NBIA NEWSLETTER

A MESSAGE FROM THE DIRECTOR

Poul Henrik Damgaard

The recent detection of gravitational waves will stand out as one of the major scientific discoveries of this century. Already now it has spawned a new research area under the broad title of gravitational astrophysics. It has implications on numerous fronts: a need to better understand both analytic and numerical predictions of Einstein's theory of general relativity, new insight into the structure of neutron stars as strong tidal forces rip them apart, and a new window on events where signals coincide with bursts of electromagnetic radiation and possibly neutrinos. From this wealth of data we will learn not only about the astrophysics of these fascinating compact objects but also about the nuclear processes producing them, gaining new insight into the production of heavy elements in such explosive environments. Most spectacularly, perhaps: we can now watch, through gravitational waves, the final stages of two black holes spiraling towards each other and eventually merging. At the turn of the year, NBIA will welcome leading expert on gravitational physics Vitor Cardoso, who will build up, on a large scale, a new research group at NBIA dedicated to gravitational physics. Recipient of a Villum Investigator grant, Vitor Cardoso will provide a major new boost to the already existing research groups at NBIA working on these topics from a variety of directions. True to its spirit of interdisciplinary research, NBIA has also expanded significantly into research in the life sciences this fall thanks to generous funding from the Novo Nordisk Foundation.

NEWS IN BRIEF

INDEPENDENT RESEARCH FUND GRANT

NBIA Associate Professor N. Emil J. Bjerrum-Bohr received a grant from Independent Research Fund Denmark for a new avenue towards computation of gravitational wave signals. The project, 'Black Holes and Extreme Gravitational Forces', strives for a strengthened theoretical effort that builds on precise modern computational methods for scattering amplitudes as a way to boost theoretical calculation of classical observables in Einstein gravity. The grant will allow the hire of a post-doctoral fellow and an active visitor program in this field.

MILLA BALDO CEOLIN PRIZE 2020

The National Institute for Nuclear Physics (INFN) in Italy has awarded the 2020 Milla Baldo Ceolin Prize to NBIA's PhD student Ersilia Guarini. The Milla Baldo Ceolin award is awarded to the best MSc theses in theoretical physics defended in Italy by female students. Ersilia defended her MSc thesis on October 28, 2020 at the University of Bari, Italy. Her thesis "Axion emissivity from photon conversions in the solar magnetic field" stood out in the INFN competition for the importance and the originality of its results. Ersilia is now a Ph.D. student in the AstroNu group led by Irene Tamborra where she researches multi-messenger astrophysics.

NOVO NORDISK NERD GRANT

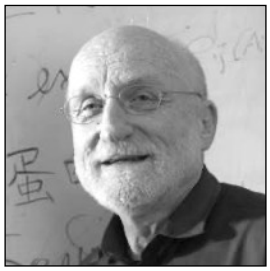
Assistant Professor Amin Doostmoohammadi has just received a large grant from the Novo Nordisk Foundation under their NERD program. He will explore a novel form of cellular sensing and communication dubbed "Topography-Mediated Cellular Self-Organization (TopoMed)". Cells autonomously and actively exploit folding and topographical restructuring of their substrates as a means of guidance and communication. The work is expected to deliver a powerful, state-of-the-art, predictive framework to simulate multicellular self-organization on substrates, to help engineer novel biomaterials for repair and regeneration of cellular tissues, and to provide exciting inspiration for previously inconceivable biomimetic designs.

NEW NBIA MEMBERS

This Fall, the NBIA welcomes a number of new staff members and visitors. You can find a brief description of their work below. We also give a warm welcome to our new PhD student, Katherine Mørch Groth, and our new MSc students, Jonathan Bödewadt, Arun Krishna Ganesan, Garðar Sigurðarson, Marie Ernø-Møller, Jitze Hoogeveen, Youyou Li, Rasmus Strid, and Andreas Forum.

Maria Bergemann joins us as a Visiting Professor this Fall from the Max Planck Institute for Astronomy in Heidelberg. Her research interests include radiative processes in astrophysics, spectroscopy and stellar physics, the origins of chemical elements, and Galactic archeology.

Debora Marks from Harvard Medical School (HMS) returns as Novo Nordisk Foundation Visiting Professor at NBIA this Fall. Debora is a mathematician and computational biologist with a track record of using novel algorithms and statistics to successfully address unsolved biological problems.



Novo Nordisk Foundation Visiting Professor Chris Sander from HMS is the Director of the cBio Center at the Dana-Farber Cancer Institute. He works on solutions to biological problems using methods of bioinformatics, statistical physics, data sciences, statistics, computer science, and mathematics.

Assistant Professor Andres Luna is interested in the interface between gravitation and scattering amplitudes in quantum field theories. He currently works on the generalization of the double copy to classical systems, and in applying scattering amplitude techniques to gravitational-wave physics.

Karel Proesmans is a new Assistant Professor working on non-equilibrium statistical mechanics, particularly on stochastic thermodynamics, a framework which enables study of thermodynamics of small-scale systems arbitrarily far from equilibrium. At the NBIA, he tries to apply this to biological systems.

Ben Brown returns to the NBIA as a Postdoc. His research focuses on quantum error correction, exploiting the physics of different quantum phases of matter to find new ways to construct robust, scalable quantum computers. He has explored fault-tolerant logic gates and searched for a self-correcting quantum memory.

New Assistant Professor Weria Pezeshkian develops computational microscopes to couple molecular interactions to biological forms. Recent achievements include the first simulation of mitochondrial membranes with realistic size and SARS-CoV-2 virion envelope with a near-atomistic resolution.

Postdoc Anne Spiering focuses on the interplay between infinite-dimensional symmetries and their manifestation in observables. This includes how quantum integrability (and its absence) constrains superconformal field theories, as well as connecting universal soft divergences and asymptotic symmetries in non-abelian gauge theories.

Robin Marzucca is a new Postdoc at the NBIA. His research focuses on precision calculations relevant for the LHC and in N=4 supersymmetric Yang-Mills theory. He is interested in the structure of scattering amplitudes and the various special functions they are composed of, as well as how we can utilise them for more efficient computations.

OUTREACH EVENTS AT NBIA

The Niels Bohr International Academy continued the public lecture series "Frontiers of Physics" this Fall. These lectures were organised jointly with Folkeuniversitetet and were held at the Niels Bohr Institute in the historic Auditorium A. Speakers were visiting Profs. Maria Bergemann and Chris Sander, Asst. Profs. Matthew von Hippel and Daniel D'Orazio, and Prof. Darach Watson. www.fukbh.dk

UPCOMING WORKSHOPS AND SCHOOLS

Please visit our NBIA web page for details and updates.

- NBIA Workshop on New Ideas in Cosmology (May 18-20)
- NBIA Workshop on Radiation Transfer in Astrophysics (June 6-10)

NEWS IN BRIEF (CONTINUED)

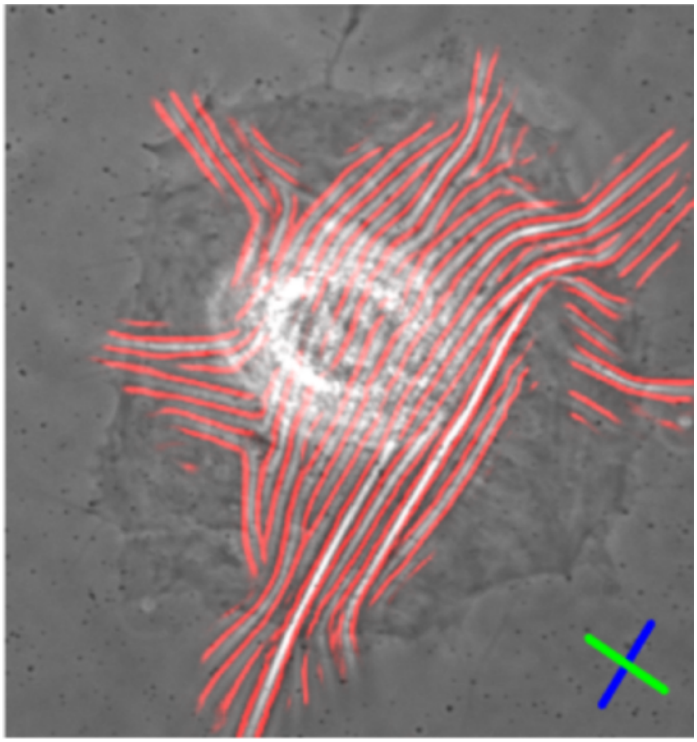
MARIE SKŁODOWSKA-CURIE FELLOWSHIP

NBIA postdoc Jim Talbert has been awarded an EU Marie Curie Individual Fellowship for a project called `Nu Flavour', which aims to formalize mathematical frameworks for studying beyond Standard Model flavour and neutrino physics. He plans to extend the all-orders `geometric' formulation of the Standard Model Effective Field Theory, the so-called GeoSMEFT (introduced by Helset, Martin, & Trott in 2020), into the neutrino mass and mixing sector. The proposal will also focus on novel phenomenological probes of flavour physics in theories beyond the Standard Model. The ultimate goal is to bound realistic models to address open questions in neutrino and flavour physics.

RESEARCH HIGHLIGHT on Biophysics

Aleksandra Ardaseva

Cell-sensing and cell decision-making, the processes by which cells perceive and adapt, are fundamental to life yet are so mysterious that they are often referred to as the 'black box of biology'. While many biochemical signals are known, the profound role of mechanical forces in regulating cell behaviour is being increasingly recognised in a variety of cell types. In tissues, cells rely on the balance between internal pulling forces, dictated by tensions and cytoskeleton, and external forces that arise from the microenvironment. Mechanical forces impact protein distribution and gene expression within cells, inducing specific cell functions, such as cell division, stem cell differentiation, and cell death. In other words, they act as messengers, rapidly informing cells of changes in their surroundings. Moreover, cells not only respond to the environment, but actively modify it by exerting contractile forces generated by cross-bridging interactions of actin and myosin filaments while moving. Contractile forces cause rapid and long-ranged topographic anisotropies in the underlying substrate, such as wrinkles or strains, which provide environmental cues and the means for substrate-mediated cell interactions. Here, at NBIA, we explore a mechanical form of cellular sensing and communication that we term "Topography-Mediated Cellular Self-Organization". Guided by experimental observations we develop computational models, in which cells can autonomously exploit folding and topographical restructuring of their underlying substrates as a means of self-induced guidance and communication mechanism to coordinate their individual and collective behaviours. Such way of interaction between cells and environment has enormous potential both for improved medical interventions and for new strategies in regenerative medicine in which mechanical signals will be used to direct the repair of tissues and organs that have been damaged by trauma or disease.



A cell culture exerting contractile forces on a substrate, with wrinkles marked in red. From Hongchan Li, et al., "Wrinkle force microscopy: a new machine learning based approach to predict cell mechanics from images" available at https://arxiv.org/abs/2102.12069.