CMBXC autumn meeting @ Milan / IASF

CMBXC autumn meeting: Simulations&Covariances

(P. Vielzeuf, S. Haridasu, M. Calabrese, C. Carbone, E. Carella, F. Lacasa, L. Legrand, G. Fabbian, M. Baldi, etc.)

Simulations for CMBX - WP1

Developments in WP1: simulations for CMBX

Pre-launch KP-CMBX-2 paper-1 “CMBX Mock Simulations”: in preparation

Large (2Gpc/h) **N-body simulations**:
DEMNUni (**dynamical DE + neutrinos**) & DUSTGRAIN (**f(R) + neutrinos**)
Simulated observables:

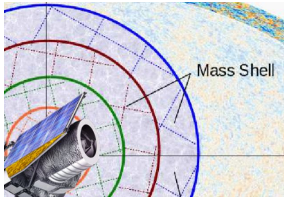
- CMB-Lensing (kCMB convergence)
- Weak Lensing Convergence maps (Sources at fixed redshift or tomographic covariances with Euclid n(z) sources)
- Galaxy maps from simulations (→ SHAM method)
- Lensing potential from estimators on Lensed-CMB

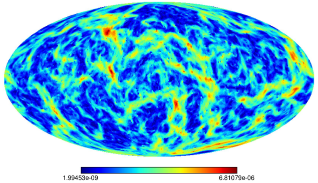
Main Goals:

1. Focus on the **cross-correlation** between CMB observables and Euclid probes (GC+WL)
2. **Impact of a different cosmological scenarios** on these cross-correlation signals.

Courtesy of CMBX simulation team: Calabrese, Carbone, Carella, Fabbian, Baldi

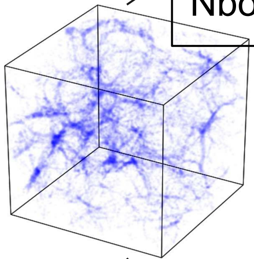
End-to-end Pipeline (from left to right)





Lightcone production

Map-making,
projection on full-sky



Nbody sim

- kCMB + ISWRS maps
- WL (fixed z_source)
- WL euclid spec. n(z)
- Euclid galaxies
- Magnification Bias
- Intrinsic Alignment

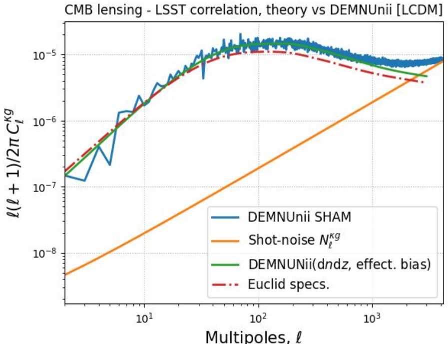
CMB Lensing
[Lenspyx]

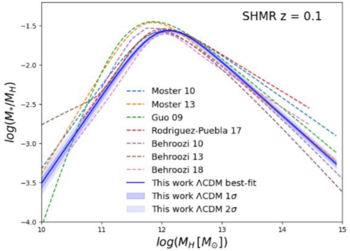
- lensed CMB T,E,B field

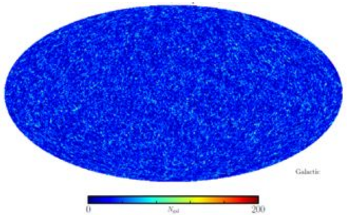
Lensing Estimation
[planckLens]

- reconstructed lensing pot.

Cross-correlation







Objects detection
[SUBFIND]

Galaxy population
[SHAM]

Map-making,
projection on full-sky

- Projected Galaxy Maps

Courtesy of CMBX simulation team: Calabrese, Carbone, Carella, Fabbian, Baldi

Simulations for CMBX - WP1

Developments in WP1: simulations for CMBX
Data Products: Updates

Simulation	3d halo lightcone (FoF/SubFind/SO)	SHAM galaxies	CMBL	CMBL Q.E. (S.O. noise)	WL photo-n(z) 11 bins| 13 bins	Euclid galaxies (photo-n(z), FS2 bias) 11 bins| 13 bins
LCDM	✅(FoF)✅(SO)	✅	✅	✅	✅✅	✅✅
Mnu 0.16 eV	✅(FoF)	✅	✅	✅	✅✅	✅✅
Mnu 0.32 eV	✅(FoF)	✅	✅	✅	✅✅	✅✅
Mnu 0.53 eV	✅(FoF)	✅	✅	✅	✅✅	✅✅
LCDM (DUSTGRAIN same as DEMNUni)	✅(SubFind)	⏰	✅	✅	✅✅	✅✅
fR5 + Mnu 0.10 eV	⏰	⏰	✅	✅	✅✅	✅✅
fR5 + Mnu 0.16 eV	⏰	⏰	✅	✅	✅✅	✅✅
M. Calabrese	Halo (θ,φ,z, M, …)	mixed	Healpix maps (nside=4096, full-sky)			

State of the **KP paper**

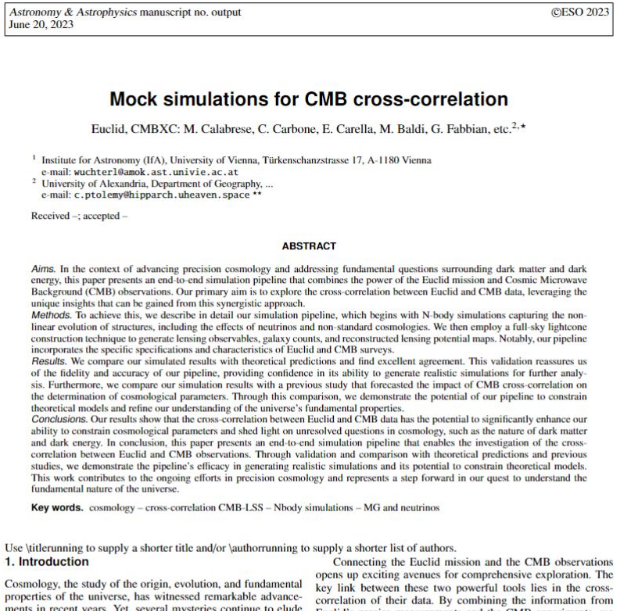
https://www.overleaf.com/read/zszffnjnhffn

1. Introduction
2. nbody simulations
3. Methods: algorithm description
4. Validation and results
5. Conclusions

Who? Calabrese, Carbone, Carella, Baldi, Fabbian, Vielzeuf, Lacasa, Haridasu, Legrand, …

Things to do: Introduction/ theory sections completed (editing). Methods: validation phase done. Results/validation: final checks, updating results on SHAM.

Timeline: First (preliminary) draft, sim&cov group discussion.



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Mock simulations for CMB cross-correlation

Euclid, CMBXC: M. Calabrese, C. Carbone, E. Carella, M. Baldi, G. Fabbian, etc.[2,⋆]

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Received –; accepted –

ABSTRACT

Aims. In the context of advancing precision cosmology and addressing fundamental questions surrounding dark matter and dark energy, this paper presents an end-to-end simulation pipeline that combines the power of the Euclid mission and Cosmic Microwave Background (CMB) observations. Our primary aim is to explore the cross-correlation between Euclid and CMB data, leveraging the unique insights that can be gained from this synergistic approach.
Methods. To achieve this, we describe in detail our simulation pipeline, which begins with N-body simulations capturing the non-linear evolution of structures, including the effects of neutrinos and non-standard cosmologies. We then employ a full-sky lightcone construction technique to generate lensing observables, galaxy counts, and reconstructed lensing potential maps. Notably, our pipeline incorporates the specific specifications and characteristics of Euclid and CMB surveys.
Results. We compare our simulated results with theoretical predictions and find excellent agreement. This validation reassures us of the fidelity and accuracy of our pipeline, providing confidence in its ability to generate realistic simulations for further analysis. Furthermore, we compare our simulation results with a previous study that forecasted the impact of CMB cross-correlation on the determination of cosmological parameters. Through this comparison, we demonstrate the potential of our pipeline to constrain theoretical models and refine our understanding of the universe's fundamental properties.
Conclusions. Our results show that the cross-correlation between Euclid and CMB data has the potential to significantly enhance our ability to constrain cosmological parameters and shed light on unresolved questions in cosmology, such as the nature of dark matter and dark energy. In conclusion, this paper presents an end-to-end simulation pipeline that enables the investigation of the cross-correlation between Euclid and CMB observations. Through validation and comparison with theoretical predictions and previous studies, we demonstrate the pipeline's efficacy in generating realistic simulations and its potential to constrain theoretical models. This work contributes to the ongoing efforts in precision cosmology and represents a step forward in our quest to understand the fundamental nature of the universe.

Key words. cosmology – cross-correlation CMB-LSS – Nbody simulations – MG and neutrinos

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1. Introduction

Cosmology, the study of the origin, evolution, and fundamental properties of the universe, has witnessed remarkable advancements in recent years. Yet, several mysteries continue to elude

Connecting the Euclid mission and the CMB observations opens up exciting avenues for comprehensive exploration. The key link between these two powerful tools lies in the cross-correlation of their data. By combining the information from

Numerical covariances simulations for CMBXc

Baseline Covariance matrix

(6x2pt, ISW not included)

$$\vec{\mathcal{O}}_{XC}(\ell) = \{\overbrace{\underset{\uparrow}{C_\ell^{\kappa_{\rm CMB},\kappa_{\rm CMB}}}, \underbrace{C_\ell^{\kappa_{\rm CMB},{\rm GCph_i}}, C_\ell^{\kappa_{\rm CMB},{\rm WL_i}}}_{\text{Xcorr: 400 elements in total (over l and z)}}}^{\text{420 elements in total}}, \underbrace{C_\ell^{\rm GCph_i,GCph_j}, C_\ell^{\rm WL_i,WL_j}, C_\ell^{\rm WL_i,GCph_j}}_{\text{Euclid 3x2pt data vector: 4200 elements in total}}\}$$

CMB lensing: 20 elements in total (over *l*)

- N_l = 20 ell bins
- N_z =10 redshift bins

	$C_\ell^{\kappa_{\rm CMB},\kappa_{\rm CMB}}$	$C_\ell^{\kappa_{\rm CMB},{\rm GCph_i}}$	$C_\ell^{\kappa_{\rm CMB},{\rm WL_j}}$	$C_\ell^{\rm GCph_i,GCph_j}$	$C_\ell^{\rm WL_i,WL_j}$	$C_\ell^{\rm WL_i,GCph_j}$
$C_\ell^{\kappa_{\rm CMB},\kappa_{\rm CMB}}$	Cov(kk, kk)	Cov(kk, k-GC$_i$)	Cov(kk, k-WL$_j$)	Cov(kk, GC$_i$-GC$_j$)	Cov(kk, WL$_i$-WL$_j$)	Cov(kk, WL$_i$-GC$_j$)
$C_\ell^{\kappa_{\rm CMB},{\rm GCph_i}}$		Cov(k-GC$_j$, k-GC$_i$)	Cov(k-GC$_i$, k-WL$_j$)	Cov(k-GC$_i$,GC$_j$-GC$_k$)	Cov(k-GC$_i$,WL$_j$-WL$_k$)	Cov(k-GC$_i$,WL$_j$-GC$_k$)
$C_\ell^{\kappa_{\rm CMB},{\rm WL_j}}$			Cov(k-WL$_i$, k-WL$_j$)	Cov(k-WL$_i$, GC$_i$-GC$_j$)	Cov(k-WL$_i$, WL$_i$-WL$_j$)	Cov(k-WL$_i$, WL$_i$-GC$_j$)
$C_\ell^{\rm GCph_i,GCph_j}$				**EUCLID 3X2pt COVARIANCE MATRIX** **[N_l N_z ($2N_z$+1)] X [N_l N_z ($2N_z$+1)]** **4200 X 4200**		
$C_\ell^{\rm WL_i,WL_j}$	*Cov(A B, A' B')* $= \frac{\delta^{\rm K}_{\ell\ell'}}{(2\ell+1)}\left[\Delta C_{ik}^{AA'}(\ell)\Delta C_{jl}^{BB'}(\ell') + \Delta C_{im}^{AB'}(\ell)\Delta C_{jk}^{BA'}(\ell')\right]$ $\Delta C_{ij}^{AB}(\ell) = \frac{1}{\sqrt{f_{\rm sky}\Delta\ell}}\left[C_{ij}^{AB}(\ell) + N_{ij}^{AB}(\ell)\right]$					
$C_\ell^{\rm WL_i,GCph_j}$						

WP1 - CMBX FLASK vs Nbody sim

How?

Using **Flask**, we create 2500 maps for all the relevant observables:
kCMB, weak lensing + intrinsic alignment (L), galaxies + magnification bias (G)

Ingredients

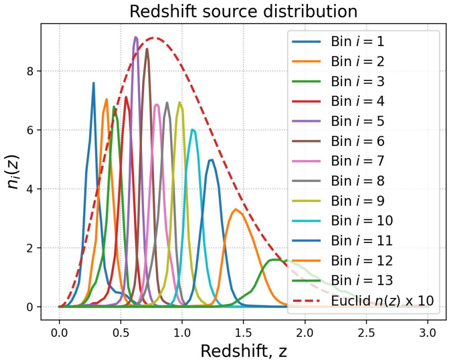
n(z) for each 13 euclid bins, galaxy bias from FS2, IA and MB parameters as 3x2pt recipe

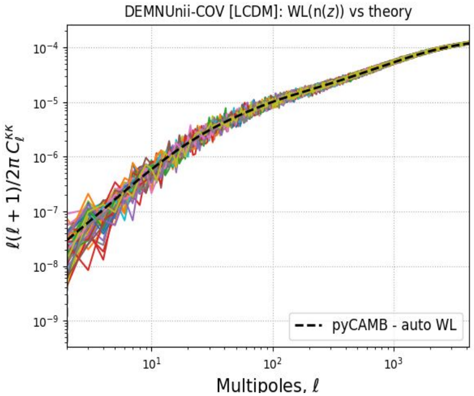
Results

N=2500 healpix maps, full-sky, following Euclid specs.
nside=2048, lmax=6144

Validation

Maps are validated by comparing to **50 unique n-body simulations** (DEMNUNI-COV) → shifts parameters





Map validation : higher order statistics compare vs DEMNUni maps

Very good agreement between corrected-FLASK & DEMNUni-Cov Nbody maps

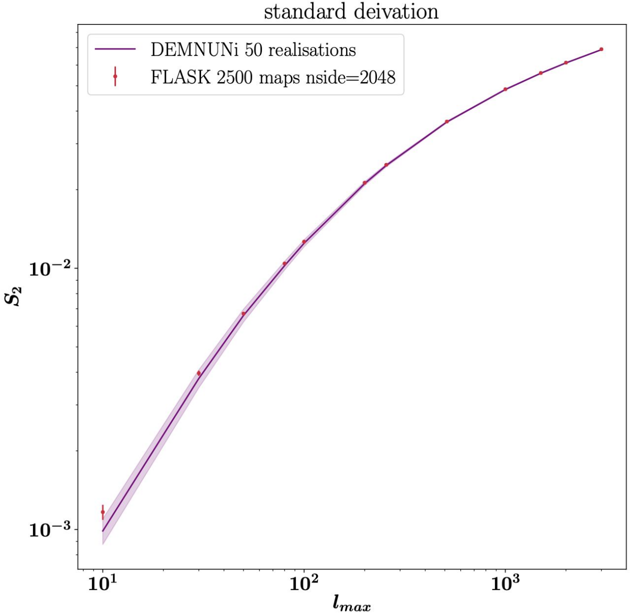
P. Vielzeuf

Shift parameter to recover DEMNUni Skewness

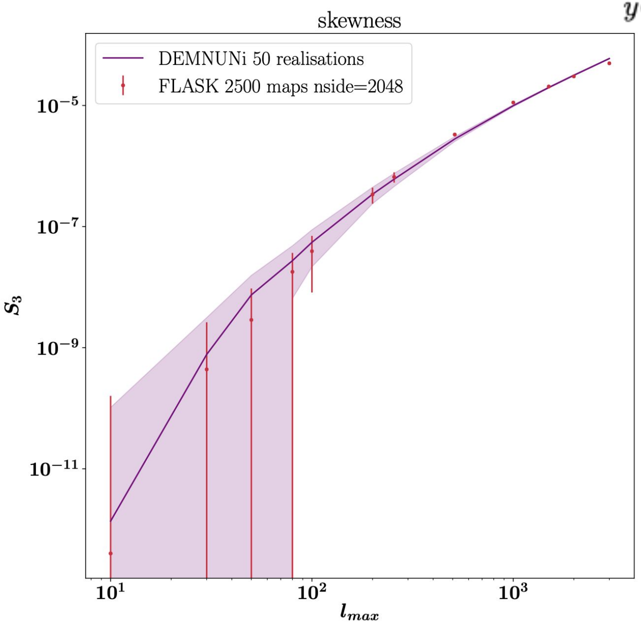
$$\lambda = \frac{\sigma}{\tilde{\mu}_3}\left(1 + y(\tilde{\mu}_3)^{-1} + y(\tilde{\mu}_3)\right) - \langle\kappa\rangle,$$

$$y(\tilde{\mu}_3) = \sqrt[3]{\frac{2 + \tilde{\mu}_3^2 + \tilde{\mu}_3\sqrt{4 + \tilde{\mu}_3^2}}{2}},$$

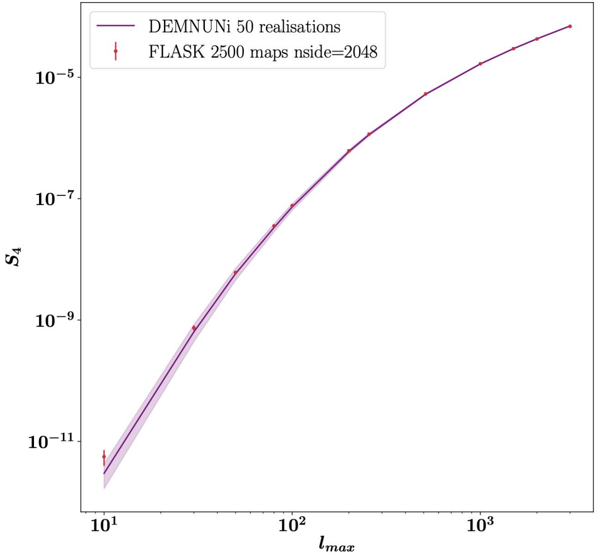
standard deivation



skewness



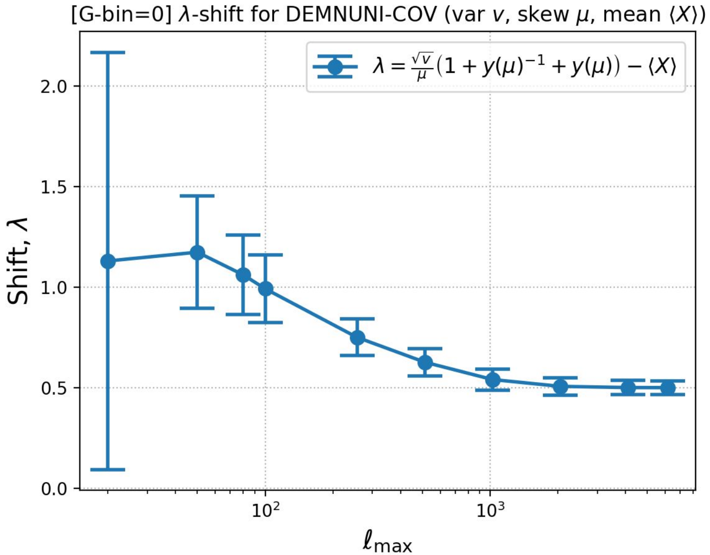
kurtosis

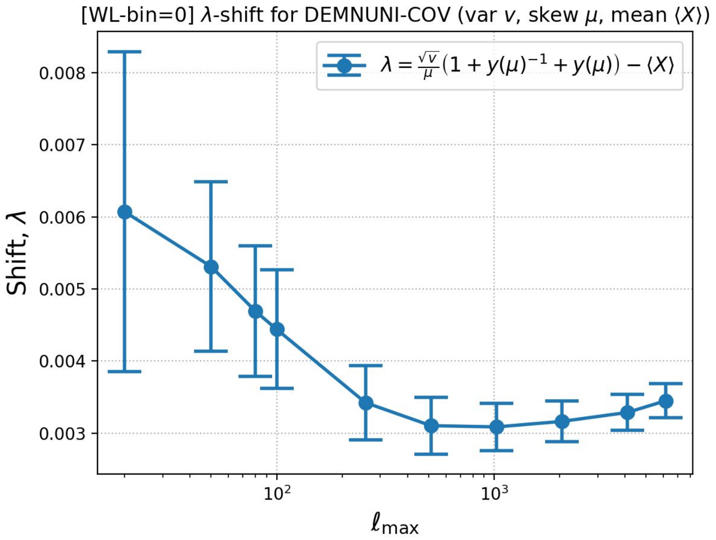


https://arxiv.org/abs/2012.07771

Work in progress

1. measure the **log-shifts** from the new DEMNUni-COV maps with corrections for IA and MB [G, L, kCMB], for the 13 euclid bins

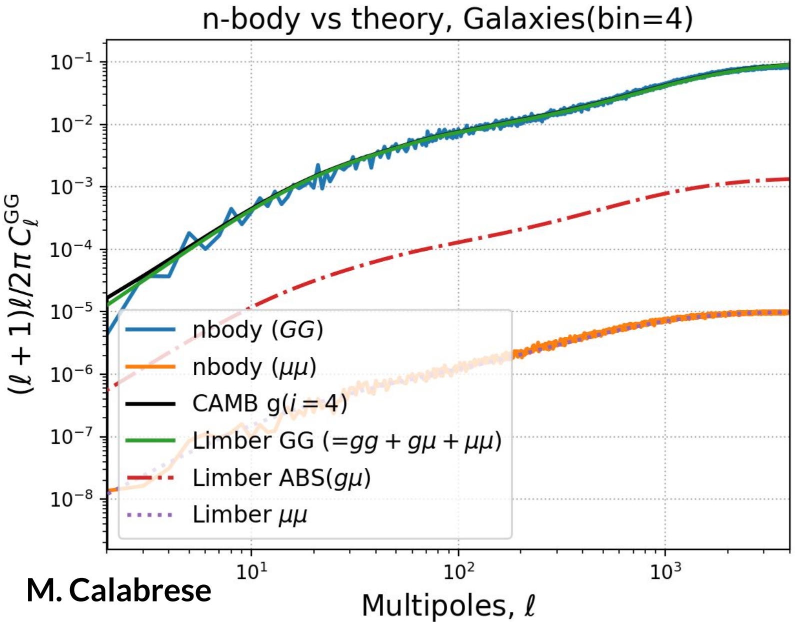


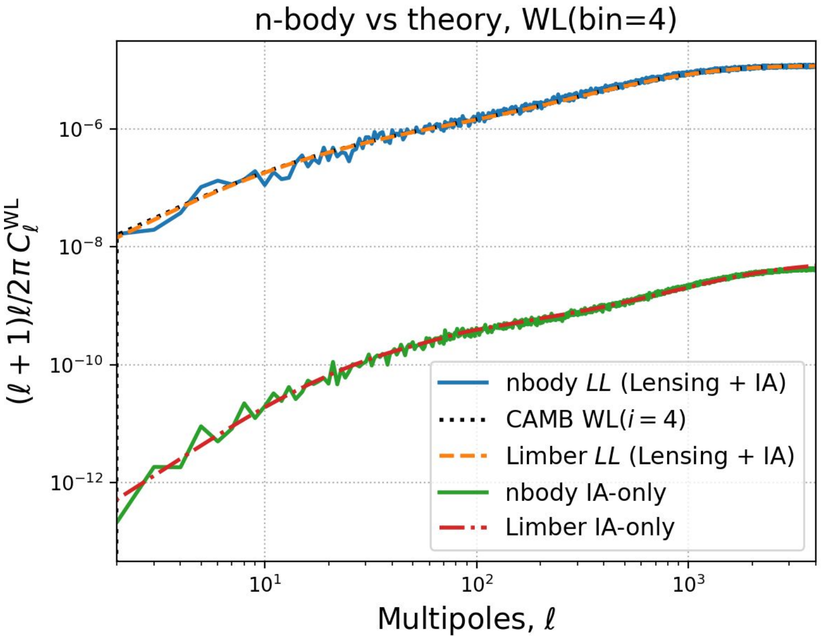


M. Calabrese

Work in progress

2. Computation of **Cl** to include MB and IA effects: 13 euclid bins, FS2 bias. [G, L, kCMB] for each bins, for each cross-correlation.





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