
Stellar Physics



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Objectives

The students will learn how to use fundamental physical laws to explain the structure of stars and their evolution and how to relate stellar models to observable quantities. The basic knowledge on stellar atmospheres and the formation of stellar spectra will be presented. In the part 3 of this course The students learn the basics of the fundamental stellar physics, by use of observation and theoretical methods, and they will be able to deal with the Stellar Evolution and Structure challenges. Moreover, a complementary part can be reached by the SPE METEOR –Stellar Pulsation and Evolution–. The part 1 & 2 can be complemented by the METEOR FISS (Formation and Interpretation of Stellar Spectra) as well.

Evaluation

The three parts have equal weights in the final mark.
Part 1: written exam (40 %), two homeworks + lab report (60%).
Part 2: written exam (75%), oral presentation of one exercise (25%).
Part 3 : written exam (50%), oral presentation (50%).

Main progression steps

- The students will progressively get deeper insight on the main properties of stars by first deriving simple models from simplifying assumptions and by further performing experiments with more sophisticated numerical codes and data analysis algorithms.
- Parts 1 and 2 take place in parallel during the first four weeks.
- Parts 3 takes place during the fifth and sixth weeks.
- Last week : Examination, Written and oral presentations.

Bibliography & Resources

- Asteroseismology C. Aerts, J. Christensen and D.W. Kurtz 2010
- Introduction to stellar astrophysics E. Boehm-Vitense Vol. 3 Stellar structure and evolution, Cambridge University Press 1992
- HDR –Habilitation a Diriger les Recherches– Stellar Pulsation and Evolution, M. Chadid 2014
- An introduction to stellar astrophysics, F. Leblanc Willey Ed. 2010
- Astrophysique. Etoiles, univers et relativit , J. Heyvaerts, Dunod 2012 (French Version)
- Stellar Structure and Evolution R. Kippenhahn and A. Weigert 2012
- <http://mauca.unice.fr/index.php/documents-for-stellar-physics/>
- <http://www.staff.science.uu.nl/rutte101/>
- <https://astro.phys.au.dk/jcd/evolnotes/>

Contents

Part 1: Stellar Structure

by ORLAGH CREEVEY

1. Chapter 1: Observable and fundamental properties of stars
 - (a) Stars in the Universe
 - (b) Fundamental quantities of stars
 - (c) Observed properties of stars
 - (d) Stellar timescales
2. Chapter 2: Stellar Structure
 - (a) Assumptions
 - (b) Equation of hydrostatic equilibrium
 - (c) Equation of mass conservation
 - (d) Virial Theorem
 - (e) Equation of energy conservation
 - (f) Transport of energy
 - (g) Convection
 - (h) Equation of State
 - (i) Stellar structure models

Part 2: Stellar atmospheres

by MARIANNE FAUROBERT

1. Chapter 1: Basics of radiative transfer
 - (a) Interactions of radiation and matter
 - (b) Radiative transfer equation
 - (c) Radiative transfer at large optical depths. Rosseland mean opacity.
2. Chapter 2: Stellar atmospheres
 - (a) The equations of the model
 - (b) Equation of radiative equilibrium
 - (c) Gray atmospheres in radiative equilibrium
 - (d) Some simple cases
3. Chapter 3: Spectral lines
 - (a) Line broadening
 - (b) Spectral line formed under Local Thermodynamical Equilibrium (LTE)
 - (c) Spectral lines formed in NLTE (2-level atom vs multi-level atom)

Part 3: Asteroseismology and Stellar Structure & Evolution

by MERIEME CHADID

1. Chapter 1: Asteroseismology and Stellar Structure
 - (a) Equations of Stellar Structure
 - (b) Oscillations and Asteroseismology
 - (c) Pulsations across the HR diagram
 - (d) Pulsation modes and identification
 - (e) Pulsation mechanisms and physical phenomena induced by shock waves
 - (f) Different types of stellar pulsators and properties
 - (g) Applications: Light curves, radial velocities. Circumpolar and space observations.
2. Chapter 2: Stellar Evolution
 - (a) Introduction to stellar evolution
 - (b) The equations of stellar evolution
 - (c) Instable regions
 - (d) The theory of the Main Sequence, relationship Mass-Radius, Mass-Luminosity
 - (e) Evolution before/after the Main Sequence