PHAS3135, The Physics of Stars: Proposed Module Outline

This new course develops PHAS 3134 (The Physics and Evolution of Stars; Yr 3, Term 1), consolidating selected material previously taught under PHAS G/M318 (Stellar Atmospheres & Stellar Winds; Yr 4, Term 1). This consolidation is motivated principally by the retirement of G/M318 (advanced stellar astrophysics) in favour of the new M336 course (advanced physical cosmology), and by the wish to produce a stellar-astrophysics course covering a wide range of basic material at intermediate level. The opportunity is taken to rationalize the content in the context of material covered in PHAS 2112 so that the two form a better-integrated succession of topics.

It is expected to replace PHAS 3134 in the third-year, first-term timetable. It shares the pre-requisite of PHAS 2112 (Astrophysical Processes), and will be taught by Ian Howarth in the first instance. It will be available to the same cohort as PHAS 3134 (all Astro plus selected Nat Sci students), currently ca. 24 students.

1 Aims

- To provide a quantitative introduction to the physical nature of stellar atmospheres
- To develop the basic theory of stellar structure through analytical models.
- To provide an intermediate-level description of how stars evolve.

2 Objectives

On successful completion of this course, a student should be able to:

- Understand the basic concepts of opacity and emissivity in the context of stellar atmospheres and interiors,
- Describe the basic physical atomic processes that contribute to the opacity, and the main frequency and temperature dependences.
- Understand the interaction of radiation and matter, through the equation of radiative transfer in plane-parallel, static geometry (atmospheres) and diffusive transport (interiors).
- Derive the formal solution of the equation of radiative transfer, and have an appreciation of the grey-atmosphere solution.
- Understand the basics of the construction of LTE model atmospheres, and their limitations.
- Understand the basic processes leading to the calculation of model lines and continua in model atmospheres.

- Describe the process of energy transport by convection in stellar interiors and atmospheres.
- Construct simple stellar models based on polytropes, and understand their relationships to real stars.
- Describe the major stages of stellar evolution
- Understand the effects of initial mass on evolution

3 Course structure & assessment.

Thirty lectures plus four problem-solving classes. Assessment based on final examination (90%) and three problem sheets (10%).

4 Core recommended texts.

D. F. Gray: The Observation and Analysis of Stellar Photospheres (CUP, 2008).
D. Prialnik: An Introduction to the Theory of Stellar Structure and Evolution (CUP, 2009).

A longer reading list will be provided to students, including selected articles in the on-line *Encyclopedia of Astronomy & Astrophysics,* together with detailed lecture notes (after lectures).

5 Draft Syllabus

- Introduction: overview [2]

  Motivation: the spectroscopic determination of stellar properties, and their interpretation through stellar structure & evolution.

  Review of basic equations: Mass continuity, hydrostatic equilibrium, radiation field & opacity; equation of radiative transfer along a ray.

- Introduction: opacity sources [2]

  Bound-bound, bound-free, free-free opacities; electron & Rayleigh scattering. Rosseland mean opacity; Kramer's opacity law.

- Stellar atmospheres: structures & continua [6]

  Equation of radiative transfer in stellar atmospheres; formal solution. Grey atmosphere. Eddington, Milne-Eddington approximations. Eddington-Barbier relation, limb darkening.

  'Real-world' construction of LTE model atmospheres (Lambda, Unsold-Lucy iteration).

- Stellar atmospheres: spectral-line formation [6]

  Transfer equation and source function for lines. Calculation of line profiles in LTE. Breakdown of LTE. P-Cygni profiles.

- Stellar structure: radiative and convective energy transport in interiors [3]

  Gas, electron, and radiation pressures. Equations of state for an ideal gas and a polytrope. Diffusive radiative transfer. Schwarzschild criterion, mixing-length formalism.

- Stellar structure: simple models [4]

  Polytropic models; Lane-Emden equation. Application to stars. Mass-radius relationship. Eddington standard model. Chandrasekhar mass.

- Stellar Evolution: pre-main-sequence [2]

  Jeans mass. Pre-main-sequence phase. Hayashi (fully convective) tracks.

- Stellar Evolution: main sequence [3]

  Homologous stellar models. Evolution on the main sequence.

- Stellar Evolution: post-main-sequence [2]

  Evolution off the main sequence, to the red-giant branch. End-points of stellar evolution; dependence on initial mass.