

The Halo Model with beyond-linear halo bias

Constance Mahony
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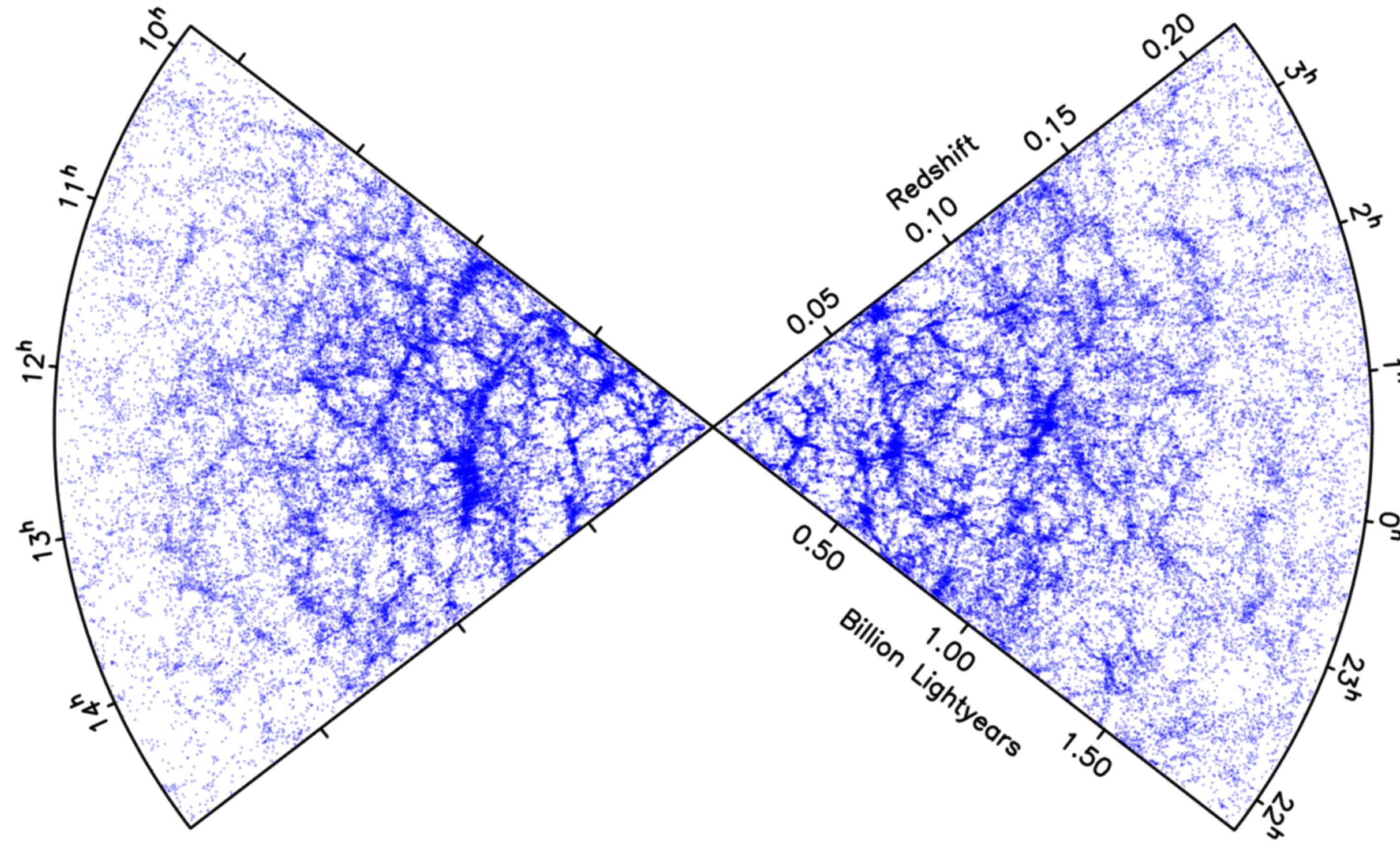
GCCL Seminar 25/3/22



Plan

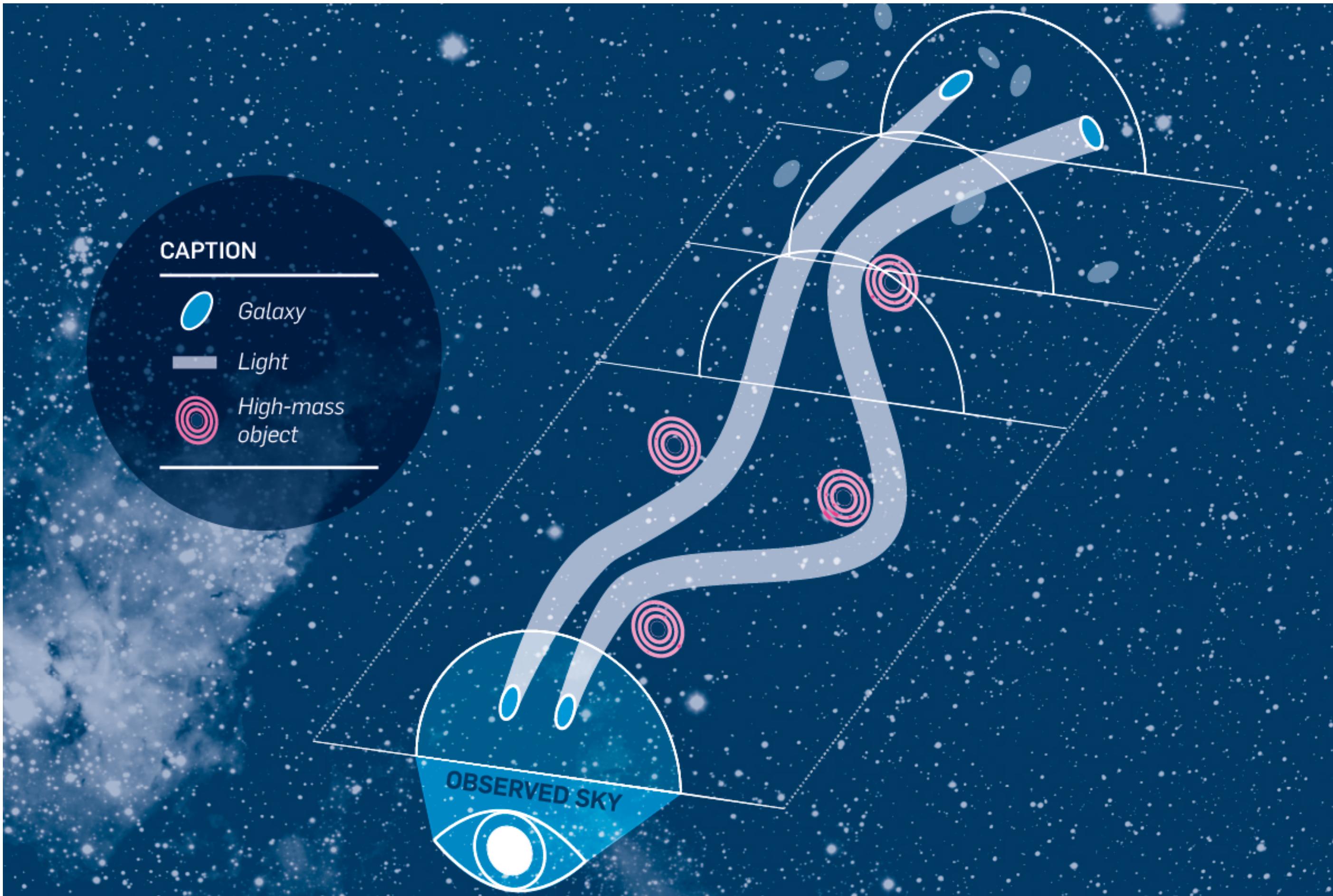
- Introduction to halo modelling
- Beyond-linear halo bias correction
- Offsets in cosmological parameters from neglecting beyond-linear halo bias
- Comparison to alternative approach

Galaxy clustering



2dF Galaxy Redshift Survey

Galaxy-galaxy lensing



RUB

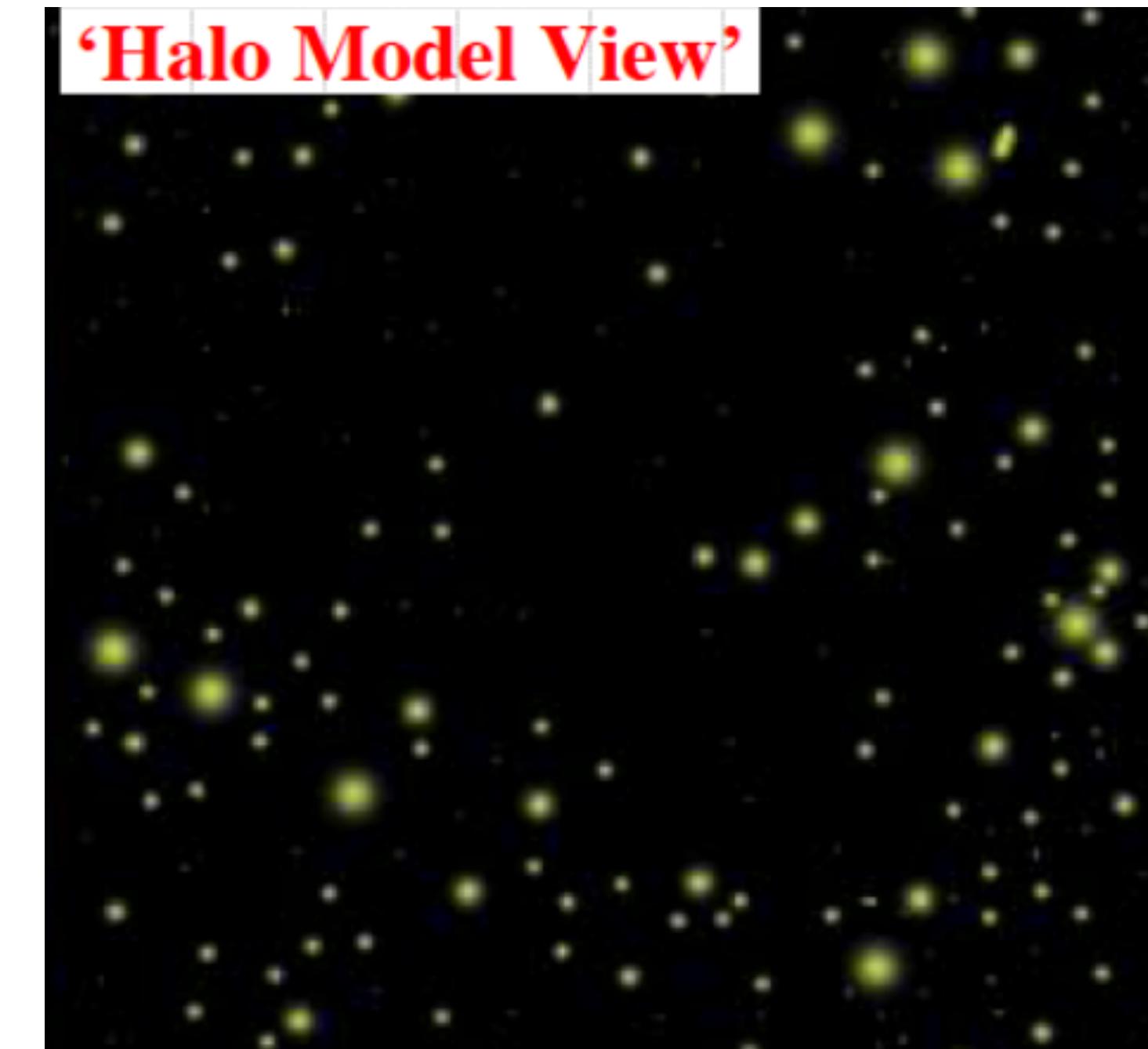
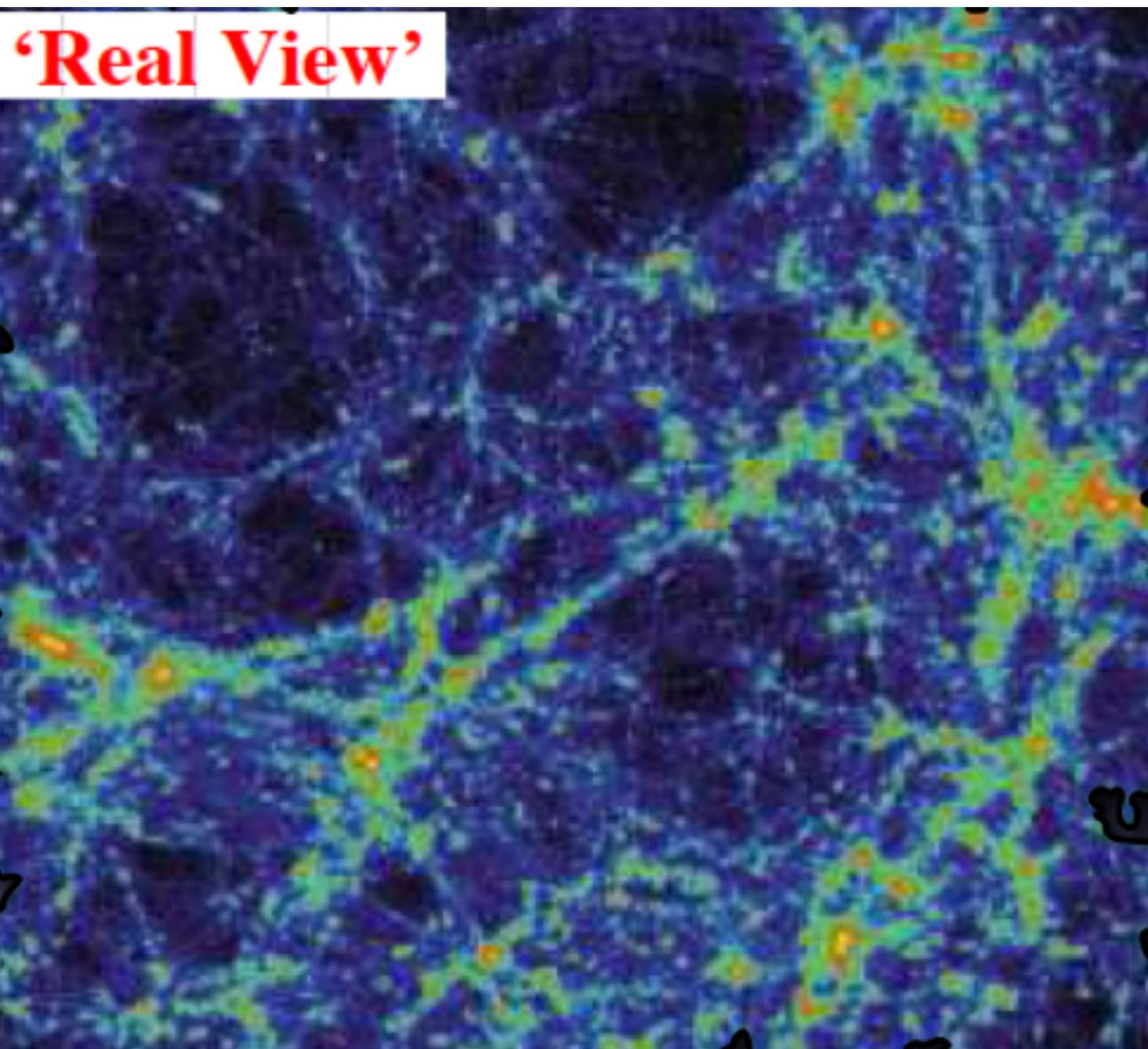
Matter distribution

Galaxies



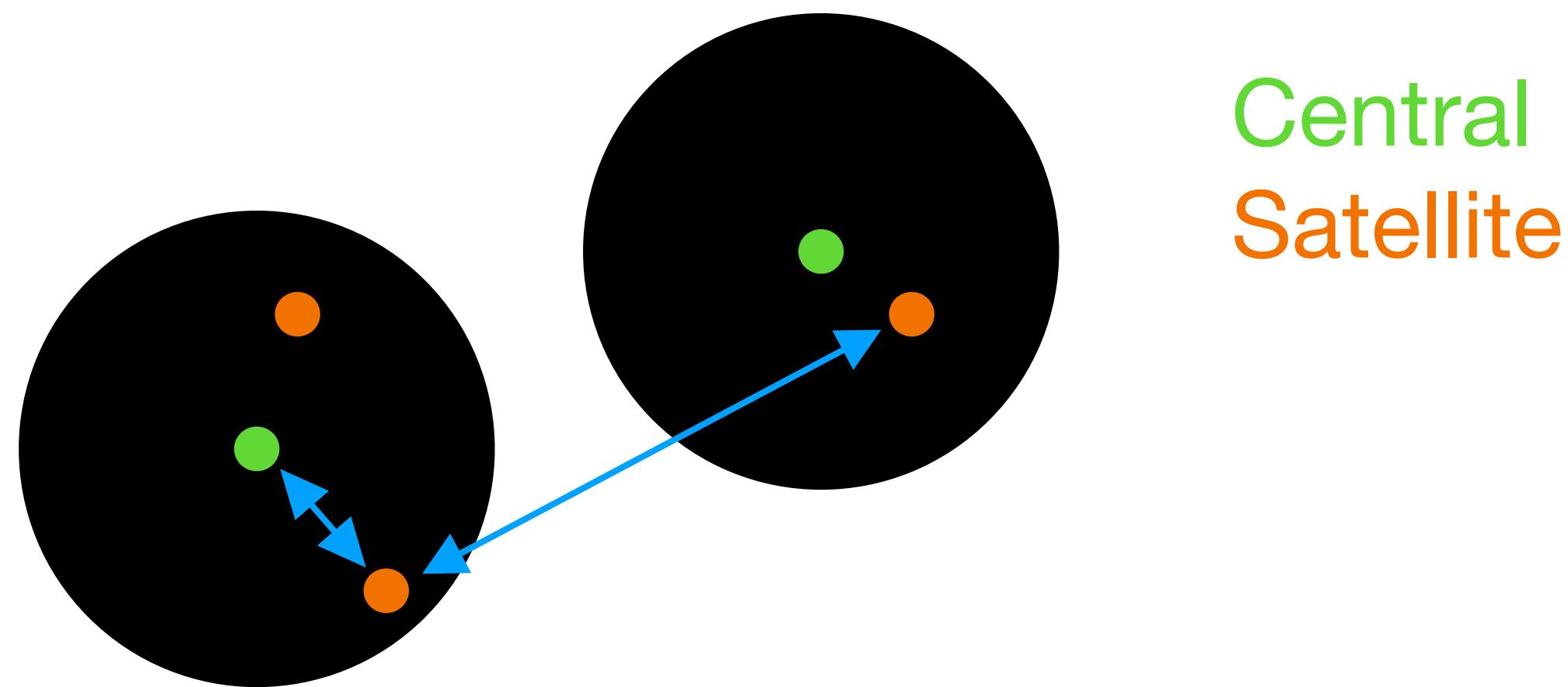
Dark Matter

Halo Model



van den Bosch

Halo model contributions



$$P_{gg} = 2P_{cs}^{1h} + P_{ss}^{1h} + P_{cc}^{2h} + 2P_{cs}^{2h} + P_{ss}^{2h}$$

$$P_{g\delta} = P_{c\delta}^{1h} + P_{s\delta}^{1h} + P_{c\delta}^{2h} + P_{s\delta}^{2h}$$

Halo model power spectra

$$P_{xy}^{1h}(k, z) = \int_0^{\infty} \mathcal{H}_x(k, M, z) \mathcal{H}_y(k, M, z) n(M, z) dM$$

$$\begin{aligned} P_{xy}^{2h}(k, z) = & P_{\delta\delta}^{\text{lin}}(k, z) \int_0^{\infty} dM_1 \mathcal{H}_x(k, M_1, z) n(M_1, z) b(M_1, z) \\ & \times \int_0^{\infty} dM_2 \mathcal{H}_y(k, M_2, z) n(M_2, z) b(M_2, z) \end{aligned}$$

Halo model power spectra

$$P_{xy}^{1h}(k, z) = \int_0^{\infty} \mathcal{H}_x(k, M, z) \mathcal{H}_y(k, M, z) n(M, z) dM$$

Halo Profile

Halo Mass Function

Halo Bias

$$\begin{aligned} P_{xy}^{2h}(k, z) &= P_{\delta\delta}^{\text{lin}}(k, z) \int_0^{\infty} dM_1 \mathcal{H}_x(k, M_1, z) n(M_1, z) b(M_1, z) \\ &\quad \times \int_0^{\infty} dM_2 \mathcal{H}_y(k, M_2, z) n(M_2, z) b(M_2, z) \end{aligned}$$

Beyond-linear halo bias β^{NL}

$$P_{\text{hh}}(M_1, M_2, k, z) \simeq b(M_1, z)b(M_2, z)P_{\delta\delta}^{\text{lin}}(k, z)$$

$$b(M_1, z)b(M_2, z)P_{\delta\delta}^{\text{lin}}(k, z)[1 + \beta^{\text{NL}}(M_1, M_2, k, z)]$$

Mead and Verde 2021

Beyond-linear halo bias β^{NL}

$$P_{\text{hh}}(M_1, M_2, k, z) \simeq b(M_1, z)b(M_2, z)P_{\delta\delta}^{\text{lin}}(k, z)$$

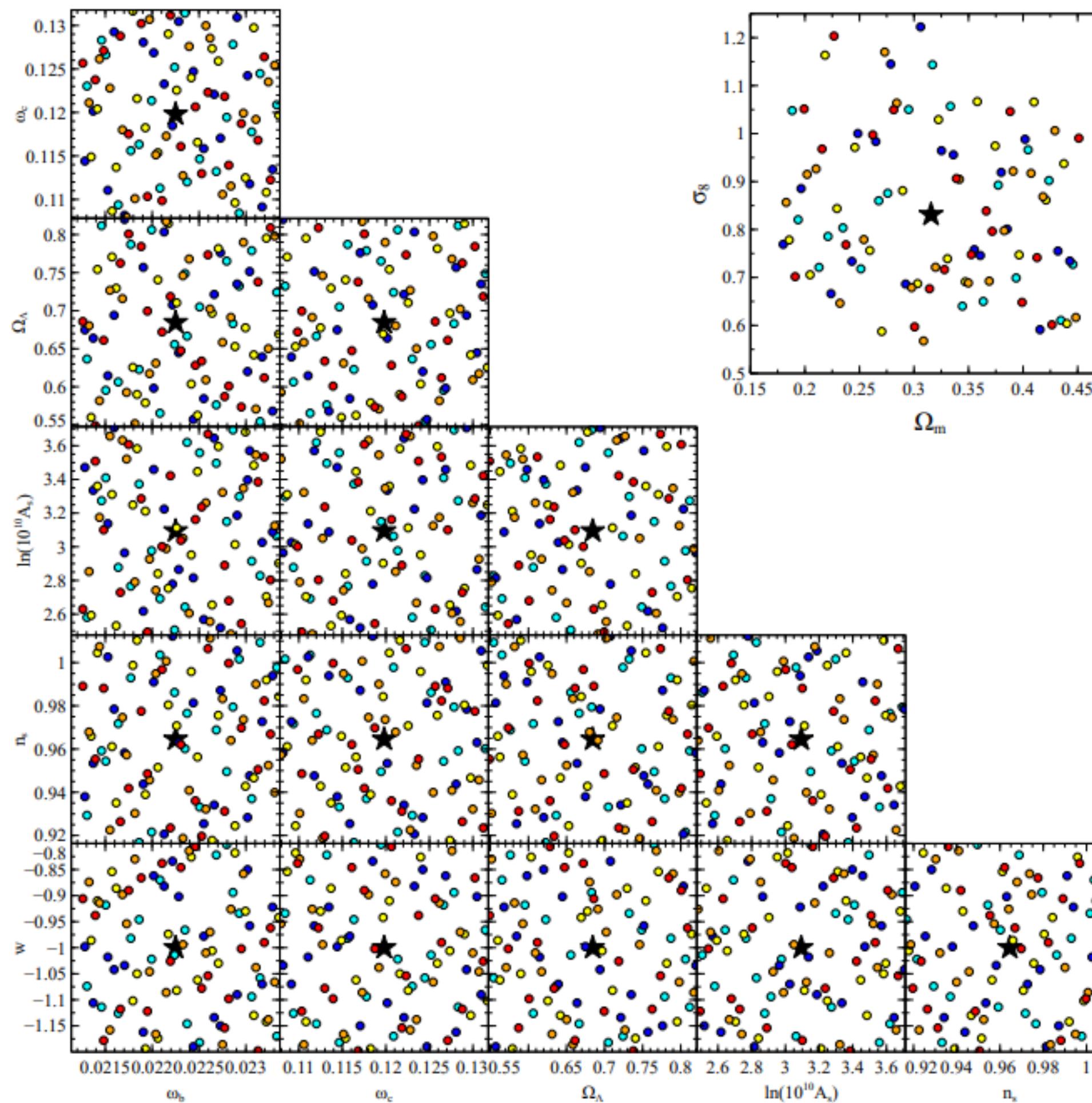
DarkEmulator

$$b(M_1, z)b(M_2, z)P_{\delta\delta}^{\text{lin}}(k, z)[1 + \boxed{\beta^{\text{NL}}(M_1, M_2, k, z)}]$$

Mead and Verde 2021

DarkEmulator

<https://darkquestcosmology.github.io/>

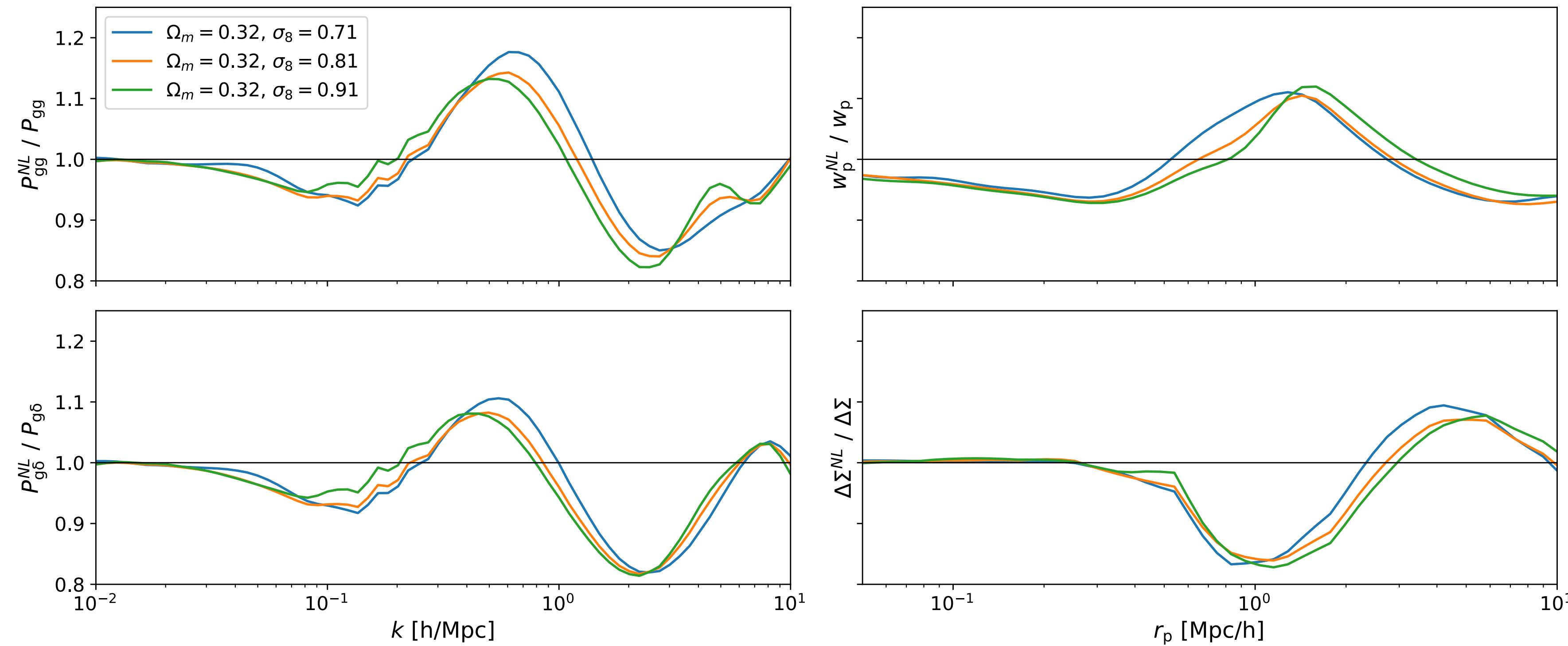


Nishimichi et al. 2019

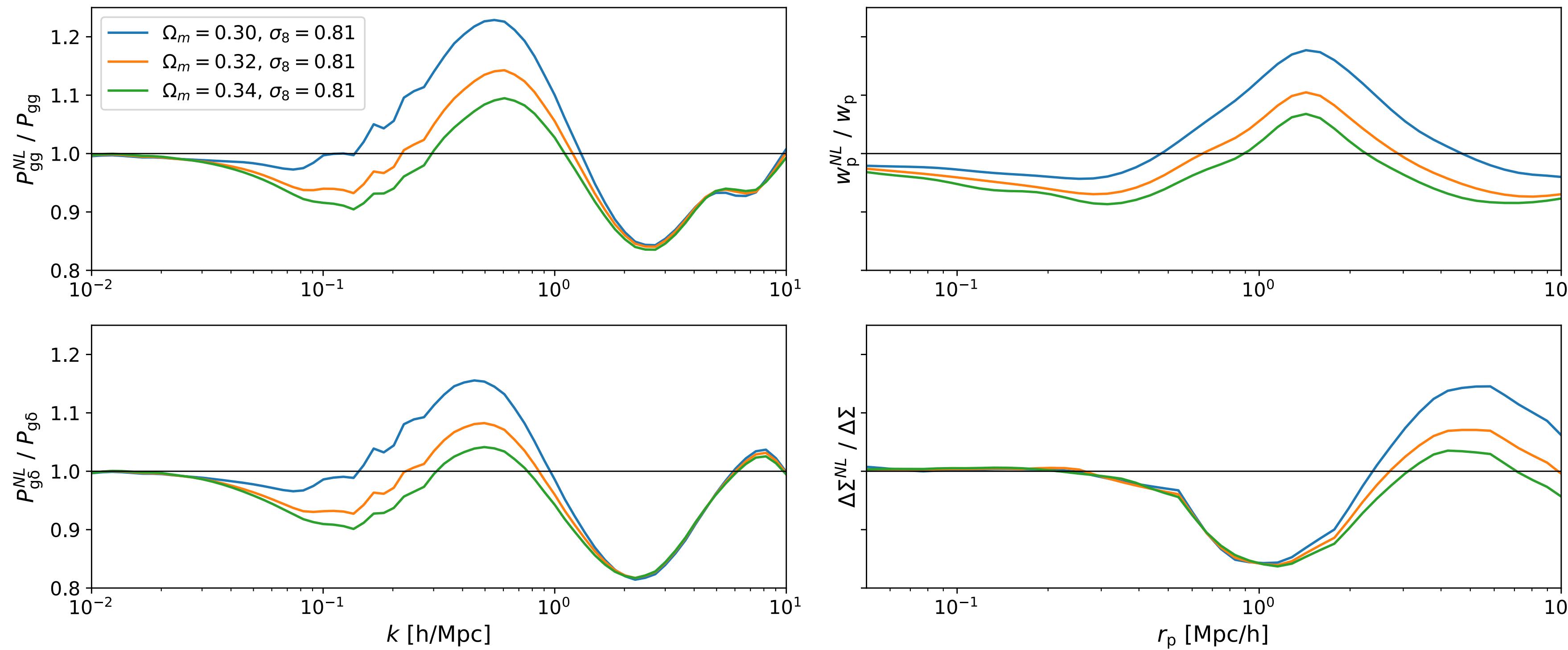
The Kilo-Degree Survey: KiDS-1000



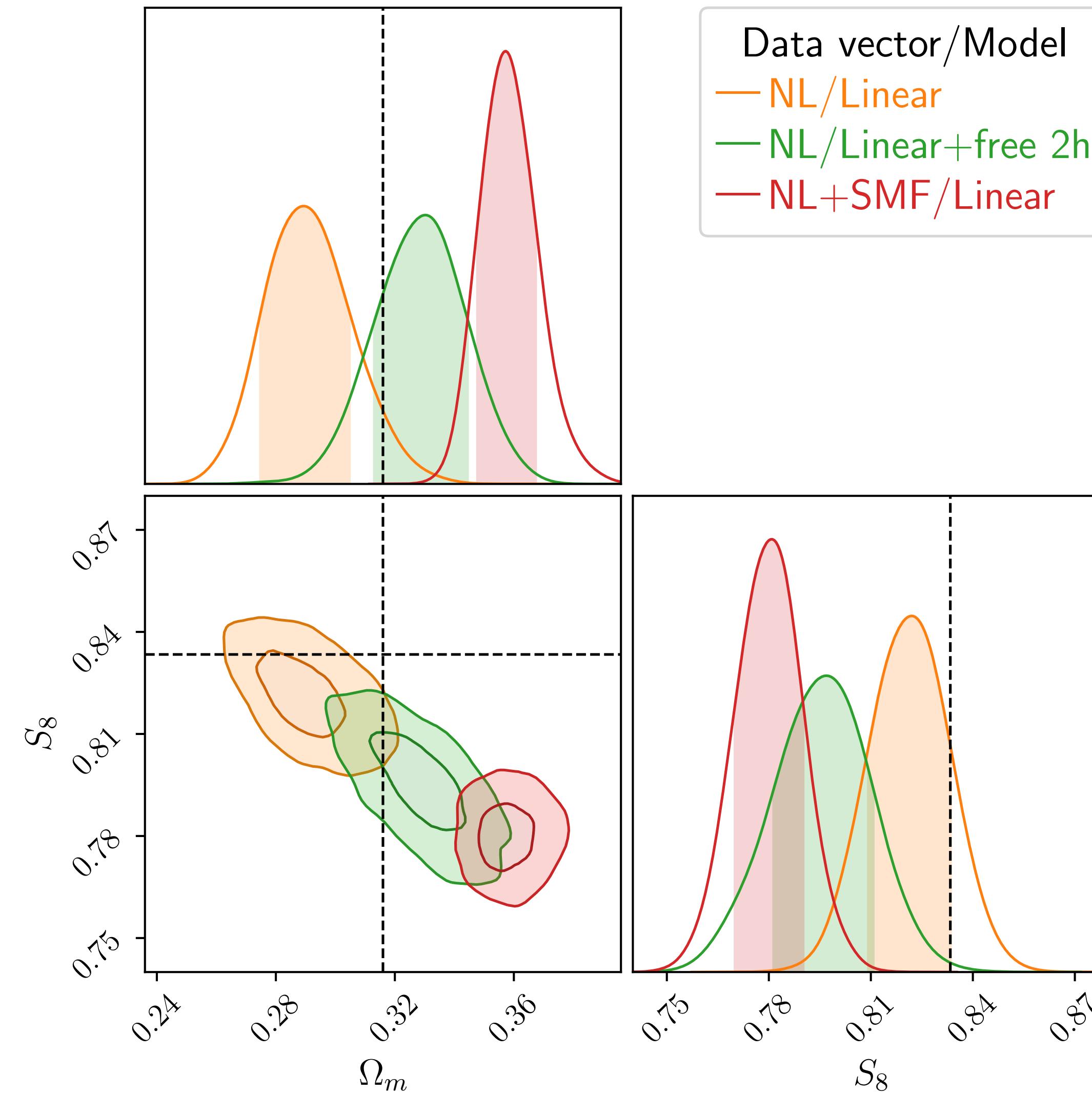
Cosmology Dependence σ_8



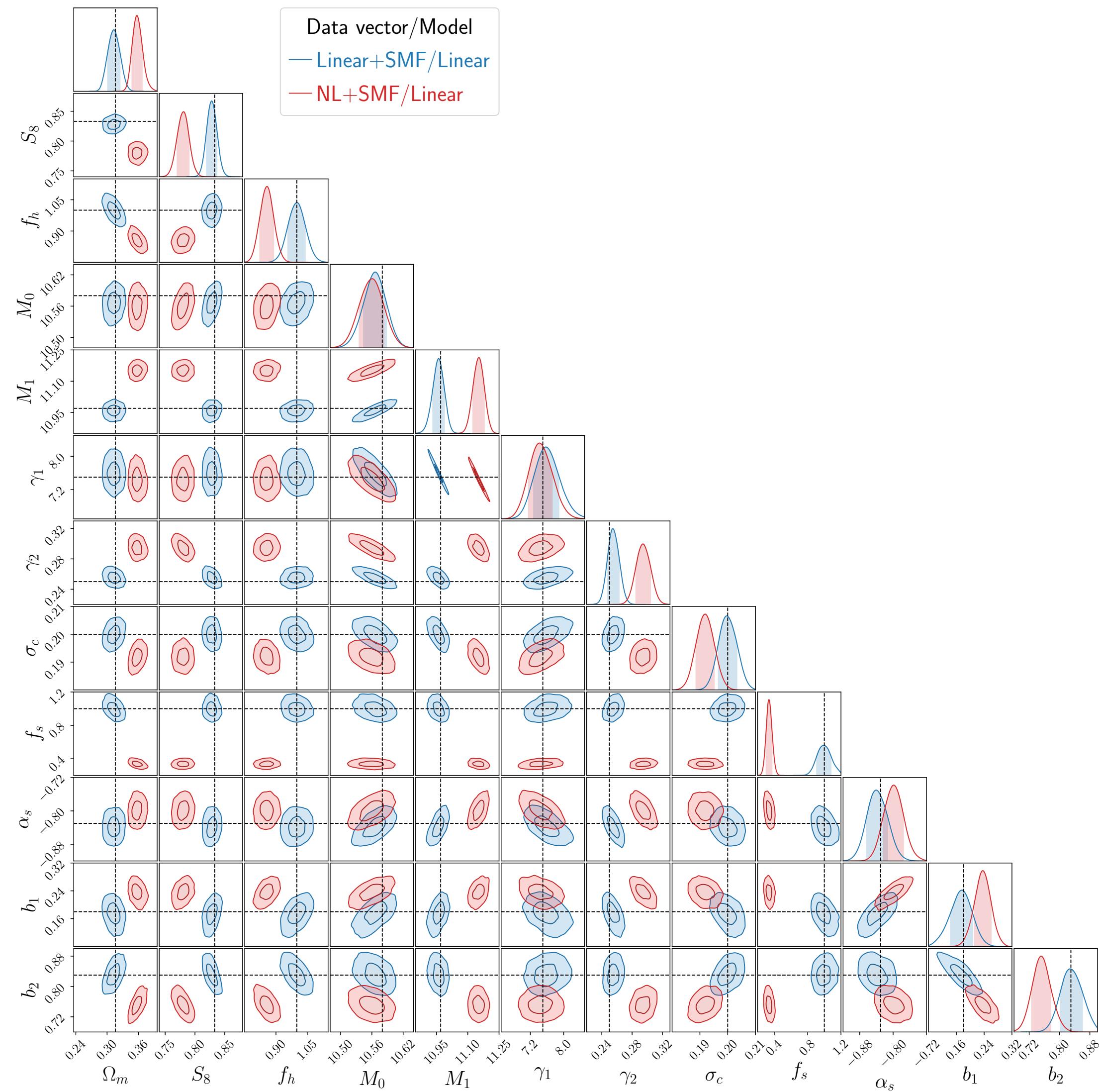
Cosmology Dependence Ω_m



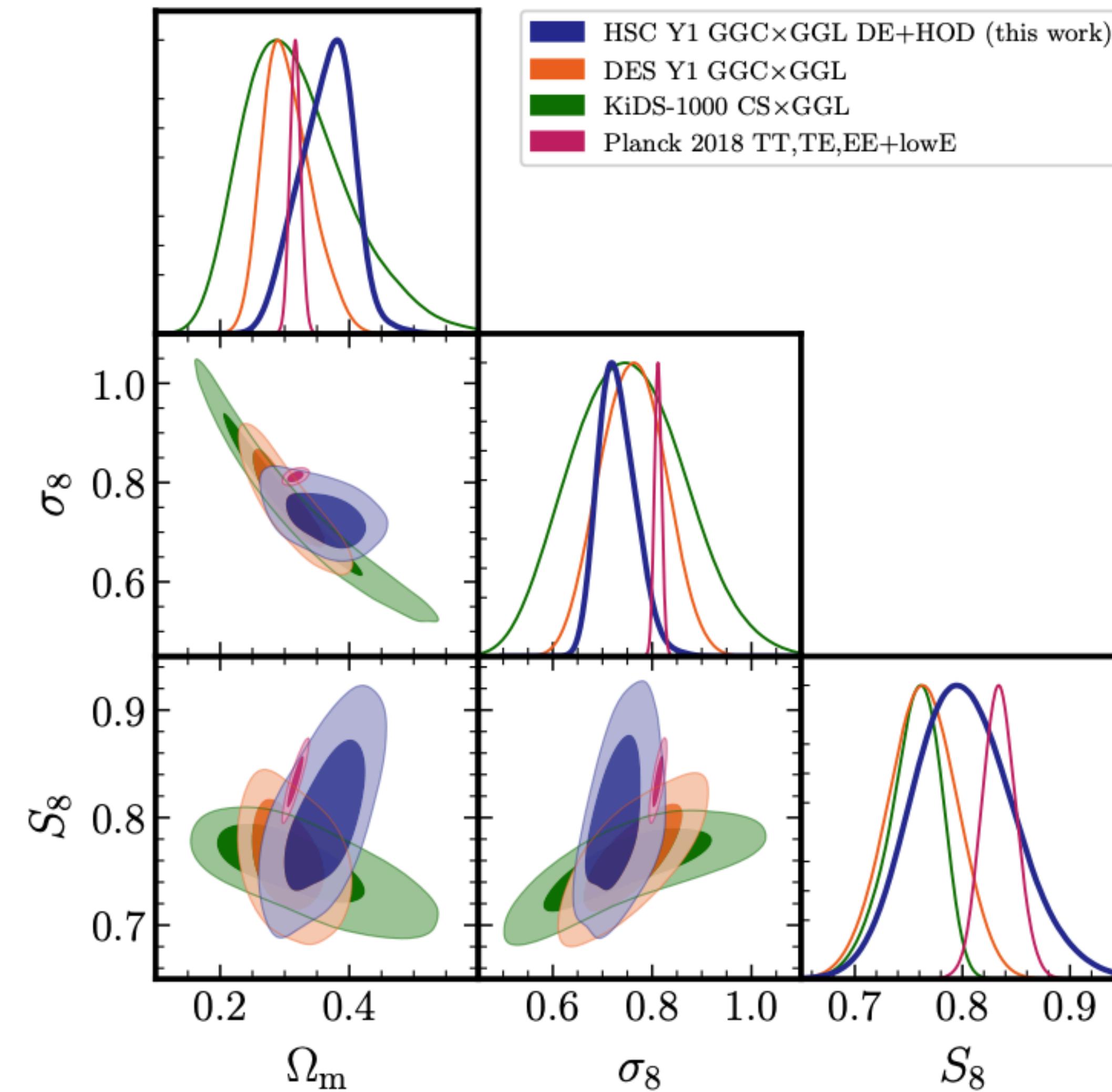
KiDS galaxy-galaxy lensing and clustering



Stellar Mass Function

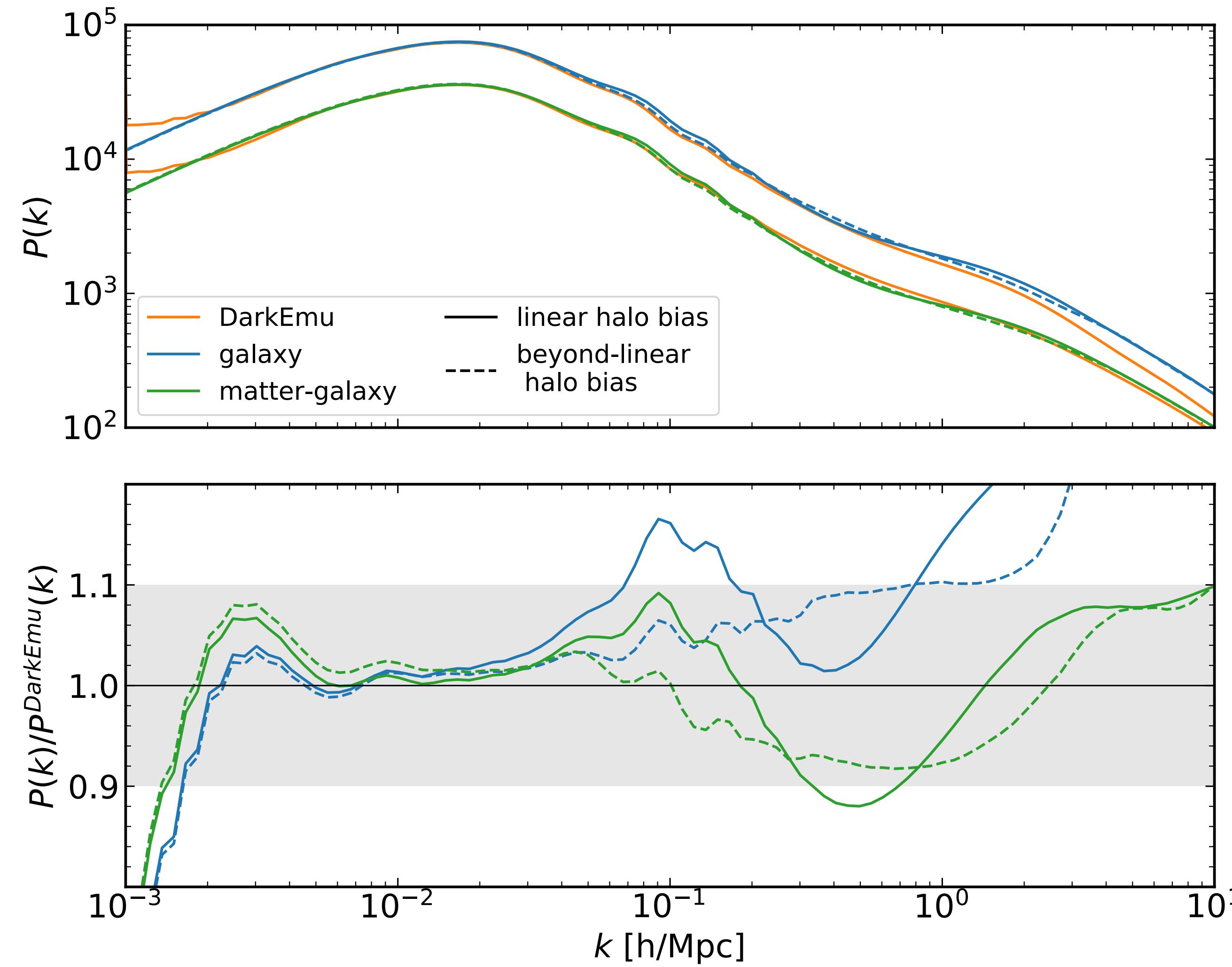


HSC Y1 results with DarkEmulator+HOD

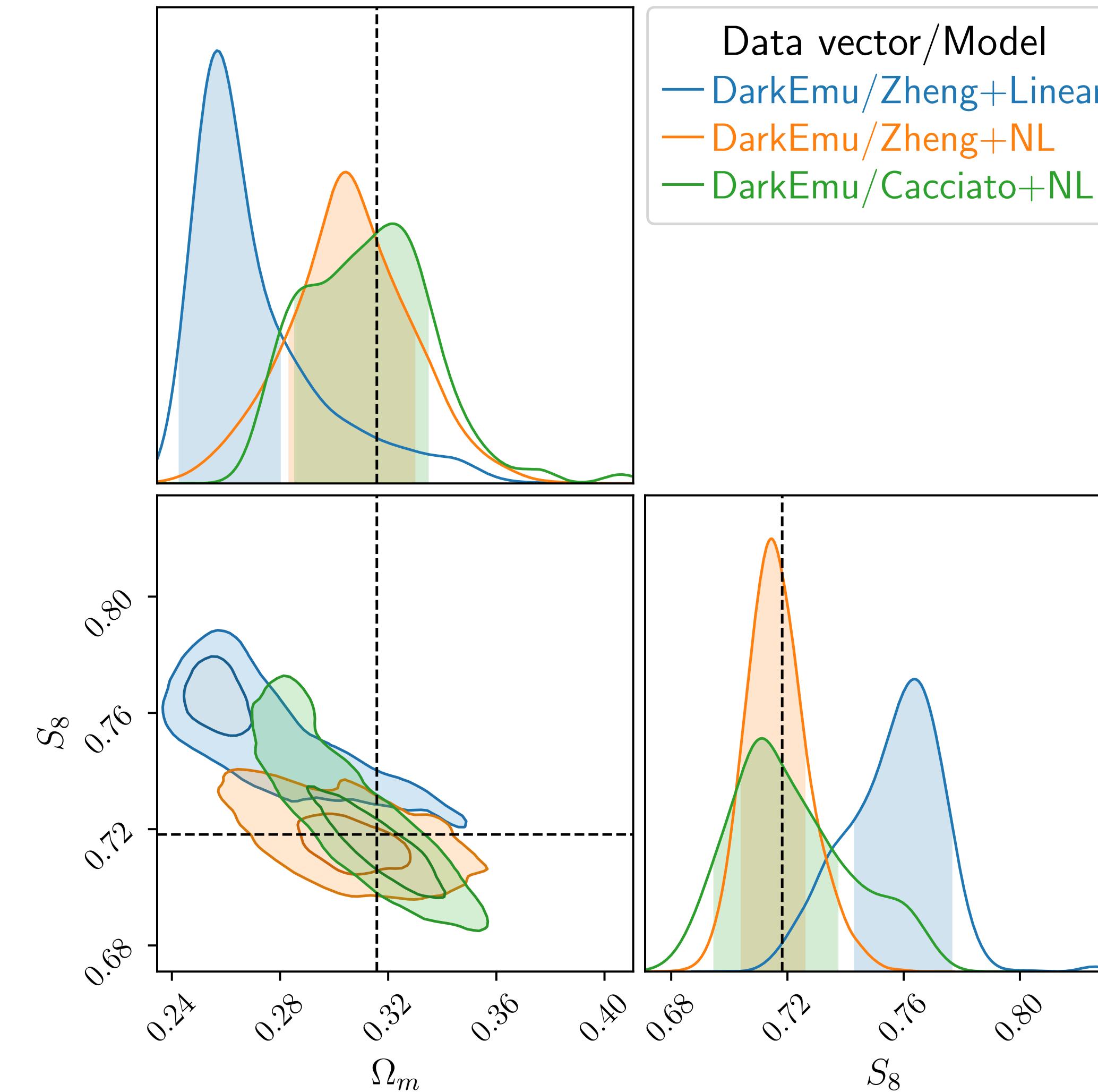


Miyatake et al. 2021

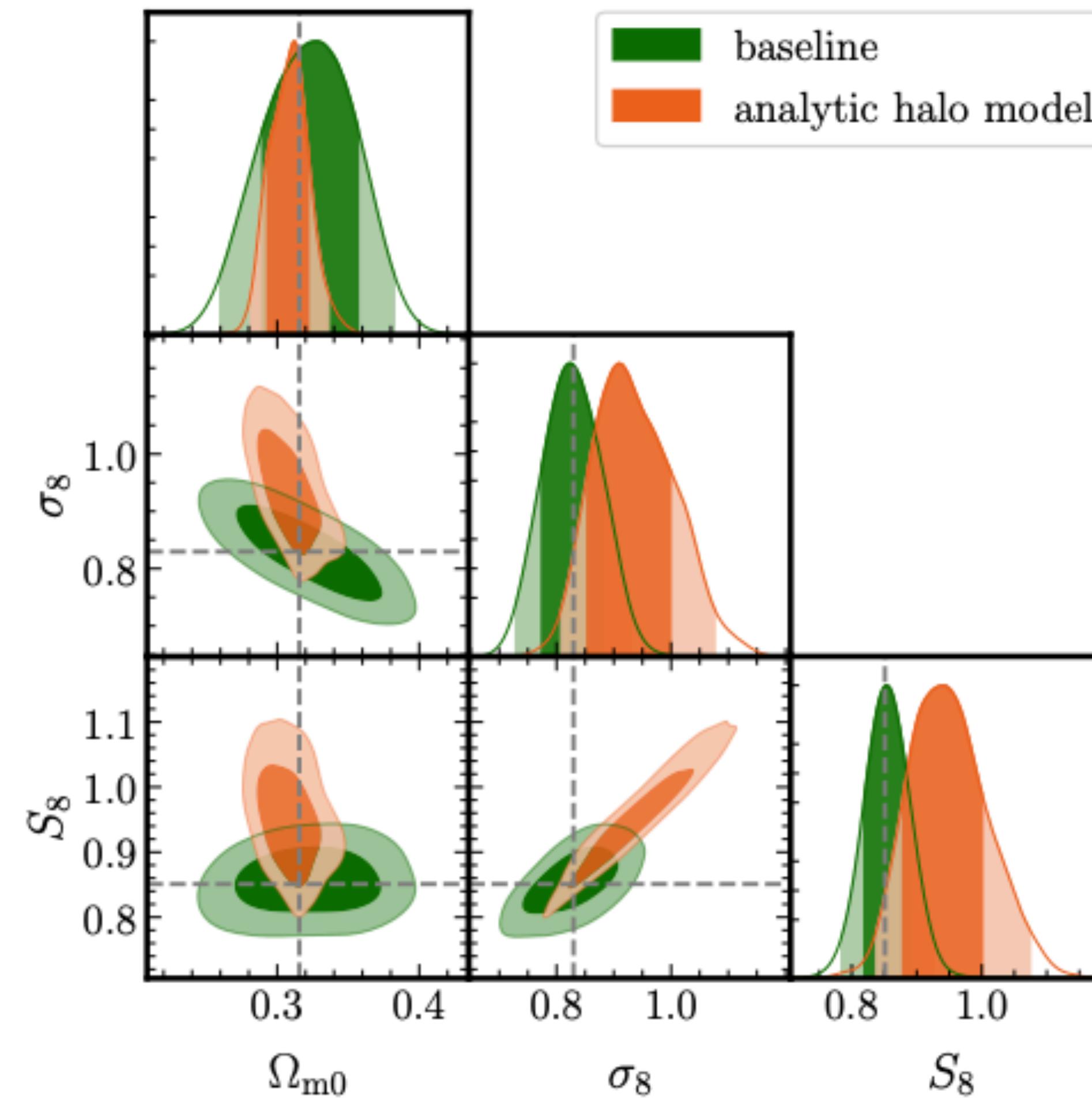
Comparison to DarkEmulator+HOD



DarkEmulator+HOD Mock Analysis



DarkEmulator+HOD Results



Miyatake et al. 2020

Summary

- Beyond-linear halo bias must be included in future galaxy clustering and galaxy-galaxy lensing analyses
- Not possible to mitigate its impact with conservative scale cuts
- Direction of offsets depends on the freedom afforded to the halo model through other nuisance parameters
- Adding a simulation calibrated β^{NL} , instead of emulating the observables directly, retains the flexibility of the halo model

Bonus: Beyond-linear halo bias I^{NL}

$$\begin{aligned} P_{\text{xy}}^{2\text{h}}(k, z) &= P_{\delta\delta}^{\text{lin}}(k, z) \int_0^\infty dM_1 \mathcal{H}_x(k, M_1, z) n(M_1, z) b(M_1, z) \\ &\quad \times \int_0^\infty dM_2 \mathcal{H}_y(k, M_2, z) n(M_2, z) b(M_2, z) \\ &\quad + P_{\delta\delta}^{\text{lin}}(k, z) I_{\text{xy}}^{\text{NL}}(k, z) \end{aligned}$$

$$\begin{aligned} I_{\text{xy}}^{\text{NL}}(k, z) &= \int_0^\infty \int_0^\infty dM_1 dM_2 \beta^{\text{NL}}(k, M_1, M_2, z) \\ &\quad \times \mathcal{H}_x(k, M_1, z) \mathcal{H}_y(k, M_2, z) n(M_1, z) \\ &\quad \times n(M_2, z) b(M_1, z) b(M_2, z) . \end{aligned}$$