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)

$$H^- + H \rightarrow H_2 + e^-$$

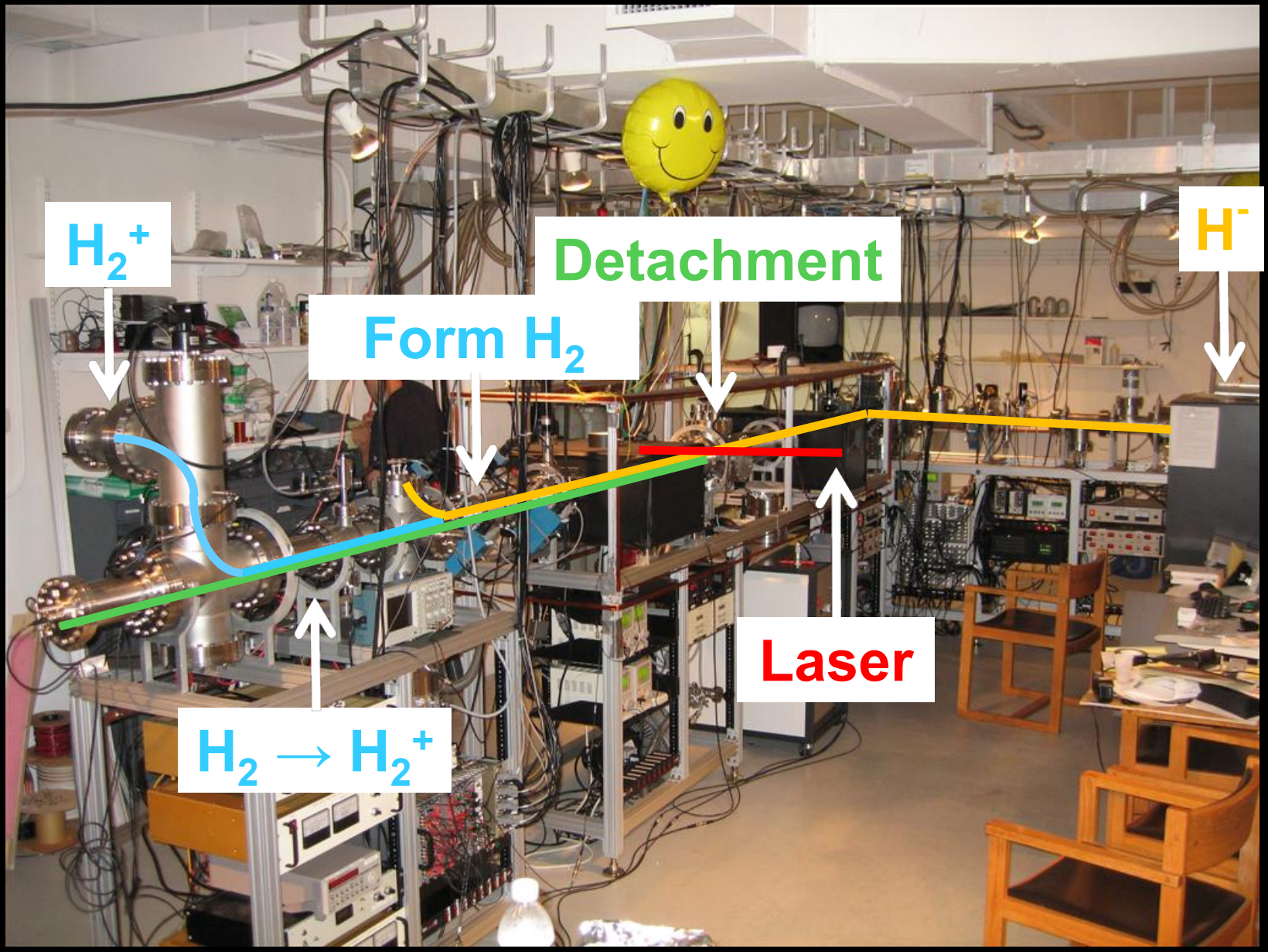
How well do we understand this simple reaction?

- Factor of ten spread.

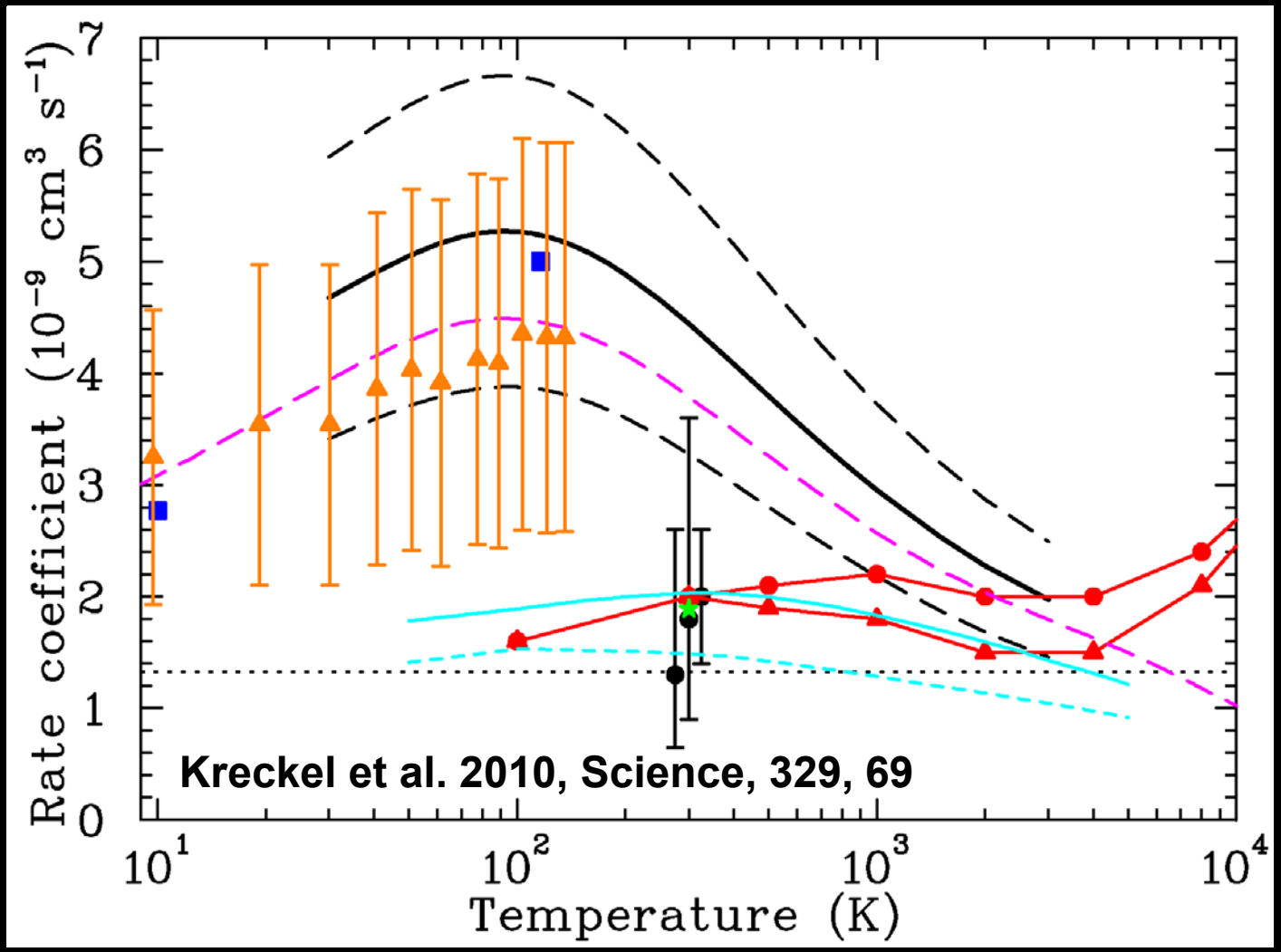
Are there cosmological implications?

- Yes!

The apparatus the day after first signal



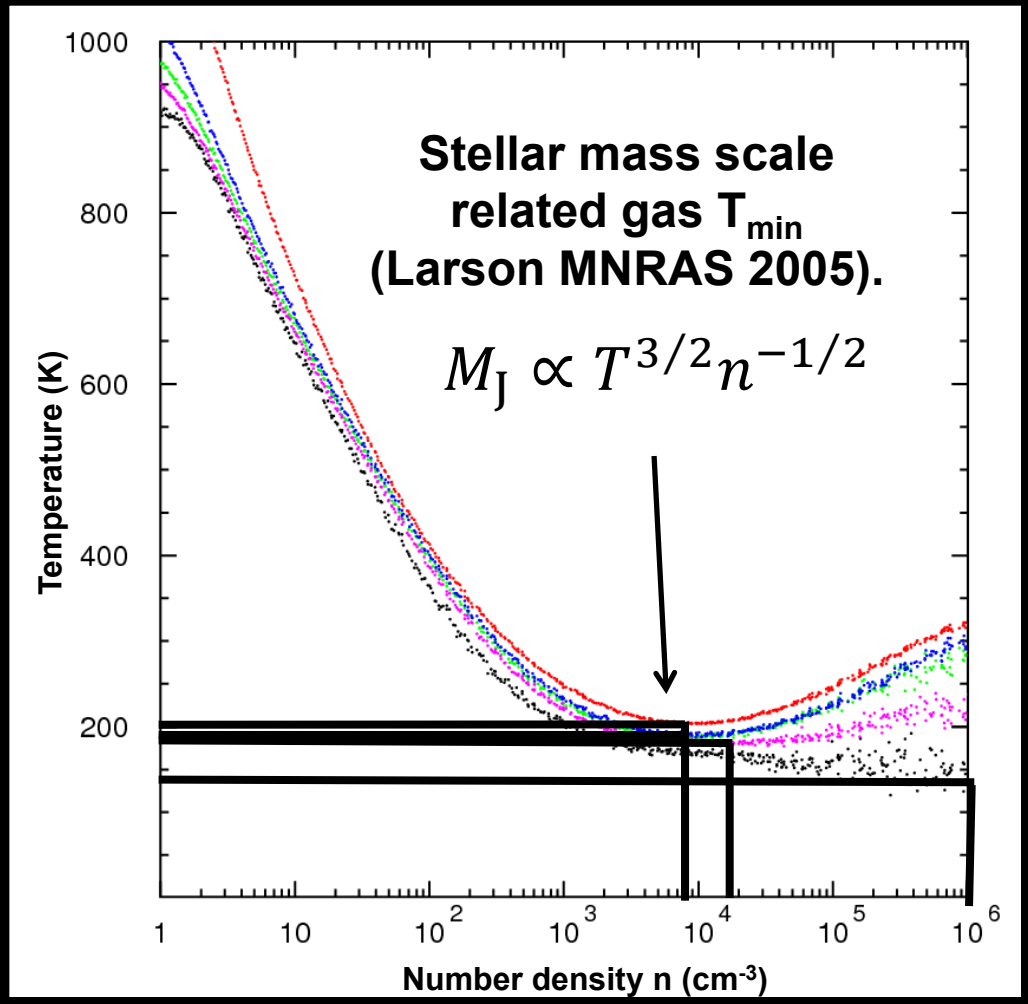
$H^- + H \rightarrow H_2 + e^-$ rate coefficient



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!



(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.

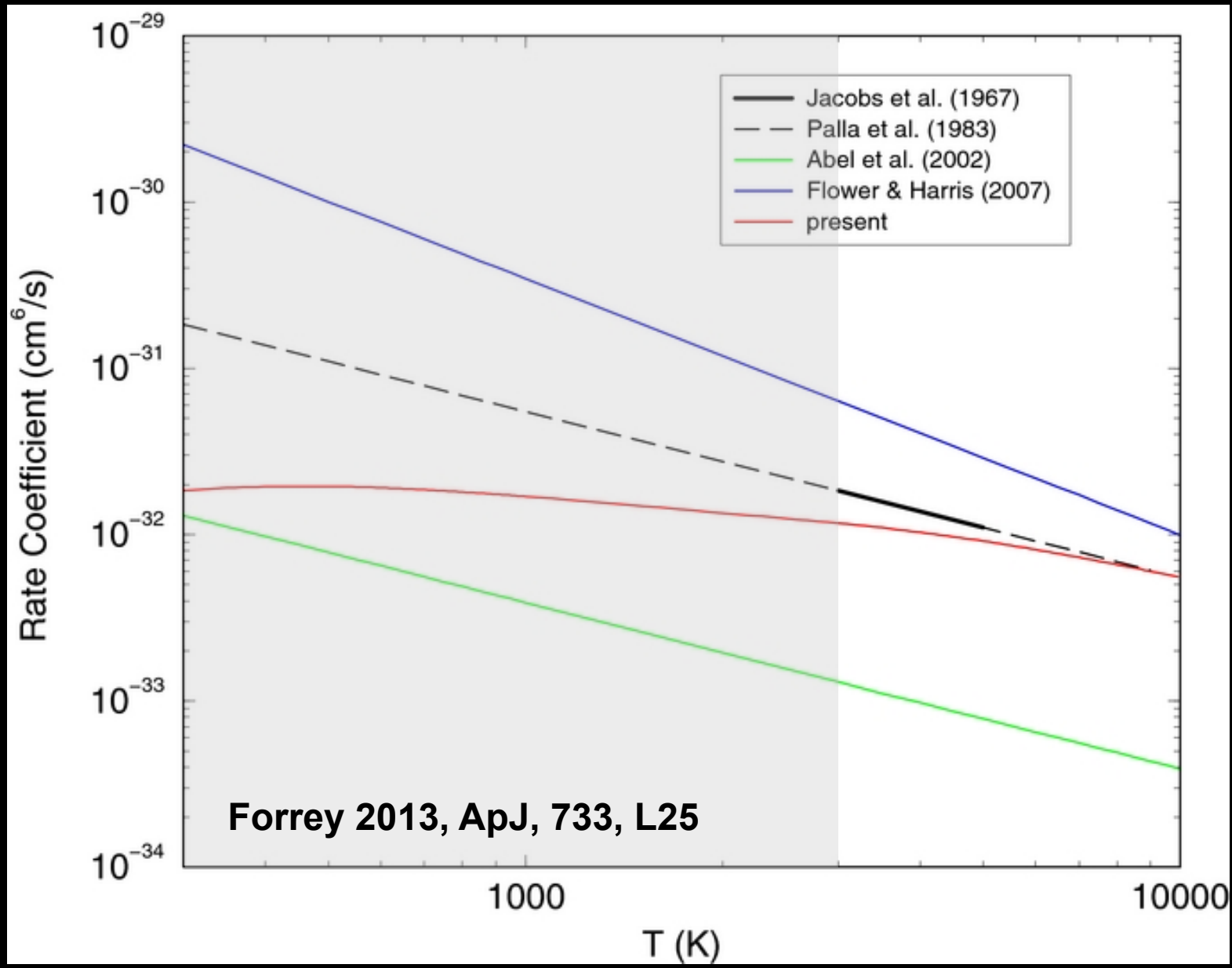
How does the cloud go fully molecular?

Three Body Association (3BA)

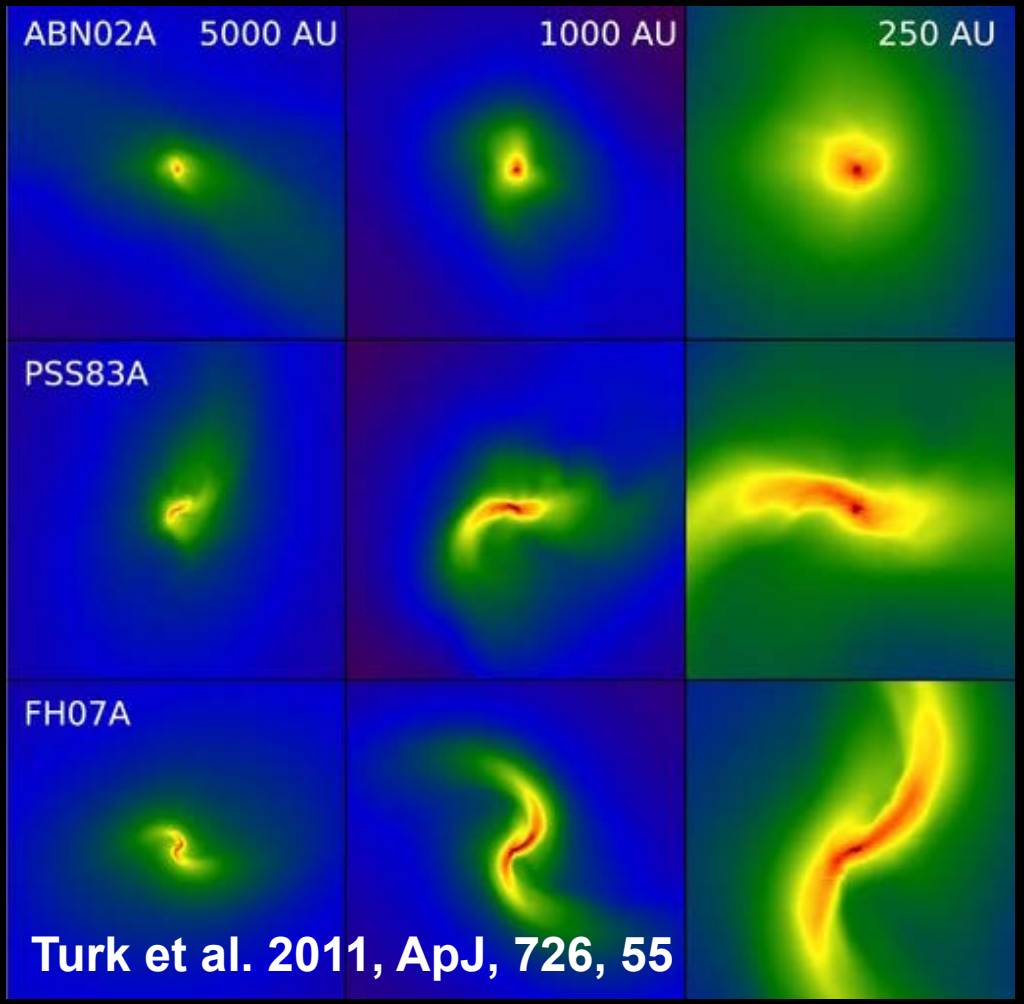
$$H + H + H \rightarrow H_2 + H + 4.48\ eV$$

Factor of ~ 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

- $H^- + H \rightarrow H_2 + e^-$ is now well understood.
- $H + H + H \rightarrow H_2 + H$ needs laboratory data.
- Sensitivity studies are needed to identify critical AMO data needs.