Projects update, errata and corrections to the
MPhys Projects Trinity Term 2018

****** Update****** ***INT01*** *change in project title:* **Design and build an electronic circuit of your choice** *from* **Construction and test of Pulsed NMR Spectrometer for hydrocarbon analysis**

More information from the supervisor.

Supervisor: ***Prof J Gregg***

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****** Update****** ***PP18*** **Improved understanding of proton structure**

The Large Hadron Collider (LHC) is the world's highest energy particle collider. Following the discovery of the Higgs boson, the machine continues to collect a wealth of data. Among the primary physics goals of the machine are to search directly for new, high mass particles, as well as to precisely measure the properties of the Higgs, which may also reveal evidence of as-yet unknown physics. One of the dominant uncertainties, which can limit the ability to discover new physics, is an imprecise knowledge of the structure of the proton. This project will investigate the prospects to improve our knowledge of proton structure, using either existing LHC data, or by looking at simulated data from possible future colliders. A set of proton parton distribution functions (PDFs) will be determined, and the impact of any improvements on the prospects for new physics discovery or Higgs properties will be investigated. This is a computing project. Some prior experience of C++ would be an advantage.

Supervisor: ***Dr C Gwenlan***
Email: ***Claire.Gwenlan@physics.ox.ac.uk***

IND013 **Optimising the use of ensemble information in forecasts of wind power generation**

Numerical weather prediction (NWP) model output, such as that from the European Centre for Medium-Range Weather Forecasts (ECMWF, based in Reading, UK) and the National Oceanic and Atmospheric Administration's (NOAA, based in the US) GFS models, is used daily to make decisions about the likely electricity generation output from windfarms across Europe. Ensemble forecasts, where the weather forecast models are run several times in parallel with small perturbations to their initial state and uncertain model formulations, provide additional, but imperfect, information about the uncertainties of the forecast. Basic approaches to using some of this information exist, and there is evidence that more sophisticated approaches could yield significant improvements which could either increase profitability of a trading strategy, or help decrease carbon emission outputs if used in decisions to dispatch thermal generation plant.

In this project, the student will develop an understanding of how wind generation output forecasts are created, and then look to create a new methodology harnessing the probabilistic information contained within the ensembles. A number of options on how to go about this exist: these can be discussed and then the student can decide which approach to try, or – if time – contrast two approaches.

The project is a collaboration between the sub-department of Atmospheric, Oceanic and Planetary Physics (AOPP) in Oxford and our industrial partner Lake Street Consulting, based in Wheatley near Oxford. It requires an interest in the application of weather forecasts, spreadsheet data handling experience (or a willingness to learn) and demands programming skills (which language is less important than the ability to structure a piece of code).

Industrial Supervisor: ***Dr I Finney*** (Lake Street Consulting)
Oxford Supervisors: ***Dr A Weisheimer***, ***Prof T Palmer***

IND014 **Development of complex algorithm for electric vehicle (EV) fast charging**

ZapGo Ltd (ZapGo) is a high technology business founded in Oxford, UK, in 2013. We have developed a solution to the problems encountered by all the current generation of appliances, devices and vehicles powered by lithium: slow charging. Called Carbon-Ion, in contrast to Lithium-ion, this technology is based on carbon nano-materials including the 'wonder-material' graphene. The technology and a growing patent portfolio is in part derived from Oxford University, and in part developed independently by ZapGo's own scientists. The company is at the proof of concept stage with a number of prototype demonstrators. Our power module is due to enter the production phase in 2018. The Company currently has 25 employees.

The goal is to develop a complex algorithm that can be turned into a computer program to enable extreme fast charging (XFC) of electric vehicles. Since XFC operates at very high charge rates, it is necessary to buffer the national electricity grid by storing energy in large energy storage containers. EV's are then charged from the stored energy, not directly from the electricity grid.

The code can be written in MATLAB or any suitable computer language. Some advanced queuing theory could be used to allow for multiple variables of when vehicles arrive for charging, their frequency of arrival, the maximum charge rate, how much energy they need to store and then the speed at which the energy can be stored in the container and replenished by the national grid.

This assignment could lead to a full-time role at the Company.

Industrial Supervisor: ***SVoller*** (ZapGo)
Oxford Supervisors: ***tbc***

AO28 Mapping Venus

Venus is completely enveloped by a thick layer of clouds, extending from 50 – 70 km altitude. New images of this cloud layer, of unprecedented resolution, are being obtained by the Japanese Akatsuki orbiter, at a range of wavelengths. Of particular interest are images form the IR2 camera at wavelengths of 1.7 and 2.3 microns, which reveal patterns in the lower clouds, backlit by thermal radiation from the deep atmosphere [1, 2]. The ratios between these radiances can be used to constrain cloud properties in particular cloud droplet size [3].

In this project, the student will learn to process and reproject planetary mission data, creating maps and analyses of IR emission of Venus and analysis of cloud feature lifetime. This project will be computer based, using IDL, Matlab or Python languages; experience in at least one of these would be an advantage.

References

[1] https://www.springeropen.com/collections/akt

[2] A new look at Venus with Akatsuki, http://www.planetary.org/blogs/guest-blogs/2018/0116-a-new-look-at-venus-with-akatsuki.html

[3] Wilson et al, Evidence for anomalous cloud particles at the poles of Venus, JGR-Planets, https://doi.org/10.1029/2008JE003108

Supervisor: ***Dr C Wilson***
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****** Update****** *AO17* A wind sensor for Titan

One of the most intriguing bodies in our solar system is Titan, the largest moon of Saturn. Its atmosphere is composed mostly of nitrogen, and has a hydrological cycle not of water but of methane and ethane. With an atmospheric density five teams greater than Earth but a gravitational acceleration seven times weaker, it is an ideal place for flying exploration vehicles.

We are designing a thermal wind sensor which will be not only crucial not only for science but also to reduce flight risks for Titan exploration craft [1]. The design needs to be tested in Earth conditions, and the laws for scaling this to Titan conditions need to be tested. The project will involve mainly lab testing, and so would suit someone with an interest in electronics and data acquisition, but some Computational Fluid Dynamics simulations may also be performed.

References:

[1] Wilson & Lorenz, Design of a Thermal Anemometer for a Titan Lander, https://www.hou.usra.edu/meetings/lpsc2017/pdf/1859.pdf

Supervisor: ***Dr C Wilson***
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******WITHDRAWN****** *AO11* Infra-red absorption of atmospheric ions in the laboratory

Natural radioactivity and cosmic rays constantly ionise the air to produce nanometre-sized cluster-ions, which are hydrogen bonded to a central ion. The hydrogen bond rotations and vibrations absorb infra-red radiation (this is the same technique by which many gases are identified, and that satellites use to detect water vapour in the atmosphere). This infra-red absorption from the hydrogen bonds in cluster-ions has been detected both in the atmosphere and in laboratory experiments, but the sensitivity of the effect to the cluster-ion concentration is not yet well known. Previous projects have suggested that each sign of ion produces different effects.
This project will involve running laboratory experiments to create ions with radioactive sources (to produce both positive and negative ions) and with corona sources (to produce just one sign of ion), measuring the associated infra-red absorption with a radiometer and establishing how it varies with the ion concentration. Electric fields can also be applied to the set-up as a "clearing field" to remove one sign of ion.
The theory behind this project is most closely linked to the atmospheric physics major option, with a small particle physics overlap, though neither option is essential.
Supervisor: ***Dr K Aplin*** Email: ***karen.aplin@physics.ox.ac.uk***

*******WITHDRAWN*******

AO12 **Miniaturised radioactivity detector**
A miniature radioactivity detector has been developed in the Physics Department and is currently being exploited for applications in atmospheric physics, for example, measuring the variation of atmospheric ionization with altitude and solar activity to investigate ionization effects on weather and climate. The production of energetic particles in the lower atmosphere by thunderstorms and solar storms is also a "hot topic" which is poorly understood. This project will involve an experimental investigation of how the detector responds to cosmic ray muons, which are an important aspect of its background signal. There is also scope for other or additional work based on the interests of the student, for example, investigating whether energetic particles are enhanced during thunderstorms. The detector is now being sold to other researchers around the world, so there are opportunities for a student interested in entrepreneurship and/or engineering to investigate commercial aspects such as production engineering and optimization of the sensors, circuit, and software.
Some interest in instrumentation and electronics is essential, and the ideal (but not essential) major option combination to accompany this project is atmospheric and particle physics.
Background reading: K.L. Aplin et al, Measuring ionizing radiation in the atmosphere with a new balloon-borne detector, Space Weather (2017)
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017SW001610
Supervisor: ***Dr K Aplin***
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*******WITHDRAWN******* ***AS33*** **Strategies for finding high-redshift radio galaxies**
Many high-redshift radio galaxies have been found by selecting radio galaxies with ultra-steep spectral energy distributions (SED) at radio wavelengths, and following up with optical observations to determine the redshift. Highredshift radio galaxies are indicative of dense environments in the distant Universe, and are thought to evolve into the most massive galaxies we see today. They are therefore an interesting link in studying the evolution of massive galaxies. Recent work has shown that simply selecting based on radio SEDs will bias high-redshift samples towards only extreme galaxies. In order to select a more representative sample of candidate high-redshift radio galaxies, it is necessary to consider other indicators like compact size. New low-frequency radio surveys with unprecedented sensitivity and resolution offer the possibility to select samples of more "normal" high-redshift radio galaxies. This project will involve (1) determining a strategy based on the available data to select a complete sample of high-redshift galaxy candidates and (2) applying the strategy to low-frequency radio surveys.

Requirements: This project is computational and will involve manipulating large catalogues, making plots, etc. Any experience in this would be helpful, but should not put off anyone interested in the project.
Supervisors: ***Prof M Jarvis***; ***Dr L Morabito*** and ***Dr R Bowler***
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*******WITHDRAWN******* ***A&L13*** **Functional analysis of X-ray spectroscopy data using machine learning**

X-ray spectroscopy is an extremely information-rich diagnostic in plasma physics, and is one of the most important techniques used to study extreme states of matter found in astrophysical objects and fusion plasmas. But interpreting the complex and noisy experimental data, often measured as integrated over the time and space of emission, remains a significant challenge.

In this project, the student will investigate how machine learning techniques can be applied to the interpretation of X-ray emission data. This will involve applying a range of data reduction techniques to raw experimental and synthetic datasets, and building supervised machine learning algorithms to extract information on key parameters of the plasma systems such as their temperature, density, time evolution and spatial gradients. The project demands good analytical and programming skills (C/C++, Python, or similar).

Supervisor: ***Dr S M Vinko***
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****** Update****** ***A&L14*** **Interpretation of inelastic X-ray scattering measurements using machine learning**

X-ray inelastic (Thomson) scattering is a popular and information-rich diagnostic in plasma physics, commonly used to study the temperature and density conditions of extreme states of matter similar to those found in astrophysical objects and fusion plasmas. But interpreting the complex and noisy experimental data, normally measured integrating over the time and space of emission, remains a significant theoretical challenge.

In this project, the student will investigate how machine learning techniques can be applied to the robust interpretation of X-ray scattering data, and will deploy algorithms to evaluate the uncertainties in data published in the literature. This work will be used to both validate current results and conclusions, but also to inform future experimental setups and investigations.

The project demands good analytical and programming skills (C/C++, Python, or similar).

Supervisors: ***Dr S M Vinko*** and ***Prof G Gregori***
Email: ***Sam.Vinko@physics.ox.ac.uk***

A&L18 **Coherent X-ray microscopy for nano-imaging**

The development of bright, coherent x-ray pulses from free-electron laser (FEL) sources is revolutionising x-ray science, allowing advances across a diverse range of fields ranging from non-linear x-ray optics and biomolecular imaging to the investigation of matter in extreme conditions. Many experiments require stringent control over the parameters of the x-ray pulses interacting with the studied samples, but the single-shot characterisation of femtosecond FEL pulses still poses significant practical challenges.

In this project, the student will perform Fourier analysis on interferometric data obtained at the Coherent X-ray Imaging endstation (CXI) of the LCLS x-ray FEL at SLAC (https://lcls.slac.stanford.edu), using a newly developed two-frequency shearing method. The results of the analysis will yield the full phase and intensity profile of the nano-focused x-ray beam at CXI, for a single ultra-short x-ray pulse. The aberrations of the beam and the quality of the nano focus vs. the alignment of the focussing mirrors will be investigated, and the developed algorithms fielded at the LCLS.

The project demands good analytical and programming skills (C/C++, Python, or similar).

Reading: Schropp et al., Scientific Reports 3, 1633 (2013), DOI: 10.1038/srep01633

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IND013 **Optimising the use of ensemble information in forecasts of wind power generation**

Numerical weather prediction (NWP) model output, such as that from the European Centre for Medium-Range Weather Forecasts (ECMWF, based in Reading, UK) and the National Oceanic and Atmospheric Administration's (NOAA, based in the US) GFS models, is used daily to make decisions about the likely electricity generation output from windfarms across Europe. Ensemble forecasts, where the weather forecast models are run several times in parallel with small perturbations to their initial state and uncertain model formulations, provide additional, but imperfect, information about the uncertainties of the forecast. Basic approaches to using some of this information exist, and there is evidence that more sophisticated approaches could yield significant improvements which could either increase profitability of a trading strategy, or help decrease carbon emission outputs if used in decisions to dispatch thermal generation plant.

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Industrial Supervisor: ***Dr I Finney*** (Lake Street Consulting)
Oxford Supervisors: ***Dr A Weisheimer***, ***Prof T Palmer***

AO27 Measuring the Earth's atmosphere from a novel small satellite infrared radiometer

Smaller spacecraft cost less to launch and operate, and have been leading a small revolution in how remote sensing data can be gathered from Low Earth Orbit compared with conventional large operational spacecraft. Oxford Physics, working with colleagues at the Rutherford Appleton Laboratory (RAL), have designed and built a small infrared radiometer (the Compact Modular Sounder) to measure the composition and temperature of the Earth's atmosphere as part of the UK's TechDemoSat-1 spacecraft, successfully launched in 2014. The instrument's main task is to demonstrate that an infrared instrument on a small satellite can deliver the same, well-calibrated data products as an instrument on a larger spacecraft, and incorporates several novel new bits of technology developed in the department and at RAL.

The Compact Modular Sounder (CMS) has now been operational for ~36 months and we have loads of new data to explore. This project will provide you with an insight into how data from a new instrument is calibrated, converted into a useful data product and then analysed to help solve problems in weather forecasting and climate monitoring. The first part of the project will be to help the team at Oxford and RAL convert the raw measurements from CMS into data with pointing (i.e. latitude and longitude) and radiances which are necessary for scientific exploitation (derivation of atmospheric properties) of the data. This conversion activity will be ongoing throughout the project and is likely to evolve as the spacecraft operations team at Harwell get used to running the mission! Once we have a mapped data product, the project will then build on the material covered in the C5 'Physics of Atmospheres and Oceans' major option to calculate some example atmospheric temperature profiles and surface temperature maps from the new dataset, using sophisticated radiative-transfer software tools developed in-house at Oxford Physics and used extensively in the analysis of Earth, planetary and exoplanetary data. This project will require use of computers and some programming experience will be an advantage. It should be of high interest to students interested in working in the space industry on instrument development and/or applications of satellite data for bot Earth observation and planetary exploration.

Recommended reading: Elementary Climate Physics, (Taylor), The Physics of Atmospheres (Houghton), C5 Major option lecture notes

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