



## Undergraduate study at the IfA

The Institute for Astronomy (IfA) is a research and teaching group within the School of Physics, University of Edinburgh. It is one of the UK's major centres of astronomical research, with cosmology, active galaxies and star formation being particular strengths. The IfA runs introductory courses in astronomy both specifically for science students and for students of any discipline at first year level, Honours Degree courses in Astrophysics (both BSc and MPhys), and research degrees leading to the award of PhD.

### Introductory Courses

**Astronomy 1** courses are aimed at scientists, and are recommended, for example, to be taken by those students registered for Astrophysics.

**Astronomy 1S: Stellar and Planetary Science** concentrates on the physics and life-story of stars and planets and how this illuminates our understanding of the Universe.

**Astronomy 1G: Galaxies and Cosmology** concentrates on the physics and appearance of galaxies and our current understanding of the Universe that we inhabit.

**Discovering Astronomy** courses are accessible to students taking a variety of subjects.

**Discovering Astronomy S: Stars and Planets** is an introduction to the Solar System, extrasolar planets, the formation and evolution of stars, and the possibility of life elsewhere in the Universe.

**Discovering Astronomy G: Galaxies and Cosmology** is an introduction to the concepts and methods used by astronomers and discusses what, as a consequence, we know about our Universe.

### Honours Degree Courses

**Astrophysics Junior Honours** combines core physics material with specialist lecture courses given

at the Royal Observatory. Topics include the physics of stars, galaxies, and quasars, cosmology, and the techniques of observations. Practical and observational work strengthens the understanding of physics Universe-wide, and provides a basis for the more intense development of these themes at Senior Honours and Masters levels.

Students can choose to study for either a BSc or an MPhys degree. The final year or two years involves project work and some research as well as more taught courses:

#### **Astrophysical Cosmology**

The meaning of time and space in an expanding universe are discussed, and the dynamics of the expansion are solved, yielding the tools needed to relate astronomical observations to the physical properties of objects seen at great distances. The time history of the expansion is studied, starting from the prediction of a hot big bang, and discussing the relics that remain from early times, especially light elements, dark matter and the microwave background. The initial conditions for the expansion are seen to require careful tuning, and the best modern explanation for this lies in the theory of inflation, which removes the idea of a big bang. Inflation not only can explain the existence of a uniform expanding universe, but also seed fluctuations via amplified quantum fluctuations, so that structures such as galaxies can form at late times. The course closes with a survey of open observational challenges.

#### **Advanced Cosmology**

This course is intended to present the current understanding of some of the main topics in cosmology, at a sufficiently high level that it allows a contact with the research literature. The focus will be on the development of structure in the universe, and how this can be related to cosmological initial conditions and exotic physical processes that operate at early times and energies. The course will be self-contained, but builds on the material covered in Astrophysical Cosmology.

#### **Astronomical Statistics and Instruments**

**Statistics:** A section on probability and statistics for astronomers introduces the elements of probability theory, the calculus of probabilities and the central limit theorem, going on to consider various uses of statistics, including hypothesis testing, estimation, Bayes' theorem, and the investigation of correlation and regression and the effect of biases in

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data; the emphasis is on methods that are common in astronomical research, and how to avoid the notorious pitfalls that frequently trap the unwary.

**Instruments:** The course is concerned with astronomical instrumentation right across the electromagnetic spectrum from radio waves to gamma rays. A little attention is devoted to telescopes and a lot to the instruments and detectors that they feed. Instrumentation for photometry, imaging, astrometry and spectroscopy is covered, as are interferometers of all kinds. The emphasis throughout is on the physical processes exploited in the design and construction of instrumentation, while the main design principles used at each wavelength are presented in a mathematical way, making use of important general tools such as Fourier methods. The course is not historical and is concerned principally with instrumentation currently in use by professional astronomers or under development.

### **Stellar Evolution**

This course investigates particularly the post main sequence stages of stellar evolution. The physical processes involved are applied to the evolution of core and envelope through the red giant phase to the final fate as a Supernova explosion.

### **General Relativity**

This course treats the subject in a way which should be accessible to all, not just to Mathematical Physicists, by making the subject as simple as possible (but not simpler). The classic results such as light bending and precession of the perihelion of Mercury are obtained from the Schwarzschild metric by variational means. Einstein's equations are developed, and used to obtain the Schwarzschild metric and the Robertson-Walker metric of cosmology.

### **High Energy Astrophysics**

Starting from Maxwell's equations, this

course develops the classical theory of radiation from an accelerated charge, and generalises to the relativistic case. Topics include: synchrotron radiation from relativistic electrons gyrating in a magnetic field; the acceleration of particles to relativistic energies; Faraday rotation and depolarisation; loss mechanisms and their effect on the observed radiation spectrum; relativistic beaming; the nozzle mechanism for relativistic jets; bremsstrahlung.

### **Radiation and Matter**

We start by learning the physics of radiation and its quantal interaction with matter, then go on to study this interaction in various astrophysical environments to define the nature and limitations of observation. Finally we apply these techniques to several important and characteristic astronomical observations, such as the 21cm radiation of atomic hydrogen used to weigh galaxies, the carbon monoxide emission used to map star nurseries, and the hydrogen Lyman alpha line forest used to determine the distribution of galaxy forming matter throughout the Universe.

### **Computational Astrophysics**

This course provides an introduction to advanced computational techniques used for numerical simulations in astrophysics involving gravity and/or fluids. The topics include N-body methods for solving gravity problems and numerical hydrodynamics techniques for fluids. Astrophysical topics for which the methods are used include cosmological simulations of structure formation in the Universe, the evolution of stellar systems (galaxies and star clusters), the formation of stars and planetary systems, and the collisions of neutron stars and black holes as a model for Gamma-Ray Bursts.

### **E-Science Courses**

There are also four e-Science MSc courses that are open to MPhys students with a suitable computational

background by agreement with the e-Science MSc Programme Director and subject to constraints of space in the MSc teaching lab:

- Introduction to Scientific Data
- The Virtual Observatory
- Distributed Computing for e-Science 1
- Distributed Computing for e-Science 2