**Stará Lesná 2021 - List of Presentations**

**Blažek Tomáš** (Comenius U)

**Title:** High-Energy Physics News 2021  
**Abstract:**  
Latest News from High-Energy Physics will be presented in a colloquial-type of talk.

**Chadzitaskos Goce** (FNSPE CTU)

**Title:** Interesting properties of an asymmetric oscillator  
**Abstract:**  
We present a method to introduce a Fock representation for an asymmetric harmonic oscillator and the effect of "quantum beats" in the time evolution of the mean value of the position operator for the superposition of its own states. An ordinary harmonic oscillator is then a special case.

**Ďalak Frederik** (Comenius U)

**Title:** Newton-Cartan Theory.  
**Abstract:**  
In years 1923 and 1924 Elie Cartan published two articles in which he introduced a theory that became known as the Newton-Cartan theory of gravity. Cartan used the language of differential geometry to reformulate the Newtonian theory of gravity as curvature of four-dimensional spacetime. First we define mathematical structures needed to introduce the Cartan's formulation of Newtonian gravity. In space-time \((\\mathbb{R}\times\\mathbb{R}^{3}, \nabla)\) we establish the structure of linear connection \(\nabla\) as shown by Cartan. We show that trajectories of a point mass moving in the gravitational field are represented by geodesics in \(\\mathbb{R}\times\\mathbb{R}^{3}\). We derive the explicit expression for the Riemann curvature tensor and the Ricci tensor in Cartan's space-time. We then formulate the Newton-Cartan theory field equations connecting the Ricci tensor and density of mass.

**Fecko Marián** (Comenius U)

**Title:** Saint-Venant's compatibility condition and Einstein tensor  
**Abstract:**  
In the first part of the talk we remind what Saint-Venant's compatibility condition (from mathematical elasticity theory) says. In the second part we show how Saint-Venant's operator (present in the condition) is related to Einstein tensor. This link provides an insight leading to an easy proof of an old theorem.

**Kováč Juraj** (FNSPE CTU)

**Title:** A WKBJ analysis of reaction-diffusion equations.  
**Abstract:**  
Asymptotic analysis has yielded a number of worthwhile insights in multiple fields, including pattern formation. With this in mind, we present a set of approximation theorems that generalize scalar WKBJ theory to multicomponent systems, relying on their spectral properties. Subsequently, we relate these
properties to a typical reaction-diffusion (Turing) system and demonstrate the main results obtained via a WKBJ analysis.

Kováčik Samuel (Comenius U)

Title: Hawking-Radiation Recoil of Microscopic Black Holes

Abstract: Hawking radiation would make microscopic black holes evaporate rapidly, which excludes them from many astrophysical considerations. However, it has been argued that the quantum nature of space would alter this behaviour: the temperature of a Planck-size black hole vanishes, and what is left behind is a Planck-mass remnant with the cross-section of ~10^-70 m^2, which makes a direct observation nearly impossible. Such black hole remnants have been identified as possible dark matter candidates. Here, we argue that the final stage of evaporation has a recoil effect that gives them a velocity up to ~10^-1 c. This could lead to a disagreement with the cold dark matter cosmological model.

Kubů Ondřej (FNSPE CTU)

Title: Superintegrability in the presence of magnetic fields: the cylindrical case.

Abstract: We present our recent results concerning superintegrability with magnetic fields. We explore the consequences of a conserved canonical momentum on the integrals of motion. It leads to a lower-dimensional problem or constrains the integral. This yields a family of higher-order superintegrable systems. Next, we apply the results to superintegrable systems separating in cylindrical coordinates with second-order integrals. Here we find several new minimally superintegrable systems, concluding the classification. We conclude with a brief comparison with the Cartesian case.

Lehečková Tereza (FNSPE CTU)

Title: Relativistic systems - superintegrability and separability

Abstract: The systematic study of (super)integrability is a rapidly developing field in the investigation of classical and quantum systems. Recently, there have also been efforts to extend it to special relativistic systems. This can be done, for example, by using the so-called Dirac form of Hamiltonian relativistic dynamics, working in the 3+1 splitting of Minkowski spacetime. This presentation summarizes some of the specifics and issues encountered in the search for and description of relativistic (super)integrable systems with electromagnetic fields (and their comparison with classical systems). It also discusses the use of one particular method of finding integrable systems (and their corresponding integrals of motion) using the separability of the Hamilton-Jacobi equation for relativistic systems. It gives a list and some properties of systems separable in Cartesian coordinates in instant and front Dirac form, and also presents some observations, classification and examples of separability (and the resulting integrability) in general coordinates.
Malachov Martin (FNSPE CTU)  
**Title:** Chaos in purification protocols with polynomials of higher degree.  
**Abstract:**  
Quantum information and communication relies on qubits. These superpositions of basal states can be entangled which makes a valuable resource for interesting algorithms like quantum teleportation, Shor algorithm, Deustch-Jozsa algorithm etc. As a physical object, qubit is subject to environment which makes its state decay and disturb the entanglement. Purification protocols and error correction codes aim on repairing the qubit states and retaining their entanglement. One of proposed protocols use a copy of the qubit to act as a specific environment but such action has been shown to induce chaotic behavior, particularly there are states undergoing deterministic chaos when the protocol is iterated on them. Mathematically, the protocol manifests as rational polynomial functions of degree two. We propose a series of more general algorithms with polynomials of higher degree and investigate their properties compared to the original algorithm which features are also described in detail. We focus on fractal structures of chaotic states, symmetries and other general properties of the protocols.

Maták Peter (Comenius U)  
**Title:** Diagrammatic connection between the classical and quantum kinetic theory  
**Abstract:**  
Dark matter relic density or matter-antimatter asymmetry in the early universe is often estimated using the Boltzmann equation. In its simplest form, the description is based on kinetic theory of classical point-like particles that reveal their quantum nature only in interactions. A more precise alternative is based on the Keldysh-Schwinger formalism of non-equilibrium quantum field theory accounting correctly for quantum effects in the medium. In this presentation, we demonstrate how to formulate these results within the classical Boltzmann equation.

Mészáros Peter (Comenius U)  
**Title:** Solid matter with zero shear modulus in flat universe  
**Abstract:**  
For a perfect fluid, the quantity defined through mixed components of the stress-energy tensor \( \omega = (T_i^i/3)/(-T_0^0) \) is independent on the choice of coordinates only for two values of the pressure to energy density ratio \( w = p/\rho \): for radiation with \( w = 1/3 \), and for dark energy with \( w = -1 \). With other choices of \( w \), the quantity \( \omega \) is coordinate dependent, and \( \omega = w \) only in the local rest frame of the fluid. We show that the same is true also for solid matter with shear stress Lamé coefficient set to zero in a flat Friedmann-Lemaître-Robertson-Walker universe with perturbed metric as well as stress-energy tensor. We call the two different solids with coordinate independent \( \omega \) radiation-like solid and dark energy-like solid, and we restrict ourselves to these two special cases. By analysing second order perturbations we discover two one parametric sets of such solid matter models containing special cases of radiation and dark energy as perfect fluids. We also study equations for perturbations up to the second order for both sets of models.
Novotný Dominik (Comenius U)

Title: Rare kaon decays at the NA62 experiment

Abstract:
Measuring branching ratios of rare kaon decays is one way to test the Standard Model and a possibility to see hints of new physics. One of such experiments is the NA62 Experiment at CERN. Its main goal is to measure the branching ratio of the $K \rightarrow \pi \nu \nu$, but its physics program is much broader and it also measures other rare kaon decays.

In this talk we start with an introduction to kaons. Then we show why measuring the branching ratio of the $K \rightarrow \pi \nu \nu$ decay was chosen as the main goal of the NA62 experiment. We then take a sneak peak at another rare kaon decay: the $K \rightarrow \pi \gamma \gamma$ decay, which is the topic of my thesis.

Novotný Petr (FNSPE CTU)

Title: Weyl orbit functions and G2 dual weight single-particle model.

Abstract:
Weyl orbit functions and their properties are introduced. Model of a free non-relativistic quantum particle propagating on the dual weight lattice inside the scaled fundamental domain is described and solved using Weyl orbit functions. Example concerning G2 root system is presented.

Parýzková Magdaléna (FNSPE CTU)

Title: Quantum walks in discrete and continuous time

Abstract:
Quantum random walk is a quantum alternative to the well-known classical random walks. It has found application in fields such as quantum computing, quantum information, biology, or chemistry. This talk will give an introductory overview of quantum walks on graphs and their possible applications. We will review basic information about both discrete-time (DTQW) and continuous-time quantum walks (CTQW). Afterward, we will point out their differences and compare them to the classical random walks. At last, we will also review known applications to search algorithms on a quantum computer and coherent transport on systems represented by graphs.

Semorádová Iveta (FNSPE CTU)

Title: Diverging eigenvalues in domain truncations of Schrödinger operators with complex potentials

Abstract:
Domain truncations of Schrödinger operators with complex potentials are known to be spectrally exact. However, several examples suggest that additional eigenvalues escaping to infinity seem to be a generic feature. We find conditions on the presence of such eigenvalues and obtain their asymptotic expansions. Our approach also yields asymptotic formulas for diverging eigenvalues in a strong coupling regime for the imaginary part of the potential.
Skoupý Stanislav (FNSPE CTU)

Title: Search and state transfer by means of quantum walk on M-partite graph

Abstract:
We present search and state transfer algorithm based on discrete-time quantum walks on general graph. Then we show how search and state transfer work on complete M-partite graph with one self loop at each vertex. At last we introduce new state transfer algorithm based on the search algorithm and we prove that new algorithm performs better than the original state transfer algorithm on M-partite graph.

Šmolka Rudolf (FNSPE CTU)

Title: Courant algebroids in the language of graded symplectic geometry

Abstract:
It has been shown that there exists a one-to-one correspondence between a certain class of symplectic non-negatively graded manifolds and Courant algebroids. In the presented work we give the definition of a Courant algebroid along with the Ševera classification of all exact Courant algebroids, we provide a chapter concerning the sheaf of derivative endomorphisms for any vector bundle and we finish by going through both sides of the mentioned correspondence.

Staněk Matyáš (FNSPE CTU)

Title: Logical operations on OAM superpositions

Abstract:
Light has many degrees of freedom and one of them is the orbital angular momentum (OAM). Beams carrying an OAM are usually described in the orthonormal basis of Laguerre-Gaussian modes, in which the integer l corresponds to the value of the OAM of the given basis state. In this talk, we show how to take advantage of the unbounded nature of the index l to encode information in its binary representation. Designs of optical elements for manipulating the OAM beams are also presented.

Tekel Juraj (Comenius U)

Title: Fuzzy field theories in the string modes formalism

Abstract:
Fuzzy spaces are, among other things, toy models for spaces with discreet structure at small distances. As such, they provide a laboratory to study the consequences of this discreetness on the properties of physical theories, such as the theory of scalar fields. The standard approach to this theory is very similar to the usual treatment of field theories on continuous spaces - momentum basis, Feynman diagrams, and loop integrals. In this talk we present a different formulation of the scalar field theory on the fuzzy sphere - in terms of the string modes, which are functions optimally localized in position and momentum space. We show how this greatly simplifies the computation of the loop contributions in position space and provides some new insights into the structure of the effective action of the theory.

Vedl Šimon (FNSPE CTU)

Title: Applications of Clifford’s Geometric Algebra in Gauge Theories
Abstract:
In this talk we try to approach concepts in differential geometry from a different angle while heavily utilising the formalism of Clifford. First, we explore the geometry of surfaces in Euclidean spaces. There we introduce parallel transport as a rotor transformation and then define the shape operator and curvature as bivector-valued forms. Motivated by this case, we introduce the idea of a vector bundle equipped with Clifford product. And afterwards we define connection and curvature on this vector bundle. Gauge transformations are implemented as fiber-wise rotations. Inspired by the embedded geometry, we introduce the concept of a shape gauge. We showcase this approach on the simplest gauge theory - the electromagnetism - and present shape gauges for some usual examples of electromagnetic fields. Finally, we concern ourselves with the relationship of connections on the vector bundle and connections on the tangent bundle of the base manifold. And towards the end we explore the Einstein equations of general relativity using these new variables.