

Syllabus and Commentary for Stellar Structure and Evolution C3101, Spring 2007

www.astro.columbia.edu/~caleb/class/c3101.html

Caleb Scharf

Room 1011 Pupin Hall, caleb@astro.columbia.edu, Office Tel: 854-4451

Principal Text : AN INTRODUCTION TO MODERN STELLAR ASTROPHYSICS, Ostlie & Carroll, Addison-Wesley Co. **2nd Edition**. For about 20 bucks more you could get AN INTRODUCTION TO MODERN ASTROPHYSICS, Carroll & Ostlie, Addison-Wesley Co. 2nd Edition, which *contains* the stellar book in addition to broader, extragalactic, astrophysics material - it's your choice, I'll assume only the first, smaller stellar book.

For more details on all manner of things, see the course web site

There is, unfortunately, no unique way to structure a course on stellar astrophysics. There are many steps involved in arriving at our modern picture of "how stars work", and often one has to jump ahead and back again in order to understand different components - a linear approach is hard when the final bits of the jigsaw must be assembled more or less simultaneously. The textbooks all suffer this problem to differing degrees. Consequently, in this course we attempt to blend the stages of a few approaches - while we broadly stick to the Ostlie & Carroll pattern you will find noticeable liberties taken with the arrangements - don't panic, 95% of the material is still in that text, just maybe a bit more scattered. We will also often repeat some things, as a means to demonstrate the interconnectivity of the problem, as well as to improve our memory !

Introduction: Stars & The Universe

What are stars ?

Overview of structure and evolution

Observational Overview

Fundamentals of Stellar Astrophysics

Stellar Distances, Magnitudes

Brightness and Luminosity

Inverse Square Law

Distance Modulus

Radiation

Specific Intensity

Constancy of Intensity in Free Space

Mean Intensity, Flux

- Energy Density, Radiation Pressure
- Quantum Mechanics/Relativity Primer (Handout)
- Black-Body Radiation
 - Planck Distribution
 - Stefan-Boltzmann Law
- Interaction of Radiation with Matter/Radiative Transfer
 - Absorption/Extinction Coefficient, Optical Depth
 - Scattering and Absorption, Opacity - Kramers Law
 - Mean Free Paths

Stellar Atmospheres

- 1-D Equation of Radiative Transfer: Temperature Structure of a Star
 - Source Function, Emission
 - Local Thermodynamic Equilibrium (LTE)
 - Solution to 1-D Transfer Equation
 - Plane Parallel Atmosphere, Gray Atmosphere
 - Flux and Pressure Expressions
- The Eddington Approximation
 - A Form for the Temperature Structure of a Star, $T(\tau)$
- Confirmation and Consequences of $T(\tau)$
 - Limb Darkening
- Spectral Lines
 - Introduction, Fraunhofer & The Solar Spectrum, Helium
 - Kirchoff's Laws
- The Structure of Spectral Lines
 - Equivalent Width
 - Natural Broadening, Lorentzian
 - Doppler Broadening, Gaussian
 - The Maxwell Boltzmann Distribution, Turbulence
 - Pressure & Collisional Broadening
 - The Voigt Profile
 - Line Profiles, Saturation
 - Curve of Growth, Relative Abundances, Column Density
- The Boltzmann Law
- The Saha Equation

Stellar Interiors and Structure

- Macro & Microscopic quantities
- Mass fractions
- Hydrostatic Equilibrium

- Static stars, Minimum Stellar Central Pressure
- The Virial Theorem
- Kelvin-Helmholtz Timescale
- Pressure Equation of State and Polytropes
 - Gas and Radiation Pressure
 - Polytropes: The Lane-Emden Equation, Simple Stellar Models
 - Central Pressure, Density and Temperature for Sun
- Energy Transport
 - Radiation
 - Convection, and Convection criterion
 - Conduction
- Stellar Energy Sources & Nucleosynthesis
 - Binding Energy, Fusion Temperature, Quantum Tunneling
 - Proton-Proton Chain, Solar Neutrinos
 - The CNO Cycle
 - The Triple Alpha Process
 - Late Stages of Nucleosynthesis
- Building Stellar Models
 - Vogt-Russell Theorem
 - Running a Stellar Code

Stellar Evolution

- The Zero-Age Main Sequence (ZAMS)
- Proto-stars
 - The Jeans Mass and Jeans Length
 - The Hayashi Track
- Evolution on and Beyond the Main Sequence
- Pulsating Stars
 - Cepheids, RR Lyrae and Mira variables

Stellar Remnants

- White Dwarfs
 - Degenerate Matter
 - The Chandrasekhar Limit, White Dwarf Cooling
- Neutron Stars
 - Pulsars
 - Intro to Special and General Relativity
- Black Holes
 - Event Horizons
 - Hawking Radiation

Binary Star Systems

- Close Binary Systems

Roche Lobes and Mass Transfer

Accretion Disks, X-ray Binaries

Type Ia Supernovae

Stars in the Universe

Globular Clusters and Galaxies

Star Formation and the Early Universe