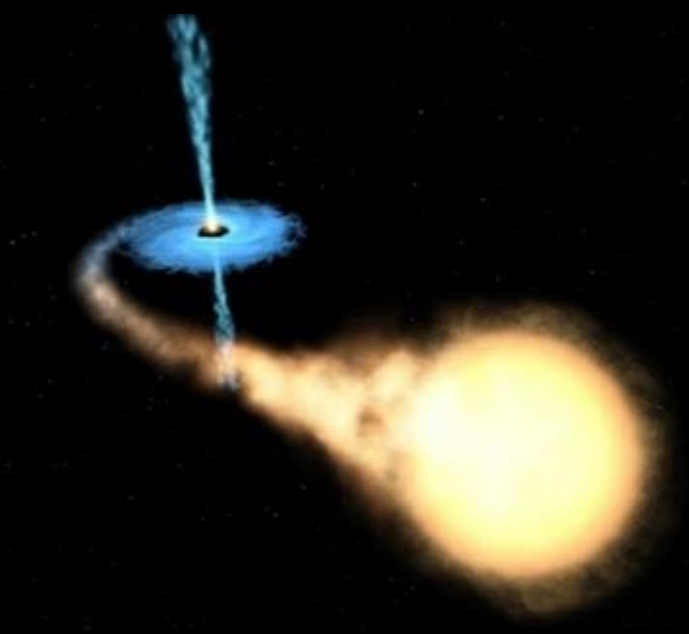
University of Glasgow | School of Physics & Astronomy



ASTRO4009
High Energy Astrophysics

Course Information Guide

Course Details

Cover page image credit: **NASA, ESA**

		Schedule:	HEAI - 11 lectures, semester 1 HEAII - 11 lectures, semester 2
Credits:	15	ECTS Credits:	7.5
Assessment:	2 hour exam (100%)	Exam Diet:	April/May
Level:	Honours	SCQF Level:	10
Year Cycle:	A (odd years)	Course website:	Moodle Link

Course Aims

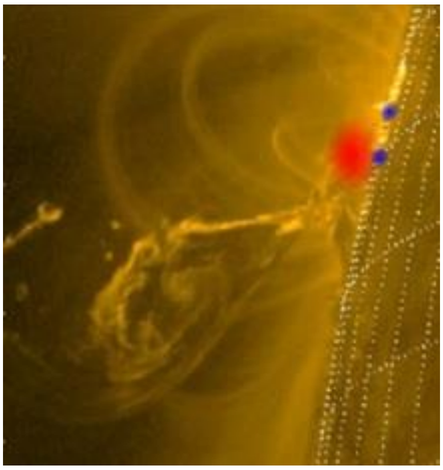
- To introduce students to the physical processes responsible for X-Ray production and the concept of a reaction cross-section. To explain how to calculate X-Ray emission rates and spectra from specified source conditions.
- To develop further the ideas and tools introduced, and apply them in some specific astrophysical situations.

Intended Learning Outcomes

- To describe and analyse processes, relationships and techniques relevant to the topics in the course outline, applying these ideas to solve problems with unseen elements.
- To write down and either prove or explain astrophysical laws relevant to the course topics, discussing their applications and appreciating their relation to other courses taken.

Semester 1 Course Outline

- *Introduction*: Types of radiation - soft X-rays, thermally-generated X-rays, atomic line contributions, hard X-rays, gamma-ray lines and continuum. Other signatures of energetic processes - solar and galactic cosmic rays, neutrinos and gravitational waves. Telescopes and detectors for high energy photons: crystal spectrometers; grazing incidence optics and Wolter telescopes; collimating optics; CCDs at high energy, proportional counters, scintillation counters, solid state detectors.
- *Basic Definitions*: - Planck spectrum, Stefan-Boltzmann Law, black-body X-ray sources; optically thick/thin sources. Reaction Cross-Section definitions and derivation of relation between reaction rate, incident flux and cross-section. Thomson Scattering, classical electron radius and Thomson cross-section; derivation of Thomson cross-section from photon flux from a single, scattered electron.
- *Bremsstrahlung Emission*: Emission from non-relativistic plasma for thermal and power-law electron energy distribution; derivation of photon spectra for a low energy cut-off in the electron energy distribution, and for a non-thermal electron energy distribution. Inhomogeneous plasmas; source emission measure function; emissivity for spherically symmetric plasmas.



X-ray emission from a Solar flare.
Credit: **Battaglia and Kontar A&A 2011**

- *Inverse Compton and Synchrotron Emission*: Inverse Compton derivation of energy gain for head-on photon-electron collision; derivation of inverse Compton luminosity and spectrum for a power law distribution of electron energies; inverse Compton lifetime of fast electron. Synchrotron Radiation synchrotron frequency, luminosity, spectrum and polarisation; derivation of synchrotron luminosity and spectrum for a power law distribution of electron energies; synchrotron lifetime of a fast electron. Gamma-rays nuclear de-excitation lines, annihilation line, and neutron capture line.

Semester 2 Course Outline

- *Collisional Bremsstrahlung*: Recap of thermal/non-thermal emission, emission measure; inverse problem and ill-posedness. Hot stellar winds and coronal loops, thermal conduction, other transport and loss processes. Derivations of differential emission measures and spectra.
- *Astrophysical X-ray Sources*: Cyclotron lines from neutron stars; emission from supernova remnants; inference of source magnetic field; the Crab nebula (and Crab Nebula electron acceleration problem); derivations of source field, lifetime, size. Inverse Compton X-ray Sources - quasars, active galactic nuclei, synchrotron self-Compton processes and luminosity; derivation of synchrotron-IC bootstrap properties. Accreting X-ray binaries - theory: accretion luminosity, Roche lobe and wind accretion, accretion disk formation and Eddington luminosity; luminosity derivations; disk structure derivation; derivation of orbit evolution. Accreting X-ray binaries - observations: thermal structure and spectrum of accretion disk, X-ray bursters, quasars as supermassive accretion sources.
- *The Cosmic X-ray Background*: Observations; general derivation for diffuse emission; inverse expressions for Compton scattering of starlight/cosmic microwave background by cosmic rays, bremsstrahlung by intergalactic gas, contribution of distant discrete sources.
- *Gamma-Ray and Cosmic-Ray Sources*: Gamma-ray bursters, TeV sources, solar flare gamma-rays, annihilation line from the galactic centre, solar (and atmospheric) gamma-rays, pulsar emission, properties and origins of cosmic rays.

Crab Pulsar imaged in optical (red) and x-ray (blue) wavelengths.
Credit: **NASA/HST/CXC/ASU/J. Hester et al**

Further Information

Recommended texts

M. S. Longair	*High energy astrophysics*	Cambridge	2011 (3rd edition)
Carroll & Ostlie	*Introduction to Modern Astrophysics*	Pearson	2014 (2nd edition)

Physics & Astronomy reading lists.

Course specifications - More details about the course in relation to other courses and degree paths on the course catalogue website.
Time and location of lectures - will be available during term time on the course website via Moodle.
Enrolment - Through MyCampus, details on the Astronomy 345 Moodle page.