Bogoliubov Laboratory of Theoretical Physics

Report and proposal of a theme: "Modern Mathematical Physics: Gravity, Supersymmetry and Strings"

Leaders: A.P.Isaev, S.O.Krivonos, A.S.Sorin

Scientific leader: A.T.Filippov

49th meeting of the PAC for Particle Physics, June 18, 2018

Modern Mathematical Physics:
Strings and Gravity, Supersymmetry, Integrability
Strusture: 3 projects

- **Quantum Groups and Integrable Systems**

  Leader: A.P.Isaev

- **Supersymmetry**

  Leader: E.A.Ivanov

- **Quantum Gravity, Cosmology and Strings**

Leaders: A.T.Filippov, V.V.Nesterenko, A.S.Sorin

Administrative division and staff

Sector I
N.A.Tyurin
(A.P. Isaev)
11 + 1

Sector II
E.A. Ivanov
11 + 0

Sector III
I.G.Pirogenko (A.T. Filippov
V.V.Nesterenko, A.S.Sorin)
11 + 3

Doctor of science - 17
PhD - 16
Without degree - 4
(including -
2 reserchers
2 students)

Total: 33 + 4 = 37

Countries:

Russia – 24
Armenia – 4
Rep. of Belarus – 1
Bulgaria – 1
Czech Republic – 3
Poland – 2
Ukraine – 1
Peru – 1

Publications & Talks at the Conferences

Journal publications	~ 180
Proceeding of Conferences	~ 40
Books – 1	
Total	~ 220

Defended Theses

Doctor of Science – 2

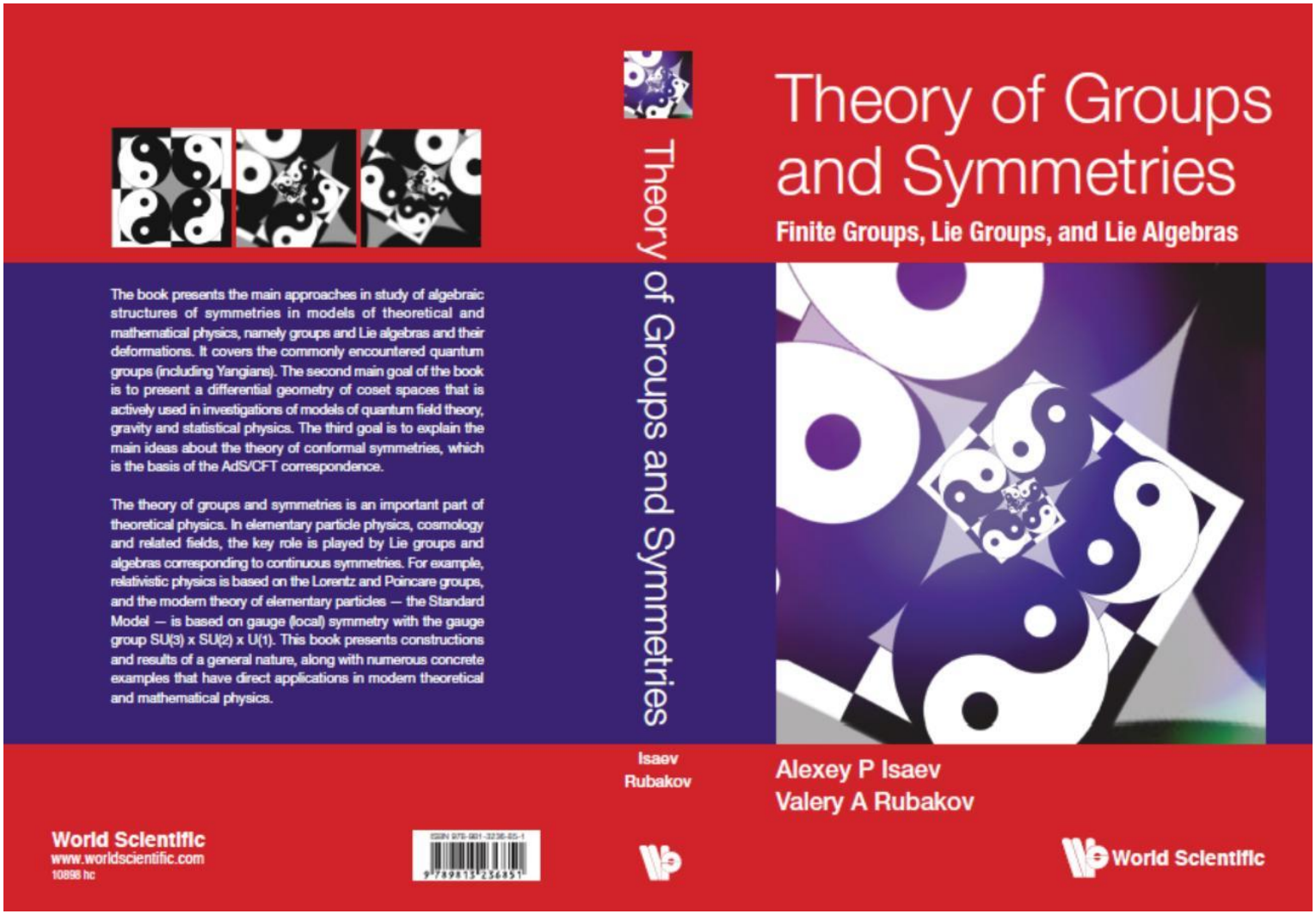
Candidate of Science (PhD) – 2

Lecture courses – 11

Dubna University, Moscow Ins. of Physics and Technology, JINR Univ. Center, Physics Faculty of M.V.Lomonosov MSU, Higher School of Economics, Sofia University, Belarussian State University

A.P.Isaev and V.A.Rubakov, Theory of Groups and Symmetries. *Finate Groups, Lie Groups and Lie Algebras*.

World Scientific, 2018



Organized Conferences and Schools

2014

1. February 2 - 8, Dubna, Russia,
   XIIth Winter School on Theoretical Physics
2. March 3 – 5, EU-Russia-JINR@Dubna Round Table,
   What next?: Theoretical and Experimental Physics after the discovery of the Brout-Englert-Higgs boson
3. June 24 - 28, Prague, Czech Republic, XXII International Colloquium
   Integrable Systems and Quantum Symmetries
4. August 2 - 9, Dubna, International School
   Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems
5. September 11 - 13, Dubna, International Workshop
   Supersymmetry in Integrable Systems (SIS' 2014)
6. October 12 - 18, Dubna, XVI International Conference
   Symmetry Methods in Physics

2015

7. June 23 - 27, Prague, Czech Republic XXIII International Colloquium,
   Integrable Systems and Quantum Symmetries
8. August 6 - 11, Tsakhkadzor, Armenia, The IVth International School,
   Symmetry in Integrable Systems & Nuclear Physics
9. July 13 - 18, Yerevan, Armenia, The 9th International Conference
   Quantum Theory and Symmetries (QTS-9)

Organized Conferences and Schools

10. July 13 - 18, Yerevan, Armenia, The 9th International Conference
    Quantum Theory and Symmetries (QTS-9)
11. August 3 – 8, Dubna, International Workshop
    Supersymmetries and Quantum Symmetries (SQS'2015)
12. August 16 – 21, Dubna, International School
    Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems
13. November 24 – 28, Italy-Russia@Dubna Round Table
    Hundred years from GR's birth, SUGRA gets into its forties

2016

14 . June 14 - 18, Prague, Czech RepublicXXIV International Colloquium
    Integrable Systems and Quantum Symmetries
15. July 30 - August 6, Dubna, International School
    Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems
16. August 28 - September 10, Dubna, Helmholtz - DIAS International Summer School
    Cosmology, Strings and New Physics
17. September 19 - 24 Tianjin, China, International Workshop
    Classical and quantum integrable systems and supersymmetry

2017

18. June 6 - 10, Prague, Czech Republic XXV International Colloquium
    Integrable Systems and Quantum Symmetries

Organized Conferences and Schools

19. July 10 - 15, Yerevan, Armenia, XVIIth International Conference,
    Symmetry Methods in Physics (SYMPHYS)
20. July 16 - 23, Tsakhkadzor, Armenia, International School
    Symmetry in Integrable Systems and Nuclear Physics
21. July 24 - 29, Dubna, International Conference
    Classical and Quantum Integrable Systems (CQIS-2017)
22. July 31 - August 5, Dubna, International Workshop
    Supersymmetries and Quantum Symmetries (SQS'2017)
23. August 6 - 12, Dubna, International School
Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems

+ 2 Conferences in 2018

24. July 9 - 13, Prague, Czech Republic, The 32nd International Colloquium
    Group Theoretical Methods in Physics
25. August 13 - 16, Dubna, International Workshop
    Supersymmetries in Integrable Systems (SIS'18)

Grants

RF Government grant (mega-grant) – 1 ,
RNF grants – 2,
RFBR (-Armenia,-Germany…) grants ~ 15,
DFG (Germany) – 1,
IN2P3 (France) –1,
Volkswagen Foundation Grant – 1,
Alexander von Humboldt Institutes linkage program, Oldenburg-Minsk -1
DAAD Ostpartnerschaft Programme University of Oldenburg - BSU Minsk-1

JINR Prize for 2017

First Prize (Theoretical Physics Research)
N. Tyurin ***«Pseudotoric structures: Lagrangian tori and Lagrangian fibrations»***

Basic directions of investigations

development of methods of modern mathematical physics with their applications to the fundamental problems of theoretical physics

I. Quantum groups and integrable systems

Development of nonperturbative methods in QFT and in Stat.Mechanics: new mathematical methods for investigation and description of a variety of classical and quantum integrable models and their exact solutions.
Study of the new types of symmetries (Yangians, Quantum Groups, …).

II. Supersymmetry

Analysis of a wide range of problems in supersymmetric theories including models of superstrings and superbranes, study of nonperturbative regimes in supersymmetric gauge theories

III. Quantum gravity, cosmology and strings

Study of string theories and gravity. Development of cosmological models of the early Universe, primordial gravitational waves and investigation of theories of black holes.

I. Quantum groups and integrable systems

Main results were obtained in the following topics:

- **Study of new type infinite dimensional symmetries of classical and quantum integrable models (Yangians, Quantum Groups, etc)**

- **Investigations of Integrable Heisenberg type spin chains by using methods of the representation theory of the braid group and its factors. Development of Bethe Ansatz technics in solving of integrable quantum systems such as Heisenberg spin chains**

- **Researches of Lagrange foliations, toric manifolds, pseudo-toric structures, mirror symmetry**

- **Development of twistor and two-spinor approaches for describing of massless and massive particles of higher spins**

- **Investigations in Conformal Field Theories, Holography and AdS/CFT correspondence**

- **Study N=4 supersymmetric mechanics of many particles on curved spaces: generalizing the necessary conditions for SUSY including the WDVV equations; finding of the conditions for acceptable potentials, solve them in particular cases.**

II. Supersymmetry

Main results were obtained in the following topics :

- Further development of the Harmonic superspace

- Construction and invesitagion of Chern-Simons matter theories in harmonic superspace

- Performing the multy-loop calculations in 6D supersymmetric Yang-Mills theory in the harmonic superspace approach

- Researches of supersymmetric Landau models and 2d conformal field theories

- Construction of new supersymmetric, superconformal, and multidimensional mechanics including supersymmetric extensions of multiparticles Calogero models

- Canonical twistor field quantization

- Description of Einstein manifolds related to supersymmetric hyper-Kaehler sigma-models and models in nonabelian monopole backgraund

- Construction of new multisoliton solutions of the Skyrme, Faddeev-Skyrme model and generalized Einstein-Skyrme theory. New solutions of the Yang-Mills theory coupled to the R^2 gravity

III. Quantum gravity, cosmology and strings

Main results were obtained in the following topics:

- Construction of Affine generalized gravity and its applications to modern ideas in models of branes and cosmology

- Researches of multi-exponential models of (1+1)-gravity and integrable models of (1+1)-gravity

- Investigations of black hole solutions and billiards in supergravity theories (integrable structures in supergravity and in cosmologies)

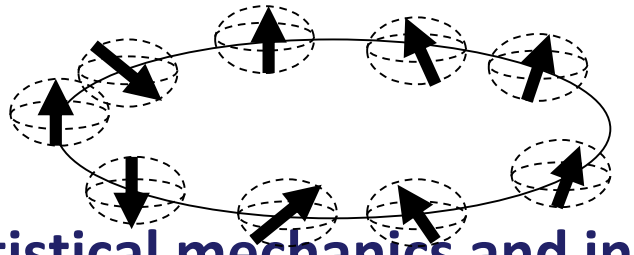
- Multiverse, modified gravity, gauge fields in cosmology, primordial gravitational waves

- Studies of Gravitational lensing and search for exoplanets

- Dark matter and dark energy in cosmological models, cosmic strings

- Vacuum energy and QFT under external conditions (boundaries, temperature, curvature). Investigations of Casimir effects (e.g. between non-planar surfaces)

Integrable open (spin) chain models of gl(n|m)- and osp(n|m)-type were formulated in algebraic terms. It helps to investigate these models (which generalize Heisenberg spin chains) from unified point of view. In particular the energy spectrum for these spin chains were explicitly found in special cases of chains. Bethe ansatz equations were formulated for these models.



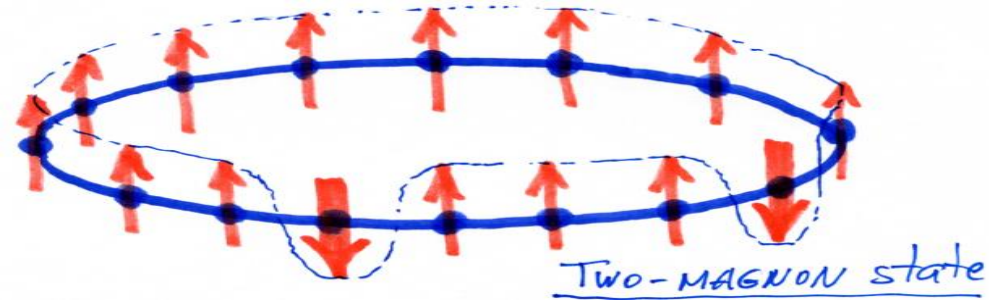
These investigations are important in statistical mechanics and in (super) Yang-Mills field theories (which respect conformal invariance).

E.g., ***energy spectrum for special spin chains =***
= anomaly dimensions in QCD for high energies !!!

C. Burdik, J. Fuksa, A.P. Isaev, S.O. Krivonos, O. Navratil,
Remarks towards the spectrum of the Heisenberg spin chain type models,
PEPAN (Phys.Part.Nucl.) 46 (2015) 3, 277-309; Spin Chain Models of Free Fermions,
Springer Proc.Math.Stat. 111 (2014) 301-309

Scalar products for the nested Bethe vectors:

The most important problem in the theory of quantum integrable systems is the calculation of the correlation functions. For the models solvable by the nested Bethe ansatz this problem was addressed in the series of papers, where the problem of calculation of the scalar products for the nested Bethe vectors in *GL*-invariant integrable models was investigated.



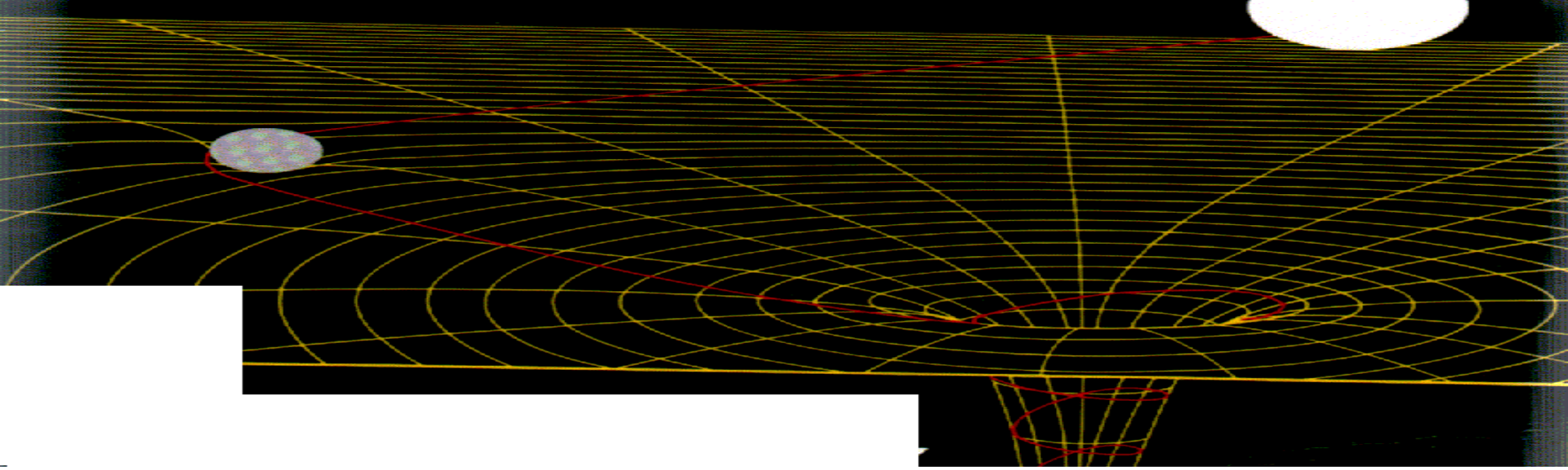
S. Belliard, S. Pakuliak,

E. Ragoucy, N.A. Slavnov a.o.

1. Scalar products of Bethe vectors in the models with gl(m|n) symmetry. **Nucl.Phys. B923 (2017) 277-311**

2. Norm of Bethe vectors in models with gl(m|n) symmetry. **Nucl.Phys. B926 (2018) 256-278**

3. Scalar products of Bethe vectors in models with gl(2|1) symmetry 2. Determinant representation. **J.Phys. A50 (2017) no.3, 034004**



Integrable (super)string and (super)gravity cosmologies and black holes

Global issues in minimal supergravity models, where a single field inflaton potential emerges, were considered. In a particular case the authors reproduced the Starobinsky model and its description which are dual to a certain formulation of R+R^2 supergravity. For definiteness the analysis is confined to spaces at constant curvature, either vanishing or negative. Five distinct models arise, two flat models with respectively a quadratic and a quartic potential and three based on the SU(1,1)/U(1) space where its distinct isometries, elliptic, hyperbolic and parabolic are gauged. Fayet-Iliopoulos terms are introduced in a geometric way and they turn out to be a crucial ingredient in order to describe the de Sitter inflationary phase of the Starobinsky model.

S. Ferrara, P. Fre, A.S. Sorin, On the Topology of the Inflaton Field in Minimal Supergravity Models, JHEP 1404 (2014) 095, Fortsch.Phys. 62 (2014) 277-349.

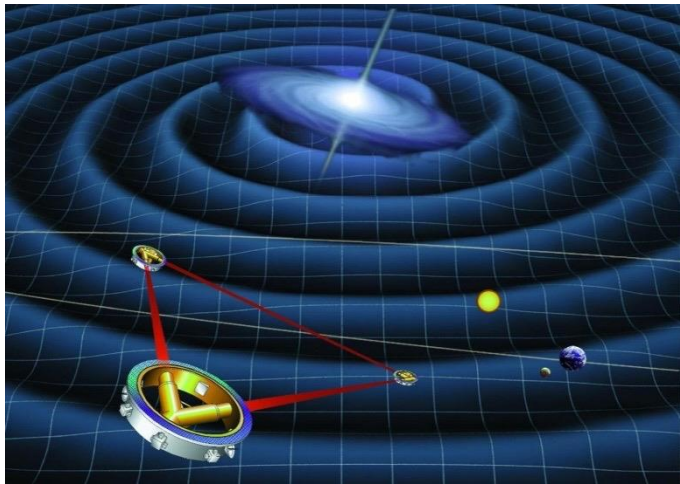
New models of compact stars with different equations of states in the model of minimal dilaton gravity were developed. Densities of energy and pressure for dark energy and dark matter were introduced and their role in forming of compact stars was shown . It was shown that in minimal dilaton gravity the effects of dark energy and dark matter can be described with the help of one single scalar field, which is scalar component of gravity theory.

1. **P.Fiziev,** ***Compact static stars in minimal dilatonic gravity, Mod.Phys.Lett. A32 (2017) no.27, 1750141.***
2. **P.Fiziev,** ***Dark Energy and Dark Matter in Stars Physic*****, PoS FFP14 (2016) 080**
3. **P.Fiziev,** ***Compact statis stars with polytropic equation of state in minimal dilatonic gravity*****, Bulg.Astron.J. 23 (2015) 3.**

LIGO *Laser Interferometer Gravitational-Wave Observatory (present)*

LISA *The Laser Interferometer Space Antenna (future)*

Results are aimed to experiments on present and future gravitational waves detectors



Proposal for inclusion into TOPICAL PLAN for JINR researches and international cooperation:

Modern Mathematical Physics:
gravity, supersymmetry and strings

For period: 2019-2023

Leaders: A.P.Isaev, S.O.Krivonos, A.S.Sorin

Scientific leader: A.T.Filippov

The main purpose of researches in modern mathematical physics is the development of mathematical methods for solving the most important problems in modern theoretical physics such as:

- clarifying the **nature of fundamental interactions and their symmetries.**
- construction and study of effective field models arising in the **theory of (super)strings and other extended objects such as (super)branes.**
- disclosure and investigations of new type symmetries (**Yangians, quantum groups, etc**) and **integrable structures** in (super)string and (super)gravity theories;
- study of **unified theories of all fundamental interactions**, including **quantum gravity**.
- **development of cosmological models** for description of the early Universe, investigations of **black holes and primordial gravitational waves**
- study of the **nonperturbative regimes** in (supersymmetric) **gauge theories.**
- Construction and investigation of new **multisoliton solutions** in gauge and gravity models. Investigation of **QFT under external conditions, Casimir effects**.

The structure of Theme Projects

1. **Quantum Groups and Integrable Systems** — **Leaders: Isaev A.P., Tyurin N.A.**

- development of new mathematical methods for investigation and description of a variety of classical and quantum integrable models and their exact solutions.

2. **Supersymmetry** — **Leader: Ivanov E.A.**

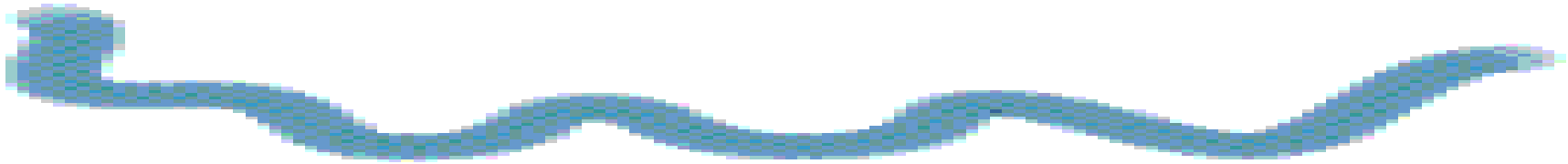
- analysis of a wide range of problems in supersymmetric theories including models of superstrings and superbranes, study of nonperturbative regimes in supersymmetric gauge theories.

3. **Gravity, Cosmology and Strings** — **Leaders: Filippov A.T., Nesterenko V.V., Pirozhenko I.G.**

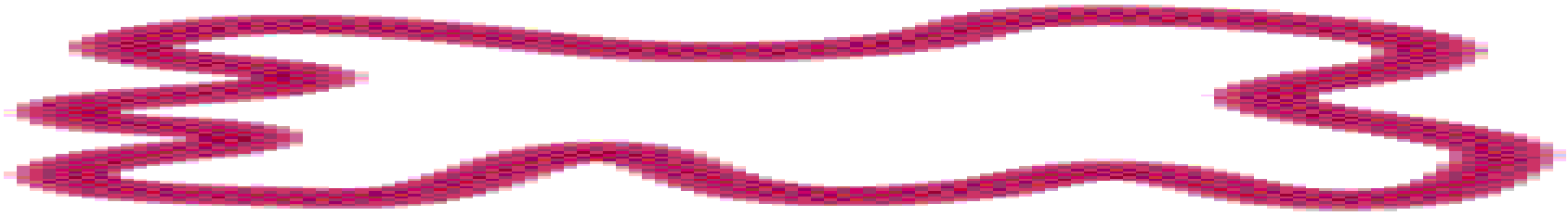
- development of cosmological models of the early Universe, primordial gravitational waves and black holes.

International cooperation:

with scientific centers in JINR member states and in other countries: Australia, Austria, Brazil, Canada, France, Great Britain, Germany, Greece, India, Italy, Japan, Spain, Serbia, USA;
with specialists from CERN and ICTP.



MATHEMATICAL PHYSICS
IS
“KNOW-HOW”
IN THEORETICAL PHYSICS



Thank you for your attention!