XXXIV International (ONLINE) Workshop on High Energy Physics ”From Quarks to Galaxies: Elucidating Dark Sides”

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Book of Abstracts

Contents

BSM physics and cosmology 1

Bigravity 1

Chiral effects in QCD and other theories 1

Chiral effects: an update 1

Closing Address 1

Contemporary status of inflation 1

Covariant dynamics on the momentum space 2

Dense quark matter: effective model approach 2

Discussion 1 (discussion leader D.S. Gorbunov) 3

Discussion 2 (discussion leader Yu.M. Zinoviev) 3

Discussion 3 (discussion leader A.F. Zakharov)) 3

Discussion 4 (discussion leader - A. Nakamura) 3

Discussion 5 (discussion leader O.V. Teryaev) 3

Discussion 6 (discussion leader O.V. Teryaev) 3

Discussion 7 (discussion leader V.A. Petrov) 3

Ether is alive! New derivation of the cosmological constant 3

Evolution of a Quantum System: New Results. 4

Four-Quark Nature of Light Scalar Mesons 5

Fractional Analytic QCD for space-like and time-like processes 5

Gravitational wave astronomy and its implications for cosmology 5

Heavy-ion physics at LHC 5

Heisenberg's Uncertainty Principle and Particle Trajectories 6

Higgs-scalaron inflation 6

Holography approach to QCD 6

Interpretation of galaxy rotational curves 6

Life of the homogeneous and isotropic universe in dynamical string tension theories . . 7

Massive gravity theories and Higgs mechanism for gravity 7

Mass–energy connection without special relativity 8

New Wine in an Old Bottle? Surprise with Angular Momentum 8

New searches in the ATLAS experiment 8

Opening address 9

Phases of Strong Interactions: the lattice approach 9

RG Equations in Non-renormalizable Theories 9

Relativity Theory: Genesis and Completion 9

Representation of the RG-invariant quantities in perturbative QCD through powers of the conformal anomaly 10

Screw calculus: from machinery to twistors 10

Search for light dark matter. NA64 experiment 10

Trajectories of bright stars and shadows near supermassive black holes as tests of gravity theories 10

Unfree gauge symmetry 11

Unimodular gravity 11

Valery Rubakov and Contemporary status of cosmology 11

Afternoon session 22/11/2002 / 38

BSM physics and cosmology

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Evening session 22/11/2022 / 44

Bigravity

Afternoon session 23/11/2022 / 36

Chiral effects in QCD and other theories

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We report on some non-trivial results in the domain of chiral transport, that have been recently obtained, and that seems to us today to be significant. We pay considerable attention to the relationship between chiral effects and corresponding anomalies. We show non-universality of this dependence using examples of chiral separation and chiral vortical effects.

Morning session 24/11/2022 / 52

Chiral effects: an update

Afternoon session 24/11/2022 / 58

Closing Address

Morning session 22/11/2022 / 26

Contemporary status of inflation

At the present state-of-the-art, the simplest inflationary models, based either on scalar fields in General Relativity or on modified f(R) gravity, which produce the best fit to all existing observational data, require only one dimensionless parameter taken from observations. These models include the pioneer $R + R^2$ one [1], the Higgs model, and the mixed R^2-Higgs model that has been shown to be effectively one-parameter, too [2]. They predict scale-free and close to scale-invariant power spectra of primordial scalar perturbations and gravitational waves generated during inflation. Their target prediction for the tensor-to-scalar ratio is $r = 3(1 - n_s)^2 = 0.004$. The difference between these models is in their post-inflationary behaviour which becomes especially interesting and complicated in the mixed R2-Higgs case [3,4]. Still future observations, in particular discovery of primordial black holes, may prove that the primordial scalar power spectrum has additional local peaks what requires

at least two new parameters. I discuss mechanisms to produce such features including the recently proposed one which arise in many-field inflation with a large non-minimal kinetic term of an inflaton field leaving inflation before its end [5]. In this case, in addition to PBHs, small-scale secondary gravitational waves are generated, too. As for local non-scale-free features at cosmological scales, the present CMB data do not favor them, but are not able to exclude them completely [6].

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Afternoon session 24/11/2022 / 13

Covariant dynamics on the momentum space

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A geometrical interpretation of Schrödinger’s kinetic and potential energy operators is proposed, allowing for a covariant momentum space formulation of the dynamics that is relevant for the theories with the generalization of the geometry of the momentum space. Some specific examples are discussed in the context of Euclidean Snyder (spherical momentum space) model. In this formulation the dynamics for different versions of the Snyder model turn out to be dynamically equivalent. Furthermore, a scalar field theory is constructed on an energy-momentum background of constant curvature. The generalization of the usual Feynamn rules for the flat geometry follows from the requirement of their covariance. The main result is that the invariant amplitudes are finite at all orders of the perturbation theory, due to the finitness of the momentum space. Finally, the relation with a field theory in spacetime representation is briefly discussed.

Morning session 23/11/2022 / 59

Dense quark matter: effective model approach

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Dense quark matter has been under debate for more than 40 years. This kind of matter appears in heavy-ion collision experiments and could exist in some types of compact stars. Its fundamental theory is quantum chromodynamics (QCD). But as a consequence of the asymptotic freedom, the perturbative technique is not applicable to investigate the condensed quarks (long-range phenomenon).
There are two approaches to investigating dense quark matter. QCD on the lattice and effective field theories (EFT). The first one is a potent numerical tool from the first principles. But due to the sign problem, it can’t describe the region of the QCD phase diagram with non-zero density and low temperature. So to achieve this region, EFT is the most common tool.
Although the EFT method has been developed for several decades, it is still commonly applied and developing.

We will review the milestones of EFT as a tool for investigating dense quark matter, especially the Nambu–Jona-Lasinio model and its applications.

Morning session 22/11/2022 / 37

Discussion 1 (discussion leader D.S. Gorbunov)

Afternoon session 22/11/2002 / 41

Discussion 2 (discussion leader Yu.M. Zinoviev)

Evening session 22/11/2022 / 45

Discussion 3 (discussion leader A.F. Zakharov))

Morning session 23/11/2022 / 48

Discussion 4 (discussion leader - A. Nakamura)

Afternoon session 23/11/2022 / 51

Discussion 5 (discussion leader O.V. Teryaev)

Morning session 24/11/2022 / 54

Discussion 6 (discussion leader O.V. Teryaev)

Afternoon session 24/11/2022 / 57

Discussion 7 (discussion leader V.A. Petrov)

Afternoon session 24/11/2022 / 8

Ether is alive! New derivation of the cosmological constant

Xiao Song Wang[None]

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General theory of relativity (GR) can be regarded as a phenomenological theory because there are no mediums in GR. Einstein’s equations is a basic assumption in GR. Many attempts to reconcile the theory of general relativity and quantum mechanics by using the techniques in quantum electrodynamics failed. Therefore, it seems that new considerations on the ether theories of gravitation is needed. Since Newton’s law of gravitation was published in 1687, this action-at-a-distance theory was criticized by the French Cartesian. Sir I. Newton pointed out that his inverse-square law of gravitation did not touch on the mechanism of gravitation. He tried to obtain a derivation of his law based on Descartes’ scientific research program. At last, he proved that Descartes’ vortex ether hypothesis could not explain celestial motions properly. Newton himself even suggested an explanation of gravity based on the action of an etherial medium pervading the space. In the years 1905-1916, Einstein abandoned the concepts of ether. However, H. A. Lorentz believed that GR could be reconciled with the concept of an ether at rest and wrote a letter to A. Einstein. Einstein changed his view later and introduced his new concept of ether. In order to compare fluid motions with electric fields, J. C. Maxwell introduced an analogy between source or sink flows and electric charges. B. Riemann speculates that that space is filled with a substance which continually flows into ponderable atoms, and vanishes there from the world of phenomena, the corporeal world. H. Poincar$\acute{e}$ also suggests that matters may be holes in fluidic ether. A. Einstein and L. Infeld think that what impresses our senses as matter is really a great concentration of energy into a comparatively small space. They regard matter as the regions in space where the field is extremely strong. We suppose that the universe may be filled with a kind of fluid which may be called the $\Omega(0)$ substratum, or we say the gravitational ether. Particles are modeled as sink flows in the $\Omega(0)$ substratum. Thus, Newton’s inverse-square law of gravitation is derived by methods of hydrodynamics based on a sink flow model of particles. Generalized Einstein’s equations in Fock coordinate systems are derived. If the field is weak and the reference frame is quasi-inertial, these generalized Einstein’s equations reduce to Einstein’s equations. For convenience, we may call these theories as the theory of vacuum mechanics (VM). The Einstein’s equations are rigorous in GR. In VM, however, they are only valid approximately under three conditions. Another feature of VM is that the gravitational constant and masses of particles are variable with time and position in space. In 1990-1999 two groups discovered the cosmic vacuum, or dark energy, by studying remote supernova explosions. They discovered that some high redshift supernovae appeared fainter and thus more distant than they should be in a gravitationally decelerating universe. This discovery gives the first indication that the universe is accelerating. A possible explanation is that vacuum may contain some kind of ethers which behave like Einstein’s antigravity cosmological constant. Lord Kelvin believed that the electromagnetic ether must also generate gravity. Presently, we have no methods to determine the density of the electromagnetic ether, or we say the $\Omega(1)$ substratum. Thus, we also suppose that vacuum is filled with another kind of continuously distributed substance, which may be called the $\Omega(2)$ substratum. Thus, the cosmological constant is calculated theoretically. The predicted cosmological constant $\Lambda_{\rm the} = 1.093(65) \times 10^{-52}{\rm m}^{-2}$ is consistent with the observational value of the cosmological constant $\Lambda_{\rm obs} = 1.088(30) \times 10^{-52}{\rm m}^{-2}$. The $\Omega(1)$ and $\Omega(2)$ substrata may be a possible candidate of the dark energy. According to VM, only those energy-momentum tensors of sinks in the $\Omega(0)$ substratum are permitted to act as the source terms in the generalized Einstein’s equations. Thus, the zero-point energy of electromagnetic fields is not qualified for a source term in the generalized Einstein’s equations.

Morning session 24/11/2022 / 33

Evolution of a Quantum System: New Results.

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A description of the evolution of a quantum system is considered. Within the framework of the path integration method, the probability of a system transition between quantum states is determined as a double functional integral of a real functional. Its interpretation from the point of view of probability

theory is given. The transition probability is the sum of the probabilities of pairwise joint random events (virtual trajectories between states). A model of quantum processes in the extended space of random joint events is proposed. Within the framework of the proposed model, the probability of a system transition is represented by a series of twofold, threefold, etc. integrals of real functionals of joint event trajectories. The expression coincides with the transition probability in quantum theory if only pairwise joint random trajectories are taken into account in the model.

Afternoon session 23/11/2022 / 18

Four-Quark Nature of Light Scalar Mesons

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It is shown that all predictions for the light scalars, based on their four-quark nature, are supported by experiment. The future research program is outlined also.

Afternoon session 23/11/2022 / 19

Fractional Analytic QCD for space-like and time-like processes

Anatoli Kotikov[1]

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A review of the main elements of (fractional) analytical QCD is
presented. The main part of the review is focused on the introduction of the Shirkov-Solovtsov and Bakulev-Mikhailov-Stefanis approaches and their recent extension beyond the leading order of perturbation theory. We present various representations in Euclidean and Minkowski spaces, details of their construction and show their applicability.

Morning session 22/11/2022 / 27

Gravitational wave astronomy and its implications for cosmology

Morning session 23/11/2022 / 10

Heavy-ion physics at LHC

Yuri Kharlov[1]

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Overview of recent experimental QCD measurements at LHC will be presented.

Afternoon session 24/11/2022 / 56

Heisenberg’s Uncertainty Principle and Particle Trajectories

S. Aristarkhov [1]

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In this talk I will critically analyse W. Heisenberg’s arguments against the ontology of point particles following trajectories in quantum theory, presented in his famous 1927 paper and in his Chicago lectures (1929). Along the way, we will clarify the meaning of Heisenberg’s uncertainty relation and help resolve some confusions related to it.

Afternoon session 22/11/2002 / 39

Higgs-scalaron inflation

Morning session 23/11/2022 / 35

Holography approach to QCD

Irina Aref’eva[1]

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Magnetic properties of quark-gluon plasma within holographic approach are discussed. Particular attention is paid to the different behavior of holographic models for heavy and light quarks.

Afternoon session 22/11/2002 / 9

Interpretation of galaxy rotational curves

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After more than 40 years of observational, experimental, and theoretical efforts, the nature of dark matter (DM) remains unknown. In this talk I will review the observational status of the DM paradigm on galaxy scales. Remarkably, the rotation curves of disk galaxies reveal a close link between baryons’ distribution and observed dynamics, which can be expressed by a set of empirical laws akin to Kepler’s laws for planetary systems. A tight baryon-DM coupling is unexpected in the standard LCDM paradigm. To reproduce such coupling, either the galaxy formation process must be very fine-tuned or the DM particle must somehow interact with baryons beyond standard gravity. Intriguingly, the empirical laws of galactic rotation were predicted a-priori by Milgrom’s Modified Newtonian Dynamics (MOND), which alters Newton’s laws at low accelerations (weak gravitational fields) rather than adding particle DM. One possible way to distinguish between particle DM and MOND is the so-called external field effect, which results from the breakdown of the Strong Equivalence Principle in the MOND regime. I will describe recent efforts to test the MOND external field effect and discuss other possible tests to distinguish between the two paradigms.

Evening session 22/11/2022 / 12

Life of the homogeneous and isotropic universe in dynamical string tension theories

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Cosmological solutions are studied in the context of the modified measure formulation of string theory , then the string tension is a dynamical variable and the string the tension is an additional dynamical degree of freedom and its value is dynamically generated. These tensions are then not universal, rather each string generates its own tension which can have a different value for each of the string world sheets and in an ensemble of strings. The values of the tensions can have a certain dispersion in the ensemble. We consider a new background field that can couple to these strings, the “tension scalar” which is capable of changing locally along the world sheet and then the value of the tension of the string changes accordingly. When many types of strings probing the same region of space are considered this tension scalar is constrained by the requirement of quantum conformal invariance. For the case of two types of strings probing the same region of space with different dynamically generated tensions, there are two different metrics, associated to the different strings. Each of these metrics have to satisfy vacuum Einstein’s equations and the consistency of these two Einstein’s equations determine the tension scalar. The universal metric, common to both strings generically does not satisfy Einstein’s equation . The two string dependent metrics considered here are flat space in Minkowski space and Minkowski space after a special conformal transformation. The limit where the two string tensions are the same is studied, it leads to a well defined solution. If the string tension difference between the two types of strings is very small but finite, the approximately homogeneous and isotropic cosmological solution lasts for a long time, inversely proportional to the string tension difference and then the homogeneity and and isotropy of the cosmological disappears and the solution turns into an expanding braneworld where the strings are confined between two expanding bubbles separated by a very small distance at large times. The same principle is applied to the static end of the universe wall solution that lasts a time inversely proportional to the dispersion of string tensions. This suggest a scenario where quantum fluctuations of the cosmological or static solutions induce the evolution towards braneworld scenarios and decoherence between the different string tension states.

Evening session 22/11/2022 / 43

Massive gravity theories and Higgs mechanism for gravity

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Afternoon session 24/11/2022 / 32

Mass–energy connection without special relativity

Germano D’Abramo[1]

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In 1905, Einstein gave his first derivation of the mass-energy equivalence by studying, in different reference frames, the energy balance of a body emitting electromagnetic radiation and assuming special relativity as a prerequisite. In this presentation, I reassess the logical soundness of Einstein’s approach and the validity of one assumption crucial for the derivation (that has nothing to do with special relativity). If we accept that assumption as valid, the essence (but not the formula) of the mass-energy equivalence can be derived without the need for special relativity or any full-fledged physical theory. However, the assumption is unsupported from a physical viewpoint, and its use makes Einstein’s 1905 derivation circular. I also show why the widely received interpretation of E=mc^2 (i.e., every kind of energy has a mass and vice versa) is problematic.

Morning session 24/11/2022 / 17

New Wine in an Old Bottle? Surprise with Angular Momentum

Koba Turashvili[None]

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We analyzed mathematical conditions that are used in obtaining the eigenvalue spectrum of the orbital angular momentum operator in non-relativistic quantum mechanics. As it turns out, if one retains only those conditions that are the mathematical realization of physical requirements, the eigenvalue spectrum is discrete, admitting integer, as well as non-integer eigenvalues. Relation for the eigenvalues reads |m| = L - k, where L is the eigenvalue of the square of the angular momentum operator, m is the eigenvalue of the third component of the angular momentum operator and k are the integers that do not contradict the non-negativity of |m|. The eigenfunctions corresponding to this spectrum, form an orthonormalized basis and the Hilbert space of physical states can be constructed through them. As an auxiliary task, the uniqueness of the exponential function of the complex variable and its invariance with regard of axes rotations at 2π was considered. It is shown that the well-known Euler-De Moivre prescription used to define the power function of the complex variable as a single-valued function is just one of the special cases for unambiguously determining power function with the non-integer exponent, spontaneously breaking invariance of the initial expression with regard rotations at 2π for non-integer exponents. We present another prescription for uniquely defining power function of the complex variable in the framework of which the rotational invariance is preserved for integer as well as non-integer exponents.
Main point is that from quantum mechanics it does not follow that the eigenvalues of the angular momentum operator are necessarily integer.

Afternoon session 23/11/2022 / 49

New searches in the ATLAS experiment

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Morning session 22/11/2022 / 68

Opening address

Morning session 23/11/2022 / 69

Phases of Strong Interactions: the lattice approach

Maria Paola Lombardo[None]

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Quantum Chromodynamics has a rich phase structure which can be explored
by formulating the theory in a discrete space-time – the lattice. We will give a general overview of the phase structure in the space spanned by the number of flavours, quark masses, temperature and chemical potentials of conserved charges. We will focus on the physical case: in particular we will discuss the region explored by ultra relativistic heavy ion; and the higher temperatures, up to the freeze-out of the hypothesised QCD axion. We will examine critically the limitations of the lattice approach, and discuss current strategies to overcome them. Finally, we will briefly elaborate on QCD-like theories as a possible paradigm for Beyond Standard Model physics.

Morning session 24/11/2022 / 14

RG Equations in Non-renormalizable Theories

Dmitry Kazakov[1]

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We construct the RG equations for the scattering amplitudes and effective potential
In a a set of non-renormalizable theories. We show that they are a consequence of locality
rather than multiplicative renormalizability. These RG equations sum up the leading log terms
in all orders of PT and allow one to explore the high energy/field behaviour.

Afternoon session 24/11/2022 / 63

Relativity Theory: Genesis and Completion

Vladimir Petrov[1]

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This a concise survey of both the first pioneering ideas in the beginning of formation of the Relativity Theory (2nd half of the XIXth century) and its conceptual and essential completion in 1910s .

Afternoon session 23/11/2022 / 61

Representation of the RG-invariant quantities in perturbative QCD through powers of the conformal anomaly

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We consider the possibility of representing the perturbative series for renormalization group invariant quantities in QCD in the form of their decomposition in powers of the conformal anomaly $\beta(\alpha_s)/\alpha_s$ in the \msbar-scheme. We remind that such expansion is possible for the Adler function of the process of e^+e^- annihilation into hadrons and the Bjorken polarized sum rule for the deep-inelastic electron-nucleon scattering, which are both related by the Crewther-Broadhurst-Kataev relation. In addition, we study the cases of the static quark-antiquark Coulomb-like potential, its relation with the quantity defined by the cusp anomalous dimension and the Bjorken unpolarized sum rule of neutrino-nucleon scattering. The arguments in favor of the validity of the considered representation are given.

Morning session 24/11/2022 / 15

Screw calculus: from machinery to twistors

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Wrenches and twists are considered as generalizations of the concepts of force and angular velocity, respectively, and the corresponding mathematical formalism is reviewed. Manifolds of forces or angular velocities that naturally emerge in the screw theory are compared with the Grassmann manifold associated with the Penrose twistor space.

Afternoon session 22/11/2002 / 40

Search for light dark matter. NA64 experiment

Morning session 22/11/2022 / 2

Trajectories of bright stars and shadows near supermassive black holes as tests of gravity theories

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Observations of bright near the Galactic Center give an opportunity to test GR predictions but also to constrain alternative gravity parameters, in particular, to limit graviton mass for the case of massive gravity theories.
Due to an expected progress of observational facilities Zakharov et al. (2005a) proposed to use global and ground – space VLBI observations in mm band to detect a shadow at Sgr A* to use it as a tool to evaluate a black hole spin and a position angle of distant observer. In particular, it was predicted that the shadow diameter is around 52 μas for the Sgr A* case and this prediction was remarkably confirmed by the Event Horizon Telescope (EHT) Collaboration on 12 May 2022. Also Zakharov et al. (2005b) showed that a black hole charge may be evaluated from shadow observations. Zakharov (2014) generalized these relations for the tidal charge case. In 2019 the EHT Collaboration reconstructed shadows at M87* in 2019 and at Sgr A* in 2022. As it was shown by Zakharov (2022) black hole charge may be found analytically from these observations.

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Morning session 24/11/2022 / 30

Unfree gauge symmetry

The gauge symmetry is said unfree if the gauge transformation leaves the action functional unchanged provided for the gauge parameters are constrained by the system of partial differential equations. The best known example of this phenomenon is the volume preserving diffeomorphism being the gauge symmetry of unimodular gravity (UG). Various extensions are known of the UG, including the higher spin analogs – all with unfree gauge symmetry. In this talk, we begin with noticing the common features shared by all the known examples of unfree gauge symmetry. In particular, all these field theories admit "global conserved quantities'' that are unrelated to any conserved local current. The simplest example is the cosmological constant in the UG, We find previously unknown higher spin analogs of Lambda. After this empirical introduction, we work out the structure relations of algebra of general unfree gauge symmetry. It turns out that the existence of the global conserved quantities originates from this algebra, being in a sense modification of the second Noether theorem for the case of unfree gauge symmetry. Proceeding from the unfree gauge symmetry algebra we deduce the modification of the Faddeev-Popov quantization rules accounting for the operators of gauge parameter constraints. Also the BV-BRST field-antifield formalism is modified to account for the unfree gauge symmetry. The unfree gauge symmetry is also considered from the perspective of constrained Hamiltonian formalism. The structure functions are identified in the involution ralations such that are responsible for the equations imposed on the gauge parameters. Hamiltonian BFV-BRST formalism is adjusted to account for the gauge parameter constraints.

Evening session 22/11/2022 / 42

Unimodular gravity

Morning session 22/11/2022 / 25

Valery Rubakov and Contemporary status of cosmology