Theoretical challenges in LSS

- role of priors on EFT parameters; prior-volume effects and impact of prior choice on e.g. σ_8; (dis)agreement of various methods/codes e.g. 2309.04468
- perturbation theory vs simulation-based inference
  e.g. simbig 2310.15256
- Beyond EdS kernels e.g. bootstrap 2109.09573 or cosmology-specific kernels (e.g. 2309.11496 for long-range forces, 2205.11533 for massive neutrinos, 2205.10026 2308.06096 for time-dependent kernels at 2loop,...)
- pushing to higher loops; renormalization, bias, fftlog methods, ... e.g. 2211.17130 bispectrum, 2308.07379 power spectrum in redshift space
- pushing to higher n-point functions or other statistics e.g. trispectrum; skew spectra 2210.12743,...
- perturbation theory of collisionless Vlasov-Poisson instead of the usual fluid-Poisson e.g. 2210.08089

Theoretical challenges/perspectives of LSS

- What kind of new physics can we hope to constrain/discover?

- How to quantify (possible) tensions?

- What will be the legacy of LSS experiments?
  What is our ”nightmare scenario”?

theoretical challenges in LSS

some next steps

- higher loops, higher N-point functions
  - 2-loop PS, 2-loop bisp., 1-loop trisp.
  - gain ~30% using 1-loop bisp.

D'Amico, ML, Senatore, Zhang 22
D'Amico, Donath, ML, Senatore, Zhang 22 (2)
D'Amico, Donath, ML, Senatore, Zhang 22 (1)
Philcox, Ivanov, Cabass, Simonović, Zaldarriaga 22

- new methods for integration
  - FFTlog, massive propagators
  - 1-loop bisp. only possible with this new technology

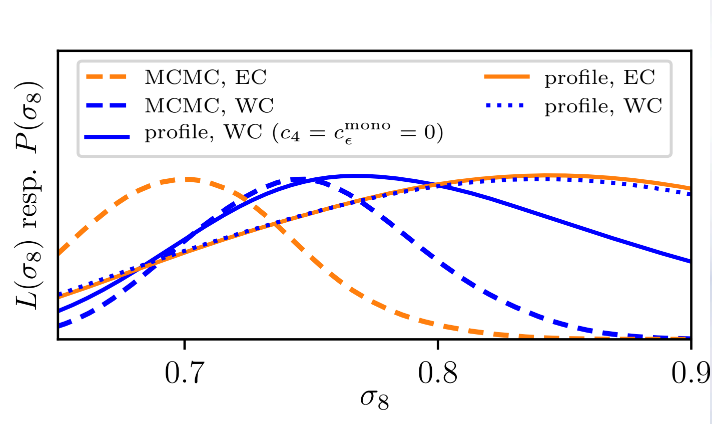
Simonović, Baldauf, Zaldarriaga, Carrasco, Kollmeier 17
ML, Senatore 18
Anastasiou, Bragança, Senatore, Zheng 22

- new theory results
  - non-locality in time and galaxy formation
  - needs high order (5th) computation
  - new recursion relation

Donath, ML, Senatore 23

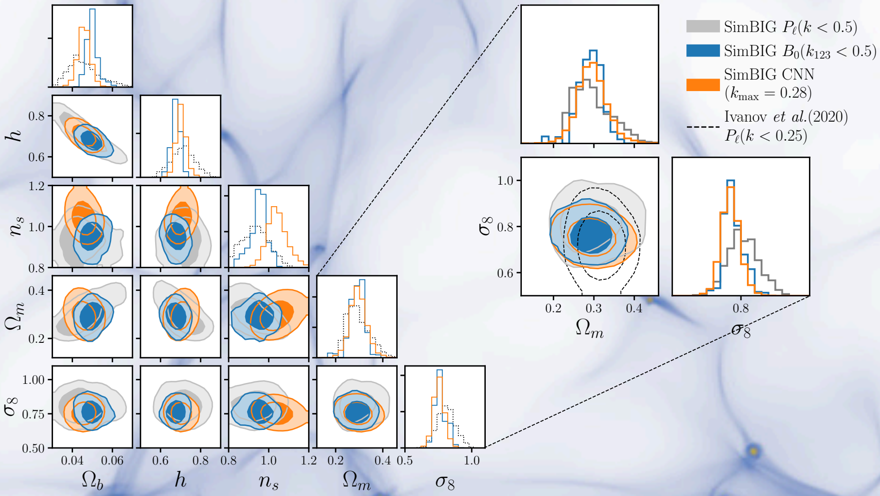
Galaxies meet QCD
workshop at ETH
with P. Zhang

Role of priors on EFT parameters



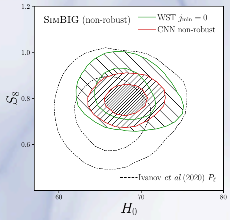
Bayesian analysis of BOSS full shape + BAO data with prior on counterterms vs profile likelihood (no priors) Holm, Herold, Simon, Ferreira, Hannestad, Poulin, Tram 2310.15256

Simulation-based inference



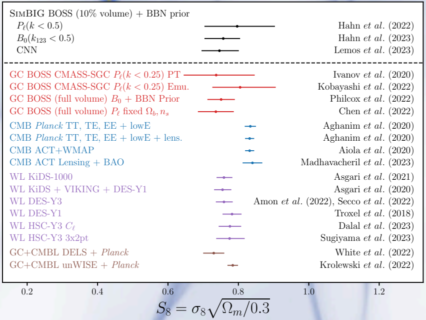
SimBig applied to subvolume of BOSS with 9-param HOD model 2310.15246

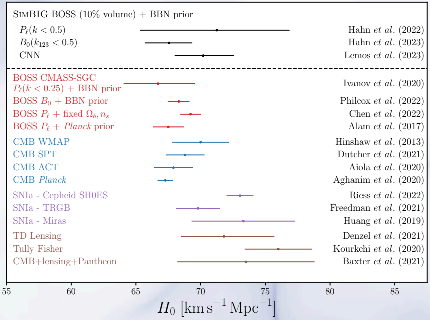
Simulation-based inference



"The full constraining power of neither the CNN nor the WST can currently be robustly exploited. This is because these statistics identify cosmological imprints that are specific to our forward model. One way to robustly exploit these statistics is to use a more flexible and generalizable forward model that can describe the WST and CNN across the different test simulations. Alternatively, we can also construct clustering statistics more robust to model misspecification" 2310.15246

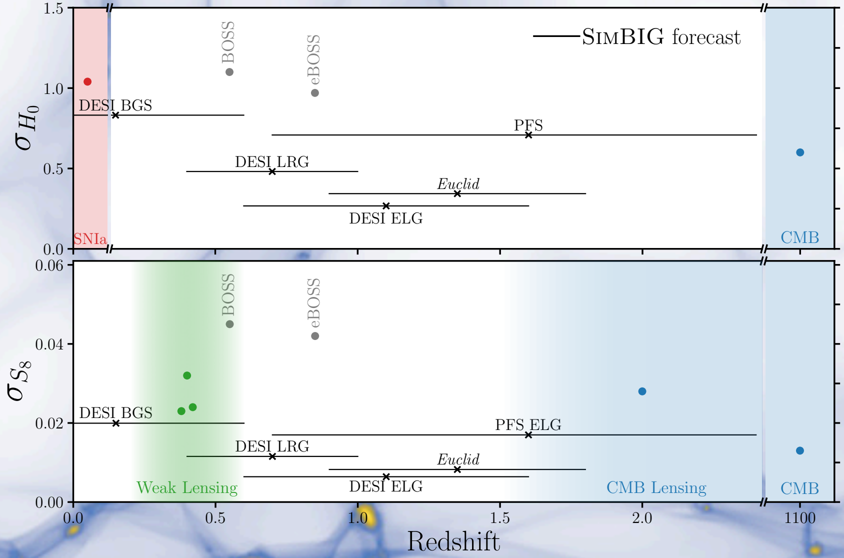
Simulation-based inference



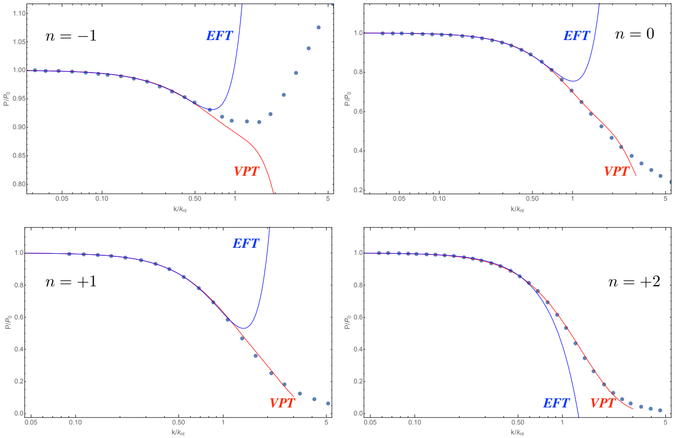


SimBig applied to subvolume of BOSS with 9-param HOD model 2310.15246

Simulation-based inference



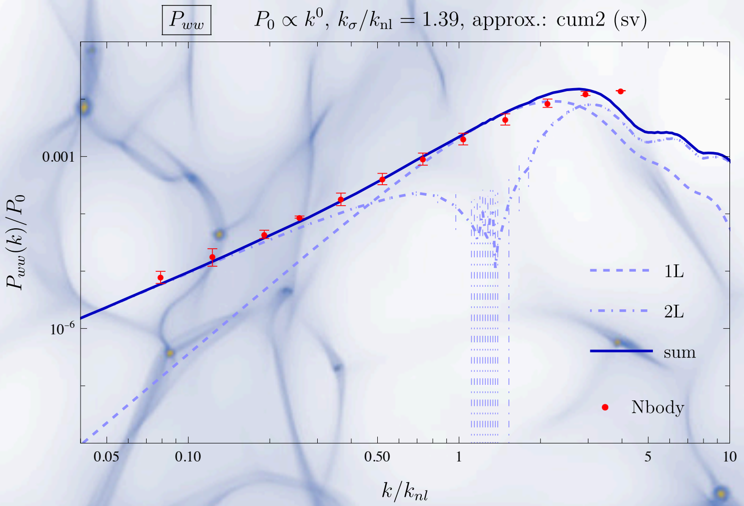
Vlasov-Poisson-PT (VPT) vs fluid+EFT



blue=EFT 2-param, red=VPT (1-param), points=N-body (for $n_s = -1, 0, 1, 2$)

MG, Laxhuber, Scoccimarro 2210.08089

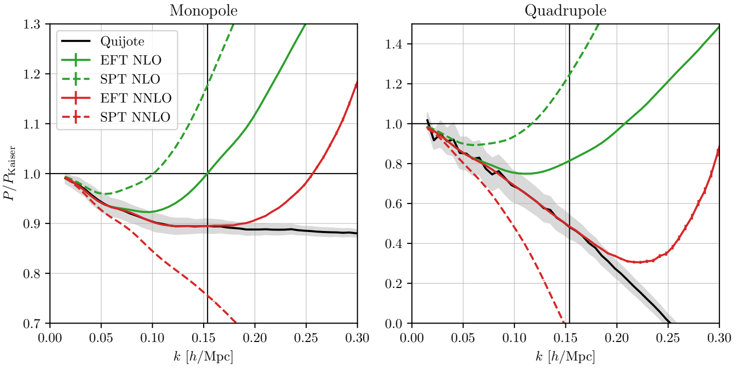
Vlasov-Poisson-PT (VPT) vs fluid+EFT



Vorticity $P_{ww} \propto k^2$ (not k^4). Need VPT and NNLO to get this in PT

MG, Laxhuber, Scoccimarro 2210.08089

Pushing to higher orders (ex: two-loop matter Pk + RSD)

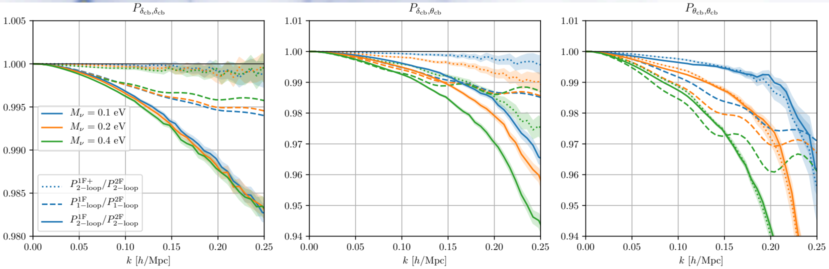


Taule, MG 2308.07379

and many other (bispectrum,...).

Higher order bias for galaxies needed...information gain on cosmo param?

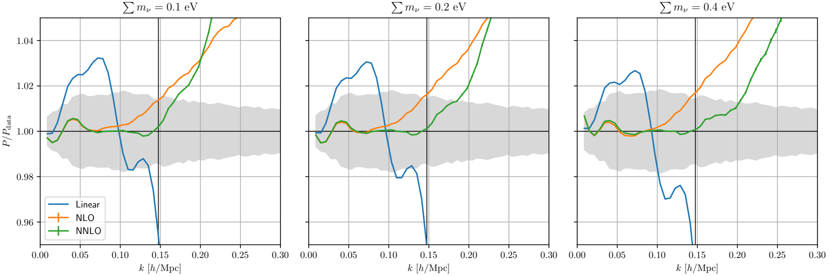
Beyond EdS kernels (here: for massive ν)



dashed = ratio "usual" EdS vs full $m_\nu\Lambda$CDM-kernels (for lin+1loop)
solid = ratio "usual" EdS vs full $m_\nu\Lambda$CDM kernels (for lin+1+2loop)
dotted = ratio ΛCDM vs full $m_\nu\Lambda$CDM kernels (for lin+1+2loop)

Taule, MG 2205.11533

Beyond EdS kernels (here: for massive ν)



ratio EFT vs Nbody (Quijote) at LO, NLO, NNLO and $\sum m_\nu = 0.1, 0.2, 0.3$eV

Taule, MG 2205.11533

theoretical challenges in LSS

some next steps

galaxy formation time

Donath, ML, Senatore 23

$$\delta_g(\vec{x},t)\big|_N = \sum_{n=1}^{N} \delta_g^{(n)}(\vec{x},t)$$

$$\delta_g^{(n)}(\vec{x},t) = \sum_{\mathcal{O}_m} \int^t dt' H(t') c_{\mathcal{O}_m}(t,t') \times \left[\mathcal{O}_m(\vec{x}_{\rm fl}(\vec{x},t,t'),t')\right]^{(n)}$$

$$\left[\mathcal{O}_m(\vec{x}_{\rm fl}(\vec{x},t,t'),t')\right]^{(n)} = \sum_{\alpha=1}^{n-m+1} \left(\frac{D(t')}{D(t)}\right)^{\alpha+m-1} \mathbb{C}^{(n)}_{\mathcal{O}_m,\alpha}(\vec{x},t)$$

$$\vec{x}_{\rm fl}(\vec{x},t,t') = \vec{x} + \int_t^{t'} \frac{dt''}{a(t'')} \vec{v}(\vec{x}_{\rm fl}(\vec{x},t,t''),t'')$$

$$\delta_g^{(n)}(\vec{x},t) = \sum_{\mathcal{O}_m} \sum_{\alpha=1}^{n-m+1} c_{\mathcal{O}_m,\alpha}(t)\, \mathbb{C}^{(n)}_{\mathcal{O}_m,\alpha}(\vec{x},t)$$

26 basis elements for local

29 basis elements for non-local

theoretical challenges in LSS

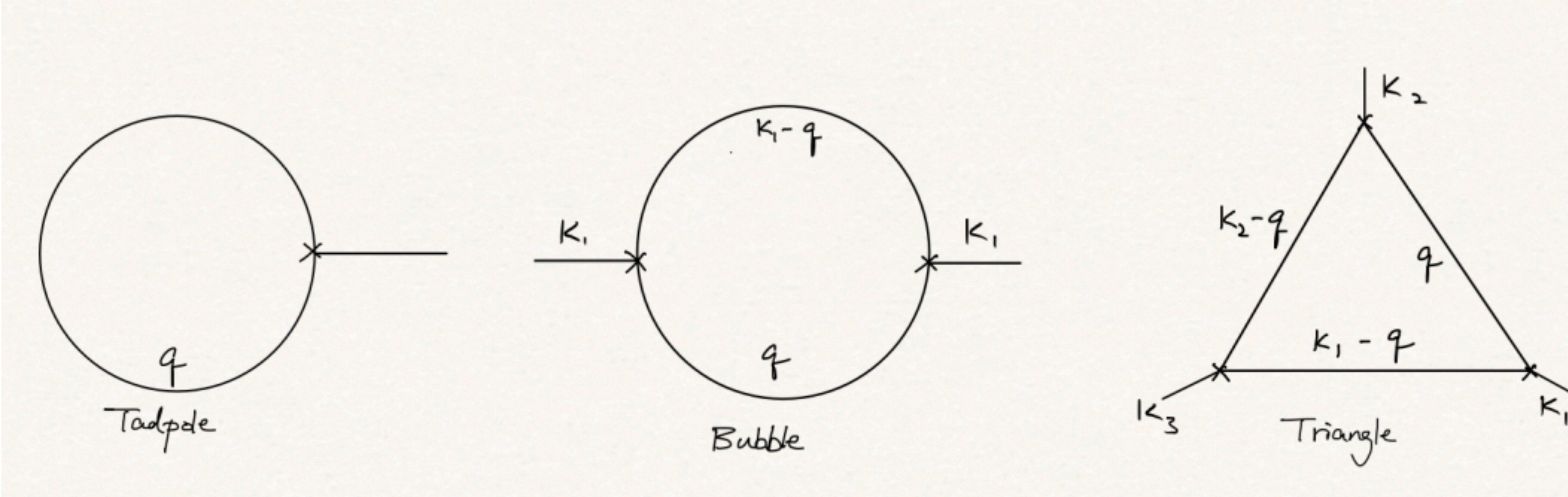
1-loop bispectrum integrals

some next steps

Anastasiou, Bragança, Senatore, Zheng 22

$$P_{\text{fit}}(k) = \frac{\alpha_0}{1+\frac{k^2}{k^2_{\text{UV},0}}} + \sum_{n=1}^{N-1} \alpha_n f(k^2, k^2_{\text{peak},n}, k^2_{\text{UV},n}, i_n, j_n) = \sum_{n=0}^{N-1} \alpha_n f_n(k^2)$$

$$f(k^2, k^2_{\text{peak}}, k^2_{\text{UV}}, i, j) \equiv \frac{\left(k^2/k_0^2\right)^i}{\left(1+\frac{(k^2-k^2_{\text{peak}})^2}{k^4_{\text{UV}}}\right)^j}$$



$$B_{\text{master}}(k^2, M_1, M_2) = \int \frac{d^3\boldsymbol{q}}{\pi^{3/2}} \frac{1}{(q^2+M_1)(|\boldsymbol{k}-\boldsymbol{q}|^2+M_2)}$$

$$T_{\text{master}}(k_1^2, k_2^2, k_3^2, M_1, M_2, M_3) = \int \frac{d^3\boldsymbol{q}}{\pi^{3/2}} \frac{1}{(q^2+M_1)(|\boldsymbol{k}_1-\boldsymbol{q}|^2+M_2)(|\boldsymbol{k}_2+\boldsymbol{q}|^2+M_3)}$$

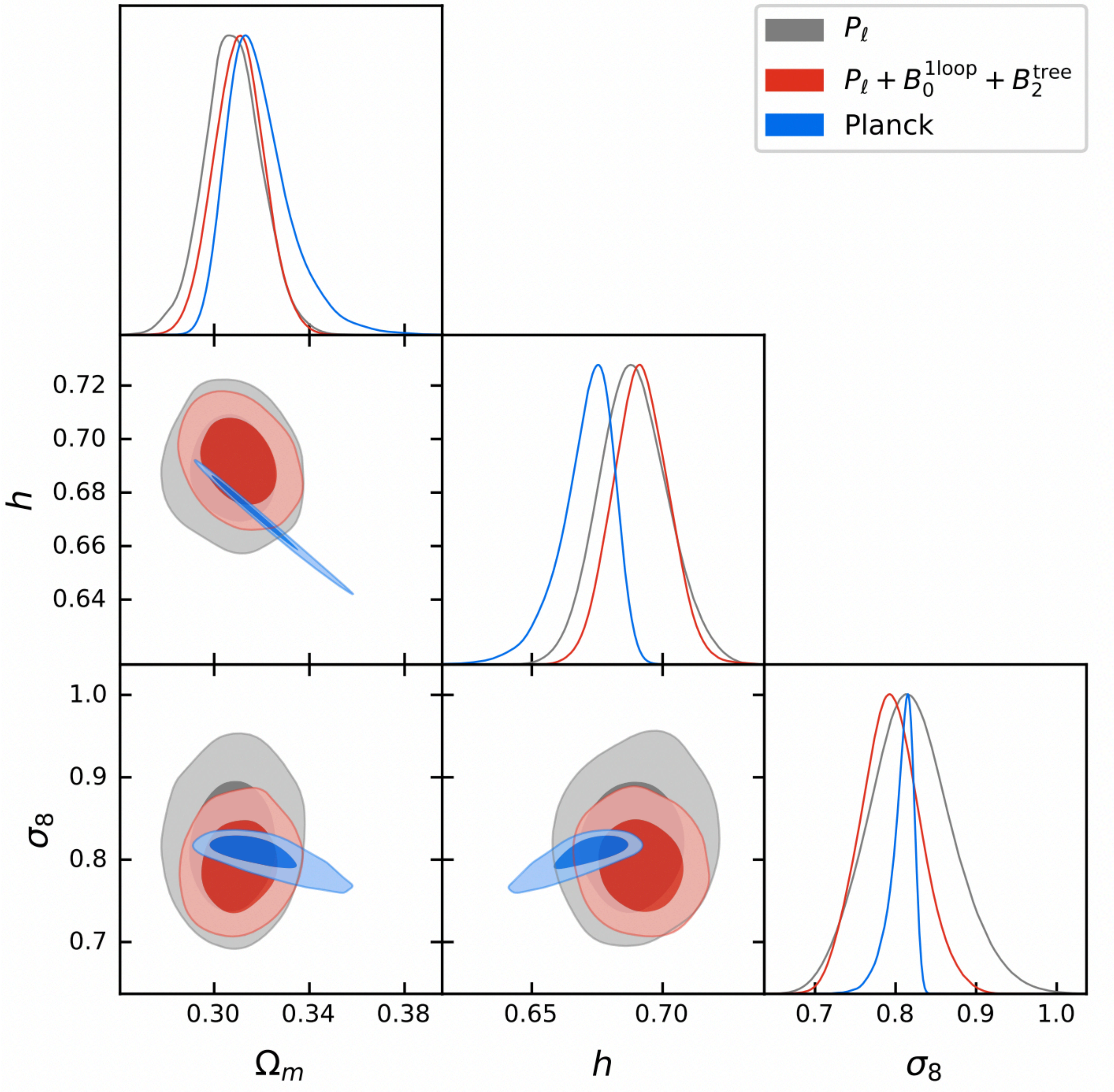
theoretical challenges in LSS

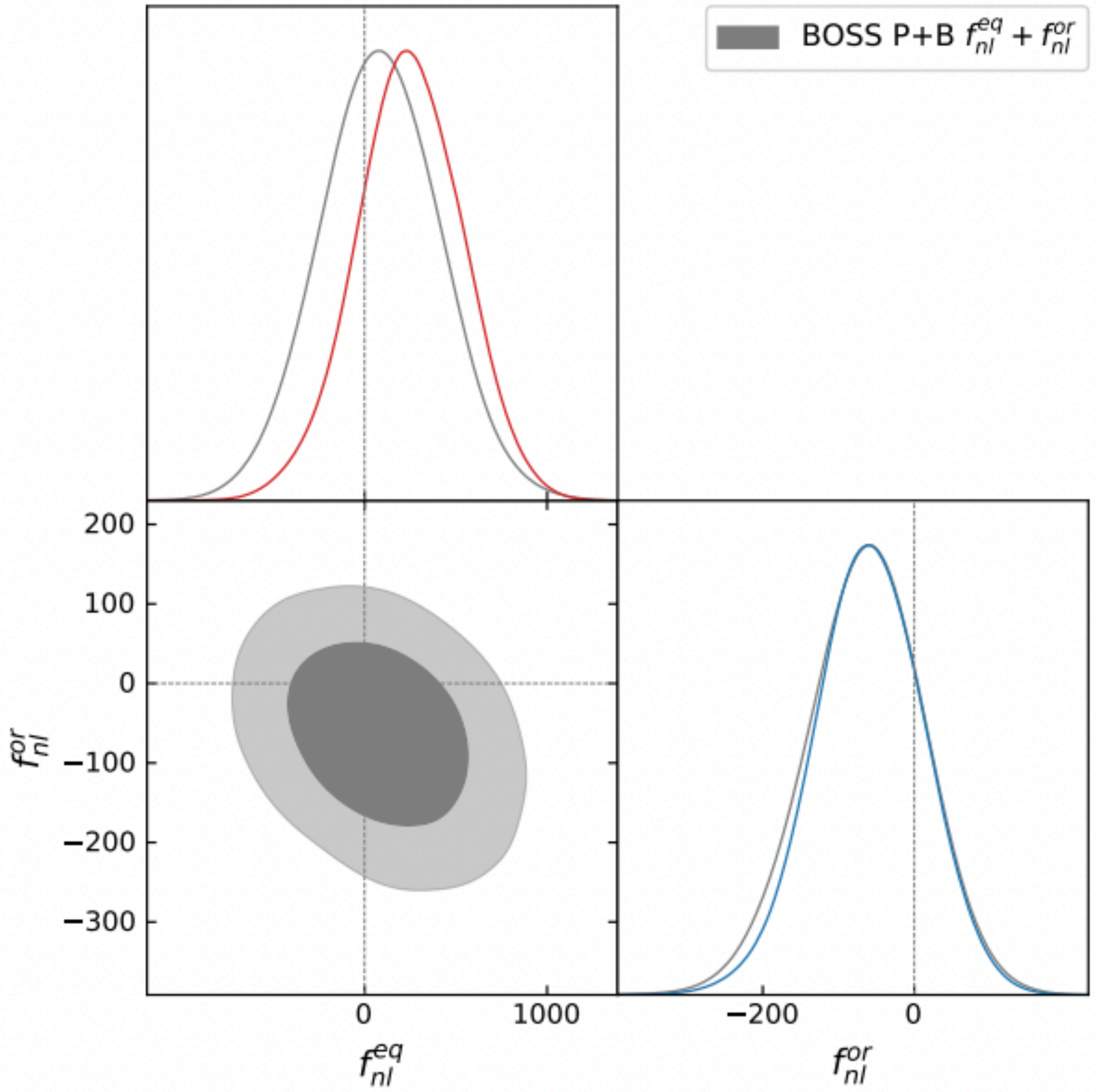
some next steps

1-loop bispectrum constraints

D'Amico, Donath, ML, Senatore, Zhang 22 (1)

D'Amico, ML, Senatore, Zhang 22





	BOSS
$f_{\rm NL}^{\rm equil.}$	245 ± 293
$f_{\rm NL}^{\rm orth.}$	-60 ± 72
$f_{\rm NL}^{\rm loc.}$	7 ± 31