Cross correlation of cosmic shear from CSST with CMB lensing from AliCPT

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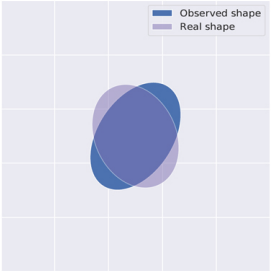
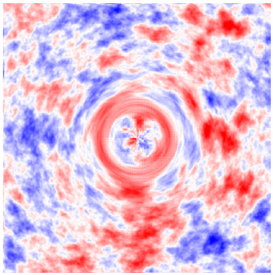
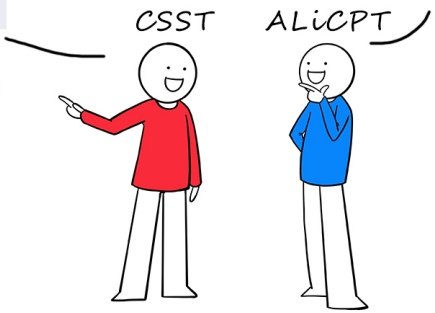


Cross−correlation?

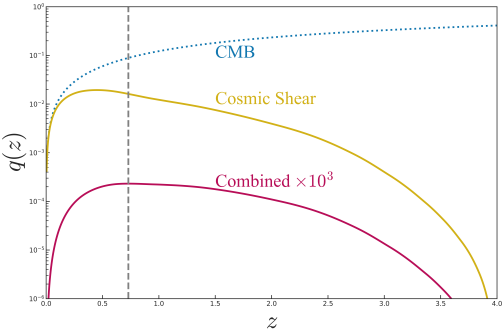


$$\varepsilon = \frac{\varepsilon_s + \mathrm{g}}{1 + \mathrm{g}^* \varepsilon_s} \approx \varepsilon_s + \gamma$$



$$\tilde{\Theta}(\boldsymbol{\theta}) = \frac{\Delta T}{\bar{T}_{\mathrm{CMB}}} = \Theta(\boldsymbol{\theta} + \mathbf{d}(\boldsymbol{\theta}))$$
$$= \Theta(\boldsymbol{\theta}) + \nabla^i \psi \nabla_i \Theta(\boldsymbol{\theta}) + \mathcal{O}(\psi^2)$$

Cross-correaltion



- Galaxy shape survey (CSST)
  $\rightarrow$ cosmic shear
- CMB experiment (AliCPT-1)
  $\rightarrow$ CMB lensing reconstruction
- The signals are correlated but noises are not.

$$C_\ell^{XY} = \int_0^{z_*} \frac{\mathrm{c}\mathrm{d}z}{H(z)} \frac{q^X(z) q^Y(z)}{\chi^2} P_\delta(k = \frac{\ell + 1/2}{\chi}, z)$$

Map realisation

Maps of signal:

$$M_1(\boldsymbol{\ell}) = \zeta_1(\boldsymbol{\ell}) s_{11}$$

$$\vdots$$

$$M_i(\boldsymbol{\ell}) = \zeta_1(\boldsymbol{\ell}) s_{1i} + ... + \zeta_i(\boldsymbol{\ell}) s_{ii}$$

$$\vdots$$

$$M_n(\boldsymbol{\ell}) = \zeta_1(\boldsymbol{\ell}) s_{1n} + ... + \zeta_n(\boldsymbol{\ell}) s_{nn}$$

$$\langle M_i M_j \rangle = \sum_{k=1}^{i} s_{ki} s_{kj} = C_{ij} \ (1 \leq i \leq j)$$

$$\langle \zeta_i(\boldsymbol{\ell}) \zeta_j(\boldsymbol{\ell}) \rangle = \delta_{ij}$$

s_{ij} recursion formulism

$$s_{ij} = \frac{C_{ij} - \sum_{k=1}^{i-1} s_{ki} s_{kj}}{\left(C_{ii} - \sum_{k=1}^{i-1} s_{ki}^2 \right)^{1/2}}$$

$M_i(\boldsymbol{\ell})$s are convergence in harmonic space, we can obtain shear by:

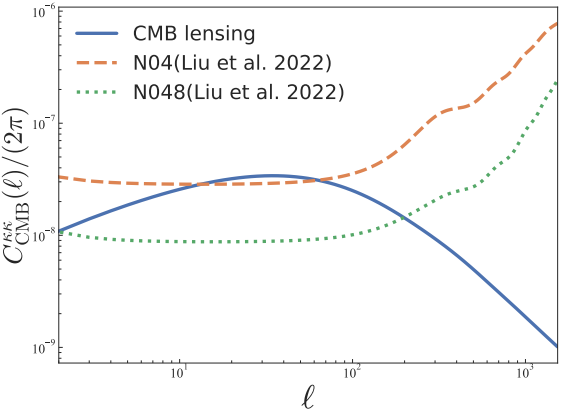
$$\gamma(\boldsymbol{\ell}) = \left(\frac{\ell_1^2 - \ell_2^2 + 2i\ell_1\ell_2}{|\boldsymbol{\ell}|^2} \right) M(\boldsymbol{\ell})$$

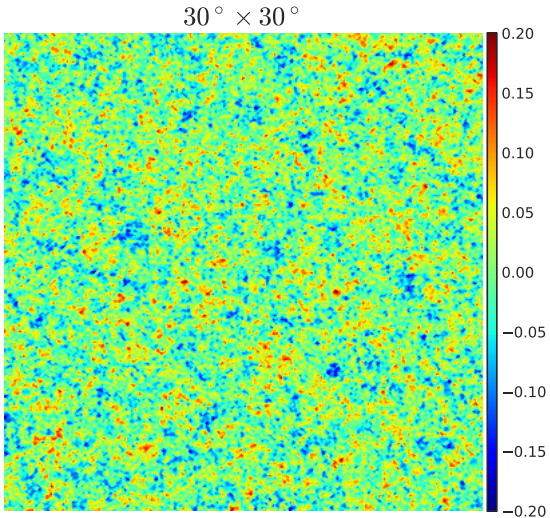
Maps of noise:

$$M_N(\boldsymbol{\ell}) = \hat{\zeta}(\boldsymbol{\ell}) \sqrt{N(\ell)}$$

CMB lensing

We adopt N0 bias from the reconstruction of CMB lensing as the noise of it

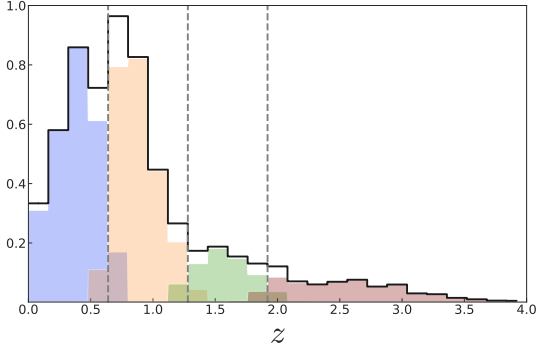




Galaxy samples and cosmic shear

$\varepsilon = \varepsilon_s + \gamma^G + \gamma^I$

$\sigma_\varepsilon = 0.3$ (Miao et al. 2022) $\bar{n}_g = 20\ \mathrm{arcmin}^{-2}$



$n(z)$ obtained from the COSMOS 2015 catalog (Cao et al. 2018)

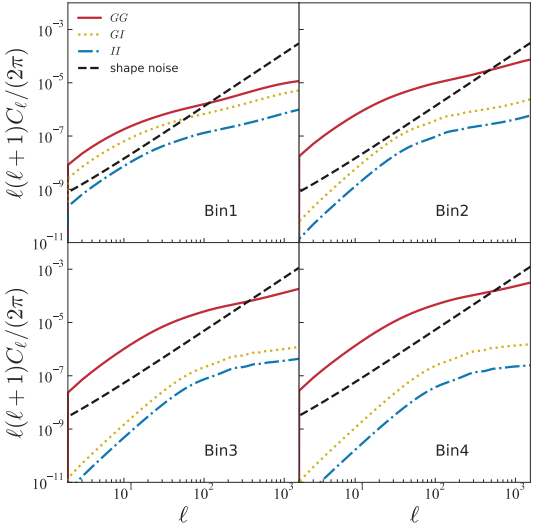


photo-z error

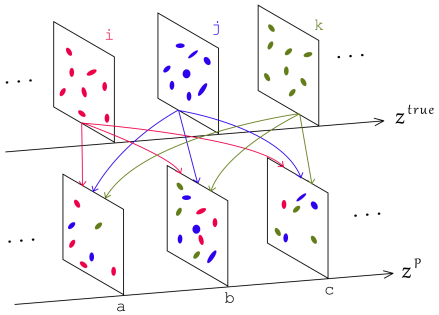


Photo-z error for maps:

$$\hat{\gamma}_a(p) = \sum_i w_{i\to a}(p)(\gamma_i(p) + \varepsilon_{si}(p)) \Big/ \sum_i w_{i\to a}(p)$$

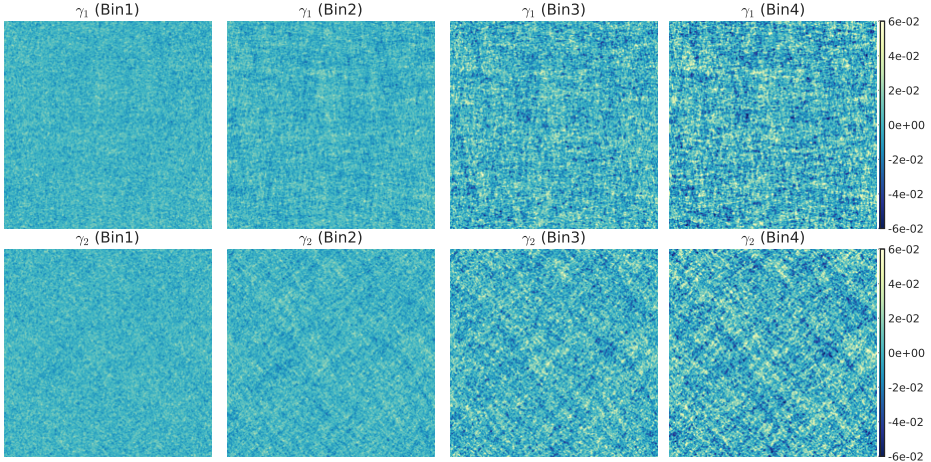
p denotes pixel index, and $w_{i\to a} \sim M\{N_{\rm bins}, [P_{i\to a}]\}$ where

$$p(z^P|z) = \frac{1}{\sqrt{2\pi}\sigma_z(1+z)} \exp\left[-\frac{(z - z^P - \Delta_z^i)^2}{2(\sigma_z(1+z))^2}\right]$$

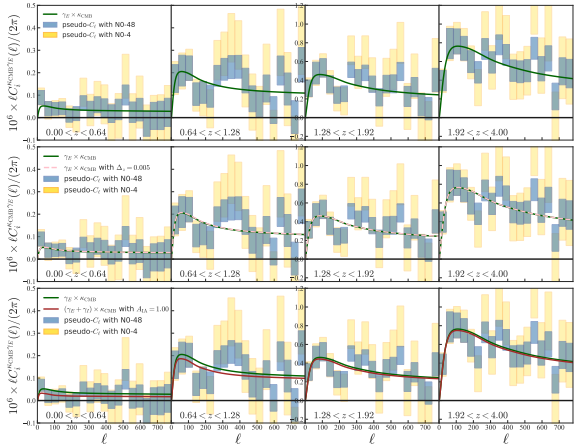
$\sigma_z = 0.05,\ \Delta_z = 0.005$

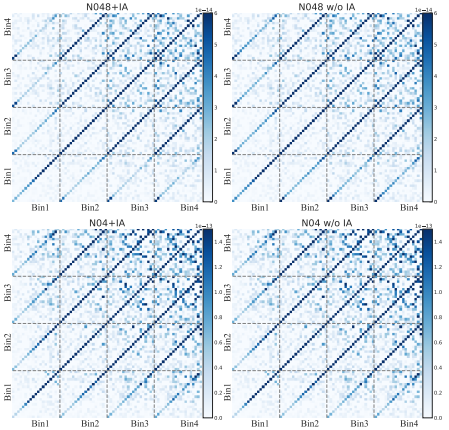
$$P_{i\to a} = \int_{z^P_{a,\rm min}}^{z^P_{a,\rm max}} {\rm d}z^P p(z^P|z_i)$$

cosmic shear maps



pseudo-C_ℓ and Covariance matrix





Cosmological constraint

Parameters	Fiducial value	Prior
Ω_m	0.314	$(0.05, 0.7)$
h	0.67	fixed
Ω_b	0.049	fixed
σ_8	0.811	$(0.3, 1.3)$
n_s	0.96	fixed
$A_{\rm IA}$	1.0	$(-5, 5)$
Δ_z^1	0.005	fixed
Δ_z^2	0.005	fixed
Δ_z^3	0.005	fixed
Δ_z^4	0.005	fixed
σ_z	0.05	fixed

Table: The fiducial values are adopted from Planck-2018 (Aghanim et al. 2020b) and COSMOS 2015 (Cao et al. 2018).

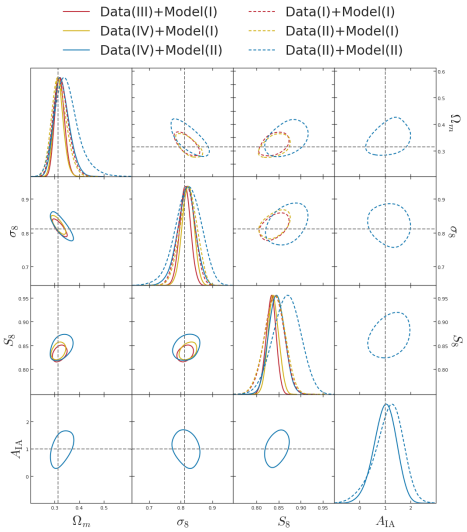
Likelihood

$$-2\log\mathcal{L}(\hat{D}_\nu^{XY}|\boldsymbol{\theta}) = \chi^2 = \sum_{\nu\nu'}\left(\hat{D}_\nu^{XY} - D_\nu^{XY}(\boldsymbol{\theta})\right)^T \tilde{\mathbb{C}}^{-1}_{\nu\nu'}\left(\hat{D}_{\nu'}^{XY} - D_{\nu'}^{XY}(\boldsymbol{\theta})\right)$$

$$S_8 = \sigma_8\left(\frac{\Omega_m}{0.3}\right)^\alpha$$

We use the PCA(principal component analysis) method to fit α

Constraint results



Where

	Data	Model
I	N04+σ_z	G
II	N04+σ_z+IA	G+I
III	N048+σ_z	
IV	N048+σ_z+IA	

Summarize

- A pipeline of the cross-correlation between cosmic shear tomography from the Chinese Survey Space Telescope (CSST), and CMB lensing from Ali CMB Polarization Telescope (AliCPT-1) in Tibet.
- The total cross-correlation:
  SNR≈ 15 (AliCPT-1 "4 modules*yr") and SNR≈ 22 (AliCPT-1 "48 modules*yr")
- The exclusion of intrinsic alignment: $\sim 0.5\sigma$ increment in σ_8 but without changing the S_8 value.
- For AliCPT-1 first and second stages, the cross-correlation of CSST cosmic shear with CMB lensing gives: $\sigma_8 = 0.817 \pm 0.026$,$S_8 = 0.840 \pm 0.022$ and $\sigma_8 = 0.814 \pm 0.017$, $S_8 = 0.833 \pm 0.011$, respectively.

THANKS!