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A74 EXERCISES: Bremsstrahlung (5)

1. Consider two possible places for Bremsstrahlung: HII regions (regions of ionized hydrogen surrounding massive stars) and the ionized gas in galaxy clusters (such as the Coma cluster, highlighted in the lecture notes). HII regions have $n_e \sim 10^3$ cm^{-3} and $T = 10^4$ K. Galaxy clusters have $n_e = 0.1$ cm^{-3} at their cores and $n_e = 10^{-3}$ cm^{-3} in the outskirts, and $T \sim 10^8$K.

   This problem will be our very first introduction to the concept of *cooling time*! The cooling time is the timescale on which a specific radiative process will cool a gas. Timescales can range from a hundred to a billion years, depending on the property of the gas and the radiative process in question. The zeroth order method to calculate a cooling time is to divide the total energy in the gas by the rate of energy loss. This is a totally fine approach. You could alternatively consider an integral, which is often not very hard to do either, but the answer will generally only differ by a factor of two.

   (a) At what frequency is the cut-off frequency for Bremsstrahlung in the HII region and galaxy cluster core?

   (b) Determine the cooling time for a gas of a given temperature T and electron density n_e, assuming cooling is due to energy losses from Bremsstrahlung. Evaluate all the constants numerically.

   (c) Evaluate the cooling time for the HII region and galaxy cluster core. Is cooling effective?

2. The interstellar medium of our Galaxy contains a diffuse ionized component, of which the warm component is $T = 10^4$K, and contributes to Bremsstrahlung (free-free) absorption. From the observed brightness spectrum in the direction perpendicular to the disk, Cane (1979, MNRAS, 189, 465) found that $\tau = 1$ at $\nu = 3$ MHz.

   (a) To what wavelength regime does this correspond?

   (b) Use this result to estimate the typical electron density of the warm ISM. You may assume that there are equal numbers of electrons and ions.

Second question adapted from NRAO.