

# CO Chemisorbed on Bare Grain Surfaces: the Potential for Heterogeneous Chemistry

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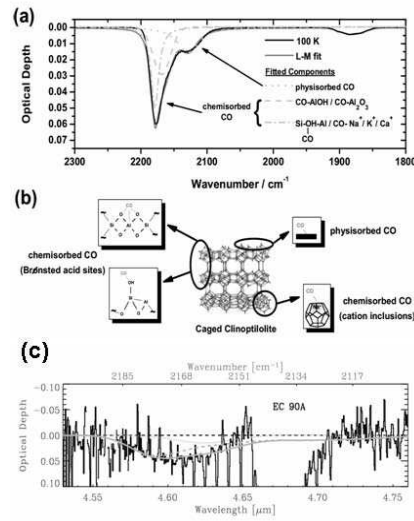
## Abstract.

For some time it has been known that interstellar dust is composed from a predominantly silicate core, most closely resembling amorphous Olivine or Pyroxene - but in reality the silicate bands arise from the 'bulk' of the dust grains. We have little if any information in the *surfaces* of interstellar dust grains. Over 50 low-mass and intermediate mass star-forming regions were surveyed using the VLT-ISAAC spectrometer: in the K-band spectra a previously undetected band was observed at  $2175\text{ cm}^{-1}$  (see Fig. 1) (Pontoppidan, *et al.* (2003)). Careful analysis of the data showed that the band was not CO-ice, nor wholly attributable to  $\text{OCN}^-$  (Fraser, *et al.* (2005)). A monte-carlo fit to the line-centre positions of the detected bands clearly showed that feature could be deconvolved into two peaks, with no evidence that the peaks had to have an identical carrier. The redder of the two peaks was centred at  $\approx 2166\text{ cm}^{-1}$ : the bluer peak at  $\approx 2175\text{ cm}^{-1}$ .

Comparisons between laboratory spectra of ices containing  $\text{OCN}^-$  and the  $2166\text{ cm}^{-1}$  feature indicate the presence of  $\text{OCN}^-$  towards a large fraction of these low-mass star forming regions (van Broekhuizen, *et al.* (2005)). From these data we are able to place upper limits on the abundance of  $\text{OCN}^-$  in interstellar ices around low-mass protostars, and, since these abundances vary widely in proximate objects in the same cloud, speculate as to the chemical routes by which the  $\text{OCN}^-$  might have formed, given additional constraints on the chemical nature of the ice, from concurrent detections of CO,  $\text{H}_2\text{O}$ ,  $\text{CO}_2$  and  $\text{CH}_3\text{OH}$  on the same lines of sight (Pontoppidan, *et al.* (2003), Thi, *et al.* (2005), van Broekhuizen, *et al.* (2005)).

A series of laboratory experiments were undertaken to identify the feature at around  $2175\text{ cm}^{-1}$ . CO was adsorbed to the clean surface of a naturally occurring Zeolite, Clinoptilolite, under high-vacuum and low-temperature conditions. Using transmission FTIR measurements, spectra of the adsorbed CO were taken, down to temperatures of 100 K, then compared directly with the astronomical data (Fraser, *et al.* (2005)). In the laboratory, absorption bands were detected at  $2177$  and  $2168\text{ cm}^{-1}$  (corresponding to CO chemisorbed at the Zeolite surface), and  $2130\text{ cm}^{-1}$  (corresponding to CO physisorbed at the Zeolite surface), (see Fig. 1(a) and (b)), and gave an excellent match to the observational data (see example in Fig. 1(c)).

Consequently this result has far-reaching implications for laboratory astrochemistry. So far, studies have concentrated on the chemistry and physics occurring on-top of, in the bulk of, and involving the icy mantles of interstellar dust grains. Using the band-strength of the CO-adsorbate band (estimated to be  $\approx 4 \times 10^{-19}\text{ cm molecule}^{-1}$ ), the abundance of CO adsorbed at bare grain surfaces ranges from 0.06 to 0.16 relative to  $\text{H}_2\text{O}$  ice, or around half the abundance of CO in  $\text{H}_2\text{O}$ -rich ice environments. These findings imply that interstellar grains have a large (catalytically-active) surface area, providing a refuge for interstellar species. Furthermore, with the existence of impurities embedded in the grains, the potential exists for heterogeneous chemistry to occur involving CO molecules in unique surface chemistry pathways not currently considered in gas-grain models or laboratory studies of interstellar chemistry. We speculate regarding these potentially powerful routes to forming many simple and complex molecules in



**Figure 1.** (a) The laboratory spectrum of CO chemisorbed and physisorbed on Clinoptilolite, a naturally occurring Zeolite, showing the Levenberg-Marquet non-linear least squares fitting of the spectrum, used to identify and subsequently assign the binding sites, as illustrated in (b). (c) Comparison between the observational spectrum of one low-mass object (black line), with a computed fit to the observation (solid grey line), convolved from the laboratory CO-zeolite spectrum (grey dashed line), and a contribution from  $\text{OCN}^-$  ions (dotted grey line). Adapted from Fraser, *et al.* (2005).

interstellar space, and explain how this avenue of research will be pursued in the new astrochemistry laboratory in Strathclyde.

**Keywords.** astrochemistry - line:identification - molecular data - molecular processes - methods:laboratory

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