NITheCS Mini-school

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The Geometry of Constraints: From Dirac's Formalism to the Batalin–Tyutin Construction

Dr Partha Nandi (*NITheCS*) & Mr Raphael De Sousa (*University of Oxford*)

Attend 3 online lectures:
Wednesday 10, 17 & 24 June 2026 | 14h00-15h00

ABSTRACT

Constrained dynamical systems occupy a central position in modern theoretical physics, providing the mathematical framework underlying gauge theories, gravity, string theory, and many other fundamental physical models. The presence of constraints introduces subtle geometric and algebraic structures that reshape our understanding of physical degrees of freedom, symmetries, and quantisation.

This lecture offers an introduction to the Hamiltonian theory of constrained systems, emphasising both its geometric foundations and practical applications. Beginning with Dirac's classification of constraints, we explore the distinction between first-class and second-class constraints, the emergence of gauge symmetries, and the construction of the reduced phase space. A geometric perspective will be developed throughout, highlighting the role of constraint surfaces, symplectic structures, and gauge orbits in determining the physical content of a theory.

Building on these ideas, we introduce the Batalin–Tyutin construction, a systematic procedure for converting second-class constrained systems into gauge-invariant first-class systems through an extension of phase space. This approach not only provides a powerful tool for quantisation but also reveals hidden gauge structures that may be obscured in the original formulation. Illustrative examples will be used to demonstrate how the formalism operates in practice and why it remains an important ingredient in contemporary theoretical physics.

The lecture is intended for advanced undergraduate and graduate students, as well as early-career researchers interested in the geometric and algebraic foundations of modern gauge theories and constrained dynamical systems.

BIOGRAPHIES

Dr Partha Nandi is a Postdoctoral Fellow at NITheCS. His research focuses on the interface of quantum mechanics, gravity, and spacetime structure, with particular interests in quantum aspects of gravitational waves, gravitationally induced entanglement, quantum spacetime phenomenology, noncommutative geometry, and constrained dynamical systems. He has authored several research articles in leading international journals on quantum signatures of gravity, quantum coherence in curved spacetime, and Planck-scale modifications of quantum dynamics. His current research aims to develop experimentally accessible probes of quantum gravity through gravitational-wave physics and quantum systems.

Raphael De Sousa is an incoming PhD student at the University of Oxford and a Rhodes Scholar-elect for 2026. His research interests lie in mathematical methods in theoretical physics, particularly quantum field theory and its foundational structures. He recently completed his Honours degree in Physics at the University of Cape Town, following a triple major in Physics, Mathematics, and Applied Mathematics. His academic work reflects a strong interest in the mathematical foundations of modern theoretical physics and their application to fundamental questions in high-energy physics and related fields.

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