Bled Workshop 2026 — Abstracts
"What Comes Beyond the Standard Models"

July 6–15, 2026

Addazi, Andrea

Title I: Aspects of Meta-Geometric Gravity: Emergence of Einstein's Theory from a Spontaneously Broken Gauge Symmetry

We introduce an alternative framework for unifying quantum mechanics and general relativity. In this approach, the metric tensor is not a fundamental field, nor are the Planck mass and cosmological constant taken as the primordial UV and IR scales of nature. Instead, these quantities arise emergently from an $SO(4,1)$ gauge theory equipped with a Higgs mechanism. We assume no background metric, working solely on a $1+3$-dimensional topological manifold. The gravitational sector's only fundamental degrees of freedom are the $SO(4,1)$ gauge fields and a Higgs field in the gauge group's fundamental representation.

We first show that when the scalar field's vacuum expectation value vanishes, the theory becomes purely topological, ensuring that the deep UV regime is divergence-free. After spontaneous symmetry breaking from $SO(1,4)$ to the Lorentz group $SO(1,3)$, the theory reproduces Einstein–Cartan gravity in the infrared regime, with the metric tensor, Planck scale, and cosmological constant emerging naturally. Specifically, the tetrads correspond to the generators of the spontaneously broken symmetry, while the spin connections are identified with the gauge potentials of the surviving Lorentz group $SO(1,3)$. We further discuss the Hamiltonian formulation, a meta-geometric Wheeler–DeWitt equation, and the emergence of Ashtekar–Barbero variables. Finally, we address key aspects of quantizing this meta-geometric theory.

Title II: Implications of Meta-Geometric Gravity for the Early Universe, Dark Matter, Dark Energy, Black Hole Physics

We present several new results within the framework of meta-geometric theories. First, we discuss novel implications for the cosmological constant problem. We predict a topological quantization of the cosmological constant and show that any destabilization is suppressed by large Higgs potential barriers separating multiple vacua. Furthermore, we demonstrate that pre-geometric corrections can transform vacuum energy into a dynamical entity, potentially explaining the DESI anomaly.

In the Higgsed phase, the theory exhibits a rich spectrum of topological defects, including cosmic strings/flux tubes, vortices, domain walls, bubbles, and gravitational monopoles. These defects are sustained by the Higgs field, which interpolates between vacua via a kink profile. Being remnants of topological phase transitions, these defects are stable and provide natural dark matter candidates. The theory also admits new exotic compact objects — which we dub "Top-Stars" — that are singularity-free and possess well-defined thermodynamics.

From an early universe perspective, Loop Quantum Gravity spin networks are reinterpreted as the strongly interacting dynamics of topological strings. In the classical limit, the string gas approximation with flat spin connections becomes dual to a metric theory described by Einstein's equations. Finally, we comment on possible avenues for unification, emergent supergravity, and connections to M-theory via the $OSp(\mathbb{R}|32)$ groups.

Ayala Oña, R. I., and Shestakova, T. P.

Particle creation in an isotropic universe in the framework of the extended phase space approach

We explore particle creation in the framework of the extended phase space approach. We consider a path integral with the effective action describing a scalar field in an isotropic closed universe. For the path integral, a mixed representation is chosen: a coordinate representation for the scale factor and a holomorphic representation for the scalar field. The scalar field is slightly non-conformal. We consider the terms describing a small deviation from conformality as a perturbation. A specific difficulty arises because the perturbation terms depend not only on the field variables but also on their velocities. As a rule, in the path integral approach, perturbations are usually assumed to be velocity independent. We discuss how to overcome this problem and derive a Schrödinger equation. The perturbation initiates transitions between states of the unperturbed Hamiltonian, which are states with a certain number of created particle pairs. Thus, our approach differs from the generally accepted one to particle creation that is based on the canonical formalism and Hamiltonian diagonalization. Within our framework, one can hope to understand the mechanism of vacuum restructuring, i.e. how the interaction modifies the ground state. We discuss results that can be obtained in both approaches.

Yaroslav Basov

Investigation of the possibility of final-state radiation suppression in decays of dark matter particles

We explore gamma-ray suppression mechanisms in decays of bosons of dark matter as a possible resolution to the positron anomaly observed in cosmic rays. We examined scalar and vector particles with electric charges Q=0, +1, +2. Analytic partial widths are derived for all charge assignments, and the corresponding photon energy spectra are modeled using Monte Carlo generators MadGraph 5 and CompHEP. Our results demonstrate that the most significant suppression occurs for the Q=+1 boson decay mode, in which the final state contains only a single charged particle: the photon yield above 100 GeV is reduced by two orders of magnitude relative to the neutral scalar particle. In contrast, configurations with two charged final-state particles yield suppression factors of order unity at best. We further identify and discuss intrinsic biases in the Monte Carlo event generators when handling such processes. Among the considered scenarios, the charge +1 boson model emerges as the most viable candidate for reconciling the positron anomaly with the observed gamma-ray constraints.

Zurab Berezhiani

Baryogenesis and matter conversion to antimatter: future sources of energy?

The possibility of matter conversion into antimatter was discussed only in Sci-Fi. However, the present picture of mirror world related to the genesis of dark matter and matter-over-antimatter asymmetry in the Universe suggests that there exist baryon-violating processes which imply the possibility of the neutron-mirror neutron and neutron-antineutron conversions in experimentally controllable conditions (Asimov machine or Majorana machine). This scenario is also motivated by present paradoxes in cosmic rays.

Rita Bernabei

MODEL-INDEPENDENT RESULTS FROM DAMA/LIBRA-PHASE2-EMPOWERED

The DAMA/LIBRA-phase2 experiment was upgraded in 2021 to enhance its sensitivity by lowering the software energy threshold while maintaining a large efficiency. The new configuration, referred to as DAMA/LIBRA-phase2-empowered, collected data for three years. This extends the investigation of the long-standing, model-independent annual modulation effect pointed out by the DAMA highly radiopure NaI(Tl) experimental setups at the Gran Sasso National Laboratory, using different experimental configurations. The software energy threshold of DAMA/LIBRA-phase2-empowered is below 1 keV, and the exposure is 0.541 tyr. Adding these new results to the previously released DAMA/LIBRA-phase2, the exposure is 2.07 tyr over 11 independent annual cycles, yielding evidence for a signal that fulfills all the requirements of the model-independent Dark Matter annual modulation signature at a confidence level of 13.9 in the 1–6 keV energy region. In the 2–6 keV interval, where data from DAMA/NaI and DAMA/LIBRA-phase1 are also available, the combined exposure reaches 3.40 tyr, corresponding to a confidence level of 15.3 . No systematic effect or side process capable of simultaneously satisfying all the distinctive features of the exploited Dark Matter annual modulation signature and accounting for the observed modulation amplitude is available.

Timur E. Bikbaev, Maxim Yu. Khlopov

Quantum-Mechanical Model of OHe –Nucleus Interaction and Lifetime of OHe –Nucleus Bound State

Talk given between 13. and 15. July

The composite dark matter scenario, in which stable doubly negatively charged particles O^{--} form neutral OHe dark atoms with primordial helium, offers a compelling explanation for the long-standing DAMA/LIBRA annual modulation signal. In this framework, the interaction of slow OHe dark atoms with sodium nuclei in the detector leads to the formation of low-energy bound states, accompanied by photon emission in the 2–6 keV energy range. This work presents two complementary investigations: (i) the reconstruction of the effective interaction potential for the OHe –Na system using a quantum-mechanical three-body approach, and (ii) the calculation of the lifetime of the OHe –Na quasi-stationary bound state within a two-well potential model.

Bonora, Loriano (SISSA, Trieste)[1]

(schedule his talk on July 14 or 15)

Standard Model, Gravity and Conformal Symmetry

An accurate study of anomalies shows that when the Standard Model and General Relativity are minimally coupled and merged into a unique quantum field theory, the cancellation of gauge and gravity anomalies gives important information on the structure of the overall theory. In this talk I make a proposal for the overall anomaly-free theory. The latter consists of two sectors, left and right, with chirally mirror fermions and scalars, as well as $SU(3)$ and $U(1)$ gauge fields, while the $SU(2)$ gauge fields as well as the metric are in common to both sectors. This structure is dictated by the request to cancel all dangerous anomalies. The left sector consists of the fermion, gauge, and scalar fields of the SM, minimally coupled to gravity. The right sector is a mirror image of the left, with distinct fields, except the common metric and the $SU(2)$ gauge potentials. I suggest and discuss the interpretation of the right sector as the

[1]Will be able to actively attend from July 14th onward due to family engagements.

dark matter world. I then consider the role of Weyl symmetry and its possible applications to cosmology, in particular to the cosmological constant problem, but also its theoretical fallouts on renormalization and unitarity. In a conformal theory like the one I consider, the surprising aspect is that conformal anomalies do not properly exist, but nevertheless their phantoms play a major role. I will explain this puzzle and explain why these anomalies-non-anomalies may be a blessing for renormalization and unitarity.

Dembitskaia, A. I., and Khlopov, M. Yu.

Energy release from non-surviving antimatter domains

According to current understanding, our Universe is baryon-asymmetric. Nevertheless, under certain conditions, the local generation of antimatter domains, caused by non-homogeneous baryosynthesis, is possible. Globally, the Universe is filled with baryonic matter; however, local regions, or domains, may exist within it where antimatter predominates. The evolution of antimatter can be described analogously to the evolution of matter. The AMS-02 experiment makes it possible to detect anti-helium nuclei among the helium nuclei of cosmic rays. If such results are obtained, this would confirm the possibility of the existence of isolated antimatter domains in the Universe. There are certain limitations imposed on the mass of a domain required for its survival. Such constraints come from the annihilation processes that occur at the boundary of the domain. If the mass of a domain is less than $10^3\, M_{\odot}$, the domain will be destroyed. The process of annihilation releases energy that could theoretically be observed. In this work, the energy release processes are studied, the size of the glow region is estimated, and the evolution of such a region is described.

Dmitrieff, Elia

1. Effective Mass-Squared Operators without a Mass Basis: Flavor Oscillations from Tangential Hydrodynamic Modes and Topological Wall Defects

We propose a unified hydro-topological framework where neutrino flavor oscillations are generated without invoking a fundamental bare rest mass parameter ($m_{\text{bare}} = 0$) or an underlying mass eigenbasis. Space-time is modeled as a 4D flat torus with a highly compactified cyclic spatial dimension that maps onto the temporal dimension cw in the effective Minkowski space. Active neutrino flavors emerge as three discrete, incompressible flow modes ($\nabla \cdot \vec{v}_{4\text{D}} = 0$) of a 4D quasi-liquid traveling strictly tangential along a 3D minimal-surface domain wall. We show that localized spatial fluctuations in the domain wall's periodicity skew the generator of translations, inducing an exponential derivative shift that manifests as a non-diagonal mass-squared matrix in the flavor basis. Furthermore, we show that when the incompressibility condition breaks down, entangled pairs of topological defects are born. These defects force localized wall drift, mapping inertial mass to a permanent excess of brane hyperarea ($\Delta A > 0$) and discretizing electric charge via the excess of 4D domain hypervolume bounded by the Euler characteristic (χ) of the brane.

2. The Hidden Multi-Line Geometry of Rational Fractions: Resolving Indeterminate Forms and Path Entropy via Extraction Operators

Classical analysis treats the indeterminate form $0/0$ as undefined, collapsing removable and essential singularities in rational functions into zero-dimensional topological holes or asymptotic boundaries. We introduce an alternative structural framework where $0/0$ is modeled as an under-determined relation satisfied by the entire field container ($0/0 = \mathbb{R}$ or $\mathbb{C}$). To resolve the type-theoretic conflict of equating scalars to sets, we define an entropy-lowering choice operator

E_d. We prove that under oblique coordinate transformations, this relational approach exposes an inherent, coexisting multi-line geometry. Furthermore, we show that calculus at these self-intersection vertices is inherently multivalued, where calculating a limit or derivative acts as a path-dependent filter requiring exactly 1 bit of structural data to eliminate topological Shannon entropy. Extensions to complex manifolds and essential singularities with negative zero-powers demonstrate the robust scalability of the model.

3. Algebraic Treatment of Infinities in Integrals: Resolving Infinities in $\int x^{-1}\,dx$ and $\int x^{dx}$ through Inherent Boundary Entanglement and Landauer's Principle Reveals Adiabatic Character of Definite Integration

In this work we explore the algebraic treatment of infinities and indeterminate forms through an information-theoretic calculus framework where divergent structures are treated as formal properties akin to negative powers of zero (0^{-1}). We apply this perspective to two notation traps: the integration pole of $\int x^{-1}\,dx$ and the non-standard exponential differential integral $\int x^{dx}$. We demonstrate that under indefinite integration, a uniform constant infinity can be absorbed by the open integration constant C without destroying the underlying functional residue. Crucially, we re-evaluate the definite integral $\int_a^b x^{dx}$ through Landauer's Principle, which dictates that localized state-selection reduces information entropy and enforces a physical dissipation penalty ($\Delta S > 0$). We demonstrate that the Fundamental Theorem of Calculus naturally circumvents this cost; by operating on space-like separated, entangled uncertainties rather than demanding a localized numerical definition for non-numerical infinities, definite integration functions as a strictly adiabatic process ($\Delta S = 0$). This zero-emission property natively accounts for its seamless compliance within quantum and relativistic domains.

Recai Erdem

Impact of Gravitational vacuum polarization on cosmological tensions: Some comments and future prospects

In some papers I had shown that the gravitational vacuum polarization manifestation of gravitational particle production (that is a generic phenomenon in quantum field theory in curved spacetime) may relieve the Hubble tension(while not worsening the s8 tension) if there are sufficiently heavy particles in the spectrum of the corresponding particle physics model. This approach implies presence of two sets of Hubble constant, namely, the one that is measured directly from the expansion rate of the universe (e.g. in SN Ia, the method of Tip of Red-Giant Branch) and the one that is measured indirectly with contributions from the energy densities (e.g. as in CMB measurements, fast radio bursts). In the talk, first I will summarize these points in some detail, and then mention and discuss some possible implications and related some potential points and prospects.

Ghoshal, Anish

Vector-induced Gravitational Waves sourced via Primordial Magnetic Fields

We develop a generic formalism for the study of tensor perturbations induced at second order by first-order vector metric perturbations, dubbing these induced tensor modes as vector-induced gravitational waves (VIGW) in the presence of primordial magnetic fields. Based on `arXiv:2504.10477`.

Sonia Kabana

The sexaquark

The sexaquark is a stable state with quark content (u u d d s s) hypothesized by [1] which might be a candidate for dark matter in the Universe. We present results [2] on the coalescence production of the sexaquark using the parton and hadron cascade model PACIAE in p+p collisions at sqrt(s) = 7 TeV. The yields, yield ratios, and dependences of the spatial parameters (the size of the diquark D 0 and the radius of the sexaquark R 0) of a (anti)sexaquark are predicted. The yields of the hadronic H-dibaryon molecule H (   ) generated in the final hadronic state are also compared. These estimates provide references for future sexaquark searches and other exotic state studies, such as dibaryons. [1] Stable Sexaquark, Glennys R. Farrar(New York U., CCPP), e-Print: 1708.08951 [2] Coalescence production of sexaquark with three diquarks in high-energy nuclear collisions, Zhi-Lei She(Wuhan Textile U.) et al., Phys.Rev.D 112 (2025) 3, 034002 • e-Print: 2502.17381 [hepph]

Kaganovich, Alexander B. (Ben Gurion University of the Negev)

The Two-Measure Theory (TMT) and the Two-Measure Standard Model (TMSM)

What is Two-Measure Theory (TMT). Considering Palatini's formulation of gravity from the point of view of the applied mathematical apparatus, we inevitably come to the conclusion that we are dealing with a 4D differentiable manifold at the stages of equipping it with an affine connection and a metric structure. If we really believe in the effectiveness of mathematics in studying nature, we can go further and add a volume 4-form dV_Υ, which exists on the 4D differentiable manifold even before it is equipped with an affine connection and a metric structure:

$$dV_\Upsilon = \Upsilon\, d^4x \equiv \varepsilon^{\mu\nu\gamma\beta}\, \varepsilon_{abcd}\, \partial_\mu\varphi^a\, \partial_\nu\varphi^b\, \partial_\gamma\varphi^c\, \partial_\beta\varphi^d\, d^4x = 4!\, d\varphi_1 \wedge d\varphi_2 \wedge d\varphi_3 \wedge d\varphi_4.$$

Here φ^a $(a = 1, \ldots , 4)$ are 4 scalar functions defined on the 4D differentiable manifold. Including this volume element in the action integral of field theories in 4D spacetime, along with the usual $dV_g = \sqrt{-g}\, d^4x$, and adding φ_a functions to the set of all other fields participating in the least action principle, is the basic idea of TMT. The novelty in the structure of the TMT action is that each term $\sqrt{-g}\,\mathcal{L}_i$ in the Lagrangian density of conventional theory is replaced by a term reducible to $(b_i\sqrt{-g} \pm \Upsilon)\,\mathcal{L}_i$, where b_i are additional model parameters. The possibility of both signs in front of Υ is due to the sign-indefiniteness of Υ. Self-consistency of the equations obtained from the original action has the form of an algebraic constraint defining the scalar $\zeta(x) = dV_\Upsilon/dV_g \equiv \Upsilon/\sqrt{-g}$ as a polynomial function of the matter fields. The scalar ζ is present in all equations of motion and has a significant effect on the field dynamics. Unlike conventional field theories, the original action must include gravity: TMT models cannot be formulated directly in Minkowski space. Description of matter in Minkowski space is possible only as a result of the transition in all equations of motion to a state close to vacuum with zero cosmological constant.

The Two-Measure Standard Model (TMSM) and main results. Incorporating the electroweak SM into TMT in a way that fully accounts for the TMT structure leads to the TMSM. The TMSM is realized in the context of cosmology as a set of cosmologically modified copies of the Glashow–Weinberg–Salam (GWS) theory, each existing as a local quantum field theory defined on the classical cosmological background at the appropriate stage of its evolution. The evolution of the FRW universe is driven by a scalar field that is the cosmologically averaged real part of the neutral component of the SM Higgs doublet. The model is studied for two stages of background evolution: slow-roll inflation and approach to vacuum. Due to the presence of ζ in all equations of motion, all TMSM coupling constants turn into a kind of "running" (classical) TMT-effective parameters. The main new results:

1. The classical "running" TMT-effective Higgs self-coupling increases from $\lambda \sim 10^{-11}$ (providing Higgs inflation consistent with Planck CMB data at non-minimal coupling $\xi = 1/6$) to $\lambda \sim 0.1$ near vacuum. This avoids the unnaturally large ξ ($10^4 \lesssim \xi \lesssim 10^8$) required in conventional Higgs inflation.
2. The mass term in the TMT-effective Higgs potential changes sign from positive to negative, providing spontaneous symmetry breaking in the standard GWS way.
3. The classical "running" gauge and Yukawa couplings change by several orders of magnitude.
4. GWS theory is reproduced when the Yukawa constant in the original action is universal for the three fermion generations.
5. Unlike conventional Higgs inflation, TMSM on the slow-roll background is renormalizable.
6. One-loop quantum corrections preserve slow-roll inflation and vacuum stability.
7. A preliminary study shows that fermion preheating soon after inflation can be effective.
8. Applied to the very beginning of classical evolution, under certain initial conditions cosmological dynamics can begin with a "pathological" or phantom regime preceding inflation; however, if evolution begins with normal dynamics, it proceeds only as inflation, and the initial-conditions problem does not arise.

Finally, all b_i values are very close to unity (except one, close to 1/2), so the obtained results seem quite natural.

Kauffman, Louis [TO BE SCHEDULED, some time 13,14, or 15 July, CT]

Non-Commutative Worlds

Note to organizers: Prof. Kauffman will present via Zoom and has requested one of the following dates: **July 13, 14, or 15 (Chicago CT)**. Abstract pending; presentation slot to be confirmed.

Ketov, Serguei

Higgs mass and wino dark matter in Starobinsky supergravity gravitationally coupled to MSSM

A framework connecting Cosmic Microwave Background (CMB) observables with high-energy particle phenomenology is proposed, based on Starobinsky supergravity coupled to the Minimal Supersymmetric Standard Model (MSSM). In this approach, the amplitude of primordial perturbations during inflation fixes the vacuum expectation values (VEVs) of scalar fields in the hidden sector arising from the Starobinsky supergravity rewritten in Einstein frame. These VEVs trigger spontaneous supersymmetry breaking and set the soft masses in the MSSM. The three-loop renormalization group (RG) running is performed between the inflationary scale of 10^{13} GeV and the electroweak scale of 10^2 GeV. The RG evolution shows consistency with the measured Higgs boson mass m_H and current particle data. The framework is highly constrained and, in its simplest version, has no free parameters. Our approach allows split-SUSY with heavy scalar sparticles having masses at the inflationary scale and a light wino with mass of about 3 TeV as the lightest supersymmetric particle (LSP). The wino LSP is a viable thermal dark matter candidate that can be decisively probed at future colliders via its characteristic disappearing-track signature.

Maxim KHLOPOV

Open problems on the way to new Standard models

The necessity to go beyond the Standard models of fundamental interactions (including gravity) and hints to deviations from the now Standard paradigm of Inflationary Universe with Baryosynthesis and LambdaCDM model of structure formation leads to formulation of new Standards of Fundamental Physics and Cosmology. I briefly outline the dark atom model of dark matter, as well as models of primordial nonhomogeneity of dark and baryonic matter, possible evidence for them in DAMA/LIBRA, JWST, PTA and AMS02 results and discuss the open problems in development of these approaches to explain the resuilts of direct dark matter searches, early galaxy formation, stochastic gravitational wave background and piossible existence of antihelium components of cosmic rays. It provides the Introduction to specific results to be presented by my students and colleagues.

Maxim KRASNOV

Strong primordial inhomogeneities of axion-like field in Einstein–Gauss–Bonnet gravity

In this work we consider complex scalar field with Mexican hat potential coupled with Gauss-Bonnet scalar resulting in restored U (1) symmetry at the stage of inflation, correspond- ing to the modern cosmological horizon. In our model, the phase transition takes place during inflation, avoiding large-scale axion isocurvature perturbations. Our model provides strong primordial inhomogeneities on small scales and ultra-light axion-like particle as either a fuzzy dark matter candidate or a candidate for inhomogeneous dark energy. We also study the possibility of black hole formation and gravitational wave background in this scenario. We find that in the case when the symmetry breaking field does not backreact on inflation, black hole production is not feasible. However, under specific conditions, gravitational waves fitting the NANOGrav band can be obtained.

Astri Kleppe

CP-violation and fermion mass matrices

Last year I discussed how the Jarlskog invariant binds the two quark mass matrices tightly together; this talk is a sequel. My reference throughout has been the democratic scenario, whose mass matrix is an instance of a *circulant* matrix. Studying circulant matrices in connection with the Jarlskog invariant, I find that when one mass matrix is circulant its eigenvectors are frozen to the discrete Fourier basis, and the Jarlskog invariant collapses to an expression involving only the *other* sector. This empties invariant J_{CP} of the relational content that defines it. For the quarks, where J_{CP} is measured and nonzero, this excludes a circulant mass matrix. In the charged-lepton sector, where no CP-violating invariant is established, the situation is quite different: I show that a circulant hermitian matrix reproduces the Koide relation exactly, concluding that the quark and lepton sectors may be more different than one usually imagines.

How CP-violation constrains the structure of fermion mass matrices

Last year I talked about how quark mass matrices are constrained by the Jarlskog invariant. Because of the CP-violation, the quark mass matrices are tightly bound together, and this bonding is formulated in the Jarlskog invariant. Today' talk is a sequel to the earlier discussion. My reference has all along been the democratic scenario. The democratic matrix is an example of a *circulant* matrix, and continuing to dig into the landscape of mass matrices, I have looked into circulant matrices in connection with the Jarlskog invariant. I then found a result that might be interesting concerning CP-violation in the lepton sector, leading to the suspicion that the quark sector and the lepton sector are maybe more different than one imagines.

Himanshu Kumar

This presentation proposes a theoretical framework for weak gravitational anomalies based on a Yukawa-type modification of Newtonian gravity generated by a peculiar massive-photon dynamics in an extended-space model. The paper examines deviations from the inverse-square law in the weak-acceleration regime around $10^{-9}ms^{-2}$, motivated by both astrophysical indications and short-range experimental limits. Using a local U'(1) symmetry and an extra-dimensional construction, virtual photons are allowed to acquire an effective mass inside an analytic region bounded by a characteristic scale of order 30 micrometres. The work further introduces a complex mass function, its Cauchy-integral interpretation, and an analytic continuation scheme to connect submicrometre behavior with locally Lorentzian gravitational domains. The framework is presented as a bridge between laboratory-scale null results, weak-field gravitational anomalies, and broader open questions in modified gravity, vacuum inertia, Mach's principle, dark matter, and quantum-gravitational corrections.

N.S. Mankoč Borštnik

What new can the unified description of all fermion and boson fields, with gravity included, bring into understanding of all observed fermion and boson fields and the interactions among these fields in our Universe?

The description of the internal spaces of fermion and boson fields with the "basis vectors", which are the superposition of odd (for fermions) and even (for bosons) products of the operators γ^a, offers in $d = 2(2n + 1)$-dimensions,

in particular $d = (13 + 1)$, a unified picture of all so far observed fermions and bosons, determines the interactions among the fields, and offers predictions. Quarks, leptons, antiquarks, and antileptons appear in families - each family contains fermions and antifermions. Bosons - gravitons, photons, weak bosons, gluons, and scalars – which carry the spatial index α (for tensors and vectors $\alpha = (0, 1, 2, 3)$ and for scalars $\alpha \geq 5$), appear in two orthogonal groups.

The author will compare the proposed description with the Dirac's second quantized fields description and the *quantum fields theory*, nd discuss what new the proposed description can offer in comparison with the so far used.

N.S. Mankoč Borštnik, H.B. Nielsen

How to present and interpret the Feynman diagrams in the theory describing fermion and boson fields in a unique way, in comparison with the Feynman diagrams so far presented and interpreted?

Although the internal spaces which describe spins and charges of fermions' and bosons' second-quantised fields have such different properties, yet we can all describe equivalently with the "basis vectors" which are a superposition of odd (for fermions) and even (for bosons) products of γ^a's. In an even-dimensional internal space, as it is $d = (13+1)$, odd "basis vectors" appear in $2^{\frac{d}{2}-1}$ families with $2^{\frac{d}{2}-1}$ members each and have their Hermitian conjugate partners in a separate group, while even "basis vectors" appear in two orthogonal groups. Algebraic multiplication of boson and fermion "basis vectors" determines the interactions between fermions and bosons, and among bosons themselves, and correspondingly also their action. Tensor products of the "basis vectors" and basis in ordinary space-time determine states for fermions and bosons, if bosons obtain in addition the space index α. We study properties of massless fermions and bosons with the internal spaces determined by the "basis vectors" while assuming that fermions and bosons are active only in $d = (3+1)$ of the ordinary space-time. We discuss the Feynman diagrams in this theory, in comparison with the Feynman diagrams of the theories so far presented and interpreted.

Antonino Marcianò

I would like to propose three different topics:

i) "Fermion Condensate Inflation, Dynamical Waterfall Mechanism and Primordial Black Holes"

Fermion condensate inflation, where inflation emerges from four-fermion interactions induced by spacetime torsion, removes the need for additional scalar fields beyond the Standard Model. In this framework, the fermion field can be decomposed into two distinguished sectors, each giving rise to bound states. After integrating out fermions, the bound fields play the roles of the inflaton and the auxiliary fields, resembling hybrid inflation with a waterfall mechanism. The inclusion of an axial chemical potential naturally introduces a mechanism to end inflation and trigger instant preheating. During the waterfall phase, the effective potential of the fermion condensate supports the formation of non-topological solitons such as Q-balls, which act as seeds of primordial black holes. This model is intrinsically connected to Chern-Simons gravity, which implies a parity-violating universe. Consequently, both the primordial black hole (PBH) dark-matter abundance and parity-violation signatures could provide observational tests of the model. From a work with A. Alexander, P. Chen, M. Sasaki et al.

ii) "Phantom crossing from the Standard Model of particle physics and General Relativity" from a work with J. Liu and T. Manton and Y.-F. Cai

Suggestions of a late-time phantom crossing from DESI baryon acoustic oscillation measurements, combined with cosmic microwave background and Type-Ia supernova observations, have renewed interest in non-standard dark energy models. Here we propose a new realization of a low redshift phantom crossing using only well understood ingredients from fermion condensation and general relativity. Our construction relies on the interplay between effective quintom-like dark energy and backreaction from non-linear structure formation. The full cosmological evolution is consistent with ΛCDM until $z \sim 2-3$, where the total dark energy equation of state crosses $w_{\mathrm{DE}} = -1$ and evolves to de Sitter in the asymptotic future.

iii) "A geometric phase approach to quark confinement from stochastic gauge-geometry flows" from a work with T. Asselmeyer-Maluga, R. Pasechnik and E. Zappala

Understanding the origin of color confinement in quantum chromodynamics remains a central open problem in theoretical physics. Here we show that confinement can emerge as a geometric phase induced by stochastic topology change of the QCD vacuum. We formulate a coupled stochastic flow of geometry and Yang–Mills fields, in which fluctuations of the underlying manifold dynamically generate and annihilate center vortices. These topological transitions convert Wilson loops from perimeter-law to area-law scaling, providing a direct dynamical mechanism for confinement. We further demonstrate that singularities in the gauge–geometry flow correspond to instanton transitions associated with non-trivial bundle topology, linking vortex formation to topological invariants. Remarkably, the scaling behavior of the stochastic flow yields an emergent infrared scale consistent with Λ_{QCD}, suggesting a direct connection between Planck-scale geometry and hadronic physics. Our results establish confinement as a universal consequence of topology change in gauge–geometry systems, opening a new route to non-perturbative quantum field dynamics.

E. Miztani

1. Categorification for Theory of Dimensionality

Abstract. A new mapping or projection is given from any point in its original dimensional space to another dimensional space. In the series of mappings, any point has invariant or symmetry. In other words, the degree of freedom, meaning the number of variables of any point, is unchangeable in the series of mappings. Here, we explain mathematical definitions in terms of quotient vector space. The first aim of this work is to define our new notions in a simpler mathematical way. The second aim is to illustrate more concrete mappings from a higher dimensional space to a lower dimensional one and vice versa.

2. Many-worlds Interpretation from a Mathematical Viewpoint

Abstract. We will analyse how to treat a particle between different dimensional spaces. Here, we discuss mappings from lower to higher dimensional space.

Valery Nikulin, Ivan Letyagin

Direct surface-based simulation of primordial black hole clusters formation via collapse of non-spherical domain walls

Abstract: One possible mechanism for the formation of primordial black holes (PBHs) is the collapse of domain walls. Previous such theoretical models considered PBH formation in the spherical approximation, whereas full field-theoretic simulations of non-spherical domain walls clusters are too computationally demanding to accumulate sufficient statistics. In this work, we derive the equations of motion of a domain wall in the thin-wall approximation and propose a numerical method for evolving the wall surface using triangular mesh algorithms. For prescribed field configurations of a cluster, the method yields the differential mass spectrum of the resulting PBHs. Based on a Monte Carlo ensemble, we obtain $dN/dM \propto M(\alpha)$ with $\alpha = 2.31{+}0.010.02$, significantly larger than the theoretical value $\alpha \approx 1.75$ for spherical-wall collapse, indicating a larger fraction of low-mass PBHs. This deviation is presumably due to the fragmentation of walls with complex geometry, which is absent in the spherical approximation.

Jan Novak

Accelerated expansion of the Universe as a quantum gravity phenomenon

We have known approximately 100 years that the Universe is expanding. But the striking discovery came at the end of 20th century, when we found that it is expanding with acceleration. Since then, many models have been developed in cosmology to explain this phenomenon. One of the possible elucidations is that the theory of gravity must be modified at the classical level. But many such models were already excluded by the gravitational wave experiments. Therefore, we must slowly start to ask a much more urgent question: could accelerated expansion of the Universe be a phenomenon of quantum gravity ? We review the basic models of how we explain the origin of dark energy or the cosmological constant in metastring theory, discrete approaches to quantum gravity, group field theory, non-commutative geometry, causal dynamical triangulation, asymptotic safety, models based on holography and entropic gravity. We mention at the end a newly formed approach to the quantization of gravity, the ring paradigm, which would, just after the application to cosmology, naturally model the late-time accelerated expansion epoch in the Universe. But what is completely striking is that the final formulation of this theory would ultimately solve the old problem of the cosmological constant.

J. Solà Peracaula

Running vacuum in the Universe: a unified framework for inflation and dark energy within quantum field theory

Abstract: In this talk I will expose the basics of the running vacuum model (RVM) framework, based on quantum field theory (QFT) in curved spacetime. In it, quantum effects induce a vacuum energy density (VED) which is a function of the Hubble rate H and its time derivatives. Currently, the VED evolves very slowly around the current value associated with the cosmological 'constant', but with a quadratic component in H carrying a small coefficient that is calculable in QFT. This fact provides a possible fundamental origin of dark energy (DE), conceived as dynamical vacuum energy. The equation of state of the VED receives quantum corrections and is no longer -1; it departs slightly from it and is also dynamical. These facts make it possible to describe the currently observed dynamical DE by DESI observations in terms of the dynamics of the quantum vacuum. On the other hand, in the very early universe, the vacuum fluctuations of the quantized matter fields induce higher (even) powers of the Hubble rate, e.g. H^4, capable of triggering fast inflation in a very short period in which H is very large and approximately constant. This is the mechanism of 'RVM-inflation'. It does not require an 'inflaton' field since inflation is brought about by pure QFT effects on the dynamical background. It differs significantly from Starobinsky's inflation, where H is never constant. Putting things together, the RVM appears as a QFT framework for dark energy and inflation, which can be considered a candidate for a realistic unified theory of the cosmic evolution on fundamental grounds. A possible smoking gun of the RVM approach in the present universe is its dynamical equation of state, which can mimic quintessence and phantom dark energy behaviors (both observed using different parameterizations of the DE) without postulating the existence of ad hoc scalar fields.

Danila Sopin

1. Dark matter in sphaleron transitions: a general case

In dark matter scenarios where new particles carry electroweak charges, the ratio is determined by sphaleron transitions. A system of linear equations for quantum number densities is solved in a model-independent framework. The results are applied to benchmark models, specifically a sequential fourth generation and a walking technicolor model. Constraints on the maximum mass of new particles are derived, consistent with current bounds on the lepton asymmetry.

2. Nucleosynthesis in the presence of multiply charged particles

Stable, massive, multiply charged particles X can act as the cores of dark atoms, whose shells are composed of light nuclei during Big Bang Nucleosynthesis (BBN). We present the results of numerical calculations of capture reactions rates. The role of excited states in the neutralization of the heavy core is analyzed, as well as the dependence of the final abundances of bound states on the mass and charge of the heavy particle X.

Stepanyantz

Application of approximate renormalization group invariants to the study of the Yukawa unification

For supersymmetric extensions of the Standard Model, we construct some expressions which slightly depend on scale throughout the whole renormalization group evolution. Using these approximate renormalization group invariants we try to estimate a value of $\tan\beta$ and construct possible relations satisfied by the Yukawa couplings of the third and second generations at the scale of Grand Unification. We then investigate whether these relations are really satisfied in the MSSM and other similar theories. It appears that they are not valid for the MSSM, but can be satisfied for a supersymmetric theory containing exotic superfields forming 3 representations $5+\bar{5}$ of the group $SU(5)$ with masses of order 10^2 TeV. We argue that this can indicate a possible underlying E_6 gauge symmetry and demonstrate how the Yukawa relations under consideration can be derived from a certain E_6 invariant.

Aarav Shah, Paulo Moniz, Oem Trivedi, Meet Vyas

Memory-Induced Effects in Quantum Cosmology

We study memory effects in quantum cosmology by extending the semiclassical Wheeler-DeWitt framework beyond its standard local form. We incorporate a causal memory kernel at sub-leading order, from which fractional time evolution emerges as an effective description. Applying this framework to cosmological perturbations in de Sitter space, we find corrections to the primordial power spectrum, including a time-dependent departure from post-horizon freezing and a distinctive $k^{3/4}$ scaling. These effects predominantly modify high l CMB temperature anisotropies. Since the corresponding memory coefficient influences small-scale structure formation, its value may require fine-tuning to produce favorable astrophysical environments. We argue that a cyclic extension of the Hawking-Hartle no-boundary proposal provides a possible mechanism through which the effective memory strength may evolve toward phenomenologically preferred values. These results provide a physically consistent realization of fractional quantum cosmology and suggest observational signatures of memory-based quantum gravitational effects

Oem Trivedi

The $w - c_s^2$ Plane and the Misalignment Interpretation of Cosmic Tensions

In this talk, I will introduce the $w - c_s^2$ plane as a new diagnostic space for dark energy, where background expansion and perturbative microphysics are treated on equal footing. I will show how trajectories in this plane classify smooth, clustering, phantom and non-canonical dark energy models beyond what $w(z)$ alone can reveal alone. A central object will be the introduction of the new microphysical flow parameter $F = dc_s^2/dw$, which measures how the sound speed evolves relative to the equation of state. I will then connect this flow to the joint behavior of H_0 and σ_8, motivating cosmic tensions as possible misalignments between expansion, growth and microphysical eigenmodes. The goal is to present a framework in which future surveys can test not only whether dark energy evolves, but whether its background and perturbative sectors evolve coherently and whether dark energy is actually microphysically active.

S.Weiss

Self consistent treatment of the annihilation at the border of antimatter domain in baryon asymmetrical Universe”

A self-consistent model of primordial antimatter domain evolution, incorporating annihilation pressure feedback into an effective diffusion coefficient. By comparing “Swiss Cheese” and “Chinese Boxes” topologies, we define a survival corridor between 10^3 and $10^5\,M_\odot$. Predicted anti-helium fluxes (10^{-8} to 10^{-6}) and ^{3}He enrichment are consistent with AMS-02 sensitivity, constrained by a total annihilated fraction $f < 10^{-4}$.