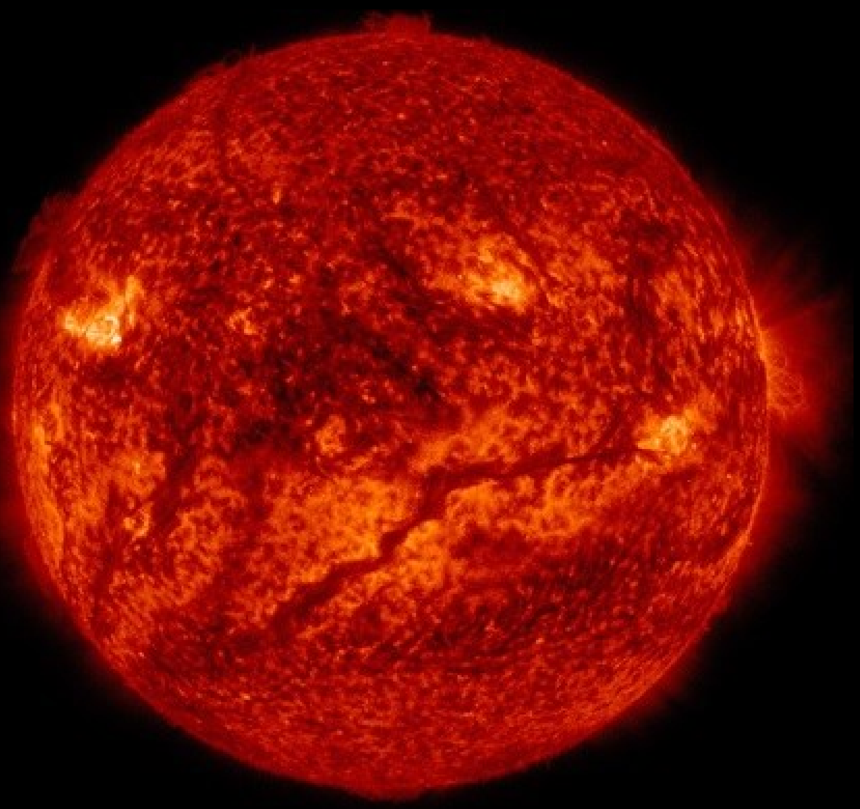
University of Glasgow | School of Physics & Astronomy



ASTRO4011
Stellar Structure and Evolution

Course Information Guide

Course Details

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		Schedule:	SSEI - 11 lectures, semester 1 SSEII - 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 recap basic ideas of stellar physics then to develop these to an appreciation of the main observational, physical and mathematical issues involved in understanding the structure and evolution of stars and the origin of elements.

Intended Learning Outcomes

SSEI

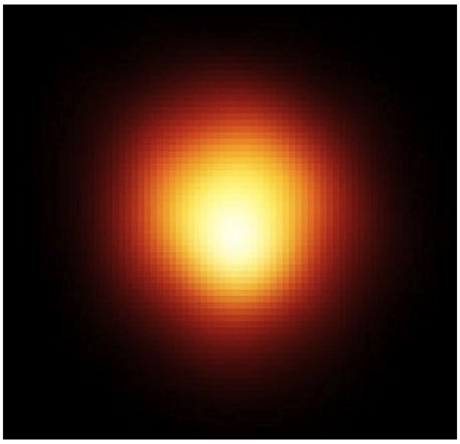
- Revise basic stellar concepts based on order-of-magnitude arguments.
- Describe the interior properties of main sequence stars.
- Develop and solve the equations of stellar structure.
- Explain relationships between mass, luminosity and temperature in groups of stars.

SSEII

- Describe the main features of the Hertzsprung-Russell diagram in relation to our understanding of stellar evolution.
- Present the steps of star formation and evolution on and off the main sequence.
- Describe the various chains of thermonuclear fusion reactions in stellar cores.
- Explain how solar neutrinos are detected, how the solar neutrino problem was solved and what impact this has on our understanding of stellar structure and evolution.
- Describe the main properties of the stellar end states (white dwarfs and the three different types of supernovae).

Semester 1 Course Outline

- *Introduction*: Main Sequence (MS) observations - distance, luminosity, temperature, radius, mass and the HR and mass-luminosity diagrams. Forces and timescales - potential energy of a star and the Kelvin-Helmholtz timescale; nuclear and dynamical timescales; equation of hydrostatic equilibrium, virial theorem.
- *Order of magnitude approaches*: central pressure and temperature in stars supported by gas or radiation pressure; ignition temperature and minimum stellar mass; radiation pressure and the Eddington mass.
- *Simplified Equilibrium Stellar Models*: Combining hydrostatic equilibrium and mass conservation - estimation of central pressure and temperature; simple mass distributions. Polytropic stars - equations of state of stellar matter; the polytropic equation of state; derivation of the Lane-Emden equation and its solutions; mass of a polytrope.

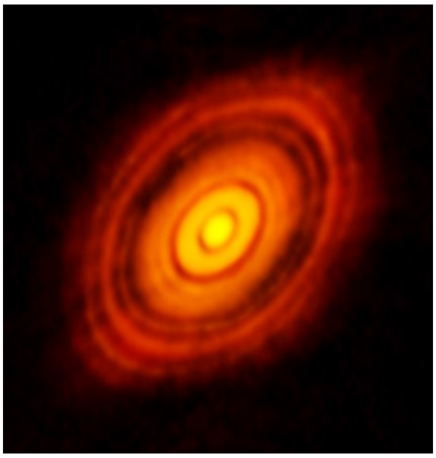


Red supergiant Betelgeuse imaged by Hubble.
Credit: **NASA/ESA**

- *Structure of Main Sequence Stars*: Nuclear fusion - main branch of the p-p chain; energy generation and luminosity equations. Radiative transport - the radiation field and opacity; development of the expression for radiative temperature gradient; sources of opacity; photon diffusion timescale. Convection breakdown in radiative equilibrium and conditions for convection; temperature gradient of convecting star; structure of high/low mass MS stars.
- *Star clusters and homology*: homology equations; derivation of mass-luminosity and temperature-luminosity relations.

Semester 2 Course Outline

- *Observational Evidence for Stellar Evolution*: Pre-main sequence objects (e.g. T Tauri, Herbig Ae/Be stars) and post-MS objects (e.g. white dwarfs, red giants, supergiants), positions on HR diagram.
- *Star Formation and Pre-Main Sequence Evolution*: Calculation of the Jeans' mass. Stellar collapse and fragmentation. The initial mass function. Slope of Hayashi and Henyey tracks on the HR diagram, lithium burning.
- *Nuclear Burning on the Main Sequence*: The p-p chain and the CNO cycle. Barrier penetration and reaction rates. Fusion of heavy elements. Solar neutrino problem – significance, principles of experimental investigations and solution of problem.
- *Evolution on the Main Sequence*: Core-depletion and shell-burning. Evolution in low vs. high mass stars.



A T Tauri star and its protoplanetary disk.
Credit: **ALMA/NSF**

- The red giant phase - transition from the MS. Core collapse. Development of convective envelopes and dredge-up. He flash, He core burning. Horizontal branch. Asymptotic Giant Branch. The pulsation phase - importance of H and He ionisation; derivation of the period-luminosity relationship from physics of stellar gas.
- *Stellar End States*: White dwarfs (structure and cooling). Supernovae and end products.

Further Information

Recommended texts

Dina Prialnik	*An Introduction to the Theory of Stellar Structure and Evolution*	CUP	2010 (2nd edition)
Bradley Carroll & Dale Ostlie	*An Introduction to Modern Astrophysics*	CUP	2017 (2nd edition)
Mike Guidry	*Stars and Stellar Processes*	CUP	2019

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.