters

• **CMB lensing** : Planck
• **Galaxy** :
  sky coverage : $f_{sky} = 0.1$
  surface density : $n_g = 50$ [deg^{-2}]
  peak-redshift : $z_{peak} = 1.2$
• **Cosmic Shear** :
  sky coverage : $f_{sky} = 0.1$
  surface density : $n_s = 50$ [arcmin^{-2}]
  peak-redshift : $z_{peak} = 1.2$

3.Fisher Information Matrix

(Tegmark et al. 1997)

• We estimate the parameters error by Fisher matrix analysis.

$$F_{ij} = \sum_{l=2}^{l_{\max}} \sum_{XX',YY'} \frac{\partial C_l^{XX'}}{\partial \theta_i} ({\rm Cov}_l^{-1})_{XX'YY'} \frac{\partial C_l^{YY'}}{\partial \theta_j}$$

${\rm Cov}_l$: Covariance matrix

(XX',YY' ∈ TT, EE, TE, ψψ, gg, γγ, Tψ, Tg, Tγ, ψg, ψγ, gγ)

• Marginalized 1σ error **:** $\sigma(\theta_i) = \sqrt{(F^{-1})_{ii}}$

4. Result 1: Parameter forecast (CMB + Galaxy)

To see the contribution of ψg for construing NG, compare the 3 cases.

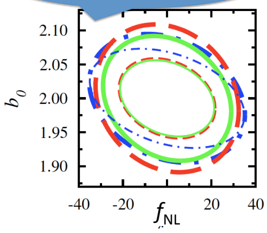
without cosmic shear

• Case I : C_l^{TT}, C_l^{EE}, C_l^{TE}, $C_l^{\psi\psi}$, $C_l^{T\psi}$, C_l^{gg}, ~~C_l^{Tg}~~, ~~$C_l^{\psi g}$~~ (without C_l^{Tg}, $C_l^{\psi g}$)
• Case II : C_l^{TT}, C_l^{EE}, C_l^{TE}, $C_l^{\psi\psi}$, ~~$C_l^{T\psi}$~~, C_l^{gg}, ~~C_l^{Tg}~~, $C_l^{\psi g}$ (without C_l^{Tg}, $C_l^{T\psi}$)
• Case III: C_l^{TT}, C_l^{EE}, C_l^{TE}, $C_l^{\psi\psi}$, $C_l^{T\psi}$, C_l^{gg}, C_l^{Tg}, $C_l^{\psi g}$ (full)

• $f_{\rm NL}$ degenerates especially with linear bias parameter b_0, however, does not degenerate with other cosmological parameters so much.

• The error of $f_{\rm NL}$ become smaller by including ψg. This aspect can be seen more clearly for CMBPol, which is more sensutuve survey to CMB lensing than Planck.

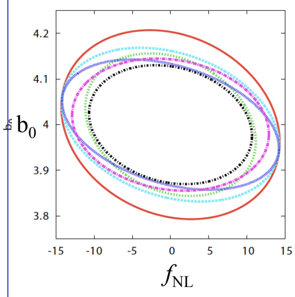
• Planck (Thick line)
• CMBPol (Thin line)

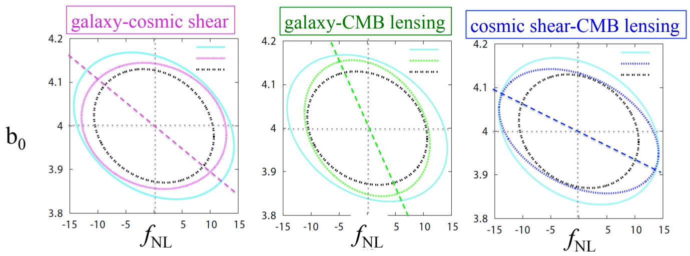


5. Result 2: CMB + Galaxy + Cosmic Shear

Let's include the cosmic shear above result, and see the effects of CMB-cosmic shear & Galaxy-cosmic shear cross-correlations.

• **CMB + Galaxy :**
CMB + C_l^{gg}, ~~$C_l^{\gamma\gamma}$~~, ~~C_l^{Tg}~~, ~~$C_l^{T\gamma}$~~, ~~$C_l^{\psi g}$~~, ~~$C_l^{g\gamma}$~~, ~~$C_l^{\psi\gamma}$~~
• **CMB + Galaxy + Shear :**
CMB + C_l^{gg}, $C_l^{\gamma\gamma}$, ~~C_l^{Tg}~~, ~~$C_l^{T\gamma}$~~, ~~$C_l^{\psi g}$~~, ~~$C_l^{g\gamma}$~~, ~~$C_l^{\psi\gamma}$~~
• **(CMB × Galaxy) + Shear :**
CMB + C_l^{gg}, $C_l^{\gamma\gamma}$, C_l^{Tg}, ~~$C_l^{T\gamma}$~~, $C_l^{\psi g}$, ~~$C_l^{g\gamma}$~~, ~~$C_l^{\psi\gamma}$~~
• **(CMB × Shear) + Galaxy :**
CMB + C_l^{gg}, $C_l^{\gamma\gamma}$, ~~C_l^{Tg}~~, $C_l^{T\gamma}$, ~~$C_l^{\psi g}$~~, ~~$C_l^{g\gamma}$~~, $C_l^{\psi\gamma}$
• **CMB + (Galaxy × Shear) :**
CMB + C_l^{gg}, $C_l^{\gamma\gamma}$, ~~C_l^{Tg}~~, ~~$C_l^{T\gamma}$~~, ~~$C_l^{\psi g}$~~, $C_l^{g\gamma}$, ~~$C_l^{\psi\gamma}$~~
• **CMB × Galaxy × Shear :**
CMB + C_l^{gg}, $C_l^{\gamma\gamma}$, C_l^{Tg}, $C_l^{T\gamma}$, $C_l^{\psi g}$, $C_l^{g\gamma}$, $C_l^{\psi\gamma}$



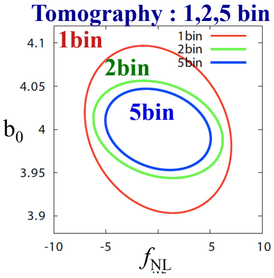


• The error of bias b_0 is fairly reduced by cosmic shear. (**red - shy blue**)

• The case considering the all cross-correlations can constrain on $f_{\rm NL}$ tighter than no cross-correlations. (**sky blue - black**)

• The lensing ***tomography*** method for "**black**" case is effective against constraint of $f_{\rm NL}$. **(right figure)**

Tomography : 1,2,5 bin



6.Summary & Conclusion

We estimated the effect of the cross-correlations between CMB lensing, galaxy distribution & cosmic shear for constraint of $f_{\rm NL}$.

• Cross-correlation ψg plays an important role to break some degeneracy between $f_{\rm NL}$ and b_0.

• Cosmic shear can fairly reduce the error of bias. Considering their cross-correlations, we can constrain on $f_{\rm NL}$ more tightly.

• The lensing tomography method is effective against constraint of $f_{\rm NL}$.