ISSN 0202-2893, Gravitation and Cosmology, 2018, Vol. 24, No. 1, pp. 1–12. © Pleiades Publishing, Ltd., 2018.

Statistical Cosmological Fermion Systems with Phantom Scalar Interaction of Particles

Yu. G. Ignat'ev, A. A. Agathonov, and D. Yu. Ignatyev

Kazan Federal University, Kremlyovskaya ul. 35, Kazan, 420008 Russia

Received 2016; in final form, 2017

Abstract—The article represents a research of the cosmological evolution of fermion statistical systems with phantom scalar interaction where the "kinetic" term's contribution to the total energy of a scalar field is negative. As a result of analytical and numerical simulation of such systems, we have revealed the existence of four possible scenarios depending on the system's parameters and the initial conditions. Among them are scenarios with an early, intermediate and late nonrelativistic stages of the cosmological evolution, all of which also have a necessary inflationary stage. This paper contains only a small part of the research results. In a more complete form, they are presented in arXiv: 1608.05020 [1].

DOI: 10.1134/S0202289318010085

1. INTRODUCTION

Fundamental scalar fields play an important role in understanding the dynamics of the early Universe (see, e.g, [2, 3]); with a help of various modifications of the gravitation theory suggested both by Einstein [4] (the cosmological Λ term) and thereafter by Utiyama and Fukuyama [5], Minkevich [6, 7] (Poincarè gauge theory of gravity), Starobinsky [8] ($f(R)$ gravity), fundamental scalar fields can apparently explain certain basic observational facts of cosmology. Nevertheless, some important facts of observational cosmology are still not explained fairly convincingly in the framework of the standard cosmological scenario. For instance, the existence of a non-relativistic stage of the Universe extension, being a requirement for formation of its structure, is reckoned among such obvious facts. Particularly in this context at present they consider a wide range of *phenomenological theories* 3of fundamental nonminimally coupled scalar fields where various couplings between the scalar and gravitational fields are introduced (potential, kinetic, combined). The corresponding field-theoretical constructions usually pursuit one goal: select such a phenomenological Lagrangian of interaction and its parameters which will provide a cosmological scenario with all necessary stages, namely, inflation $\rightarrow$ ultrarelativistic stage $\rightarrow$ nonrelativistic stage $\rightarrow$ secondary acceleration. Herewith, the preceding standard cosmological scenario which was generally accepted in the 60s-80s (Gamov's hot model) fits between the early and late cosmological acceleration stages.

In this paper we consider cosmological models based on a fundamental scalar interaction. In contrast to phenomenological nonminimal models of scalar interactions, we consider dynamic models of statistical systems of scalar charged particles where certain particle sorts can directly interact with a scalar field through a certain fundamental *scalar charge*. A statistical system possessing a scalar charge and being itself a source of the scalar field, can effectively influence on the scalar field managing its behavior. Such a scalar interaction was introduced into general-relativistic kinetic theory in 1982 by one of the authors [9–12] and later on by G.G. Ivanov [13]. In particular, in [10, 11], on the basis of the kinetic theory, obtained was a self-consistent set of equations describing the statistical system of particles with scalar interaction. In [14] investigated were the group properties of equilibrium statistical configurations with scalar interaction. In [15, 16], the cosmological equations were formulated on the basis of statistical Fermi systems with scalar interaction, and attempts of a numerical simulation of such systems were made. The macroscopic theory of statistical systems with scalar interaction was significantly improved and extended to the case of phantom scalar fields in [17–21].[1] . It was also extended to the sector of negative effective masses of scalar interacting particles in [25, 26]; the same papers investigated the transformation properties of mathematical models of the statistical systems with scalar interaction relative to transformations of charge, chemical potential and other parameters of the model. The mathematical model of cosmological systems with scalar interaction was extended to the case of a conformally invariant scalar field in [27, 28]. In these papers, the asymptotic

[1] See also the monographs [22, 23] and the review [24].