The impact of baryons and sensitivity of dark energy measurements

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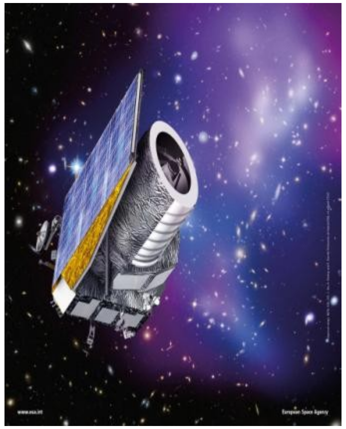
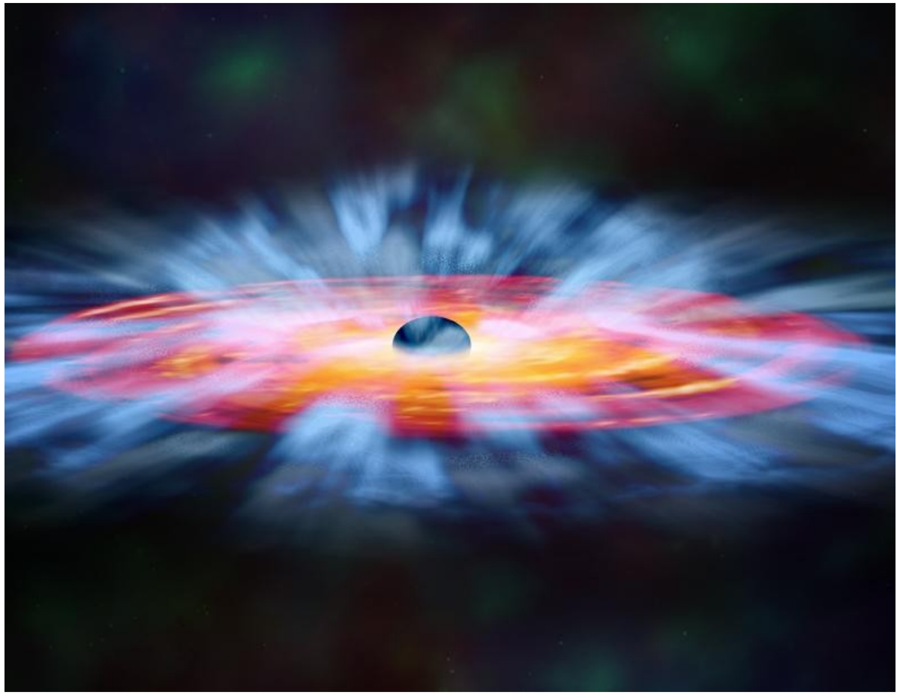
Precision cosmology complicated by baryon feedback

Stage IV surveys (DESI, Euclid, LSST etc.) use vast number of observations to probe dark energy signatures in **large scale structure** via weak gravitational lensing and galaxy clustering

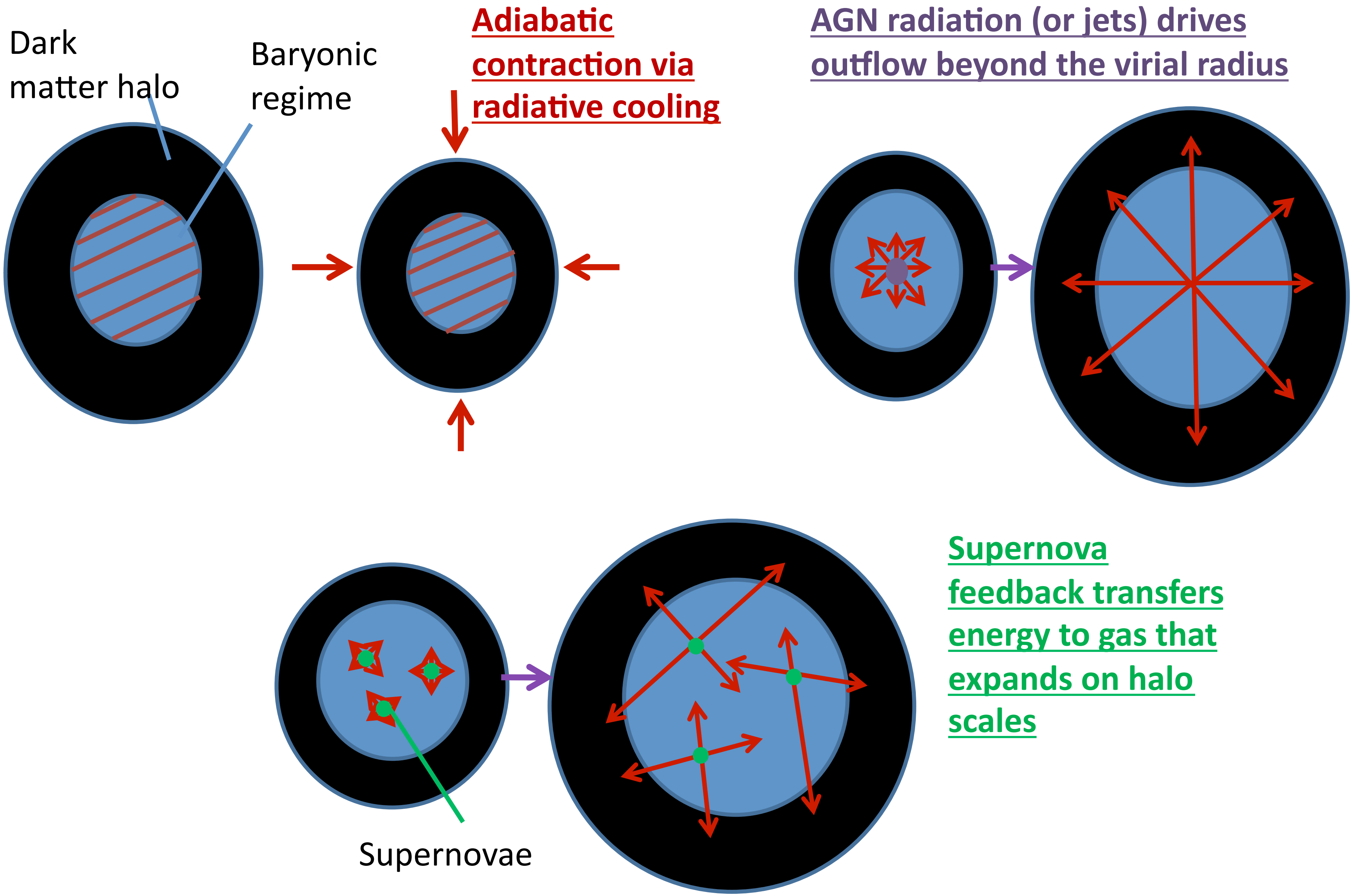




Baryonic astrophysics makes LSS tougher to model: poor physical understanding of effects that impact a large range of scales.

Potential to obscure signatures of DE by mimicking its effects?
(Require percent level precision)

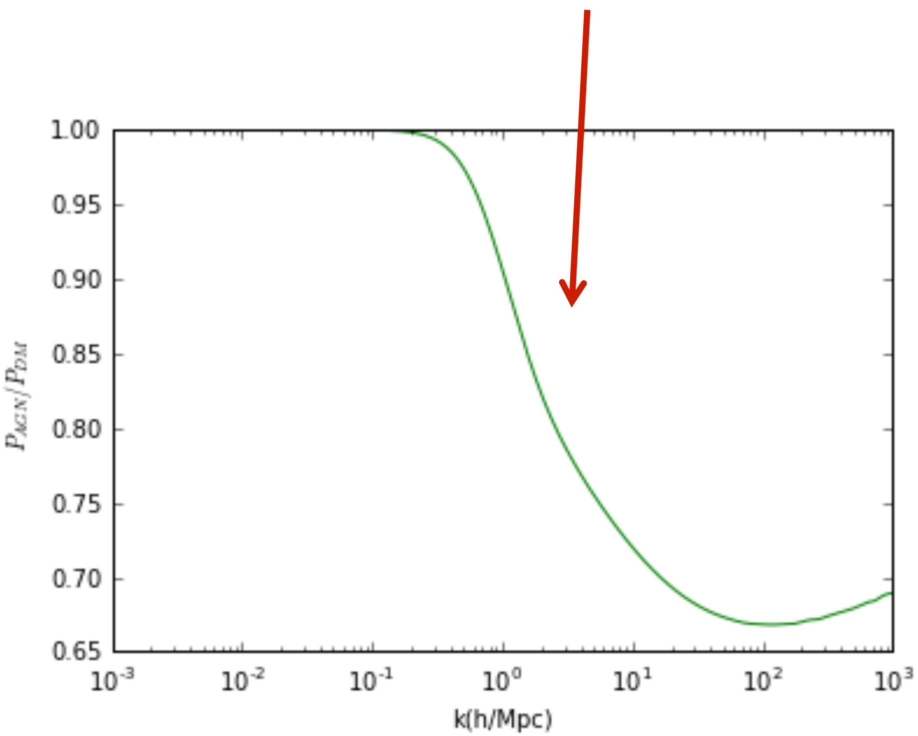
Some baryonic phenomena...

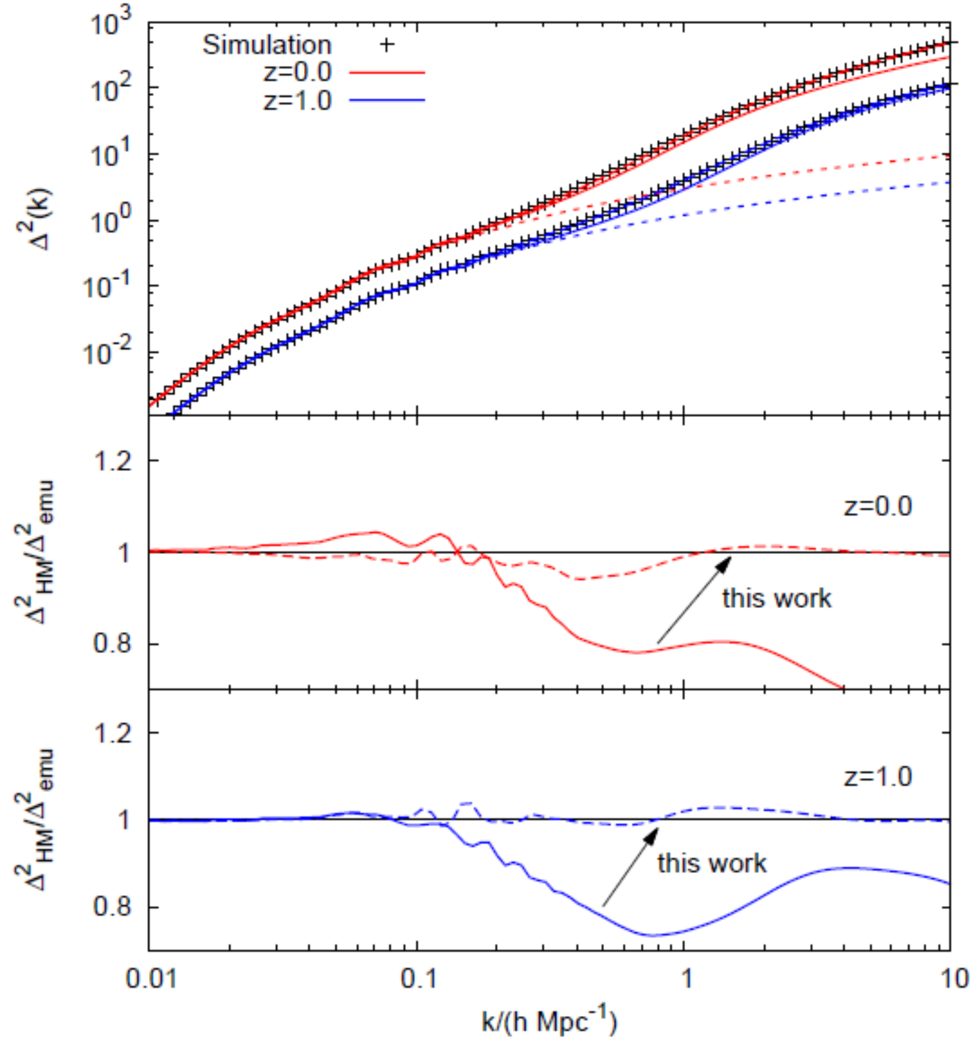


Motivation for a generic baryon-halo model?

How robust are simulations as a solution?
Ultimate limitations in sub-grid physics.

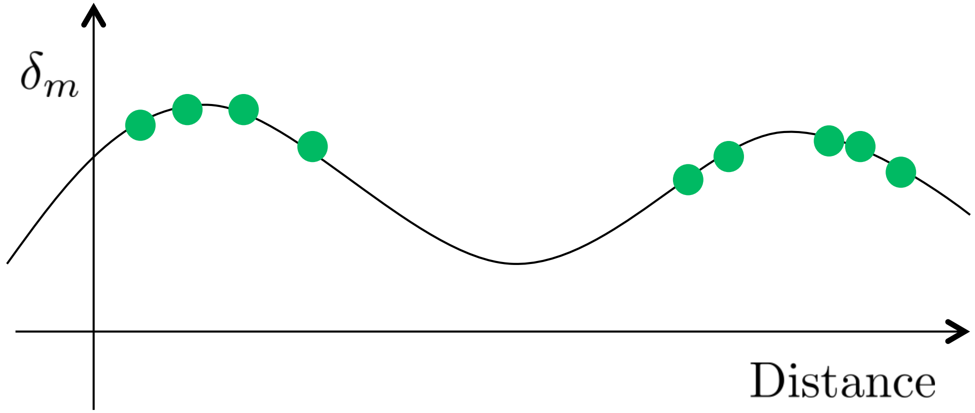
But for degeneracies with DE, we're interested in impact on broad LSS descriptors like δ_m and *P(k).*



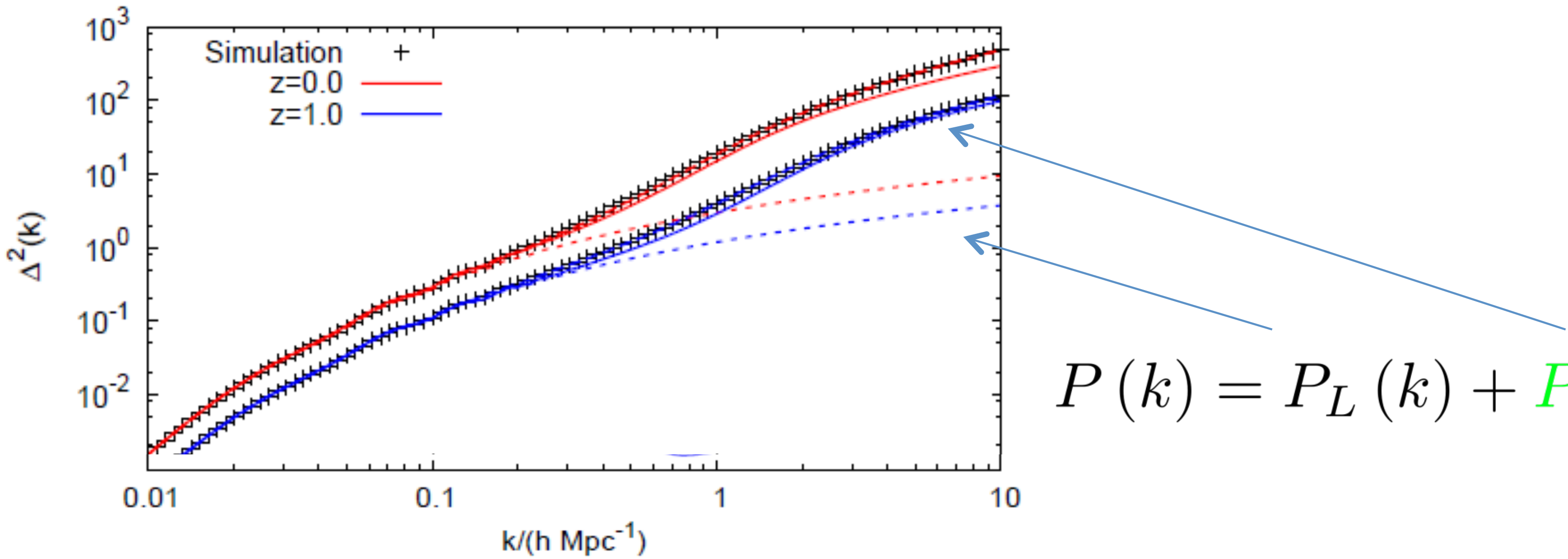


Mead *et al.*, MNRAS, 2015

Haloes are effective characterisations of non-linear structure



Halo model for non-linear P(k):

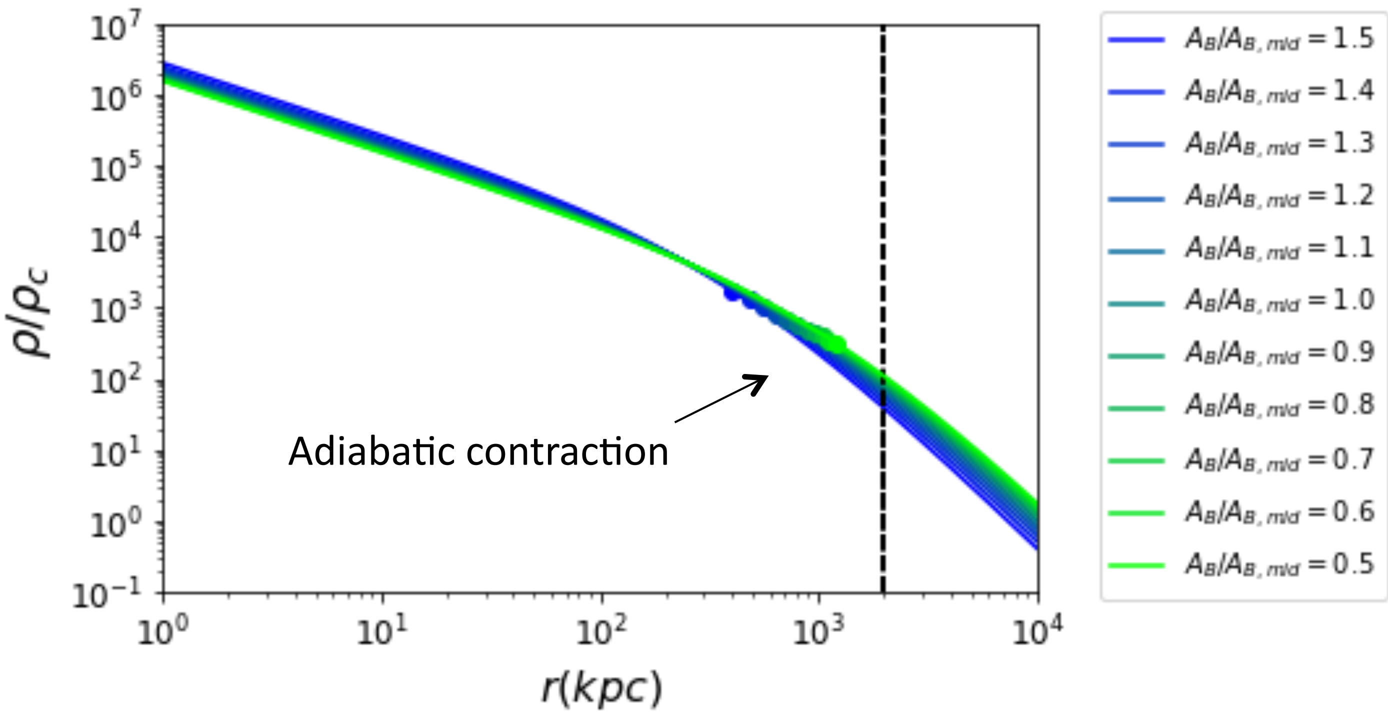


$$P(k) = P_L(k) + P_{1h}(k)$$

Mead *et al.*, MNRAS, 2015

Adiabatic contraction captured by modifying concentrations

1) A_B controls the amplitude of the halo profile via the concentration factor (Mead *et al.*, MNRAS, 2015)



$$\rho\left(r\right) = \frac{\rho_N}{\frac{r}{r_s}\left(1+\frac{r}{r_s}\right)^2}$$

↓

$$r_s = \frac{r_v}{c}$$

↓

$$c\left(M,z\right) = A_B\left(\frac{1+z_f}{1+z}\right)$$

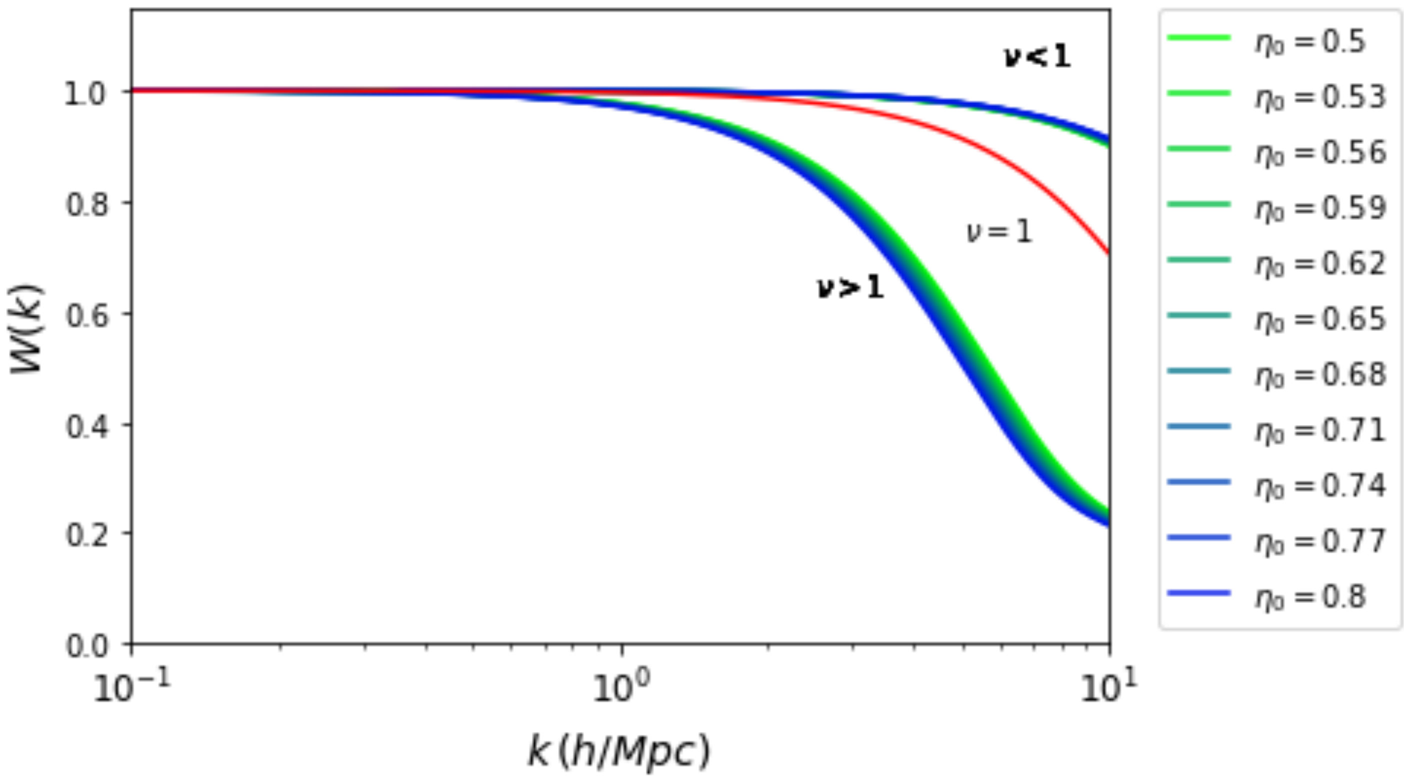
NFW profile

Impact of feedback varies over scale and mass

2) η_0 introduces a **mass-dependent** modification of the halo shape (Mead *et al.*, MNRAS, 2015)

$$\Delta^2_{1h}(k) = \frac{k^3}{2\pi^2}\int_0^\infty M^2\, W^2(k,M)\, F(M)\, \mathrm{d}M \qquad W(k,M) = \int_0^{r_v} r^2\, \frac{\sin(kr)}{kr}\rho(r,M)\, \mathrm{d}M$$

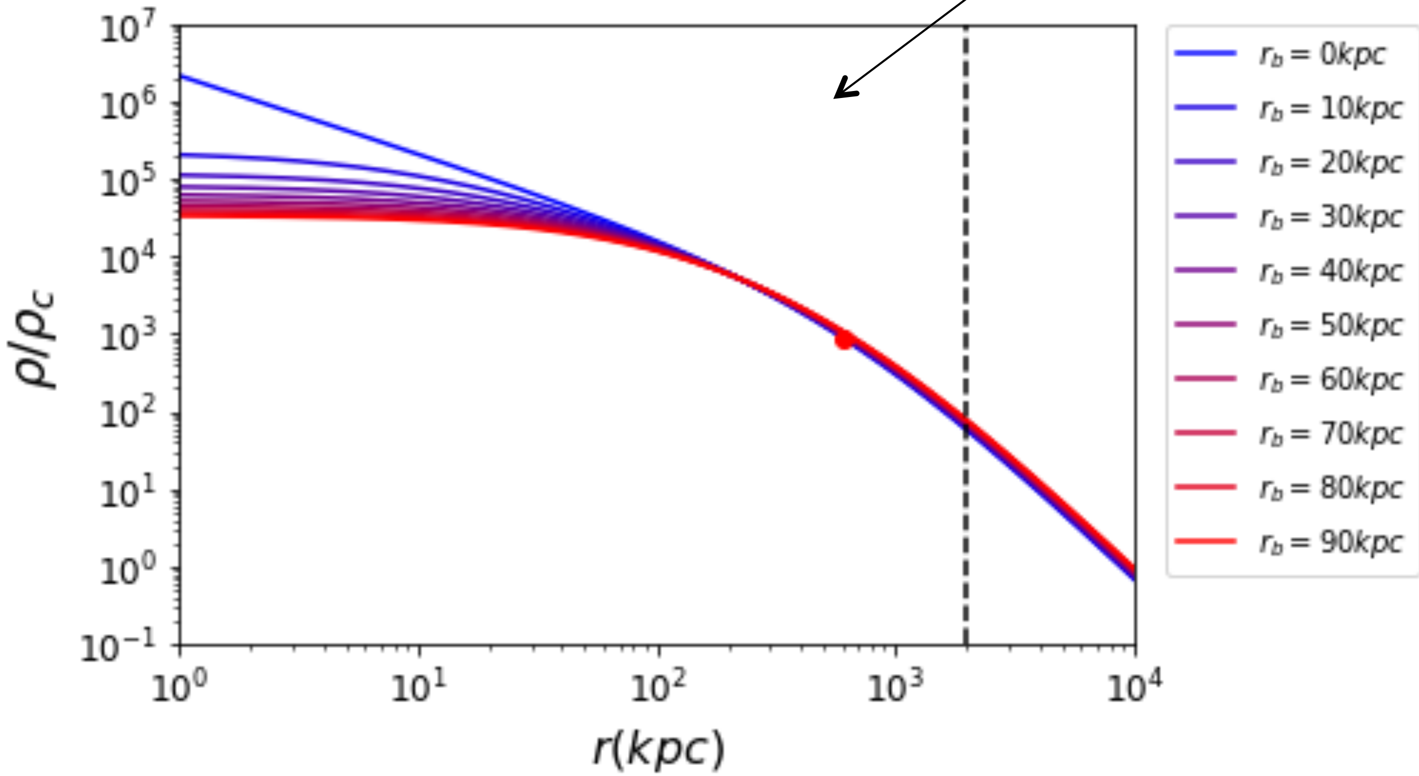
$$W(k,M) \rightarrow W(\nu^\eta k, M) \qquad \nu = \frac{\delta_c}{\sigma(M)} \qquad \eta = \eta_0 - 0.3\sigma_8(z)$$



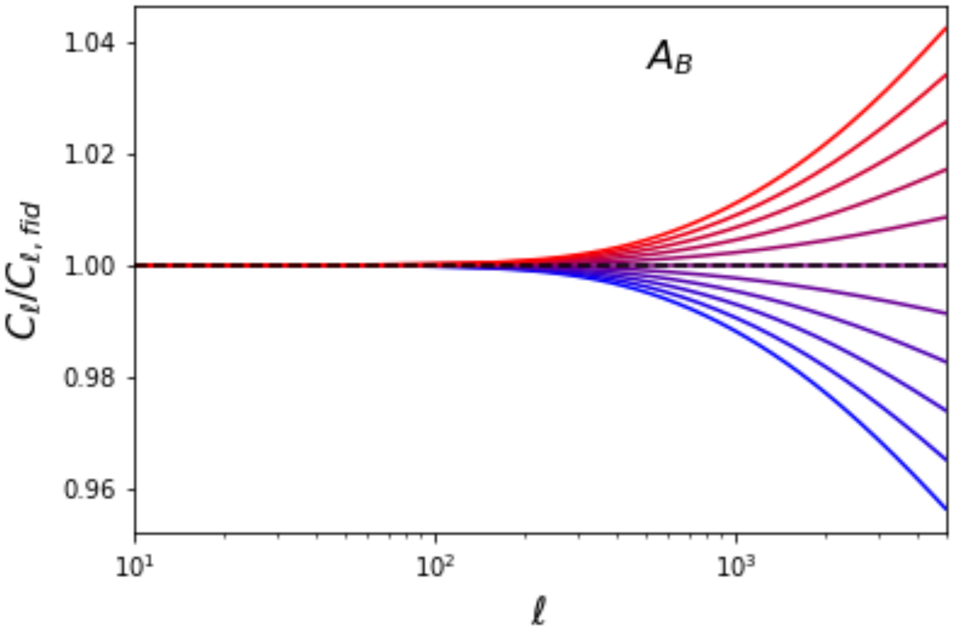
Small-scale physics captured by parameterising a core (instead of a cusp)

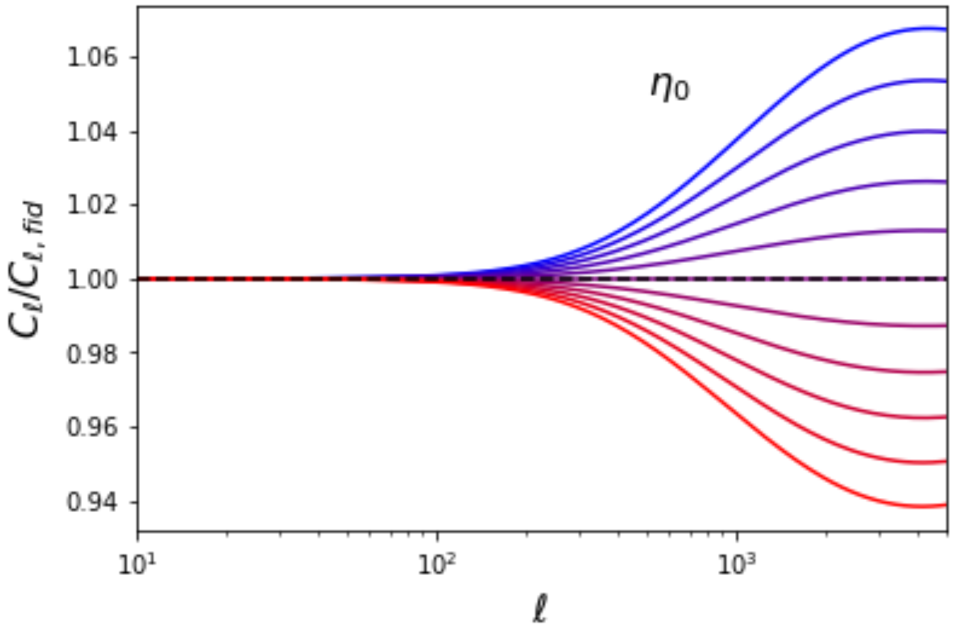
3) Baryon-induced (or via e.g. self-interacting DM) core introduces a second break scale, r_b

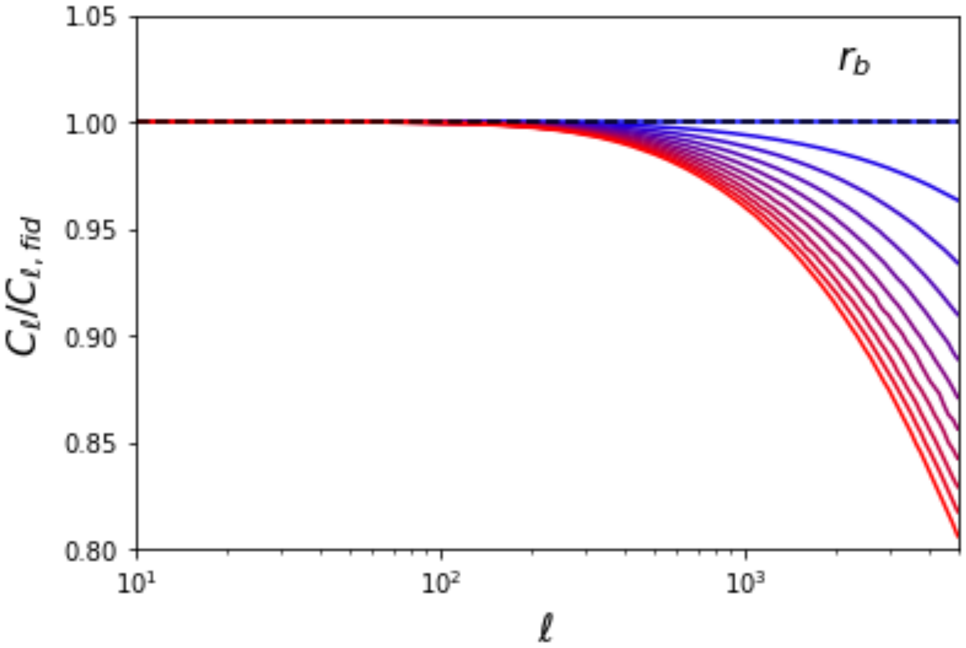
$$\rho(r) = \frac{\rho_N}{\left(\frac{r_b}{r_s} + \frac{r}{r_s}\right)\left(1 + \frac{r}{r_s}\right)^2}$$



Distinct baryon effects on weak lensing power spectrum







Θ	Θ_{min}	Θ_{max}	Θ_{fid}
A_B	2.00	4.00	3.13
η_0	0.4	0.8	0.603

Bluer (redder) lines correspond to lower (higher) values of the parameters

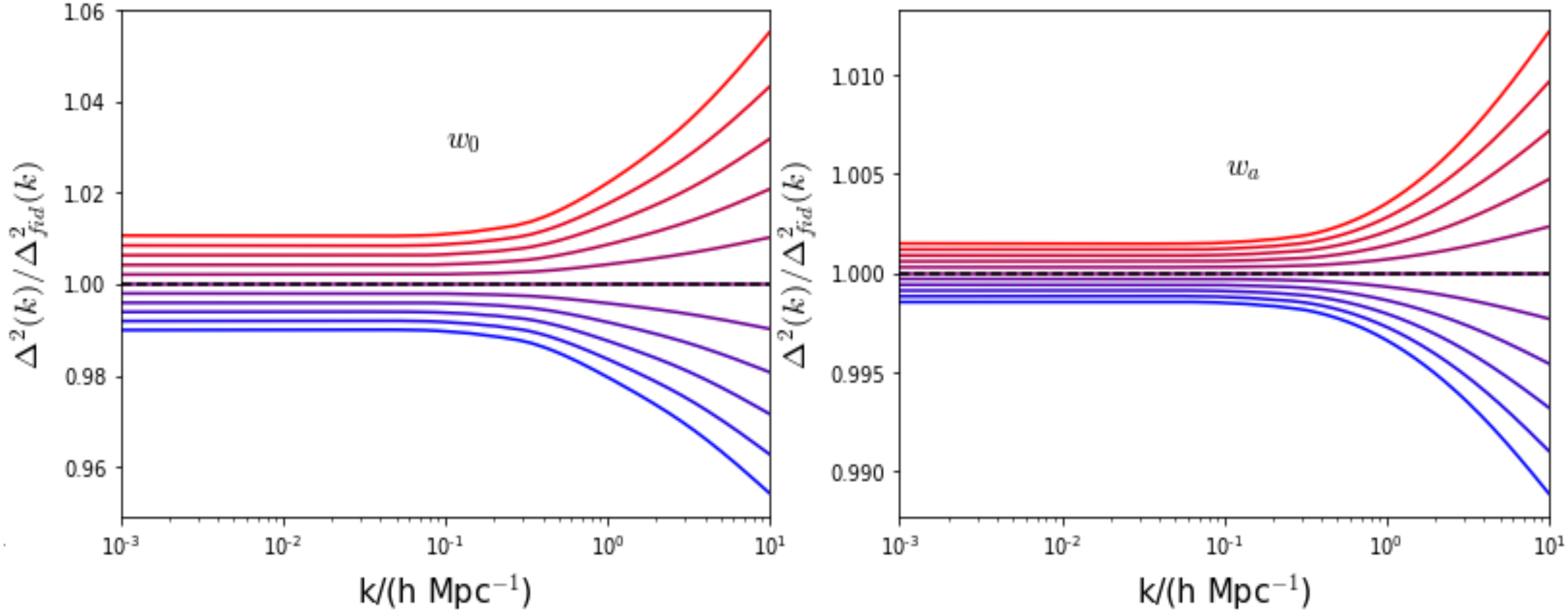
Dark energy effects on matter power spectrum

We assume a simple DE model parameterised by the scale factor:

$$w\left(a\right) = w_0 + \left(1 - a\right) w_a$$

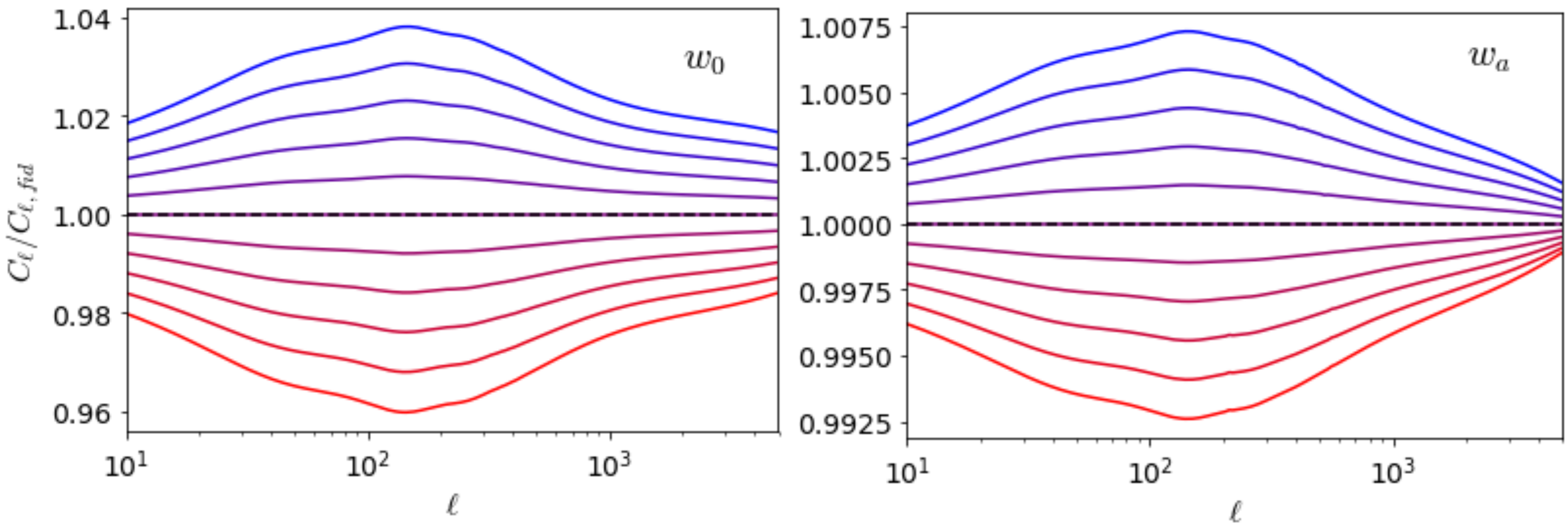
$$w = \frac{P}{\rho} < -\frac{1}{3}$$

Θ	Θ_{min}	Θ_{max}	Θ_{fid}
w_0	-1.3	-0.7	-1
w_a	-0.3	0.3	0

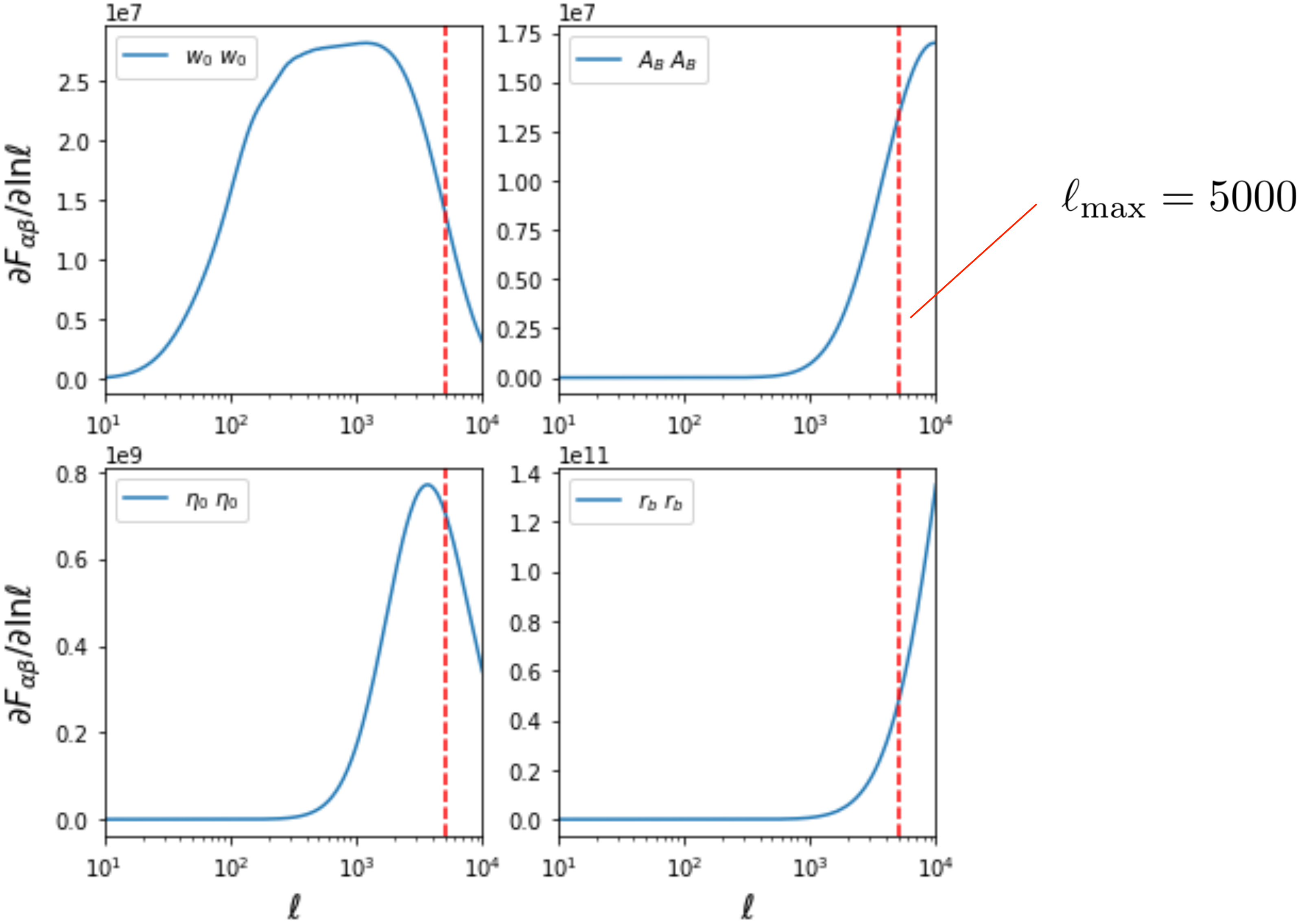


Dark energy effects on weak lensing power spectrum

$$C_{ij}^{\kappa} = \frac{9}{4}\Omega_m^2 \left(\frac{H_0}{c}\right)^4 \int_0^{\chi_{max}} \mathrm{d}\chi \, \frac{q_i(\chi)\, q_j(\chi)}{a^2(\chi)} \, P_\delta\left(k = \frac{\ell}{f_K(\chi)}, \chi\right)$$



Fisher information sensitivity

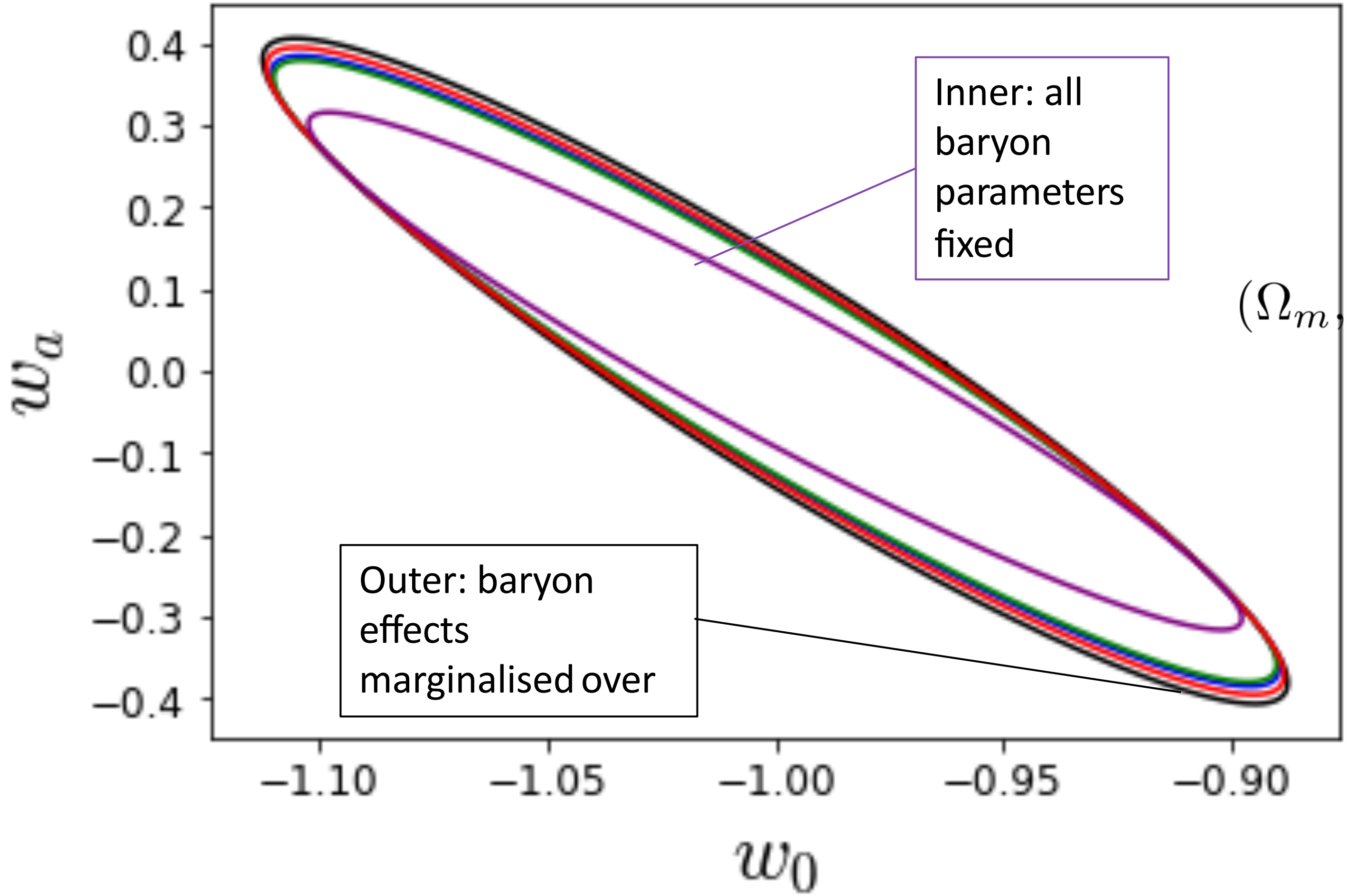


10% level impact on Dark Energy

10 parameter Fisher analysis for weak lensing projection of matter power spectrum (Euclid-like survey) : 3 Baryon + 7 w_0w_aCDM

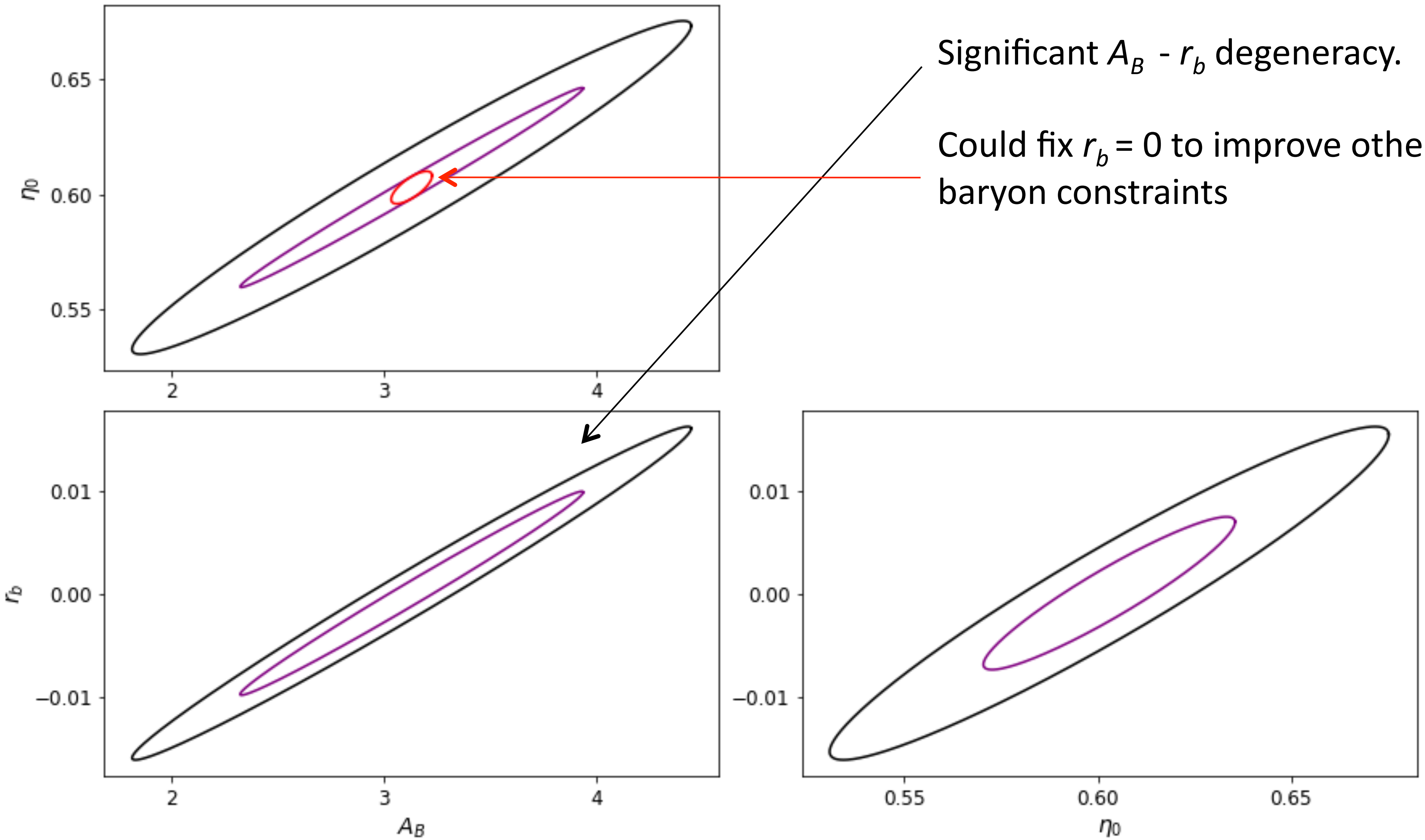
(A_B, η_0, r_b)

$(\Omega_m, \Omega_b, h, n_s, \sigma_8, w_0, w_a)$



Baryon constraints sensitive to cosmology

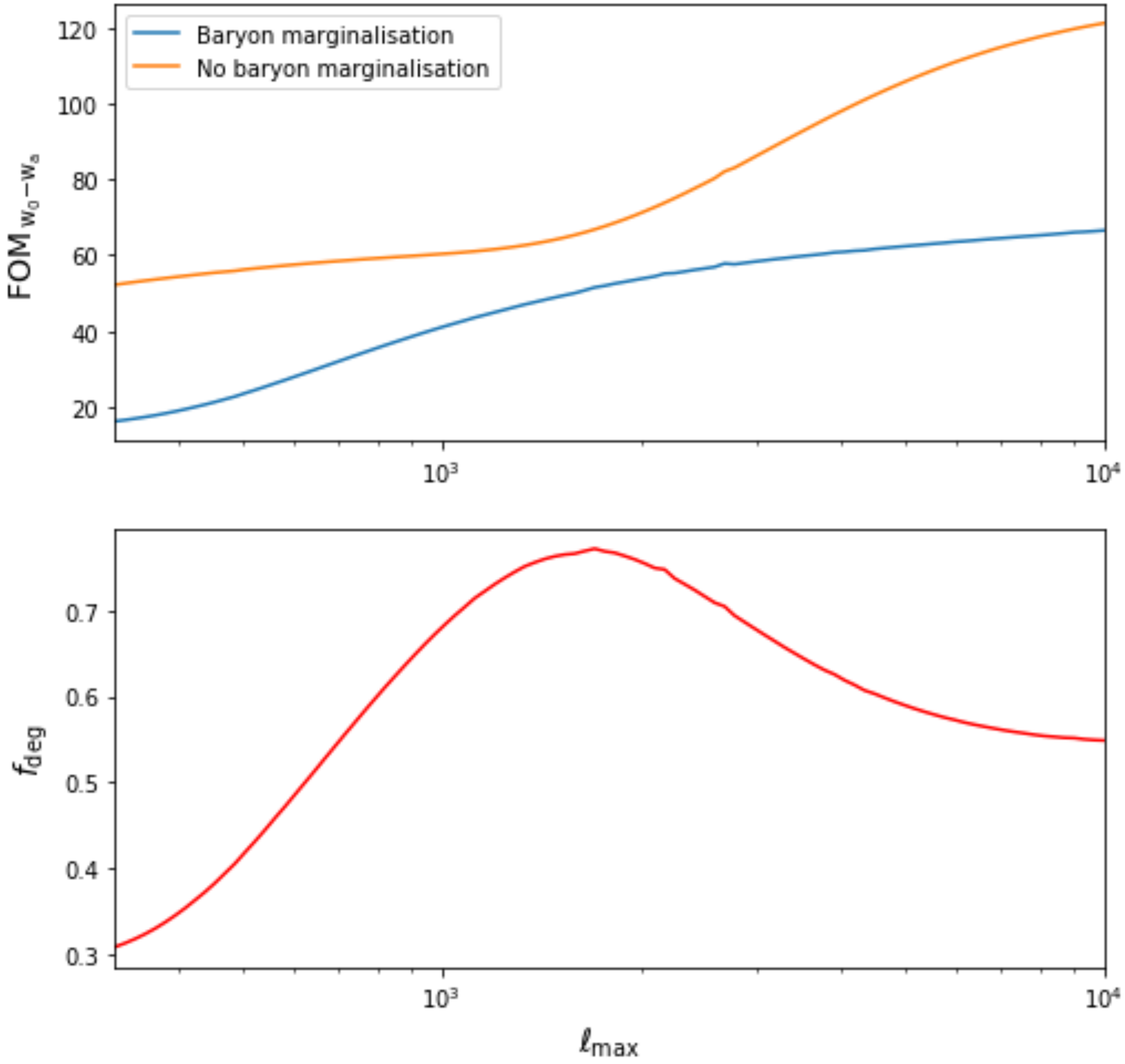
Conversely, constraining baryon effects themselves depends significantly on the precision to which cosmology is measured.



Significant A_B - r_b degeneracy.

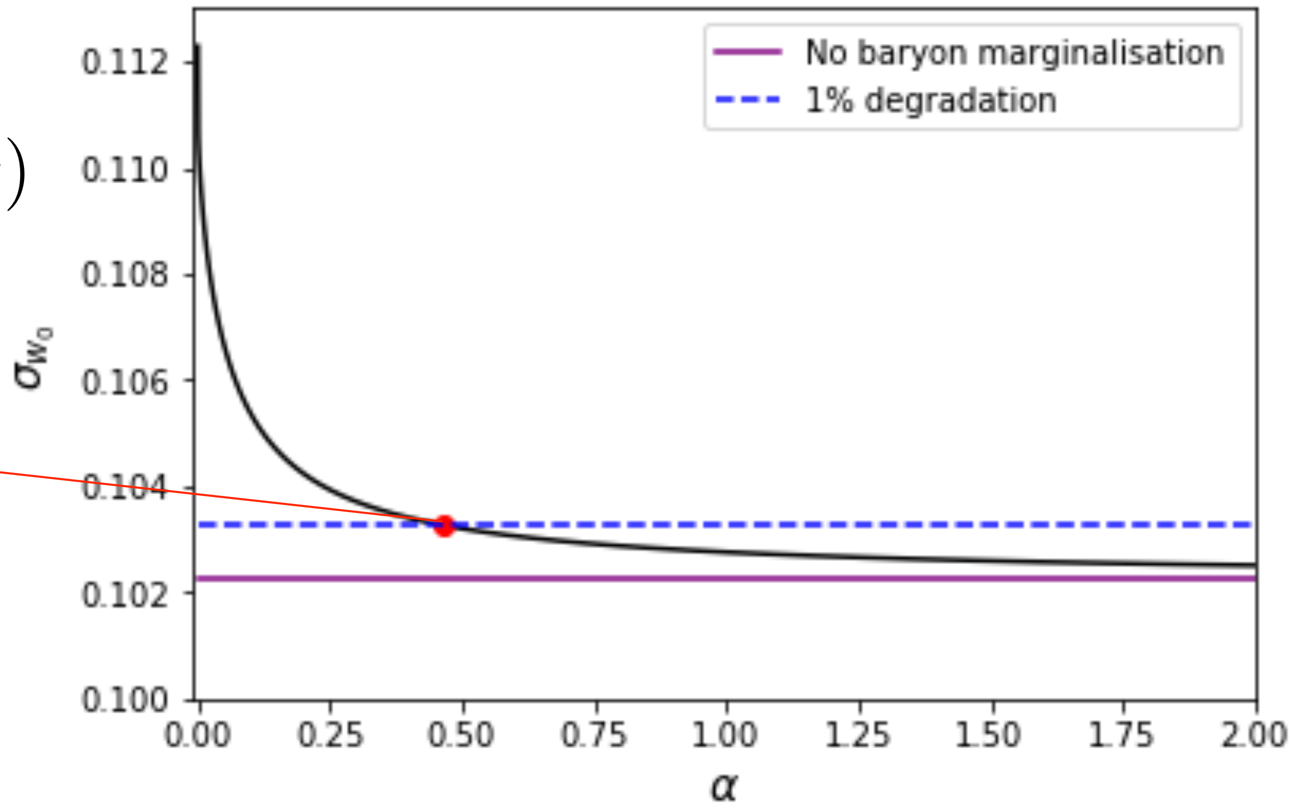
Could fix $r_b = 0$ to improve other baryon constraints

Increasing ℓ_{max} doesn't help much...



Required improvement factor from external sources

$$F'_{BB} = F_{BB}\,(1+\alpha)$$



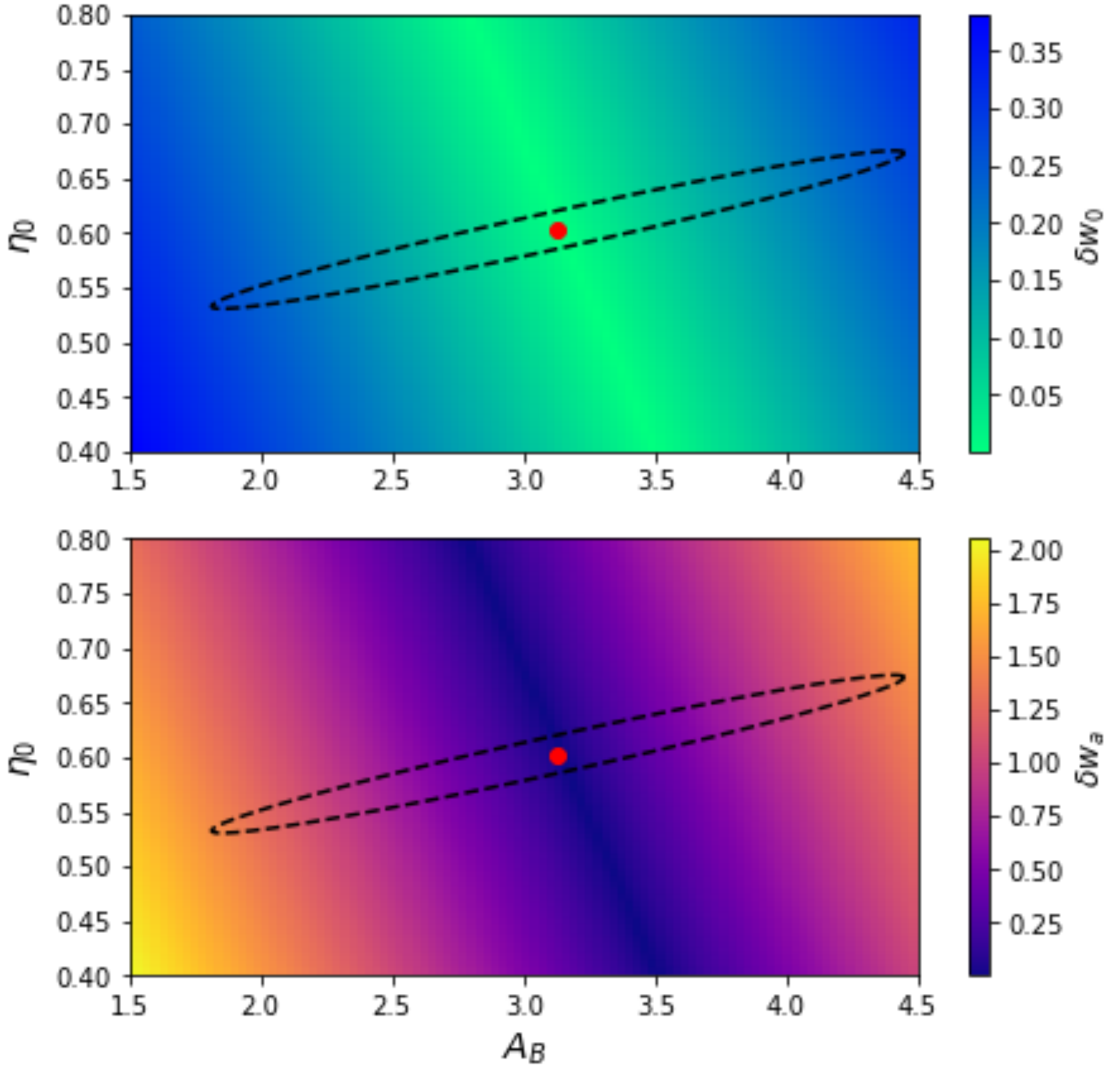
$$\alpha_{1\%} = 0.47$$

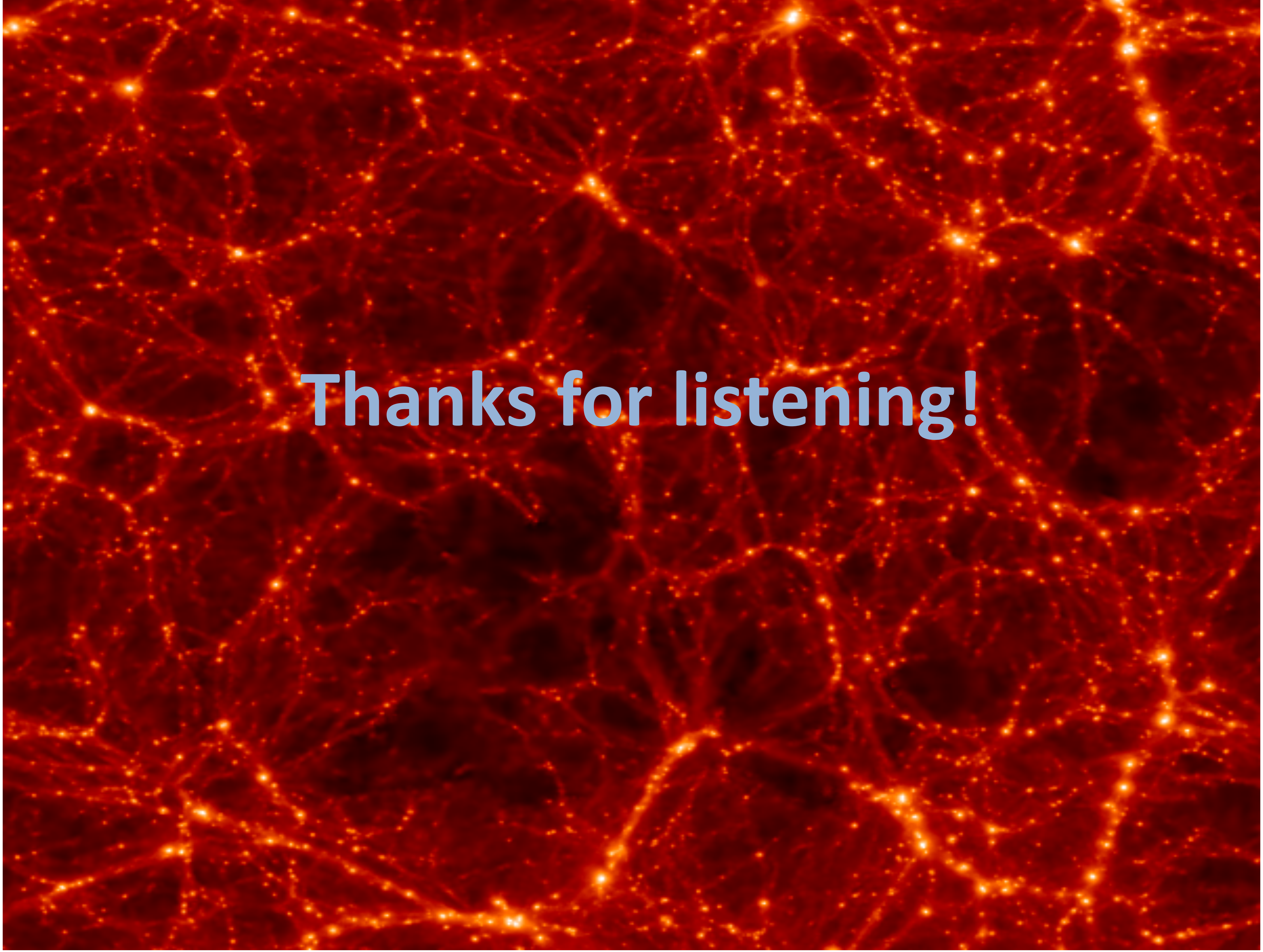
$$\sigma_{B,\mathrm{prior}} = 2.13\,\sigma_{B,\mathrm{con}}$$

Summary

- Baryons affect the matter power spectrum *P(k)* beyond the percent level.
- Generic baryon-halo model can be used to investigate impact on forecasts for cosmological parameters.
- **~10 % impact for dark energy parameters for a Euclid-like survey.**
- Can also constrain baryon effects themselves from future surveys.
- Increasing $\ell_{\max}$ has a very limited improvement, as relative baryon degradation increases.
- To mitigate degradation to 1 % level, we require additional baryon priors approximately twice the conditional errors obtained by Euclid alone.

Model bias




Thanks for listening!