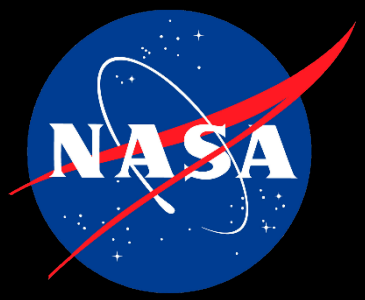
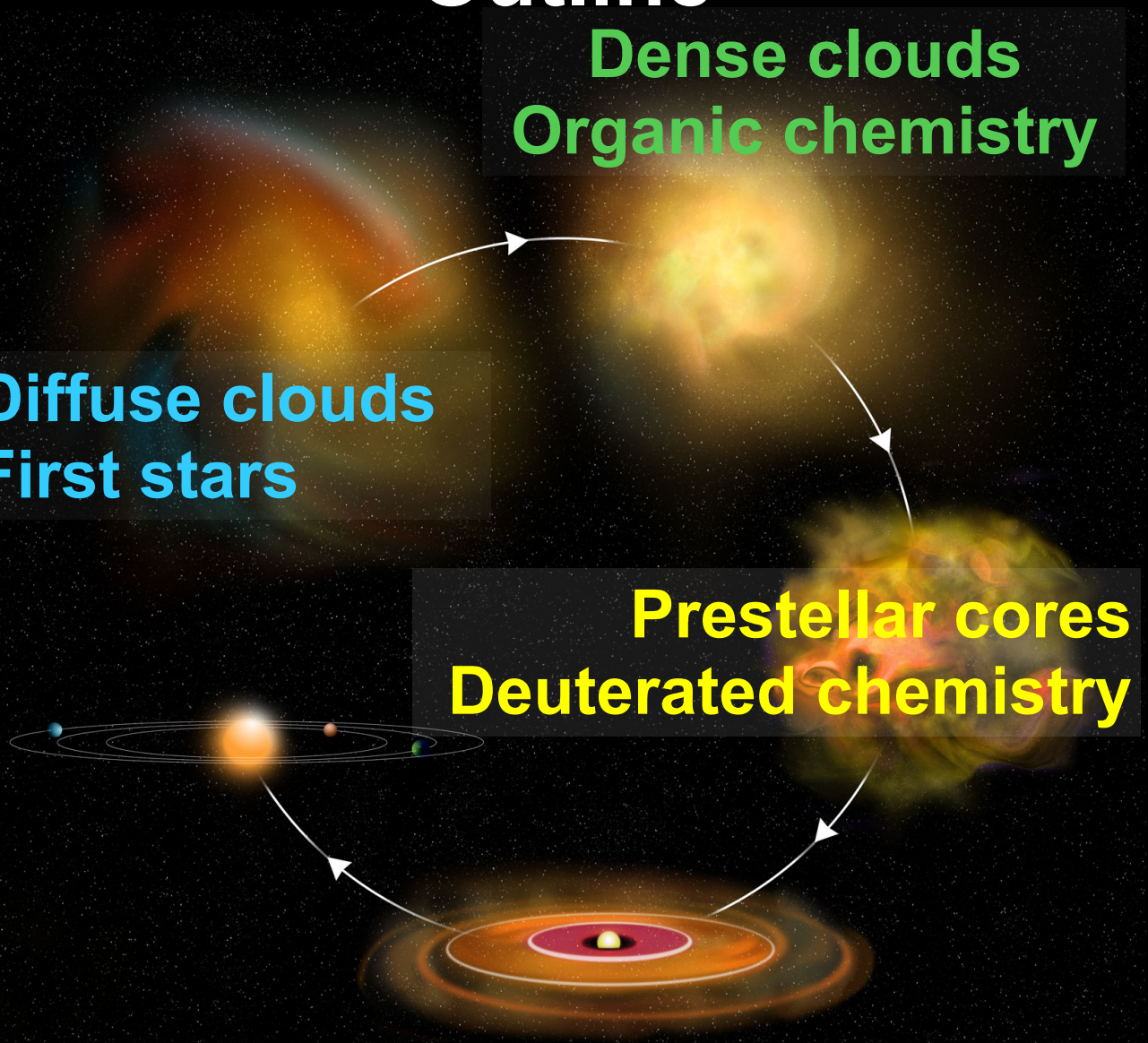
Ion-Neutral Reactive Scattering Studies for Astrophysics

Daniel Wolf Savin
Columbia University



Outline


Dense clouds
Organic chemistry
Diffuse clouds
First stars
Prestellar cores
Deuterated chemistry

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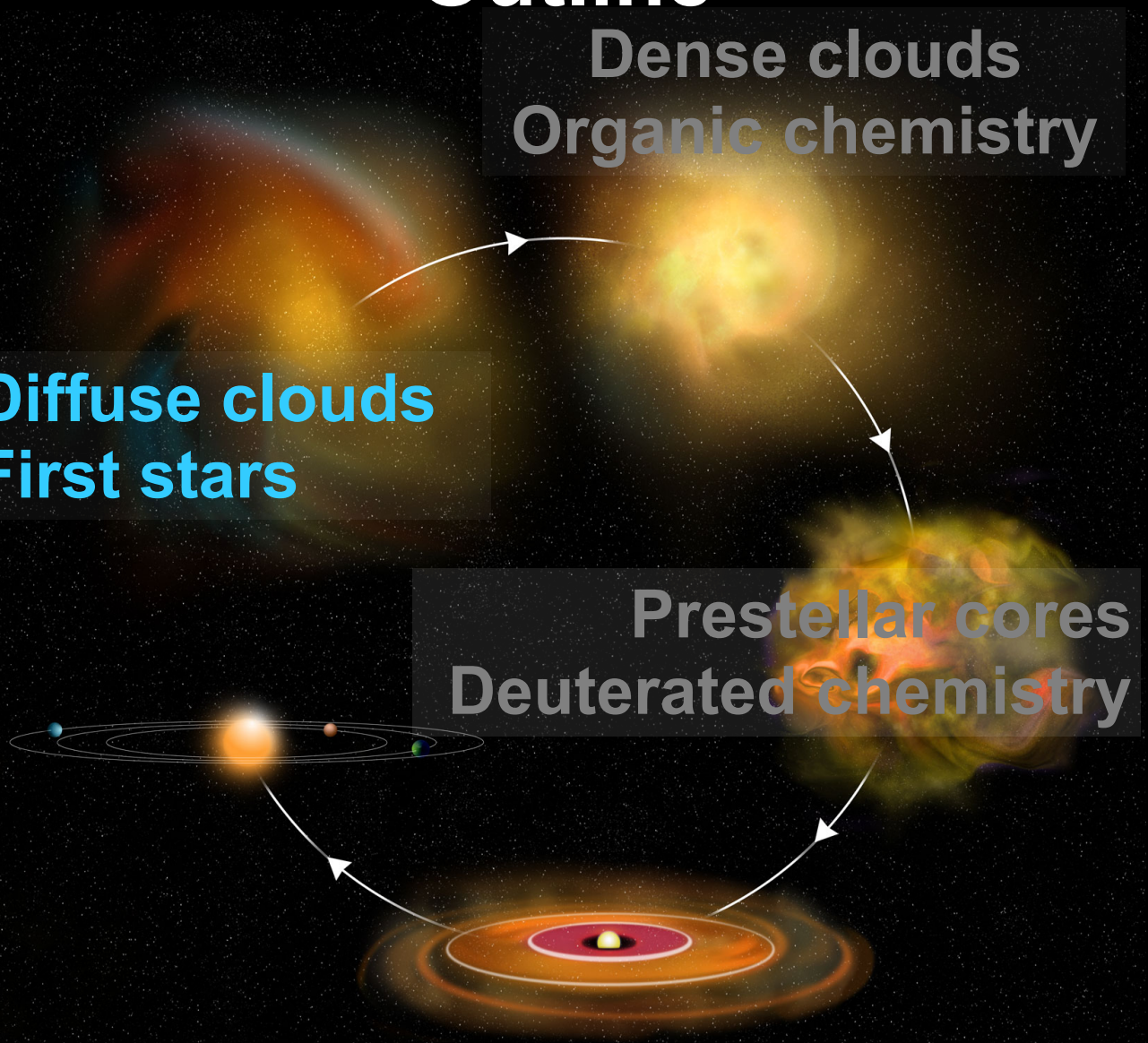
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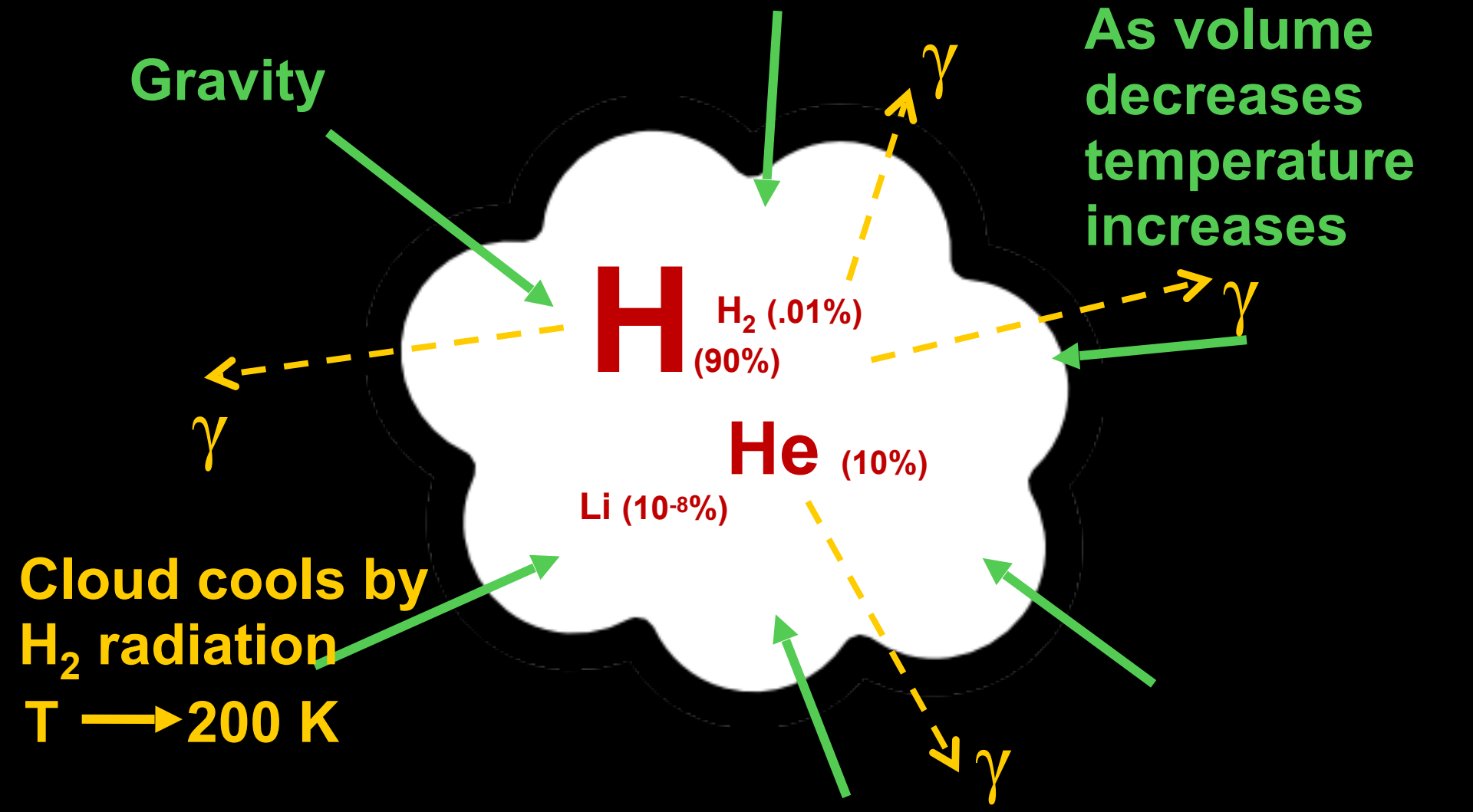
Formation of stars in the early universe



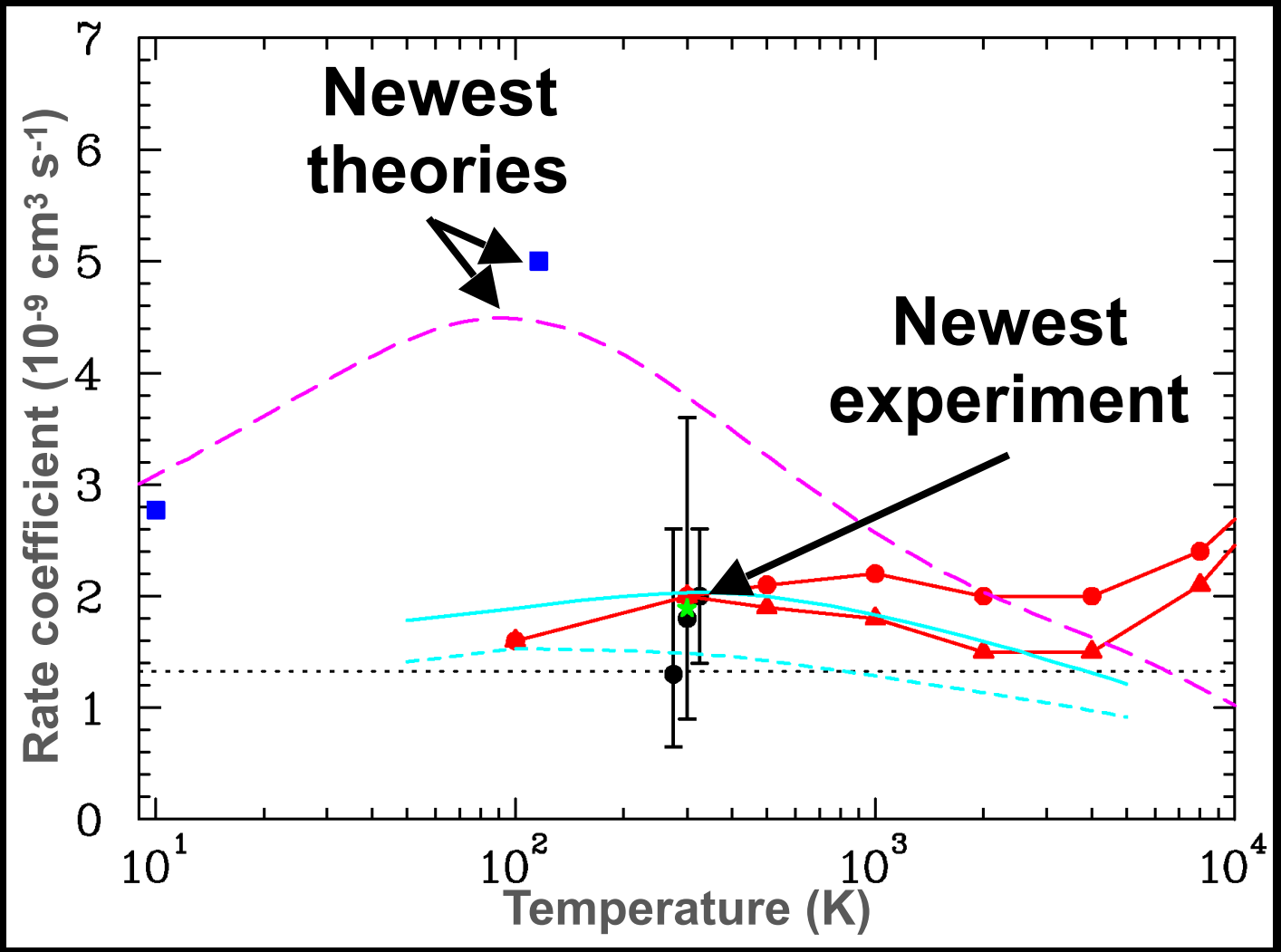
These clouds are galactic is size.

Forming H_2 in the early Universe

Associative detachment (AD)

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

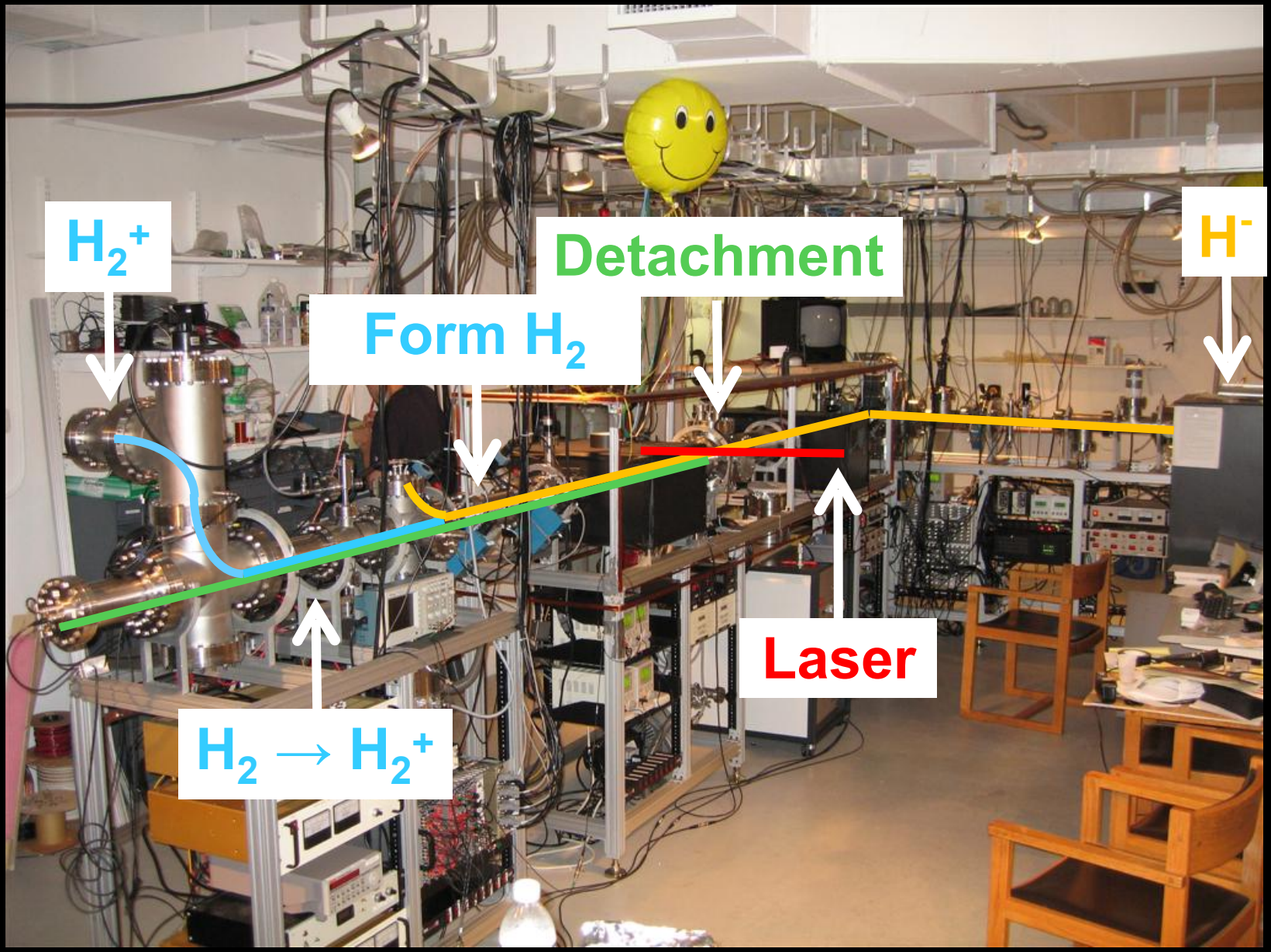
Published data for $H^- + H \rightarrow H_2 + e^-$



There is nearly an order of magnitude spread.

This has significant cosmological implications.

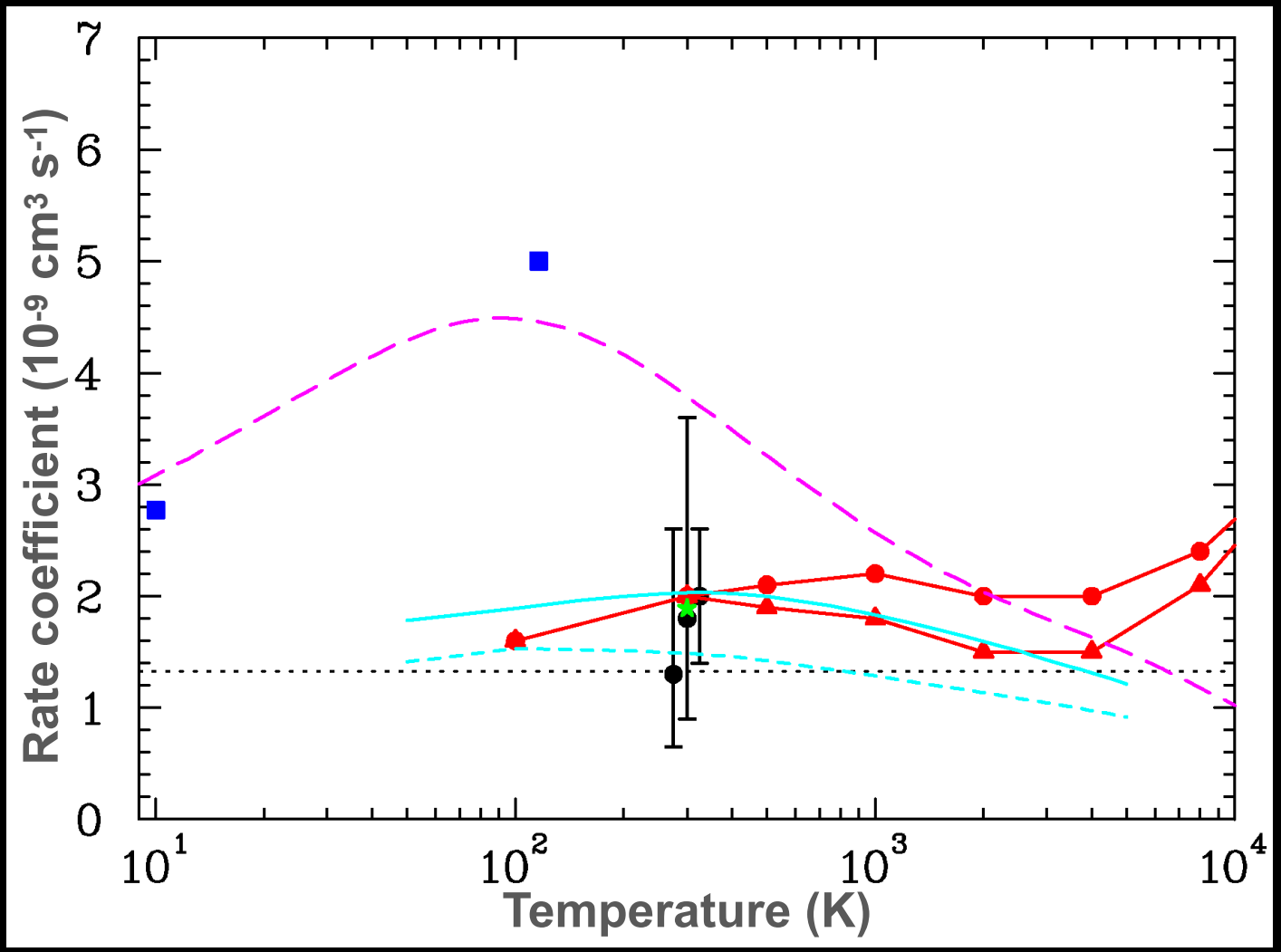
The apparatus the day after first signal



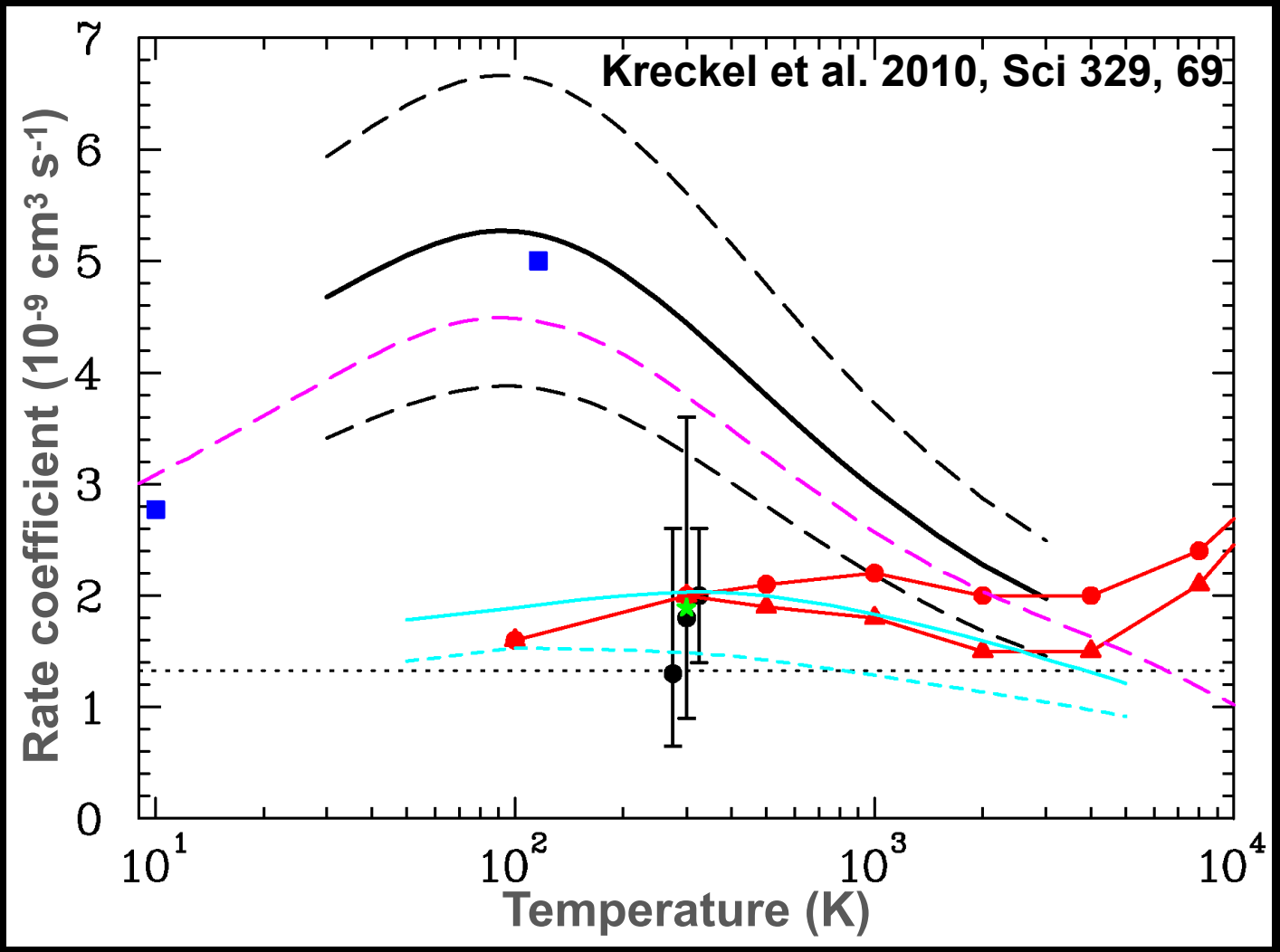
Celebrating our success!

K. A. Miller, DWS, H. Kreckel, X. Urbain, H. Bruhns

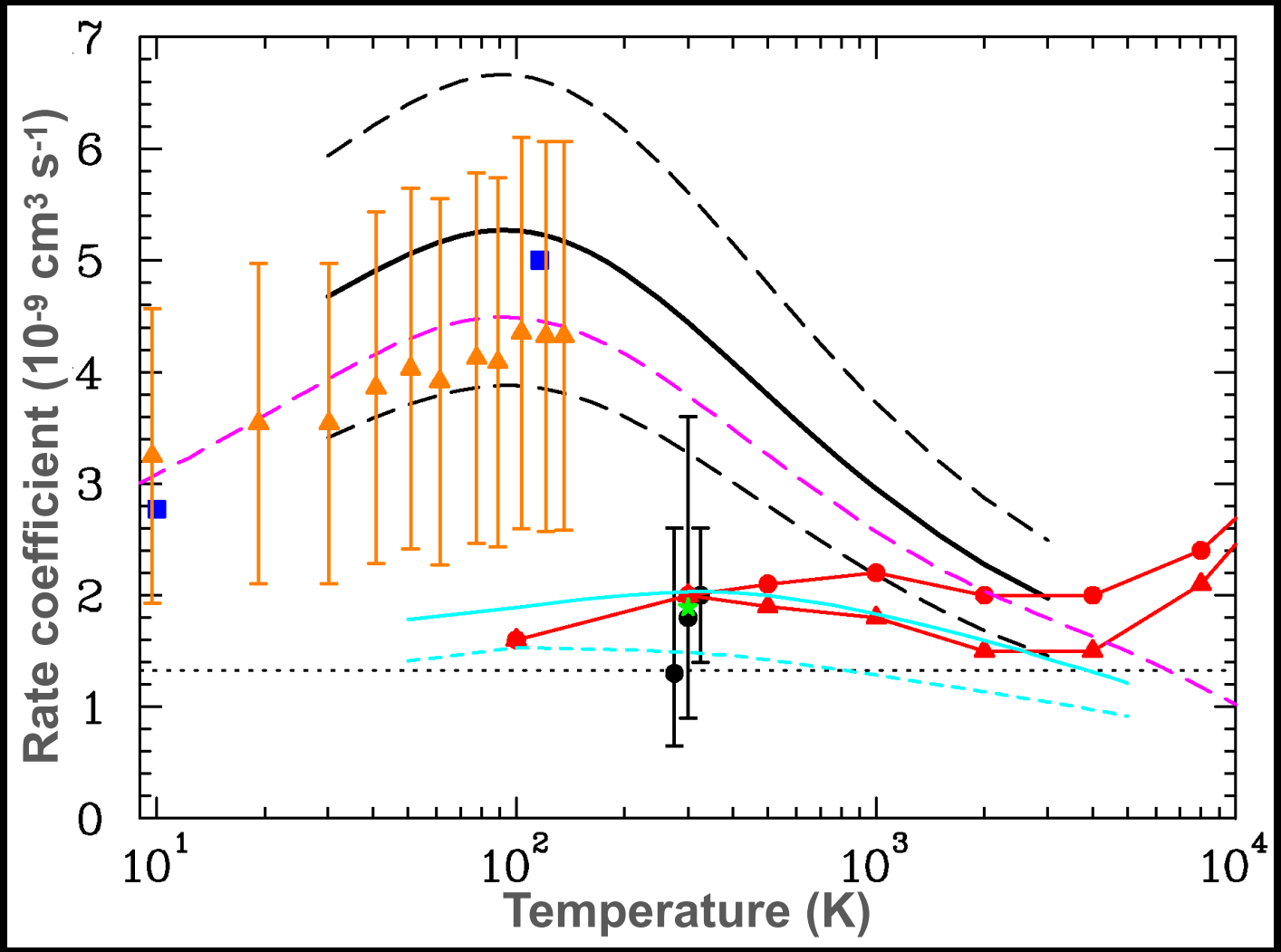
Thermal data for $H^- + H \rightarrow H_2 + e^-$



Adding in our results

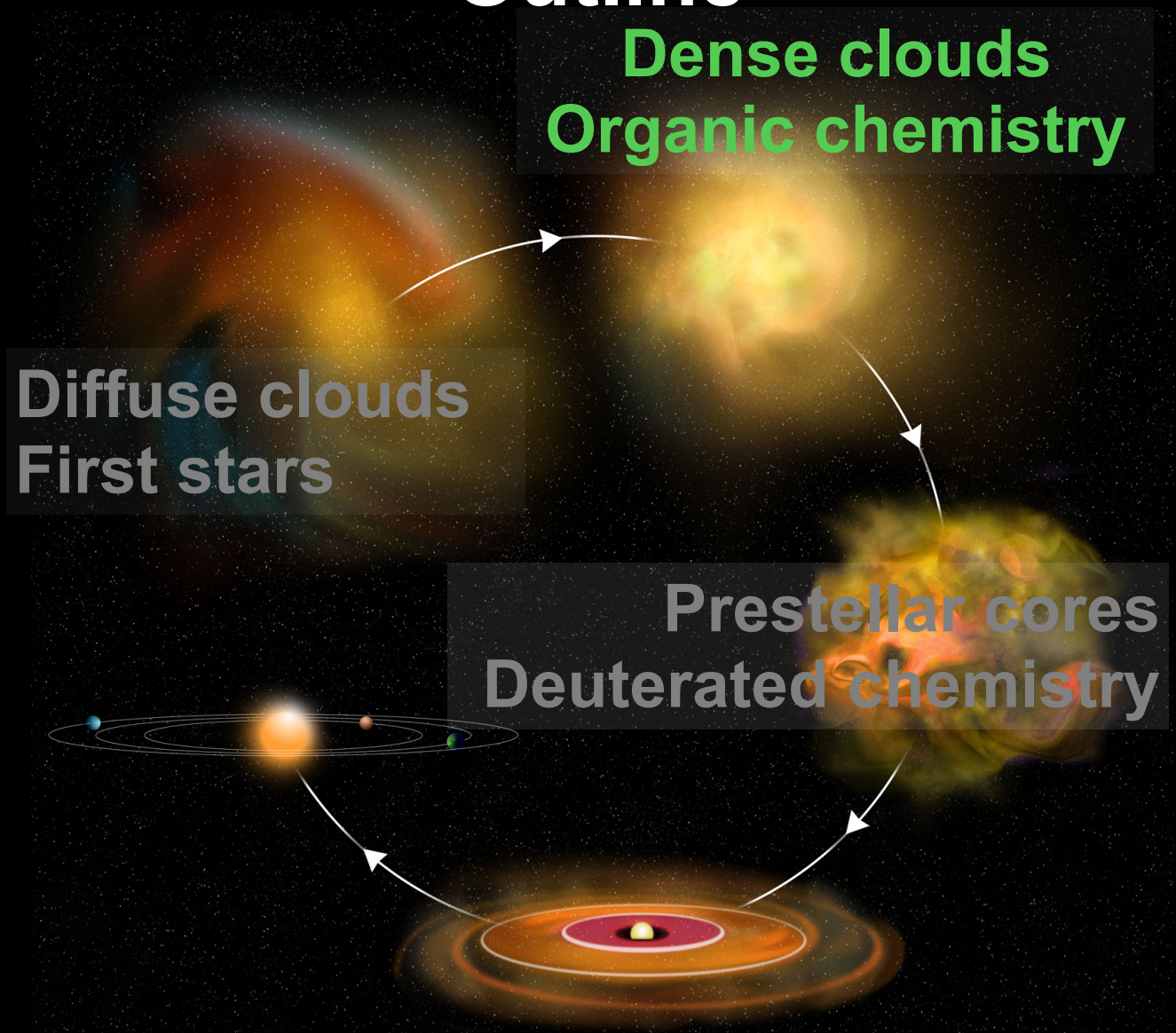


And with yet newer measurements



Theory and experiment have finally converged.

Outline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Pathway from atoms in space to life on Earth is full of unknowns

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How far did interstellar chemistry take us on this pathway towards life?

Some gas-phase pathways for forming the chemicals needed for life

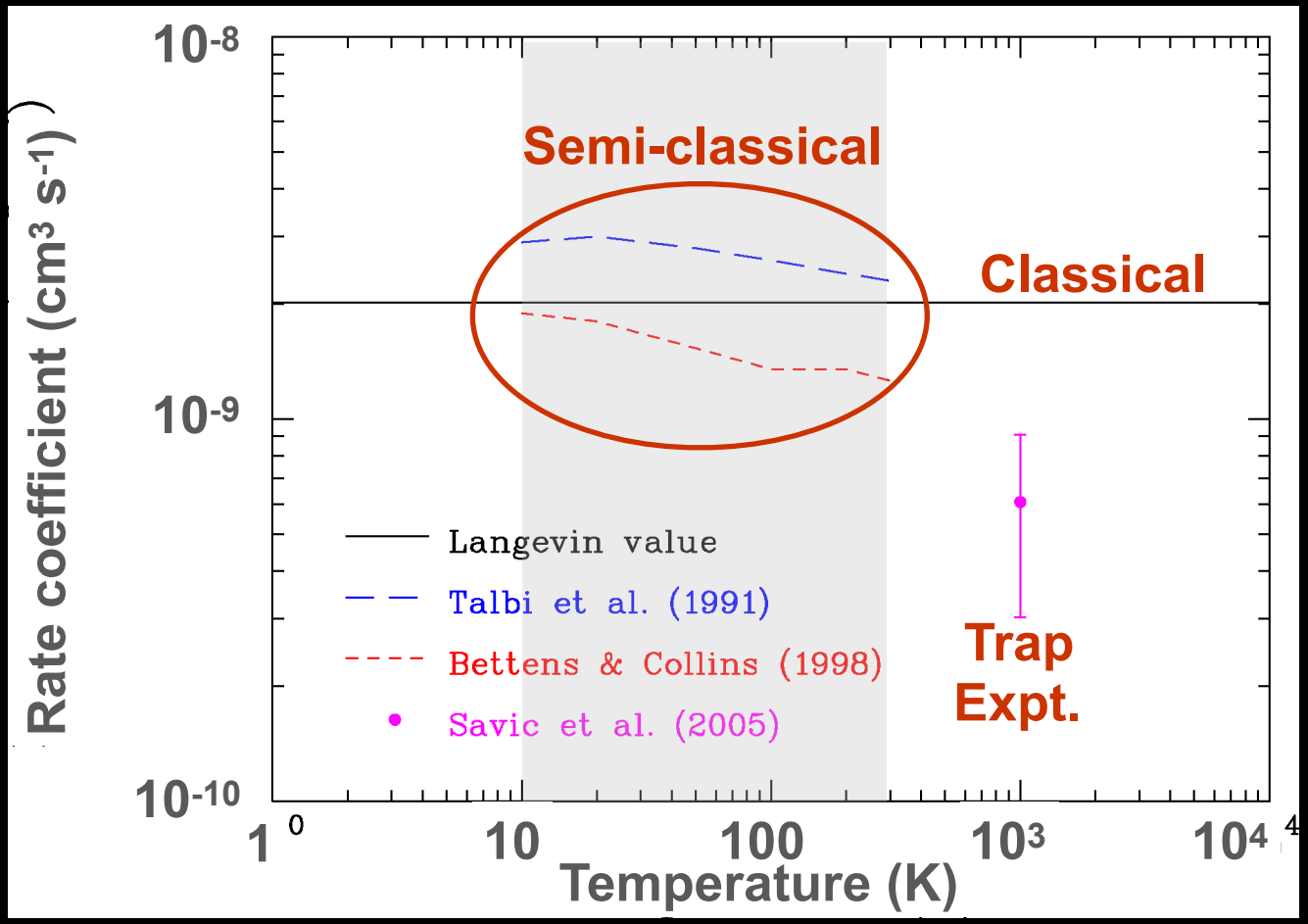
Conditions in dense molecular clouds:

$n_H \sim 10^4$ cm^{-3} → **Binary Reactions**

$T_{gas} \sim 10$ K → **Ion-neutral chemistry**

$$\{H_2\} \rightarrow \boxed{H_3^+ + C \rightarrow CH_n^+} + \{H, C, N, O\} \rightarrow \begin{matrix}\text{carboxyl}\\ \text{cyano}\\ \text{amino}\end{matrix}$$

Published data for $C + H_3^+ \rightarrow CH^+ + H_2$



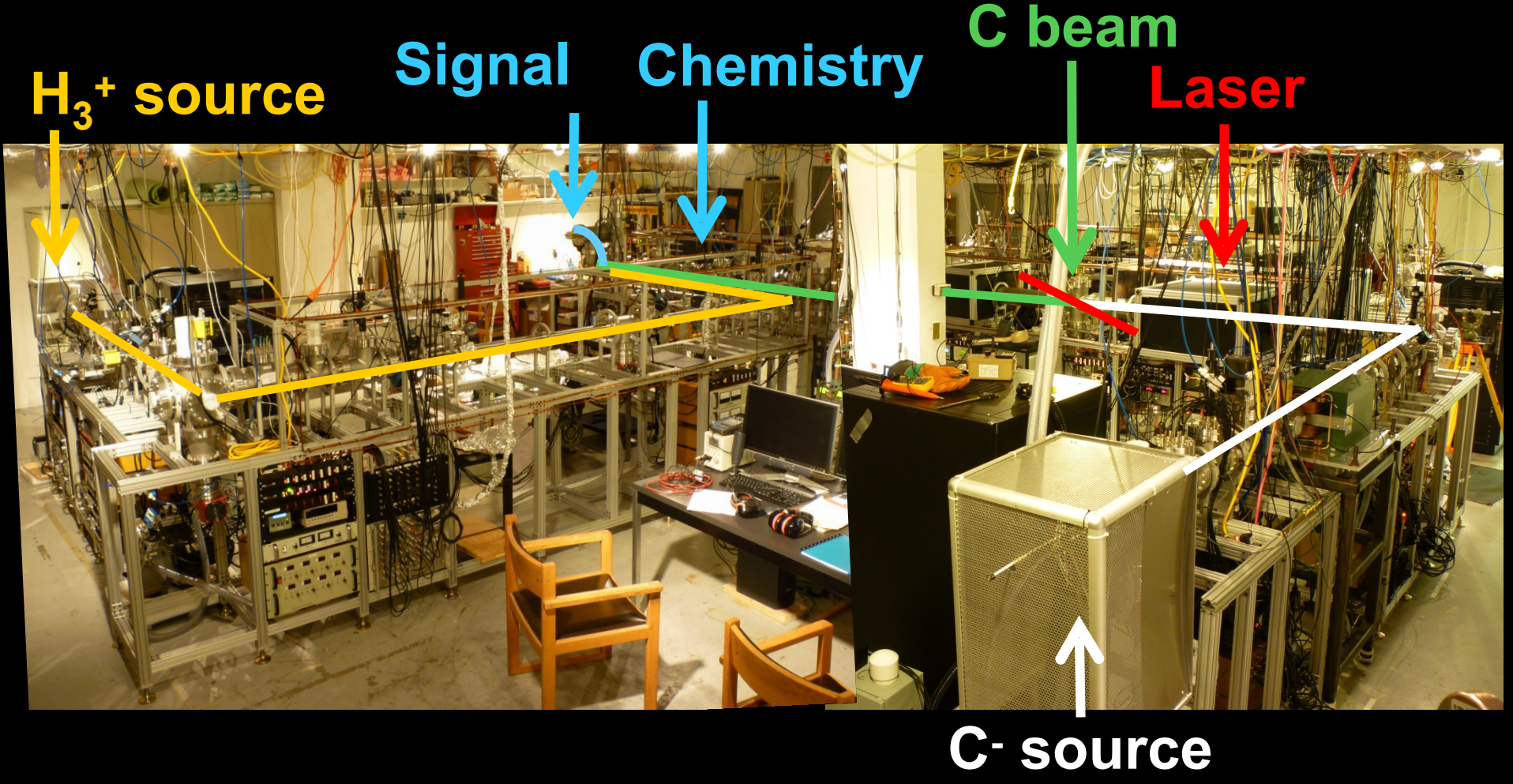
QM calc's beyond current theoretical abilities.

No lab data exist at molecular cloud temperatures.

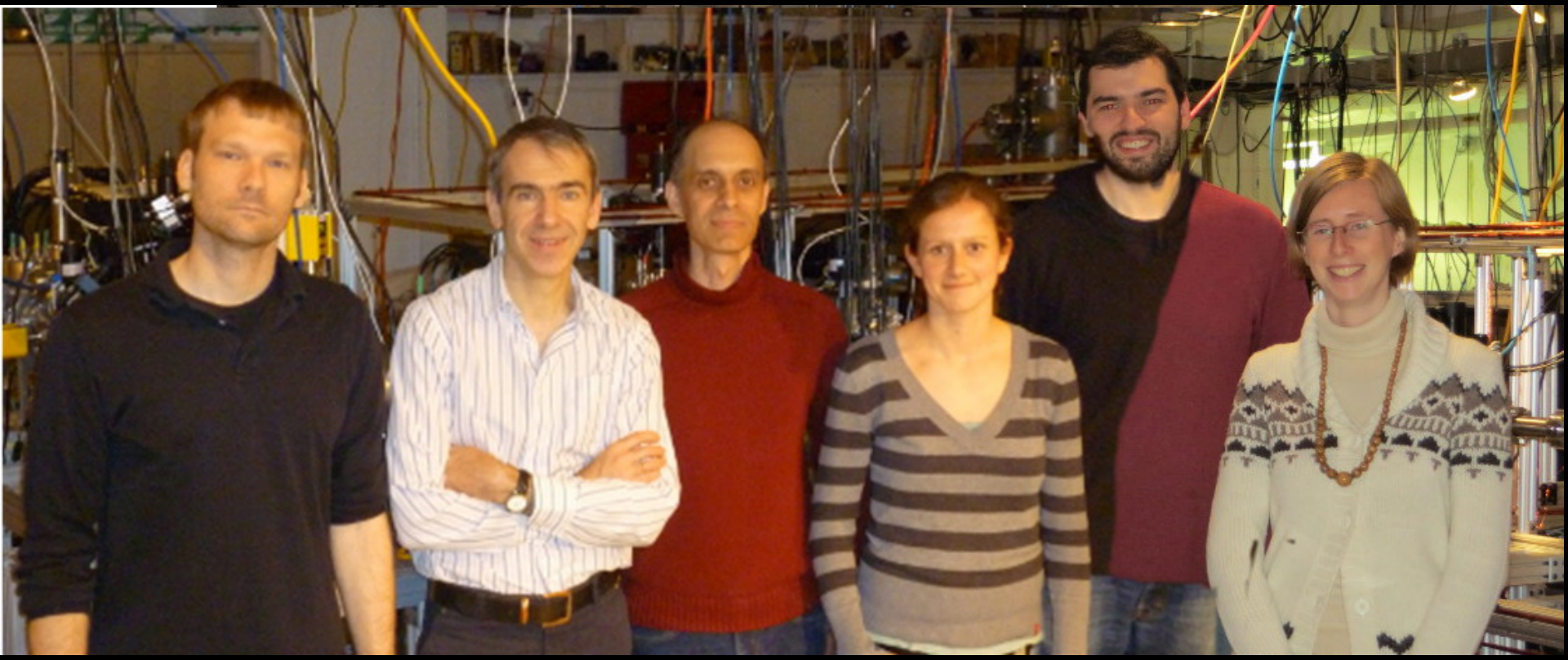
Over factor of 2 uncertainty in the rate coefficient.

We have built an apparatus to study

$$C + H_3^+ \rightarrow CH_n^+ + H_{3-n}$$

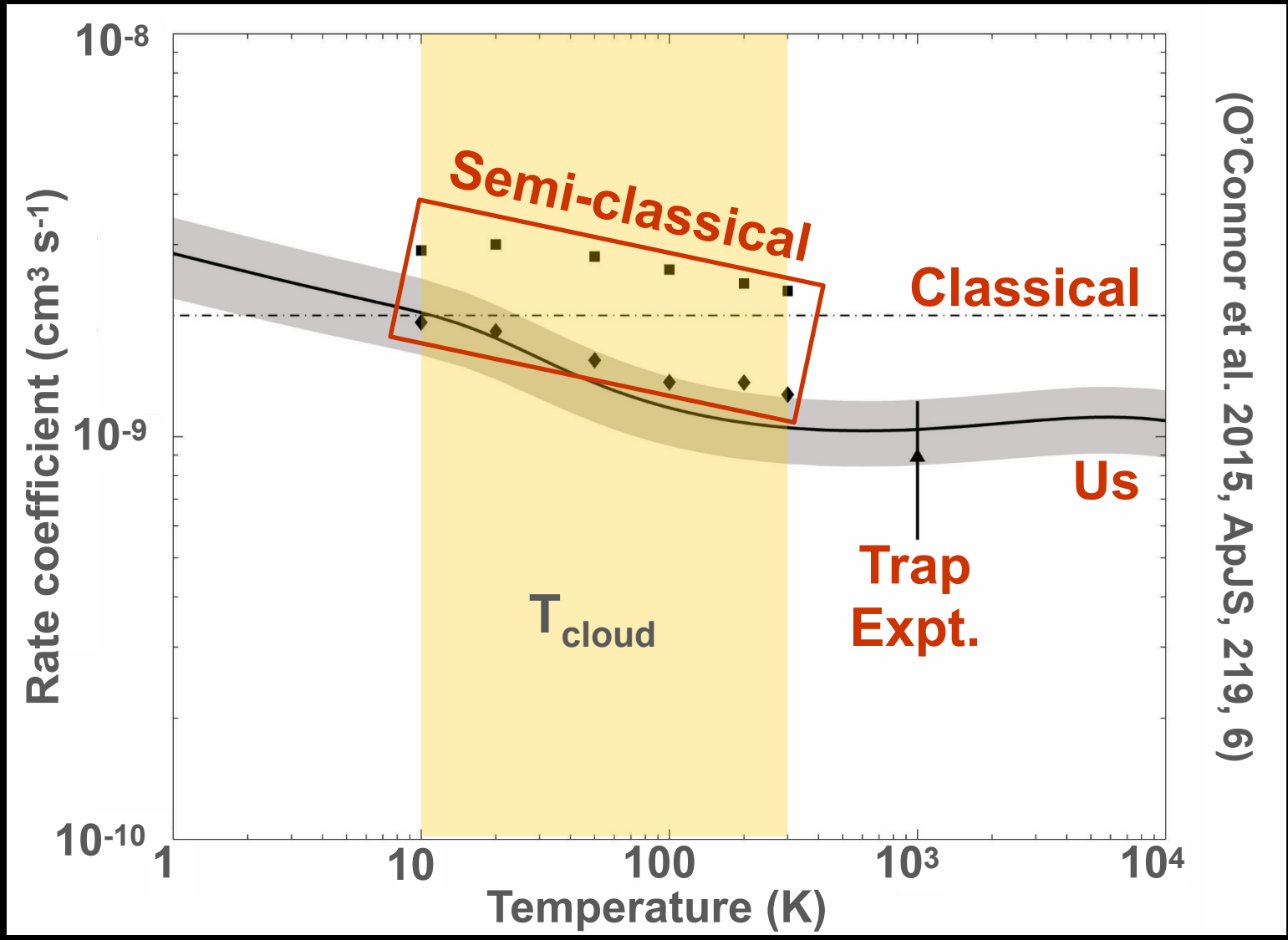


The Team Members



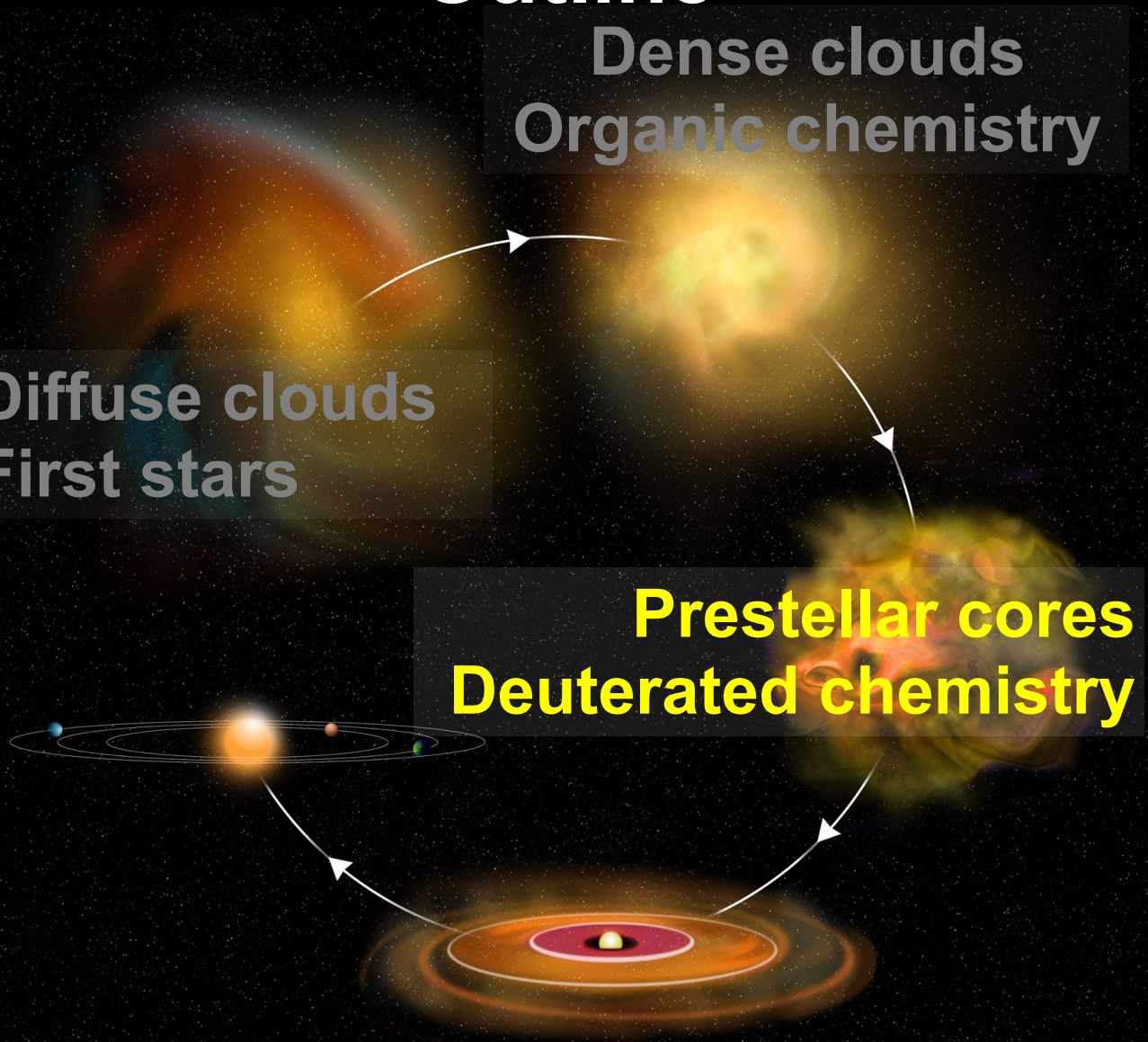
Ken Miller, X. Urbain, DWS, Jule Stützel, A. O'Connor, Nathalie de Ruette

C + H_3^+ summed thermal rate coefficients



Reduced uncertainty from factor of >2 to <20%.

Outline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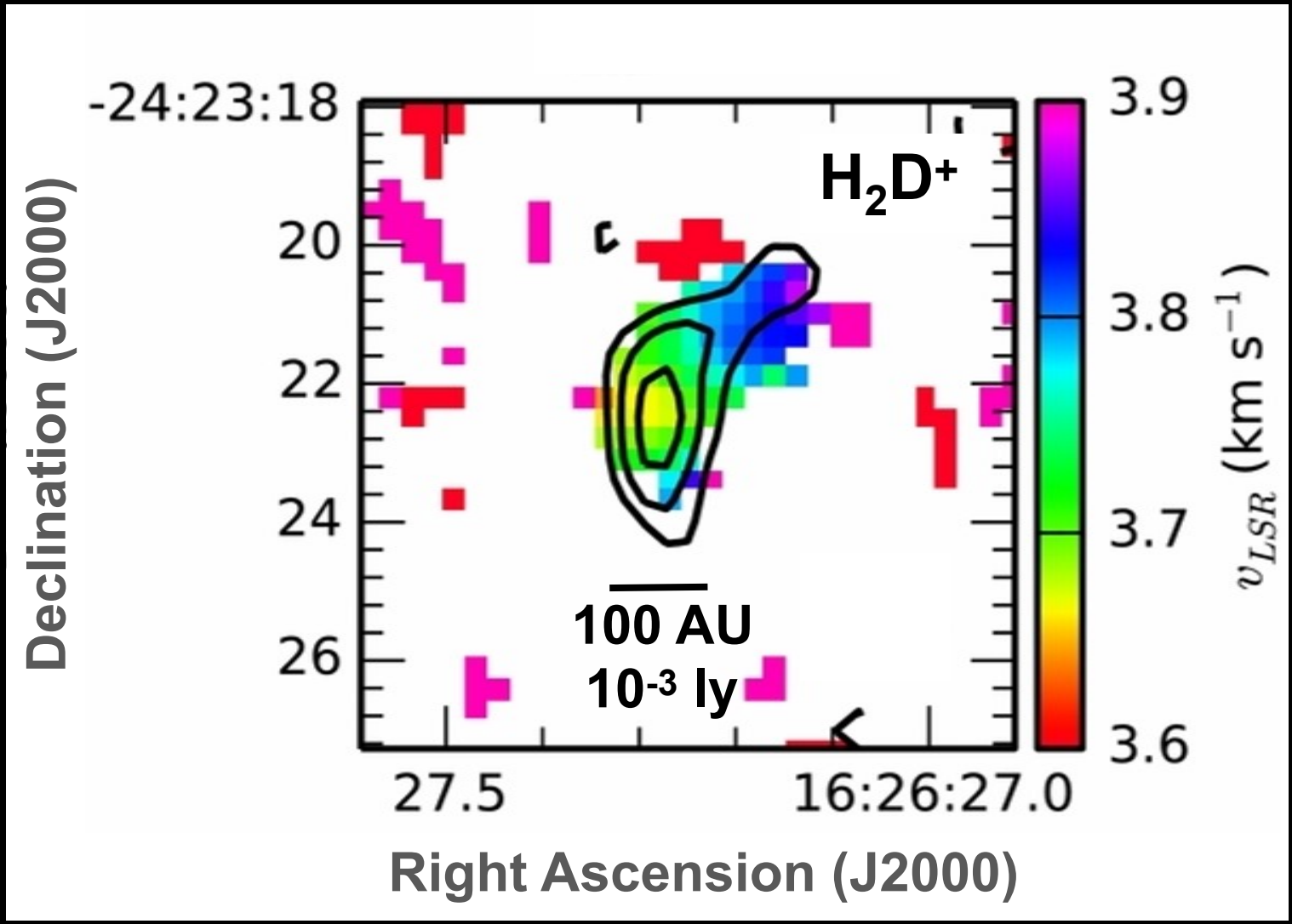
Prestellar core properties can be probed using H_2D^+ and D_2H^+

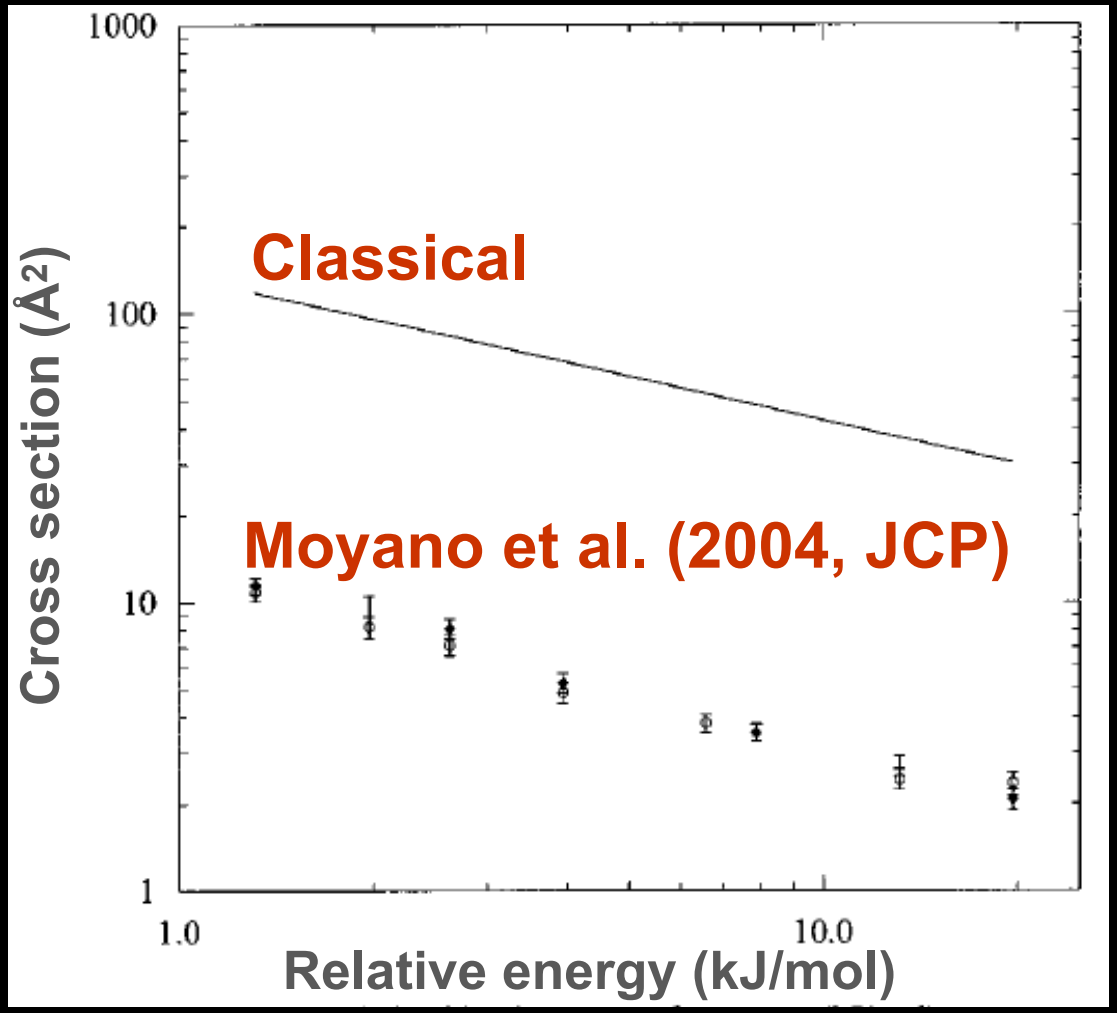


Ionization fraction is inferred using measured H_2D^+ and D_2H^+ abundances

Reaction	Rate Coefficient (10 K)	Uncertainty
	1.70e-09	15%
	8.10e-10	15%
	6.40e-10	15%
	1.10e-09	15%
	7.00e-10	15%
	1.00e-09	Factor of 2
	2.00e-09	Factor of 2
	2.00e-09	Factor of 2

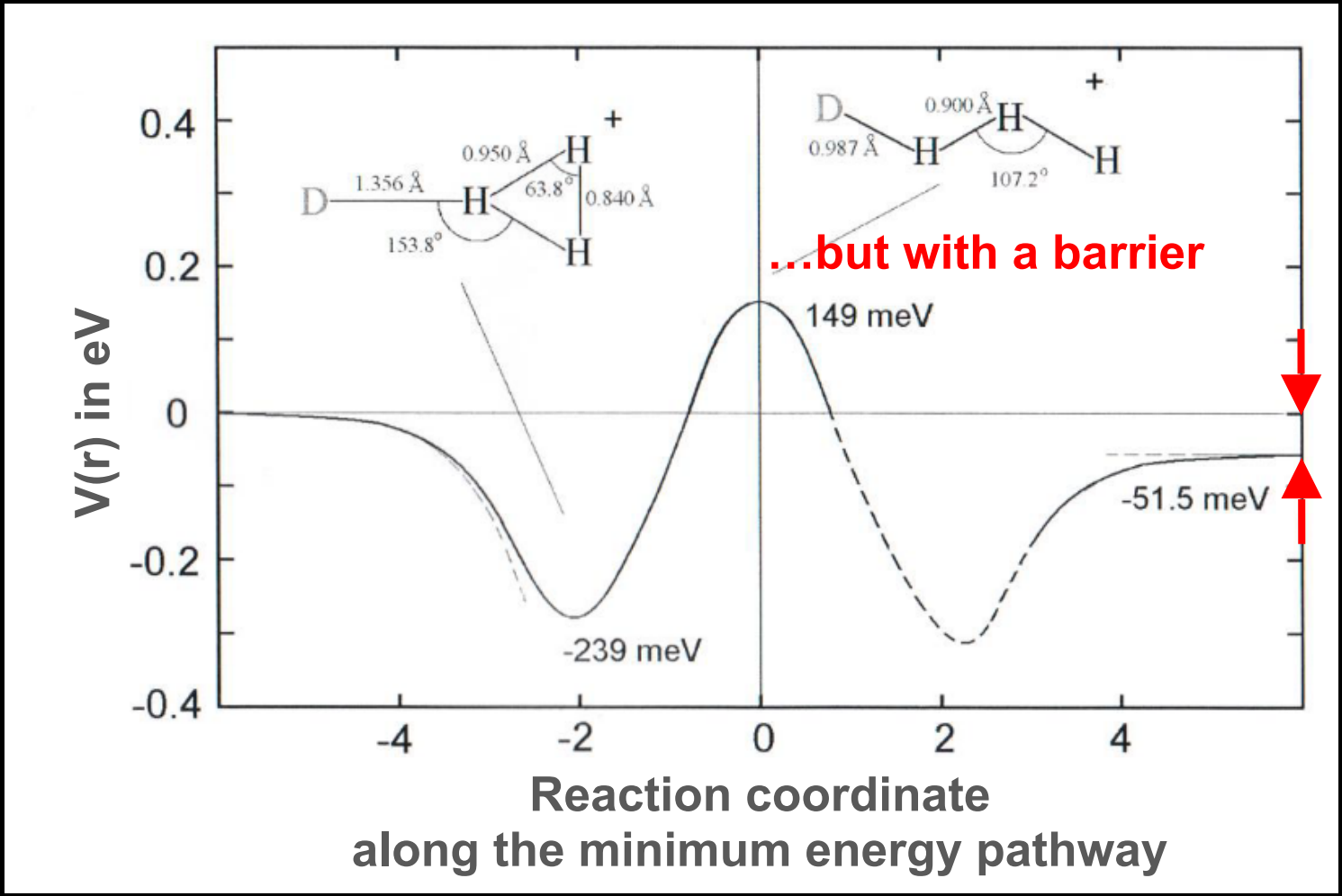
We are measuring these last three reactions.

Published data for $D + H_3^+ \rightarrow H_2D^+ + H$



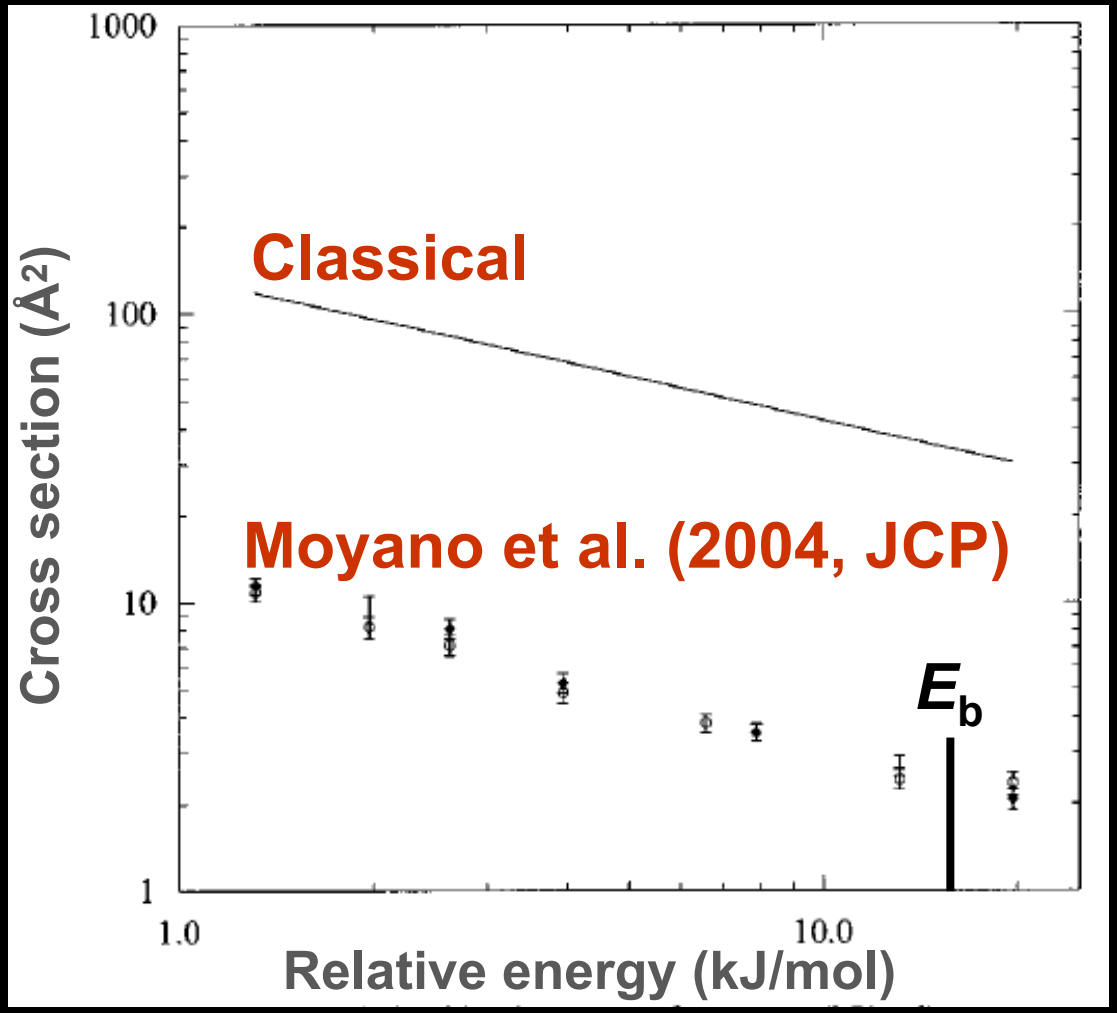
Langevin and semi-classical results differ by nearly an order of magnitude.

D + H_3^+ exoergically forms H + H_2D^+…



Moyano et al. (2004) predict a 1700 K barrier.
Reaction should be closed for prestellar cores.

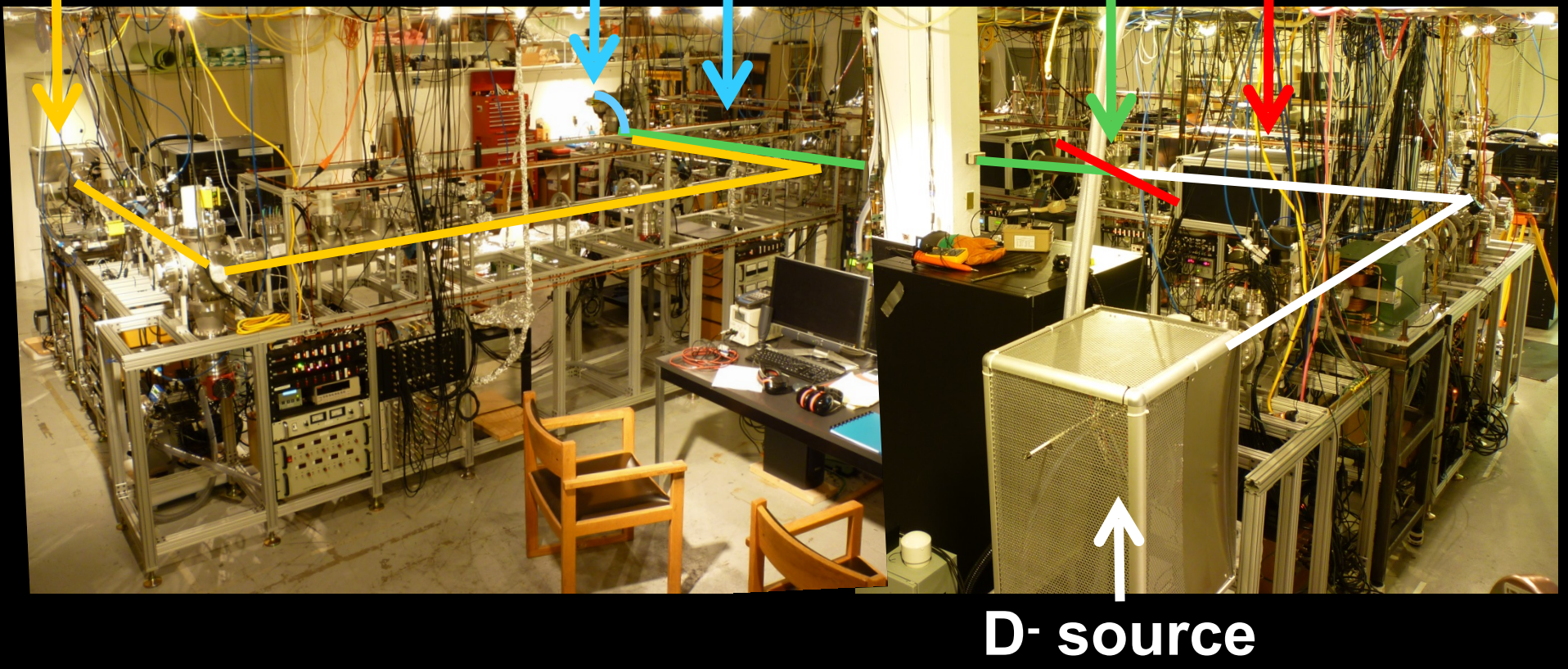
Published data for $D + H_3^+ \rightarrow H_2D^+ + H$



Why do Moyano et al. predict a non-zero cross section below the barrier energy?

We have changed the source to study

$$D + H_3^+ \rightarrow H_2D^+ + H$$



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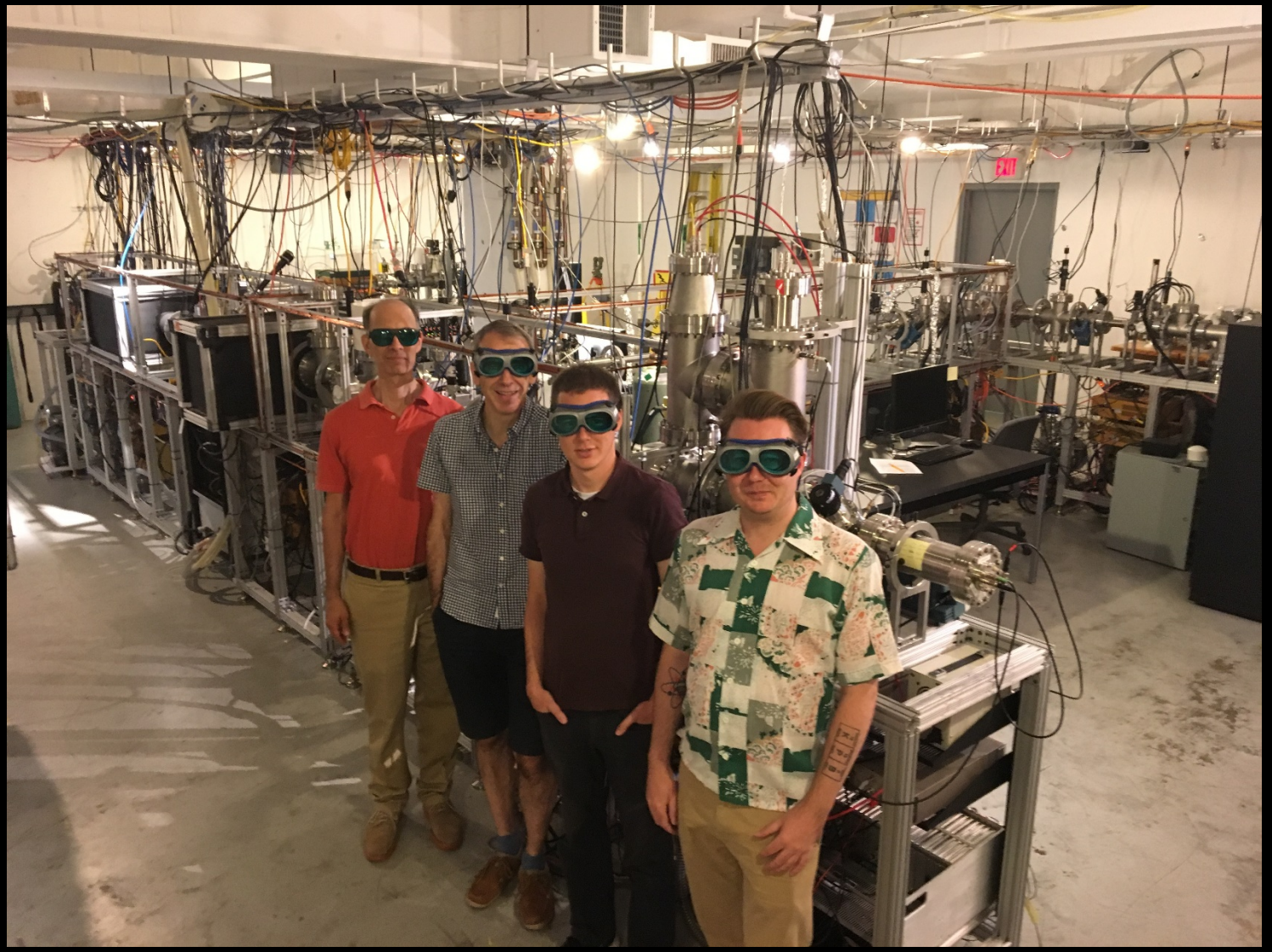
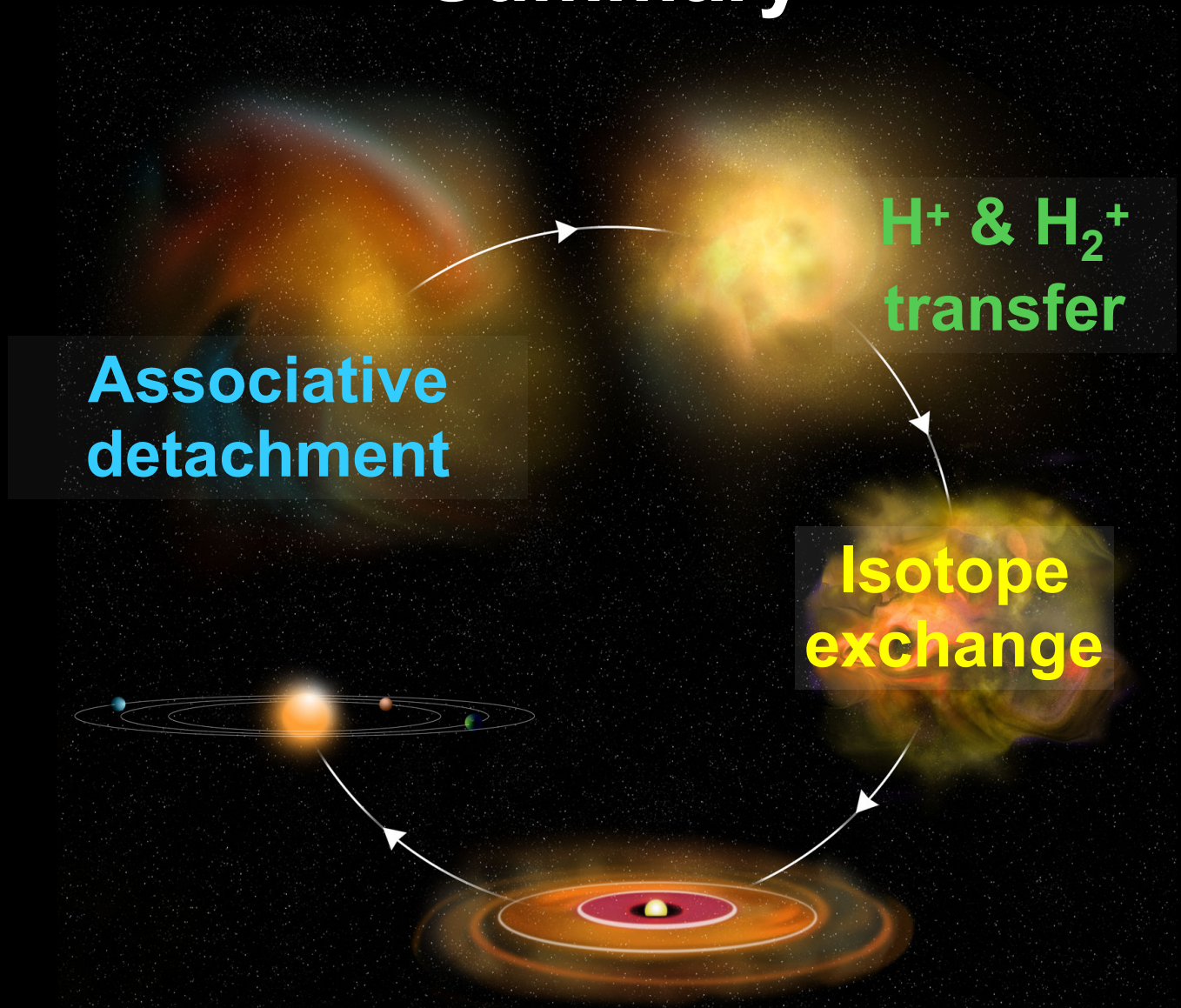


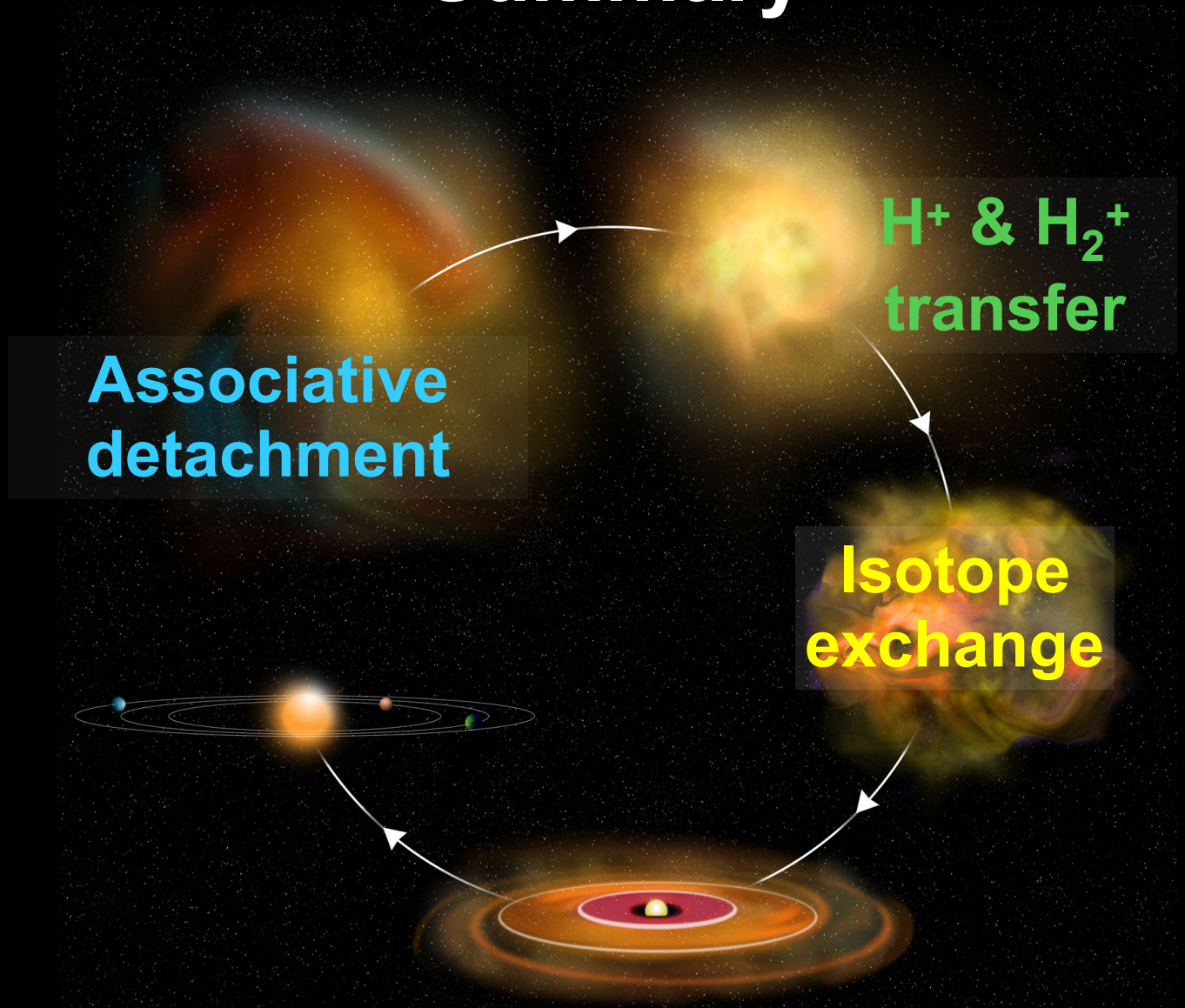
DWS, Xavier Urbain, Pierre-Michel Hillenbrand, and Kyle Bowen

Summary



We can study collision energies from 2 meV to 20 eV.

Summary



Thanks for your attention. Questions?