Photodesorption of interstellar ice analogues

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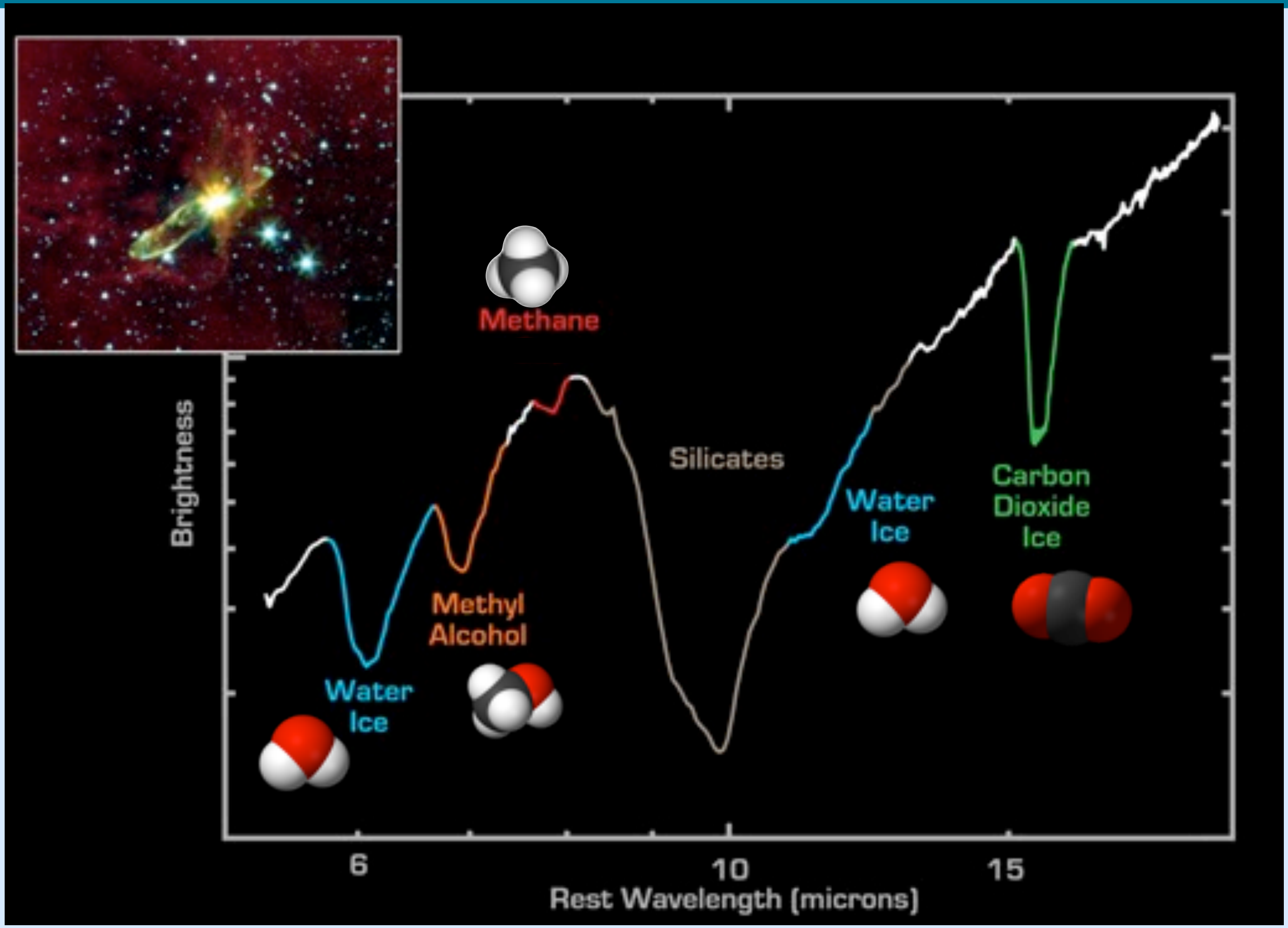
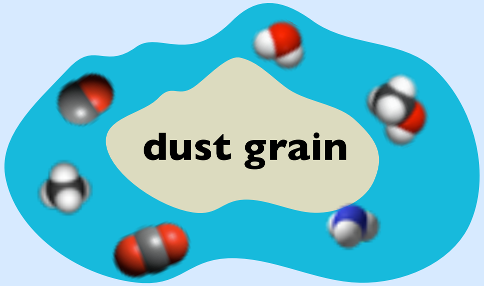
Ices in star forming regions

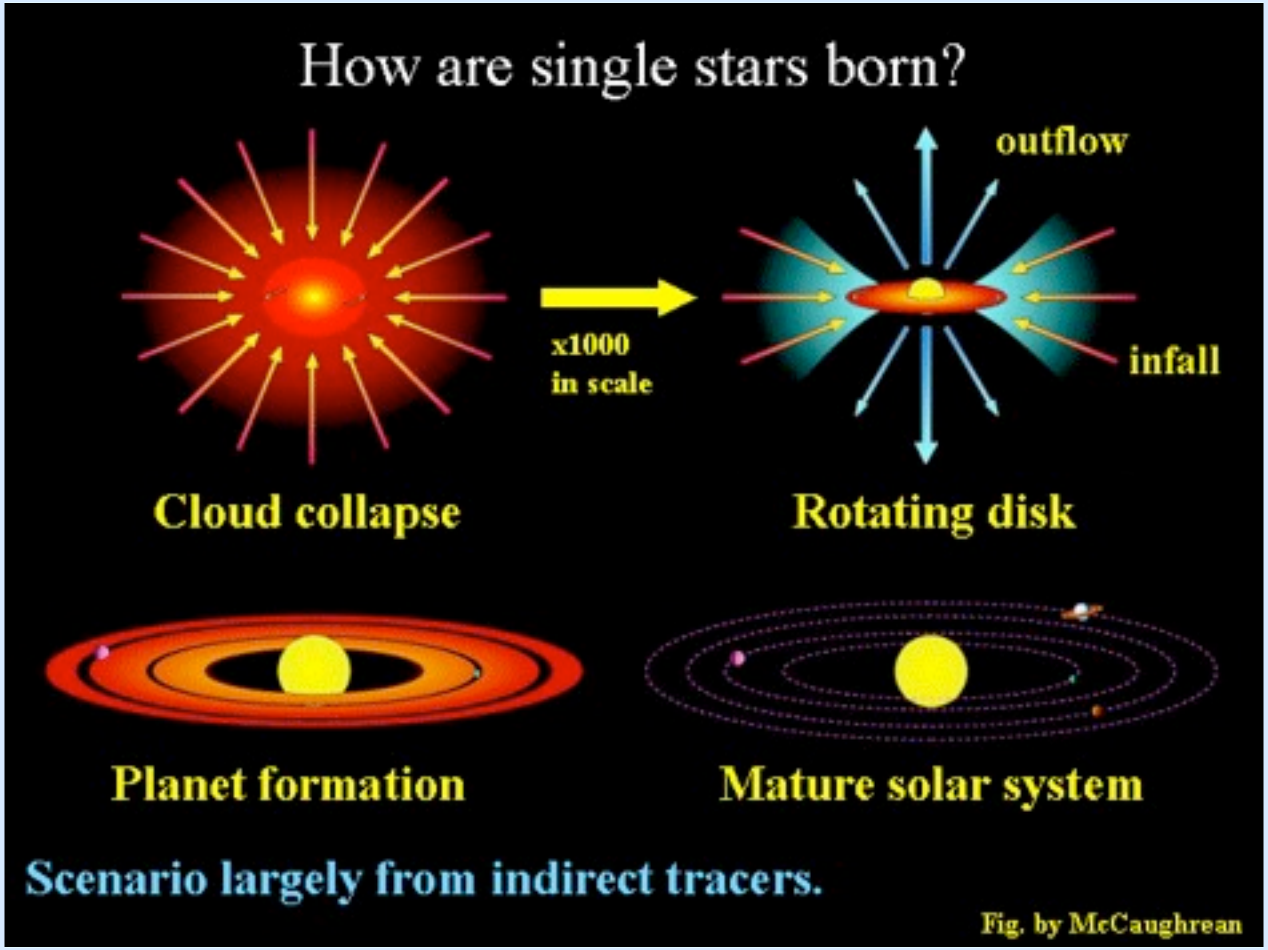


HH 46/47 with Spitzer/IRS - Credit: NASA/JPL-Caltech/A. Noriega-Crespo (SSC/Caltech)



- Molecules are found in gas and solid phase
- The main species in the condensed phase are H_2O, CO, CO_2

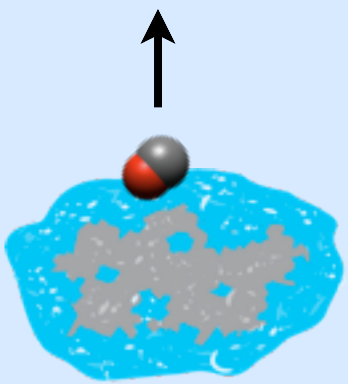
Low-mass star forming environments



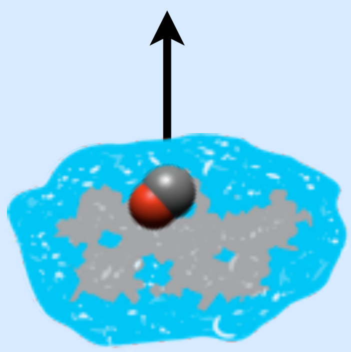
- Molecules can freeze out/form on dust grains.
- The amount of ice and composition evolve during star formation process

Ice to gas

- Mechanisms

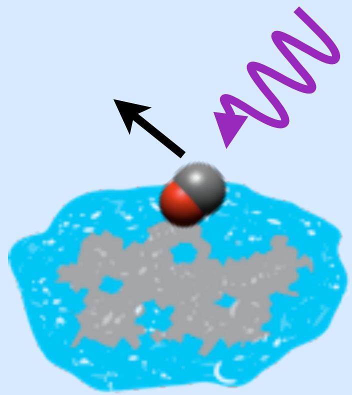


from surface



with water ~100K

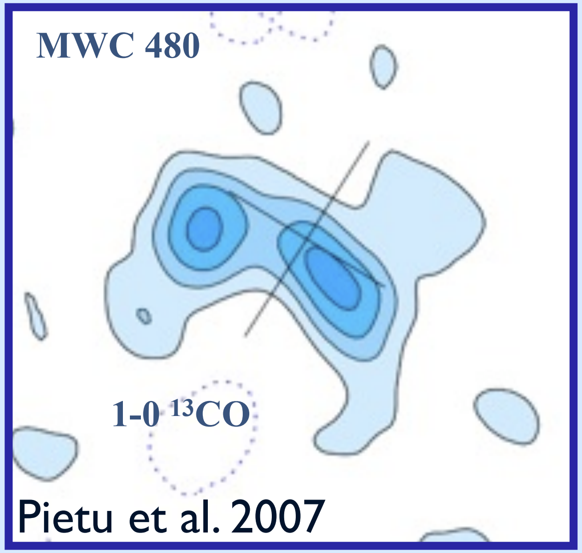
Thermal desorption



Non-thermal desorption

Sputtering
Exothermic chemistry
Electron induced desorption
UV induced photodesorption

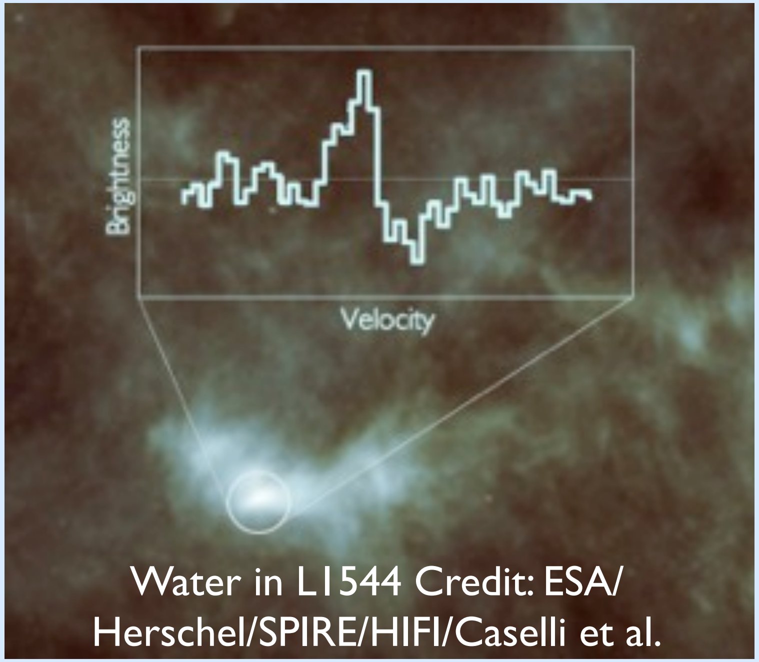
Photodesorption



Pietu et al. 2007

e.g. Dominik et al 2005, Hersant et al 2009, Hollenbach 2009, Oka et al 2012

- Non-thermal desorption is required to explain the presence of gas in cold and UV exposed regions.

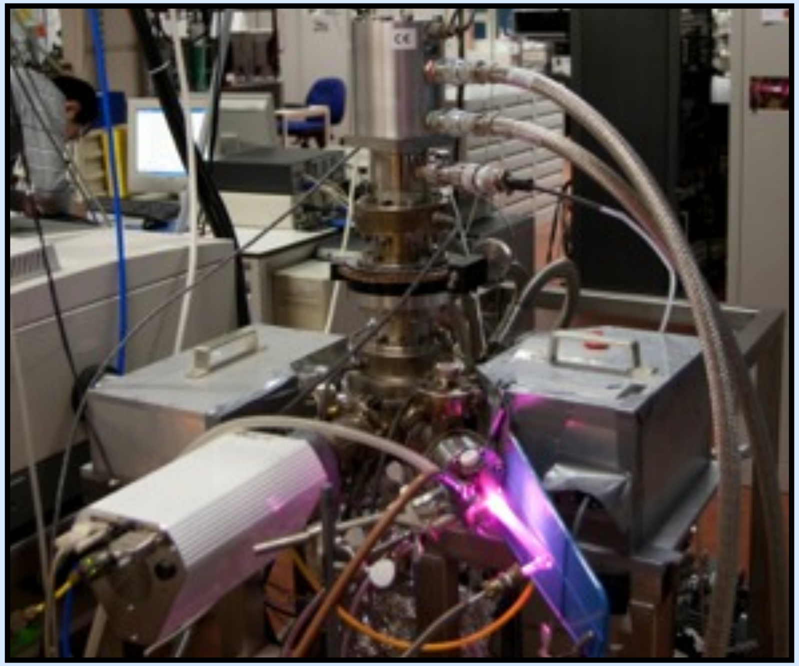


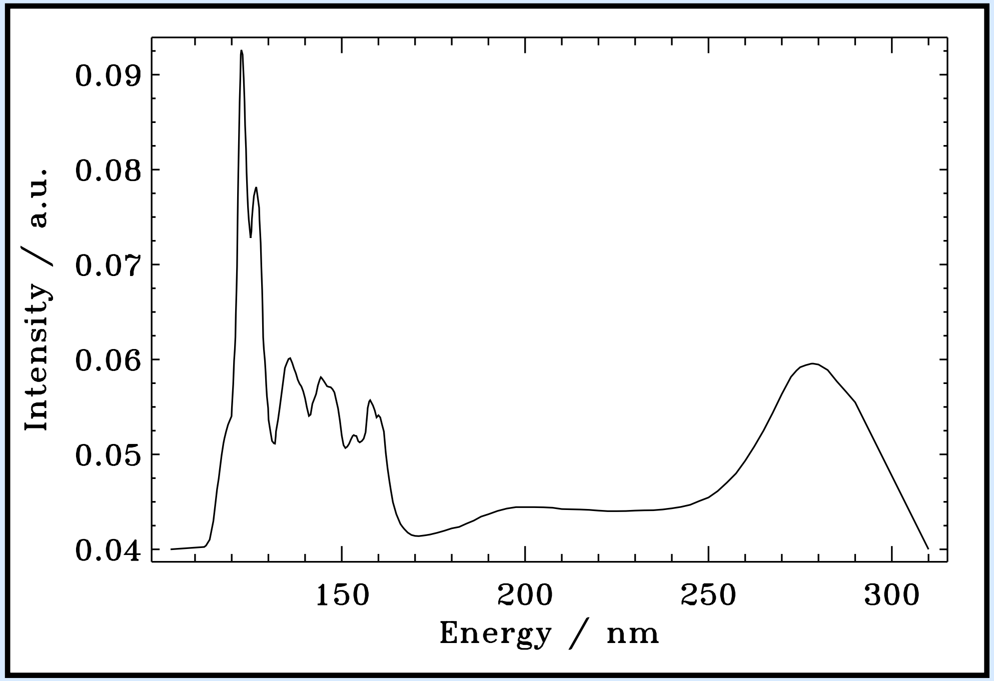
Water in L1544 Credit: ESA/ Herschel/SPIRE/HIFI/Caselli et al.

- Cold gas possibly originates from photodesorption of ice grain mantles.

Photodesorption in the lab

- Photo-induced processes studied using H_2 discharge lamp to simulate Interstellar radiation.



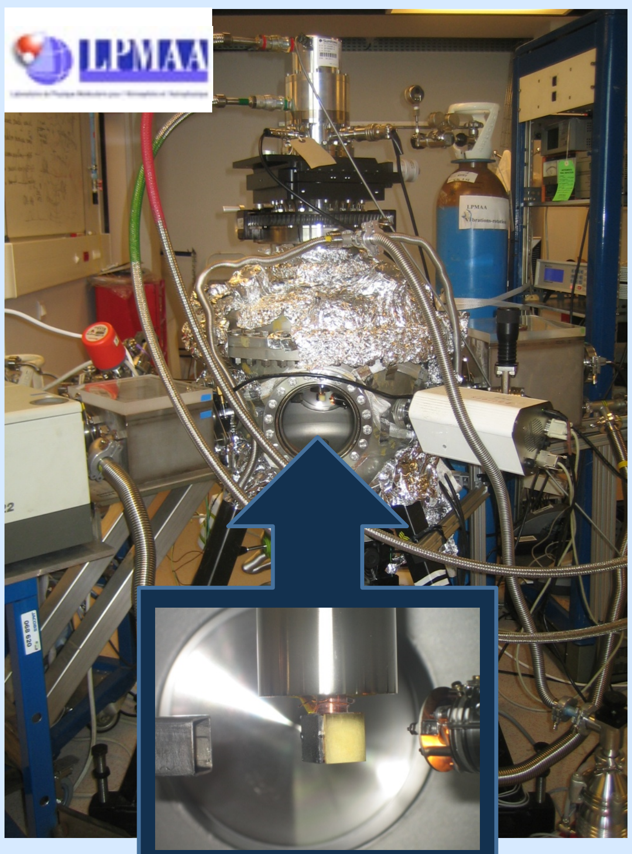


H_2 discharge lamp emission profile - Munoz-Caro et al 2003

e.g. Westley et al 1995, Oberg et al 2007, 2009, Munoz-Caro et al 2010

CO photodesorption

- Use of monochromatic light: SOLEIL synchrotron + SPICES set-up
- Wavelength-dependent measurements: application to various ISM environments (different UV field)
- Unveil the underlying molecular mechanism

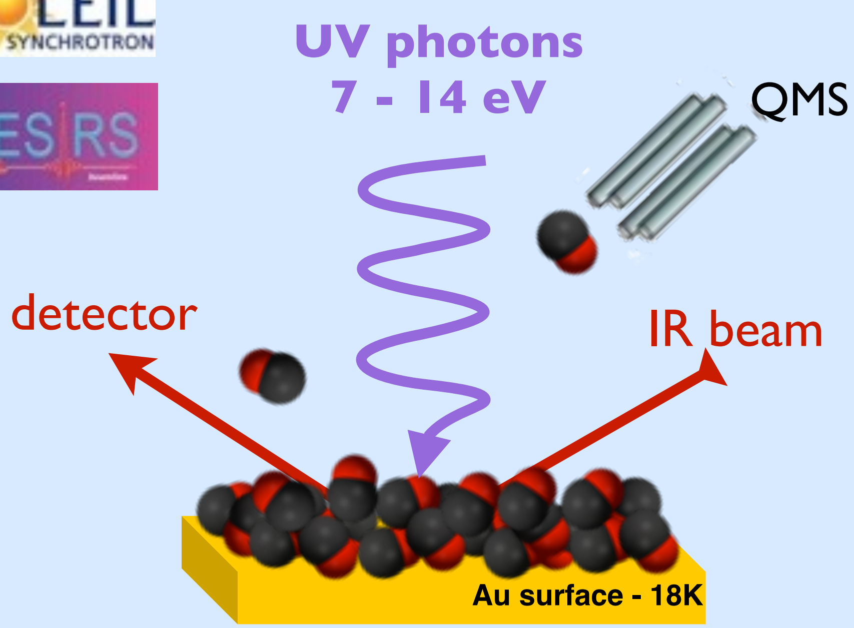


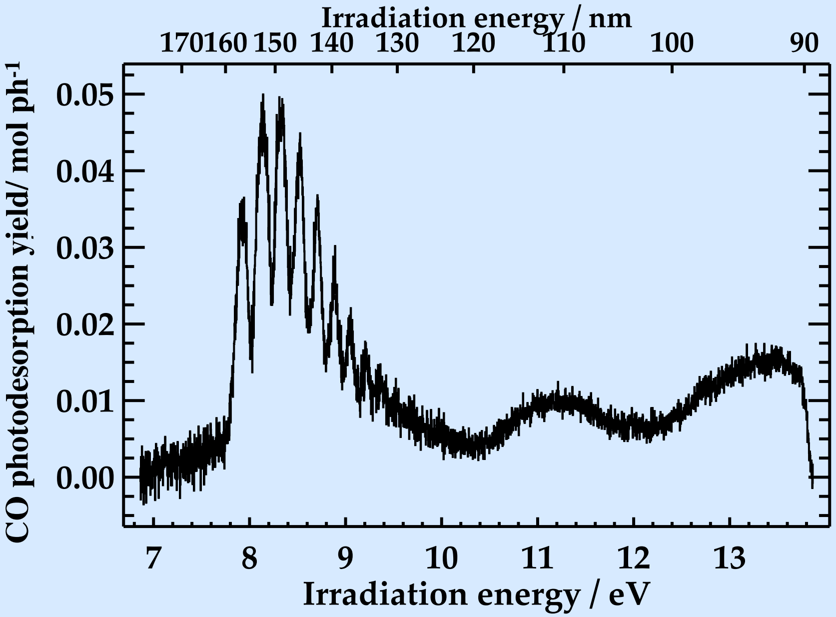
SOLEIL SYNCHROTRON

DESIRS

CO photodesorption

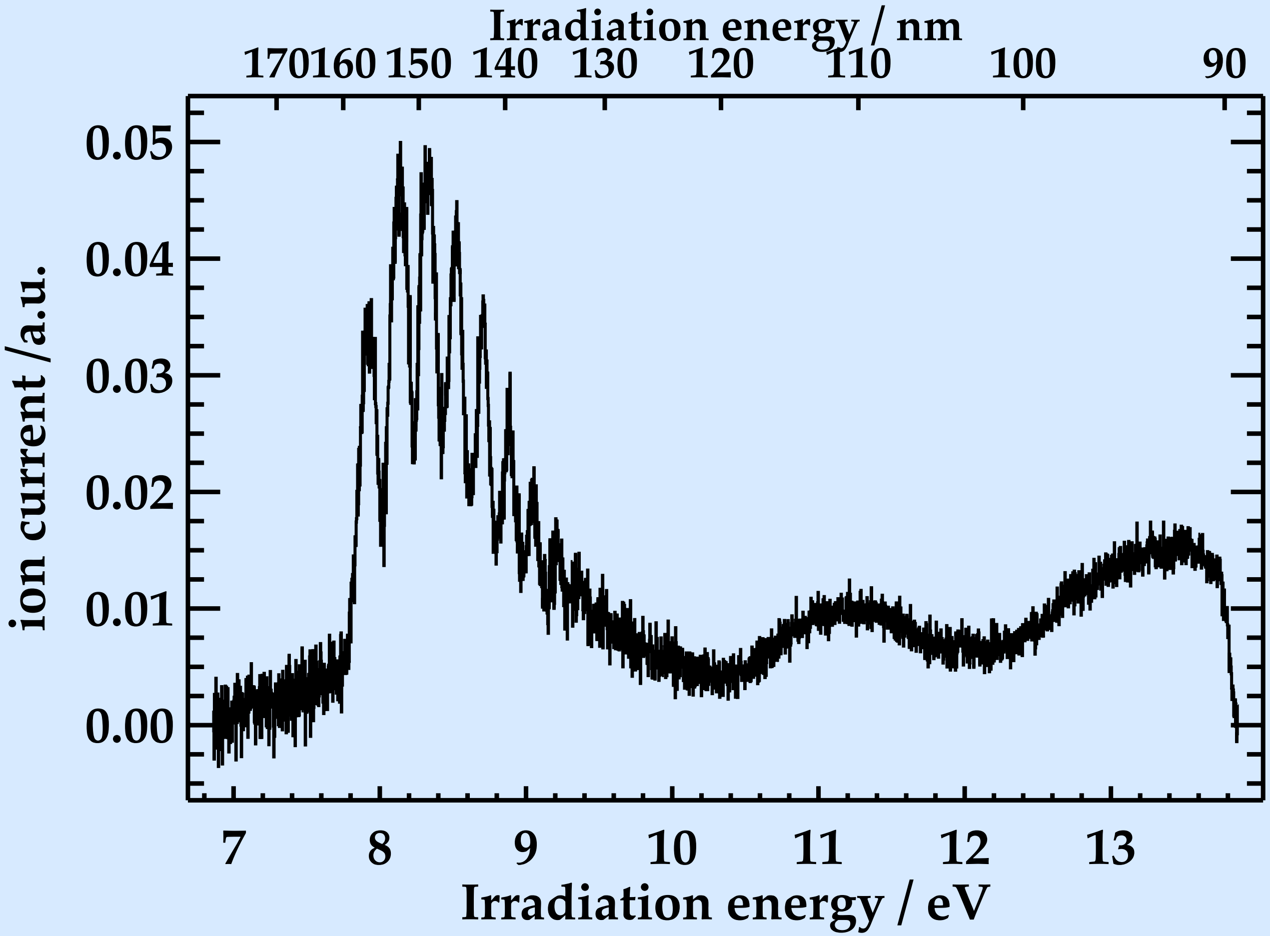
- Irradiation using monochromatic radiation between 7 - 14 eV
- Ice loss detection through Reflexion Infra-Red Spectroscopy
- Gas phase desorption detection using mass spectrometry

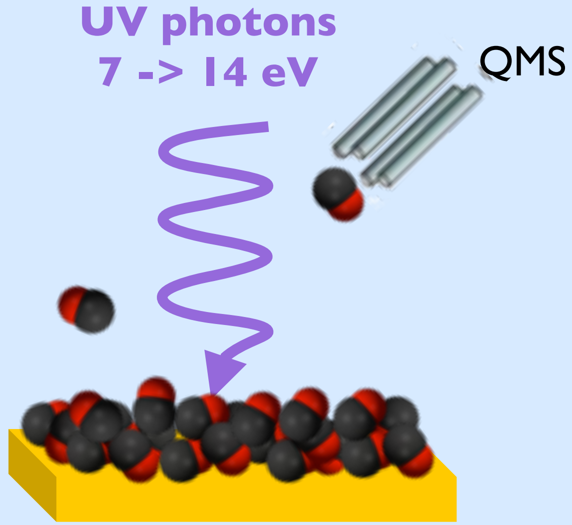




CO photodesorption

- Increasing irradiation energy from 7 to 14 eV

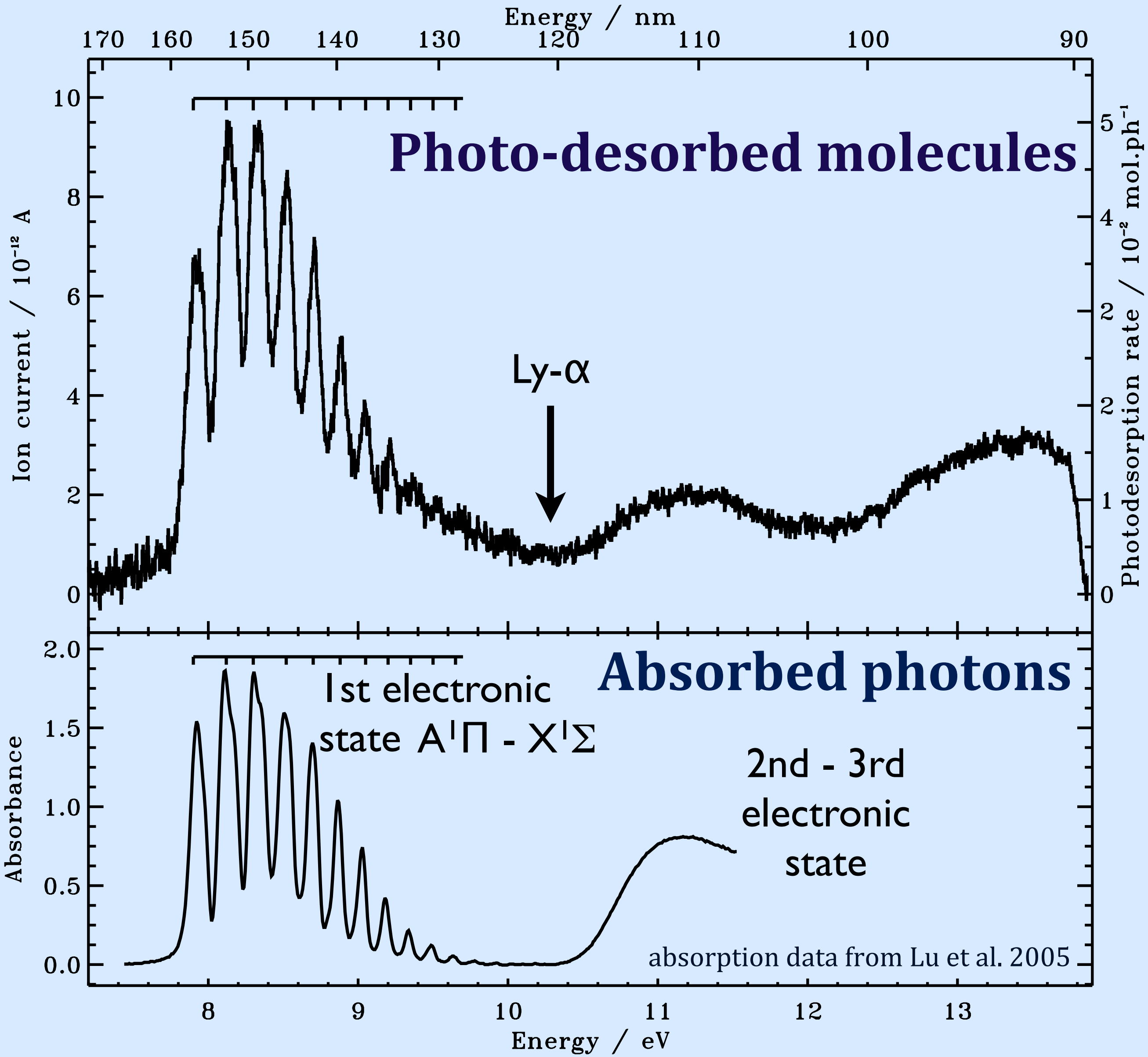


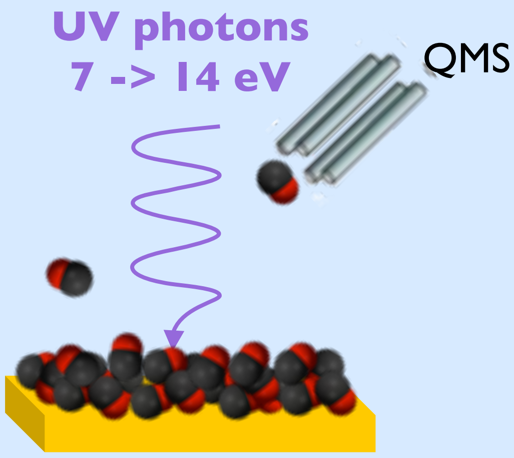


- Clear, **structured** wavelength dependence of CO photodesorption

Fayolle et al. 2011

CO photodesorption





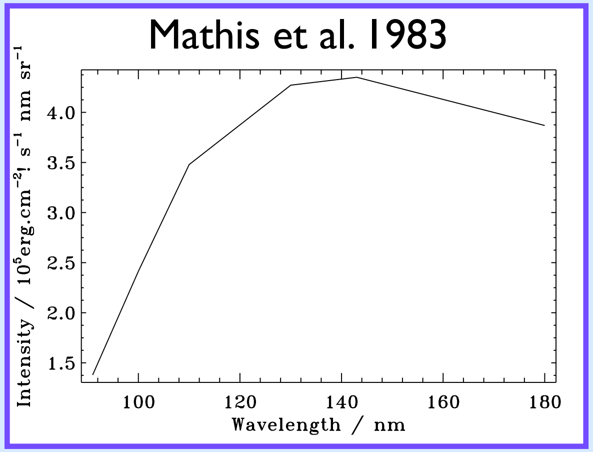
- Desorption efficiency sensitive to the wn
- Desorption Induced by Electronic Transition process
- Maximum desorption at 8.2 eV, 5 x 10^{-2} $mol.ph^{-1}$

Fayolle et al. 2011

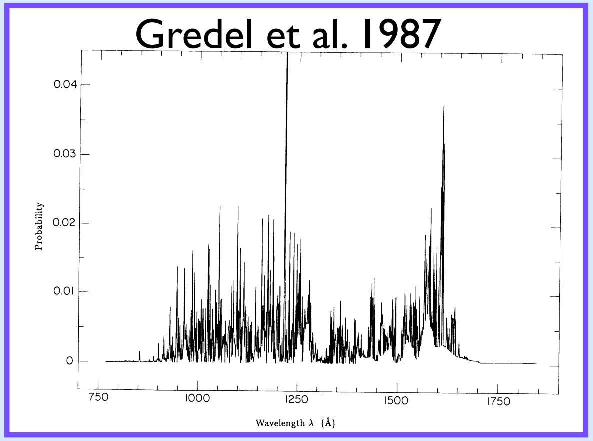
Implication for astrochem models

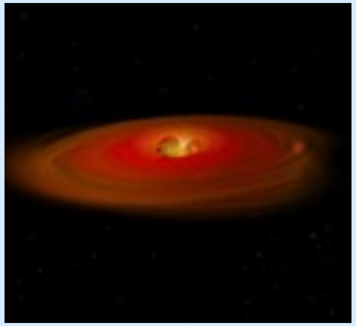
- Specific sublimation rates -> better interpretation of CO observation

ISRF dominated regions:
1.2 x 10^{-2} molecule.ph^{-1}

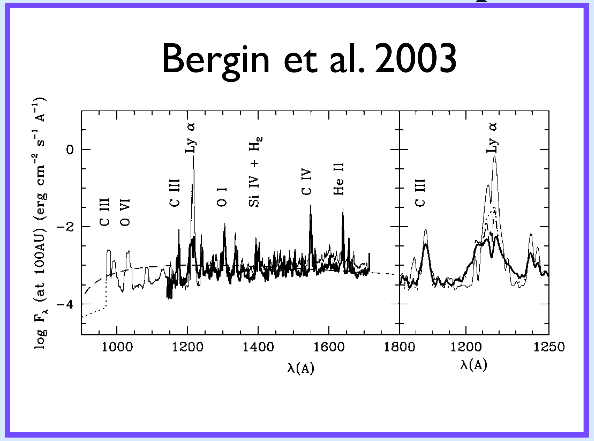


Pre-stellar cores - cosmic-rays excited H_2 emission
9.4 x 10^{-3} molecule.ph^{-1}





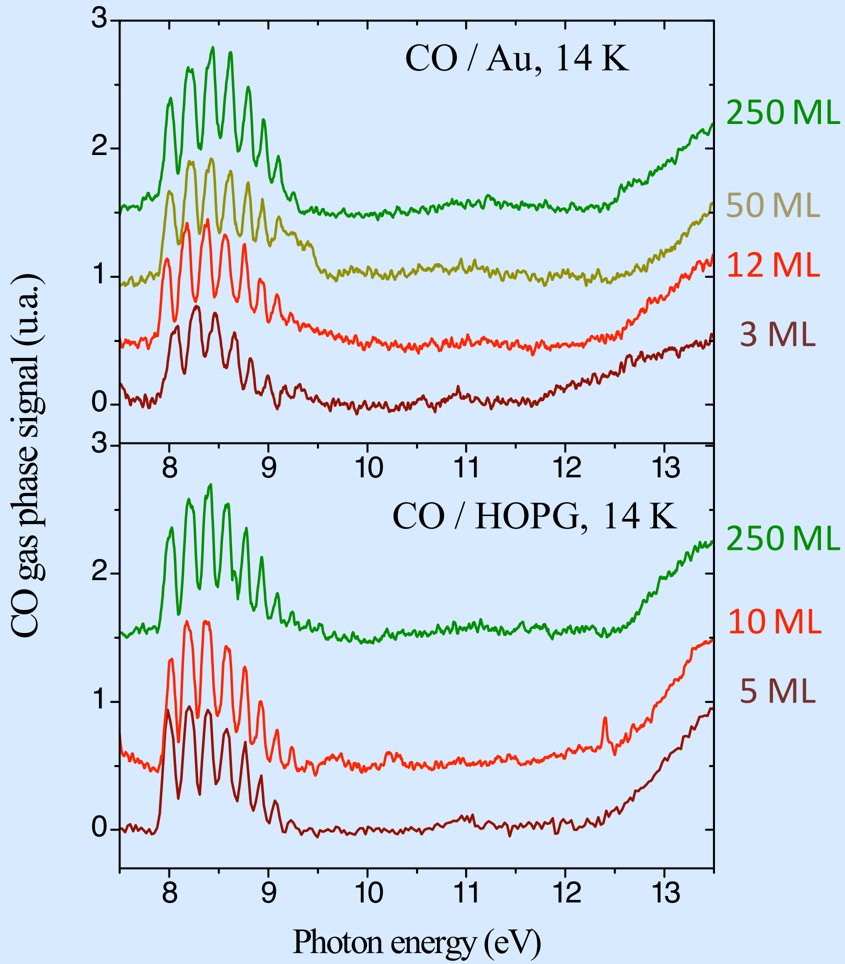
Protoplanetary disks - TW-hydrae emission
6.6 x 10^{-3} molecule.ph^{-1}



Fayolle et al. 2011

Substrate & coverage influence

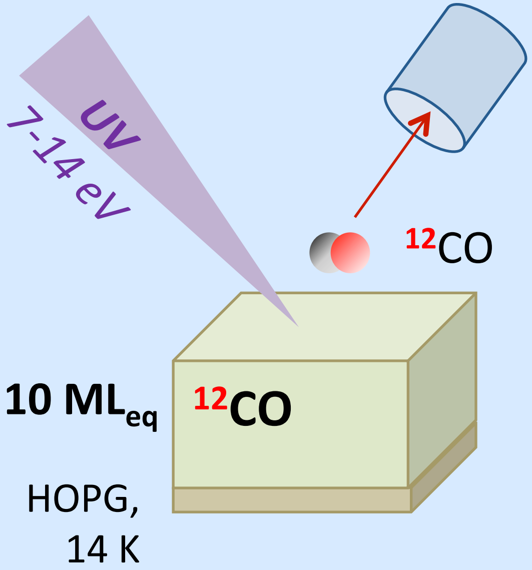
- UV photons on gold sample: photoelectrons for E_{photon} > 4.4 eV
- Irradiation for different coverage, different substrate

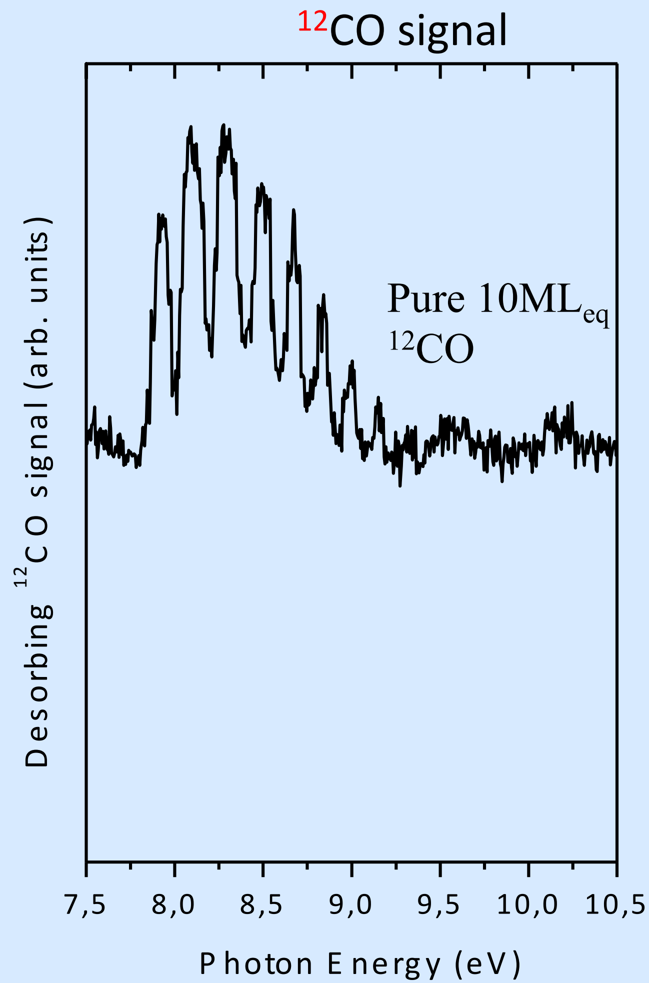


- PSD spectra are very similar for CO coverages between 3 and 250 ML
- **No effect due to the substrate** is seen in the photodesorption spectra.
- **CO photodesorption is a DIET process** involving only the CO ice. Hot and photoelectron contribution is not observed

Bertin et al. 2012

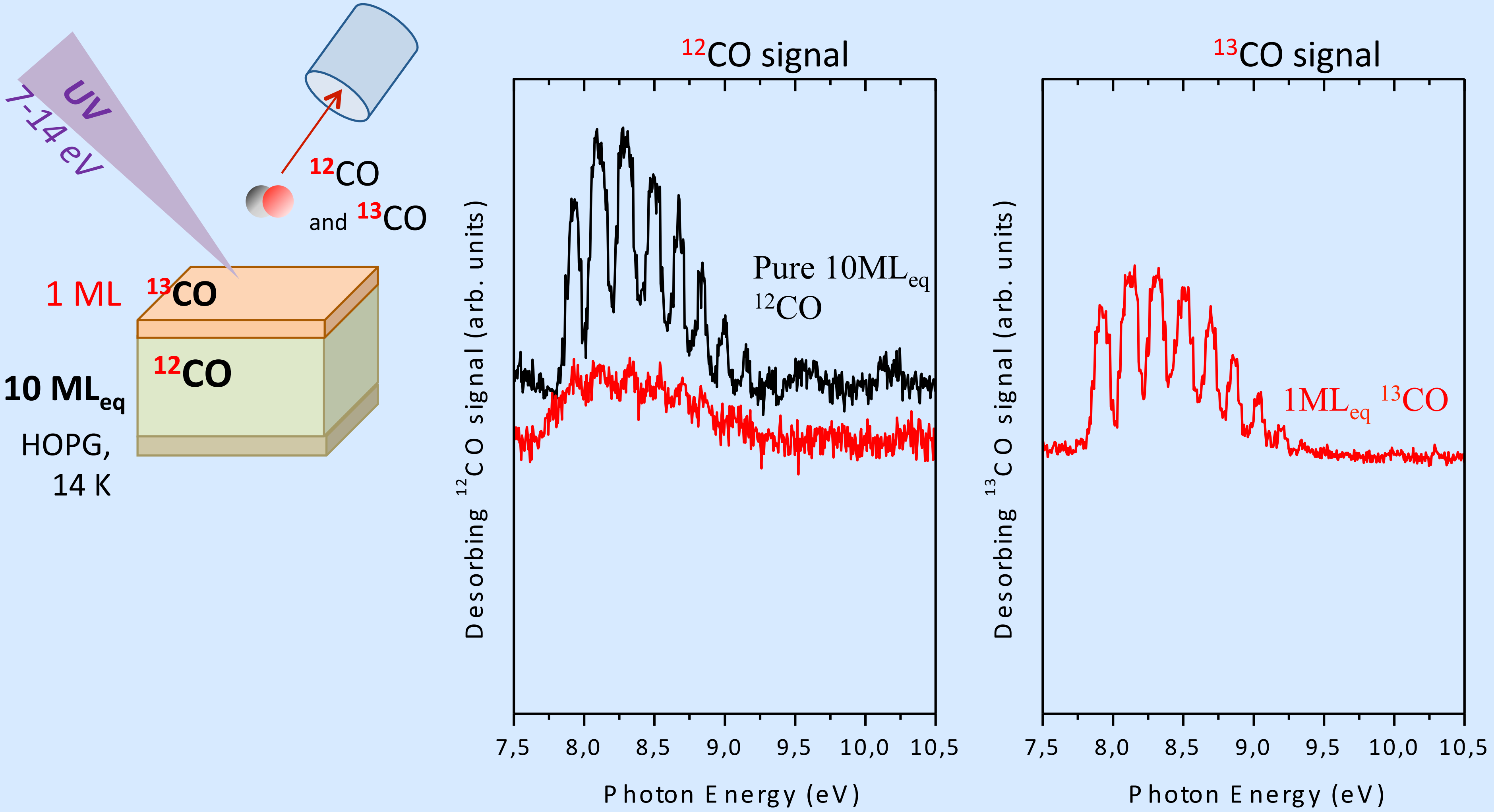
Surface vs bulk process





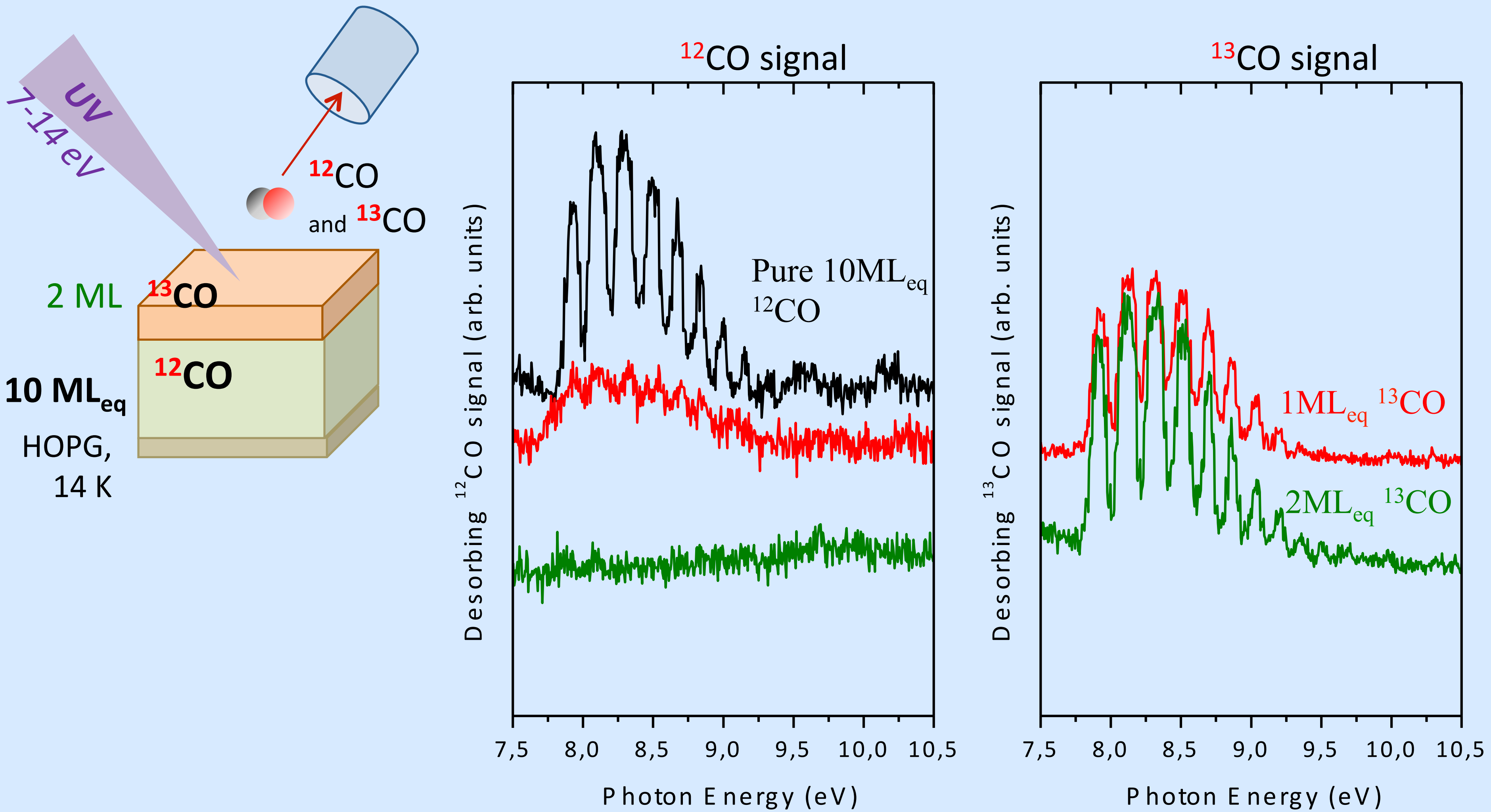
Bertin et al. 2012

Surface vs bulk process



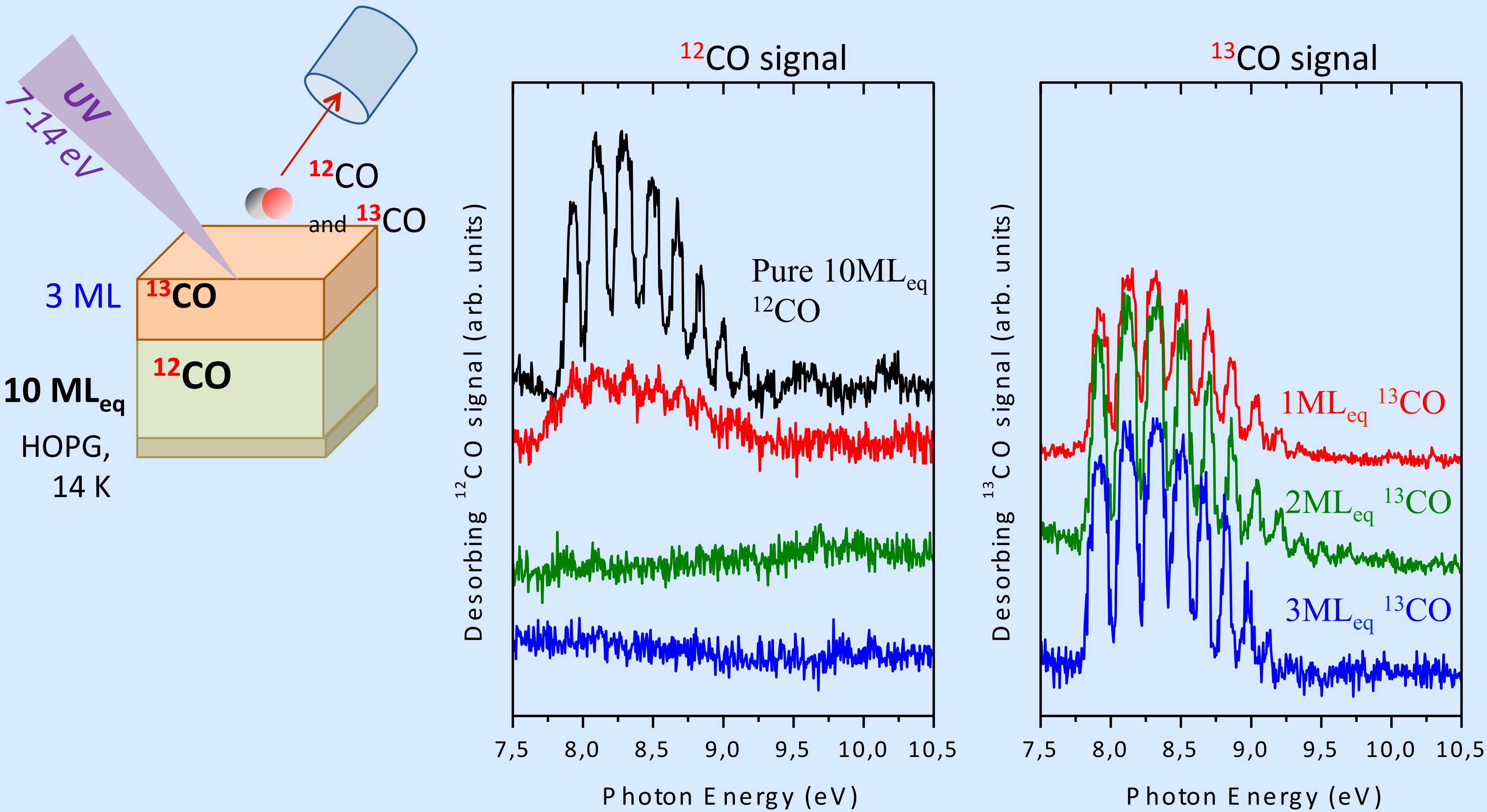
Bertin et al. 2012

Surface vs bulk process



Bertin et al. 2012

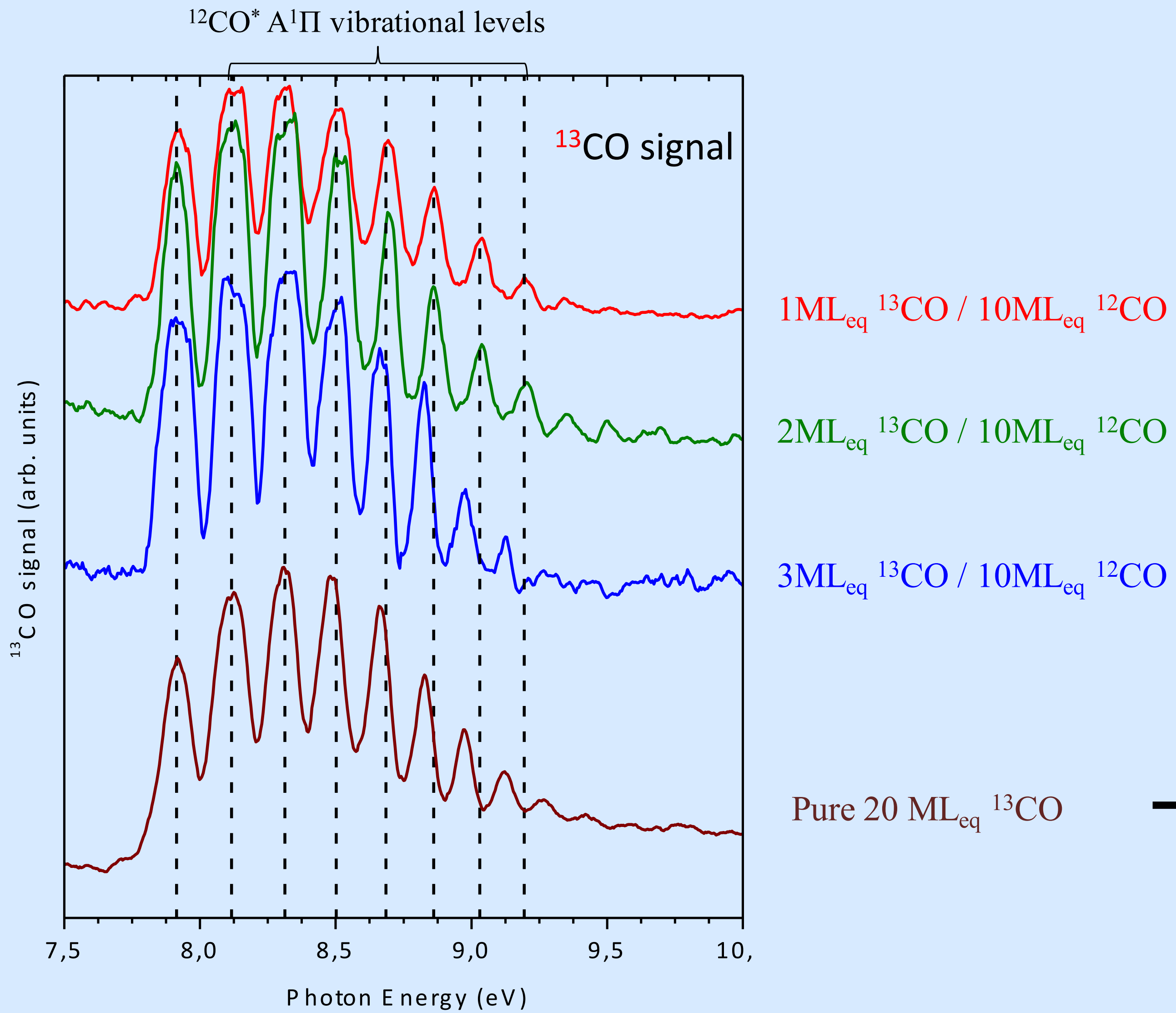
Surface vs bulk process

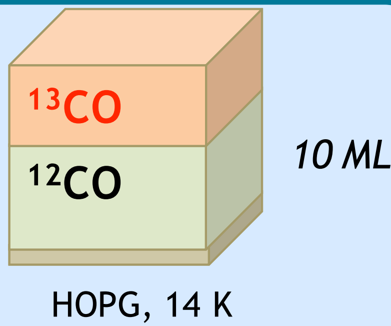


- ^{12}CO photodesorption is hindered by only 1-2 ML of ^{13}CO overlayer
- **Photodesorption originates from the two top-most layers**

Bertin et al. 2012

Surface vs bulk process





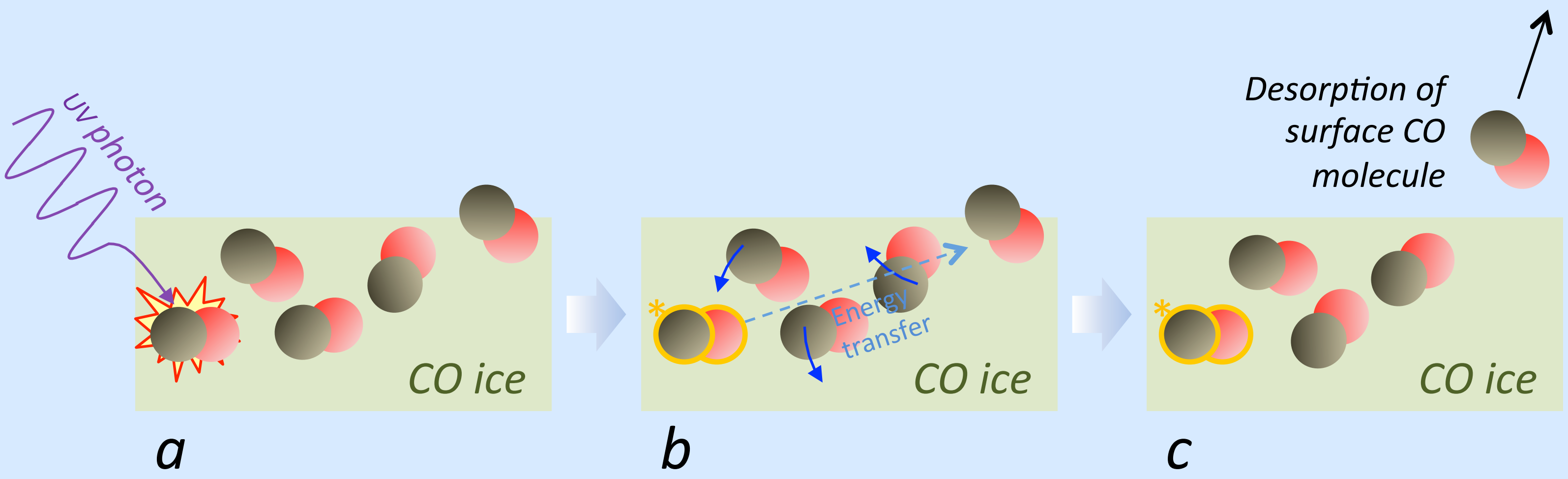
^{13}CO photodesorption is triggered by the excitation of the underlying ^{12}CO

→ Shift from ^{12}CO to ^{13}CO vibronic progression

Bertin et al, 2012

Proposed mechanism

- The initial excitation step takes place below the **top-most layers**
- CO photodesorption is a **(sub)surface process**

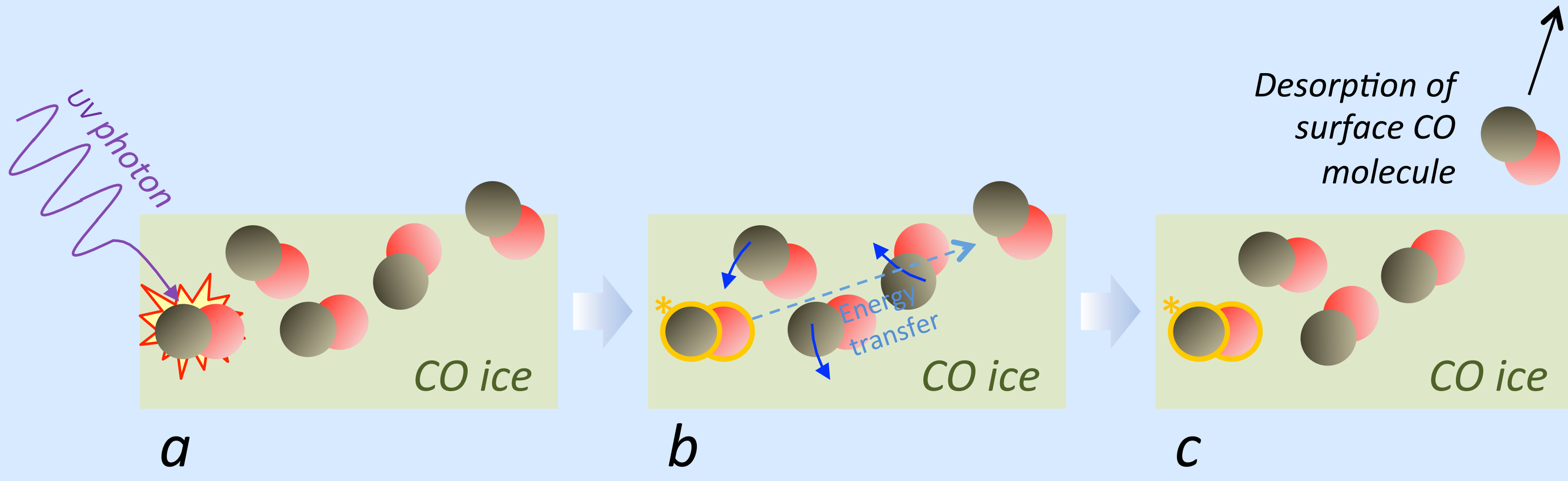


- The role of energy transfer between the excited molecule and the desorbing molecule is a key parameter that drives the desorption efficiency !

Bertin et al, 2012

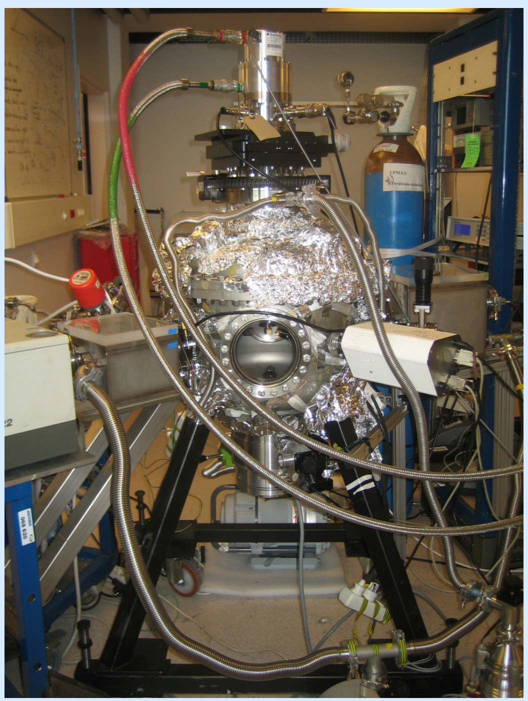
Take home

- Photodesorption yields are wavelength-dependent.
- Quantitative yields can be used to predict photodesorption efficiency in various ISM regions.
- Local molecular environment matters and should accounted for in astrochemical networks.



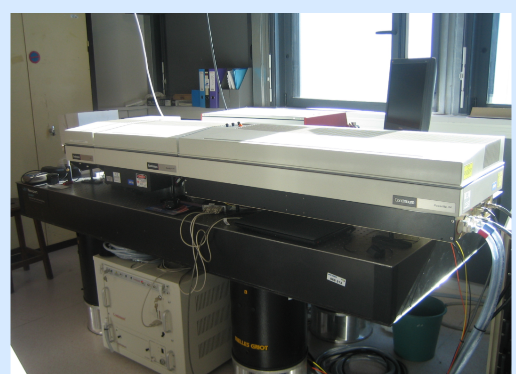
Stay tuned...

- Currently: O_2, H_2O/D_2O, CH_3OH, mixtures... photodesorption under analysis
- Perspective: CO_2 photodesorption, pump probe system to unveil photodesorption energy balance



SPICES set-up

SOLEIL synchrotron



Laser @ UPMC

Thank you for your attention

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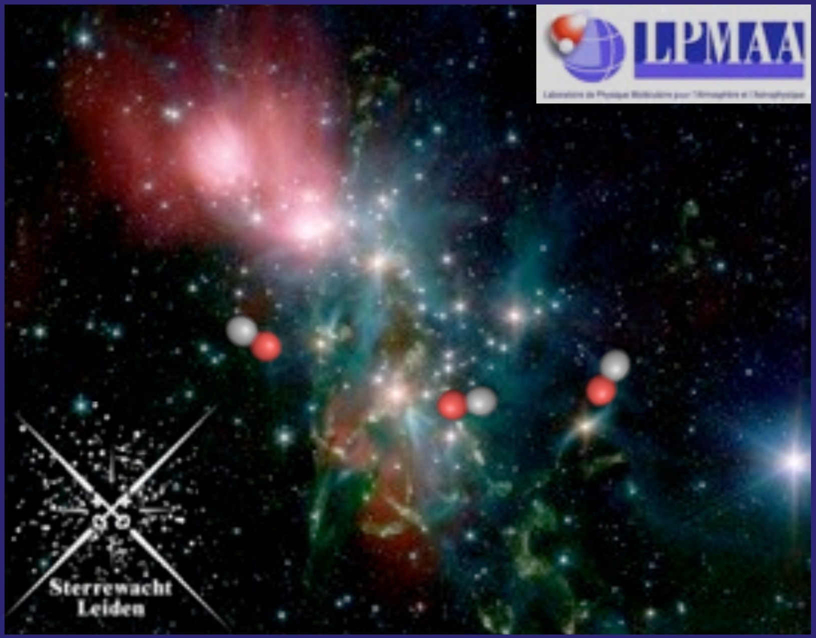

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