Lecture 5 : Interstellar Medium - Atomic Gas

“Yes, a busy space, the interstellar medium. Empty space, near vacuum: and yet still, not vacuum itself, not pure vacuum. There are forces and atoms, fields..” This is how the Interstellar Medium (ISM) has been described in the science fiction novel ‘Aurora’ (2015) by Kim Stanley Robinson. More than a century has elapsed since the discovery of ISM in 1904 by the Argentinian astronomer Hartman to its appearance in popular culture today. But the science behind our understanding of this tenuous medium remains as fascinating.

Ultraviolet radiation from newly formed hot stars ionize the relic gas from which they formed. When the ions ‘recombine’ with electrons, spectacular gaseous nebulae are produced. The vast space between the stars is not empty. There is widespread diffuse gas, as well as gas clouds - just like in our atmosphere. In this lecture we shall discuss the distribution of ‘atomic gas’ in our Galaxy. This gas, mostly Hydrogen, emits, and absorbs, radio radiation at a wavelength of 21 cm. The basic physics of how this radiation arises is discussed in detail, as well as how this radiation is detected. The resultant model of the interstellar medium, the “Raisin Pudding” model is described.

For your viewing pleasure -

A Celebration of Colour in Astronomy by David Malin
Current Science, 1991, Vol.60(1)
edited by G. Srinivasan & S. Ramaseshan
Indian Academy of Sciences, Bangalore

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Suggested Problems

1. (a) Show that the young, massive stars with surface temperatures in excess of 20,000 K, must predominantly radiate in the ultra-violate regime.

   (b) Show that such ultra-violet radiation is capable of pushing electron in Hydrogen atoms to very high Rydberg levels.

   (c) Using Bohr's atomic theory, show that -

   i) The transitions of the Lyman series and the Balmer series, of Hydrogen, with electrons dropping to n=1 and n=2 levels, give rise to radiation in the ultra-violet and the visible ranges respectively.

   ii) A certain gaseous Nebula is detected in emission using the Giant Meterwave Radio Telescope (GMRT), operating in the approximate frequency range of 50-1500 Hz. Find the minimum value of n required if the radiation is coming from the Recombination Radiation of atomic Hydrogen.

2. The upgraded GMRT operates in the following 5 frequency bands - 50-80 MHz, 120-250 MHz, 250-500 MHz, 550-850 MHz, 1050-1450 MHz. In which frequency band should the hyperfine transition of neutral Hydrogen be detected, if there is no relative motion between the observatory and the source of radiation? If the operating bands are very sharply defined (they are not) then what would be the maximum relative velocity of the source for which hyperfine transition can be detected?

3. Estimate the mean time between the collisions between two atoms (or molecules, as appropriate) in the room you are sitting in. How does it depend on density and temperature? Do the same calculation for a gas of Hydrogen atoms for a density of 1 atom per cubic centimeter and at a temperature of 100 K. Convince yourself that the mean collision time in the second case is extremely large which allows for the hyperfine transition in the Interstellar Medium to happen.

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