Cosmology in the non-linear regime : the small-scale miracle

Based on
Lacasa 2018 - arXiv: 1711.07372
Lacasa 2019a - arXiv: 1909.00791
Lacasa 2019b in prep

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Cosmology

vs

Astrophysics

Outline

Introduction: Galaxy clustering and $C_\ell^{\rm gal}$

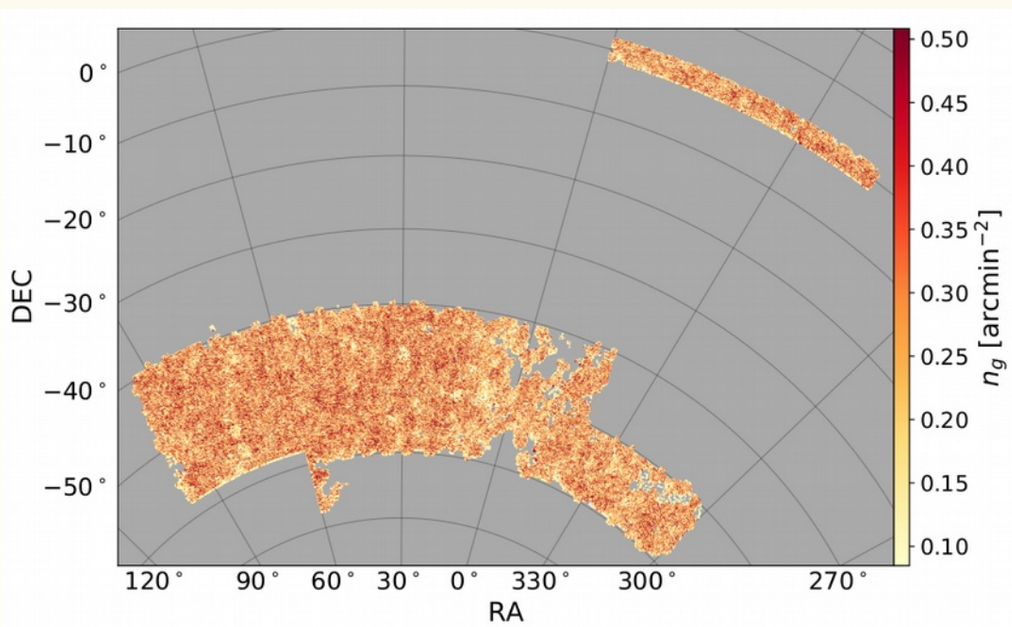
I. Non-linear covariances

II. Impact for a baseline cosmological analysis

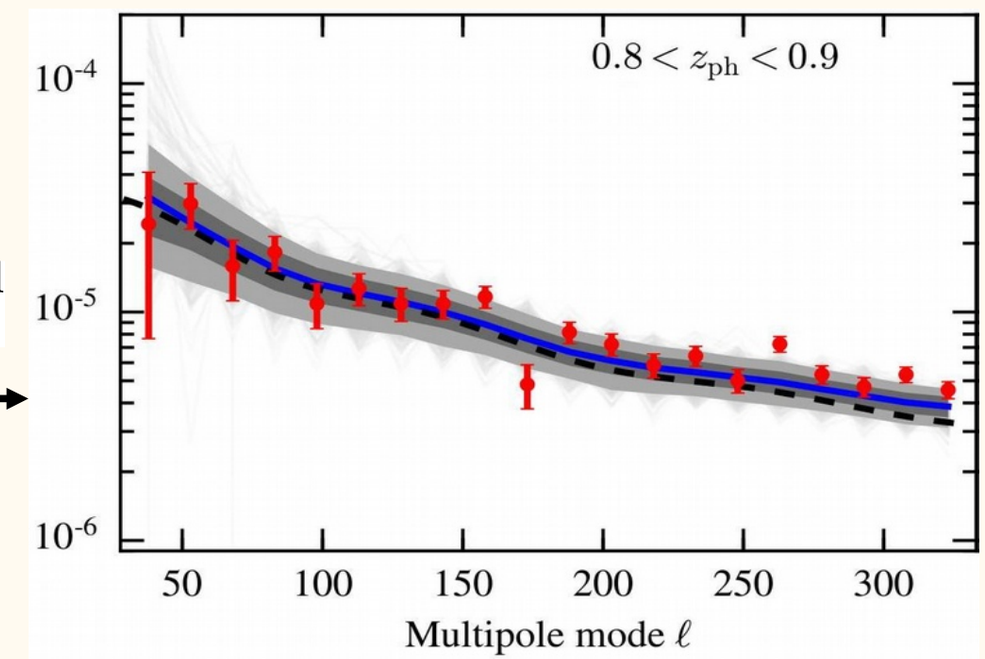
III. Pushing to small scales

Galaxy clustering

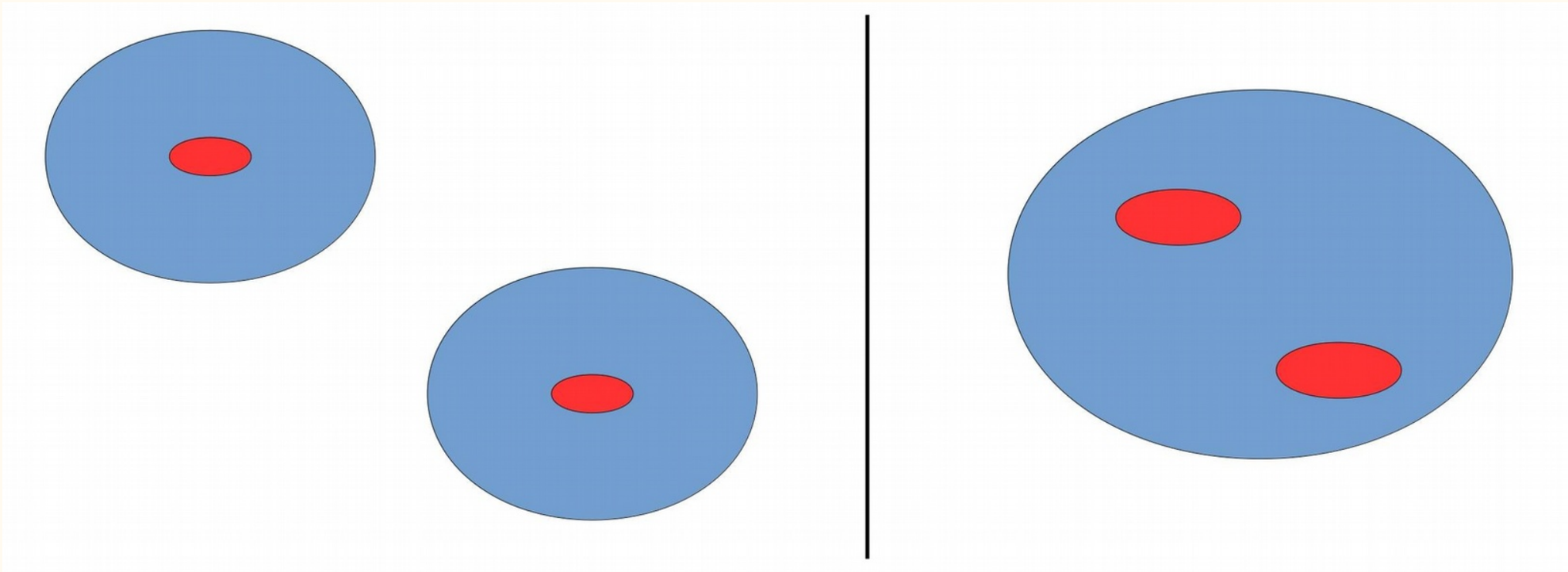
Angular power spectrum



$C_\ell^{\rm gal}$



Modeling



2-halo

$$P_{2h}(k) \propto \int \mathrm{d}M_1 \mathrm{d}M_2 \cdots P_{\mathrm{halo}}(k\ M_1, M_2)$$

↓

Cosmological perturbation theory
+ bias expansion

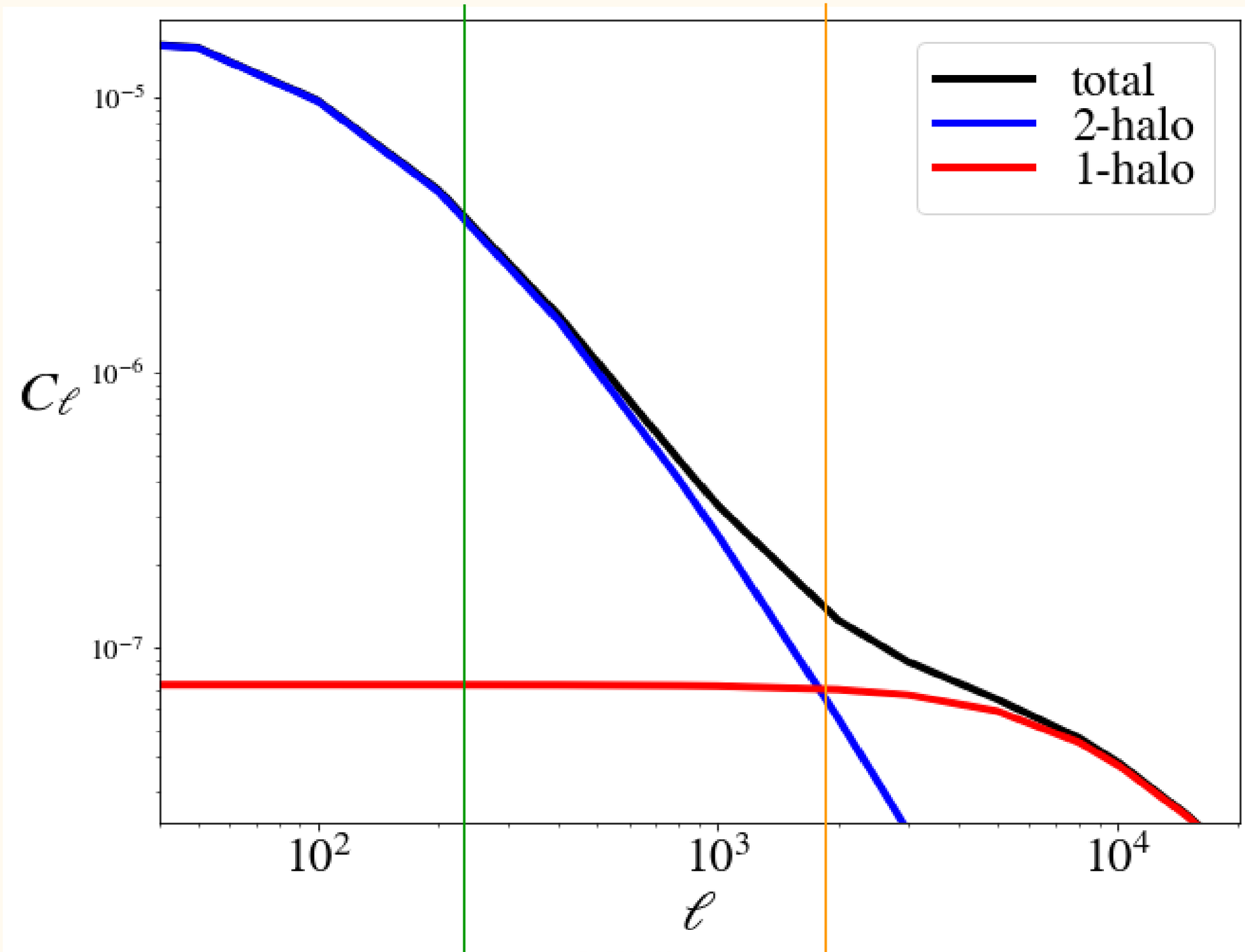
1-halo

$$P_{1h}(k) \propto \int \mathrm{d}M \frac{\mathrm{d}n}{\mathrm{d}M} \left\langle N_{\mathrm{gal}}^{(2)} \right\rangle u(k\ M, z)^2$$

↓

Halo Occupation Distribution
(HOD)

Scales



z=1

Regime

Linear

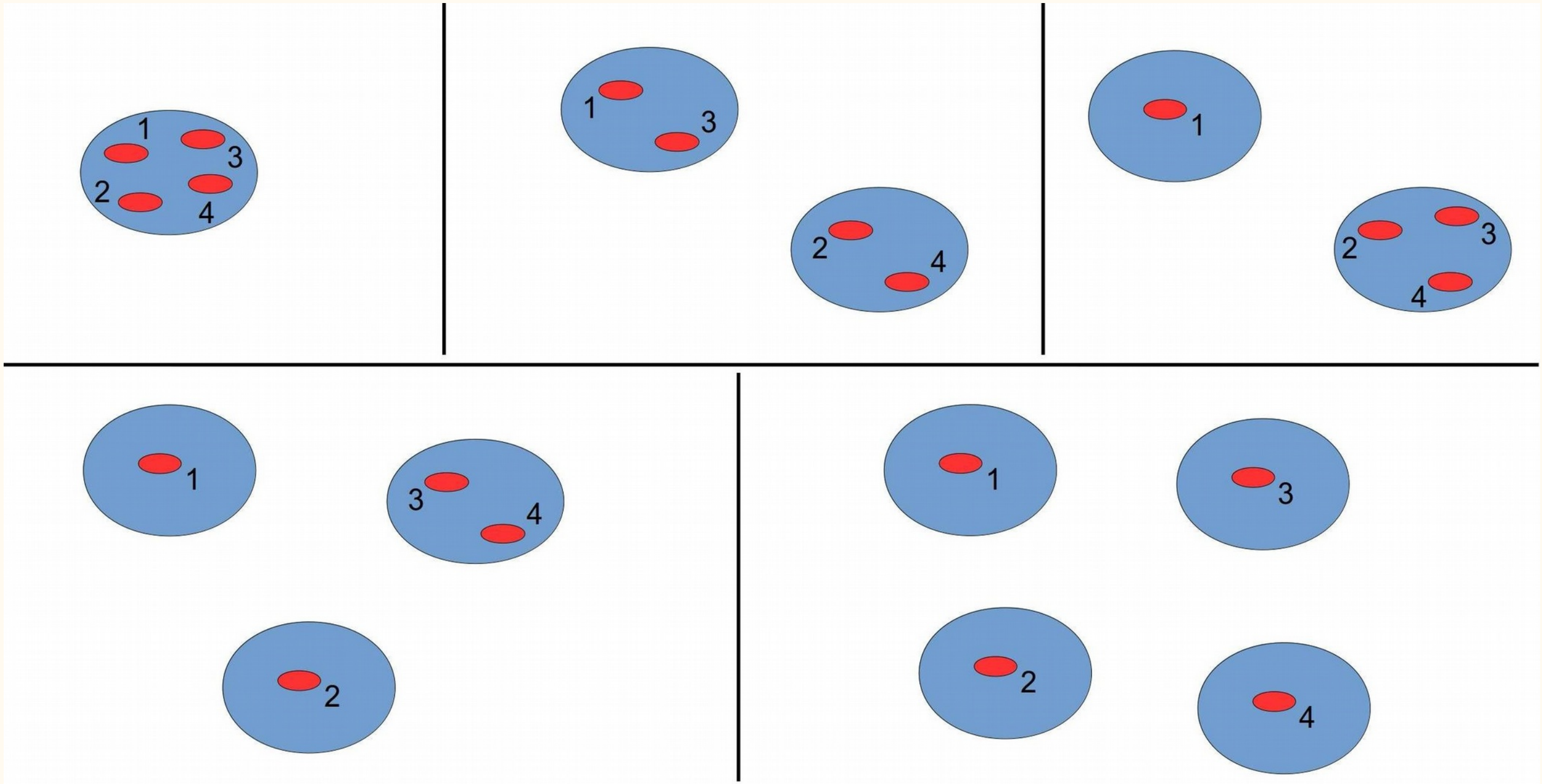
Mildly non-linear

Highly non-linear

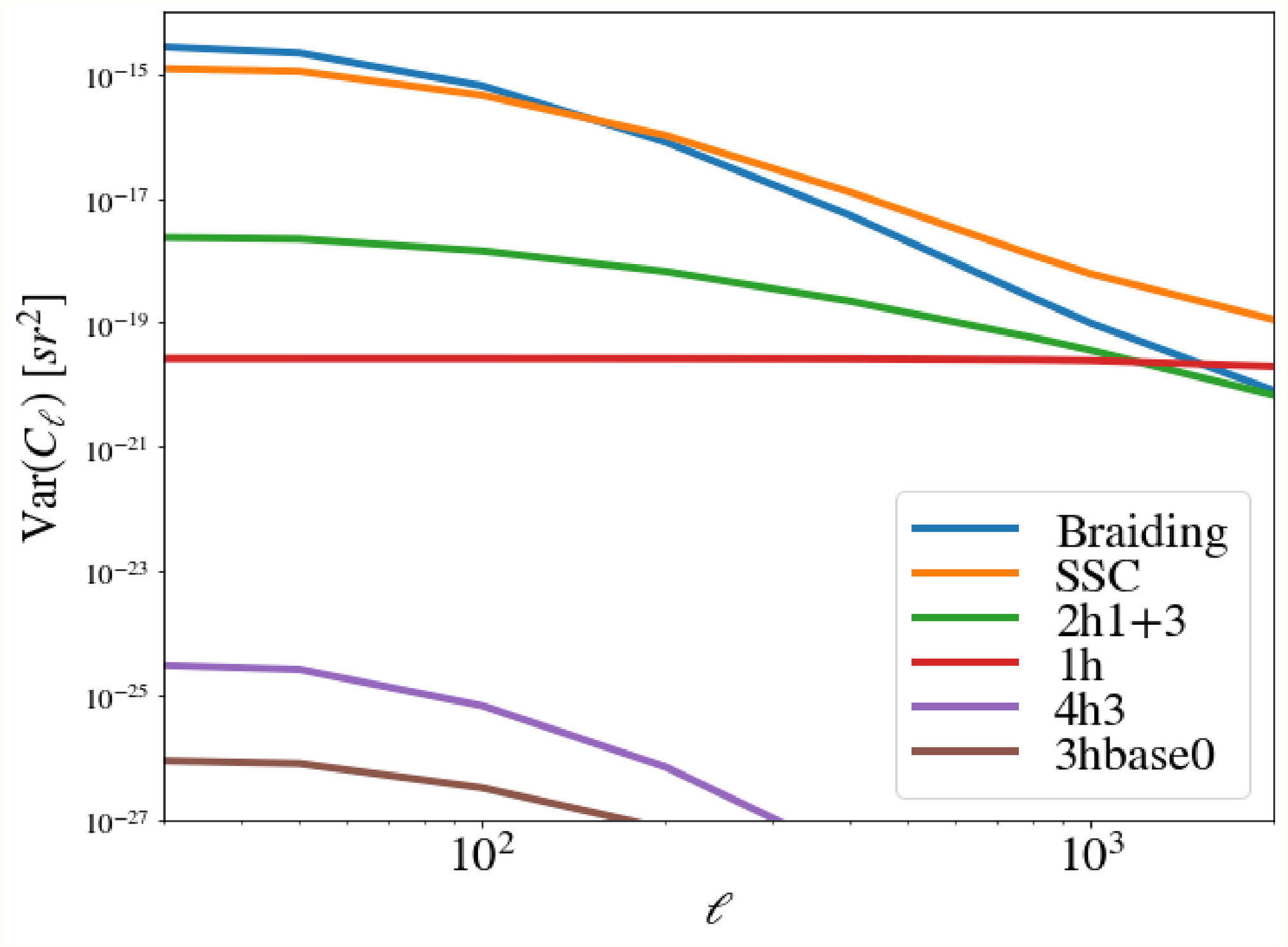
I. Non-linear covariances

Lacasa 2018 - arXiv: 1711.07372

Diagrams for Cov(CI)



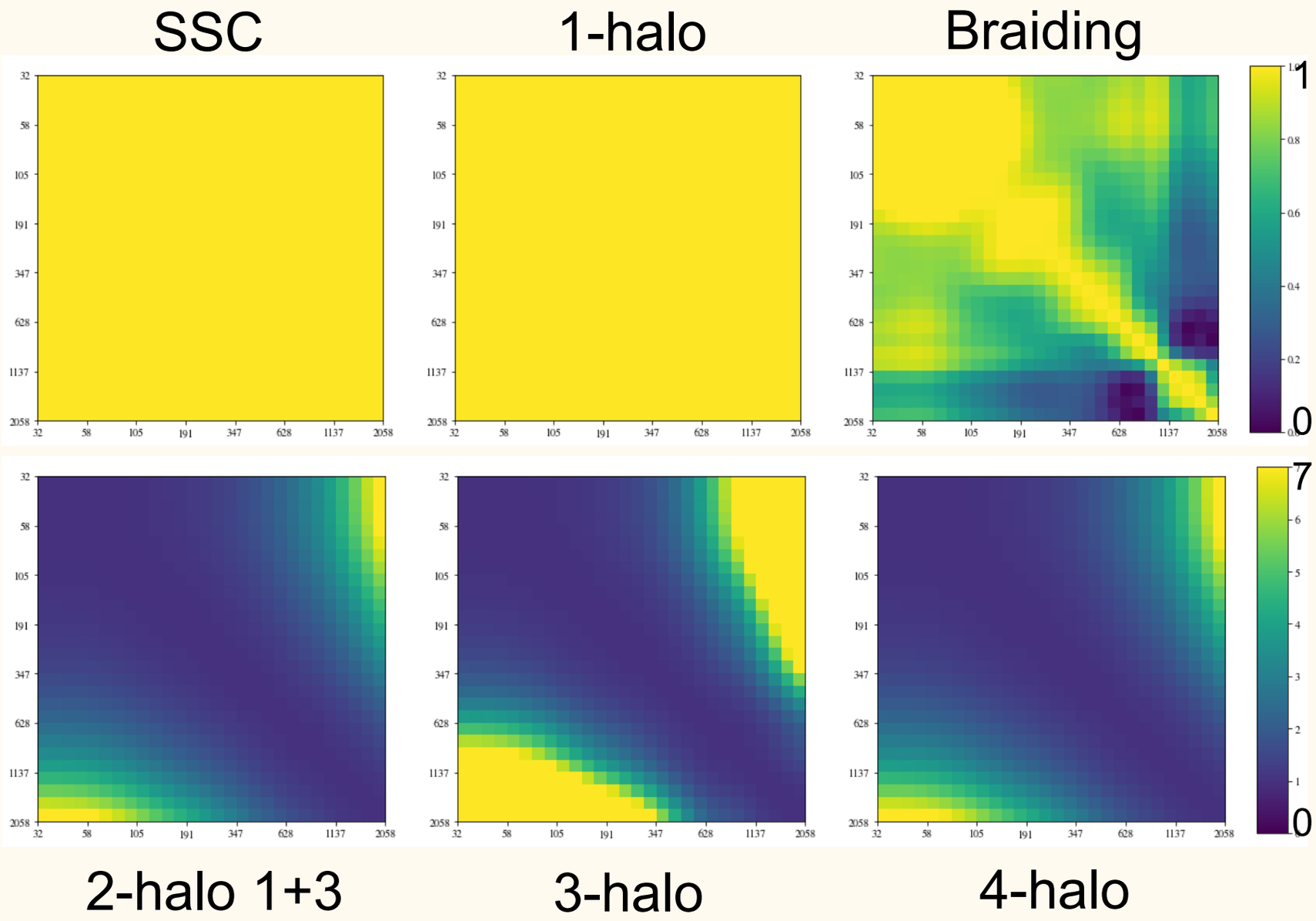
Variance : non-Gaussian terms



z=1

Covariance matrices

$$\frac{C_{a,b}}{\sqrt{C_{a,a}\,C_{b,b}}}$$



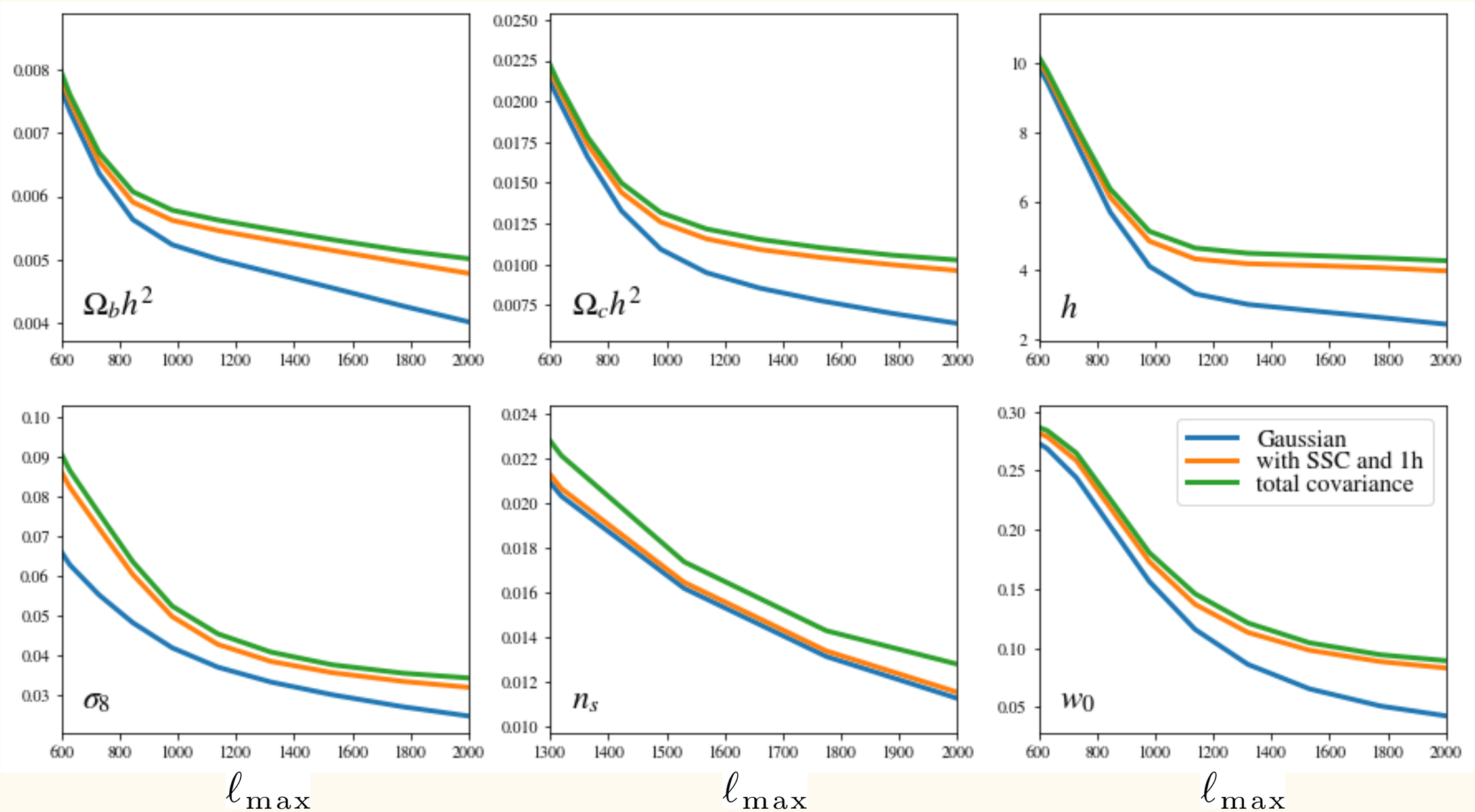
z=1

II. Impact for a baseline cosmological analysis

Lacasa 2019a - arXiv: 1909.00791

Euclid : data public on github.com/fabienlacasa/BraidingArticle
SKA 2 : public soon

Cosmological error bars



all z

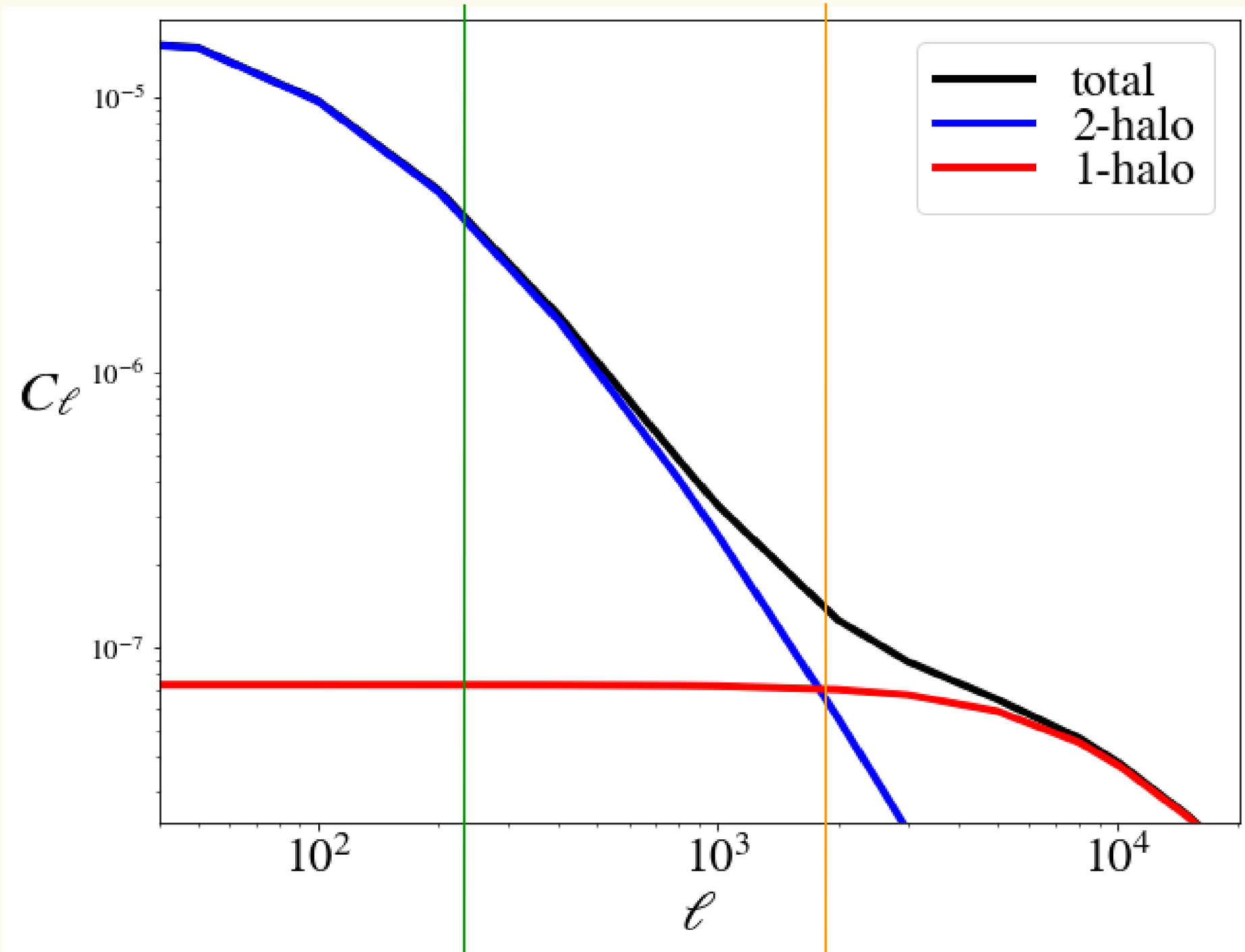
Increase of error bars due to non-Gaussianity

	with marginalisation	without marginalisation
σ_8	+41%	+360%
n_S	+15%	+84%
w	**+120%**	+310%

III. Pushing to small scales

Lacasa 2019b in prep

Scales



z=1

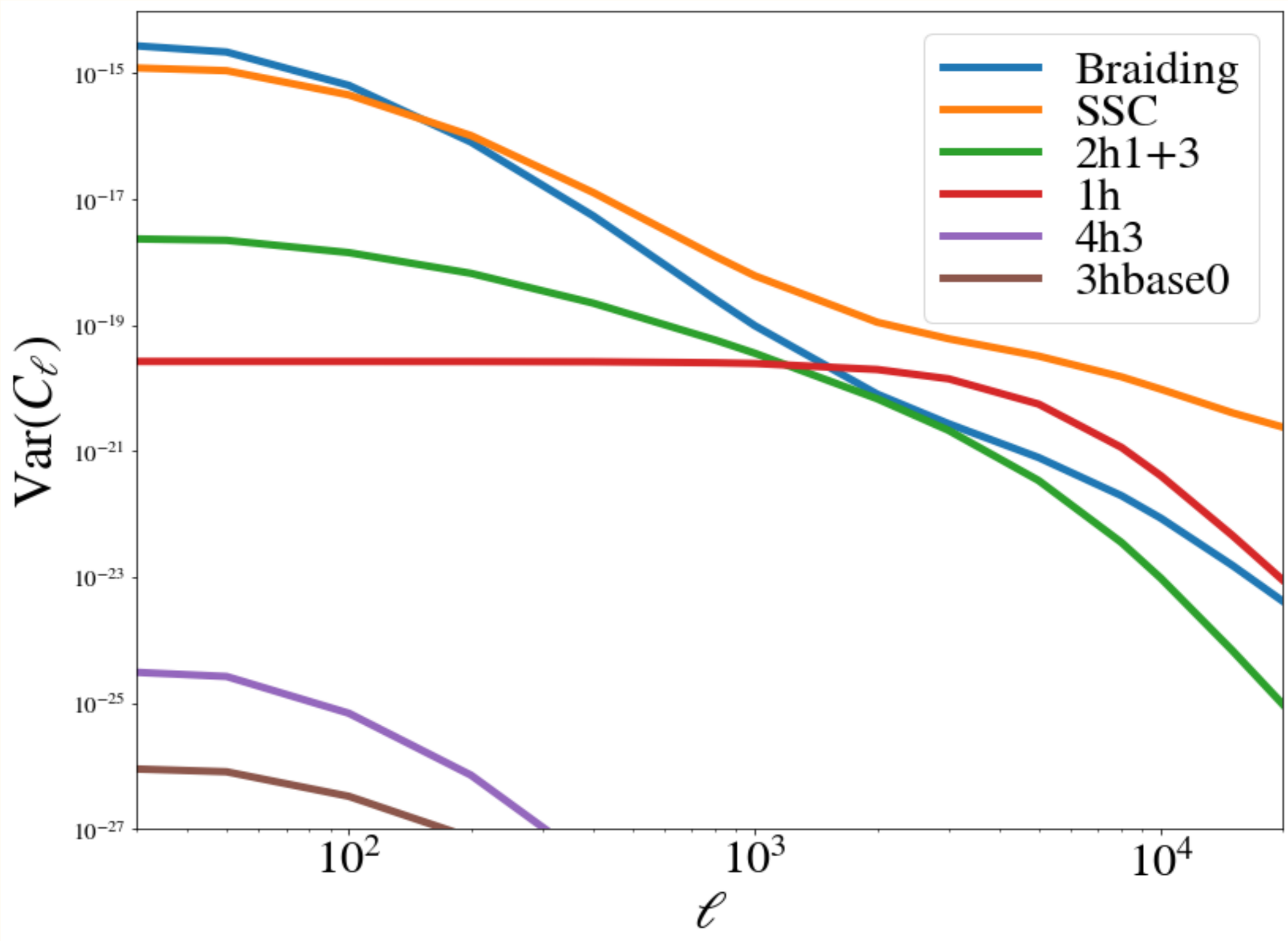
Regime

Linear

Mildly non-linear

Highly non-linear

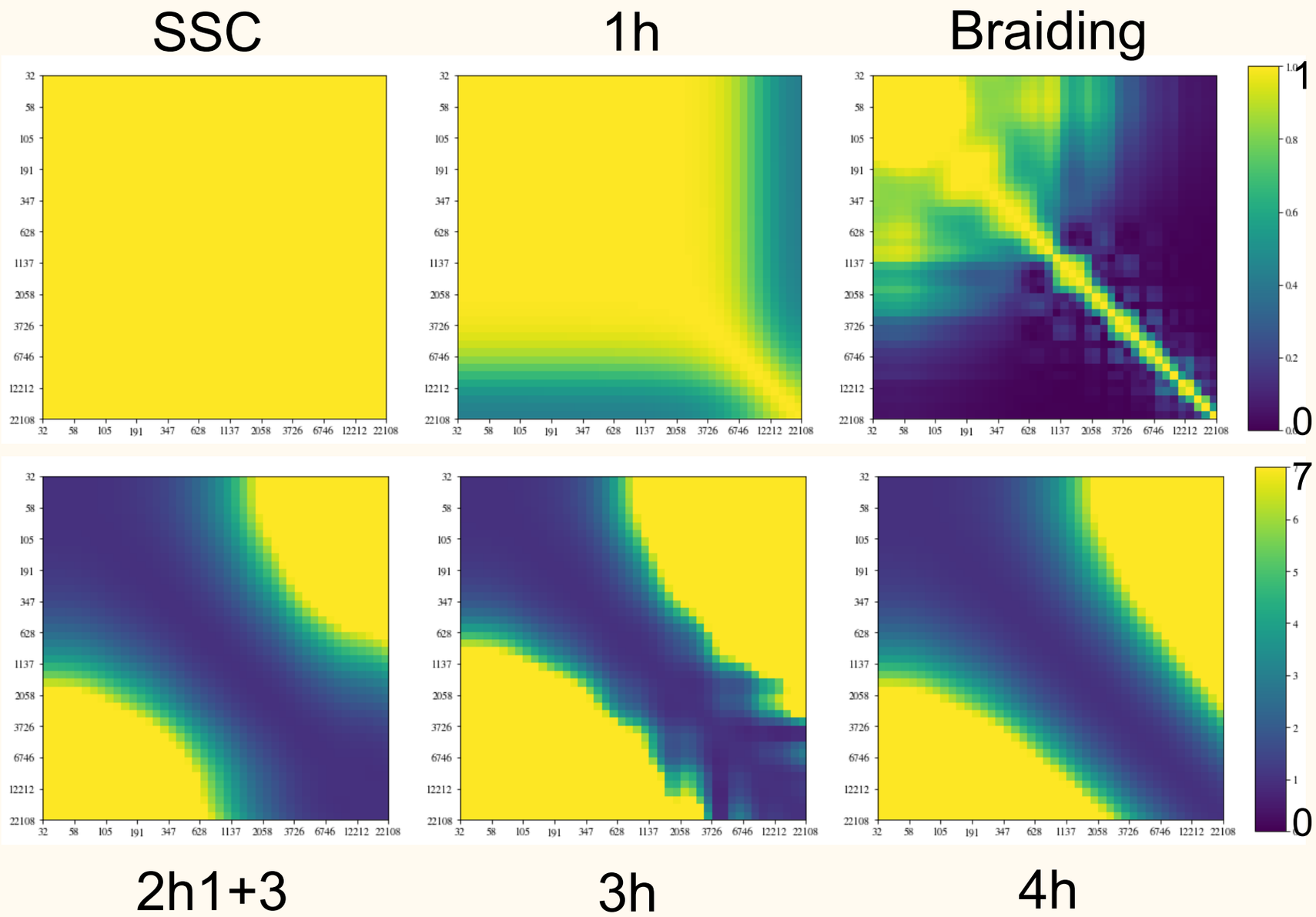
Variance


Braiding
SSC
2h1+3
1h
4h3
3hbase0
10^{-15}
10^{-17}
10^{-19}
10^{-21}
10^{-23}
10^{-25}
10^{-27}
$\mathrm{Var}(C_\ell)$
10^2
10^3
10^4
ℓ

z=1

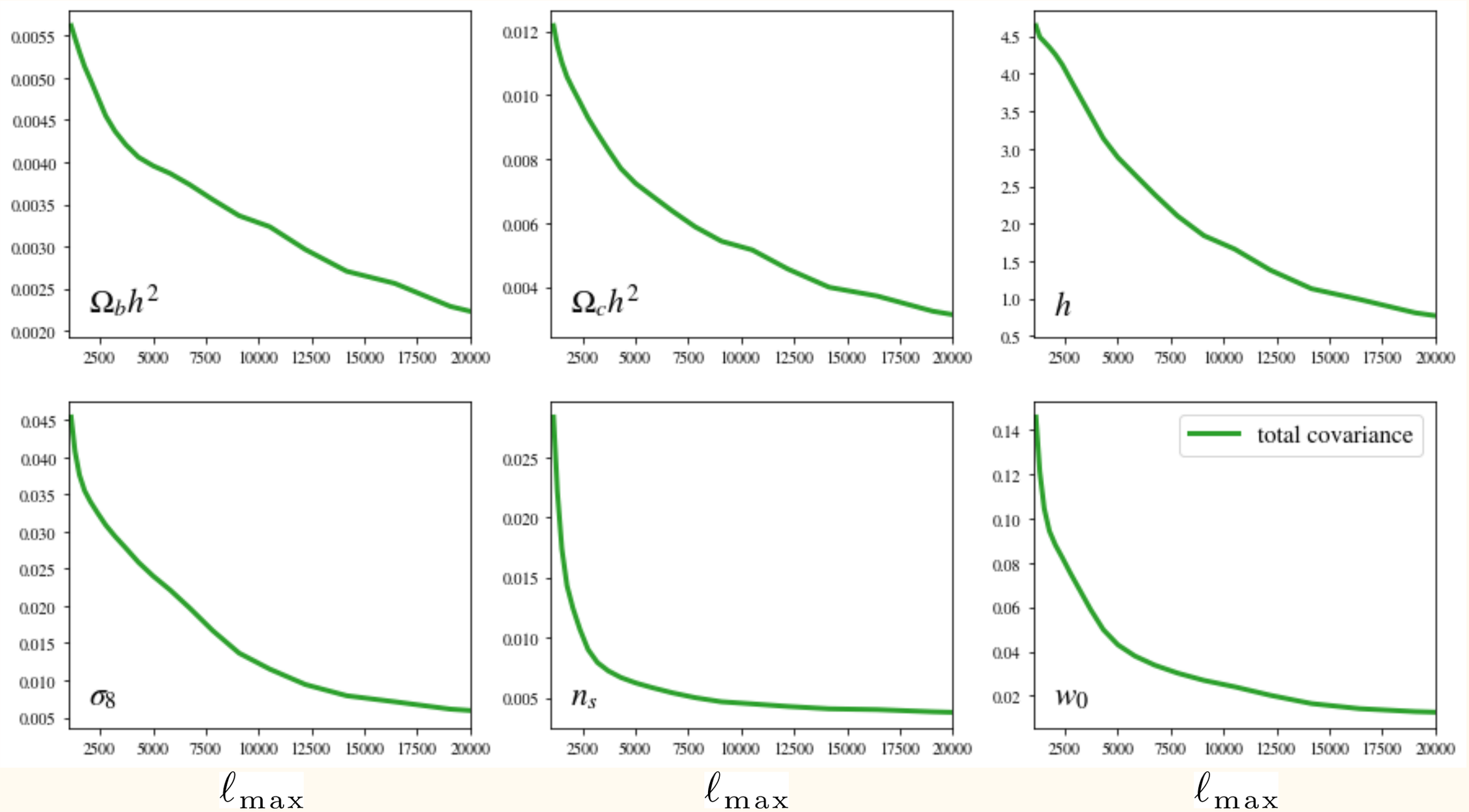
Covariance matrices

$$C_{a,b} \quad \sqrt{C_{a,a}\, C_{b,b}}$$



z=1

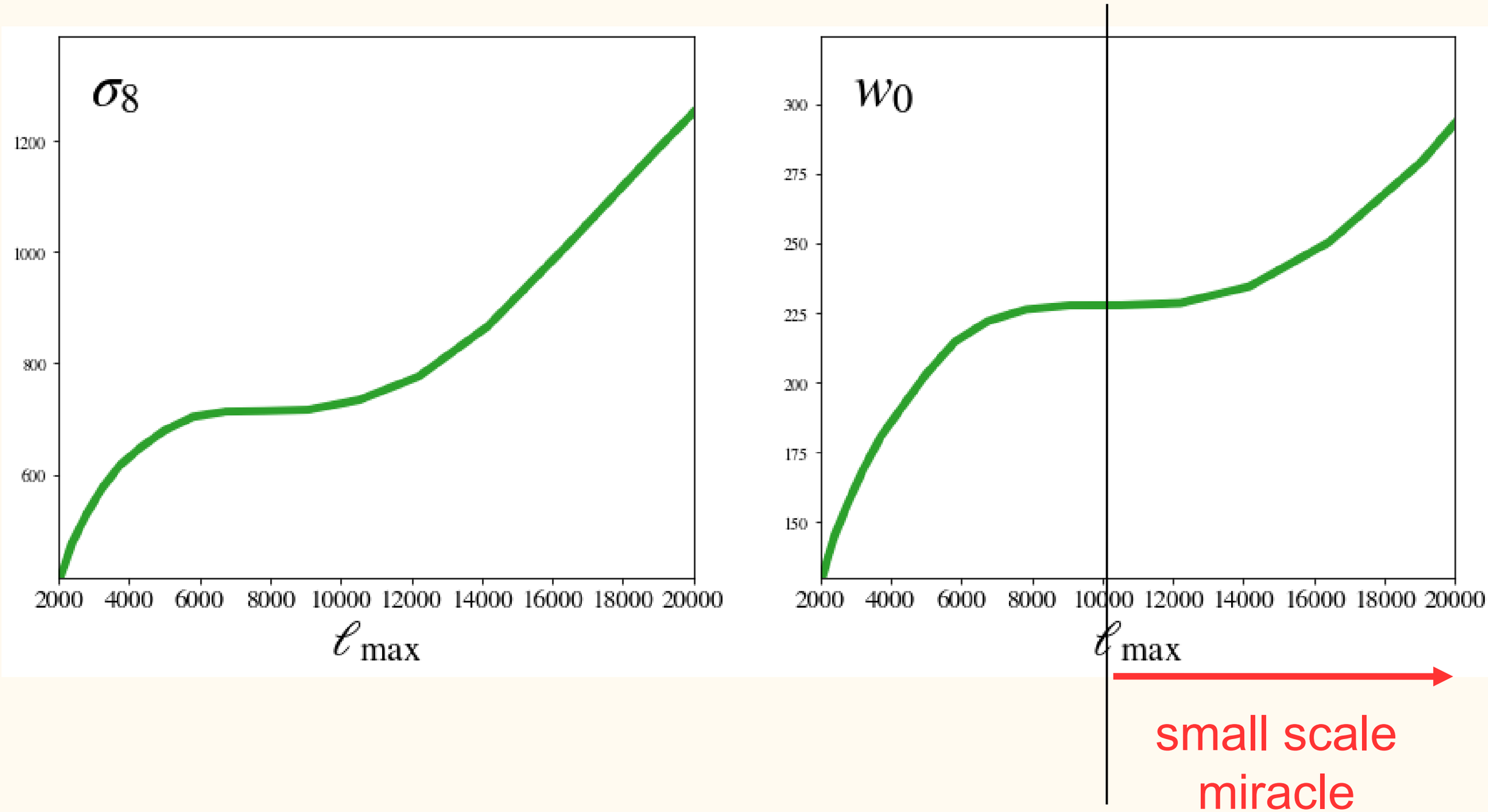
Cosmological error bars

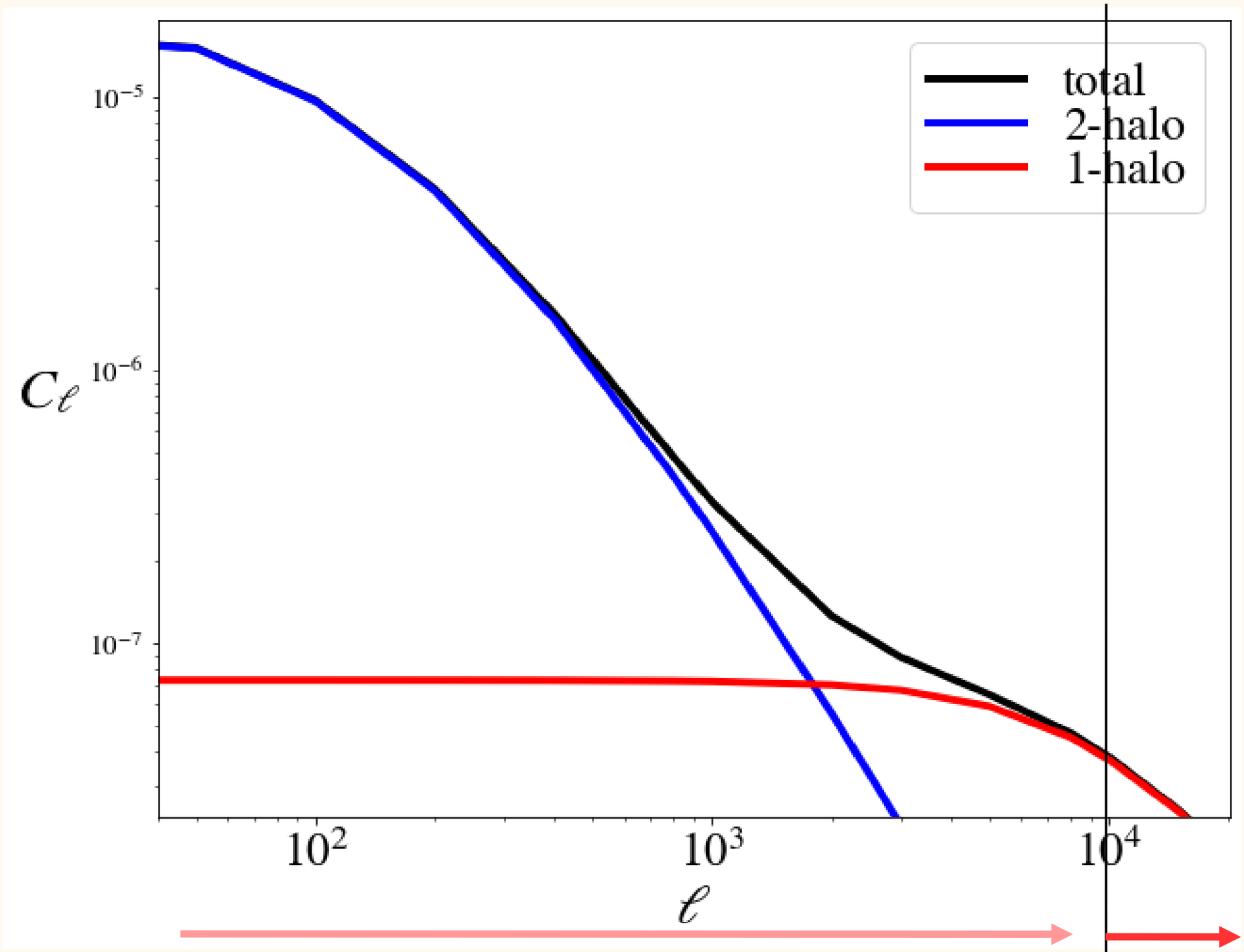


all z

Fisher: single redshift bin

z=1





z=1

1-halo dominated by rare objects

small scale miracle

Conclusion

Highly non-linear regime

- Precise measurement with next-gen surveys

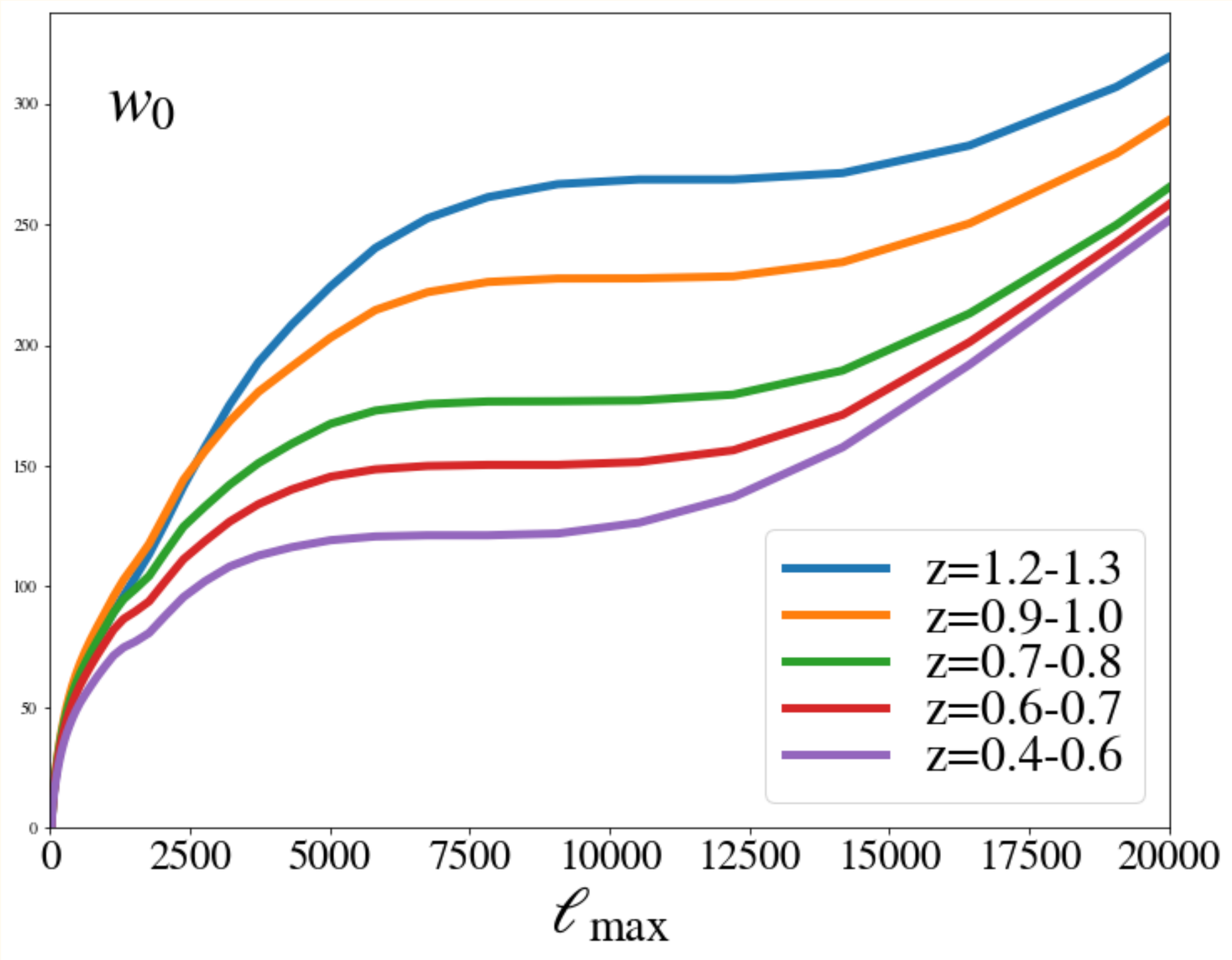
- Information rises again : small scale miracle

→ **a lot to gain with joint cosmo+astro analysis !**

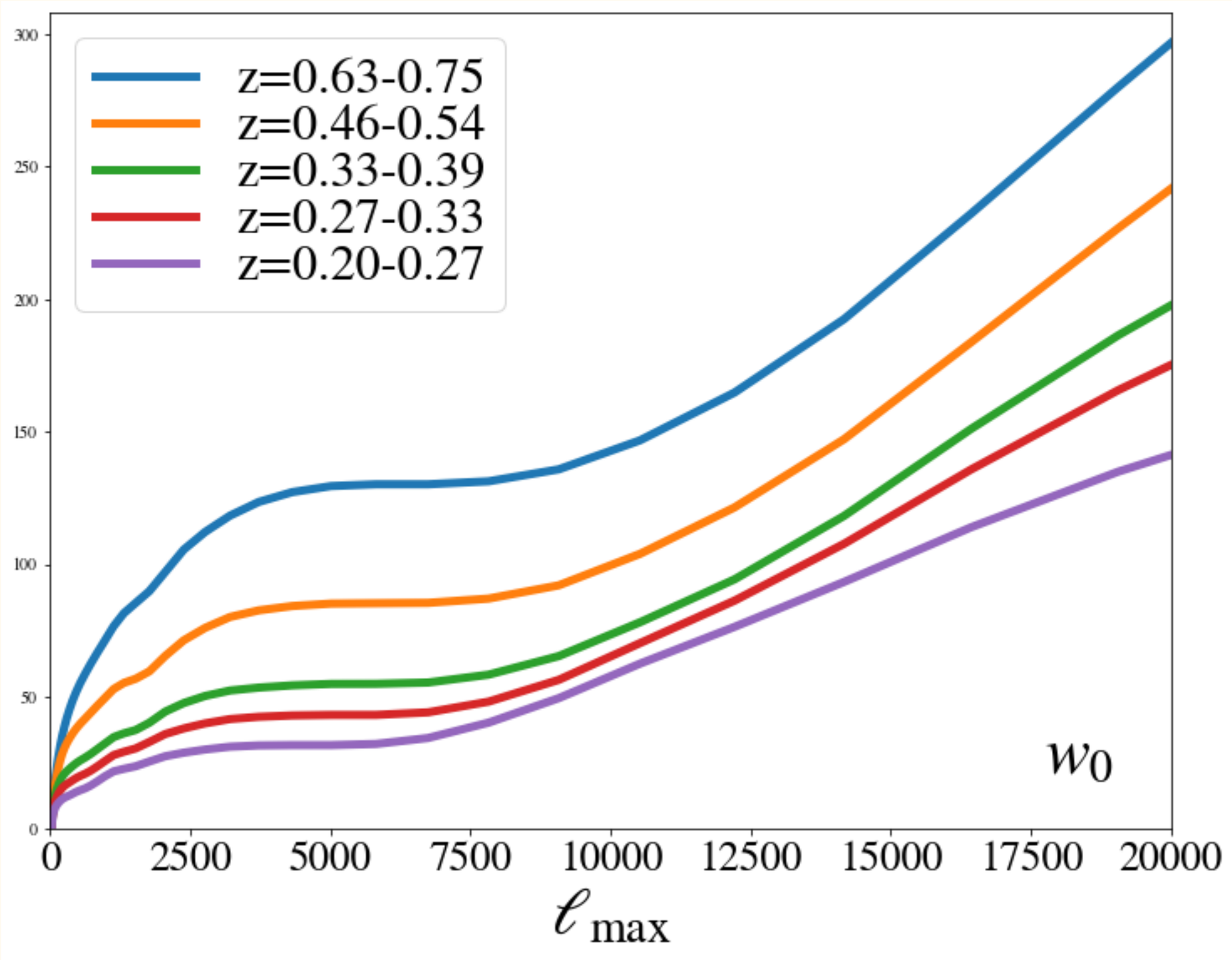
Thank you

Additional slides

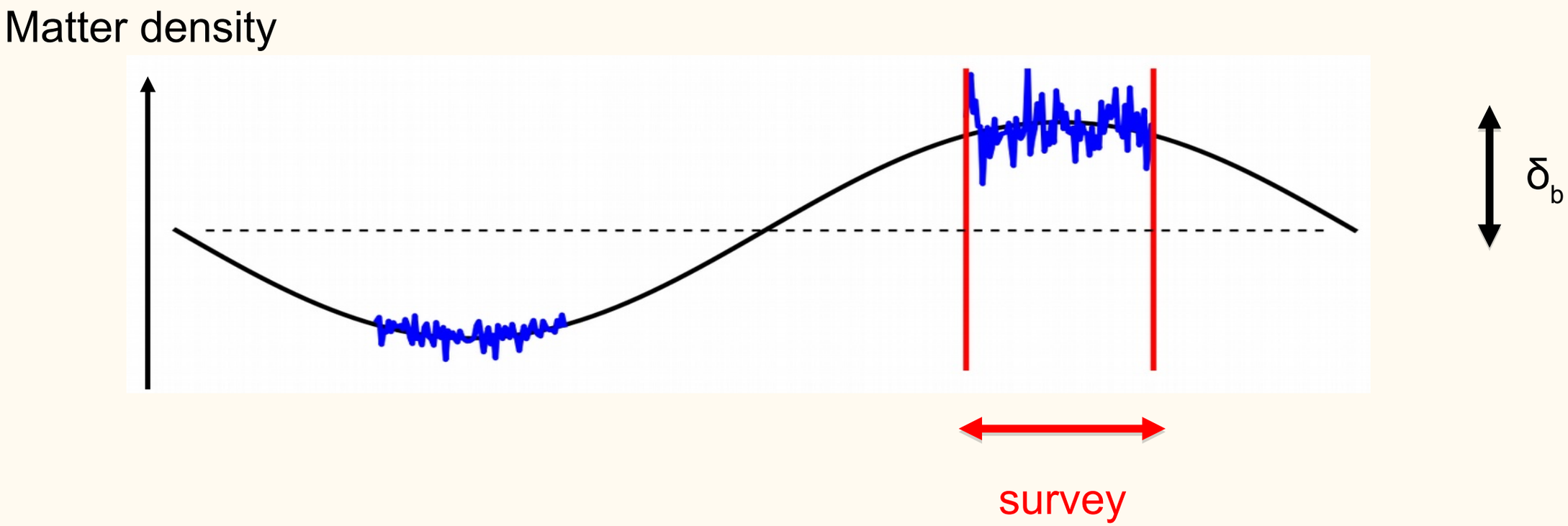
Fisher per redshift bin



Fisher: SKA2

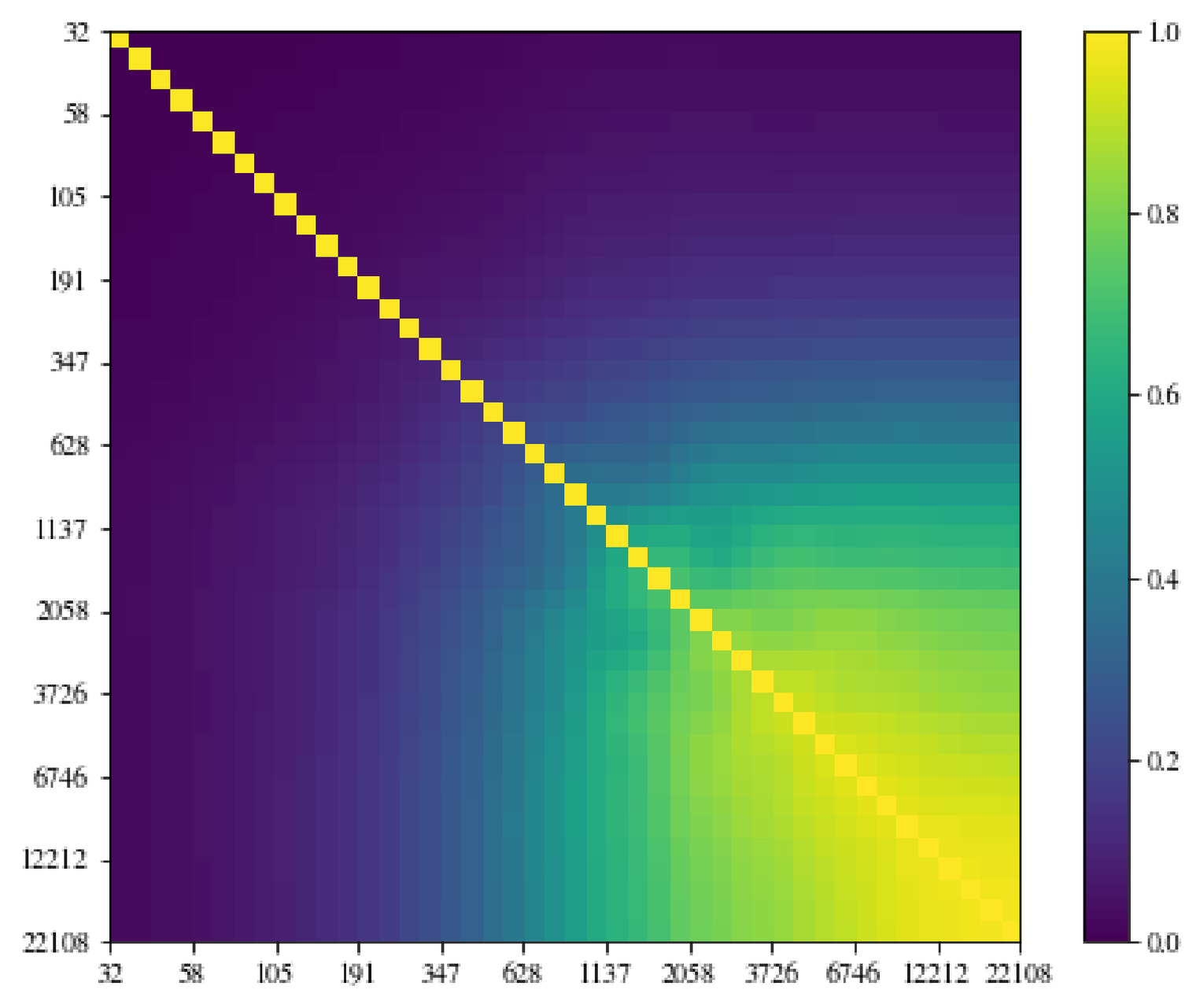

z=0.63-0.75
z=0.46-0.54
z=0.33-0.39
z=0.27-0.33
z=0.20-0.27
w_0
0
50
100
150
200
250
300
0
2500
5000
7500
10000
12500
15000
17500
20000
$\ell_{\max}$

Super-sample covariance (SSC)



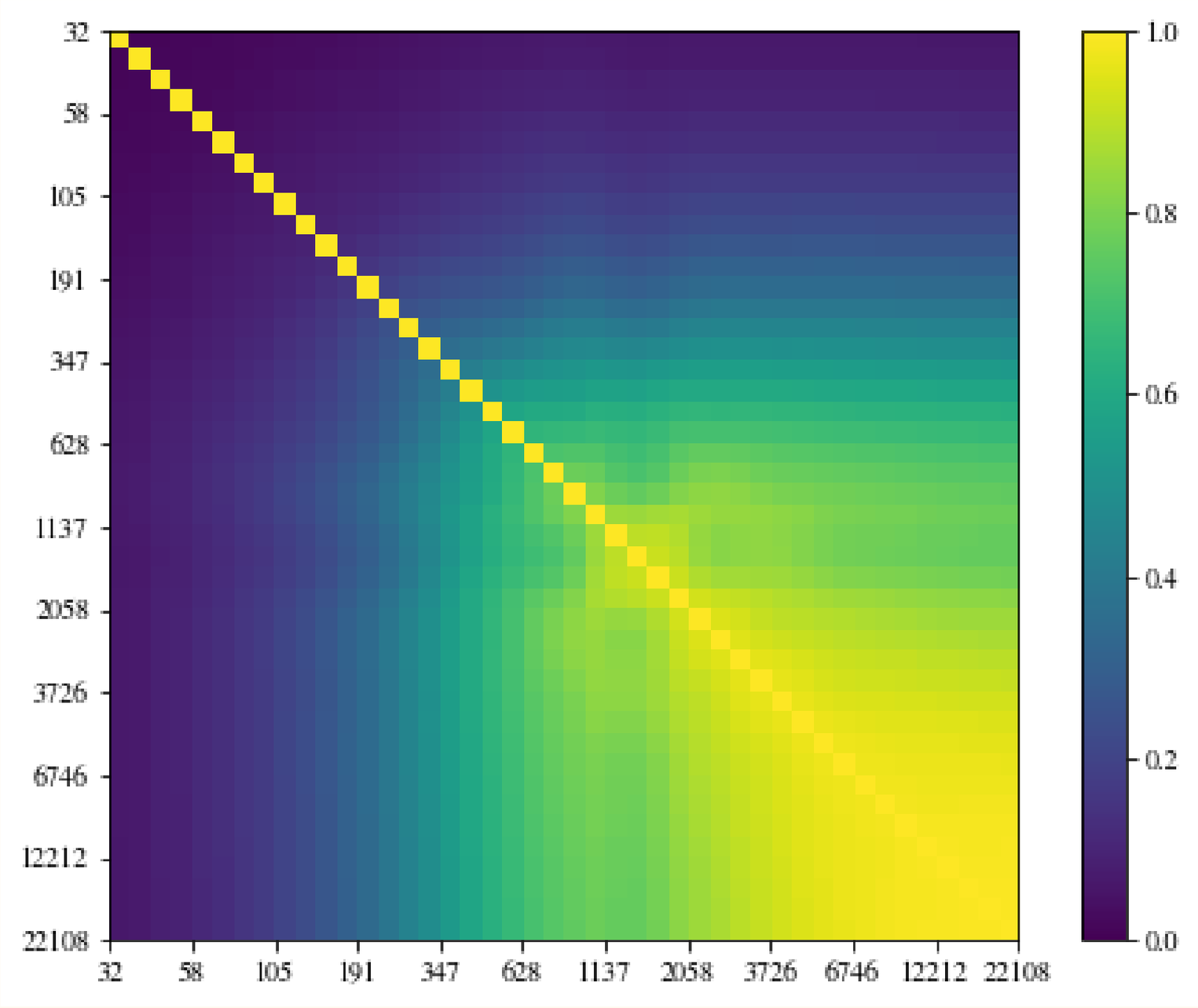
<u>Separate universe argument :</u> (Wagner et al. 2015)
can simulate region δ_b in cosmo Ω by change of cosmo $\Omega'(\Omega,\delta_b)$

Total covariance : Euclid



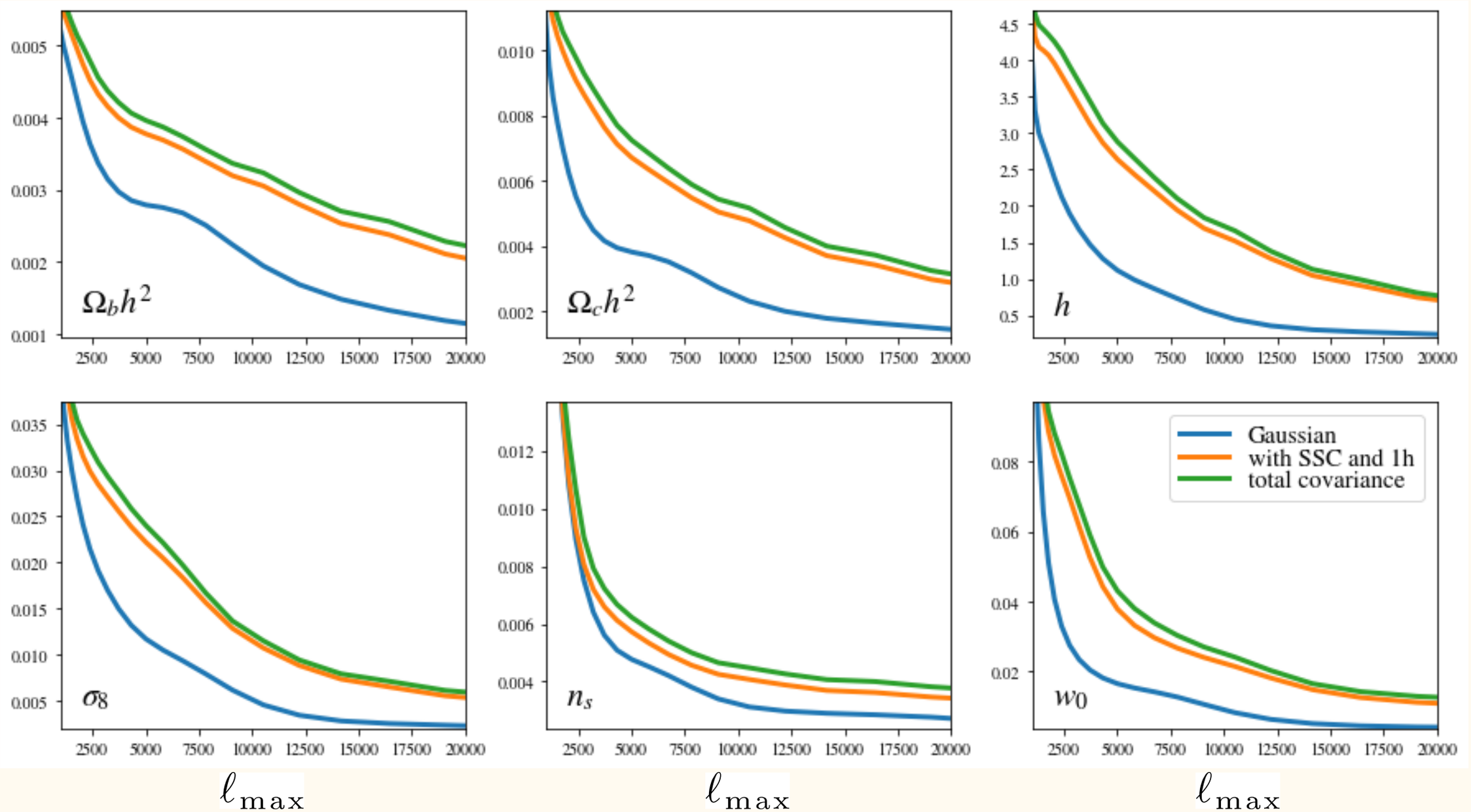
z=0.9-1

Total covariance : SKA 2



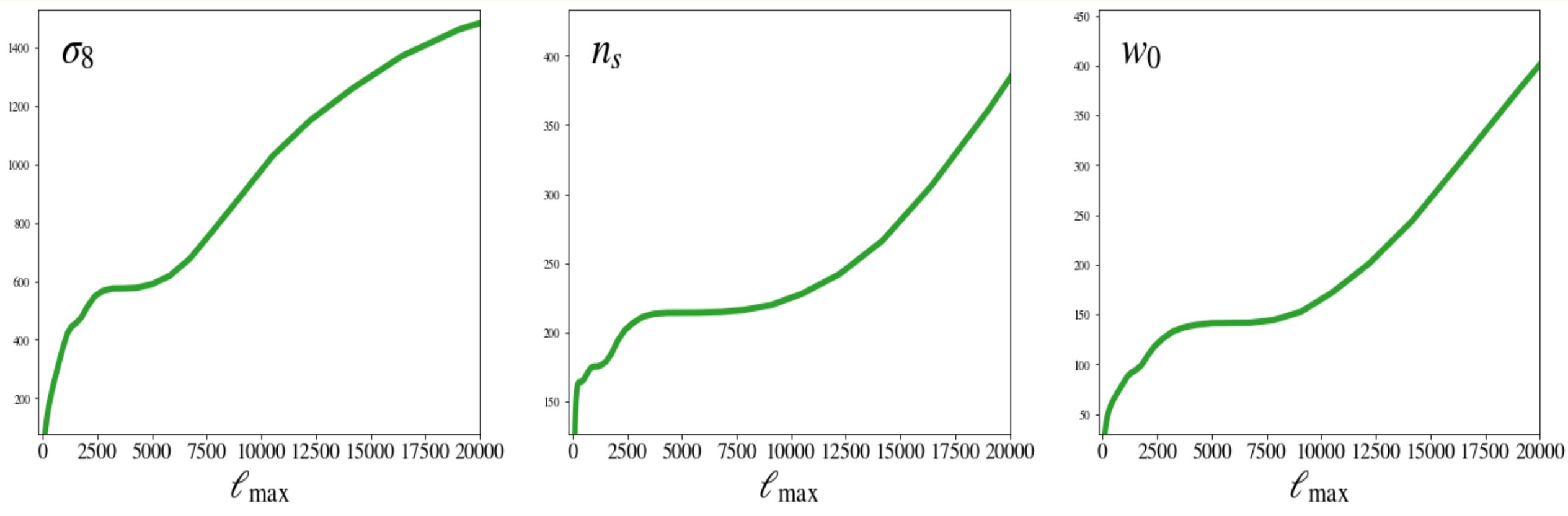
z=0.46-0.54

Cosmological error bars



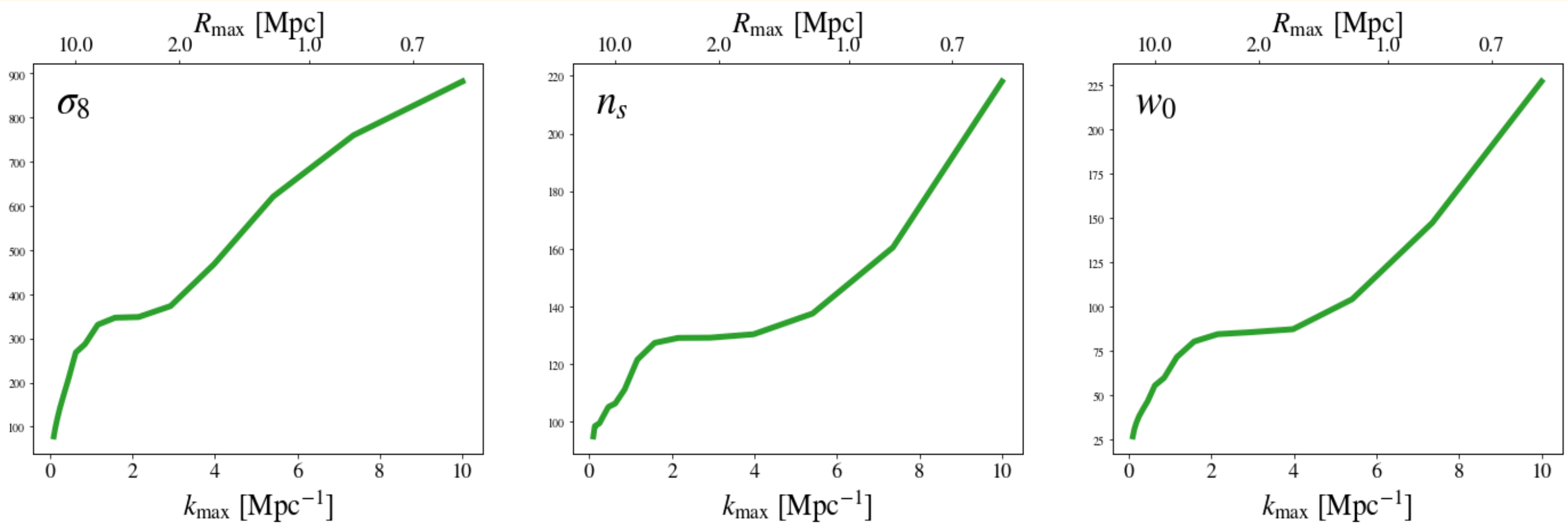
all z

Information vs lmax : SKA2



z=0.46-0.54

Information vs kmax : SKA2

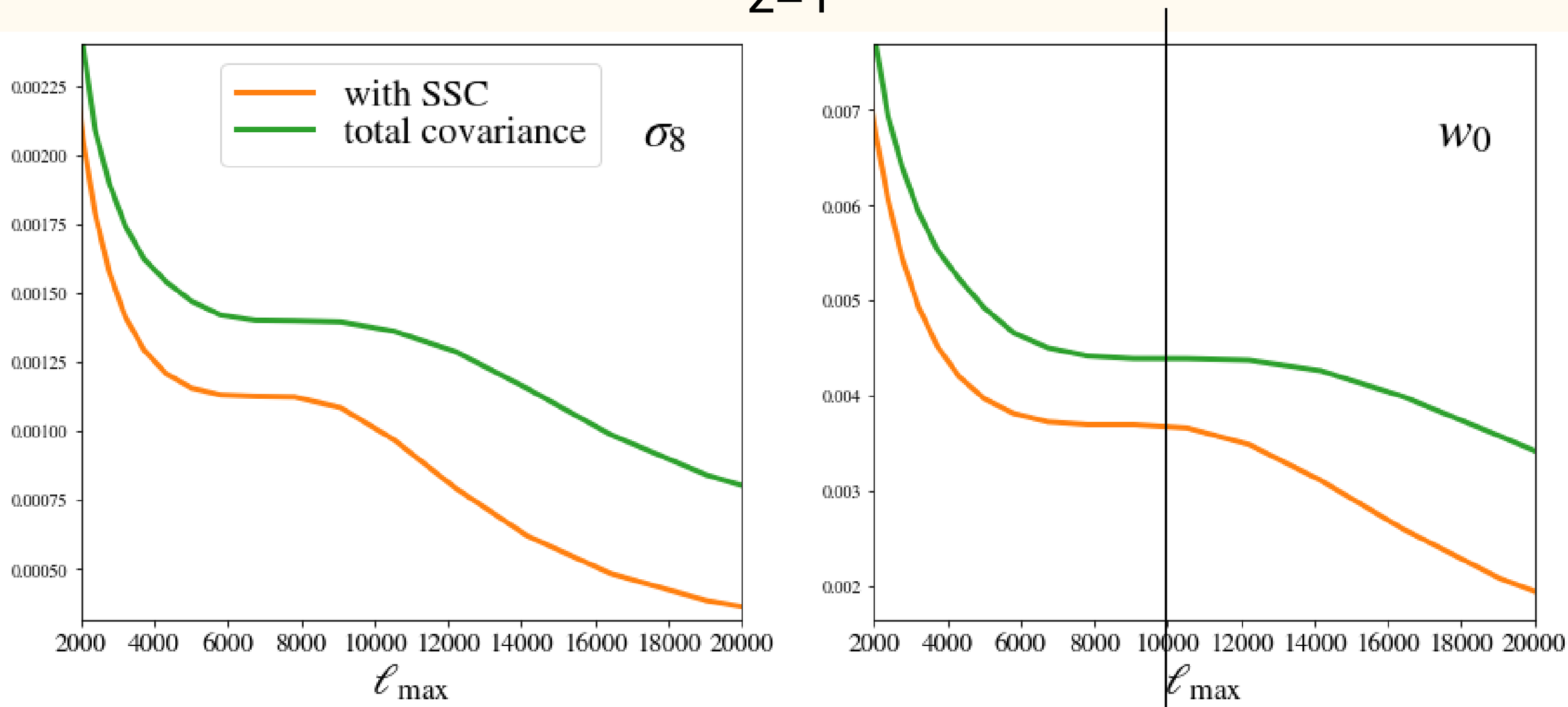


z=0.46-0.54

Errors: single redshift bin

(Euclid, without marginalisation)

z=1

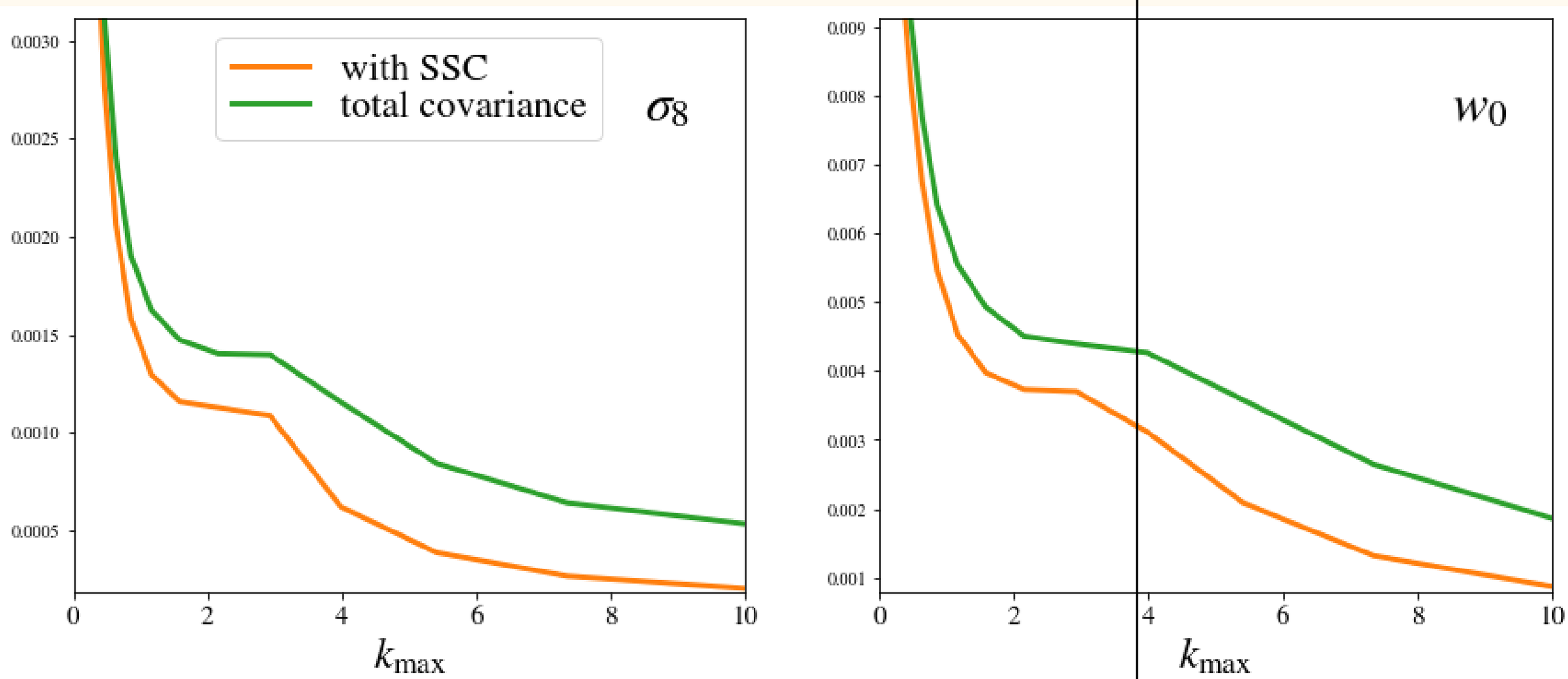


small scale miracle

Errors: single redshift bin

(Euclid, without marginalisation)

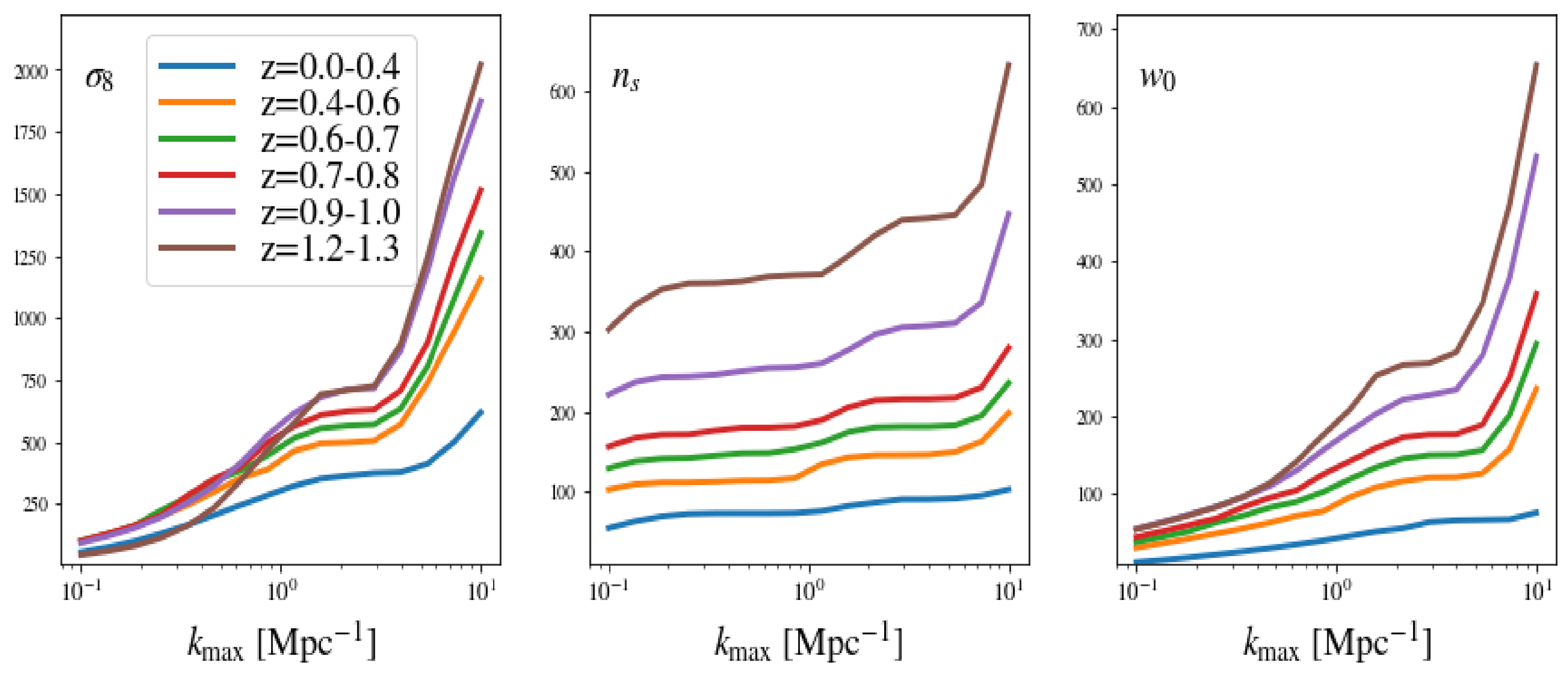
z=1



small scale miracle

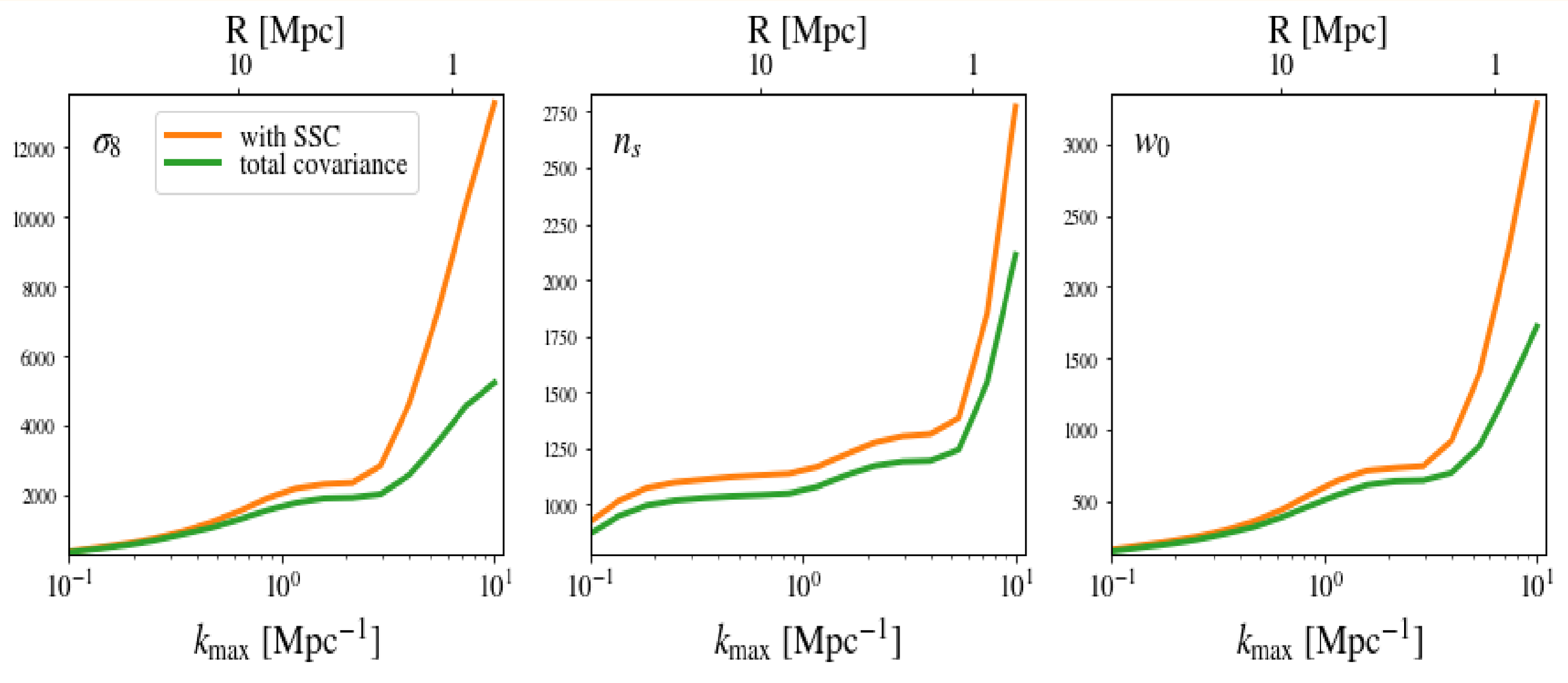
Information per redshift bin

(Euclid, without marginalisation)



Information all redshifts

(Euclid, without marginalisation)



Increase of error bars by non-Gaussianity : Euclid

	Before marginalisation		After marginalisation	
	SSC +1h	total	SSC +1h	total
σ_8	+340%	+360%	+31%	+41%
n_S	+70%	+84%	+3%	+15%
w	+290%	+310%	+100%	+120%