ABSTRACT

of dissertation for the Philosophy Doctor (PhD) degree in specialty "6D060400 – Physics" by Zhadyranova Aliya Amirbekovna on the topic "**INVESTIGATION OF SYMMETRY AND SOLUTIONS OF SOME NONLINEAR FIELD THEORY MODELS FOR A SPACETIME MANIFOLD**"

This PhD is devoted to the study of symmetry and solutions of some nonlinear field theory models for a spacetime manifold.

Relevance of the dissertation theme

Currently, the study of symmetry and solutions of nonlinear field theory models for a space–time manifold provides good breakthroughs in the study of the properties and evolution of the Universe. The dynamics of changes in the universe is one of the most interesting and rapidly developing branches of physics and astronomy. Of great interest is the study of the influence of the interaction between dark energy and dark matter on the evolution of the Universe, especially the influence of various forms of interaction on cosmological parameters. The current accelerating expansion of the universe can be explained with the help of an exotic ideal dark energy liquid with negative pressure, which satisfies the barotropic equation of state. Negative pressure in the logarithmic power law model becomes dominant when the volume of the universe exceeds a certain value. This scenario corresponds to the logotropic dark energy model. There are modes in which logotropic dark energy with a power law is equivalent to logotropic dark energy. Interacting dynamics involves a continuous exchange of energy and momentum energy tensor between dark energy and dark matter. The modern universe is in the stage of accelerated expansion. Now it is considered that the sources of such expansion of the Universe are dark energy, which has a large negative pressure. In modern cosmology, various generalized models of the standard theory of gravity are used to obtain a model of dark energy and describe the current stages of the evolution of the Universe. Observations of cosmic microwave background radiation and large-scale structure in a good approximation predict that our universe is homogeneous and isotropic on the largest scale, and in the future it is almost spatially flat. The description of the Universe of the present time on a small scale can be performed using a logarithmically corrected power equation of state in the Debye approximation in terms of a logarithmically corrected fluid with a power law. A liquid with logarithmic power law correction has properties similar to those of crystalline solids under isotropic deformations, even in cases where the pressure is negative. This formalism makes it possible to model the model and explain the accelerating expansion of the late universe in terms of a logotropic dark fluid.

The current standard model of cosmology - the model effectively explains the evolution and content of the universe by adding two dark sectors to its visible content: dark matter and dark energy. Dark matter plays a crucial role in the stabilization of galaxies and clusters, while dark energy is necessary to describe the acceleration of the universe in recent times. However, even with these additions and remarkable efforts, the

model still suffers from serious problems, such as problems with coincidence and the cosmological constant. In addition, a fairly new problem has appeared, which reveals another problem with the physical background – this is tension. The term tension refers to the difference between the early measurements and the late values of the Hubble constant . The true source of the difference between the early measurements and the late values of the Hubble constant is still unclear. A fair number of attempts to solve the tension problem are based on the idea that the tension of the Hubble constant is not just a statistical discrepancy or artifact, but that it is actually related to physical considerations. However, it should be noted that despite very serious attempts to determine how this challenges the understanding of the universe, there is still no reliable hint of the actual origin of the problem, and there is still a lot of work to be done. To solve this problem, a Bayesian machine learning algorithm is used. Bayesian machine learning uses model-based generative processes to improve data problems. Limiting the cosmological scenario to observational data is the main tool for assessing whether the model is applicable or not. It is important to study and make sure that the created models have passed cosmological and astrophysical tests, especially now when various observation missions are operating that provide a lot of new data. Moreover, it is extremely important to limit the parameters of the model and study the appropriate consequences, because restrictions on background dynamics are necessary to understand the nature of interacting dark energy, structure formation and future singularity problems. In this regard, the development and use of methods that make it possible to obtain reconstructions using learning procedures in a way independent of the model, for example, directly published observations, are of great importance.

One of the most popular and widely used examples of such methods in cosmology are Gaussian processes, which are based on a specific machine learning algorithm that indicates how machine learning in general can be used in cosmology, astrophysics or in any other field of science where analysis data is crucial.

Recently, due to the problem of dark matter and its possible description in the framework of scalar tensor theory, interest in scalar equations has grown significantly. Exact solutions of the Klein-Gordon-Fock equation are used to construct realistic models of relativistic quantum mechanical systems.

Based on the modern problems of cosmology listed above, the dissertation: « **INVESTIGATION OF SYMMETRY AND SOLUTIONS OF SOME NONLINEAR FIELD THEORY MODELS FOR A SPACETIME MANIFOLD»** is devoted to the research of the role of symmetry and nonlinear models in the formation of the structures of the Universe and its accelerated expansion.

The main goal of work

The study of a logotropic modified model with a viscous fluid, cosmological $f(T)$ gravity models explaining the accelerated expansion of the Universe, as well as the study of symmetry operators for groups of motions of a space-time manifold.

The object of the research

logotropic modified models with viscous fluid, power-law cosmological model of Bengochea and Ferraro, exponential cosmological model of Linder, symmetry

operators for groups of motions of a space-time manifold.

The subject of the study

Equation of state of dark energy, Hubble parameter, deceleration parameter, dark matter density, redshift, cosmological parameters.

Research methods

Analytical and numerical methods for solving differential equations, Bayesian machine learning method, maximum likelihood method, Monte Carlo method, Kullback-Leibler method, neural networks, deep probabilistic learning, algebra of symmetry operators.

In order to achieve the above stated goal, it is necessary to carry out the following tasks:

1 Description of the dynamic evolution of the Universe of the present time using a modified power equation of state with logarithmic correction in the presence of volumetric viscosity;

2 Limitation of gravity-based cosmological models using a probabilistic Bayesian machine learning approach;

3 Investigation of the Klein-Gordon-Fock equation for a charged test particle under transitivity conditions on a two-dimensional subspace V_2 of the motion group of a space-time manifold G_3, $r \leq 3$;

Scientific novelty of the dissertation results

For the first time in this work:

1 Based on a logarithmically corrected power-law modified equation of state in the presence of volumetric viscosity, a model of the dark energy Universe is determined.

2 Using Bayesian machine learning, a solution to the problem of tension in gravity has been found.

3 The conditions for the existence of the algebra of symmetry operators of the classical and quantum equations of motion for a charged scalar test particle in an external electromagnetic field under transitivity conditions are found.

The main provisions for the defense:

1) A logarithmically corrected power-law modified equation of state, in the presence of a volumetric viscosity$\zeta(H, t)$, in a homogeneous and isotropic spatially flat spacetime, describes the accelerating expansion of the late Universe in terms of a logotropic dark liquid.

2) Limiting gravity-based cosmological models using a probabilistic Bayesian machine learning approach eliminates the problem of the difference between early measurements and late values of the Hubble constant.

3) The Klein-Gordon-Fock equation using the method of complete separation of variables correctly describes the interaction of the axion field with the electromagnetic field under transitivity conditions on the two-dimensional subspace V_2 of the motion group of the space-time manifold G_3.

Practical and theoretical importance of the dissertation

The results obtained in the dissertation work make a significant contribution to

the study of the thermodynamic aspects of the evolution of the late Universe, as well as the influence of thermal radiation on the formation of a singularity and can be used in the interpretation of data from the cosmic microwave background and baryon acoustic oscillations. The considered metrics can be used in cosmology, especially in the study of processes occurring at the early stages of the evolution of the Universe and in the construction of models of the interaction of the axion field with the electromagnetic field, which is of interest in the study of the problem of dark matter.

The reliability and validity of the results first of all, it is determined by the fact that they are well confirmed by consistency with existing observational data. In addition, the results obtained are consistent with the conclusions about the accelerated expansion of the Universe. In addition, the reliability and validity of the results are confirmed by the presence of publications in foreign journals with a high impact factor, in collections of international scientific and practical conferences and in publications recommended by the authorized body of the Republic of Kazakhstan:

Brevik I., Myrzakulov K., ZhadyranovaA. et al. Viscous coupled fluids in terms of a log-corrected equation-of-state // International Journal of Geometric Methods in Modern Physics.– 2021.– Vol. 18, №12. – P. 2150198

Aljaf M., Elizalde E., Zhadyranova A. et al. Solving the H_0 tension in f(T) gravity through Bayesian machine learning // The European Physical Journal C. – 2022.– Vol. 82, №12. – P. 1130

Obukhov V.V., Myrzakulov K.R., Guselnikova U.A., Zhadyranova A.A. Algebras of Symmetry Operators of the Klein–Gordon–Fock Equation for Groups Acting Transitively on Two-Dimensional Subspaces of a Space-Time Manifold // Russian Physics Journal.– 2021.–Vol. 64, №7.– P. 1320-1327.

Бахрам А.Ж., Жадыранова А.А. Хаббл шиеленісін тұтқыр қара сұйықтықты қолданып шешу // XVIII Международная научная конференция студентов и молодых ученых «GYLYM JANE BILIM - 2023» - 2023 - С. 72-76,

Өсербай Ж.Қ., Жадыранова А.А. F(T) модельдерінің фондық динамикасын зерттеу үшін Байес машиналық оқытуды қолдану // XVIII Международная научная конференция студентов и молодых ученых «GYLYM JANE BILIM - 2023» -2023- С. 123-128,

Жадыранова А.А. Использование программного обеспечения Python в космологии // Научный журнал «Доклады НАН РК» -2023 – Т. 346, № 2. – С. 5–18.

To date, the results of the work published by the applicant have been cited in 6 independent peer-reviewed publications.

The personal contribution of the author lies in the fact that the entire volume of the thesis, the choice of the research method and numerical calculations were performed by the author on his own. The setting of tasks and discussion of the results were carried out jointly with the supervisors.

Publications

Based on the materials of the dissertation, 6 publications were published:
3 in journals of foreign countries with an impact factor included in the international information resource Web of Science (Clarivate Analytics) and Scopus; 2 works in the materials of International scientific conferences and 1 work in publications

recommended by the authorized body of the Republic of Kazakhstan.

Approbation of the dissertation. The results obtained in the dissertation were presented and discussed:

– at the seminar of the Department of Physics of the California State University, Fresno, USA on the topic "Nonlinear models of field theory for a space-time manifold";

– at a seminar organized within the framework of the Decade of Science at L.N. Gumilyov ENU on the topic: "Investigation of symmetry and solutions of some nonlinear field theory models for a space-time manifold";

– at the Kazakh-Uzbek seminar on the topic: "Investigation of symmetry and solutions of some nonlinear field theory models for a space-time manifold";

–at the XVIII International Scientific Conference of Students and Young Scientists "GYLYMJANEBILIM - 2023" (ENU, 2023).

Relation of the dissertation theme to the plans of scientific research within the framework of the project 2020-2022 on the topic "Research of integrable models of strong gravitational fields in the framework of the theory of solitons" and IRN: AP08052034".

The scope and structure of the thesis

The thesis consists of an introduction, 4 sections, conclusion and list of references from 234 titles, contains 116 pages of basic computer text, including 19 figures, 302 formulas and 5 tables.