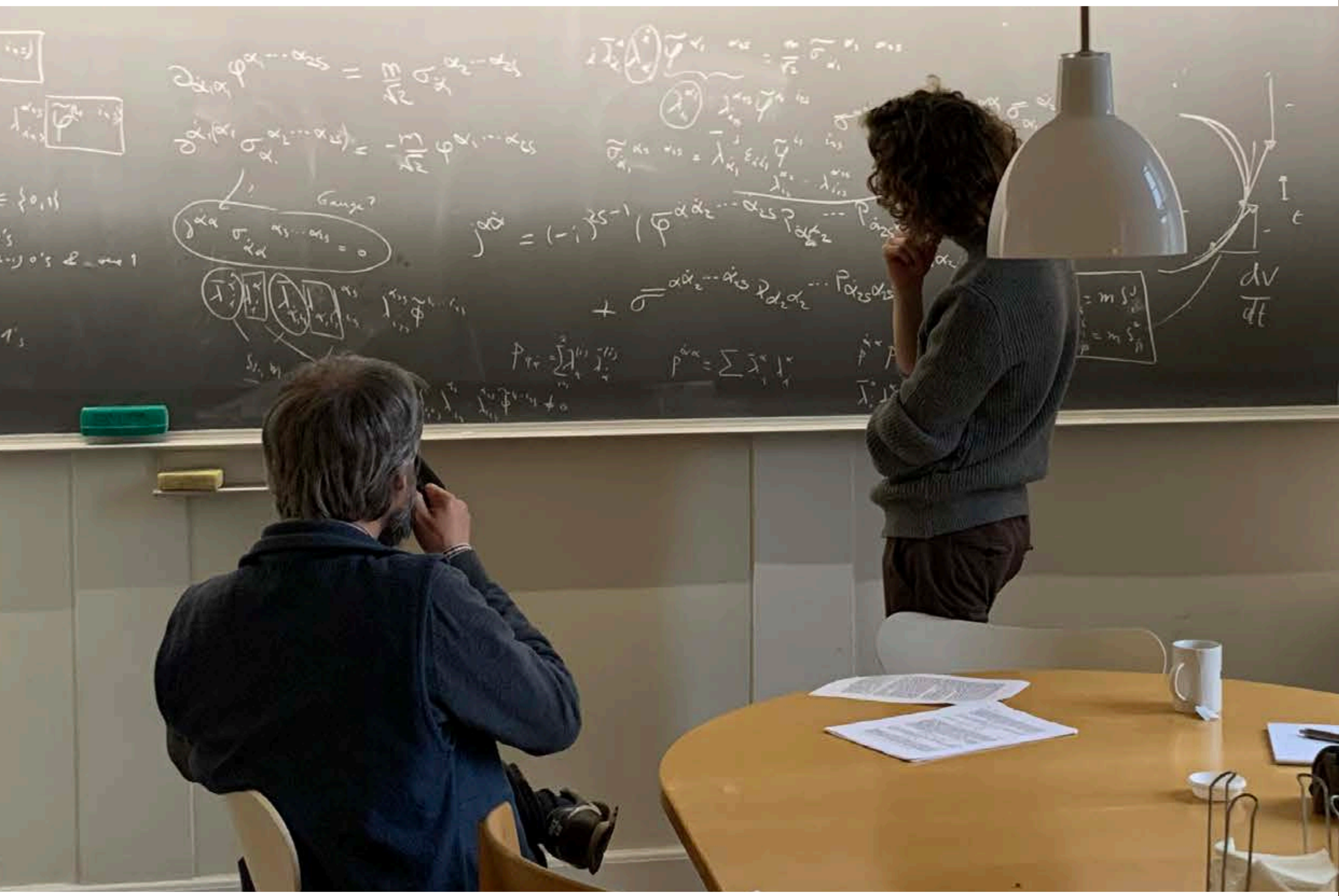
The Niels Bohr International Academy



Annual Report 2021

The Niels Bohr International Academy

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The Academy

NBIA Governance

International Advisory Board and Director's Council:

The Niels Bohr International Academy receives scientific advice from an International Advisory Board consisting of leading names in today's theoretical and mathematical physics as well as important advice and support from its Director's Council, which consists of prominent members of Danish society.

Current Members of the International Advisory Board:

- **Poul Henrik Damgaard**, Niels Bohr Institute (Director)
- **Martin E. Pessah,** Niels Bohr Institute (Deputy Director)
- **David Gross**, KITP Santa Barbara
- **Charles Marcus**, Niels Bohr Institute (Interim Chairman)
- **Itamar Procaccia**, Weizmann Institute
- **Barry Simon**, California Institute of Technology
- **Paul Steinhardt**, Princeton University
- **Frank Wilczek**, Massachusetts Institute of Technology

Current Members of the Director's Council:

- **Peter Landrock** (Chairman)
  Founding Director of Cryptomathic, Professor of Mathematics and Fellow, Churchill College
- **Kirsten Smedegaard Andersen**
  Board Chair Movotec, Board member LD, Bodum, and other public and private organizations
- **Connie Hedegaard**
  Chair of the KR Foundation, former Minister and EU Commissioner
- **Niels Due Jensen**
  Former CEO of Grundfos and former Chairman of Poul Due Jensen Foundation
- **Per Magid** (Vice Chairman)
  Lawyer, Rovsing & Gammeljord
- **Bjørn Nørgaard**
  Prof. Royal Academy of Fine Arts, Guest Prof. China National Academy of Arts
- **Michael K. Rasmussen**
  Former Vice President, Brand in VELUX Group, private consultant

The Niels Bohr International Academy

From the Director

In textbooks explaining the fundamental forces of nature, gravity is traditionally dismissed as being weak, almost ridiculously weak. There is a pedagogical point in this because for first-year students intuition may seem to say otherwise. Climbing a staircase we do not think of the other fundamental forces, but gravity is definitely real and it feels strong. We learn that this is "just" because gravity acts on all matter (and antimatter!) with the same sign: it always attracts. This apparently innocent little detail is behind the revenge of gravity on macroscopic bodies such as astrophysical objects. We do not claim that the sun shines because of gravity but we do know that the sun and its surrounding planets would not have formed without gravity. Now science has taken one step further and today we are able to observe the glow of gravity itself: gravitational waves. Although the signal is unbelievably faint, two black holes circling around each other and finally merging to form one single black hole can be observed by terrestrial gravitational-wave detectors even if it has happened billions of lightyears away. At the time of writing, close to one hundred such spectacular gravitational-wave events have been recorded and this number will soon grow into thousands due to improved detectors. The weak force of gravity has returned to the center stage.

At NBIA this turn of events has had a strong impact on the research of several previously distinct groups. Clearly from gravitational astrophysics itself (a new subject that has emerged due to the detection of gravitational waves) to the theoretical astrophysics group. But most interestingly: also the astroparticle physics group is now linked to the gravitational physics of very compact objects such as neutron stars through the possibility of observing gravitational waves. And finally the perhaps biggest surprise: the theoretical particle physics group is now using quantum field theoretic methods to calculate the predicted gravitational wave signals from Einstein's theory of general relativity. In the coming year research in all of these directions will receive a significant boost with the appointment of a large number of young researchers. With this, NBIA is poised to become one of the strongest theory groups in this subject, world-wide.

Remarkably, a totally different subject is also flourishing and rapidly expanding at NBIA right now. Also this subject has emerged at the interface of widely differing disciplines. I am talking here about biological physics in one of its recent and most exciting directions: the understanding of what has become known as Active Matter. Here, the laws of physics are used to describe crucial aspects of life itself without reference to genetics. In this way, specific manifestations of life can be explained by non-equilibrium physical processes of a universality that is not tied to the genetic code. The boundary between living and dead matter is becoming blurred.

But these two highlighted subjects only describe a fraction of all the research activities at NBIA right now. In the interdisciplinary environment of NBIA, many other discoveries have been made in different directions as well. You can read more about some of these recent developments in the following pages.

Poul Henrik Damgaard

From the Chairman of the Council

The Merriam-Webster definition of Science in all its simplicity is “knowledge about or study of the natural world based on facts learned through experiments and observation”. In physics, science has led to the discovery of the fundamental laws of nature, but long before these were discovered another fundamental law was recognised – the law of logic. This universe is based on logic, as opposed to, e.g., the universe of religion, or of dreams. (We all spend hours every day in the latter).

For this observation exactly, mathematics has been developed and refined over millennia, partly as a tool to describe the world we live in, partly in its own right, such as in Euclid’s Elements. We often differentiate between pure and applied mathematics (math), and it is not unfair in a short note to basically describe physics as applied mathematics. As a very simple example, counting and basic arithmetic is applied math, whereas describing the integers as a domain where every number in one and only one way can be factored into primes is pure math, known as number theory. It is a very interesting empirical fact that most sensible pure math eventually may lead to essential applied math as well, such as digital signatures which is based on number theory. Billions of digital signatures are generated all over every day (e.g., NemID in Denmark).

We all know Pythagoras’ theorem, which is a very early example of pure mathematics being applied, but few know of a wonderful generalisation discovered by the astronomer and mathematician Ptolemy: A quadrilateral can be circumvented by a circle (i.e. would have four corners on a circle) if and only if the sum of the products of the lengths of opposites sides equals the product of the lengths of the diagonals – which specialises to Pythagoras’ theorem when the quadrilateral is a rectangle. Ptolemy used that to “prove” that planets are moving in circles - a good approximation!

Newton refined mathematical methods with a quantum leap when he discovered gravity, which is a good example of applied math being ahead of pure math. Pure mathematics was prepared when the next revolutions hit physics: Einstein’s Relativity Theory, and Quantum Mechanics, initialized not least by Niels Bohr’s discovery of the structure of the atom. Both fundamental discoveries were without any anticipation of applications - which more than anything stresses how much mankind depends on fundamental research.

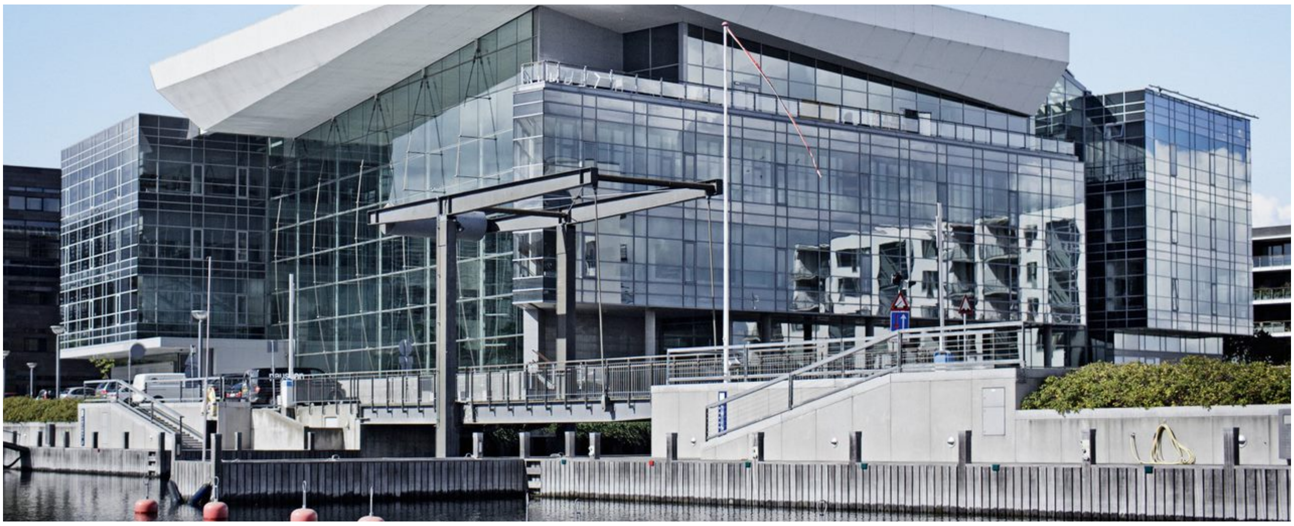
The refined mathematical tools of Quantum mechanics were subsequently completed by Paul Dirac and by John von Neumann, one of the most versatile mathematicians at the time. This mathematical machinery describes the nature of quantum mechanics perfectly, and some discussions over the last century – initiated not least by our two heroes, Einstein and Bohr – getting perhaps entangled by the shortcomings of intuition and philosophical considerations are based on trying to avoid the mathematics, which leaves no space for philosophy. To ask if the moon is really there if it is not observed is absurd – and can never be verified anyway.

Science is not down to applied math only, as we need models to simplify in order to make useful deductions about behaviours and predictions. "All models are wrong, but some are useful" is a well-known quote. We have seen an abundance of wrong models applied as an argument for lockdowns in several countries, while politicians claim that “they are just following the science”. But as we know, a model only works if the input reflects all important aspects adequately. Making a sales budget if you want to use it for borrowing in the bank may look quite different if you want it to be realistic.

Peter Landrock

Novo Nordisk Foundation Grant

The largest institutional grant to NBIA since the endowed Villum Kann Rasmussen Professorship in 2007 came from the Novo Nordisk Foundation in 2018. This grant of 35 MDKK aims at establishing up to five Novo Nordisk Foundation Assistant Professors, Novo Nordisk Foundation Associate Professors, or Novo Nordisk Foundation Full Professors at NBIA. The new research directions should have potential for relevance within life science research. The time is indeed ripe for this expansion into areas in life sciences that are bordering physics, and it has for several years been the ambition of NBIA to again establish a stronghold in theoretical biological physics (one of the first topics of research when NBIA was founded in 2007). The large grant from the Novo Nordisk Foundation takes this to a much larger scale. It will massively support research at NBIA that may potentially have large impact on the life sciences. For NBIA new areas of focus are (apart from biological physics and the more general area of biocomplexity): systems biology, computational biology, modern genetic studies and even close contact to laboratory work in the biological sciences. All of these are areas where physics-driven methods may provide new and groundbreaking results. In addition to making these new fixed-term appointments, NBIA provides the interdisciplinary atmosphere, the close contact with both theoretical physicists and mathematicians, and the steady flow of leading scientists regularly visiting NBIA every year. The first Novo Nordisk Foundation Assistant Professor Amin Doostmohammadi started his NBIA appointment in the fall of 2019 and based on a Villum Young Investigator grant, support from Independent Research Fund Denmark, and the NERD program under the Novo Nordisk Foundation he has already established his own junior research group. As this report is going to the press, Amin Doostmohammadi has in addition just received an ERC Starting Grant. In 2021 Amin Doostmohammadi was joined by two new Novo Nordisk Foundation Assistant Professors: Weria Pezeshkian, who works on computational biophysics, and Karel Proesmans, who works on applying thermodynamic and statistical mechanics methods to biological systems. During a brief spell where Copenhagen University was open in the fall of 2021, new Novo Nordisk Visiting Professors Debora Marks and Chris Sander from the Department of Systems Biology and Dana-Farber Cancer Institute at Harvard University visited NBIA.



Louis-Hansen Foundation Grant

In 2018 the Aage & Johanne Louis-Hansen Foundation provided NBIA with an important grant of 10 MDKK to hire Louis-Hansen Assistant Professors on 5-year fixed-term contracts at NBIA. The grant is totally flexible and will allow NBIA to seek the brightest young scientists in all areas of the physical sciences. This strategy is at the heart of the foundation of NBIA and it opens up the opportunity to strike out in brand-new research directions that are not currently pursued at NBIA or at the Niels Bohr Institute itself. The overarching principle when making these new appointments is to let the individual talent of applicants be the decisive criterion while simultaneously hoping for a renewal of research topics. Fortunately, these two strategic points of view often merge together, demonstrating that the best scientists move towards areas that are most promising. No one has better nose for this than young scientists who have had a PhD-education from some of the best universities in the world, followed by some post-doctoral years where they have been able to liberate themselves from their thesis topics and thus defined their own research directions. These are scientists who can drive the NBIA in the coming years and who we now invite to join us. The generous grant from the Louis-Hansen Foundation is a significant milestone in the short history of NBIA and it is leaving its strong mark. Current Louis-Hansen Assistant/Associate Professors, working in as diverse topics as condensed matter physics, particle physics, astrophysics, and gravitational-wave astrophysics, are Evert van Nieuwenburg, Michael Trott, Pablo Benitez-Llambay, and Johan Samsing.

Husman Foundation Grant

A large donation from the Ernst & Vibeke Husman Foundation given to the NBIA in 2019 allows us to attract top talent from around the world as Husman Foundation Visiting Scholars. Stays at the NBIA can last from less than a week for researchers invited to speak in our series of NBIA Colloquia and/or more specialized seminars, and up to four or six weeks for longer research visits and Husman Foundation Visiting Professorships. This program builds on and expands the internationalization that is at the core of NBIA's activities, which is essential for keeping scientists at the NBIA abreast of new scientific developments. Thanks to this donation and through the use of some additional resources from individual research grants, the NBIA is now fulfilling its dream of organizing a weekly NBIA Colloquium in which a broad range of new scientific areas is being exposed to all members of the Niels Bohr Institute on Friday afternoons. While this program has been partly on hold due to the pandemic, we expect it to take off in 2022. Husman Foundation Scholarships will be also awarded to collaboration partners of NBIA scientists in order to facilitate these interactions.

ERNST & VIBEKE HUSMANS FOND

INTERACTIONS — EU-COFUND

Close interactions among scientists from a wide range of cultures is in the DNA of the Niels Bohr International Academy. It is a tradition dating back to the original institute Niels Bohr created on the premises on Blegdamsvej almost a century ago. In 2019, with the valuable support of the European Commission through the COFUND program under the Marie Skłodowska-Curie Actions, NBIA launched an unprecedented and ambitious Fellowship Program to enhance interactions among young scientists across theoretical physics and across Europe. The INTERACTIONS Fellowship Program will promote and ensure exposure of the fellows to other scientists within neighboring areas. The program also encourages interactions among scientists with different cultural backgrounds and from different scientific traditions. To this end, NBIA has teamed up with five of the strongest theoretical physics institutes in Europe who are partners of the INTERACTIONS program:

- University of Cambridge — Department of Applied Maths & Theoretical Physics
- University of Oxford — Department of Theoretical Physics
- Max Planck — Institute for Astronomy, Heidelberg
- CERN — Theoretical Physics Department
- Saclay — Institut de Physique Theorique

These institutions have been chosen for their excellence in research, for their existing strong ties to NBIA, for their breadth in theoretical physics, and for their wide distribution both geographically and in terms of science culture. A formalized, structured, and long-term collaboration with these partners is of importance for the overall success of the program, literally taking the concept behind INTERACTIONS to the top European level. It is a unique opportunity for fellows to be introduced to different research environments, to build personal networks within Europe, and to intensify long-term collaborations between these institutions. This will increase network and research opportunities for the fellows, and at the same time bring our institutions closer together. So far, 17 INTERACTIONS fellows have been employed under this program, and the third call for applications closed in late 2021. Relevant information can be found at http://nbia.nbi.ku.dk/interactions.

LIGO Formation
Channels:
Binary Evolution I
Dr. Alejandro Vigna-Gómez
Credits: R. Hurt/Caltec
Participants
Chat
Share Screen
Record
Reactions
Apps

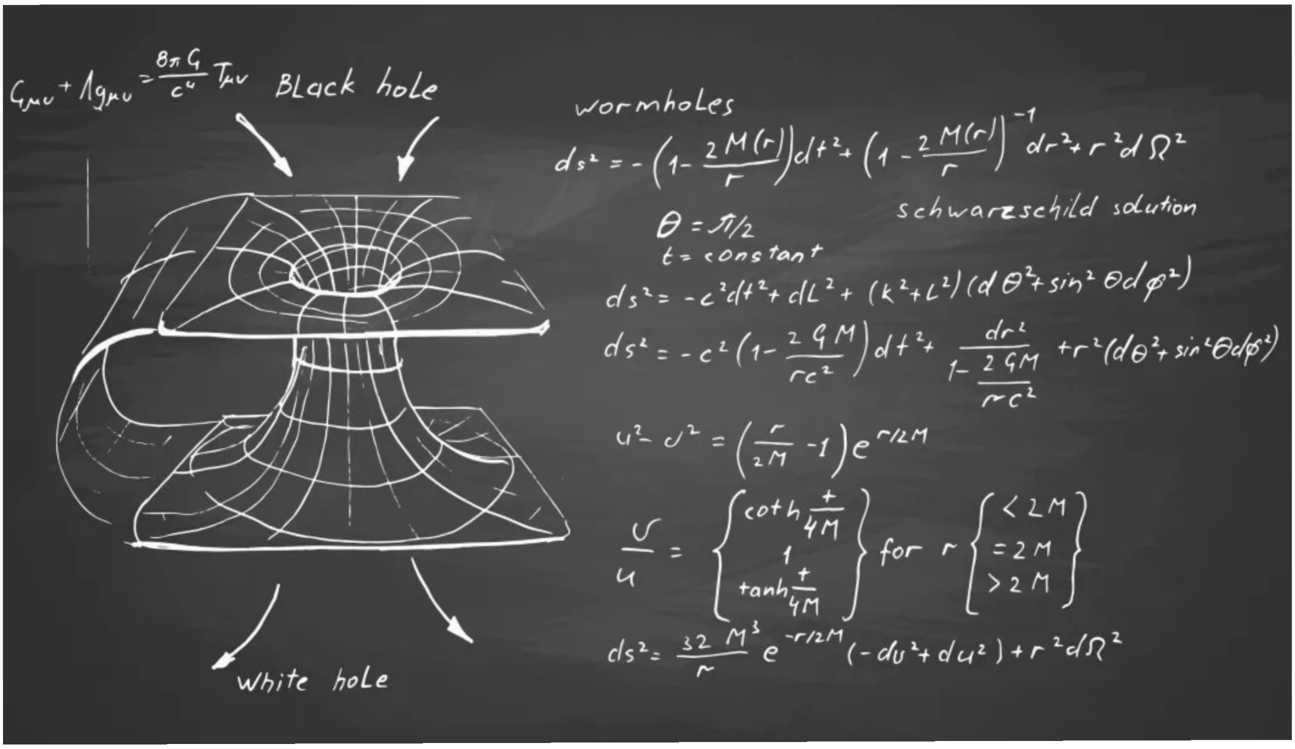
NBIA Research

Theoretical Particle Physics

Research in the theoretical particle physics group at NBIA has been expanding in the direction of classical gravity over the past few years. Remarkably, quantum field theory methods have proven to be extremely efficient for computing classical quantities in general relativity. At the core are new developments that have revolutionized the way we calculate scattering amplitudes. These methods transcend the original practical goals and point toward entirely new ways of understanding perturbative quantum field theory. One starts with an approximation ("tree level") and then builds up a sum of new terms ("loops"), now involving integrations. The most powerful methods for such computations initially focused on establishing compact expressions for the integrands. Work at NBIA has now moved very strongly ahead on how to integrate these expressions. The big surprise is that these methods can be directly carried over to classical gravity, where the integrations can be understood as generalized Fourier transforms of the real-space dynamics of, for example, the scattering of two black holes. Such computations are of crucial importance for the accurate determination of physical parameters such as masses and spins of merging black holes from observations of gravitational waves.

The NBIA group has contributed to the foundational basis of these new developments by demonstrating the equivalence of two competing analytical methods and by deriving a direct relationship between parameters of the effective potential governing the two-body interactions and the classical part of the amplitudes as computed in perturbation theory. The striking new relationship between classical general relativity and modern amplitude computations is a prime example of the surprising twists and turns in science, and the unexpected results that can come out of different subjects being investigated in the same scientific environment such as NBIA. During 2021 the group also became leading in the computation of spin effects to high orders in the so-called Post-Newtonian expansion. Also here expertise from modern amplitude calculations has played an important role and the possibility of bringing these two topics together at NBIA has given the field a significant boost.

Scattering amplitudes have also been most urgently needed for experiments based on the so-called Standard Model of particle physics, a theory with gauge bosons, fermions, and a single scalar particle, the Higgs particle. Most prominent scattering processes relevant for the Large Hadron Collider (LHC) at CERN are known up to third order in perturbation theory, corresponding to what is known in the field as two-loop order. Current efforts of the particle theory group consist in extending this in several directions. First, it is widely believed that what is today called the Standard Model of particle physics is only a small part of the full story, valid at the energies accessible today at the LHC. At higher energies new interactions are almost certain to emerge, hidden today by the large amount of energy required to see even small traces of them.



Part of the group at the NBIA is leading the effort to establish the most general framework for parametrizing the effects of interactions at higher energies. Known as Standard Model Effective Field Theory, it uses the sophisticated language of effective field theory to concisely pinpoint experimental consequences of the hidden interactions at higher energies, given the known particle content and symmetries of the Standard Model at the energies currently probed at the LHC. On the theoretical side, there is no escape from the fact that the Standard Model of particle physics then becomes augmented by a large number of new interaction terms. But order-by-order, in an ordering dictated by available energy, the number of new terms is finite and they can be treated by the conventional tools of quantum field theory. Crucial to this program is the computation of the contribution of these new terms to the already established scattering amplitudes of the Standard Model alone. The group at the NBIA has been leading this program and continues to push it forward.

A major direction of research in the particle physics group at the NBIA concerns the efficient computation of scattering amplitudes in quantum field theories in bigger generality. The immediate impact of this program is the availability of new methods that allow other groups to compute scattering amplitudes in the Standard Model to yet higher order. Moreover, the general development in just these years shows that the original methods for such computations (based on so-called Feynman diagrams) have become completely replaced by modern techniques that have allowed computations up to complexities that just a few years ago were thought impossible. This concerns both the number of particles in the final states of the processes and the order in perturbation theory for a given fixed number of particles in the final states. The latter problem, the computation of scattering amplitudes at what is known as high loop order is generically a daunting task. Much progress appears through first understanding the complexities in a theory similar to the Standard Model of particle physics, but with a large amount of so-called supersymmetry. The group at the NBIA has been very actively pursuing this program of high loop order calculations. Many surprises have appeared already in the theory with large amount of supersymmetry, and will surely leave their marks also on high loop-order calculations in the Standard Model of particle physics.

Particle Astrophysics

The research of the Particle Astrophysics Group lies at the rich interface between astrophysics, cosmology, and fundamental physics. We are particularly interested in exploring the Universe through cosmic rays (energetic charged particles), photons, neutrinos, and gravitational waves. The range of scientific questions that can be addressed with these cosmic messengers is quite broad.

A strong focus of our research lies on neutrinos. Neutrinos are weakly interacting elementary particles emitted from various terrestrial, astrophysical and cosmological sources over a wide energy range. We work to grasp the role of neutrinos in powering their sources, use them as powerful probes of the hidden source interiors, and seek to unveil the fundamental properties of neutrinos from investigating their interactions in dense environments, on cosmic backgrounds, as well as from their detection in neutrino telescopes.

Presently, the most sensitive neutrino telescope in the TeV-PeV energy range is the IceCube observatory at the South Pole. Our group maintains a strong collaboration with the experimental IceCube group at NBI. In 2013, IceCube made the first observation of high-energy (TeV-PeV) neutrinos whose origin is presently unknown and one of the main scientific questions presently addressed in our research. This observation does not only probe the origin of cosmic rays but also allows to test fundamental neutrino physics at extreme energy and distance scales and probe the physics of extreme cosmic accelerators.

One of the most exciting results from IceCube in 2021 was the first observation of a Glashow resonance event, a phenomenon predicted by Nobel laureate physicist Sheldon Glashow in 1960 while he was a postdoc at what is today the Niels Bohr Institute. With this detection, scientists provided another confirmation of the Standard Model of particle physics. It also further demonstrated the ability of IceCube to probe fundamental physics.

In 2021, we modeled the production of neutrinos in the gamma-ray bursts originating in the aftermath of the death of massive stars as supernova explosions. We have shown that it is crucial to understand the mechanism powering these energetic sources since, in contrast to the routinely observed electromagnetic radiation, the neutrino signal strongly depends on the mechanism powering the source. We have also found that much insight on electromagnetic features of these objects (such as jumps in their observed optical lightcurve), currently poorly understood, could be gained through neutrinos. With the advent of real-time neutrino astronomy, we have explored the exciting possible associations of neutrino events detected by IceCube with the electromagnetic emission from extreme astrophysical transients, such as the tidal disruption of a star in the proximity of a supermassive black hole or superluminous supernovae.

The astroparticle group is also working on understanding the origin of cosmic rays and mechanisms of cosmic ray transport in Galactic and extragalactic environments. We have been working on cosmic ray transport and acceleration associated with strong winds associated with star clusters, star-formation/starburst galaxies, and active galaxies. The multi-messenger emission in the form of gamma-rays and neutrinos allows to test these astrophysical model predictions with experimental data. We were also active in the analysis and interpretation of weak anisotropies in cosmic ray arrival directions.

One of the most burning questions in Particle Astrophysics revolves around the role of neutrinos in compact astrophysical sources. In particular, the early universe, compact binary mergers, and core-collapse supernovae host a high density of neutrinos such that neutrino-neutrino interactions

are not negligible. We have focused on understanding under which conditions such interactions could lead to non-negligible flavor conversions. Notably, we have explored the impact of neutrino flavor conversions in compact binary mergers quantitatively, as well as the role of neutrinos on the synthesis of the heavy elements. Because of the complications intrinsic to the numerical modeling of this problem, we have also outlined a strategy to forecast the outcome of flavor mixing in dense source without solving the equations of motion numerically.

Neutrinos have been studied for a long time. However, some of their properties, e.g., their possible interactions beyond the ones foreseen by the Standard Model, remain to be unraveled. Our group has focused on modeling and constraining various scenarios of non-standard physics by employing neutrinos of astrophysical and cosmological origin. For example, we have worked on understanding how the physics of astrophysical sources would be affected by non-standard scatterings of neutrinos among themselves and neutrinos on nucleons. At higher neutrino energies, we have studied the prospects of using the relative number of each type of neutrino that arrives at Earth to test non-standard neutrino properties.

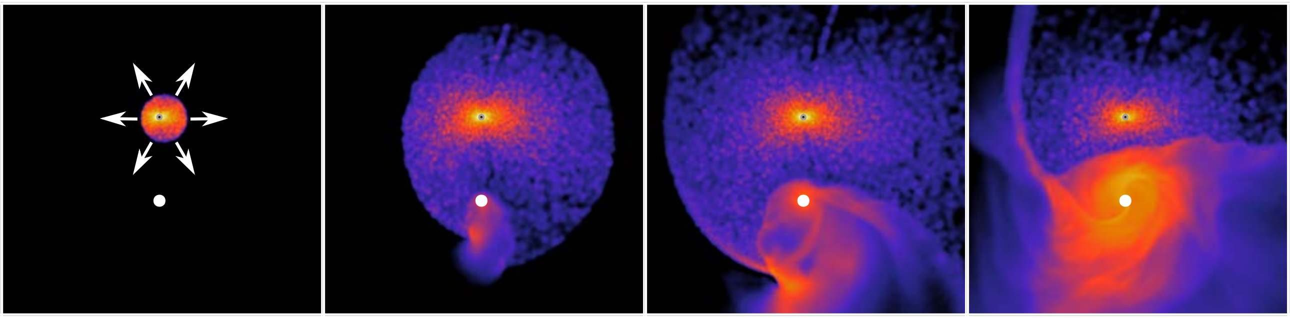
During 2021, scientists in our group continued maintaining strong ties with researchers at the Max Planck Institutes in Garching through the Collaborative Research Center sponsored by the Deutsche Forschungsgemeinschaft. We also led part of the efforts of the Particle Physics Community Planning Exercise ("Snowmass") organized by the American Physical Society, as well as the ones of the European Consortium for Astroparticle Theory (EuCAPT) Astroparticle Community by coordinating and contributing to outline the EuCAPT roadmap for the next decade. We have been active in a number of outreach activities, in particular through the lunch of an ongoing research project at the interface between art and science, which has received the 2021 Vision Exhibition Award. Despite the ongoing pandemic, we have run a successful online seminar series. Members of our group joined forces in 2021 to help organise the International PhD Summer School on Neutrinos: "Here, There & Everywhere." This one-week school aimed to bring students up to date with the latest developments in neutrino physics, from theoretical issues to experimental results, including astrophysical and cosmological aspects. The school was attended by about 110 PhD and advanced MSc students. The student and lecturer feedback was overwhelmingly positive — in spite of the virtual format this year — and we are presently planning the next instalment for 2022.

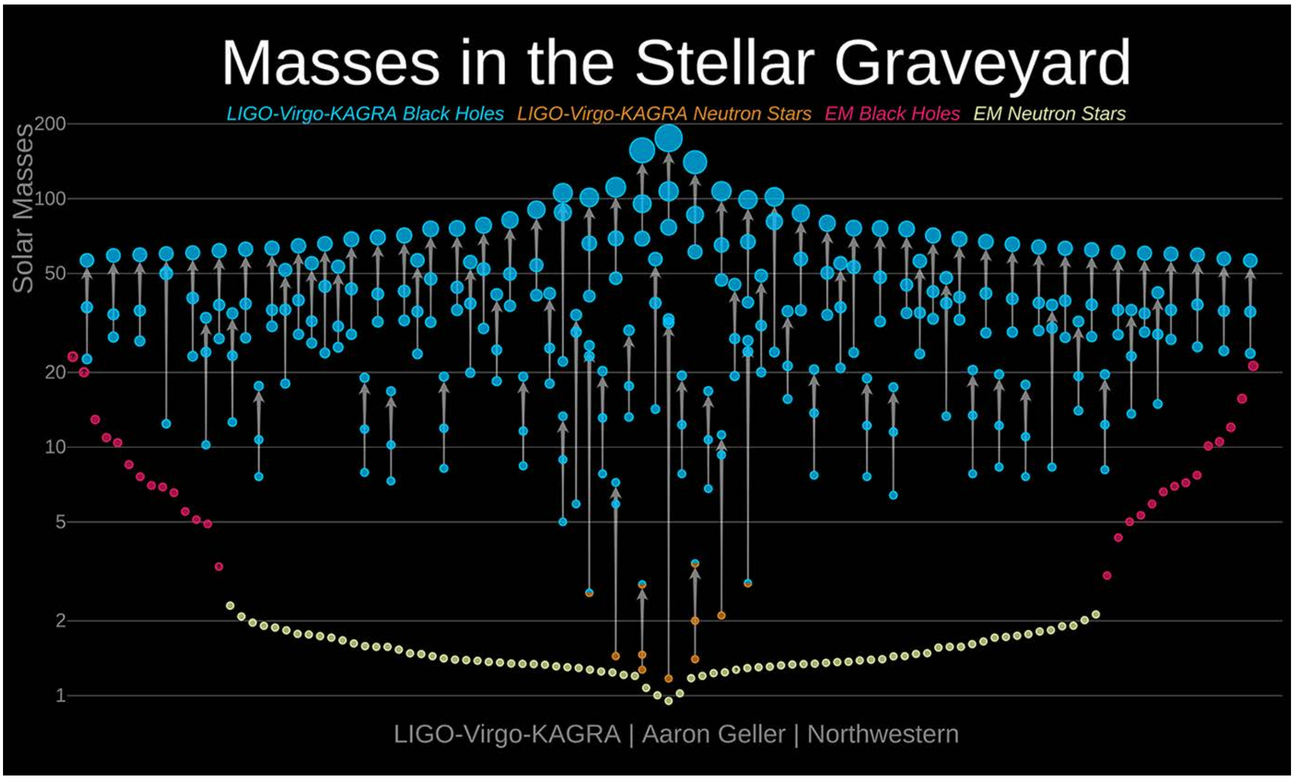
Theoretical Astrophysics

The Theoretical Astrophysics Group at the Niels Bohr International Academy strives for a comprehensive approach to astrophysics. Current research areas encompass protoplanetary disks and planet formation, black hole accretion disks, the physics of gravitational-wave sources, and tidal disruption events. All of these problems are tackled with a very wide perspective, ranging from fundamental theoretical aspects to state-of-the-art simulations that make it possible to link theory with observations.

The formation and evolution of planetary systems, including our own, remains a major open problem. Clues about how planets form are starting to be gathered from detailed observations of nearby planet-forming systems. Observations of the continuum radiation emitted by dust particles reveal complex substructure in disks around young stellar objects. The possibility that nascent planets may be responsible for some of these features is fueling an international race to connect observations with realistic theoretical models of protoplanetary disk dynamics. Meeting this challenge demands detailed models of the interaction between planets and the "multispecies" disk combined with precise and detailed calculations of solid/gas dynamics. In this context, the Theoretical Astrophysics group is pursuing several lines of research at the forefront of this active field. We are developing improved one-dimensional models of disks perturbed by planetary torques that can accurately describe the most important disk properties revealed by 2D hydrodynamical simulations. These models will allow us to self-consistently study the global dynamics of planets embedded in disks for the first time. In a parallel effort, we are optimizing the multispecies framework that we developed recently with the aim of simulating protoplanetary disks composed by dozens, or even hundreds, of dust species efficiently on GPU clusters. In order to accomplish this goal, we designed and implemented an efficient parallelization scheme that allows us to optimally utilize computational resources. Our work is bringing us a step closer to connecting theoretical models with observations of protoplanetary disks.

When a star gets too close to a supermassive black hole, it gets torn apart by strong tidal forces in a so-called tidal disruption event. The stellar debris then evolves into a stream of gas progressively fueling the compact object through an accretion disc, causing a powerful electromagnetic emission that represents a unique probe of these otherwise dormant supermassive black holes. Understanding the dynamical evolution of this stream of gas is critical for predicting the observational signatures and inferring physical properties. Because of the disparate scales involved, current numerical simulations are unable to accurately follow the return of this matter near the black hole, where most of the electromagnetic radiation is emitted. We presented an analytical model that captures for the first time the entire evolution of the stream around the black hole, which will be crucial to fully exploit the thousands of new TDE detections made by the Rubin Observatory (LSST) starting next year.





Gravitational-wave astrophysics is thriving as a new branch in the Theoretical Astrophysics Group. Since the first pioneering gravitational wave observation in 2015 of two merging black holes, we have now seen ~90 merger events between stellar-mass black holes as well as neutron stars, with many more to come in the near future. This has sparked a new field with unique potential to gain insight into how black holes and neutron stars form, grow and interact over cosmic time. In the Theoretical Astrophysics group we are developing new ideas and computational tools for describing these processes with a special focus on the dynamical formation of merging black holes in stellar clusters and galactic nuclei. We are also working to uncover the yet undetected mergers of supermassive black holes. Such events result from the pairings of black holes millions to billions of times more massive than our Sun in the center of galaxies. Detection of supermassive black hole mergers, expected in the coming decade, will offer the next great milestone in gravitational-wave astrophysics, lending insight into the formation of the biggest black holes in our Universe, and their co-evolution with their host galaxies. The Theoretical Astrophysics group is modeling the physical processes that bring these monstrous black holes together, specifically focusing on the interaction of these pairs with the surrounding gas. This will help us to predict how often such mergers should happen and importantly what imprints of formation will be visible in the emitted gravitational waves, as well as through the electromagnetic emission that results from gas accretion onto the black holes. Ultimately, we aim to build a multi-messenger approach, providing predictions that combine both electromagnetic and gravitational-wave observables into a tool kit that will help us to unravel the mysteries of black hole binary formation and merger from the smallest to the biggest black holes in our Universe.

At a more fundamental level, we have studied the thermodynamics of classical plasmas. The Bohr-van Leeuwen theorem implies that the magnetization of such plasmas vanishes in statistical equilibrium. In its original form, this theorem assumes that the charged particles interact only via position-dependent forces (such as the electric force $q\boldsymbol{E}$). It has been suggested relatively recently that the theorem breaks down when velocity-dependent forces (such as the magnetic force $q\boldsymbol{v}\times\boldsymbol{B}$) are considered. We have shown that this is *not* the case: the Bohr-van Leeuwen theorem continues to hold. In particular, we have shown that taking into account the semi-relativistic Darwin interaction does not invalidate the theorem.

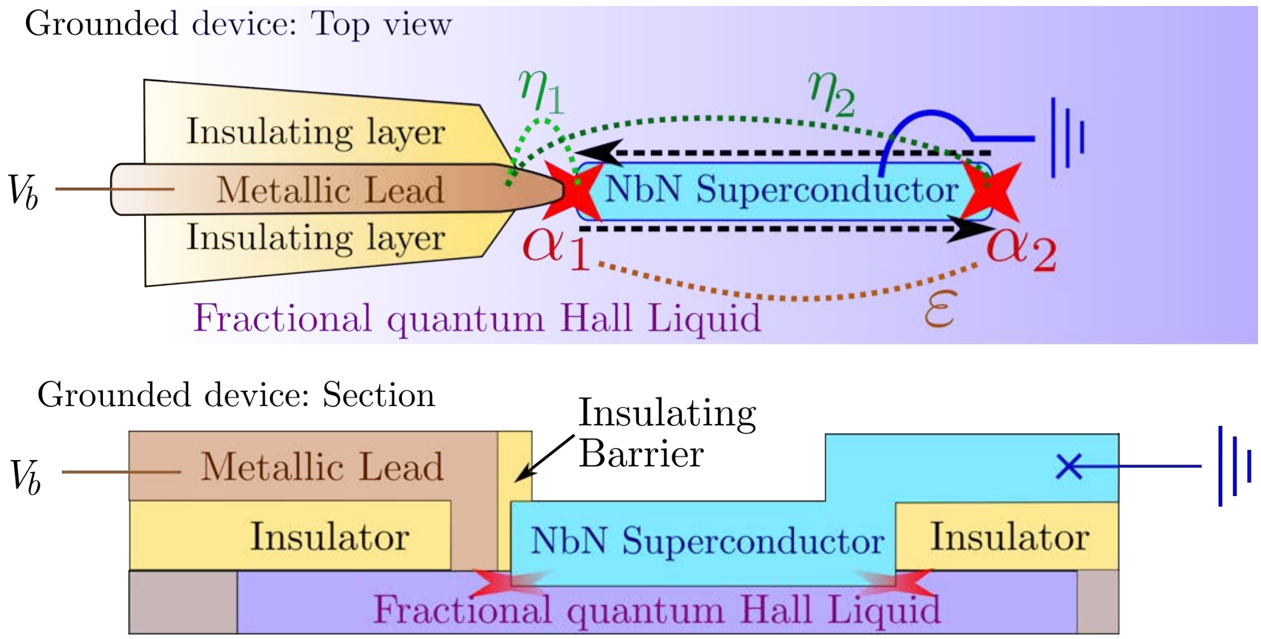
Condensed Matter Physics

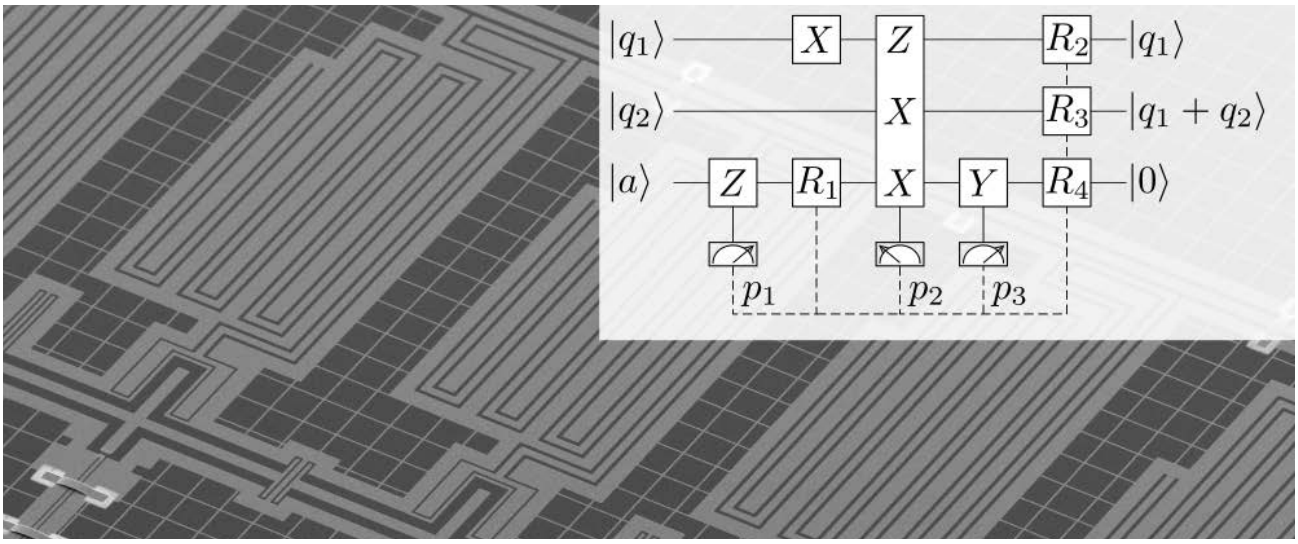
In the condensed matter theory group at NBIA we aim to discover new quantum phenomena and phases of matter. Our work covers a broad spectrum of topics, from solid state nano- and mesoscopic systems and quantum bits to hybrid and bulk topological materials, cold atom systems, and more general aspects of quantum many-body dynamics and information. We maintain close ties with experimentalists at the Center for Quantum Devices as well as other groups worldwide.

The study of condensed matter systems is at the core of the development of novel quantum devices. In the last years, small-scale quantum computers and other platforms for quantum simulations have become a reality, and the theory of many-body quantum systems provides the tools to describe, design and manipulate these physical platforms. Furthermore, many research subjects investigated with current quantum technologies are inspired by open problems in this field and many of the techniques to create stable and reliable quantum memories stem from achievements in condensed matter theory.

One of the most pervasive subjects in the field is the study of topological phenomena. These phenomena are peculiar due to their incredible robustness against perturbations, and provide intriguing possibilities for engineering quantum platforms protected against local noise.

A prominent example of the implications of topology in condensed matter systems is the quantized Hall effect: when a two-dimensional electron system (as found in common semiconductor heterostructure devices, or graphene) is subjected to a strong magnetic field, the system's Hall conductance takes on a precisely quantized value, which is equal to an integer or simple rational fraction times a combination of fundamental constants (the electron charge and Planck's constant). What is so amazing about this phenomenon is that the quantization of this macroscopically measurable quantity is accurate to better than one part in one billion, independent of sample size and shape, as well as material composition, and survives in the presence of all of the “dirt” that inevitably permeates real-world solid state systems. Due to the exquisite precision of this effect, the quantized Hall conductance is now used as a measurement standard for the definition of resistance.





From a fundamental point of view, the robustness of the quantized Hall effect arises from a beautiful mathematical (topological) structure of the quantum mechanical wave function of the electrons in the system. This theoretical realization spurred a worldwide effort to seek out additional types of robust phenomena that could support a similar level of "topological protection." Intriguingly, when realized in one- or two-dimensional materials, topological systems are predicted to host exotic new types of emergent particles, with peculiar properties that have no analogues in the familiar world of the "usual" fundamental particles that are free to explore our full three-dimensional universe. These properties have, for example, even been proposed as forming the basis for an extremely powerful and fault-tolerant architecture for quantum computing. Seeking means to realize the quantum states necessary for observing the emergence of these new particles comprises an important piece of our research in condensed matter theory at NBIA. Toward this end, we are continuing to develop new paradigms for obtaining topological states and phenomena. Our research is built on a combination of analytical work and numerical simulations that support our analysis and allow us to explore regimes beyond where analytical techniques can be applied.

The study of quantum many-body systems is indeed a very challenging field and the condensed matter theory group at NBIA is pioneering the use of novel numerical techniques for advancing the science of our field. This is a multi-pronged effort that includes the application of machine learning and tensor networks for the study of many-body systems. On one side, we are exploring how learning machines can assist in the design of new quantum information processing protocols, as well as in the efficient simulation of quantum dynamics. In this respect, we are working closely with experimentalists at the Center for Quantum Devices to develop machine learning based techniques for quantum experiments. On the other side, we are developing tools based on tensor networks for the simulation of devices in which the electron interactions play a crucial role, including several platforms for the experimental observation of topological phenomena.

The machine learning based techniques for quantum experiments allow for enhanced measurement and data processing capabilities, as well as for automatic tuning of quantum devices. Both of these are especially relevant for the development of near term quantum devices. The former enables real-time feedback for manipulating the quantum state, by improving the readout accuracy and speed. The latter enables tuning of devices with a multitude of parameters that all depend on each other in a complex way. Manually tuning large and dependent sets of parameters becomes tedious if not impossible already for near term quantum devices.

We also use other concepts coming from machine learning to investigate more fundamental questions, such as whether artificially intelligent (AI) agents can learn to harness quantum resources. This can come in the form of AI agents learning to do quantum cryptography, or in the form of AI agents learning to control quantum systems using (weak) measurements.

Soft Matter Physics & Active Matter

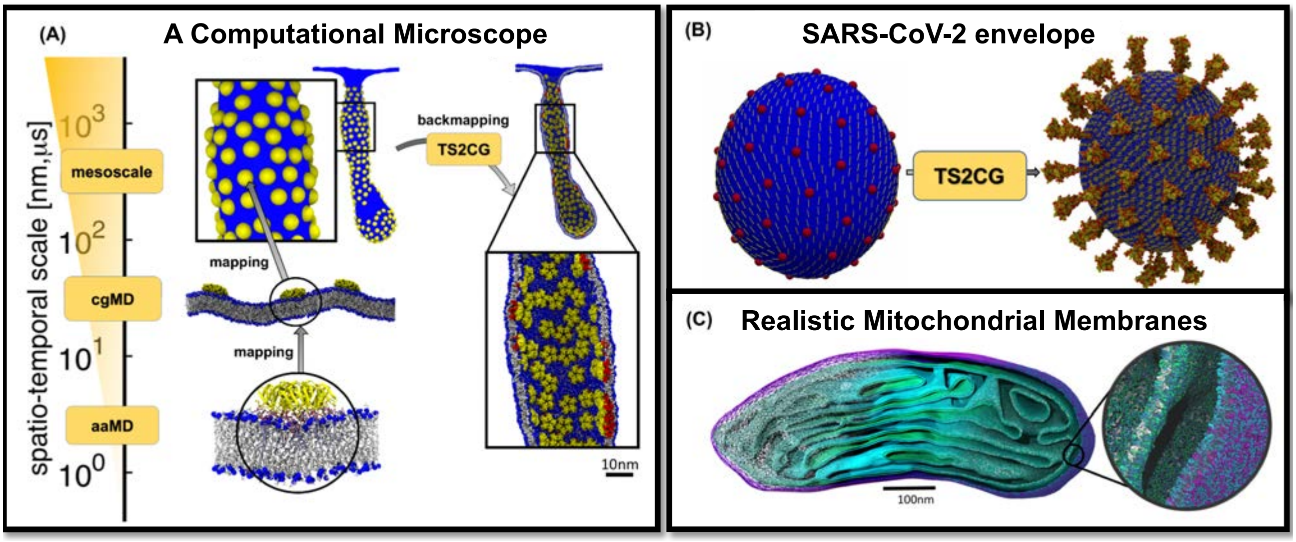
Soft matter physics lies at the heart of a quantitative understanding of many biological processes. From subcellular protein-driven flows to multicellular organ formation, biological matter continuously drives itself away from thermodynamic equilibrium using internal biochemical processes. In addition to their important biological roles, these intrinsically multiscale systems provide novel ideas for fundamental theories of non-equilibrium statistical physics and biomimetic inspiration for synthetic micro-machines capable of locomotion and self-organization. To tackle these diverse subjects, NBIA has recently launched an exciting new initiative to expand into soft matter physics, particularly the hot topic of active, self-organizing matter. Specifically, the research is focused on several fundamentally important areas in biophysics:

Bioinspired, Self-Organizing Active Matter — A material that organizes itself? Odd as this might sound, nature has found ways to make it happen: bacterial colonies, cellular tissues, and filaments inside living cells all work as engines converting the chemical energy of their environment into motion and are classified as "active materials". The unifying feature of active materials is the continuous conversion of chemical energy to motion by individual particles, and the ability to create motion on scales that are significantly larger than the size of an individual. This swarm-like behavior is termed collective motion: simple building blocks organize into moving structures that are often complex and chaotic.

Under the right conditions, active systems are capable of self-organization from chaotic flows into coherent flows: groups of active particles move together as a unit in a directed manner, forming a self-pumping fluid. However, the exact nature of these 'right conditions' is currently the focus of intense study as many biological processes - including subcellular flows, formation of bacterial biofilms, morphogenesis, and collective tumor invasion – demonstrate active coherent flows. An outstanding question is how the activity of particles at the individual particle level is translated into self-sustained coherent flows.

The key challenge is the gap between the scale of an individual particle and the scale of the collective motion. With an expertise in both discrete models and continuum theories, which enables us to explore the differing scales of the active matter, we are one of the pioneering groups to tackle this challenge. Specifically, our research has resulted in understanding.

Mechanotransduction: How Mechanics Guides Biochemical Signaling — There is growing evidence that mechanical forces can activate biochemical signaling for tissue regeneration, stem cell differentiation, and morphogenesis. Importantly disruption of this effect by changes in the microenvironment leads to pathological responses including tissue fibrosis and cancer. The connection between mechanical forces and cell response is the process of mechanotransduction: mechanical forces activate biochemical signals



by changing the concentration of mechanosensing proteins inside the cells. For example, putting cells under excessive tension localizes proteins that control cell division inside cell nuclei, leading to hyper-proliferation. The diffusion of chemical signals is too slow to be able to convey the mechanical information across the tissue. On the contrary, the force transmission between the cells provides a fast and long-range mechanism for propagation of mechanical cues over large spatial scales. Therefore, it is essential to understand the mechanism of mechanotransduction in the context of multicellular aggregates.

At NBIA we combine multiscale modeling – discrete and continuum simulations of cell mechanics with in-house experiments to reveal the impact of mechanical forces from multicellular motion on signaling and the mechanical feedback from the activation of biochemical signaling. Thermodynamics in Biology — Currently, one main research interest in the group is on how thermodynamics puts constraints on biological processes. More specifically, the focus is on questions such as to what extent are biological processes, such as DNA replication, optimised, which role does thermodynamics play in biological evolution, and what are the thermodynamic constraints necessary to create non-equilibrium phenomena, such as chemical oscillations and motility-induced phase-separation. We also study the stochastic thermodynamics of synthetic biological circuits. Over the last two decades synthetic biology has lead to important applications s uch as drug delivery and biosensors. By creating a consistent framework for the thermodynamics of these circuits, we aim to propose new optimisation schemes and design principles for future a pplications.

Computational Microscopy — We use computational microscopes to understand fundamental biological processes at the cellular level. For instance, how cells repair their membranes after injury or how toxic particles hijack cellular machinery for their entry. These mechanisms include many exciting physical phenomena such as fluctuations induced forces, phase transition, phase coexistence, and molecular condensations. The latest works include the first simulation of mitochondrial membranes with realistic size and SARS-CoV-2 virion envelope with a near-atomistic resolution. The current focus is to understand the molecular mechanisms that control the form of subcellular factories.

Finally, links with experiments are important in conducting these researches. We have launched exciting collaborations with international experimental groups in France (University Paris Diderot) and Japan (Osaka University), as well as with the Danish Stem Cell Center to profile NBIA as one of the leading institutions in these rapidly growing areas of research.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NBIA Staff

Faculty

Niels Emil J. Bjerrum-Bohr completed his Ph.D. in Copenhagen in 2004. He was a postdoc in Swansea 2004 - 2006, concentrating his research on amplitudes for gauge theories and quantum gravity. He was a Member at the Institute for Advanced Study in Princeton from 2006 until 2009. Emil was appointed Knud Højgaard Assistant Professor at the NBIA in 2010, at the same time being awarded a Steno grant from the Danish Science Research Council. He was appointed Associate Professor in 2016. He is currently a Lundbeck Foundation Junior Group Leader and Associate Professor at the NBIA. Emil's current research focuses on amplitudes in Yang-Mills theory and quantum gravity.

Matthias Christandl is a Professor at the Department of Mathematical Sciences in Copenhagen. His research is in the area of Quantum Information Theory. It is his aim to improve our understanding of the ultimate limits of computation and communication given by quantum theory. Concrete research results include a proposal for a perfect quantum wire and a new method for the detection of entanglement. Matthias received his PhD from the University of Cambridge in 2006. He then became a Thomas Nevile Research Fellow at Magdalene College Cambridge. In 2008, he joined the faculty of the University of Munich and 2010 - 2014 he was assistant professor at ETH Zurich. He moved to the University of Copenhagen in April 2014.

Jacob Bourjaily joined NBIA as Assistant Professor in 2014 and became Associate Professor in 2019. Jacob completed his Ph.D. at Princeton University in 2011, writing a thesis on scattering amplitudes in quantum field theory under the supervision of Nima Arkani-Hamed at the Institute for Advanced Study. Jacob continued this research while a Junior Fellow in the Harvard Society of Fellows at Harvard University 2011-2014 before taking up his current position at the NBIA. The primary focus of Jacob Bourjaily's research has been working toward an emerging reformulation of quantum field theory. He has contributed in numerous ways to the subject, including the discovery of a recursive description of scattering amplitudes to all orders of perturbation theory. For this work, Jacob was awarded a MOBILEX grant from the Danish Council for Independent Research.

Poul Henrik Damgaard did his undergraduate studies at the University of Copenhagen and then went to Cornell University, where he received his PhD in 1982. He has held postdoctoral positions at Nordita, CERN, and the Niels Bohr Institute, and has for a period of six years been Scientific Associate at the Theory Group of CERN. In 1995 he took up a position as Senior Lecturer at Uppsala University and that same year moved to the Niels Bohr Institute on a similar position. He has been Professor of Theoretical Physics since 2010 and Director of Niels Bohr International Academy since its beginning in 2007. His current research interests include modern techniques for amplitude computations, non-perturbative studies of supersymmetric theories on a space-time lattice, and constraints on so-called electroweak baryogenesis from the Large Hadron Collider (LHC).

Tobias Heinemann joined the NBIA as an Associate Professor after postdoctoral appointments at the IAS in Princeton, at the University of California at Berkeley and KITP, University of California, Santa Barbara. His research interests span a wide spectrum of problems in astrophysical fluid dynamics and magnetohydrodynamics.

Andrew Jackson is Professor at the NBIA. Born in New Jersey, he was educated at Princeton University and received his PhD in experimental nuclear physics. After almost three decades at the State University of New York at Stony Brook as professor of Theoretical Physics, Andrew joined the Niels Bohr Institute in 1996. He is a Fellow of the American Physical Society and the American Association for the Advancement of Science and is also a member of the Royal Danish Academy of Sciences and Letters. His current interests include the biophysics of the action potential, the study of cold atomic gases, and various topics in the history of science.

D. Jason Koskinen is an Associate Professor and local group leader for the IceCube Neutrino Observatory. From 2009-2013 he was a postdoc at the Pennsylvania State University, with a brief trip to the South Pole for IceCube calibration studies. His focus is on neutrino oscillations, further physics beyond the Standard Model, and detector extensions to IceCube to probe fundamental properties of particle physics. Jason's research on neutrino mixing and neutrino probes of the universe is graciously supported by a Villum Young Investigator award.

Charles Marcus was an undergraduate at Stanford University (1980-84). He received his Ph.D. at Harvard in 1990 and was an IBM postdoc at Harvard 1990-92. He was on the faculty in Physics at Stanford University from 1992-2000 and Harvard University from 2000 to 2011. In 2012, Marcus was appointed Villum Kann Rasmussen Professor at the Niels Bohr Institute and serves as the director of the Center for Quantum Devices, a Center of Excellence of the Danish National Research Foundation, and director of Microsoft StationQ – Copenhagen. He is an affiliate of the Niels Bohr International Academy — and acting Chair of the International Advisory Board starting in 2021. Marcus' research interests involve fabrication and low-temperature measurement of quantum coherent electronics in semiconductors and superconductors, including nanowires, quantum dots, quantum Hall systems, and Josephson devices. Current activities include the realization of spin qubits for quantum information processing and topological quantum information schemes based Majorana modes in nanowires and 5/2 fractional quantum Hall systems.

Ben Mottelson received a Bachelor's degree from Purdue University in 1947, and a Ph.D. in nuclear physics from Harvard University in 1950. He moved to Institute for Theoretical Physics (later the Niels Bohr Institute) in Copenhagen on the Sheldon Traveling Fellowship from Harvard, and remained in Denmark. In 1953 he was appointed staff member in CERN's Theoretical Study Group, which was based in Copenhagen, a position he held until he became professor at the newly formed Nordic Institute for Theoretical Physics (Nordita) in 1957. In 1971 he became a naturalized Danish citizen. He received the Nobel prize in 1975.

Pavel Naselsky did his undergraduate studies at the Southern Federal University of Russia and received his PhD in 1979 at Tartu University. In 1989 he got Doctor Habilitation at Moscow State University, Russia, working with theoretical astrophysics group of Zeldovich. In 2000 Pavel Naselsky took up a position as Associate Professor at the Theoretical Astrophysics Center (Copenhagen, Denmark) and in 2003 he was appointed as Lecturer at the Niels Bohr Institute. He has been Professor of Theoretical Physics since 2015 and group leader of the Theoretical Particle Physics and Cosmology group at the Niels Bohr Institute. His current research interests include modern cosmology, theory of the primordial black holes formation, physics of dark energy and dark matter, physics of the CMB etc. Since 2000 Pavel Naselsky has been working on the Planck project.

Martin Pessah his first degree in Astronomy in 2000 from the University of La Plata, Argentina. He received his PhD in Theoretical Astrophysics from the University of Arizona in 2007. He was a Member at the Institute for Advanced Study in Princeton until 2010 when he moved to Copenhagen as a Knud Højgaard Assistant Professor at NBIA and started building the Theoretical Astrophysics Group at NBIA. Martin became Associate Professor in 2013 and Professor MSO in 2015. Since 2016 Martin has been Deputy Director of NBIA. His research interests span a broad range of subjects in astrophysical dynamics, fluid dynamics, and magnetohydrodynamics, including planet formation in protoplanetary disks, black-hole accretion, the dilute plasma in galaxy clusters, and more recently tidal disruption events and gravitational wave astrophysics.

Christopher Pethick is Professor at NBIA. He did his undergraduate and graduate studies at Oxford, and received his D. Phil degree in 1965. After a period as a postdoc at the University of Illinois, he joined the teaching faculty there, be-coming full professor in 1973. In that year he also became a professor at Nordita. In 2008 he received the Lars Onsager Prize of the American Physical Society for his work on quantum liquids and cold atomic gases, and in 2011 the Society's Hans Bethe Prize for his work in nuclear physics and astrophysics. His research focuses on condensed matter in the laboratory and in the cosmos. Current interests include neutron stars (especially the properties of their outer layers), and ultracold atomic gases.

Mark Rudner is an Associate Professor at NBIA. Mark received his PhD in Condensed Matter Theory from MIT in 2008. After his PhD, Mark spent three years as a postdoc at Harvard. In 2012 Mark landed in Copenhagen to lead the Condensed Matter Theory group at NBIA. Mark's group has been supported generously by the Villum Foundation through the Young Investigator Award Program and by an ERC Starting Grant from the EU. Mark's research spans a broad range of topics in quantum dynamics and many-body physics. Cur-rent topics of interest include coherence and control in solid state qubits, nonlinear dynamics of many-body spin systems, topology and dynamics in strongly driven systems, and semiclassical dynamics of electrons in topological materials. The condensed matter theory group at NBIA maintains strong links with the Center for Quantum Devices, with a healthy interplay between theory and experiment.


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Jan Philip Solovej did his undergraduate studies in Copenhagen and his PhD in mathematics at Princeton in 1989. He was then a postdoc at University of Michigan, University of Toronto, and IAS Princeton before becoming Assistant Professorship at Princeton University 1991-1995. In 1995 he became a research professor at Aarhus University and in 1997 he became a full professor at the Mathematics Department in Copenhagen. He works in mathematical physics and in particular quantum physics. His current research interests include systems such as atoms, molecules, and gases of fermions and bosons. His research addresses issues such as stability of matter, superconductivity and -fluidity, and quantum information theory. He currently leads the Centre for the Mathematics of Quantum Theory (QMATH) in the Department for Mathematical Sciences.

Irene Tamborra is Professor and leader of the AstroNu group. Irene completed her Ph.D. at the University of Bari in 2011. Before joining the Niels Bohr Institute in January 2016, Irene has held research appointments at the Max Planck for Physics in Munich, as the Alexander von Humboldt Fellow, and at GRAPPA, Center of Excellence of the University of Amsterdam. Irene's research activity is in the area of theoretical particle astrophysics and astrophysics. In particular, Irene is interested in exploring the role of weakly interacting particles, such as the neutrino, in astrophysics and cosmology. Within a multi-messenger framework, she also aims at unveiling what can be learnt by adopting neutrinos as probes of extreme astrophysical sites not otherwise accessible.

Junior Faculty

Markus Ahlers received his Ph.D. in Theoretical Particle Physics from the University of Hamburg (DESY) in 2007. He has been a Postdoc in Oxford and Stony Brook before becoming a John Bahcall Fellow for Neutrino Astronomy at the University of Wisconsin-Madison. He joined NBIA in 2017 as an Assistant Professor. Markus research focus is centered on astroparticle physics. He studies the origin and transport of cosmic rays, the associated emission in gamma rays and neutrinos as well as beyond-the-SM probes by cosmic messengers. He has been a member of the IceCube Collaboration since 2007.

Pablo Benitez-Llambay received his Ph.D. at the University of Cordoba, Argentina, and moved to the NBIA as a postdoc in 2016. One year later, he was granted a Marie Curie Fellowship to extend his studies about planet and disk dynamics. Currently, Pablo is an Assistant Professor at the NBIA. Pablo's research focuses on studying the dynamics of multi-species protoplanetary disks linked to the formation and evolution of planetary systems. He is particularly interested in planet-disk interaction, gas/dust dynamics, disk instabilities, and high-performance computing.

Paolo Benincasa joined NBIA as Assistant Professor in November 2017. After completing his PhD at the University of Western Ontario and Perimeter Institute in Canada in 2008, where he developed the first studies on the hydrodynamics of non-conformal strongly-coupled plasmas using holography as well as on the perturbative structure of scattering amplitudes, he held postdoctoral position at the University of Durham, Santiago de Compostela as Juan de la Cierva fellow and at the Instituto de Física Teórica in Madrid as well as a visiting researcher position at Perimeter Institute in 2017. Paolo's current research focuses on reformulating quantum field theory directly in terms of observables and the application of this idea to cosmology.

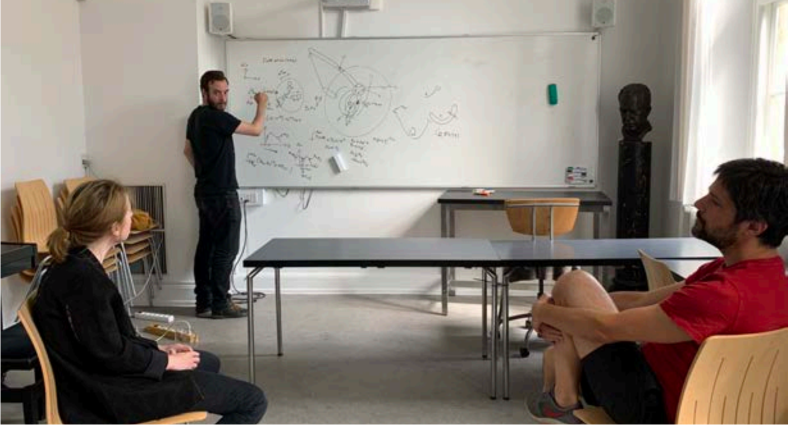
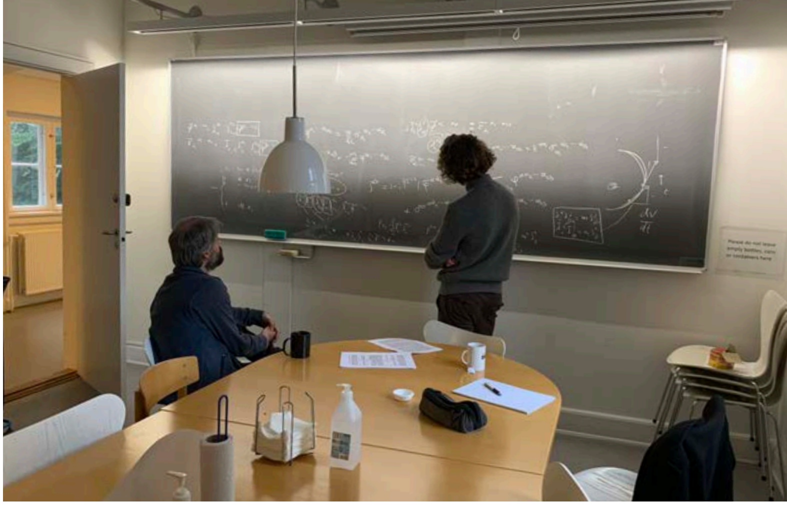
Michele Burrello joined NBIA in 2016 and is Associate Professor in condensed matter theory. He completed his Ph.D. in statistical physics at SISSA (Trieste) in 2011, and worked as a postdoc in Leiden and at the Max Planck Institute for Quantum Optics. Since 2019 he has been leading the NBIA research group on topological phases of matter thanks to the generous support of the Villum Foundation. Michele's research focuses on the study of topological phenomena in many-body systems. He aims at applying their emergent and exotic properties to novel quantum technologies and platforms for quantum computation. Michele works on different low-temperature setups, including ultracold atoms and superconducting devices, and he is interested in the common theoretical frameworks underlying such diverse systems.

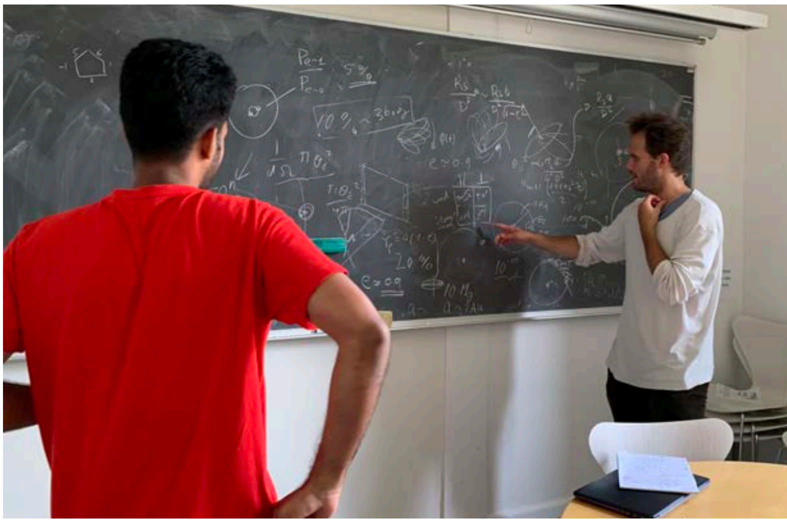
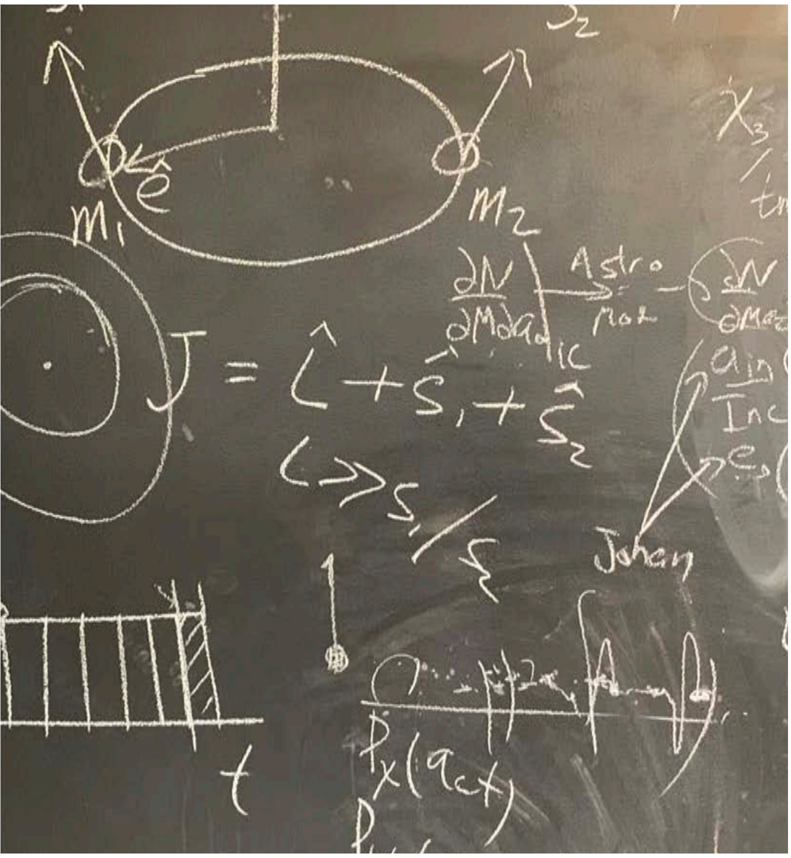
Mauricio Bustamante is an Assistant Professor at the NBIA. He completed his PhD at the University of Würzburg and DESY in 2014. Following that, he was a postdoc at the Center for Cosmology and AstroParticle Physics (CCAPP) of The Ohio State University before joining the Niels Bohr Institute in 2017. His research is in the field of astroparticle physics, with a focus on high-energy astrophysical neutrinos and ultra-high-energy cosmic rays. He is interested in two open issues with far-reaching implications in astrophysics and physics: what are the sources of high-energy cosmic rays, neutrinos, light, and gravitational waves — and how are these connected — and what can we learn about fundamental particle physics from astrophysical messengers with energies far above those achievable in the lab.

Daniel D'Orazio After a Fulbright Fellowship at the University of Zürich, Daniel completed his PhD in 2016 as an NSF Graduate Research Fellow at Columbia University. Afterwards he was awarded a NASA Einstein Postdoctoral Fellowship and an Institute for Theory and Computation Fellowship at Harvard University. He joined the NBIA as an Assistant Professor in 2020. Daniel's research lies at the interface of theory and observation and spans a wide range of topics in high energy astrophysics. His primary interests lie in harnessing the tools of multi-messenger astrophysics to uncover the origin of compact object binaries, spanning the mass scale from neutron stars to supermassive black holes. He has been awarded a Sapere Aude Research Leader Grant to establish a group at the NBIA dedicated to supermassive black hole binaries.

Amin Doostmohammadi is a Novo Nordisk Foundation Assistant Professor at the NBIA. He also has a cross-appointment as Specially Appointed Assistant Professor at Bioengineering in Osaka University, Japan. Amin received his PhD from the University of Notre Dame, followed by a postdoc in Oxford University and held a prestigious Royal 1851 Research Fellowship at Oxford before joining NBIA. Amin is leading the Active Intelligent Matter research group that works at the interface between physics and biology, modeling active materials as diverse as bacterial colonies, molecular motors and cellular tissues. In particular, their recent finding of the correlation between topological defects in tissues and the sites for cell death is a page-turner for the field of tissue biology, challenging the consensus, and bring physics of liquid crystals into studying diverse biological problems. Currently the research at Amin's group enjoys generous support from Novo Nordisk Foundation and DFF-ERC grant.

Michèle Levi got her academic education in Israel and earned her PhD from the Hebrew University of Jerusalem for her thesis "Effective Field Theory approach in General Relativity". Michèle then held research appointments at the Lagrange Institute of Paris of the Sorbonne University and at the Institute of Theoretical Physics of CEA Saclay and the University of Paris-Saclay. Michèle has been developing the application of concepts and methods from Quantum Field Theory (QFT) to gravitational-wave measurements and uncovering relations between QFTs and gravity since her graduate studies. Michèle joined the Niels Bohr International Academy as Assistant Professor in Fall 2019 where she is leading the research in the group "Gravity from Particle Amplitudes".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Andres Luna completed his education in Mexico City and then earned his PhD at the University of Glasgow in 2018. He held a postdoctoral position in the Mani L. Bhaumik Institute for Theoretical Physics at UCLA before joining the NBIA as an assistant professor in 2021. His research interests lie at the interface between gravitation and scattering amplitudes in Quantum Field Theory. He is currently working on the generalization of the double copy to black holes and other interesting classical solutions in General Relativity, as well as in the application of these, and other modern scattering amplitudes techniques to the description of the dynamics of binary black holes and its application to the burgeoning field of gravitational-wave physics.

Karel Proesmans joined the NBIA as an assistant professor in October 2021. After obtaining his PhD in 2017 at Hasselt University in Belgium, he worked as a post-doctoral researcher in Canada and Luxembourg. During this time, he worked on non-equilibrium statistical mechanics, with particular focus on the development of a general framework, known as stochastic thermodynamics, to study the thermodynamics of mesoscopic systems. Currently, his main research interest is on how thermodynamics puts constraints on biological processes. More specifically, his focus is on questions such as to what extend are biological processes, such as DNA replication, and what are the thermodynamic constraints necessary to create non-equilibrium phenomena motility-induced phase-separation.

Weria Pezeshkian is a biophysicist. He received his PhD from the University of Southern Denmark. Before joining NBIA he was a postdoctoral fellow at the University of Groningen. He develops and uses computational microscopes to understand fundamental biological processes at the cellular level. For instance, how cells repair their membranes after injury or how toxic particles hijack cellular machinery for their entry. These mechanisms include many exciting physical phenomena such as fluctuations induced forces, phase transition, phase coexistence, and molecular condensations. His latest works include the first simulation of mitochondrial membranes with realistic size and SARS-CoV-2 virion envelope with a near-atomistic resolution. His current focus is to understand the p molecular mechanisms that control the form of subcellular factories.

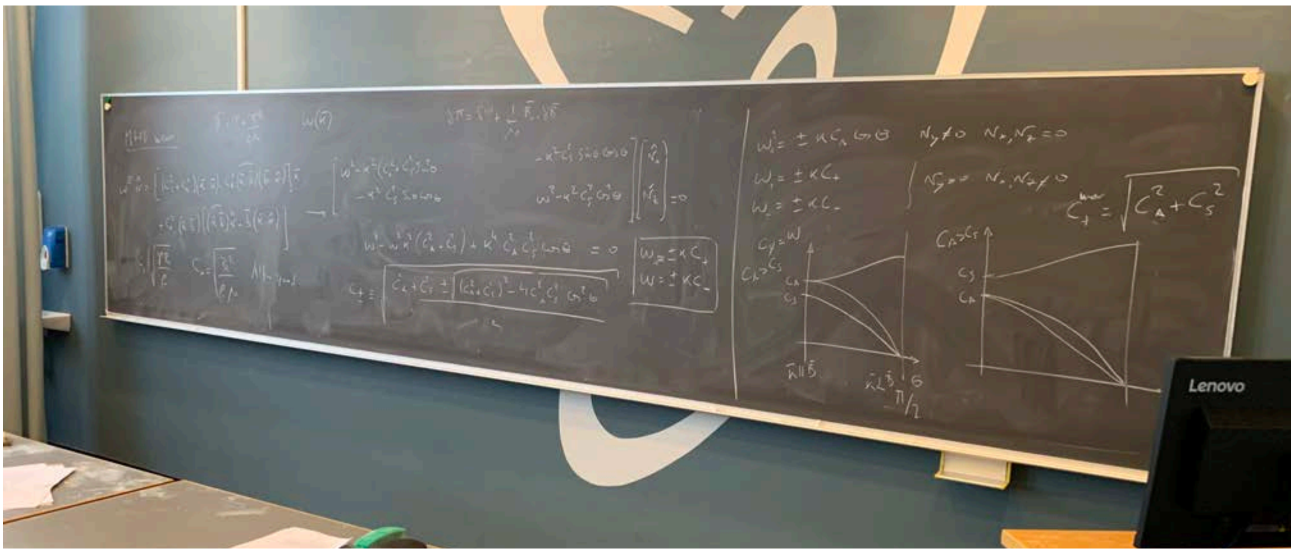
Johan Samsing joined the NBIA as a Louis-Hansen Assistant Professor and Marie Curie Fellow in 2019. In 2020 he received a Villum Young Investigator Grant to establish a group at the NBIA dedicated to gravitational-wave astrophysics. Johan received his PhD from the Niels Bohr Institute (DARK) in 2014, after which he moved to Princeton University, first as an Einstein Fellow and then as a Spitzer Fellow. He currently works on the astrophysical formation of gravitational-wave sources and the origin of black hole mergers.

Evert Van Nieuwenburg's As assistant professor at the NBIA, Evert's research focuses on using machine learning to advance the state-of-the-art in condensed matter physics. Examples are the use of neural networks to predict physical properties of many-body systems, genetic algorithms for quantum error correction, and reinforcement learning for controlling experimental quantum systems. He contributes to the development of quantum games for outreach and education (quantumchess.net and quantumtictactoe.com) and is an organizer for virtualscienceforum.org.

Cristian Vergu graduated from Ecole Normale Superieure (Paris, France) and obtained his PhD in Theoretical Physics from Paris VI University and IPhT Saclay. He held postdoctoral positions at Brown University, USA, ETH Zürich, Switzerland and King's College London, UK. He is interested in twistor theory, AdS/CFT, integrability and scattering amplitudes in N=4 super-Yang-Mills theory.

Albert Werner obtained his PhD at the Leibniz University of Hannover in 2013 on propagation properties of quantum walks. He then joined Jens Eisert's group at the FU Berlin for a postdoc working on disordered quantum many-body systems. Albert has joined QMath with a Feodor Lynen Fellowship (a Humboldt Foundation sponsorship). He works within Matthias Christandl's Quantum Information Theory group and with Michael J. Kastoryano at the NBIA.

Matthias Willhelm received his PhD from Humboldt University Berlin before joining NBIA in 2015. His research interests lie within the field of quantum field theory and high-energy theory, with a focus on gauge theories, the gauge-gravity duality and exact methods. He works on the number theory behind scattering amplitudes, on form factors and on thermodynamics as well as on the effects of introducing defects.



Postdoctoral Fellows

Aleksandra Ardaševa received her DPhil from the Mathematical Institute at the University of Oxford. Her doctoral work focused on studying evolutionary adaptation strategies of cancer cells in dynamic environments using analytical and numerical techniques. She currently studies physico-chemical coupling in active biological matter by utilising phase-field modelling approach and continuum theory of liquid crystals.

Clément Bonnerot received his PhD from Leiden Observatory in the Netherlands, after which he was a postdoctoral scholar at the California Institute of Technology. His research focuses on the theoretical modeling of transient and high-energy phenomena, particularly tidal disruption events. He especially aims at predicting the observational signatures from these astrophysical systems by means of analytical methods and computer simulations.

Benjamin Brown works in quantum information, more specifically on quantum error correction and fault-tolerant quantum computing. He researches quantum error-correcting codes; the many-body quantum systems that will store quantum information robustly and on decoding algorithms; classical algorithms that support quantum error-correcting codes. Ben also develops fault-tolerant quantum logic gates; dynamical processes that manipulate quantum information that is stored on a quantum error correcting code while still keeping track of the errors the quantum computer experiences as the gate progresses.

Morten Holm Christensen is a postdoc with Mark Rudner at NBIA. He obtained his PhD in condensed matter physics from the Niels Bohr Institute in 2017, after which he spent three years at the University of Minnesota working as a postdoctoral researcher. He joined the NBIA in September 2020. His research is focused on condensed matter physics. In particular, he is interested in emergent phenomena in strongly correlated electronic systems, such as unconventional superconductivity and topology.

Tyler Corbett completed his PhD at Stony Brook University in 2015 and completed a postdoc at Melbourne University before joining NBIA. Tyler's research interests include the Standard Model Effective Field Theory, collider phenomenology and models explaining the baryon asymmetry of the Universe.

Georg Enzian obtained his PhD from the University of Oxford for work in Brillouin cavity optomechanics. He is interested in the preparation and study of non-classical states of mechanical motion. At NBI he currently focuses on the preparation of number states of the motion of silicon-nitride membranes suspended inside an optical cavity. Preparation of exotic quantum states of massive systems can directly test quantum mechanics in thus far unexplored regimes and might shed new light on the foundations of the theory.

Hjalte Frellesvig's main field of research is scattering amplitudes in particle physics, with a focus on Feynman integrals and their mathematical properties. This includes work on the use of the mathematical disciplines of intersection theory and "symbol" algebra for simplifying and systematizing the manipulation and evaluation of Feynman integrals and associated special functions. He also works on particle scattering phenomenology including a project on the production of the Higgs boson, and one on electro-weak corrections to the production of the Z and W bosons. He has his PhD from the NBI, and has done postdocs in Greece, Germany, and Italy.

Seiji Fujimoto is a DAWN / INTERACTIONS postdoctoral fellow studying observational extragalactic astrophysics. He obtained his PhD from the University of Tokyo in 2019, where he carried out a large statistical study of rest-frame far-infrared properties in distant galaxies. He has interested in the formation and evolution of galaxies and supermassive black holes in the early universe. He has been awarded dozens of world-leading telescope observing hours as PI, including NASA's James Webb Space Telescope Cycle 1.

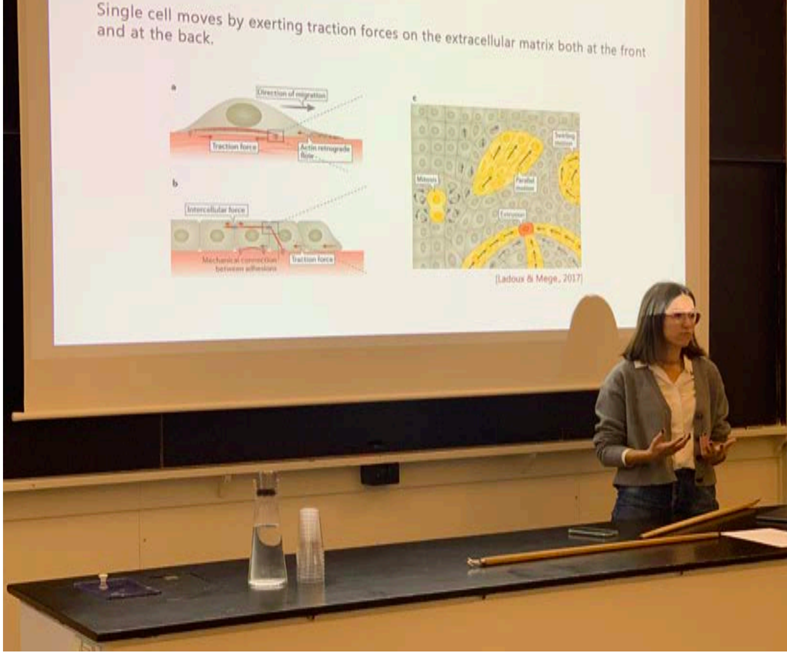
Yoann Genolini received his PhD in theoretical physics at LAPTh (Annecy, France) in 2017. He later became a postdoctoral fellow at the Université Libre de Bruxelles. His research focuses on astroparticle physics, cosmic-ray transport and phenomenology. He is also interested in dark matter phenomenology and its indirect probe by astrophysical observables, especially those related to compact objects.

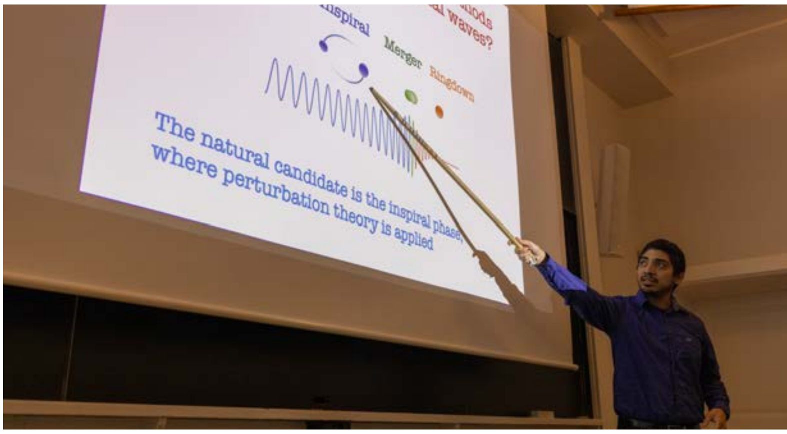
Mathias Luidor Heltberg's research is focused on complex dynamics and how this affects regulation and signaling in biological organisms. It is situated at the interface between the physical disciplines of dynamical systems theory and statistical physics. He has previously shown how dynamical properties of regulatory proteins can be used as a way to control groups of genes and it is his goal to shed light on how cells can use physical signals to control their production.

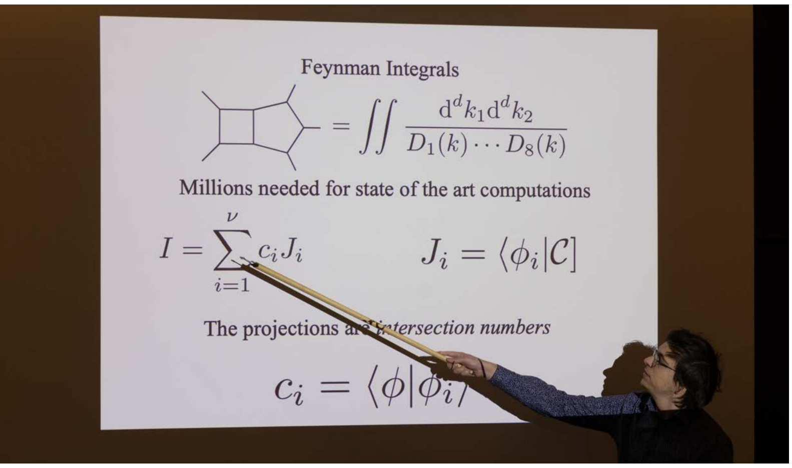
Rajika Kuruwita is an INTERACTIONS fellow at NBI doing numerical simulations of star formation. She obtained her PhD from the Australian National University in July 2019, where she completed both observational and theoretical work on binary star formation. She has a keen interest in the early evolution of young binary and multiple star systems and how their dynamical interactions could affect planet formation. She is also the treasurer of Kvinder I Fysik, and founder of Astronomy on Tap: Copenhagen.

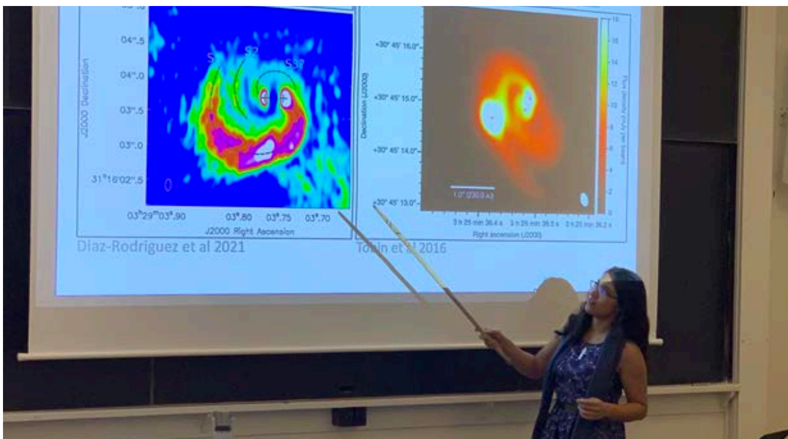
Natascha Leijnse is an experimental biophysicist who received her PhD from the University of Copenhagen. After a postdoc at Stanford University she returned to the University of Copenhagen. Her research helps unravel cellular responses to mechanical stimuli, using, for example, optical tweezers in combination with fluorescent live cell imaging. She is now a member of the Active Intelligent Matter Group where she focuses on understanding mechanotransduction of transcription factors relevant in cancer development.


wind, a possible
candidate


Single cell moves by exerting traction forces on the extracellular matrix both at the front and at the back.
Direction of migration
Traction force
Intercellular force
Traction force
(Ladoux & Mege, 2017)


Merger
Ringdown
The natural candidate is the inspiral phase
where perturbation theory is applied

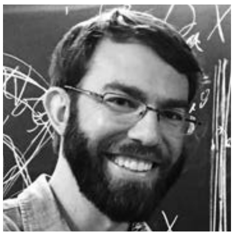

Feynman Integrals
$= \iint \frac{d^d k_1 d^d k_2}{D_1(k) \cdots D_8(k)}$
Millions needed for state of the art computations
$I = \sum_{i=1}^{\nu} c_i J_i$
$J_i = \langle \phi_i | \mathcal{C}]$
The projections are intersection numbers
$c_i = \langle \phi | \phi_i \rangle$


J2000 Declination
J2000 Right Ascension
Diaz-Rodriguez et al 2021
Tobin et al 2016

Bin Liu received his Ph.D. in China in 2016 and held postdoctoral positions at Shanghai Astronomical Observatory and Cornell University. He joined NBIA in 2019 as an INTERACTIONS fellow. Bin is interested in a wide range of dynamical problems, including exoplanetary systems, dynamical formation of binary black holes, and dynamics and merger of compact objects near super-massive black holes in the disks of active galactic nuclei.

Robin Marzucca obtained his PhD at UCLouvain in 2019, after which he went on to become a postdoctoral research associate at Durham University and finally at the NBI. His research focuses on the study of the mathematical structure of scattering amplitudes in particle physics with the goal to find new, efficient ways for their computation. He further works on the application of these techniques to the computation of scattering amplitudes for particle collisions at the Large Hadron Collider.

Rasmus Lundkvist received his PhD in Astronomy from Aarhus University in September 2015. Afterwards, he held an Alexander von Humboldt fellowship at Max-Planck-Institut für Kernphysik in Heidelberg before coming to NBIA. His research focuses on neutrino oscillations in the early Universe and in supernova explosions, but he is also interested in related topics such as dark matter and high energy neutrinos.



Andrew McLeod received his PhD from Stanford University in 2017. He is interested in understanding the mathematical structure of scattering amplitudes in quantum field theory, elucidating their unexpected properties, and developing novel computational techniques. His research focuses on developing novel formulations of scattering amplitudes in quantum field theory. Currently, he is investigating the analytic, geometric, and infrared properties of gauge theory.

Lorenzo Maffi received his PhD in 2020 from the University of Florence. The topic of his research has been the edge dynamics of topological states of matter by means of conformal field theory approaches. He focused on the quantum Hall states and topological insulators in 3D. Currently he's working on low temperature phases in nanowire-leads systems, and, in particular, on stability of topological Kondo effect.

Chandana Mondal has in the past worked in the area of theoretical soft condensed matter physics. Using analytical and computational methods she studied mechanical properties of amorphous solids and amorphous magnetic thin films, self-assembly, pattern formation, glass transition and rheology of patchy, network-forming colloids, kinetics of template-assisted phase ordering of solids etc. She has also worked on granular materials and studied stress propagation in such media. At NBIA she works on active soft matter systems.

Yavor Novev joined the NBI after a brief postdoc with Julia Yeomans in the Oxford Physics Department. He also obtained his doctorate in Physical & Theoretical Chemistry at Oxford and prior to that did his Master's and Bachelor's degrees at the University of Sofia in Bulgaria. Yavor uses computational and analytical methods to study soft matter systems such as polymeric aggregates and thin liquid films.

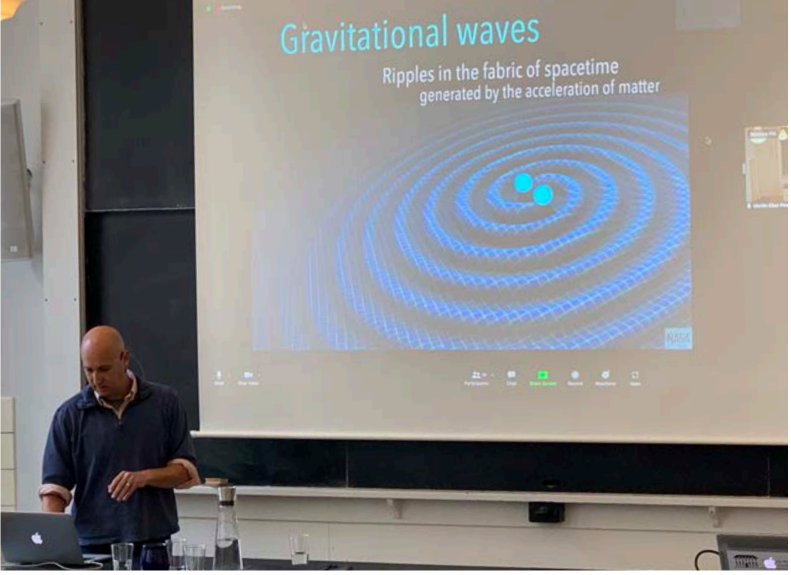
Francesca Rizzo received her PhD from the Ludwig-Maximilians-Universität in Munich in 2020. Her research focuses on the study of the physical processes shaping galaxies across cosmic time through the analysis of the galactic dynamics. At NBI, she is developing new tools for constraining the fraction of galaxy mergers during the Epoch of Reionization. She is also interested in studying the impact of stellar feedback and gravitational instabilities in driving the turbulence within the interstellar medium of galaxies

Enrico Peretti obtained his PhD in Astroparticle Physics at the Gran Sasso Science Institute (L'Aquila, Italy) in July 2020 and he joined the Niels Bohr Institute in September 2020. His research interests are in astroparticle physics and focus on the transport of high energy particles and its multimessenger implications in extreme astrophysical environments, most notably starburst galaxies. He is also interested in non-thermal phenomena taking place in relativistic jets such as gamma-ray bursts.

Shashank Shalgar received his PhD from Northwestern University in 2013. He later became a postdoctoral fellow at the University of New Mexico and Los Alamos National Laboratory. His research is focused on neutrino physics in extreme astrophysical environments and the early Universe. He is especially interested in the non-linear evolution of the neutrino flavor that occurs in these astrophysical environments.

Ximena Ramos has been a postdoc at the NBIA since 2019. Ximena received her PhD in Planetary Science from the University of Córdoba, Argentina. After her PhD, she was a postdoc at Observatoire de la Côte d'Azur, France. Ximena's research focuses on N-body dynamics and protoplanetary disks. She is particularly interested in planet migration, its connection with the underlying disk-structure, and the associated impact with the final configurations observed in exoplanetary systems.

Anne Spiering received her PhD from Trinity College Dublin. Her research focusses on the interplay between infinite-dimensional symmetries at the core of physical models and their manifestation at the level of the model's observables. This includes the research on how the existence, and absence, of quantum integrability constrains the physical data of superconformal field theories, and in particular the mathematical structure of scattering amplitudes.


Gravitational waves
Ripples in the fabric of spacetime
generated by the acceleration of matter


ADAPTERS

Anna Suliga obtained her master's degree under the supervision of Prof. Irene Tamborra at NBIA in 2018. She has then continued to work as PhD fellow within the same research group. The focus on Anna's research is the exploration of new physics scenarios in the context of astrophysical environments. Anna has successfully defended her PhD thesis in October 2021 and she is now a postdoctoral fellow at the University of California, Berkeley.

Alejandro Vigna-Gómez received his PhD from the University of Birmingham (UK). He is interested in massive stars, which are the progenitors of gravitational-wave sources and other extremely energetic transients. He uses numerical methods to study multiple-star systems and populations of double compact objects.

Jim Talbert received his PhD from Oxford in 2016 and held a DESY Fellowship between 2016-2019. His work applies effective field theory techniques to various topics in particle phenomenology. He has contributed precision calculations for particle colliders and neutrino observatories and has also explored deeper problems in particle physics e.g. the origins of flavor, CP violation and new fundamental symmetries.

Matt von Hippel received his PhD from Stony Brook. Before joining NBIA, he was a postdoctoral fellow at the Perimeter Institute. He develops new techniques for calculating scattering amplitudes in quantum field theory. He is well known for polylogarithmic bootstrap methods.

Matteo Wauters is interested in a variety of non-equilibrium phenomena in quantum physics, ranging from topological transport properties to reinforcement learning techniques for quantum control and quantum computation. At the moment he focuses on the modeling and numerical analysis of topological Kondo effect in nanowire systems, aiming to a qualitative comparison with experimental results.

Chi Zhang received his PhD in 2020 from the Institute of Theoretical Physics, Chinese Academy of Sciences. He works on scattering amplitudes in gauge theories and string theory. He is interested in studying the underlying mathematical structures of scattering amplitudes as well as developing new techniques for computing amplitudes.

PhD Students

Benjamin Halager Andersen joined the Active Intelligent Matter (AIM) group at NBIA in November as a PhD fellow, where he will be using a combination of numerical and analytical methods to study systems of active matter. Prior to this, Benjamin obtained both his master's and bachelor's degrees from NBI, the former on the topic of complex systems physics and the phenomenon of fully developed turbulence in 2D as well as 3D.

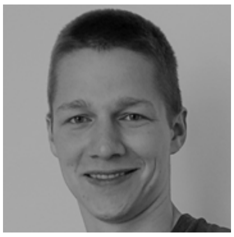
Kathrine Mørch Groth obtained her MSc degree at the NBIA in 2021 working on multi-messenger emission of ultra-high energy cosmic rays. Since October 2021 she has been a PhD student in the astroparticle group under the supervision of Markus Ahlers. Her project aims to clarify the origin of the high-energy cosmic neutrino flux through studies of candidate neutrino sources in the context of multi-messenger observations.

Andrea Cristofoli obtained his Master degree in Theoretical physics with Laude at the University of Padova. During his studies he also spent brief research periods at SISSA (International School for Advanced Studies) and at the Département de Physique Théorique of Geneva specializing in General Relativity. Currently, founded by a Marie Curie Grant, he is working at the Niels Bohr Institute with Poul Henrik Damgaard on the connections between Perturbative Quantum Gravity and classical General Relativity.

Ersilia Guarini is a PhD student working under the supervision of Irene Tamborra. She joined NBI in January 2021, after obtaining her MSc degree from Bari University (Italy) with a thesis on axion-like particles production in photon conversions in large-scale coherent magnetic fields. She is currently working on multi-messenger astrophysics. In particular, her project aims to investigate non-thermal neutrino production in astrophysical transients.

Raffael Gawatz's research focuses on non-equilibrium dynamics of quantum many-body systems. In his studies he employs both exact diagonalization/evolution-type numerical simulations and approximate schemes based on the efficient representation of quantum many-body states using tensor networks. Using these methods, he is exploring how new universal, topological phenomena can emerge in the (quasi) steady states of periodically-driven systems.

Kays Haddad received his MSc from McGill University in 2018, having worked on beyond-the-standard-model phenomenology. He joined the NBIA later in the same year. Working under the supervision of Poul Henrik Damgaard, his research focuses on using effective field theories and modern scattering amplitude techniques to describe classical gravitational scattering.

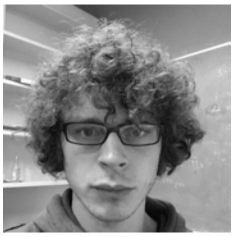


Alexander T. Kristensson obtained his MSc degree in theoretical physics from the University of Copenhagen and recently started his PhD in the research group of theoretical high-energy physics at the NBI. His research focuses on understanding the strange behavior of the smallest components of all matter, the quarks, via the maximally supersymmetric Yang-Mills theory.

Ian Padilla-Gay started a position as PhD student at NBIA under the supervision of Irene Tamborra after obtaining his MSc degree from Lund University (Sweden). Since then, he has been working on numerical simulations to understand the flavor evolution of neutrinos in compact astrophysical objects such as neutron star binaries.

Tetyana Pitik is a PhD student working in the Astro-Nu group under the supervision of Irene Tamborra. She obtained her MSc degree in Theoretical Physics from the University of Perugia (Italy) with a thesis on force-free electrodynamics approach to magnetospheres of extremal Kerr black holes. Tetyana's research activity at NBIA focuses mainly on developing a new, self-consistent estimation of particle acceleration in astrophysical transients to compare with observations.

Victor Valera is a PhD student working under the supervision of Mauricio Bustamante. He completed the Postgraduate Diploma Programme in High Energy Physics at the International Centre for Theoretical Physics (Italy) with a thesis on resonance refraction effects on neutrino oscillations due to non-standard neutrino-scalar interactions as an explanation of the MiniBooNE anomaly. Victor's research at NBIA focuses on the study of ultra-high energy neutrinos and their potential to probe new physics using current and future neutrino telescopes.



Matthias Volk obtained his MSc degree from the University of Copenhagen with a project on one-point functions in a defect ver-sion of the AdS/CFT correspondence. With his supervisors Charlotte Kristjansen and Jacob Bourjaily he is now working on topics related to integrability and scattering amplitudes in conformal field theories.

Laurie Walk obtained her masters at the Theoretical High Energy Physics group at Lund University. Her project focused on model building in Grand Unification Theory. In October of 2017, she began her PhD in the Astroparticle Physics group at NBIA, under the supervision of Irene Tamborra. Laurie's PhD research has focused on identifying neutrino properties from 3D core-collapse supernova simulations. Laurie has successfully defended her PhD thesis in January 2021. She now works in the research and development sector of a multinational tech company.

MSc Students

Alicia Astorga Elcarte — Particle Physics

ltunbas Beydaş — Astroparticle Physics

Daniel Abdulla Bobruk — Astroparticle Physics

Jonathan Bödewadt — Astroparticle Physics

Marie Ernø-Møller— Particle Physics

Lasse Frederik-Boon — Biophysics

Arun Krishna Ganesan — Astroparticle Physics

Marie Cornelius Hansen — Astroparticle Physics

Katharina Hauer — Particle Physics

Jitze Hoogeveen — Particle Physics

Gustav Uhre Jacobsen — Particle Physics

Youyou Li — Astroparticle Physics

Zheng Ma — Cosmology

Kjartan Másson — Astroparticle Physics

Roger Morales — Particle Physics

Marie-Louise Riis — Astroparticle Physics

Lila Sarfati — Astroparticle Physics

Garðar Sigurðarson — Astroparticle Physics

Salik Ahmad Sultan — Biophysics

Rasmus Strid — Particle Physics

Edwin Vargas — Particle Physics

Anna Louise Juul Willumsen — Particle Physics

Adjuncts & Associates

Oliver Gressel — Theoretical Astrophysics (AIP, Potsdam, Germany)

Åke Nordlund — Computational Astrophysics (NBI and Rosseland Center, Oslo, Norway)

Igor Novikov — Theoretical Astrophysics (Lebedev Physics Institute, Moscow, Russia)

Subodh Patil — Particle Physics and Cosmology (Leiden University, The Netherlands)

Jørgen Rasmussen — Mathematical Physics (University of Queensland, Australia)

Meng Ru Wu — Particle Astrophysics (Institute of Physic, Academia Sinica, Taipei, Taiwan)

Administrative Staff

Jane Elvekjær is NBIA administrative officer. She is responsible for the organization of schools and workshops, secretarial support, visa applications, and budget allocation. She has a Master of Law from Århus University.

Financial Officers: During 2021, NBIA members received assistance in all matters related to budgets in applications and grants by Aida Coric, Ljiljana Markovic, and Mina Martinez-Diaz in the finance team at the Niels Bohr Institute.

Student Assistants: During 2021, students Marie Ernø-Møller and Rasmus Strid assisted the NBIA administrative officer run daily NBIA activities.

Visitors

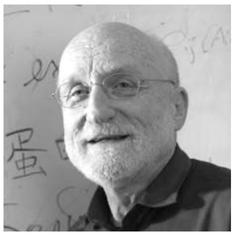
The NBIA maintains a vigorous visitor program, which usually attracts anywhere from 50 to 100 scientists every year. These visitors actively engage in daily activities at the NBIA and the Niels Bohr Institute. Needless to say, the calendar year 2021 was highly unusual in this respect, with fewer-than-usual visitors able to travel to Copenhagen.

Name	Affiliation	Arrival	Departure
G. Farrar	NY Univ.	02.12.21	09.12.21
D. Fiorillo	Univ. of Napoli	21.11.21	23.11.21
G. Baym	Illinois	10.11.21	14.12.21
A. Serenelli	CSIC	01.11.21	05.11.21
M. Murrell	Yale	23.10.21	30.10.21
O. Gressel	AIP	11.10.21	15.10.21
J. Kopp	CERN	07.10.21	08.10.21
P. Serpico	LAPTh	07.10.21	10.10.21
O. Schlotterer	Univ. of Uppsala	27.09.21	29.09.21
A. Serenelli	CSIC	13.09.21	24.09.21
R. Hoppe	MPIA Heidelberg	06.09.21	06.10.21
P. Eitner	MPIA Heidelberg	06.09.21	06.10.21
C. Sander	Dana Farber Cancer Institute	31.08.21	08.09.21
D. Marks	Harvard Medical School	31.08.21	08.09.21
L. Zwick	Univ. of Zürich	05.09.21	10.09.21
K. Bering	Masaryk Univ.	08.08.21	22.08.21
C. Combet	LPSC Grenoble	18.08.21	25.08.21
D. Maurin	LPSC Grenoble	18.08.21	25.08.21
H.J. Munch	University of Padua	09.08.21	31.08.21
K. Bering	Masaryk Univ.	08.08.21	22.08.21
Z. Marka	Columbia Univ.	03.08.21	04.08.21
J.B. Kanner	LIGO Caltech	01.08.21	07.08.21
M. Bergemann	MPIA Heidelberg	01.08.21	31.07.22
J. Andrews	Northwestern Univ.	31.07.21	07.08.21
J. Randrup	Berkeley	15.06.21	15.06.21

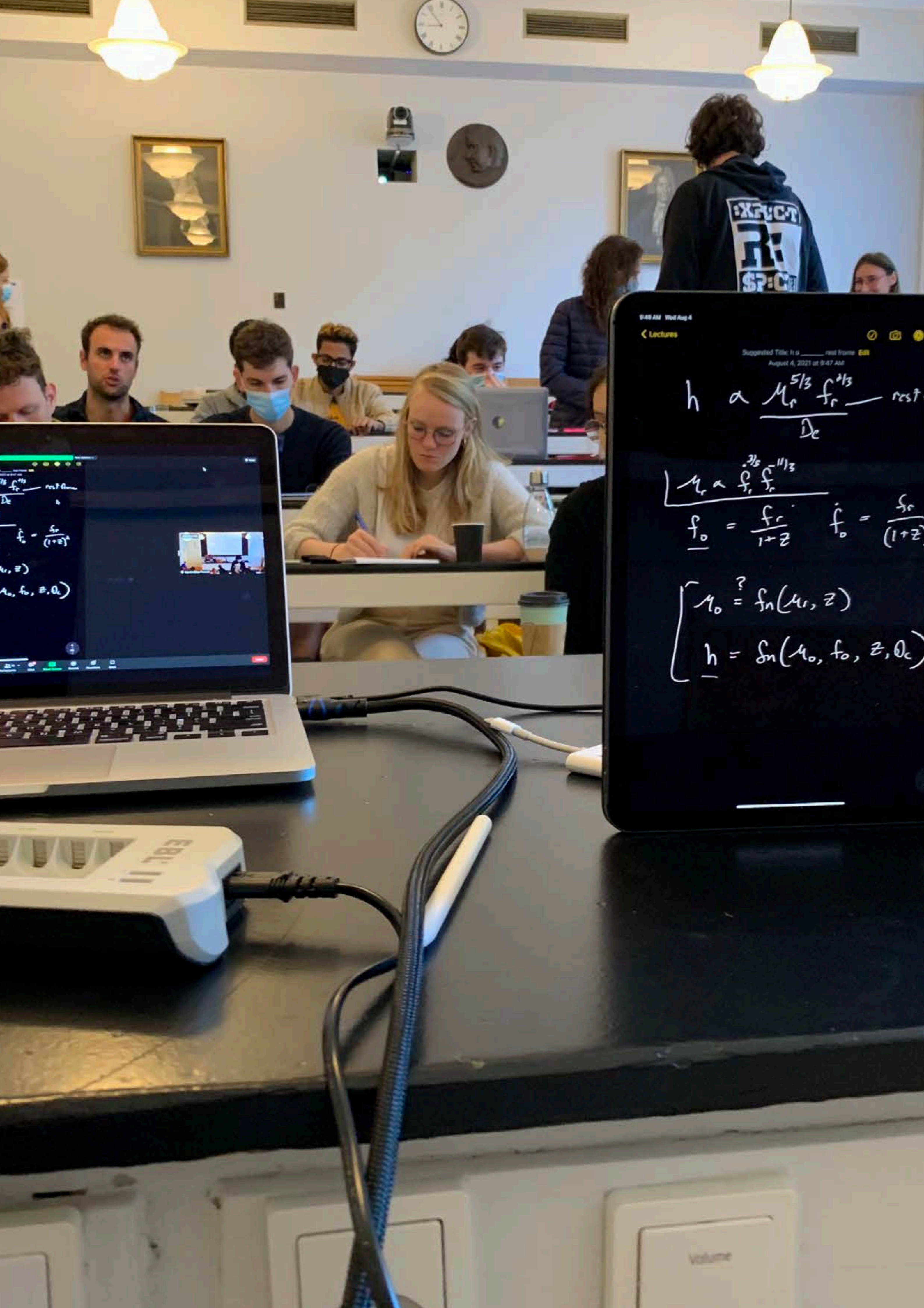
Visiting Professors

Maria Bergemann joins NBIA during the academic year 2021/2022 as SCIENCE Visiting Scholar at Copenhagen University. Maria Bergemann holds a prestigious position as "Lise Meitner Research Group Leader" at the Max Planck Institute for Astronomy in Heidelberg, Germany and she has recently been awarded an ERC Starting Grant for the project ELEMENTS, which will provide detailed abundances of elements representing all major processes of nucleosynthesis for over 300,000 stars in our galaxy. Maria Bergemann is a world expert in numerous areas of stellar astrophysics, including radiative transfer, spectroscopy, the origins of chemical elements, and Galactic archeology, that overlap with several groups at the Niels Bohr Institute, the Museum of Natural History, and the Globe Institute.

Debora Marks, a world-leading scientist and Associate Professor of Systems Biology at Harvard Medical School, returned 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.



Chris Sander from Harvard Medical School, Director of the cBio Center at the Dana-Farber Cancer Institute, returned this Fall to NBIA as Novo Nordisk Foundation Visiting Professor. Chris works on solutions to biological problems using methods of bioinformatics, statistical physics, data sciences, statistics, computer science, and mathematics.


Lectures
Volume

NBIA Activities


BÅDTEATRET

NBIA Simons Foundation Program

Based on a generous grant from the Simons Foundation in New York, NBIA has established a highly successful series of Simons Visiting Professorships and associated scientific programs built around these appointments. The program was launched in the fall of 2016 with first Simons Visiting Professor Viatcheslav "Slava" Mukhanov, Chair of Cosmology at the Arnold Sommerfeld Center for Theoretical Physics in Munich. It was in connection with that visiting professorship, and a high-profile workshop in August 2016, that the NBIA also brought Stephen Hawking to Denmark (for only the second time in Hawking's life). In 2017 the program continued with Simons Visiting Professor Steve Simon from Oxford who stayed at the NBIA in the spring of 2017. The subject concerned new topics in condensed matter physics, and the program included both a series of visiting scientists and two highly successful meetings, one of them organized jointly with Center for Quantum Devices (QDev) at the Niels Bohr Institute. In the fall of 2017, member of NBIA's Scientific Advisory Board Itamar Procaccia, Professor of Chemical Physics at the Weizmann Institute, was Simons Visiting Professor, helping organize two workshops. The first was on hot topics in the theory of turbulence, while the second focused on the physics of new materials and novel states of matter. The Simons Visiting Professors of the spring and fall of 2018 were Charles Bennett (IBM Fellow, IBM Research) and Oxford Professor Alex Schekochihin. Michael B. Green (Professor of Theoretical Physics at Cambridge University and Queen Mary University London) was Simons Visiting Professor during the spring of 2019 with a program largely focusing on amplitude calculations in string theory and field theory. The Simons Visiting Professors for the fall/spring of 2019/20 were Charles Bennett (IBM Fellow, IBM Research) and Paul Steinhardt (Albert Einstein Professor of Science, Princeton University). Because of the pandemic, activities have been postponed until 2022.

NBIA Colloquia

NBIA Colloquia consist of talks on a wide variety of subjects aimed at scientists who are not necessarily experts on the subject matter. Topics are not limited to physics but can cover any subject of interest to the wide spectrum of researchers and students at NBIA. In the past we have had talks on such varied topics as ancient DNA, the geological history of the Earth, the science of textile archeology, the theory of paintings from a science perspective, and many other fascinating topics. During 2021, the majority of the talks were delivered remotely. This was a challenge for the speakers but it was well worth the effort. The NBIA Colloquia was the only weekly institute-wide activity that remained uninterrupted in spite of the pandemic, reaching audiences of more than a hundred for the most attended talks. The NBIA Colloquia in 2021 are listed below. Remote talks are indicated with (R).

Maria Bergemann (MPI for Astronomy in Heidelberg & NBIA) — 12.11.2021
“All you wanted to know about stars but were afraid to ask”

Michael Murrell (Yale University) — 29.10.2021
“The Mechanics of Active Interfaces”

Sune Olander Rasmussen (NBI) — 18.06.2021 (R)
“Abrupt Climate Changes and Greenland Ice Cores”

Paul Chaikin (New York University) — 11.06.2021 (R)
“Artificial Life, Self-replication, Exponential growth, Directed evolution, Colloidal Architecture, DNA Activated Colloidal Machines”

Ramin Golestanian (Max Planck Institute) — 04.06.2021 (R)
“How living matter self-organizes while breaking action-reaction symmetry”

Holger Pedersen (NBI) — 28.05.2021 (R)
“The Krasnoyarsk meteorite: one or many?”

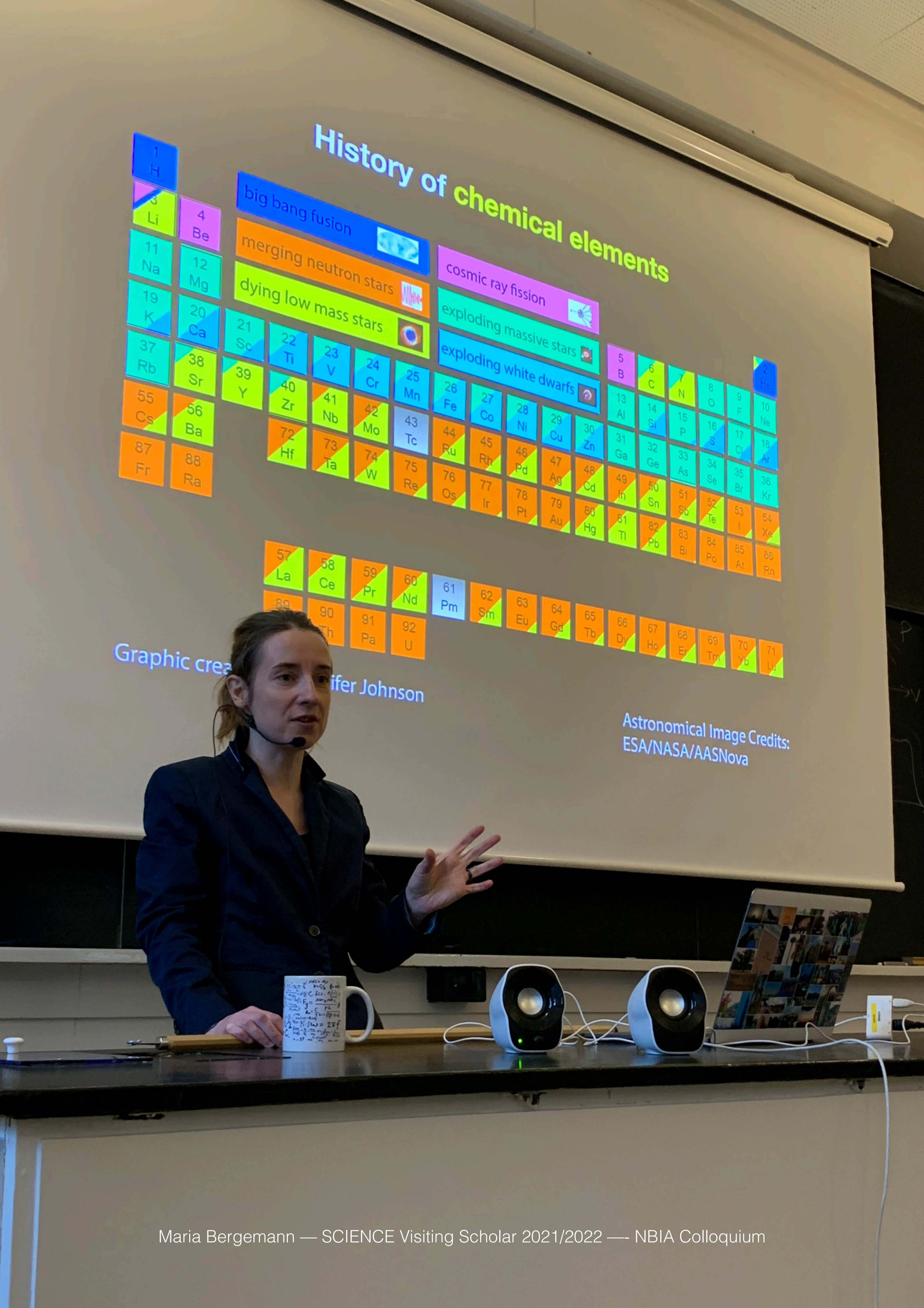
Thea Kølsen Fischer (Univ. of Copenhagen) — 21.05.2021 (R)
“SARS-CoV-2 Origin Tracing - key findings from first mission 'back to where it all started'.... ”

Daniel D'Orazio (NBIA) — 07.05.2021 (R)
“A Multi-messenger Exposé of the Biggest Black Hole Pairs in the Universe”

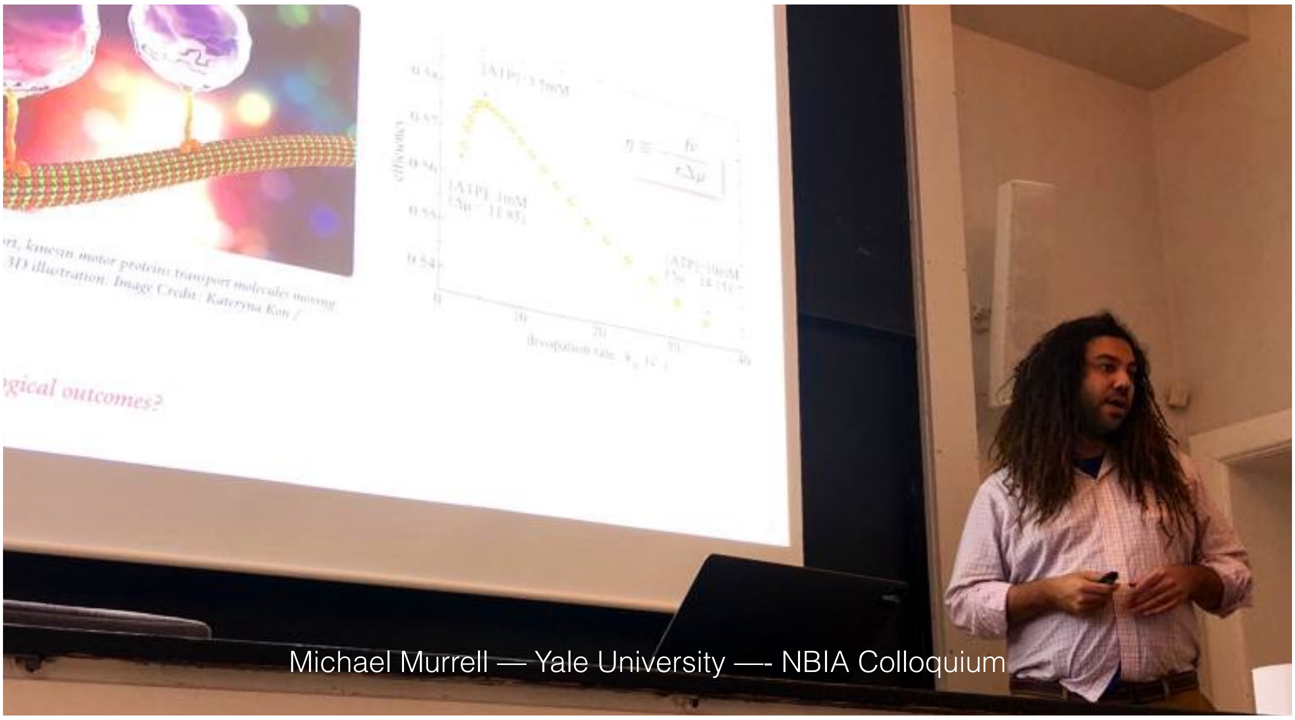
Volker Naulin (DTU, EUROfusion) — 23.04.2021 (R)
“Fusion energy, always 20 years away?”

Albert Schliesser (NBI) — 16.04.2021 (R)
“Mechanics at the Quantum Limit: Quantum Measurement and Control of Macroscopic Motion”

Francesca Rizzo — INTERACTIONS Fellow —- INTERACTIONS Fellows' Day 2021



Maria Bergemann — SCIENCE Visiting Scholar 2021/2022 —- NBIA Colloquium



Michael Murrell — Yale University —- NBIA Colloquium

Jeffrey Hangst (Univ. Aarhus and CERN) — 09.04.2021 (R)
"Illuminating Antimatter: the ALPHA antihydrogen experiment at CERN"

Gordon Baym (University of Illinois, Champaign-Urbana) — 26.03.2021 (R)
"Neutron stars & matter under extreme conditions: from Copenhagen to the Golden Age"

Michèle Levi (NBIA) — 19.03.2021 (R)
"Effective Field Theories and Gravitational Waves"

Itamar Procaccia (Weizmann Institute) — 12.03.2021 (R)
"Homer the Astronomer, or When did Odysseus Return Home"

Daan Frenkel (Cambridge University) — 05.03.2021 (R)
"Counting the Uncountable: Entropy, granular Entropy and Information"

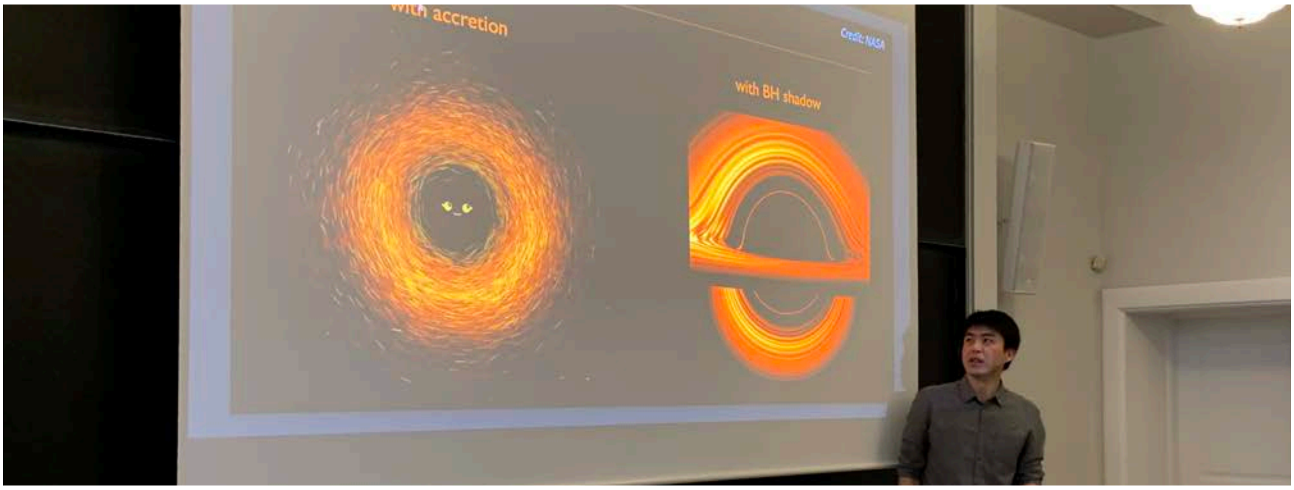
Ray Goldstein (Cambridge University) — 26.02.2021 (R)
"Stirring Tails of Evolution"

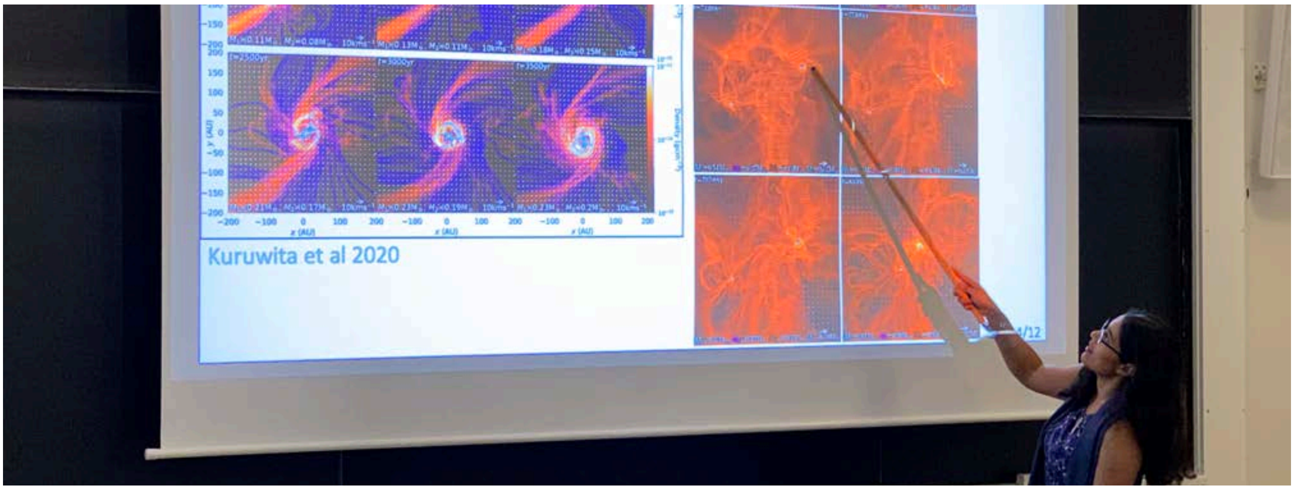
Renato Renner (ETH, Zurich) — 12.02.2021 (R)
"Testing quantum theory with thought experiments"

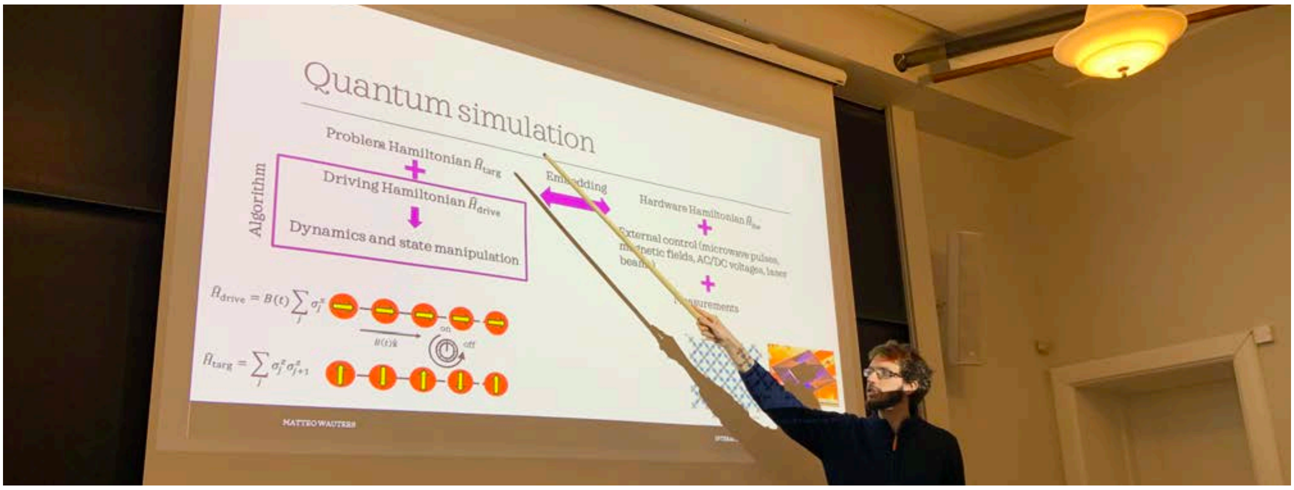
Brian Fields (University of Illinois, Champaign-Urbana) — 05.02.2021 (R)
"When Stars Attack! Near-Earth Supernova Explosions Revealed by Deep-Ocean and Lunar Radioactivity"

Roberta Sinatra (IT University of Copenhagen, ISI, and Complex Systems Hub) — 29.01.2021 (R)
"Quantifying the dynamics of impact in science and art"


(Postdoc)


accretion
Credit: NASA
with BH shadow

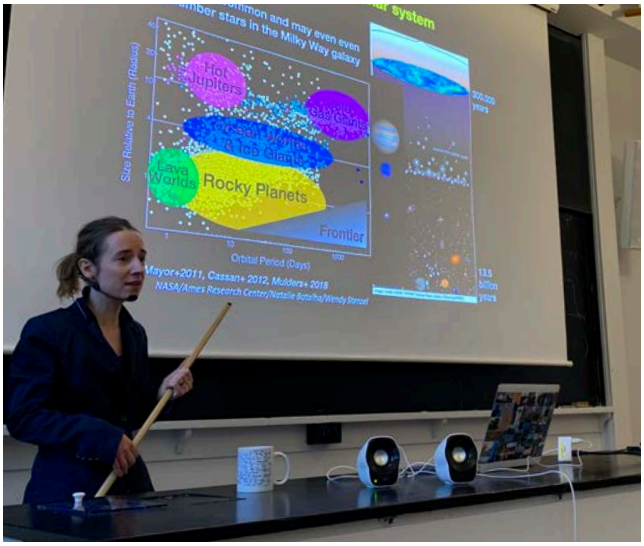

Kuruwita et al 2020

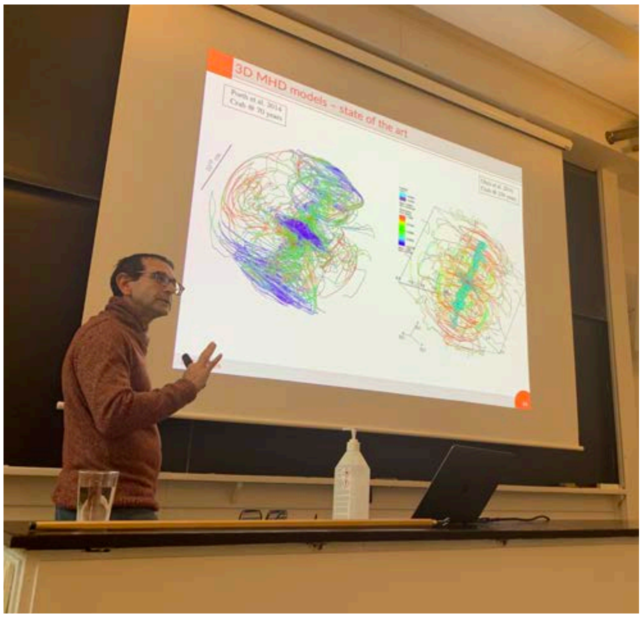

Quantum simulation
Algorithm
Driving Hamiltonian
Dynamics and state manipulation
MATTEO WAUTERS

NBIA Seminars & Talks

Apart from the weekly series of NBIA Colloquia, members of the NBIA organize or co-organize numerous more specialized seminars and lectures. Members of the particle theory group at the NBIA co-organize up to two specialized seminars every week, held by visitors to the group. In condensed matter physics there is a flurry of activities and seminars organized through the QDev Center of Excellence, to which NBIA's condensed matter physics group belongs. In astrophysics the talks co-hosted by members of the NBIA are often held together with the Center for Star and Planet Formation. Astroparticle physics talks are customarily held on Mondays, often partially overlapping in topics with both astrophysics and particle physics. On any given week, it will be rare to find a day in which not at least one scientific event is being organized or co-organized by NBIA members. Topics range from gravitational waves emitted from black holes merging to the intricate mathematical structures behind quantum field theory amplitudes at high orders in perturbation theory.

A special opportunity for attracting scientific visitors and thus creating a flow of seminar and colloquium speakers is the NBIA programs for Visiting Professors, which typically open up for the opportunity to focus on a particularly hot subject in an area of interest to the Visiting Professor. The group working on biological physics at the NBIA has its own program of talks and lectures, also in conjunction with the new Novo Nordisk Foundation Visiting Professor program.





Zsuzsa Marka — Columbia University —- NBIA Summer School on Gravitational Wave Astrophysics

NBIA Workshops & PhD Schools

Building on Niels Bohr's vision, NBIA members engage in several activities aimed at promoting and enhancing the traditions of internationalism, interdisciplinarity and excellence in physics. The NBIA is instrumental in running approximately ten high-profile, international events every year to the benefit of the wider Institute community. The following events were organized by NBIA members during 2021:

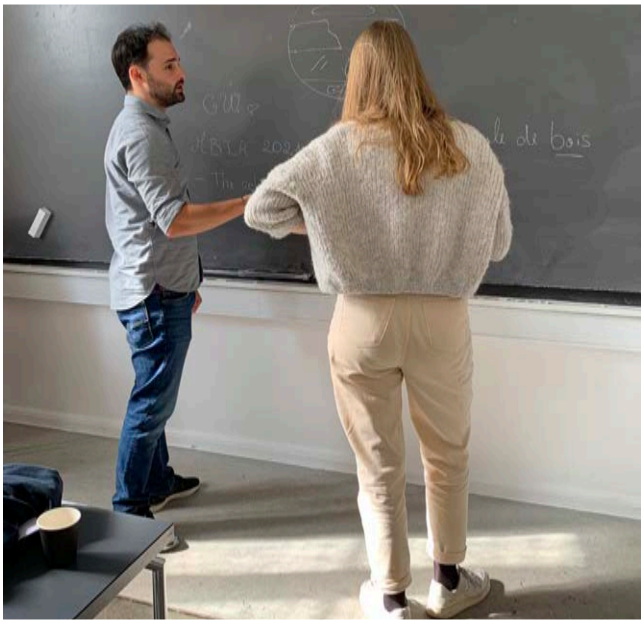
"Amplitudes 2021 International Conference" — 16.08 / 20.08.2021 (Virtual Workshop)

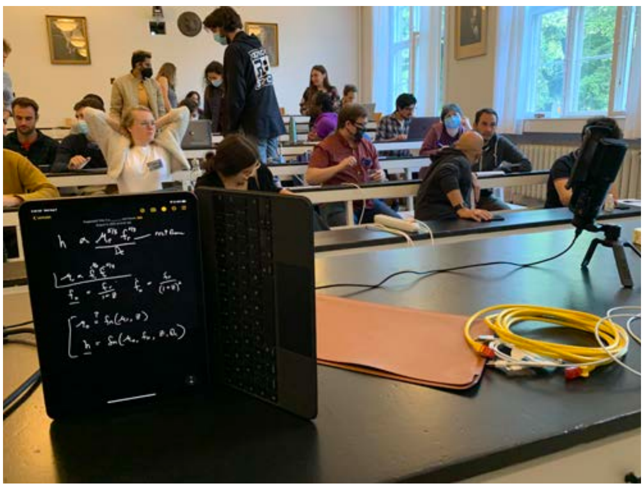
"SAGEX PhD-school on Amplitudes" — 09.08 / 13.08.2021 (Virtual School)

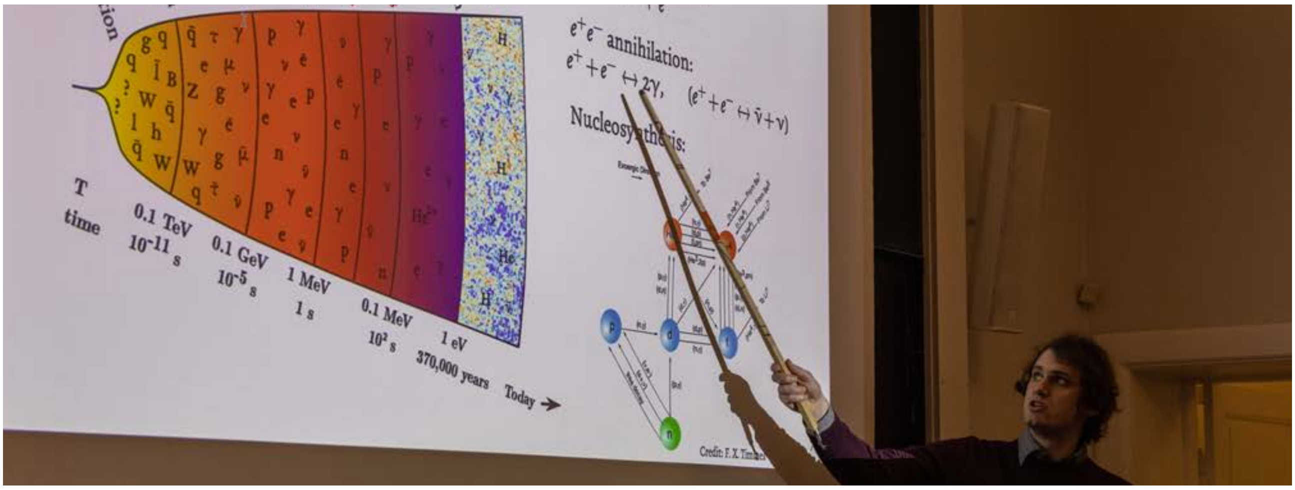
"NBIA Summer School on Gravitational-wave Astrophysics" — 02.08 / 06.08.2021

"NBIA Summer School: Neutrinos: Here, There & Everywhere" — 05.07 / 09.07.2021 (Virtual School)

"Simons Program: Forefronts of Cosmology and Gravitation" — 14.06 / 18.06.2021 (Postponed)

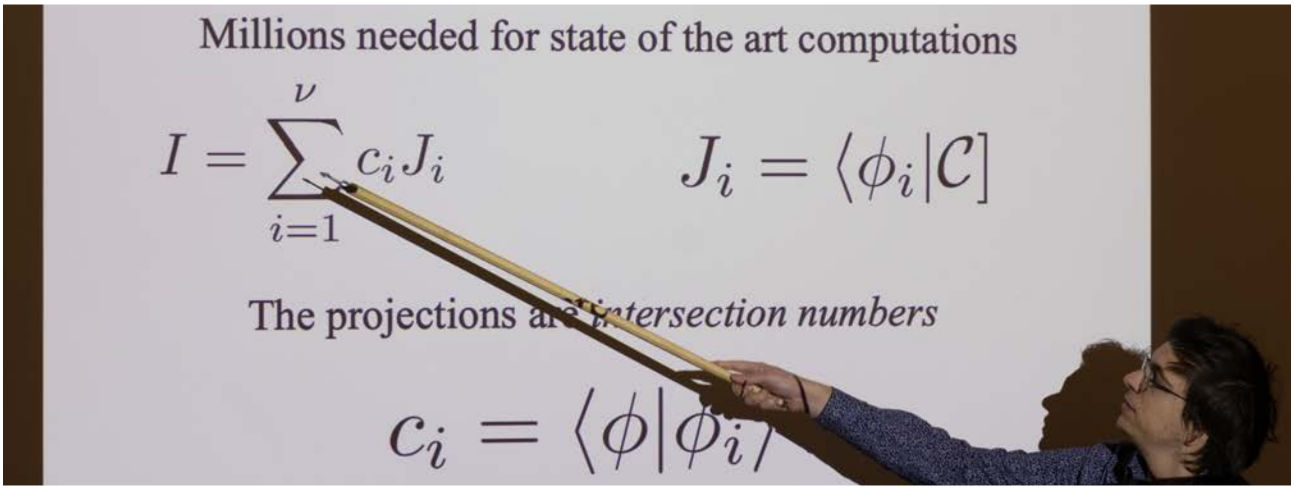




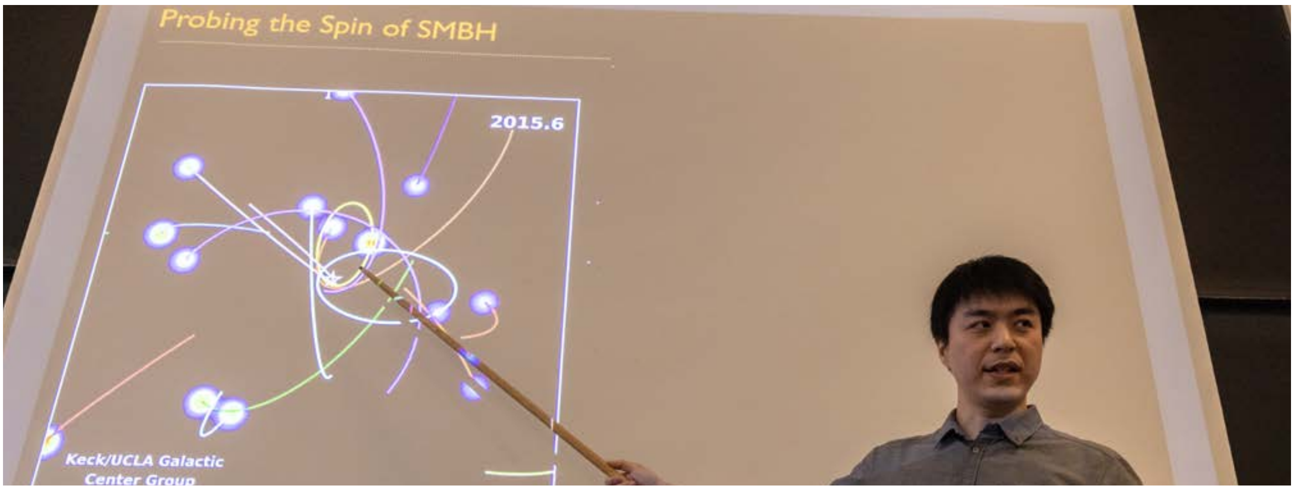


e+e- annihilation:
T
time
0.1 TeV
10-11 s
0.1 GeV
10-5 s
1 MeV
1 s
0.1 MeV
102 s
1 eV
370,000 years
Today

The Niels Bohr International Academy



Millions needed for state of the art computations
$I = \sum_{i=1}^{\nu} c_i J_i$
$J_i = \langle \phi_i | \mathcal{C}]$
The projections
intersection numbers



Probing the Spin of SMBH
2015.6
Keck/UCLA Galactic Center Group

INTERACTIONS Fellows' Day 2021

As the restrictions imposed by the pandemic started to relax, on December 1st, 2021, NBIA held the first of a series of "INTERACTIONS Fellows' Day". The meeting took place in the famous Auditorium A on Blegdamsvej 17. Fellows and mentors participated in a stimulating event that included scientific talks and an informative presentation about networking and transferable skills given by staff from SCIENCE. The Fellows had the opportunity to interact with each other during coffee breaks and a very tasty lunch.

NBIA MSc Day 2021

October 13, 2021
Niels Bohr Institute
Europe/Copenhagen timezone

Enter your search term

- Overview
- Program
- Research
- Registration
- Participant List
- NBIA Brochure

Contact

markus.ahlers@nbi.ku.dk
matthias.wilhelm@nbi.k...

NBIA MSc Day 2021

The Niels Bohr International Academy (NBIA) invites prospective MSc students to an informal event "MSc Projects @ NBIA" on **Wednesday, October 13, 9am-1:30pm**. Join us on that day to learn more about the diverse research program at NBIA. You will have the chance to chat with scientists about their research and the possibilities to carry out your MSc project at NBIA.

We ask you to please register if you are interested in attending in order to receive updates on the event agenda.

The NBIA is an independent center of excellence hosted by the Niels Bohr Institute. Our mission is to attract the best and the brightest to Denmark and provide the environment to enable breakthrough research in the physical sciences and mathematics, such as astroparticle physics, biophysics, condensed matter, quantum devices, particle physics, cosmology, and theoretical astrophysics.

You can find more information on our NBIA website and brochure.

The NBIA staff includes several Professors, some of which hold prestigious positions as Villum Kann Rasmussen and Niels Bohr Professorships. A significant number of NBIA Assistant Professors and Associate Professors have started new research groups in their disciplines by attracting prestigious national and European grants. The NBIA hosts a large number of post-docs, PhD-students, and MSc-students. We have a steady stream of international visitors, who are invited to give seminars or collaborate with NBIA members.

The NBIA hosts around ten workshops, symposia and PhD-schools every year. We also reach out to the public with a number of activities, including an annual series of public lectures in collaboration with the Danish Open University. All in all the NBIA offers an incredible stimulating environment for students!

Starts Oct 13, 2021, 9:00 AM
Ends Oct 13, 2021, 11:00 PM
Europe/Copenhagen

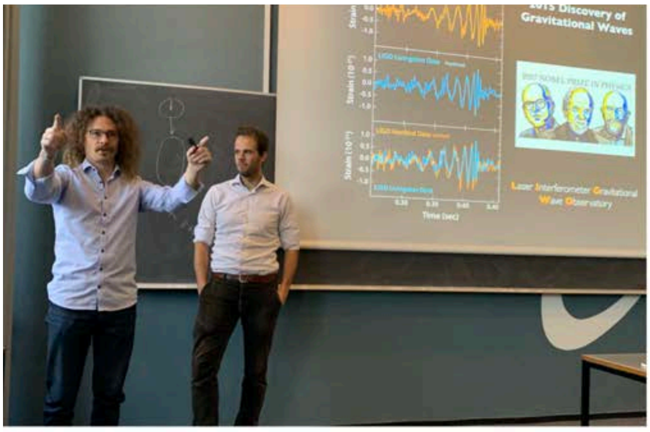
Niels Bohr Institute
Auditorium M
Blegdamsvej 17
DK-2100 Copenhagen

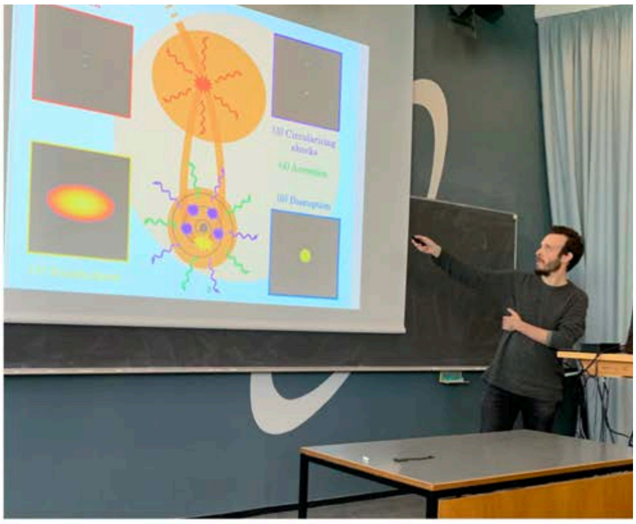
Markus Ahlers
Martin Pessah
Matthias Wilhelm
N. E. J Bjerrum-Bohr

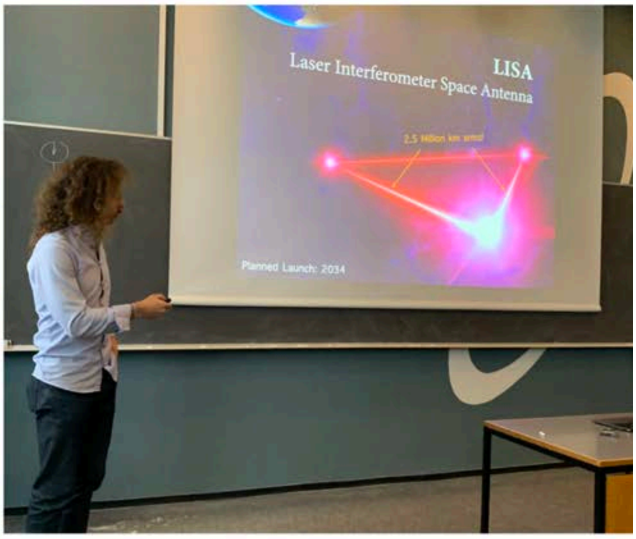
blegdamsvej_17.jpg
MScDay2021.pdf
nbia-brochure-2021.pdf

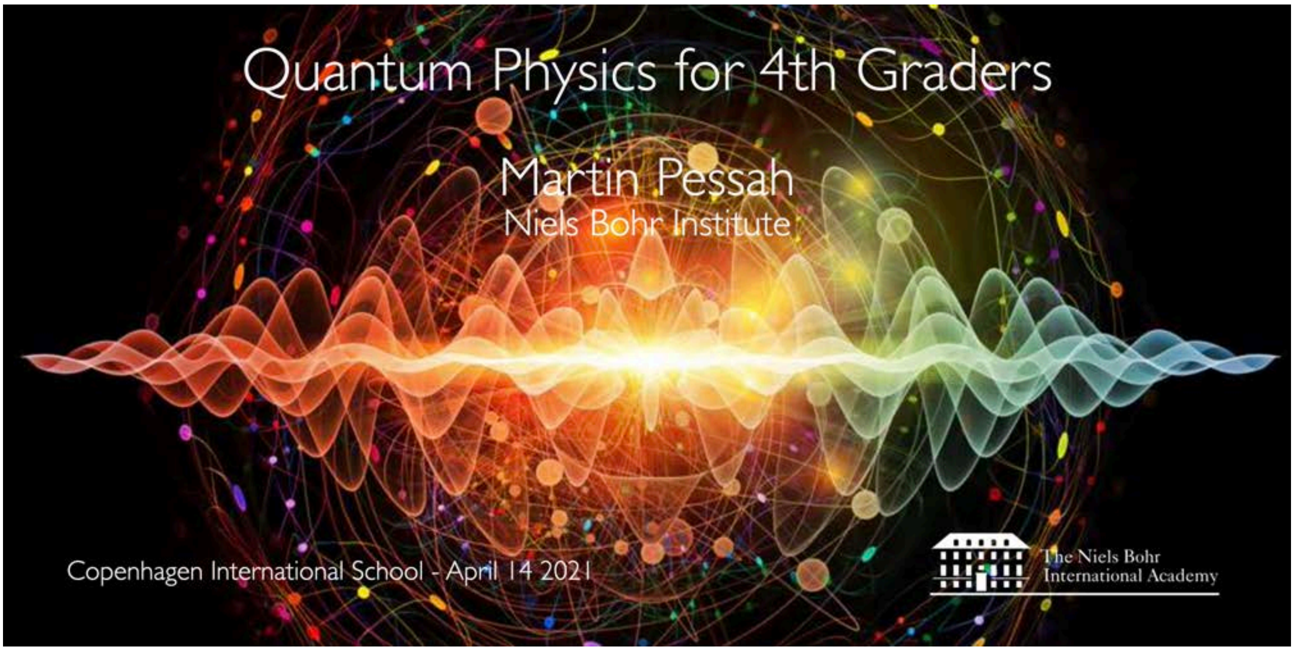
NBIA MSc Day 2021

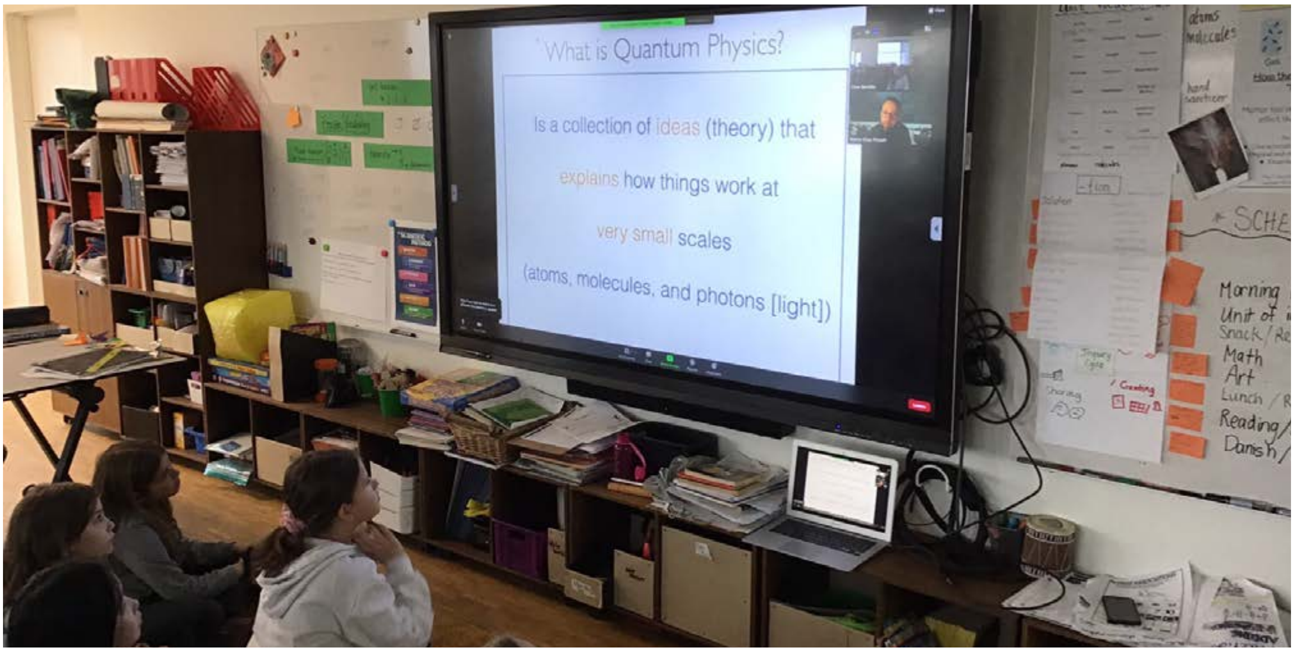
Starting in 2018, scientists at NBIA began organizing an annual gathering for MSc students for them to learn more about the diversity of research opportunities at NBIA. During this one-day event, the students have the opportunity to attend a series of talks and meet with postdocs and young faculty members in order to discuss their research interests and the possibilities of carrying out Masters projects at NBIA.

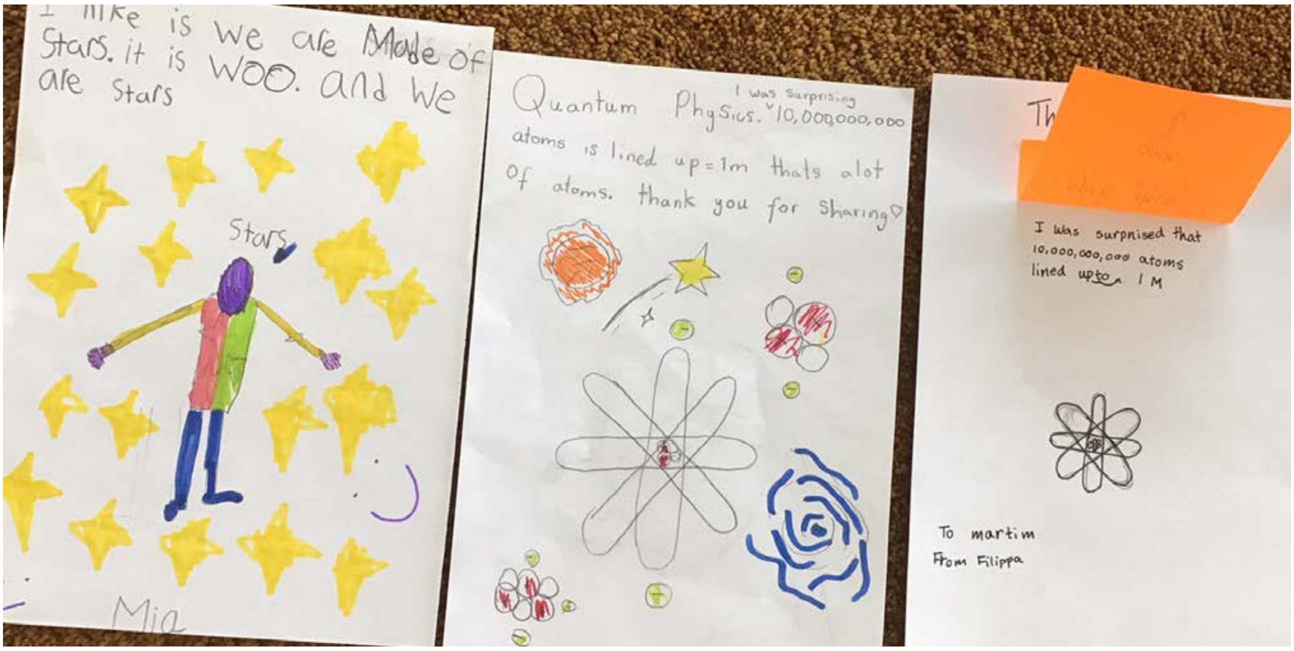







Quantum Physics for 4th Graders
Martin Pessah
Niels Bohr Institute
Copenhagen International School - April 14 2021
The Niels Bohr International Academy


What is Quantum Physics?
Is a collection of ideas (theory) that
explains how things work at
very small scales
(atoms, molecules, and photons [light])


is we are Made of Stars. it is WOO. and We are Stars
Stars
Mia
Quantum Physics. I was Surprising 10,000,000,000 atoms is lined up = 1m thats alot of atoms. thank you for sharing
I was surprised that 10,000,000,000 atoms lined up to 1 M
To martim
From Filippa

NBIA Public Lectures & Outreach

Since 2011 the NBIA has organized an annual series of public lectures on physics in collaboration with the Danish Open University "Folkeuniversitetet". All lectures take place at the historic Auditorium A. The idea was from the start to let the public benefit from the presence of young and enthusiastic scientists at the NBIA, each of them speaking about a topic very close to their actual on-going research, but at a level appropriate for an audience with no background in science. By design, these lectures would then cover a wide range of topics in modern theoretical physics, giving a glimpse of the questions, ideas and approaches that are now at the scientific forefront. This formula turned out to be a success, and although the subjects covered are at the forefront of present-day research, the attendance keeps increasing.

Noticing that several of the attendees who signed up came back year after year, the NBIA has introduced a Friends of the NBIA circle of interested and supportive laypeople who also receive the biannual Newsletter. As it develops and grows, the plan is to offer special opportunities for this group of people also beyond what they sign up for through the Open University. This year's lectures included:

Darach Watson (NBI) — 23.11.2021
"How we came to be: Origin of heavy elements in supernovae and colliding neutron stars"

Daniel D'Orazio (NBIA) — 16.11.2021
"When Black Holes Collide: the new Era of Gravitational Waves"

Chris Sander (Dana-Farber Cancer Center Institute and Harvard Medical School) — 09.11.2021
"Computational Models of Cell Biology Inspired by Physics"

Matt von Hippel (NBIA) — 02.11.2021
"The Unreasonable Effectiveness of Mathematics"

Maria Bergemann (Max Planck Institute for Astrophysics and NBIA) — 26.10.2021
"Everything You Always Wanted to Know About Stars But Were Afraid to Ask"

Outreach is not limited to this series of lectures. Scientists at the NBIA who speak Danish are often called upon for interviews in radio or TV, and some write in newspapers and Danish popular science journals on a regular basis. Likewise, popular talks are often given outside of the Copenhagen area, at public libraries or through local cultural organizations.

A most successful outreach activity for the youngest was initiated in 2019 by NBIA astrophysicists with the series "Astrophysics for 3rd Graders". An incipient tradition jointly organised with Copenhagen International School which caters to the most curious of all minds. In 2021, this series expanded to include the instantly successful "Quantum Physics for 4th Graders". When asked to reflect on (and draw!) the most interesting things they learned, several students chose to emphasise how fascinating they found learning that about 10,000,000,000 atoms can be lined up in 1 meter. Equally revealing was the realisation that we are all made of "star dust"!

Amin Doostmohammadi receives the prize from Lars Kann-Rasmussen

Katrine Krogh Andersen — Dean of SCIENCE

Jan Thomsen — Head of Niels Bohr Institute

Jan Thomsen, Katrine Krogh Andersen, Amin Doostmohammadi, Lars Kann-Rasmussen, and Poul Henrik Damgaard

Lars Kann-Rasmussen Prize

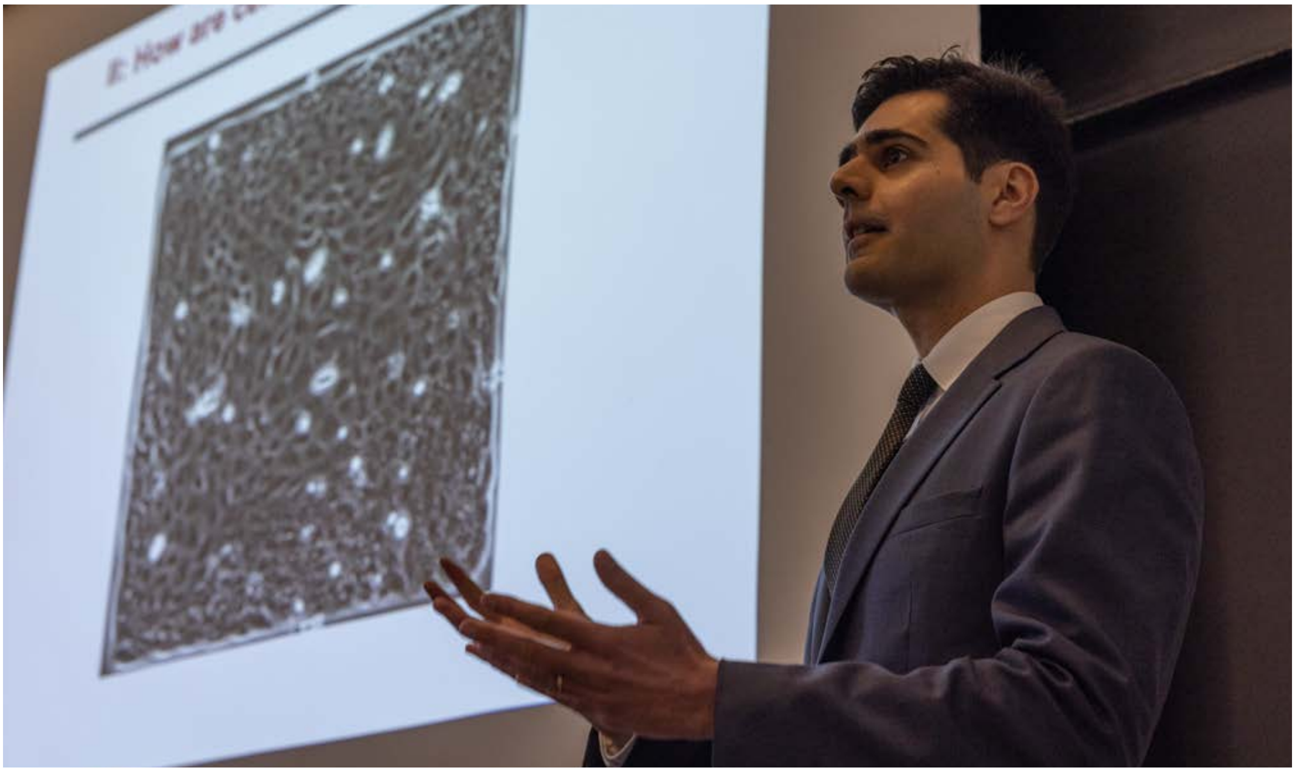
In 2021 NBIA inaugurated a new annual science award: the **Lars Kann-Rasmussen Prize.** This prize will be given every year to a young scientist, who has made unique contributions to physics and related areas.

The first award, which comes with a personal prize of 25,000 Kr, was presented by former Chairman of NBIA's Director's Advisory Council Lars Kann-Rasmussen, in whose honor the Prize has been established, to NBIA Assistant Professor Amin Doostmohammadi at an official ceremony on December 2nd in Auditorium A on Blegdamsvej.

Amin Doostmohammadi received this first award for his pioneering work in the interdisciplinary field of biological physics, the precise citation being: "*For his fundamental and original contributions to the development of the field Active Matter by the application of physical laws to the understanding of life itself*".

Amin Doostmohammadi is leading and shaping a new field that lives on the interface of physics and biology and which has been given the name Active Matter. Briefly stated, the aim is to understand the physical mechanisms that turn chemical energy into motion in living matter. Amin Doostmohammadi works at the forefront of this new field using theoretical concepts from physics and mathematics (such as topology) and often in close collaborations with experimental scientists. At NBIA Amin Doostmohammadi has established a strong junior research group based on a Villum Young Investigator grant and, most recently, also a NERD grant from the Novo Nordisk Foundation. His work has attracted well-deserved attention and is likely to pave the way for further breakthroughs in the future.

Present at the ceremony was Dean of SCIENCE Katrine Krogh Andersen, and Head of Niels Bohr Institute Jan Thomsen. At the same event, a portrait of Lars Kann-Rasmussen made by renowned portrait-painter Mikael Melbye was unveiled.




UNDERSTANDING

NBIA Publications

Refereed Papers

1. **Extensive Lensing Survey of Optical and Near-infrared Dark Objects (El Sonido): HST H-faint Galaxies behind 101 Lensing Clusters**
Sun, Fengwu, Egami, Eiichi, Pérez-González, Pablo G. et al., 2021, ApJ, 922, 114 - ArXiv: 2109.01751

2. **Big Three Dragons: A [N II] 122 µmm Constraint and New Dust-continuum Detection of a z = 7.15 Bright Lyman-break Galaxy with ALMA**
Sugahara, Yuma, Inoue, Akio K., Hashimoto, Takuya et al., 2021, ApJ, 923, 5 - ArXiv: 2104.02201

3. **Populating the Black Hole Mass Gaps in Stellar Clusters: General Relations and Upper Limits**
Samsing, Johan, Hotokezaka, Kenta, 2021, ApJ, 923, 126 - ArXiv: 2006.09744

4. **Gravitational self-lensing in populations of massive black hole binaries**
Kelley, Luke Zoltan, D'Orazio, Daniel J., Di Stefano, Rosanne et al., 2021, MNRAS, 508, 2524-2536 - ArXiv: 2107.07522

5. **Subaru/FOCAS IFU revealed the metallicity gradient of a local extremely metal-poor galaxy**
Kashiwagi, Yuri, Inoue, Akio K., Isobe, Yuki et al., 2021, PASJ, 73, 1631-1637 - ArXiv: 2110.05030

6. **Detecting low-mass haloes with strong gravitational lensing I: the effect of data quality and lensing configuration**
Despali, Giulia, Vegetti, Simona, White, Simon D. M. et al., 2021, MNRAS - ArXiv: 2111.08718

7. **Gravitational Lensing and Wormhole Shadows**
Bugaev, M. A., Novikov, I. D., Repin, S. V. et al., 2021, Astronomy Reports, 65, 1185-1193 - ArXiv: 2106.03256

8. **Impact of massive binary star and cosmic evolution on gravitational wave observations I: black hole-neutron star mergers**
Broekgaarden, Floor S., Berger, Edo, Neijssel, Coenraad J. et al., 2021, MNRAS, 508, 5028-5063 - ArXiv: 2103.02608

9. **Activity-induced instabilities of brain organoids**
Kristian Thijssen, Guido L. A. Kusters, Amin Doostmohammadi et al., 2021, The European Physical Journal E, 44 - ArXiv: 2111.03121

10. **Dynamical properties of z 4.5 dusty star-forming galaxies and their connection with local early-type galaxies**
Rizzo, Francesca, Vegetti, Simona, Fraternali, Filippo et al., 2021, MNRAS, 507, 3952-3984 - ArXiv: 2102.05671

11. **The ALPINE-ALMA [C II] Survey: kinematic diversity and rotation in massive star-forming galaxies at z 4.4-5.9**
Jones, G. C., Vergani, D., Romano, M. et al., 2021, MNRAS, 507, 3540-3563 - ArXiv: 2104.03099

12. **Accurate dust temperature determination in a z = 7.13 galaxy**
Bakx, Tom J. L. C., Sommovigo, Laura, Carniani, Stefano et al., 2021, MNRAS, 508, L58-L63 - ArXiv: 2108.13479

13. **Topological van Hove singularities at phase transitions in Weyl metals**
Fontana, P., Burrello, M., Trombettoni, A. et al., 2021, Phys. Rev. B, 104, 195127 - ArXiv: 2106.05771

14. **Constraints on Weak Supernova Kicks from Observed Pulsar Velocities**
Willcox, Reinhold, M, el, Ilya et al., 2021, ApJ, 920, L37 - ArXiv: 2107.04251

15. **Fallback Supernova Assembly of Heavy Binary Neutron Stars and Light Black Hole-Neutron Star Pairs and the Common Stellar Ancestry of GW190425 and GW200115**
Vigna-Gomez, Alejandro, Schroeder, Sophie L. et al., 2021, ApJ, 920, L17 - ArXiv: 2106.12381

16. **The effect of active galactic nuclei on the cold interstellar medium in distant star-forming galaxies**
Valentino, F., Daddi, E., Puglisi, A. et al., 2021, A&A, 654, A165 - ArXiv: 2109.03842

17. **Obtaining efficient thermal engines from interacting Brownian particles under time dependent periodic drivings**
Mamede, Iago N., Harunari, Pedro E., Akasaki, Bruno A. N. et al., 2021, arXiv e-prints, arXiv:2110.09235 - ArXiv: 2110.09235

18. **Electrical Properties of Selective-Area-Grown Superconductor-Semiconductor Hybrid Structures on Silicon**
Hertel, A., Andersen, L. O., van Zanten, D. M. T. et al., 2021, Physical Review Applied, 16, 044015 - ArXiv: 2104.03621

19. **Quasiperiodic Floquet-Thouless Energy Pump**
Nathan, F., Ge, R., Gazit, S. et al., 2021, Phys. Rev. Lett., 127, 166804 - ArXiv: 2010.11485

20. **Physics of liquid crystals in cell biology**
Amin Doostmohammadi, Benoit Ladoux, 2021, Trends in Cell Biology - ArXiv: 2110.03207

21. **Gravitational waves as a probe of globular cluster formation and evolution**
Romero-Shaw, Isobel M., Kremer, Kyle, Lasky, Paul D. et al., 2021, MNRAS, 506, 2362-2372 - ArXiv: 2011.14541

22. **The ALPINE-ALMA [CII] survey. The contribution of major mergers to the galaxy mass assembly at z ~ 5**
Romano, M., Cassata, P., Morselli, L. et al., 2021, A&A, 653, A111 - ArXiv: 2107.10856

23. **Subaru High-z Exploration of Low-luminosity Quasars (SHELLQs). XIV. A Candidate Type II Quasar at z = 6.1292**
Onoue, Masafusa, Matsuoka, Yoshiki, Kashikawa, Nobunari et al., 2021, ApJ, 919, 61 - ArXiv: 2106.13807

24. **Relaxation-speed crossover in anharmonic potentials**
Meibohm, Jan, Forastiere, Danilo, Adeleke-Larodo, Tunrayo et al., 2021, Phys. Rev. E, 104, L032105 - ArXiv: 2107.07894

25. **EMPRESS. III. Morphology, Stellar Population, and Dynamics of Extremely Metal-poor Galaxies (EMPGs): Are EMPGs Local Analogs of High-z Young Galaxies?**
Isobe, Yuki, Ouchi, Masami, Kojima, Takashi et al., 2021, ApJ, 918, 54 - ArXiv: 2004.11444

26. **Using gravitational wave parallax to measure the Hubble parameter with pulsar timing arrays**
D'Orazio, Daniel J., Loeb, Abraham, 2021, Phys. Rev. D, 104, 063015 - ArXiv: 2009.06084

27. **The mass-ratio distribution of tertiary-induced binary black hole mergers**
Su, Yubo, Liu, Bin, Lai, Dong et al., 2021, MNRAS, 505, 3681-3697 - ArXiv: 2103.01963

28. **ALMA Lensing Cluster Survey: a strongly lensed multiply imaged dusty system at z ≥ 6**
Laporte, N., Zitrin, A., Ellis, R. S. et al., 2021, MNRAS, 505, 4838-4846 - ArXiv: 2101.01740

29. **ALMA Lensing Cluster Survey: A spectral stacking analysis of [C II] in lensed z ~ 6 galaxies**
Jolly, Jean-Baptiste, Knudsen, Kirsten, Laporte, Nicolas et al., 2021, A&A, 652, A128 - ArXiv: 2106.09085

30. **SpaceHub: A high-performance gravity integration toolkit for few-body problems in astrophysics**
Wang, Yi-Han, Leigh, Nathan W. C., Liu, Bin et al., 2021, MNRAS, 505, 1053-1070 - ArXiv: 2104.06413

31. **Chemically homogeneous evolution: a rapid population synthesis approach**
Riley, Jeff, M, el, Ilya et al., 2021, MNRAS, 505, 663-676 - ArXiv: 2010.00002

32. **Objectives of the Millimetron Space Observatory science program and technical capabilities of its realization**
Novikov, I. D., Likhachev, S. F., Shchekinov, Yu A. et al., 2021, Physics Uspekhi, 64, 386-419

33. **First light from tidal disruption events**
Bonnerot, Clément, Lu, Wenbin, Hopkins, Philip F. et al., 2021, MNRAS, 504, 4885-4905 - ArXiv: 2012.12271

34. **Suppressed heat conductivity in the intracluster medium: implications for the magneto-thermal instability**
Berlok, Thomas, Quataert, Eliot, Pessah, Martin E. et al., 2021, MNRAS, 504, 3435-3454 - ArXiv: 2007.00018

35. **Genome-wide mapping of human DNA replication by optical replication mapping supports a stochastic model of eukaryotic replication**
Weitao Wang, Kyle N. Klein, Karel Proesmans et al., 2021, Molecular Cell, 81, 2975–2988.e6 - ArXiv: https://www.biorxiv.org/content/10.1101/2020.08.24.263459v3

36. **Symmetries and conserved quantities of boundary time crystals in generalized spin models**
Piccitto, G., Wauters, M., Nori, F. et al., 2021, Phys. Rev. B, 104, 014307 - ArXiv: 2101.05710

37. **Spatiotemporal model of cellular mechanotransduction via Rho and {YAP}**
Javor K Novev, Mathias L Heltberg, Mogens H Jensen et al., 2021, Integrative Biology, 13, 197–209 ArXiv: 2011.08060

38. **Zeeman-driven parity transitions in an Andreev quantum dot**
Whiticar, A. M., Fornieri, A., Banerjee, A. et al., 2021, Phys. Rev. B, 103, 245308 - ArXiv: 2101.09706

39. **Closing of the induced gap in a hybrid superconductor-semiconductor nanowire**
Puglia, D., Martinez, E. A., Ménard, G. C. et al., 2021, Phys. Rev. B, 103, 235201 - ArXiv: 2006.01275

40. **Long chain sphingomyelin depletes cholesterol from the cytoplasmic leaflet in asymmetric lipid membranes**
Karlsen, Maria Lyngby, Bruhn, Dennis S., Pezeshkian, Weria et al., 2021, RSC Advances, 11, 22677-22682

41. **Subaru High-z Exploration of Low-luminosity Quasars (SHELLQs). XIII. Large-scale Feedback and Star Formation in a Low-luminosity Quasar at z = 7.07 on the Local Black Hole to Host Mass Relation**
Izumi, Takuma, Matsuoka, Yoshiki, Fujimoto, Seiji et al., 2021, ApJ, 914, 36 - ArXiv: 2104.05738

42. **Orbital Evolution of Equal-mass Eccentric Binaries due to a Gas Disk: Eccentric Inspirals and Circular Outspirals**
D'Orazio, Daniel J., Duffell, Paul C., 2021, ApJ, 914, L21 - ArXiv: 2103.09251

43. **Multilevel effects in quantum dot based parity-to-charge conversion of Majorana box qubits**
Schulenborg, J., Burrello, M., Leijnse, M. et al., 2021, Phys. Rev. B, 103, 245407 - ArXiv: 2103.16958

44. **Searching for gravitational waves via Doppler tracking by future missions to Uranus and Neptune**
Soyuer, Deniz, Zwick, Lorenz, D'Orazio, Daniel J. et al., 2021, MNRAS, 503, L73-L79 - ArXiv: 2101.11975

45. **Magnetic-Field-Compatible Superconducting Transmon Qubit**
Kringhøj, A., Larsen, T. W., Erl et al., 2021, Physical Review Applied, 15, 054001 - ArXiv: 2101.05194

46. **EMPRESS. II. Highly Fe-enriched Metal-poor Galaxies with ~1.0 $(Fe/O)_{\odot}$ and 0.02 $(O/H)_{\odot}$: Possible Traces of Supermassive (300 $M_{\odot}$) Stars in Early Galaxies**
Kojima, Takashi, Ouchi, Masami, Rauch, Michael et al., 2021, ApJ, 913, 22 - ArXiv: 2006.03831

47. **Connecting X-ray nuclear winds with galaxy-scale ionised outflows in two z ~ 1.5 lensed quasars**
Tozzi, G., Cresci, G., Marasco, A. et al., 2021, A&A, 648, A99 - ArXiv: 2102.07789

48. **SILVERRUSH X: Machine Learning-aided Selection of 9318 LAEs at z = 2.2, 3.3, 4.9, 5.7, 6.6, and 7.0 from the HSC SSP and CHORUS Survey Data**
Ono, Yoshiaki, Itoh, Ryohei, Shibuya, Takatoshi et al., 2021, ApJ, 911, 78 - ArXiv: 2104.02177

49. **Hierarchical black hole mergers in multiple systems: constrain the formation of GW190412-, GW190814-, and GW190521-like events**
Liu, Bin, Lai, Dong, 2021, MNRAS, 502, 2049-2064 - ArXiv: 2009.10068

50. **ALMA Lensing Cluster Survey: Bright [C II] 158 μm Lines from a Multiply Imaged Sub-L^* Galaxy at z = 6.0719**
Fujimoto, Seiji, Oguri, Masamune, Brammer, Gabriel et al., 2021, ApJ, 911, 99 - ArXiv: 2101.01937

51. **Creasing of flexible membranes at vanishing tension**
Pezeshkian, Weria, Ipsen, John H., 2021, Phys. Rev. E, 103, L041001

52. **Activity pulses induce spontaneous flow reversals in viscoelastic environments**
Emmanuel L. C. VI M. Plan, Julia M. Yeomans, Amin Doostmohammadi et al., 2021, Journal of The Royal Society Interface, 18 - ArXiv: 2102.03309

53. **The Evolution of the IR Luminosity Function and Dust-obscured Star Formation over the Past 13 Billion Years**
Zavala, J. A., Casey, C. M., Manning, S. M. et al., 2021, ApJ, 909, 165 - ArXiv: 2101.04734

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