H_2D^+

A light on Baryonic Dark Matter?

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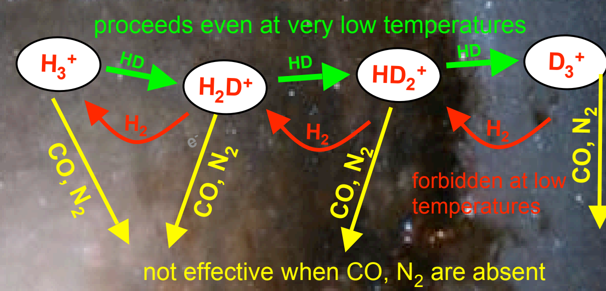
Baryonic Dark Matter

The luminous matter (stars and gas) in the Universe constitutes only 0.15% of the total mass (Fugita & Peebles 2004). The rest of the matter largely belongs to the so--called ``dark sector'' (95.4%), consisting of dark energy (72%) and dark matter (23%). 4.5% are present in the form of baryonic matter. Stars therefore account for only 3% of the derived baryonic mass of the Universe. The remaining 97% are dark, and their nature unknown.

In galaxies, the evidence that most of the mass is *not* contained in the stellar or any other observed component stems from the study of rotation curves, derived from stellar light and HI gas emission (Rubin et al 1962). If the visible mass was dominating the gravitational potential, the observed rotation velocity should decrease approximately as the square root of distance in the outer regions of a galaxy, according to Keplers law. But the velocity is observed to remain constant out to great distances, indicating the presence of a large invisible mass surrounding the galaxies.

The dark halos cannot be diffuse gas, because both neutral or molecular gas would be detected in one way or another. For this reason, it has been proposed that it may be non-baryonic in nature. However, there are many reasons to assume that the dark matter in galaxies may be mostly baryonic (Pfenninger et al 1994, Gerhard & Silk 1996). Condensed objects like brown dwarfs or massive compact halo objects (MACHOS) have now been ruled out as significant contributors (Alcock et al 2001). Another possibility is that baryonic dark matter is present in the form of cold (<10K), molecular clouds, also called ``cloudlets'' (Pfenninger et al 1994, Pfenninger & Combes 1994). A number of studies have tried to constrain mass and radius of these cloudlets (e.g. Gerhard & Silk 1996) but the uncertainties are large. In this Poster, we propose a new method to test this hypothesis: observations of the ground state transition of the ortho-H2D+.



Deuteration of H_3^+

In cold and dense gas, the most abundant molecule is always H_2. HD is present as well, and generally is the main reservoir of deuterium, with an abundance of $3x10^{-5}$ relative to H_2, reflecting the cosmic abundance of deuterium (Linsky 2003). At low temperature, chemistry is generally driven by ion-neutral reactions. The process of ionization, and the following reactions, is therefore determining the chemical structure and abundances in such gas. Cosmic rays ionize H_2 and quickly lead to the formation of H_3^+, which, together with H^+, is the main charge carrier in the gas. H_3^+ is destroyed by reactions with grains, heavy element bearing molecules like CO and N_2 and, at a very low rate through direct recombination with electrons. It also reacts with HD, and this is the starting point of deuterium enrichment chemistry whose overwhelming importance has only recently been recognized. H_3^+ reacts with HD to form H_2D^+. The reaction is endothermic, i.e. the reverse reaction $H_2D^+ + H_2 \rightarrow H_3^+ + HD$ is practically forbidden at temperatures below ~30 K. Therefore, a deuterium atom captured in this way into an H_3^+ isotopologue remains there until it is returned by a reaction neutralizing the ion. The relevant reactions are those with dust grains, CO and N_2 molecules, and direct recombinations with electrons. As in cold and/or metal-poor environments the abundance of those species is low, H_2D^+ tends to attract the entire molecular positive charge. Of course, H_2D^+ can itself react with HD to form HD_2^+, and a further step leads to D_3^+.

The low metallicity in primordial gas also affects directly the abundances of CO, N_2, and dust grains. In our model, we scale the abundance of these species with a factor Z/Z_{sun} denoting the metallicity of the material relative to solar abundances.