***Annex 2.***

***Theme / Large Research Infrastructure Project Form***

 **APPROVED**

 **Director of Laboratory**

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**REPORT ON THEME**

**1. General information on the Theme**

**1.1. Theme code : 01-3-1138-2019/2023**

**1.2. Laboratory : Bogoliubov Laboratory of Theoretical Physics**

**1.3. Scientific field : Theoretical Physics**

**1.4. Title of the Theme : “Modern Mathematical Physics: Integrability, Gravity and Supersymmetry”**

**1.5. Theme Leaders: Isaev A.P., Krivonos S.O., Sorin A.S.**

**1.6. Projects in the Theme**

**2. Scientific report on the Theme / LRIP**

**2.1. Annotation**

The main tasks of the Theme were: development of mathematical methods for solving the most important problems of modern theoretical physics, namely, the development of new mathematical methods for studying and describing a wide class of classical and quantum integrable systems and their exact solutions, analyzing and searching for solutions to a wide range of problems of supersymmetric theories, including models of strings and other extended objects; study of nonperturbative regimes in supersymmetric gauge theories, development of cosmological models of the early Universe, gravitational waves and black holes.

Mathematical physics in recent years has been characterized by a growing interest in revealing and effectively using the properties of integrability in its various fields, in applying powerful mathematical methods of quantum groups, supersymmetry, and noncommutative geometry both in quantum theories of fundamental interactions and in classical models. When solving the problems of the Theme **“Modern Mathematical Physics: Integrability, Gravity and Supersymmetry”**, the decisive factor was the use of these methods. The essential part of the Theme was devoted to the construction of new theories with extended supersymmetry and gauge invariance in various dimensions, to the study of their quantum structure and classical solutions of the soliton type with cosmological applications. The main efforts were concentrated on the construction of new supersymmetric gauge theories, including higher spins and the development of new approaches and methods for studying their quantum structure. Within the Theme, we succeeded in the solutions of numerous of actual problems which are posed by the modern development of the supersymmetric field theory and superstring/brane theory. The part of the Theme

was devoted to the solution of the fundamental problems of classical and quantum gravity and conducting advanced theoretical research at the national and world level in this area at BLTP JINR. In classical gravity, we focused on studying all kinds of gravitational wave phenomena, including shock waves in General Relativity, as well as various sources of gravitational wave background, such as cosmic strings. One of the directions of the researches was the elaboration of cosmological models that explain the properties of the observable Universe based on field theory methods and modified gravity. In the field of quantum gravity, we continue the developing of the apparatus of quantum field theory in an external classical gravitational background and new methods for an approximate estimation of the effective gravitational action in various regimes. Asymptotic symmetries in gravity, the relationship between gravity, thermodynamics and quantum entanglement, the holographic properties of gravity, and the AdS/CFT correspondence were also partially explored.

**2.2. A detailed scientific report**

Over the past five years, 175 papers have been published in leading foreign and 23 in

Russian journals. Among the main publications we note the following:

1. N. Kozyrev, S. Krivonos,

(Super)Schwarzian mechanics,

Journal of High Energy Physics, ISSN:1029-8479, 03, 120, 2022

2. Elena Apresyan, Gor Sarkissian, Vyacheslav P. Spiridonov,

A parafermionic hypergeometric function and supersymmetric 6j-symbols,

Nuclear Physics B, ISSN:0550-3213, eISSN:1873-1562, 990, 116170, 2023 >

3. Mukhanov V. F., Sorin A. S.,

About the Coleman instantons in D dimensions,

Phys. Lett. B, 827, 136951-136954, 2022

4. C. Herdeiro, I. Perapechka, E. Radu, Ya. Shnir,

Asymptotically flat spinning scalar, Dirac and Proca stars,

Physics Letters B, ISSN:0370-2693, eISSN:1873-2445, 797, 134845 (8pp), статья, 2019

5. Petr V. Tretyakov,

Bianchi I cosmological solutions in teleparallel gravity,

Modern Physics Letters A, 37, 08, 2250046, 2022

6. G.A. Sarkissian and V.P. Spiridonov,

Complex hypergeometric functions and integrable many-body problems,

Journal of Physics A: Mathematical and Theoretical, ISSN:1751-8113, eISSN:1751-8121, 55, 38, 385203, 2022

7. N. Kozyrev,

Component d = 6 Born-Infeld theory with N = (2, 0) - > N = (1, 0) supersymmetry breaking,

Journal of High Energy Physics, ISSN:1029-8479, 1908, 136, 2019 >>

8. Evgeny Ivanov, Stepan Sidorov,

Couplings of N=4, d=1 mirror supermultiplets,

Physical Review D, ISSN:1550-7998, eISSN:1550-2368, 105, 8, 086027, 2022

9. E. Ivanov, A. Nersessian, H. Shmavonyan,

CPN-Rosochatius system, superintegrability, supersymmetry,

Physical Review D, ISSN:1550-7998, eISSN:1550-2368, 99, 8, 085007, 2019

10. N. Kozyrev, S. Krivonos, O. Lechtenfeld, A. Nersessian, A. Sutulin,

Curved WDVV equation and supersymmetric mechanics,

Journal of Physics: Conference Series, 965, 1, 012026, 2018

11. A.P.Isaev, M.A.Podoinitsyn,

D-dimensional spin projection operators for arbitrary type of symmetry via Brauer algebra idempotents,

Journal of Physics A: Mathematical and Theoretical, ISSN:1751-8113, eISSN:1751-8121, 53, 39, 2020

12. Evgeny Ivanov, Olaf Lechtenfeld, Stepan Sidorov,

Deformed N=8 mechanics of (8,8,0) multiplets,

Journal of High Energy Physics, 1808, 193, 2018

13. Sergey Fedoruk, Evgeny Ivanov, Stepan Sidorov,

Deformed supersymmetric quantum mechanics with spin variables,

Journal of High Energy Physics, ISSN:1126-6708, eISSN:1029-8479, 1801, 132 (1-20), 2018

14. M. Bordag, I.G. Pirozhenko,

Dispersion Forces Between Fields Confined to Half Spaces,

Symmetry, ISSN:2073-8994, 10, 3, 74 (1-10), 2018

15. D.V. Fursaev and I.G. Pirozhenko,

Electrodynamics under the action of null cosmic strings,

Physical Review D, ISSN:1550-7998, eISSN:1550-2368, 107, 025018, , Phys. Rev. D 107, 025018, 2023

16. Ivanhoe B. Pestov,

Emergent Spin and Duality of Time,

Journal of Physics: Conference Series 1435(2020)012056 doi: 10.1088/1742-6596/1435/1/012056, 1435, 012056, 1-4, 2020

17. Erik Khastyan, Sergey Krivonos, Armen Nersessian,

Euler top and freedom in supersymmetrization of one-dimensional mechanics,

Physics Letters A, ISSN:0375-9601, eISSN:1873-2429, 452, 128442, 2022

18. Irina Ya. Aref'eva, Anastasia A. Golubtsova, Giuseppe Policastro,

Exact holographic RG flows and the A1?A1 Toda chain,

Journal of High Energy Physics, ISSN:1029-8479, 5, (2019)117, 1-50, 2019

19. S.Krivonos, O.Lechtenfeld, A.Provorov, A.Sutulin,

Extended supersymmetric Calogero model,

Physics Letters B, ISSN:0370-2693, eISSN:1873-2445, 791, 385-389, 2019

20. Zhyrair Gevorkian, Mher Davtyan, and Armen Nersessian,

Extended symmetries in geometrical optics,

Physical Review A, 101, 2, 023840, 2020

21. Sergey Fedoruk, Evgeny Ivanov, Jerzy Lukierski,

From N=4 Galilean superparticle to three-dimensional non-relativistic N=4 superfields,

Journal of High Energy Physics, ISSN:1126-6708, eISSN:1029-8479, 1805, 019 (1-42), 2018

22. I.L. Buchbinder, E.A. Ivanov, B.S. Merzlikin, K.V. Stepanyantz,

Gauge dependence of the one-loop divergences in 6D, N=(1,0) abelian theory,

Nuclear Physics B, ISSN:0550-3213, eISSN:1873-1562, 936, 638-660, 2018

23. N. Kozyrev, S. Krivonos,

Generalized Schwarzians,

Physical Review D, ISSN:2470-0010, eISSN:2470-0029, 107, 2, 026018, 2023

24. Sergey Fedoruk, Evgeny Ivanov, Andrei Smilga,

Generic HKT geometries in the harmonic superspace approach,

Journal of Mathematical Physics, ISSN:0022-2488, eISSN:1089-7658, 59, 8, 083501 (1-33), 2018

25. Sergey Krivonos, Armen Nersessian, Hovhannes Shmavonyan,

Geometry and integrability in N=8 supersymmetric mechanics,

Physical Review D, ISSN:1550-7998, eISSN:1550-2368, 101, 4, 045002, 2020

26. H. Dimov, M. Radomirov, I.N. Iliev, R. C. Rashkov, and T. Vetsov,

Global and local thermodynamics of the (2+1)-dimensional rotating Gauss-Bonnet black hole,

Physical Review D, ISSN:2470-0010, Vol. 105, 044033, 1-16, статья, Published 15 February 2022, 2022

27. Evgeny Ivanov, Luca Mezincescu,

Global Symmetries of Quaternion-Kahler N=4 Supersymmetric Mechanics,

Journal of High Energy Physics, ISSN:1029-8479 (Online), 2101, 01, 081 (1-25), arXiv:2007.12985 [hep-th], 2021 >>

28. I.L. Buchbinder, E. Ivanov, B. Merzlikin, K. Stepanyantz,

Harmonic Superspace Approach to the Effective Action in Six-Dimensional Supersymmetric Gauge Theories,

Symmetry, ISSN:2073-899411, 1, 68, статья, 2019 >>

29. Irina Ya. Aref’eva, Anastasia A. Golubtsova and Eric Gourgoulhon,

Holographic drag force in 5d Kerr-AdS black hole,

JHEP, 04, (169)1-36, JHEP 04 (2021) 169, 2021

30. H. Dimov, I. N. Iliev, M. Radomirov, R. C. Rashkov, T. Vetsovv,

Holographic Fisher Information Metric in Schrodinger Spacetime,

The European Physical Journal Plus, volume 136, Article number: 1128 (2021), 1-33, Published: 10 November 2021, 2021

31. I.L. Buchbinder, S.A. Fedoruk, A.P. Isaev,

Light-front description of infinite spin fields in six-dimensional Minkowski space,

The European Physical Journal C, ISSN:1434-6044, eISSN:1434-6052, 82, 8, 733 (1-11), 2022

32. I.L. Buchbinder, S.A. Fedoruk, A.P. Isaev, M.A. Podoinitsyn,

Massless finite and infinite spin representations of Poincare group in six dimensions,

Physics Letters B, ISSN:0370-2693, eISSN:1873-2445, 813, 136064 (1-8), 2021

33. Sergey Fedoruk, Evgeny Ivanov,

Multiparticle N=8 mechanics with F(4) superconformal symmetry,

Nuclear Physics B, ISSN:0550-3213, eISSN:1873-1562, 938, 714–735, 2019

34. Anton Galajinsky Sergey Krivonos,

N=4 super-Schwarzian derivative via nonlinear realizations,

Phys Rev D, 102, 10, 106015, 2020

35. Sergey Krivonos, Olaf Lechtenfeld,

N=4 supersymmetric Calogero-Sutherland models,

Physical Review D, ISSN:1550-7998, eISSN:1550-2368, 101, 8, 086010, 2020

36. F. Delduc, E. Ivanov,

N=4 supersymmetric d=1 sigma models on group manifolds,

Nuclear Physics B, ISSN:0550-3213, eISSN:1873-1562, 949, 114806(1- 32), 2019

37. N. Kozyrev, S. Krivonos, O.Lechtenfeld, A. Nersessian, A. Sutulin,

N=4 supersymmetric mechanics on curved spaces,

Physical Review D, 97, 8, 085015, arXiv:1711.08734, 2018

38. E.A. Davydov, D.V. Fursaev, V.A. Tainov,

Null cosmic strings: Scattering by black holes, optics, and spacetime content,

Physical Review D, ISSN:2470-0010, eISSN:2470-0029, 105, 8, 083510, 2022

39. I. Buchbinder, E. Ivanov, N. Zaigraev,

Off-shell cubic hypermultiplet couplings to N = 2 higher spin gauge superfields,

Journal of High Energy Physics, ISSN:1126-6708, eISSN:1029-8479, 2205, 104 (1-37), статья, 2022

40. J. M. Guilarte, J. M. Munoz-Castaneda, I. Pirozhenko, L. Santamaria-Sanz,

One-dimensional scattering of fermions on delta-impurities,

Frontiers in Physics, 7, 109, original research article, Front.in Phys. 7 (2019) 109, e-Print: arXiv:1903.05568 [math-ph] , 18 pages, 2019

41. А.П. Исаев, М.А. Подойницын,

Тензоры поляризации для массивных частиц с произвольным спином и проекционный оператор Берендса–Фронсдала,

Teor.Mat.Fiz., 198, 1, 101-112, 2019

42. Nikolay A. Tyurin,

Lagrangian Geometry of Algebraic Manifolds,

Письма ЭЧАЯ, ISSN:1814-5957, eISSN:1814-5973, 19, 4, 337 – 342, 2022

43. Nikolay Tyurin,

The Moduli Space of D-Exact Lagrangian Submanifolds,

Siberian Mathematical Journal, ISSN:0037-4474 (print), 60, 4, 709-719, 2019

44. Н.А. Тюрин,

Лагранжевы циклы Миронова в алгебраических многообразиях,

Математический сборник, ISSN:0368-8666, 212, 3, 128-138, 2021

45. Г. А. Саркисян, В. П. Спиридонов,

Модулярная группа и гиперболический бета-интеграл,

Успехи Математических наук, ISSN:0042-1316, 75, 3, 187-188, 2020

46. Н.А. Тюрин,

Монотонные лагранжевы торы стандартного и нестандартного типа в торических и псевдоторических многообразиях Фано,

Труды Математического Института Российской академии наук им. Стеклова, ISSN:0371-9685 (print), 307, 1-15, https://doi.org/10.4213/tm4030, 2019

47. Н.А. Тюрин,

О кэлеризации многообразия модулей бор-зоммерфельдовых лагранжевых подмногообразий,

Математические заметки, ISSN:0025-567X, 107, 6, 945-947, 2020

48. А.П. Исаев, М.А. Подойницын,

Тензора поляризации для массивных частиц с произвольным спином и проекционный оператор Берендса-Фронсдала,

Teor.Mat.Fiz., 198, 1, 101-112, 2018

49. А.П. Исаев, М.А. Подойницын,

Унитарные представления Вигнера группы ISL(2,C) и двухспинорное описание массивных частиц с произвольным спином,

Teor.Mat.Fiz., 195, 3, 331-361, 2018

Among the invited reports at international conferences and meetings, the following should be noted:

1. Classical and quantum superfield invariants in N=(1,1),6D SYM theory,

XXV International Conference on Integrable Systems and Quantum Symmetries (ISQS-25), Czech Technical University Prague & BLTP JINR, Prague, Czech Republic,

Evgeny Ivanov, 012021 (10 pages), J.Phys.Conf.Ser., 965, 1, 2018 >>

2. Conformally flat N=4 supersymmetric multiparticles mechanics,

XXV International Conference on Integrable Systems and Quantum Symmetries (ISQS-25), Czech Technical University Prague & BLTP JINR, Prague, Czech Republic,

N.Kozyrev, S. Krivonos, O. Lechtenfeld, A. Nersessian, A. Sutulin, 012026, J.Phys.Conf.Ser., 965, no.1, 2018 >>

3. Curved WDVV equations and superfields,

The 32nd International Colloquium on Group Theoretical Methods in Physics (Group32), Czech Technical University, Prague, Czech Republic,

N.Kozyrev, 012061, Institute of Physics and IOP Publishing Limited, J.Phys.Conf.Ser. 1194 (2019) no.1, 012061, 1194, 1, arXiv:1812.01406, 2018 >>

4. Elliptic, hyperbolic, complex gamma functions and physics in the various dimensions,

RDP Online Workshop: Aspects of Symmetry, , ,,

Саркисян Гор, 1-10, Sissa Medialab, PoS, Regio2021, 037, 1824-8039, 2022 >>

5. Holographic Fisher Information Metric for Models with Non Relativistic Symmetry,

,ISSN - 1223 - 6039WORKSHOP ON QUANTUM FIELDS AND NONLINEAR PHENOMENA, Craiova, Romania, 2020, University of Craiova, Craiova, Romania,

H. Dimov, M. Radomirov, R. C. Rashkov and T. Vetsov, 85-95, University of Craiova, Romania, Annals of the University of Craiova, Physics AUC, vol. 30(part II), 1223 - 6039, 2021

6. New approach to N=2 supersymmetric Ruijsenaars–Schneider model,

RDP Online Workshop on Mathematical Physics, Uni. Bonn-TSU-YerPhI, Bonn-Tbilisi-Yerevan, Germany-Giorgia-Armenia,

Н.Ю. Козырев, С.О. Кривонос, О. Лехтенфельд, 018, Sissa Medialab, Proceedings of Science, Regio2020, https://doi.org/10.22323/1.394.0018, 2021

7. New approach to N=2 supersymmetric Ruijsenaars–Schneider model,

RDP online workshop `Recent Advances in Mathematical Physics` (Regio2020), Yerevan, Armenia, N.Yu. Kozyrev S.O.Krivonos O. Lechtenfeld, 018, SISSA, 2021

8. Remarks on fields with a holographic dual,

,ISSN - 1223 - 6039WORKSHOP ON QUANTUM FIELDS AND NONLINEAR PHENOMENA, Craiova, Romania, 2020, University of Craiova, Craiova, Romania,

H. Dimov, R. C. Rashkov and T. Vetsov, 35-51, University of Craiova, Romania, Annals of the University of Craiova, Physics AUC, vol. 30(part II), 1223 - 6039, 2021

9. SU(2|1) chiral superfields and spinning models,

Recent Advances in Mathematical Physics, Regional Doctoral Program in Theoretical and Experimental Particle Physics, Georgia, Armenia,

Stepan Sidorov, 019, PoS Regio2020, Online Workshop, 2021

10. Supersymmetric Calogero models,

International Bogolyubov Conference, Problems of Theoretical and Mathematical Physics (dedicated to the 110th anniversary of the birth of N.N. Bogolyubov (1909-1992)), Russian Academy of Sciences; Steklov Mathematical Institute RAS, Moscow;Joint Institute for Nuclear Research, Dubna, Dubna, Russia,

S.Krvonos, O.Lechtenfeld, A.Sutulin, 2019

11. Supersymmetric Calogero models,

Supersymmetries and Quantum Symmetries – SQS`19, BLTP JINR and YerPhI, Yerevan, Armenia, S.Krivonos, O.Lechtenfeld, A.Sutulin, 2019

Over the past six years, five JINR First Prizes in Theoretical Physics have been received:

1. 2017, N.A. Tyurin,

"Pseudotoric Structures: Lagrangian Tori and Lagrangian Foliations"

2. 2018, S. O. Krivonos, O. Lekhtenfeld, A. O. Sutulin,

"Higher-dimensional supersymmetric mechanics, the Witten-Dijkgraaff-Verlinde-Verlinde equation and its generalization".

3. 2019, A.P. Isaev, V.A. Rubakov,

«Theory of groups and symmetries. Representations of Lie groups and Lie algebras. Applications".

4. 2020, J. Kunz, I. Perapechka, J. Schnir,

"Scalar solitons, bosonic stars, and black holes with matter fields".

5. 2022, E.A. Ivanov, I.L. Buchbinder, B.S. Merzlikin, K.V. Stepanyants,

"New methods in classical and quantum field theory with extended supersymmetry".

Research on the topic was carried out in full accordance with the plan. Below is a selection of some of the important results for 2018-2023.

Important results have been obtained in integrable systems. Supergravity solutions are constructed that describe intersecting D- and M-branes, and solutions without a horizon (bosonic stars) with asymptotics in the form of Lifshitz spaces are found and analyzed. Kerr-Vadya and Kerr-Newman-Vadya solutions are constructed with asymptotics in the form of AdS space for D=5 supergravity model. We obtain effective formulas for the action of monodromy matrix elements on universal Bethe vectors for quantum integrable systems associated with supersymmetric extensions of the Yangian double. The moduli variety of special Bohr-Sommerfeld cycles in the algebraic case is constructed and investigated. It is shown that in the algebraic case such moduli varieties are finite-dimensional. On the basis of unitary Wigner representations for the covering group ISL(2,C) of the Poincaré group, spin-tensor wave functions of free massive particles with arbitrary spin are obtained that satisfy the Dirac-Pauli-Fierz equations. It is shown that the condition for the existence of supersymmetry is a generalization of the well-known Witten-Dijkgraf-Werlinde-Werlinde equation, called the curved WDVV equation. Solutions of this equation on isotropic spaces are found, and generalizations of the potentials and solutions of WDVV known in the plane case to these spaces are constructed.

A large number of works have been devoted to supersymmetry. SU(2|1) and SU(2|2) extensions of the Calogero-Moser models are constructed and studied as deformations of N=4 supersymmetric extensions. Superfield actions are constructed for multiparticle systems with N=4 deformed supersymmetry. A superfield formulation of the sigma model with the Wess-Zumino term, which has N=4 deformed supersymmetry and describes the interaction of a spin particle with an external gauge background, is obtained. Models of spin particles and superparticles are constructed using pulsed twistors. The transition amplitudes are obtained by the BFV–BRST method of the functional integral. The geometries described by N=4 supersymmetric quantum mechanical sigma models with various dynamical, semidynamical and gauge supermultiplets are determined.

Significant results have been obtained in cosmological theories. Observational data on bright stars near the Galactic Center are used to obtain constraints on the behavior of gravitational forces, in particular, on the modification of Newton's law in the weak field approximation. Inflation mechanisms are studied that are consistent with the observational data of Plank-2015 and use the classical Yang-Mills fields that interact not minimally with gravity. The vacuum energy of quantum fields in the presence of crossed cosmic strings is calculated, and its finite part, which depends on the mutual arrangement of cosmic strings, is isolated.

Selected publications and results:

 A.P. Isaev, M.A. Podoinitsyn,

Wigner unitary representations of the ISL(2,C) group and two-spin description of massive particles with arbitrary spin, Theoretical and Mathematical Physics 195, 3, 331-361, 2018

Based on unitary Wigner representations for the covering group ISL(2,C) of the Poincaré group, spin-tensor wave functions of free massive particles with arbitrary spin are obtained that satisfy the Dirac–Pauli–Fierz equations. In the framework of the two-spinor formalism, polarization spin vectors are constructed and conditions are obtained that fix the corresponding density matrices (Behrends–Fronsdal projection operators) that determine the numerators in the propagators of the fields of such particles. Using these conditions, explicit expressions are found for the density matrices of particles with integer (Behrends–Fronsdal projection operators) and half-integer spin. A generalization of Behrends–Fronsdal projection operators is obtained for the case of an arbitrary number D of space-time dimensions.

N. Kozyrev, S Krivonos, O. Lechtenfeld, A. Nersessian, A. Sutulin,

N=4 supersymmetric mechanics on curved spaces, Physical Review D, 97, 8, 085015, 2018

Within the framework of the Hamiltonian formalism, N= 4 supersymmetric mechanics are studied particles on curved spaces, described by several N=4, d=1 linear multiplets. It is shown that the condition for the existence of supersymmetry is generalization of the well-known Witten-Dijkraff-Werlinde-Werlinde equation, called curved equation WDV V. Solutions of this equation are found on isotropic spaces, generalizations of the potentials and solutions of WDVV known in flat case, on these spaces.

N .A. Tyurin,

 Special Bohr–Sommerfeld Lagrangian submanifolds in algebraic Manifolds,

Izvestiya RAN, Volume 82, Number 3 (2018) pp. 170-191

In this paper, we continue to study special Bohr–Sommerfeld submanifolds in the case when the ambient symplectic manifold has a compatible integrable complex structure, i.e., when the ambient variety is algebraic. In this case, we show how the special Bohr–Sommerfeld geometry reduces to Morse theory on complements to ample divisors. This implies the construction of the Lagrangian shadow of an ample divisor in an algebraic variety, which is an example of the “algebraic vs symplectic” duality. A condition for the existence of a Lagrangian shadow is proposed, and examples of Lagrangian shadows of some ample divisors on the projective plane, complex quadric, and flag variety are given.

M. Bordag, I.G. Pirozhenko.

Dispersion Forces Between Fields Confined to Half Spaces. Symmetry 10 (3), 74 (2018)

We calculate the Casimir force between two half spaces separated by a gap $L$ in which a scalar field is confined by the Dirichlet boundary conditions. The field interacts via the Yukawa coupling with another scalar field residing in the whole space. We computed the reflection coefficients of the half spaces in terms of one-loop polarization operators derived in the considered QFT model. These reflection coefficients completely define the separation dependent finite part of the vacuum energy. The first successful model this type with one of the interacting fields restricted to a plane was the Dirac model of graphene. There is an upcoming interest in such type of calculations, caused by high precision measurement of dispersion forces (up to femtonewton) and the need to account for internal dynamical properties of the interacting bodies.

P. V. Tretyakov,

Cosmology in modified f(R, T)-gravity. The European Physical Journal C - Particles and Fields, 78, 11, 896, 2018

We propose further modification of *f*(*R*,*T*)-gravity (where *T* is trace of energy-momentum tensor) by introducing higher derivatives matter fields. We discuss stability conditions in proposed theory and find restrictions for parameters to prevent appearance of main type of instabilities, such as ghost-like and tachyon-like instabilities. We derive cosmological equations for a few representations of theory and discuss main differences with convenient *f*(*R*,*T*)-gravity without higher derivatives. It is demonstrated that in presented theory inflationary scenarios appears quite naturally even in the dust-filled Universe without any additional matter sources. Finally we construct inflationary model in one of the simplest representation of the theory, calculate main inflationary parameters and find that it may be in quite agreement with observations.

E.A. Davydov.

Discreteness of dion-dilaton black holes, Teor.Mat.Fiz., 197 no. 2 (2018), 311.

As is known, many black hole type solutions acquire undesirable properties due to the phenomenon of mass inflation, when the inner horizon becomes singular. This phenomenon is universal and arises due to the scattering of falling matter on the inner horizon (which always happens in the real world). According to our result [1], the phenomenon of mass inflation does not occur for a whole class of solutions: if in the effective phase space, the corresponding solutions do not allow energy transfer between the degrees of freedom. A distinctive feature of such solutions is a kind of “quantization” of the measured parameters of the model.

E. Ivanov, A. Nersessian, S. Sidorov, H. Shmavonyan,

Symmetries of deformed supersymmetric mechanics on Kähler manifolds,

Phys. Rev. D 101 (2020) 025003, arXiv:1911.06290 [hep-th]

Construction of deformed models of N=4 and N=8 supersymmetric mechanics on Kahler manifolds, in interaction with a constant magnetic field, and study of their symmetries. In the works of A. Nersesyan and S. Bellucci (arXiv:hep-th/0211070, hep-th/0401232), N=4 supersymmetric models on Kahler manifolds were studied, where the presence of a constant magnetic field leads to a deformation of the N=4 Poincaré supersymmetry to called "weak supersymmetry" (A. Smilga, arXiv:hep-th/0311023). In our works by E. Ivanov and S. Sidorov (arXiv:1307.7690 [hep-th], arXiv:1312.6821 [hep-th]) it was shown that the N=4 Poincaré supersymmetry is deformed into SU(2|1) supersymmetry, and the magnetic the field plays the role of the deformation parameter. The SU(2|1) superfield formalism was developed, with the help of which the previously studied models with weak supersymmetry were reproduced and new ones were constructed.

Results: Deformed N=4 and N=8 (SU(2|1) and SU(4|1), respectively) supersymmetric mechanics on Kähler manifolds are constructed on the basis of the systematic Hamiltonian and superfield approaches. SU(2|1) supersymmetric Kähler oscillators are constructed and found to include, in particular, the superintegrable models of Smorodinsky Winternitz on C^N and Rosochatius on CP^N. It is shown that the proposed supersymmetric extensions inherit all the kinematic symmetries of the original bosonic models. In the case of the C^N Smorodinsky-Winternitz system, we have obtained hidden (non-kinematic) symmetries expressed by the Uhlenbeck tensor. The formulation of the Uhlenbeck tensor for the supersymmetric Rosochatius model on CP^N remains an open problem

In the paper [S.Krivonos, O.Lechtenfeld, A.Sutulin, N--extended supersymmetric Calogero models, Phys. Lett. B784 137 (2018)} a new N-extended supersymmetric su(n) Calogero spin model was proposed. Using the generalized Hamiltonian reduction applied to the supersymmetric case, a new rational Calogero model of n-particles with an arbitrary even number of supersymmetries was explicitly constructed. It is shown that the considered model has Nn^2 fermion fields, instead of a set of Nn, as well as arbitrarily high powers in fermions in supercharges and the Hamiltonian.

In the paper [S.Krivonos, O.Lechtenfeld, A.Sutulin, Supersymmetric many-body Euler-Calogero-Moser model, Phys.Lett. B790 191 (2019)], a supersymmetric so(n) Calogero spin model with an arbitrary even number N of supersymmetries was constructed.

This model has 1/2 Nn (n + 1) fermionic coordinates, as opposed to the standard set of Nn fermions, and a very simple supercharge and Hamiltonian structure. It is shown that the resulting supercharges and the Hamiltonian, together with additional conserved currents, form the superalgebra osp(N|2). A description in superspace for the simplest case, namely N=2 supersymmetry, is presented.

In the paper [S.Krivonos, O.Lechtenfeld, A.Provorov, A.Sutulin, Extended supersymmetric Calogero model, Phys.Lett. B791 385 (2019)], a nontrivial redefinition of the matrix fermionic fields of the N-extended supersymmetric Calogero model A\_{n-1} was found, which made it possible to construct supercharges in the so-called standard form, namely, cubic in fermionic fields. into the non-canonical and nonlinear properties of the complex (Hermitian) conjugation of fermions. It is shown that the reduction of the model A\_{2n-1}+A\_1 generalized to the supersymmetric case, described in terms of the obtained supercharges and the Hamiltonian, leads to rational B\_n, C\_n and D\_n Calogero models with an arbitrary even number of supersymmetries.

 New twistorial description of the infinite spin particles and superparticles are obtained and investigated in [I.L. Buchbinder, S. Fedoruk, A.P. Isaev, A. Rusnak, *''Model of massless relativistic particle with continuous spin and its twistorial description'',* JHEP 1807 (2018) 031;

I.L. Buchbinder, S. Fedoruk, A.P. Isaev, *'' Twistorial and space-time descriptions of massless infinite spin (super)particles and fields'',* Nucl. Phys. B945 (2019) 114660.]

 The infinite spin particles are massless, but different from massless particles with a fixed helicity. Interest in them is caused by the identical spectrum of massless states of the infinite spin theory and the higher spin theory.

 Although of the physical status of such unitary infinite-dimensional Poincare representations is still not very clear, applications of such systems may arise in constructing the string theory and in solving the current "hot" problem of dark matter.

 Using the powerful tools of Penrose twistors allows to build new field formalism for describing the infinite spin particles.

 In the paper [S. Fedoruk, E. Ivanov, O. Lechtenfeld, *'‘Supersymmetric hyperbolic Calogero-Sutherland models by gauging '',* Nucl. Phys. B944 (2019) 114633 ] novel N=2 and N=4 supersymmetric extensions of the Calogero-Sutherland hyperbolic systems are obtained by gauging the U(n) isometry of matrix superfield models.

I.G.Pirozhenko, Casimir force between Dirac lattices at finite temperature, arXiv:1911.06510 [quant-ph] Mod. Phys. Lett. A

At a finite temperature, the scalar field is considered against the background of gratings

Dirac delta potentials. An asymptotic expansion of the kernel is constructed heat conduction equations (heat kernel) and high- and low-temperature free energy asymptotics.

J. M. Guilarte, J. M. Munoz-Castaneda, I. Pirozhenko, L. Santamaria-Sanz,

One-dimensional scattering of fermions by delta impurities, Аront. in Phys. 7, 109 , 2019 arXiv:1903.05568 [math-ph]

The spectrum of the one-dimensional Dirac Hamiltonian in a static delta potential is studied. The most general form of such a potential is considered, the differences in the spectra of delta potentials of the “electrostatic” type and the “mass jump” type are investigated. Scattering states and bound states are found.

There is a wonderful way, proposed by Vogel, to parameterize all simple complex Lie algebras by three parameters, which are defined up to a common factor and permutations. In the paper of A.P.Isaev and S.O.Krivonos entitled “Split Casimir operator for simple Lie algebras, solutions of Yang-Baxter equations and Vogel parameters”, published in the Journal of Mathematical Physics 62 (2021) 8, 083503, it was shown how this description arises when considering the split (polarized) Casimir operators - the main building blocks used in calculating of the color factors in the amplitudes in the nonabelian gauge field theories. The characteristic identities were constructed for the split Casimir operators of all simple complex Lie algebras in the defining and adjoint representations. Using these identities, the explicit formulas were obtained for the projectors onto invariant subspaces of the representation T x T in two cases, when T is the defining and when T is the adjoint representation. In the adjoint representation, the constructed characteristic identities and the corresponding projectors were investigated from the standpoint of a universal description of all simple complex Lie algebras in terms of the Vogel parameters.

I. Y. Aref 'eva, A. A.Golubtsova and E.Gourgoulhon,

«Holographic drag force in 5d Kerr-AdS black hole» JHEP 04 (2021)169,

 The energy losses of a heavy quark in a rotating quark-gluon plasma in N =4 SYM on R × S3 are studied using holographic duality. The general case of a Kerr-AdS5 black hole is considered as a holographic twin. In the holographic approach, the motion of a quark in a medium is dual to the dynamics of an open string, the end of which is fixed at the boundary of the background under consideration. The static quark mass, the friction force acting on the quark, and the jet damping coefficient are calculated. A dependence of the observed data on the phase transition temperature is found. It is shown that in the limit of high temperatures, the contributions from rotation are suppressed and the relations for the static quark mass and the jet damping coefficient coincide with the expressions for the case N=4 SYM on . In addition, it is shown that the phase transition temperature in a rotating quark-gluon plasma in N=4 SYM does not decrease with increasing angular velocity.

N. Kozyrev, Partial breaking of arbitrary amount of d=3 supersymmetry, Phys.Rev.D 102 (2020) 2, 026011

 Among supergravity solutions with partial spontaneous breaking of supersymmetry, there are those in which not half of the supersymmetry is broken, but 3/4, 7/8, etc. As a rule, these are systems of several intersecting multidimensional objects - branes. In order to find out whether it is possible to construct component effective actions of such systems using the method of nonlinear realizations, simplified models of M scalar and vector Goldstone multiplets of N=1, d=3 supersymmetry, with additional SO(M) invariance, were investigated. It was shown that in the case of scalar multiplets, the action exists for any number M of broken supersymmetries and is uniquely (except for M=4) fixed by them. At M=1.2 it is the Nambu-Goto action and reduces to membrane actions at D=4.5, and at M=5 there is a hidden unbroken supersymmetry. For M=4, the action contains a free parameter, with a special choice of which describes the membrane in D=7 (with 3 hidden supersymmetries). In all other cases, it is not a Nambu-Goto action, and its interpretation must be clarified. Goldstone fermions enter into action in a standard way, through the modification of derivatives and measures of integration in the spirit of Volkov-Akulov, and also through the Wess-Zumino term. It is also shown that for M vector multiplets SO(M) there is no invariant action.

I. Buchbinder, E. Ivanov, N. Zaigraev,

Off-shell cubic hypermultiplet couplings to N = 2 higher spin gauge superfields JHEP 05 (2022) 104, e-Print: 2202.08196 [hep-th]

We construct manifestly 4D,N=2 supersymmetric and gauge invariant off-shell cubic couplings of matter hypermultiplets to the higher integer spin gauge N=2 multiplets introduced in [arXiv:2109.07639](https://arxiv.org/abs/2109.07639) [hep-th]. The hypermultiplet is described by an analytic harmonic 4D,N=2 superfield q+ with the physical component spins s=(1/2,0) and an infinite number of auxiliary fields. The cubic coupling constructed has the schematic structure q+\*H^++\_(s)\*q+, where H^++(s) is a differential analytic operator of the highest degree (s−1) accommodating the massless gauge N=2 multiplet with the highest spin s. For odd s the gauge group generators and couplings are proportional to U(1)\_{PG} generator of the internal SU(2)\_{PG} symmetry of the hypermultiplet and so do not exist if SU(2)\_{PG} is unbroken. If this U(1)\_{PG} is identified with the central charge of 4D,N=2 supersymmetry, a mass for the hypermultiplet is generated and the odd s couplings vanish in the proper massless limit. For even s the higher-spin gauge transformations and cubic superfield couplings can be defined for both massive and massless (central-charge neutral) hypermultiplets without including U(1)\_{PG} generator. All these features directly extend to the case of n hypermultiplets with the maximal internal symmetry USp(2n)×SU(2).

**Theme leader**

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