ANNOTATION

of the PhD thesis for the Specialty 6D060400-Physics
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«Research of cosmological models in the framework of the general relativity and of the modified theory of gravity»

Topic actuality. Over the past decade cosmology is going through a great increase of activity, especially in connection with obtaining a huge number of observational data. Inflation in the early universe, and the accelerated expansion of the universe has been confirmed by the recent observations of cosmic microwave radiation. Also, the accelerated expansion of the universe was represented by recent observations of supernovae of type Ia, large-scale structure of the universe, baryon acoustic oscillations and weak lensing. In this sense, observations of supernovae type Ia by two independent groups in 1998 (S. Perlmutter and A. Riess) first showed the luminosity deviation on the distance which actually was interpreted as a consequence of the accelerating expansion of the universe. These well-confirmed observations in conjunction with the assumption that the universe on a large scale is homogeneous and isotropic, have led to a large number of proposals which are able to explain this anomalous behavior.

The introductions of so-called dark energy, in the framework of the general theory of relativity, or modified theories on a large scale allow to explain this cosmic acceleration. Consequently, to reproduce the accelerating expansion, in the equations of Friedmann-Lemaitre-Robertson-Walker, which is good describes the Universe on a large scale theoretically, must be applied negative pressured fluid to description of dark energy. The behavior of this fluid can be calculated by several ways: a positive cosmological constant, a scalar field, vector field, the modified gravity theory of general relativity or by other ways. With regard to possible modifications of general relativity which could lead to the equivalent behavior of dark energy and able to implement late-time accelerated expansion of the Universe, it is possible, the so-called $f(R)$ theory of gravitation which is the most famous alternative, in which the synthesis of the simplest Hilbert-Einstein action to a more general function of a scalar Ricci. However, in addition to the curvature invariants have been studied other alternatives of general relativity, also leading to the theory like a term of the Gauss-Bonnet which is capable to present very well the cosmological expansion.

To solve the problem of dark energy have been considered some generalizations, the so-called teleparallel theory of gravity. For build gravitational action instead of Levi-Civita connection in teleparallel theory of gravity supposed application of Weitzenbock connection. In this case curvature invariant vanishes, while scalar torsion is not zero, so that the operation consisting of linear members leads to an equivalent torsion of general relativity. Consequently, teleparallel theory of gravity leads to the same equations FLRW as the standard general relativity. Solutions of equations of motion teleparallel theory of gravity describing

dark energy lead to an accelerated expansion of universe. However, by analogy with $f(R)$ theories have been proposed, some generalizations teleparallel theory called the $f(T)$ theory of gravitation, which are able to reproduce an era of dark energy. This possibility was analyzed in many works, where investigated conventional cosmological models and their properties in the framework of the $f(T)$ theory of gravity. The aim of the $f(R)$ theory is to reproduce the era of dark energy only by gravity, without the need for any additional fields. However in comparison with the $f(R)$ theory in which the equations of motion are the fourth-order equations of the gravitational field the $f(T)$ theory of second-order equations, their easy and leads to the same model of gravitational waves in general relativity. In addition, other theoretical aspects of the theory of gravity have been investigated, such as the problem of causality, inflation, the behavior of cosmological perturbations, some conformal symmetry in teleparallel theory or local Lorentz invariance theory.

On the other hand, also was studied the ability to represent dark energy through the spinor fields. In this sense, any cosmological solution can be reconstructed appropriately interacting term of the spinor field in the framework of general relativity, or higher-order terms, such as the $f(R)$ theory so that the cosmological history could explain by such sources as the Dirac field. Also were offer some models of inflation with spinor fields, and models which simulate some well-known models of dark energy - quintessence model with an equation of state of Chaplygin gas type. There also have been investigated cosmological solutions with spinor fields in gravitational theories with no non-zero torsion.

There are two singularities in the history of the expansion of the Universe. One of the singularity is a singularity of the big bang. Another singularity is the finite-time occurs in the last step or the Big Crunch singularity.

To avoid these singularities, in various cosmological scenarios were proposed cyclic Universes models, ecpiriotic universes, pulsating universes.

In addition to cyclic universes include nodal universes. Using the Jacobi and Weierstrass functions was reconstructed equation of state for the cyclic universe in the homogeneous and isotropic space of FLRW.

Necessity of studying the modified teleparallel theory of gravity with spinor fields and the cosmological models have generalized the equations of state is caused by the following reasons

Firstly, there is the problem of dark energy. A number of different models describes the accelerated expansion of the universe today. However, at present it is not possible to choose for a particular model. It is due, in particular, to the inability to direct experimental studies of these models under terrestrial conditions. Today, hopes in this area are connected with the further refinement of astronomical observations. In this situation, there is a wide range and variety of simple models described the current accelerated expansion of the universe, which will allow in the future to opt for the most adequate. Field equations of modified teleparallel theory of gravity allow to obtain cosmological models which are easier to analyze, due to the fact that they contain derivatives of not higher than second order.

Second, existing cosmological models describing dark energy have a significant drawback - they contain a singularity. It is therefore necessary to build cosmological models which are don't conclude such «objects» and have consistent with the evolution of the universe.

The aim of the research and scientific results - the construction of advanced models of the universe with the generalized equation of state.

The scientific results obtained in the thesis

1. Within the framework of the classical model of Einstein gravity studied cosmological models with an effective k-essence, models with the intersection of the phantom divide and phantom cosmological models with periodic and quasi-periodic parameter of equation of state. Investigated cosmological models arising from the reductions of the Weierstrass elliptic functions.

2. To describe the process of the accelerated expansion of the universe proposed Weierstrass elliptic function as a generalization of models with Chaplygin gas type equation of state.

3. Investigated cosmological models based on a modified teleparallel theory of gravity with a spinor field. Reconstructed the cosmological models of dark energy, containing spinor field with the equation of state of the Chaplygin gas, generalized Chaplygin gas and modified Chaplygin gas. Reconstructed the cosmological solutions corresponding to ΛCDM-model and power solutions.

4. Within the framework of $f(T)$ theory of gravity with f-essence was received cosmological solution by Noether symmetry approach describing rapidly expanding Universe. For the corresponding Lagrangian obtained generator symmetry of vector field and conservation law.

The object of the research is - evolution of the Universe at the classical level.

The subject of the research is - searching cosmological solutions of the gravitational equations with matter, which adequately describe the era of dark energy of the Universe.

The scientific novelty of the results of the study consists in:

– Researched the model of modified teleparallel theory of gravity with a spinor field. Shown that for a definite choice of term in action of modified teleparallel theory of gravity as a candidate for the role of dark energy may qualify a spinor field.

– Cosmological models with Chaplygin gas type equations of state, generalized Chaplygin gas and modified Chaplygin gas were reconstructed. Shown that the spinor field can serve as a candidate for the role of dark energy with these equations of state.

– The model of the classical Einstein's gravity was investigated. Within the model of k-essence, phantom models and models with the intersection of the phantom divide made the reconstruction of cosmological models possessing periodic and quasi-periodic parameter of equation of state.

The results of the thesis can be applied in the educational process for reading elective courses to undergraduates and doctoral specialty "Physics".

Objectives of the research. The main objectives of the thesis consist in the following:

1. Within the framework of general relativity to get cosmological models describing the accelerated expansion of the universe. Consider as a generalization of Chaplygin gas models such as the Weierstrass elliptic function.

2. Within the framework of the modified theory of gravity with a spinor field show that the spinor field Chaplygin gas type equations of state, generalized Chaplygin gas and modified Chaplygin gas can act as the candidate of the dark energy.

3. Within the framework of F (T) theory of gravity with f-essence by Noether symmetry approach obtain the cosmological solution describing rapidly expanding universe and obtain the model corresponding to the Lagrangian, symmetry generator of vector field and conservation law.

Statements for the defense:

– Developed advanced models of the Universe, with effective k-essence, with intersection of the phantom dividing and phantom cosmological models which have generalized equation of state of matter that describes dark energy.

– Weierstrass' elliptic function, as a generalization of the equations of state in cosmological models, with Chaplygin gas type equation of state.

– Cosmological models based on modified teleparallel theory of gravity with spinor field which obeys to the equations of state of Chaplygin gas, generalized Chaplygin gas and modified Chaplygin gas, which also able to describe the process of the accelerated expansion of the Universe.

– Cosmological models based on a modified teleparallel theory of gravity with f-essence, and the obtained solutions of its, which are able to describe the process of the accelerated expansion of the Universe.

The practical significance of the results.

The dissertation work is theoretical. Its results can be used to construct models of dark energy and explanations of modern observational data, indirectly demonstrating the phenomenon of accelerated expansion of the universe. The results obtained in the thesis accurate solutions can be use for further research in modern cosmology.

The results of the thesis can be applied in the educational process for reading elective courses to undergraduates and doctoral specialty «Physics».

Personal contribution of the author. In process of implementation of research under the supervision scientific advisors, author was directly involved in all stages of work: spent all calculations, built graphics, found solutions, personally prepared publications.

Testing research results and publications. The results obtained in the thesis, reported and discussed at

– Astrophysics, Gravity and Cosmology. I Eurasian International Conference. Astana, 2012;

– Актуальные проблемы современной физики. Международная научная конференция, посвященная 75-летию академика НАН РК Абдильдина М.М. – Алматы. – 2013;

– Валихановские чтения – 17. Международная научно-практическая конференция. Кокшетау. – 2013;

– Ломоносов – 2013. Международная научная конференция студентов, магистрантов и молодых ученных. – Астана. – 2013;

– Science and education -2013. VIII International Scientific Conference for students and young scientists. Astana. – 2013;

– Актуальные проблемы современной физики. Международная научная конференция, посвященная 70-летию академика НАН РК Такибаева Н.Ж. Алматы. – 2013;

– Astrophysics, Gravity and Cosmology. II Eurasian International Conference. Astana, 2014;

– XIII International Conference on Mathematical Physics and Application. Istanbul. – 2015;

– Science and education -16. XI International Scientific Conference for students and young scientists. Astana. – 2016.

In addition, the results were presented and discussed at scientific seminars of the Department of General and Theoretical Physics L.N. Gumilyov ENU, on seminars of Eurasian International Centre for Theoretical Physics and seminars of Department of California State University, Physics, Fresno.

Publications. According to the results of the thesis was published 15 publications, including 2 articles in international journals with high impact factor entering in the Thomson Reuters and Scopus databases; 5 articles in periodicals of the Republic of Kazakhstan, recommended by the Committee for Control of Education and Science of the MES RK; 1 article in international conferences abroad; 4 Article and 2 short thesis (abstract) in the materials of international conferences (1 conference work was published in foreign journal); 1 monograph.

Impact factor of journals. In general, a doctoral student has published 7 papers in international journals, including 5 in journals with high impact factor.

H-index and cited works. Doctoral student has the following scientometric indicators on Google Scholar and Thomson Reuters databases, which are listed in the table.

Table - Scientometric indicators

Database	H-index	Cited
Google Scholar	5	173
Thomson Reuters	3	59

Volume and structure of the thesis. The thesis consists an introduction, three chapters, conclusion and list of references with 184 titles, includes 100 pages of main computer text, including 20 figures and 2 tables.