2026 JRG LEADER SELECTION SYMPOSIUM

2026 May 13 (Wed) | #512 Headquarters, APCTP & Online via ZOOM

Time	Program	
09:00 – 09:10	Opening Remark by President	
09:10 – 10:10	**Alexander Jahn** (Freie Universität Berlin)	Quantum computation and emergent quantum gravity
10:10 – 11:10	**Anamaria Hell** (Kavli-IPMU, University of Tokyo)	Uncovering the fundamental degrees of freedom of the Universe
11:10 – 11:20	Break	
11:20 – 12:20	**Albert Escrivà Mañas** (Nagoya University)	Gravitational Collapse in the Early Universe: Primordial Black Holes and Gravitational Waves
12:20 – 14:00	Lunch	
14:00 – 15:00	**Mathias Casiulis** (New York University)	Understanding and harnessing complexity, from point patterns to materials
15:00 – 16:00 **(Online)**	**Deepak Gupta** (Technical University of Berlin)	Efficient control of the F1 molecular motor

■ ZOOM Webinar

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아태이론물리센터는 정부의 과학기술진흥기금 및 복권기금 지원으로 공익적 가치 제고에 힘쓰고 있습니다.

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Quantum computation and emergent quantum gravity

Dr. Alexander Jahn

Freie Universität Berlin

In recent years, quantum information theory has become a powerful tool for approaching questions of quantum gravity. It has become particularly relevant when considering quantum gravity as an emergent theory from quantum degrees of freedom, such as in holographic bulk/boundary dualities. In this talk, I will show how the study of quantum gravity as a quantum-computational process leads to new insights in theoretical physics: It allows us to construct new types of quantum error-correcting codes with relevant features for future applications on quantum devices, leads to a new understanding of spacetime in terms of operator algebras, and allows us to describe the dynamics of quantum-gravitational systems using tensor-network methods. Finally, I will show how this program fits into the broader research landscape of the Asia-Pacific region, expanding existing collaborations into new directions.

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Uncovering the fundamental degrees of freedom of the Universe

Dr. Anamaria Hell

Kavli-IPMU, University of Tokyo

We live in an exceptional era of precision cosmology, marked by rapidly advancing observational probes that explore the Universe across many length scales. While these experiments offer clues about the geometry, dynamics, and large-scale structure of the cosmos, they still leave the origin and much of the evolution and structure of the Universe unknown. My research aims to address these questions by uncovering the building blocks of theoretical models in both linear and non-linear regimes.

In this seminar, I will show how I have overcome challenges in understanding physical modes across different theories, and outline my plans to tackle fundamental questions through constrained gravity and non-linear studies of ghost modes. I will first explain the importance of non-linearities in theories beyond standard models. I will then present methods for uncovering physical degrees of freedom, and introduce the framework of constrained gravity. I will conclude by presenting how these ideas can help address long-standing challenges in fundamental physics and open new directions across disciplines.

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Gravitational Collapse in the Early Universe: Primordial Black Holes and Gravitational Waves

Dr. Albert Escrivà Mañas

Nagoya University

Primordial black holes provide a unique window into the physics of the early Universe, connecting gravitational collapse, high-energy cosmology, dark matter, and gravitational-wave astronomy. In this talk, I will present my research on primordial black-hole formation and its observational implications, with emphasis on how nonlinear gravitational dynamics can leave measurable signatures in the present-day Universe.

I will first summarize recent progress in understanding the conditions under which large primordial fluctuations collapse to form black holes, highlighting the role of initial perturbation profiles, critical phenomena, and peak statistics. I will then discuss how N-body simulations can be used to follow the nonlinear evolution of nonspherical primordial overdensities, including their collapse dynamics and the associated gravitational-wave emission.

Finally, I will outline my future research plans and vision for APCTP. The aim is to develop a unified theoretical and numerical program for primordial black-hole physics, linking early-Universe gravitational collapse with gravitational-wave observations and cosmological probes. At APCTP, this research direction would contribute to research activities at the interface of gravity, cosmology, and astroparticle physics, while fostering international collaboration.

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Understanding and Harnessing Complexity, from Point Patterns to Materials

Dr. Mathias Casiulis

New York University

Paradigmatic examples of useful materials are crystals, that display a variety of interesting properties, e.g. optical. It is not by chance: by virtue of their periodicity, these structures possess long-range order ranging from the scale of the atom to that of a block of material.

Yet, from bird feathers to weevil scales, many biological systems instead rely on aperiodic structures, that look disordered at short range but display correlations at long range, to achieve functions such as structural color. The study of such correlated disordered structures is challenging both numerically and experimentally.

In this talk, I present an algorithm, the Fast Reciprocal-Space Correlator (FReSCo), that enables me to embed arbitrary correlations into point patterns at lightning speed. I then discuss how FReSCo can be used to functionalize disorder using the example of bandgap materials.

I finally discuss how the optimization approach in FReSCo can be paired to the study of high-dimensional energy landscapes to quantify the number of solutions that an inverse-design problem has, thus giving precious insight on both geometric and physical constraints in correlated disordered materials.

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Efficient control of the F1 molecular motor

Dr. Deepak Gupta

Institut für Physik und Astronomie, Technische Universität Berlin

In this talk, I will discuss designing efficient driving protocols for the ATPase. First, I will show the optimal protocols, obtained using a linear response framework [1], to drive the ‘s γ-shaft to synthesize ATP. These optimal protocols dissipate lower energy compared to constant driving protocols [2]. In the second part of my talk, I will discuss our recent experimental results on the ATPase motor, where we compare the dissipation of driving this motor using two experimentally viable protocols: angle- and torque-clamp. Our experimental results (supported by analytical findings) suggest that angle-clamp driving requires less work than that of the torque-clamp [3].

[1] Sivak, D. A. & Crooks, G. E. Phys. Rev. Lett. 108, 190602 (2012).

[2] Gupta, D., Large, S.J., Toyabe, S., & Sivak, D.A. J. Phys. Chem. Lett. 13 (51), 11844-11849 (2022).

[3] Mishima, T., Gupta, D., Nakayama, Y., Wareham, W. C., Ohyama, T., Sivak, D. A., & Toyabe, S. Phys. Rev. Lett. 135 (14), 148402 (2025).

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