XIV SCHOOL ON GEOMETRY AND PHYSICS

Białystok, Poland

23 June - 27 June 2025

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LIST OF COURSES

1. **Francisco CORREA SANTANDER** — *University of Santiago de Chile, Chile*

   Geometric pathways: From integrable models to black hole physics

   A short course on integrable systems, Chern–Simons theory, and their role in black hole physics.

   In this lecture series, I will explore how integrable systems and their defining properties can be given a natural geometric interpretation within the framework of black hole physics.

   The first lecture introduces foundational concepts in integrable models, including the Lax pair formalism, the zero curvature condition, and the appearance of hyperelliptic curves in certain nonlinear integrable hierarchies.

   The second lecture focuses on Chern–Simons theory, with a detailed discussion of how (2+1)-dimensional gravity with a negative cosmological constant can be reformulated in terms of two $sl(2,\mathbb{R})$ Chern–Simons connections.

   In the final lecture, we synthesize the previous ideas to show how the zero curvature condition arising in Chern–Simons gravity provides a geometric language to reinterpret various integrable systems. We will demonstrate how several features of integrable models discussed earlier emerge naturally in the context of integrable black hole solutions and their associated asymptotic symmetries.

2. **Laszlo FEHER** — *University of Szeged / Wigner RCP, Budapest, Hungary*

   Integrable Hamiltonian systems from reductions of doubles of compact Lie groups

   We deal with reductions of integrable 'master systems' living on the 'classical doubles' of any semisimple, connected and simply connected compact Lie group G. The doubles in question are the cotangent bundle, the Heisenberg double and the internally fused quasi-Poisson/quasi-Hamiltonian double, each of which carries two natural integrable systems. In the cotangent bundle case, one of the integrable systems is generated by the class functions of G and the other one by the invariant functions of its Lie algebra. The reduction is defined by taking quotientby the cotangent lift of the conjugation action of G on itself, and this generalizes to the other two doubles. The quotient space of the internally fused double represents the moduli space of flat principal G-connections on the torus with a hole. We explain that degenerate integrability of the master systems is inherited on the smooth component of the Poisson quotient corresponding to the principal orbit type for the pertinent G-action, and present explicit formulas for the reduced Poisson structure and equations of motion in terms of dynamical r-matrices after further restriction to a dense open subset.

   Lecture 1. The integrable master systems on the classical doubles and the definition of their Poisson reductions. The warm up case of the cotangent bundle.

   Lecture 2. Degenerate integrability on the Poisson quotient of the Heisenberg double corresponding to the principal orbit type and the interpretation of the reduced systems as Ruijsenaars–Schneider (RS) type many-body models extended by 'spin' degrees of freedom. A detour towards the spin RS models of Krichever and Zabrodin.

   Lecture 3. The case of the quasi-Poisson double. Specific examples on small symplectic leaves for $G = SU(n)$. Ruijsenaars duality in the framework of Hamiltonian reduction. Open problems.

3. **Jean-Pierre GAZEAU** — *University of Białystok, Poland*

   Quantum formalism in lower-dimensional real and complex Hilbert spaces

   Key concepts of quantum formalism, including quantum measurement, entanglement, Bell and CSHS inequalities, circuit complexity, open systems, will be presented using simple systems such as light polarization, spin-$\frac{1}{2}$, two-level atoms, colors and more.

4. **Piotr KIELANOWSKI** — *University of Białystok, Poland*

   Renormalization group

   The lecture schedule is as follows:

   1. General discussion of classical and quantum fields.
   2. Renormalization in quantum field theory.
   3. Renormalization group.

   The discussion will be straightforward and some elementary knowledge of classical and quantum mechanics is assumed. All examples will be based on the scalar quantum field.

5. **Karen STRUNG** — *Czech Academy of Sciences, Czech Republic*

   Graph C^*-algebras and their applications to quantum spaces

   This short course will serve as an introduction to C^*-algebras through the lens of graph algebras, with an emphasis on their role as noncommutative topological spaces. After a short introduction to the basics of C^*-algebras, we will show how to construct of C^*-algebras from directed graphs. Graph C^*-algebras are a class of examples which are both rich and tractable. In particular, we will see how the combinatorics of the graph can determine key C^*-algebraic properties such as ideal structure and K-theory.

   Building on this foundation, we will explore how certain C^*-algebras arising in noncommutative geometry, which we think of as algebras of functions on "quantum spaces", can be realized within this framework, by considering the C^*-algebras of quantum flag manifolds in the sense of Drinfeld and Jimbo.

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