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”FROM CLASSICAL TO MODERN PHYSICS”

Session of lectures in the frame of CEEPUS program

- **Vladimir Gerdjikov** - Riemann–Hilbert Problems, Polynomial Lax Pairs and Integrable Equations.

Abstract: The Lecture is based on a previous paper. The standard approach to integrable nonlinear evolution equations (NLEE) usually uses the following steps:
1. Lax representation $[L,M]=0$; 2. Construction of fundamental analytic solutions (FAS); 3. Reducing the inverse scattering problem (ISP) to a Riemann-Hilbert problem (RHP) $\xi^{+}(x,t,\lambda) = \xi^{-}(x,t,\lambda)\, G(x,t\lambda)$ on a contour Γ with sewing function $G(x,t,\lambda)$; 4. Soliton solutions and possible applications.
Step 1 involves several assumptions: the choice of the Lie algebra g underlying L, as well as its dependence on the spectral parameter, typically linear or quadratic in λ. Our idea is to use another approach that substantially extends the classes of integrable NLEE. Its first advantage is that one can effectively use any polynomial dependence in both L and M. We use the following steps: A. Start with canonically normalized RHP with predefined contour Γ; B. Specify the x and t dependence of the sewing function defined on Γ; C. Introduce convenient parametrization for the solutions $\xi^{\pm}(x,t,\lambda)$ of the RHP and formulate the Lax pair and the nonlinear evolution equations (NLEE); D. use Zakharov--Shabat dressing method to derive their soliton solutions. This requires correctly taking into account the symmetries of the RHP; E. Define the resolvent of the Lax operator and use it to analyze its spectral properties.

- **Marija Dimitrijevic-Ciric** - A brief introduction to theory of relativity: from Newtonian mechanics to Einstein's gravity.

Abstract: In this lecture we will introduce the basic concepts of Special Relativity. In the introduction part we will review the Galilean transformations in classical mechanics, explain why they are not compatible with Maxwell electrodynamics and describe the Michelson–Morley experiment. In the Special Relativity part we will present the postulates of Special Relativity and discuss their consequences. We will introduce concepts of Minkowski spacetime, metric tensor, causal structure and Lorentz transformations. Motivated by the twin paradox, we will finally very briefly discuss basic concepts of General Relativity: equivalence principle, Einstein equations, their properties and some solutions.

- **Goran Djordjevic** - **Modern Cosmology - between Newtonian dynamics and Lagrangian formalism**

Abstract: Modern cosmology, and cosmology itself, is based on the General Theory of Relativity. However, it has been shown that the basic equations on which Friedman's cosmological models are based can be derived from Newtonian dynamics. What will be demonstrated. During the 1970s it became clear that the ``Standard Cosmological Model'' contained problems that could not be solved within the model itself. The theory of inflation solved a number of these problems in a surprisingly successful way. But the very mechanism of inflation and its origin remain unknown till know. One of the ``non-standard'' approaches to cosmological inflation is based on the non-canonical - Dirac-Born-Infeld Lagrangian(s). Although the motivation and interpretation of this approach are part of the (super)string theory and branes, the mechanical interpretation of the processes described by DBI Lagrangians is simple, intuitive, instructive, to which the last part of the lecture will be devoted.

- **Dragoljub Dimitrijevic** – **Scalar Fields in Cosmology**

Abstract: Cosmological observational data has been collected over the last thirty years. These include the precise measurement of CMB radiation, evidence of the accelerated expansion of the Universe, the discovery of gravitational waves, an image of the black hole at the center of the supergiant elliptical galaxy and many others.
In order to study for example Cosmological Inflation or primordial black holes we need to use real scalar fields in curved space-time background. The scalar fields in use are canonical and non-canonical scalar fields. This is introductory story of one interesting non-canonical scalar field - tachyon scalar field.