



Photo: Alan Segar

2011 - 2012

Physics



MPhys Projects Handbook

2011-2012



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 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 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 candi-*

date 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 cm² 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 cm² 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 10 - 12 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 cm² 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

In week 9, 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 B**) 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.

Submitting your report 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 of size A4 or larger:

- (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 must be clearly written in the top right corner of the envelope. You can obtain your candidate number from your confirmation of entry, or online via student self service.

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

Go to the reception desk in the Examination Schools' main hall, and obtain a receipt form (candidates with dyslexia should obtain an additional cover sheet). 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.

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 your report you will be handed a receipt. Outside these hours work cannot be receipted, since staff will not be present.

Monday 12 noon of 1st week of Trinity Term 2011 is the deadline for submission of your project.

Note: It is the responsibility of each candidate to ensure that he or she hands in all the material he or she wishes to be considered by the examiners and to comply with the regulations relating to the submissions of the written work such as dissertations, essays and project reports. Once a candidate has submitted a piece of written work he or she may not withdraw that piece of work and substitute a revised version in the same examination without Proctors' consent.

Penalties for late submission of work

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 2011**. 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.

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 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 2011.

Weightings for the MPhys

The Examiners are responsible for the detailed weightings of papers and projects but guidance from the Academic Committee suggests the following relative weightings for the papers in the different parts of the MPhys examination.

After Part C of the MPhys, candidates will be ranked on the basis of a total mark that is obtained by adding the scaled marks (0-50 for short options, 0-100 for the papers) of individual elements multiplied by the following weightings.

MPhys

Each Part A paper (3)	0.70
Part A Short Option	0.35
Part A Practicals*	0.70
Each Part B paper (3)	1.00
Part B Short Option	0.50
Part B Practicals**	1.00
Each Part C Major Option (2)	1.50
MPhys Project	1.75

*Part A half practicals 0.35 plus second short option 0.35

**Part B half practicals 0.5 plus second short option 0.5

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 Innovation in software an 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; [§]new prize

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 ^{57}Fe ” 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 anisotropic 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 Achilles Kapanides.

Project Prize winners in 2009- 2010

(a) Merlin Frederick Wilmot Cooper, Corpus Christi College, won 'The Gibbs Prize for the best use of experimental apparatus in a MPhys project'. Project title: "Balanced Homodyne detection for Pulsed Optical Homodyne Tomography" supervised by Dr Brian Smith.

(b) Vassilis Pandis, Mansfield College, won 'The BP Prize for the best final year Theoretical Physics Project'. Project title: "Multi-gluon radiation in Higgs hadroproduction" supervised by Dr Francesco Hautmann.

(c) Philip David Hall, Wadham College, won 'The Johnson Memorial Prize for a project in Astrophysics'. Project title: "The Redshift Dependence of the Gamma-Ray Burst Rate" supervised by Prof Philipp Podsiadlowski.

(d) Peter Alan Gazzi Watson, Wadham College, won

'The Johnson Memorial Prize for a project in Atmospheric, Oceanic and Planetary Physics'. Project title: "The effect of recovery in stratospheric ozone concentrations on southern hemisphere winds in the climateprediction.net experiment" supervised by Dr Myles Allen and colleagues.

(e) Thomas Stephen Williams, Corpus Christi College, "won 'The John Thresher Prize for a project in Particle and Nuclear Physics'. Project title: "W and Z cross section ratio" supervised by Dr Tony Weidberg.

(f) Christopher James Ballance, Somerville College, won 'The Oxford Lasers Prize for a project in Optical Physics'. Project title: "Methods for Measuring and Manipulating Quantum States of Light" supervised by Dr Axel Kuhn.

(g) Saman Ghannadzadeh, Lincoln College, won 'A prize for a project in Condensed Matter Physics'. Project title: "MBE growth and characterisation of epitaxial FePt/mgO/FePt perpendicular magnetic tunnelling junctions" supervised by Dr Roger Ward.

(h) Tristan J Irvine, St John's College, won 'The Data Connection Prize for the best use of Software in a MPhys Project'. Project title: "Wii-remote control software for n-body visualisation and virtual navigation" supervised by Dr Kristian Zarb Adami.

(i) Steven N Ball, Brasenose College, won 'The Rolls-Royce Prize for Innovation' Project title: "Measurements and Modelling of Thermal Response of High Temperature Superconducting (HTS) Coils" supervised by Dr Ziad Melhem and Prof Harry Jones.

(j) Andrew J Garner, St Edmund Hall, won 'The Tessella Prize for Innovation in software'. Project title: "Simulations of the interactions of a laser with an electron beam" supervised by Dr Nicolas Delerue.

(k) Alexandru Dafinca, Merton College, won 'The Winton Capital Prize for the Best MPhys Research Project'. Project title: "Radiative corrections to QCD splitting kernels and LHC Phenomenology" supervised by Dr Francesco Hautmann.

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 2011

Week 0	Distribution of the <i>MPhys Projects Handbook</i>	Colleges
Week	Compulsory Safety Lecture Failure to attend means that the project cannot be started. Final Risk Assessments to be completed and project period starts. Completion and submission of your <i>Risk Assessment</i> form. You will NOT be allowed to start your project if have not completed and submitted your <i>Risk Assessment</i> form to the Physics Teaching Faculty .	Please consult the lecture list for details

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 <i>Project Choice Form</i> (see Appendix A) [Hand in the <i>Project Choice Form</i> by internal post or by e-mail] Late submission may result in a project being chosen for you	Physics Teaching Faculty
Week 5 (Fri)	Publication of the Project Allocation List [e-mail notification]	http://www.physics.ox.ac.uk/teach
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 2012

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 (Fri)	Hand in a draft (as complete as possible) of MPhys report to your supervisor. You and your supervisor must complete and sign the <i>MPhys Draft Form</i> (see Appendix A).	
Week 10	Deadline for receiving comments from supervisor.	

Trinity Term 2012

Week 1 (Mon 12 noon)	MPhys project reports handed in. 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.)	Examination Schools
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*subject to change, see lecture list

Timetable for supervisors

Early Michaelmas Term 2011

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 2011

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 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.

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 2012

Week 1 **MPhys students** should complete safety requirements and risk assessments, undertake any necessary computer training and preparatory reading. You should keep the completed *Risk Assessment* form.

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 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 Comments by supervisor on draft report is given to the student.

Trinity Term 2012

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 Projects Safety lecture and complete the *Risk Assessment form* with the supervisor. **Return the completed Risk Assessment form to the Teaching Faculty.**
- 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.
- 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*): 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

Please remember to keep systematic and professional records in your logbook throughout the project. More details are given in *Practical Course Handbook*, Section 1.3.2. Please hand your logbook to your supervisor at the end of the project period.

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 inform the students fully of risks associated with the project and to complete and submit the *Risk Assessment* form before the start of the project. **Return the completed Risk Assessment form to the Physics Teaching Faculty.**
- 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.

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 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): 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): 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 2 pm 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 to know your views on the matter.

MPhys project descriptions

Atomic and Laser projects

A&L01 Studying graphene in a Paul trap

The objective of this experimental project is to hold a single flake of graphene at a fixed position the centre of vacuum chamber using oscillating electric fields. The graphene flake is charged and behaves like an ion in a Paul trap. Most of the necessary apparatus has been constructed in previous undergraduate projects, closely following the work of Kane [1]. During this project the student should verify the results obtained by Kane on the translational and rotational motion of the graphene, and then go further. Amongst the numerous directions for additional work is an investigation how flakes move through a low-pressure gas; such two-dimensional objects will behave very differently from the spherical objects usually considered in kinetic theory. Note that although this project involves some practical work, there is considerable scope for original theoretical calculations.

[1] Levitated spinning graphene flakes in an electric quadrupole ion trap. B.E. Kane. Phys. Rev. B 82, 115441 (2010)

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

A&L02 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&L03 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&L04 Error tolerant rotations for quantum computation

Quantum computing requires the ability to drive a quantum-system through a series of unitary operations called quantum logic gates. The project will involve using simulations to study the stabilization of quantum gates against systematic errors. You should enjoy quantum mechanics and computing; familiarity with mathematical packages such as Matlab and Mathematica would be very helpful.

References:

Physical Review A 67, 042308 (2003)

Physical Review A 73, 032334 (2006)

Supervisor : **Prof J Jones** Physics Tel No : 272247
Email : jonathan.jones@qubit.org

A&L05 Two-wavelength laser system for 2-D imaging of temperature in combustion

A novel laser will be constructed which will allow it to emit two distinct and separately tunable wavelengths within 1 microsecond. The aim is to provide a way of exciting atomic or molecular species from two different energy levels in order to probe the population of the states. Following excitation the atom or molecule emits fluorescence whose intensity indicates the initial state population. This Laser Induced Fluorescence, LIF, can then be imaged using a fast CCD camera to record the distribution of atomic/molecular state populations. Using the two images recorded at the two different wavelengths the relative populations can be deduced from the relative LIF intensities and from this data the temperature can be derived at each point in the image. The project will build a laser incorporating a fast electro-optic switch to couple the gain medium to two separate cavities that can be independently wavelength tuned. If time permits the laser system will be used to image atomic or molecular distributions to provide a 2-D map of temperature inside a controlled laboratory flame.

Knowledge of basic laser physics and atomic physics will be useful.

Supervisor : **Prof P Ewart** Physics Tel No : 272340
Email : p.ewart@physics.ox.ac.uk

A&L06 An optical system for “stem cell farming” – growing new hearts

Current research in regenerative medicine involves harvesting stem cells at critical phases of their development into specific cell types. Adult stem cells (i.e. stem cells derived from adult cells rather than embryonic cells) can be induced to develop as cardiac myocytes when appropriate stresses are applied at certain stages of their development. Very little is known about how, when and why the cells differentiate into the various types required for a complete organism. Nonetheless recent progress has allowed the growing of cardiac myocytes and it is now important to provide a reliable source of cells at the appropriate culture stage and to identify and separate them into purified colonies. At present the research is significantly limited by having to separate the cells manually. The project will investigate the possibility of using diffraction of laser light from the cell cultures to identify automatically cells colonies as a precursor to automatic labelling and separation. An alternative approach using image processing software will also be investigated.

Knowledge of 2nd year Optics will be sufficient and computer expertise will be a distinct advantage.

Supervisor : **Prof P Ewart** Physics Tel No : **272340**
Email : p.ewart@physics.ox.ac.uk

A&L07 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**
Email : v.vedral@physics.ox.ac.uk

A&L08 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**
Email : v.vedral@physics.ox.ac.uk

A&L09 Studies of super-luminal wave-front propagation

Light waves propagate in free space with a constant phase velocity c . Whilst this well-known statement is true for plane waves, it does not always hold for more complicated waves, such as those with transverse structure. A well-known manifestation of this is the Gouy phase shift experienced by a focused beam.

In this project the super-luminal propagation of light waves in the shadow of an opaque disc is investigated experimentally.

Interferometric techniques will be used to measure the phase velocity of the waves in the region of the Poisson spot as a function of position behind the disc. Phase velocities up to approximately $1.2c$ are expected.

The project will involve setting up an interferometer and interfacing a CCD camera with a computer. The student will have to write computer programs to extract the two dimensional phase of the diffracted wave-front from the interference pattern. If time permits, numerical calculation of the Fresnel diffraction pattern behind the disc could be undertaken. These will be used to compare directly the measured and calculated two-dimensional interference patterns.

A description of the experimental method, and further relevant references, may be found in: M. Vasnetsov et al. Optics Letters Vol. 32 p. 1830 (2007).

Supervisor: **Prof S Hooker** Physics Tel No: **282209**
Email: s.hooker@physics.ox.ac.uk

A&L10 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 (10^{18} 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&L12 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
Email : l.corner@physics.ox.ac.uk

A&L13 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&L14 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.gregori@physics.ox.ac.uk

***A&L15 tbc**

Supervisors : **Prof I Walmsley** and **Dr A Datta**
Email : i.walmsley1@physics.ox.ac.uk,
a.datta1@physics.ox.ac.uk
**this project is reserved*

A&L16 Two-photon time-frequency entanglement characterization

Entanglement, the nonlocal correlations between measurement outcomes performed on non-separable quantum systems, lies at the heart of quantum physics and its advantages in applications such as quantum information processing and quantum metrology. In the domain of quantum optics, photons can be entangled in many degrees of freedom such as their polarization states to their frequency-time behavior. To realize the full potential of quantum applications requires the ability to determine the amount of entanglement for a given quantum source.

In this project we will examine an approach to set bounds on the amount of entanglement of a two-photon time-frequency entangled state. The student will gain working knowledge of the state-of-the-art for producing photon pairs from spontaneous parametric down conversion and spontaneous four wave mixing. To characterize two-photon spectral-temporal entanglement the student will construct a device to measure the joint-spectral intensity of an ensemble of photon pairs produced by such a source. The joint-spectral intensity measurements will then be performed on a working two-photon source to bound the spectral-temporal entanglement.

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 grating-based spectrometers will also be useful.

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

A&L17 Optical phase estimation *for phase sensitive quantum light detection*

Optical quantum technologies aim to utilize the nonclassical behavior of light to execute certain tasks with performance beyond what is possible with only classical resources. For example, quantum-enhanced metrology uses nonclassical states of light to perform measurements with increased precision over what can be achieved classically. To realize these quantum technologies requires the ability to create, manipulate and measure quantum states of light.

The main goal of this project is to construct a fast optical phase sensor based upon a Mach-Zehnder interferometer to be used for a phase-sensitive quantum detector. The student will gain both experimental and theoretical experience in classical and quantum optics including interferometry and balanced homodyne detection.

Knowledge of classical optics and interferometry are necessary. It would be helpful if the student has seen field quantization in terms of creation and annihilation operators.

Supervisor : **Dr B Smith** Physics Tel No : 272206
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A&L18 tbc

More details from the supervisor.

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

A&L19 tbc

More details from the supervisor.

Supervisor : **Prof A Steane** Physics Tel No : 272385
Email : a.steane@physics.ox.ac.uk

Atmospheric, Oceanic and Planetary Physics projects

A001 Periodicities in atmospheric electricity data

Thunderstorms in equatorial regions charge up the electrically conductive upper atmosphere (ionosphere) with respect to the surface, leading to a permanent atmospheric electric field of -100V/m. Atmospheric ions formed by natural radioactivity and cosmic rays drift in this electric field, and make the air slightly electrically conductive. Like many meteorological parameters, daily and seasonal variations are clearly visible in the data when it is analysed using Fourier techniques. Other periodicities such as the 27-day rotation of the sun can sometimes occasionally be detected, when local effects are not dominating the signal. An interesting 11-day periodicity has been spotted in several atmospheric electricity parameters, but it only appears to be present in polluted urban air. The project will investigate periodicities in different atmospheric electricity data sets at a variety of sites and what causes them. An interest in atmospheric and/or space physics is essential, and the student must be willing to write code to process data.

Supervisors: **Dr K Aplin** and **Dr A Bennett** (Met Office/Bath University)

Physics Tel No: 273491

Email: k.aplin@physics.ox.ac.uk

A002 Investigating the atmospheric circulation of tidally-locked extrasolar planets using a laboratory analogue

In the last fifteen years the diversity of known planetary orbits has greatly expanded as hundreds of planets are being discovered around other stars. In particular, 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 any planetary atmosphere are gravity, planetary rotation, the spatial and temporal distribution of incoming stellar radiation, and internal heat sources. A laboratory experiment called the rotating annulus can reduce a planetary atmosphere to a fluid system acted upon only by these effects, and so study a wide range of potential atmospheres under controlled conditions. 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.

The annulus has not yet been used to investigate the much wider diversity of potential atmospheric conditions that might be found on these strange extrasolar worlds. Of particular interest is the situation corresponding to tidally-locked planets: slow rotation combined with non-axisymmetric temperature forcing or non-uniform heating from below.

The student will adapt a comprehensive model of the rotating annulus to account for the external heating of tidally-locked exoplanets and use this model to explore the range of atmospheric circulation patterns we might expect to find there.

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 but is not required. A prior familiarity with Fortran programming will be necessary. Prior experience with IDL and Linux shell scripting would also be very useful, although there should be sufficient time beforehand to get up to speed.

Suggested reading:

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

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

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

HA Knutson et al. (2007) "A map of the day-night contrast of the extrasolar planet HD 189733b", *Nature*, 447, 183-186. doi:10.1038/nature05782

Supervisors : **Dr R Young** and **Prof P Read**

Physics Tel No : 2720982, 272082

Email : young@atm.ox.ac.uk; p.read@physics.ox.ac.uk

A003 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 Sensing", 2nd edition Cambridge University Press 2003.

Supervisors: **Dr N Bowles**, **Dr I Thomas**

Physics Tel No: 272097

Email: bowles@atm.ox.ac.uk

A004 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 ($\ll 1$ mm) 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 University of Washington.

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**

A005 Oceanic and stratospheric influences on European climate

European weather and climate are affected by small changes to the position of the North Atlantic mid-latitude storm track. Projected changes of European climate from state-of-the-art climate models of the coupled ocean-atmosphere are highly uncertain. The dynamical influences of the ocean and the stratosphere on mid-latitude climate have been largely debated over the recent years and their role has been brought forward as a possible explanation for the uncertain future of our climate. In this project, the student will be involved in investigating the effects of stratospheric and oceanic processes on regional temperature changes obtained from a newly developed complex climate model which includes the full stratosphere (Hardiman et al. 2011, *J. Atmos. Sci.* 67, 1509-1525).

Supervisors: **Prof L Gray** and **Dr L Zanna**
Physics Tel No : **272909**
Email: **gray@atm.ox.ac.uk; zanna@atm.ox.ac.uk**

A006 Electrostatic modelling of a spacecraft

A space mission, Marco Polo, is planned to return a sample of surface material from an asteroid to Earth. Asteroid surface material is expected to be electrically charged due to photoelectron emission, and the spacecraft will also become charged on its journey through space. The attraction, repulsion or current flow expected from differential asteroid/spacecraft charging could be relevant when it comes to obtaining a sample of surface material. Instruments are therefore being developed to measure the charge state of the asteroid. This project will use 3D electrostatic modelling software of an engineering model of the spacecraft to investigate the implications of the expected charging effects, and also to determine where best to position the proposed instruments.

Supervisors: **Dr K Aplin** and **Dr N Bowles**
Physics Tel No: **273491**
Email: **k.aplin@physics.ox.ac.uk**

A007 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 will be analysed using simple radiative transfer tools, and techniques such as Principal Component Analysis to probe the large scale variation in clouds across the planet, and search for diagnostic spectral structures.

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**

A008 Consequences of the nonlinear equation of state of seawater

The equation of state of seawater is fundamentally nonlinear, for example, density is a nonlinear function of temperature, salinity and pressure. This has many fascinating and counter-intuitive consequences! Recently, a new equation of state for seawater has been defined (www.teos-10.org) based on a Gibbs function formulation from which thermodynamic properties such as entropy, potential temperature, enthalpy and potential enthalpy are calculated directly. In this project, the student will investigate some of the consequences of this nonlinear equation of state. The initial focus will be on the concept of neutral surfaces, along which fluid parcels can move without doing work against the earth's gravitational field; the student will study the extent to which paths along neutral surfaces do not close, related to a concept known as "helicity". However, there are numerous opportunities for students to develop the project along secondary lines of investigation. The work will require a strong background in thermodynamics, mathematical analysis, and the use of Matlab (for which a complete set of thermodynamic routines are available).

Supervisor: **Prof D Marshall** Physics Tel No : **272099**
Email: **marshall@atm.ox.ac.uk**

AO09 Eddy shapes in unstable oceanic jets

Many key ocean phenomena are strongly influenced by the presence of eddies. The details of the global-scale and long-time-mean flow of the ocean are critically dependent upon the fluxes of momentum and heat resulting from the much smaller and more quickly evolving eddies.

However, global climate models cannot generally be run at a resolution sufficient to capture such small-scale processes. Hence there is an interest in understanding the dynamics of ocean eddies, and their influence on the large-scale flow.

In this project, the student will study eddies in a simplified system: an unstable two-dimensional jet (the Kuo problem). A geometric interpretation of the influence of the eddies on the mean-flow will be applied in order to determine their shape and orientation. This could potentially be extended to systems with an additional vertical structure. Use will be made of numerical tools in order to derive the geometric properties.

This project will require an aptitude for fluid dynamics and mathematical analysis. The project will also involve the use of Matlab or an equivalent software package.

Supervisors: **Prof D Marshall** and **Dr J Maddison**
Physics Tel No : 272099
Email: marshall@atm.ox.ac.uk
maddison@atm.ox.ac.uk

AO10 Modelling the spectra of exoplanets

The Cassini spacecraft has been in orbit about Saturn since their discovery in 1995, several hundred exoplanets, i.e. planets orbiting other stars, have now been found. For some exoplanets, observations have been made of their primary and secondary transit spectra, which can be compared with radiative transfer models to infer atmospheric structure and composition. In this project, the student will develop a simple model to simulate the vertical temperature/pressure profile of exoplanets with different atmospheric compositions and proximity to their stars. This model will then be used with an existing radiative transfer code to predict the likely observed spectra of different classes of exoplanets with the aim of identifying key spectral wavelength ranges and resolutions to discriminate between different planet types.

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

AO11 Chaos in a simple model of Earth's climate

The simple model of Hogg (2008) represents the Earth's climate with a pair of coupled ordinary differential equations for global mean temperature and the partial pressure of carbon dioxide in the atmosphere. Together these equations are able to model several key features of observed glacial/inter-glacial cycles, such as the rise in temperature preceding that of carbon dioxide. However, the system has only a single fixed point, the glacial state, which is stable to perturbations in temperature and carbon dioxide. Hence, given sufficient time, the model always returns to a cold climate with low carbon dioxide levels. In this project, the student will add a third equation to the model for the temporal evolution of

ice albedo, in order to represent variability in the reflection of incoming shortwave radiation with changes in ice cover. This will introduce nonlinearity to the system of equations and allow for the possibility of multiple fixed points and chaotic states. Through the use of dynamical systems theory, they will establish the existence and stability criteria of the expanded model's fixed points and its potential for deterministic chaos. In addition, simple numerical modeling will allow the student to investigate more qualitative aspects of the expanded system, such as the shape and topology of its attractors (strange or otherwise). There is further scope for the interested student to develop the model as they see fit, such as increasing physical realism or the addition of further climate feedbacks.

This project would suit a student with a strong interest in nonlinear dynamical systems and a good mathematical background. A student interested in physical climate problems will likely gain the most from this project. Basic Matlab code for the initial stages will be provided, although the student will be expected to modify this code to accommodate the ice albedo equation and more accurate numerical methods. Whilst previous experience with numerical modeling and/or Matlab (or equivalent) would clearly be an advantage, it is not essential prior to beginning this project

Suggested reading:

Hogg, A.M., 2008: Glacial cycles and carbon dioxide: A conceptual model. *Geophys. Res. Lett.*, 35, L01701, doi:10.1029/2007GL032071.

Strogatz, S.H., 1994: *Nonlinear Dynamics and Chaos*, Westview Press, Perseus Books Publishing, pp. 498.

Supervisors: **Prof D Marshall** and **Dr D Munday**
Physics Tel No : 272099
Email: marshall@atm.ox.ac.uk
munday@atm.ox.ac.uk

AO12 Synchronisation of tropical winds within the Met Office global climate model

Recent evidence for the synchronisation of winds within the tropical stratosphere suggest a new understanding for the dynamical feedbacks controlling tropical covariability. The tropical low to mid-stratosphere is characterised by winds changing from easterly to westerly and back again over an approximately 30 month period; a phenomenon known as the quasi-biennial oscillation (QBO). This variability is thought to be driven by the action of small scale waves originating in the troposphere. Higher up in the atmosphere, winds cycle between easterly to westerly and back again over a period of 6 months; and is referred to as the semi-annual oscillation (SAO). This behaviour is thought to originate from the local action of small scale waves and large scale waves at higher latitudes. Separately these oscillations are thought well understood, however, the presence of synchronisation between these suggests a need to review their coupled behaviour.

The student will use a combination of complex time series and recurrence analyses to examine the presence or otherwise of synchronisation within tropical variability in simulations of the Met Office global climate model. The project will introduce and require the use of the IDL programming language and the handling of large climate datasets.

Supervisors: **Dr S Osprey**, **Prof P Read** and **Prof L Gray**
Physics Tel No : 282434
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gray@atm.ox.ac.uk

AO13 The Changing Evolution of the Polar Vortices Final Breakdown over the 21st Century

The stratospheric polar vortices are evident as large-scale rotations of the atmosphere located in the polar winter hemispheres. They are formed by radiative processes that result in an equator-pole temperature gradient, this gradient reverses in winter compared to summer so that the winter vortex is made up of westerlies and the summer vortex is made up of easterlies. The transition between westerlies and easterlies is known as “the final warming” and the timing of this transition can influence surface climate.

This project will look at how the structure of the polar vortices change throughout the 21st century going into the final warming. It is already known that the southern and northern hemisphere final warmings have different vertical structures as seen from a zonal-wind framework. Here the student will look at the geometry of the vortices using, in part, potential-vorticity fields, firstly to determine if a similar final warming structure is observed in present day periods and secondly to determine if this structure changes over the 21st century. The geometric analysis will primarily comprise of using the 2D-vortex moment diagnostics which have been shown to give a more indepth analysis of the vortices compared to zonal-wind diagnostics. The final aim of this study is to further understand the dynamics of the annual vortex breakdown and how this may change into the future under differing climate scenarios.

The project will require analysis of timeseries as well as longitude/latitude fields and as such a knowledge of computer programming such as IDL or matlab is required. The nature of the project is such that a more dynamically minded student would be suited.

Suggested Reading:

1. Mitchell et al., “The Structure and Evolution of Stratospheric Polar Vortices Using 2D-Moment Analysis”. 2011. *J.Atmos.Sci.*
2. Hardiman, S., et al., “The Climatology of the Middle Atmosphere in a Vertically Extended Version of the Met Office’s Climate Model. Part 1: Mean State”. 2010. *J.Atmos. Sci.*
3. Andrews, D., Holton, J., and Leovy, C., “Middle Atmosphere Dynamics”. 1987.

Supervisors: **Dr D Mitchell, Prof L Gray** and **Dr S Osprey**

Physics Tel No : 282434

Email: mitchell@atm.ox.ac.uk, sgray@atm.ox.ac.uk; osprey@atm.ox.ac.uk;

AO14 To m-infinity and beyond

The Intergovernmental Panel on Climate Change identified aerosols as an important contribution to climate change uncertainty. Understanding the aerosols absorption and scattering of solar and thermal radiation is essential; this is termed the aerosols direct effect. The direct effect is determined by the aerosol refractive index and particle size. Aerosols also have a critical role in cloud formation which is poorly characterised, and causes additional climatic effects; the aerosol indirect effect.

Accurate characterisation of the optical aerosol properties (scattering and absorption) is thus essential. Accurate optical properties are also need for the retrieval of aerosol parameters from remote sensing satellite instruments. These instruments can provide a global quantification of both the direct and indirect effects.

This project will provide the student the opportunity to partake in current cutting edge research to determine aerosol optical properties. Experimental optical data has been collected on a number of different aerosols types. Our unique analysis method requires information on an anchor value in the aerosols refractive index for each type at short wavelengths (m-infinity). The project will explore a new analysis method to determine this value. This essential work will help underpin future research on aerosols effects on the climate.

Good programming and theoretical skills would be an advantage.

Supervisors : **Dr D Peters** and **Dr R D Grainger**

Physics Tel No : 272892, 272888

Email : d.peters@physics.ox.ac.uk

r.grainger@physics.ox.ac.uk

AO15 Aerosol refractive index of volcanic ash

The Intergovernmental Panel on Climate Change identified During the recent eruption of Eyjafjallajökull in April/May 2010 the key observations were ground, airborne and satellite remote sensing, and in situ measurements of the ash size distribution using optical probes. All of these measurements relied on a sparse number of optical property measurements from volcanic ash that are available in the literature, and hence they are subject to significant uncertainties.

This project will provide the student the opportunity to partake in current cutting edge research to determine aerosol optical properties. Current refractive index data for solid aerosols in the infrared has been traditionally collected by taking samples of aerosol particles and compressing them into a matrix of infrared transparent material. Spectral absorption and reflection data is then taken to infer the refractive index of the particles. These methods have ignored (or crudely corrected for) scattering of the particles in the matrix. In this experiment you measure the transmission spectra of aerosol loaded pellets including the recent volcanic ash from Eyjafjallajökull volcanic plume. You will apply a newly developed method that takes into account both the scattering and absorption to determine the particles refractive index.

Good programming and experimental skills would be an advantage.

Supervisors : **Dr D Peters, Dr N Bowles** and **Dr R D Grainger**

Physics Tel No : 272892, 272097, 272888

Email : d.peters@physics.ox.ac.uk, bowles@atm.ox.ac.uk

r.grainger@physics.ox.ac.uk

AO16 Investigating the Radiance Emitted by the Earth Using ATSR satellite instruments

The Along Track Scanning Radiometers (ATSR) are a series of satellite instruments that image the Earth's surface at range of wavelengths from the visible to the thermal infrared. They were designed, with substantial involvement of Oxford Physics, to measure the sea-surface temperature to the accuracy required for climate monitoring. To achieve this they employ both on-board calibration and a unique "dual-view" measurement system whereby they view the Earth vertically and at an angle along the satellite's orbit track, to provide observations of the same point on the Earth's surface using two different atmospheric path lengths. The first of these instruments was launched in 1990, with ATSR-2 replacing it in 1995, followed by Advanced-ATSR in 2002. The series is to continue in 2013 with the launch of the improved Sea and Land Surface Temperature Radiometer (SLSTR). The dual-viewing system and on-board calibration, combined with the now 15 years of continuous measurements, make ATSR-2 onwards a very important source of information on the long-term behaviour of the atmosphere.

This project will centre on understanding long-term measurements of the radiation emitted or reflected by the Earth. The task will be to create a time series of the radiation measurements and to understand their variability and stability. Whilst the ultimate goal is to investigate if there are any trends in the radiance emitted by the Earth's atmosphere, the student will need to take a prosaic approach by eliminating any possible factors that could manifest themselves in any observed trend, e.g. those due to instrument calibration changes or changes in the orbital behaviour of the spacecraft. As this project relies on the manipulation of very large datasets it would suit someone with experience of or interest in computing and programming.

Supervisors : **Dr G E Thomas** and **Dr R D Grainger**

Physics Tel No : **272894, 272888**

Email : **g.thomas@physics.ox.ac.uk**

r.grainger@physics.ox.ac.uk

AO17 Ash detection and characterisation in IASI data

The ability to detect volcanic ash from space (as in the recent Eyjafjallajökull eruption: <http://www.eumetsat.int/Home/Main/News/Features/718040>) is a high priority scientific goal. Volcanic ash and other species (desert dust, cirrus cloud, water cloud) have different infrared absorption spectra. Therefore it should be possible to distinguish different aerosol types using high-resolution infrared spectrometer measurements from the Infrared Atmospheric Sounding Interferometer (IASI) in an atmospheric window (e.g. 800-1250 cm⁻¹, excluding the ozone band).

In this project the student will develop a test for determining the presence of ash and to distinguish ash from other species. The student will first need to become familiar with the existing literature. They will then need to develop code to detect different aerosol species (ash, possibly more than one ash type, dust, cloud). The test will be applied to different case studies in order to understand if a single ash test is feasible or if differing ash composition produces discernable infrared spectral behaviour.

The student will use existing code to: (1) load IASI spectra, (2) compute aerosol optical properties with different refractive indices and size distributions (and possibly simulate the radiative transfer) in the IASI configuration in order to better understand the spectral behaviour of different aerosol species.

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**

Physics Tel No : **272915, 272888**

Email : **e.carboni@physics.ox.ac.uk**

r.grainger@physics.ox.ac.uk

AO18 Satellite tracking of volcanic eruption plumes using ash and SO₂

Over the past two years the potential of volcanic eruptions to disrupt air travel has become very apparent in Europe, with both the Eyjafjallajökull and Grimsvöten eruptions in Iceland grounding air traffic. Improved measurements of the location and, critically, the height of volcanic ash plumes is vital if the forecasting of ash dispersion is to be improved, thus allowing such disruptions to be minimised.

The detection and analysis of volcanic eruption plumes from satellites is an active field of research within AOPP and has been tackled through the measurement of both the ash itself and the SO₂ emitted along with it. In particular, using the Met-Op weather satellite, SO₂ plumes can be identified, and the SO₂ concentration and plume height can be measured, on a twice daily basis anywhere on the globe. However, an open question is how well SO₂ plumes correspond to the ash emission. In this project the student will compare SO₂ measurements from the Eyjafjallajökull, Grimsvöten and Puyehue eruptions with retrievals of ash height from the AATSR satellite instrument to evaluate SO₂ as a proxy for ash location.

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 G E Thomas**, **Dr E Carboni** and **Dr R D Grainger**

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AO19 Space-based assessment of the relationship between atmospheric parameters and terrestrial photosynthesis

The Along Track Scanning Radiometers (ATSR) are a series of instruments on board the Earth Radiation Budget Experiment (ERBE) satellite. The gross carbon uptake of terrestrial vegetation through photosynthesis is a crucial parameter in climate change research. A global, observation-based characterisation of ecosystem gross primary production can only be performed with satellite measurements. High-spectral resolution observations of the Earth by the Fourier Transform Spectrometer onboard the GOSAT satellite have very recently made possible the retrieval from space of vegetation chlorophyll fluorescence. This parameter is directly linked to vegetation photosynthesis and is available for the first time on a global scale. This project proposes to investigate how atmospheric conditions control fluorescence dynamics over large vegetation covers such as boreal forests and the Amazon rainforest. The core of the project will be the investigation of temporal and spatial correlations between fluorescence and environmental parameters such as surface temperature, precipitation, illumination intensity or secondary organic aerosol (SOA) components emitted by active vegetation. This unprecedented data set will improve our understanding of vegetation photosynthesis and this can eventually provide a better constraint of future carbon models and programming.

Supervisors : **Dr L Guanter, Dr G E Thomas and Dr R D Grainger**

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AO20 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 CO₂ molecules with ¹³C atoms compared to the normal ¹²C. Others, e.g. H₂O, 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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AO21 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.

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 near the centre of the cylinder (representing the polar regions). 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 (possibly using thermographic imagery with an infrared camera).

Suggested reading:

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

Schneider, T., "The tropopause and thermal stratification in the extratropics of a dry atmosphere". *J.Atmos.Sci.*, 61, 1317-1340, 2004

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

Supervisor : **Prof P Read** Physics Tel No : 272082
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AO22 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
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AO23 Are increases in cloud top height due to aerosol invigoration or enhanced cloud cover?

The scientific evidence for the impact of anthropogenic activities on Earth's climate is generally undisputed. Atmospheric aerosols (small airborne particles) play a key role in the climate system, despite being less prominent than greenhouse gases. Aerosol particles influence the global radiation budget directly, by scattering and absorption, as well as indirectly, by the modification of cloud radiative and microphysical properties. Clouds, which cover about 60% of the Earth's surface, are responsible for up to two-thirds of the planetary albedo, thus small anthropogenic changes to the cloud cover, cloud optical thickness, and cloud height will have large radiative effects. Cloud feedbacks are the largest source of uncertainty in estimating climate sensitivity, therefore understanding clouds and cloud feedbacks is crucial in assessing anthropogenic climate change.

Aerosols interact with the microphysical processes in clouds by acting as cloud condensation nuclei, leading to enhanced cloud droplet numbers and smaller droplet radii. In general this leads to increased cloud cover due to reduced precipitation efficiency. Nevertheless, for convective clouds (buoyancy driven, such as thunderstorms), satellite retrievals show strong positive correlations between cloud top height and aerosol extinction. This led to hypotheses that increase in aerosol invigorate these clouds and lead to deeper clouds with higher cloud tops. However, the theoretical basis of these theories remains weak. On the other hand, the observed increase in cloud top height could simply be a statistical consequence of higher cloud fractions with increasing aerosol optical depth. Both processes lead to an increase in cloud height, however, for very different reasons. In this study we

will try to estimate the increase of cloud top height due to increase in cloud cover. We will start from a theoretical model of increase of cloud cover with increase of aerosols. From satellite data we will create probability density functions of cloud heights for different atmospheric aerosol loadings and evaluate our theoretical model. Finally, we will compare our estimates to data from studies of cloud top height increases due to convective cloud invigoration. Our aim is to quantify the fractions of increase of cloud top height with increasing aerosol due to increase in cloud cover and due to invigoration of convective clouds.

The project involves data analysis and programming in NCL/Python/IDL or similar under Linux. Ideally, you bring some basic experience in programming but this can be compensated with enthusiasm.

Supervisors: **Dr P Stier** and **Dr T Wagner**
Physics Tel No: 272887
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AO24 Is there an anomaly of aerosol optical depth in the Southern Atlantic?

The scientific evidence for the impact of anthropogenic activities on Earth's climate is generally undisputed. Atmospheric aerosols (small airborne particles) play a key role in the climate system, despite being less prominent than greenhouse gases. Aerosol particles influence the global radiation budget directly, by scattering and absorption, as well as indirectly, by the modification of cloud radiative and microphysical properties. Contrary to the well-constrained radiative perturbation by greenhouse gases, aerosol radiative perturbations are not sufficiently understood, making them arguably the single greatest source of uncertainty in the assessment of anthropogenic climate change.

In the Southern Atlantic, MODIS satellite observations suggest elevated aerosol optical depth (AOD, column integrated extinction) but some studies have suggested that this is an artifact in the satellite retrievals (e.g. due to cloudiness). Nevertheless, aerosol transport models suggest that sea salt loads should be higher due to larger wind speeds. This study attempts to bridge those two views. Data from a network of marine sunphotometers (AERONET) in the Southern Atlantic show increased AOD with increased wind speed although there is a large spread in the data. In this work, we will study marine AERONET observations and attempt to quantify their correlation with other environmental variables, such as windspeed. Once this is better understood, co-located MODIS AOD will be examined for biases. Our aim is to estimate, in a climatological sense, how much of Southern Atlantic MODIS AOD is real, and how much is due to retrieval artifacts.

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

Supervisors: **Dr P Stier** and **Dr N Schutgens**
Physics Tel No: 272887
Email: philip.stier@atm.ox.ac.uk

AO25 A satellite-based assessment of the impact of Megacities on Earth's radiative balance and climate

The scientific evidence for the impact of anthropogenic activities on Earth's climate is generally undisputed. Atmospheric aerosols (small airborne particles) play a key role in the climate system, despite being less prominent than greenhouse gases. Aerosol particles influence the global radiation budget directly, by scattering and absorption, as well as indirectly, by the modification of cloud radiative and microphysical properties. Contrary to the well-constrained radiative perturbation by greenhouse gases, aerosol radiative perturbations are not sufficiently understood, making them arguably the single greatest source of uncertainty in the assessment of anthropogenic climate change.

The assessment of the anthropogenic aerosol effects from space is generally not possible because current satellites sensors cannot reliably distinguish aerosol microphysical properties or even general aerosol types. In this project we will use Megacities (cities with a population in excess of 10 million) as proxy to assess the impact of anthropogenic aerosols on clouds and climate. Compositing satellite retrieved properties of aerosol and clouds in a Megacity-centric coordinate system will provide a first systematic analysis of their radiative effects as enhancement from the background fields. A scale analysis will serve as guidance for climate model developments as such models generally simulate the Earth on scales much larger than individual cities.

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

Supervisor: **Dr P Stier** Physics Tel No: **272887**
Email: philip.stier@atm.ox.ac.uk

AO26 Testing the potential for space-based monitoring of air pollution

Satellite-based measurements allow the detection and long-range tracking of pollutants providing vertically resolved measurements from the urban to global scale. They are now increasingly being used to help initialise air-quality models to allow forecasts of pollutant transport and deposition in much the same way as meteorological forecasts are already performed. The Infrared Atmospheric Sounding Interferometer (IASI) on board the MetOp platform, which routinely provides meteorological soundings of pressure, temperature and humidity for numerical weather prediction, is now being used to measure key atmospheric trace species affecting the climate and air-quality. In this project the student will test the potential of the instrument to provide measurements of major pollutants for various scenarios such as urban pollution and biomass burning events. A set of feasible target species will be identified through simulations of the radiative transfer and IASI measurement process. The student will then become familiar with inverse measurement theory and will help to advance newly developed techniques applying them to real data to test the potential for the observation and monitoring of pollution events.

This project is entirely computational and will require running radiative transfer code and processing and displaying satellite data. Knowledge of, or an interest in learning, scientific computing would be an advantage (especially IDL and linux).

Supervisors: **Dr J Walker** and **Dr A Dudhia**
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Astrophysics projects

AS01 Measuring rotation periods for the host stars of Kepler transiting planet candidates

Since it was launched by NASA in 2009, the Kepler satellite has been monitoring over 100,000 stars continuously to look for small dips in brightness caused by planets passing in front of their host stars.

Kepler is the first observatory that is capable of detecting transiting habitable planets around Sun-like stars, and has already announced over 1200 planet candidates. This objective of this project will be to measure the rotation periods of the host stars of these candidates, using the Kepler light curves themselves. This will be done by modelling the quasi-periodic brightness variations outside the transits, which are caused by star-spots rotating in and out of view and evolving. The light curves analysis will be done Bayesian modelling tools based on Gaussian processes. The rotation period can then be used as an indicator of the star-planet system's age, as stars steadily lose angular momentum throughout their lives via a stellar wind. Combined with the properties of the planet candidates themselves - radius and orbital period - the resulting age estimates will provide valuable insights into the evolution of planetary systems.

Special skills: This is primarily a data analysis project, requiring the student to use pre-existing code and develop their own programs in python (preferably) or Matlab, but prior knowledge of either of these languages is not required. On the other hand, the student will need to become intimately familiar with Gaussian processes, which requires a good understanding of the basic rules of probability theory and linear algebra. The interpretation of rotation periods in terms of stellar ages involves some basic astrophysical knowledge, but this can be learnt during the project.

Special requirements: The project requires the use of pre-existing code that is not installed by default on the Physics lab Macs. Either this will need to be installed, or the student will need to be given an Astrophysics account and access to an astrophysics Mac desktop.

Supervisors : **Dr F Clarke** and **Dr S Aigrain**
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*AS02 The dynamics of the Universe in Eddington Gravity

The objective is to take the theory proposed in Banados and Ferreira (PRL, 105:011101,2010.) and study (both numerically and analytically) the evolution of the scale factor. In doing so the student will be asked to try and find exact, analytic solutions to the different regimes and try to understand if, at any point there is superluminal expansion.

Supervisor : **Prof P Ferreira**
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*** this project is reserved**

AS03 Hidden Gems in the Milky Way Project

The Zooniverse's Milky Way Project asks members of the public to draw features on infrared data of our galaxy, taken with the Spitzer Space Telescope. As well as recording 1.5 million drawings of objects in our galaxy, the Milky Way Project also encourages users to discuss interesting finds on a community forum called 'Talk'. For this project, a student would become part of that online forum and seek out interesting objects, to try and identify and explain them. This will involve comparing the positions of such objects with online catalogues and reading about them in the literature.

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.

Supervisor : **Dr R Simpson** Physics Tel No : **273638**
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AS04 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.

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AS05 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**

AS06 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**

AS07 Forming Binary Planets around Solar-Type Stars

We presently live in a golden age for the discoveries of exo-solar planets around stars like the Sun. Two current space missions (Kepler and CoRoT) are discovering 100s of new planets and planetary systems, ranging from Earth mass to brown-dwarf mass. The discovery of binary planets, i.e. a pair of planets bound to each other orbiting a central star, are of particular interest, as such systems can be used to constrain the planets' interior structures. The purpose of this project is to explore the formation of such binary planets, assuming that they form by a tidal-capture process in the dynamically active early phase of the planetary system, and to examine the interplay between the orbital dynamics and the tides raised in the planets, a process that is known to be "chaotic". This will involve Monte-Carlo simulations of the tidal capture for different assumed planet masses and initial configurations. These results will then be used to determine the expected properties of the resulting binary planets and to develop detection strategies for the Kepler and CoRoT missions. The project will require modifying an existing, highly accurate numerical code for the dynamical calculations by including the effects of time-varying tides, using well established prescriptions.

Prerequisites: Good Mathematical Background and Basic Numerical Computing (knowledge of a computer language such as Fortran or C is recommended)

Recommended: Classical Mechanics (Short Option S07)

Supervisor : **Prof P Podsiadlowski**

Physics Tel No : **273343**

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AS08 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**

AS09 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**

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AS10 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**

AS11 Superconductors

Superconducting detectors have made huge impact on millimeter and submillimetre astronomy in the last 20 years. The employment of sub-micron superconducting devices (allowed the construction of very sensitive receivers the were (or will be) installed in the focal plane of ground based or space radiotelescopes.

For example the space telescope Herschel has already been launched carrying these detectors and the and the 64-dish ALMA which is now being constructed at the Atacama desert on top of the Andes in Chile will use superconducting tunnel junctions (STJ) to detect spectral lines from galaxies and molecular clouds at a frequency range 100 GHz to 1THz.

The experimental cosmology group at Oxford is a world leader in developing heterodyne superconducting detector for submillimetre astronomy and cosmology instruments. We model the electromagnetic and quantum behaviour of these detectors to optimize their design. We also have state of the art cryogenic laboratory to test the performance their performance and analyse their physical properties.

At the moment we have two possible MPhys projects one for the experimentally minded student and the second for students who prefer to focus on theory and computation. Although the two projects are linked to state of the art astronomy research the physics involved is not pure astronomy. Here is a brief description of both:

AS1101 A novel feed for radio-telescopes.

A very important component of any radio, mm or sub-mm telescope is the feed horn which sits in the telescope focal plane and couples the incoming astronomical signal from the dish to the detector. At wavelengths below 1mm, the traditional corrugated horn becomes very difficult and expensive to fabricate. At Oxford, we have developed a new smoothwalled feed horn which promises excellent performance coupled with ease of fabrication. The project would first involve the student understanding the electromagnetic theory behind the design of feed horns. The student would then learn to use our genetic algorithm based horn optimisation package. At this stage, the student will improve the software with his/her own custom extensions. The final aim is to extend the useable bandwidth of our horns to up to 30%, which is a very important requirement for many astronomical and cosmological applications. We also have a fully developed horn test range, so the student will have the opportunity to experimentally characterise prototype horns in the lab. The project would suit a student with interests and expertise in computational and experimental physics/astronomy.

AS1102 A THz probe based SIS mixer:

We have recently joined a European consortium that includes the major millimeter detector research groups in Europe, in a research proposal to develop the next generation of detectors for submillimetre astronomy.

The proposal was funded by the FP7 EU scheme and Oxford will be leading a 0.5 M EUR project to develop a 1.3 THz SIS (Superconductor-Insulator-Superconductor) mixer for an ALMA receiver. The target is to detect NII and CII from distant galaxies in two atmospheric windows. This is quite an exciting project since SIS mixers have not yet been developed with high performance at this frequency.

The aim of this project is to model the behaviour of a probe in a waveguide that will be used to feed an SIS tunnel junction at 1.3 THz. The student will start by learning the electromagnetic properties of planar circuits then how to model their behaviour using a well known commercial software package (HFSS). We shall compare various geometries of probes in circular and rectangular waveguides. The optimized design will then be used in conjunction with an SIS tunnel junction and the detector behaviour will be modeled using our own software to optimize the design.

The student will be helped by a team of students and post-docs who are developing SIS detectors for astronomy projects.

Supervisor : **Prof G Yassin** Physics Tel No : **273440**

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AS12 Lensing of the Cosmic Microwave Background

The Atacama Cosmology Telescope is measuring the Cosmic Microwave Background at high resolution, providing a window on the early universe. As well as probing cosmology, it is also sensitive to infrared emission from star-forming galaxies at high redshift. By measuring higher point statistics in the ACT microwave maps, it should be possible to separate out the emission from these galaxies from the CMB and other contributions. This project will involve computing the bispectrum and other statistics of ACT maps, and comparing to theoretical predictions to better understand star-formation at early cosmic times. This project will be mostly computational, with some theory and statistics. Familiarity with python would be an advantage.

Supervisor : **Dr J Dunkley** Physics Tel No : **273298**
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AS13 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**
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AS14 Finding the expansion history of the Universe with supernovae and Gaussian processes

The rate of the expansion of the universe reflects two things: the laws of gravity and the contents of the cosmos. It is through the latter dependence that we discovered the dark energy effect 12 years ago - it was then that the earliest measurements of high-redshift supernovae showed the unexpected acceleration we have given that name. With better supernova data we can better characterise the nature of dark energy; in particular we are looking for its equation of state $w(z)$, the relation between its effective pressure and density, with redshift. Finding any variation in this function would rule out the simplest cosmological constant model of dark energy.

Unfortunately, relating the observations - which consist of supernovae with distance and brightness measurements - to the underlying $w(z)$ is not trivial - there are a large number of methods which try to parameterize w or otherwise constrain it. Part of the difficulty is that we are trying to model a continuously varying function, whereas most statistical methods deal with individual parameters. This is why I'd like to investigate using Gaussian Processes. GPs are a method of generating a probability distribution that characterises the information about a whole function all the way along its range, rather than at a few points. They are a topic of active research in machine learning, but have only recently been introduced to astrophysics.

Like most modern cosmology, this work is computational - I'd like a student to work on the development (which I've begun) of a computer code to fit the GP models to the best supernova data available. It's not clear at this stage exactly how well the equation of state can be constrained in this method, nor how much prior information we need to add to get these constraints - this will need to be investigated. If it does work well then the output of the analysis would be a distribution showing how the state can vary with redshift and still be consistent with the data, and a corresponding one showing the expansion history of the universe. Since this will involve a lot of coding it's essential that you have programming experience and enjoy doing it! The code I already have is written in the Python language, so you'll preferably have some fluency using that, with bonus points for having done numerical programming.

If you make good progress in this work then there are various directions to go. We might stick with the method but change fields, and apply GPs to other astrophysical problems. Alternatively, we could generate figures of merit for upcoming experiments using the results, or see how other types of data could be integrated into the system.

Computer programming skills essential - in particular familiarity with the Python language would be a major plus.

Supervisor : **Dr J Zuntz** Physics Tel No : **283019**
Email : **j.zuntz@physics.ox.ac.uk**

AS15 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**

AS16 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

AS17 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 hyperplane 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 (imaging) and the GEMINI 8m ground based telescope (imaging and spectroscopy). This homogeneous data set allows 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 imaging and spectroscopic data from the GEMINI GMOS instrument to measure the FP parameters of the cluster RXJ0027.6+2616 at $z=0.365$.

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

AS18 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 : cxcg@astro.ox.ac.uk

AS19 The Origin of Gas in Early Type Galaxies (ETGs)

The SAURON survey has shown that around 75% of early type galaxies (ETGs: Ellipticals and S0s) display emission from ionised gas in their spectra. While some cases can clearly be attributed to recent star formation, the source of the gas in the other galaxies is not understood (Sarzi et al. 2006) and could be from the ejection from older evolved stars in the galaxy (internal source), gradual accretion from the intergalactic medium (external source) or a direct merger of another gas rich galaxy (external source). The misalignment of gas and stellar rotation has long been seen as evidence of the external acquisition of gas although it tells us nothing about how the acquisition took place. Kannappan et al. (2009) recently used long-slit spectra of ETGs to identify substructure in the line-of-sight velocity profile of the stars that correlates with the (misaligned) gas kinematics: in effect, a kinematically decoupled structure rotating with the gas.

The purpose of this project is to identify if similar decoupled stellar components exist and co-rotate with the ionised gas emission in 36 SAURON galaxies (where emission is present). Unlike long-slit spectroscopy, integral field SAURON data could show if the axes of the decoupled stellar rotation and the gas rotation are truly aligned. Furthermore, the extensive analysis that has already been performed on these galaxies aids a quick comparison with stellar populations and gas ionisation ratios: are these decoupled systems correlated with angular momentum parameter, λ or gas line ratios? Are such systems related to young or old stars?

Special requirements:

The project is mathematical in nature although problems are mostly solved numerically; basic proficiency with computers is essential although prior experience in programming is not a pre-requisite.

Supervisor : **Dr R Houghton** Physics Tel No : **283011**
Email : rcwh@astro.ox.ac.uk

AS20 tbc

Galaxies in the universe can be divided into spirals and early-types.

The general idea is that early-type galaxies form via mergers of spirals. However recent evidence suggest that, contrary to the hierarchical merger paradigm, a significant number of the lenticular galaxies may form via the simple fading of spirals, without any significant merger involved. The fading would involve the rapid removal of gas from star-forming spiral galaxies to produce a red and dead lenticular galaxy.

In principle it should be easy to test the hypothesis that lenticulars are faded spirals. One could just look at their shape: do they appear like spiral galaxies when the dust is removed?

In practice this simple test cannot be performed for two reasons: (i) the inclination of early-type galaxies cannot be derived from the observations, due to the lack of dust to trace the disk geometry. Only the projected shape can be measured and not the intrinsic one. One must use a statistical approach; (ii) Some of the early-type galaxies belong to a class of triaxial objects. A statistical study of the shape cannot be performed unless the two classes can be separated.

Recent results have shown that using integral-field observations of the stellar kinematics one can clearly separate the triaxial and the lenticular early-type galaxies, even when the disks are seen almost face-on. In this project the student will use a cleanly selected sample of genuine lenticular early-type galaxies, obtained from the Atlas3D survey with SAURON, to perform a statistical inversion of their shape. He will test whether the shape of a major fraction of lenticulars is consistent with that of dead spiral galaxies. If true, this would represent a significant challenge for the currently accepted hierarchical merging paradigm for galaxy formation.

Special Requirements

The student should have some familiarity with a programming language (e.g. IDL). He will work with images to measure galaxy shapes. He will write short procedures to perform the statistical inversion of the galaxy shape distribution.

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

AS21 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*

AS22 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*

AS23 Measuring rotation periods for the host stars of Kepler transiting planet candidates

Since it was launched by NASA in 2009, the Kepler satellite has been monitoring over 100,000 stars continuously to look for small dips in brightness caused by planets passing in front of their host stars.

Kepler is the first observatory that is capable of detecting transiting habitable planets around Sun-like stars, and has already announced over 1200 planet candidates. This objective of this project will be to measure the rotation periods of the host stars of these candidates, using the Kepler light curves themselves. This will be done by modelling the quasi-periodic brightness variations outside the transits, which are caused by star-spots rotating in and out of view and evolving. The light curves analysis will be done Bayesian modelling tools based on Gaussian processes. The rotation period can then be used as an indicator of the star-planet system’s age, as stars steadily lose angular momentum throughout their lives via a stellar wind. Combined with the properties of the planet candidates themselves - radius and orbital period - the resulting age estimates will provide valuable insights into the evolution of planetary systems.

Special skills: This is primarily a data analysis project, requiring the student to use pre-existing code and develop their own programs in python (preferably) or Matlab, but prior knowledge of either of these languages is not required. On the other hand, the student will need to become intimately familiar with Gaussian processes, which requires a good understanding of the basic rules of probability theory and linear algebra. The interpretation of rotation periods in terms of stellar ages involves some basic astrophysical knowledge, but this can be learnt during the project.

Special requirements: The project requires the use of pre-existing code that is not installed by default on the Physics lab Macs. Either this will need to be installed, or the student will need to be given an Astrophysics account and access to an astrophysics Mac desktop.

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

AS24 Measuring the Expansion of the Universe with Supernovae

One 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 expansion of the Universe.

Requirements

You will use the Philip Wetton telescope here in Oxford to obtain your data. This will obviously require nighttime working, under the

supervision of astrophysics graduate students. Expect to spend 5—6 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.

Supervisors : **Dr F Clarke and Dr M Sullivan**

Physics Tel No : **283140, 283029**

Email : fraser.clarke@physics.ox.ac.uk; sullivan@astro.ox.ac.uk

AS25 Probing the distribution of dust in comet tails

Comets are often described as ‘dirty snowballs’, being made of ice and dust. As these snowballs come into the inner solar system, the sun heats their surfaces, boiling off clouds of gas and dust which become the impressive cometary tails we see in the sky. These tails are typically studied by imaging the sun light reflected off of the gas and dust particles. However, as the comet tail passes in front of background stars, the dust in the tail should absorb and scatter the star light, effectively making the stars ‘twinkle’ as the comet passes by. In this project, we will attempt (possibly for the first time) to measure the physical properties of the cometary dust (distribution and size) by measuring its effect on background stars.

The STEREO project consists of two satellites in orbit around the Sun, with the key science objective of detecting solar coronal mass ejections headed towards the Earth. The satellites have very wide field imaging cameras, which continuously monitor a large area of the sky. As such, they are also very well suited to detecting a range of astronomical phenomena, such as comets (e.g. http://stereo.gsfc.nasa.gov/gallery/stereoimages_other.shtml). Dr Davies and Prof Swinyard have shown that STEREO can detect the measure the variability of background stars caused by cometary dust, and that the simple scattering physics allows one to interpret this variability in terms of dust particle size and distribution.

Your project will involve analysing more STEREO data to build up a much more detailed study of the dust distribution from the light curves of stars. You will then model the light curve variability in terms of dust scattering physics to understand better the properties of the dust particles in the comet tail. Time permitting, you will hopefully be able to use ground-based archival data to study the structures at finer scales than the space based data.

Requirements

The project is computer based, and uses archival data which is already in hand. You will be required analyse this data using existing programmes to measure the brightness of stars and derive light curves. You will then have to use these lightcurves to build a physical model of the cometary dust distribution. This will require some study and understand of dust scattering physics theory.

This will be a joint project between University of Oxford and the Rutherford Appleton Laboratory (RAL). You may have the option of spending some time working on the project at RAL, which is accessible from Oxford by public transport.

Supervisors : **Dr F Clarke, Dr C Davies and Prof B Swinyard**

Physics Tel No : **283140**

Email : fraser.clarke@physics.ox.ac.uk, chris.davies@stfc.ac.uk and bruce.swinyard@stfc.ac.uk

Biological Physics projects

BIO01&02 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**

BIO03 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**

BIO04 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**

BIO05 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**

BIO06 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**

Condensed Matter Physics projects

***CMP01 Heat transfer in a microcalorimeter**

Thin-film chip calorimeters are extremely versatile devices to allow investigating phase transitions in magnetic and superconducting materials which can only be grown in micron size crystalline form. This project aims to understand the heat transfer and the necessary corrections related to these microcalorimeters to be able to measure the absolute values of the heat capacity on a newly developed probe in the Clarendon Laboratory. The measurements will be performed over a large temperature range between 1.5K to 300 K on various test materials. A good knowledge of instrument interfacing using Matlab and good understanding of Thermal Physics is necessary for this project.

For further reading please see:

A.A. Minakov et al., Review of Scientific Instruments, 76, 043905 (2005) A. A. Miankov et al., Meas. Sci. Technol., 17, 199 (2006)

For further information please contact:

Dr Amalia Coldea (amalia.coldea@physics.ox.ac.uk) <http://www.physics.ox.ac.uk/users/coldeaa/>

Supervisor : **Dr A Coldea** Physics Tel No : **272267**

Email : **a.coldea@physics.ox.ac.uk**

***this project is reserved**

CMP02 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**

CMP03 Reflection high energy electron diffraction (RHEED) studies of thin film growth

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 be exposed to the MBE growth of thin films and heterostructures. 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 deduced. These then have to be compared with patterns simulated starting from established models of the surface by performing kinematical and dynamic scattering simulations.

Recommended reading: A. Ichimiya and P.I. Cohen: "Reflection High Energy Electron Diffraction", Cambridge University Press, 2004.

LabView skills are required and a basic knowledge of Matlab/Mathematica is an advantage.

Supervisor : **Dr T Hesjedal** Physics Tel No : **272235**

Email : **t.hesjedal@physics.ox.ac.uk**

CMP04 Superconducting marine propulsion

MHD is a novel variant on the familiar Lorentz force. Current is passed through a duct containing seawater with an orthogonal magnetic field. The resultant force, orthogonal to both field and current can be used to propel a boat. Efficiencies are not very high but using superconducting magnets in the future, the method may well have specialist applications. Meanwhile, as part of existing applied research programmes, we want to build an optimized demonstration model boat that can be used for teaching and to show visitors this relatively unknown electromagnetic phenomenon. There are many short term projects connected with MHD using conventional electromagnets, powerful permanent magnets and, possibly, superconducting magnets that can be undertaken. Details to be discussed. This project is suitable for more than one candidate as there are several sub-projects possible. Please contact the supervisor for more details.

Supervisor : **Prof H Jones** Physics Tel No : **272326**

Email : **h.jones@physics.ox.ac.uk**

CMP05 X-ray diffraction studies of epitaxial thin films and heterostructures

X-ray diffraction (XRD) is the primary tool for the characterization of the type, phase, quality, and thickness of single-crystalline thin films. The thin film structures are synthesized in the Clarendon Laboratory in a dedicated molecular beam epitaxy (MBE) system. MBE allows for the atomic level engineering of thin film systems that are used in a wide range of applications (e.g. lasers, HEMTs, ...) and for quantum device structures (e.g. for studying the Fractional Quantum Hall Effect). The Clarendon MBE is a dedicated system for the growth of magnetic materials and devices for spin-electronics applications.

In this project you will be carrying out the MBE growth of a set of metallic thin films and heterostructures. You will retrofit an existing XRD system with new stepper motors and develop the LabView software for controlling the system. By performing XRD studies and by optimizing the setup, you will be able to determine the structural properties of your samples with great precision and learn about resolution limits and crystalline quality.

Recommended reading: B. E. Warren, "X-Ray Diffraction", Dover, 2004.

LabView and mechanical skills are required.

performing kinematical and dynamic scattering simulations.

Recommended reading: A. Ichimiya and P.I. Cohen: "Reflection High Energy Electron Diffraction", Cambridge University Press, 2004.

LabView skills are required and a basic knowledge of Matlab/Mathematica is an advantage.

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

CMP06 Superconducting Energy storage

Sustainable energy sources, e.g., wind power, are all very well but it can be feast or famine. Energy storage systems are needed for when the wind doesn't blow - or whatever. On paper, energy storage using superconducting magnets is a good method. Practically, however, there are lots of problems. The magnet group has always had a low level effort on SMES for many years.

Come and have a go, it's fun. You need to do some electromagnetic and energy calculations (using computers or not - that's up to you) then get your hands dirty winding magnets, using cryogenics and building demos, e.g., water spouts, loud noises, chemical ignition - whatever your imagination can come up with. Then you've got to explain the physics Please contact the supervisor for more details.

Supervisor : **Prof H Jones** Physics Tel No : 272326
Email : h.jones@physics.ox.ac.uk

CMP07 Spectrum of spin fluctuations in a spin liquid on the diamond lattice

Most magnetic materials form a long-range ordered ground state at sufficiently low temperatures where magnetic moments point in well-defined relative orientations to minimize their mutual interactions and it is rather unusual to find magnetic systems that do not order. Iron is a prototypical

example of a strong ferromagnet with a very large ordering temperature of over 1000K, so it was rather surprising when recent experiments showed that an iron-based magnet, FeS₂, with Fe²⁺ ions arranged on a diamond lattice, showed a "spin liquid" ground state with no magnetic order down to mK temperatures. This was proposed to occur because in this material the Fe²⁺ ions have both a spin and an orbital angular momentum, and under certain conditions those could point in opposite directions and form an entangled spin-orbital singlet with no net magnetic moment. If this is indeed the case one would expect very interesting dynamics at high energies with spin and orbital fluctuations coupled together. The aim of this project is to take this idea forward and predict the spectrum of excited energy levels observable by inelastic neutron scattering experiments. Of particular interest is also the effect of an external applied magnetic field which may "break" the spin-orbital singlet and drive a phase transition from the spin liquid to an ordered magnetic state. The project will require analytical calculations of the magnetic ground state and energy levels of a single Fe²⁺ ion including the spin and orbital components in the electrostatic crystal field of the lattice, then include the effects of interactions between neighbouring sites perturbatively using spin-wave theory methods. Matlab coding will be used to find eigenvalues of matrices and to plot the results graphically, in particular plot the magnetic density of states observable by neutron scattering experiments.

This project would require the ability to learn independently from books and papers and some programming experience. (Suitable for 1 student taking the CMP option, the Theory option is not required). More details from the supervisor.

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

CMP08 Measurements and Modelling of Thermal Response of High Temperature Superconducting (HTS) Coils

High Temperature Superconducting materials will have a pivotal role in the next generation of Energy Applications. Understanding and characterising the thermal response of energy components fabricated from HTS materials is required to ensure reliable performance of the various energy applications. This Project will cover design, modelling and fabrication of small test coils using HTS materials and assess their performance under different operating conditions. It will involve using modelling tools and measurements under different cryogenic temperatures and fields.

Supervisors : **Dr Z Melheim (Oxford Instruments), Prof H Jones (Physics)**
Physics Tel No : 272326
Email : Ziad.MELHEM@oxinst.com
h.jones@physics.ox.ac.uk

CMP09 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**

CMP10 Electrical properties of deposited graphene and carbon nanotubes

The last three years have seen an enormous rise in interest in carbon based semiconductors and semi-metals, since the discovery of monolayer graphene. The project will involve the measurement of the electrical conductivity of carbon nanotubes and graphene flakes which are deposited from solution onto substrates which have lithographically defined metallic electrodes. The conduction properties of these structures will depend on factors such as temperature, voltage and the deposition process and can be expected to show a variety of new features. The student will join a graduate student and post doctoral researcher who are working on this project already and will perform measurements on structures which they are currently developing. It is hoped that by January these devices will be at the stage of making contacts to single nanotubes and flakes of graphene.

Suggested reading:

K.S. Novoselov, A.K. Geim, S.V.Morozov, D.Jiang, M.I.Katsnelson, I.V.Grigorieva, S.V.Dubonos & A.A.Firsov Two-Dimensional Gas of Massless Dirac Fermions in Graphene, *Nature* 438, 197-200 (2005).

A.K. Geim & A.H. MacDonald Graphene: Exploring Carbon Flatland, *Physics Today* 60, 35-41 (2007).

A.K. Geim & K.S. Novoselov The Rise of Graphene, *Nature Materials* 6, 183-191 (2007)

Supervisor : **Prof R Nicholas** Physics Tel No : **272250**
Email : **r.nicholas@physics.ox.ac.uk**

CMP11 Interband absorption in bulk semiconductors and Quantum Wells

The aim of the project is to develop a miniaturised fibre optic based interband absorption measurement which will enable measurements of direct and indirect band gaps in thin films of semiconductors which can then be cooled to investigate the temperature dependence of the band gaps of different materials. The aim will be to develop a simple, laptop based measurement system using a miniaturized hand held spectrometer which can be used for demonstration and possibly practical course experimentation. There will be opportunities to extend the measurements to look at the optical properties of newly developed carbon nanotubes and polymer semiconductors using thin films and solutions.

Suggested reading:

Introductory chapters on quantum wells and optical properties in *Optical properties of solids* by A.M. Fox (OUP, 2001)

Chapters 1 and 8 in *Semiconducting and Metallic Polymers* By AJ Heeger, N S Sariciftci and E. B. Namdas (OUP, just published, Aug 2010)

Highly selective dispersion of singlewalled carbon nanotubes using aromatic polymers A. Nish, J.Y. Hwang, J. Doig and R.J. Nicholas, *Nature Nanotechnology*, 2, 640, 2007, <http://www.nature.com/nnano/journal/v2/n10/abs/nnano.2007.290.html>

Supervisor : **Prof R Nicholas** Physics Tel No : **272250**
Email : **r.nicholas@physics.ox.ac.uk**

Interdisciplinary projects

INT01 PIN diode radiation detector

It is possible to make a small, low cost radiation detector using a PIN diode that is screened from natural light. This is potentially useful, firstly as there is a worldwide shortage of Geiger counters, and secondly for possible 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 and noise reduction
- 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 across electronics, nuclear and solid state physics.

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

INT02 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**

INT03 & 04 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**

INT05 Users’ behavior analysis of online social networks

Users of online systems, such as Netflix Youtube or Flickr, behave in ways that show group relationships among them. This is clearly displayed in the choices made by users when they select objects (products, movies or videos). In this project, we will empirically analyze the dynamic properties of user-item systems (such as Netflix, Movielens, Youtube data sets and so on). With the use of complex network techniques, we analyze these systems using bi-partite networks of two kinds of nodes (users and objects), and form links between them. We also focus on the evolution mechanism of the users’ interest correlation. This study is relevant to recommendation systems. The student working on the project will extract users’ behavior patterns from large-scale data sets, analyze the evolving mechanism of users’ interest-based community structure and present the evolution model that explains the empirical results. This project seems well suited for a student interested in statistical methods, but all students interested are welcomed to apply.

Supervisors: **Dr E Lopez** and **Dr Jianguo Liu**
Email: **eduardo.lopez@sbs.ox.ac.uk**

INT06 Functional connectivity and phase transitions

When one considers a system to be connected (data network, road network, etc), usually one refers to connection of the structure. However, in many real systems, this is only a necessary condition for connectivity, but not always sufficient. Consider a commute from home to work: if road works or conditions affect the main access routes, it may occur that minor roads are not satisfactory to commute effectively, illustrating the fact that the existence of a structural route does not guarantee functional connectivity; function plays a mayor role when considering real-world connectivity. I am interested in studying concrete realizations of this problem in which specific kinds of functional constraints are introduced in a path, and determine whether a network that is initially functionally connected can become disconnected by way of a phase transition. The student working on the project will be able to choose, based on interests and strengths, numerical simulations and/or analytical calculations to perform in order to learn about this kind of phenomenon and work on potential publications. This project seems well suited for a theory track student, but all students interested in it are welcomed to apply, as the specific knowledge necessary is mostly available in all tracks. The main skills necessary are interest in the problem and in making substantial progress.

The project may accommodate one or two students.

Supervisor: **Dr E Lopez**
Email: **eduardo.lopez@sbs.ox.ac.uk**

INT07 Improving the measurement of the Mossbauer effect

The Mossbauer experiment is one of the most sensitive measurements possible in an undergraduate laboratory. The Doppler shift is used to modify the energy of gamma rays from a ^{57}Co source and to study their reabsorption. This effect is so sensitive that it was used by Pound, Rebka and Snyder (PRS) in the famous 1960s experiment to measure general Relativistic gravitational redshift, a shift of 5×10^{-15} over a vertical distance of 22.6m. We will never be permitted a source as strong as the one PRS used, so we will not be able to measure the GR effect ourselves, but we are interested in pushing the apparatus to see how far it can go - The mossbauer effect also has many useful industrial applications, in particular in the manufacture of iron and steel.

Last year, in an M.Phys project, we successfully operated a new configuration in which the source was moved by an actuator coil and a real-time estimate of the speed of the source was registered each time a decay was observed. This configuration allows the apparatus to measure a complete spectrum automatically (the old version required about 100 manual measurements at fixed speeds to measure the spectrum). We are now interested in improving the configuration further in either/both the following directions: (1) Adding an interferometer to measure the instantaneous speed rather than estimating it and/or (2) investigating the use of a much cheaper, more compact semiconductor X-ray detector.

This project gives the opportunity for a lot of hands-on activity and has scope for plenty of ideas in improving the experiment. It may give an opportunity for learning and using either labView (a widely available software framework for data acquisition) or FPGA design software (for designing field programmable gate array electronic logic circuitry). Both involve considerable point-and-click and little procedural code writing.

It is not a prerequisite to have done the experiment in the 3rd year and doesn't require knowledge from any of the 4th year options.

Web page: <http://www-pnp.physics.ox.ac.uk/~barr/mphys/project2012.html>

Supervisor : **Dr G Barr** Physics Tel No : **273446**
Email : g.barr1@physics.ox.ac.uk

INT08 Studying geomagnetism with SQUIDS

Geomagnetic observatories use fluxgate magnetometers to monitor the three components of the Earth's magnetic field. SQUID magnetometers can achieve a much better resolution, but their long term stability is limited by nature of the device. This project will involve looking at data from geomagnetic observatories, and data recorded by SQUID systems in an underground laboratory, to see what we can learn about the properties of the surrounding rock and possible local sources of magnetic field, such as groundwater flow. 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

INT09 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

INT10 Optimal Trading Strategies in Financial Markets

Many participants in financial markets spend considerable time and effort trying to optimize the way that they trade – oftentimes by trial and error rather than through mathematical analysis. This project involves analyzing trading strategies in a methodological way, by treating the price series of a financial product as a random walk and analyzing trading as an optimal stopping problem. The obtained results will be used to comment on the stochastic properties of real financial price series. This project is considered part of the growing field known as 'Econophysics', and many of the techniques that will be used are taken directly from statistical physics.

Requirements: No experience with stochastic processes or financial markets is required, although the student should be willing to do any necessary background reading in these areas.

Supervisors: **Dr A Gerig** and **Dr E Lopez**
Tel No: **01865 278815**
Email: austin.gerig@sbs.ox.ac.uk;
eduardo.lopez@sbs.ox.ac.uk

INT11 tbc

More details from the supervisor.

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

Particle and Nuclear Physics projects

***PP01 Weighing WIMPs at the LHC**

Various of kinematical methods have been proposed for measuring the mass of any weakly interacting particles that be produced at the LHC. The aim of this project is gain analytical and/or computational insight into the extra precision that might be obtained by exploiting on-shell constraints for intermediate particles in cascade decays.

Prerequisites: Related to particle physics and theory options. You will need to know c++ (or similar computing language) and be able to use appropriate mathematical methods for constrained extremization.

Supervisor : **Dr A Barr** Physics Tel No : **273636**

Email : **a.barr@physics.ox.ac.uk**

***this project is reserved**

PP02 Accelerator-driven reactors

It has been proposed that we might generate power using subcritical nuclear reactors (also known as “energy amplifiers”). Such reactors produce insufficient neutrons from fission fragments/ beta decays to sustain chain reactions, so spallation neutrons from a high-intensity proton accelerators are injected to maintain net criticality. The aim of the project is to investigate the operating parameters required for such reactors, and to explore the technical difficulties that might be encountered in their operation.

Prerequisites: You should be willing to explore the literature, and able to perform independent calculations based on your previous knowledge.

Supervisor : **Dr A Barr** Physics Tel No : **273636**

Email : **a.barr@physics.ox.ac.uk**

PP03 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**

PP04 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**

PP05 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**

PP06 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.

Largely computer-based project. Some experimental work possible. Should have C++ experience, or similar programming language. The software package GEANT4 will be used.

Supervisor : **Prof H Kraus** Physics Tel No : 273361
Email : h.kraus1@physics.ox.ac.uk

PP07 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.

Largely computer-based project. Some experimental work possible. Should have experience with C++ and/or ROOT, be quick in acquiring new programming skills or learn some VHDL. Basic understanding of electronics would help.

Supervisor : **Prof H Kraus** Physics Tel No : 273361
Email : h.kraus1@physics.ox.ac.uk

PP08&09 Plasma accelerators

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. Two different projects are offered to study aspects of this alternative method. One project will be on creation of plasma by laser light via quantum tunneling followed by electron acceleration in the field of the laser and the other one on excitations of plasma oscillations by laser light; there the emphasis will be on a transition from non-relativistic to relativistic electron motion

and sensitivity to the laser pulse shape. The work will involve solving relevant differential equations analytically and 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.walczak1@physics.ox.ac.uk

PP10 B⁰ Meson Tagging

The B⁰ meson is bound state of the bottom quark and the down quark. These mesons are produced at the Fermilab Tevatron in generous amounts. Our understanding of quantum mechanics indicates that the neutral B meson will spontaneously change into its anti-particle and then change back as it travels through space before it decays. This effect is called 'mixing' and has already been observed in the neutral kaon system and in the neutral B⁰ mesons. It has only recently been observed in the B_s meson.

B_s mixing occurs quite rapidly. Current experimental measurements on BS mixing indicate that the B_s changes into the anti-BS on average 17 times before decaying. This is astonishing when one realizes that the B_s lifetime is just a little over one picosecond. B⁰ meson mixing, however, takes place at a more stately pace, requiring approximately 5 lifetimes of the meson for one complete mixing oscillation.

Before one can measure mixing however we need to know whether the meson started out life as a particle or an antiparticle. The meson needs to be 'tagged' as either one or the other.

The goal of this project is to explore various tagging techniques on neutral B mesons using the CDF data taken at 2.0 TeV centre of mass energy. The student will attempt to measure the efficiency and dilution of tagging methods in these two cases in CDF data and compare these to the measured rates for charged hadrons and also MC simulations.

Specialized equipment needed: Computer Access

Knowledge of Computer programming required: Yes, C++ programming is best.

Suggested Reading:

See Dr. Huffman's web site under the MPhys project section for a reference about B mesons at CDF.

<http://www-pnp.physics.ox.ac.uk/~huffman/>

Introduction to Elementary Particles, by David Griffiths, section 4.8 gives a very good explanation of mixing in the kaon system. Apart from the fact that the BS meson has a much shorter lifetime, the arguments are identical. The original Kaon paper is referred to here and that too is recommended.

Collider Physics, by Barger and Phillips. In particular the sections on B meson physics and B meson mixing.

F. Abe et. al. (The CDF Collaboration), Phys. Rev. D60, 072003; The first page and its references give an overview of mixing but this is a very advanced paper.

Supervisor : **Dr T Huffman** Physics Tel No: 273402
E-mail: t.huffman@physics.ox.ac.uk

PP11 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: Griffiths, 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/~isserver/Homepage/Papers/papers_extra.html

PP1101 Precision Measurement of the W Boson Mass

The search for the Higgs boson is one of the primary purposes of the LHC.

A key input to this search is its allowed mass, which is constrained by electroweak data such as the measurement of the W boson mass. The final Tevatron data taken this year will provide the most precise measurement of this mass, and thus the most stringent constraint on the Higgs boson mass. This project will focus on reducing the key systematic uncertainties on the measurement in order to achieve the highest precision possible.

Supervisor : **Dr C Hays** Physics Tel No : **283105**
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PP1102 W and Z cross section ratio

ATLAS has already acquired 1 pb⁻¹ of data at 7 TeV which provides a large sample of W and Z. This data will be used in the project to determine the W/Z cross section ratio.

The analysis programme will require a development of an efficient selection for electrons while simultaneously having a good rejection power for the QCD background.

This will require a combination of analysis of the real ATLAS data as well as simulated Monte Carlo samples in order to determine efficiencies and backgrounds. Finally all the information can be combined to make an interesting measurement which can be compared to the precise Standard Model prediction.

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

PP1103 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

PP12 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 cause the radioactive background to mimic an annual modulation signal. Some knowledge of C++ would be helpful.

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

PP13 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**

PP14 B_s Meson Lifetime

The B_s⁰ meson is the bound state of the bottom quark and the anti-strange quark. This meson is produced at the Fermilab Tevatron in generous amounts. This particle is expected to exist in two states called 'Heavy' and 'Light' which are the quantum mechanical mixture of the B_s meson and its antiparticle partner. The two states should have different lifetimes. A measurement of the BS lifetime is the first step towards finding out if, in the data, there are in fact B_s mesons decaying with two different time signatures.

Part of the challenge to understanding this data is the fact that, in order to find the BS meson, a trigger on the decay $J/\psi \rightarrow \mu^+ \mu^-$ is used. The student will try to find and fit a BS lifetime in the CDF detector data at the Tevatron along with Monte Carlo simulations. Time permitting (but unlikely), the student will attempt to find any lifetime difference in CP even and CP odd parts of the decay $B_s \rightarrow J/\psi f$.

Specialized equipment needed: Computer Access

Knowledge of Computer programming required: Yes, C++ programming is best.

Suggested Reading:

See the MPHYS section of Dr. Huffman's web site at: <http://www-pnp.physics.ox.ac.uk/~huffman/> for a reference about B mesons at CDF.

Introduction to Elementary Particles, by David Griffiths, section 4.8 gives a very good explanation of mixing in the kaon system. Apart from the fact that the BS meson has a much shorter lifetime, the arguments are identical. The original Kaon paper is referred to here and that too is recommended.

Collider Physics, by Barger and Phillips. In particular the sections on B meson physics and B meson mixing.

F. Abe et. al. (The CDF Collaboration), Phys. Rev. D60, 072003; The first page and its references give an overview of mixing but this is a very advanced paper.

Supervisor : **Dr T Huffman** Physics Tel No: **273402**
E-mail: **t.huffman@physics.ox.ac.uk**

Theoretical Physics projects

TP01 Dynamical Chaos in Elastic Rods

Can dynamical chaos occur in elastic rods? Although the answer is likely positive, this has never actually been demonstrated. Prior research has considered rods with spatially chaotic behavior, but those studies entail the examination of initial value problems, and physically meaningful chaotic dynamics in elastic rods actually entails the investigation of a boundary value problem. This project will proceed as follows: To attempt to find physically meaningful chaotic dynamics in a rod, one can take an elastic rod and twist so that it is very close to its instability point. One can then develop equations to describe the rod's dynamics in this situation, and the study the interaction of the first few modes of the system. The results obtained by studying these equations will also be compared to numerical simulations of the full equations that describe the rod's dynamics.

References:

1. A. Goriely, Tabor, M. *Physica D* (105) pp 20-44, 1997 Nonlinear dynamics of filaments I: Dynamical instabilities
2. Mielke, A. and Holmes, P., *Arch. Ration. Mech. Analysis*, (101) pp. 319-348, 1988 Spatially Complex Equilibria of Buckled Rods
3. Heijden, G. H. M. van der and Champneys, A. R. and Thompson, J. M. T *SIAM J. Appl. Math.* (59), pp. 198-221, 1998. The spatial complexity of localized buckling in rods with non-circular cross-section

Supervisors : **Dr M Porter** and **Prof A Goriely**
Physics Tel No : **280608**
Email : **porterm@maths.ox.ac.uk**

TP02 Bose-Einstein condensates with spatially inhomogeneous scattering lengths

Experimental investigations of Bose-Einstein condensates (BECs) have yielded astounding physical insights during the last 15 years. Of particular interest have been BECs loaded into optical lattices, which allow one to examine interactions between nonlinearity and spatial heterogeneity. The mean-field dynamics of BECs can be modeled by the Gross-Pitaevskii (GP) equation, and an interesting generalization of the idea of an optical lattice potential is to consider BECs with spatially inhomogeneous scattering lengths, which entail the use of spatially-dependent nonlinearity coefficients in the GP equation. I am particularly interested in situations in which the scattering lengths are spatially periodic or quasiperiodic. There have been a number of theoretical studies of this setting, and upcoming experiments in the I. Spielman group at the University of Maryland offer the potential for accompanying experimental investigations. This requires theoretical (numerical and perhaps analytical) research to help drive those investigations, and ideally this project can help provide this.

References:

Carretero-González, R.; Frantzeskakis, D. J.; & P. G. Kevrekidis. "Nonlinear Waves in Bose-Einstein Condensates: Physical Relevance and Mathematical Techniques" *Nonlinearity*, 2008, 21, R139-R202.

Beck, M.; Knobloch, J.; Lloyd, D. J. B.; Sandstede, B.; & Wagenknecht, T. "Snakes, Ladders, and Isolates of Localised Patterns" *SIAM Journal of Mathematical Analysis*, 41(3), 936-972.

Porter, M. A. & Kevrekidis, P. G. "Bose-Einstein Condensates in Superlattices" *SIAM Journal on Applied Dynamical Systems*, 2005, 4(4), 783-807.

Porter, M. A.; Kevrekidis, P. G.; Malomed, B. A.; & Frantzeskakis, D. J. "Modulated Amplitude Waves in Collisionally Inhomogeneous Bose-Einstein Condensates" *Physica D*, 2007, 229(1), 104-115.

Zhang, Y. & Wu, B. "Composition Relation between Gap Solitons and Bloch Waves in Nonlinear Periodic Systems" *Physical Review Letters*, 2009, 102, 093905.

Supervisor : **Dr M Porter** Physics Tel No : **280608**
Email : **porterm@maths.ox.ac.uk**

TP03 Time-Dependent Networks

A network, usually modelled as a graph, consists of a set of entities and the connections between them. The study of networks has exploded during the past twenty years, and techniques from subjects such as statistical mechanics, graph theory, information theory, and computer science have played major roles in these investigations. Most of this work, however, has concentrated on static networks even though most networks in the real world dependent on time. This is starting to change, as scientists attempt to generalize concepts applied to static networks for time-dependent situations. My projects on time-dependent networks will assist with these efforts through investigation of concepts such as time-dependent centralities, social balance, and community structure. Both data-driven and theory-driven projects are possible.

References:

Bassett, D. S.; Wymbs, N. F.; Porter, M. A.; Mucha, P. J.; Carlson, J. M.; and Grafton, S, T. "Dynamic Reconfiguration of Human Brain Networks During Learning" *Proceedings of the National Academy of Sciences*, 2011, 118(18), 7641-7646.

Mucha, P. J.; Richardson, T.; Macon, K.; Porter, M. A.; & Onnela, J.-P. "Community Structure in Time-Dependent, Multiscale, and Multiplex Networks" *Science*, 2010, 328(5980), 876-878.

Newman, M. E. J. "The Structure and Function of Complex Networks" *SIAM Review*, 2003, 45(2), 167-256.

Newman, M. E. J., *Networks: An Introduction*, 2010, Oxford University Press.

Porter, M. A.; Onnela, J.-P.; & Mucha, P. J. "Communities in Networks" *Notices of the American Mathematical Society*, 2009, 56(9), 1082-1097, 1164-1166.

Supervisor : **Dr M Porter** Physics Tel No : **280608**
Email : **porterm@maths.ox.ac.uk**

TP04 The search for dark matter

Over 80% of the matter in the universe is “dark” i.e. its presence is inferred only from its gravitational dynamics (assumed to be governed by general relativity).

It may well be made of new stable relic particles arising in physics beyond the Standard Model hence searches for new physics at the LHC usefully complement attempts to directly detect dark matter particles in underground nuclear recoil experiments or look for the products (gamma rays, antiprotons, positrons, neutrinos) of their annihilations elsewhere in the Galaxy. This project will focus on one or more aspects of this multifaceted problem, depending on the interests and abilities of the student.

Special skills: computing ability

Supervisor : **Prof S Sarkar** Physics Tel No : **273962**
Email : **s.sarkar@physics.ox.ac.uk**

TP05 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 mathematical/maple) most welcome.

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

TP06 Understanding the self-assembly of DNA nanostructures

The ability to design nanostructures which accurately self-assemble from simple 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. Double-stranded DNA (dsDNA) 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 simplified theoretical model of DNA that appears to capture the dominant physics involved. In this project you would apply the model to study a simple nanostructure. You will mainly be using Monte Carlo simulations and theoretical calculations to study these processes.

Supervisor : **Dr A A Louis** Physics Tel No : **273999**
Email : **a.louis@physics.ox.ac.uk**

TP07 The physics of biological evolution

“Nothing in Biology Makes Sense Except in the Light of Evolution.” wrote the great naturalist Theodosius Dobzhansky, but to really understand evolution, a stochastic optimization process in a very high dimensional space, will require

techniques from statistical physics. In this project you will use theoretical tools and computer simulations to study a number of simplified models we have been developing in our group to understand the physics of evolution.

Supervisor : **Dr A A Louis** Physics Tel No : **273999**
Email : **a.louis@physics.ox.ac.uk**

TP08 Biological Evolution and Genetic Algorithms

Biological evolution is the complex process by which Darwin’s “endless forms most beautiful” have emerged from the simple chemistry of prebiotic Earth. This process can be pictured as a stochastic optimisation problem on a complex landscape, and many ideas from the physics of complex systems have recently been applied to the analysis of evolution. Thanks to biological and computational advances and physical insights over the last decade, we now have unprecedented knowledge of the structure of the spaces underlying evolutionary processes. However, in order to make real-world predictions with this knowledge, a consistent and rigorous means of modelling evolutionary dynamics must be found. This project aims to propose such a dynamic modelling approach, using analytic results from quasispecies theory[1] and computational results from genetic algorithms[2]. In doing so, we aim to refine and direct the varied and often physically dubious ways in which evolution has been modelled in the scientific literature[3].

[1] C. O. Wilke, Quasispecies theory in the context of population genetics, *BMC Evol. Biol.* 5 44 (2005)

[2] See Chapter 1 in M. Mitchell, *An Introduction to Genetic Algorithms*, MIT Press (1998)

[3] See Appendix A in I. G. Johnston, *Exploration, Exploitation & Complexity in Biological Evolution and Self-Assembly*, [doctoral thesis] (2010) at http://www.physics.ox.ac.uk/users/JohnstonI/final_single.pdf

Supervisors : **Dr A A Louis** and **Dr I Johnston**
Physics Tel No : **273999**
Email : **a.louis@physics.ox.ac.uk**

TP09 Modelling the translocation of biopolymers

Understanding how short polymers move through nanochannels is important in the design of nanoscale filters, to technologies aimed at sequencing DNA quickly, and to understanding cellular transport. We shall use theory and modelling to investigate how polymer chains move through constrictions and nanopores, focusing on the generic properties of the transport processes: how they depend on the shape of the channels and on interactions between the biopolymers and the pores, and how translocation is affected by knots in the chain.

Reading:

Physical approaches to DNA sequencing and detection, M. Zwolak, *Reviews of Modern Physics* 80 141 (2008).

Biomimetic smart nanopores and nanochannels, X. Hou, W. Guo and L. Jiang, *Chem. Soc. Rev.* 40 2385 (2011).

Complex dynamics of knotted filaments in shear flow, R. Matthews, A.A. Louis, J.M. Yeomans, *EPL* 92 34003 (2010).

Supervisor : **Prof J Yeomans** Physics Tel No : **273992**
Email : **j.yeomans1@physics.ox.ac.uk**

TP10 Bacterial motility

We will investigate how micron-scale swimmers and pumps, such as bacteria and cilia, interact with their fluid environment. At these length scales Reynolds numbers are close to zero and swimming mechanisms are counter-intuitive, with no analogue in our everyday experience. Low Reynolds number motility is important in many contexts such as the formation of biofilms, fabricating artificial swimming robots for drug delivery and understanding the pumping mechanism of mats of cilia.

You will learn about Oseen tensor solutions to the Stokes equations and use them to map out the flow fields of swimming organisms. The project could involve analytic and/or numerical work, depending on the preferences of the student.

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

TP11 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

TP12 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

TP13 Inflation and String Theory

You will learn about inflationary cosmology and develop the formalism to deal with single- and multi-field inflationary models. You can then apply this formalism to a particular example which arises in the context of string theory. The main goal is to find out how and to what extent inflation can be realised in such a string model and to extract predictions for cosmological fluctuations.

Special Requirements:

For this project, you should have some basic knowledge of General Relativity and cosmology and a strong background in theoretical physics and mathematical methods. Familiarity with Maple or Mathematica will be helpful.

Supervisor : **Prof A Lukas** Physics Tel No : **273953**
Email : a.lukas1@physics.ox.ac.uk

TP14 Action integrals for particles in N-body simulations

The formation of galaxies is now simulated using large numbers of particles moving in a self-consistent gravitational field. Unfortunately it isn't easy to characterise such simulations, nor to relate them to observations of galaxies, especially our own. A big step in this direction would be to derive action-space densities for these models. To do that a robust and efficient method is needed to determine the action integrals of orbits. The project involves exploring a new way of doing this. The project involves programming in a language such as C++.

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

TP15 Invariant sets on chaotic orbits

Orbits of Hamiltonian systems are divided into "regular" and "chaotic". However, chaotic orbits often consist of regular sections between which transitions are made at random. The project is to apply a novel method of identifying the regions in phase space to which an orbit is confined during regular motion. Successful implementation might open up a new approach to understanding the long-term evolution of barred galaxies such as our own. The project involves programming in a language such as C++.

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

TP16 Discrete stellar dynamics

The evolution of stars within galaxies is governed by the Collisionless Boltzmann equation, a first-order PDE relating the galaxy's potential and its phase-space distribution function. This equation is essential when fitting galaxy models to observations or testing the stability of such models. It is also very awkward to deal with.

One alternative is to partition phase space into cells and split time into discrete slots. Then the Collisionless Boltzmann equation becomes a straightforward (albeit time-dependent) linear map of phase space onto itself, but the memory requirements for using this in practice are prohibitively expensive. The purpose of this project is to investigate how the mere existence of such discretization schemes can help one to reason about some open problems in stellar dynamics.

Prerequisite: familiarity with the material from the classical mechanics short option.

Further reading:

Syer D., Tremaine S., "Lattice stellar dynamics", Mon.Not. Roy.Astron.Soc. 276 467 (1995)

<http://uk.arxiv.org/abs/astro-ph/9503104>

Supervisor : **Dr J Magorrian** Physics Tel No : 273993
Email : j.magorrian@physics.ox.ac.uk

TP17 tbc

More details from the supervisor.

Supervisor : **Dr F Hautmann** Physics Tel No : 273966
Email : f.hautmann1@physics.ox.ac.uk

TP18 Statistical physics of mixing in suspensions of swimming bacteria

It has long been appreciated that fluctuations are inherent to life at the microscale. Brownian motion, the random walk of a particle suspended in a fluid, is fundamental to our understanding of biological physics and has drawn interest from theoreticians for more than 100 years. Caused by many independent collisions with surrounding molecules, Brownian motion is quintessentially a Gaussian process and a beautiful manifestation of the central limit theorem in Nature.

Remarkably, a number of recent experiments indicate that a rather different situation occurs in active suspensions, like a population of swimming bacteria or motor proteins traveling along a cytoskeletal network. Not only can material transport be increased by a factor of 10 compared to Brownian motion alone, but the necessary condition for Gaussian fluctuations is broken, leading us to novel statistical physics. From an ecological perspective, such enhanced diffusion may be important to both the dispersal of feeding nutrients and signalling molecules.

The aim of the project is to investigate mixing and transport in active suspensions, with an ideal application being how chemical reactions occur in these environments. There are options for either analytic calculations or numerical simulations, depending on the preferences of the student.

Reading:

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

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).

Lévy fluctuations and mixing in dilute suspensions of algae and bacteria, I.M. Zaid, J. Dunkel and J.M. Yeomans, Journal of the Royal Society Interface 8 1314 (2011).

Movies:

http://www.rowland.harvard.edu/labs/bacteria/index_movies.html and <http://www.haverford.edu/physics/Gollub/OscSwimmers.rar>

Supervisor : **Prof J Yeomans** Physics Tel No : 273992
Email : j.yeomans@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 document 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

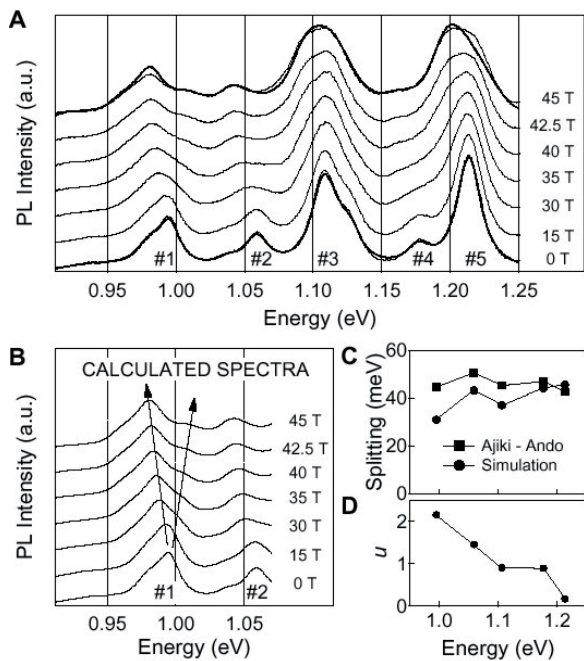


Figure 1: A complex figure which displays a substantial amount of information quite efficiently, but requires a long and well organised figure caption (Zaric et al., Science, **304** 5674 (2004)).

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

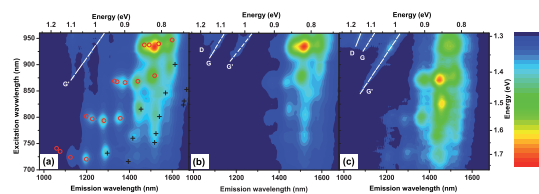


Figure 2: An overcomplicated figure which has been reduced to such an extent that it is no longer useful.

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 cm² 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 cm² 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

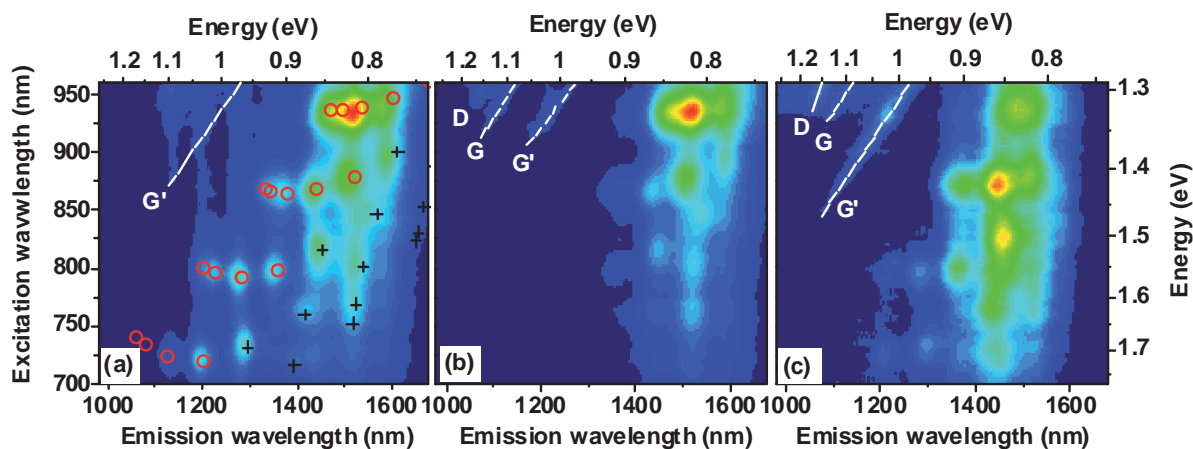


Figure 3: An improved version of Figure 2 which allows you to present a large amount of complex data in a relatively small area. Such a figure will need a substantial amount of explanation in both the figure caption and the text and would be almost meaningless if printed out on a black and white printer.

Typesetting a Report conforms to these when the report is approximately 10 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;

Risk Assessment Form (SPECIMEN)

UNIVERSITY OF OXFORD • DEPARTMENT OF PHYSICS

HEALTH AND SAFETY FORM FOR UNDERGRADUATE PROJECTS

Name Area/Group/Project
(Please print) (incl. room nos, if appropriate)

Supervisor Sub Dept

UNDERGRADUATE PROJECT SAFETY TALK

I have either i) attended the undergraduate project safety talk, or
ii) watched the video of the undergraduate project safety talk.
(please tick)

Signed..... Date.....

LASER SAFETY AND EYE HEALTH DECLARATION

Please complete either section A (working with lasers) or section B (not working with lasers)

(A) All potential Laser users (see Work Hazard Checklist) must complete sections Ai, Aii, and Aiii,

i) I do not suffer from diabetes or glaucoma or have any past history of eye disease, eye damage or malfunction.
(Please contact the Laser Safety Supervisor if you are unable to sign this section).

Signed..... Date.....

ii) I have read and agree to follow the safety principles laid down in the publications "Safety In Universities: Notes Of Guidance, Part 2:1 Lasers, Revised 1992" and University Guidance Note S3/04 "Laser Safety" (available from your Supervisor).

Signed..... Date.....

iii) I have watched the Laser safety video and have read and understood the written information that accompanied it.

Signed..... Date.....

(B) I shall not be using Lasers or working in a Laser designated area during the course of my work.

Signed..... Date..... continued

DECLARATION FOR WORKING WITH (OR NEAR) MAGNETIC FIELDS

I do not have i) a heart pacemaker ii) artificial heart valves or iii) surgically implanted metallic clips or pins.
(Please contact the Physics Area Safety Officer if you are unable to sign this section).

Signed..... Date.....

RADIATION PROTECTION DECLARATION

Please complete either section C (working with ionising radiation) or section D (not working with ionising radiation)

(C) My work is likely to involve the use of ionising radiation (see Work Hazard Checklist).
Please inform the Senior Radiation Protection Supervisor of this, on my behalf.

Signed..... Date.....

(D) I shall not be using ionising radiation or working in a designated area for ionising radiation during the course of my work.

Signed..... Date.....

HEALTH AND SAFETY HANDBOOK

I have read the “Department of Physics - Health and Safety Handbook” which includes the Statement of Safety Organisation (available from your Supervisor)

Signed..... Date.....

RISK ASSESSMENT DECLARATION

My Supervisor has made available to me the written Risk Assessment(s)* relating to my work in the Department of Physics.
I understand that if, at any time, I am unclear on working procedures I must consult either my Supervisor, or the Department Safety Officer or the Physics Area Safety Officer.

Signed..... Date.....

* Please give details of the Risk Assessment(s) for the work activities in which you will be involved:

Risk Assessment(s)
(Reference number, Title etc.)

continued

TO THE SUPERVISOR:

1) Work Hazard Checklist: Tick the hazards and/or work activities, listed below, that are likely to give rise to significant Health and Safety risks to the named person whilst performing his or her work. You must ensure that written risk assessments are prepared for those hazards that you tick, prior to the named person commencing work, in accordance with University Policy Statement S2/ 97-revised November 1998 (Risk Assessment).

NB. Model risk assessments are available for guidance for all hazards indicated by a single asterisk. Safety supervisors or assessors are to be consulted prior to commencing work with hazards indicated with a double asterisk.

- | | |
|---|--|
| <input type="checkbox"/> Pressure Systems* | Chemicals: |
| <input type="checkbox"/> Compressed Gases and Gas Cylinders* | <input type="checkbox"/> Toxic* |
| <input type="checkbox"/> Electrical or Electronic Equipment* | <input type="checkbox"/> Flammable* |
| <input type="checkbox"/> Liquid Refrigerants* | <input type="checkbox"/> Corrosive* |
| <input type="checkbox"/> Ultra Violet Lamps* | <input type="checkbox"/> Reactive/Unstable* |
| <input type="checkbox"/> Glassware and Sharps* | <input type="checkbox"/> General, Not Laboratory Specific, Chemical Preparations (cleaning agents etc.)* |
| <input type="checkbox"/> High Magnetic Fields* | <input type="checkbox"/> Paints, Resins and Glues containing Isocyanates* |
| | <input type="checkbox"/> General Painting* |
| | <input type="checkbox"/> Electrophoresis Equipment* |
| Engineering Workshops*: | <input type="checkbox"/> Lasers** |
| <input type="checkbox"/> Machine Tools / Metalworking Fluids / Lifting Equipment / Manual Handling* | <input type="checkbox"/> Radioactive Substances** |
| <input type="checkbox"/> Abrasive Wheels* | <input type="checkbox"/> Particle Accelerators**/ Neutron Sources** |
| <input type="checkbox"/> Hand Tools* | <input type="checkbox"/> X-Ray Generators** |
| <input type="checkbox"/> Ladders* | <input type="checkbox"/> Noise** |
| <input type="checkbox"/> Welding/Cutting* | <input type="checkbox"/> Personal Protective Equipment** |
| <input type="checkbox"/> Lift Trucks* | <input type="checkbox"/> Manual Handling** |
| <input type="checkbox"/> Tower Scaffolding* | <input type="checkbox"/> Display Screen Equipment** (eg. Computers) |
| <input type="checkbox"/> Others (specify): | |
| Woodworking Workshops*: | |
| <input type="checkbox"/> General Assessment / Machine Tools / Manual Handling* | |
| <input type="checkbox"/> Others (specify): | |
| <input type="checkbox"/> NONE OF THE ABOVE | |
| <input type="checkbox"/> OTHERS (specify): | |

2) Complete the table below by listing the work hazard(s) ticked above in (1) and defining the associated risk (categorised A to D) for the named person

- A** Work must not be undertaken unless the Supervisor named above is present.
- B** Work must not be undertaken unless another member of staff, nominated by the Supervisor named above, is present.
- C** Work must not be started without the advice of the Supervisor named above or his/her nominee.
- D** Work with risks, other than A, B and C above, where it is considered essential that workers are adequately trained and competent in the procedures involved.

Identified hazard from (1)	Risk Category A, B, C or D	Person supervising when B or C risk categories have been identified

DECLARATION OF SUPERVISOR:

I believe that the circumstances under which the work will be undertaken have been properly declared. I have

- a) in accordance with University Policy Statement S2/97 (revised November 1998) ensured that written risk assessments, including methods of working to minimise risks, have been prepared and made available to personnel
- b) indicated the category of risk and required level of supervision
- c) named the person(s), other than myself, who will immediately supervise the work of risk category type B and C
- d) ensured that work of sufficiently high risk undertaken outside the Department's normal working hours has adequate risk control measures in place and that adequate numbers of personnel are available to deal with any emergency that may arise (University Policy Statement S2/97-revised November 1998), and
- e) wherever the work involves lasers, added the persons name to the list of authorised users on the relevant laser record forms and ensured that he/she has signed these forms, if required, to indicate that he/she has read and understood the contained information.

Signed:

Date:

PLEASE RETAIN THE COMPLETED FORM FOR YOUR INFORMATION AND SEND A COPY TO MRS D THOMASON, PHYSICS AREA SAFETY OFFICER, DENYS WILKINSON BUILDING.

h&s08.UG

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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 2011.**

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:

MPhys Project Draft Form 2011 - 2012

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.**



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 2011-2012*.

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*