The Niels Bohr International Academy

Annual Report 2018

The Niels Bohr International Academy

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NBIA Governance

International Advisory Board and Director's Council:

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

Current Members of the International Advisory Board:

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

Current Members of the Director's Council:

- **Lars Kann-Rasmussen** (Chairman)
  Former CEO of the VELUX Group and Villum Foundation
- **Kirsten Smedegaard Andersen**
  Board member LD, Bodum, DanChurchAid, and other public and private organizations
- **Connie Hedegaard**
  Chair of the KR Foundation, former Minister and EU Commissioner
- **Niels Due Jensen**
  Former CEO of Grundfos and former Chairman of Poul Due Jensen Foundation
- **Per Magid** (Vice Chairman)
  Lawyer, Rovsing & Gammeljord
- **Bjørn Nørgaard**
  Prof. Royal Academy of fine Arts, Guest Prof. China National Academy of Arts
- **Michael K. Rasmussen**
  Former Vice President, Brand in VELUX Group, private consultant

The Niels Bohr
International Academy

From the Director

The extraordinary large amounts of research funds that have been flowing to the Niels Bohr Institute in the past ten years led to instabilities and financial difficulties that had to be dealt with in the past year. The impact could be felt at every corner of the institute and also at the Niels Bohr International Academy (NBIA). To an outsider it must look paradoxical that while receiving more external research funds than ever before the Niels Bohr Institute could find itself in such financial difficulties. Here is not the place to try to answer the question of how this could come about, but it is important background for this annual report.

External research funding is absolutely crucial for the running of the NBIA. The major part of the funding comes from individual research grants to NBIA's young scientists. In the past year it is has been a pleasure to see the extraordinary success NBIA's young scientists have in this respect. In 2018, prestigious research grants such as a Villum Young Investigator Grant from the Villum Foundation, a Sapere Aude Starting Grant from Independent Research Fund Denmark, a Distinguished Associate Professor Fellowship from the Carlsberg Foundation, a large ITN grant from the EU, and a research grant from Independent Research Fund Denmark have allowed new research groups in hot topics to start up at the NBIA. Younger NBIA researchers distinguished themselves at both European and national levels: two EU Marie Curie Fellowships and a Carlsberg Foundation Postdoctoral Fellowship will support three young NBIA scientists over the next few years.

At the institutional level, the NBIA received its largest research grant ever in 2018. With the generous support of 35 MDKK from the Novo Nordisk Foundation the NBIA can now launch a new program in life sciences, building on the interdisciplinary environment of the NBIA and the proximity of strong research groups in both biological physics and biology. This grant will transform the NBIA over the coming years and we are already well underway with our new strategy in that direction.

A most important institutional grant of 10 MDKK came from the Aage and Johanne Louis-Hansen Foundation. This grant will allow for the hire of new Louis-Hansen Foundation Assistant Professors in open competition across all disciplines in the physical sciences. The possibility to hire young researchers solely based on their demonstrated excellence and potential for breaking new ground independently of their specific research area is absolutely essential for keeping the high level of excellence at the NBIA. In next year's report we will see some of the exciting consequences of this fabulous new opportunity.

While this report is going into press, it can also be mentioned that the NBIA has been fortunate to receive a 19 MDKK grant from the EU under the COFUND program. This EU grant will essentially allow us to double the contract years of young NBIA post-docs over the coming five years.

Poul Henrik Damgaard
2018

From the Chairman of the Board

From its inception in 2007, the goal of the Niels Bohr International Academy has been to support excellence in theoretical physics at the Niels Bohr Institute. The intention was to interpret "theoretical physics" as broadly as possible. This was to be done through an active program of post-doctoral fellows, senior visitors, and short-term guests. Continuing economic constraints at the NBI meant that this goal has remained an unrealized vision. Lacking adequate financial means of its own, the NBIA has been obliged to adopt an alternate strategy in which bright young scientists have been encouraged to seek external support for their own research and for the support of other post-docs. The good news is that this strategy has been extraordinarily successful. The continuing ability to attract truly significant funding from public and private sources provides a convincing indicator of the quality of the NBIA's young people. Unfortunately, this strategy has also meant that the intellectual focus has necessarily been more inward looking than we would like. Our desire to provide more visible benefits to the NBI as a whole has been deferred; it has not been forgotten.

As Poul Henrik Damgaard has described, the past year has seen a dramatic improvement in the economy of the NBIA. We are extremely thankful for the good advice and active help from the Director's Council that has contributed to this success. With a total of approximately 64 MDKK for the institutional support of the NBIA, we can look ahead to the coming decade with confidence. This success brings with it both promise and challenges. The promise is obvious. A significant fraction of these funds will support new Assistant Professor positions that will enable us to continue to attract that best and brightest young people to Copenhagen. Much of the remainder will be used to co-fund post-doctoral positions. Most importantly, we will now be able to begin the realization of the goal of broad support for theoretical physics. Some of these funds are explicitly designated for biological physics. It will now be possible to venture into areas not currently represented at the NBIA and even consider appointments in emerging fields of potential interest to the NBI. The challenge lies in the realization of this promise.

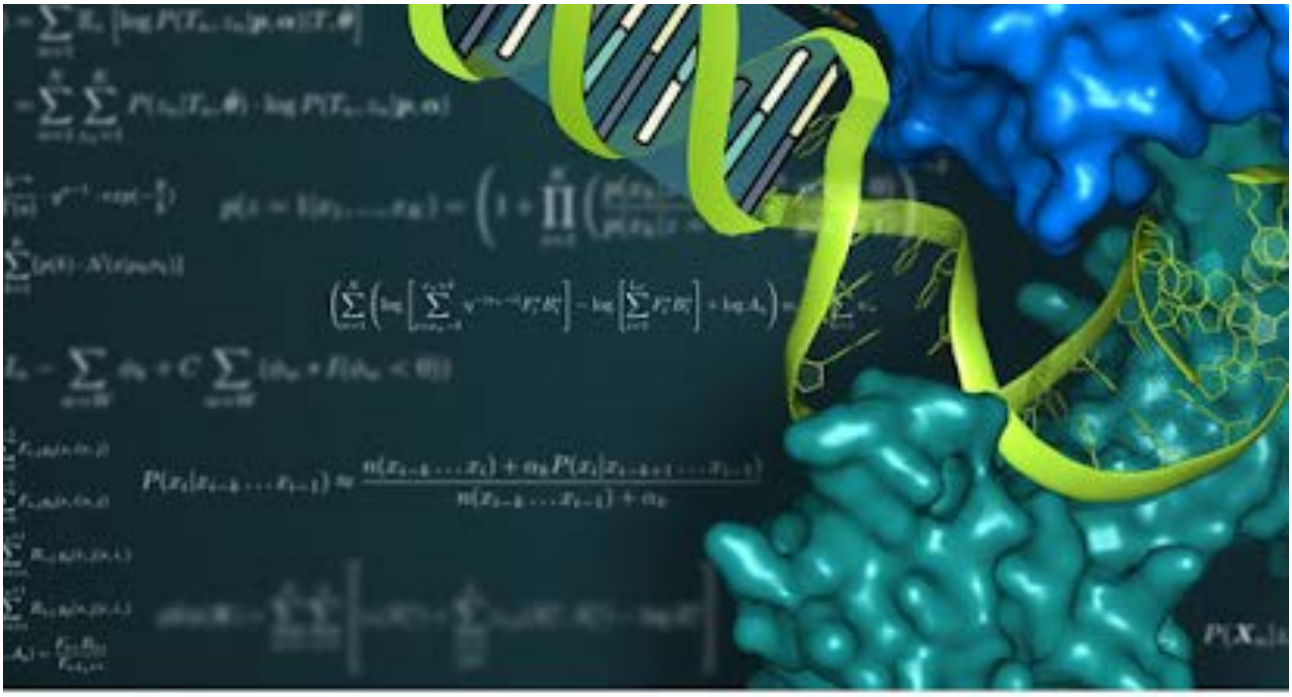
The wise use of these new and broader possibilities in both the selection of areas and the recruitment of young scientists will require considerable expertise. The staff and leadership of the NBIA will require advice and assistance to make optimal use of these new resources. In this process we will turn to our NBI colleagues and, not least, to the wisdom of the NBIA Scientific Board.

We look forward to both the promises and the challenges that these new resources present. We are excited by the prospect of being able to work directly towards the NBIA's primary goal of consolidating and extending the Niels Bohr Institute's historical record of excellence in theoretical physics. The future starts now!

Andrew Jackson
2018

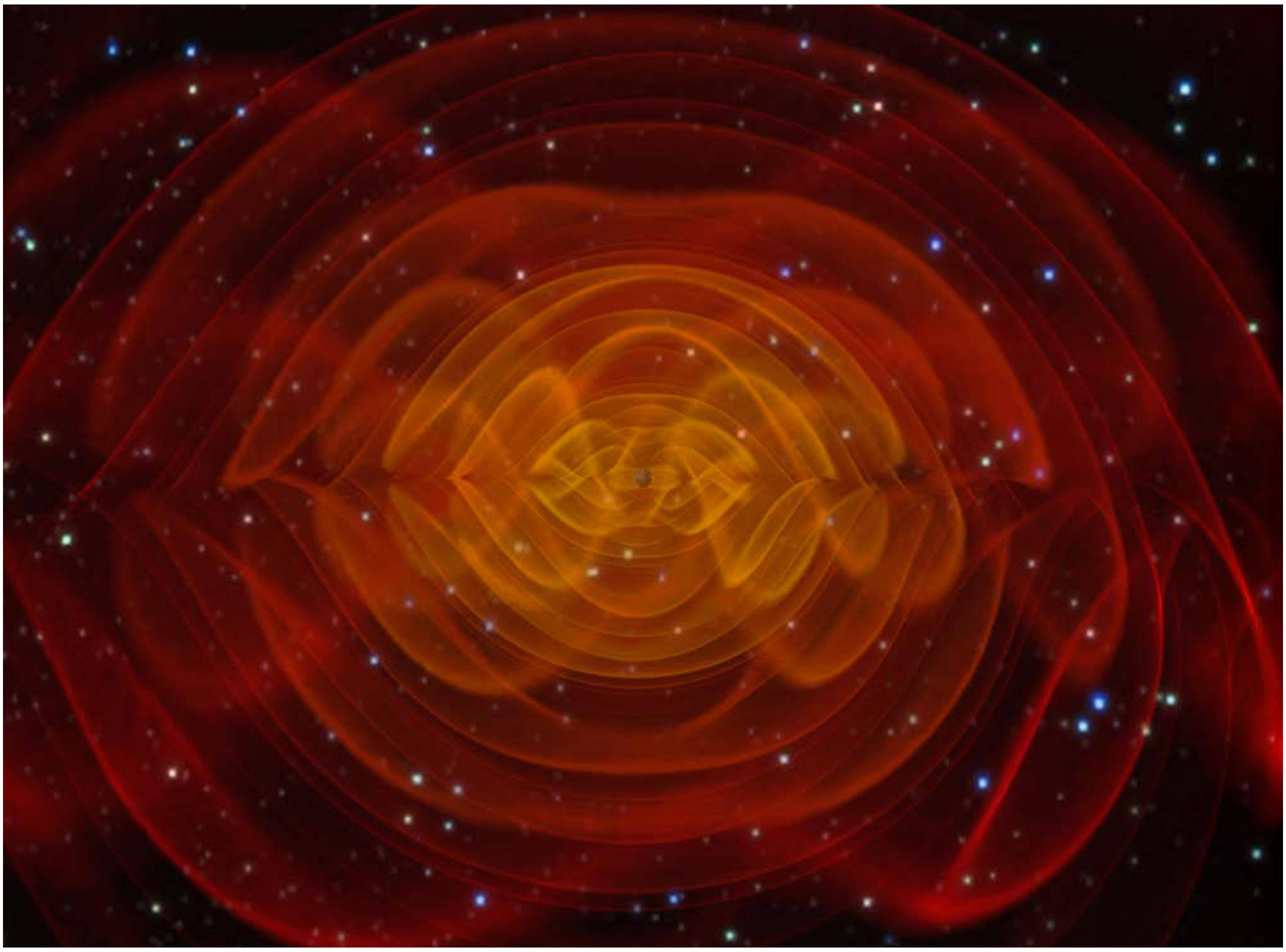
New Grant - Novo Nordisk Fonden

The biggest institutional grant to the NBIA in 2018 came from the Novo Nordisk Foundation. This grant of 35 MDKK aims at establishing up to five Novo Nordisk Foundation Assistant Professors, Novo Nordisk Foundation Associate Professors, or Novo Nordisk Foundation Full Professor at the NBIA. The new research directions should have *potential for relevance within life science research*. The time is ripe for this expansion into areas in life sciences that are bordering physics, and it has for several years been the ambition of the NBIA to again establish a stronghold in theoretical biological physics (one of the first topics of research when the NBIA was founded in 2007). The large grant from the Novo Nordisk Foundation takes this to a much larger scale with much more massively supporting research at the NBIA that potentially may have large impact on the life sciences. For the NBIA new areas that naturally come to mind are, apart from biological physics and the more general area of biocomplexity, systems biology, computational biology, modern genetic studies and even close contact to laboratory work in the biological sciences. All of these are areas where physics-driven methods may provide new and groundbreaking results. In addition to making these new fixed-term hires the NBIA will provide the interdisciplinary atmosphere, the close contact with both theoretical physicists and mathematicians, and the steady flow of leading scientists that visit the NBIA every year. The strategic decisions on the precise implementation of these new and bold ideas are currently underway and the first Novo Nordisk Foundation Assistant Professor (Amin Doostmohammadi, currently Independent Research Fellow at the Rudolf Peierls Centre for Theoretical Physics at the University of Oxford) has already been selected. Amin Doostmohammadi will start his appointment in the fall of 2019. In the spring of 2020 he will be joined for three months by Novo Nordisk Foundation Visiting Professor Julia Yeomans from Oxford University. More appointments will be made as we identify outstanding candidates in the coming years.



New grant - Louis-Hansens Fond

In 2018 the Aage and Johanne Louis-Hansen Foundation provided the NBIA with a crucial grant of 10 MDKK to hire Louis-Hansen Assistant Professors on 5-year fixed-term contracts at the NBIA. The grant is totally flexible and will allow the NBIA to seek the brightest young scientists in all areas of the physical sciences. This strategy is at the heart of the foundation of the NBIA and it opens up the opportunity to strike out in brand-new research directions that are not currently pursued, neither at the NBIA nor at the Niels Bohr Institute itself. The overarching principle when making these new appointments will thus be to let the individual talent of applicants be the decisive criterion while simultaneously hoping for a renewal of research topics. Fortunately, these two strategic points of view often merge together, demonstrating that the best scientists move towards areas that are most promising. No one has better noses for this than young scientists who have had a PhD-education from some of the best universities in the world, followed by some post-doctoral years where they have been able to liberate themselves from their thesis topics and thus defined their own research directions. These are scientists who can drive the NBIA in the coming years and who we now invite to join us. The generous grant from the Louis-Hansen Foundation is a most important milestone in the short history of the NBIA and it is bound to leave an important mark on the research done here.



New NBIA Postdoctoral Program
EU COFUND — INTERACTIONS

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

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

These top institutions have been chosen for their excellence in research, for their existing strong ties to the NBIA, for their breadth in theoretical physics, and for their wide distribution both geographically and in terms of science culture. A formalized, structured and long-term collaboration with these partners is of immense importance for the development of the fellows and the overall success of the program, literally taking the concept behind INTERACTIONS to the top European level. It is a unique opportunity for fellows to be introduced to different research environments at the highest level, to build personal networks within Europe, and to intensify long-term collaborations between these institutions. This will increase network and research opportunities for the fellows, and at the same time bring our institutions much closer together at the European level. The INTERACTIONS programme links together the pinnacles of physics research across Europe, benefitting fellows, institutions and European research alike.

NBIA Research

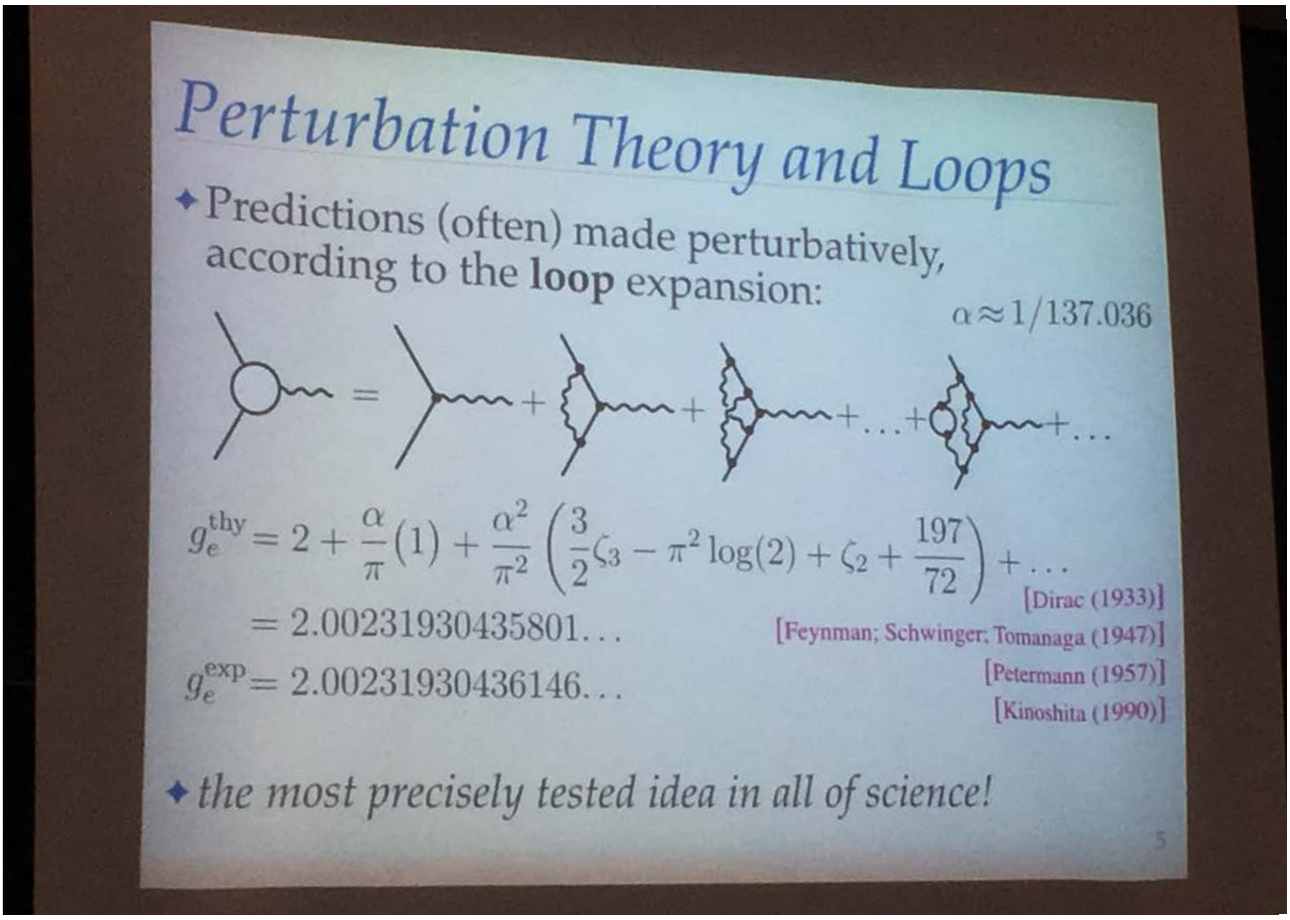
Theoretical Particle Physics

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.

Amplitudes are computed in what is known as perturbation theory. One starts with a rough approximation ('tree level') and then gradually builds up a sum of new terms ('loops'). The most powerful methods for such computations have so far mostly focused on establishing compact expressions for the the integrands of such amplitudes. Work at the NBIA is now moving strongly ahead on how to integrate these expressions. This work at the NBIA has interesting ramifications in mathematics and indeed proceeds hand in hand with new developments in pure mathematics. The NBIA group has been expanding greatly into this area in 2018 and the number of publications, visitors, and seminars on this topic have risen dramatically.

A completely 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. Work on quantum amplitudes suddenly finds new and unusual applications in the urgently needed analytical approximations to the scattering and bound state problem of two heavy masses (such as two black holes). The development has been long underway, but it received new momentum with an NBIA publication linking classical general relativity to scattering amplitudes in 2018. 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 classical gravity. This topic will play a increasingly big role for the NBIA group in the coming years.

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 has been leading this program and continues to push it forward.



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

A remarkable interplay between string theory and quantum field theory has led to the invention of an entirely new method for calculations of scattering amplitudes known as the Cachazo-He-Yuan (CHY) formalism. Recent developments in this direction at the NBIA have revealed a novel factorization property of such scattering amplitudes at tree level from what is known as a 'double cover'. Work at the NBIA now explores this new direction as well as the application of the CHY-formalism to the classical physics of scattering in gravity.

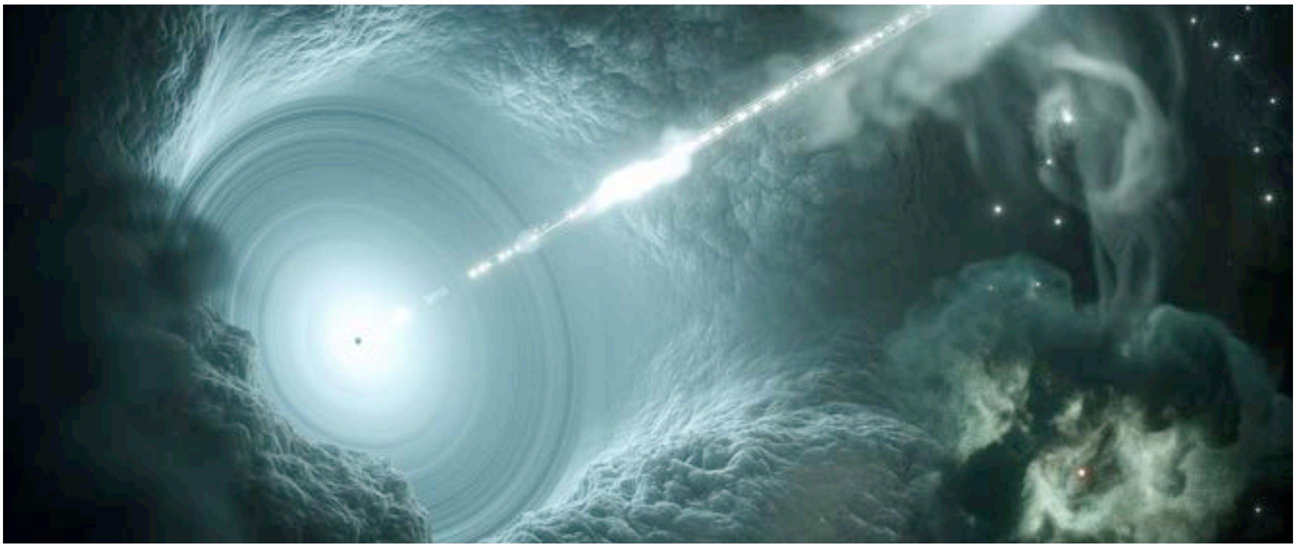
Astroparticle Physics & Cosmology

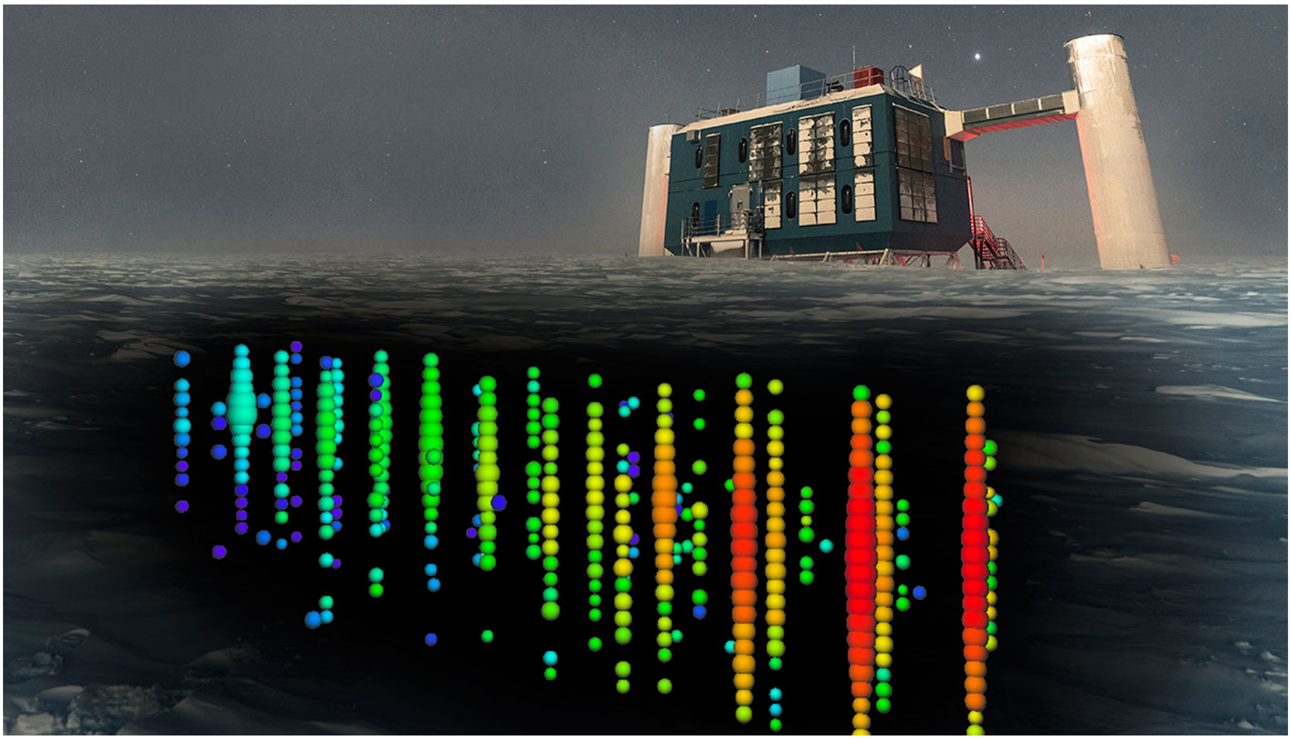
The Astroparticle Physics Group at the Niels Bohr International Academy is interested in the rich interface between astrophysics, cosmology and fundamental physics. This is in area that has become more and more exciting in recent years, given the wealth of data coming from various instruments observing photons, cosmic rays, neutrinos and gravitational waves. These "multi-messenger" observations allow to address fundamental questions such as the nature of dark matter and dark energy, the physical mechanism behind primordial inflation, the origin of the baryon asymmetry of the Universe, or the origin of extremely energetic particles and their acceleration mechanisms.

Our group maintains a strong collaboration with the IceCube group at the Discovery Center. On September 22nd, 2017 IceCube observed a high-energy muon that entered the detector from a direction a few degrees below the Horizon (see illustration to the right). These "up-going" events are unlikely the result of known backgrounds and herald the arrival of a high-energy neutrino from a cosmic source. The NBIA group is involved in vetting these special events, before they are sent out as neutrino alerts to partner observatories to find hints of electromagnetic emission from the same part of the Universe. After one week the Fermi satellite reported that this neutrino alert was spatially coincident with a known γ-ray source, the blazar TXS 0506+056, that was undergoing a period of enhanced γ-ray emission, a so-called "flare".

A blazar is a giant elliptical galaxy that hosts a super-massive black hole at its core that easily outweighs one million copies of our Sun (see illustration on next page). A signature feature of blazars is that twin jets of light and elementary particles are emitted from the poles along the rotation axis of the black hole. TXS 0506+056 is located just off the left shoulder of the constellation Orion and is an estimated 3.7 billion light years from Earth.

The chance correlation of the neutrino alert with the γ-ray source is at the level of 3σ and provides evidence that the blazar was responsible for the neutrino-induced event. Looking through archival data, IceCube was also able to identify a period in 2014/15, where a prolonged outburst of 13±5 neutrinos was already visible from this source. A chance correlation of this neutrino outburst can be excluded at a confidence level of 3.5σ. Together with the earlier observation, this provides compelling evidence that this blazar is a source of high-energy neutrino.





The observation of high-energy neutrinos from blazars helps to resolve a more than century-old riddle about which sources in our Universe are capable of producing high-energy cosmic rays. We now know that blazars play a role in this, but we are still far away from a comprehensive model.

The extreme energies of high-energy neutrinos and the very long travel distance from their sources allow to probe physics beyond the Standard Model. We showed that invisible neutrino decay might help to resolve tensions in present IceCube neutrino data. We also showed that the neutrino flavor composition observed at Earth is constrained by unitarity bounds and serves as an additional measure for non-standard neutrino interactions.

Another mystery in astroparticle physics is the origin of ultra-high energy (UHE) cosmic rays (CRs), which reach energies 10 million times higher than those energies achievable at the Large Hadron Collider. A key issue is the propagation and acceleration of charged particles in astrophysical plasmas. Our group was involved in laser experiments conducted at the LULI laser facility at École Polytechnique (France). These experiments allow to analyze particle propagation in laser-produced turbulent plasmas. We also analyzed UHE CR arrival directions observed with the Auger Observatory in Agentina to study the presence of large- and medium-scale anisotropies. An indirect probe of UHE CR models are cosmogenic neutrinos produced during CR propagation. Our group made model predictions and studied the feasibility of their detection in IceCube or future large-scale radio arrays like GRAND.

The recent discovery of gravitational waves has opened new vistas onto the early universe. We showed that particle physics hidden sectors can be constrained with observations of the stochastic background of primordial gravitational. The recently observed black hole mergers has led to speculations about their origin to be primordial. We showed that mechanisms to generate primordial black holes are significantly constrained by observations of cosmic microwave background spectral distortions and bounds from pulsar timing arrays.

We also studied bulk flows in the local Universe that can be estimated from recent galaxy catalogues. Our studies indicate that this flow is faster and extends to larger scales than a typical ΛCDM observer. This has consequences for the measurement of cosmic acceleration inferred from type Ia supernova surveys and reduces the statistical significance of dark energy in the data.

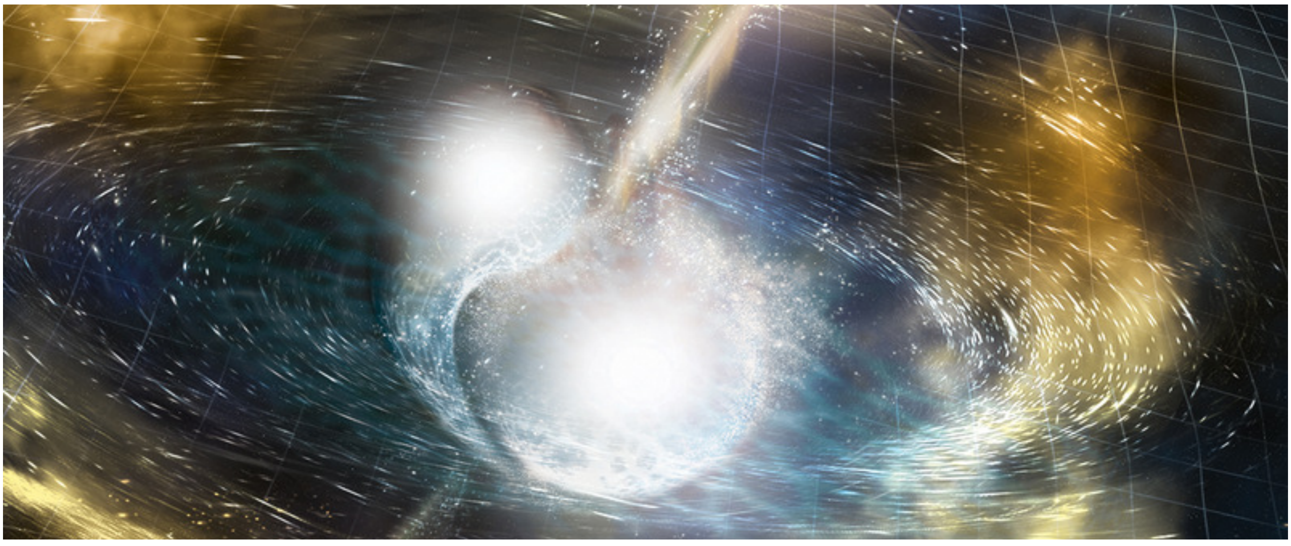
Neutrino Astrophysics

The Neutrino Astrophysics (AstroNu) group at NBIA aims at using a weakly interacting elementary particle, the neutrino, as messenger of poorly understood extreme astrophysical phenomena. Neutrinos are copiously produced in a number of astrophysical environments, ranging from the Sun to the most extreme transients and play a crucial role in powering those sources. The AstroNu group investigates how neutrinos affect the dynamics of these phenomena and explores what can be learnt on standard and non-standard properties of neutrinos through astrophysical sources and terrestrial experiments.

In 2018, the AstroNu group maintained strong tights with scientists at the Max Planck Institutes for Physics and Astrophysics through the Collaborative Research Center: Neutrinos and Dark Matter in Astro- and Particle Physics sponsored by the Deutsche Forschungsgemeinschaft. Moreover, thanks to the partnership between NBIA and the Academia Sinica in Taiwan, Dr. Wu (former postdoc of the AstroNu group) became affiliated member of our group, and we have ongoing collaborations. In summer 2018, we successfully hosted the “NBIA & DARK PhD School: Multi-Messengers from Compact Sources” in Copenhagen.

Although neutrinos have been studied since long time now, some of their properties remain to be unveiled. For example, the mass ordering of the neutrino eigenstates is still unknown as well their possible non-standard interactions. Various neutrino detectors are currently collecting data for discovering such interactions. Moreover, the Long Baseline Neutrino Facility and the Deep Underground Neutrino Experiment are being planned in the United States to finally pinpoint the unknown neutrino properties. The AstroNu group worked on improving our understanding and interpretation of the neutrino conversion probabilities in existing and upcoming experimental facilities and to discover signatures of New Physics in the neutrino sector.

Another research direction pursued by the group in 2018 concerns the possibility of characterizing the properties of the core-collapse supernova population through neutrinos. In fact core-collapse supernovae originate from the death of massive stars and are extremely dense in neutrinos; neutrinos are produced in the core of the star and can be therefore used as probes of the stellar dynamics. By employing three-dimensional hydrodynamical simulations of core-collapse supernovae with sophisticated neutrino transport, we pointed out that neutrinos can be stellar gyroscopes.



The diffuse flux of neutrinos coming from all supernovae exploding somewhere in the Universe has not been detected yet, but its detection is now within reach given the enrichment of the Super-Kamiokande detector with Gadolinium that will dramatically improve the signal over noise ratio. We investigated the possibility of constraining global properties of the supernova population, such as the rate of supernovae and the fraction of supernovae evolving into black holes with next-generation neutrino detectors. These constraints will be competitive with and complementary to the ones placed by electromagnetic surveys.

The AstroNu group also focused on exploiting the increasing amount of high energy neutrino events detected by the IceCube Neutrino Telescope to better understand the yet mysterious origin of these neutrinos as well as constrain unknown properties of neutrinos and their sources. For example, IceCube currently detects two event topologies (so-called tracks and cascades); experimental data hint towards a possible tension between the spectral features of the two data sets. By employing the possibility that neutrinos decay in invisible particles while propagating on their way to Earth, we have been able to explain the apparent discrepancy in the data. At the same time, by using the IceCube neutrino data, we placed an independent constraint on the neutrino decay lifetime.

The energy spectrum observed by the IceCube Neutrino telescope shows an excess of neutrino events in the region around 100 TeV. It is very difficult to explain this excess through standard production mechanisms occurring in astrophysical sources while keeping into account multi-messenger data. Hence, hidden cosmic sources (i.e., sources that cannot be observed electromagnetically, but do emit neutrinos) were proposed as a solution. We found that a self-consistent modeling of the neutrino production in hidden sources does not allow to explain the excess of neutrino events contrarily to what previously reported in the literature. In parallel, the AstroNu group also adopted the high-energy neutrinos detected by IceCube to constrain the unitarity of the neutrino mixing and the poorly known long-range interactions.

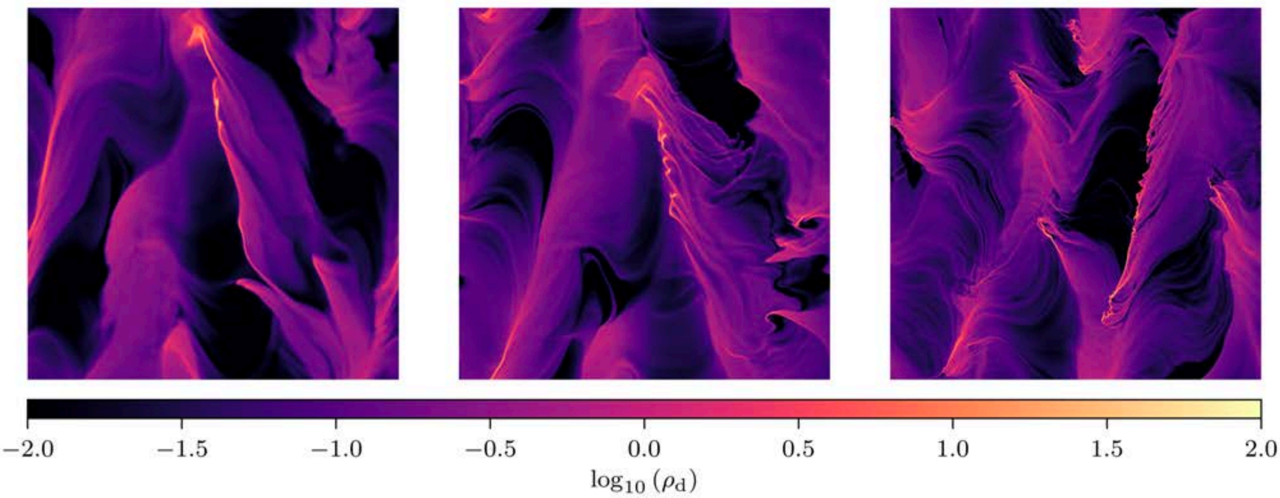
The origin of cosmic rays remains very mysterious. Upcoming radio-array neutrino facilities could help to finally unravel the origin of these particles as well as allow to explore the neutrino energy distribution at ultra high energies for the first time. The AstroNu group has been involved in defining the science goals of the next-generation neutrino experiment GRAND. For example, we showed that the detection of ultra-high-energy neutrinos in GRAND could constrain the yet unknown composition of cosmic rays as well as the redshift evolution of their sources.

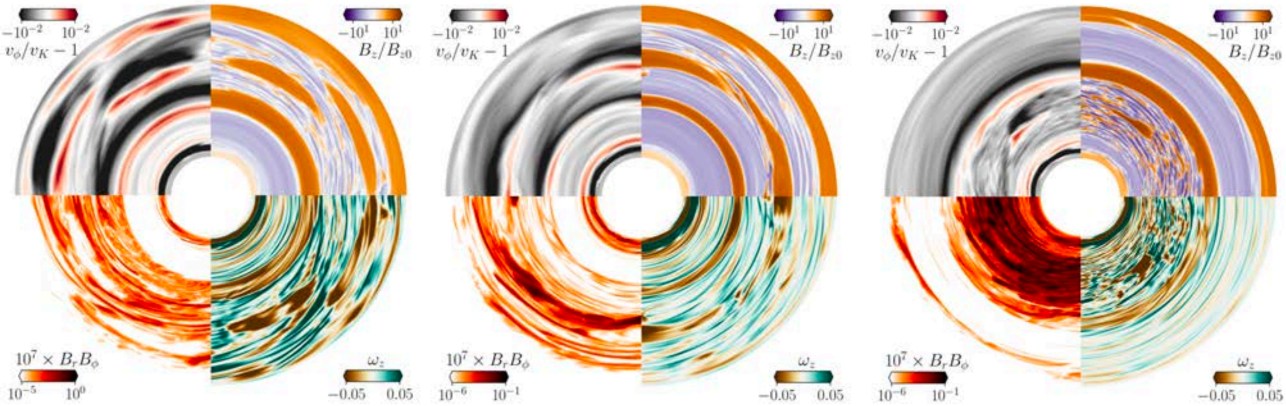
Theoretical Astrophysics

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.

Imaging of the dust continuum emitted from disks around nearby protostars reveals diverse substructure. In recent years, theoretical efforts have been intensified to investigate how far the intrinsic dynamics of protoplanetary disks (PPDs) can lead to such features. In this context we have continued the development several lines of work in order to build 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.

We developed an asymptotically and unconditionally stable numerical method to account for the momentum transfer between multiple species. Momentum is conserved to machine precision. Aimed at studying dust dynamics, we implemented this numerical method in the publicly available code FARGO3D being developed by group members. To validate our implementation, we developed a test suite for an arbitrary number of species, based on analytical or exact solutions of problems related to perfect damping, damped sound waves, shocks, local and global gas-dust radial drift in a disk and, linear streaming instability. In particular, we obtained first-order, steady-state solutions for the radial drift of multiple dust species in protoplanetary disks, in which the pressure gradient is not necessarily small. We additionally presented non-linear shearing-box simulations of the streaming instability and compare them with previous results obtained with Lagrangian particles. Carrying out successfully a large number of tests, we showed that our scheme is suitable, and very robust, to study the self-consistent dynamics of several fluids. In particular, it can be used for solving the collisions between gas and dust in protoplanetary disks, with any degree of coupling. These capabilities are critical in order to investigate a wide range of phenomena in dusty protoplanetary disks, including dust growth, dust and planetesimal dynamics and, ultimately how planets form.





Turbulence in the realm of non-ideal magnetohydrodynamics (MHD) is one candidate for explaining the generation of zonal flows, which can lead to local dust enhancements. Adopting a radially varying cylindrical disk model, we performed 3D non-ideal MHD simulations aimed at studying self-organization induced by the Hall effect in turbulent disks. To this end, we incorporated new modules into the NIRVANA-III and FARGO3D MHD codes developed by group members. We moreover included dust grains, treated in the fluid approximation, in order to study their evolution subject to the emerging zonal flows. In the regime of a dominant Hall effect, we robustly obtained large-scale organized concentrations in the vertical magnetic field that remained stable for hundreds of orbits. We demonstrated that the emerging features are capable of accumulating dust grains for a range of Stokes numbers. Our study can help us understand recent Atacama Large Millimeter Array observations, which have revealed the presence of large scale structures in the dust distribution in several protoplanetary disks.

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. Throughout the year, we continued our close collaboration with 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. 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.

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. 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.

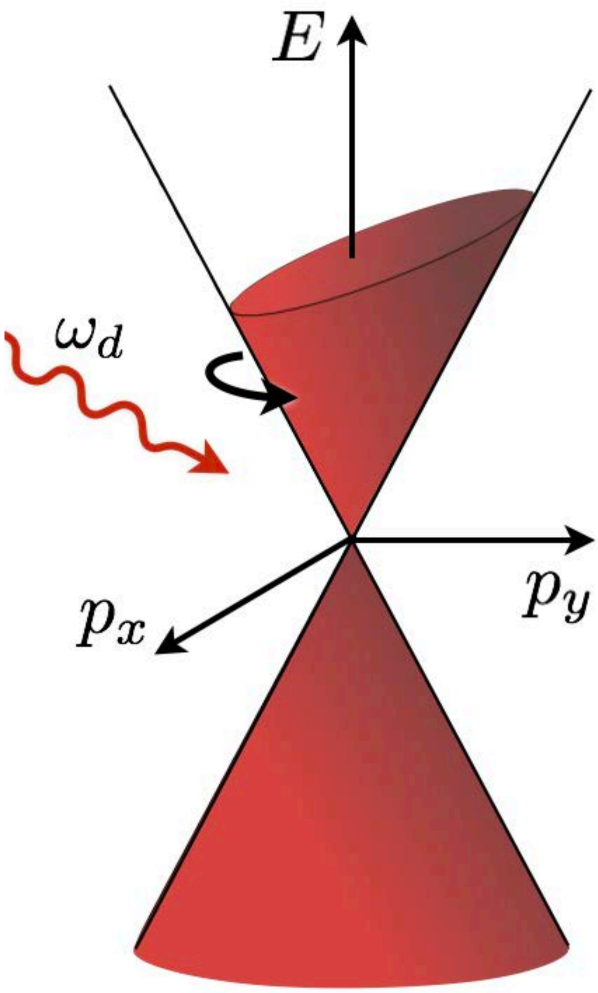
Group members also worked on several key problems in modern astrophysical fluid dynamics. In particular, we studied the dynamics of magnetorotational instability (MRI) turbulence with a net vertical field in a local disk model. Analyzing the turbulence dynamics in Fourier space, we identified three types of active modes that define its characteristics: (i) the channel mode, (ii) the zonal flow mode and (iii) the rest (parasitic) modes, which are governed by the interplay of the linear and nonlinear processes. The former consist of disk flow nonmodality modified classical MRI, while the main nonlinear process is the transfer of modes over wavevector angles—the transverse cascade. The channel mode exhibits episodic bursts supplied by MRI, while the nonlinear processes oppose this, draining the channel energy and redistributing it to the rest modes. The zonal flow is fed by nonlinear interactions of the rest modes.

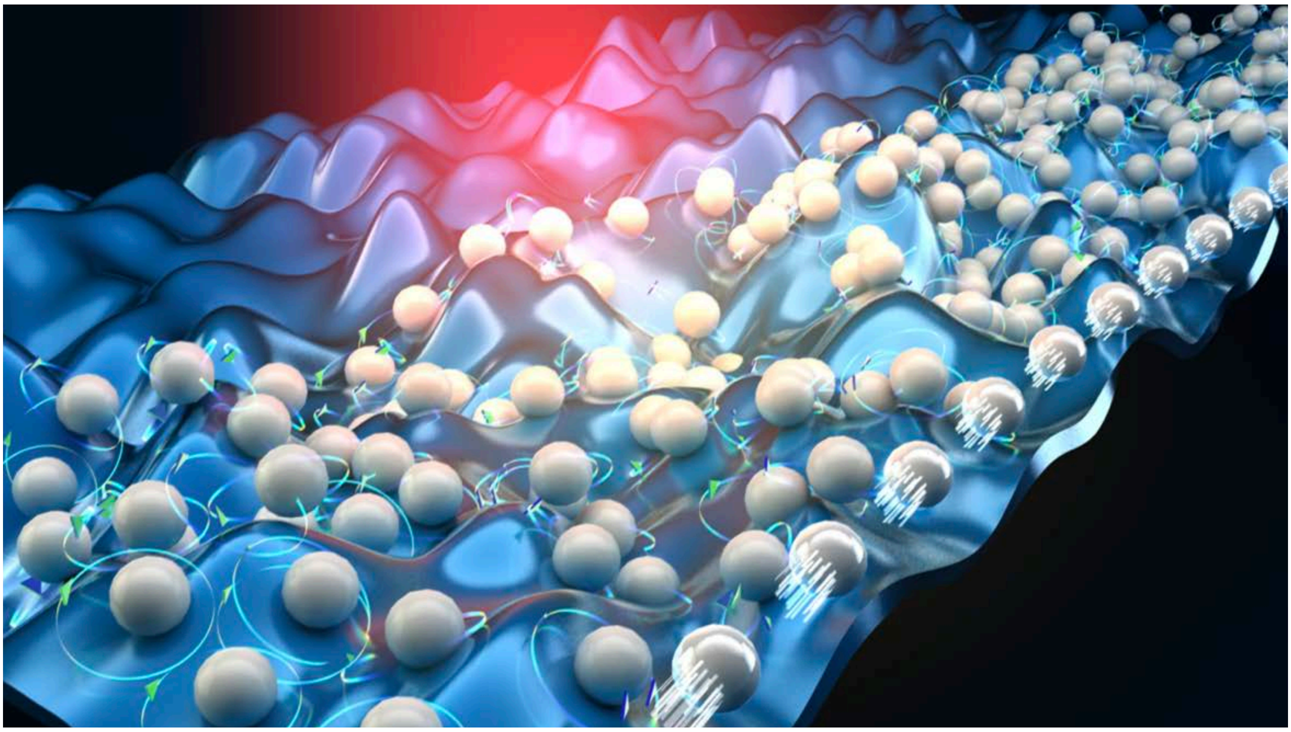
Condensed Matter Physics

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.

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, they system's Hall conductance takes on a precisely quantized value, which is equal to an integer or simple rational fraction times a combination of fundamental constants (the electron charge and Planck's constant). What is so amazing about this phenomenon is that the quantization of this macroscopically measurable quantity is accurate to better than one part in one billion, independent of sample size and shape, as well as material composition, and survives in the presence of all of the "dirt" that inevitably permeates real-world solid state systems. Due to the exquisite precision of this effect, the quantized Hall conductance is now used as a measurement standard for the definition of resistance.

From a fundamental point of view, the robustness of the quantized Hall effect arises from a beautiful mathematical (topological) structure of the quantum mechanical wave function of the electrons in the system. This theoretical realization spurred a worldwide effort to seek out additional types of robust phenomena that could support a similar level of "topological protection." 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 comprises an important piece of our research in condensed matter theory at NBIA. In 2018 we achieved several key results in this area, wherein we have described new models and experimental platforms for realizing topological states, as well as new theoretical tools for analyzing certain topological phases that have until now eluded numerical simulation beyond the few-particle level.





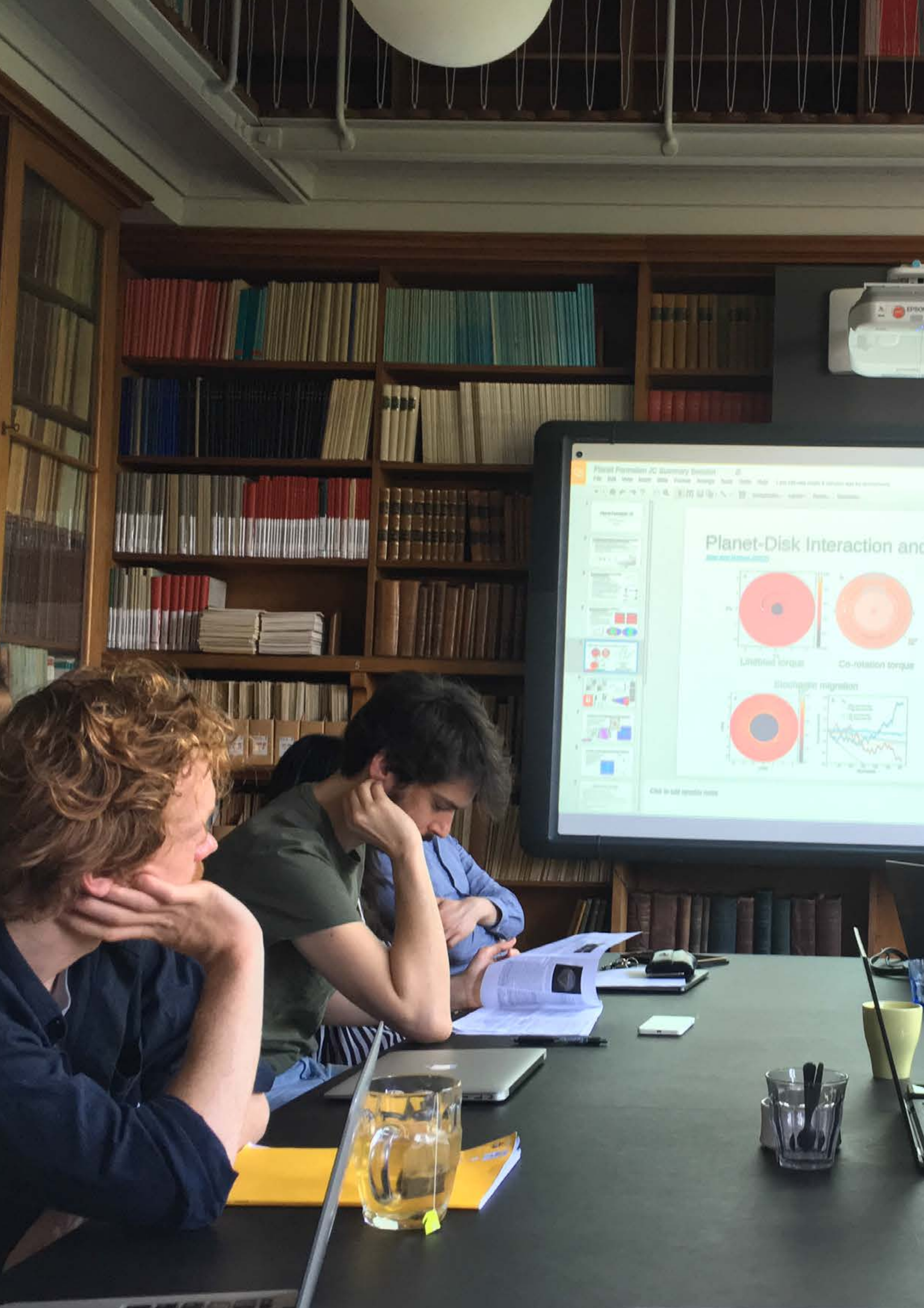
One of the major aims of our research on quantum dynamics is to uncover new ways of dynamically engineering material properties through non-equilibrium driving. In particular, we are field leaders in the area of topological phenomena in periodically driven, or "Floquet" systems. Over the past 10-15 years, experimentalists have made great progress in developing new tools for probing and controlling the dynamics of solid state and cold atomic quantum many-body systems, e.g., using lasers and strong microwave fields. In 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, Technion Institute of Technology, and the Weizmann Institute of Science.

Finally, at NBIA we are pioneering the investigation of novel collective modes of quantum and hybrid materials. This work is both of fundamental interest, and may lead to applications. In particular, in 2018 we laid out a new paradigm of spontaneous symmetry breaking in the collective dynamics of non-equilibrium many-body systems. This work arose out of a key conceptual advance, in which we pointed out that oscillating internal electric fields in electronic systems driven out of equilibrium could replace the external laser or microwave driving fields that previous studies had shown can modify the electronic properties of materials. In the new setting that we propose, these underlying material properties take on their own internal dynamics, coupled to the motion of electrons in the system. This coupling forms the basis for intriguing new nonlinear collective phenomena in electronic systems. We have developed a simple proof of concept model to illustrate this phenomenon, and are currently working with experimentalists to facilitate its observation in graphene plasmonic devices while also seeking additional platforms and manifestations of this novel type of nonlinear collective behavior.

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 NBIA has a natural place in this exciting network of quantum information theory activities in the Copenhagen. Located in the buildings where the foundations of quantum mechanics were discovered a century ago, quantum scientists working in any direction under that more general heading expect to find modern quantum physics in the buildings. Having to rely on external funding, the NBIA's own quantum computing group wound down its activities during 2018. Fortunately, two Visiting Professors, Si-Hui Tan from Singapore University of Technology and Design, and IBM Senior Scientist Charles Bennett kept up activities in this field through the year. Much activity surrounded Charles Bennett who held the Simons Visiting Professor position during the spring of 2018: a workshop focused on the new and fascinating interplay between traditional quantum information theory and aspects of what is known of holography, string theory and quantum gravity. Later a Master Class brought world-leading experts to Copenhagen for a school organized jointly with QMATH at the Mathematics Department. Charles Bennett also delivered a unique series of lectures of quantum information theory during this program. Set to visit the NBIA again in the fall of 2019, we can look forward to an exciting three-month period with focus on quantum encryption and quantum computation.


Planet-Disk Interaction

NBIA Staff

Faculty

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

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

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 involves 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 starts 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.

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

Subir Sarkar has been Niels Bohr Professor at NBIA since 2013 and is 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. Irene leads the AstroNu group at NBIA with focus on these subjects.

Junior Faculty

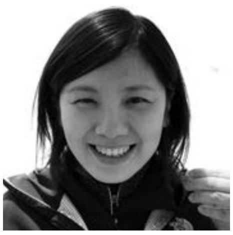
Markus Ahlers received his Ph.D. in Theoeretical Particle Physics from the University of Hamburg (DESY) in 2007. He has been a Postdoc in Oxford and Stony Brook before becoming a John Bahcall Fellow for Neutrino Astronomy at the University of Wisconsin-Madison. He joined NBIA in 2017 as an Assistant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

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 2011-2104 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 as 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 modelling the turbulent interstellar medium, the large-scale galactic dynamo, and magnetic turbulence in protoplanetary 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.

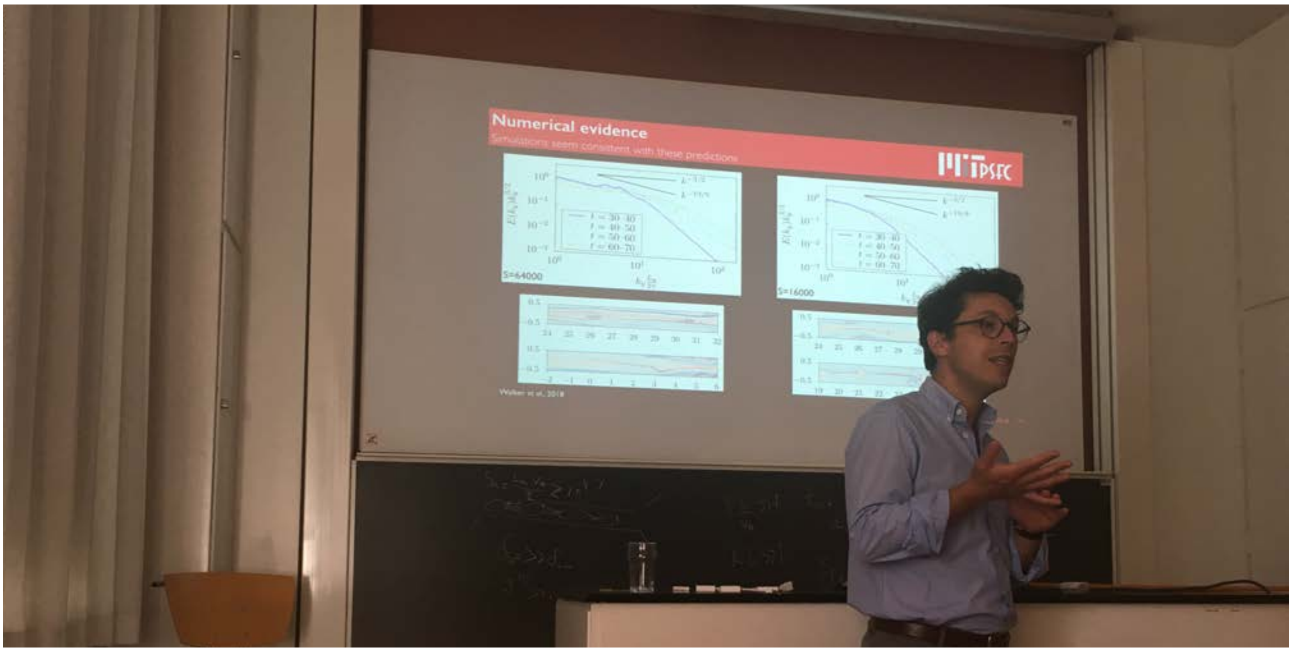
Michael Kastoryano joined NBIA in 2014 as a Carlsberg Postdoctoral fellow and as a Villum Young Investigator. Michael earned his MSc in Physics at Yale University in 2008, and his PhD in Quantum Information Theory at the Niels Bohr Institute in 2011. Before joining NBIA he was a Humboldt fellow at the 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. He works mainly on quantum information motivated questions in many body physics. Recently his focus has shifted towards topologically ordered systems and topological computation.

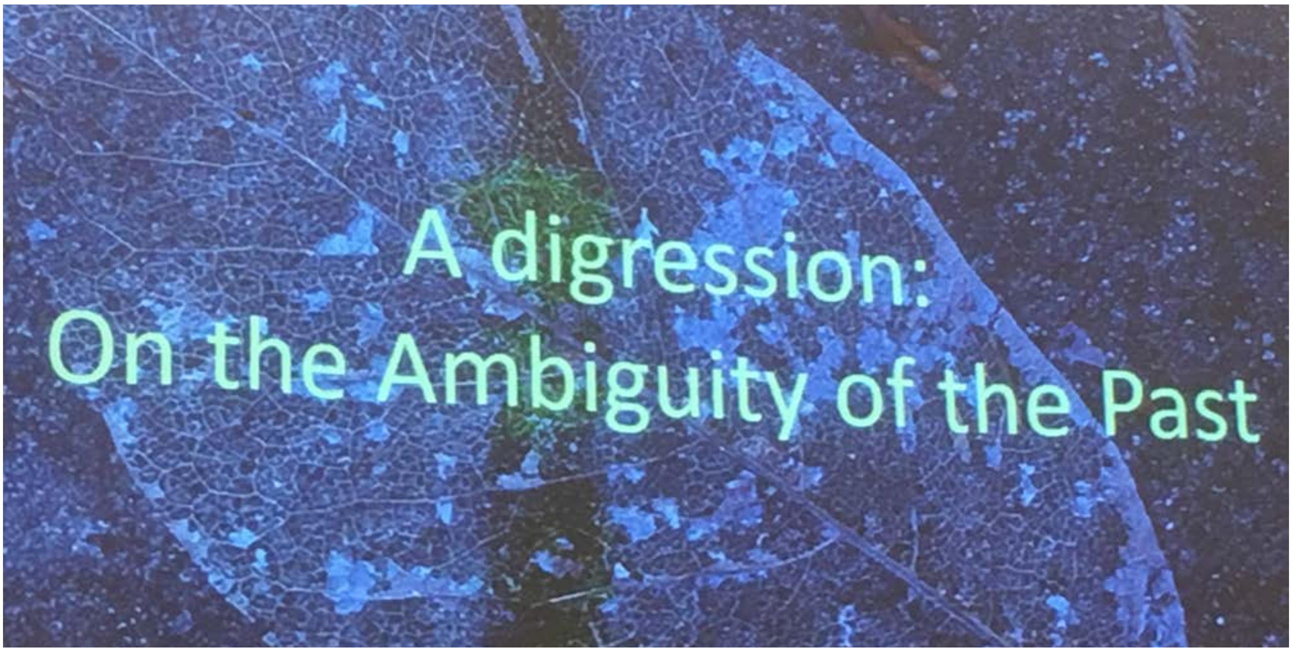
D. Jason Koskinen is an Assistant Professor and local group leader for the IceCube Neutrino Observatory. From 2009-2013 he was a postdoc at the Pennsylvania State University, with a brief trip to the South Pole for IceCube calibration studies. His focus is on neutrino oscillations, further physics beyond 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 ofBerlin (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.


Numerical evidence
Simulations seem consistent with these predictions


A digression:
On the Ambiguity of the Past


Secure Quantum Computations
Si-Hui Tan
SUTD, EPD/IDC

Postdoctoral Fellows

Ajit C. Balram's research interests are in the 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.

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

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

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 PhD at U.C. Davis in 2015. 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.

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

George Mamatsashvili received PhD in 2011 from the University of Edinburgh, UK, in Astrophysics. He joined NBIA as Marie Curie Fellow in July 2018 after postdoctoral positions at Turin Astrophysical Observatory, Italy, and Helmholtz Center Dresden, Germany, with a Humboldt Fellowship. George's research focuses on dynamics and evolution of astrophysical disks and shear flows. At NBIA, he works on magnetorotational turbulence in disks, applying new tools to study its dynamics in Fourier space.

Shashank Shalgar did his Ph.D. from Northwestern University in 2013. After which he was a postdoctoral fellow at the University of New Mexico and Los Alamos National Laboratory. His research is primarily focused on neutrino physics in extreme astrophysical environments and the early Universe. He is especially interested in the non-linear evolution of the neutrino flavor that occurs in these astrophysical environments..

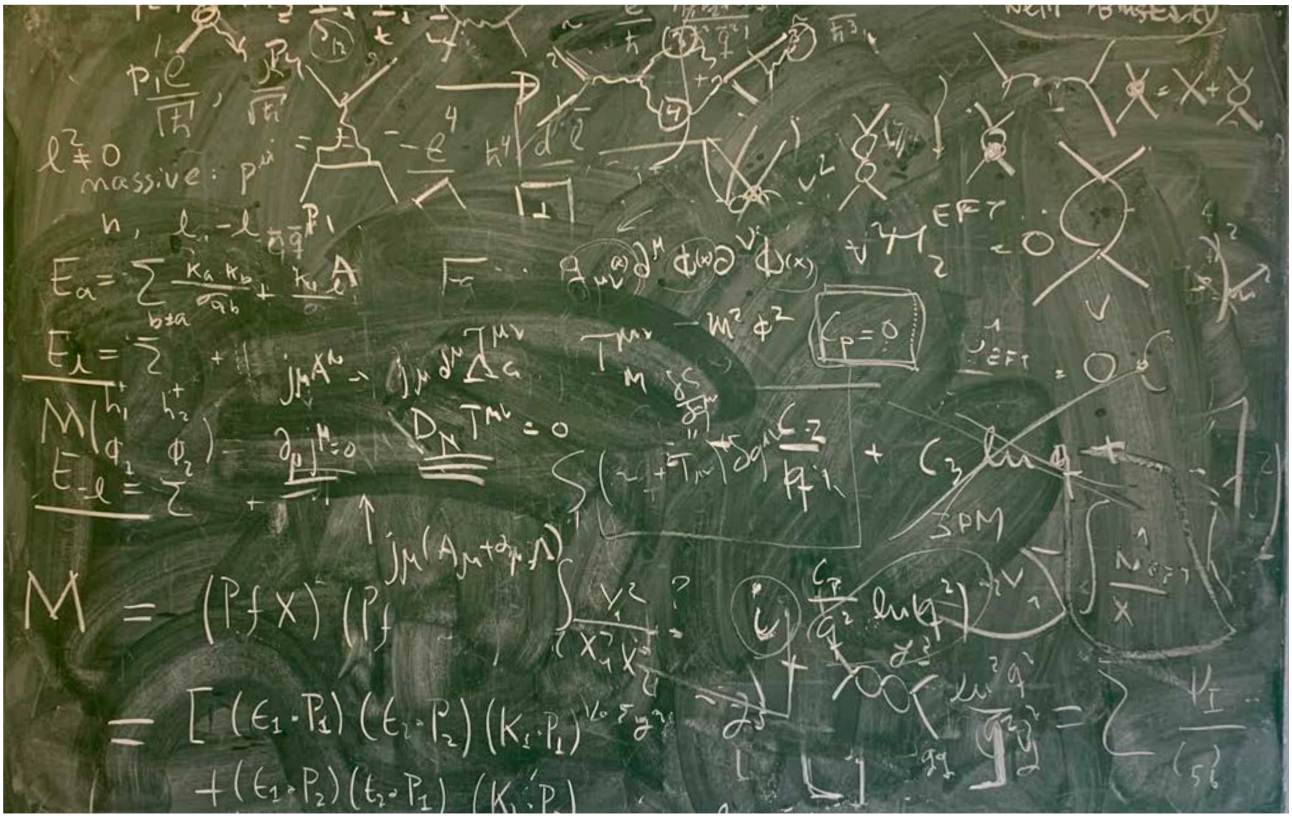
Farrukh Nauman obtained his PhD at the University of Rochester in 2015. His research focuses on turbulence in astrophysical fluids and plasmas with a particular emphasis on understanding the origin, survival and influence of large scale magnetic fields in accretion disks. This involves both theoretical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

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

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.

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.

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.



PhD Students

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

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.

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

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.

PhD Students

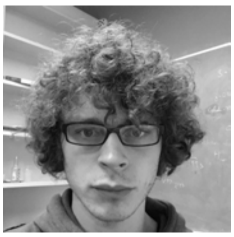
Gopakumar Mohandas graduated with an M.Sc. in Physics at the Chennai Mathematical Institute. Gopakumar joined the Theoretical Astrophysics group at the NBIA in the fall of 2013. He currently works, with his principal supervisor Martin Pessah, on analysing the stability and dynamics of accretion disks using magneto-hydrodynamic theory. He has also worked on the stability of charged particle orbits in planetary magnetospheres and on modeling exoplanetary atmospheres.

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

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

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.



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

MSc Students

Abdurrahman Barzinji — Astroparticle Physics
Peter Daly — Astroparticle Physics
David Damgaard — Theoretical Physics
Gregory Gold — Astroparticle Physics
Lea Halser — Astroparticle Physics
Taus Munk Hansen — Astroparticle Physics
Henrik Jessen Munch — Particle Physics
Solvej Knudsen — Theoretical Physics
Stavros Mougiakakos — Astroparticle Physics
Klaes Møller — Astroparticle Physics
Charlotte Rosenstrøm — Astroparticle Physics
Matt Steinberg — Quantum Information
Johannes Sørensen — Particle Physics
Loui Wentzel — Astroparticle Physics

Visiting Professors

Charles Bennett is Simons Visiting Professor this fall. He is a Senior Research Scientist at IBM. He co-discovered the concept of quantum cryptography and is one of the founding fathers of modern quantum information theory.

Alex Schekochihin is Simons Visiting Professor during the fall. He is Professor of Theoretical Physics and Fellow of Merton College at Oxford University. He is particularly well known for his work on plasma physics and astrophysics.

Yuri Fujii is Assistant Professor at Nagoya University. Her research interests span several fundamental aspects of protoplanetary and circumplanetary disks dynamics, including the formation and evolution of planets and moons.

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

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.

Visitors

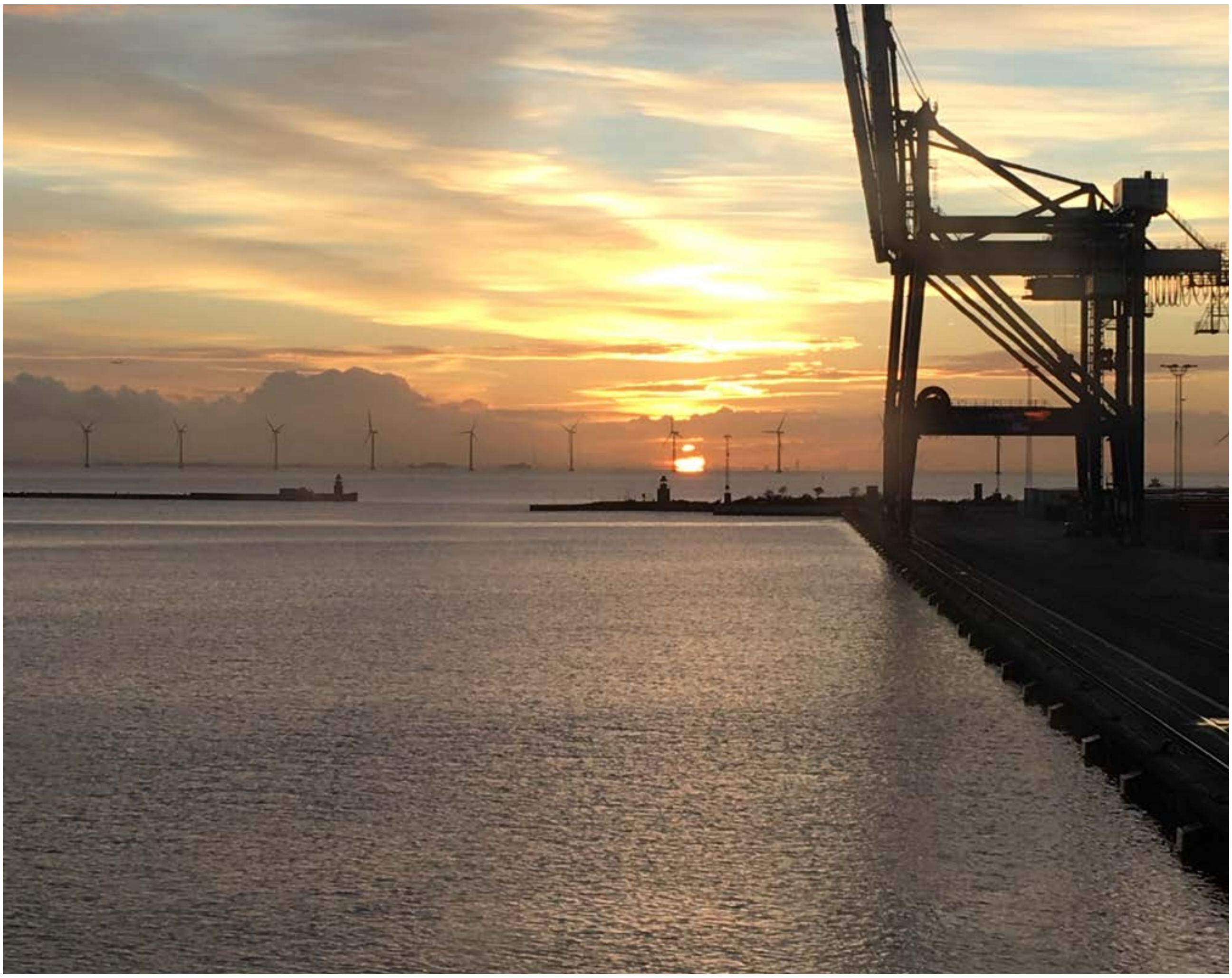
The NBIA maintains a vigorous visitor program, with close to 80 visitors a year. These visitors actively engage in daily activities at the NBIA and the Institute.

S.H. Tan	Singapore	01.12.18	31.05.19
C. Hays	Oxford	19.11.18	21.11.18
Y. Chen	Taiwan	06.11.18	07.11.18
A. Schekochihin	Oxford	21.10.18	23.10.18
F. Herzog	NIKHEF	10.10.18	12.10.18
S. Perez	Santiago	08.10.18	11.10.18
M.A. Papa	Hannover	10.04.18	10.04.18
H. Hansson	Nordita	24.09.18	25.09.18
J. Farrow	Durham	24.09.18	26.09.18
Y. Zhang	U. Munich	23.09.18	26.09.18
T. Lehner	Meudon	18.09.18	21.09.18
A. Schneider	Stockholm U.	16.09.18	21.09.18
C. Delgado	Madrid	16.09.18	21.09.18
O. Schnetz	Erlangen u.	17.09.18	18.09.18
S. He	CAS Beijing	12.09.18	22.09.18
S. Mizera	Perimeter I.	09.09.18	15.09.18
B. Chandran	New Hampshire	09.09.18	15.09.18
E. Churazov	MPA Garching	09.09.18	14.09.18
A. Spitkovsky	Princeton	09.09.18	14.09.18
W. Dorland	Maryland	04.09.18	16.09.18
C. Brønnum-Hansen	Edinburg	03.09.18	07.09.18
C. Contaldi	Imperial	02.09.18	03.09.18
R. Durrer	U. Geneva	02.09.18	03.09.18
F. Dulat	SLAC	27.08.18	31.08.18
N. Loureiro	MIT	22.08.18	27.08.18
F. Rincon	Toulouse	19.08.18	25.08.18
A. Schekochihin	Oxford	19.08.18	15.09.18

J. Toner	U. Oregon	19.06.18	27.06.18
S. Mu	Caltech	18.06.18	31.08.18
P. Cole	Sussex U.	10.06.18	12.06.18
C. Byrnes	Sussex U.	10.06.18	12.06.18
E. Siggia	Rockefeller U.	31.05.18	03.06.18
M. Mojaza	AEI Berlin	29.05.18	03.06.18
P.E. Lindelof	Cph U	25.05.18	25.05.18
G. Mamatsashvili	Dresden	23.05.18	25.05.18
R. Gomez-Ambrosio	Durham	16.05.18	18.05.18
P. Vanhove	Saclay	14.05.18	16.05.18
R. Lundkvist	Heidelberg	14.05.18	15.05.18
G. Smith	U.Colorado	13.05.18	19.05.18
Y. He	Oxford	08.05.18	10.05.18
Y. Fujii	Nagoya U.	07.05.18	11.05.18
S. Dib	Atacama U.	07.05.18	27.07.18
C. Vergu	King's College	06.05.18	11.05.18
G. Papathanasiou	DESY	24.04.18	27.04.18
E. Panzer	Oxford	17.04.18	20.04.18
E. Furlan	ETH Zurich	02.04.18	03.04.18
C. Bennett	IBM Research	01.04.18	01.07.18
A. Tolley	Imperial	26.03.18	29.03.18
K. Sen	Tokyo U.	24.03.18	01.04.18
F. Levkovich-Maslyuk	Paris	14.03.18	16.03.18
J. Henn	Munich U.	11.03.18	14.03.18
M. Mostafa	Penn State	11.03.18	13.03.18
J. Vines	AEI Berlin	07.03.18	11.03.18
S. Dib	Atacama U.	05.03.18	23.03.18

K. Beyer	Oxford	08.08.18	22.08.18
X. Ramos	Nice	06.08.18	17.08.18
C. Brønnum-Hansen	Edinburgh	06.08.18	09.08.18
B. Penante	CERN	06.08.18	09.08.18
C. Duhr	CERN	05.08.18	08.08.18
A. Volovich	Brown U.	31.07.18	03.08.18
M. Spradlin	Brown U.	31.07.18	03.08.18
A. Lande	Groningen	14.07.18	09.08.18
P. Kumar	Texas	04.07.18	11.07.18
M. Green	Cambridge	04.07.18	07.07.18
H. Klahr	Heidelberg	04.07.18	05.07.18
H. Latter	Cambridge	04.07.18	06.07.18
K. Sen	Tokyo U.	02.07.18	19.07.18
T. Berlok	AIP Potsdam	02.07.18	06.07.18
A. Furuta	Cambridge	21.06.18	24.06.18

A. Smirnov	Heidelberg	04.03.18	06.03.18
E. Ye Yuan	Princeton	04.03.18	10.03.18
D. Hofman	Amsterdam U.	28.02.18	01.03.18
R. Britto	Dublin	26.02.18	02.03.18
H. Zechlin	Turin U.	18.02.18	19.02.18
T. Ekelöf	Uppsala U.	13.02.18	14.02.18
B. Mistlberger	CERN	07.02.18	09.02.18
S. Parke	Fermilab	03.02.18	07.02.18
J. Golden	U. Michigan	28.01.18	03.02.18
R. Alonso	CERN	27.01.18	31.01.18
D. Hidalgo	Valdivia	22.01.18	22.11.18
F. Renaud	U. Surrey	18.01.18	18.01.18
S. Davis	U. Virginia	12.01.18	16.01.18
S. Dib	Atacama U.	01.01.18	26.01.18
M. Kastoryano	Cologne U.	01.01.18	30.05.18




NIELS BOHR INSTITUTET
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NBIA Activities

Simons Foundation — New York

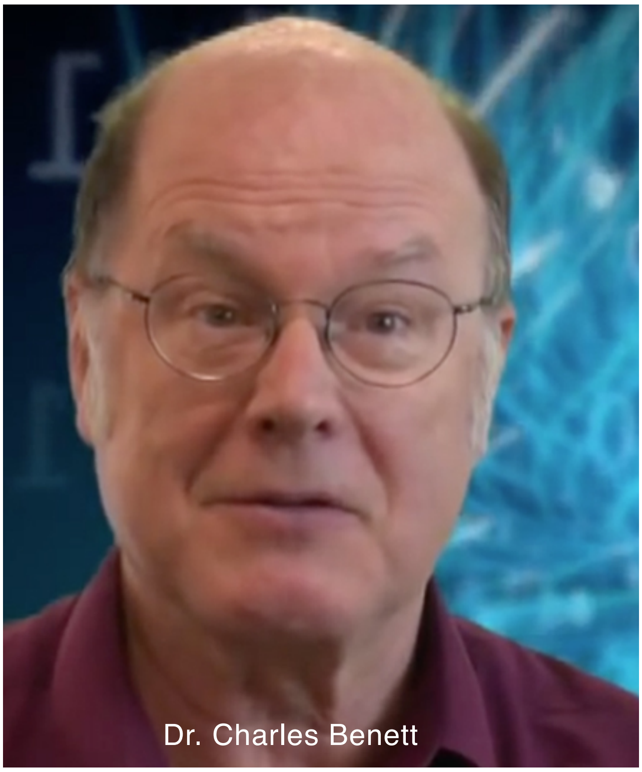
NBIA Simons Foundation Program

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

"*Simons Program: Plasma Physics and Astrophysics*" — 19.08.2018 / 16.09.2018

"*Simons Program: QMath Masterclass on Tensors: Geometry and Quantum Information*" — 18.06.2018 / 22.06.2018

"*Simons Program: Quantum Information and Cosmology*" — 09.04.2018 / 12.04.2018



Dr. Charles Benett

Prof. Alexander Schekochihin

Dr. Ilaria Brivio — Fall 2018

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. In 2018 NBIA Colloquia covered topics from the quantization of black holes, through the hydrodynamics of flocking to a talk by Charles Bennett, one of the founding fathers of modern quantum information theory, on private information.

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 Alexander Schekochihin delivered a special public NBIA lecture entitled "*Turbulent plasma: from fusion power plants to intergalactic space and back*" 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'. All lectures take place at the historic Auditorium A. The idea was from the start to let the public benefit from the presence of young and enthusiastic scientists at the NBIA, each of them speaking about a topic very close to their actual on-going research, but at a level appropriate for an audience with no background in science. By design, these lectures will then cover a wide range of topics in modern theoretical physics, giving a glimpse of the questions, ideas and approaches that are now at the scientific forefront. This formula turned out to be a success, and although the subjects covered are at the forefront of present-day research, the attendance is increasing.

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

Alexander Schekochihin (Oxford) — 22.10.2018

"Turbulent plasma: from fusion power plants to intergalactic space and back"

David McGady (NBIA) — 29.10.2018

"String Theory, Black Holes and Information"

Mark Rudner (NBIA) — 05.11.2018

"Controlling quantum nanosystems"

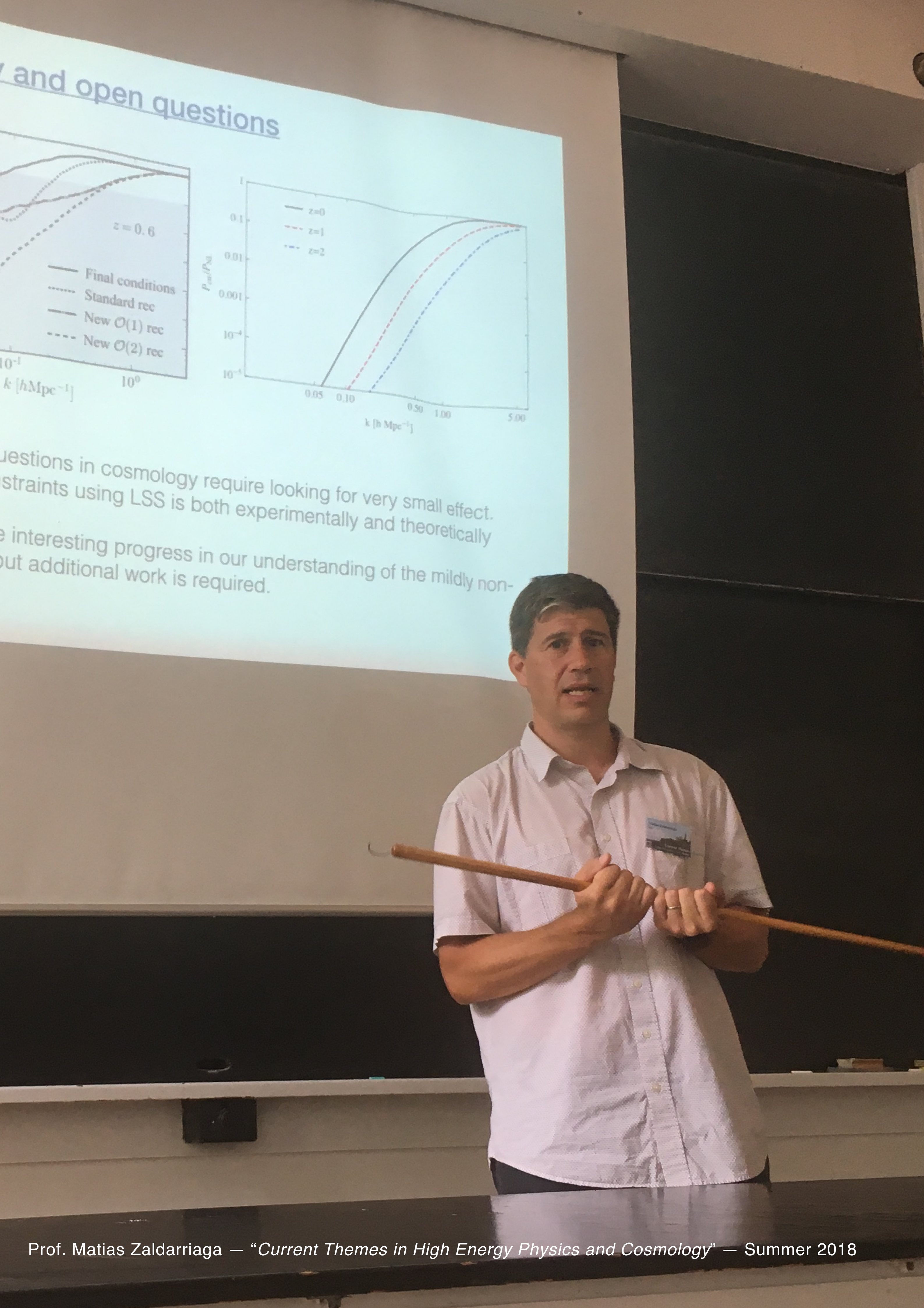
Jason Koskinen (Niels Bohr Institute) — 12.11.2018

"ICECUBE: the south pole neutrino detector"

Subodh Patil (NBIA) — 19.11.2018

"The big rip, the ultimate fate 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.



Prof. Matias Zaldarriaga — “*Current Themes in High Energy Physics and Cosmology*” — Summer 2018

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 2018.

"*Quantum Materials: QDev/NBIA PhD Summer School* " — 19.08 / 24.08.2018

"*Current Themes in High Energy Physics and Cosmology*" — 13.08 / 17.08.2018

"*TIARA Summer School on Origins of the Solar System*" — ASIAA, Taiwan — 16.07 / 20.07.2018

"*NBIA & DARK Summer School: Multi-Messengers from Compact Sources*" — 02.07 / 06.07.2018

"*Deciphering Hidden Dynamics of Soft matter: 7th NBIA Meeting ESS Science*" — 25.06 / 29.06.2018

"*Emergent Symmetries in Particle Physics, Cosmology & Condensed Matter System*" — 20.06 / 22.06.2018

"*SDC Workshop on particle/astroparticle/astro-physics*" — UCAS, China — 18.04 / 20.04.2018

Prof. Gerard t'Hooft — *NBIA Colloquia* — Fall 2018

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 2018 are listed below.

Gerard 't Hooft (Utrecht University) — 17.08.2018
"The quantization of black holes and its impact on particle physics and general relativity?"

John Toner (U. of Oregon) — 22.06.2018
"Hydrodynamic theory of flocking"

Eric Siggia *(Rockefeller) — 01.06.2018*

"Exploring embryonic patterning with colonies of human embryonic stem cells?"

Poul Erik Lindelof (NBI) — 25.05.2018
"Applying Modern Physics to Archaeology"

Charles Bennett (IBM) — 18.05.2018
"Is there such a thing as private information"

Peter Ditlevsen (NBI) — 09.02.2018
"Micro- and Nanostructures for Oral Drug Delivery and Sensing"

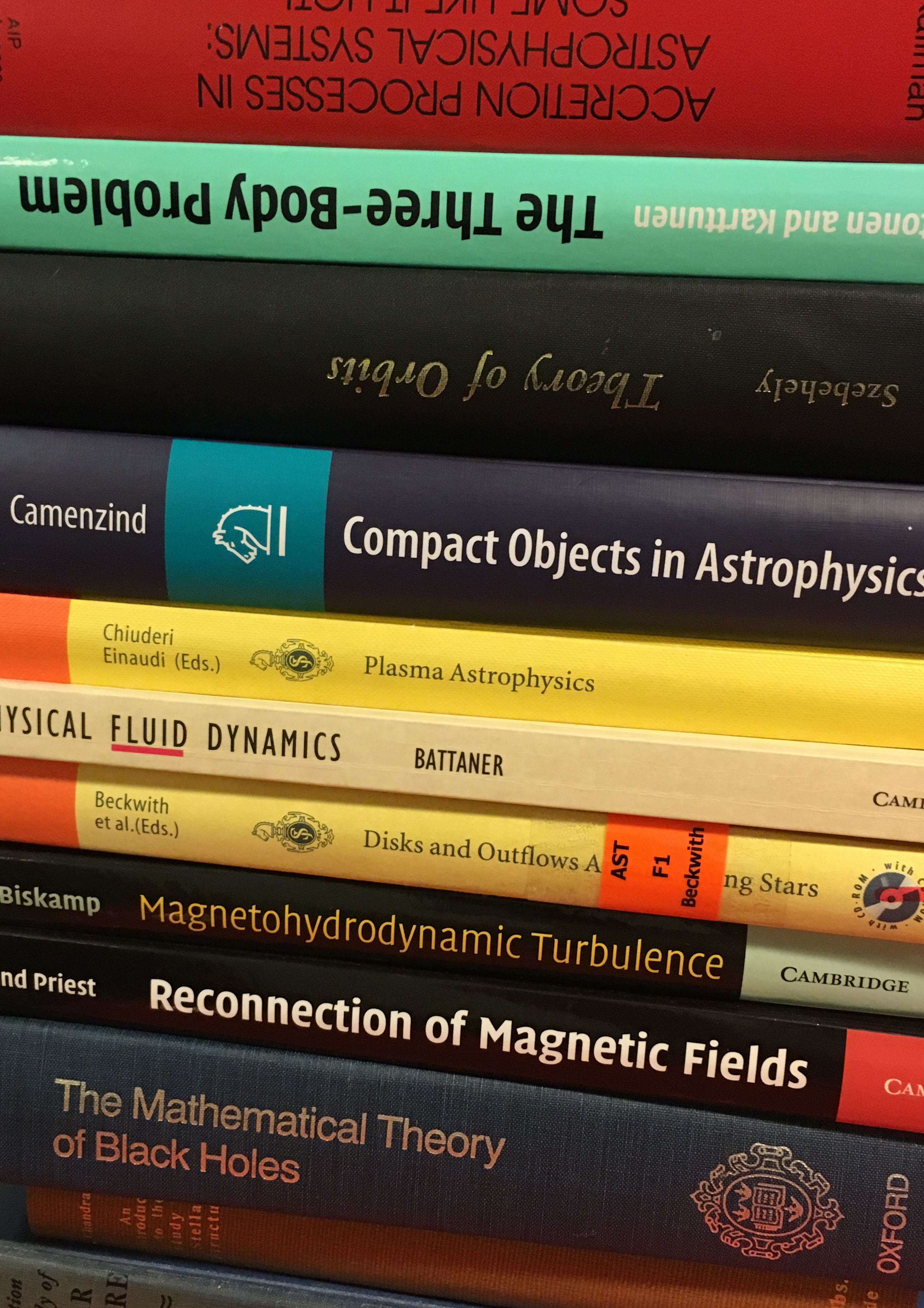
"*TIARA Summer School on Origins of the Solar System*" — ASIAA, Taiwan — Summer 2018

Joint Activities with ASIAA

During the summer of 2018 scientists from the Niels Bohr International Academy at the Niels Bohr Institute and the Center for Star and Planet Formation at the Natural History Museum of Denmark jointly organized the PhD school "Origins of the Solar System" together with the members of the Theoretical Institute for Advanced Research in Astrophysics (TIARA) in Academia Sinica Institute for Astronomy and Astrophysics (ASIAA) in Taipei, Taiwan.

This is projected to be the first of a number of joint activities between ASIAA and the Niels Bohr International Academy and the Center for Star and Planet Formation at the University of Copenhagen, based on the mutual interests of members of their respective institutions in cosmochemistry, theoretical astrophysics, and star and planet formation.

The themes of the summer school are closely related to the broad interests and expertise present in all institutions involved and forms the foundation for exchanges and efforts for collaborating and cooperating. The planned topics in this first summer school ranged from nucleosynthesis, the influence of the interstellar medium, the formation and evolution of protoplanetary systems, and the planetary materials that contribute to the making of planets. The objectives are to bring researchers and students alike worldwide to participate in the exciting journey through the exploration of multidisciplinary studies.


ACCRETION PROCESSES IN
ASTROPHYSICAL SYSTEMS:
AIP
The Three-Body Problem
tonen and Karttunen
Theory of Orbits
Szebehely
Camenzind
Compact Objects in Astrophysics
Chiuderi
Einaudi (Eds.)
Plasma Astrophysics
YSICAL FLUID DYNAMICS
BATTANER
Beckwith
et al.(Eds.)
Disks and Outflows A
ng Stars
AST
F1
Beckwith
Biskamp
Magnetohydrodynamic Turbulence
CAMBRIDGE
nd Priest
Reconnection of Magnetic Fields
The Mathematical Theory
of Black Holes
OXFORD

NBIA Publications

Refereed Papers

1. **Off-axis afterglow light curves and images from 2D hydrodynamic simulations of double-sided GRB jets in a stratified external medium**
   Granot, J., De Colle, F., Ramirez-Ruiz, E. et al., 2018, MNRAS, 481, 2711-2720 - ArXiv: 1803.05856

2. **Dyonic zero-energy modes**
   Munk, Morten I. K., Rasmussen, Asbjørn, Burrello, Michele et al., 2018, Phys. Rev. B, 98, 245135

3. **Evidence for Cosmic-Ray Escape in the Small Magellanic Cloud Using Fermi Gamma Rays**
   Lopez, L. A., Auchettl, K., Linden, T. et al., 2018, ApJ, 867, 44 - ArXiv: 1807.06595

4. **Fractional Quantum Hall Effect at ν =2+6/13: The Parton Paradigm for the Second Landau Level**
   Balram, Ajit C., Mukherjee, Sutirtha, Park, Kwon et al., 2018, Phys. Rev. Lett., 121, 186601

5. **Transport properties of Keplerian flows in extended local domains with no imposed field**
   Nauman, F., Pessah, M. E., 2018, MNRAS, 480, 204-209

6. **Dust Segregation in Hall-dominated Turbulent Protoplanetary Disks**
   Krapp, L., Gressel, O., Benítez-Llambay, P. et al., 2018, ApJ, 865, 105 - ArXiv: 1808.07660

7. **Active Modes and Dynamical Balances in MRI Turbulence of Keplerian Disks with a Net Vertical Magnetic Field**
   Gogichaishvili, D., Mamatsashvili, G., Horton, W. et al., 2018, ApJ, 866, 134 - ArXiv: 1808.06147

8. **The White Dwarf Initial—Final Mass Relation for Progenitor Stars from 0.85 to 7.5 M$_\odot$**
   Cummings, J. D., Kalirai, J. S., Tremblay, P.-E. et al., 2018, ApJ, 866, 21 - ArXiv: 1809.01673

9. **Activating the fourth neutrino of the 3+1 scheme**
   Denton, Peter B., Farzan, Yasaman, Shoemaker, Ian M. et al., 2018, MNRAS, 480, L12-L17 - ArXiv: 1806.05125

10. **On the Dynamics of Pebbles in Protoplanetary Disks with Magnetically Driven Winds**
    Shadmehri, M., Khajenabi, F., Pessah, M. E. et al., 2018, ApJ, 863, 33 - ArXiv: 1806.10572

11. **Stellar wind retention and expulsion in massive star clusters**
    Naiman, J. P., Ramirez-Ruiz, E., Lin, D. N. C. et al., 2018, MNRAS, 478, 2794-2811 - ArXiv: 1206.5002

12. **Thermal and non-thermal emission from the cocoon of a gamma-ray burst jet**
    De Colle, F., Lu, W., Kumar, P. et al., 2018, MNRAS, 478, 4553-4564 - ArXiv: 1701.05198

13. **Black Hole Formation in Fallback Supernova and the Spins of LIGO Sources**
    Schrøder, S. L., Batta, A., Ramirez-Ruiz, E. et al., 2018, ApJ, 862, L3 - ArXiv: 1805.01269

14. **Many-Body Dynamics and Gap Opening in Interacting Periodically Driven Systems**
    Kandelaki, Ervand and Rudner, Mark, 2018, Phys. Rev. Lett., 121, 036801

15. **Parton construction of a wave function in the anti-Pfaffian phase**
Balram, Ajit C., Barkeshli, Maissam, Rudner, Mark S. et al., 2018, Phys. Rev. B, 98, 035127

16. **First results from the IllustrisTNG simulations: a tale of two elements - chemical evolution of magnesium and europium**
Naiman, J. P., Pillepich, A., Springel, V. et al., 2018, MNRAS, 477, 1206-1224 - ArXiv: 1707.03401

17. **A Stringent Limit on the Mass Production Rate of r-process Elements in the Milky Way**
Macias, P., Ramirez-Ruiz, E., 2018, ApJ, 860, 89 - ArXiv: 1609.04826

18. **A Unified Model for Tidal Disruption Events**
Dai, L., McKinney, J. C., Roth, N. et al., 2018, ApJ, 859, L20 - ArXiv: 1803.03265

19. **Resonance capture and dynamics of three-planet systems**
Charalambous, C., Martí, J. G., Beaugé, C. and Ramos X. S., 2018, MNRAS, 477, 1414-1425 - ArXiv: 1803.05305

20. **Topological phase transition measured in a dissipative metamaterial**
Rosenthal, Eric I., Ehrlich, Nicole K., Rudner, Mark S. et al., 2018, Phys. Rev. B, 97, 220301

21. **Axial anomaly in multi-Weyl and triple-point semimetals**
Lepori, Luca, Burrello, Michele, Guadagnini, Enore et al., 2018, Journal of High Energy Physics, 2018, 110

22. **Quantized transport and steady states of Floquet topological insulators**
Esin, Iliya, Rudner, Mark S., Refael, Gil et al., 2018, Phys. Rev. B, 97, 245401

23. **Analytical Models of Exoplanetary Atmospheres. V. Non-gray Thermal Structure with Coherent Scattering**
Mohandas, G., Pessah, M. E. et al., 2018, ApJ, 858, 1 - ArXiv: 1803.00629

24. **The resonant state at filling factor ν = 1/2 in chiral fermionic ladders**
Andreas Haller, Matteo Rizzi, Michele Burrello et al., 2018, New Journal of Physics, 20, 053007

25. **Structure of protoplanetary discs with magnetically driven winds**
Khajenabi, F., Shadmehri, M., Pessah, M. E. et al., 2018, MNRAS, 475, 5059-5069 - ArXiv: 1801.05455

26. **Tidal Disruptions of Main-sequence Stars of Varying Mass and Age: Inferences from the Composition of the Fallback Material**
Gallegos-Garcia, M., Law-Smith, J., Ramirez-Ruiz, E. et al., 2018, ApJ, 857, 109 - ArXiv: 1801.03497

27. **Topological Floquet-Thouless Energy Pump**
Kolodrubetz, Michael H., Nathan, Frederik, Gazit, Snir et al., 2018, Phys. Rev. Lett., 120, 150601

28. **Ultrafast outflow in tidal disruption event ASASSN-14li**
Kara, E., Dai, L., Reynolds, C. S. et al., 2018, MNRAS, 474, 3593-3598 - ArXiv: 1711.06090

29. **Torques Induced by Scattered Pebble-flow in Protoplanetary Disks**
Benítez-Llambay, P., Pessah, M. E., 2018, ApJ, 855, L28 - ArXiv: 1801.07913

30. **Geometrically protected triple-point crossings in an optical lattice**
Fulga, I. C., Fallani, L., Burrello, M. et al., 2018, Phys. Rev. B, 97, 121402

31. **Characterizing the Variable Dust Permeability of Planet-induced Gaps**
Weber, P., Benítez-Llambay, P., Gressel, O. et al., 2018, ApJ, 854, 153 - ArXiv: 1801.07971

32. **Dissipative Evolution of Unequal-mass Binary-single Interactions and Its Relevance to Gravitational-wave Detections**
Samsing, J., MacLeod, M., Ramirez-Ruiz, E. et al., 2018, ApJ, 853, 140 - ArXiv: 1706.03776

33. **A Comparison of the X-Ray Emission from Tidal Disruption Events with those of Active Galactic Nuclei**
Auchettl, K., Ramirez-Ruiz, E., Guillochon, J. et al., 2018, ApJ, 852, 37 - ArXiv: 1703.06141

34. **Tensor Bounds on the Hidden Universe**
del Rio, Adrián, Durrer, Ruth, Patil, Subodh P. et al., 2018, JHEP, 12, 094 - ArXiv: 1808.09282

35. **Identifying rotation in SASI-dominated core-collapse supernovae with a neutrino gyroscope**
Walk, Laurie, Tamborra, Irene, Janka, Hans-Thomas et al., 2018, Phys. Rev., D98, 123001 - ArXiv: 1807.02366

36. **Neutrinos from Supernovae**
Tamborra, Irene, Murase, Kohta, 2018, Space Sci. Rev., 214, 31

37. **Electron acceleration by wave turbulence in a magnetized plasma**
Rigby, A. et al., 2018, Nature Phys., 14, 475-479

38. **The dipole anisotropy of AllWISE galaxies**
Rameez, M., Mohayaee, R., Sarkar, S. et al., 2018, Mon. Not. Roy. Astron. Soc., 477, 1772-1781 - ArXiv: 1712.03444

39. **Measuring the supernova unknowns at the next-generation neutrino telescopes through the diffuse neutrino background**
Møller, Klaes, Suliga, Anna M., Tamborra, Irene et al., 2018, JCAP, 1805, 066 - ArXiv: 1804.03157

40. **Axion-Driven Cosmic Magnetogenesis during the QCD Crossover**
Miniati, Francesco, Gregori, Gianluca, Reville, Brian et al., 2018, Phys. Rev. Lett., 121, 021301 - ArXiv: 1708.07614

41. **A blind search for a common signal in gravitational wave detectors**
Liu, Hao, Creswell, James, von Hausegger, Sebastian et al., 2018, JCAP, 1802, 013 - ArXiv: 1802.00340

42. **On interference and non-interference in the SMEFT**
Helset, Andreas, Trott, Michael, 2018, JHEP, 04, 038 - ArXiv: 1711.07954

43. **Gauge fixing the Standard Model Effective Field Theory**
Helset, Andreas, Paraskevas, Michael, Trott, Michael et al., 2018, Phys. Rev. Lett., 120, 251801 - ArXiv: 1803.08001

44. **The Hagedorn temperature of AdS_5/CFT_4 at finite coupling via the Quantum Spectral Curve**
Harmark, Troels, Wilhelm, Matthias, 2018, Phys. Lett., B786, 53-58 - ArXiv: 1803.04416

45. **Hagedorn Temperature of AdS_5/CFT_4 via Integrability**
Harmark, Troels, Wilhelm, Matthias, 2018, Phys. Rev. Lett., 120, 071605 - ArXiv: 1706.03074

46. Reconstruction of a direction-dependent primordial power spectrum from Planck CMB data
Durakovic, Amel, Hunt, Paul, Mukherjee, Suvodip et al., 2018, JCAP, 1802, 012 - ArXiv: 1711.08441

47. Defect multiplets of $\mathcal{N}$=1 supersymmetry in 4d
Drukker, N., Shamir, I., Vergu, C. et al., 2018, JHEP, 01, 034 - ArXiv: 1711.03455

48. Exploring the Properties of Choked Gamma-ray Bursts with IceCube's High-energy Neutrinos
Denton, Peter B., Tamborra, Irene, 2018, Astrophys. J., 855, 37 - ArXiv: 1711.00470

49. Invisible Neutrino Decay Could Resolve IceCube's Track and Cascade Tension
Denton, Peter B., Tamborra, Irene, 2018, Phys. Rev. Lett., 121, 121802 - ArXiv: 1805.05950

50. The Bright and Choked Gamma-Ray Burst Contribution to the IceCube and ANTARES Low-Energy Excess
Denton, Peter B., Tamborra, Irene, 2018, JCAP, 1804, 058 - ArXiv: 1802.10098

51. Rotations Versus Perturbative Expansions for Calculating Neutrino Oscillation Probabilities in Matter
Denton, Peter B., Parke, Stephen J., Zhang, Xining et al., 2018, Phys. Rev., D98, 033001 - ArXiv: 1806.01277

52. The effective Δm^2_{ee} in matter
Denton, Peter B., Parke, Stephen J., 2018, Phys. Rev., D98, 093001 - ArXiv: 1808.09453

53. Addendum to "Compact perturbative expressions for neutrino oscillations in matter"
Denton, Peter B., Parke, Stephen J., 2018, JHEP, 06, 109 - ArXiv: 1801.06514

54. Testing large non-standard neutrino interactions with arbitrary mediator mass after COHERENT data
Denton, Peter B., Farzan, Yasaman, Shoemaker, Ian M. et al., 2018, JHEP, 07, 037 - ArXiv: 1804.03660

55. Exploring cosmic origins with CORE: Survey requirements and mission design
Delabrouille, J. et al., 2018, JCAP, 1804, 014 - ArXiv: 1706.04516

56. Degeneracy of gravitational waveforms in the context of GW150914
Creswell, James, Liu, Hao, Jackson, Andrew D. et al., 2018, JCAP, 1803, 007 - ArXiv: 1803.02350

57. Exploring Extended Scalar Sectors with Di-Higgs Signals: A Higgs EFT Perspective
Corbett, Tyler, Joglekar, Aniket, Li, Hao-Lin et al., 2018, JHEP, 05, 061 - ArXiv: 1705.02551

58. Anomalous neutral gauge boson interactions and simplified models
Corbett, Tyler, Dolan, Matthew J., Englert, Christoph et al., 2018, Phys. Rev., D97, 115040 - ArXiv: 1710.07530

59. What is the Amplituhedron?
Caron-Huot, Simon, Dixon, Lance J., von Hippel, Matt et al., 2018, Not. Amer. Math. Soc., 65, 167-169 - ArXiv: 1806.01361

60. Anomalous dimensions at finite conformal spin from OPE inversion
Cardona, Carlos, Sen, Kallol, 2018, JHEP, 11, 052 - ArXiv: 1806.10919

61. Rationalizing Loop Integration
Bourjaily, Jacob L., McLeod, Andrew J., von Hippel, Matt et al., 2018, JHEP, 08, 184 - ArXiv: 1805.10281

62. **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

63. **Traintracks through Calabi-Yau Manifolds: Scattering Amplitudes beyond Elliptic Polylogarithms**
Bourjaily, Jacob L., He, Yang-Hui, Mcleod, Andrew J. et al., 2018, Phys. Rev. Lett., 121, 071603 - ArXiv: 1805.09326

64. **General Relativity from Scattering Amplitudes**
Bjerrum-Bohr, N. E. J., Damgaard, Poul H., Festuccia, Guido et al., 2018, Phys. Rev. Lett., 121, 171601 - ArXiv: 1806.04920

65. **Analytical estimates of proton acceleration in laser-produced turbulent plasmas**
Beyer, Konstantin, Reville, Brian, Bott, Archie et al., 2018, J. Plasma Phys., 84, 905840608 - ArXiv: 1808.04356

66. **A new insight into the phase transition in the early Universe with two Higgs doublets**
Bernon, Jrmy, Bian, Ligong, Jiang, Yun et al., 2018, JHEP, 05, 151 - ArXiv: 1712.08430

67. **Equations of Motion for the Standard Model Effective Field Theory: Theory and Applications**
Barzinji, Abdurrahman, Trott, Michael, Vasudevan, Anagha et al., 2018, Phys. Rev., D98, 116005 - ArXiv: 1806.06354

68. **Joint Constraints on Galactic Diffuse Neutrino Emission from the ANTARES and IceCube Neutrino Telescopes**
Albert, A. et al., 2018, Astrophys. J., 868, L20 - ArXiv: 1808.03531

69. **Non-planar one-loop Parke-Taylor factors in the CHY approach for quadratic propagators**
Ahmadiniaz, Naser, Gomez, Humberto, Lopez-Arcos, Cristhiam et al., 2018, JHEP, 05, 055 - ArXiv: 1802.00015

70. **Probing Particle Physics with IceCube**
Ahlers, Markus, Helbing, Klaus, Pérez de los Heros, Carlos et al., 2018, Eur. Phys. J., C78, 924 - ArXiv: 1806.05696

71. **Opening a New Window onto the Universe with IceCube**
Ahlers, Markus, Halzen, Francis, 2018, Prog. Part. Nucl. Phys., 102, 73-88 - ArXiv: 1805.11112

72. **Unitarity Bounds of Astrophysical Neutrinos**
Ahlers, Markus, Bustamante, Mauricio, Mu, Siqiao et al., 2018, Phys. Rev., D98, 123023 - ArXiv: 1810.00893

73. **Searching for All-Scale Anisotropies in the Arrival Directions of Cosmic Rays above the Ankle**
Ahlers, Markus, 2018, Astrophys. J., 863, 146 - ArXiv: 1805.08220

74. **WCxf: an exchange format for Wilson coefficients beyond the Standard Model**
Aebischer, Jason et al., 2018, Comput. Phys. Commun., 232, 71-83 - ArXiv: 1712.05298

75. **Search for Nonstandard Neutrino Interactions with IceCube DeepCore**
Aartsen, M. G. et al., 2018, Phys. Rev., D97, 072009 - ArXiv: 1709.07079

76. **Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A**
Aartsen, M. G. et al., 2018, Science, 361, eaat1378 - ArXiv: 1807.08816

77. Neutrino emission from the direction of the blazar TXS 0506+056 prior to the IceCube-170922A alert
Aartsen, M. G. et al., 2018, Science, 361, 147-151 - ArXiv: 1807.08794

78. Differential limit on the extremely-high-energy cosmic neutrino flux in the presence of astrophysical background from nine years of IceCube data
Aartsen, M. G. et al., 2018, Phys. Rev., D98, 062003 - ArXiv: 1807.01820

79. Search for neutrinos from decaying dark matter with IceCube
Aartsen, M. G. et al., 2018, Eur. Phys. J., C78, 831 - ArXiv: 1804.03848

80. A Search for Neutrino Emission from Fast Radio Bursts with Six Years of IceCube Data
Aartsen, M. G. et al., 2018, Astrophys. J., 857, 117 - ArXiv: 1712.06277

81. Neutrino Interferometry for High-Precision Tests of Lorentz Symmetry with IceCube
Aartsen, M. G. et al., 2018, Nature Phys., 14, 961-966 - ArXiv: 1709.03434

82. Measurement of Atmospheric Neutrino Oscillations at 6-56 GeV with IceCube DeepCore
Aartsen, M. G. et al., 2018, Phys. Rev. Lett., 120, 071801 - ArXiv: 1707.07081

83. Astrophysical neutrinos and cosmic rays observed by IceCube
Aartsen, M. G. et al., 2018, Adv. Space Res., 62, 2902-2930 - ArXiv: 1701.03731

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