

Decaying Dark Matter and Lyman- α forest constraints

Lea Fuß, Mathias Garny
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New Physics from Galaxy Clustering (CERN 2022)

Decaying Dark Matter Model

potential problems with Λ CDM:

- ▶ Hubble tension
- ▶ S_8 tension

DM model that generates suppression on small scales

→ **Decaying Cold Dark Matter (DCDM)**

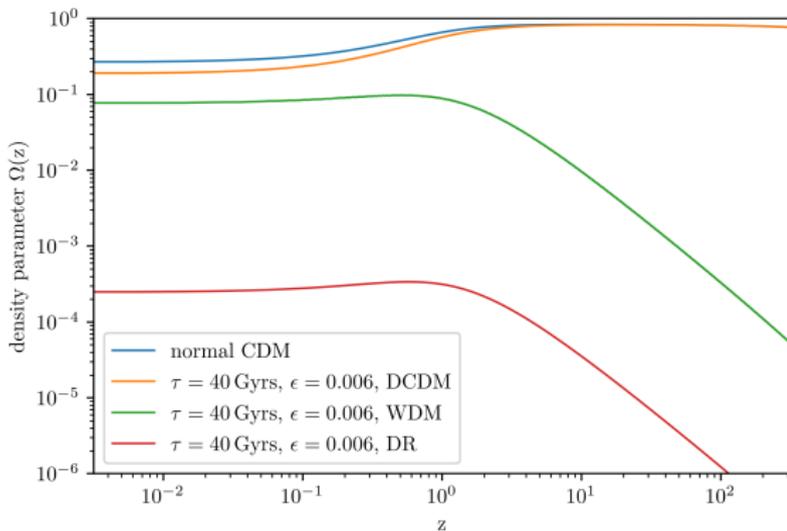
CDM → WDM + DR

2 parameters: lifetime τ , mass splitting $\epsilon = \frac{1}{2} \left(1 - \frac{m^2}{M^2} \right)$

$$\dot{\bar{\rho}}_{\text{dcdm}} = -3\mathcal{H}\bar{\rho}_{\text{dcdm}} - a\Gamma\bar{\rho}_{\text{dcdm}}$$

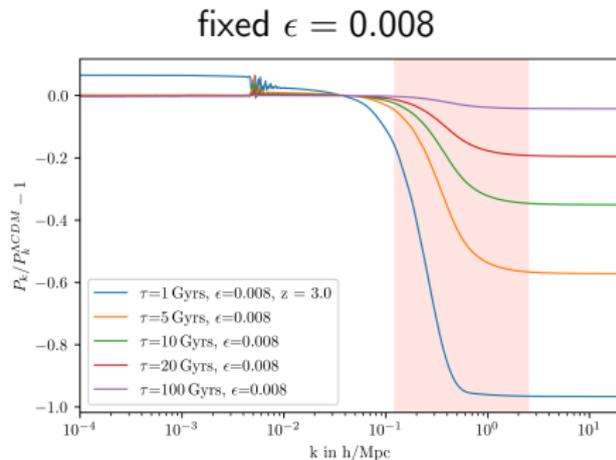
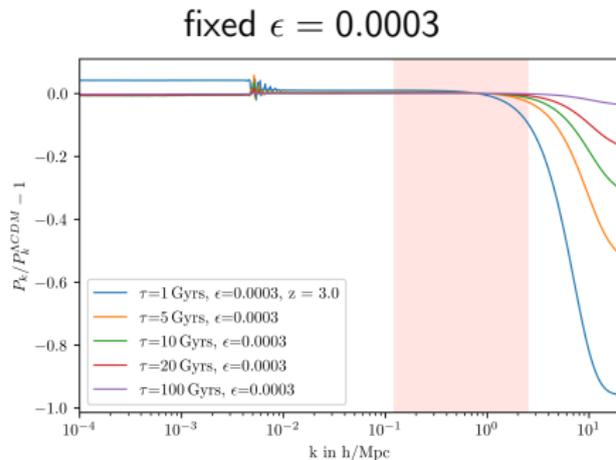
$$\dot{\bar{\rho}}_{\text{wdm}} = -3(1+\omega)\mathcal{H}\bar{\rho}_{\text{wdm}} + (1-\epsilon)a\Gamma\bar{\rho}_{\text{dcdm}}$$

$$\dot{\bar{\rho}}_{\text{dr}} = -4\mathcal{H}\bar{\rho}_{\text{dr}} + \epsilon a\Gamma\bar{\rho}_{\text{dcdm}}$$



Effects on the Power Spectrum

- ▶ computed with modified CLASS code from [Abellan et al, 2021, arXiv:2102.12498]



- ▶ ϵ controls onset and τ steepness of suppression
- ▶ orange region refers to weakly non-linear BOSS region

Effective Lyman- α model

- ▶ $\delta_F(\delta, \theta) = \frac{F}{\bar{F}} - 1$
- ▶ effective and perturbative model applicable to BOSS scales
- ▶ consider Jeans-scale k_F , broadening effects k_s , SiIII absorption κ_{SiIII} and integrate over line of sight k_{\parallel}

$$P_{F,1D}(k_{\parallel}, z) = A(z) \cdot \kappa_{\text{SiIII}}(k_{\parallel}, z) \cdot e^{-(k_{\parallel}/k_s)} \\ (I_0 + I_{ct}(z) + 2\beta(z)I_2 + \beta(z)^2 I_4)$$

$$I_0(k_{\parallel}, z) = \int_{k_{\parallel}} dk k \cdot e^{-(k/k_F)^2} P_{\delta\delta}(k, z)$$

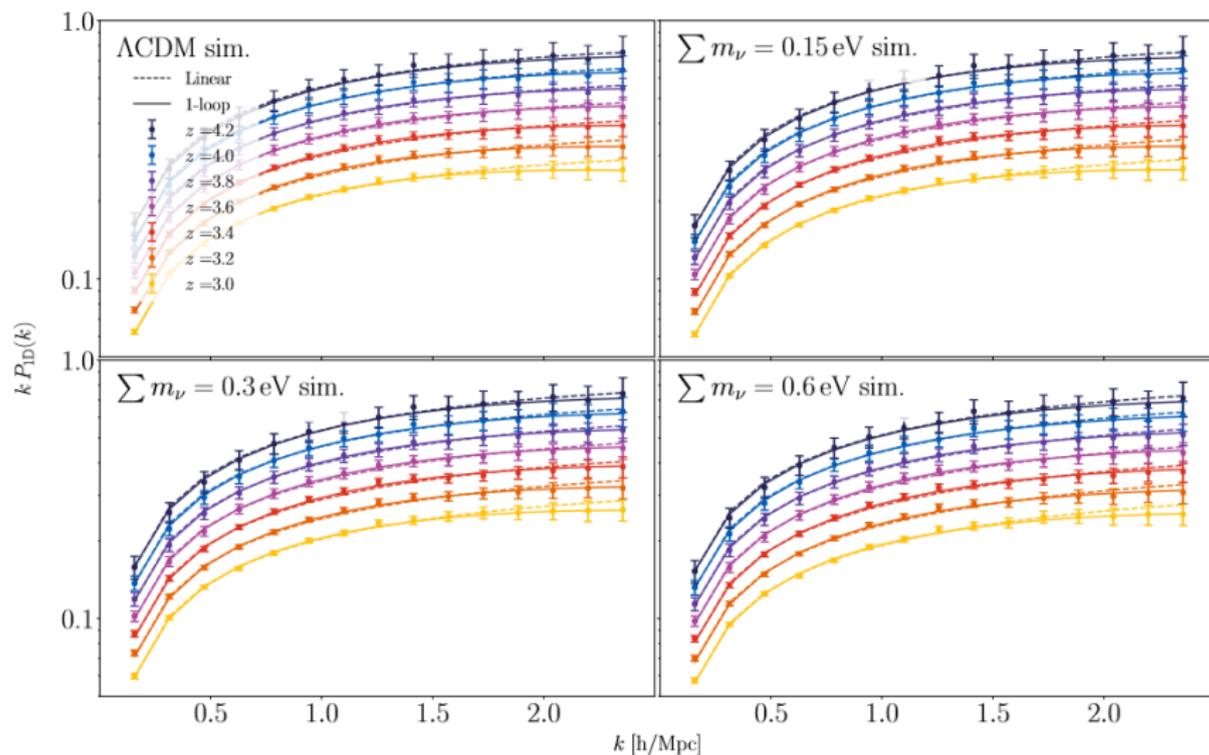
$$I_2(k_{\parallel}, z) = \int_{k_{\parallel}} dk \frac{k_{\parallel}^2}{k} \cdot e^{-(k/k_F)^2} P_{\delta\theta}(k, z)$$

$$I_4(k_{\parallel}, z) = \int_{k_{\parallel}} dk \frac{k_{\parallel}^4}{k^3} \cdot e^{-(k/k_F)^2} P_{\theta\theta}(k, z)$$

6 free parameters:

- ▶ $A(z) = \alpha_F \left(\frac{a(z_p)}{a(z)} \right)^{\beta_F}$
- ▶ $\beta(z) = \alpha_b \left(\frac{a(z_p)}{a(z)} \right)^{\beta_b}$ for IGM physics
- ▶ $I_{ct}(z) = \alpha_{ct} \left(\frac{a(z)}{a(z_p)} \right)^{\beta_{ct}}$ for non-linearities

Verification

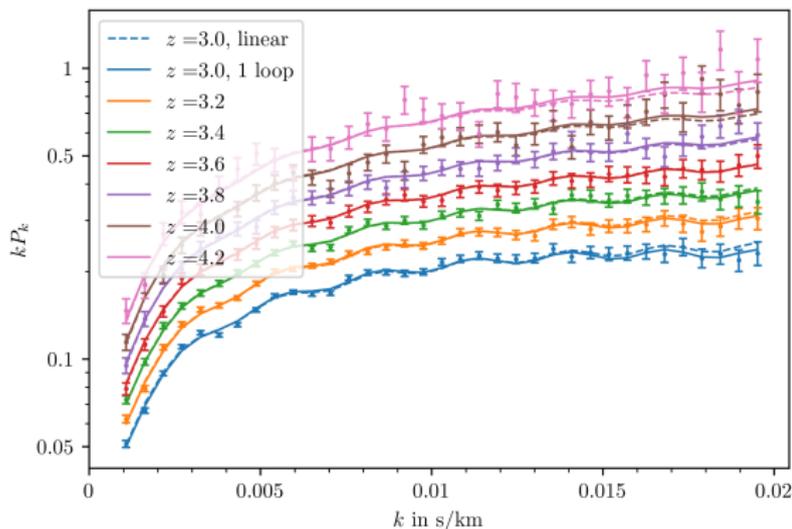


- model verified with hydrodynamical simulations in [Garny et al, 2020, arXiv:2011.03050]

Our Approach

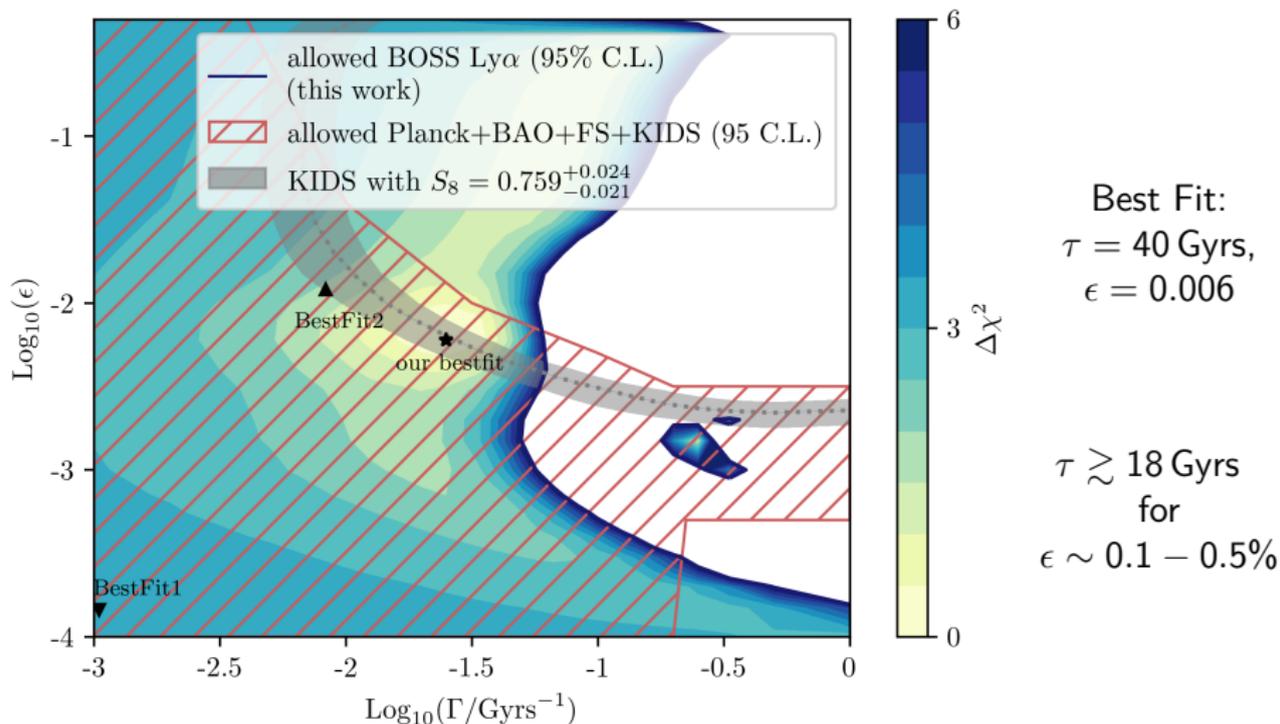
1. compute power spectrum and 1-loop corrections
2. model the 1-dimensional flux power spectrum from the matter power spectrum
3. fit to BOSS DR14 data with $z = 3.0, 3.2, \dots, 4.2$ and $k \sim 0.1 - 2 \text{ h/Mpc}$
4. compare χ^2 with ΛCDM fit to extract parameter bounds for DCDM

ΛCDM Fit
linear to 1-loop: $\Delta\chi^2 = -13.4$



→ compute profile likelihood for (ϵ, τ) grid

Results



(red contour from [Simon et al, 2022, arXiv:2203.07440])

⇒ **DCDM still a viable candidate to solve S_8 tension**