Oxford Master's Course
in
Mathematical and Theoretical Physics

COURSE HANDBOOK

2023-2024

This handbook applies to students starting the Master's of Mathematics and Physics (MMathPhys) or the MSc in Mathematical and Theoretical Physics in Michaelmas term 2023. The information in this handbook may be different for students starting in other years.

The Examination Regulations relating to this course are available at **https://examregs.admin.ox.ac.uk/**.

If there is a conflict between the information in this handbook and the Examination Regulations then you should follow the Examinations Regulations.
If you have any concerns please contact **mathematical.physics@maths.ox.ac.uk**.

The information in this handbook is accurate as of 1 October 2023, however it may be necessary for changes to be made in certain circumstances, as explained at **https://www.ox.ac.uk/coursechanges/**. If such changes are made the department will publish a new version of this handbook together with a list of the changes and students will be informed.

Version 1.0

Welcome

Welcome to the Oxford Master's Course in Mathematical and Theoretical Physics. Our course provides a high-level education in the areas of Theoretical Particle Physics/String Theory, Condensed Matter Theory, Theoretical Astrophysics/Fluids, and Mathematical Foundations of Theoretical Physics up to the level of research.

As you are probably aware, there is considerable flexibility in designing your path through the course; you can decide to focus on one of the above areas or study more widely across areas. It is important that you consider your choices carefully. Consult the syllabi and the case studies in this handbook for more information and, if in doubt, talk to your personal tutor or an academic related to the programme.

For an advanced programme of this kind written examinations are not always the best form of assessment. You will find that the way we evaluate your work often correlates with the nature of the material. Typically, there will be formal written exams for the basic, foundational courses, other forms of assessment such as take-home exams or mini-projects for intermediate courses and a homework completion requirement for advanced courses. There are certain constraints on assessment—for example you have to sit four units of written exams. Be sure that your course choices are consistent with these constraints. Also note that Trinity term is devoted to advanced courses and there is no designated "revision" period.

Passing exams is a necessary and important part of learning and education but we hope you agree that there is significantly more to it. Enthusiasm, engagement with the subject, the desire for deep and profound understanding is what truly motivates us and we hope this is how you will engage with the course. We wish you a successful, productive and insightful year.

Best wishes,

Prof Lionel Mason and Prof Caroline Terquem

Contents

1 Introduction

This handbook contains important information about the Masters course in Mathematical and Theoretical Physics. It is intended as a guide and reference for you throughout the course. There are a number of other sources of information that you will need to refer to during your course and links to these are given below, together with a list of key contacts.

1.1 Key Sources of Information

Course website: http://mmathphys.physics.ox.ac.uk/

The course schedule, course synopses, details of seminars and the online course handbook can all be found here.

Mathematical Institute website: http://www.maths.ox.ac.uk/

Department of Physics website: http://www.physics.ox.ac.uk/

Examination Regulations: https://examregs.admin.ox.ac.uk/

The University's examination regulations govern all academic matters within the University and contain the general regulations for the conduct of University examinations, as well as specific regulations for each degree programme offered by the University.

Examination Conventions: http://mmathphys.physics.ox.ac.uk/students/

The examination conventions for the course set out how each unit will be assessed and how the final degree classification will be derived from the marks obtained for the individual units.

Seminars: http://mmathphys.physics.ox.ac.uk/seminars/

University web pages for students: http://www.ox.ac.uk/students/

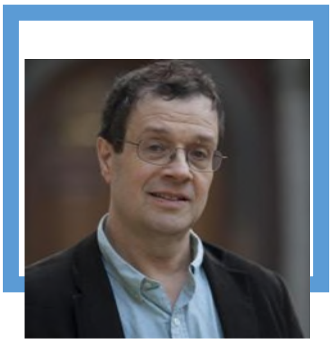
This website provides access to information, services and resources.

Oxford Student Handbook: https://www.ox.ac.uk/students/academic/student-handbook/

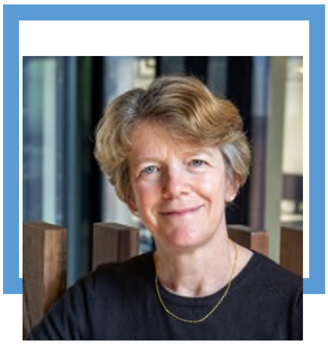
This contains general information and guidance about studying at the University of Oxford, and gives you formal notification and explanation of the University's codes, regulations, policies and procedures.

College Handbook: The handbook for your college will be available on the college website.

1.2 Key contacts

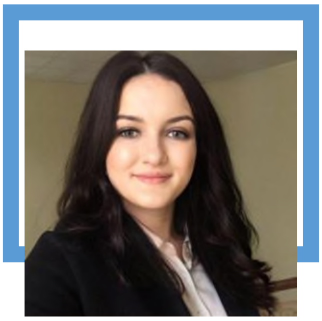


Course Director Prof Lionel Mason
Email: lmason@math.ox.ak



Chair of JSC Prof Caroline Terquem
Email: caroline.terquem@physics.ox.ac.uk

Head of Academic Administration Charlotte Turner-Smith
Email: charlotte.turner-smith@maths.ox.ac.uk



MSc MTP Administrator Diana Yatsyshyn
Email: mathematical.physics@maths.ox.ac.uk

Mathematical Institute Reception: reception@maths.ox.ac.uk

Department of Physics Reception: reception@physics.ox.ac.uk

1.3 The Academic Year

The course lasts three terms, from the beginning of October to the end of the following June. Some work is carried out in the vacations.

For the academic year 2023–2024, the course begins with an induction on 3 October 2023. The dates of the University Full Terms for the Academic Year 2023–2024 are:

MT = Michaelmas Term 2023	**8 October – 2 December**
HT = Hilary Term 2024	**14 January – 9 March**
TT = Trinity Term 2024	**21 April – 15 June**

A calendar of important dates is given in Appendix A.

1.4 Finding Your Way Around

Teaching for the course (where in-person teaching occurs) will take place in the Mathematical Institute (**http://www.maths.ox.ac.uk/about-us/travel-maps**) and in the Denys Wilkinson Building or in the Clarendon Laboratory of the Department of Physics. To enter the Denys Wilkinson Building, go up the wide concrete steps from Keble Road; turn left at the top and the entrance is facing you:

https://www.accessguide.ox.ac.uk/denys-wilkinson-building#collapse1426661

The main entrance to the Clarendon Laboratory in on Parks Road, next to the University Parks:

https://www.accessguide.ox.ac.uk/clarendon-laboratory#collapse2861361

At the Mathematical Institute, all lecture rooms and classrooms are located on the mezzanine level.

A searchable, interactive map of all college, department and libraries can be found at **https://maps.ox.ac.uk/bd821e30-d8ba-11eb-a363-059e537832a1**.

2 The MSc Course

2.1 Overview

The Master's Course in Mathematical and Theoretical Physics is offered in two modes, the MMathPhys for existing Oxford undegraduates and the MSc for students from outside Oxford. The academic content is identical for both modes. If you are an Oxford MPhys, MMath or MPhysPhil student who transfers to the MMathPhys you will graduate as a "Master of Mathematical and Theoretical Physics" with a double classification for Parts A and B as previously assigned by the Part B Examiners in the subject in which you sat those parts. If you are a student on the MSc course, you will graduate with an "MSc in Mathematical and Theoretical Physics."

These qualifications may be compared to national standards for higher education qualifications through the Framework for Higher Education Qualifications (FHEQ). The University awards framework (UAF) maps the awards of the University against the levels of the FHEQ. The FHEQ level for both the MMathPhys course and MSc course is 7. The relevant subject benchmark statements for the course, which set out expectations about standards of degrees in a given subject area, are Physics & Astronomy (QAA 2008) and Mathematics, Statistics & Operational Research (QAA 2015).

2.2 Aims

The Oxford Master's Course in Mathematical and Theoretical Physics aims to provide students with high-level, internationally competitive training in mathematical and theoretical physics, right up to the level of modern research in the area.

As a graduate of this programme you will be in a prime position to compete for research degree places in an area of Theoretical and Mathematical Physics at leading research universities in the UK or overseas; or to pursue a research-related career, based on the acquired high-level ability in mathematics and its applications to physical systems, outside academia.

2.3 Learning Outcomes

During the course you will develop a knowledge and understanding of:

- Theoretical and Mathematical Physics, focusing on one of the areas of Theoretical Particle Physics, Theoretical Condensed Matter Physics, Theoretical Astrophysics/Fluids, or studying across these areas.
- A broad range of physical phenomena and their description within Theoretical and Mathematical Physics.
- A wide range of advanced mathematical techniques and structures and how they are applied in Theoretical Physics.

You will also have the opportunity to develop the following skills.

Intellectual Skills

- An appreciation of the principles of Theoretical and Mathematical Physics and their application to natural phenomena.
- The ability to model physical phenomena and deploy a wide range of mathematical methods for their description.

- A working knowledge of high-level mathematical methods and their application to systems in physics and beyond.

Practical Skills

- Ability to apply mathematical methods to practical problems.
- Ability to construct, write-up and communicate logical arguments of some complexity.

Transferable Skills

- Ability to solve problems effectively and to apply high-level mathematical methods to a wide range of problems.
- Ability to manage your time and to acquire a complex body of knowledge in a limited time.
- Ability to manage your own learning and study for research or other professional qualifications.

2.4 Course Structure

The programme consists of a large array of lecture courses covering the main areas of modern Theoretical/Mathematical Physics and Applied Mathematics. The courses are subdivided into the following *strands:*

- **Quantum Field Theory, Particle Physics, and String Theory**
- **Theoretical Condensed Matter Physics**
- **Theoretical Astrophysics, Plasma Physics, and Physics of Continuous Media**

Furthermore, each of these strands can be studied from the perspective of their mathematical foundations.

Various areas of Theoretical and Mathematical Physics are interconnected, grounded in universal principles and thrive on ideas that cross many sub-field boundaries. A number of courses are shared between the three strands and emphasise the unity of the subject. This applies especially to the *foundational courses* offered in Michaelmas term. These are followed by increasingly specialised courses in Hilary and Trinity terms, although those too will strive to make connections between subject areas.

There are no compulsory courses and you will thus be able to choose a path reflecting your intellectual tastes or career choices; Appendix B gives examples of different pathways through the course. An overview of the courses can be found in the table accompanying this section. Detailed synopsis for each course can be found at https://mmathphys.physics.ox.ac.uk/course-schedule and a table providing details of the assessment method for each course can be found in Appendix A of the examination conventions.

You will be required to undertake at least 10 units, with 1 unit normally corresponding to 16 hours of lectures. This means that 16-hour lecture courses count as one unit, while, for example, 24-hour lecture courses count as 1.5 units. More specifically you are required to offer at least:

(a) **four units that are assessed by written invigilated exams;**

(b) **three units that are assessed by written invigilated exams or by other formal assessments;**

(c) **three other units (which may be from courses with homework completion requirement only or from assessed courses).**

One or two of the 10 units in (b) or (c) can be replaced by a dissertation. There are no other formal constraints on course choices and students are otherwise free to design their own pathways (although paying close attention to the guidance offered is strongly recommended). Note however that you should be careful about the number of units you undertake each term, and that taking too many units in Trinity term may be difficult as exams start on week 6. In practice it may be difficult to fit in more than 12 units in total. **Please note that it is your responsibility to ensure that you fulfil the requirements for the overall number of units and the number of assessed units**. The modes of assessment and details on completion requirements for all courses are provided in Appendix A of the exam conventions.

You will be offered detailed academic guidance from the Director of Studies or an Academic Adviser designated by the Director of Studies on choosing an individual path suitable for you. Course lecturers will also advise on the recommended background for their courses or possible follow-up courses you might wish to choose.

2.5 Additional Courses

In addition to the courses listed in the table, which are offered explicitly as part of the MMathPhys/MSc programme, you will also be allowed to choose a maximum of three-units worth of *additional* MMath Part C: https://www.maths.ox.ac.uk/members/students/undergraduate-courses/teaching-and-learning or MPhys Part C: https://www3.physics.ox.ac.uk/lectures/ lecture courses that are not listed here, subject to approval by the Director of Studies, Prof Lionel Mason at lmason@maths.ox.ac.uk. Once the Director of Studies has granted approval, your request will then be passed on by the Course Administrator to the Associate Head of Department of Mathematics or the relevant individuals in the Department of Physics, who will provide the final approval contingent upon there being space in the Part C courses in question.

MPhys part C courses will usually be counted as two units. However, there is often significant overlap with courses on the MTP/MMathPhys and the courses there are recommended over their MMPhys Part C counterparts. If the more experimental point of view that these courses offer is nevertheless preferred by a candidate, these courses may be allowed by the course director, but if taken in conjunction with an overlapping MTP/MMathPhys course, only a reduced equivalent number of units might be allowed by the Course director.

Approval for MT additional courses should be sought by Monday of week 1 of MT. Approval for HT additional courses should be sought by week 9 of MT. Part B courses will only approved in exceptional circumstances and will need to be supplemented by extra material to bring them up to the level of a part C course.

Legend for fonts, colours, and superscripts in the Table:

Bold: a foundational course;

Plain: an interdisciplinary course shared between strands;

Italic: a course special to a particular strand;

Red*(PU:NN)*: a course also taught (in some cases in part) as a Part C course in Physics, NN is its number;

Blue*(MU:NNN)*: a course also taught as a Part C course in Mathematics, NNN is its number;

Purple*(MG)*: a course also taught as a PG course in Mathematics;

Black: an MMathPhys/MSc course, also taught as a PG course in Physics;

'M' a course where lectures and classes are taught at the Mathematical Institute;

'P' a course where lectures and classes are taught at the Department of Physics;

'Phil' a course where lectures and classes are taught at the Department of Philosophy.

Overview of Lecture Courses			
	Theoretical Particle Physics	*Theoretical Condensed Matter Physics*	*Theoretical Astrophysics, Plasma Physics & Physics of Continuous Media*
MT	**Quantum Field Theory** (P) (24)		
	Algebraic Topology(MU:C3.1) (M) (16)	**Advanced Quantum Theory**(PU:C6) (P) (20)	
	Algebraic Geometry(MU:C3.4) (M) (16)	**Kinetic Theory** (P) (28)	
	Lie Algebras(MU:C2.1) (M) (16)	*Introduction to TPM* (P) (16)	*Quantum Processes in Hot Plasma* (P) (12)
	General Relativity I(MU:C7.5) (M) (16)		
	Perturbation Methods(MU:C5.5) (M) (16)		
		Networks(MU:C5.4) (M) (16)	
	Numerical Linear Algebra(MU:C6.1) (M) (16)		
	Groups and Representations (P) (24)		
		Topics in Fluid Mechanics(MU:C5.7) (M) (16)	
	Differentiable Manifolds(MU:C3.3) (M) (16)		
	Advanced Philosophy of Physics (Phil.) (16)		
HT	*Advanced QFT* (P) (24)	Advanced Fluid Dynamics (P) (16)	
	String Theory I(MG) (M) (16)	**Nonequilibrium Statistical Physics** (P) (16)	
	Supersymmetry & Supergravity (M) (16)		*High Energy Density Physics* (P) (16)
	Geometric Group Theory(MU:C3.2) *(M) (16)*		*Collisionless Plasma Physics* (P) (8)
	Riemannian Geometry(MU:C3.11) (M) (16)		*Geophysical Fluid Dynamics* (P) (16)
	Introduction to Quantum Information(MU:C7.4) (M) (16)		
	Low-Dimensional Topology & Knot Theory(MU:C3.12) (M) (16)		
	General Relativity II(MU:C7.6) (M) (16)		
	Cosmology (P) (16)		
	Random Matrix Theory(MU:C7.7) (M) (16)		
	Applied Complex Variables(MU:C5.6) (M) (16)		
	Advanced Philosophy of Physics (Phil.) (16)		
	Statistical Mechanics and Computer Algorithms (P) (16)		
TT	Conformal Field Theory (M) (16)		*Collisionless Plasma Physics* (P) (10)
	String Theory II(MG) (M) (16)		*Collisional Plasma Physics* (P) (18)
	Quantum Field Theory in Curved Space-Time (M) (16)	*Quantum Matter* (P) (16)	*Galactic & Planetary Dynamics* (P) (16)
	The Standard Model and Beyond I (P) (16)		*Advanced Topics in Plasma Physics* (P) (8)
	The Standard Model and Beyond II (P) (16)	Renormalisation Group (M) (16)	
		Topics in Soft & Active Matter Physics (P) (8)	
	Dissertation, replacing one (or two) 16-hour lecture course(s)		

3 Teaching and Learning

3.1 Organisation of Teaching

Teaching for the course will be provided jointly by the Department of Physics and the Mathematical Institute through lectures and classes. In addition, students undertaking a dissertation will have supervision meetings with their dissertation supervisor.

3.2 Lectures

Depending on the options you take, you should normally have 6-8 hours of lectures per week. A lecture timetable for each term will be made available on the course website **here**. You will also be able to access recorded lectures and live-streamed lectures when available. Please do not share these links outside your cohort. If you have a friend on another Maths/Physics related degree at the University of Oxford who would like to access lecture links, please direct them to either the course lecturer or the MTP Course Administrator.

Course Material

Course material, such as lecture notes and problem sheets, will be published on the Mathematical Institute website and the Department of Physics website. Students should follow the links to the appropriate pages from the lecture schedule on the course website.

3.3 Class Registration

Lecture courses will normally be accompanied by problem sets and weekly or fortnightly problem classes. Classes will normally contain 10–15 students. For most courses you will need to sign-up for a set of classes at the start of each term; this is usually done via an online sign-up system.

For classes held at the Mathematical Institute and at the Department of Physics, you will receive an email in week 0 from mathematical.physics@maths.ox.ac.uk notifying you that class registration is open and providing details regarding the registration process. You will not be able to attend classes unless you have registered for them beforehand. You will be able to view the classes for which you have successfully signed up on TMS (**https://tms.ox.ac.uk/**).

To see which lectures take place in each department, please refer to the table on page 7 of this handbook. Lectures for a course followed by a (P) are held at the Department of Physics, while those for a course followed by an (M) are held at the Mathematical Institute.

If you are taking the Advanced Philosophy of Physics option, you will arrange tutorials directly with the course tutor. The MTP Course Administrator will circulate an e-mail with the name of the course tutor and instructions for arranging tutorials at some point in MT. There will not be a separate class registration process.

3.4 Class Withdrawal

For classes held at the Mathematical Institute or the Department of Physics, you will have until Monday week 4 of each term to request a class switch or to decide that you would no longer like to attend a particular class. To do so, please contact your class tutor as well as the MTP Course Administrator.

It is important to withdraw from a class if you no longer wish to take it. If you do not withdraw from a class, then your college will be charged for your attendance. Furthermore, when you withdraw from a class, your tutor and teaching assistant will know not to expect you to attend, and will not need to be concerned about your absence from classes.

If you have made an official exam entry for a course via student self-service (see page 12) and decide that you no longer wish to take that course, please note that in addition to withdrawing from the classes that accompany the lecture course and assessment, **you must also withdraw from the assessment itself**. If you do not do so, then you will receive a technical fail when you do not submit the assessment/attend the exam. You will need to contact your college office to officially withdraw from any exams, formal assessments, or homework options for which you have made an official exam entry.

Online Submission Process

Whether you are taking a course which is assessed by homework completion, or are submitting problem sheets for an examined or formally assessed course, you will be required to submit your homework online by the deadlines specified on the course. If you are submitting problem sheets for a Physics course, you will submit via Canvas:

https://canvas.ox.ac.uk/courses/226235

If you are submitting problem sheets for a Maths course, you will submit via Moodle:

https://courses.maths.ox.ac.uk/course/index.php?categoryid=148

Ensure that your name and college e-mail address are on your work, but NOT your candidate number. (The candidate number is used to render you anonymous, but in the instance of homework, your teaching assistant needs to know your name so they can return your work to you.)

Include your name PDF filename you submit as your homework. Write the name of the lecture course and problem sheet at the top of your work, *e.g.*, “Groups and Representations Problem Sheet 1”.

It is your responsibility to ensure that your work has been submitted, especially if you are submitting your homework for the purpose of homework completion. If you are concerned that your internet connection may have been interrupted and your work did not submit, you should contact your Teaching Assistant as soon as possible to confirm it has been received.

3.5 Dissertations

You may opt to offer a dissertation as one, or with special permission two, of your ten units. A dissertation offers a substantial opportunity for independent study and research, and would be undertaken under the guidance of a member of the Department of Physics or the Mathematical Institute. A dissertation involves investigating and then presenting in writing a particular area of Mathematical Physics or Theoretical Physics; you would not be required to (but may) obtain original results. A list of possible dissertation topics is given in Appendix C, but you are not limited to this list and may propose your own topic instead.

The exact process to apply for a dissertation can be found via the Dissertation Guidance document here: https://mmathphys.physics.ox.ac.uk/sites/default/files/mmathphys/documents/media/dissertation_guidance_students.pdf

The following link includes a LaTeX template you can use for formatting your dissertation:
https://www.maths.ox.ac.uk/members/it/faqs/latex/thesis-class

You can view past students dissertations via the following link:
https://www.maths.ox.ac.uk/members/students/undergraduate-courses/mmathphys-msc-mtp/past-dissertations
(You will need to log in via the top right corner using your Single Sign On.)

You should plan on beginning work on your dissertation soon after your abstract has been approved. You are advised to bear in mind that you will need to use your time in the Easter vacation and early Trinity term wisely to balance preparing for the Trinity term exams, working on your dissertation, and completing work for other courses you may be taking.

Your supervisor will read and provide feedback on the initial draft of your dissertation (provided that it is submitted to them in good time).

The submitted dissertation should conform to the following points.

- The dissertation must include an abstract and a bibliography.
- The dissertation must be word-processed and have a font size of 12pt.
- The text should be double spaced
- The dissertation should have a title page which includes the following:
  - the title of dissertation,
  - the candidate's examination number,
  - the title of the candidate's degree course,
  - the term and year of submission.
- The length should not exceed 30 pages for a single unit and 60 pages for a double unit. The page count may exclude any table of contents, diagrams, tables, bibliography, dedications/acknowledgements, abstract, and the texts of computer programs. However, any footnotes and appendices must be included.

3.6 Advice on Teaching and Learning Matters

There are a number of people you can consult for advice on teaching and learning matters. Academic advisors will be appointed for all students at the start of the course and will be available for consultation on any academic matter. Students can also seek guidance on academic matters from their college personal tutor. All students will receive academic guidance from the Director of Studies.

If you have any issues with teaching or supervision please raise these as soon as possible so that they can be addressed promptly. Details of who to contact are provided in Section 7.2 Complaints and Appeals.

3.7 Skills and Learning Development

Expectations of Study

You are responsible for your own academic progress. Therefore, in addition to the formal teaching you receive through lectures, classes and dissertation tutorials, you will be expected to undertake a significant amount of self-directed, independent study both during term time and in the vacations. You are advised to read the University's guidance on undertaking paid work at **http://www.ox.ac.uk/students/life/experience**.
You should seek advice from your advisor if you find it impossible to complete your academic work without spending significantly longer than 48 hours per week on a regular basis.

Your academic progress will be monitored by your academic advisor and also your college advisor. College advisors will receive reports from the class tutors for the classes you attend. In addition, academic advisors of MSc students will submit termly reports on their student's progress via the Graduate Supervision Recording (GSR). These reports are reviewed by the Director of Studies. If you are concerned about your academic progress please contact your college tutor, academic advisor or the Director of Studies.

For MSc students, it is also mandatory to complete a self-assessment report via GSR for every reporting period. You can access GSR via the following link: **https://www.ox.ac.uk/students/selfservice**. Students will be sent a GSR automated email notification with details of how to log in at the start of each reporting window, and who to contact with queries.
Completing the self-assessment will provide the opportunity to:

- Review and comment on your academic progress during the current reporting period
- Measure your progress against the timetable and requirements of your programme of study
- Identify skills developed and training undertaken or required
- List your engagement with the academic community
- Raise concerns or issues regarding your academic progress to your Academic Advisor
- Outline your plans for the next term (where applicable)

If you have any difficulty completing this you must speak to your Academic Advisor or Director of Studies. Your self-assessment report will be used by your Academic Advisor as a basis to complete a report on your performance this reporting period, for identifying areas where further work may be required, and for reviewing your progress against agreed timetables and plans for the term ahead. GSR will alert you by email when your Academic Advisor has completed your report and it is available for you to view.

University Lectures and Departmental Seminars

University lectures in all subjects are open to all students. A consolidated lecture list is available on the University website at: **http://www.ox.ac.uk/students/academic/lectures/**.

Seminars and colloquia given in the Mathematical Institute and Physics Department, often by mathematicians and physicists of international repute, are announced on the departmental notice boards:

https://www.maths.ox.ac.uk/events/list

https://www.physics.ox.ac.uk/seminars-and-colloquia

you are encouraged to attend any which interest you.

Particle Theory seminars are listed here and here.

Study Skills

Much of the advice and training in study skills will come in the regular class teaching you receive. A wide range of information and training materials are available to help you develop your academic skills – including time management, research and library skills, referencing, revision skill and academic writing–through the Oxford Student website: https://www.ox.ac.uk/students/academic/guidance/skills

3.8 Key Teaching Links

Lecture Timetable: http://mmathphys.physics.ox.ac.uk/course-schedule

https://www.maths.ox.ac.uk/members/students/lecture-lists

Class Lists: https://tms.ox.ac.uk/

Physics Class Information: https://mmathphys.physics.ox.ac. uk/course-schedule (follow links to course pages)
https://canvas.ox.ac.uk/courses/226235 (on Canvas)

Problem Sheet Submission: https://courses.maths.ox.ac.uk/course/index.php?categoryid=148 (maths)
https://canvas.ox.ac.uk/courses/226235/assignments (physics)

4 Examinations and Assessments

4.1 Assessment of the Course

All of the units you undertake will have either a component of formal assessment (written invigilated exam, take-home exam, mini-project or dissertation) or a homework completion requirement. Each unit will be assessed by the method most suited to the material being taught. The table in the examination conventions indicates which courses are assessed and by which method and it indicates which courses have a homework completion required. The examinations are governed by the University's Examination Regulations and the course examination conventions.

4.2 Examination Conventions

The examination conventions for the course are the formal record of the specific assessment standards for the course. They set out how each unit will be assessed and how the final degree classification will be derived from the marks obtained for the individual units. They include information on marking scales, marking and classification criteria, scaling of marks, formative feedback, resits and penalties for late submission. The examination conventions for 2023–24 can be found on the course website at **http://mmathphys.physics. ox.ac.uk/**.

4.3 Examination Entries

You must formally enter for the units on which you wish to be assessed, including for those courses which only have a homework completion requirement. This is done by completing an examination entry form online through Student Self Service (**https://evision.ox.ac.uk/**).

Further information on the process can be found at **http://www.ox.ac.uk/students/academic/exams/entry**.

For this course there will be three examination entry dates:

- **2nd November, week 4 of Michaelmas term** for courses examined by invigilated written examination in Hilary term;
- **25th January, week 2 of Hilary term** for Michaelmas term practicals (homework), Hilary term submissions (such as mini-projects released in Hilary term), and all courses assessed by invigilated written examination in Trinity term.
- **9th May, week 3 of Trinity term** for Hilary and Trinity term practicals (homework) and Trinity term submissions (such as the dissertation).

When completing your examination entry, try to ensure that the decisions you make are as final as possible. Nevertheless, if you subsequently change your mind about which courses to be assessed on, it is possible to make changes to your entry. To change an option after the examination entry deadline has passed you must apply for permission in writing through your Senior Tutor or other college officer using the change of options form available from your College Office. You will be charged a fee for making a late change to your examination entry.

If you have entered for assessments in additional courses (beyond the required ten units) but subsequently decide not to take the additional assessments, then you should inform your College Office. You must do this prior to either the examination date for written examinations or the submission date for coursework.

4.4 Examination Dates and Submission Deadlines

The calendar of important dates (Appendix A) gives the expected start dates for the invigilated written examinations and coursework submission deadlines. The final examination timetable for invigilated written examinations will be set by the Examination Schools and published online at:
http://www.ox.ac.uk/students/academic/exams/timetables.

4.5 Preparation and Submission of Coursework

4.5.1 Mini-Projects and Take-Home Examinations

Some units will be assessed wholly or partially by submitted work. This will take one of two forms: mini-project or take-home examination. The deadline for the submission of the assessment for each unit is given in the table included in the examination conventions.

The examiners will send out notices to candidates detailing where your work should be submitted and what format your submission should be in (*e.g.*, handwritten or word-processed). Candidates will be required to submit an electronic copy and instructions on the online submission process will be included in the notice to candidates.

It is vital that you submit your work by the deadline as late submissions will be reported to the Proctors and a late submission penalty may be applied (see section 5 in the examination conventions). See the examination conventions and the website http://www.ox.ac.uk/students/academic/exams/submission for advice on what to do if you are unable to submit your work on time due to medical emergency or other urgent cause.

4.5.2 Dissertation

The deadline for submission of the dissertation is 12 noon on Monday of week 6, Trinity Term. Dissertations must be submitted electronically and instructions on the online submission process will be included in the notice to candidates. Please note the information in section 4.5.1 regarding the importance of submitting your work on time.

4.5.3 Plagiarism

Plagiarism is presenting someone else's work or ideas as your own—with or without their consent—by incorporating it into your work without full acknowledgement. All published and unpublished material, whether in manuscript, printed, or electronic form, is covered under this definition. Plagiarism may be intentional or reckless, or unintentional. Under the regulations for examinations, intentional or reckless plagiarism is a disciplinary offence. See the University's guidance on plagiarism for further information:
http://www.ox.ac.uk/students/academic/guidance/skills/plagiarism

4.6 Sitting Invigilated Written Examinations

Information on the standards of conduct expected in examinations and on what to do if you would like examiners to be aware of any factors that may have affected your performance before or during an examination (such as illness, accident, or bereavement) are available in Section 8.2 of the examination convention and on the Oxford Student website: (**http: //www.ox.ac.uk/students/academic/exams**).

4.7 Examination Prizes

One or more prizes may be awarded by the Examiners for excellence in examination for the Master of Mathematics and Physics (MMathPhys) or MSc in Mathematical and Theoretical Physics. The assessors of a dissertation that, in their view, shows particular originality and/or insight may recommend to the Examiners that this dissertation be given a commendation.

4.8 Key Assessment Links

Dissertation Guidance: http://mmathphys.physics.ox.ac.uk/students

Examination Regulations: https://examregs.admin.ox.ac.uk/

Examination Timetables: http://www.ox.ac.uk/students/academic/exams/timetables

Online Submission for Dissertations, Mini-Projects, and Take-Home Exams:
https://oxford.inspera.com/

Online Submission for Problem Sheets:
https://courses.maths.ox.ac.uk/ (Maths)
https://canvas.ox.ac.uk/courses/174015/assignments (Physics)

Past Examination Papers: https://mmathphys.physics.ox.ac.uk/past-examination-papers

Past Examiners' Reports: http://mmathphys.physics.ox.ac.uk/students

5 Resources and Facilities

5.1 Departmental Work and Social Spaces

You will be able to use the computers and desks in the Mezzanine Study Room to work within the Mathematical Institute. The study room has power sockets for students wishing to use their own laptops and there is wi-fi throughout the building.

The Institute's café is also located on the mezzanine level and has seating and tables for 100. The café serves drinks, snacks and meals from 08.30–16.15.

5.2 Libraries

College Library

The main source of borrowed books is your own College library.

Radcliffe Science Library (RSL)

Website: https://www.bodleian.ox.ac.uk/libraries/rsl

The Radcliffe Science Library is the science Library of the Bodleian and includes mathematics books at graduate and research level. Your University card will provide access.

Information about all Bodleian Libraries can be found here: https://www.bodleian.ox.ac.uk/libraries

Whitehead Library

Website: https://www.maths.ox.ac.uk/members/library

Students completing a dissertation may request a book for consultation if it is held only by the Whitehead Library (and not held by their College library, RSL or as an e-book), by emailing the Librarian at: libary@maths.ox.ac.uk . The book will be sent to the RSL where it can be consulted for reference (not borrowing).

5.3 Computing Facilities

Information regarding the University's IT Services can be found at **http://www.it.ox.ac.uk/**.

IT and Email accounts

MSc students will receive a University 'single-sign-on' IT account. This will have an email address associated with it which will be of the format

firstname.lastname@college.ox.ac.uk.

It is important that students read this email. MMathPhys students will retain the account they were issued with at the start of their degree.

For further information about Departmental IT matters, including rules and regulations surrounding the use of IT facilities, please see **http://www.maths.ox.ac.uk/members/it**.

You will have access to various licenses for further details go to **http://www.maths.ox.ac.uk/members/it/software-personal-machines**.

5.4 Careers and Employability

Careers guidance is provided by the *Careers Service* (**http://www.careers.ox.ac.uk/**), which also provides training in writing applications, interview techniques and analysis of transferable skills. The Careers Service provides information about occupations and employers, and advertises work experience opportunities.

In addition to its general programme, the Careers Service runs an annual 'Jobs for Mathematicians' half-day, in collaboration with the Mathematical Institute. At this event there are talks from alumni working in various industries and a talk for those interesting in continuing on to further postgraduate study. Further information about postgraduate study opportunities can be found at:

- https://www.maths.ox.ac.uk/study-here/postgraduate-study (Mathematical Institute)
- https://www.physics.ox.ac.uk/study/postgraduates (Department of Physics)

6 Student Representation and Feedback

6.1 Student Representation

Students will be able to nominate two representatives to sit on the Joint Supervisory Committee (JSC) which oversees the course. Volunteers will be sought at the Induction Session and an election held if necessary. The student representatives will be able to raise matters with the JSC on behalf of the cohort.

6.2 Consultative Committee for Graduates – Mathematics

The Consultative Committee for Graduates meets regularly once a term and discusses any matters that graduate students wish to raise. Students will be invited to nominate a representative to serve as the Mathematics and Physics rep on this committee via email in Michaelmas term.

6.3 The Physics Joint Consultative Committee

The Physics Joint Consultative Committee (PJCC) has elected undergraduate members who meet twice in MT and HT, and once in TT to discuss both academic and administrative matters with academic staff representatives. See **https://pjcc.physics.ox.ac.uk/** for more information.

6.4 Divisional and University Representatives

The MPLS Division also runs a divisional Undergraduate Joint Consultative Forum, a divisional Graduate Joint Consultative Forum, and is establishing a Joint Consultative Forum for Graduate Taught Courses. Each Forum is chaired by the senior MPLS Academic who is responsible for that area across the Division, an undergraduate or graduate representative from each department, the undergraduate or graduate representative on the Academic Committee and Divisional Board, and the Oxford Union Student Union (OUSU) Vice-President (Access and Academic Affairs) or Vice-President (Graduates).

Student representative sitting on the MPLS Divisional Board are selected through a process organised by OUSU. Details can be found on the OUSU website along with information about student representation at the University level.

6.5 Opportunities to Provide Feedback

Students will be asked to complete questionnaires evaluating the teaching received for each unit. Please take time to complete these as your feedback is valuable for future course planning.

MSc students, like all students on matriculated courses, will be surveyed on all aspects of their course (learning, living, pastoral support, college) through the annual Student Barometer. Previous results can be viewed by students, staff and the general public at: **https://www.ox.ac.uk/students/life/student-surveys**. MMathPhys students, as final year undergraduates, will be surveyed through the National Student Survey instead. Results from previous NSS can be found at **https://www.thestudentsurvey.com/**.

6.6 Key Student Representation Links

CCG: https://www.maths.ox.ac.uk/members/students/postgraduate-courses/doctor-philosophy/consultative-committee-graduates (Minutes of meetings and list of student representatives.)

Oxford SU: http://oxfordsu.org/

University Surveys: https://www.ox.ac.uk/students/life/student-surveys

7 Student Support and Academic Policies

7.1 Where to Find Help

Generally speaking for graduate students, departments are the main source of academic support and colleges are the main source of pastoral support. For undergraduate students, colleges also play a key role in providing academic support.

Every college has their own systems of support for students, please refer to your college handbook or website for more information on who to contact and what support is available through your college.

Details of the wide range of sources of support available more widely in the University are available from the Oxford Student website (**http://www.ox.ac.uk/students/welfare**), including in relation to mental and physical health and disability.

7.2 Complaints and Academic Appeals within the Department of Physics and the Mathematical Institute

The University, the Mathematical, Physical and Life Sciences Division, the Department of Physics and the Mathematical Institute all hope that provision made for students at all stages of their course of study will result in no need for complaints (about that provision) or appeals (against the outcomes of any form of assessment).

Where such a need arises, an informal discussion with the person immediately responsible for the issue that you wish to complain about (and who may not be one of the individuals identified below) is often the simplest way to achieve a satisfactory resolution.

Many sources of advice are available from colleges, faculties/departments and bodies like the Counselling Service or the OUSU Student Advice Service, which have extensive experience in advising students. You may wish to take advice from one of those sources before pursuing your complaint.

General areas of concern about provision affecting students as a whole should be raised through Joint Consultative Committees or via student representation on the faculty/department's committees.

Complaints

If your concern or complaint relates to teaching or other provision made by the faculty/department, then you should raise it with Associate Head of Department (Dr Richard Earl (Maths), Prof Hans Kraus (Physics)) or with the Director of Graduate Studies (Prof Raphael Hauser (Maths)) as appropriate. If your concern relates to the course as a whole, rather than to teaching or other provision made by one of the faculties/departments, you should raise it with Prof Caroline Terquem, Chair of the Joint Supervisory Committee for the Master of Mathematical and Theoretical Physics/MSc in Mathematical and Theoretical Physics. Complaints about departmental facilities should be made to the Head of Administration/Head of Physical Resources (Dr Jocasta Gardner (Maths), Mr Simon Probert (Physics)). If you feel unable to approach one of those individuals, you may contact the Head of Department Prof James Sparks (Maths), Prof Ian Shipsey (Physics). The officer concerned will attempt to resolve your concern/complaint informally.

If you are dissatisfied with the outcome, you may take your concern further by making a formal complaint to the Proctors under the University Student Complaints Procedure **https://www.ox.ac.uk/students/academic/complaints**.

If your concern or complaint relates to teaching or other provision made by your college, you should raise it either with your tutor or with one of the college officers, Senior Tutor, Tutor for Graduates (as appropriate). Your college will also be able to explain how to take your complaint further if you are dissatisfied with the outcome of its consideration.

Academic Appeals

An academic appeal is an appeal against the decision of an academic body (*e.g.*, boards of examiners, *etc.*), on grounds such as procedural error or evidence of bias. There is no right of appeal against academic judgement. If you have any concerns about your assessment process or outcome, it is advised to discuss these first informally with your college advisor, Senior Tutor, course director, director of studies, supervisor, or college or departmental administrator as appropriate. They will be able to explain the assessment process that was undertaken and may be able to address your concerns. Queries must not be raised directly with the examiners. If you still have concerns, you can make a formal appeal to the Proctors who will consider appeals under the University Academic Appeals Procedure.
(For further information, see **https://www.ox.ac.uk/students/academic/complaints**.)

7.3 Buddy System

The Buddy System is an initiative to help our new MSc students integrate with current MMath/MPhys/MPhysPhil students who are transferring to the MMathPhys for their final year. Once an MSc student's offer has become unconditional, they will be paired with a buddy from the same college, or a nearby college, and will receive their buddy's college e-mail address. New students can seek advice from their MMathPhys buddy about aspects of student life which interest them such as exams, social events, or courses.

7.4 Student Societies

There are number of Mathematics and Physics student societies which you may like to join. Details of the main societies are given below. In addition, there are also over 200 clubs and societies covering a wide range of interest which you may join or attend. A full list is available at **http://www.ox.ac.uk/students/life/ clubs/list/**.

Invariants

The Oxford University's student society for Mathematics. The society promotes Maths and hosts informal lectures, often given by leading mathematicians. Website: **http://www.invariants.org.uk/**.

LGBTI∧3

LGBTI∧3 is the student group for all LGBTQ+ identifying students in Maths, Stats and Computer Science. Contact: **oxlgbtqubed@gmail.com**.

Mirzakhani Society

The Mirzakhani Society is a society aimed at supporting women and non-binary students in Oxford who are studying maths. Contact: **mirzakhanisociety@gmail.com**.

The Oxford University Physics Society

The Oxford University Physics Society (PhysSoc) is a student society that exists to promote and encourage an interest in Physics in and around Oxford University. PhysSoc hosts talks most weeks during term time in the Physics Department, often by leading experts and also holds social events which are a great opportunity to get to know others with an interest in all things Physics. Website: https://oxfordphyssoc.wordpress.com/.

7.5 Maths Outreach

The Department has an active Outreach programme **https://www.maths.ox.ac.uk/outreach** which runs throughout the year, with events and programmes for school students aged 5-18. You can take a look at what's currently happening on the website. Keep an eye out throughout the year for e-mails asking for volunteers for various events and other ways to get involved. Contact Mareli Grady mareli.grady@maths.ox.ac.uk or James Munro james.munro@maths.ox.ac.uk if you have any questions or ideas you would like to discuss.

7.6 University Policies

The University has a wide range of policies and regulations that apply to students. These are easily accessible through the A–Z of University regulations, codes of conduct and policies available at http://www.ox.ac.uk/students/academic/regulations/a-z. Particular attention is drawn to the following University policies.

Equal Opportunities Statement:
https://edu.admin.ox.ac.uk/equality-policy

Intellectual Property Rights:
https://www.ox.ac.uk/students/academic/guidance/intellectual-property

Code on Harassment: https://edu.admin.ox.ac.uk/harassment-advice

Policy on Plagiarism: http://www.ox.ac.uk/students/academic/guidance/skills/plagiarism

Policy on Students Recording Lectures:

https://www.ox.ac.uk/sites/files/oxford/field/field_document/Recording of lectures and other teaching sessions by students.pdf

7.7 Departmental Safety Policies

You are urged to act at all times responsibly, and with a proper care for your own safety and that of others. Departmental statements of safety policy are posted in all departments, and you must comply with them. Students should note that they (and others entering onto departmental premises or who are involved in departmental activities) are responsible for exercising care in relation to themselves and others who may be affected by their actions.

In the Mathematical Institute accidents should be reported immediately to reception, telephone 73525, who keep the accident book. There is a first aid room located on the ground floor of the South wing. If you require access to this room please report to reception.

Each lecture theatre has its own proper escape route and you are urged to familiarise yourself with these. Those for the Mathematical Institute lecture and seminar rooms, are set out online at **http://www.maths.ox.ac.uk/members/building-information/security-safety-and-reporting-building-issues**. In the case of evacuation of the lecture theatre give heed to the instructions of the lecturer.

7.8 Key Student Support Links and Contacts

Disability Co-ordinator (Mathematics):
Charlotte Turner-Smith (academic.administrator@maths.ox.ac.uk)

Information on Disability and Accessibility:
https://www.maths.ox.ac.uk/members/policies/disability
https://www.maths.ox.ac.uk/members/building-information/accessibility

Disability Co-ordinator (Physics): Carrie Leonard-McIntyre (c.leonard-mcintyre@physics.ox.ac.uk)

University's Disability Advisory Service: **http://www.ox.ac.uk/students/welfare/disability**

Counselling Service: (tel: (2)70300) email: counselling@admin.ox.ac.uk

Proctors' Office: (tel: (2)70090) email: proctors.office@proctors.ox.ac.uk

Departmental Harassment Advisors: a list can be found by clicking here

Oxford University Student Union, Vice President (Welfare):
(tel: (2)88452) email: welfare@ousu.ox.ac.uk

A Course Calendar

Michaelmas Term	
Tuesday 3rd October, (week 0)	Induction
Monday 9th October (week 1)	Michaelmas term lectures begin
Thursday 2nd November (week 4)	Examination entry for courses assessed by invigilated written examination in Hilary term
Friday 1st December (week 8)	Michaelmas term lectures end
Hilary Term	
Monday 8th January (week 0)	Provisional start date for HT invigilated examinations
Monday 15th January (week 1)	Hilary term lectures begin
Thursday 25th January (week 2)	Examination entry for: Michaelmas term practicals; Hilary term submissions; all courses assessed by invigilated written examination in Trinity term
Monday 4th March (week 8)	Hilary term mini-projects released
Friday 8th March (week 8)	Hilary term lectures end
Monday 25th March, 12noon (week 11)	Hilary term mini-project submission deadline
Trinity Term	
Monday 15th April (week 0)	Provisional start date for first set of Trinity term week 0
Monday 22th April (week 1)	Trinity term lectures begin
Thursday 9th May (week 3)	Examination entry for: Hilary and Trinity practicals; Trinity term submissions (including dissertation)
Monday 27th May (week 6)	Provisional start date for second set of Trinity term invigilated examinations
Monday 29th May, 12noon (week 6)	Dissertation submission deadline
Friday 21st June (week 8)	Trinity term lectures end
Monday 24th June – Wednesday 26th June (week 9)	Trinity term take-home examinations released between these dates
Wednesday 26th June – Friday 28th June (week 9)	Submission deadlines for Trinity term take-home examinations between these dates

B Case Studies

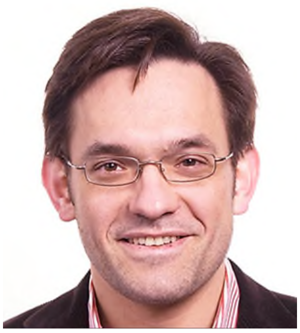
The following table details some examples of possible pathways through the Programme. These case studies are for illustrative purposes only. Some of these pathways do not contain the full 10 units and will require extra units from outside the given specialization to make up a full schedule. They nevertheless provide templates that can be adapted to the current course list and are indicative of the breadth and diversity of the programme. Many other paths through the course are possible—in fact, much more eclectic or more generalist selections of courses may be appropriate for students who have not settled on a specialisation they intend to pursue. Indispensable courses ("core") for each given case study are indicated in bold. One unit normally represents 16 lectures; at least 10 units have to be taken over three terms. Note that some of the Case Studies below are sufficiently broad to allow multiple pathways within them, however you should ensure that your chosen pathway allows you to fulfil the requirements for the overall number of units and the number of assessed units. Please see the examination conventions for further details of these requirements.

Pathway	*MT*	*HT*	*TT*
Generalist Theoretical Physicist *"TEORICA UNIVERSALIS"* **Core 6.25 units** Total 11.25-12.25 units	**1. QFT (24)** **2. Kinetic Theory (28)** **3. GR I (16)** **4. Pert. Methods (16)**	**1-3.** *Three of:* **Noneq. Stat. Phys (16)** Advanced Fluid Dynamics (16) Advanced QFT (24) Collisionless Plasma Physics (8) Cosmology (16) Random Matrix Theory (16)	**1-3.** *Three or four of:* Collisionless Plasma Phys. (10) Quantum Matter (20) Renormalisation Grp. (16) SM and Beyond I (16) SM and Beyond II (16) Dissertation
Applied Mathematician *"APPLICATA"* **Core 6.75-7.75 units** Total 12.75 units	**1. Kinetic Theory (28)** **2. GR I (16)** **3. Pert. Methods (16)** **4. Diff. Manifolds (16)** **5.** Num. Lin. Algebra (16) **6.** Networks (16)	**1. Advanced Fluid Dyn. (16)** **2. Applied Complex Var. (16)** **3.** *One of:* **Noneq. Stat. Physics (16)** Collisionless Plasma Physics (8) Geophysical Fluid Dynamics (16) GR II (16) Random Matrix Theory (16) Riemannian Geometry (16)	**1.** Collisional Plasma Phys. (16) **2.** Collisionless Plasma Phys. (10) **3.** Galactic Dynamics (16) **4.** Dissertation
Fluid Dynamicist *"CONTINUA"* **Core 3.75 units** Total 9.75 units	**1. Kinetic Theory (28)** **2. Pert. Methods (16)**	**1. Advanced Fluid Dyn. (16)** **2.** Collisionless Plasma Phys. (8) **3.** Geophysical Fluid Dyn. (16) **4.** Applied Complex Var. (16) **5.** Noneq. Statisical Phys (16)	**1.** Collisional Plasma Phys. (16) **2.** Collisionless Plasma Phys. (10) **3.** Dissertation
Mathematician with a Physics Streak *"GEOMETRA"* **Core 5.5 units** Total 10.5–11.5 units	**1. QFT (24)** **2. GR I (16)** **3. Diff. Manifolds (16)** **4.** *One of:* Groups & Repr. (24) Algebraic Topology (16) Algebraic Geometry (16)	**1. String Theory I (16)** **2.** *One of* Advanced QFT (24) SUSY & SUGRA (16) Geom. Group Theory (16) GR II (16) Low Dimensional Topo. (16) Random Matrix Theory (16) Riemannian Geometry (16)	**1. String Theory II (16)** **2.** CFT (16) **3.** SM and Beyond I (16) **4.** SM and Beyond II (16)

Particle Phenomenologist *"PARTICULATA"* **Core 5.5 units** Total 10.5 units	**1. QFT (24)** **2. Groups & Repr. (24)** **3.** *One of:* GR I (16) Pert. Methods (16)	**1. Advanced QFT (24)** **2. SUSY & SUGRA (16)** **3-4.** *Two of:* String Theory I (16) GR II (16) Cosmology (16)	**1-2.** *Two of:* String Theory II (16) SM and Beyond I (16) SM and Beyond II (16)
Hardcore String Theorist *"SUPERCORDULA"* **Core 7.5 units** Total 10.5 units	**1. QFT (24)** **2. Groups & Repr. (24)** ***3.*** *One of* GR I (16) Pert. Methods (16) Diff. Manifolds (16) Algebraic Geometry (16)	**1. Advanced QFT (24)** **2. String Theory I (16)** **3.** *One of:* Cosmology (16) GR II (16) Low Dim. Topo. & Knots (16) Riemannian Geometry (16) SUSY & SUGRA (16)	**1. String Theory II (16)** **2. CFT (16)** **3.** *One of:* SM and Beyond I (16) SM and Beyond II (16)
Condensed Matter Theorist *"CONDENSATA"* **Core 3.5 units** Total 12.75–13.5 units	**1. QFT (24)** **2.** Adv. Quant. Theory (20) **3.** *One of:* Kinetic Theory (28) Intro to TPM (16)	**1. Noneq. Stat. Phys. (16)** **2.** Advanced QFT (24) **3.** Adv. Fluid Dyn. (16) **4.** Random Matrix Theory (16) **5.** Low Dim. Topo. & Knots (16)	**1. Quantum Matter (16)** **2.** Renorm. Grp. (20) **3.** CFT (16)
Hardcore Hard Condensed Matter Theorist *"DURACELLA"* **Core 3.75 units** Total 12–12.5 units	**1. QFT (24)** **2. Adv. Quant. Thy. (20)** **3.** Kinetic Theory (28) **4.** Pert. Methods (16)	**1-3.** *Three of:* Adv. Fluid Dyn. (16) Advanced QFT (24) Low Dim. Topo. & Knots (16) Noneq. Stat. Phys. (16) Random Matrix Theory (16) String Theory I (16)	**1. Quantum Matter (16)** **2.** CFT (16) **3.** Renorm. Group (20)
Soft Condensed Matter Physicist/ Biophysicist *"MOLLIS"* **Core 5.25 units** Total 10.75 units	1. QFT (24) **2. Kinetic Theory (28)** **3.** Pert. Methods (16) 4. Networks (16)	**1. Adv. Fluid Dyn. (16)** **2. Noneq. Stat. Phys. (16)** **3. Soft Matter (16)** **4.** Collisionless Plasma (8)	**1. Topics in Soft Matter (8)** **2.** Collisionless Plasma Phys. (10) **3.** Dissertation

All Around Astrophysicist *"ASTRA-STELLA"* **Core 4.75 units** Total 10.75–11.25 units	**1. Kinetic Theory (28)** **2. GR I (16)** **3-4.** *Two of:* QFT (24) Quantum Processes in Hot Plasma (16) Perturbation Methods (16)	**1. Galactic Dynamics (16)** **2. Cosmology (16)** **3-5.** *Three of:* Adv. Fluid Dyn. (16) Collisionless Plasma Phys (8) Astroparticle Phys. (16) High Energy Density (16)	**1.** Collisionless Plasma Phys. (10) **2.** Dissertation
Dedicated Cosmologist *"COSMICOSMICA"* **Core 3 units** Total 10.25 units	**1. GR I (16)** 2. QFT (24) 3. Kinetic Theory (28) 4. Pert. Methods (16)	**1. Cosmology (16)** **2. GR II (16)** **3.** Galactic Dyn. (16) **4.** Low Dim. Topo. & Knots (16)	**1.** Dissertation
Geophysicist/ Climate Physicist *"GAIA"* **Core 2 units** Total 8.75 units	1. Kinetic Theory (28) 2. **Pert. Methods (16)** 3. Networks (16)	**1. Geo. Fluid Dyn. (16)** **2.** Adv. Fluid Dynamics (16) **3.** Noneq. Stat. Phys (16)	**1.** Dissertation
Plasma Theorist *"PLASMA"* **Core 4.75 units** Total 9.75 units	**1. Kinetic Theory (28)** **2. Pert. Methods (16)** **3.** Quantum Processes in Hot Plasma (16)	**1. Adv. Fluid Dyn. (16)** **2. Collisionless Plas. Phys. (8)** **3.** Noneq. Stat. Phys. (16) **4.** *One of:* Applied Complex Variables (16) High Energy Density (16)	**1.** Dissertation **2. Collisionless Plas. Phys. (10)** **3.** Collisional Plasma Phys. (16)

C Suggested Dissertation Topics



Supervisor: **Prof Alexander Schekochihin**

(alex.schekochihin@physics.ox.ac.uk)

Langmuir Turbulence and Modulational Instabilities

Abstract: This dissertation is devoted to the theory of nonlinear states that emerge in systems of interacting Langmuir waves ("plasmons") and sound waves ("phonons") in plasmas. Besides being a rich and interesting topic in itself, this is also the paradigm for many (indeed, most) other plasma turbulence systems, as it is in this context that most of the relevant toolkit was developed: weak turbulence theory, modulational instabilities, soliton solutions, Langmuir collapse, thermodynamic (Jeans) states, strong-turbulence theories, *etcetera.* A specific path through this material is negotiable and should be discussed at the start of the dissertation. There is scope for research-level contributions if the student's time and energy level allow.

Relevant Courses: Kinetic Theory (MT), Collisionless Plasma Physics (HT), Nonequilibrium Statistical Physics (MT), a course in fluid dynamics

Reading:

See sec 7.2 and 8 of these lecture notes:

http://www-thphys.physics.ox.ac.uk/people/AlexanderSchekochihin/KT/2015/KTLectureNotes.pdf

and references therein.

Solvable Models for Passive Turbulent Fields

Abstract: Normally it is (or has so far been) impossible to obtain analytic solutions for correlation functions in turbulent systems. However, for a class of models, analytical treatment is possible: those concern the turbulent advection of scalar and vector fields in an imposed random flow — most often white-in-time Gaussian random velocity field is used, as a far-fetched but solvable model of turbulent flow. Exact analytical results can be obtained for this model and it is remarkable how well they tend to work. The two main applications are the advection of a scalar, describing turbulent mixing of a temperature field in a fluid (or perhaps of the concentration of an admixture), and the advection of a vector, describing the evolution of a weak magnetic field in a turbulent conducting fluid. The latter is a model for the so-called "turbulent dynamo" amplification of mean magnetic energy via random stretching and tangling by a turbulent flow, believed to be responsible for the origin of cosmic magnetism (dynamically strong tangled magnetic fields observed in the interstellar and intergalactic medium, on the surface of the Sun and in many other places). This dissertation will help the student learn both the physics of passive advection and a suite of analytical techniques for handling stochastic systems. While most of the material is standard, there is some potential for research-level calculations, which can be attempted if the student so desires.

Relevant Courses: Nonequilibrium Statistical Physics (MT), a course in fluid dynamics, MHD part of Advanced Fluid Dynamics (HT) or equivalent.

References:

1. Lecture notes: ask supervisor.
2. Ya. B. Zeldovich, A. A. Ruzmaikin & D. D. Sokoloff, *The Almighty Chance* (World Scientific 1990).
3. N. G. van Kampen, *Stochastic Processes in Physics and Chemistry* (Elsevier 1992).
4. a selection of research articles.

Hydrodynamic and MHD Turbulence

Abstract: Kolmogorov's 1941 scaling theory of developed turbulence. Structure of statistical correlations of an isotropic vector field (fluid velocity). von Karman-Howarth equations and the exact scaling law for 3rd-order moments (the 4/5 law). Theory of intermittency: Kolmogorov and She-Leveque.

If student's time and energy permit, this dissertation can also cover the theory of MHD turbulence (or, alternatively, the student can skip some of the hydro topics and skip to MHD):

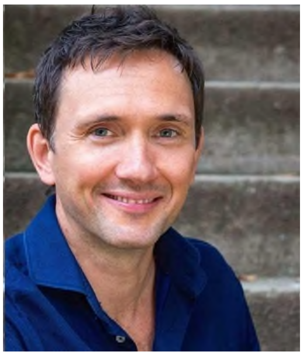
Scaling theories: Goldreich-Sridhar theory, critical balance, dynamic alignment. Weak turbulence theory for Alfven waves. Intermittency models and further refinements. (These latter topics contain some potential for research-relevant contributions.)

Other optional topics that can be covered in addition or instead of MHD: Application of the critical balance principle to rotating and stratified turbulence. Kolmogorov-style theory for turbulence in kinetic (collision-less) plasma.

Relevant Courses: a course in fluid dynamics; MHD part of Advanced Fluid Dynamics (HT) or equivalent if the student wishes to cover MHD turbulence.

References:

1. Lecture notes: http://www.mathphys.physics.ox.ac.uk/people/AlexanderSchekochihin/notes/SummerSchool07/
2. L. D. Landau & E. M. Lifshitz, *Fluid Mechanics*, Butterworth-Heinemann 1995 (Sec 33, 34).
3. U. Frisch. *Turbulence*. The Legacy of A. N. Kolmogorov. CUP 1995.
4. P. A. Davidson. *Turbulence — An Introduction for Scientists and Engineers*. OUP 2004.
5. A. A. Schekochihin, "MHD turbulence: a biased review," J. Plasma Phys. 88, 155880501 (2022).



Supervisor: **Prof Ard Louis**

(ard.louis@physics.ox.ac.uk)

Biological Evolution and a Bias towards Simplicity?

Abstract: Evolution proceeds by mutations to genotypes that in turn change phenotypes (the organism). But since the number of genotypes is much larger than the number of phenotypes, concepts of genetic entropy must enter into the equations, which means methods from statistical mechanics become relevant. In this project you will study some recent advances that use algorithmic information theory to argue for a bias towards simplicity in biology. See, for example, the papers below:

Symmetry and simplicity spontaneously emerge from the algorithmic nature of evolution
Iain G Johnston, Kamaludin Dingle, Sam F. Greenbury, Chico Q. Camargo, Jonathan P. K. Doye, Sebastian E. Ahnert, Ard A. Louis PNAS 119, e2113883119 (2022).

Bias in the arrival of variation can dominate over natural selection in Richard Dawkins' biomorphs View ORCID ProfileNora S. Martin, Chico Q. Camargo, Ard A. Louis doi:
https://doi.org/10.1101/2023.05.24.542053

Sloppy Systems

Abstract: Many models in biology, engineering and physics have a very large number of parameters. Often many of these are only known approximately. Moreover, in John von Neuman's famous quip "with four parameters I can fit an elephant, and with five I can make him wiggle his trunk." suggests that only a small set of these parameters are actually relevant? Could there be a fundamental theory of these complex systems that allows us to work out what the key parameters are?

References:

1. Transtrum, Mark K., Machta Benjamin, Brown Kevin, Daniels Bryan C., Myers Christopher R., and Sethna James P. , *Perspective: Sloppiness and Emergent Theories in Physics, Biology, and Beyond*, J. Chem. Phys., Volume 143, Issue 1, (2015).
2. Machta, Benjamin B., Chachra Ricky, Transtrum Mark K., and Sethna James P. , *Parameter Space Compression Underlies Emergent Theories and Predictive Models*, Science, Volume 342, p.604-607, (2013).
3. Gutenkunst, R. N., Waterfall J. J., Casey F. P., Brown K. S., Myers C. R., and Sethna J. P., *Universally sloppy parameter sensitivities in systems biology models*, PLoS Computational Biology, Volume 3, p.1871-1878, (2007).
4. Waterfall, J. J., Casey F. P., Gutenkunst R. N., Brown K. S., Myers C. R., Brouwer P. W., Elser V., and Sethna J. P. , *Sloppy-model universality class and the Vandermonde matrix*, Physical Review Letters, Volume 97, p.150601, (2006).

Theory of Deep Learning

Abstract: Deep neural networks (DNNs) have revolutionised machine learning. In spite of their great success, many questions remain about why they work so well. One key issue is why they generalise so well in the overparameterised regime, where classical learning theory predicts that they should heavily overfit. We have recently used concepts from Algorithmic Information Theory (AIT) to argue that that DNNs are exponentially biased towards functions with low Kolmogorov complexity. If this inductive bias reflects patterns seen in nature, then this may explain the conundrum of good generalisation in the overparameterised regime. But many questions remain, and in this project you would use a combination of theory and simulations to peer into the DNN black box, and to hopefully understand what makes them so special.

See http://www.physicsmeetsml.org/posts/sem 2020 06 03/ for some more background.

Supervisors: **Prof Sunetra Gupta and Prof Ard Louis**

(sunetra.gupta@biology.ox.ac.uk and ard.louis@physics.ox.ac.uk)

Effects of Mass Vaccination on the Dynamics of SIRS Systems with Seasonal Variation in Transmissibility

Abstract: For many pathogens, infection-blocking immunity is transient even though immunity against severe disease (whether acquired through natural infection or vaccination) may be lifelong. The interplay between seasonal changes in HIT and loss of infection blocking immunity is therefore a critical determinant of dynamics of pandemic spread and of the characteristics of endemic equilibrium of any emerging pathogen. This project will focus on how

i. how the time of arrival of the pathogen within the seasonal cycle of transmissibility affects the initial dynamics of infection and subsequent establishment of an endemic equilibrium;
ii. how these dynamics are affected by pre-existing immunity (for example, due to exposure to related pathogens);
iii. how mass vaccination can alter these dynamics.

We will refer to available data on SARS-CoV-2 in various settings to test and refine the hypotheses generated by these exercises.

Supervisor: **Prof Caroline Terquem**

(caroline.terquem@physics.ox.ac.uk)

Parametric Instabilities in Fluids

Abstract: When the pivot of a simple pendulum is subject to a periodic acceleration, the rest state becomes unstable if the frequency of the acceleration is close to twice that of the pendulum natural frequency. This is called a 'parametric' instability as it is caused by the time-dependence of one of the parameters (here the gravitational field). In fluids, similar instabilities arise when a forced oscillation resonate with waves that can propagate freely in the fluid (normal modes of oscillation). Systems subject to periodic forcing can be described by Mathieu's equation and Floquet's theory, which is a convenient formalism to study the conditions for instabilities. Parametric instabilities can also be described by (non-linear) mode-mode interactions, which is a better framework to understand how the energy of the oscillation is exchanged with that of normal modes.

Pre-requisites: Basic Fluid Dynamics

Supervisor: **Prof James Binney**

(binney@physics.ox.ac.uk)

Resonances and Linear Theory

Abstract: Resonances give rise to divergent responses - in celestial mechanics the "problem of small divisors". The assumptions that underlie linearisation are clearly violated near a resonance. Yet a huge amount of physics, both quantum and classical, is associated with resonances.

One might account for the success of linear theory by arguing that a small stimulus can produce only a small response in finite time; divergences arise on Fourier transforming because the stimulus at an exact frequency has to endure for ever. In the treatment of stimulated emission/absorption of radiation we recover from the physically absurd result that the transition amplitude is proportional to time a valid result by integrating over a continuum of stimulations. In the related derivation of the Fermi golden rule, we integrate over a continum of end states.

In celestial and stellar dynamics the non-linear phenomenon of resonant trapping is key. In particular it's now agreed that stars like the Sun diffuse from one near circular orbit to another by transient resonant trapping. More

generally we think of chaos and associated orbital diffusion as arising from repeated resonant scattering. The Balescu-Lenard equation describes diffusion from purely linear theory via obscure manipulations of poles in the complex-frequency plane. Can a linear theory, and one that starts by Lapace-Fourier transforming in time, really handle phenomena associated with resonant trapping? It seems likely that it can and because everything happens in finite time, but a proper understanding is needed.

Swing amplification of spiral waves is known to be key to understanding the evolution of galaxies like ours. The classic study of it (Julian and Toomre 1966) does not Fourier transform in time, but derives a Fredholm equation that is integrated in the time domain. The deep insight that this provides contrasts with the confusion generated by the frequency-based wave mechanics of Lin and Shu (1964). Magorrian (2021) has analysed the periodic cube (a very useful toy system) with an analogous integral equation and illustrated the importance of finite-time effects.

Quantum mechanics largely revolves around normal modes (a.k.a. stationary states). Engineers make extensive use of normal modes. Plasma physicists chatter about Landau modes, which lack all the key properties of normal odes (orthogonality, completeness, additive energies) and neglect van Kampen modes, which enjoy all these properties. They often argue that van Kampen modes are unphysical because their distribution functions are singular. This singulatity is a natural consequence of the fact that a collisionless system has to have a normal-mode spectrum that's continuous. Physical results emerge after integrating over frequency, when the Dirac deltas vanish. There's a connection here to the Fermi rule business and finite-time effects, but it needs to be teased out.

Reading:

https://ui.adsabs.harvard.edu/link_gateway/2021MNRAS.508.2210F/PUB_PDF

https://ui.adsabs.harvard.edu/link_gateway/2020MNRAS.496..767B/PUB_PDF

https://ui.adsabs.harvard.edu/link_gateway/1964ApJ...140..646L/ADS_PDF

https://ui.adsabs.harvard.edu/link_gateway/2021MNRAS.507.4840M/PUB_PDF

https://ui.adsabs.harvard.edu/link_gateway/2021MNRAS.507.2562L/PUB_PDF

Supervisor: **Dr Jasmine Brewer**

(jasmine.brewer@physics.ox.ac.uk)

Thermalisation in Heavy-ion Collisions

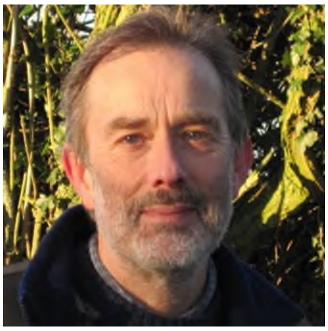
Abstract: High-energy collisions of heavy nuclei like lead and gold create a plasma where the quarks and gluons that are usually confined in hadrons are deconfined, called the quark-gluon plasma. The properties of this material are a unique testbed for the many-body physics of Quantum Chromodynamics, the theory governing the interactions of quarks and gluons. Highly-energetic quarks and gluons produced in this high-temperature plasma thermalize through a turbulent cascade from the original quark or gluon energy down to the scale of particles in the plasma. We will explore the universal features of this cascade, especially focusing on how a high-energy quark

or gluon deposits energy and momentum in the quark-gluon plasma. Though some aspects of this problem have been studied semi-analytically and the project will include a review of these works, research advances in this direction will involve numerical studies.

Useful reading:

Blaizot, Iancu, Mehtar-Tani, "Medium–induced QCD Cascade: Democratic Branching and Wave Turbulence." Phys. Rev. Lett. 111, 052001 (2013).

Schlichting, Mehtar-Tani, "Universal quark to gluon ratio in medium-induced parton cascade." J. High Energy Phys. 2018, 144 (2018).



Supervisor: **Prof John Chalker**

(john.chalker@physics.ox.ac.uk)

Foundations of Statistical Mechanics and the Eigenstate Thermalisation Hypothesis

Abstract: *Why does statistical mechanics work?* This long-standing question has recently acquired a new focus, partly because of experimental developments and partly as a result of new theoretical ideas. In particular, we can ask what happens if we attempt to evaluate thermal averages simply as quantum expectation values in a single eigenstate of a system. The eigenstate thermalisation hypothesis is the idea that – in a system of many interacting particles – this should lead to the same results as the canonical ensemble with its average over contributions from many eigenstates.

References:

1. L. D'Alessio, Y. Kafri, A. Polkovnikov and M. Rigol, Advances in Physics **65**, 239 (2016).
2. J.M. Deutsch, Phys. Rev. A **43**, 2046 (1991).
3. M. Srednicki, Phys. Rev. E **50**, 888 (1994).
4. M. Rigol, V. Dunjko and M. Olshanii, Nature **452**, 854 (2008).

Weight: single unit.

Quantum Dimer Models

Abstract: Quantum dimer models provide very simple examples of highly correlated systems which can show topological order and fractionalised quantum numbers. They illustrate how useful, minimal models can be constructed in theoretical condensed matter physics, with interesting emergent features in their long-distance properties.

References:

1. R. Moessner and K. S. Raman, https://arxiv.org/abs/0809.3051.
2. D. Rokhsar and S. Kivelson, Phys. Rev. Lett. **61** 2376 (1988).

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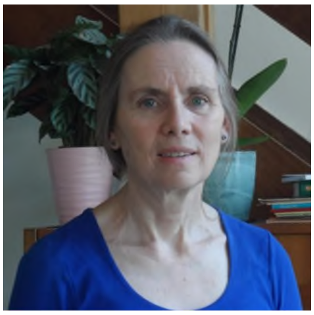


Supervisor: **Prof Julia Yeomans**

(julia.yeomans@physics.ox.ac.uk)

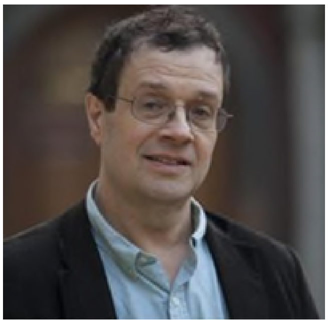
Active Matter

Abstract: Active systems take energy from their surroundings on a single particle level and use it to do work. This means that they naturally operate out of thermodynamic equilibrium and provide examples of non-equilibrium statistical physics. Dense active matter has many surprising properties such as active turbulence and motile topological defects, motility induced phase separation, odd viscosities and the breakdown of detailed balance. The dissertation will probe more deeply into an aspect of active materials; possible examples are spontaneous flow in confined active systems, swimming at low Reynolds number, active wetting or forces in confluent cell layers.

References:

G Gompper et al, The 2020 motile active matter roadmap, J. Phys.: Condens. Matter 32 193001
(lots of short articles introducing active matter)

A. Doostmohammadi, J. Ignés-Mullol, J.M. Yeomans, and F. Sagués, Active nematics. Nat. Commun. 9, 3246 (2018) (for a review of active nematics)



Supervisor: **Prof Lionel Mason**

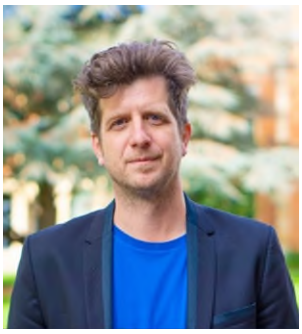
(lionel.mason@maths.ox.ac.uk)

Scattering Amplitudes

Abstract: Scattering amplitudes are one of the basic outputs of quantum field theory for testing theoretical predictions in the LHC. They also have many fascinating mathematical properties, both at tree level where there are interesting recursion relations, relations to twistor theory, polyhedra and positive geometries, and CHY/ambitwistor-string formulae, and at loops where they interact with the mathematical theory of polylogs. There are many directions that a project can take in reviewing various approaches, for different theories including string theory, where string amplitudes are their own corner of the subject, and using recursion methods to calculate examples.

Prerequisites: Quantum Field Theory is essential. Advanced QFT and Supersymmetry are also useful.

Reading list: Henriette Elvang & Yu-tin Huang (Scattering Amplitudes, https://arxiv.org/abs/1308.1697).



Supervisor: **Prof Renaud Lambiotte**

(renaud.lambiotte@maths.ox.ac.uk)

How Directed Are Directed Networks?

Abstract: Many real-world networks are composed of directed edges that are not necessarily reciprocated. While several algorithms have been generalised to the case of directed networks, conceptual challenges, i.e. to quantify the level of hierarchy (and its impact on dynamics). In this project, we will investigate the notion of hierarchy in directed networks from different, possibly complementary viewpoints. The two main challenges will be to design embedding techniques allowing to rank nodes according to their importance, while grouping "similar nodes", and to investigate how hierarchies impact on linear dynamics, more specifically via the non-normality of the coupling matrices.

Prerequisites:
Taking the course C5.4. Networks is recommended.

Reading list:

MacKay, Robert S., Samuel Johnson, and Benedict Sansom. "How directed is a directed network?." *Royal Society open science* 7.9 (2020): 201138.

Lambiotte, Renaud, and Michael T. Schaub. *Modularity and Dynamics on Complex Networks*. Cambridge University Press, 2021.

Supervisor: **Prof Steven Balbus**

(steven.balbus@physics.ox.ac.uk)

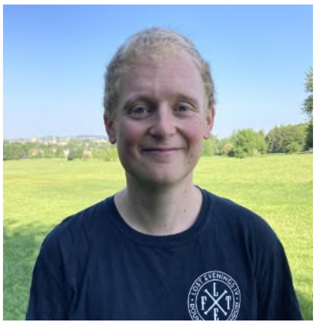
Dynamical Instabilities in Black Hole Accretion Discs

Abstract: It has been forty-nine years since the seminal paper of Shakura & Sunyaev (1973) laid down the foundations of turbulent accretion disc theory and twenty-five years since the establishment of the magnetorotational instability (MRI) as the fundamental physical basis for disc turbulence (Balbus & Hawley 1991). Yet, major features of disc behaviour remain poorly understood, especially transient behaviour around black holes. Discs can spontaneously change their emission profile, and perhaps their gross physical state. Depending on the black hole mass, this can occur over a wide variety of time scales. In addition, there is another major class of black hole transients, so-called tidal disruption events (TDEs), in which a star passing near a massive (in excess of $10^6 M\odot$ black hole is pulled apart by the hole's tidal forces, with some fraction of the star's mass ultimately accreting into the hole. These objects are intrinsically time-dependent. While time-dependent disc theory following Newtonian gravity (Lynden-Bell & Pringle 1974) is by now well-established, the extension of this to Kerr black holes is very recent (Balbus 2017).

In this dissertation we shall study the theory of accretion around Kerr black holes, and apply this knowledge to better understand observations of TDEs. The behaviour of dynamical instabilities is of particular interest, as these can affect the disc's turbulent stress, accretion rate, and subsequent emission. The Lightman-Eardley instability, which afflicts regions of the TDE disc dominated by radiation pressure, will be an important focus of this work. The project can take many different directions (*e.g.*, modelling, numerical study, analysis) depending upon the student's interest and background.

References and Background Reading:
Balbus, S. A. 2017, MNRAS, 471, 4832.
Balbus, S. A., & Hawley, J. F. 1991, ApJ, 376, 214.
Balbus, S. A., & Mummery, A. 2018, MNRAS, 481, 3348.
Franck, J., King, A.,& Raine, D. 2002, *Accretion Power in Astrophysics* (CUP: Cambridge).

Lightman, A.P. & Eardley, D,M. 1974, ApJ (Letters), 187, 1.
Lynden-Bell, D., & Pringle, J. 1974, MNRAS, 168, 603.
Mummery, A., & Balbus, S. A. 2019, *MNRAS* 489, 132.
Page, D. N., & Thorne, K. S., 1974, ApJ, 191, 499.
Shakura, N. I., & Sunyaev, R. A. 1973, A&A, 24, 337



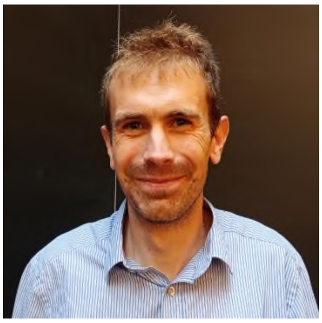
Supervisor: **Dr Andrew Mummery**

(andrew.mummery@physics.ox.ac.uk)

The Tidal Forces Experienced on Parabolic Fly-Bys of Spinning Black Holes

Abstract: Stars which reside in galactic centres are only tenuously bound to their galaxy's supermassive black hole, and as such their orbits are well approximated as being parabolic. N-body gravitational interactions can occasionally scatter an unfortunate star onto a near-radial orbit about the central black hole, and during this close encounter the star will experience extreme tidal forces and may even be destroyed in its entirety (often referred to as "spaghettification"). Whether or not a particular stellar orbit will result in the tidal disruption of the star requires the computation of the evolving tidal force experienced by the star over a parabolic fly-by. Existing solutions of the relevant orbital equations are known for bound orbits, but the parabolic limit has only previously been studied numerically. The student will explore Carter's orbital equations for the Kerr metric and look to extend existing bound solutions to the parabolic limit.

For relevant literature please contact Dr Mummery directly. The student will need to have some prior knowledge of general relativity but need not have studied the Kerr metric previously.



Supervisor: **Prof Edward Hardy**

(edward.hardy@@physics.ox.ac.uk)

Cosmic strings and Yang Mills

Abstract: High energy extensions of the Standard Model of particle physics suggest that there might be additional "hidden sectors" that are weakly coupled to the ordinary matter that we know. If such a hidden sector exists and is a pure Yang Mills theory (e.g. it is similar to QCD but without quarks) it can lead to cosmic strings in the early Universe. These are macroscopically large, topologically stable, objects that have non-trivial interactions with each other. The project will involve studying the formation of such strings and potentially doing a new calculation of the rate at which strings break in the case that there are hidden sector "quarks" with mass slightly above the hidden sector strong coupling scale.

References:
https://arxiv.org/abs/1506.04039
https://arxiv.org/abs/2204.13123

The Strong CP Problem and Axions

Abstract:: One of the outstanding mystery of the Standard Model of particle physics is the absence of CP violation in the strong sector. This project involves first reviewing the origin of CP violation in gauge theories, which has a fascinating connection to non-perturbative dynamics. Possible solutions to the strong CP problem will also be studied. A two unit project could extend to analysing a recent paper that claims (possibly erroneously) that there is in fact no strong CP problem.

References:
Advanced Topics in Quantum Field Theory, Shifman (widely available in libraries)
https://inspirehep.net/literature/1707528

D Glossary of Key Terms

A list of useful terms for new students.

Battels: The charges made to a member of a college (student or Fellow) for accommodation, meals, *etc*.

Candidate Number: A number assigned to each student for the use of formal assessments and written examinations, which is usually available to students via student self-service after they have made their first exam entry. Candidate numbers are used instead of names to anonymise students during assessments. It is different from the student number.

Classes: Each Part C and MTP lecture course is accompanied by a set of classes (called 'intercollegiate classes' if they are held at Maths Institute and 'classes' if they are held in Physics.) For Maths courses, these will be run by a tutor and teaching assistant (TA), for Physics courses, these will be led by a TA, and will cover any problems that have arisen from the problem sheets.

College Office: The academic office based at your college who will be able to assist you with changing your examination entries if needed.

Consultation Sessions: Revision sessions which take place for courses run by the Maths Institute in Weeks 2-5 of Trinity term.

Consultative Committee for Graduates (CCG): A committee consisting of postgraduate representatives from the Mathematical Institute and the departments two DGSs.

Degree Days: Various days throughout the year on which students may graduate.

DGS: Director of Graduate Studies.

Don: A professor, a lecturer, or a Fellow.

Examination Conventions: The Examination Conventions act as a supplement to the Examination Regulations. The Conventions explain how a student will be assessed for their course within the framework of the Examination Regulations.

Examination Regulations: Sometimes referred to as the 'Grey Book', the Examination Regulations govern all academic matters within the University.

Examination Schools: The building located on High Street where written examinations are held for the MMathPhys/MSc in Mathematical and Theoretical Physics degree, and where students hand in hard copies of their dissertations, mini-projects, and take-home examinations.

Formal Assessment: In the context of your degree, these are dissertations, mini-projects and take-Home Exams.

Invariants: A society run by students at the Mathematical Institute, which aims to promote Mathematics and to provide a social environment for students of Mathematics.

GSO: Graduate Studies Office, part of the central University.

GSR: Graduate Supervision Reporting. Supervisors will submit termly reports through GSR on their student's academic progress.

Hilary term: The second term of an academic year, running from January to March.

JSC: Acronym for the Joint Supervisory Committee in Mathematical and Theoretical Physics, consisting of Maths and Physics academics who meet at least once a term to make decisions about the degree. Student representatives for the degree also attend these meetings.

Lectures: Known as classes at some other institution, this is where the lecturer will present their subject to you as a larger audience. Classes at Oxford are where students split into smaller groups to work through problem sheets based on the lectures with a tutor and sometimes a teaching assistant.

Lecturer: Lecturers are those who have the responsibility to deliver lectures.

LGBTI∧3: A group of students aiming to provide a friendly environment for those LGBTQ-identifying individuals studying within the Mathematical Sciences.

Matriculation: Matriculation confers membership of the University on those students who are enrolled at the University of Oxford and following a degree-level course.

MCF: Masters in Mathematical and Computational Finance. An Master's course run by the Mathematical Institute.

MFoCS: Masters in Mathematics and Foundations of Computer Science. An MSc course run jointly by the Mathematical Institute and the Department of Computer Science.

Michaelmas term: The first term of an academic year, running from October to December.

Minerva: A system used by teaching staff to record attendance and marks for the students in their class at Maths. The class times, days and locations are exported from this system and are advertised to students through the departmental class lists.

Mirzakhani Society: A society at the Mathematical Institute for female and non-binary students.

MMSC: Masters in Mathematical Modelling and Scientific Computing. An MSc course run at the Mathematical Institute.

MPLS: Mathematical, Physical and Life Sciences Division.

MTP: The acronym for your degree, Mathematical and Theoretical Physics.

OMMS: Oxford Master's course in Mathematical Sciences.

Oxford SU: Oxford University Student Union.

Papers: Constituent parts of an examination.

Part C: The term given to the fourth-year undergraduate students studying for an integrated Masters. Part C is used to describe the courses that are open to these students.

PhysSoc: Oxford University Physics Society.

Practicals: In the context of your degree, this means the homework options you choose.

Proctors: The two Proctors (Senior and Junior) are elected each year by colleges in rotation to serve for one year. The statutes provide that they shall generally ensure that the statutes, regulations, customs, and privileges of the University are observed. They serve on the University's main committees, and where not members of committees, may receive their papers and attend meetings but not vote. They have responsibilities under the statutes and regulations for aspects of student discipline, for ensuring the proper conduct of examinations and for dealing with complaints. They also carry out ceremonial duties, *e.g.*, at degree ceremonies.

Student number A number used to identify you as a student in day to day tasks, and can be used in conjunction with your name, unlike your candidate number.

Student Self Service: Student Self Service allows a student to access their student record and complete other tasks such as examination entry, and viewing examination results.

Sub fusc: Formal attire worn by students and academics on formal occasions, including matriculation, examinations and graduation.

Trinity term: The third term of an academic year, running from April to June.

Vac: Abbreviation of vacation.

Week 0: The week preceding the start of each term. Week 0 in Michaelmas Term is sometimes referred to as 'noughth week'**.**