

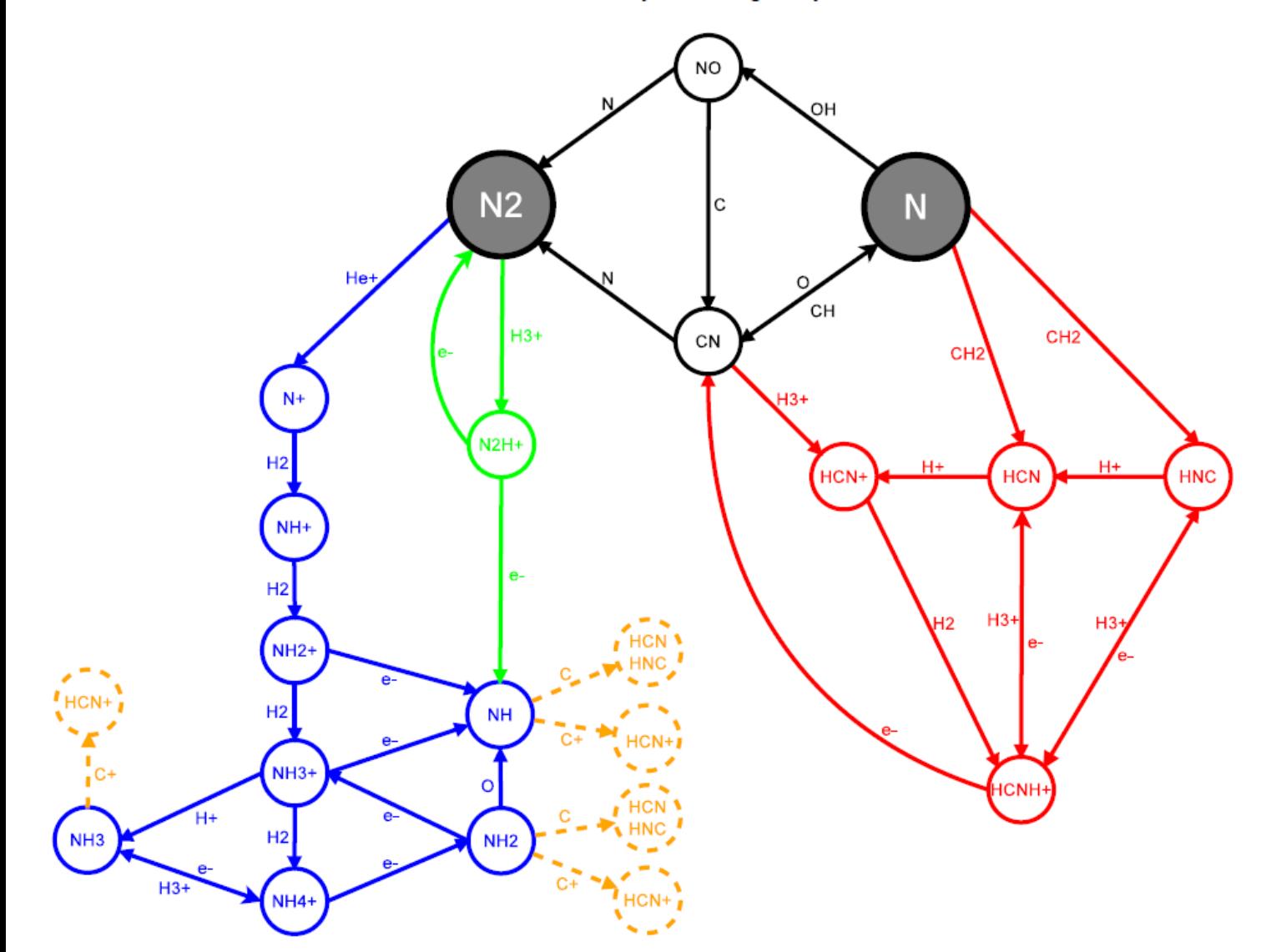
# The interstellar gas-phase chemistry of HCN and HNC including $^{13}\text{C}$ , $^{15}\text{N}$ and D isotopologues

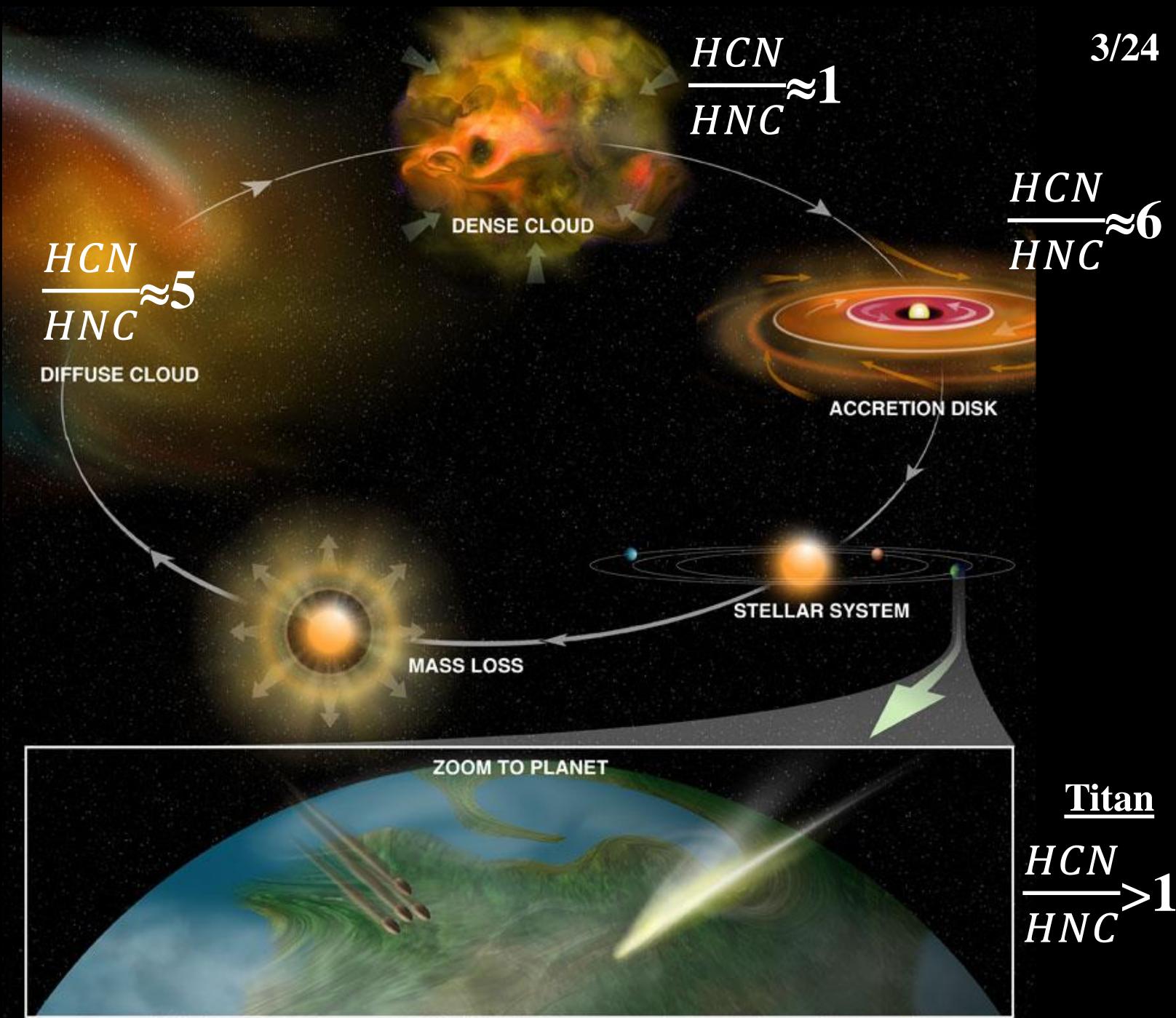
Jean-Christophe Loison,  
Kevin M. Hickson, Valentine Wakelam, Evelyne Roueff,  
Astrid Bergeat, Laura Reboussin

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PCMI-Rennes 2014

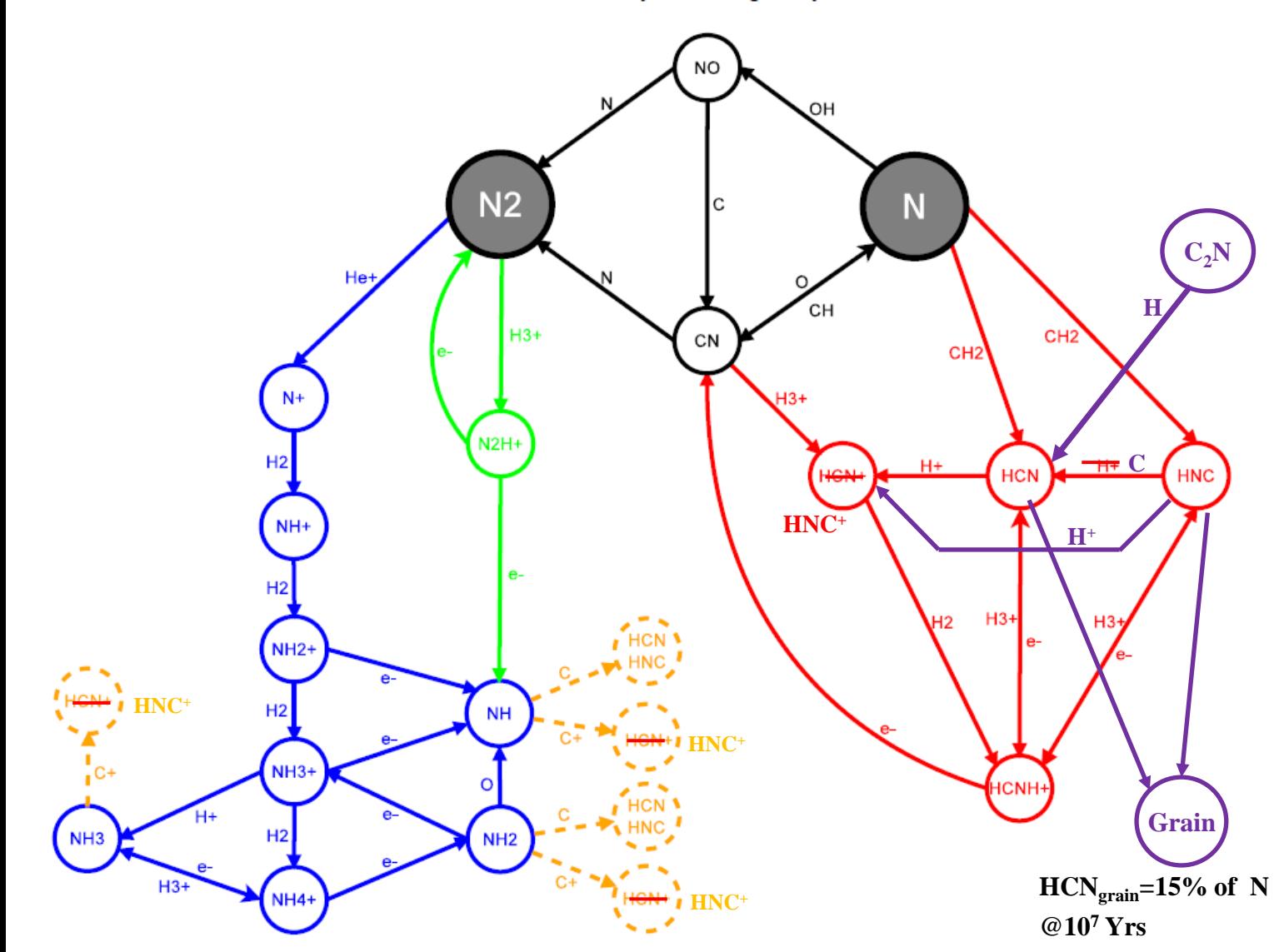
# Formation (Molecular clouds):





- **HCN<sup>+</sup> less stable than HNC<sup>+</sup>**
- **H<sub>2</sub>CN important when CH<sub>4</sub> desorbs from Ice**
- **H-C-C-N system under estimated**

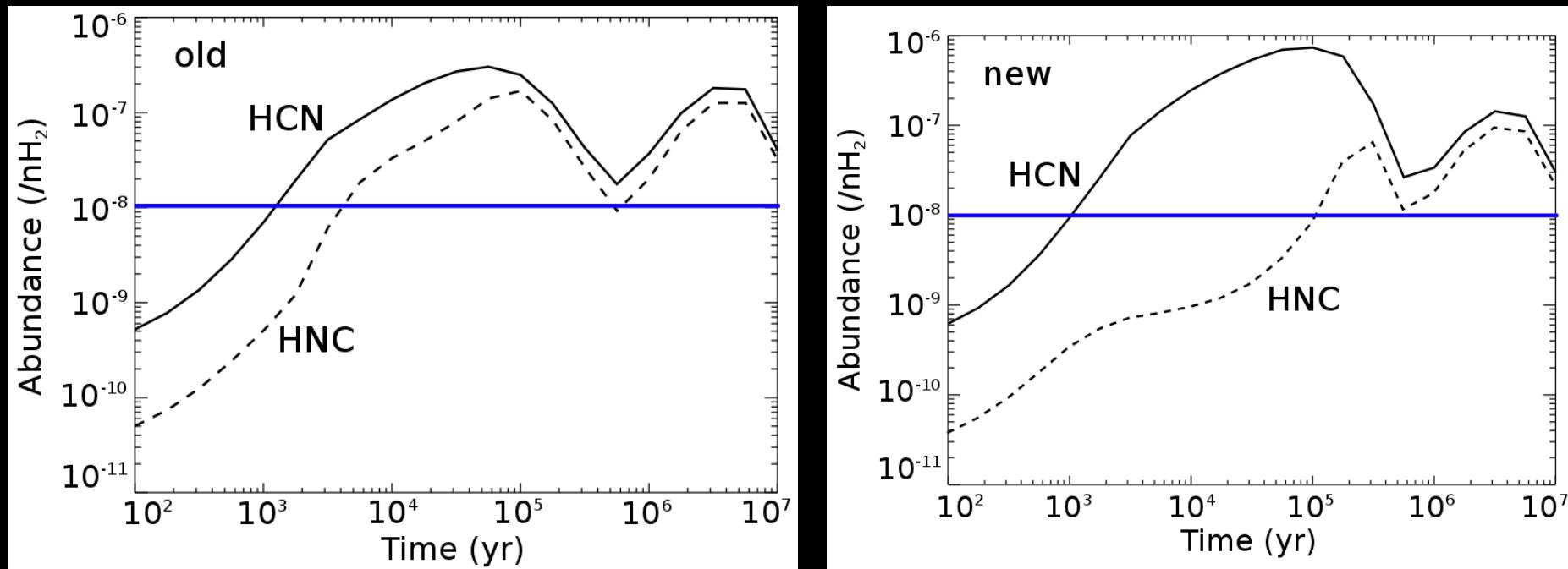
# Formation (Molecular clouds):



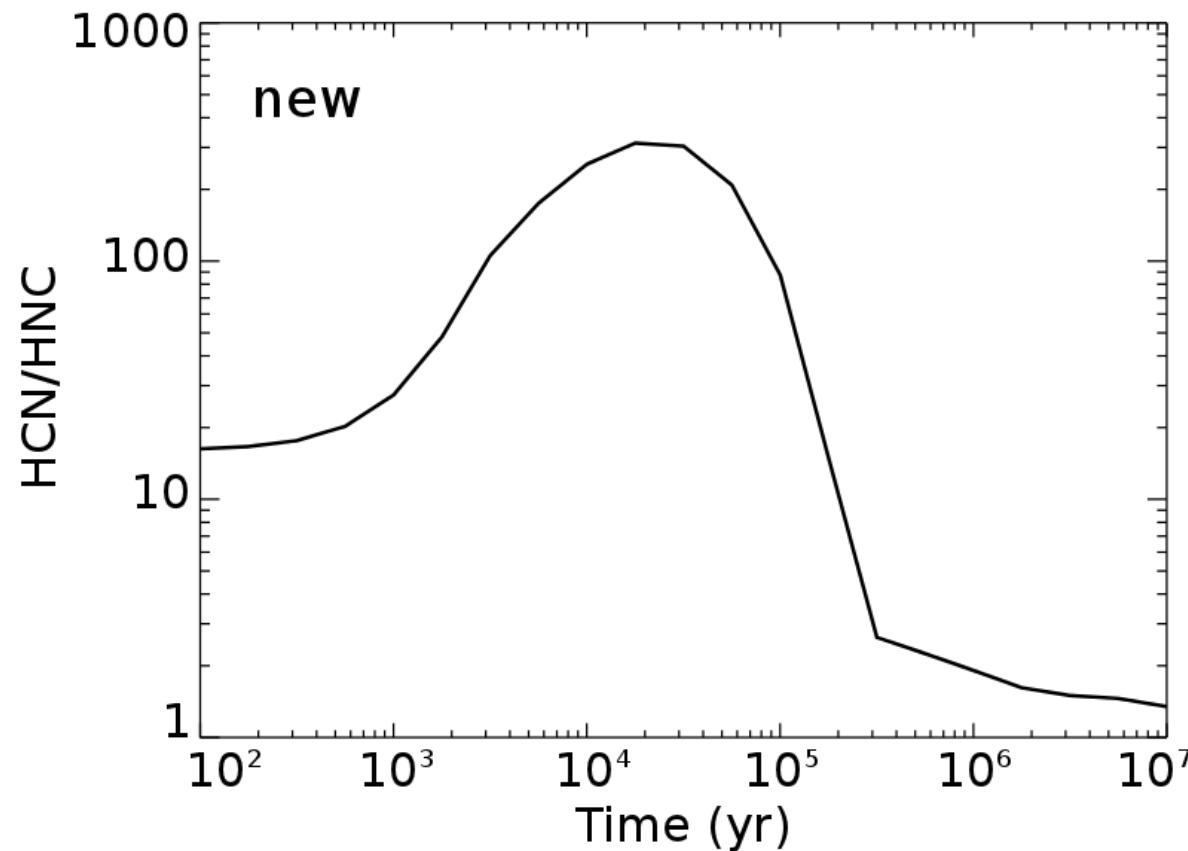
$$H_2 = 2 \times 10^4 \text{ cm}^{-3}$$

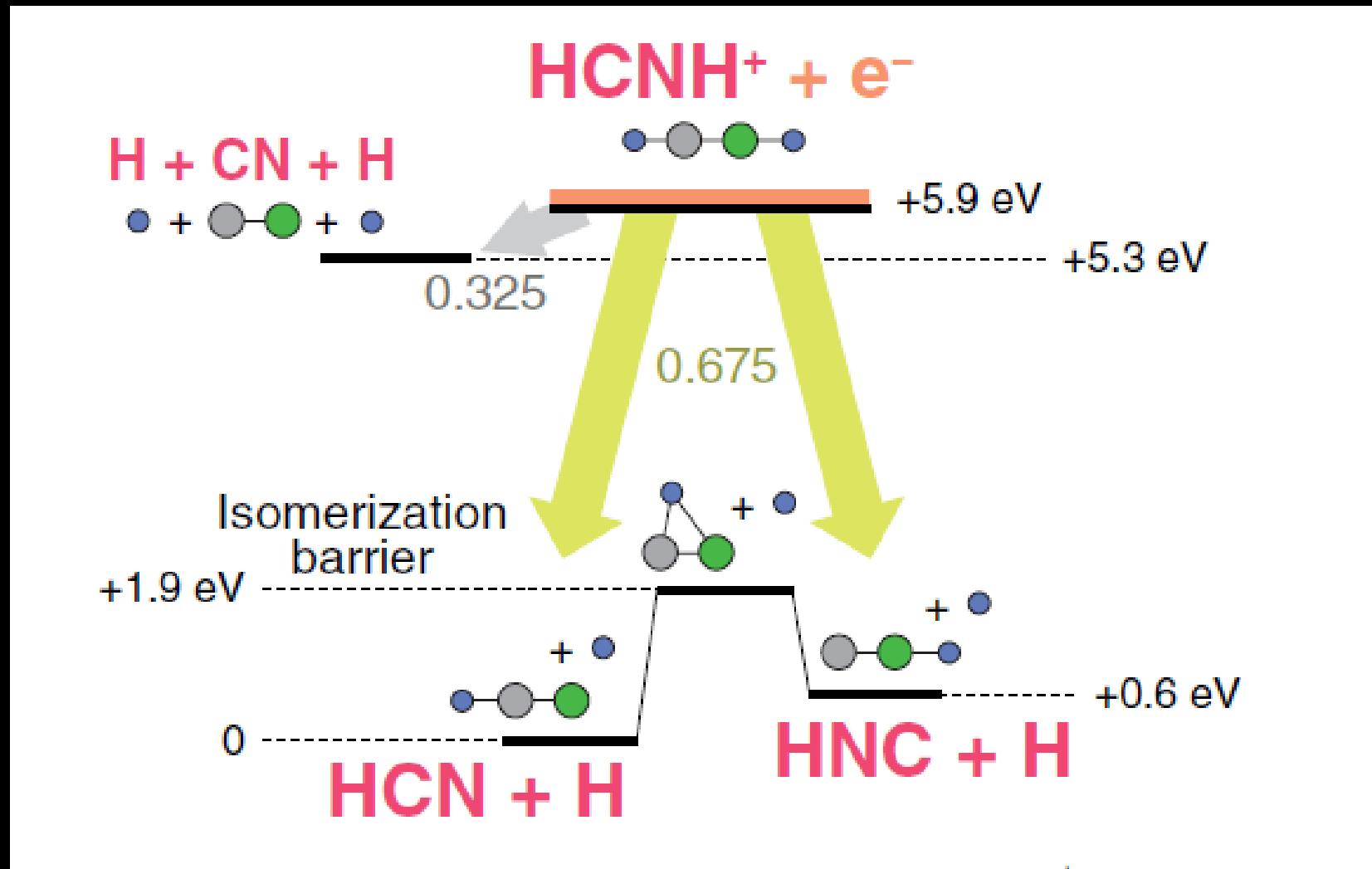
$$T = 10 \text{ K}$$

$$\text{CR ionisation} = 1.3 \times 10^{17} \text{ s}^{-1}$$

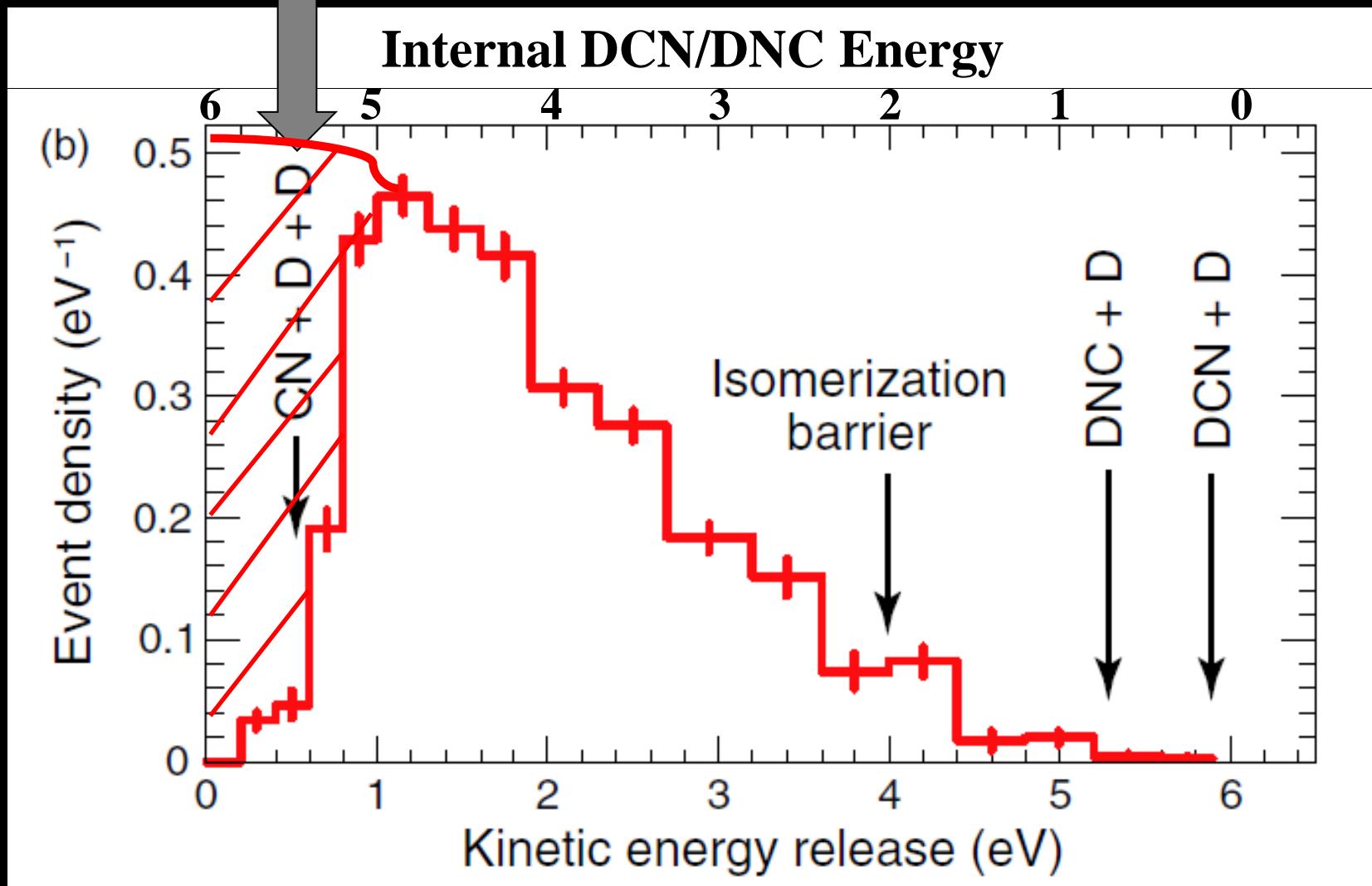


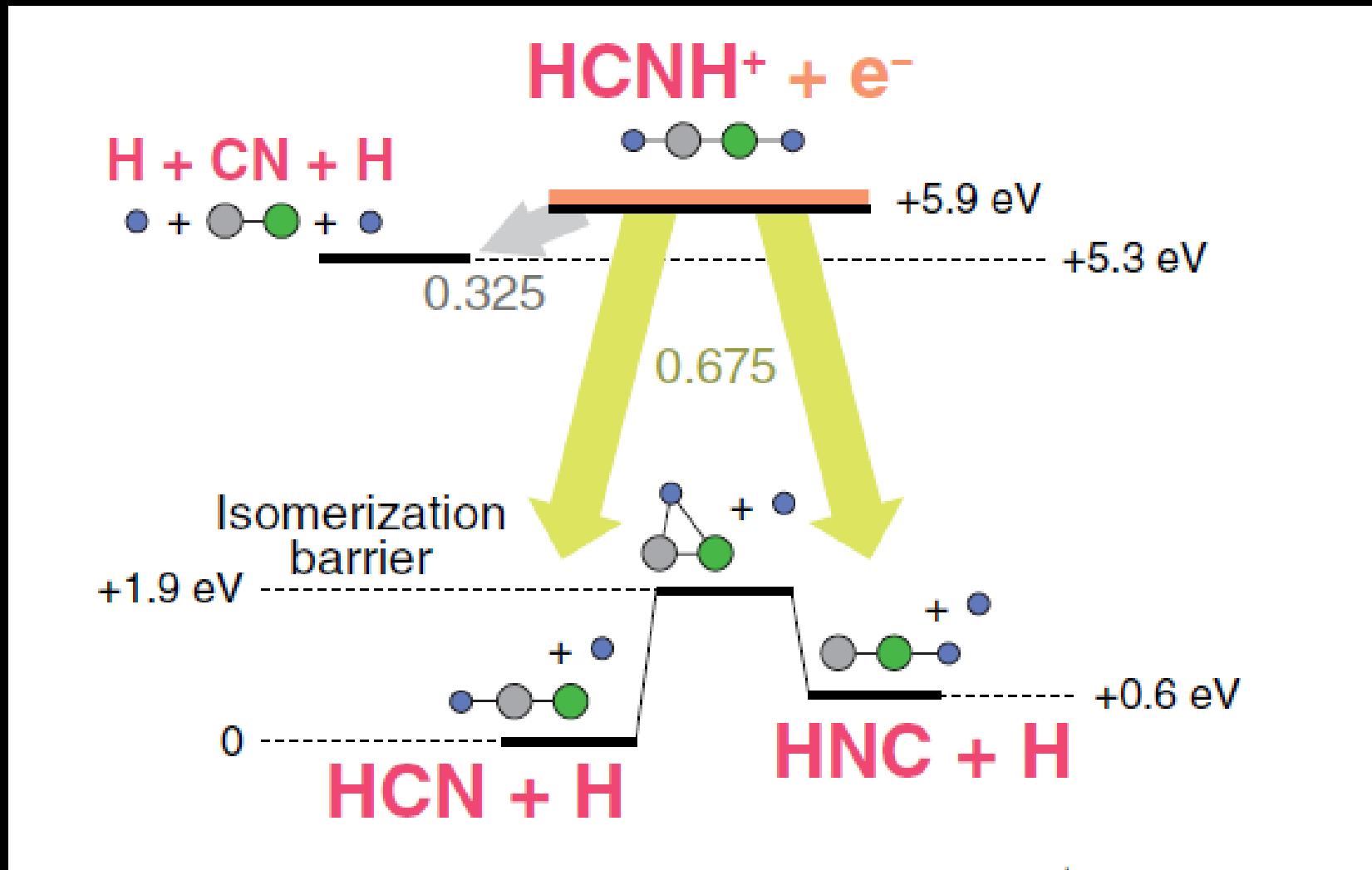
Loison, Wakelam, Hickson MNRAS 2014  
 The interstellar gas-phase chemistry of HCN and HNC

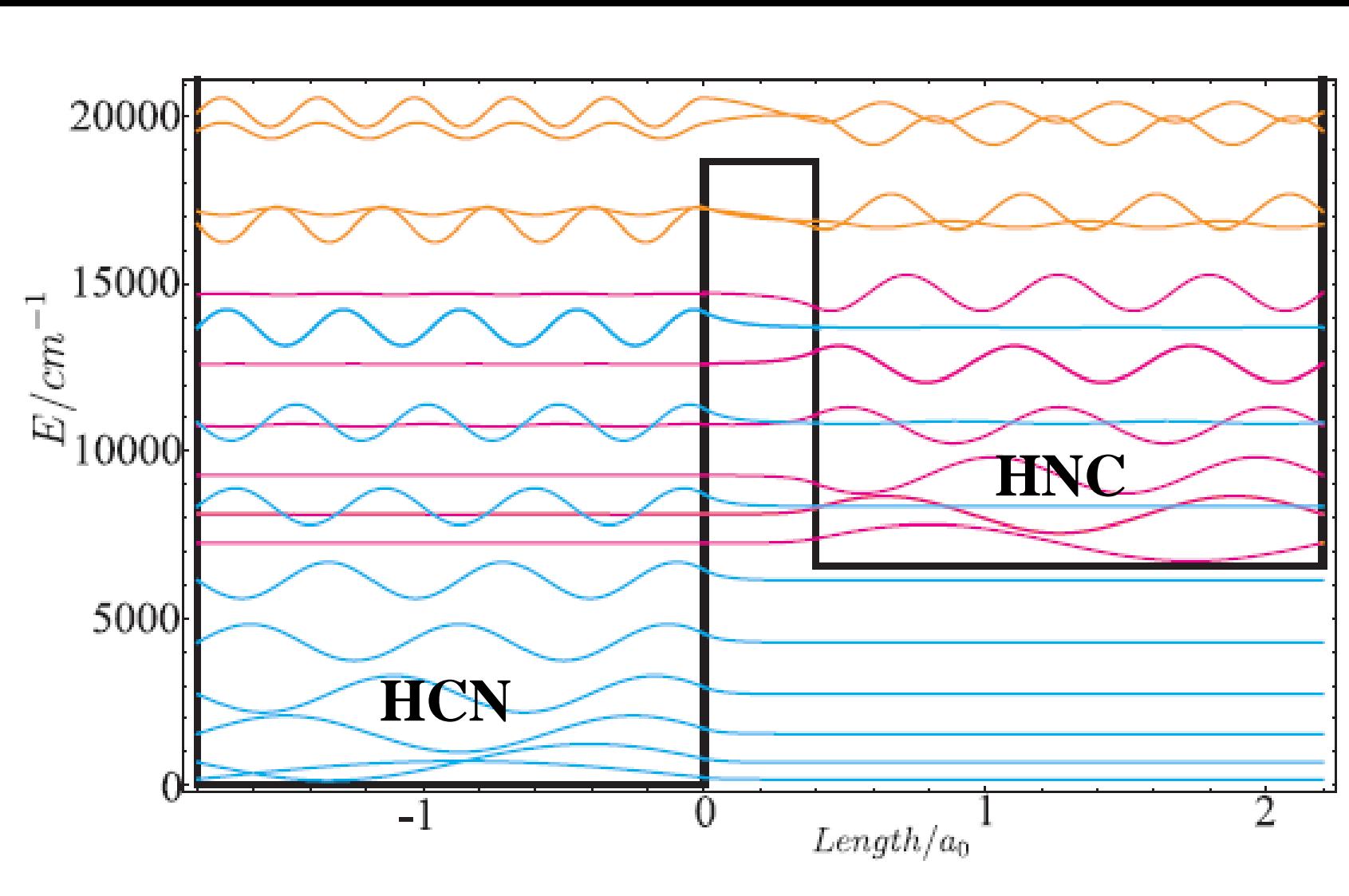
$\frac{HCN}{HNC}$ 

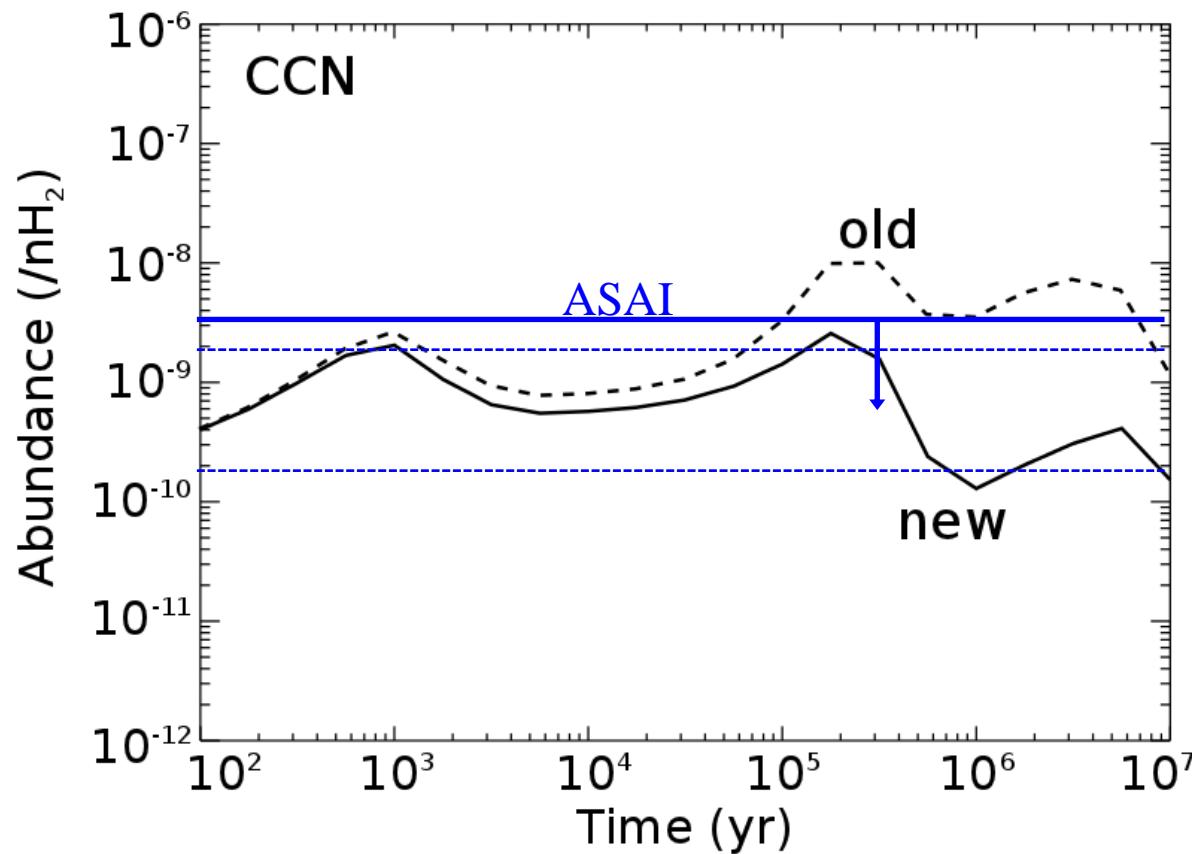


$\text{CN} + \text{D} + \text{D} = 30\%$   
Semaniaik 2001





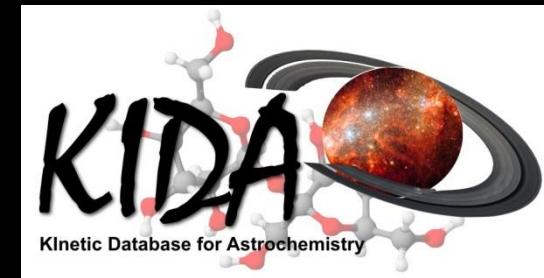




Old: after Loison et al MNRAS 2014  
‘The gas-phase chemistry of carbon chains in dark cloud chemical models’

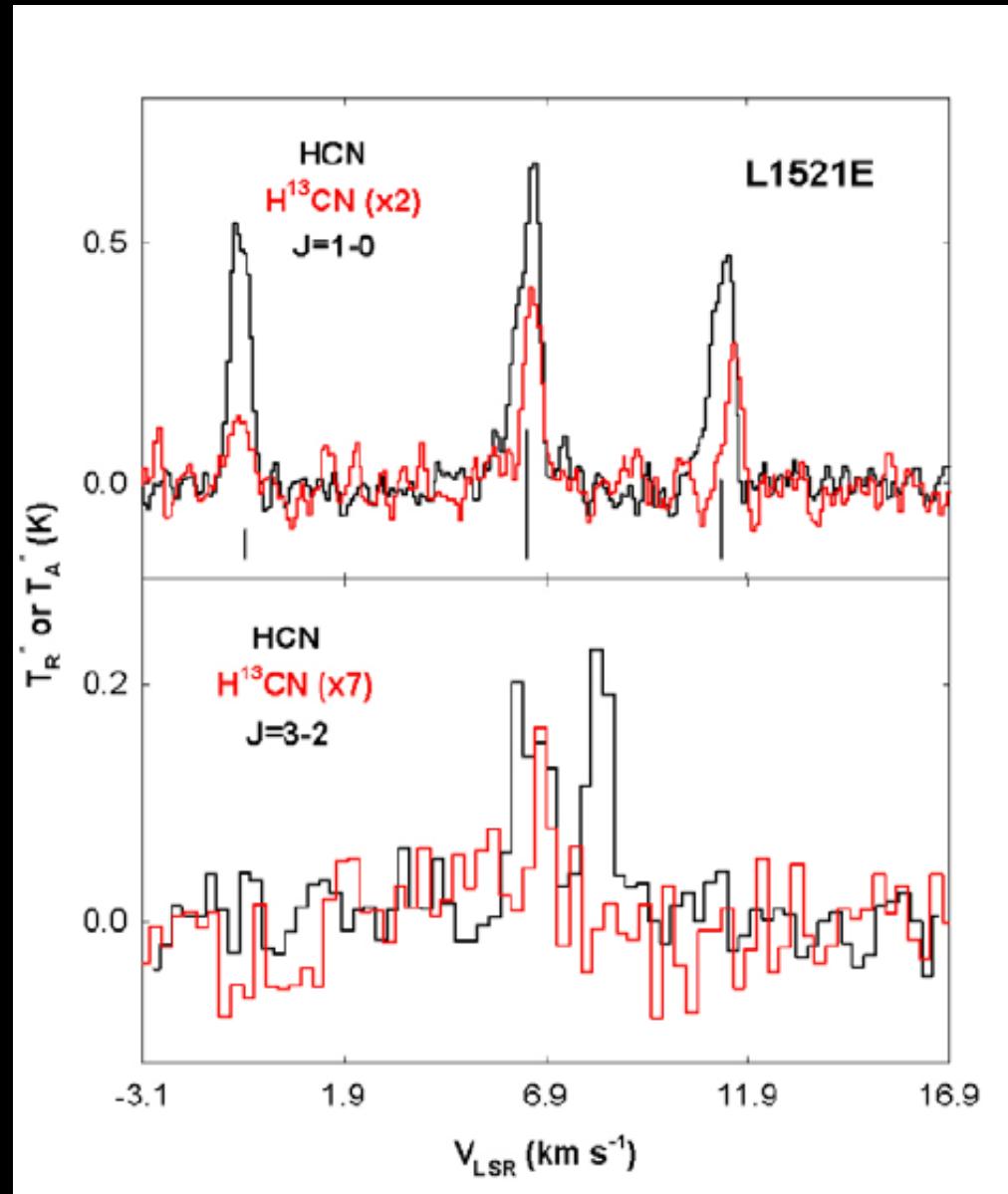
## 1<sup>ère</sup> Conclusion

- $\text{H} + \text{CCN} \rightarrow \text{C} + \text{HCN}$
  - $\text{C} + \text{HNC} \rightarrow \text{C} + \text{HCN}$
  - HCN/HNC/CN Chemistry in Protoplanetary Disks (role of  $\text{HNC}^+$ ,  $\text{H}_2\text{CN}$ )  
see Poster of Laura Reboussin
- HNC photolysis

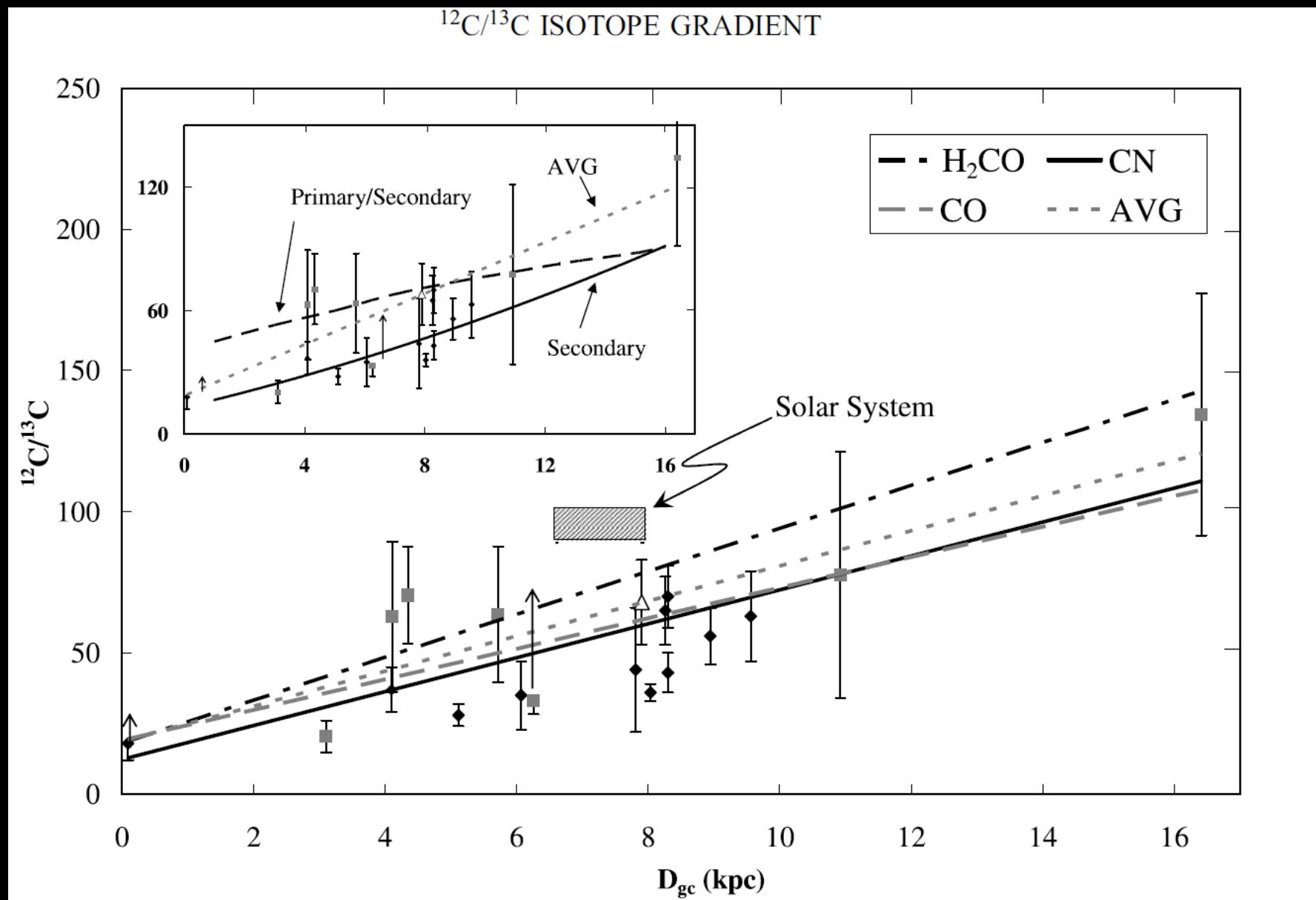


# Observations

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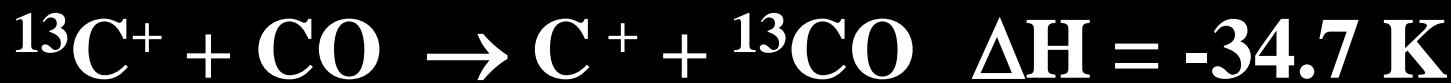
Milam 2012



# **Isotopic fractionation of carbon, deuterium and nitrogen: a full chemical study**

E. Roueff<sup>1</sup>, J.C. Loison<sup>2</sup>, and K.M. Hickson<sup>2</sup>

**Soumis à A&A**



$$\boxed{^{13}\text{C}}$$

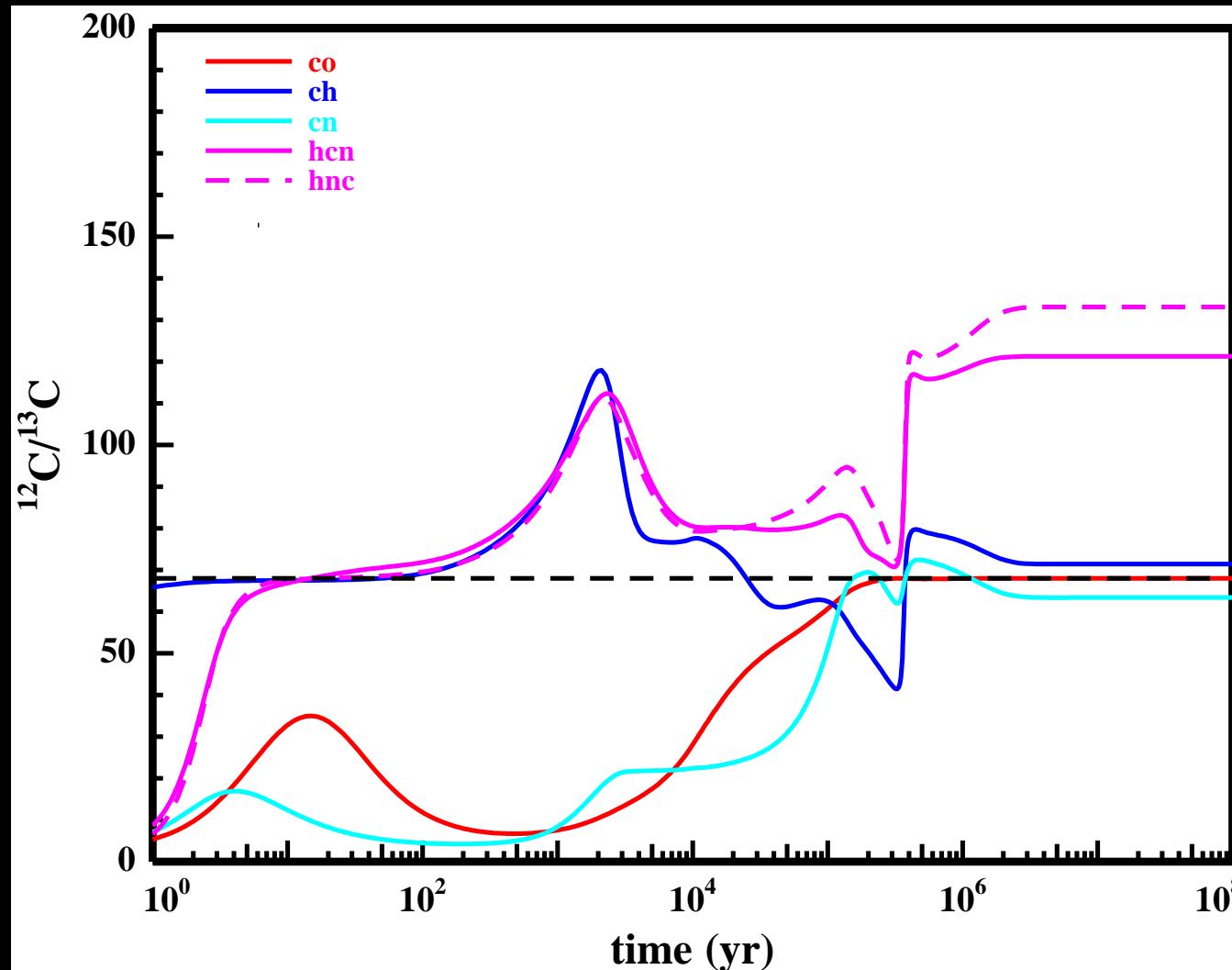

# Meudon code without grains

$$\text{H}_2 = 2 \times 10^5 \text{ cm}^{-3}$$

$$\text{C} = 1.4 \times 10^{-5}$$

$$\text{N} = 2.1 \times 10^{-5}$$

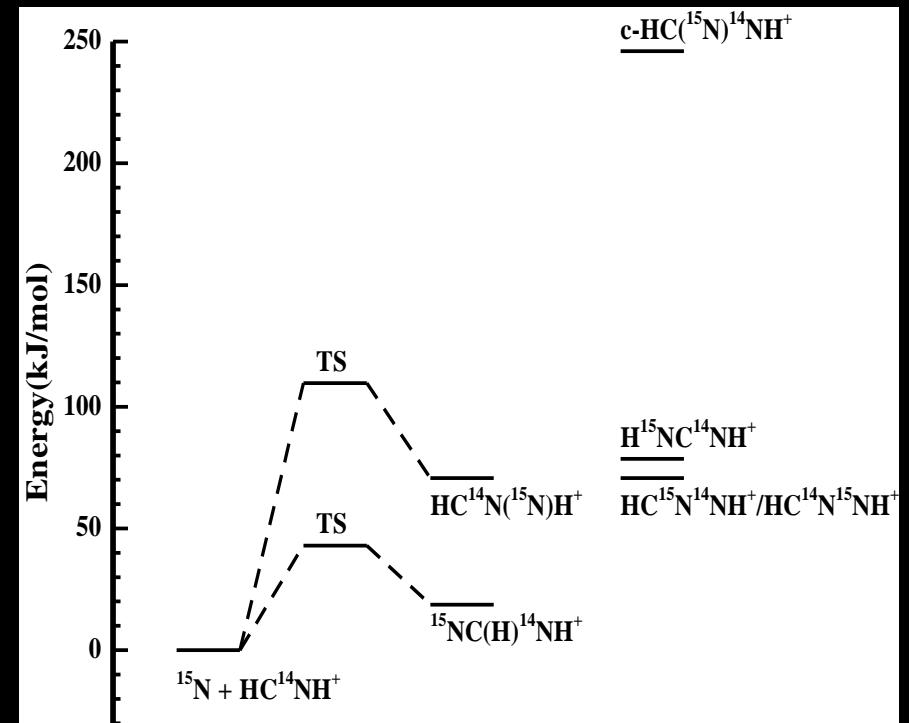
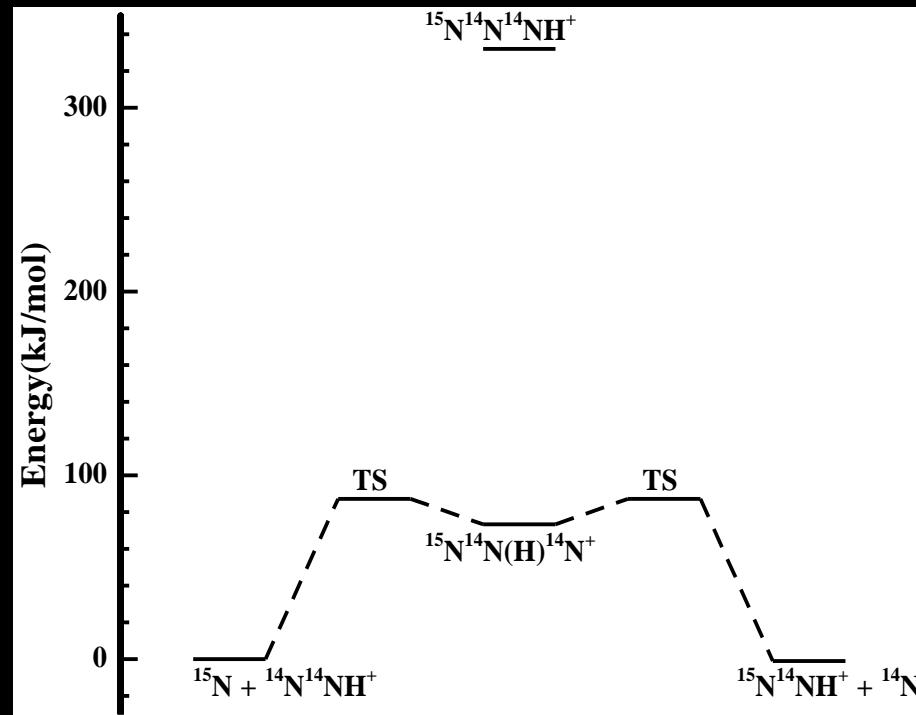
$$\text{O} = 2.0 \times 10^{-5}$$



$$\boxed{^{15}\text{N}}$$

## Terzieva & Herbst 2000

Reaction	$f(B, m)$ (10 K)	$\Delta E_0/k$ (K)	$K$ (10 K)
$\text{N}^{15}\text{N} + \text{HN}_2^+ \rightleftharpoons \text{N}_2 + \text{H}^{15}\text{NN}^+$	0.494	10.7	1.44
$\text{N}^{15}\text{N} + \text{HN}_2^+ \rightleftharpoons \text{N}_2 + \text{HN}^{15}\text{N}^+$	0.499	2.25	0.63
$^{15}\text{N}^+ + \text{N}_2 \rightleftharpoons \text{N}^+ + \text{N}^{15}\text{N}$	1.959	28.3	33.2
$^{15}\text{N}^+ + \text{NO} \rightleftharpoons \text{N}^+ + {}^{15}\text{NO}$	0.979	24.3	11.1
$^{15}\text{N} + \text{CNC}^+ \rightleftharpoons \text{N} + \text{C}^{15}\text{NC}^+$	0.938	36.4	35.7
$^{15}\text{N} + \text{HN}_2^+ \rightleftharpoons \text{N} + \text{H}^{15}\text{NN}^+$	0.968	36.1	35.8
$^{15}\text{N} + \text{HN}_2^+ \rightleftharpoons \text{N} + \text{HN}^{15}\text{N}^+$	0.977	27.7	15.6
$^{15}\text{N} + \text{HCNH}^+ \rightleftharpoons \text{N} + \text{HC}^{15}\text{NH}^+$	0.968	35.9	35.1



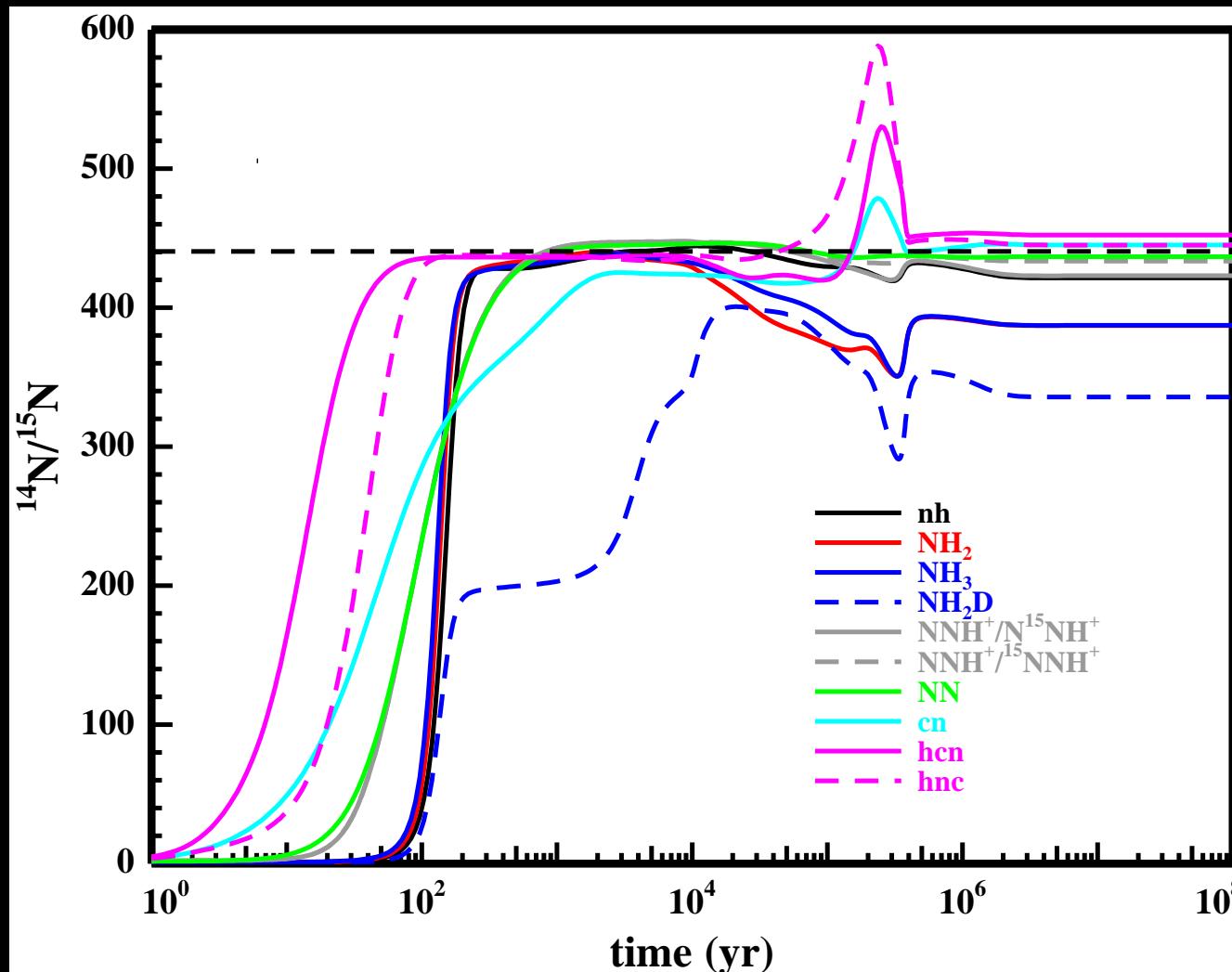
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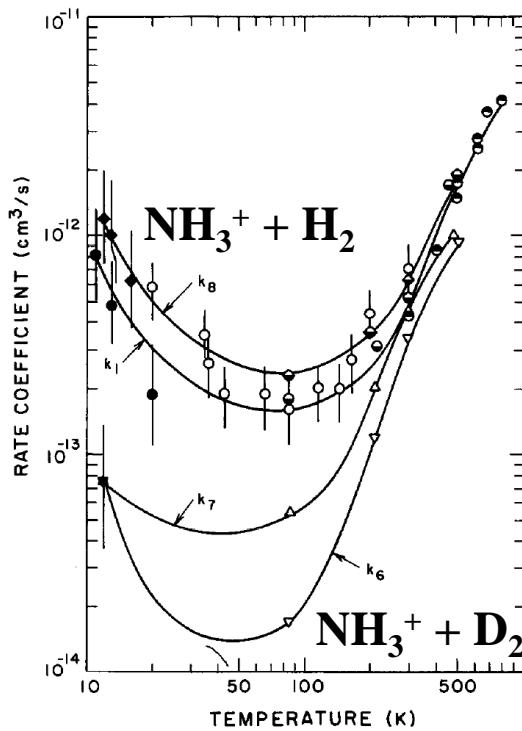
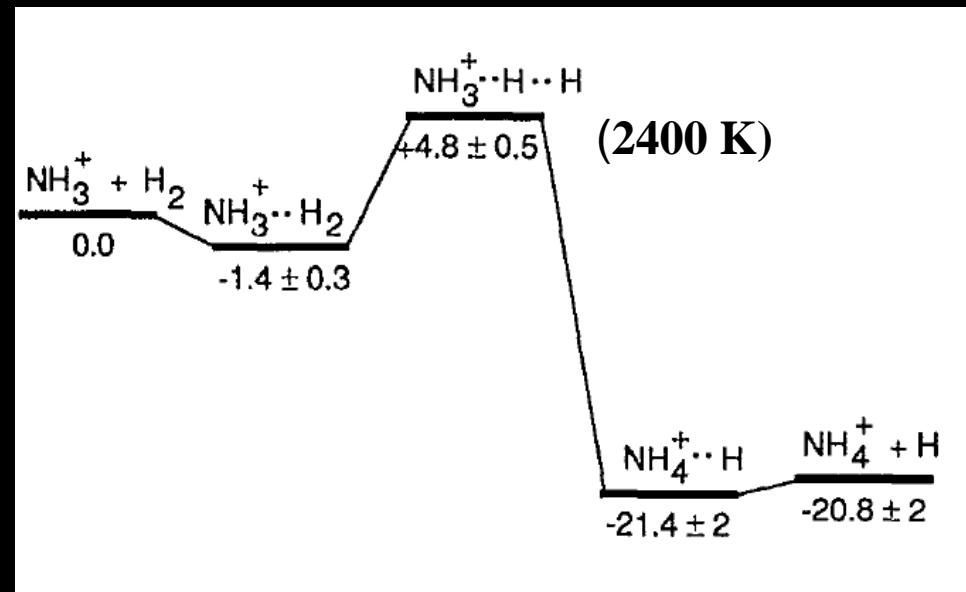
$\text{NH}_3^+ + \text{H}_2$ 


Fig. 2. Summary of ammonium formation reaction. Curves through the data are for visual purposes only.  $k_8$  [ $\text{ND}_3^+ + \text{H}_2$ ],  $\blacklozenge$ , this work;  $\lozenge$ , ref. 11 (total).  $k_1$  [ $\text{NH}_3^+ + \text{H}_2$ ],  $\bullet$ , this work and refs. 12 and 13;  $\circ$ , ref. 14;  $\bullet$ , refs. 10 and 11;  $\bullet$ , ref. 6.  $k_7$  [ $\text{ND}_3^+ + \text{D}_2$ ],  $\triangle$ , this work;  $\Delta$ , ref. 11.  $k_6$  [ $\text{NH}_3^+ + \text{D}_2$ ],  $\nabla$ , this work;  $\nabla$ , ref. 11 (total).

Barlow et al 1987

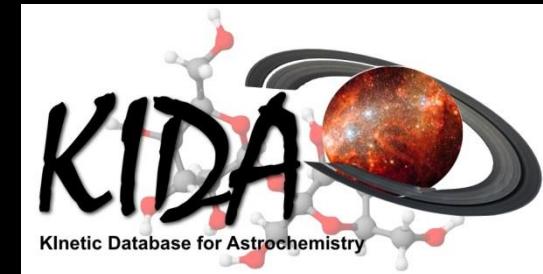


Herbst et al 1991

# Conclusion

- $\text{H} + \text{CCN} \rightarrow \text{C} + \text{HCN}$
- $\text{C} + \text{HNC} \rightarrow \text{C} + \text{HCN}$
- HCN/HNC/CN Chemistry in Protoplanetary Disks  
**(Poster of Laura Reboussin)**

→ HNC photolysis



• Low chemical  $^{15}\text{N}$  fractionation

• Variable  $^{13}\text{C}$  fractionation

→ Isotopologues on grain (Poster of Maxime Ruaud)

→  $\text{N}_2$ ,  $^{15}\text{NN}$ ,  $\text{NH}_3$  and  $^{15}\text{NH}_3$  photolysis