RevMexAA (Serie de Conferencias), **40**, 25–25 (2011)

FIRST STARS FORMATION WITH THE PRESENCE OF A PRIMORDIAL MAGNETIC FIELD

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The problem of the metal-free Pop III stars cooling is considered. The importance of the cyclotron cooling in the presence of the primordial magnetic field is discussed. It is shown that the cyclotron cooling must be taken into account as well as cooling due to $\mathbf{H_2}$, HD and LiH molecules.

In the current scenario for the formation of primordial objects, the most relevant molecule is H_2 (e.g., Bromm et al. 2002). The only reason for this is the high abundance of H_2 when compared with all other molecules. Apart from H_2, another species that have been proposed as a possible cooling mechanism, are HD (Lipovka et al. 2005) and LiH (Prieto et al. 2008) molecules. These molecules possess finite dipole moments that allows high probabilities for the radiative transitions form the rotational levels pumped by collisions with H and He. Also, the effects of cooling from the other minor ionic and molecular species (H_2^+, H_2D^+, HeH^+, LiH^+, etc.) have been explored (Glover & Savin 2009); it is found that such species are never significant. In this work, we argue that another cooling mechanism should to be taken in account, namely, the cooling for electrons spiraling in a primordial magnetic field. The cooling function per unit of volume is defined, for example, for the electrons moving in a primordial magnetic field, as:

$$\Lambda_e = n_e W_e \,, \tag{1}$$

where W_e is the Cooling function in units erg/s per free electron

$$W_e = \sum_{n=1}^{N} \frac{8\pi^2 e^2 \nu_B^2}{c} \frac{(n+1)\left(n^{2n+1}\right)}{(2n+1)!} \left(\frac{v}{c}\right)^{2n} . \tag{2}$$

Here ν_B is the cyclotron frequency given by

$$\nu_B = \frac{eB}{2\pi mc} \,, \tag{3}$$

where B is the magnetic field in the halo, given by

$$B = B_0 \left(\frac{\rho}{\rho_0}\right)^{\frac{2}{3}} . \tag{4}$$

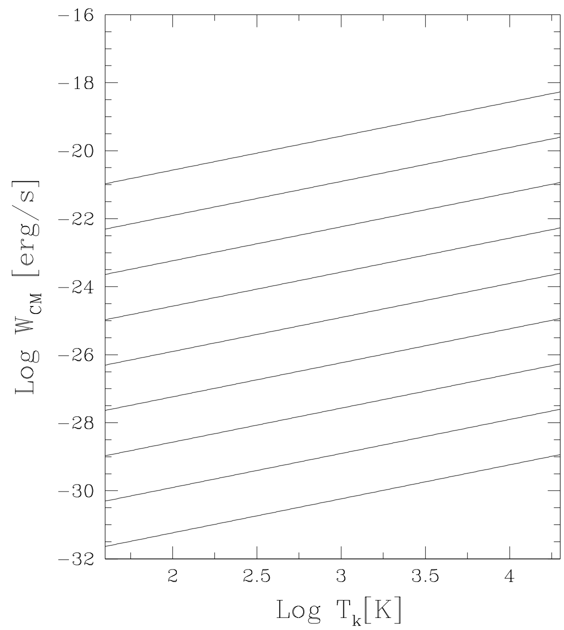

Fig. 1. cooling Function due to electrons spiraling in a primordial magnetic field.

The cooling function due to electrons spiraling in a magnetic field was calculated in the wide range of the number densities n_H from 1 to 10^8 cm^{-3} (bottom-top in Figure 1) and for the kinetic temperature T_k from 10^2 to 2×10^4 K.

We find that the cooling function due to electrons spiraling in a magnetic field can became relevant for high densities and medium and low temperatures when this is compared with the functions obtained for others ionic and molecular species. This work suggests the importance of taking into consideration the cooling function calculated here in the simulations and models of the first baryonic objects in the Universe.

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