CMB lensing likelihood

CMBX Meeting Milan October 2023

Louis, Angelo, Raphael, and the
CMBX likelihood group

The joint likelihood

Joint data vector:

$$\{C_\ell^{\kappa_{\rm CMB},\kappa_{\rm CMB}}, C_\ell^{\kappa_{\rm CMB},{\rm GCph_i}}, C_\ell^{\kappa_{\rm CMB},{\rm WL_i}}, C_\ell^{{\rm GCph_i},{\rm GCph_j}}, C_\ell^{{\rm WL_i},{\rm WL_j}}, C_\ell^{{\rm WL_i},{\rm GCph_j}}\}$$

- CMB lensing,
- Galaxy weak lensing,
- Galaxy clustering photometric,
- And all cross correlations

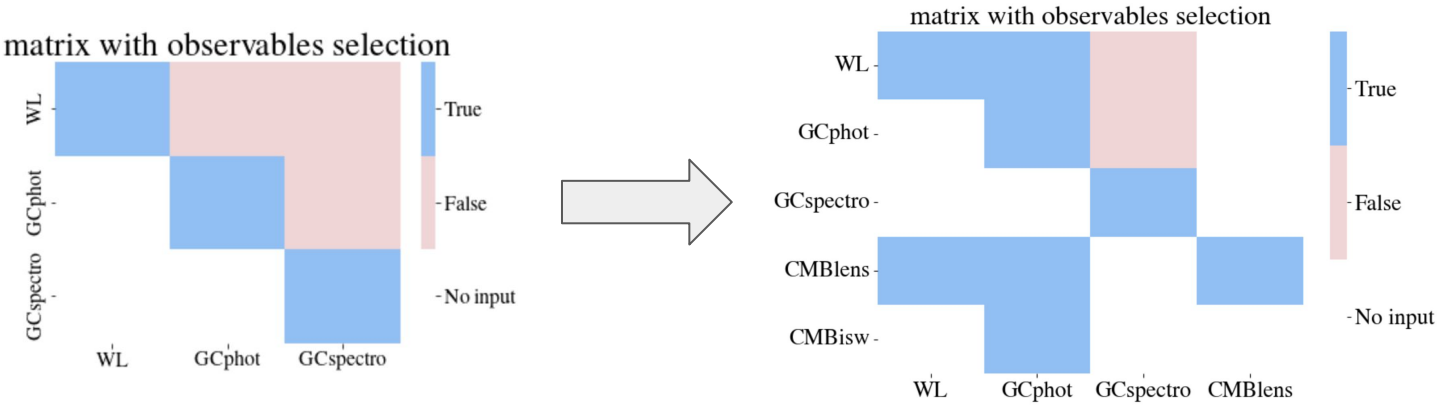
Gaussian Likelihood: $\ln L \propto (\hat{C}_\ell - C_\ell^{\rm th})^{\rm T} {\rm Cov}^{-1} (\hat{C}_\ell - C_\ell^{\rm th})$

Gaussian covariance matrix:

$${\rm Cov}\left[C_{ij}^{AB}(\ell), C_{kl}^{A'B'}(\ell')\right] = \frac{\delta^{\rm K}_{\ell\ell'}}{(2\ell+1)}\left[\Delta C_{ik}^{AA'}(\ell)\Delta C_{jl}^{BB'}(\ell') + \Delta C_{im}^{AB'}(\ell)\Delta C_{jk}^{BA'}(\ell')\right]$$

$$\Delta C_{ij}^{AB}(\ell) = \frac{1}{\sqrt{f_{\rm sky}\Delta\ell}}\left[C_{ij}^{AB}(\ell) + N_{ij}^{AB}(\ell)\right]$$

Implementation in CLOE



- GOAL: perform **joint analysis** of Euclid with **CMB observables**: iSW and CMB lensing
- Interfaced with the Euclid likelihood code: CLOE
- Several discussions with the IST:Likelihood group to decide on how to implement our modifications

CMB Lensing power spectrum with CLOE

- CMB lensing auto power spectrum can be computed:
  - with CAMB (a little bit faster)
  - with the matter power spectrum of CLOE (consistent with other observables)
- Low redshift (z<4) using the P(k) of CLOE

$$C_\ell^{\kappa\kappa} = \ell^2(\ell+1)^2 \int_{\chi(z=4)}^{\chi_*} d\chi \left(\frac{\chi_* - \chi}{\chi^2 \chi_*}\right)^2 P_\Psi\left(\frac{l+0.5}{\chi}, z(\chi)\right) + c\int_{z=0}^{z=4} \frac{dz}{H(z)\chi^2(z)} W^\phi(z)^2 P_{\delta\delta}\left(\frac{\ell+1/2}{\chi}, z\right)$$

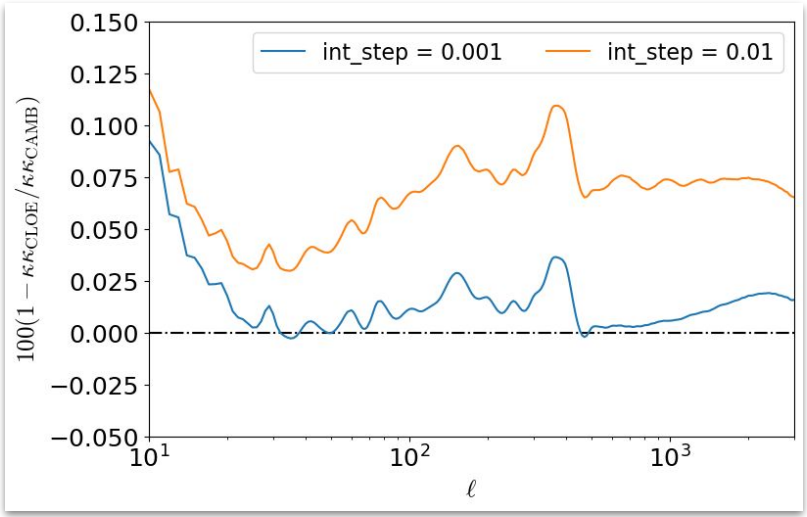
Weyl potential from CAMB

Matter power spectrum from CLOE

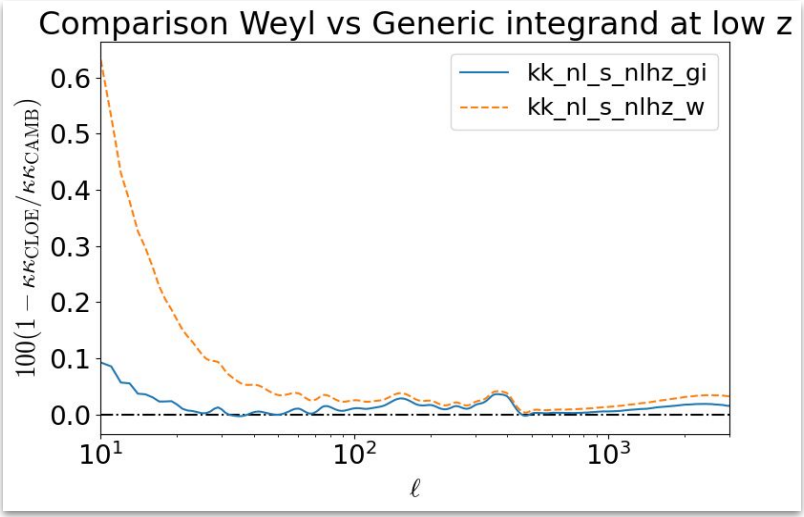
- The code is now essentially as fast as CLOE without CMB lensing
- Validated the recipes against CAMB (such as integration step)

Some tests

Integration step



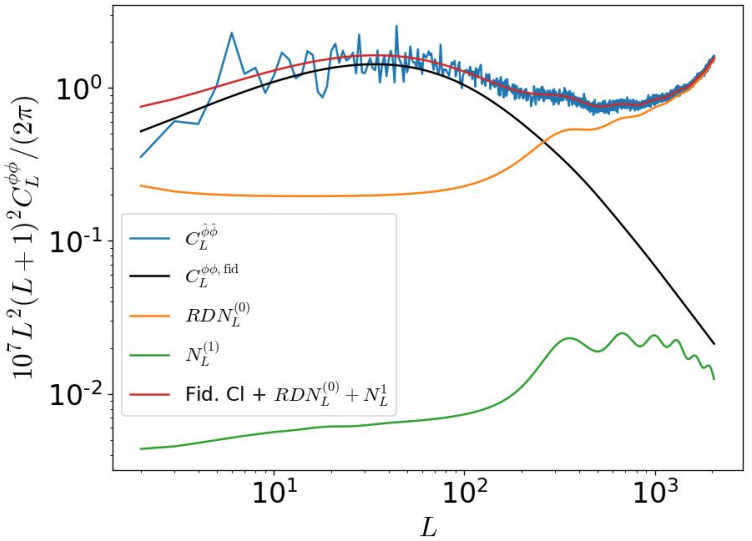
Low redshift integral

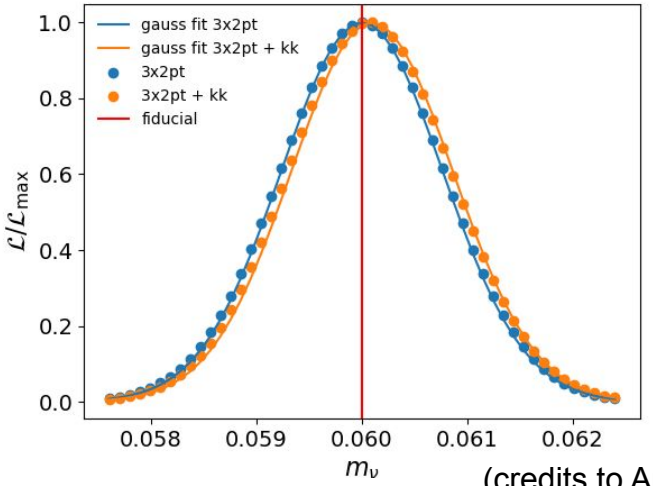


(credits to Angelo F.)

Validation of likelihood

- Simulate a lensed CMB field with SO noise level
- Reconstruct the lensing field with a quadratic estimator
- Use the auto power spectrum of CMB lensing as mock data vector
- Sample the likelihood on a grid, varying one or two parameters at a time
- Unbiased posterior on this grid





(credits to Angelo F.)

Next steps for the CMB lensing likelihood

- Current version of the lensing likelihood has been validated with our CMBX internal review process, and merged with the iSW likelihood
- From now on: focus on the analysis of Euclid DR1 + Planck CMB lensing?
- Take into account both masks: Euclid and Planck
  - The standard lensing QE uses a set of simulations to have unbiased Cls normalisation
  - The cross correlation between the lensing QE and GC and WL will also requires a set of simulations, with correlated galaxy density / shear fields and CMB lensing field
- Add the biases of the CMB lensing auto power spectrum into the likelihood
- We can probably safely neglect the non gaussian LSS bias (N3/2) bias for now
- Validate the full pipeline with a mock data vector from DEMNUNI simulations (interface with the simulation group)