Photo: Alan Segar

2012 - 2013

Physics

MPhys Projects Handbook

2012-2013

Open Days in the Martin Wood Complex

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Foreword

The MPhys project, as a major part of the MPhys course has often been considered the most enjoyable part of the course. From the comments made by students over several years, many students get a real buzz from a good project. Read this booklet carefully to find out which projects are available and what you have to do.

You will start your Major Option Classes this Michaelmas Term, but may have been given some reading or work to do over the long vacation, and you will therefore be a little better informed and prepared when selecting your project. The project may be your first insight into life in a physics research group and be a chance to see developments at the cutting edge of the subject. It is also a first look at problems whose solution may well be unknown, to both you and your supervisor.

To get the most out of your project you must choose carefully and prepare well. Contact your project supervisor early and discuss preparation, both in background reading and computing technique. You will find the project supervisors and the Assistant Head of Teaching (Academic) very willing to talk to you during the choosing and preparation stages so do take this opportunity to come and see us.

“The project has been really interesting and challenging so far. A lot of extra computer programming and software had to be learnt in order to complete various parts of the project, or to even just understand them. My supervisor has been a great help, he gives a lot of his time to helping me whenever I need it and helps to keep the project flowing at a good pace.”

“INT12: Ray tracing Galileo’s telescopes. The project is unusual and interesting and allows interdisciplinary studies between the Physics department and the MHS. I was annoyed that I got my 10th choice especially as I am doing my masters’ elsewhere next year and was hoping to get a related subject. That said I am enjoying my project, though the history side is challenging.”

“The project has been challenging but I’ve really enjoyed it. It has helped me better understand the area of physics on which it is based and has given me a better idea of what a PhD in that area might be like. It would have been nice to have been able to spend more time on the project as it seems that I’d just got into the main part of the project when I had to stop.”

“I found the Project very interesting and thoroughly enjoyed working in the lab. I could very easily see myself applying for a PhD due to the great time I’ve had doing my project whereas beforehand I didn’t really want to...”

“Overall I enjoyed my project and felt that there was a reasonable amount of scope for ingenuity. I think my supervisor gave me excellent guidance and we met regularly to discuss the work I was doing.”

“I really enjoyed doing my project - it has definitely been the most interesting part of my entire degree, and I wish it lasted longer than 8 weeks .. I could never get bored by doing it - there were several different aspects - theoretical calculations, followed by some numerics and plotting graphs, trying to understand the experiments relevant to it, learning new theoretical techniques that are widely applicable to other things as well ... I probably learned more useful things in these two months, than I did in my entire 3rd year.”

I hope you enjoy your project. Please do contact me or the Assistant Head of Teaching (Academic) if you have any questions.

Prof. Nick Jelley, Head of the Physics Teaching Faculty

The MPhys project report

Introduction

The projects on offer inevitably differ greatly in their scientific potential, and any genuine research project can simply fail to work out: research is about probing the unknown, so unpleasant surprises can be encountered. Consequently, the Examiners cannot base their assessment of your report on the quality of the science that you do in your project. Rather they will assess the efforts you made to come to grips with a scientific problem, and the clarity and completeness of your exposition of the problem and what you have learned from it. It is through reading your report that they will make this assessment, so understanding that would gain you credit should be apparent in your report. You must therefore strive to make the report the clearest piece of scientific writing possible.

Target audience

When writing it is always important to know what audience you are trying to reach. **Your report should be aimed at a physicist who has not worked in the area of your project. The assessors may deduct a significant number of marks if they are unable to understand the project report.** For example, if your project is about high-energy physics, imagine that your reader works on laser physics, if your project is in condensed matter physics, imagine that your reader is an astrophysicist. You won't go far wrong if you imagine that your report is being read by one of your abler contemporaries.

The genre

Although different fields and journals have slightly different styles, scientific papers nearly always conform to the following pattern. The Introduction describes the background to the problem that the paper addresses: what the problem is, how it came to the attention of the community, why the problem is interesting, what significant work has been done on it, and what questions remain open. Finally, the Introduction says how the paper advances the field and explains the paper's layout. The sections that follow describe, in order, methods, data, results and their interpretation. The final section starts by summarizing the paper's achievements and goes on to speculate on their significance for the wider field, and to indicate what further work would be profitable. The concluding section is invariably followed by a list of references, after which there may be one or more appendices, to which important but tedious details, or peripheral results, are relegated.

The Abstract and figures are the most important parts of a paper, as they are the only parts many readers of a paper will look at. They help to draw readers in to the other sections. If the Abstract and figures are interesting, one often scans the Introduction, paying particular attention to the last part, and then moves to the first part of the Conclusions. The middle sections are often only read much later, if at all. Your report should be structured like a paper. Go into the RSL or online and browse through some journals such as Physical Review Letters, or Monthly Notices of the Royal Astronomical Society and study the structure of a few papers. Be aware, however, that many papers are targeted at quite narrow audiences so they tend to have much shorter Introductions than your report will require; the acid test is, will your target readership understand what the problem is, and why it's worth addressing? At the end of this document we list some classic, highly cited papers that are worth analysing from a structural viewpoint.

Figures

You should take great care choosing and structuring your figures. They are the most memorable part of a paper, and the best help a paper can have to become a highly cited paper - the holy grail of scientific life - is to contain figures that reviewers choose to show at meetings and colloquia.

Things to think about include:

Can I combine these two figures into one?

Is this figure too busy?

Are all the lines and data points clearly labelled?

Is the figure big enough?

Would the labels on the axes be clearly visible from the back of a lecture theatre when the figure was shown by a reviewer?

Would plotting the data in an entirely different way make a stronger impact?

Citations and Plagiarism

Statements about prior work and results used must be supported by references to a bibliography, and the sources of any borrowed figures or tables must be cited. Acknowledgment of sources will protect you from a charge of plagiarism, which the Proctors consider a serious offence.

The University's Regulations state that: *No candidate shall present for an examination as his or her own work any part or the substance of any part of* *another person's work... passages quoted or closely paraphrased from another person's work must be identified as quotations or paraphrases, and the source of the quoted or paraphrased material must be clearly acknowledged.* (Proctors' and Assessor's Memorandum, Section 9.5 http://www.admin.ox.ac.uk/proctors/pam/index.shtml)

Your report would automatically be compared with a wide range of potential source material, and should any unacknowledged borrowing be detected, the matter will be referred to the Proctors, who not infrequently press charges. If you are unsure whether you need to acknowledge a source, discuss the problem with your supervisor. If you follow his/her advice, you won't be judged harshly even if that advice is later judged defective. "*Turnitin* is a tool that allows papers to be submitted electronically to find whether parts of a document match material which has been previously submitted .... This is very useful in training students in good citation practice when used in formative assessment in cases like tutorial work." [Ref: Oxford University Computing Service.]

Joint projects

If you have conducted, shared and done the experimental aspects of your project with another student you must produce independent reports. Should it be necessary to make specific reference to this student, you must refer to them as your colleague.

It is also important that you make it quite clear in your report what your contribution has been. It is particularly important in very technical or theoretical projects that you distinguish between your own work and that of others, which you are only including to provide background.

The front page of the report

The front page of your report must have the following information only:
Candidate number: e.g. 99994
Project number : e.g. INT55
Project Title: e.g. A Project Report
The supervisor's name: e.g. Professor A Lecturer
Word count: 99996

An example of a report with the appropriate information can be found on page 50. A separate front page can also include this information, should you wish to do so.
Students are reminded that your name and/or college MUST NOT appear anywhere in the report.

Page limit

Scientists more often than not write to a restrictive page limit - for example Letters journals generally restrict papers to 3 - 5 pages, and the Case for Support in a research grant application is often of similar length even though it is asking for well over £100k of funding. Imposing a tight page limit not only saves paper and readers' time, but can also increase clarity by forcing the writer to focus on the key points and to present only the key data. Since the restriction is one of overall space, the writer is forced to consider the relative benefits of a figure, or a paragraph of text, or a table. Together the text and figures of an MPhys report must not occupy more than 4 500 cm^2 of paper and the fontsize used for the main text may not be smaller than 11pt and the distance between successive lines must be at least 4 mm (13pt). The bibliography and appendices may extend beyond the 4 500 cm^2 area, but the Examiners will not normally read them. The report must be printed on A4 paper. You may use any word-processing package, but the LaTeX documentclass "proc" used in the document Typesetting a Report (TeX file) conforms to these when the report is approximately 12.3 pages long. If all available space were used for text, the report would contain about 10 000 words. If you use 11pt type and the full width of A4 paper, you should consider using a double-column format to avoid the difficulty a reader's eyes have in scanning long lines of small type.

Some classic papers:

Bachilo, S.M, Strano, M.S., et al., 2002, Structure-Assigned Optical Spectra of Single-Walled Carbon Nanotubes, Science, 298, 2361

Davies, R.L., Efstathiou, G., Fall, S.M., Illingworth, G., & Schechter, P.L., 1983, The Kinematic Properties of Faint Elliptical Galaxies, ApJ, 266, 41.

Guth, A., 1980, Inflationary Universe ...., Phys.Rev. D, 23, 347

Press, W.H. & Schechter, P., 1973, Formation of Galaxies ...., ApJ, 187, 425

Resource Checklist

Students are encouraged to complete the blank search checklist document on page 53. The checklist can be printed from http://www.physics.ox.ac.uk/teach/exammatters.htm and students hand it in with your report. It is a useful tool for supervisors and assessors when checking if students have searched scientific resources for their project work.

Presentation of your reports

You are required to provide three (3) paper copies of your report. Each copy of the report must be put in a separate plastic folder. Recycled (used) plastic folders are available, at no cost, from the Physics Teaching Faculty Office in Clarendon Laboratory, on a first come first served basis.

For readability, students are advised to print their reports on one side of the paper (single-sided). You are also required to include a pdf file of your report with your submission.

University Policy on Intellectual Property Rights

The University of Oxford has in place arrangements governing the ownership and exploitation of intellectual property generated by students and researchers in the course of, or incidental to, their studies. See the *Physics Undergraduate Course Handbook* for details.

Frequently asked questions

(i) The use of active or passive, singular or plural tenses:

(a) I am unclear as to whether the Examiners prefer experimental sections written using passive clauses '...was done', the first-person plural 'we did...' or the first-person singular 'I did...'.

Answer: Clarity is everything. Sometimes it is clearer to use the passive because it diminishes the danger that the author is distracting, but often it's easier to say "I found this". Sometimes one says "we follow Smithers" meaning the author & the reader.

(b) I tend to think that passive clauses have a tendency to be obfuscating and hard to read. For example, 'It was decided that...' and 'It was found that...' doesn't convey who did the deciding or the finding - was it me or was it my supervisor or both?!

Answer: agreed

(c) I noticed that in one of the example papers provided by the physics department on the subject of inflation that the writer wrote in the first-person singular 'In this paper I discuss...', but I thought that this was considered bad practice (I can't remember why!).

Answer: It isn't bad practice. What _is_ bad practice is to irritate the reader by letting your person distract from the subject matter.

(ii) I have written the experimental section exclusively in the first-person plural: 'we decided that...'. However, almost all of what I have written was performed by myself, not 'we'.

Answer: Then use I

(iii) Do the appendices count in the printed area limit... as it is impossible to get more than 10,000 words in the main body of the project report, this point is very important with regards to the allowable length of the appendices.

Answer: You can have as much appendix as you like, but the Examiners won't normally read appendices.

(iv) Suppose my project leads to a published paper? In my MPhys write-up, I am referencing papers of which I am a co-author. If these are published by the time my project is marked -- and if whoever marks my project happens to look at them -- I may be accused of plagiarism, as my writeup is inevitably similar to them. Of course, it isn't possible to plagiarise myself (as far as I'm aware), but it occurs to me that proving my innocence would involve revealing my identity. Is this likely to be a problem? It seems that given the title of the project and a list of project allocations, we are not really anonymous to anyone marking the projects, so am I still right to worry about this? If so, I would be very grateful if you can tell me how I should submit my project, and whom I should get to sign what.

Answer: In the unlikely event that the paper is out & noticed, the affiliation of the authors would make the situation perfectly clear, so you don't have to worry.

(v) What is the area of my report? I would be very grateful if you could help clear up a query I have regarding the area limit of 4500 cm^2 for the MPhys projects. Does this area include the whole of each A4 page, i.e. the blank margins surrounding the body of text, or is it purely for the body of text itself?

Answer: The area does not include margins, only the rectangle used by text & figures.

(vi) A very advanced project?.. My main concern is that I will not have enough space to explain the background of my project to a level sufficient to allow a general audience to follow the rest of my paper. I am currently working on inflationary cosmology in the context of string theory for which the background I will need to give is; inflationary cosmology, including the problems it is designed to solve, supersymmetry, supergravity and possibly some string theory. This is a tall order to fit in ~5 pages if I am wanting to leave the other 5 for my project. This is a concern for a number of people I know, for instance someone

I know is studying Higgs phenomenology at the LHC for which they have learnt a large amount about non-abelian gauge theories, which seems unlikely to be common knowledge.

(a) How much of this material am I allowed to reference? (b) Is there some list of subject areas we can assume knowledge of - for instance it is not clear to me whether an Atmospheres and Oceans physicist will know about Lie algebras/groups etc. or for that matter general relativity or quantum field theory. Will I have to preface my report with an introduction to GR?

Answer: MPhys projects are not mini DPhil projects, and the reports on them simply have to be understandable by the available assessors. Each senior assessor will read several reports, and in the interests of establishing a degree of fairness between subject areas, these reports need to come from research groups different from the senior assessors. The senior assessor will be assisted by junior assessors who are closer scientifically to the topic. Each junior assessor read at least 6 reports, so s/he can establish a comparative baseline.

If you think of the range of science done within TP alone (standard-model phenomenology, strings, early-universe phenomena, galactic dynamics, stellar winds, scaling & phase changes, soft matter, market models, etc.) you will see how impracticable it is to have expert readers. You should bear this in mind when writing your report.

We hope that you have a well defined exercise to address, and one that is both worthwhile and readily assessed.

It is up to you how you deploy your space allocation - though you will certainly benefit from advice from your supervisor on this. You know what goal is to be achieved. You will probably decide that you cannot communicate your entire understanding of the problem. That's how life is. Communicate as much as you can as exactly as you can, and make appropriate decisions about breadth and depth of the understanding that you endeavour to communicate.

When devising a grade, the junior and senior assessor will bear in mind a report from your supervisor on the way you have addressed the project, and through this report you may get credit for a deeper level of understanding than can be communicated to non-experts. However, do not rely on this. Make sure your report is understandable to a non-expert physicist.

(vii) Do we would need to wear full academic dress to the meeting (viva)?

Answer: No, the idea is to have an informal meeting

(vii) What should I bring along to the meeting?

Answer: Only a copy of your project. Students will be expected to give a verbal short summary of their project. The purpose of this meeting is to help the assessors with assessing the candidates written report. Crucially the meeting helps clarify any issues that the assessors have after having read the written report. The assessors will read the supervisor's report on the project to learn what special difficulties were encountered, the extent of the initiative shown by the candidates, and so on.

Draft MPhys reports

From week 9 onwards, students should hand in a full draft of their MPhys report to their supervisor. You and your supervisor must complete and sign the *MPhys Draft Form* (see **Appendix C**) returning the form to the Assistant Head of Teaching (Academic) soon after.

The supervisor should advise the student by reading and criticising the report **ONCE** only.

A checklist for submitting your work at Examination Schools

The MPhys project is a requirement for completion of Part C of the Physics Honour School (Finals). Students hand in their reports at the Examination Schools.

The following must be placed in **one** sealed envelope which is bigger than the size of your reports:

(i) **three** copies of the final report along with
(ii) **one** copy of the declaration of authorship (see **Appendix C**). Put this in a small envelope and put the small envelope inside the main one which contains the work and
(iii) **one** copy of the report in pdf format on a CD. **Your candidate number must be written on the CD.**

Your **candidate number** can be obtained from your Student Self Service account. Computers are available by the Student Information Desk in the Main Hall of the Examination Schools (Student Information Officers will provide guidance should you have any questions);

The envelope must be addressed to "The Chairman of the Examiners, Honour School of Physics".

Failure to include any of the material will deem your examination material INCOMPLETE.

Examination Schools

The core opening hours of the Examination Schools building are 8.30 am to 5.00 pm, Monday to Friday; the reception desk is staffed throughout this period. When you hand in you report you will be handed a receipt. Outside these hours work cannot be receipted, since staff will not be present.

Go to the reception desk in the Examination Schools' main hall, and obtain a receipt form. Candidates with any Specific Learning Difficulty, for example dyslexia, should also obtain a cover sheet to be attached to their work. Complete the receipt form (and any cover sheet), with details as specified. Hand the work (in its envelope) and the receipt form to Schools staff at the desk. Schools staff will add date and time to the receipt form and sign it to confirm receipt. Schools staff will give a copy of the receipt form to the student.

Each assessment handed in to the Submissions Desk staff must be sealed in a separate envelope (Note: if you are required to hand in three copies of the same assessment, these should be sealed in the same envelope).

If work/receipt is not clearly addressed/completed, it will not be identifiable and may be reported as not submitted.

Keep your receipt safe in case of any queries.

You are **permitted** to submit your project reports in advance of the deadline.

Submitted work may not be withdrawn for revision or re-submission without the Proctor's permission, as stated in the *Proctors' and Assessor's Memorandum.*

For more details and guidance on submitting work, see http://www.ox.ac.uk/students/exams/submissions/

Penalties for late submission of work (after the deadline)

The Proctors may impose financial and/or academic penalties for submission of work beyond the deadline of **Monday 12 noon of 1st week of Trinity Term.** This may affect the classification of your degree.

Any application for late submission should be made by the candidate, NOT the supervisor, **through the candidate's college**. Therefore if special factors make it likely that you will not make a deadline, you should ensure that well before the deadline you follow the procedure laid out in the *Examination Regulations* to seek Proctorial permission to submit late.

Work submitted after the deadline will be processed in the standard manner and, in addition, the late submission will be reported to the Proctors' Office. Any candidate who is late in handing work in should consult his/her college Senior Tutor (via the college office) as a matter of urgency.

Monday 12 noon of 1st week of Trinity Term is the deadline for submission of your project.

Note: It is your responsibility to ensure that your work is submitted by the deadline. Responsibility for the work rests with you at all times until issue of the receipt, regardless of the method of submission.

Choosing your MPhys project

How to go about choosing a project

Around two thirds of the 4th year students may expect to be allocated one of their choices of project. For the remaining third we try to allocate a project in a similar area of interest and also taking the students choice of Major Options into account. Some projects are more popular than others, for instance projects relating to Biophysics, therefore you are advised to select carefully your lower choices. Perhaps there is a project that you would like to do, but this is not listed in the handbook, in which case you may approach potential supervisors with your ideas.

Please inform the Assistant Head of Teaching (Academic) of the topic, the title and the supervisor, if you have made your own arrangements. You are also encouraged to write a short statement on the back of the choice form if you have any particular strengths or experience relating to your choices, or if you are choosing a project with your future career in mind.

Although every effort is made to include all possible information about and on the MPhys projects offered, new projects may become available after the publication of this *MPhys Projects Handbook*, and infrequently a project may have to be withdrawn. All changes will be communicated by e-mail.

Project allocation

Projects are allocated by the Assistant Head of Teaching (Academic) using the students's choices on the *Project Allocation: CHOICE FORM,* see **Appendix A**.

For the allocation exercise, the student name and college are hidden to prevent any bias. All the project choice forms are entered into an access database. All eight choices are listed in order of preference and additional comments are recorded.

For very popular choices we use the following procedure:

(i) Supervisors are consulted as they may be contacted by prospective students about the projects they are offering, although this is not essential for the allocation of the project. Supervisors' input is essential in trying to match projects to students;

(ii) Should it still prove difficult to assign the project, each student who wishes to be allocated the specific project is assigned a number and then the winner is drawn from a hat;

(iii) The PJCC (Physics Undergraduate Consultive Committee) is also consulted on an annual basis about the process. If you are not happy with the MPhys project you have been allocated, you are encouraged to discuss other possibilities with the Assistant Head of Teaching (Academic).

Project risk assessment

Assessing risks is an essential elemnet of training for project work. It is good practice for students and supervisors to complete the risk assessment associated with the project before starting. See page 56.

Project assessment

A Project Assessment Committee is set up every year to assess all the MPhys projects. The assessors are appointed by the relevant physics sub-departments, the Physics Department or less frequently from another department of the University. The assessors on this committee are usually not Physics Finals examiners, but they may serve in this capacity.

The junior assessor will generally come from the sub-department to which the project is assigned and they will have more specialist knowledge in the field of the project, or one closely related. The senior assessor will generally work in a different area of physics from the subject of the report and will mark reports chosen from other physics sub-departments. Each written MPhys report will be assessed by a junior and a senior assessor.

Each MPhys candidate will be expected to attend a meeting ('viva') with the two assessors of their project to discuss the written report. The purpose of this meeting is to help the assessors with assessing the candidates written report. Crucially the meeting helps clarify any issues that the assessors have after having read the written report. The assessors will read the supervisor's report on the project to learn what special difficulties were encountered, the extent of the initiative shown by the candidates, and so on.

The meeting will last about 20 minutes and will be rather informal. It will not require the preparation of a special presentation; indeed no visual aids other than your report (and your log book, if appropriate) will be allowed. The candidate will be expected to start the meeting by giving a short summary of the project, typically not lasting more than a few minutes, followed by a question and answer period.

The meetings with the candidates have been provisionally scheduled for Monday and Tuesday of 5th week in Trinity Term.

The precise criteria for the overall assessment of the project will finalised by the examiners in Hilary Term. How the final project mark is calculated will be published in the Examination conventions produced by the examiners. The overall assessment embraces the quality both of the underlying scientific work and the presentation in the report.

The *MPhys Project Assessment form* will be published on the Examination Matters webpage http://www.physics.ox.ac.uk/teach/exammatters before the beginning of Hilary Term.

Examination Conventions

The Examiners are responsible for the detailed weightings of papers and projects. The precise details of how the final mark is calculated is published on the Examination matters webpage at www.physics.ox.ac.uk/teach/exammatters.htm. Students are notified by e-mail when they become available.

Weightings for the MPhys and Papers

The precise details of how the final mark is calculated is published in the *Examination Conventions* on the Examination matters webpage at www.physics.ox.ac.uk/teach/exammatters.htm.**Project outcomes**

The outcomes of projects are very flexible and the results may not be precisely as described by the project description in this handbook. Remember that they are intended as an introduction to research and the unexpected often happens!

According to the QAA benchmark statements for physics 'Open-ended project work should be used to facilitate the development of students' skills in research and planning (by use of data bases and published literature) and their ability to assess critically the link between theoretical results and experimental observation' ref.: Quality Assurance Agency for Higher Education, subject benchmark.

Project prizes

(a) The Gibbs Prize for the best use of experimental apparatus in an MPhys project.

(b) The BP Prize for the best final year Theoretical Physics Project.

(c) The BP Prize for a project in Astrophysics.

(d) The Johnson Memorial Prize for a project in Atmospheric, Oceanic and Planetary Physics.

(e) The John Thresher Prize for a project in Particle and Nuclear Physics.

(f) A prize for a project in Atomic and Lasers Physics.

(g) A prize for a project in Condensed Matter Physics.

(h) The MetaSwitch Network* Prize for the best use of Software in an MPhys Project.

(i) The Rolls-Royce Prize for Innovation in an MPhys Project.

(j) The Tessella Prize for software development in a MPhys Project.

(k) The Winton Capital Prize for Best MPhys Research Project.

(l) The NTT Prize for the Best MPhys Project in Biological Physics

*formerly the Data Connection Prize

Project Prize winners in 2011- 2012

(a) Jonasz Slomka, Mansfield College won 'The Gibbs Prize for the best use of experimental apparatus in a MPhys project'. Project title: "Heat transfer in a microcalorimeter" supervised by Dr Amalia Coldea.

(b)Harry Desmond,St John's College won 'The BP Prize for the best final year Theoretical Physics Project'. Project title: "The Baryonic Tully Fisher Relation in the context of cold dark matter" supervised by Prof Subir Sarkar.

(c) Justin Alsing, St Edmund Hall won 'The Johnson Memorial Prize for a project in Astrophysics'. Project title: "Source counts of faint sub-mm galaxies" supervised by Dr Jo Dunkley.

(d) Gavin Peter John Fourie, Brasenose won 'The Johnson Memorial Prize for a project in Atmospheric, Oceanic and Planetary Physics'. Project title: "The refractive index of volcanic ash aerosols" supervised by Dr Daniel Peters.

(e) Valentin Aslanyan, St Catherine's College won the 'The John Thresher Prize for a project in Particle and Nuclear Physics' in 2011-2012. Project title: "Phase retrieval techniques for longitudinal bunch profiling using coherent Smith-Purcell radiation" supervised by Dr Riccardo Bartolini.

David Peter Wallis Freeborn St Hugh's College won the 'The John Thresher Prize for a project in Particle and Nuclear Physics' in 2010-2011. Project title: "Gluon distribution function in quantum chromodynamics at very high energies" supervised by Dr Francesco Hautmann.

(f) Owen Matthew Truscott Thomas, St Edmund Hall won 'A Physics Prize for an MPhys Project in Atomic and Laser Physics'. Project title: "DNA as a (quantum) measurement apparatus" supervised by Prof Vlatko Vedral.

(g) Samuel David McMullan, Jesus College won ‘A prize for a project in Condensed Matter Physics’. Project title: “Determination of the Electronic properties of graphene from experimental observation of the quantum Hall effect and weak localisation” supervised by Prof Robin Nicholas.

(h) Samuel Frederick Blake, The Queen’s College won ‘The Metaswitch Prize for the best use of Software in a MPhys Project’. Project title: “Electronic structure of novel superconducting materials” supervised by Dr Amalia Coldea.

(i) Samuel Tusk, St Hilda’s, won ‘The Rolls-Royce Prize for Innovation’ Project title: “Attempted optical observation of the stepwise motion of a synthetic DNA motor” supervised by Prof Andrew Turberfield.

(j) Christian Alexander Schröder, Exeter College, won ‘The Tessella Prize for Innovation in software’. Project title: “Biological Evolution and Genetic Algorithms” supervised by Dr Ard Louis.

(k) Vitaliy Babenko, Wadham, won ‘The Winton Capital Prize for the Best MPhys Research Project’. Project title: “Digital holographic microscopy for 3D tracking of bacterial swimming” supervised by Dr Richard Berry.

Project Prize winners in 2010- 2011

(a) Neven Blaskovic Kraljevic, Somerville College, won ‘The Gibbs Prize for the best use of experimental apparatus in a MPhys project’. Project title: “Mossbauer recoil-free nuclear resonance in 57Fe” supervised by Dr Giles Barr.

(b) Jakub Sikorowski, Jesus College, won ‘The BP Prize for the best final year Theoretical Physics. Project’. Project title: “Quasi-normal frequencies of black holes and black branes” supervised by Dr Andrei Starinets.

(c) Lea Philomena Kraemer, Somerville College, won ‘The Johnson Memorial Prize for a project in Astrophysics’. Project title: “Building a galaxy bar to order” supervised by Dr John Magorrian

(d) Stephen Ian Thomson, New College, won ‘The Johnson Memorial Prize for a project in Atmospheric, Oceanic and Planetary Physics’. Project title: “A study of Mars’ North Polar warming in December 2003 and its relation to the Polar Vortex and atmospheric dust” supervised by Dr Luca Montabone and Prof Peter Read.

(e) There was no recipient for the ‘The John Thresher Prize for a project in Particle and Nuclear Physics’.

(f) Peter John Reader-Harris, Brasenose College, won ‘A Physics Prize for an MPhys Project in Atomic and Laser Physics’. Project title: “Compressed giant laser pulses for laser induced grating spectroscopy” supervised by Professor Paul Ewart.

(g) Scott William Riseborough, St Catherine’s College, won ‘A prize for a project in Condensed Matter Physics’. Project title: “Skyrmionics” supervised by Prof Paola Radaelli.

(h) Amy Ishbel Wells Morreau, Worcester College, won ‘The Metaswitch Prize for the best use of Software in a MPhys Project’. Project title: “Development of analysis software for back-scattered Laue X-ray diffraction” supervised by Dr Radu Coldea.

(i) David George Wood, St Anne’s College, won ‘The Rolls-Royce Prize for Innovation’ Project title: “Automated tracking of microtubules in a kinesin gliding assay” supervised by Prof Andrew Turberfield.

(j) William Frederick Berk, Christ Church, won ‘The Tessella Prize for Innovation in software’. Project title: “An investigation into transitions from disorder to order in driven systems of antisotropic particles” supervised by Dr Radek Eban and Dr Nick Jones.

(k) Felix Alexander Pollock, St Anne’s College, won ‘The Winton Capital Prize for the Best MPhys Research Project’. Project title: “Quantum correlations as a form of curvature” supervised by Prof Vlatko Vedral.

(l) Michael Joseph Senior, Oriel College, won ‘The NTT Prize for the Best MPhys Project in Biological Physics’. Project title: “Energy transfer along a DNA photonic wire” supervised by Dr Achillefs Kapanides.

Examples of reports

A limited selection of past MPhys project reports is available for reference from the Assistant Head of Teaching (Academic) in the Physics Teaching Faculty Office, Clarendon Laboratory toward the end of Hilary Term.

Timetable for students

Michaelmas Term 2012

Week 0 Distribution of the *MPhys Projects Handbook* **Colleges**

Week 7 **Compulsory Safety Lecture** **Please consult the lecture list for details**
Failure to attend means that the project cannot be started.
All Risk Assessments to be completed before project starts.
Completion and submission of your *Risk Assessment Acknowledgement* form.
You will **NOT** be allowed to start your project if have not completed and submitted your *Risk Assessment* form to the **Physics Teaching Faculty**.

Michaelmas Term Weeks 1 and 2

Before deciding on a project students are encouraged to discuss any projects in which they are interested with supervisors, but there is no obligation to do so and allocation of projects does not depend on doing this.

Week 2 (Fri 3 pm) Complete the *Project Choice Form* (**see Appendix A**) **Physics Teaching Faculty**
[Hand in the *Project Choice Form* at Clarendon Reception by internal post or by e-mail]
Late submission may result in a project being chosen for you

Week 5 (Fri) Publication of the Project Allocation List **http://www.physics.ox.ac.uk/teach**
[e-mail notification]

Week 6 -8 Talk to your college tutor about the project you have been allocated.

Weeks 7 & 8 Students meet supervisors to get reading and any other instructions for the Christmas vacation (there **MUST** be at least one meeting before the end of term).

Hilary Term 2013

Weeks 1 - 8 MPhys project period
If the supervisor has to leave Oxford for any time during this period a deputy supervisor will be allocated to you.

Week 2* 'How to write an MPhys Project Report' lecture **Please consult the lecture list for details**

Week 3 or 4 Discuss plan of project report with supervisor. Talk to your college tutor about the progress of your project.

Week 9 *onwards* Hand in a draft (as complete as possible) of MPhys report to your supervisor. You and your supervisor must complete and sign the *MPhys Draft Form* (see **Appendix A**).

Week 10 *onwards* Deadline for receiving comments from supervisor.

Trinity Term 2013

Week 1 (Mon 12 noon) MPhys project reports handed in. **Examination Schools**
Three copies of project or essay & the Declaration of Authorship & a copy of the report in pdf format on a CD.
(One of these copies will be given to the supervisor for their record.)

***subject to change, see lecture list**

Timetable for supervisors

Early Michaelmas Term 2012

Students may contact you to learn more about your projects. They are not obliged to do this and the allocation of projects is not in any way dependent on them doing so.

Michaelmas Term 2012

Week 4 Draft project allocation sent to Physics college tutors and supervisors.
This is only a draft and the information should not be disclosed to students.

Week 5 Project allocations announced.

Week 7/8 **Compulsory meeting with students allocated to your projects**
The Project Committee has agreed that a meeting in late Michaelmas Term before the project period period in Hilary Term is necessary. This is so that the supervisor can assess the student's ability both in the physics content of the project and in computing skills, and the student can assess the aims of the project and preparation required. All Risk Assessments to be completed before project starts. Completion and submission of your *Risk Assessment Acknowledgement* form (see **Appendix B**)

Students need to understand that outcomes of projects are very flexible and the project may change from the description originally provided in this handbook. In particular, some students will need to be persuaded that the work is not necessarily predictable. Projects are supposed to be an introduction to research.

If you are not able to meet the students allocated to your projects in week 7/8, please arrange another time well before the start of the project period.

Hilary Term 2013

Week 1 **MPhys students** must complete safety requirements and risk assessments, undertake any necessary computer training and preparatory reading.

Weeks 1 - 8 **MPhys project period:** during this period all of the experimental and theoretical work necessary for the project should be completed. You should meet the student regularly and leave your contact details for the student to contact you should the need arise. You should encourage the student to begin the project write-up as early as possible.

If you have to leave Oxford during this period please ensure that you have a deputy to undertake project supervision in your absence.

Week 9 *onwards* Full as possible draft of the MPhys report handed in by student to you and *MPhys Draft Form* (**see Appendix A**). The completion of the *MPhys Draft Form* confirms that the draft report has been seen and the form must be sent to **Physics Teaching Faculty**, signed by both student and supervisor.

Week 10 *onwards* Comments by supervisor on draft report is given to the student.

Trinity Term 2013

Week 1 MPhys Student hands in copies of the final report to Examination School with a single copy of the Declaration of Authorship & a copy of the report in pdf format on a CD.
(Three copies, one of these copies will be given to the supervisor for their records.)

Week 2 Deadline for return of Supervisor's Report Form.

Guidelines for MPhys students

Student responsibilities

- Hand in *Project Allocation: CHOICE FORM* (see **Appendix A**) by Friday, week 2.
- To check the project allocation.
- To attend the Compulsory Projects Safety lecture. Complete the appropriate risk assessments with the supervisor. Return the completed *Risk Assessment Acknowledgement* form (see **Appendix B**) to the Safety Office.
- To attend regular meetings with the supervisor during the project period and to contact the supervisor promptly should there be difficulties.
- At your regular meetings, you will be asked about your logbook. It is important that it is sufficiently detailed and includes dates and times of day.
- To ensure that the supervisor has been given a full draft of the project in 9th week onwards or by arrangement with the supervisor. Complete the *BA Project Draft Form*, see **Appendix C**.
- Hand in **3 (three)** copies of the MPhys report with **one** copy of the declaration of authorship and **one** copy of the report in pdf format on a CD to the Examination Schools on time.
- Prepare for the meeting with the assessors from the Project Assessment Committee.

Schedule

It is particularly important that you take note of the overall schedule. This has been established in conjunction with the Finals Examiners. Please read the notes in conjunction with the timetables on pages 14 and 15.

Hilary Term (*Weeks 1 - 8*): Project work

This is a very concentrated period of work during which all experimental work must be completed and it is essential that you work systematically from the start of term. It is intended that the total effort devoted to the project be equivalent to 4 weeks full time activity. ***[For example, the average time spent in a lab is 20 days.]*** Any restrictions on when and how you may work, if doing a laboratory based project, will have been agreed between you and your supervisor during the preparatory meetings.

Hilary Term (*Weeks 3/4*): Planning the write- up

You will find it very useful to start planning your report as soon as possible. Your logbook and your notes will assist you in preparing for the draft report.

Hilary Term (*Week 9 onwards*): Draft report (as complete as possible)

Your supervisor will be expecting your report and they will be writing comments which you must receive back in 10th week or sooner.

Trinity Term (*Week 1*): Examination Schools

The final version of the MPhys report is handed into Examination Schools on **Monday 12 noon of 1st week of Trinity Term**.

Trinity Term (*Week 5*): Project Assessment

Students meet the assessors of their MPhys report.

Logbooks

During your project it is important to keep systematic and professional records. Your records must be kept by using paper copy or in an electronic format. This will instrumental when you compile your final report. More details are given in *Practical Course Handbook*, Section 1.3.2.

Why three copies of your project report?

One copy is given to your supervisor for their own records with the other two copies retained for assessment purposes. Please note these reports are not returned to you after the publication of the results, as they are examinable material.

Students are strongly encouraged to make a copy for your own records.

Why do I need a declaration of authorship?

As you will see from the section on **Citation and Plagiarism**, we require students to make a statement regarding their project. Students will be expected to have made this declaration before any formal assessment takes place.

Student feedback to the Department

We are always keen to hear about your experiences while doing the project you have been allocated. Your contribution, in this way, provides useful feedback to the Department. Please write or e-mail your comments to the Assistant Head of Teaching (Academic).

Competitions and Publications

The Science, Engineering and Technology (SET) student of the year is one of a number of national competitions which provides project students with the opportunity to have the excellence of their project work recognised. More details can be found on their website http://www.setawards.org/.

Good reports from previous years have also been published in reputable journals e.g. European Journal of Physics.

Guidelines for MPhys project supervisors

These notes give guidelines for supervision of MPhys Projects in the Physics Department. We would like to emphasise that this is a large element of Part C of the course and has been very well thought of by past students. We have constructed these notes in the light of advice from previous examiners, including the external examiner, as well as that from the students and previous supervisors. We hope they will provide a useful source of information for you. Please do get in touch with the Assistant Head of Teaching (Academic) if there are other issues you feel need addressing.

Teaching duties of MPhys supervisors

- To ensure that the projects are matched to student needs.
- To ensure that there are proper equipment and resources available to students during the project period.
- To arrange training for the students in any specialised techniques or IT packages used on the project.
- To complete the appropriate risk assessments with the student(s). Return the completed *Risk Assessment Acknowledgement* form to the Safety Office.
- To have regular meetings with the student during the project period and to arrange for a suitable deputy to cover during absence if necessary.
- At your regular meetings, you should check that the student's logbook is sufficiently detailed and includes dates and times of day.
- To read and comment constructively on the first draft of the project report.
- Complete the MPhys supervisor report for each MPhys student you have supervised.

Resources

The Department has allocated a budget for projects. This is taken up in the main with requests for small items. The project equipment and consumables funds will be allocated at the start of Michaelmas Term.

Guidelines for writing the project report

The guidance given to students on the MPhys report can be found on page 6.

Schedule

It is particularly important that you take note of the schedule for the year. This has been established in conjunction with the Finals Examiners. Please read the notes below in conjunction with the timetables on pages 14 and 15. The timetables provide the framework and indicate the deadlines by which actions must be completed. It is expected that student and supervisor will work out mutually convenient working arrangements within this framework.

Michaelmas Term (*Weeks 7&8*):
Compulsory meeting with supervisor

Students will come to you during this period for preparatory material to study in the Christmas Vacation. This meeting is a compulsory one for students so it is essential that you contact your student to make alternative arrangements (by e-mail or telephone) in weeks 6 or 9 if you have to be away during this period.

The students will have covered about half the lectures for the Major Options but will still have much to learn and absorb. Preparation before the project has a profound effect on student performance, so make sure they understand this and emphasise what is most important. You should also stress that outcomes of the project are flexible and may not be as described in this handbook.

It may be necessary to arrange some computer or other specialist training. This should be done either at the end of Michaelmas Term or during 0th week of Hilary Term. Please contact the Assistant Head of Teaching (Academic) if you need assistance.

Hilary Term (*Week 1*): Final preparation

This is time for students and supervisors to ensure adequate preparation has been made. This will include the joint process of filling out the *Risk Assessment* form for the project. This is a legal requirement for the project to proceed. Students will have been issued with the forms at the Compulsory Safety Meeting (see lecture list for details) but if you need a form or any advice, you should get in contact with the Physics Teaching Faculty Office in the first instance then to the appropriate Safety Officer. This is also the time for completing computer training.

Hilary Term (*Weeks 1 – 8*): Main project period

Exactly how the project will proceed and whether there are restrictions on when equipment may be used (e.g. because of the need for liquid He) will have been outlined in the project description and in discussion with the student. Not only must all experimental work be completed during this period but a start on the project writeup is also strongly recommended. It is essential that the students are launched into the work rapidly and that arrangements are made for regular meetings throughout the term.

The total effort devoted to the project should be equivalent to 4 weeks full time activity. ***[For example, the average time spent in a lab is 20 working days.]***

If you are delegating aspects of the supervision to any other member of the department be sure that they and the student are fully aware of the arrangements.

You should keep notes on the effort and achievement of project students as they proceed, as you will be asked to give a full account to the examiners.

Hilary Term (*Week 9 onwards*): Draft Report (as complete as possible)

A draft (as complete as possible) of the report to be handed to the supervisor by the student and a receipt signed and returned to the student. Your advice and interaction with the student on the content of the report is an important part of the project so please do allow sufficient time for this interaction. The specification of the form the report should take is detailed in this handbook.

Hilary Term (*Week 10 onwards*): Draft Report feedback

The supervisor should advise the student by reading the report and criticising it ONCE only. This should be done before Friday of 10th week.

The project report should be aimed at a physicist who has not worked in the area of your project. The assessors may deduct a significant number of marks if they are unable to understand the project report. Reports from previous years are available from the Assistant Head of Teaching (Academic) in the Physics Teaching Faculty Office, Clarendon Laboratory for supervisors to read to take note of the standards reached. Some journals (e.g. European Journal of Physics) encourage the publication of good reports.

Trinity Term (*Weeks 0 - 1*): Supervisor Report Form

Supervisors complete a supervisor report for each MPhys student they have supervised no later than 1st week in Trinity.

Trinity Term (*Week 1*): Examination Schools

The final version of the MPhys report is handed into Examination Schools on **Monday 12 noon of 1st week of Trinity Term**.

Trinity Term (*Week 5*): Project Assessment

Students meet their assessors of your MPhys project.

Logbooks

One of the essential habits we have tried to instil in students is keeping systematic records of their work. Please check that students are using their logbooks in a professional manner throughout the project. Encourage them to make a thorough record of all their investigations, including any problems they encounter.

Supervisor copy of the final project report

A copy of the final report handed in to the Examination schools will be given to you for your records. Please emphasise to your student that they should make a copy for their own records, as the reports are not returned.

Supervisor feedback to the Department

At the end of the project, as well as helping with the assessment, we would very much like to hear from you on how the project ran from the supervisor's point of view. Please do tell us if the allocation process worked sensibly. We will be working with colleagues to ensure a good match but we would like

MPhys project descriptions

Atomic and Laser projects

A&L01 **Molecular photo-physics**

Laser excitation of excited molecular states is followed by relaxation to the ground state by a number of decay mechanisms including radiation i.e. fluorescence, or collision-assisted energy transfer to other states within the same or different molecules. Understanding these decay mechanisms is vital for understanding the photo-physics of large molecules and for quantitative measurements using laser techniques such as laser induced fluorescence, LIF, or laser induced grating spectroscopy, LIGS. This project will use LIF to study the photo-physics of acetone and seek to relate the observations to the structure of excited molecular states and the various decay mechanisms that govern energy transfer during collisions with oxygen and nitrogen.

This is an experimental project using high power pulsed lasers with computer assisted data acquisition and analysis. Knowledge of molecular physics at the level of the B2: III. Quantum, Atomic and Molecular Physics course will be assumed with C2 Laser Science and Quantum Information Processing being the most relevant 4th year option.

Supervisors ***: Prof P Ewart*** **and** ***Dr B Williams***
Physics Tel No ***: 272340; 272220***
Email ***: p.ewart@physics.ox.ac.uk;***
b.williams2@physics.ox.ac.uk

A&L02 **Simulation of third order nonlinear optical wave mixing**

When laser radiation interacts with matter the coherence and intensity of the light leads to nonlinear effects because the refractive index of the material is altered by the optical electric field in the light wave itself. The usual methods of Quantum Theory used to describe such effects, based on Perturbation Theory, often break down when the frequency of the light is resonant with an atomic or molecular transition. Simulation of such situations usually involves numerical solution of the nonlinear master equations governing such interactions but these are computationally expensive and ill-suited to spectral simulation. Our group developed an analytical but non-perturbative method to calculate the third-order nonlinear interaction underlying an important class of nonlinear effects – degenerate four wave mixing, DFWM. This project will translate the computer simulation of DFWM spectra based on our theory, developed previously, into a Matlab program suitable for web-access. The aim is to provide fast spectral simulation software for the international community. This will enable researchers using DFWM spectroscopy to simulate spectra of molecular species for comparison with experimental data.

This projects requires a good level of theoretical physics and computational ability. Familiarity with MATLAB or similar high level computer language would be an advantage. The most relevant 4th year options are: C2 Laser Science and Quantum Information Processing and/or C6 Theoretical Physics.

Supervisors ***: Prof P Ewart*** and ***Dr B Williams***
Physics Tel No ***: 272340; 272220***
Email ***: p.ewart@physics.ox.ac.uk;***
b.williams2@physics.ox.ac.uk

A&L0301 **Multi-species sensing using Multi-Mode Absorption Spectroscopy**

Remote sensing of molecular species using lasers is important in a wide range of applications including environmental monitoring, medical diagnostics and industrial process control. In many cases several different species need to be detected and measured and this requires several separate lasers and detectors with appropriate multiplexing and de-multiplexing. As a result such detection schemes are cumbersome and expensive. We have developed a novel method to detect multiple species using a single multi-mode laser and a single detector known as Multi-Mode Absorption Spectroscopy, MUMAS. This project will develop a system to detect simultaneously the important molecules CO and CO2 which are indicators of the completeness of combustion in engines and power stations. The aim is to make a remote sensor that can monitor and control combustion to ensure fuel efficiency and minimize environmental pollution and explosion hazards.

This is an experimental project requiring good practical skills and involving computer assisted data acquisition and analysis. Knowledge of molecular and laser physics at the level of the B2: III. Quantum, Atomic and Molecular Physics course will be assumed with C2 Laser Science and Quantum Information Processing being the most relevant 4th year option.

Supervisors ***: Prof P Ewart*** **and** ***Dr B Williams***
Physics Tel No ***: 272340; 272220***
Email ***: p.ewart@physics.ox.ac.uk;***
b.williams2@physics.ox.ac.uk

A&L0302 also A&L08 **Laser plasma accelerators; a study of the coupling between transverse and longitudinal electric fields**

It has been proposed that we might generate power using sIt has been experimentally proven that very high electric fields can be created and used to accelerate particles by plasma oscillations of electrons in a background of quasi static ions. Normally, the oscillations are excited by a single, high intensity laser pulse. An alternative method, under study, is to excite plasma oscillations step by step, in a resonant way by using a train of laser pulses of lower intensity that the intensity needed for one pulse excitation.

When sufficient energy is accumulated in the plasma oscillations, relativistic effects cannot be neglected and transverse and longitudinal oscillations become coupled.

That might limit time available for plasma excitation in the resonant way. The work on this project will involve solving relevant differential equations with a help of Mathematica (no prior knowledge of Mathematica is required) interpreting them and concluding with proposals for experimental work.

Supervisor : ***Dr R Walczak*** Physics Tel No : ***273324***
Email : ***r.walczak@physics.ox.ac.uk***

A&L04 **Electrostatic trapping and manipulation of graphite/graphene/graphene oxide flakes**

The objective of this experimental project is to trap a single microscopic flake at the centre of a vacuum region using an ac electric field. This allows the sample to be studied by light scattering, e.g., the radiation force exerted by circularly polarized light was used to spin up flakes to extremely high rotation rates—this is possible because of the high mechanical strength of the material. Much of the apparatus has been constructed in previous projects but there is a lot of scope for innovative experimental work with these remarkable single-layer materials that are now readily available and can be electrically charged in an electrospray. This project involves the application of kinetic theory, electromagnetism and etc. to new problems. A good introduction to what can be achieved with simple apparatus is described in ref. [1].

[1] Levitated spinning graphene flakes in an electrostatic quadrupole ion trap. arXiv 1006.3774. Phys. Rev. B 82, 115441 (2010).

Supervisors: ***Prof C Foot*** Physics Tel No: ***272256***
Email: ***c.foot1@physics.ox.ac.uk***

A&L05 **Numerical modelling of a magnetic trap for ultracold atoms**

In this computing project the student will design a new form of miniature magnetic trap for cold atoms using millimetre scale conductors to create high field gradients. The main aim of the project is to optimise the thermal management using available software so that the temperature of the conductors is maintained within acceptable limits and the dissipated power is efficiently conducted to the water cooling. The student will gain experience of CAD programs a combined with various powerful Finite Element Method (FEM) solvers designed for non-linear problems. Such methods are of very widely applicability and the student will have the opportunity to apply them to other problems, e.g., smaller micron-sized traps (aka atom chips) made in a novel way from atomically thin layers of graphene.

Supervisors: ***Prof C Foot*** Physics Tel No: ***272256***
Email: ***c.foot1@physics.ox.ac.uk***

A&L06 **Modelling of motion of graphene flakes in viscous gases**

The Brownian motion of nonspherical particles in a gas has many interesting features, e.g., the coupling of rotational and translational motion. These can be investigated by numerical methods that simulate the systems by tracking all the atomic trajectories individually. Although a very demanding computational task for a large number of atoms there are many algorithms have been proposed to attack the problem. This project involves a mix of analytical and computational work in kinetic theory.

Supervisors: ***Prof C Foot*** Physics Tel No: ***272256***
Email: ***c.foot1@physics.ox.ac.uk***

A&L07 **A computer programming and electronics project: design of a feedback and control systems using Field Programmable Gate Array**

FPGAs are reconfigurable devices that are used in many modern electronic applications. The aim of this project is to design a system to control an experiment involving several lasers and other optical devices, e.g., using the boards available from http://www.opalkelly.com/ . The project is suitable for students with a strong interest in electrical engineering.

[1] arXiv 1208.2607. A Distributed GUI-based Computer Control System for Atomic Physics Experiments.

A. Keshet and W. Ketterle

Supervisors: ***Prof C Foot*** Physics Tel No: ***272256***
Email: ***c.foot1@physics.ox.ac.uk***

A&L08 also A&L0302 **Laser plasma acceleration; a study of the sensitivity to laser light parameters for laser plasma excitation by a train of laser pulses**

It has been experimentally proven that very high electric fields can be created and used to accelerate particles by plasma oscillations of electrons in a background of quasi static ions. Normally, the oscillations are excited by a single, high intensity laser pulse. An alternative method, under study,

is to excite plasma oscillations step by step, in a resonant way by using a train of laser pulses of lower intensity that the intensity needed for one pulse excitation.

The efficiency to excite plasma this way depends on shape of laser pulses, their spacing and on their variations from pulse to pulse. This project should answer questions on tolerances which are required for the efficiency to be high. The work will involve solving relevant differential equations with a help of Mathematica (no prior knowledge of Mathematica is required) interpreting them and concluding with proposals for experimental work.

Supervisor : ***Dr R Walczak*** Physics Tel No : ***273324***
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A&L09 **Quantum tomography**

Quantum physics promises to revolutionize a wide range of applications, such as measurement precision beyond the classical limit, secure communications, and exponentially fast information processing. At the heart of these quantum-enhanced technologies lies the concept of a quantum experiment. A quantum experiment can be divided into three stages: state preparation, processing, and measurement. To ensure the optimal performance of quantum-enhanced technologies requires the ability to accurately characterize each stage of a quantum experiment. Quantum state, process, and detector tomography respectively prescribe a procedure to completely characterize these stages. This is done by making multiple measurements on identically prepared quantum systems resulting in a set of probabilities for each possible outcome. These probabilities can be inverted to determine the mathematical representation of the state, process, or detector.

The aim of this project is to develop an approach to efficiently invert experimental data to reconstruct the different stages of a quantum experiment. The student will gain working knowledge of state-of-the art quantum optical sources and detection techniques and tomography methods. To reconstruct the different stages of a quantum experiment the student will develop data analysis algorithms to invert experimental data.

Thorough understanding of quantum mechanics is required. It will be helpful if the student has seen field quantization in terms of creation and annihilation operators. Basic programming skills and experience with Matlab are desirable.

Supervisor : ***Dr B Smith*** Physics Tel No : ***272206***
Email : ***b.smith1@physics.ox.ac.uk***

A&L10 **Single-photon spatial-state characterization**

Single photons are the fundamental quantum excitation of the electromagnetic field and are essential resources for many quantum-enhanced technologies such as quantum communication and quantum metrology. The quantum state of a single photon completely describes all of its degrees of freedom: time-frequency, spatial-momentum, and polarization characteristics. To realize the full potential of quantum applications requires the ability to determine the complete quantum state of a single-photon source.

In this project we will develop an experimental approach to characterize the spatial-momentum state of a single-photon source. The student will gain working knowledge of the state-of-the art for producing photon pairs from spontaneous parametric down conversion. To determine the spatial-momentum state of an ensemble of heralded single photons produced by a down conversion source the student will construct a photon-counting device to measure the transverse position and momentum distributions. This data will then be used to infer the spatial state of the single-photon source.

Thorough understanding of quantum mechanics is required. It will be helpful if the student has seen field quantization in terms of creation and annihilation operators. Basic knowledge of classical optics - particularly Gaussian-beam and Fourier optics will also be essential.

Basic computer programming skills (Labview and Matlab) to interface experimental equipment, acquire and analyze data.

Supervisor : ***Dr B Smith*** Physics Tel No : ***272206***
Email : ***b.smith1@physics.ox.ac.uk***

A&L11 **Electromagnetically induced transparency (EIT) in hot Rb vapour**

Coherent storage and retrieval of light in atomic vapours has been intensively studied during the last decade. A coherent-control technique, known as ‘electromagnetically induced transparency’ (EIT) has been successfully employed for slowing down light and for transferring light pulses to/from dark-state polaritons, which are a pure state of matter. Many proposals have been made to use this scheme for storing just one single photon. The latter would render the technique very useful for optical quantum computing, as it would be a way to freeze the quantum state of light.

The goal of this project is the modification and control of the absorption properties of Rb vapour using EIT with a weak driving laser pulse. The latter should eventually be optimised to allow for the storage and retrieval of single photons. Basic knowledge of coherent light-matter interaction is required (Atomic Physics by C. J. Foot, OUP, gives a great discussion).

Supervisor ***: Dr A Kuhn*** Physics Tel No ***: 272333***
Email ***: a.kuhn@physics.ox.ac.uk***

A&L12 **Ion Trap Quantum Computing**

More details from the supervisor.

Supervisor : ***Dr D Lucas*** Physics Tel No : ***272346***
Email : ***d.lucas@physics.ox.ac.uk***

A&L13 **tbc**

This is a project in laser-plasma physics, either theoretical, experimental or computational. More details from the supervisor.

Supervisor ***: Dr G Gregori*** Physics Tel No ***: 282639***
Email ***: g.gregori1@physics.ox.ac.uk***

A&L14 **Assembly and characterisation of high-finesse optical cavities**

Modern experiments in quantum information processing and communication often rely on interfaces between single quantum systems, such as single atoms and single photons. For instance, a single atom located in a high-finesse cavity constitutes such an interface, which is capable of single-photon emission, and which allows the mapping of quantum states between matter and light.

This project is aiming at the assembly and characterisation of Fabry-Perot type cavities, consisting of either a pair of individual mirrors, a pair of glass-fibre tips or a combination of both. This does also encompass the frequency locking of these cavities to a reference laser by means of sideband modulation or lock-in techniques. Basic knowledge of laser-cavity design is required (Laser Fundamentals by W.T. Silfvast, chapters 11-13, Cambridge, gives a great discussion)

Supervisor ***: Dr A Kuhn*** Physics Tel No ***: 272333***
Email ***: a.kuhn@physics.ox.ac.uk***

A&L15 **Quantum entanglement as a form of curvature**

This project will apply the standard methods of gauge field theory – namely, the Wilson loop – to study entanglement between many quantum bits. Entanglement will thus be seen as a form of curvature that arises as quantum measurements are parallel transported using many qubit states as the underlying base. Understanding many body entanglement is important both from the perspective of the developing quantum technologies as well as from the fundamental angle of probing the boundary (if such a thing exists) between the quantum and classical worlds.

Supervisor ***: Prof V Vedral*** Physics Tel No ***: 272389***
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A&L16 **DNA as a (quantum) measurement apparatus**

Based on a very simple model of the DNA (a coupled chain of quantum harmonic oscillators) we have recently found that electron clouds centred on nearest neighbouring base pairs are, in fact, quantum entangled. This entanglement is of the standard Einstein-Podolsky-Rosen type, namely in the position (and momentum) degrees of freedom. This is surprising, but is this entanglement important for the functioning of DNA? This project will investigate how to model mutations in the DNA due to absorption of a single quantum of radiation as interaction between the quantized harmonic chain representing DNA and the incoming quantized radiation. It belongs to a growing field of quantum biology, whose importance is seen in realising that some bio-processes simply cannot be understood properly (or even at all) without the full machinery of quantum mechanics.

Supervisor ***: Prof V Vedral*** Physics Tel No ***: 272389***
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A&L17 **Laser development for efficient plasma generation**

Laser plasma acceleration is a new method of producing a very high gradient accelerating field that has been successfully used to generate 1 GeV beams of electrons with a small energy spread. This method is being studied intensively as it has the potential to replace current rf accelerating technology and drastically reduce the length of high energy accelerators from the km to the m scale. Most current research in laser plasma acceleration focuses on using a very high energy, ultrashort laser pulse (1018 W/cm2) to produce the plasma from a low density gas, requires access to national scale specialist laser facilities. However, it has been shown that efficient excitation of a plasma wave may also be achieved by a train of multiple laser pulses of lower energy, with adjustable pulse durations and separations (ref?). In this project, the student will be investigating methods of generating suitable trains of pulses from a laser oscillator producing identical pulses at a regular frequency. Making variable pulse trains from such a source may involve splitting the pulse trains and recombining them in fibre, or using other techniques as necessary. This project will be predominantly experimental in nature, using lasers and fibre optics, and it may be helpful, but not necessary if the student has taken the S19 option in accelerator science, the S16 option in plasma physics or the C2 course in laser physics.

Supervisor : ***Dr L Corner*** Physics Tel No : ***273470***
Email : l.corner@physics.ox.ac.uk

A&L18 **Diagnostics of plasma generation for efficient particle acceleration**

Laser plasma acceleration is a new method of producing a very high gradient accelerating field that has been successfully used to generate 1 GeV beams of electrons with a small energy spread. We are investigating a new method of efficiently exciting a suitable accelerating plasma wave using trains of low energy laser pulses. In this project the student will work on diagnostics to detect the generated plasma, predominantly laser based interferometric techniques to measure the electron density. The project could be either mostly practical or theoretical in nature, depending on the student's interests. The practical side would involve working in a laser laboratory, and it may be helpful, but not necessary, if the student has taken the S19 option in accelerator science, the S16 option in plasma physics or the C2 course in laser physics.

Supervisor : ***Dr L Corner*** Physics Tel No : ***273470***
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A&L19 **Attoscience: Measurement and control of electron dynamics**

Attoscience, a result of relatively recent revolutions in laser technology and metrology, is the dynamical study of fundamental processes on unprecedented timescales that are critical in many areas of physics, chemistry and biology. Its emergence is predicated on not only the ability to generate and control attosecond duration sources, but the means to fully characterize these sources and the electromagnetic field or photoionized electrons scattered from the systems under study. Over the past few years, we have developed methods to fully characterize the temporal and spatial extreme ultraviolet (XUV) fields emitted from high harmonic generation (HHG) — the most common method of generating attosecond pulses — as well as techniques to study attosecond phenomenon during HHG. The next logical step is to implement these methods to the study and control of dynamical processes that occur on an attosecond timescale. Key to the realization of this will be developments in high intensity few-cycle UV sources to initiate and control the dynamics, and improving the efficiency of the HHG process to provide bright tunable attosecond pulses to probe the subsequent dynamics. We have a range of options within this project, experimental and/or numerical, involved in the development and utilization of both the UV and XUV sources.

Supervisors : ***Dr A Wyatt*** and ***Prof I Walmsley***
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A&L20 **tbc**

More details from the supervisor.

Supervisor : ***Dr P E G Baird*** Physics Tel No : ***272204***
Email : ***p.baird@physics.ox.ac.uk***

A&L21 **tbc**

More details from the supervisor.

Supervisor : ***Prof A Steane*** Physics Tel No : ***272385***
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Atmospheric, Oceanic and Planetary Physics projects

AO01 **Can various natural aerosols be distinguished using IASI data?**

The composition and distribution of atmospheric aerosols are key uncertainties in understanding of the Earth's radiative balance (IPCC, 2007). Recent work has shown that the Infrared Atmospheric Sounding Interferometer (IASI) is able to detect volcanic ash using methods developed for the detection of trace gases such as sulphur dioxide and ammonia (e.g. http://dx.doi.org/10.5194/amt-4-1567-2011). The aim of this project is to show that other natural aerosols such as biomass burning plumes, and desert dust can also be detected using the same techniques. Additionally, the varying infrared (IR) signatures of these aerosols should allow them to be distinguishable.

The student will use IASI data, and adapt computer code already written to detect volcanic ash from this data, so that it is also able to flag these additional species. Research into measurements of the IR spectrum of the new species of interest (through investigation of the scientific literature) will be a vital first step, and an end goal of the project will be to find IASI scenes with multiple aerosol types in which a demonstration of the ability to distinguish the species will be possible. Well known events, such as the Australian Black Saturday wildfires of 2009, and Saharan dust events will provide additional demonstrations of the method's validity.

The project is computer-based, using the Interactive Data Language (IDL) on machines which run the Linux operating system. Prior experience of either of these would be useful but in no way essential.

Supervisors : ***Dr A Smith, Dr E Carboni*** and ***Dr R D Grainger***
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Email : ***smith@atm.ox.ac.uk, carboni@atm.ox.ac.uk r.grainger@physics.ox.ac.uk***

AO02 **Impact of mixing state of freshly emitted carbons on aerosol radiative forcing**

The IPCC fourth assessment report (2007) concluded that aerosols (small airborne particles) represent a major contribution to the uncertainty in the radiative forcing due to the changing composition of our atmosphere. This radiative forcing is the primary driver of climate change and to better understand the future evolution of global warming, it is important to better understand aerosols. In particular the contribution of carbon aerosols, both organic and black carbon, is uncertain as we still now relatively little about their composition and chemical evolution. We propose to study one specific aspect of this uncertainty: the mixing state of freshly emitted carbons. The mixing state strongly influences both the dynamical and chemical evolution of aerosol after emission as well as their radiative properties.

The study will be primarily a modelling study in which the state-of-the-art model ECHAM-HAM will be used to calculate global distributions of aerosol and the associated forcings. The student will modify the model to allow for various scenarios of mixing at the time of emission. The student will then conduct model experiments and analyse the results. If time permits, comparison to SSA observations by the AERONET network and/or black carbon mass observations from the HIPPO campaigns will also be made.

During this study, the student will need to aquire skills in FORTRAN (for modifying ECHAM-HAM) and the IDL or Python software tools (for data analysis). Prior experience will be useful but is not required.

Supervisors: ***Dr N Schutgens*** and ***Dr P Stier***
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AO03 **What influences global CCN concentrations?**

The IPCC fourth assessment report (2007) concluded that aerosols (small airborne particles) represent a major contribution to the uncertainty in the radiative forcing due to the changing composition of our atmosphere. This radiative forcing is the primary driver of climate change and to better understand the future evolution of global warming, it is important to better understand aerosols. By modifying cloud properties, aerosols exert a so-called indirect effect on the radiative forcing. This is primarily achieved by modifying the concentration of cloud concentration nuclei (CCN). We propose to study the temporal and spatial variations in CCN in a 30 year hindcast of the global ECHAM-HAM model. This dataset contains CCN estimates for a wide variety of conditions (regions, climates, aerosol emissions). Another dataset of CCN observations is available for comparison but due to the limited accuracy and spatio-temporal sparseness of those observations, we here propose a different strategy.

In this study, the student will first compare observations from the AERONET network to ECHAM-HAM aerosol simulations to assess the model. Next, a study of CCN variability in the model will be made and an emulator derived. This emulator predicts CCN based on simulated bulk properties of aerosol. Using this emulator and observed (!) bulk properties (from AERONET observations) deficiencies in simulated CCN will be attributed. Our goal will be to better understand what influences CCN concentrations and to what extent the model is able to capture this.

During this study, the student will need to aquire skills in the software tools IDL or Python (for data analysis). Prior experience will be useful but is not required.

Supervisors: ***Dr N Schutgens*** and ***Dr P Stier***
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AO04 **DP1: High accuracy electronics for in flight satellite calibration**

This project will involve working closely with RAL Space (http://www.stfc.ac.uk/ralspace/), the commercial project partner. The work will include visits/placement to develop space flight hardware.

Accurate radiometric calibration of radiometers, both in-flight and ground based is essential in monitoring climate change and interpreting remote sensing measurements in the thermal-infrared. The instrument calibration systems consist one or more know blackbody radiance source(s). The calibration radiometric emission is inferred from it's temperature and the Planck radiation law.

State-of-the-art measurements of temperature sources uses platinum resistance thermometry to determine the blackbody temperature. Traditional high accuracy electronics use a series of transformers that have know turn ratios to allow direct comparison to a resistance standard; these instruments really on the highly linear nature of the transformers. There is the potential for high accuracy analogue-to-digital converters to replace the transformer based systems. This project will examine the potential of inherently linear sigma-delta ADC's to be used in the development of space based radiometers.

Good experimental skills would be an advantage.

Supervisors: ***Dr R D Grainger, Dr D Peters and Dr T Nightingale***
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AO05 **DP2: Instrument to sample and return airborne particles in a volcanic plume**

Unmanned aerial vehicles (UAVs) have developed to the stage of cheap mass production. This opens the possibility of taking air parcel samples from hostile environments such as volcanic plumes, where the risk of UAV loss is high. If such technology was available during the 2010 eruptions of Eyjafjallajökull more accurate ash mass loadings could have be made leading to less restrictive no-fly zones. In this project you will work in conjunction with the Rutherford Appleton laboratory to design and test the instrument payload for a UAV. The payload consists of a sampling instrument to directly deposit aerosol samples directly onto a set of TEM/SEM grids that would be subsequently analysed.

In this project you will characterise and test the sampler and help improve its novel multi-grid design. This will involve testing the sampler with aerosol and so characterising the sampler's efficiency.

Good experimental skills would be an advantage.

Supervisors: ***Dr R D Grainger*** **and*****, Dr D Peters***
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Email: ***r.grainger@physics.ox.ac.uk, d.peters@physics.ox.ac.uk***

AO06 **DP3: Scanning electron microscope analysis of fractal aerosols**

This project will investigate fractal aerosol particles and help to reduce uncertainties on the climatic effect of these aerosols. The fractal aerosol consists of a collection of black carbon (BC) primary particles that form larger fractal aerosol particles. Most BC is anthropogenic generated from incomplete combustion and has a complex particle morphology which evolves rapidly and whose optical properties are poorly known. Current direct radiative forcing estimates of BC are comparable to methane and are important on global and regional scales. It is suggested that black carbon aerosol may alter precipitation patterns and cloud life times. Snow reflectivity may also be decreased, increasing melting of snow and ice. Accurate optical properties of BC are essential for understanding its radiative forcing on the atmosphere and to allow quantitative remote sensing of black carbon from satellite, LIDAR and ground based radiometers.

Despite these requirements the optical properties are poorly known and the literature reports a wide spread of values. In 2004 Bond proposed a possible explanation for this spread, the void fraction. BC has a fractal like morphology and Bond proposes this could cause voids within individual BC particles; differences in the void fraction could explain the range of optical properties observed. As part of this project you will use the Department's Hitachi S-4300 scanning electron microscope system (http://www2.physics.ox.ac.uk/enterprise/sem) to investigate the nano-scale particle morphology. Current research within the group is quantifying the optical properties of different BC samples experimentally, your work will discover if the void fraction can explain the observed optical properties.

Good experimental and programming skills would be an advantage.

Supervisors: ***Dr R D Grainger*** and ***Dr D Peters***
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AO07 **Study of volcanic degassing from satellite**

Volcanoes are one of the most important sources of SO2 in atmosphere, but there are large uncertainties associated with these emissions. Satellites provide data globally, and are the only source of information for active volcanoes where there isn't ground monitoring. The SO2 emitted to the middle troposphere interacts with atmospheric constituents (mainly water vapour) to become H2SO4 vapour and sulphate aerosol. This project that will help to characterise how satellite remote sensing can be used to estimate volcanic SO2 emission and evolution and to reduce the uncertainties associated with these process..

A new highly accurate SO2 retrieval scheme has been developed for IASI data. The retrieval has an average error of 2 Dobson units at an altitude 2-3 km (typical of a volcanic source). The accuracy is still not good enough to monitor volcanic degassing using a single measurement but the volcanic SO2 can be measured by taking a time average (e.g. monthly mean maps show a volcanic signal over Bagana and Tungurahua).

In this project the student will use the IASI SO2 retrieval and associated meteorological wind data to study volcanic emission. The student will quantify the information obtainable from monthly mean measurements. The student was also investigate improvements in the signal-to-noise found by rotating the IASI data according to the wind direction and by rescaling it with the wind speed. The student will use existing IASI SO2 data, existing code to analyse the IASI data, and to read meteorological wind fields (ECMWF data). It is expected the monthly mean map an be interpreted in terms of the volcanic SO2 flux and its oxidation to sulphuric acid. If time permits the student can repeat the analysis for several different volcanic locations.

The project is computer based. It will involve the analysis and display of satellite data, requiring some simple programming in IDL. Some experience with the Linux operating system and/or the IDL programming language would be an advantage but is not essential.

Supervisors : ***Dr E Carboni*** and ***Dr R D Grainger***
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AO08 Consistency of multi-satellite global aerosol data

The impact of aerosols, both directly and through their interaction with clouds, is the most uncertain element in our understanding of the radiative balance of the atmosphere. Improving our measurements of global aerosol loading and its is thus a key element in improving our understanding of the climate system.

The Along Track Scanning Radiometer satellite instruments (ATSR-2 and Advanced-ATSR) provide a near-continuous record of 17 years of global measurements, which is one of the longest available, and are well suited to the determination of atmospheric aerosol loading. However, the utilisation of this long-term record in monitoring aerosol has been limited, in part due to issues of instrument calibration. Recently, work has been done to overcome the calibration problems and a consistent set of measurements from both instruments is now available.

This project involves comparing aerosol data derived from both instruments during the period when both were operational (2002-2003). The student will develop code to collocate large volumes of data from the two instruments and perform statistical comparisons with the goal of answering key questions:

• Do the aerosol properties derived from the two instruments agree within the limits of instrument noise and the difference in measurement time between them?

• Is the agreement between them consistent for different regions across the globe and over land and ocean?

• Is the agreement consistent throughout the instrument overlap period?

Answering these questions will greatly improve confidence in the ATSR data record, with implications not only for aerosol science, but also other fields where ATSR can provide data (clouds, surface properties).

The project will involve extensive computer based analyse and will make use of the IDL coding language in a Linux environment. Although familiarity with Linux and IDL are not a requirement for the project, general computing skills and some experience of programming would be advantageous.

Supervisors : ***Dr G E Thomas*** and ***Dr R D Grainger***
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AO09 Exploring the spatial and vertical variation of the clouds of Saturn and Jupiter

The Cassini spacecraft has been in orbit about Saturn since 2004. One of its instruments, the Visible and Infrared Mapping Spectrometer (VIMS), records reflected sunlight from 0.8 to 3.5 μm and thermal emission from below the cloud decks from 3.5 to 5.1 μm. VIMS has been observing Saturn since before Cassini's arrival at Saturn and also observed Jupiter during the spacecraft's flyby of that planet in 2000. In this project, the VIMS observations of Saturn and Jupiter will be analysed using simple radiative transfer tools and techniques such as Principal Component Analysis to probe the horizontal and vertical distribution of clouds/hazes across these planets. The aim will be to relate these distributions to photochemical and dynamical processes within these atmospheres. The VIMS data are of exceptional quality, but have been surprisingly little analyzed to date so this project represents a real opportunity to advance our understanding of these atmospheres. The student would be joining a group of several post-docs and graduate students working on related studies of the atmospheres of the outer solar system planets.

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

Supervisor***: Prof P Irwin*** Physics Tel No ***: 272083***
Email: ***p.irwin@physics.ox.ac.uk***

AO10 Probing dust within a cometary coma with the ESA Rosetta spacecraft

In 2014 ESA's Rosetta spacecraft, which was launched in 2004, will rendezvous with Comet Churyumov-Gerasimenko in 2014 at a distance from the Sun of over 3 AU and go into orbit about the comet so that it can observe the heating and sublimation of the comet's surface as it approaches the Sun and subsequent formation of the tail. The spacecraft will orbit about the comet right through its closest approach to the Sun in 2015 and will also deploy a lander, Philae, to study the conditions on the surface of the comet itself.

Comets represent some of the oldest and least processed bodies in the solar system and are believed to be leftover building blocks from the period of formation of the planets 4.6 billion years ago. From observation of the D/H ratio in the comets compared with those in the giant planets and on the Earth, it is believed that comets actually delivered the bulk of the Earth's water and perhaps even some of Earth's complex organics and thus the study of these remote, beautiful bodies can tell us much about the Earth itself.

One of the instruments carried but the orbiter, called VIRTIS, will map the cometary nucleus and its transient atmosphere, called the coma, over a wide range of wavelengths from the visible to the near infrared, and these observations will be used to probe the comet nucleus and measure the outgassing of gas and dust as the comet warms near the Sun. VIRTIS will also be used to determine the composition of the coma and measure the relative abundance of gas and dust.

In this project the student will use a state-of-the-art multiple-scattering radiative transfer model to simulate the observations that Rosetta/VIRTIS will make, depending on different assumptions of dust/gas production rates, dust composition, and observing strategies. These simulations will be of vital importance in designing the Rosetta observations.

Supervisor***: Prof P Irwin*** Physics Tel No ***: 272083***
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AO11 Jupiter's Strange Weather: Infrared Observations to probe Atmospheric Structure

For the past six years, Oxford planetary astronomers have been using ground-based thermal infrared imaging and spectroscopy of Jupiter and Saturn to study the dynamics, chemistry and structure of giant planet atmospheres. The VISIR instrument (Rio et al., 2004, SPIE 3354, p615-626) on the Very Large Telescope in Chile, along with a host of other facilities around the world, have provided stunning images and spectra of both planets, revealing their temperature structure, gaseous composition and aerosol distribution. These results have been used to study the response of Jupiter's atmosphere to giant asteroidal collisions; the evolution of seasonal storm activity on Saturn; and the environmental properties at the heart of Jupiter's Great Red Spot. However, much of this vast dataset has yet to be exploited, and this project would involve the reduction and analysis of new observations constraining 'global upheavals' in Jupiter's banded cloud structure. Jupiter has taken on a sequence of rare environmental states since 2008, culminating in 2012 in unusual dynamic activity in the dark brown belts not seen for over a century. We have the infrared data required to understand the physical and chemical changes that are driving this unusual activity, and collaborate closely with amateur observers tracking the colour and circulation changes.

The successful candidate would use IDL and Fortran-based codes to determine the temperatures, aerosol opacity and chemistry associated with these large changes. Imaging and spectroscopy will be reduced and calibrated, and modelled using Oxford's suite of remote sensing software known as NEMESIS (Fortran based algorithm, Irwin et al., 2008, JQSRT 109, p1136-1150). The principle target of this study is the spatial distribution of ammonia, phosphine and aerosols, which are transported vertically in the centre of the storms by strong convection rising up from Jupiter's deep interior, and reveal the strength of vertical mixing from the hidden depths of the gas giant. This ongoing infrared project will allow us to provide supporting ground-based observations for upcoming spacecraft missions (e.g., Juno and JUICE) to the jovian system.

The student will require a Linux workstation within AOPP, and space to perform their work. No laboratory equipment or space is required. Familiarity with a UNIX/LINUX operating system is preferred, and experience with IDL (Interactive Data Language) would be extremely helpful.

Supervisors***: Dr L Fletcher*** and ***Prof P Irwin***
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AO12 Measurement of Isotopic ratios in the Stratosphere

Some of the major infrared absorbing molecules in the atmosphere are assumed to maintain their surface ratios of minor isotopes, e.g. fraction of CO_2 molecules with ^{13}C atoms compared to the normal ^{12}C. Others, e.g. H_2O, are known to vary due to the mass-dependence of various chemical processes.

The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) is part of the payload of the European Space Agency's ENVISAT satellite launched in March 2002. MIPAS is a fourier-transform spectrometer which measures the infrared emission spectra of the earth's atmosphere from 4-15 microns with sufficient spectral resolution to identify minor isotopic lines of a number of different molecules.

This project is to investigate simple techniques which can be applied to such spectral signatures to extract isotopic ratios, and compare the results with previous measurements or predictions.

The project is entirely computer-based so some knowledge of scientific computing and/or linux would be useful.

Supervisor***: Dr A Dudhia*** Physics Tel No ***: 272922***
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AO13 Measurement of Trace Gases in the Stratosphere

The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) is part of the payload of the European Space Agency's ENVISAT satellite launched in March 2002. MIPAS is a fourier-transform spectrometer which measures the infrared emission spectra of the earth's atmosphere from 4-15 microns.

The usual retrieval procedure is to use a sequence of 27 limb emission spectra from different tangent heights to obtain atmospheric profiles of temperature, pressure, and some of the major emitting species (eg ozone, water vapour, methane) every 500 km along the orbit track.

The signatures of many other species are present in the spectra but retrievals are not attempted on a profile-by-profile basis due to low signal/noise.

The aim of this project is to average a large number (~100s) of limb-scan sequences within particular latitude bands ("zonal means") to reduce S/N and

(a) identify features from minor species, and

(b) attempt to retrieve zonal profiles of these species from the averaged spectra

The project is entirely computer-based so some knowledge of scientific computing and/or linux would be useful.

Supervisor***: Dr A Dudhia*** Physics Tel No ***: 272922***
Email: ***dudhia@atm.ox.ac.uk***

AO14 Investigating the atmospheric circulation of tidally-locked extrasolar planets using a laboratory analogue

In the last twenty years the diversity of known planetary systems has greatly expanded as hundreds of planets are being discovered around other stars. Many of these planets are tidally locked to their stars like the Moon is to the Earth, and so are strongly heated on one side only while the other side never sees the star. This is unlike anything in our Solar System and much remains to be discovered about these worlds.

The main effects acting on a planet's atmosphere are gravity, planetary rotation, the distribution of stellar irradiation, and internal heat sources. The rotating annulus laboratory experiment reduces a planet's atmosphere to a fluid system incorporating only these effects. In its 'classic' configuration of a hot outer cylinder and cool inner cylinder with fluid between them, heated axisymmetrically, this experiment has been used to study the physics behind atmospheres in the Solar System for several decades.

We are interested in the much wider diversity of potential atmospheric conditions that might be found on these strange extrasolar worlds, and how we might be able to understand them using the annulus experiment. In particular, the annulus can represent the tidally-locked situation using a slowly-rotating tank with non-axisymmetric heating.

We have a comprehensive model of the rotating annulus which has been adapted previously to cool one half of the outer cylinder and heat the other half - a simple representation of the tidally-locked case. A more physically realistic configuration is to supply a heat flux into the fluid through the base of the tank, corresponding to heating of the base of the atmopshere by radiation reaching the ground. The irradiation reaching the star-facing side varies strongly with latitude and longitude, and this can be represented by heating different parts of the tank's base by different amounts. The student will adapt our model to represent and study this configuration and possibly other situations that might be relevant to extra-solar planet atmospheres.

This project would suit a student interested in the Solar System, fluids, atmospheres, or extrasolar planets. Attendance at the 4th year Physics of Atmospheres and Oceans option is highly desirable, and the Astrophysics option would be useful. A prior familiarity with Fortran or a similar programming language will be necessary. Prior experience with IDL, Linux shell scripting, or Matlab would also be very useful.

Suggested reading:

Chapter 10.1 of J. Houghton (2004) "The Physics of Atmospheres", CUP, 0-521-01122-1.

R Hide (2010), "A path of discovery in geophysical fluid dynamics", Astronomy & Geophysics, 51, 4.16-4.23. doi:10.1111/j.1468-4004.2010.51416.x

AP Showman et al. (2009) "Atmospheric Circulation of Exoplanets", arXiv:0911.3170v1. http://arxiv.org/abs/0911.3170

BM Boubnov et al. (1991) "Convection in a rotating cylindrical annulus with azimuthally non-uniform heating", Geophys. Astrophys. Fluid Dyn., 57, 1-18. doi:10.1080/03091929108225225

Supervisors : ***Dr R Young*** and ***Prof P Read***
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AO15 Applying an inverse modelling framework to assess cloud condensation nuclei closure

Clouds are recognised as one of the most important modulators of radiative processes in the atmosphere. Globally clouds contribute to a net cooling of the Earth's surface by reflecting incoming shortwave radiation. Cloud reflectance is partially dependent on the concentration of available aerosol particles to act as cloud condensation nuclei (CCN). These CCN are made up of aerosols, microscopic particles suspended in the Earth's atmosphere. The impact of anthropogenic aerosols on climate, and in particular on cloud albedo, is still a major uncertainty in our understanding of climate change.

In order evaluate the impact of pollution on the global climate we need to accurately represent cloud radiative and microphysical properties in climate models. This requires a detailed understanding of the processes surrounding the growth of aerosol particles into cloud droplets.

The assessment of the accuracy of current models is typically performed by comparing modelled and measured CCN properties, termed CCN closure. However, previous CCN closure studies have limitations in that they do not simultaneously assess the uncertainty in model input and output parameters.

In this project we will use a novel state of the art statistical procedure by embracing an inverse modelling closure framework to compare predictions of CCN to measurements from detailed aircraft flights performed in the vicinity of stratocumulus cloud layers.

The student will implement into this framework different parameterisations of varying complexity. Subsequent analysis of the discrepancy between the model and measurements as a function of model input parameters will allow us to provide not only the parameter values that give the best possible fit to the observations, but also their uncertainty. This will provide guidance for climate model developments as to the accuracy of these parameterisations and the directions in which they can be improved.

This project involves data analysis with Matlab under Linux. Ideally, you bring some basic experience in programming but this can be compensated with enthusiasm.

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AO16 Seasonal phase-synchronisation of ENSO within observations and the Met Office global climate model

The largest known mode of climate variability occurs in the tropical Pacific ocean, and is characterised by sea-surface temperature (SST) anomalies migrating across the Pacific, a phenomenon whose phases are known as El Nino/La Nina. The atmosphere responds to these migrating regions of warm and cold SST with anomalously active areas of convection, corresponding to areas of low and high pressure. Together these closely linked processes constitute a phenomenon known as ENSO. The migrating SST anomalies oscillate to and fro with a period of roughly a few years. It is well known that the El Nino phase builds up during the northern hemisphere summer, peaking in northern winter, and so is linked with the annual cycle. Recent work has suggested a more subtle correspondance between the annual cycle and developing ENSO phases, whereby El Nino is purported to phase-synchronise with the annual cycle. In this project we will further examine the possible phase-synchronisation of El Nino/La Nina within observations and long simulations of the Met Office global climate model, HadGEM2.

The student will use a combination of complex time series analysis, including Hilbert transforms, to examine for the presence (or otherwise) of phase-synchronisation within tropical ocean variability. The project will introduce, and require the use of, the IDL programming language and the handling of large climate datasets.

Suggested reading:

Stein K., A. Timmermann and N. Schneider, "Phase Synchronization of

the El Niño-Southern Oscillation with the Annual Cycle",

Phys. Rev. Lett. 107, 128501 (2011)

Supervisors***: Dr S Osprey*** and ***Prof P Read***
Physics Tel No ***: 282434***
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AO17 What’s lurking in the Moon Zoo? Analysing features on the Moon in the visible and thermal-infrared.

Moon Zoo (http://www.moonzoo.org/) is a ‘Zooniverse’ citizen science project that takes images of the Moon taken by the high-resolution camera (called LROC) on NASA’s Lunar Reconnaissance Orbiter (LRO) and then allows people to, amongst other things, count craters and boulders and highlight ‘unusual’ features in the images. This project will take data derived from the Moon Zoo project, such as some of the larger unusual features and look for correlations with data measured in the mid to far infrared by the Diviner radiometer instrument, also on LRO, and that we have co-investigators based here at Oxford.

The data from Diviner can give clues as to the mineral composition and abundance of rocks in the image at lower spatial resolution, so by looking at the connections between the visible image and infrared data we can attempt to classify different types of features and investigate their context compared with other regions of the lunar surface.

This project will be computer based and some knowledge of scientific programming techniques will be useful.

Given the public involvement in gathering the data set, this project will also provide a good opportunity for someone interested in science communication and outreach, although this isn’t a necessary requirement.

Suggested Reading:
De Pater and Lissauer “Planetary Sciences” chapter 5 Cambridge University Press 2001
Hanel, R. A. et al. “Exploration of the Solar System by Remote Sensin”, 2nd edition Cambridge University Press 2003.

Supervisors: ***Dr N Bowles, Dr I Thomas***
Physics Tel No: ***272097***
Email: ***bowles@atm.ox.ac.uk***

AO18 The Impact of Climate Change on Stratospheric Dynamics

The stratosphere is a distinct region of the atmosphere between 10-50km, characterised by the presence of the ozone layer. Two dominant features of stratospheric variability are the polar vortex: a region of westerly winds encompassing the polar stratosphere, and the quasi-biennial oscillation (QBO): an alternating easterly-westerly wind regime in the equatorial stratosphere. When the QBO is in its easterly phase, the polar vortex is more variable, and vice versa. This relationship is known as the Holton-Tan mechanism, and can lead to changes in surface weather and climate.

In this project, the student will consider how stratospheric variability, and in particular the Holton-Tan mechanism, changes due to climate change. The project will employ 2 different climate runs from 1960-2100, where the historical period will be governed by observed climate forcings, and the future period will be governed by the latest prescriptions of climate forcings. The first climate run will include only natural forcings, i.e. from solar and volcanic activity; the second run will include only greenhouse gas forcings, i.e. from changes in emissions of carbon dioxide and methane. By comparing the two climate simulations, the student will isolate changes due to human activity, and those due to natural variability. These will be compared with historical observations to understand better how we might expect climate change to affect stratospheric dynamics, and subsequent surface climate.

The project will require analysis of time series, as well as longitude/latitude fields. Some basic programming skills will be required. This project would suit those students interested in climate dynamics.

Suggested Reading:

1. Mitchell et al., “The Structure and Evolution of Stratospheric Polar Vortices Using 2D-Moment Analysis”. 2011. J.Atmos.Sci.

2. Andrews, D., Holton, J., and Leovy, C., “Middle Atmosphere Dynamics”. 1987.

Supervisors***: Dr D Mitchell, Prof L Gray***
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AO19 Stochastic closure of ocean mesoscale eddies

The ocean contains a vigorous mesoscale eddy field at spatial scales from 100 km and smaller, evolving over time scales from weeks to months. These eddies are important in establishing the ocean’s circulation and tracer properties. Grid spacing of roughly 10 km and smaller are necessary to properly simulate the eddy field and their effect in current climate models needs to be parametrized. The goal of this project is to construct a stochastic parameterization of mesoscale eddies in ocean models in order to replace or improve current deterministic closure schemes.

In this project, the student will be involved in deriving equations for the evolution of the probability distribution function (PDF) associated the mesoscale eddy field which later will be used as the basis for a stochastic parametrization. The derived theory for the PDF evolution will be based on the output of a high resolution numerical model or available observations.

This project will require a strong interest in fluid dynamics and mathematical analysis. The project will also involve the use of Matlab (or an equivalent software).

Suggested Reading:

Gent, P.R., Willebrand, J., McDougall, T.J., McWilliams, J.C., 1995. Parameterizing eddy induced transports in ocean circulation models. J. Phys. Oceanogr. 25, 463–474.

Shutts, G. J., T. N. Palmer, 2007: Convective Forcing Fluctuations in a Cloud-Resolving Model: Relevance to the Stochastic Parameterization Problem. J. Climate, 20, 187–202.

Supervisor: ***Dr L Zanna*** Physics Tel No ***: 272925***
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AO20 How fast does a snowflake fall?

In addition to providing aesthetic shapes of natural beauty, snowflakes and ice crystals play an important role in cloud processes and precipitation in cold environments. The fall velocity of ice crystals is an important parameter in certain models of cloud ice and snowfall, and is typically supplied from empirical fits to the mean trend in observations and experiments. Ice crystals fall at a terminal velocity when the aerodynamic drag force acting on the crystal balances the weight of the crystal. To build theoretical insight into falling ice crystals, this project will carry out numerical simulations of fluid flow past some example shapes of ice crystals, to determine how drag varies with flow speed. Rather than directly solving the Navier-Stokes equations for viscous fluid flow, the increasingly popular Lattice-Boltzmann method provides an elegant and computationally simple method for simulating fluid flows in complicated geometries. The student will write and apply a Lattice-Boltzmann computer code to simulate two-dimensional flow past a simple ice-crystal shape, and analyse the physics of the results. The simulations can be extended to describe a range of more complicated snowflake geometries, providing further avenues for an interested student to explore.

This project would suit a student interested in fluid dynamics and learning about numerical simulation methods. The project is underpinned by the development of numerical code, so knowledge of a programming language such as Matlab, Fortran, or C would be an advantage.

The project will require writing of computing programs in a language of the student's choosing. Whilst there is a clear advantage for students with prior programming experience, there may also be potential for an enthusiastic student to learn the necessary programming skills with a little extra work and background reading during the project.

Supervisors***: Dr A Wells*** Physics Tel No ***: 282425***
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AO21 Modelling the exchange of carbon dioxide and other chemicals between young sea ice and the ocean

At any one time, more than 10 million square kilometres of the world's oceans are covered with sea ice, which plays an important role in the climate system. Rather than forming an impermeable layer covering the polar oceans, sea ice is a reactive porous material, comprised of ice crystals bathed in liquid brine. Fluid flow can transport dissolved gases and biologically-relevant chemicals between the interior of the porous ice and the ocean. Such physical exchanges have important consequences for sea-ice ecosystems, and modelling of biogeochemistry and the carbon cycle. In particular, it is important to understand the rate at which dissolved gases and other chemicals are rejected into the ocean as ice grows during winter freeze up, and what fraction of these substances remain trapped and stored in the ice cover.

This project will study tracer transport during steady-state ice growth, providing insight into ice--ocean exchange processes during brine drainage from young sea ice. Previous numerical simulations have quantified the relevant buoyancy-driven flow during solidification. The student will apply this velocity field to numerically solve an advection--diffusion equation for tracer transport by adapting a supplied Fortran code. The model will be used to search for scaling behaviour, with the aim of providing a physical interpretation of the results. Further lines of enquiry include extending the model to account for chemical reactions.

The project is underpinned by numerical modelling and requires adaptation of a pre-supplied Fortran code for solving partial differential equations. Whilst experience of Fortran itself is not a pre-requisite, prior experience of at least one programming language such as Matlab, Fortran, or C would be advantageous. The project would suit a student interested in geophysical applications of fluid dynamics, who is also interested in learning about numerical simulation methods to solve partial differential equations.

The project will require use and modification of Fortran computing code, but it should be straightforward for a student to learn the necessary commands if they have some background experience in another programming language. Whilst there is a clear advantage for students with prior programming experience, there may also be potential for an enthusiastic student to learn the necessary programming skills with a little extra work and background reading during the project.

Supervisors***: Dr A Wells*** Physics Tel No ***: 282425***
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AO22 Mapping the clouds of Venus

Venus Express is a European spacecraft which has been orbiting Venus since April 2006. It carries a suite of instruments to study the surface, atmosphere, and ionosphere of Venus. One of these instruments is VIRTIS (the Visible and InfraRed Thermal Imaging Spectrometer), which returns images of the Venus atmosphere and surface at 860+ wavelengths ranging from 0.25 - 5 microns. Numerous minor gaseous species including water vapour and sulphur dioxide are active in the VIRTIS range and so can be measured from this dataset.

The visible and ultraviolet wavelengths from VIRTIS have not yet been analysed. These wavelengths reveal cloud-top properties as well as abundances of gases which may be produced by active vulcanism. The student's role will be to analyse the VIRTIS dataset in search of temporal and spatial variations, looking for unusual cloud-top properties or gas abundances which might indicate volcanic activity.

This work is done using programming in IDL and Linux shell - previous experience would be an advantage but is not required.

Supervisors***: Dr C Wilson*** Physics Tel No ***: 272086***
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AO23 Comparison of multiple tropopause events in different configurations of a chemistry-climate model

A feature which has become more common is the existence of multiple tropopause (MT) structures (Añel et al., 2008). Castanheira et al. (2010) found a positive trend in the last decades in the number of MT events. One of the problems to study this trend is that MTs can have several different origins, such as tropopause foldings caused by meteorological conditions or overlappings of tropical tropopause over the extratropical tropopause.

In this work the student will compare the representation of multiple tropopause cases in outputs from different climate simulations performed with the Whole Atmosphere Community Climate Model WACCM – version 3.5.48 used for the CCMVal2 report of the World Meteorological Organization). Such simulations have different configurations (extended chemistry, aquaplanet and high vertical resolution in the UTLS).

References and useful reading

Santer et al. (2003) Contributions of Anthropogenic and Natural Forcing to Recent Tropopause Height Changes, 301, 479-483, DOI: 10.1126/science.1084123.

Añel et al. (2008) Climatological features of global multiple tropopause events, J. Geophys. Res., 113, D00B08, doi: 10.1029/2007JD009697.

Castanheira et al. (2010) Increase of upper troposphere/lower stratosphere wave baroclinicity during the second half of the 20th century, Atmos. Chem. Phys., 9, 9143-9153, doi:10.5194/acp-9-9143-2009 WACCM webpage: http://www.cesm.ucar.edu/working_groups/WACCM/ CCMVal webpage: http://www.pa.op.dlr.de/CCMVal/

Supervisors***: Dr J A Añel, Prof L Gray***
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AO24 Altimetric Imaging Velocimetry

In a rapidly rotating fluid, the pressure field is closely connected to the horizontal velocity via the geostrophic balance relation. In a shallow layer of fluid with a free surface, dynamical variations in pressure are reflected in variations in the height of the surface. Such variations in the surface elevation of the Earth's oceans may be on the order of cm - metres, and are now routinely measured by radar altimetry from orbiting satellites. On a laboratory scale, however, these perturbations to the free surface may be extremely small (<< 1mm) and difficult to measure.

In this project, we will set up an optical system to measure and map such small perturbations to the interface in a flow pattern obtained under laboratory conditions. Rhines, Lindahl & Mendez (2007) have recently demonstrated a novel method of measuring the free surface elevation of a rotating fluid, by using it as a parabolic, Newtonian telescope mirror to form an image of a carefully designed light source in a CCTV camera. Small perturbations from dynamical motions in the fluid result in distortions of an image reflected from the free surface that can be used to determine the local elevation to a precision of 1 micron or better. This project will use the method of Rhines et al. (2007) to study and measure simple, barotropically unstable flow patterns set up in a cylindrical tank on a rotating table. Colour images from this experiment will be calibrated and analysed using a set of MatLab software provided by researchers at the Universities of Washington and Newfoundland.

The student will therefore need good experimental skills and some computing ability to make use of existing analysis software for image processing and diagnostics.

Suggested Reading:

Andrews, D.G., "An introduction to atmospheric physics", Cambridge University Press, 2000

Rhines, P. B., Lindahl, E. G. & Mendez, A. J. 2007 "Optical altimetry: a new method for observing rotating fluids with applications to Rossby- and inertial waves on a polar beta-plane", J. Fluid Mech., 572, 389-412, 2007

Afanasyev, I., P.B.Rhines and E.G.Lindahl, 2009: Velocity and potential vorticity fields measured by altimetric imaging velocimetry in the rotating fluid., Experiments in Fluids, May 2009, doi: 10.1007/s00348-009-0689-3.

Supervisor : ***Prof P Read*** Physics Tel No : ***272082***
Email : ***p.read@physics.ox.ac.uk***

AO25 Validating satellite measurements of aerosol

The impact of aerosols, both directly and through their interaction with clouds, is the most uncertain element in our understanding of the radiative balance of the atmosphere. Improving our measurements of global aerosol loading and its is thus a key element in improving our understanding of the climate system.

The measurement of aerosols from space is being actively pursued in the US and in Europe. One of Oxford's contributions to this research has been the development of ORAC, an algorithm to determine aerosol optical depth and effective radius from the radiometric measurements in the visible and near infrared. A by-product of this retrieval are parameters that describe the contribution of surface reflection to the top-of-atmosphere signal. A major difficulty in the retrieval is the confusion between high aerosol loading and thin cloud.

This project involves comparing aerosol data derived from satellite instruments (AATSR, MODIS) with ground based optical depth measurements made by sunphotometers that are part of the AERONET measurement network. The aim of this project is to use statistical techniques to identify how well each dataset discriminates aerosol and cloud. At second validation task is to examine time series of surface properties retrieved by ORAC for consistency and credibility.

The project will involve extensive computer based analyse and will make use of the IDL coding language in a Linux environment. Although familiarity with Linux and IDL are not a requirement for the project, general computing skills and some experience of programming would be advantageous.

Supervisors : ***Dr G E Thomas*** and ***Dr R D Grainger***
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***AO26* Modelling tropical/midlatitude atmosphere/ ocean heat transport in the laboratory**

In the oceans and atmospheres of the Earth and Mars, fluid motions transport heat from the strongly convective tropical regions close to the equator, where solar heating of the surface is most intense, towards the cooler polar regions. While the basic mechanisms that achieve this transport are reasonably well understood, the way heat is passed from the highly turbulent region of intense convection in the tropics into the stably-stratified sub-tropics and mid-latitudes is still rather unclear. The tendency of tropical convection to push the atmosphere towards a statically unstable or neutral state is somehow counteracted by baroclinic weather systems at mid-latitudes to produce a mean atmospheric state that is statically stable. This suggests that the mid-latitude atmosphere acts a bit like a 'thermostat', adjusting the thermal structure of the atmosphere towards a particular configuration, although the details are not well understood (see the refs by Zurita-Gotor & Lindzen and Stone below).

In this project we will investigate a laboratory model of this situation, using a cylindrical convection tank on a rotating table. Unstably stratified convection is produced by heating the bottom of the tank near the outer rim of the cylinder (representing the tropics), and by cooling near the top of the tank (representing radiative cooling near the top of the atmosphere outside the tropics). At intermediate radii the flow is free to evolve and develop a relatively unconstrained thermal structure. This mainly experimental project will entail setting up the experimental tank and rotating table, and making measurements of horizontal flow velocities (using existing image tracking software from CCTV images of tracer particles in the flow) and temperature (using thermocouple probes and possibly using thermographic imagery with an infrared camera). The student will need good experimental skills and some computing ability to make use of existing analysis software for image processing and diagnostics.

Suggested reading:

Andrews, D.G., "An introduction to atmospheric physics", Cambridge University Press, 2000

Zurita-Gotor, P. & Lindzen, R. S. "Theories of Baroclinic Adjustment and Eddy Equilibration" in The Global Circulation of the Atmosphere, T. Schneider and A.H. Sobel, Eds., Princeton University Press, pp1–21, 2007

Stone, P. H., "The atmospheric general circulation: Some unresolved issues", Dyn. Atmos. Oceans, 44, 244–250 (2008)

Supervisor : ***Prof P Read*** Physics Tel No : ***272082***
Email : ***p.read@physics.ox.ac.uk***

***AO27* Effects of bottom pressure torques on oceanic western boundary currents**

Western boundary currents are major ocean currents of climatic importance. For example, the heat transport of the Gulf Stream is crucial in maintaining the climate of northern Europe. However, aspects of their dynamics, such as their separation from the coastline and interaction with bottom topography, are still poorly understood. This project will involve using a numerical model of the wind-driven barotropic circulation to investigate the influence of bottom topography on the path and physics of western boundary currents. This flexible framework will allow for simple modification of forcing and topography, allowing the interested student to develop the project as they see fit.

This project would suit a student with an interest in the fundamental fluid dynamics of the ocean and numerical models of ocean circulation. A numerical model (written in Fortran) and basic Matlab scripts will be provided, although the details of the project will require the student to modify both. Previous experience with Fortran and/or Matlab would be an advantage, but is not necessary for the success of the project.

Suggested reading:

Vallis, G.K., 2006: Atmospheric and Oceanic Fluid Dynamics, Fundamentals and Large-Scale Circulation. Chapter 14: Wind-Driven Gyres.

Dengg, J., 1993: The problem of Gulf Stream separation: A barotropic approach. J. Phys. Oceanogr., 23, 2182–2200.

Supervisors***: Dr D Munday*** and ***Prof D Marshall***
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***AO28* Stochastic processors in numerical weather and climate models**

The quality and resolution of numerical weather and climate models is limited by the performance of state-of-the-art supercomputers. One of the major expenses of a supercomputer is its power consumption. It may be possible to increase the performance and reduce the power consumption of a supercomputer significantly by using so-called stochastic processors, but stochastic processors are not exact. In some operations of a stochastic processor bits will be calculated incorrectly, or flipped. Before these processors can be used in real simulations, the influence of the errors on the quality of the model integrations needs to be tested. It could also be possible that the errors have a positive effect on the simulations, since they could mimic the behavior of scales that can not be resolved in the model.

The project will emulate the influence of stochastic processors on the Lorenz (1963) model. The Lorenz (1963) model is a simplified nonlinear model for atmospheric convection, which can show chaotic behavior. The results will give us an idea on how the errors that are caused by stochastic processors could influence the simulations of numerical weather and climate models, and give an estimate of the limits and prospects for the use of inexact computers.

Since most of the work involves numerics, some basic knowledge of programming and Linux would be useful, but most of the set of tools can be learned during the project.

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AO29 The climate using stochastic models

One of the grand challenges in science today is to accurately predict changes to the Earth's climate and associated uncertainties. This is related to another more fundamental challenge, that of turbulent closure, which is one of the great unsolved problems in classical physics.

The atmosphere and oceans of the Earth are modelled as a rotating fluid under the influence of many physical processes. These models are only approximation of the full climate system and are numerically solved using powerful super computers. The problem is, that even with the huge computing resources at our disposal, we cannot simulate the influence of the smallest temporal and spatial scales. Typically a large diffusive term is added to the equations instead, and we have to come up with some kind of correction to mimic the effects of the unresolved scales.

A recent approach is to use stochastic modelling where the influence of these unresolved scales is approximated by a random process. Stochastic models, fitted to atmospheric and oceanic data sets, are able to provide short term (seasonal to interannual) predictions with some accuracy.

The goal of the project is to assess the validity of linear stochastic models as applied to the atmosphere of the Earth, e.g., examining their representation of the climate, the error growth (or Lyapunov exponents) associated with the anomalies. You will be required to push these models to their limits using arguably the most accurate historical record of the atmosphere widely available today, and you will frame your conclusions in an intuitive but quantitative way, to inform those who do not specialise in stochastic modelling. Stochastic models are widely used in the world of finance, for example in the Black–Scholes model, and this project will provide an excellent practical introduction to their use (and misuse).

Requirements: The project will require a student with a strong interest in fluid mechanics, dynamical systems and mathematical methods. The project will involve the analysis of data sets using Matlab (or similar software).

Recommended reading:

(1) Penland, C., and P. D. Sardeshmukh, 1995: The optimal growth of tropical sea surface temperature anomalies, J. Climate, 8, 1999-2024.

(2) TN Palmer, R Buizza, FJ Doblas-Reyes, T Jung, M Leutbecher, GJ Shutts, M Steinheimer, A Weisheimer. 2009. Stochastic parametrization and model uncertainty. ECMWF Tech Memo. (2009) 598

Supervisors: ***Dr F Cooper*** and ***Dr L Zanna***
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AO30 Blocking in present and future climates

Blocking of the tropospheric jet stream is a well-known meteorological phenomenon associated with extremes of temperature and precipitation, such as summer heat waves and winter cold snaps. Much current research is devoted to improving our understanding of blocking and its representation in climate models, as well as to predicting future changes in blocking under increased greenhouse gas forcing. In this project the student will use blocking statistics that have been computed for state-of-the-art climate models (at present count, 23 models from the CMIP5 archive) to assess the representation of present-day blocking in these models, as well as examine future trends. This work will build on the findings of Anstey et al. 2012, who used this dataset to assess Northern Hemisphere winter (Dec-Jan-Feb) blocking activity. There are a number of potential questions that could be addressed, and the precise direction of the project may be tailored to suit the student's particular interests. Suggested directions include an assessment of Northern Hemisphere summertime blocking (e.g. the type of event that led to the infamous 2010 Russian heat wave), blocking in the Southern Hemisphere, and links between blocking activity and stratospheric variability (including Sudden Stratospheric Warmings). On the practical side, the project will require programming for data analysis (in a language such as python, IDL or matlab), and the student will gain experience in handling large datasets.

Supervisors: ***Dr J Anstey, Prof L Gray***
Physics Tel No***: 282434***
Email: ***anstey@atm.ox.ac.uk; gray@atm.ox.ac.uk***

Astrophysics projects

AS01 The polarised Galaxy and inflationd

One of the big goals in cosmology is to detect gravitational waves, ripples in space-time that were imprinted during inflation. They leave a distinctive signature in the polarization of the Cosmic Microwave Background. However, this signal is tiny, and obscured by polarized emission from our Galaxy. Current and upcoming experiments plan to look at patches of sky where the Galaxy is 'dark'. In this project you will take estimates of what the Galactic foregrounds are, and investigate optimal sky areas and observing frequencies for finding the inflationary signal. This will involve use of python and some f90 code, so experience with python would be an advantage.

Supervisor : ***Dr J Dunkley*** Physics Tel No : ***273298***
Email : ***j.dunkley@physics.ox.ac.uk***

AS02 Dark matter and the stellar initial mass function in galaxies

The stellar initial mass function (IMF) describes the distribution of stellar masses when the population formed. Virtually every prediction of galaxy properties requires knowledge of the IMF. For this reason the IMF is central to our understanding of galaxy evolution.

For half a century the IMF has been assumed to be universal in all types of galaxies. But recent studies have demonstrated that the IMF actually varies systematically with galaxy properties generating a large interest in IMF studies.

In the proposed project the student will use galaxy dynamical models to reproduce Hubble Space Telescope photometry, stellar kinematics and mass determinations obtained via strong gravitational lensing, for a sample of galaxies. The models will be able to constrain both the hotly-debated IMF variation and the amount of dark matter in galaxies, providing key constrain to galaxy formation models.

Special requirements: The student should have or should be willing to learn some basic skills of the IDL programming language.

Supervisor : ***Dr M Cappellari*** Physics Tel No : ***273647***
Email : ***cappellari@astro.ox.ac.uk***

AS03 Observations of W Ursa Majoris Variables in NGC 188 with the Philip Wetton Telescope

W Ursa Majoris variables are binaries where the two stars are almost in contact. Light curves and periods are known to show changes over time.

The Philip Wetton Telescope will be used to obtain light curves of W Ursa Majoris variables in the old open cluster NGC 188; these will be compared with earlier data obtained in Oxford and published in the literature.

Recommended Reading:

Li L, Han Z & Zhang F, 2004 MNRAS 351, 137 Zhang XB, Deng L, Zhou X & Xin Y, 2004 MNRAS 355, 1369

Supervisor : ***Dr A E Lynas-Gray*** Physics Tel No : ***273363***
Email : ***aelg@astro.ox.ac.uk***

AS04 A Study of Hot Stars Discovered by the Sloan Digital Sky Survey

The Sloan Digital Sky Survey (SDSS) is a comprehensive imaging and spectroscopic survey of a large part of the optical sky. The main interest and motivation behind the SDSS is the identification of high redshift objects needed for observational cosmology. A large number of zero redshift objects are also found and where these are blue, they are likely to be evolved stars in our own galaxy, and in some cases the previous evolution will not be well understood. The Sixth Data Release of the Sloan Digital Sky Survey (Adelman-McCarthy et al. 2008) provides more precise photometry and spectra with a better wavelength calibration than earlier releases.

A study of blue stars in the SDSS could potentially result in some interesting discoveries though in order to secure a well-defined project, it is suggested the student selects five subdwarf-B (sdB) stars observed with the SDSS and studies helium abundances as functions of effective temperature and gravity. Helium is depleted in sdB stars when compared with the Sun due to diffusion but this depletion can vary by one or two orders of magnitude. The intention is to see if any pattern emerges which can be used to constrain theoretical models.

Adelman-McCarthy et al., 2008 ApJS 175, 297

Supervisor : ***Dr A E Lynas-Gray*** Physics Tel No : ***273363***
Email : ***aelg@astro.ox.ac.uk***

AS05 A imperfect classifier approach to exoplanet discovery

PlanetHunters.org is a citizen science project which has had more than 100,000 people examine data from the Kepler space telescope in order to find exoplanet discoveries. The project has been somewhat successful, but the aim of this project is to be more systematic in sorting through the results, applying bayesian techniques for combining multiple imperfect classifiers. This is a heavily statistical/computational project and would suit someone comfortable with programming. There may be some chance of observational follow-up of interesting targets identified during the course of the project.

Skills : Programming experience, preferably in MATLAB or Octave.

Supervisor : ***Dr C Lintott*** Physics Tel No : ***273638***
Email : ***cjl@astro.ox.ac.uk***

AS06 Halo Model simulations

The halo model is an analytical approach to modeling large scale structure in cosmology. The student will develop a mathematica library for generating large scale structure samples from the halo model. Some familiarity with computer programming is required. Some background in mathematica, statistics, and/or cosmology would be particularly useful but not essential.

Supervisor ***: Dr C Gordon*** Physics Tel No ***: 273641***
Email ***: cxg@astro.ox.ac.uk***

AS07 **Measuring the Expansion of the Universe with Supernovae**

Brown dwarfs bridge the gap between stars and planets; tOne of the most striking developments in astronomy in the last 10 years is the discovery that the Universe is not only expanding, but accelerating. This discovery made use of Type Ia supernovae, cosmic explosions that act as standard candles and allow accurate distances to be measured in the universe. The Palomar Transient Factory (PTF) is a new search for Type Ia supernovae in which Oxford is involved, and will generate the next generation sample of Type Ia supernova in the local universe for cosmology.

This MPhys project will involve obtaining photometric (brightness) measurements of a set of type Ia supernovae with the Philip Wetton telescope here in Oxford. The telescope is equipped with a CCD camera and set of standard filters, allowing you to measure the lightcurve of the supernovae as they evolve. For an example of the data you will obtain, see: http://astroweb1.physics.ox.ac.uk/~fclarke/MPhys/supernovae.html. The observations you take will give you the apparent magnitude of the supernovae. Combining this with knowledge of the absolute magnitude of the supernovae, and the redshift of the host galaxy from literature and PTF data, you will be able to plot distance vs redshift, and calculate the local expansion rate of the Universe.

Requirements

You will use the Philip Wetton telescope here in Oxford to obtain your data. This will obviously require night time working, under the supervision of astrophysics graduate students. Expect to spend ~7 nights observing over a two month period. If bad weather prevents you gathering enough data, you will use data obtained with other telescopes to achieve the goals of the project. You will learn to use astronomical data reduction software to reduce and analyse your data, and measure brightnesses for the supernovae.

Supervisor: ***Dr F Clarke*** Physics Tel No : ***283140***
Email : ***fraser.clarke@physics.ox.ac.uk;***

AS08 **Measuring the Physical Structure of Extra-Solar Planets**

As of June 2010, 464 planets have been discovered around other stars. 87 of these planets transit in front of their parent star, blocking out some of its light for a few hours. These subset of planets are of particular interest to astronomers, as they give us the opportunity to probe the physical nature of the planets, such as their size, composition and even atmospheric make-up.

Perhaps surprisingly, this is one area of modern astrophysics which does not require a very large telescope. In fact, we can make scientifically useful observations of these objects with the 0.4m Philip Wetton telescope here in Oxford. By measuring the brightness of the parent star before, during, and after the transit of an extrasolar planet, we get a direct measurement of the size of the planet. We can then combine this size with a mass estimate from radial velocity observations (taken elsewhere) to work out the density of the planet.

Different kinds of planets have different densities; for example the Earth has a density of 5000kg/m3, whereas Saturn has a density of only 700kg/m3 (i.e. Saturn would float in water!). The density therefore gives us a strong indication of the physical nature of the planet. This has been done for extrasolar planets using exactly the method you will employ, and shows that most are, as expected, gas giant planets like Jupiter and Saturn.

In this project you will measure the density of 3--4 extrasolar planets, and interpret their physical properties in terms of planetary structure and formation models. These will be known and previously studied systems, but if the opportunity arises during the period of the project, you may be able to participate in global efforts to characterise newly discovered transiting planets. Based on your work, we plan to develop a simplified version of this project to be run in the 3rd year astrophysics labs.

Requirements

You will use the Philip Wetton telescope here in Oxford to obtain your data. This will obviously require night time working, under the supervision of astrophysics graduate students. Expect to spend 3--4

nights observing over a one month period. If bad weather prevents you gathering enough data, you will use data obtained with other telescopes to achieve the goals of the project. You will learn to use astronomical data reduction software to reduce and analyse your data, and measure light curves of the transiting planets. You will then combine your measurements with archival radial velocity measurements to get the planet's mass and size, therefore placing it on a mass vs density diagram to probe the planet's composition.

Supervisors : ***Dr F Clarke*** and ***Dr S Aigrain***
Physics Tel No : ***283140, 273339***
Email : ***fraser.clarke@physics.ox.ac.uk***
suzanne.aigrain@astro.ox.ac.uk

AS09 **Magnetohydrodynamics in a GR background**

Relativistic plasma jets from active galaxies are some of the most spectacular, powerful astrophysical objects, yet it is not clear what the precise mechanism for their production is. Relativistic jets seem to be related to accreting black holes, and is generally thought that the rotational energy of black holes spun-up from accretion can provide the huge amount of power required to produce the jets of up to 10^40 W seen in the most luminous quasars.

As in many cases of unknown mechanisms in astrophysics, magnetic fields are invoked, and a fairly simple long-standing calculation tells us that the required energy is at least available in a spinning black hole (this is the famous Blandford-Znajek mechanism). The present state-of-the-art involves massively computationally intense numerical simulations; however, there is still an essential role for analytical theoretical work to investigate the behaviour of magnetic field around a black hole in simple cases, so that the detailed numerical simulations may have a reference point. This project involves investigating what happens to matter and magnetic fields when they are dragged towards a spinning black hole and whether the wound up magnetic field can result in the production of a relativistic plasma jet.

This project will be a mix of theory and computing so requires a sound knowledge of B(v) General Relativity and B(ii) electrodynamics and confidence in coding (in a language of the student's choice). The project will involve new research and results. Please email me to arrange a time to discuss the project.

Supervisor: ***Dr G Cotter*** Physics Tel No: ***273604***
Email: ***garret@astro.ox.ac.uk***

AS10 **Measuring the position and momentum of the highest-energy photons**

Extreme astrophysical objects such as pulsars and quasars produce the highest energy photons that have ever been detected, with energies up to 10^15 eV. We observe these by using the Earth's atmosphere as a particle detector - when an incident very-high-energy gamma ray hits the nucleus of an atom in the atmosphere, a shower of particles continuing downwards at relativistic speeds is produced. Charged particles in the shower, moving faster than the speed of light in air, produce a flash of Cherenkov radiation. This can be detected by ground-based telescopes.

The next-generation Cherenkov telescope, the Cherenkov Telescope Array (CTA), is now entering the prototyping phase, and at Oxford we are involved in the development of the new techniques which will be used to measure the properties of the incident photons. CTA will use multiple telescopes observing the same patch of sky to detect the Cherenkov flashes from astronomical targets - as an individual shower occurs, the different telescopes will see it track across their cameras at different speeds and directions. This "stereoscopic" approach gives unprecedented resolution in position and energy - but it will depend on intensive Monte-Carlo simulation of the showers and optimisation of the algorithms for triggering the camera readouts and tracking the path of each flash across each camera. The aim of this project is to begin investigating such models. It demands good computing skills and, especially, a sound knack for statistical analysis and hypothesis testing. Please email me to arrange a time to discuss the project.

Supervisor: ***Dr G Cotter*** Physics Tel No: ***273604***
Email: ***garret@astro.ox.ac.uk***

AS11 **Serendipitous Discovery in the Milky Way Project**

The Zooniverse's Milky Way Project (http://www.milkywayproject.org) asks members of the public to draw features on infrared data of our galaxy, taken with the Spitzer Space Telescope. The MWP has recruited more than 40,000 people and collected more than 2 million drawings of objects. This projects seeks to use the MWP's large database of crowdsourced data, alongside our community discussion forum, to search for interesting and unexpected objects in our galaxy. This projects involves comparing the positions of such objects with online catalogues and the literature. The aim is to follow-up on, and catalogue, any interesting objects that are found.

The student would ideally be studying astrophysics and would need an understanding of MySQL. They would need the use of a computer for the duration of the project. I don't think there are any other special resource requirements.

Supervisor : ***Dr R Simpson*** Physics Tel No : ***273638***
Email : ***Robert.Simpson@astro.ox.ac.uk***

AS12 **Be X-ray Binaries and Supernova Kicks**

Be X-ray binaries are binary systems in which a neutron star accretes matter from the wind of a companion star, making it a bright X-ray object. It has been established for almost 20 years now that neutron stars, when they are born in a supernova, receive a large velocity `kick' (of several 100 km/s) caused by some poorly understood asymmetries in the explosion mechanism. If a neutron star is born in a binary and the binary remains bound, this produces an imprint in the distribution of orbital parameters of the binary (in particular, the eccentricity distribution). In the last few years, there has been mounting evidence that a subset of neutron stars, however, do not receive a large kick, producing a bimodal distribution of neutron-star properties. A very recent study of the orbital parameters of Be X-ray binaries (Knigge, Coe and Podsiadlowski 2011; Nature 479, 372) seems to confirm that there are two populations of neutron stars with different formation histories. The purpose of this project is to use these observations to constrain the natal properties of neutron stars and their implications for the different supernova mechanisms and specifically the formation of double neutron-star binaries which are believed to be one of most important class of systems for the direct discovery of gravitational waves. This will be done with Monte-Carlo simulations of the Be X-ray binary population, starting from a massive binary and statistically simulating the various phases that lead to a Be X-ray binary. Since this is a continuation of a project started in 2012, many of the basic codes (written in C) will already be available.

Prerequisites: Basic Numerical Computing

Supervisor : ***Prof P Podsiadlowski***
Physics Tel No : ***273343***
Email : ***podsi@astro.ox.ac.uk***

AS13 **Constraining the Progenitors of Gamma-Ray Bursts from their Host Galaxies**

Long-duration gamma-ray bursts (GRBs) are caused by some of the most energetic explosions in the Universe. They are rare events that can be detected throughout the whole Universe. However, it is still not understood what special evolution produces the progenitors of GRBs. Observations of relatively nearby GRBs show that they preferentially occur in smaller host galaxies. Since smaller galaxies have lower metallicity, this has been interpreted as implying that GRB progenitors require low metallicity (as this, e.g., affects the wind mass loss from the progenitor). On the other hand, recent observations also show that they prefer galaxies which have a higher star-formation rate per unit mass. This rather puzzling observation may suggest a rather radical alternative interpretation of the GRB -- host-galaxy correlations, which is only indirectly related to metallicity: low-metallicity galaxies may just from a proportionately larger fraction of massive stars, e.g. because the initial mass function (IMF) for massive stars is metallicity dependent (a suggestion that has been made before in other contexts). The purpose of this project is to explore whether a metallicity-dependent IMF can reconcile the various observed correlations between GRBs and their host galaxies, and to quantify the constraints on GRB progenitors (such as metallicity and initial mass).

Prerequisites: Basic Numerical Computing

Supervisor : ***Prof P Podsiadlowski***
Physics Tel No : ***273343***
Email : ***podsi@astro.ox.ac.uk***

AS14 Post-starburst galaxies in the distant universe

Galaxies whose star formation ceased about a hundred million years ago show a pronounced spectral break due to strong hydrogen absorption in A-stars (stars 3-5 times as massive as our sun, which dominate the light of stellar populations of this this age). We can select such “post-starburst” galaxies at high redshift (great distances, when the Universe was young) by imaging in different colour filters, at wavelengths below and above this break. An important question in astrophysics is what caused the star formation to cease.

By studying high-resolution images from Hubble, we can classify the shape of these galaxies to explore this problem.

The project will involve image analysis using astrophysics computers.

Experience with computer programming an advantage. This project is for students doing the C1 Astrophysics major option.

Supervisors : ***Dr A Bunker*** and ***Dr S Wilkins***
Physics Tel No : ***283126***
Email : ***a.bunker@physics.ox.ac.uk***

AS15 Seeing the glow of the distant Universe

The universe at redshifts out to 5 (corresponding to 90 per cent of history) is predominantly comprised of plasma, with compact regions of neutral gas associated with overdensities (including galaxies). The plasma is kept ionized by energetic photons, produced by quasars and the formation of hot, massive stars. The strength of this ionizing background of photons is uncertain, and a measurement is important to models of galaxy formation.

With very sensitive spectroscopy on large telescopes, it might be possible to see the outer shells of the neutral hydrogen regions glow in the light of the atomic transition lines, as they are ionized by the background photons then recombine. By measuring the brightness and size of these emission line regions we can hope to perhaps detect this effect. We have extremely long spectroscopic exposures taken with the 8-m Gemini telescopes which are suitable for this work.

The project will involve image analysis using astrophysics computers. Experience with computer programming an advantage.

This project is for students doing the C1 Astrophysics major option.

Supervisor : ***Dr A Bunker*** Physics Tel No : ***283126***
Email : ***a.bunker@physics.ox.ac.uk***

AS16 The peculiar velocities of local clusters

The standard ΛCDM cosmological model makes predictions for the peculiar velocities of galaxy clusters; these predictions can be tested if you know the distance and redshift of many clusters. Local galaxy clusters harbour a large number of old early type galaxies (ETGs), which form a remarkably tight Fundamental Plane (FP, relating the effective radius, average surface brightness and average velocity dispersion of ETGs; Dressler et al. 1987, Djorgovski & Davis 1987). The FP can be used as distance indicator for individual clusters and relies on spectroscopic observations, providing redshifts for free. This project aims to use published data on the FPs of local clusters to test ΛCDM predictions regarding the dispersion of cluster peculiar velocities.

Special skills:
The project is mathematical/statistical in nature although problems are mostly solved numerically; basic proficiency with computers is essential. Although prior experience in programming is not a pre-requisite, knowledge of the python language would be advantageous.

Supervisors : ***Dr R Houghton, Dr E Macaulay, Prof R Davies***
Physics Tel No : ***283011***
Email : ***rcwh@astro.ox.ac.uk***

AS17 Monte-Carlo calculation of X-ray spectra from black-hole winds

We have recently discovered that actively-accreting supermassive black hole systems in active galaxies produce energetic outflows of gas that leave significant features in the X-ray spectrum of the active nucleus.

This project will pursue a monte-carlo approach, firing virtual photons through simulated gas distributions, to calculate both the X-ray spectra and arrival time delays caused by scattering of photons. These results will be compared with recent X-ray spectra obtained by our group. The project requires some experience of programming in C as modification of existing code will be required.

Supervisor : ***Prof L Miller*** Physics Tel No : ***273342***
Email : ***l.miller@physics.ox.ac.uk***

AS18 The Evolution of the Fundamental Plane

The Fundamental plane (FP, Djorgovski & Davis 1987) relates the effective radius, average surface brightness and the average velocity dispersion of elliptical galaxies. It is remarkable that all local elliptical galaxies, regardless of their total size or mass appear to obey such a simple yet tight relation. The Virial theorem predicts a similar plane but the observed and predicted planes are tilted with respect to one another. There are currently two competing explanations: either the ratio of Dark Matter (DM) to baryonic matter changes with galaxy mass or the mass-to-light ratio of the stars changes with galaxy mass.

The GEMINI-HST Cluster Survey (P.I. Prof R. Davies, Oxford) observed 15 clusters from redshift z=0.15 to z=1 with the Hubble Space Telescope (HST, imaging) and the GEMINI 8m ground based telescope (imaging and spectroscopy). A handful of these clusters have been further imaged with HST in the CLASH survey (Postman et al. 2012), providing some of the deepest imaging of galaxy clusters to date. These datasets allow us to rigorously study the evolution of the FP from when the Universe was less than half its current age. In this project the student will reduce and analyse existing HST/CLASH imaging and GEMINI/GMOS spectroscopic data to study the FP in the cluster MACSJ0717 at z=0.55.

Special skills:

Basic proficiency with computers is essential although prior experience in programming is not a pre-requisite.

Supervisors : ***Dr R Houghton, Prof R Davies***
Physics Tel No : ***283011***
Email : ***rcwh@astro.ox.ac.uk***

AS19 High-redshift disk formation

Although unobserved as yet, galaxies in their infancy about 500 million years after the Big Bang are already being simulated by computational cosmologists. These early galaxies are predicted to form at the intersections of the cosmic web that grows out of the seed perturbations imprinted after the Big Bang. This project will study how gas streaming along filaments in the cosmic web can form rapidly rotating, dense, gaseous disks at their intersections in the high redshift Universe. In the simulations, these gaseous disks appear to be rotating as fast as the Milky Way but they are about a tenth of its size. Under such extreme conditions, a disk can become gravitationally unstable and fragment into massive gas "clumps" which could collapse into star clusters. Therefore understanding how these high redshift galaxies acquire their rapid rotation is crucial to making sense of high-redshift star formation.

The goal of this project, is to explain these rapidly rotating, small disks. This will involve converting outputs from ultra-high resolution hydrodynamical cosmological simulations into a format that is readable by a sophisticated three-dimensional visualization software, and then measuring the orientation of the filaments relative to the disk. From the geometrical information, and measurements of the gas velocities in the filaments, an explanation for the disk orientation and extreme rotational disk velocities will be constructed.

Good programming skills required.

Supervisors : ***Dr A Slyz, Dr J Devriendt***
Physics Tel No : ***283020***
Email : ***slyz@astro.ox.ac.uk; jeg@astro.ox.ac.uk***

AS20 Characterisation of young, low-mass eclipsing binaries discovered by CoRoT

Detached eclipsing binary stars are very important objects, because it is possible to measure the masses, radii, luminosities and effective temperatures of both stars to a precision of a few percent. These measurements can then be compared to the predictions of theoretical models of stellar evolution, and enable to learn about the limitations of the latter and improve them. Finding and characterising very young eclipsing binaries is particularly important, because the earliest stages of stellar evolution are among the most rapid, but also those for which we have fewest observational constraints. The CoRoT spacecraft observed the 3 Myr old star forming region NGC2264 for two continuous runs of one month each in 2008 and 2011, leading to the discovery of a number of new eclipsing binaries. The project will use data from CoRoT, as well as follow-up photometry and radial velocity data from other ground- and space-based instruments, to measure the fundamental parameters of the most interesting among them.

This project is suitable for students who are taking the astrophysics option, and who undertook at least some of the astrophysics practicals in year 3 (preferably including AS33). It is primarily a data analysis project, mainly using existing code and data, but it may require a small amount of programming.

Supervisor : ***Dr S Aigrain***
Physics Tel No : ***273339***
Email : ***suzanne.aigrain@astro.ox.ac.uk***

AS21 tbc

More details from the supervisor..

Supervisors : ***Prof M Jones, Dr A Taylor***
Physics Tel No : ***273441, 273367***
Email : ***m.jones3@physics.ox.ac.uk, a.taylor3@physics.ox.ac.uk***

Biological Physics projects

BIO01 **Reading DNA, one (fluorescent) polymerase at a time**

Our chromosomes store an enormous amount of biological information in the form of DNA; this information needs to be copied and decoded at the right time, at the right place and at the right level to keep us healthy. We study molecular machines (DNA and RNA polymerases) responsible for transferring genetic information to new DNA and messenger RNA molecules; the latter are central to gene expression, the process that translates genes into proteins. We study the polymerase machines at the single-molecule level and make "molecular movies" of their movements and their conformational changes. Our work has also biomedical importance, since it contributes to the grand challenge of real-time sequencing of single DNA molecules.

This project will allow the student to use ultra-sensitive microscopes equipped with multiple lasers to excite fluorescent probes in polymerases and in DNA. The student will process information from the emitted photons to measure nanoscale distances within the machinery and elucidate how these machines work; some theoretical modelling of the process may also be possible. No special skill or prior knowledge or experience of biophysics is necessary. Introductory literature will be provided.

Supervisor : ***Dr A Kapanidis*** Physics Tel No : ***272401***
Email : ***a.kapanidis@physics.ox.ac.uk***

BIO02 **Digital holographic microscopy for 3D tracking of bacterial swimming**

The aim of the project is to construct a digital holographic microscope that is able to track, in 3 dimensions, small objects like swimming bacteria or microspheres that are markers of flow fields.

A hologram is a 2-dimensional image of the pattern formed by interference between the light scattered by an object and a coherent reference beam of known phase. A hologram records the phase of the object beam relative to the reference beam, which allows reconstruction of the object beam - and therefore a 3-dimensional image of the object. Traditional holograms are recorded on photographic film, and the object beam is reconstructed via diffraction of a copy of the reference beam by the hologram. With modern cameras, holograms can be recorded digitally at video rates, and the object beam reconstructed numerically using high-speed computing, generating 3-dimensional videos.

The student will have the choice of two distinct holographic configurations, either in-line (only the amplitude of the scattered light is used in a reconstruction) or off-axis (the phase of the scattered light is also recovered before a reconstruction). All the required computer programmes are already written. After the microscope is built, the student will use it to track swimming bacteria and diffusing particles, and/or to measure the flow fields around swimming and falling objects.

Requirement: Some familiarity with optics and computer programming would be useful, but no specific prior experience is necessary. Please contact the supervisor if you are interested in the project

Supervisor : ***Dr R Berry*** Physics Tel No : ***272288***
Email : ***r.berry@physics.ox.ac.uk***

BIO03 **DNA biosensors**

Transcription factors are proteins that control gene expression; they act as robust natural biosensors and switches, receiving chemical and physical signals from the cellular environment and regulating the copying of DNA to messenger RNA. A remarkable variety of signals modulate transcription-factor activity, including temperature shifts, light exposure, levels of biochemicals (such as sugars, metals, and hormones), population density and oxidative status. Due to their central role in gene expression, transcription factors can serve as indicators of disease and other physiological conditions. We recently developed DNA biosensors for ultra-sensitive detection of transcription factors and their signals using single-molecule spectroscopy.

Potential projects in this area include design of improved DNA biosensors for existing transcription factors; developing novel biosensors to detect different stimuli; and real-time biosensing in living cells (using single-molecule imaging or fluorescence correlation spectroscopy). No special skill or prior knowledge or experience of biophysics is necessary. Introductory literature will be provided.

Supervisor : ***Dr A Kapanidis*** Physics Tel No : ***272401***
Email : ***a.kapanidis@physics.ox.ac.uk***

BIO04&05 **DNA Nanostructures**

DNA is a wonderful material for nanometre-scale fabrication. Short lengths of DNA can be designed such that Watson-Crick hybridization between complementary sections leads to the self-assembly of complex nanostructures. Nanostructures can be used to deliver a payload into a cell, as a scaffold for protein crystallography or as both track and motor components of a molecular assembly line. The project will involve design, fabrication and characterization of a DNA nanostructure.

Supervisor ***: Prof A Turberfield*** Physics Tel No ***: 272359***
Email ***: a.turberfield@physics.ox.ac.uk***

BIO06 **Structure/function studies of ion channels**

The project will involve determining the relationship between the structure and function of a number of different ion channels found in the membranes of living cells which control cellular electrical excitability. We principally study K+ ion channels using a combination of molecular biology, protein biochemistry and electrophysiology.

Requirement: Although no previous experience is required, some interest in biological systems is essential as there will be a certain amount of background reading required.

Supervisor : ***Dr S Tucker*** Physics Tel No : ***285835***
Email : ***s.tucker@physics.ox.ac.uk***

Condensed Matter Physics projects

CMP01 Demagnetizing effects in SQUID measurements of magnets and superconductors

MHD is a novel variant on the familiar Lorentz force. Cur- Measurements of the magnetic properties of superconductors depend on the sample shape. This is because of the effect of demagnetizing fields. In this project, the effect of these demagnetizing fields will be systematically studied using calculations and the results compared with specially designed experiments on model systems using a SQUID magnetometer in the Clarendon Laboratory. These results will then be used to obtain a quantitative determination of the superconducting volume fraction in a recently synthesized iron-based superconductor.

Background reading:

[1] J. A. Osborn, Phys. Rev. 67, 351 (1945).

[2] R. I. Joseph and E. Schlömann, J. Appl. Phys. 36, 1579 (1965).

[3] M. Beleggia, M. De Graef, J. Magn. Magn. Mater. 263, L1 (2003).

Supervisor *: **Prof S Blundell*** Physics Tel No *: **272347***
Email *: **s.blundell@physics.ox.ac.uk***

CMP02 Calculation of the magnetic properties of molecular2spin chains

New molecular magnets have been prepared which consist of chains of molecular ions linked by organic groups. Experiments on these systems can be used to study the magnetic properties of low-dimensional magnets and compare them with theoretical expectations. In this project, the magnetic properties of spin chains will be studied using computational techniques with the aim of making contact with experimental results which have been obtained in our group. A SQUID magnetometer in the Clarendon laboratory will also be used to obtain some experimental measurements on some model systems which can be compared with the theoretical predictions. The project has a theoretical, a computational and an experimental element.

Background reading:

[1] S. J. Blundell and F. L. Pratt, J. Phys.: Condens. Matter 16, R771 (2004).

[2] S. J. Blundell, Contemp. Phys. 48, 275 (2007).

[4] P. A. Goddard, J. L. Manson, J. Singleton, I. Franke, T. Lancaster, A. J. Steele, S. J. Blundell, C. Baines, F. L. Pratt, R. D. McDonald, O. E. Ayala-Valenzuela, J. F. Corbey, H. I. Southerland, P. Sengupta, and J. A. Schlueter, Phys. Rev. Lett. 108, 077208 (2012).

Supervisor *: **Prof S Blundell*** Physics Tel No *: **272347***
Email *: **s.blundell@physics.ox.ac.uk***

CMP03 Searching for topological superconductors

The superconductivity found in certain candidate topological insulators is predicted to have a significant effect on understand fundamental physics in particular in the search for Majorana fermions as well as from the applications point of view to pave the way towards designing novel dissipationless devices.

This project aims search for superconductivity in doped Bi2Se and Bi2Te2 systems as well as other new materials both experimentally and computationally. Measurements will be performed at low temperatures using liquid helium and in certain cases also high magnetic fields. The project will use also band structure calculations to understand the electronic properties of these materials. A suitable candidate for this project should be familiar with condensed matter courses and computation skills would be valuable to the project.

For further questions please email amalia.coldea@physics.ox.ac.uk

For further reading see: Topological insulators and superconductors, Rev. Mod. Phys. 83, 1057-1110 (2011) or http://arxiv.org/abs/1008.2026

Supervisor : ***Dr A Coldea*** Physics Tel No : ***272267***
Email : ***a.coldea@physics.ox.ac.uk***

CMP04 Electronic structure of novel superconducting materials

In 2008 a new class of superconductors containing iron has been discovered which has generated a surge of activity in understanding the origin of superconductivity in these materials. Iron is one of the most unexpected elements found in a superconductor due to its strong ferromagnetic properties which is often found detrimental to sustaining a superconducting state. One of the important aspects for understanding the superconductivity in these iron pnictides is to test their electronic behaviour, as their superconductivity emerges from a bad metallic and magnetic state.

This project aims to investigate new candidate superconductors in high quality single crystalline materials both experimentally and computationally in order to reveal the relevance of altering the structural arrangements on the superconducting properties. Measurements will be performed in high magnetic fields and at low temperatures where the quantized behaviour of electrons can be observed. These experiments will be performed on high quality single crystals and the results will be compared with the prediction of the band structure calculations. A suitable candidate for this project should be familiar with condensed matter courses and computation skills would be valuable to the project.

For further questions please email amalia.coldea@physics.ox.ac.uk

For further reading use:

Nature Physics 6, 645–658 (2010)

Phys. Rev. Lett. 101, 216402 (2008)

Phys. Rev. Lett. 103 103, 026404 (2009)

Supervisor *: Dr A Coldea* Physics Tel No ***: 272267***
Email ***: a.coldea@physics.ox.ac.uk***

CMP05 **Evaporation Cells for Thin Film Growth**

Molecular beam epitaxy (MBE) is a superior tool for the precise engineering of quantum materials – in the form of thin films, nanowires, or self-assembled quantum dots. MBE is at the root of many discoveries and developments in physics such as the fractional quantum Hall effect, semiconductor lasers, or high electron mobility transistors. Materials growth in MBE is carried out in an ultra-high vacuum environment (UHV; pressure typically < 5•10-10 Torr) and cleanliness is key to obtaining materials of superior quality.

The goal of the project is to develop a temperature and a flux controller for a material evaporation source. The source performance in terms of stability will be characterized by analyzing thin films.

Reading list:

1.http://www.arduino.cc/

2. MBE: e.g. Herman & Sitter – Molecular Beam Epitaxy

3. Electronics: Horowitz & Hill – The Art of Electronics

4. Vacuum: O'Hanlon – A User's Guide to Vacuum Technology

Special skills required:

For this project, power supplies, flux and temperature sensors need to be interfaced with the open-source electronics prototyping platform Arduino. Consequently, solid computer, programming and electronics skills are required.

Supervisor ***: Dr T Hesjedal*** Physics Tel No ***: 272235***
Email ***: t.hesjedal1@physics.ox.ac.uk***

CMP06 **Reflection high energy electron diffraction (RHEED)**

The in situ study of thin film growth, and the resulting understanding of growth modes, surface reconstructions, and phase transitions, is one of the key components that make molecular beam epitaxy (MBE) a superior tool for the precise engineering of quantum materials. In a RHEED system, which is an integral part of an ultra-high vacuum MBE chamber, electrons are diffracted off of the growing surface under grazing incidence. The low incident angle makes the method very surface-sensitive. The constructively interfering electrons give rise to a diffraction pattern on the RHEED screen that is recorded by a camera system. Elastically and inelastically scattered electrons contribute to the diffraction pattern, making the quantitative analysis rather difficult. A qualitative analysis of the pattern, on the other hand, is already sufficient to determine many of the characteristics of the growing crystalline films. In this project you will set up our new RHEED camera and develop some simple tools in LabView to record and analyze the data during growth. Following the digitization of the patterns, reciprocal space maps of the surface will be deducted. These then have to be compared with patterns simulated starting from established models of the surface by performing kinematical and dy**namic scattering simulations.**

Reading list:

1. Basic crystallography (cubic and hexagonal systems, Miller indices)

2. Diffraction (X-rays and electrons), reciprocal lattice: Kittel, ch.1,2; Hammond

3. MBE and RHEED: Herman & Sitter, Arrott, Ichimiya & Cohen

Special skills required:

The RHEED system is computer-controlled and LabView code has to be developed or modified. The data analysis has to be done on- or offline using public domain software (ImageJ, Java). Consequently, solid computer and programming skills are required.

Supervisor ***: Dr T Hesjedal*** Physics Tel No ***: 272235***
Email ***: t.hesjedal1@physics.ox.ac.uk***

CMP07 **Automation of Molecular Beam Epitaxy Processes**

Molecular beam epitaxy (MBE) is a superior tool for the precise engineering of quantum materials – in the form of thin films, nanowires, or self-assembled quantum dots. MBE is at the root of many discoveries and developments in physics such as the fractional quantum Hall effect, semiconductor lasers, or high electron mobility transistors. Materials growth in MBE is carried out in an ultra-high vacuum environment (UHV; pressure typically < 5•10-10 Torr) and cleanliness is key to obtaining materials of superior quality.

The goal of the project is to automate many of the routine function associated with the operation of the MBE, This project is suitable for several students and the practical work can be performed in a group or individually.

Reading list:

1. http://www.arduino.cc/

2. MBE: e.g. Herman & Sitter – Molecular Beam Epitaxy

3. Electronics: Horowitz & Hill – The Art of Electronics

4. Vacuum: O'Hanlon – A User's Guide to Vacuum Technology

Special skills required:

MBE kits are complex systems and automation is key to their safe operation. For this project, ultra-high vacuum pumps, valves, heaters, and pressure controllers need to be interfaced with the open-source electronics prototyping platform Arduino. Consequently, solid computer, programming and electronics skills are required.

Supervisor ***: Dr T Hesjedal*** Physics Tel No ***: 272235***
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***CMP08* Molecules, magnets and high fields**

Can we can control of the building blocks of magnetism? If so, it would make possible the design and growth of bespoke magnetic materials. This project seeks to explore to what extent we are currently able to do this by subjecting the most cutting-edge molecular materials to high magnetic fields.

Coordination polymers are self-organizing materials consisting of arrays of metal ions linked via molecular ligands. The choice of initial components in the initial mix permits a high level of control over the final product, enabling many different polymeric architectures to be obtained. These materials thus provide a route to successful crystal engineering, and as well as magnetism a number of other functionalities are being actively studied, including gas storage, optoelectronics and ferroelectricity. This is a fast moving field with new materials being synthesized on a regular basis. The determination of the magnetic properties of the materials is as crucial as the structural investigations, and involves a multi-technique approach encompassing electron-spin resonance, muon-spin rotation and high-field magnetometry. The projecteer will perform experiments on new examples of magnetic systems in the Nicholas Kurti High Magnetic Field Laboratory, which is located within the Clarendon and provides the highest magnetic fields available in the UK.

Supervisor : ***Dr P Goddard*** Physics Tel No : ***272370***
Email : ***p.goddard@physics.ox.ac.uk***

***CMP09* Preparation and characterisation of ferromagnetic topological insulators**

Topological insulators represent a new form of quantum matter which is insulating in the bulk but has a metallic surface which is protected by a topological feature in the electron bands. When topological insulators are placed in proximity to other materials, exotic and interesting phenomena are predicted to emerge which could have practical uses. One way to achieve this is to introduce magnetic order into a topological insulator, which leads to a breaking of time reversal symmetry.

In this project you will prepare single crystals of the topological insulator Bi2Se3 combined with the ferromagnetic material Fe7Se8 in different ratios. The aim is to obtain a topological insulator which is ferromagnetic at room temperature, and to explore its properties. The crystals will be characterised by a range of techniques including X-ray diffraction, magnetic measurements, and electrical and thermal transport. The project is experimental and is a mix of materials preparation and physical measurements.

Supervisors: ***Dr D Prabhakaran, Prof A Boothroyd***
Physics Tel No : ***272376***
Email : ***a.boothroyd@physics.ox.ac.uk***

***CMP10* Pyroelectric and magnetoelectric measurements on novel multiferroics**

The last few years have seen a renaissance of research in the field of magnetoelectric and multiferroic materials. These compounds, which are typically transition metal oxides, develop an electrical polarisation either upon application of an external magnetic field or, spontaneously, at the onset of a magnetic ordering transition. In both cases it is possible to enact mutual control of the magnetic and electric properties – a feature may lead to a new functional paradigm for information recording and reading. Last year, we ran a very successful project, which produced a complete measurement system, employing the so-called integrated pyroelectric and magnetoelectric currents method, for measurements up to 14 T down to T=2 K, including the software to control the power supply and collect the data. In this approach, the sample, typically a single crystal with evaporated metallic electrodes, is cooled in an external electric field applied by a CD power supply. One then measures the electric currents flowing between the two electrodes as the electrical polarisation of the crystal changes as a function of temperature and fields. By integrating these currents up to a known paraelectric state (e.g., above the ferroelectric Curie temperature) one can reconstruct the absolute value of the polarisation at any stage of the cycle. The aim of this year's project is to extend the capabilities of the system to measurements of the AC/DC dielectric constants and magnetocapacitance. The student will have the opportunity to perform measurements on a variety of novel multiferroics and magnetoelectrics that are grown in the Department in single crystal form, and to participate in an active research project on the new multiferroic YbFe2O4.

Supervisor : ***Prof P Radaelli*** Physics Tel No : ***270957***
Email : ***p.radaelli@physics.ox.ac.uk***

***CMP11* De-twinned single crystals: preparation and properties**

Topological insulators represent a new form of quantum mattSingle crystals are a very special form of matter, having crystalline perfection in all directions. In reality, however, many single crystals contain defects which reduce their usefulness in fundamental studies and technological applications. A common form of defect is called "twinning". This occurs when the crystal undergoes a symmetry-breaking phase transition which results in two or more equivalent structural domains related by symmetry. One way to remove twinning defects is to apply pressure to the crystal at elevated temperatures and then cool the crystal through the phase transition.

In this project you will re-assemble a de-twinning apparatus in the Clarendon Laboratory, and develop a user interface to control pressure and temperature in the apparatus, and to record images from a microscope. Once the apparatus is operational it will be applied to de-twin a number of different magnetic crystals of interest and, if time permits, the de-twinned crystals will be studied with x-ray diffraction and magnetic and transport measurements.

Supervisors: ***Dr D Prabhakaran, Prof A Boothroyd***
Physics Tel No : ***272376***
Email : ***a.boothroyd@physics.ox.ac.uk***

CMP12 Optical properties of graphene-like materials calculated from first principles

Graphene has become established as an important material for investigating fundamental physics, and also promises to be a building block of future electronic devices. However, there are also a range of other two dimensional nanosheets that offer great potential for uncovering new physics and have huge potential for future devices.

Materials that are of particular interest are BN, transition metal oxides, transition metal dichalcogenides (TMDs), and 2D topological insulators (e.g. Bi2Te3 and Bi2Se3). The diverse physical properties of these materials become even more interesting when they are only a few layers thick. For example the TMD MoS2 is an indirect-gap semiconductor in the bulk phase, yet becomes direct-gap when only a few atomic layers thick [1, 2].

First principles calculations (based on density functional theory) will be utilised to determine the electronic bandstructure of two-dimensional semiconductors (e.g. MoS2, BN). The complex dielectric function will be calculated in the visible range from the determined eigenfunctions, and compared with literature where possible. The influence of various parameters such as lattice strain upon observable properties will be investigated. Computational consistency will be established by verifying the findings for various exchange functionals (e.g. LDA, LSDA, GGA).

This project would suit a student with a keen interest in learning and applying computational techniques in solid state physics.

Specials Sills:

Knowledge of Linux and a programming language such as Python would be advantageous.

Further reading:

[1] K. F. Mak et al., Phys Rev Lett 105, 127404 (2010).

[2] A. Splendiani et al., Nano Lett 10, 1271 (2010).

Supervisors: ***Dr J Lloyd-Hughes, Dr M Johnston***
Physics Tel No : ***272267, 272236***
Email : ***j.lloyd-hughes1@physics.ox.ac.uk, m.johnston1@physics.ox.ac.uk***

CMP13 Photoluminescence Spectroscopy of Zinc Blende and Wurtzite InAs Nanowires

Graphene has become established as an important material Semiconductor nano-wires are currently generating intense research interest owing to potential applications in next generation electronics, optoelectronics and photovoltaics [1,2]. Nanowires are typically just 50nm in diameter and can be grown to a length 10microns, thus they may be used as one-dimensional building blocks for devices. Collaborators at the Australian National University have recently developed a method to tailor the crystal structure of InAs nano wires [3]. Thus for the first time is is possible to produce a single crystal of InAs in wurtzite crystal structure (InAs usually only forms a Zinc Blende Crystal). In this project you will use a state-of-the-art Fourier Transform Infrared Spectrometer to measure the photoluminescence from bulk InAs, zinc-blende InAs nanowires and wurizite InAs nano wires. Measurements will be performed as a function of temperature to reveal the band structure of wurtzite nano wires, and you will have the opportunity to model your experimental data. The project is best suited to a student who wishes to continue in research.

Reading:

[1] Nat. Mater., 6:841-850 (2007)

[2] Prog. Quantum Electron., 35:23-75 (2011)

[3] Nano Lett., 10:908-915 (2010)

[4] Nano Lett., 12:3378-3384 (2012)

Supervisor: ***Dr M Johnston*** Physics Tel No : ***272236***
Email : ***m.johnston1@physics.ox.ac.uk***

CMP14 First principles determination of the electronic structure of multiferroic thin film oxides

Magnetoelectric multiferroics based on transition metal oxides exhibit a coupling between electric and magnetic order parameters [1]. They are of substantial interest due to the exotic physics that they exhibit, and show potential in advanced device applications in spintronics or electrically controlled magnetic memories.

First principles calculations (based on density functional theory - DFT) will be utilised to determine the electronic bandstructure of multiferroic transition metal oxides. The complex dielectric function will be calculated in the visible range for model room temperature multiferroics such as BiFeO3 and Pb Ti0.5 Fe0.5 O3. Comparison with optical absorption provides a stringent test of DFT predictions [2], and will allow a suitable exchange correlation functional to be chosen (LDA, LSDA, GGA, Hubbard U). The electrical polarisation will be determined using the Berry phase formalism. The influence of biaxial and triaxial lattice strain upon observable properties will be investigated.

This project would suit a student with a keen interest in learning and applying computational techniques in solid state physics.

Special Skills:

Knowledge of Linux and a programming language such as Python would be advantageous.

Further reading:

[1] S.W. Cheong et al., Nat. Mater. 6, 13 (2007)

[2] S. Ju et al., J. Chem. Phys 130, 214708 (2009)

Supervisor: ***Dr J Lloyd-Hughes*** Physics Tel No : ***272267***
Email : ***j.lloyd-hughes1@physics.ox.ac.uk***

CMP15 Monte Carlo simulation of excitation transfer in nanoparticles used for biosensing

Nanoparticles are interesting systems to study because of their large range of potential uses in biological imaging and sensing. In particular, nanoparticles composed of organic polymer chains or self-assembled molecular aggregates have several key advantages over inorganic semiconductor quantum dots or conventional probes. For example, molecular nanoparticles are not cytotoxic and do not impair a cell's functionality. Molecular nanoparticles have been successfully used to target, track, and image specific biomolecules. Energy transfer within such nanoparticles has proven to be a particularly powerful approach towards enhancing the sensitivity of a nanoparticle to particular environmental parameters.

The aim of this project is to model the transfer of photo-excitations within such molecular nanoparticles. The result will allow us to establish fundamental design criteria for efficient energy transfer from the nanoparticle core to the perimeter where target bio-molecules may attach. The model will assume excitation transfer between molecular subunits of the nanoparticles to result from point-dipole coupling in a first approximation, and be based on a Monte Carlo simulation (using the programming language C). The calculated excitation dynamics will be compared with existing data derived from time-resolved photoluminescence measurements.

Suggested reading (copies can be obtained from the supervisor):

K. Petkau et al. J. Am. Chem. Soc. 133, p. 17063 (2011).

A.L. Stevens et al. ACS Nano 6, 4777 (2012)

Supervisor : ***Prof L Herz*** Physics Tel No : ***282214***
Email : ***L.Herz1@physics.ox.ac.uk***

CMP16 Micro- and nano-fabrication for experiments on microscopic crystals

This project will contribute to efforts to make electrical contacts to micron-scale single crystals of interesting materials in condensed matter physics. You will have the opportunity to use cutting-edge equipment and processes in a clean-room environment for developing devices with nanometre-sized features. If the project goes well you will take your devices into the high-magnetic-field lab and measure their properties at extremely low temperatures (below 4K) and very high fields (up to 15 T). The project would suit someone who is interested in experimental condensed matter physics and/or devices and who wants to make a significant contribution to ongoing ground-breaking research.

Supervisors ***: Dr A Ardavan*** and ***Mr B H Williams***
Physics Tel No : *272*366
Email ***: arzhang.ardavan@physics.ox.ac.uk, b.williams3@physics.ox.ac.uk***

CMP17 tbc

More details from the supervisor.

Supervisor ***: Dr R Coldea*** Physics Tel No ***: 272225***
Email ***: r.coldea@physics.ox.ac.uk***

CMP18 High coherence superconducting microwave cavities

It has recently been shown that highly quantum coherent superconducting electrical circuits can be realised if their electromagnetic environment is controlled by enclosure in high quality superconducting cavities, a vital step towards realising quantum computers based on such circuits. In this project, you will look at the lifetimes of microwave photons in a range of different superconducting cavities, and employing some special techniques to enhance their quality. The project will involve a range of activities; design and simulation of the superconducting cavities, measuring them at microwave frequencies and temperatures ranging from 300K down to 10mK, and understanding the physics of the photon lifetimes from the results. If time allows there may also be an opportunity to participate in superconducting qubit measurements inside the cavities, and to create quantum states of microwave light.

Supervisor : ***Dr P J Leek*** Physics Tel No : ***272370***
Email : ***peter.leek@physics.ox.ac.uk***

CMP19 High coherence superconducting microwave cavities. Surface acoustic resonators for quantum memories

Many different systems are investigated experimentally for their potential use in the growing field of quantum information. In this project, we will look at a completely new system for this application - surface acoustic wave devices on piezoelectric crystals. Such devices are widely used in electronic engineering, but little is known about their properties at low temperatures. If resonators can be made at sufficiently high quality, they could be good candidates for quantum memories integrated into superconducting electrical circuits. The project will involve some modelling, high frequency and low temperature electrical measurements, and interpretation of the results in terms of the limiting mechanisms for the phonon lifetimes. Depending on results, there may be an opportunity to measure an acoustic resonator integrated into a superconducting circuit or cavity, employed as a quantum memory.

Supervisor : ***Dr P J Leek*** Physics Tel No : ***272370***
Email : ***peter.leek@physics.ox.ac.uk***

Interdisciplinary projects

INT01&02 An Electronics Project

Design, build and test a piece of electronic equipment of your choice. The project will take place on the Practical Course electronics laboratory.

Suggested Reading:

Horowitz and Hill

Any book on electronics.

Supervisor ***: Dr R Nickerson*** Physics Tel No ***: 273118***
Email ***: r.nickerson@physics.ox.ac.uk***

INT03 Geophysics applications for SQUID magnetometry

SQUID magnetometers have enormous potential for geophysics applications as they can monitor magnetic fields to a resolution over 1000 times better than conventional fluxgate magnetometers. This project will investigate possible applications by simulating signals and comparing these to data recorded by sensors in an underground laboratory, to determine the sensitivity. The dominant magnetic field fluctuations are due to ionospheric currents. We aim to use the data from multiple SQUID sensors to subtract this background and search for local magnetic signals which could provide a means to track the flow of underground water, or study earthquake trigger mechanisms. This is an interdisciplinary project using data from an instrument developed for the cryoEDM particle physics experiment, in order to investigate geomagnetic phenomena. Some knowledge of C++ would be helpful.

Supervisor : ***Dr S Henry*** Physics Tel No : ***273458***
Email : ***s.henry@physics.ox.ac.uk***

INT04 Control of thermionic emission

Precise control of thermionic emission is at the heart of much surface science instrumentation and is an essential part of the functioning of Auger Spectroscopy, Low Energy Electron Diffraction and the working of the Bayard-Alpert vacuum gauge. The project is to design, build and characterise the performance of a high quality, stable thermionic emission controller using discrete component electronics.

Essential prior knowledge: understanding the operation of simple electronics including transistors and operational amplifiers.

Desirable prior knowledge: an understanding of feedback control and the Nyquist stability criterion, ability to solder.

Recommended reading: Dorf and Bishop, "Modern Control Systems"

Supervisor : ***Prof J Gregg*** Physics Tel No : ***272209***
Email : ***j.gregg@physics.ox.ac.uk***

INT05 Low voltage AC power control

Techniques for high efficiency control of mains voltage power are well established and use thyristors or triacs that are fired in either "burst-fire" or "phase control" mode. However, using this technique at low voltage is complicated by the fact that the firing devices that are commercially available are designed to trigger at mains voltages only. The project is to design, build and characterise a working AC power control circuit for low voltage (12-24 Volt) operation.

Essential prior knowledge: an understanding of simple electronics.

Desirable prior knowledge: ability to solder.

Supervisor : ***Prof J Gregg*** Physics Tel No : ***272209***
Email : ***j.gregg@physics.ox.ac.uk***

INT06 Low Frequency Network Analyser

The project is to design, construct and characterise a simple, cost-effective network analyser that can be used for teaching purposes. The resulting circuit should be capable of making transmission measurements on circuitry between 10Hz and 1MHz and to display the measured transfer functions in real time in Bode plot format.

Essential prior knowledge: an understanding of simple electronics and of elementary AC theory.

Desirable prior knowledge: Bode plots, swept variable frequency oscillators, ability to solder.

Supervisor : ***Prof J Gregg*** Physics Tel No : ***272209***
Email : ***j.gregg@physics.ox.ac.uk***

INT07 Detection of Electromagnetic signals Using Superconducting Tunnel Junctions

Modern cosmology instruments aiming to detect the Cosmic Microwave Background (CMB) polarization require unprecedented sensitivity for the detection of very weak signals. The receivers of these instruments therefore employ large focal plane arrays equipped with ultra-sensitive superconducting bolometers. The Superconducting Tunnel Junction (SIS) detector consists of two small area (~1μm2) thin films sandwiching a very thin insulator (20 A^0). When a photon hits one of the films it breaks a Cooper pair allowing a normal electron to tunnel across the potential barrier between the two films and get detected as dc current. In this project the student will investigate the potential sensitivity of the SIS device as a direct detector of electromagnetic signals at submillimetre wavelengths and compare the performance with that of state of the art bolometers. The student will first learn how to model these devices using commercial and home-made software and then test devices that we have already fabricated in a fully operational cryogenic system, at temperatures between 300 mK and 4 K. The sensitivity of the device will be tested by illuminating the detector with a blackbody radiation at variable temperature and measuring the tunneling current across the device.

The project would suit an experimentally minded student who is interested in learning how to use state of the art research systems for testing physical models. There are no requirements of knowledge of superconductivity or special experimental techniques.

Supervisor : ***Prof G Yassin*** Physics Tel No : ***273440***
Email :***g.yassin@physics.ox.ac.uk***

INT08 Phase Modulation in Cosmology Instruments

A well known technique used in astronomy instruments to help distinguish the signal from systematic effects and to reduce noise is phase modulation of the received signal. While this is straightforward to do at microwave frequencies, it is quite tricky at millimeter wavelengths where modern cosmology instruments are attempting to measure the Cosmic Microwave Background polarization. The key component of phase modulation is a fast and low loss on/off switch. At Oxford, we have developed an on/off superconducting nano-switch by fabricating a NbN nanostrip (0.5 µm wide and 20 nm thick) across the electrodes of a transmission line, using electron beam lithography. An external current source is used to switch the strip between the normal and superconducting states, presenting a short or an open circuit to the incoming signal.

We have fabricated and thoroughly tested several switch chips and have shown them to work but the dynamic range was much lower than expected. We are therefore seeking an MPhys. Student to investigate the physics of these devices. This will be done by simulating the behaviour of the nano-switch using software packages and comparing the computed results with measured data. This work will hopefully lead to modified designs that we will fabricate and test in the future. The project is mainly computational based on the physics of electromagnetism and superconductivity. No prerequisite courses are need and the student will learn how to use relevant theories as part of the project.

For further details contact Prof. Ghassan Yassin.

Supervisor : ***Prof G Yassin*** Physics Tel No : ***273440***
Email :***g.yassin@physics.ox.ac.uk***

INT09 Advances in exoplanetary atmospheric science with next-generation space telescopes

In the last decade, space missions such as CoRoT and Kepler and extensive ground-based observing programmes have resulted in a vast increase in the number of known extrasolar planets. The launch of the James Webb Space Telescope and proposed missions such as the ESA space telescope EChO will enable us to go a step further and characterise the atmospheres of a large number of these planets. We can compare spectra obtained when the planet transits its parent star with synthetic spectra generated by a radiative transfer model to infer atmospheric composition and structure.

The student will use a pre-existing radiative transfer code to explore the likely information that could be obtained from JWST and EChO. The investigation will be initially based on planets whose transit spectra and inferences therefrom are well documented in the literature, but for which investigation so far has been limited by the available data. The student will explore whether JWST and EChO will provide sufficient spectroscopic information to distinguish between alternative scenarios already postulated for planets such as HD189733b, HD209458b and GJ 1214b.

Familiarity with Unix/Linux systems, and some knowledge of programming languages such as Fortran or IDL, are desirable.

Supervisors : ***Dr J Eberhardt*** and ***Prof P Irwin***
Physics Tel No : ***283004, 272083***
Email : ***jo.barstow@astro.ox.ac.uk, irwin@atm.ox.ac.uk***

INT10 How much of a 'hit' song can you make in *Mathematica?* Just how much does Cheryl Cole owe to Joseph Fourier?

Modern music production techniques often rely heavily on signal processing theory and computer based algorithms, and most people are now familiar with the concept of the 'Auto-tune' and other types of automated pitch correction that use some of these techniques. This project will investigate how these algorithms work, with the aim of integrating them into demonstrations for use in public lectures, as well as the opportunity to investigate new types of software instruments.

This project will be computer based and some knowledge of scientific programming techniques will be useful, the use of Mathematica is an example and is not compulsory! Given that one of the eventual aims of the project is to provide demonstrations as part of a lecture an interest in public outreach would also be desirable.

Supervisors: ***Dr N Bowles, Dr S Owen, Mr A Smith***
Physics Tel No: ***272097***
Email: ***bowles@atm.ox.ac.uk***

INT11 Optical aberrations in the human eye

In the last 15 years there have been huge advances in our ability to image the living human retina with high resolution. Aberrations in the optical components of the human eye blur the image they form on the retina. Ocular aberrations also have the same effect on light reflected from the retina making high resolution images of the photoreceptors difficult to obtain in vivo. Adaptive optics is a technology that compensates for the aberrations in an optical system allowing diffraction limited images to be recorded. This is a new project based within the Department of Experimental Psychology aimed at building an adaptive optics scanning laser ophthalmoscope (AOSLO) to capture high resolution images of the photoreceptor mosaic.

We are also interested in the effect of ocular aberration on the quality of the image formed on the retina and how they affect visual performance. Low order aberrations can be corrected with spectacles, contact lenses or laser eye surgery but there are higher order aberrations that remain and these can be significant. We have recently shown that their effect on vision is dependent not only on the type of aberration but also on the visual task in question. This has important consequences in a clinical setting where one may wish to directly measure the aberrations in the eye and predict their effects on vision or predict the improvements to vision by correcting for them.

Projects will involve modelling the effects of aberrations on vision and the opportunity to contribute to the building and testing of the AOSLO. These projects will include work on signal detection theory, optical design, optical alignment and programming of real-time control systems. There is scope for a student to develop this project in a direction of their choice.

Supervisors : ***Prof N Thatte, Dr L Young and Dr H Smithson (both Experimental Psychology)***
Physics Tel No : ***273412***
Email : ***n.thatte@physics.ox.ac.uk***

INT12 **Precise analogue electronic simulation of linear and nonlinear systems**

Improving the performance of an analog simulator. The simulator exists, some modifications will be required and a data acquisition system (16 bit, 4 channel, labview) will need to be added.

Some familiarity with analog electronics would be helpful.

Supervisor : ***Dr G Peskett*** Physics Tel No : ***272883***
Email : ***g.peskett@physics.ox.ac.uk***

INT13 **Listening to Champagne**

A gas bubble in liquid resonates acoustically at a well-defined frequency that depends on its radius and the density, ambient pressure and surface tension of the liquid. A submillimetre aqueous bubble typically has its resonance in the high kilo-Hertz or low MegaHertz.

Moreover, when provoked into resonance by an acoustic stimulus, bubbles emit secondary acoustic radiation at their resonant frequencies. The purpose of this project is to investigate experimentally the practicality of stimulating, capturing and processing this secondary emission data to characterise the state of an inhomogeneous gas/liquid phase. Practical applications include measuring gas inclusions in hydrocarbon fuel pipelines: and the ability to obtain and recognise acoustic signatures that allow differentiation of different quality beverages in the fizzy drinks industry. Candidates undertaking this project need to feel at home with high frequency electronics and have the strength of character to play with cheap champagne without drinking it all.

Supervisor : ***Prof J Gregg*** Physics Tel No : ***272209***
Email : ***j.gregg@physics.ox.ac.uk***

INT14 **PIN diode radiation detector**

We have made a prototype radiation detector using a PIN diode. This is useful, firstly as there is a worldwide shortage of Geiger counters, and secondly for measurement of environmental radioactivity from weather balloons. The student will investigate various characteristics of this radiation detector, with the aim of producing a well-understood and useful instrument. The characterisation will include some or all of the following:

- detector circuitry
- calibration to count rate and energy
- possibility of using the instrument as a simple energy spectrometer
- effect of using different types of PIN diode on energy/activity sensitivity

The student should be an experimentalist with multi-disciplinary interests.

Supervisor: ***Dr K Aplin*** Physics Tel No: ***273491***
Email: ***k.aplin@physics.ox.ac.uk***

INT15 **tbc**

More details from the supervisor.

Supervisor ***: Dr W Lau*** Physics Tel No ***: , 273446***
Email:***w.lau@physics.ox.ac.uk***

INT16 **Addressing Patient Motion-Induced Image Corruption in Vessel Wall Imaging Data**

Magnetic resonance imaging is a powerful medical imaging technology that is increasingly being used in clinical trials and industrial development for making objective measurements of human anatomy and physiology. The MR Physics Group at the John Radcliffe Hospital develops novel MRI approaches to measuring brain structure and function, using state-of-the-art scanners. We recently developed a novel technique for suppressing the signal from moving fluids so that pathology in the vessel walls of the carotid arteries can be visualized. However, a significant proportion of patient scans show image corruption caused by patient motion, that can sometimes render the images uninterpretable.

In this project the student will work on methods that seek to correct the imaging data at source. This will involve developing algorithms to detect when motion has occurred (by assessing the integrity of the Fourier domain MRI data as it is being acquired). Corrupted data would then be labeled so that it can be re-acquired at the end of the scan. During the short project the student will assess real MRI data in which motion corruption has been intentionally generated, and will compare this with data without motion present. The student will also help develop methods that will acquire the required 'navigator' data to allow real-time assessment of motion corruption.

Requirements

An aptitude for computer programming (or a willingness to learn) and a competence in using advanced software packages. Knowledge of UNIX, MATLAB and/or IDL would be a distinct advantage.

Reading

Li et al, Magnetic Resonance in Medicine, 2012 in press (PubMed ID = 22246917)

See also: http://www.fmrib.ox.ac.uk/physics

Location: FMRIB Centre, John Radcliffe Hospital

Supervisors: ***Dr L Li*** and ***Prof. PJezzard***
Email : ***linqing@fmrib.ox.ac.uk, peterj@fmrib.ox.ac.uk***

INT17 **Assessing Radiofrequency Heating Patterns in the Human Head Arising from Ultra-High Field MRI Scanning**

Magnetic resonance imaging is a powerful medical imaging technology that is increasingly being used in clinical trials and industrial development for making objective measurements of human anatomy and physiology. The MR Physics Group at the John Radcliffe Hospital develops novel MRI approaches to measuring brain structure and function, using state-of-the-art scanners. We recently installed a state-of-the-art 7 Tesla human MRI scanner at the John Radcliffe Hospital site, one of only two in the UK, and of approximately 40 in the world. An exciting opportunity to increase image quality at 7 Tesla is to use novel parallel transmit technologies to excite the NMR resonance in the subject/patient by use of arrays of transmit coils. However, the safety of these new devices must be assessed using electromagnetic simulations before they can be used in practice.

In this project the student will use a dedicated electromagnetic field simulation package (SEMCAD X) to simulate the B-fields and E-fields generated in a simulated human head when transmitting on one or more RF channels of a parallel transmit RF coil that forms part of the FMRIB Centre 7 Tesla scanner. An accurate model of the RF coil has already been constructed, and a set of "virtual humans" has been tissue segmented and assigned electrical properties. The student will run a series of simulations using humans of various sizes and positions within the coil in order to determine the "worst case" RF heating that arises from the creation of electrical currents in tissue with finite conductivity that lies within an E-field. If time allows the student will also simulate a realistic tissue sample that will be compared with experimental measurements.

Requirements

An aptitude for computer programming (or a willingness to learn) and a competence in using advanced software packages. Knowledge of UNIX, MATLAB and/or IDL would be a distinct advantage.

Reading

I Graesslin et al. Magnetic Resonance in Medicine, 2012 in press (PubMed ID = 22231647)

G Eichfelder and M Gebhardt, Magnetic Resonance in Medicine, 66:1468-1476 (2011)

CM Collins et al. Magnetic Resonance in Medicine, 40:847-856 (1998)

CM Collins and Z Wang, Magnetic Resonance in Medicine, 65:1470-1482 (2011)

See also: http://www.fmrib.ox.ac.uk/physics

Location: FMRIB Centre, John Radcliffe Hospital

Supervisors: () and Prof. Peter Jezzard (peterj@fmrib.ox.ac.uk)

Location: FMRIB Centre, John Radcliffe Hospital

Supervisors: ***Mr K Papoutsis*** and ***Prof. PJezzard***
Email : ***konstantinos.papoutsis@stcatz.ox.ac.uk, peterj@fmrib.ox.ac.uk***

Particle and Nuclear Physics projects

PP01 **Background simulations for dark matter search experiments**

A number of experimental searches are underway, aiming to detect dark matter particles that are believed to account for almost a quarter of the density of universe. This project deals with exploration and simulation of possible background sources that could limit the sensitivity for such experiments. In particular, items (mechanical structures, connectors, cabling) in direct vicinity of the actual detectors need to exhibit a high level of radio-purity. How pure is pure enough is the main topic of this project. The GEANT4 software framework will be used to carry out the simulations, assessing impact of various impurities on the experiment, and viable solutions for the components (choice of material, geometry, etc) in question should be developed. A software framework for simulating the EDELWEISS detector exists already (to be used together with GEANT4), as do C++ classes for simulation of the basic infrastructure and the cabling. This project should develop the simulation framework further and include new aspects (to be decided) into the analysis.

Computer-based project.

Required: Must have C++ experience (this is an essential requirement). The software package GEANT4 will be used. Prior experience with GEANT4 would be useful.

Supervisor : ***Prof H Kraus*** Physics Tel No : ***273361***
Email : ***h.kraus@physics.ox.ac.uk***

PP02 **Triggers for rare event searches**

Rare event searches, such as dark matter or double beta decay experiments generate a surprisingly large data set. Most of this is of course background events and calibration data. In addition, for reason of flexibility and cost reduction, an increasing amount of capability is, in modern experiments, implemented in software / firmware rather than in hardware. Digitization of data is performed at an early stage. To keep the data to be recorded within manageable amounts, sophisticated triggers have to be developed that allow recording of the interesting data, while discarding periods without signal. Robustness and reliability are key to the success of such readout. This project deals with the development of the triggers, the setting up of data simulators (partly done) to determine the efficiencies of the triggers and their reliability, and possibly carrying out small experiments for trying the triggers in a real experiment.

Computer-based project.

Required: Must have C++ experience (this is an essential requirement). Experience with the ROOT software package and/or data acquisition electronics would be useful.

Supervisor : ***Prof H Kraus*** Physics Tel No : ***273361***
Email : ***h.kraus@physics.ox.ac.uk***

PP03 **Investigation of dark matter annual modulation signal**

One way to search for dark matter is to look for an annual modulation in the event rate in an underground particle detector, correlated with the movement of the Earth through the dark halo of our galaxy. The DAMA dark matter experiment based in the Gran Sasso laboratory claim to have detected such a signal; but this has not been confirmed by other experiments, and is dismissed by some as a systematic effect. This project will involve investigating and modelling possible effects which could produce a radioactive background to mimic an annual modulation signal, such groundwater and cosmic ray muons. Some knowledge of C++ would be helpful.

Supervisor : ***Dr S Henry*** Physics Tel No : ***273458***
Email : ***s.henry@physics.ox.ac.uk***

PP04 &05 **Analysis of proton-proton collision data from the LHCb experiment at CERN**

The student will analyse data collected by the LHCb experiment at CERN, which allows study of the precise behaviour of beauty and charm hadrons. Such measurements are sensitive to the possible contribution of beyond-the-Standard-Model processes through the participation of new, heavy particles in loop-level processes.

Experience/skills: prior knowledge of C++ will be helpful

Supervisor : ***Prof G Wilkinson***
Physics Tel No : ***283110***
Email : ***g.wilkinson@physics.ox.ac.uk***

PP06 **Distance measurements using acetylene absorption features as a frequency standard for Frequency Scanning Interferometry (FSI)**

Conventional frequency scanning interferometry measures absolute optical path lengths by comparison with the known length of a reference interferometer. We aim to replace the expensive reference interferometer with a less expensive acetylene absorption cell that provides many well understood absorption features in the relevant wavelength range. The student will set up FSI interferometers and absorption cells and compare the two methods.

Special skills required:

A good grasp of undergraduate optics is needed. The experiments are controlled and read out using computers. For this purpose some LabView programs may have to be written or existing ones modified.

The analysis of the data is done using custom JAVA or Matlab software provided by the group which will need modifications and some extensions to suit the projects needs.

The above means that basic skills in computer programming are essential. Knowledge of JAVA or Matlab will be helpful and knowledge of another OO language will also help. The work involves lasers and is restricted to students who pass laser safety tests.

Supervisor ***: Dr A Reichold*** Physics Tel No ***: 273358***
Email: ***a.reichold@physics.ox.ac.uk***

PP07 **Comparison of acetylene and Rubidium absorption features using frequency scanning interferometry**

The MONALISA group has recently finished constructing a highly stabilised fibre laser that is frequency doubled and then locked against the absorption features of Rubidium using saturated absorption spectroscopy techniques. The base wavelength of the laser is in the 1550nm regime where acetylene provides other well understood absorption features. This experiment aims to verify our understanding of the acetylene features by comparing them to the Rubidium features. The student will use a tuneable laser, the highly stabilised laser and a reference interferometer to transfer the Rubidium frequency knowledge to the measurement of the acetylene absorption spectrum and compare the two frequency scales with each other. This experiment could also be used to provide an absolute length calibration for the reference interferometer.

Special skills required:

A good grasp of undergraduate optics is needed. Understanding of basic atomic physics is also advantageous. The experiments are controlled and read out using computers. For this purpose some LabView programs may have to be written or existing ones modified.

The analysis of the data is done using custom JAVA or Matlab software provided by the group which will need modifications and some extensions to suit the projects needs.

The above means that basic skills in computer programming are essential. Knowledge of JAVA or Matlab will be helpful and knowledge of another OO language will also help. The work involves lasers and is restricted to students who pass laser safety tests.

Supervisor ***: Dr A Reichold*** Physics Tel No ***: 273358***
Email: ***a.reichold@physics.ox.ac.uk***

PP08 Smith-Purcell radiation

Recent work at Oxford has confirmed that the measurement of the spectral distribution of coherent Smith-Purcell radiation can be used to determine the time profile of intense, highly relativistic electron bunches that are only a few picoseconds long. The work has recently been extended down to the femtosecond regime using the 20GeV electron beam of the FACET facility at SLAC. The student will work on the development of the data analysis code that is required for the analysis of the FACET experimental results. The basic form of the code already exists in Matlab and the student will concentrate on the investigation of the 'phase recovery' problem, which is essential for the accurate reconstruction of the bunch profile. Part of the student's time may be spent at the Diamond facility near Oxford.

Skills required: Knowledge of (or willingness to learn) Matlab. An interest in classical Electromagnetism would be an advantage.

Supervisors: ***Dr R Bartolini, Dr G Doucas*** and
Dr A Reichold
Physics Tel No : ***273301***
Email : ***r.bartolini1@physics.ox.ac.uk***

PP09 ATLAS Physics

The world's highest energy particle accelerator – the Large Hadron Collider (LHC), at CERN has just started operation at the high-energy frontier. Constructed in a 27 km long circular tunnel, 100 meters underground, it accelerates two counter-rotating proton beams and brings them into collision at center-of-mass energies of up to 14 TeV. By pushing the energy frontier by an order of magnitude above that previously accessible it offers unprecedented opportunities to explore the fundamental constituents of the universe.

The ATLAS detector measures the final products of proton-proton collisions at one of the two interaction points of the LHC. ATLAS aims to supply answers to the many of the most important fundamental questions of particle physics. For example ATLAS will also be able to discover (or disprove the existence of) the Higgs boson, the missing particle of the Standard Model which is thought to be responsible for the mass of the fundamental particles.

Although the Standard Model has been very successful it has known shortcomings – for example it does not explain the masses of the elementary particles; it cannot explain the matter-antimatter imbalance in nature; it gives no explanation of the Dark Matter in the universe; nor does it include gravity in its description of nature. Hence a primary goal of ATLAS is to explore physics of the Standard Model in the new energy regime and to discover new physics signatures beyond the Standard Model. Indirect evidence from colliders as well as cosmology suggest the existence of heretofore unknown physics at energy scales of approximately 1 TeV, which is well within reach of the LHC. Possibilities include Supersymmetry (SUSY) as well as models which posit the existence of additional spatial dimensions beyond our normal experience.

In addition, the LHC is a "factory" for W and Z bosons and top quarks, enabling not only systematic studies of their properties but also their use as precision tools to probe the deep structure of the proton and to guide searches for physics beyond the Standard Model.

Suggested material for further reading; this is not a requirement

• Particle Physics Detectors: Grupen, Claus (1996)

Particle Detectors, Cambridge Monographs on Particle Physics, Nuclear Physics and Cosmology), ISBN: 0521552168

• The Standard Model: Griffi ths, David J. (1987). Introduction to Elementary Particles. Wiley, John & Sons, Inc. ISBN 0471603864.

• SUSY: http://en.wikipedia.org/wiki/SUSY; Cooper, F., A. Khare and U. Sukhatme. "Supersymmetry in Quantum Mechanics." Phys. Rep. 251 (1995) 267-85 arXiv:hep-th/9405029: http://arxiv.org/PS_cache/hep-th/pdf/9405/9405029.pdf).

• Extra Dimensions and Microscopic Black Holes: http://www-pnp.physics.ox.ac.uk/~issever/Homepage/Papers/papers_extra.html

PP0901 Precise measurement of the W boson mass with the CDF detector

Prior to the discovery of the Higgs boson, its mass was predicted by precision measurements of electroweak parameters, including the W boson mass. The knowledge of this mass provides a key constraint in determining what might lie beyond the Higgs boson. Measuring the W boson mass with the full CDF data set will significantly reduce the current uncertainty on this quantity and further constrain the properties of new particles (or suggest their existence). This project will focus on reducing the important uncertainties in the measurement.

Supervisor : ***Dr C Hays*** Physics Tel No : ***283105***
Email : ***hays@physics.ox.ac.uk***

***PP0902* Measurement of Higgs boson production in decays to tau leptons**

The 2012 observation of a new resonance with properties consistent with that of a Higgs boson provides the first step in understanding the source of particle mass.

However, the observation has only directly probed the coupling of the Higgs boson to other bosons. A key prediction of the standard model of particle physics is that the Higgs boson couples to fermions in proportion to their masses. This prediction can be tested by observing and measuring Higgs boson decays to tau leptons. Using the full 2012 ATLAS data set, this project will contribute to a first observation and measurement of this process.

Supervisor : ***Dr C Hays*** Physics Tel No : ***283105***
Email : ***hays@physics.ox.ac.uk***

***PP0903* Measurement of W and Z boson production via vector-boson fusion**

In high-energy particle collisions, the incoming particles can radiate electroweak bosons, which then fuse to form a single boson such as a W, Z, or Higgs boson.

Measurements of Higgs boson production via vector-boson fusion (VBF) will provide important information on the coupling properties of the Higgs boson. There are numerous experimental challenges in such a measurement, and studies of VBF W and Z production can address these challenges with high-statistics data samples. In this project, one aspect of the measurement of VBF W and Z production using 2011 and 2012 ATLAS data will be investigated.

Supervisor : ***Dr C Hays*** Physics Tel No : ***283105***
Email : ***hays@physics.ox.ac.uk***

***PP0904* W Charge Asymmetry**

ATLAS has already acquired 1 pb-1 of data at 7 TeV which The charge asymmetry in W decays at the LHC is an interesting Standard Model measurement which can be used to determine the ratio of u/d quark distributions in the proton. The project has a theoretical component in that the asymmetry can be predicted based on the quark parton model and the patron distribution functions. The main part of the project would involve analysing ATLAS data to measure the W charge asymmetry. This would require development of the tools need to do physics analysis. This includes code to measure backgrounds and detector efficiencies and acceptances.

Supervisor : ***Dr T Weidberg*** Physics Tel No : ***273370***
Email : ***t.weidberg1@physics.ox.ac.uk***

***PP0905* Signatures of extra-dimensional models at the LHC**

The energy frontier soon to be opened by the Large Hadron Collider could probe spatial dimensions beyond the conventional three, as hypothesized in a number of extensions to the Standard Model of particle physics. Possible signatures include the production of exotic heavy quarks and quantum black holes and their decay to highly energetic final states. The student will investigate the characteristics of such signatures, their comparison with the Standard Model, and thus the potential for observing them in early LHC data. Data from the ATLAS detector will be used if available.

Supervisor : ***Dr J Tseng*** Physics Tel No : ***273398***
Email : ***j.tseng1@physics.ox.ac.uk***

***PP10* Search for neutrinoless double beta decay at SNO+**

SNO+ is an experiment designed to look for neutrinoless double beta decay in Neodymium and to study low energy solar and geoneutrinos. The experiment will use 1000 tonnes of liquid scintillator as the target loaded with around a tonne of Neodymium. The project will be to investigate the effect of low energy radioactive backgrounds on the sensitivity of the experiment. Some familiarity with C++ coding would be an advantage.

Supervisor : ***Prof S Biller*** Physics Tel No : ***273386***
Email : ***s.biller@physics.ox.ac.uk***

***PP11* Modelling and time profile reconstruction of femtosecond long electron bunches**

The ability to measure non-destructively the time profile of individual, femtosecond-long electron bunches is extremely important to modern accelerator science and will determine the speed of development of the future compact sources of coherent radiation. The demand for single-shot capability arises from the rapid developments in the field of laser-driven particle acceleration and Free Electron Lasers. One of the ways to measure such profiles is to use coherent Smith-Purcell radiation (cSPR) which is observed when a relativistic electron bunch passes over a metallic grating. As the electron bunch travels above the grating, its image charge on the grating's corrugated surface oscillates, resulting in the excitation of electromagnetic radiation over a broad frequency range. The grating disperses this radiation, allowing the measurement of the radiation spectrum (similar to a diffraction grating). The longitudinal bunch profile can then be reconstructed from the inverse Fourier transform of this spectrum.

You will be working in a dynamic group which collaborates with the Stanford Linear Accelerator Centre (SLAC), USA to measure cSPR at the FACET accelerator. The main tasks will be modelling of the SP phenomenon using 3D Particle in Cell codes, analysis of the accumulated data using a custom code package called Cauchy and comparison of the simulations with the data observed at SLAC.

Requirements:

This project will be a mix of electromagnetic theory and computer-based simulation and analysis and it requires an interest in Electrodynamics and Special relativity, Mathematical methods in Physics (Fourier Analysis) and Numerical Computing. Knowledge of a computer languages C as well as ability to use MATLAB would be an advantage.

Supervisor*s: **Dr I Konoplev, Dr G Doucas***
Physics Tel No ***: 273405***
Email ***: Ivan.Konoplev@physics.ox.ac.uk***

PP12 **Cosmic Ray Detector**

This project is about the development of a simple and cheap cosmic ray detector. This would be based on the readout of a small slab of scintillator with plastic fibres and a silicon photo-multiplier (SiPM). The SiPM is a new device which has high efficiency and does not require a high voltage (>50V) power supply. The student would develop code and procedures to calibrate the detector and the associated electronics. This could then be used for a lab measurement of the muon lifetime. A way of storing data locally or transmitting it would be developed. After this it could be flown on a balloon (there are regular balloon flights which we could use) to measure the cosmic ray flux as a function of height.

Supervisor : ***Dr T Weidberg*** Physics Tel No : ***273370***
Email : ***t.weidberg1@physics.ox.ac.uk***

Theoretical Physics projects

TP01 **Nonequilibrium evolution in quantum in many-body systems**

It has recently become possible in experiments on ultra-cold trapped atoms to measure the time evolution of many-particle quantum systems after imposing a local perturbation. Such perturbations prepare the system in a quantum state that is not translationally invariant and not an eigenstate of the Hamiltonian.

The goal of this project is to study the non-equilibrium time evolution of observables like the particle density theoretically for models of strongly correlated fermions and quantum spins.

The project is suitable for a mathematically able student taking the Theoretical Physics option and should provide an opportunity to learn about an area of active research. It will involve analytical calculations and probably some limited computing based on Matlab or Mathematica.

An introduction to the background theoretical ideas is given in Chapter 1 of Quantum Phase Transitions by S. Sachdev.

Supervisor : ***Prof F Essler*** Physics Tel No : ***273971***
Email : F***.Essler1@physics.ox.ac.uk***

TP02 **Topics in Geometry and Gauge/String Theories**

We present the student with a manageable (appropriate for a mathematically and theoretically inclined fourth-year), self-contained project in a specific problem in the realm of the interaction of geometry and gauge/string theory.

Topics have included finite graphs and field theory, Calabi-Yau manifolds and compactification, as well as modern geometrical aspects of the standard model from string theory.

The project will provide an opportunity for the student to some rudiments of, for example, differential geometry, field/string theory and advanced algebra.

Some programming experience (with C and mathematica/maple) most welcome.

Supervisor : ***Dr Y-H He*** Physics Tel No : ***273974***
Email : ***y.he1@physics.ox.ac.uk***

TP03 & 04 **Bacterial stirring**

This project will investigate how micron-scale swimmers and pumps, such as bacteria and cilia, mix the fluid that surrounds them. This process is important to enhance nutrient uptake, and there are (controversial) arguments that microorganisms provide a significant contribution to mixing the oceans that need to be better understood.

You will learn about Oseen tensor solutions to the Stokes equations and use them to map out the flow fields of swimming organisms. Details of the project will depend on the work currently in progress in my research group and the student will be co-supervised by a post-doc or senior graduate student. Two projects could be available, one analytical for a student keen on theoretical physics, one involving simulations for a student interested in computational physics.

Reading:

Life at low Reynolds number, E. M. Purcell, American Journal of Physics 45 3 (1977).

Lévy fluctuations and mixing in dilute suspensions of algae and bacteria, I.M. Zaid, J. Dunkel and J.M. Yeomans, J. Royal Soc. Int. (2011)

Enhancement of biomixing by swimming algal cells in two-dimensional films, K. Hyeseyin, J.S, Guasto , K.A. Johnson and J.P. Gollub, Proceedings Of The National Academy Of Sciences 108 10391 (2011)

Movies: http://www.rowland.harvard.edu/labs/bacteria/index_movies.html

Supervisor : ***Prof J Yeomans*** Physics Tel No : ***273992***
Email : ***j.yeomans@physics.ox.ac.uk***

TP05 **Active nematics**

Active systems produce their own energy. Examples range from molecular motors and suspensions of bacteria to flocks of birds or fish. Large numbers of active entities often form patterns, topological defects or states that look turbulent. It is not yet understood how much of this behaviour is generic and how much is specific to a particular active system.

The aim is to construct and study a simple continuum model of an active system to try to understand the pattern formation induced by the activity. This project would suit a student who enjoys theoretical work and is interested in understanding how differential equations can be used to describe natural phenomena.

Reading:

Soft Active Matter, M.C. Marchetti et al, arXiv:1207.2929

Stripe formation in differentially forced binary systems, C. M. Pooley and J.M. Yeomans, Phys. Rev. Lett. 93 184501 (2004).

Supervisor : ***Prof J Yeomans*** Physics Tel No : ***273992***
Email : ***j.yeomans@physics.ox.ac.uk***

TP06 **Twitching motility of bacteria near surfaces**

Bacteria move around using all kinds of ingenius mechanisms, and have an astonishing ability to adapt their motility strategy to the physical conditions of the environment. A number of bacteria (such as Pseudomonas aeruginosa) utilise a strategy that is termed as twitching motility, when they are settled on solid surfaces. This essentially amounts to catapulting many microscopic muscle fibres along random orientations until they hit a suitably stirdy anchor point, "measuring up" how things are along each of these, and deciding which way is best to proceed by pulling a bit more on the relevant muscle fibre and perhaps breaking off one or two fibres at the back (that will be retracted and prepared for the next catapult shot).

We aim to study this process by constructing a simple mechanical model that has the right ingredients in terms of the dynamics (elasticity, friction, noise), and examining analytical and numerical solutions of the simple dynamical equations (Langevin dynamics).

Supervisor : ***Prof R Golestanian*** Physics Tel No : ***273968***
Email : ***r.golestanian1@physics.ox.ac.uk***

_TP07_ Topological Insulators and the Dirac Equation

Electrical insulators, as is taught in an undergraduate conElectrical insulators, as is taught in an undergraduate condensed matter physics course, are materials in which the chemical potential for electrons lies within a band gap. Until very recently, it had been believed that this was pretty much the end of this story. In the last few years, however, it has been realised that there can be more than one type of electrical band insulator. The new types are called topological insulators and are different from ordinary ones in the sense that, although they are insulators within their bulk, they have electron states at their surface which can carry current. Several classes of materials are now known to be examples of this new type of insulator.

The aim of this project will be to examine some of the basic quantum physics of topo- logical insulators using simple models. The project is suitable for a mathematically able student who is interested in theoretical physics and should provide an opportunity to learn about an area of active contemporary research. The necessary condensed matter physics background is covered in B2. Knowledge from the theory option (C6) is not essential.

A short introduction is: C. L. Kane, Nature Physics, 4, 348 (2008). A review article is: M.Z. Hasan and C.L. Kane, Reviews of Modern Physics, to appear and available as arXiv:1002.3895 from http://arxiv.org

Supervisor : ***Prof J Chalker*** Physics Tel No : ***273973***
Email : ***j.chalker1@physics.ox.ac.uk***

_TP08_ Self-consistent models of our Galaxy with well-defined DFs

Galaxies should be thought of as probability distributions (of stars and WIMPS) in 3-d action space. We now have a very good idea what these distribution of stars and WIMPS should be for our Galaxy. The project would involve for the first time determining the 6-d phase-space distribution implied by the action-space distributions when Poisson's equation is invoked.

The project has a significant computational element and involces programming in C++.

Supervisor : ***Prof J Binney*** Physics Tel No : ***273979***
Email : ***j.binney1@physics.ox.ac.uk***

_TP09_ Exotic Quasiparticles in Condensed Matter Systems

We are used to the idea that in quantum mechanics all particles can be classified either as fermions or as bosons, but the arguments that lead to this conclusion in fact depend on the particles being free to move in three-dimensional space. Condensed matter systems may offer more types of particle: first, they often have particle-like excitations that are distinct from the electrons and nuclei of which the system is composed; and second, in some cases these excitations, or quasi-particles, are constrained to move in two dimensions. Research in this area is currently at a very interesting stage: it is confidently believed that exotic quasiparticles are present in some of the samples studied in labs today, and there are some plausible claims of sightings, but much remains open.

The aim of this project will be to understand some of this field and to do some basic calculations that illustrate some of the ideas. The project is suitable for an independently-minded and mathematically able student who is interested in theoretical physics, and should provide an opportunity to learn about an area of active contemporary research. It is essential that the student doing the project should take the theory option (C6).

Some background material, in order of increasing sophistication is: R. F. Service, Science

332 193-195 (2011); A. Stern, Nature 464, 187-193 (2010); F. Wilczek, Nature Physics, 5,

614 (2009); J. Alicea, arXiv:1202.1293 available from http://arxiv.org

Supervisor : ***Prof J Chalker*** Physics Tel No : ***273973***
Email : ***j.chalker1@physics.ox.ac.uk***

_TP10_ Calabi-Yau Manifolds

Six-dimensional Calabi-Yau manifolds play an important role in string theory. They are the spaces typically used to compactify 10-dimensional string theory to the four space-time dimensions we observe.

The goal of the project is to understand the mathematics of Calabi-Yau manifolds, to construct a certain class of such manifolds and analyze some of their properties relevant to string theory. The first part of the project involves learning the required mathematics, in particular complex differentiable manifolds and some basic algebraic geometry. In the second part, these methods are applied to a specific class of Calabi-Yau manifolds in order to determine their topological and symmetry properties.

If time permits, implications of the results for string compactifications may be discussed. The second part involves ``by-hand" calculations as well as computer work.

Special skills: strong background in theoretical physics and mathematical methods, willingness to learn new mathematics, genuine interest in the subject.

Supervisor : ***Prof A Lukas*** Physics Tel No : ***273953***
Email : ***a.lukas1@physics.ox.ac.uk***

_TP11 &12_ Understanding the biophysics of DNA nano-structures

The ability to design nanostructures which accurately self-assemble from imple units is central to the goal of engineering objects and machines on the nanoscale. Without self-assembly, structures must be laboriously constructed in a step by step fashion. DNA has the ideal properties for a nanoscale building block, and new DNA nanostructures are being published at an ever increasing rate. Here in the Clarendon the world-leading experimental group of Andrew Turberfield has created a number of intriguing nanostructures using physical self-assembly mechanisms. We have recently developed a new theoretical model of DNA that is complex enough to capture the dominant physics involved, but simple enough to be tractable In this project you would apply the model to study physics of a simple nanostructure. You will mainly be using computer simulations and theoretical calculations to study these processes. You can read more at http://dna.physics.ox.ac.uk

Supervisors : ***Dr A A Louis and Mr T Ouldridge***
Physics Tel No : ***273999***
Email : ***a.louis@physics.ox.ac.uk***

TP13 Bell Tests for Mode Entanglement

Entanglement is a strong nonlocal quantum correlation that is a necessary ingredient in many quantum communication and quantum information protocols. In systems of indistinguishable bosons entanglement often resides between localized regions of space (or modes) as opposed to between the particles themselves. While spatial mode entanglement of massive particles has still not been directly confirmed in experiments, in recent work we demonstrated that pairs of mode entangled systems can allow for violation of a Bell inequality similar to the well known CHSH inequality, thereby theoretically indicating entanglement is present in such systems. This theoretical project will be concerned with investigating possible extensions to this basic Bell test. For instance, how would the violation change if one considered fermionic particles instead of bosons and could one design a new Bell inequality that would allow for a higher violation than in the basic case. The student who undertakes this project will learn about entanglement, Bell inequalities and ultracold atomic systems.

Special skills: Excellent knowledge of Quantum Mechanics, interest in theoretical aspects of physics.

Supervisors ***: Prof D Jaksch*** **and** ***Dr L Heaney***
Physics Tel No ***: 272319, 272388***
Email ***: d.jaksch@physics.ox.ac.uk***
l.heaney1@physics.ox.ac.uk

TP14 Understanding reaction-diffusion systems using quantum algorithms

Some of the most intriguing properties of physical systems arise from strong interactions between their constituents. These interactions lead to strong correlations and complex real time dynamics. Well known classical examples are vehicular traffic flow, the spread of diseases, classical spin systems, queuing networks and reaction-diffusion systems. The latter are used to describe local chemical reactions between substances, and diffusion which causes these substances to spread in space. Two particle interactions also play an important role in quantum mechanics where they lead to entanglement and can be exploited for quantum information processing. Based on recent insights into the structure of entanglement efficient numerical algorithms have been developed for simulating the time-evolution of strongly correlated quantum systems in one spatial dimension. The aim of this project is to adapt these quantum algorithms to classical strongly correlated systems. In particular this project will study how the concentration of substances is dynamically distributed in space through diffusion and in the presence of chemical reactions. Finally, if some time is left, the project will also aim to apply the quantum algorithms to simulating thermodynamic properties of classical spin systems in two spatial dimensions.

The student should have a good knowledge of quantum mechanics and the basics of quantum information processing. Knowledge in condensed matter physics will be of advantage. A good computing ability and knowledge of Matlab are essential.

Supervisors ***: Prof D Jaksch*** **and** ***Dr S Clark***
Physics Tel No ***: 272319, 272388***
Email ***: d.jaksch@physics.ox.ac.uk***
s.clark1@physics.ox.ac.uk

TP15 Made-to-measure N-body models of galaxies

A fundamental problem in galaxy dynamics is inferring a galaxy's mass distribution (visible matter plus unseen, dark matter) from samples of stellar positions and velocities. This is usually tackled by breaking it into two steps: (i) make a guess for the mass distribution and calculate the corresponding potential (easy); (ii) find the distribution of orbits in that potential that best matches the observed sample and use this to calculate the likelihood of the guessed potential (not easy). The issue of *what* mass distributions to try in step (i) is left open.

An alternative is to try to fit the potential and orbit distribution simultaneously, for example, by adjusting a live N-body model on the fly. This purpose of this project is to investigate schemes for carrying out this adjustment, testing them against simple model galaxies.

Supervisor ***: Dr J Magorrian*** Physics Tel No ***: 273993***
Email ***: j.magorrian@physics.ox.ac.uk***

TP16 Non-axisymmetric tokamak plasma equilibrium and stability

A significant increase in global energy demand over the long term has been predicted and concerns about global warming also mean that future energy sources should be low carbon. Controlled nuclear fusion could be a future large scale source of low carbon energy. A tokamak is a device that seeks to contain a plasma of hydrogen isotopes in a magnetic field sufficiently long for fusion reactions to occur. Traditionally tokamaks have an axisymmetric magnetic geometry however it has been discovered experimentally that a small non-axisymmetric field can mitigate or even suppress instabilities at the edge of the plasma called Edge Localized Modes (ELMs). ELMs have the potential to cause significant damage to a future fusion power plant and so understanding how to control them is important. Theoretical understanding of ELMs is still developing and this project will look at how non-axisymmetric magnetic fields can influence ELMs.

A magnetohydrodynamic (MHD) model of the plasma will be assumed. The student may use computer codes to calculate non-axisymmetric plasma equilibrium states and then test the stability of these equilibria. These numerical results can then be compared to experimental results. The student may alternatively investigate equilibrium and stability by solving the equations with perturbation methods.

Further information: www.ccfe.ac.uk

Wesson J "Tokamaks" Oxford University Press, 2004

I T Chapman et al. Plasma Phys. Control. Fusion 54 105013 (2012)

Supervisors ***: Dr C Ham, Dr A Schekochihin***
Tel: ***01235 466535***
Physics Tel No ***: 273980***
Email ***: christopher.ham@ccfe.ac.uk***, ***a.schekochihin1@physics.ox.ac.uk***

TP17 Turbulence and fluctuation measurements in view of transport analysis in JET, the world's largest fusion reactor

JET is based in Oxfordshire and is the world's largest fusion reactor (The Joint European Torus, a tokamak) and the most important device in preparation for ITER. Currently ITER is under construction near Aix en Provence in the south of France and will be the first burning plasma device where we aim to produce a fusion output power which equals tenfold the applied heating power (Q=10). In order to achieve this goal we need to obtain a plasma confinement quality in ITER which equals H98=1. The energy confinement factor H98 is obtained from a multi-device confinement scaling database and is based on a simple regression of the obtained energy confinement factors in more than 10 tokamak devices.

Using this 'scaling law' for predicting the performance in ITER is risky as it is based on an extrapolation to a device that has ten times the plasma volume of JET. In order to improve the prediction of the ITER performance we need to understand the underlying particle and heat transport processes that drive the energy loss. These transport processes are predominantly of a turbulent nature and developing a fundamental understanding of these is key to developing a successful model for energy confinement for future fusion reactors. The Oxford group led by Dr Alex Schekochihin is specialised in studying turbulent transport processes.

The aim of this project is to amalgamate the theoretical understanding of the group in Oxford with the experimental expertise of the physicists at JET.

JET is equipped with a new suite of turbulence and fluctuation measurement systems. These systems are based on microwave technology as well as diagnostic beam technology. A brief description of the available systems, including weblinks for more back-ground reading, is available on request.

The student will learn to understand the measurement capabilities of the new diagnostic systems and will investigate which transport physics processes can be studied. This project should be seen as a kick-off of a hopefully fruitful collaboration between JET and the Oxford Plasma Theory Group and as such will have high impact. The work will be carried out within the international environment of the JET project and supervision will be carried out by both JET and Oxford scientists.

Supervisors ***: Dr M Beurskens, Dr A Schekochihin***
Tel: ***01235 464532***
Physics Tel No ***: 273980***
Email***: Marc.Beurskens@ccfe.ac.uk***, ***a.schekochihin1@physics.ox.ac.uk***

An example of typesetting a project report

Candidate Number: 99998
Word Count: 9876

INT67: A Project Report

Supervisor: Professor A. Lecturer

The Abstract will provide a short summary of your work to enable others to judge quickly if it covers material which they consider important or are otherwise interested in reading.

This documents explains what the Examiners will look for in your project report, and how it should be written.

Introduction

The projects on offer inevitably differ greatly in their scientific potential, and any genuine research project can simply fail to work out: research is about probing the unknown, so unpleasant surprises can be encountered. Consequently, the Examiners cannot base their assessment of your report on the quality of the science that you do in your project. Rather they will assess the efforts you made to come to grips with a scientific problem, and the clarity and completeness of your exposition of the problem and what you have learned from it. It is through reading your report that they will make this assessment, so understanding that is not apparent in the report will gain you no credit. You must therefore strive to make the report the clearest piece of scientific writing possible.

Target audience

When writing it is always important to know what audience you are trying to reach. Your report should be aimed at a physicist who has not worked in the area of your project. For example, if your project is about high-energy physics, imagine that your reader works on laser physics, if your project is in condensed-matter physics, imagine that your reader is an astrophysicist. You won't go far wrong if you imagine that your report is being read by one of your abler contemporaries.

The genre

Although different fields and journals have slightly different styles, scientific papers nearly always conform to the following pattern. The Introduction describes the background to the problem that the paper addresses: what the problem is, how it came to the attention of the community, why the problem is interesting, what significant work has been done on it, and what questions remain open. Finally, the Introduction says how the paper advances the field and explains the paper's layout. The sections that follow describe, in order, methods, data, results and their interpretation. The final section starts by summarizing the paper's achievements and goes on to speculate on their significance for the wider field, and to indicate what further work would be profitable. The concluding section is invariably followed by a list of references, after which there may be one or more appendices, to which important but tedious details, or peripheral results, are relegated. The Abstract and figures are the most important parts of a paper, as they are the only parts many readers of a paper will look at. They help to draw readers in to the other sections. If the Abstract and figures are interesting, one often scans the Introduction, paying particular attention to the last part, and then moves to the first part of the Conclusions. The middle sections are often only read much later, if at all. Your report should be structured like a paper. Go into the RSL or online and browse through some journals such as *Physical Review Letters*, or *Monthly Notices of the Royal Astronomical Society* and study the structure of a few papers. Be aware, however, that many papers are targeted at quite narrow audiences so they tend to have much shorter Introductions than your report will require; the acid test is, will your target readership understand what the problem is, and why it's worth addressing? At the end of this document we list some classic, highly cited papers that are worth analyzing from a structural viewpoint.

Figures

You should take great care choosing and structuring your figures. They are the most memorable part of a paper, and the best help a paper can have to become a highly cited paper - the holy grail of scientific life - is to contain figures that reviewers choose to show at meetings and colloquia. Things to think about include: can I combine these two figures into one? is this figure too busy? are all the lines and data points clearly labelled? is the figure big enough? would the labels on the axes be clearly visible from the back of a lecture theatre when the figure was shown by a reviewer? would plotting the data in an entirely different way make a stronger

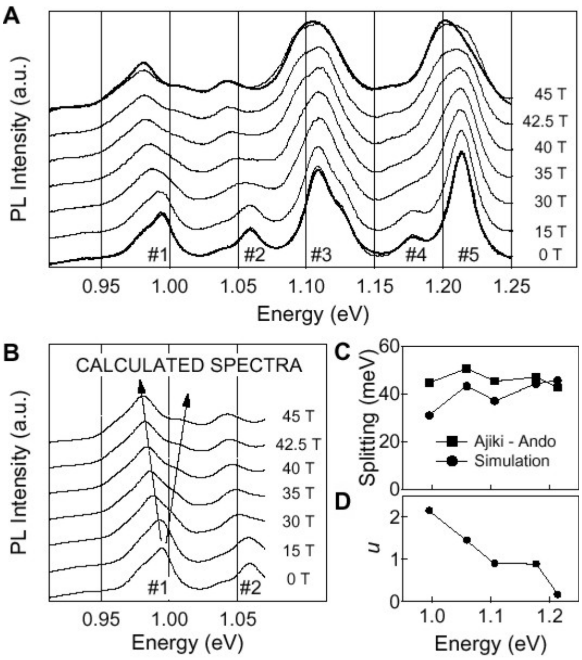

Figure 1: A complex figure which displays a substantial amount of information quite efficiently, but requires a long and well organised figure caption (Zaric et al., Science, **304** 5674 (2004)).

impact?

Citations

Statements about prior work and results used must be supported by references to a bibliography, and the sources of any borrowed figures or tables must be cited. Acknowledgment of sources will protect you from a charge of plagiarism, which the Proctors

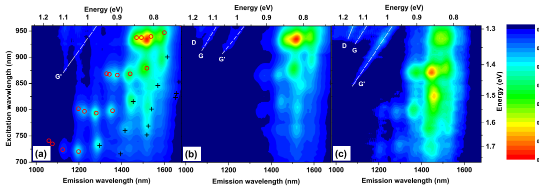

Figure 2: An overcomplicated figure which has been reduced to such an extent that it is no longer useful.

consider a serious offence.

Page-limit

Scientists more often than not write to a restrictive page limit - for example Letters journals generally restrict papers to 3 - 5 pages, and the Case for Support in a research grant application is often of similar length even though it is asking for well over £100k of funding. Imposing a tight page limit not only saves paper and readers' time, but can also increase clarity by forcing the writer to focus on the key points and to present only the key data. Since the restriction is one of overall space, the writer is forced to consider the relative benefits of a figure, or a paragraph of text, or a table. Together the text and figures of an MPhys report must not occupy more than 4,500 cm^2 of paper and the fontsize used for the main text may not be smaller than 11pt and the distance between successive baselines must be at least 4 mm (13pt). The bibliography and appendices may extend beyond the 4,500 cm^2 area, but the Examiners will not normally read them. The report must be printed on A4 paper. You may use any word-processing package, but the LaTeX documentclass "proc" used in the document

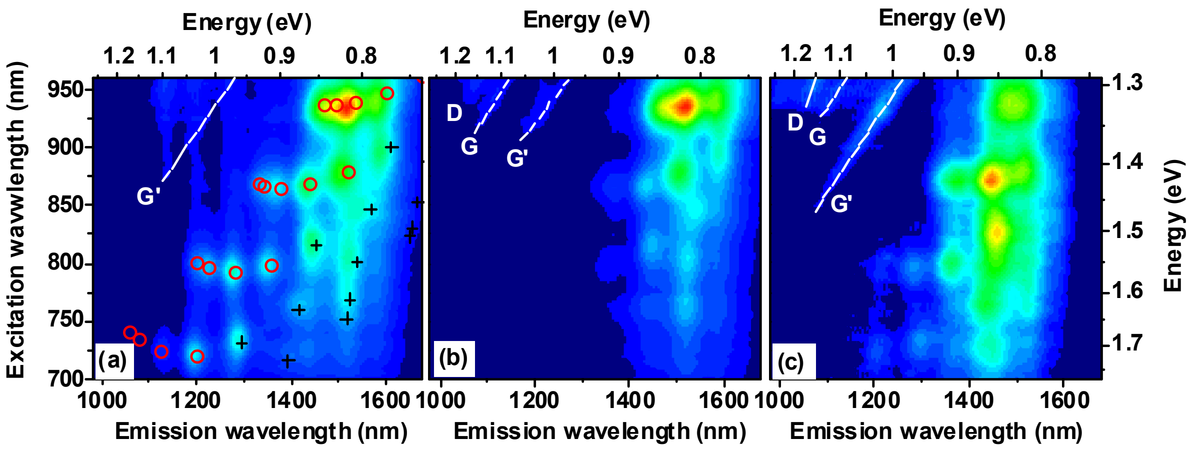

Figure 3: An improved version of Figure 2 which allows you to present a large amount of complex data in a relatively small area. Such a figure will need a substantial amount of explanation in both the figure caption and the text and would be almost meaningless if printed out on a black and white printer.

Typesetting a Report conforms to these when the report is approximately 12.3 pages long. If all available space were used for text, the report would contain about 10,000 words. If you use 11pt type and the full width of A4 paper, you should consider using a double-column format to avoid the difficulty a reader's eyes have in scanning long lines of small type.

Assessment

The form used to grade reports is published at *http://www.physics.ox.ac.uk/teach/exammatters.htm*.

References

Some classic papers.

1) Bachilo, S.M, Strano, M.S., et al., 2002, *Structure-Assigned Optical Spectra of Single-Walled Carbon Nanotubes*, Science, 298, 2361

2) Davies, R.L., Efstathiou, G., Fall, S.M., Illingworth, G., & Schechter, P.L., 1983, *The Kinematic Properties of Faint Elliptical Galaxies*, ApJ, 266, 41.

3) Guth, A., 1980, *Inflationary Universe* ...., Phys.Rev.D, 23, 347

4) Press, W.H. & Schechter, P., 1973, *Formation of Galaxies* ...., ApJ, 187, 425

Check list for resources

This checklist should be used to document that you have searched **scientific sources** of information for your research project.

--PROJECT TITLE: CANDIDATE NUMBER: DATE:

RESEARCHING FOR YOUR PROJECT OR DISSERTATION

SEARCH CHECKLIST

Resource name	**Period of time searched**	**Searched, Not searched, N/A**	**Search Results No of references**
Core databases			
INSPEC			
Compendex EI (Engineering Index)			
Additional databases			
Chemical Abstracts –			
High Technology Research			
Solid State and Super-conductivity Abstracts (CSA)			
Energy Citations Database			
Geobase			
MathSciNet			
Metadex (CSA)			
Scopus – Elsevier Service			
Web of Knowledge –			
Electronic journals			
Oxford University e-journals			
DOAJ			
ArXiv.org			
ZETOC			
Dissertations			
Dissertation Abstracts Online			
Index to Theses			
Library Catalogues			
Internet Gateways			
AstroWeb			
Intute Physics Gateway			
High Energy Physics			

This checklist should be used to document that you have searched **scientific sources** of information for your research project.

Physics Web			
The PubChem Project-NCBI			
NIST National Institute for Standards and Technology			
PhysMathCentral			
Other sources			

SEARCH STRATEGY

Please provide the search strategy you used to search bibliographic databases. Describe your research topic using subject headings, controlled vocabulary terms, index terms, CAS number, and keywords.

No	***List of Keywords***	***Combined*** ***Not combined*** ***N/A***
1		
2		
3		
4		

Indicate how you combined keywords into a search strategy
(e.g using Boolean Operators AND, OR, NOT).

KEEPING YOUR REFERENCES

Indicate the method you used to keep your references:

Display			
Save			
E-mail			
Export to	RefWorks:	ENdNoteWeb:	EndNote:

Additional information:

Please use this space to describe inclusion or exclusion criteria you used when selecting articles for your bibliography; any observations related to type of publications, number of retrieved references, quality of research articles;

Examples of Risk Assessments

An example of Risk Assessment for an experimental undergraduate project

RISK ASSESSMENT – Experimental undergraduate project

Dear Supervisor

The Safety Office requires that all undergraduate projects have an individual Risk Assessment. Below is a template of the risk assessment for an experimental project. You must fill in the areas indicated or clearly state that the hazard is not relevant to the student's project. We have provided a sample risk assessment matrix (wherever) to help you to assess the risks involved.

DEPARTMENT: **Sub-Department:**

NAME OF PROJECT SUPERVISOR(S):

DATE OF ASSESSMENT: **REVIEW DATE:**

Hazard (Cause and consequences)	Affected groups	Existing Controls	Risk	Further action	Emergency Action
Display Screen Equipment (DSE) – injury from inappropriate arrangements	Staff, academic visitors, students	Undergraduate students are provided with basic induction and information for correct DSE use, with examples of good and bad practice. The following handouts will be made available to students at their Project Safety lecture before starting their projects: (a) Seating and Posture for typical office tasks. (b) Some practical points to consider when using portable computers.	Low	None required.	

Slips/trips/falls - injury	Staff, academic visitors, students	The standard precautions taken for everyone in the Physics Buildings.	Low	None required.	
Out of hours working – threat to personal safety and lack of help in case of illness or injury	Staff, academic visitors, students	**TO BE COMPLETED BY THE SUPERVISOR**	**TO BE COMPLETED BY THE SUPERVISOR**	**TO BE COMPLETED BY THE SUPERVISOR**	**TO BE COMPLETED BY THE SUPERVISOR**
Fire - potential for loss of life, property and research materials.	Staff, academic visitors, students cleaners, contractors	No flammable materials stored on site. Waste cleared daily, no significant ignition sources. Fire alarm tested weekly and maintained by approved contractor. Escape routes clearly signed and kept clear. Fire extinguishers, alarm and emergency lighting systems maintained by approved contractor. Fire drills held annually and staff apprised of fire action at safety induction. Students are made aware of fire procedures in their work area.	Low	Supervisors must explain local fire evacuation procedures to students.	Raise alarm if necessary by dialling 999, then follow standard departmental fire evacuation procedure
Noise - potential for hearing damage due to exposure to noise.	Print room staff, occasionally students.	Photocopiers are new machines with reduced noise emissions and are regularly maintained. Old printing presses are considered 'noisy' although noise emissions measured at < 80dB. No regular maintenance is undertaken – breakdown cover only. Plans to scrap machines in next two years.	Medium	Ensure presses receive a full service to eliminate spurious sources of noise. Monitor performance to ensure the emissions do not exceed 80dB until machines are scrapped. Review if additional machines introduced.	Contact safety office if there are problems with excessive noise
Lifting and carrying –	students	**TO BE COMPLETED BY THE**	**TO BE**	**TO BE COMPLETED BY**	**TO BE**

inappropriate technique or load causing injury		**SUPERVISOR**	**COMPLETED BY THE SUPERVISOR**	**THE SUPERVISOR**	**COMPLETED BY THE SUPERVISOR**
Travel related to project – threats to personal safety, loss of valuables.	students	**TO BE COMPLETED BY THE SUPERVISOR**	**TO BE COMPLETED BY THE SUPERVISOR**	**TO BE COMPLETED BY THE SUPERVISOR**	**TO BE COMPLETED BY THE SUPERVISOR**
Hazardous substances – e.g. chemicals	Staff, academic visitors, students cleaners, contractors	**TO BE COMPLETED BY THE SUPERVISOR**	**TO BE COMPLETED BY THE SUPERVISOR**	**TO BE COMPLETED BY THE SUPERVISOR**	**TO BE COMPLETED BY THE SUPERVISOR**
Use of lasers – eye damage	Staff, academic visitors, students cleaners, contractors	**TO BE COMPLETED BY THE SUPERVISOR, DEMONSTRATING THAT DEPARTMENTAL LASER SAFETY PROCEDURES ARE IN PLACE**	**TO BE COMPLETED BY THE SUPERVISOR, DEMONSTRATING THAT DEPARTMENTAL LASER SAFETY PROCEDURES ARE IN PLACE**	**TO BE COMPLETED BY THE SUPERVISOR, DEMONSTRATING THAT DEPARTMENTAL LASER SAFETY PROCEDURES ARE IN PLACE**	**TO BE COMPLETED BY THE SUPERVISOR**
Use of radioactive materials – life threatening conditions	Staff, academic visitors, students cleaners, contractors	**TO BE COMPLETED BY THE SUPERVISOR, DEMONSTRATING THAT DEPARTMENTAL RADIOACTIVITY SAFETY PROCEDURES ARE IN PLACE**	**TO BE COMPLETED BY THE SUPERVISOR, DEMONSTRATING THAT DEPARTMENTAL RADIOACTIVITY SAFETY PROCEDURES ARE IN PLACE**	**TO BE COMPLETED BY THE SUPERVISOR, DEMONSTRATING THAT DEPARTMENTAL RADIOACTIVITY SAFETY PROCEDURES ARE IN PLACE**	**TO BE COMPLETED BY THE SUPERVISOR**

Use of hand and machine tools		TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR
Cryogenics including liquid refrigerants		TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR
Pressure systems		TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR
Compressed gases and gas cylinder		TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR
Ultraviolet lamps		TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR
Glassware and sharps		TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR
Use of electrical or electronic equipment including high voltage		TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR	TO BE COMPLETED BY THE SUPERVISOR

Any additional risks associated with the project to be completed by the supervisor.

An example of Risk Assessment for Computer-based undergraduate projects

RISK ASSESSMENT – Computer-based undergraduate projects ONLY

Dear Supervisor

The Safety Office requires that all undergraduate projects have an individual Risk Assessment. We appreciate that for theoretical physics projects the risks may be minimal but it is important that the risk is assessed by each supervisor. Below is a template of the risk assessment for a computer based project. As we anticipate that the main risk will be out of hours working we do require you to assess the local area arrangements to ensure that any risks from out of hours working are low. Any work carried out in a laboratory will require an additional risk assessment.

DEPARTMENT: Physics **Sub-Department:**

NAME OF PROJECT SUPERVISOR(S)

DATE OF ASSESSMENT: **REVIEW DATE:**

Hazard (Cause and consequences)	Affected groups	Existing Controls	Risk	Further action	Emergency Action
Display Screen Equipment (DSE)	Staff, academic visitors, students	Undergraduate students are provided with basic induction and information for correct DSE use, with examples of good and bad practice. The following handouts will be made available to students at their Project Safety lecture before starting their projects: (a) Seating and Posture for typical office tasks. (b) Some practical points to consider when using portable computers.	Low	None required.	

Slips/trips/falls	Staff, academic visitors, students	The standard precautions taken for everyone in the Physics Buildings.	Low	None required.	
Out of hours working	Staff, academic visitors, students	**TO BE COMPLETED BY THE SUPERVISOR**	**TO BE COMPLETED BY THE SUPERVISOR**	**TO BE COMPLETED BY THE SUPERVISOR**	**TO BE COMPLETED BY THE SUPERVISOR**
Fire - potential for loss of life, property and research materials. Subject to UPS S10/07.	Staff, academic visitors, students cleaners, contractors	No flammable materials stored on site. Waste cleared daily, no significant ignition sources. Fire alarm tested weekly and maintained by approved contractor. Escape routes clearly signed and kept clear. Fire extinguishers, alarm and emergency lighting systems maintained by approved contractor. Fire drills held annually and staff apprised of fire action at safety induction. Students are made aware of fire procedures in their work area.	Low	Supervisors must explain local fire evacuation procedures to students.	Raise alarm if necessary by dialling 999, then follow standard departmental fire evacuation procedure
Noise - potential for hearing damage due to exposure to noise. This topic is subject to policy UPS S1/06.	Print room staff, occasionally students.	Photocopiers are new machines with reduced noise emissions and are regularly maintained. Old printing presses are considered ‘noisy’ although noise emissions measured at < 80dB. No regular maintenance is undertaken – breakdown cover only. Plans to scrap machines in next two years.	Medium	Ensure presses receive a full service to eliminate spurious sources of noise. Monitor performance to ensure the emissions do not exceed 80dB until machines are scrapped. Review if additional machines introduced.	Contact safety office if there are problems with excessive noise

Any additional risks associated with the project to be completed by the supervisor.

Risk Matrix		Likelihood			
		High	Medium	Low	Negligible
Consequences	Severe	High	High	Medium	Effectively zero
	Moderate	High	Medium	Medium/low	Effectively zero
	Insignificant	Medium/low	Low	Low	Effectively zero
	Negligible	Effectively zero	Effectively zero	Effectively zero	Effectively zero

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Appendix A

Project Allocation: CHOICE FORM

Please make your 8 project choices. It is important that you list your choices in order of preference, 1 being the highest and 8 lowest. Each project is listed using its own unique identifier, e.g. **AS1**.

If you wish to add any further information to assist in the allocation process please add a **brief** comment to the back of this form. **You will be contacted by e-mail if you are required to make further choices.**

Are you doing Physics and Philosophy?......................I'm doing the following Major Options: ....

....

Return the form to the Physics Teaching Faculty, Clarendon Laboratory
Deadline: Friday 2nd week, 3.00 pm of Michaelmas Term 2012.

Name: ....

College: ....

MPhys Project

1. First Choice
Project Title: ....

.... Project Number: .... Supervisor: ....

2. Second Choice
Project Title: ....

.... Project Number: .... Supervisor: ....

3. Third Choice
Project Title: ....

.... Project Number: .... Supervisor: ....

4. Fourth Choice
Project Title: ....

.... Project Number: .... Supervisor: ....

5. Fifth Choice
Project Title: ....

.... Project Number: .... Supervisor: ....

6. Sixth Choice
Project Title: ....

.... Project Number: .... Supervisor: ....

7. Seventh Choice
Project Title: ....

.... Project Number: .... Supervisor: ....

8. Eighth Choice
Project Title: ....

.... Project Number: .... Supervisor: ....

RISK ASSESSMENT ACKNOWLEDGEMENT FORM

MPhys Projects 2012-2013

I confirm that I have attended the Compulsory Project Safety Lecture ☐

I have completed a project risk assessment with my supervisor(s) ☐

Name ……………………………………………………..…………………

College ………………………………………………………..…..………..

Project Number (e.g. A&L01): ……………………………

Title of project: ……………………………………………………………….

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

Supervisor: ……………………………………………………………….

……………………………………………………………………………………...

Student Signature: ……………………………………………………………..

Supervisor Signature: ………………………………………………………

Date: ……………………………………………………………

This form **must** be returned to the **Teaching Faculty Office before** starting the project
Deadline is Friday 1st week of Hilary Term

A **copy** will be sent to the **Safety Office, Denys Wilkinson Building**

MPhys Project Draft Form
2012 - 2013

The completed form confirms that your supervisor has **seen a draft** of your project report

To be completed by the student:

Name of student ....

College ....

Project Number (e.g. AS1) and **Title** of Project ....

....

....

....

Signed ....

Date ....

To be completed by the Supervisor:

Supervisor ....

Signed ....

Date ....

Please return this form after both you and your supervisor have completed it to the Physics Teaching Faculty, Clarendon Laboratory.

Appendix D

FINAL HONOUR SCHOOL OF PHYSICS

DECLARATION OF AUTHORSHIP

[This certificate should be completed and placed in a sealed envelope, bearing on the outside your examination number only, addressed to the Chairman of the Examiners, Honour School of Physics and taken by hand to the Examination Schools in the High Street **Monday 12.00 noon of 1st week of Trinity Term**]

Name (in capitals): **Candidate number:**

College (in capitals): **[Supervisor/Adviser:]**

Title of [thesis/extended essay] (in capitals):

Word count: _________

Please tick to confirm the following:

I am aware of the University's disciplinary regulations concerning conduct in examinations and, in particular, of the regulations on plagiarism. ☐

The [thesis/extended essay/project] I am submitting is entirely my own work except where otherwise indicated. ☐

It has not been submitted, either wholly or substantially, for another Honour School or degree of this University, or for a degree at any other institution. ☐

I have clearly signalled the presence of quoted or paraphrased material and referenced all sources. ☐

I have acknowledged appropriately any assistance I have received in addition to that provided by my [supervisor/adviser]. ☐

I have not sought assistance from any professional agency. ☐

The report conforms to the requirements defined in the *MPhys Projects Handbook 2012-2013.* ☐

I have had regular meetings with my supervisor or deputy during the project period. ☐

A draft of my report has been seen by my supervisor. ☐

I am submitting my report in electronic and in hard copy. Both the electronic and hard copies of the report are identical. I agree that my work being checked using 'Turnitin' software for plagiarism and confirm my word count.

Candidate's signature: …………………………………………….. *Date* …………………………