Kandidatexamensarbeten 2021

Fysik

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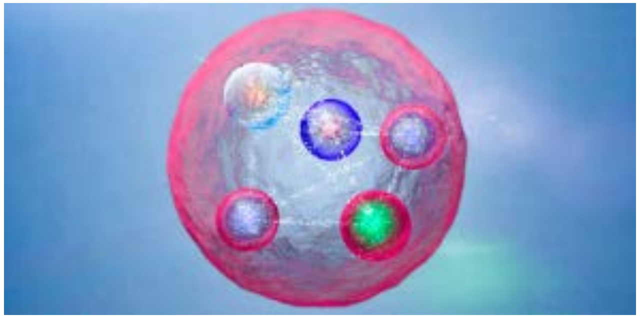
Ytterligare projekt kan tillkomma!

H1 Exotiska hadroner

Handledare: Tommy Ohlsson (tohlsson@kth.se)

Tetrakvarkar och pentakvarkar är exotiska hadroner sammansatta av fyra respektive fem kvarkar. Under den senaste tiden har det rapporterats resultat från flera experiment om existensen av sådana hadroner. Studera modeller för dessa partiklar i den existerande litteraturen och härled relevanta ekvationer. Beräkna numeriskt masspektrum för partiklarna i dessa modeller. Diskutera också dessa modeller i anknytning till standardmodellen för partikelfysik samt till gruppteori.



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H2 Neutrinooscillationer vid ESSnuSB-experimentet

Handledare: Tommy Ohlsson (tohlsson@kth.se)
Studera neutrinooscillationer och härled formler för sådana i fallet med två neutrinosmaker. Diskutera även utvidgningar till tre neutrinosmaker. Undersök också hur materia påverkar neutrinooscillationer. I Lund byggs just nu ESS och undersöks om denna experimentella anläggning kan utökas med ett neutrinoexperiment som kallas ESSnuSB. Beräkna neutrinooscillationer för ESSnuSB-experimentet och undersök speciellt hur materia och den s.k. CP-fasen påverkar dessa neutrinooscillationer.

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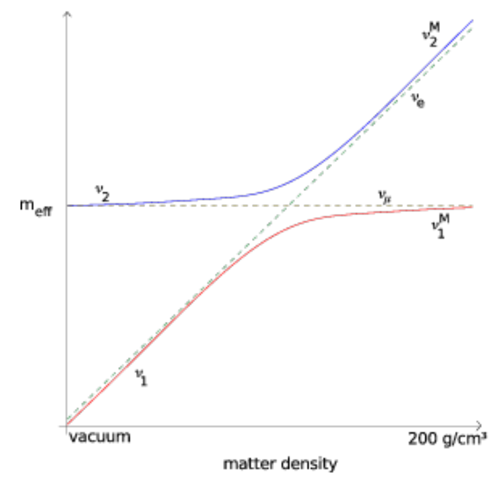
H3 Mikheyev-Smirnov-Wolfenstein-effekten

Handledare: Tommy Ohlsson (tohlsson@kth.se)
Studera fenomenet neutrinooscillationer i materia. Härled den s.k. MSW-effekten och diskutera i vilka experimentella sammanhang som den är väsentlig. Illustrera med några exempel där den är av avgörande betydelse. Undersök speciellt neutrinooscillationer för solneutriner men även för neutriner som propagerar genom jorden.



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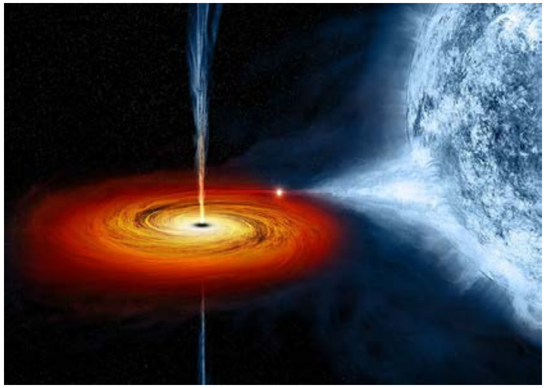
A1 X-ray polarimetry - seeing black holes and neutron stars in a new light

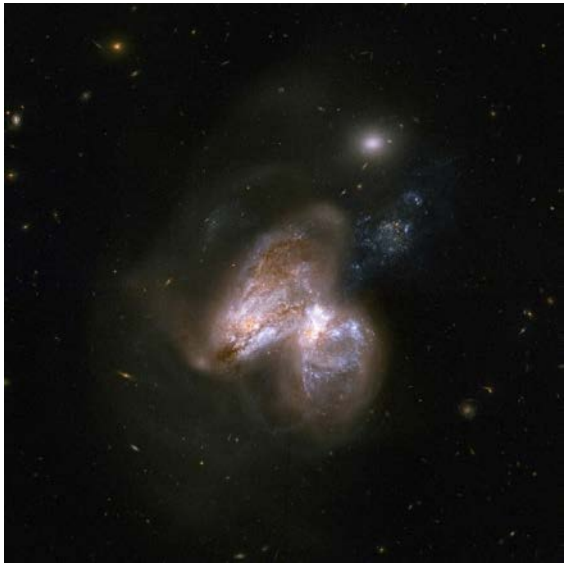
Supervisors: Nirmal Iyer, Mózsi Kiss, Mark Pearce (pearce@kth.se)



Stellar-mass black holes and neutron stars provide a means to study extreme physical environments. Since they are too small and distant to be directly imaged, our knowledge stems from studying the high-energy (X-ray) radiation which they emit, and inferring physical attributes from spectral and timing measurements. Interpretations are often model-dependent, which currently limits our knowledge. A new approach is to measure the polarisation (orientation of the electric field vector) of the X-ray radiation. Such independent observations can be used to break model degeneracies. One of the highlights of astrophysics during this decade will be establishing X-ray polarimetry as a new window on the high-energy universe.

The astroparticle physics group at KTH develops X-ray polarimeters for astrophysics, and has made pioneering observations of celestial objects (such as the binary black-hole system, Cygnus X-1, shown in the image) from a balloon-borne platform in the stratosphere at 40 km altitude. In collaboration with groups in Japan and USA, we are now developing second generation balloon-borne instrumentation to allow significant improvement in measurement sensitivity.
In this project, you will study the design of this new X-ray polarimeter through computer simulations. Software development, e.g. in the Python programming language, is required. You will learn about Monte Carlo simulation techniques, statistical data analysis, and instrumentation for the detection of X-rays. Your studies will help us to improve the design of the polarimeter!

A2 The Supernova Population of Interacting Galaxies



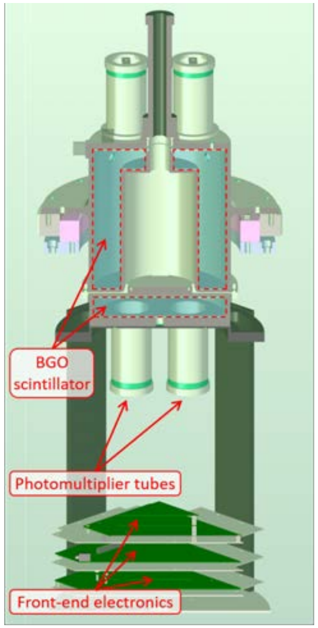
Supervisor: Tuomas Kangas (tuomask@kth.se)
Supernovae (SNe), the explosions of massive stars, are among the most luminous events in the universe and accompany the births of the most extreme objects such as black holes and neutron stars. In addition, they are a major source of information about the dying stars themselves and their evolution. One important piece of this puzzle is the link between different SNe and their progenitor stars, whose ages and masses can be examined through their locations within their host galaxies. In this project you will use statistical methods to analyze the connection between different SNe and strongly star-forming regions in their interacting and merging host galaxies, with atypical environmental conditions and, according to recent evidence, a similarly atypical SN population. You will then compare the results to normal galaxies; this way the differences between the SN populations can beprobed, which can give us more information on the progenitor stars and the environments they are born in.

Reference:

Anderson, J. et al. 2012: *Progenitor mass constraints for core-collapse supernovae from correlations with host galaxy star formation,* MNRAS, 424, 1372 (https://arxiv.org/pdf/1205.3802.pdf)

A3 Background radiation shielding for a stratospheric balloon telescope

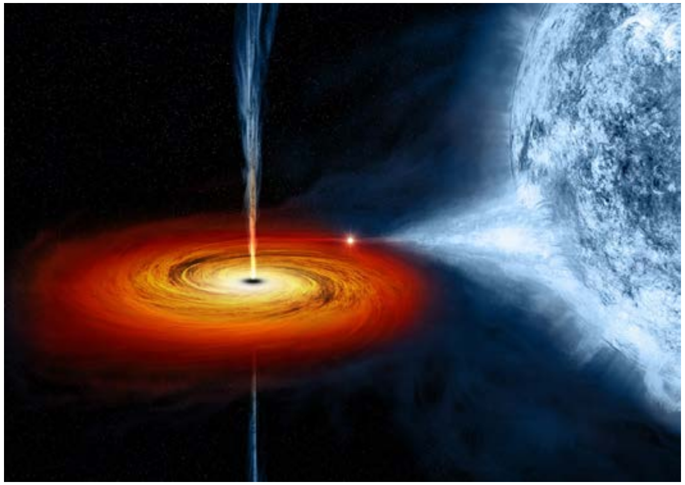
Supervisor: Mózsi Kiss (mozsi@kth.se)
Stratospheric balloons can be used to carry scientific payloads up to altitudes of ~40 km, from where it is possible to observe X-rays and gamma-rays which are otherwise absorbed in the atmosphere. The strong cosmic ray background can pose a challenge to such measurements. This project concerns the testing and optimization of components of an active anticoincidence shield for the balloon-borne hard X-ray telescope "XL-Calibur", to be launched in 2022. You will be working with scintillators, photo-multiplier tubes, analog front-end electronics and more, and your work may directly influence the scientific capabilities of the instrument!"



A 4 Extrema astrofysikaliska transienter

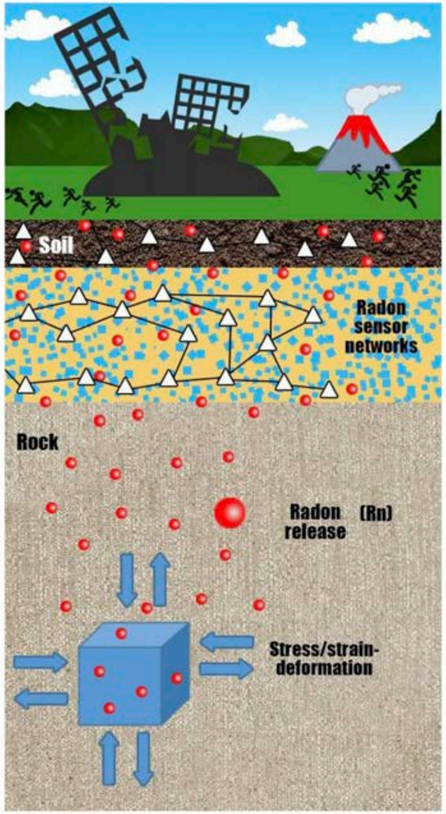
Handledare: Dennis Alp, Josefin Larsson
Många av de mest extrema fenomenen i universum är så kallade transienter. Med transienter menar man objekt som enbart är synliga under en begränsad tidsperiod och ofta uppvisar kraftiga variationer under korta tidsskalor. Detta inkluderar oftast någon form av explosion eller kollision, såsom supernovor eller gammablixtar. Det här projektet handlar om att identifiera och analysera tidsserier av transienter för att på så sätt mäta fysikaliska egenskaper hos objekten. I praktiken kommer projektet att involvera Python-scripting och möjligen användande av specialiserad mjukvara.

A5 Oidentifierade astronomiska röntgenkällor



Handledare: Dennis Alp, Josefin Larsson
Röntgenastronomi lämpar sig för att studera många av de mest extrema fenomen i universum; till exempel svarta hål, neutronstjärnor, och supernovor. Röntgenobservationer fokuserar ofta på ett givet objekt men fångar ofta ett tiotal andra källor inom samma synfält. Majoriteten av dessa objekt studeras aldrig i detalj och nu finns observationer av tusentals objekt som inte har analyserats. I det här projektet kommer speciellt intressanta sådana objekt att identifieras och sedan studeras i mer detalj. I praktiken kommer projektet innebära enklare programmering (Pythonskripts) och analys av data från röntgenteleskop.

N1 Development of a detector system which can register the enhancement of radon gas prior to an earthquake



Supervisor: Ayşe Ataç Nyberg

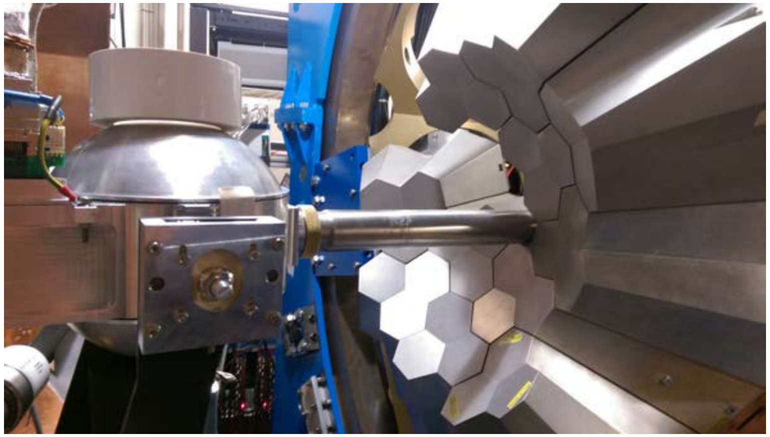
Prediction of earthquakes is an unresolved scientific problem which requires cross-disciplinary research. The ultimate goal is to develop a reliable, effective warning system with respect to location and magnitude with a time window of 2-3 days. One of the precursor signals which has a potential of giving early warning signals, is also very interesting from the nuclear physics point of view. It has been repeatedly reported that there is an enhancement of radon gas in groundwater and soil prior to an earthquake. Radon (222Rn) is a naturally occurring radioactive gas which is part of the uranium decay series. Together with its carrier gases (CO2, N2 etc.) it can migrate upwards from the deep layers of the crust and their concentration is enhanced during large scale seismic movements.

In this work, you will design a gamma-ray detector system that will measure radioactivity from radon and its daughter products in the ground water. The system will be developed by using the simulation toolkit Geant4 and it will later be tested at the Gran Sasso Underground Nuclear Physics Laboratory in Italy.

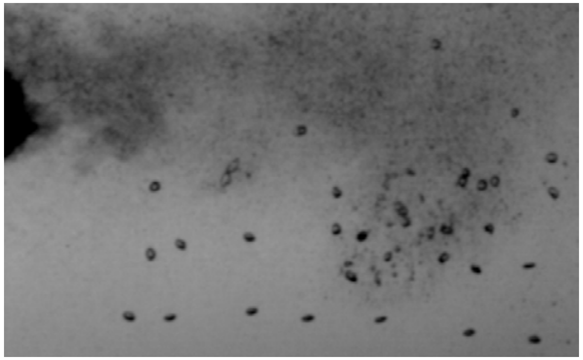
N2 Identification of gamma rays and neutrons in AGATA detectors using neural network and gamma-ray tracking.

Supervisor: Ayşe Ataç Nyberg

Discriminating between the detection of gamma rays and neutrons, which are emitted following nuclear reactions, is a difficult task. Standard gamma-ray detectors show clear signs of neutron interactions in the spectra. The state-of-the-art AGATA gamma-ray spectrometer is based on being tracking the paths of individual gamma rays that hit the high- purity germanium detectors of the spectrometer. New methods of discriminating between gamma rays and neutrons are needed. In this work, you will use artificial neural networks for classifying these two types of particles and investigate how this will effect the gamma-ray tracking results. The data that you will work with will be produced by the AGATA simulation package, which is based on the Geant4 simulation toolkit.



N3 Application of 3D imaging for the analysis of water entrainment by condensing steam jets



Supervisors: Pavel Kudinov, Dmitry Grishchenko

Project description: In case of the primary coolant system depressurization in a Boiling Water Reactor the steam from the primary system can be directed into the pressure suppression pool (PSP). The PSP is designed to serve an important element of plant safety system. However, if thermal stratification is developed in the pool its pressure suppression capacity is significantly reduced. Pool thermal stratification is dependent above all on competition between sources of heat and momentum induced by steam condensation. One of the important elements needed for the momentum model development is the data on the water entrainment around the condensing jets in different injection regimes.

The goal of this project is to estimate water entrainment rates using 3D image analysis of small gas bubbles moving in the vicinity of the jet. The following tasks will be carried out : (i) stereoscopic image analysis of bubbles rising in a water pool underneath water and steam jet injection; (ii) determining water velocity based on the velocity of the bubbles and (iii) calculation of the water entrainment characteristics for water and condensing steam jets (including comparison of the water jets results to the literature data).

In the course of the thesis student will learn about (i) turbulent jets single- and two-phase condensing jets and respective entrainment characteristics, (ii) 2D and 3D (stereoscopic) image analysis techniques and their implementation in Matlab, (iii) using tracers and high speed 3D video recording for estimation of liquid velocity, (iv) quantification of experimental uncertainty. The project will help to develop expertise in the field thermal-hydraulics and nuclear engineering.

Involved faculty: The project will be supervised by Prof. Pavel Kudinov, Dr. Dmitry Grishchenko from the division of Nuclear Engineering.

N4 Coupling of Nuclear Power Generation with Greenhouse Gas Capture (NGC) Technology

Supervisors: Pavel Kudinov, Dmitry Grishchenko, Henryk Anglart

Project description: Humankind has to urgently find solutions to two major and tightly coupled problems: (i) transition to CO_2-free energy and (ii) mitigation of climate change. Both problems are targeted in the UN sustainable development goals and must be achieved by 2030. Four scoping scenarios aiming to limit global temperature rise to 1.5ºC were summarized by the 2015 Intergovernmental Panel on Climate Change. All of the scenarios rely on two- to six-fold increase by 2050 in nuclear energy production and require mass deployment of negative emission technologies, i.e. greenhouse gas capture (GGC). Mass deployment of the GGC technology will need a source of a CO_2-free electric power and high-temperature heat. Nuclear energy can provide both.

Courtesy of NASA, Elena11/Shutterstock.com

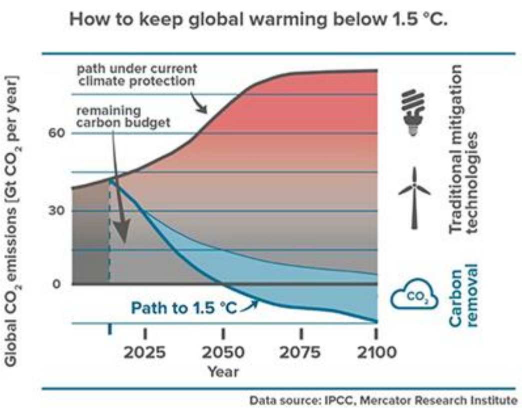
The goal of this project is to develop and demonstrate solutions for the climate control and CO_2-free energy production using nuclear power coupled with GGC technology. A set of approaches will be developed and optimized for coupling between a number (1-2) of GGC technologies with a variety of existing and expressly designed nuclear power installations. The project will work on optimization of energy extraction from a NPP thermal cycle and electricity generation to efficiently support coupled GGC facilities. The work will aim to (i) provide a number of scalable solutions for the deployment of the coupled nuclear-GGC technology, and (ii) develop analytical methods to assess NGC efficiency and long term environmental impact.
The project will help to develop expertise in the fields of nuclear engineering and environmental aspects of GGC.

Involved faculty: The project will be supervised by Prof. Pavel Kudinov, Dr. Dmitry Grishchenko and Prof. Henryk Anglart from the division of Nuclear Engineering.

N5 Model Development for technology of Direct Air Capture of CO2 (DAC) coupled with Nuclear Power

Supervisors: Pavel Kudinov, Dmitry Grishchenko, Pär Olsson

Project description: Humankind has to urgently find solutions to two major and tightly coupled problems: (i) transition to CO_2-free energy and (ii) mitigation of climate change. Both problems are targeted in the UN sustainable development goals and must be achieved by 2030. Four scoping scenarios aiming to limit global temperature rise to 1.5ºC were summarized by the 2015 Intergovernmental Panel on Climate Change. All of the scenarios rely on two- to six-fold increase by 2050 in nuclear energy production and require mass deployment of negative emission technologies, i.e. greenhouse gas capture (GGC). Mass deployment of the GGC technology will need a source of a CO_2-free electric power and high-temperature heat. Nuclear energy can provide both.



The goal of this project is to develop a model for CO2 from the atmosphere. In the course of this project the following tasks will be pursued: (i) a model for GGC will be implemented using available in the literature data, sensitivity analysis and uncertainty quantification will be carried out for ranges of possible conditions; (ii) efficiency of CO2 capture will be evaluated using developed predictive model; (iii) technological requirements for deployment of the technology including requirements to the coupled nuclear power / greenhouse gas capture solution will be formulated.

The project will help to develop expertise in the field the physical-chemistry of GGC and nuclear engineering. The work will be performed in close cooperation with a related project on coupling of GGC technology with nuclear thermal cycle.

Involved faculty: The project will be supervised by Prof. Pavel Kudinov, Dr. Dmitry Grishchenko and Prof. Pär Olsson from the division of Nuclear Engineering.

N6 Response matrix based Monte Carlo simulations of nuclear reactors

Supervisor: Jan Dufek
Simulations of nuclear reactor can be based on deterministic of Monte Carlo methods. Deterministic methods are fast, but codes that use them require to be tailored to a specific reactor design, which makes them impractical for research and development (R&D) of new reactors. Therefore, R&D of new reactors is commonly done with codes based on Monte Carlo methods that are flexible in their application. Monte Carlo codes, however, require a large computing time. New methods are therefore being developed for the acceleration of Monte Carlo codes.
It has been shown recently that Monte Carlo simulations can be accelerated using the application of the so-called response matrix. The project aims at analysing the response matrix based Monte Carlo simulations. The benefits of the method will be weighted against the possible drawbacks.

N7 **Monte Carlo–simulering för mikro- och nanodosimetri:** beräkna medelkordan i jonkammare med olika geometrier och anoder

Handledare: Linda Eliasson och Torbjörn Bäck
KTH har i samarbete med Strålsäkerhetsmyndigheten ett forskningsprojekt där vi estimerar doser i väldigt små volymer, såsom celler och DNA. Forskningen har implikationer speciellt inom strålbehandling, men även för att få grundläggande förståelse för hur DNA påverkas av joniserande strålning i allmänhet.
En viktig dosimetrisk kvantitet inom mikro- och nanodosimetri är den så kallade lineala energin, dvs hur mycket energi som deponeras över en specifik medelkordlängd. Eftersom medelkordan är geometrisk egenskap hos jonkammaren, ändras den beroende på om jonkammaren är sfärisk eller cylindrisk, samt med centrum-anodens tjocklek.
I detta projekt vill vi involvera två studenter som kan beräkna medelkordan för de jonkammare vi använder och planerar att använda samt undersöka effekten av olika anodtjocklekar.
Programspråk: Frivilligt, förslagsvis Python, C
Detta projekt passar studenter som vill förena matematik och fysik.

N8 **Skriv ut en jonkammare för nanodosimetri med 3D-skrivare**

Handledare: Linda Eliasson och Torbjörn Bäck
Inom ett på KTH pågående forskningsprojekt inom mikro/nanodosimetri så studerar vi responsen från olika jonisationskammare, med olika geometrier och vid olika gastryck. För närvarande så är vi speciellt intresserade av mätningar med gasdetektorer vid låga tryck, för att studera variationen av dosfördelning i volymer med en simulerad storlek strax under 10 nm.
Detta KEX-projekt går ut på att med en 3D-skrivare, där en kommbination av isolerande plast och ledande plast kan användas, bygga en jonisationskammare (eventuellt flera olika geometrier), och mäta upp dess respons i högintensiva gammastrålfält (på Strålsäkerhetsmyndighetens Riksmätplats).
Inledande försök i studentprojet tidigare år har gett mycket lovande resultat, och vi tror att metodutveckling på 3D-skrivarsidan kan ge forskningen nya möjligheter att mäta med olika detektorgeometrier.
Detta project passar studenter som vill bygga en egen detektor och sedan testa den i ett verkligt gammastrålfält. Vi hoppas i detta projekt kunna använda KTH:s nya makerspace i Albanova, med flexibel tillgång till 3D-skrivare och andra verktyg.

N9 **Monte Carlo-simulering för mikro- och nanodosimetri:** Simulera responsen i en vävnadsekvivalent proportionalkammare

Handledare: Linda Eliasson och Torbjörn Bäck

KTH har i samarbete med Strålsäkerhetsmyndigheten ett forskningsprojekt där vi mäter fördelningen av absorberad dos i väldigt små volymer, såsom celler och DNA. Denna forskning har betydelse speciellt inom strålbehandling, men även för att få grundläggande förståelse för hur DNA påverkas av joniserande strålning i allmänhet.

En viktig dosimetrisk kvantitet inom mikro- och nanodosimetri är den så kallade lineala energin, dvs hur mycket energi som deponeras över en specifik medelkordlängd. Eftersom medelkordan är geometrisk egenskap hos jonkammaren, ändras den beroende på om jonkammaren är sfärisk eller cylindrisk, samt med centrum-anodens geometri.

Detta projekt passar studenter som är intresserad av att få en introduktion till Monte Carlo-simuleringsverktyget MCNP. Ni kommer att simulera dos-responsen, inklusive den lineala energin, i olika detektorgeometrier och strålfält samt jämföra med tidigare uppmätta data.

Programspråk: MCNP

N10 Bygg en egen mångkanalanalysator för gammaspektroskopi

Handledare: Linda Eliasson och Torbjörn Bäck
Inom experimentell fysik, tex kärn- och partikelfysik, så används ofta s.k. mångkanalanalysatorer (MCA). I KTH:s studentlab så har vi en uppsättning kommersiella MCA:er som används för att generera energi-spektra från radioaktiva preparat. Dessa MCA:er går sönder emellanåt och behöver bytas ut. Nu vill vi utveckla våra egna MCA:er för på sikt att bli mer oberoende av kommersiell mjukvara och hårdvara. Projektet inkluderar grundläggande elektronik-utveckling (inkl. lite lödning), (eventuellt arbete med 3D-skrivare) samt data-insamling på Arduino- och/eller Raspberry Pi-plattformen. Målet är att koppla utrustningen till våra existerande detektorer och få fram ett energispektrum av god kvalitet från gammastrålningen från kända radioaktiva preparat, bl.a. Cs-137. Grundläggande datorkod (i tex C eller Python) för generering av bilder och för export till standardformat av spektra ingår i uppgiften.
Detta projekt passar studenter som vill bygga en egen mångkanalanalysator och sedan testa den med gammadetektorer (NaI-scintillator samt Ge-detektor) som vi använder på KTH. Vi kommer i detta projekt kunna använda KTH:s nya makerspace i Albanova, med flexibel tillgång till lödutrustning, 3D-skrivare och andra verktyg.

S1 Fysiken bakom gejsrar

Handledare: Tommy Ohlsson (tohlsson@kth.se)

Gejsrar är springkällor som med jämna mellanrum slungar ut hetvatten och ånga, vilka bland annat finns på Island. Studera den bakomliggande fysiken för gejserutbrott i litteraturen och försök att skapa en enkel modell för en gejser med hjälp av kunskaper från fysikens matematiska metoder samt numeriskt med hjälp av t.ex. finita elementmetoder. Använd modellen för en specifik gejser (t.ex. gejsern Strokkur på Island) för att se om den fungerar. Kan modellen beskriva gejserns periodicitet och hur högt vattnet slungas ut?

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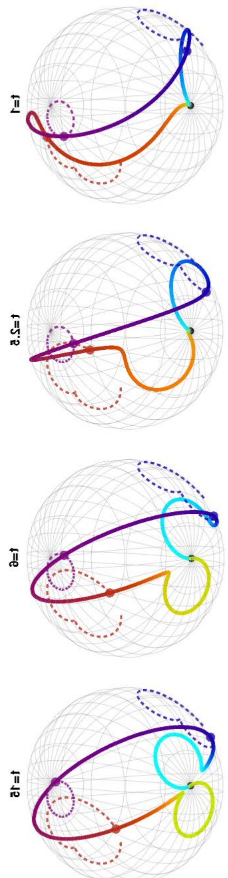
S2 Integrable systems of Calogero-Moser-Sutherland type and solitons



Supervisor: Edwin Langmann

As you know from your basic courses in physics, exactly solvable models like the Kepler problem or the harmonic oscillator have played an important role in the history of physics. There are many fascinating recent examples of such models which are the subject of current research. This research field is fascinating due its mathematical beauty and wide applicability: typically, an integrable systems discovered in one area of physics, finds, in the long run, many other applications. For me, this is the field of mathematical miracles which describe interesting things in the real world.

I can propose several different projects related to Calogero-Moser systems, Ruijsenaars-Schneider systems, and solitons. If you want to know more about what this is about, I recommend the following introductions written by pioneers:

http://www.scholarpedia.org/article/Calogero-Moser_system

http://www.scholarpedia.org/article/Ruijsenaars-Schneider_model

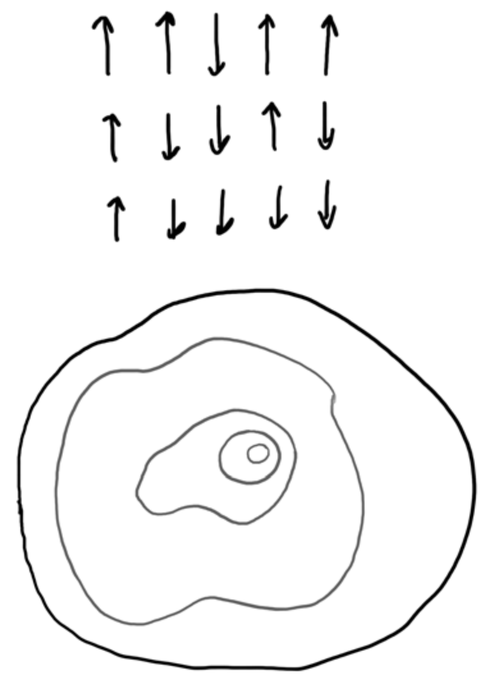
http://www.scholarpedia.org/article/Soliton

The project would be very suitable for several groups to work on at the same time. For each group, I would propose some paper(s) to understand in detail and test by numerical methods. So, you will have understand some non-trivial mathematics, and then do some numerical simulations - how much of one or the other will depend on what you choose.

I have a list of papers I can suggest - you are welcome to contact me if you are interested: we can meet on zoom where I can tell you more.

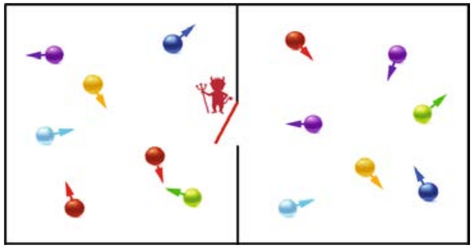
S3 Beräkna tillståndstäthet och hitta grundtillstånd till klassiska spin-modeller

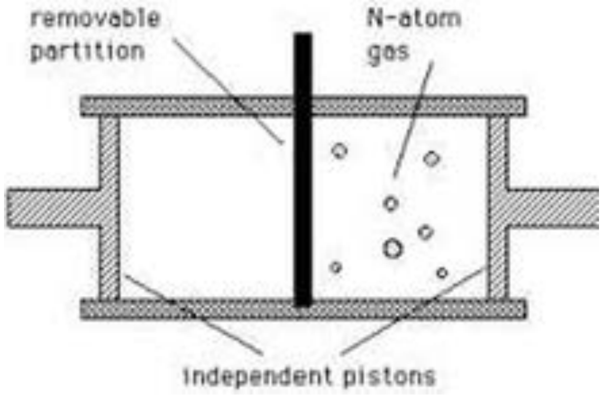
Handledare: Jack Lidmar (jlidmar@kth.se)
I statistisk mekanik vill man ofta räkna ut egenskaper hos en modell vid låga energier vilket kan vara numeriskt mycket svårt om systemet har ett komplicerat energilandskap. Ett exempel ges slumpmässigt oordnade magnetiska material, sk spin-glas.
I detta projekt undersöks en Monte Carlo metod för att beräkna tillståndstäthet och hitta grundtillstånd i klassiska spin-modeller genom parallella simuleringar vid lägre och lägre energi.
Referens: Au, S.K.; Beck, James L., "Estimation of small failure probabilities in high dimensions by subset simulation". Probabilistic Engineering Mechanics. 16 (4): 263–277 (2001).



S4 Kan man bryta mot termodynamikens andra lag? Simulering av Szilard maskinen

Handledare: Jack Lidmar (jlidmar@kth.se)
Termodynamikens andra lag säger att entropin för ett slutet system inte kan minska med tiden. En ekvivalent formulering går ut på att energin i termiska fluktuationer inte kan användas för att utföra arbete. Tittar man noggrannare på detta så gäller dessa dels bara i medel och dels om man bortser från eventuella informations flöden.
I detta projekt ska du använda Monte Carlo simuleringar för att studera hur man kan utvinna arbete ur jämviktsfluktuationer med hjälp av den sk Szilard maskinen.





Referens:
Colloquium: The physics of Maxwell's demon and information
Koji Maruyama, Franco Nori, and Vlatko Vedral
Rev. Mod. Phys. 81, 1 (2009).

S5 Virveln i handfatet

Handledare: Mattias Blennow

Det är lite av en myt att virveln i handfatet på norra och södra halvkloten snurrar åt olika håll. I stället är andra effekter så som handfatets utformning och små strömmar som resulterar från hur det fyllts oftast det som har störst inverkan. Hur långt behöver vi gå för att faktiskt kunna mäta effekten av jordens rotation? Projektet går ut på att replikera experiment ursprungligen gjorda vid MIT samt att kvantitativt uppskatta effekten av jordens rotation samt de övriga effekter som kan inverka på experimentet.

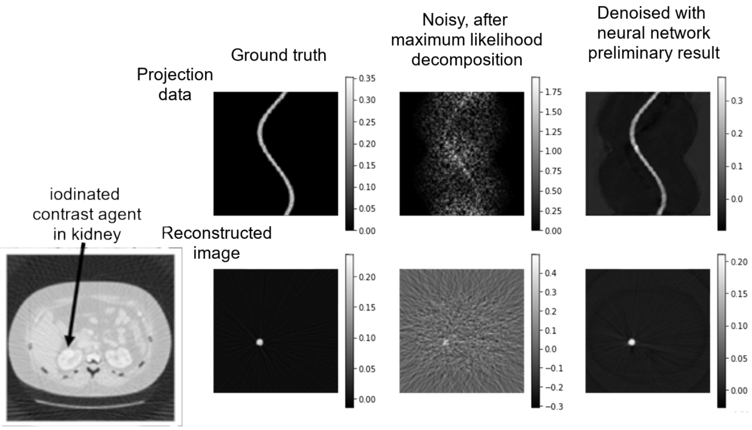
Referenser:
Ascher H. Shapiro, Bath-Tub Vortex, Nature 196 (1962) 1080-1081
Veritasium upprepade experimentet
https://www.youtube.com/watch?v=mXaad0rsV38

M1 Deep-learning image reconstruction for photon-counting spectral computed tomography

Supervisors: Alma Eguizabal (almaeg@kth.se), Mats Persson (mats.persson@mi.physics.kth.se)

X-ray computed tomography is a very widely used technology for medical imaging and is based on acquiring x-ray images from the patient from different angles, so that a three-dimensional image of the patient can be reconstructed. At the department of Physics at KTH, we have developed a new x-ray detector, a photon-counting detector, which can generate images with higher resolution, lower noise, and more spectral information than the detectors in use today. But how the data from this new detector should be processed to generate the best possible images is still an open research question.

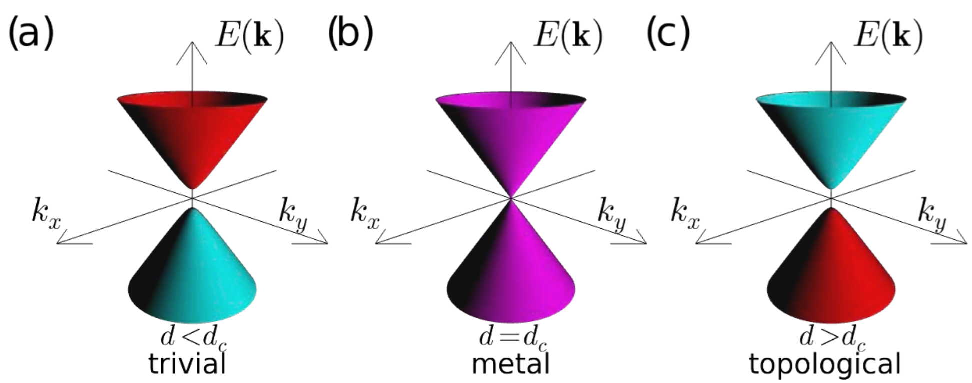
A technology that has generated considerable interest recently is to use deep neural networks for image reconstruction, which enables improved image quality compared to previous algorithms. In this project, we will use this technology to develop a reconstruction method for photon-counting computed tomography and tune the network architecture to optimize the resulting image quality. This project is at the front line of a very hot research area and can pave the road for better medical diagnoses in the future, for diseases such as stroke, cancer and covid-19.



Reference: G. Wang, J. C. Ye, K. Mueller and J. A. Fessler, "Image Reconstruction is a New Frontier of Machine Learning," in *IEEE Transactions on Medical Imaging*, vol. 37, no. 6, pp. 1289-1296, June 2018

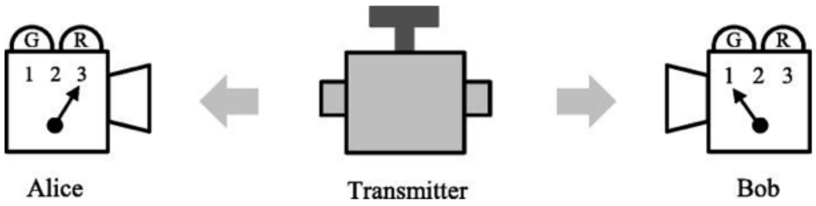
Q1 Domain wall states in topological quantum matter

Supervisors: Julia Hannukainen and Jens H Bardarson (bardarson@kth.se)
In this project we will explore the physics of boundary states in topological insulators. A topological insulator is a material that is insulating in the bulk but has robust metallic surface states. We will explore the connection of these boundary states to the Berry phase of the bulk fermion states by exploring a two dimensional model of a massive Dirac fermion. First we will see how the Dirac fermion is characterised by a topological quantum number, which is the so-called Chern number, which is a certain integral of the Berry phase. This Chern number depends only on the sign of the mass of the Dirac fermion. In a system where this mass can vary in space, one can have a domain wall between a region of positive mass and negative mass. We will study how there are necessarily massless states that appear at this domain wall.
Reference: János K. Asbóth, László Oroszlány, András Pályi, A Short Course on Topological Insulators, https://arxiv.org/abs/1509.02295



Q2 Computer simulation of Mermin's quantum device

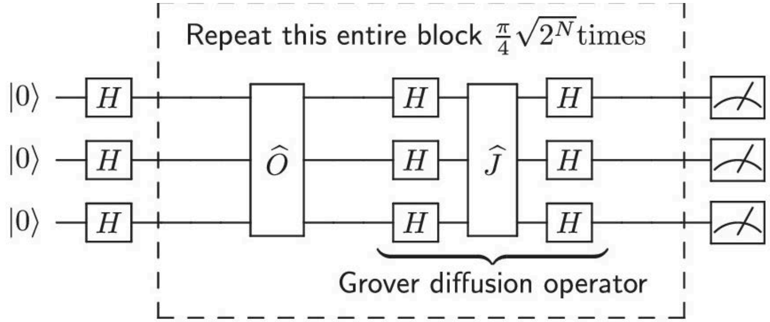
Supervisor: Mats Wallin
Entanglement is a main feature of quantum mechanics. The effect can be studied with a thought experiment using a device suggested by David Mermin. The device consist of a transmitter and two receivers. The receivers each had a three-position switch and two lights, one red and one green. Analysis of the operation of the device follows the predictions of quantum mechanics. The purpose of the project is to analyze the experiment and perform numerical simulations of the operation of the device.



Reference: American Journal of Physics **88**, 483 (2020); https://doi-org.focus.lib.kth.se/10.1119/10.0000833

Q3 GROVER'S QUANTUM SEARCH ALGORITHM

Suppose you want to find a a phone number in a telephone directory with D persons. How many entries do you have to look at to find the person with the wanted number? With a sequential search O(D) attempts are needed. With Grovers search algorithm the number of attempts is reduced to O(D^{1/2}). If D is big this is an enormous saving. The key step of the algorithm is to place the database in a the form of a quantum oracle: a quantum mechanical operation that accepts superpositions of questions and returns superpositions of answers. The aim of the project is to analyze the search algorithm and implement it on a computer and do numerical tests to simulate its performance on small databases.



Referens:
American Journal of Physics **83**, 688 (2015); https://doi-org.focus.lib.kth.se/10.1119/1.4922296