Lecture 5 Notes: Stellar Structure and Flux Measurements

Summary Notes

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1 Learn programming

- Python programming recommended for astronomy
- Reference: https://web.iucaa.in/ ace/programs/

2 Fluxes and Magnitudes

2.1 Apparent Magnitude

- Basic equation: $m_1 - m_2 = -2.5 \log_{10}(f_1/f_2)$
- Key characteristics:
  - Logarithmic scale
  - Base $100^{1/5}$
  - Inverted (brighter objects have lower magnitude)
  - Measurements are relative
  - Small flux changes: fractional change in flux $\sim$ magnitude change

2.2 Magnitude Systems

1. Vega system (historical standard)
2. STMAG system (HST standard)
   - $m_\lambda(\lambda) = -2.5 \log_{10} F_\lambda(\lambda) - 21.1$
   - F_λ in erg s^{-1} cm^{-2} Å^{-1}
3. AB magnitude system
   - $m_\nu(\lambda) = -2.5 \log_{10} F_\nu(\lambda) - 48.6$
   - F_ν in erg s^{-1} cm^{-2} Hz^{-1}

2.3 Jansky Units

- 1 Jy = 10^{-23} erg/sec/Hz/cm^2
- Conversion: $f = 3631$ Jy $\times 10^{-0.4m}$
- Common in radio and far-infrared astronomy

3 Distance Measurements

3.1 Distance Modulus

- $\mu = m - M = 5 \log_{10}(D_L) - 5$
- D_L is luminosity distance in parsecs
- Interpretation:
  - $\mu > 0$: object farther than 10 parsecs
  - $\mu < 0$: object closer than 10 parsecs

4 Stellar Structure and Evolution

4.1 Definition of a Star

Two key conditions:

1. Bound by self-gravity
2. Powered by internal energy source

4.2 Hydrostatic Equilibrium

- Balance between gravity and pressure
- Key assumptions:
  - No magnetic field
  - Non-rotating star
  - General relativity not significant

4.3 Eddington Luminosity

- Maximum luminosity while maintaining hydrostatic equilibrium
- Classical formula: $L_{\text{Edd}} = \frac{4\pi G M m_p c}{\sigma_T}$
- Modified by opacity: $L_{\text{Edd,mod}} = \frac{4\pi G M c}{\kappa}$

- Applications:
  - Limits on stellar masses
  - Accretion rates onto black holes
  - AGN feedback mechanisms

5 Energy Transport in Stars

Three main mechanisms:

1. Conduction
2. Radiation
3. Convection (most complex mechanism)

6 Equations of State

- Ideal gas: $P = nkT/V$
- Non-relativistic degenerate electron gas: $P = K(n/V)^{5/3}$
- Relativistic degenerate electron gas: $P = K'(n/V)^{4/3}$
- Polytropic equations: $P = K\rho^{\gamma} = K\rho^{1+1/n}$

7 Nuclear Fusion

7.1 Proton Chain

Net reaction: $4^1H \rightarrow^4 He + 2\nu_e$ + 26.7 MeV

- Sun produces 4×10^{26} joules per second
- Approximately 9.36×10^{37} reactions per second
- Efficiency around 0.7%

8 Solar Composition

Mass fractions:

- Hydrogen (X): 0.70
- Helium (Y): 0.28
- Metals (Z): 0.02