Interstellar medium - Summary

by Dr. Helga Dénes (hdenes@yachaytech.edu.ec)

This summary is based on the book Chapter 12 from Carroll, Bradley W., and Dale A. Ostlie. An Introduction to Modern Astrophysics

Interstellar medium has two components: dust + gas

1 Interstellar dust

Dust → interstellar extinction → change in apparent magnitude due to extinction. The change in magnitude due to extinction is approximately equal to the optical depth along the line of sight.

- dust grain column density
- the amount of extinction depends on the amount of interstellar dust that the light passes through

The Mie Theory if the wavelength of light becomes very large relative to the dust grains → no extinctions. If the wavelength of light becomes small relative to the dust grains → extinction. → Extinction is wavelength dependent. → interstellar reddening (blue light gets absorbed easier by dust grains).

Other effects: Scattering of light

The amount of scattering and absorption depends on:

- the number density of dust grains,
- the wavelength of the light,
- and the thickness of the cloud.

Why is dust extinction important?

- Characterising the distribution and properties of Dust in the Milky Way
- Extinction is a problem for light that is coming from all objects outside the Milky Way

Why is the interstellar dust mad of?

- Graphite
- polycyclic aromatic hydrocarbons (PAHs)
- silicates

2 Interstellar gas

Hydrogen comprises approximately 70% of the mass of matter in the ISM

The hydrogen can be at a range of temperatures and states:

- HI neutral atomic
- HII ionised
- H_2 molecular

2.1 HI

21cm HI line radiation - spin flip transition

Why is it usefull?

- mapping the location and density of H I
- measuring radial velocities using the Doppler effect, and
- estimating magnetic fields using the Zeeman effect.
- 21-cm radiation is particularly valuable in determining the structure and kinematic properties of galaxies, including our own.

Observation suggests that dust and gas are distributed together throughout the ISM. Optically thick dust clouds shield hydrogen from dissociation by UV photon → enhance the H2 formation rate. → The number density of atomic hydrogen decreases significantly as the hydrogen becomes locked up in its molecular form.

2.2 H_2

H_2 is very difficult to observe directly → tracers: CO, CH, OH, CS, C3H2, HCO+, and N2H+. Molecular tracers can provide information about the environment within a molecular cloud. Molecular gas is mostly distributed in the disks of spiral galaxies.

CO has rotational line transitions in the radio band.

Classification of Interstellar clouds:
- diffuse molecular clouds
- Giant molecular clouds (GMCs)
- Dark cloud complexes
- clumps
- dense cores
- hot cores → young O and B stars embedded within them, → regions of recent star formation.
- Bok globules - large visual extinction → they have inside them young low-luminosity stars

ISM is rich in other molecules → hundreds of molecules → depend on the density and temperature of the gas, as well as its composition and the presence of dust grains. → icy mantles on the grains.

OH → part of molecular clouds, masers around evolved stars

Heating and cooling of the ISM → Much of the heating of the interstellar medium comes from cosmic rays.

Heating mechanisms:
- ionization of hydrogen atoms and molecules as a result of collisions with cosmic ray protons
- ejected electron that interacts with the ISM to increase the average kinetic energy of the ISM via collisions with molecules
- collide with other molecules in the gas, distributing thermal kinetic energy
- ionization of carbon atoms by ultraviolet starlight resulting in ejected electrons
- the photoelectric ejection of electrons from dust grains by ultraviolet starlight
- the absorption of light energy into the lattice of dust grains
- ionization of hydrogen by stellar X-rays
- Shocks from supernovae or strong stellar winds can also produce some heating of molecular clouds in special cases

Cooling mechanisms:
- emission of infrared photons → IR photons can pass more easily through the molecular cloud → transport energy out of the cloud.
- Collisional excitations

Dust grains make up only about one percent of the mass of a molecular cloud.

The source of dust grains:
- in the envelopes of very cool stars
- Dust grains are also formed as a product of supernova explosions and stellar winds
- coagulation within the molecular clouds