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Exact cosmological solutions of models with an interacting dark sector

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In this work we extend the First Order Formalism (FOF) for cosmological models that present an interaction between a fermionic and a scalar field. Cosmological exact solutions describing universes filled with interacting dark energy and dark matter have been obtained. Viable cosmological solutions with an early period of decelerated expansion followed by late acceleration were obtained. In one this was obtained by a dark matter component dominating in the past and a dark energy component dominating in the future. In another, the dark energy alone was the responsible for both periods, like a Chaplygin gas. Solutions with only acceleration were also obtained.

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1. Exact Solutions for the Interacting Dark Energy Model with FOF

The present work is based on the article [1] and it is an attempt to solve exactly the cosmological equations for a theoretical model based on an Yukawa like interaction between dark energy, a canonical scalar field, and dark matter, a fermionic field. The equations are:

$$\ddot{\phi} + 3H\dot{\phi} + V^{'}/l = \beta F^{'}\bar{\psi}\psi/l, \quad H^2 = (8\pi/3M_p^2)\left\{(\ell\dot{\phi}^2/2 + V(\phi) + [M - \beta F(\phi)]\alpha\right\}, \quad (1.1)$$

where $H = \dot{a}/a$ and $\alpha = \bar{\psi}\psi/a^3$. This is done by assuming $H(t) = W(\phi(t))$, based on the works of [2], and making the *ansatz*: $a(t)^{-3} = \sigma\ \dot{\phi}^n\ J(\phi)$. We evaluated the energy density, pressure and equation of state separately for the dark energy, dark matter and for the interaction.

With this it is possible to solve the equations (1.1) exactly. Assuming a constant $H(t)$, we obtained two solutions with only accelerated expansion for all times. We also obtained viable cosmological solutions, where we have an early period of decelerated expansion followed by an accelerated one. In the upper pannel of Figure 1 we show the 3^{rd} example of [1], where $n = 1, \sigma = 1$ and functions $W(\phi) = \phi + H_0$ and $J(\phi) = -1/C^2$ (C in MeV). We can see that dark matter dominates in the past and it decelerates the expansion, while dark energy dominates near today and this component accelerates the universe at late times.

In the lower pannel of Figure 1 we show the 4^{th} example of [1], where $n = 3, \sigma = 1$ and functions $W(\phi) = P/\phi\Gamma$ and $J(\phi) = -\phi^2/[4\alpha P(M - \beta F(\phi))]$($P$ in MeV^4). We obtained a good cosmological solution given only by the dark energy that domintes during all the evolution but behaves like "dust" in the early universe, decelerating the universe, and like a dark energy in the late universe, accelerating the expansion. This component behaves like a "Chaplygin gas", that behaves like different components at different times.

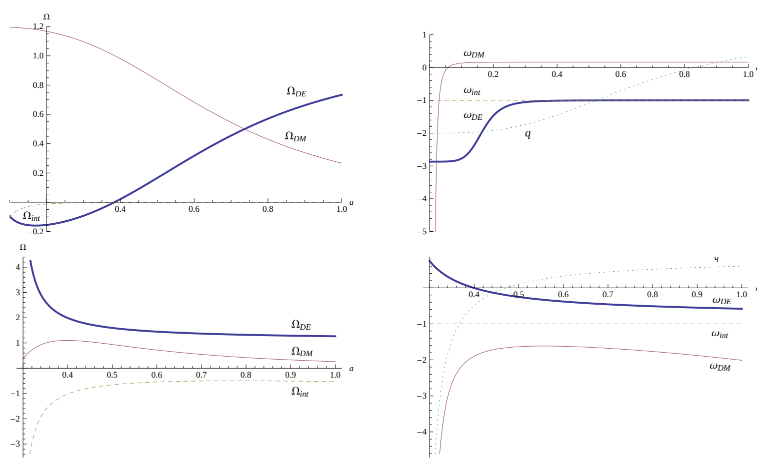

Figure 1: Density parameter Ω (left panel) and equation of state parameter ω and acceleration parameter (right panel) for the 3^{rd} Example (upper) and 4^{th} Example (lower).

References

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