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CMB XC - Euclid SWG Updates on Simulations

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Starting point: Nbody numerical simulations

What do we have?

(Big) N-Body simulation for CMB Cross

DEMNUni (C. Carbone)

volume: (2 Gpc/h) and N : 2 x 2048 (CDM+ν) particles
baseline Planck cosmology + neutrinos & DE

DUSTGRAIN (M. Baldi)

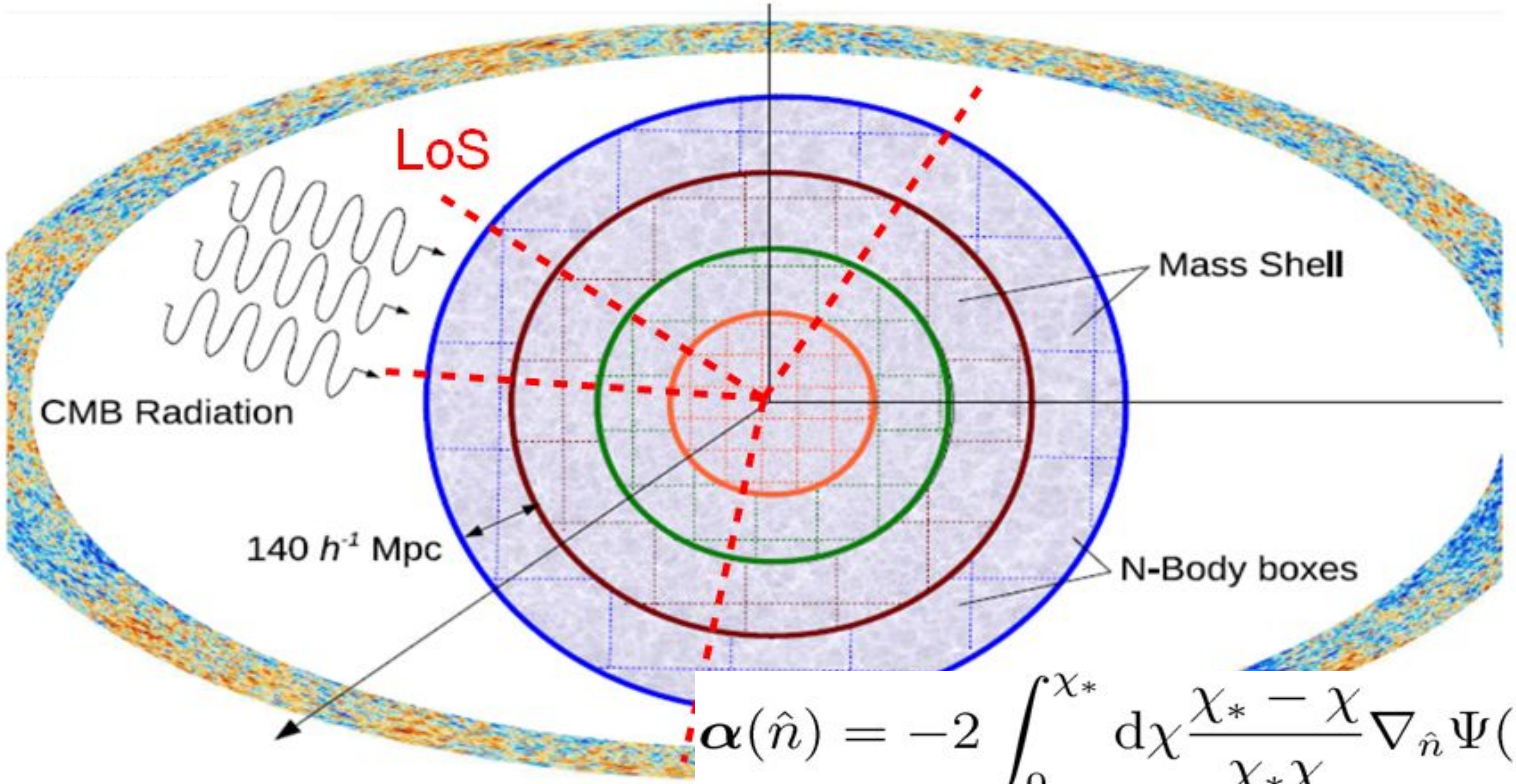
volume: (2 Gpc/h) and N : 2 x 2048 (CDM+ν) particles
baseline Planck cosmology + f(R) gravity with massive neutrinos

(Smaller) N-Body sims for covariances

	Number of sims	Cosmology (background)	BoxSize / NumPart	Number of snapshot (+FoF, SubGroups, M200, ...)
LCDM (Euclid official)	**50 sims**	OmeBr = 0.05 OmNeu = 0.0 OmCDM = 0.27 OmLam = 0.6800	Box Size = 1 Gpc/h Num Part = 1024^3	63 z in [0,99]
LCDM + Mnu= 0.16	**50 sims**	OmeBr = 0.05 OmNeu = 0.0 OmCDM = 0.27 OmLam = 0.6800	Box Size = 1 Gpc/h Num Part = 1024^3	63 z in [0,99]

Covariances project: MC, C. Carbone, G. Fabbian, ...

Light-cone production: map making



$$\boldsymbol{\alpha}(\hat{n}) = -2\int_0^{\chi_*} \mathrm{d}\chi \frac{\chi_* - \chi}{\chi_* \chi} \nabla_{\hat{n}} \Psi(\chi\hat{n}, \chi)$$

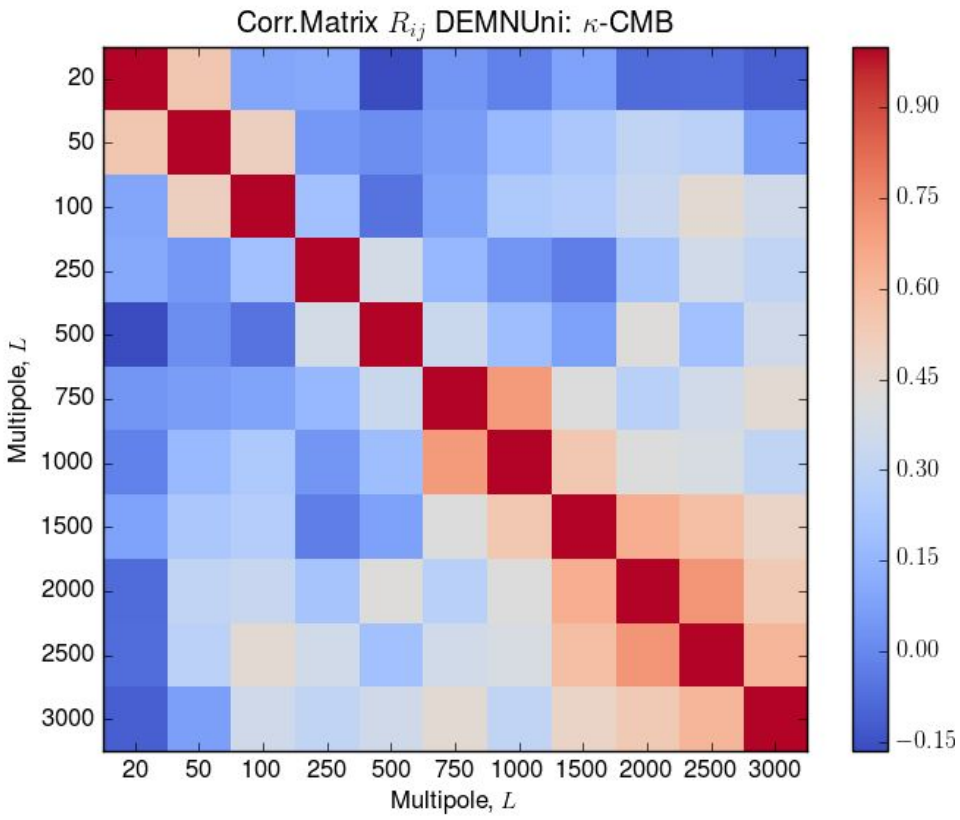
Available healpix maps

Particle Maps	• 50 x 63 Surface Mass Density Maps (for each snapshot/redshift, for each nbody simulation) • 50 x 63 CMB-Convergence Maps (for each snapshot/redshift, for each nbody simulation) → 50 <u>CMB-Convergence Integrated Map</u> (in Born approx. for each nbody simulation) 50 CMB-Lensed maps (via LensPix)
Grid maps	• 50 CMB-lensing potential & ISW/RS (in LCDM) • 50 CMB-lensing potential & ISW/RS (in Mass(nu)=0.16 eV) • 50 CMB-Lensed maps (via LensPix) (in LCDM) • 50 CMB-Lensed maps (via LensPix) (in Mass(nu)=0.16 eV) • 50 WL maps with sources placed at z=8,5,2,1 (in LCDM) • 50 WL maps with sources placed at z=8,5,2,1 (in Mass(nu)=0.16 eV)

Covariances from Grid potential maps

First steps.

Cov. Matrix: k-CMB auto-spectrum [LCDM]



C_L CMB-Convergence DEMNUni → Covariance Matrix

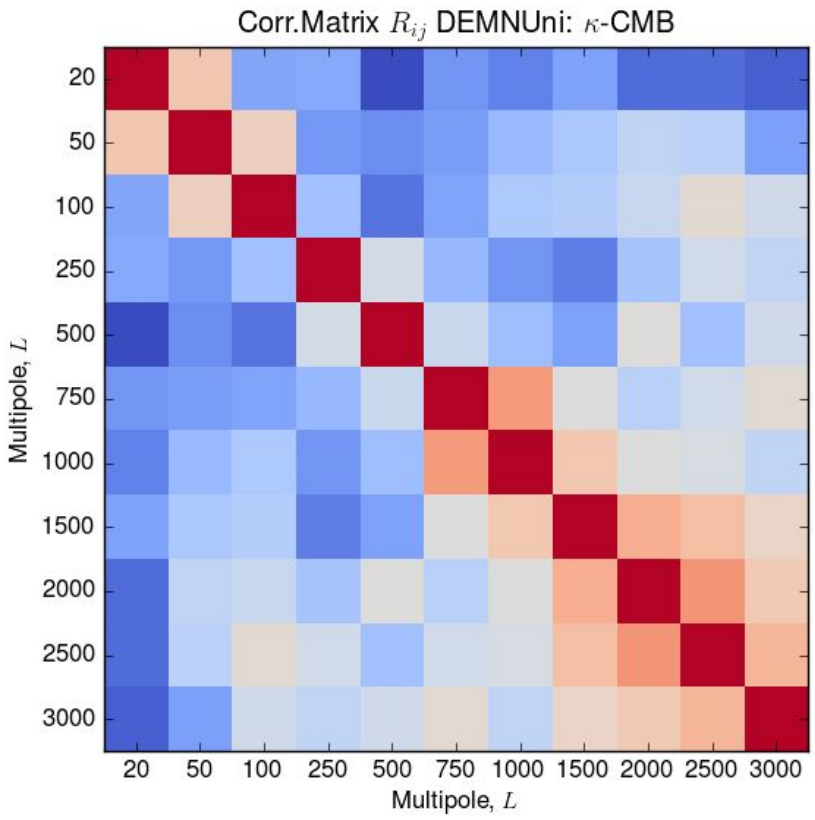
11 Bins in multipole, L = {20,50,100,250,500,750,1000,1500,2000, 2500,3000}

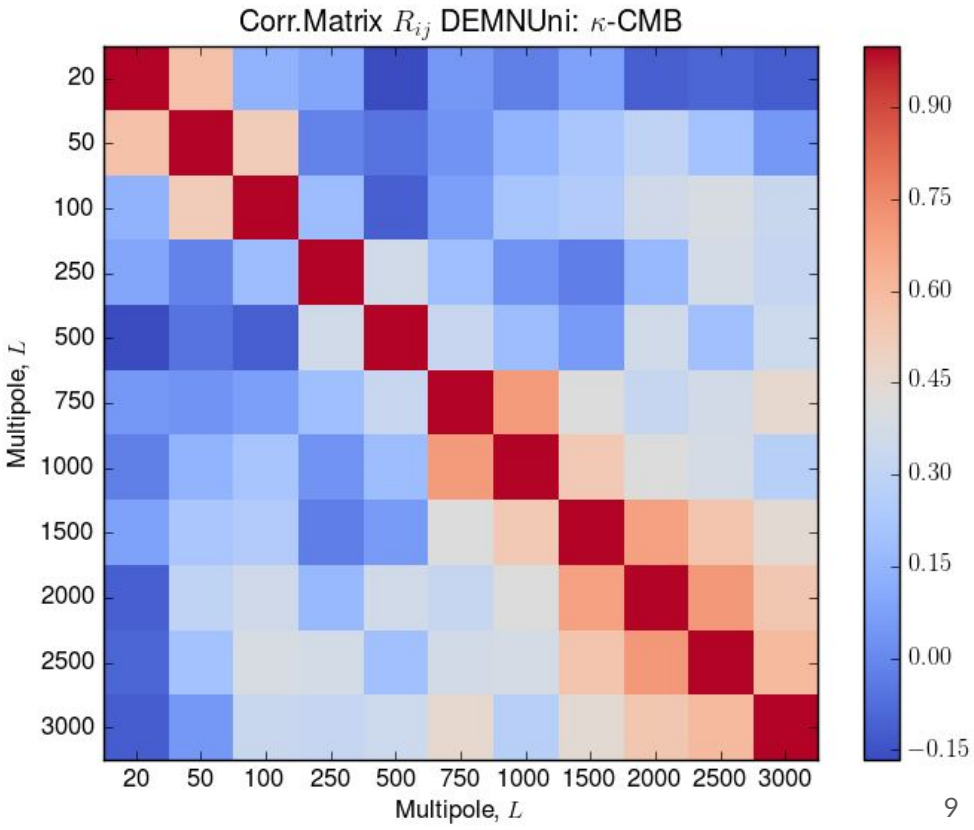
Nside Convergence maps = 2048
Number of Simulations = 50

LCDM and Mnu=0.16

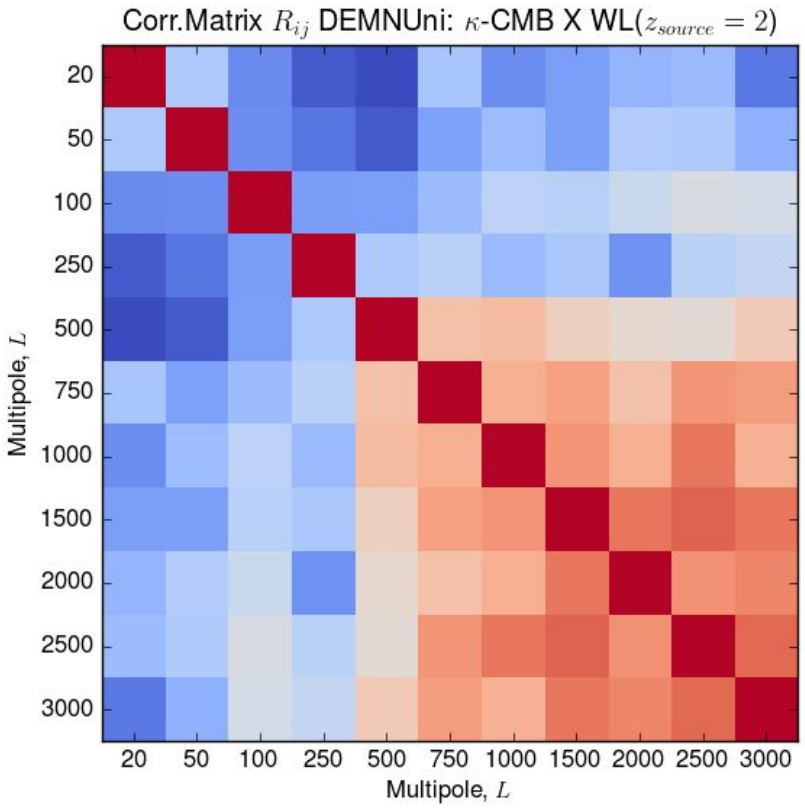
<u>Figures are Correlation Matrix</u>
(Covariances normalized to diagonal variances)

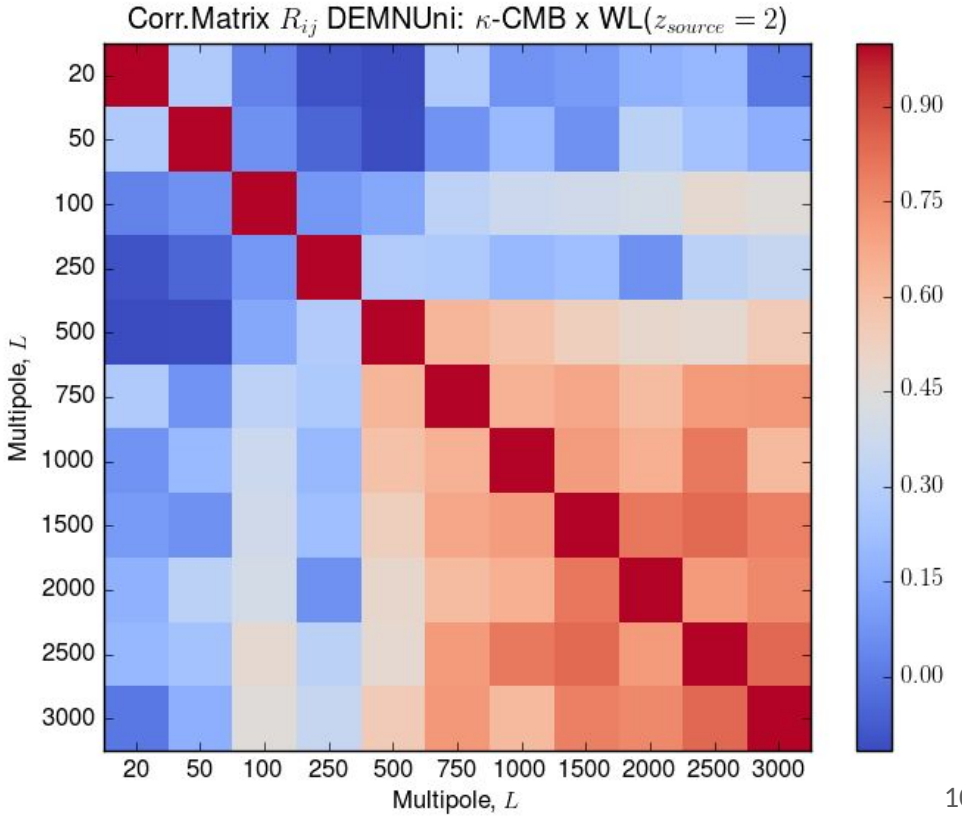
k-CMB auto-spectrum [LCDM vs M(nu)=0.16 eV]



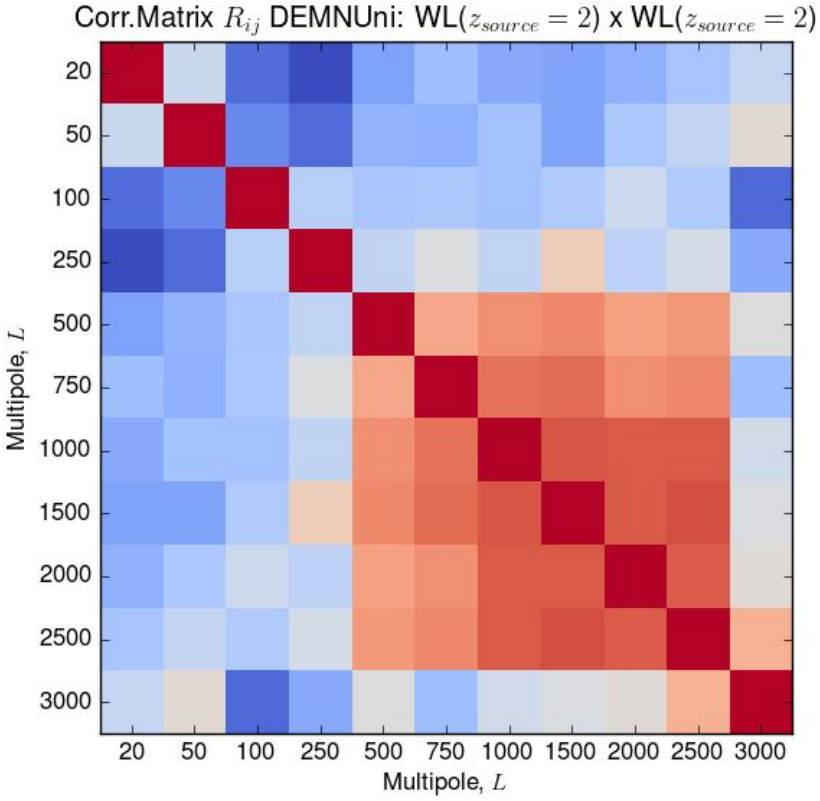


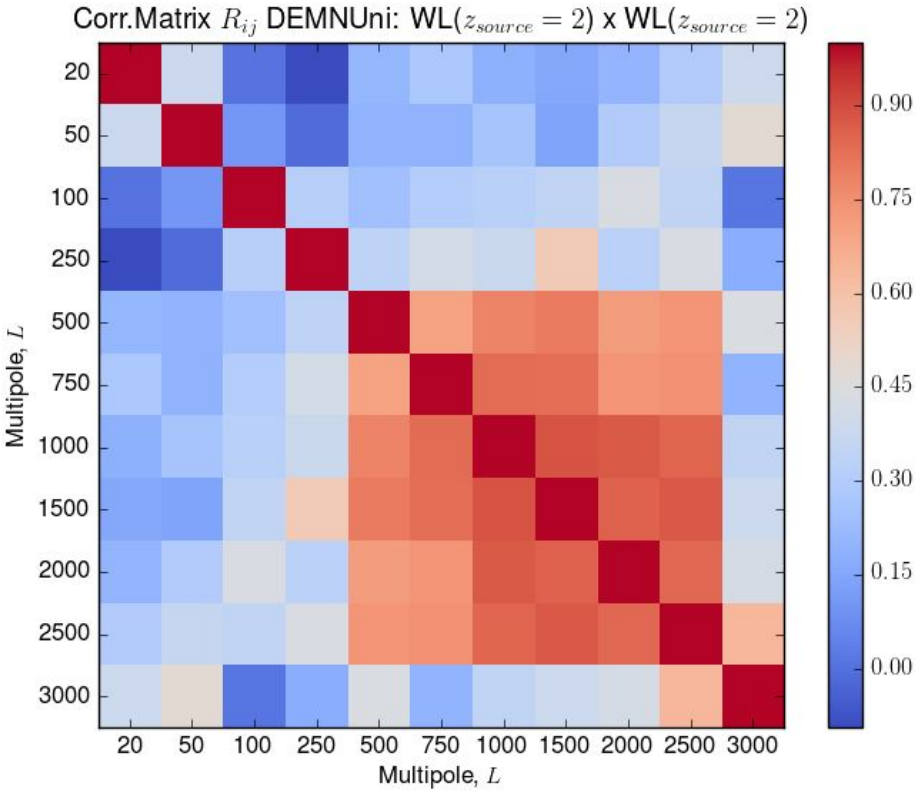
cross k-CMB X WL(z=2) [LCDM vs M(nu)=0.16 eV]

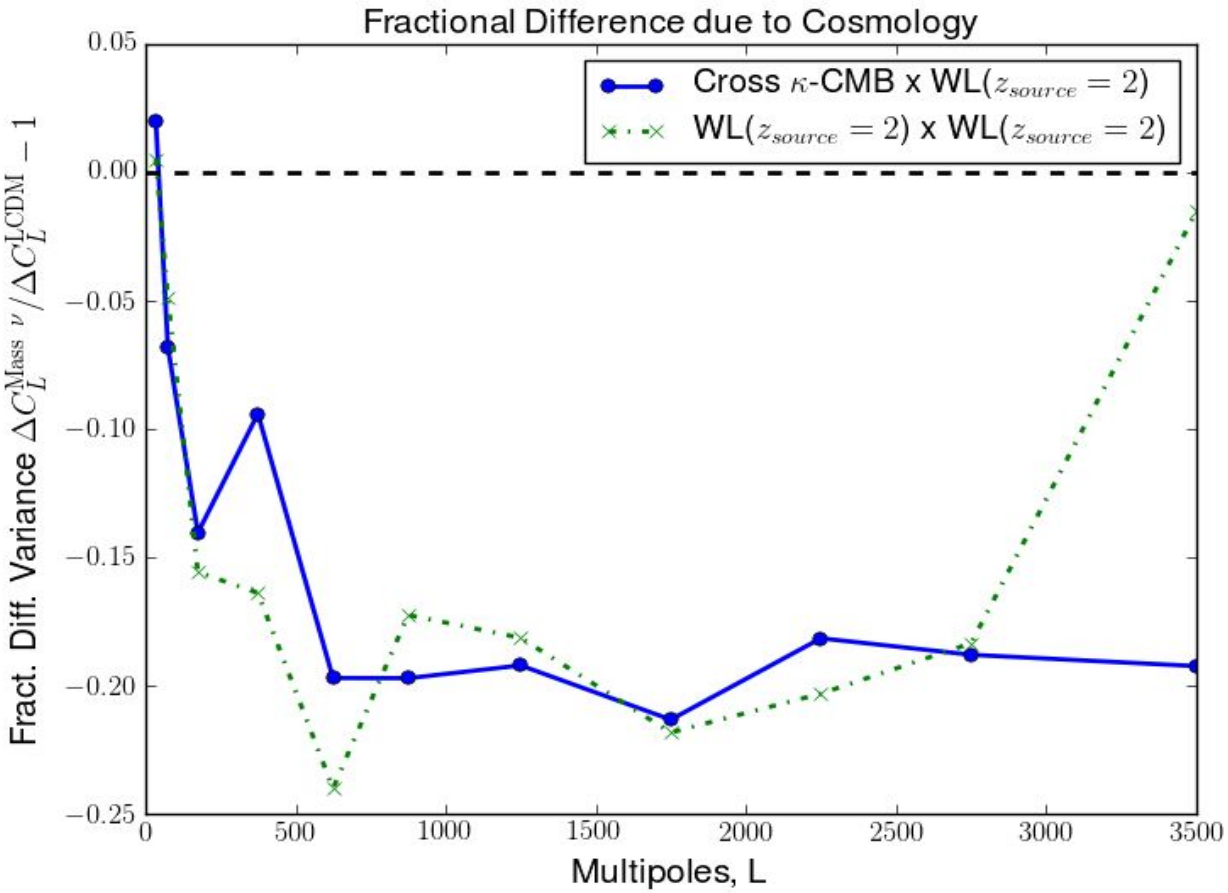




WL(z=2) auto-spectrum [LCDM vs M(nu)=0.16]






Fractional Difference due to Cosmology
Cross κ-CMB x WL($z_{source} = 2$)
WL($z_{source} = 2$) x WL($z_{source} = 2$)
Fract. Diff. Variance $\Delta C_L^{\mathrm{Mass}\ \nu} / \Delta C_L^{\mathrm{LCDM}} - 1$
Multipoles, L
0.05
0.00
−0.05
−0.10
−0.15
−0.20
−0.25
0
500
1000
1500
2000
2500
3000
3500

Signal-to-noise from covariances

Measuring significance.

From Covariances to Signal-to-Noise Ratio (SNR)

from Nbody Simulations → Light-cone and 2D maps of matter

↓

from maps → angular power spectrum and covariances

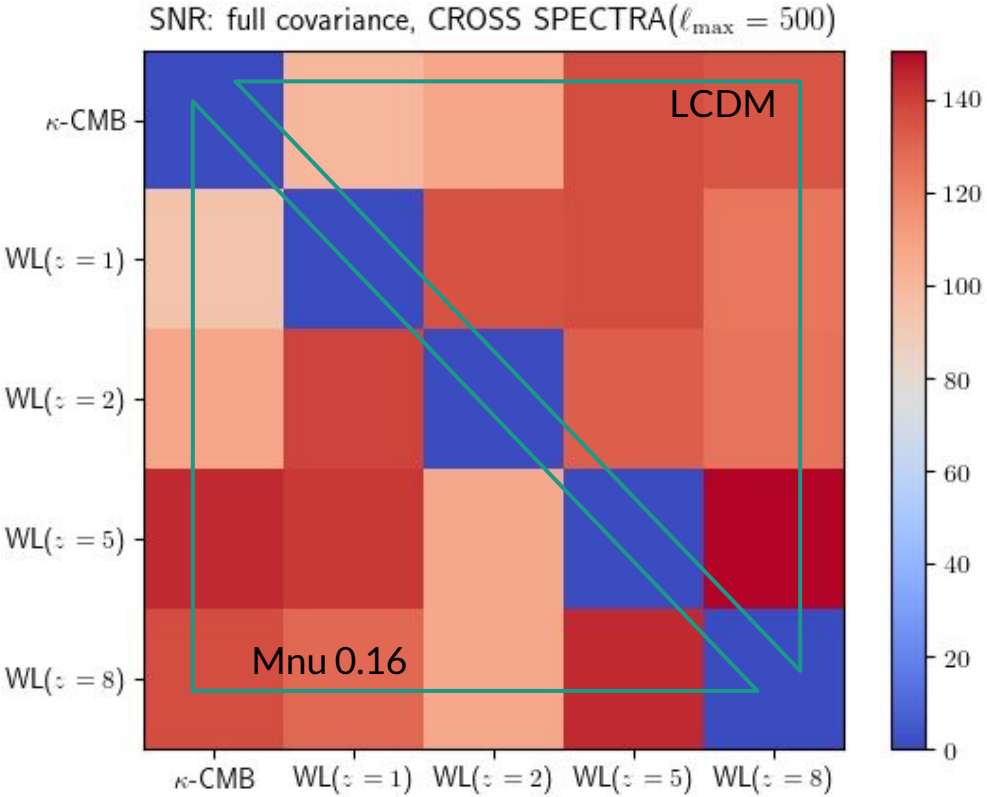
↓

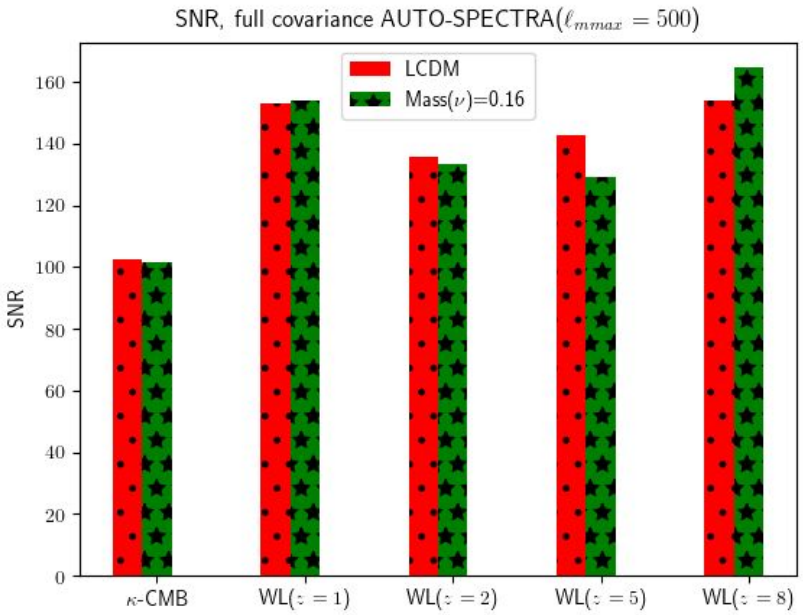
from covariances → signal-to-noise ratio

Observable	k-CMB	WL(z=1)	WL(z=2)	WL(z=5)	WL(z=8)
k-CMB					
WL(z=1)					
WL(z=2)					
WL(z=5)					
WL(z=8)					

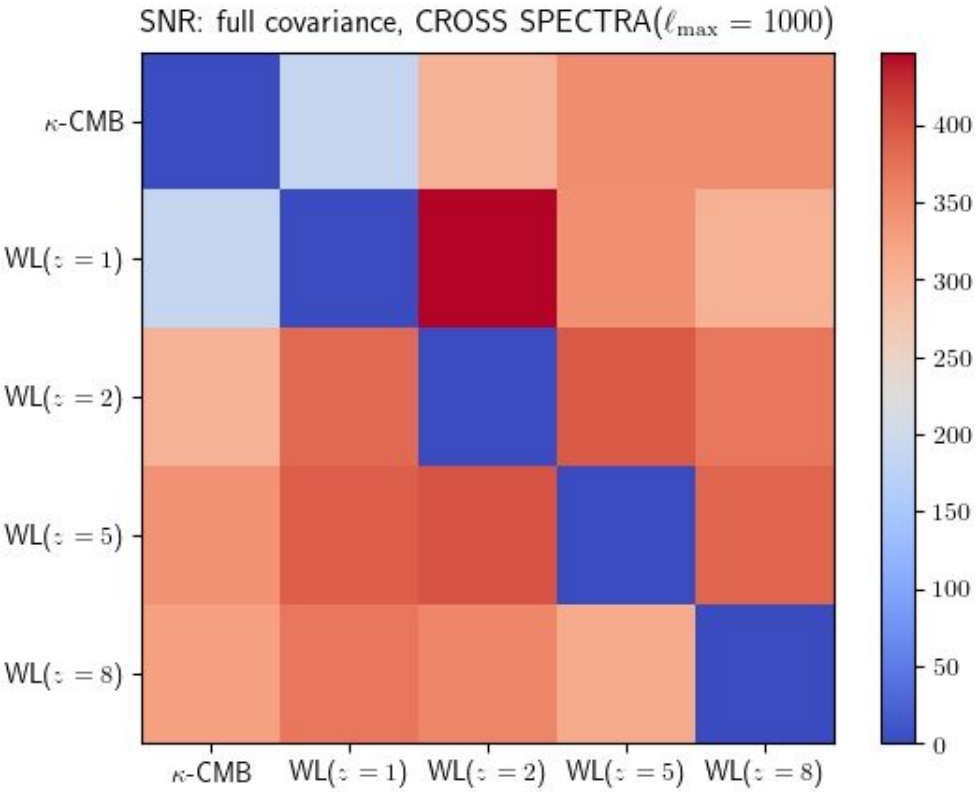
$$(S/N)^2 = \sum_{\ell,\ell'}^{\ell_{\max}} C_\ell^{\mathrm{XY}} \mathrm{Cov}_{\ell\ell'}^{-1} C_{\ell'}^{\mathrm{XY}}$$

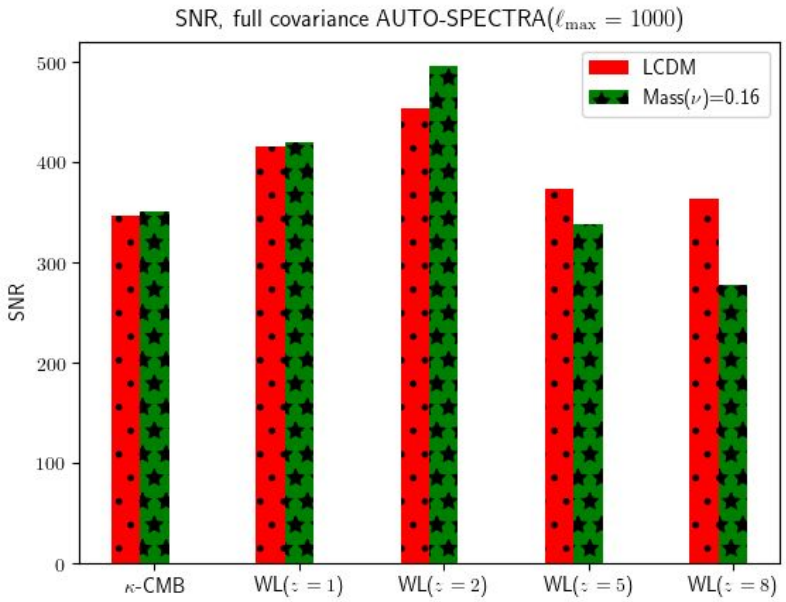
SNR for different observ. lmax = 500



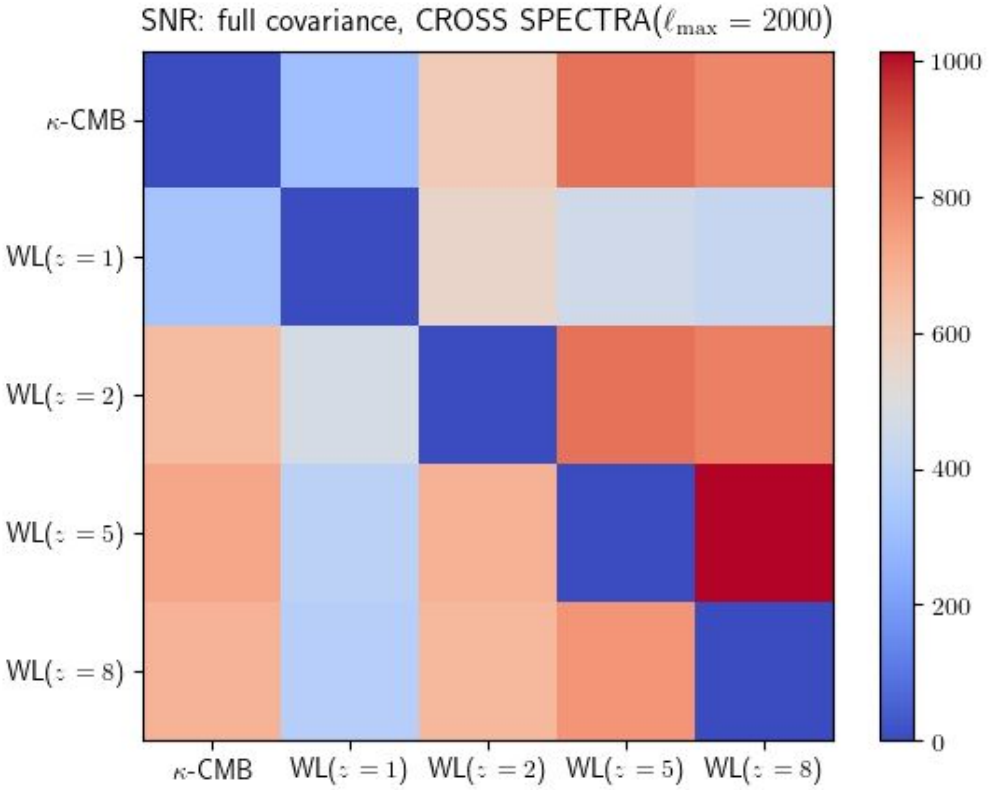


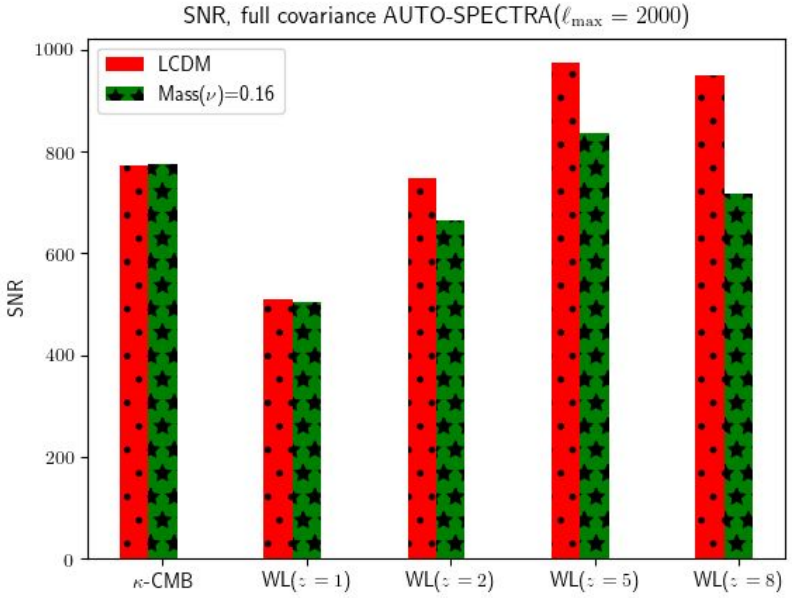
SNR for different observ. lmax = 1000



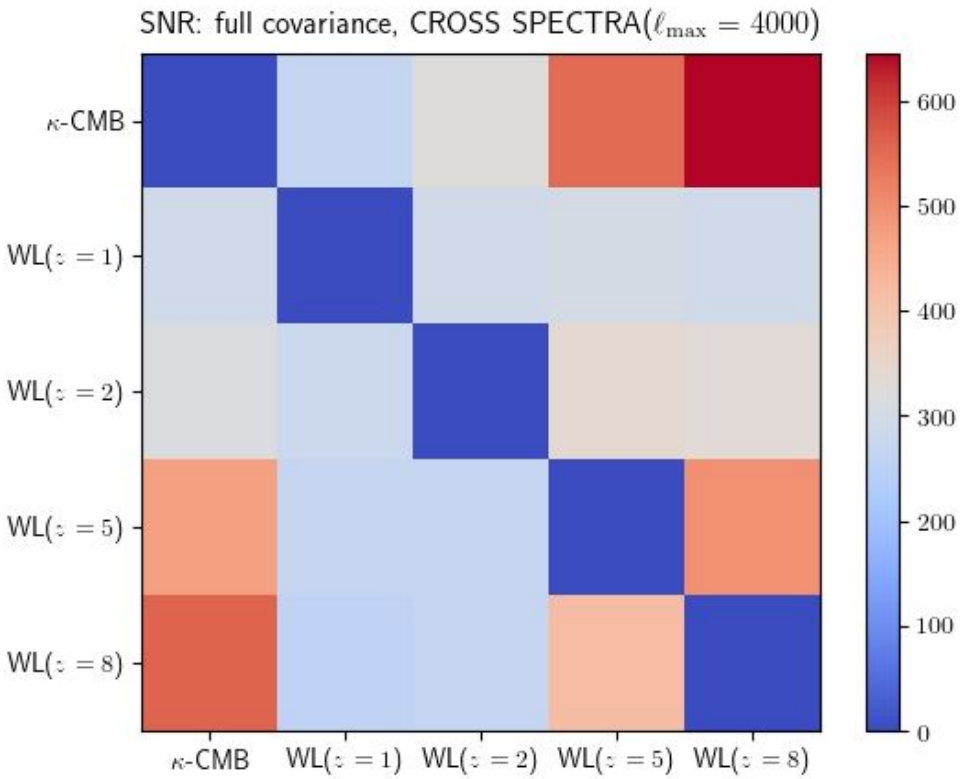


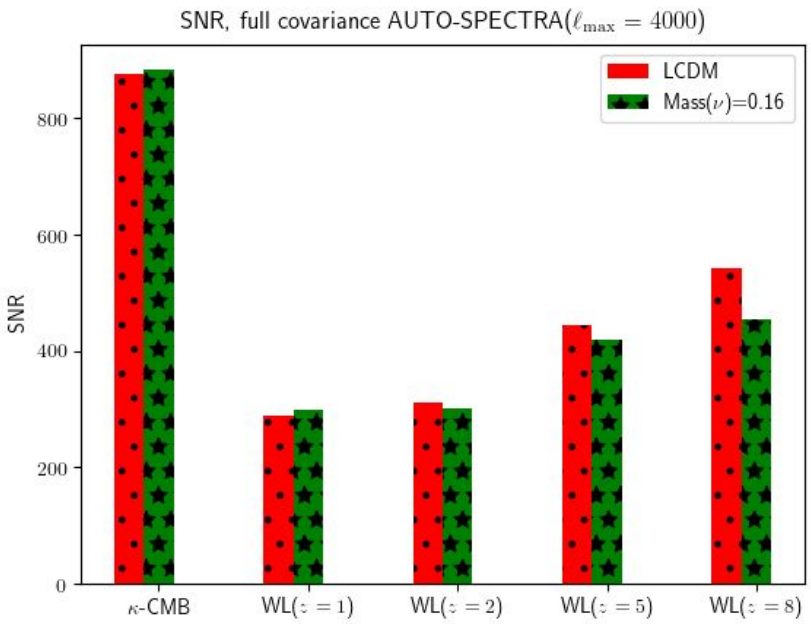
SNR for different observ. lmax = 2000

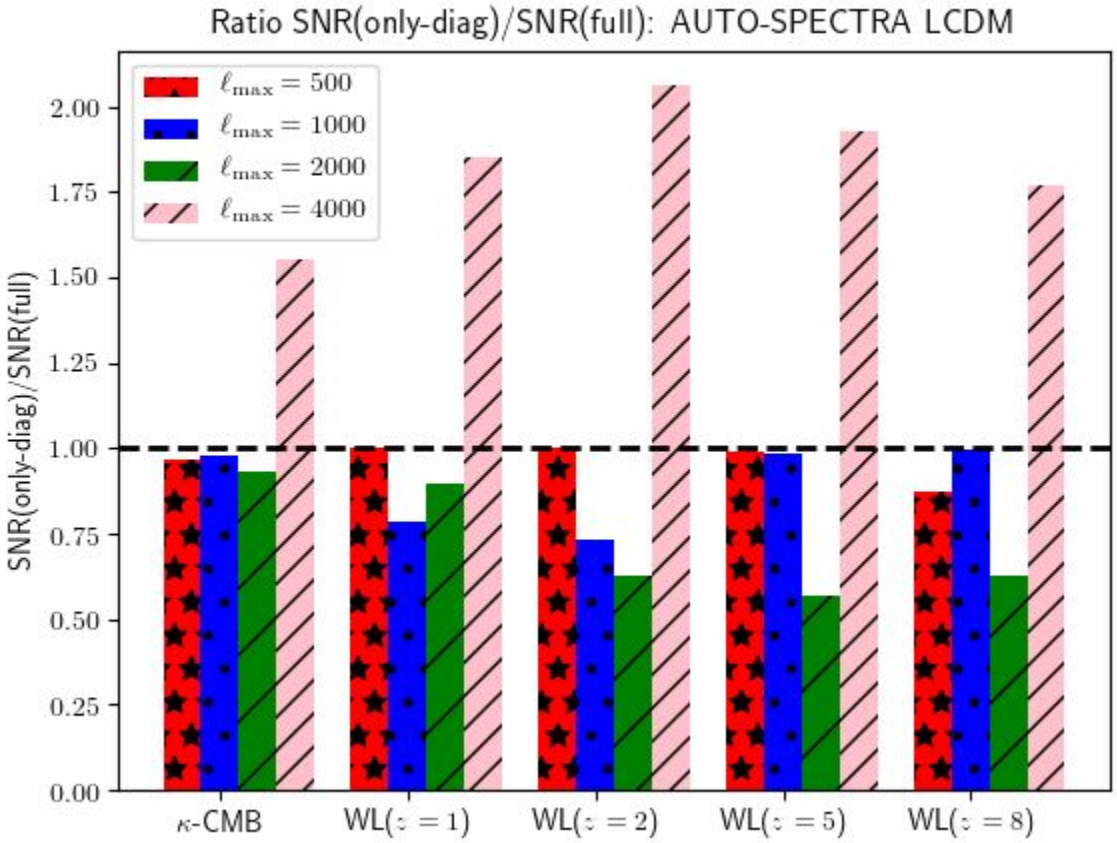


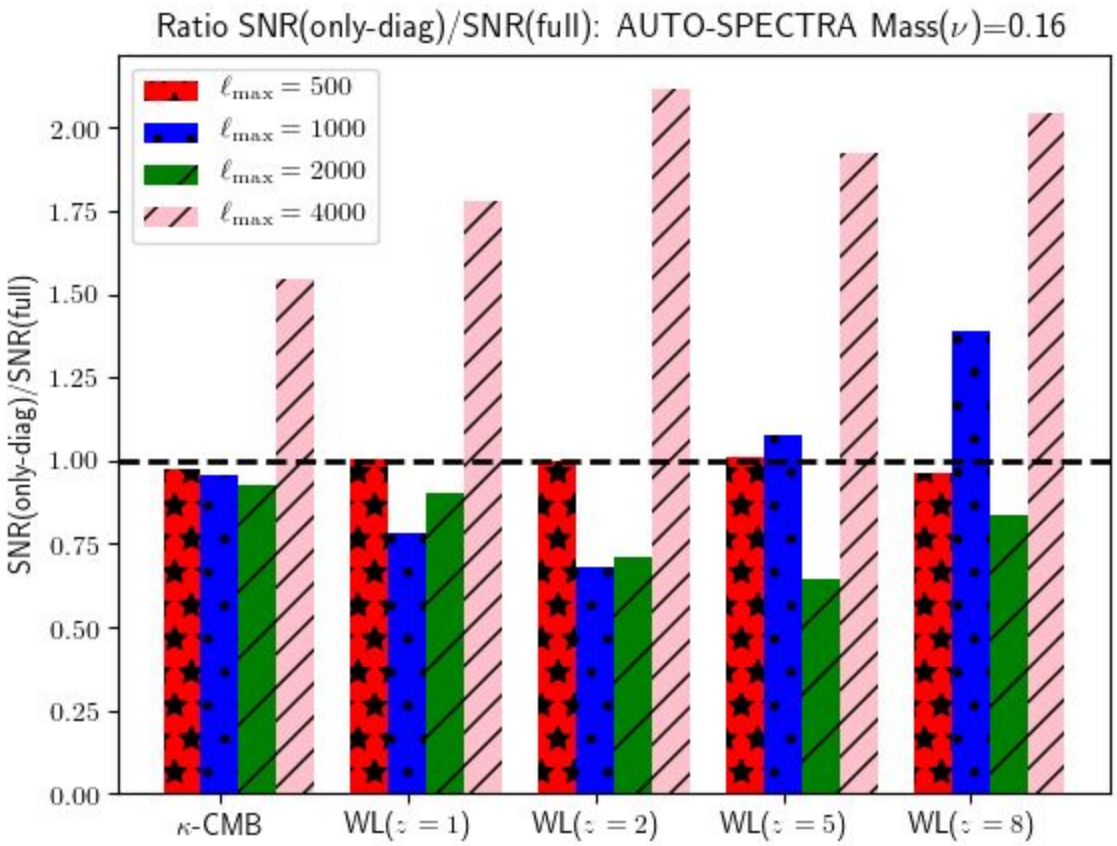


SNR for different observ. lmax = 4000






Ratio SNR(only-diag)/SNR(full): AUTO-SPECTRA LCDM
$\ell_{max} = 500$
$\ell_{max} = 1000$
$\ell_{max} = 2000$
$\ell_{max} = 4000$
SNR(only-diag)/SNR(full)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
κ-CMB
WL($z = 1$)
WL($z = 2$)
WL($z = 5$)
WL($z = 8$)


Ratio SNR(only-diag)/SNR(full): AUTO-SPECTRA Mass(ν)=0.16
$\ell_{\max} = 500$
$\ell_{\max} = 1000$
$\ell_{\max} = 2000$
$\ell_{\max} = 4000$
SNR(only-diag)/SNR(full)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
κ-CMB
WL($z = 1$)
WL($z = 2$)
WL($z = 5$)
WL($z = 8$)

Lensing pot. reconstruction

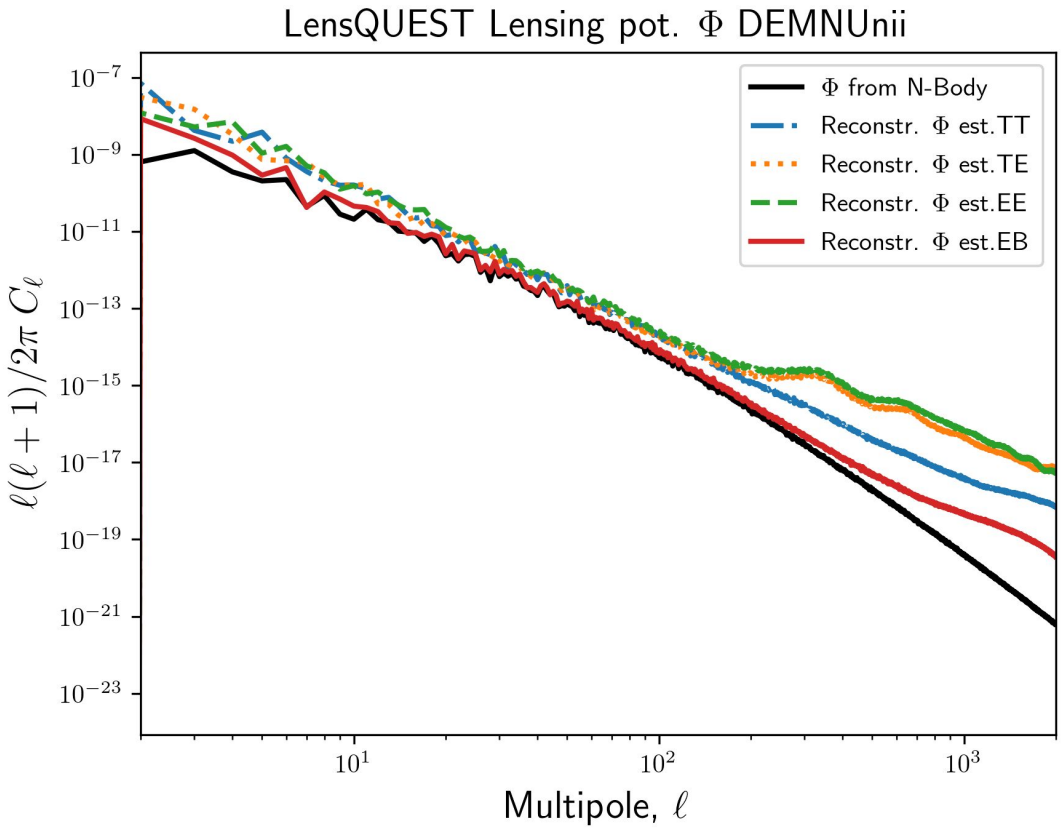
from Nbody Simulations → Light-cone and 2D maps of matter

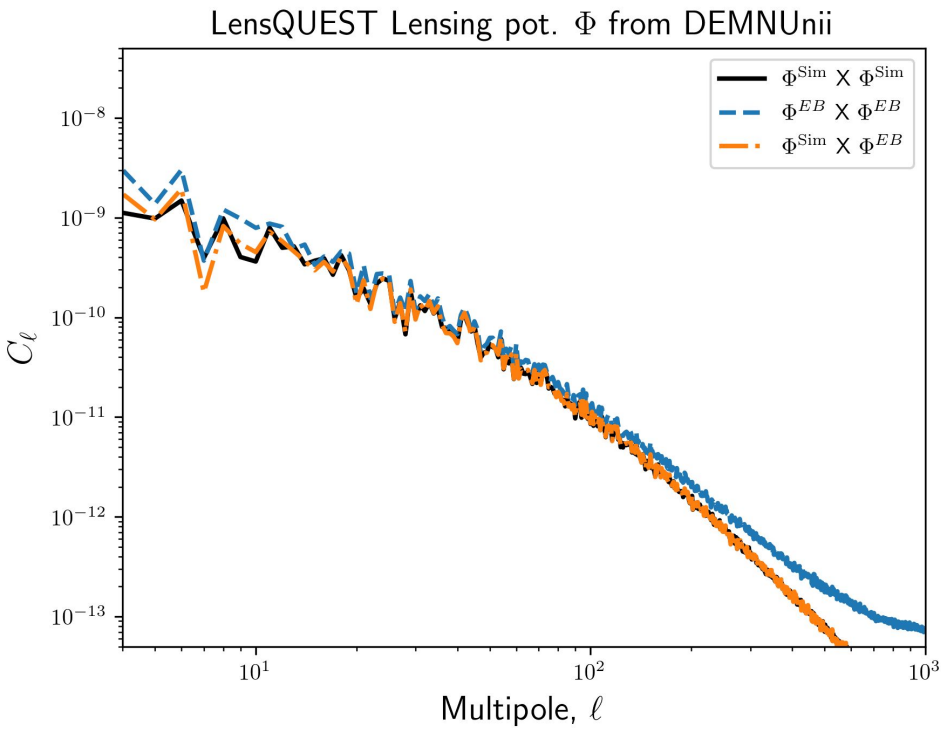
↓

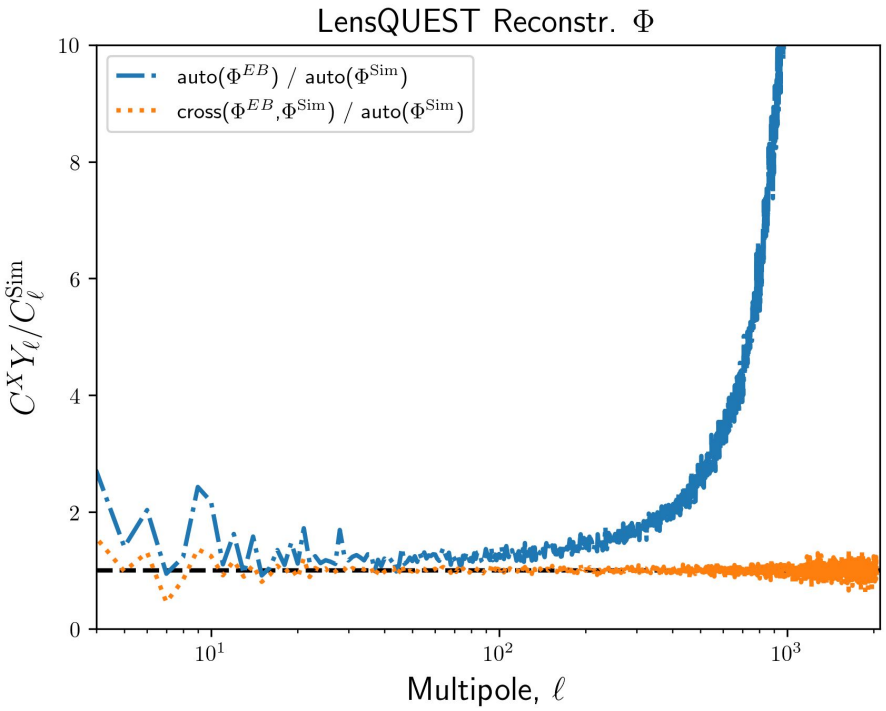
from CMB unlensed power spectrum → Lensed CMB field using LensPix and lensing potential maps from sims.

↓

from lensed CMB field → lensing potential reconstruction via Hu&Okamoto

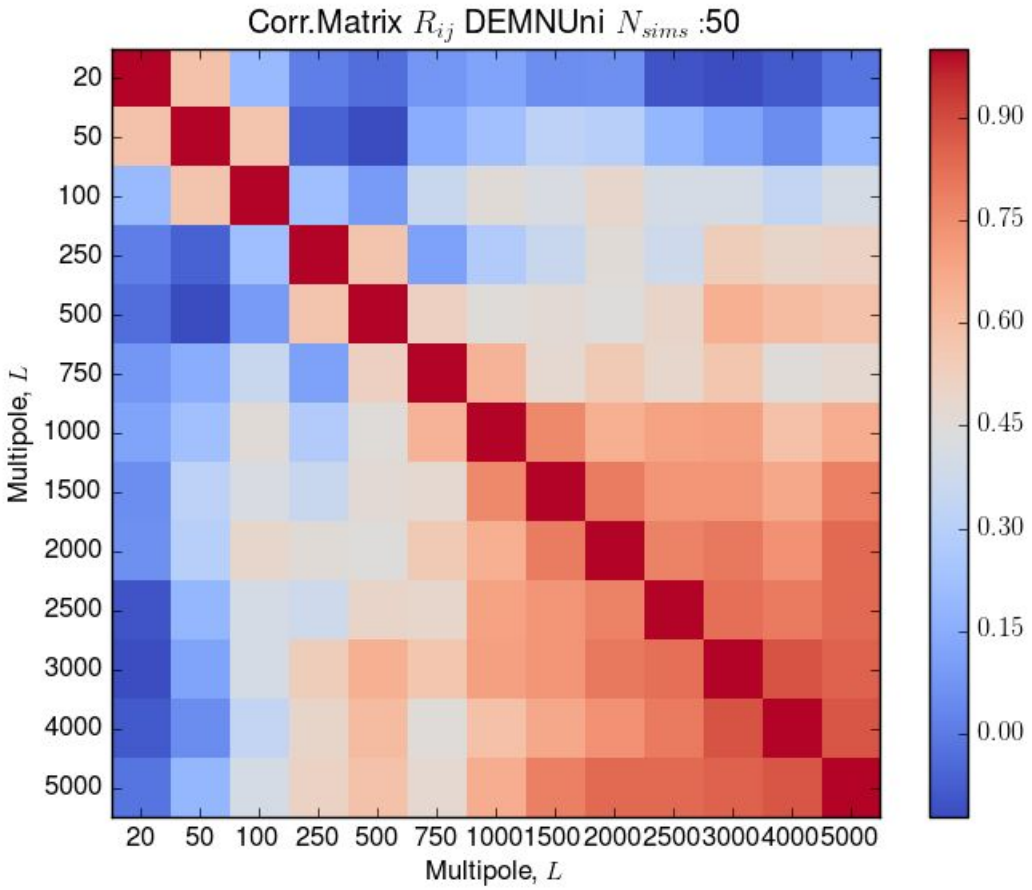



LensQUEST Lensing pot. Φ from DEMNUnii
$\Phi^{\rm Sim} \times \Phi^{\rm Sim}$
$\Phi^{EB} \times \Phi^{EB}$
$\Phi^{\rm Sim} \times \Phi^{EB}$
C_ℓ
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^1
10^2
10^3
Multipole, ℓ


LensQUEST Reconstr. Φ
auto(Φ^{EB}) / auto($\Phi^{\rm Sim}$)
cross(Φ^{EB},$\Phi^{\rm Sim}$) / auto($\Phi^{\rm Sim}$)
$C^{XY}_\ell / C^{\rm Sim}_\ell$
0
2
4
6
8
10
10^1
10^2
10^3
Multipole, ℓ

Covariances from particle maps

Towards tomography.



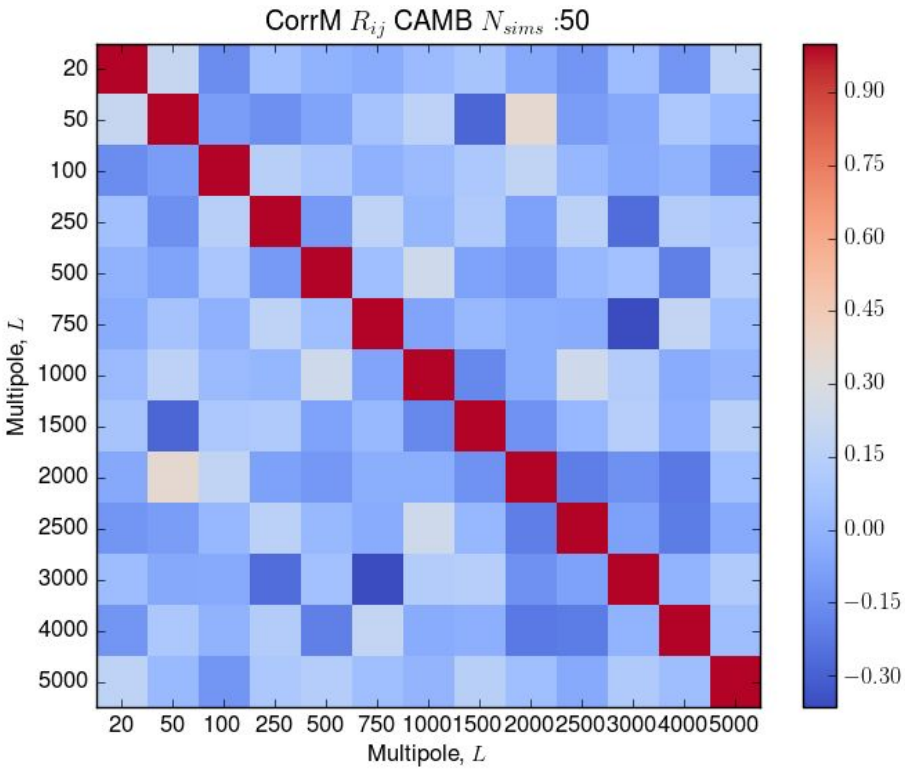
C_L CMB-Convergence DEMNUni → Covariance Matrix

13 Bins in multipole, L = {20,50,100,250,500,750,1000,1500,2000, 2500,3000,4000,5000}

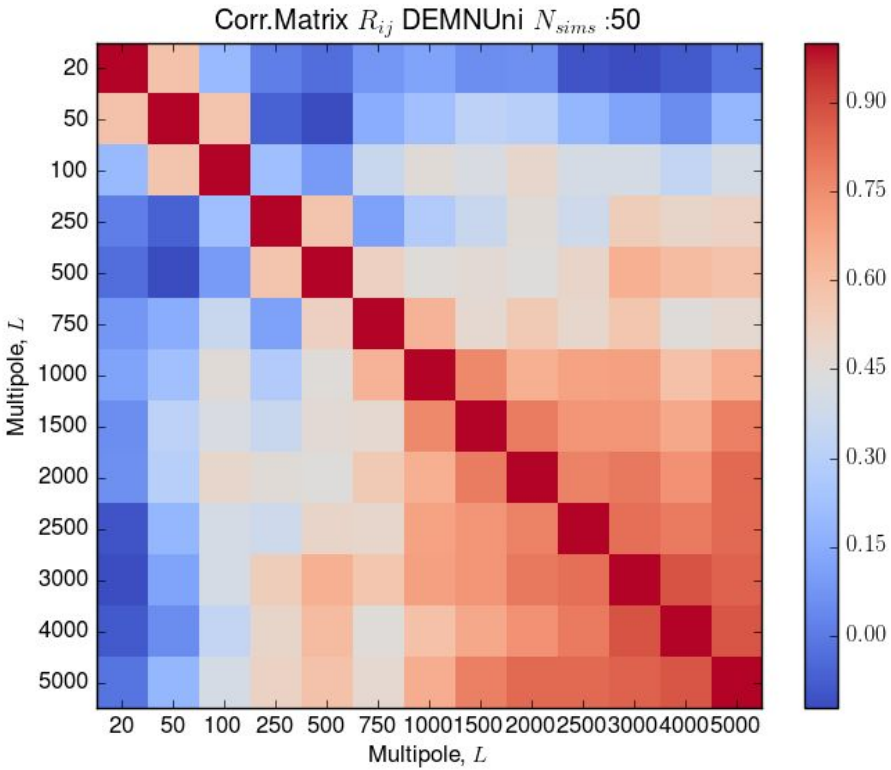
Nside Convergence maps = 4096
Number of Simulations = 50

LCDM and Mnu=0.16

<u>Figures are Correlation Matrix</u>
(Covariances normalized to diagonal variances)

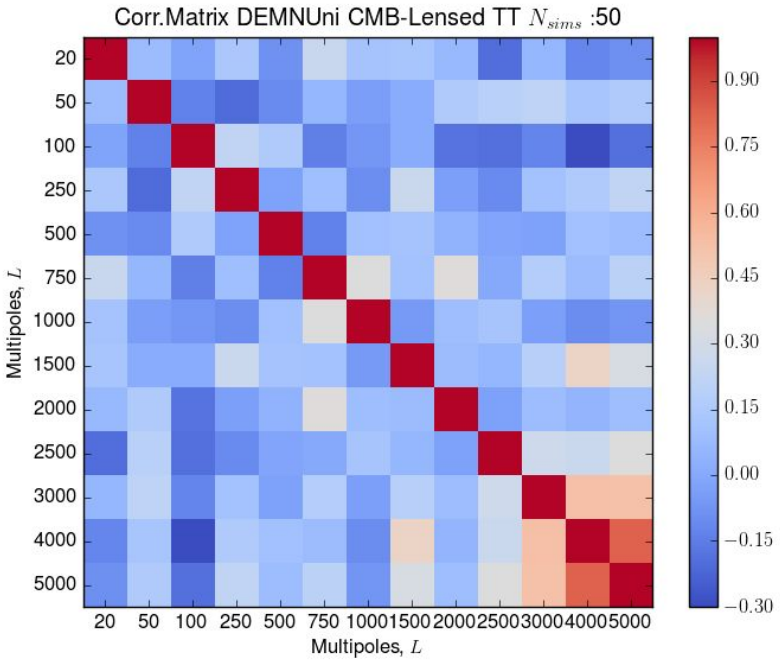


C_LCAMB → Covariance Matrix

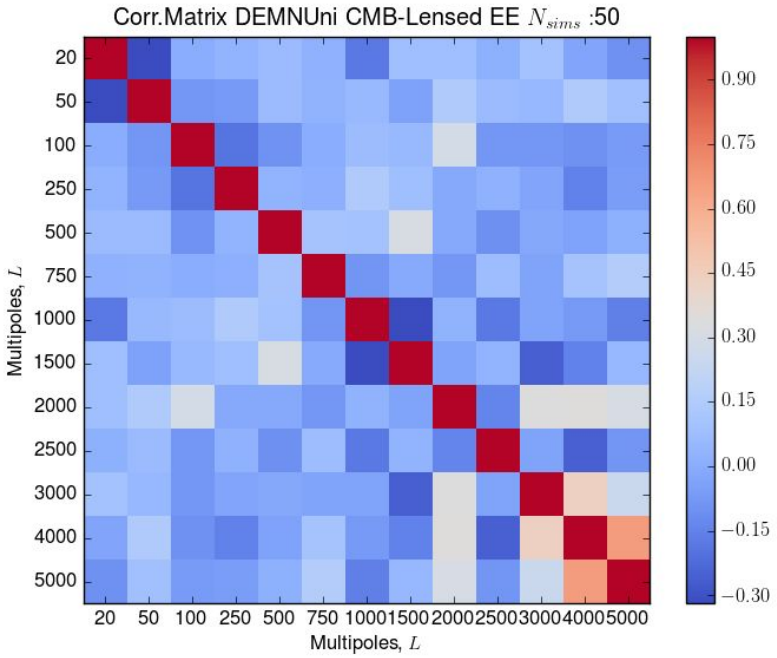


C_LDEMNUni → Covariance Matrix

Lensed CMB Covariances: TT and EE

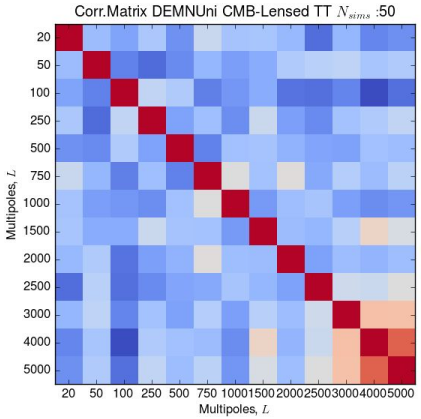


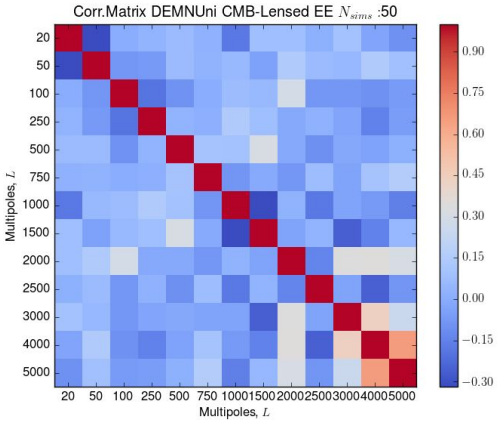
TT: CMB + Lensed(DEMNUni) → Covariance Matrix on TT spectrum



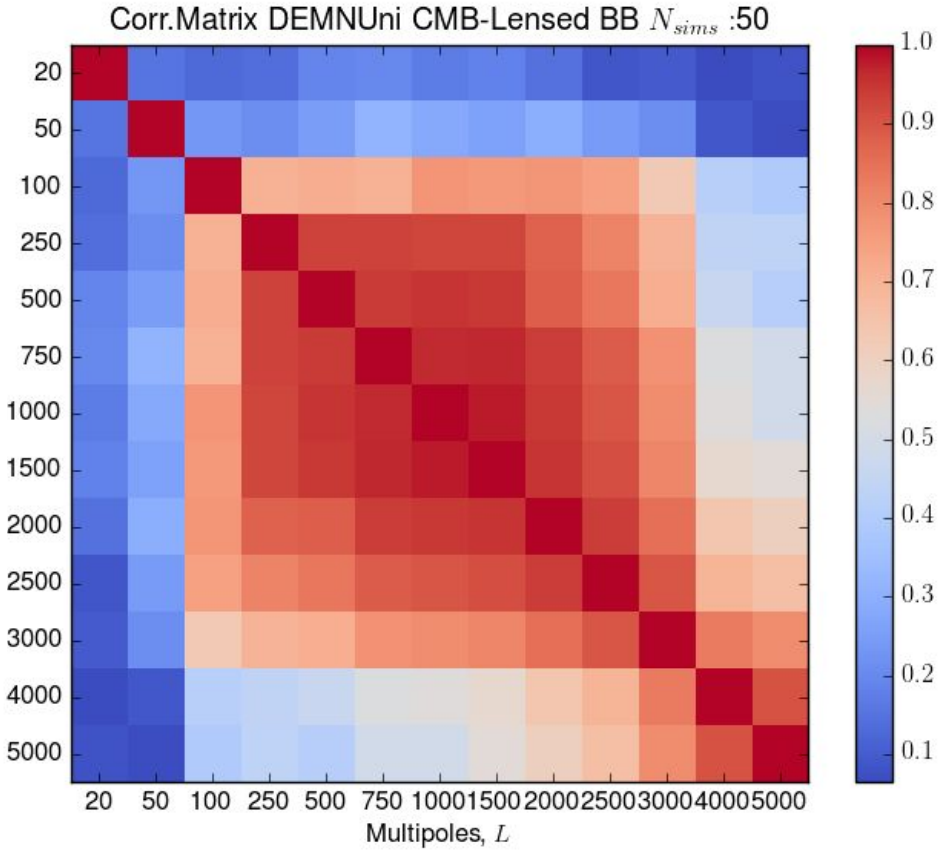
EE: CMB + Lensed(DEMNUni) → Covariance Matrix on EE spectrum

Cov. on lensed BB



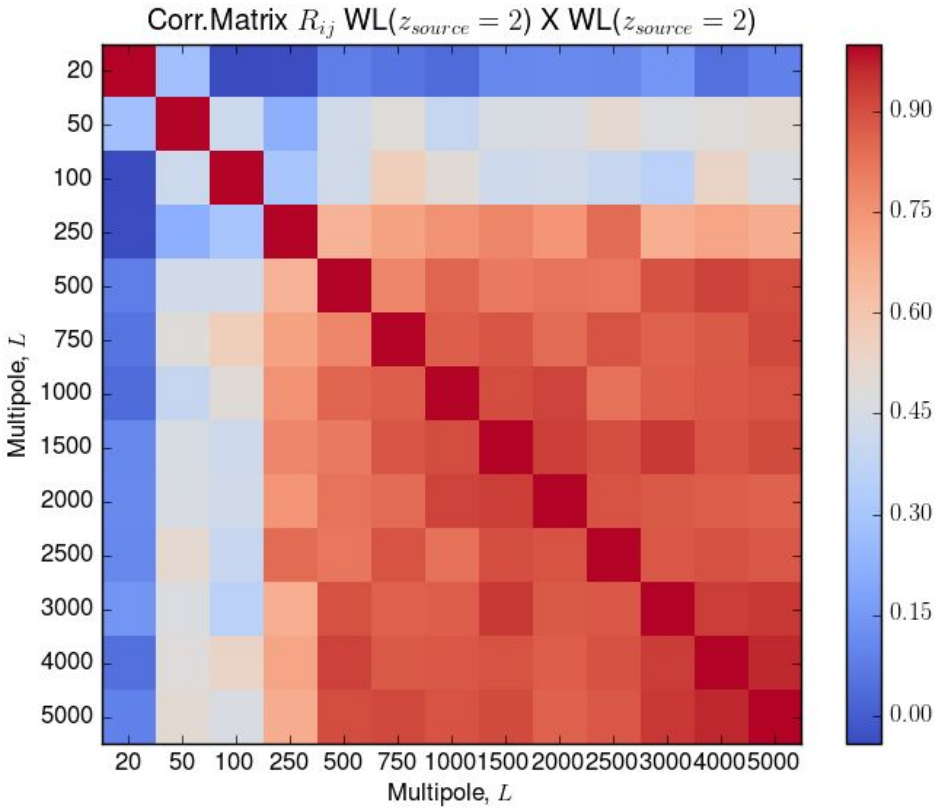


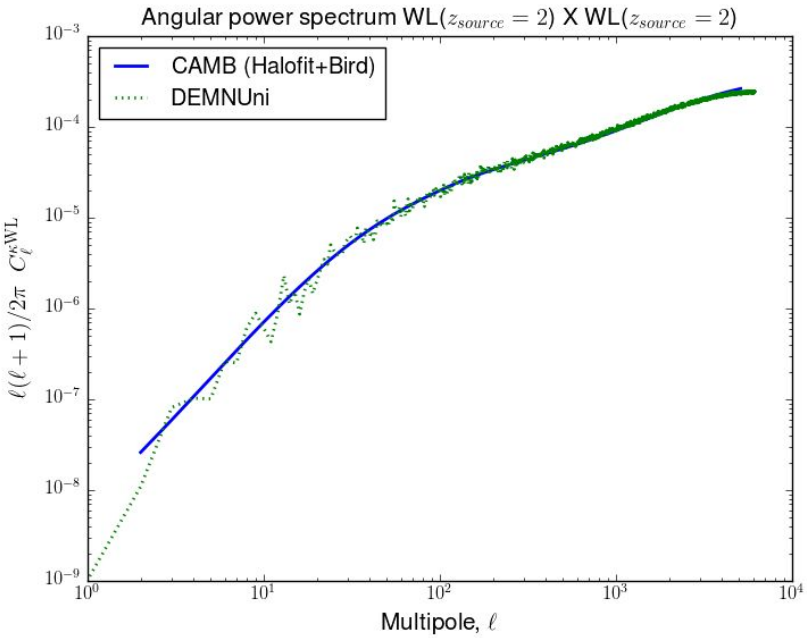
primordial-CMB + DEMNUni-Convergence using LensPix → Covariance Matrix on TT, EE and BB spectrum



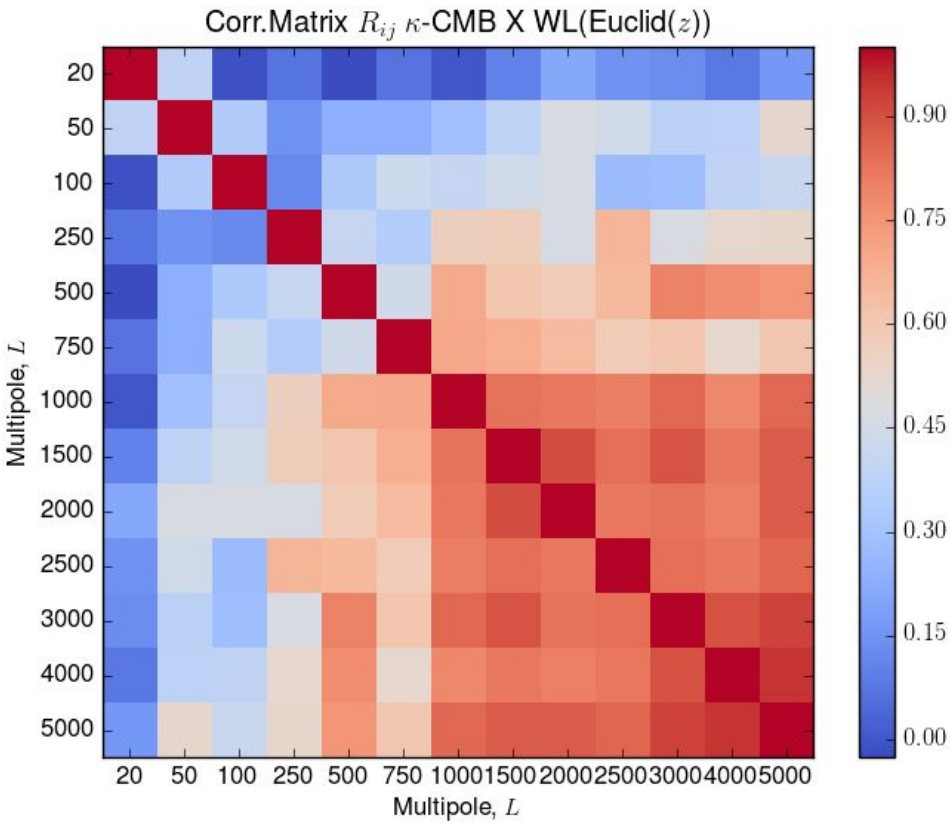
BB: CMB + Lensed(DEMNUni) → Covariance Matrix on BB spectrum

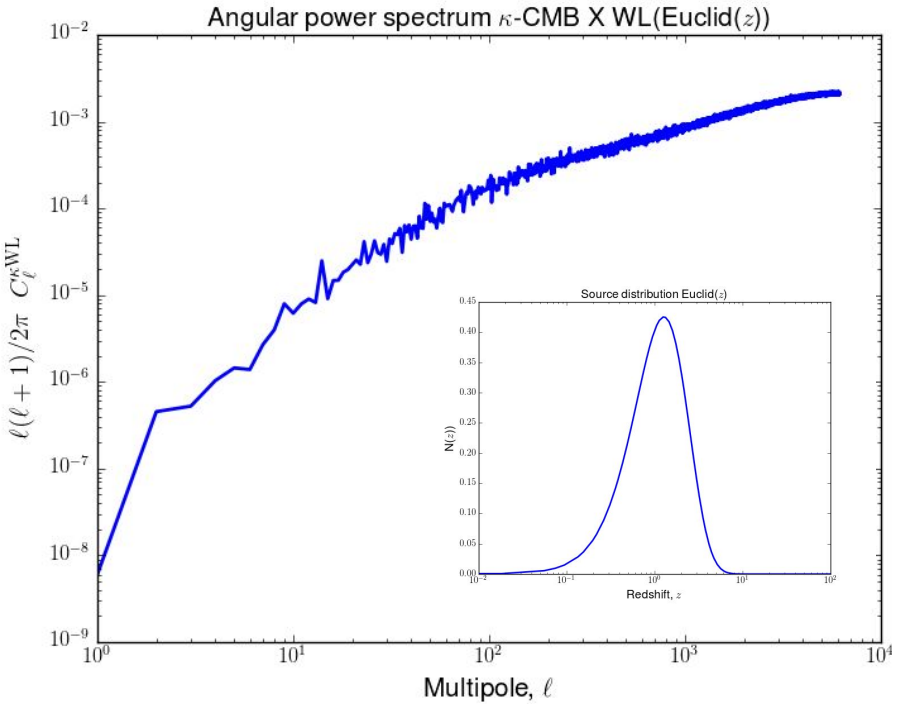
Covariances from Particle grids: WL(z=2) auto-spec.



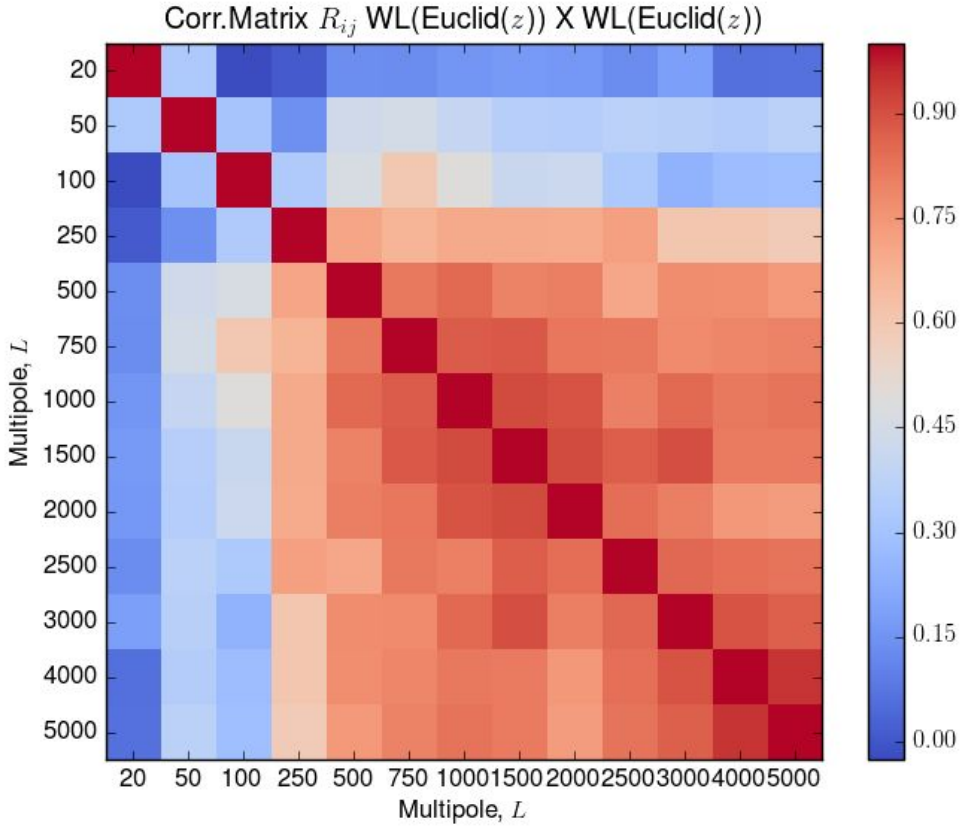


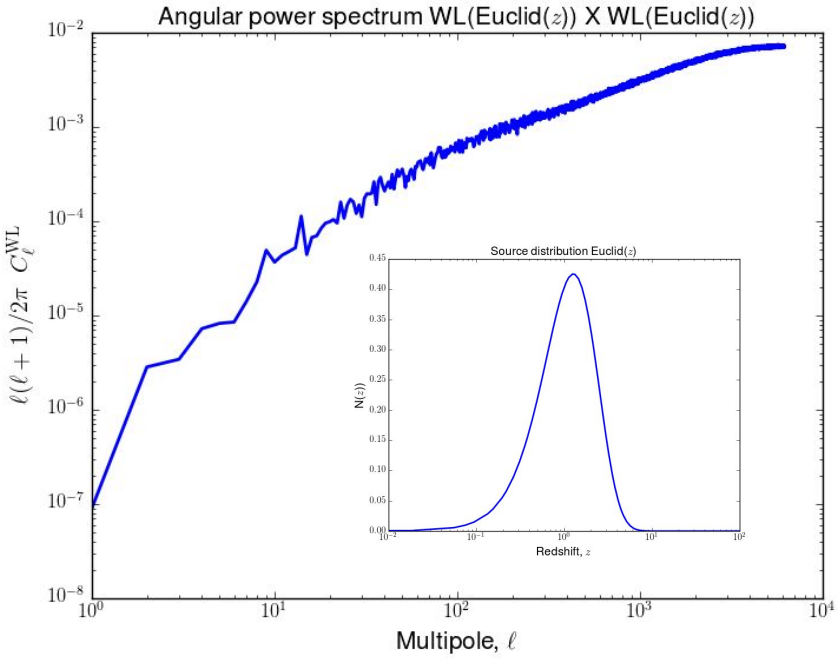
Cov. from Particle grids: WL(euclid) x kCMB





Cov. from Particle grids: WL(euclid) x WL(euclid)





Recap and conclusions

Finally!

What we have so far...

- N-body numerical simulations in different cosmologies:
  → Objective 1: **cosmology-dependent covariances** Matrix from Numerical simulations
- 2D healpix maps for different lensing observables
  → Objective 2: Covariances from different observables (k-CMB, WL, ISW, lensed-CMB,...)
  → Objective 3: Impact of non-linearities and off-diagonal terms on covariances matrix
- Numerical simulation to forecast model accuracy and estimations:
  → Objective 4: **Signal-to-noise** ratio measurement and its impact
- Lightcone and map-making
  → Objective 5: Potential grids vs particle grids
  → Weak Lensing Convergence maps → **tomographic covariances with Euclid-n(z) sources**
- Cross correlation between different lensing observables
  → Objective 6: **Cross correlation** CMB-Temperature (lensed) X WeakLensing
  → **tomographic covariances of Tk cross-correlation with Euclid-n(z) sources**

… what we plan to do

WIP

- Galaxy maps from simulations (in different cosmologies)
  → SHAM methods → **Cross (CMB-Convergence / WL-Convergence) X (Galaxies)**
  → HOD methods → **Cross (CMB-Convergence / WL-Convergence) X (Cluster / SZ)**
- New covariances from different observables: ISW and Lensing potential reconstruction from Hu&Okamoto

Planned/next

- Cross correlation (T-ISW) X (CMB-Convergence / Lensed CMB)
- Comparison Born approximation vs Multiple Lens CMB-lensing and WL covariances
- New obsevables extracted from simulations, e.g. SZ or Voids

Thanks.

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