ASTR-1020: Astronomy II
Course Lecture Notes
Section IV

Dr. Donald G. Luttermoser
East Tennessee State University

Edition 4.0

Abstract

These class notes are designed for use of the instructor and students of the course ASTR-1020: Astronomy II at East Tennessee State University.

IV. The Interstellar Medium

A. The Interstellar Matter

1. The dust and gas that lie between the stars is called the **interstellar medium** (ISM). Naked-eye visible evidence for the ISM is present when viewing the band of light in the night sky called the Milky Way through the appearance of dark regions. These dark regions are regions of dust and gas that obscures (blocks) the light from background stars.

2. The composition of this interstellar matter is:

a) Gas (98-99% of the ISM by weight):

i) By weight, 75% of this gas is hydrogen (H) and 25% is helium (He).

ii) By particle number, 90% of this gas is hydrogen (H) and 10% is helium (He).

iii) In addition to H and He, there are trace amounts carbon (C), nitrogen (N), oxygen (O), magnesium (Mg), calcium (Ca), sodium (Na), and heavier elements.

b) Dust (1-2% of the ISM by weight):

i) Composed of carbon-based, iron-based, and silicon-based (silicates) dust.

ii) We use the effects that dust has on starlight to measure both the amount and size of interstellar dust.

iii) Usually, a beam of light can only be *absorbed* and *scattered* by particles having diameters comparable or larger than the wavelength of radiation involved.

iv) The size of a typical interstellar dust grain is about 10^{-7} m (1 μm, where the μ symbol means "micro," and μm is typically called "micron" $\Longrightarrow$ this is the size of cigarette smoke particles). Thus this dust is transparent to infrared, microwave, and radio waves but opaque to optical (visible), ultraviolet and shorter wavelengths.

c) The overall dimming of starlight by interstellar gas and dust is called **extinction**.

d) Both gas and dust scatter blue light more effectively than red, hence stars appear redder when their light travels through interstellar gas and dust $\Longrightarrow$ this effect is called **interstellar reddening**.

i) Photon scattering by <u>gas</u> results from **Rayleigh scattering** which has a $1/\lambda^4$ wavelength dependence.

ii) Photon scattering by <u>dust</u> results from **Mie scattering** which has a $1/\lambda$ wavelength dependence.

3. Structure of the ISM.

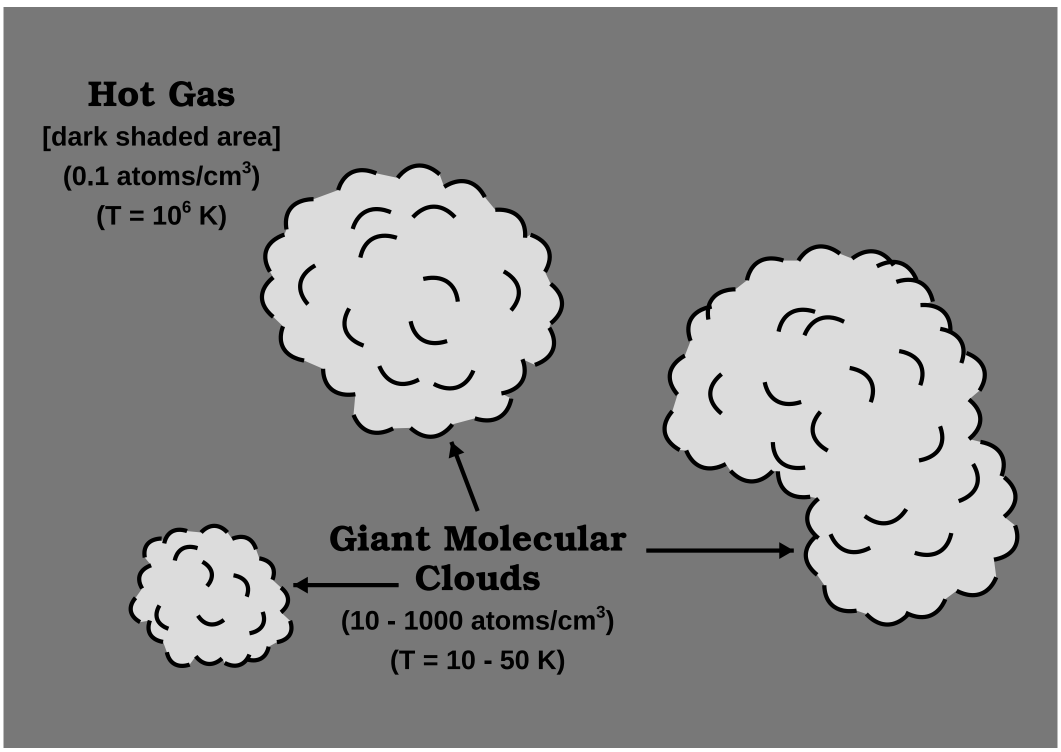
a) Every part of interstellar space of our Milky Way Galaxy contains gas and dust in varying amounts. Overall there are 10^6 atoms per cubic meter (=1 atom per cubic centimeter), though ranges from 10^4 to 10^9 atoms/m^3.

b) Matter this diffuse is far less dense than the best vacuums obtained in laboratories on Earth (about 10^{10} atoms/m^3).

c) Two distinct regions exist in the ISM:

i) **Giant Molecular Clouds** (GMC) where densities range between 10^7 to 10^9 particles/m^3 (10 to 1000 particles/cm^3) and temperatures range between 10 to 50 K.

ii) **Hot Diffuse Gas** where densities typically lie in the 10^4 to 10^5 particles/m^3 (0.01 to 0.1 particles/cm^3).



B. Emission Nebula

1. The GMCs are frequently associated with **stellar nurseries** — regions in space where stars are born.

a) Historically, astronomers have used the term **nebula** to refer to any “fuzzy” patch (bright or dark) on the sky.

b) We have already mentioned the "dark" nebula above. There are however two different types of bright (also called emission) nebula. These nebula are bright since they ale located near hot, luminous, massive stars.

i) **Reflection nebula** result when starlight from these massive stars scatter from dust particles in the nebula. Some of the starlight gets scattered towards the direction of the Earth (the light is actually scattered in all directions). Such nebula typically have a bluish appearance from the Mie scattering by dust.

ii) **H II Regions** result when this portion of the ISM is close enough to the massive stars such that the starlight actually *ionizes* the hydrogen gas (as well as other species) in the cloud (note that Roman numeral 2, "II" is the ionization state of this atom: 'I' for neutral, 'II' for singly ionized, 'III' for triply ionized, etc.). These nebula glow as free electrons recombine with the ions and emit photon as the electron cascade back down the various bound levels in the atom. Such nebula typically have a reddish appearance (when photographed) due to the Hα transition in hydrogen which is in the red part of the spectrum.

2. Besides seeing nebula, the existence of the ISM can be seen by:

a) Narrow absorption lines seen in the spectra of stars — lines formed in stellar atmospheres are broader due to pressure broadening (see text for further details).

b) Forbidden lines — these lines are normally not seen in stellar atmospheres since they only be formed in low density gas (see text for further details).

3. Stars are formed out of the ISM! We know this from noting that the following objects are all found where there is a lot of ISM:

a) Young open star clusters are often associated with nebula. All stars form in clusters when they are first formed.

b) Protostars are seen in GMCs as strong infrared sources.

c) T-Tauri type stars (see the next section) are also seen near GMCs.

4. Within the last 60 years, we have learned how stars are born. We see star formation going on at the present time in various regions of our Galaxy (called **star-forming regions** or as previously mentioned, stellar nurseries) — brand new stars are currently coming *on-line*! The Sun (and whole Solar System) formed in its own stellar nursery some 4.6 to 5 billion years ago. We will describe this star-formation process in detail in the next section.