Power spectrum and bispectrum joint fits for Stage-IV surveys

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Stage-IV spectroscopic surveys

Mapping the Universe over unprecedented volumes $\longrightarrow$ high precision measurements

- Need **fast** and **accurate** tools
- Robust validation on simulations/synthetic datavectors
- Modelling/understanding **systematics** is crucial (*both theoretical AND observational!*)

PBJ: *A joint likelihood pipeline for galaxy power spectrum + bispectrum*

- EFT model for power spectrum $\longrightarrow$ **ported to Euclid likelihood CLOE**
  - FastPT for fast loop corrections
  - Emulators for P_L (or Boltzmann solver)
  - wiggle-nowiggle decomposition for infra-red resummation
- Tree level bispectrum
- Beyond ΛCDM: massive neutrinos, w_0, w_a, γ, nDGP, dark scattering

PBJ: *A joint likelihood pipeline for galaxy power spectrum + bispectrum*

- Fully in python
- Extremely fast: P_{gg} evaluation in ~ 0.04s, B_{ggg} in ~ 0.1s
  - Euclid-like datavector: convergence in $\mathcal{O}(10)$ cpu hours
- Analytic marginalisation for nuisance parameters
- Option to run in fast mode when cosmology is fixed
- Several samplers: Metropolis-Hastings, affine invariant (`emcee`), nested (`ultranest`), ML powered (`pocomc`, `nautilus`)

see also PyBird, CLASS-PT, Comet, Velocileptor, FOLPSν, CLASS-OneLoop

Power spectrum model

EFTofLSS [Baumann+10, Carrasco+12, Pietroni+11]

$$P_{gg}(\vec{k}) = Z_1^2(\vec{k})P_L(k) + 2\int d^3q Z_2^2(\vec{q}, \vec{k}-\vec{q})P_L(q)P_L(|\vec{k}-\vec{q}|)+$$

$$6Z_1(\vec{k})P_L(k)\int d^3q Z_3(\vec{k}, \vec{q}, -\vec{q})P_L(q) +$$

$$\left[\tilde{c}_0 + \tilde{c}_2\ f\ \mu^2 + \tilde{c}_4\ f^2\ \mu^4\right]\ k^2 P_L(k) + c_{\nabla^4\delta}\ f^4\ \mu^4\ Z_1(\vec{k})\ k^4\ P_L(k)+$$

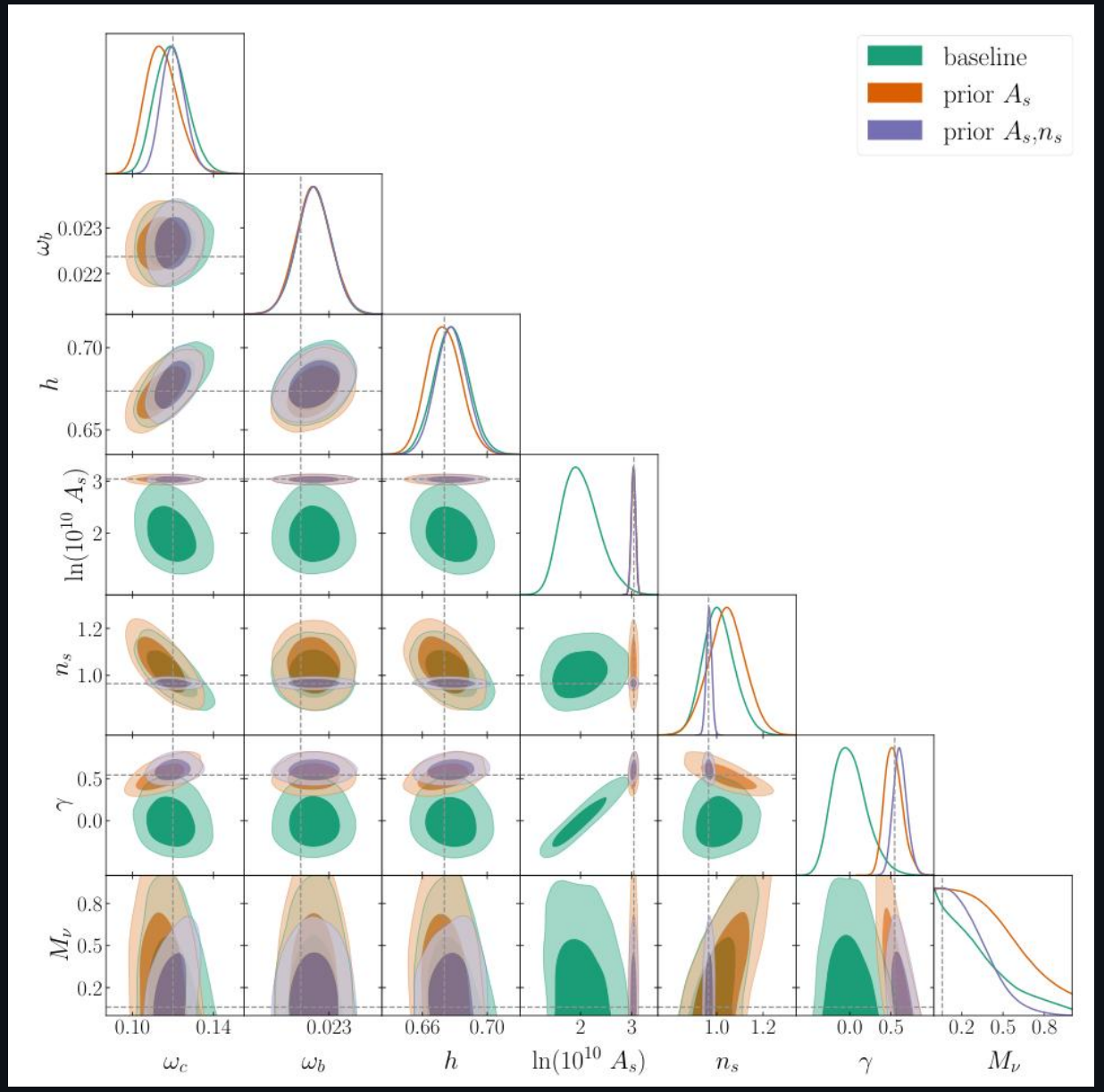
$$\frac{1}{\bar{n}}\left[(1+\alpha_P) + \epsilon_{0,k^2}\ k^2 + \epsilon_{2,k^2}\ k^2\ \mu^2\right]$$

11 nuisance parameters + cosmology: $\{b_1, b_2, b_{\mathcal{G}_2}, b_{\Gamma_3}\ c_0, c_2, c_4, c_{k^4}, \alpha_P, \epsilon_0, \epsilon_2\}$ *x N redshift bins* $+\ \{\omega_c, \omega_b, h, A_s, n_s, \dots\}$

BOSS analysis: growth index and massive neutrinos

[Moretti+23, 2306.09275]

- constraints on γ + M_ν from full shape
- forecasts for Stage-IV surveys
- profile likelihood to mitigate projection/prior volume effects

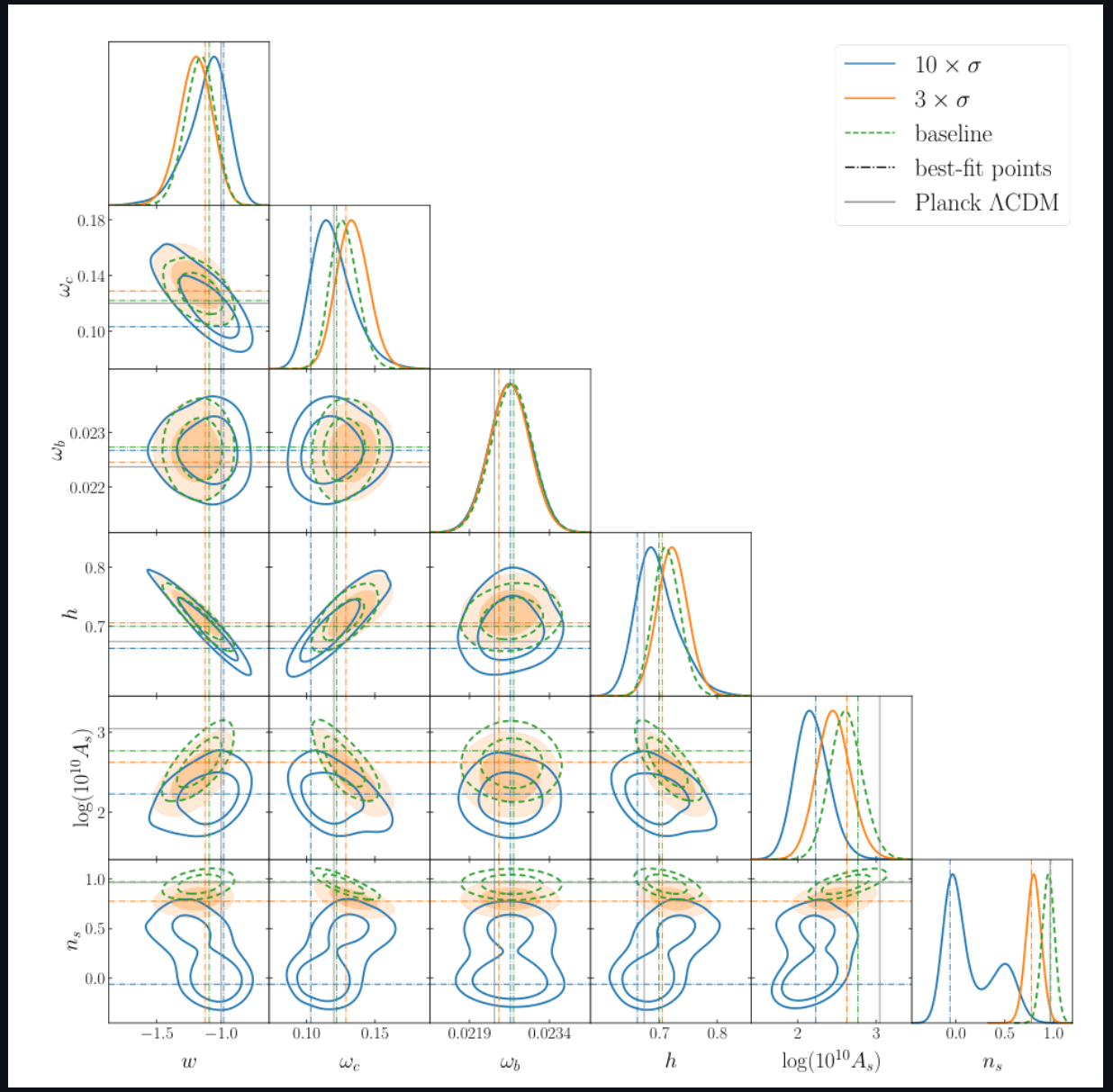


BOSS analysis: Dark Scattering

Model: momentum exchange between DM and DE

BOSS analysis: [Carrilho+23, 2207.14784]

- constraints on w + A
- **priors on nuisance params matter! projections**



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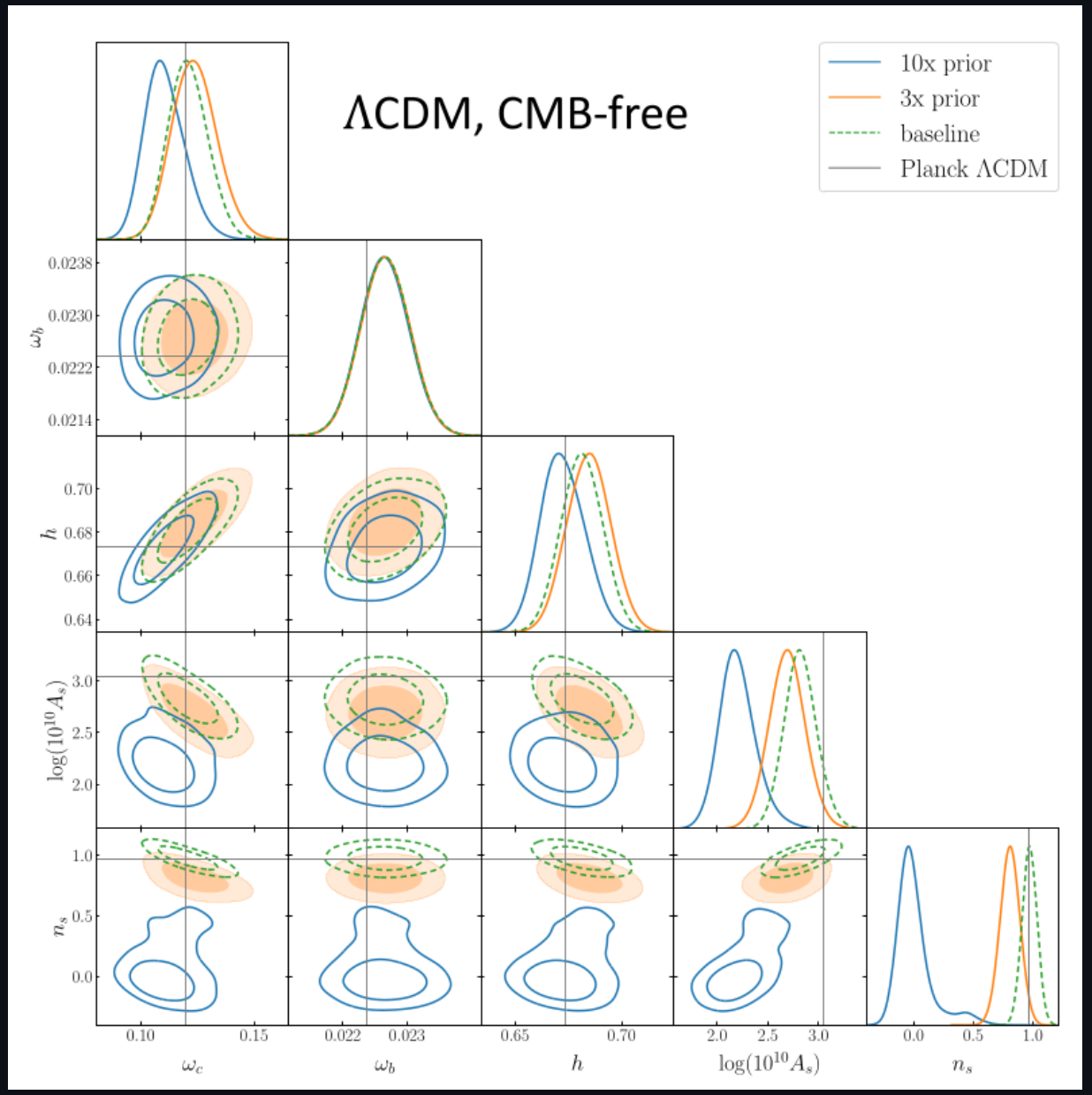


Euclid: Updated forecasts

a.k.a. projection/prior volume effects

[Moretti+, in prep]

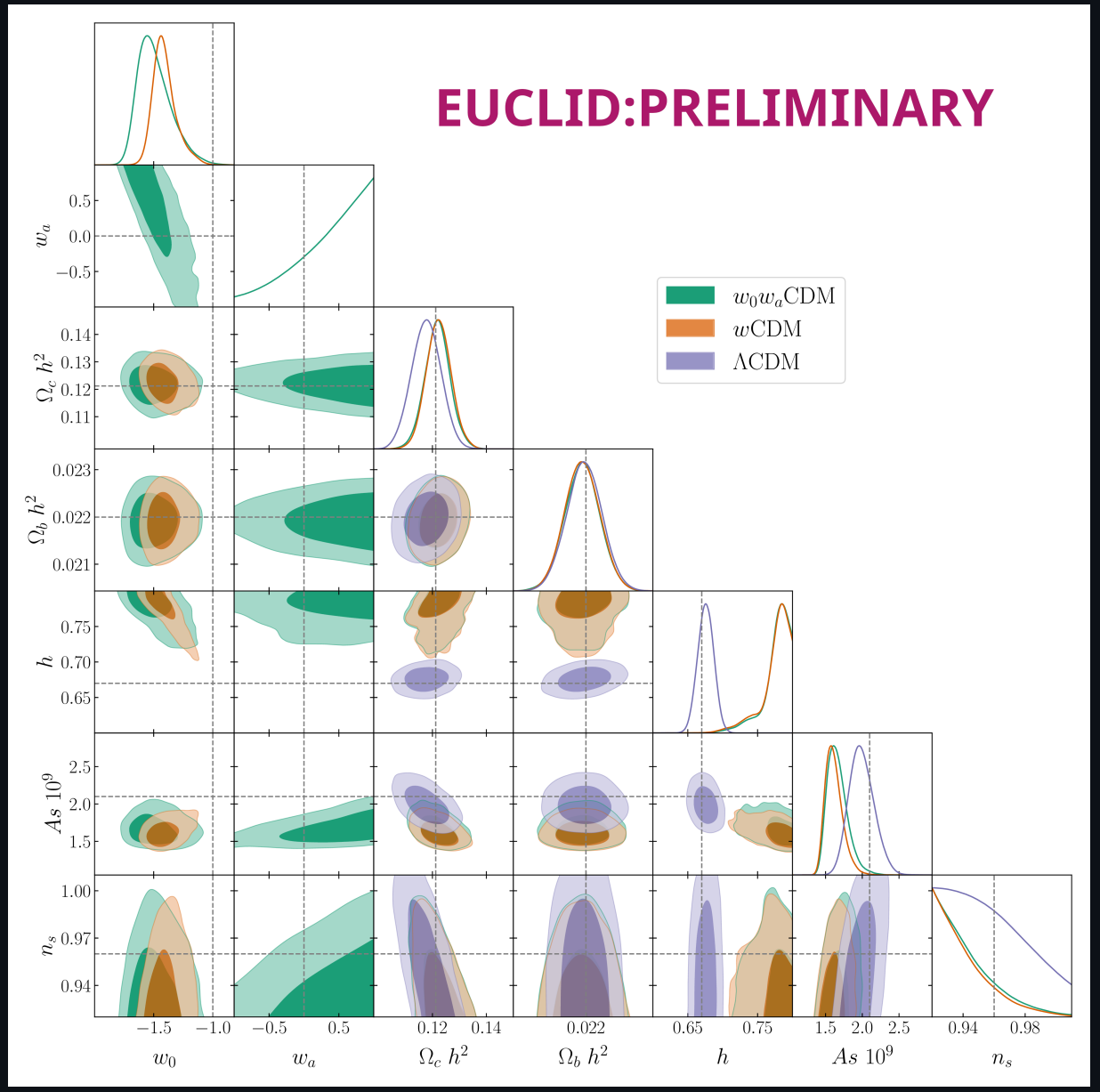
- Due to strong degeneracies in parameter space
- Already there for ΛCDM, become a real issue for extended models
- Still under investigation

Euclid: Updated forecasts

a.k.a. projection/prior volume effects

[Moretti+, in prep]

- fix priors → trust simulations
- different model? bacco, VDG...
- profile likelihood (not Bayesian...) / Jeffrey's priors
- more data / probes → combine consistently



Euclid: Updated forecasts

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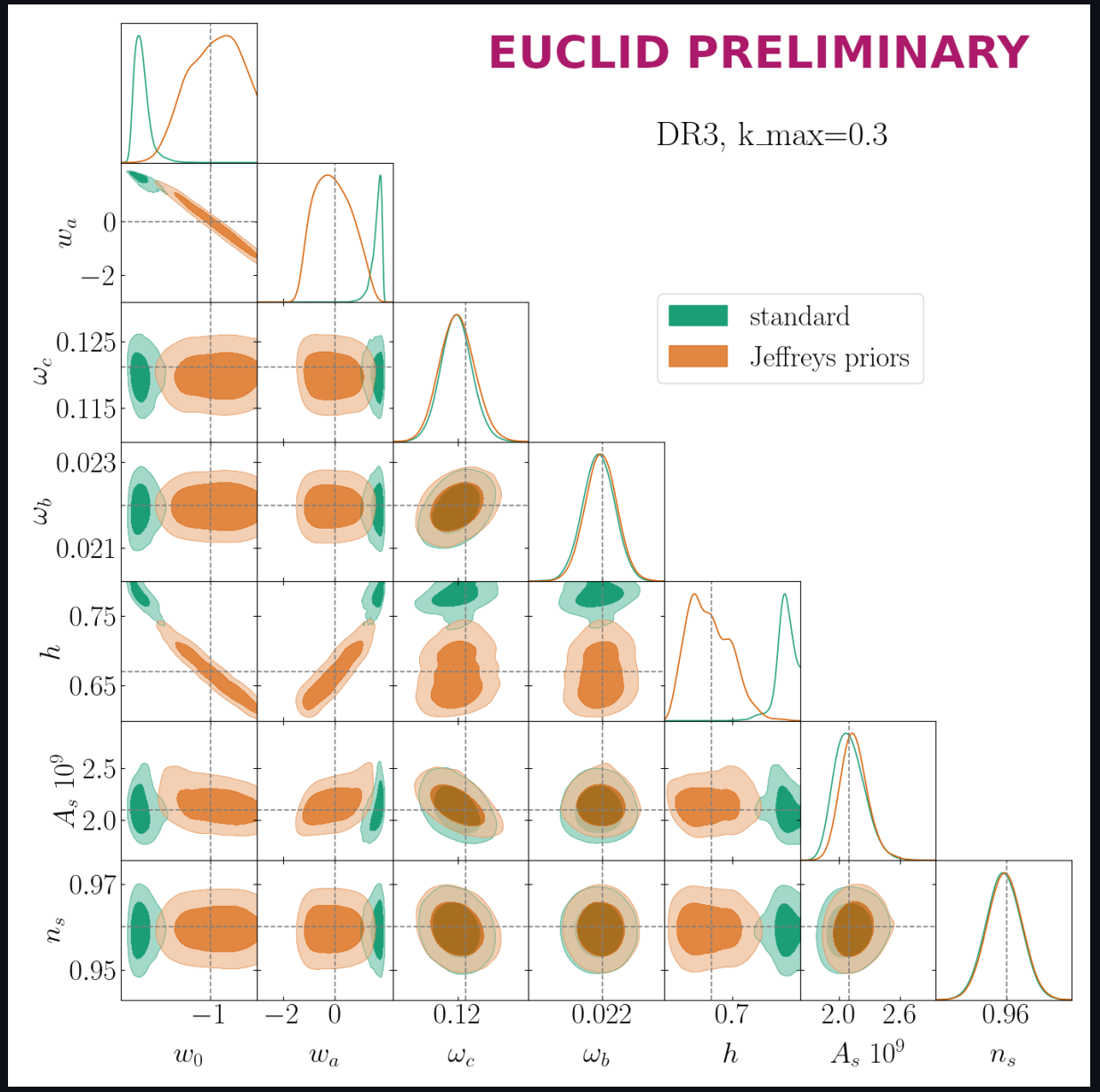
Jeffrey's priors on *linear* parameters (equivalent to profile likelihood)



Work in progress

BAO joint analysis [with Elena Sarpa]

Combine full shape and post-reconstruction BAO

- Non-linearities are removed at the catalog level
- Modelling focused on BAO scales
- 3 nuisance parameters + 2 physical:
  - $\{\Sigma_\parallel, \Sigma_\perp, \beta\}$ + $\{\alpha_\parallel, \alpha_\perp\}$ + broadband polynomial
- less parameters $\rightarrow$ tighter constraints (up to 30% improvement in configuration space fits)

Limited to ΛCDM!; Does not constrain cosmological params directly

Summary

- PBJ: a ⚡ fast pipeline to analyse P+B from spectroscopic surveys
- Robust validation on simulations + applied to BOSS data
- Beyond-ΛCDM modeling: massive neutrinos, growth index, nDGP, dark scattering
- WIP: **BAOs** (Elena Sarpa, Cecilia Oliveri), **massive neutrinos** (Emilio Bellini, Francesco Verdiani), **window convolution** (Jacopo Salvalaggio, Yousry Elkhashab), **Euclid forecasts** (IST:nonlinear team), **fits for beyond-ΛCDM** (Guido d'Amico), **interlopers** (Matilde Barberi Squarotti, Sujeong Lee)

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