SCHOOL OF PHYSICS AND ASTRONOMY
UNDERGRADAUTE PROJECTS ABSTRACTS
SPA7912U Physics Instigative Project
SPA7400U Physics Research Project

This booklet contains a series of abstracts designed to help students pick their supervisor for the final year project component of the MSci programme.

In the fourth year of the MSci students can pick either a 30 credit project (SPA7912U) or a 45 credit project (SPA7400U).

Once you have read through these abstracts and decided on which 8 supervisors you wish to list in the online form please go to the online selection area make your choices about which supervisor you prefer. If you do not pick 8 different supervisors you will be randomly allocated supervisors to fill the remaining slots (i.e. if you only pick one person we will add in the remaining 7 choices for you!).

Project selections must be submitted by 13h June 2014. You will be notified by email of your supervisor in early July.

When choosing a supervisor you must make sure that their abstracts correlate with your degree programme. Therefore students on the Astrophysics programme must do a project related to Astrophysics. Students on the Theoretical Physics programme must undertake a theory project (although this could be theoretical astrophysics and theoretical condensed matter as well as projects supervised by CRST staff). Students on Physics with Particle Physics must likewise select a project related to their degree programme.

The abstracts in this booklet are listed by research group and then alphabetically by staff member within that group.

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ASTRONOMY UNIT

Craig Agnor

Origin and Evolution of Planetary Systems

Origin and Evolution of Planetary Systems

With the expanding inventory of extrasolar planets, multiple robotic missions roaming the solar system, and the continued discovery of additional primitive bodies (e.g., near Earth asteroids, planetary satellites, Kuiper Belt objects and comets) planetary astrophysics is the fastest growing area in astronomy. The formation and evolution of planetary systems involves a wide range of physical process (e.g., stellar evolution, collisions, tidal interactions, gravitational dynamics, atmospheric evolution, geodynamics, giant collisions, orbital migration, ...etc.). In this project, the student will study a particular system of interest (e.g. the giant planets of the solar system, systems of satellites, Earth's Moon, planetary rings, planetary rings, the asteroid or Kuiper belts, or an extrasolar planetary system) conduct a critical review of the fundamental processes that best account for the origin of its properties. The student will then use analytical and numerical approaches to explore the dynamics and history of the system.

Prerequites: programming background and an interest in numerical modeling.

Nonlinear Dynamics in Planetary Systems

The Planetary systems exhibit nonlinear dynamics and chaos in a variety of ways. For example, observations indicate the saturnian satellite Hyperion's rotation axis wobbles so much that its orientation in space is unpredictable. Analytic arguments and numerical experiments have shown the orbits of the solar system's planets exhibit chaotic variations, are unpredictable on timescales as short as a few million years and may be unstable on timescales of a few Gyr. In this project the student will be introduced to nonlinear dynamics and the approaches used to describe chaotic systems. The student will then review how nonlinear dynamics is expressed in planetary systems and will develop a numerical model to explore and characterise the chaotic evolution of a satellite or planetary system of interest.

Prerequisites: Strong analytical skills, good performance in PHY5304 Physical Dynamics and an interest in numerical modelling.

Guilem Anglada-Escude

Measuring accurate mass-radius of super-Earths detected by Kepler

Masses of transiting extra-solar planets can be measured by analyzing the instants of transits in multiplanet systems. The mutual gravitational interactions produce transit-timing variations that encode the masses of the bodies. While most masses from the Kepler mission have been estimated using this method, it is known that non-trivial correlations and the existence of multiple solutions satisfying the data can produce strongly biased results, producing density estimates that are likely unphysical (<0.05 g/cm^3 compared to 1.0 g/cm3 of water). In this project we will use Bayesian Monte Carlo methods combined with numerical integration of planetary orbits to properly explore the space of allowed solutions and produce uniformly derived mass-radius measurements of Earth/super-Earth sized objects detected by the Kepler mission.

Prerequisites : interest in planetary system dynamics and numerical methods.

David Burgess

The outer boundary of the heliosphere

The solar wind is an example of an astrophysical plasma. As the solar wind expands away from the sun it eventually interacts with the local interstellar medium. A number of important boundaries form as the solar wind decelerates including the termination shock and heliopause. This project will investigate what is known from observations by the Voyager and IBEX missions about the outer limits of the heliosphere. The project will require study of some basic plasma physics including particle motion in electromagnetic fields and plasma waves. Some analysis of spacecraft data may be possible. Prerequisites: A high level of understanding of basic electromagnetism, and a good level of mathematical ability especially in vector calculus.

Atmospheric Electricity and Space Weather

The atmosphere has a low level of ionization due to Galactic cosmic rays and natural sources of radiation. The low level of conductivity allows a global electric circuit to form, driven by the global agglomeration of lightning in thunderstorms. One result is that everywhere on the Earth there is a potential of about 250 kV between the ionosphere and the Earth's surface. It is possible to measure this potential locally and the extremely small current that it drives. The ionosphere and cosmic ray flux is affected by space weather changes attributable to solar activity. This project will explore the nature of the global electric circuit, and the evidence for connections to space weather. There will be the opportunity to use data from atmospheric electricity experiments, and to explore observational and data analysis techniques.

Prerequisites: A high level of understanding of basic electromagnetism, a willingness to learn about plasma physics and space weather effects.

Bernard Carr

Primordial black holes

This project will examine the various ways in which black holes may have formed in the early universe and their possible cosmological consequences. Sufficiently small ones will have evaporated through Hawking emission but could still leave observable signatures through their contribution to the background radiation, their influence on cosmological nucleosynthesis, their generation of cosmic rays, and a variety of other effects. Larger ones would still exist and could have a variety of interesting dynamical, lensing and astrophysical effects. Students much choose to focus on one of more of these consequences.

Quantum black holes

This project will examine the way in which black holes provide an interface between quantum theory and general relativity. The most famous example of this is black hole radiation. Although this was discovered nearly 40 years ago, several outstanding issues are still unresolved, such as the black hole information paradox and the nature of the processes which occur in the final explosive phase of an evaporating black hole. There is also the issue of what happens as the black hole mass falls towards the Planck scale, which impinges on theories of quantum gravity. If there are large extra dimensions, Planck black holes may be detectable in accelerators like the LHC. Students much choose to focus on one of more of these aspects.

Baryonic and non-baryonic dark matter

This project will examine the evidence for the dark matter in the universe (known to comprise about 25% of its total mass density) and its possible explanations. Candidates are generally classified as non-baryonic (WIMPs) or baryonic (MACHOs), with a wide variety of candidates in each category. There is still no definite evidence for any of the candidates, but a huge range of data from both astronomy and particle physics constrains the possible proposals. Students may choose to focus on one or more of the candidates in greater detail.

Multiverse proposal and cosmological fine-tuning

This project will examine the possible evidence for fine-tuning in the universe, involving both the constants of particle physics and various cosmological parameters. The weight of evidence for these tunings and their possible interpretation will be critically assessed. In particular, the possible relationship to the multiverse proposal, in which our universe is just one of a huge ensemble of universes, will be considered. There are many different multiverse scenarios, so students may choose to focus on some of these in more detail. This project also offers the possibility of a slightly more philosophically-oriented topic.

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James Cho

Climate

What was the temperature structures of Earth's Pliocene (about 5.3 to 2.6 M years ago) like? What is its link to the general circulation pattern? what are its implication, if any, for present-day global climate change? In this project, the student will review climate dynamics theory and current ideas about Earth's climate in the recent past. The project will involve performing a critical analysis of several recent papers and developing tests for simple general circulation model simulations.

Fluid Dynamics

What is nonlocal wave turbulence? What is its role in plasma and geophysical flows? In this project, the student will review wave turbulence -- i.e., dynamics of many random waves. The student will focus on the nonlocal aspect of the wave turbulence problem and its application in fusion and weather prediction. A simple nonlinear fluid dynamics model will be used to study zonal flow (flow in a preferred direction, as in a east-west jet stream on the Earth) growth.

Richard Donnison

The derivation and use of the restricted three-body problem in Astronomy

The restricted three-body problem involves the motion of a body of an infinitesimal mass moving under the gravitational forces of two finite masses. In this project the equations of motion and constants of motion can be derived. These can be applied to a large variety of physical systems in Astronomy both analytically and numerically. In this project the applications would be confined to the Solar System, particularly asteroids, comets and moons or to Extrasolar planetary systems.

James Lidsey

Inflationary Cosmology

Early Universe cosmology. This project will discuss the flatness and horizon problems of the standard, Big Bang theory and explain how a period of accelerated expansion (inflation) can resolve these problems. The cosmic dynamics of massive scalar fields that drove inflation will be developed. Observational parameters (that are ultimately determined by particle physics considerations) will be derived. The methods for linking such parameters with anisotropies in the Cosmic Microwave Background will be explained and some specific models analysed. The consequences for inflation of the first-year data from the Planck satellite will be discussed.

Inflationary Cosmology and Large-Scale Structure Inflationary Cosmology

Inflationary Cosmology, whereby the universe underwent a phase of accelerated expansion in its most distant past, is the cornerstone of modern, Early Universe cosmology. The flatness/horizon problems of the standard Big Bang will be discussed. The resolution of these problems through inflation will be explained. This project will focus on how the cosmic dynamics of inflation laid down the initial conditions for the formation of galaxies and clusters of galaxies, by the present era. The linear theory of density perturbation growth will be developed to provide a link with recent observations. Some specific models will be tested.

Mathematical Aspects of Inflationary and Dark Energy Cosmologies

Modern observations strongly indicate that the universe underwent a phase of accelerated expansion in its most distant past (inflation) and is currently undergoinng a second phase of such expansion at the present epoch (dark energy/quintessence). Although the underlying physics is manifestly different in each scenario, the ordinary differential equations that determine the cosmic expansion share many mathematical features. This project will discuss various mathematical techniques, such as change orf variables, that can be employed to solve these equations analytically in a variety of settings. Some exact solutions will be derived.

Karim Malik

Inflationary Cosmology

In the first part of this project the student will review the "standard model" of modern cosmology, including the period of accelerated expansion in the early universe called inflation. In the second part of the project the student will either deepen the review of modern cosmology, possibly including also the late time acceleration of the universe due to dark energy, and study the different models proposed for inflation. Or the student will derive the equations necessary to compare models of inflation to the observational data, and study these models using the latest data.

Late universe project

In the first part of this project the student will review some basic general relativity and the "standard model" of modern cosmology. The late time acceleration of the universe and observational evidence for this acceleration will be discussed, with a brief introduction to dark energy and modified gravity. In the second part of the project the student will either deepen the review of dark energy and modified gravity. Or the student will derive the equations for the evolution of the density perturbation in the Newtonian limit for different cases, for example a matter dominated universe. Analytical and numerical solutions will be derived using computer algebra packages and/or python.

Carl Murray

Saturn's F ring

Cassini images of Saturn's F ring show a complicated structure that is determined by a combination of the gravitational and collisional effects of nearby satellites. There are regular features due to the perturbing effect of the moon Prometheus but there are also several smalland large-scale "jets" which are the product of collisions with small moonlets orbiting nearby. The aim of the project is to analyse existing image mosaics of the ring using software tools developed in Mathematica. The student would be expected to write their own routines to characterise the nature of the ring and its changing appearance over time; this would include looking for periodicities in the ring as well as tracking the motion of clumps seen in the images. They would also be expected to draw conclusions about the nature and distribution of the objects affecting the ring.

Ring-satellite interactions

There are several examples in the solar systems of planetary rings being gravitationally perturbed by nearby satellites. This is a computational project involving a numerical study of how the orbits of rings particles are affected by their encounters with a satellite with applications to real examples of ring-satellite interactions in the solar system. The student would be expected to develop their own code to study the time evolution of the orbital elements of the ring particles by solving the relevant equations of motion and then relate these to spacecraft observations of features such as edge waves, clumps, streamers and channels observed in ring systems.

The structure of planetary ring systems

The planets Jupiter, Saturn, Uranus and Neptune all possess ring systems of differing sizes and complexity. The aim of the project is to make use of the latest space- and ground-based observations to review current knowledge of the dynamical structure of each planetary ring system as well as the theories that have been proposed to account for them. The student would be expected to summarise the key features of each system, identifying the basic properties and the physical processes involved in determining ring structure at each planet. Any examples of the same processes operating in different ring systems should be identified.

Richard Nelson

Extrasolar planets and planet formation

Since 1995 more than 1000 confirmed planets have been discovered orbiting stars other than the Sun, with many additional discoveries being announced on a weekly basis. In this project you will review the detection methods used to discover these systems, the range of planetary system architectures that have been discovered, and our current understanding of how planetary systems form. The project will involve writing and/or running a computer code to examine one of the following issues: (i) The dynamical stability of multi-planet systems and the origins of the orbital eccentricity of extrasolar planets; (ii) Orbital migration of planets due to interaction with the protoplanetary disc in which they form and the formation of short-period extrasolar planets.

Alexander Polnarev

Polarization of Cosmic Microwave Background (CMB) and Cosmological Gravitational waves(CGWs)

The Physics of CMB polarization based on the Tompson scattering of anisotropic CMB radiation on free electrons in pre-galactic plasma. The E and B- modes of polarization and the detection of CGWs. Experiment Bicep2. Gravitational lensing versus CGWs in the generation of B-mode polarization.

Prerequisites: Any courses on Cosmology and General Relativity as well as on Electromagnetism including the propagation of electromagnetic waves in plasma

Supermassive Binary Black Holes

Formation of the binary black holes in the course of galaxies mergers. The subsequent evolution of the Binary due to different mechanisms such as 1) dynamical friction, 2) tidal disruption of stars, 3) interaction of smaller black hole with accretion disks around more massive central black hole and 4) gravitational radiation at the final stages of the binary evolution . This project also includes the analysis of observational evidence of Binary black Holes in AGNs and QSOs.

Prerequisites: any course on Extragalactic Astrophysics and General

Will Sutherland

Baryon Acoustic Oscillations

Baryon acoustic oscillations are created by sound waves in the baryon-photon plasma in the early universe; these both create the famous series of "acoustic peaks" in the microwave background, and also leave a faint imprint in the distribution of galaxies today; there is a slight excess of galaxy pairs separated by a distance near 450 million light years. This project will explore the ways in which observations of the BAO signature can be used to constrain cosmological parameters.

Some basic computations with Mathematica, Python or IDL will be required.

Dark matter in dwarf galaxies

The theory of cold dark matter is very successful on scales larger than the Milky Way, but has some problems on sub-galactic scales; in particular, it appears to predict too many dwarf galaxies and too much dark matter in the inner regions of large galaxies. This project will review this problem from both an observational and theoretical perspective, and study some possible solutions, including non-standard properties of dark matter.

David Tsiklauri

Magnetic fields in the solar corona

The project involves (i) writing a numerical code to produce potential extrapolation of magnetic fields from solar photosphere to corona; (ii) comparison with observations (iii) critical analysis of the literature on importance of magnetic field reconnection in solar coronal heating.

Dissipation of Alfven waves via phase mixing

The project involves (i) analytical calculations; (ii) writing a numerical code to study the dissipation of Alfven waves via phase mixing; (iii) critical analysis of the literature on importance of MHD wave dissipation in solar coronal heating.

Sergei Vorontsov

Asteroseismology with Kepler mission

NASA space mission Kepler, targeted primarily at habitable-planet finding, has delivered unprecedented amount of high-quality photometric measurements of stellar oscillations. The project is expected to give a comprehensive review of the results obtained for different stars, a review which would be a current review at the date of submitting the project. Basic understanding of the physical nature of different types of stellar pulsations (p-, f- g- and mixed modes), and of their diagnostic capability (frequency- and period spacings, frequency splittings) is required, which is expected to be gained as part of the work on the project principally by reading the relevant literature, suggested by the supervisor.

CENTRE FOR CONDENSED MATTER AND MATERIALS PHYSICS

Mark Baxendale

Complex thermoelectric materials

Themoelectric materials convert waste heat energy to usable electrical energy. The primary figure of merit for these materials is the Seebeck coefficient, i.e. the ratio of the voltage measured across the sample in response to a small temperature gradient. This project aims to synthesise and measure the Seebeck coefficient of some new candidates for thermoelectric energy generation and to make a comparison with that of the best known thermoelectric material, bismuth telluride (~100 uV/K at room temperature. These new materials are based on a carbon nanotube network and a conducting polymer - the flows of electrical and thermal energy follow complex filamentary paths. The temperature variation of the Seebeck coefficient will then be measured and the behaviour interpreted in terms of the possible underlying mechanisms. The aim is to develope a new category of thermoelectric devices capable of harvesting energy from sources of waste heat encountered in everyday life, e.g. computers, body heat, car exhausts.

John Dennis

Synthesis, purification and spectroscopic characterisation of isomer-pure fullerenes

Fullerene have been synthesised in the range C60-96. As the number of carbon atoms increases, the number of possible structural isomers (same number of atoms, but different arrangements of them) also increases. For example, C60 has only one isomer, but C84 has 24 possible isomers. Despite the huge number of possible isomers, relatively few have actually been purified (about 20). The student will be tasked with using chromatographic separation techniques to purify a fullerene for which no isomers have previously been purified (e.g., C88) from an as-produced mixture of fullerenes (which range from C60 – C96). After which, the student will further purify their sample into its individual isomers. The isomer pure samples will then be characterised by a number of spectroscopic techniques.

Synthesis, purification and spectroscopic characterisation of thermodynamically stable C70 adducts as precursors for targeted drug delivery systems

Unlike C60, where all carbon atom environments are identical, C70 is a fullerene, which is still available in high yields, has several (5) different carbon-atom environments. Hence, unlike C60, the synthetic chemistry of C70 exhibits both chemo- and region-selectivity. The synthetic chemistry of C70 has until recently been kinetically rather than thermodynamically driven (i.e. the products are those that form the fastest rather than those that are the most stable). Indeed the most thermodynamically stable products were never formed. Recently, we have developed high temperature techniques whereby the most stable product is formed. These have the advantage that a thermodynamically stable anchor can be added to C70, which cannot be removed under normal chemical processes. Hence, C70 can be made water soluble (by adding –OH groups) without affecting the anchor. The anchor on the water-soluble fullerene can then be exploited whereby a drug is attached to it. By also adding a specific tissue-targeting group, a local drug-delivery system may be produced. Research in this area is at an early stage, but the student will have the task synthesising and purifying a thermodynamically stable carbonyl (-C=O) adduct of C70 using out new high temperature techniques. The student will then prove that they have produced the adduct by a number of spectroscopic techniques (including Mass, Infra-red (vibrational), and/or 1H and 13C NMR spectroscopy).

Kevin Donovan

Carbon Nanotubes as Langmuir Blodgett Films
Many organic molecules that possess hydrophilic and hydrophobic parts may be floated on a clean water surface as Langmuir films and compressed in a controlled fashion to form a rigid film of single molecule thickness. This floating film may be transferred to a substrate (eg glass slide) as a single or multilayer Langmuir-Blodgett film by passing the substrate through the water/film interface. It is possible to modify carbon nanotubes, CNTs, such that they are amenable to this process. Using this technique a mixed film of CNTs and a well understood LB molecule, ω tricosenoic acid, ωTA, will be created and its optical and electrical properties studied as the ratio of CNT to ωTA is varied in the film.

Induced Optical Anisotropy in Nanotube Suspensions
Single walled carbon nanotubes in suspension will, under the influence of a pulsed electric field align in that field. This alignment may be observed in real time by observing the temporal growth of induced optical birefringence and or dichroism. This project will use the induced optical birefringence to measure the polarisability of the nanotubes along with their average length and their effect on the viscosity of the suspending medium as their concentration is increased.

The Length Distribution of Single Walled Carbon Nanotubes
Single walled carbon nanotubes, SWCNTs, in suspension will, under the influence of a pulsed electric field align in that field. Once the field is switched off the nanotubes will slowly return to their state of random orientation. The rate of randomisation may be followed by observing the optical anisotropy of the suspension. The rate at which this randomisation occurs will depend on the length of the SWCNT. and therefore the length distribution of the nanotubes may be inferred from the decay. This project will involve using the fitting of such decays to a model where there are many different length SWCNTs present and thus finding the length distribution of the SWCNTs. A good knowledge of Mathematica and/or C++ will be necessary to carry out the fitting.

Drift Velocity of Electrons on One Dimensional Molecular Wires

Charge carriers (electrons or holes) in one dimensional, 1D, semiconductors is that a single electron (hole) in the 1D conduction (valence) band will strongly interact with the 1D lattice forming an electron plus lattice deformation, the composite object being called a solitary wave acoustic polaron, SWAP. A remarkable property of the SWAP is that the charge will travel at the velocity of sound (a relatively low velocity) but will achieve this velocity at very low electric fields entailing and ultra-high mobility. Such a 1D semiconductor is provided by single crystal polydiacetylenes, PDAs, and the properties of the SWAP may be studied through the photoconductive properties of the PDA following excitation by a rapid laser pulse. The object of this project is to measure the transient photocurrent and the total charge created by such a laser pulse and thus deduce the drift velocity of carriers on PDA chains and how it varies with applied electric field.

Growth of Single Crystals of Polydiacetylene Toluene Sulphonate

All polymers with the exception of polydiacetylenes when in the solid state will exist as a high entropy collection of random chains (eg. polyethylene in plastic bags). It is possible, however in the case of polydiacetylenes, to grow large (several mm) single crystals of the monomer diacetylene, DA, provided the DA has appropriate sidegroups allowing particular parameters for the monomer crystal to be achieved. One such sidegroup is the toluene sulphonate sidegroup which allows topochemical solid state polymerisation of the monomer crystal to take place with a resulting highly perfect polymer single crystal where all of the polymer chains are aligned. Such polymer chains behave as one dimensional wires and as such are of great interest to semiconductor physics. This project involves perfecting the oxygen free growth of such monomer crystals and their polymerisation.

Martin Dove

Disordered crystalline materials; what can we learn from novel diffraction methods

We have a strong interest in understanding the fluctuations in the positions of atoms within crystal structures that appear to have a lot of structural disorder. Examples include materials in which some atoms diffuse at a fast rate through the background crystal structure (so called fast-ion conductors that are used as electrolytes in solid-state batteries), and molecular materials where the orientations are disordered and tumbling when the positions are ordered on a lattice, or liquid crystals where the molecules have well-defined orientations but disordered positions.

In this project we will combine a diffraction-based method (using either neutrons or x-rays) with subsequent date-oriented computer simulation to study one specific example (this will be chosen by the student). You will be using state-of-the-art experimental methods (which may include a visit to the UK neutron scattering facility, and the use of an x-ray facility at Queen Mary) together with novel analysis methods developed in part by Queen Mary scientists.

The end result will be a new insight into the local structure and fluctuations of a material, which will certainly be publishable in the scientific literature.

Capture of carbon dioxide using porous crystalline materials

One critically important environmental problem for modern societies is that of controlling the mount of CO_2 we put into the environment. One solution is to capture CO_2 at the industrial sources. Current methods are expensive, and there is a lot of interest in looking for new materials for this task. One approach is to use porous crystalline materials, with a lot of interest in hybrid metal-organic materials that form crystal structures that contain large pores and channels.

The project is to use computer simulations to understand the mechanisms of CO_2 absorption in materials. The approach is to use a technique called molecular dynamics, which is a form of virtual reality at atomic length and time scales. The project will involve setting up a simulation of passing gases across a sample and observing the way that the material soaks carbon dioxide out of the gas stream. The project will require simulations over a range of temperatures and for a range of gas compositions, and will focus on both the capture of CO_2 and it subsequent release. The end result will be an evaluation of a specific type of material for capture of CO_2, which can be published as a scientific paper.

Anomalous properties of framework materials

One very curious property of some materials is that they shrink when heated, contrary to the normal case of expanding. We have ideas about why this might be so, and here I am offering two projects, both of which are based on computer simulations. Both will lead to results we will publish as scientific papers.

1. One family of materials that displays negative thermal expansion is zeolites, which have chemical formula SiO_2 and in which the structure forms SiO_4 tetrahedra that are linked at corners to form infinite connected networks. The existence of negative thermal expansion is associated with the ability of the network to flex with low energy cost. The project will involve simulations of the dynamics, using lattice dynamics calculations and molecular dynamics (a form of virtual reality). The aim will be to identify negative thermal expansion in a group of zeolites (those with hexagonal crystal structure) and to then assess it against models of network flexibility.

2. A second family, represented by the formula ZrP_2O_7, shows negative or positive thermal expansion depending on the detailed chemical composition. The crystal structure consists of ZrO_6 octahedra and PO_4 tetrahedra linked at corners to form an infinite connected network. This network, however, is not flexible, and the origin of negative thermal expansion must lie in the ability of

either the octahedra or tetrahedra to distort. The project will use ab initio lattice dynamics calculations (calculations based on a form of quantum mechanics) to evaluate the phonons, and we will then match the associated atomic motions with flexibility models. The aim will be to identify the mechanism of negative thermal expansion, and to understand why some members of this family of structures show negative thermal expansion whereas other members don't.

Alan Drew

Excited State Muon Spectroscopy

As part of the MuSES project (further details can be found at http://muses.ph.qmul.ac.uk), this PhD project will pioneer the use of laser muon spectroscopy to probe excited electronic states in organic semiconductors and biologically relevant molecules. Muons have several unique advantages over the traditional optical pump-probe techniques, but perhaps most importantly is that site-specific information on electron dynamics can be gained. Because of the local nature of the probe, one is able to assemble the time evolution of the transient electron's wavefunction on different parts of the molecule, thus measuring the timescales of each individual step of the electron's motion from donor to acceptor. This is the only technique capable of offering both spatial and temporal information on the transient electron and has recently undergone a successful proof of principle experiment. As such, the purpose of this pioneering project is to set out the boundary conditions of the technique, opening the door to the next decade of research. These boundary conditions will be set by first working on a well known and well characterised class of organic semiconductors. Several functionalised pentacenes will be measured to understand the role of excitation of muoniated radicals in organic molecules. The project will then move on to understanding electron transfer processes in biological molecules (such as carotenoids).

Exciton Dynamics in Organic Photovolatics and Light Emitting Diodes

Organic electronics has emerged as a vibrant field of research and development, spanning chemistry, physics, materials science, engineering, and technology. Whilst not destined to replace silicon-based technology, organic semiconductors promise fully flexible devices for large-area displays, solid-state lighting and solar cells. These devices mentioned share a common trait: their performance critically depends on exciton dynamics, which are not particularly well understood. This project is to characterize the exciton dynamics in organic semiconductors using a new technique that we are pioneering: photo-excited muon spin spectroscopy. This technique can be thought of as a traditional pump-probe technique, where electrons in the material are excited by light, and then the dynamics of this excitation is studied with a muon.

Local Probe Investigation of Multiferroic Materials

Multiferroicity is a widely sought-after property for modern technological applications, yet relatively few multiferroic materials are currently known to exhibit magneto-electric coupling at room temperature. There is a clear need not only to develop new materials, but also to develop a systematic methodology for materials discovery and characterisation. One of the key aspects of multiferroics not currently well understood is how localised modifications to structural, electronic and magnetic states alter the macroscopic ferroic order parameters. Many such modifications are possible, resulting in changes to local dynamic fluctuations, local correlations, or long-range order/disorder effects (e.g., in the vacancy distribution or positional cation order). This PhD project is part of a larger research activity aimed at performing a systematic cross-technique approach designed to span all the relevant length scales in a variety of promising material classes. It will correlate how macroscopic ordering changes with doping, strain or chemical pressure, which are all local properties, then use modelling to understand the structure-function relationships. This combined knowledge will then guide targeted synthesis towards the discovery of new materials.

David Dunstan

The Size Effect in Small-Scale Plasticity

The student will join an on-going research programme on the strength of soft metals and the increase in strength when a characteristic dimension (wire diameter, foil thickness ...) is small, on a length-scale of microns. According to the student's interests, they may develop new equipment, take data, and undertake theoretical analysis.

A new medical instrument for monitoring diabetes

Together with a small optics and lighting company, we are developing an instrument intended to measure the loss of nerve function that triggers many complications in diabetic patients. There are a range of problems which a student on this project may choose to work on, ranging from writing software, building hardware, to inventing and testing measurement protocols.

Bill Gillin

Energy transfer and population inversion in organic lanthanide materials

We have recently demonstrated the onset of population inversion in erbium ions in an organic host material. This observation opens the possibility of producing optical amplifiers and lasers that can be integrated directly onto silicon wafers. The approach we used was to have two organic molecules, one of which contains the erbium ions and the other of which is a chromophore. This is an organic molecules which strongly absorbs light and yet can transfer the energy from the absorbed photon directly into the erbium. Using this approach we have been able to increase the effective absorption cross-section for the erbium by a factor of 10000, which means that we can use very low optical pump powers to produce population inversion. This project will look at investigating the effect of changing the chromophore molecules on the energy transfer and excitation of the erbium.

Theo Kreouzis

Charge photogeneration and dielectric changes in Organic Semiconductors
Free charges can be photogenerated in Organic Semiconductors by illumination. These free carriers can subsequently cause changes in the dielectric properties of the organic material. Previous work by us has shown that there are significant discrepancies between measured dielectric changes and calculated charge densities (the experiment works too well by a factor of 104!), thus the aim of this project is to use steady state illumination experiments to directly measure the photogenerated charge density in the semiconductor as well as the changes in its dielectric properties

Alston Misquitta

Advanced electrostatic models for simulations

NOTE: This is not one project but many interrelated ones.
The electrostatic interaction is the simplest of the intermolecular and intra molecular interactions. Yet it is also the most important: if you want to get the structure of hydrogen-bonded complexes correct you need to have a reasonably good description of the electrostatic interactions of the species. Likewise, a good description of the electrostatic interactions is essential when modelling complex structures like metal-organic frameworks (MOFs are materials that exhibit unusual properties like negative thermal expansion – see the models in the Physics Museum cabinets).

In these projects we will use a state-of-the-art method for partitioning molecules into atomic-like parts to compute electrostatic models. This method, known as the iterative stockholder atoms (ISA) approach was developed by Wheatley and Lillestolen [1] and I have recently developed a robust numerical algorithm to implement it.

This model for atoms in a molecule surpasses any available for its numerical properties and the physical nature of the atoms.

Consequently it will allow us to explore:

* Charge-penetration effects

  These are the effects of inter-penetrating quantum densities.

They are missing from most empirical potentials.

* Changes in multipole moments as function of vibration

  This is particularly important: how do the atomic moments

  alter as bonds stretch or bend?

* Comparison of ISA multipole moments to those from other methods.

  This will include learning how to calculate reference

  electrostatic energies using SAPT(DFT).

Day-to-day: Review of literature on electrostatic methods. Using the CamCASP program to calculate and analyse intermolecular interactions; understand how molecule partitioning methods work; compare models with the literature.

Pre-requisites: (not all essential, but will need to be acquired) The Linux shell, basic Python scripting, basic Fortran90, Quantum Mechanics.

T. C. Lillestolen and R. J. Wheatley, "Redefining the atom: atomic charge densities produced by an iterative stockholder approach", Chem. Commun., 2008, 5909-5911 (2008).

<u>Charge-Transfer</u>
The hydrogen-bond remains one of the most versatile and often-seen types of intermolecular bonds in biological systems: Base-pairs are bonded by hydrogen bonds in a zipper-like manner; water forms hydrogen bonds to give ice its open hexagonal structure. A characteristic of these bonds is charge-transfer which can be understood as the delocalisation or sharing of electronic charge between the bonded molecules. This sharing leads to stabilization and consequently to the strength of the bond. Charge-transfer poses a considerable problem for interaction models (the simple potentials used to model large proteins) and quantum mechanical methods like density functional theory. The more we understand about charge-transfer the better. In this project we will use state-of-the-art perturbation theory methods to investigate charge transfer in a variety of situations and novel charge-density analysis methods to see the extent of this transfer in complex systems.

Day-to-day: Review of literature on charge-transfer complexes; review of basic ideas in intermolecular perturbation theory; review of current literature on charge-transfer; get hands-on experience with using the CamCASP program to calculate and analyse intermolecular interactions; identify a set of systems that we will perform calculationson; calculate charge-transfer energies for these systems; understand how charge-density-decomposition methods work; use theseto develop an understanding of the charge flow in the system; compare results with literature; make well-defined statements about the charge-transfer process and, possibly, on the many-body aspects of this process.

Pre-requisites: (not all essential, but will need to be acquired) The Linux shell, basic Python scripting, basic Fortran90, Quantum Mechanics.

Anthony Phillips

Ab initio computational studies of flexible frameworks

Background: Framework materials consist of metal ions linked together into a 3D network by organic molecules. These materials have recently attracted substantial attention for their unusual and interesting properties, some of which are described below. This project will involve running ab initio computer simulations -- that is, simulations based entirely on calculation, rather than using experimental data -- in order to shed light on the origins of these remarkable properties. We will then compare our results to experimental data where available.

There are two choices for materials to work on:

(a) A molecular escape artist
We will study a material in which guest molecules can escape from the pores even when they appear to be blocked. This appears to be because the framework can break apart temporarily, then heal itself again. The aim will be to demonstrate that this is indeed occurring and to produce a scientifically accurate video of this happening.

(b) Negative thermal expansion
We will study materials that shrink, rather than expanding, when they are heated. What is the connection between this property and the materials' structure? In particular we will aim to explain why materials with similar structures can have substantially different coefficients of thermal expansion.

Prerequisites (for either choice): Some familiarity with Linux/Unix systems would be useful.

Andrei Sapelkin

Photoluminescence excitation system for quantum dot research
Within this project we will set up a laser–based photoluminescence excitation (PLE) system and develop Labview software to control data acquisition. The PLE system will be used to access the light emitting properties of variety of off-the-shelf and in-house made quantum dot systems.

Prerequisites: basic optics, some knowledge of computer programming/analysis (VBasic, C, C++, Origin, etc.

Synthesis and characterization of germanium quantum dots
Quantum dots – materials reduced in size down to just a few nanometers possess a range of interesting physical properties due to effect of quantum confinement of charge carriers (electrons and holes) and a large surface-to-volume ratio. These properties can be used in variety of applications including tagging of living cells and observation of communication in neuron networks. This experimental project involves preparation of Si and Ge quantum dots by colloidal synthesis; optical (photoluminescence) and structural (Raman, SEM/TEM).
Prerequisites: basic optics, basic laboratory skills

Synthesis and characterization of gold quantum dots
Quantum dots – materials reduced in size down to just a few nanometers possess a range of interesting physical properties due to effect of quantum confinement of charge carriers (electrons and holes) and a large surface-to-volume ratio. These properties can be used in variety of electronic, engineering and bio applications and it is essential to understand the relationship between the structure of these materials on the atomic level and their physical properties. Within this project we will synthesise gold quantum dots and will tune the light emission between 530 nm and 630 nm by cooperation ligand exchange using 11- mercaptoundecanoic acid (11-MUA) and D-penicillamine (DPA). Quantum dots will be characterized using photoluminescence and TEM/SEM.
Prerequisites: basic optics, basic laboratory skills

Kostya Trachenko

The phonon approach to liquid thermodynamics
Historically, liquids have been the toughest objects to deal with from the theoretical point of view. As a result, despite very long history of research, liquids remain least understood theoretically, in contrast to other two basic forms of matter, gases and solids. Recently, we have developed an approach to liquid thermodynamics based on phonons. As such, this approach views liquids as systems related to solids much closer than thought previously. This is in contrast to the previous theories that viewed liquids as strongly interacting gases. In this project, the link between the previous and recent theories will be explored. For a model system, liquid energy and heat capacity will be calculated as an integral over interatomic interactions and correlation functions, and will be compared with the equation derived from the phonon theory. This effort will require the ability to perform analytical calculations as well as using scientific software such as Matlab. The result will be the link between the structure of the liquid and its dynamics, an exciting missing link in the theory of liquids.

Dr David Berman – experimental project

Optimising quinine extraction from Cinchona bark for the production of natural tonic water

Most commercially available tonic waters use industrially synthesized quinine. This project will produce natural tonic water through extracting quinine from Cinchona bark. The variables in the extraction process include bark concentration, grind size and temperature, all these should be optimised. The final quinine concentration will be determined by constructing a simple spectral analyser to measure the quinine florescence and implementing the Beer-Lambert law. The effects of bark impurities will also be examined.

If you would like to do this project please note that you want to do Dr Berman's experimental project in the 'other information' box on the project choice form.

CENTRE FOR RESEARCH IN STRING THEORY

David Berman

Generalised geometry in string and M-theory
The project will review how one may generalise geometry so as to describe how strings see spacetime. This is a heavily mathematically based project and only suitable for the most mathematically able student. The topics covered include: the generalised metric, determining the local symmetries, global aspects such as fibre bundle and grebe structures and the construction of duality invariant actions.

Experimental project

Optimising quinine extraction from Cinchona bark for the production of natural tonic water
Most commercially available tonic waters use industrially synthesized quinine. This project will produce natural tonic water through extracting quinine from Cinchona bark. The variables in the extraction process include bark concentration, grind size and temperature, all these should be optimised. The final quinine concentration will be determined by constructing a simple spectral analyser to measure the quinine florescence and implementing the Beer-Lambert law. The effects of bark impurities will also be examined.

If you would like to do this project please note that you want to do Dr Berman's experimental project in the 'other information' box on the project choice form.

Andi Brandhuber

Black hole physics
One of the most fascinating objects predicted by Einstein's theory of General Relativity (GR) are black holes and a complete understanding of the quantum physics of black holes remains a challenge for theoretical physics. This project will introduce the student to the basic concepts of black holes, starting with their classical description in terms of solutions of Einstein's equation, moving on to the quantum description and the thermodynamics of black holes. Later stages of the project will also touch on (some of) the following topics: microscopic description of certain black holes using (super)string theory, derivation of black hole radiance as a quantum mechanical tunnelling effect or from quantum field theory on curved spacetimes, thermodynamic phase transitions and black holes in Anti-de-Sitter (AdS) space. The project may also include a review of the existing indirect experimental evidence for the existence of black holes.

(Prerequisites: PhD, STG, QMB, RWQF, ideally also a more advanced GR course, some experience with Mathematica/Maple is essential)

String theory/gauge theory duality

In 1996 Juan Maldacena proposed a duality between (super)strings moving on Anti-de-Sitter (AdS) spacetimes and certain gauge theories that are close cousins of gauge theories relevant for the standard model of particle physics. In this project the student will be introduced to the main aspects of this duality and study simple examples to understand the dictionary between physical quantities on the two sides of this duality. A particularly simple and important class of quantities is the static potential V(r) between electric/magnetic test charges which is related to Wilson loops. The phases of gauge theories can be characterised by the shape of this potential and the student will analyse, from the dual string theory point of view, how for example the Coulomb law (1/r potential) between electric charges and confinement (linear potential) between quarks arise in different set-ups of the duality. If time permits more complicated physical observables will be considered.

Prerequisites: QMB, QMS, STG, RWQF, ideally also a more advanced GR course, some experience with Mathematica/Maple is essential

Sanjaye Ramgoolam

Gauge invariance and permutation groups.

Gauge invariance is a fundamental ingredient of quantum field theory, the mathematical structure underlying the standard model of particle physics. The gauge group of the standard model is a continuous group. This project will study the link between gauge invariance with continuous groups and the mathematics of finite groups, such as permutation groups. Permutation groups provide powerful tools for the classification of gauge invariants and the computation of their correlators. The project requires a knowledge of MT4 as background, and may also involve working with computational software for group theory, which would be learned during the project.

Rodolfo Russo

Thermodynamics of Black holes in D-dimensions

Black Holes in Einstein gravity (and its generalisations) satisfy some simple laws that are identical to the basic equations of thermodynamics. As an introduction, some BH solutions for standard Einstein gravity are reviewed and generalised to the case of higher dimensional theories. Then the thermodynamics laws for BH will be studied and their relevance for a theory of quantum gravity will be discussed.

Steve Thomas

From classical strings to photons and gravitons

The project starts with manipulating equations describing the geometry of string worldsheets and their embedding in space-time. This is followed by working through aspects of formal quantum mechanics and special relativity. It builds up to the worldsheet quantum theory construction of space-time physical states such as photons and gravitons. These investigations can also be extended to the case of D-branes. There is also scope to study numerically, solutions describing classical open strings, closed strings as well as D-branes via use of Mathematica or Matlab software packages. Zwiebach's string theory book provides the main reference.

Inflationary Cosmology

Inflation has been proposed as a 'paradigm' whereby the Universe undergoes a period of exponential expansion during which spatial regions as small as 10^{-25cm} get blown up to something of the order of a few cms in size in only 10^{-32} sec! Such a model explains some long-standing problems in standard Friedman-Roberston-Walker big bang cosmology, namely the so-called horizon and flatness problems as well as (potentially) solving the singularity problem. At the same time it also explains the near scale-invariant spectrum of perturbations that we can observe today through their imprints on the CMB radiation. One particular type of perturbation predicted is a primordial spectrum of gravitational waves whose affect is to polarise, in a very particular way, the microwave light from the CMB. In a spectacular recent experiment, this polarisation has been detected by the BICEP2 collaboration using telescopes based in the South Pole.

This project covers some fundamental aspects of inflationary cosmology. Beginning from the FRW Big Bang model in general relativity, the student will then work through the details of inflation and the conditions required for it to occur. This will primarily involve so called slow roll inflation models and examples will be studied motivated by both particle physics and string theory. Other kinds of inflation such as 'chaotic' and 'eternal' inflation will also be covered, by way of comparison. Classical field evolution and quantum fluctuations will be investigated with the latter giving rise to various perturbation spectra that the student will derive. The resulting cosmological observables will also be derived and predictions tested against current precision CMB data. There is scope within the project to use Mathematica or MatLab as numerical tools.

Brian Wecht

Classical and Quantum Strings

In this project, we'll start with the equations describing the geometry of string worldsheets and their embeddings in spacetime. This is followed by working through aspects of formal quantum mechanics and special relativity, and builds up to the worldsheet quantum theory construction of spacetime physical states found in string theory, such as photons and gravitons.

Supersymmetric Quantum Mechanics

Supersymmetry is a speculative idea that posits a relation between fermions and bosons in certain models. Although most supersymmetric models require the knowledge of quantum field theory, it's also possible to study supersymmetric models that only use quantum mechanics (which is quantum field theory in 0+1 dimensions). In this project, we'll develop the basic technology used in supersymmetry, and study its consequences in quantum mechanics. Time permitting, we'll move on to supersymmetric models in field theory as well.

Donovan Young

You have 15 minutes to save the Neutrons

The universe was once hot enough that neutrons and protons were constantly turning into each other through weak nuclear interactions, but at some point things expanded and cooled down sufficiently so that neutrons and protons were isolated. Protons are stable but neutrons decay with a half-life of about a quarter hour -- they had to find their way into Helium nuclei (where they are protected against decay) quickly, or else the universe would be neutron-free! In this project you will find out how this miracle occurred, and even calculate how much helium we should expect to find.

PARTICLE PHYSICS RESEARCH CENTRE

Adrian Bevan

PeV energy scale particle physics

The Large Hadron Collider represents the high energy frontier in particle physics with 14Te collision energy expected in 2015 once the current upgrade period has finished. This collision energy will be enough for physicists to search for new physics up to 10^12 eV. Accelerator technology is not expected to significantly push beyond this limit without some radical new breakthrough. Cosmic rays can provide particles with energy up to 10^21 eV, with low rates. What can we do with those to further our understanding of physics, and how will we do it?

Flavour physics at the LHC

The ATLAS detector triggers on di-muon events, and as a result collects data suitable for rare decay studies. The study of such decays is complementary to the high energy direct detection approach and relies on understanding subtle interference patterns between different contributions to the final states. There are two ares of interest for this project: The first pertains to B physics: The family of decays including a b quark transition to a strange quark and di-muon pair is being studied by our at ATLAS. Recent results provide some hint that all may not be well with the Standard Model and we are working on trying to understand if this anomaly is statistical in nature or a hint of something new. I am also expanding my interest in rare top decays, which forms the second possible are for project research. This second area is more challenging as it is less well defined and require students opting for this route to take more initiative in order to understand and define the scope of the project. The former route has the option of allowing students to re-analyse 2011 data from ATLAS in the context of recent theoretical developments.

Marcella Bona

Inputs to the Unitarity Triangle fit.

To completely characterise the Standard Model, we need to extract the values of some parameters from various high energy experiments and theoretical calculation. The UTfit project is a global fit analysis that using the Bayesian statistics extracts SM parameters and SM predictions on various observables using the most updated results from experiments and lattice QCD. Some of the inputs need special statistical treatments and analyses that have to be regularly updated.

C++ programming is necessary.
The analysis is performed within the Root package (root.cern.ch) that should be installed on the used computer.

Invariant Mass Fits For The Search Of Rare B Decays Into Two Muons.
The B mesons can decay into two muons and the probability of this decay is very low but accurately calculated within the Standard Model. ATLAS experiment at LHC is searching for these decays and the crucial part of the analysis is calculating the invariant mass of any pair of two muons in the collision events and then perform a fit to the invariant mass distribution taking into account all the signal and background components.

C++ programming is necessary.
The analysis is performed within the Root package (root.cern.ch) that should be installed on the used computer.

Multivariate analysis methods for rare B decays
As the B mesons decay into two muons with a very low probability, it is fundamental to develop methods to distinguish between the actual signal and the random background component that is dominant in the collision data. There are several methods that can be used to exploit the different topologies and event characteristics and obtaining a single variable that can be used to separate between signal and background. Fisher discriminant, Boosted Decision Tree, Neural Network have to be tested and the optimal method selected for the purpose of the search of rare B decays.

C++ programming is necessary.
The analysis is performed within the Root package (root.cern.ch) that should be installed on the used computer.

Jon Hays

Beyond the Standard Model Higgs at the LHC
Though the Higgs boson discovered by the LHC in 2012 looks, with current measurements, very much like that predicted by the standard model of Particle physics, this does not rule out richer theories with multiple Higgs bosons where only one of them looks like that predicted in the standard model. This project will identify kinematic variables to distinguish between standard model Higgs production, Higgs production in multi Higgs doublet models and standard model background processes. It involves programming in C++ to run event generators based on Monte-Carlo simulation techniques and simple analysis with the ROOT software.

Prerequisites: Strong C++ programming skills

Improving the categorization of events in the search for the Higgs boson in its decays to b quarks

The Higgs boson was discovered at the LHC in the Summer of 2012 with a mass of around 125 GeV. There is strong evidence for its production in a number of its decay modes. However, as yet, there is not a statistically significant signal in the channel where the Higgs decays to a b quark and an anti-b quark. A key parameter in the performance of the search in this important channel is the resolution with which the mass of the Higgs can be reconstructed from measurements of the decay products. Being able to separate events where the mass is well measured from those where it is poorly measured may have an important impact on the sensitivity of the analysis. In this project you will investigate multivariate approaches to estimating the mass resolution on an event-by-event basis.

Prerequisites: Strong C++ programming skills

Teppei Katori

Test of Lorentz violation with neutrinos
work type = phenomenology
Lorentz symmetry is a fundamental symmetry of both Quantum Field Theory (QFT) and General Relativity (GR). However, ultra high energy theories, such as String Theory, imply a violation of Lorentz symmetry, and a tiny violation could be observable in our energy scale. Therefore, test of Lorentz violation offers a rare opportunity to test Planck-scale physics directly. In the effective field theory, Lorentz violation is realized by additional coordinate-dependent couplings with vacuum, and the QFT including Lorentz violation, so-called the "Standard Model Extension (SME)" is a general formalism to test Lorentz violation.

Neutrinos are least known fundamental particles, and their Lorentz violating nature, if it exists, is particularly interesting. In this project, we study the phenomenology of Lorentz violation with neutrinos in SME formalism, and formulate the new phenomenological expression suitable to test Lorentz symmetry by high intensity long-baseline neutrino experiment, such as T2K in Japan.

MiniBooNE experiment data analysis of neutrino interactions
work type = data analysis
MiniBooNE is a neutrino oscillation experiment at Fermilab, USA.
Besides oscillation results, the neutrino interaction data from the MiniBooNE experiment are also valuable for nuclear physics community.
In this project, using the real MiniBooNE data, we further analyze them to provide more useful information to nuclear theorists in the world.
I am especially interested in to provide new kinematic distributions of muon neutrino charged-current quasi-elastic (CCQE) scattering. By the way MiniBooNE is taking data right now to look for possible dark matter production in the beamline. We will participate data taking, which is the quickest way to learn how a real particle physics experiment works.

Electromagnetic calorimeter (ECal) reconstruction for T2K experiment
work type = software development
ECal module is a part of detector being used in T2K neutrino experiment, Japan. The ECal was partially built in Queen Mary, and it was tested at CERN before shipped to Japan. Particle tracks and electromagnetic showers are reconstructed in ECal, to study the nature of neutrino interactions. Now we need a better algorithm to reconstruct lower energy shower-like events.

In this project, we examine the detail of track and shower finding algorithm of ECal, and further develop it to identify especially low energy shower events. Low energy shower events are key to understanding neutral pion productions which is one of the largest background for neutrino oscillation search. Therefore, developing the ECal reconstruction algorithm is a critical component of T2K neutrino oscillation program.

Atmospheric neutrino study for general new physics search in IceCube experiment
Work type = data analysis
IceCube is the 1 kilometer detector located at the Antarctica, 1 kilometer under the ice. The IceCube detector is so unique and special, and the main goal of IceCube is the detection of ultra high energy neutrinos from the universe. Atmospheric neutrinos are mere backgrounds of such high energy neutrinos. Although we know neutrinos from the atmosphere since 1960's, there is no comprehensive study to find new physics from atmospheric neutrinos.

In this project, we analyze IceCube atmospheric neutrino data to provide kinematic distributions for particle theorists in the world.
Well, I am not smart enough to find any new particles from these data, but hopefully some smartest people in the world could find Nobel prize winning physics from data we provide!

Neutrino interaction development for IceCube and PINGU
work type = data analysis, software development
For particle physics experiments, it is fundamental to understand, and simulate basic interactions. All discoveries (Higgs particle, neutrino oscillation, etc) are based on the knowledge of all known interactions and precise simulation. However, in the reality very few people understand actual interactions in the simulation, and those processes are treated like a "black box" for many physicists. Therefore, people who understand interactions are like "wizards" (meaning people working on something really complicated which nobody understands). This is true for neutrino experiments, too.

In this project, I hope you feel you will become a wizard of neutrino experiments! We develop the global neutrino interaction code called "GENIE". It contributes all neutrino experiments all over the world. I am particularly interested in the development of GENIE hadronization model for the IceCube experiment at Antarctica. This will improve the sensitivity of IceCube experiment and it's follower, called PINGU experiment.

Eram Rizvi

Studies of Di-Muon production at the LHC
The LHC has been designed to produce copious quantitites of the Z0 boson whose properties have been determined by the SLC and LEP accelerators

previously. In this project simulated LHC data will be used to study the reaction rate (or cross section) of two muons from Z0 decays. Statistical techniques will be used to filter the data and determine the event rate and assess the measurement capability of the ATLAS detector. A knowledge of C++ and linux will be required.

Matthew Machowski (PLEASE CONTACT DR RIZVI WITH ENQUIRIES)

Politics of Physics: The Iranian Bomb
As we sit on the brink of a potential Western/Israeli-led pre-emptive war with Iran over their alleged nuclear weapons programme, this project investigates the impact of nuclear weapons (technology) acquisition on international politics and security. Iran's nuclear programme has now spanned over three decades, much in defiance of both international demands and legal constraints. Despite much political rhetoric and decades-long accusations against Iran, both the IAEA and all the Western intelligence agencies struggle to provide irrefutable evidence for either the presence or the extent of Iran's weaponisation.

This project is predominantly aimed at students considering a career in politics, security, risk management and science policy, but also those willing to investigate the correlation between nuclear physics and current affairs. Although you are encouraged to develop you own niche theme, issues surrounding nuclear weapons technology, nuclear deterrence, legal and political anti- and counter-proliferation efforts, nuclear intelligence gathering and analysis, or support for nuclear terrorism may be of particular interest here.

Bio: Matthew is a Middle Eastern security specialist and a former research analyst for the Middle East and North Africa Programme of the Royal United Services Institute for Defence and Security Studies (RUSI). He has so far consulted the UK Parliament and governments of Japan, Poland and Qatar. He has additional experience in journalism and human rights advocacy. He spent over four years living in the Middle East, where among others he worked for one of the region's royal families. His commentary was featured in international media, including The Times, NHK World News etc.

Jeanne Wilson

SNO+ Modelling and detector response
SNO+ is a multi-purpose neutrino experiment based in an active nickel mine in Sudbury, Canada, due to start data taking in 2013. The SNO+ detector consists of a large volume of liquid scintillator, surrounded by around 9000 PMTs. The experiment will detect neutrinos from the Sun, Earth, nuclear reactors and possibly also SuperNovae allowing precision measurements of neutrino oscillation parameters. In a separate phase of the experiment, Neodymium will be added to the scintillator to allow a search for the rare process of double beta decay which would probe the fundamental properties

of the neutrino. These measurements require extremely low levels of radioactive background, and a very precise understanding of the detector response which is achieved through accurate modeling and calibration of the detector. This project would contribute directly to the testing and development of the C++ based Monte Carlo simulation package that is being written by the SNO+ collaboration for this purpose. The student would use the package to simulate various physics quantities that must be compared against theory or experimental calibration data.
(Prerequisite: an understanding of C++ and linux will be required.)

Study of medipix detector chips
Queen Mary is involved in the so-called CERN@School project which involves equipping several schools with a CERN Medipix chip connected to a laptop in order to gather data about secondary cosmic rays in the atmosphere which is then shared between the schools. The project will involve studying the behaviour of the chip under various conditions (voltage, threshold etc) and with different radiation sources suitable for use in schools. The student will work to interpret the data using and developing existing monte carlo and plotting tools and to develop projects suitable to be carried out in schools.