Astrophysics - Summary - Introduction

1. $\boxed{\text{Units}}$: - 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, bolometric)

$$m - M = 5\log_{10}\frac{d}{10}$$ → 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

<u>Planck's law</u> - blackbody radiation

Radiation transfer - how does radiation propagate

amount of radiation

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

<u>Radiation Flux</u>: $F_\nu = \int I_\nu \cos\theta \, d\Omega$ $\qquad F = \int F_\nu \, d\nu$

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

<u>Energy density</u>: $u_\nu = \int \frac{I_\nu}{c} \, d\Omega$ $\qquad$ density of energy in a cylinder filled by radiation

<u>Radiation pressure</u>: pressure associated with radiation

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

<u>Radiative transport</u>: how dos radiation propagate trough things

- in empty space: the radiation does not change
- through matter: emission and absorption

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

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

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

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

$$I_\nu(\tau_\nu) = \underbrace{I_\nu(0)}_{\text{before absorption}} e^{-\tau_\nu}$$

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:

$$j_\nu = \alpha_\nu \underbrace{B_\nu(T)}$$

emission coef. absorption coef × 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 actualy 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 ~ 10^4 years

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Stellar Physics

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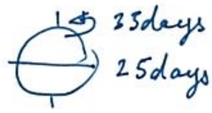
Solar phenomena :

rotation : differential rotation → from oscillations
→ movement of sunspots



magnetic field: sunspots : colder spots associated with magnetic fields

solar cycle : 11 years of variation for number of sunspot
+ polarity change ⇒ 22 years cycle

solar flares + CME's → space weather, Aurorae

Exo planets : 5 methods for detection:
- radial velocity
- transit
- direct imaging
- gravitational micro lensing
- astrometry

End state of stars :

- White dwarf
- neutron star
- BH

} discussed

White dwarfs : Fermi gas (not ~~Boltzmann~~ Maxwellian velocity) → degeneracy pressure
↳ degenerate e^- gas

For the pressure we have two cases
→ relativistic case $P = K_2 \rho^{4/3}$
→ non relativistic case $P = K_1 \rho^{5/3}$

5.) degenerate matter → stellar structure symplifies: only need to solve ~~two~~ 3 of the stellar structure equations → the first 2 combine

⇒ $R \propto M^{-1/3}$ → increasing mass → smaller star

depending on the ~~size~~ mass of the star we can use ~~seat~~ non-rel for low mass and relativistic pressure for higher masses

↳ mass limit for white dwarf: Chandrasekar mass limit

→ mass of a star in the size of a planet (10^4 km)

Neutron star: degenerate neutron gas → "neutron drip" neutrons drip out of atoms at very high pressures, $e^- + p^+ \rightarrow n + \nu$

→ degenerate pressure

→ also have ~~a~~ mass limit

→ mass of a star in a size of a city (10 km)

→ rotating neutron star: pulsar

→ binary pulsar → grav waves

→ milisecond pulsars → binary system

↳ X-ray binaries

The Milky Way