

## I. Introduction

- Neutral gas, molecular gas, general viewpoint -6-
- Dust -8-
- Ionized Gas -9-
  - photoionization
  - collisions
  - cosmic rays
- Phases of interstellar gas -12-
- Magnetic fields and cosmic rays -13-
- Pressure sources -14-

## II. Statistical physics in the ISM -16-

- The “Big Four”
  1. Maxwell distribution -16-
  2. Boltzmann distribution of energy levels in atoms and molecules
  3. Saha equation for ionization equilibrium
  4. Planck function for radiation
- Detailed Balancing -19-
- Statistical equilibrium -22-

## III. Radiative Transfer -24-

- (a) radiative transfer equation -26-
- (b) Einstein Coefficients -28-
- (c) Line profile function -31-
  - i. Natural Line Width
  - ii. Doppler and Collisional Broadening
    - A. Doppler – thermal and bulk (turbulence)
    - B. Collisional (pressure)

## IV. HI

- (a) Atomic H in the ISM -33-
- (b) 21 cm line -34-
- (c) Single layer of gas -38-
  - i.  $\tau_{\nu_o} \gg 1$
  - ii.  $\tau_{\nu_o} \ll 1$
- (d) Observing Brightness Temperature -40-
- (e) HI emission and absorption -41-
  - i. absorption of external background source (BGS)
- (f) Conclusions -45-
  - i. 1
  - ii. 2
  - iii. 3
  - iv. 4
- (g) Relevant Results -47-
  - i. 1
  - ii. 2

iii.	3
iv.	4
v.	5 Problem with Different Temperatures along LOS
(h)	Special Cases -48-
(i)	Additional Points on HI -49-
V.	Atomic Structure
•	electron spin -I6-
•	spin-orbit coupling -I8-
•	atoms with multiple electrons -II0-
•	transition rules
•	x-ray emission, Zeeman effect -I20-
VI.	HII Regions -51-
•	Stromgren Theory -52-
•	HII Region spectra
–	Continuum Radiation -63-
*	2-photon
*	free-free
*	free-bound
*	dust
–	Line Radiation -69-
*	Recombination lines -69-
·	radio -71-
·	optical and IR -72-
*	Collisionally excited lines -79-
•	Types of HII Regions -85-
–	“Blister model” – cavity inside GMC
–	“Champagne model” – half cavity at edge of GMC
–	Compact – only visible at radio and FIR wavelengths
VII.	Spectra in the ISM -89-
•	Interstellar absorption lines in stellar and quasar spectra -89-
•	Theory of formation of (interstellar) absorption lines -90-
–	Equivalent width (W) -90-
•	Growth curves in practice -94-
•	UV absorption lines from H and H <sub>2</sub> -96-
VIII.	Dust -104-
•	Far infrared emission from dust -104-
–	General properties of dust -104-
–	Absorption efficiency: the Q parameter -105-
–	Calculating dust mass from FIR fluxes -106-
*	Spectrum emitted by dust grains → modified blackbody spectrum -108-
–	Dust temperatures -109-
•	Interstellar extinction -116-
–	The extinction law -117-

- Interstellar reddening -118-

## IX. Molecular Hydrogen and CO -124-

- Molecular gas and CO as a tracer -128-
- Collisional Excitation and Ionization -142-
- Properties of hot ionized gas and spectrum -145-

## X. Heating and Cooling -151-

- General
  - Primary heat source: photoionization -152-
  - Primary cooling source: inelastic collisions -153-
- HII regions (ionized) -154-
  - Heating -154-
  - Cooling -155-
- HI gas (neutral) -160-
  - Dominant cooling line from CII ( $IP = 11.26 \text{ eV}$ )
  - HI naturally cool, but observe very warm HI!
  - General players:
    - \* Cooling function -160-
    - \* Heating function -161-