Cosmological solutions from two-measures model with inflaton field

Denitsa Staicova [1] Mihail Stoilov [1]

[1]INRNE, Bulgarian Academy of Sciences

VI Meeting on Fundamental Cosmology,
Granada, 28-30 May 2018

The two-measures model Guendelman, Nissimov and Pacheva 2014, 2016

The action of the model $S = S_{darkon} + S_{inflaton}$ is :

$$S_{darkon} = \int d^4x\sqrt{-g}(R(g,\Gamma)) + \int d^4x(\sqrt{-g} + \Phi(C))L(u,X)$$

$$S_{inflaton} = \int d^4x\Phi_1(A)(R + L^{(1)}) + \int d^4x\Phi_2(B)\left(L^{(2)} + \frac{\Phi(H)}{\sqrt{-g}}\right)$$

where we have auxiliary fields $\Phi_i(X) = \frac{1}{3}\epsilon^{\mu\nu\kappa\lambda}\partial_\mu X_{\nu\kappa\lambda}$ and

$$L(u,X) = -\frac{1}{2}g^{\mu\nu}\partial_\mu u\partial_\nu u - W(u)$$

$$L^{(1)} = -\frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi - V(\phi),\ V(\phi) = f_1 e^{-\alpha\phi}$$

$$L^{(2)} = -\frac{b}{2}e^{-\alpha\phi}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi + U(\phi),\ U(\phi) = f_2 e^{-2\alpha\phi}$$

From **the equations of motion** we obtain the following new constants:

$$L(u,X) = -2M_0 = const, \frac{\Phi_2(B)}{\sqrt{-g}} = \chi_2 = const$$

$$R + L^{(1)} = -M_1 = const, L^{(2)} + \frac{\Phi(H)}{\sqrt{-g}} = -M_2 = const$$

and **the effective potential**:

$$U_{eff}(\phi) = \frac{(V_1(\phi) + M_1)^2}{4\chi_2(U(\phi) + M_2)} \text{ with asymptotics } U_- = \frac{f_1^2}{4\chi_2 f_2}, U_+ = \frac{M_1^2}{4\chi_2 M_2}$$

The equations in FLRW metric

The system of equations we need to solve is:

$$v^3 + 3\mathbf{a}v + 2\mathbf{b} = 0 \text{ for } \mathbf{a} = \frac{-1}{3}\frac{V(\phi) + M_1 - \frac{1}{2}\chi_2 b e^{-\alpha\phi}\dot{\phi}^2}{\chi_2(U(\phi) + M_2) - 2M_0}, \mathbf{b} = \frac{-p_u}{2a(t)^3(\chi_2(U(\phi) + M_2) - 2M_0)} \tag{1}$$

$$\dot{a}(t) = \sqrt{\frac{\rho}{6}}a(t), \quad \rho = \frac{1}{2}\dot{\phi}^2(1 + \frac{3}{4}\chi_2 b e^{-\alpha\phi}v^2) + \frac{v^2}{4}(V + M_1) + \frac{3p_u v}{4a(t)^3} \tag{2}$$

$$\frac{d}{dt}\left(a(t)^3\dot{\phi}(1 + \frac{\chi_2}{2}be^{-\alpha\phi}v^2)\right) + a(t)^3(\alpha\frac{\dot{\phi}^2}{4}\chi_2 b e^{-\alpha\phi}v^2 + \frac{1}{2}V_\phi v^2 - \chi_2 U_\phi\frac{v^4}{4}) = 0 \tag{3}$$

The parameters of this system are 12:

$$\{\alpha, b_0, M_0, M_1, M_2, f_1, f_2, p_u, \chi_2\}$$

Initial and boundary conditions:

$$I.\, a(0) = 10^{-12}, \phi(0) = \phi_0, \dot{\phi}(0) = 0 \quad \text{– initial conditions}$$
$$II.\, a(1) = 1 \quad \text{– normalization}$$
$$III.\, a''(t) = 0 \quad \text{– in 3 points}$$

Constraints on the parameters:

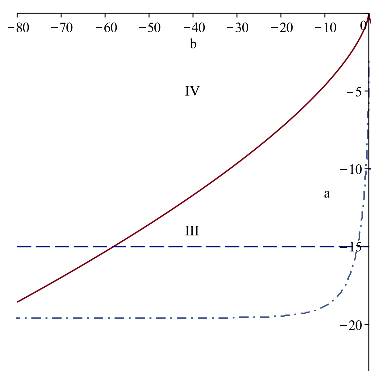
$$f_1^2/f_2 >> M_1^2/M_2$$

In Planck units: $M_{Pl} = \sqrt{2}$:

$$M_1 = 4.10^{-60}, M_2 = 4, f_1 \sim 10^{-8}, f_2 \sim 10^{-8}$$

The evolution of the Universe in the $[a, b]$ plane

Staicova & Stoilov, Mod. Phys. Lett. A, **32**, 1 (2017)
Staicova & Stoilov, arXiv:1801.07133



Evolution of the parameters $[\mathbf{a}(t), \mathbf{b}(t)]$ for the darkon (dash) and the inflaton (dot-dash).

The evolution of the Universe starts from $b \to -\infty$ and finishes at $b \to 0$
We have chosen the parameters in such a way that: $b = \frac{-p_u}{2a(t)^3(\chi_2(U+M_2)-2M_0)} < 0$.

Numerical solutions

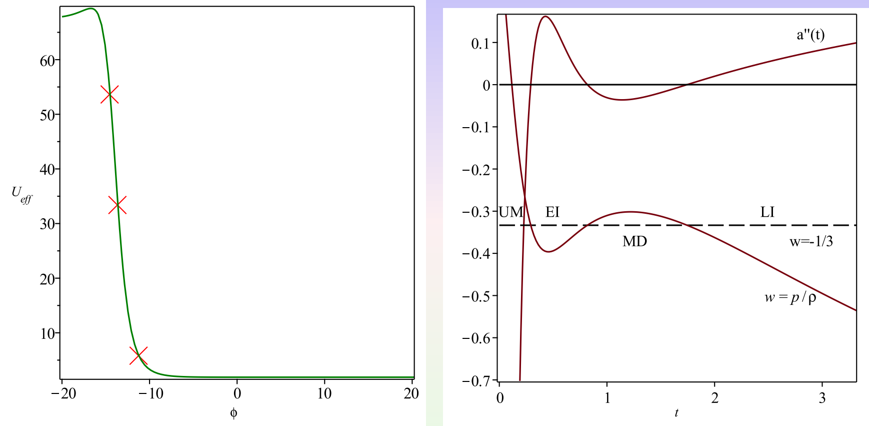
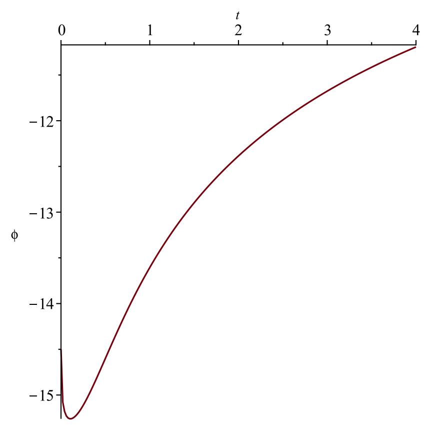
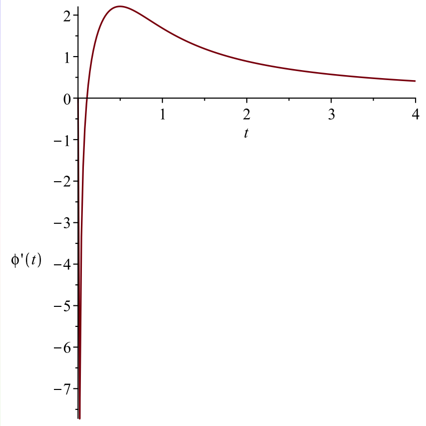


Figure: a) The effective potential.
b) $\ddot{a}(t)$ and $w = p/\rho$, where UM is ultra-relativistic matter domination , EI – the early inflation, MD – the matter domination (MD) and LI – the late inflation.

Strong friction term on ϕ!



(a) $\phi(t)$



(b) $\dot{\phi}(t)$

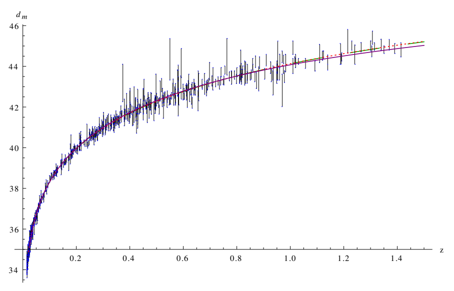
From asymptotical analysis: assuming $a(t) = e^{Ht}$, we obtain:

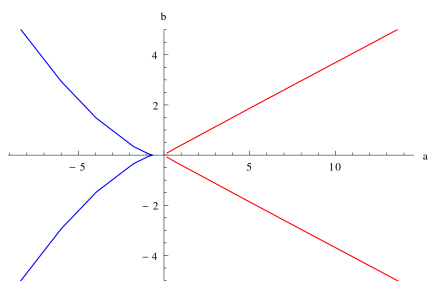
$$\phi(t) = C_1 + C_2 e^{-3Ht}$$

Conclusions:

1. We could not confirm the parameter estimation in the original work.
2. It is not possible to start from the left plateau and to obtain physically realistic solutions
3. Friction term which stops the evolution of the inflaton
4. The theory can produce "realistic" Universe if evolution starts from the slope.

Staicova & Stoilov, Mod. Phys. Lett. A, **32**, 1 (2017)
Staicova & Stoilov, arXiv:1801.07133

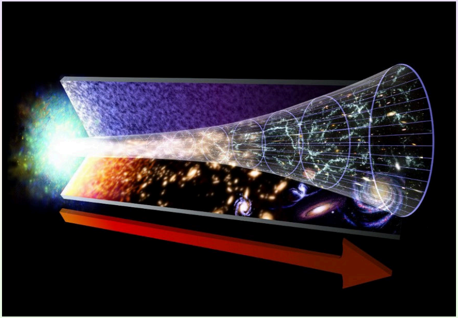




Fitting the darkon only model with data from Supernovae Type Ia.

Thank you for you attention!

The work is supported by BAS contract DFNP 49/21.04.2016, Bulgarian NSF grant DN-18/1/10.12.2017 and by Bulgarian NSF grant 8-17



References

- E. Guendelman, R. Herrera, P. Labrana, E. Nissimov, S. Pacheva, *Emergent Cosmology, Inflation and Dark Energy*, General Relativity and Gravitation **47** (2015) art.10, arXiv:1408.5344 [gr-qc]
- E. I. Guendelman, E. Nissimov and S. Pacheva.,*Dark Energy and Dark Matter From Hidden Symmetry of Gravity Model with a Non-Riemannian Volume Form*, European Physics Journal C, arXiv: arXiv:1609.06915[gr-qc]
- D. Staicova, M. Stoilov, *Cosmological Aspects Of A Unified Dark Energy And Dust Dark Matter Model*, Mod. Phys. Lett. A, Vol. 32, No. 1 (2017) 1750006, arXiv:1610.08368
- D. Staicova, M. Stoilov, *Cosmological solutions from models with unified dark energy and dark matter and with inflaton field* , arXiv: 1801.07133