Surface formation of CO_2 ice at low temperatures

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Introduction

- *Infrared Space Observatory and Spitzer Space Telescope observations* have shown that H_2O, CO, CO_2 and in some cases, CH_3OH represent the bulk of solid-state species in dense molecular clouds and star-forming regions.
- Several of these species are assumed to be formed in solid state reactions on the surfaces of icy dust grains.
- A few of them have been measured in the laboratory at low temperatures and under ultra high vacuum (UHV) conditions.
- Hydrogenation of CO ice at low temperatures (12–20 K) leads to the subsequent formation of H_2CO and CH_3OH.

$$\mathrm{CO} \xrightarrow{\mathrm{H}} \mathrm{HCO} \xrightarrow{\mathrm{H}} \mathrm{H_2CO} \xrightarrow{\mathrm{H}} \mathrm{H_3CO} \xrightarrow{\mathrm{H}} \mathrm{CH_3OH}$$

- Hydrogenation of O_2 ice, which leads to the formation of H_2O_2 and H_2O.

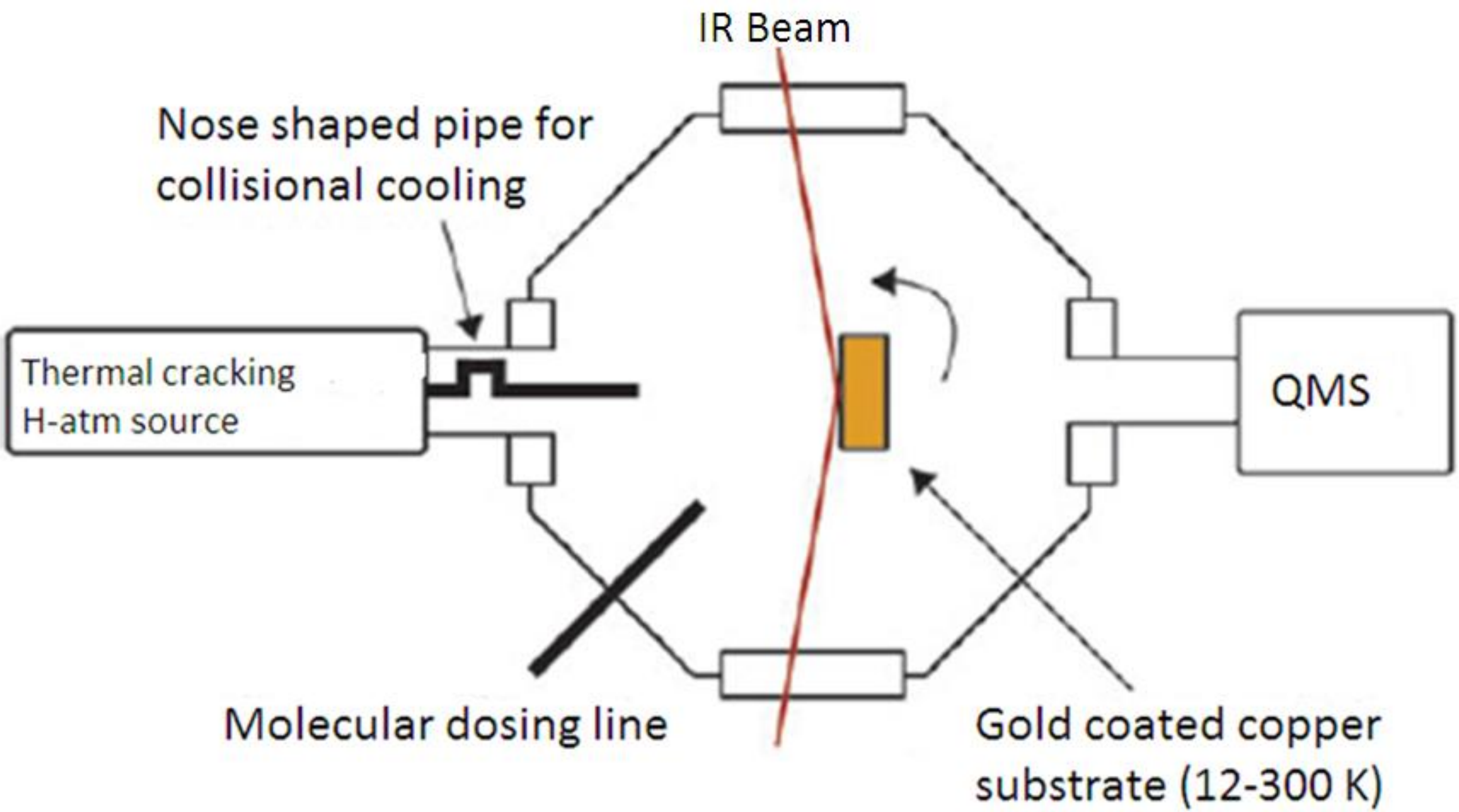
$$O_2 \xrightarrow{2H} H_2O_2 \xrightarrow{2H} 2H_2O$$

- CO_2 is one of the most common and abundant ices.
- It is widely accepted that CO_2 is formed efficiently in solid phase and not in the gas phase (CO_2^{gas} /CO_2^{ice} << 1; van et al. 1996; Boonman et al. 2003).

In this paper..................

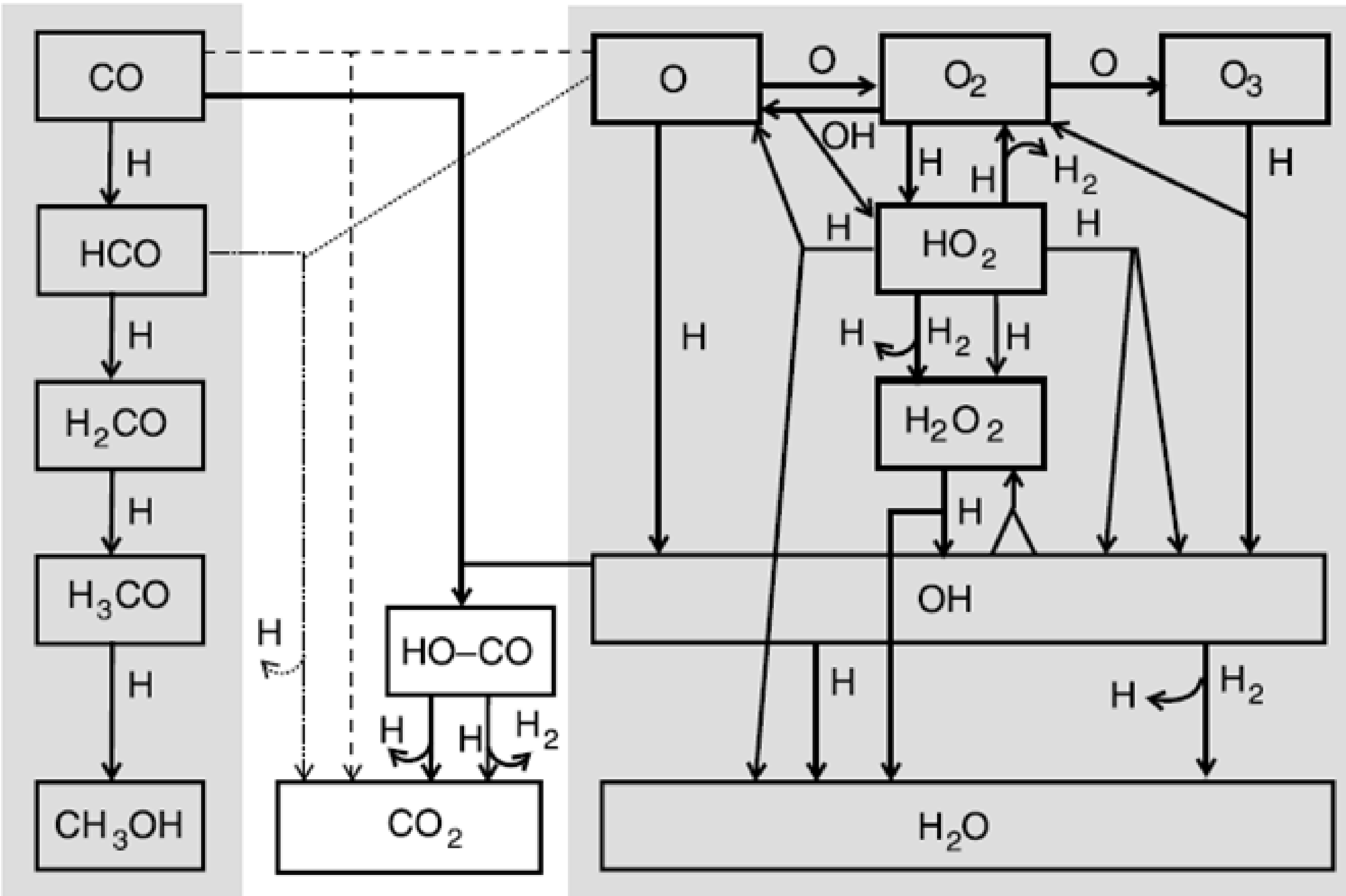
- The formation of solid CO_2 through hydrogenation of a binary $CO:O_2$ ice mixture have been studied.
- The competition between the two separate hydrogenation channels (CO + H and O_2 + H) have been investigated.

Experimental

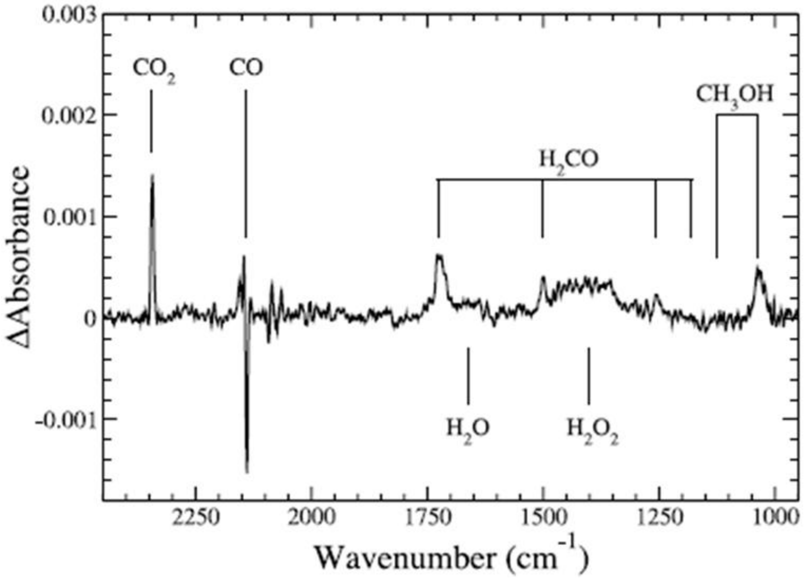


Schematic top-view of the solid-state experimental UHV set-up.

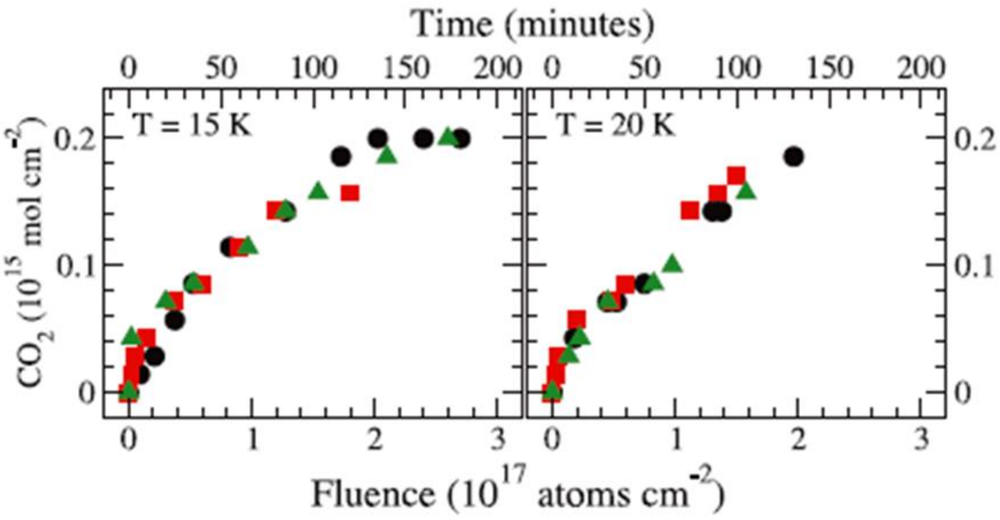
Discussion



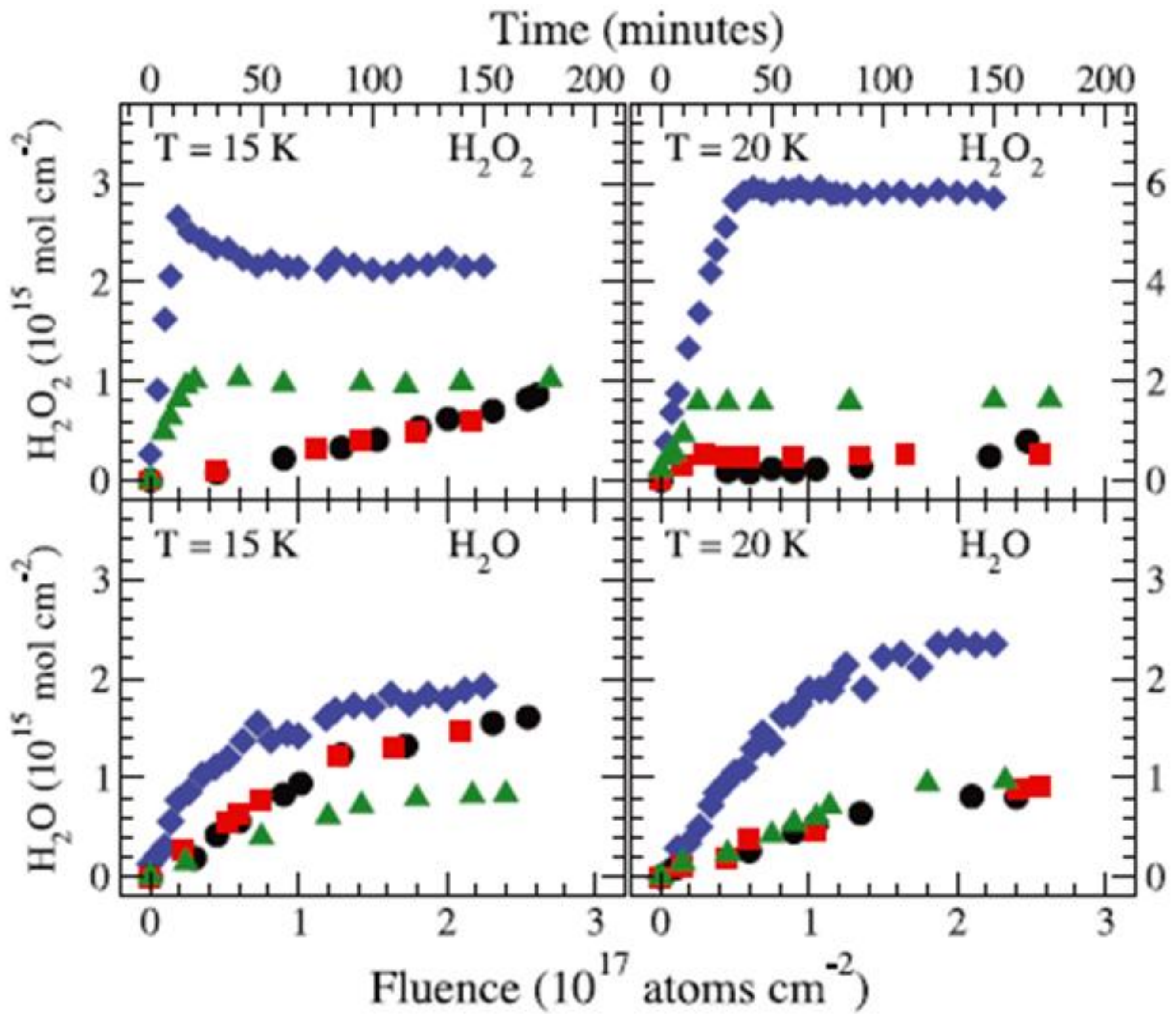
A schematic representation of the reaction network as discussed in the present study



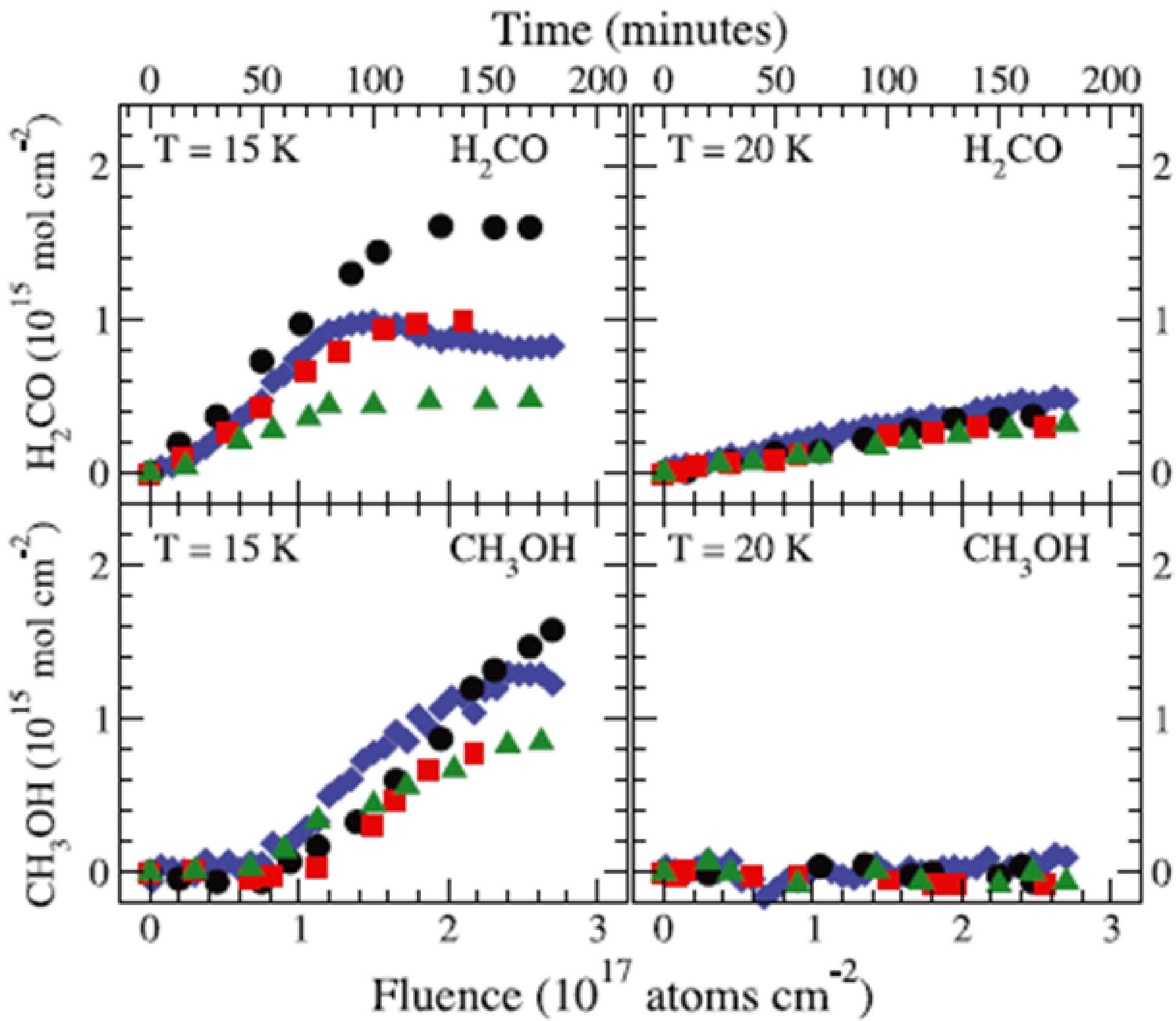
RAIR difference spectrum of the $CO:O_2$ = 1:4 ice at 15 K



CO_2 column density as a function of the H-atom fluence and time of H-atom exposure for the 3 mixtures studied: $CO:O_2$ = 4:1 (circle), 1:1 (square), and 1:4 (triangle)



H_2O_2 and H_2O column densities as a function of the H-atom fluence and time of H-atom exposure for the three mixtures studied: $CO:O_2$ = 4:1 (circle), 1:1 (square), and 1:4 (triangle). For comparison results from hydrogenation of pure O_2 ice are plotted (diamond).



H_2CO and CH_3OH column densities as a function of H-atom fluence and time of H-atom exposure at 15K and 20K for the three mixtures studied:CO:O2 = 4:1 (circle), 1:1 (square) and 1:4 (triangle). For comparison, results from the hydrogenation of pure CO ice are plotted (diamond).

Conclusions

- Solid CO_2 can be formed at astronomically relevant temperatures via a thermal CO + OH reaction path.
- CO_2 is formed efficiently and no strong dependency on temperature or ice composition is found.
- The formation of CO_2 competes with the hydrogenation of O_2 and CO.
- These experiments chemically link CO_2 and H_2O, consistent with the observation of CO_2 in H_2O-rich environments in space.

Future plans

- We can study the hydrogenation of CO on solid water surface.

Thank you