**CMP22**  Modelling the structural and magnetic diffraction pattern from layered materials

Many materials of current research interest for novel electronic and magnetic properties have a layered crystal structure made up of stacked two-dimensional atomic layers. When layers are weakly bonded to one another then occasionally there will be faults in the regular stacking sequence, when the origin position in a certain layer would slide by some in-plane offset to a position that is not in register with the layers below. Such faults are manifested in the x-ray diffraction pattern in a diffuse scattering signal with certain characteristics in addition to the Bragg peaks associated with the ideal structure. The aim of this project is to develop an efficient way to calculate the diffraction pattern in the presence of such faults to compare with experimental x-ray diffraction data and identify the microscopic types of stacking faults that occur in honeycomb magnets of current research interest in the group such as RuCl3 and Na2IrO3 with novel magnetic properties stabilized by the combined effect of a strong spin orbit coupling and a two-dimensional honeycomb lattice for the magnetic ions. It is anticipated that Matlab or Python will be used to write code to calculate the expected structural and magnetic diffraction pattern with the flexibility to capture different types of stacking faults and magnetic orders.

This project would require the ability to learn independently from books and papers and a keen interest and some experience in programming (Suitable for 1 student taking the C3 CMP option).

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***WITHDRAWN***

**CMP22**  Specific heat measurements of quantum magnets in applied field and at low temperatures

This project is to work in the quantum magnetism group in the Clarendon Laboratory to improve and extend the current experimental capabilities to measure the heat capacity (specific heat) of single crystal magnetic materials down to low temperatures and in applied magnetic fields. Heat capacity is a very sensitive probe to detect thermodynamic signatures of structural and magnetic phase transitions. This project is optimise the performance of an existing design for a measurement platform onto which the sample, resistive heater and thermometer sensors will be mounted and interfaced with measurement equipment that monitors how the sample temperature changes upon passing a known electric current through the heater. This setup will be cooled inside a cryostat where magnetic fields can also be applied. We would like to expand the capabilities of the system to include the option to measure the magnetocaloric effect (variation of sample temperature upon sweeping the magnetic field due to changes in entropy upon crossing phase boundaries). This will require modifications to both the hardware (adding new components) and software (changes to the control software). This experimental setup will be used to measure novel materials of current research interest synthesized in the Clarendon Laboratory, such as quantum magnets with novel ordered phases at low temperatures and in high applied magnetic fields.

This project would be suitable for a student with a keen interest in practical, hands-on experimental work, who is taking the C3 CMP option.

Useful reference:
High-resolution alternating-field technique to determine the magnetocaloric effect of metals down to very low temperatures, Y. Tokiwa and P. Gegenwart, Rev. Sci. Instrum. 82, 013905 (2011).
http://rsi.aip.org/resource/1/rsinak/v82/i1/p013905_s1

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**AS20 &21 also INT13 &14**  Very-high-energy gamma-ray astrophysics with the Cherenkov Telescope Array

Very high-energy gamma-ray astrophysics is an exciting field spanning fundamental physics and extreme astrophysical processes. It will soon be revolutionized by the construction of the international Cherenkov Telescope Array...
Array (CTA; http://www.cta-observatory.org/). This will be the first open observatory for very-high energy gamma-ray astronomy, and will be sensitive to photon energies up to $10^{15}$ eV. Its science goals are:

1. Understanding the origin of cosmic rays and their role in the Universe.
2. Understanding the natures and variety of particle acceleration around black holes.

CTA will consist of up to one hundred imaging air Cherenkov telescopes using state-of-the-art Silicon Photomultiplier detectors and high-speed digital signal processing to detect and characterize the electromagnetic air shower caused when an astrophysical gamma-ray enters the Earth’s atmosphere.

I expect to be able to take up to two M.Phys. students this year working on either experimental or theoretical aspects of the CTA programme. These would suit students taking either the Astrophysics or Particle Physics options.

In the lab, we work on the design and construction of the cameras for CTA’s small-sized unit telescopes. These will have ~2k pixel SiPM detectors and front-end amplifiers which feed into custom electronics using ASICs and FPGAs. This gives a system that can image at a rate of a billion frames per second.

On the theoretical/observational side of the programme, recently we have developed new theoretical models for the broad-spectrum emission from steady-state jets (Potter & Cotter 2012, 2013a,b,c) that let us use the gamma-ray observations and those at other wavelengths to investigate the physical properties of the jet and the black hole at its base. We now propose to extend these models to look in particular at (i) rapid variability and flaring in jets and (ii) entrainment of heavy particles as the jets propagate through their host galaxy, and the resulting possibility of hadronic particle processes within the jets. We will investigate how CTA may be used to determine the physical conditions that lead to flaring and the presence, and extent, of emission from hadronic processes.

References

Supervisor: Dr G Cotter
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AS18  Investigating the evolution of cores in early-type galaxies

Galaxies exist in many different shapes, sizes and morphologies. The structures we see are a direct reflection of the way stars move in the gravitational potential of a galaxy and so by studying the appearance of galaxies we can learn about the orbits on which stars move and the nature of the gravitational potential. Late type galaxies (LTGs) exhibit beautiful spiral arms, rings, bars and a plethora of prominent substructure but early type galaxies (ETGs) are relatively featureless by comparison. However, closer inspection has revealed that ETGs contain a variety of different, subtle structures.

The surface brightness of ETGs usually increases monotonically towards the centre. However, in some massive ETGs, the central surface brightness is flat within the central kiloparsec. Such a feature is called a ‘core’. All massive galaxies appear to hold a super-massive black hole (SMBH) at their centres. When two massive galaxies collide and merge, their SMBHs will also merge. It is commonly thought that cores are formed when two SMBHs are merging: through dynamical interactions, the SMBHs eject the stars (transferring away angular momentum) in order to tighten the SMBH binary. It takes time to form SMBHs (accretion is limited by the Eddington rate) so one might expect cores to be small and rare at earlier times. However, due to the expansion of the Universe, galaxies were closer together in the past and mergers were orders of magnitude more common; should cores then be more common in the past?

The aim of this project is to investigate the frequency and sizes of cores in ETGs during the latter half of the Universe’s history. The HST CLASH survey observed 25 galaxy clusters with redshifts between 0.19 (2 Gyrs ago) and 0.89 (7 Gyrs ago) in 16 filters. Galaxy clusters hold the most massive ETGs at any redshift and are an ideal environment to study the prevalence and properties of cores.
The project is computational in nature although code is already written and well tested; basic proficiency with computers is essential. Although prior experience in programming is not a pre-requisite, knowledge of the IRAF language would be advantageous.

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PP21 A new electron gun for the Intense Beam Experiment (IBEX)
The Intense Beam Experiment (IBEX) is being constructed at the Rutherford Appleton Laboratory in collaboration with the University of Hiroshima, Japan. The experiment will investigate the dynamics of particle beams in high intensity hadron accelerators, including future upgrades to the LHC, but without using an accelerator. To do this, it relies on a non-neutral Argon plasma in a device called a linear Paul Trap, which mimics the dynamics of a beam in a particle accelerator. Designing a stable and reliable electron gun is one of the key issues of the IBEX project. The electron gun is used to ionise the Argon gas, and control how many ions are present in the trap. The final goal of the project is to find the shape and electrical parameters of the electron gun to maximise the ionisation of the Argon using CST Studio, an electromagnetic modelling tool for charged particles. The resulting design, if successful, will be manufactured and used by the collaboration as an ongoing electron source. Some experience with computer programming is desirable, but not essential. Experimental work at RAL is also possible if desired.

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PP22 Design and simulation of a new multipole plasma trap for the Intense Beam Experiment (IBEX)
The Intense Beam Experiment (IBEX) is being constructed at the Rutherford Appleton Laboratory in collaboration with the University of Hiroshima, Japan. The experiment will investigate the dynamics of particle beams in high intensity hadron accelerators, including future upgrades to the LHC, but without using an accelerator. To do this, it relies on a non-neutral Argon plasma in a device called a linear Paul Trap, which mimics the dynamics of a beam in a particle accelerator. Up until now only quadrupole traps have been used. A more advanced multipole trap would allow non-linear lattice elements to be simulated and broaden the range of experiments that can be conducted to include topics of real interest for future particle physics accelerators and high intensity machines. Since there are a number of topics that require study in such a trap, there is some flexibility in the project specification. Some experience with computer programming is desirable, but not essential. Experimental work at RAL is also possible if desired.

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*****WITHDRAWN*****

INT01 Making a plasma dry-etching system for micro-scale superconductor thin film patterning
Patterned superconducting thin films may be used to make exotic electromagnetic resonator structures for use in magnetic resonance and quantum technologies. Optical lithography using spun photoresist is capable of micron-scale resolution which is suitable for the devices in question. This project is to make a plasma etcher that is capable of converting a Niobium thin film covered in developed photoresist into a micropatterned structure. The project involves constructing, commissioning and testing a high mass-throughput vacuum system containing a custom magnetron sputter platform fed by a radiofrequency matching network.

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*****WITHDRAWN*****

AS02 Star formation history of local galaxies
Understanding how and when galaxies form stars is a critical piece in our attempts to model galaxy formation and evolution. This project uses a new code which applies Bayesian statistics to the problem of fitting star formation histories to observational data from large surveys and the GalaxyZoo.org project. Questions which might be addressed...
include the question of whether bars promote or hinder star formation in disks (or both), the effect of mergers on the
galaxy population or correlations between behaviour and the intergalactic environment. Some familiarity with Python
will be useful.

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AO27  Evolution and dynamics of Jupiter’s cloudy atmosphere

Since the spectacular observations of Jupiter by the two Voyager spacecraft in 1979, the atmosphere, and especially
the clouds of Jupiter have fascinated planetary scientists and public alike. Further space missions, such as Galileo
(1995 – 2003) and Cassini (2000) have made follow-up observations, but these have been for limited periods only or
with limited data downlink. In the meantime, the capability of ground-based observations has grown exponentially.
Starting in 1995 a continuous programme of observations has been conducted by collaborators at the Jet Propulsion
Laboratory using NASA’s Infrared Telescope Facility (IRTF) in Hawaii. In this programme Jupiter has been observed
numerous times with a set of near-infrared filters that either detect sunlight reflected off clouds at different levels in
Jupiter’s atmosphere or detect thermal emission from below the clouds. The data from this ongoing programme cover
a 20-year period during which Jupiter’s atmosphere has changed hugely: the Great Red Spot has changed from oval to
become nearly circular; several ‘White Spots’ have merged and/or changed colour; and the South Equatorial Belt has
faded and then revived. The data thus constitute a unique record of changes in Jupiter’s atmosphere during this period
of upheaval, but surprisingly have never been systematically sorted, calibrated and analysed. In this project, these
observations will be assessed, processed and interpreted with our world-leading radiative transfer and retrieval tool,
Nemesis, to determine the composition and cloud structure of key Jovian cloud features and determine how they have
evolved during the last 20 years. This analysis will shed light on the underlying dynamics of Jupiter’s atmosphere and
will also provide an invaluable reference benchmark against which to test the observations of Cassini and Galileo, and
the forthcoming observations of NASA’s Juno spacecraft, due to go into orbit about Jupiter in July 2016.

A familiarity with Unix systems would be highly desirable and some knowledge of programming languages such as
Fortran, C, or IDL etc. is essential.

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*****WITHDRAWN*****AS17  Measurement methods for weak gravitational lensing

The clumpy distribution of dark matter in the universe causes gravitational lensing of distant galaxies, which may be
measured from the statistical distortion of galaxy shapes that results. So-called “weak lensing surveys” aim to measure
this effect to high accuracy and use it to constrain cosmological models. The European Space Agency is launching the
Euclid mission around 2020 to measure it with unprecedented accuracy. However, all current measurement methods
suffer from bias. The aim of this project is to develop and test new methods of making the measurements in a bias-
free way, as preparation for Euclid. Skills at handling datasets and programming would be useful for this project.

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