

The Niels Bohr International Academy



Annual Report 2017



The Niels Bohr
International Academy

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NBIA Governance

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The Niels Bohr
International Academy

From the Director



At the British Association for the Advancement of Science in 1900 Lord Kelvin famously stated “There is nothing new to be discovered in physics now. All that remains is more and more precise measurement.” This was just before the discovery of the laws of quantum mechanics and the special and general theories of relativity. Of course, Lord Kelvin made numerous statements that are amusing to read with our advantage point of hindsight, including the equally spectacular “I can state flatly that heavier-than-air flying machines are impossible” from 1895. But the feeling that humankind will run out of new things to discover can descend the best of minds. In 1981 Stephen Hawking wrote a paper with the title “Is the End in Sight for Theoretical Physics?” In it, Hawking found it likely that “we might have a complete, consistent and unified theory of the physical interactions which would describe all possible interactions” before the year 2000. Fortunately (or

unfortunately?), also this prediction was a bit off the mark. In fact, physics keeps peeling off layers upon layers, always finding surprises. Fundamental science does not seem to ever stop moving forward. It just always looks difficult to see where the new discoveries or important new ideas are likely to be.

At the NBIA, scientists face the challenge every day. Progress can seem slow on a day-by-day basis. But when we look back, as we now do, at the year 2017, highlights are evident. In this report, you can read about the most important contributions, as seen by the NBIA scientists themselves. Topics range from fundamentals of quantum mechanics as explored in the growing area of quantum information theory to new understanding of how planets form and develop stable orbits around stars. From the complex higher-order scattering amplitude calculations relevant for theoretical particle physics to the understanding of novel condensed matter materials. And from neutrinos measured at the IceCube detector at the South Pole to exploding supernovae. Apart from the research of the in-house NBIA scientists, the NBIA visitor program plays an important role in defining the heart and soul of the institution. The Simons Program is a most important contributor to this, and in 2017 allowed us to set up scientific programs around the two Simons Visiting Professors Steve Simon and Itamar Procaccia. A number of visitors pass by the NBIA every week, giving seminars, and discussing and collaborating with local scientists.

We could not function without generous support from a number of funding agencies and private foundations. In 2017 NBIA Assistant Professor Jacob Bourjaily received a Villum Young Investigator Grant from the Villum Foundation and later the same year an ERC Starting Grant from the European Union. NBIA Associate Professor Michael Trott received a grant from Independent Research Fund Denmark. NBIA post-docs Pablo Benitez-Llambay and Mohamed Rameez received post-doctoral Fellowships from the European Union and the Carlsberg Foundation, respectively.

Poul Henrik Damgaard

2017

From the Chairman of the Board

In the spring of 1963, I had to decide whether I would enrol for a PhD in physics or chemistry. Although hindsight suggests that the answer was obvious, I asked a number of senior scientists for advice. With his 2+ Nobel Prizes, Linus Pauling was an excellent person to consult. After offering me a vitamin C tablet from a cut glass bowl on his desk and assuring me that it could do no harm, he described the start of his own daily routine: We would begin every day of the week by writing down ten new ideas before breakfast. Immediately after breakfast, he would review the ten ideas he had precisely one week earlier and discard most of them. Every day. My surprise must have been obvious. Pauling gently reminded me that practice is the best way to improve any skill. Since “having ideas” is a prerequisite for “having great ideas”, he practiced having ideas every day. What evidently worked for Linus Pauling would never have worked for me. Like everyone else, I



had to find my own style. The fact is that successful scientists all acquire the skill of asking the right questions and develop strategies for finding their answers. While this activity is strictly extracurricular and there are no relevant courses to take, there are ways to make the task easier. Young scientists should be encouraged to interact with senior colleagues who have already demonstrated their ability to make original and significant accomplishments. The goal is not to copy the interests or strategies of others but rather to respond by adapting them and, ultimately, forming a personal view of their own science and its practice.

In my view, the development of young scientists is probably the most important task of the NBIA. Post-doctoral fellows are selected with extreme care regarding scientific quality. While they will frequently contribute to pre-existing NBIA programs, they are not bound to work on specific projects. Indeed, we expect that they will have the professional maturity and the curiosity that will lead them and the NBIA in new and exciting directions. The truly remarkable success of young NBIA scientists in attracting external funding for projects of their own design suggests that this expectation is being fulfilled. Our “open door” policy, frequent seminars and colloquia, Friday N-talks, and daily afternoon tea all serve to encourage informal and spontaneous interactions between NBIA members of all ages. There is ample opportunity to see how others do physics and to construct a personal style of one’s own. While Linus Pauling’s vitamin C tablets are optional, new ideas every day are strongly recommended.

Andrew Jackson

2017



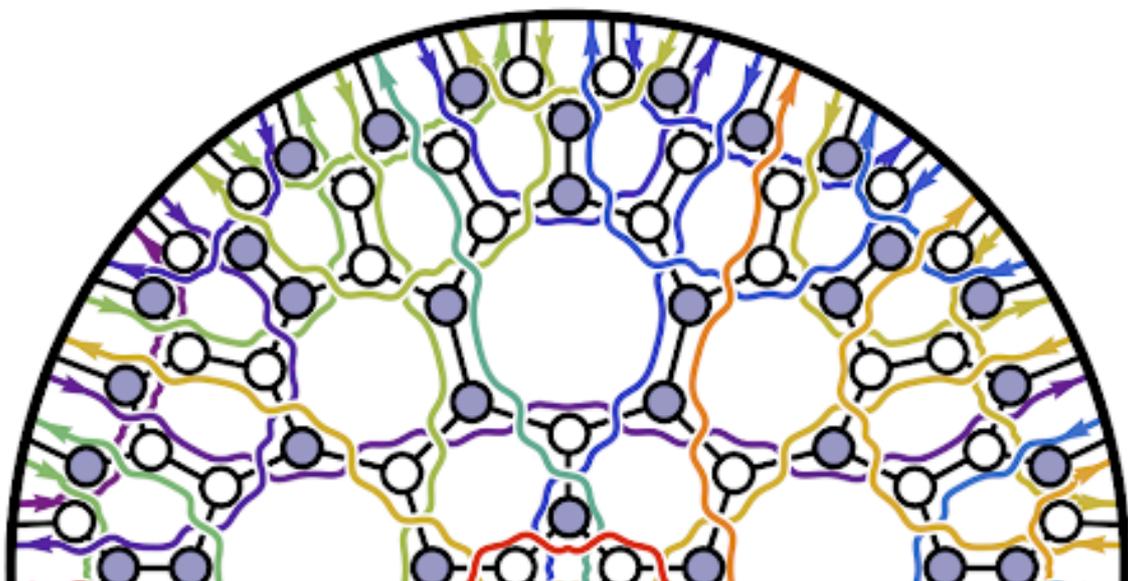
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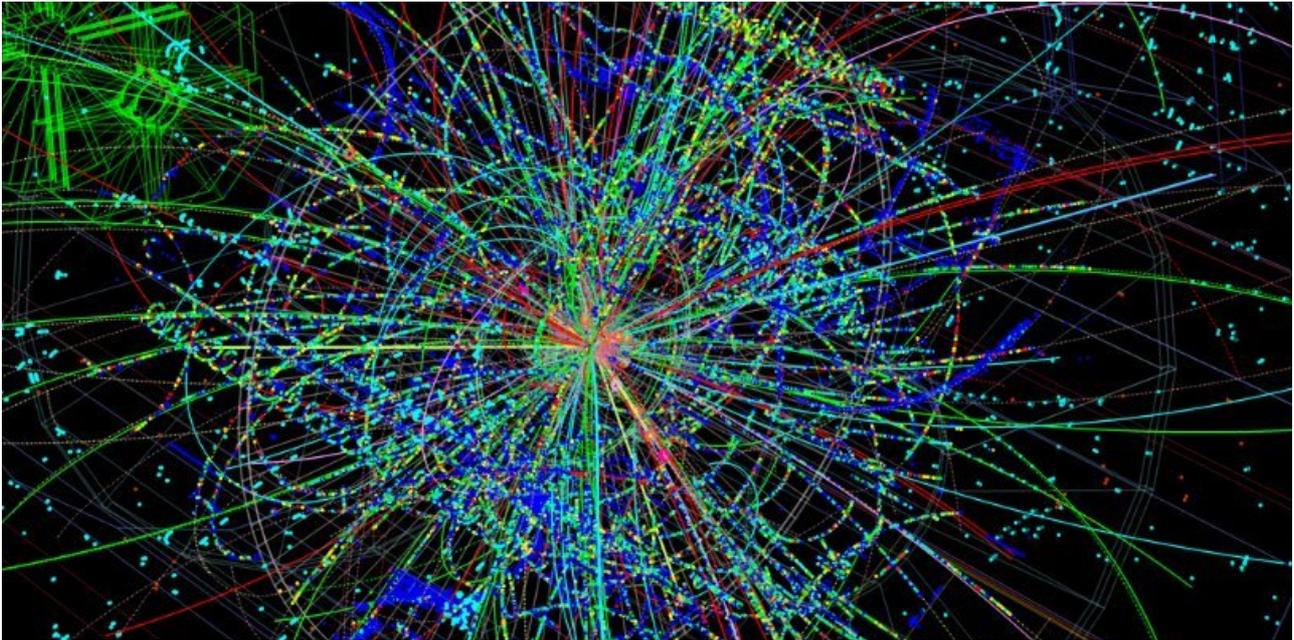
NBIA Research

Theoretical Particle Physics

A common theme of the theoretical particle physics group is the evaluation of scattering amplitudes. They are needed for the understanding of data from the Large Hadron Collider (LHC) at CERN, they are at the core of relativistic quantum field theory, and in recent years there has been a surge in new methods for computing them.

Those scattering amplitudes that have been most urgently needed for experiments are based on the so-called Standard Model of particle physics, a gauge theory with gauge bosons, fermions, and a single scalar particle, the Higgs particle. Most prominent scattering processes relevant for the LHC are known up to third order in perturbation theory, corresponding to what is known in the field as two-loop order. Current efforts of the particle theory group consist in extending this in several directions. First, it is widely believed that what is today called the Standard Model of particle physics is only a small part of the full story, valid at the energies accessible today at the LHC. At higher energies new interactions are almost certain to emerge, hidden today by the large amount of energy required to see even small traces of these new interactions. Part of the group at the NBIA is leading the effort to establish the most general framework for parametrizing the effects of interactions at higher energies. Known as Standard Model Effective Field Theory, it uses the sophisticated language of effective field theory to concisely pinpoint experimental consequences of the hidden interactions at higher energies, given the known particle content and symmetries of the Standard Model at the energies currently probed at the LHC. On the theoretical side there is no escape from the fact that the Standard Model of particle physics then becomes augmented by a large number of new interaction terms. But order-by-order, in an ordering dictated by available energy, the number of new terms is finite and they can be treated by the conventional tools of quantum field theory. Crucial to this program is the computation of the contribution of these new terms to the already established scattering amplitudes of the Standard Model alone. The group at the NBIA laid out this program in a long review in 2017 and simultaneously pursued avenues for testing the whole framework through comparison to new data. A publicly available computer code named SMEFTsim allows for such comparisons to new data from the LHC. This code is being adopted systematically by the LHC experimental collaborations.





Work in 2017 also included a novel way of understanding the so-called Higgs mechanism, that is: establishing the scale that provides masses to all known elementary particles, by linking it to the as yet unknown mechanism that produces tiny masses to neutrinos. Dubbed the Neutrino Option, this method promises to unite these two different puzzles of the Standard Model of particle physics.

A major direction of research in the particle physics group at the NBIA concerns the efficient computation of scattering amplitudes in quantum field theories in general. The immediate impact of this program is the availability of new methods that allow other groups to compute scattering amplitudes in the Standard Model to yet higher order. Moreover, the general development in just these years shows that the original methods for such computations (based on so-called Feynman diagrams) have become completely replaced by modern techniques that have allowed computations up to complexities that just a few years ago were thought impossible. This concerns both the number of particles in the final states of the processes, and the order in perturbation theory for a given fixed number of particles in the final states. The latter problem, the computation of scattering amplitudes at what is known as high loop order is generically a daunting task. Much progress appears through first understanding the complexities in a theory similar to the Standard Model of particle physics, but with a large amount of a hypothetical symmetry known as supersymmetry. The group at the NBIA has been very actively pursuing this program of high loop order calculations, moving from first establishing very compact expressions for the functions that need to be integrated, to studying the functions that appear after integrations. Many surprises have appeared already in the theory with large amount of supersymmetry, surely to leave their marks also on high loop-order calculations in the Standard Model of particle physics, without supersymmetry.

A new area of interest to the particle physics group at the NBIA has been the use of methods from theoretical particle physics to the evaluation of physical observables in general relativity, both at the classical level, and at the quantum level where gravity is treated in the sense of effective field theory. Here the two different avenues described above fuse together, and both effective field theory and new and efficient amplitude computations are needed in order to understand the subtle and small effects of higher order perturbation theory in both classical and quantum gravity.

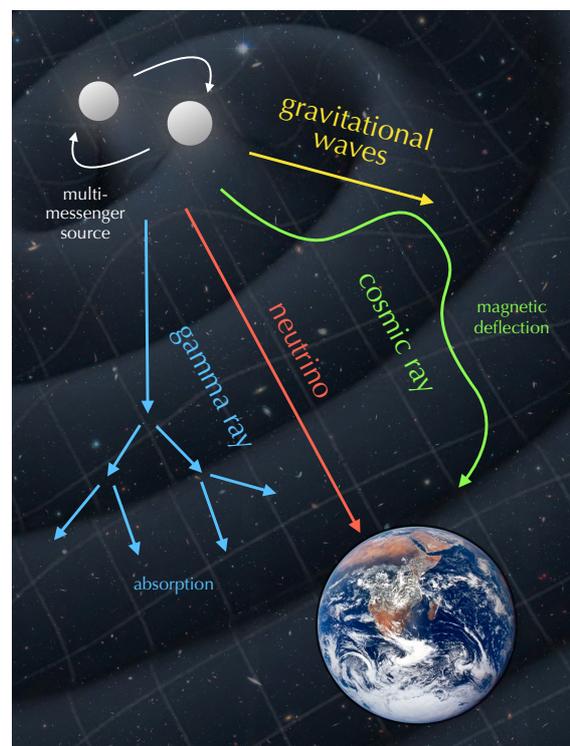
Astroparticle Physics & Cosmology

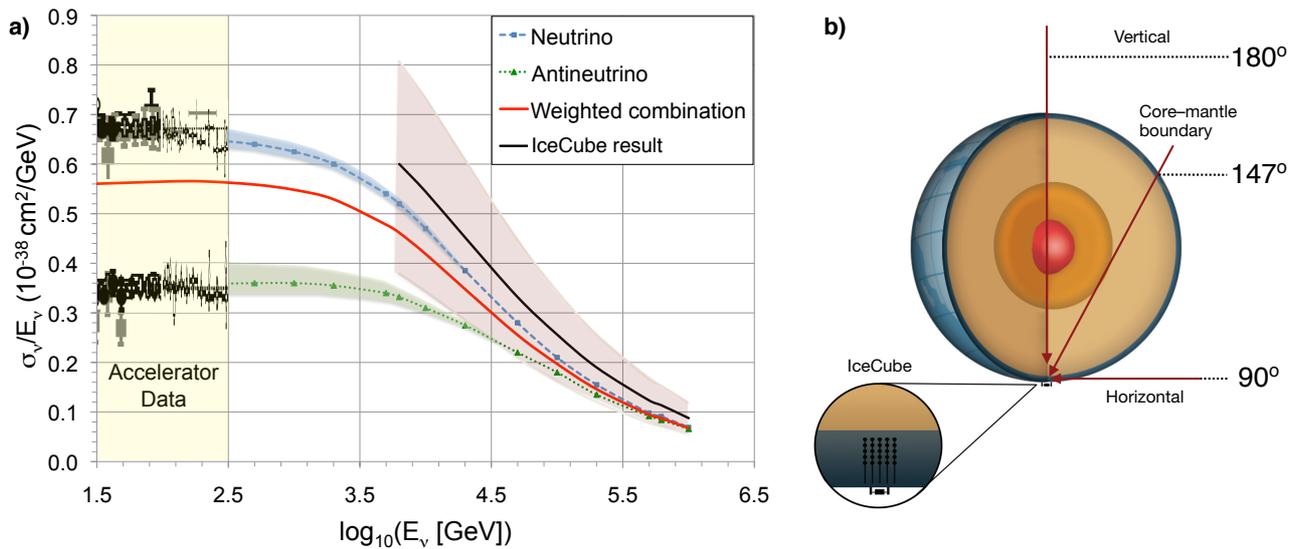
The interface between astrophysics, cosmology and fundamental physics has become very interesting in recent years. The wealth of data from various instruments observing photons, cosmic rays, neutrinos and gravitational waves allows the study of the Universe as a whole, as well as individual astrophysical phenomena. These ‘multi-messenger’ observations also address fundamental questions: what is the nature of dark matter and dark energy? what is the physical mechanism behind primordial inflation? how was the baryon asymmetry of the universe created? what are the astrophysical sources of high energy particles and their acceleration mechanisms? The Astroparticle Physics Group at NBI tackles such complex interconnected issues with new theoretical ideas, as well as a concerted observational programme.

In particular we work closely with the IceCube group in the NBI Discovery Centre. The IceCube observatory buried under the South Pole is the world’s most sensitive neutrino telescope and in 2013 made the first observation of cosmic neutrinos in the TeV-PeV energy range. Their origin is however still unknown. In 2017 we extended the search for muon neutrinos coincident with γ -ray bursts in IceCube data, and set a restrictive bound on the contribution to the diffuse flux from blazars. We did an all-sky search using all seven years of IceCube data for time-integrated neutrino emission from astrophysical sources, and also searched for such sources using ‘cascade’ events. Members of our Group are working on theoretical models and statistical methods to identify the as yet unknown neutrino source populations.

On another tack we carried out a multi-wavelength follow-up of a rare IceCube neutrino multiplet (three neutrino candidates arriving within 100 s) but found no associated electromagnetic signal. 2017 was nevertheless an exciting year for multi-messenger astronomy. At 14.41 CET on 17 August, the LIGO collaboration made the first observation of gravitational waves from a binary neutron star merger. The post-merger debris was observed in electromagnetic emission from optical through X-ray to γ -rays. IceCube too was part of the extended campaign searching for neutrino emission. Although no neutrinos were observed from GW170817, this too was an interesting result and we shared in the Science/Physics World “2017 Breakthrough of the Year” award marking the birth of multi-messenger astronomy.

The scientific program carried out with IceCube is diverse and goes well beyond neutrino astronomy. In 2017 we continued the search for high energy neutrino signals of dark matter annihilation in the Earth and in the Sun. We determined the parameters for neutrino oscillations with precision comparable to long baseline experiments using the DeepCore infill array and reviewed the physics prospects for its proposed PINGU extension. We extended the search for ‘sterile’ neutrinos, setting new exclusion limits. Non-standard neutrino interactions were constrained by using data from accelerator experiments.





A highlight was our measurement of the neutrino cross-section at very high energies with IceCube (Fig. a). This confirmed theoretical calculations by members of our Group of the expected cross-section in the Standard Model of particle physics. The measurements exploit the fact that neutrinos that ought to reach the IceCube detector from “below” (having passed through the Earth; Fig. b) are partly depleted due to their interactions with matter. Since the incident flux of neutrinos produced through cosmic ray interactions in the Earth’s atmosphere is isotropic, their observed zenith angle dependence is thus a direct measure of the interaction cross-section – at energies up to 1000 TeV (i.e. ~ 100 times higher than can be achieved at the Large Hadron Collider at CERN Geneva). Since the result is consistent with the expectation in the Standard Model, it puts stringent bounds on speculations about new physics beyond the Standard Model involving e.g. new compact dimensions and hypothetical particles called leptoquarks. Our result attracted wide interest because it demonstrates the power of a non-accelerator experiment, using a natural particle beam, to probe new fundamental physics. At still higher energies where the proposed extension IceCube-Gen2 is expected to detect the cosmogenic flux of neutrinos due to cosmic ray interactions with the cosmic microwave background, the neutrino cross-section is sensitive to the possible formation of a ‘colour glass condensate’ in quantum chromodynamics, so the result is eagerly awaited.

In work by group members on dark matter, a likelihood calculator (LikeDM) for dark matter detection was developed. It was argued that 3-body decaying dark matter may be responsible for the positron excess in cosmic rays observed by AMS-02 on the International Space Station.

Concerning the origin of cosmic radiation we discussed the capabilities of the Cherenkov Telescope Array to distinguish between leptonic and hadronic emission mechanisms for the γ -rays observed from the nearby supernova remnant RXJ1713.7-3946, and thereby establish whether it is indeed accelerating cosmic ray nuclei. The origin of small-scale anisotropies in the flux of Galactic cosmic rays was reviewed.

It was shown that the damping of gravitational waves from astrophysical sources by intervening matter is negligible, but Landau damping of primordial gravitational waves is indeed possible.

On the cosmological front, a careful analysis demonstrated that our velocity in the rest frame of radio galaxies at high redshift is four times higher than that inferred from the dipole anisotropy of the cosmic microwave background. With present radio catalogues the significance of this anomaly is only 2.81σ but if forthcoming observations by the Square Kilometer Array confirm this rather surprising finding then the standard model of cosmology will indeed need radical revision.

Neutrino Astrophysics

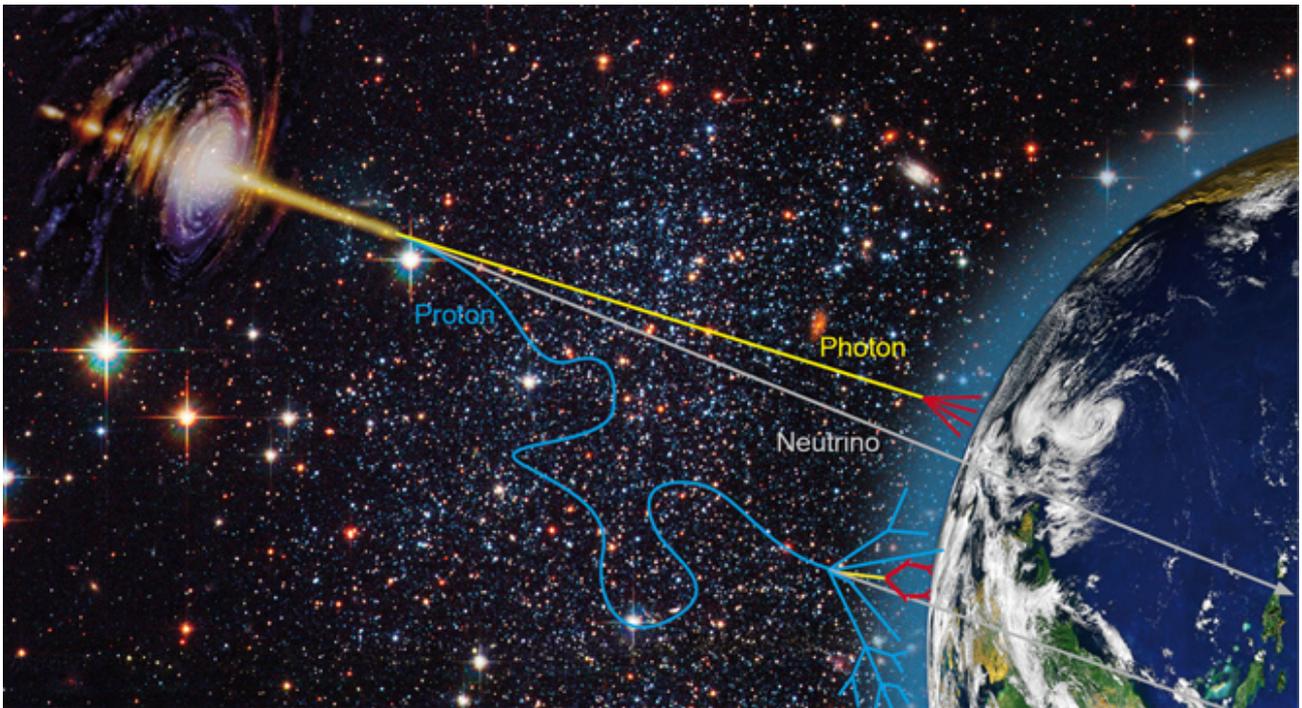
Neutrinos are the second most abundant particles in our Universe, after photons. Neutrinos are almost massless and interact only weakly. Three distinct species (“flavors”) of neutrinos exist, they oscillate (convert) into each other by flavor mixing. Neutrinos are copiously produced in various astrophysical environments, ranging from the Sun to the most extreme astrophysical transients.

The Neutrino Astrophysics (AstroNu) group at NBIA adopts neutrinos as messengers for exploring as yet poorly understood extreme astrophysical phenomena and, at the same time, investigates how neutrinos and their flavor conversions can affect the dynamics of these astrophysical phenomena. The AstroNu group is also interested in exploring what can be learnt on standard and non-standard neutrino properties through astrophysical sources and terrestrial experiments. In 2017, the interdisciplinary nature of the AstroNu research has been strengthened through a partnership with the Collaborative Research Center: Neutrinos and Dark Matter in Astro- and Particle Physics hosted by the Technical University of Munich and sponsored by the Deutsche Forschungsgemeinschaft.

One of the research directions pursued by the group in 2017 concerns the investigation of neutrino flavor conversions in neutrino-dense media such as core-collapse supernovae and neutron star mergers. Core collapse supernovae originate from the death of stars at least 8 times heavier than our Sun. The 99% of the energy released during the supernova explosion is carried by neutrinos. Neutrinos are thus crucial particles in the supernova mechanism. A core-collapse supernova may leave behind a neutron star. If two neutron stars happen to be close to each other, they start to orbit into each other until they merge (neutron-star merger). Similarly to supernovae, compact mergers are extremely rich in neutrinos. The role of neutrinos and flavor conversions in these environments although fundamental is still poorly understood.

An intriguing recently discovered phenomenon occurring in these environments concerns the fast pairwise neutrino conversions. Fast conversions are exclusively induced by the neutrino-neutrino interactions and their conversion rate is “fast” in the sense that it depends on the neutrino density instead than on the usual neutrino mixing parameters. Fast conversions may be especially dangerous as they may induce flavor equilibration (i.e., neutrinos of different flavors acquire the same spectral distribution) within scales of few cm and affect the supernova explosion as well as the dynamics of binary mergers. Our understanding of this phenomenon is extremely preliminary. In a Letter led by the AstroNu group, a novel approach to understand fast conversions has been proposed: a dispersion relation for the frequency and wave number of disturbances in the flavor field. This work changed the approach to investigate flavor oscillations in dense media by stressing the importance of the neutrino angular distributions, beyond their energy/spectral distribution. AstroNu has further investigated the specific shape of the angular distributions of neutrinos through hydrodynamical simulations of core-collapse supernova progenitors.





Neutrino flavor conversions in compact binary mergers are almost an uncharted territory given our poor understanding of mergers. Just before the discovery of gravitational waves from neutron star mergers in August 2017 (GW170817), the AstroNu group dedicated efforts to shed light on the impact of neutrinos in the physics of mergers. For the first time, we investigated whether fast conversions occur in compact binary mergers. In fact, fast conversions are even more likely to occur in compact mergers than in supernovae. By adopting inputs from hydrodynamical simulations of neutron star merger remnants, the AstroNu group found that neutrino conversions strongly affect the element production in compact binary mergers, strongly enhancing the production of lanthanides. Hence, the observation of the related kilonova (radioactively powered electromagnetic transient occurring in the aftermath of a compact binary merger) could be affected by neutrinos. Our findings are relevant in the context of the increasing sample of observed kilonova events and our understanding of the origin of the elements heavier than iron. Furthermore, the optical and near-infrared emission and the detection chances of kilonovae have also been explored by the AstroNu group.

Another research direction pursued by AstroNu at NBIA revolves around the flux of neutrinos with extremely high energy observed by the IceCube telescope, a neutrino detector deployed deep in the Antarctic ice. The origin of these neutrinos seems to be astrophysical, although their sources are still mysterious. The AstroNu group investigated the contribution coming from our Galaxy to the IceCube neutrino flux, concluding that this should be at most few percent. Hence, the origin of the observed neutrinos is mostly extragalactic.

The AstroNu group also developed the first one-point fluctuation analysis of the high-energy neutrino sky, showing that this statistical method is especially useful for the current low-statistic sample of high-energy neutrino data and it puts stringent limits on the components of the flux of high-energy neutrinos observed by IceCube. In order to quantify the detection prospects of high-energy neutrinos from astrophysical sources with existing and next generation neutrino telescopes, AstroNu also employed the matter anisotropies of the local universe as from astronomical catalogues and correlated them with clusters of neutrino events.

Theoretical Astrophysics

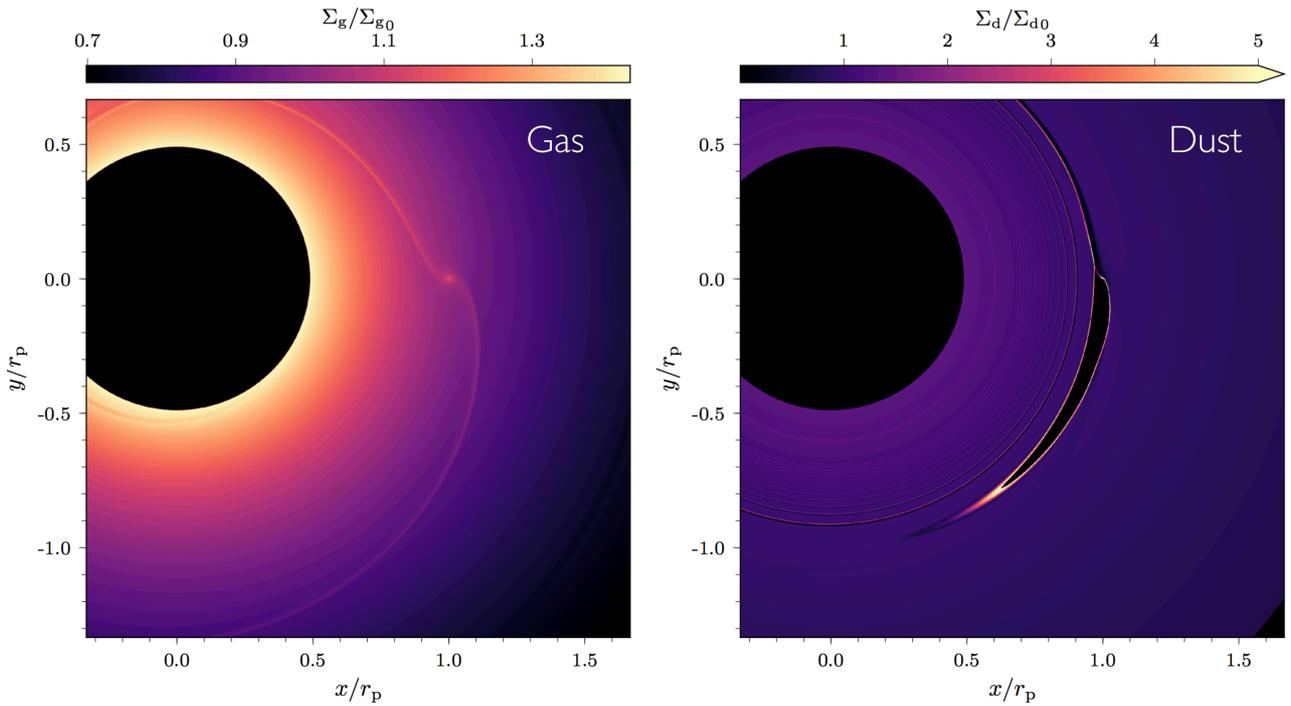
The members of the Theoretical Astrophysics Group at NBIA work on a wide variety of problems in astrophysical fluid dynamics and magnetohydrodynamics. Current areas of interest include accretion flows onto planets, stars, and black holes, as well as gas dynamics in the interstellar and intergalactic media. All of these problems are tackled with a very wide perspective, ranging from fundamental theoretical aspects to state-of-the-art simulations that make it possible to link theory with observations.

In the context of protoplanetary disks, we have continued the development of a comprehensive multi-fluid framework to study dust dynamics in protoplanetary disks, including gas-dust interaction via drag forces, which is crucial for obtaining the mutual distribution of gas and dust, providing more physically realistic environments to investigate planet formation. This framework is critical for investigating the dynamical interactions between nascent planets and the disks in which they form and evolve.

Young planets can interact dynamically with the disk within which they form and evolve carving up a gap in the gaseous disk. Dust particles, which are constantly drifting inwards due to drag, may be prevented from reaching the star in the presence of such a gap in the disk. Using state-of-the-art codes developed at NBIA, we carried out a systematic study employing long-term, multifluid hydrodynamical simulations in two dimensions aimed at characterizing the critical size for dusty particles to be retained outside a gap as a function of particle size, and various key parameters defining the protoplanetary disk model. We found that the permeability of the gap depends both on dust dynamical properties and the gas disk structure: while small dust follows the viscously accreting gas through the gap, dust grains approaching a critical size are progressively filtered out. Our results indicate that gap-opening planets may act to deplete the inner reaches of protoplanetary disks of large dust grains—potentially limiting the accretion of solids onto forming terrestrial planets.

The previous project set the theoretical foundations and numerical framework for a follow-up work involving several members of the Center for Star and Planet Formation at the Natural History Museum of Denmark to investigate the efficacy of the gas giants, Jupiter and Saturn, to act as dust traps for different dust particle sizes as a function of the physical conditions in the protosolar disk. The outcome of these simulations was compared to cosmochemical data. The combination of state-of-the-art numerical models and laboratory data gives new insight into the architecture of the young Solar System. By comparing the size distribution and relative mass abundance of calcium-aluminum rich inclusions in ordinary chondrites to that in outer Solar System CV chondrites we can also estimate the ratio of dust mass in the protosolar disk inside and outside of Jupiter.

In a parallel development, we also carried out the first study addressing the dynamical role of dust in the migration history of planetary embryos. By analyzing a large suite of multifluid hydrodynamical simulations addressing the interaction between the disk and a low-mass planet on a fixed circular orbit, we demonstrated that dust-induced torques can halt, or even revert, inward planetary migration. This realization has the potential to solve the long-standing problem of fast inward migration, perhaps in the simplest possible way. Our results will enable the incorporation of the effect of dust dynamics on migration into population synthesis models. We anticipate that dust-driven migration could play a dominant role during the formation history of planets and that our findings will have a profound impact on future works on planet formation and evolution.



The physical conditions in protoplanetary disks imply that the gas is only partially ionized and thus the standard ideal magnetohydrodynamic approach needs to be relaxed in order to incorporate non-ideal effects. In 2017, we performed the very first global cylindrical simulations of a protoplanetary disk including the Hall effect, Ohmic diffusion and dust dynamics considering gas/dust drag. We studied the possibility for dust to be trapped in regions with strong concentration of magnetic flux. These regions are induced by a strong and dominant Hall effect which is capable of organizing a turbulent magnetic field by generating large-scale axisymmetric zonal flows. Over these zonal flows the plasma velocity turns super-Keplerian and becomes an efficient dust trap for different Stokes numbers. Our study has the potential to help us understand recent observations with the Atacama Large Millimeter Array, which have revealed the presence of large scale structures in the dust distribution in a number of nearby protoplanetary disks. Throughout the year, we continued working on coupling the numerical codes used to model protoplanetary disks with a sophisticated software pipeline for post-processing in order to include the effects of chemistry, molecular excitation, and radiative transfer. Taken in concert, our work is a crucial step forward for interpreting observations of thermal dust emission in the sub-mm band in order to better understand the processes that lead to planet formation and evolution in protoplanetary disks.

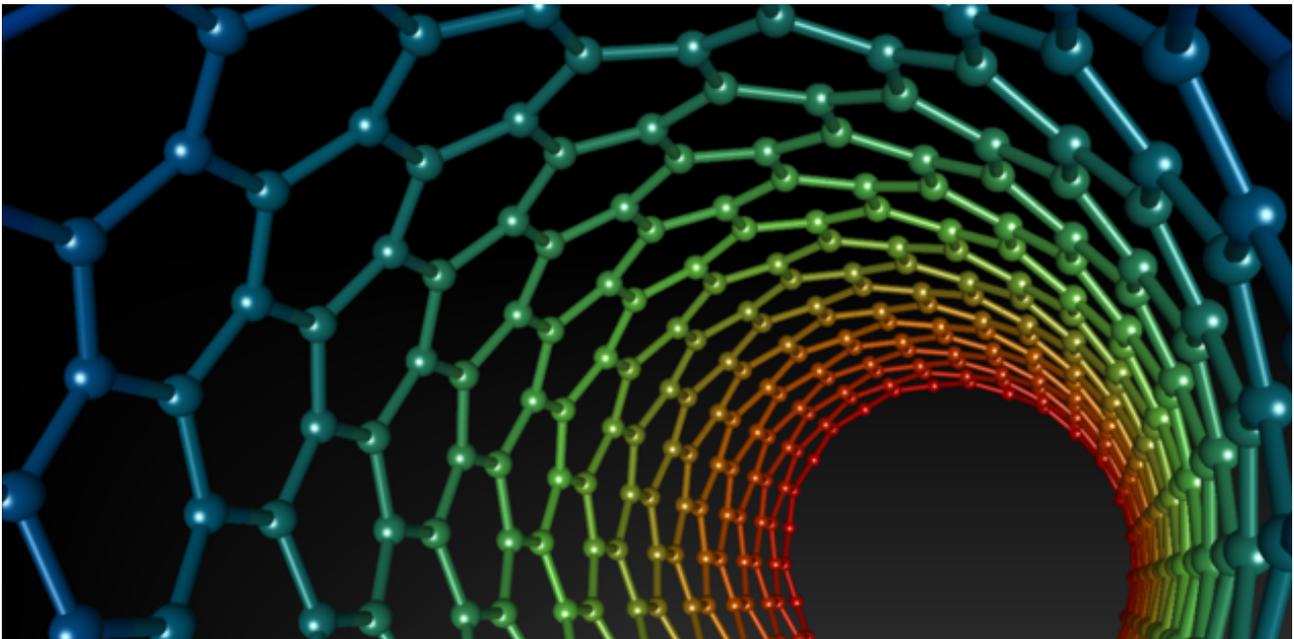
In addition to these important developments concerning protoplanetary disks, group members also worked on several important problems in astrophysical fluid dynamics. We investigated the formation and evolution of circumplanetary disks using radiation hydrodynamic simulations to understand how the gas thermodynamics can influence the dynamical flow of the gas toward the vicinity of the planet. This process may be critical for determining the final mass and possibly the surface temperature of gas giants. We generalized previous treatments to calculate the thermal structure of an irradiated, non-gray exoplanetary atmosphere to include the effects of scattering. The model we derived can accommodate for a wider set of physical effects than previous models and may be used to derive more realistic estimates for the thermal structure of irradiated exoplanetary atmospheres. We investigated the stability of test-particle equilibrium orbits in axisymmetric, but otherwise arbitrary, gravitational and electromagnetic fields. We extended previous studies of this problem to include a toroidal magnetic field. We investigated the implications of our findings for the dynamical stability of dust grains in planetary magnetospheres. In the context of accretion onto black holes, we investigated long-standing questions concerning the dynamical evolution of global magnetic fields in turbulent accretion disks.

Condensed Matter Physics

In the condensed matter theory group at NBIA we aim to discover new quantum dynamical phenomena and phases of matter. Our work spans a wide range of areas, from solid state nano- and mesoscopic systems and quantum bits, to hybrid and bulk topological materials, cold atom systems, and more general aspects of quantum many-body dynamics. We maintain close ties with experimentalists at the Center for Quantum Devices and Microsoft Station Q Copenhagen.

In the realm of quantum dynamics, we are field leaders in the area of topological phenomena in periodically driven, or “Floquet” systems. Topological phenomena have become the subject of intense interest in recent years due to their incredible robustness against perturbations. A shining example of such behavior is the quantized Hall effect — when a two-dimensional electron system (as found in common semiconductor heterostructure devices, or graphene) is subjected to a strong magnetic field, the system's Hall conductance takes on a precisely quantized value, which is equal to an integer or simple rational fraction times a combination of fundamental constants (the electron charge and Planck's constant). What is so amazing about this phenomenon is that the quantization of this macroscopically measurable quantity is accurate to better than one part in ten billion, independent of sample size and shape, as well as material composition, and survives in the presence of all of the “dirt” that inevitably permeates real-world solid state systems. Due to the exquisite precision of this effect, the quantized Hall conductance is now used as a measurement standard for the definition of resistance.

From a fundamental point of view, the robustness of the quantized Hall effect arises from a beautiful mathematical (topological) structure of the quantum mechanical wave function of the electrons in the system. This theoretical realization spurred a worldwide effort to seek out additional types of robust phenomena that could support a similar level of “topological protection”. Such effects have, for example, even been proposed as forming the basis for an extremely powerful and fault-tolerant architecture for quantum computing. Seeking means to realize the quantum states necessary for building such a topological quantum computer is one piece of our research in condensed matter theory at NBIA.





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

In the 21st century, cold atomic gases have emerged as one of the most versatile, well-controlled, and cleanest platforms for studying quantum many-body phenomena. Within the condensed matter theory group at NBIA we are actively studying the dynamics of such systems, developing proposals for realizing exotic phases in neutral atoms. One particularly intriguing direction that we are exploring is the use of internal states of the atoms as “synthetic” dimensions: in a gas comprised of atoms with several internal states, transitions between these states can be viewed as hops between sites of a lattice. As an example, using the synthetic dimension paradigm, we used a model of a one dimensional chain of multilevel atoms to study the physics of quantum Hall states (which naturally exist in two-dimensional systems). By applying powerful analytical and numerical techniques developed for one dimensional systems to this problem, we were able to uncover the topological edge state properties of the $\nu = 1/2$ quantum Hall state in a “ladder”-type geometry.

Finally, at NBIA we are pioneering the investigation of novel collective modes of topological and hybrid materials. This work is both of fundamental interest, and may lead to applications. For example, we discovered a chiral plasmonic mode that can arise in magnetic or optically-excited materials, in the absence of an applied magnetic field. This effect could one day form the basis for magnetic field free on-chip non-reciprocal electronic and optoelectronic devices. Inspired by the recent revolution in the fabrication of two-dimensional hybrid materials, we are exploring a variety of other new collective phenomena that emerge from the intriguing combinations of material properties (such as superconductivity, magnetism, and nontrivial band topology) that can now be brought together.

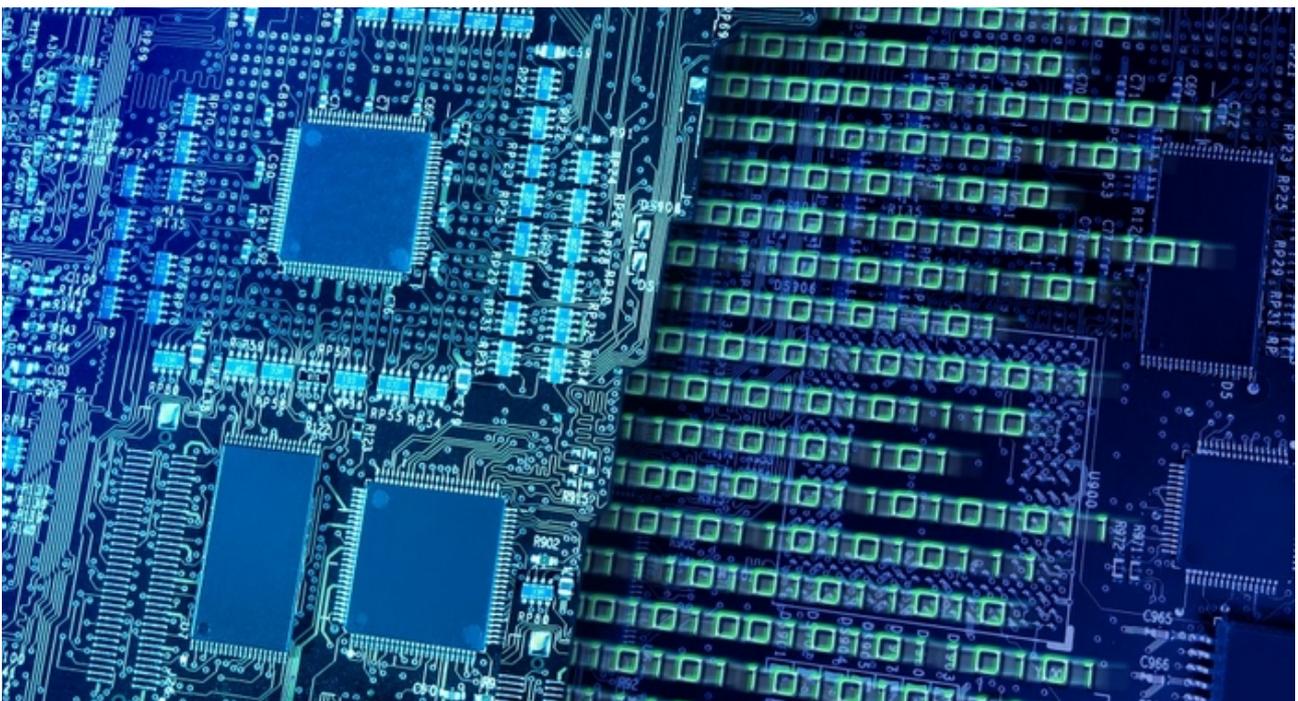
Quantum Information Theory

Quantum information science is a highly interdisciplinary field with two important goals: (a) to provide decisive conceptual insight for solving important problems in many body physics, condensed matter and recently high energy physics, and (b) to develop the necessary scientific foundation for emerging quantum technologies, including quantum computing, quantum communications and quantum cryptography.

Recently, Copenhagen has positioned itself as a world leader in quantum information sciences with the world class research centers of excellence in quantum plasmonics (BigQ), quantum photonics (Hy-Q), quantum mathematics (QMATH) and quantum devices (QDev). Furthermore, industrial efforts at launching the quantum revolution have also reached the city, with Microsoft station Q Copenhagen leading the way. The quantum information group at the NBIA forms an important node in the quantum information network in Copenhagen.

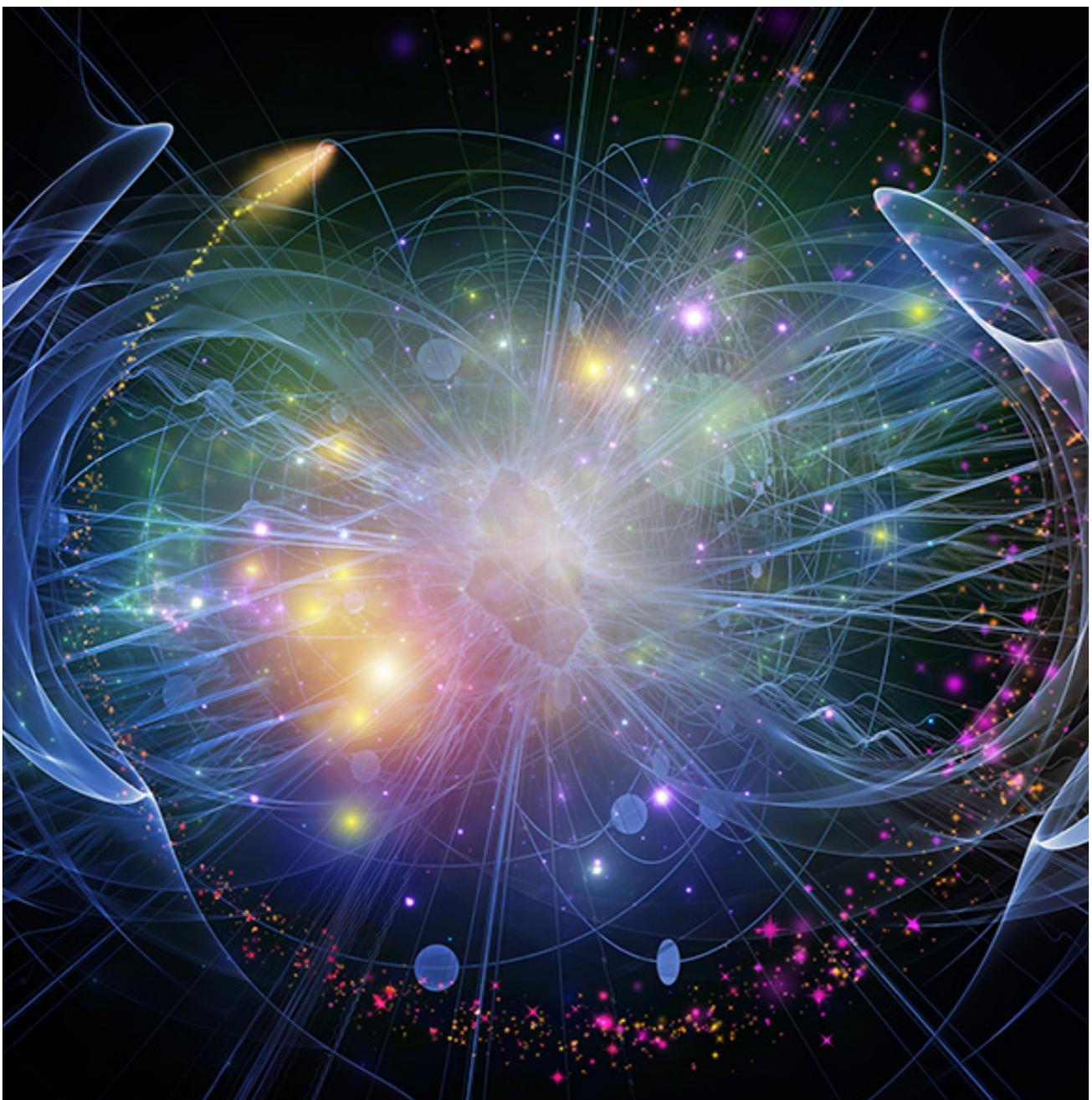
The NBIA quantum information group works on a number of conceptual and practical problems in quantum information sciences, with main focuses in quantum many body theory, quantum error correction and mathematical physics. Some noteworthy accomplishments include (i) models of holography using tensor networks, (ii) quantum error correction and fault tolerance, and (iii) quantum machine learning.

(i) The principle of Holography loosely prescribes that there is a correspondence between the physics in the bulk of a system and the 'holographic' image at the boundary. In the context of high energy physics this correspondence manifests itself in the form of the celebrated AdS/CFT correspondence, while in condensed matter systems, it takes the form of a bulk-boundary correspondence of topological order. In a series of projects, we have explored the holographic correspondence using the tools of tensor networks. In particular, we describe a one dimensional (critical) CFT by a MERA network. We show that the MERA network naturally defines an encoding circuit for an approximate error correcting code, thus



(ii) We have worked on a number of projects in fault tolerance research including a new protocol for performing fault tolerant gates in the Toric code by braiding corners and fault lines. These braiding operations can be seen as a spin analogue of Majorana braiding, hence connecting two apparently unrelated notions of topology. We have also introduced a new framework for approximate quantum error correction which allows for making robust statements of error preservation, and for expressing the actual limits of information storage in many body systems. Finally, we have introduced new statistical mechanical models to explore the low error rate behavior of quantum error correcting codes, revealing that entropic effects are very important close to threshold.

(iii) A new direction that the group has embarked on is to explore the new intersection between machine learning and quantum information. In particular, we show how certain constructions originally intended to describe many body systems allow for new insight in explaining how and why deep learning algorithms perform so well.





Faculty



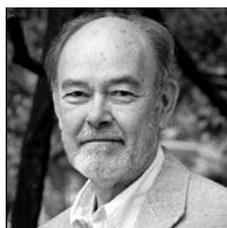
Niels Emil J. Bjerrum-Bohr completed his Ph.D. in Copenhagen in 2004. He was postdoc in Swansea 2004 - 2006, concentrating his research on amplitudes for gauge theories and quantum gravity. He was a Member at the Institute for Advanced Study in Princeton 2006-09. Emil was appointed Knud Højgaard Assistant Professor at the NBIA in 2010, at the same time being awarded a Steno grant from the Danish Science Research Council. He was appointed Associate Professor in 2016. He is currently a Lundbeck Foundation Junior Group Leader and Associate Professor at the NBIA. Emil's current research focuses on amplitudes in Yang-Mills theory and quantum gravity.



Matthias Christandl is a Professor at the Department of Mathematical Sciences in Copenhagen. His research is in the area of Quantum Information Theory. It is his aim to improve our understanding of the ultimate limits of computation and communication given by quantum theory. Concrete research results include a proposal for a perfect quantum wire and a new method for the detection of entanglement. Matthias received his PhD from the University of Cambridge in 2006. He then became a Thomas Nevile Research Fellow at Magdalene College Cambridge. In 2008, he joined the faculty of the University of Munich and 2010-14 he was assistant professor at ETH Zurich. He moved to the University of Copenhagen in April 2014.



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 so-called electroweak baryogenesis from the Large Hadron Collider (LHC).



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



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. Marcus' research interests involve fabrication and low-temperature measurement of quantum coherent electronics in semiconductors and superconductors, including nanowires, quantum dots, quantum Hall systems, and Josephson devices. Current activities include the realization of spin qubits for quantum information processing and topological quantum information schemes based Majorana modes in nanowires and $5/2$ fractional quantum Hall systems.



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



Pavel Naselsky did his undergraduate studies at the Southern Federal University of Russia and received his PhD in 1979 at Tartu University. In 1989 he got Doctor Habilitation at Moscow

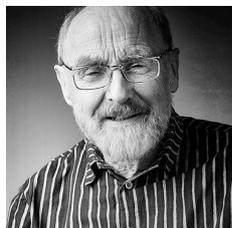
State University, Russia, working with theoretical astrophysics group of Zeldovich. In 2000 Pavel Naselsky took up a position as Associate Professor at the Theoretical Astrophysics Center (Copenhagen, Denmark) and at 2003 he was appointed as Lecturer at the Niels Bohr Institute. He has been Professor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



Martin Pessah obtained his first degree in Astronomy in 2000 from the University of La Plata, Argentina. He received his PhD in Theoretical Astrophysics from the University of Arizona in

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

Faculty



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



Mark Rudner is an Associate Professor at the NBIA. Mark received his PhD in Condensed Matter Theory from MIT in 2008. After his PhD, Mark spent three years as a postdoc at Harvard. In 2012 Mark landed in Copenhagen to take charge of the Condensed Matter Theory group at the NBIA. Currently Mark's group is enjoying the generous support of the Villum Foundation through the Young Investigator Award Program. He and his group is further supported by an ERC Starting Grant from the EU. Mark's research spans a broad range of topics in quantum dynamics and many-body physics. Current topics of interest include coherence and control in solid state qubits, nonlinear dynamics of

many-body spin systems, topology and dynamics in strongly driven systems, and semiclassical dynamics of electrons in topological materials. The condensed matter theory group at NBIA maintains strong links with the Center for Quantum Devices, with a healthy interplay between theory and experiment.



Subir Sarkar is Niels Bohr Professor at NBIA since 2013 and Head of the Particle Theory Group at the University of Oxford. He was educated in India, obtaining Bachelors & Masters degrees in physics at the Indian Institute of Technology, Kharagpur. He did both experimental and theoretical work on cosmic rays at the Tata Institute of Fundamental Research, Bombay and was awarded a PhD in 1982. Subsequently he held positions at Oxford, SISSA, CERN and Rutherford Laboratory and worked for a year in science education & outreach in Bhopal. He returned to Oxford in 1990 where he was appointed Lecturer in 1998 and Professor in 2006. He now divides his time between Oxford and Copenhagen where he has been building up an Astroparticle Physics Group with the support of the Danish National Research Foundation. Subir's interests are at the interface between fundamental physics, astrophysics and cosmology and he participates in the IceCube experiment at the South Pole. In 2017 he was awarded the IUPAP-TIFR Homi Bhabha medal & prize.



Jan Philip Solovej did his undergraduate studies in Copenhagen and his Phd in mathematics at Princeton University in 1989. He was then a postdoc at University of Michigan, University of

Toronto, and IAS Princeton before taking up an assistant professorship at Princeton University 1991-1995. In 1995 he became a research professor at Aarhus University and in 1997 he became a full professor at the mathematics department of the University of Copenhagen. He works in mathematical physics and in particular quantum physics. His current research interests include systems such as atoms, molecules, and gases of fermions, and bosons. His research addresses issues such as stability of matter, superconductivity and -fluidity, and quantum information theory. He currently leads the Centre for the Mathematics of Quantum Theory (QMATH) in the Department for Mathematical Sciences.



Irene Tamborra is Knud Højgaard Associate Professor at the NBIA since 2016. Irene completed her Ph.D. at the University of Bari in 2011. Irene has held research appointments at the

Max Planck for Physics in Munich, as Alexander von Humboldt Fellow, and at GRAPPA Center of Excellence of the University of Amsterdam. Irene's research activity is in the area of theoretical particle astrophysics. Irene is interested in exploring the role of weakly interacting particles, such as active and sterile neutrinos, in astrophysical environments. She also aims at unveiling what can be learnt from the observation of neutrinos from the most extreme but yet mysterious astrophysical transients occurring in our Universe, such as core-collapse supernovae, neutron star mergers and gamma-ray bursts. Thanks to generous support from the Villum Foundation, Irene leads the AstroNu research group at the NBIA with focus on these subjects.



Junior Faculty



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



Christian Brinch joined the NBIA as Assistant Professor in August 2016. Brinch received his Ph.D. in astronomy from Leiden University in 2008. After two postdoctoral appointments at the university of Bonn and at Leiden university, he moved to the Niels Bohr Institute in 2011. Brinch's research is focused on understanding the formation and evolution of young stellar objects and protoplanetary disks. Dealing both with observations in sub-millimeter wavelengths and numerical simulations of star formation, Brinch's main contribution has been the development of a unique molecular excitation and radiative transfer code which is used to post-process simulations in order to make direct comparison between models and observations. Brinch

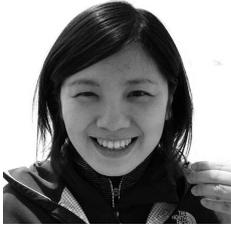
is currently working on extending this to models of planet formation in order to make predictions about, and potentially be able to detect, embedded protoplanets during their formation.



Paolo Benincasa joined the NBIA as Assistant Professor in 2016. He received his PhD in statistical physics from SISSA (Trieste) in 2011 and then he worked as a postdoc in Leiden University (2011-13) and in the Max Planck Institute for Quantum Optics (2013-16). His main research focus is the study of topological phases of matter, their engineering and the possibility they offer for quantum computation. He works on different quantum many-body systems, ranging from ultracold atoms to topological superconductors and he is interested in the common theoretical framework underlying these diverse systems.



Michele Burrello joined the NBIA as Assistant Professor in 2016. He received his PhD in statistical physics from SISSA (Trieste) in 2011 and then he worked as a postdoc in Leiden University (2011-13) and in the Max Planck Institute for Quantum Optics (2013-16). His main research focus is the study of topological phases of matter, their engineering and the possibility they offer for quantum computation. He works on different quantum many-body systems, ranging from ultracold atoms to topological superconductors and he is interested in the common theoretical framework underlying these diverse systems.



Jane Dai received her PhD in Physics at Stanford University in 2012. Before joining NBIA as an assistant professor in 2017, she was a joint postdoctoral fellow at Yale and the University of Chile, and later a research associate at the University of Maryland. Her research interest is mainly in theoretical astrophysics with focus on black hole accretion and jet physics, physics of transients, as well as general relativistic simulations related to physics near black holes.



Oliver Gressel joined NBIA as an Assistant Professor in 2013. He received his Ph.D from Potsdam University in 2009, and was a postdoc at the University of London 2009-2011. In 2012, he held a Nordic Fellowship at Nordita in Stockholm to work on mean-field magnetohydrodynamics and dynamo theory. He was awarded a MOBILEX grant in 2013 to study accretion disk turbulence. He received an ERC Starting Grant in 2014, which has allowed him to build his own research group at the NBIA. Oliver's current research is centered around astrophysical turbulence and magnetohydrodynamics, with special emphasis on dynamo theory. Applications included the modelling of the turbulent interstellar medium, the large-scale galactic dynamo, and magnetic turbulence in protoplanetary accretion discs, including its influence on the formation of planets.



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



Michael Kastoryano joined NBIA in 2014 as a Carlsberg Postdoctoral fellow and as a Villum Young Investigator. Michael earned his MSc in Physics at Yale University in 2008, and his PhD in Quantum Information Theory at the Niels Bohr Institute in 2011. Before joining NBIA he was a Humboldt fellow at the Dahlem Center at the Freie University Berlin. His arrival at the NBIA coincided with an upswing in activity in theoretical quantum information sciences at the university of Copenhagen. Michael has been building a quantum information group at the NBIA as part of a larger operation to make Copenhagen a pole of excellence in this dynamic field of research. He works mainly on quantum information motivated questions in many body physics. Recently his focus has shifted towards topologically ordered systems and topological computation.

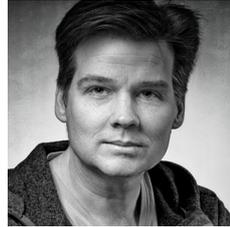


D. Jason Koskinen is an Assistant Professor and local group leader for the IceCube Neutrino Observatory. From 2009-2013 he was a postdoc at the Pennsylvania State University, with a brief trip to the South Pole for IceCube calibration studies. His focus is on neutrino oscillations, further physics beyond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

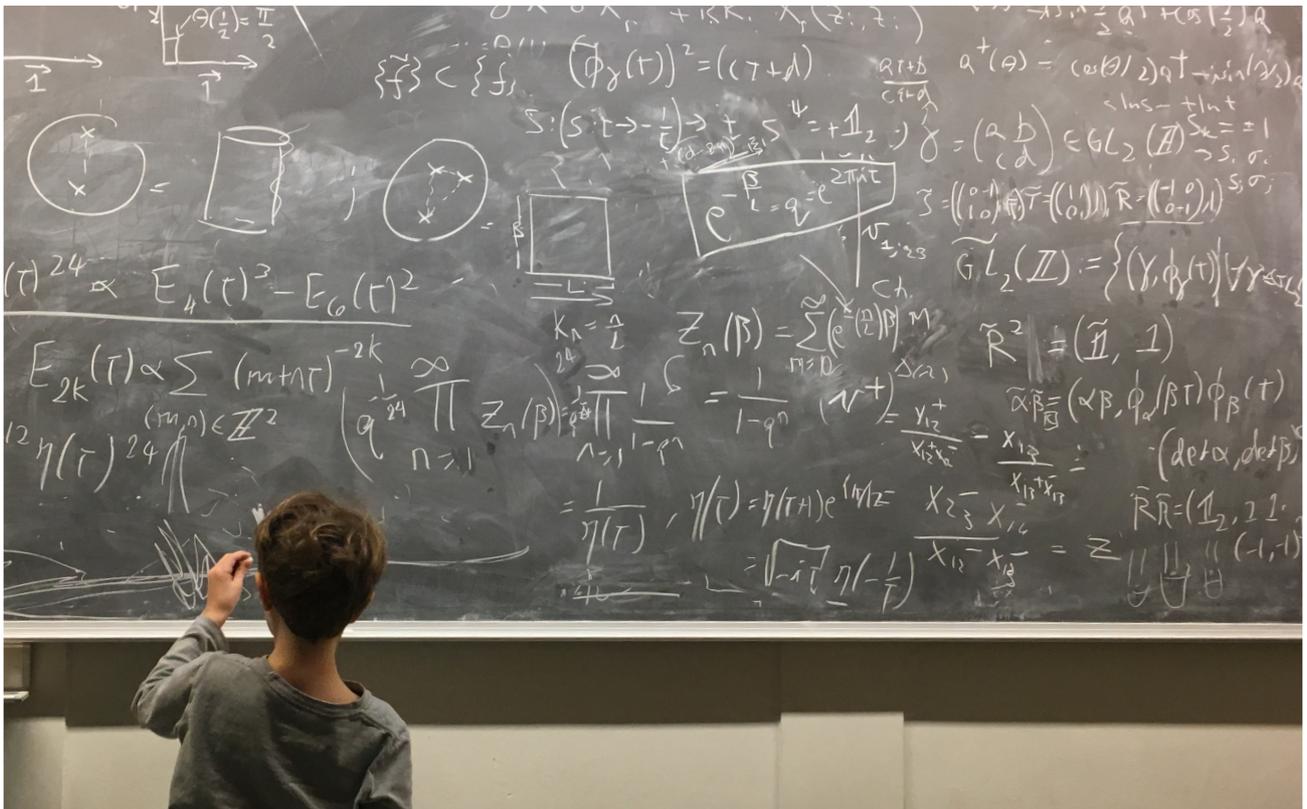
Junior Faculty

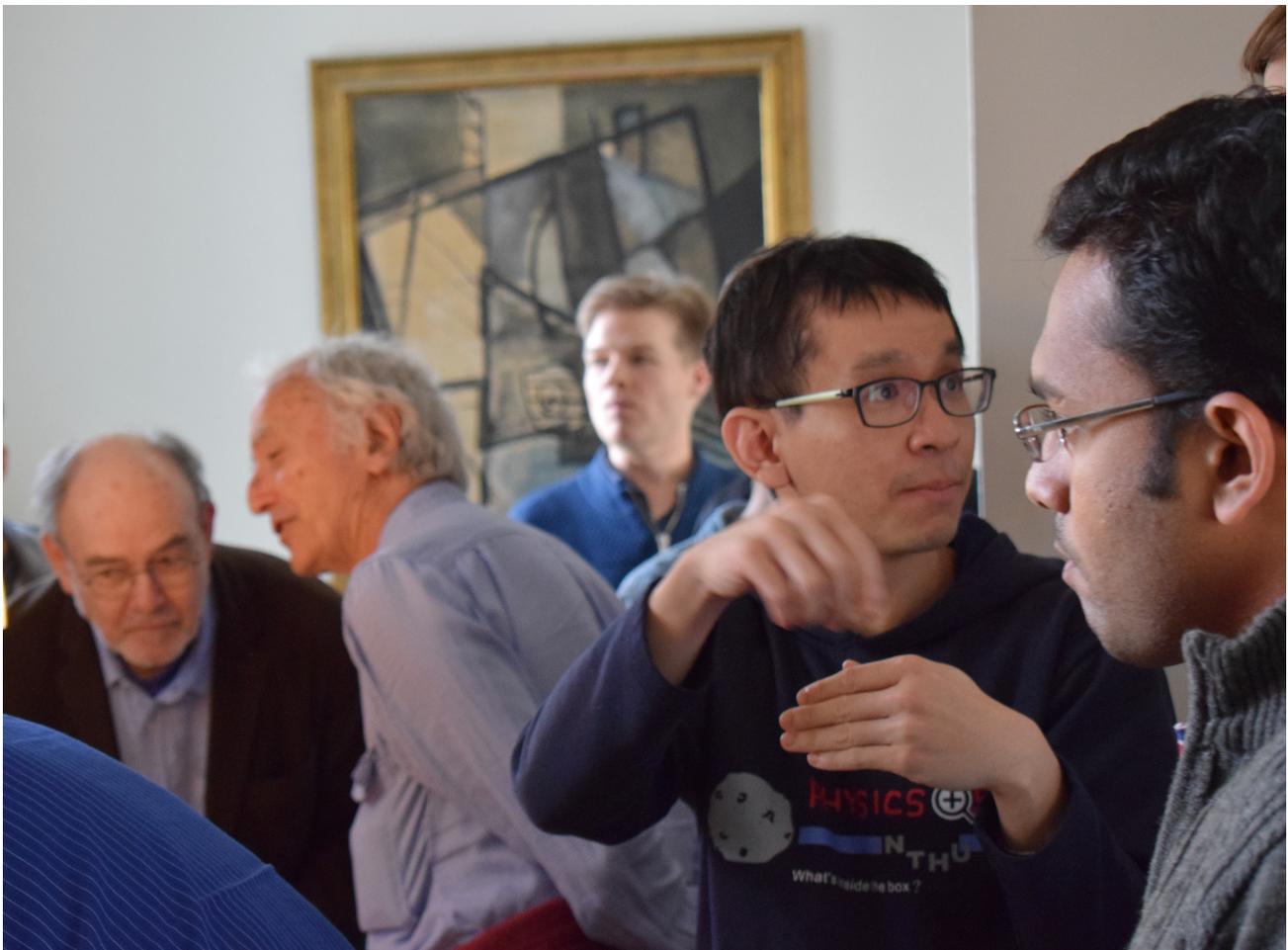


Subodh Patil joined the NBIA in the fall of 2016 as an Assistant Professor after post-doctoral stints at the University of Geneva (2015-16), CERN (2012-15, as Marie Curie Intra-European Fellow from 2012-14), CPHT Ecole Polytechnique (2009-12), and the Humboldt University of Berlin (2007-9), having obtained his Ph.D from McGill university in 2007. He works on broadly defined themes in early universe cosmology, gravity and related aspects of beyond the standard model and string phenomenology.



Michael Trott is leading the particle physics phenomenology group and is an Associate Professor at the NBIA. Michael completed his Ph.D. at the University of Toronto in 2005 and later held research appointments at UC San Diego (2005-2008), Perimeter Institute (2008-20011) and CERN (20011-2014) before joining NBIA in the fall of 2014. Michael has broad and continuing research interests in the areas of Higgs physics, Beyond the Standard Model physics, collider phenomenology, Flavour physics and Neutrinos, as well as precision Standard Model calculations and even Cosmology. In pursuing research projects into all of these areas, the common unifying tool used is Effective Field Theory. Michael was awarded a Villum Young Investigator award in 2015.





Postdoctoral Fellows



Ajit C. Balram's research interests are in field of theoretical condensed matter with emphasis on the physics of the fractional quantum Hall effect and topological insulators.



Pablo Benítez-Llambay received his PhD in Astronomy from the Universidad Nacional de Córdoba, Argentina in December 2015 and joined the NBIA as a postdoc in the Theoretical

Astrophysics group in July 2016. Pablo's research focuses on studying the processes that determine the large-scale dynamics of planetary embryos as they interact with the protoplanetary disk in which they form. In December 2016 Pablo obtained a Marie Curie Fellowship that will allow him to explore the impact of more detailed physics on planet migration processes, with the potential to produce a leap forward in our understanding of how planetary orbits evolve. Pablo's goal is to improve current models for the formation of planetary systems.



Mauricio Bustamante received his PhD in 2014 from the University of Würzburg, while also working at DESY. He was a CCAPP Fellow at The Ohio State University until 2017,

before joining NBIA as a postdoc. He studies particle physics using high-energy astrophysical neutrinos and models high-energy astroparticle sources.



Ilaria Brivio carried out undergraduate studies at the University of Padua and obtained her PhD in 2016 from the Universidad Autónoma de Madrid. Her

research focuses on the use of Effective Field Theories to study the phenomenology of electroweak interactions and the properties of the Higgs boson. Her interests are broad and related to main open questions of particle physics, from the nature of Higgs boson to neutrinos, flavor and Dark Matter. A relevant component of her research is the development of new ideas and theoretical tools to improve the interpretation and understanding of experimental data.



Carlos Cardona Giraldo interest concerns to scattering amplitudes in both flat and curved spaces. In particular the study of mathematical structures of the S-matrix, as well as the use of

it in several aspects of Gauge/Gravity correspondence.



Peter Denton received his PhD from Vanderbilt University and spent a year at Fermilab. His work includes high energy cosmic ray and neutrino anisotropies, astrophysical neutrino production, and

lower energy neutrino oscillation studies both in the context of the standard model and beyond. He is also interested in new ways to look for new physics at high energies at the LHC and in cosmic ray interactions.



Yuri Fujii completed her PhD at Nagoya University, Japan in March 2015 and moved to Tokyo Tech as a postdoc before coming to the Niels Bohr Institute in July 2015. Her research interest is dynamics of protoplanetary and circumplanetary disks that are the birthplaces of planets and moons. She performs non-ideal MHD simulations of those disks with time-dependent ionization chemistry. She also works on modeling of circumplanetary disks and satellite formation.



Xiaoyuan Huang has worked on dark matter indirect detection and high energy gamma-ray astrophysics using Fermi-LAT data. He is also interested in particle acceleration and multimessenger Astrophysics.



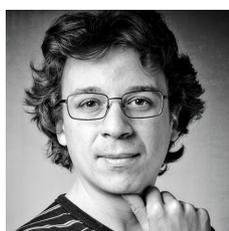
Yun Jiang obtained his Ph.D. degree at U.C. Davis in 2015 with the highest honor Outstanding Academic Achievement Award. He was the 2013 LHC Theory Initiative Graduate Fellow

and the winner of the 2014 National Award for Outstanding Chinese Students Studying Abroad. Prior to his Ph.D., he earned his M.Sc. degree at National University of Singapore in 2011 and B.S. degree at Zhejiang University in China. The focus of his research is new physics beyond the Standard Model, including Higgs physics and dark matter. He is now expanding his research area from particle physics to cosmology, particularly on baryogenesis and early universe inflation.



Ervand Kandelaki completed his PhD at Ruhr-University Bochum before joining the NBIA in 2015. Ervand's research interests include various areas of condensed matter physics.

Currently, his focus lies in non-equilibrium quantum physics, especially with regard to the impact of interactions on many-body effects and topological properties. He is aiming at understanding gapped phases in periodically driven systems going beyond the one-particle picture and looking for genuine many-body phenomena.



Angelo Lucia works in the Quantum Information group of Michael Kastoryano, and at QMATH in the Department of Mathematical Sciences. He did his Master studies in University of

Pisa, and completed his PhD in Mathematics in July 2016 at the Universidad Complutense de Madrid, Spain. Angelo's research interest lies in the interactions between quantum information theory and many-body quantum physics. He has worked on open dissipative dynamics, area laws, and he is now focusing on tensor network states.



David McGady completed his PhD at Princeton University before coming to the Niels Bohr Institute in 2015. David's research interests are spread across high energy physics and

quantum field theory. Currently, he is actively focused on analytic structures in scattering processes in quantum field theories, and in elucidating both the fundamental cause of, and the consequences derived from, a recently discovered symmetry of partition functions under reflection of temperatures.

Postdoctoral Fellows



Andrew McLeod received his PhD from Stanford University in 2017. His research focuses on developing novel formulations of scattering amplitudes in quantum field theory. Currently, he is investigating the analytic, geometric, and infrared properties of gauge theory.



Farrukh Nauman obtained his PhD at the University of Rochester in 2015. His research focuses on turbulence in astrophysical fluids and plasmas with a particular emphasis on understanding the origin, survival and influence of large scale magnetic fields in accretion disks. This involves both theoretical and computational work.



Mohamed Rameez received his PhD from the University of Geneva in 2016, working on Dark Matter indirect detection and point source searches with the IceCube detector. While at NBIA, he is seeking a better understanding of Cosmology and local universe anisotropies.



Michael Schecter obtained his Ph.D. at the University of Minnesota. At QDev/NBIA, his research is focused on understanding the low-temperature magnetic structure of atoms placed on a metallic or superconducting substrate.



Matt von Hippel received his PhD from Stony Brook. Before joining NBIA, he was a postdoctoral fellow at the Perimeter Institute. He develops new techniques for calculating scattering amplitudes in quantum field theory. He is well known for polylogarithmic bootstrap methods, which compute higher-loop scattering amplitudes from minimal physical assumptions. This year, he received a prestigious Marie Curie Fellowship.



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



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

Bloch 1994:

Spectral stability (Merker)

$$\ddot{x} + \alpha x = 0$$
$$\dot{y} = g(x, y, z_0)$$
$$\dot{z} = 0 \Rightarrow z = z_0$$

$$x = x(t, x_0, y_0, z_0)$$
$$\dot{y} = g(x, y, z_0)$$
$$\dot{z} = 0 \Rightarrow z = z_0$$

$$|\lambda| > \sqrt{-\alpha} + \sqrt{-\beta}$$

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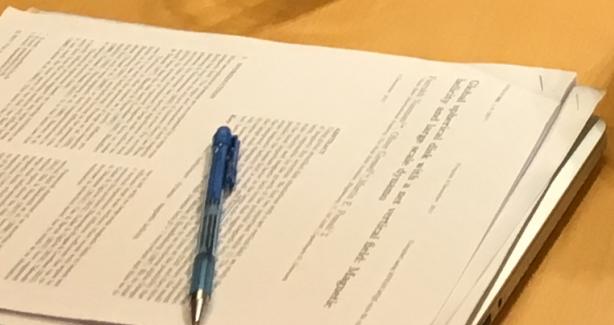
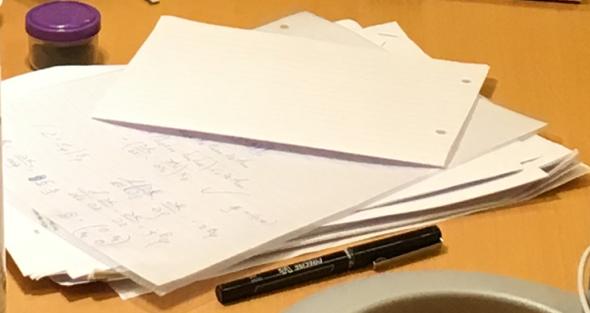
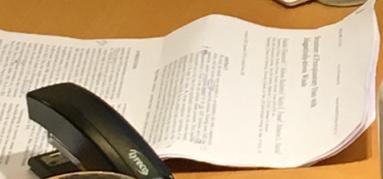
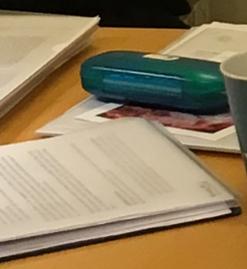
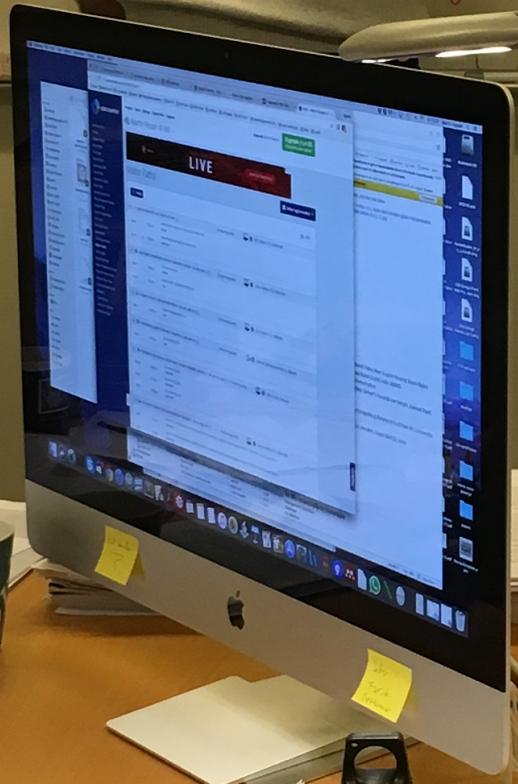
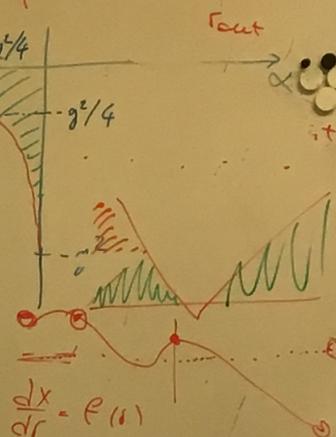
Lustabil

Gen

$$g^2 \text{tr} Q < 0$$
$$-g^2 + 4 \text{tr} Q < 0$$

Prop

$$\frac{X_{i+1} - X_i}{t_i - t_{i-1}} - f(x_i, y_i) = 0 \quad (N-1)$$
$$g(x_{N-1}, x_{N-1}) = 0$$
$$x_{N-1} = \dots$$



PhD Students



Thomas Berlok began his studies at the University of Copenhagen in 2008, initially specialising on quantum optics and cold atoms. He joined the Theoretical Astrophysics group at NBIA in the spring of 2013 as a MSc student and obtained his PhD in October 2017. During his time at NBIA, he worked together with Martin Pessah, Tobias Heinemann, and Troels Haugbøelle (NBI) to understand the dynamics of the intracluster medium of galaxy clusters and develop a numerical code for studying collisionless plasmas.



Laure Berthier obtained her MSc in Cambridge. In 2014, she joined NBIA to do her PhD. Her research focuses on setting constraints on new physics beyond the Standard Model using Electroweak data and effective field theories. Laure develop a new method for fitting small parameters with missing higher order corrections. She now works on non-relativistic UV completion of the Standard Model to obtain a naturally light Higgs with Kevin Grosvenor.



Amel Durakovic undertook his postgraduate studies in theoretical physics at Imperial College London. He completed these by writing a dissertation under the supervision of Michael Duff on division algebras and supergravity. Amel now works with Subir Sarkar studying aspects of cosmological inflation and the reconstruction of primordial power spectra from observations.



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



Leonardo Krapp obtained his degree of Licenciado from Cordoba University in Argentina in 2015 and started his PhD working with Oliver Gressel at the NBIA in 2016. His research interest involve studying gas and dust dynamics in protoplanetary disks using the codes NIRVANA and FARGO3D. He is studying numerical algorithms to couple the Hall effect with ambipolar and Ohmic diffusions with the goal of performing non-ideal MHD simulations of protoplanetary disks including non-equilibrium ionization.



Meera Machado received her MSc at the University of Sao Paulo, with her thesis “Event-by-event Hydrodynamics for LHC”. She currently works with Poul Henrik Damgaard and Ante Bilandzic on her PhD project “The Little Bang of High-Energy Heavy-Ion Collisions”, whose aim is to analyse the anisotropic flow of heavy-ion collisions by using statistical tools employed in the analysis the Cosmic Microwave Background.



Gopakumar Mohandas graduated with an M.Sc. in Physics at the Chennai Mathematical Institute. Gopakumar joined the Theoretical Astrophysics group at the NBIA in the fall of

2013. He currently works, with his principal supervisor Martin Pessah, on analysing the stability and dynamics of accretion disks using magneto-hydrodynamic theory. He has also worked on the stability of charged particle orbits in planetary magnetospheres and on modeling exoplanetary atmospheres.



Anagha Vasudevan received her MSc in 2017 from RWTH Aachen. She is currently working on phenomenological studies in the standard model effective field theory and the intersec-

tion between effective field theories and modern methods in scattering amplitudes under Prof. Michael Trott and Prof. Emil Bjerrum-Bohr.



Jeppe Trøst Nielsen began his studies in 2009 with a transition from accelerator physics through condensed matter and particle physics all the way to cosmology and the large scale structure

of the universe in his PhD which he started at the International Academy in 2013. His work has focused on the framework of interpreting experiments through theories. With rigorous statistics as the main tool this resulted in a widely read and recognized paper in Nature Scientific Reports. His current research interests include determining to which degree future experiments may discriminate between theories of the early and old universe. Observing the CMB and large scale structures will only takes us so far!



Laurie Walk obtained her masters at the Theoretical High Energy Physics group at Lund University. Her project focussed on model building in Grand Unification Theory. In October of

2017, she began her Ph.D in the Astroparticle Physics group at NBIA. She is currently working on identifying neutrino properties from 3D core-collapse supernova simulation.



Philipp Weber obtained his MSc from Heidelberg in 2016 and subsequently started his PhD at NBIA working with Oliver Gressel. He is developing an advanced implementation of

dust in protoplanetary disks for the FARGO3D and NIRVANA codes. This development will enable realistic studies of disk features such as planet opened gaps and vortices. Previously, often a static vertical profile had to be assumed, but our framework will allow the self-consistent study of the vertical disk structure of the coupled gas and dust.

MSc Students

Abdurrahman Barzinji — Particle Physics

David Damgaard — Theoretical Physics

Solvej Knudsen — Theoretical Physics

Stavros Mougikakos — Astroparticle Physics

Klaes Møller — Astroparticle Physics

Janet Rafner — Theoretical Physics/Art

Matt Steinberg — Quantum Information

Anna M. Suliga — Astroparticle Physics

Loui Wentzel — Astroparticle Physics

Visiting Professors



Jim Cline visited NBIA from McGill University during Fall 2017. His interests include astroparticle and collider phenomenology, models of dark matter, and the baryon asymmetry in the

universe.



Steve Simon Professor of Physics at Oxford University and Fellow of Somerville College, Oxford. He is particularly known for his work on topological phases of matter and the fractional

Quantum Hall Effect.



Itamar Procaccia is Simons Visiting Professor this fall. He is a physicist (and chemist) who works at the interface of subjects in statistical physics, nonlinear dynamics and the theory of

turbulence.



Simon Caron-Huot is Assistant Professor at McGill University. He works on a wide range of topics in theoretical particle physics, including the development of new techniques for the computation of scattering amplitudes.

Adjunct & Associates

Per Rex Christensen — Niels Bohr Institute

Zohar Komargodski — Stony Brook

Benny Lautrup — Niels Bohr Institute

Alan Luther — Nordita

Åke Nordlund — Niels Bohr Institute

Igor Novikov — Lebedev Physics Institute

Anders Tranberg — University of Stavanger

Meng-Ru Wu — Academia Sinica

Administrative Staff



Anette Studsgård is NBIA administrative coordinator, She is responsible for the organization of schools and workshops, secretarial support visa applications, and budget allocation. She has a

Master of Arts in Cognitive Sciences from Lund University.



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



Prof. Jim Cline — "NBIA Tea Time" — Summer 2017

Visitors

The NBIA maintains a vigorous visitor program, with close to 80 visitors a year. These visitors actively engage in daily activities at the NBIA and the Institute.

S. Zhiboedov (Harvard)	20.12.2017	23.12.2017
E. Resconi (Munich)	18.12.2017	18.12.2017
A. Romano (Birmingham)	13.12.2017	16.12.2017
S. van Tongeren (Humboldt)	13.12.2017	14.12.2017
R. Catena (Gothenburg)	11.12.2017	12.12.2017
F. Bishara (Oxford)	06.12.2017	08.12.2017
B. Sherwin (Cambridge)	04.12.2017	06.12.2017
R. Ruiz (Durham)	03.12.2017	05.12.2017
Y. Dirian (Geneva)	27.11.2017	01.12.2017
A. Krikun (Leiden)	27.11.2017	29.11.2017
A. Franckowiak (DESY)	26.11.2017	28.11.2017
G. Compère (Bruxelles)	23.11.2017	23.11.2017
A. Plascencia (Durham)	21.11.2017	23.11.2017
S. Stieberger (Max Planck)	20.11.2017	21.11.2017
E. Waxman (Weizmann)	19.11.2017	20.11.2017
I. Valenzuela (Max Planck)	15.11.2017	17.11.2017
F. Vernizzi (IPhT)	11.11.2017	13.11.2017
M. Guica (Uppsala)	08.11.2017	09.11.2017
A. Taylor (DESY)	06.11.2017	07.11.2017
J.J. Carrasco (Carrasco)	30.10.2017	03.11.2017
F. Donato (Torino)	29.10.2017	31.10.2017
L. Sironi (Columbia)	26.10.2017	28.10.2017
M. Mojaza (Stockholm)	23.10.2017	27.10.2017
M. Paraskevas (Ioannina)	18.10.2017	20.10.2017
J. Drummond (S. Hampton)	16.10.2017	17.10.2017
H. Gomez (Santiago de Cali)	15.10.2017	20.10.2017
S. Weinzierl (Mainz)	11.10.2017	13.10.2017
T. Azevedo (Uppsala)	02.10.2017	05.10.2017

D. Powell (Santa Cruz)	19.07.2017	25.07.2017
A. Lande (Groningen)	15.07.2017	18.07.2017
M. von Hippel (Perimeter)	15.07.2017	21.07.2017
F. Khajenabi (Golestan)	01.07.2017	15.08.2017
M. Shadmehri (Golestan)	01.07.2017	15.08.2017
M. Sen (Tata Institute)	21.06.2017	24.06.2017
H.G. Zuniga (Santiago)	20.06.2017	27.07.2017
K. Murase (Penn. State)	11.06.2017	17.06.2017
S. Caron-Huot (McGill)	01.06.2017	31.07.2017
P. Steinhardt (Princeton)	24.05.2017	28.05.2017
L. Blanchet (Paris)	17.05.2017	19.05.2017
A. Schreiber (Heidelberg)	17.05.2017	19.05.2017
S. Simon (Oxford)	15.05.2017	31.07.2017
L. Baulieu (Univ. Paris)	10.05.2017	11.05.2017
I. Antoniadis (CERN)	08.05.2017	11.05.2017
S. Dib (Univ. de Atacama)	01.05.2017	14.07.2017
A. Boisen (Copenhagen)	28.04.2017	28.04.2017
W. Shepherd (Mainz)	23.04.2017	28.04.2017
G. Mamatsashvili (Tbilisi)	23.04.2017	28.04.2017
A. Addazi (Fudan)	08.04.2017	11.04.2017
R. Leane (Melbourne)	03.04.2017	15.06.2017
J. Chluba (Manchester)	01.04.2017	04.04.2017
L. Lopez Honorez (Vrije)	26.03.2017	28.03.2017
M. Cirelli (Paris)	20.03.2017	20.03.2017
A. Green (Nottingham)	12.03.2017	15.03.2017
M. Lemoine (IAP Paris)	05.03.2017	08.03.2017
A. Gjedde (Copenhagen)	03.03.2017	03.03.2017
H. Eklund (Copenhagen)	01.03.2017	30.04.2017

E. Hermann (Caltech)	01.10.2017	07.10.2017
M. Laplante (McGill)	27.09.2017	11.10.2017
P. Vanhove (Saclay)	27.09.2017	29.09.2017
G. Festuccia (Stockholm)	26.09.2017	29.09.2017
S. Petcov (SISSA)	25.09.2017	27.09.2017
G. Hentschel (Emory)	24.09.2017	01.10.2017
D. Broadhurst (OU)	17.09.2017	20.09.2017
Q. Shafi (Bartol)	10.09.2017	13.09.2017
S. Dib (Univ. de Atacama)	04.09.2017	17.11.2017
J. Vieira (Sussex)	15.08.2017	31.12.2017
B. Gavela (Madrid)	31.08.2017	01.09.2017
J. Cline (McGill)	08.09.2017	31.12.2017
R. Mohayaee (IAP Paris)	07.08.2017	11.08.2017
I. Procaccia (Weizmann)	01.08.2017	31.10.2017
J. Murphy (Florida State)	29.07.2017	03.08.2017

K. Temme (IBM Research)	26.02.2017	03.03.2017
A. Kataoka (Heidelberg)	23.02.2017	24.02.2017
D. Blas (CERN)	20.02.2017	22.02.2017
C. Cardona (Taiwan)	18.02.2017	23.02.2017
M. Cheng (Amsterdam)	16.02.2017	16.02.2017
G. Watanabe (Zhejiang)	12.02.2017	19.02.2017
A. Bauswein (HITS)	05.02.2017	07.02.2017
T. Plehn (Heidelberg)	02.02.2017	03.02.2017
D. Kosower (Saclay)	01.02.2017	09.02.2017
A. Nagar (IHES)	30.01.2017	01.02.2017
D. Malyshev (FAU)	29.01.2017	02.02.2017
S. Galli (IAP, Paris)	16.01.2017	18.01.2017
J.J. Carrasco (Saclay)	12.01.2017	13.01.2017
M. Søgaard (Standford)	07.11.2016	15.01.2017
S. Matsuura (Keio)	01.03.2016	31.01.2017



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NBIA Activities



NBIA Simons Foundation Program

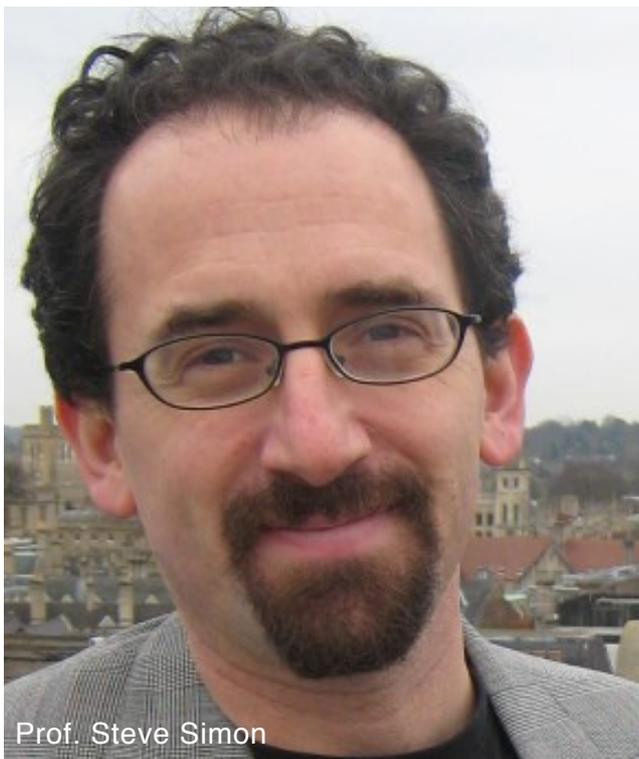
Based on a generous grant from the Simons Foundation in New York, the NBIA has established a highly successful series of Simons Visiting Professorships to the NBIA, and associated scientific programs built around these visiting professors. The program was launched in the fall of 2016 with first Simons Visiting Professor Viatcheslav “Slava” Mukhanov, Chair of Cosmology at the Arnold Sommerfeld Center for Theoretical Physics in Munich. It was in connection with that visiting professorship, and a high-profiled workshop in August 2016, that the NBIA also brought Stephen Hawking to Denmark, for only the second time in Hawking’s life. In 2017 the program continued with Simons Visiting Professor Steve Simon from Oxford University who stayed at the NBIA in the spring of 2017. The subject concerned new topics in condensed matter physics, and the program included both a series of visiting scientists and two highly successful meetings, one of them organized jointly with Center for Quantum Devices (QDev) at the Niels Bohr Institute. In the fall of 2017 member of NBIA’s Scientific Advisory Board Itamar Procaccia Professor of Chemical Physics at the Weizmann Institute) was Simons Visiting Professor, helping to organize two workshops. The first was on hot topics in the theory of turbulence, while the second focused on the physics of new materials and novel states of matter. The Simons Visiting Professor of the spring of 2018 will be Charles Bennett (IBM Fellow, IBM Research).

“Simons Program: States of Matter” — 20.11.2017 / 23.11.2017

“Simons Program: Transition to Turbulence” — 23.10.2017 / 27.10.2017

“Simons Program: Frontiers in Quantum Hall Physics” — 10.07.2017 / 13.07.2017

“Simons Program: New Directions in Condensed Matter” — 21.05.2017 / 24.05.2017



Prof. Steve Simon



Prof. Itamar Procaccia



Prof. Chris Pethick — "NBIA Tea Time" — Summer 2017

NBIA Seminars & Talks

The NBIA organizes a handful of Colloquia every semester. These are broad talks aimed at non-experts, but at a level from PhD-students and up. Topics are not limited to physics, but can cover any subject under the sun that is of interest to NBIA scientists. In the past we have had talks on such varied topics as ancient DNA, the geological history of the earth, the science of textile archeology, the theory of paintings from a science perspective, and many other fascinating topics. This past year NBIA Colloquia covered topics from the history of the theory of gravitational waves, through strategies to meet the future energy needs to a talk by Sir Roger Penrose on topics from his new book.

A more informal series of talks are given on Friday afternoons. Known as “N-Talks”, this is the opportunity for NBIA scientists to explain their fellow Academy members what their current research is about in very simple terms! The rule is simple: 15 minutes at most, slides only (exceptions are tolerated), and totally simple. This is more difficult than one could imagine, but it is a very useful exercise for the speaker and a rewarding experience for the audience. The subsequent refreshments in the NBIA Lounge often continue directly with the social activities (in town) known as NBIA Social Nights.

Being part of the existing research groups at the Niels Bohr Institute, all scientists at the NBIA also participate in (and several help organize) the regular seminar programs on more focused subjects, aimed at experts. Not many days pass by without an opportunity to participate in one of these seminars.





NBIA Public Lectures & Outreach

In 2017 Simons Visiting Professor Itamar Procaccia delivered a special public NBIA lecture entitled “*Numbers in Nature, Art, and Architecture*” in the historic Auditorium A at Blegdamsvej. In addition, NBIA scientists continue contributing with enthusiasm to the series of public lectures that are becoming increasingly more popular.

Since 2011 the NBIA has organized an annual series of public lectures on physics in collaboration with the Danish Open University ‘Folkeuniversitetet’. The idea was from the start to let the public benefit from the presence of young and enthusiastic scientists at the NBIA, each of them speaking about a topic very close to their actual on-going research, but at a level appropriate for an audience with no background in science. By design, these lectures will then cover a wide range of topics in modern theoretical physics, giving a glimpse of the questions, ideas and approaches that are now at the scientific forefront. This formula turned out to be a success, and although the subjects covered are at the forefront of present-day research, the attendance is increasing. All lectures take place at the historical Auditorium A and for the first time we had to introduce two parallel series of talks in 2015 in order to accommodate everybody who had signed up. Noticing that several who signed up came back year after year, the NBIA has introduced a Friends of the NBIA circle of interested and supportive laymen who also receive the biannual Newsletter. As it develops and grows, the plan is to offer special opportunities for this group of people also beyond what they sign up for through the Open University. This year’s lectures included:

Oliver Gressel (NBIA) — 07.11.2017 & 09.11.2017

“Enigmatic Protoplanetary Disks”

Matt von Hippel (NBIA) — 14.11.2017 & 11.11.2017

“The quest for Quantum Gravity”

Ilaria Brivio (NBIA) — 21.11.2017 & 23.11.2017

“Tales of the Particle World”

Johan Fynbo (Niels Bohr Institute) — 28.11.2017 & 30.11.2017

“Gamma ray bursts & gravitational waves”

Subir Sarkar (NBIA and Oxford University) — 05.12.2017 & 07.12.2017

“Seeing the Edge of the Universe”

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.

$$\frac{\partial u}{\partial x} \Big|_{\Delta t} \approx \frac{u(x+\Delta x) - u(x)}{\Delta x}$$

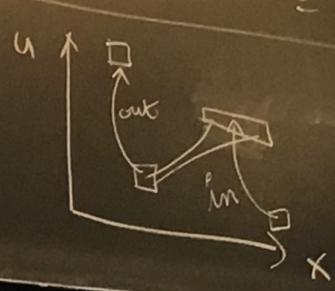
$$\frac{\partial^2 u}{\partial x^2} \Big|_{\Delta t} \approx \frac{u(x+\Delta x) - 2u(x) + u(x-\Delta x))}{\Delta x^2}$$

$f(x(t), u(t), t) = f_0$

chain rule

$$\frac{\partial f}{\partial t} + \frac{\partial f}{\partial x} \cdot \dot{x} + \frac{\partial f}{\partial u} \cdot \dot{u} = 0$$

$$\frac{\partial f}{\partial t} + u \frac{\partial f}{\partial x} + a \frac{\partial f}{\partial u} = 0$$



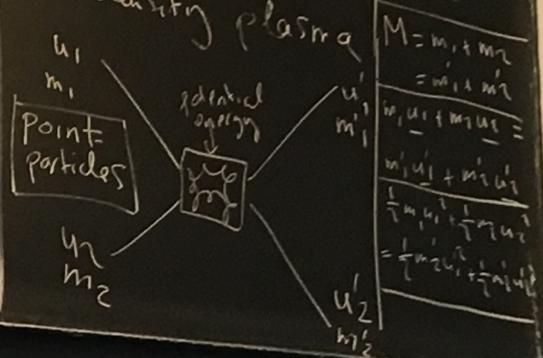
$$RHS = \left(\frac{Df}{Dt} \right)_{in} - \left(\frac{Df}{Dt} \right)_{out} \neq 0$$

collisions

↳ Boltzmann Equation

Binary Elastic Collisions

Low density plasma



rate

$$\left(\frac{Df}{Dt} \right)_{out} = \int_1 \int_2 b db d\varphi d^3u_2$$

Definition: $b db = \sigma \sin \theta d\theta$

↑ cross-section

$$\left(\frac{Df}{Dt} \right)_{out} = \int_1 \int_2 \sigma v \sin \theta d\theta d\varphi d^3u_2$$

$d\Omega$

$$\left(\frac{Df}{Dt} \right)_{in} = \int_{\mathbb{R}^3} \int_{4\pi} f_1 f_2 \sigma v d\Omega d^3u_2$$

$$\left(\frac{Df}{Dt} \right)_{in} = \int_{\mathbb{R}^3} \int_{4\pi} f_1' f_2' \sigma v d\Omega d^3u_2$$

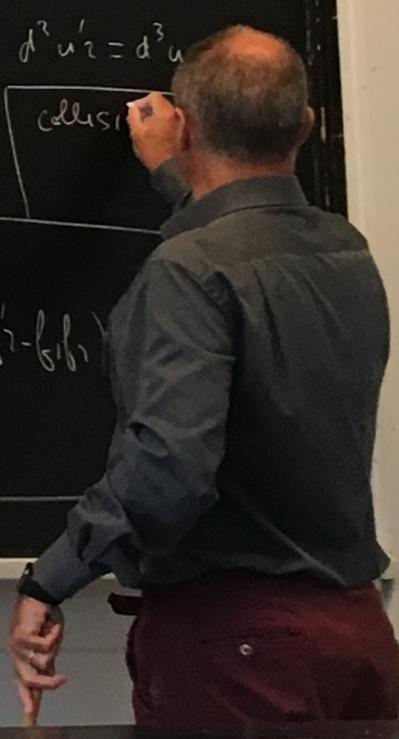
$\sigma' = \sigma$

$v' = v$

$\int (u_1' \cdot u_1) = 1$

collisions

$$\left(\frac{Df}{Dt} \right)_{coll} = \int_{\mathbb{R}^3} \int_{4\pi} (f_1' f_2' - f_1 f_2) \sigma v d\Omega d^3u_2$$



NBIA Workshops & PhD Schools

Building on Niels Bohr's ideas and vision, NBIA members engage in several activities aimed at promoting and enhancing the traditions of internationalism, interdisciplinarity and excellence in physics. The NBIA is instrumental in running of the order of ten high-profile, international events every year to the benefit of the wider Institute community. The list below contains the events organized during 2017.

“NBIA Summer School on Astrophysical Plasmas” — 28.08.2017 / 01.09.2017

“Current Themes in High Energy Physics and Cosmology” — 21.08.2017 / 25.08.2017

“Self-Interacting Dark Matter” — 31.07.2017 / 04.08.2017

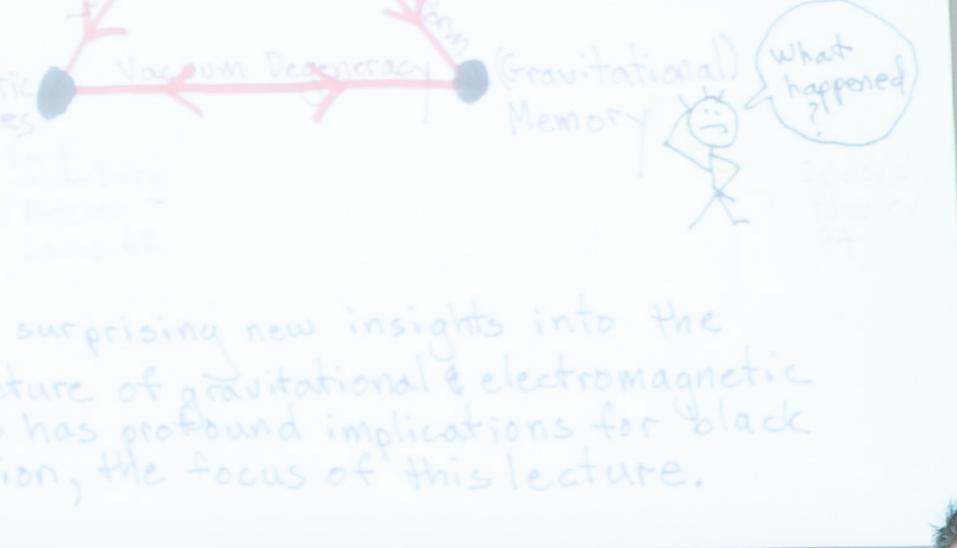
“Kavli Summer Program in Astrophysics 2017” — 10.07.2017 / 18.08.2017

“A Holographic Sampling” — 15.05.2017 / 16.05.2017

“Baltic Meeting on Computational and Theoretical Astrophysics” — 04.05.2017 / 05.05.2017

“Nordic Winter School on Cosmology and Particle Physics 2017” — 02.01.2017 / 07.01.2017





NBIA Colloquia

NBIA Colloquia consist of broad talks aimed at scientist who are not necessarily experts on the subject matter. Topics are not limited to physics, but can cover any subject of interest to the wide spectrum of researchers and students at NBIA. In the past we have had talks on such varied topics as ancient DNA, the geological history of the earth, the science of textile archeology, the theory of paintings from a science perspective, and many other fascinating topics. The NBIA Colloquia in 2017 are listed below.

Eli Waxman (Weizmann) — 20.11.2017

“High energy neutrino astronomy: What have we learned?”

Jim Cline (McGill University) — 03.11.2017

“Is there a multiverse?”

L. Mahadevan (Harvard University) — 25.09.2017

“Morphogenesis: geometry, physics and biology”

Andrew Strominger (Harvard University) — 23.08.2017

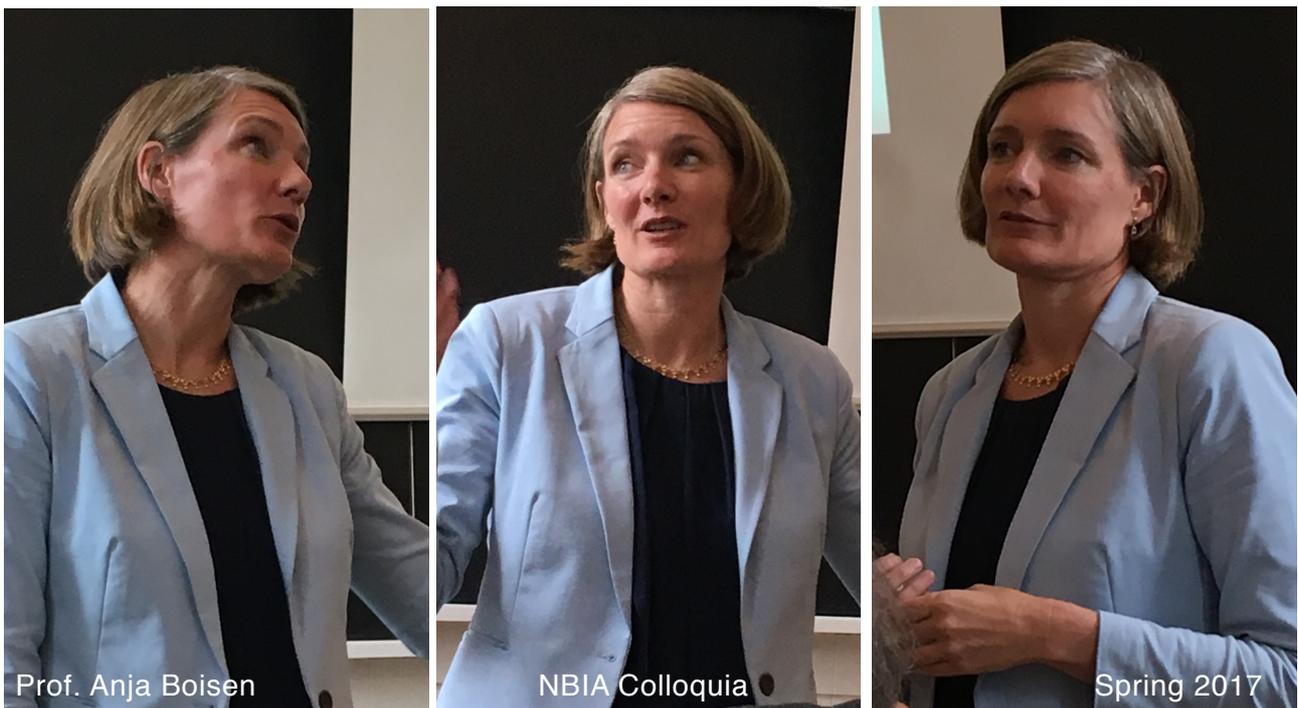
“Soft Hair on Black Holes”

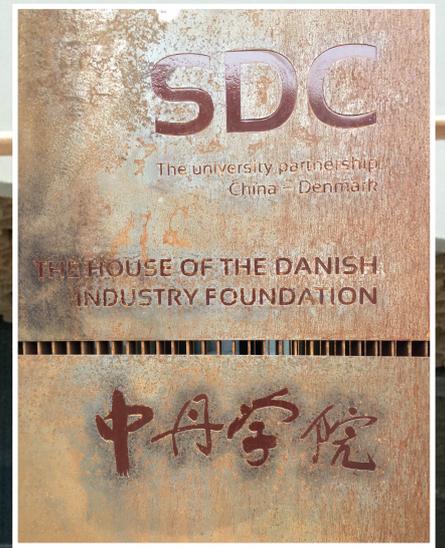
Anja Boisen (DTU Nanotech) — 21.04.2017

“Micro- and Nanostructures for Oral Drug Delivery and Sensing”

Albert Gjedde (University of Copenhagen) — 03.03.2017

“Learning by doing: Neuroimaging of sensation-seeking as learned behavioral addiction”



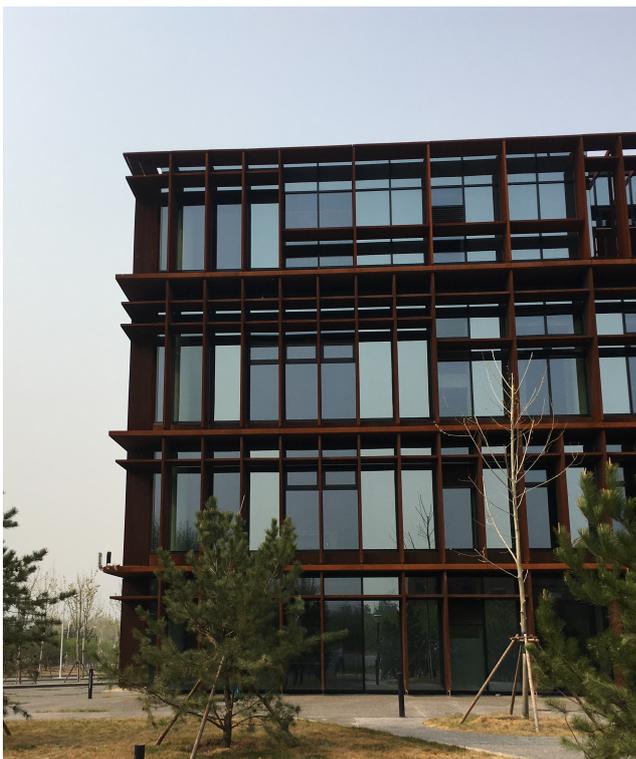


SDC Building – University of Chinese Academy of Sciences Campus

New Relations with China

In October 2017 a delegation from the University of Chinese Academy of Sciences (UCAS) in Beijing visited the NBIA for the purpose of establishing closer ties in the areas of astrophysics, astroparticle physics and particle physics. Also scientists from the Technical University of Denmark, University of Southern Denmark and Aarhus University were invited to join. The collaboration is intended to proceed through the already established Sino-Danish Center (SDC) at UCAS in Beijing. A few weeks later a brand-new building for the House of the Danish Industry Foundation at UCAS, which will also house the SDC, was inaugurated at UCAS. Designed by Danish architects Lundgaard & Tranberg, and built by the help of substantial support from the Danish Industry Foundation, this building can also serve as home for the new joint Danish-Chinese activities planned in the areas described above, where the NBIA has particularly strong research groups. The building includes guest apartments for visiting scientists and of course immediate access to the campus at UCAS. Having grown out of the Graduate University of the Chinese Academy of Sciences (GUCAS), the faculty at UCAS is based on all the research professors at the Chinese Academy of Sciences, thus ranking it as perhaps the strongest graduate school in China.

At this point it appears most likely that collaboration will start at the researcher level, including post-doc exchanges and perhaps joint PhD-students. Included in the collaboration will, in addition to Chinese scientists at UCAS itself, also be members of the Chinese Academy of Sciences in Beijing, Tsinghua University in Beijing, Beijing University, and scientists at the National Astronomical Observatories, Chinese Academy of Sciences. In a grander perspective, it is envisaged that the collaboration can extend to an actual joint PhD-program in the above subjects. At a later stage, an educational program at the MSc-level may be established, with lectures being delivered at the SDC in Beijing, and Chinese students being given the opportunity to visit and collaborate with Danish scientists. It is hoped that the joint research program can start already during the academic year 2018/19.



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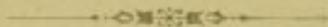
ON
THE QUANTUM THEORY
OF LINE-SPECTRA

BY

N. BOHR

PART I

D. KGL. DANSKE VIDENSK. SELSK. SKRIFTER, NATURVIDENSK. OG MATHEM. AFD., 8. RÆKKE, IV, 1



KØBENHAVN

BIANCO LUNOS BOGTRYKKERI

1918

Refereed Papers

- 1. On interference and non-interference in the SMEFT**
Helset, Andreas, Trott, Michael, 2018, JHEP, 04, 038 - ArXiv: [1711.07954](#)
- 2. Hagedorn Temperature of AdS₅/CFT₄ via Integrability**
Harmark, Troels, Wilhelm, Matthias, 2018, Phys. Rev. Lett., 120, 071605 - ArXiv: [1706.03074](#)
- 3. Elliptic Double-Box Integrals: Massless Scattering Amplitudes beyond Polylogarithms**
Bourjaily, Jacob L., McLeod, Andrew J., Spradlin, Marcus et al., 2018, Phys. Rev. Lett., 120, 121603 - ArXiv: [1712.02785](#)
- 4. Low mass planet migration in magnetically torqued dead zones - I. Static migration torque**
McNally, C. P., Nelson, R. P., Paardekooper, S.-J. et al., 2017, MNRAS, 472, 1565-1575 - ArXiv: [1708.05721](#)
- 5. Particle-hole symmetry for composite fermions: An emergent symmetry in the fractional quantum Hall effect**
Balram, A. C., Jain, J. K., 2017, Phys. Rev. B, 96, 245142 - ArXiv: [1711.01771](#)
- 6. Fermi wave vector for the partially spin-polarized composite-fermion Fermi sea**
Balram, Ajit C., Jain, J. K., 2017, Phys. Rev. B, 96, 235102 - ArXiv: [1707.08623](#)
- 7. Fermi arc plasmons in Weyl semimetals**
Song, J. C. W., Rudner, M. S., 2017, Phys. Rev. B, 96, 205443 - ArXiv: [1702.00022](#)
- 8. Interferometric view of the circumstellar envelopes of northern FU Orionis-type stars**
Fehér, O., Kóspál, Á., Ábrahám, P. et al., 2017, A&A, 607, A39 - ArXiv: [1709.07458](#)
- 9. Exact diagonalization of cubic lattice models in commensurate Abelian magnetic fluxes and translational invariant non-Abelian potentials**
Burrello, M., Fulga, I. C., Lepori, L. et al., 2017, Journal of Physics A Mathematical General, 50, 455301 - ArXiv: [1706.09745](#)
- 10. Orbital Advection with Magnetohydrodynamics and Vector Potential**
Lyra, W., McNally, C. P., Heinemann, T. et al., 2017, AJ, 154, 146 - ArXiv: [1708.05057](#)
- 11. Disk Evolution and the Fate of Water**
Hartmann, L., Ciesla, F., Gressel, O. et al., 2017, Space Sci. Rev., 212, 813-834 - ArXiv: [1708.03360](#)
- 12. Nematic Bond Theory of Heisenberg Helimagnets**
Schechter, Michael, Syljuåsen, Olav F., Paaske, Jens et al., 2017, Phys. Rev. Lett., 119, 157202 - ArXiv: [1705.08917](#)
- 13. Quantized Magnetization Density in Periodically Driven Systems**
Nathan, Frederik, Rudner, Mark S., Lindner, Netanel H. et al., 2017, Phys. Rev. Lett., 119, 186801 - ArXiv: [1610.03590](#)

- 14. Mixing Properties of Stochastic Quantum Hamiltonians**
E. Onorati, O. Buerschaper, M. Kliesch et al., 2017, Communications in Mathematical Physics, 355, 905--947 - ArXiv: [1606.01914](https://arxiv.org/abs/1606.01914)
- 15. Planetary migration and the origin of the 2:1 and 3:2 (near)-resonant population of close-in exoplanets**
Ramos, X. S., Charalambous, C., Benítez-Llambay, P. et al., 2017, A&A, 602, A101 - ArXiv: [1704.06459](https://arxiv.org/abs/1704.06459)
- 16. Positions of the magnetoroton minima in the fractional quantum Hall effect**
Balram, Ajit C., Pu, Songyang, 2017, The European Physical Journal B, 90, 124 - ArXiv: [1609.01703](https://arxiv.org/abs/1609.01703)
- 17. Shearing box simulations in the Rayleigh unstable regime**
Nauman, F., Blackman, E. G., 2017, MNRAS, 467, 1652-1660 - ArXiv: [1507.04711](https://arxiv.org/abs/1507.04711)
- 18. Toward realistic simulations of magneto-thermal winds from weakly-ionized protoplanetary disks**
Gressel, O., 2017, preprint, 837, 012008 - ArXiv: [1611.09533](https://arxiv.org/abs/1611.09533)
- 19. Poking Holes and Cutting Corners to Achieve Clifford Gates with the Surface Code**
Benjamin J. Brown, Katharina Laubscher, Markus S. Kesselring et al., 2017, Physical Review X, 7 - ArXiv: [1609.04673](https://arxiv.org/abs/1609.04673)
- 20. H₂CO Distribution and Formation in the TW HYA Disk**
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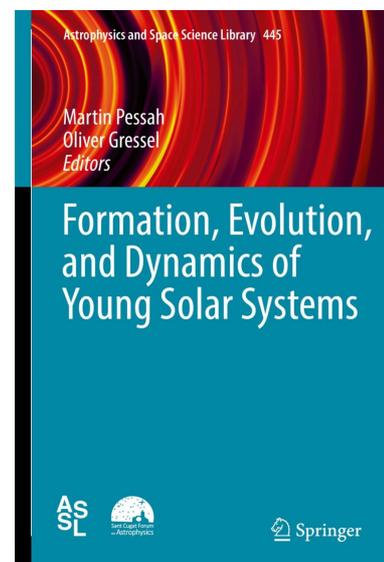
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Blegdamsvej 17
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