Cosmological Effects of Coupled Dark Matter

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arxiv:1304.2196 “Cosmological effects of coupled dark matter” - SCFM, Anne Green, Antonio Padilla, Ewan Tarrant
In prep: “Constraints on coupled dark matter using Planck data” - SCFM, Anne Green

Outline

- Introduction
- Background Cosmology
- Perturbations
- CMB power spectrum and constraints
- Conclusion

Introduction

- Quintessence scenarios with scalar field dark energy often couple to dark matter
- Main differences with literature
  - Only a fraction of CDM coupled to scalar field
  - No potential i.e. massless scalar

Background Cosmology

- Friedmann equation

$$H^2 = \frac{8\pi G}{3}\left(\rho_\Lambda + \rho_{\rm SM} + \rho_{\rm c} + \frac{1}{2}\dot{\phi}^2 + \rho_* e^{\alpha\phi}\right)$$

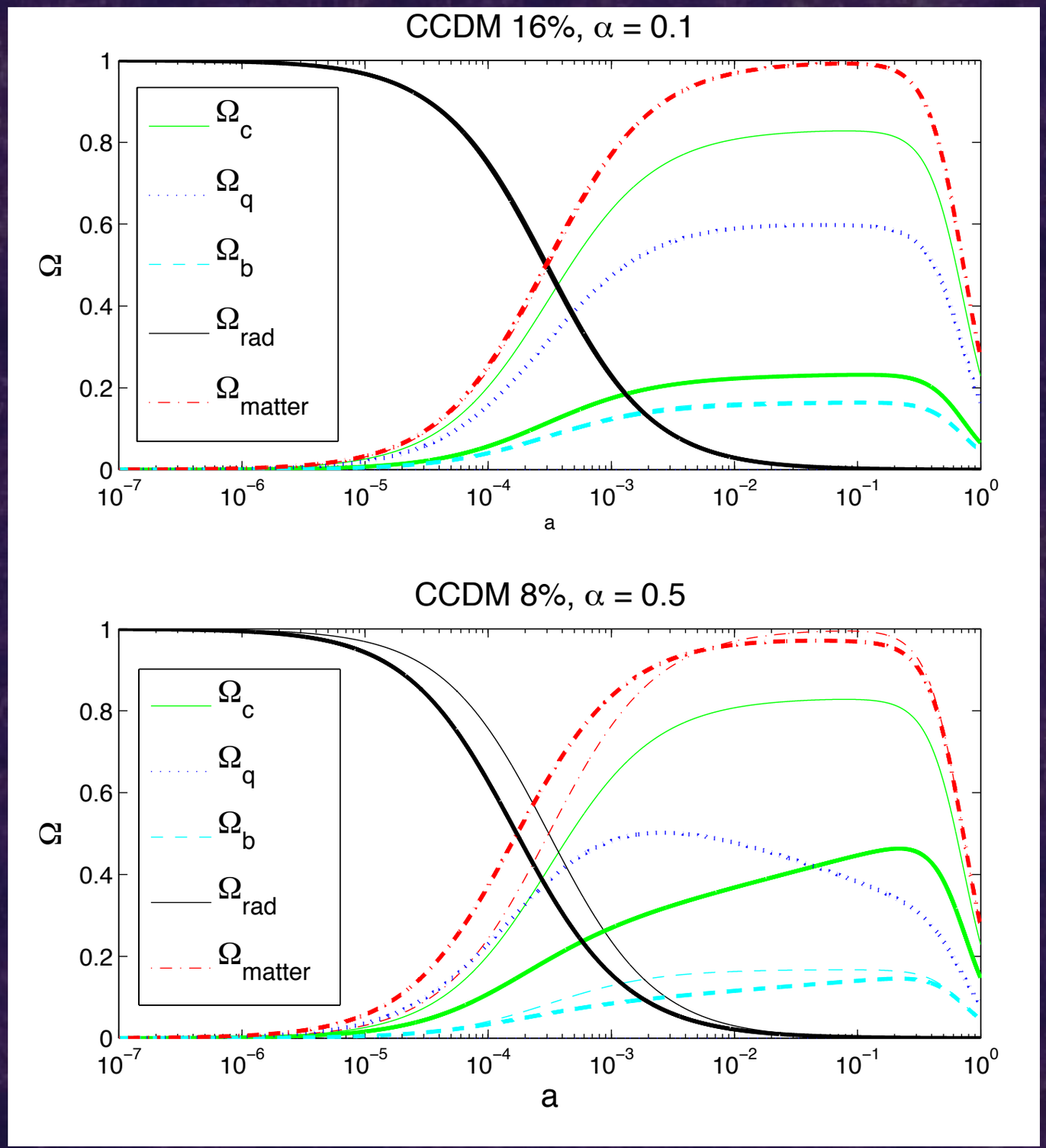
- Klein Gordon equation

$$\ddot{\phi} + 3H\dot{\phi} + \alpha\rho_* e^{\alpha\phi} = 0$$

ρ_* - is conserved density of coupled CDM obeying the fluid equation

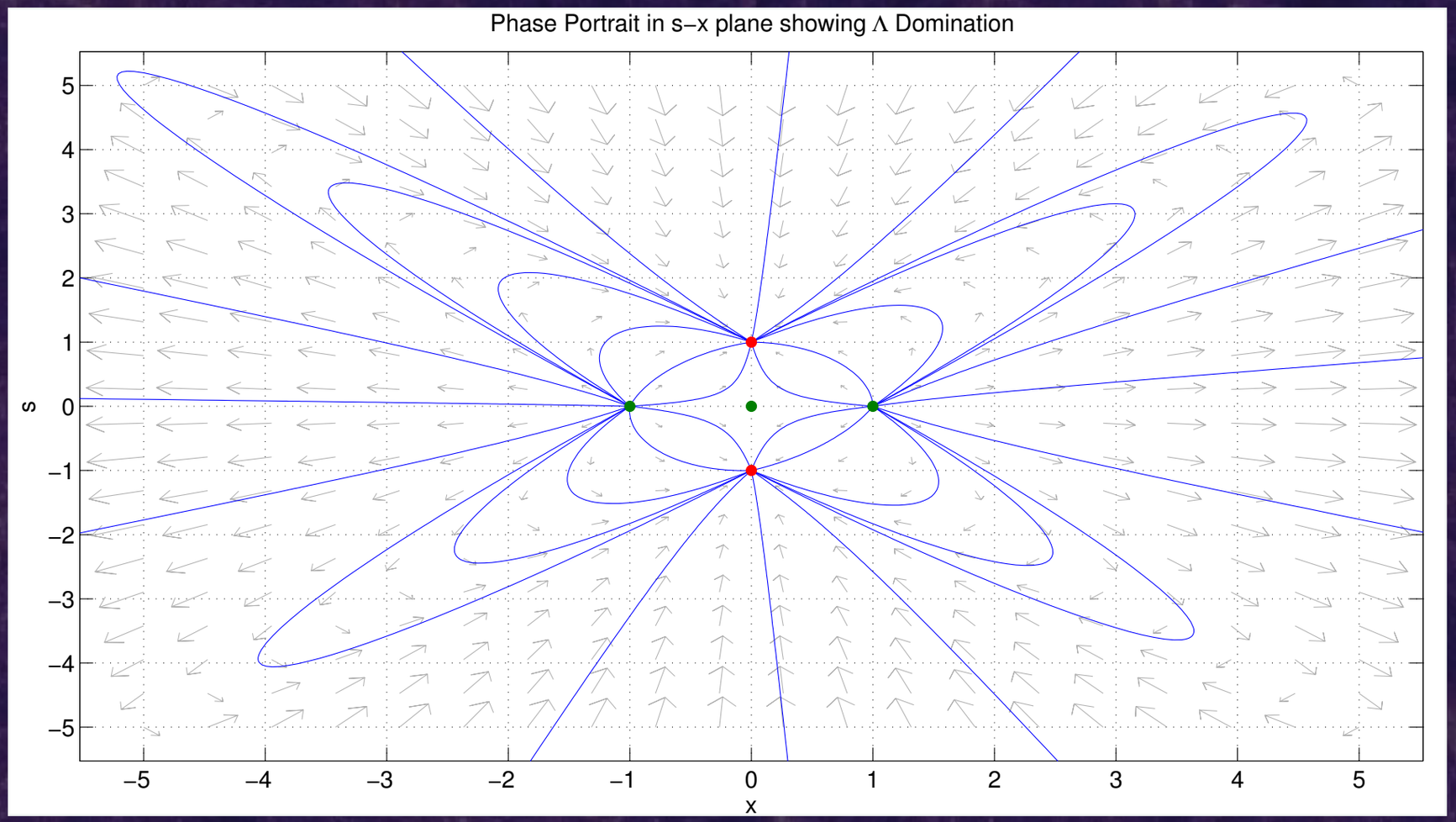
α - coupling constant i.e. strength of coupling to scalar field

Background Evolution



- Our model - thick lines
  ΛCDM - thin lines
- Cannot assume ΛCDM background

Dynamical Systems



All solutions end in Λ domination (red points) and other solutions are unstable (green points)

$$x \equiv \frac{\dot{\phi}}{\sqrt{6}H} \quad y \equiv \frac{1}{H}\sqrt{\frac{\rho_\gamma}{3}} \quad z \equiv \frac{1}{H}\sqrt{\frac{\rho_* e^{\alpha\phi}}{3}} \quad s \equiv \frac{1}{H}\sqrt{\frac{\rho_\Lambda}{3}}$$

Perturbations

- Coupled dark matter density and velocity perturbations

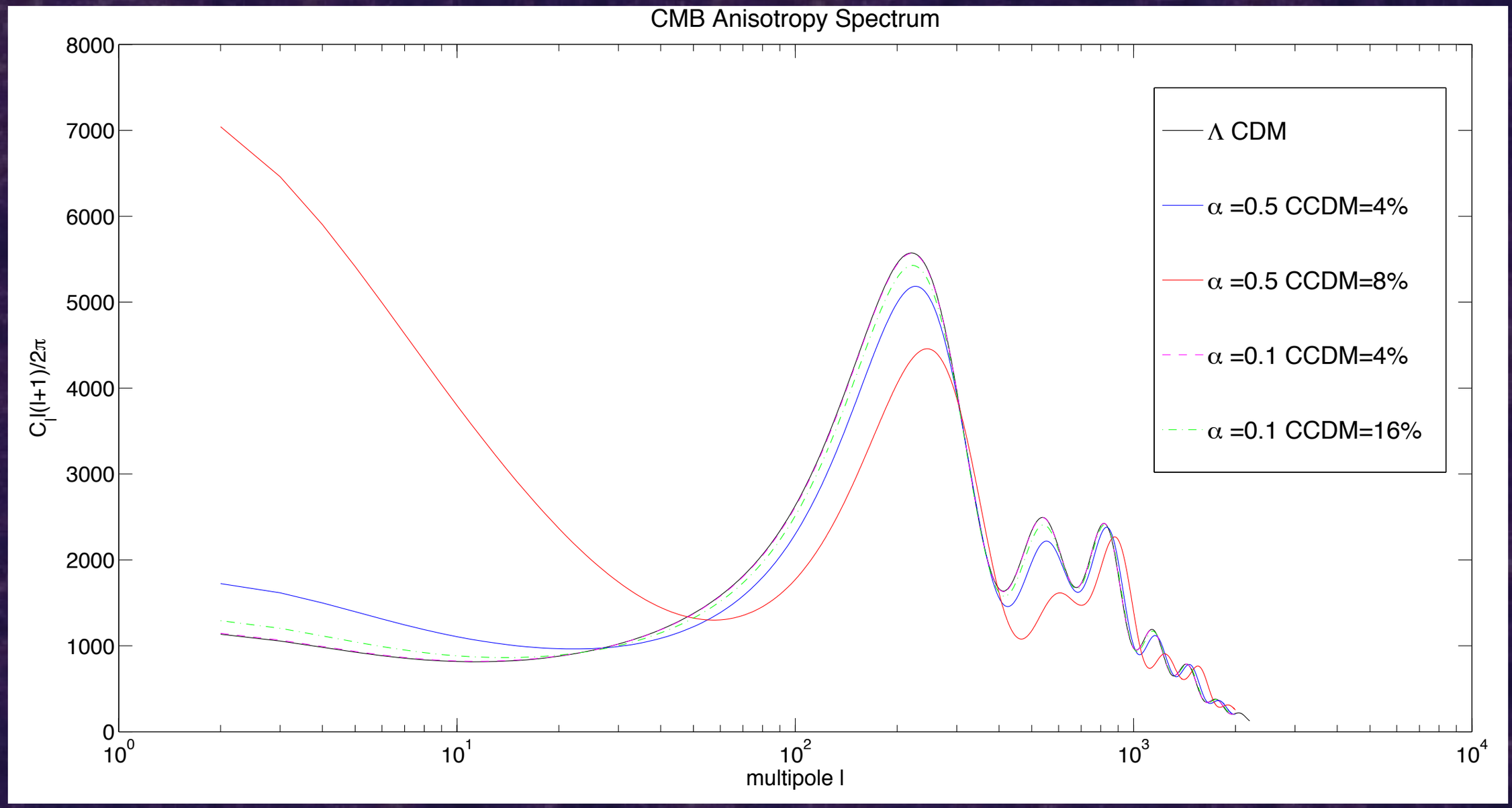
$$\delta_q' = -\theta_q - \frac{1}{2}h' + \alpha\delta\phi'$$

$$\theta_q' = -\theta_q\mathcal{H} + \alpha(k^2\delta\phi - \phi'\theta_q)$$

- Perturbed scalar field equation

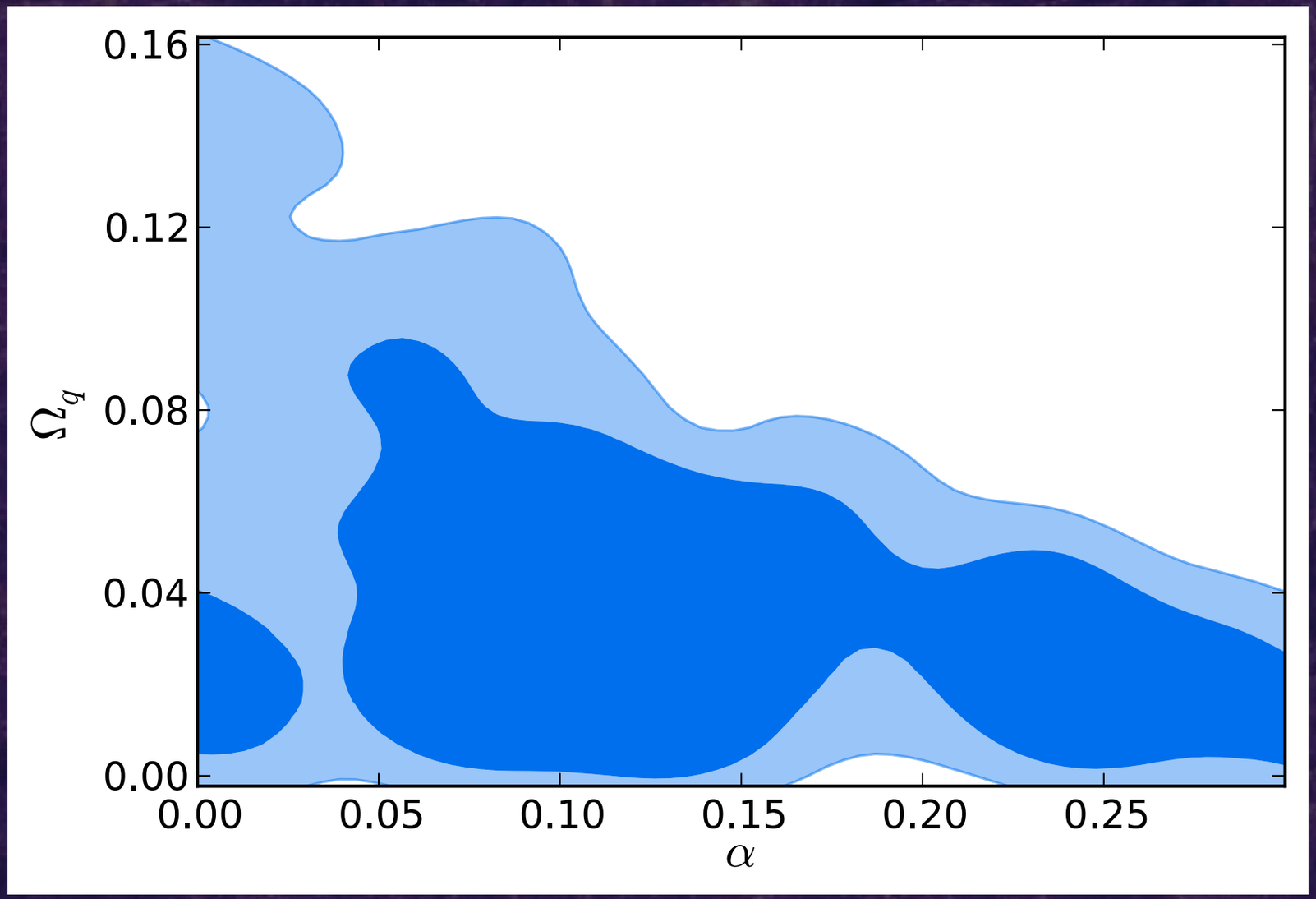
$$\delta\phi'' + 2\mathcal{H}\delta\phi' + k^2\delta\phi + \frac{1}{2}h'\phi' = -\alpha a^2\delta\rho_q$$

CMB anisotropy spectra



With over half of dark matter in coupled form CMB is very close to ΛCDM

CosmoMC constraints

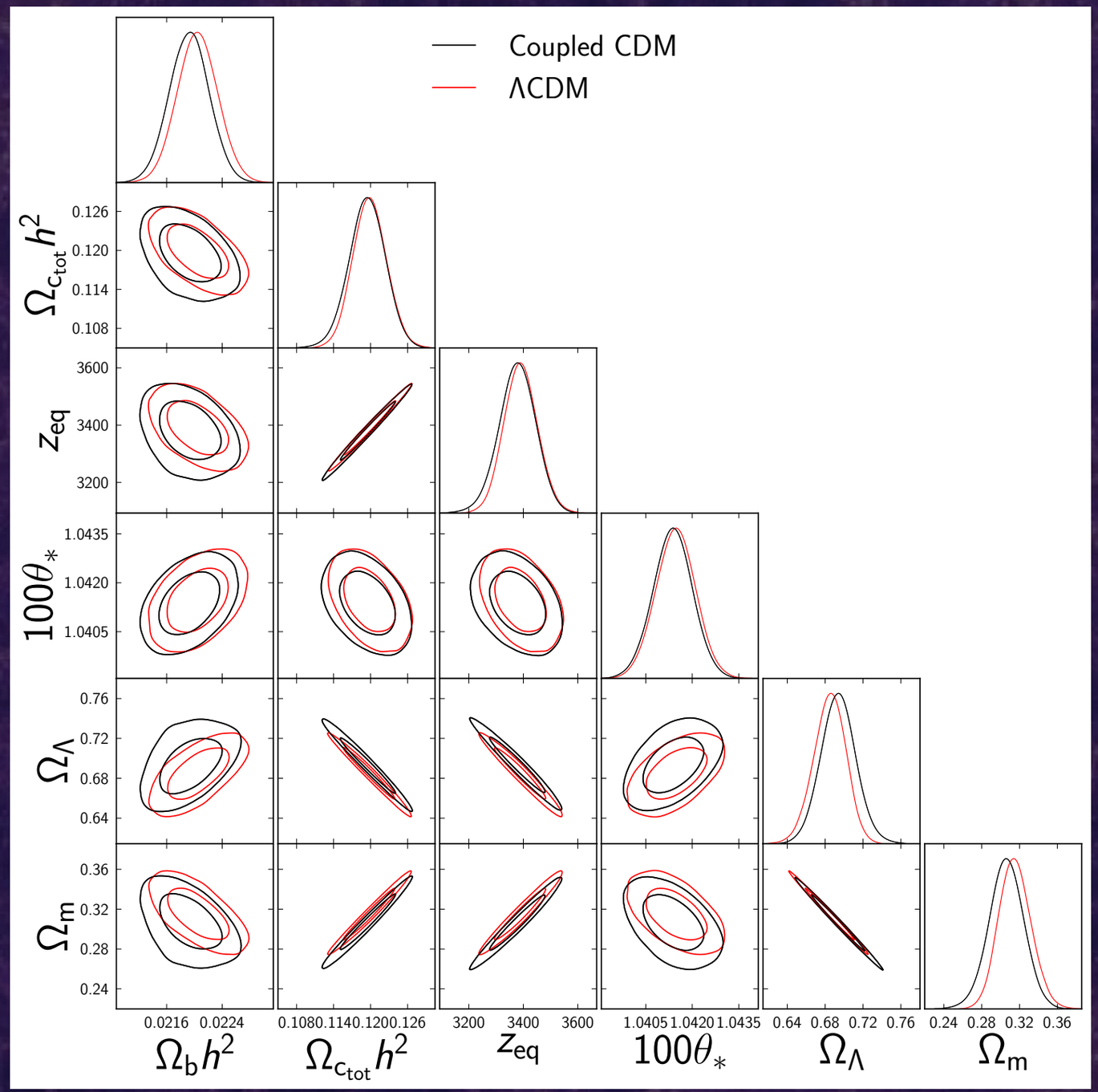


95% confidence limits

$\Omega_q < 0.13$

$\alpha < 0.26$

CosmoMC constraints



Even for tightly constrained parameters we still match the ΛCDM parameters very well

Conclusions

- Cannot assume ΛCDM background
- Removing potential leaves only unstable solutions resulting in Λ domination
- Can have over half of CDM in coupled form and still obtain a good match to observations