

# NBIA NEWSLETTER

## NEWS IN BRIEF

### CARLSBERG FELLOWSHIP

Former NBIA PhD student Hjalte Frellesvig has received a Carlsberg Foundation Reintegration Fellowship to continue his work on theoretical particle physics at the NBIA. Hjalte's project with the title "Feynman integrals and their mathematical structure" exploits a novel approach to amplitude computations based on a connection to the mathematical theory of multivariate intersection numbers. Hjalte is also one of the recipients of this year's INTERACTIONS Fellowships from NBIA's EU COFUND program.

### EU MARIE CURIE FELLOWSHIPS

Four researchers have been awarded two-year EU Marie Curie individual fellowships hosted by NBIA.

Caltech Postdoc Clément Bonnerot has been awarded for a project that aims to understand astrophysical tidal disruption events that result from stellar encounters with supermassive black holes. These events represent unique laboratories to probe the extreme phenomena that take place in the vicinity of black holes. The project will provide new insight into this process by means of self-consistent magneto-hydrodynamical simulations combined with a treatment of radiative processes.

Former NBIA Postdoc Benjamin Brown has been awarded for a proposal based on an investigation of quantum error correction in quantum computing. This subfield of quantum information looks at how to put noisy quantum systems together in such a way that we can still build a working quantum computer, even if some of its components fail. Ben's project aims to design practical new blueprints for a working quantum computer using modern laboratory apparatus.

NBIA Postdoc Tyler Corbett has been awarded for a proposal called SMEFT ONE. Tyler's project aims to improve on calculations in the mathematical framework referred to as the "Standard Model Effective Field Theory" (SMEFT) by extending them beyond the leading perturbative order. His work will improve our understanding of the data coming from the Large Hadron Collider and inform decisions relating to future collider projects' designs.

NBIA Assistant Professor Evert van Nieuwenburg has been awarded for a proposal called ConQuER. Evert will continue shaping the application of artificial intelligence to experimental control in condensed matter quantum systems. The proposed research utilises "Reinforced Learning", a type of machine learning where a computer proposes actions on the environment which in return provides a reward. The project involves close collaboration with the Center for Quantum Devices.

## A MESSAGE FROM THE DIRECTOR

**Poul Henrik Damgaard**

For the first time, the NBIA Newsletter goes beyond two pages. The impact of three new Villum Young Investigator grants to NBIA scientists in 2020 is evident in the extended list of new NBIA members on the next page. It is wonderful to see how subjects range from the physics of living cells to gravitational waves, from topological matter and quantum computation to astroparticle physics, scattering amplitudes, and particle physics phenomenology. In addition, we welcome Novo Nordisk Foundation Visiting Professors Debora Marks and Chris Sander from Harvard Medical School. Debora and Chris, who both work on the interface between physics, mathematics, and computational biology, will return for a much longer stay with us in 2021 as we ramp up a massive expansion into the exciting research areas bordering between physics and biology. This constant renewal of research topics is at the heart of NBIA and we already now ask ourselves the question: What is next?

## THE VIEW FROM THE BOARD

**Andrew D. Jackson**

A year ago no one had heard of Zoom; today physicists around the world rely on it. It looks like it is here to stay. This is both good news and bad news. The good news is exemplified by a new CERN-supported global seminar entitled "All things EFT...". This series will deal with the many areas of physics in which effective field theory has become an important theoretical tool. Steven Weinberg delivered the kickoff lecture to an enormous world audience. The NBIA's Michael Trott and Michèle Levi will serve as European contacts for this exciting new project. The "bad" news is that Zoom talks can be rather boring. Many of us fail to appreciate that a good talk is not a monologue. Actors and musicians are sensitive to the silent reactions from a live audience and routinely use this information to fine-tune their performances. While the medium is not the message, mastery of the medium can enable us to present our message more effectively. We have a new skill to be learned.

## UPCOMING WORKSHOPS AND SCHOOLS

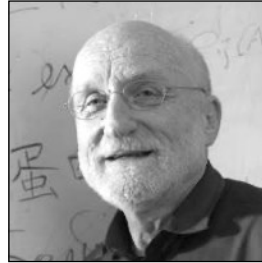
The following list of upcoming workshops is preliminary. An updated list can be found on our [NBIA web page](#).

- Simons Program: Frontiers of Cosmology and Gravitation (June 14–18, 2021)
- SAGEX PhD-School on Amplitudes (August 9-13, 2021)
- Current Themes in High Energy Physics and Cosmology (August 17–21, 2021)

## NEW NBIA MEMBERS & VISITORS

This Fall, the NBIA welcomes a number of new staff members and two Novo Nordisk Foundation Visiting Professors. You can find a brief description of their work below. Here and in the "Research Highlight", we also highlight the work of **Pablo Benitez-Llambay** and **Mauricio Bustamante**, who have recently been promoted to NBIA Assistant Professors. We give a warm welcome to our new PhD students, **Benjamin Halager Andersen** and **Victor Valera**, and our new MSc students, **Alicia Elcarte Astorga**, **Katharina Hauer**, **Kjartan Másson**, **Roger Morales**, **Kathrine Mørch Groth**, **Alexander Schierbeck-Hansen**, and **Edwin Vargas**.

**Debora Marks** from Harvard Medical School (HMS) is 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.

**Daniel J. D'Orazio** is a new Assistant Professor working on a wide range of topics in high-energy astrophysics. His primary interests lie in the origin of compact-object-binary sources of gravitational radiation, spanning the mass scale from neutron stars up to supermassive black hole binaries.



Assistant Professor **Pablo Benitez-Llambay** studies the dynamics of multi-species protoplanetary disks linked to the formation and evolution of planetary systems. He is particularly interested in the problem of planet-disk interaction, gas/dust dynamics, disk instabilities, and high-performance computing.

**Clément Bonnerot** will join the NBIA as a Marie Curie fellow to study the disruption of stars by the strong tidal forces of supermassive black holes present in the centre of galaxies. Tidal disruption events can be used as probes of these compact objects and the extreme processes at play in their vicinity.



Postdoc **Hjalte Frellesvig** is working on scattering amplitude calculations, mostly within the Standard Model. His research focusses on Higgs Physics, the computation of Feynman integrals, and the use of the mathematical field of intersection theory in Feynman integral computations.

Postdoc **Mathias Heltberg** works on regulation and signalling in biological organisms. He has previously studied dynamical properties of regulatory proteins and how this can be used as a way to control groups of genes. He plans to shed light on how cells can use physical signals to control their production.



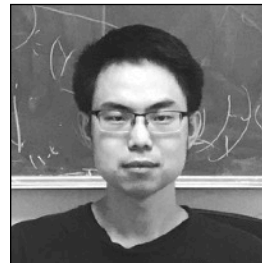
**Natascha Leijnse** is a new Postdoc joining the Biophysics Group at NBIA. She is working on mechanosensing in cells. Natascha experimentally studies how living cells respond to mechanical stimuli using, for example, confocal microscopy in combination with optical tweezers.

Postdoc **Bin Liu** is working on the dynamical evolution of black hole systems, with focus on the formation of black hole binaries and gravitational wave sources. At NBIA, he will expand on his work on how black holes merge near supermassive black holes and what the observable signatures are.



**Enrico Peretti** is a new Postdoc joining the Astroparticle Physics Group. He is interested in studying the most extreme astrophysical environments where high-energy neutrinos and non-thermal radiation are copiously produced by particles accelerated to the highest energies currently measured.

**Matteo Wauters** is a new Postdoc working on topological phases of matter. He is interested in a variety of non-equilibrium phenomena in quantum physics, ranging from the engineering of topological transport properties to reinforcement learning techniques for quantum control and quantum computation.



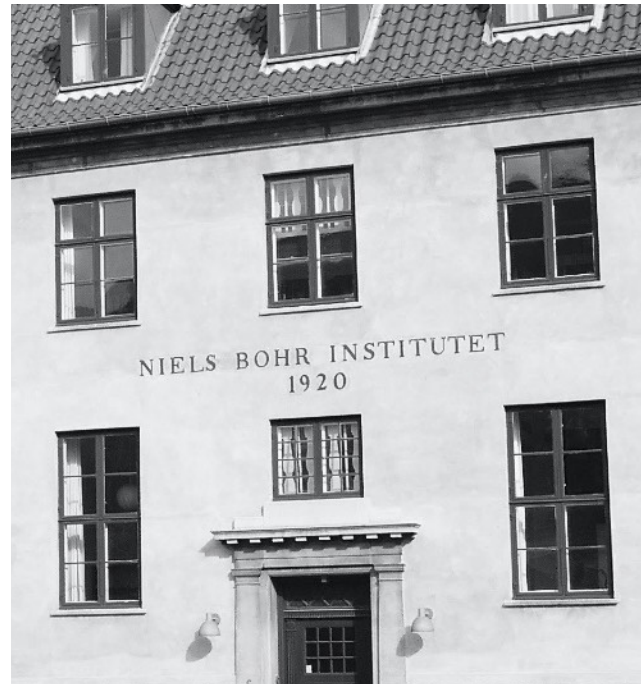
Postdoc **Chi Zhang** is working on scattering amplitude calculations. He is interested in studying the worldsheet formalism of perturbative quantum field theory and the underlying geometric structures of scattering amplitudes as well as new structures of loop integrals.



## RESEARCH HIGHLIGHT on Astroparticle Physics

### Mauricio Bustamante

High-energy cosmic neutrinos offer great power to answer a long-standing question that lies at the core of Physics and that speaks to the NBIA spirit: what is Nature like at its most fundamental level? Today, we know that the Standard Model of particle physics is incomplete, but we lack experimental guidance to extend it. Historically, we made progress by accessing ever-higher energies, where new particles and interactions would become apparent. High-energy neutrinos of cosmic origin, with energies millions of times higher than accelerators, allow us to continue our exploration. They were discovered in 2013 by the Ice-Cube neutrino telescope – of which NBI is a member – after decades of searches. They have the highest known neutrino energies – over  $10^{15}$  eV – and travel the breadth of the observable Universe. These features make them powerful probes of new physics at energies unreachable by other means, even if the effects are tiny in size. At NBIA, we use high-energy cosmic neutrinos to tread new ground in the vast theory landscape of neutrino physics. This includes, for instance, new neutrino interactions, the possibility of neutrinos being unstable, insights into the nature of dark matter, and the breaking of fundamental symmetries. Our ultimate goal is to discover evidence of physics beyond the Standard Model; along the way, we find what works and what does not. NBIA has become a hub for neutrino research: we also study neutrino astrophysics and non-cosmic neutrinos. In the coming decade, our collective effort should see our leading position galvanised.



## NEWS IN BRIEF (CONTINUED)

### CARLSBERG GRANT

Assistant Professor Pablo Benitez-Llambay and Professor MSO Martin Pessah have received a Carlsberg Foundation Research Infrastructure Grant. The Theoretical Astrophysics Group at the NBIA is one of the world leaders in developing numerical codes to fully exploit the capabilities of computers based on so-called GPU processors. The grant will allow to acquire a powerful GPU server to carry out – in a sustainable way – simulations that are vital to understanding how planets form and evolve.

### VILLUM EXPERIMENT GRANT

NBIA Associate Professor Tobias Heinemann is among the recipients of this year's Villum Experiment Grants. The grant supports Tobias' research in theoretical astrophysics and will allow him to study under what circumstances favourable conditions for planet formation can be met in a wide range of astrophysical conditions. The study will have important implications for our understanding of planet formation, with broad implications across astrophysics.

### H.C.ØRSTED GOLD MEDAL

The Society for the Dissemination of Natural Science (SNU) is honouring Villum Kann Rasmussen Professor Charles Marcus with the society's H.C. Ørsted Gold Medal in physics. He is awarded for his key role in developing and communicating the field of quantum coherent electronics, which is now rapidly evolving towards quantum technologies that can harness and exploit quantum mechanics in the field of quantum computing. Charles, who is also the Scientific Director of the Copenhagen Microsoft Quantum Lab, is the first non-Danish recipient of this award.

## OUTREACH EVENTS AT NBIA

The Niels Bohr International Academy continues the public lecture series "Frontiers of Physics" this Fall. These lectures are organised jointly with Folkeuniversitetet and will be held at the Niels Bohr Institute in the historic Auditorium A, from 5.15pm to 7.00pm. The five talks on various topics in modern theoretical physics are listed below. The speakers will give you a glimpse of the questions, ideas, and approaches right now at the scientific forefront. [www.fukbh.dk](http://www.fukbh.dk)

### "Gravitational waves - the revolution in gravitational physics"

Asst. Prof. Michèle Levi, NBIA — October 20

### "Theoretical physics in an era of machine learning"

Asst. Prof. Evert van Nieuwenburg, NBIA — October 27

### "Physics and mathematics solving problems in life sciences"

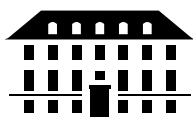
Asst. Prof. Debora Marks, Harvard — November 3

### "Active matter - engines at the cellular level"

Prof. David Nelson, Harvard — November 10

### "Mars and the origin of water"

Prof. Martin Bizarro, Globe Institute, KU — November 17



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