Solid-state formation of aldoses and polyols by CO hydrogenation under prestellar core conditions

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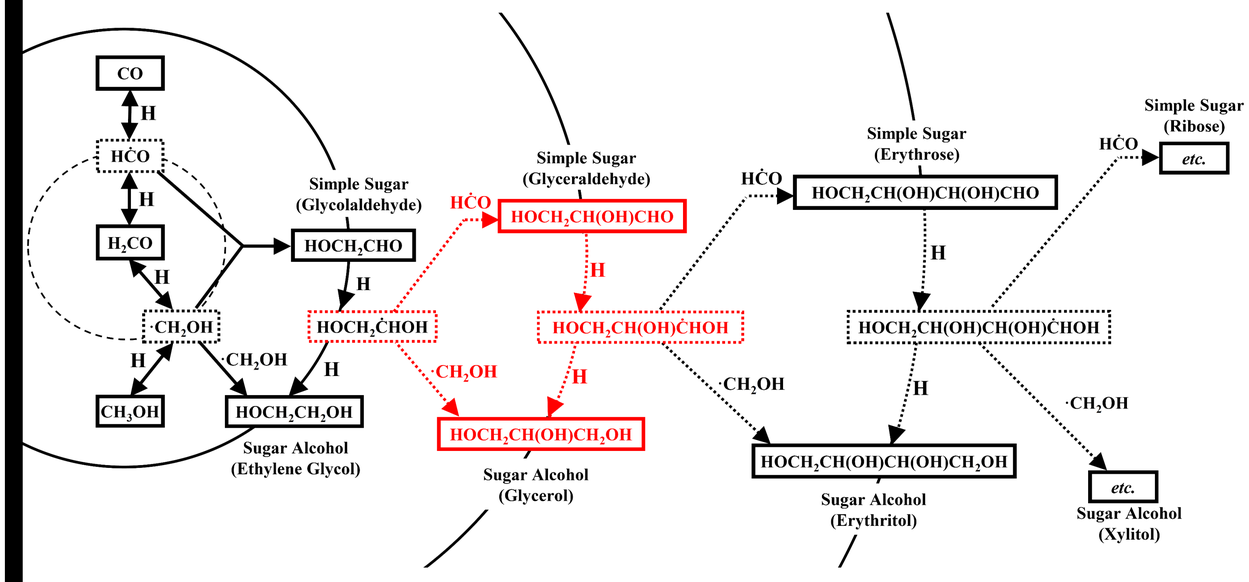
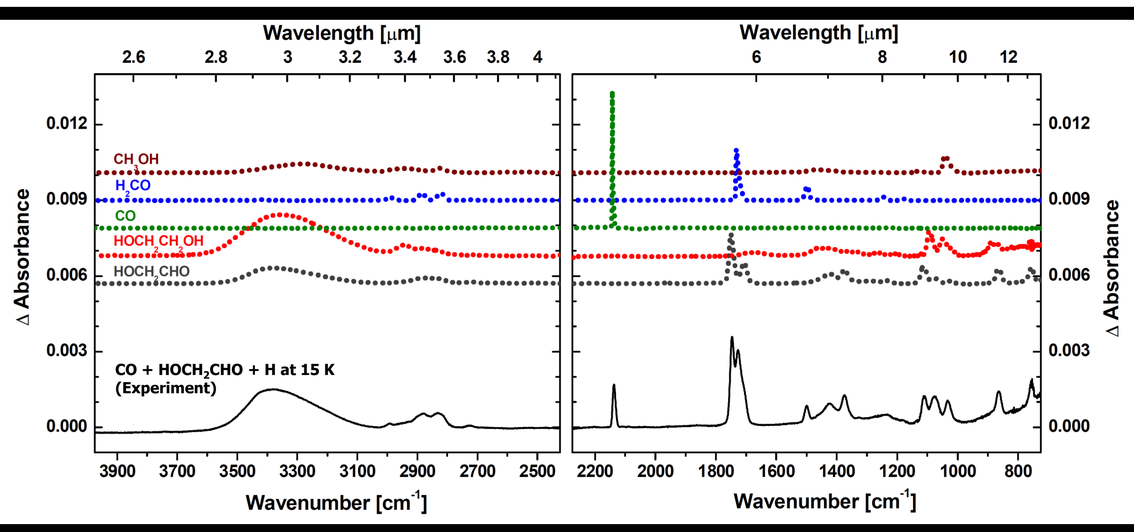
Motivation

The identification of complex organic molecules (COMs) in prestellar cores [1] is particularly important as this stage sets up the initial chemical composition for further star formation stages. Previous laboratory findings [2,3] demonstrate that molecules as complex as two-carbon bearing polyol ethylene glycol and aldose glycolaldehyde are efficiently formed on icy dust grains *via* 'non-energetic' atom addition reactions between accreting H atoms and CO molecules during the 'CO-freeze out stage' in dense cores. The present study aims to demonstrate that this formation mechanism results in the formation of 3-carbon bearing analogues of these COMs, polyol glycerol and aldose glyceraldehyde, and can be successfully generalised on the formation of n(carbon)≥4 representatives of polyol and aldose rows.

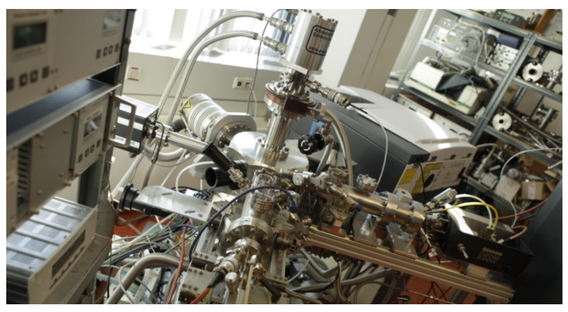


Example of obtained RAIRS data



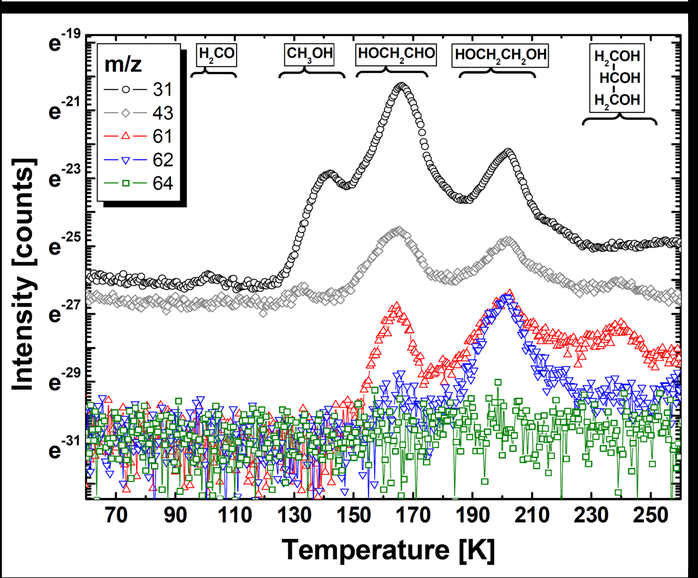
Analysis and Methods (SURFRESIDE²)

A steady abundance decrease is expected with increasing of COM size. Thus, two sets of experiments are performed. Initially, formation of first n(carbon)=1 and second n(carbon)=2 generation products is observed by hydrogenation of pure deposited CO molecules. Then hydrogenation of pure CO in presence of n(carbon)=2 generation products is performed to observe formation of n(carbon)=3 species.

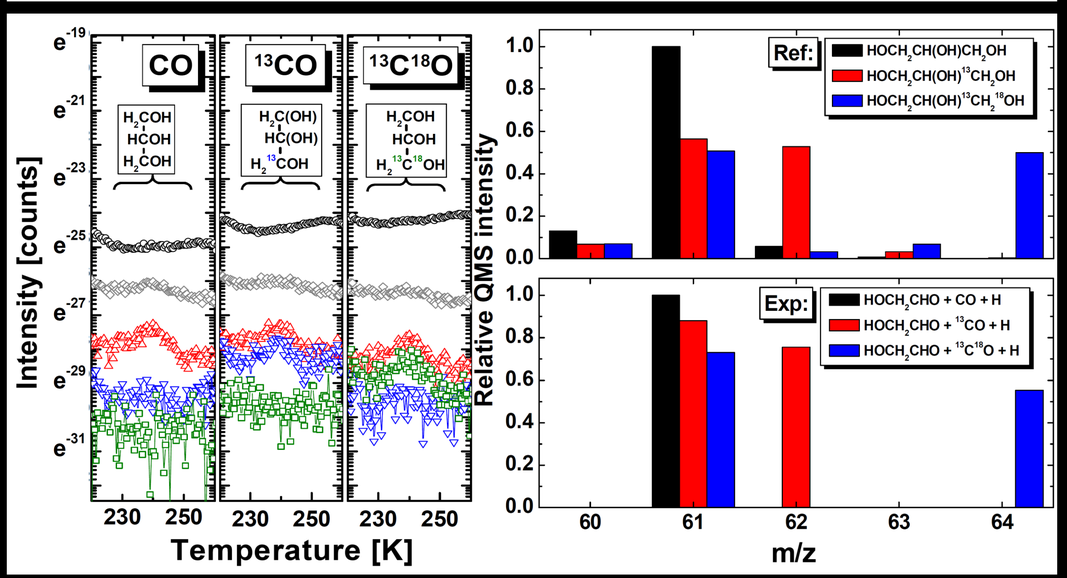


$p \sim 10^{-10}$ [mbar], T = 15 [K]
H flux: 8×10^{12} [cm^{-2} s^{-1}]
Molecular fluxes: 3×10^{11} [cm^{-2} s^{-1}]
Ice thicknesses: 10-20 monolayers

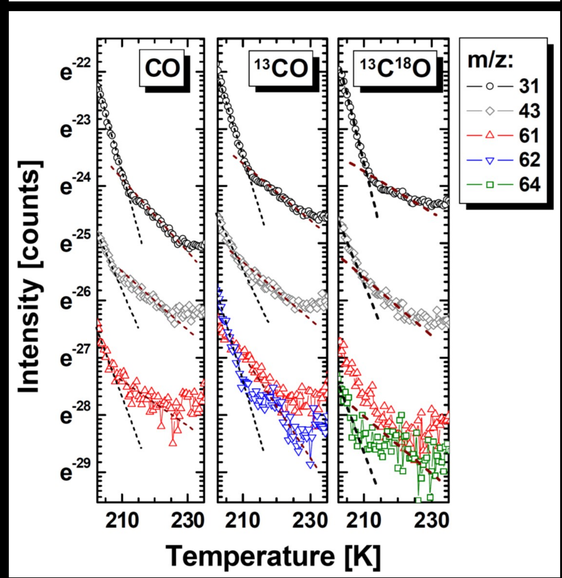
Application of QMS TPD



Unambiguous detection of Glycerol in the dedicated set of isotope labelling experiments



Tentative detection of Glyceraldehyde (peak at 220 K)



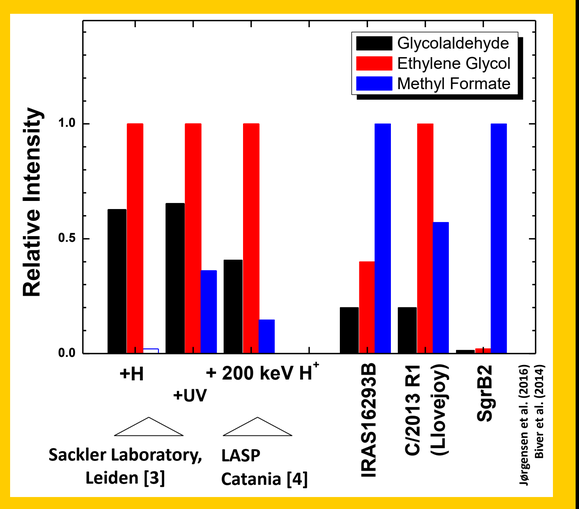
Conclusions

- **Laboratory results [5] demonstrate that Glycerol, a 3-carbon bearing sugar alcohol necessary for the formation of membranes of modern living cells and organelles, is efficiently formed during the 'CO-freeze out stage' in dense cores.**
- **While its sugar analogue glyceraldehyde can be tentatively identified in our study.**
- **Formation of these species is fully consistent with the suggested reaction chain that should result in the formation of even more complex representatives of sugar (aldoses) and sugar alcohols (polyols) rows already at the dark cloud stage prior to the formation of the hot core of the protostar.**

...and more:

a comparison between various chemical triggers for n(carbon)=2 COMs formation is now possible

Dark Clouds:	Laboratory:
Time: ~1×10^5 years	Time: few hours
H-atoms Density: ~ 1-10 cm^{-3} Fluence: ~ $1 \times 10^{15\text{-}16}$ cm^{-2}	H-atoms Flux: ~ 1×10^{12} cm^{-2} s^{-1} Fluence: ~ 2×10^{16} cm^{-2}
UV irradiation Flux: ~ 1.4×10^4 eV cm^{-2} s^{-1} Dose: ~ 0.04 eV per 16u (20 nm ice mantle)	UV irradiation Flux: ~ 3×10^{13} eV cm^{-2} s^{-1} Dose: ~ 0.05 eV per 16u
Ion irradiation (1 MeV H^+) Flux: ~ 1×10^6 eV cm^{-2} s^{-1} Dose: ~ 0.03 eV per 16u (20 nm ice mantle)	Ion irradiation (200 keV H^+) Flux: ~ 2×10^{16} eV cm^{-2} s^{-1} Dose: interpolation to ~ 0.03 eV per 16u



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[2] Fedoseev et al., MNRAS 448, 1228 (2015)
[3] Chuang, K.-J. et al., MNRAS 467, 2552 (2017)
[4] Modica, P. & Palumbo M. E., A&A 519, A22 (2010)
[5] Fedoseev, G. et al., ApJ 842, 52 (2017)