## Unit 1 Energy Generation


1.1 Basics
- 1.1.1 Energy equilibrium
- 1.1.2 Nuclear interactions
- 1.1.3 Nuclear reaction rates
- 1.1.4 Energy release in nuclear reactions
- 1.1.5 Binding energy

1.2 Hydrogen burning
- 1.2.1 PP-I chain
- 1.2.2 PP-II and PP-III chain
- 1.2.3 CNO cycle

1.3 Things not discussed


## Unit 2 Hydrostatics


2.1 Are stars approximately a one-fluid plasma?

2.2 Time scales of stars
- 2.2.1 Dynamical timescale
- 2.2.2 Thermal timescale
- 2.2.3 Nuclear timescale

2.3 Equation of state
- 2.3.1 Preliminaries
- 2.3.2 Mean molecular weight ($\mu$)
- 2.3.3 Ideal monatomic gas
- 2.3.4 Completely degenerate gas
- 2.3.5 Partially degenerate gas
- 2.3.6 —
- 2.3.7 Radiation Pressure
- 2.3.8 Density-temperature equation of state landscape
- 2.3.9 Thermodynamics of an ideal gas
- 2.3.10 Mixture of ideal gas and radiation: pressure effects
- 2.3.11 Mixture of ideal gas and radiation: ionization effects

2.4 Hydrostatic equilibrium
- 2.4.1 Derivation

2.5 The Virial Theorem

2.6 Polytropes
- 2.6.1 Motivation and derivation
- 2.6.2 Lane-Emden equation
- 2.6.3 Polytrope solutions

# Unit 3 Energy Transport

3.1 Radiation

3.1.1 Basics

3.1.2 Diffusion: Fick's Law, temperature gradient

3.1.3 Frequency dependence of radiation: Rosseland mean opacity

3.1.4 Opacity sources

- Scattering of photons from electrons
- Free-free absorption
- Bound-free absorption
- Bound-bound absorption
- $H^-$

3.1.5 Consequences (Plots!)

3.1.6 Eddington Luminosity

3.1.7 Final tools:

- **The True Driving Gradient** $\nabla$
- Radiation gradient $\nabla_{rad}$
- Adiabatic gradient $\nabla_{ad}$

3.2 Conduction

3.3 Convection

3.3.1 The convective instability: considering $P$ and $\rho$ as a blob is displaced, Schwarzschild criterion

3.3.2 Another useful formulation

3.3.3 Semiconvection (*Ledoux criterion*)

3.3.4 One more useful formulation

3.3.5 Physical conditions for convection onset

3.3.6 Mixing length theory

3.3.7 Convective overshoot

3.3.8 Depth of outer convection zones

- $T_{eff}$
- chemical abundances

# Unit 4 The Main Sequence

4.1 Summary of stellar structure

4.2 Homology relations for stars in **radiative equilibrium**

4.2.1 Basic idea

4.2.2 Dependence on mass

4.2.3 Dependence on $T_{eff}$

4.2.4 Dependence on mean molecular weight ($\mu$)

4.2.5 Dependence on heavy metal abundances

4.2.6 Contracting stars in radiative equilibrium

4.2.7 Convective stars

4.3 Evolution on the main sequence

4.3.1 Low-mass stars

4.3.2 High-mass stars

4.3.3 A note about *very* low mass stars

4.4 Summary of Main-Sequence properties

# Unit 5 The Post Main Sequence


5.1 General considerations
- 5.1.1 Schonberg-Chandrasekhar Limit
- 5.1.2 The subgiant branch

5.2 Toward and up the RGB
- 5.2.1 High-mass stars
- 5.2.2 Low-mass stars
- 5.2.3 RGB properties
- 5.2.4 Summary

5.3 Helium burning
- 5.3.1 Quick tour of non-hydrogen nuclear reactions
- 5.3.2 Horizontal Branch
- 5.3.3 Location of the ZAHB
- 5.3.4 Horizontal branch evolution
- 5.3.5 Asymtotic giant branch
- 5.3.6 Thermal pulses

5.4 Last stages of evolution: low-mass stars
- 5.4.1 Production of $s$ elements
- 5.4.2 Planetary nebula
- 5.4.3 White dwarfs
- 5.4.4 Further WD properties
- 5.4.5 Type Ia supernovae

5.5 Last stages of evolution: low-mass stars
- 5.5.1 Nuclear burning
- 5.5.2 Type II supernova – core collapse
- 5.5.3 Neutron star
- 5.5.4 Black hole