Astronomy Unit (School of Mathematical Sciences)

Astronomy Unit, School of Mathematical Sciences, Queen Mary, University of London, Mile End Road, London E1 4NS
Tel: +44 (0)20 7882 5440, Fax: +44 (0)20 8981 9587

Postgraduate Modules in Astronomy and Relativity

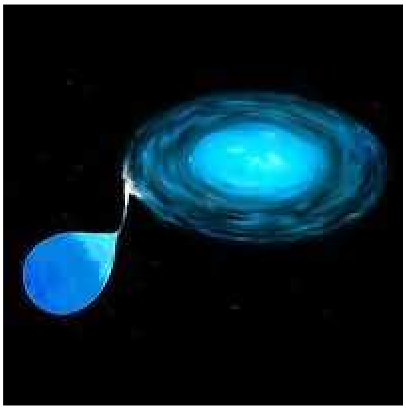
Lectures are given by staff in the Astronomy Unit and cover most areas of modern astronomy and astrophysics. Modules include

- ASTM001: Solar System
- ASTM002: The Galaxy
- ASTM003: Angular Momentum and Accretion Processes in Astrophysics
- ASTM005: Research Methods in Astronomy
- ASTM041: Relativistic Astrophysics and Gravitation
- ASTM052: Extragalactic Astrophysics
- ASTM108: Cosmology
- ASTM109: Stellar Structure and Evolution
- ASTM112: Astrophysical Fluid Dynamics
- ASTM115: Astrophysical Computing

- *ASTM116: Astrophysical Plasmas (Not offered in 2007-8)*

Please note that not all modules are offered each year. Some modules take place during the day whilst others meet Tuesday or Thursday evenings.

Angular Momentum and Accretion Processes in Astrophysics (ASTM003)



- Semester 2 in 2007-8
- Daytime
- 0.5 course units: 12 hours of lectures (or equivalent)
- Lecturer: Prof Richard Nelson
- Core for **MSc in Astrophysics**

Also available for:

- Postgraduate Certificate in Astrophysics

- MSc in Mathematics

Course outline

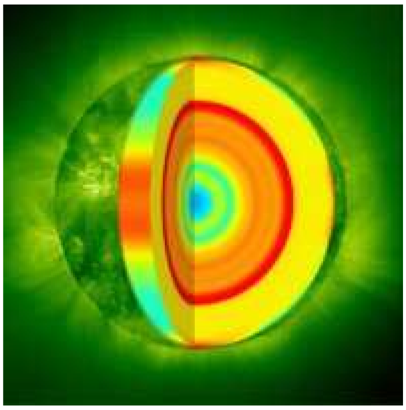
Gas falling towards a massive astronomical body tends to form a rotating accretion disc due to its angular momentum. Large amounts of energy can be liberated as material slowly spirals inwards through an accretion disc. Accretion processes play an important role in many areas of astrophysics including star and planet formation, X-ray binaries, cataclysmic variables, and quasars. This course considers the formation of accretion discs in binary star systems and around protostars, the liberation of energy as a result of viscosity disc, the spectra of the radiation emitted, and the effects of magnetic fields. Planet formation in protoplanetary discs is also discussed.

Syllabus

The material presented in this module consists of the following:

- Differentially rotating systems in astrophysics.
- Discs as systems in which centrifugal forces dominate.
- Virial theorem for rotating systems including Lorentz forces.
- Disc formation through gravitational collapse, protostellar discs. Disc formation in close binary systems through mass transfer.
- Necessity of angular momentum transport, review of possible mechanisms.
- Standard viscous disc theory, steady states and time dependent diffusion equation, vertical structure.
- Application to accreting neutron stars, white dwarfs and AGN. The boundary layer, disruption by a stellar magnetic field, spin up and spin down. Application to T Tauri stars and neutron stars.
- Simple ideas about planetary formation, gap formation and migration. Application to extrasolar planets.

Astrophysical Fluid Dynamics (ASTM112)



- Semester 2 in 2007-8
- Evening
- 1.0 course unit: 24 hours lectures (or equivalent)
- Lecturer: Dr Sergei Vorontsov
- Core for **MSc in Astrophysics**

Also available for:

- Postgraduate Certificate in Astrophysics
- MSc in Mathematics

Course outline

This course studies the structure and dynamical behaviour a variety of astrophysical regimes, using the basic equations of fluid dynamics. Starting from the simplest applications, such as sound-waves and gravitational instability, it proceeds to topics of current research, such as solar and stellar seismology. It considers the influence of rotation at the initial stages of gravitational collapse, which leads eventually to the formation of compact objects, rotational distortion of stellar and planetary configurations, and tidal interaction in binary stars. The course also considers settings where nonlinear equations are applicable, such as spherically-symmetric accretion of gaseous clouds, and addresses briefly the formation and evolution of nonlinear waves and shocks.

Syllabus

The material presented in this module consists of the following:

- Fluid dynamical model in astrophysics.
- Gravitational stability, gravitational collapse.
- Stellar stability, stellar oscillations, variable stars.
- Helioseismology.
- Stellar rotation, structure of rotating stars.
- Binary stars, tidally distorted models.
- Rotationally and tidally distorted planets.

Astrophysical Plasmas (ASTM116)

- Not offered in 2007-8
- Evening
- 1.0 course unit: 24 hours lectures (or equivalent)

Also available for:

- Postgraduate Certificate in Astrophysics

- MSc in Mathematics

Course outline

A plasma is an ionized gas where the magnetic and electric field play a key role in binding the material together. Plasmas are present in almost every astrophysical environment, from the surface of pulsars to the Earth's ionosphere. This course explores the unique properties of plasmas, such as particle gyration and magnetic reconnection. The emphasis is on the plasmas found in the Solar System, from the solar corona and solar wind to the outer reaches of the heliosphere and the interstellar medium. Fundamental astrophysical processes are explored, such as the formation of supersonic winds, magnetic energy release, shock waves and particle acceleration. The course highlights the links between the plasmas we can observe with spacecraft and the plasmas in more distant and extreme astrophysical objects.

Syllabus

What is a plasma? The material presented in this module consists of the following:

- The plasma state as found in astrophysical contexts.
- Particle motion in electromagnetic fields, cyclotron motion, drifts and mirroring, with application to the radiation belts and emission from radio galaxies.
- Concepts of magnetohydrodynamics (MHD); flux freezing and instabilities.
- The solar wind, including MHD aspects, effects of solar activity, and impact on the terrestrial environment.
- Magnetic reconnection; models and application to planetary magnetic storms and stellar flares and coronal heating.
- Shock waves and charged particle acceleration.

Cosmology (ASTM108)

- Semester 1 in 2007-8
- Evening
- 1.0 course unit: 24 hours lectures (or equivalent)
- Lecturer: Prof James Lidsey
- Core for **MSc in Astrophysics**

Also available for:

- Postgraduate Certificate in Astrophysics
- MSc in Mathematics

Course outline

Cosmology is a rapidly developing subject that is the focus of a considerable research effort worldwide. It is the attempt to understand the present state of the universe as a whole and thereby shed light on its origin and ultimate fate. Why is the universe structured today in the way that it is, how did it develop into its current form and what will happen to it in the future? The aim of this course is to address these and related questions from both the observational and theoretical perspectives. The course does not require specialist astronomical knowledge and does not assume any prior understanding of general relativity.

Syllabus

The material presented in this module consists of the following:

- Observational basis for cosmological theories.
- Derivation of the Friedmann models and their properties.
- Cosmological tests; the Hubble constant; the age of the universe; the density parameter; luminosity distance and redshift.
- The cosmological constant.
- Physics of the early universe; primordial nucleosynthesis; the cosmic microwave background (CMB); the decoupling era; problems of the Big Bang model.
- Inflationary cosmology.
- Galaxy formation and the growth of fluctuations
- Evidence for dark matter.
- Large and small scale anisotropy in the CMB.

Extragalactic Astrophysics (ASTM052)

- Semester 2 in 2007-8
- Evening
- 0.5 course units: 12 hours lectures (or equivalent)
- Lecturer: Dr Alexander Polnarev
- Core for **MSc in Astrophysics**

Also available for:

- Postgraduate Certificate in Astrophysics

Course outline

Recent observations of extremely remote objects in the universe have revealed violent events accompanied by the release of tremendous levels of energy in objects such as quasers and Active Galactic Nuclei. These are assumed to contain super massive black holes or even binary systems of super massive black holes. After a brief introduction to the classification and morphology of galaxies, the course considers active galactic nuclei and quasars, where massive black holes are supposed to exist. It surveys the observational evidence for the presence of these exotic objects and discusses how massive black holes interact with surrounding matter through, for example, accretion and tidal disruption of stars.

Syllabus

The material presented in this module consists of the following:

- Classification and morphology of galaxies.
- Active and starburst galaxies; mergers and cannabalism.
- Active galactic nuclei (AGN): properties, emission mechanisms, jets, superluminal motion, feeding the radio lobes, accretion onto a massive blackhole.
- Binary black holes.

The Galaxy (ASTM002)

- Semester 1 in 2007-8
- Daytime
- 1.0 course unit: 24 hours lectures (or equivalent)
- Lecturer: Dr Bryn Jones
- Core for **MSc in Astrophysics**

Also available for:

- MSc in Mathematics

Course outline

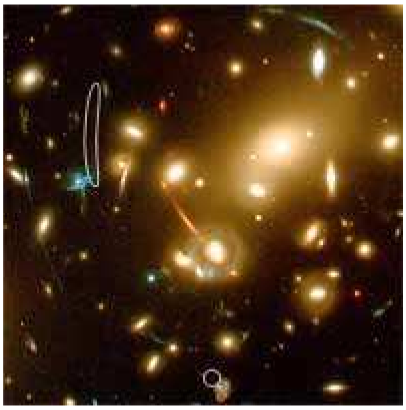
The course considers in detail the basic physical processes that operate in galaxies, using our own Galaxy as a detailed example. This includes the dynamics and interactions of stars, and how their motions can be described mathematically. The interstellar medium is described and models are used to represent how the abundances of chemical elements have changed during the lifetime of the Galaxy. Dark matter can be studied using rotation curves of galaxies, and through the way that gravitational lensing by dark matter affects light. The various topics are then put together to provide an understanding of how the galaxies formed.

Syllabus

The material presented in this module consists of the following:

- Introduction: galaxy types, descriptive formation and dynamics.
- Stellar dynamics: virial theorem, dynamical and relaxation times, collisionless Boltzmann equation, orbits, simple distribution functions, Jeans equations.
- The interstellar medium: emission processes from gas and dust (qualitative only), models for chemical enrichment.
- Dark matter - rotation curves: bulge, disk, and halo contributions.
- Dark matter - gravitational lensing: basic lensing theory, microlensing optical depth.
- The Milky Way: mass via the timing argument, solar neighbourhood kinematics, the bulge, the Sgr dwarf.

Relativistic Astrophysics and Gravitation (ASTM041)



- Semester 1 in 2007-8
- Evening
- 0.5 course units: 12 hours lectures (or equivalent)
- Lecturer: Dr Alexander Polnarev
- Core for **MSc in Astrophysics**

Also available for:

- Postgraduate Certificate in Astrophysics
- MSc in Mathematics

Course outline

Recently there have been numerous discoveries of objects in the Universe which possess gravitational fields so strong that physical interpretations of their properties cannot be conducted within the framework of Newtonian gravity. Instead it is essential to employ the general relativistic framework, which drastically changes the fundamental concepts of gravity, space and time. This concerns the applications of general relativity in astrophysics. It begins with a brief introduction to general relativity and proceeds to consider relativistic effects in the Solar System, white dwarfs, neutron stars and black holes. It also discusses general ideas about the generation and detection of gravitational waves.

Syllabus

The material presented in this module consists of the following:

- Conceptual introduction to special and general relativity: Lorentz transformation, Minkowski spacetime, equivalence principle, curved spacetime, geodesics, field equations.
- Heuristic understanding of gravitational redshift, light deflection, perihelion shift, gravitational radius.
- Schwarzschild metric and orbits therein.
- Black holes: gravitational collapse, event horizon, singularity, charged and rotating holes.
- Accretion by white dwarfs, neutron stars and black holes.
- Evidence for black holes in binary systems, galactic nuclei, quasars.
- Primordial black holes and associated quantum effects.
- Gravitational waves: sources and detection.
- Gravitational lensing and dark matter.

Research Methods in Astronomy (ASTM005)

- Semester 1 in 2007-8
- Evening
- 0.5 course units: 12 hours of lectures (or equivalent)
- Lecturer: Dr Bryn Jones
- Core for **MSc in Astrophysics**

Also available for:

- Postgraduate Certificate in Astrophysics

Course outline

The course describes the techniques used in scientific research, with emphasis on how researchers access scientific information. The lectures show how information can be found and evaluated, at a general level and at research level. The techniques used in scientific writing are discussed, including the style required for research papers. Data archives are introduced. The course provides an essential foundation for the skills needed for MSc project work.

Syllabus

Research in astronomy builds on a vast body of literature and archived data. This course is an introduction to research methods which exploit existing information, and thus serves as an introduction to the MSc project.

The material presented in this module consists of the following:

- Finding and evaluating information.
- Using data archives.
- Critical analysis of scientific articles.
- Scientific writing including appropriate style and presentation.
- The context of astronomy research in society.

The timetable includes:

- Information sources for research in astronomy (2 weeks)
- Critical analysis of scientific articles (2 weeks)
- Scientific writing, including group work and presentation (2 weeks)

Solar System (ASTM001)

- Semester 2 in 2007-8
- Daytime
- 1.0 course unit: 24 hours lectures (or equivalent)
- Lecturer: Dr Craig Agnor
- Core for **MSc in Astrophysics**

Also available for:

- MSc in Mathematics

Course outline

As the planetary system most familiar to us, the Solar System presents the best opportunity to study questions about the origin of life and how enormous complexity arise from simple physical systems in general. This course surveys the physical and dynamical properties of the Solar System. It focuses on the formation, evolution, structure, and interaction of the Sun, planets, satellites, rings, asteroids, and comets. The course applies basic physical and mathematical principles needed for the study, such as fluid dynamics, electrodynamics, orbital dynamics, solid mechanics, and elementary differential equations. However, prior knowledge in these topics is not needed, as they will be introduced as required. The course will also include discussions of very recent, exciting developments in the formation of planetary and satellite systems and extrasolar planets (planetary migration, giant impacts, and exoplanetary atmospheres).

Syllabus

The material presented in this module consists of the following:

- General overview/survey.
- Fundamentals: 2-body problem, continuum equations.
- Terrestrial planets: interiors, atmospheres.
- Giant planets: interiors, atmospheres.
- Satellites: 3-body problem, tides.
- Resonances and rings.
- Solar nebula and planet formation.
- Asteroids, comets and impacts.

References

- C.D. Murray and S.F. Dermott, *Solar System Dynamics*, (Cambridge University Press).
- P. Parinella, B. Bertotti and D. Vokrouhlicky, *Physics of the Solar System*, (Kluwer Academic Publishers).

Other References

- J.K. Beatty, C.C. Petersen and A. Chaikin, *The New Solar System (4th edition)*, (Cambridge University Press, Sky Publishing).
- J.S. Lewis, *Physics and Chemistry of the Solar System (2nd edition)*, (Elsevier Academic Press).
- I. de Pater and J.J. Lissauer, *Planetary Sciences*, (Cambridge University Press).

Stellar Structure and Evolution (ASTM109)

- Semester 2 in 2007-8
- Daytime
- 1.0 course unit: 24 hours lectures (or equivalent)
- Lecturer: Prof Iwan Williams
- Core for **MSc in Astrophysics**

Also available for:

- MSc in Mathematics

Course outline

Stars are important constituents of the universe. This course starts from well known physical phenomena such as gravity, mass conservation, pressure balance, radiative transfer of energy and energy generation from the conversion of hydrogen to helium. From these, it deduces stellar properties that can be observed (that is, luminosity and effective temperature or their equivalents such as magnitude and colour) and compares the theoretical with the actual. In general good agreement is obtained but with a few discrepancies so that for a few classes of stars, other physical effects such as convection, gravitational energy generation and degeneracy pressure have to be included. This allows an understanding of pre-main sequence and dwarf stages of evolution of stars, as well as the helium flash and supernova stages.

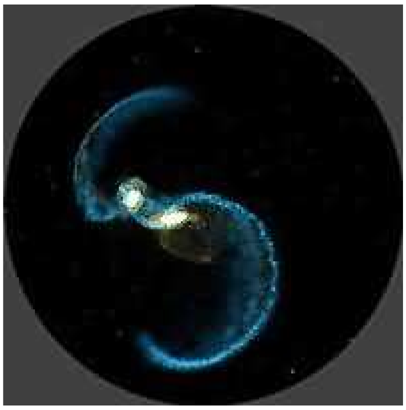
Syllabus

The material presented in this module consists of the following:

- Observational properties of stars, the H-R diagram, the main sequence, giants and white dwarfs.
- Properties of stellar interiors: radiative transfer, equation of state, nuclear reactions, convection.
- Models of main sequence stars with low, moderate and high mass.
- Pre- and post-main sequence evolution, models of red giants, and the end state of stars.

The course includes some exposure to simple numerical techniques of stellar structure and evolution; computer codes in Fortran.

Astrophysical Computing (ASTM115)



- *Semester 1 in 2007-8*
- Daytime
- 1.0 course unit: equivalent to 24 hours of lectures
- Lecturer: Dr David Burgess
- Core for **MSc in Astrophysics**

Also available for:

- Postgraduate Certificate in Astrophysics
- MSc in Mathematics

Syllabus

This course is an introduction to the use of computers in astrophysics.

The material presented in this module consists of the following:

- Basic notions of computer algorithms.
- Introduction to numerical analysis: approximations, errors, convergence, stability, etc.
- Finite difference method: solution of ordinary and partial differential equations.
- Introduction to numerical methods used in data analysis: image processing, spectral analysis, etc.

The concepts will be illustrated with examples from astrophysics, such as solar system dynamics, astrophysical fluids, stellar structure, etc. Computer practical courseworks are a major element of the course. Students are expected to write simple programs, and present their results in written reports. The course is intended to cater for students with very different levels of programming expertise.

ASTM024 MSc Astrophysics Project

This information applies to full-time MSc students and part-time MSc Astrophysics students in their second year.

The elements on which the award of an MSc is based are the end-of-year examinations and the **project**. The project is an important component of the MSc, corresponding to 4 units, and you should devote substancial effort to it during the year. The examinations and the project must both be passed for the award of the MSc and distinction can only be attained in the MSc if it is also attained in the project.

The project gives the student the opportunity to work independently and critically on the topic of interest to them. It may be a theoretical topic, a critical examination of the literature, or more occasionally it may involve computational or experimental work. In all cases the emphasis the emphasis should be on the astrophysics within the field chosen. The relevance of the work in the wider context of the subject should be explained as part of the introductory section. The project will normally require the study of original papers and show evidence of critical assessment. It need not include original research by the student, but it will be regarded favourably if it does. The report should not normally exceed around 10,000 words. In assessing the project, the examiners will pay particular attention to clarity of presentation, evidence that the student has worked critically and independently. and adequacy of references to original papers. Students must choose a topic and find a supervisor by the beginning of January.

Students may wish to use the LaTeX system to prepare their project dissertation. Several introductions to LaTeX are available on the web, including Getting Started with LaTeX, by D.R. Wilkin, and LaTeX for Complete Novices, by N.L.C. Talbot.

Web:
http://www.maths.qmul.ac.uk/postgraduate/msc-astrophysics/modules