H₂D⁺
A light on Baryonic Dark Matter?
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Baryonic Dark Matter

The luminous matter (stars and gas) in the Universe constitutes only 0.18% of the total mass (Frieman & Peebles 2004). The rest of the matter largely belongs to the so-called “dark matter,” consisting of dark energy (27%) and dark matter (23%). 4.2% are present in the form of baryonic matter. Stars therefore account for only 3% of the known 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 circular and red shift studies. Rubin & Ford (1970) postulated that the rotation velocity should decrease approximately as the square root of distance in the outer regions of a galaxy, according to Kepler’s 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 & Silv 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 (10⁴K) 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).

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In this case, we propose a new method to test this hypothesis: observations of the ground state transition of the ortho-H2D⁺.

Deuteration of H₂⁺

In cold and dense gas, the most abundant molecule is always H₂. HD is far less abundant (Kahn et al 1978) by about 10⁶. However, an abundance of 3x10⁻³ relative to H₂ refutes the cosmic abundance of deuterium (Linsky 2002). At low temperature, H₂⁺ is generally driven by ion-neutral reactions. This process of ionization, and the following reactions, is therefore determining the atomic and molecular abundances in such gas. Cosmic rays ionize H₂⁺, which together with H⁺ is then charge exchanged in the gas. H₂⁺ is then recombined with HD, and HD is not destroyed by reactions with the ions, neutrals, and heavy elements (e.g. CO, N₂, H₂). H₂⁺ and HD are all recombined with HD, and HD is destroyed by reactions with H₂ and CO. HD is also out of equilibrium at low temperatures (Rubin et al 1962). The visible mass was inferred from stellar light and HI gas emission (Rubin et al 1962). If the gas was invisible, it would be detected in one way or another. For this reason, it has been proposed that the dark matter in galaxies may be mostly baryonic (Pfenninger et al 1994, Alcock et al 2001). Another possibility is that baryonic dark matter is present in the form of cold (10⁴K) 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).

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