# Determining the photodesorption rate of CO and $H_2O$ ice
## *-a novel approach-*

Daniel M. Paardekooper

G. Fedoseev, A. Riedo and H. Linnartz

Sackler Laboratory for Astrophysics, Leiden University

*dmpaardekooper@strw.leidenuniv.nl*

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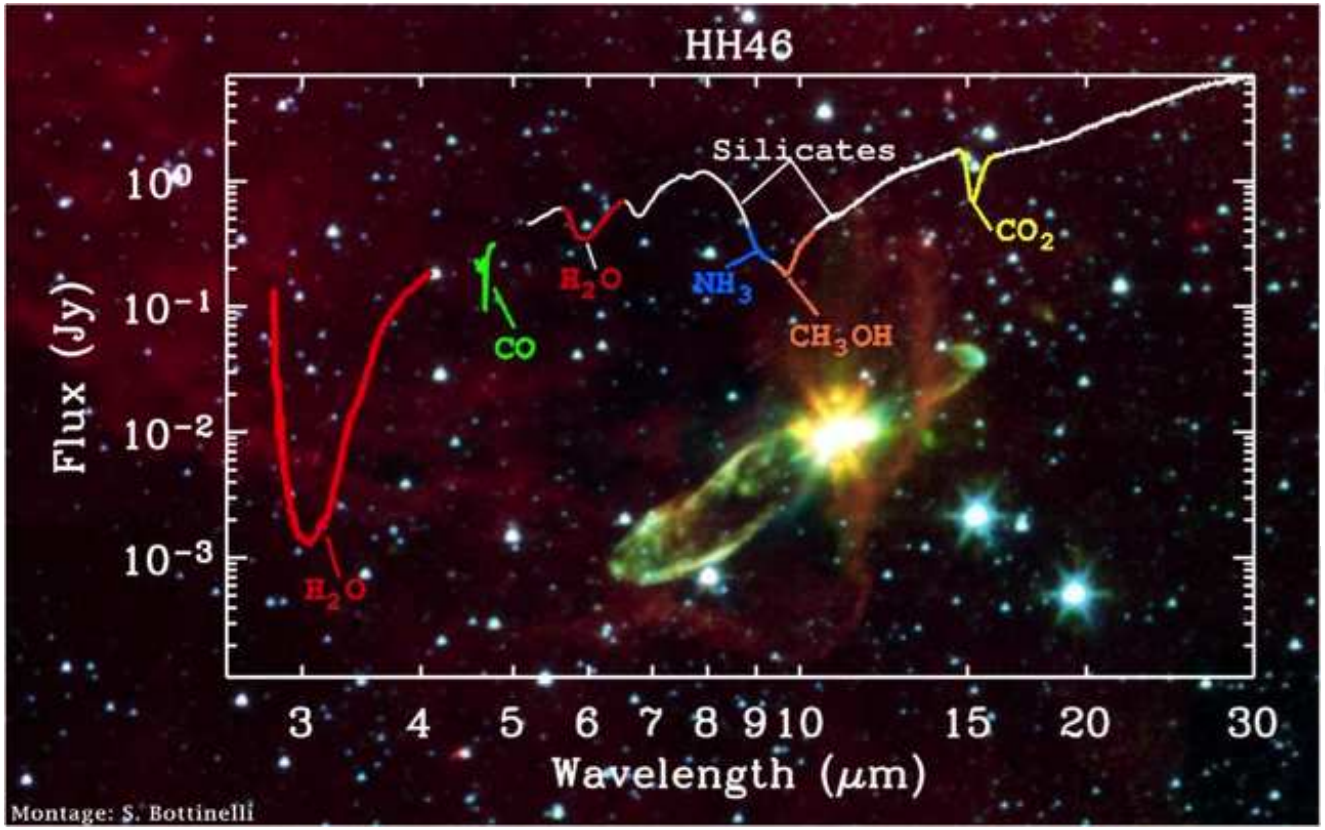
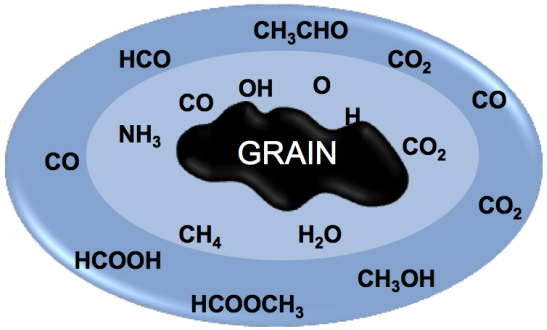
# Ices in star forming regions

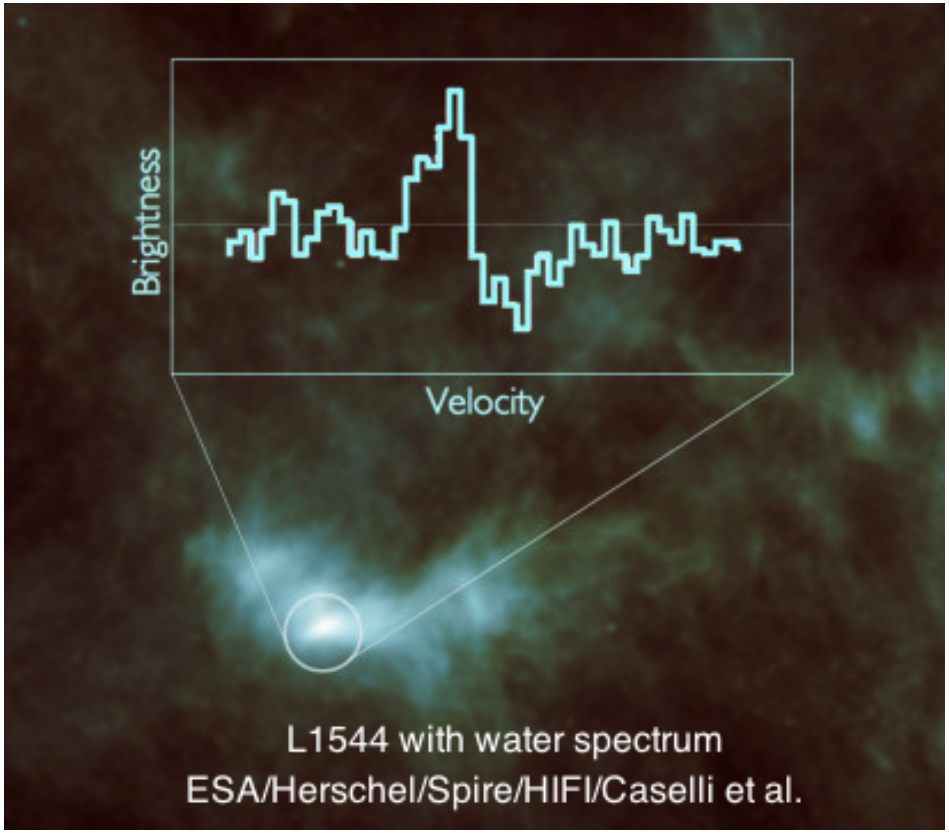



T= 10-20 K

- Molecules are found in the gas and solid phase.
- Important species in the solid phase: $H_2O$, CO, $CH_3OH$...

# Gas phase species observed in cold regions



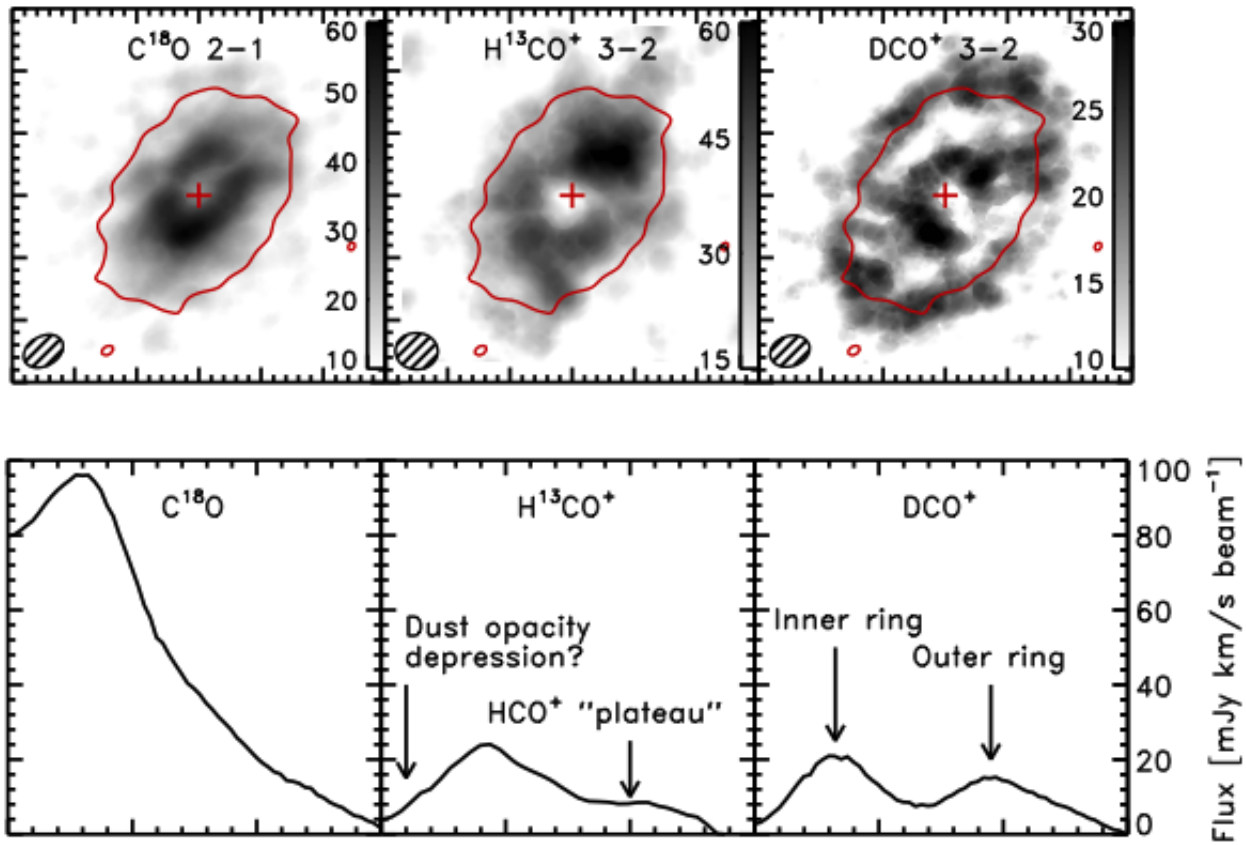

Water in prestellar core

- Gas phase formation route

Non-thermal desorption from dust grains by:

- Cosmic ray spot heating
- Exothermic chemistry
- Electron induced desorption
- VUV induced photodesorption

# Gas phase species observed in cold regions

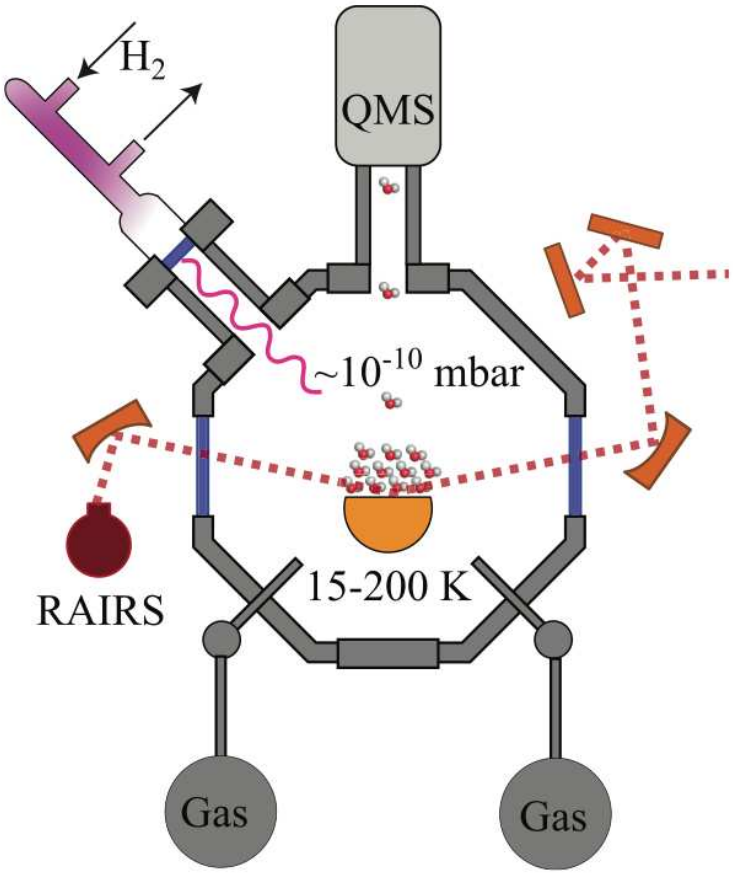



Double ring structure explained by thermal and VUV photodesorption. Öberg et al. (2015)

# Photodesorption in the lab

Broadband discharge lamps ($H_2$) are used as VUV light source.

Detection scheme: infrared (IR) spectroscopy in conjuction with quadrupole mass spectrometry (QMS).




Cryopad [Öberg et al.]

# Literature on photodesorption

CO: broadband discharge lamp ($H_2$) is used as VUV light source:

| | Öberg (2007) | Muñoz Caro (2010) | Chen (2014) |
|---|---|---|---|
| Photodesorption rate (molecules/photon) | $(2.7 \pm 1.3)$ $10^{-3}$ | $(3.5 \pm 0.5)$ $10^{-2}$ | $(2.12 \pm 0.03)$ $10^{-1}$ |

CO Photodesorption value spans 3 orders of magnitude

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CO: Synchrotron as photon source, see Fayolle (2011)

8.2 eV $(2.8 \pm 1.7) \cdot 10^{-2}$ molecules/photon

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$H_2O$ photodesorption: $3 \cdot 10^{-3}$ (35 K) Westley et al. (1995)

$H_2O$ photodesorption: $2 \cdot 10^{-3}$ (20 K) Öberg et al. (2010)

# Photodesorption in the lab

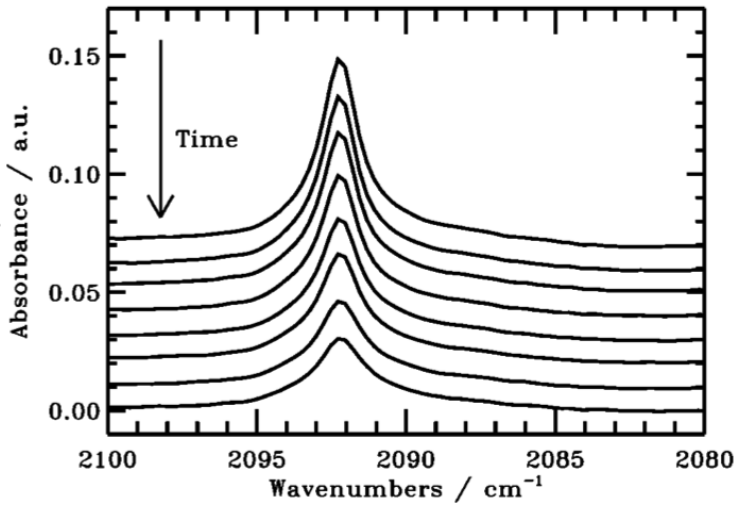
Both methods come with restrictions;

IR spectroscopy:

- Hard to discriminate between signal loss due photodesorption or other processes (e.g. photochemistry)

QMS:

- Challenge to convert the gas-phase abundance into (photo)desorption rate.




Öberg et al. (2007)

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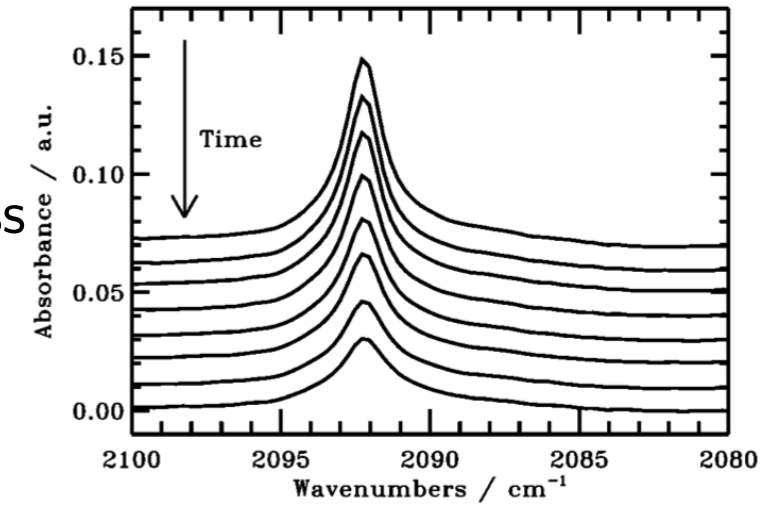


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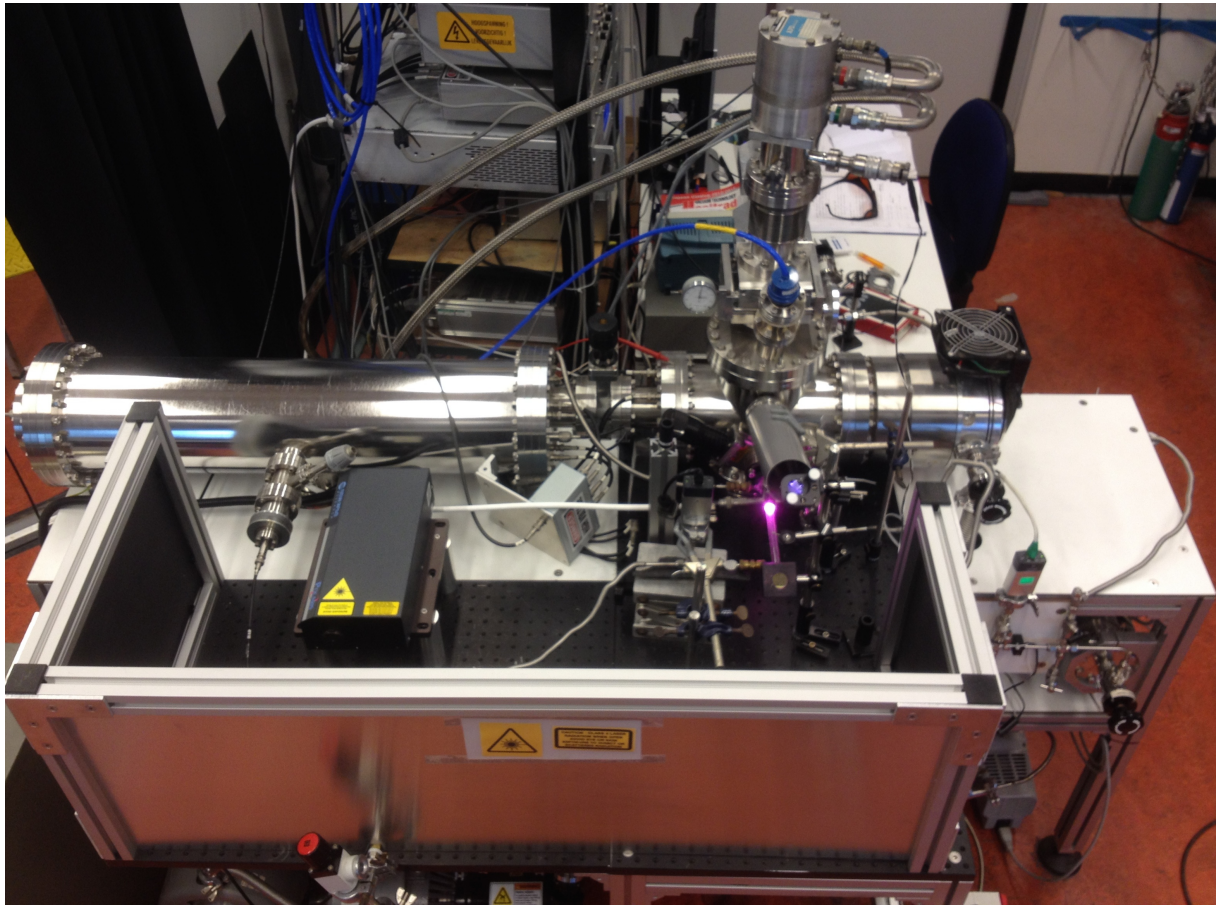
Determine the photodesorption rate with an alternative detection scheme.



MATRI$^2$CES (Mass Analytical Tool for Tracing Reactions in ICES.)
(Paardekooper et al. 2014)

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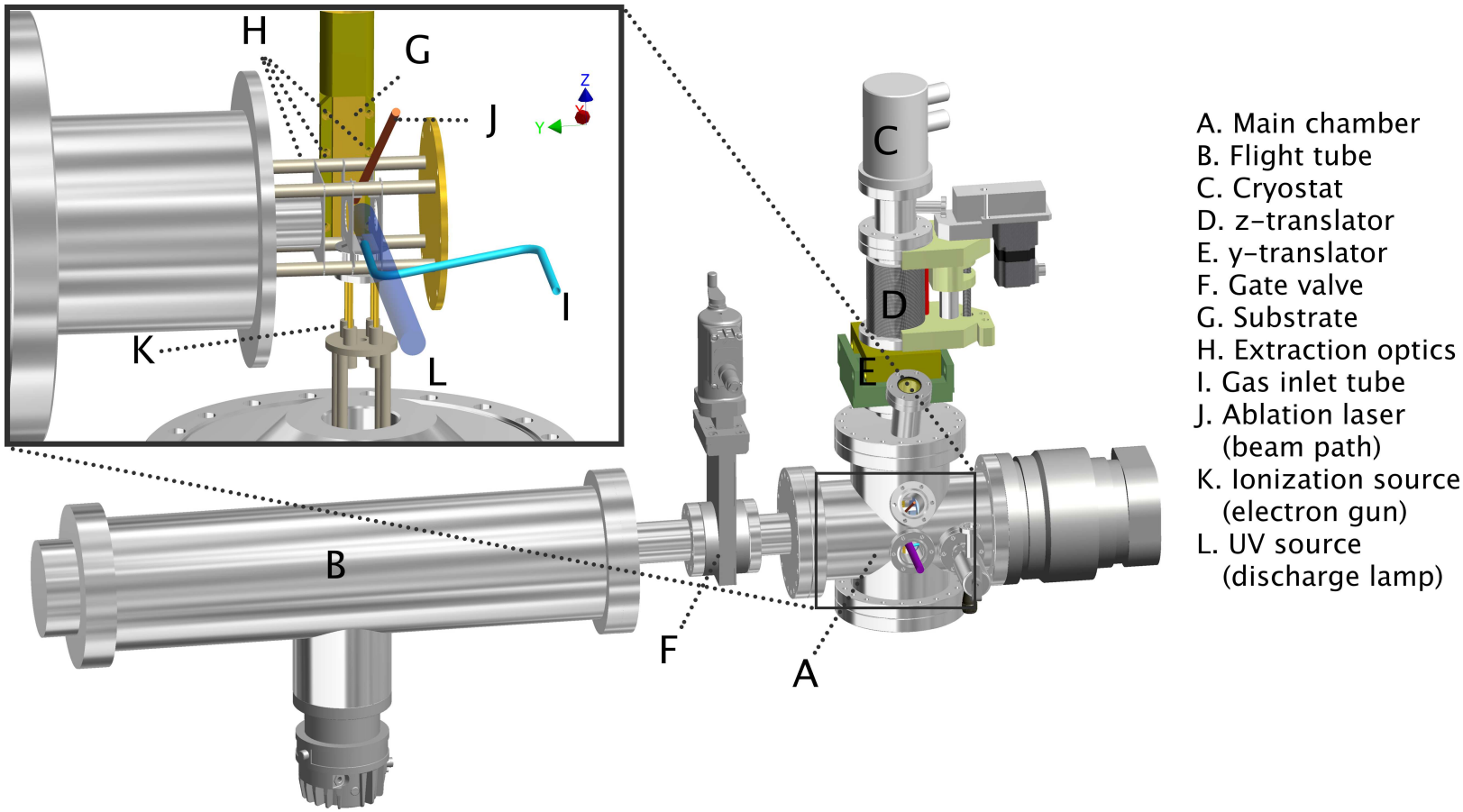


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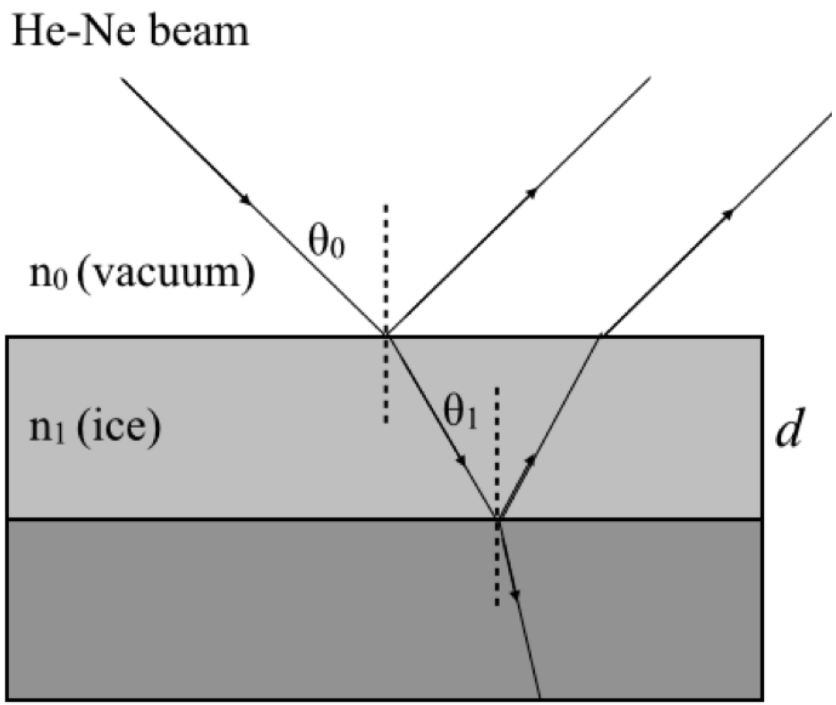
# Deposition rate calibration (HeNe interference)



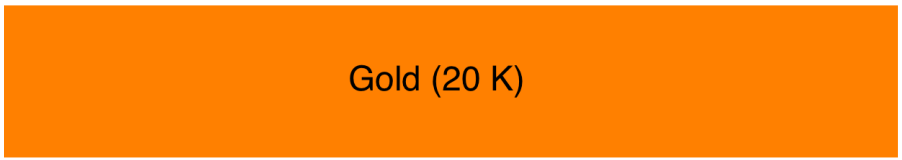

$$d = \frac{\lambda}{2n_1/n_0 \cdot cos(\theta_1)} \quad (1)$$

$$\text{Deposition rate} = \frac{d \cdot \rho \cdot N_a}{M \cdot t} \quad (2)$$

Deposition rate for CO: $1.7 \cdot 10^{13}$ molecules cm$^{-2}$ s$^{-1}$
Deposition rate for $H_2O$: $3.0 \cdot 10^{13}$ molecules cm$^{-2}$ s$^{-1}$

CO at 20 K, $\rho = 0.80$ g cm$^{-3}$ and $n_1 = 1.27$ (Roux et al. 1980)
$H_2O$ at 125 K, $\rho = 0.93$ g cm$^{-3}$ and $n_1 = 1.31$ (Brown et al. 1996)

# Detection scheme



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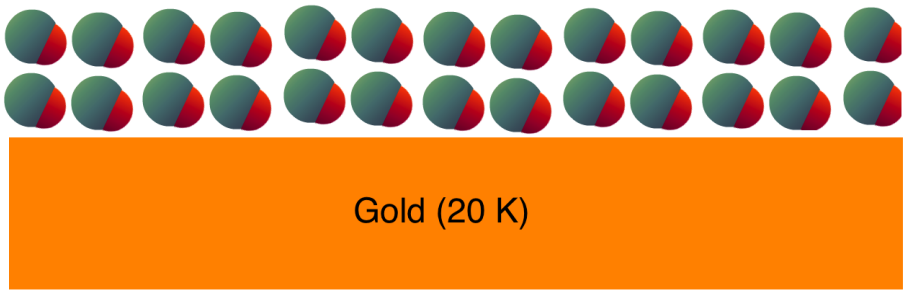

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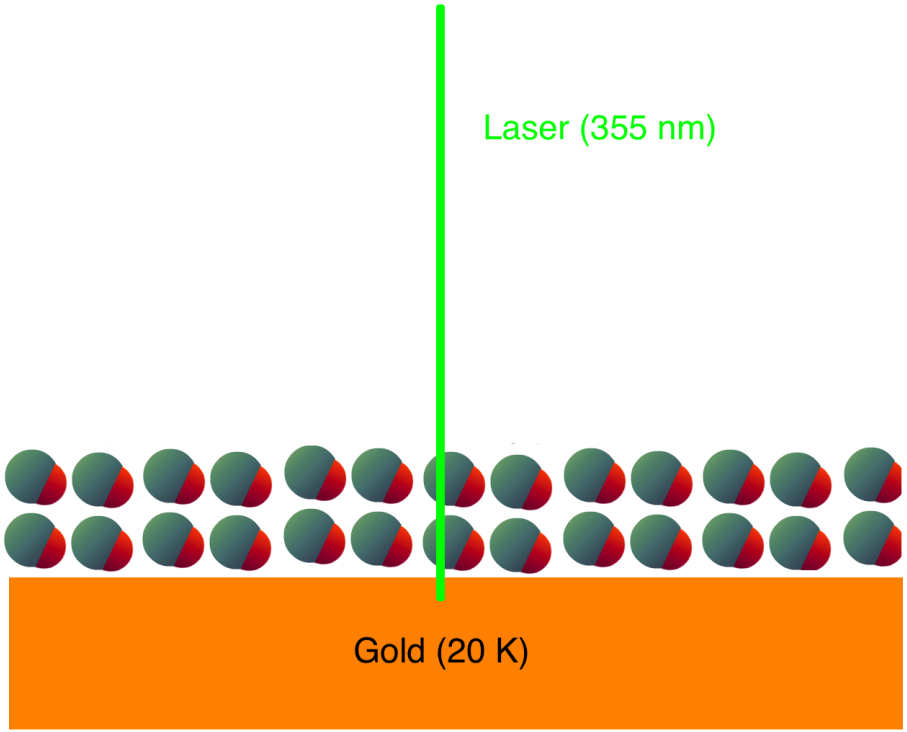

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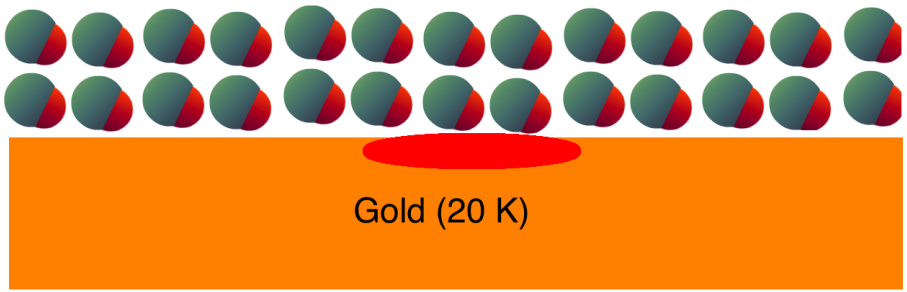

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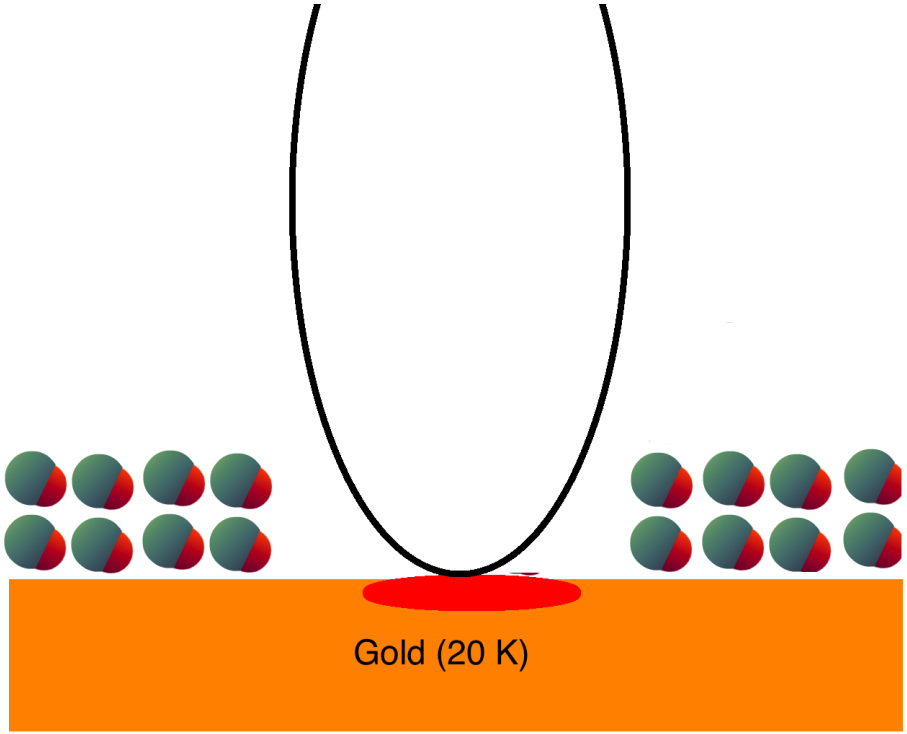


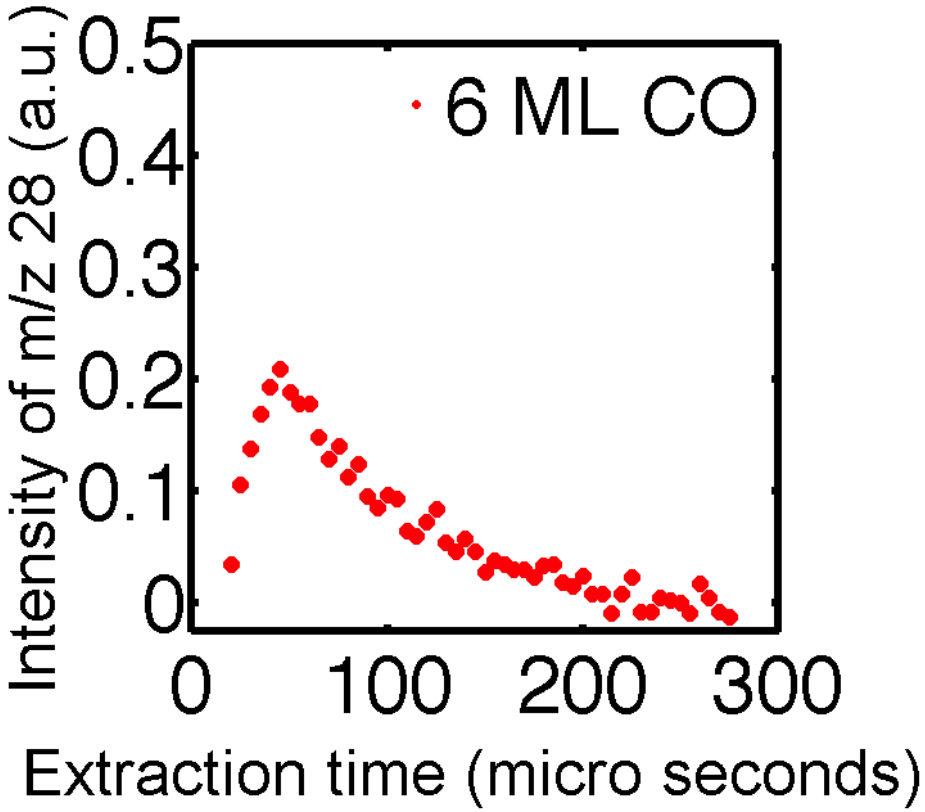

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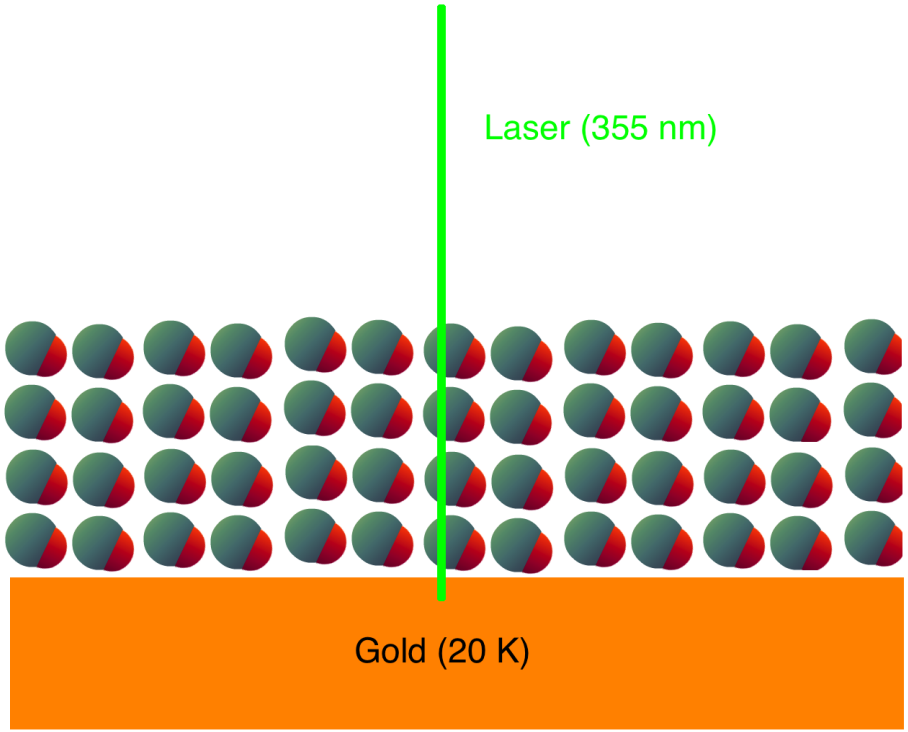

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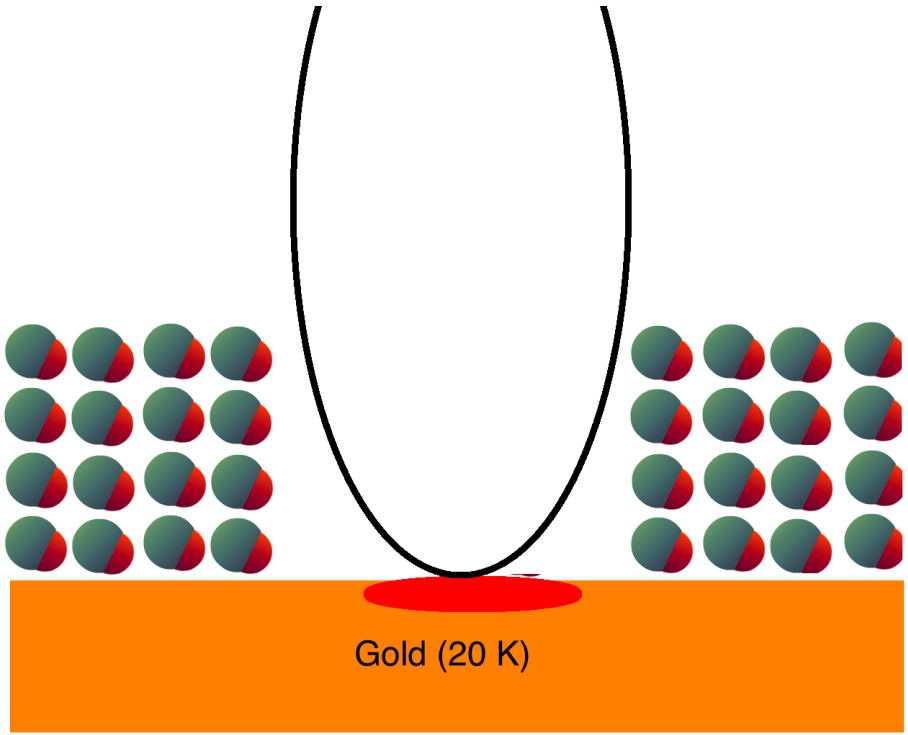
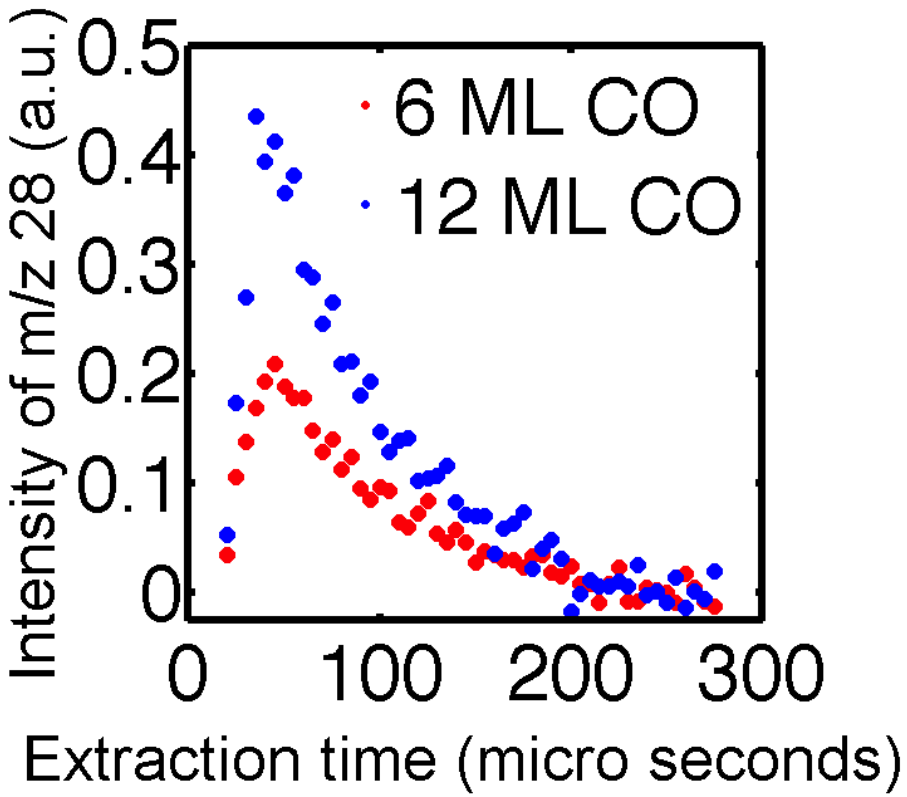
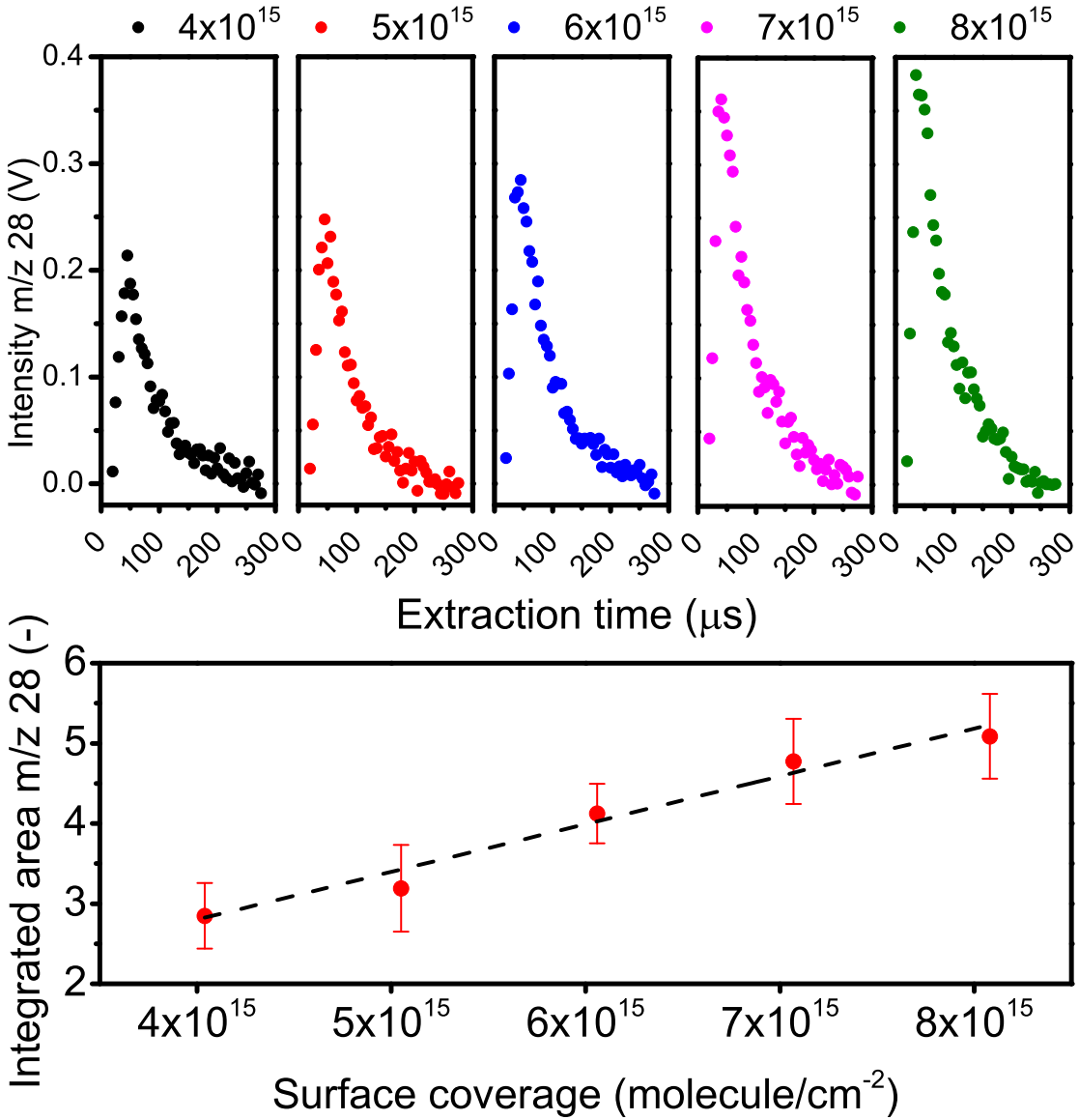


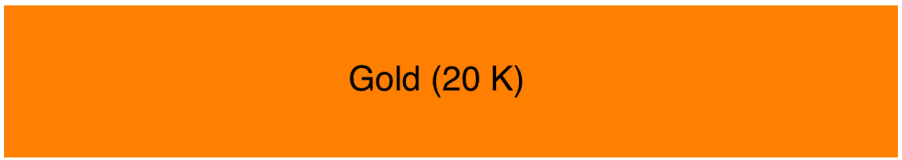
# Plume structure calibration

Different surface coverages show different laser induced desorption plume profiles.

Using this calibration we can trace the surface coverage.



# Typical photodesorption experiment




1. Ice deposition with specific surface coverage
2.
3.

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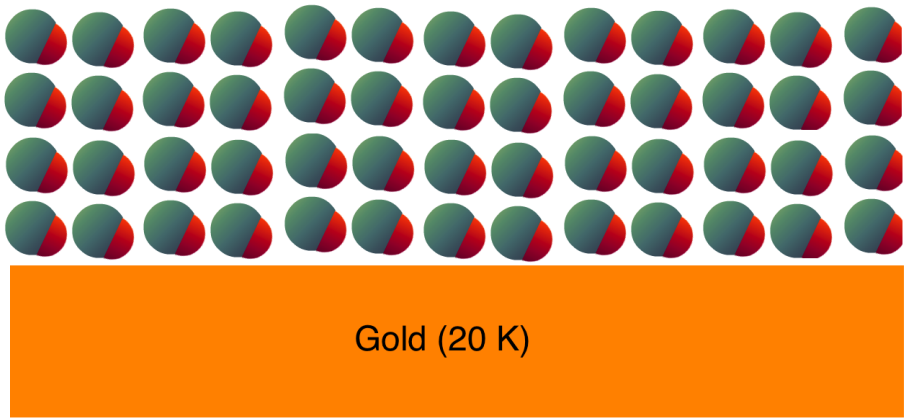


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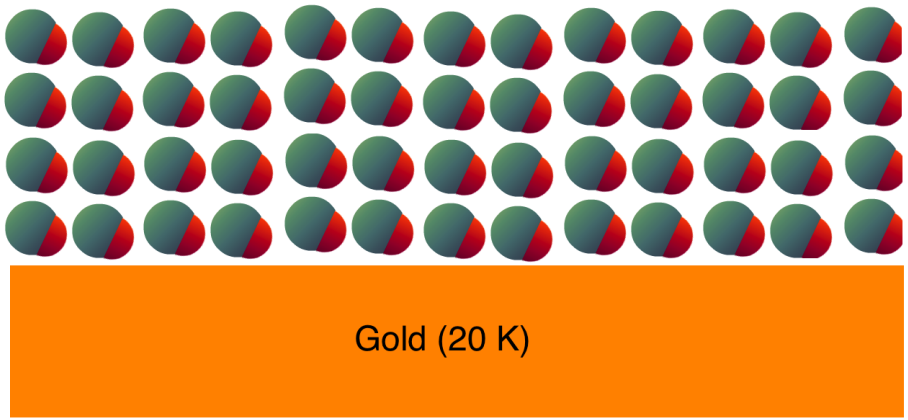


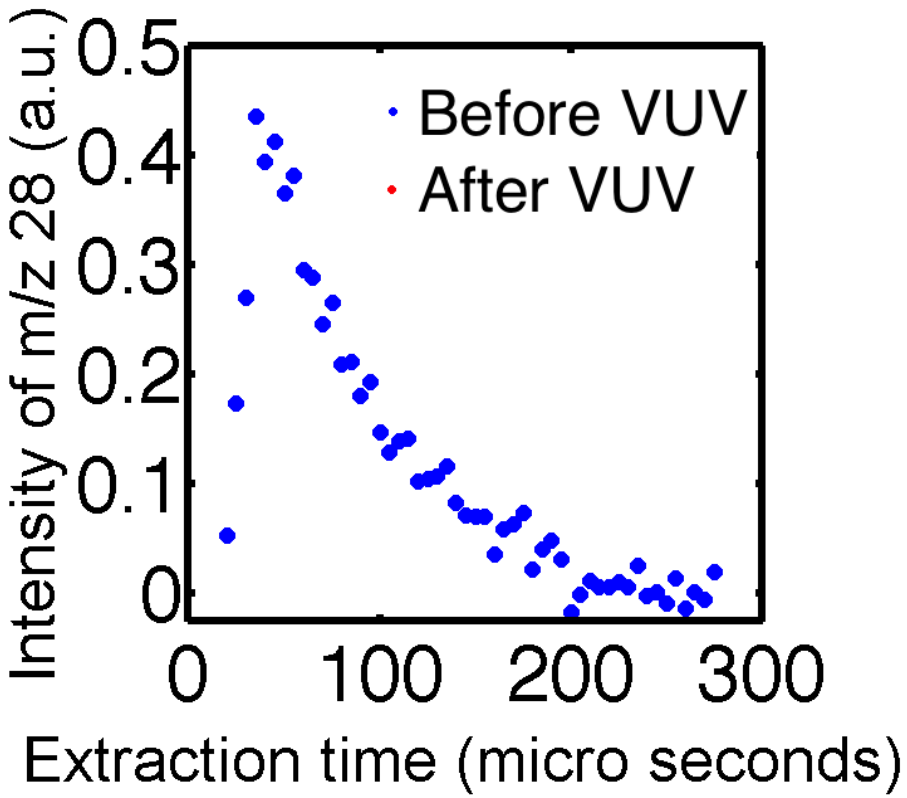


1. Ice deposition with specific surface coverage
2. Obtain spectrum
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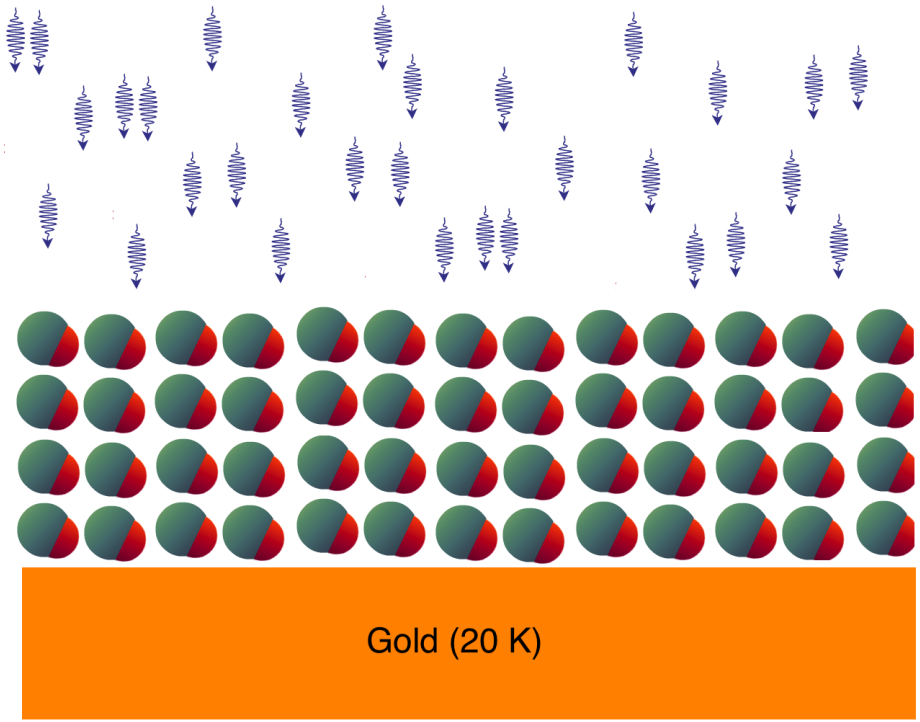
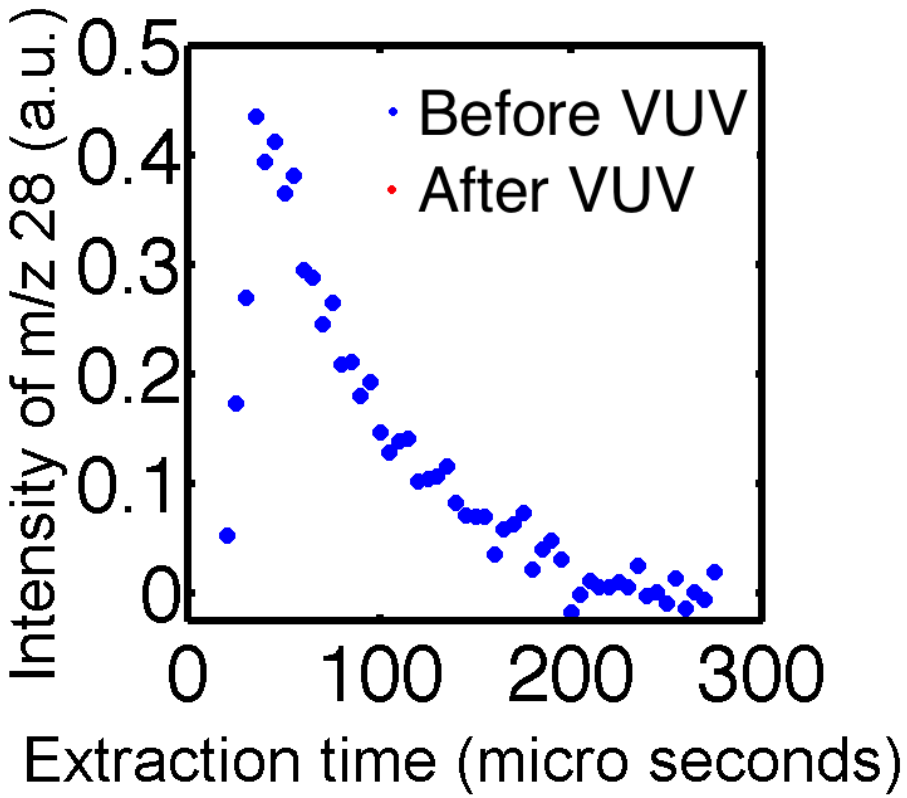
VUV photons from the $H_2$ lamp

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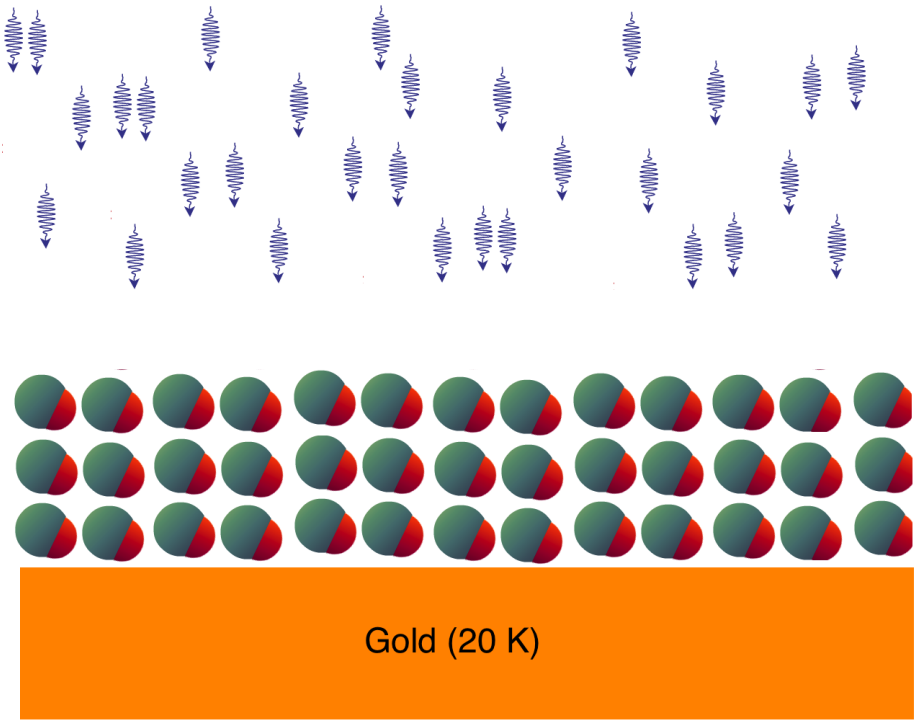
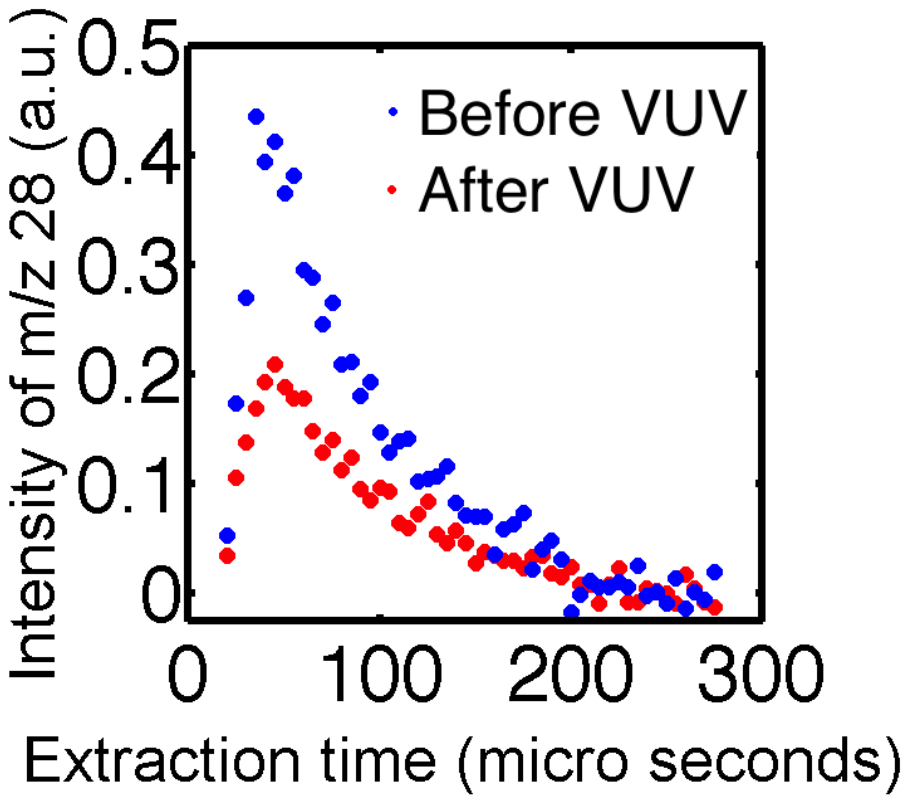
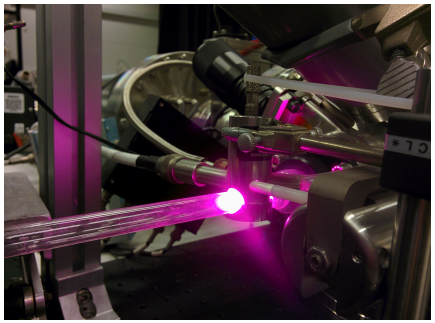


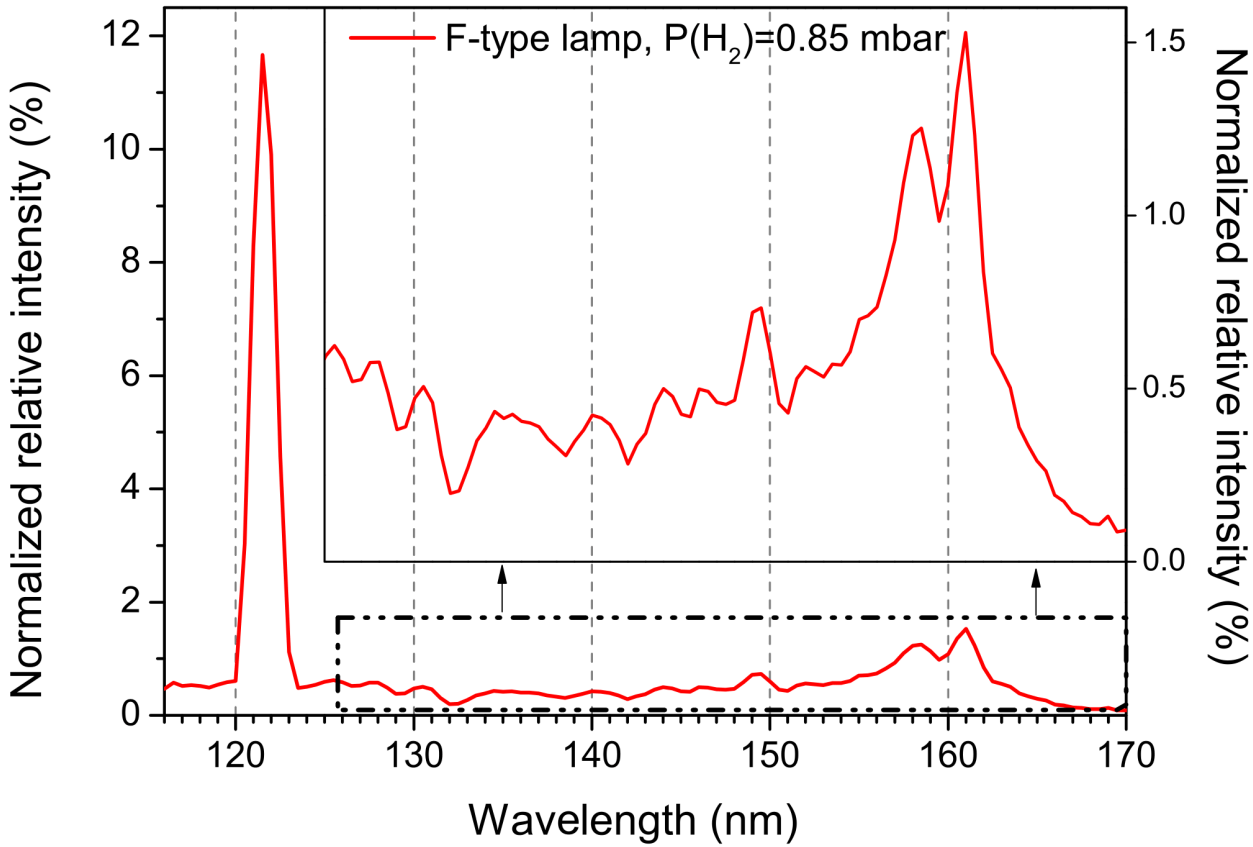




1. Ice deposition with specific surface coverage
2. Obtain spectrum
3. Obtain spectrum after VUV processing

# VUV flux calibration (NIST calibrated photodiode)

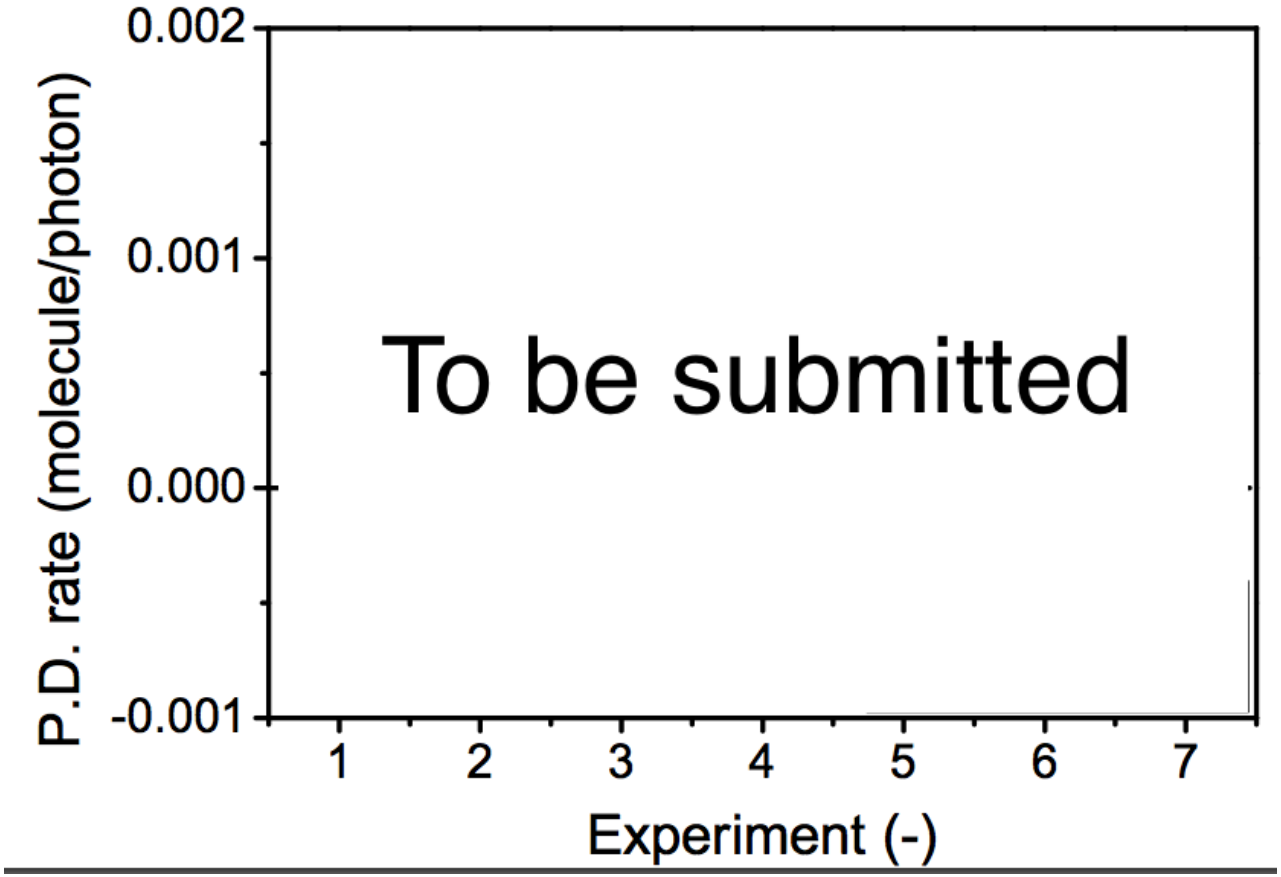
Absolute spectrum known (Ligterink, Paardekooper, et al. 2015)





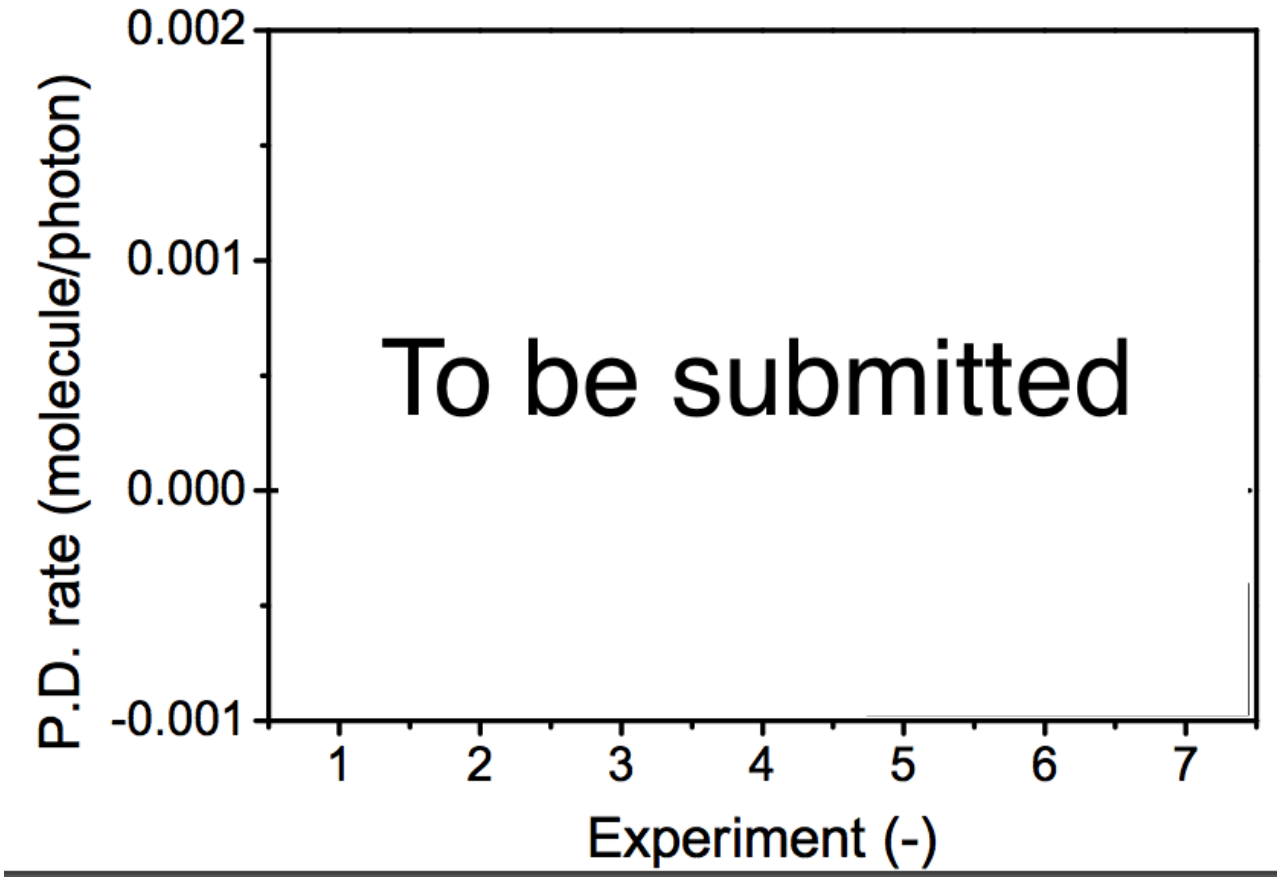

Flux at sample position: $(2.4 \pm 0.7) \cdot 10^{14}$ photon $\mathrm{cm}^{-2}\mathrm{s}^{-1}$

# Photodesorption of CO ice (20 K)




Photodesorption rate [20 K]:$(1.4 \pm 0.7) \cdot 10^{-3}$ molecules/photon
Photochemistry: $CO_2$ formation $\leq 2\%$ after $5 \cdot 10^{18}$ photons $cm^{-2}$

# Photodesorption of $H_2O$ ice (preliminary results)



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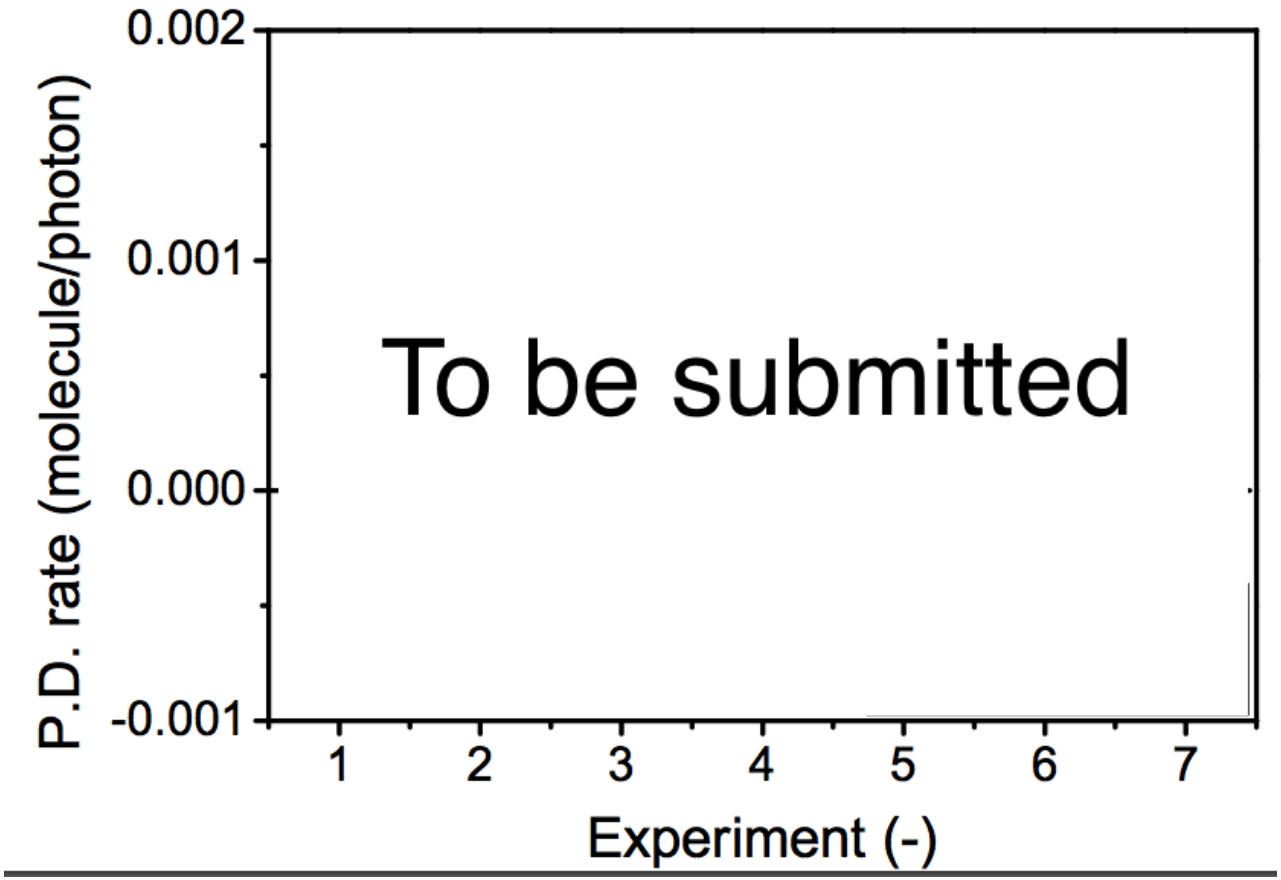


$H_2O$ photodesorption rate [125 K]: $(1.5 \pm 0.7) \cdot 10^{-3}$ molecules/photon

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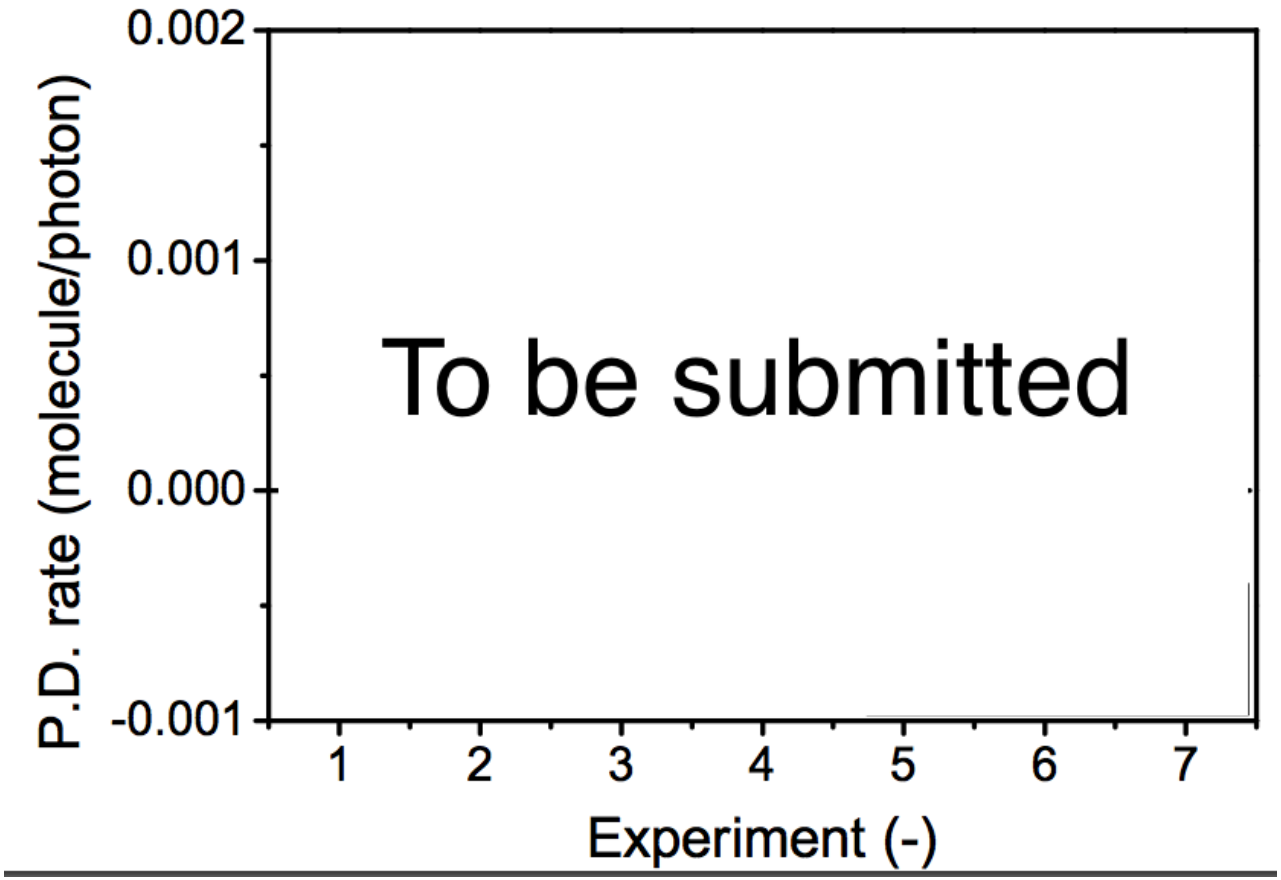


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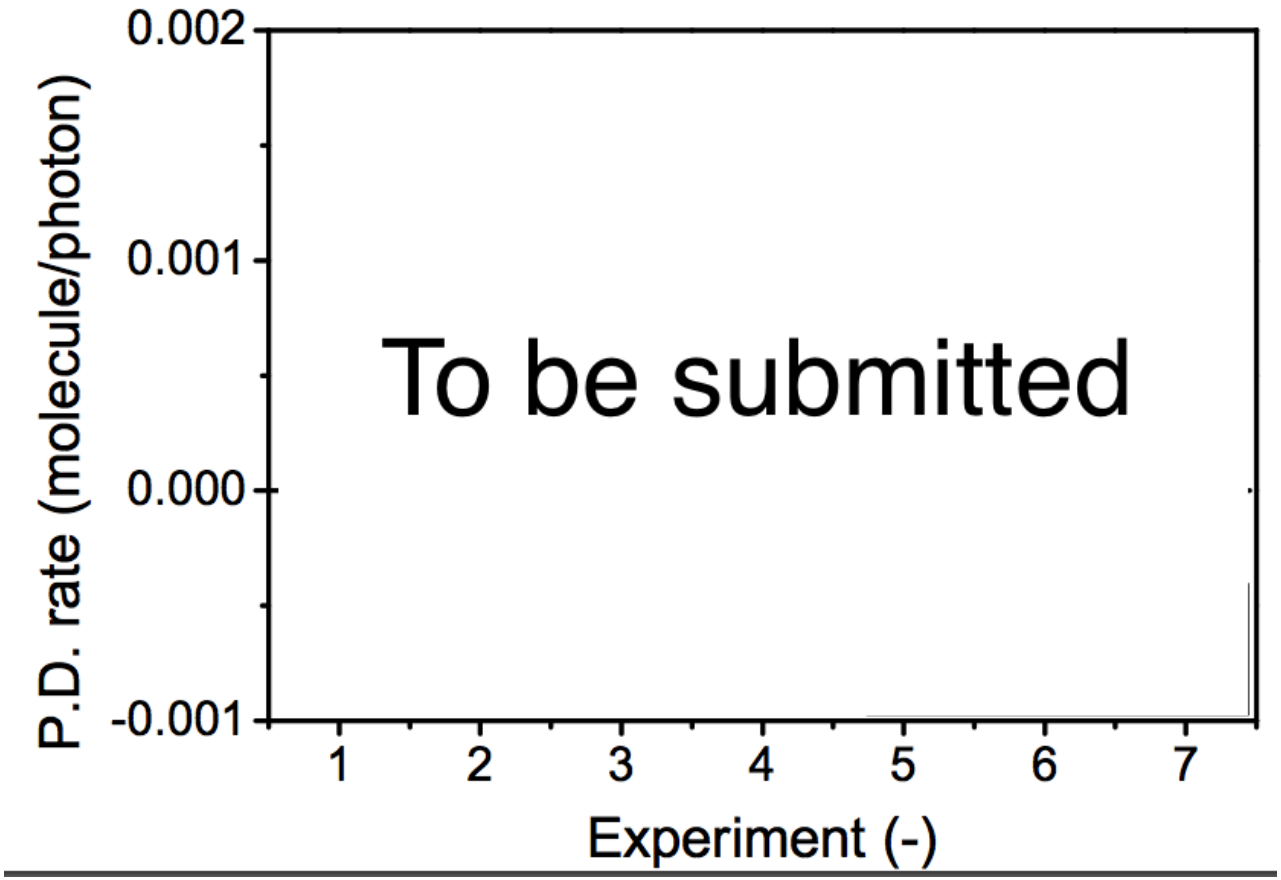


$H_2O$ photodesorption rate [125 K]: $(1.5 \pm 0.7) \cdot 10^{-3}$ molecules/photon

$H_2O$ photodesorption rate [20 K]: $\leq 6 \cdot 10^{-4}$ molecules/photon

# Conclusion

MATRI$^2$CES is a, sensitive and versatile tool, the setup can be used as independent method to quantify photodesorption.

- For CO ice at 20 K: the photodesorption rate is $(1.4 \pm 0.7) \cdot 10^{-3}$ molecules/photon.
- $CO_2$ formation during VUV processing $\leq 2\%$ after $5 \cdot 10^{18}$ photons $cm^{-2}$.
- For $H_2O$ ice at 125 K: the photodesorption rate is $\sim 1.5 \cdot 10^{-3}$ molecules/photon.
- For $H_2O$ ice at 20 K: we obtained an upper limit of $\sim 6 \cdot 10^{-4}$ molecules/photon, 3 (!) times lower than previously measured by Öberg (2010).

# Thank you for your attention