Decaying dark matter

Andreas Nygaard

andreas@phys.au.dk

Department of Physics and Astronomy,

Aarhus University

Supervisors:

Steen Hannestad, *Professor*

Thomas Tram, *Associate professor*

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  - Late-time production of relativistic species

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  - The core-cusp problem
  - The missing satellites problem

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- Decaying dark matter
  - Decaying cold dark matter
  - Dark radiation as decay product
  - Two-body decay

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- Hubble tension
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- Other problems
  - The core-cusp problem
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- Decaying dark matter
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  - Dark radiation as decay product
  - Two-body decay
- Implementation of general decay scheme in CLASS

Progress so far

- Recent publication

Prepared for submission to JCAP

Updated constraints on decaying cold dark matter

Andreas Nygaard,[a] **Thomas Tram,**[a] **Steen Hannestad**[a]

[a]Department of Physics and Astronomy, Aarhus University, DK–8000 Aarhus C, Denmark

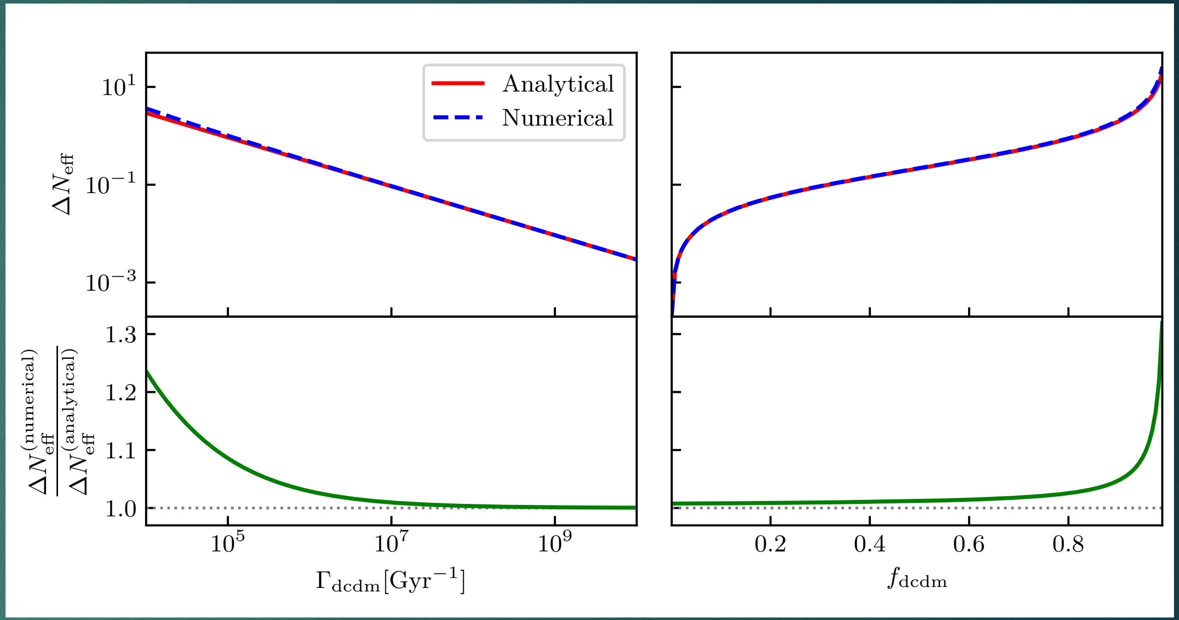
E-mail: andreas@phys.au.dk, thomas.tram@phys.au.dk, steen@phys.au.dk

Abstract. In this paper we update the constraints on the simple decaying cold dark matter (DCDM) model with dark radiation (DR) as decay product. We consider two different regimes of the lifetime, i.e. short-lived and long-lived, and use the most recent CMB data from Planck (2018) to infer new constraints on the decay parameters with which we compare the constraints inferred by the previous Planck data (2015). We hereby show that the newest CMB data constrains the fractional amount of DCDM twice as much as the previous data in the long-lived regime, leading to our current best 2σ upper bound of $f_{\rm dcdm} < 2.44\%$. In the short-lived regime, we get a slightly looser 2σ upper bound of $f_{\rm dcdm} < 13.1\%$ compared to the previous CMB data. If we include Baryonic Acoustic Oscillations data from BOSS DR-12, the constraints in both the long-lived and the short-lived regimes relax to $f_{\rm dcdm} < 2.62\%$ and $f_{\rm dcdm} < 1.49\%$, respectively. We also investigate how this model impacts the Hubble and σ_8 tensions, and we find that each of the decay regimes can slightly relieve a different one of the tensions. The model can thus not accommodate both tensions at once, and the improvements on each are not significant. We furthermore improve on previous work by thoroughly analysing the impacts of short-lived DCDM on the radiation density and deriving a mapping between short-lived DCDM and a correction, $\Delta N_{\rm eff}$, to the effective number of massless neutrino species.

arXiv:2011.01632v3 [astro-ph.CO] 12 May 2021

Progress so far

- Recent publication
  - Mapping between DCDM and ΔN_{eff}



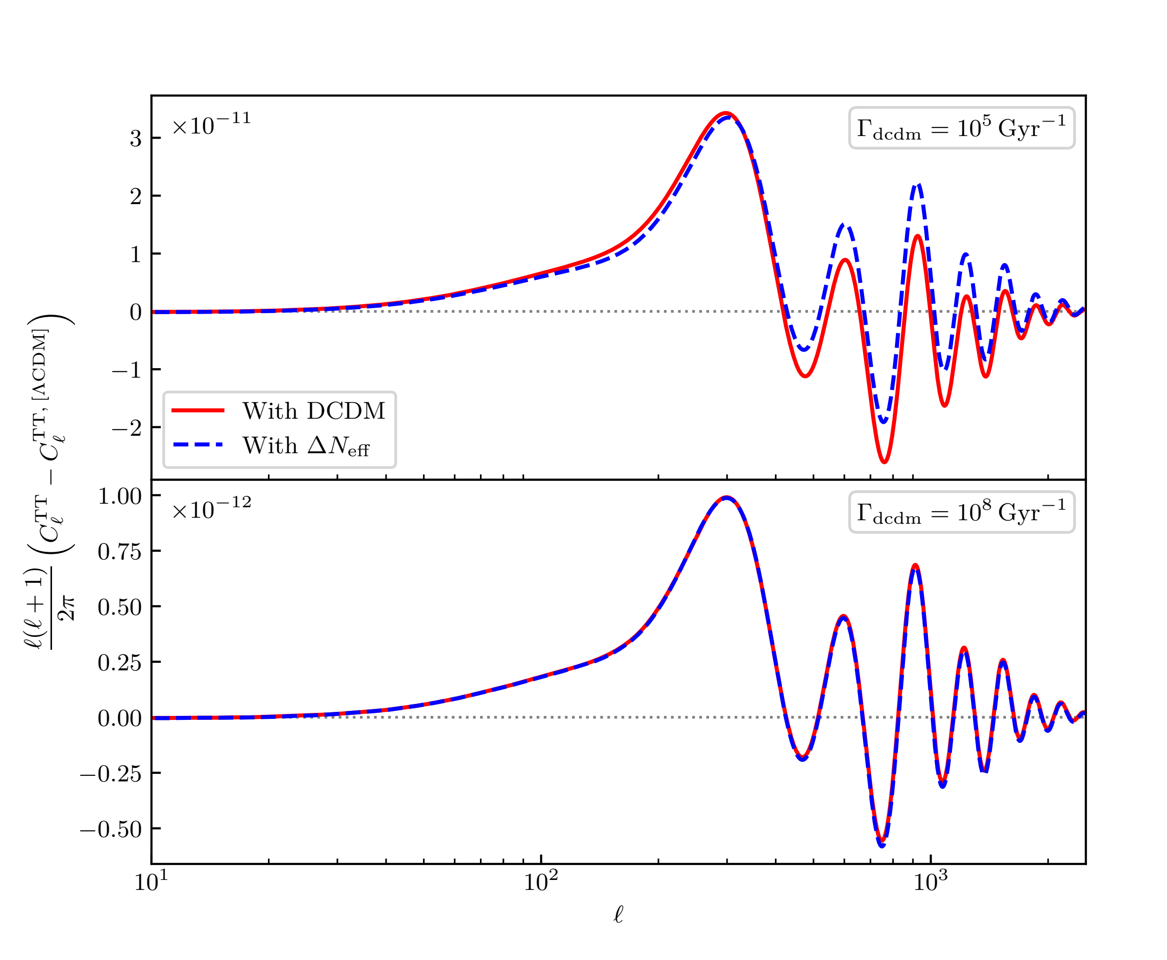
[Nygaard et al. (2020)]

$$\Delta N_{\mathrm{eff}} \approx 5.74\Omega_{\mathrm{dm},0}h^2 \frac{f_{\mathrm{dcdm}}}{1-f_{\mathrm{dcdm}}}\Gamma_6^{-1/2}$$

$$\Delta N_{\mathrm{eff}}^{(\mathrm{analytical})} = \left.\frac{\rho_{\mathrm{dr}}}{\rho_\nu^{N=1}}\right|_{t\gg t_{\mathrm{d}}}$$

Progress so far

- Recent publication
  - Mapping between DCDM and ΔN_{eff}



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Nygaard et al. (2020)

Progress so far

- Current task

[astro-ph.CO] 14 Jun 2020

CMB constraints on late-universe decaying dark matter as a solution to the H_0 tension

Steven J. Clark,* Kyriakos Vattis,† and Savvas M. Koushiappas‡
Department of Physics, Brown University, Providence, RI 02912-1843, USA and
Brown Theoretical Physics Center, Brown University, Providence, RI 02912-1843, USA
(Dated: June 16, 2020)

It has been suggested that late-universe dark matter decays can alleviate the tension between measurements of H_0 in the local universe and its value inferred from cosmic microwave background fluctuations. Decaying dark matter can potentially account for this discrepancy as it reshuffles the energy density between matter and radiation and as a result allows dark energy to become dominant at earlier times. We show that the low multipoles amplitude of the cosmic microwave background anisotropy power spectrum severely constrains the feasibility of late-time decays as a solution to the H_0 tension.

PACS numbers:

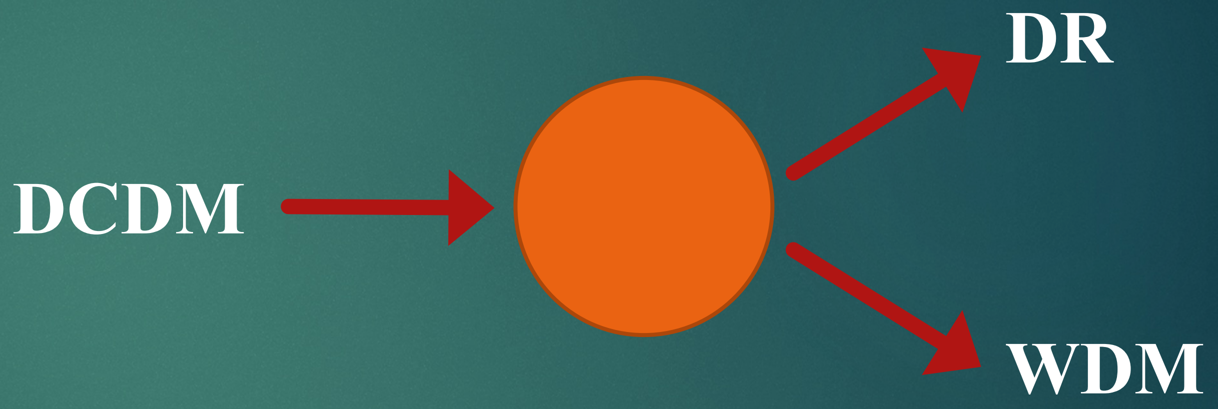
I. INTRODUCTION

The standard ΛCDM model has been established during the past decades as the standard cosmological model consisting of 70% dark energy in the form of a cosmological constant Λ, 25% cold dark matter (CDM) and 5% baryonic matter. It has been very successful at describing the evolution of the Universe by accounting for a large range of observations, from cosmological scales (Cosmic Microwave Background (CMB) measurements [1], Baryon Acoustic Oscillations (BAO)[2], redshift space distortions [3]) to galactic rotation curves [4] and galaxy cluster dynamics [5]. Despite the success of ΛCDM, as experimental measurements have improved, two prominent tensions have arisen. The first is the Hubble tension between early time cosmology with Cosmic Microwave

der measurement by the Dark Energy Survey (DES) [10]. In this case, the distances of SNIa are calibrated using BAOs, and the deduced value of H_0 is found to be consistent with the measurements inferred directly from the CMB [1]. In contrast, an independent inverse distance ladder measurement using quasars as an anchor by H0LiCOW [11] is in agreement with the local measurement [7], fuelling the tension between early and late time universe. Yet another independent measurement of H_0 was made possible using gravitational waves produced from a binary neutron star merger [12, 13]. Such gravitational wave "standard siren" measurements of H_0 are extremely important because they do not rely on light, and they are governed by different systematic errors, though the observation of more events is needed to reduce the uncertainty to the percent level [14–19].

Progress so far

- Current task
  - Two-body decay

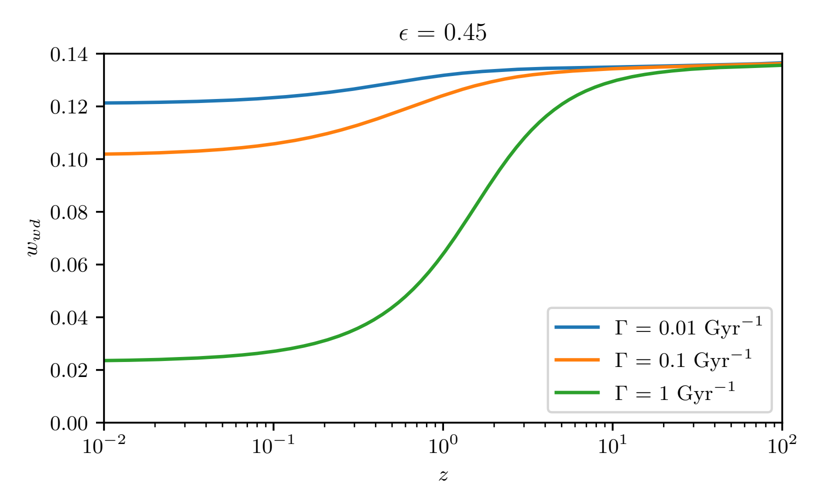


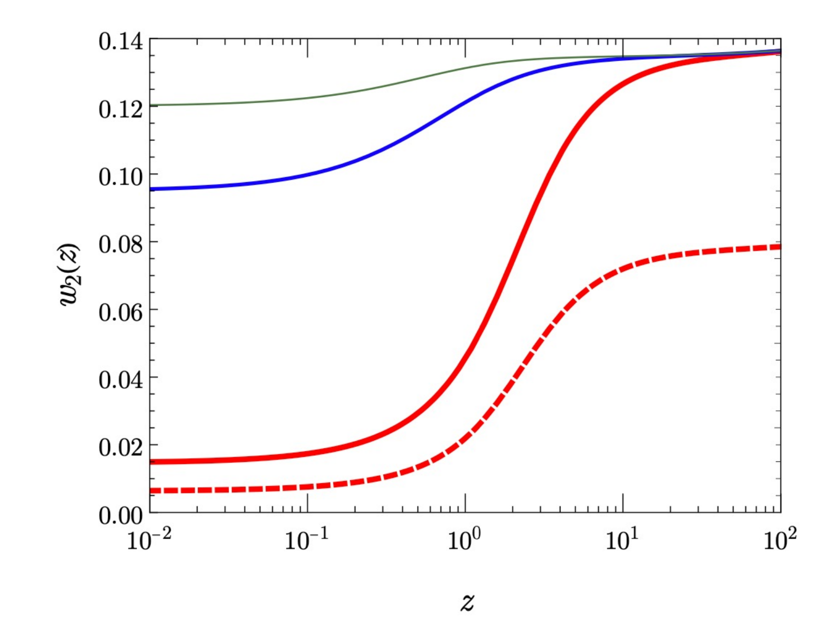
Progress so far

- Current task
  - Two-body decay
  - Background implementation
    - Integro-differential equation

$$
\begin{aligned}
w_2(a) &= \frac{1}{3}\frac{\Gamma\beta_2^2}{e^{-\Gamma t_\star}-e^{-\Gamma t}} \\
&\times \int_{a_\star}^{a} \frac{e^{-\Gamma t_D}\ \mathrm{d}\ln(a_D)}{H_D[(a/a_D)^2(1-\beta_2^2)+\beta_2^2]}
\end{aligned}
$$

Clark et al. (2020)





Clark et al. (2020)

Progress so far

- Current task
  - Two-body decay
  - Background implementation
    - Integro-differential equation
  - Perturbations
    - Boltzmann hierarchy
    - Fluid approximation

$$\dot{\delta}_{\rm wdm} = -3\mathcal{H}(c_{\rm s}^2 - w)\delta_{\rm wdm} - (1+w)\left(\theta_{\rm wdm} + \frac{\dot{h}}{2}\right) + (1-\varepsilon)a\Gamma\frac{\bar{\rho}_{\rm dcdm}}{\bar{\rho}_{\rm wdm}}(\delta_{\rm dcdm} - \delta_{\rm wdm}), \tag{33}$$

$$\dot{\theta}_{\rm wdm} = -\mathcal{H}(1 - 3c_g^2)\theta_{\rm wdm} + \frac{c_{\rm s}^2}{1+w}k^2\delta_{\rm wdm} - k^2\sigma_{\rm wdm} - (1-\varepsilon)a\Gamma\frac{1+c_g^2}{1+w}\frac{\bar{\rho}_{\rm dcdm}}{\bar{\rho}_{\rm wdm}}\theta_{\rm wdm}. \tag{34}$$

Abellán et al. (2021)

Yet to be done

- General two-body neutrino decay scheme
  - Implementation of limiting cases
  - Testing general implementation

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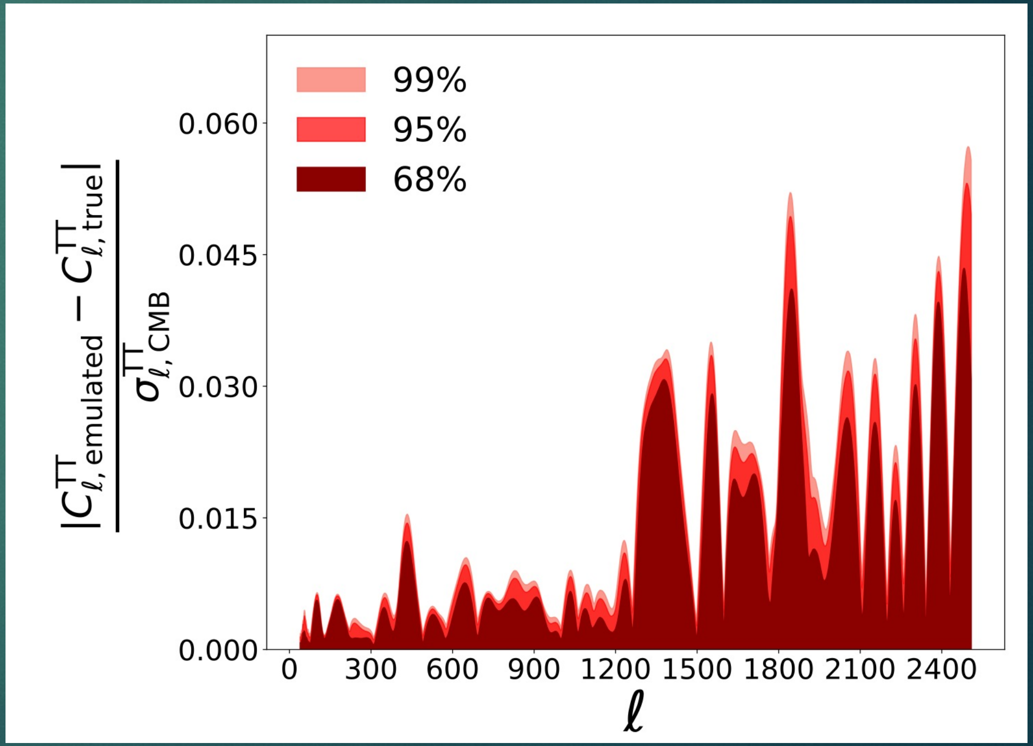
- Neural network (*CosmoPower*)
  - Emulating power spectra



Mancini et al. (2021)

Yet to be done

- General two-body neutrino decay scheme
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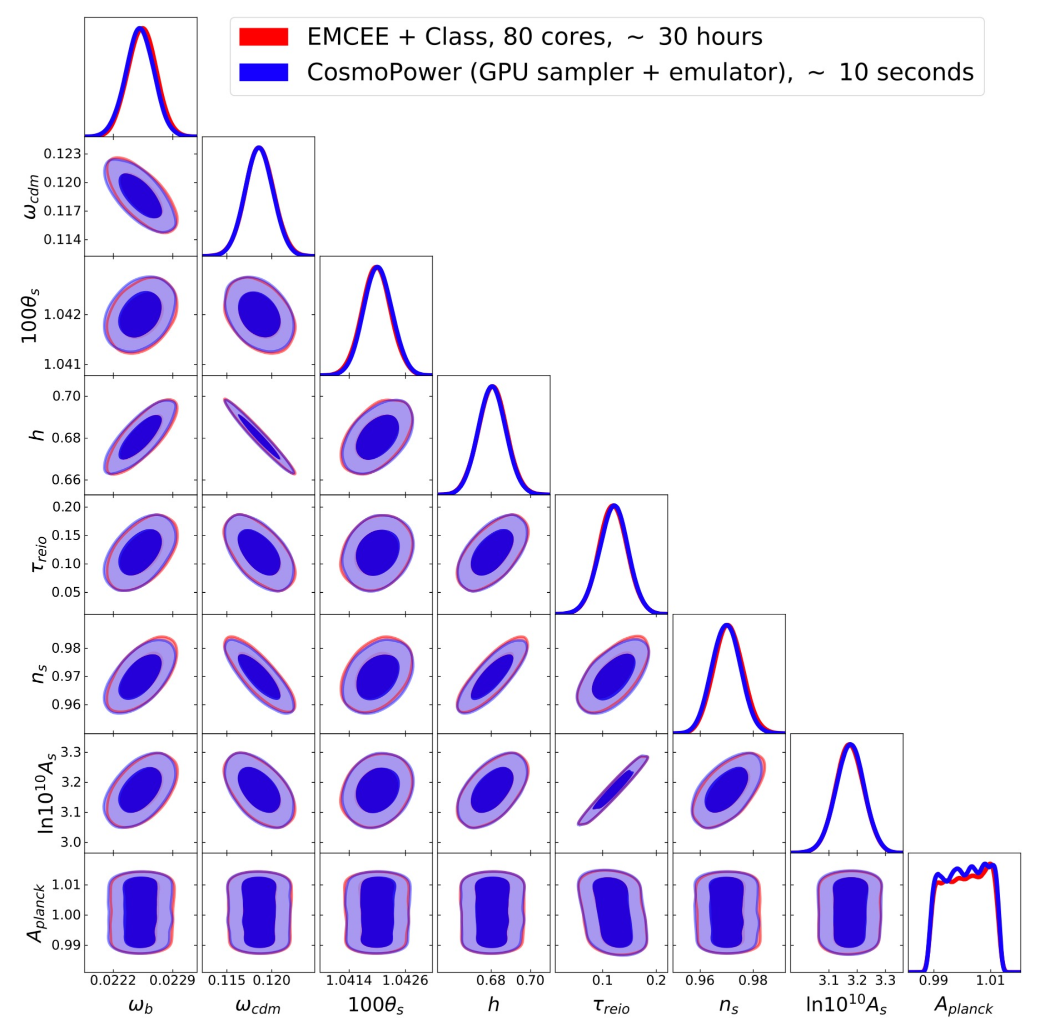
  - Inference of Planck posteriors in 10 seconds!



Mancini et al. (2021)

Yet to be done

- General two-body neutrino decay scheme
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  - Testing general implementation
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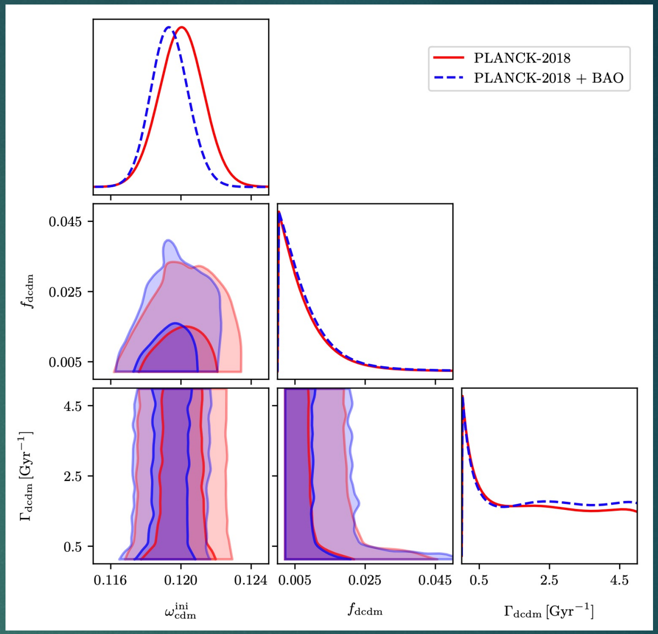
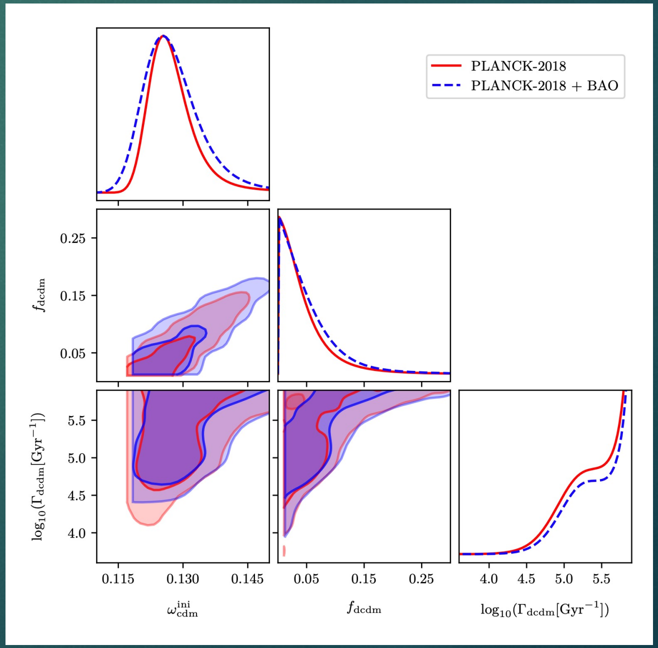
  - Inference of Planck posteriors in 10 seconds!
  - Testing DCDM results etc.





Nygaard et al. (2020)

Thank You for your time

- Questions?

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