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Measurement of the associative detachment reaction $H^- + H \rightarrow H_2 + e^-$ using a merged-beams method

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Synopsis Using a merged-beams method, we have performed absolute, energy-resolved measurements for the associative detachment reaction $H^- + H \rightarrow H_2 + e^-$. Our results remove a long-standing discrepancy between theory and experiment for this fundamental reaction. In particular, we find excellent agreement with theoretical results which previously seemed to be ruled out by a recent flowing afterglow experiment.

During the epoch of first star formation molecular H_2 is formed via the associative detachment (AD) reaction

$$H^- + H \rightarrow H_2 + e^-. \quad (1)$$

These AD-formed molecules are an important coolant for primordial clouds leading to the formation of the first stars and protogalaxies. Uncertainties in the rate coefficient for this reaction limit our ability to model whether a protogalactic halo can cool rapidly enough to form a protogalaxy [1]. This atomic physics uncertainty also introduces a factor of 20 uncertainty in the Jeans mass of the first stars [2].

Recently [3] has used a flowing afterglow method to measure reaction (1) at 300 K. Their results are discrepant with the most sophisticated theoretical calculations published to date [4]. However [3] provides no information on the energy or temperature dependence of the reaction. This limits the ability of their measurements to benchmark theory.

Here we report on a novel merged-beams apparatus we have developed to perform energy-resolved studies for reaction (1). This approach is free of many of the uncertainties to which flowing afterglows may be prone. A detailed description of the apparatus can be found in [5, 6].

In Figure 1 we show our experimentally-derived Maxwellian rate coefficient for reaction (1). We find excellent agreement with the calculations of [4] but not with the results of [3]. A more detailed discussion of the atomic physics is given in [6]

The implications of our results for cosmology and first star formation are presented in [2]. The uncertainty in the predicted characteristic mass of primordial stars is reduced from a factor of 20 to ~ 2 by using our results.

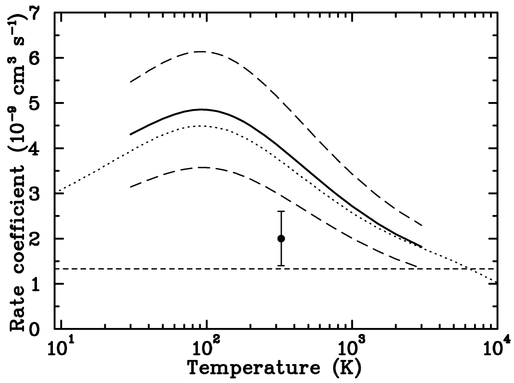

Figure 1. Thermal rate coefficients for reaction (1). The solid curve gives our experimentally-derived Maxwellian rate coefficient and the long-dashed curves the 1σ total experimental uncertainty. The circle with the error bars gives the 300 K flowing afterglow data of [3]. The dotted curve is the theoretical calculation of [4], while the short-dashed line represents the Langevin limit.

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