LSS vs 5th Forces 2

Results from galaxy surveys

Based on Archidiacono, Castorina, Redigolo, Salvioni 2204.08484
Bottaro, Castorina, MC, Redigolo, Salvioni 2309.11496

Marco Costa (Perimeter Institute), 6 Nov 2023 New Physics from Galaxy Clustering 2

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LSS Observables

Galaxy Power Spectrum

$$P_g(\vec{k}, z) = \langle \delta_g(\vec{k}, z)\, \delta_g(-\vec{k}, z) \rangle$$

Galaxy over density : "Composite" Field

Fundamental fields:

$$\delta_m \equiv f_\chi \delta_\chi + (1 - f_\chi)\delta_b = \left(1 + \frac{6}{5}\beta f_\chi^2 \log(z_{\rm eq}/z)\right) D_{1m}^{\rm CDM}(z)\delta_0(k)$$

$$\delta_r \equiv \delta_\chi - \delta_b = \beta f_\chi D_{1m}^{\rm CDM}(z)\delta_0(k)$$

Negligible feature if

$f_\chi > \log z_{\rm eq}/z \simeq 1/8$

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Bias expansion: based on symmetries of theory

$$\delta_g = b_1\delta_m + b_r\delta_r + b_\theta\theta_r + \frac{b_2}{2}\delta_m^2 + b_s(K_{ij}\delta_m)^2 \ \ldots$$

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Example: tree level P_g real space

$$P_g \simeq b_1^2 P_{mm} \simeq b_1^2 \left(1 + \frac{12}{5}\beta f_\chi^2 \log(z_{\rm eq}/z)\right) P_m^{\rm CDM}(k)$$

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Computing Non-linearities

At non-linear level 5th forces symmetries = CDM symmetries at $\mathcal{O}(\beta \log)$ (if $f_\chi \gtrsim 1/8$)

- Can use existing pipeline as **PyBird** for **BOSS** P_g w. RSD and **FishLSS** for Fisher Forecast

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Sailer Castorina Ferraro White 21

- Use CLASS with 5fth Force (2204.08484) for P_m

(Thanks Pierre!)

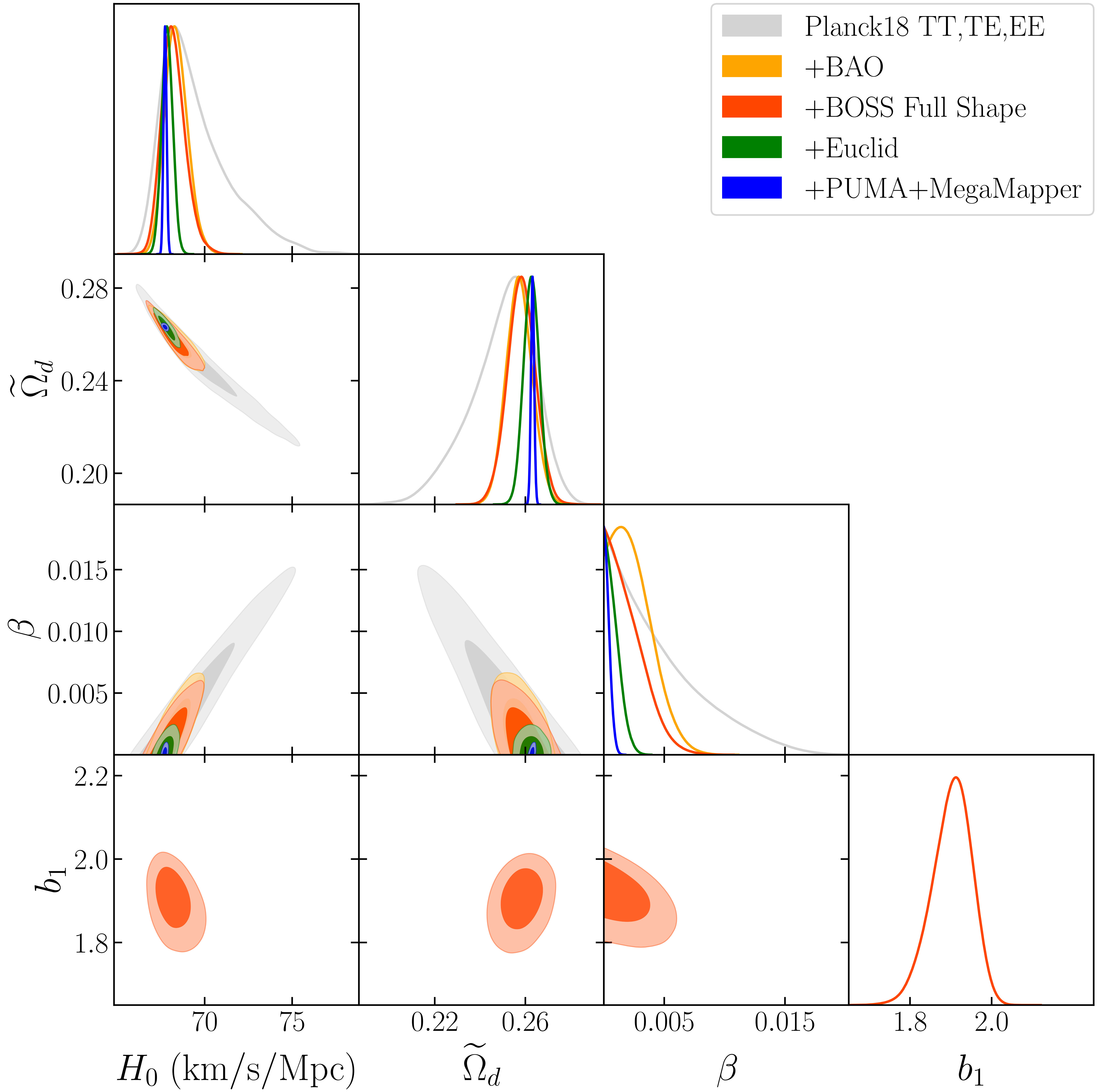
- (Also RSD kernel is the same at $\mathcal{O}(\beta \log)$!)

- 6 CDM pars + β +(CT, biases, SN)x z bin

Results

FS@1-loop+EFT, RSD

- **CMB only**: $\beta \lesssim 0.01$ @ 95%
- **+ BAO** (w.reco): $\beta \lesssim 5 \times 10^{-3}$
- **+ BOSS FS** no improvement: strong degeneracies between β, b
- Future surveys FS will improve bound!
  - **+Euclid**: $\beta \lesssim 2 \times 10^{-3}$
  - **+ PUMA+MM**: $\beta \lesssim \times 10^{-3}$

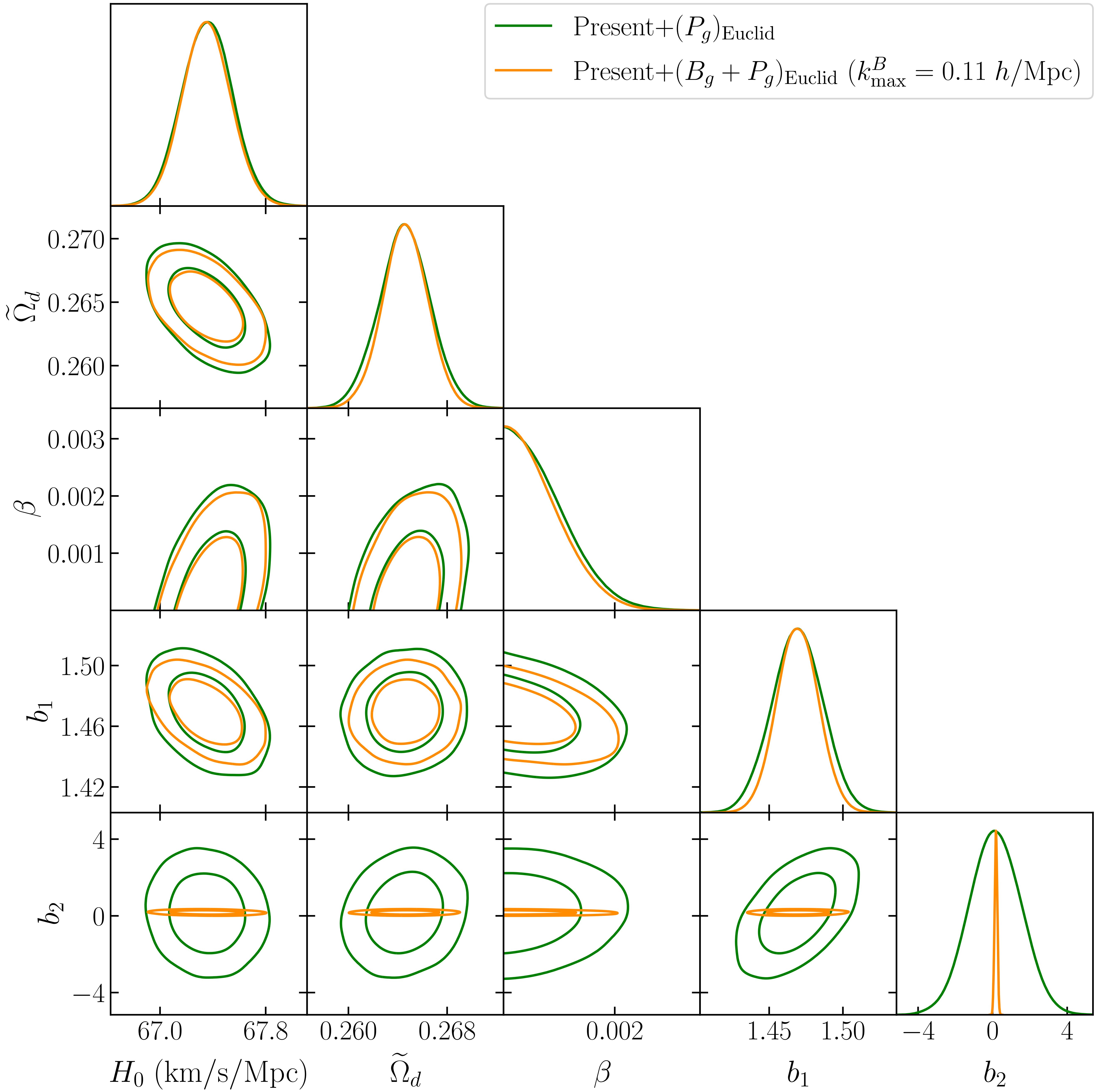


Bispectrum

Real Space, Tree level

$$B_g(k_1, k_2, k_3) = \langle \delta_g(k_1)\ \delta_g(k_2)\delta_g(k_3) \rangle$$

- Potentially more modes!
- For linear modes, improve only NL bias



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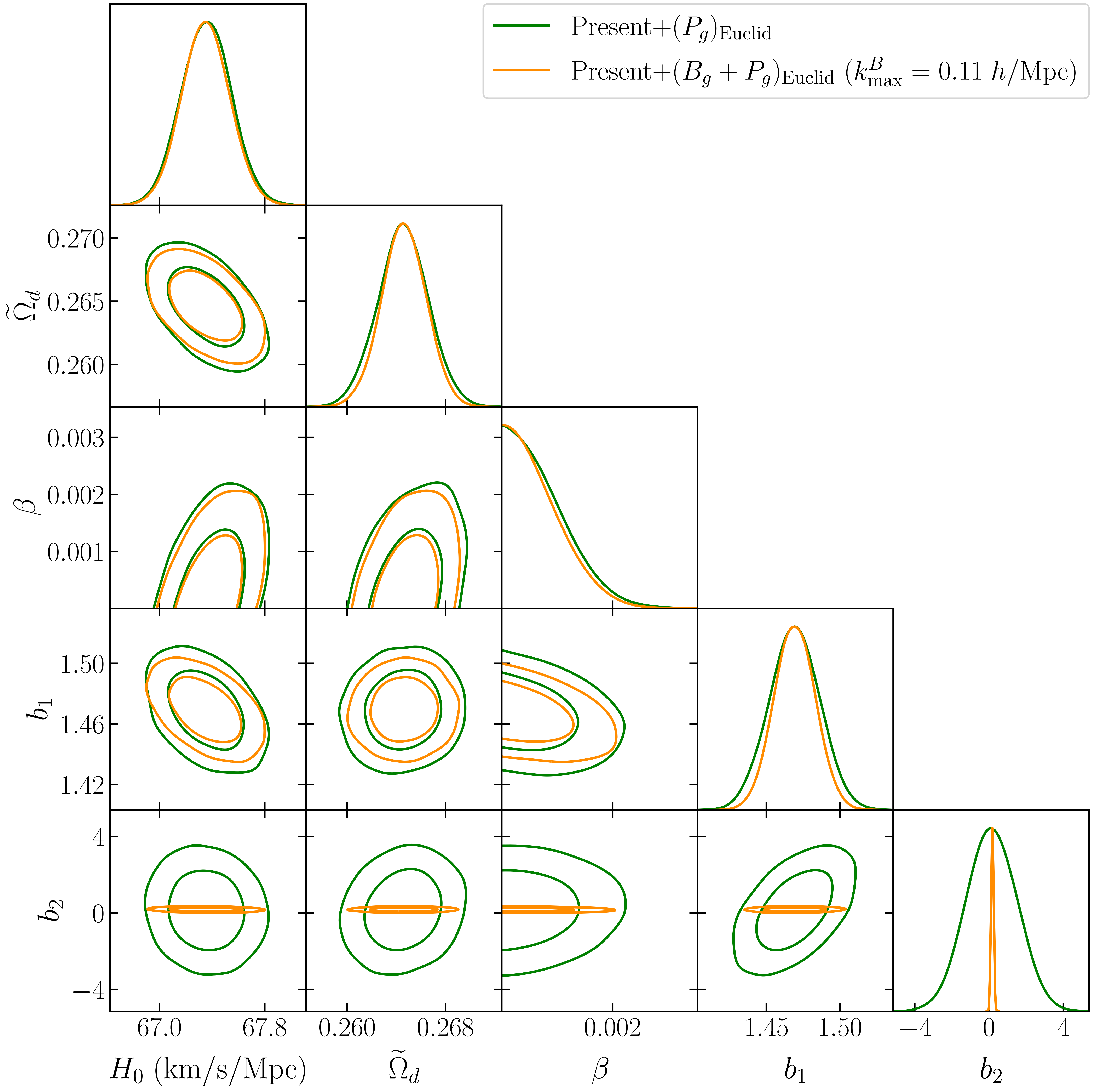
- For linear modes, improve only NL bias
- Violation of EP: squeezed limit pole (different infall rate in long mode bkg):

$$\left. \frac{B_g^{AAB}(\vec{p}, \vec{p}_1, \vec{p}_2)}{P^{\rm CDM}(p)^{\rm CDM}(p_1)} \right|_{p\to 0} \sim \beta f_\chi \frac{\vec{p}\cdot\vec{p}_1}{p^2} \Delta b^{AB}$$

- Still subleading for $f_\chi \sim 1$...



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Conclusions

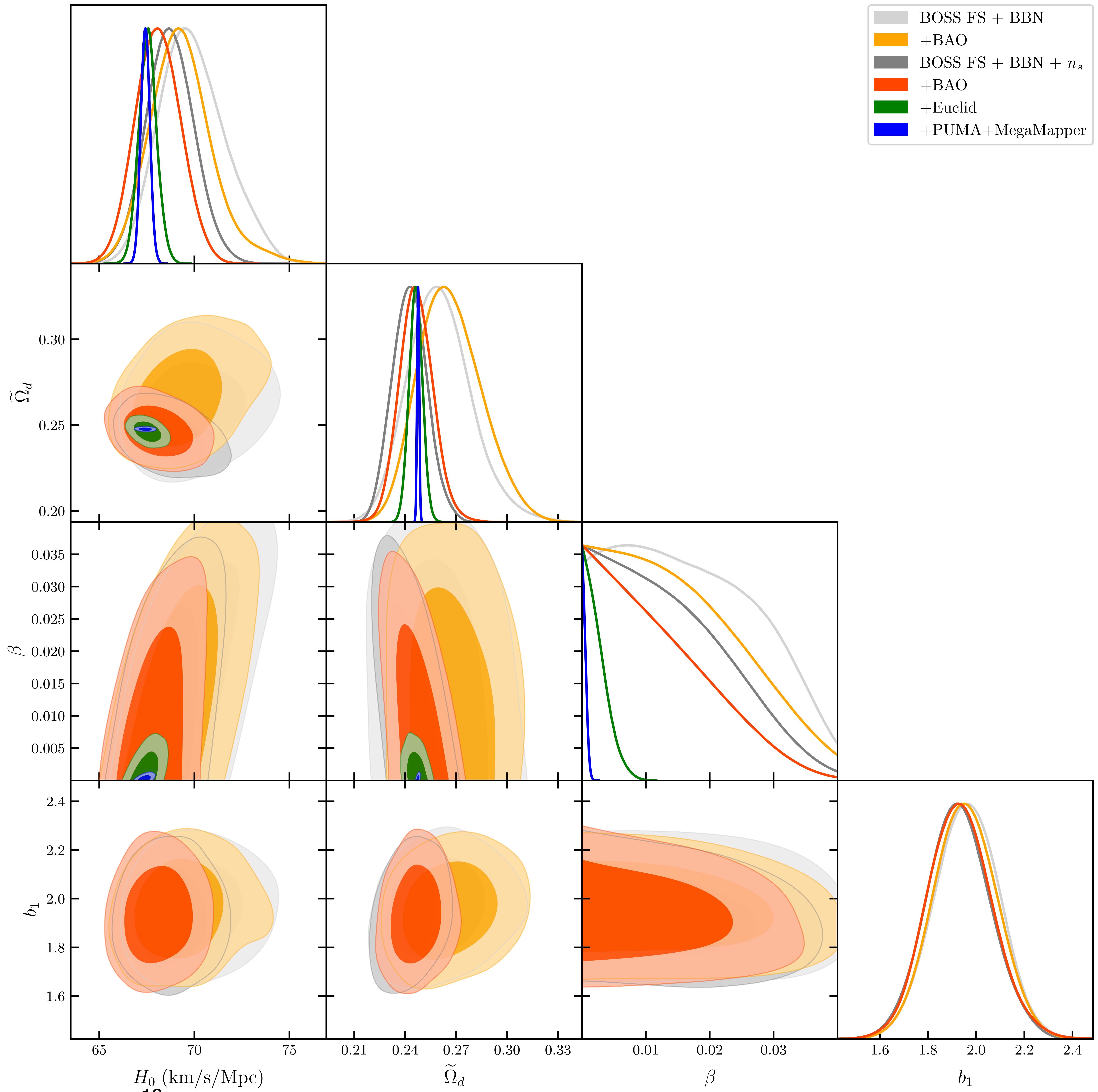
- Future galaxy surveys offer useful observables as P_g, B_g
- **Structure of 5th Force = CDM** at $\mathcal{O}(\beta \log)$ for $f_\chi \gtrsim 1/8$
- **BOSS FS**: no improvement over $\beta < 5 \times 10^{-3}$ (**CMB+BAO**)
- + **Euclid FS**: $\beta \lesssim 2 \times 10^{-3}$, + **PUMA+MegaMapper FS**: $\beta \lesssim 10^{-3}$
- **Bispectrum**: no improvement on cosmo pars @ tree lvl, better measurement of non-linear biases. Potentially interesting pole structure for multitracers.

Thanks for the attention!

Backup

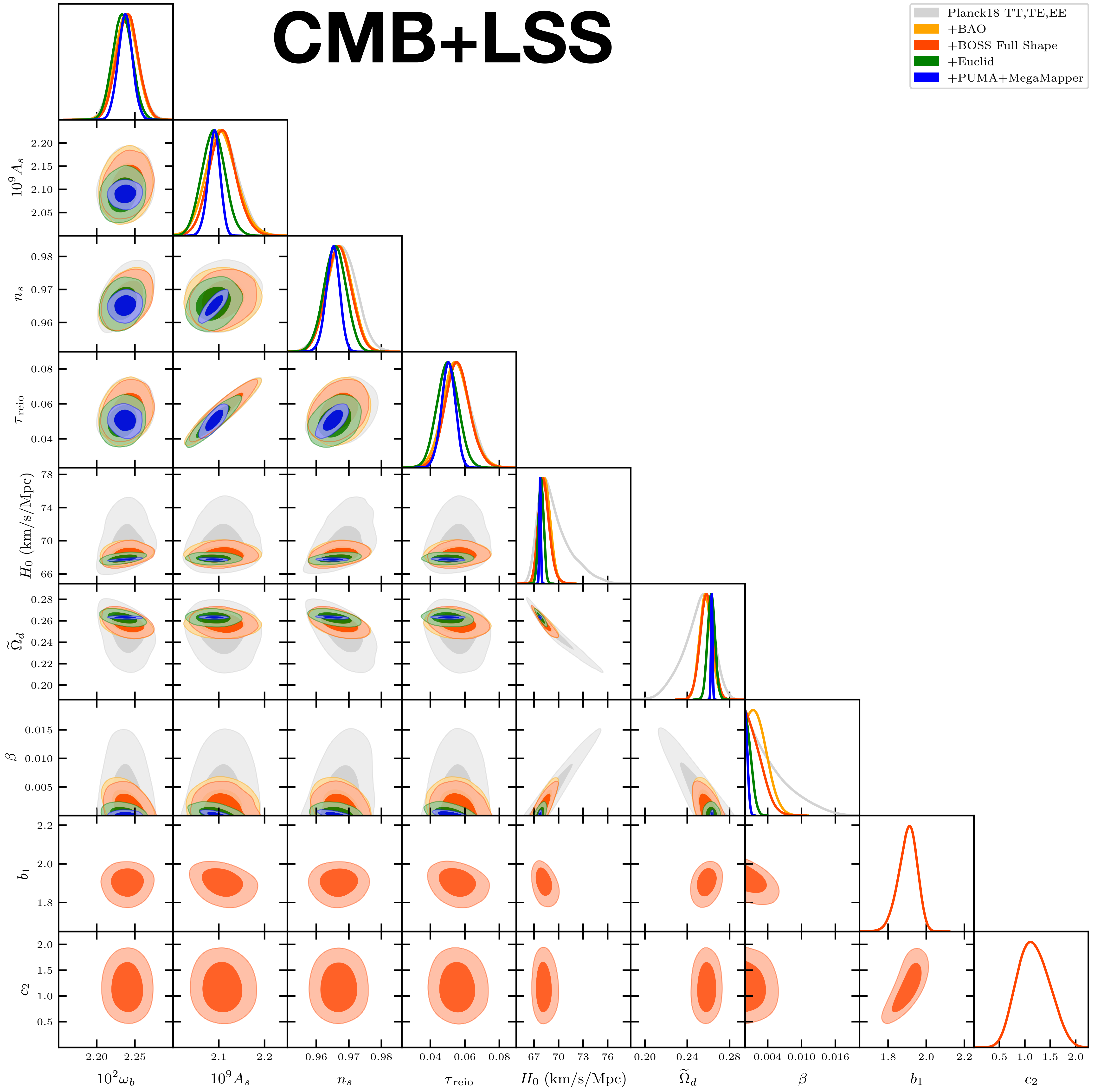
LSS only results

- BOSS FS + BAO with no n_s prior comparable with CMB alone bound

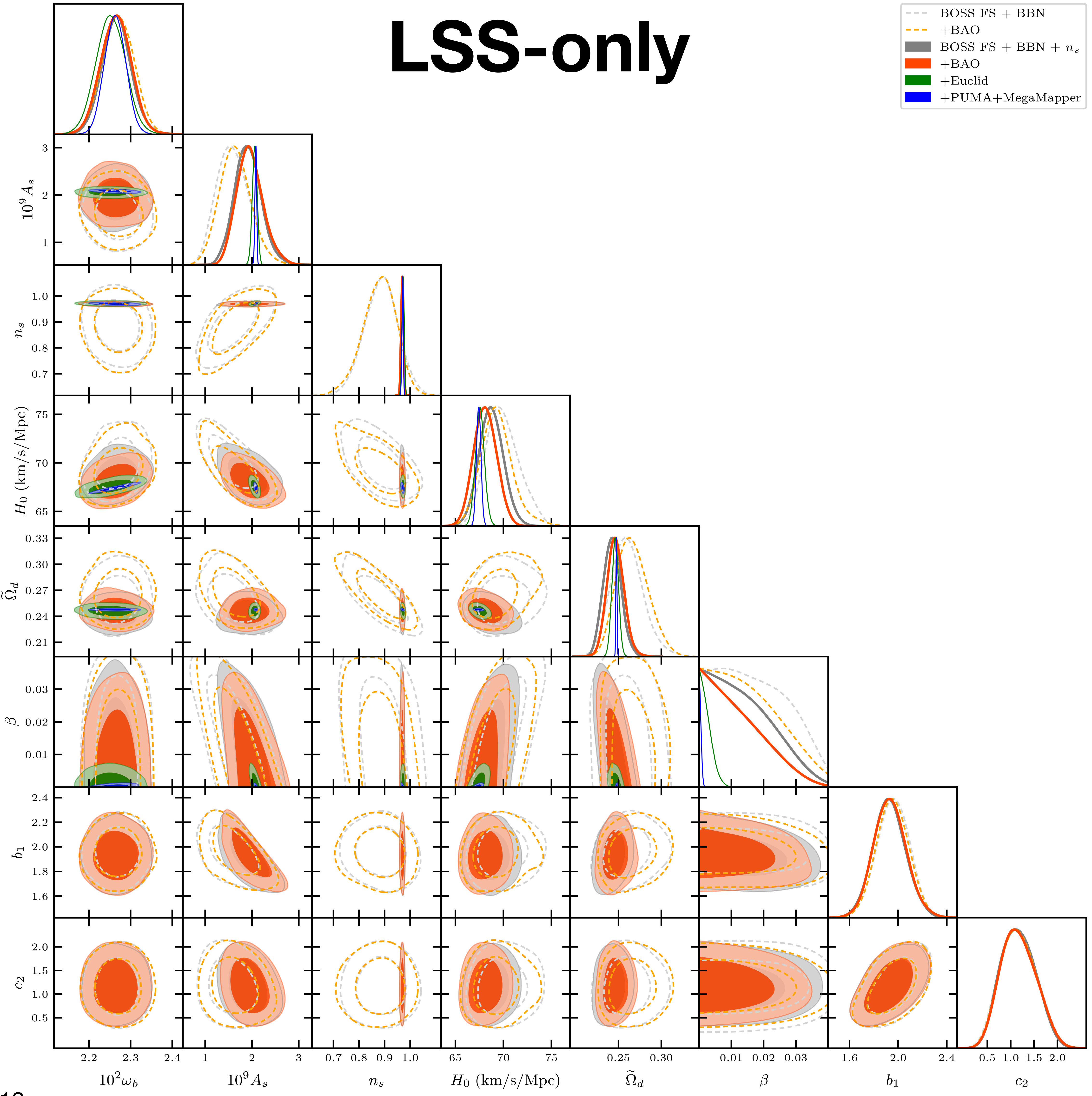


Full results

CMB+LSS

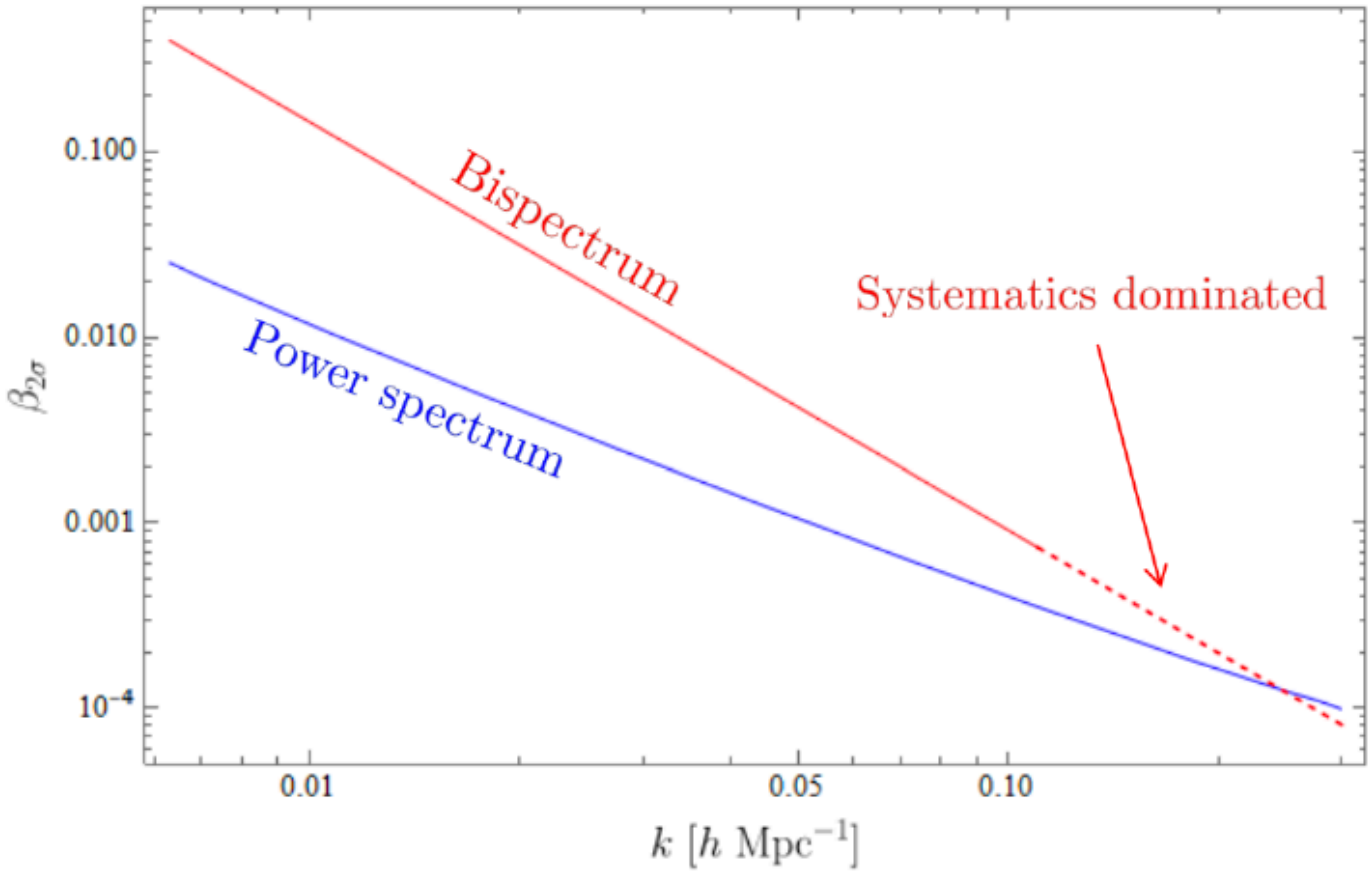


LSS-only



1D analytic estimates

- $\beta_{2\sigma,P} \propto (k_{\rm min}/k_{\rm max})^{1.5}$
- $\beta_{2\sigma,B} \propto (k_{\rm min}/k_{\rm max})^{2.2}$
- $B_g \sim P_g$ when $k_{\rm max} \gtrsim 0.2h/{\rm Mpc}$
: need 1-loop computation!



Estimated fraction bounds