Laboratory work

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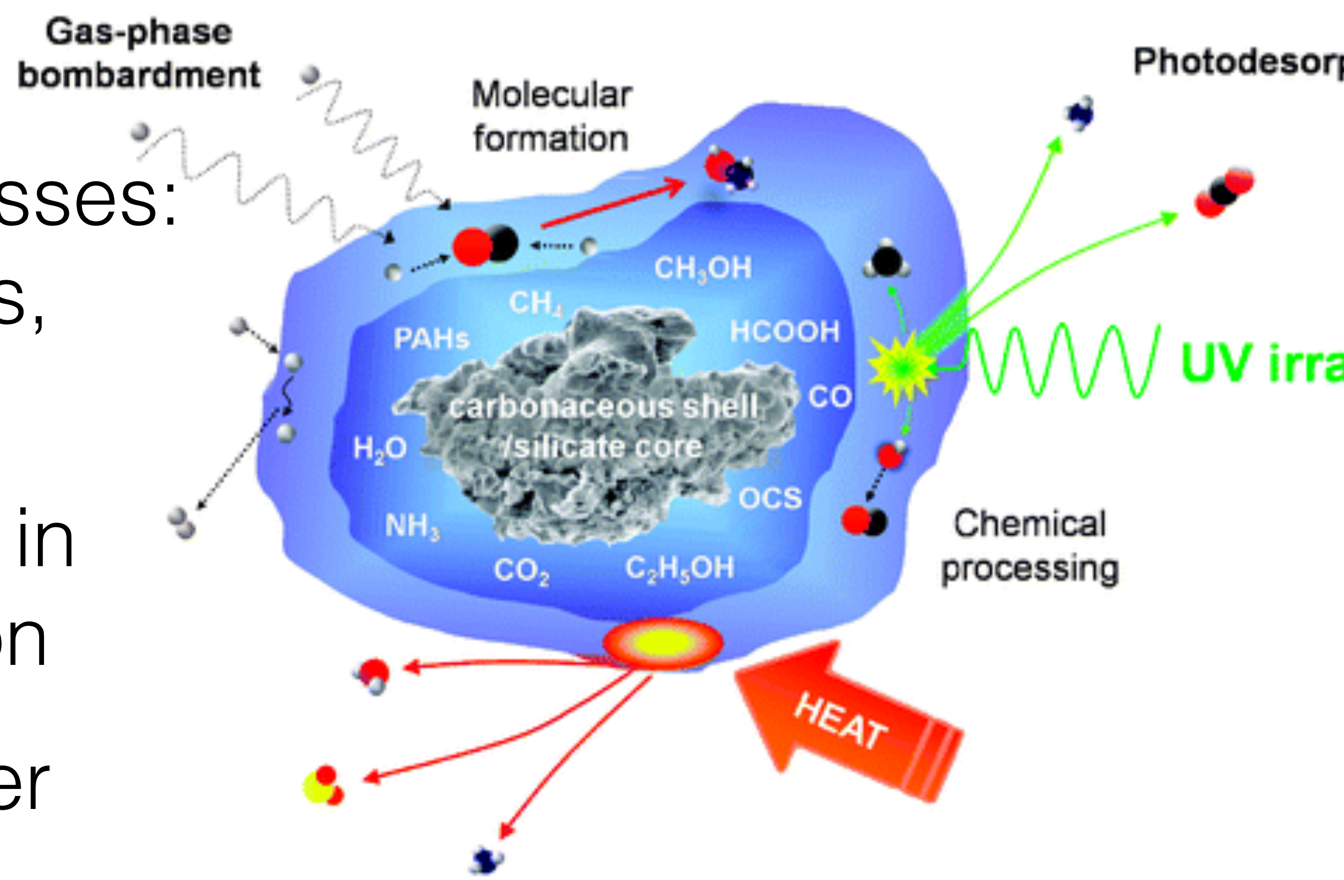
Contents

- Experimental setups
- Types of studies
- Deriving fundamental chemistry (Adi Ding)

Recap last week

- Molecules freeze out on dust grains forming ice mantles
- Ice mantles experience processes: radiation, atom bombardments, thermal processing
- Ices can be observed directly in infrared (vibrational) absorption
- Solid state features are broader than gas features
- Ice chemistry required to explain complex molecule abundances!

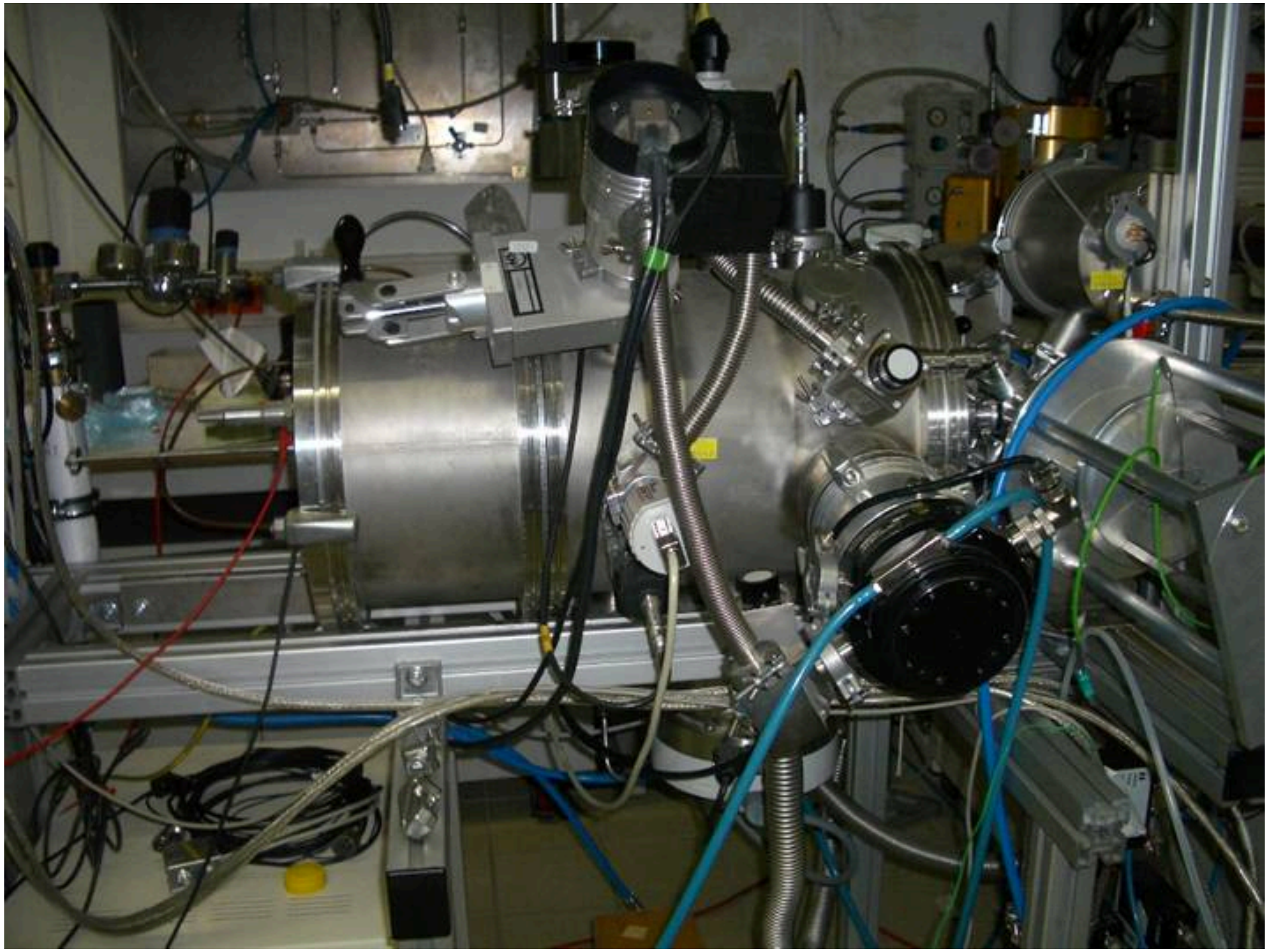


Laboratory astrochemistry

- Primary focus: solid state (ice or PAH) chemistry in a controlled environment
- Experimental work easier than mathematical/analytical derivation!
- Goals
  - Identification and quantification of vibrational features
  - Testing astrochemical processing (formation, destruction, diffusion, segregation, thermal/non-thermal desorption)
  - Deriving rate equations

Experimental setup

- Setups big and complex: why? what components do we need?



Experimental setup

- Largest component: pumps => vacuum
  - High vacuum (~10^{-7} - 10^{-8} mbar) vs ultrahigh vacuum (~10^{-10} - 10^{-11} mbar): sea level ~1 bar
  - Reason: “pollution” ice by air molecules, primarily H_2O: HV experiments have to be run in a few hours and ice needs to be thick in comparison (>0.1 μm or ~3000 L, L~few monolayers)
  - UHV only possible since the last decade

Experimental setup

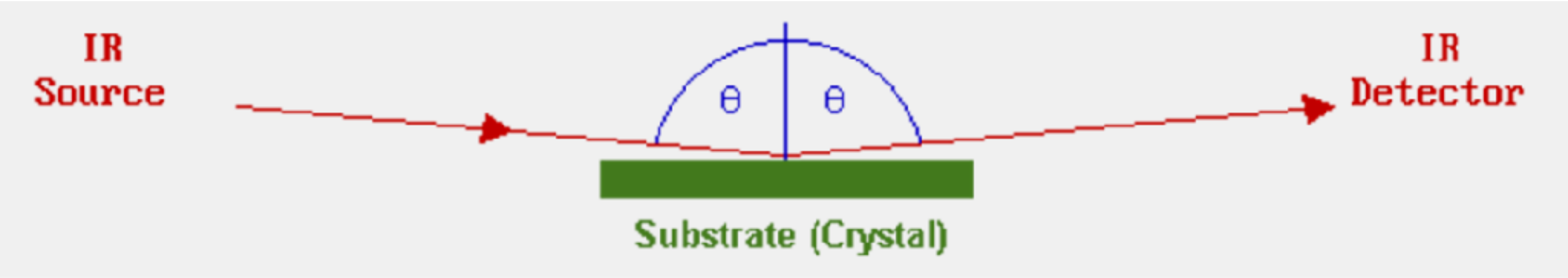
- Closed-cycle cryostat: usually helium => cooling down to <15 K
- Heating device for controlled temperature rise
- Vacuum chamber with substrate: non-reactive material, e.g. gold-coat
- Outlet for connecting gas bottles

Experimental setup

- Measuring devices:
  - FTIR spectrometer: ice-phase
  - Quadrupole Mass Spectrometer (QMS): essentially measuring ions (gas) mass/charge ratios
- Processing sources: UV lamp, atomic source

Experimental setup

- Spectroscopy:
  transmission or reflection-absorption (RAIRS)

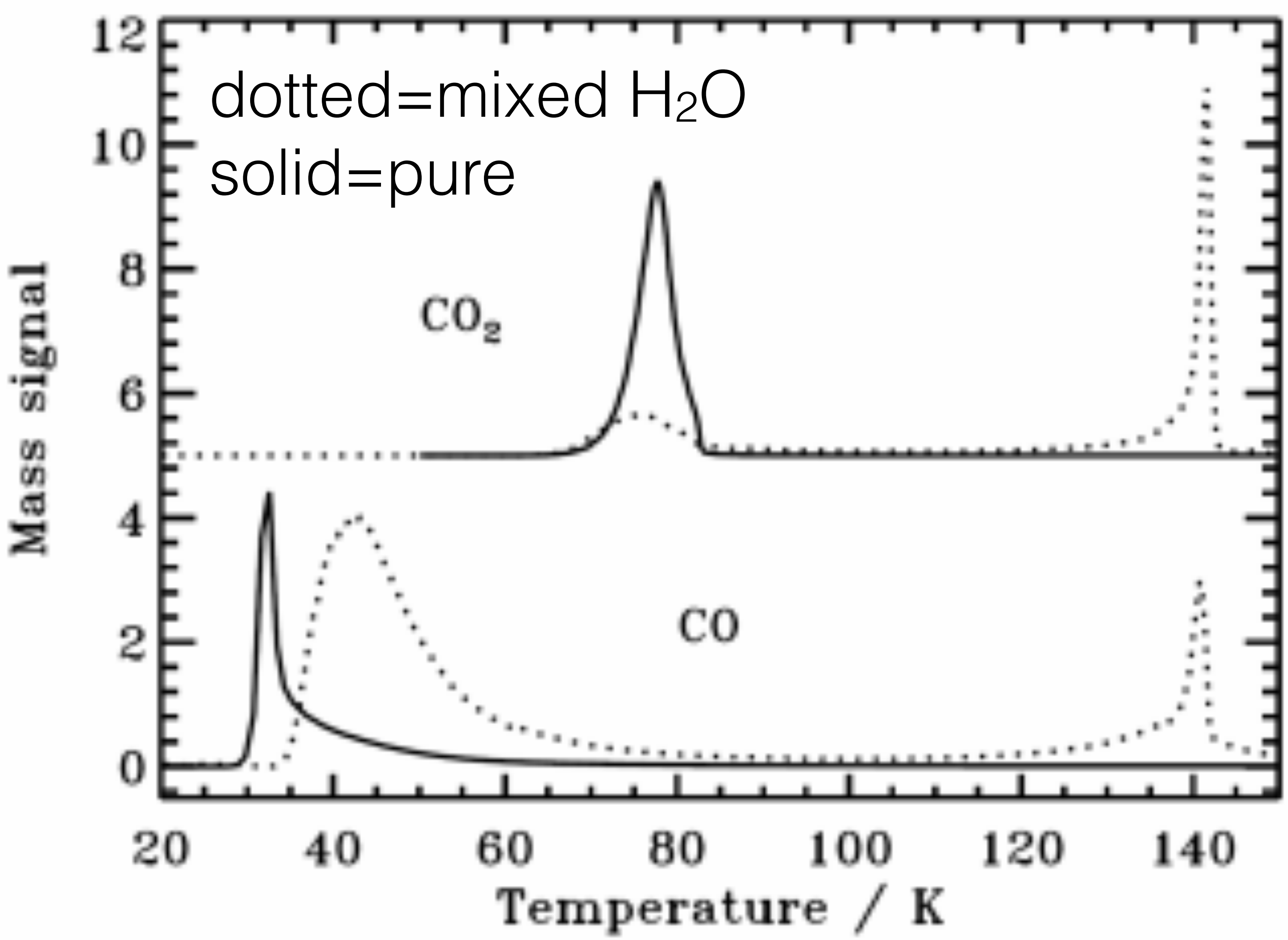


- Advantage RAIRS: increase path-length and thus sensitivity of monolayers

- Disadvantage RAIRS: no direct comparison to astrophysical spectra => more suitable for study ice processes

Experimental setup

- QMS for a TPD (temperature programmed desorption) experiment: monitor gas-phase species desorbed from the ices

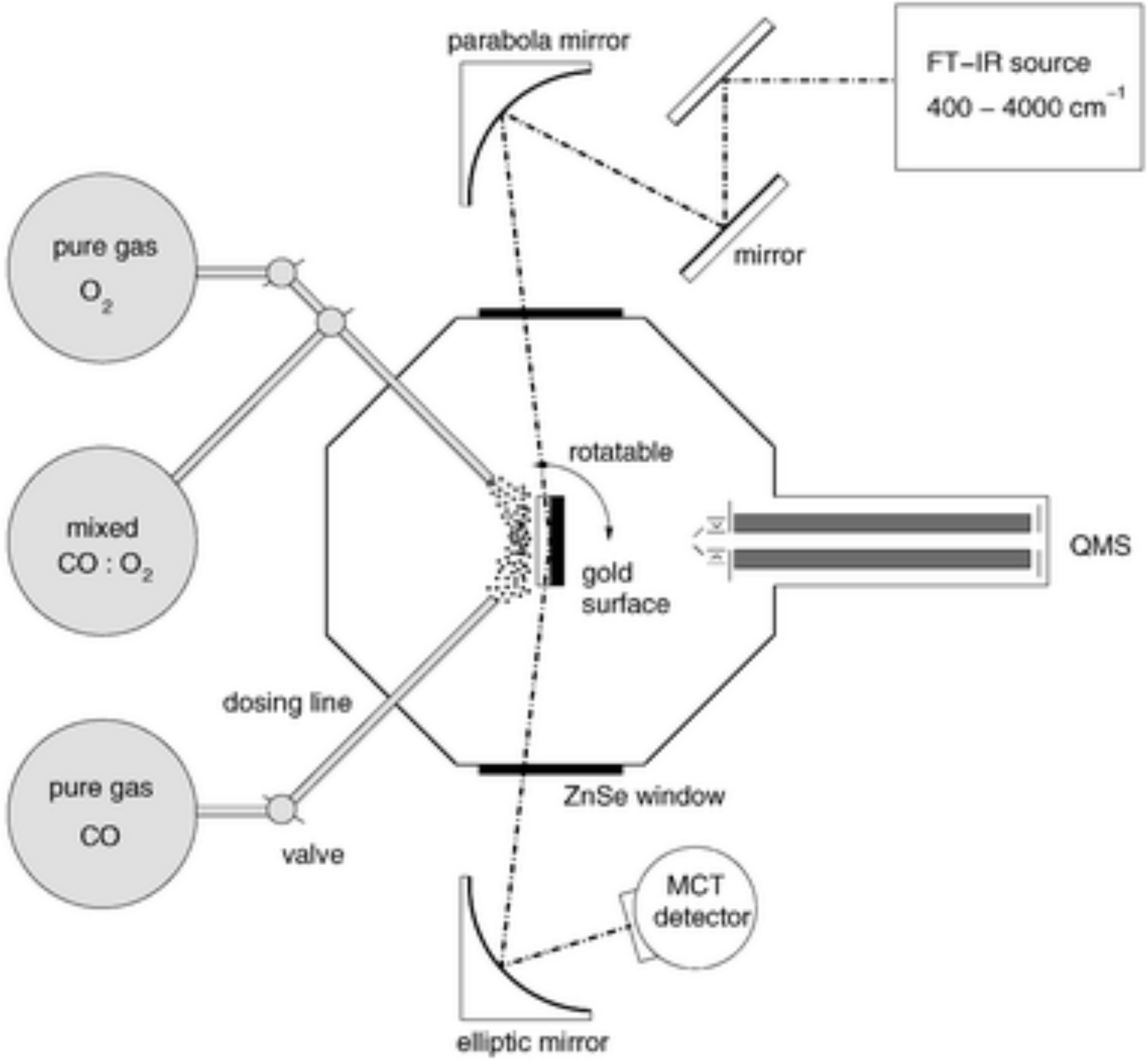


TPD vs spectrometry:

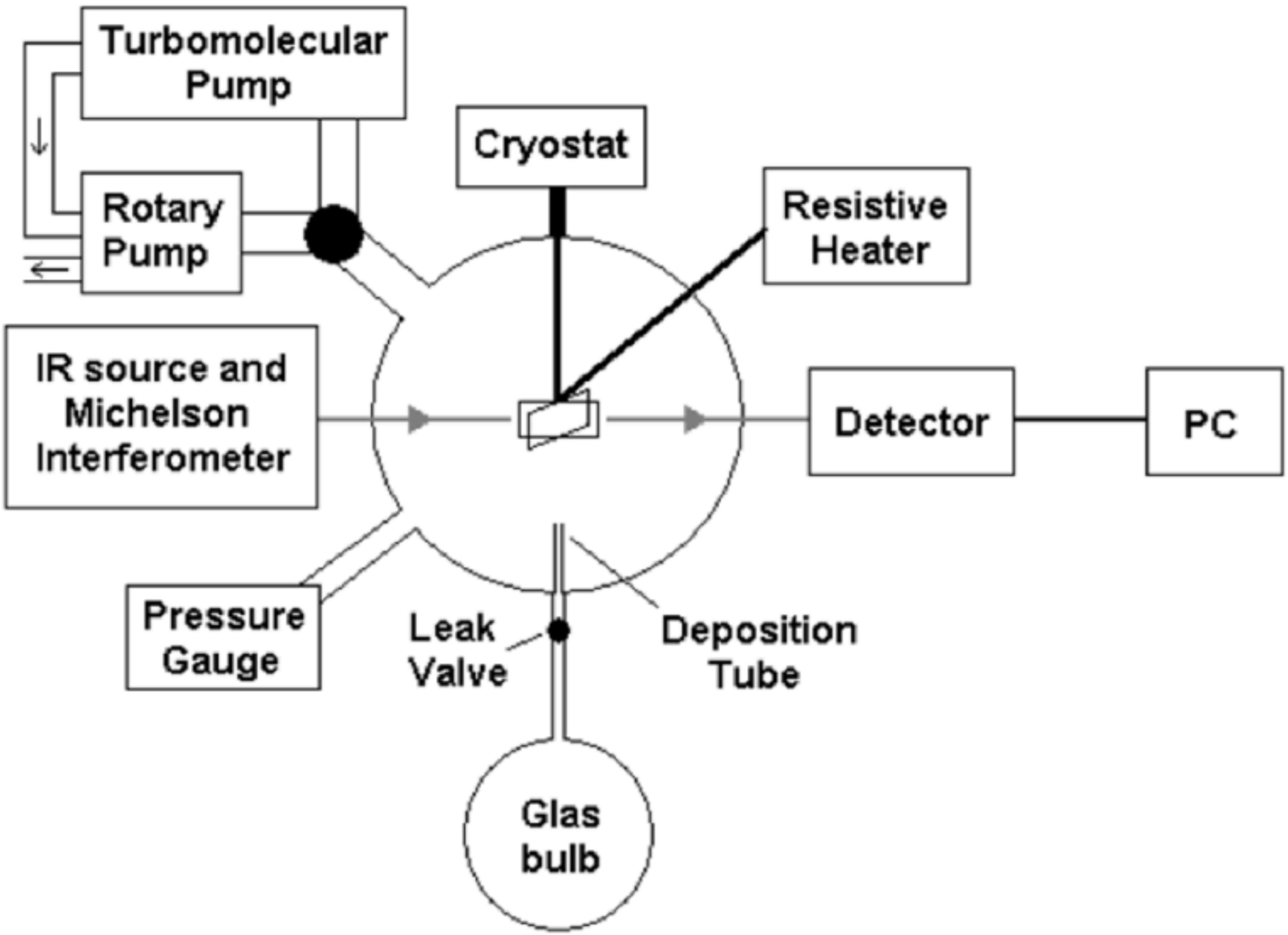
- possible reactions during TPD
- similar masses cannot be distinguished

Oberg et al. 2009

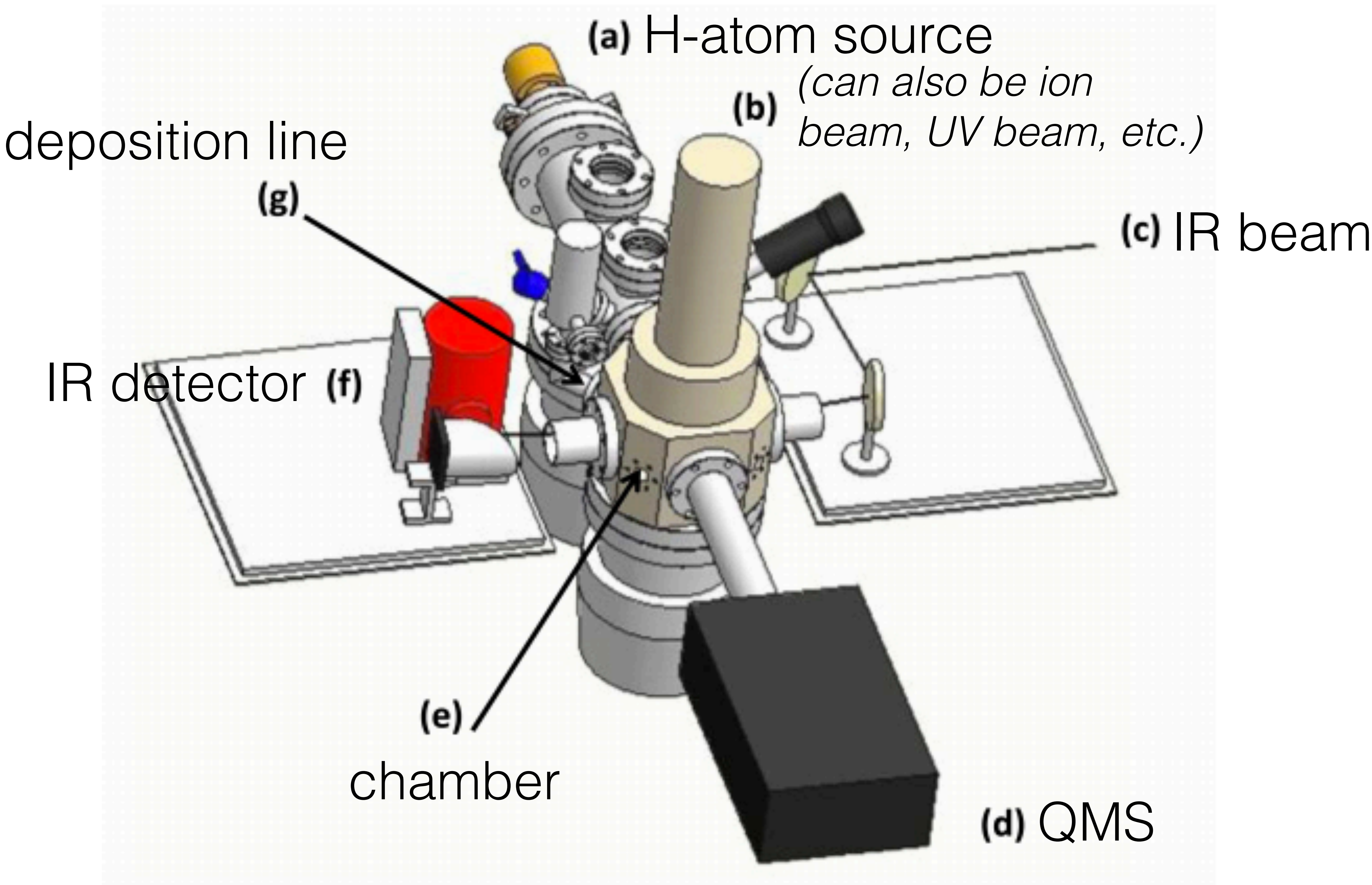
Experimental setup



Experimental setup

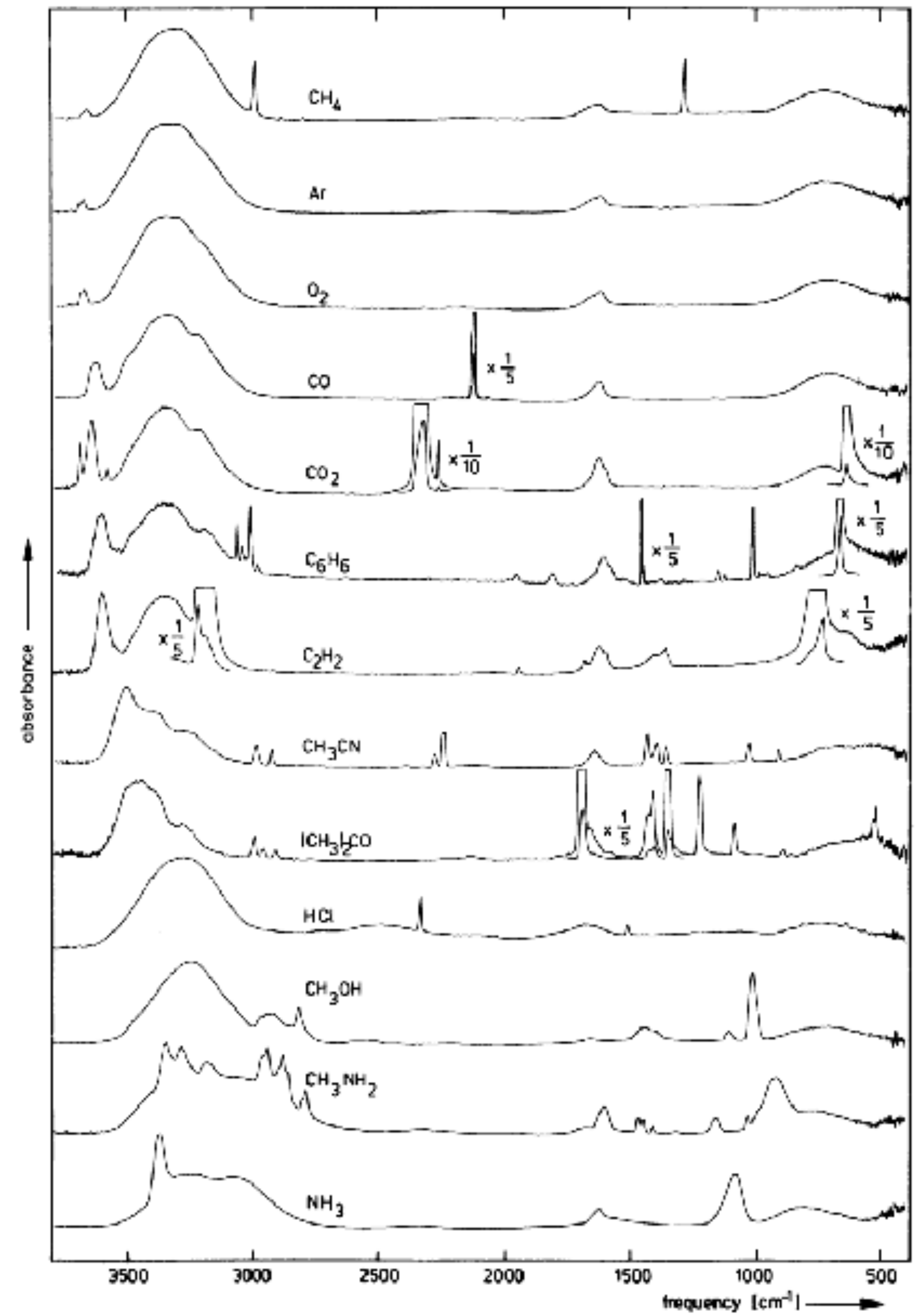


Experimental setup



Types of studies

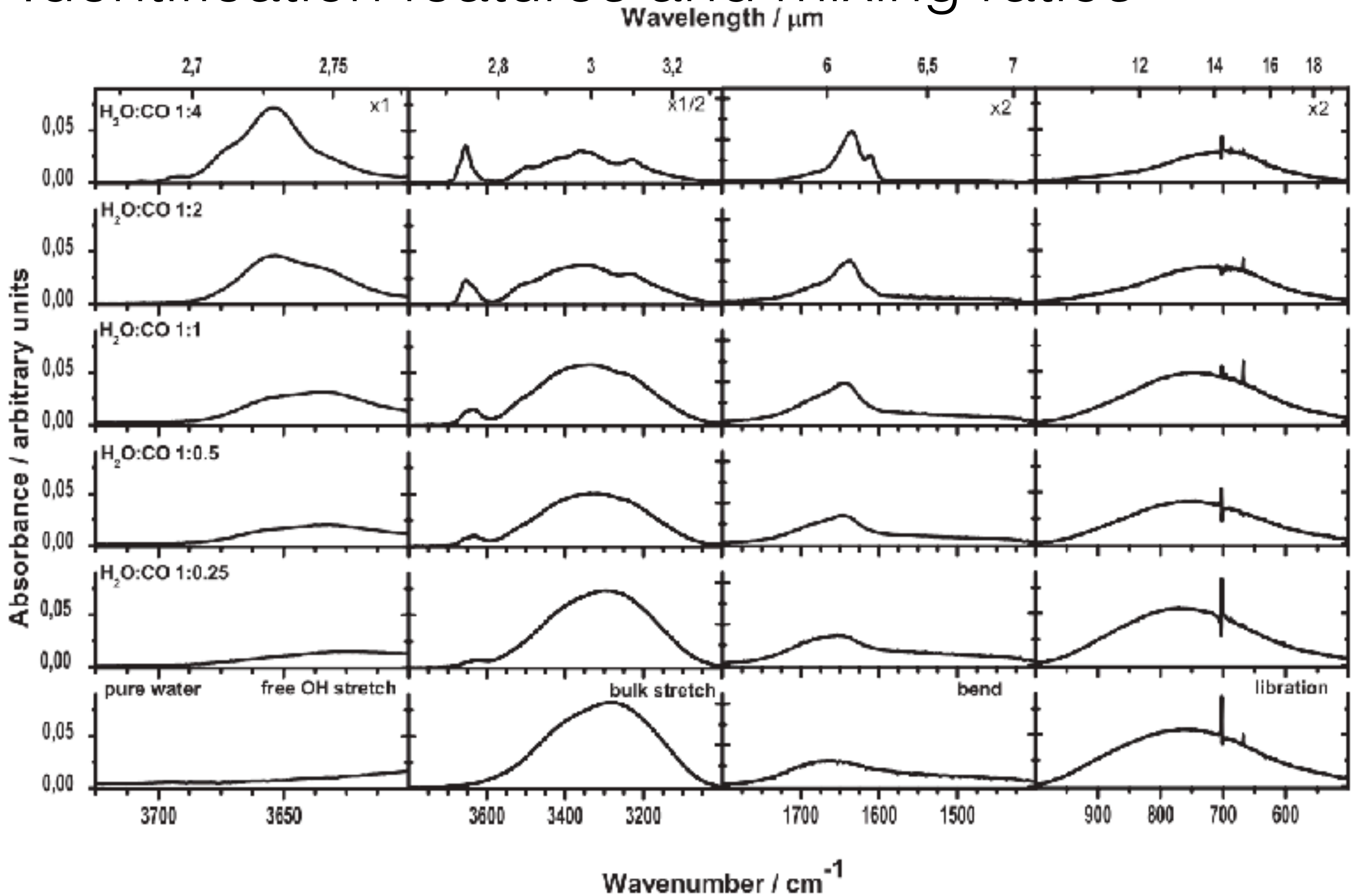
- Identification infrared features and mixing ratios
- **Note: absorption positive!**
- Procedure: isolate, cool down, vacuum, freeze-out, stabilize, spectrum, desorb



Hagen et al. 1983

Types of studies

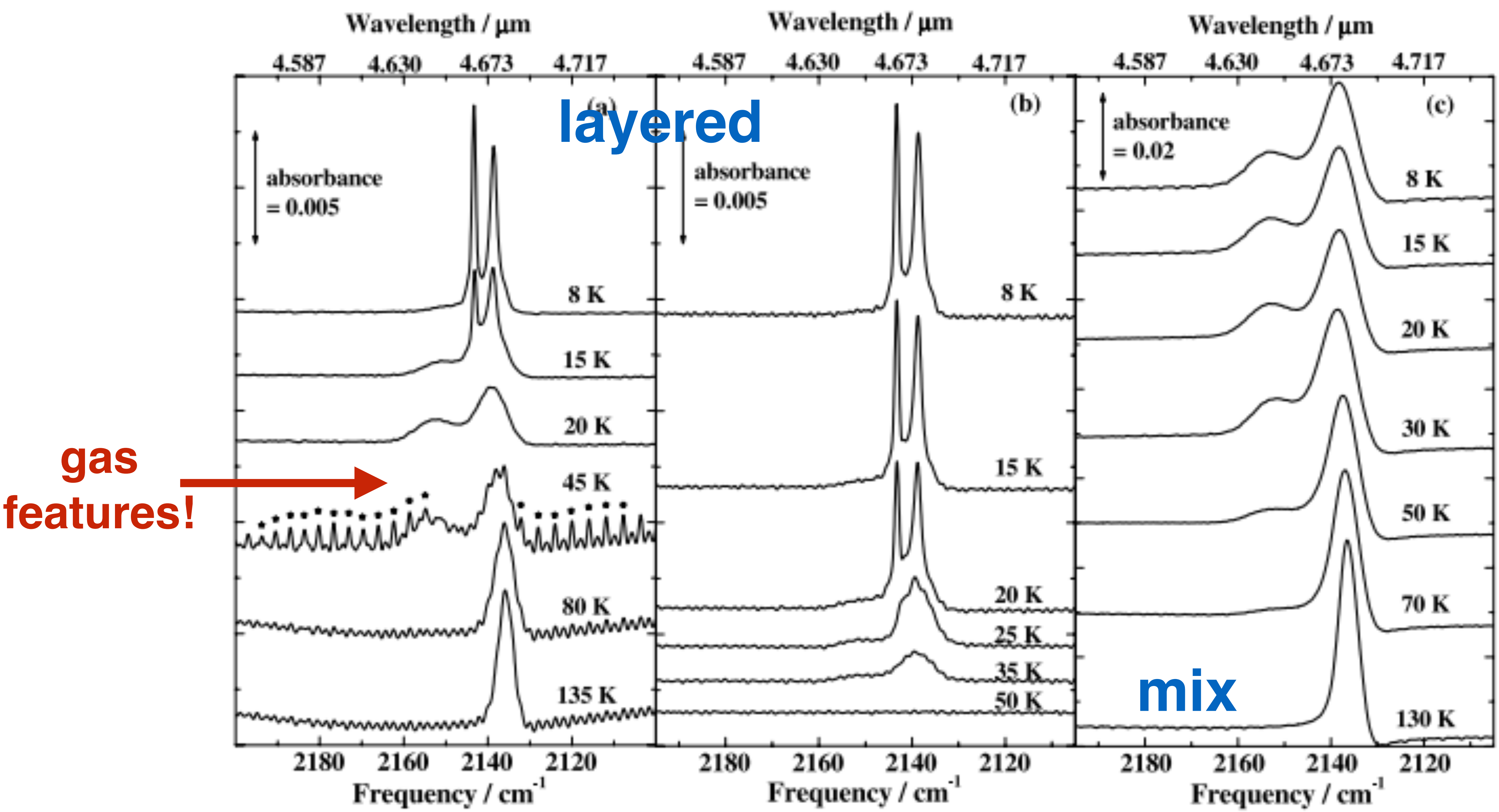
- Identification features and mixing ratios



Bouwman et al. 2007

Types of studies

- Temperature dependence ice features of CO/H_2O

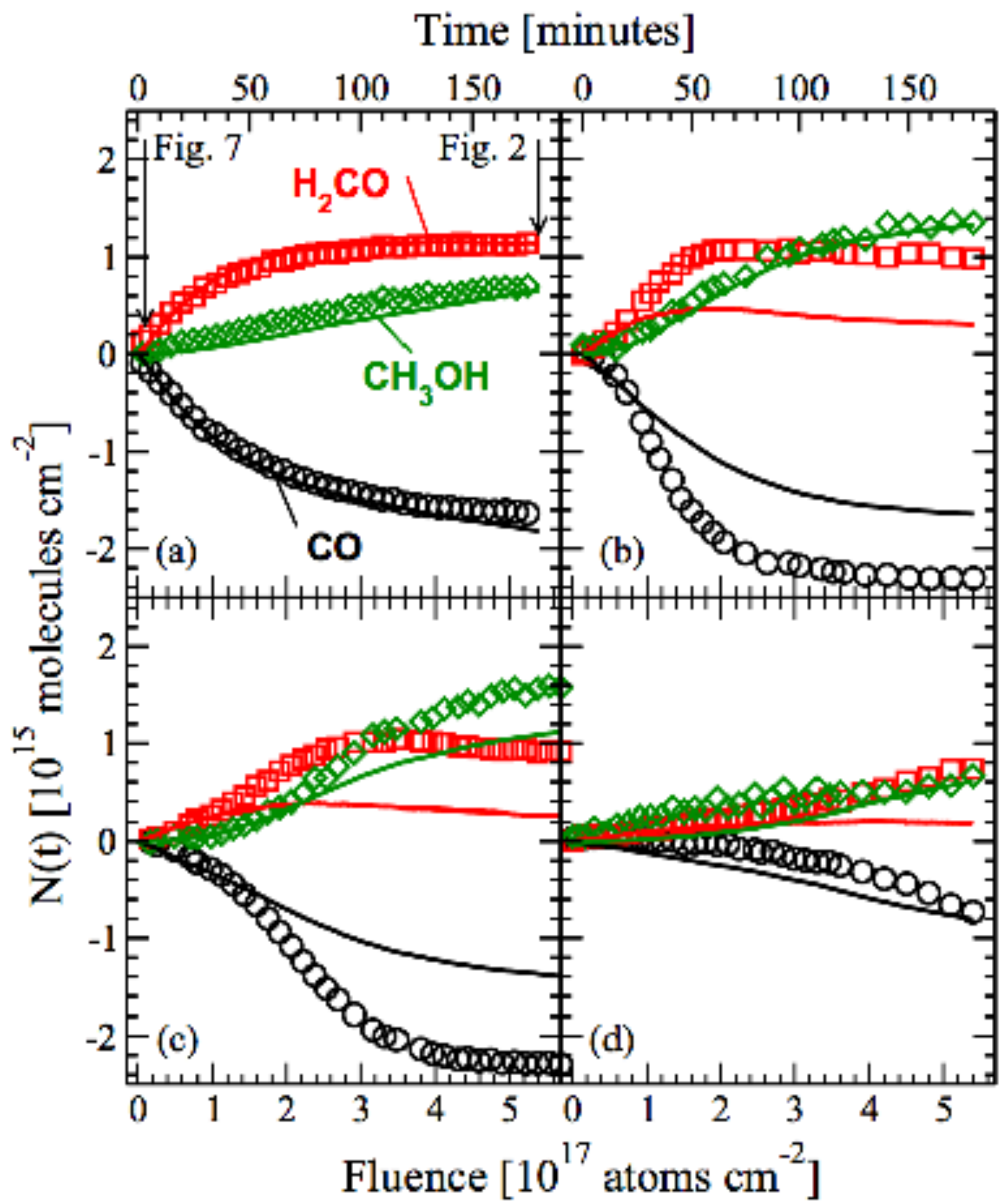


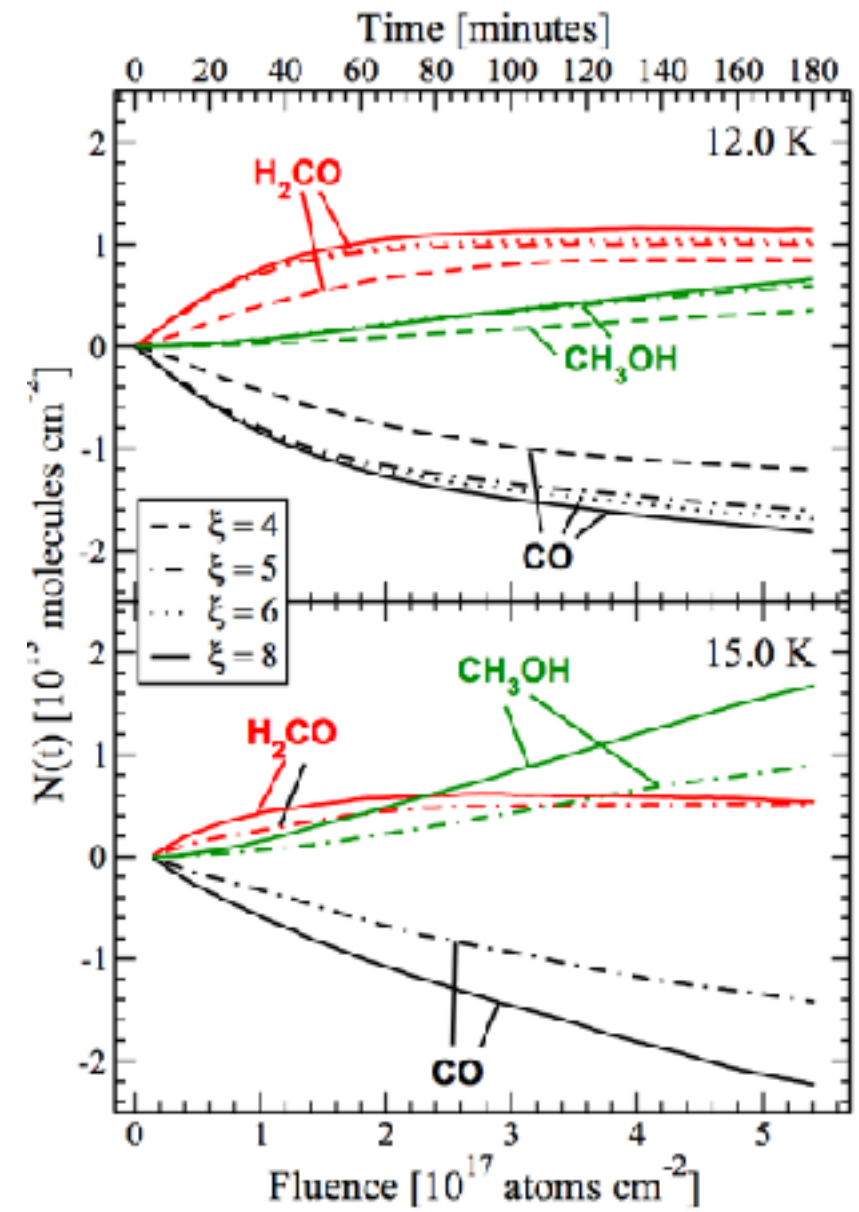
Collings et al. 2003

Types of studies

- Formation H_2CO and CH_3OH: hydrogenation CO ice

experiment (12,13.5,15,16.5 K)





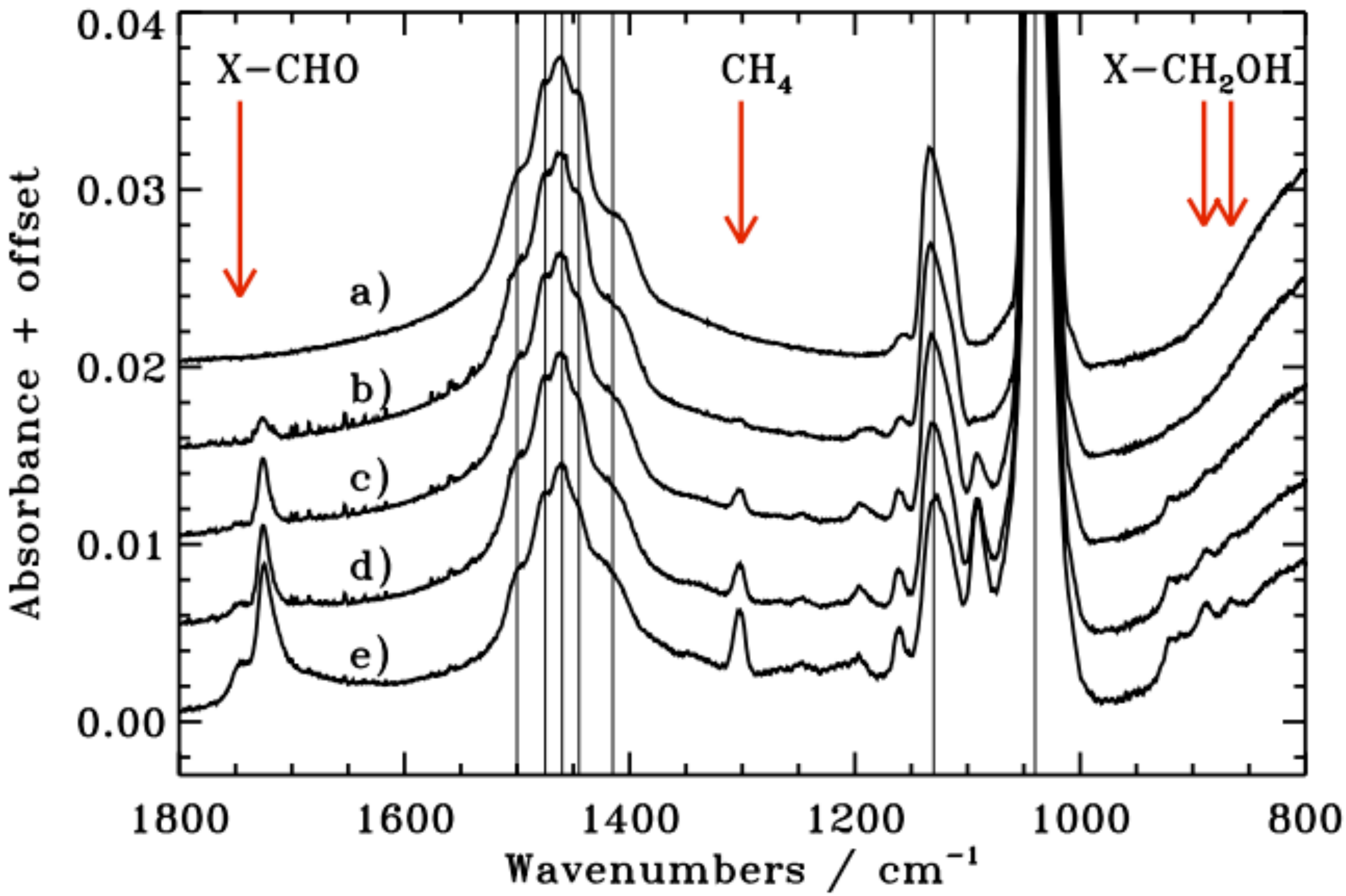
MC simulation

$$CO + H \rightarrow HCO \xrightarrow{H} H_2CO \xrightarrow{H} H_3CO \xrightarrow{H} CH_3OH$$

Fuchs+2009

Types of studies

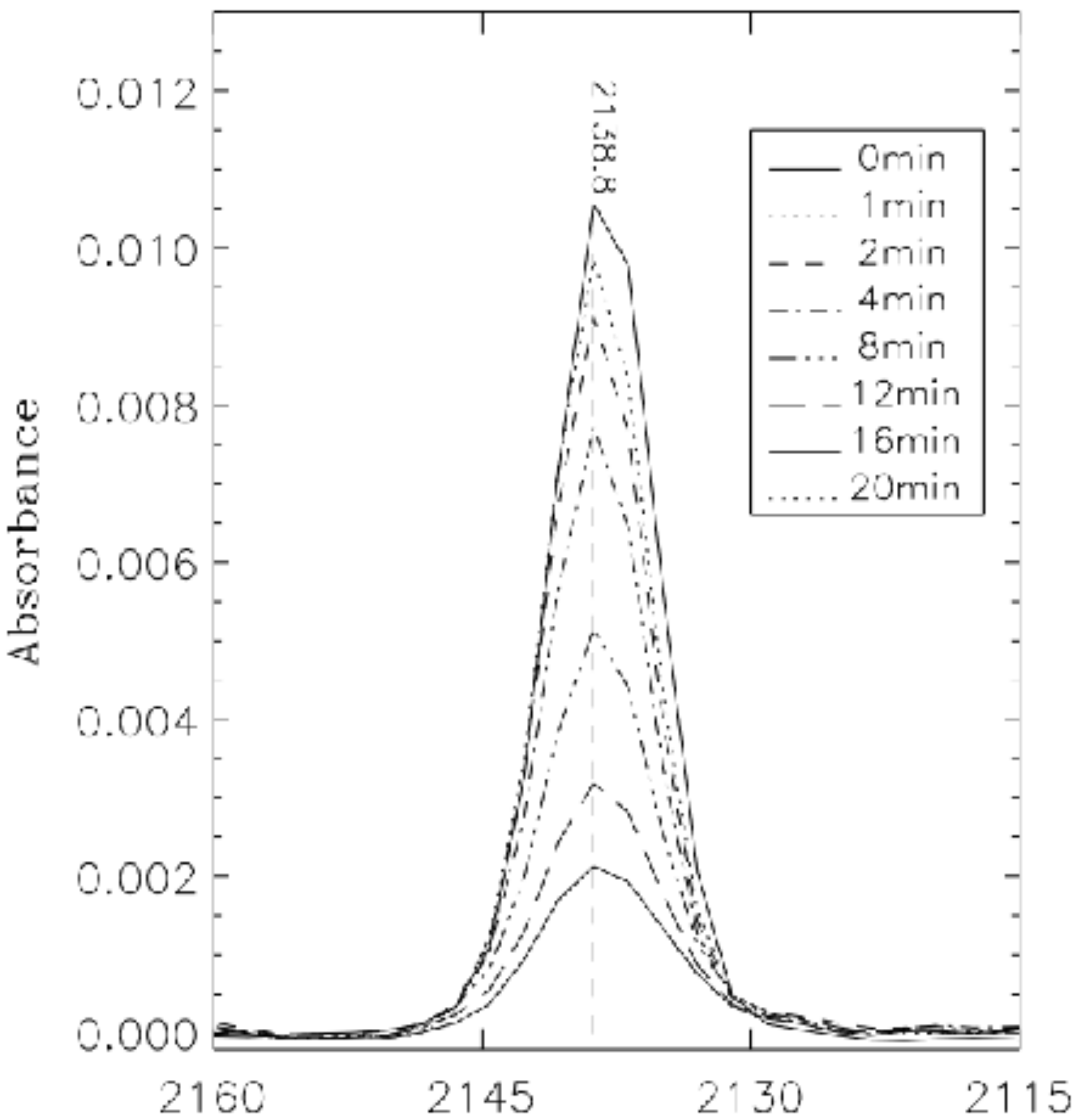
- Photolysis (UV radiation) products of CH_3OH ice

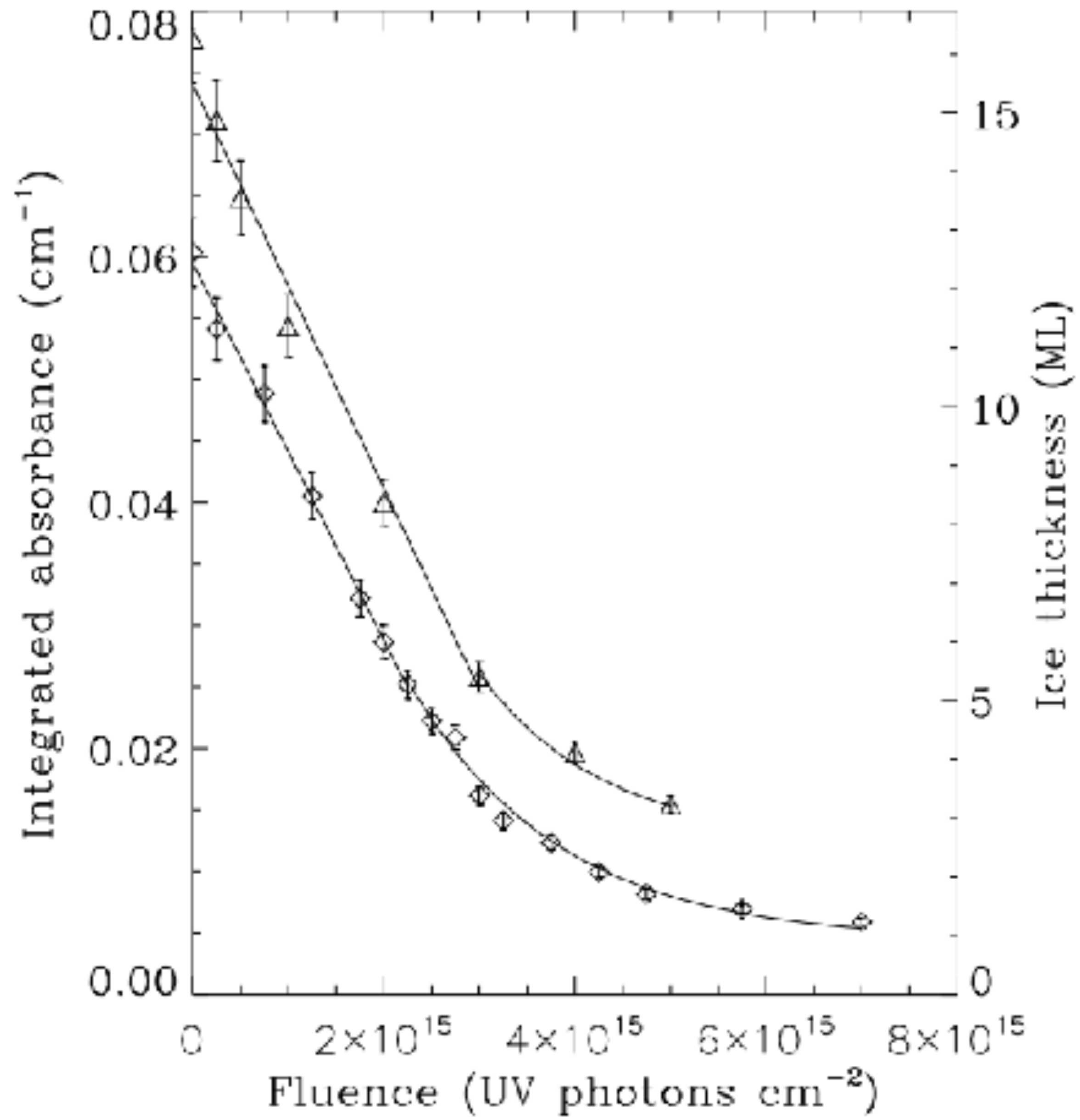


Oberg et al. 2009

Types of studies

- CO photodesorption rates (UV lamp)

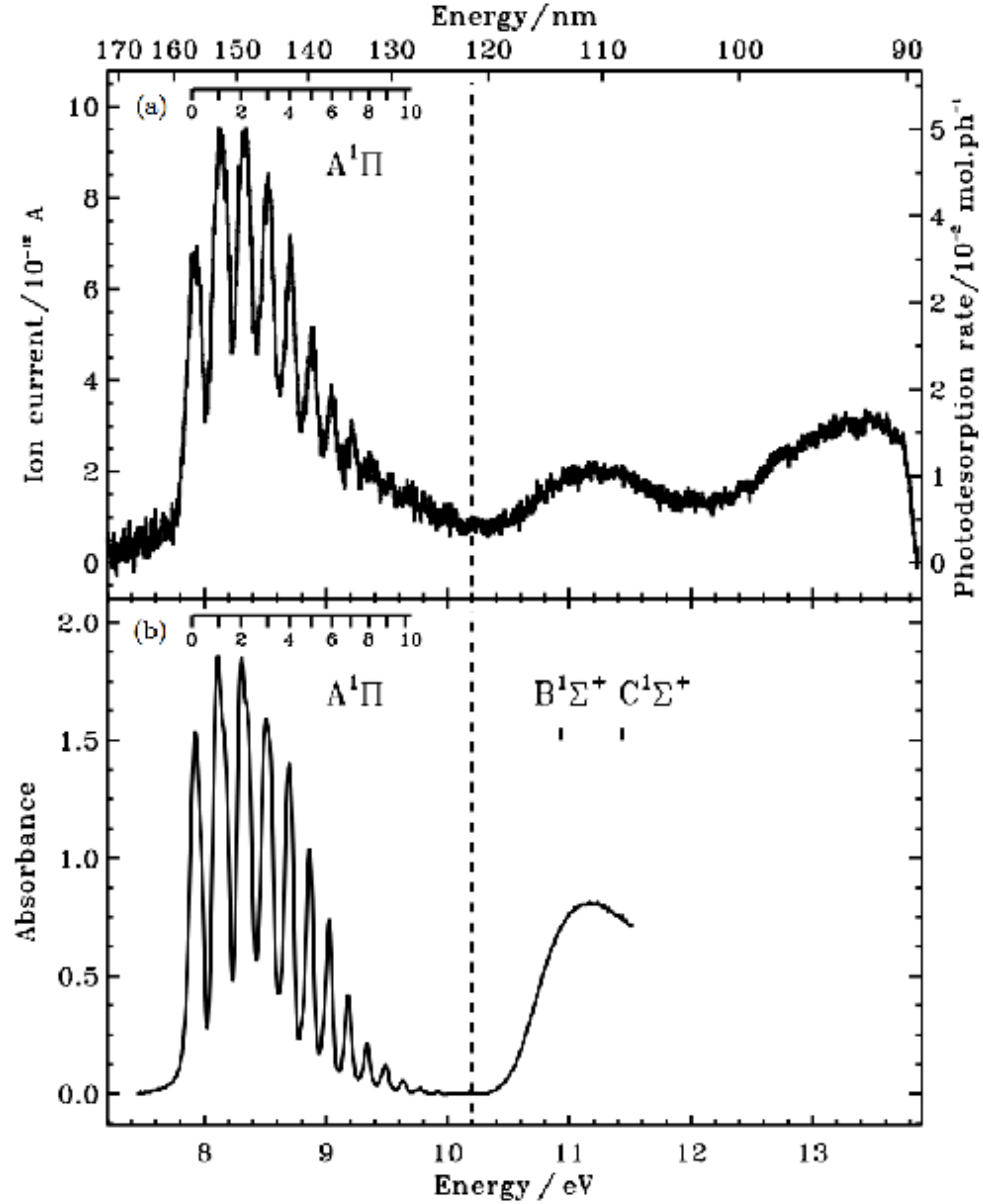




Munoz Caro et al. 2010

Types of studies

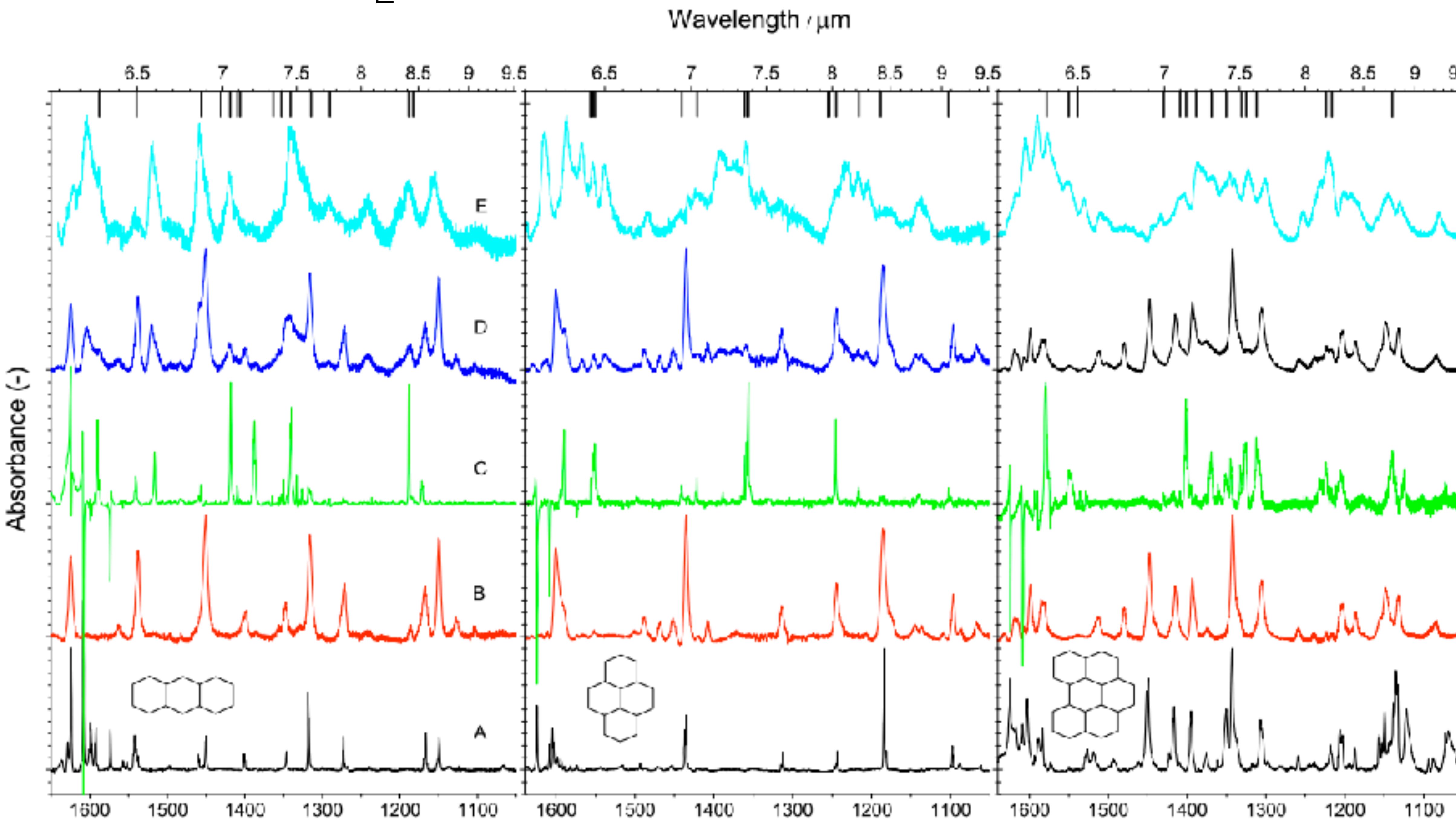
- UV-dependence studies: FUV beam line at SOLEIL synchrotron (Paris)
- Note wavelength range: UV (90-170 nm): => electronic states



Fayolle et al. 2011

Types of studies

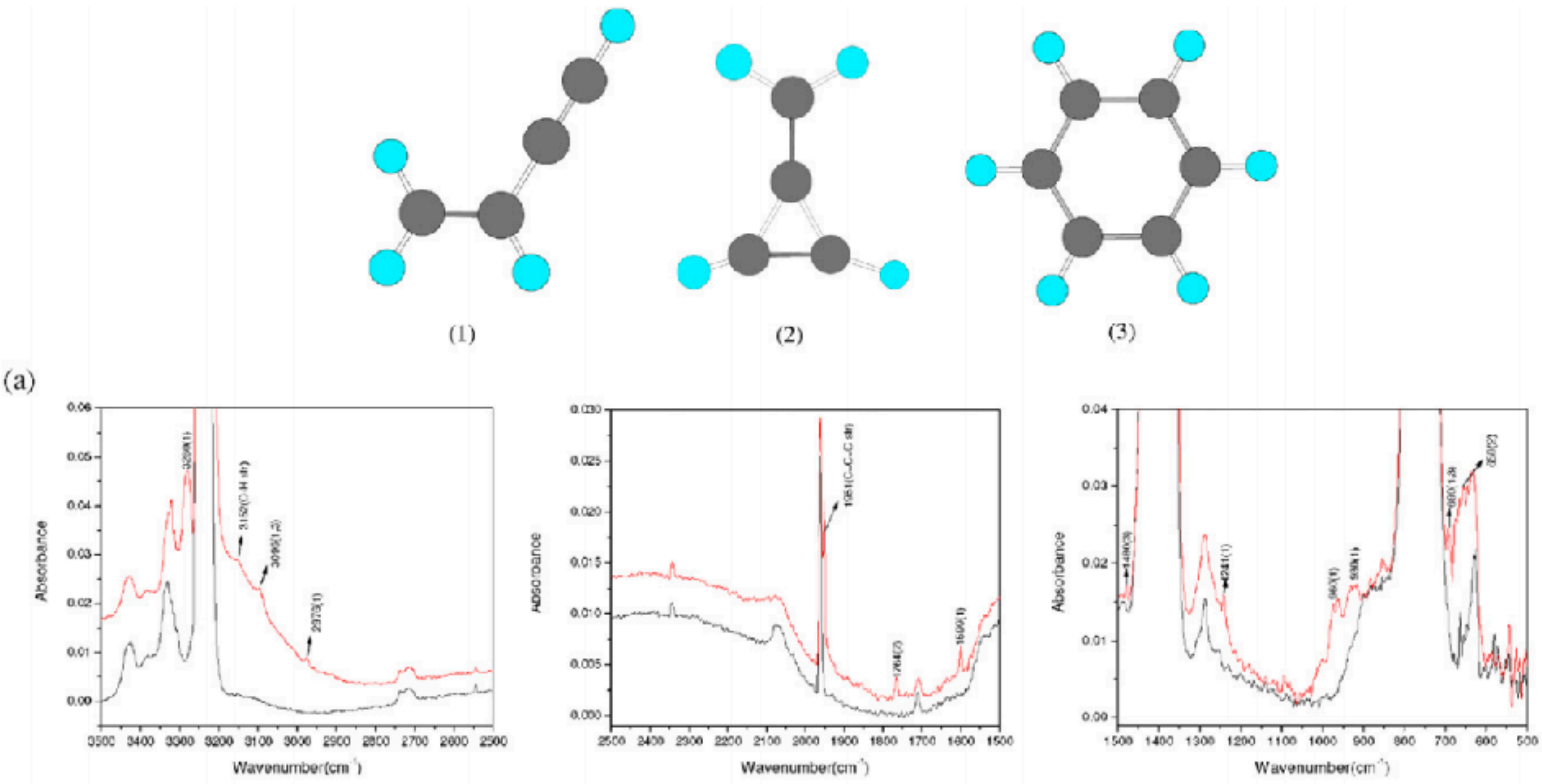
- PAHs in H_2O matrices



Bouwman et al. 2011

Types of studies

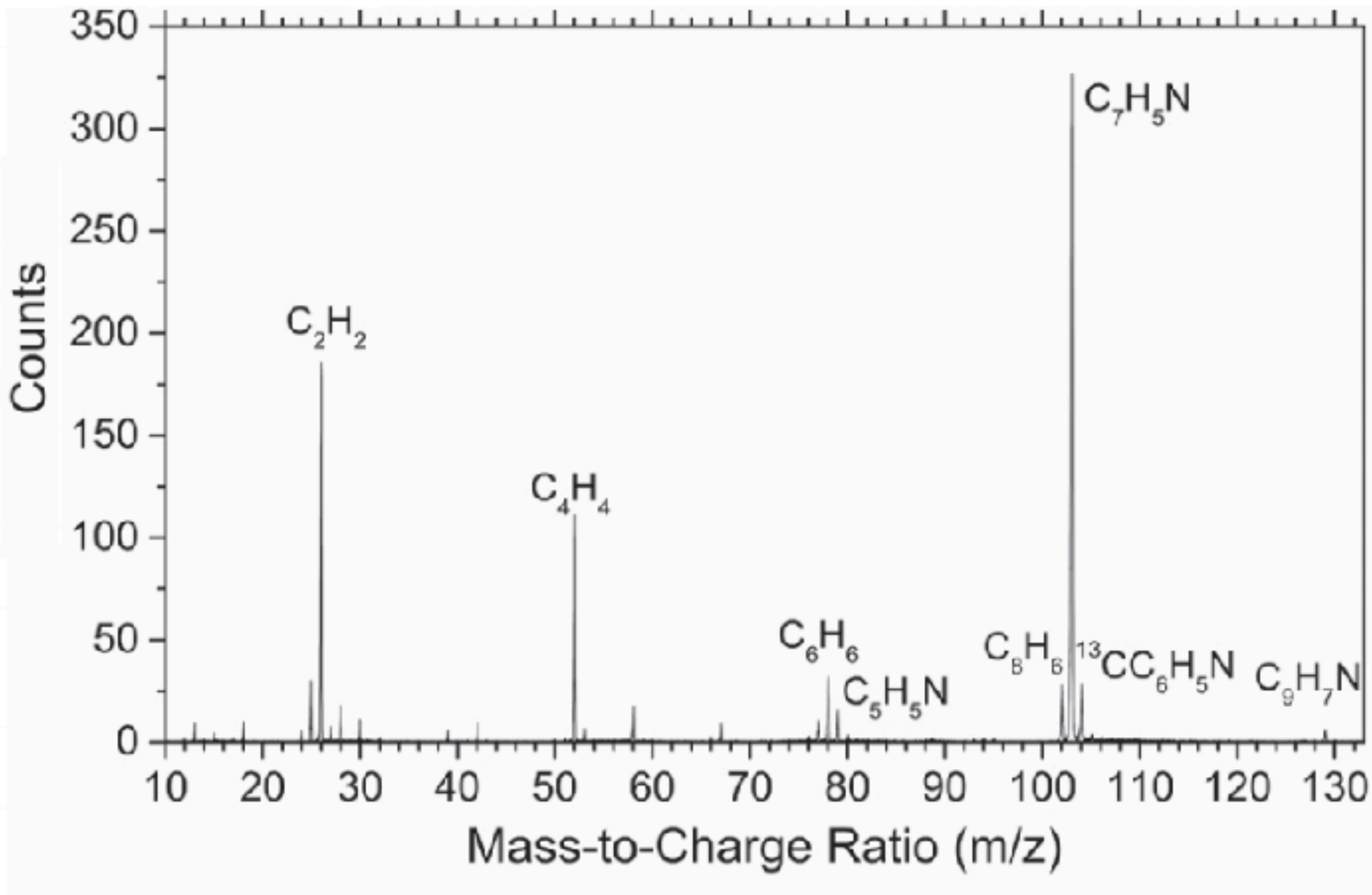
- Cosmic ray-induced formation of benzene (Titan)



Zhou et al. 2010

Types of studies

- Nitrogen-PAHs formation around environments similar to envelopes of carbon stars



Parker, Kaiser et al. 2015

Astrochemistry labs

- Generally a mix of physicists, chemists and astronomers: very interdisciplinary! Also collaboration with modellers
- Experimental work: failures, calibration and money
- Examples labs:
  - Kaiser lab UH (Kaiser)
  - Strathclyde, Heriot-Watt in UK Virginia (Herbst)
  - Alabama (Gerakines)
  - NASA Ames (Sandford)
  - Harvard (Oberg)
  - Sackler lab Leiden (Linnartz)
  - Strathclyde, Heriot-Watt (McCoustra, Fraser)
  - Laboratoire d’Astrophysique Bordeaux, France (Wakelam)

http://www.astrochymist.org/astrochymist_whom.html

Talk Adi

Next week

- Using ALMA to look for molecules
  - Splatalogue
  - Basic interferometry
  - ALMA dataset
  - Imaging
  - Tutorial (please install CASA!)