Inserting L-ISW in the numerical CMBX full covariance

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New pipeline for the numerical covariance

- Production of CMB-κ , Galaxy clustering , Weak-Lensing maps with *Flask*

➢ Production of **Late-ISW** (L-ISW) maps properly correlated with CMB-κ and Galaxy clustering

➢ Production of T and E maps (**NOT including L-ISW**) with *CAMB*

➢ **Addition of L-ISW maps to T and E maps** (NOT including L-ISW) to obtain T and E maps **properly correlated with Flask maps**

- Lens T and E maps with Flask CMB-Φ
- Computation of the full numerical covariance

L-ISW maps production

Correlated fields :
$(C_\ell^{12} \neq 0)$

1 → C_ℓ^{11} → $a^1_{\ell m} = \xi_a \sqrt{C_\ell^{11}}$ → **map1**

C_ℓ^{12}

2 → C_ℓ^{22} → $a^2_{\ell m} = \xi_a \frac{C_\ell^{12}}{\sqrt{C_\ell^{11}}} + \xi_b \sqrt{C_\ell^{22} - \frac{(C_\ell^{12})^2}{C_\ell^{11}}}$ → **map2**

L-ISW maps production

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2 → C_ℓ^{22}, C_ℓ^{12} → $a^2_{\ell m} = \xi_a \frac{C_\ell^{12}}{\sqrt{C_\ell^{11}}} + \xi_b \sqrt{C_\ell^{22} - \frac{(C_\ell^{12})^2}{C_\ell^{11}}}$ → **map2**

In our case:

map1 , $a^1_{\ell m}$, C_ℓ^{11} from *Flask*

C_ℓ^{12} , C_ℓ^{22} from *CAMB*

→ $a^2_{\ell m} = \frac{C_\ell^{12}}{C_\ell^{11}} a^1_{\ell m} + \xi_b \sqrt{C_\ell^{22} - \frac{(C_\ell^{12})^2}{C_\ell^{11}}}$ → **map2**

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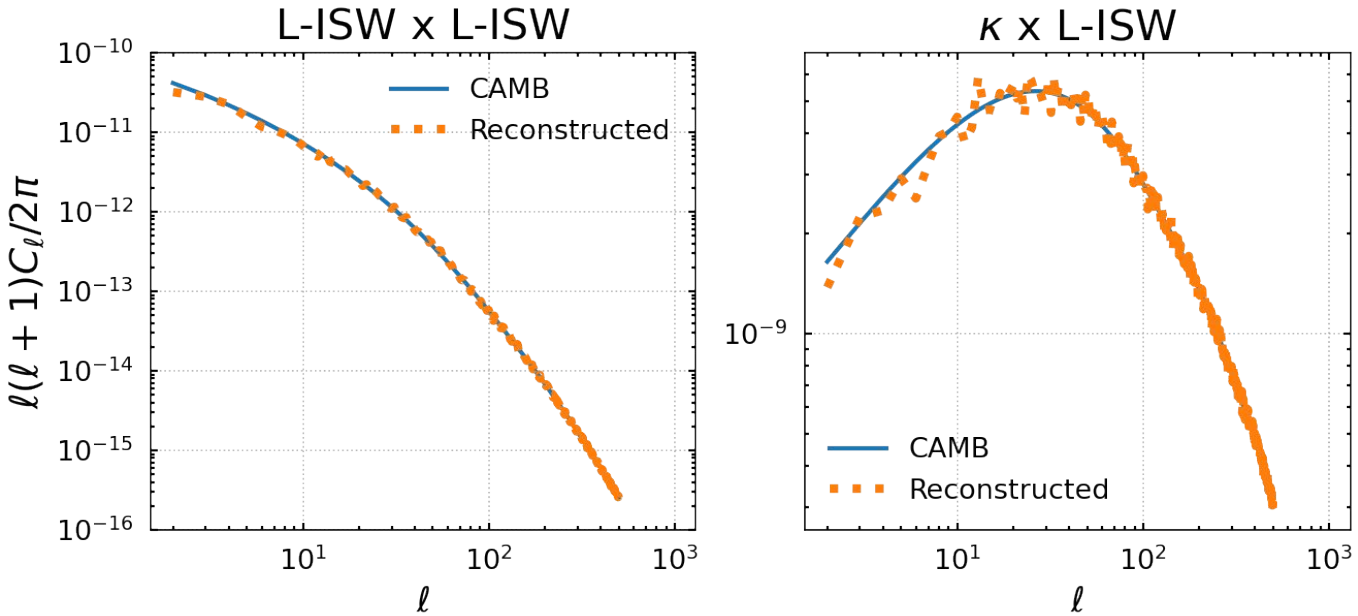
L-ISW maps from CMB-κ

$$a_{\ell m}^{LISW} = \frac{C_\ell^{\kappa - LISW}}{C_\ell^{\kappa-\kappa}} a_{\ell m}^{\kappa} + \xi \sqrt{C_\ell^{LISW-LISW} - \frac{(C_\ell^{\kappa-LISW})^2}{C_\ell^{\kappa-\kappa}}}$$

$a_{\ell m}^{\kappa}$, $C_\ell^{\kappa-\kappa}$ from *Flask*

$C_\ell^{\kappa-LISW}$, $C_\ell^{LISW-LISW}$ from *CAMB*

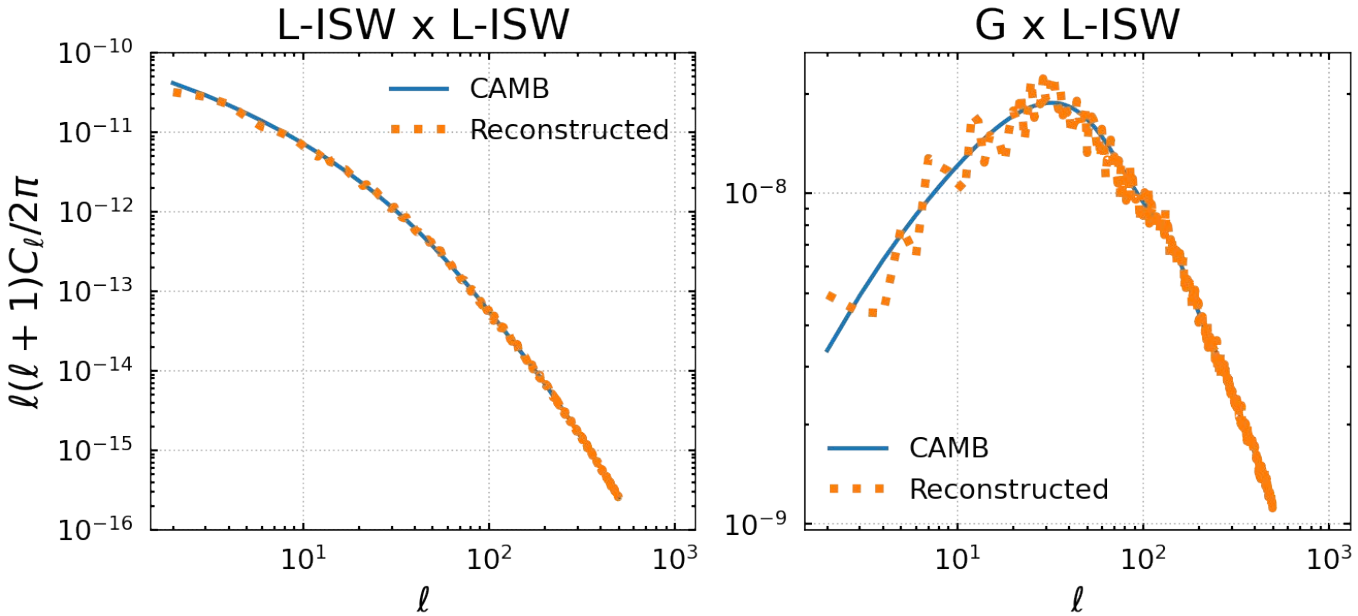


L-ISW maps from non-tomographic Galaxy clustering

$$a_{\ell m}^{LISW} = \frac{C_\ell^{g-LISW}}{C_\ell^{g-g}} a_{\ell m}^{g} + \xi \sqrt{C_\ell^{LISW-LISW} - \frac{(C_\ell^{g-LISW})^2}{C_\ell^{g-g}}}$$

$a_{\ell m}^{g}$, C_ℓ^{g-g} from *Flask*

C_ℓ^{g-LISW} , $C_\ell^{LISW-LISW}$ from *CAMB*



L-ISW from 3-fields combination

Cholesky Decomposition Matrix of 3 fields

$$\begin{pmatrix} a^{\kappa}_{\ell m} \\ a^{g}_{\ell m} \\ a^{LISW}_{\ell m} \end{pmatrix} = \begin{pmatrix} L^{11}_{\ell} & 0 & 0 \\ L^{21}_{\ell} & L^{22}_{\ell} & 0 \\ L^{31}_{\ell} & L^{32}_{\ell} & L^{33}_{\ell} \end{pmatrix} \times \begin{pmatrix} \xi_a \\ \xi_b \\ \xi_c \end{pmatrix}$$

$$\begin{cases} a^{\kappa}_{\ell m} = \xi_a L^{11}_{\ell} \\ a^{g}_{\ell m} = \xi_a L^{21}_{\ell} + \xi_b L^{22}_{\ell} \\ a^{LISW}_{\ell m} = \xi_a L^{31}_{\ell} + \xi_b L^{32}_{\ell} + \xi_b L^{33}_{\ell} \end{cases}$$

$$a^{LISW}_{\ell m} = \frac{L^{31}_{\ell}}{L^{11}_{\ell}} a^{\kappa}_{\ell m} + \frac{L^{32}_{\ell}}{L^{22}_{\ell}} \left(a^{g}_{\ell m} - \frac{L^{21}_{\ell}}{L^{11}_{\ell}} a^{\kappa}_{\ell m} \right) + \xi_b L^{33}_{\ell}$$

$$\begin{aligned} L^{11}_{\ell} &= \sqrt{(C^{\kappa-\kappa}_{\ell})} \\ L^{21}_{\ell} &= \frac{C^{\kappa-g}_{\ell}}{L^{11}_{\ell}} \\ L^{22}_{\ell} &= \sqrt{C^{g-g}_{\ell} - (L^{21}_{\ell})^2)} \\ L^{31}_{\ell} &= \frac{C^{\kappa-LISW}_{\ell}}{L^{11}_{\ell}} \\ L^{32}_{\ell} &= \frac{C^{g-LISW}_{\ell} - L^{21}_{\ell} L^{31}_{\ell}}{L^{22}_{\ell}} \\ L^{33}_{\ell} &= \sqrt{C^{LISW-LISW}_{\ell} - (L^{21}_{\ell})^2 - (L^{31}_{\ell})^2} \end{aligned}$$

Outlook

- We are including **L-ISW** in the numerical covariance matrix to properly consider all the **cross-correlation** for the **joint ISW – CMB-Lensing cross Euclid** Likelihood analysis
- Our pipeline is working and we are improving it **combining** the information from $\boldsymbol{\kappa}$ and $\mathbf{g}$

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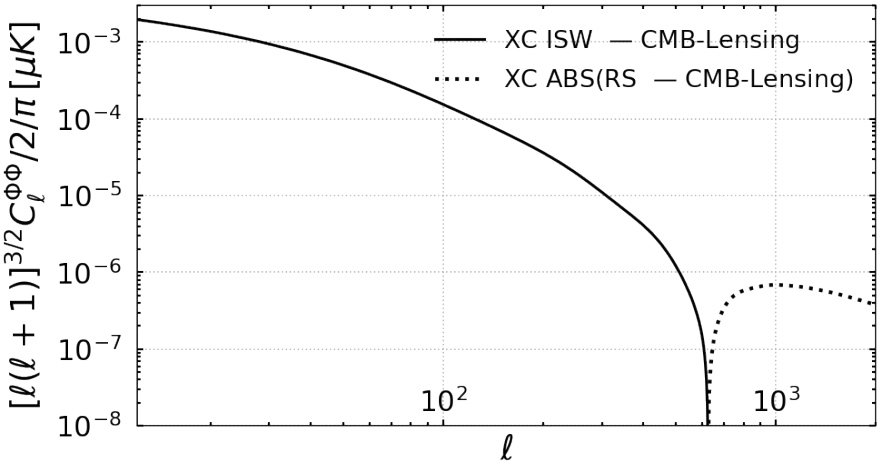
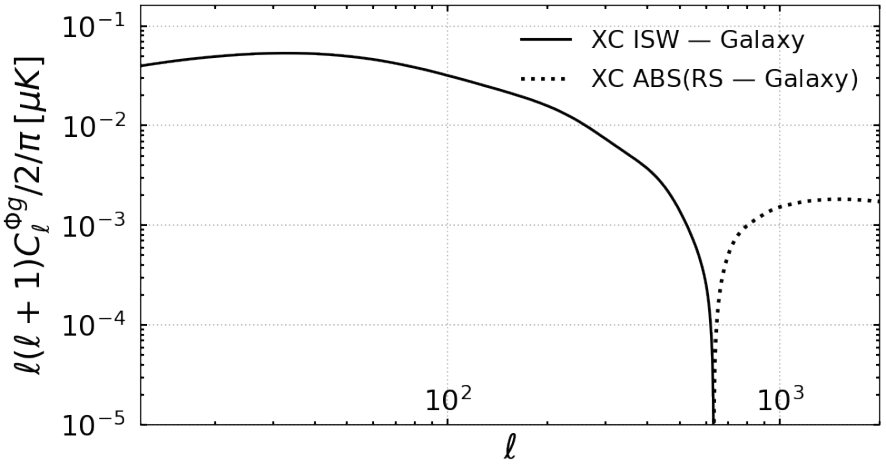
Next steps:

- Producing **L-ISW–RS** maps, producing C_ℓ^{12}, C_ℓ^{22} analytically (see ***Cuozzo+*, 2023**)





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Next steps:

- Producing **L-ISW-RS** maps, producing C_ℓ^{12}, C_ℓ^{22} analytically (see ***Cuozzo+*, 2023**)
- Reconstruct the **L-ISW** map from the **combination** of **all** the *Flask* maps (N Galaxy bins + CMB-$\boldsymbol{\kappa}$)

$$a_{\ell m}^{x} = \sum_{k=1}^{x} \xi_k L_{kx} \qquad \text{with } x = 1,\ldots N \quad \rightarrow$$

$$L_{kx} = \sqrt{C_\ell^{xk} - \sum_{y=1}^{k-1} (L_{ky})^2} \qquad \text{if } k=x$$

$$L_{kx} = \frac{C_\ell^{xk} - \sum_{y=1}^{k-1} L_{ky} L_{xy}}{L_{xx}} \qquad \text{if } k>x$$