2nd Annual Niels Bohr Institute MSc. Student Symposium

Friday, 31 March 2023 - Friday, 31 March 2023

H.C. Ørsted Institute

Book of Abstracts

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Spectral Integrability In Twisted N = 4 Super Yang-Mills Theory

Author: Anna Bjerregaard[1]

[1] *NBI*

$\mathcal{N} = 4$ Super Yang-Mills theory has been hailed as the "hydrogen atom of the 21st century", owing to it's similarity to Quantum Chromodynamics (QCD) albeit with much larger symmetry allowing for simplification of otherwise extremely difficult computations.
The model is believed to be "Integrable", meaning that it is well behaved and solveable to all orders in pertubation theory, regardless of coupling strength (a property not shared by QCD).
My thesis examines this integrability in the γ_i-twisted limit where most of the super-symmetry is broken allowing for a less obstructed look at the (hopefully) integrable structure of the theory. Remarkably, the theory can be identified with a closed Heisenberg-like spin chain, relating this problem of theoretical particle physics to a very well-studied problem in condensed matter systems! The emergent spin chains are analyzed through the lens of Random Matrix Theory (RMT), making for a merger of high-energy theory, condensed matter physics and good old statistics!

Field of study:

Quantum Physics

Supervisor:

Anne Spiering, Matthias Wilhelm

Poster session: Enjoy the posters!!! / 2

Detailed simulation of neutron scattering from phonons in highly oriented pyrolytic graphite

Authors: Dorothy Xiaoyu Wang[1]; Kim Lefmann[1]; Kristine Krighaar[1]

[1] *Niels Bohr Institute, University of Copenhagen*

Pyrolytic graphite (PG) is often used in neutron instruments, for example much PG is used in the multiplexing indirect Time-of-flight (ToF) spectrometer BIFROST at ESS. To simulate possible background effects of PG, experiments and modeling of the experimental data by the simulation package McStas have been done.

In this poster I will present the progress of modeling of the phonon in PG with Born-von Karman method along with the testing of the component in McStas, including results from theoretical calculations, and from simulations. This new component takes up to fourth-nearest neighbors into consideration, and will help building a better model of PG.

Field of study:

Physics of Complex Systems

Supervisor:

Kim Lefmann

Oral presentation / 3

Effective bond theory for frustrated magnets

Author: Oliver Solow[1]

[1] *University of Copenhagen*

Frustrated magnets are a class of materials where competing interactions between magnetic moments leads to complex behavior. As this complex behavior emerges from relatively simple rules, studying these materials can give us insight into how competing interactions can lead to the plethora of phenomena we see in strongly correlated materials, as well as insight into the nature of magnetic materials more generally. On the theoretical side, however, these materials present a number of challenges, and are usually treated with numerical methods like Monte Carlo, which are computationally inefficient, especially when considering large systems. Here, I will describe how certain materials can be treated with another method, the so-called Nematic Bond Theory, which is much more computationally efficient. I will describe this method, and show how it allows us to quickly compute observables like heat capacities and critical temperatures, even in systems with long-range interactions where considering large systems is required.

Field of study:

Quantum Physics

Supervisor:

Jens Paaske

Poster session: Enjoy the posters!!! / 4

Simulations of background scattering from a 15 T magnet

Author: Petroula Karakosta[1]

Co-authors: Alexander Holmes [2]; Kim Lefmann [1]; Kristine M. L. Krighaar [1]; Mads Bertelsen [2]

[1] *Niels Bohr Institute, University of Copenhagen*

[2] *European Spallation Source, ERIC*

Neutron scattering allows for quite complicated sample environments with control over the sample conditions, such as controlled temperature, as well as the presence of strong magnetic fields.
The presence of magnets in scattering experiments necessitates a significant amount of materials in the structure. The coils of the magnets, which are not in the direct beam, add more material into the structure and could influence the experiments, since neutrons would scatter multiple times before reaching the detector. Additionally, they exert large forces on the structure that need to be withstood, requiring more material to safeguard the structural integrity of the system.
In an attempt to investigate the effect of the sample environment on the resulting background scattering, simulations of inelastic neutron scattering data in the presence of multiple scattering from the sample environment are carried out with the Union tool in McStas, a neutron ray-trace simulation package.
A model of the 15 T magnet for the BIFROST spectrometer at ESS is constructed and incorporated into models of existing spectrometers, such as triple-axis, direct TOF and indirect TOF. Optimisation of the sample environment is pursued in such a way as to minimize background scattering within a variety of particular instruments and structures.

Field of study:

Computational Physics

Supervisor:

Kim Lefmann

Oral presentation / 5

Structural properties of kagome-layered crystals

Author: Luca Buiarelli[1]

[1] *NBI - CMT*

Recently, a family of kagome metals, AV3Sb5, has been synthesized and found to display superconductivity at low temperatures. Before the onset of superconductivity, a new phase appears at which the material seems to undergo a structural transition which causes the unit cell to double in size. Evidence has been found suggesting that this phase transition is not just a normal structural transition, but that the electronic degrees of freedom are playing an important role, such that this phase has been called Charge Density Wave (CDW). There's a long history of studies surrounding the CDW and its relation to Fermi surface nesting, but the microscopic nature of the order parameter is still under debate.

A kagome-layered structure can be hosted in a number of different materials. A class of them which have received a lot of attention lately, are the shandites A3M2Ch2. In this presentation, we display a symmetry analysis and some first-principles simulations, to investigate if any of the shandites could host a CDW phase like the kagome metals. This would help further our understanding of the nature of the order parameter for a CDW transitions.

Field of study:

Quantum Physics

Supervisor:

Brian M. Andersen

Oral presentation / 6

Exploring Demographic Drift: A Redshift Dependent Two-Population Model of Type Ia Supernovae and Its Implications for Dark Energy

Author: Jacob Osman Hjortlund[1]

[1] *DARK, NBI, University of Copenhagen*

Type Ia supernovae have played a significant role in measuring the acceleration of the Universe's expansion and the existence of dark energy. However, understanding the nature of the supernovae and the impact of population, originating from two distinct progenitor channels (single- and double-degenerate), changes over cosmic time is crucial to accurately measuring these phenomena. In this talk, we present a novel Bayesian hierarchical two-population model of Type Ia supernovae which enables us to measure the properties of the two populations, redshift evolution of their relative fractions and thus investigate the impact of these elements on the precision and accuracy of constraints on the dark energy equation of state.

Our model builds on earlier work by accounting for the varying fraction of two distinct Type Ia supernova populations over cosmic time. By modeling the redshift dependence of the two populations, we can estimate their respective fractions at different epochs and explore the impact of these changes on our measurement of dark energy.

We apply our model to both simulations and to observational data from Pantheon+. We show that observational data has signatures of redshift-dependent fractions of the supernova populations and discuss these results in the framework of basic expectations related to the star formation history. We find that this demographic drift has important implications for measuring the properties of dark energy, as it affects the derived distance and spectral properties of Type Ia supernovae.

Finally, we discuss the implications of our results for future observations and the study of dark energy. Our model provides a framework for incorporating demographic drift into the two population model of Type Ia SNe, which could lead to more accurate measurements of the properties of dark energy. We also highlight the importance of continued observational efforts to constrain the properties of Type Ia supernovae and their progenitor scenarios.

In conclusion, our Bayesian two-population model of Type Ia supernovae provides a powerful tool for exploring the demographic drift of these populations and its implications for measuring dark energy. By accounting for the changing fraction of the two populations over cosmic time, we can improve our understanding of the nature of Type Ia supernovae and their use as cosmological probes. We hope that our results will motivate further observational and theoretical studies of these important astrophysical phenomena.

Field of study:

Astrophysics

Supervisor:

Radek Wojtak

Poster session: Enjoy the posters!!! / 7

Dust circulation in self-similar protoplanetary discs

Author: Rasmus Nielsen[1]

[1] *NBI*

Planetary formation presents many unanswered questions which are very difficult to answer, observationally since they are deeply embedded, theoretically due to the very nonlinear dynamics and computationally due to the hundreds of thousands of orbits over which the formation occurs. Current models of the early solar system have difficulties explaining the existence of dust reservoirs observed in meteorites, how to overcome the metre barrier among other questions pertaining to dust dynamics.

We present a new efficient method for simulating massive particles in 3 dimensions for millions of orbits, using realistic dust friction and turbulence modelling. Applying this method to a simplified protostellar disc model, we find interesting out-of-disc trajectories where particles are "carried" by the outflow, allowing the particle to circulate for much longer than simple in-disc calculations would predict. These dynamics are qualitatively resiliant to the friction model, as well as significant turbulent perturbations.

In the future this opens the possibility of studying dust dynamics in large scale 3d MHD models, hopefully offering new insight into the early solar system.

Field of study:

Astrophysics

Supervisor:

Troels Haughbølle

Poster session: Enjoy the posters!!! / 8

Alternative to Cosmological Constant with new dark matter force

Author: Bence Takacs[1]

[1] *Københavns Universitet*

Proposing a new theory based on hierarchical structure formation of dark matter adding a new velocity dependent force which replaces the cosmological constant

Field of study:

Astrophysics

Supervisor:

Steen Hansen

Poster session: Enjoy the posters!!! / 9

Spacetime Algebra as a tool to study the Milky Way's plane of satellites

Author: Irati Lizaso Berrueta[1]

[1] *University of Copenhagen*

A new gravitational force term derived from Spacetime Algebra is numerically implemented in order to explain the Milky Way's plane of dwarf galaxies.

Field of study:

Astrophysics

Supervisor:

Steen Hansen

Oral presentation / 10

Improving Neutrino Oscillation Measurements by using the Earth's layer structure

Author: Amalie Albrechtsen[None]

One persisting question of the Standard Model and particle physics is the Neutrino Mass Ordering. Even though we know that neutrinos have masses, we do not know how these masses are ordered from lowest to highest. Because of the quantum-mechanical nature of neutrinos and their reluctance to interact, measurements of their properties are difficult and convoluted. I will show how the earth' s layer structure helps us make precise measurements of the Standard Model and present current estimates of the IceCube Upgrade's sensitivity to the Neutrino Mass Ordering.

Field of study:

Quantum Physics

Supervisor:

Jason Koskinen

Poster session: Enjoy the posters!!! / 11

Probing nuclear structure in heavy-ion collisions with cumulants of transverse momentum fluctuations

Author: Frederik Rømer[None]

The structure of atomic nuclei can be described by a multipole expansion of the parton distribution function. Most nuclies generally have intrinsic deformation, where the quadrupole moment carries the most significant contribution. The shape of a quadrupole deformed nuclies is described by the deformation strength β_2, and an axial symmetry component γ. In ultra-relativistic heavy-ion collision, the nuclear shape directly affects the energy density of the created Quark-Gluon-Plasmsa (QGP) and the radial flow blast. We present a direct measurement of cumulants of transverse momentum fluctuation as a fine probe for accessing initial stage properties of deformed nuclies. Using the AMPT model Xe-Xe collisions at $\sqrt{s_{NN}} = 5.44$TeV are simulated with different quadrupole moments defined by both strength β_2, and triaxiality γ. The results show the higher-order cumulant of transverse momentum fluctuation to have a sensitive response to both β_2 and γ.

Field of study:

Quantum Physics

Supervisor:

You Zhou

Poster session: Enjoy the posters!!! / 12

A Forward Hadronic Calorimeter for ALICE at the LHC

Author: Laura Marie Dufke[1]

[1] *University of Copenhagen*

Studying the gluon density in nucleons and nuclei require measurements at low-x. The Forward Calorimeter (FoCal) upgrade for ALICE will provide just such measurements. FoCal comprises two components, an Electromagnetic calorimeter (FoCal-E) and a Hadronic Calorimeter (FoCal-H). This poster will present results from the first prototype that informed the design of the second prototype. In particular, I will present recent results from testbem measurements performed with FoCal-H second prototype at the CERN SPS, and how this compare to Monte Carlo simulations using different

GEANT physics lists. Finally, I will present simulations of physics processes of interest based on realistic performance parameters of FoCal-H.

Field of study:

Quantum Physics

Supervisor:

Ian Bearden

Oral presentation / 13

Mechanisms behind Induced Polarization Effects in Water and Brines Confined in Clay Minerals Oriented Films

Author: Aliki Gerakianaki[1]

[1] *Niels Bohr Institute*

The dynamic behavior of water molecules in soils has been extensively studied throughout the years and the understanding of the diffusion processes that occur are of primary importance especially when it comes to waste manage- ment. The main goal of this master project is to study how water molecules confined in clay minerals are moving regarding to salinity and how an electric field stimulation affects the diffusion processes. For the purpose of this study samples of hydrated montmorillonite and beidellite (clay minerals and more specifically smectites) with different salt concentrations were analysed using quasi elastic neutron scattering at the time of flight spectrometer AMATERAS (J-PARC, Japan). A first superficial analysis of the data showed that both the application of electric field as well as the addition of salt indeed affect the diffusion of the water molecules. More specifically, an increase in the mobility is observed when electric field is applied, while on the other hand the presence of salt concentrations indicated a slowing down in the mobility of the water molecules in the sample. In order to analyze the smectite data, the analysis of previous samples of bulk-water using quasi elastic neutron scattering at the backscattering spectrometer IRIS (ISIS, UK) was needed in order to com- prehend the already used data analysis methods, i.e. Swingi-Schölander and minimal model as well as to confirm the correlation between the application of different approaches. After analysing all the data sets, a next step for sam- ples treatment will be to apply Thermogravimetric Analysis to determine the thermal stability and Infrared Spectroscopy to get insight into how interlayer salt and external electrical field may influence structural components of the clay mineral.

Field of study:

Physics of Complex Systems

Supervisor:

Heloisa N. Bordallo, Will P. Gates

Poster session: Enjoy the posters!!! / 14

Simulating the vibrational dynamics of molecules using a quantum dot induced non-linearity

Author: Amelia White[1]

[1] *Niels Bohr Institute*

We aim to develop quantum algorithms that can effectively simulate molecular vibrational dynamics. While simulating quantum dynamics using classical algorithms is trivial for systems approximated as harmonic oscillators, challenges arise when dealing with molecules containing anharmonicity, such as H2O. To overcome this challenge, we propose mapping molecular vibrations to photons and exploiting a non-linearity induced by quantum dots.

Field of study:

Quantum Physics

Supervisor:

Anders Søndberg Sørensen

Poster session: Enjoy the posters!!! / 15

Probe a small droplet of Quark-Gluon Plasma with flow-vector fluctuations at the LHC

Author: Mikkel Petersen[None]

In the early universe, a special state of matter called quark-gluon plasma (QGP) existed. It consisted of the fundamental matter particles (quarks) and the force carriers of the strong interaction (gluons). By colliding heavy-ions at ultrarelativistic energies using the Large Hadron Collider (LHC) at CERN, we can recreate the early universe in a little "Little Bang" and study it under controlled conditions. A central method to study the QGP produced in accelerator collisions is the so-called anisotropic flow technique, that allows to study fundamental properties of the produced QGP droplets. It reveals that the QGP behaves like a near perfect fluid (close to the theoretical lower limit). The present paradigm has been established for collisions of heavy nuclei (Pb). However, recent measurements suggest that, contrary to expectations, flow phenomena have been seen in collisions between much smaller objects.
In this study, a new series of flow observables based on two-particle correlations will be measured using the LHC Run 2 data of small systems (p-Pb). Several analytic methods to measure the flow observables will be presented, each method uses a unique way to remove so-called non-flow (particles that were not created in the initial collision). This study is meant as an initial look at flow observables from small system collisions, which will lead to the systematic study of different small system collisions (p-p) with the necessary examination of the different analysis methods. Thus, giving a better understand if the flow observables in small systems are from the QGP or other mechanisms.

Field of study:

Computational Physics

Supervisor:

You Zhou

Poster session: Enjoy the posters!!! / 16

Greenland ice sheet surface water vapour fluxes from automatic weather station records

Author: Maiken Kristiansen Revheim[1]

Co-authors: Jason E. Box [2]; Christine S. Hvidberg [3]; Baptiste Vandecrux [2]

[1] *NBI, GEUS*

[2] *GEUS*

[3] *NBI*

The mass balance of the Greenland ice sheet is influenced by surface water vapour fluxes. Sublimation and evaporation remove mass from the surface, while condensation and frost deposition adds mass. The energy spent on sublimation and evaporation cools the surface and thus reduces melting, whereas frost deposition and condensation will have the opposite effect. Box and Steffen (2001) estimated the net surface water vapour flux of the ice sheet using data from the Greenland Climate Network (GC-Net) automatic weather station (AWS) from 1995 to 2000. In the last 22 years, the Arctic has been warming at an increasing rate. This project aims to extend the work of Box and Steffen (2001) to the GC-Net AWS data up to 2022 and to investigate how the water vapour fluxes are influenced by arctic warming. The determination of instrument height is crucial for estimating water vapour fluxes but is complicated by the accumulation of new snow at the surface and by the AWS mast being raised periodically to keep the sensors from being buried. Here, we use field notes, photogrammetry and surface height change measured by acoustic sounders to reconstruct the instrument heights. For the time periods with two working levels of temperature, humidity, and wind speed data, we will estimate the net water vapour fluxes and compare with regional climate models.

Work Cited

- Box, J. E. and Steffen, K.: Sublimation on the Greenland Ice Sheet from automated weather station observations, J. Geophys. Res., 106, 33965–33981, https://doi.org/10.1029/2001jd900219, 2001.

Field of study:

Earth & Climate Physics

Supervisor:

Christine S. Hvidberg

Poster session: Enjoy the posters!!! / 17

Complex organic chemistry toward young stars

Author: Martine Lützen[1]

[1] *University of Copenhagen*

The origin of life remains a fundamental question in many scientific fields. From an astrochemical perspective a key element to understanding this question is through the formation and evolution of complex organic molecules (COMs) as they are thought to constitute the precursor for the building blocks of life. Methanol (CH_3OH) is one of many COMs detected in the interstellar medium and is of particular interest due to its simplicity and high abundance. Furthermore, methanol is thought to be the starting point for creating more complex molecules. However, its optical depth varies significantly and as such, this must be considered when interpreting results. This work aims at producing synthetic spectra of methanol observed throughout the hot corino of the isolated core B335. We ultimately find that some of the methanol lines become optically thick at different depths in the core, meaning that the implementation of both a temperature and density gradient is necessary to accurately reproduce a realistic scenario when creating the synthetic spectrum. This model can then be applied to further studies of protostellar systems, such as those observed in the newly accepted large ALMA program, COMPASS –a systematic and unbiased survey of several protostellar regions.

Field of study:

Astrophysics

Supervisor:

Jes K. Jørgensen

Oral presentation / 18

Classifying the first large clean neutrino sample in real data from the IceCube Neutrino Observatory using a Graph Neural Network

Authors: Morten Holm[1]; Peter Andresen[1]; Troels Petersen[2]

[1] *Niels Bohr Institute (Copenhagen University)*

[2] *Niels Bohr Institute*

The IceCube Neutrino Observatory (IceCube) uses a cubic kilometre of the Antarctic ice sheet to detect neutrinos. IceCube carries out neutrino oscillation measurements using atmospheric neutrinos. Furthermore, it contributes to multi-messenger astronomy, searching for the extragalactic origins of neutrinos. All this interesting research relies on accurate neutrino classification and reconstruction methods. Therefore a Graph Neural Network (GNN) was developed by Rasmus Ørsøe, supervised by Troels Christian Petersen, and has been further developed as the open-source Python framework GraphNeT. The GNN has been shown to outperform existing methods on low-energy Monte Carlo neutrinos, while simultaneously speeding up the process by several orders of magnitude. This presentation shows that the GNN not only works in Monte Carlo, but can also select a large clean neutrino sample in actual data. Neutrino samples from Monte Carlo and real data are compared across a wide range of reconstructed and calculated variables. Finally, the number of neutrinos in the clean GNN selection is compared to the existing methods in the IceCube Oscillation workgroup, indicating that the GNN method can generate a more extensive sample at a similar purity. Implementing the GNN in IceCube could increase the neutrino rate and open up the possibility of creating early warnings for electromagnetic telescopes using low-energy neutrinos.

Field of study:

Computational Physics

Supervisor:

Troels Christian Petersen

Poster session: Enjoy the posters!!! / 19

On-chip Frequency Conversion with a GaAs platform

Author: Nikolaos Andrianopoulos[None]

Frequency conversion is a well studied effect of nonlinear optics, in which the nonlinear dielectric polarization of a material describes the response to an incident optical field. The result is the generation of new secondary fields of different frequencies, enabling a variety of applications. For instance, in the field of quantum communication it is used to produce entangled photon pairs and photons of telecommunication wavelength.

An approach to achieve high conversion efficiency is to include a highly responsive material. This is the motivation behind GaAs, since it has one of the largest second and third order nonlinear optical coefficients. Now the case of GaAs is well documented in academic literature, where several techniques has been demonstrated. The research interest of the project is to transfer this phenomenon in an integrated setup, where compact size and better scalability are exploited compared to the free-space alternative.

Field of study:

Quantum Physics

Supervisor:

Leonardo Midolo

Poster session: Enjoy the posters!!! / 20

Reading out a hadronic calorimeter: testning a readout system for the ALICE FoCal-H

Author: Alexander Buhl[1]

[1] *Copenhagen University*

One of the major upgrades to ALICE for LHC Run 4 is the Forward Calorimeter (FoCal). This calorimeter comprises two sections, an Electromagnetic Calorimeter (FoCal-E) and a Hadronic Calorimeter (FoCal-H). Among the physics goals for FoCal is the study of physics at low-x, a regime in which one expects to see signals related to the gluon density in the initial nucleons which form the initial state for the ultra-relativistic collisions ALICE measures. In this poster, I will present results from the first two prototypes of FoCal-H. These prototypes were constructed of copper capillary tubes containing scintillating optical fibers. The scintillation photons produced in the fibers are read out by 6x6 mm^2 Silicon photomultipliers (SiPM). The primary focus of this poster is the performance of the readout and control electronics used for the SiPM. To date, we have tested two commercially available systems from CAEN (A1702 and DT5202) and a system based on VMM ASICs coupled to a CERN SRS module. I will discuss both the results we have obtained to date and our planned path forward to the final detector which will be installed in ALICE in 2028.

Field of study:

Quantum Physics

Supervisor:

Ian G. Bearden