QUINTESSENCE AND PHANTOM ENERGY INHOMOGENEITIES AT LATE STAGES OF UNIVERSE EVOLUTION

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ABSTRACT. As it directly follows from the scalar perturbations, applied to the late stages of evolution of the Universe, filled with dark energy, nonrelativistic matter and, possibly, quintessence or phantom energy, the last two components can not be homogeneous.

We demonstrate that ω=-1/3 is only admissible negative parameter in the non-vacuum equation of state, determine the corresponding gravitational potentials and discuss their main properties.

Key words: quintessence, phantom field, scalar perturbation, cosmology

At the present time the most popular cosmological model, describing evolution of the homogeneous and isotropic Universe, is well known ΛCDM-model. The dark energy can be presented in the form of a perfect fluid with the linear equation of state $p=\varepsilon\omega$ (ε is the energy density and p is the pressure), where the parameter ω is constant and equal to -1.

In the case when parameter ω is arbitrary, these perfect fluids are usually called quintessence ($-1<\omega<0$) or the phantom field ($\omega<-1$). The acceleration is achieved for $\omega<-1/3$.

Our work is devoted to the test of quintessence and phantom field with the constant negative parameter ω for compatibility with the theory of scalar cosmological perturbations at late stages of the Universe evolution. Inside the cell of uniformity (the spatial region with the scale ~150 Mpc) hydrodynamics in inapplicable, so we use the mechanical approach. We showed that the investigated fluids can not be homogeneous. Therefore, we perturb the background values of their energy density and pressure. Then we try to derive formulas for gravitational potentials of usual point-like masses in closed, flat and open Universes. This procedure leads to severe constraints imposed on the parameter ω. As a result, we single out unforbidden cases deserving further investigation.

We used the background metrics

$$ds^2 = a^2\left(d\eta^2 - \gamma_{\alpha\beta}dx^\alpha dx^\beta\right),\quad \gamma_{\alpha\beta} = \frac{\delta_{\alpha\beta}}{\left[1+\frac{1}{4}\mathcal{K}(x^2+y^2+z^2)\right]^2},\quad \alpha,\beta = 1,2,3,$$

and the corresponding Friedmann equations

$$\frac{3\left(\mathcal{H}^2+\mathcal{K}\right)}{a^2} = \kappa\overline{T}^0_0 + \Lambda + \kappa\varepsilon\,,\quad \frac{2\mathcal{H}'+\mathcal{H}^2+\mathcal{K}}{a^2} = \Lambda - \kappa p = \Lambda - \kappa\omega\varepsilon,$$

where $\overline{T}^0_0$ is the average energy density of the usual nonrelativistic dust-like, K is the spatial curvature, $\mathcal{H}\equiv a'/a$ and $\kappa\equiv 8\pi G_N/c^4$ (c is the speed of light and G_N is Newton's gravitational constant), Λ is the cosmological constant and a is the time-dependent scale factor.

Finally, in ω=-1/3 we get respectively

$$\delta\varepsilon = \frac{2\varepsilon_0 a_0^2}{c^2 a^3}\varphi,\quad \Delta\varphi + \left(3\mathrm{K} - \frac{8\pi G_N}{c^4}\varepsilon_0 a_0^2\right)\varphi = 4\pi G_N(\rho - \overline{\rho}).$$

The produced investigation of inhomogeneous quintessence and phantom field with a constant parameter ω in the linear equation of state allows to draw the following three main conclusions:

the phantom field is completely forbidden;

the models containing quintessence may be viable only if $-1/3\le\omega<0$;

in the boundary case ω=-1/3 the gravitational potential are defined for all generally accepted types of spatial topology, and some of them demonstrate satisfactory asymptotical behaviour and allow the averaging procedure, i.e. these gravitational potentials have clear physical meaning.

References

Mukhanov V., Feldman H., Brandenberger R.: 1992, *Phys. Rep.*, **215**, 203.

Eingorn M., Zhuk A.: 2012, *JCAP*, **09**, 026.

Gorbunov D., Rubakov V.: 2011, *World Scientific*.

Gonzalez-Diaz P.: 2000, *Phys. Rev. D*, **62**, 023513.

Chernin A., Santiago D., Silbergleit A.: 2002, *Phys. Lett. A*, **294**, 79-83.