

Effects of Primordial Magnetic Fields (PMFs) in the linear and non-linear regimes

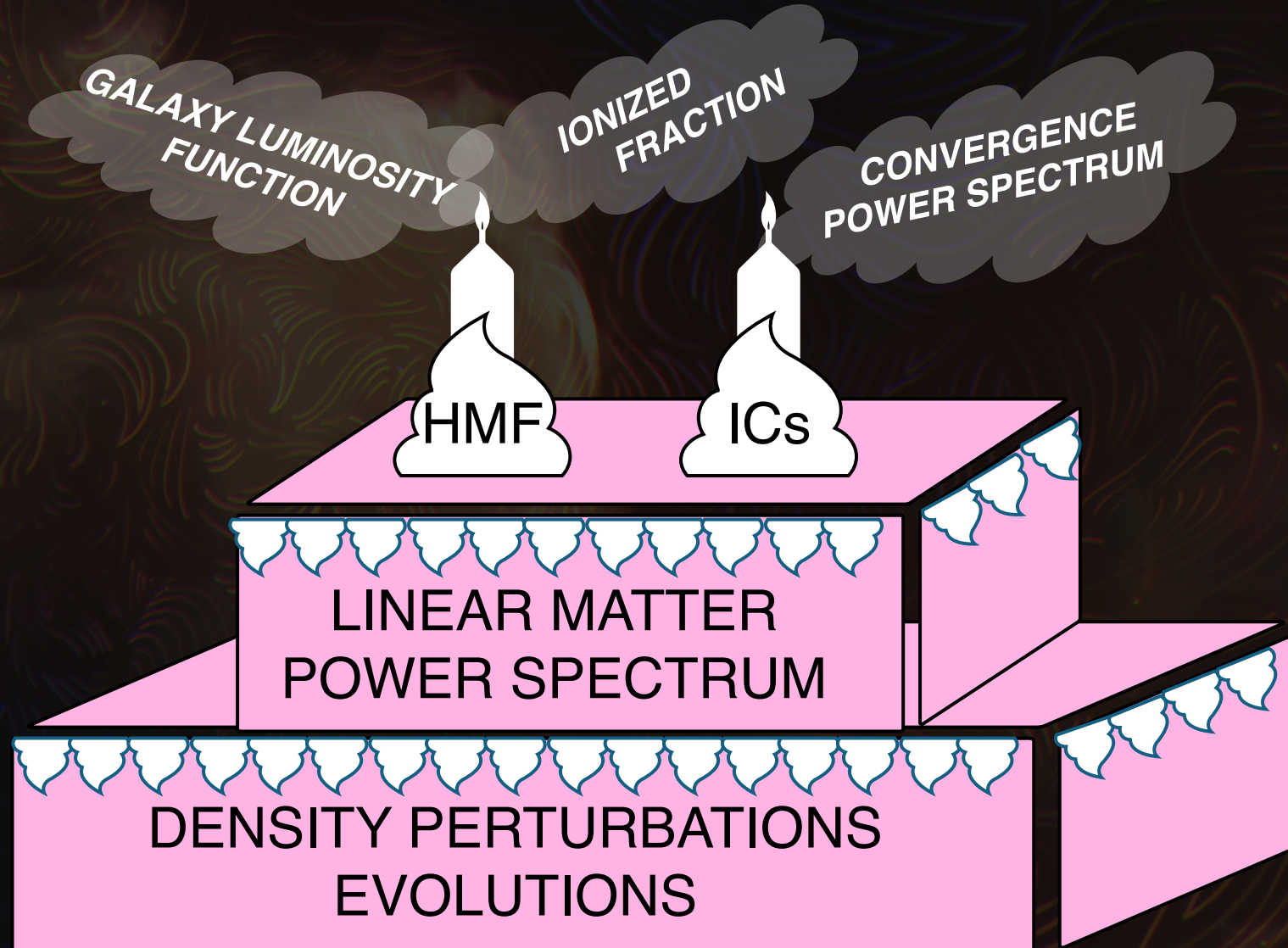
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COSMO-26 – Leiden

26/08/2026

What happens to cosmological observables in the presence of PMFs?

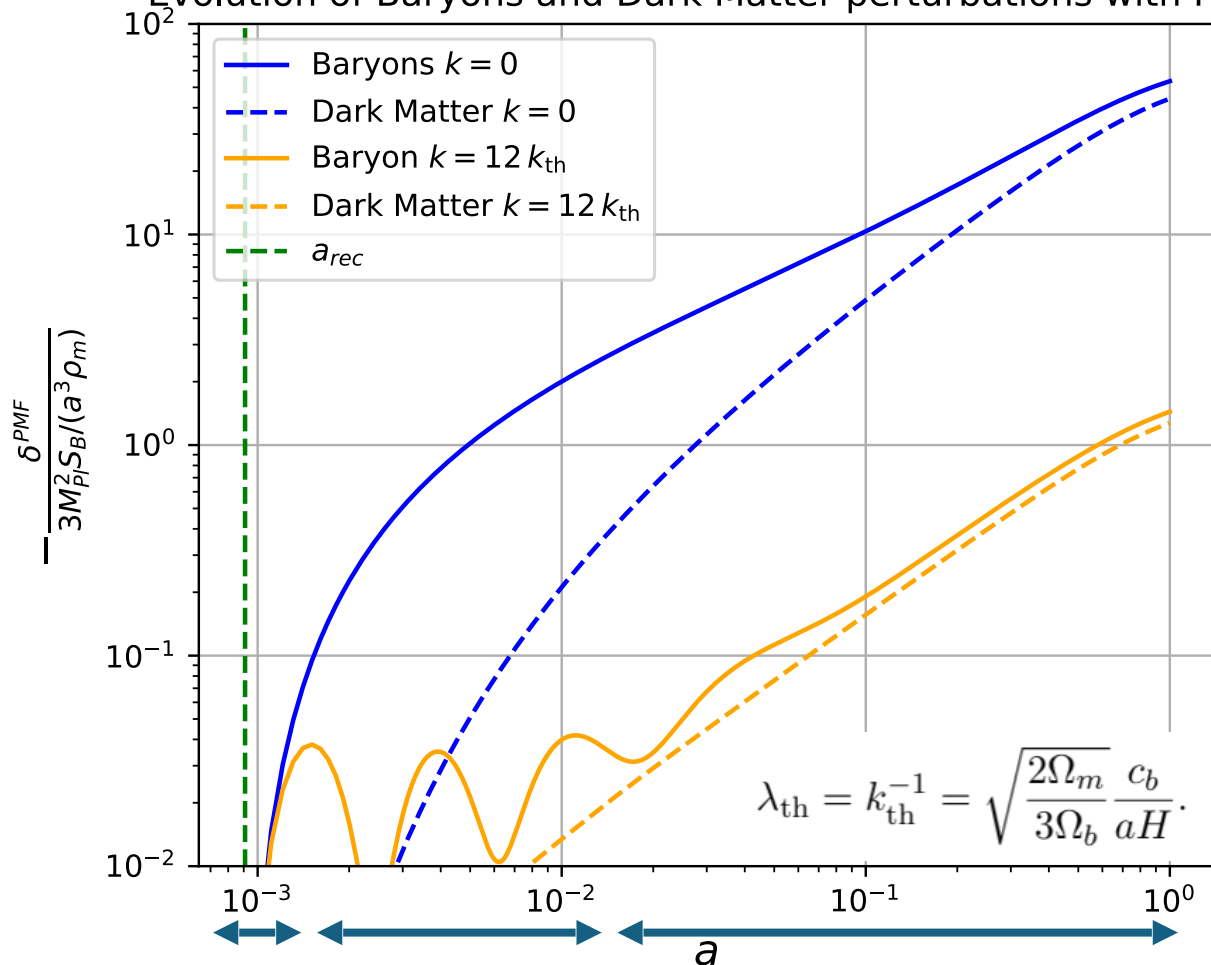


Density perturbations evolution

Evolution of **baryons** (solid) and **dark matter** (dashed) perturbations in the presence of magnetic fields, in the post-recombination era, in the large scale limit ($\lambda > \lambda_D$)

$$S_B = \frac{\nabla \cdot \left[\left(\nabla \times \vec{B} \right) \times \vec{B} \right]}{4\pi\rho_{m0}}$$

Evolution of Baryons and Dark Matter perturbations with PMF



Lorentz force

Baryon thermal pressure $\sim$ Lorentz force

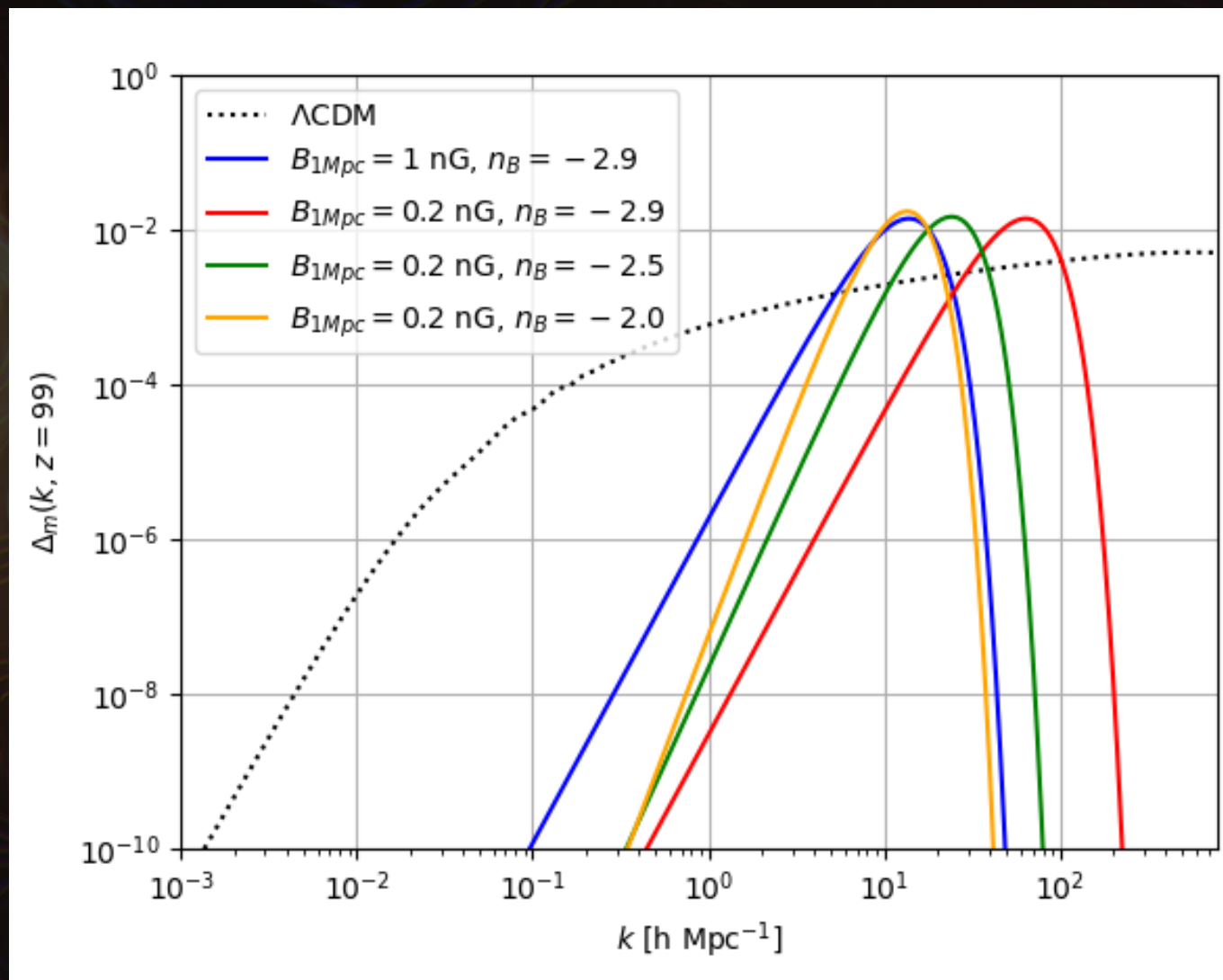
Gravity prevails

Linear matter power spectrum

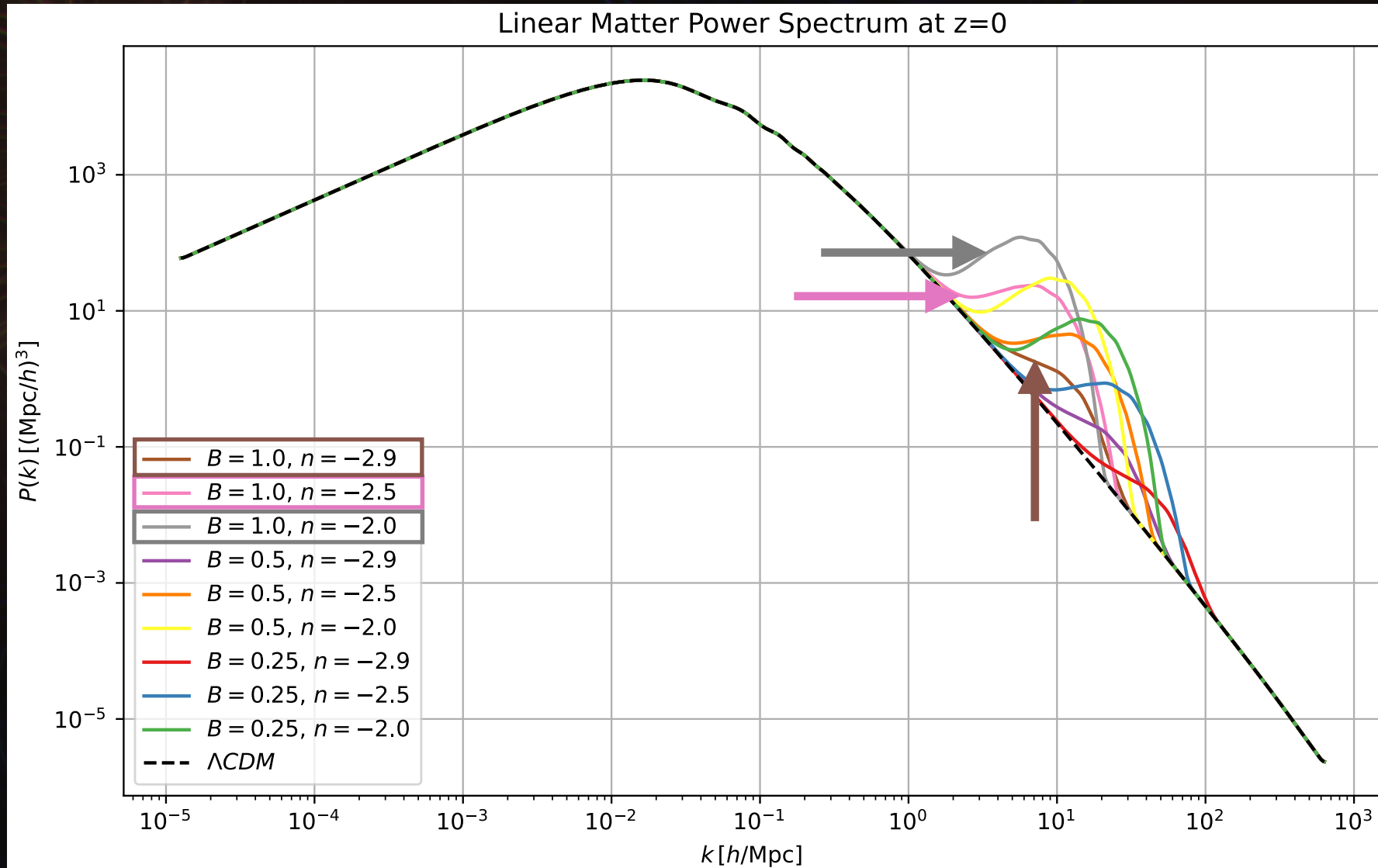
Ralengakar+2025

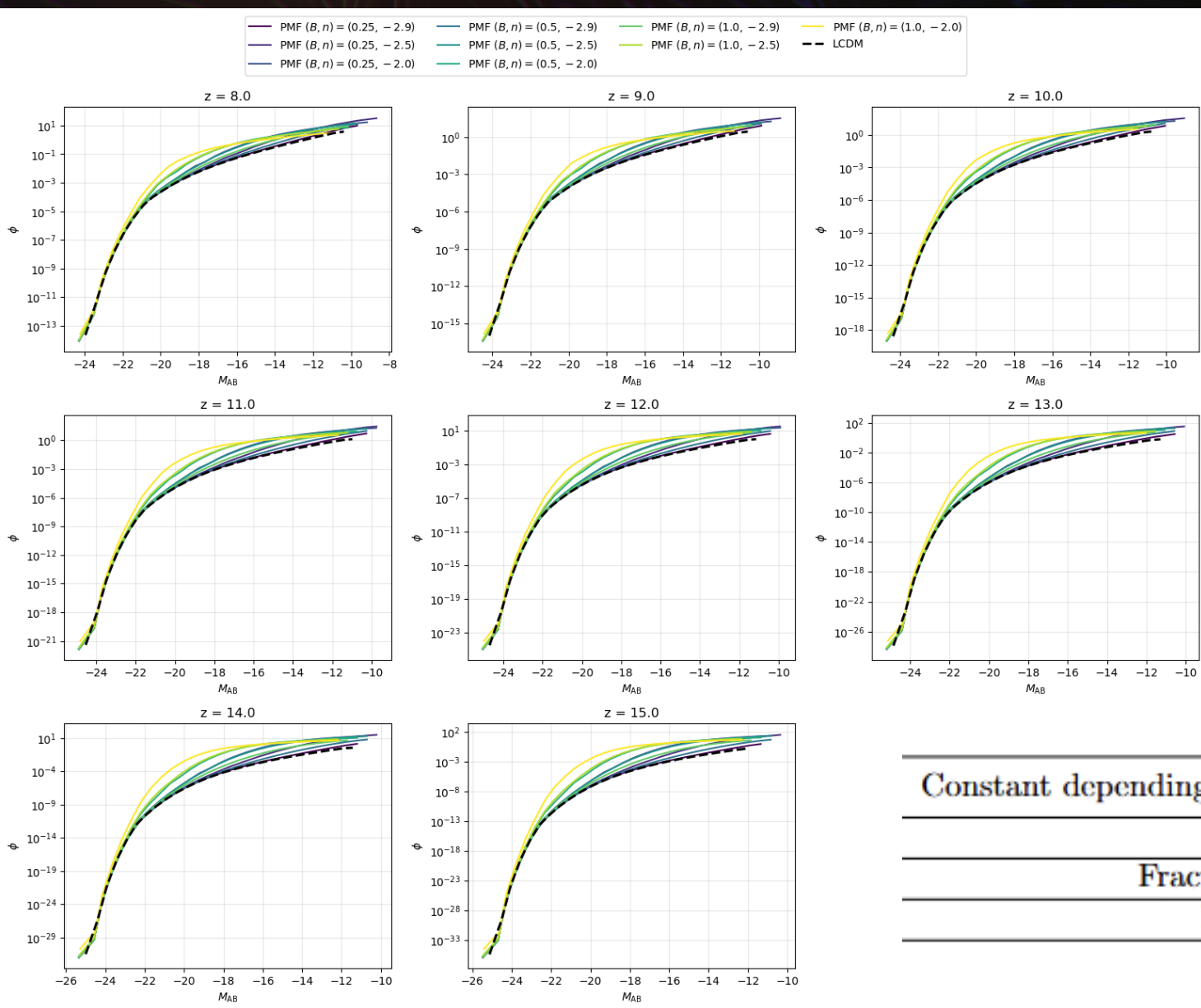
To calculate the matter power spectrum we assume a **power law** for the magnetic field power spectrum

$$P_B(k) \propto B_{1Mpc}^2 k^{n_B} e^{-k^2 \lambda_D^2}$$



Linear analysis



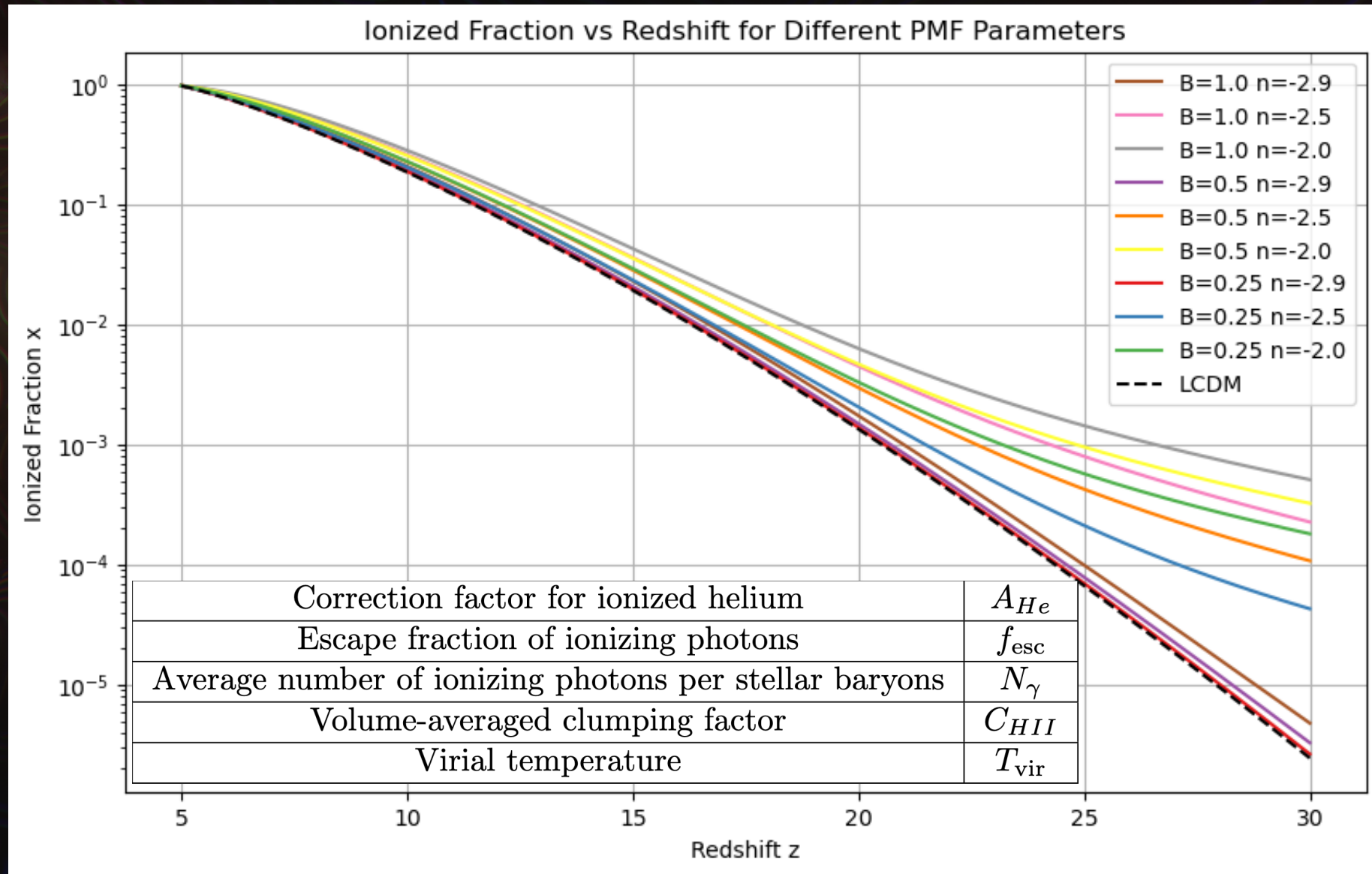


Galaxy luminosity function for different PMFs parameters for fixed astrophysical parameters

Constant depending on the IMF, star formation history, metallicity...	K_{UV}
Limit of $f_{\star}$	$f_{\star, max}$
Fraction of energy released in the wind	ϵ_K
Energy released in supernovae	ω_{49}

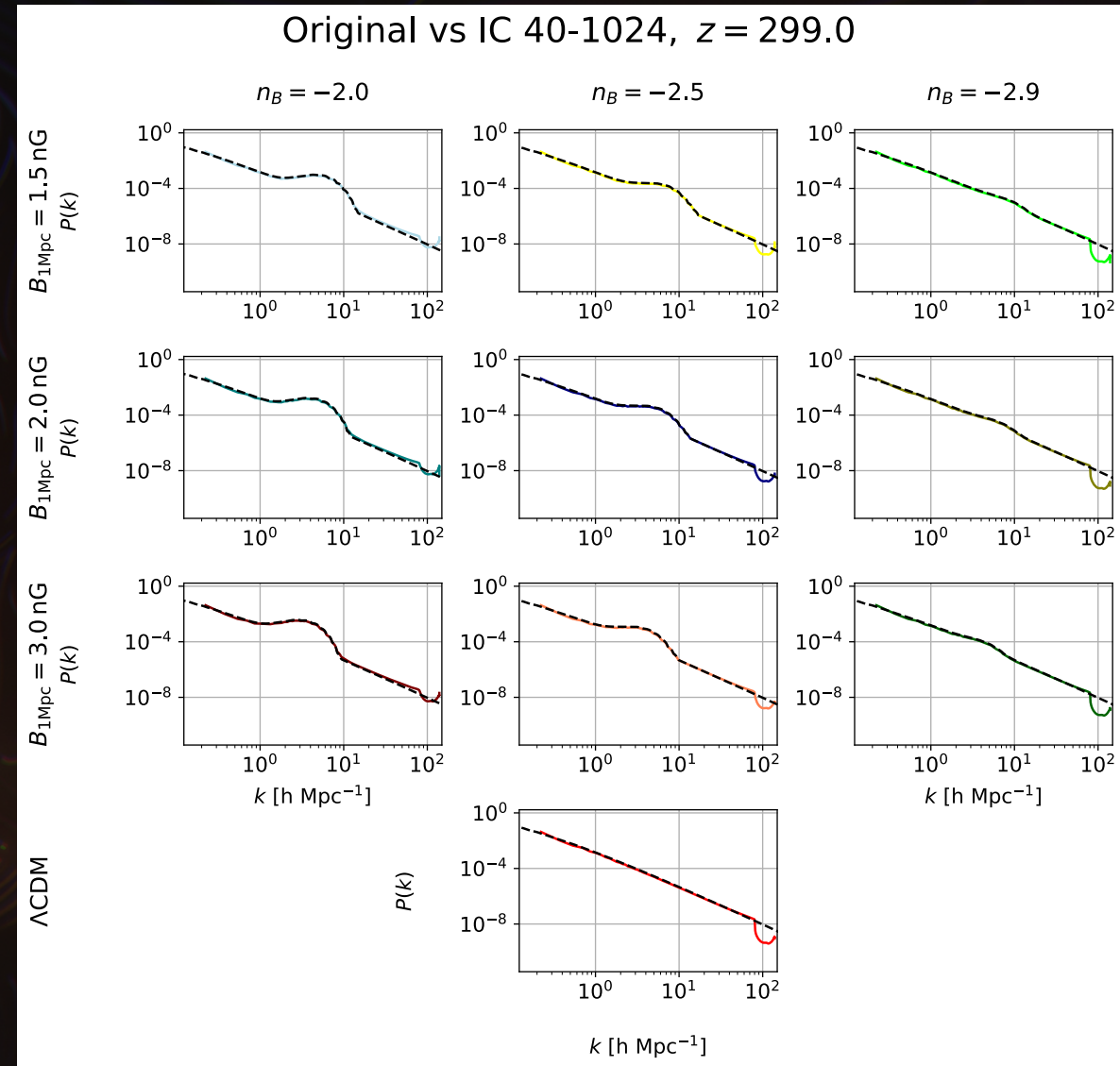
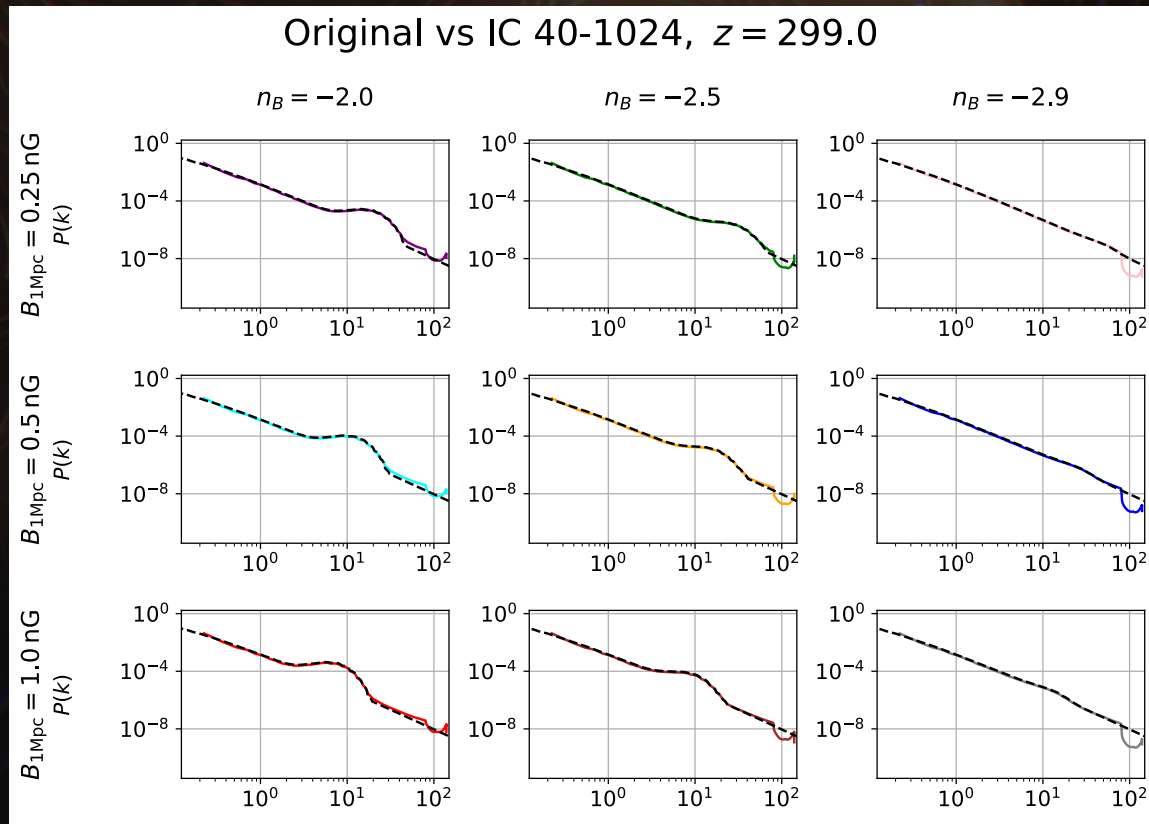
Irsic+2020
Furlanetto+2016

Ionized fraction for different PMFs parameters for fixed ionization and recombination parameters

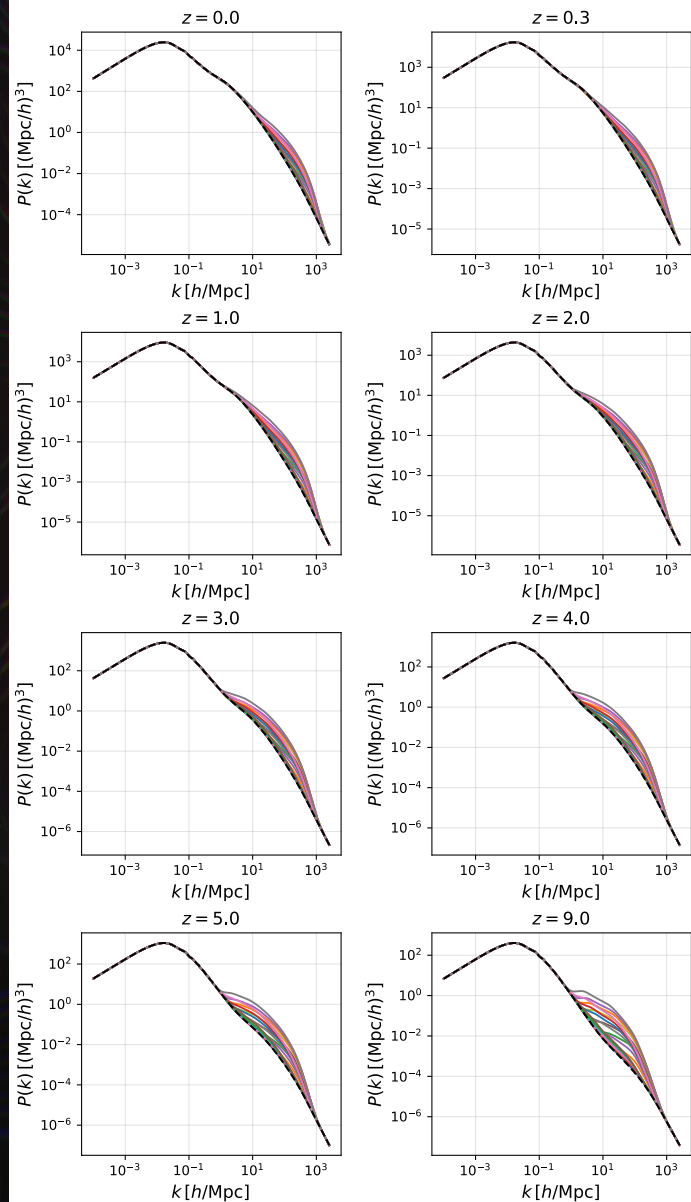
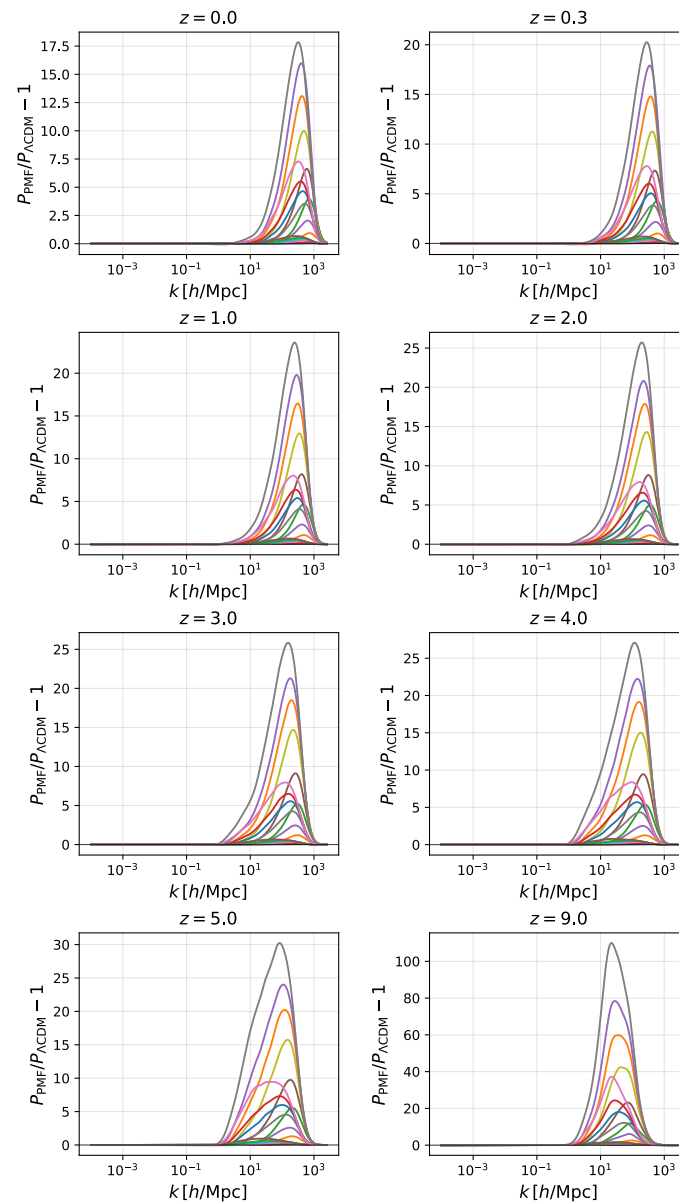


Non-linear analysis

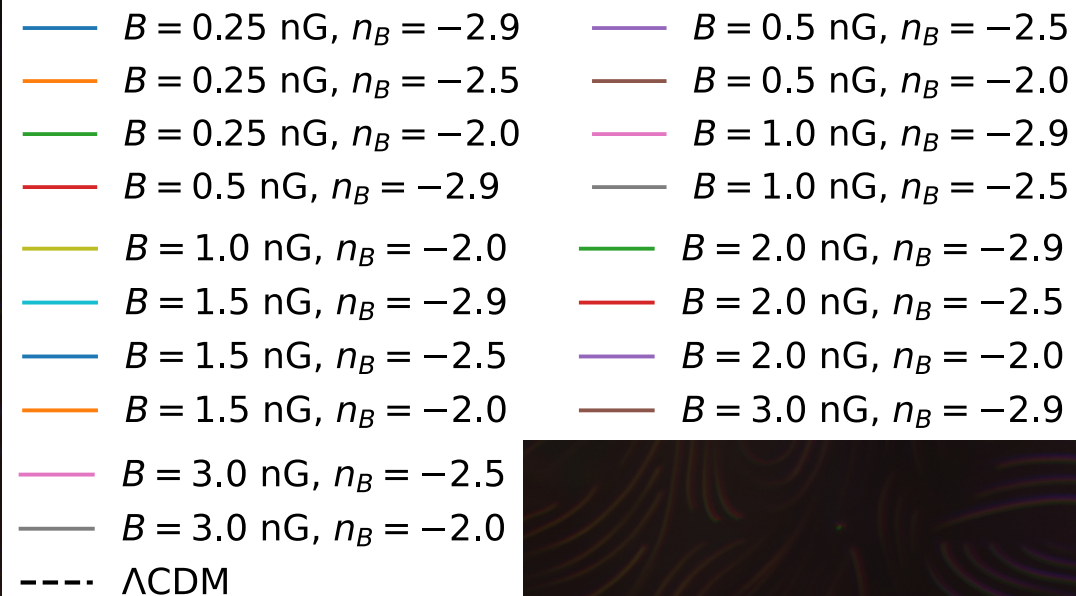
Initial conditions at $z = 299$ for N-body simulations with linear box-size of 40 Mpc/h and 1024^3 particles in each box.

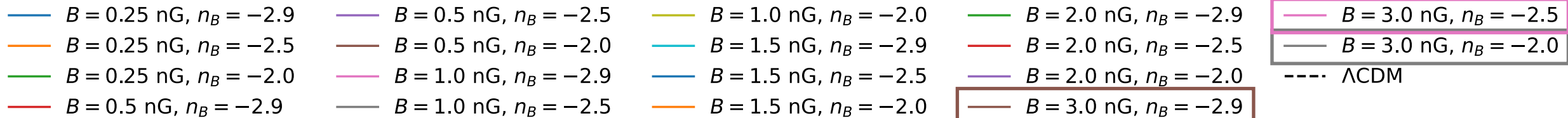
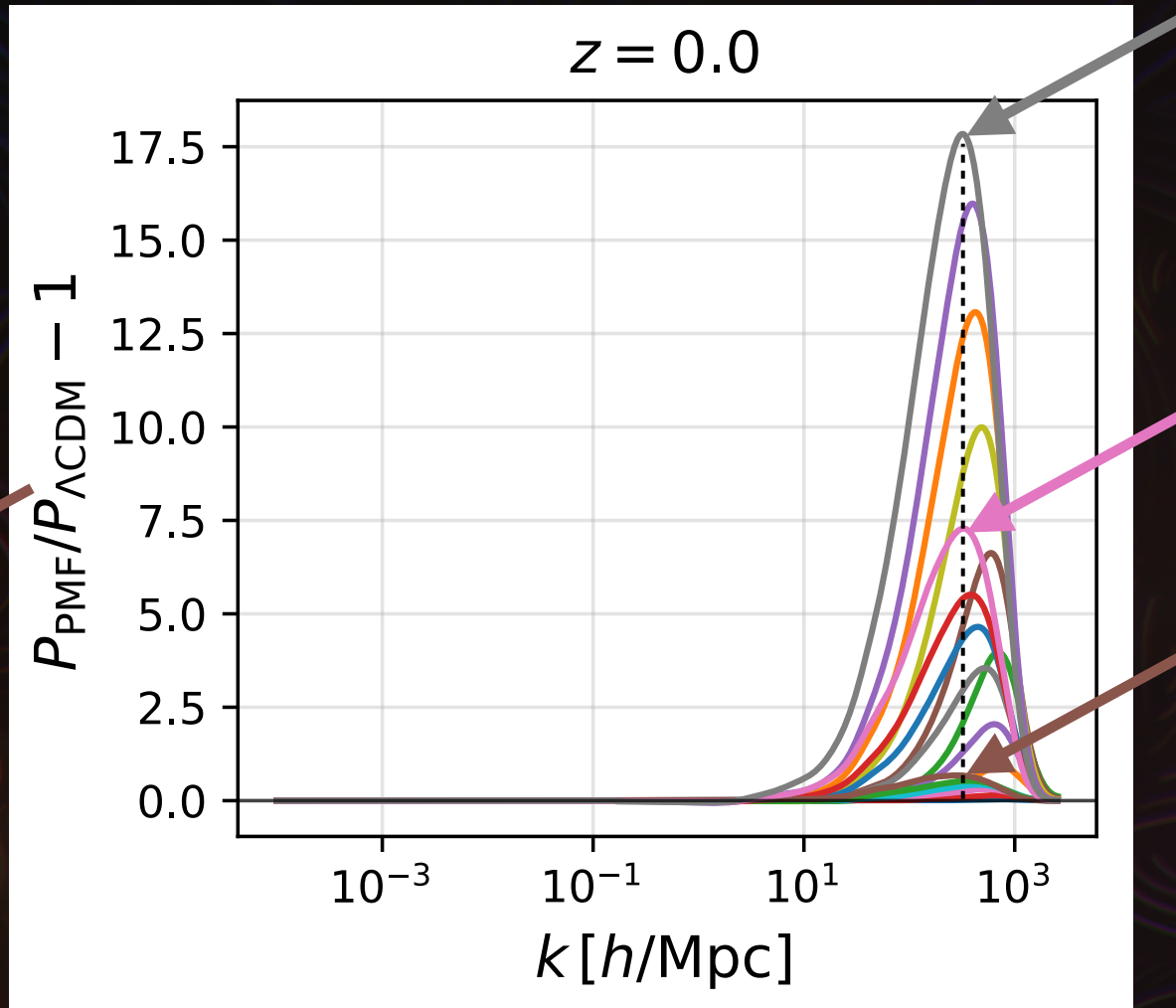
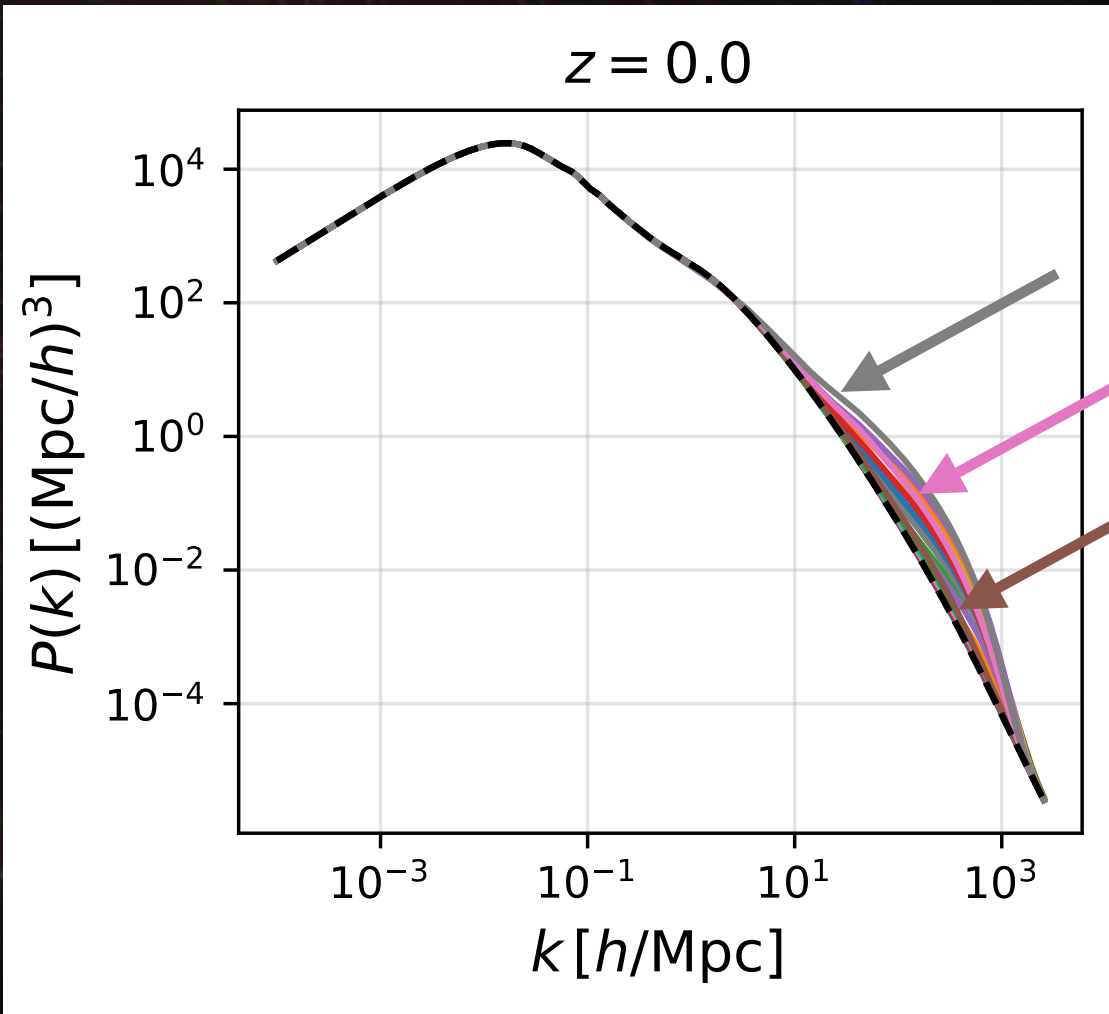


Power spectrum

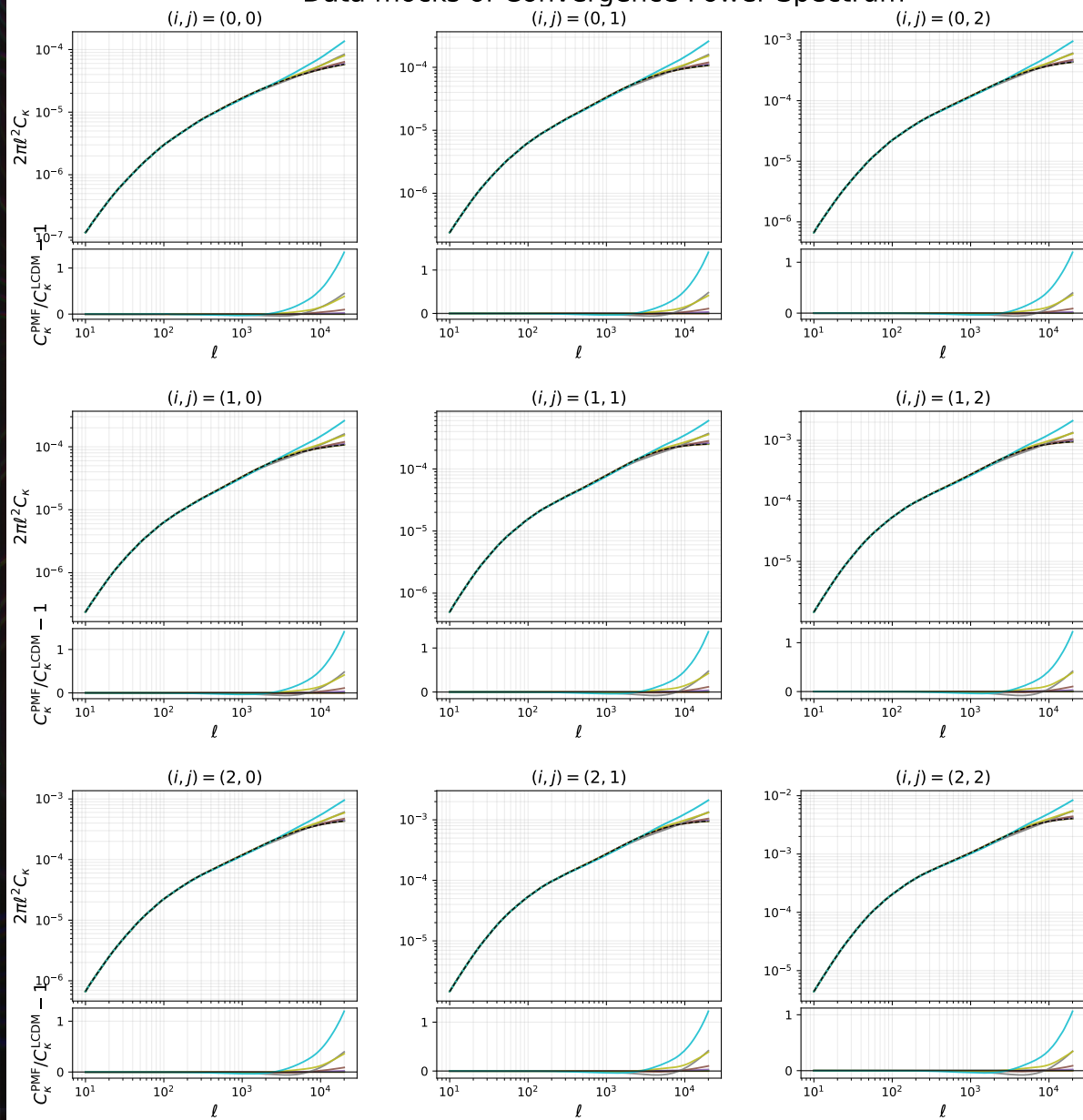
Residual with respect to Λ CDM

Non-linear matter power spectrum from snapshots.

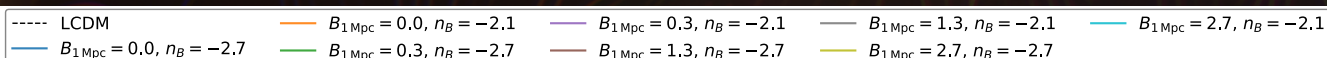




Data mocks of Convergence Power Spectrum



Convergence power spectrum of weak lensing, including intrinsic alignment and baryon feedback (*Parimbelli+19*), for different PMF and all other parameters fixed



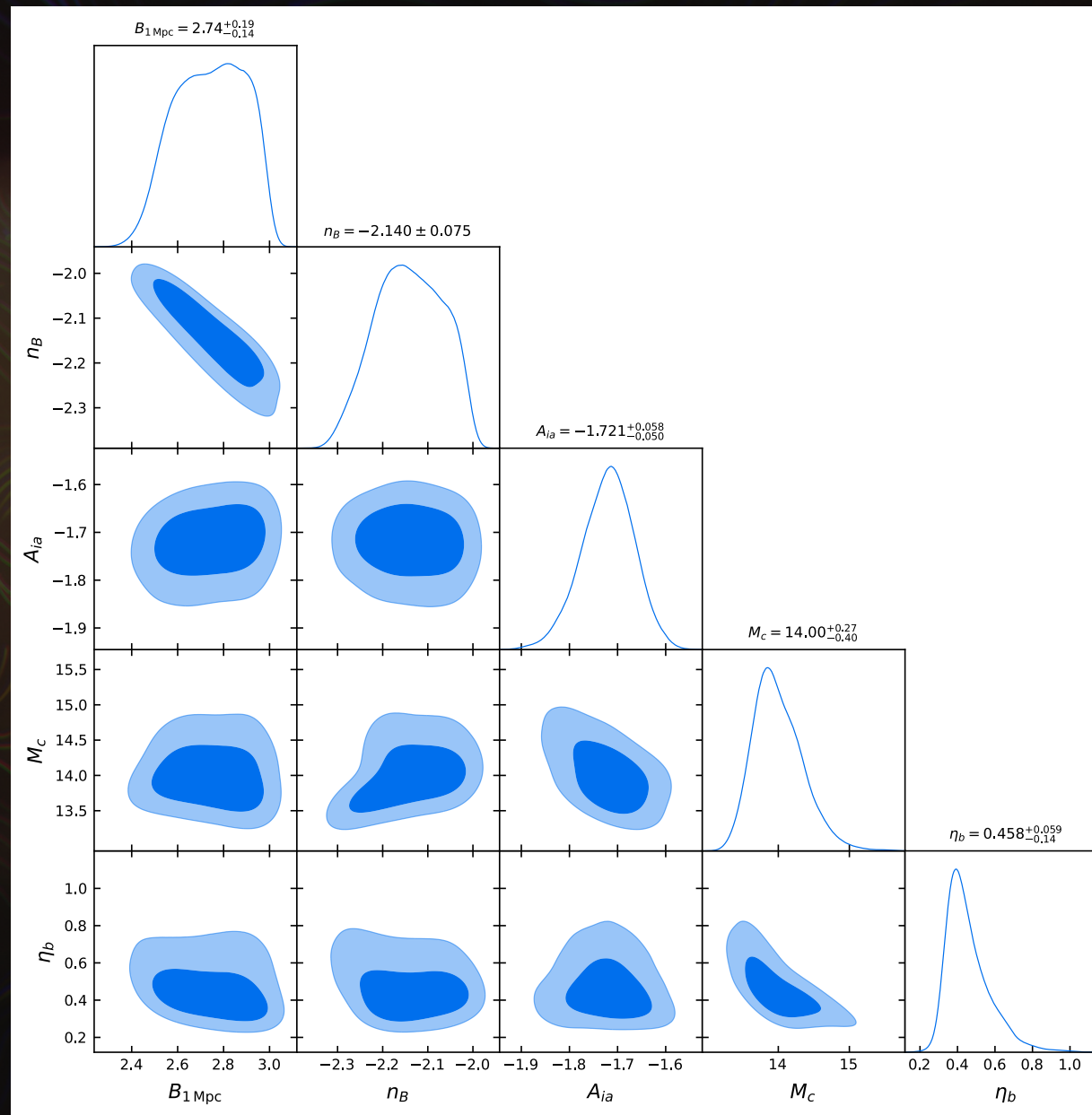
Different values of ℓ_{max} : 5k, 10k, 20k

$\ell_{\text{max}} = 20000$

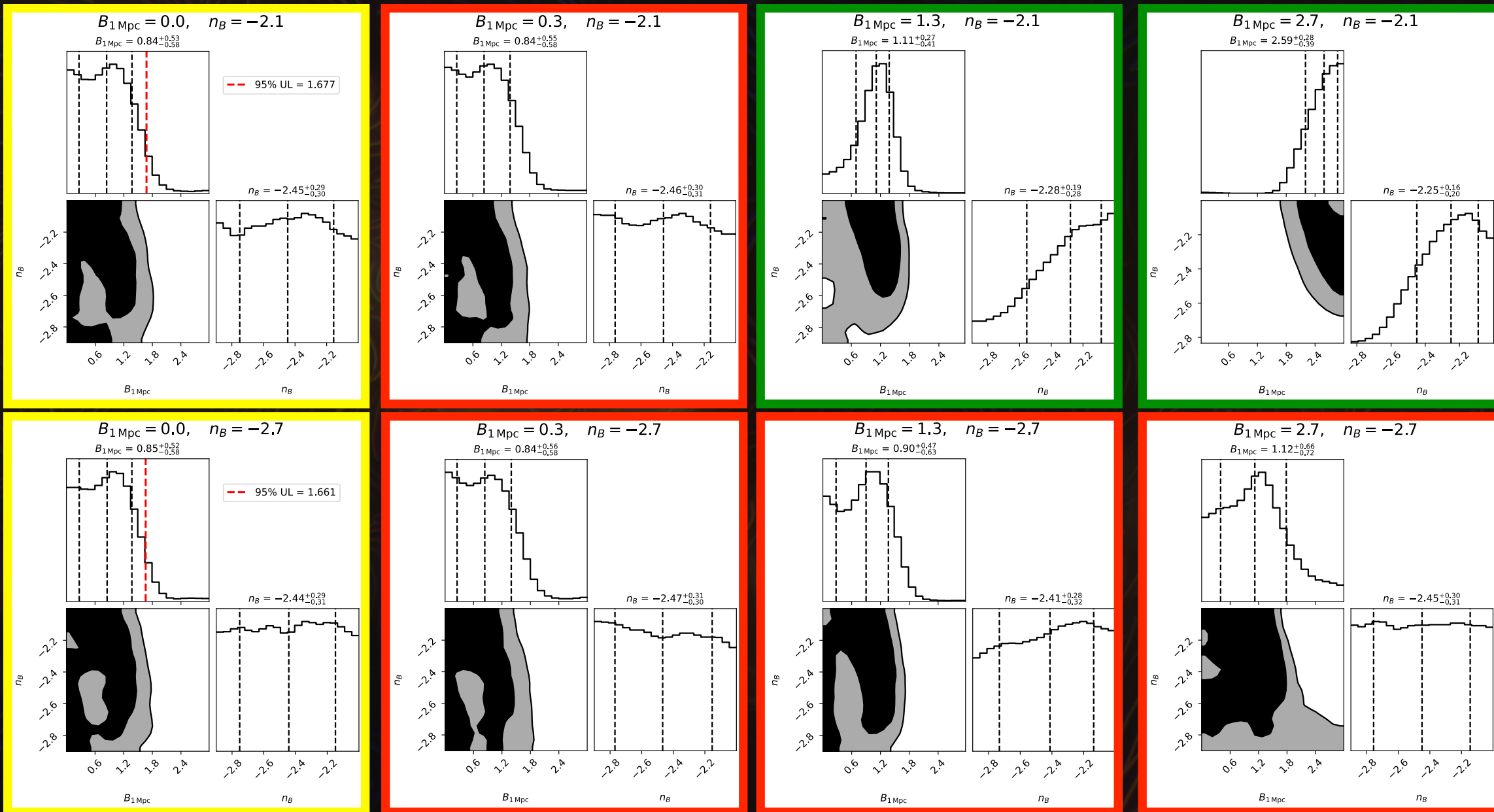
PMF

Intrinsic Alignment

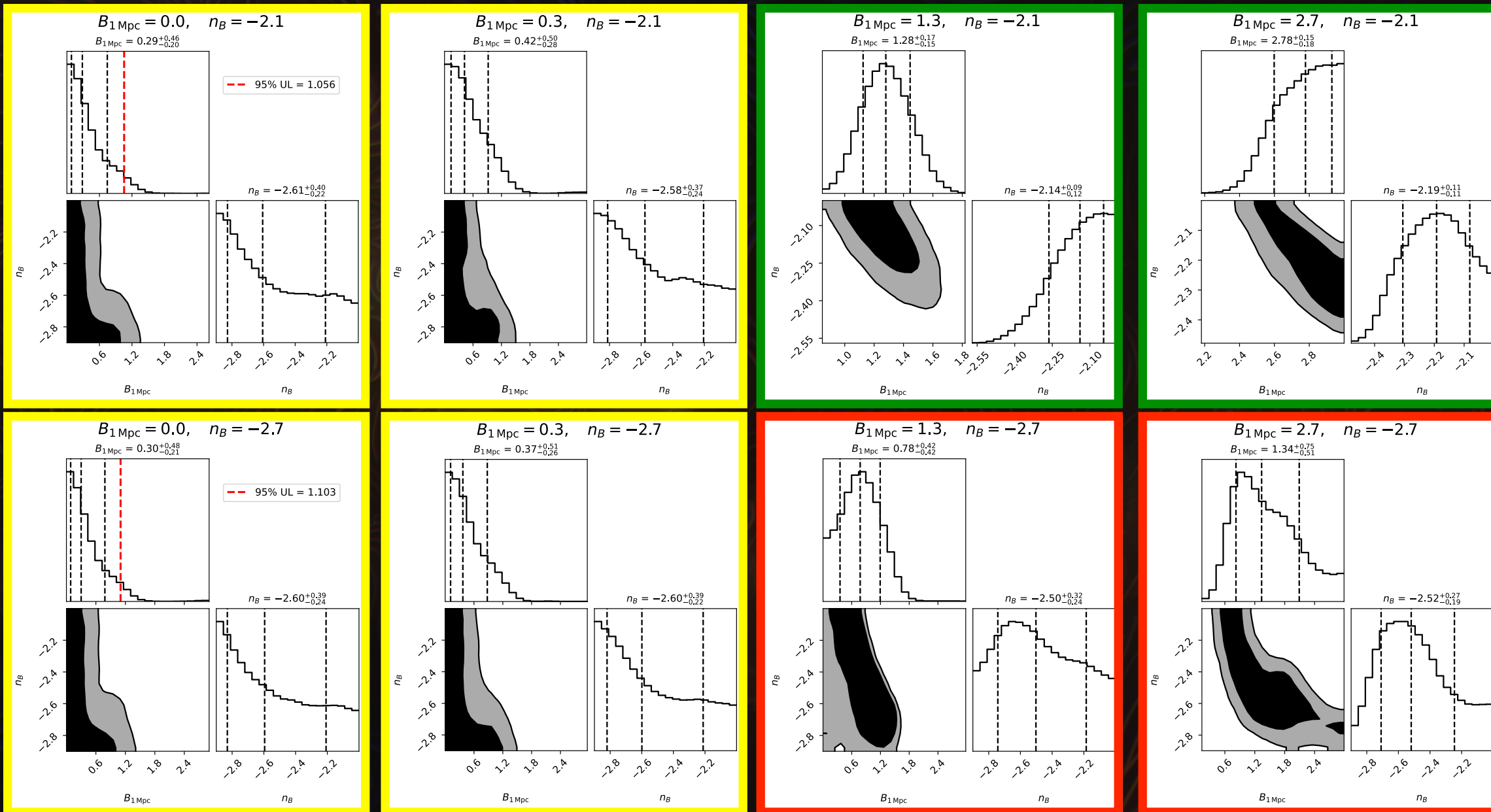
Baryon Feedback

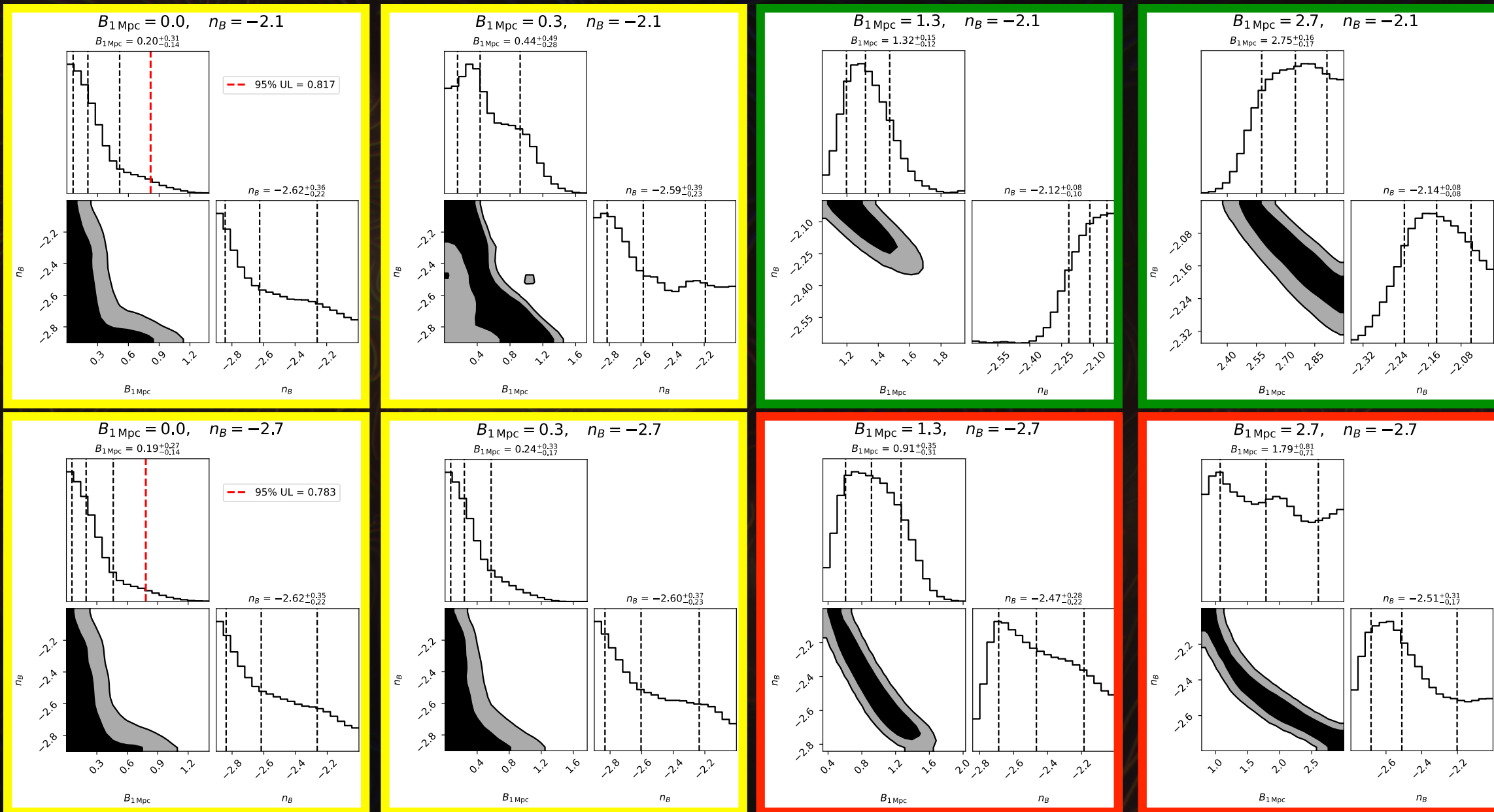


$\ell_{\max} = 5000$



$\ell_{\max} = 10000$





Conclusions

- Assuming the presence of Primordial Magnetic Fields (PMFs) the **matter power spectrum sees and increase** at a scale and of amplitude dependent on the PMFs parameters chosen.
- PMFs leave an **imprint on cosmological observables** both when considering the linear and non-linear matter power spectrum.
- The effect on the convergence power spectrum lies at scales that make it **difficult to observe** using current experiment.
- But in some parameters regimes it's **already possible to put upper limit constraints on the strength of PMFs** and to distinguish between different models.

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