The Niels Bohr International Academy

Annual Report 2020

The Niels Bohr International Academy

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Table of Contents

The Academy 5

NBIA Governance 6
From the Director 8
From the Chairman of the Board 9
Novo Nordisk Foundation Grant 10
Louis-Hansen Foundation Grant 11
Husman Foundation Grant 12
INTERACTIONS - EU COFUND 13

NBIA Research 15

Theoretical Particle Physics 16
Particle Astrophysics 18
Theoretical Astrophysics 20
Condensed Matter Physics 22
Soft Matter Physics & Active Matter 24

NBIA Staff 27

Faculty 28
Junior Faculty 34
Postdoctoral Fellows 38
PhD & MSc Students 44
Adjunct & Associates 48
Visiting Professors 48
Visitors 50
Administrative Staff 51

NBIA Activities 53

NBIA Simons Foundation Program 55
NBIA Colloquia 56
NBIA Seminar & Talks 59
NBIA Workshops & PhD Schools 61
NBIA Public Lectures & Outreach 63
Distinctions 65

NBIA Publications 69


NIELS BOHR INSTITUTET
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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)
- **Andrew D. Jackson**, Niels Bohr Institute (Chairman)
- **Martin E. Pessah,** Niels Bohr Institute (Deputy Director)
- **David Gross**, KITP Santa Barbara
- **Charles Marcus**, Niels Bohr Institute
- **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:

- **Lars Kann-Rasmussen** (Chairman)
  Former CEO of the VELUX Group and Villum Foundation
- **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

When Nordita moved to Stockholm, some of its key staff chose to remain in Copenhagen, thus significantly contributing with intellectual strength and management skills in getting NBIA up and running in 2007. Most notably, Chris Pethick stayed with us, keeping on Blegdamsvej both a scientific authority and a curious mind about everything under the sky. Legendary Nordita Administrator Helle Kiilerich juggled two roles with now both (part of) Nordita and NBIA in her hands, establishing the tradition of can-do and minimal fuss: every problem solved, one way or another. But newly appointed Chairman of NBIA's International Science Advisory Board, Andrew Jackson, played a most central role in setting the standards and the style of NBIA: with profound knowledge of an extraordinary range of subjects much beyond science, with the quickest of minds, and with a wit of highest caliber. The combination of these elements provided the most fun and fertile atmosphere for young scientists to develop.

Over the years, many post-docs at NBIA have benefited from this lively environment. Historically, Niels Bohr was famous for cultivating such a culture of open, brilliant, and non-hierarchical discussions. In many famous cases it gave young scientists the freedom to develop their own, often wild, ideas — ready to be shot down if they did not hold water! It is only by totally disarming ourselves, and welcoming all critical questions, that we can make real progress in research. By insisting on this open and relaxed atmosphere, Andrew Jackson has made many young NBIA post-docs feel at ease and at home in a supportive, but also critical, research environment. Beyond being an invaluable pillar contributing to NBIA's daily life since the beginning, Andrew Jackson has played an equally important role as Chairman of NBIA's International Science Advisory Board: Always critically analyzing strategic matters, insisting on excellence as the primary goal. It is with enormous gratitude we think of his many contributions to NBIA over the years, and we thank him in particular for always taking the time to support and give advice to NBIA's young scientists. Towards the end of 2020 Andrew Jackson handed over the baton to new acting Chairman of the International Science Advisory Board, Charles Marcus, who is writing his own, first column in this Annual Report.

The year 2020 also marks the end of Lars Kann-Rasmussen's term as founding Chairman of the Director's Advisory Council. As former Chairman of the Villum Foundation, Lars Kann-Rasmussen had been involved in many important donations to the Niels Bohr Institute and we were delighted when he accepted to establish a Director's Advisory Board in parallel with the International Science Advisory Board. Members of the advisory council are chosen among prominent Danes who wish to help and support our efforts to build on the Niels Bohr legacy of open and world-leading research in the famous Blegdamsvej complex. Lars Kann-Rasmussen and the full council have played indispensable roles in all matters of strategic importance during his term as Chairman. We are immensely thankful to Lars Kann-Rasmussen for all his contributions to NBIA.

New Chairman of the Director's Advisory Council will be Peter Landrock, CEO of Cryptomatic. We are most grateful to both Peter Landrock and Charles Marcus for having accepted to step in and help NBIA move forward. With the end of the current pandemic in sight, we have reasons to hope that 2021 may bring NBIA back to that normal mode of operation we so strongly long for.

Poul Henrik Damgaard

From the Chairman of the Board

In the face of the global pandemic, it appears that salvation will not come from policy or personal discipline—where, to my American eyes, Denmark is a model for the world—but from science. Several points are relevant for NBIA. First, mRNA vaccines were made possible by basic research funding. It took 30 years of incremental progress and exploration of many dead ends to be ready. It is easy today to follow the branches, and tempting to wonder: couldn't we have followed the *right* branches, skipped all the wrong ones, and gotten to the end point more quickly? No, that's not how it works. We cannot look at the wealth of ideas in science, and say: let's streamline, let's take the right branches going forward. Science doesn't work that way. Second, the pandemic and vaccine have shown how neither crises nor solutions respect national borders. The "I" in "NBIA" is most important here. NBIA should lead the University and Denmark as an international gathering point for science. This is the great tradition of Bohr's institute, and one that should inform every step we take going forward. Third, observe how many scientific disciplines had a role in addressing the Covid Crisis: biology, of course, but also mathematics, computer science, fluid dynamics. What about gravity research? Quantum physics? Yup. Without general relativity and atomic clocks, GPS wouldn't exist, so no Smittestop. NBIA will need to evolve to reflect the intertwining of fields.

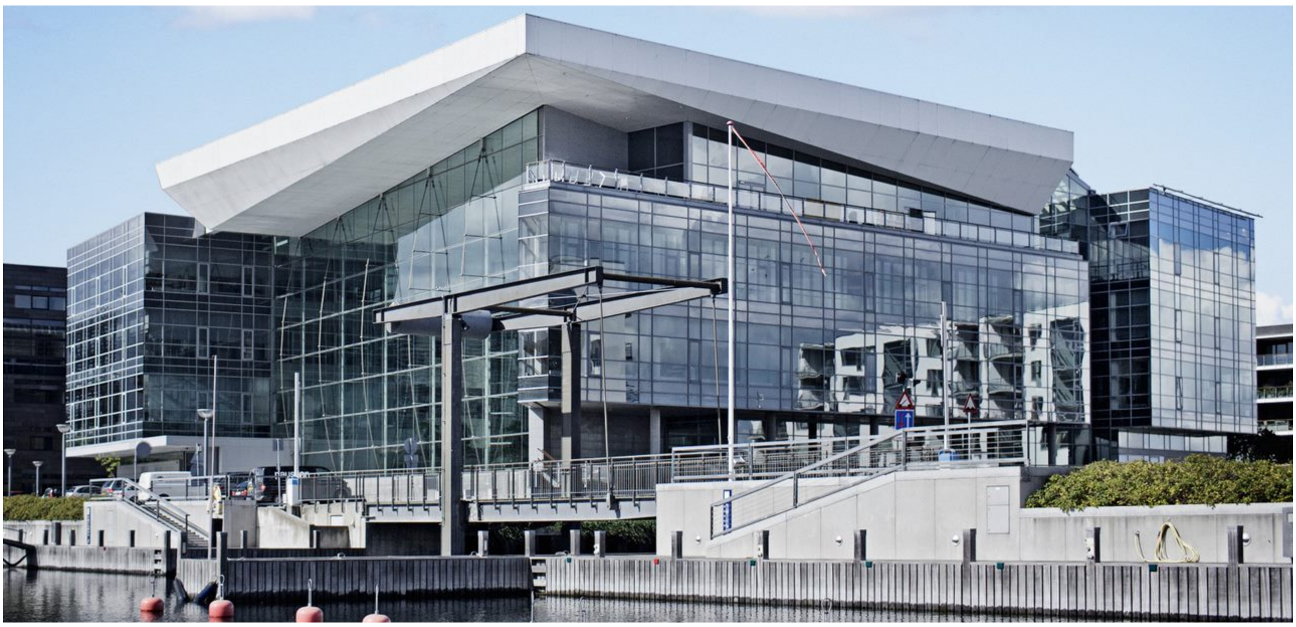
In 2020, a growing fraction of science funding is moving toward socially motivated targets, but we cannot neglect the need for basic exploration, particularly across fields, blind alleys and all. There is no other method. Legendary physicist and protege of Niels Bohr, Victor Weisskopf remarked: "The value of fundamental research does not lie only in the ideas it produces. There is more to it. It affects the whole intellectual life of a nation by determining its way of thinking and the standards by which actions and intellectual production are judged… Applied sciences and technology are forced to adjust themselves to the highest intellectual standards which are developed in the basic sciences".

I have accepted the position of acting Chair of NBIA's International Science Board from 2021 because I firmly believe in the mission of NBIA and because I recognize that it is time to take the next step: to establish a center of interdisciplinary science in the famous Blegdamsvej complex. In my own field of research, quantum physics, this place is sacred. But more importantly, the idea of an ''institute'' fostered by Niels Bohr reaches out far beyond current boundaries of scientific disciplines. Just as we today cannot even imagine tomorrow's new challenges, we also cannot imagine where the new revolutions will happen in science. We can see promising outlines, new connections between fields, new avenues opening up in existing fields, and the emergence of completely new directions. Some of these developments will likely fail or become important on much larger time scales, but some will blossom and revolutionize our lives. To keep Denmark on the forefront of developments, as it has proudly been in the past and is still today, we must insist on an open and unrestricted approach to science. Establishing a new interdisciplinary center for basic research on the premises of Niels Bohr's Institute for Theoretical Physics would be a most brilliant way to celebrate its centenary in 2021. I will help as much as I can towards achieving this goal.

Charles Marcus
Villum Kann Rasmussen Professor
Niels Bohr Institute

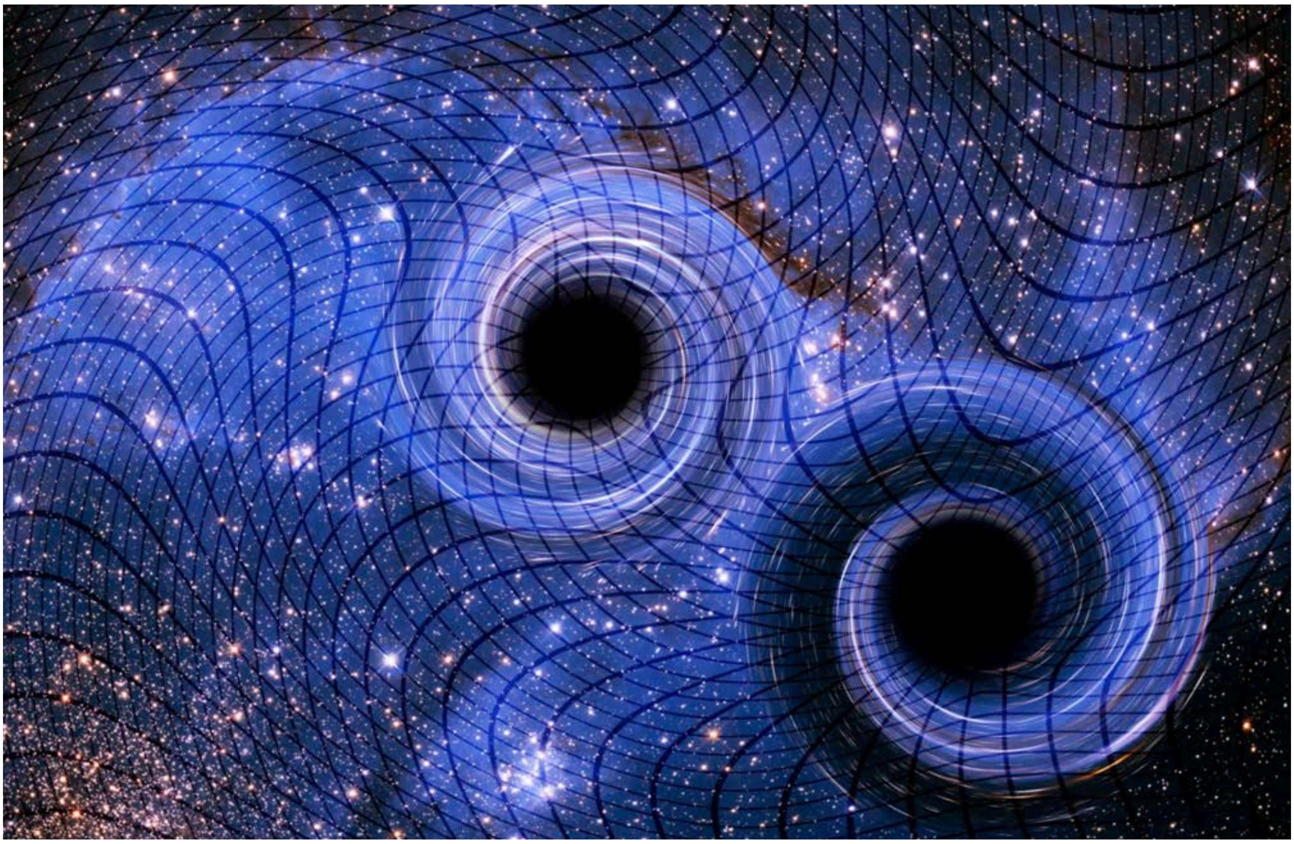
Novo Nordisk Foundation Grant

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 the 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 will provide the interdisciplinary atmosphere, the close contact with both theoretical physicists and mathematicians, and the steady flow of leading scientists that visit 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 personal Villum Young Investigator grant and support from Independent Research Fund Denmark he is now establishing his own junior research group. In the spring of 2020 he was joined for three months by Novo Nordisk Foundation Visiting Professor Julia Yeomans from Oxford. Later in the year, new Novo Nordisk Visiting Professors Debora Marks and Chris Sander from Department of Systems Biology and Dana-Farber Cancer Institute at Harvard University visited NBIA prior to their taking up longer visiting appointments in 2021. More appointments will be made as we identify outstanding candidates in the coming years.



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 noses 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 most important 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, and which is so important 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 the pandemic has put this program on hold in 2020, we expect it to take off in 2021. Husman Foundation Scholarships will be also awarded to collaboration partners of NBIA scientists in order to facilitate these scientific 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 and 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 scientist 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. Ten INTERACTIONS fellows have been employed under this program in 2020 and the second call for applications closed in late 2020. Relevant information can be found at http://nbia.nbi.ku.dk/interactions.

DANISH HEALTH AUTHORITY

corona | covid-19

Face masks must be worn

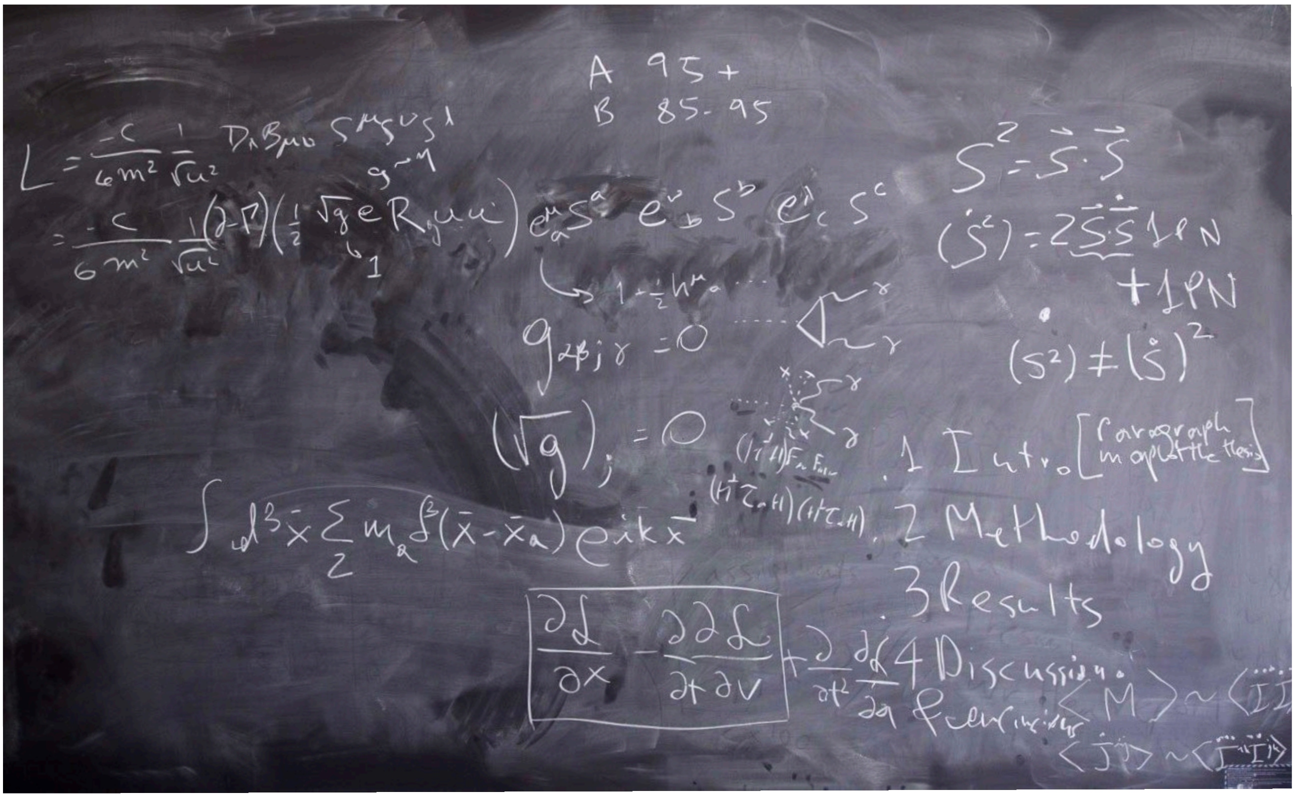
NBIA Research

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 completely 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 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 2020 the group has also become 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

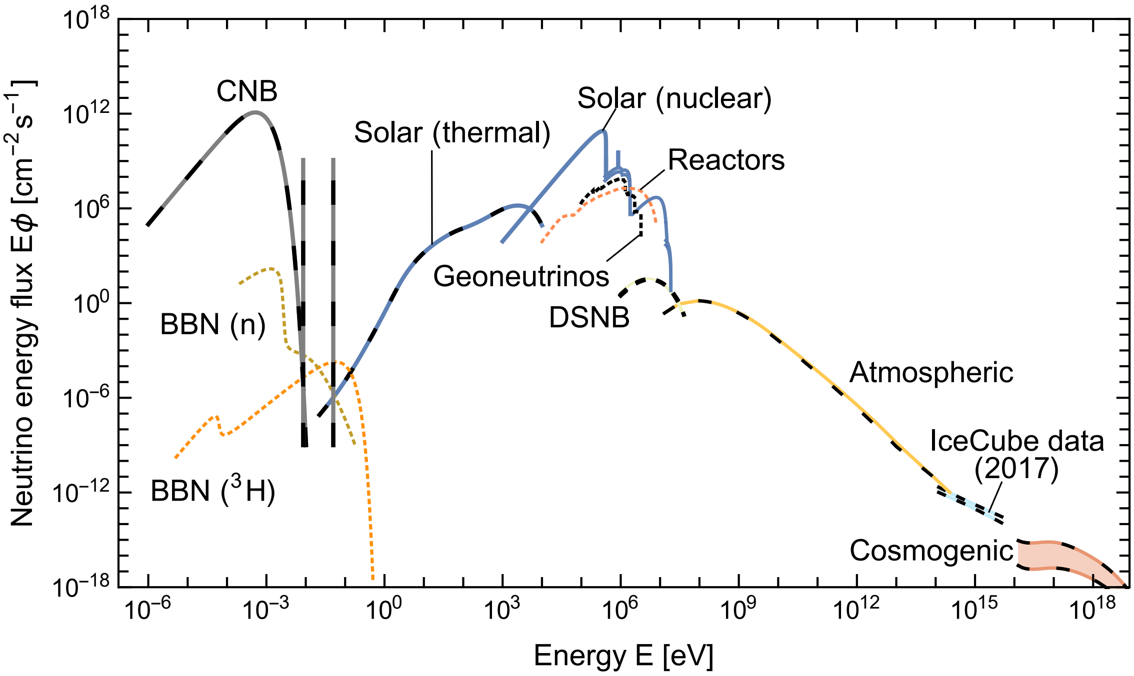
The research of the Particle Astrophysics Group lies at the rich interface between astrophysics, cosmology, and fundamental physics. We are particularly interested in exploring the Universe through cosmic rays (energetic charged particles), photons, neutrinos, and gravitational waves. The range of scientific 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, as shown in the summary plot below from a recent review from one of our Group members. We work to grasp the role of neutrinos in powering their sources, use as powerful probes of the hidden source interiors, and seek to unveil the fundamental properties of neutrinos from studying their interactions in dense environments and on cosmic backgrounds, and from their detection in neutrino telescopes.

In 2020, scientists in our group have maintained strong ties with researchers at the Max Planck Institutes for Physics and Astrophysics through the Collaborative Research Center sponsored by the Deutsche Forschungsgemeinschaft. Thanks to the partnership between NBIA and the Academia Sinica in Taiwan, we have continued to have active scientific collaborations with Dr. Wu (former postdoc at NBIA). We have also led part of the efforts of the Particle Physics Community Planning Exercise ("Snowmass") organized by the American Physical Society. In addition, we have been active in a number of outreach activities and run a successful seminar series.

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 developed the first multidimensional numerical modeling of the flavor evolution in compact astrophysical sources and in the early universe, moving beyond the limitations intrinsic to the analytical models adopted until now. For the first time, we have also 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.

Another research direction pursued in 2020 concerns the possibility of characterizing the properties of core-collapse supernovae through neutrinos and gravitational waves. For example, by employing three-dimensional hydrodynamical simulations of the core collapse, we have pointed out that neutrinos carry detectable imprints of the physics of stellar collapses in the instants preceding black hole formation.

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 sterile neutrinos with keV-mass (extra neutrino species currently considered dark matter candidates) and by non-standard scatterings of neutrinos among themselves and neutrinos on nucleons. Our research highlights the dramatic relevance of a self-consistent modeling of non-standard scenarios within the stellar core. 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.



Scientists in our group have also proposed a new concept for a neutrino observatory, the RES-NOVA project. RES-NOVA will hunt solar, atmospheric, and supernova neutrinos via coherent elastic neutrino-nucleus scattering using an array of archaeological lead-based cryogenic detectors. The high cross section of the target material and the ultra-high radiopurity of archaeological lead enable the operation of a high-statistics experiment with reduced detector dimensions in comparison with existing neutrino observatories and easy scalability to larger detector volumes.

Presently, the most sensitive neutrino telescope in the TeV-PeV energy range is the IceCube observatory at the South Pole. 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. Members of the NBI IceCube group have published in 2020 the results of an analysis studying neutrino emission from nearby galaxies. In addition, we have employed current data to constrain properties of the sources, such as their magnetic field. Our group was also involved in planning the next generation of neutrino telescopes: IceCube-Gen2, GRAND, POEMMA, and TAMBO. These will use different detection strategies to increase the statistics of TeV-PeV neutrinos and discover EeV cosmogenic neutrinos.

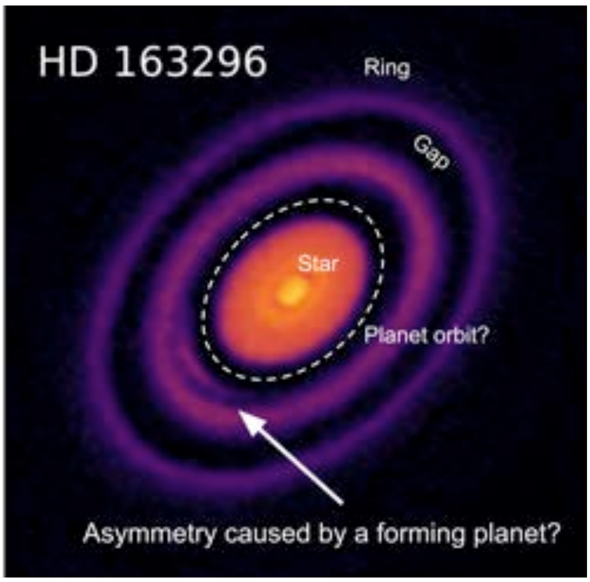
Recent precision measurements of cosmic rays allow to test the origin of cosmic rays and mechanisms of cosmic ray transport in Galactic and extragalactic environments. In particular, members of our group have used data from AMS-02 on board the International Space Station to constrain Galactic diffusion parameters. Our group was also part of an analysis studying the presence of local sources in the spectrum of ultra-high energy cosmic rays using recent data from the Pierre Auger Observatory. We were also active in the analysis and interpretation of weak anisotropies in cosmic ray arrival directions and are presently studying the effect of local magnetic turbulence on the large-scale anisotropy.

The Particle Astrophysics Group is also interested in observational features of dark matter – the mysterious form of matter that contributes about one quarter of the energy density in our Universe today. Primordial black holes produced in the early universe could account for a fraction of dark matter. Members of our group led an analysis that studied the prospects of primordial black hole capture in neutron stars and discovered a number of novel features with phenomenological consequences.

Theoretical Astrophysics

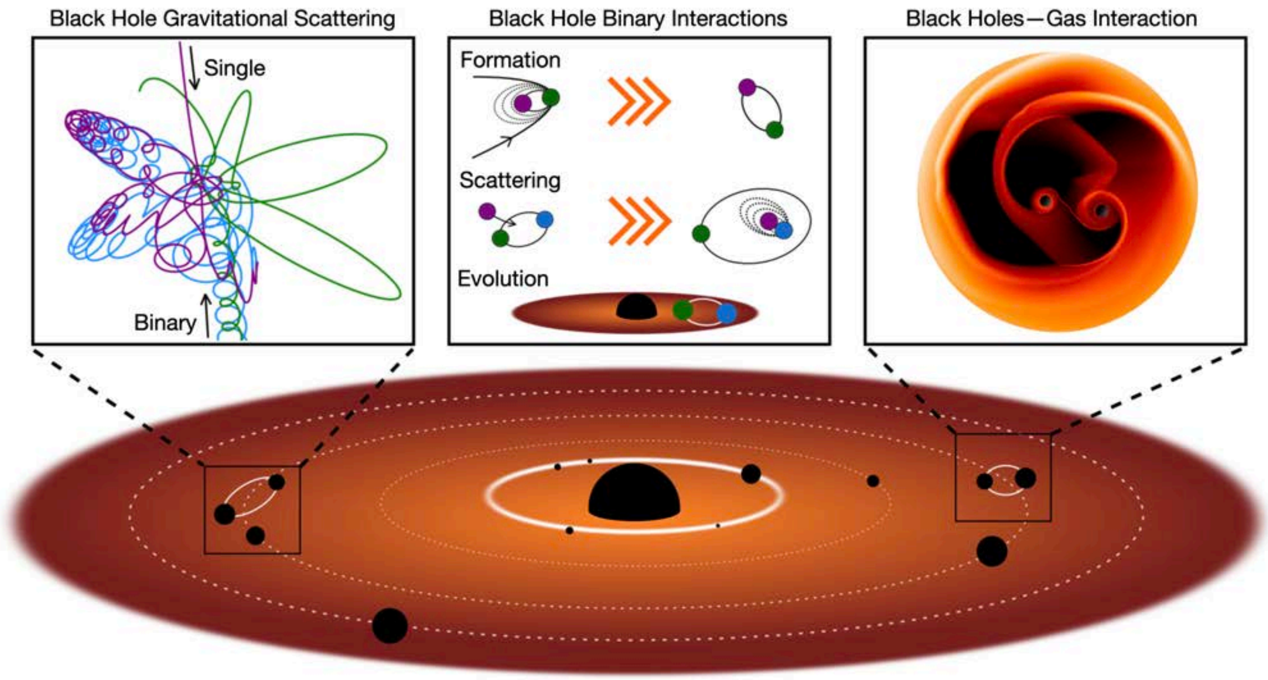
The Theoretical Astrophysics Group at the Niels Bohr International Academy strives for a comprehensive approach to astrophysics. Current research areas encompass protoplanetary disks and planet formation, black hole accretion disks, the physics of gravitational-wave sources, and the intracluster medium in galaxy clusters. 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. This scheme, combined with the recent "nested-meshes" feature in our numerical code will enable us to study the planet-disk interaction from a global disk down to the planetary atmosphere in an unprecedented way. This will allow us to accurately compute the disk-opacity and the impact of solid-accretion on the heating-rate of a planet, the latter being crucial for planet migration via the so-called thermal torques. Finally, given that dust-layers in disks can become quite dense, the disk self-gravity can become significant. We developed a framework to account for this effect and incorporated it into our numerical code. This will enable the self-consistent study of disk-instabilities that may be related to observational features of protoplanetary disks bringing us a step closer to connect theoretical models with observations.

We have continued advancing our understanding of turbulence in astrophysical plasmas. By performing and analyzing in novel ways a series of numerical simulations of differentially rotating plasmas we have shed light on the mechanisms that enable the sustenance of turbulence at low magnetic Prandtl numbers, relevant to protoplanetary disks. In the context of the intra-cluster



medium in galaxy clusters, we investigated the efficiency of the magnetothermal instability to drive turbulence when heat transport along magnetic field lines is reduced due to micro-scale plasma instabilities. Our study suggests that the nonlinear saturation of the magnetothermal instability is surprisingly robust.

Gravitational wave astrophysics has opened 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 ~50 stellar mass black hole mergers with many more to come in the near future. This has sparked a new research field with unique potential to gain insight into how black holes 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 on 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 mutual 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 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.

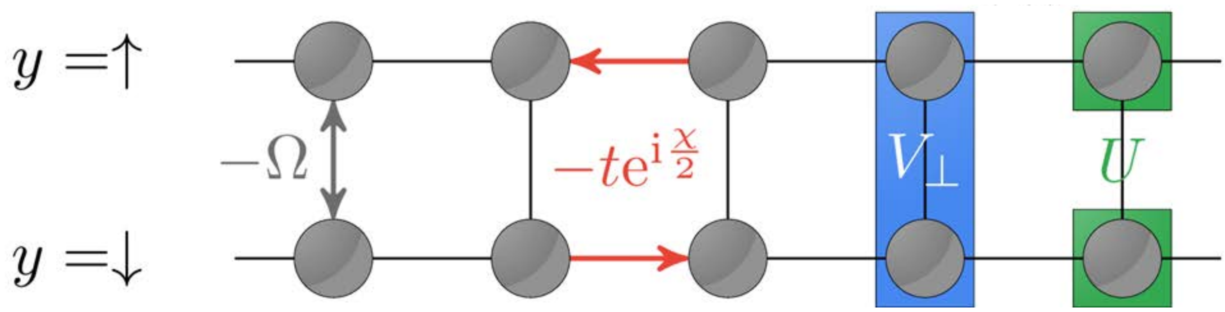
In the context of dense stellar systems, we have developed a unified kinetic theory of stellar systems in angle-action variables that bridges two previous complementary approaches: the Balescu-Lenard kinetic theory, relevant for two-body encounters, and quasilinear theory, appropriate for describing large-scale density waves. Our theory is a first step towards a comprehensive description of those stellar systems for which the previous approaches do not suffice, such as open clusters and galactic disks.

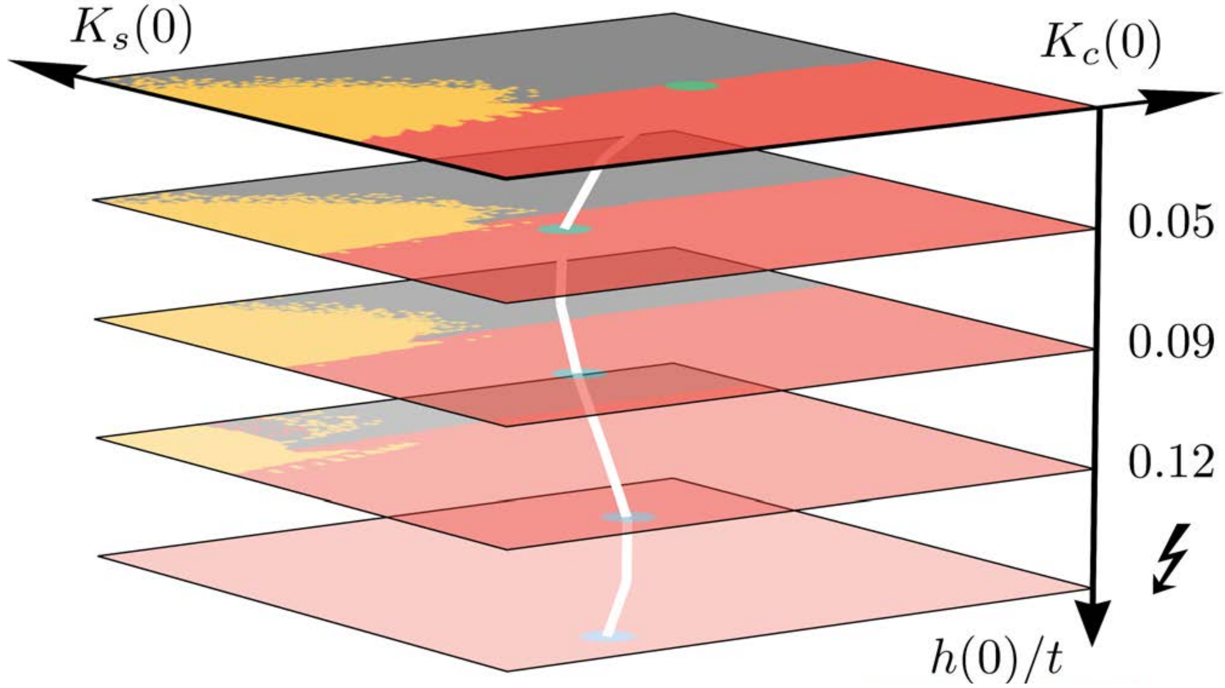
Condensed Matter Physics

In the condensed matter theory group at NBIA we aim to discover new quantum dynamical 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. We maintain close ties with experimentalists at the Center for Quantum Devices and Microsoft Station Q Copenhagen, as well as other groups worldwide.

Topological phenomena are the subject of intense interest in the field due to their incredible robustness against perturbations. A prominent example of such behavior 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 analogs 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, both in thermodynamic equilibrium and in dynamical steady states of systems driven far from equilibrium. 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.





One of the major aims of our research on quantum dynamics is to uncover new ways of dynamically engineering material properties through non-equilibrium driving. In particular, we are field leaders in the area of topological phenomena in periodically driven, or "Floquet" systems. Over the past 10-15 years, experimentalists have made great progress in developing new tools for probing and controlling the dynamics of solid state and cold atomic quantum many-body systems, e.g., using lasers and strong microwave fields. In our research we aim to bring together these new capabilities with modern theoretical notions of topological states, prethermalization, and many-body localization, to identify new routes for realizing and exploring topological phenomena out of equilibrium. The fruits of this work are two-fold: 1) time-periodic driving provides means to dynamically control the effective electronic structures of materials, potentially opening the opportunity to realize a variety of material properties on-demand, in a single system, and 2) by leaving the world of thermodynamic equilibrium (and the many constraints it imposes) behind, we find wholly new types of interesting and potentially useful robust quantum phenomena, which fundamentally can not occur in equilibrium. We have already uncovered a number of such phenomena, and continue to seek more, to study their properties, and to provide guidance to experimentalists to enable their realization in the lab. This work involves close collaborations with colleagues at Caltech, University of Geneva, Nanyang Technological University, Technion Institute of Technology, and the Weizmann Institute of Science.

Alongside and in conjunction with our efforts to discover novel phases of matter and quantum dynamical phenomena, 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 which 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 enhanced measurement and data processing capabilities. 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.

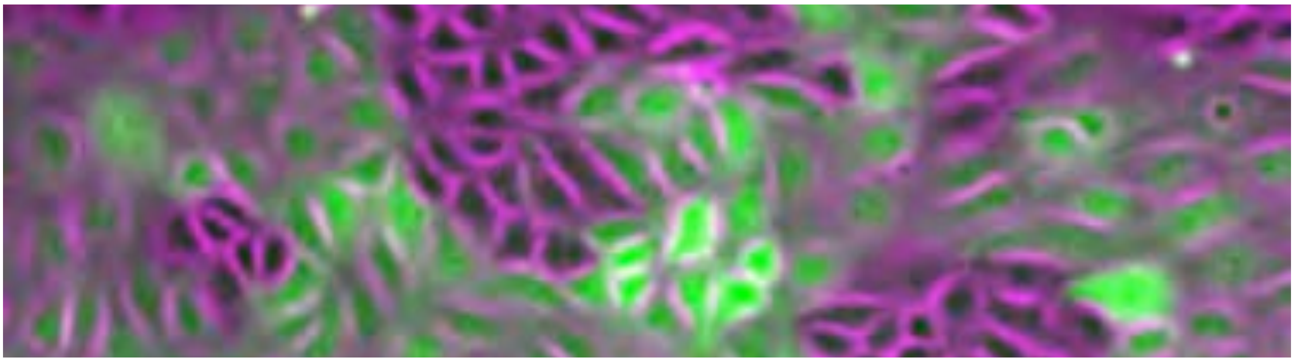
Soft Matter Physics & Active Matter

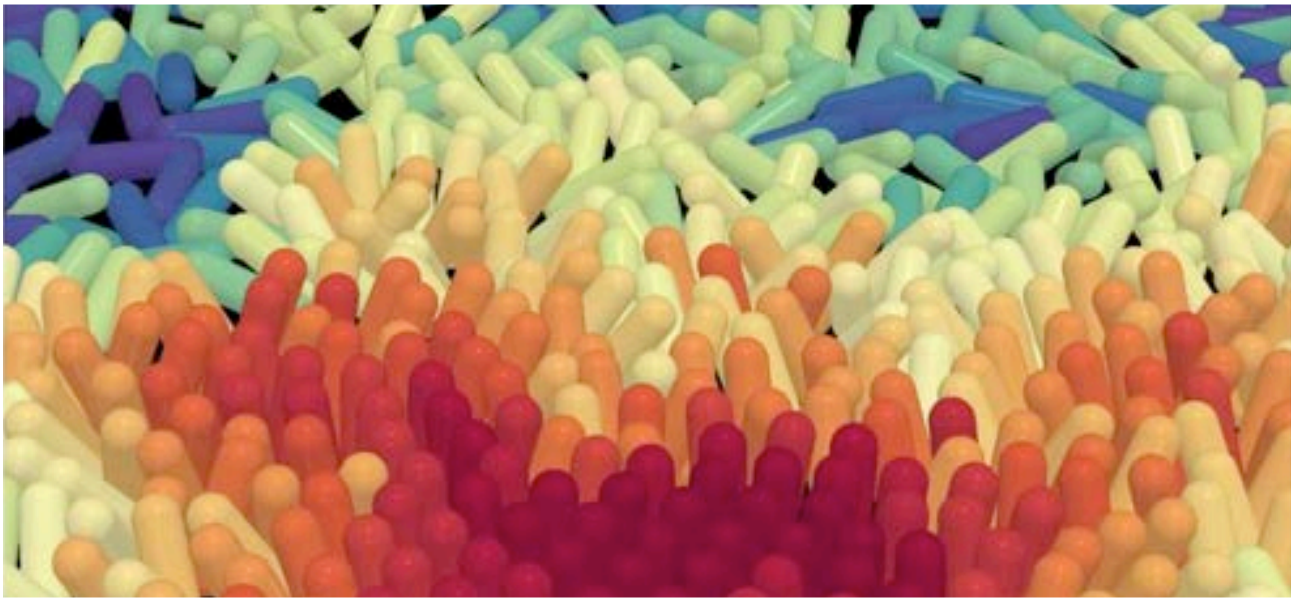
Soft matter physics lies at the heart of a quantitative understanding of many biological processes. From subcellular protein-driven flows to multicellular organ formation, biological matter continuously drives itself away from thermodynamic equilibrium using internal biochemical processes. In addition 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, the Active Intelligent Matter group at NBIA works on developing theoretical, computational and experimental methods in soft and biological active matter.

In particular, the group focuses on various strategies to tame, otherwise chaotic, active flows. It is a longstanding challenge to be able to control biological systems to perform specific tasks. Earlier this year, in collaboration with researchers in the United States and the United Kingdom, we found a way to control bacteria to transport microscopic cargos. Bacteria form the largest biomass in the world, larger than all the animals and plants combined, and they are constantly moving, but their movement is chaotic. We pursued the idea that if this motion can be controlled, we might be able to develop it into a biological tool. As such we used a liquid crystal to dictate the direction of the bacterial movement, and added a microscopic cargo for the bacteria to carry, more than 5 times the weight of the bacteria.

Another area of research within the soft matter physics and active matter group at NBIA is the study of topological defects in biological systems. The group has pioneered developing novel theoretical and computational tools to understand these singularities in the context of living systems. Very recent experimental realizations of topological defects in various biological systems has sparked a renewed interest in linking liquid crystal physics to mesoscale living fluids. Since the beginning of 2016, there have been reports on the important role of topological defects in a wide range of living systems from assemblies of motor protein/filaments as the mechanical building blocks of individual cells to stem cells and epithelial tissues. An outstanding challenge, however, is to design and control dynamically ordered structures of living topological defects.

This year, we uncovered a new form of topological defect structures in active matter: self-propelled defects can bind together in stable vortex-like and aster-like structures reminiscent of full-integer topological defects. Using numerical simulations and analytical arguments we explained the mechanism of this bound defect pair formation based on the intricate synergy between active flows and the response of particles to their self-generated flow gradients. We further provided a full phase-space that characterizes the formation of vortex- and aster-like stable topological defects. These findings show a promising direction towards the design and stabilization of active materials and challenge the current consensus that





monolayers of active nematics are characterized by collection of only half-integer defects. It should be feasible to look for these new structures in experiments on active systems such as microtubules driven by molecular motors, microswimmers or cell layers. The ability to induce stable full-integer defects will contribute to advancing the design of biomimetic materials and could stimulate new microfluidic experiments based on topological features of active matter.

Building on these theoretical and computational advances, the group has also recently reported a new biological functionality for topological defects: In collaboration with researchers in the United Kingdom, we combined genetics experiments, custom image analysis algorithms and theoretical physics to investigate the efficiency of the bacterial invasion, showing that fast-moving bacteria can get trapped in their self-made topological defects. How the competition between fast and slow moving bacteria determines their ability to invade and expand their territory is essential to pathological processes. Bacterial-induced infections and biofilm formation are often driven by motility of individual cells within an expanding colony. However, in order to expand their territory bacterial colonies translate these individual motilities into a collective motion, where groups of cells move together in coordination. The work showed that bacteria move slowly and prudently in order to avoid crashes and jams, making them capable of moving efficiently in dense and massive, multimillion population crowds. The result may have implications for how we treat infections in a future in which superbacteria, immune to antibiotics, pose a threat to human health.

In addition to the works on active matter, the group also focused on mechanobiology of cellular tissue, studying how cells in a tissue sense, adapt, and respond to mechanical forces from their environment. We have developed a parallel theory-computational, modeling-experiment framework to systematically address the process of cellular decision-making in response to mechanical forces. This is important since 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.

Finally, links with experiments are important in conducting these researches. We have launched exciting collaborations with international experimental groups in US (Caltech, Kent State, Penn State), UK (Oxford, Sheffield), France (University Paris Diderot), and Japan (Osaka University, Kyoto 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.

NBIA Staff

Faculty

Niels Emil J. Bjerrum-Bohr completed his Ph.D. in Copenhagen in 2004. He was 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 2006-09. 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 2010-14 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.

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, becoming 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.

Martin Pessah obtained 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 2007-10. In 2010, Martin moved to Copenhagen as a Knud Højgaard Assistant Professor at the NBIA. In 2012, he started to build a new group in Theoretical Astrophysics after receiving grants from the Villum Foundation and the European Research Council. He became Associate Professor in 2013 and Professor MSO in 2015 and is now leading an active, young group working at the forefront of theoretical and computational astrophysics. His research interests span a broad range of subjects in plasma astrophysics, astrophysical fluid dynamics and magnetohydrodynamics, including fundamental aspects of accretion physics in young stars and black holes, the interstellar medium, and galaxy clusters.

Enrico Ramirez-Ruiz has been Niels Bohr Professor at the DARK Center since 2016. He was educated at Cambridge University in England and was a long-term member at the Institute for Advanced Study in Princeton. Enrico Ramirez-Ruiz is currently Professor and Chair of the Department of Astronomy and Astrophysics at the University of California, Santa Cruz. He is also the Head of Theoretical Astrophysics at the Santa Cruz Institute for Particle Physics. His research seeks to address some of the pressing open questions surrounding the most violent phenomena in the Universe such as how stars explode as supernovae and the origin of Gamma-Ray Bursts; how stars end their lives and become compact objects such as white dwarfs, neutron stars, and black holes; how black holes grow in mass by ripping apart orbiting stars and swal-lowing the stellar debris; and what happens when two compact objects merge by emitting gravita-tional waves.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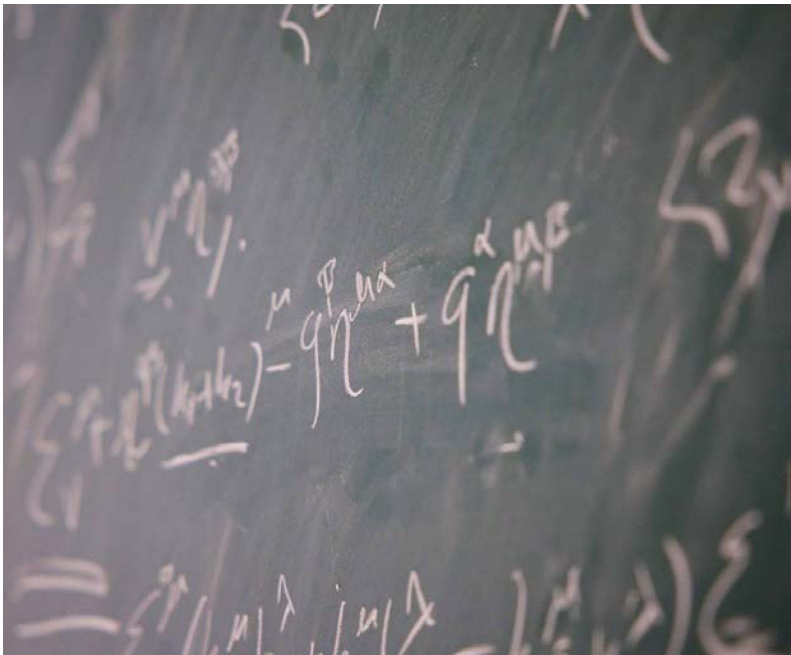

Mark Rudner is an Associate Professor at the NBIA. Mark received his PhD in Condensed Matter Theory from MIT in 2008. After his PhD, Mark spent three years as a postdoc at Harvard. In 2012 Mark landed in Copenhagen to lead the Condensed Matter Theory group at NBIA. Mark's group has been supported generously 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 main-tains strong links with the Center for Quantum Devices, with a healthy interplay between theory and experiment.

Irene Tamborra has been Knud Højgaard Associate Professor at the NBIA since 2016. Irene completed her Ph.D. at the University of Bari in 2011. Irene has held research appointments at the Max Planck for Physics in Munich, as 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. Irene is interested in exploring the role of weakly interacting particles, such as active and sterile neutrinos, in astrophysical environments. She also aims at unveiling what can be learnt from the observation of neutrinos from the most extreme but yet mysterious astrophysical transients occurring in our Universe, such as core-collapse supernovae, neutron star mergers and gamma-ray bursts. Irene leads the AstroNu group at NBIA with focus on these subjects.

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 is-sues 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.

Michael Trott is leading the particle physics phenomenology group and is an Associate Professor at the NBIA. Michael completed his Ph.D. at the University of Toronto in 2005 and later held research appointments at UC San Diego (2005-2008), Perimeter Institute (2008-2011) and CERN (2011-2014) before joining NBIA in the fall of 2014. Michael has broad and continuing research interests in the areas of Higgs physics, Beyond the Standard Model physics, collider phenomenology, Flavour physics and Neutrinos, as well as precision Standard Model calculations and even Cosmology. In pursuing research projects into all of these areas, the common unifying tool used is Effective Field Theory. Michael was awarded a Villum Young Investigator award in 2015.

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 in reformulating quantum field theory directly in terms of observables and the application of this idea to cosmology.

Michele Burrello joined the NBIA as Assistant Prof. in 2016. He received his PhD in statistical physics from SISSA (Trieste) in 2011 and then he worked as a postdoc in Leiden University (2011-13) and in the Max Planck Institute for Quantum Optics (2013-16). His main research focus is the study of topological phases of matter, their engineering and the possibility they offer for quantum computation. He works on different quantum many-body systems, ranging from ultracold atoms to topological superconductors and he is interested in the common theoretical framework underlying these 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, where he conducted research until joining 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 tools of the burgeoning era of multi-messenger astronomy for uncovering the origin of compact-object-binary sources of gravitational radiation, spanning the mass scale from neutron stars up 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 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 brings physics of liquid crystals into studying diverse biological problems. Currently the re-search 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 on Fall 2019 where she is leading the research in the group "Gravity from Particle Amplitudes".


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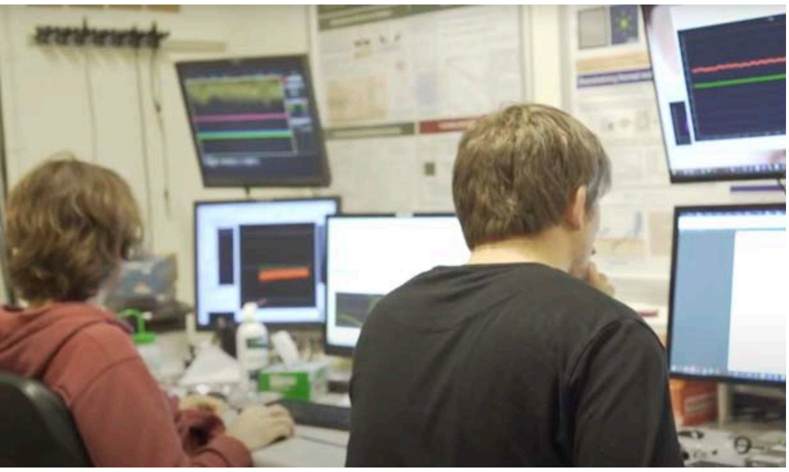

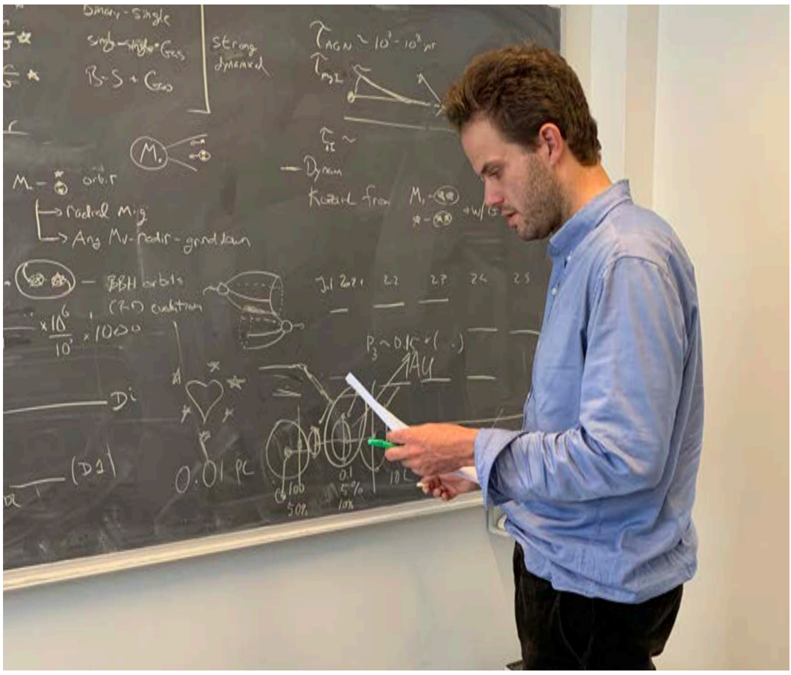

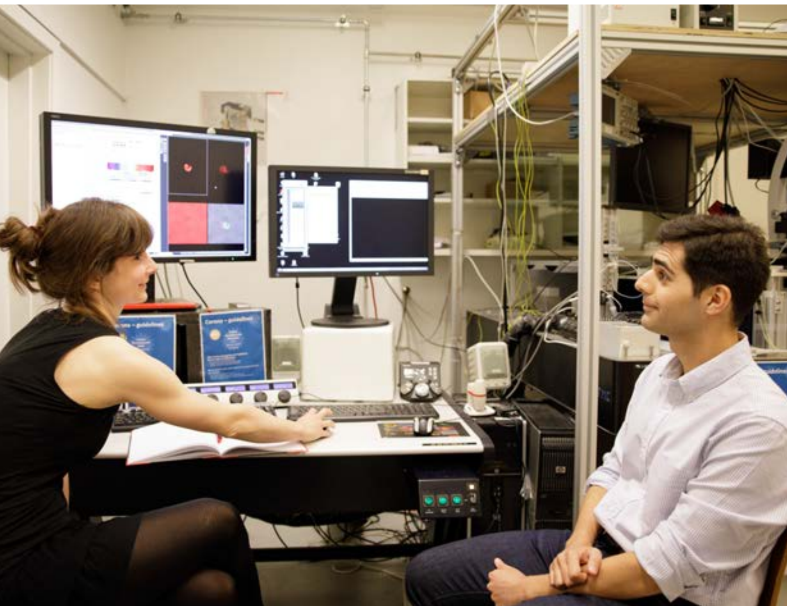


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Subodh Patil joined the NBIA in the fall of 2016 as an Assistant Professor after post-doctoral stints at the University of Geneva (2015-16), CERN (2012-2015, as Marie Curie Intra-European Fellow from 2012-14), CPHT Ecole Polytechnique (2009-12), and the Humboldt University of Berlin (2007-9), having obtained his Ph.D from McGill university in 2007. He works on broadly defined themes in early universe cosmology, gravity and related aspects of beyond the standard model and string phenomenology.

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.

Johan Samsing joined the NBIA as a Louis-Hansen Assistant Professor and Marie Curie Fellow in 2019. He 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.

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.

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.

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

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.

Chia-Min Chung's research uses numerical techniques, in particular tensor network states, to simulate interacting quantum many-body systems. He has previously worked on exploring the phase diagram of a lattice gauge theory model on a ladder geometry. He is now working on a system that is proposed as a realization of the topological qubits. He aims to calculate the quantities, for example the conductance, that can be directly compared with experiments and demonstrate the non-local properties of a topological qubit.

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 before returning.


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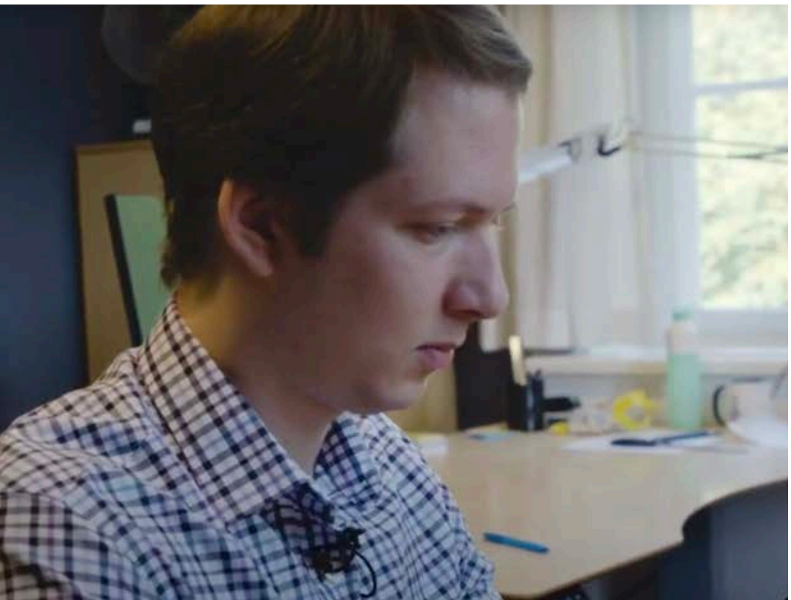
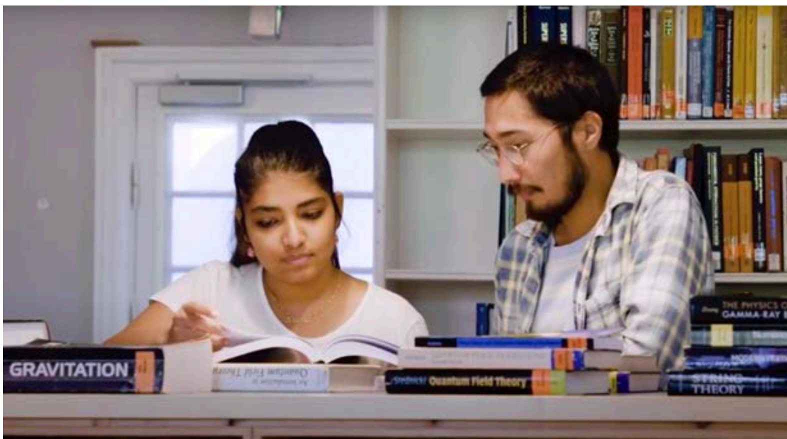
ELECTROMAGNETIC THEORY




GRAVITATION
STRING THEORY

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, notably 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.

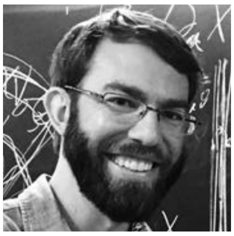
Rajika Kuruwita is an INTERACTIONS fellow at NBI doing numerical simulations of star formation. She obtained her PhD from the Australian National University in July 2019, where she completed both observational and theoretical work on binary star formation. She has a keen interest in the early evolution 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.

Humberto Gomez Zuniga got his PhD at the IFT in São Paulo, Brazil. His research focuses on computing scattering amplitudes in string theory using the pure spinor formalism. Currently, he is working on developing methods, uses and extensions of the so-called Ambitwistor string. Particularly, the study of underlying mathematical structures encoded in the scattering equations as well as developed techniques to make analytic computations.

Natascha Leijnse is an experimental biophysicist who received her PhD from the University of Copenhagen. After a postdoc at Stanford University she returned to 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.

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.

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.

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.

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 amor-phous 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 NBI she will be working on active soft matter systems.

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.

Frederik Nathan received his PhD from University of Copenhagen in 2018. His research focuses on novel driving-induced phenomena in quantum systems, including new topological phases, time-translation symmetry breaking, and energy pumping mechanisms. A second direction of research aims at developing an efficient and intuitive description of open and noisy quantum systems that may be applied to driven many-body quantum systems.

Mohamed Rameez received his PhD from the University of Geneva in 2016, working on Dark Matter indirect detection and point source searches with the IceCube detector. He is now seeking a better understanding of Cosmo-logy and local universe anisotropies.


IAS

Ximena Ramos works on planetary systems dynamics. In particular, she studies planet migration and its relation with the final configurations observed in exoplanetary systems and the resulting disk-structure. She uses N-body and hydrodynamical simulations combined with analytical calculations.

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.

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.

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.

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.

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

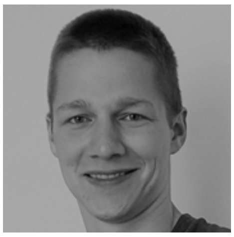
Benjamin Halager Andersen joined the Active Intelligent Matter (AIM) group at NBIA in November as a PhD fellow, where he will be using a combination of numerical and analytical methods to study systems of active matter. Prior to this, Benjamin obtained both his master's and bachelor's degree from NBI,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

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.

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.

Andreas Helset received his MSc degree at the Norwegian University of Science and Technology in 2017. He is currently working on his PhD project titled "Scattering Amplitudes and the Standard Model Effective Field Theory" under the supervision of Profs. N. Emil J. Bjerrum-Bohr and Michael Trott. The project lies at the intersection of the fields of modern methods for scattering amplitudes and effective field theories.

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.



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.

Ida E. Nielsen received her MSc from the University of Copenhagen in 2019 with a thesis on exotic modes in hybrid quantum systems. In October 2019 she started her PhD with Prof. Michele Burrello. Her project focuses on the scattering theory of devices hosting multiple Majorana or parafermionic zero-energy modes, with potential applications for the realization of novel platforms to perform error-protected quantum computation.

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 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.

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.

David D. Ribers received his Master's Degree at the Niels Bohr institute with his thesis "Lattice String Theory and Quantum Fields on a World-Line". In October 2019 he began his PhD at the NBIA under the supervision of Markus Ahlers. His project aims to clarify the origin of the cosmic neutrino flux through studies of candidate neutrino sources in the context of cosmic- and gamma-ray observations.

Yueting Pan is a PhD student at Beijing Normal University. She is currently working on her PhD project "Interacting ultracold hardcore bosons on the ladder model under a magnetic field" at the Niels Bohr Institute, under the supervision of Michele Burrello. The project is based on the bosonization method of a 1D model and the renormalization group.

Anna Suliga obtained her master's degree working with the Neutrino Astrophysics group at the Niels Bohr International Academy, under the supervision of Prof. Irene Tamborra. The title of the thesis was "Diffuse supernova neutrino background". Anna has continued to work with the Neutrino Astrophysics group as a PhD fellow since September of 2018. She is currently working on determining the role of neutrinos in the supernovae.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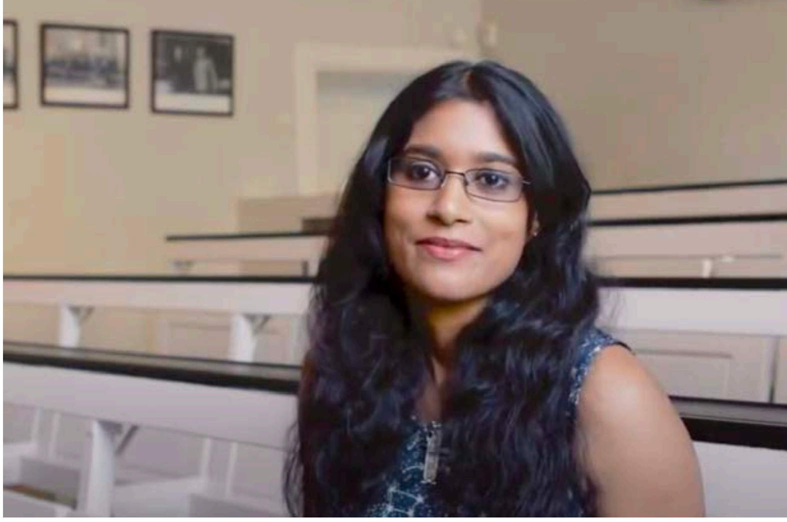
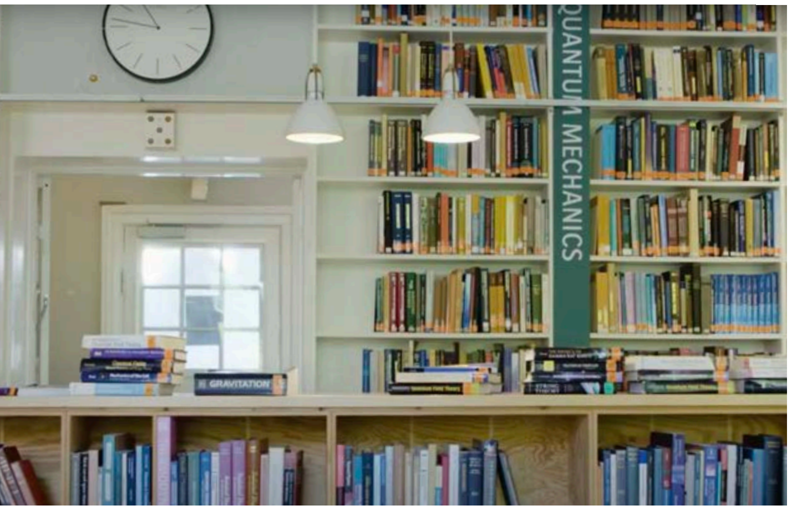
1920


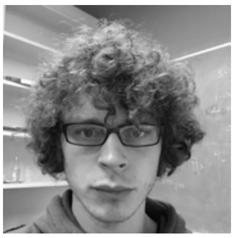


QUANTUM MECHANICS
GRAVITATION

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.

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. She is currently working on identifying neutrino properties from 3D core-collapse supernova simulations.

Anagha Vasudevan received her MSc in 2017 from RWTH Aachen. She is currently working on phenomenological studies in the standard model effective field theory and the intersection between effective field theories and modern methods in scattering amplitudes under Prof. Michael Trott and Prof. Emil Bjerrum-Bohr.

Philipp Weber obtained his MSc from Heidelberg in 2016 and later started his PhD at NBIA with Oliver Gressel and Pablo Benitez-Llambay. During his PhD Philipp investigated the impact of planets embedded in dusty protoplanetary disks and their associated observable signatures. His work employs an interdisciplinary approach, combining theory, cosmochemistry and observations. Philipp obtained his PhD degree in May 2020.



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.

MSc Students

Alicia Elcarte Astorga — Particle Physics

Daniel Abdulla Bobruk — Astroparticle Physics

Taro Valentin Brown — Particle Physics

Daniel Lozano Gomez — Particle Physics

Kathrine Mørch Groth — Astroparticle Physics

Katharina Hauer — Particle Physics

Gustav Uhre Jacobsen — Particle Physics

Emil Kozuch — Particle Physics

Rohan Kumar — Astroparticle Physics

Zheng Ma — Cosmology

Kjartan Másson — Astroparticle Physics

Roger Morales — Particle Physics

Marie-Louise Riis — Astroparticle Physics

Christian Dissing Schiøtt — Particle Physics

Salik Ahmad Sultan — Soft Matter Physics

Edwin Vargas — Particle Physics

Mariana Andrade Vieira — High Energy and Gravity Theory

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)

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

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

Visiting Professors

Si-Hui Tan is a Research Scientist at the Singapore University of Technology and Design. Her research interests lie in quantum information science, which is at the intersection of quantum mechanics and information theory.

Julia Yeomans was Novo Nordisk Foundation Visiting Professor during the spring of 2020. She is Professor of Physics at Oxford University. Known earlier for her ground-breaking work in statistical mechanics, Julia Yeomans now works on a variety of problems in soft matter and biological physics.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1920

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 2020 was highly unusual in this respect, with very few visitors able to travel to Copenhagen.

Name	Affiliation	Arrival	Departure
R. Samsing	Århus University	02.11.20	07.11.20
D. Marks	Harvard Medical School	11.10.20	01.11.20
C. Sander	Dana Farber Cancer Institute	11.10.20	01.11.20
H. Pfeiffer	Max Planck	04.03.20	07.03.20
C. Weniger	University of Amsterdam	24.02.20	20.03.20
M.R. Nejad	University of Oxford	19.02.20	27.02.20
J. Prost	Institut Curie, Paris	17.02.20	22.02.20
S. Weinzierl	Johannes Gutenberg Universität	10.02.20	13.02.20
A. Heinesen	École Normale Supérieure de Lyon	10.02.20	14.02.20
J. Steinhoff	Max Planck	10.02.20	13.02.20
D. D'Orazio	Harvard University	03.02.20	07.02.20
H. Théveniaut	IRSAMC, Toulouse	01.02.20	31.03.20
B. Allanach	University of Cambridge	29.01.20	31.01.20
K. Thijssen	University of Oxford	27.01.20	01.02.20
A. Klemm	University of Bonn	26.01.20	28.01.20
K. Tuominen	University of Jyväskyla, Finland	22.01.20	22.01.20
R. Safari	University of Bonn	20.01.20	22.01.20
A. Di Tucci	Max Planck Potsdam	08.01.20	11.01.20

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.

Kaare Møller is the finance officer responsible for the grants received by researchers at the NBIA.

Johan Lausen is a student helper at NBIA. He helps with NBIA colloquia, workshops, and day to day practical tasks. He is doing his MSc in Physics at NBI.

Maria T. Søgaard is a student helper at NBIA. She helps with NBIA colloquia, workshops and travel reimbursements. She is doing her MSc jointly between NBI and Herlev Hospital.

NBIA Activities

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-profiled 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 to 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 2021.

NBIA Colloquia

NBIA Colloquia consist of talks in a broad 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 2020, 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 2020 are listed below. Remote talks are indicated with (R).

Alexander Glaser (Princeton) — 11.12.2020 (R; Joint NBIA-NBA Colloquium)
"Confronting the Perpetual Menace: Can We Have Nuclear Disarmament without Nuclear Transparency?"

Alex Wellerstein (Stevens Institute of Technology) — 04.12.2020 (R; Joint NBIA-NBA Colloquium)
"Seeing the Unthinkable - Historical and Contemporary Approaches to the Visualization of Nuclear War"

Niels Obers (Nordita and NBI) — 27.11.2020 (R)
"Gravity between Newton and Einstein"

Martin Greiner (Aarhus University) — 20.11.2020 (R)
"Renewable Energy Networks - a playground for Applied Theoretical Physics"

Ravit Helled (University of Zurich) — 13.11.2020 (R)
"Revealing the Mysteries of Giant Planets"

Leonardo Midolo (NBI) — 30.10.2020 (R)
"Nanomechanics meets quantum photonics: a new approach to quantum information processing"

Victor Silva Aguirre (Aarhus University) — 23.10.2020 (R)
"Galactic archaeology, unraveling the history of the Milky Way"

Anders Johansen (Globe Institute, UCPH and Lund Observatory) — 16.10.2020 (R)
"The Physics of Planet Formation"

Samir Bhatt (Imperial College London) — 09.10.2020 (R)
"Comparing the responses of the UK, Sweden and Denmark to COVID-19"

Gemma C. Solomon (UCPH) — 02.10.2020 (R)
"How Low Can We Go? The Search For Quantum Interference Based Single-molecule"

Viola Priesemann (Max Planck Institute) — 24.06.2020 (R)
"Phase transitions in complex systems: Shaping information flow in neural networks and changing the spreading dynamics of SARS-CoV-2"

Mogens Høgh Jensen (NBI) — 19.06.2020 (R)
"Chaos in Cells"

Michel Janssen (University of Minnesota) — 12.06.2020 (R)
"Drawing the line between kinematics and dynamics in special relativity and in quantum mechanics"

Darach Watson (DAWN) — 29.05.2020 (R)
"The cosmic origin of the rapid neutron capture elements"

Kim Sneppen (NBI) — 22.05.2020 (R)
"Facts and failures in models of Covid-19"

Troels Haugbølle (NBI) — 15.05.2020 (R)
"Changes in the Eternal Heavens"

Evert van Nieuwenburg (NBIA) — 01.05.2020 (R)
"Physics with Machine Learning and Quantum Games on top"

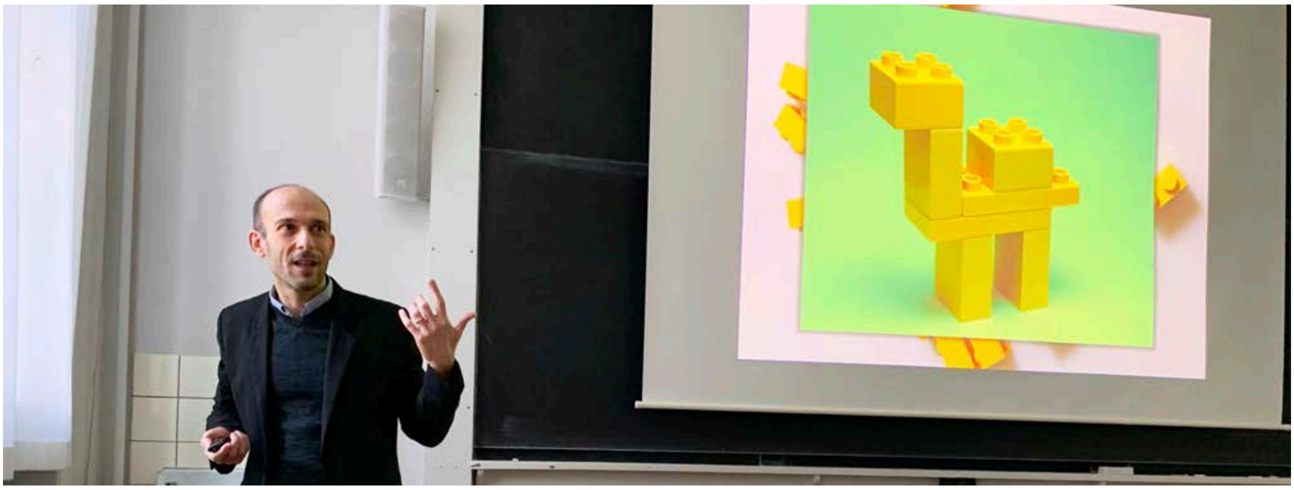
Mark Rudner (NBIA) — 24.04.2020 (R)
"Dynamical Quantum Materials"

Johan Samsing (NBIA) — 17.04.2020 (R)
"Probing the Origin of Black Hole Merger"

Jacques Prost (Institut Curie, Paris) — 21.02.2020
"A physical approach to cells and tissues"

Brian Møller Andersen (NBI) — 07.02.2020
"Superconductivity 2020"

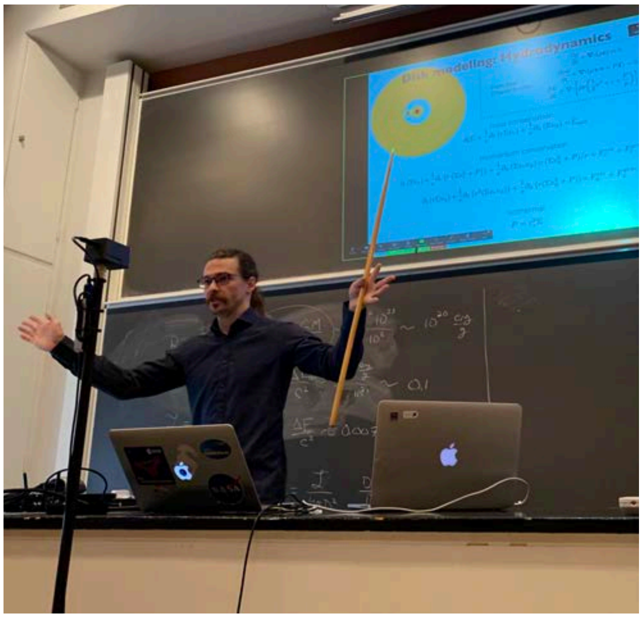
Leonardo Fallani (Univ. of Firenze) — 17.01.2020
"Synthetic quantum systems with multi-component atoms"



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. In the fall of 2019 the group working on biological physics at the NBIA began its own program of talks and lectures, also in conjunction with the new Novo Nordisk Foundation Visiting Professor program.



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 of the order of ten high-profile, international events every year to the benefit of the wider Institute community. The following events were organized by NBIA members during 2020:

"*All Things EFT*" — Zoom series co-organized by NBIA

"*Newest Results from LIGO O3*" — 18.10.2020 (Zoom workshop)

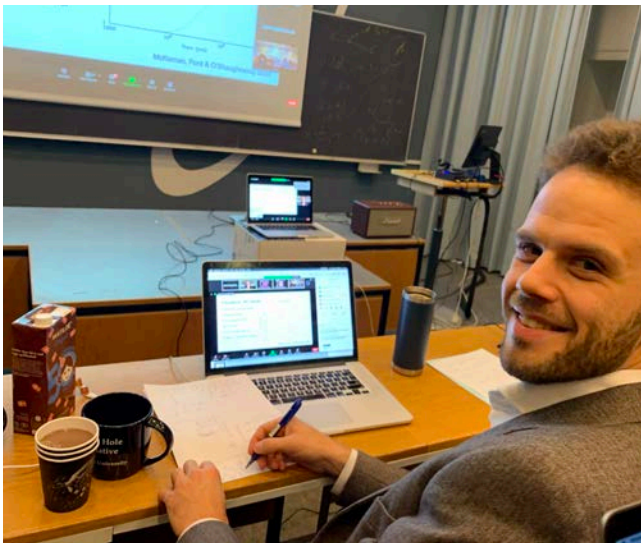
"*Elliptics and Beyond*" — 07.09 / 11.09.2020 (Virtual Workshop)

"*Current Themes in High Energy Physics and Cosmology* " — 17.08 / 21.08.2020 (Postponed)

"*Simons Program: Forefronts of Cosmology and Gravitation*" — 15.06 / 19.06.2020 (Postponed)

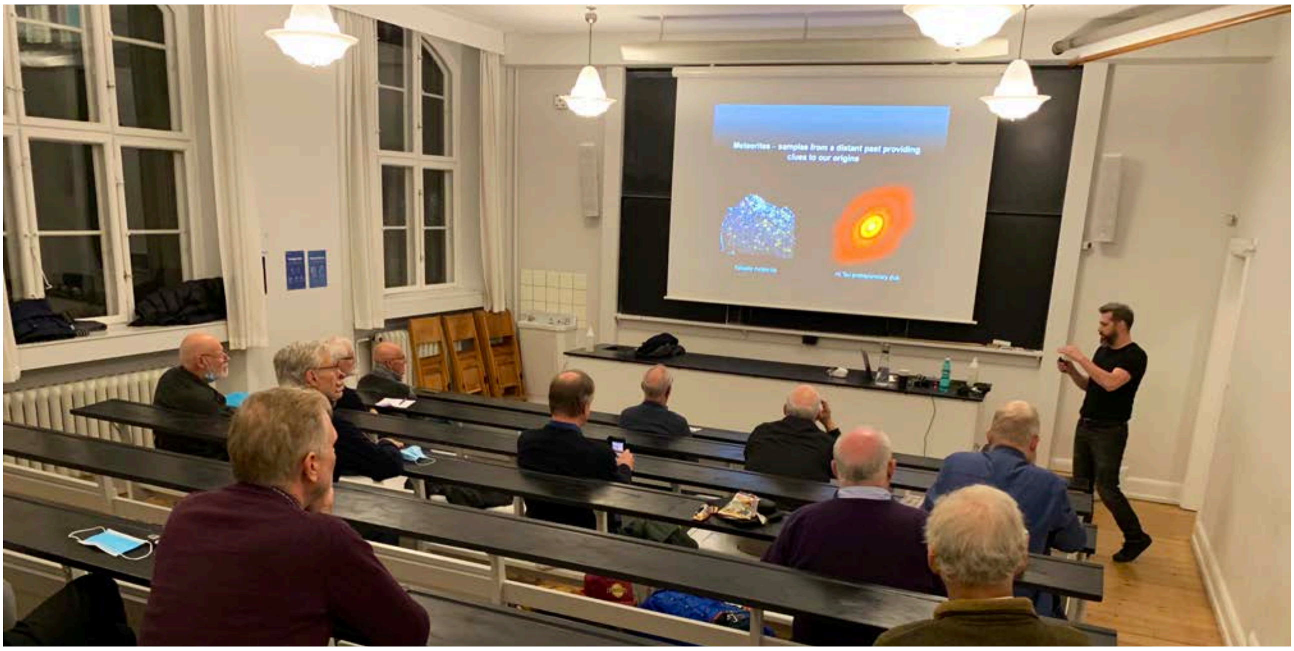
"*Thinkshop on Protoplanetary Disk Chemodynamics*" — 11.05 / 15.05.2020 (Cancelled)

"*Gravitational Wave Science in Denmark* " — 31.01.2020




Astrophysics for 3rd Graders
Martin Pessah
Niels Bohr Institute
Copenhagen International School - Jan. 16 2020
The Niels Bohr
International Academy


ANY QUESTIONS?


Meteorites – samples from a distant past providing
clues to our origins

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 will 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 is 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 laymen 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:

Evert van Nieuwenburg (NBIA) — 20.10.2020
"Theoretical physics in an era of machine learning"

Debora Marks (Harvard) — 27.10.2020
"Physics and mathematics solving problems in life sciences"

Michele Levi (NBIA) — 03.11.2020
"Gravitational waves - the revolution in gravitational physics"

David Nelson (Harvard) — 10.11.2020
"Active matter - engines at the cellular level"

Martin Bizarro (Center for Star and Planet Formation and Globe Institute, UCPH) — 17.11.2020
"Mars and the origin of water"

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.

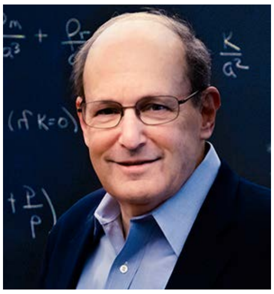
A most successful outreach activity for the youngest was initiated in 2019 by NBIA astrophysicists with the series "Astrophysics for 3rd Graders". An incipient tradition jointly organised with Copenhagen International School which caters to the most curious of all minds.

Distinctions

Women in Physics Prize to Irene Tamborra

The Danish Network for Women in Pysics (KIF) awarded the 2020 honorary prize to NBIA's Knud Højgaard Associate Professor Irene Tamborra. The prize is awarded annually to raise awareness about the importance of women in physics and engineering. The 2020 award was given to a woman who acts as a role model and inspiration within the field of physics. Specifically, Irene Tamborra receives the award because of her exceptionally strong scientific profile. In the citation KIF's award committee noted that Irene Tamborra has built a highly visible research group around her as head of the AstroNu group at NBIA. The KIF Prize was presented to Irene Tamborra just one year after she had received, in succession, both the international MERAC Prize and the Shakti P. Duggal Award.

Niels Bohr Institute Medal of Honor to Paul Steinhardt



Paul Steinhardt, member of NBIA's International Science Advisory Board and frequent visitor at NBIA, has been awarded the Niels Bohr Institute Medal of Honor 2020. This medal is awarded annually to a distinguished scientist working in the spirit of Niels Bohr. Specifically, Paul Steinhardt receives the medal for his seminal and creative contributions to a remarkably wide range of subjects within the natural sciences, for his tireless advocacy of the unity of sciences, for his critical reconsideration of every scientific hypothesis that is not backed by experimental evidence, and for his remarkable skills of conveying to the public the excitement of scientific discovery. The award will be presented to Paul Steinhardt at a ceremony in 2021.

Wheeler Prize to Igor Novikov

The first John Archibald Wheeler International Prize and Medal has been awarded to Igor Novikov, Chief Researcher at the Lebedev Physics Institute of the Russian Academy of Sciences in Moscow and long-time Associated Scientist at NBIA. Igor Novikov receives the prize for his contribution to the general theory of relativity and black hole theory. The John Archibald Wheeler Prize 2020, which Igor Novikov shares with Kip Thorne (Caltech, Nobel Prize 2017) and Roger Penrose (Oxford, Nobel Prize 2020), is awarded for research and discoveries in scientific fields the American scientist John Archibald Wheeler was involved in. The citation emphasizes the contribution of Igor Novikov's Moscow group to the development of the theory of general relativity. As far back as 1975, Igor Novikov and his colleagues formulated a theory regarding the existence of closed time-like curves, which later made it possible to explain some paradoxes of time travel. This theory and idea is called the Novikov principle. It was John Archibald Wheeler who introduced the concept of black holes into scientific (and later also public) terminology.


CARL. OTTILIA JACOBSEN


H.C.
ØRSTED
Charles M. Marcus

Ørsted Medal to Charles Marcus

In the bicentenary of Danish scientist Hans Christian Ørsted's discovery of electromagnetism, the Society for the Dissemination of Natural Sciences awarded the Ørsted Gold Medal to Charles Marcus. The award was presented by the Queen of Denmark at a ceremony in the Central Hall of Copenhagen's "Glyptotek" in November. This is only the second time the Gold Medal has been awarded in the last 30 years. Previous recipients include Nobel laureates Niels Bohr (1924) and his son Aage Bohr (1970). It is awarded for extraordinarily impactful research in chemistry or physics.

Charles Marcus received the Ørsted Gold Medal for pioneering work on quantum coherent devices that now is moving towards full-fledged quantum technologies that aim for quantum information processing. In a partnership with Microsoft, Charles Marcus leads a large research effort in Copenhagen with the ambitious goal of building a many-qubit quantum computer. The acknowledged potential of this research is vast. For example, in quantum chemistry and quantum biochemistry, quantum computers can simulate large, complex molecules, eventually allowing medicines to be designed by simulation rather than developed through arduous experimentation and trial-and-error. As in the early days of ordinary classical computing, there is no way to predict the giant leaps that may eventually be taken on the basis of large-scale quantum computing.

In addition to his many activities in the lab, Charles Marcus has been a constant supporter of NBIA since taking up his position as Villum Kann Rasmussen Professor, the first endowed Chair in Denmark. The Villum Kann Rasmussen Professorship was donated by the Villum Foundation to NBIA in 2007.

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NBIA Publications

Refereed Papers

1. **Polynomial scaling of the quantum approximate optimization algorithm for ground-state preparation of the fully connected p-spin ferromagnet in a transverse field**
Wauters, Matteo M., Mbeng, Glen B., Santoro, Giuseppe E. et al., 2020, Phys. Rev. A, 102, 062404 - ArXiv: 2003.07419

2. **Quantum frequency locking and downconversion in a driven qubit-cavity system**
Nathan, Frederik, Refael, Gil, Rudner, Mark S. et al., 2020, Phys. Rev. Research, 2, 043411 - ArXiv: 2003.05648

3. **Disintegration and expansion of wormholes**
I.D. Novikov, D.I. Novikov, S. V. Repin et al., 2020, Physical Review D, 102 - ArXiv: 2012.13788

4. **Exploring helical phases of matter in bosonic ladders**
Haller, Andreas, Matsoukas-Roubeas, Apollonas S., Pan, Yueting et al., 2020, Phys. Rev. Research, 2, 043433 - ArXiv: 2010.02740

5. **Radiogenic Heating and Its Influence on Rocky Planet Dynamos and Habitability**
Nimmo, Francis, Primack, Joel, Faber, S. M. et al., 2020, ApJ, 903, L37 - ArXiv: 2011.04791

6. **Black Hole Mergers from Hierarchical Triples in Dense Star Clusters**
Martinez, Miguel A. S., Fragione, Giacomo, Kremer, Kyle et al., 2020, ApJ, 903, 67 - ArXiv: 2009.08468

7. **Zero Net Flux MRI Turbulence in Disks: Sustenance Scheme and Magnetic Prandtl Number Dependence**
Mamatsashvili, George, Chagelishvili, George, Pessah, Martin E. et al., 2020, ApJ, 904, 47 - ArXiv: 2009.14736

8. **Double-peaked Balmer Emission Indicating Prompt Accretion Disk Formation in an X-Ray Faint Tidal Disruption Event**
Hung, Tiara, Foley, Ryan J., Ramirez-Ruiz, Enrico et al., 2020, ApJ, 903, 31 - ArXiv: 2003.09427

9. **Bacteria solve the problem of crowding by moving slowly**
O. J. Meacock, A. Doostmohammadi, K. R. Foster et al., 2020, Nature Physics - ArXiv: 2008.07915

10. **Mesoscale modelling of polymer aggregate digestion**
Javor K. Novev, Amin Doostmohammadi, Andreas Zöttl et al., 2020, Current Research in Food Science, 3, 122--133 - ArXiv: 1911.07510

11. **Binding self-propelled topological defects in active turbulence**
Thijssen, Kristian, Doostmohammadi, Amin, 2020, Physical Review Research, 2, 042008 - ArXiv: 2007.13443

12. **LB-1 Is Inconsistent with the X-Ray Source Population and Pulsar-Black Hole Binary Searches in the Milky Way**
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13. **On the Maximum Stellar Rotation to form a Black Hole without an Accompanying Luminous Transient**
Murguia-Berthier, Ariadna, Batta, Aldo, Janiuk, Agnieszka et al., 2020, ApJ, 901, L24 - ArXiv: 2005.10212

14. **Constraining delay time distribution of binary neutron star mergers from host galaxy properties**
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15. **Equation of State Constraints from Nuclear Physics, Neutron Star Masses, and Future Moment of Inertia Measurements**
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17. **Contrasting lattice geometry dependent versus independent quantities: Ramifications for Berry curvature, energy gaps, and dynamics**
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18. **The Art of Modeling Stellar Mergers and the Case of the B[e] Supergiant R4 in the Small Magellanic Cloud**
Wu, Samantha, Everson, Rosa Wallace, Schneider, Fabian R. N. et al., 2020, ApJ, 901, 44 - ArXiv: 2006.01940

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Saade, M. Lynne, Stern, Daniel, Brightman, Murray et al., 2020, ApJ, 900, 148 - ArXiv: 2001.08870

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24. **A possible universal role for {mRNA} secondary structure in bacterial translation revealed using a synthetic operon**
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Gallegos-Garcia, Monica, Burkhart, Blakesley, Rosen, Anna L. et al., 2020, ApJ, 899, L30 - ArXiv: 2006.14626

27. **Common Envelope Wind Tunnel: Range of Applicability and Self-similarity in Realistic Stellar Envelopes**
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Izzo, L., Auchettl, K., Hjorth, J. et al., 2020, A&A, 639, L11 - ArXiv: 2004.05941

33. **Common Envelope Wind Tunnel: The Effects of Binary Mass Ratio and Implications for the Accretion-driven Growth of LIGO Binary Black Holes**
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46. Low-mass planet migration in three-dimensional wind-driven inviscid discs: a negative corotation torque
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48. Polar jets of swimming bacteria condensed by a patterned liquid crystal
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49. The Stars in M15 Were Born with the r-process
Kirby, Evan N., Duggan, Gina, Ramirez-Ruiz, Enrico et al., 2020, ApJ, 891, L13 - ArXiv: 2002.09495

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51. Updated parameter estimates for GW190425 using astrophysical arguments and implications for the electromagnetic counterpart
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Andrews, Jeff J., Breivik, Katelyn, Pankow, Chris et al., 2020, ApJ, 892, L9 - ArXiv: 1910.13436

53. Nagaoka ferromagnetism observed in a quantum dot plaquette
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54. Active nematics with anisotropic friction: the decisive role of the flow aligning parameter
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55. **Activity Induced Nematic Order in Isotropic Liquid Crystals**
Santhosh, Sreejith, Nejad, Mehrana R., Doostmohammadi, Amin et al., 2020, Journal of Statistical Physics, 180, 699-709 - ArXiv: 1912.05201

56. **Active matter in a viscoelastic environment**
Plan, Emmanuel L. C. M., VI, Yeomans, Julia M., Doostmohammadi, Amin et al., 2020, Physical Review Fluids, 5, 023102 - ArXiv: 2001.02331

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Naoz, Smadar, Will, Clifford M., Ramirez-Ruiz, Enrico et al., 2020, ApJ, 888, L8 - ArXiv: 1912.04910

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61. **Thermal Evolution of Neo-neutron Stars. I. Envelopes, Eddington Luminosity Phase, and Implications for GW170817**
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65. **Neutrino emission characteristics of black hole formation in three-dimensional simulations of stellar collapse**
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66. **Grand Unified Neutrino Spectrum at Earth: Sources and Spectral Components**
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Pattavina, Luca, Ferreiro Iachellini, Nahuel, Tamborra, Irene et al., 2020, Phys. Rev. D, 102, 063001 - ArXiv: 2004.06936

72. **A Novel Algorithm for Nested Summation and Hypergeometric Expansions**
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73. **Comparison of the Planck 2018 CMB polarization maps in the BICEP2/Keck region**
Liu, Hao, Creswell, James, Naselsky, Pavel et al., 2020, JCAP, 06, 023 - ArXiv: 2005.03170

74. **Effective Field Theories of Post-Newtonian Gravity: A comprehensive review**
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Lang, Rodrigo Guedes, Taylor, Andrew M., Ahlers, Markus et al., 2020, Phys. Rev. D, 102, 063012 - ArXiv: 2005.14275

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Hasegawa, Takuya, Hiroshima, Nagisa, Kohri, Kazunori et al., 2020, JCAP, 08, 015 - ArXiv: 2003.13302

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92. **The Steinmann Cluster Bootstrap for N = 4 Super Yang-Mills Amplitudes**
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94. **Bounds on secret neutrino interactions from high-energy astrophysical neutrinos**
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