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Cosmology with the Euclid galaxy bispectrum

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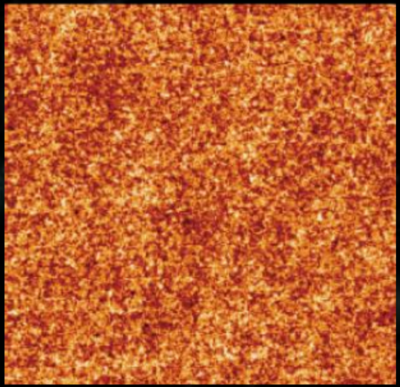
Outline

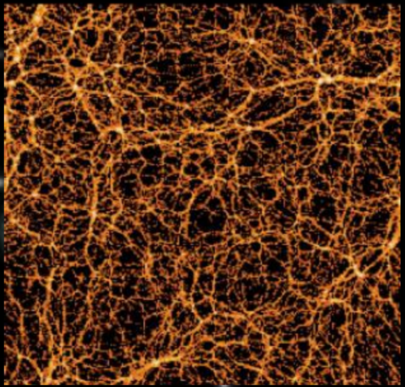
- Introduction
- Aim of the work
- Power Spectrum and Bispectrum
- Fisher-matrix formalism and Covariance matrix
- Results
- Conclusions

ESA's Euclid mission

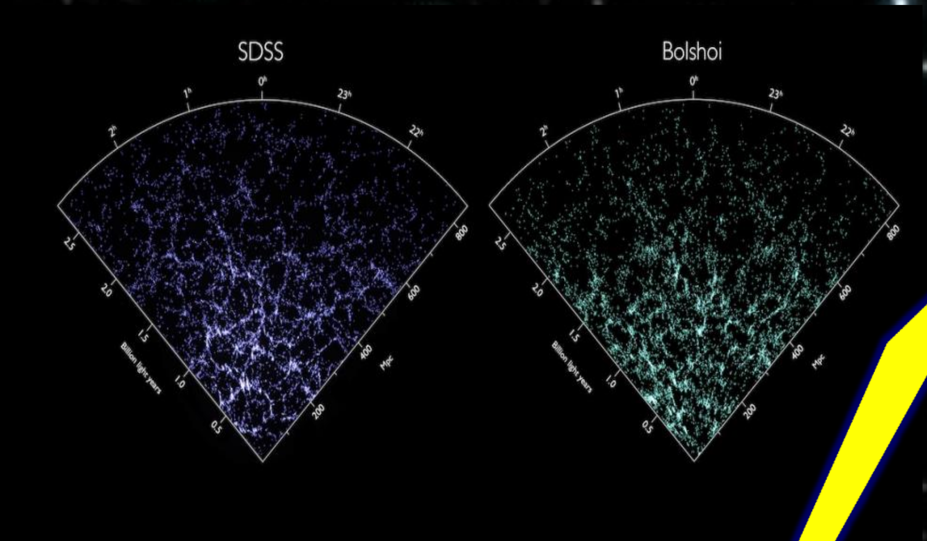
WP
Higher-Order statistics



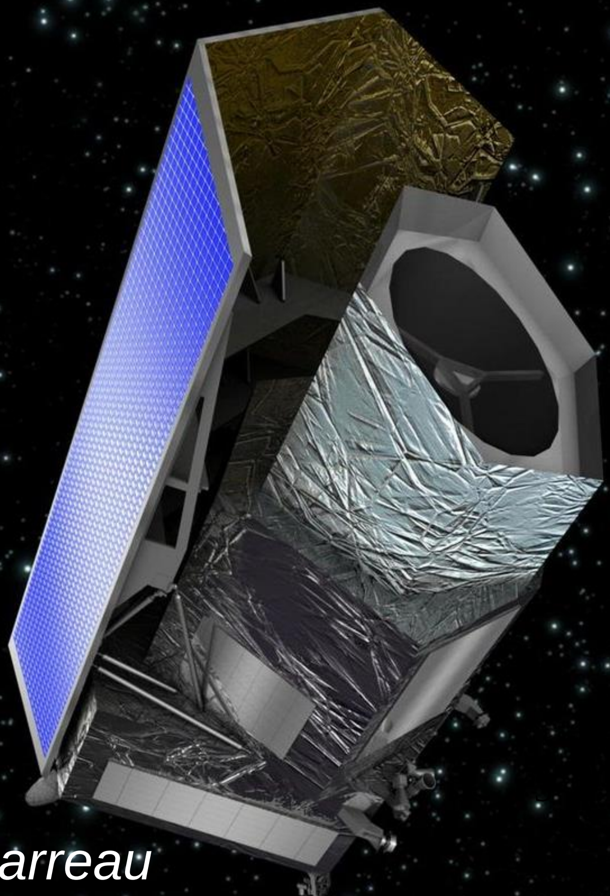
$$B(k_1,k_2,k_3)=0$$



$$B(k_1,k_2,k_3)\neq 0$$



Galaxy bias



Euclid. *Credit: ESA/C. Carreau*

Aim of the work

Make forecasts for the cosmological parameters for Euclid data

$$\Lambda\text{CDM model}: \ \Omega_m, \Omega_b, \ n, \ h, \ A, \sigma_p, b_1, b_2, b_{s^2}$$

$$\text{wCDM model}: \ w, \Omega_m, \Omega_b, \ n, \ h, \ A, \sigma_p, b_1, b_2, b_{s^2}$$

$$w_0 w_a\text{CDM model}: \ w_0, w_a, \Omega_m, \Omega_b, \ n, \ h, \ A, \sigma_p, b_1, b_2, b_{s^2}$$

Perturbation theory (leading order)

Advantages of the combination of the power spectrum and the bispectrum in comparison with a single probe

Power Spectrum

$$P(\mathbf{k},\mu) = Z_1^2(\mathbf{k},\mu) P_0(k) e^{-(k\mu\sigma_p)^2},$$

$$Z_1(\mathbf{k},\mu) = b_1 + f\mu^2, \qquad \mu = \frac{k_z}{\mathbf{k}}$$

Bispectrum

$$B(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3,\mu_1,\varphi) =$$

$$2\left[Z_2(\mathbf{k}_1,\mathbf{k}_2) Z_1(\mathbf{k}_1,\mu_1) Z_1(\mathbf{k}_2,\mu_2) P(k_1) P(k_2) + \text{cyc}\right]\cdot$$

$$\cdot \exp\left[-(k_1^2\mu_1^2 + k_2^2\mu_2^2 + k_3^2\mu_3^2)\sigma_p^2\right]$$

Galaxy bias parameters:

b_1 – linear, b_2 non-linear, b_{s^2} – tidal bias

Fisher Matrix

$$F_{\alpha\beta} = \sum_{\mathbf{k}}^{\mathbf{k}_{max}} \sum_{\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3}^{\mathbf{k}_{max}} \frac{\partial^t \mathbf{S}}{\partial x_\alpha} C^{-1} \frac{\partial \mathbf{S}}{\partial x_\beta} \qquad \mathbf{S} = \begin{pmatrix} P(\mathbf{k}) \\ B(\mathbf{k}_1,\mathbf{k}_2,\mathbf{k}_3) \end{pmatrix}$$

$$\alpha,\beta : \Omega_m, \Omega_b, n, h, A, \sigma_p, b_1, b_2, b_{s^2}, w, w_0, w_a, f$$

$$C_{PP} \qquad\qquad C_{BB}$$

$$\mathbf{C}(\mathrm{diag}) = \begin{pmatrix} C_{PP} & 0 \\ 0 & C_{BB} \end{pmatrix} \qquad \mathbf{C} = \begin{pmatrix} C_{PP} & C_{PB} \\ C_{BP} & C_{BB} \end{pmatrix}$$

Covariance matrix

$$C_{PP} = \frac{4\pi}{V_s k^2 \Delta k \Delta\mu} \tilde{P}^2(k) \qquad \tilde{P}(k) = \left[Z_1^2(k,\mu) P(k) + n_g^{-1} \right]$$

$$C_{BB} = S_B \frac{8\pi^4}{V_s k_1 k_2 k_3 (\Delta k)^3 \Delta\mu \Delta\varphi} \tilde{P}_1(k) \tilde{P}_2(k) \tilde{P}_3(k)$$

$$C_{PB} = S_{PB} \frac{4\pi}{V_s k^2 \Delta k \Delta\mu} \tilde{P}(k) \tilde{B}\left(\mathbf{k}_1, \mathbf{k}_2, \mathbf{k}_3, \mu_1, \varphi\right)$$

$$\tilde{B} = B + \left[P(k_1) + P(k_2) + P(k_3) \right] / n_g + n_g^{-2}$$

Results:

$$\mathbf{k}_{max} = 0.15\, h\, Mpc^{-1}$$

$$k_F = \frac{2\pi}{\sqrt[3]{V_s}}$$

$$\Delta k = k_F$$

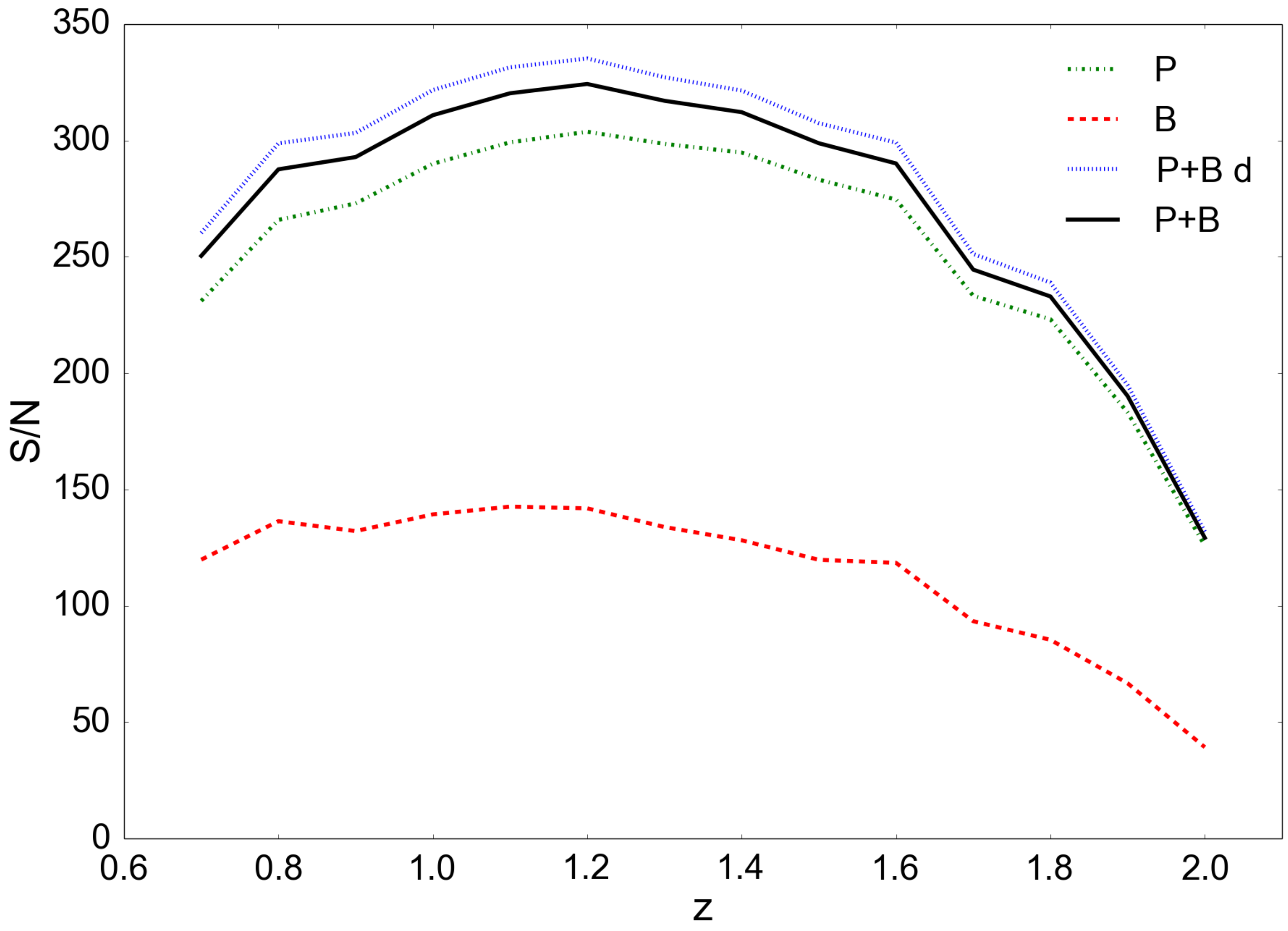
$$\Delta\mu = 0.5,$$

$$\mu \in [-1, 1]$$

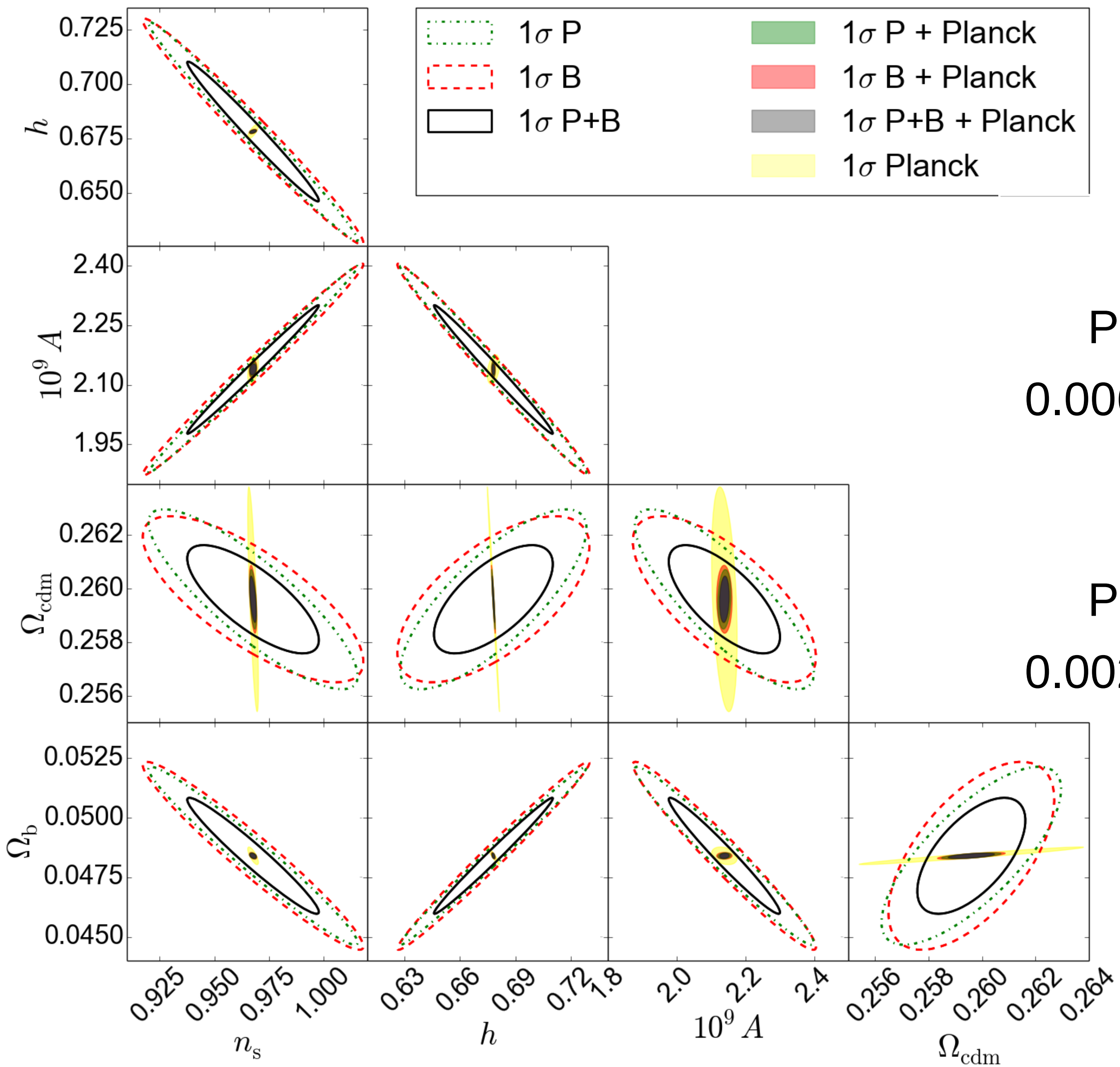
$$\Delta\varphi = \pi/4,$$

$$\varphi \in [-\pi/2, \pi/2]$$

Signal-to-Noise



ΛCDM model



$1\sigma(\Omega_{cdm})$

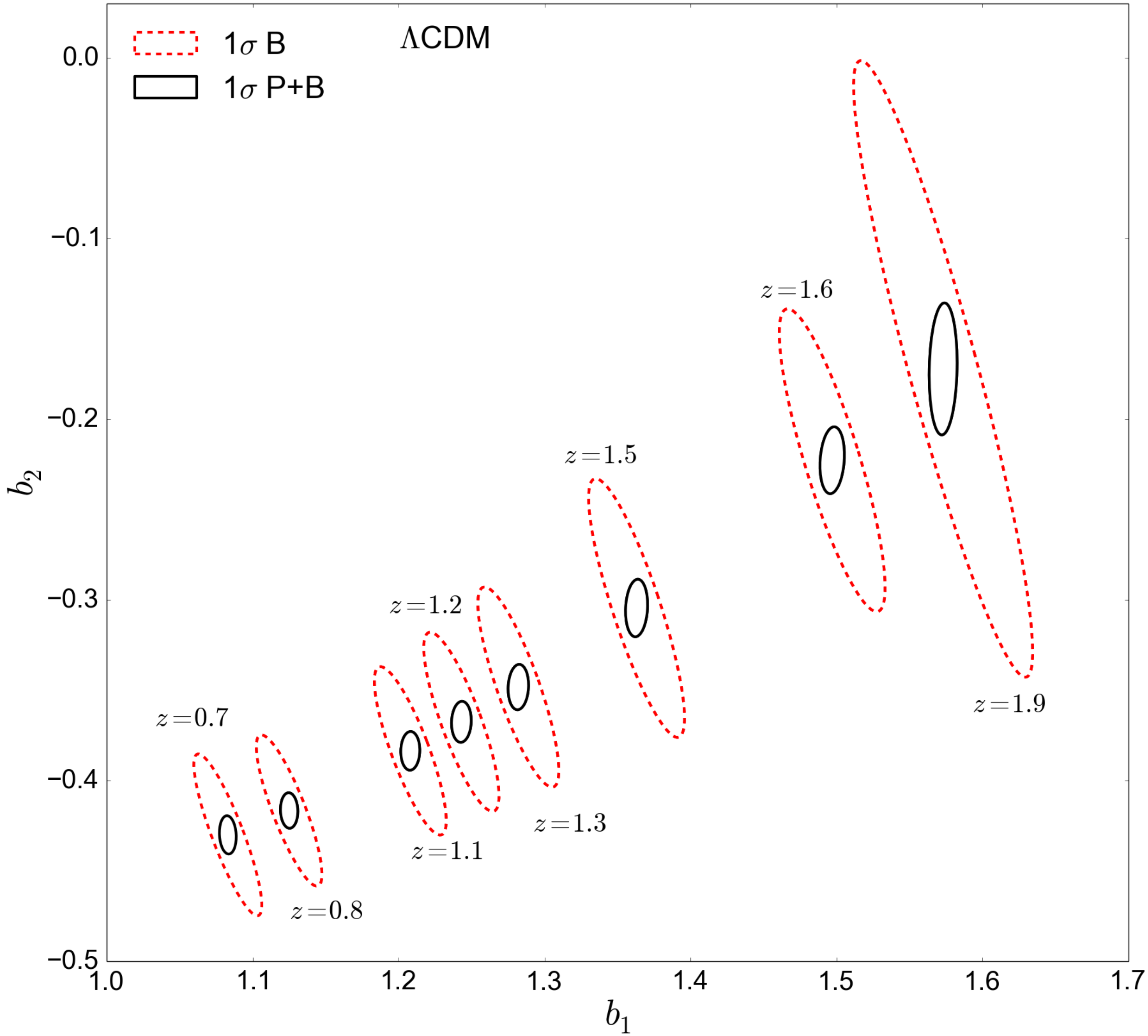
Euclid

P	B	P + B
0.0067	0.0062	0.0040

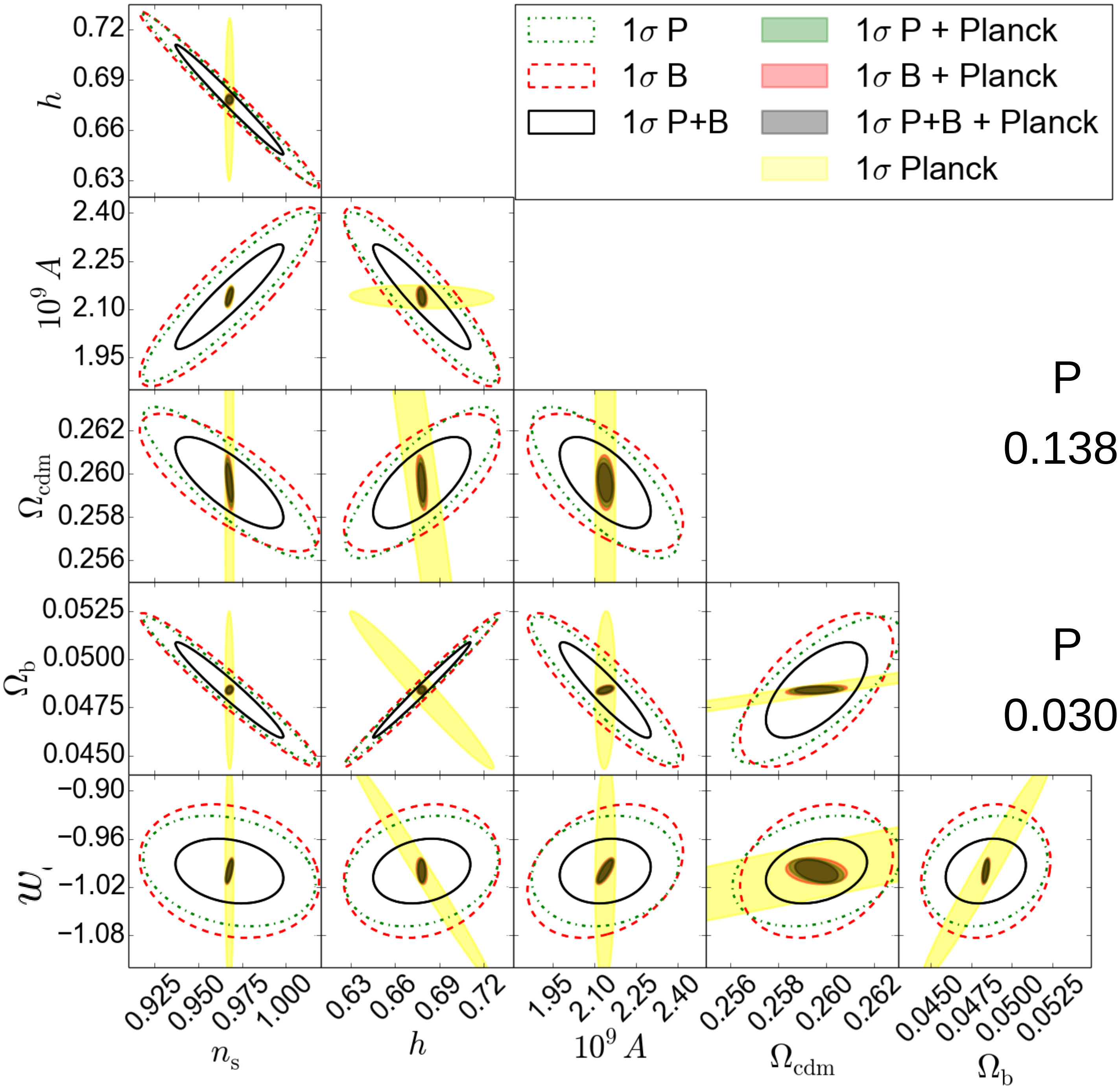
Euclid + Planck

P	B	P + B
0.0022	0.0025	0.0017

ΛCDM model Δb_1 Δb_2



wCDM model



$1\sigma(w)$

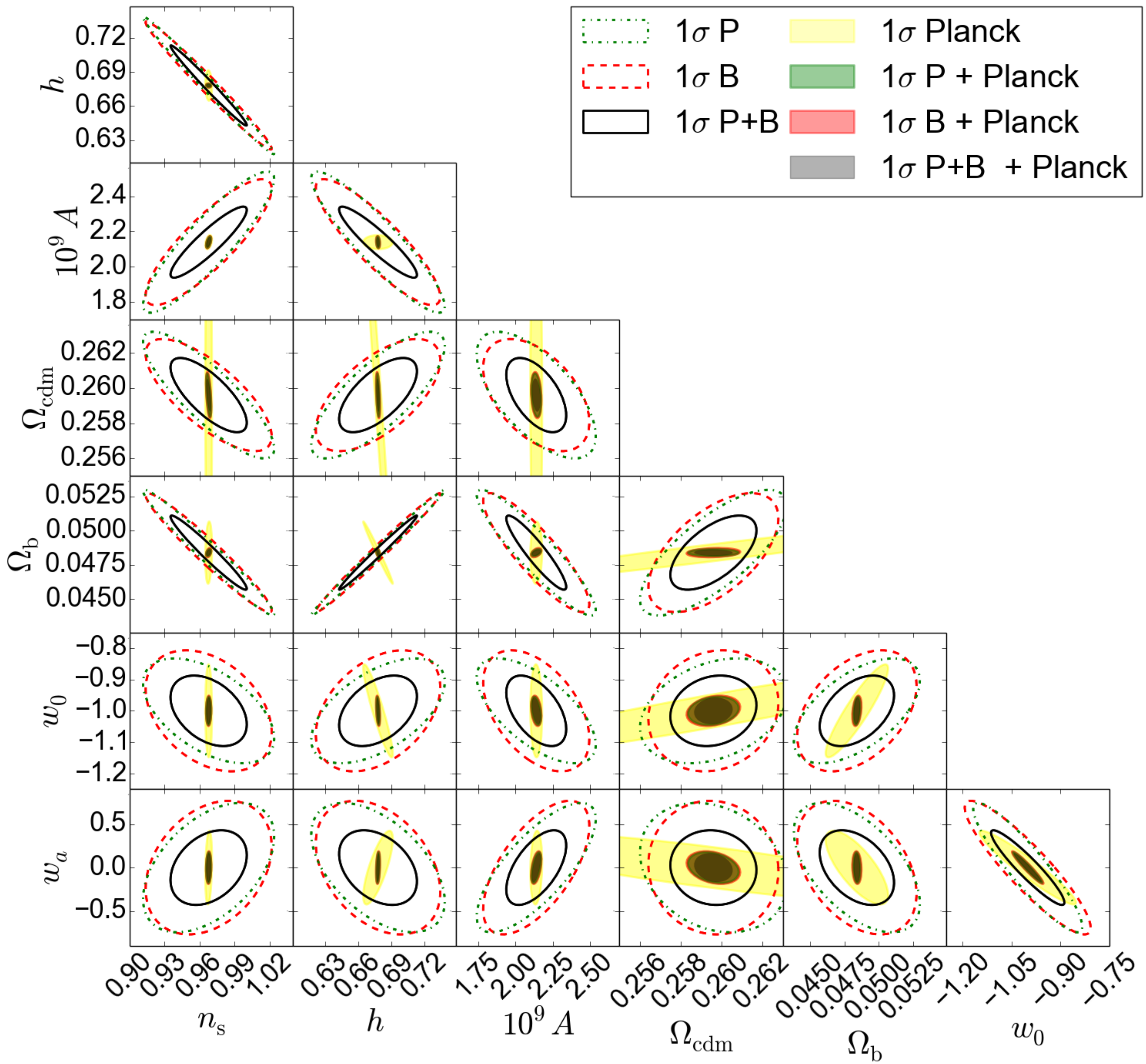
Euclid

P	B	P + B
0.138	0.166	0.081

Euclid + Planck

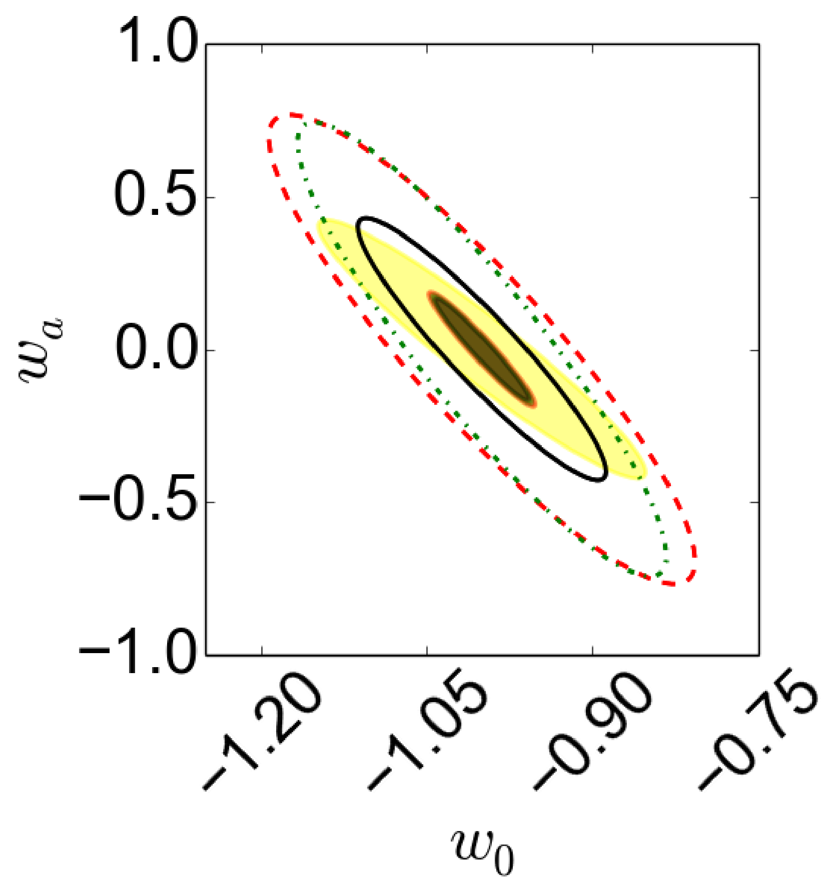
P	B	P + B
0.030	0.033	0.028

$w_0 w_a$CDM model

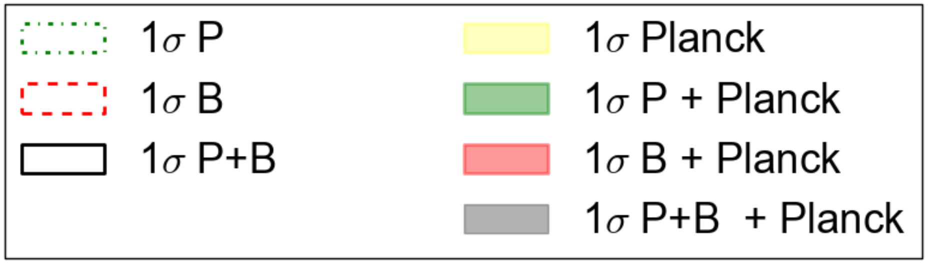


$w_0 w_a$CDM model

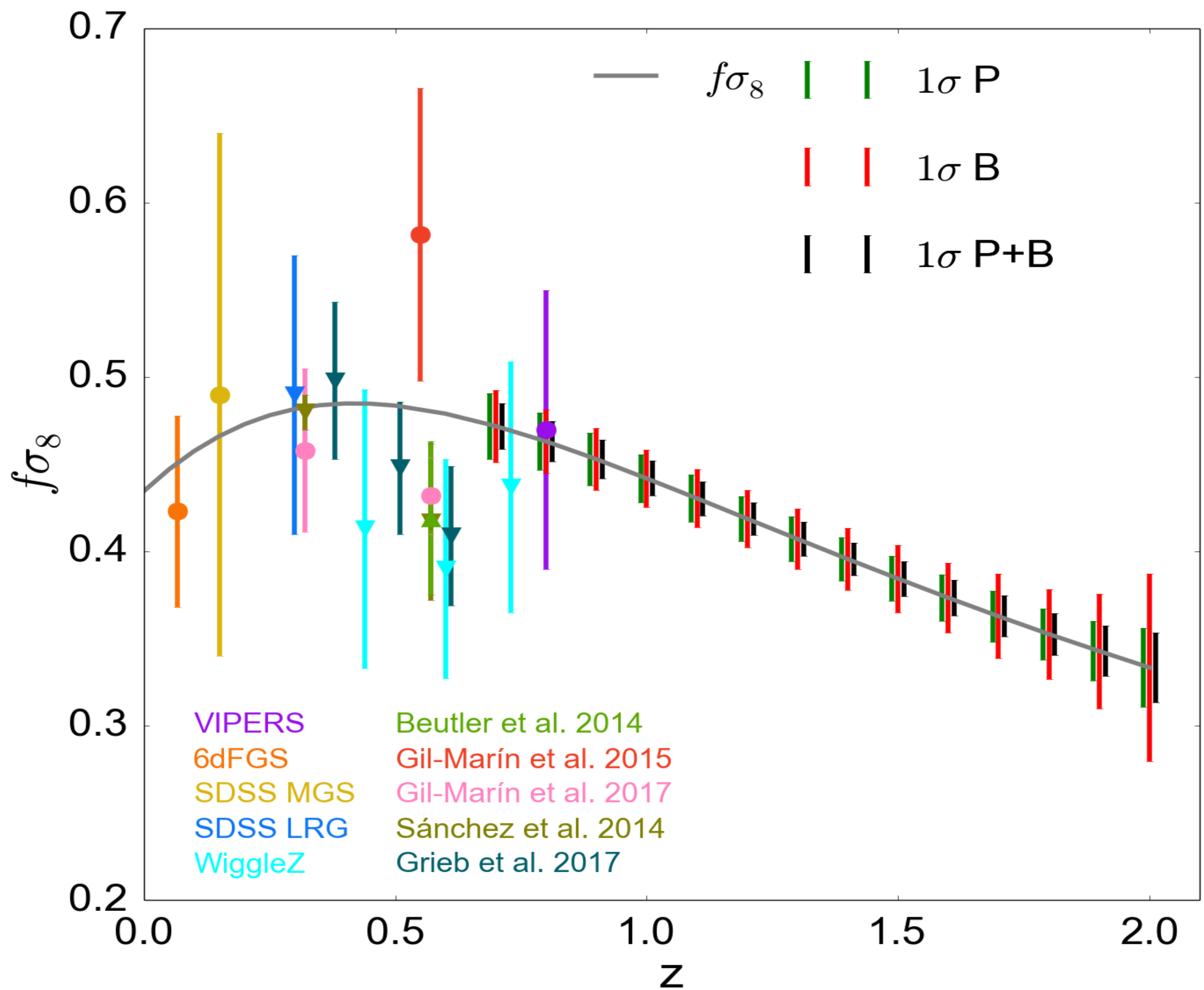
	P	B	P + B	P + Planck	B + Planck	P+B + Planck
FoM	0.58	0.47	1.72	14.61	11.75	17.55



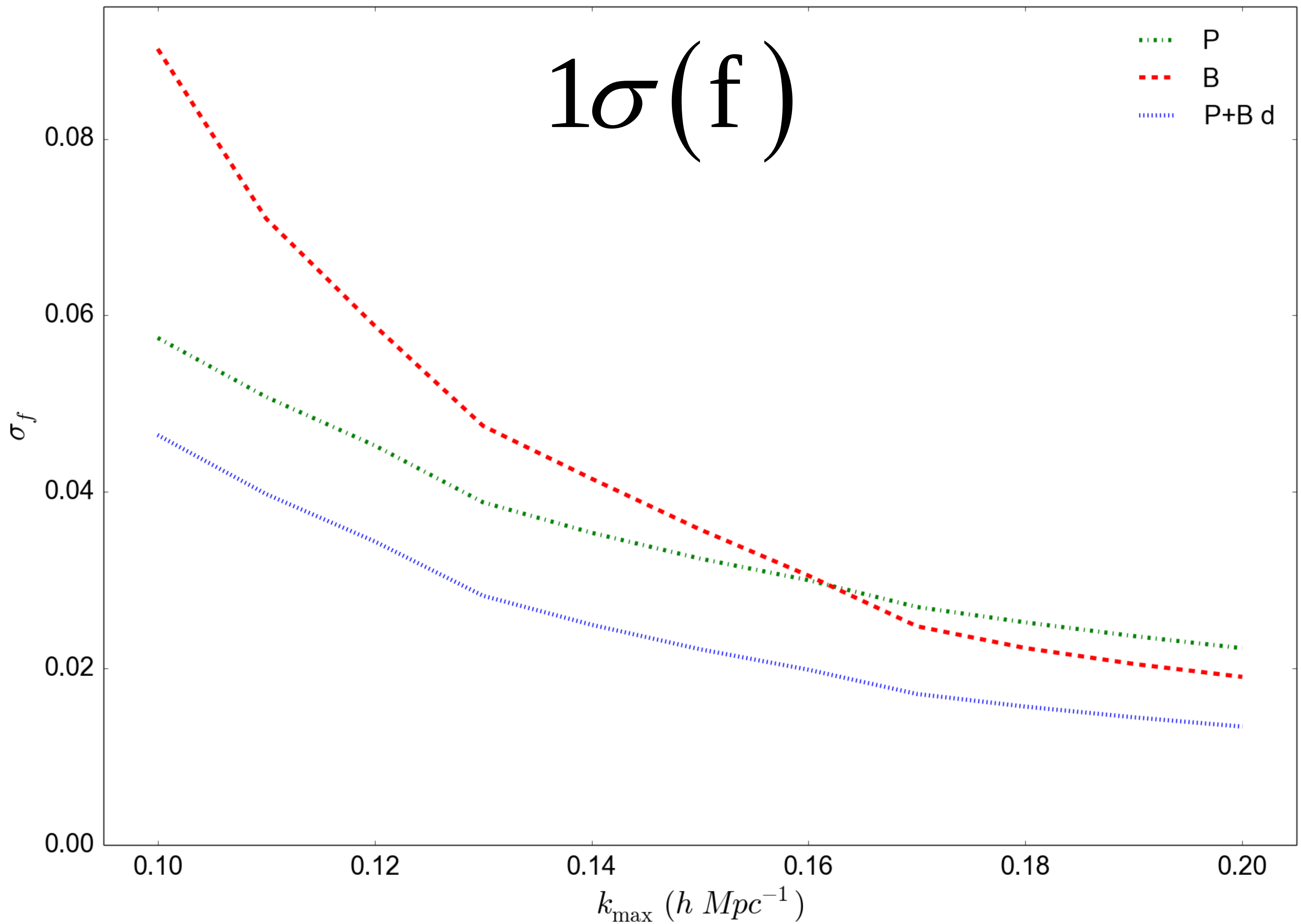
$$\mathrm{FoM} = \frac{1}{6.17\pi\sqrt{\det\left(\mathrm{Cov}(w_0 w_a)\right)}}$$



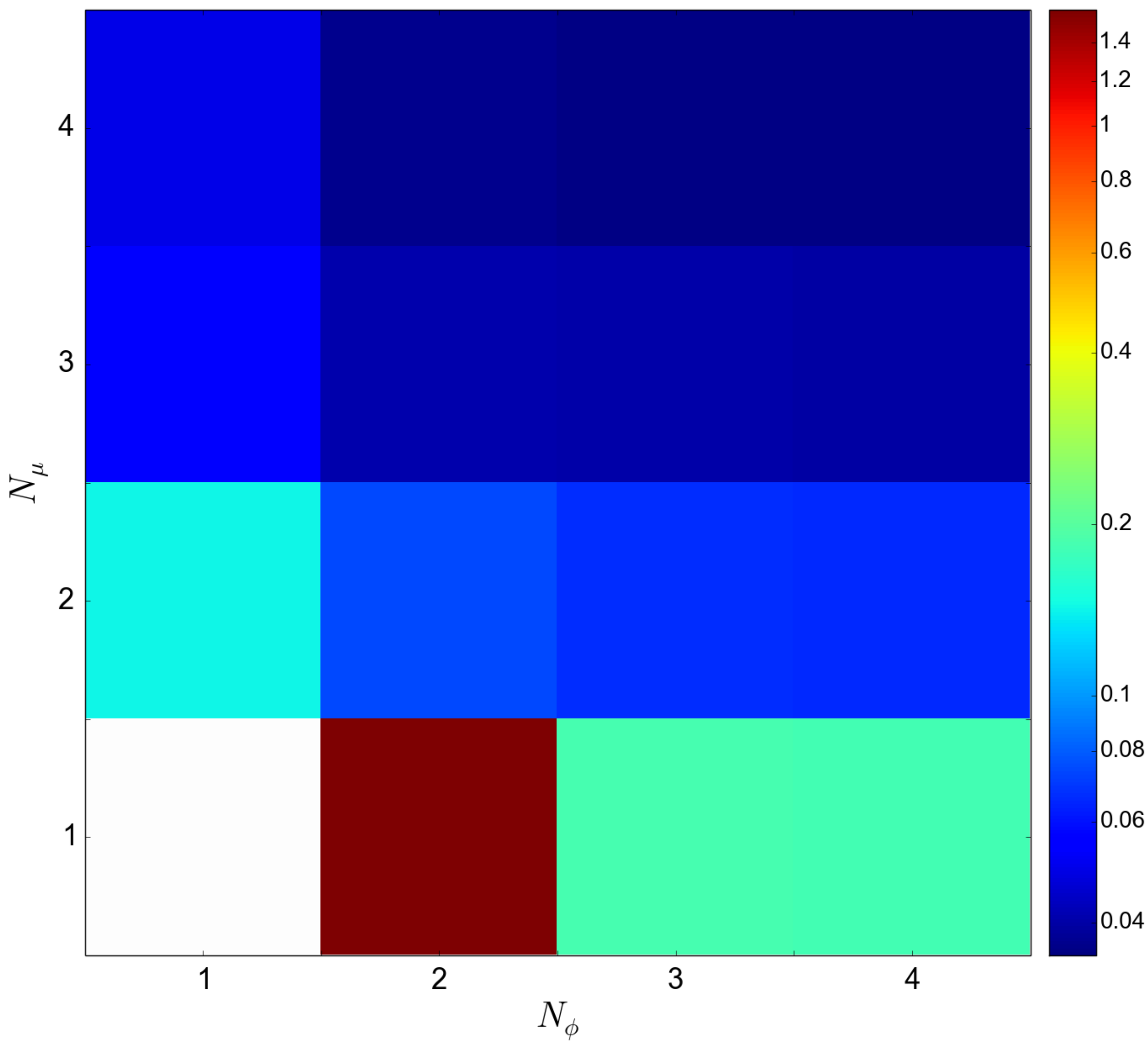
ΛCDM *fixed cosmology*



Dependence on k_{max}



Dependence on N_μ, N_ϕ : $1\sigma(f)$



Conclusions

Euclid forecast (including Planck):

$$\Lambda\mathrm{CDM},\ w\mathrm{CDM},\ w_0 w_a\mathrm{CDM}\ \text{models}$$

$$+$$

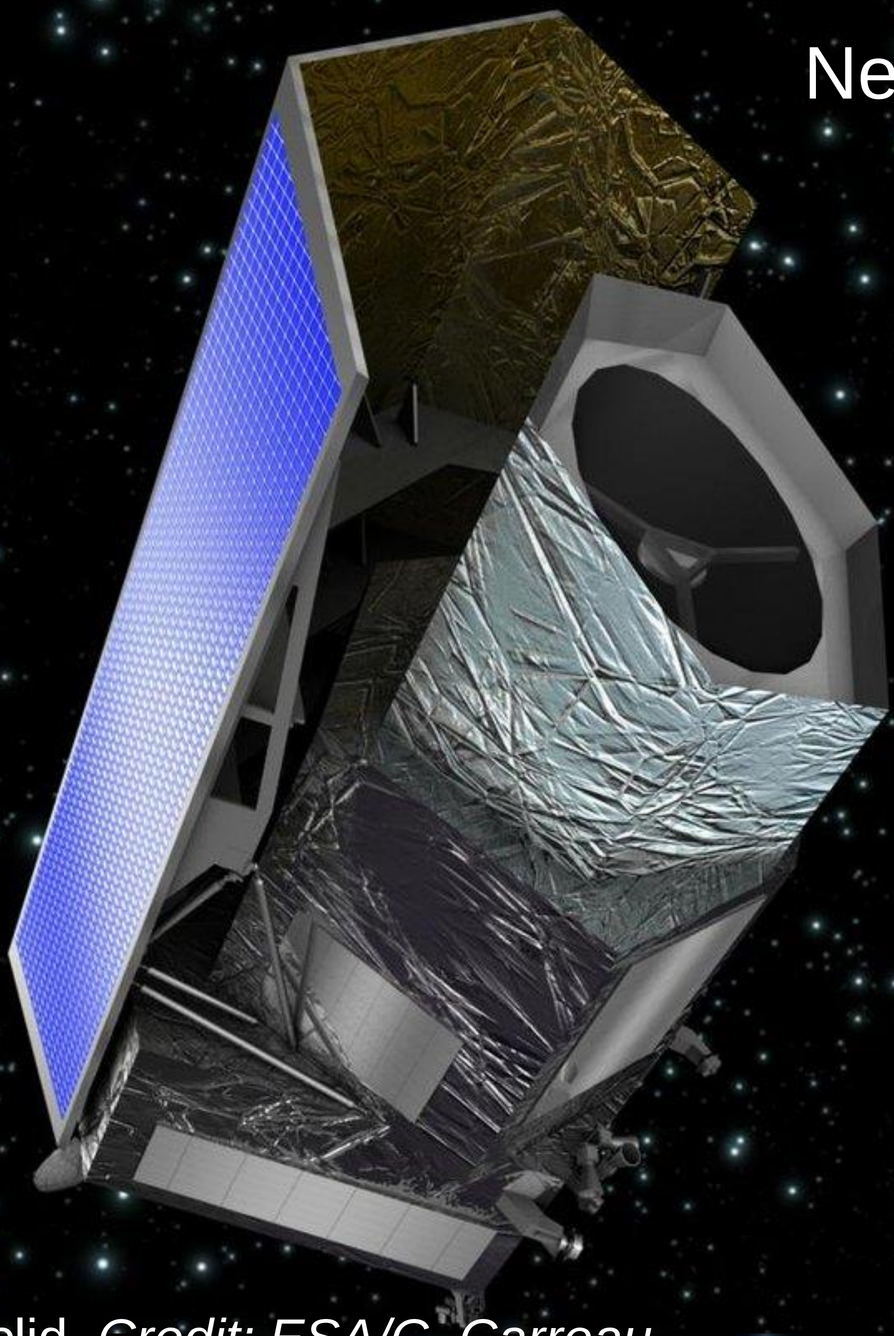
$$\text{Galaxy bias}\ \ b_1, b_2, b_{s^2}$$

$$\text{Fixed cosmology model}:\ f, \sigma_p, b_1, b_2, b_{s^2}$$

Combination of the power spectrum and the bispectrum provides much more accurate results than single probes

For details: Yankelevich&Porciani 2017, in prep.

New frontiers of cosmology
is not far away



Thank you for your attention

Euclid. *Credit: ESA/C. Carreau*