Astrophysics - Summary - Introduction

1. Units :- mass : solar mass
- length : AU, pc, kpc, Mpc, Gpc
- time : regular time
- coordinates : Ra. Dec Equatorial system -> precession
l, b Galactic system

- brightness: magnitudes - log scale (absolute, apparent, bolometri

$$m - M = 5\log_{10}\frac{d}{10}$$ -> distance measurments

+ colour of objects (B-V)

Sources of astronomical information:
- EM radiation
- neutrinos -> Sun + supernovas
- gravitational waves -> black hole & neutron star mergers
- cosmic rays -> energetic objects

EM radiation : - various wavelengths
- atmosperic windows (throughput)
- Imaging + Spectroscopy
- Blackbody or syncrotron + spectral lines

Optical : resolution $\theta = 1.22\frac{\lambda}{D}$

Radio astronomy: single dish vs. interferometry

X-ray astronomy: only from space

Infrared astronomy:

Gamma-ray astronomy: directly only from space

name a few sources + where are the observatories in general

2.) Radiation transfer - Summary

Describes how radiation interacts with matter
- Macroscopic: using emission and absorption coeficients
- Microscopic: calculating the emission & absorption coeficients

Planck's law - blackbody radiation

Radiation transfer - how does radiation propagate

amount of radiation

$$dE_\nu d\nu = I_\nu \underbrace{\cos\theta}_{\substack{\text{angle}\\\text{of direction}}} \underbrace{dA}_{\text{area}} \underbrace{dt}_{\text{time}} \underbrace{d\Omega}_{\text{solid angle}} d\nu$$

~~solid~~

Radiation Flux: $F_\nu = \int I_\nu \cos\theta \, d\Omega$ $\quad F = \int F_\nu d\nu$

↳ integrate the intensity $\quad$ ↳ integrate over frequency

Energy density: $u_\nu = \int \frac{I_\nu}{c} d\Omega$ $\quad$ density of energy in a cylinder filled by radiation

Radiation pressure: pressure associated with radiation

$$P_\nu = \frac{1}{3} u_\nu$$

Radiative transport: how dos radiation propagate trough things
- in empty space: the radiation does not change
- through matter: emission and absorption

emission coef: j_ν $\quad\Big\}$ all matter has this
absorption coef α_ν

radiation transfer equation: $\boxed{\frac{dI_\nu}{ds} = j_\nu - \alpha_\nu I_\nu}$

if the matter only absorbes: $j_\nu = 0$ $\quad \frac{dI_\nu}{ds} = -\alpha_\nu I_\nu$

optical depth: $d\tau_\nu = \alpha_\nu ds \rightarrow \tau_\nu = \int_{s_0}^{s} \alpha_\nu(s') ds'$

$$I_\nu(\tau_\nu) = \underline{I_\nu(0)} e^{-\tau_\nu}$$

3) $\tau \gg 1$ optically thick
$\tau \ll 1$ optically thin (can neglect optical depth)

source function: $\boxed{S_\nu = \frac{j_\nu}{\alpha_\nu}}$ describes matter

Kirchofs law: In thermodynamic equilibrium:

$$\underset{\text{emission coef.}}{j_\nu} = \underbrace{\alpha_\nu B_\nu(T)}_{\text{absorption coef} \times \text{blackbody}}$$

- Thermodynamic equilibrium -> Maxwellian velocity distribution (e.g. stars)

Boltzmann distribution law: $\frac{n_e}{n_0} = \exp\left(-\frac{E}{k_B T}\right)$ -> fraction of excited atoms

Saha equation: fraction of ionised gas

- Local thermodynamical equilibrium
- Radiative transfer trough stellar atmospheres -> general considerations
  - plane parallel atmosphere layers, no variation in <-> direction
  - LTE
  - radiation field is anisotropic (radial temperature gradient)
  - grey atmosphere model -> no dependence on ν (simplification)
  - limb darkening: intensity depends on direction
- Formation of spectral lines (absorption)
  - -> layers with different α_ν
  - -> matter actually has α dependent on ν
- Radiative energy transport inside stars:
  - opacity(χ): $\alpha_R = \rho \chi$ depends on density and absorption coef.
  - Kramers's law $\chi \propto \frac{1}{T^{3.5}}$ depends on temperature -> higher T lower χ

However: opacity drops at low temperatures!

4) Thompson scattering : radiation scattering on free electrons
elastic scattering - wavelength does not change

-> additional opacity due to thompson scattering

Spectral lines : Equivalent width : the integral of the fractional dip in intensity for an absorption line

$$W_\lambda = \int \frac{I_c - I_\nu}{I_c} \, d\lambda$$

I_c - continuum intensity
I_ν = absorption line

photon diffusion inside the Sun -> it takes a very long time for photons to get out from the core $\sim 10^4$ years