Preliminar results

# Scalar fields as DM and EDE

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## 1) Scalar Field cosmology

Scalar fields have been proposed as a possible explanation for the unknown components of the Universe, along this work, the dark sector, dark matter (DM) and early dark energy (EDE) are described by canonical scalar fields, that evolve according the Klein-Gordon (K-G) equation in a perturbed FLRW universe in synchronous gauge:

$$\ddot{\phi} + 3H\dot{\phi} + \partial_{,\phi}V(\phi) = 0\,,$$

$$\ddot{\varphi} + 3H\dot{\varphi} + \left(k^2 + \frac{d^2V}{d\phi^2}\right)\varphi + \frac{\dot{h}\dot{\phi}}{2} = 0$$

Each scalar field has its own K-G equation and are coupled only through gravity.

## 2) SFDM

For this component we use angular variables [1], and its corresponding modified version of CLASS, valid for different scalar field potentials:

$$V(\phi) = \begin{cases} m_\phi^2 f^2\left[1+\cos(\phi/f)\right]\,, & \text{if } \lambda > 0 \\ \frac{1}{2}m_\phi^2\phi^2\,, & \text{if } \lambda = 0 \\ m_\phi^2 f^2\left[1+\cosh(\phi/f)\right]\,, & \text{if } \lambda < 0 \end{cases} \qquad \lambda = \mp 3/\kappa^2 f^2$$

- The numerical solutions corresponds to the trigonometric potential.
- The EoS oscillates very rapidly but can be averaged as zero, just like CDM (Figs. 1-2).
- The deviations in the CMB are very small compared with LCDM.
- The nonlinearities of the trigonometric potential induce a cut-off in the MPS as well as the other potentials, but also produce a bump at small scales. (Fig.3)

## 3) Quintessence

While it is established that DE dominates at late times, there is a possibility that it does not vanish in the early universe. One potential that can provide a small contribution in the early universe, meeting the required fraction today, is the Albrecht-Skordis (AS) potential:

$$V(\psi) = \left\{(\psi - B)^2 + A\right\}\mathrm{e}^{-\alpha\psi}\,,$$

The EoS (Fig. 1) and density parameter evolution (Fig. 2) show the scaling behavior of this potential with respect radiation, to then reach the observed fraction of dark energy today.

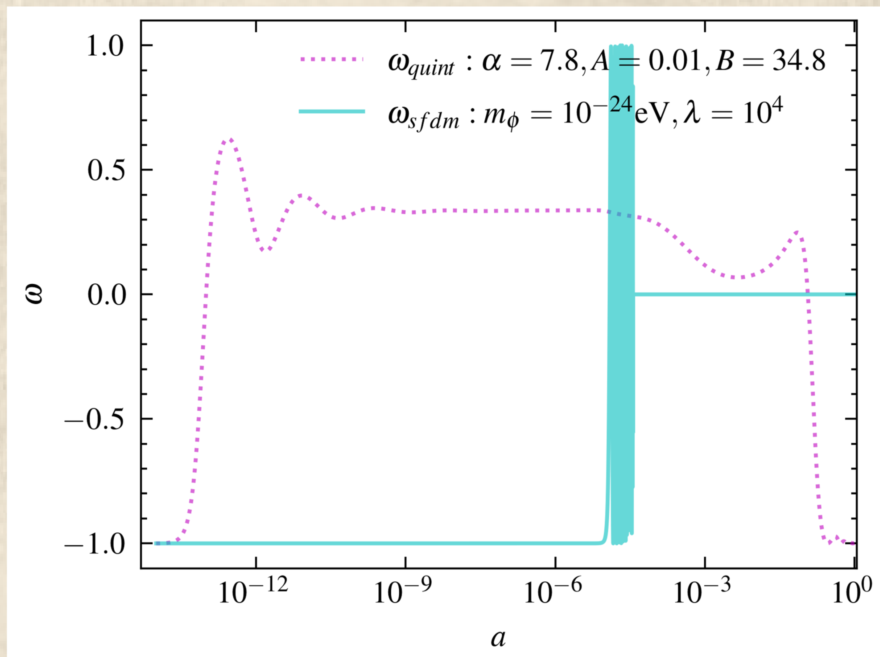


Fig.1 EoS of the quintessence and DM scalar fields.

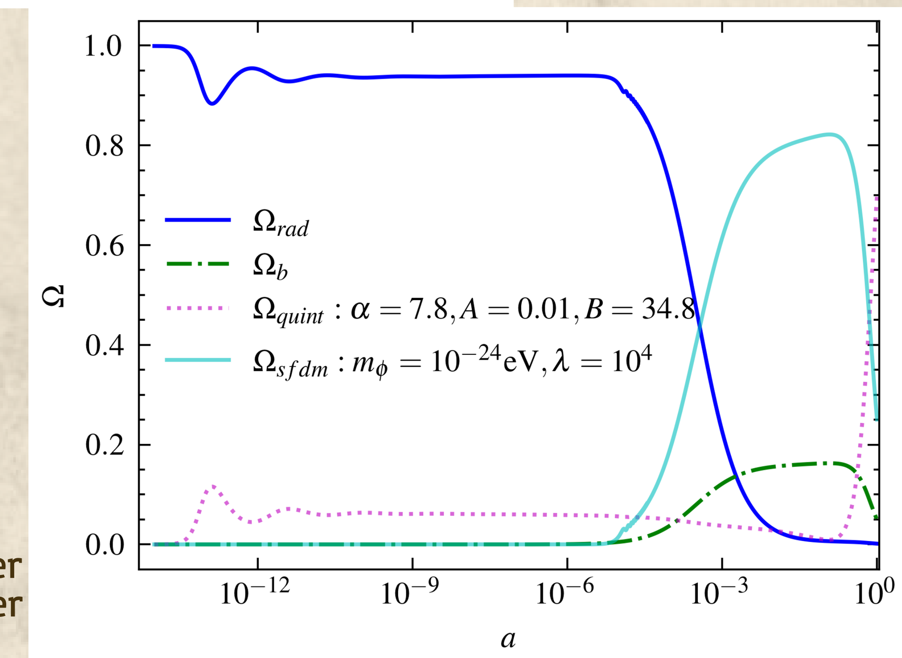


Fig.2 Density parameter evolution of the matter components.

## Both scalar fields

When only one dark component is described by a scalar field, it induces a deviation in the CMB-TT and matter power (MP) spectra, which differs from the case when both components are scalar fields. In this study, we demonstrate that these effects can be partially compensated for, even when the coupling is not direct.

The remaining matter components and cosmological parameters are fixed as in LCDM (Planck18).

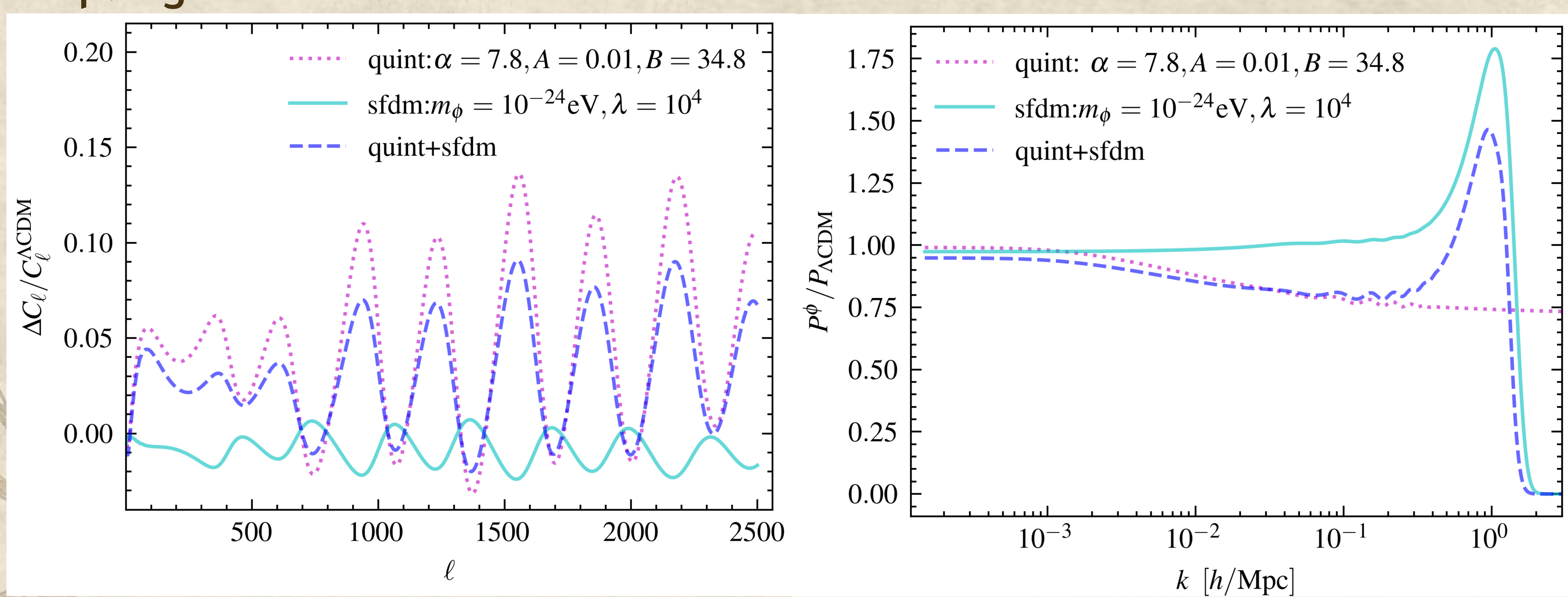


Fig.3 Left panel is for the residual CMB-TT with respect LCDM, while the right panel is for the ratio of the MPS.

- The suppression in the MPS induced by EDE leads to an enhancement in the CMB-TT spectra, usually requiring additional DM to slow down the photon fluctuations. However, in the scenario where both components are scalar fields, this suppression is compensated by the bump associated with the trigonometric potential.

[1] L. A. Ureña López and A. X. Gonzalez-Morales, JCAP 07, 048 (2016), 1511.08195