The Niels Bohr International Academy

Annual Report 2024

The Niels Bohr International Academy

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The Academy

NBIA Governance

International Advisory Board and Director's Council:

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

Current Members of the International Advisory Board:

- **Poul Henrik Damgaard**, Niels Bohr Institute (Director)
- **Martin E. Pessah,** Niels Bohr Institute (Deputy Director)
- **David Gross**, KITP Santa Barbara
- **Irene Tamborra**, Niels Bohr Institute (Chair)
- **Itamar Procaccia**, Weizmann Institute
- **Steve Simon**, Oxford University
- **Paul Steinhardt**, Princeton University
- **Frank Wilczek**, Massachusetts Institute of Technology

Current Members of the Director's Council:

- **Peter Landrock** (Chair)
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- **Kirsten Smedegaard Andersen**
  Board Chair Movotec, Board member LD, Bodum, and other public and private organizations
- **Bertel Haarder**
  Former MP, Minister and former member of European Parlament
- **Anne Birgitte Gammeljord**
  Lawyer, Rovsing & Gammeljord
- **Bjørn Nørgaard**
  Prof. Royal Academy of Fine Arts, Guest Prof. China National Academy of Arts
- **Michael K. Rasmussen**
  Former Vice President, Brand in VELUX Group, private consultant

The Niels Bohr International Academy

From the Director

In 2021 a group of scientists at the Niels Bohr Institute helped put together a book (in Danish) celebrating the centenary of what was for decades known as Bohr's Institute. The idea was to provide a broad overview of modern topics that was then pursued at the institute, one hundred years after its inception. I was grateful for being invited to provide a chapter on the view from NBIA and the building complex on Blegdamsvej. But when I learned that the working title of the book was “Gamma-ray Bursts”, I balked. Such an inane choice! Instead, I suggested to the book editor that the title of the book could be “The Light from Bohr”. The editor fortunately listened, and this became the final title. The light from Bohr has multiple meanings: from the explanation of spectral lines based on the original Bohr model of the atom, through atomic physics, quantum optics, quantum electrodynamics (and its so-called non-Abelian generalizations that form the cornerstone of today's theory of elementary particles), theoretical astrophysics and the theory of why stars shine, to quantum computing, and what today goes under the general heading "Quantum Sciences". But it also reaches beyond these developments inside the conventional sphere of physics: in 1933 Niels Bohr published in Nature an influential paper with the title "Light and Life" which condensed ideas around at that time that biology might be close to a revolution that would turn over tables in the same way that quantum mechanics had revolutionized physics. The seed had been sown for a new topic in science: biological physics. Finally, and this shall be the theme of this brief essay, the light from Bohr illustrates the power of tradition, role models, and inspiration in science.

Almost weekly, prominent visitors from abroad are shown around on the Blegdamsvej complex of buildings which form the original Institute of Theoretical Physics that Bohr created and shaped during his lifetime. From ambassadors, foreign science ministers, heads of state, royalty, to groups of interested students literally on some kind of intellectual pilgrimage to the place that for an important moment in history shook the world of science. The Niels Bohr Institute is now close to having fully moved into the new Niels Bohr Building across the park but everybody fortunately acknowledges how detrimental it would be if it were to let go of the original site on Blegdamsvej. This is not just due to the dignitaries that would be disappointed to see it having disappeared forever but mostly because of all the foreign scientists that would feel the loss. It seems appropriate to analyze this interesting phenomenon in a brutally honest manner. Who cares about a building? Is it not the scientists presently working at the Niels Bohr Institute that matter? Should that not be what both scientists from abroad and the many groups of visitors should flock to? Even the most shallow analysis will reveal that there is some crucial piece of information missing in that kind of logic. It can be condensed into an awareness of history, and our own place in the historical perspective. No-one is puzzled by all of us finding inspiration in grand works of art, the music of Bach played in a cathedral, or the awe we can feel when entering a building of historical significance. Students, scientists, and scholars find the same kind of inspiration in the grand halls of Oxford and Cambridge universities, or, for example, in Fuld Hall of the Institute for Advanced Study in Princeton. Knowing that Albert Einstein spent decades there gives the place a touch that surely has been a contributing factor in attracting the most stellar scientists from around the world many, many years after Einstein passed away. Similarly, the feel and touch of the hard wooden benches of the historical Auditorium A on Blegdamsvej, the place that was so central for the quantum mechanical revolution in physics, makes it irreplaceable. It is a tremendous capital to have been given to us, down through generations.

While the move into the new Niels Bohr Building across the park is close to being finished, the Blegdamsvej complex will remain bustling with life. The Novo Nordisk Foundation Quantum Computing Program NQCP already occupies almost all of the space in the buildings to the north, and just this year Vitor Cardoso has been awarded a new Center of Excellence ('Center of Gravity') from the Danish National Research Foundation. With the addition of also a new ERC Synergy grant with Maarten van de Meent as P.I. this will bring to the building complex on Blegdamsvej a large number of Assistant Professors, post-docs, and PhD-students who together with the scientists already here will create one of the largest and strongest groups in the world on this topic. And NBIA remains in the buildings, promoting interdisciplinary science and seeking new avenues beyond present research topics.

A small group of people, including members of NBIA's Director's Advisory Council, is currently helping the Niels Bohr Institute undertake a gentle renovation of the area outside Niels Bohr's office. The idea is to turn it back to its original appearance, remove the vinyl that has been glued to the original wooden floor, remove the lowered ceiling, change the neon-bright lamps and turn the area into a comfortable lounge in which scientists can relax and discuss informally. Discreet exhibits of items such as letters to and from Niels Bohr from other luminaries in science will be installed by the Niels Bohr Archive. The idea driving this renovation is to turn the area into a space that is equally appropriate for heads of state wishing to see Niels Bohr's office and as lounge for scientists working in the buildings. Mixing functionality with history in this manner is one of the fabulous opportunities available to us on the Blegdamsvej complex of buildings. If NBIA can help and be conducive to such a development we will have achieved quite a bit. The next step may be to seek funds for establishing a modern auditorium on the premises, discreetly meshed in with the historical buildings, and capable of seating up to 120 people. But that may be for next year's Annual Report.

Poul Henrik Damgaard

From the Chair of the Council

If you ask which Nobel Prize in physics not granted is the most astonishing, the likely answer is that Einstein never got it for his fundamental discovery of the Theory of Relativity, but for something less impressive. It was likely too breathtaking for many, and it took years to appreciate the fact that it is true.

In contrast many were caught by surprise when the Nobel Prize in Physics 2024 was awarded to John Hopfield and Geoffrey Hinton for their fundamental research in AI.

I have the luck to have known Hinton personally, as we both served on the Technical Advisory Board of the Microsoft Research Lab in Cambridge (UK!) for a number of years until 2010. Obviously, Hinton joined because of his enormous insight into machine learning, by then a fast-growing research field. I thus knew of his profoundness and was not really surprised when the Nobel Prize was announced.

To really understand the entire development of AI, I was made aware (by my son) of a recent book by Anil Ananthaaswamy: Why Machines Learn: The Elegant Math Behind Modern AI, Dutton 2024, characterized as "A masterpiece" by Hinton. I cannot recommend it enough, not least to anybody caught by surprise by the Nobel Prize in Physics 2024.

In a nutshell, AI relies heavily on applications of linear algebra, calculus, statistics and probability, like Bayesian decision theory. The approach is an ingenious combination of math taught at the first-year undergraduate level at our universities. The building stones in deep learning models are neurons, nodes through which data and computations flow. They receive input signals, perform some calculations using weights, and pass the output to the next layer of the neural net, eventually producing a result. The challenge is to find the right weights through a "learning" process.

Several concepts in AI come from physics, just as Entropy from classical Thermodynamics was later introduced in Information Theory to measure randomness in bit combinations. Hopfield was looking for a neurological problem which gave insight into how the brain computes. The one he finally settled for was "associative memory". What inspired him was the physics of ferromagnetism, based on the well-known Ising model, and he built a (Hopfield) network of neurons, the fundamental property of which is that if such a network in a stable state is perturbed, it will dynamically transition through different states until it settles into a stable state that represents an energy minimum.

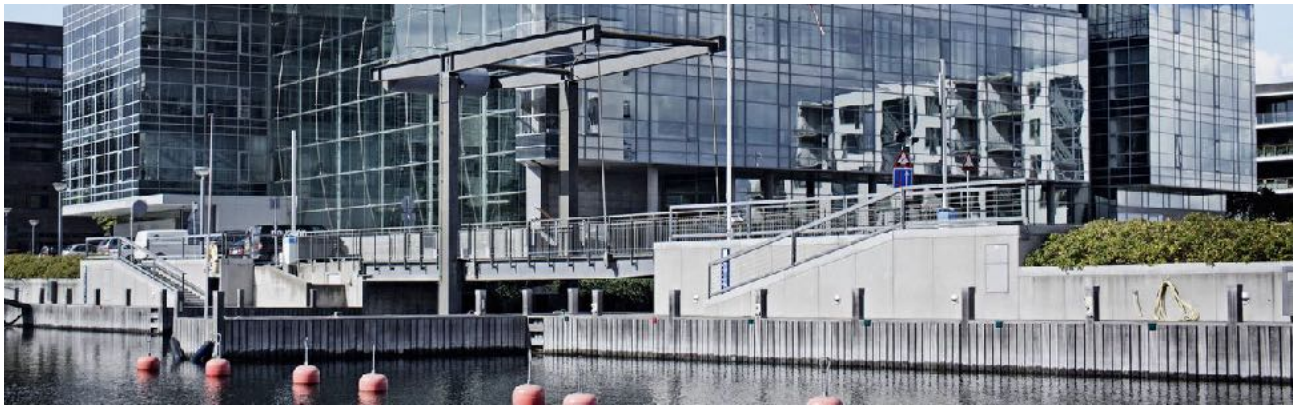
Geoffrey Hinton took this a lot further to a new type of network, the so-called Boltzmann machine, which can be trained on a given type of data. Hinton used tools from statistical physics by feeding it huge amounts of data. It can then be used to classify, e.g., images as well as create new examples of the type of pattern on which it was trained. (Hinton in fact did much more than this as explained well in the book referred to above.)

Regardless of whether this is physics or not, it is simply so profoundly important scientific progress that it should be recognized, and what better way to do it? The applications are mind-boggling and appear almost daily in all disciplines of sciences - as in the case of the Nobel Prize in Chemistry 2024, and in business and education as well. In contrast though, some of the predicted future improvements of AI appear more than farfetched, such as proving non-trivial results in mathematics and theoretical physics. AI totally lacks serendipity, and the "I" in AI still stands for intelligence in the meaning of producing information.

Peter Landrock

Novo Nordisk Foundation Grant

The largest institutional grant to NBIA since the endowed Villum Kann Rasmussen Professorship in 2007 came from the Novo Nordisk Foundation in 2018. This grant of 35 MDKK aims at establishing up to five Novo Nordisk Foundation Assistant Professors, Novo Nordisk Foundation Associate Professors, or Novo Nordisk Foundation Full Professors at NBIA. The new research directions should have potential for relevance within life science research. The time is indeed ripe for this expansion into areas in life sciences that are bordering physics, and it has for several years been the ambition of NBIA to again establish a stronghold in theoretical biological physics (one of the first topics of research when NBIA was founded in 2007). The large grant from the Novo Nordisk Foundation takes this to a much larger scale. It will support research at NBIA that may potentially have large impact on the life sciences. These are research 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 normally 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, support from Independent Research Fund Denmark, the NERD program under the Novo Nordisk Foundation, and, most recently, an ERC Starting Grant, he has already established a large junior research group. Amin Doostmohammadi received tenure at the Niels Bohr Institute in 2023. In 2021 the NBIA life-science program extended further by the simultaneous hire of Weria Pezeshkian (who works on computational biophysics) and Karel Proesmanns (who works on applying thermodynamic and statistical mechanics methods to biological systems). Weria Pezeshkian, who has also received an EU Marie Curie Fellowship, has already established his own junior research group based on Sapere Aude grant from Independent Research Fund Denmark and a project grant from the Novo Nordisk Foundation. Karel Proesmanns has also received an EU Marie Curie Fellowship and has already started his own junior research group based on a project grant from the Novo Nordisk Foundation. In the fall of 2023 the NBIA bio-group extended further in new directions through the hire of Mary Wood who has a background in chemistry and who is pushing for new understanding of bio-electronic materials. After a mid-term reeview of the grant in 2024 NBIA was given the go-ahead to complete the program within the total time-frame of twelve years.



Husman Foundation Grant

A large donation from the Ernst & Vibeke Husman Foundation given to NBIA allows us to attract top talent from around the world as Husman Foundation Visiting Scholars. After a two-year hold 2020-21 due to the pandemic, the Husman Foundation Visiting Scholar program has been up and running since 2022. 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 as well as 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 NBIA abreast of new scientific developments. Husman Foundation Scholarships are also available for invitations of collaboration partners for NBIA scientists and funds from the grant can be used to organize specialized smaller workshops. During 2024 this grant has in particular supported Visiting Professors Henriette Elvang (from University of Michigan) and James Cline (McGill University), as well as visiting scientists on shorter stays at NBIA.

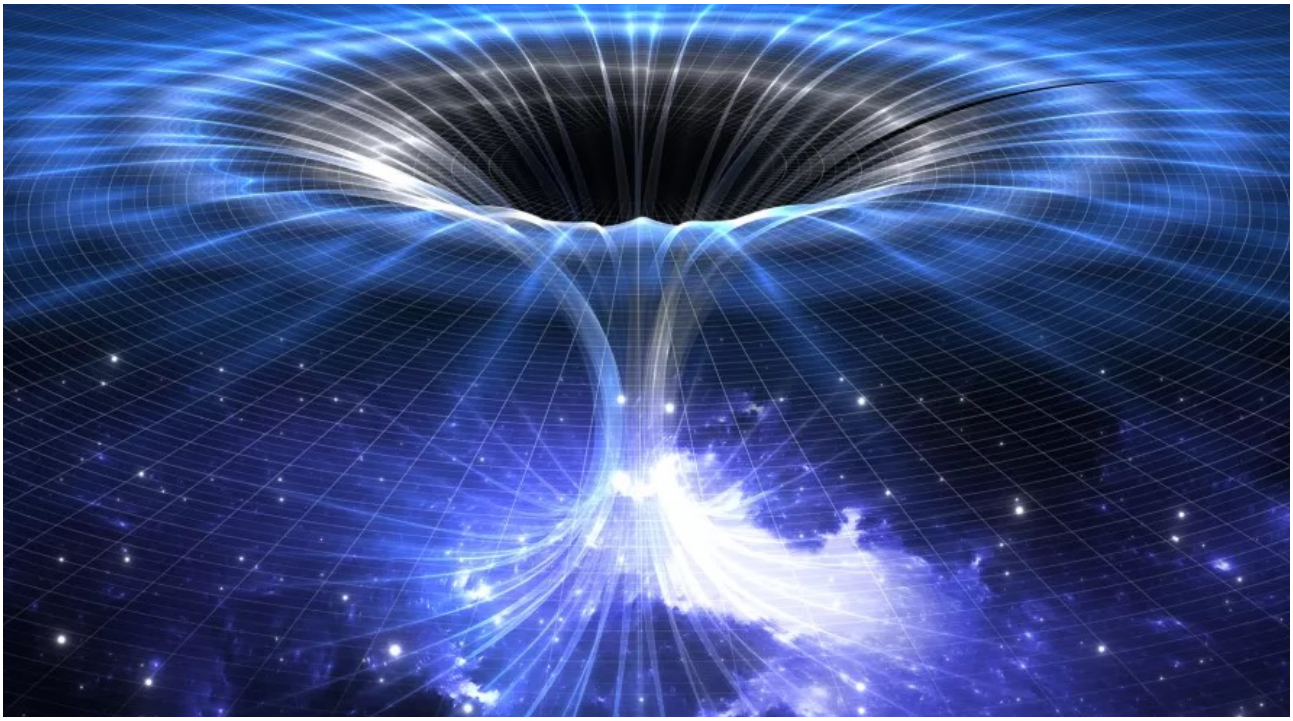
ERNST & VIBEKE HUSMANS FOND


MAGASIN DU NORD


ROLEX

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 Foundation Assistant Professors on 5-year fixed-term contracts at NBIA. The grant is totally flexible and has allowed 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 has opened 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 postdoctoral years where they have been able to liberate themselves from their thesis topics and thus define their own research directions. These are scientists who can drive the NBIA in the coming years and who we now have invited 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 Foundation Assistant Professor Johan Samsing has already received an individual EU Marie Curie Fellowship, a Villum Young Investigator grant, and, most recently, an ERC Starting Grant which enables him to establish his own junior research group. In 2023 NBIA appointed Apoorv Tiwari as new Louis-Hansen Foundation Assistant Professor. Apoorv Tiwari, who received a Villum Young Investigator grant in 2024, works in the new and rapidly growing field of non-invertible or so-called categorical symmetries which bridges between condensed matter physics and quantum sciences to high energy physics.



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 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 ambitious Fellowship Program with the aim to enhance interactions among young scientist in theoretical physics.

The INTERACTIONS Fellowship Program promotes and ensures 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. 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 increases the network and research opportunities for the fellows, and at the same time has the potential to bring our institutions closer together. The last call for new INTERACTIONS fellows closed in 2022 but towards the end of 2023 NBIA was given permission to extend some of the current contracts beyond the original end-date of 2024 so that some INTERACTIONS Fellows will now continue longer, some all the way to the end of 2026. More detailed information can be found at http://nbia.nbi.ku.dk/interactions.

NBIA Research

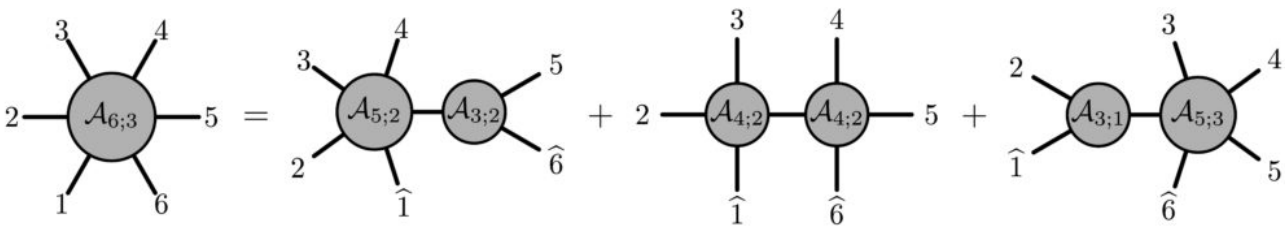
Theoretical Particle Physics

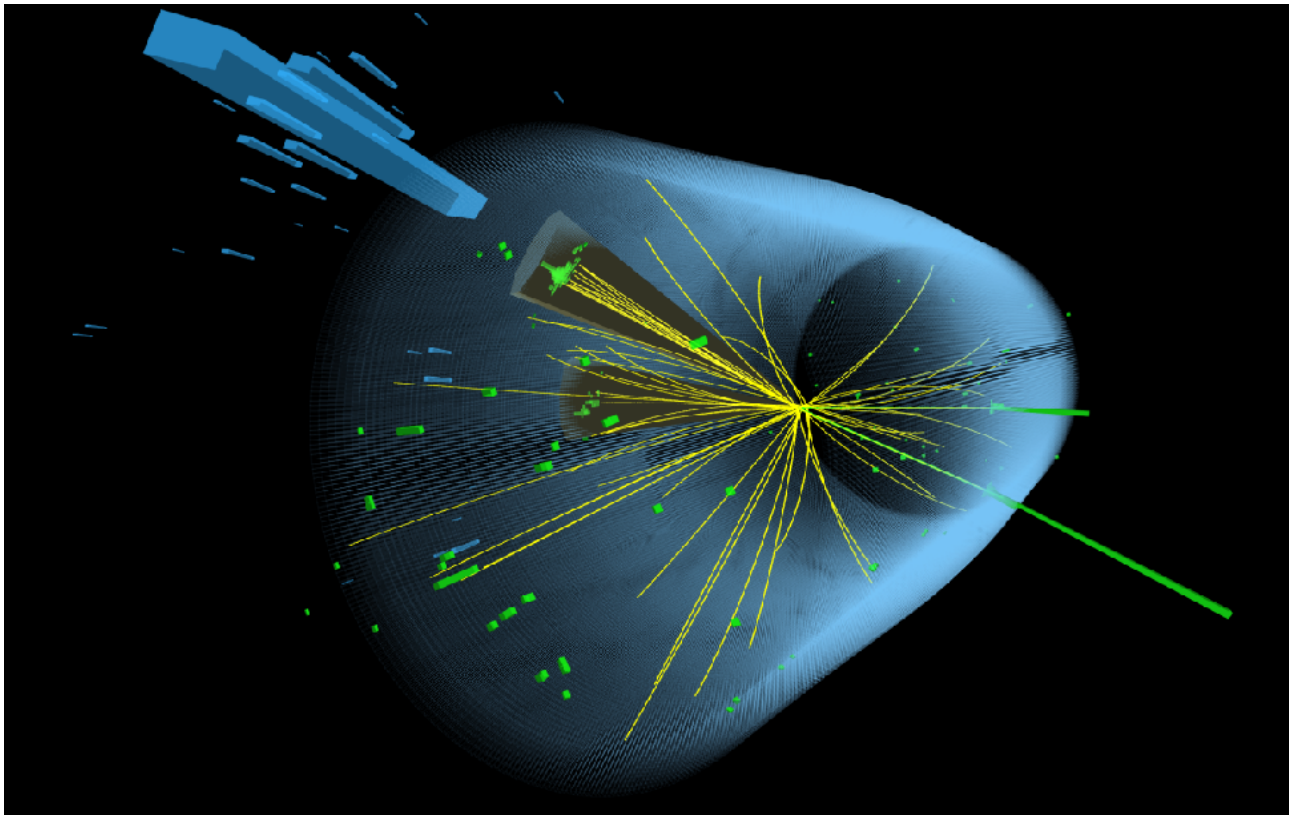
The theoretical particle physics group concentrates on research at the frontier of our understanding, such as the foundation of quantum field theory, general relativity, string theory, neutrino astrophysics, cosmology, and multi-messenger astrophysics, fields that encompass both vast cosmic scales and the fundamental aspects of physics.

Recently, the group has expanded its focus toward classical gravity, specifically black holes—nature's most enigmatic phenomena, which play a crucial role in our knowledge of gravity. Einstein suggested in his general theory that the gravitational attraction from merging black holes is so intense that it can warp space-time and produce propagating ripples. However, it took another hundred years before the extremely sensitive Laser Interferometer Gravitational-Wave Observatory (LIGO) could detect these ripples on Earth. With these newfound observational capabilities that enabled the detection of gravitational waves, gravity has emerged as a captivating focal point within particle physics. NBIA scientists have recently calculated corrections to the two-body scattering angle up to the fourth post-Minkowskian order using amplitude-based techniques, with fifth-order results currently in progress. Research on gravitational waveforms and black holes with classical spin within a post-Minkowskian framework is another critical area of focus within the post-Minkowskian gravitational research frontier.

The extreme gravitational forces that hold together a black hole are so intense that classically, we predict that time has to halt at their edges and that light is prevented from escaping. It leads to intriguing questions concerning black holes' quantum properties, and to advance understanding, group members have explored the applications of quantum holography and the AdS/CFT gauge/gravity duality in string theory to uncover how black holes potentially retain quantum information and can emit Hawking radiation.

As we are still investigating the foundation of the fundamental high-energy realization of quantum gravity, we approach the quantized theory as an effective field theory. This approach extends the theory with infinite operators to prevent divergences at very high energies while providing robust predictions for low-energy theories. Current cutting-edge research on the gravitational dynamics of binary mergers ranges from examining the phenomenology of observed gravitational wave signals to studying the theoretical implications of strong-field gravity and testing Einstein's theory using enhanced computational techniques. Notably, methods from quantum field theory have proven to be effective in calculating classical values within the framework of general relativity. A key aspect of this is the innovative developments that have changed how we compute scattering amplitudes in particle physics, particularly in the context of the Standard Model.





Modern particle physics is theoretically based on the Standard Model, which comprises 17 fundamental particles (gauge bosons, fermions, and a single scalar particle, the Higgs particle) governed by unified electromagnetic, strong, and weak forces. Consequently, a vital research frontier involves testing the Standard Model experimentally. These experiments mainly focus on the most elusive particles: the Higgs boson, detected with low statistics, and neutrinos, whose oscillations are now known to violate essential principles within the Standard Model. Investigating the properties of the Higgs boson will remain a crucial area of focus at the CERN Large Hadron Collider (LHC) for the foreseeable future.

The Large Hadron Collider's experimental capabilities and gravity applications have also prompted a quest for new and efficient theoretical approaches for scattering amplitude computations. The reformulation of perturbation theory in quantum field theories can utilize new scattering amplitude techniques. Via this, we seek to develop new innovative computational techniques for integrals and loops, guiding a thrilling intersection of pure theory, informed phenomenology, and applied mathematics. The consequence of these novel approaches for calculating scattering amplitudes proposes a new geometric perspective for carrying out quantum field theory computations. An extended focus has been on calculating amplitudes appropriate for general relativity, and it offers complementary, precise inputs for analyzing new gravitational data from LISA and LIGO/VIRGO observations. Such vital developments aid in maintaining the precision and reliability of theoretical predictions in the field.

Investigations into the characteristics of maximally supersymmetric conformal gauge theories, the physics of integrable models, string theory, and gauge/gravity duality form another recent theoretical area of focus. The application of AdS/CFT methods to simulate condensed matter systems and analyze defect conformal field theories is an important research area. These techniques offer new perspectives on strongly coupled quantum field theories necessary for comprehending fundamental particle physics at energy levels presently unreachable by existing particle accelerators.

Particle Astrophysics

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

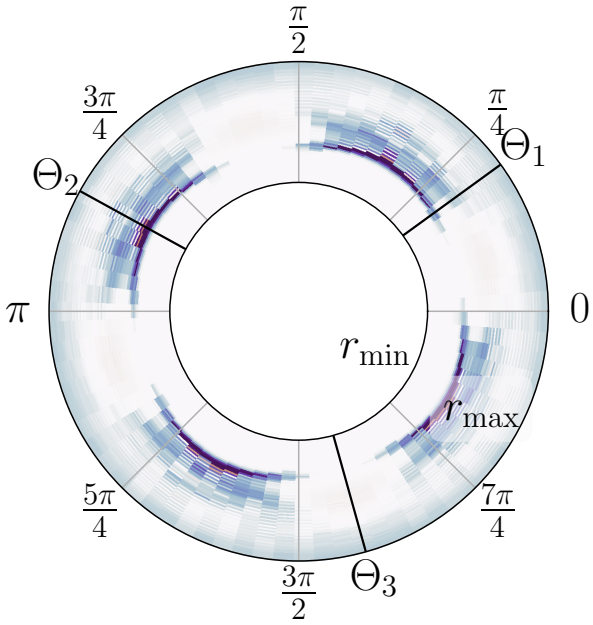
A strong focus of our research lies on neutrinos. Neutrinos are weakly interacting elementary particles emitted from various terrestrial, astrophysical, and cosmological sources over a wide energy range. We work to grasp the role of neutrinos in powering their sources, use them as powerful probes of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

One of the most burning questions in Particle Astrophysics revolves around the role of neutrinos in compact astrophysical sources. In particular, neutron star 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. To this purpose, we have developed sophisticate numerical simulations that track the neutrino flavor conversion in the core of compact sources in multi-dimensions. Our group is also involved in the development of the next generation general-relativity magneto-hydrodynamic simulation to track the collapse of massive stars and the merger of two neutron stars, integrating the physics of neutrino flavor conversion.

The exciting prospects of an upcoming detection of the diffuse background of neutrinos emitted from all supernovae exploding somewhere in the universe have pushed us to investigate the contribution of magneto-rotational collapses to this background. Intriguingly, existing electromagnetic and neutrino data can already provide insight on the supernova population. Moreover, we have also assessed the chances of discovering physics beyond the one foreseen by the Standard Model from this diffuse signal.

The nature of dark matter as well as the possible interactions of neutrinos 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 as well as electromagnetic and gravitational wave signals.

In 2024, we have modeled the production of neutrinos and electromagnetic radiation in a number of astrophysical transients (such as short gamma-ray bursts), pinpointing the efficient sites of particle acceleration and assessing the impact of nuclei heavier than hydrogen in the acceleration of particles along the jet. In order to do that, we have solved the particle transport equations relying on general relativistic magnetohydrodynamic simulations and developed Monte Carlo simulations to track the nuclear decay. We have shown



that it is crucial to move beyond naive models of particle production and take into account the non-linear mixing of matter in the source to model the electromagnetic and neutrino signals. In this context, we have also provided a possible solution to the long-standing open question of the origin of the non-thermal photon spectral distribution observed in gamma-ray bursts. We have also investigated the most promising multi-messenger detection strategies, highlighting the need for multi-wavelength electromagnetic data to inform neutrino searches.

Presently, the most sensitive neutrino telescope in the TeV-PeV energy range is the IceCube observatory at the South Pole. Our group maintains a strong collaboration with the experimental IceCube group at NBI, and participates in the planning of future neutrino telescopes. Moreover, members in our group were heavily involved in the deployment of a neutrino telescope, the Giant Radio Array for Neutrino Detection (GRAND) in the Gobi Desert, in China, whose goal is to eventually discover ultra-high-energy cosmic neutrinos, first predicted in 1969. The experiment consists of an array of antennas that target the radio emission that is expected when these neutrinos collide with the Earth's atmosphere, triggering large particle showers that travel in the air and that emit distinct, short-lived radio pulses that travel for up to 100 km before hitting the ground. In 2024, the existing prototype array was expanded to comprise 48 antennas, getting closer to its target goal of 300 antennas. Members of our group are part of the Executive Board of the experiment, coordinate its publications, and guide its science output.

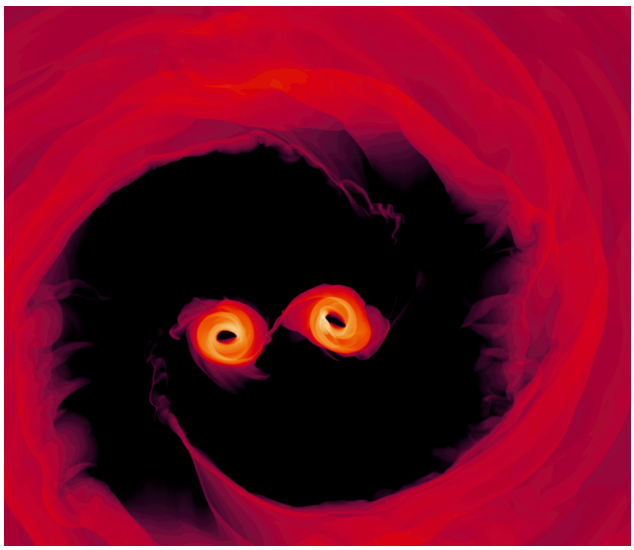
In 2024, scientists in our group have maintained strong ties with researchers at the Max Planck Institutes in Garching through the Collaborative Research Center sponsored by the Deutsche Forschungsgemeinschaft and we have been active in a number of outreach activities. Moreover, we have hosted the NBIA Nordic Winter School on Multimessenger Astrophysics; this one-week school brought graduated students up to date with the latest developments in the burgeoning field of multi-messenger astrophysics. We also hosted the annual NBIA conference Current Themes, this year focused on Transient Astrophysics and Cosmology, as well as an Aspen summer program on Multi-messenger transients from binary mergers and stellar explosions. All these events were extremely successful, gathering many participants from around the world.

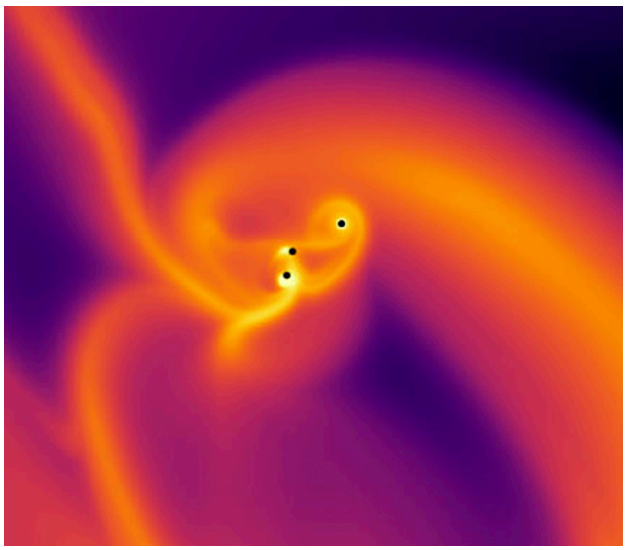
Theoretical Astrophysics

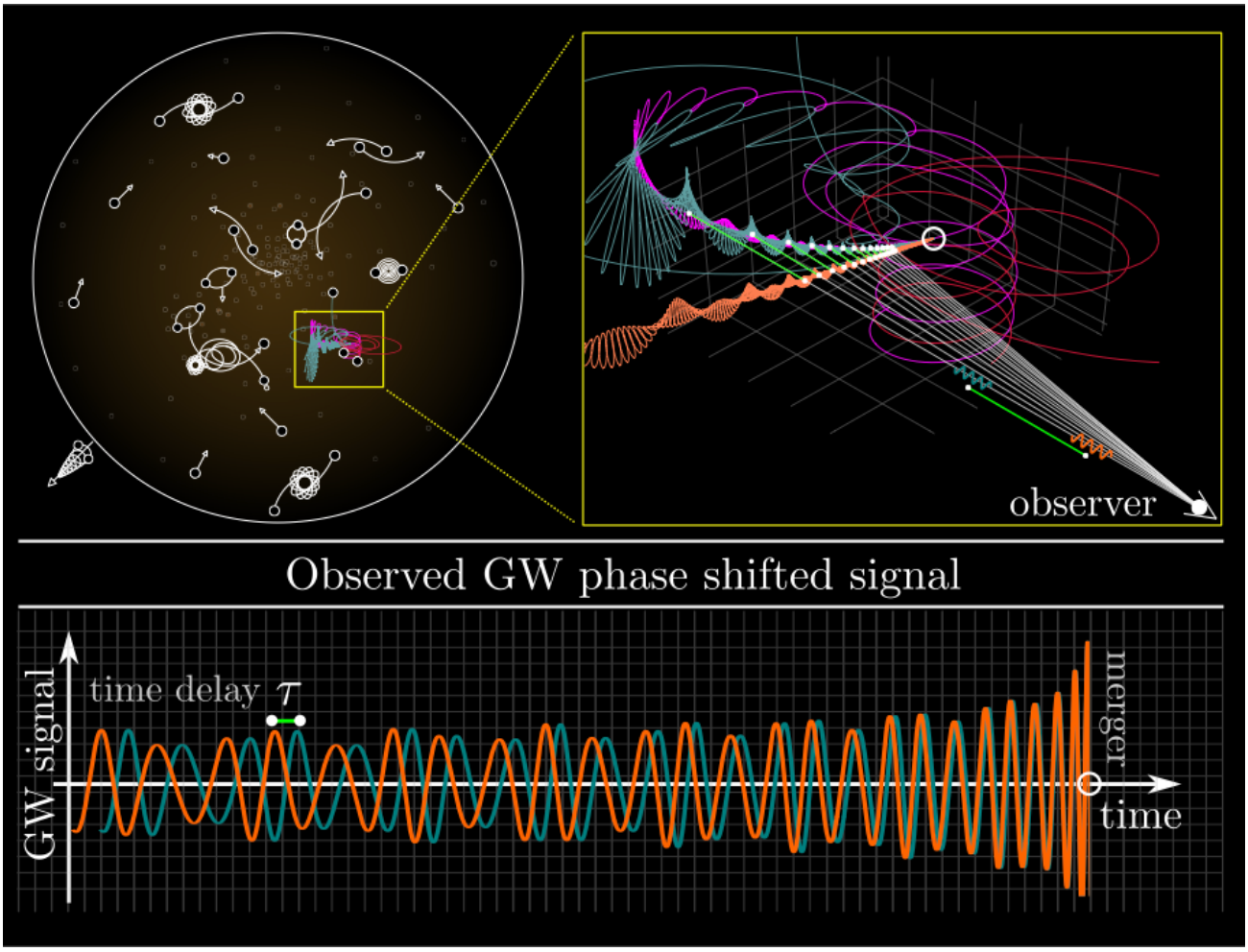
The Theoretical Astrophysics Group at NBIA strives for a comprehensive approach to astrophysics. Current research areas encompass protoplanetary disks and planet formation, accretion disks surrounding compact objects, galaxy clusters, and the physics of gravitational-wave sources. All problems are tackled with a wide perspective, ranging from fundamental theoretical aspects to state-of-the-art simulations with the aim of linking theory and models with observations. A summary of research activities during 2024 follows below.

The formation and evolution of planetary systems remains a major open problem. Fast inward migration of planetary cores embedded in gaseous disks is a common problem in the current planet formation paradigm. Although dust constitutes only about 1% of the mass in a protoplanetary disk, our group has shown that torques exerted by dust can have a substantial impact on intermediate-mass planetary cores. We have carried out the first comprehensive analysis of the dust torque's influence on the evolution of growing planetary embryos as they migrate through a protoplanetary disk and undergo gas and pebble accretion. Our findings demonstrate that dust torque significantly affects planetary migration patterns, particularly facilitating prominent outward migration for planets forming within the water ice line. Overall, our findings highlight the critical role of dust torque in shaping the migration of low- and intermediate-mass planets, particularly in conditions where increased dust concentrations amplify its effects. These insights have significant implications for understanding the formation timescales, mass distributions, and compositional characteristics of emerging planetary systems.

Magnetohydrodynamic turbulence plays a fundamental role in many astrophysical processes. In disks around compact objects, turbulence driven by the magnetorotational instability (MRI) is responsible for efficient angular momentum transport, determining their structure and evolution. This process is mediated by the exponential amplification of the magnetic field whose final amplitude is envisioned to be limited by secondary (parasitic) instabilities. Our group carried out the most accurate calculation of the amplification factor to which the MRI can grow before the fastest parasitic modes reach a comparable amplitude. With these results, we built an effective model for MRI-driven magnetic field amplification. This new model will enable going beyond the standard prescription for viscous transport currently employed in numerical simulations when the MRI cannot be explicitly resolved.







Gravitational wave astrophysics continues developing vigorously at NBIA. Since the first pioneering gravitational wave observation in 2015 of two merging black holes, we have now seen ~100 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 over a wide range of black hole masses and astrophysical environments. We have committed special focus to the dynamical formation of the stellar mass black holes in dense star clusters and in active 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. his 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.

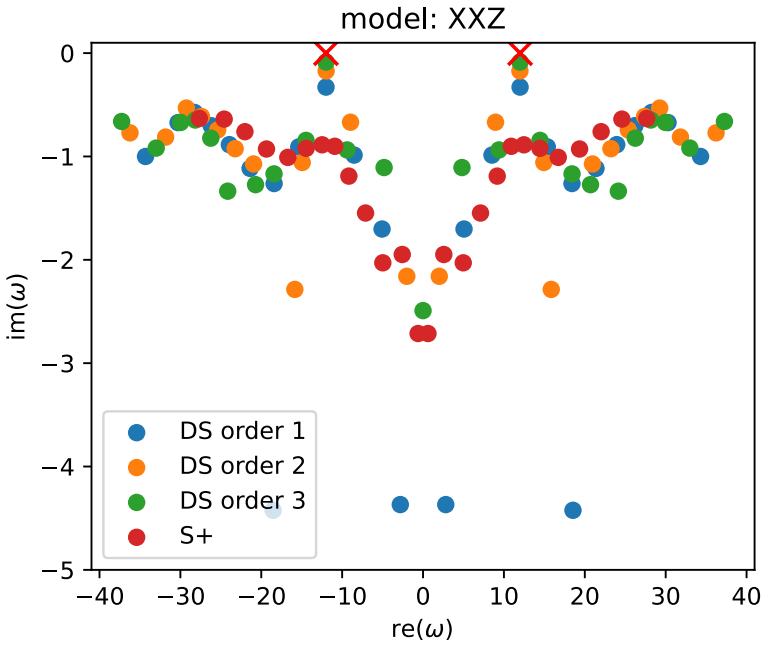
Condensed Matter Physics

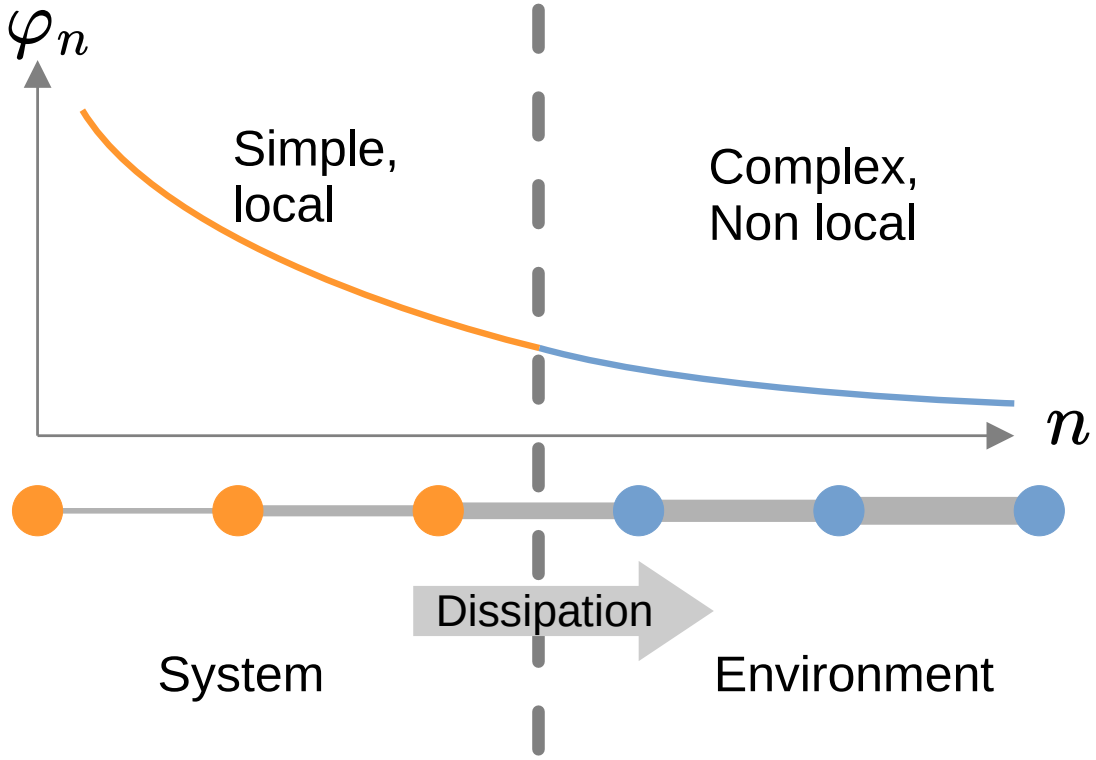
The condensed matter theory group at NBIA researches two broad topics (i) non-equilibrium dynamics in quantum many-body systems and (ii) applications of generalized symmetries in the understanding of the phase structure of interacting quantum matter.

Non-equilibrium dynamics in quantum many-body systems is one of the most active areas in physics interconnecting diverse fields in physics, including condensed matter physics, atomic physics, and even high energy physics and gravity. One of the main topics of the group is non-stationary quantum dynamics, described by time-dependent states. Non-stationary is all around us in day-to-day life e.g., average temperature oscillations from summer to winter and all types of biophysical processes. Understanding such dynamics from the exact microscopic laws is of both fundamental importance to theoretical physics and of potential technological significance, i.e., such an understanding would contribute to the development of quantum technology, e.g., quantum computers. Only with the very recent work of the group have we started to understand non-stationary behavior in such a way. The groups approach is based on identifying novel algebraic structures that can be used to find analytical solutions to the dynamics. The work of the group is therefore mainly mathematical, but the group also has collaboration with experimentalists including those working on cold atomic gases at ETH Zurich.

An important concept to understand non-stationary dynamics are dynamical symmetries. These are predictable types of dynamics that only oscillate and/or decay with time. More general dynamics can typically be explained in terms of a combination of dynamical symmetries.

Our recent approach is to study these dynamical symmetries in Krylov subspace, a representation that maps the physics of the initial system to a simple single-particle problem. This is possible because simple local observables typically spread in time into more complex non local observables. This idea is formally captured by Krylov subspace methods that identify diffusion in the space of observables to diffusion of a single particle hopping on a 1D chain. Studying the dynamical properties of the initial many body system is then equivalent to studying the spectral properties of the 1D Krylov chain. In order to do so, we also work on new numerical methods that are particularly adapted to exploit the algebraic structure of local observables. To make this practical, we are developing the Julia package PauliStrings.jl [https://github.com/nicolasloizeau/PauliStrings.jl] that exploits the Pauli strings representation to efficiently simulate many body systems.





In our second research area, Apoorv Tiwari's team at NBIA is examining different aspects of generalized symmetries in quantum matter. Symmetry is a key concept in modern physics, and lately, there's been a renewed interest in using symmetry-based approaches to classify and understand quantum phases of matter. The realization that topological operators can serve as symmetry operators in quantum systems has driven this renewed interest.

The mathematical structures of higher fusion categories play a crucial role in describing generalized symmetries, with connections to quantum condensed matter physics, high-energy theory, mathematical physics, and quantum information theory. Over the past year, our work has focused on understanding how to manipulate symmetries in quantum systems. These manipulations are applicable to both quantum field theories and quantum lattice models, leading to the development of new dual theories characterized by rich generalized symmetry structures.

We are currently investigating the dynamic implications of symmetries in quantum lattice models, aiming to understand how these symmetries contribute to the classification of quantum matter. Our research is guided by key questions, such as exploring the potential emergence of new phases and phase transitions stabilized by these symmetries. We seek to identify general order parameters and characterize the excitation spectra within these phases.

Additionally, we are exploring whether an understanding of the structure of symmetry and topological operators can lead to the development of quantum platforms capable of realizing universal gate sets for quantum computation. Our research also encompasses the examination of how these symmetry structures interact with non-topological symmetries, particularly crystalline symmetries.

In the upcoming year, our research agenda will be centered around addressing these questions, with the aim of deepening our understanding of the intricate interplay between symmetries and the dynamic behaviors exhibited by quantum lattice models.

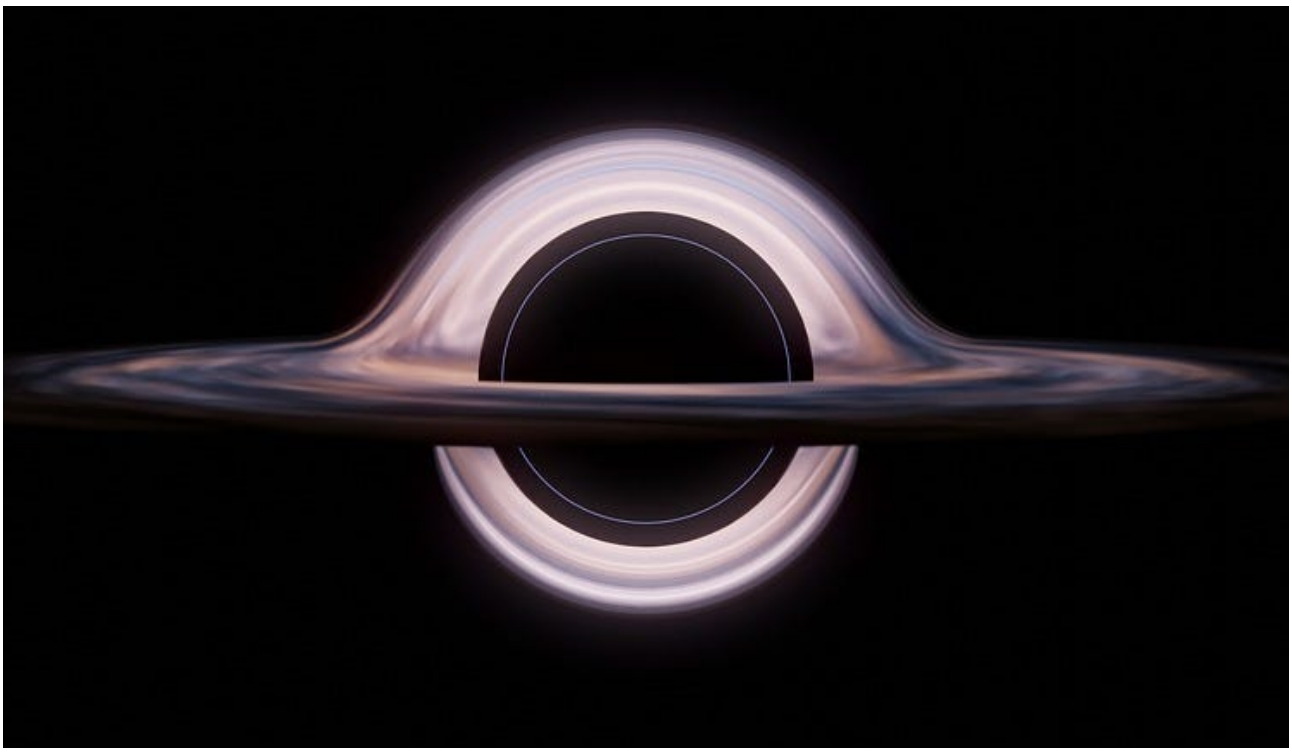
Gravitational Physics

The Strong group at NBIA studies fundamental questions, which relate to gravity in mostly unexplored regimes. We want to shine light on the biggest unknowns in the cosmos: is gravity described by Einstein's theory? Do black holes exist? What happened at the beginning of the Universe? Can we use black holes as probes of other interactions? To realize the tremendous underlying discovery potential, we combine unique know-how in theory together with observations.

Our ability to understand gravity is at a turning point. Increasingly precise LIGO/Virgo gravitational-wave observations and imaging of black hole shadows by long-baseline radio interferometry opened unprecedented windows onto gravity at its strongest. The decision of the European Space Agency to devote its third large-class mission to a gravitational-wave observatory (LISA) highlights the timeliness and relevance of the topic. During the next few years, we expect to observe hundreds of black-hole mergers from operating detectors worldwide. Strong-field gravity is expanding beyond the domain of mathematical physics to become a precision experimental science. Black holes are the simplest, most compact, and physically elusive macroscopic objects in the Universe, playing a central role in this new era. Among astronomical targets, they are extraordinary in their ability to convert energy into radiation, and the study of their stability and dynamics challenges our knowledge of partial differential equations and of numerical methods. Meanwhile, the information paradox and the existence of unresolved singularities in classical general relativity point to deep inconsistencies in our current understanding of gravity and quantum mechanics. It is clear that the main conceptual problems in black hole physics hold the key to many fundamental issues in physics.

One of the holy grails of gravitational-wave astronomy is to provide observational evidence for the general relativistic prediction that black holes in our universe belong to the Kerr family. An exciting tool to address this issue is *black hole spectroscopy*, introduced and led by the Strong team, and explored by a wide community worldwide. Here, black hole vibration spectra are used to infer its properties, relying on uniqueness results of General Relativity and the ensuing simplicity of vacuum black holes. We pioneered innovative analysis techniques rigorously incorporating statistical and systematic uncertainties, included nonlinearities as well as predictions of theories that extend General Relativity. Gravitational waves are direct probes of gravity down to the horizon scale and can also shed light on one of the outstanding open issues in physics: the nature of compact, dark objects. It has been tacitly assumed that these are black holes, but several arguments suggest that new physics might set in during gravitational collapse. Large efforts of our group are devoted to the challenge of quantifying the presence of horizons in spacetime. These efforts have shown that gravitational waves have the potential to inform us on the nature of compact objects (do black holes exist?) and on the strong-field behavior of gravity (do they behave as in General Relativity?). One of the unexpected findings by our team concerns the sensitivity of the spacetime response to fluctuations close to resonances, and the instability of the spectrum itself under small perturbations of the scattering potentials. Because astrophysical black holes are not isolated, this question is of paramount importance, as it may have an impact across disciplines.

A complementary opportunity to probe the nature of black holes and their dynamics is offered by gravitational waves produced by small black holes orbiting massive ones. The small black hole acts as a sensitive probe mapping the geometry of the massive one (and possibly its environment), providing unequaled measurements of its properties as predicted by General Relativity.



We have world-leading expertise in the modeling of such extreme mass-ratio inspirals as a perturbative series in the smaller mass, i.e., the gravitational self-force formalism.

With precise tests of the black hole geometry under control with spectroscopy, one needs to step away from the vacuum paradigm. There is overwhelming evidence for the existence of dark matter interacting gravitationally. Understanding its microscopic nature is arguably one of the outstanding challenges. The Strong team at NBIA is a well-known leader in the study of the gravitational physics of new fundamental fields. We showed that massive bosons outside black holes lead to smoking-gun effects (superradiant instabilities and floating orbits), allowing new competitive constraints on their masses and couplings.

In addition to encoding details about their sources, gravitational waves carry precious information about their astrophysical environments. It is hard to overstate the role of black holes in the search for new fields or environmental properties. However, to realize the immense potential of gravitational-wave astronomy, it is imperative to model accurately the interaction with matter. For example, to quantify the impact of an entire galaxy on the propagation of gravitational waves, one needs to model accurately the geometry, and to solve the dynamics of the binary in this complex environment.

As the sensitivity of detectors improves, more distant black holes will be observed. Inevitably, along the billions of years of travel, gravitational waves will encounter inhomogeneities, in the form of galaxies at the largest scales or compact objects at the smallest scales. Lensing of gravitational waves opens unique frontiers to understand the foundations of our Universe. It allows us to map the dark matter distribution in uncharted regions of the cosmos, and it offers a precise gravity laboratory, where gravitational fields can be constrained to their limits. The Strong group leads the search for lensed waves and their implications for fundamental physics.

We are exploring foundational issues, deepening our understanding of matter and of gravitation as a fundamental interaction. Wherever possible, we will confront our predictions with gravitational waves and other observational data, addressing critical problems: how can we use current and future gravitational-wave data to test fundamental physics? How can we optimally design next-generation detectors to probe the nature of black holes? The road ahead is challenging, but exciting.

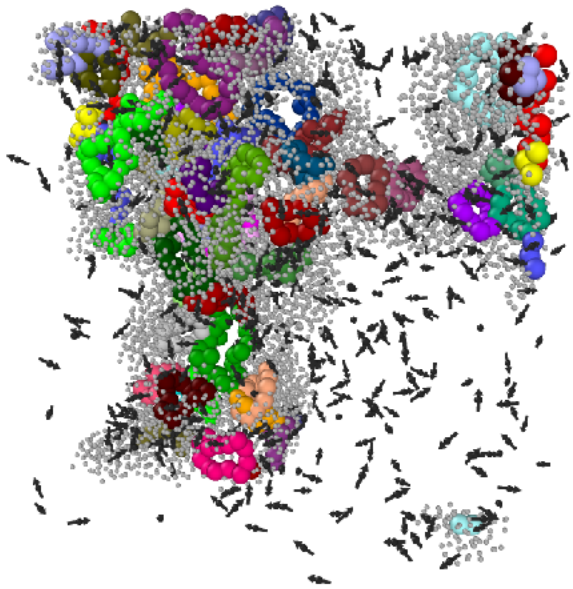
Soft Matter Physics & Active Matter

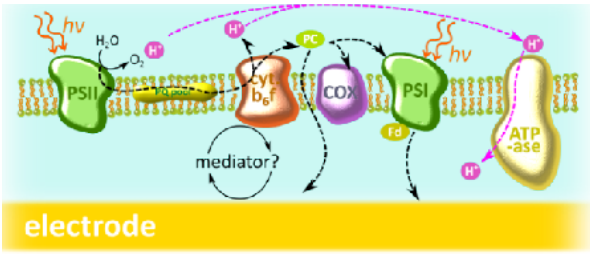
Soft matter physics lies at the heart of a quantitative understanding of many biological processes. From subcellular protein-driven flows to multicellular organ formation, biological matter continuously drives itself away from thermodynamic equilibrium using internal biochemical processes. In addition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

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

The core idea is to design a novel class of Living Matter, comprised of a viscoelastic and adaptive phase freely embedded within spontaneously flowing biofluids. We have launched the development of a state-of-the-art modeling framework that combines artificial intelligence, with physical modelling of active matter, and mathematical modeling of complaint materials, to study the interaction of active matter with adaptable and responsive environments.

Mechanostransduction: How Mechanics Guides Biochemical Signaling — There is growing evidence that mechanical forces can activate biochemical signaling for tissue regeneration, stem cell differentiation, and morphogenesis. Importantly disruption of this effect by changes in the microenvironment leads to pathological responses including tissue fibrosis and cancer. The connection between mechanical forces and cell response is the process of mechanotransduction: mechanical forces activate biochemical signals by changing the concentration of mechanosensing proteins inside the cells. For example, putting cells under excessive tension localizes proteins that control cell division inside cell nuclei, leading to hyper-proliferation. Diffusion of chemical signals is too slow to be able to convey the mechanical information across the tissue. On the contrary, the force transmission between the cells provides a fast and long-range mechanism for propagation of mechanical cues over large spatial scales. Therefore, it is essential to understand the mechanism of mechanotransduction in the context of multicellular aggregates.





Starting in September 2022 and funded by an ERC Starting Grant, our group will combine multiscale modeling – discrete and continuum simulations of cell mechanics with in-house experiments to reveal the impact of mechanical forces from multicellular motion on signaling and the mechanical feedback from the activation of biochemical signaling.

Topological analyses of biological data — The group also works on developing and applying methods from computational and applied geometry and topology to characterize and understand the emergence of order and self-assembled structures in a variety of soft matter and biophysical systems. This work takes place at the interfaces between theory, simulation, and experiments, with the aim of providing clear ways to interpret and relate results from various sources directly to one another.

Thermodynamics in Biology — Currently, one main research interest in the group is on how thermodynamics puts constraints on biological processes. More specifically, the focus is on questions such as to what extend are biological processes, such as DNA replication, optimised, which role does thermodynamics play in biological evolution, and what are the thermodynamic constraints necessary to create non-equilibrium phenomena, such as chemical oscillations and motility-induced phase-separation. We also study the stochastic thermodynamics of synthetic biological circuits. Over the last two decades synthetic biology has lead to important applications such as drug delivery and biosensors. By creating a consistent framework for the thermodynamics of these circuits, we aim to propose new optimisation schemes and design principles for future applications.

Computational Microscopy — We develop and use computational microscopes to understand fundamental biological processes at the cellular level. For instance, how cells repair their membranes after injury or how toxic particles hijack cellular machinery for their entry. These mechanisms include many exciting physical phenomena such as fluctuations induced forces, phase transition, phase coexistence, and molecular condensations. Our latest works include obtaining the molecular architecture of SARS-CoV-2 virion envelope through integrative modeling techniques and FreeDTS, a software package to simulate a biological membranes at the mesoscale. Our current focus is to understand how biomolecules come together and form the architecture of the cellular powerhouse.

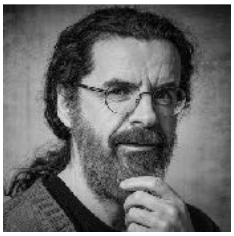
A new toolbox to reveal bioelectronic interfaces — We aim to unravel and rewire the complex biointerfaces between photosynthetic biofilms and electrode surfaces, which lie at the heart of the rapidly growing field of bioelectronic devices that use photosynthetic organisms such as cyanobacteria wired to electrodes to renewably generate electrical energy, fuels and chemical feedstocks. These technologies are extremely promising, but remain limited by slow electron transfer at the biofilm/electrode interface, which has proven particularly challenging to surmount, due to poor understanding of the key mechanisms at these interfaces. Of particular interest is the thylakoid membrane, which is the site of photosynthesis in plants and cyanobacteria. These thylakoid membranes can be extracted and deposited directly onto the electrode for improved light harvesting, but are still limited by our poor understanding of their electron transport mechanisms.

Finally, links with experiments are important in conducting this research. We have launched exciting collaborations with international experimental groups in France (University Paris Diderot and Curie Institute) and Japan (Osaka University), as well as with the Novo Nordisk Foundation Center for Stem Cell Medicine and Novo Nordisk Foundation Center for Protein Research to profile NBIA as one of the leading institutions in these rapidly growing areas of research.

NBIA Staff

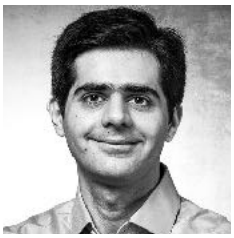
Faculty

Niels Emil J. Bjerrum-Bohr completed his Ph.D. in Copenhagen in 2004. He was a postdoc in Swansea from 2004 to 2006 and was a member of the Institute for Advanced Study in Princeton from 2006 to 2009. Emil was appointed Knud Højgaard Assistant Professor at the NBIA in 2010 and awarded a Steno grant from the Danish Science Research Council. He was appointed Associate Professor in 2016. Emil's research focuses on amplitudes in Yang-Mills theory and quantum gravity, and he currently works on computing classical observables in Einstein's gravity from scattering amplitudes supported by a grant from the Independent Research Fund Denmark.

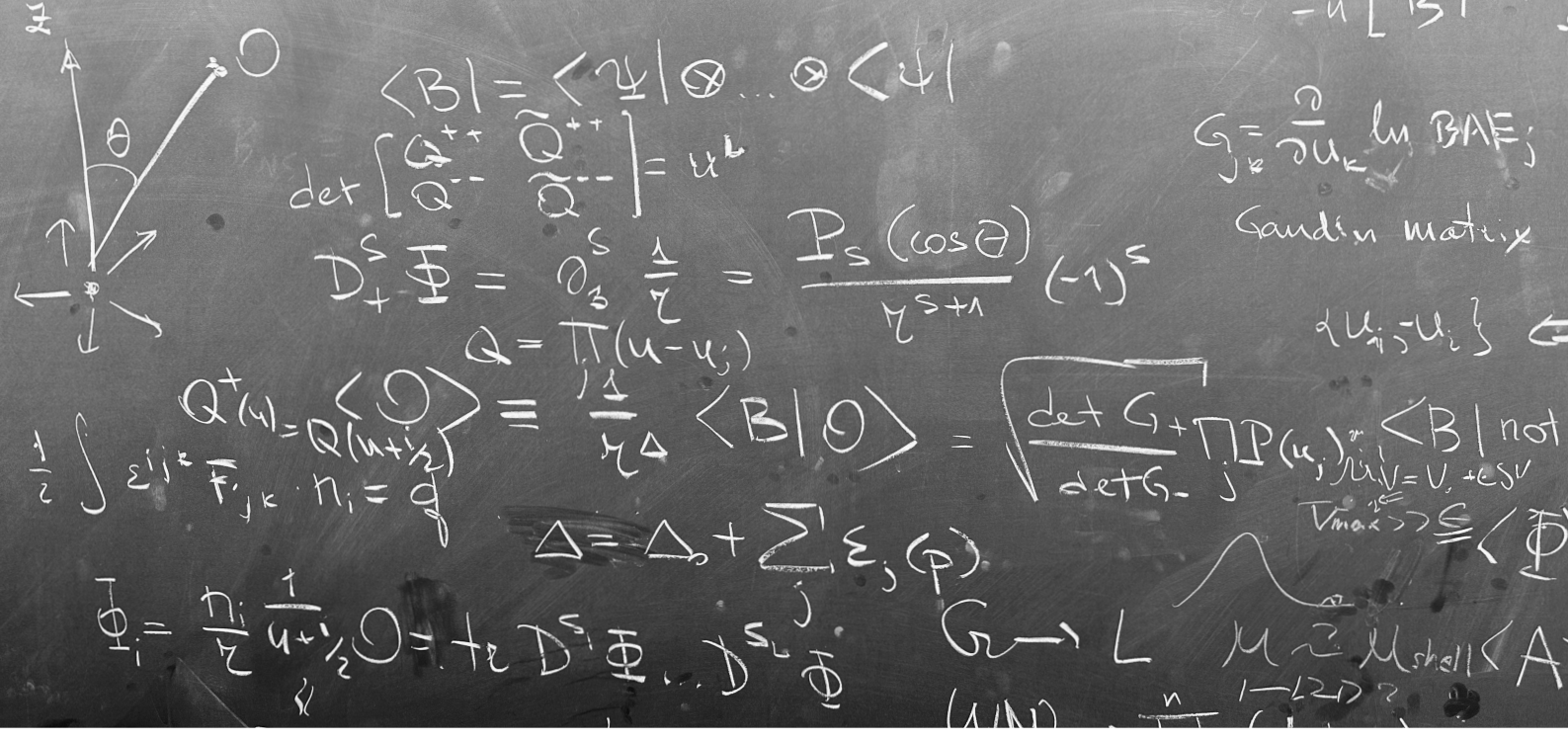


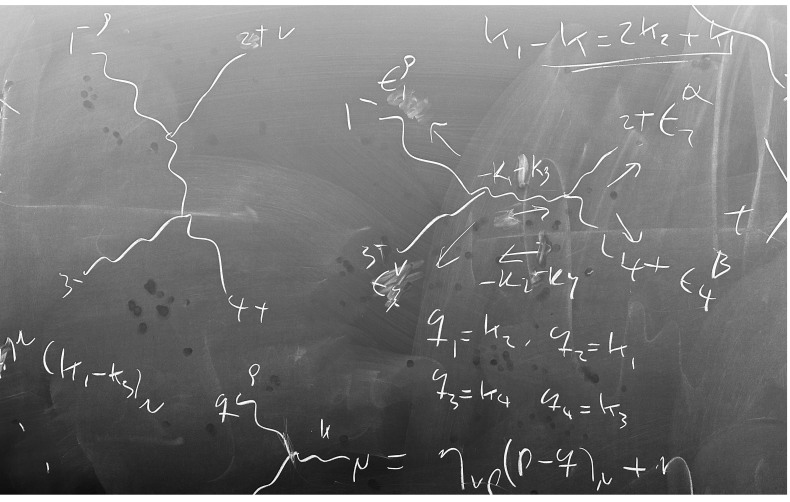
Vitor Cardoso did his PhD in Técnico Lisbon in 2003. Professor of Physics at Técnico since 2016, he was a Fellow at Amsterdam, Belém do Pará, CERN, Perimeter Institute, Rome, Waseda at the Yukawa Institute. He joined NBIA in 2022, as a Villum Foundation Investigator and a DNRF Chair and leader of the Strong team. His research interests are mainly focused on strong-gravity problems, with implications for gravitational-wave and black-hole physics, high-energy and particle physics. He is the co-author of one book and of over 200 scientific papers. He is a member of the Lisbon Academy of Sciences and an IST Distinguished Professor. His researchv was recognized by the European Research Council, with three prestigious ERC Grants. He was awarded the “Ordem de Sant’Iago da Espada” presidential title, for contributions to science and is an “Honourable Citizen” of Póvoa de Varzim.

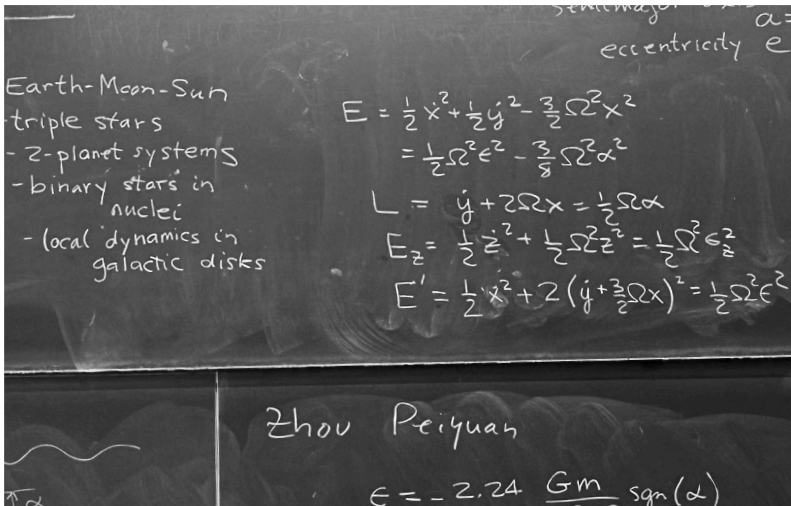
Poul Henrik Damgaard did his undergraduate studies at the University of Copenhagen and then went to Cornell University, where he received his PhD in 1982. He has held post-doctoral positions at Nordita, CERN, and the Niels Bohr Institute, and has for a period of six years been Scientific Associate at 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 electroweak baryogenesis from the Large Hadron Collider (LHC).

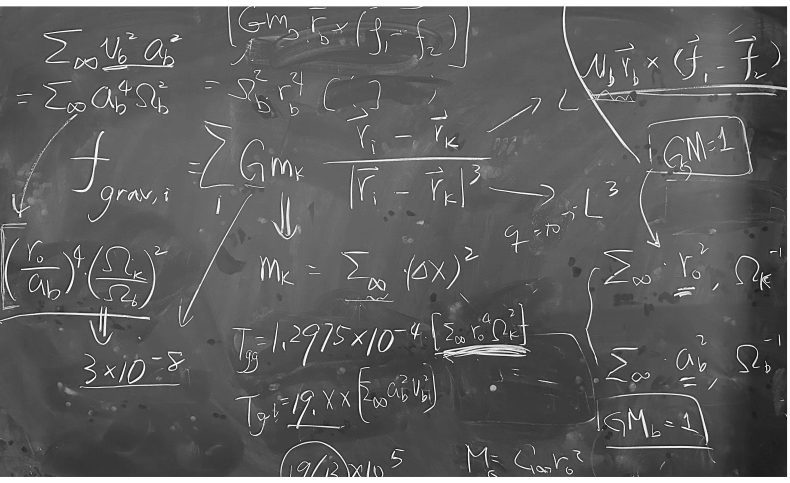


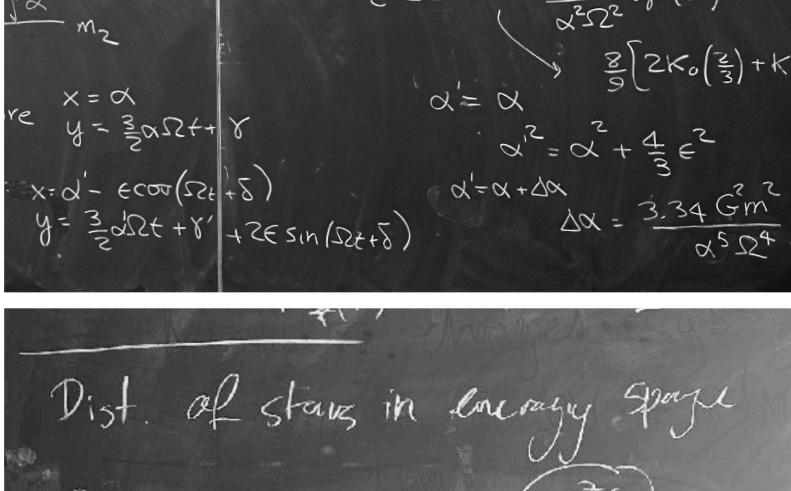
Amin Doostmohammadi is a Novo Nordisk Foundation Associate Professor at NBIA. He also has a cross-appointment as Specially Appointed Assistant Professor at Bioengineering in Osaka University, Japan. He received his PhD at University of Notre Dame and held a prestigious Royal 1851 Research Fellowship at Oxford before joining NBIA. Amin leads the Active Intelligent Matter research group working at the interface between physics and biology, modeling active materials. Their recent finding of the correlation between topological defects in tissues and the sites for cell death is a page-turner for the field of tissue biology, challenging the consensus, and bring physics of liquid crystals into studying diverse biological problems. Currently, Amin’s group is generously supported by the Novo Nordisk and Villum Foundations and an ERC Starting Grant.

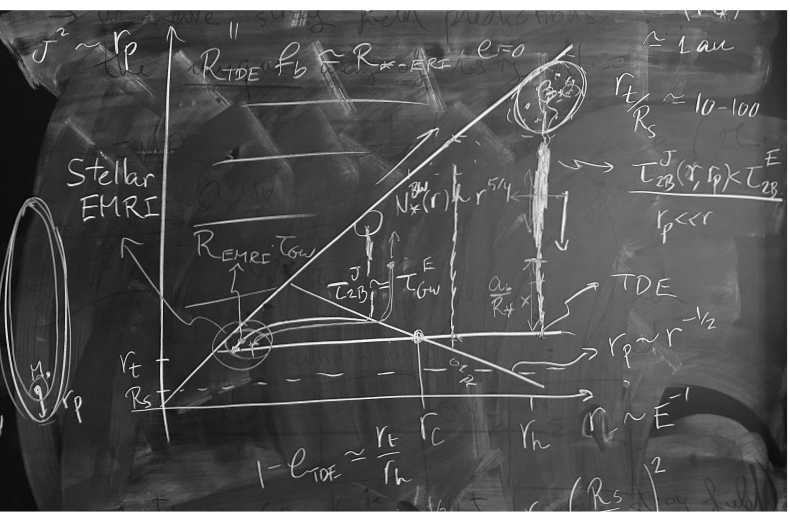

$\langle B| = \langle \psi | \otimes \dots \otimes \langle \psi |$
$\det \begin{bmatrix} Q^{++} & \tilde{Q}^{++} \\ Q^{--} & \tilde{Q}^{--} \end{bmatrix} = u^k$
$D_+^s \Phi = \partial_3^s \frac{1}{z} = \frac{P_s(\cos\theta)}{r^{s+1}} (-1)^s$
$Q = \prod_i (u - u_i)$
$G_{jk} = \frac{\partial}{\partial u_k} \ln$ B/AE;
Gaudin matrix
$\{u_i, -u_i\}$
$Q^+(u) = Q(u + i/2)$
$\langle O \rangle \equiv \frac{1}{r\Delta} \langle B | O \rangle = \sqrt{\frac{\det G_+}{\det G_-}} \prod_j P(u_j) \langle B |$ not
$\frac{1}{2} \int \varepsilon^{ijk} F_{jk} \cdot n_i = Q$
$\Delta = \Delta_0 + \sum_j \varepsilon_j(\varphi)$
$\Phi_i = \frac{n_i}{r} \frac{1}{u + i/2} O = \dots D^{s_i} \Phi \dots$
$G \to L$
$M \sim M_{shell}$

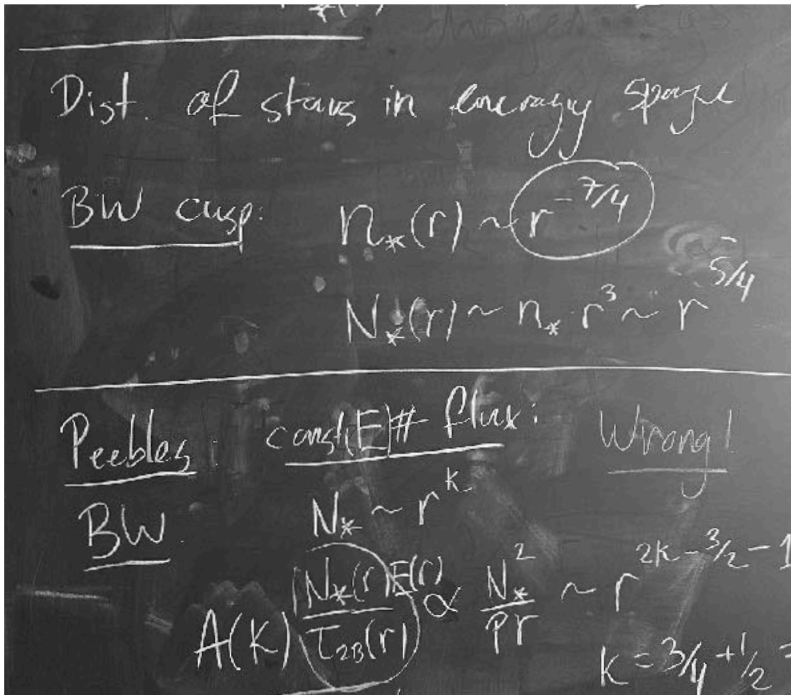

$k_1 - k_4 = 2k_2 + k_1$
$-k_1 + k_3$
$q_1 = k_2, \; q_2 = k_1$
$q_3 = k_4, \; q_4 = k_3$
$\mu = \eta_{\nu\rho}(p - q)_\mu + \dots$


eccentricity e
Earth-Moon-Sun
triple stars
- 2-planet systems
- binary stars in nuclei
- (local dynamics in galactic disks
$E = \frac{1}{2}\dot{x}^2 + \frac{1}{2}\dot{y}^2 - \frac{3}{2}\Omega^2 x^2$
$= \frac{1}{2}\Omega^2 \epsilon^2 - \frac{3}{8}\Omega^2 a^2$
$L = \dot{y} + 2\Omega x = \frac{1}{2}\Omega a$
$E_z = \frac{1}{2}\dot{z}^2 + \frac{1}{2}\Omega^2 z^2 = \frac{1}{2}\Omega^2 \epsilon_z^2$
$E' = \frac{1}{2}\dot{x}^2 + 2\left(\dot{y} + \frac{3}{2}\Omega x\right)^2 = \frac{1}{2}\Omega^2 \epsilon^2$


$\sum_\infty v_b^2 a_b^2 = \sum_\infty a_b^4 \Omega_b^2$
$f_{grav,i} = \sum_k \frac{Gm_k}{|\vec{r}_i - \vec{r}_k|^3} (\vec{r}_i - \vec{r}_k)$
$\left(\frac{r_0}{a_b}\right)^4 \left(\frac{\Omega_k}{\Omega_b}\right)^2$
3×10^{-8}
$m_k = \sum_\infty (\Delta x)^2$
$T_{gg} = 1.2975 \times 10^{-4} \left[\sum_\infty r_0^4 \Omega_k^2\right]$
$T_{gb} = 19.1 \times \left[\sum_\infty a_b^2 v_b^2\right]$
$M = \rho_{bar} r^3$
$GM = 1$
$\sum_\infty r_0^2 \Omega_k^{-1}$
$\sum_\infty a_b^2 \Omega_b^{-1}$
$GM_b = 1$


Zhou Peiyuan
$\epsilon = -2.24 \frac{Gm}{a^2\Omega^2} \text{sgn}(\alpha)$
$\alpha' = \alpha$
$\alpha'^2 = \alpha^2 + \frac{4}{3}\epsilon^2$
$\alpha' = \alpha + \Delta\alpha$
$\Delta\alpha = \frac{3.34 G^2 m^2}{a^5 \Omega^4}$
m_2
$x = a$
$y = \frac{3}{2}a\Omega t + \gamma$
$x = a' - e\cos(\Omega t + \delta)$
$y = \frac{3}{2}a\Omega t + \gamma' + 2e\sin(\Omega t + \delta)$

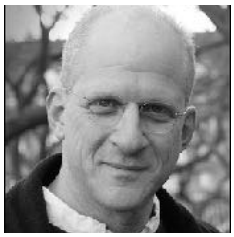

Stellar EMRI
$R_{TDE} \; f_b \sim R_{*-EMRI} \; e=0$
~ 1 au
$r_t/R_s \sim 10-100$
$T_{2B}^J(r, r_p) < T_{2B}^E$
$r_p \ll r$
R_{EMRI}
T_{GW}
TDE
$r_p \sim r^{-1/2}$
r_t/R_s
r_p
r_c
r_h
$r \sim E^{-1}$
$1 - e_{TDE} \simeq \frac{r_t}{r_h}$
$\left(\frac{R_s}{r_t}\right)^2$


Dist. of stars in energy space
BW cusp: $n_*(r) \sim r^{-7/4}$
$N_*(r) \sim n_* r^3 \sim r^{1/4}$
Peebles
BW
const E # flux:
$N_* \sim r^k$
Wrong!
$A(k) \frac{N_*(r) E(r)}{T_{2B}(r)} \propto \frac{N_*^2}{Pr} \sim r^{2k-3/2-1}$
$k = 3/4 + 1/2$

Faculty

Troels Harmark is Associate Professor at NBIA. He received his PhD from NBI in 2001 and became postdoc at Harvard University with Andrew Strominger. He received grants from DFF and Carlsberg to work as researcher at NBI and subsequently an assistant professorship at Nordita in 2009. Since 2012 he has been at NBI, becoming permanent in 2015. From 2017 he held the large project grant from DFF (together with N. Obers). He has led the Theoretical High Energy, Astroparticle and Gravitational Physics section since 2018. His current research includes astrophysical applications of general relativity, such as magnetospheres of black holes and tidal forces on binary systems, as well as non-relativistic limits of the holographic principle and string theory.

Charlotte Fløe Kristjansen got her PhD from NBI and afterwards held postdoc positions at IPhT Saclay, Nordita and NBI where she became Associate Prof. in 2006 and Professor in 2011. She had long term visiting positions at Tokyo Institute of Technology and at the MPI for gravitational physics in Potsdam. Charlotte's research interests are centered around exact solutions to problems in quantum field theory and string theory. She is currently working on defect conformal field theories with holographic duals. Other key interests are integrability in the AdS/CFT correspondence, spin chains and graphene. Earlier she has worked on discrete models of quantum gravity and on random matrices. She has been a member of the national research council for six years.



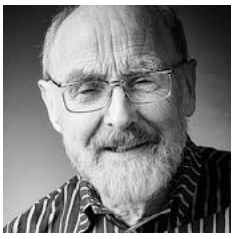
Charles Marcus was an undergraduate at Stanford University (1980-84). He received his Ph.D. at Harvard in 1990 and was an IBM postdoc at Harvard 1990-92. He was on the faculty in Physics at Stanford University from 1992-2000 and Harvard University from 2000 to 2011. In 2012, Marcus was appointed Villum 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.

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.

Faculty

Niels Obers is Professor at NBIA. He did is undergraduate studies at Nijmegen University and received his PhD degree from the University of California, Berkeley in 1991. He subsequently held postdoctoral positions at Bonn, Ecole Polytechnique, CERN and Nordita. During 2000-2002 he was an assistant professor at Utrecht University and moved in 2002 to NBI for an associate professor position, becoming full professor in 2012. From 2012-2018 he was deputy head of departement as well as acting head of department for a period in 2017. He has done research on conformal field theory, non-perturbative string dualiies and the dynamics of higher-dimensional black holes and branes. Recently he has been developing non-relativistic gravity, string theory, and holography using non-Lorentzian geometries.

Martin Pessah obtained his first degree in Astronomy in 2000 from the University of La Plata, Argentina and received his PhD in Theoretical Astrophysics from the University of Arizona in 2007. He was a Member at the Institute for Advanced Study in Princeton until 2010 and later moved to Copenhagen as a Knud Højgaard Assistant Professor to break ground for the new Theoretical Astrophysics Group at NBIA. Martin became Associate Professor in 2013, Professor MSO in 2015, and was appointed Professor of Theoretical Astrophysics in 2023. He has been Deputy Director at NBIA since 2016. Martin's research interests span a broad range of subjects in astrophysical dynamics, fluid dynamics, and magnetohydrodynamics.



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

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

Faculty

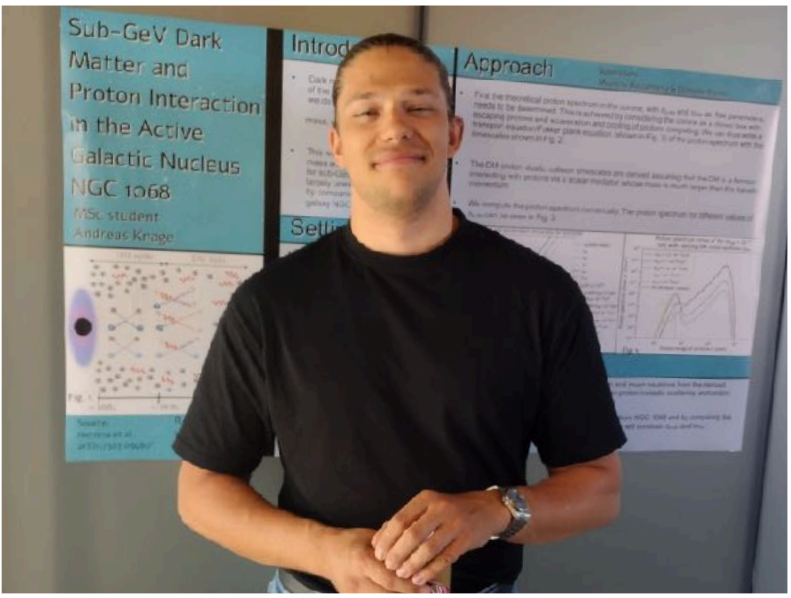
Matthias Wilhelm received his PhD from Humboldt University Berlin before joining NBIA in 2015. His research interests lie within the field of quantum field theory and high-energy theory, with a focus on gauge theories, the gauge-gravity duality and exact methods. He works on the number theory behind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

Konstantin Zarembo received his PhD from the Steklov Mathematical Institute in Moscow in 1997. After that he worked at UBC in Vancouver, Uppsala University and École Normale Supérieure in Paris. He became a Nordita Professor in 2010 and holds a joint appointment between NBI and Nordita since 2019. Konstantin's field of research is theoretical high-energy physics, with main interests in quantum field theory, string theory and integrable systems. He pioneered the use of integrability and the Bethe ansatz in the AdS/CFT correspondence, which gave rise to new nonperturbative methods in quantum field theory. He has also worked on various aspects of string theory, statistical mechanics, and mathematical physics.

Associate Faculty

Jácome (Jay) Armas completed his Ph.D. at the Niels Bohr Bohr Institute in 2012. He was postdoctoral researcher at the University of Bern 2013-2014 and Université Libre de Bruxelles 2015-2017. He joined the University of Amsterdam in 2018 as tenured Assistant Professor and became coordinator of the Dutch Institute for Emergent Phenomena. His research is now focused on hydrodynamics and symmetries with applications to astrophysics, quantum matter, soft and active matter as well as high-energy physics. He is PI of the interdisciplinary program Foundations and Applications of Emergence as well as Emergent Phenomena in Society: Polarisation, Segregation and Inequality where he works on applying quantum methods to complex systems with applications to living systems and social/economic problems. In addition he is founder and main organizer of the internationally renowned and award-winning Science & Cocktails event series. He is also Associated Professor at NBIA and a member of the Institute for Advanced Study in Amsterdam since 2022.

Marta Orselli joined the Strong Gravity group at NBIA in 2023. She is an Associate Professor at the University of Perugia and Affiliate Associate Professor at the Niels Bohr Institute. After obtaining her PhD from Parma University, Marta held postdoc positions at NORDITA and at the Niels Bohr Institute, receiving grants from the Carlsberg Foundation, the European Community (ERG) and from the Danish Natural Science Research Council. Marta's research interests include the study of systems in a s strong gravity regime, gravitational-wave physics, black-hole physics and high-energy physics.


Sub-GeV Dark Matter and Proton Interaction in the Active Galactic Nucleus NGC 1068
MSc student
Andreas Kroge
Approach

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.

Berislav Buca has joined NBIA in November 2022 as an Assistant Professor on a Villum Young Investigator grant. His field of research is theoretical physics of non-equilibrium quantum many-body systems. Berislav obtained his PhD (2015) at the University of Ljubljana discovering 'weak' and 'strong' symmetries in open quantum systems. During his postdoc (2017-2022) at Oxford University he discovered a novel algebraic principle determining the dynamics of quantum many-body-systems out-of-equilibrium. He lectured for Keble College Oxford and remains a visitor at Oxford. At NBIA Berislav will study exact solutions of dynamics in quantum many-body systems. This will enable discovery of novel kinds of phases of quantum matter out-of-equilibrium, which have not been theoretically accessible before.

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

Mauricio Bustamante is an Assistant Professor at NBIA. He completed his PhD at the University of Würzburg and DESY in 2014. He later became 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: 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.

Junior Faculty

Gang Chen completed his PhD. in Nanjing University and worked junior faculty in there. Then he moved to Uppsala, Queen Mary University as postdoc. From 2022, he joint in NBI and employed as assistant professor from 2023. Now he works on scattering amplitude, gravitational wave and high spin field theory. He is currently focus on the kinematic algebra and double copy in various theories, and applies them to gravitational-wave and black hole physics.

Daniel D'Orazio is a DFF Sapere Aude Research Leader and Assistant Professor at NBIA. After a Fulbright Fellowship at the University of Zürich, Daniel completed his PhD in 2016 as an NSF Graduate Research Fellow at Columbia University. Before joining the NBIA in 2020 he was a NASA Einstein Fellow and an Institute for Theory and Computation Fellow at Harvard University. 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 multimessenger 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.

Jose M. Ezquiaga joined NBIA as an Assistant Professor in 2022. Previously, he was a NASA Einstein Fellow at the University of Chicago. He obtained his PhD from Universidad Autonoma de Madrid in 2019. Jose exploits gravitational-wave data to explore uncharted regions of the Universe. His research lies at the intersection of fundamental physics, cosmology and astrophysics and aims at probing gravity and unveiling the nature of dark energy and dark matter. Jose is a Villum Young Investigator and PI of the Niels Bohr Institute LIGO group. He is also a member of LISA and Cosmic Explorer.

Asta Heinesen is an assistant professor working on questions within cosmology and general relativity. Her current research is focused the novel cosmic drift measurements for determining the expansion rate of the Universe, developing geometric methods for analysing cosmic observables (cosmographic methods), developing dictionaries between fully general-relativistic models of cosmology and Newtonian descriptions, as well as deriving results for the propagation of light in non-trivial space-times. She is also working with statistical analyses of astrophysical datasets (BOSS-SDSS, Joint Lightcurve Analysis, Pantheon+, and Gaia) with the purpose of consistency testing and constraining the standard model as well as alternative cosmological models.

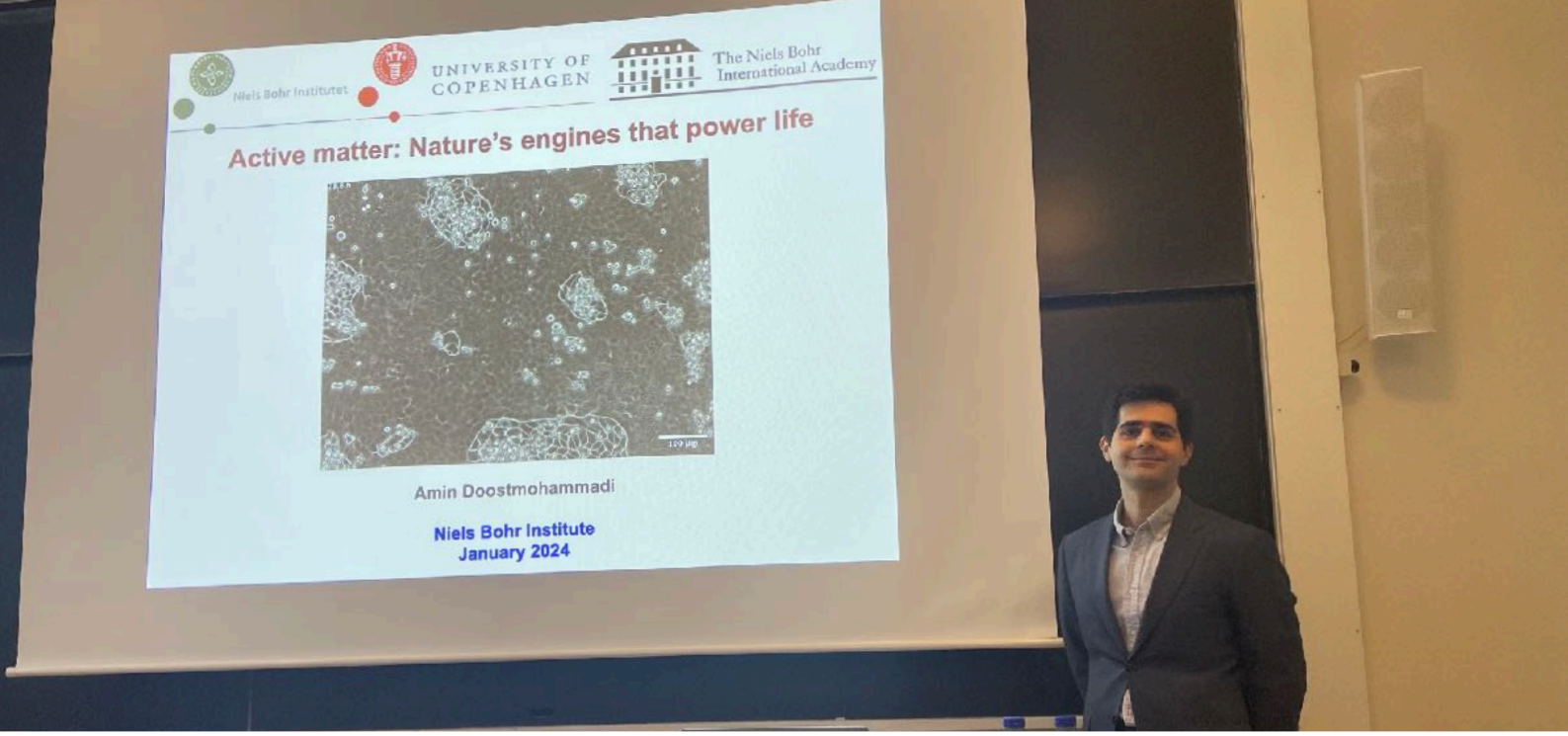
Junior Faculty

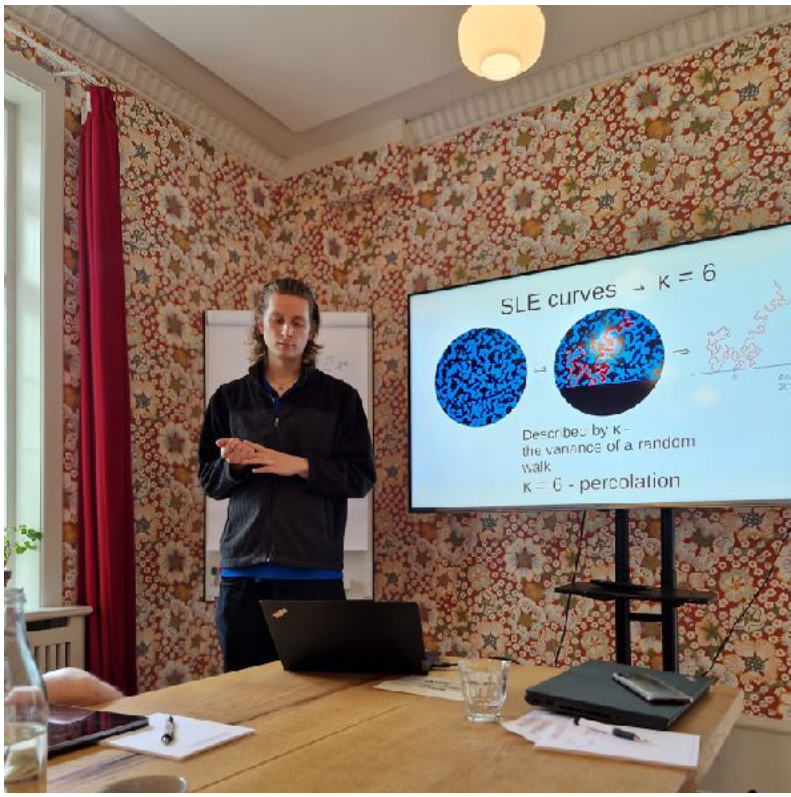
Natascha Leijnse is an experimental biophysicist working in the Active Intelligent Matter Research group. After she obtained her PhD at University of Copenhagen she worked as a postdoc at Stanford University and returned to Copenhagen. She is studying cell properties and mechanotransduction processes in living cells using optical tweezers combined with fluorescent imaging. Her latest work uncovered an active mechanism that filopodia, “cellular fingers”, use to exert forces during embryonic- but also cancer development.

Zhengwen Liu received his Doctorate from the Université catholique de Louvain in 2019. Before joining the NBIA as an assistant professor in the fall of 2022, Zhengwen was a postdoctoral fellow at the DESY in Hamburg. He is interested in understanding the fundamental interactions in nature, with a particular focus on scattering amplitudes and Feynman integrals in quantum field theory, ranging from their mathematical structures to their applications to collider physics and gravitational-wave observations. He currently works on developing novel computational methods to solve the gravitational two-body problem by importing cutting-edge techniques from high energy physics and mathematics, including effective field theory and iterated integrals.

Andres Luna completed his education in Mexico City and then earned his PhD at the University of Glasgow in 2018. He held a postdoctoral position in the Mani L. Bhaumik Institute for Theoretical Physics at UCLA before joining the NBIA as an assistant professor in 2021. His research interests lie at the interface between gravitation and scattering amplitudes in Quantum Field Theory. He is currently working on the generalization of the double copy to black holes and other interesting classical solutions in General Relativity, as well as in the application of these, and other modern scattering amplitudes techniques to the description of the dynamics of binary black holes and its application to the burgeoning field of gravitational-wave physics.

Martin Cramer Pedersen is an Assistant Professor working in the field of soft matter and biophysics. He is particularly interested in using methods from computational and applied differential geometry and topology to characterize and understand the emergence of order, disorder, and self-assembled geometries in e.g. colloidal and polymer systems, cellular and other active materials, crystals and quasicrystals, or reticular chemical systems. Furthermore, Martin works on extracting and quantifying shape and order from a variety of experimental data and simulations of such systems; and consequently development and curation of data scientific methods, efficient simulation methods, and high-performance computing are central aspects of his research as well.


Niels Bohr Institutet
UNIVERSITY OF COPENHAGEN
The Niels Bohr International Academy
Active matter: Nature's engines that power life
Amin Doostmohammadi
Niels Bohr Institute
January 2024


SLE curves → κ = 6
Described by κ -
the variance of a random
walk
κ = 6 - percolation


Hornbæk
Presentation

Junior Faculty

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

Alessia Benedetta Platania is currently an assistant professor and a Villum Young Investigator at the NBI. Her research interests lie at the interface between quantum gravity, effective field theory, and black-hole physics. The idea underlying her research is that effective field theory provides a lens through which we can (i) compare the predictions of different theories and (ii) contrast them with theoretical and observational bounds. The overarching goal is to narrow down the set of effective field theories stemming from different quantum gravity theories and determine their intersections and compatibility with theoretical constraints. Ultimately, this will allow us to identify the most promising approaches and potential connections between different theories. The focus of Alessia's Villum Young Investigator grant is applying these ideas to two approaches where a clear connection to effective field theory already exists: asymptotically safe gravity and string theory.

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

Johan Samsing joined the NBIA as a Louis-Hansen Assistant Professor and Marie Curie Fellow in 2019. In 2020 he received a Villum Young Investigator Grant to establish a group at the NBIA dedicated to gravitational-wave astrophysics. In 2022, Johan also received an ERC Starting Grant from the European Union for the project “Gravitational Wave Astrophysics and Dynamical Formation of Black Hole Mergers”. Johan received his PhD from the Niels Bohr Institute (DARK) in 2014, after which he moved to Princeton University, first as an Einstein Fellow and then as a Spitzer Fellow. He currently works on the astrophysical formation of gravitational-wave sources and the origin of black hole mergers.

Junior Faculty

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.

Apoorv Tiwari joins NBIA as an assistant professor. He is interested in applying concepts related to generalized symmetries, anomalies and topological aspects of quantum field theories and quantum lattice models to the study of phase diagrams of quantum matter. He is also interested in the discovery of novel properties of quantum matter that is far from equilibrium realized for example in driven, open or monitored quantum systems. He recently received the Villum Young Investigator grant.

Maarten Van de Meent joined the NBIA in 2022 as an assistant professor in the "Strong Gravity" group. After obtaining his PhD from Utrecht University under supervision of Gerard 't Hooft, Maarten held an NWO Rubicon Fellowship at the University of Southampton, and a Marie Skłodowska–Curie Fellowship at the Max Planck Institute for Gravitational Physics in Potsdam. He is interested in the relativistic 2-body problem describing the inspiral and merger of black hole binaries. In particular, he is an expert on the gravitational self-force formalism, which solves the 2-body problem as a perturbative expansion in the ratio of the masses. He leverages this knowledge to develop and improve waveform models for gravitational wave observations.

Matt von Hippel received his PhD from Stony Brook. He was a postdoctoral fellow at the Perimeter Institute, before joining NBIA first as a postdoctoral fellow and now as an assistant professor. He researches scattering amplitudes in gauge and gravity theories. In particular, he has developed new methods to calculate multi-loop scattering amplitudes in N=4 super Yang-Mills based on the properties of polylogarithmic functions. Currently, he is interested in extending these techniques, both to more general theories and to elliptic integrals.

Mary Wood has a background in surface chemistry and obtained her PhD at the University of Cambridge in 2016 studying adsorption phenomena at metal/liquid interfaces. She held postdoctoral positions in Cambridge and Birmingham, studying corrosion and lipid bilayers respectively, before moving to EPFL in Switzerland to take up a Human Frontiers Science Programme cross-disciplinary fellowship. Her interests lie in bioelectronic interfaces, particularly photosynthetic membranes supported on electrode surfaces, with broader applications in the fields of renewable energies and green treatment of polluting waste.

Postdoctoral Fellows

Shunke Ai obtained his PhD from the University of Nevada, Las Vegas (USA) in 2022. He then conducted postdoctoral research at Wuhan University (China) and joined NBIA in September 2024 as member of the AstroNu group. His research interests include the electromagnetic counterparts of gravitational waves, the physics of gamma-ray bursts as well as other high-energy explosive transients, and high-energy neutrino production.

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

Thomas Berlok is a Marie Skłodowska-Curie fellow working on the physics of the intracluster medium found in galaxy clusters, plasma physics and astrophysical fluid dynamics. All current cosmological simulations of turbulence in the intracluster medium have assumed that the plasma is fully collisional. At NBIA, Thomas intends to improve on this by producing the first cosmological galaxy cluster simulations that move beyond the collisional assumption, enabling predictions for future X-ray observations.

Jonas Berx is a post-doctoral researcher in non-equilibrium statistical mechanics. He has worked on topics ranging from active matter and surface growth to knot theory. He did his PhD at the University of Leuven and worked as a post-doctoral researcher at the Max Planck Institute for Dynamics and Self-Organisation and at the University of Leiden. He joined NBIA as a Marie Curie fellow to investigate the thermodynamics of replication processes at the molecular scale.

Gregorio Carullo is a Marie Skłodowska Curie Interactions Fellow in the newly formed Strong gravity group. Before, he received his PhD from the University of Pisa and was a Della Riccia Fellow at the University of Jena. His research focuses on extracting fundamental physics implications from gravitational waves observations and testing the black hole paradigm, mainly using spectroscopy techniques. He is also interested in dynamical captures and measuring black hole horizon effects using LISA.

Postdoctoral Fellows

Adam Chalabi is a postdoc working in theoretical high-energy physics. He joined NBI in 2022 after completing his PhD at the University of Southampton. His research interests include conformal field theory, gauge theory, and supersymmetry. Adam's current work investigates the role of boundaries and defects in conformal field theory, with some inspiration drawn from string theory and condensed matter physics. Boundaries and defects encode crucial information about quantum systems, and they are necessary to describe many realistic physical phenomena.

Jayeeta Chattopadhyay is a postdoctoral researcher interested in active matter. Her research focuses on studying non-equilibrium properties of active nematics at the continuum level through computer simulation. She is also interested in understanding fundamental properties in tissue mechanics, including cell death, cell integration, collective cell motions, etc., which are governed by activating biochemical signals through mechanical stress generation.

Yifan Chen obtained his PhD from Sorbonne Universite in 2019. Before joining NBIA as a postdoc, he worked at Institute of Theoretical Physics, Chinese Academy of Science. His research is in the intersection of particle physics, strong gravity, string theory and quantum sensor. Recently, he focuses on detection of ultralight bosons, such as axions and dark photons, by exploiting Event Horizon Telescope observations on supermassive black holes, or a network of sensors like cavities and magnetometers.

Damiano Fiorillo obtained his PhD in late 2021 from the University of Naples and joined the group of Mauricio Bustamante at NBIA in early 2022. His research interests encompass many facets of high-energy multi-messenger astrophysics: he has worked on various topics in dark matter, axions, gamma rays, and high-energy neutrinos. At NBIA, his focus is on how cosmic neutrinos can test both high-energy particle physics and astrophysics, both using present-day observations and forecasting future opportunities with upcoming detectors.

Hjalte Frellesvig received his PhD from the NBI, and has done postdocs in Greece, Germany, and Italy. His 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 problems related to the production of the Higgs boson and electro-weak corrections to the production of the Z and W bosons.

Postdoctoral Fellows

Mariam Gogilashvili obtained her PhD from the Florida State University (USA) and joined NBIA in September 2024 as part of the AstroNu group. Her work focuses on core-collapse supernova explosions. She is interested in exploring the role of neutrino oscillations in supernovae and mergers, and their influence on explosion dynamics, nucleosynthesis, and galactic chemical evolution.

Emil Have received his PhD in 2023 from the University of Edinburgh. After a brief postdoctoral position at the same institution, he joined the NBI in the autumn of 2023 working on holographic dualities in quantum gravity and string theory. His research currently focuses on the application of non-Lorentzian geometry in the contexts of holography, string theory, gravity and fluids.

Shilpa Kastha is a postdoctoral researcher in the Strong group at NBIA. She finished her Ph.D. from the Institute of Mathematical Sciences, India in 2019. Before joining NBIA, she was a junior scientist at the Albert Einstein Institute. She has explored the physics of gravitational waves with cutting - edge analytical and numerical tools. Her present interests encompass post-Newtonian modeling of compact binaries, black hole spectroscopy, astrophysical implication of gravitational wave detections, and parameter estimation. She is also interested in the formulation of various tests of general relativity, and studying black hole horizon dynamics using marginally outer trapped surfaces within numerical relativity.

Takuya Katagiri joined NBIA in April 2023. He completed his PhD at Rikkyo University in Japan in March 2022 and was then a postdoc at Tohoku University in Japan for a year. He is currently interested in interactions of black holes with astrophysical environments or particles beyond the standard model, the underlying symmetric structure of phenomena in strong gravity within General Relativity, and fundamental understandings of gravity towards a test of theories of gravity with gravitational waves.

Timofey Kozhukov is a postdoctoral researcher working with Dr. Kristian Thijssen. During his PhD at the University of Edinburgh, Tim worked on developing algorithms for simulating active nematic liquid crystals and characterising their behaviour. His current research focusses on advancing simulation tools for active fluids, with particular emphasis on passive and active solutes as well as complex boundaries.This work enables in-depth studies of biological mechanoreciprocity.

Postdoctoral Fellows

Sameer Kumar is a post-doctoral researcher, currently investigating time evolutions and pattern formation in active matter by writting the equations of motion for the density and orientation of living objects of anisotropic shape, coupled to an incompressible fluid. The Naviar-Stokes equation to describe the motion of the flow field (fluid velocity). Numerical solutions to these coupled equations are obtained using the Lattice-Boltzmann method, allowing the study of different patterns formed in the system under various input conditions.

Nicolas Loizeau is a postdoc in condensed matter theory, interested in quantum chaos and the emergence of classicality and locality. I received a PhD from New York University where I studied the emergence of preferred tensor decompositions from the spectrum of quantum systems. Right now my research focuses on studying thermalization and dynamical symmetries in closed systems using Krylov space approaches. I'm also developing new numerical techniques for efficiently simulating many body quantum systems using Pauli strings representation.

Rico (Ka Lok) Lo joined NBIA in August 2023, after completing his PhD at the Caltech. At the Strong group, he works on both data-analysis and theoretical aspects of gravitational waves. His current research focuses on gravitational lensing of gravitational waves and its implications to cosmology and tests of general relativity. He is also a member of the LIGO Scientific Collaboration contributing to many of its lensing and testing general relativity analyses.

Rodrigo Panosso Macedo joined the NBIA as a senior post-doctoral fellow in March 2023. Before the NBI, Rodrigo has worked in Brazil (USP), Germany (Max Planck Institute-Potsdam and University of Jena) and the UK (Queen Mary University of London and University of Southampton), with regular visits to CENTRA (Lisbon, Portugal) and the University of Bourgogne (Dijon, France). He develops a novel framework for gravitational wave and black-hole physics by applying Penrose's conformal treatment of infinity to perturbation theory.

Elisa Maggio is a Marie-Skłodowska Curie Postdoctoral Fellow at the Max Planck Institute for Gravitational Physics in Potsdam (Germany). She visited NBI for five months as part of her secondment. Her research is focused on tests of gravity in the strong-field regime with gravitational-wave observations. She works on tests of the nature of the astrophysical sources by modeling the inspiral and ringdown of compact binary coalescences.

Postdoctoral Fellows

Pablo Martínez-Miravé obtained his PhD at the University of Valencia (Spain) and he joined NBIA in October 2023 as part of the AstroNu group. His work focuses on particle astrophysics. He is interested in exploring standard and non-standard neutrino properties relying on terrestrial experiments, the Sun, the early Universe, as well as core-collapse supernovae and binary neutron star mergers.

Marica Minucci joined the Strong Group at the NBIA as a Marie Skłodowska-Curie Fellow in August 2024. She earned her PhD in Mathematical Sciences from Queen Mary University of London and served as a Lecturer in Mathematics at Northeastern University London. Her research focuses on the stability of asymptotically de Sitter spacetimes and the asymptotic structure of gravitational fields. At the NBIA, she is developing a framework for black hole spectroscopy to enhance understanding of gravitational wave signatures.

Siavash Monfared received his PhD at MIT followed by a postdoc position at Caltech. His research is at the interface of granular physics, statistical mechanics and active matter. He is interested in understanding the link between the physics of force transmission and collective self-organization in biological systems through developing theoretical models and high performance computational tools.

David Pereñiguez obtained his PhD from the Institute of Theoretical Physics, in the Autonomous University of Madrid. He joined NBI in October 2022. His research focuses on black hole physics. At NBI, he works on theoretical aspects of gravitational wave propagation in black hole spacetimes, and studies how these encode information about the black hole structure, with special emphasis on signatures of new physics.

Francesco del Porro is currently a Postdoc in the Quantum Gravity group. He obtained his PhD in September 2024 at SISSA (Trieste), with a thesis on several aspects of Quantum Gravity and Quantum Field Theory in Curved Spacetime. In particular he focused on the ultraviolet properties Horava Gravity – a Lorentz violating Quantum Gravity proposal – as well as quantum properties of black holes, such as Hawking radiation. His current research investigates different approaches to Quantum Gravity, including Asymptotic Safety, together with black hole physics and semiclassical effects in gravity.

Postdoctoral Fellows

Neda Rahmani was a postdoc in the Computational Material Group at Southern Denmark University. Her research focused on finding new functional materials, specifically multiferroic and half-metallic double perovskites, for photovoltaics and spintronics through density functional theory calculations. Now, as a postdoc at NBIA, she is exploring biomaterials and biological processes using multiscale computer simulation techniques. Currently, Neda is focusing on the design of a nanoscale force sensor to measure interactions between membrane proteins.

Connar Rowan joined the NBIA as a postdoctoral researcher in 2024 after completing his PhD at The University of Oxford. His research focuses on the dynamics of black hole interactions and mergers in gaseous media, particularly black holes embedded in the gas discs around supermassive black holes, and their potential as sources of gravitational waves.

Pankaj Saini is a postdoctoral fellow working in gravitational wave astronomy. He joined NBIA in September 2024 after completing his PhD at Chennai Mathematical Institute, India. His research interests encompass gravitational wave astrophysics, strong field tests of general relativity, formation channels of compact binaries, and exploring the scientific potential of future gravitational wave detectors. His primary area of study is the gravitational waves produced by compact binaries in eccentric orbits.

Fabian Schuhmann did his PhD at the Carl-von-Ossietzky University in Oldenburg, Germany. His research focused on tailored tools to analyze single protein dynamics and their conformational changes. For instance, he developed the Python package SiMBols, which makes similarity measures easily accessible for biological systems and the comparison of spatio-temporal data. As a postdoc at NBIA, he is building on the computational foundation to transfer and find new ways to analyze and simulate protein clusters and systems, including membranes in coarse-grained and all-atom settings.

Nabha Shah joined NBI as a postdoctoral researcher working in theoretical high energy physics after receiving her Ph.D. from Caltech in 2024. Her research focuses on the interface between quantum scattering amplitudes, effective field theory, and gravity. In particular, she is interested in exploring structure in gravitational effective field theory and in the application of field theoretic techniques to computations relevant for gravitational wave physics.


GALST
KRØGS FISKERESTAURA
LITTLE
GREEN DOOR
MUNDO
COCKTAIL
BAR
LITTLE
GREEN
DOOR

Postdoctoral Fellows

Prashant Singh is a postdoctoral researcher at NBIA working with Prof. Karel Proesmans. He obtained his PhD from the ICTS in Bangalore, India in November 2022. The general theme of his research has been non-equilibrium statistical mechanics. More precisely, he has worked on Brownian motion and random walks, active particles, stochastic resetting, extreme-value statistics, single-file motion and functional statistics. At NBIA, he is exploring the field of stochastic thermodynamics with a primary focus on its applications in biological settings.

Janos Takatsy is a new postdoctoral fellow in gravitational wave astrophysics. He did his PhD in Budapest, which was focusing on field theoretical description of neutron star matter equation of state, and looking for signatures of phase transitions inside neutron stars. He is interested in the formation and dynamics of eccentric compact binaries, the composition of neutron stars and their tidal dynamics, as well as effective field theories of the strong interaction.

Kristian Thijssen is a computational soft matter physicist interested in the dynamics of emergent collective phenomena and how those systems (e.g., bacteria colonies and cellular tissues) interact with reconfigurable surroundings. He obtained his MSc at the Eindhoven University of Technology, after which he did a PhD in physics under the tutelage of Julia Yeomans in Oxford. After holding a postdoctoral position under Robert Jack in Cambridge, he joined the NBI Copenhagen with a Marie-Curie fellowship.

Christopher Tiede received his PhD from New York University in May, 2022 before joining the NBIA as a postdoc in the Fall. His research is in the development and application of high-performance hydrodynamics simulations to astrophysical systems. Chris's primary focus is in the study of gas dynamics around binary black holes and how such accretion phases both alter the life cycles of these binaries and enable their multi-messenger observational prospects. In 2024 Chris received a MCSA Fellowship at NBIA.

Alessandro Alberto Trani joined the NBIA as an INTERACTIONS Senior Fellow. He received his PhD from SISSA in 2017, before moving to The University of Tokyo as a JSPS Postdoctoral Fellow. His main research focus is the study of collisional self-gravitating systems, which include star clusters, galactic nuclei, binary stars, and planetary systems. With the advent of gravitational wave astronomy, he is leveraging the few-body problem to unveil the astrophysical origin of gravitational wave events. In 2023 Alessandro received a MCSA Fellowship at NBIA.

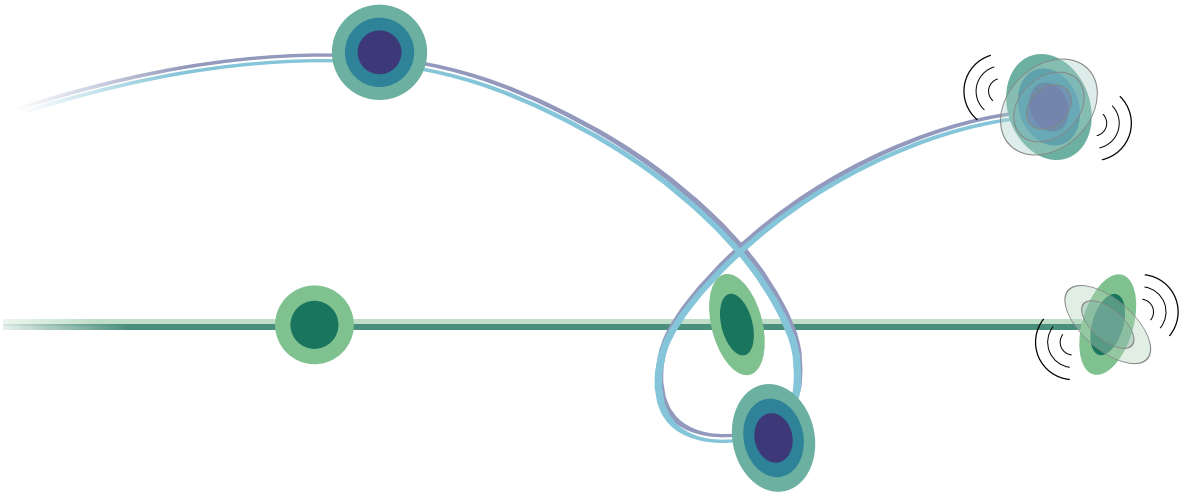
Postdoctoral Fellows

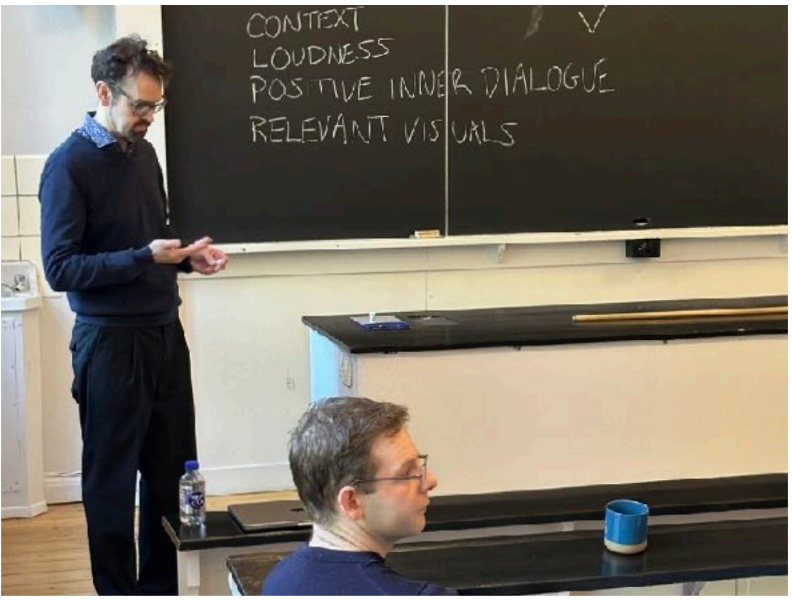
Matteo Wauters is interested in a variety of non-equilibrium phenomena in quantum physics, ranging from topological transport properties to reinforcement learning techniques for quantum control and quantum computation. At the moment he focuses on the modeling and numerical analysis of topological Kondo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

Lorena Magaña Zertuche joined the NBIA Strong group as a postdoctoral fellow in August 2024 after completing her PhD at the University of Mississippi. Her research on black hole spectroscopy focuses on high-precision ringdown modelling. Currently, she is working towards understanding the effects of lensing on the ringdown of the remnant black hole. She is a member of the LIGO Scientific Collaboration and plays an active role as a ringdown group co-chair within the LISA Consortium.

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.

Lorenz Zwick joined NBIA as a postdoctoral fellow in 2023 to study the variety of perturbations that astrophysical backgrounds imprint on gravitational waves. Due to the multidisciplinary nature of this endeavor, Lorenz works on a broad range of topics. These include the formation and the dynamical evolution of black hole binaries, accretion discs and the origin of high red-shift quasars.





INTERACTIONS Fellow's Day 2024

PhD Students

Nigar Abbasova started her PhD in the Active Intelligent Matter group at NBIA supervised by Prof. Amin Doostmohammadi in September 2024. She joined the group after earning her MSc in Physics from the University of Oslo, where she focused on experimentally investigating the dynamics of cellular monolayers. Her current research extends this work by exploring the mechanical forces involved in multicellular motion, aiming to provide new insights into the biophysics of mechanotransduction across biological tissues.

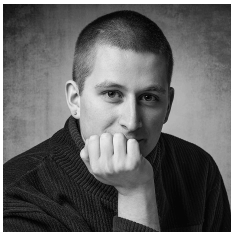
Marina De Amicis is a PhD candidate at Strong under the supervision of Vitor Cardoso. Originally from Rome, she obtained her MSc degree at La Sapienza University, where she investigated how black holes evolve due to quantum effects. In her PhD, she is exploring the interaction between gravitational waves and astrophysical systems, with a particular interest on stochastic backgrounds. Her primary interest is studying the signal generated during the coalescence of black holes, with specific emphasis on the post-merger phase known as the "ringdown".

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

Simon Guldager Andersen is a PhD student in the Active Intelligent Matter (AIM) group under the supervision of Assoc. Prof. Amin Doostmohammadi. He is particularly interested in the near-critical behavior of active matter, which he will be studying using numerical and analytical methods. He obtained his MSc at NBI, during which he studied the spatiotemporal structure of topological defects in active nematics, in addition to developing software for analyzing cell images in collaboration with experimentalists.

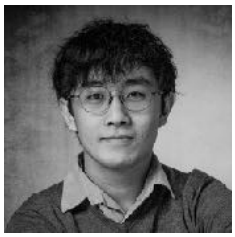
Robin Bölsterli is pursuing a PhD in the Active Intelligent Matter group under the supervision of Professor Amin Doostmohammadi. After obtaining his MSc in Interdisciplinary Sciences at ETH Zurich, he started his PhD in August 2023. In his research, he is modelling and theoretically studying the critical phenomena occurring in Collective Mechanotransduction and Active Matter. To this end, he also collaborates with experimentalists.

PhD Students



Lasse Bonn obtained his MSc and one year of research experience working as a research assistant at NBIA in the Active Intelligent Matter group working on the properties of topological defects in fluctuating active nematics under the supervision of Amin Doostmohammadi. He has now started as a PhD student in the same group and will be looking at turbulent flows in active systems using continuum fluid dynamics simulations.

Adrian Vidal Bravo is a PhD student at NBIA working in the Computational Microscopy group under the supervision of Weria Pezheskian. He obtained his Master's degree at Aarhus University with a thesis on the dynamic and thermodynamic properties of a system of interacting autonomous thermal motors. Now, his main focus is studying biological membranes' passive and active fluctuations using numerical simulations.



Chun Lung Chan (Juno) obtained his MSc degree in Physics from the Chinese University of Hong Kong with a thesis on detecting strongly lensed gravitational waves and the asteroseismology of magnetars. He is now working in the Strong group under the supervision of Jose Maria Ezquiaga and Vitor Cardoso. His research at NBIA focuses on numerical simulations of magnetars and detecting lensed gravitational wave signals.

Marta Cocco is a PhD student at the University of Perugia and NBIA in Copenhagen, working in the Strong Group under the supervision of Marta Orselli and Troels Harmark. She obtained her MSc degree at the University of Perugia, where she studied how tidal forces from a supermassive black hole affect the dynamics of an inner black hole binary.She continues tofocus on tidal effects in triple black hole systems, especially when they are in resonance, using the formalism of General Relativity.

Conor Dyson is a PhD student in the Strong Gravity at the Niels Bohr International Academy working under the supervision of Maarten van de Meent and Vitor Cardoso. His research is in the field of black hole perturbation theory, with a specific focus on applying the self-force formalism (a type of singular perturbation theory) to model post-adiabatic and environmental effects in black hole binaries.

PhD Students

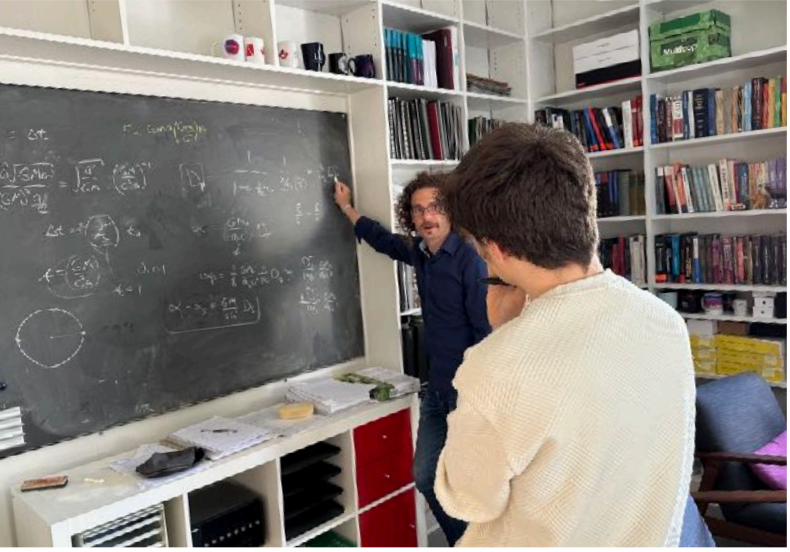
Roger Morales Espasa joined the NBIA in April 2022 as a PhD student under the supervision of Matthias Wilhelm after obtaining his MSc degree from NBIA too. In his master's thesis, he studied the coalescence of a black hole binary system through the post-Newtonian effective field theory of gravity. Now, his PhD project is devoted to the study of scattering amplitudes and the special mathematical functions that occur in Feynman integrals, focusing on elliptic and higher-dimensional geometries.

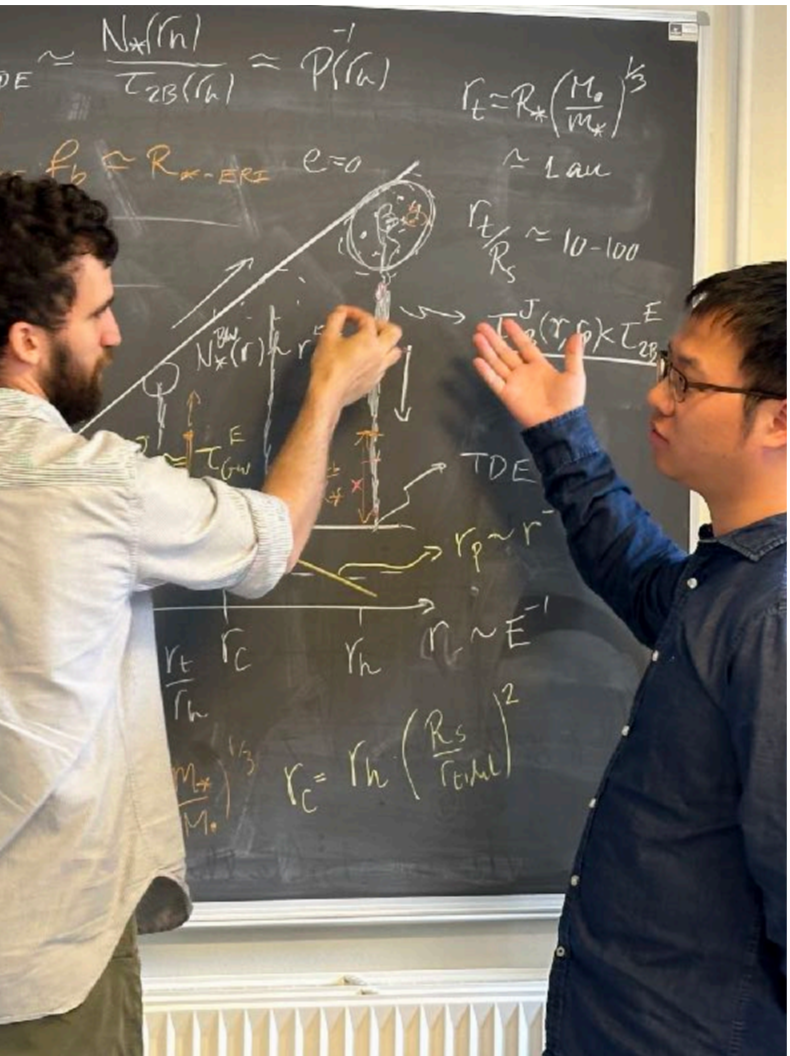
Evelyn-Andreea Ester is a member of the Strong Gravity group and works on quantum field theory in curved spacetimes. She completed a Mathematics BSc and a Physics MSc at Royal Holloway, University of London, focusing on Hawking radiation - specifically on the information paradox and on analyzing the production of dark matter by decaying primordial black holes. Her research continues to highlight quantum effects in the strong gravity regime by investigating the backreaction of quantum processes on classical black hole geometries.

Gaia Fabj obtained her MSc degree at the University of Heidelberg in 2021. She is currently a PhD student in the gravitational astrophysics group at NBIA. She is working under the supervision of Johan Samsing on the formation and evolution of black-hole binaries in Active Galactic Nuclei (AGN) accretion disks in order to investigate the AGN channel for gravitational-wave detection.

Francesco Ferrarin is a PhD student at the Niels Bohr Institute and a member of the Quantum Gravity Group led by Professor Alessia Platania. He completed both his Bachelor's and Master's degrees at the University of Pisa, conducting a research thesis on cosmological backreaction under the supervision of Professor Giovanni Marozzi. His primary interests lie at the intersection of gravity and effective field theories, specifically focusing on testing the consistency of Asymptotically Safe Gravity by studying the landscape of EFTs compatible with it. More broadly, he is passionate about both primordial and late-time cosmology, black-hole physics, and also investigating quantum gravity phenomenology in these contexts.

Manuel Goimil García received his MSc degree at the Niels Bohr Institute working on high-energy cosmic ray transport and neutrino production in tidal disruption events. He started his PhD in particle astrophysics in fall 2023 under the supervision of Irene Tamborra. His PhD work aims to explore how collective phenomena affect neutrino flavor conversion in dense astrophysical environments, such as supernovae and binary neutron star mergers.




TDE


Vilde
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UDSTILLING
EXHIBITION

PhD Students

Beatrice Geiger is a PhD fellow at NBI since March 2024. Here, she explores configurations of membranes and surfaces with high-topological genus using multiscale computer simulations. She obtained her master's and bachelor's degrees in physics from Ruprecht-Karls University, Heidelberg, Germany. Her research focus has been on theoretical and computational biophysics, complemented by an internship in medical physics.

Marcela Grcic received her Master's degree in physics from the University of Copenhagen in 2022 with a thesis on eccentric circumbinary disks. In October 2022, Marcela started working on her PhD with the NBI Astrophysics group. She works under the supervision of Daniel J. D'Orazio and Martin Pessah. Marcela's research at NBIA includes theoretical analysis of the interaction of astrophysical binary systems and surrounding accretion disks, with a focus on the resulting disk eccentricity evolution.

Elisa Grilli obtained her master's degree at University of Perugia with a thesis on tidal deformation in a binary system in a Kerr-MOG background. Currently, she is a PhD student both at NBIA and University of Perugia, working in the Strong Group under the supervision of Marta Orselli and Troels Harmark. Her research primarily focuses on the study of gravitational waves using the Effective One Body (EOB) model. In particular, she investigates the memory effect contributions of gravitational waves and how to integrate them into an EOB waveform model.

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

Valeriia Grudtsyna completed her biomedical engineering degree at Lund University and gained research experience as a part of Vinay Swaminathan's group, Laboratory of Cell and Molecular Mechanobiology, at Lund University. Currently, she is pursuing her PhD under Amin Doostmohammadi at the Active Intelligent Matter Research Group. Her focus is on experimental investigations of the underlying physics of collective mechanotransduction in epithelial cells.

PhD Students

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

Marie Cornelius Hansen received her MSc degree at the Niels Bohr Institute with a thesis on probing the properties of axion-like dark matter using astrophysical high-energy neutrinos observed in IceCube. She started her PhD in November 2022 under the supervision of Irene Tamborra. Marie's work is within the field of particle astrophysics. Specifically, her PhD project focuses on numerical simulations of the flavor evolution of neutrinos in dense astrophysical environments, such as core-collapse supernovae and neutron star mergers.

Kai Hendriks joined the NBIA as a PhD student in November 2022, to work on the astrophysical formation channels of black hole binaries and imprints on their gravitational wave signals with Johan Samsing. Kai obtained his BSc and MSc at Maastricht University and Radboud University respectively, with research on neutron star binaries with numerical relativity as well as models of electromagnetic counterparts to gravitational wave sources.

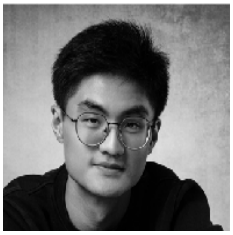
Dana Taylor Kamp obtained her MSc degree at NBI in 2021 contributing to the soliton theory of nerve signalling by combining numerical, theoretical and experimental work. Her PhD-work focuses on theoretical frameworks for non-equilibrium circuits with biological perspectives under the supervision of Karel Proesmans.

Philip Jon Østergaard Kirkeberg finished his Masters project in the GWastro group at NBIA in spring 2024 and has extended his time in the group by beginning his PhD the following summer. He is interested in the interplay between dynamical gravitational systems and surrounding gaseous media, and works with tools from theoretical and numerical magnetohydrodynamics. His current research is concerned with the gaseous effects on the formation and evolution of black hole binaries embedded in the disks of active galactic nuclei.

NBIA BBQ 2024

PhD Students

Isabell Lindahl is a new PhD-student in Biophysics in the biocomplexity group. Her project is theoretical and about exploring the mechanisms governing mitochondrial membrane shapes at the molecular scale. Mitochondria are often called the "powerhouse of the cell" as they produce the vast majority of cellular ATP supply through respiration. Isabell is creating computational models of the respiratory chain complexes in the mitochondrial membrane called the cristae and investigating the protein-membrane interactions and whether the complexes induce curvature of the membrane. In this project, molecular dynamic simulations of coarse-grained protein-membrane systems will provide essential insights into the energy balance of cells and promote our understanding of mitochondrial diseases.



Tianxiang Ma is a PhD student in the Active Intelligent Matter group at NBIA, supervised by Prof. Amin Doostmohammadi. He received his MEng in Biomedical Engineering from Beihang University and began his PhD in June 2024. His research focuses on integrating computational modeling with biological experiments to investigate active transport and mechanotransduction in multicellular systems, aiming to understand the role of mechanochemical cues in regulating collective cell behavior.

Maryna Mesiura obtained her MSc degree from the University of Zurich, where she focused on gravitational memory. In September 2024, she began her PhD under the supervision of Irene Tamborra. Her research aims to develop quantum neutrino transport methods in the remnants of binary neutron star mergers.

Elsa Messi completed her undergraduate studies in Biomedical Sciences at the International Hellenic University in Greece. During an internship at the University of Helsinki, she worked on neuroplasticity and TrkB receptor signaling, exploring how the nervous system adapts and remodels in anxiety models in mice. She did her Masters in Neuroscience in Copenhagen. Currently, she is a PhD candidate in Biophysics at the Niels Bohr Institute, where she is conducting experiments under the supervision of Amin Doostmohammadi and Poul Martin Bendix. Her work focuses on mechanotransduction, investigating how cells sense and respond to mechanical forces, with a particular emphasis on cellular behavior and signaling mechanisms in response to physical stimuli.

David O'Neill began his masters in physics at the university of Copenhagen in 2020, before joining the Astrophysics group for his thesis in black hole binary formation. Further pursuing this work, he began his PhD in September 2022 interested in supermassive black hole binaries. His projects aim to investigate the environments and dynamics of the most massive objects in the universe and to explore possible observational signatures they may exhibit.

PhD Students

Daniele Pica is a PhD student both at NBIA and University of Perugia, working in the Strong Group under the supervision of Troels Harmark and Marta Orselli. He obtained his Master's Degree at University of Perugia with a thesis on charged black hole binary merger. He is now working on three body systems, specifically on black holes triple systems, trying to understand analytically how the presence of a supermassive black hole affects the dynamics of a binary system.

Brian Damith Ratnasinghe is a biophysicist from the United States specializing in Molecular Dynamics simulations. He received my both my bachelor's and master's degrees at Virginia Tech. In his MSc thesis, he focused on the utility of polarizable molecular dynamics in the modeling of non-canonical nucleic acid structures. Here, at the University of Copenhagen, he uses multi-scale molecular dynamics simulations to describe the process of wood secondary cell wall formation.

Martin Seltmann's research aims to employ algebraic methods in the field of many-body physics to investigate non-equilibrium phenomena in open and closed quantum systems to gain new structural insights into the complex dynamics of those systems. Questions to be addressed include dynamical symmetries and the uniqueness of steady states for open systems. A primary focus is the relaxation behavior of systems with local observable algebras; the first milestone is to show the impossibility of optical bistability.

Thomas Spieksma is a PhD student working in the group of Vitor Cardoso since September 2022. He obtained his MSc degree at the University of Amsterdam, where he mainly worked on the dynamics of fundamental fields around black holes. He continues to do so in a broader setup, studying both black holes in binary systems and the ringing down of a black hole after it has undergone merger. This work uses tools from black hole perturbation theory as well as numerical relativity.

Chenliang Su is a PhD student working with Charlotte Kristjansen. He is mainly working in AdS/CFT correspondence, integrability and defect CFTs. He is currently investigating the one-point function in ABJM theory with a domain wall. The intriguing problems include extending the overlap formula between Bethe eigenstates and integrable boundary states, which determines the form of one-point functions, to general values of the bond dimension and to the higher loop orders.

PhD Students

Bernanda Telalovic received her MSc degree in Mathematical Physics from the University of Tübingen in late 2021, with a thesis on the Littlewood-Richardson rule, which has applications in QCD calculations. She joined NBIA as a PhD student in early 2022, under the supervision of Mauricio Bustamante. The work of Bernanda is within particle astrophysics. Her PhD project is on looking for signs of new physics in the distribution of the incoming directions of high-energy neutrinos, and related subjects.

Varun Venkatesh began his masters in physics at the university of Copenhagen in 2020. He joined the Active Intelligent matter group for his thesis in 2021 about the jamming and unjamming of active flexible filaments. Continuing in the same group under the supervision of Amin Doostmohammadi, he began his PhD in February of 2023 on topographical active matter. His project looks at the interplay of substrate wrinkle deformations with cell motility and collective self-organization.

Luka Vujeva is a PhD student in the Strong Group at NBIA working with Jose Maria Ezquiaga and Vitor Cardoso. His previous work ranged from studying the Interstellar Medium in the local Universe to designing survey strategies that employ strong gravitational lenses as discovery tools to find the highest redshift galaxies in the Universe. He is currently studying the effects of gravitational lensing of gravitational waves, and trying to pair these with electromagnetic observations to learn about cosmology.

Jaime Redondo-Yuste is a PhD student in the Strong group under the supervision of Vitor Cardoso. He obtained his MSc degree at the Perimeter Institute (Canada) with a thesis on the duality between the dynamics of black hole horizons and Carrollian fluids. He combines analytical and numerical techniques in his research to understand the consequences of the non-linear nature of Einstein's equations. This modifies the emission and propagation of gravitational waves, opening a unique window to test General Relativity.

Xin Qian did his bachelor in Lanzhou, China, followed by a gap year for self-study. He then decided to continue his career in Copenhagen, where there are a number of researchers with similar research interests. Xin joined Prof. Charlotte Kristjansen's group for his master thesis, mainly to work on the field theory side of AdS/CFT correspondence by using the integrability technique. Xin is now a PhD. student supervised by Charlotte Kristjansen's, working on extending the study he carried out in his MSc thesis to ABJM superconformal field theory.

MSc Students

Qassim Hasan Ali Alnasheet - Gravitational Physics

Dimitrios Anastasiou - Biophysics

Stavros Bakandreas - Particle Astrophysics

Adam Brcek - Particle Astrophysics

Julien Combel - Particle Astrophysics

Valentin De Lia - Particle Astrophysics

Shuhua Du - Gravitational Physics

Carl Eriksen - Gravitational Physics

Julie Kiel Holm - Particle Astrophysics

Johannes Voss Jacobsen - Particle Astrophysics

Philip Kirkeberg - Theoretical Astrophysics

Andreas Tsigkas Jouvelis - Gravitational Physics

Andreas Knage - Particle Astrophysics

Casper Juul Lorentzen - Gravitational Physics

Miller MacDonald - Particle Astrophysics

Marco Manno - Particle Astrophysics

Shang Miao - Gravitational Physics

Jakov Mozetic - Gravitational Physics

Pablo L. Ortega - Gravitational Physics

Konstantinos Papadimos - Gravitational Physics

Jonas P. S. Rasmussen - Gravitational Physics

Filip Ristovski - Gravitational Physics

Leart Sabani - Gravitational Physics

Lucia Velez Tartajo - Gravitational Physics

Yan Yu - Gravitational Physics

Yi Zhou - Gravitational Physics

Adjunct Faculty

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

James Cline — McGill University, Montreal, 01.10.24 — 31.12.24

Henriette Elvang — University of Michigan, Ann Arbor, 01.08.24 —30.07.25

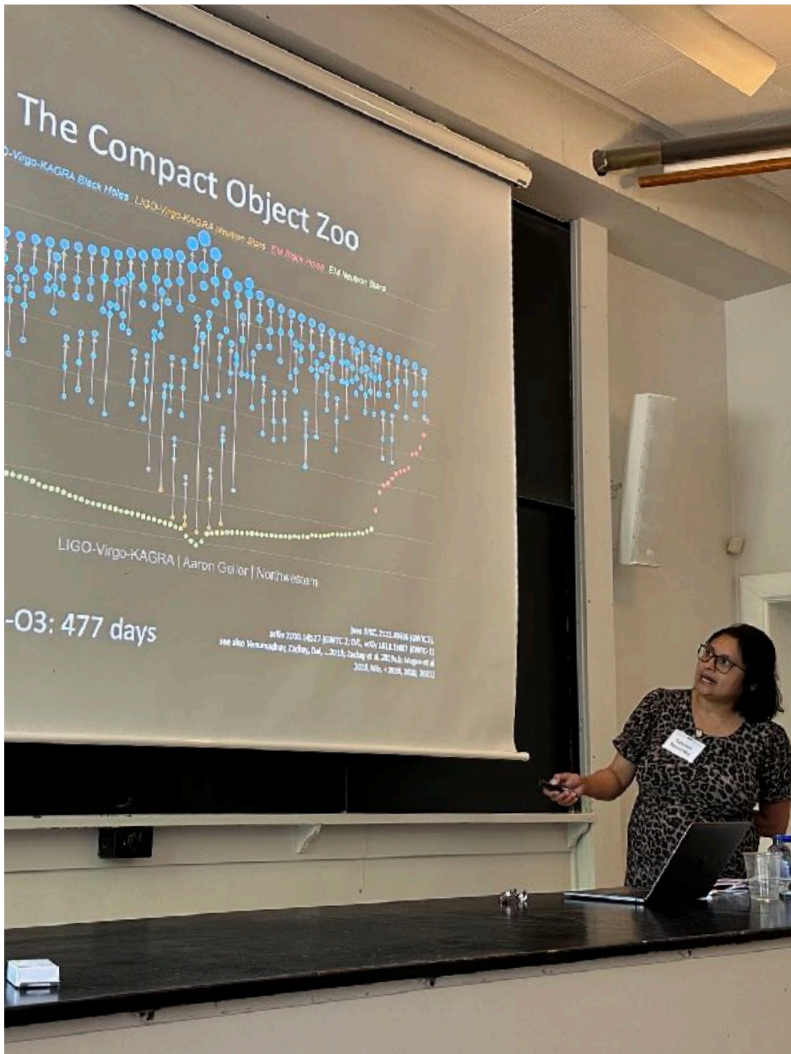
Gianluca Grignani — University of Perugia, Perugia, 28.01.24 — 02.03.24,
20.05.24 — 30.05.24, 18.08.24 — 31.08.24

Can Kozcas - Bogazici University, Istanbul, Turkey

Visitors

The NBIA maintains a vigorous visitor program, usually attracting a large number of scientists from all over the world every year. These visitors actively engage in daily activities at the NBIA and the Niels Bohr Institute. The list of visitors for the calendar year 2024 follows below.

Name	Affiliation	Arrival	Departure
V. Velucci	SISSA	18.12.24	31.12.24
N. Turok	University of Edinburgh	16.12.24	19.12.24
C. Baadsgaard	Korean Institute for Advanced Study	12.12.24	03.01.25
N. Albin Nilsson	Institute for Basic Science, South Korea	09.12.24	20.12.24
P. Vallarino	University of Turin	09.12.24	13.12.24
L. Guerrini	University of Warsaw	04.12.24	06.12.24
D. Kresse	Max Planck Institute for Astrophysics	01.12.24	03.12.24
S. Muddu	Albert Einstein Institute	27.11.24	29.11.24
C. Gardiner	University of Western Australia	26.11.24	24.01.25
T. May	Perimeter Institute	24.11.24	30.11.24
P. di Vecchia	Nordita, Stockholm	21.11.24	02.12.24
S. Rychkov	Institut des Hautes Études Scientifiques	20.11.24	23.11.24
K. Stelle	Imperial College	19.11.24	21.11.24
R. Gonzo	University of Edinburgh	18.11.24	22.11.24
A. Zhiboedov	CERN	13.11.24	15.11.24
N. Geiser	University of Michigan	11.11.24	25.11.24
G. Carullo	Birmingham University	11.11.24	15.11.24
S. Ghosh	IIT Gandhinagar	11.11.24	16.11.24
H. Delaporte	Odense University	06.11.24	08.11.24
Z. Yan	Nordita, Stockholm	06.11.24	08.11.24
D. Artico	Humboldt University, Berlin	04.11.24	08.11.24


The Compact Object Zoo
LIGO-Virgo-KAGRA | Aaron Geller | Northwestern
-O3: 477 days

M. Manno	University of Salento	04.11.24	29.11.24
P. Hoyer	University of Helsinki	01.11.24	01.11.24
C. Bambi	Fudan University	31.10.24	03.11.24
R. Carballo-Rubio	University of Southern Denmark	31.10.24	31.12.24
J. Bardarson	KTH, Stockholm	30.10.24	02.11.24
J. Ambjørn	Radboud University	29.10.24	01.11.24
V. Niarchos	University of Crete	23.10.24	25.10.24
S. - K. Chen	Michigan University	21.10.24	24.11.24
L. Lin	Michigan University	21.10.24	13.12.24
A. Muller	Max Planck Institute	14.10.24	18.10.24
S. Goyal	Max Planck Institute	14.10.24	18.10.24
H. Stone	Princeton University	14.10.24	15.10.24
D. Fielding	Flatiron Institute	09.10.24	09.10.24
L. Binachi	University of Turin	08.10.24	11.10.24
G. Uhre Jacobsen	Humboldt University, Berlin	08.10.24	09.10.24
S. Giardino	Max Planck Institute	07.10.24	26.10.24
A. Tokareva	Hangzhou Institute for Advanced Studies	07.10.24	10.10.24
R. Hajjar	Valencia University	04.10.24	10.12.24
M. Heller	University of Ghent	02.10.24	04.10.24
J. Cline	McGill University	01.10.24	31.12.24
S. Komatsu	CERN	30.09.24	04.10.24
R. Ma	USTC Hefei & MPI Munich	30.09.24.	01.10.24
C. Zhang	University of Bonn	30.09.24	07.10.24
A. Wallberg	Uppsala University	30.09.24	04.10.24
K. Mack	Perimeter Institute	19.09.24	20.09.24
O. Castro	University of London	19.09.24	23.09.24
K. Lee	Institut of Advanced Study, Seoul	18.09.24	29.09.24

J. Ambjørn	Radboud University	17.09.24	20.09.24
S. Patil	Leiden University	17.09.24	23.09.24
G. Baym	UIUC	16.09.24	18.09.24
J. Santos	IST Tecnico	16.09.24	20.09.24
J. Berman	University of Michigan	09.09.24	13.09.24
J. Hartong	University of Edinborough	09.09.24	13.09.24
A. Castro	University of Cambridge	09.09.24	13.09.24
K. Zarembo	Stockholm University	09.09.24	20.09.24
E. Mier Alonso	Instituto de Física Teórica (IFT), UAM-CSIC	09.09.24	07.12.24
O. Gottlieb	Flatiron Institute	08.09.24	13.09.24
B. Tlatelpa	University of Mexico	05.09.24	29.11.24
C. Navarrete-Benlloch	University of Valencia	05.09.24	07.09.24
P. Cano	Barcelona University	02.09.24	06.09.24
J. Berman	University of Michigan	02.09.24	18.12.24
E. Seo	University of Glasgow	02.09.24	01.12.24
N. Gaspari	Radboud University	02.09.24	04.09.24
P. Steinhardt	Princeton University	28.08.24	30.08.24
G. Hentschel	Emory University	27.08.24	01.09.24
I. Procaccia	Weizmann Institute of Science	27.08.24	01.09.24
Z. Bern	UCLA	26.08.24	31.08.24
D. Gross	UC Santa Barbara	26.08.24	31.08.24
E. Barausse	SISSA	26.08.24	31.08.24
A. Buonanno	Max Planck Institute for Gravitational Physics	26.08.24	31.08.24
S. Knibbeler	Artist in residence	26.08.24	29.08.24
K. Maeda	Waseda University	25.08.24	08.09.24
J. Nian	University of Chinese Academy of Sciences	21.08.24	31.08.24
T. Harada	Rikkyo University	21.08.24	19.09.24


HAVFRUEN

E. Trincherini	Scuola Normale Superiore	19.08.24	21.08.24
A. Chung	University of Illinois, Urbana-Champaign	19.08.24	21.08.24
G. Grignani	Perugia University	18.08.24	31.08.24
P. di Vecchia	Nordita, Stockholm	17.08.24	08.09.24
S. Maenaut	Leuven University	14.08.24	21.08.24
M. Park	Institute for Basic Science, S. Korea	12.08.24	15.08.24
D. Theocharis	Artist in residence	12.08.24	14.08.24
P. H. Croti Siqueira	Federal University of ABC - UFABC, Brazil	12.08.24	12.11.24
L. T. de Paula	Federal University of ABC - UFABC, Brazil	12.08.24	12.11.24
R. Li	University of California, Berkeley	12.08.24	16.08.24
H. Rein	University of Toronto	12.08.24	16.08.24
J. Nibauer	Princeton University	12.08.24	16.08.24
S. Tremaine	University of Toronto	12.08.24	16.08.24
P. Pang	Utrecht University	05.08.24	09.08.24
A. Pound	Southampton University	05.08.24	11.08.24
H. Elvang	University of Michigan	01.08.24	30.07.25
C. Bennett	IBM	17.07.24	21.07.24
C. Bonnerot	University of Birmingham	16.07.24	24.07.24
X. Chen	Univ. of Science and Technology of China	15.07.24	10.10.24
J. Nian	UCAS - Beijing	11.07.24	31.08.24
K. Bering	Institute for Theoretical Physics, Brno	10.07.24	29.07.24
Y. Guo	Fudan University	06.07.24	05.10.24
X. Xue	University of Hamburg and DESY	06.07.24	22.07.24
J. Li	Peking University	06.07.24	20.09.24
F. Vafa	Harvard University	01.07.24	17.07.24
J. Rasmussen	University of Brisbane	01.07.24	07.07.24
M. Korzynski	Polish Academy of Sciences	01.07.24	03.07.24

H. Ooguri	Caltech & IPMU, Tokyo	27.06.24	27.06.24
J. Ambjørn	Radboud University	26.06.24	28.06.24
J. Li	Peking University	23.06.24	20.09.24
F. Charton	Meta	19.06.24	21.06.24
D. Velasco	Princeton University	19.06.24	21.06.24
W. Cao	University of Tokyo	18.06.24	23.06.24
P. Di Vecchia	Nordita, Stockholm	17.06.24	24.06.24
E. Maggio	Albert Einstein Institute	17.06.24	15.11.24
M. Malato	Federal University of Para, Brazil	14.06.24	30.11.24
M. MacDonald	Harvard University	12.06.24	24.08.24
P. Chi Kit Cheong	University of California, Berkeley	12.06.24	14.06.24
P. Saha	University of Zurich	12.06.24	14.06.24
S. Mazumdar	Okinawa Inst. of Science and Technology	10.06.24	14.06.24
M. Kachelriess	Norwegian Univ. of Science and Technology	10.06.24	11.06.24
A. Wandel	Hebrew University	07.06.24	07.06.24
M. Heyl	University of Augsburg	06.06.24	07.06.24
O. Aksoy	MIT	05.06.24	09.06.24
S. Maenaut	Leuven University	01.06.24	16.06.24
A. Puhm	Amsterdam University	30.05.24	31.05.24
L. Plante	NBI	29.05.24	03.06.24
V. Vitelli	University of Chicago	29.05.24	29,05.24
P. Orland	Baruch College, CUNY	28.05.24	15.08.24
A. Farah	University of Chicago	27.05.24	14.06.24
A. Placidi	Perugia University	21.05.24	24.05.24
G. Uhre Jakobsen	Humboldt, Berlin	21.05.24	21.05.24
G. Grignani	Perugia University	20.05.24	30.05.24
T. Ortin	Institute of Theoretical Physics, Madrid	19.05.24	26.05.24

T. Hertog	LU Leuven	15.05.24	16.05.24
J. Ambjørn	Radboud University	15.05.24	16.05.24
J. Figueroa-O´Farrill	Edinburgh University	15.05.24	18.05.24
I. Rothstein	Carnegie Mellon University	13.05.24	15.05.24
T. Harada	Rikkyo University	08.05.24	16.06.24
E. Frey	LMU Munchen	07.05.24	08.05.24
S. Koksbang	University of Southern Denmark	07.05.24.	07.05.24
C. Baadsgaard Jepsen	Korean Institute of Advanced Study	03.05.24	16.05.24
G. Mussardo	SISSA, Trieste	03.05.24	06.05.24
G. Uhre Jakobsen	Humboldt University, Berlin	02.05.24	03.05.24
T. Ma	Chinese Academy of Sciences	01.05.24	31.05.24
J. Takatsy	NBI	22.04.24	25.04.24
J. Lazar	Oxford University	21.04.24	24.04.24
K. Zarembo	Stockholm University	15.04.24	26.04.24
A. Vijaykumar	Canadian Inst. for Theoretical Astrophysics	14.04.24	27.04.24
P. Di Vecchia	Nordita, Stockholm	11.04.24	19.04.24
J. Eby	Stockholm University	07.04.24.	14.04.24
C. Bonnerot	University of Birmingham	02.04.24	19.04.24
A. Vigna Gomez	Max Planck Institute for Astrophysics	02.04.24	05.04.24
C. Rowan	Oxford University	02.02.24	07.04.24
D. Theocharis	Artist in residence	02.04.24	30.06.24
S. Knibbeler	Artist in residence	01.04.24	01.06.24
F. Bautista	Institut de Physique Theorique	01.04.24	03.04.24
J. Touma	American University of Beirut	22.03.24	05.04.24
M. Lancaster	University of Manchester	19.03.24	31.03.24
K. Lee	Institut of Advanced Study, Seoul	19.03.24	30.03.24
S. Elijah	Artist in residence	16.03.24	01.04.24

S. Moudgalya	Technical University of Munich	13.03.24	15.03.24
K. Sun	Uppsala University	11.03.24	12.03.24
J. Assaad	ENS de Lyon	11.03.24	28.06.24
A. McLeod	University of Edinburgh	11.03.24	14.03.24
J. Kosinski	EMBL Hamburg	07.03.24	07.03.24
J. Ambjørn	Radboud University	07.03.24	08.03.24
S. Knibbeler	Artist in residence	01.04.24	01.06.24
A. More	IUCAA, India	06.03.24	09.03.24
V. Glorieux	University of Toulouse	04.03.24	15.07.24
S. Baiguera	Ben Gurion University	26.02.24	15.03.24
P. Di Vecchia	Nordita, Stockholm	23.02.24	01.03.24
G. Oling	Edinburgh University	21.02.24	23.02.24
L. Perrone	Leibniz Institute for Astrophysics Potsdam	20.02.24	22.02.24
M. Himmelmann	Potsdam University	19.02.24	20.02.24
A. Mughal	Aberystwyth University	19.02.24	20.02.24
M. Evans	Potsdam University	19.02.24	20.02.24
L. Bhardwaj	Oxford University	14.02.24	14.03.24
S. Räsänen	University of Helsinki	14.02.24	16.02.24
S. Green	University of Nottingham	12.02.24	16.02.24
L. Sberna	University Of Nottingham	12.02.24	16.02.24
S. Markoff	University of Amsterdam	08.02.24	10.08.24
S. P. Caron-Huot	McGill University	04.02.24	10.02.24
P. Di Vecchia	Nordita, Stockholm	01.02.24.	09.02.24
G. Grignani	Perugia University	28.01.24	02.03.24
S. Schneider	University of Tokyo	24.01.24	25.01.24
S. Jafarzadeh	Max Planck Inst. for Solar System Research	19.01.24	31.08.24
D. Blas	University of Barcelona	15.01.24	19.01.24

J. Vasconcelos	IST	08.01.24	12.01.24
S. Albanesi	University of Turin	07.01.24	15.03.24
Y. Porto	Federal University of ABC, Brazil	07.01.24	27.01.24
J. Vasconcelos	IST	08.01.24	12.01.24
S. Albanesi	University of Turin	07.01.24	15.03.24
Y. Porto	Federal University of ABC, Brazil	07.01.24	27.01.24

Administrative Staff

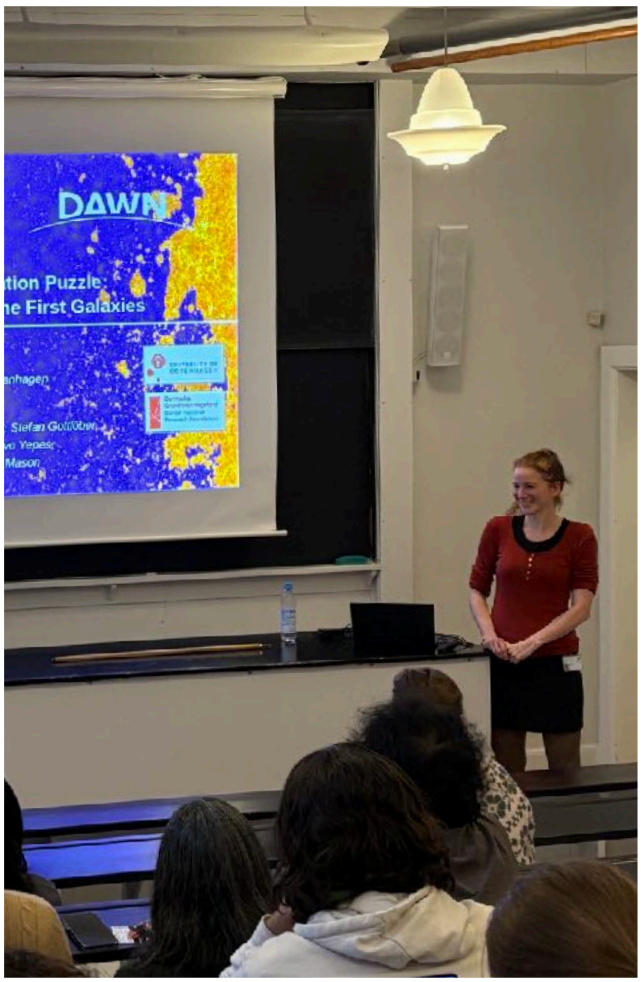
Gosia Dekempe is the NBIA administrator. She is responsible for onboarding new employees, coordination of guests and visitors, NBIA office overview and organization of events, workshops, and seminars. She handles HR matters and budget allocation. She holds a master's degree in economics from the Main School of Economics in Warsaw, Poland.

Julie de Molade is the Research Coordinator for the Strong Group at NBIA and PA to Prof. Vitor Cardoso. She is responsible for the daily running of the Strong Group, event coordination, communication, reporting, budget, HR, and general grant administration (DNRF Chair and Villum Foundation). She holds a Master of Arts in English and French from Roskilde University.

Student Assistants: During 2024, students Sofia Elisabeth Lorentzen and Leon Bojčić assisted the NBIA administration with running daily NBIA activities.

Rashid Sunyaev — Current Themes 2024 — NBIA Colloquium

NBIA Activities



Adam Riess — Current Themes 2024

NBIA Colloquia

NBIA Colloquia consist of talks on a wide variety of subjects aimed at scientists who are not necessarily experts on the subject matter. Topics are not limited to physics but can cover any subject of interest to the wide spectrum of researchers and students at NBIA. In the past year we have had talks on such varied topics as the geological-scale time history of the carbon cycle, the many-world interpretation of quantum mechanics, ecological diversity on mountains, and behavior patterns behind economic inequality. The list of talks and speakers follows below.

João Manuel Mendonça (Technical University of Denmark) — 23.02.2024
"Building the First Universal Climate Model"

Sune Lehmann (DTU) — 01.03.2024
"Using Sequences of Life-Events To Predict Human Lives"

Roman Gold (University of Southern Denmark) — 15.03.2024
"News from the Event Horizon Telescope"

Jeppe Dyre (Roskilde University) — 12.04.2024
"Physical Aging of Glasses: The Exciting Physics of Boring Data"

Giuseppe Mussardo (SISSA, Trieste) — 03.05.2024
"Random Walks, Bethe Ansatz and Riemann's Zeros"

Amri Wandel (Hebrew University) — 07.06.2024
"Extending the Horizons for Searching Life in Space: Beyond the Limits of the Habitable Zone"

Søren Hauberg (Technical University of Denmark) — 21.06.2024
"Invariance in generative Artificial Intelligence"

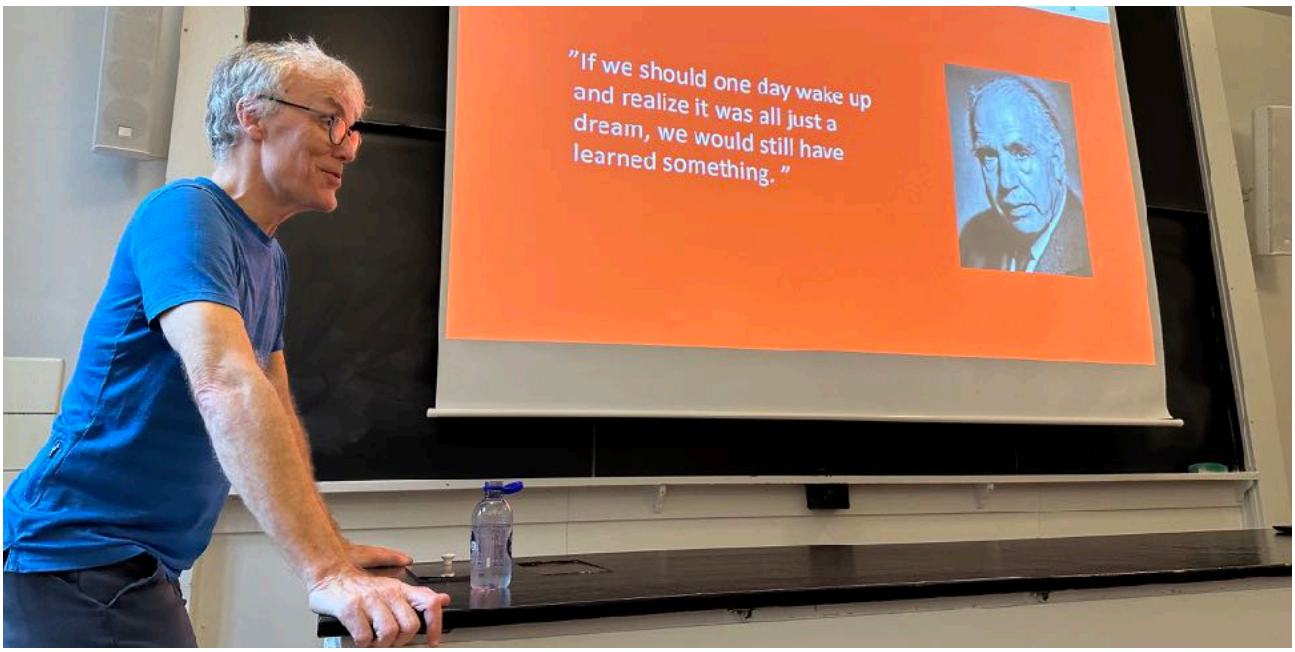
Rashid Sunyaev (Max-Planck Institute for Astrophysics and Russian Academy of Sciences) — 28.06.2024
"The map of the entire Sky in X-rays and its variability over time"

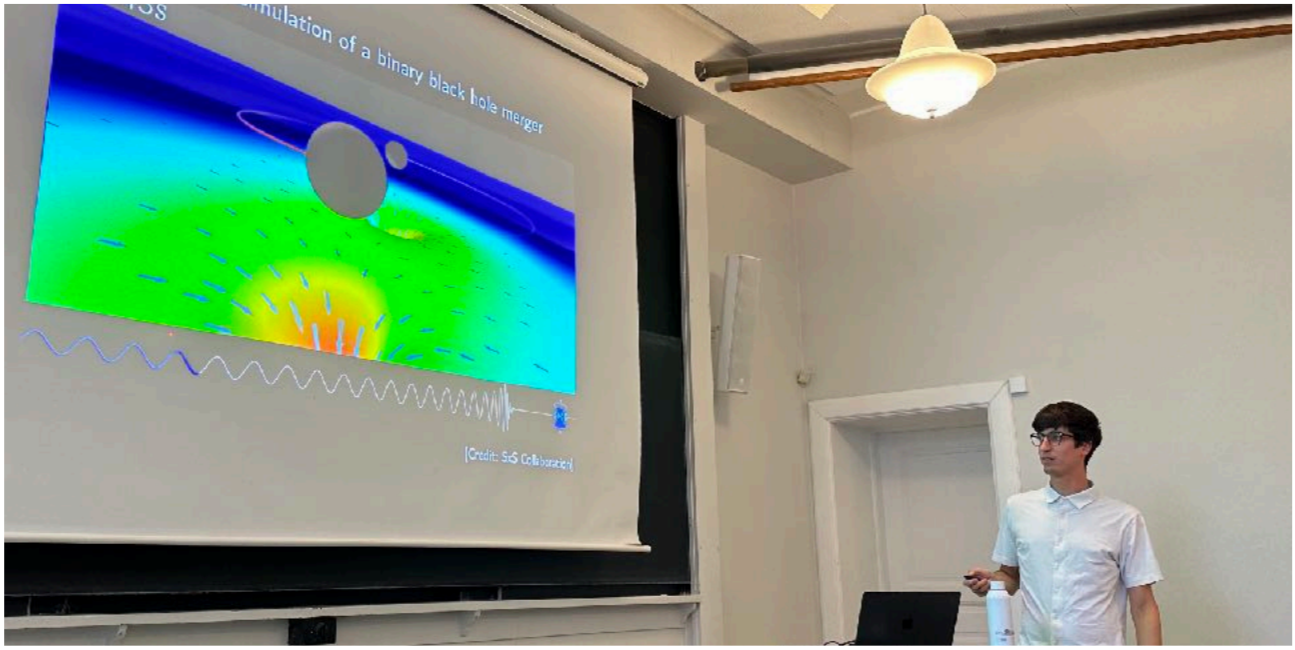
Charles H. Bennet (IBM Research) — 19.07.2024
"Using algorithmic information to evade the hard problem of consciousness in cosmology and ethics"

Ehud Meron (Ben Gurion University) — 07.08.2024
"To be or not to be: The crucial roles vegetation patterns play in maintaining ecosystem health"

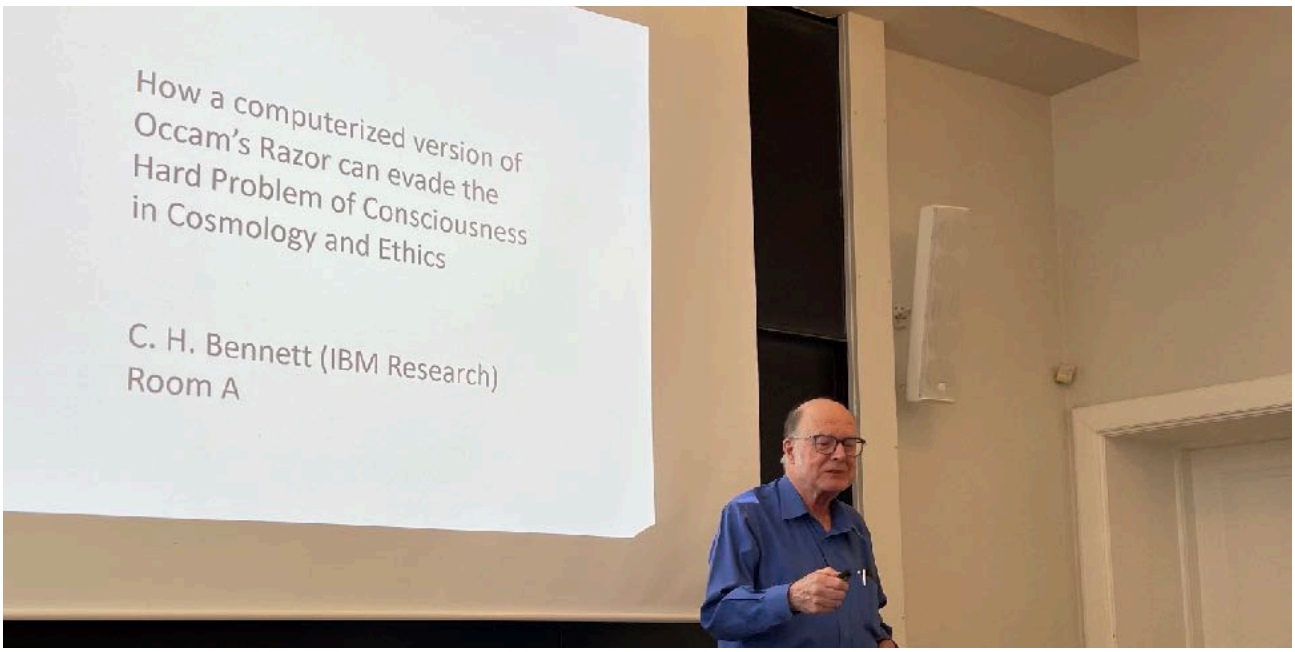
Uri Alon (Weizmann Institute) — 30.08.2024
"Mathematical Essence of Ageing"

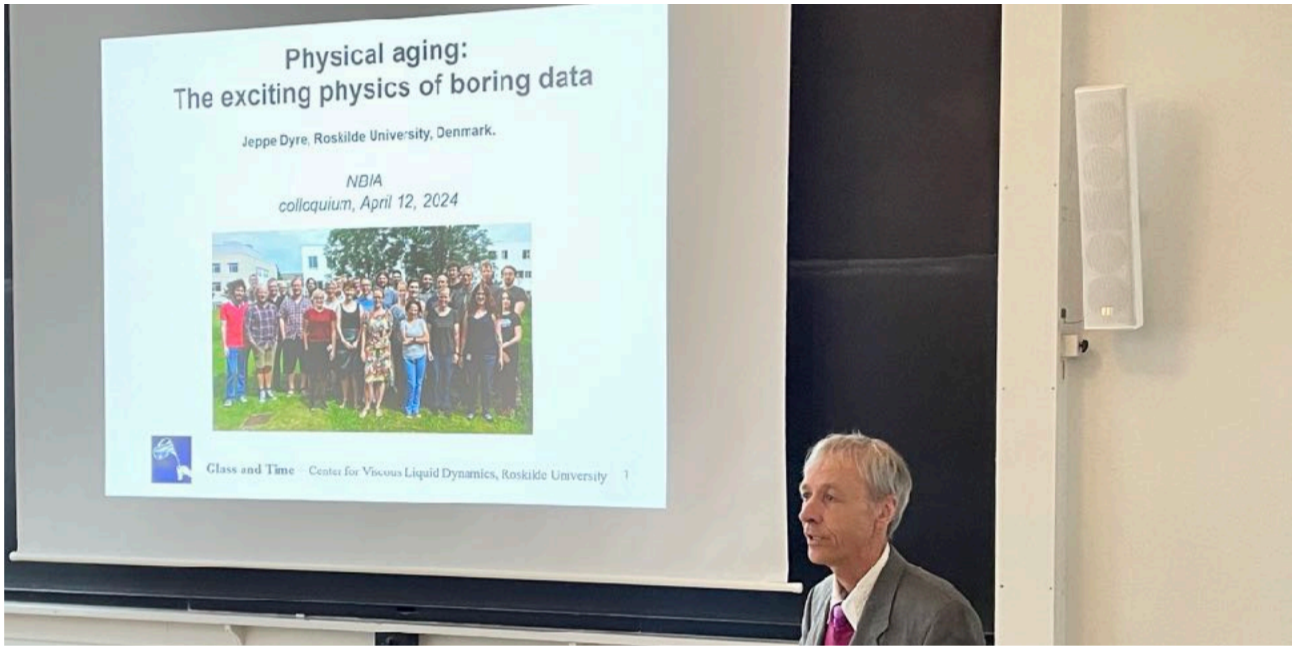
Thomas Sinkjær (Aalborg University) — 27.09.2024
"Peering the Peer review System"


"If we should one day wake up
and realize it was all just a
dream, we would still have
learned something."


mulation of a binary black hole merger
[Credit: SxS Collaboration]


nordisk fonden
erc


How a computerized version of
Occam's Razor can evade the
Hard Problem of Consciousness
in Cosmology and Ethics
C. H. Bennett (IBM Research)
Room A


Physical aging:
The exciting physics of boring data
Jeppe Dyre, Roskilde University, Denmark.
NBIA
colloquium, April 12, 2024
Glass and Time · Center for Viscous Liquid Dynamics, Roskilde University


Networks
Life2vec: Predicting personality, death, emigration,
and other life-events from embeddings of registry data
ehmann
or of Complexity and Network Science (Technical University of Denmark)
or of Data Science (University of Copenhagen)

Lecture by Nobel laureate Adam Riess

NBIA Colloquia

Drummond Fielding (Flatiron Institute) — 09.10.2024
"Bridging the Divide: A Multi-Scale Approach to Galaxy Formation"

Howard Stone (Princeton University) — 15.10.2024
"Soft materials, from biofluid mechanics to molecular biology"

Klaus Mølmer (Niels Bohr Institute) — 25.10.2024
"*Quantum Foundations, Quantum Technologies, and the 'Stuck-In-the-Elevator Talk' "*

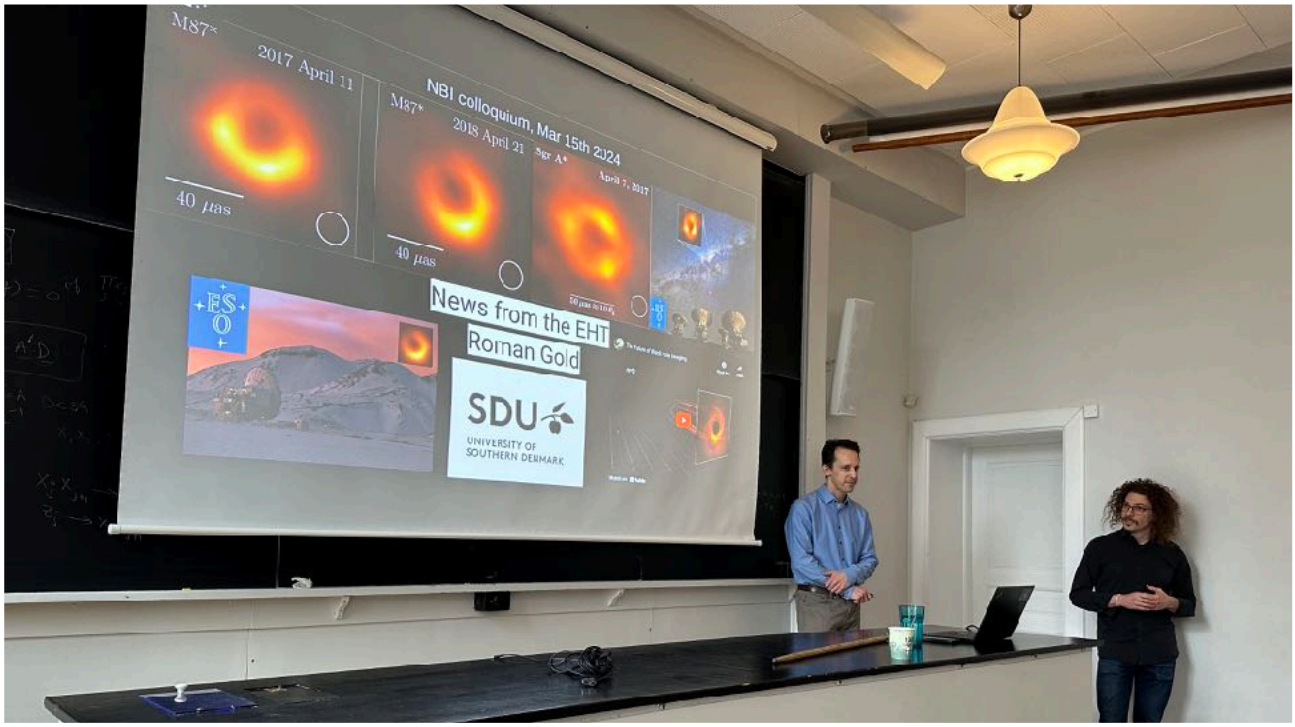
Jose Maria Ezquiaga (Niels Bohr Institute) — 01.11.2024
"Exploring the uncharted Universe with Gravitational Waves"

Klaus Pontoppidan (Space Telescope Science Institute) — 13.11.2024
"The origins of habitable worlds and the case for infrared telescopes in space"

James Cline (McGill University) — 15.11.2024
"What is Dark Matter?"

Johannes Jakob Lohmann (NBI) — 29.11.2024
"*Predictability and early-warning of climate tipping points"*

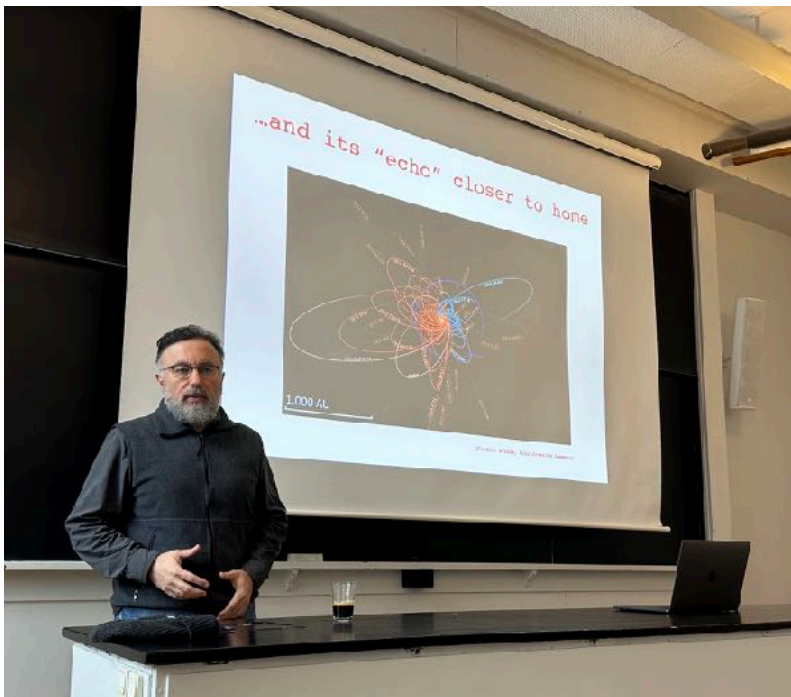
Nergis Mavalvala (MIT School of Science) — 10.12.2024
"Gravitational waves: a new window to the Universe"




Modeling jets and disks around forming massive stars
André Oliva
Postdoc
Institut für Numerische Astrophysik (AG Kuiper)
Universität Duisburg-Essen


Migration of Accreting Planets and Black Holes in Disks
Rixin Li

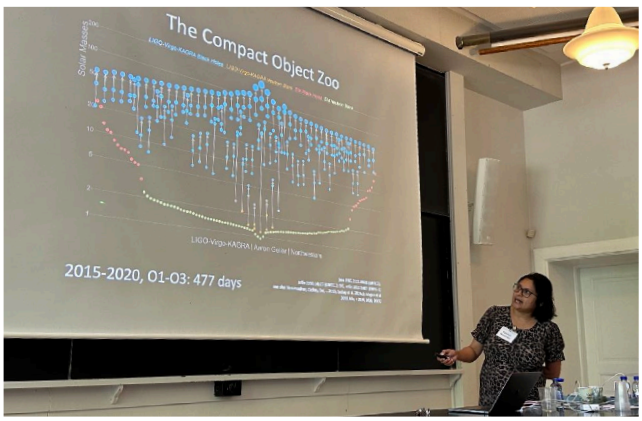

WHAT THE POPULATION OF GRAVITATIONAL WAVE SOURCES
CAN DO FOR YOU
BIA GRAVITY SEMINAR, 11 JUNE 2024

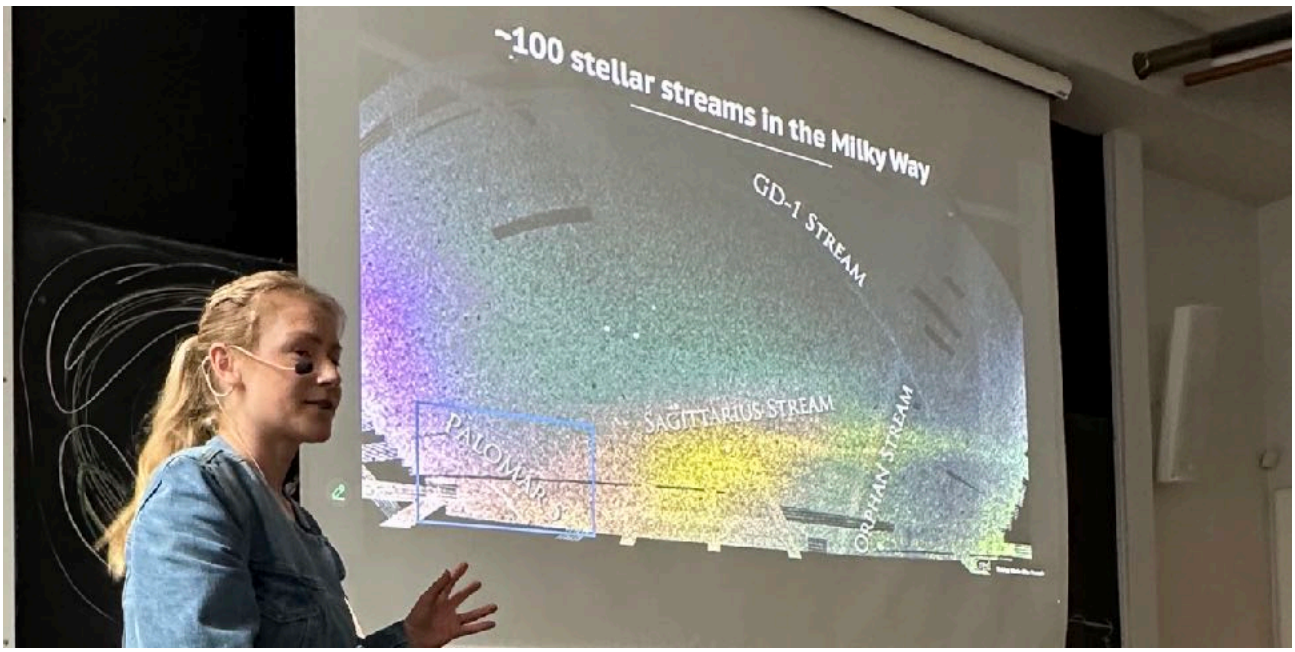

...and its "echo" closer to home
1,000 AL

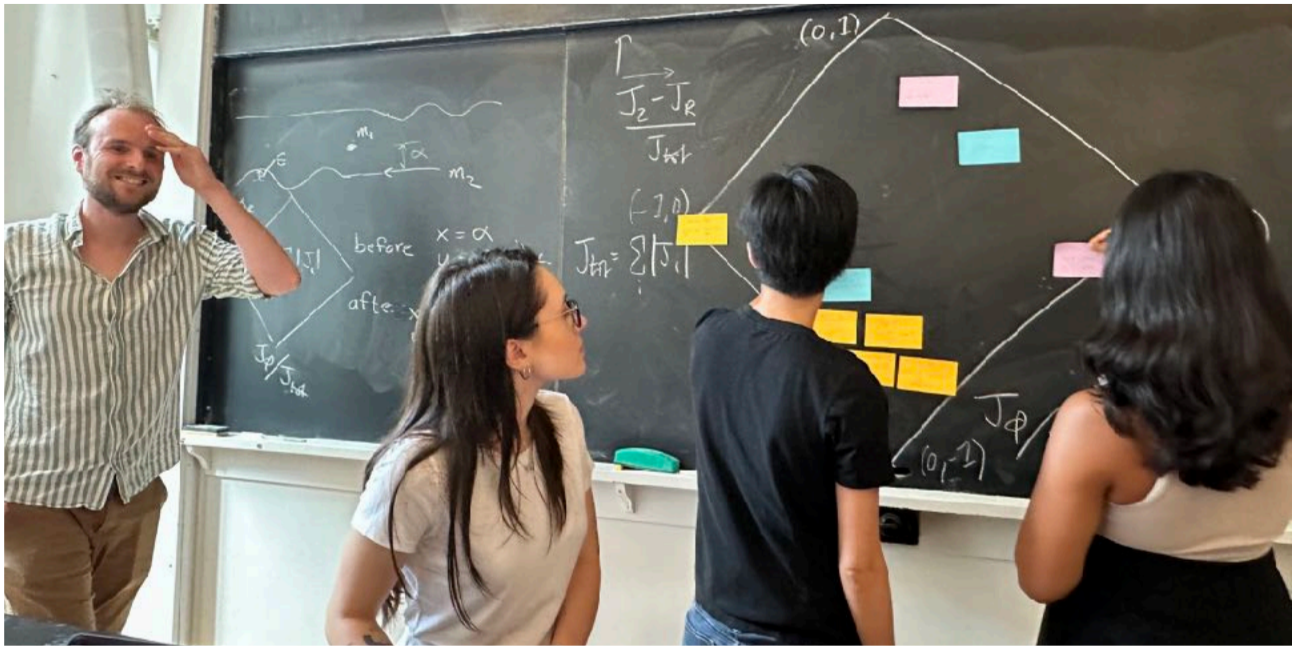
NBIA Seminars & Talks

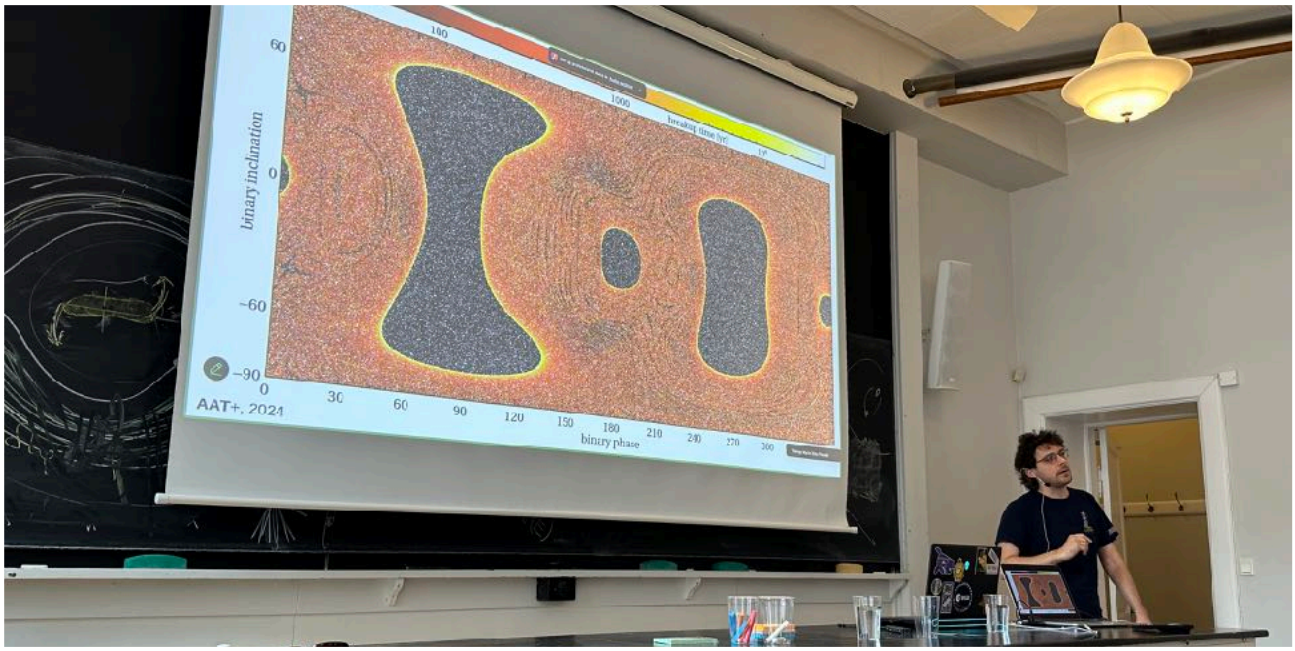
Apart from the weekly series of NBIA Colloquia, members of the NBIA organize or co-organize numerous more specialized seminars and lectures. Members of the particle theory group at the NBIA co-organize up to two specialized seminars every week, held by visitors to the group. In condensed matter physics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

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




~100 stellar streams in the Milky Way
GD-1 STREAM
SAGITTARIUS STREAM
PALOMAR 5
ORPHAN STREAM


(0,1)
(-1,0)
(0,-1)
before
after


binary inclination
binary phase
AAT+, 2024

NBIA Workshops & PhD Schools

Building on Niels Bohr's vision, NBIA members engage in several activities aimed at promoting and enhancing the traditions of internationalism, interdisciplinarity and excellence in physics. The NBIA is instrumental in running approximately ten high-profile, international events every year to the benefit of the wider Institute community. The following events were organized by NBIA members during 2024:

"Nordic Winter School on Multimessenger Astrophysics" — 28.01 / 02.02.2024

"Workshop on Geometry and Topology in Soft Materials" — 19.02.2024

"Current Themes in Transient Astrophysics and Cosmology " — 24.06 / 28.06.2024

"NBIA Summer School on Astrophysical Dynamics of Gravitating Systems" — 12.08 / 16.08.2024

"New Ideas on the Origin of Black Hole Mergers" — 12.08 / 16.08.2024

"Ringdown Inside and Out" — 22.08 / 24.08.2024

"Black Holes Inside and Out" — 26.08 / 30.08.2024

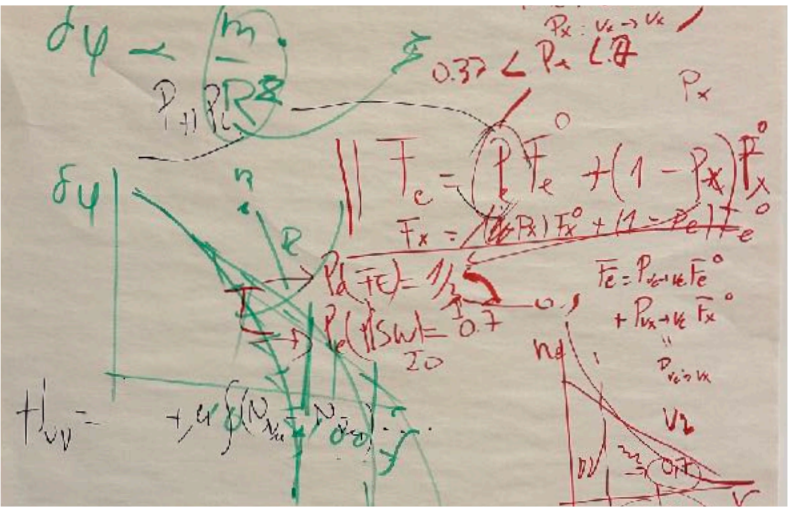
"Mini-Symposium on Quantum Sciences" — 26.08 / 27.08.2024

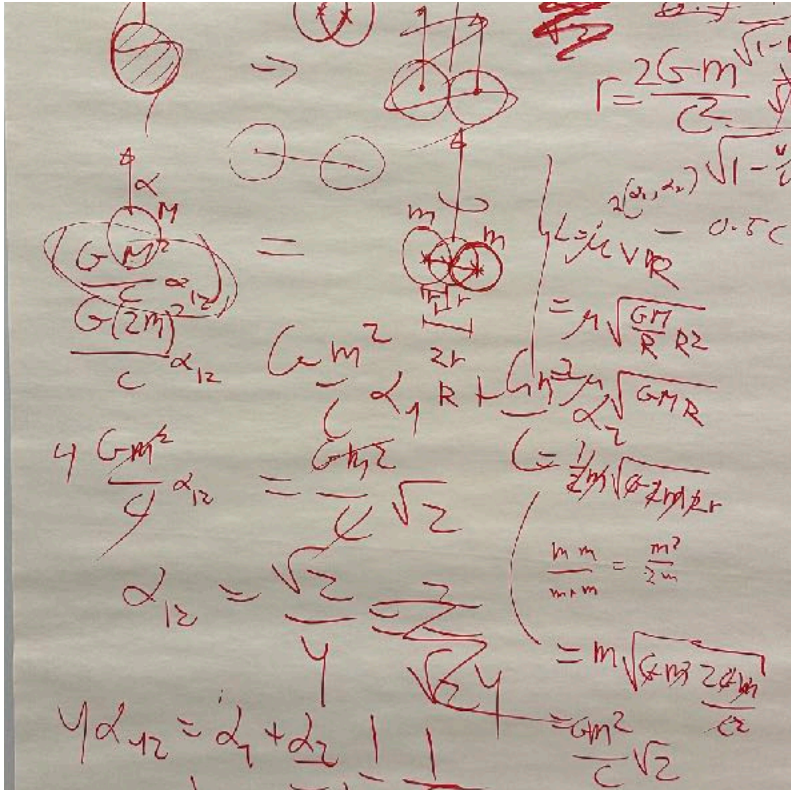
"NBIA Summer School on Frontiers in Gravity" — 09.09 / 13.09.2024

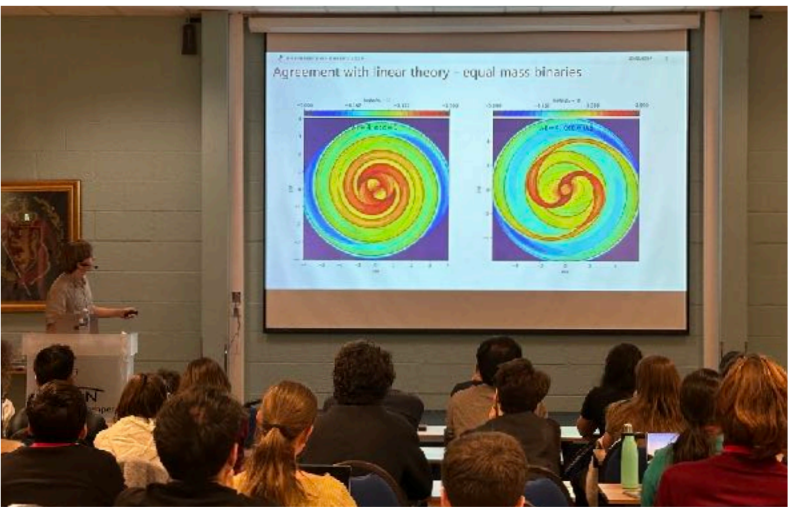
"INTERACTIONS DAY: Presentation Techniques for Science Talks" — 04.10.2024

"Current Themes in Biological and Soft Matter: Advances in Molecular Modeling" — 09.12 / 10.12.2024

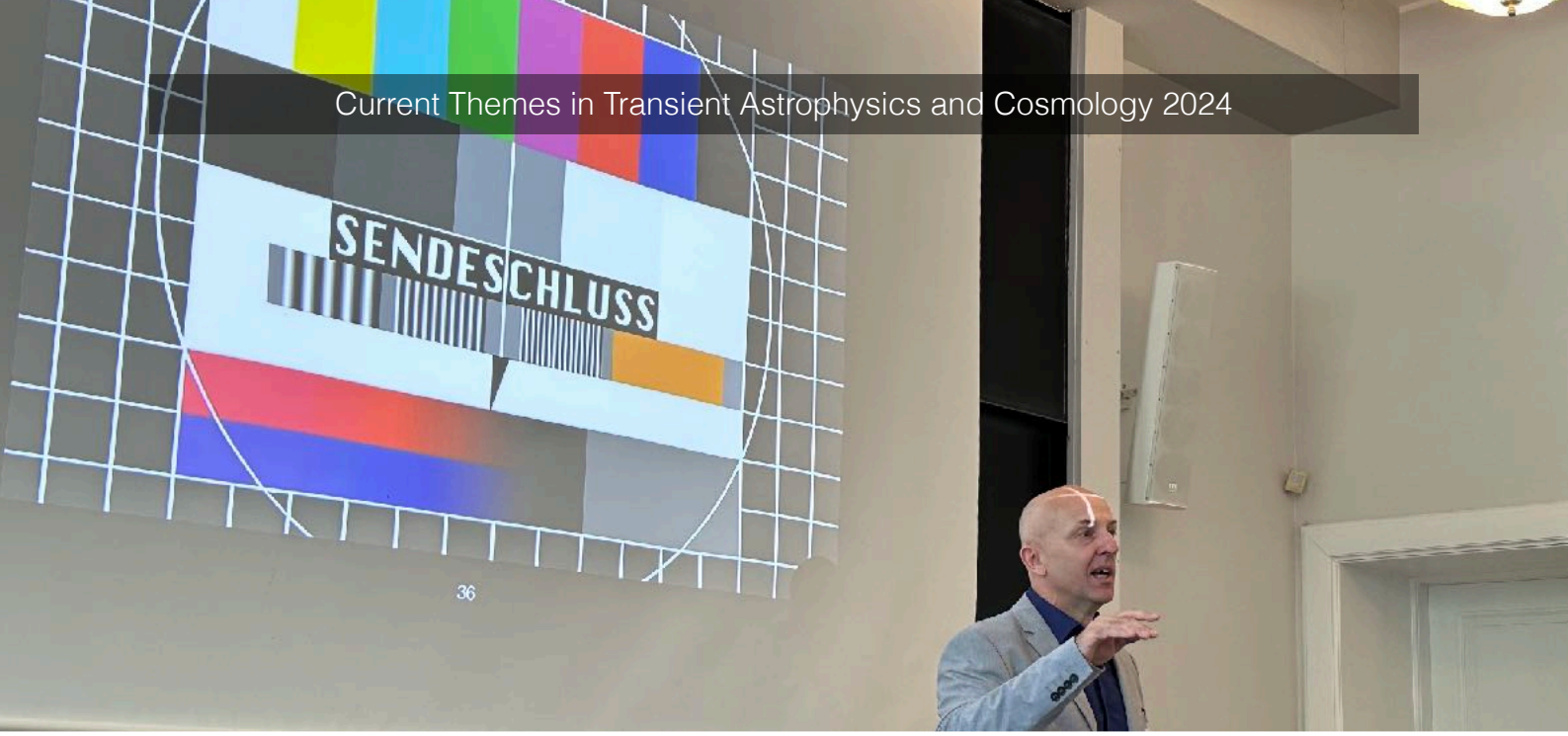
Nordic Winter School on Multimessenger Astrophysics 2024

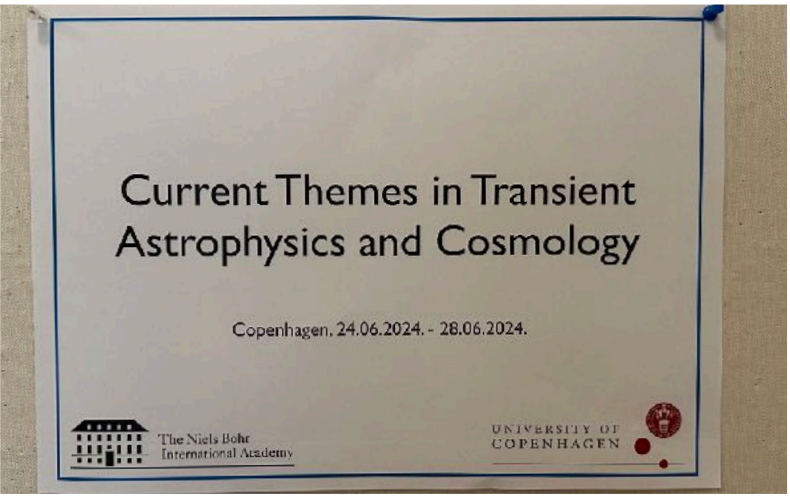




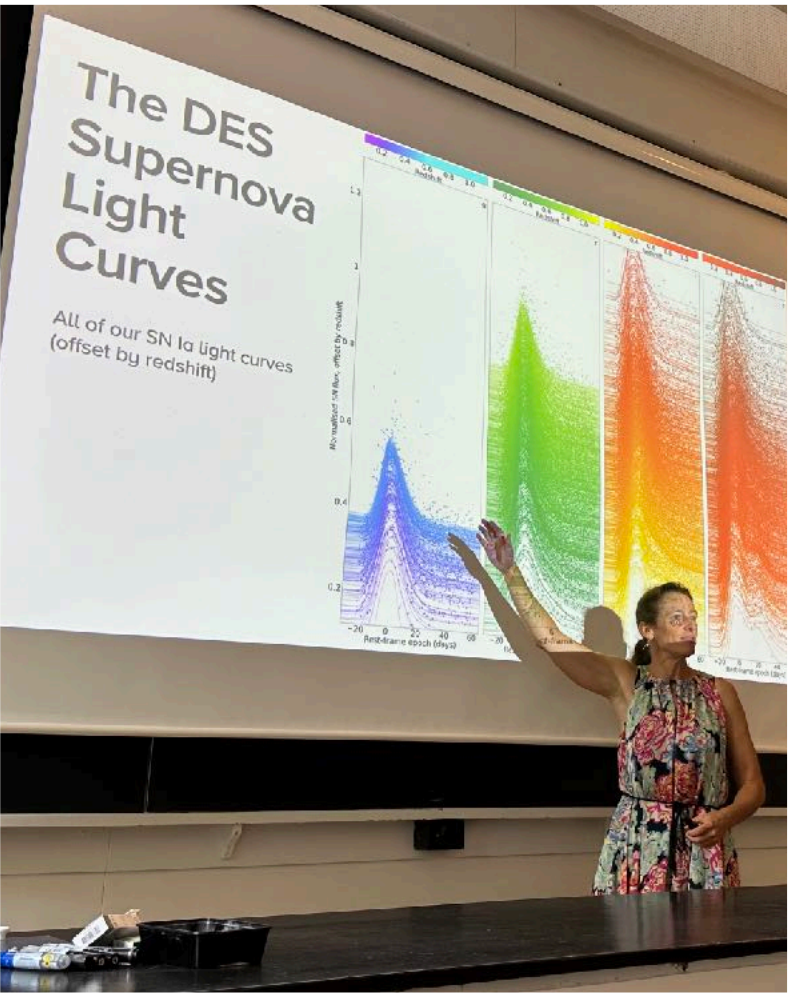


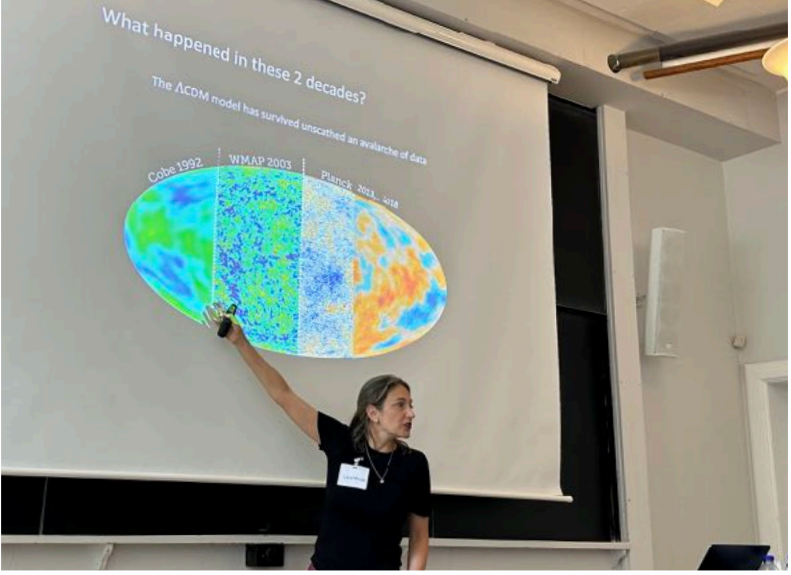
Nordic Winter School on Multimessenger Astrophysics 2024


Current Themes in Transient Astrophysics and Cosmology 2024
SENDESCHLUSS
36


Current Themes in Transient Astrophysics and Cosmology
Copenhagen. 24.06.2024. - 28.06.2024.
The Niels Bohr International Academy
UNIVERSITY OF COPENHAGEN

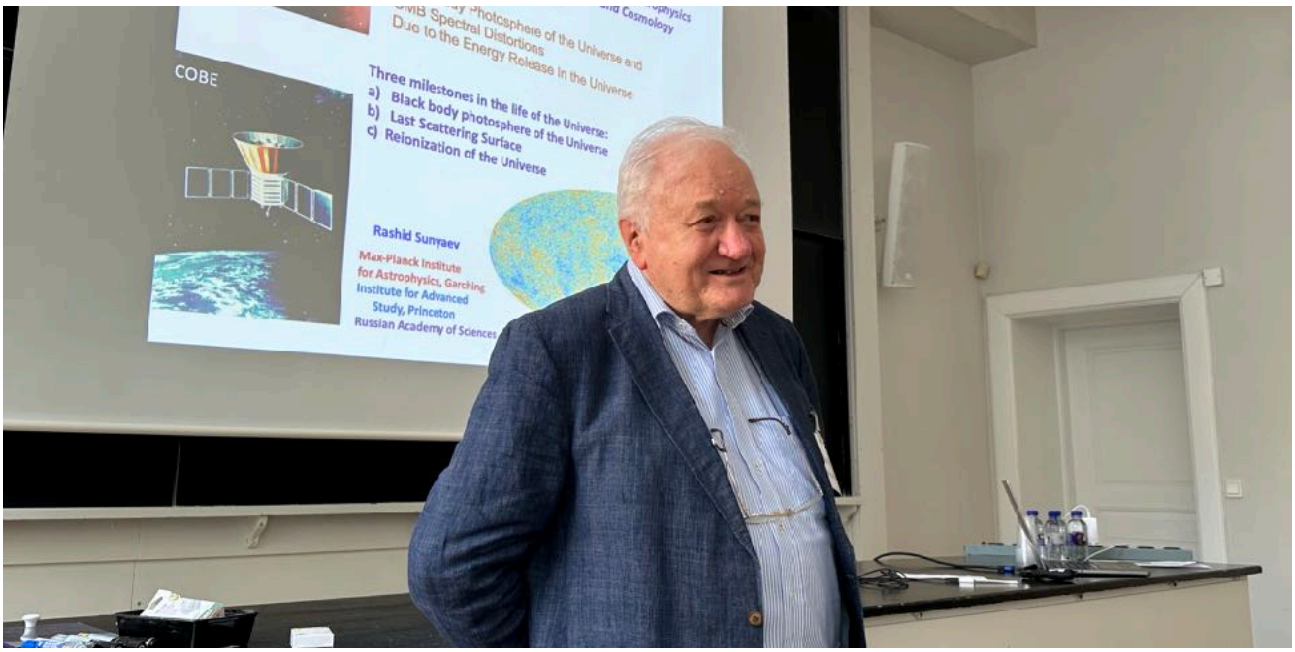

Harnessing AI/ML for Disruptive Advances in Compact Object Astrophysics
Dimitrios Psaltis
Georgia Tech

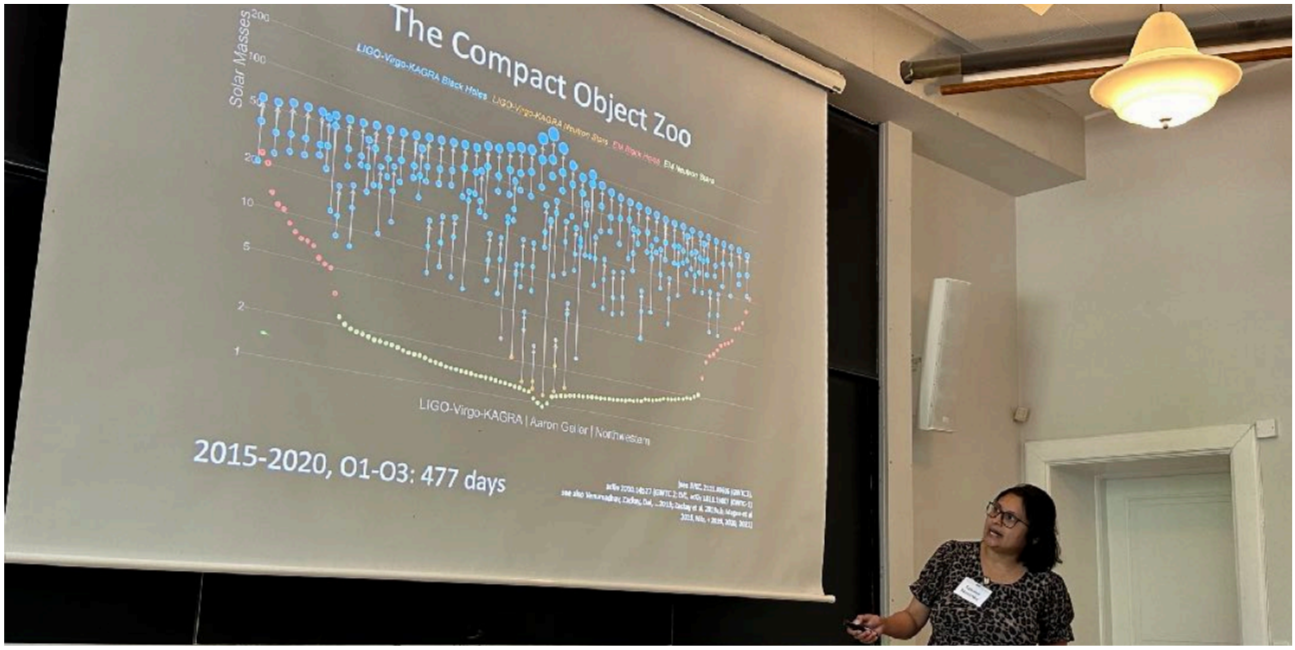

The DES Supernova Light Curves
All of our SN Ia light curves (offset by redshift)

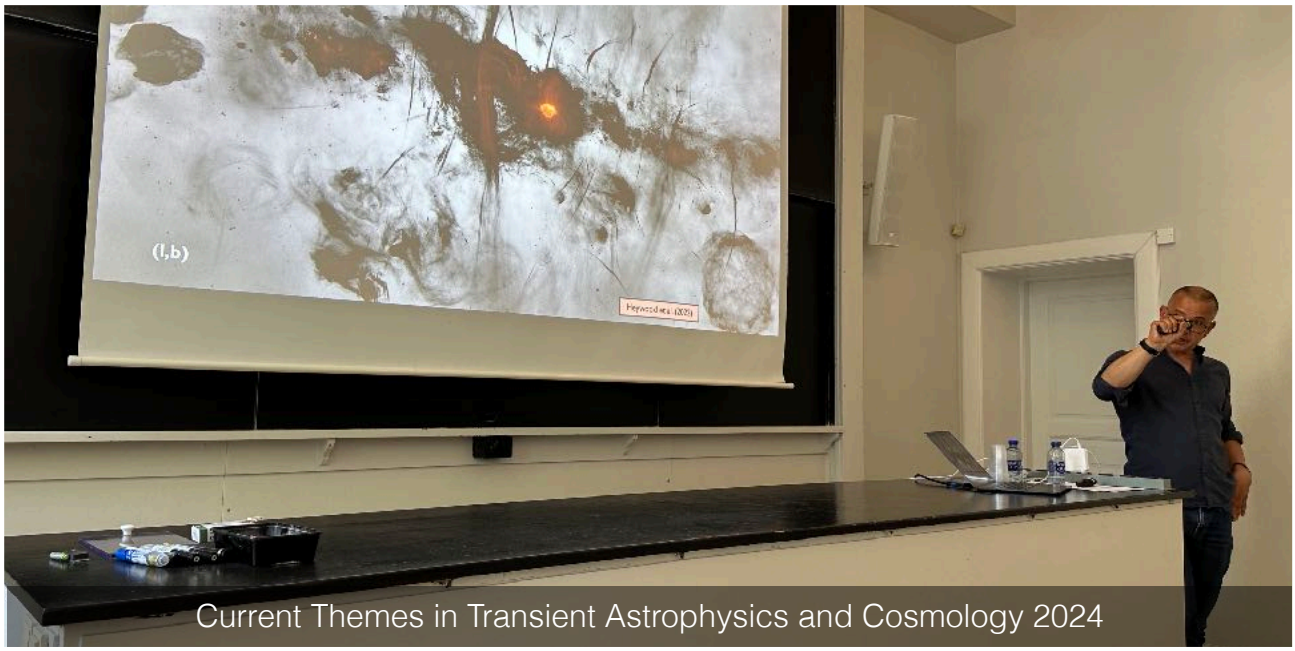

What happened in these 2 decades?
The ΛCDM model has survived unscathed an avalanche of data
Cobe 1992
WMAP 2003
Planck 2013, 2018


What can they teach us about massive stars?
IONIZING RADIATION
gravitational waves
TRANSIENT FORMATION
Massive Binary Stars

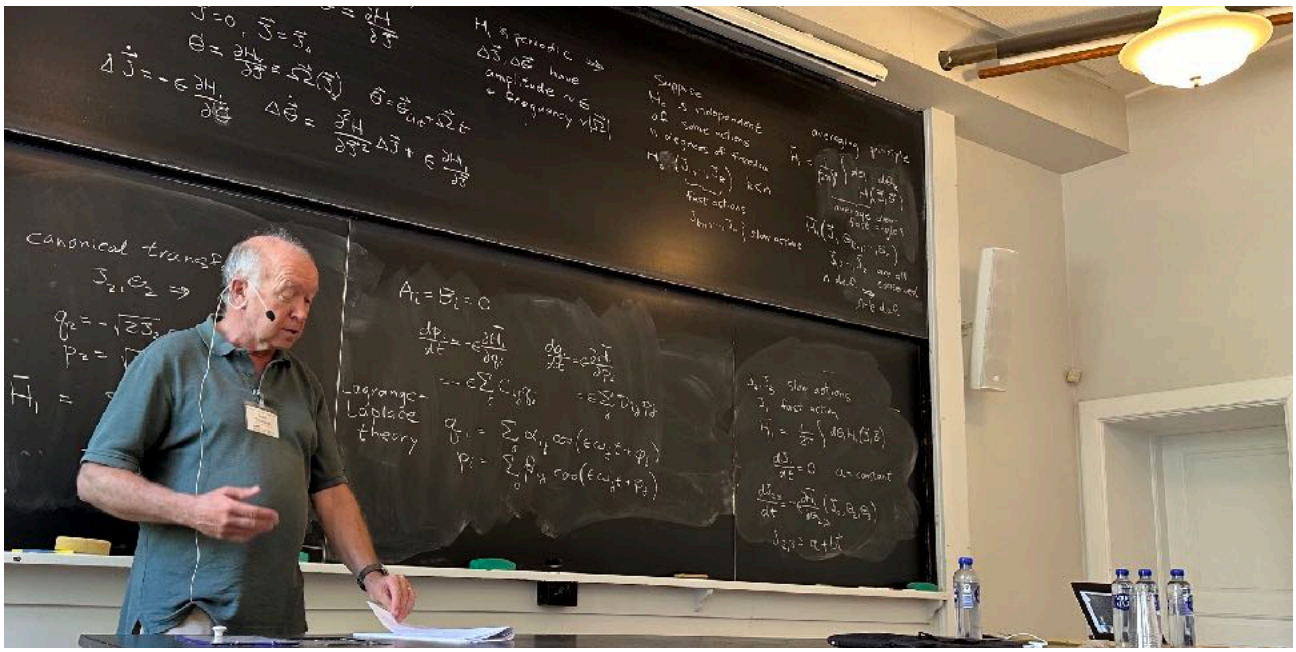

Current Themes in Transient Astrophysics and Cosmology 2024







Current Themes in Transient Astrophysics and Cosmology 2024


Canonical transf
Lagrange-
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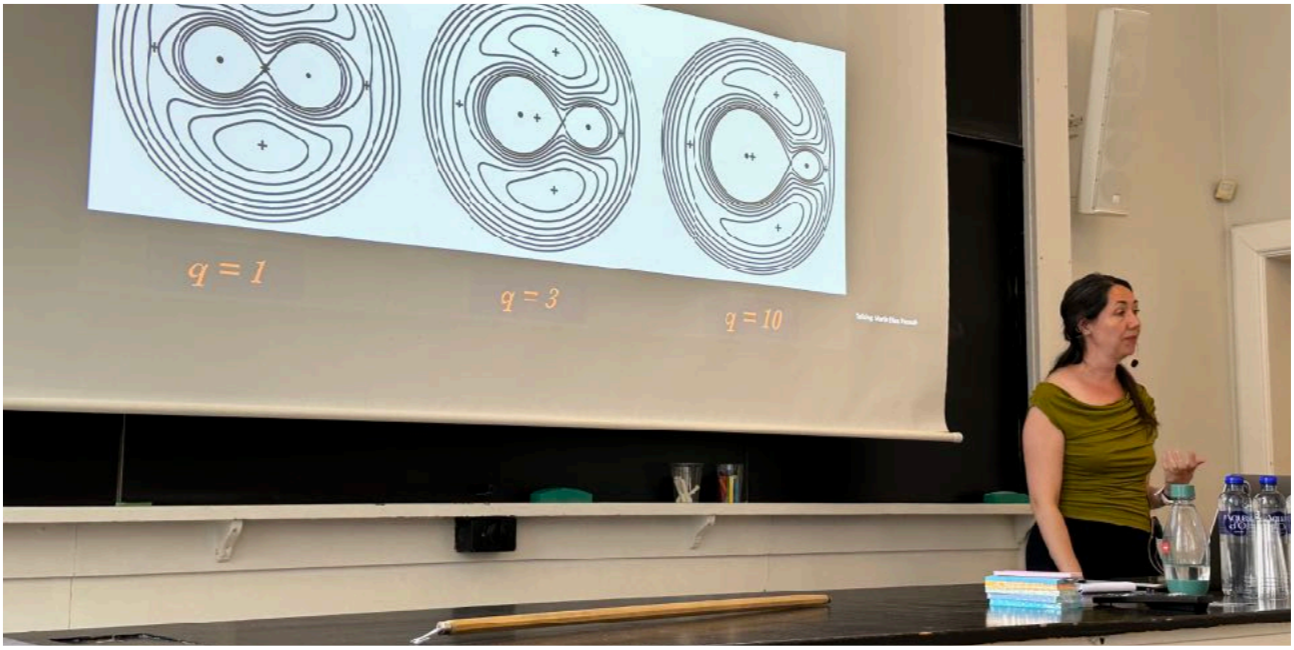
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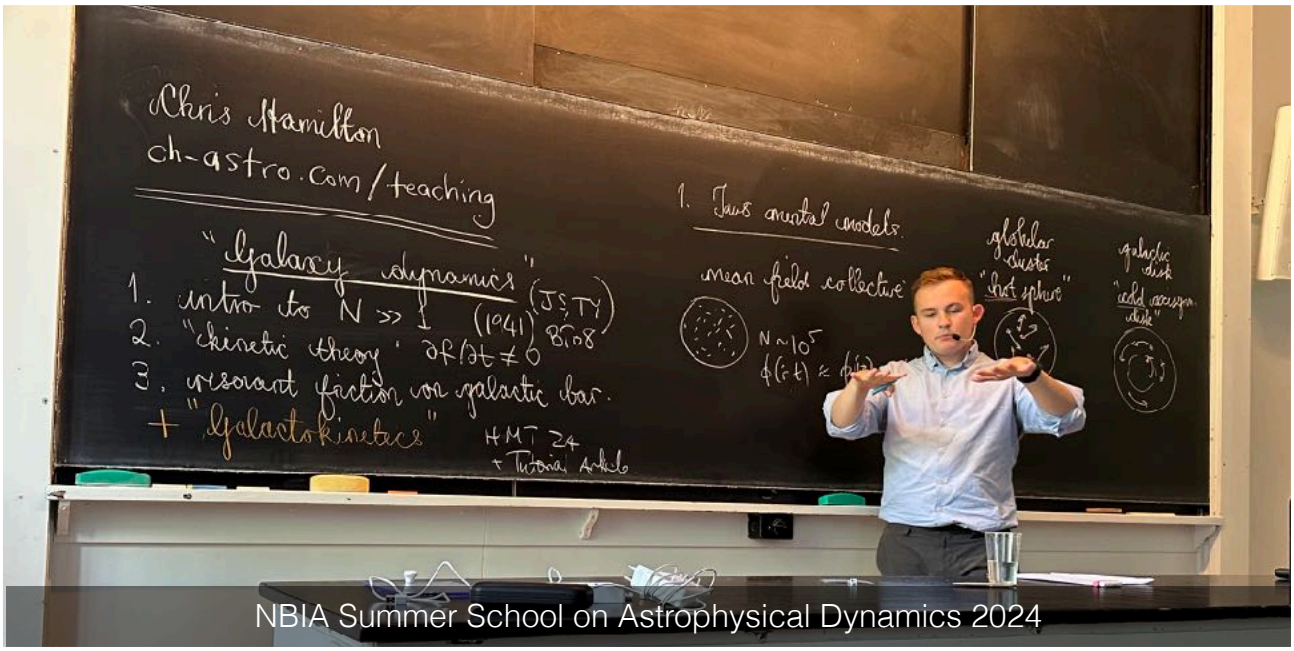
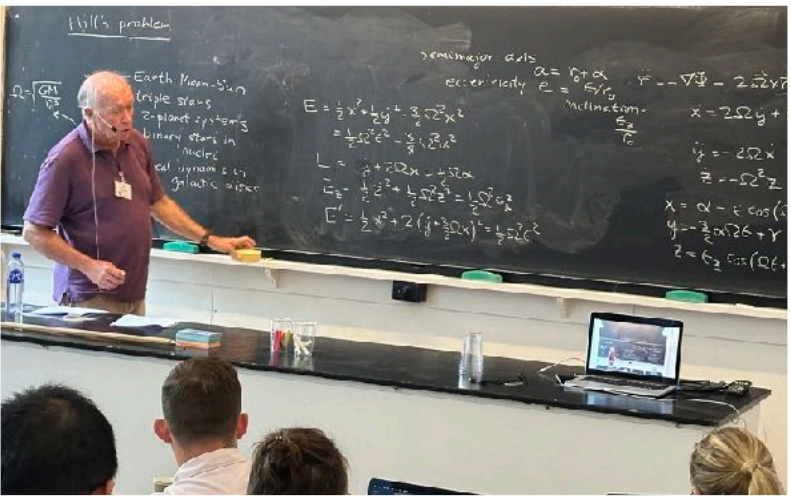
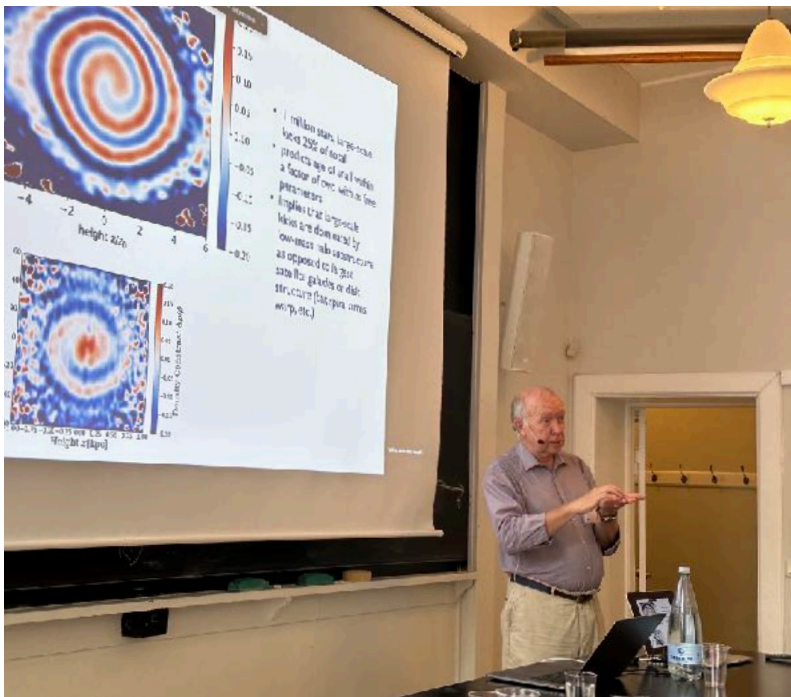
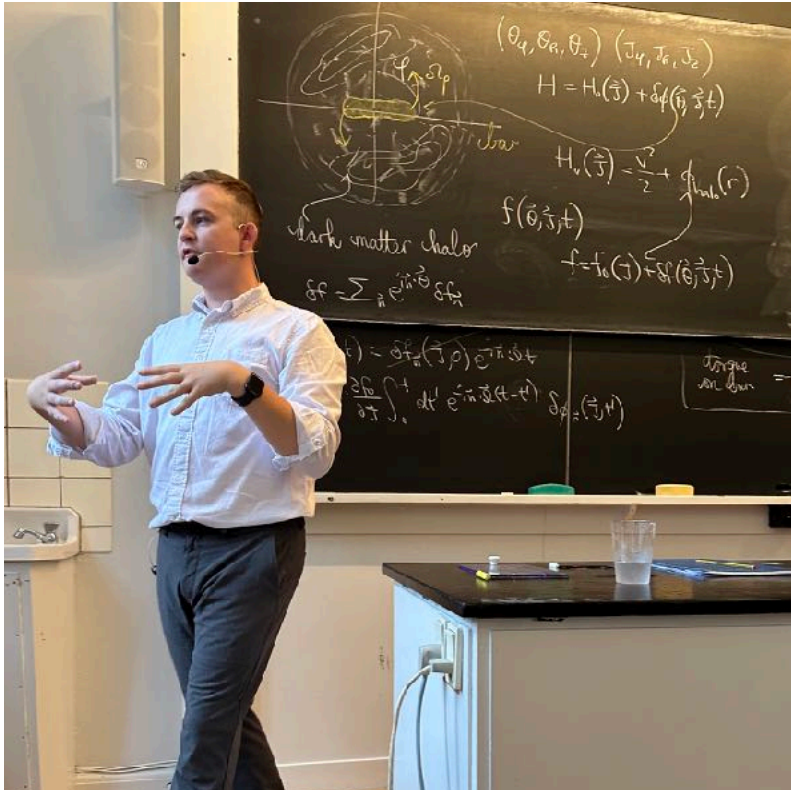
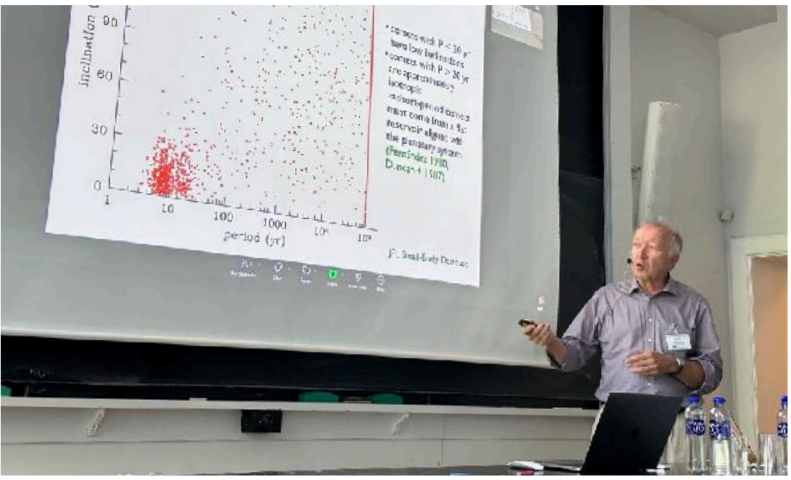

Chris Hamilton
ch-astro.com/teaching
"Galaxy dynamics"
1. intro to N >> 1 (1941)
2. "kinetic theory" ∂f/∂t ≠ 0
3. resonant friction on galactic bar.
+ "Galactokinetics"
HMT 24
+ Tutorial Article
1. Two orbital models
mean field collective
globular clusters
"hot sphere"
galactic disk
"cold accretion disk"

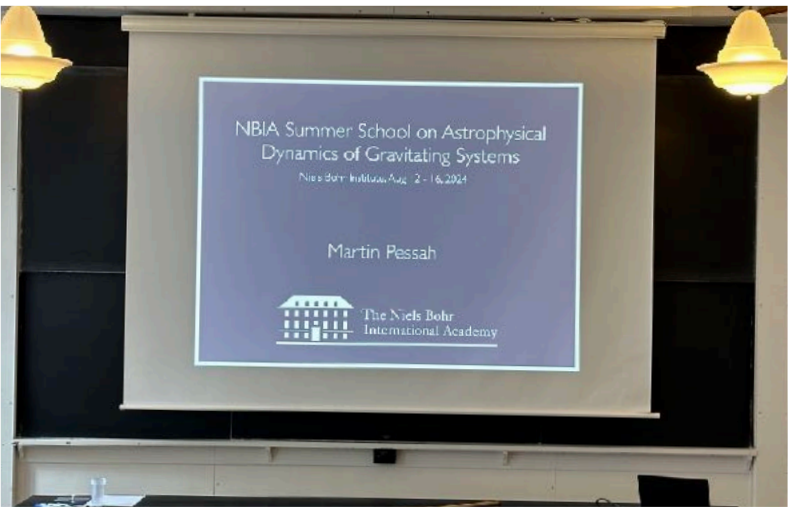
NBIA Summer School on Astrophysical Dynamics 2024











NBIA Summer School on Astrophysical Dynamics 2024

NBIA MSc Day 2024

October 8, 2024
Niels Bohr Institute
Europe/Copenhagen timezone

Enter your search term

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- Program
- Research
- Registration
- Participant List
- NBIA Brochure
- NBIA Linkedin
- Find your supervisor

Contact
mpessah@nbi.dk
mbustamante@nbi.ku.dk

NBIA MSc Day 2024

The Niels Bohr International Academy (NBIA) invites prospective MSc students to an informal event "MSc Projects @ NBIA" on **Tuesday, October 8, 09:00 a.m. to 1:00 p.m. (lunch included!).** Join us on that day to learn more about the diverse research program at NBIA. You will have the chance to chat with scientists about their research and the possibilities of carrying out your MSc project at NBIA.

The Niels Bohr International Academy (NBIA) is a center of excellence for theoretical physics and neighboring disciplines at the Niels Bohr Institute. Our mission is to attract the best and the brightest to Denmark and provide the environment to enable breakthrough research in theoretical particle physics, gravitational physics and astrophysics, theoretical astrophysics, biophysics and active matter, particle astrophysics, and condensed matter theory.

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

The NBIA staff includes several Professors, including a Villum Kann Rasmussen Professor and a DNRF Chair. Many NBIA Assistant Professors and Associate Professors have started new research groups in their disciplines by attracting prestigious national and European grants. The NBIA hosts many post-docs, PhD students, and MSc students. We have a steady stream of international visitors invited to give seminars or collaborate with NBIA members.

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

Starts Oct 8, 2024, 9:00 AM
Ends Oct 8, 2024, 1:30 PM
Europe/Copenhagen

Niels Bohr Institute
Auditorium A
Blegdamsvej 17
DK-2100 Copenhagen

Martin Pessah
Mauricio Bustamante
N. E. J Bjerrum-Bohr

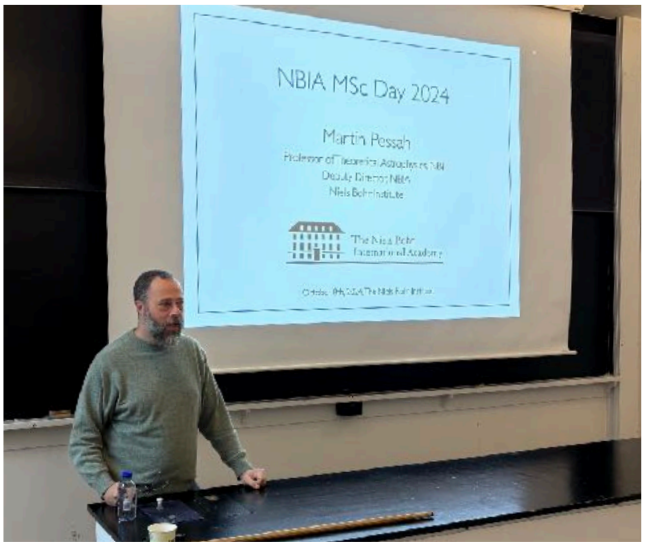
nbia-brochure-2024.pdf

Registration
Registration for this event is currently open.

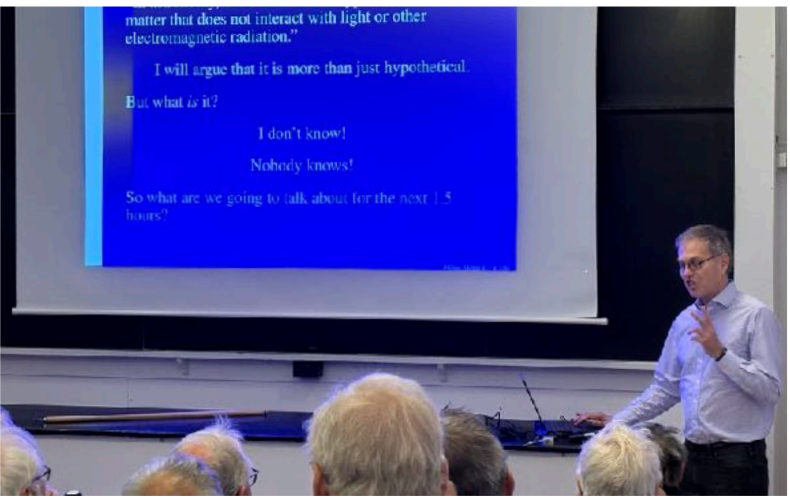
44 Register now

NBIA MSc Day 2024

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



NBIA Public Lectures 2024



NBIA Public Lectures & Outreach

Since 2011 NBIA has organized an annual series of public lectures on physics in collaboration with the Danish Open University "Folkeuniversitetet". All lectures take place in the historic Auditorium A in Blegdamsvej 17. The idea was from the start to engage the public and benefit from the presence of scientists and visitors at NBIA. The talks are at a level appropriate for an audience with no background in science and the speakers present topic very close to their on-going research. By design, these lectures 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 turned out being a very successful formula! There is always good attendance to learn about a broad range to topics at the forefront of present-day research. In 2024, the lectures were organized by Emil J. Bjerrum-Bohr (NBI), with the following program:

Sarah Pearson (NBI) — 08.10.24
"From Stellar Streams to the Invisible Universe"

Jørgen Christensen-Dalsgaard (Aarhus University) — 22.10.2024
"Probing the Interiors of Red Giant Stars with the Kepler Mission"

Peter Ditlevsen (NBI) — 29.10.2024
"Tipping Points in the Climate?"

Eugene Polzik (NBI) — 05.11.2024
"Quantum Sensing for Biomedical Applications"

James Cline (McGill University) — 12.11.2024
"What is Dark Matter"

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.

Lars Kann-Rasmussen presents Simon Caron-Huot with the Lars Kann-Rasmussen Prize 2024

Lise Arleth — Associate Dean of Research, College of Science, University of Copenhagen

Martin Pessah, Lise Arleth, Simon Caron-Huot, Lars Kann-Rasmussen, and Poul Henrik Damgaard

Lars Kann-Rasmussen Prize 2024

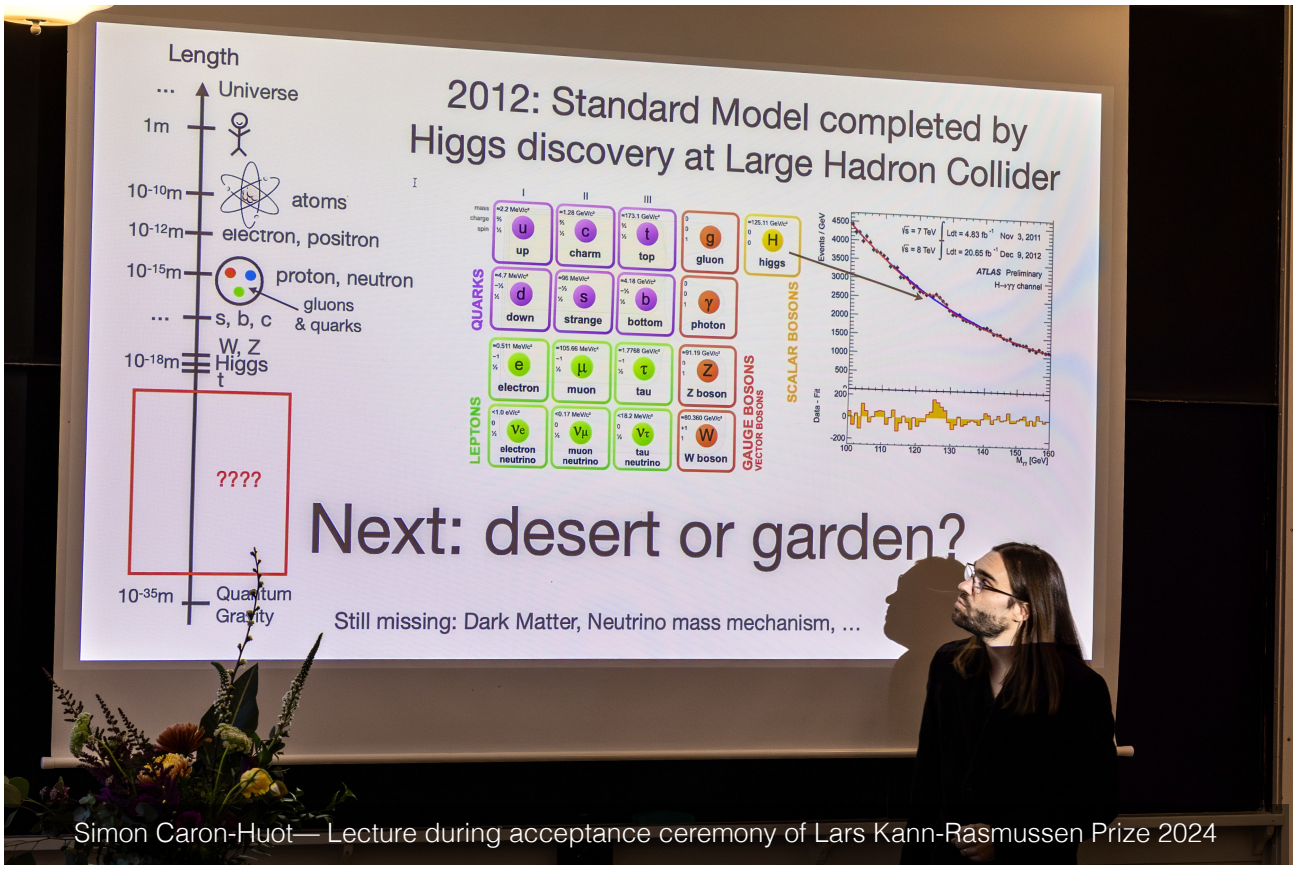
At an award ceremony on February 7th, former NBIA Asisstant Professor Simon Caron-Huot received the Lars Kann-Rasmussen Prize for 2024. The Prize was presented by Lars Kann-Rasmussen to Simon Caron-Huot in Auditorium A following speeches by Deputy Dean of Research Lise Arleth and NBIA Director Poul Henrik Damgaard.

After finishing his PhD-studies at McGill University in 2009, Simon Caron-Huot became a postdoctoral member of Institute for Advanced Study 2009-14 (the last two years on a joint appointment with NBIA). He was Assistant Professor at NBIA 2012-16, at which point he took up a faculty position at McGill University, where he has been since.

Simon Caron-Huot is the author of a large number of papers that in remarkable ways have shed new light on quantum field theoretic phenomena. His research is characterized by an unusual combination of very strong physical intuition with very strong analytical skills. For his work he has already received numerous awards and honors, including the Gribov Medal in 2017, the Hermann Weyl Prize in 2018, the New Horizon Breakthrough Prize in 2020, the Herzberg Medal in 2021, and the Larkin Junior Researcher Award in 2023.

Simon Caron-Huot receives the Lars Kann-Rasmussen Prize

"*For his fundamental and deeply original contributions to quantum field theory that have led to significant advancement of the understanding of physical systems ranging from high-density nuclear matter, statistical mechanics near critical points, to the interactions of black holes and the emission of gravitational waves*".



Simon Caron-Huot— Lecture during acceptance ceremony of Lars Kann-Rasmussen Prize 2024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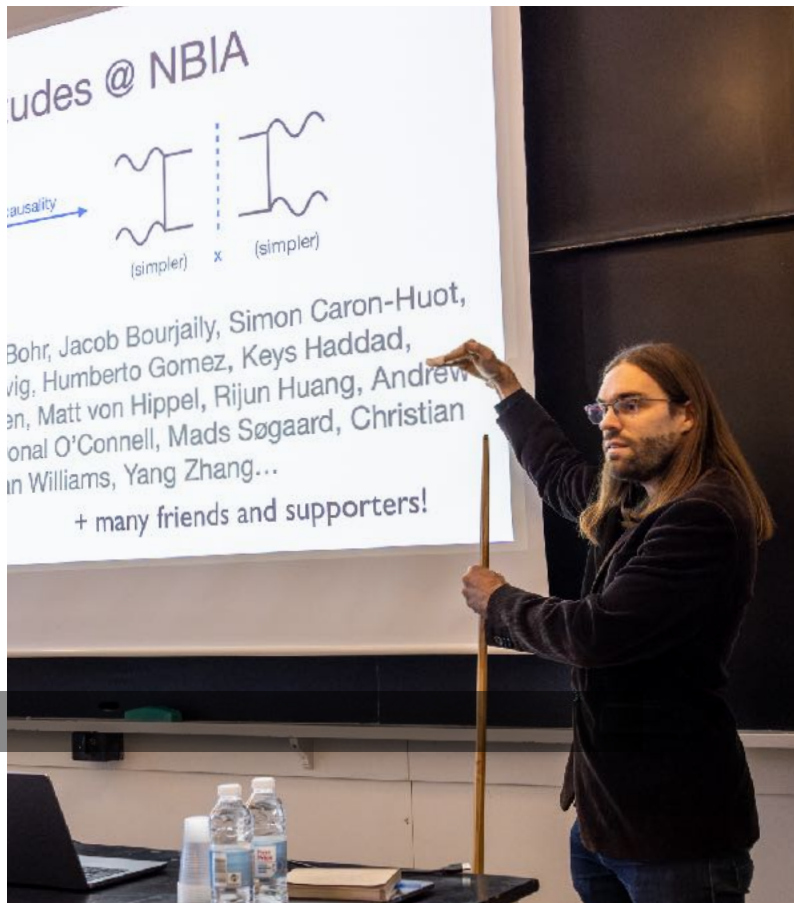
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onal O'Connell, Mads Søgaard, Christian
n Williams, Yang Zhang...
+ many friends and supporters!

Christina Egelund, Minister of Education and Research, Irene Tamborra, and HM The Queen. Credit: Søren Kjeldgaard

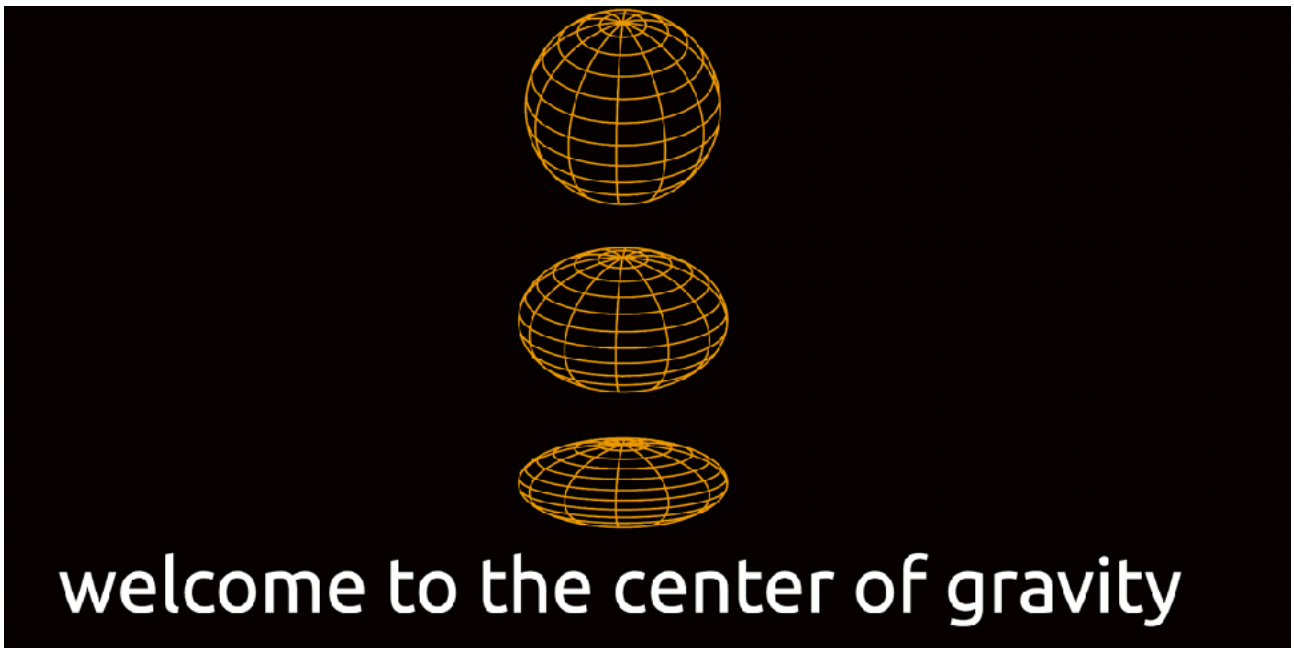
Irene Tamborra and Katrine Krogh Andersen — Dean, College of Science, University of Copenhagen

Elite Research Award - I.Tamborra

At an award ceremony at the Black Diamond building in Copenhagen, Queen Mary and Minister of Higher Education and Science Christina Egelund presented the Elite Research Award to NBIA Professor Irene Tamborra for her research in the burgeoning field of multi-messenger astrophysics and in particular for her contributions to the understanding of the role neutrinos play in explosive astrophysical events such as supernova and in collisions involving neutron stars.

Irene Tamborra joined NBIA in 2016 as Knud Højgaard Foundation Assistant Professor. She was promoted to Associate Professor in 2017 and Professor in 2021. Irene Tamborra has established the AstroNU group at NBIA with a broad spectrum of research topics within astroparticle physics. She has received prestigious grants such as Villum Young Investigator grants, a Sapere Aude grant, and, most recently, an ERC Consolidator Grant from the EU. The Elite Research Award includes a research grant of 1 MDKK and 200,000 DKK as a personal recognition award.

Irene Tamborra, Elite Forsk Award Ceremony, Black Diamond Library. Credit: Søren Kjeldgaard


welcome to the center of gravity


UNIVERSITY OF COPENHAGEN
NIELS BOHR INTERNATIONAL ACADEMY
BLACK HOLES
INSIDE AND OUT


BLACK HOLES
INSIDE AND OUT
COPENHAGEN

Center of Gravity - V. Cardoso

The Niels Bohr Institute will host a new DNRF Center of Excellence, the Center of Gravity (CoG). The CoG will bring together forefront research in observations of black holes and in the formal theory and quantum aspects of gravity, completing the visions of Bohr and Einstein for the gravitational interaction. The research endeavor will span from data analysis to theoretical disciplines within astrophysics and high-energy physics, driving gravitational wave physics to an exciting future. The Center will capitalize on the remarkable talent at the Niels Bohr Institute, to promote synergies linking fundamental physics with observations.

The Center of Gravity will be run by Center leader, Prof. Vitor Cardoso and his co-PIs: Prof. Emil Bjerrum-Bohr (NBI), Prof. Alessandra Buonanno (AEI), Prof. Troels Harmark (NBI), Prof. Niels Obers (NBI) and Assist. Professor Maarten van de Meent (NBI/AEI).

The Center will focus on five research themes: 1) Motion in curved spacetimes, 2) Spectroscopy of black holes, 3) Quantum effects for black holes and gravity, 4) Precision tools for understanding astrophysical environments, and 5) Templates and new data analysis tools for gravitational waves.

A Center of Excellence is a center funded by the Danish National Research Foundation (DNRF) for a 6-year period with the possibility of a 4-year extension.

Danmarks Grundforskningsfond
Danish National Research Foundation


Vitor Cardoso

NBIA Publications

Refereed Papers

1. **Precision-dissipation trade-off for driven stochastic systems**
Proesmans, Karel, 2023, Communications Physics, 6, 226 - ArXiv: 2203.00428

2. **Thermodynamics of interacting systems: The role of the topology and collective effects**
Mamede, Iago N., Proesmans, Karel, Fiore, Carlos E. et al., 2023, Physical Review Research, 5, 043278 - ArXiv: 2308.02255

3. **Inferring entropy production from time-dependent moments**
Singh, Prashant, Proesmans, Karel, 2024, Communications Physics, 7, 231 - ArXiv: 2310.16627

4. **Eccentric mergers in AGN discs: influence of the supermassive black hole on three-body interactions**
Fabj, Gaia, Samsing, Johan, 2024, MNRAS, 535, 3630-3645 - ArXiv: 2402.16948

5. **Fast Methods for Computing Photometric Variability of Eccentric Binaries: Boosting, Lensing, and Variable Accretion**
D'Orazio, Daniel J., Duffell, Paul C., Tiede, Christopher et al., 2024, ApJ, 977, 244 - ArXiv: 2403.05629

6. **Observing of background electromagnetic radiation of the real sky through the throat of a wormhole**
Bugaev, Mikhail, Novikov, Igor, Repin, Serge et al., 2024, arXiv e-prints, arXiv:2412.06872 - ArXiv: 2412.06872

7. **Novel category of environmental effects on gravitational waves from binaries perturbed by periodic forces**
Zwick, Lorenz, Tiede, Christopher, Trani, Alessandro et al., 2024, Phys. Rev. D, 110, 103005 - ArXiv: 2405.05698

8. **Observability of dynamical tides in merging eccentric neutron star binaries**
Takátsy, János, Kocsis, Bence, Kovács, Péter et al., 2024, Phys. Rev. D, 110, 103043 - ArXiv: 2407.17560

9. **Accretion-mediated spin-eccentricity correlations in LISA massive black hole binaries**
Garg, Mudit, Tiede, Christopher, D'Orazio, Daniel J. et al., 2024, MNRAS, 534, 3705-3712 - ArXiv: 2405.04411

10. **Imprints of massive black-hole binaries on neighbouring decihertz gravitational-wave sources**
Stegmann, Jakob, Zwick, Lorenz, Vermeulen, S et al., 2024, Nature Astronomy, 8, 1321-1331 - ArXiv: 2311.06335

11. **Gaseous Dynamical Friction on Elliptical Keplerian Orbits**
O'Neill, David, D'Orazio, Daniel J., Samsing, Johan, Pessah, Martin, 2024, ApJ, 974, 216 - ArXiv: 2401.16166

12. **The boring history of Gaia BH3 from isolated binary evolution**
Iorio, Giuliano, Torniamenti, Stefano, Mapelli, Michela et al., 2024, A&A, 690, A144 - ArXiv: 2404.17568

13. **Search for Eccentric Black Hole Coalescences during the Third Observing Run of LIGO and Virgo**
Abac, A. G., Abbott, R., Abe, H. et al., 2024, ApJ, 973, 132 - ArXiv: 2308.03822

14. **Disc novae: thermodynamics of gas-assisted binary black hole formation in AGN discs**
Whitehead, Henry, Rowan, Connar, Boekholt, Tjarda et al., 2024, MNRAS, 533, 1766-1781 - ArXiv: 2312.14431

15. **Isles of regularity in a sea of chaos amid the gravitational three-body problem**
Trani, Alessandro Alberto, Leigh, Nathan W. C. et al., 2024, A&A, 689, A24 - ArXiv: 2403.03247

16. **Close Encounters of Wide Binaries Induced by the Galactic Tide: Implications for Stellar Mergers and Gravitational-wave Sources**
Stegmann, Jakob, Vigna-Gómez, Alejandro et al., 2024, ApJ, 972, L19 - ArXiv: 2405.02912

17. **The evolution of accreting population III stars at $10^{-6} - 10^{3}$ $M_{\odot}$ yr^{-1}**
N, al, Devesh, Zwick, Lorenz et al., 2024, A&A, 689, A351 - ArXiv: 2407.06994

18. **Gravitational Wave Astronomy With TianQin**
Li, En-Kun, Liu, Shuai, Torres-Orjuela, Alejandro et al., 2024, arXiv e-prints, arXiv:2409.19665 - ArXiv: 2409.19665

19. **Merging hierarchical triple black hole systems with intermediate-mass black holes in population III star clusters**
Liu, Shuai, Wang, Long, Hu, Yi-Ming et al., 2024, MNRAS, 533, 2262-2281 - ArXiv: 2311.05393

20. **Long-term evolution of binary orbits induced by circumbinary disks**
Valli, Ruggero, Tiede, Christopher, Vigna-Gómez, Alejandro et al., 2024, A&A, 688, A128 - ArXiv: 2401.17355

21. **The Black Hole Explorer: astrophysics mission concept engineering study report**
Peretz, Eliad, Kurczynski, Peter, Johnson, Michael D. et al., 2024,, 13092, 130922F

22. **The Santa Barbara Binary-disk Code Comparison**
Duffell, Paul C., Dittmann, Alex, er J. et al., 2024, ApJ, 970, 156 - ArXiv: 2402.13039

23. **On Binary Formation from Three Initially Unbound Bodies**
Atallah, Dany, Weatherford, Newlin C., Trani, Alessandro et al., 2024, ApJ, 970, 112 - ArXiv: 2402.12429

24. **Ultralight vector dark matter search using data from the KAGRA O3GK run**
Abac, A. G., Abbott, R., Abe, H. et al., 2024, Phys. Rev. D, 110, 042001 - ArXiv: 2403.03004

25. **Gas assisted binary black hole formation in AGN discs**
Whitehead, Henry, Rowan, Connar, Boekholt, Tjarda et al., 2024, MNRAS, 531, 4656-4680 - ArXiv: 2309.11561

26. **Shape of the membrane neck around a hole during plasma membrane repair**
Martin Berg Klenow, Magnus Staal Vigsø, Weria Pezeshkian et al., 2024, Biophysical Journal, 123, 1827--1837

27. **Hall-magnetohydrodynamic simulations of X-ray photoevaporative protoplanetary disc winds**
Sarafidou, Eleftheria, Gressel, Oliver, Picogna, Giovanni et al., 2024, MNRAS, 530, 5131-5142 - ArXiv: 2310.01985

28. **pAGN: the one-stop solution for AGN disc modelling**
Gangardt, Daria, Trani, Alessandro Alberto et al., 2024, MNRAS, 530, 3689-3705 - ArXiv: 2403.00060

29. **NuSTAR Observations of Candidate Subparsec Binary Supermassive Black Holes**
Saade, M. Lynne, Brightman, Murray, Stern, Daniel et al., 2024, ApJ, 966, 104 - ArXiv: 2304.06144

30. **MRI turbulence in vertically stratified accretion discs at large magnetic Prandtl numbers**
Held, Loren E., Mamatsashvili, George, Pessah, Martin E. et al., 2024, MNRAS, 530, 2232-2250 - ArXiv: 2310.00453

31. **Bending of a lipid membrane edge by annexin A5 trimers**
Mayank Prakash Pandey, Paulo Cesar Telles de Souza et al., 2024, Biophysical Journal, 123, 1006--1014

32. **Three-body encounters in black hole discs around a supermassive black hole. The disc velocity dispersion and the Keplerian tidal field determine the eccentricity and spin-orbit alignment of gravitational wave mergers**
Trani, A. A., Quaini, S., Colpi, M. et al., 2024, A&A, 683, A135 - ArXiv: 2312.13281

33. **Disk-induced Binary Precession: Implications for Dynamics and Multimessenger Observations of Black Hole Binaries**
Tiede, Christopher, D'Orazio, Daniel J., Zwick, Lorenz et al., 2024, ApJ, 964, 46 - ArXiv: 2312.01805

34. **Work statistics at first-passage times**
Mamede, Iago N., Singh, Prashant, Pal, Arnab et al., 2024, New Journal of Physics, 26, 033034 - ArXiv: 2401.12583

35. **Universal thermodynamic bounds on the Fano factor of discriminatory networks with unidirectional transitions**
Berx, J., Proesmans, K., 2024, EPL (Europhysics Letters), 145, 51001 - ArXiv: 2312.01051

36. **Star-forming environments in smoothed particle magnetohydrodynamics simulations II: re-simulating isolated clumps to determine equivalence of extracted clumps and parent simulations**
Wurster, James, Rowan, Connar, 2024, MNRAS, 528, 2257-2273 - ArXiv: 2401.04267

37. **Black hole binaries in AGN accretion discs - II. Gas effects on black hole satellite scatterings**
Rowan, Connar, Whitehead, Henry, Boekholt, Tjarda et al., 2024, MNRAS, 527, 10448-10468 - ArXiv: 2309.14433

38. **Measurement of three-body chaotic absorptivity predicts chaotic outcome distribution**
Manwadkar, Viraj, Trani, Alessandro A. et al., 2024, Celestial Mechanics and Dynamical Astronomy, 136, 4 - ArXiv: 2302.08312

39. **Active Matter under Control: Insights from Response Theory**
Davis, Luke K., Proesmans, Karel, Fodor, Étienne et al., 2024, Physical Review X, 14, 011012 - ArXiv: 2305.11078

40. **LISA Definition Study Report**
Colpi, Monica, Danzmann, Karsten, Hewitson, Martin et al., 2024, arXiv e-prints, arXiv:2402.07571 - ArXiv: 2402.07571

41. **Twisting tales: The emergent twist in filopodia dynamics and its role in cellular function**
Bendix, Poul M., Leijnse, Natascha, Barooji, Younes F. et al., 2024, Biophysical Journal, 123, 178a

42. **Modeling membrane neck formation during plasma membrane repair: Toward a mechanism for hole sealing**
Adam Cohen Simonsen, Martin Berg Klenow, Magnus Staal Vigsoe et al., 2024, Biophysical Journal, 123, 512a--513a

43. **Dissecting the stochastic gravitational wave background with astrometry**
Çalişkan, Mesut, Chen, Yifan, Dai, Liang et al., 2024, JCAP, 05, 030 - ArXiv: 2312.03069

44. **Eccentric binaries in retrograde discs**
Tiede, Christopher, D'Orazio, Daniel J., 2024, MNRAS, 527, 6021-6037 - ArXiv: 2307.03775

45. **Direct Formation of Massive Black Holes via Dynamical Collapse in Metal-enriched Merging Galaxies at z 10: Fully Cosmological Simulations**
Mayer, Lucio, Capelo, Pedro R., Zwick, Lorenz et al., 2024, ApJ, 961, 76 - ArXiv: 2304.02066

46. **Electrically charged black hole solutions in semiclassical gravity and dynamics of linear perturbations**
del Rio, Adrián, Ester, Evelyn-Andreea, 2024, Phys. Rev. D, 109, 105022 - ArXiv: 2401.08783

47. **Mesoscale simulation of biomembranes with FreeDTS**
Weria Pezeshkian, John H. Ipsen, 2024, Nature Communications, 15, 548

48. **Constraints on Neutrino Natal Kicks from Black-Hole Binary VFTS 243**
Vigna-Gómez, Alejandro et al. et al., 2024, Phys. Rev. Lett., 132, 191403 - ArXiv: 2310.01509

49. **Loop equations for generalised eigenvalue models**
Vescovi, Edoardo, Zarembo, Konstantin, 2024, SciPost Phys., 17, 017 - ArXiv: 2402.13835

50. **New limits on neutrino decay from high-energy astrophysical neutrinos**
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