Atomic, Molecular, and Optical Physics in the Early Universe: From Recombination to Reionization

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Outline

Pop III star formation in low mass halos

- $H^- + H \rightarrow H_2 + e^-$
- $H + H + H \rightarrow H_2 + H$
H$_2$ formation during atomic phase of primordial clouds

Associative detachment (AD)

\[ \text{H}^- + \text{H} \rightarrow \text{H}_2 + \text{e}^- \]

How well do we understand this simple reaction?

- Factor of ten spread.

Are there cosmological implications?

- Yes!
The apparatus the day after first signal

\[ \text{H}_2^+ \rightarrow \text{H}_2 \rightarrow \text{H}_2^+ \]

Detachment

Form \( \text{H}_2 \)

Laser

\[ \text{H}_- \]
H⁻ + H → H₂ + e⁻ rate coefficient

Theory and experiment have now converged on the rate coefficient for this reaction.
Implications for Pop III.2 star formation

- Initially ionized gas
- 3D simulation.
- Red & black due to previous AD uncert.
- Other points show new ±25% uncert.
- $M_J$ uncertainty goes from 20 to 2!

Stellar mass scale related gas $T_{\min}$ (Larson MNRAS 2005).

\[ M_J \propto T^{3/2} n^{-1/2} \]

(Kreckel et al. 2010, Science, 329, 69)
What was the IMF for the Pop III stars?

AD is important when cloud is < 0.01% H$_2$.
Plays a key role in setting the upper limit for $M_j$.
But the mass of first stars still a big unknown.
Depends on physical conditions of initial cloud.
Depends on how cloud go to fully molecular H$_2$. 
How does the cloud go fully molecular?

Three Body Association (3BA)

\[ \text{H} + \text{H} + \text{H} \rightarrow \text{H}_2 + \text{H} + 4.48 \text{ eV} \]

Factor of \( \sim 100 \) spread in data at relevant \( T \).
Overview of published 3BA data

Implications of 3BA uncertainty

Has potentially important implications for ability of gas to fragment and form multiple stars.

Conclusions

- $\text{H}^{-} + \text{H} \rightarrow \text{H}_2 + \text{e}^{-}$ is now well understood.
- $\text{H} + \text{H} + \text{H} \rightarrow \text{H}_2 + \text{H}$ needs laboratory data.
- Sensitivity studies are needed to identify critical AMO data needs.