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(национальный исследовательский университет)»

# ФИЗИЧЕСКИЕ ИНТЕРПРЕТАЦИИ ТЕОРИИ ОТНОСИТЕЛЬНОСТИ (PIRT–2023)

## XXIII Международная научная конференция

Москва, 3–6 июля 2023 г.

**СБОРНИК ТЕЗИСОВ**

V.Monakhov. The impossibility of the existence of Majorana spinors as physical particles. In: Abstracts of XXIII International Scientific Conference "Physical Interpretations of the Relativity Theory" (PIRT-2023), p.123.

# PHYSICAL INTERPRETATIONS OF RELATIVITY THEORY (PIRT–2023)

## XXIII International Scientific Conference

Moscow, July 3–6, 2023

**ABSTRACTS**

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Конференция PIRT — это международное научное мероприятие, которое впервые было организовано в 1988 году в Имперском колледже Лондона, а с 2003 года проводится раз в два года в МГТУ им. Н.Э. Баумана в Москве. Конференция посвящена следующим вопросам: обсуждение физической, геометрической и математической интерпретации теории относительности и ее современных обобщений; обсуждение наблюдаемых эффектов и экспериментальная проверка теории относительности; методы регистрации гравитационных волн; эффекты релятивистской электродинамики и оптики движущихся сред; астрофизические наблюдения и космические эксперименты.

Конференция проводится при поддержке Комитета Государственной Думы по образованию РФ, Российского гравитационного общества, Московского физического общества, Международного общества общей теории относительности и гравитации, Калькуттского математического общества.

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# Релятивистская одностепенная аналитическая модель системы Земля — Луна

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Предлагается парадоксальная формально одностепенная модель относительной динамики системы Земля — Луна, идеологически восходящая к П.Л. Капице. Эта модель представляет собой канонический релятивистский шар — общее односвязное аналитическое возмущение однородного геометрического шара.

Данная динамическая система представляет гамильтонову систему с одной аналитической степенью свободы — фазовый поток математического маятника, находящегося в строго вертикальном равновесии, или, что то же самое, фазовый поток канонического аналитического осциллятора.

Эта модель представляет собой каноническую маятниково-колебательную нормировку аналитического продолжения на бесконечность формального времени фазового потока общих классических уравнений Эйлера-Пуассона над комплексным временем [1]. Поэтому мы называем эту модель «маятниково-осцилляторной» моделью.

Уравнения Эйлера — Пуассона (ЭП) в рамках этой модели с одной степенью свободы реализуются известным уравнением Пенлеве *VI*. Земля и Луна моделируются диполем гравитирующих шаров с центрами на концах аналитического осциллятора и являются вычетами *L*-функционального гамильтониана осциллятора с релятивистской структурой. Этот диполь является каноническим инвариантным множеством односвязного двулистного покрытия трехмерной сферы отображением авторекурсивной временной обратимости симметрии общих уравнений ЭП над комплексным временем.

В рамках маятниково-осцилляторной модели путем анализа структуры вычетов в ее сингулярностях реализуются: объяснение ориентационной устойчивости вращения Земли и Луны, качественное объяснение эффекта Чандлера движения полюсов Земли и Луны [2]. Математически и механически необходимая коррекция классического объяснения [3] эффекта Джанибекова как канонической глобальной параметризации 3D-сферы.

На основе введенной чисто математической модели скорости света рассчитывается реалистичное модельное расстояние между центрами Земли и Луны. Выявлена также корреляция модели с одной из современных теорий происхождения Земли и Луны.

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## Relativistic Analytical One-Degree of Freedom Model of the Earth-Moon system

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The paper proposes a paradoxical model of the relative dynamics in the Earth-Moon system, formally featuring a single degree of freedom. The idea behind the model may be traced back to those of P.L. Kapitsa. This model amounts to a canonical relativistic ball, that is, a total simply connected analytical perturbation of a homogeneous geometric ball.

This dynamical system represents a Hamiltonian system with one analytical degree of freedom, that is, a phase flow of a mathematical pendulum in perfect vertical equilibrium, or, in other words, a phase flow of a canonical analytical oscillator.

This model is a canonical pendulum-oscillatory normalization of the analytical continuation to infinity of the formal time concerning the phase flow in the classical general Euler-Poisson equations over complex time [1]. Therefore, we call this model the “pendulum-oscillatory” model.

Within the framework of this model featuring one degree of freedom, the Euler-Poisson (EP) equations are represented by the well-known Painlevé *VI* equation. The Earth and the Moon are modeled by a dipole formed by gravitating balls whose centers are located at the extremities of an analytical oscillator and are the residues of an *L*-functional Hamiltonian for an oscillator with a relativistic structure. This dipole is a canonical invariant set of a simply connected two-sheet covering of a three-dimensional sphere by a mapping of an autorecursive temporal reversibility of the symmetry in the general EP equations over complex time.

By analyzing the structure of residues in its singularities, the pendulum-oscillator model is capable of the following: explaining the orientation stability in the rotation of the Earth and the Moon; qualitatively explaining the Chandler effect of the Earth and the Moon pole motion [2]; introducing a mathematically and mechanically necessary correction to the classical explanation [3] of the Dzhanibekov effect as a canonical global parametrization of the 3D sphere.

Based on the purely mathematical model of the speed of light introduced here, we calculated a realistic simulated distance between the centers of the Earth and the Moon. We also discovered a correlation between our model and one of the modern theories of the origin of the Earth and the Moon.

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# Electromagnetic Radiation of Accelerated Charged Particles in the Framework of a Semiclassical Approach

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In a recent work by Bagrov, Gitman, Shishmarev, and Farias [1], the so-called semiclassical approach for describing quantum properties of radiation of currents of charged particles was proposed. In this approach, currents generating the radiation are considered classically, whereas the quantum nature of the radiation is taken into account exactly. Universal formulas describing multiphoton radiation are derived. The approach does not require knowledge of the exact solutions of relativistic wave equations with external fields; hence technical difficulties associated with using the Furry picture do not arise. Instead, the back reaction of the radiation field to charged particles can be taken into account by solving the Lorentz equations with radiation-reaction terms. The effectiveness of the semiclassical approach was demonstrated in calculating synchrotron and undulator radiations [1, 2]. Here we apply the semiclassical approach to study electromagnetic radiation by uniformly accelerated charged particles [3]. We calculate electromagnetic energies and rates radiated by these particles. Then we compare our results with those obtained by other authors [4, 5] in the framework of the classical radiation theory and QED.

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## Non-singular Bouncing Solution of the Universe in Extended Symmetric Teleparallel Gravity

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In this paper, the matter bounce scenario of the Universe has been studied in an extended symmetric teleparallel gravity, the $f(Q)$ gravity. The bounce cosmology is the solution of the loop quantum cosmology (*LQC*). Motivated by this work, $f(Q)$ has been obtained against the backdrop of Friedmann-Lemaitre-Robertson-Walker (FLRW) space-time. The e-folding parameter has been achieved in the nonmetricity term for the matter-dominated case. It is a well-known fact that the slow roll condition does not hold in the bounce context. We used a conformal equivalence between $f(Q)$ and the scalar-tensor model to apply the bottom-up reconstruction technique in the bouncing model. The dynamics of the model have been studied through phase space analysis, where both the stable and unstable nodes are obtained. Also, the stability analysis has been performed with the first-order scalar perturbation of the Hubble parameter and matter energy density to verify the stability of the model.

## A Unified Field Theory of Gravitation

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Feynman famously considered: ‘although the three known force fields are quantized, there is no *a priori* necessity for gravity to also be quantized’. We introduce the possibility of this scenario utilizing a preliminary form of an Einstein-like Unified Field Theory (UFT) called an Ontological-Phase Topological Field Theory (OPTFT) with an inherent cyclical duality between Quantum Field Theory (QFT) and General Relativity (GR) entailing a virtual quantization of gravity at the semi-quantum limit — an asymptotic Planck-scale singularity cycle never reached. When this Kaluza-Klein-like cyclicality repeats, the dual quantum field correlated with gravitational field coordinates flips as a phase oscillated annihilation-creation cycle repeats. In terms of a rudimentary OPTFT proposed, mediation of the field occurs by continuous ontological-phase transitions (energyless) where topological switching (conceptually like the ambiguous vertices of a Necker Cube) by topological charge mediates information exchange in an energyless manner. Further, we elevate the Penrose Conformal Cyclic Cosmology (CCC) he called an “Outrageous New Perspective” to a new conformal scale-invariant Principle of particle physics. Penrose claimed the CCC iterates through infinite cycles, which we extend by conformal scale-invariance to correlate with an asymptotic Planck-scale singularity (never reached) for every point in spacetime with each previous iteration by a new modified form of continuous cycle Leapfrog — Seesaw mechanism of ontological-phase transformations.

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# Пульсар: метрическое обобщение времени-пространства небесной и квантовой механики

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В инерциальной системе тело движется по законам Кеплера — Ньютона (инерциальность в обычном механическом смысле).

В инерциальной системе уравнение распространения фронта электромагнитной волны определяет инерциальность также и в отношении поля.

Оба эти принципа теории относительности Пуанкаре нами были распространены на хронометрирование пульсаров, измеримые параметры вращения которых определяют шкалу времени в инерциальных системах.

Фронт волны электромагнитного излучения пульсара при взаимодействии с микрочастицами, обладающими волновыми свойствами, по своей шкале фиксирует изменение во времени их механических состояний, а по наблюдаемой последовательности сменяющихся дискретных состояний фиксирует их движение по определенной траектории.

При прохождении фронта волны электромагнитное поле пульсара, взаимодействуя с электромагнитным полем микрочастиц, по своей шкале фиксирует их дискретные механические состояния с точностью до кванта времени, разрешаемого пульсарной шкалой. Измеренные по пульсарной шкале дискретные механические состояния микрочастиц кратны постоянной величине $\partial T = 5{,}551115123125780 \cdot 10^{-17}$ с, они повторяются в любой инерциальной системе координат. Их число конечно, независимо от продолжительности измерений.

Тем самым показано, что решение обратной задачи небесной механики во временной области по уравнению распространения фронта электромагнитного излучения пульсара полностью исключает влияние инструмента — радиотелескопа в измерениях дискретных состояний микрочастиц, обобщаемых в 4-мерном пространстве по пульсарной шкале времени.

Поскольку уравнение Шредингера инвариантно относительно преобразований Лоренца, опирающихся на принцип относительности Галилея, отсюда следует существование ряда операторов квантовой механики и существование квантовомеханических инвариантов, связанных с преобразованиями Галилея, аналогичных преобразованиям в небесной механике.

Таким образом, физические процессы небесной и квантовой механики протекают в пространстве инерциальных координатных систем синхронно во всем диапазоне возможных движений — от наблюдаемых движений небесных тел до взаимодействий электромагнитных полей и квантовых частиц. Атомные объекты обнаруживаются и фиксируются непосредственным детектированием упругих волновых взаимодействий по пульсарной шкале времени в своих естественных состояниях, исключающих столкновения частиц, подобные столкновениям в коллайдере.

## Pulsar: Metric Generalization of Time-Space of Celestial and Quantum Mechanics

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In the inertial frame, the body moves according to the Kepler-Newton laws (inertiality in the usual mechanical sense).

In an inertial system, the equation for the propagation of an electromagnetic wave front also determines the inertiality with respect to the field.

Both of these principles of Poincare's theory of relativity were extended by us to the timing of pulsars, whose measurable rotation parameters determine the time scale in inertial systems.

When the pulsar electromagnetic radiation wavefront interacts with microparticles having wave properties, the pulsar records the change in time of the mechanical states of the microparticles on its own scale, and records their movement along a certain trajectory based on the observed sequence of changing discrete states.

During the passage of the wave front, the electromagnetic field of the pulsar, interacting with the electromagnetic field of microparticles, fixes their discrete mechanical states on its scale with an accuracy of up to a quantum of time allowed by the pulsar scale. The discrete mechanical states of microparticles measured on the pulsar scale are multiples of the constant value $\partial T = 5{,}551115123125780 \cdot 10^{-17}$ s, they are repeated in any inertial coordinate system. Their number is finite, regardless of the duration of the measurements.

Thus, it is shown that the solution of the inverse problem of celestial mechanics in the time domain according to the equation for the propagation of the front of electromagnetic radiation of a pulsar completely excludes the influence of an instrument — a radio telescope in measurements of discrete states of microparticles, generalized in 4-dimensional space on a pulsar time scale.

Since the Schrödinger equation is invariant under Lorentz transformations based on the Galilean principle of relativity, this implies the existence of a number of quantum mechanics operators and the existence of quantum mechanical invariants associated with Galilean transformations, similar to those in celestial mechanics.

Thus, the physical processes of celestial and quantum mechanics proceed in the space of inertial coordinate systems synchronously in the entire range of possible movements — from the observed movements of celestial bodies to the interactions of electromagnetic fields and quantum particles. Atomic objects are recognized and fixed by direct detection of elastic wave interactions on a pulsar time scale in their natural conditions, excluding particle collisions, as in a collider.

## Уравнение Шредингера для модели Шварцшильда

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Целью данной работы является изучение фундаментальных проблем геометродинамики Уилера — Де Витта, которая была первой попыткой получить квантовую теорию гравитации и объяснить происхождение и последствия проблем применения этой теории к модели Шварцшильда. В качестве альтернативы квантовой геометродинамике Уилера — Де Витта был использован подход, основанный на формализме расширенного фазового пространства, в рамках которого можно получить уравнение Шредингера, описывающее эволюцию во времени физического объекта, в которое входят калибровочные степени свободы. Физически введение этих переменных означает, что, выбирая разные калибровки, можно выбрать разных наблюдателей в разных системах отчета, что и согласуется с классической теорией относительности, в которой, невозможно найти решения уравнений Эйнштейна, если не была введена система отчета. В результате нашего исследования было получено уравнение Шредингера для модели Шварцшильда, и анализ этого уравнения подчеркивает его важность для построения квантовой теории гравитации.

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## Schrodinger Equation of the Schwarzschild Metric

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The objective of this work is to study the fundamental problems of the Wheeler — DeWitt geometrodynamics, which was the first attempt to obtain a quantum theory of gravity and explain the origins and consequences of the problems in the application of this theory to the Schwarzschild metric. As an alternative to the Wheeler – DeWitt quantum geometrodynamics we consider the extended phase space formalism, within the framework of this approach, one can obtain the Schrodinger equation describing the evolution of a physical object over time that includes gauge degrees of freedom. Physically, the introduction of these variables means that by choosing different gauge variables, one can choose different observers in different referent systems, which is consistent with the classical relativity theory, in which one cannot find a solution of the Einstein's equations without fixing a reference frame. As a result of our research, the Schrodinger equation for the Schwarzschild model was obtained, and the analysis of this equation emphasizes its importance for the construction of a quantum theory of gravity.

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# Geometric Criteria for Gravitational Waves and the Hodge-de Rham Laplacian

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A differential form is called *harmonic* if the action of the Hodge-de Rham Laplacian, $\Delta^{(HR)} = DD^* + D^*D,$ on it is identically zero. Here $D$ is a covariant differential, $D^*$ is a covariant co-differential. For a 4-dimensional Lorentzian manifold $D^* = {}^*D^*$, where $^*$ is the Hodge dualization. The Einstein space is the space in which the equation $R_{\alpha\beta} = \Lambda g_{\alpha\beta}$ is fulfilled in vacuum.

Earlier in the literature, the following statement was given as a criterion of gravitational waves: Einstein spaces are harmonic if and only if they belong to Petrov type N. However, *this statement is not correct*, although it is given in a well-known monograph on gravitational waves [1].

In [2], a detailed calculation of the result of the action of the Hodge-de Rham Laplacian on the curvature 2-form $\tilde{\mathrm{R}}$ of the Riemann space is presented and it is shown that for all Einstein spaces the equality is valid, $\Delta^{(HR)}\tilde{\mathrm{R}} = 2(e^{\sigma} \otimes e^{\rho}) \otimes (R_{\mu[\sigma;\rho]})_{;\nu} (\theta^{\mu} \wedge \theta^{\nu}) = 0,$ since the action of the Codazzi equation in the Einstein space leads to the equality $R_{\mu[\sigma;\rho]} = 0.$ Thus, the following statement is true: *all Einstein spaces are harmonic*.

Note that this statement was stated in [3], and obtained by mathematicians, see [4].

The authors have calculated the result of the action of the Hodge-de Rham Laplacian on the curvature 2-form of the Riemann–Cartan space. As a result, it has been concluded: *all solutions in vacuum of the Einstein–Cartan theory of gravity are harmonic.*

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# Модель открытой вселенной с космологической постоянной как задача о движении частицы в силовом поле

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Рассмотрена возможность нахождения точных космологических решений уравнений Эйнштейна с космологической постоянной для открытой модели вселенной путем сведения проблемы к эквивалентной задаче о движении массивной частицы в силовом поле. Взятая космологическая модель заполнена материей в приближении идеальной жидкости с отличными от нуля давлением и космологической постоянной, вообще говоря. Метрика четырехмерного пространства — времени берется в форме Фока как метрика, конформная метрике Минковского с зависимостью от одной переменной, квадрат которой есть произведение опережающего и запаздывающего времен.

Использование механической интерпретации для уравнений тяготения приводит к возможности рассмотрения различных силовых полей, в частности потенциальных, с последующей физической интерпретацией получаемых точных космологических решений.

Прежде всего рассматривается движение свободной частицы единичной массы (механическая сила отсутствует), то есть частица движется по инерции. Конформный множитель космологической конформно-плоской метрики есть четвертая степень найденного закона движения. Этот случай при отсутствии космологической постоянной соответствует точному космологическому решению без давления, совпадающему с известным решением Фридмана для открытой Вселенной.

Затем рассматривается силовой потенциал в виде линейной функции. Полученное точное космологическое решение, асимптотически описывает как некогерентную пыль, так и ультрарелятивистскую материю, которую можно было бы интерпретировать как равновесное излучение.

Далее в качестве потенциала выбирается квадратичная функция без линейного члена и постоянной. Такой потенциал можно интерпретировать как потенциал свободного осциллятора отвечающего линейной по смещению силе (силе Гука). Решение соответствующего уравнения движения записывается в виде функции косинуса с некоторой начальной фазой, связанной с отношением параметров, определяющих пылевидную и ультрарелятивистскую материю. Этот вывод становится очевиден после асимптотического рассмотрения давления и плотности энергии. Космологическая модель оказывается обобщением решения Фридмана с равновесным излучением и веществом, которые заполняют вселенную. Рассмотрены примеры моделей при наличии космологического члена.

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## The Open Universe Model with the Cosmological Constant as a Particle Movement Task in a Force Field


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The possibility of deriving of exact cosmological solutions of the Einstein equations with the cosmological constant for the open universe model by reducing the problem to an equivalent task of the movement of a mass particle in the force field is considered. Taken cosmological model is filled by substance in an approximation of the perfect fluid with nonzero pressure and cosmological constant, generally speaking. A four-dimensional space-time metric is taken in Fock's form as the metric, conformal to the Minkowski metric. This metric depends on one variable. A square of the variable is a product of advanced and retarded times.

The using of mechanical interpretation of the gravitation equations leads to a possibility of consideration of various force fields, in particular the potential fields, with the subsequent physical interpretation of found exact cosmological solutions.

First of all the movement of free particle with an unit mass (a mechanical force is absent) is considered, that is to say the particle moves on inertia. The fourth degree of finded law of movement is a conformal factor of cosmological conformally-flat metric. This case corresponds to the exact cosmological solution without cosmological constant and pressure, coinciding with known the Friedman solution for the open universe.

After that the force potential is taken in the form of linear function. Found exact cosmological solution asymptotically describes both an incoherent dust, and the ultra-relativistic matter which could be interpreted as an equilibrium radiation.

Further a square-law function without a linear term and a stationary value is taken as a potential. Such potential can be interpreted as potential of the free oscillator corresponding to linear shift force (Hooke's force). The solution of corresponding equation of motion is written in the form of a cosine function with some initial phase related to the correlation of parameters which define dust-like and ultra-relativistic matter. The cosmological model is the generalization of Friedman's model with the equilibrium radiation and substance which fill the universe. Examples of models in the presence of the cosmological constant are considered.

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# Измерение гравитационного красного смещения сигналов радиосвязи с помощью спутника РадиоАстрон на высокоэллиптической орбите

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Представлены текущие результаты обработки измерений эффекта гравитационного красного смещения [1] со спутника РадиоАстрон в период 2015–2017 гг. с помощью бортового водородного мазера и аналогичных стандартов на станциях слежения Пушино (АСК ЛПИ РАН, Россия) и Green Bank (NRAO, США) [2, 3]. В докладе обсуждается усовершенствованный метод обработки радиосигналов с гравитационным красным смещением без использования традиционных счетчиков частоты на станциях слежения, которые имеют ограниченную точность. В новом методе параметры частотной эволюции радиосигналов связи определяются по коэффициентам информационной матрицы Фишера, а их точность оценивается с учетом предельной границы Крамера — Рао. При большом отношении сигнал шум эта методика повышает точность измерения частоты на порядок. В свою очередь, становится возможным получить более низкое значение параметра влияния ОТО, близкое к оценкам, полученным из наблюдений спутников Galileo [4, 5].

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# Measurements of the Gravitational Frequency Shift of Radio Communication Signals with RadioAstron Satellite in a Strongly Elliptical Orbit

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This report presents the current results of processing measurements of the gravitational redshift effect [1] from the RadioAstron satellite in the period 2015–2017. With an onboard hydrogen maser and similar standards at the Pushino tracking station (ASC LPI RAS, Russia) and Green Bank (NRAO, USA) [2, 3]. The report discusses an improved method for processing gravity data without the use of conventional frequency counters at tracking stations, which have limited accuracy. In the new method, the parameters of the frequency evolution of communication radio signals are determined by the coefficients of the Fisher information matrix, and their accuracy is estimated taking into account the limiting Cramer — Rao boundary. With a large SNR, this technique improves the frequency measurement accuracy by an order of magnitude. In turn, it becomes possible to obtain a lower value of the GR violation parameter, close to the estimates made from observations of the Galileo satellites [4, 5].

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## Conformal Invariance and Cosmology

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If we assume that the universe was created from “nothing” [1], then additional symmetry increases the probability of such an event. This is one of the reasons why the local conformal invariance looks like a good candidate to become the fundamental symmetry of the Nature. Thereby we consider the conformally invariant action of gravity. In Riemannian geometry this type of gravity action leads to the fact that all the cosmological metrics turn out to be the vacuum solutions [2, 3].

Using the example of an action for an ideal fluid with a variable number of particles [4], a phenomenological description of the processes of particle production against the background of strong external fields for the homogeneous and isotropic cosmological model is studied. In particular, gravity and scalar field are considered as sources of particle creation.

The conformal invariance of the left-hand side of the particle production law leads to restrictions on the form of the source function Φ, which depends on the invariants of external fields responsible for the creation processes. This result is of great importance, because it does not depend on the gravitational Lagrangian. In the absence of classical external fields, particles are born exclusively due to vacuum polarization caused by the influence of the gravitational field, therefore the only choice for Φ is the square of the Weyl tensor. Only quadratic terms are considered in order not to go beyond the one-loop approximation of the quantum field theory.

When an external scalar field is introduced into the creation law, from the tracelessness of the energy-momentum tensor due to the conformal invariance of the action of gravity it follows that for dust the energy density is proportional to the scalar field, while for radiation it does not depend on the scalar field. Moreover, in contrast to the previous case, for a model with a scalar field, the zero energy-momentum tensor does not necessarily imply the absence of matter. Namely, certain types of solutions for dust, radiation and matter with an arbitrary equation of state were found and investigated using the freedom to choose a gauge, which is provided by the conformal invariance of the equations of motion.

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# Точные степенные решения в космологии скалярного кручения

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Обобщенная скалярно-торсионная гравитация [1] с действием

$$S = \int \left[ \frac{M_{pl}^2}{2} F(\phi) T + P(\phi, X) - G(\phi, X) \Box \phi \right] \tag{1}$$

исследуется с выбором параметров $P = -\omega X + V$, $G = 0$, $F \neq 0$. Здесь ω, $P$, $F$ и $V$ являются произвольными функциями и/или $X$, и $X = \frac{1}{2}\dot{\phi}^2$. Поиск решений ведется в метрике Фридмана — Робертсона — Уокера $ds^2 = -dt^2 + a^2 \delta_{ij} dx^i dx^j$ с наложенной стандартной геометрией фона $e_\mu^A = \mathrm{diag}\{1, a, a, a\}$, где $a = a(t)$, является масштабным фактором. В нашем рассмотрении мы определили функцию $F$ следующего вида $F = \left(\frac{H}{\lambda}\right)^n$, где λ, $n$ являются произвольными константами. Тогда фоновые космологические уравнения для действия (1) принимают вид

$$V = \frac{H^n M_{pl}^2}{\lambda^n} \left( 3H^2 + \dot{H}(1+n) \right); \tag{2}$$

$$\omega \dot{\phi}^2 = -2M_{pl}^2 \left(\frac{H}{\lambda}\right)^n \dot{H}(1+n). \tag{3}$$

В данном докладе будут представлены решения системы уравнений (2), (3) для степенной инфляции $H = m/t; \left(a(t) = a_0 t^m\right)$ при разных значениях $n = 0, 1, 2, 1/2, 3/2, -1, -2, -1/2$.

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## Exact Power-Law Solutions in the Scalar-Torsion Cosmology

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Generalized scalar-torsion gravity [1] with the action

$$S=\int\left[\frac{M_{pl}^2}{2}F(\phi)T+P(\phi,X)-G(\phi,X)\Box\phi\right] \quad (1)$$

are studied with the parameters' choice $P=-\omega X+V,\ \ G=0,\ \ F\neq 0.$ Here ω, *P*, *F* and *V* are arbitrary functions of and/or $X$ , and $X=\frac{1}{2}\phi^2.$ The search for solutions is carried out in the Friedmann — Robertson — Walker metric $ds^2=$ $=-dt^2+a^2\delta_{ij}dx^i dx^j$ with superimposed standard background geometry $e_\mu^A=\mathrm{diag}\{1,a,a,a\},$ where $a=a(t)$ is a scale factor. In our consideration, we define the function F of the following form $F=\left(\frac{H}{\lambda}\right)^n,$ where λ, *n* are arbitrary constants. Then the background cosmological equations for the action (1) take the form

$$V=\frac{H^n M_{pl}^2}{\lambda^n}\left(3H^2+\dot{H}(1+n)\right); \quad (2)$$

$$\omega\dot{\phi}^2=-2M_{pl}^2\left(\frac{H}{\lambda}\right)^n\dot{H}(1+n). \quad (3)$$

This report will present solutions to the system of equations (2), (3) for power inflation $H=m/t;\ \left(a(t)=a_0 t^m\right)$ at different values $n=0,1,2,1/2,3/2,-1,-2,-1/2.$

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# Вакуумные средние тензора энергии-импульса и тока спинорного поля в постоянном электрическом поле

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В рамках квантовой электродинамики с сильным электрическим полем, которое не зависит от времени и имеет постоянное направление, и сосредоточено в ограниченной пространственной области (в так называемой x-ступеньке электрического потенциала) исследуются вакуумные средние плотности тока и тензора энергии-импульса квантованного спинорного поля, помещенного в так называемое $L$-постоянное электрическое поле. Под последним можно понимать, например, электрическое поле, заключенное между обкладками конденсатора, отстоящими друг от друга на достаточно большое расстояние $L$. Во-первых, исследованы особенности непертурбативного расчета средних значений в квантовой электродинамике сильного поля в x-ступеньках электрического потенциала, и, в $L$-постоянном электрическом поле, в частности. Мы предлагаем новые процедуры перенормировки и объемной регуляризации. Найдены необходимые представления для сингулярных спинорных функций Грина для $L$-постоянного электрического поля. С их помощью мы вычисляем вакуумные средние тензора энергии-импульса и тока спинорного поля. Показано, как в полученных выражениях, разделить глобальные вклады, связанные с рождением частиц, и локальные вклады, связанные с поляризацией вакуума.

# Vacuum Mean Values of Spinor Field Current and Energy-Momentum Tensor in a Constant Electric Background

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In the framework of strong-field QED with x-steps, we study vacuum mean values of the current density and energy–momentum tensor of the quantized spinor field placed in the so-called L-constant electric background. The latter background can be, for example, understood as the electric field confined between capacitor plates, which are separated by a sufficiently large distance L. First, we reveal peculiarities of nonperturbative calculating of mean values in strong-field QED with x-steps in general and, in the L-constant electric field, in particular. We propose a new renormalization and volume regularization procedures that are adequate for these calculations. We find necessary representations for singular spinor functions in the background under consideration. With their help, we calculate the above mentioned vacuum means. In the obtained expressions, we show how to separate global contributions due to the particle creation and local ones due to the vacuum polarization.

# Решение Керра — Ньюмана объединяет гравитацию с квантовой теорией

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Рассмотрено известное решение для сверх-вращающейся черной дыры (ЧД) Керра — Ньюмана (КН), которое (как обнаружил Картер) при параметрах электрона (массе $m$, заряде $e$ и параметре вращения $a = \lambda_c/2 = \hbar/(2mc)$) моделирует гравитирующий электрон в виде тонкой кольцевой струны радиуса $a$, равного половине комптоновской длины волны электрона. При $a > m$ горизонты ЧД исчезают, и электрон превращается в двулистное пространство Эйнштейна — Розена, в котором конгруэнция Керра переходит аналитически с положительного листа метрики ($r > 0$) на отрицательный ($r < 0$). В моделях Израэля и Лопеза отрицательный лист решения КН отсекался как излишний.

В рассматриваемой здесь новой модели электрона [1], отрицательный лист КН заменяется «зеркальным» листом, описывающим запаздывающее излучение электрона, а лист метрики связанный с входящим волновым полем интерпретируется как «позитронный лист электрона» и используется как лист опережающих потенциалов. Это удвоение структуры электрона соответствует формированию электронно-позитронного вакуума в КЭД, и мы рассматриваем отдельно «голый» и гравитационно «одетый» электрон. «Голый» электрон является моделью классической безмассовой релятивистской струны, которая описывает волновые свойства электрона, *устраняя противоречие* между протяженной частицей теории гравитации и точечным электроном квантовой теории.

«Одетый» электрон формируется вектор потенциалом решения КН, который затягивается гравитацией (frame-dragging), образуя две противоположно ориентированные петли Вильсона, порождающие электронно-позитронную пару монополя и антимонополя с сильной магнитной связью.

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# Kerr — Newman Solution Combining Gravitation and Quantum Theory

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The paper examines the well-known Kerr–Newman (KN) solution for an over-rotating black hole (BH), which (as Carter discovered), if the parameters match those of the electron (mass $m$, charge $e$, and rotation parameter $a = \lambda\!\!\!^{-}_c/2 = \hbar/(2mc)$), simulates the gravitating electron in the form of a thin circular string of a radius $a$ equal to half the Compton wavelength of the electron. When $a > m$, the black hole horizons disappear, and the electron turns into a two-sheeted Einstein-Rosen space, in which the Kerr congruence moves analytically from the positive sheet of the metric ($r > 0$) to the negative one ($r < 0$). In the models of Israel and Lopez, the negative sheet of the KN solution was disregarded as redundant.

In the new electron model discussed here [1], the negative KN sheet is replaced by a “mirror” sheet describing the delayed emission of the electron, while the metric sheet associated with the incoming wave field is interpreted as the “positron sheet of the electron” and used as a sheet of advanced potentials. This doubling of the electron structure corresponds to the formation of the electron-positron vacuum in QED, so we consider separately the “naked” and gravitationally “clothed” electrons. The “naked” electron is a model of a classical massless relativistic string that describes the wave properties of the electron, *eliminating the contradiction* between the extended particle in the theory of gravity and the point electron theory of quantum physics.

The “clothed” electron is formed by a vector potential of the KN solution, which is tightened by gravitation (frame-dragging), forming two oppositely oriented Wilson loops that generate an electron-positron pair of a monopole and an antimonopole with a strong magnetic bond.

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## Электрон Керра — Ньюмана как адаптивная система

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В докладе рассматривается известное решение для вращающейся черной дыры (ЧД) Керра — Ньюмана (КН), которое моделирует непертурбативный гравитирующий электрон, и делается предположении, что известный эксперимент с двумя щелями может быть объяснен свойствами электрона как элементарной адаптивной системы.

В координатах Керра — Шильда метрика КН имеет вид $g_{\mu\nu} = \eta_{\mu\nu} + 2Hk_\mu k_\nu$, где $\eta_{\mu\nu}$ соответствует плоской метрике пространства Минковского, и $H$ — скалярная функция $H = \dfrac{mr - e^2/2}{r^2 + a^2\cos\theta}$ [1]. Нулевое поле $k^\mu$ $(k_\mu k^\mu = 0)$ образует дважды линейчатую поверхность — однополостный гиперболоид вращения. В решении КН для ЧД конгруэнция Керра, пересекая плоскость $\theta = \pi/2$, переходит аналитически с положительного листа метрики ($r > 0$) на отрицательный ($r < 0$), и фокусируется на сингулярном кольце Керра. В моделях электрона, рассмотренных ранее Израэлем и Лопезом, отрицательный лист решения КН отсекался как ненужный. В рассмотренной новой модели электрона [2], отрицательный лист решения КН заменяется «зеркальным» листом конгруэнции Керра, который описывает запаздывающее излучение электрона. В то же время, лист метрики, связанный с входящим полем конгруэнции Керра, использован как лист опережающих потенциалов, и интерпретируется как «позитронный лист электрона». Такое удвоение структуры электрона соответствует КЭД [3]. Затягиваемый гравитацией вектор-потенциал решения КН образует две противоположно ориентированные и противоположно заряженные петли Вильсона, затянутые гравитационным полем и порождающие электронно-позитронную пару монополя и антимонополя с сильной магнитной связью. В результате, гравитация КН оказывается сильной, и КН электрон приобретает комптоновскую массу, что формирует сверхпроводящее ядро электрона [2].

В предлагаемой модели сингулярное кольцо электрона КН излучает узконаправленную радиацию подобно антенне. В опыте с двумя щелями падающий электрон дифрагирует на щелях, а затем принимается «позитронной» стороной решения КН, которая действует как приемная антенна. Сравнение частот переданного и принятого сигнала формирует обратную связь и вырабатывает сигнал ошибки. Таким образом, электрон КН может действовать подобно другим адаптивным системам как простейшая самоорганизующаяся адаптивная система, выбирая путь в соответствии с принципом наименьшего действия.

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## The Kerr — Newman Electron as an Adaptive System

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The report examines the well-known Kerr–Newman (KN) solution for a rotating black hole (BH), which simulates a non-perturbative gravitating electron, and suggests that the well-known double-slit experiment can be explained by the properties of the electron as an elementary adaptive system. In the Kerr-Schild coordinates, the KN metric has the form $g_{\mu\nu} = \eta_{\mu\nu} + 2Hk_\mu k_\nu$, where $\eta_{\mu\nu}$ corresponds to the flat metric of Minkowski space and $H$ is a scalar function $H = \dfrac{mr - e^2/2}{r^2 + a^2 \cos\theta}$ [1]. The zero field $k^\mu$ $(k_\mu k^\mu = 0)$ forms a doubly ruled surface — a one-sheet hyperboloid of revolution. In the KN solution for BH, the Kerr congruence, crossing the $\theta = \pi/2$ plane, moves analytically from the positive metric sheet ($r > 0$) to the negative one ($r < 0$), focusing on the Kerr ring singularity. In the electron models considered earlier by Israel and Lopez the negative sheet of the KN solution was disregarded as unnecessary. In the new model of the electron [2] under consideration the negative sheet of the KN solution is replaced by a “mirror” sheet of the Kerr congruence, which describes the delayed emission of the electron. At the same time, the metric sheet associated with the incoming Kerr congruence field is used as a sheet of advanced potentials and interpreted as the “positron sheet of an electron”. This doubling of the electron structure is as per QED [3]. The gravitationally tightened vector potential of the KN solution forms two oppositely oriented and oppositely charged Wilson loops, tightened by the gravitational field and generating an electron-positron pair of a monopole and an antimonopole with a strong magnetic bond. As a result, the KN gravity proves to be strong, while the KN electron acquires a Compton mass, which forms a superconducting nucleus in the electron [2].

In the model proposed, the ring singularity of the KN electron emits directional radiation similarly to an antenna. In the double-slit experiment, the incident electron diffracts through the slits and is then accepted by the “positron” side of the KN solution, which acts as a receiving antenna. Comparison of the transmitted and received signal frequencies generates feedback and emits an error signal. Thus, the KN electron may act similarly to other adaptive systems as a simple self-organizing adaptive system, choosing the path in accordance with the principle of least action.

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# Исследование киральной космологической модели $f(R,\Box R)$- гравитации

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Изучаем модифицированную гравитацию $f(R,\Box R)$ [1], которая может быть сведена к киральной космологической модели специального типа:

$$S=\int d^4x\sqrt{-g}\left[\frac{R}{2}-\frac{1}{2}g^{\mu\nu}\chi_{,\mu}\chi_{,\nu}-\frac{1}{2}e^{-\sqrt{\frac{2}{3}}\chi}g^{\mu\nu}\varphi_{,\mu}\phi_{,\nu}+\frac{1}{4}e^{-2\sqrt{\frac{2}{3}}\chi}\left(f(\phi,\varphi)-\varphi B(\phi,\varphi)\right)-\frac{1}{4}e^{-\sqrt{\frac{2}{3}}\chi}\phi\right].$$

с ненулевыми компонентами $h_{11}=1,\ h_{23}=\frac{1}{2}e^{-\sqrt{\frac{2}{3}}\chi}$ и потенциалом

$$W(\chi,\phi,\varphi)=\frac{1}{4}e^{-\sqrt{\frac{2}{3}}\chi}\phi-\frac{1}{4}e^{-2\sqrt{\frac{2}{3}}\chi}\left(f(\phi,\varphi)-\varphi B(\phi,\varphi)\right).$$

Рассмотрены различные типы космологических решений, основанные на точных аналитических решениях, приближении медленного скатывания, методе суперпотенциала, включении дополнительных материальных полей, а также редукции многополевой модели к однополевой. Таким образом, в работе представлены актуальные методы анализа космологических моделей, основанные на эффективной многополевой интерпретации предложенной модифицированной гравитации.

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# Investigation of the Chiral Cosmological Model of $f(R,\Box R)$ Gravity

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We study modified $f(R,\Box R)$ [1], gravity which can be reduced to the chiral cosmological model of the special type:

$$S=\int d^4x\sqrt{-g}\left[\frac{R}{2}-\frac{1}{2}g^{\mu\nu}\chi_{,\mu}\chi_{,\nu}-\frac{1}{2}e^{-\sqrt{\frac{2}{3}}\chi}g^{\mu\nu}\varphi_{,\mu}\phi_{,\nu}+\frac{1}{4}e^{-2\sqrt{\frac{2}{3}}\chi}\left(f(\phi,\varphi)-\varphi B(\phi,\varphi)\right)-\frac{1}{4}e^{-\sqrt{\frac{2}{3}}\chi}\phi\right].$$

with non-zero components $h_{11}=1,\ h_{23}=\frac{1}{2}e^{-\sqrt{\frac{2}{3}}\chi}$ and potential

$$W(\chi,\phi,\varphi)=\frac{1}{4}e^{-\sqrt{\frac{2}{3}}\chi}\phi-\frac{1}{4}e^{-2\sqrt{\frac{2}{3}}\chi}\left(f(\phi,\varphi)-\varphi B(\phi,\varphi)\right).$$

Various types of cosmological solutions are considered based on exact analytical solutions, the slow-roll approximation, the superpotential method, the inclusion of additional material fields and reduction multi-field model to single-field one as well. Thus, our contribution presents topical methods for analyzing cosmological models based on an effective multi-field interpretation of the proposed modified gravity.

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# Торсионная скалярная гравитация с полем самодействия галилеонного типа

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Рассматривается обобщенная скалярно-торсионная гравитация [1]:

$$S=\int\left[\frac{M_{pl}^2}{2}F(\phi)T+P(\phi,X)-G(\phi,X)\Box\phi\right]$$

с параметрами $P=-\omega X+V$, $G=\gamma X$, $F\neq 0$, где $\omega$, $P$, $F$, $G$ — произвольные функции от $\phi$ и/или $X$, причем $X=\frac{1}{2}\dot{\phi}^2$, в метрике Фридмана — Робертсона — Уокера $ds^2=-dt^2+a^2\delta_{ij}dx^i dx^j$ с накладываемой стандартной однородной и изотропной фоновой геометрией $e_\mu^A=\mathrm{diag}\{1,a,a,a\}$. Для модели записаны фоновые уравнения и найдены решения для случая канонического поля при $\omega=1$, $F=\mathrm{const}$ и различного выбора скалярного поля $\phi$. Рассмотрен случай специального выбора функции $\omega=3H\dot{\phi}\gamma$, где $\gamma$ — произвольная постоянная, в рамках которого задана функция $F=\left(\frac{H}{\lambda}\right)^n$ и параметр Хаббла $H=m/t$, где $\lambda$, $m$, $t$ — произвольные постоянные. Решения для этого случая записываются следующим образом:

$$\phi=\left(\frac{A}{\lambda^n}\right)^{\frac{1}{3}}m^{\frac{n+1}{3}}\frac{3}{2-n}t^{\frac{2-n}{3}}+\phi_*;\quad F=\left(\frac{m}{\lambda}\right)^n\left(\frac{\lambda^n}{Am^{n+1}}\right)^{\frac{n}{n-2}}\left[\frac{2-n}{3}(\phi-\phi_*)\right]^{\frac{3n}{n-2}};$$

$$V=\left[\left(\frac{3}{2}\gamma+3\right)\frac{m^{n+2}}{\lambda^n}-\left(\frac{A}{6}+M_{pl}^2\right)\frac{(n+1)m^{n+1}}{\lambda^n}\right]\left(\frac{\lambda^n}{Am^{n+1}}\right)^{\frac{n+2}{n-2}}\left[\frac{2-n}{3}(\phi-\phi_*)\right]^{\frac{3(n+2)}{n-2}},$$

где $n\neq 2$, $A=-\frac{12}{\gamma}M_{pl}^2$.

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## Torsion Scalar Gravity with a Galileon-Type Field Self-Interaction

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Generalized scalar-torsion gravity is considered [1]:

$$S = \int \left[ \frac{M_{pl}^2}{2} F(\phi)T + P(\phi, X) - G(\phi, X)\Box\phi \right]$$

with parameters $P = -\omega X + V$, $G = \gamma X$, $F \neq 0$, were ω, *P*, *F*, *G* — arbitrary functions of $\phi$ and/or *X*, and $X = \frac{1}{2}\dot{\phi}^2$, in Friedmann — Robertson — Walker metric $ds^2 = -dt^2 + a^2\delta_{ij}dx^i dx^j$ with overlay standard homogeneous and isotropic background geometry $e_\mu^A = \text{diag}\{1, a, a, a\}$. Background equations are written for the model and solutions are found for the case of a canonical field for $\omega = 1$, $F = \text{const}$ and different choice of a scalar field $\phi$. We consider the case of a special choice of the function $\omega = 3H\dot{\phi}\gamma$, where $\gamma$ is an arbitrary constant. Within our choice the function is specified $F = \left(\frac{H}{\lambda}\right)^n$ and the Hubble parameter $H = m/t$, were λ, *m*, *t* — arbitrary constants. Solutions for this case are written as follows:

$$\phi = \left(\frac{A}{\lambda^n}\right)^{\frac{1}{3}} m^{\frac{n+1}{3}} \frac{3}{2-n} t^{\frac{2-n}{3}} + \phi_*; \quad F = \left(\frac{m}{\lambda}\right)^n \left(\frac{\lambda^n}{Am^{n+1}}\right)^{\frac{n}{n-2}} \left[\frac{2-n}{3}(\phi - \phi_*)\right]^{\frac{3n}{n-2}};$$

$$V = \left[\left(\frac{3}{2}\gamma + 3\right)\frac{m^{n+2}}{\lambda^n} - \left(\frac{A}{6} + M_{pl}^2\right)\frac{(n+1)m^{n+1}}{\lambda^n}\right]\left(\frac{\lambda^n}{Am^{n+1}}\right)^{\frac{n+2}{n-2}} \left[\frac{2-n}{3}(\phi - \phi_*)\right]^{\frac{3(n+2)}{n-2}},$$

were $n \neq 2$, $A = -\frac{12}{\gamma} M_{pl}^2$.

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## О лептонах в теории пространственно-временной пленки

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В качестве единой полевой модели рассматривается нелинейная полевая модель экстремальной пространственно-временной пленки [1–5]. Исследуются ее пространственно-локализованные решения, представляющие элементарные частицы. В частности, рассматриваем полевую конфигурацию в виде закрученного светоподобного солитона, движущегося вдоль кольца тороидальной системы координат. Точные решения в виде закрученных светоподобных солитонов, движущихся прямолинейно, были найдены в работе [1]. Как было показано в этой работе, солитоны определенного подкласса найденных решений могут рассматриваться как фотоны. В настоящей работе мы рассматриваем приближенное периодическое по времени решение в квази-цилиндрической тороидальной системе координат с вращением. Обратная величина радиуса кольца принята в качестве малого параметра. В качестве начального приближения рассматриваются точные решения в цилиндрической системе координат, найденные в работе [1]. Предложено начальное приближение в виде комбинации статической заряженной трубчатой оболочки и закрученного светоподобного солитона. Рассмотрены методы для определения значений параметров начального приближения. Обсуждается соответствие рассматриваемого класса решений реальным лептонам.

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## About Leptons in Space-Time Film Theory

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Nonlinear field model of extremal space-time film is considered as unified field model [1–5]. Its space-localized solutions representing the elementary particles are investigated. In particular, we consider the field configuration having a form of the twisted lightlike soliton moving along the ring of the toroidal coordinate system. The exact solutions in the form of twisted light-like solitons moving in a straight line were found in [1]. As was shown in this work, the solitons of defined subclass of obtained solutions can be considered as photons. In the present work, we consider the approximate time-periodic solution in the quasi-cylindrical toroidal coordinate system with rotation. The inverse ring radius appears as a small parameter. We consider the exact solutions in the cylindrical coordinate system obtained in the work [1] as the initial approximation. We propose the initial approximation in the form of combination of the charged tubular shell and twisted lightlike soliton. Methods for determining the values of parameters of the initial approximation are considered. The correspondence of this class of solutions to real leptons is discussed.

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# Алгебраический куб физических теорий

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1. Вершины «куба физических теорий», являющегося «неотъемлемой частью современного физического фольклора» [1], «соответствуют различным фундаментальным физическим теориям в зависимости от того, учитываются ли в них постоянные *c*, *G* и *h*». «*cGh*-куб» [2] (куб Зельманова) служит классификатором физических теорий [3, с. 17].

2. Развиваемый автором подход требует смены аксиоматического базиса физики [4, с. 47]. В заключении к методическим заметкам «О группах Галилея, Пуанкаре, де Ситтера, бикватернионах Гамильтона и их расширениях», обсуждавшимся в 2022 году в журнале «Успехи физических наук», построен алгебраический (теоретико-групповой) куб физических теорий, вершинам которого сопоставляются фундаментальные группы пространственно-временных преобразований (или соответствующие им алгебры Ли).

3. Отметим характерные особенности теоретико-группового куба физических теорий: 1) рассматриваемая автором *G*-теория отличается от ньютоновой [5]; 2) *cG*-вершине куба сопоставляется конформная группа, что предполагает построение релятивистской теории гравитации, отличающейся от «общей теории относительности» (ОТО) [4, с. 153]; 3) сопоставление *cGh*-вершине *cGh*-куба 16-параметрической расширенной конформной группы (в [6] рассмотрен ее нерелятивистский аналог) требует отказа от «традиционных подходов к теории гравитации и квантовой теории», но физическое сообщество считает, что «это время еще не наступило» [3, с. 240]. Здесь символы c, G и h обозначают, соответственно, релятивистское, гравитационное и квантовое направления расширения механики, основанной на группе Галилея, а не «фундаментальные константы физики».

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# Algebraic Cube of Theoretical Physics

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1. The corners of the Cube of Theoretical Physics, which has become “an integral part of the modern physics lore” [1], “correspond to different fundamental physical theories depending on whether they factor in the *c*, *G* and *h* constants”. The “*cGh* cube” [2] (the Zelmanov cube) is a system for classifying physical theories [3, p. 17].

2. The approach developed by the author necessitates a change in the axiomatic foundations of physics [4, p.47]. In the conclusion to the methodological notes “On Galileo, Poincare, de Sitter groups, Hamilton’s biquaternions and their extensions”, which were discussed in 2022 in the *Physics-Uspekhi* journal, an algebraic (group theory) cube of theoretical physics was constructed, the corners of which are mapped to fundamental groups of spacetime transformations (or their corresponding Lie algebras).

3. Of note are the following features of the group theory cube of theoretical physics: 1) the *G*-theory considered by the author differs from the Newtonian theory [5]; 2) the *cG*-corner of the cube is mapped to a conformal group, which implies constructing a relativistic gravitation theory that differs from General Relativity (GR) [4, p. 153]; 3) mapping *cGh*-corner of the *cGh*-cube to a 16-parameters extended conformal group ([6] deals with its non-relativistic analogue) necessitates abandoning “traditional approaches to gravitation theory and quantum theory” but the physics community believes that “the time to do that hasn’t come yet” [3, p. 240]. Here symbols c, G and h stand for relativistic, gravitational, and quantum extensions of the mechanical theory based on the Galileo group, respectively, rather than the “universal physical constants”.

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## The Secret of Planets' Perihelion between Newton and Einstein

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It is shown that, contrary to a longstanding conviction older than 160 years, the advance of Mercury's orbit can be achieved in Newtonian gravity with a very high precision by correctly analysing the situation without neglecting Mercury's mass. General relativity remains more precise than Newtonian physics, but Newtonian framework is more powerful than re-searchers and astronomers were thinking till now, at least for the case of Mercury. The Newtonian formula of the advance of planets' orbits breaks down for the other planets. The predicted Newtonian result is indeed too large for Venus and Earth. Therefore, it is also shown that corrections due to gravitational and rotational time dilation, in an inter-mediate framework which analyzes gravity between Newton and Einstein, solve the problem. By adding such corrections, a result consistent with the one of general relativity is indeed obtained. Thus, the most important results of this Lecture are two: i) It is not correct that Newtonian theory cannot predict the anomalous rate of advance of planets' orbits. The real problem is instead that a pure Newtonian prediction is too large. ii) Advance of planets' orbits can be achieved with the same precision of general relativity by extending Newtonian gravity through the inclusion of gravitational and rotational time dilation effects. This second result is in agreement with a couple of recent and interesting papers of Hansen, Hartong and Obers. Differently from such papers, in the present Lecture the importance of rotational time dilation is also highlighted. Finally, it is important to stress that a better understanding of gravitational effects in an intermediate framework between Newtonian theory and general relativity, which is one of the goals of this Lecture, could, in principle, be crucial for a subsequent better understanding of the famous Dark Matter and Dark Energy problems. This Lecture arises from the research paper C. Corda, Physics of the Dark Universe 32 (2021) 100834.

## Modelling of Compact Objects in Support of Observational Data by Exploring the Intrinsic Connection between the Equation of State Parameter and Tidal Love Number

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The tidal deformability became a new probe to detect the interior structure and properties of neutron stars after the gravitational wave of binary compact stars mergers has been measured by the LIGO and Virgo Collaborations. This physical quantity in theoretical calculation is strongly dependent the equation of the state of the neutron star. Tidal deformability measures the deformation of one member of a binary in the gravitational field of its companion and is completely quantified by the tidal Love number (TLN). In the study of the compact object, at the extreme condition a proper understanding of pressure and density relation i.e., equation of state (EoS) is not known properly. The estimation of the TLN [1, 2] of a compact star is used to constrain the EoS of a neutron star. In this paper, we developed a new model corresponding to a compact star with anisotropic stresses inside the matter distribution. By assuming a particular metric potential and a linear EoS we solved the field equations. The exterior solution is assumed as the Schwarzschild metric and is joined with the interior metric obtained across the boundary of the star. These matching of the metrics along with the condition of the zero radial pressure at the boundary lead us to determine the model parameters. The model is shown to follow all the regularity, causality and stability conditions. Particularly, the current estimated data of pulsar 4U 608-52 [3] has been shown to fits all the physical parameters and is in good agreement with the model. We further show the intrinsic connection between the equation of state parameter and TLN. We have shown that the TLN decreases with the increase of EoS parameter which in turn constrains the compactness of the compact object. Also for different values of EoS parameter the variation of TLN with compactness has been shown graphically. TLN increases gradually with increase of compactness (C) up to a certain value of C and then decreases with further increase of C. Our results also confirms that for $C = 0.5$ which is the black hole limit, TLN goes to zero. We have shown that the upper bound on C is different for different EOS parameter ($\alpha$) and is increases with increase of $\alpha$.

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## Спины сверхмассивных черных дыр

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Форма изображения черной дыры, видимая удаленным наблюдателем, зависит от распределения светящегося вещества вокруг черной дыры. Есть две астрофизические возможности: (1) яркий стационарный фон позади черной дыры (излучение фотонов вне фотонных сфер); в этом случае наблюдается классическая тень черной дыры, которая является сечением захвата фотонов в гравитационном поле черной дыры; (2) яркий аккреционный поток вблизи горизонта событий черной дыры (излучение фотонов внутри фотонных сфер); в этом случае наблюдается тень самого горизонта событий черной дыры, которая является линзированным изображением глобуса горизонта событий.

Эта тень горизонта событий проектируется на небесной сфере внутри возможного положения классической тени черной дыры, которая не видна в случае M87* и SgrA*. Существование горячего аккреционного потока вблизи горизонта событий черной дыры предсказывается механизмом Блэндфорда-Знайека, который подтверждается обще-релятивистскими МГД симуляциями на наиболее мощных суперкомпьютерах. Важной особенностью механизма Блэндфорда — Знайека является существование электрического тока, проходящего через черную дыру и сильно нагревающего аккреционный диск вблизи горизонта событий черной дыры. Этот нагрев обеспечивает основной вклад в излучение аккрецирующей черной дыры. Следует отметить, что светимость такого аккреционного диска на много порядков превышает соответствующую светимость стационарного астрофизического фона позади черной дыры. Темное пятно в центре изображения черной дыры в механизме Блэндфорда — Знайека является линзированным изображением глобуса горизонта событий черной дыры.

С помощью будущих наблюдений на Космической обсерватории Миллиметрон можно будет реконструировать формы темных пятен на изображениях сверхмассивных черных дыр SgrA* и M87*, используя модель геометрически тонкого акреционного диска, подсвечивающего черную дыру вблизи ее горизонта событий. Такая реконструкция позволит, в частности, определить спины этих сверхмассивных черных дыр.

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## Spins of Supermassive Black Holes

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Shapes of black hole images, viewed by a distant observer, depend on the distribution of emitting matter around black holes. There are two distinctive astrophysical cases: (1) Luminous stationary background behind the black hole (emission of photons outside the photon spheres). In this case the dark classical black hole shadow is viewed, which is a capture photon cross-section in the black hole gravitational field. (2) Luminous accretion inflow near the black hole event horizon (emission of photons inside the photon spheres). In this case the dark event horizon shadow is viewed, which is a lensed image of the event horizon globe. This event horizon shadow is projected at the celestial sky within the possible position of the classical black hole shadow.

The existence of hot accreting matter in the vicinity of black hole event horizons is predicted by the Blandford-Znajek mechanism, which is confirmed by recent General Relativistic MHD numerical simulations at the most powerful supercomputers. The basic feature of the Blandford — Znajek mechanism is the existing of electric current embracing the black hole and heating the accretion disk very near the black hole event horizon providing the main contribution to the black hole luminosity. This luminosity exceeds in many orders the corresponding luminosity from the stationary background behind the black hole. A dark spot at the black hole image in the Blandford — Znajek mechanism is a lensed image of the event horizon globe.

It would be possible to reconstruct the dark spot forms at the images of supermassive black holes SgrA* and M87* with the Millimetron Space Observatory, by using the model of geometrically thin accretion disk highlighting black hole in the vicinity of its event horizon. This reconstruction also provides the possibility for spin determinations of these supermassive black holes.

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## Dynamical Systems Analysis in *f(T*, φ) Gravity

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Teleparallel-based cosmological models provide a description of gravity in which torsion is mediator of gravitation. Several extensions have been made within the so-called Teleparallel equivalent of general relativity which is equivalent to general relativity at the level of the equations of motion where attempts are made to study the extensions of this form of gravity and to describe more general functions of the torsion scalar T. One of these extensions is f(T, φ) gravity; T and φ respectively denote the torsion scalar and scalar field. In this work, the dynamical system analysis has been performed for this class of theories to obtain the cosmological behavior of a number of models. Two models are presented here with some functional form of the torsion scalar and the critical points are obtained. For each critical point, the stability behavior and the corresponding cosmology are shown. Through the graphical representation, the equation of state parameters and the density parameters for matter-dominated, radiation-dominated and dark energy phases are also presented for both the models.

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## Аксионное расширение эфирной теории Эйнштейна — Дирака

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В рамках аксионного расширения эфирной теории Эйнштейна — Дирака в данной работе рассмотрен квартет самодействующих космических полей, который включает динамический эфир, представленный единичным времениподобным векторным полем, аксионную темную материю, описываемую псевдоскалярным полем, спинорное поле, ассоциированное со спинорными частицами и гравитационное поле.

Модифицированный периодический потенциал псевдоскалярного (аксионного поля) построен на основе управляющей функции, зависящей от одного инварианта, одного псевдоинварианта и двух кросс-инвариантов, включающих спинорное и векторное поля.

Полная система основных уравнений, относящихся к этой модели, решена для случая изотропной, однородной космологической модели; найдены точные решения для управляющей функции для различного набора управляющих параметров.

Получено выражение для эффективной массы спинорных частиц, взаимодействующих с аксионной темной материей и динамическим эфиром.

Рассмотрены осцилляции эффективной массы спинорных частиц, индуцированные аксионной темной материей в присутствии динамического эфира.

В работе были подтверждены следующие положения:

• Космическое спинорное поле влияет на состояние аксионной темной материи через управляющую функцию (аргумент периодического потенциала аксионного поля), которая является зависящим от времени аналогом аналогом вакуумного среднего значения псевдоскалярного поля.

• Спинорные частицы (массивные и безмассовые) приобретают эффективные массы за счет взаимодействия с аксионной темной материей; вариации этой эффективной массы предопределяются динамикой расширения Вселенной.

• Эффективная масса спинорного поля пропорциональна квадрату аксионной массы, обратно пропорциональна квадрату константы аксион-фотонного взаимодействия, зависит от космологического времени, и подвергается колебаниям с частотой пропорциональной аксионной массе.

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## Axionic Extension of Einstein-Dirac-Aether Theory

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Within the framework of the axion extension of the Einstein-Dirac ether theory, this paper considers a quartet of self-acting cosmic fields, which includes a dynamic ether represented by a unit timelike vector field, axion dark matter described by a pseudoscalar field, a spinor field associated with spinor particles and a gravitational field.

The modified periodic potential of the pseudoscalar (axion) field is built on the basis of a control function that depends on one invariant, one pseudo-invariant and two cross-invariants, including the spinor and vector fields.

The complete system of basic equations related to this model is solved for the case of an isotropic, homogeneous cosmological model; found exact solutions for the control function for a different set of control parameters

An expression is obtained for the effective mass of spinor particles interacting with axion dark matter and dynamic ether.

Oscillations of the effective mass of spinor particles induced by axion dark matter in the presence of a dynamic ether are considered.

The following points were confirmed in the work:

• The cosmic spinor field influences the state of the axion dark matter through the control function (argument of the periodic potential of the axion field), which is a time-dependent analogue of the analogue of the vacuum mean value of the pseudoscalar field.

• Spinor particles (massive and massless) acquire effective masses due to interaction with axion dark matter; variations of this effective mass are predetermined by the dynamics of the expansion of the Universe.

• The effective mass of the spinor field is proportional to the square of the axion mass, inversely proportional to the square of the axion-photon coupling constant, depends on cosmological time, and oscillates at a frequency proportional to the axion mass.

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# О сохраняющихся величинах для движущейся черной дыры в телепараллельном эквиваленте ОТО

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В [1, 2] разработан формализм для построения сохраняющихся величин в телепараллельном эквиваленте ОТО, где динамическими переменными являются компоненты тетрад. Сохраняющиеся токи и суперпотенциалы как координатно ковариантны, так и инвариантны относительно локальных лоренцевых вращений тетрад, что в тензорной форме было сделано впервые. Это преимущество достигнуто благодаря введению инерциальной спиновой связности (ИСС) и использованию теоремы Нетер. Поскольку ИСС — это не внутренняя величина теории, она определяется благодаря специальному принципу «выключения гравитации». Оказалось [2], что даже использование этого разумного принципа приводит к различным определениям ИСС, для тех же тетрад, что ведет к различным результатам. Пары ИСС и тетрад, не связанных гладкими преобразованиями, называют калибровками. Эти неопределенности изучены в [2] для черной дыры Шварцшильда (ЧДШ).

Цель настоящего исследования — это анализ упомянутых преимуществ нового формализма и его проблем на примере движущейся ЧДШ. Мы объединяем результаты наших статей [3].

Движущаяся ЧДШ соответствует статической ЧДШ, которая с постоянной скоростью движется относительно удаленных наблюдателей. Сначала мы демонстрируем возможности нового формализма. В расчетах, используя аналогии с движущимся материальным шаром в пространстве Минковского и только «статическую» калибровку, получаем ожидаемые массу и импульс. Затем изучаем проблему двусмысленности, связанную с различным определением калибровок. Сравниваем «статическую» и «движущуюся» калибровки. Оказалось, они совпадают! Таким образом, ожидаемой двусмысленности нет, и в обоих случаях получены те же масса и импульс. Единая калибровка в [3] сравнивается с введенными ранее [1, 2].

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## On Conserved Quantities for a Moving Black Hole in TEGR

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In [1, 2], an approach for constructing conserved quantities in Teleparallel Equivalent of General Relativity (TEGR) where dynamical variables are tetrad components has been developed. Conserved currents and superpotentials are both coordinate covariant and invariant with respect to local Lorentz rotations of tetrads that, in the tensorial formulation, is original. This advantage is achieved owing to introducing an inertial spin connection (ISC) and applying the Noether theorem. Because ISC is not an inner quantity in the theory it is determined by a special "turning off gravity" principle. However, it turns out [2] that even with using this reasonable principle one obtains different definitions of ISC related to the same tetrad that leads to different results. Pairs of concrete ISCs and tetrads not connected by smooth transformations are named as gauges. Namely these ambiguities have been studied in [2] on the example of the Schwarzschild black hole (SBH).

The main goal of the present research is analyzing aforementioned advantages of the new formalism and its problems on the example of the moving SBH. We unite the results of our papers [3].

Solution for a moving SBH is derived from the static SBH that moves with a constant velocity with respect to distant static observers. First, we demonstrate possibilities of the double covariant formalism. In calculations, we use analogies with a moving matter ball in Minkowski space, the only one "static gauge". In the result we obtain quite acceptable mass and momentum for the system. Second, we check the problem of an ambiguity in constructing conserved quantities that follows from different definitions of gauges. We have analyzed two gauges "static" and "moving" ones. For the model under consideration, we have shown that such gauges coincide. Thus, in this a concrete case, we avoid an ambiguity in calculations supporting the remarked above mass and momentum values. The unique found gauge [3] is compared with previous ones introduced in [1, 2].

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## On the Time Problem in Quantum Cosmology

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The four-dimensional space-time is split into time and a three-dimensional space of instantaneous configurations, forming a superspace of 3-geometries in quantum cosmology, whereas its classical limit describes the Universe's time evolution. Therein lies the time problem in quantum cosmology, which was considered by philosophers, mainly on the level of interpretations [1, 2].

Consider this problem in the framework of quantum geometrodynamics. Wheeler — DeWitt's equation in the scale factor minisuperspace is of the form:

$$\frac{d^2\psi}{da^2} - V(a)\psi = 0,$$

where

$$V(a) = \frac{1}{l_{pl}^4}\left(ka^2 - \frac{8\pi G\varepsilon a^4}{3c^4}\right).$$

The WKB wave function $\sim e^{iS/\hbar}$, where the action $S = \hbar\int\sqrt{-V}\,da$. On the other hand, $S = -m_{pl}c^2 l_{pl}^3 \int \frac{Vdt}{a}$,, where $t$ is a synchronous time. Hence

$$t = \frac{\hbar}{cl_{pl}^2}\int\frac{ada}{dS/da}.$$

Since the synchronous time is defined by the phase of the WKB wave function, the classical world proves to be programmed on a quantum level [3]. The dependences for the Universe's wave function phase is related to those for the scale factor time dependence, e.g. $a(t) = r_0 e^{ct/r_0}$ and $S = \frac{\hbar a^3}{3r_0 l_{pl}^2}$ for de Sitter's vacuum; $a(t) = r_0\sqrt{\frac{2ct}{r_0}}$ and $S = \frac{\hbar r_0 a}{l_{pl}^2}$ for radiation.

The Universe's birth, as a result of a quantum fluctuation [4], is interpreted as a tunnelling of the planckeon through a potential barrier, under which time is imaginary.

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# Инфляционные модели на основе обобщенных точных космологических решений

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Рассматриваются модели космологической инфляции ранней вселенной со скалярным полем, основанные на гравитации Эйнштейна в пространственно плоской вселенной Фридмана [1, 2]. Предложено следующее представление уравнений космологической динамики (уравнений Эйнштейна — Фридмана), упрощающее процедуру построения обобщенных точных космологических решений

$$V\left(\varphi(t)\right) = 3H^2 + \dot{H};$$

$$\varphi(t) = \pm A \ln\left[\frac{E\dot{\sigma}}{\left(C\sigma(t)+F\right)^2}\right] \mp ABt + \varphi_0;$$

$$H(t) = A^2 \ln\left[\frac{u^{K/2}(t)\dot{\sigma}^B}{\left(C\sigma(t)+F\right)^{2B}}\right] + \frac{2A^2C\dot{\sigma}}{C\sigma(t)+F} - \frac{A^2B^2}{2}t + \lambda,$$

где функции $\sigma = \sigma(t)$ и $u = u(t)$ связаны уравнением

$$\left(\frac{\ddot{\sigma}}{\dot{\sigma}}\right)^2 + K\frac{\dot{u}}{u} = 0, \quad \sigma \neq \text{const},$$

и точка означает производную по космическому времени $\dot{\sigma} = d\sigma/dt$.

Представлены различные классы точных решений уравнений космологической динамики, для различного вида функции $\sigma = \sigma(t)$. Также рассматриваются критерии верификации полученных космологических моделей, как на уровне фоновой динамики, так и по наблюдательным ограничениям на параметры космологических возмущений.

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# Inflationary Models Based on the Generalized Exact Cosmological Solutions

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Models of cosmological inflation of the early universe with a scalar field based on Einstein's gravity in a spatially flat Friedmann universe are considered [1, 2]. The following representation of the equations of cosmological dynamics (the Einstein-Friedman equations) is proposed, which simplifies the procedure for constructing generalized exact cosmological solutions

$$V\left(\varphi(t)\right)=3H^2+\dot{H};$$

$$\varphi(t)=\pm A\ln\left[\frac{E\dot{\sigma}}{\left(C\sigma(t)+F\right)^2}\right]\mp ABt+\varphi_0;$$

$$H(t)=A^2\ln\left[\frac{u^{K/2}(t)\dot{\sigma}^B}{\left(C\sigma(t)+F\right)^{2B}}\right]+\frac{2A^2C\dot{\sigma}}{C\sigma(t)+F}-\frac{A^2B^2}{2}t+\lambda,$$

where functions $\sigma=\sigma(t)$ and $u=u(t)$ are related by equation

$$\left(\frac{\ddot{\sigma}}{\dot{\sigma}}\right)^2+K\frac{\dot{u}}{u}=0,\quad \sigma\neq\text{const},$$

and the dot means the derivative with respect to cosmic time $\dot{\sigma}=d\sigma/dt$.

Different classes of exact solutions of the equations of cosmological dynamics are presented for various types of function $\sigma=\sigma(t)$. The criteria for verification of the obtained cosmological models are also considered, both at the level of background dynamics and in terms of observational restrictions on the parameters of cosmological perturbations.

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## Time-Frequency Gravitational Wave Data Analysis

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Time-frequency (TF) representations are aimed at displaying the time-dependent spectral (frequency) energy content of a waveform, and are therefore highly suited for dealing with non-stationary signals. Such representations include the short-time Fourier, Wavelet, Gabor, Wigner-Ville, Bertrand and Hilbert-Huang transform, and generalizations thereof, each with its own strong and weak features.

Non-stationary signals, e.g., the inspiral and merger gravitational waveforms produced by inspiraling/coalescing binary systems (BCS) and the non-stationary transient disturbances of environmental/instrumental origin affecting interferometric detectors, are of key relevance to gravitational wave data analysis. Despite its potential, a clever use of TF techniques has been rather limited so far in mainstream gravitational wave data analysis (GWDA).

We shall briefly review the key properties of available TF representations relevant to GWDA, and discuss possible improvements, with special emphasis on the compressed-sensing paradigm [1].

Specific applications of TF representations to BCS waveforms, including the simultaneous estimation of orbital eccentricity and chirp mass [2], the estimation of the wave direction of arrival in a network of three (or more) detectors [3], and the study of noise transients [4] will be reviewed.

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## Anisotropic Cosmological Models with Non-Minimal Derivative Coupling

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Due to detailed analysis of Cosmic Microwave Background (CMB) it is known that CMB is anisotropic. This observation allows us to assume that our universe was anisotropic on early stages of evolution. In this study, we consider cosmological models with non-minimal derivative coupling in anisotropic space background. We are focusing on analysis of Bianchi I, V, IX models in Bianchi classification, that allows us to study the influence of anisotropy on early and late stages of universe evolution. As a result, with numerical modeling we get inflation stage in all three models of Bianchi-type I, V, IX and isotropisation of universe at late stage of evolution.

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## New Tetrads in Geometrodynamics and their Applications in Quantum Theories and Astrophysics

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A new technique is presented in order to build tetrads in a four-dimensional Minkowski-Maxwell spacetime or even Einstein — Maxwell spacetime. These tetrads have special useful properties in general relativity, astrophysics, quantum theories and also particle physics [1, 2].

A new fundamental result is proved in group theory. The group $U(1)$ (electromagnetic gauge transformations) is isomorphic to the group $SO(1,1)\times Z_2 \times Z_2 \,|\oplus|\, \{light\,|\,cone\,|\,gauge\}$ where the light cone gauge includes the four solutions to the differential equations in the local future and past light cones established in manuscripts [3–7]. The first $Z_2$ is given by $\{I_{2\times 2}, -I_{2\times 2}\}$ and the second $Z_2$ is given by $\{I_{2\times 2}, \text{the swap}|(01|10)\}$. One of these discrete transformations is the full inversion or minus the identity two by two. It is a Lorentz transformation and we designated this discrete transformation above by the notation, $-I_{2\times 2}$. The other discrete transformation is given by $\Lambda^{o}_{\;\|o}=0$, $\Lambda^{o}_{\;\|1}=1$, $\Lambda^{1}_{\;\|o}=1$, $\Lambda^{1}_{\;\|1}=0$, which is not a Lorentz transformation because it is a reflection [3]. We designated this discrete transformation above by the notation, $\text{the swap}|(01|10)$.

The electromagnetic local gauge group is proved to be isomorphic to the local group of transformations of these particular kind of tetrads. Therefore, establishing a concrete link between internal and spacetime local groups of transformations. These new tetrads also diagonalize the electromagnetic stress-energy tensor for non-null electromagnetic fields, any stress-energy tensor, in a general, covariant and local way. These new tetrads also introduce maximum simplification in the Einstein — Maxwell differential equations, and introduce maximum simplification in the expression of the electromagnetic field itself, in any curved four-dimensional Lorentzian spacetime, allowing for the identification of its degrees of freedom in two local scalars. These tetrads enable the link with new proposed experiments using the Aharonov — Bohm effect in order to change the causality of spacetime [8, 9]. For example in order to induce full inversions as explained above. We will explain these proposed experiments. These tetrads introduce simplification in spacetime evolution algorithms, specially in relativistic astrophysics problems related, for example, to neutron stars [10–15], etc.

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# Анизотропные и неоднородные космологические модели в скалярно-тензорной теории гравитации с неминимальной кинетической связью

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Исходя из наблюдаемых фактов, хорошо известно, что на данный момент Вселенная является однородной и изотропной. Однако не существует данных, из которых бы следовало, что так было изначально. В связи с этим можно задаться следующим вопросом: могла ли Вселенная быть изначально неоднородной и анизотропной? В своих исследованиях мы изучаем механизм перехода Вселенной из неоднородной фазы в однородную в рамках скалярно-тензорной теории гравитации[1], в которой скалярное поле имеет неминимальную кинетическую связь с кривизной [2, 3]. В качестве модели неоднородной анизотропной вселенной мы рассматриваем пространство-время, которое описывается поляризованной метрикой Гауди с топологией тора [4, 5]. В рамках этой модели нами выписана полная система полевых уравнений и проведен детальный анализ полевых уравнений для случая с минимальной связью.

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# Anisotropic and Heterogeneous Cosmological Models in the Scalar-Tensor Theory of Gravitation with a Non-Minimal Kinetic Coupling

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At the moment the Universe is known to be homogeneous and isotropic, as supported by the facts observed. However, there is no evidence that this was the case originally. In this regard, we may pose the following question: might the Universe have been heterogeneous and anisotropic initially? In our research, we study the mechanism behind the Universe transitioning between its heterogeneous and homogeneous stages within the framework of the scalar-tensor theory of gravitation [1], in which the scalar field shows a non-minimal kinetic coupling with curvature [2, 3]. We model a heterogeneous anisotropic universe as a space-time described by the polarized Gaudi metric with a toroidal topology [4, 5]. Within this model, we formed a complete system of field equations and conducted a detailed analysis of field equations for the case of minimal coupling.

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## Magnon — Antimagnon Production on Magnetic Field Inhomogeneities

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Magnons, or quantized spin waves occur in various types of ordered magnets. They present collective excitations of the electron spin structure in a crystal lattice. Using magnons as information carriers has various advantages, in particular, the low power-consumption. Althoughspin systems are originally described as lattice models, similar to Dirac models of nanostructures,one can describe low-energy dynamics of the spin systems based on a continuum field theory at energy scales much lower than the inverse lattice spacing. In various publications an effective fieldtheoretical description (EFTD) of the dynamics of the spin systems at low energies in the presence of some external fields was developed. The magnon spin current can be modified (in particular, amplified) by placing magnets in appropriate external magnetic fields. In terms of the EFTD it is important to take into account the vacuum instability (the Schwinger effect) under the magnon- antimagnon production on magnetic field inhomogeneities (an analog of particle-antiparticle creation by constant inhomogeneous electric-like fields). In the case of an inhomogeneousmagnetic field applied to the antiferromagnet in the collinear (homogeneous) ground state, the EFTD corresponds to strong-field QED of a charged scalar field interacting with an electric potential step. Magnetic moment plays here the role of the electric charge, and magnons and antimagnos differ from each other in the sign of the magnetic moment. In this way, magnon- antimagnon pair production is technically reduced to the problem of charged-particle creation fromthe vacuum by an electric potential step. Problems of such kind in strong-field QED were recentlyconsidered by us for different types of potential steps. In the present work we use these results to study the magnon-antimagnon pair production on magnetic field inhomogeneities. We consider the number of magnetic steps that allows exact solving the corresponding Klein-Gordon equation and apply these solutions calculating pertinent physical quantities. We find and analyze vacuum fluxes of energy and magnetic moments of created magnons.

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## Запутывание фотонов заряженной средой и внешним магнитным полем

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Рассмотрена модель описания КЭД-системы, состоящей из фотонного пучка, взаимодействующего с квантованными заряженными бесспиновыми частицами. Мы ограничимся фотонным пучком, состоящим из фотонов с двумя разными импульсами, движущимися в одном направлении. Фотоны в каждый момент времени могут иметь две возможные линейные поляризации. Точные решения соответствуют двум независимым подсистемам, одна из которых соответствует электронной среде, а другая описывается векторами в фотонном гильбертовом подпространстве и представляет собой совокупность некоторых квазифотонов, не взаимодействующих друг с другом. Кроме того, найдено точное решение модели, соответствующее той же системе, помещенной в постоянное магнитное поле. В качестве примера возможных приложений используются решения модели расчета запутывания фотонного пучка квантованной электронной средой и постоянным магнитным полем. Таким образом, мы вычисляем меры запутанности (информационную и шмидтовскую) фотонного пучка в зависимости от приложенного магнитного поля и параметров электронной среды.

# Photon Entanglement by Charged Medium and External Magnetic Field

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We consider a model for describing a QED system consisting of a photon beam interacting with quantized charged spin less particles. We restrict ourselves by a photon beam that consists of photons with two different moments moving in the same direction. Photons with each moment may have two possible linear polarizations. The exact solutions correspond to two independent subsystems, one of which corresponds to the electron medium and another one is described by vectors in the photon Hilbert subspace and is representing a set of some quasi-photons that do not interact with each other. In addition, we find exact solution of the model that corresponds to the same system placed in a constant magnetic field. As an example, of possible applications, we use the solutions of the model for calculating entanglement of the photon beam by quantized electron medium and by a constant magnetic field. Thus, we calculate the entanglement measures (the information and the Schmidt ones) of the photon beam as functions of the applied magnetic field and parameters of the electron medium.

# О детектировании высокочастотных реликтовых гравитационных волн

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Рассматривается специфика спектра реликтовых гравитационных волн, образованных на инфляционной и постинфляционной стадиях эволюции ранней вселенной для космологических моделей, основанных на модифицированных теориях гравитации по отношению к случаю стандартных инфляционных моделей, основанных на гравитации Эйнштейна [1, 2]. Рассматривается возможность детектирования высокочастотных реликтовых гравитационных волн посредством использования процесса конверсии гравитонов в фотоны в постоянном и переменном магнитном поле [3]. Чувствительность детекторов данного типа сопоставляется с чувствительностью других существующих и перспективных детекторов высокочастотных гравитационных волн [4]. На основе анализа оценки чувствительности различных типов детекторов высокочастотных гравитационных волн сделан вывод о перспективах непосредственной верификации моделей космологической инфляции с помощью гравитационно-волновых детекторов.

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## Inflationary Models based on the Generalized Exact Cosmological Solutions

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The specificity of the spectrum of relic gravitational waves formed at the inflationary and post-inflationary stages of the evolution of the early universe is considered for cosmological models based on modified theories of gravity in relation to the case of standard inflationary models based on Einstein's gravity [1, 2]. The possibility of detecting high-frequency relic gravitational waves by using the process of converting gravitons into photons in a constant and alternating magnetic field is considered [3]. The sensitivity of detectors of this type is compared with the sensitivity of other existing and prospective detectors of high-frequency gravitational waves [4]. Based on the analysis of the sensitivity assessment of various types of high-frequency gravitational wave detectors, a conclusion is made about the prospects for direct verification of cosmological inflation models using gravitational-wave detectors.

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## Процессы конверсии гравитационных и электромагнитных волн и возможность их реализации в земных условиях

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Обнаружение гравитационных волн является одной из важнейших задач современности, представляющей несомненный интерес как с фундаментальной точки зрения, так и для дальнейших многочисленных приложений. Интерес к решению этой проблемы существенно возрос после непосредственного обнаружения гравитационных волн в 2016 году. Для непосредственной регистрации гравитационного излучения, испускаемого астрофизическим объектом, в настоящее время используется лазерный интерферометр со свободно подвешенными зеркалами, играющими роль осциллирующих масс, на которые действуют силы, порождаемые гравитационными волнами.

В связи с появлением современных мощных лазеров, развитием прецизионной оптики появляется возможность для разработки схем экспериментов по наблюдению гравитационно-электромагнитной конверсии в земных условиях.

Разработана схема генерации гравитационных волн в лабораторных условиях, использующая в качестве источника низкочастотных гравитационных волн систему нескольких стоячих электромагнитных волн в электромагнитных резонаторах. Для оценки эффективности предложенного метода генерирования гравитационных волн рассмотрены методы сопоставления характеристик гравитационных волн, связанных с электромагнитным полем внутри резонатора, и гравитационных волн в пустом пространстве.

Проведен анализ различных типов существующих и перспективных детекторов низкочастотных гравитационных волн, получена оценка характеристик источника, необходимых для успешного детектирования гравитационных волн, генерируемых посредством данного метода с учетом диапазона частот, соответствующего оптимальной чувствительности детекторов.

# Processes of Gravitational and Electromagnetic Wave Conversion and the Possibility of Implementing them in Terrestrial Conditions

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Detection of gravitational waves is one of the most important contemporary problems, doubtlessly of interest both for fundamental research and multiple potential applications. Direct detection of gravitational waves in 2016 led to an even deeper interest in this problem. At present, to directly record the gravitational radiation emitted by an astrophysical object, it is customary to use a laser interferometer with floating mirrors that act as oscillating masses affected by the forces generated by the gravitational waves.

The emergence of modern powerful lasers and advances in precision optics make it possible to design experiments in observing gravitational-to-electromagnetic conversion in terrestrial conditions.

We developed an arrangement for generating gravitational waves in laboratory conditions, using a system of several standing electromagnetic waves in electromagnetic resonators as a source of low-frequency gravitational waves. To assess the efficiency of the gravitational wave generation method proposed, the paper considers methods of comparing the characteristics of gravitational waves associated with the electromagnetic field inside the resonator to those of gravitational waves in empty space.

We analysed various types of existing and prospective low-frequency gravitational wave detectors and assessed the source characteristics required to successfully detect gravitational waves generated by this method, taking into account the frequency range corresponding to the optimal detector sensitivity.

# Использование реликтового излучения для построения новой системы навигации

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Одним из перспективных направлений в области развития современных систем ориентации и навигации космических аппаратов является использование анизотропии космического реликтового электромагнитного излучения в качестве навигационного поля. Реликтовое излучение является одним из наиболее стабильных полей во Вселенной. Спектр реликтового излучения соответствует спектру излучения абсолютно черного тела с температурой 2,725 K. Его максимум приходится на частоту 160,2 ГГц, что соответствует длине волны 1,9 мм. Для определения параметров движения в пространстве можно использовать естественную анизотропию частоты фонового электромагнитного излучения Вселенной, а также анизотропию, появляющуюся вследствие движения космического аппарата. Локальная дипольная анизотропия реликтового излучения возникает за счет эффекта Доплера, возникающего при движении Солнечной системы относительно реликтового фона со скоростью примерно 370 км/с в сторону созвездия Льва.

Исследована возможность создания новой перспективной системы автономной навигации космических аппаратов на основе детектирования реликтового излучения. В результате выполненных аналитических и численных оценок и экспериментальных исследований сделан вывод о возможности создания перспективной, нетрадиционной системы автономной навигации в миллиметровом диапазоне длин волн.

Стабильность, непрерывность и неповторимость распределения реликтового излучения по небесной сфере позволяет построить систему навигации с привязкой к любой удобной области небесной сферы, так как не требуется сканирование в широком диапазоне углов, нет ограничений, накладываемыми мощными астрономическими источниками электромагнитного излучения (Солнце, Луна).

## Using the Cosmic Microwave Background Radiation to Develop a Novel Navigation System

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As far as development of advanced spacecraft attitude control and navigation systems is concerned, one of the most promising avenues is using the anisotropy of cosmic microwave background radiation as a navigation field. Cosmic microwave background radiation (CMBR) is one of the most stable fields in the universe. The CMBR spectrum is that of an ideal blackbody at a temperature of 2725 K. It peaks at a frequency of 160.2 GHz, which corresponds to a wavelength of 1.9 mm. To determine the parameters of motion in space, it is possible to use the natural anisotropy of the CMBR frequency, as well as the anisotropy resulting from the movement of the spacecraft. Local dipole anisotropy occurs in the CMBR due to the Doppler effect stemming from the solar system motion relative to the CMBR at a speed of about 370 km/s towards the Leo constellation.

The paper investigates the possibility of developing a promising novel autonomous spacecraft navigation system based on CMBR detection. Our analytical and numerical assessments and experimental studies enable us to conclude that it should be possible to develop a promising, unconventional autonomous navigation system in the millimeter wavelength range.

The stability, continuity and uniqueness of the CMBR distribution over the celestial sphere ensures that a navigation system using any convenient area of the celestial sphere as reference may be constructed, as neither is there a requirement for scanning in a wide range of angles, nor are there any restrictions imposed by powerful astronomical electromagnetic radiation sources such as the Sun or the Moon.

# Фазовые переходы элементарных частиц в окрестности горизонта черных дыр

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Исследование столкновений частиц в окрестности вращающихся черных дыр [1, 2] показало, что можно говорить о существовании в природе естественного суперколлайдера с энергиями столкновений, значительно превышающими достижимые на современных ускорителях частиц. Возникновение кварк-глюонной плазмы в таких столкновениях должно иметь следствием появление очень высоких температур. В [3] показано, что вблизи горизонта вращающихся черных дыр возможны температуры порядка температуры фазовых переходов (кварк-глюонного и электрослабого) в стандартной модели элементарных частиц. Такие температуры могут быть достигнуты вблизи вращающихся черных дыр (в их эргосфере) при многократных столкновениях. Для экстремально вращающихся черных дыр эффект возможен при однократных столкновениях частиц, а также при столкновениях макротел, в условиях резонанса Банадоса — Силка — Веста [1]. Даны численные оценки параметра расстояния от горизонта, а также испускаемого при столкновении частиц гравитационного и электромагнитного излучений. Даны оценки обратного влияния возникающей при фазовом переходе плотности энергии-импульса на метрику пространства-времени.

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# Phase Transfers in Elementary Particle Physics in the Vicinity of Black Hole Horizon

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A study of particle collisions in the vicinity of rotating black holes [1, 2] showed that we can talk about the existence of a natural supercollider with collision energies significantly higher than those achievable in modern particle accelerators. The quark-gluon plasma produced in such collisions should have very high temperatures. It was shown in [3] that near the horizon of rotating black holes, temperatures of the order of the temperature of phase transitions (quark-gluon and electro-weak) of the standard model of the elementary particles physics are possible. Such temperatures can be reached near rotating black holes (in their ergosphere) in multiple collisions. For extremely rotating black holes, the effect is possible with one-fold particle collisions, as well as with collisions of macroscopic bodies, under Banados-Silk-West resonance conditions [1]. The distance from the horizon and gravitational and electromagnetic radiation emitted in collisions between particles have been numerically estimated. The estimates of the inverse effect of the energy-momentum density arising at the phase transition on the space-time metric are given.

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## Аксионный дион в нелинейной электродинамике

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Аксион — гипотетический псевдоголдстоуновский бозон, который является одним из наиболее перспективных кандидатов на роль частицы — «составной части» темной материи.

Характерной особенностью аксионов является модификация классических уравнений электродинамики Максвелла посредством аксион-фотонного взаимодействия. Подобная модификация приводит к появлению эффектов, невозможных в классической электродинамике, причем такие эффекты начинаю проявляться уже в довольно простых системах.

Примером такой системы является аксионный дион — магнитный монополь, окруженный аксионным облаком. В результате взаимодействия аксионов с магнитным полем монополь приобретает эффективный электрический заряд.

В работе рассматривается поведение электрического и аксионного полей такой системы в рамках нелинейной электродинамики, которая, с одной стороны, удовлетворяет дискретной симметрии псевдоскалярного (аксионного) поля, с другой — $SO_2$-симеетрии, которая должна выполняться для любой, представляющейся разумной, теории электродинамики.

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## Axion Dyon in Nonlinar Elecnrodynamics

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Axion is a hypothetical pseudo-Goldstone boson, which is one of the most promising candidates for the role of a component of dark matter.

A characteristic feature of axions is the modification of the classical Maxwell's electrodynamics equations via the axion-photon coupling. Such a modification leads to the appearance of effects, that are impossible in classical electrodynamics, and such effects begin to manifest themselves already in simple electromagnetic systems.

An example of such a system is the axion dyon — magnetic monopole, which is surrounded by an axion cloud. As a result of the interaction of axions with a magnetic field, the monopole acquires an effective electric charge.

This work considers the behavior of the electric and axion fields in this system within the framework of nonlinear electrodynamics, which, on the one hand, satisfies the discrete symmetry of the pseudoscalar (axion) field, and, on the other hand, SO2 symmetry, which must be satisfied for any seemingly reasonable theory of electrodynamics.

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# Прогресс в парадигме масштабно-инвариантного вакуума (МИВ)

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Представлен обзор основных результатов в рамках идеи масштабно-инвариантного вакуума (МИВ) в связи с интегрируемой геометрией Вейля [1]. То есть основные результаты, связанные с МИВ и инфляцией [2], ростом флуктуаций плотности [3], применением МИВ к масштабно-инвариантной динамике галактик, МОНД, темной материи и карликовых сфероидалов [4], будут подытожены вместе с нашими последними результатами по изучению нуклеосинтеза Большого взрыва в рамках парадигмы МИВ. Если позволит время, будут выделены возможные связи космологии SIV с явлениями темной материи и ранней темной энергии, а также потенциальная связь результатов слабого поля МИВ с идеей ненадлежащей временной параметризации в рамках парадигмы репараметризации [5].

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# Progress within the Scale Invariant Vacuum (SIV) Paradigm

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A review of the main results within the Scale Invariant Vacuum (SIV) idea as related to Weyl Integrable Geometry will be presented [1]. That is, main results related to SIV and inflation [2], the growth of the density fluctuations [3], application of the SIV to scale-invariant dynamics of Galaxies, MOND, Dark Matter, and the Dwarf Spheroidals [4] will be summarized, along with our latest results on the study of the Big-Bang Nucleosynthesis within the SIV paradigm. If time permits, possible connections of the SIV cosmology to the Dark Matter and Early Dark Energy phenomena will be highlighted along with a potential connection of the weak field SIV results to the un-proper time parametrization idea within the reparametrization paradigm [5].

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## Generalization of the $C^3$ Matching Procedure

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To handle the case in which discontinuities are present along the matching hypersurface, in this work, we present a generalization of the $C^3$ matching procedure discussed in previous works. It demands that a solution of Einstein's equations also describe the hypersurface. We apply the Darmois and the $C^3$ matching conditions to three spherically symmetric spacetimes and compare the main results obtained by applying both procedures.

## Hubble Constant Determination Using Gravitational Waves Data from Smartphone

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Using gravitational waves data obtained from the GW Events app of a handheld smartphone we calculated the Hubble constant obtaining a value which is comparable to other methods for Hubble constant measurements.

## Shadow and Image of the Ellis — Bronnikov Wormhole

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Usually wormholes are considered as tunnels in spacetime with relatively narrow throats that connect two different regions of the same universe, or two different universes. If there are no light sources on one side of the wormhole, then an observer on the other side will not be able to see the wormhole in the usual sense of the word. However, if the wormhole is illuminated by an external source, then the observer will see its shadow, and the size of the shadow will depend on whether the wormhole is illuminated by a distant screen (classical shadow) or it is illuminated by matter falling on it (throat silhouette). The classical shadow is difficult to observe with the current state of the art, either due to the low brightness of the distant background or the extremely high accretion activity of the wormhole. In this regard, it is necessary to build an image of the silhouette of the throat of the wormhole.

In this paper, we obtain expressions for the size of the shadow and silhouette of the throat of the Ellis-Bronikov wormhole, compare them with the results for the Schwarzschild black hole, and build an image of the wormhole using a thin accretion disk model.

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# Имитация извлечения кинетической энергии у вращающейся черной дыры

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В докладе рассматривается внешняя часть геометрии вращающейся черной дыры, несущей электрический заряд, которая описывается метрикой Керра — Ньюмана [1]. Метрика характеризуется наличием массы *M*, спина *a* и электрического заряда *Q*

$$ds_{KN}^2 = -\frac{\Delta}{\rho^2}\left[dt - a\sin^2\theta d\varphi\right]^2 + \frac{\sin^2\theta}{\rho^2}\left[(r^2+a^2)d\varphi - adt\right]^2 + \frac{\rho^2}{\Delta}dr^2 + \rho^2 d\theta^2,$$

где $\Delta := r^2 - r_s^2 + a^2 + r_Q^2$, $\rho^2 := r^2 + a^2\cos^2\theta$, $r_s = 2GM/c^2$ — шварцшильдовский радиус; $a = J/Mcr_S$ — удельный момент импульса; $r_Q^2 = \dfrac{kGQ^2}{c^4}$ — квадрат электромагнитного радиуса. Известны несколько механизмов возможности извлечения кинетической энергии вращающейся черной дыры. Рассматривается значимость механизмов в прикладных вопросах.

Обсуждаются экспериментальные установки, в которых происходит имитация процессов диссипации энергии во внешней части эргосферы аккрекционного диска черной дыры и результаты имитирования.

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# Simulating Extraction of Kinetic Energy from a Rotating Black Hole

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The paper examines the outer geometry of an electrically charged rotating black hole described by the Kerr — Newman metric [1]. The metric is characterized by the presence of mass $M$, spin $a$ and electric charge $Q$

$$ds_{KN}^2 = -\frac{\Delta}{\rho^2}\left[dt - a\sin^2\theta d\varphi\right]^2 + \frac{\sin^2\theta}{\rho^2}\left[(r^2 + a^2)d\varphi - adt\right]^2 + \frac{\rho^2}{\Delta}dr^2 + \rho^2 d\theta^2,$$

where $\Delta := r^2 - r_s^2 + a^2 + r_Q^2$, $\rho^2 := r^2 + a^2\cos^2\theta$, $r_s = 2GM/c^2$ is the Schwarzschild radius; $a = J/Mcr_S$ — effective angular momentum; $r_Q^2 = \frac{kGQ^2}{c^4}$ is the electromagnetic radius squared. Several potential mechanisms for extracting kinetic energy from a rotating black hole are known. The paper considers their prospective importance in applied matters and discusses experimental installations simulating the processes of energy dissipation in the outer ergosphere of the black hole accretion disk, as well as simulation results.

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## Teleparallel Scalar-Tensor Gravity through Cosmological Dynamical Systems

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Scalar-tensor theories offer the prospect of explaining the cosmological evolution of the Universe through an effective description of dark energy as a quantity with a non-trivial evolution. In this work, we investigate this feature of scalar-tensor theories in the teleparallel gravity context. Teleparallel gravity is a novel description of geometric gravity as a torsional- rather than curvature-based quantity which presents a new foundational base for gravity. Our investigation is centered on the impact of a nontrivial input from the kinetic term of the scalar field. We consider a number of model settings in the context of the dynamical system to reveal their evolutionary behavior. We determine the critical points of these systems and discuss their dynamics. The phase space trajectories are investigated which support the stability conditions occurred through the signature of the eigenvalues.

# The Algebrodynamics: in Search of the Ultimate "World" Algebraic Structure

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Principles of the so-called *algebro-dynamical approach* to the construction of a unified field theory are presented, together with the realization on the basis of the linear algebra of *complex quaternions* **B** [1, 2]. In **B**-algebrodynamics one considers primary physical fields as "hyper-holomorphic" (*HH*) functions $F(Z)$ of **B**-variable $Z$ subject to "generalized Cauchy-Riemann (*CR*) equations"

$$dF = LdZ \cdot R, \tag{1}$$

$L(Z)$, $R(Z)$ being two auxiliary **B**-functions. For a commutative algebra Eq. (1) reduces to the relation $dF = GdZ$, ($G = LR$) and, in the complex case, leads to the canonical *CR*-equations.

Any matrix component of a HH-function $F(Z)$ satisfies the *complex eikonal equation* [1–3] which is nonlinear as a result of noncommutativity of **B**-algebra! After restriction of coordinate space to the subspace of Hermitian matrices $X = X^+$ corresponding to the Minkowski metrics and splitting Eq. (1) by columns, for the most interesting case $R = F$ (or $L = F$) one obtains the so-called *generating system of equations* (*GSE*)

$$d\xi = LdX\xi, \tag{2}$$

for a 2-spinor $\xi(X)$ and a complex 4-vector $L(X)$ fields which both together can be found from the over-determined system (2). The field $L(X)$ is identified as that of the electromagnetic potentials, and homogeneous Maxwell equations do hold identically on any solution to Eq. (2)! Moreover, the value of electric charge associated with any isolated singularity of the induced electromagnetic field is necessarily *self-quantized*, integer multiple to a minimal, *elementary* one [4]. Generally, singularities of the primary and secondary **B**-fields are identified with pre-particle formations and participate in (purely algebraic) *collective conservative dynamics* [5, 6].

Further on, we discuss possible realizations of algebrodynamics on a manifold equipped by the structure of a Lie group or its specific generalizations, — algebraic structures (*AS*) with ***only one operation*** (contrary, say, to linear algebras) and defined by ***a single relation*** which connect any three or four *AS*-elements. Specifically, we consider 1) the so-called ***invariant*** AS,with the principal operation denoted as (–) and the defining relation $(x - z) - (y - z) = x - y$, for any $x, y, z$; 2) ***automorphic*** AS: $(x - z) - (y - z) = (x - y) - z$ and 3) ***universal*** *AS*: $(x - y) - (z - w) = (x - z) - (y - w)$, for any $x, y, z, w$.

In the procedure,we consider fundamental physical fields as *nontrivial mappings* on the "World" AS corresponding, in particular, to the "multiplication" of any element by itself, $F(X) = x - x$.

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## Nilpotents, Clifford Algebras and Elementary Particles

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Let a and b be generators of the Clifford algebra with $a^2 = b^2 = 1$ and $ab + ba = 0.$ Let E, p and m be commuting scalars and let $U = abE + ap + bm.$ Then it follows that $U^2 = -E^2 + p^2 + m^2.$ Thus the Pythagorean relationship $E^2 = p^2 + m^2$ holds if and only if $U^2 = 0.$ Combining with physics where Planck's constant and the speed of light are set equal to 1, we see that $U^2 = 0$ corresponds to the constraints on energy, momentum and mass for special relativity. Thus, as Rowlands [1] has observed, relativistic quantum physics begins with the structure of nilpotent elements in a Clifford algebra. This talk will explore this relationship and its algebraic implications for the structure of elementary particles and its relationships with geometry and topology [2].

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## Five-Dimensional Gravity and Non-Linear Electrodynamics

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The five-dimensional generalization of Einstein's theory of gravitation has led to the Kaluza-Klein and Brans-Dicke models. However, neither of them did use the possibilities offered by the enlargement of the Einstein-Hilbert variational principle by including the Gauss-Bonnet invariant, which in 5 dimensions is no more a pure divergence, and modifies substantially the equations of motion of the theory. We investigate the generalized Kaluza-Klein theory, which leads, in the Minkowskian space-time, to an interesting variant of non-linear Electrodynamics. After discussing the modified Maxwell's equations, we show how a toroidal soliton can be constructed, and show that it deisplays the most essential features of Dirac's electron: electric charge, magnetic moment, and spin. It also predics particle-anti particle symmetry.

## Tracking Propagation of Quantum Information along Postselection-Induced Time Arrows

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In the current work we present a time-bidirectional state formalism (TBSF) [1], which bridges the gap between the standard quantum mechanical formalism and the time-symmetrized two-state vector formalism (TSVF) [2, 3]. The new formalism allows studying quantum experiments with both pre- and postselection, where postselection is realized with respect to an arbitrary positive operator-valued measure (POVM). This includes the case of trivial POVM with a single identity operator, which corresponds to no postselection. Within the TBSF, a quantum state of a particle, called time-bidirectional state (TBS), is given by a density operator defined with respect to a doubled Hilbert space: the first (second) Hilbert space corresponds to a time-forward (time-backward) propagation of quantum information. We also develop tomography protocols for experimental reconstruction of a TBS. Then we reconstruct TBSs of a qubit (two-dimensional quantum particle) transferring within a quantum teleportation protocol realized on seven-qubit cloud-accessible super-conducting quantum computer. The obtained results justify an existence of a postselection-induced qubit's proper time arrow [4], which is different from the time-arrow of a classical observer. In particular we observe decohernece of informational qubit's state during its propagation along time-lines of distinct physical qubits connected with each other via entangled state preparation and entangled state measurement.

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# Эфирная теория Эйнштейна — Янга — Миллса с нелинейным аксионным полем: распад цветного эфира и образование аксионной темной материи

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Основанная на введении единичного времениподобного векторного поля эфирная теория тесно связана со скоростью некоторого космического субстрата — динамического эфира. В дальнейшем после создания теории взаимодействия динамического эфира с электромагнитным полем была предложена SU (N) — симметричная эфирная теория Эйнштейна — Янга — Миллса как обобщение U (1) — симметричной эфирной модели Эйнштейна — Максвелла. Предполагалось, что в истории Вселенной существует критический момент времени, когда SU(N) симметричный цветной динамический эфир преобразуется в U (1) симметричный динамический эфир, а также результатом этого процесса является образование псевдоскалярного (аксионного) поля φ. Фактически была сформулирована концепция цветного динамического эфира, основанная на анализе мультиплета векторных и псевдоскалярных полей.

Процесс перехода от симметричного цветного эфира в динамический выглядит в виде спонтанной цветовой поляризации, которая сопровождается выравниванием мультиплета векторных полей вдоль выделенного направления в цветовом пространстве и появлением псевдоскалярного (аксионного) поля. Данный процесс имеет характер фазового перехода второго рода.

В данной работе исследована нелинейная версия SU(N)-симметричной теории, которая самосогласованно описывает взаимодействие между гравитационным, калибровочным, векторным и псевдоскалярным (аксионным) полями. В контексте этой теории SU(N)-симметричный мультиплет векторных полей связывается с цветным эфиром, распад которого в ранней Вселенной породил канонический динамический эфир и аксионную темную материю. SU(N)-симметричное поле Янга — Миллса, связанное с цветным эфиром, образует источник, передающий энергию распадающегося цветного эфира в аксионное поле. Нелинейная модификация модели явно предъявляет требование дискретной симметрии, задаваемой аксионным полем. Она основана на аналогии с нелинейным физическим маятником. Мы показываем, что в рамках этой нелинейной регулярной модели аксионное поле может расти до сколь угодно большого значения, что объясняет обилие аксионной темной материи во Вселенной.

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## Einstein — Yang — Mills Aether Theory with Nonlinear Axion Field: Decay of Color Aether and the Axionic Dark Matter Production

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Based on the introduction of a unit time-like vector field, the ethereal theory is closely related to the speed of some cosmic substrate — the dynamic ether. Later, after the creation of the theory of interaction of the dynamic ether with the electromagnetic field, the SU(N) — symmetric ether theory of Einstein — Yang — Mills was proposed as a generalization of U(1) — the symmetric ether model of Einstein — Maxwell. It was assumed that in the history of the Universe there is a critical moment of time when the SU(N) symmetric colored dynamic ether is transformed into U(1) symmetric dynamic ether, and the result of this process is the formation of a pseudoscalar (axion) field $\varphi$. In fact, the concept of a colored dynamic ether was formulated, based on the analysis of a multiplet of vector and pseudoscalar fields.

The process of transition from a symmetric color ether to a dynamic one looks like a spontaneous color polarization, which is accompanied by the alignment of the multiplet of vector fields along a selected direction in the color space and the appearance of a pseudoscalar (axion) field. This process has the character of a second-order phase transition.

In this paper, we study a nonlinear version of the SU(N)-symmetric theory, which self-consistently describes the interaction between gravitational, gauge, vector, and pseudoscalar (axion) fields. In the context of this theory, the SU(N)-symmetric multiplet of vector fields is associated with the colored ether, whose decay in the early Universe gave rise to the canonical dynamic ether and axion dark matter. The SU(N)-symmetric Yang-Mills field associated with the colored ether forms a source that transfers the energy of the decaying colored ether to the axion field. The non-linear modification of the model explicitly imposes the requirement of discrete symmetry, given by the axion field. It is based on an analogy with a nonlinear physical pendulum. We show that within this non-linear regular model, the axion field can grow to an arbitrarily large value, which explains the abundance of axion dark matter in the Universe.

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## Квазиклассический предел в модели замкнутой изотропной Вселенной со скалярным полем в рамках различных подходов

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Рассмотрен переход к квазиклассическому пределу в квантовой модели закрытой изотропной Вселенной со скалярным полем, разложенным по амплитудам. Проводятся вычисления в рамках трех подходов к квантованию гравитации и сравниваются полученные результаты. Первым обсуждается метод, изложенный в работах Кифера и Сингха и основанный на геометродинамике Уилера — Де Витта. В этом случае время вводится в квазиклассическом пределе как параметр вдоль классической траектории. Следующим рассматривается подход, предложенный в работах Монтани. Исходным уравнением в этом случае также является уравнение Уилера — Де Витта, но проблема времени разрешается посредством введения жидкости Кухарша — Торра, выполняющей роль системы отсчета. И далее, вычисления проводятся в формализме расширенного фазового пространства. Основным уравнением в рамках этого подхода является временное уравнение Шредингера, в которое, наряду с физическими степенями свободы, входят калибровочные. Это может трактоваться как множество систем отсчета, соответствующих различны наблюдателям, что согласуется с общей теорией относительности. Для перехода к квазиклассическому пределу используется приближение Борна-Оппенгеймера. В качестве параметра разложения используется коэффициент $M = c^3/(16\pi G)$, аналогичный коэффициенту в действии Эйнштейна — Гильберта. Уравнение в порядке разложения $O(M)$ во всех трех случаях сводится к временному уравнению Шредингера для полей материи. Интерес представляет уравнение, получающееся в $O(1/\mathrm{M})$ порядке разложения. В рамках всех рассмотренных подходов оно соответствует временному уравнению Шредингера для полей материи с квантовогравитационными поправками. При этом полученные поправки отличаются в различных подходах, и зависят от дополнительных предположений. Также в докладе уделяется внимание вопросу унитарности этих поправок.

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# The Semiclassical Limit of a Closed Isotropic Model of the Universe with a Scalar Field in Frameworks of Various Approaches

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The report focuses on studying the semiclassical limit of quantum gravity for the case of a closed isotropic model with a scalar field, decomposed into modes. Three approaches to quantinization of gravity are discussed. The first one was proposed by Kiefer and Singh [1] and based on the Wheeler — DeWitt quantum geometrodynamics. In this case time variable is considered as a parameter along a classical trajectory in the semiclassical limit. The next one is the method put forward in the paper by Maniccia and Montani [2]. Here time appears due to introducing Kuchař–Torre reference fluid. And the final one is the extended phase space approach [3]. The temporal Schrödinger equation is assumed to be fundamental in this method. The equation is gauge noninvariant and has a different form depending on a choosing reference frame. This point can be treated as a set of reference frames related to different observers, that is in accordance with concepts of General relativity. The transition to the semiclassical limit is implemented by using the Born-Oppenheimer type of approximation. The expansion parameter is chosen to be $M = c^3/(16\pi G)$, that is the coefficient in expression for the classical action of gravitational field. In each approach the $O(M)$ order of the approximation corresponds to the temporal Schrödinger equation for matter fields. The $O(1/M)$ order is of the main interest. The equation, obtained in this order, is Schrödinger equation with quantum gravitational corrections. As shown the correction terms differ in each case and depend on additional assumptions. Also, the question of unitary evolution is discussed in the work. The present results were published in the paper [4].

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## Характеристики реликтовых черных дыр

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Масса черных дыр, образовавшихся в результате коллапса звезд или процессов в ядрах галактик больше предела Оппенгеймера-Волкова. Масса реликтовых черных дыр может быть любой. Поэтому конечные стадии испарения могут происходить и в наше время. Конечная стадия процесса испарения проходит при интенсивном выделении энергии [1]. Это делает ее наблюдаемой. Таким образом, анализ характеристик реликтовых черных дыр приобретает и практическую направленность.

Законченная квантовая теория гравитации отсутствуют. Теория размерности [2] позволяет выявить некоторые связи в этой области. В частности, это касается испарения черных дыр. Однако вследствие своей общности при использовании теории размерности могут возникнуть соотношения, вводящие в заблуждение. Для их выявления нами используется прием рассмотрения полученных соотношений в многомерных пространствах. Если результат инвариантен относительно изменения размерности $D$ конфигурационного пространства, то можно надеяться на его большую надежность.

В случае размерного анализа эффектов реликтовых черных дыр получаем, что

- температура поверхности черной дыры $T = \left( \dfrac{2Mc^2}{L_G^{D-1} / L_{Pl}^{D-1}} \right) k^{-1}$;
- время жизни черной дыры $t = \left( L_G / c \right) \left( L_G^{D-1} / L_{Pl}^{D-1} \right)$;
- энтропия черной дыры $S = k \left( L_G^{D-1} / L_{Pl}^{D-1} \right)$;
- момент импульса черной дыры $W = \hbar \left( L_G^{D-1} / L_{Pl}^{D-1} \right)$.

Эти результаты инвариантны по отношению к изменению размерности $D$.

Анализ эффектов наличия заряда у реликтовых черных дыр, как оказалось, требует отдельного рассмотрения.

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# Characteristics of Relic Black Holes

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The mass of black holes, formed as a result of the collapse of stars or processes in the nuclei of galaxies, is greater than Oppenheimer — Volkov's limit. The mass of relict black holes can be arbitrary. Therefore, the final stages of evaporation can occur presently. The final stage of the evaporation process takes place with an intense release of energy [1]. This makes it observable. Thus, the analysis of the characteristics of relict black holes also becomes of utmost importance.

There is no complete quantum theory of gravity. The dimension theory [2] makes it possible to reveal some relationships in this field. In particular, this concerns the evaporation of black holes. However, when using the dimension theory, due to its generality, the may arise misleading formulae. To correct them, we use the technique of considering the obtained relations in multidimensional spaces. If the result is invariant under the change in the dimension D of the configuration space, then we can hope for its greater reliability.

In the case of a dimensional analysis of the effects of relic black holes, we obtain that

- black hole surface temperature $T = \left( \dfrac{2Mc^2}{L_G^{D-1}/L_{Pl}^{D-1}} \right) k^{-1}$;
- black hole lifetime $t = \left( L_G / c \right) \left( L_G^{D-1} / L_{Pl}^{D-1} \right)$;
- entropy of a black hole $S = k \left( L_G^{D-1} / L_{Pl}^{D-1} \right)$;
- angular momentum of the black hole $W = \hbar \left( L_G^{D-1} / L_{Pl}^{D-1} \right)$.

These results are invariant with respect to the change in the dimension of $D$.

Analysis of the effects of the presence of a charge in relict black holes, as it turned out, requires separate consideration.

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# The Confrontation between Coordinate System and Coordinate Conditions

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In the differential geometry the reference frame, the linear connection and the metric are built in the tangent space. In the case of the Einstein theory, we solve the inverse problem, the tangent space of general relativity is defined as an independent structure that exists before the solution of the Einstein equations, and in this tangent space, only after the solution of the field equations, both the metric and the connection arise.

Einstein's equations consist of six equations for ten unknown functions $g_{\alpha\beta}(x)$. The standard step for obtaining a complete system of equations is to set the coordinate conditions within the framework of the chosen arithmetization, these are four additional algebraic or differential non-covariant equations for determining the metric tensor. Only solutions of field equations that satisfy Hilbert's causality principle have physical meaning.

The solutions of these equations are not correct enough if they are not based on the concept of a class of admissible functions. For example, the reduction of the metric of centrally symmetric fields to the standard form can always be carried out only under the assumption that $g_{\alpha\beta}$ belongs to functions of the class $C^1$ [1], while the Bianchi identities impose the restriction $C^3$ on the functions $g_{\alpha\beta}$. The proof of Birkhoff's theorem is based on the use of those solutions that are sought in the class at least $C^2$ and, therefore, the wave solutions are discarded in advance.

The solutions of the Einstein equations determine the local properties of the metric tensor in the tangent space with an accuracy of four arbitrary functions by which we are trying to recreate the whole space. On this basis, we can agree with V.A. Fok [2] — an arbitrary assignment of coordinate conditions introduces fictitious gravitational fields. To eliminate this ambiguity, it is necessary to impose additional restrictions, a criterion for the admissibility of the resulting solutions is required.

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# Гравиметрический лазерно-интерферометрический комплекс

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Цель разрабатываемого нами инновационного проекта — создание нового направления научно-исследовательской деятельности, в том числе разработка и создание сверхчувствительной прецизионной лазерно-интерферометрической аппаратуры для проведения экспериментов в теории гравитации. Ранее в результате реализации научно-технического проекта «Дулкын» [1] нами были решены следующие задачи:

1. Создан детектор первого уровня «Дулкын-1». Доказана работоспособность детектора и всей вспомогательной аппаратуры в течение многих месяцев непрерывной эксплуатации в ходе проведения эксперимента «Лунный тест».

2. Достигнутая чувствительность детектора «Дулкын-1», которая составляет $10^{-12}…8 \cdot 10^{-16}$ в диапазоне частот $10^{-5}…1$ Гц, соответствует значениям, предъявляемым к детектору первого уровня, и является на сегодняшний день единственной в мире для данного диапазона инфранизких частот.

3. В результате проведения эксперимента «Лунный тест» был проверен принцип эквивалентности Эйнштейна (в части универсальности закона гравитационного «красного» смещения для часов разной физической природы) на уровне 0,9 %, что почти вдвое улучшило прежнее мировое достижение (1,7 % — США, 1983 г.). Эксперимент подобного рода проводился в России (и бывшем СССР) впервые.

4. Подтверждена правильность концепции построения ГВ-детектора «Дулкын», в основе расчета эластодинамического отклика которого лежит подход Ж. Можена, соответствующий значению феноменологического параметра $\xi = 1$, в отличие от альтернативного подхода Дж. Вебера ($\xi = 0$), поскольку экспериментальное значение, полученное при проверке принципа эквивалентности, составило $\xi = 1 \pm 0{,}009$.

В последующий период основные работы были направлены на теоретическое осмысление полученных результатов и, по результатам 1-го этапа, разработка детектора второго уровня.

Проведен цикл работ по использованию модуляционных методов детектирования гравитационного сигнала, основанных на применении амплитудно-фазовых преобразователей для формирования опорного и информационного каналов.

Проводилась отработка техники распознавания низкочастотных периодических сигналов среди мощных геофизических, техногенных и технических шумов, которая является частью планируемой работы, что в дальнейшем позволит установить пороговые критерии для детектируемости периодических гравитационно-волновых сигналов миллигерцового диапазона.

Прорабатывалась возможность разработки новой техники для мониторинга вариаций поля тяготения Земли и метрологических тестов, связанных с долгосрочными предсказаниями сейсмической активности.

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## Gravimetric Laser Interferometric Installation

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The purpose of our ongoing innovative project is to create a new research field involving design and development of ultrasensitive precision laser interferometric equipment for conducting experiments concerning the theory of gravity. Previously, as a result of completing the Dulkyn scientific and technological project [1], we solved the following problems:

1. The Dulkyn-1 first-level detector has been created. We proved the operability of the detector and its auxiliary equipment over the course of several months of continuous operation during the Lunar Test experiment.

2. The Dulkyn-1 detector achieved a sensitivity of $10^{-12}...8 \cdot 10^{-16}$ in the frequency range of $10^{-5}...1$ Hz, which satisfies the requirements for a first-level detector; in this infra-low frequency range there are currently no competitors worldwide.

3. The Lunar Test experiment verified Einstein's principle of equivalence (in terms of the universality of the gravitational "redshift" law for clocks of various physical nature) within a margin of error of 0.9 %, almost a twofold improvement over the previous international achievement (1.7 % — USA, 1983). Our experiment was the first of its kind to be conducted in Russia (and the former USSR).

4. We confirmed that the concept behind constructing the Dulkyn gravitational wave detector is correct; the basis for computing the elastodynamic response in our detector is G.A. Maugin's approach, where the phenomenological parameter $\xi = 1$, in contrast to the alternative approach of J. Weber ($\xi = 0$), as the experimental value obtained while testing the equivalence principle was $\xi = 1 \pm 0.009$.

Afterwards, we primarily worked on furthering theoretical understanding of the results obtained and developing a second-level detector based on the results of the first stage.

We conducted a series of works concerning the use of modulation methods for gravitational signal detection based on employing amplitude-phase transducers to form the reference and information channels.

We trialled the technique of recognizing periodic low-frequency signals among strong geophysical, technogenic and technological interference, which is a part of the work scheduled to establish threshold detectability criteria for periodic gravitational wave signals in the millihertz range.

We investigated the possibility of developing a new technique for monitoring variations in the Earth's gravitational field and performing metrological tests related to long-term predictions of seismic activity.

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# Феномены FRB и GRB, как проявления альтернативной гравитационной модели в Солнечной системе

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Мы представили модель двунаправленной приталкивающей гравитации (BPG) на PIRT-2021, чтобы объяснить, каким образом выравнивание небесных тел Солнечной системы с удаленными компактными объектами, а также, друг с другом вблизи астрономических слияний и противостояний, может порождать катастрофические стихийные явления, связанные с движением свободных масс в литосфере, гидросфере и атмосфере. Последующий анализ показал, что моменты регистрации быстрых радиовсплесков (FRB) и гамма-всплесков (GRB) также сопровождаются особыми положениями небесных тел Солнечной системы. В данной работе мы предлагаем механизм возникновения FRB и GRB в модели BPG [1], локализованный в Солнечной системе.

Общепризнанной модели возникновения FRB не существует [2]. Механизм действия гамма-всплесков и их послесвечения также не вполне ясен. Оба феномена связывают с высокоэнергетическими явлениями в дальнем космосе, — слиянием ЧД, НЗ, возникновением сверхновых, активным звездообразованием и т.п. Имеется наблюдательные данные, не нашедшие реализации в существующих моделях, такие как «гигантское кольцо GRB»; высокоэнергетические фотоны (18 и 251 ТЭВ) от GRB221009A, которые не могут долетать с расстояния, на котором произошел гамма-всплеск, из-за рождения пар на космическом фоновом излучении; 16-дневная периодичность повторного FRB20180916B, необъяснимая высокоэнергетическими процессами в дальнем космосе, и др.

Мы полагаем, что феномены и FRB [3] и GRB [4] обусловлены эволюциями вектора гравитационных возмущений (ГВ), индуцированных у наблюдателя движением небесных тел нашей солнечной системы, т.е. движением Солнца, Луны, планет, малых планет, крупных астероидов, далее именуемых *дефлекторами*.

Согласно BPG [1] гравитационная масса тел не является инвариантом и увеличивается с расстоянием, пропорционально коэффициенту самолинзирования массы, величина которого обусловлена компактностью тел. В результате, дальнодействие гравитации для компактных тел существенно увеличивается. Рассматривается космология стационарной замкнутой вселенной с топологией гиперсферы $S^3$ (вселенная внутри ЧД), замыкание которой допускает двунаправленное действие сил гравитации.

От удаленного источника гравитации на пробное тело в прямом направлении действует сила отталкивания (большой величины), в антиподальном направлении замкнутой вселенной мгновенно действует равная ей сила приталкивания. При отсутствии возмущений, вектор напряженности гравитационного поля отталкивания скомпенсирован вектором приталкивания, и сумма этих векторов равна нулю.

При приближении *дефлектора* к направлению на источник гравитации прицельный параметр уменьшается, и происходит релятивистское отклонение направления действия вектора отталкивания на угол малой величины. Аналогичные возмущения со стороны других *дефлекторов* также испытывает встречно направленный вектор приталкивания. Сумма отклоненных векторов отталкивания и приталкивания уже не будет равна нулю и представляет собой индуцированный вектор ГВ, действующий на пробное тело.

В условии дальнодействующей гравитации, взаимодействие тел происходит при обязательном участии третьего агента — небесной сферы, обладающей высоким удельным потенциалом отталкивания. Притяжение масс (приталкивание небесной сферой) возникает по причине экранирования гравитирующей массой сил отталкивания небесной сферы в прямом направлении.

Когда вектор ГВ приобретает достаточную величину и направлен на объект дальнего космоса, излучающий ЭМИ, и имеющий значительную массу, которая экранирует гравитационное отталкивание небесной сферы, то в соответствующем телесном угле экранирования происходит коллимация вектора ГВ. Не испытывая противодействия со стороны небесной сферы, вектор напряженности ГВ приобретает большую величину и вызывает гигантский гравитационный сдвиг частот ЭМИ объекта дальнего космоса. Частоты ИК, оптического, и прилегающих диапазонов, сдвигаются в область радиодиапазона, перенося при этом дополнительную энергию высокочастотных излучений.

В момент регистрации FRB, вектор ГВ складывается с вектором ускорения силы тяжести (УСТ) наблюдателя (радиотелескопа), который вращается в пространстве вместе с Землей. Малая продолжительность FRB обусловлена быстрым поворотом вектора УСТ относительно направления на объект дальнего космоса. При совмещении суммарного вектора (ГВ + УСТ) с направлением на объект происходит модуляция частот (гравитационный красный сдвиг), при этом, по мере совмещения направлений, высокие частоты в сигнале FRB появляются раньше, чем низкие, что интерпретируется исследователями, как значительная величина меры дисперсии (DM) радиосигнала.

В отличии от FRB, гамма-всплески [4], при аналогичном механизме, обусловлены гигантским гравитационным фиолетовым сдвигом частот объекта дальнего космоса. При этом вектор ГВ направлен в противоположную сторону от объекта дальнего космоса, излучение которого претерпевает сдвиг частот. Одновременно с FRB, гамма-всплески не наблюдаются, т.к. вектор УСТ в формировании GRB не участвует, поскольку регистрация происходит на космических аппаратах, находящихся вне пределов действия УСТ, либо оно скомпенсировано кинематическими ускорениями на орбите.

Для решения различных прикладных задач, требующих вычисления вектора ГВ, необходимо уточнение ряда параметров модели BPG, таких как значение гравитационной постоянной отталкивания тел, составление детального перечня источников гравитации, их масс и коэффициентов самолинзирования. Мы предлагаем алгоритм вычисления гравитационных возмущений в модели BPG с использованием библиотеки Skyfield (Python) [5], основанной на USNO NOVAS 3.1. Небесные координаты зарегистрированных FRB и GRB соответствуют фактическому направлению вектора ГВ в момент регистрации, и могут выступать в качестве решений при использовании методов машинного обучения для подбора параметров модели. Данная задача может потребовать выполнения интенсивных вычислений и организации специального проекта.

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## FRB and GRB Phenomena as Manifestations of Alternative Gravitation Model in our Solar System

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We presented the Bidirectional Pushing Gravitation (BPG) model at PIRT-2021 to explain how the alignment of celestial bodies in Solar System with each other and with distant compact objects in the vicinity of astronomical conjunctions and oppositions can generate catastrophic natural phenomena, associated with the movement of free masses in the lithosphere, hydrosphere and atmosphere. Subsequent analysis showed that the fast radio bursts (FRB) and gamma-ray bursts (GRB) also coincide with specific arrangement of celestial bodies. In this paper, we propose mechanism for FRB and GRB emergence in the BPG model [1], localized in our Solar System.

There is still no generally accepted model for the occurrence of FRBs [2]. Emergence of gamma-ray bursts and their afterglows also is not entirely clear. Both phenomena are associated with high-energy events in deep space, such as mergers of black holes, NSs, emergence of supernovae, active star formation, etc. Existing models cannot explain, such features as: the "giant ring GRB"; high-energy photons (18 and 251 TeV) from GRB221009A, which cannot arrive from the distance where the gamma-ray burst occurred, due to production of pairs in the cosmic background radiation; 16-day periodicity of the repeated FRB20180916B, inexplicable by high-energy processes in deep space, etc.

We believe that both phenomena of FRB [3] and GRB [4] emerge due to evolution of the gravitational perturbations (GP) vector induced at the observer by motion of celestial bodies in our Solar System, i.e. by motion of Sun, Moon, planets, minor planets, large asteroids, hereinafter referred to as *deflectors*.

According to BPG [1], the gravitational mass of bodies is not an invariant and increases with the distance, in proportion to the coefficient of self-lensing of mass, the value of which is due to compactness of the bodies. As a result, the long-range action of gravitation for compact bodies increases significantly. The cosmology of a stationary closed universe with the $S^3$ hypersphere topology (the universe inside a black hole) is considered, which closure allows for a bidirectional action of gravitational forces.

From a remote source of gravity, a repulsive force (of a large magnitude) acts on a test body in forward direction, while in the opposite, antipodal, direction of a closed universe, instantly acts equal pushing force. In the absence of disturbances, the intensity vector of repulsion gravitational field is compensated by vector of pushing, and the sum of these vectors is equal to zero.

As the *deflector* approaches the direction to the source of gravity, the impact parameter decreases, and a relativistic deflection of the repulsion vector occurs by a small angle. Similar perturbations from other *deflectors* are also experienced by the oppositely directed pushing vector. The sum of the deflected repulsion and pushing vectors will no longer be equal to zero and represents the induced GP vector acting on the test body.

In the condition of long-range gravitation, the interaction of bodies occurs with the obligatory participation of the third agent — the celestial sphere, which has a high specific repulsion potential. The attraction of masses (pushing by the celestial sphere) arises due to shielding by the gravitating mass of the repulsion of the celestial sphere in forward direction.

When the GP vector acquires a sufficient magnitude and is directed to a deep space object that emits EMR and has a significant mass that shields the gravitational repulsion of the celestial sphere, then the GP vector collimation occurs in the corresponding solid angle of shielding. Without experiencing opposite action from the celestial sphere, the GP intensity vector acquires a large value and causes a giant gravitational frequency shift of the EMR of a deep space object. The frequencies of the infrared, optical, and adjacent ranges are shifted to the radio range, while transferring additional energy of high-frequency radiation.

At the time of FRB registration, the GP vector is added to the gravity acceleration vector (GV) of the observer (radio telescope), which rotates in space together with the Earth. The short duration of the FRB is caused by the fast rotation of the GV vector relative to the deep space object. When the total vector (GP + GV) is aligned with the object, frequency modulation occurs (gravitational red shift), while, as the alignment occurs, high frequencies in the FRB signal appear earlier than low ones, which is interpreted by researchers as a significant value of the dispersion measure (DM) of radio signal.

Unlike FRBs, gamma-ray bursts [4], with a similar mechanism, are caused by a giant gravitational violet frequency shift of a deep space object. In this case, the GP vector is directed in the opposite direction from the deep space object, the radiation of which undergoes a frequency shift. Simultaneously with FRB, gamma-ray bursts are not observed, because the GV vector does not participate in the formation of the GRB, since the registration takes place on spacecraft that are outside the range of the GV, or it is being compensated by kinematic accelerations in orbit.

To solve applied problems that require calculation of the GP vector, the BPG model requires refinement of a number of parameters, such as the value of the gravitational repulsion constant for bodies, refinement of the list of gravity sources, their masses and self-lensing coefficients. We propose an algorithm for calculating gravitational disturbances in the BPG model using the Skyfield (Python) library [5] based on USNO NOVAS 3.1. The celestial coordinates of the registered FRBs and GRBs correspond to the actual direction of the GP vector at the time of registration, and can represent solutions when using machine learning methods to select model parameters. This task may require intensive calculations and the organization of a special project.

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# Finsler-Lagrange Multi-Relaxation-Time Dynamics of Cosmological 1st Order Phase Transition

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To date, the geometrothermodynamic models of cosmological phase transitions in the early universe and in the black holes are intensive developed [1]. A geometrization of the cosmological phase transition problems consists in the construction of such contact manifolds, geometric structures of which predict a character of nucleation process and phase domain growth. Previously, we have proposed the geometrodynamic model for interfacial first-order phase transition [2]. A goal of the paper is to study the dynamics of the phase transition in dependence on the relaxation-time distribution function for true and false vacuum phases.

A generalized cosmological model of nucleation has been constructed under the assumption that each *i*-th phase nucleus of true vacuum is described with a relaxation time (life time) $\tau_i$ and in the limit of infinite number of nuclei one can choose such parameterization: $\tau_i = \frac{\Delta t_i}{\Delta s} \to \tau \equiv \dot{\xi} = \frac{dt}{ds}$, where $s$ is an evolution parameter. The phase transition is modeled in the expanded configuration space $(\mathbf{r}, \xi, \dot{\mathbf{r}}, \dot{\xi}, s)$ with the pseudo-Finsler metric:

$$F^2 = -\left( A(\xi, r)\frac{\dot{\xi}^2}{\dot{r}} + B(\xi, r)\dot{\xi} - \frac{C(\dot{r}^2 + r^2\dot{\varphi}^2)}{\dot{\xi}} \right)^2 .$$

Euler — Lagrange equations have been solved numerically. It has been shown that for the weak phase transition the nucleation rate is constant and the nuclei with only critical relaxation time ($\dot{\xi} \sim 1,$ the nuclei of the critical size) are produced. The strong phase transition proceeds at high supersaturation of the system, the avalanche-like production of phase nuclei with relaxation times significantly higher than a critical one ($\dot{\xi} \gg 1$) occurs.

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## Laser Noise in the GW Detector AURIGA

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In the gravitational wave antenna OGRAN [1], the conceptual optoelectronic chain of AURIGA project had borrowed to register length variations of the aluminum acoustic resonator (bar). This chain has presented in 1998 [2] and earlier. In OGRAN project, due to intensive development, certain progress had achieved in identification and elimination of significant noise source [3]. The remaining noise level $2 \times \times 10^{-15}$ cm/Hz$^{1/2}$ (0.003 Hz/Hz$^{1/2}$) had not been identified; the abstruse conclusion had made that non-Poisson laser noise can be 1000 times larger than shot noise of photoelectrons [1]. In article [4], a well-substantiated version of excess noise origin has proposed. It has shown analytically how stochastic phenomenological process of low frequency (LF) laser power variations penetrates into the precision chain, which determines displacement noise (threshold signal) of the registration circuit.

In the AURIGA facility, noise moderately exceeding calculated values had also revealed; results have published in 2002 [5] and later. However, during these tests, another registration chain had used, it has significant differences from the initial one (OGRAN). This realized modification should considered and called as the actual chain of AURIGA GW detector.

In present report, extra effect of LF laser power noise in the main AURIGA scheme has analyzed.

Each AURIGA scheme contains two units constructed in Pound-Drever-Hall (PDH) technique [6]; each unit based on Fabry-Perot interferometer (cavity). Formal difference is which unit feed actuator of laser frequency re-tune. In the original OGRAN-AURIGA scheme, the laser frequency follow resonant frequency of the FP cavity mounted on end tops of the bar. In the actual AURIGA scheme, the laser frequency has returned by reference cavity (RC) unit corresponding classical PDH scheme [6]. Here high short-term stability of radiation frequency ensures; intrinsic stochastic deviations of laser frequency decrease, their dispersion reduces narrowing radiation line.

In the OGRAN facility, the sensor cavity (SC) of the bar superposes function of a mechanical oscillations sensor [6] with function of a reference cavity (RC) to suppress intrinsic laser frequency fluctuations. As a result, laser frequency not only follows quasi-static drifts caused by aluminum temperature expansion, but also effectively tracks fast signal variations in resonant frequency of the SC. Frequency modulated radiation is formed with very low modulation index. This radiation feed the second, optoelectronic PDH discriminator unit. On the slope of its discriminator characteristic (PDH error signal) laser frequency deviations converts into voltage signal for data processing. Here, the error signal also compel its zero to follow laser frequency drift.

In the principal AURIGA chain, the SC used as a frequency discriminator. While laser frequency is fixed, the entire PHD error signal moves along frequency axle together with quasi-harmonic signal and Brownian motion. The same effect applied in the Braginsky's conceptual displacement sensor [7]; this scheme underlies the OGRAN theory including usage of non-Poisson noise factor **B** into formulas [1].

Creative modification of initial AURIGA PDH chain aims to adapt circuitry implementation to particularity of GW signal. Extremely weak signal not feed laser frequency actuator and not send through feedback loop. This signal handling principle has realized earlier in the superconducting (SQUID) displacement meter constructed for a cryogenic GW detector [8].

The complete description of laser noise effect on threshold signal of the AURIGA displacement meter assumed concentrated study the classic version of PDH laser stabilization scheme. Thus, as an intermediate and by-product result, the expression for minimum achievable spectral density of laser frequency stochastic deviations should derived, complementing to formula of the introductory article [6] with terms describing contributions of laser noise components. Deviations of frequency $\delta\nu_L$ are given by the expression:

$$\delta\nu_{\Lambda} = \frac{I_{mC}}{D_{I0}} + \frac{\delta\nu_N}{K_0} + \Delta\nu_{II}\xi.$$

Here, the first term determines shot noise spectral density [6], $\delta\nu_N$ and $\xi$ are stochastic processes characterizing the phenomenological fluctuations of laser frequency and power, $K_0$ is feedback factor, $\Delta\nu_{\mathrm{IL}}$ is difference between laser and cavity frequencies [4].

In the complete AURIGA registration circuit, it has shown that LF laser power noise also penetrates into precision chain; its carrier is quasi-static error signal due to aluminum temperature drift.

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## On the Temperature of Hairy Black Holes

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Recent investigations showed the possibility of phase transition near the event horizon of a black hole. However, the critical Hawking temperature near horizon, at which the phase transition can happen, is reached in the vicinity of the event horizon and the radius of the region, where this effect is possible, is negligible. When one considers the particle collisions the situation becomes better because the center-of-mass energy can grow unboundly in some processes. The region near event horizon where phase transition can happen is much bigger in comparison to the Hawking temperature. However, one can try to increase the effect caused by the Hawking temperature by considering the modification of standard black hole solution and how these modifications affect the black hole temperature.

The gravitational decoupling method represents an extremely useful tool to obtain new solutions of the Einstein equations through minimal geometrical deformations. In this work, we consider the hairy charged black hole obtained by the gravitational decoupling and calculate their Hawking temperature in order to compare it with the case when the hairs are ignored. We have found out that the hairs, under some conditions of black hole parameters, affect the Hawking temperature and can increase it. We have also found out that the black hole temperature, in hairy case, doesn't depend on the electric charge.

The thermodynamics and the thermodynamics phase transitions are considered for a black hole supported by non-linear electrodynamics. We calculate Unruh-Verlinde temperature, entropy and specific heat. We plot its behaviour and find the region where phase transition might happen and compare it with Reissner-Nordstrom black hole.

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## Scalar-Nonmetricity Cosmology in the General Relativity Limit

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In symmetric teleparallel geometry the curvature and torsion tensors are assumed to vanish identically, while the dynamics of gravity is encoded by the nonmetricity. Here the spatially homogeneous and isotropic connections that can accompany flat Friedmann — Lemaitre — Robertson — Walker metric come in three sets. As the trivial set has received much attention, in this work we focus upon the two alternative sets which lack a Minkowski limit. We consider symmetric teleparallel scalar non-metricity gravity with generic coupling functions, and study under which conditions these cosmological spacetime configurations with radiation and dust matter content relax to the limit of general relativity (possibly with a cosmological constant). We derive the approximate solutions and compare the behavior with the usual scalar-tensor cosmology based on curvature.

## Searching for a Secular Variation of the Gravitational Constant using Strong Gravitational Fields

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Searching for varying dimensionless physical constants presents a meaningful characteristic in experimental and observational studies. One of the most valuable explorations of these variations could depend on the evolution of white dwarf stars. Applying the spectrum of white dwarf star: G191-B2B, we derive a robust limit on the cosmological variation of the gravitational constant $\dot{G}/G = (0.238 \pm 2.959) \times 10^{-15}\,\mathrm{yr}^{-1}$. This limit proposes a potential test of the framework of modern unification theories.

# Измерительная задача калибровки шкалы космологических расстояний: Анизотропия и крупномасштабные гравитационные диполи неоднородности

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Цель доклада — интерпретация данных о красном смещении $z$ сверхновых типа SN Ia, полученных при исследовании Глубокого (HDF) и Ультра глубокого (UHDF) полей Хаббла группой High-Z SN Search Team и названных в нобелевской лекции А. Рисса «экстраординарными доказательствами» существования «ускорения расширения Вселенной».

В ходе дискуссии о тупиковой ситуации в космологии появилась альтернатива «ускорению расширения Вселенной». Это — гравитационные диполи крупномасштабной неоднородности в виде пары «массивное сверхскопление галактик (super cluster) или аттракторов (attractor) и гигантская пустота (super void). Диполи такого рода приводят к появлению в директрисе их действия неуравновешенных гравитационных сил, вызывающих ускорение массовых потоков движения галактик.

Показано, что ориентация полей Хаббла образует гравитационный диполь Хаббла. Для этого был использован способ обнаружения гравитационных диполей по разладкам и ранговым инверсиям изотропной модели шкалы космологических расстояний, принятой группой High-Z SN Search Team. Это позволило по координатам сверхновых типа SN Ia, находящихся на границах интервалов разладок и ранговых инверсий, установить источники гравитационной дипольной анизотропии в рамках анизотропной модели — Draco super cluster + Ursa Major super cluster → Eridanus super void + Fornax void.

Таким способом в 2010–2013 годах были идентифицированы гравитационные диполи «Eridanus super void — Virgo super cluster» и «Aquarius super void — Leo super cluster». Они оказались элементами гигантского полярного гравитационного диполя «Eridanus + Cetus + Aquarius super void → Shapley + + Centaurus + Leo + Coma + Virgo super cluster».

В 2017 году по базам данных Cosmicflows о потоках галактик группа Б. Талли смоделировала 3-мерное поле гравитационных скоростей в пределах $z \approx 0{,}1$, показав зону притяжения и две зоны отталкивания. Зона притяжения — продолжение Shapley super cluster. Одна зона отталкивания, дипольный отпугиватель, расположена вблизи антиапекса космического микроволнового фонового диполя, а другая — в направлении Eridanus super void. Эти результаты рассматриваются как подтверждение методики на основе разладок и ранговых инверсий изотропной модели для более точной анизотропной модели.

Таким образом, данные диполя Хаббла нельзя рассматривать однозначно в качестве «экстраординарных доказательств» космологического ускорения расширения Вселенной.

# Measuring Problem of Calibration of the Cosmological Distances Scale: Anisotropy and Large-Scale Gravitational Dipoles of Inhomogeneity

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The purpose of the report is to interpret the data on the redshift of $z$ supernovae of type SN Ia, obtained during the study of the Deep (HDF) and Ultra Deep (UHDF) fields of Hubble by the High–Z SN Search Team. This data in the Nobel lecture by A. Riess named as "extra-ordinary evidence" of the existence of the "acceleration of the Universe expansion".

During the discussion about the impasse in cosmology, an alternative to the "acceleration of the Universe expansion" appeared. These are gravitational dipoles of large–scale heterogeneity in the form of a pair of "massive super cluster of galaxies or attractors" and a super void. Dipoles of this kind lead to the appearance of unbalanced gravitational forces in the directory of their action, causing acceleration of mass flows of motion of galaxies.

It is shown that the orientation of the Hubble fields forms a gravitational Hubble dipole. For this purpose, a method was used to detect gravitational dipoles by the irregularities and early inversions of the isotropic model of the cosmological distance scale adopted by the High-Z SN Search Team. This made it possible to determine the sources of gravitational dipole anisotropy within the framework of the anisotropic model based on the coordinates of supernovae of type SN Ia located at the boundaries of the intervals of disjunctions and rank inversions — Draco super cluster + Ursa Major super cluster → Eridanus super void + Fornax void.

In this way, the gravitational dipoles «Eridanus super void — Virgo super cluster» and «Aquarius super void — Leo super cluster» were identified in 2010–2013. They turned out to be elements of the giant polar gravitational dipole "Eridanus + Cetus + Aquarius super void → Shapley + Centaurus + Leo + Coma + Virgo super cluster".

In 2017, using Cosmicflows databases on galaxy flows, B. Tully's group modeled a 3-dimensional gravitational velocity field within $z \approx 0.1$, showing a gravity zone and two repulsion zones. The zone of attraction is a continuation of the Shapley super cluster. One repulsion zone, Dipole Repeller, is located near the antiapex of the cosmic microwave background dipole, and the other is in the direction of Eridanus super void. These results are considered as a confirmation of the methodology based on the disjunctions and rank inversions of the isotropic model for a more accurate anisotropic model.

Thus, the Hubble dipole data cannot be regarded unambiguously as "extraordinary evidence" of the cosmological acceleration of the Universe expansion.

# Исследование гравитационных эффектов порядка $c^4$ в экспериментах со стандартами частоты и времени следующего поколения

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Общая теория относительности (ОТО) и квантовая теория составляют основу современной физической картины мира. Однако, попытки построения квантовой теории гравитации неизбежно приводят к нарушению лежащего в основе ОТО эйнштейновского принципа эквивалентности (ЭПЭ). В связи с этим в настоящее время активно ведутся эксперименты по экспериментальной проверке ЭПЭ. Одним из перспективных экспериментов такого типа является измерение эффекта гравитационного красного смещения или гравитационного замедления времени [1]. Прогресс в технике создания высокостабильных и высокоточных стандартов частоты и времени, в том числе в бортовом исполнении, позволит в ближайшие 10 лет существенно повысить точность таких экспериментов, а также проводить измерения нового типа. Для теоретического описания и анализа данных таких экспериментов требуется уточнение модели, описывающей преобразования частоты и передачу времени между двумя спутниками или спутником и наземной станцией, а именно включение в рассмотрение членов 2-го порядка по гравитационному потенциалу и 4-го порядка по скорости [2]. В данной работе мы представляем такую уточненную модель и с ее помощью анализируем точность проверки ЭПЭ, которую можно достигнуть в будущих специализированных космических экспериментах в Солнечной системе.

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# Gravitational Effects of Order $c^4$ in the Next Generation of Experiments with Time and Frequency Standards

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General relativity (GR) and quantum theory form the basis of the modern physical picture of the universe. However, attempts to formulate the quantum theory of gravity inevitably lead to violations of the Einstein Equivalence Principle (EEP) which forms the basis of GR. Experiments to test the domain of validity of EEP are, therefore, an area of active research. A promising kind of such experiments is based on the measurement of the gravitational redshift or gravitational time dilation effect [1]. Recent progress in the stability and accuracy of time and frequency standards, including those qualified for operation in space, will make it possible to significantly improve the accuracy of such experiments in the next 10 years, as well as to conduct new kinds of measurements. In order to give a theoretical description of such experiments and analyze their data, it is necessary to refine the current models that describe the frequency and time transfer between two satellites, or a satellite and a ground station. In particular, it is necessary to include terms of the 2nd order in the gravitational potential and 4th order in the velocity of light [2]. We present such an improved model and use it to analyze the accuracy of EEP tests which can be performed in near-future dedicated space experiments in the Solar system.

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## Analysing the Geometrical and Dynamical Parameters of the Modified Teleparallel — Gauss — Bonnet model

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We used the parametrisation method in modified teleparallel Gauss — Bonnet gravity to generate cosmological models. Applying the parametrisation method to research cosmological models has proved attractive. The observational data may be used to test the cosmological models, which is the true advantage of this approach. The Hubble parameter ($H$), the deceleration parameter ($q$)), and the equation of state parameter (EoS) were among the cosmological parameters that were investigated. Under the traditional scenario, the reported results align with recent cosmological discoveries. It has been found that cosmic evolution is moving from a decelerating stage to an accelerating stage. The universe's accelerated expansion is caused by the EoS parameter, which is also in its quintessence phase. We also examine the strong energy condition violation, which is inevitable in modified gravitational theory. Also, we used a dynamical system approach to study the cosmological viability of $F(T, T_G)$ gravity theories.

## Search of Periodical and Aperiodical Variations of Nucleus Weak Decay Parameters

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Possible temporal variations of nucleus decay parameters were studied extensively in the last years, their observation can be the signal of unknown physical effects. Several experiments reported the annual and daily decay rate oscillations in alpha and beta-decays of some radioactive nuclides at the level of .05 % [1, 2]. Also, correlation of Mn-54 *e*-capture decay rate with electromagnetic solar activity was reported [1]. BSTU — PhIAN — INF collaboration studies decay rate variations in Co-60 β-decay and Fe-55 inverse β-decay (*e*-capture) isotopes. 1.3 Mev γ-quanta which accompanies Co-60 beta-decay were detected by cooled germanium semiconductor spectrometer. Fe-55 *e*-capture accompanied by X-ray with energy 5,9 or 6,4 KeV which in our set-up detected by cooled Si-Pin detector. Measurements of decay rate performed in 2016–2023, demonstrate that together with observed Fe-55 decay exponent with life-time 1004 days, oscillation period 29.5 ± 1.5 days corresponding to moon month is found with amplitude (0.22 ± 0.04) %; theoretical model of such decay rate deviations considered in [3, 4].

Possible influence of electromagnetic solar activity was studied during 2015–2023 for Fe-55 decay rate, simultaneously with C0-60 decay rate in Novosibirsk INF at the distance 2800 km from Moscow [5]. The deviations of similar form and size from exponential decay low at the average level (0.55 ± 0.004) % were detected in both experiments during October-December 2018. Supposedly, they can be related to solar activity minimum started in the beginning of 2018 and continued till the end of 2020. Similar deviations were observed at this period in Baksan α-decay experiment. In addition, ten decay rate dips of the order 1 % with duration from 50 to 208 hours were found. It is shown that such dips occur 48–80 hours before X-ray solar flare events with significant reliability. Observation of such correlations can have important applications for radiation safety of space flights [5]. SOLARIS project plans to perform simultaneous measurements of Fe-55, Co-60 decay parameters at International Space Station and Earth labs. to study their correlations with X-ray solar flare events.

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## О гравитационном поле черной дыры в синхронной системе координат

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Статическое состояние черной дыры во взаимодействии с темной материей рассмотрено в синхронной системе координат. Также как и в координатах Шварцшильда, в синхронных координатах существует регулярное статическое сферически симметричное решение системы уравнений Эйнштейна и Клейна — Гордона, описывающее состояние материи, предельно сжатой собственным гравитационным полем. Также нет ограничения на массу. Также существуют два гравитационных радиуса, с граничными условиями на которых решения не являются единственными. В отличие от координат Шварцшильда, в синхронных координатах определитель метрического тензора и компонента $g^{rr}(r)$ не обращаются в нуль на гравитационных радиусах. В синхронных координатах, в отличие от координат Шварцшильда, в сферическом слое между гравитационными радиусами сигнатура метрического тензора не нарушена. В синхронных координатах уравнения Эйнштейна и Клейна — Гордона сводятся к системе второго (а не четвертого) порядка. Решения получены аналитически, так что численных расчетов не потребовалось. Определен гравитационный дефект массы в модели $\lambda\psi^4$. Полная масса материи оказывается втрое больше массы Шварцшильда, определяемой удаленным наблюдателем при сопоставлении с гравитацией Ньютона.

## On the Gravitational Field of a Black Hole in a Synchronous Coordinate System

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The static state of a black hole in interaction with dark matter is considered in a synchronous coordinate system. As well as in Schwarzschild coordinates, in synchronous coordinates there is a regular static spherically symmetric solution of the system of equations of Einstein and Klein — Gordon, which describes the state of matter, which is maximally compressed by its own gravitational field. Also with no mass limit. Also there are two gravitational radii, with boundary conditions on which the solutions are not unique. In contrast to the Schwarzschild coordinates, in synchronous coordinates the determinant of the metric tensor and the component $g^{rr}(r)$ do not vanish on the gravitational radii. In synchronous coordinates, in contrast to the Schwarzschild coordinates, in the spherical layer between the gravitational radii, the signature of the metric tensor is not violated. In synchronous coordinates, the Einstein and Klein — Gordon equations reduce to a second (rather than fourth) order system. The solutions were obtained analytically, so no numerical calculations were required. The gravitational mass defect is determined in the $\lambda\psi^4$ model. The total mass of matter turns out to be three times greater than the Schwarzschild mass, determined by a distant observer when compared with Newton's gravity.

# Constraining Teleparallel Gravity with the Dynamical System Analysis and the Cosmological Implications

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Cosmological models have been analyzed through a dynamical system analysis under the modification of teleparallel gravity as follows: A) $f(T,\ )$: The dynamical system analysis of the cosmological models under $f(T,\ )$ gravity has been studied. $T$ and denote the torsion scalar and trace of the energy-momentum tensor, respectively. It explains how first-order autonomous systems may be investigated using standard dynamical system theory methods and handled as cosmological equations. The function $f(T,\ )$ is analyzed in two ways: (i) as a linear combination of linear trace and squared torsion, and (ii) as the product of trace and higher order torsion scalar. The key points are determined for each scenario, and their stability and cosmological behaviours are shown. In both models, stable critical points are found in the de-Sitter phase, while unstable critical points are found in the phase dominated by matter and radiation. The deceleration parameter exhibits the Universe accelerating behaviour at the stable critical points, while the equation of state parameter exhibits the behaviour of the $\Lambda$CDM. Lastly, the models' generated Hubble parameters are examined for cosmological data sets. B) $f(T, T_G)$: In order to explore the late-time stable solutions in a systematic manner, a dynamical analysis is necessary and exciting. The phase-space and stability analysis provides a powerful tool for revealing global features of a cosmological scenario regardless of an initial condition or a specific evolution of the universe. In teleparallel gravity, the stable critical points and the related cosmology are obtained by adding a Gauss-Bonnet topological invariant factor. One cosmologically plausible model that can characterize various stages of the known universe evolution have been presented as part of our analysis of the dynamics of the universe. Each critical point has been supplied with the value of the deceleration parameter ($q$), the total equation of the state parameter $(\omega_{tot})$, and the dark energy equation of the state parameter $(\omega_{de})$. Furthermore, discussed are the stability and existence criteria. We investigate how the phase space trajectories behave at each critical point. Lastly, compatibility with the current cosmological scenario has been noted while comparing the development of the deceleration parameter and the equation of state parameters with the starting condition of the dynamical variables. C) $f(T,\phi)$: Gravitation is described by teleparallel-based cosmological models in which torsion acts as the gravitational mediator. It has been attempted to examine the extensions of this kind of gravity and to define more broad functions of the torsion scalar $T$ via the so-called teleparallel equivalent of general relativity, which is equal to general relativity at the level of the equations of motion. One of these extensions is called "$f(T,\phi)$ gravity", where $T$ and $\phi$ stand for the torsion scalar and scalar field, respectively. For this class of theories, a dynamical system analysis has been done in this study to determine how various models behave cosmologically. Here, two models with various functional forms of the torsion scalar are shown, and the critical points are determined. The stability behaviour and associated cosmology are shown for each critical point. The density parameters for the matter-dominated, radiation-dominated, and dark energy phases are likewise shown for both models via the graphical description.

## The Hairy Regular Black Hole by Gravitational Decoupling

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The gravitational collapse of massive stars can end up in a black hole or naked singularity formation. According to the famous singularity theorem [1], the singularity must form during the gravitational collapse, if the weak energy condition is held. However, singularities are generally regarded as indicating the breakdown of the theory, and one needs to modify the theory in this region by considering the quantum effects. Quantum field theory, applied to stationary black holes, leads to Hawking radiation which requires the negative ingoing energy flux [2]. This fact means that a black hole evaporates up to the singularity. For this reason, a regular (non-singular) black hole is considered [3]. Hayward has considered the formation and evaporation of regular black holes [4].

Another famous fact, regarding black holes, is the no-hair theorem i.e. a black hole can have only three charges — mass, electric charge and angular momentum. However, it was shown, that a black hole can have soft hair [5]. Recently, it was understood, that one can obtain a hairy black hole by using the gravitational decoupling method [6, 7].

In this work, we consider the gravitational decoupling method in order to obtain a hairy regular black hole which corresponds to the Hayward model. We modify the hairy Schwarzschild solution to obtain the regular Kretschmann scalar. The energy-momentum of a new model is considered, and we show, that there is an energy exchange between its parts.

We also consider Bardeen's black hole and obtain its hairy analogy by gravitational decoupling. Then we consider the formation and evaporation of such objects.

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# Гравитационно-волновой интерферометр, от первых идей до наших дней

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В 1962 г. М.Е. Герценштейн и В.И. Пустовойт опубликовали в журнале ЖЭТФ статью, в которой предложили и обосновали использование оптического интерферометра для детектирования гравитационных волн. В настоящем докладе показано, как развивалась эта идея, совершенствовалась конструкция гравитационно-волнового интерферометра, исследовались и снижались шумы в различных элементах детектора. В результате в 2015 году детекторы LIGO (Laser Interferometer Gravitational-Wave Observatory) впервые зарегистрировали гравитационные волны от столкновения и слияния двух черных дыр. К настоящему времени детекторы LIGO и Virgo около 100 раз зарегистрировали сигналы гравитационных волн, генерируемых при слиянии компактных объектов во Вселенной далеко от Земли. Ученые из коллабораций LIGO, Virgo и KAGRA продолжают улучшать чувствительность интерферометров и вести наблюдения. Используются все более мощные высокостабильные лазеры и сжатый свет, снижаются шумы в зеркальных покрытиях пробных масс и других элементах интерферометров. Начата разработка интерферометрических детекторов гравитационных волн нового поколения, которые по чувствительности будут значительно превосходить ныне действующие, что позволит получить ответы на многие фундаментальные вопросы физики и астрономии.

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# Gravitational-Wave Interferometer, from the First Ideas to the Present Days

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In 1962, M.E. Gertsenstein and V.I. Pustovoit published an article in the journal Soviet Physics-JETP, in which they proposed and substantiated the use of an optical interferometer for detecting gravitational waves. This report shows how this idea was developed, the design of the gravitational-wave interferometer was improved, and the noise in various elements of the detector was studied and reduced. As a result, in 2015, LIGO (Laser Interferometer Gravitational-Wave Observatory) detectors detected gravitational waves from the collision and merger of two black holes for the first time. To date, the LIGO and Virgo detectors have registered about 100 times the signals of gravitational waves generated by the merger of compact objects in the Universe far from the Earth. Scientists from the LIGO, Virgo and KAGRA collaborations continue to improve the sensitivity of interferometers and conduct observations. More powerful, highly stable lasers as well as the squeezed light are used, and noises in the mirror coatings of test masses and other elements of interferometers are reduced. The development of a new generation of interferometric gravitational-wave detectors has begun, which will significantly exceed the current ones in sensitivity, which will make it possible to obtain answers to many fundamental questions of physics and astronomy.

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# The Impossibility of the Existence of Majorana Spinors as Physical Particles

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A Majorana spinor is a charge-self-adjoint (or charge-anti-self-adjoint) solution of the Dirac equation. Such solutions were found by Majorana [1]. Dirac spinor is a superposition of charge-self-adjoint and charge-anti-self-adjoint Majorana spinors. In the Majorana representation of the Dirac gamma matrices, the charge conjugation operator is the same as the complex conjugation operator, the gamma matrices are purely imaginary, and the Majorana spinors are real with respect to complex conjugation.

Majorana spinors play an important role in modern physical theories. Most of the neutrino mass generation mechanisms are based on the presence of the Majorana mass term in the Lagrangian. In particular, the seesaw mechanism of neutrino mass generation is a leading candidate for explaining the smallness of the neutrino mass [2]. This mechanism is based on the assumption of the existence of two types of neutrinos with a common mass matrix. When such a matrix is diagonalized, light and heavy neutrinos with Majorana masses appear.

Majorana solutions of the Dirac equation certainly exist. However, we proved that for the Majorana spinor the mass term of the Lagrangian is equal to zero [3]. The non-zero mass term of the Lagrangian arises only for the products of the fields of charge-self-adjoint and charge-anti-self-adjoint Majorana spinors, one of which is Dirac-conjugate. The result is the Lagrangian of the field of the Dirac spinor.

In addition, we have proved that the Majorana solutions have zero energy and momentum for both the massive and massless cases. This means that Majorana spinors cannot correspond to physically existing particles.

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## Anisotropic Compact Stars in Energy-Momentum Squared Gravity

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The main objective of this paper is to examine the viability and stability of anisotropic compact stellar objects adopting the Karmarkar condition in energy-momentum squared gravity. For this purpose, we take a static spherical metric in the inner and Schwarzschild spacetime in the outer region of the stars. The values of unknown parameters are found by the observational values of mass and radius of the considered compact stars. We consider a particular model of this theory to investigate the behavior of energy density, pressure components, anisotropy, equation of state parameters and energy bounds in the inner region of the proposed stellar objects. The equilibrium state of the stellar models is examined via the Tolman — Oppenheimer — Volkoff equation and their stability is analyzed by causality condition, Herrera cracking approach and adiabatic index. We find that Karmarkar solutions in this modified theory are physically viable and stable for anisotropic stellar objects.

## Траектории массивных тел в метрике Коттлера

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Несмотря на объяснение ΛCDM-моделью наблюдаемого ускоренного расширения Вселенной, вопрос о знаке и величине космологической постоянной (Λ-член в уравнениях Эйнштейна) остается открытым. С одной стороны, это связано с тем, что физический механизм ускоренного расширения Вселенной не однозначен. Последнее позволяет строить космологии в многочисленных теориях, либо расширяющих, либо альтернативных ОТО (новая физика и новая геометрия). С другой стороны, наличие в уравнениях гравитационного поля Λ-члена с отличными от принятых в ΛCDM-модели значениями, позволяет объяснить некоторые другие наблюдаемые астрофизические явления (например, кривые вращения некоторых галактик [1]). Указанная ситуация делает актуальными исследования следствий, обусловленных различными значениями Λ-члена в уравнениях Эйнштейна.

В настоящей работе изучаются различные типы траекторий массивных тел в центрально-симметричном гравитационном поле с учетом Λ-члена, описываемых в рамках ОТО метрики Коттлера [2]

$$ds^2 = \left(1 - \frac{r_g}{r} - \frac{1}{3}\Lambda r^2\right)(cdt)^2 - \left(1 - \frac{r_g}{r} - \frac{1}{3}\Lambda r^2\right)^{-1} dr^2 - r^2\left(d\theta^2 + \sin^2\theta d\varphi^2\right), \qquad (1)$$

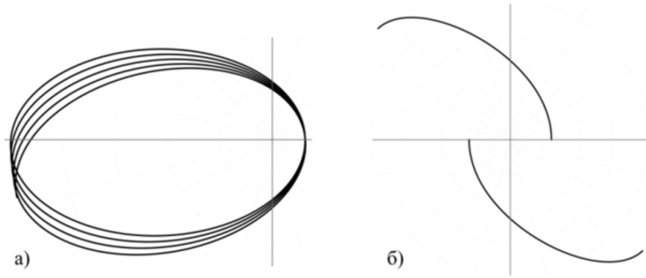
где $r_g$ — гравитационный радиус центрального тела; Λ — космологическая постоянная. Общее выражение для траектории получается стандартными методами ОТО [3] и имеет в полярных координатах вид

$$\varphi = \pm\int \frac{jdr}{\sqrt{r\left(\frac{1}{3}\Lambda\, r^5 + Kr^3 + r_g r^2 - j^2 r + j^2 r_g\right)}}, \qquad (2)$$

где $j$ — отнесенный к скорости света момент импульса, величина $K = 1 - \left(\frac{E}{mc^2}\right)^2$ характеризует относительную энергию частицы.

Правая часть уравнения (2) не выражается через эллиптические интегралы из-за наличия полинома пятой степени в подкоренном выражении. В настоящей работе, основываясь на аналитическом методе исследования корней многопараметрических полиномов, интеграл в (2) приближенно упрощается в зависимости от соотношений входящих в него параметров.

На основании такого подхода получены круговые и некруговые траектории массивных тел. Выделяются условия существования различных типов траекторий в виде неравенств на параметры уравнения. Проводится классификация типов траекторий и дается их графическое представление. Примеры типичных траекторий представлены на рисунке.




Траектории:
*а* — розетка Зоммерфельда; *б* — спираль

Различные типы траекторий возникают при разных соотношениях параметров: гравитационного радиуса центрального тела, энергии и момента импульса частицы, значения Λ. Подобные траектории могут наблюдаться в различных астрофизических системах, например, в галактиках. Сопоставление теоретически предсказанных и наблюдаемых траекторий даст возможность судить о знаке и величине постоянной Λ.

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## Orbits of Massive Particles in Köttler Metric

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Despite the fact that the ΛCDM model explains the observed accelerated expansion of the Universe, the question of the sign and magnitude of the cosmological constant (the $\Lambda$ -term in the Einstein equations) remains open. On the one hand, this is related to the physical mechanism of the accelerated expansion of the Universe being not unambiguous. The latter makes it possible to propose cosmological models in numerous theories, either expanding or alternative to general relativity (Physics beyond the Standard Model and Nijenhuis geometry). On the other hand, the presence of a Λ-term in the equations of the gravitational field with values that differ from those accepted in the ΛCDM model opens up a possibility to explain some other observed astrophysical phenomena (e. g. the rotation curves of several galaxies [1]). This situation makes it relevant to study the consequences of assuming different values of the Λ-term in the Einstein equations.

In this paper, we study various types of trajectories of massive particles in a centrally symmetric gravitational field, taking into account the lambda-term. In general relativity, such a field is described by the Kottler metric [2]

$$ds^2 = \left(1 - \frac{r_g}{r} - \frac{1}{3}\Lambda r^2\right)(cdt)^2 - \left(1 - \frac{r_g}{r} - \frac{1}{3}\Lambda r^2\right)^{-1} dr^2 - r^2\left(d\theta^2 + \sin^2\theta d\varphi^2\right), \quad (1)$$

where $r_g$ is the Schwarzschild radius of the central body, $\Lambda$ is the cosmological constant. The general equation of the trajectory is obtained by standard GR methods [3] and has the following form in polar coordinates

$$\varphi = \pm\int \frac{jdr}{\sqrt{r\left(\frac{1}{3}\Lambda r^5 + Kr^3 + r_g r^2 - j^2 r + j^2 r_g\right)}}, \quad (2)$$

where $j$ is the angular momentum reduced to the speed of light $c$, and $K = 1 - \left(\frac{E}{mc^2}\right)^2$ is related to the energy of the particle.

The right side of equation (2) cannot be expressed in terms of elliptic integrals due to the presence of a polynomial of the fifth degree in the radical expression. In the present study, we find approximations for integral given by (2) depending on the ratios of the parameters included in it, based on the analytical method for studying the roots of multiparameter polynomials. Based on this approach, circular and non-circular trajectories of massive particles are obtained. Conditions for the existence of various types of trajectories are singled out in the form of inequalities for the parameters of the equation. A classification of types of trajectories is carried out and their graphical representation is given. Examples of typical trajectories are shown in Fig.

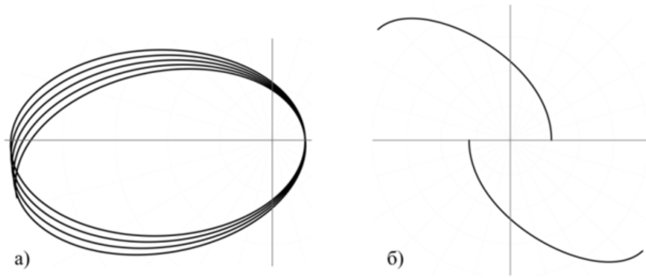


**Fig. 1. Trajectories:**
a — Sommerfeld ellipses; b — a spiral

Different types of trajectories arise at different ratios of the parameters: the gravitational radius of the central body, the energy and angular momentum of the particle, and the value of Λ. Similar trajectories can be observed in various astrophysical systems, for example, in galaxies. Comparison of the theoretically predicted and observed trajectories will make it possible to estimate the sign and magnitude of the constant Λ.

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## Phantom Cosmological Model with Observational Constraints in *f*(*Q*) Gravity

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In this paper, the cosmological model of the Universe has been presented in $f(Q)$ gravity and the parameters are constrained from the cosmological data sets. At the beginning, we have employed a well-motivated form of $f(Q)=\alpha+\beta Q^n$, where α, β and *n* are model parameters. We have obtained the Hubble parameter in redshift with some algebraic manipulation from the considered form of $f(Q)$. Then we parameterize with the recent *Hubble* data and *Pantheon* + *SHOES* data using *MCMC* analysis. We validate our obtained model parameter values with *BAO* data set. A parametrization of the cosmographic parameters shows the early deceleration and late time acceleration with the transition at $z_t \approx 0.75$. The *Om*(*z*) diagnostics gives positive slope which shows that the model in the phantom phase. Also the current age of Universe has been obtained as, $t_0 \approx 13.85\,Gyrs$. Based on the present analysis, it indicates that the $f(Q)$ gravity may provide an alternative to dark energy for addressing the current cosmic acceleration.

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# Quantum Sensitivity of Broadband Variational Measurememnt

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Optomechanical force detectors are precise measurement devices sensitive to the effects that show up at scales with order of 10-19 m. They are used in gravitational wave detectors, magnetometers and torque sensors due to their precision. Another notable application is measurement of thermal noise of mechanical oscillator and distinguishing the excess noise that may point to new mechanisms of physical interaction [1]. Resonant detectors are more sensitive and have an advantage over nonresonant in these experiments.

One of the models capable of realization of such a detector is an optomechanical scheme with three equidistant optical modes that have frequency difference equal to the frequency of the mechanical oscillator coupled to the optical cavity [2]. One of its properties is a possibility of broadband beating the standard quantum limit of force measurement related to back action evasion [3]. It is possible due to quantum mechanics free subsystems that exist in this scheme, the presence of which gives the theoretical possibility of precise measurement of a quantum observable [4].

Quantum sensitivity of such an optomechanical system is considered in this work. Presence of quantum mechanics free subsystems leading to back action evasion is shown.

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## К вопросу о геометризации классических полей

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Исследуется возможность геометризации гравитационного и электромагнитного полей в 4-мерном финслеровом [1] пространстве (Модель Вложенных Пространств — МВП [2]). Модель постулирует существование собственного метрического множества элемента распределенной материи и утверждает, что реальное пространство-время является взаимным физическим *Вложением* таких множеств. (*Вложение* можно трактовать также как частный случай расслоенного пространства [3].) Строится простейшая геометрия МВП (релятивистский финслеров вариант) со связностью, зависящей от свойств материи и ее полей (предполагается, что кручение и неметричность отсутствуют). Полевая гипотеза и ПНД системы материя — поле ведут к уравнениям типа Эйнштейна и типа Максвелла, а их нелинейности — к анизотропному полевому вкладу в затравочную массу материи. Показано, что затравочная материя играет роль физического вакуума *Вложения* и определяет космологическую константу уравнений типа Эйнштейна. В частном случае конформной метрики и векторного потенциала (гипотеза Г. Вейля [4]) уравнения типа Максвелла сводятся к самим уравнениям Максвелла и *отрицательному* полевому электромагнитному вкладу. Оценена возможность экспериментальной проверки данного результата. Упомянут также эффект “red shift” в электрическом поле [5] — как способ исследования вакуума и реликтового электрического заряда Вселенной. Изучение калибровочной структуры изложенной теории отнесено к задачам будущего.

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## On the Geometrization of Classical Fields

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The possibility of geometrization of the gravitational and electromagnetic fields in the 4-dimensional Finsler space [1] (Model of Embedded Spaces — MES [2]) is investigated. The model postulates the existence of the proper metric manifold of the distributed matter element and states that the real space-time is a mutual physical *Embedding* of such manifolds. (Embedding can also be treated as a special case of fiber space [3].) The simplest geometry of MES (relativistic Finsler version) with connectedness depending on the properties of matter and its fields is constructed (assuming that torsion and non-metricity are absent). The field hypothesis and the Least Action Principle of the matter-field system lead to the equations of Einstein- and Maxwell-types, and their nonlinearities lead to an anisotropic field contribution to the matter's seed mass. It is shown that the seed matter plays the role of the physical vacuum of the *Embedding* and determines the cosmological constant of the Einstein-type equations. In the special case of conformal metric and vector potential (H. Weyl hypothesis [4]) the Maxwell-type equations are reduced to the proper Maxwell equations and the *negative* field electromagnetic contribution. The possibility of experimental verification of this result is evaluated. The "red shift" effect in the electric field [5] is also mentioned as a way to study the vacuum and the relic electric charge of the Universe. The study of the calibration structure of the above theory belongs to the task of future research.

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# Particle Accelerators and Gravitational Waves: Old and New Perspectives

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The intersection between the Communities of Particle Accelerator (PA) and Gravitational Wave (GW) Researchers has been traditionally non-void at all levels, and the possibility of using PA technologies and facilities to implement GW experiments has been long since suggested and discussed.

The achieved milestones represented by the direct observation of gravitational waves of cosmic origin and the Higgs boson raised significantly the challenges for further advances in both fields, and the perspectives of renewed synergies between the two Communities were revived, as witnessed by a recent topical Meeting hosted at CERN [1].

Earth-bound GW detectors may explore only a relatively narrow window of the natural GW spectrum. Space-borne detectors and pulsar-timing observatories may access the LF to ELF GW spectral range, and different detectors have been proposed to probe possible GW sources in the MF to SHF range [2]. While the direct use of storage rings and colliders as sources/detectors of gravitational waves may still face substantial difficulties, significant advances of PA technologies in the field of superconducting materials, with special reference to high-field magnets, and extremely high-Q EM resonators, may boost significantly the performance of proposed HF-SHF GW detectors based on Gertsenshtein effect [3], and perhaps bring us closer to the possibility of a gravitational Hertz experiment [4].

We shall briefly review such ideas, and discuss possible directions for further cooperative work between the PA and GW Communities.

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## Внутренняя связь уравнений теории поля

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Настоящее исследование базируется на замкнутых кососимметричных внешних формах, свойства которых соответствуют законам сохранения для физических полей. Можно увидеть, что уравнения теории поля связаны с замкнутыми внешними формами определенной степени:

• замкнутые внешние формы нулевой степени соответствуют квантовой механике,

• формализм Гамильтона основан на свойствах замкнутых внешних форм первой степени,

• свойства замкнутости внешней и дуальной форм второй степени являются базисом уравнений электромагнитного поля,

• условия замкнутости внешней и дуальной форм третьей степени лежат в основе уравнений гравитационного поля.

Связь уравнений теории поля с замкнутыми внешними формами показывает, что существует внутренняя связь теорий, описывающими физические поля разного типа.

Значение внешних дифференциальных форм для теорий поля состоит в том, что они раскрывают свойства, общие для всех теорий поля и физических полей независимо от их конкретного типа. Это шаг к построению единой теории поля.

## Internal Connection of Field Theory Equations

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The present study is based on closed skew-symmetric exterior forms, the properties of which correspond to the conservation laws for physical fields. It can be seen that the equations of field theory are related to closed exterior forms of a certain degree:

- closed exterior forms of zero degree correspond to quantum mechanics,
- Hamilton's formalism is based on the properties of a closed exterior form of the first degree,
- the properties of closure of the exterior and dual forms of the second degree are the basis of the equations of the electromagnetic field,
- the conditions of closure of the exterior and dual forms of the third degree underlie the equations of the gravitational field.

The connection of the equations of field theory with closed exterior forms shows that there is an internal connection of theories describing physical fields of different types.

The significance of exterior differential forms for field theories is that they reveal properties common to all field theories and physical fields, regardless of their particular type. This is a step towards building a unified field theory.

# Multimaterial Mirrors for Interferometric Gravitational Wave Detectors: Recent Results

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The dielectric reflective multilayers coating the end-mirrors (test masses) of the optical cavities in interferometric detectors of gravitational waves are a most critical component of these instruments, ultimately setting their visibility distance [1]. Optimizing the mirror design has been crucial for the first detection [2].

The use of three or more metal oxides, and of best-tradeoff meta-heuristic optimizers to sample the related Pareto manifold efficiently, allows to meet all design requirements of next generation detectors (in terms of transmittance, absorbance and Brownian noise) with currently available technologies [3].

Design algorithms, material downselection, and latest results [4] will be reviewed, and their impact on the perspective visibility distance of 3G instruments will be discussed.

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## An extension of General Relativity with Energy Conservation and Inflation Conditions

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Within the framework of the metric gravity with gravitational action depended on the Ricci scalar ($R$) and Gauss-Bonnet topological invariant ($G$) the possible function $F(R, G)$ compatible with the conservation of the respective Hamiltonian and with the inflation conditions (the number of e-foldings, experimental data on the spectral index ($n_s$), and tensor-to-scalar ratio ($r$)) is suggested and discussed. Without cosmological constant and dark matter this model fits well SN Ia and BAO data.

# Неунитарность операторов эволюции в гравитационных полях

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В квантовой механике используется концепция неизменности нормы вектора у оператора эволюции $\hat{U}^{\dagger}\hat{U} = I$, т. е. операторы эволюции являются унитарными. Однако испарение черных дыр, ведущее к информационному парадоксу, нарушает принцип унитарности. Необходимо отметить, что унитарность операторов не является свойством природы, а является математической моделью используемой в квантовой механике, которая к тому же может нарушаться, например в процессе измерения.

В докладе будет рассмотрен вариант квантовой механики, в котором операторы эволюции не являются унитарными, а норма вектора зависит от гравитационного потенциала $\hat{U}^{\dagger}\hat{U} = Ig_{00}$, где $g_{00}$ — нулевая компонента тензора метрики, определяемая гравитационным потенциалом. Такой подход позволяет сохранить инвариантность нормы вектора состояния в четырехмерном пространстве, но приводит к нарушению инвариантности нормы вектора состояния трехмерного пространства в сильных гравитационных полях.

Зависимость нормы вектора от гравитационного потенциала приводит к таким интересным следствиям, как неинвариантности скалярного произведения двух векторов состояний в гравитационных полях и вне, изменению собственных значений наблюдаемых величин в гравитационных полях, не сохранению коммутационных соотношений и, как следствие, возможности одновременного измерения любых двух величин вблизи горизонта событий черной дыры, уменьшение вероятности обнаружения частицы в каком либо состоянии вблизи массивных тел. Также в докладе будет показана зависимость энтропии фон Неймана от расстояния до центра черной дыры. Интересным является увеличение энтропии даже для чистого состояния по мере приближении к черной дыре, которое можно трактовать как переход любой системы из чистого состояния в смешанное, и в то же время резкое уменьшение энтропии вблизи горизонта черной дыры для любого смешанного состояния.

Можно полагать, что найденное решение может служить основой для решения информационного парадокса.

## Non-Unitarity of Evolution Operators in Gravitational Fields

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Quantum mechanics uses the concept of vector norm immutability in the evolution operator $\hat{U}^{\dagger}\hat{U} = I$, meaning that the evolution operators are unitary. However, as black hole evaporation leads to the information paradox, it violates the unitarity principle. It should be noted that operator unitarity is not a property of nature, but a mathematical model used in quantum mechanics, which can also be violated, for example, during measurement.

The paper will consider a variant of quantum mechanics, in which evolution operators are not unitary, and the vector norm depends on the gravitational potential $\hat{U}^{\dagger}\hat{U} = Ig_{00}$, where $g_{00}$ is the zero component of the metric tensor, as determined by the gravitational potential. This approach makes it possible to preserve the norm invariance for the state vector in four-dimensional space, but leads to violation of the norm invariance for the state vector describing three-dimensional space in strong gravitational fields.

The fact that the vector norm depends on the gravitational potential leads to such interesting consequences as: non-invariance of the scalar product of two state vectors within and outside of gravitational fields; a change in the eigenvalues of the observed quantities in gravitational fields; non-conservation of commutation relations and, as a result, a possibility of simultaneously measuring any two quantities near the event horizon of a black hole; reducing the probability of detecting a particle in any state near massive bodies. The paper also presents von Neumann entropy as a function of distance to the center of the black hole. Of particular interest is the increase in entropy even for the pure state while approaching the black hole, which can be interpreted as the transition of any system from the pure state to the mixed state, and at the same time, a dramatic decrease in entropy near the black hole horizon for any mixed state.

We may assume that the solution discovered may serve as a basis for solving the information paradox.

# О слияниях двойных первичных черных дыр в наблюдениях LIGO-Virgo-KAGRA

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Целью работы является построение комбинированной модели для расчета ожидаемого распределения сливающихся двойных черных дыр с привлечением распределения по массам источников двойных первичных черных дыр (ПЧД) и астрофизических моделей и дальнейшее ее сравнение с эмпирической функцией распределения по данным из наблюдений O1-O3 LIGO/Virgo.

Рассматривается модель ПЧД звездных масс, которые могут образовываться из возмущений кривизны в ранней Вселенной (модель Долгова — Силка [2]). В этой модели, распределение ПЧД по массам имеет вид универсального логнормального закона [1]:

$$F(M) \equiv \frac{dN}{dM} = \frac{A}{M} \exp\left[ -\gamma \ln\left( \frac{M}{M_c} \right) \right].$$

В модели есть три свободных параметра — A можно определить из условия $\int_0^{+\infty} F(M)dM = 1,$ средняя масса первичных черных дыр $M_c$ и дисперсия $1/\sqrt{2\gamma},$ которые нельзя рассчитать теоретически, но можно определить из наблюдений черных дыр звездной массы, предполагая их первичное происхождение.

По данным GWTC-3 из недавних наблюдений O1-O3 коллаборации LIGO/Virgo [4] была построена эмпирическая функция распределения. А также, рассмотрен случай комбинированной модели, где для расчета ожидаемого распределения сливающихся двойных ПЧД по массам при регистрации наземными гравитационно-волновыми детекторами LIGO/Virgo с учетом их актуальной чувствительности в новых наблюдениях O1-O3 использовались два распределения. Одним из распределений была логнормальная функция распределения по массам источников в двойных системах, а вторым распределением была функция распределения по массам источников в двойных системах, рассчитанной из астрофизических моделей образования двойных черных дыр, предложенных в работе Постнова и Куранова 2019 года [6].

При определенных параметрах логнормального распределения, с использованием одной из астрофизических моделей, теоретическая кривая достаточно хорошо описывает эмпирическую функцию распределения, построенную по наблюдениям O1-O3 LIGO/Virgo. Наиболее хорошо эмпирическое распределение описывает комбинированная теоретическая модель с параметрами лог-нормального распределения $M_c = 33M_{Sun}$ ($M_{Sun}$ — масса Солнца) и γ = 10, а также с параметром $CO\_al = 1$ ($CO\_al$ – параметр общей оболочки) астрофизической модели.

При построении комбинированной модели в части, относящейся к ПЧД, рассматривались две модели формирования двойных ПЧД, названные “pbh 1” [3] и “pbh 2” [5]. Обе модели дают примерно одинаковые результаты. Комбинированная модель включает почти равные вклады от слияний астрофизических двойных ЧД ($x_{abh} = 0,47$)) и первичных ЧД с исходным логнормальным спектром масс ($x_{pbh} = 0,53$). Обе модели дают долю ПЧД в холодной темной материи $f_{\text{pbh}} \sim 10^{-3}$ для наблюдаемой скорости слияния ЧД + ЧД. Комбинированное распределение соответствует эмпирической функции распределения на уровне 90 % в соответствии с модифицированным тестом Колмогорова — Смирнова (КС).

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# On mergers of Primordial Binary Black Holes in LIGO-Virgo-KAGRA Observations

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The study aims to construct a combined model for computing the expected distribution of merging binary black holes using the mass distribution of binary primordial black hole (PBH) sources and astrophysical models, and then to compare the result to the empirical distribution function plotted according to the O1-O3 LIGO/Virgo observation data.

We consider the model describing PBH of stellar masses that may be formed from curvature perturbations in the early Universe (Dolgov-Silk model [2]). In this model, the PBH distribution by mass has the form of a universal log-normal law [1]:

$$F(M) \equiv \frac{dN}{dM} = \frac{A}{M} \exp\left[-\gamma \ln\left(\frac{M}{M_c}\right)\right]. \quad (1)$$

The model has three free parameters, of which A can be determined from the condition $\int F(M)dM = 1$, while the average PBH mass $M_c$ and the variance $1/\sqrt{2\gamma}$ cannot be computed theoretically, but may be determined from observations of stellar-mass black holes, assuming their primordial origin.

According to GWTC-3 data, an empirical distribution function was plotted using the recent O1-O3 observations by the LIGO/Virgo collaboration [4]. We also considered the case of a combined model using two distributions to calculate the expected mass distribution of merging binary PBH as recorded by ground-based gravitational wave LIGO/Virgo detectors, taking into account their current sensitivity in new O1-O3 observations. One of the distributions was the log-normal mass distribution function describing sources in binary systems, and the second distribution was the mass distribution function describing sources in binary systems that was computed using astrophysical models of binary black hole formation proposed by Postnov and Kuranov in 2019 [6].

For certain parameters of the log-normal distribution while using one of the astrophysical models, the theoretical curve adequately matches the empirical distribution function based on the O1-O3 LIGO/Virgo observations. The best match to the empirical distribution is provided by the combined theoretical model with the parameters of the log-normal distribution $M_c = 33M_{\text{Sun}}$ ($M_{\text{Sun}}$ — mass of the Sun) and $\gamma$ = 10, as well as with the parameter $\text{CO}_{\text{al}} = 1$ ($\text{CO}_{\text{al}}$ — the shared shell parameter) of the astrophysical model.

When devising the PBH aspects in the combined model, we considered two models of binary PBH formation, dubbed “pbh 1” [3] and “pbh 2” [5]. Both models give approximately the same results. The combined model includes nearly equal contributions from the mergers of astrophysical binary black holes ($x_{abh} = 0.47$) and the primordial black holes with the original log-normal mass spectrum ($x_{\text{pbh}} = 0.53$). Both models result in the PBH fraction in cold dark matter equal to $f_{\text{pbh}} \sim 10^{-3}$ for the observed rate of black hole merging. The combined distribution is a 90 % match to the empirical distribution function according to a modified Kolmogorov-Smirnov test (KS).

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## Cosmological Models with Big Rip and Pseudo RipScenarios in Extended Theory of Gravity

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This work aims to give an insight to the role of big rip and pseudo rip cosmological models in an extended theory of gravity. The matter field is considered to be that of perfect fluid. The geometrical parameters are adjusted in such a manner that it matches the prescriptions given by cosmological observations, to be specific to the $H_0$ range. The models favour phantom behaviour. The violation of strong energy conditions are shown in both the models, as it has become essential in an extended gravity theory to provide late time cosmic acceleration. We show that, the choice of the coupling parameter has significant effects on the evolution of the universe.

## The Coming Back of the Proca Field in Contemporary Astrophysics

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A new version of the old Weyl's unified field theory based on a strict application of the principle of gauge invariance leads to the appearance of a massive vector field, which has an entirely geometric nature and can be interpreted, under some conditions, as the Proca field. We investigate some possible consequences of the presence of this field in modern astrophysical scenario.

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## О финслеровом расширении специальной теории относительности

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Мы показываем, что определение релятивистского интервала, данное Роббом — Герохом, допускает простое и довольно естественное обобщение, ведущее к финслеровому расширению специальной теории относительности. Другое обоснование такого расширения восходит к работам Лалана и Алвея и, наконец, было поставлено на прочную основу и систематически исследовано Богословским под названием «Специально-релятивистская теория локально анизотропного пространства-времени». Группа изометрий этого пространства-времени, DISIMb(2), представляет собой деформацию группы симметрии специальной теории относительности Коэна и Глэшоу ISIM(2). Таким образом, параметр деформации $b$ можно рассматривать как аналог космологической постоянной, характеризующей деформацию группы Пуанкаре в группу де Ситтера (анти-де Ситтера). Простота и естественность финслерова расширения в контексте этой статьи придает вес аргументу о том, что следует тщательно рассмотреть возможность ненулевого значения $b$.

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## On Finslerian Extension of Special Relativity

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We demonstrate that Robb-Geroch’s definition of a relativistic interval admits a simpleand fairly natural generalization leading to a Finsler extension of special relativity. An-other justification for such an extension goes back to the works of Lalan and Alway and,finally, was put on a solid basis and systematically investigated by Bogoslovsky underthe name ”Special-relativistic theory of locally anisotropic space-time”. The isometrygroup of this space-time, DISIMb(2), is a deformation of the Cohen and Glashow’s veryspecial relativity symmetry group ISIM(2). Thus, the deformation parameterbcan beregarded as an analog of the cosmological constant characterizing the deformation of thePoincar ́e group into the de Sitter (anti-de Sitter) group. The simplicity and naturalnessof Finslerian extension in the context of this article adds weight to the argument thatthe possibility of a nonzero value ofbshould be carefully considered.

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## Maxwell — Dirac System in Cosmology

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Within the scope of a Bianchi type-I (BI) cosmological model we study the interacting system of spinor and electromagnetic fields and its role in the evolution of the Universe. In some earlier studies [1, 2] it was found that in case of a pure spinor field the energy-momentum tensor (EMT) possesses nontrivial non-diagonal elements which imposes some severe restrictions on the space-time geometry and spinor field itself. This very fact leads to the following results: (i) spinor field becomes massless and linear; (ii) the BI space-time transforms into a locally rotationally symmetric (LRS — BI) or (iii) it evolves into a FLRW space-time from the very beginning. The motivation to introduce an electromagnetic field together with the spinor one is to clarify whether this move can bring any essential changes to the space-time geometry. The interacting system is given in the form

$$L = \frac{\imath}{2}\left[\bar{\psi}\gamma^{\mu}\nabla_{\mu}\psi - \nabla_{\mu}\bar{\psi}\gamma^{\mu}\psi\right] - m\bar{\psi}\psi - \lambda_1 F(K) - \frac{1}{16\pi}F_{\tau\eta}F^{\tau\eta}H(K), \quad (1)$$

where $m$ is the spinor mass, $F(K)$ and $H(K) \equiv 1 + \lambda_2 \ddot{F}(K)$ are the functions of $K = \{I, J, I+J, I-J\}$, $I = S^2 = (\bar{\psi}\psi)^2$, $J = P^2 = (\imath\bar{\psi}\bar{\gamma}^5\psi)^2$, describe the self-coupling and interaction with the electromagnetic field, respectively. The gravitational field we choose in the form

$$ds^2 = dt^2 - a_1^2(t)dx_1{}^2 - a_2^2(t)dx_2{}^2 - a_3^2(t)dx_3{}^2. \quad (2)$$

The electromagnetic 4-potential is taken as $A_\mu = (0, A_1, A_2, A_3)$. Assuming that $\psi = \psi(t)$, $\bar{\psi} = \bar{\psi}(t)$ and $A_i = A_i(t)$, $i = 1,2,3,$ the nontrivial non-diagonal components of the EMT leads to the following interesting relation between electromagnetic, spinor and gravitational fields:

$$q_1 a_1 A^1 q_2 a_2 A^2 + q_2 a_2 A^2 q_3 a_3 A^3 + q_3 a_3 A^3 q_1 a_1 A^1 = 0, \quad (3)$$

where $q_i, a_i$ and $A^i$ are related to the electromagnetic, gravitational and spinor fields, respectively. In this case restrictions, mentioned earlier for a pure spinor field, do not occur.

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## Wormhole: Is it Science or Science Fiction?

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A wormhole is a special solution to the equations describing Einstein's theory of general relativity, connecting two distant points in space or time via a tunnel. Ideally, the length of this tunnel is shorter than the distance between those two points, making the wormhole a kind of shortcut. Though they make for good science fiction as ways for faster-than-light-speed travel between two extremely distant points in the universe. They are legitimate solutions to general relativity, but scientists have never figured out a way to maintain a stable wormhole in the real universe. Nowadays, one of the biggest arguments is ***"Wormholes are real Science or Science fiction"***. Here, we discuss the geometrical developments to present the wormhole structures and scientific measurements to test these types of theories.

## Stability of Non-Relativistic Bose Stars

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The nature of dark matter (DM) is one of the fundamental problems in modern astrophysics. Its presence in the Universe today is a well motivated by observational facts. However, it is still unknown which particles consist in DM, and a number of theories provide us with various candidates for DM.

One of the popular models of cold DM is light (pseudo)scalar bosons that form a Bose-Einstein condensate (BEC). Under gravity the condensed bosons combine into compact objects, which are called Bose stars.

There are two mechanisms preventing a gravitational collapse. The first one is so-called quantum pressure and provided by the Heisenberg uncertainty principle, when all the bosons are in the same quantum state. An alternative way implies repulsive self-interaction between the condensed particles, which balances gravity. An approach with non-interacting bosons is known as a kinetic regime. The opposite approach, when quantum pressure is ignored, is Thomas-Fermi approximation.

We study numerically stabilities of the Bose stars both for interacting and non-interacting bosons. Small perturbations in Bose stars under the Thomas-Fermi approximation were considered taking into account variations of the gravitational potential. All modes, both radial and non-radial, are oscillating, which indicates that the Bose star is stable with respect to small perturbations.

Radial perturbations in Bose stars consisting of non-interacting bosons under Cowling approximations (variations of the gravitational potential are ignored) were considered. Numerical solutions for the perturbations incorporate growing modes, which indicates that the Bose star is unstable in this case.

Studies on the stability of Bose stars, taking into account both quantum pressure and self-interaction, can give new constraints for the BEC DM models.

## Различные космологические модели инфляции с вращением

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Построены три космологические модели для метрики типа IX по Бьянки.

В первом случае построен космологический сценарий с вращением с хаотической инфляцией. Описаны фридмановские этапы космологии. Установлено, что в современную эпоху темная энергия, описываемая анизотропной жидкостью, практически не вращается.

Во втором случае рассматривается первая стадия инфляции для случая инфляции с вращением вблизи максимума потенциала. Исследована эволюция вращения темной энергии, моделируемой анизотропной жидкостью. В рассматриваемом решении на всех стадиях фридмановской эволюции зависимость масштабного фактора от времени совпадает с аналогичной во фридмановской космологии, а на поздних временах будет иметь место ускоренное расширение Вселенной.

В третьем случае рассматривается первая инфляционная стадия с вращением для двух скалярных полей — так называемая «гибридная инфляция». В качестве источников гравитации на этапе ранней инфляции используется анизотропная жидкость и два скалярных поля.

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## Various Cosmological Models of Inflation with Rotation

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Three cosmological models for the Bianchi type IX metric are constructed. In the first case, a cosmological scenario with rotation with chaotic inflation is constructed. Friedman stages of cosmology are described. It is established that in the modern era, dark energy, described by an anisotropic liquid, practically does not rotate. In the second case, the first stage of inflation is considered for the case of inflation with rotation near the maximum potential. The evolution of the rotation of dark energy modeled by an anisotropic liquid is investigated. In the solution under consideration, at all stages of Friedman evolution, the dependence of the scale factor on time coincides with that in Friedman cosmology, and at later times there will be an accelerated expansion of the Universe. In the third case, the first inflationary stage with rotation for two scalar fields is considered — the so-called "hybrid inflation". An anisotropic fluid and two scalar fields are used as sources of gravity at the stage of early inflation.

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# О теории гравитации Вейля — Дирака и ее развитии

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Столетие назад Г.Вейль предложил теорию гравитации, использующую локальную симметрию относительно калибровки измерений. Идеи Г. Вейля актуальны и сейчас. Количество публикаций, основанных на этих идеях, постоянно увеличивается.

В последние годы рассматриваются различные варианты применения вейлевской (локальной конформной) симметрии к гравитации с точки зрения модификации общей теории относительности (ОТО) для описания темной материи, темной энергии, эволюции ранней Вселенной. Модификации ОТО с учетом локальной конформной инвариантности исследуются в течение долгого времени как попытки решения различных проблем, в частности: способов перенормировок в квантовой гравитации, перенормировки тензора энергии-импульса, динамики инфляции в ранней Вселенной и появления массы у элементарных частиц.

В докладе обсуждаются модели конформной гравитации с лагранжианами, линейными по скалярной кривизне и неминимальной связью со скалярным полем. Предложен новый вариант конформного лагранжиана с двумя скалярными полями, в котором вектор Вейля заменен на вектор, преобразующийся как и вектор Вейля, но не входящий в вейлевскую связность. Пространством такой модели является интегрируемое пространство Вейля [1].

В рамках теории гравитации Вейля с неминимальной связью вещественного скалярного поля рассмотреназадача описания конформной стадии эволюции Вселенной на основе метрики Фридмана. Приведены конформно-инвариантные решения для масштабного фактора и показано, что квантовые поправки к следу тензора энергии-импульса частично компенсируются калибровкой функции Дирака, приводящей к лагранжиану общей теории относительности [2].

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## About Weyl — Dirac Theory of Gravitation and Its Development

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One hundred years ago H.Weyl proposed a theory of gravitation, which uses local symmetry with regard to measurement gauging. The ideas of H.Weyl are still urgent today. The number of papers on the basis of these ideas continuously grows.

During recent years different ways of applying Weyl (local conformal) symmetry in gravitation theory have being considered from the point of view of modification of general relativity (GR) to describe dark matter, dark energy, and evolution of early Universe. Modifications of GR with local conformal invariance have been examined for a long time as attempts to solve different problems; in particular, these are the methods of renormalization in quantum gravitation, renormalization of the energy-momentum tensor, dynamics of inflation in early Universe and the origin of masses of elementary particles.

Models of conformal gravitation that contain Lagrangians, which are linear on scalar curvature and with nonminimum connection with two scalar field, are discussed in this report. Theory of Weyl-Dirac gravitation has been reported in detail. A new version of conformal Lagrangian with two scalar fields is proposed, in which the Weyl vector is replaced with the vector which is transformed as a Weyl vector, but is not contained in Weylian connection. Weyl integrable space is the space of such model [1].

The problem of description a conformal stage in the evolution of the Universe on the basis of Friedmann metrics is considered within Weyl-Dirac gravitation theory with nonminimum connection with the real scalar field. Conformal invariant solutions for the scale factor are presented. It is demonstrated that quantum corrections to the trace of energy-momentum tensor are partially compensated by gauging the Dirac function, which results in the Lagrangian of the General Relativity theory [2].

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## Axionic Extension of the Einstein — Maxwell Aether Theory

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We work in the framework of the axionic extension of the dynamic aether theory, which is a modified vector-tensor theory of gravity. The key elements of the theory are the dynamic aether velocity four-vector [1] and the pseudoscalar field identified with axionic dark matter [2]. By the variational formalism, the master equations for the evolution of the axion field, the velocity field of the dynamic aether, and the gravitational field have been obtained [3, 4]. In these papers, for various potentials of the axion field, exact cosmological solutions are found. These solutions describe the isotropic Friedman cosmological model. Introducing into consideration various potentials of interaction of the axion field with the aether field, we study the concept of regulating the state of axionic dark matter due to interaction with the aether flow.

In work [5], the master equations for the evolution of the axion field, the field of the dynamic aether, the electromagnetic and gravitational fields were also obtained. The main difference of this work is an anisotropic homogeneous cosmological model of the Bianchi-I type. A feature of this model is that the covariant derivative of the aether velocity four-vector has two nonvanishing components — the extension scalar and the shear tensor, in contrast to isotropic models, where only the extension scalar is nonvanishing.

In the work [6], special attention is paid to electromagnetism. In the framework of nonlinear axion electrodynamics, the interaction of axion and electromagnetic fields in homogeneous anisotropic models of the Bianchi V and VI types with one preferred direction is considered. A feature of these models is the dependence on time and one selected spatial coordinate, however, Einstein's equations contain dependence only on time, which imposes certain restrictions on the symmetry of the electromagnetic field. The analysis of admissible particular cases, matching the symmetry of the electromagnetic field with the symmetry of the cosmological model, is carried out.

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## The Problem of Time in Quantum Gravity: Analysis of Various Approaches

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At present, the idea that time does not exist in the realm of quantum gravity, in particular, in the Very Early Universe, is widespread. It originates from the Wheeler — DeWitt quantum geometrodynamics, where there is no time evolution. After some period of criticism, new arguments were put forward in favour of this idea. In its turn, it implies that time must have appeared at the semiclassical stage of the Universe existence. In principle, quantum theory of gravity should explain the appearance of time, however, in the “semiclassical program” [1, 2] time is just a parameter along the classical trajectory. The goal of the “semiclassical program” is to obtain the Schrödinger equation for matter fields with quantum-gravitational corrections as a consequence of the Wheeler — DeWitt equation using the Born — Oppenheimer approximation.

In other approaches, time appears as a result of introducing some reference frame, like, for example, in [3, 4], where Kuchař — Torre reference fluid is considered, or in the extended phase space approach to quantization of gravity [5].

The general conclusion is that time cannot be introduced into formalism of quantum gravity without indicating some observer in a reference frame equipped by clocks. Any attempt to explain the appearance of time in a timeless universe implies that spacetime had already existed and so leads to a logical vicious circle.

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# Особенности высших калибровочных теорий

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Поле p-форм или антисимметричное тензорное поле, например, поле Калб-Рамона в теории струн, достаточно хорошо изученный объект в современной теоретической физике. Группа калибровочных преобразований p-формы такая же, как в электродинамике, то есть U(1). Неабелевым обобщением теории с 2-формой является высшая теория Янга-Миллса, основанная на 2-группе Ли [1]. Имеются неабелевые калибровочные теории, основанные для p-форм, где p больше двух [2]. Математический аппарат высших калибровочных теорий включает в себя обобщение расслоений — жербы, где старшие по степени формы могут осуществлять параллельный перенос вдоль поверхностей.

Теория неабелевой 2-формы основана на 2-группе Ли или эквивалентно 2-скрещенном модуле. 2-скрещенный модуль состоит из двух групп Ли $H$ и $G$, а также двух операций: гомоморфизма $\alpha : H \to G$ и действия $\triangleright$ группы $G$ на $H$, таким что $\alpha(g \triangleright h) = g\alpha(h)g^{-1}$, где $g \in G$, $h \in H$. Также есть две естественные аксиомы на эти операции. Как обычно, чтобы перейти к кривизне калибровочного поля, нужно рассмотреть 2-алгебру Ли или дифференциальный скрещенный модуль, который состоит из двух алгебр Ли $g$ и $h$ дифференциальных версий гомоморфизма $d\alpha$ и действия $d\triangleright$. Связности тривиального главного 2-расслоения: 1-форма $A$, которая принимает значения в алгебре $g$; 2-форма $B$, принимающая значения в алгебре $h$. Тогда через эти формы можно определить высшие аналоги кривизны 2-расслоения [1]. Также здесь можно записать высшие аналоги тождеств Бьянки, уравнений движения и действия.

В докладе мы обсудим более подробно высшую теорию Янга — Миллса, а также высшие аналоги BF-теории и теории Черна — Саймонса.

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## Features of Higher Gauge Theories

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The p-form field or antisymmetric tensor field (for example, the Kalb-Ramon field in string theory) is a well-studied object in modern theoretical physics. The p-form gauge transformation group is the same as in electrodynamics, ie U(1). A non-Abelian generalization of the theory with 2-form is the higher Yang-Mills theory based on the Lie 2-group [1]. There are non-Abelian gauge theories based for p-forms where p is greater than two [2]. The mathematical apparatus of higher gauge theories includes a generalization of bundles — gerbes, where the higher degree forms can carry out parallel transfer along surfaces.

The theory of a non-Abelian 2-form is based on a Lie 2-group or equivalently a 2-crossed module. A 2-crossed module consists of two Lie groups $H$ and $G$, as well as two operations: a homomorphism $\alpha : H \to G$ and an action $\triangleright$ of the group G on H such that $\alpha(g \triangleright h) = g\alpha(h)g^{-1}$. Here $g \in G, h \in H$. There are also two natural axioms for these operations. As usual, to get to the curvature of the gauge field, one has to consider a Lie 2-algebra or differential crossed module, which consists of two Lie algebras and differential versions of the homomorphism $d\alpha$ and action $d\triangleright$. Connections of the trivial principal 2-bundle: 1-form A that takes values in the algebra *g*; 2-form B taking values in the algebra *h*. Then, through these forms, one can define higher analogues of curvatures [1]. It is also possible to write here the higher analogues of the Bianchi identities, the equations of motion and action.

In the talk, we will discuss in more detail the higher Yang-Mills theory, as well as the higher analogues of the BF-theory and the Chern-Simons theory.

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# Constraining Graviton Production during and after Inflation

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Modern cosmological theories generically predict generation of primordial tensor perturbations (gravitational waves) during and after inflation and even at the present time. However, in contrast to already discovered primordial scalar perturbations having an approximately flat power spectrum with the slope $|n_s(k) - 1| \ll 1$, we have only an upper limit on such primordial GW background at present. The observational result that the tensor-to-scalar ratio $r \ll 1$, too, is in the excellent agreement with the generic prediction of inflationary models with the slow roll evolution during inflation. In particular, the simplest (one-parametric) inflationary models — the pioneer $R + R^2$ one [1], the Higgs model, and the mixed $R^2$-Higgs model produce the target prediction $r = 3(1 - n_s)^2 = 0.004$ below the present upper limit $r < 0.036$ [2]. However, even this upper limit provides us with much information. It excludes many inflationary models popular in the past, like those with a power-law inflaton potential (‘chaotic inflation’). It also strongly restricts possible kination-like post-inflationary behaviour of the Universe (expansion slower than that during the radiation dominated stage) [3] and the hypothetical effect of trans-Plankian creation of particles which, if exists, would show itself in large creation of gravitons even at the present epoch [4]. Finally, it leads to a lower limit on an energy scale of non-locality in possible non-local modifications of gravity at sub-Planckian curvatures which have the $R^2$-like inflationary stage leading to the observational result for the scalar spectral slope $n_s$ [5].

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## Some Cosmological and Astrophysical Aspects of Horndeski Gravity

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In this talk we will discuss the most general scalar-tensor theories of gravity which contain the only single scalar degree of freedom. These theories, known as Degenerate Higher-Order Scalar-Tensor (DHOST) theories, include Horndeski and Beyond Horndeski theories. More details, we will focus on the particular subclass of models, known as the theory of gravity with non-minimal derivative coupling, and consider isotropic and anisotropic cosmological models in such the theory [1–8]. As well, we will shortly discuss compact astrophysical objects (black holes, wormholes, neutron stars) in the theory of gravity with non-minimal derivative coupling [9].

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# Рассеяние электронов на червоточине в борновском приближении

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Известно, что функция Грина $G_o(x-x')$ уравнения Дирака для свободной частицы

$$i\gamma^{(a)}\partial_a\psi - m\psi = 0$$

удовлетворяет уравнению

$$i\gamma^{(a)}\partial_a G_o(x-x') - mG_o(x-x') = \delta(x-x')$$

и имеет вид

$$G_o(x-x') = \frac{1}{(2\pi)^4}\int\frac{\hat{p}+m}{\hat{p}^2-m^2}e^{-ip(x-x')}d^4p,$$

где $\hat{p} = \gamma^{(a)}p_a$ .

Аналогично можно определить функцию Грина $G(x-x')$ для уравнения Дирака во внешнем гравитационном поле

$$i\gamma^{\mu}\nabla_{\mu}\psi - m\psi = 0$$

как решение уравнения

$$i\gamma^{\mu}\nabla_{\mu}G(x-x') - mG(x-x') = \delta(x-x'), \qquad (1)$$

где $\gamma^{\mu} = \gamma^{(a)}e^{\mu}_{(a)}$, $e^{\mu}_{(a)}$ — ортонормированная тетрада.

Определим оператор $\hat{\Gamma}$ посредством равенства

$$\hat{\Gamma} = \gamma^{(a)}\left(e^{\mu}_{(a)}\nabla_{\mu} - e^{\ \mu}_{o(a)}\nabla_{o\mu}\right), \qquad (2)$$

где $\nabla_{\mu} = \partial_{\mu} + \Gamma_{\mu}$ — ковариантная производная в гравитационном поле; $\Gamma_{\mu} = \frac{1}{4}\gamma^{\lambda}\gamma_{\lambda;\mu}$ — спинорная связность в гравитационном поле; $\nabla_{o\mu} = \partial_{\mu} + \Gamma_{o\mu}$; $e^{\ \mu}_{o(a)}$ и $\Gamma_{o\mu}$ — ортонормированная тетрада и спинорная связность в криволинейных координатах в отсутствие внешнего гравитационного поля.

В декартовых координатах $e^{\ \mu}_{o(a)} = \delta^{\mu}_{a}$ и $\Gamma_{o\mu} = 0.$ Тогда уравнение (2) можно переписать в виде

$$i\gamma^{(\mu)}\nabla_{o\mu}G(x-x') + i\hat{\Gamma}G(x-x') - mG(x-x') = \delta(x-x').$$

Рассмотрим слабое гравитационное поле, т. е. такое поле, в котором можно применить метод последовательных приближений.

Введение оператора (2) позволяет доказать следующую теорему.

*Теорема*. Для слабого внешнего гравитационного поля справедливо уравнение

$$\psi(x') = -i\oint G(x'-x)\gamma^{\mu}(x)\psi(x)\sqrt{-g(x)}dS_{\mu}, \tag{3}$$

где $\oint \ldots \sqrt{-g(x)}dS_{\mu}$ — интеграл по трехмерной гиперповерхности; $g(x)$ — определитель матрицы $(g_{ij})$.

При этом функция Грина $G(x-x')$ удовлетворяет уравнению

$$G(x-x') = G_o(x-x') + i\int G(x-x'')\hat{\Gamma}(x'')G_o(x''-x')\sqrt{-g(x'')}d^4x''. \tag{4}$$

Пусть гравитационное поле является центральным и стационарным. Тогда имеем

$$\psi(x) = \psi(\mathbf{r})e^{-i\varepsilon t},$$

где $\varepsilon$ — энергия электрона.

В этой работе интерес представляет случай, когда функция $\psi(\mathbf{r})$ при $r \to \infty$ имеет вид суперпозиции плоской и сферической расходящейся волн

$$\psi(\mathbf{r}) \sim u_{\sigma}e^{i\mathbf{p}_0\mathbf{r}} + A(\mathbf{n})\frac{e^{ipr}}{r},$$

где $\mathbf{p}_0$ и $\mathbf{p}$ — импульсы электрона до и после рассеяния на бесконечности; $u_{\sigma}$ — биспинор, описывающий состояние электрона с импульсом $\mathbf{p}_0$ и поляризацией $\sigma$; $\mathbf{n} = \mathbf{r}/r$.

В борновском приближении из (3) и (4) следует, что биспинор $A(\mathbf{n})$ имеет вид

$$A(\mathbf{n}) = i\frac{1}{4\pi}\left(-\boldsymbol{\gamma}\cdot\mathbf{p} + \gamma^{(0)}\varepsilon + m\right)\int \Gamma(\mathbf{r}')u_{\sigma}e^{i\mathbf{K}\mathbf{r}'}d^3\mathbf{r}',$$

где $\mathbf{K} = \mathbf{p}_0 - \mathbf{p}$. Здесь функция $\Gamma(\mathbf{r})$ определяется из равенства

$$\hat{\Gamma}(\mathbf{r})u_{\sigma}e^{i\mathbf{p}_0\mathbf{r}} = \Gamma(\mathbf{r})u_{\sigma}e^{i\mathbf{p}_0\mathbf{r}}.$$

Амплитуда рассеяния электрона равна

$$f(\mathbf{n},\sigma) = \frac{1}{2m}\bar{u}_{\sigma}A(\mathbf{n}) = \frac{i}{4\pi}\bar{u}_{\sigma}\int \Gamma(\mathbf{r}')u_{\sigma}e^{i\mathbf{K}\mathbf{r}'}d^3\mathbf{r}'. \tag{5}$$

В данной работе рассмотрен случай рассеяния электронов на червоточине Эллиса — Бронникова в борновском приближении (5).

## Electron Scattering on a Wormhole in the Born Approximation

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It is known that the Green's function $G_o(x-x')$ of the Dirac equation for a free particle

$$i\gamma^{(a)}\partial_a\psi - m\psi = 0$$

satisfies the equation

$$i\gamma^{(a)}\partial_a G_o(x-x') - mG_o(x-x') = \delta(x-x')$$

and has the form

$$G_o(x-x') = \frac{1}{(2\pi)^4}\int \frac{\hat{p}+m}{\hat{p}^2-m^2} e^{-ip(x-x')} d^4 p,$$

where $\hat{p} = \gamma^{(a)} p_a$ .

Similarly, we can define the Green's function $G(x-x')$ for the Dirac equation in an external gravitational field

$$i\gamma^{\mu}\nabla_{\mu}\psi - m\psi = 0$$

as a solution of the equation

$$i\gamma^{\mu}\nabla_{\mu}G(x-x') - mG(x-x') = \delta(x-x'), \tag{1}$$

where $\gamma^{\mu} = \gamma^{(a)} e^{\mu}_{(a)}$, $e^{\mu}_{(a)}$ is an orthonormal tetrad.

Let us define the operator $\hat{\Gamma}$ by the equality

$$\hat{\Gamma} = \gamma^{(a)}\left(e^{\mu}_{(a)}\nabla_{\mu} - e^{\ \mu}_{o(a)}\nabla_{o\mu}\right), \tag{2}$$

where $\nabla_{\mu} = \partial_{\mu} + \Gamma_{\mu}$ is the covariant derivative in a gravitational field; $\Gamma_{\mu} = \frac{1}{4}\gamma^{\lambda}\gamma_{\lambda;\mu}$ is a spin connection in a gravitational field; $\nabla_{o\mu} = \partial_{\mu} + \Gamma_{o\mu}$; $e^{\ \mu}_{o(a)}$ and $\Gamma_{o\mu}$ are orthonormal tetrad and spin connection in curvilinear coordinates in the absence of external gravitational field. In a Cartesian coordinate system $e^{\ \mu}_{o(a)} = \delta^{\mu}_{a}$ и $\Gamma_{o\mu} = 0$.

Then equation (2) can be rewritten as

$$i\gamma^{(\mu)}\nabla_{o\mu}G(x-x') + i\hat{\Gamma}G(x-x') - mG(x-x') = \delta(x-x').$$

Consider a weak gravitational field, i.e. such a field in which the method of successive approximations can be applied.

The introduction of operator (2) allows to prove the following theorem:

*Theorem*. For a weak external gravitational field, the equation

$$\psi(x') = -i\oint G(x'-x)\gamma^{\mu}(x)\psi(x)\sqrt{-g(x)}dS_{\mu}, \tag{3}$$

where $\oint \ldots\sqrt{-g(x)}dS_{\mu}$ is an integral on a three-dimensional hypersurface, $g(x)$ is a determinant of the matrix $(g_{ij})$ is valid.

In this case, the Green's function $G(x-x')$ satisfies the equation

$$G(x-x') = G_o(x-x') + i\int G(x-x'')\hat{\Gamma}(x'')G_o(x''-x')\sqrt{-g(x'')}d^4x''. \tag{4}$$

Let the gravitational field be central and stationary. Then we have

$$\psi(x) = \psi(\mathbf{r})e^{-i\varepsilon t},$$

where $\varepsilon$ is the energy of an electron.

In this paper the case of interest is that the function $\psi(\mathbf{r})$ at $r \to \infty$ has the form of a superposition of plane and spherical divergent waves

$$\psi(\mathbf{r}) \sim u_{\sigma}e^{i\mathbf{p}_0\mathbf{r}} + A(\mathbf{n})\frac{e^{ipr}}{r},$$

where $\mathbf{p}_0$ and $\mathbf{p}$ are electron momenta before and after scattering at infinity; $u_{\sigma}$ is a bispinor describing the state of an electron with momentum $\vec{p}_0$ and polarization σ; $\mathbf{n} = \mathbf{r}/r$.

In the Born approximation, it follows from (3) and (4) that the bispinor $A(\mathbf{n})$ has the form

$$A(\mathbf{n}) = i\frac{1}{4\pi}\left(-\boldsymbol{\gamma}\cdot\mathbf{p} + \gamma^{(0)}\varepsilon + m\right)\int \Gamma(\mathbf{r}')u_{\sigma}e^{i\mathbf{K}\mathbf{r}'}d^3\mathbf{r}',$$

where $\mathbf{K} = \mathbf{p}_0 - \mathbf{p}$. Here the function $\Gamma(\mathbf{r})$ is defined from the equality

$$\hat{\Gamma}(\mathbf{r})u_{\sigma}e^{i\mathbf{p}_0\mathbf{r}} = \Gamma(\mathbf{r})u_{\sigma}e^{i\mathbf{p}_0\mathbf{r}}.$$

The amplitude of electron scattering is

$$f(\mathbf{n},\sigma) = \frac{1}{2m}\bar{u}_{\sigma}A(\mathbf{n}) = \frac{i}{4\pi}\bar{u}_{\sigma}\int \Gamma(\mathbf{r}')u_{\sigma}e^{i\mathbf{K}\mathbf{r}'}d^3\mathbf{r}'. \tag{5}$$

In this paper we consider the case of electron scattering on the Ellis — Bronnikov wormhole in the Born approximation (5).

# Lie Differential Geometry Aufbau of the Atoms and Molecules

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In previous PIRT conferences I have reported on a differential geometry structural make-up of the standard model of the elementary particles and the periodic system of the atoms following Marius Sophus Lie's Ph.D. dissertation *Over en Classe Geometriske Transformationer* at Christiana (now Oslo) University in 1871 [1–4]. This thesis essentially describes Nature at the infinitesimal level it appears as by "a transition from a point to a straight line as element" both mathematically and materially of digital constitution. Under nucleosynthetic conditions its partial derivative square wave steps "of length equal to zero" can go into a space-filling modular "curve-net" formation. In the first generation, from the $10^{-15}$ meter size of the Nucleon radius, this is a bi-layer wave-packet accumulation of palindromic Bohr *Aufbau* configuration, whose repeated application like in an oriental tiling or rug first outlines its pattern in the periodic table over the more than 10,000 times larger extension of the atom cross-section area. When a layer is covered by a full excursion of the knot returning to the origin, the train continues by moving one step upward the Nucleon shaft to a new horizontal sheet, and this continuous expansion goes on till the multistorey atom is equally high as wide in the form of a crystal that retains the shape of its infinitesimal module and so can self-assemble into a polymeric nanostructure cluster of itself or molecular combinations with other atoms exactly and extensively as specified in established chemical formulas. This is here exemplified by some basic and more advanced organic compounds including the proteinogenic amino acids and DNA.

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## Cosmological Implications of $f(Q, T)$ Gravity

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It has been an accepted fact that, the expansion of the Universe is accelerating at the present time. This appears as an exotic phenomenon that involves the incorporation of exotic matter fields within the general relativity. However, modified theories of gravity where the geometrical part of the action is suitably modified to explain this late time speed up issue without the need of any exotic matter fields. Of late there have been a good number of geometrically modified theories of gravity proposed in literature. In recent times, geometrically modified gravity theories involving non-metricity within teleparallel approach have gained much importance. In the present talk, we will discuss the cosmological implications of such a gravity theory, dubbed as $f(Q, T)$ theory. After the derivation of the basic field equations, we will construct accelerating cosmological models and will obtain the dynamical cosmographic parameters and the equation of state parameters. The stability of the models will be analyzed through different diagnostic techniques including the dynamical system analysis.

# Surrounded Generalized Vaidya Spacetime by Cosmological Fields

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Recent direct observations of black hole shadows gave them the status of realistic astrophysical objects. In a real astrophysical situation, a black hole loses its mass during evaporation or gains it during the accretion process. As a result, their exterior metric is not static or stationary but dynamical. Vaidya [1] and generalized Vaidya spacetimes [2] are the simplest examples of the dynamical exterior geometry, which can describe accretion or evaporation processes. Moreover, considering a black hole as a real astrophysical object, one should understand that it is not an isolated but lives in non-empty backgrounds.

In our work, we consider black holes that are described by generalized Vaidya solution in the dynamical cosmological backgrounds of stiff fluid, dust, radiation, de Sitter, quintessence and phantom fields. According to Y. Heydarzade and F. Daraby [3–5], we call it a surrounded generalized Vaidya black hole'. First of all, we obtain the solution of the Einstein equations, which describes such objects, and after it, we analyze time-like geodesics associated with the obtained solution. We find out that new corrections to Schwarzschild's black hole arise and find conditions when these corrections are not negligible. Also, we investigate the question about conformal symmetries of this solution and consider how surrounded fluid influences the gravitational collapse of generalized Vaidya spacetime.

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# Lorentz Force for Charged Particles with Negative Energy in Black Hole Binaries

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There are several ways how the energy can be extracted from a black hole. Penrose process states that in the ergoregion of a rotating black hole, the particles with negative energy might exist due to collision or decay. As the result, the energy of escaping particle is bigger than the energy of the original particle. This process is possible only in the ergorigion where the Killing vector becomes spacelike. In spherical symmetry, i.e., for Schwarzschild and Reissner-Nordstrom black holes, the Killing vector is timelike outside the event horizon and the Penrose process is impossible. However, in Reissner-Nordstrom case, one can consider the analogy of the Penrose effect because there are charged particles with negative energy. These particles can exist only in the generalized ergoregion. The border of this region is called generalized ergosphere and it depends on the test particle parameters. Thus, even in the spherically-symmetric case there is the analogue of the Penrose process for charged black holes. This process might take place in binary system which exterior geometry is well-described by The Majumdar-Papapetrou spacetime.

In this work, we consider the possibility for the existence of charged particles with zero energy and find out the region where such particles can exist. After that we calculate the Lorentz force associated with charged particles with zero and negative energy. We found out that this force for a particle with negative energy can change its action from attractive to repulsive. After that, we compare forces for such particles with ones in RN spacetime.

## Phase Correlations in Quantum Field Theory and Entanglement

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The experimentally well-grounded entanglement phenomenon admits the concrete physical representation when it is studied in the context of quantum field theory where long-range correlations are phase correlations induced by vacuum coherence. What appears at first sight as a "spooky action at a distance"‘ turns out to be the fact that Alice's and Bob's measurements are embedded in the coherent dynamics of the physical vacuum acting as a collective mode background, a feature not present in the quantum mechanics analysis. Remarkably, this conclusion emerges in fact from the very structure of quantum field theory leading to a different and more concrete perspective on the physical mechanism of entanglement. Examples considered in the entanglement analysis include quantization in curved space-time [1, 2], quantization near the event horizon [3], and for expanding geometries [4] and in general in dissipative systems [5, 6], also including application to the dissipative quantum dynamics in brain modeling [7, 8].

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## Laser Gravitational Wave Antennas and Quantum Measurements

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Laser GW antenna is the unique displacement meter measuring distance 4 km between 40-kg masses with unique sensitivity about $10^{-19}$ m. We present analysis of main fundamental reasons, which determine sensitivity of GW detectors. Current sensitivity is close to Standard Quantum Limit (SQL). We discuss the reasons of SQL measurement noise and back action) and methods to surpass it: quantum non-demolition measuremens (QND), quantum variational measurements, speed meter and usage of optical rigidity. We also consider the methods of broadband variational measurement for mechanical oscillator, so called “system free from quanum mechanics” (SFQM) and “negative mass”.

## Orbital Motion in the Reference Frame of a Blackhole

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I compare two versions of the analysis of the gravitational wave signal GW150914 presented previously by the LIGO/Virgo collaboration (LVC). The first version was presented in 2016 by this collaboration along with their announcement of the first experimental detection of gravitational waves [1]. It was based on rigorous general-relativistic treatment of the coalescing two-body problem. The second analysis of this signal by the same authors [2] was based on the quadrupole post-Newtonian (PN) approximation of General Relativity (GR). I revisit this post-Newtonian analysis and estimate the mass of the coalescing binary blackhole system using frequency values read directly from the time-frequency diagram of GW150914. My estimation, similarly to the PN-result from LVC [2], coincides with the rigorously calculated mass for this system from the LVC first publication. Additionally, I estimate the masses of other coalescing binary systems by using the same quadrupole PN-approximation formula applied to the data from the published gravitational wave transient catalogues. Practically all of my PN-approximation estimates coincide with the published masses based on the rigorous methods. In my view, this coincidence means that the rigorous theory for gravitational waveforms of coalescing blackhole binaries does not fully account for the difference between the source and detector reference frames because the PN-approximation, which is used for the comparison, does not make any distinction between these two reference frames: by design and by the principles and conditions for building the PN-approximation. I discuss possible implications of this conflict and find that the accuracy of the previously estimated characteristic (chirp) masses of coalescing binary blackhole systems is likely to be affected by a systematic error.

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## Physical Meaning of the Einstein-de Sitter Space

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Einstein-de-Sitter (EdS) space is a modification of the Einstein space made by de Sitter [1] a few months after Einstein published his first cosmological model in 1917 [2]. De Sitter found that, similarly to the Einstein space, the elliptical space, in which antipodal points of the Einstein space are topologically identified, equally satisfies Einstein's field equations. This is a static space, but de Sitter found that spectral lines of remote galaxy spectra in this space must be displaced towards longer wavelengths. Thus, de Sitter predicted the existence of the cosmological redshift well before it was discovered from observations by Lemaître and Hubble. And this was done for a *static* Universe model, as the Friedmann model did not exist yet! The topological identification of antipodal points of space is a mathematical abstraction. This can be interpreted physically as a connection between remote points via the Einstein — Rosen bridge [3], also called "wormhole". In this model, the major part of the observed cosmological redshift is gravitational by its nature. So, I use the gravitational redshift formalism to fit this model's two parameters through a minimisation of $\Sigma^2$ using the Type Ia supernovae data from the Pantheon+ sample of 1701 well-calibrated objects [4]. My fit turns out to be equivalent to the ΛCDM model fit to the same data, with the minimal $\Sigma^2$ values being similar for both models. The two models diverge in their predictions for redshifts $z$ exceeding ~ 1.5. So, since there are no available supernovae for large redshifts, I test both models against a sample of 193 gamma-ray bursts (GRB), whose redshifts extend to $z \sim 8$. The GRB distance moduli calibrated via the Amati relation [5] are currently extensively used by many authors as a standard-candle proxy for the high-redshift Universe. My GRB-verification gives about 6 % smaller $\Sigma^2$ value for the EdS model as compared with the ΛCDM model, which indicates that the static EdS model can be a viable alternative to the expanding-Universe models. This is especially important in view of the recent results from the James Webb Space Telescope (JWST), showing that there exist well-evolved galaxies with $z$ >15 formed in an impossibly short time interval of ~ 230 Myr available for them since the beginning of the Universe, according to the standard cosmological model. The EdS model provides much more time for the evolution of those galaxies, which explains the unusual JWST observations.

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## О распределении температуры в черной дыре

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Формула для температуры черной дыры $T_{bh}$ впервые была получена Хоукингом, который использовал результат Бекенштейна для энтропии этого астрофизического объекта. Однако результат Хоукинга относился фактически к тепловому излучению с поверхности черной дыры и вопрос о температуре ее внутренних областей не рассматривался. Бекенштейн, решая вопрос о сохранении информации при попадании физического тела в черную дыру, использовал голографический принцип, согласно которому эта информация записана на поверхности. В качестве этой поверхности им была выбрана поверхность горизонта, т. е. поверхность сферы с радиусом, равным гравитационному $r_g$. При этом одному биту информации соответствовала элементарная площадка с площадью, равной квадрату планковской длины. Для решения нашей задачи о распределении температуры внутри черной дыры мы ввели два предположения. Во-первых, было предположено, что поток теплового излучения одинаков на любом расстоянии от ее центра. Во-вторых, керн черной дыры имеет площадь, соответствующую одному биту информации. Эти предположения позволили получить замкнутое решение задачи в виде степенного закона изменения температуры $T$ в радиальном направлении на расстоянии $r$ от центра сферической черной дыры, а именно:

$$T = \xi^{-1/2} T_{bh}, \; \xi = r / r_g. \tag{1}$$

Оказалось, что максимальная температура $T_0$ внутри является конечной величиной и имеет зависимость от массы черной дыры $m_{bh}$ более слабую, чем в формуле Хоукинга $T_{bh} \sim 1/m_{bh}$, а именно

$$T_0 = \frac{1}{8\pi}\left(\frac{\hbar c^3}{G}\right)^{3/4}\left(\frac{c}{m_{bh}}\right)^{1/2}\frac{1}{K_B}, \tag{2}$$

где $\hbar$ — постоянная Дирака; $c$ — скорость света; $G$ — гравитационная постоянная; $K_B$ — постоянная Больцмана. Сравним температуру $T_0$ с температурой Планка $T_{Pl}$. После простых преобразований получаем искомое отношение, а именно

$$\frac{T_0}{T_{Pl}} = \left(\frac{m_{Pl}}{m_{bh}}\right)^{1/2}. \tag{3}$$

Оценим верхнюю границу этого отношения. Примем за минимальное значение $m_{bh}$ массу, равную четырем массам Солнца. После простого числового расчета имеем, что искомая верхняя граница равна приблизительно $5{,}2\cdot 10^{-20}$. Выполнены числовые оценки для известных черных дыр. Полученные результаты представлены в аналитической и графической форме. Обсуждается связь оценки планковской длины и размерности пространства-времени.

## On the Temperature Distribution in a Black Hole

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The formula for the black hole temperature $T_{bh}$ was first obtained by Hawking, who used the Bekenshtein's result for the entropy of this astrophysical object. However, Hawking's result actually referred to thermal radiation from the surface of a black hole, and the question of the temperature of its inner regions was not considered. Bekenshtein, solving the problem of the preservation of information when a physical body enters a black hole, used the holographic principle, according to which this information is recorded on the surface. As this surface, he chose the surface of the horizon, i. e. the surface of a sphere with a radius equal to the gravitational $r$= In this case, one bit of information corresponded to an elementary area with an area equal to the square of the Planck's length. To solve our problem of temperature distribution inside a black hole, we introduced two assumptions. First, it was assumed that the flux of thermal radiation is the same at any distance from its center. Secondly, the core of a black hole has an area corresponding to one bit of information. These assumptions made it possible to obtain a closed solution of the problem in the form of a power law of temperature change $T$ in the radial direction at a distance $r$ from the center of a spherical black hole, namely:

$$T = \xi^{-1/2}\, T_{bh},\ \xi = r/r_g. \tag{1}$$

It turned out that the maximum temperature $T_0$ inside is a finite value and has a weaker dependence on the black hole mass $m_{bh}$ than in the Hawking formula $T_{bh} \sim 1/m_{bh}$, namely:

$$T_0 = \frac{1}{8\pi}\left(\frac{\hbar c^3}{G}\right)^{3/4}\left(\frac{c}{m_{bh}}\right)^{1/2}\frac{1}{K_B} \tag{2}$$

where $\hbar$ is the Dirac constant, c is the speed of light, $G$ is the gravitational constant, $K_B$ is the Boltzmann constant. Let's compare the temperature $T_0$ with the Planck's temperature $T_{Pl}$. After simple transformations, we obtain the desired relation, namely:

$$\frac{T_0}{T_{Pl}} = \left(\frac{m_{Pl}}{m_{bh}}\right)^{1/2} \tag{3}$$

Let us estimate the upper bound of this ratio. Let's take as the minimum value $m_{bh}$ a mass equal to four masses of the Sun. After a simple numerical calculation, we have that the desired upper bound is approximately $5{,}2 \cdot 10^{-20}$. Numerical estimates are made for known black holes. The results obtained are presented in analytical and graphic form. Discussing the linkage of evaluation on the Plank's length and space-time dimension.

# Внегалактические TeV-ные фотоны и предел спектра нулевых колебаний

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Регистрацию фотонов очень высокой энергии (VHE), $E_\gamma$ > 100 GeV, ведут наземные установки-обсерватории, кластеры атмосферных черенковских телескопов и т. д. Внегалактические источники VHE-фотонов это активные ядра галактик, блазары (Markarian 501 [1], квазар 3C 279 [2]), а среди источников в Галактике — пульсар Крабовидной туманности (2 kpc; $E_\gamma$ свыше 100 TeV). Установка LHAASO сообщала о фотонах с энергией 1…1,4 PeV; не исключается, что часть квантов прибыла из-за пределов Галактики [3].

Вселенная не совсем прозрачна для столь жестких фотонов — из-за поглощения межгалактическим фоновым излучением (EBL; оно включает, помимо реликтовых, фотоны с энергиями $E_\gamma$ = 0,01…4 eV) в процессе образования электрон-позитронных пар. Порог связан с массой электрона $m_e$, $E_\gamma E_b > m_e^2$, и сечение (поглощение) максимально [3], если $E_\gamma E_b \approx$ ≈ 1…5 · $10^{12}$ $\mathrm{eV}^2$. Яркость (и предельные энергии $E_\gamma$) возрастают во время ***вспышек***.

Приведем три источника VHE-фотонов, с красным смещением $z$ и расстоянием $L$, а также пределом энергий $E_\gamma$; расстояние оцениваем по формуле (модель расширения $a \infty t$) $L = c\,t_0\, z/(1+z)$, $L\left|M_{pc}\right| = 4283\, z/(1+z)$ (т. е. взяли $H_0 = t_0^{-1} = 70$ km s$^{-1}$ Mpc$^{-1}$):

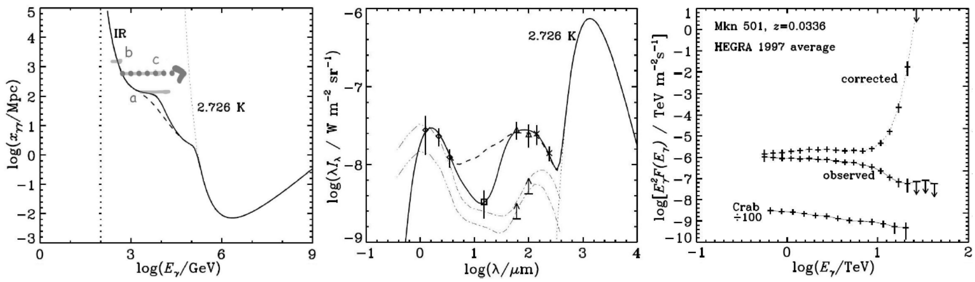
[a] блазар Mkn 501 [1] (HEGRA) $z$ = 0,0336, $L$ = 140 Mpc, $E_\gamma$ = 20 TeV;

[b] радио-квазар 3C 279 [2] (MAGIC) $z$ = 0,536, $L$ = 1,495 Gpc, $E_\gamma$ = 0,3…0,5 TeV;

[c] GRB221009A [4, 5] (LHAASO / Ковер-2) $z$ = 0,1505, $L$ = 560 Mpc, $E_\gamma$ = 18 TeV / 251 TeV.

Произошедшая 9-го октября 2022 г. гамма-вспышка (GRB) была рекордной по яркости; детали регистрации фотона 251 TeV установкой «Ковер-2» сообщались на семинарах ОТФ ИЯИ (С. Троицкий, В. Романенко)[1] [4, 5]. На рисунке можно наблюдать длину свободного пробега VHE-фотонов, спектры EBL и блазара Mkn 501, взятые из [1].

[1] Есть проблемы с этим фотоном: близость диска Галактики и 2–3 маргинальных мюона [4, 5].




Длина свободного пробега VHE-фотонов; EBL-спектр и коррекция спектра Mkn 501 [1]

Ведутся новые измерения, обсуждаются спектры фонового света (EBL) и TeV-ных источников; но многие авторы считают, что существует аномальная прозрачность межгалактического фона (EBL) для TeV-ных фотонов (см. рисунок) (скорректированный спектр Mkn 501), и что объяснение аномалии требует некой новой физики [1–6] (типа аксионо-подобных частиц [3] или моделей с нарушением лоренц-инвариантности [6]).

Проще, однако, связывать эту аномалию с проявлением границы спектра нулевых колебаний, $U_{ZV}$ (zero-point vibrations)[2]. Считаем, что ZV-граница изотропна в системе отсчета, где изотропно (с точностью $v \sim 10^{-5}$, или 3 km/s) реликтовое излучение, CMB.

Нестабильная частица (со временем жизни $\tau_0$), распад которой связан с ZVs масштаба $U_0$, при движении относительно «эфира» $ZV + CMB$ с лоренц-фактором $\gamma_e$ почувствует данную $ZV$-границу (т. е. падение $ZVs$ в одном направлении) и будет жить дольше, чем $\gamma_e \tau_0$, если $U_0 > U_{\mathrm{ZV}}/(2\gamma_e)$. Образование $e^+e^-$-пары фотонами 16 TeV и 0,3 eV идет в системе ц. и. с фактором $\gamma_e = 0{,}5\sqrt{E_\gamma / E_b} \approx 3{,}7 \cdot 10^6$, а $U_0 \approx 10^6$ eV; если считать, что $ZV$-аномалия уже в действии, то возможна оценка: $ZV \approx 7{,}4$ TeV. Было бы интересно измерить аномальный рост времени жизни (по сравнению с $\gamma\tau_0$) для частиц с β-распадом; учитывая, что $U_0^{(\beta)} \approx 80$ GeV, можно оценить лоренц-фактор начала аномалии $\gamma_e^{*(\beta)} = U_{\mathrm{ZV}}/(2U_0^{(\beta)}) \approx 46$.

Кроме мюонов (ВЭПП-4/5)[3], интересны $\beta^{\pm}$-нуклиды (LHC) $^3$H ($\tau_{\beta-}$ = = 12,3 y) и $^7$Be ($\tau_{\beta+}$ = 53 d); ($u$, $d$)-кварки уже имеют в нуклоне лоренц-факторы ~ 35…70, что существенно[4].

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[2] Вряд ли можно такую хорошую вещь, как нулевые колебания, растягивать до бесконечности.

[3] Идея $\mu^{\pm}$-коллайдера (Будкер, Скринский и др.) немного продвигается, см. MICE.iit.edu.

[4] Для bottle-beam аномалии нейтронов, см. arXiv: 1812.00626, скорость тепловых нейтронов $v_{beam}$ слишком мала; но bottle-нейтроны часто контактируют с нуклонами

Принято считать, что ZV-спектр тянется до планковской энергии. Существует, однако, 5D-теория, в которой планковская длина $\lambda_P$ является составной величиной, не отвечающей никакому характерному размеру, и где не требуется квантовать гравитацию [7].

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## Extragalactic TeV Photons and the Zero-Point Vibration Spectrum Limit


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Very-high-energy (VHE) photons, $E_\gamma > 100$ GeV, are recorded by ground-based observatory facilities, clusters of atmospheric Cherenkov telescopes, etc. Extragalactic sources of VHE photons are active galactic nuclei, such as blazars (Markarian 501 [1], quasar 3C 279 [2]), while within the Galaxy VHE photons are produced, for instance, by the Crab Nebula pulsar (2 kpc; $E_\gamma$ over 100 TeV). The LHAASO project reported photons with an energy of 1…1.4 PeV; it is probable that some of the quanta came from outside the Galaxy [3].

The universe is not entirely transparent to such hard photons, as they are absorbed by the extragalactic background light (EBL, which includes photons with energies $E_\gamma$ = 0.01…4 eV in addition to the cosmic background radiation) in the

стенки (протонами), при этом скорость их *d*-кварков («релятивизм») может снижаться — как и время жизни.

process of forming electron-positron pairs. The threshold is related to the electron mass $m_e$, $E_\gamma E_b > m_e^2$, and the cross-section (absorption) peaks [3] if $E_\gamma E_b \approx$ $\approx 1\ldots5 \cdot 10^{12}\,\text{eV}^2$. Brightness (and limiting energies $E_\gamma$) increase during ***flares***.

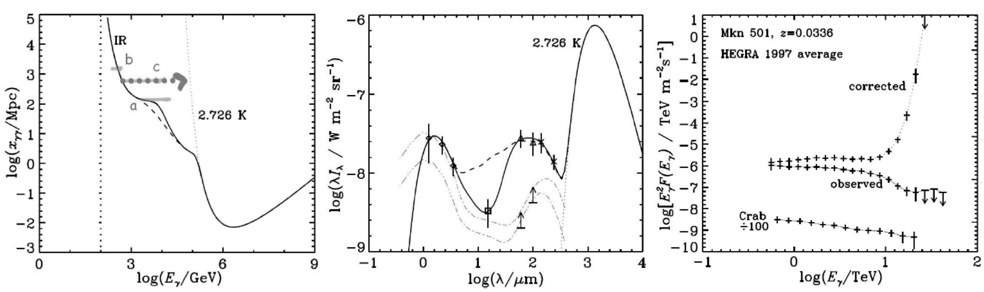
Let us consider three sources of VHE photons, at a redshift $z$, distance $L$, and energy limit $E_\gamma$; the distance is estimated via the expression (expansion model $a \infty t$) $L = ct_0 z/(1+z)$, $L \vee M_{pc} \vee 4283z/(1+z)$ (that is, we took $H_0 = t_0^{-1} =$ $= 70$ km s$^{-1}$Mpc$^{-1}$):

[a] the Mkn 501 blazar [1] (HEGRA) $z = 0.0336$, $L = 140$ Mpc, $E_\gamma = 20$ TeV;

[b] the 3C 279 radio quasar [2] (MAGIC) $z = 0.536$, $L = 1.495$ Gpc, $E_\gamma =$ $= 0.3\ldots0.5$ TeV;

[c] GRB221009A [4, 5] (LHAASO / Carpet-2) $z = 0.1505$, $L = 560$ Mpc, $E_\gamma =$ $= 18$ TeV ⁄ 251TeV.

The gamma-ray burst (GRB) of October 9th, 2022, had a record-breaking brightness; details on the Carpet-2 facility recording a 251 TeV photon were reported at the workshops of the Theoretical Physics Department of the Institute for Nuclear Research (S. Troitskiy, V. Romanenko)[1] [4, 5]. Figure 1 shows the mean free path of VHE photons along with the spectra of the EBL and the Mkn 501 blazar taken from [1].




**Mean free path of VHE photons; the EBL spectrum and the Mkn 501 spectrum correction [1]**

New measurements are being made, the spectra of background light (EBL) and TeV sources are being discussed; however, many authors believe that the extragalactic background light (EBL) is anomalously transparent for TeV photons, cf. Fig. (the corrected Mkn 501 spectrum), and that explaining the anomaly requires a certain new physics [1–6] (such as axion-like particles [3] or models violating the Lorentz invariance [7]).

[1] There are problems with this photon: the proximity of the galactic disk and 2-3 marginal muons [4, 5].

It is simpler, however, to connect this anomaly to a manifestation of the zero-point vibration spectrum limit $U_{ZV}$ [2]. We assume that the ZV boundary is isotropic in the reference system, where the cosmic microwave background (CMB) is isotropic (with an accuracy of $v \sim 10^{-5}$, or 3 km/s) as well.

An unstable particle (with a lifetime $\tau_0$), whose decay is associated with ZVs of scale $U_0$, when moving relative to the ZV + CMB "ether" with the Lorentz factor $\gamma_e$, will sense this ZV boundary (i. e., the ZVs decreasing in the same direction) and will live longer than $\gamma_e\tau_0$ if $U_0 > U_{ZV}/(2\gamma_e)$. The 16 TeV and 0.3 eV photons form $e^{+e^{-}}$ pairs in a zero-momentum frame with a factor of $\gamma_e =$ $= 0.5\sqrt{E_\gamma / E_b} \approx 3.7\cdot 10^6$, and $U_0 \approx 10^6$ eV; if we assume that the ZV anomaly is already in effect, then an estimate is possible: $U_{ZV} \approx 7.4$ TeV. It would be interesting to measure the anomalous increase in lifetime (compared to $\gamma\tau_0$) for particles featuring β-decay; given that $U_0^{(\beta)} \approx 80$ GeV, it is possible to estimate the Lorentz factor of the anomaly onset as $\gamma_e^{(\beta)} = U_{ZV}/(2U_0^{(\beta)}) \approx 46$.

In addition to muons (VEPP-4/5)[3], $\beta^{\pm}$-nuclides (LHC) $^3$H ($\tau_{\beta-}$ = 12.3 y) and $^7$Be ($\tau_{\beta+}$ = 53 d) are of interest; (*u*, *d*)-quarks already have Lorentz factors ~ 35…70 in the nucleon, which is significant[4].

It is generally accepted that the ZV spectrum extends to the Planck energy. There is, however, a 5D theory in which the Planck length $\lambda_P$ is a composite quantity that does not correspond to any characteristic dimension, and where gravity does not have to be quantized.

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[2] It is hardly possible for something as profound as zero-point vibrations to be stretched to infinity.

[3] The idea of the $\mu^{\pm}$-collider (Budker, Skrinsky, etc.) is advancing somewhat, see MICE.iit.edu.

[4] For bottle-beam neutron anomalies, see arXiv: 1812.00626, the velocity of thermal neutrons $v_{beam}$ is too low; however, bottled neutrons are often in contact with the nucleons (protons) in the wall, while the velocity of their *d*-quarks (the "relativism") may decrease — as may the lifetime.

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## Large-Scale Virial Relations in 5D Absolute Parallelism with a 4th-order Gravity

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1. Special relativity (SR) unites space and time but does not explain any field or particle. General relativity (GR) relates gravity to space-time curvature; the other fields/particles form the EMT, energy-momentum tensor, and remain unexplained. Einstein wasn't content with GR; he compared the GR-equation sides with a marble palace (the LHS, Einstein's tensor $G_{\mu\nu} = R_{\mu\nu} - g_{\mu\nu}R/2,\ \ G_{\mu\nu;\nu} \equiv 0$) and an old shed (the RHS with the EMT). Later Einstein explored the frame field $h^a_\mu(x^\nu)$, $g_{\mu\nu} = \eta_{ab}h^a_\mu h^b_\nu$, and second order equations which symmetry unites symmetries of both SR (Latin indexes; $\eta_{ab}$ is Minkowski's metric) and GR (Greek ones) — the third (or united) relativity, but Einstein call it Absolute Parallelism (AP).

The list of compatible ($2^d$-order) AP eq-ns found by Einstein and Mayer includes the two-parameter class of Lagrangian equations and three more classes. And there exists the exceptional equation (EE), non-Lagrangian, which solutions don't admit co-singularities (the principal terms do not remain regular for one-degenerate co-frame matrices), and, if $D = 5$, contra-singularities (degenerate contra-frame density of some weight) [1]:

$$\boldsymbol{E}_{a\mu} : L_{a\mu\nu;\nu} - \frac{1}{3}(f_{a\mu} + L_{a\mu\nu}\Phi_\nu) = 0, \boldsymbol{E}_{a\mu;\mu} : f_{\mu\nu;\nu} = \frac{1}{2}S_{\mu\nu\lambda}f_{\lambda\nu};$$

here $\quad L_{a\mu\nu} = \Lambda_{a\mu\nu} - S_{a\mu\nu} - \frac{2}{3}h_{a[\mu}\Phi_{\nu]}; \qquad \Lambda^a{}_{\mu\nu} = h^a{}_{\mu;\nu} - h^a{}_{\nu;\mu} \qquad (\Lambda^a{}_{[\mu\nu;\lambda]} \equiv 0);$

$S_{\mu\nu\lambda} = 3\Lambda_{[\mu\nu\lambda]};\ \Phi_\nu = h^\mu_a\Lambda^a{}_{\mu\nu};\ \mid f_{\mu\nu} = 2\Phi_{[\mu;\nu]} = \Phi_{\mu,\nu} - \Phi_{\nu,\mu}$.

The EE doesn't permit $D = 4$ at all:

$$\boldsymbol{E}_{\mu\mu} = \boldsymbol{E}^a{}_\mu h^\mu_a = \frac{4-D}{3}\Phi_{\mu;\mu} - \frac{1}{2}\Lambda^2_{abc} + \frac{1}{3}S^2_{abc} + \frac{D-1}{9}\Phi^2_a = 0\,.$$

The theory has a number of key features (remember, $D = 5$):

15 polarizations have very different functions and amplitudes (four classes; generally, a higher class means many orders smaller amplitudes) as they relate to different irreducible parts of $\Lambda$ and $\Lambda'$, such as $\Phi_\mu$ (3+1 pol-s, $2^d$- and $1^{st}$-class), $S_{\mu\nu\lambda}$ (3 pol-s, $1^{st}$-class), and the Riemannian curvature tensor (or the Weyl tensor; 5 pol-s, $3^d$-class);

three unstable pol-s (0th-class) grow linearly under action of three stable pol-s relating to $f_{\mu\nu}$ ($2^d$-class), while $h'^2$-terms are tiny: $\Lambda_{\lambda\mu\nu;\tau;\tau} =$ $= -\frac{2}{3} f_{\mu\nu;\lambda} + (\Lambda\Lambda', \Lambda^3)$; $\Box S \approx \Box\Phi \approx 0 \approx \Box f$;

non-stationary $O_4$-symmetrical solutions exist which resemble a (single) longitudinal wave in Chaplygin gas [2] (1st-class pol-n relating to $\Phi_\mu$ — others don't survive in this symmetry); the wave can serve as a cosmological shallow waveguide for tangential shorter waves, with ultrarelativistic expansion and different evolution of waves amplitudes — according to the structures of quadratic terms (whether they include 0th-class parts or only lower class ones);

non-linear localised $h$-field configurations can carry digital information — topological charges and (for symmetrical configurations) quasi-charges (when 0th-class waves become large enough), and a QM-like 4D-phenomenology emerges through averaging along the huge extra-dimension, along a length $L$, the width of large-scale $O_4$-wave in co-moving coordinates [2]; note, two thin lines in a 4d-space have tiny chances to intersect in a single approach.

2. The proper EMT (where only $f$-polarizations play the role) appears with the prolonged, forth-order symmetrical equation $[\boldsymbol{E}_{(\mu\nu);\tau;\tau}]$:

$$G_{\mu\nu;\tau;\tau} + G_{\varepsilon\tau}(2R_{\varepsilon\mu\tau\nu} - g_{\mu\nu}R_{\varepsilon\tau}/2) = -\frac{2}{9}T^{(f)}_{\mu\nu} + B_{[\mu\rho][\nu\tau]}(\Lambda^2)_{;\rho;\tau},$$

where $T^{(f)}_{\mu\nu} = f_{\mu\tau}f_{\nu\tau} - \frac{1}{4}g_{\mu\nu}f^2_{ab}$; this eq-n follows also from a "Lagrangian" quadratic in the field equation $E_{(\mu\nu)}$. Note the absence of free parameters. The scale $L$ is a parameter of solution, not the theory; and $L$ reduces to the Planck length $\lambda_P$ via multiplying by a tiny factor relating to the amplitude of $f$-waves. In other words, the "conventional scale of EMT" (where the "energy" of a photon is just ω — in natural units with $c = 1 = \hbar$) differs very-very much from the scale of $T^{(f)}_{\mu\nu}$.

So, one can consider the static 4d-equation $\Delta^2\varphi(x^\alpha) = -\rho(x^\alpha)$ and suggest that masses are very extended along the extra dimension, the length $L$. A point "mass" $aR^{-3}\delta(R)$ gives the next solution (every large mass/over-density is accompanied by an under-density, so the logarithmic growth should stop somewhere) $\varphi(R) = \frac{a}{8}\ln(R^2) - \frac{b}{R^2}$; we discard $+c + d\,R^2$.

For an $L$-extended mass $m$, at scales $r \ll L$ one gets Newton's acceleration $\varphi'_N = G_N\, m/r^2$, while for large distances $r \gg L$ it looks different: $\varphi' = G_N m/(rL)$. The second-order equation also should be accounted for and this restricts the solutions; at some constraint on the set $a, b$ the first correction to Newton's force (the Rindler term) $\Delta\varphi \sim r/L^2$ can vanish, so $\Delta\varphi(r \ll L) = \varphi - \varphi_N \sim r^2/L^3$ [2]. It seems $L$ should be about (few) hundred parsecs.

At large scales, if generally $|\mathbf{r}_{ij}| \gg L,$ a virial relation takes the form $\left( \langle\psi\rangle_T = \frac{1}{T}\int\limits_{t0}^{T+t0} \psi \, dt \right)$:

$$\left\langle \sum_i \dot{\mathbf{r}}_i \, \mathbf{p}_i + \mathbf{r}_i \, \dot{\mathbf{p}}_i \right\rangle_T \approx 0 \Rightarrow \left\langle \sum_i m_i \gamma_i \, v_i^2 \right\rangle_T \approx \left\langle \sum_{i,j\neq i} \mathbf{r}_i \frac{\partial U_{ij}(\mathbf{r}_i - \mathbf{r}_j)}{\partial \mathbf{r}_i} \right\rangle_T \approx$$

$$\approx \frac{G}{L}\left[ \left( \sum_i m_i \right)^2 - \sum_i m_i^2 \right].$$

This relation can be applied both to galaxy clusters and to large gas clouds. The (baryon) mass of a galaxy can hardly be measured accurately, and the function $L_{gal}(M_{gal})$ can be non-linear [3], $L_{gal} \sim M_{gal}^2$ — this would support the suggested theory (see also DarkMatterCrisis.wordpress.com).

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# Новая теория тяготения, осцилляции звезд и 11-летний цикл активности Солнца

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Рассмотрено применение новой теории тяготения [1, 2] к задаче описания динамического равновесия звезд [3, 4] и других астрофизических объектов, в том числе к описанию осцилляций звезд и 11-летним осцилляциям Солнца. Новая теория гравитационного поля строится на описании гравитационного поля с помощью лагранжевых переменных (маркеров) точек пространства или среды, заполняющей его. В работе излагаются основные идеи использования маркеров для описания гравитационного поля нестатических астрофизических объектов и их автомодельной эволюции. Получены общие соотношения, позволяющие применять метод маркеров для описания автомодельной динамики газопылевых астрофизических структур. В рамках развитой модели вычислена диаграмма период-светимость для осциллирующих звезд типа цефеид. Приведены результаты применения нового подхода к описанию осцилляций Солнца и объяснению 11-летнего цикла солнечной активности. Приведены основные результаты описания магнитного поля звезд и Солнца в рамках метода гидродинамических маркеров.

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# New Theory of Gravity, Stellar Oscillations and the 11-year Cycle of Solar Activity

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The paper considers the application of the new theory of gravity [1, 2] to the problem of describing the dynamic equilibrium of stars [3, 4] and other astrophysical objects, including the description of stellar oscillations and 11-year oscillations of the Sun. The new theory of the gravitational field is based on the description of the gravitational field with the help of Lagrangian variables (markers) of points in space or the medium that fills it. The paper presents the main ideas of using markers to describe the gravitational field of non-static astrophysical objects and their self-similar evolution. General relations are obtained that allow one to apply the method of markers to describe the self-similar dynamics of gas and dust astrophysical structures. The period-luminosity diagram for oscillating Cepheid-type stars is calculated within the framework of the developed model. The results of applying a new approach to describing solar oscillations and explaining the 11-year cycle of solar activity are presented. The main results of the description of the magnetic field of stars and the Sun within the framework of the method of hydrodynamic markers are presented.

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## Ultracompact Stars in the Light of Minimal Geometric Deformation

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Adopting gravitational decoupling through minimal geometric deformation (MGD) procedure, we develop an analytical version of gravastar model with non-uniform and anisotropic features, in the framework of modified gravity theory. This new non-uniform model describes an ultracompact stellar structure of Schwarzschild radius, whose interior solution smoothly joins a conformally deformed Schwarzschild exterior solution, and it is matched to the standard Schwarzschild exterior solution under certain conditions. The constructed solution presents a family of stellar models satisfying some of the fundamental properties of a stable configuration, including a positive energy density everywhere with monotonically decreasing behavior from the center to surface. Besides, a non uniform pressure is observed with monotonic behaviour. The behaviour of energy conditions is analyzed inside the stellar configurations.

## Content

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