ASTR 400/700: Stellar Astrophysics

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A700 Oral Exam

• Dec 6:
  - Archana Dobaria
    “Stellar Formation in Different Galaxies”
  - Yuzo Ishikawa
    “Understanding the Properties and Formation of Black Holes”

• Dec 8:
  - Daniel McKeown
    “Stellar Content in the Illustris Simulation”
  - Heechan Yuk
    “Structures and Mechanisms of Supernovae”
Upcoming schedule

• Oct 18: Stellar atmospheres (Chapter 9)
• Oct 20: Stellar atmospheres (Chapter 9)
• Oct 25: Stellar Atmospheres (Chapter 9)
• Oct 27: Stellar interiors (Chapter 10)
• Nov 1: Stellar interiors (Chapter 10)
• Nov 3: Stellar evolution (Chapter 13)
Stellar Atmosphere

- Light comes from the Star’s Atmosphere
  - Atmosphere is the layers of gas overlaying opaque interior of star
- Flood of photons pour from these layers releasing energy produced by the thermonuclear reactions, gravitational contraction and cooling in the star’s center
- The temperature, density and composition of the atmospheric layers determine the features of the star’s spectrum
  - No solid surface…

Photosphere: Segment of star that emits light. Typically defined to be the region down to an optical depth of $2/3$.

Chromosphere: In the Sun, a thin layer just above the photosphere that is visually more transparent than the photosphere. The spectrum of the light generated here is dominated by $\text{H}\alpha$ wavelength. Temperature of Chromosphere is up to 20,000K.

Transition Region: In the Sun, a region between the Chromosphere and Corona.

Corona: In the Sun, a type of plasma atmosphere that extends millions of kilometers into space. High temperature.
Description of the Radiation Field
Specific and Mean Intensity

\[ I_\lambda(T) \]

\[ d\Omega = \sin \theta \, d\theta \, d\phi \]
Description of the Radiation Field
Specific and Mean Intensity

Light entering trap

Light leaving trap

$dA$

$d\Omega$

$\theta$

$dL$
Specific Radiative Flux

- Net Energy having a wavelength between $\lambda$ and $\lambda+d\lambda$ that passes each second through unit area in the direction of the +z axis.

Resolved Source
Flux independent of $r$

Unresolved Source
Flux decreases as $1/r^2$
Radiation Pressure is $1/3$ of the Energy Density for Blackbody Radiation
Stellar Opacity

- Solar Spectrum

What determines features of Spectrum?
Stellar Opacity
Temperature and Local Thermodynamic Equilibrium

• The **effective temperature**, which is obtained from the Stefan–Boltzmann law (Eq. 3.17), is uniquely defined for a specific level within a star and is an important global descriptor of that star.

• The **excitation temperature** is defined by the Boltzmann equation (8.6).

• The **ionization temperature** is defined by the Saha equation (8.8).

• The **kinetic temperature** is contained in the Maxwell–Boltzmann distribution, Eq. (8.1).

• The **color temperature** is obtained by fitting the shape of a star’s continuous spectrum to the Planck function, Eq. (3.22).
Stellar Opacity

Mean free path

\[ \ell = \frac{vt}{n\sigma vt} = \frac{1}{n\sigma}. \]
Definition of Opacity

• Consider a beam of parallel light rays traveling through a gas.
• Any process that removes photons from this beam of light is called absorption.
• Absorption includes Scattering!!
• True absorption is by electronic transitions in atoms (and sometimes molecules).
  • Change in Intensity is

\[ dI_{\lambda} = -\kappa_{\lambda} \rho I_{\lambda} \, ds. \]

Proportional to:
- distance traveled
- density of gas
- absorption coefficient