Desorption of volatile molecules from interstellar carbonaceous dust analogs

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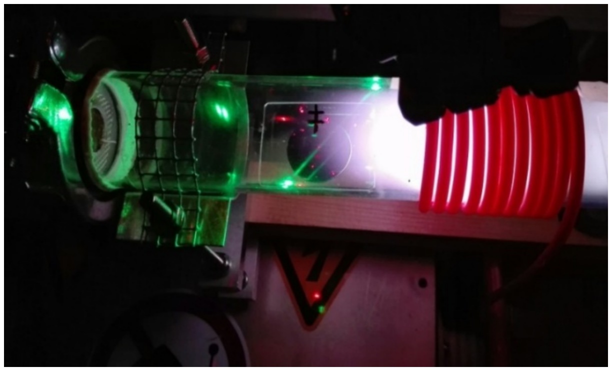
Outline

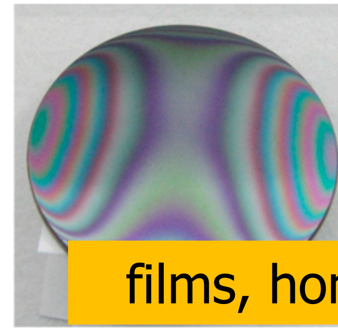
- Hydrogenated amorphous carbon as ISM dust analogs
- N_2,CO, CH_4 and CO_2 desorption from dust analogues
- Summary

Plasma generation of interstellar dust analogs



Inductive RF discharge

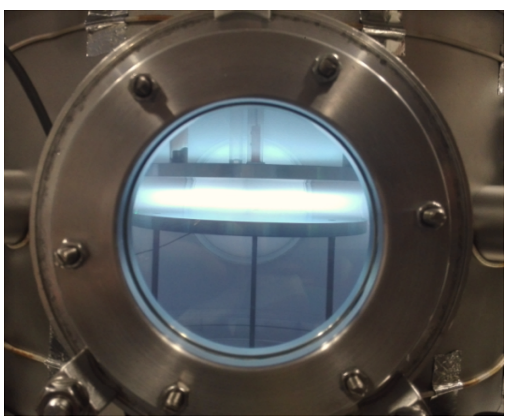
He, 10 sccm
CH_4, 5 sccm
P_{tot}, 0.27 mbar
40 W
t_{dep}, 8 min
Al substrate



HAC1

films, homogeneous

Peláez et al., 2018, Plasma Sources Sci. Technol.



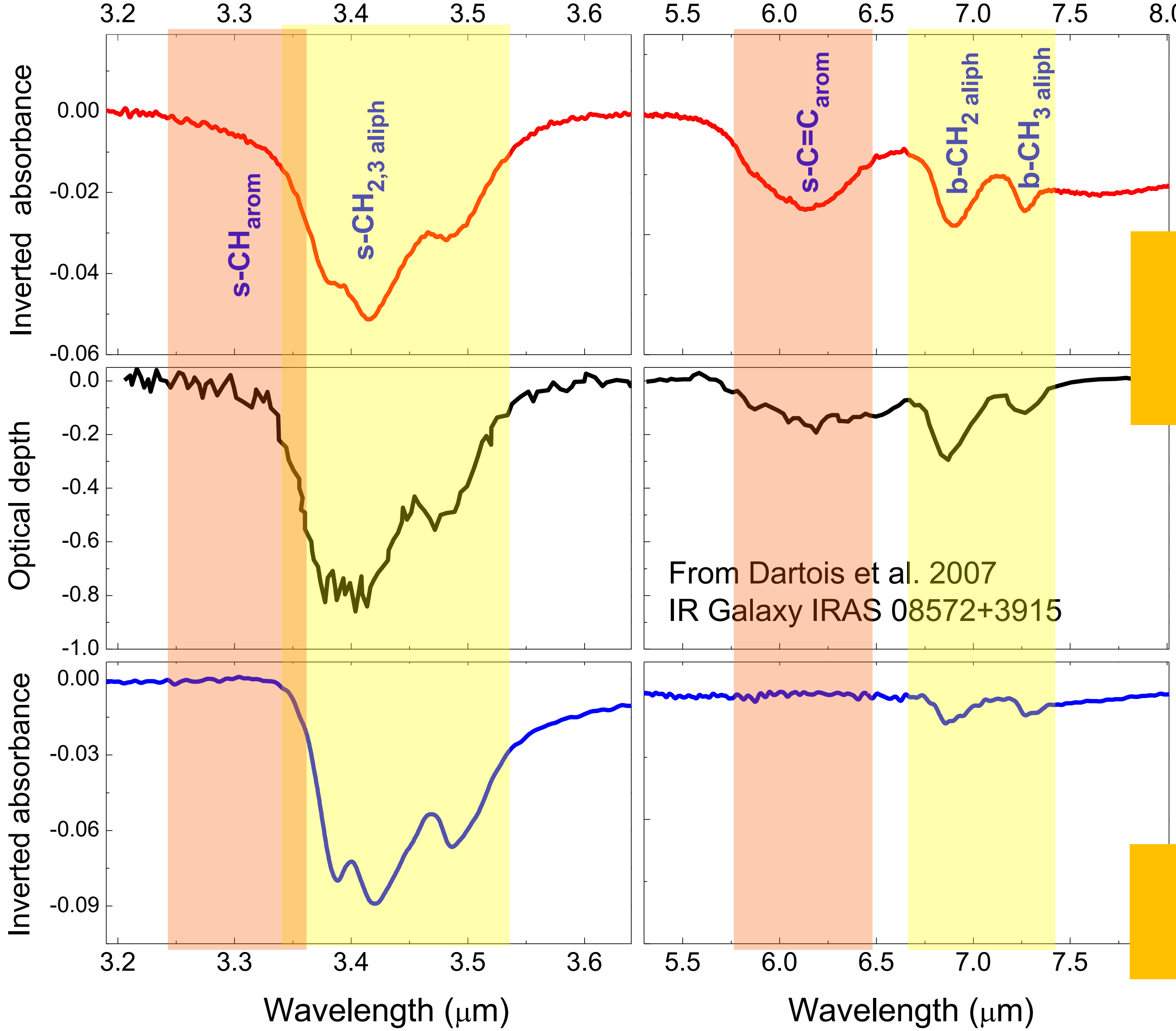
Capacitive RF discharge

Ar, 5 sccm
C_2H_2, 2 sccm
P_{tot}, 0.31 mbar
15 W
Modulation:
15 s On/ 6 s Off
t_{dep}, 80 min
Al substrate

HAC2

SEM shows agglomeration of ~150 nm diameter dust particules

IR spectra: comparison with observations



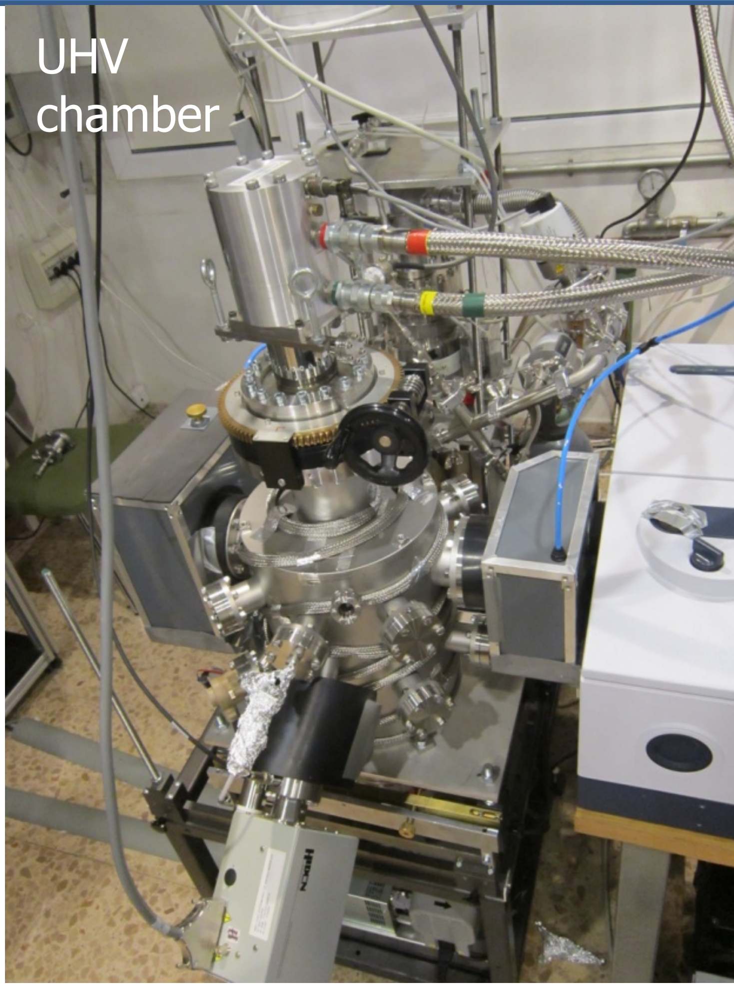
HAC2 Dust

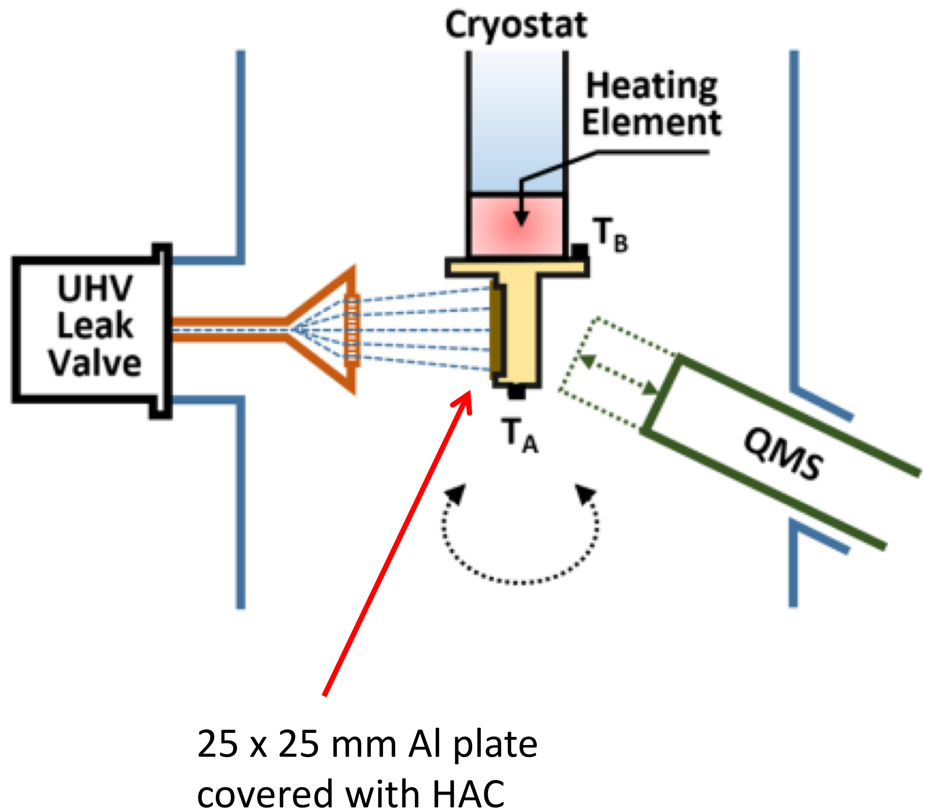
has aliphatic and aromatic structures

HAC1 film

essentially aliphatic

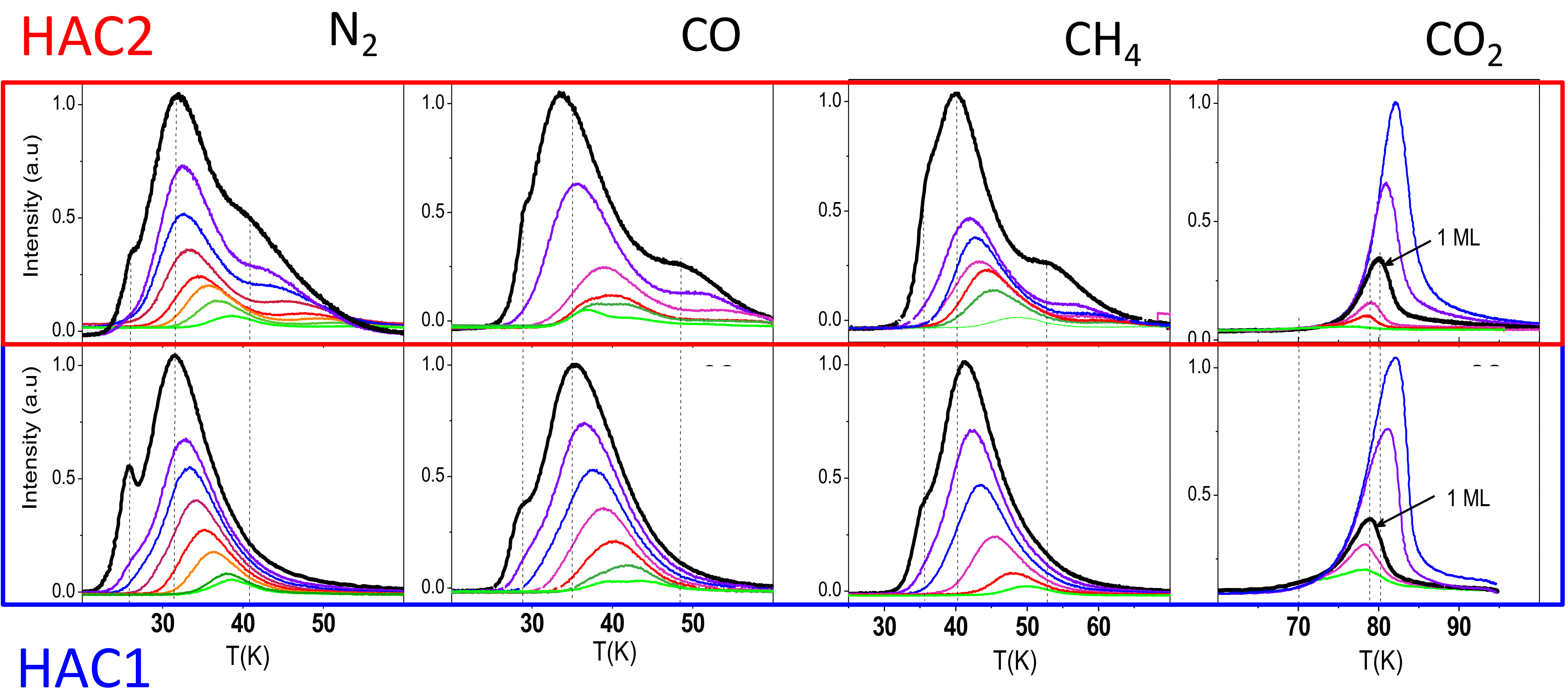
Thermal programmed desorption of N_2, CO, CH_4 and CO_2 from HAC





- Turbomolrcular pump: S=700 l s^{-1} for N_2
- He closed cycle cryostat: 15-300 K
- Precision leak valve : down to 10^{-10} mbar l s^{-1}
- Base pressure, $P_b \approx 1\ 10^{-10}$ mbar

TPD spectra of volatiles from HAC



- Desorption rate proportional to QMS signal (τ_{res}=(V/S) ≈ 10 ms)
- Heating ramp, β = 20 K/min
- I_{QMS} (t) → I_{QMS} (T)

Study of sub-monolayer coverages, (black trace, ≈ 1 ML)

Maté et al., 2019 MNRAS, submitted

Desorption energy: inversion analysis

Polanyi-Wigner equation:

$$E_d(\theta) = -k_B T \ln\left(-\frac{d\theta/dt}{\nu\theta^n}\right)$$

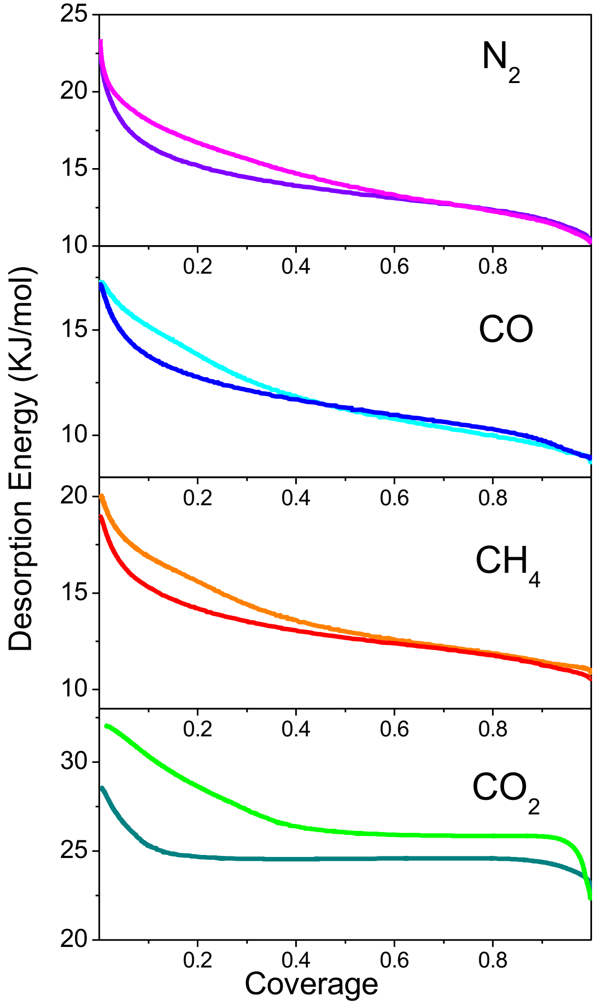
E_d (ϑ) = desorption energy

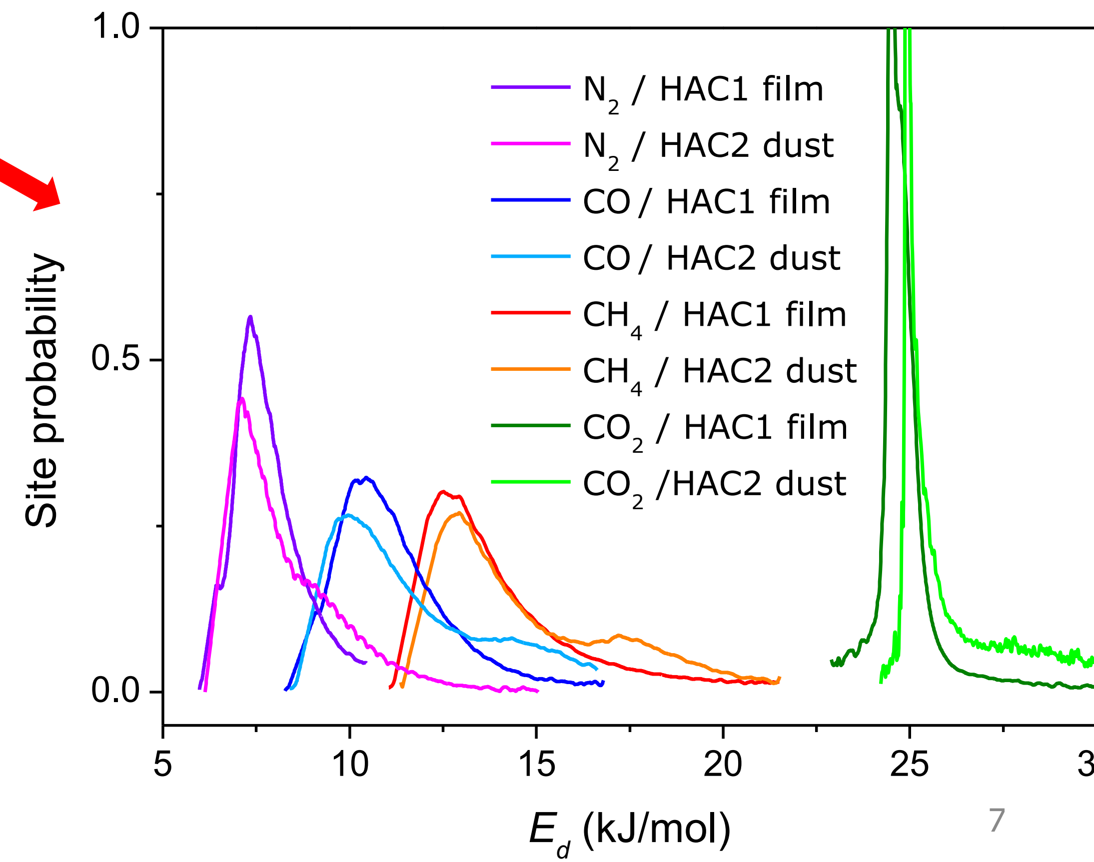
ν = pre-exponential factor **:** **10^{13}** s^{-1}.

ϑ = coverage . Applied to **θ =1 (i.e. 1 ML)**

n = desorption order .

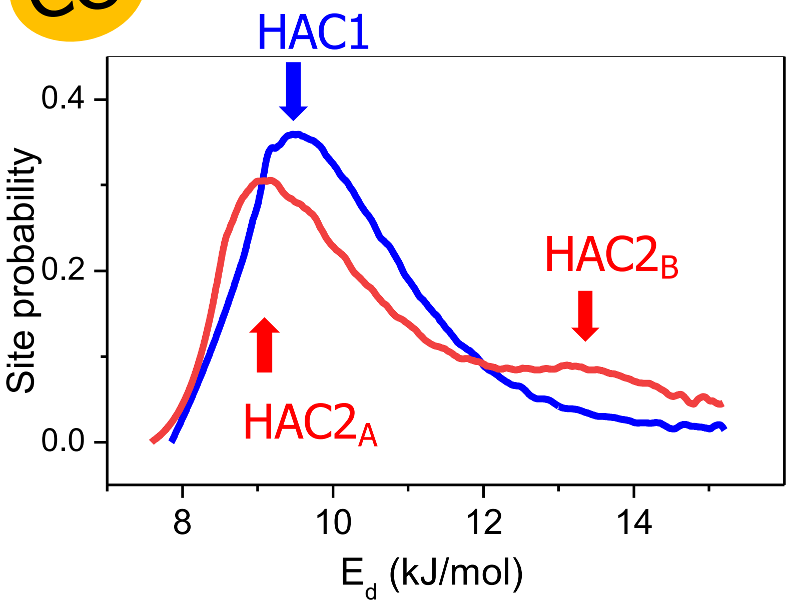
***n*=1** for N_2, CO and CH_4 ; ***n*=0** for CO_2





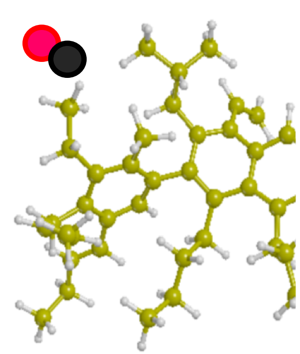
Aromatic and aliphatic surface sites

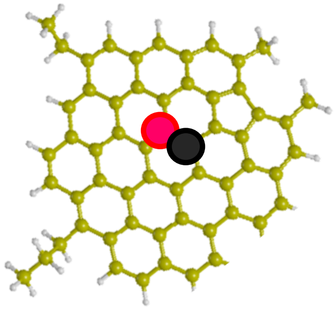
CO



E_d (kJ/mol), for 1 ML

	HAC1 film	$HAC2_A$ dust	**$HAC2_B$ dust**	**Graphite**	**Graphene**
N_2	8.5	8.6	10.9	**11.0** [a]	**11.6** [b]
CO	9.6	9.1	13.2	**12.1** [a]	**12.5** [b]
CH_4	11.2	10.8	14.7	**14.4** [a]	**14.9** [b]

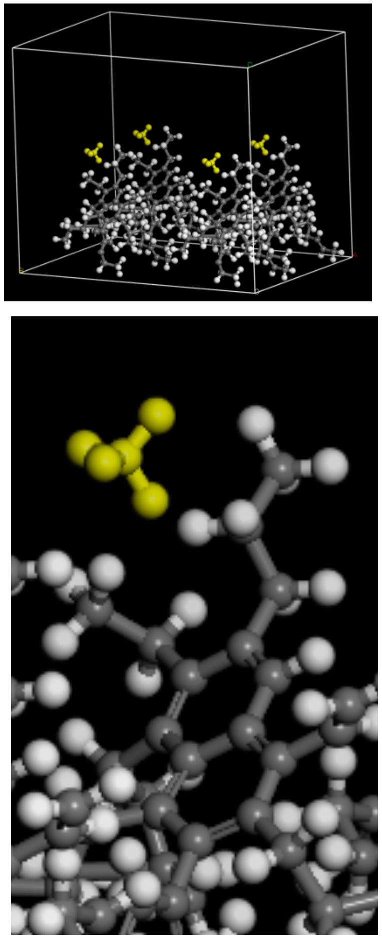




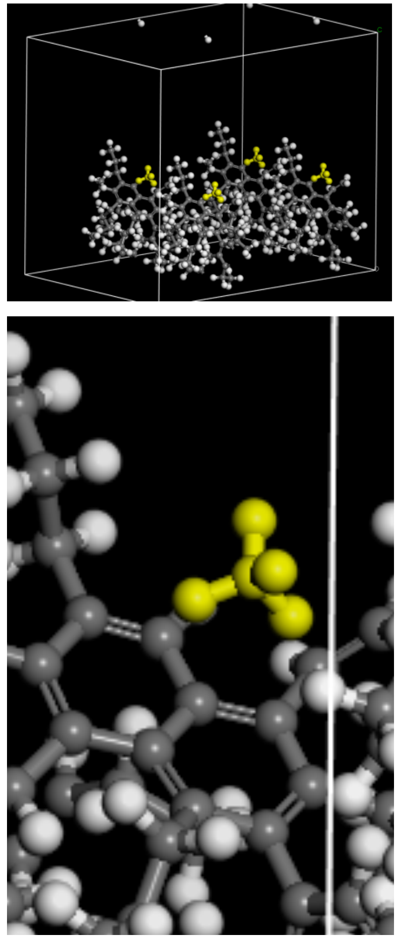
a) H. Ulbricht et al. 2006 Carbon, 44, 2931. Redhead analysis, recalculated with ν= 10^{13} s^{-1}
b) R. S. Smith et al. 2016, JPC B, 120, 1979. Inversion analysis. Average of energy distribution

Aromatic and aliphatic surface sites: DFT calculations

Aliphatic site



Aromatic site



CH_4

EXPERIMENTAL, E_d(kJ/mol)

HAC1	$HAC2_A$	$\mathbf{HAC2_B}$	**graphite Ulbrich07**
11.2	10.8	14.7	**14.4**

CALCULATIONS, E (kJ/mol) (this work, preliminary)

aliphatic site	aromatic site	**graphite**
8.6	16.7	14.5

Surfaces from HAC solids described in Molpeceres et al. 2017, PCCP.

Comparison with other astrophysical relevant surfaces

CO

Surface	Ed(kJ/mol) (pre-exp. factor)	Reference	Ed averaged
HAC1	10.3 ± 0.2 (10^{13} s^{-1})	this work	
HAC2	10.6 ± 0.2 (10^{13} s^{-1})	this work	
graphene	12.5 (1.9×10^{13} s^{-1})	Smith et al. 2016, JPC B.	11.5
HOPG	13 ± 1 (6×10^{14} s^{-1})	Ulbricht et al. 2006, C	
graphite	11	Vidali et al. 1991, SS	
SiO_x	7.2 (10^{12} s^{-1})	Noble et al. 2012, M	
SiO_x	7.3 ± 0.2 (10^{12} s^{-1})	Collings et al. 2015, M	
Mg_2SiO_x	9.3 ± 0.1 (10^{12} s^{-1})	Suhasaria et al. 2017,	
ASWcryst	7.2 (10^{12} s^{-1})	Noble et al. 2012, M	
ASWnp	8.4 (10^{12} s^{-1})	Noble et al. 2012, M	
ASWnp	11.8 (3.5×10^{16} s^{-1})	Smith et al. 2016, JPC B.	
ASWnp	8.1 (10^{12} s^{-1})	He et al. 2016, ApJ.	8.9
ASWnp	9.7 (7.1×10^{11} s^{-1})	Fayolle et al. 2016, ApJL	
ASWp	8.6 (10^{12} s^{-1})	He et al. 2016, ApJ.	

E_d (carb. dust)

$>$

E_d (ASW)

$>$

E_d (silic. dust)

Summary and conclusions

- Two HAC samples, taken as interstellar dust analogs, have been produced in plasma reactors. HAC1: film (mostly aliphatic structure). HAC2: aglomeration of dust particles (both aliphatic and aromatic structures).

- TPD experiments of N_2, CO, CH_4 and CO_2 from the two carbonaceous solids were performed. The TPD spectra from the aliphatic film present just one maximum whereas those from the aliphatic/aromatic dust sample have a maximum and a shoulder.

- The comparison with literature values suggests that the interaction of volatiles with the aromatic structures is stronger than with the aliphatic part of the solids.

- In general, interactions of volatiles with carbonaceous surfaces seem stronger than with other surfaces relevant in interstellar grains like water-ice or silicate analogs.

Thank you
for your attention

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http://www.iem.cfmac.csic.es/fismol/fmap/

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