Tomographic Galaxy Clustering with the Subaru Hyper Suprime-Cam First Year Public Data Release

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HSC Photometric Clustering within LSST DESC

Apply/test LSST pipeline on LSST-like data set

Test viability of tomographic Fourier space analysis for photometric clustering

Try to maximize sample size, i.e. go beyond e.g. LRGs, redMaGiC

Include small-scale information

LSST DESC
Dark Energy Science Collaboration

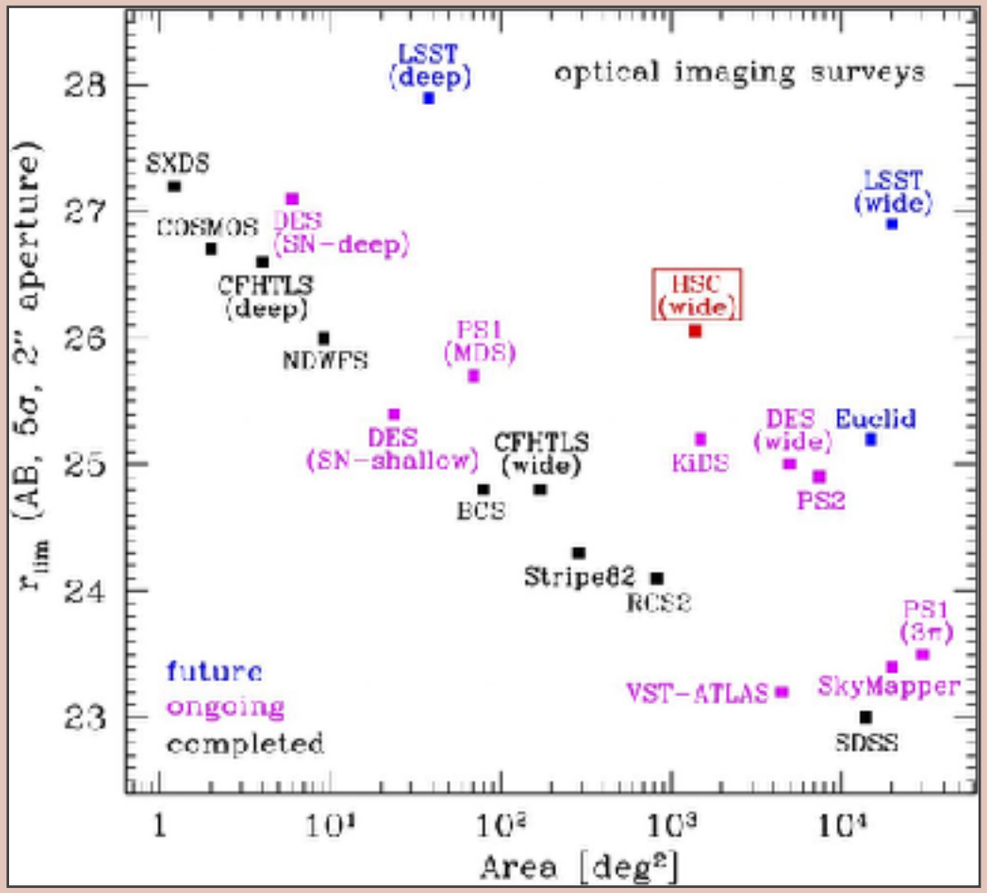
Hyper Suprime Cam (HSC) Survey

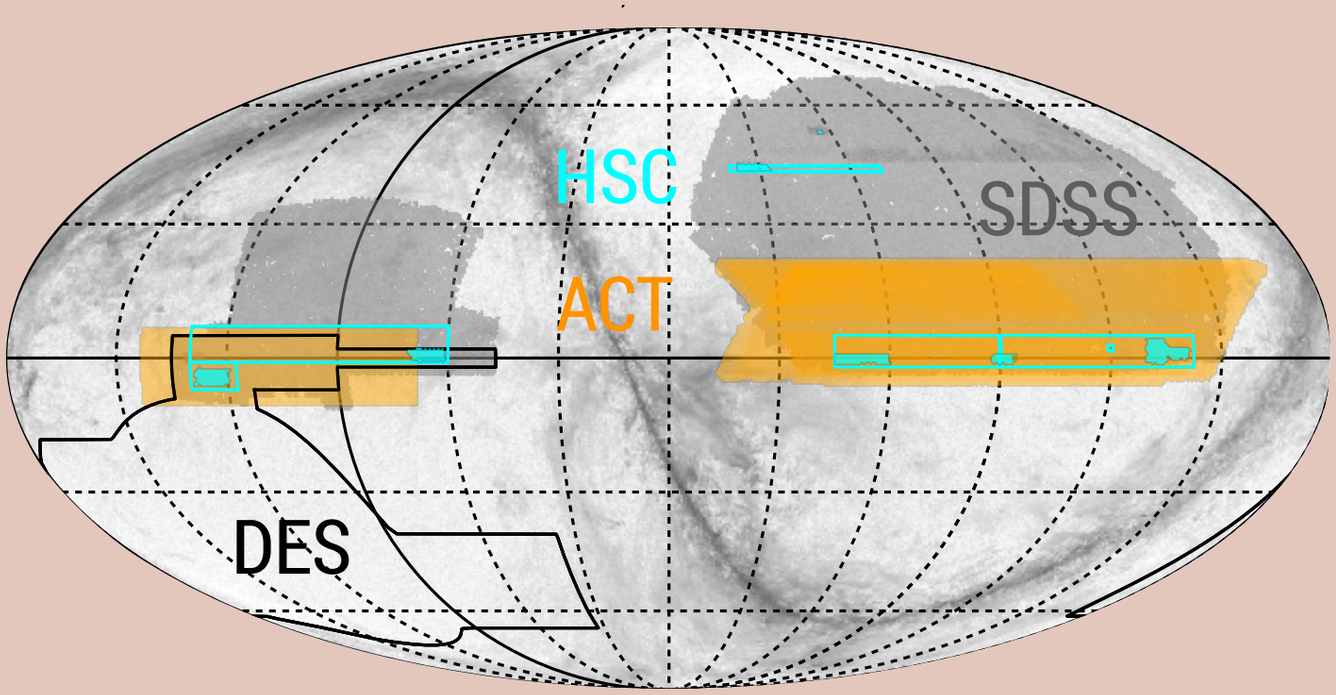
HSC: 5-year survey, covering 1000 sq. deg.

Deep ($r_{\rm lim} \sim 26$), good seeing

Precursor to LSST

Most analyses focused on 150 sq. deg. (DR1)





Survey table: HSC SSP
Footprint: E. Medezinski

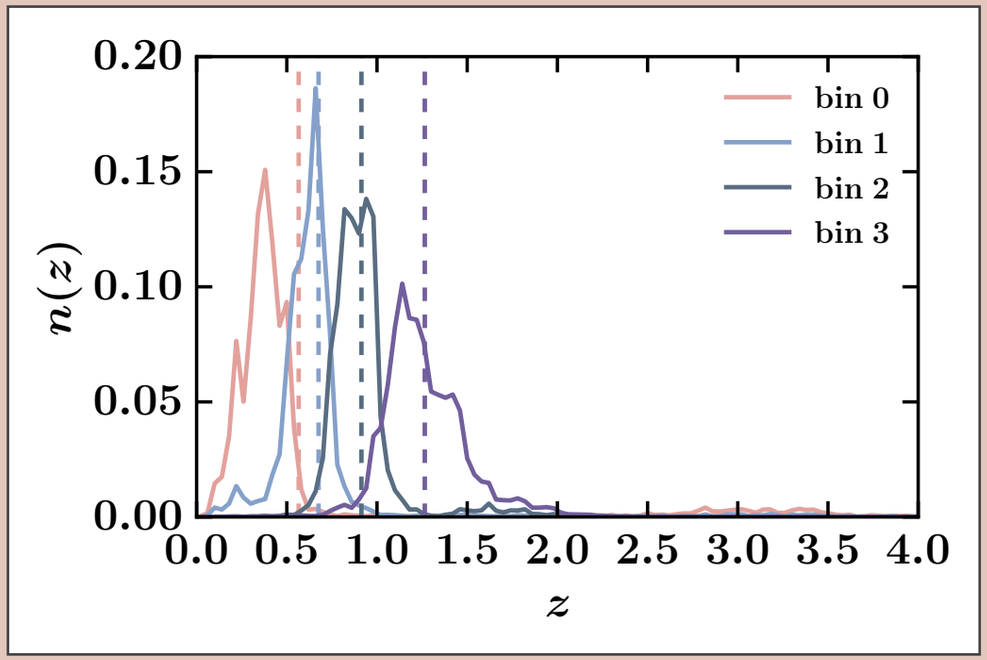
Sample Selection

HSC DR1 data

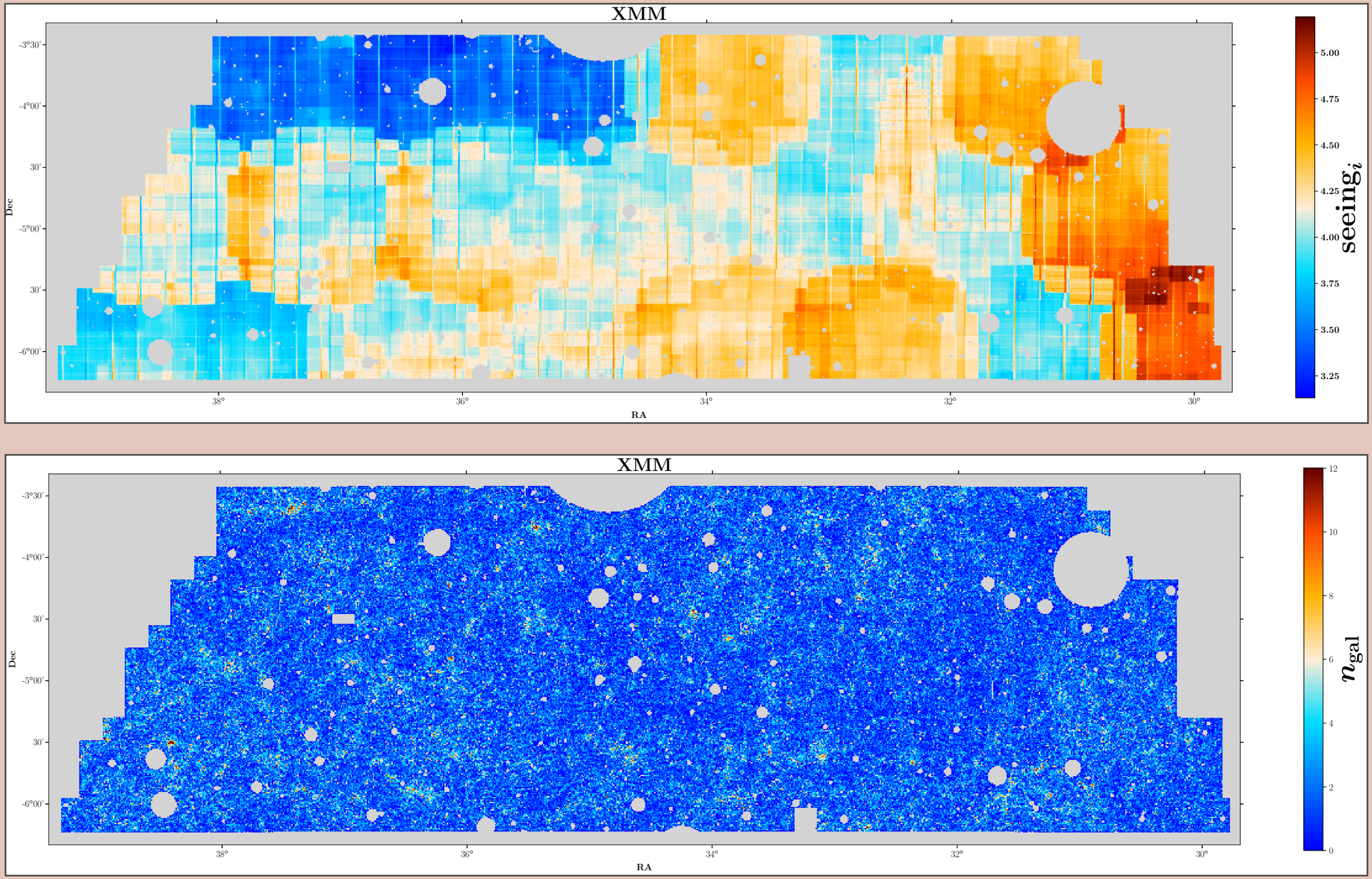
Galaxies with $mag_i < 24.5$

4 redshift bins: 0.15-0.50, 0.50-0.75, 0.75-1.00, 1.00-1.50

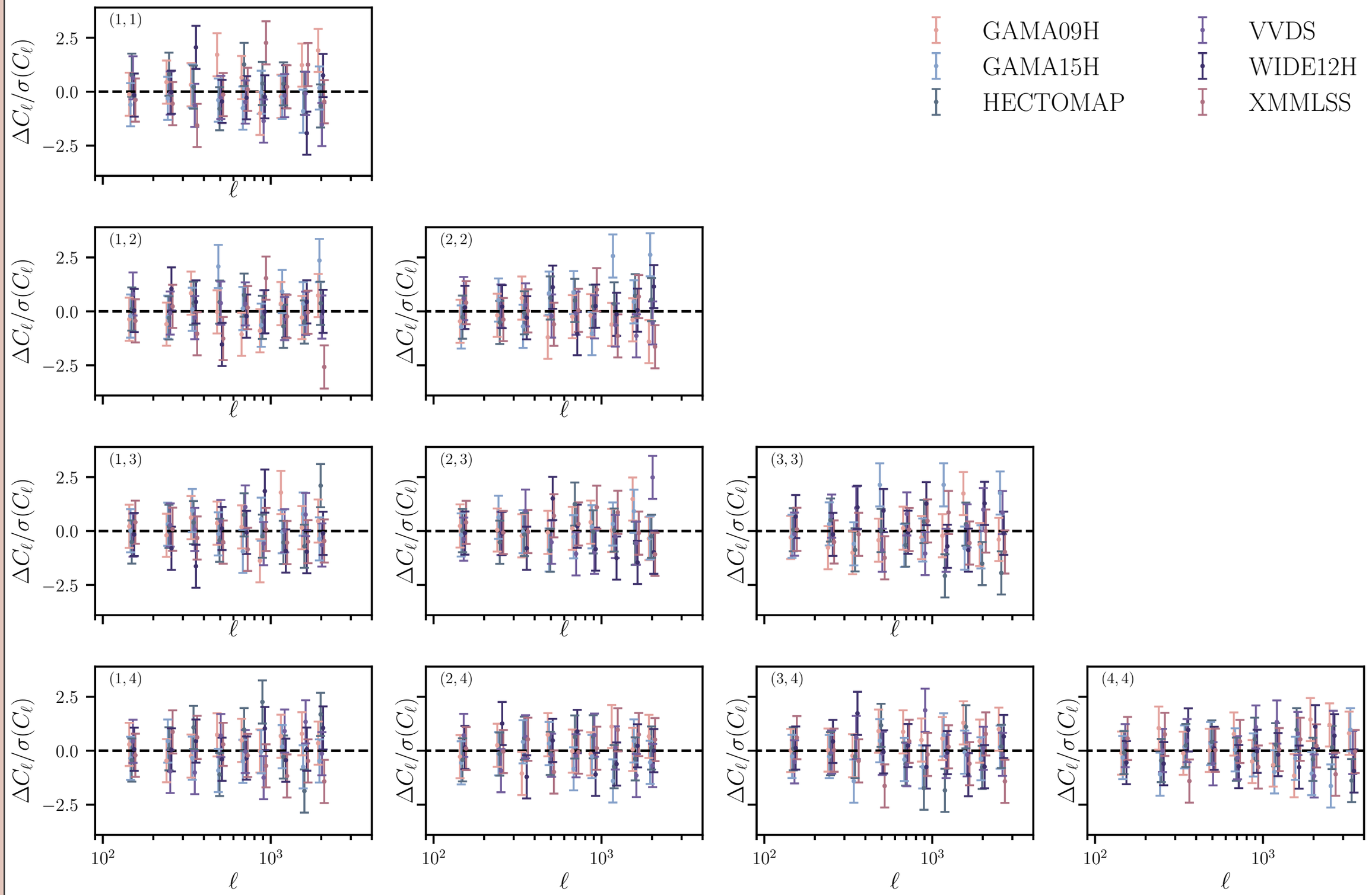
Photo-z: COSMOS reweighting



Systematics & Signal Maps



Power Spectrum Consistency Tests



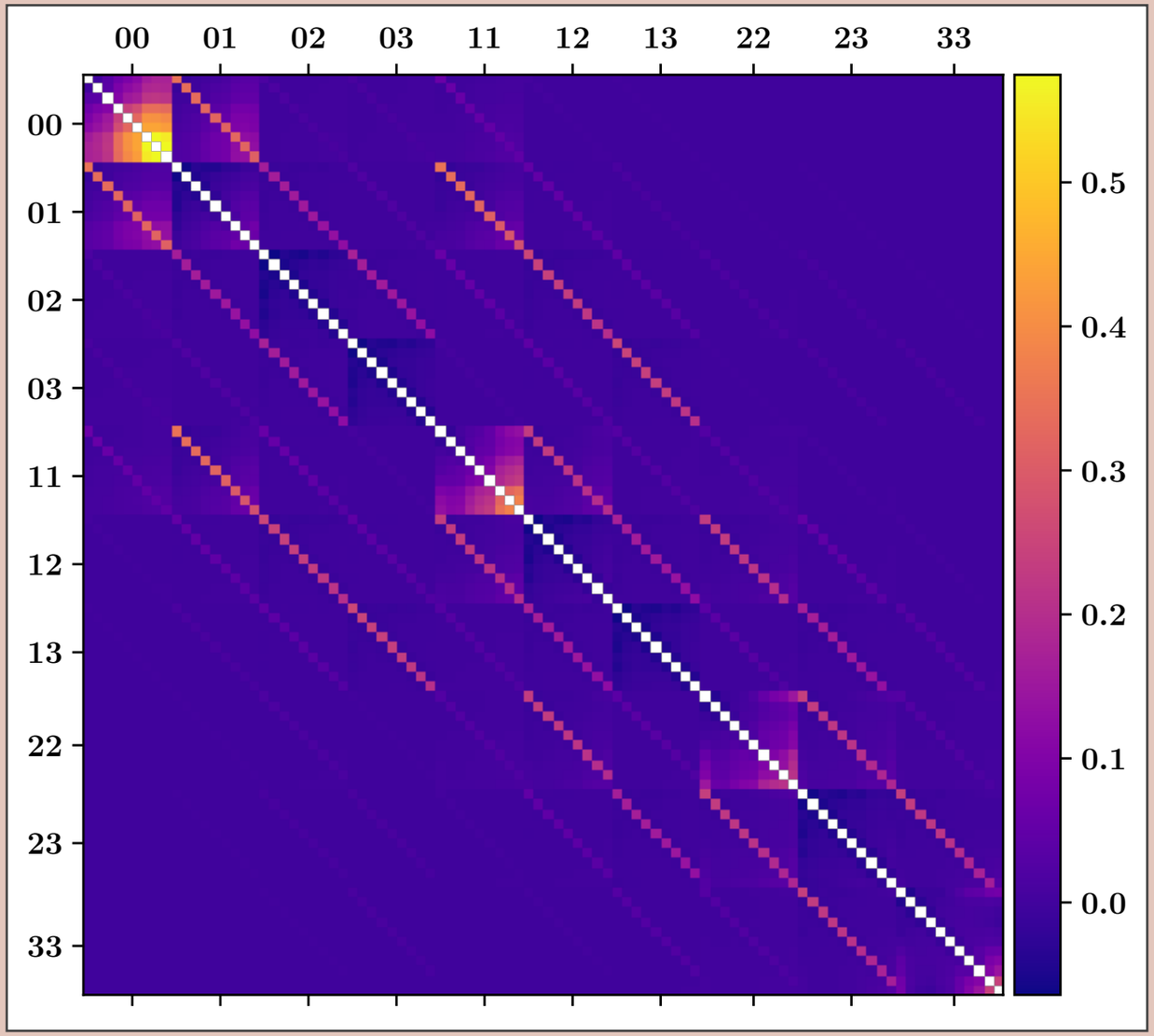
Covariance Matrix

$$\mathrm{Cov}(C_\ell, C_{\ell'}) = \mathrm{Cov}_{\mathrm{G}}(C_\ell, C_{\ell'}) + \mathrm{Cov}_{\mathrm{NG}}(C_\ell, C_{\ell'}) + \mathrm{Cov}_{\mathrm{SSC}}(C_\ell, C_{\ell'})$$

$\mathrm{Cov}_{\mathrm{G}}(C_\ell, C_{\ell'})$: computed analytically, accounting for survey geometry (NaMaster)

$\mathrm{Cov}_{\mathrm{NG}}(C_\ell, C_{\ell'})$: computed analytically using Halo Model/HOD (e.g. *Krause et al., 2017*)

$\mathrm{Cov}_{\mathrm{SSC}}(C_\ell, C_{\ell'})$

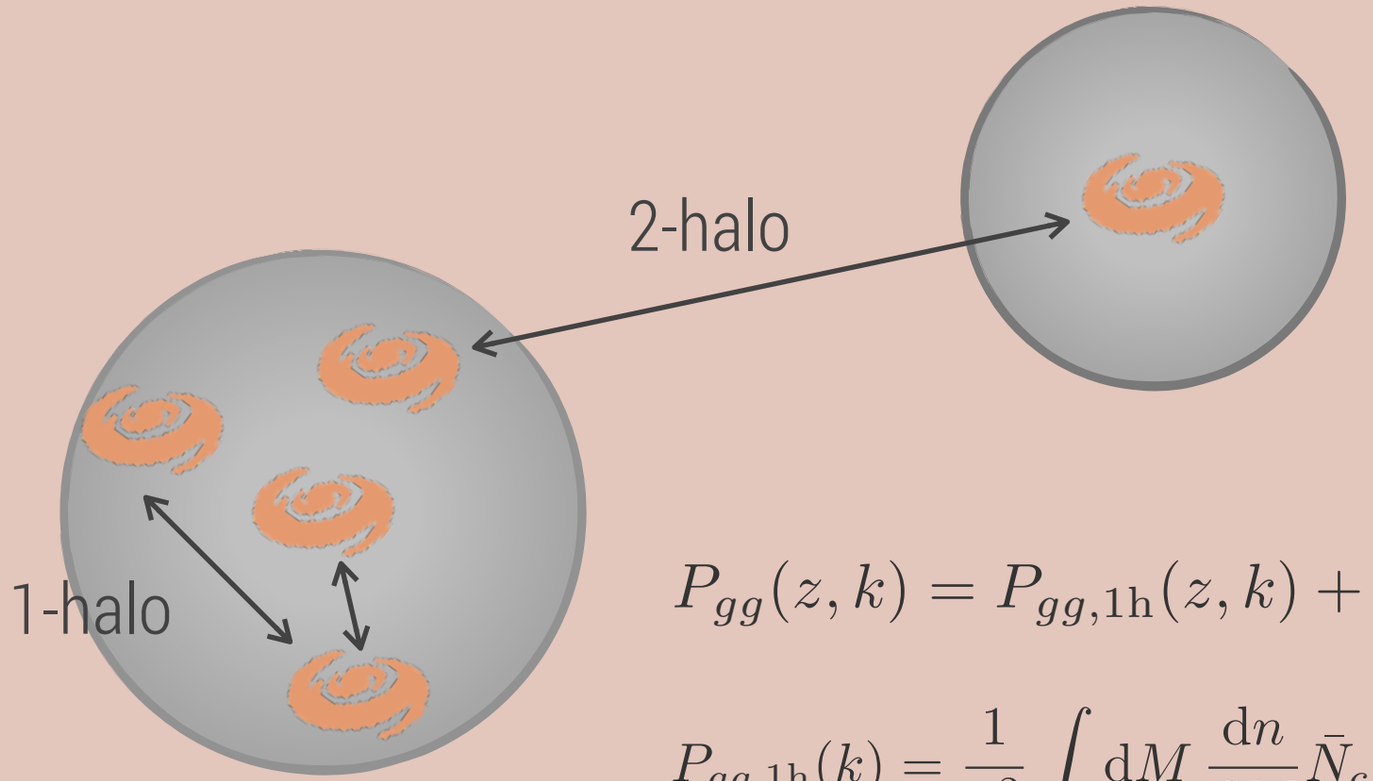


Theoretical Modeling

Small-scale clustering ($k_{max} \sim 1$ Mpc^{-1})

Halo model (e.g. *Seljak 2000*, *Peacock et al., 2000*, *Ma et al., 2000*)

Halo occupation distribution (e.g. *Berlind & Weinberg, 2002, Zheng et al., 2005*)



$$P_{gg}(z,k) = P_{gg,1\mathrm{h}}(z,k) + P_{gg,2\mathrm{h}}(z,k)$$

$$P_{gg,1\mathrm{h}}(k) = \frac{1}{\bar{n}_g^2}\int \mathrm{d}M\,\frac{\mathrm{d}n}{\mathrm{d}M}\bar{N}_c\,\left[\bar{N}_s^2 u_s^2(k) + 2\bar{N}_s u_s^2(k)\right]$$

$$P_{gg,2\mathrm{h}}(k) = \left(\frac{1}{\bar{n}_g}\int \mathrm{d}M\,\frac{\mathrm{d}n}{\mathrm{d}M}\,b_h(M)\,\bar{N}_c\,\left[1+\bar{N}_s u_s(k)\right]\right)^2 P_{\mathrm{lin}}(k)$$

HOD Modeling Details

Redshift-dependent 6-parameter HOD model

$$\bar{N}_g(M) = \bar{N}_c(M)(f_c + \bar{N}_s(M))$$

centrals: $$\bar{N}_c(M) = \frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{\log M - \log M_{\mathrm{min}}(z)}{\sigma_{\ln M}}\right)\right]$$

satellites: $$\bar{N}_s(M) = \Theta(M - M_0(z))\left(\frac{M - M_0(z)}{M_1(z)}\right)^{\alpha}$$

where

$$\log M_i(z) = \mu_i + \mu_{i,p}\left(\frac{1}{1+z} - \frac{1}{1+z_p}\right),\ i \in [\mathrm{min}, 0, 1]$$

Fiducial model

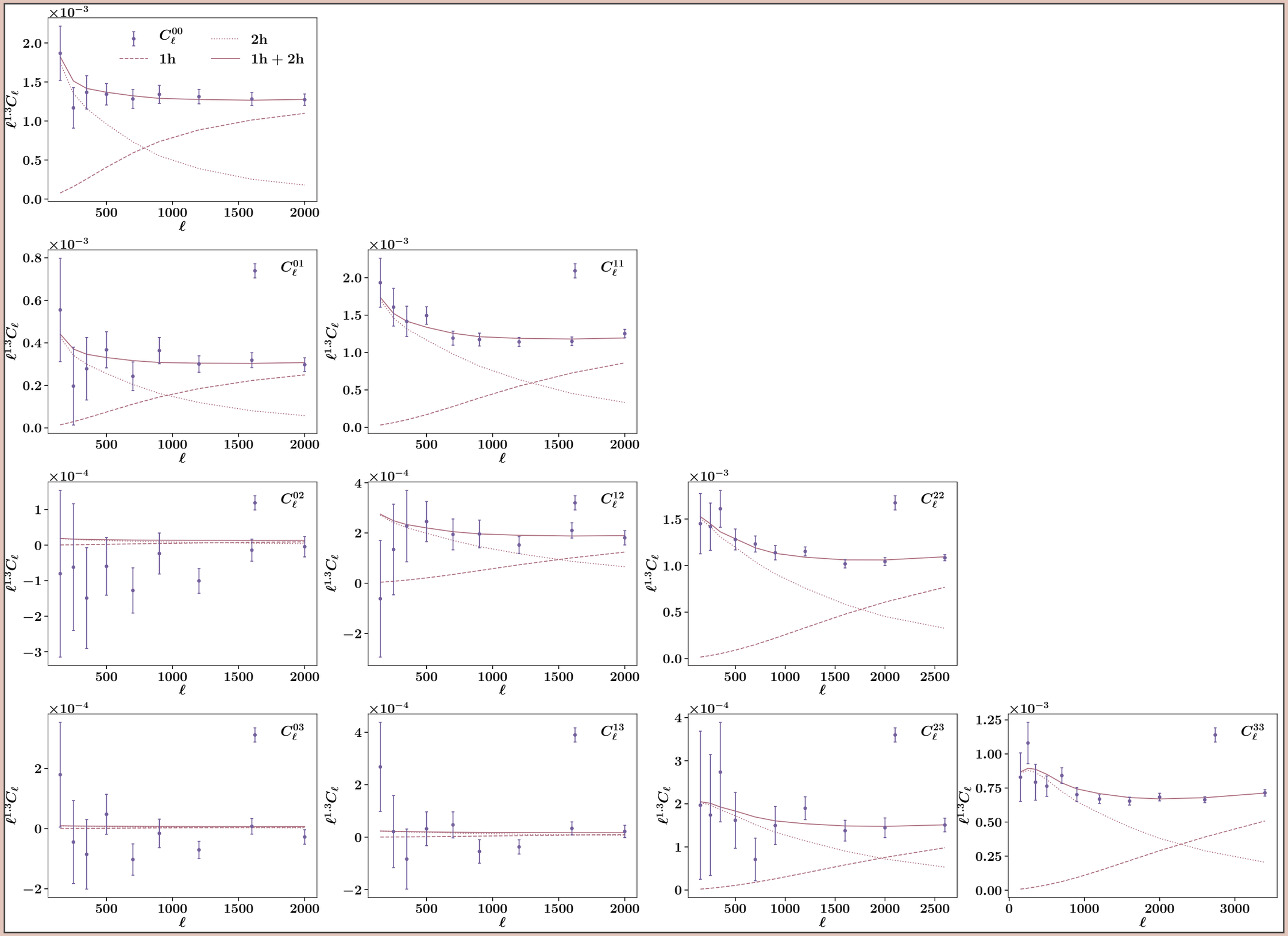
Redshift-dependent 3(+3)-parameter HOD: $M_{\mathrm{min}}(z)$ $M_0(z)$ $M_1(z)$

Remaining HOD parameters fixed to $f_c = 1$ $\alpha = 1$ $\sigma_{\ln M} = 0.4$

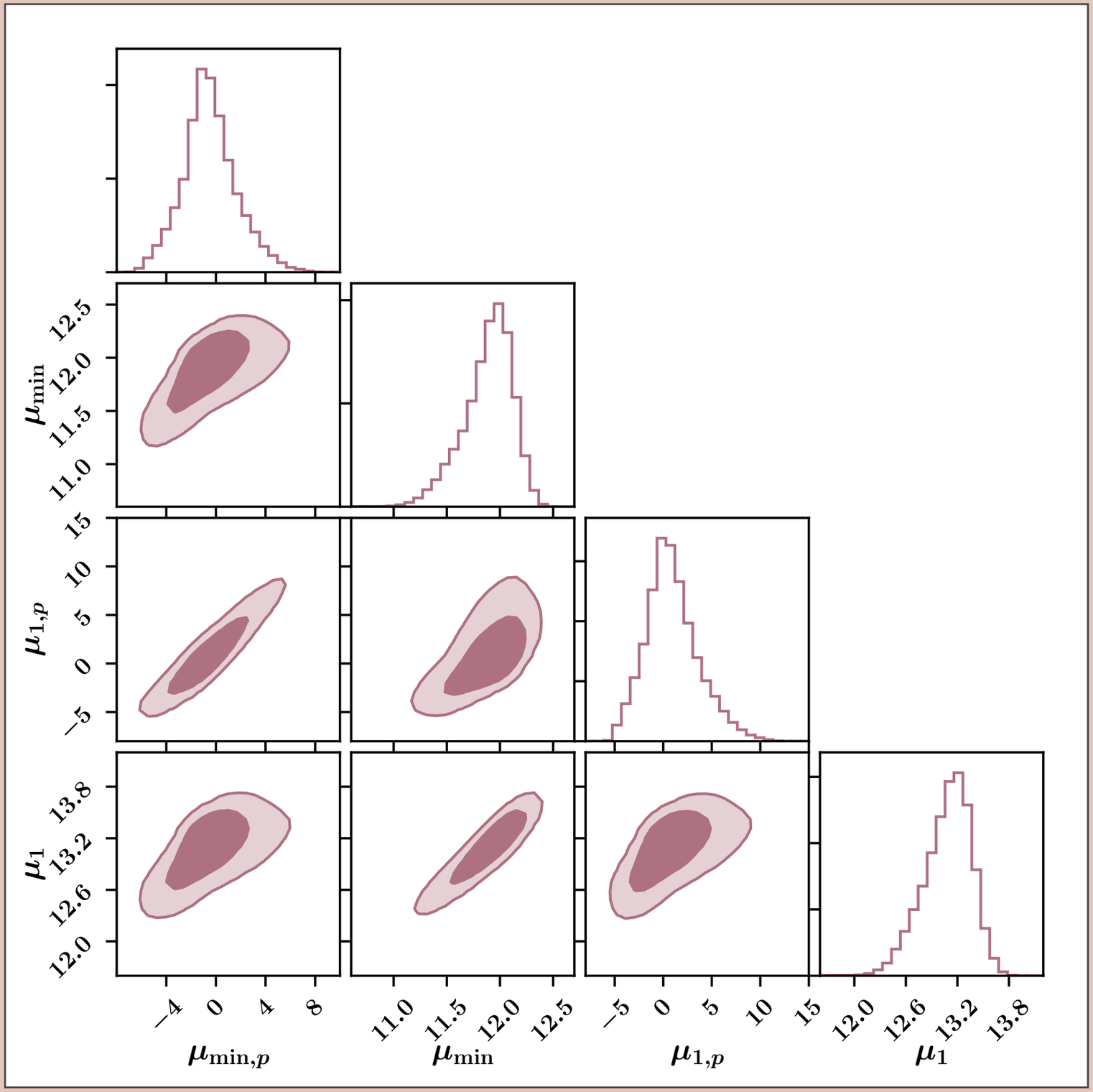
Cosmological parameters fixed to Planck 2018

Photo-z uncertainties: $p(z)$ shift Δz_i & width $z_{w,i}$

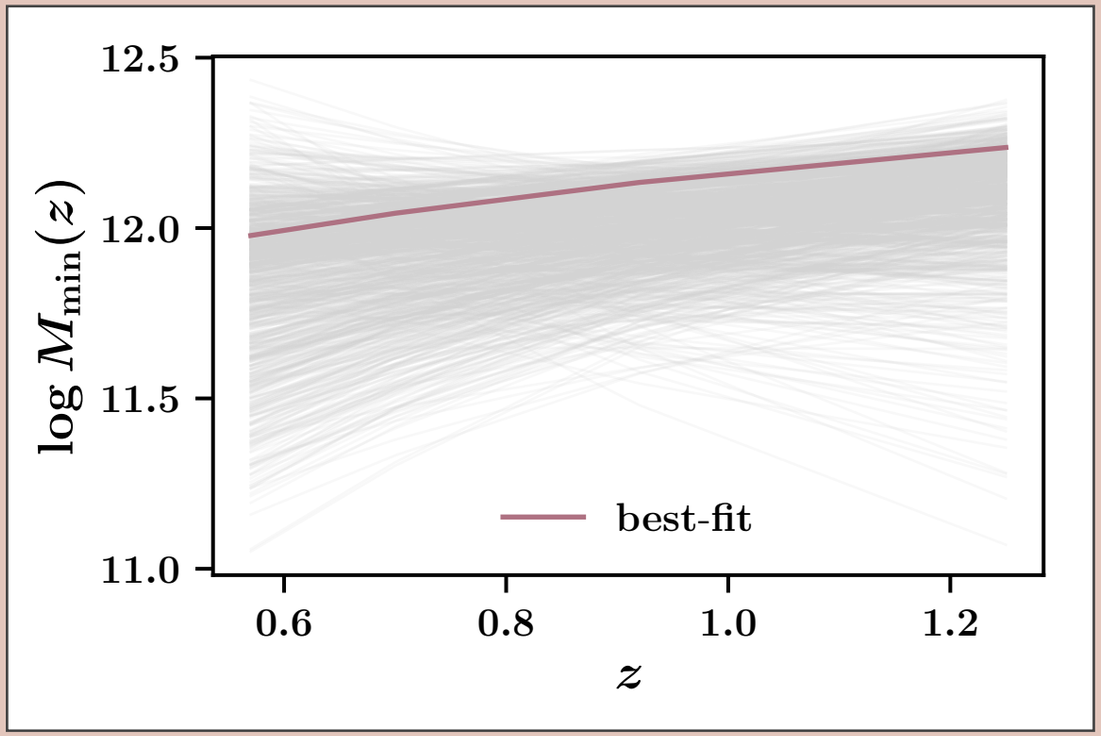
Power Spectra

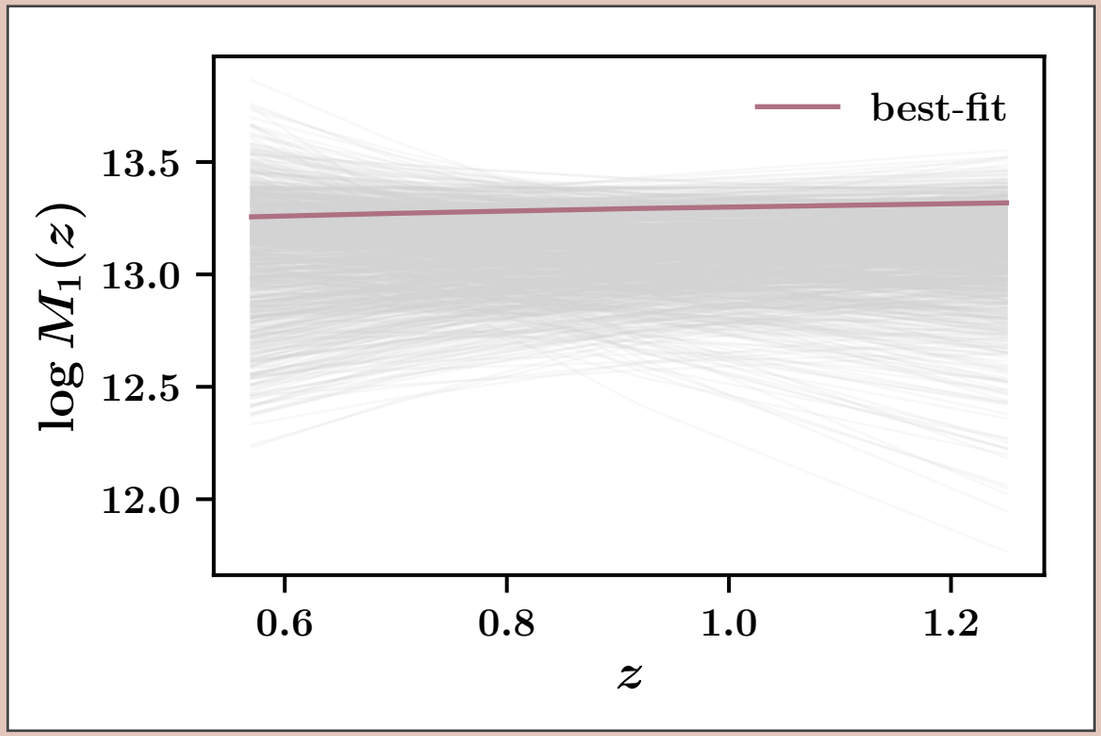


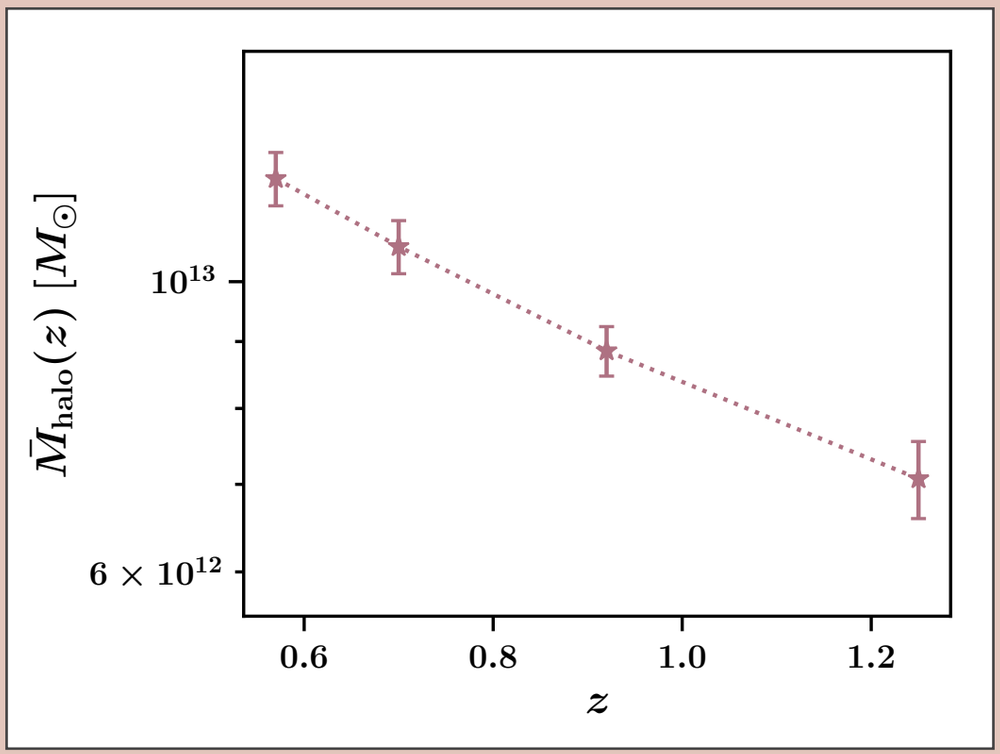
HOD Constraints



HOD Redshift Evolution







Properties of Galaxy Sample

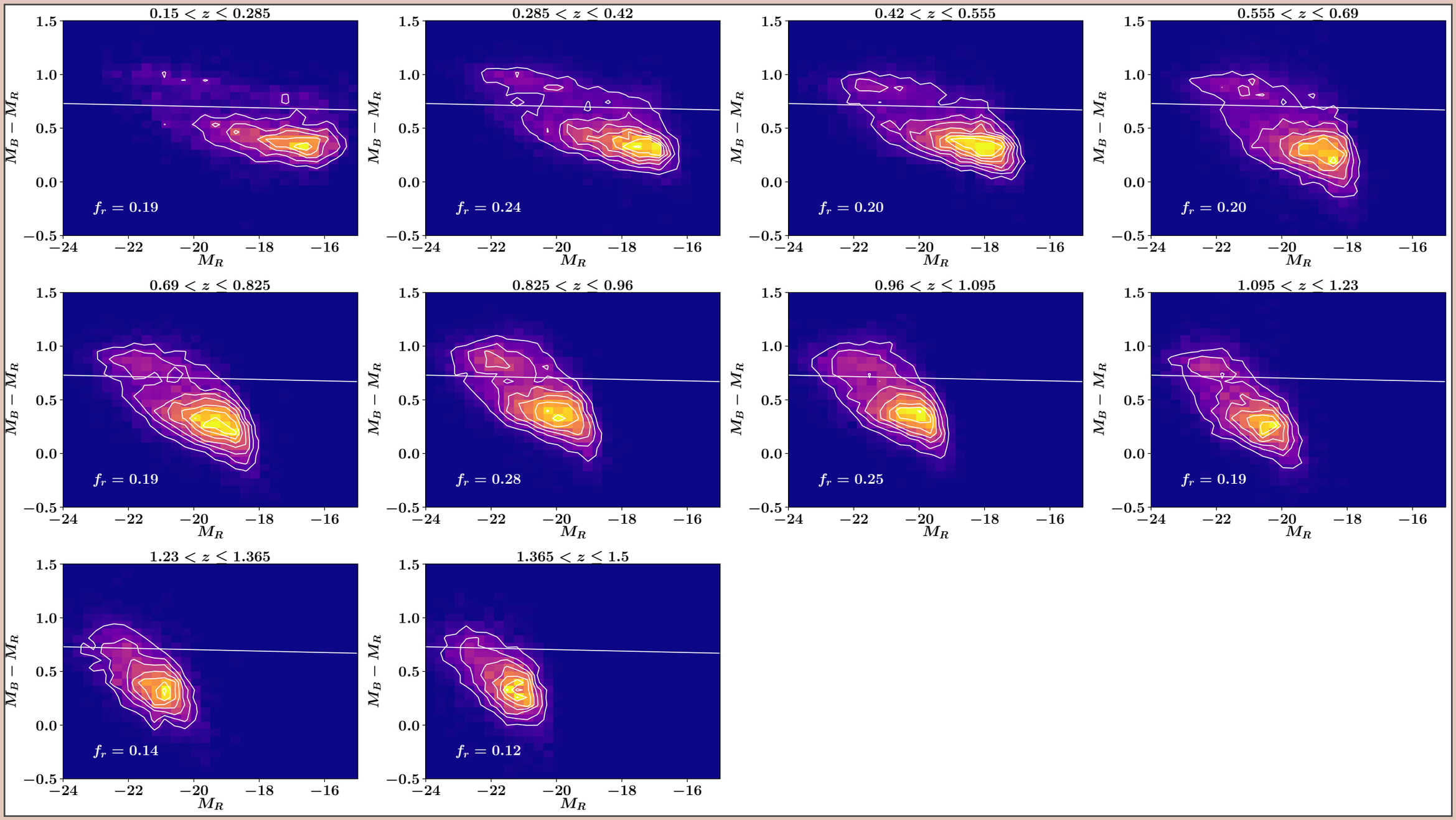
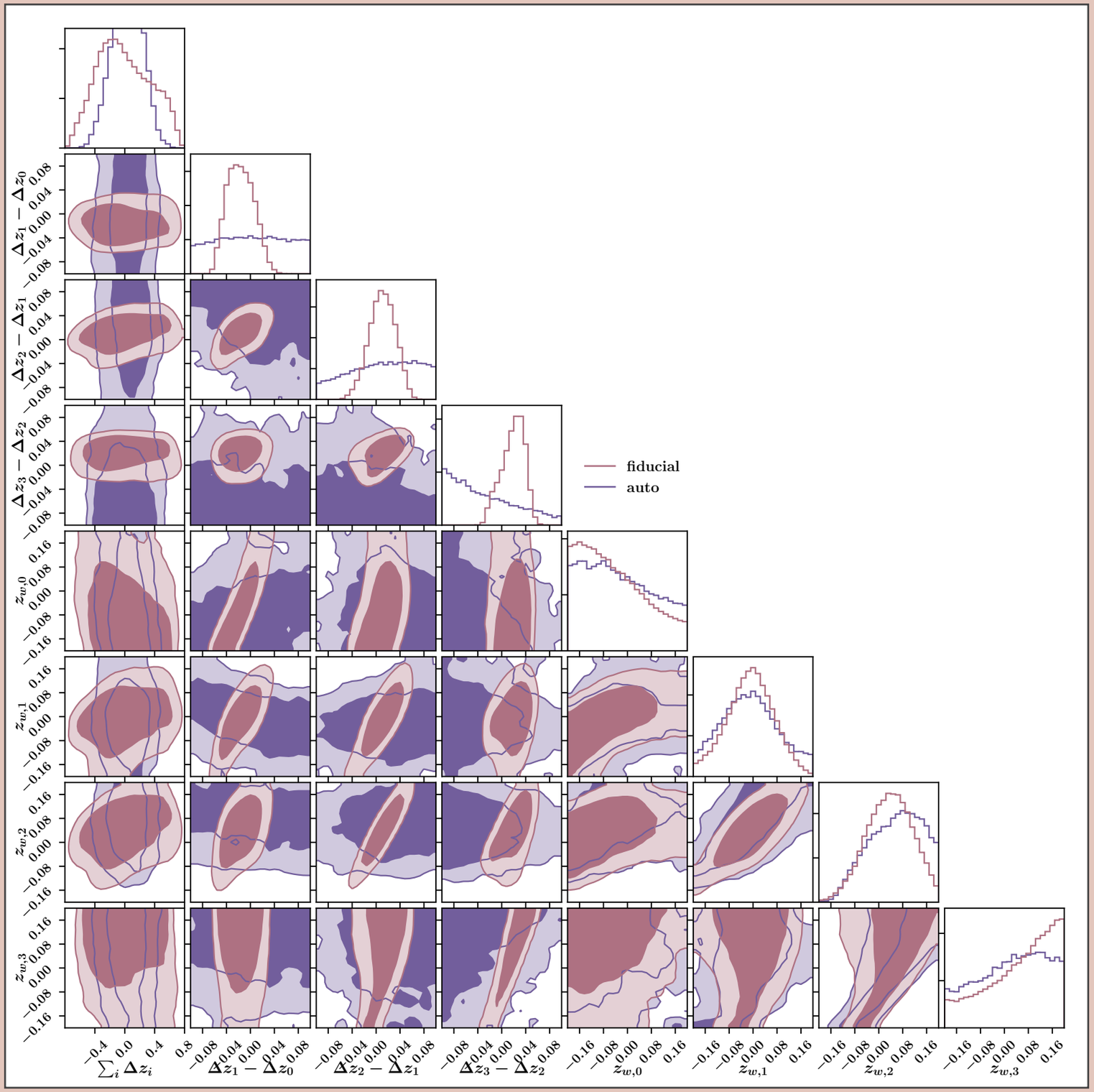
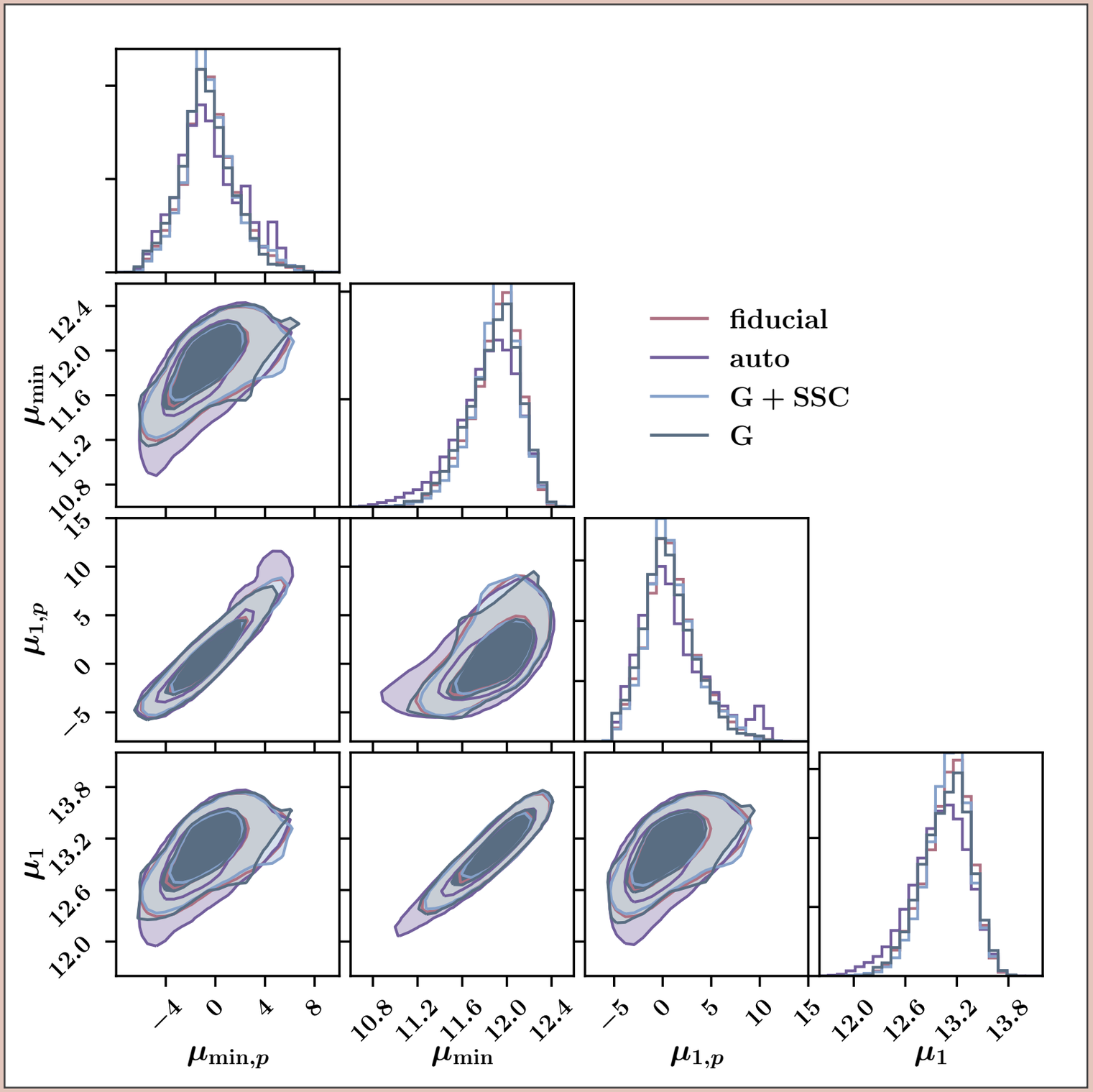


Photo-z Systematics



Stability of Results



Summary

Photometric clustering measurement with HSC DR1 data using LSST tools

Constraints on HOD & photo-z systematics parameters

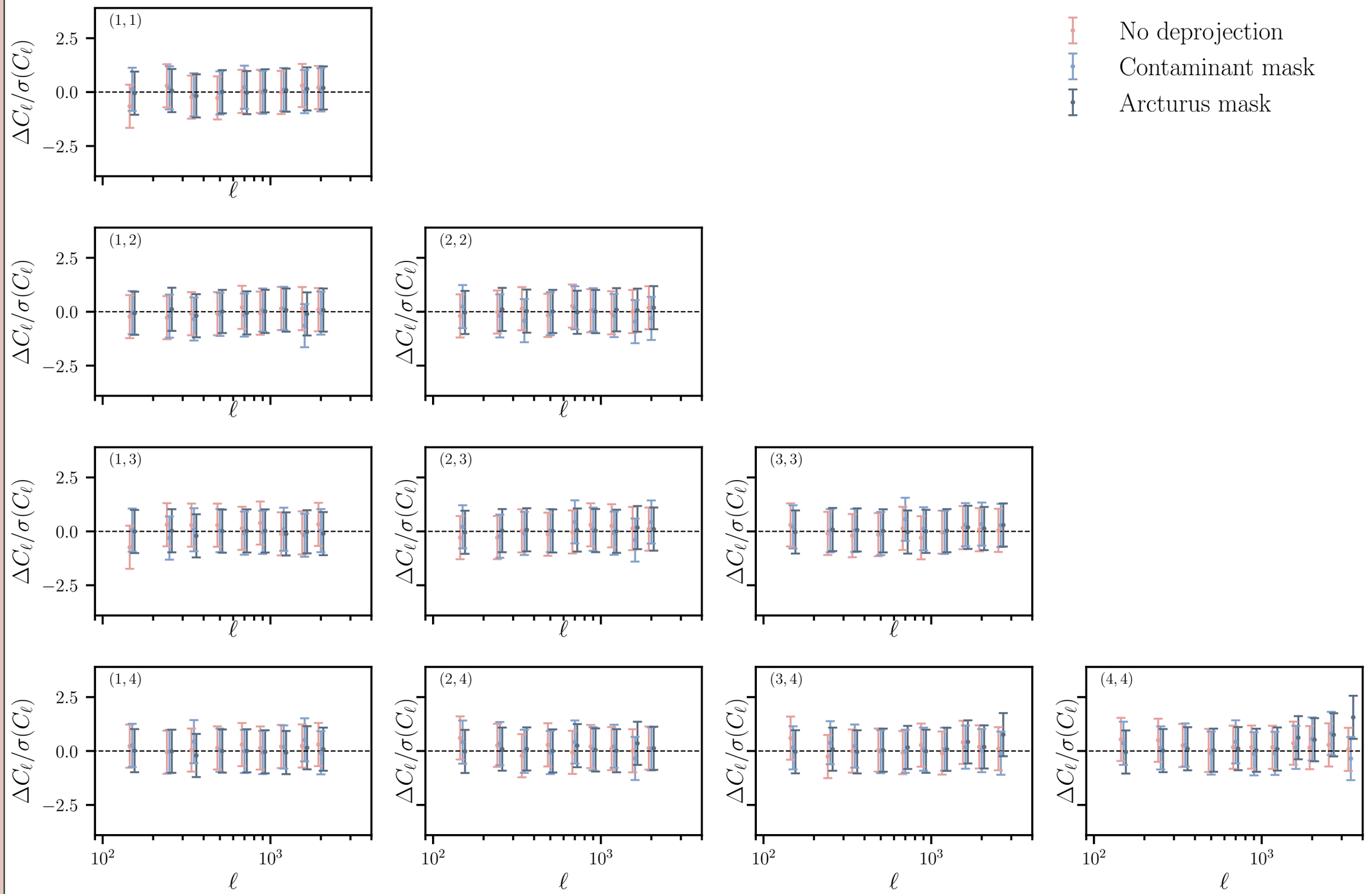
Promising for future photometric clustering analyses

Future work: joint analysis HSC & ACT, color-dependent clustering with HSC

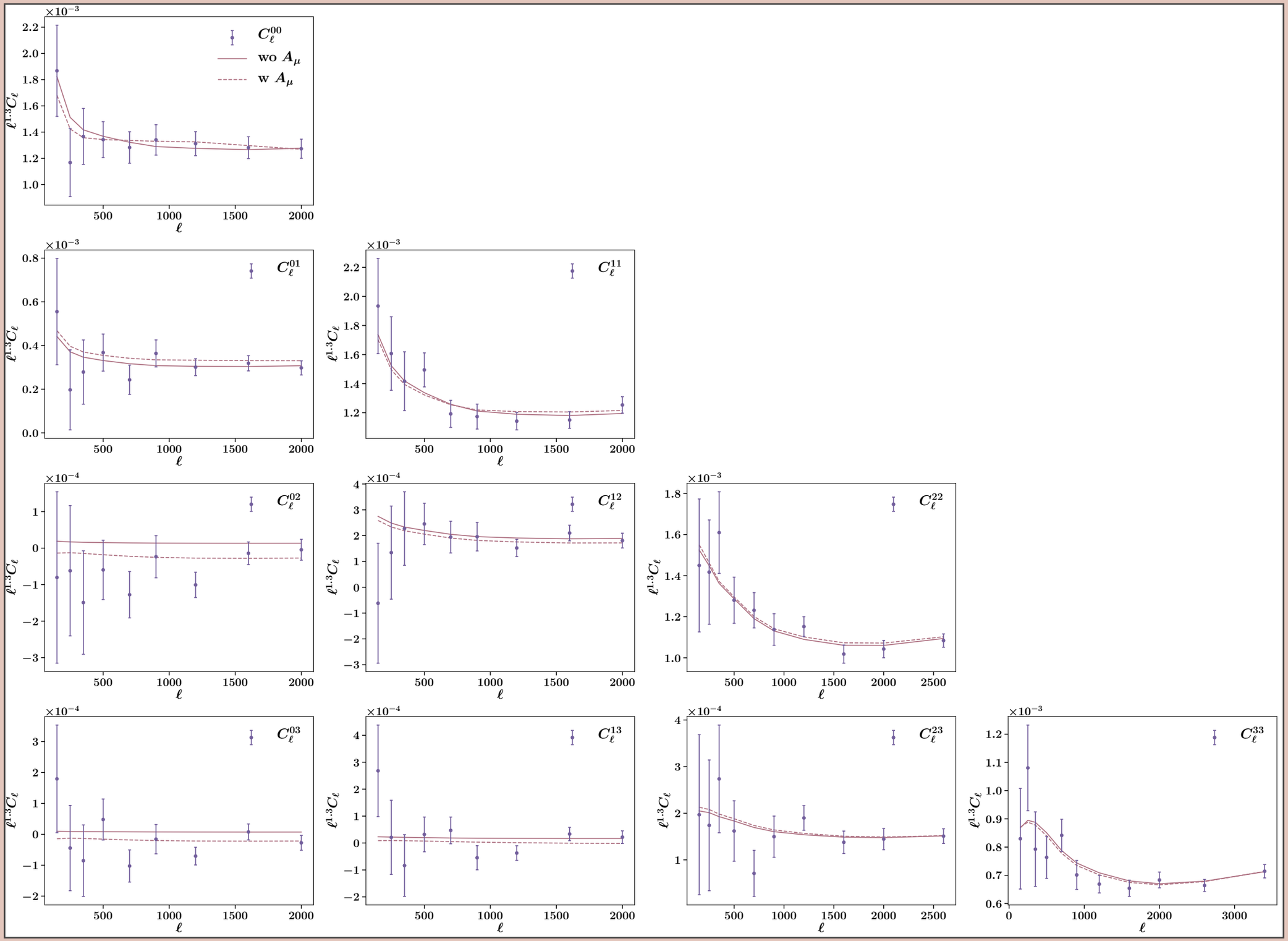
Thank you!

Backup Slides

Power Spectrum Consistency Tests



Power Spectra



Analysis Variants

Analysis variant	χ^2/ν	$\mu_{\min,p}$	$\mu_{\min}$	$\mu_{1,p}$	μ_1	A_μ	Ω_c	σ_8
fiducial	$^{86.2}/_{80}$ (0.30)	$-0.491^{+2.09}_{-2.02}$	$11.88^{+0.22}_{-0.23}$	$0.933^{+2.67}_{-2.56}$	$13.08^{+0.27}_{-0.28}$	-	-	-
auto	$^{19.2}/_{25}$ (0.79)	$-0.886^{2.19}_{-2.17}$	11.82 ± 0.28	$0.368^{+2.67}_{-2.64}$	12.99 ± 0.33	-	-	-
G cov	$^{87.2}/_{80}$ (0.27)	$-0.675^{+2.11}_{-2.08}$	$11.88^{+0.23}_{-0.24}$	$0.70^{+2.67}_{-2.61}$	$13.08^{+0.28}_{-0.29}$	-	-	-
G+SSC cov	$^{86.2}/_{80}$ (0.30)	$-0.433^{+1.96}_{-1.90}$	11.89 ± 0.20	$0.982^{+2.55}_{-2.44}$	$13.09^{+0.24}_{-0.25}$	-	-	-
no $z_{w,i}$	$^{88.0}/_{84}$ (0.36)	$-0.855^{+0.648}_{-0.653}$	11.87 ± 0.11	$0.327^{+0.889}_{-0.900}$	13.07 ± 0.15	-	-	-
no $z_{w,i}, \Delta z_i$	$^{95.2}/_{88}$ (0.28)	$-1.09^{+0.624}_{-0.771}$	11.78 ± 0.13	$-0.108^{+0.727}_{-0.940}$	12.93 ± 0.16	-	-	-
bins = 0, 1, 2	$^{44.4}/_{43}$ (0.41)	$-0.354^{+2.34}_{-2.25}$	$11.88^{+0.22}_{-0.23}$	$0.624^{+2.87}_{-2.75}$	$13.09^{+0.27}_{-0.28}$	-	-	-
bins = 1, 2, 3	$^{44.4}/_{46}$ (0.54)	$1.20^{+2.88}_{-2.94}$	$11.97^{+0.31}_{-0.36}$	$3.46^{+3.66}_{-3.63}$	$13.23^{+0.39}_{-0.43}$	-	-	-
pz = `Ephor_AB`	$^{93.6}/_{80}$ (0.14)	$0.270^{+2.05}_{-1.88}$	$12.14^{+0.19}_{-0.17}$	$1.82^{+2.87}_{-2.59}$	$13.39^{+0.24}_{-0.23}$	-	-	-
pz = `Ephor`	$^{107.2}/_{80}$ (0.023)	$0.895^{+1.97}_{-2.03}$	12.15 ± 0.17	$2.64^{+2.71}_{-2.80}$	$13.40^{+0.23}_{-0.22}$	-	-	-
pz = `DEmP`	$^{105.4}/_{80}$ (0.031)	$0.616^{+1.90}_{-1.88}$	$12.07^{+0.17}_{-0.16}$	$2.29^{+2.59}_{-2.55}$	$13.30^{+0.22}_{-0.21}$	-	-	-
pz = `FRANKEN-Z`	$^{90.8}/_{80}$ (0.19)	$0.0421^{+1.97}_{-1.76}$	$12.12^{+0.18}_{-0.16}$	$1.41^{+2.75}_{-2.44}$	$13.38^{+0.23}_{-0.22}$	-	-	-
fiducial magn.	$^{72.8}/_{80}$ (0.70)	$-0.358^{+2.56}_{-2.32}$	$11.94^{+0.21}_{-0.22}$	$1.04^{+3.32}_{-2.97}$	$13.16^{+0.26}_{-0.27}$	-	-	-
fit magn., auto+cross	$^{69.0}/_{79}$ (0.78)	$-1.78^{+2.13}_{-2.35}$	$11.79^{+0.26}_{-0.27}$	$-0.724^{+2.60}_{-2.74}$	$12.98^{+0.30}_{-0.31}$	2.18 ± 0.74	-	-
fit magn., auto	$^{19.4}/_{24}$ (0.73)	$-0.844^{+2.29}_{-2.17}$	11.81 ± 0.26	$0.409^{+2.80}_{-2.65}$	12.98 ± 0.31	$0.627^{+2.71}_{-2.61}$	-	-
fit cosmo	$^{84.4}/_{78}$ (0.29)	$0.0143^{+2.72}_{-2.53}$	$11.79^{+0.27}_{-0.24}$	$1.63^{+3.44}_{-3.20}$	$12.96^{+0.36}_{-0.35}$	-	0.237 ± 0.025	$0.807^{+0.149}_{-0.143}$

Photo-z Systematics I

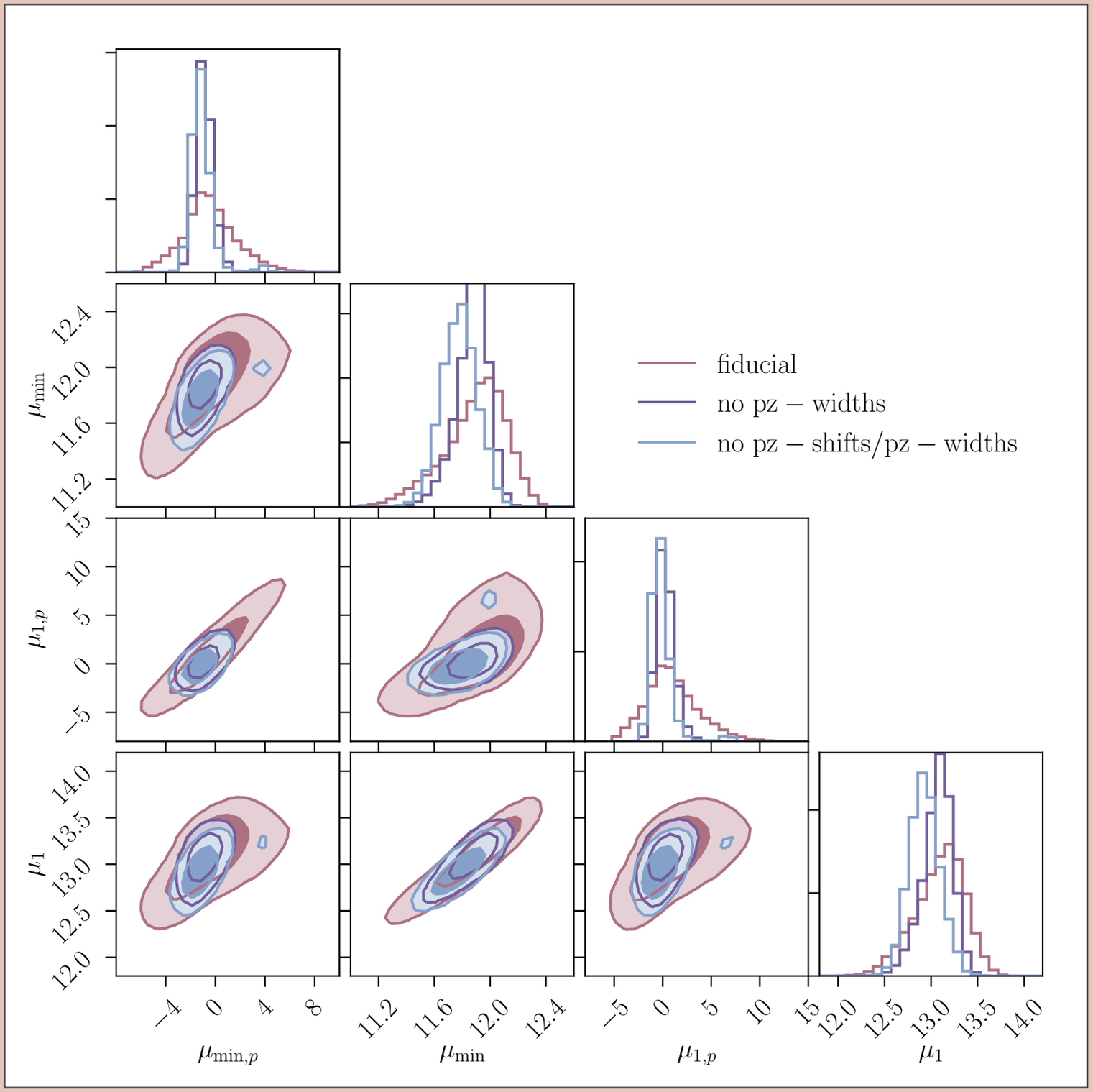


Photo-z Systematics II

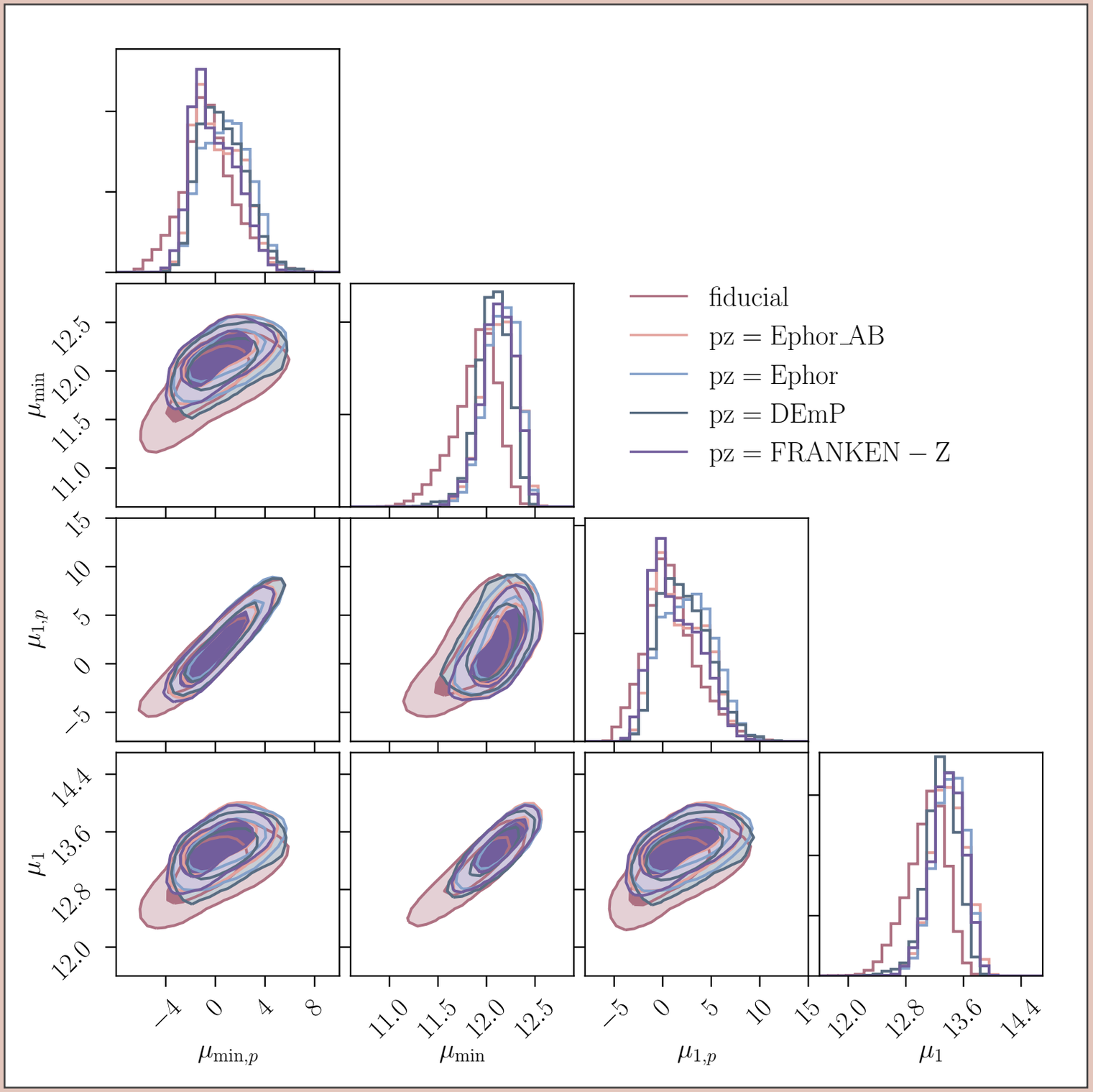
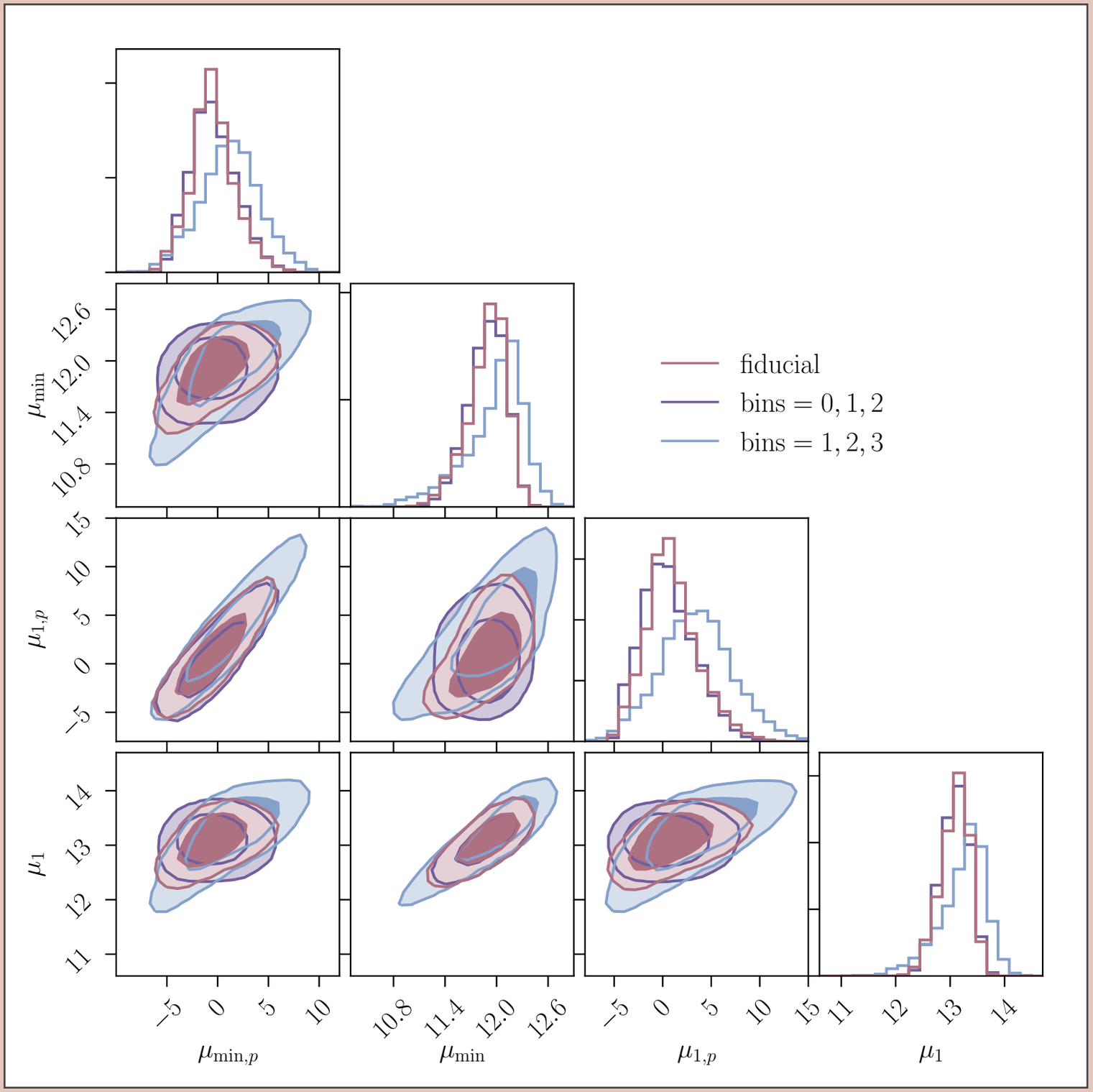


Photo-z Systematics III



Importance of Cross-Correlations