Laboratory Studies of Primordial Chemistry and Implications for First Star Formation

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Abstract.
During the epoch of protogalaxy and first star formation, H$_2$ was the dominant coolant for collapsing primordial clouds at temperatures below 8,000 K. Hence, a reliable model of H$_2$ formation and abundance is critical for our understanding of structure formation in the early Universe. The dominant H$_2$ formation mechanism during this epoch is initially the associative detachment (AD) reaction $\text{H}^- + \text{H} \rightarrow \text{H}_2 + e^-$. There are a number of reactions, however, which limit the H$^-$ abundance available to form H$_2$. One of the most important of these is the mutual neutralization (MN) reaction $\text{H}^- + \text{H}^+ \rightarrow \text{H} + \text{H}$. As a cloud continues to collapse and the density increases, the cloud converts to fully molecular, largely through the three body association (TBA) process $\text{H} + \text{H} + \text{H} \rightarrow \text{H}_2 + \text{H}$. The energy released by TBA formation of H$_2$ heats the cloud and can delay collapse of the cloud. Uncertainties in the rate coefficients for all three of these reactions have limited our understanding of structure formation in the early Universe. Here we will report recent measurements which largely remove the uncertainties for the AD and MN reactions. We will also discuss the experimental challenges of attempting to measure the TBA reaction. This work is supported in part by the NSF Division of Astronomical Sciences Astronomy and Astrophysics Grants program.