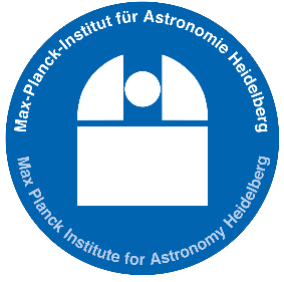
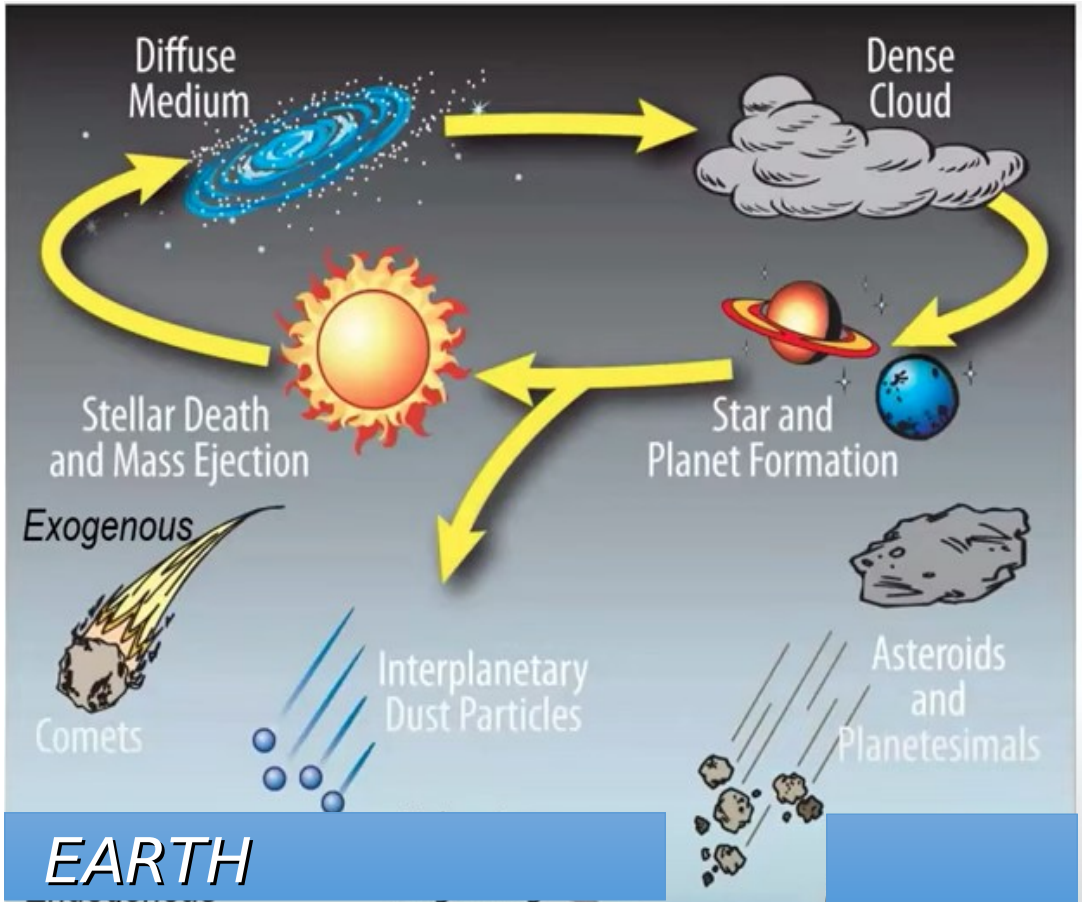
An overview on the experimental setups in the origin of life lab

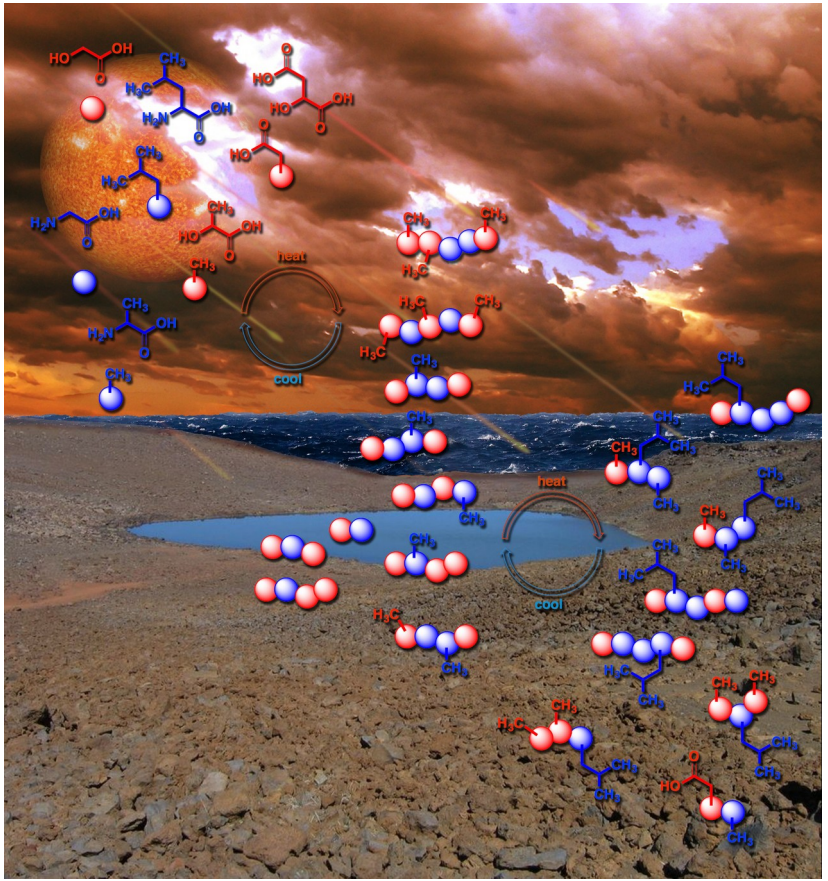
Jiao He, lab head
Tushar Suhasaria, postdoc



From molecular cloud to life on Earth



After Deamer et al. 2002



CREDIT: Karl Magnacca, John Boyer/SXC, bearfotos/Freepik, Vecteezy.com, and NASA

Presence of prebiotic molecules in comets and meteorites

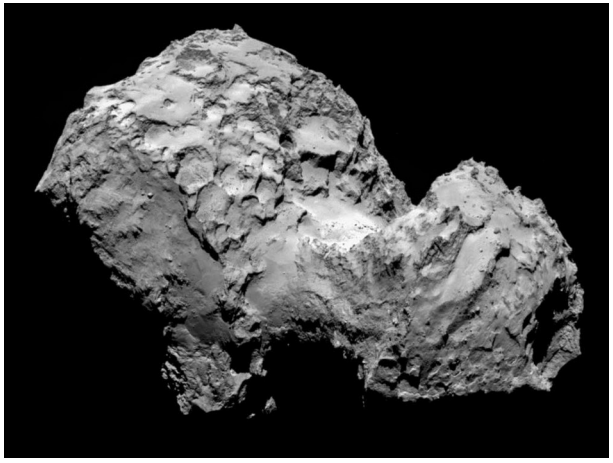


Image Credit: ESA / Rosetta / MPS for OSIRIS Team;
MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

Detected in comet 67P/CG:

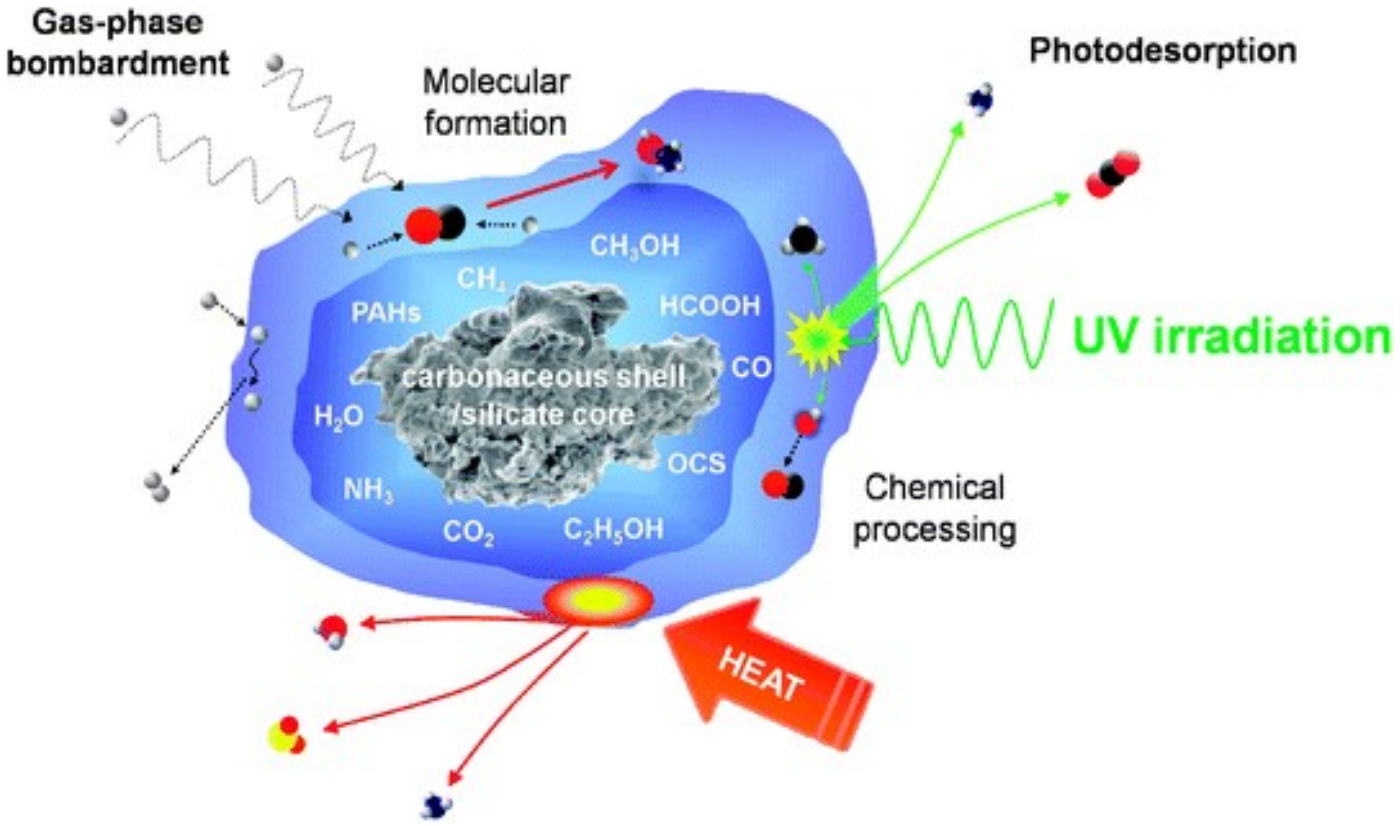
- **Examples: H_2CO, HCN, CH_3COOH, glycine ...**

SBS Eclectic Images/Alamy

Detected in meteorites:

- **Amino acids**
- **Ribose**
- **Nucleobases**
- **Fatty acids**
- **Phosphates**

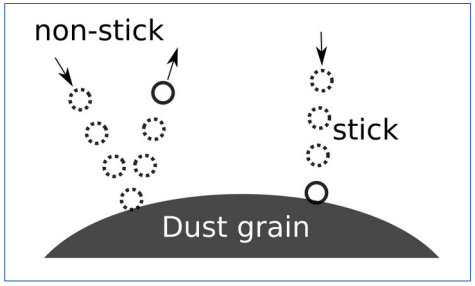
Physics and chemistry on interstellar dust grains



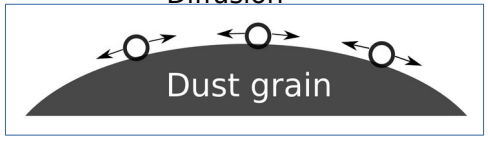
Burke & Brown 2010

Some research topics

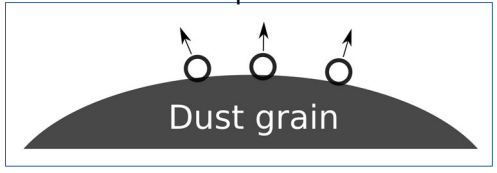
Sticking



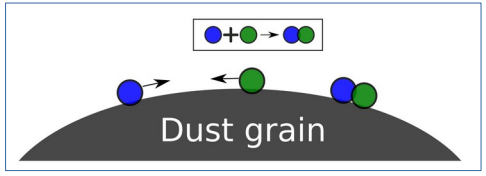
Diffusion



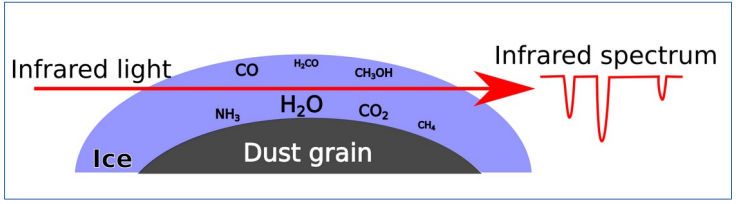
Desorption



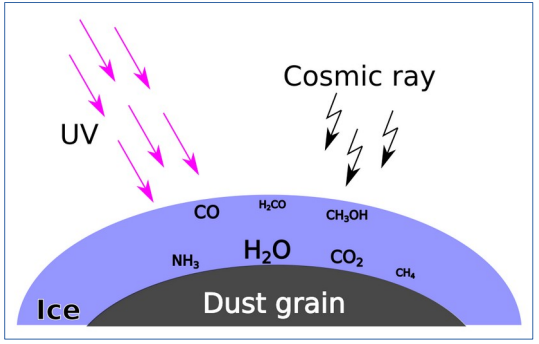
Chemistry on grain surface



Infrared spectrum of the ice mantle

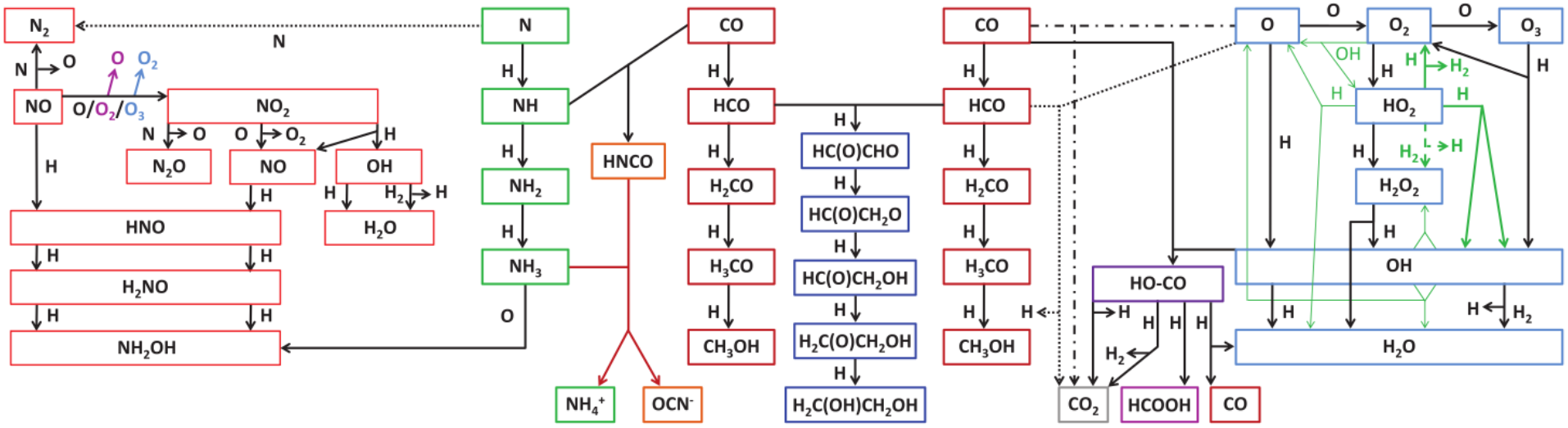


Complex organic molecules formed from ionizing irradiations



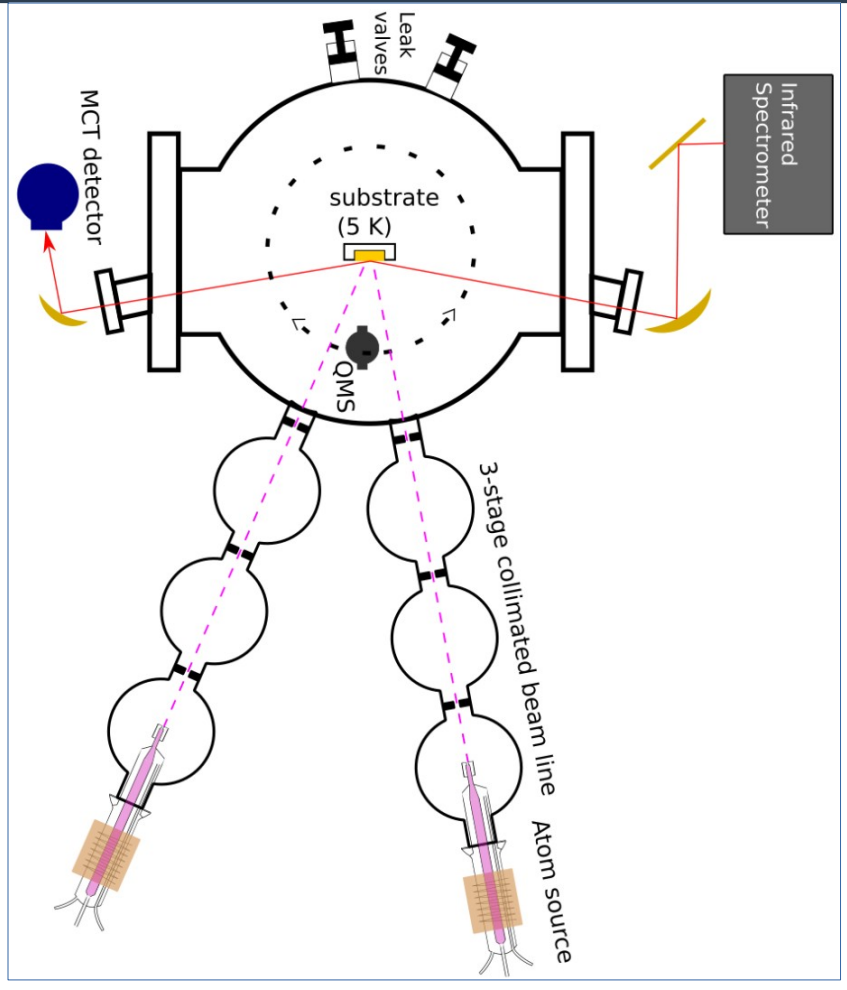
Structure of the ice mantle

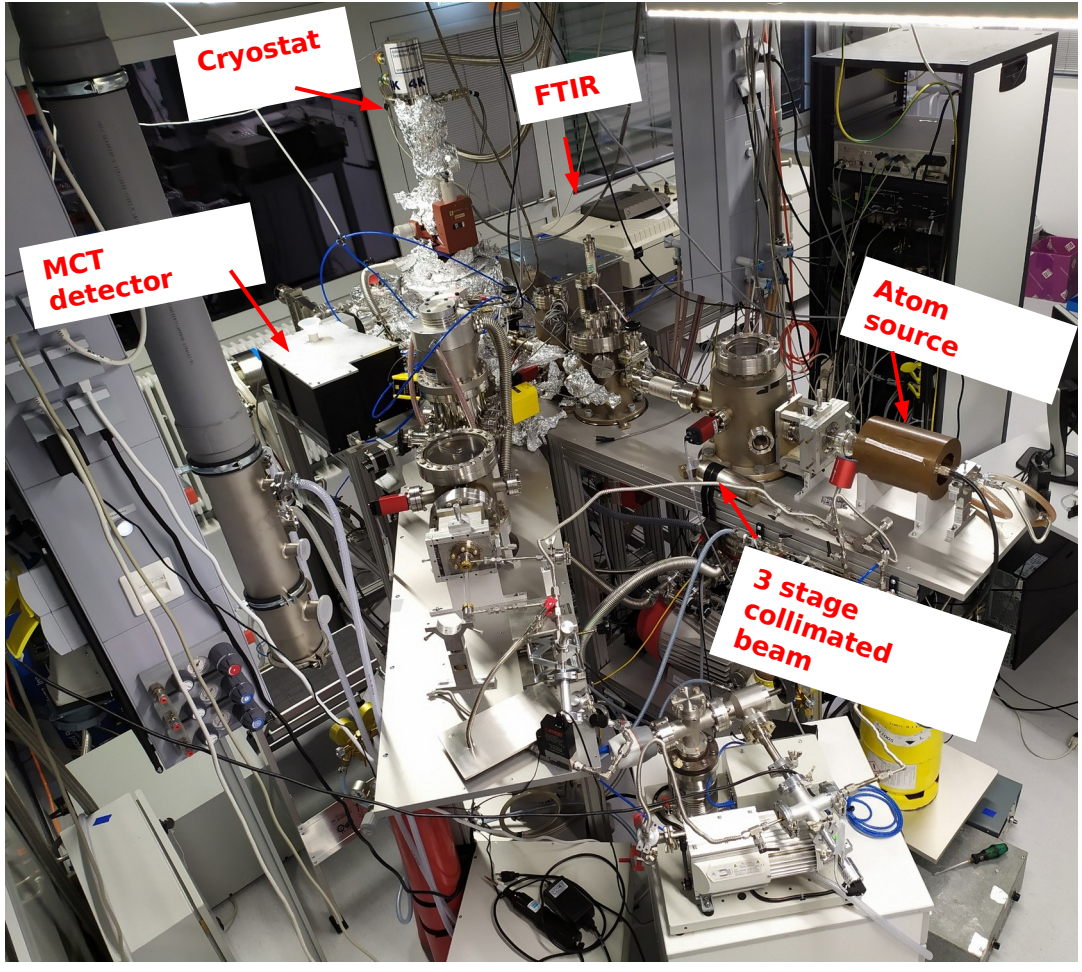
Grain surface chemistry



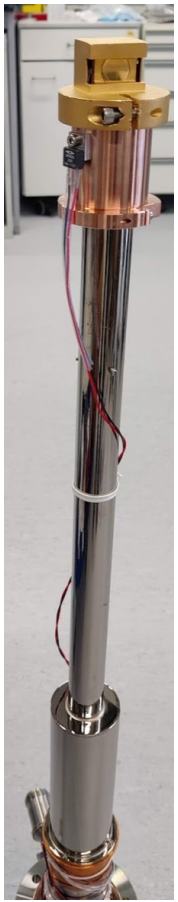
H. Linnartz+ (2015), International Reviews in Physical Chemistry, 34:2, 205-237

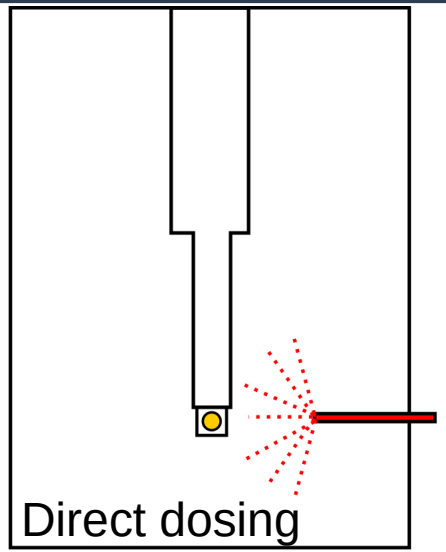
First experiment setup in the Origins Lab

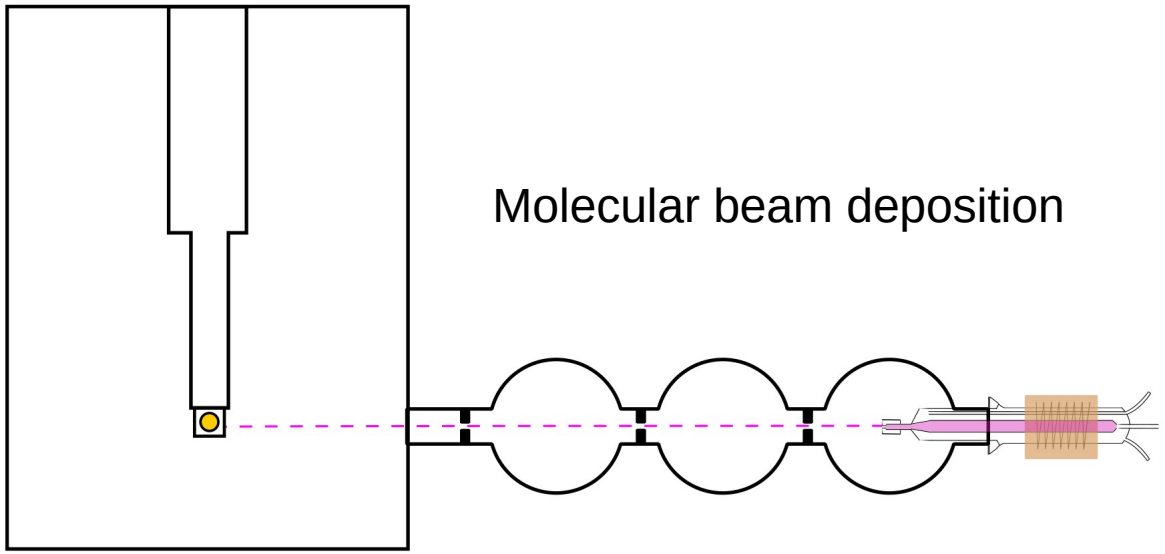


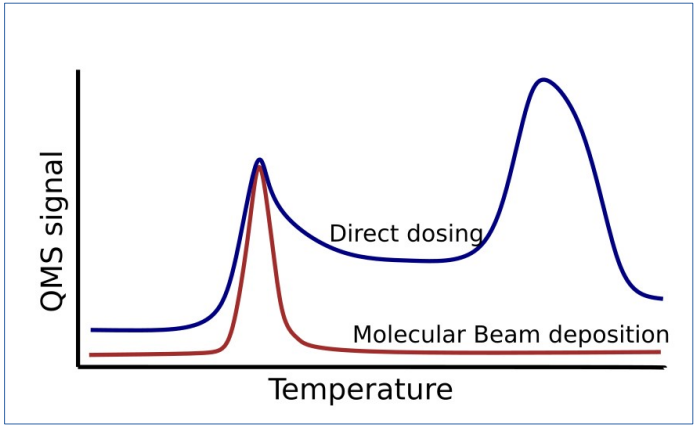


Advantage of molecular beam

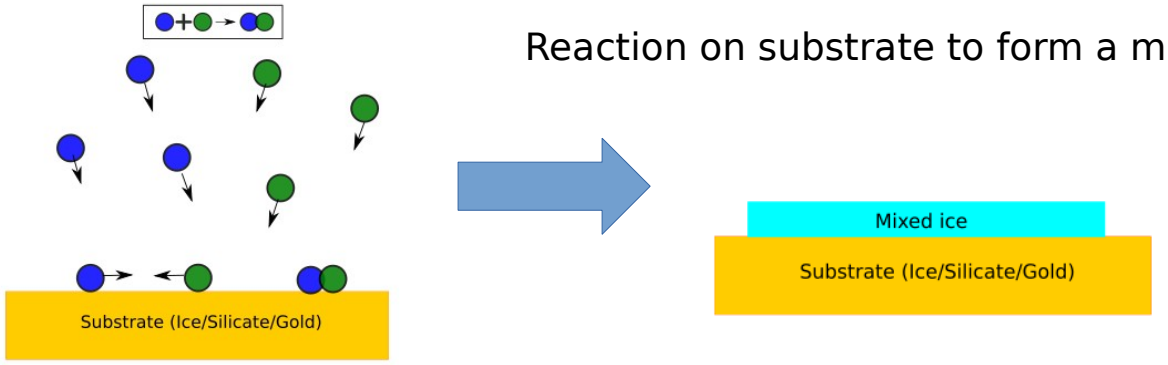






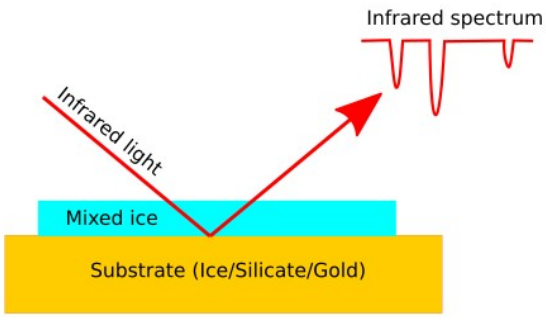


Analyzing techniques: FTIR and TPD

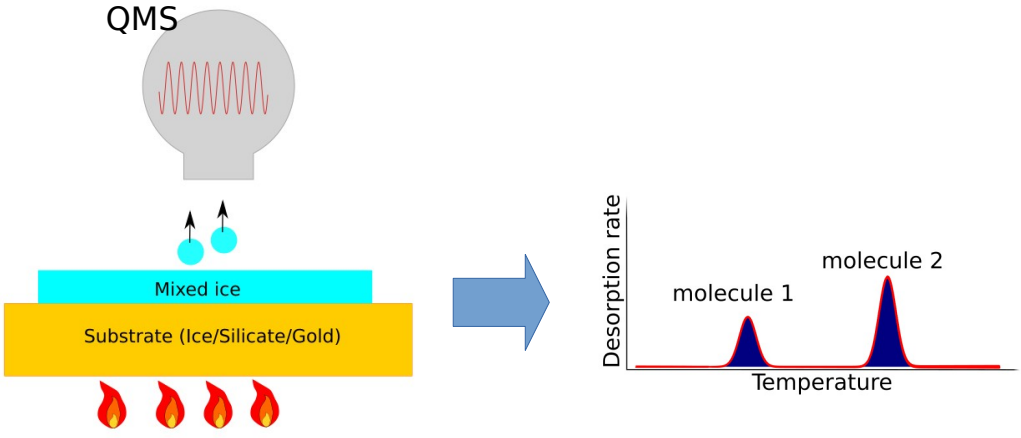


Reaction on substrate to form a mixed ice

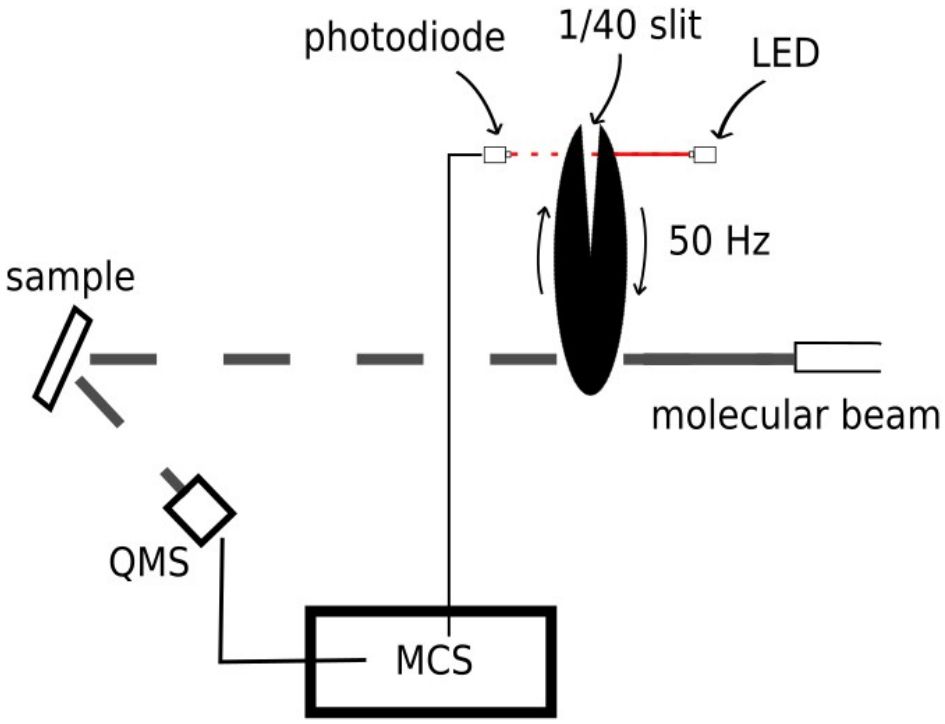
Analyzing method #1: FTIR



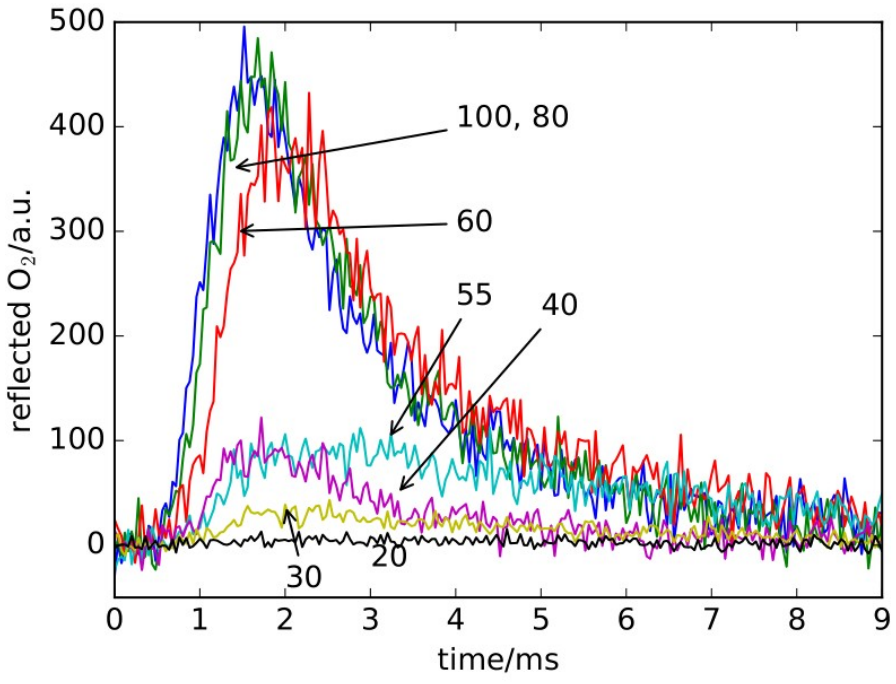
Analyzing method #2: Temperature programmed desorp



Sticking of molecules on water ice



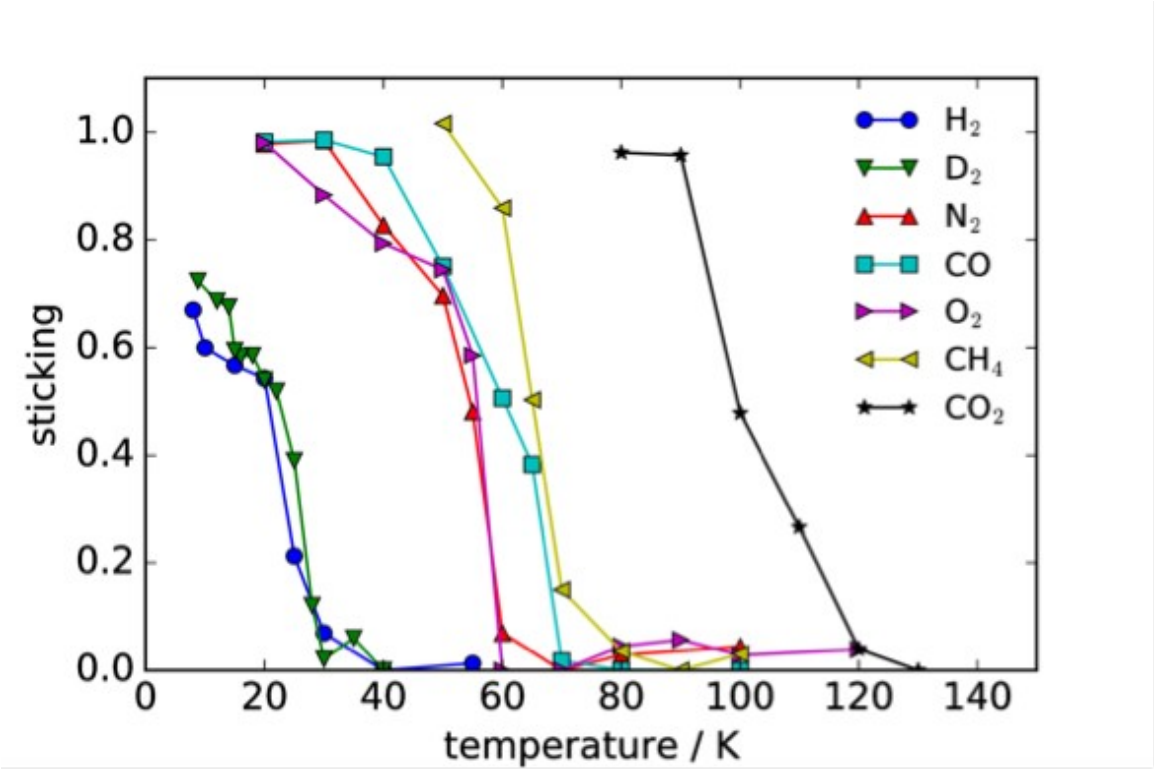
Time resolved scattering schematics



Time resolved scattering of O_2 from np-ASW at various surface temperatures

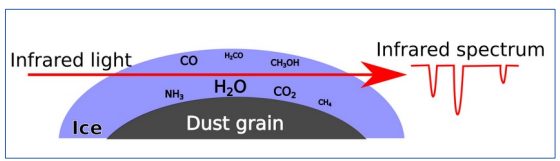
He J., Acharyya K., Vidali G., 2016, ApJ, 823, 56

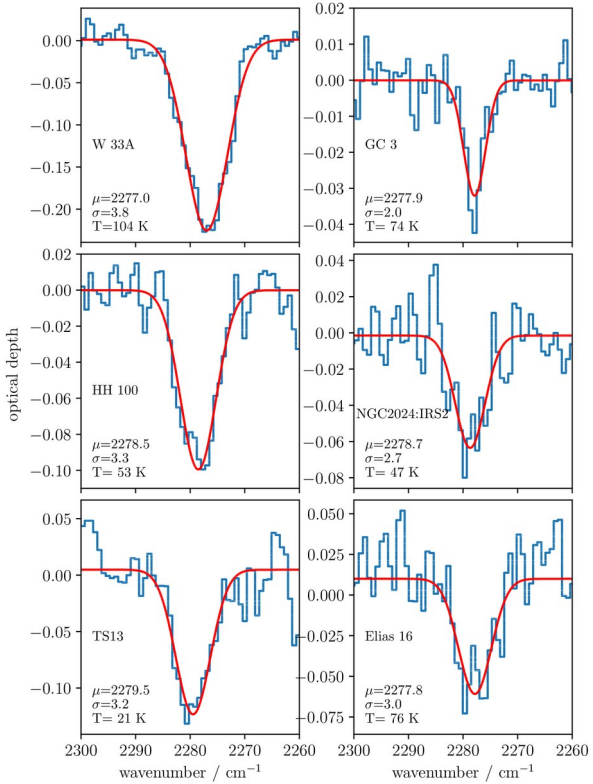
Sticking of molecules on water ice



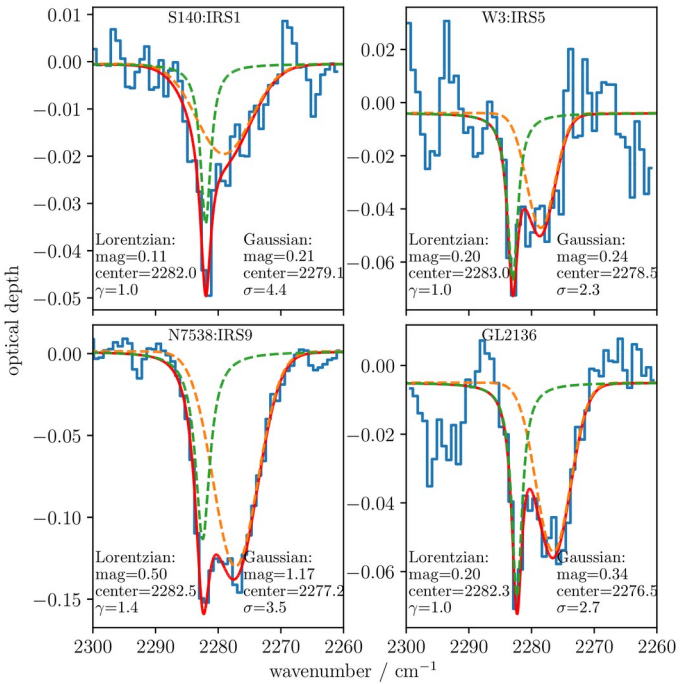
He J., Acharyya K., Vidali G., 2016, ApJ, 823, 56

Comparing Lab data with Astronomical Observations



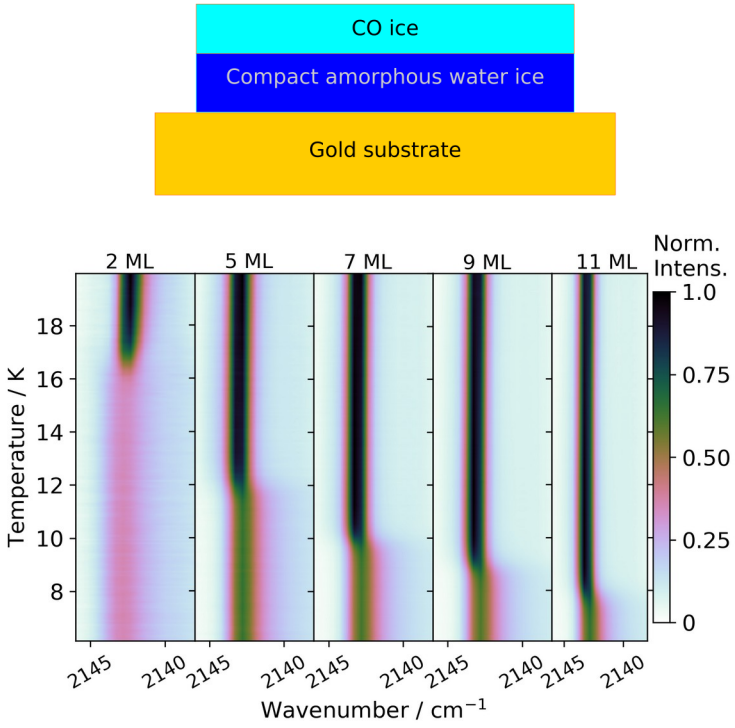


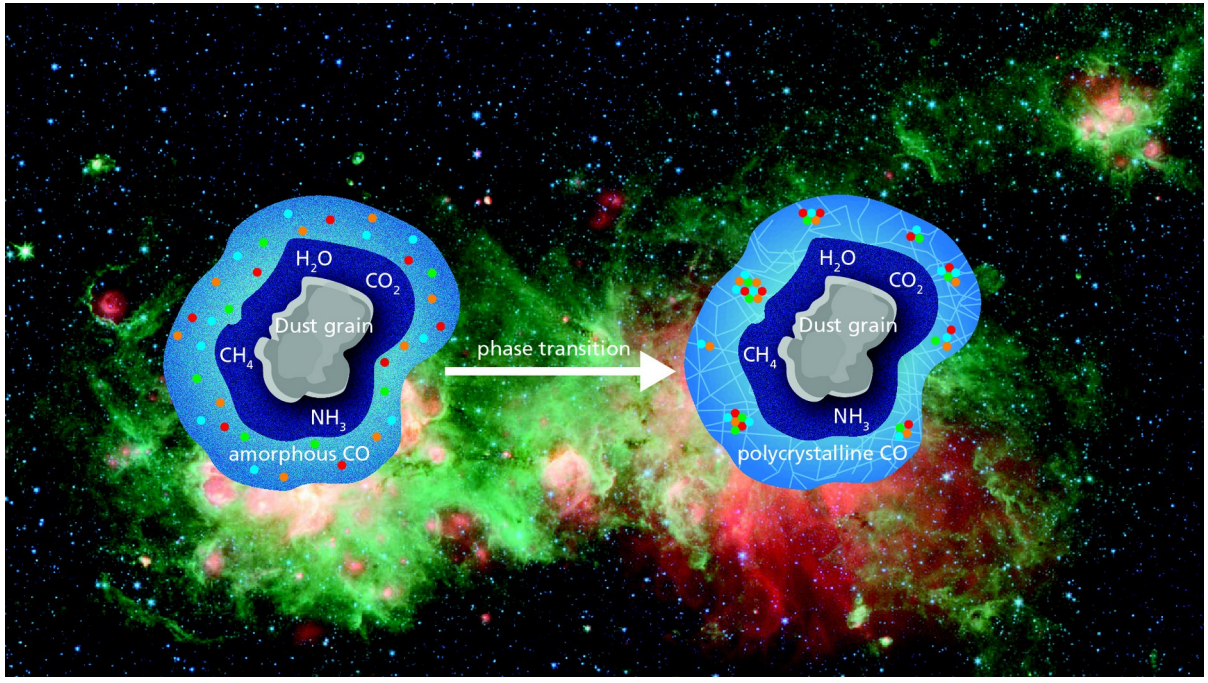
He+, 2018



ISO-SWS observations of $^{13}CO_2$ ice

Phase transition of interstellar CO ice

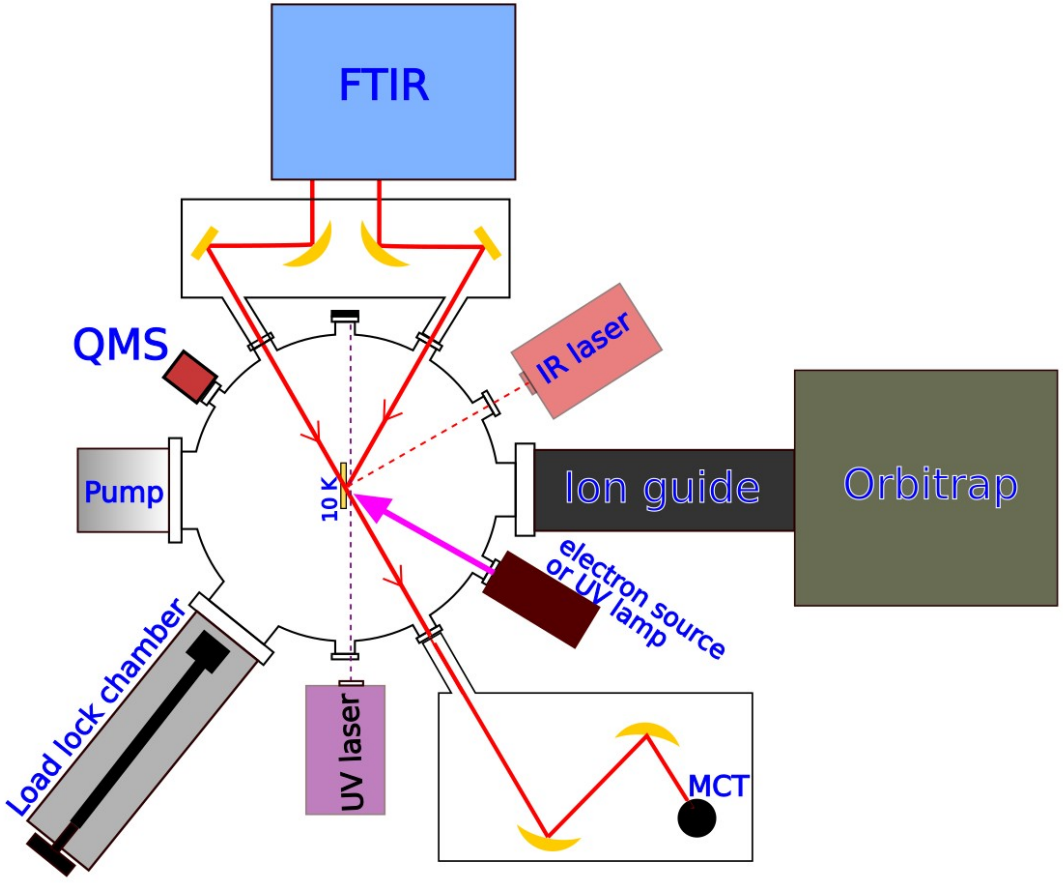




An important mechanism to form complex organic molecules in the ice.

He+, 2021

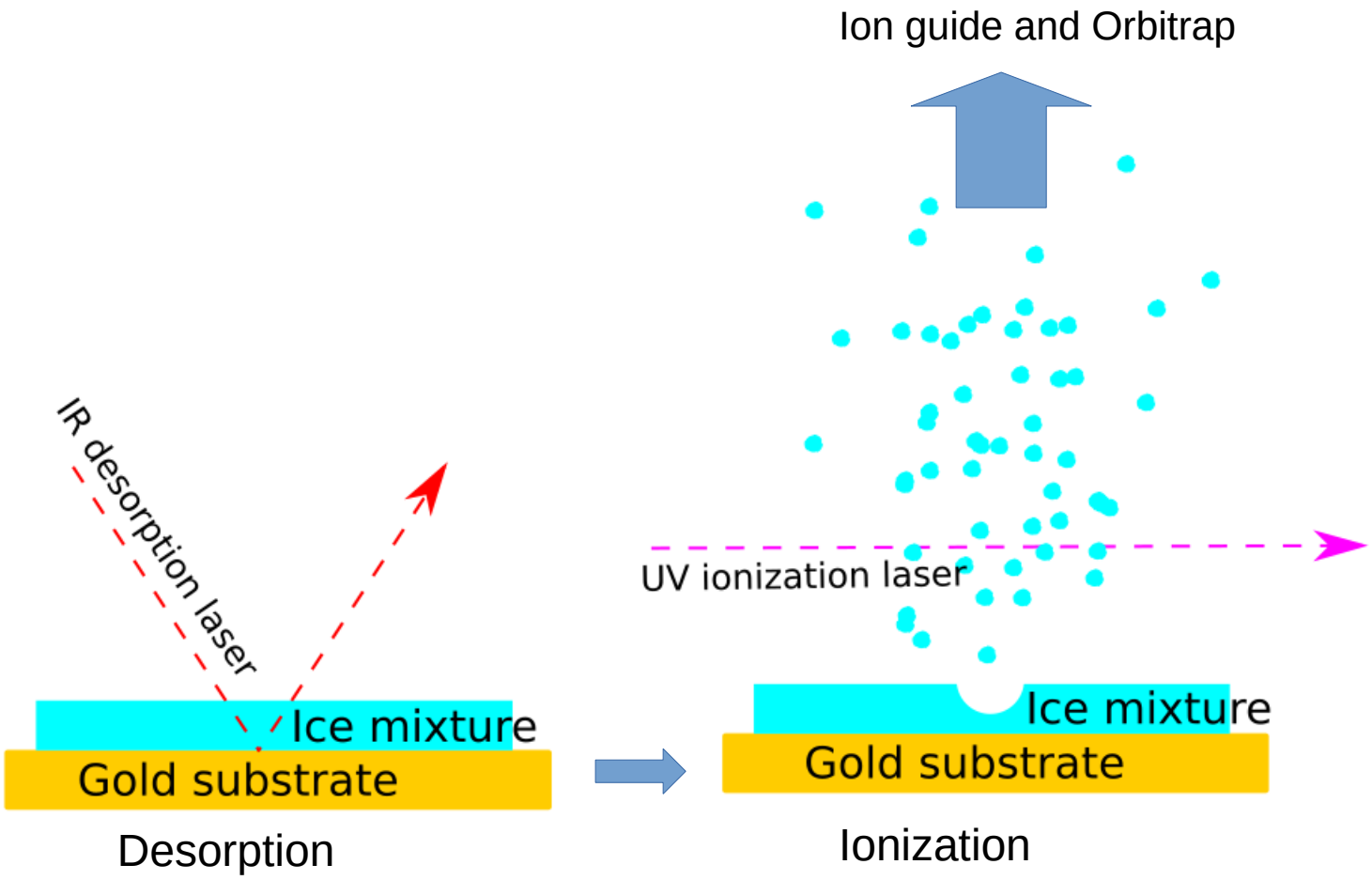
The new setup in Origins Lab (in construction)



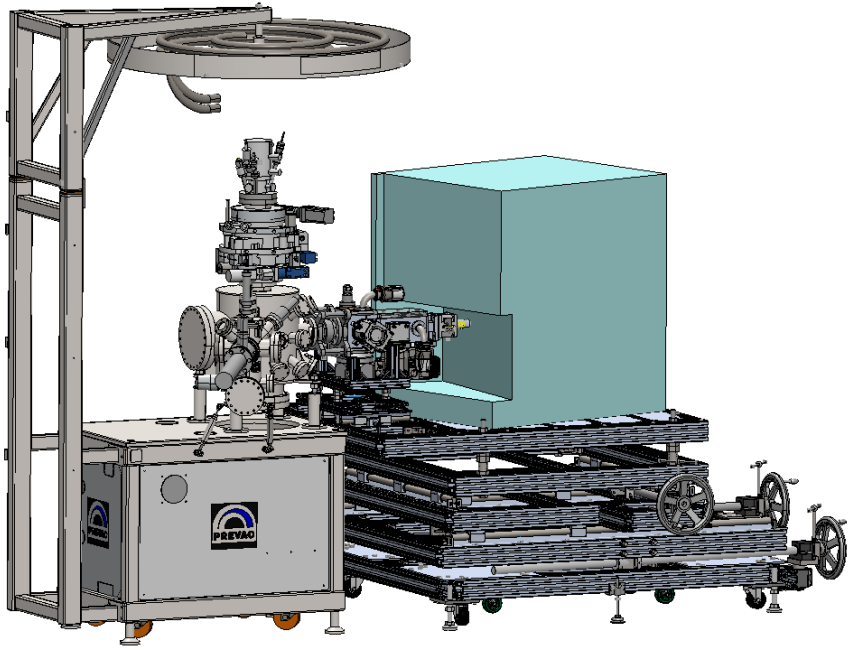
Features of the new setup:

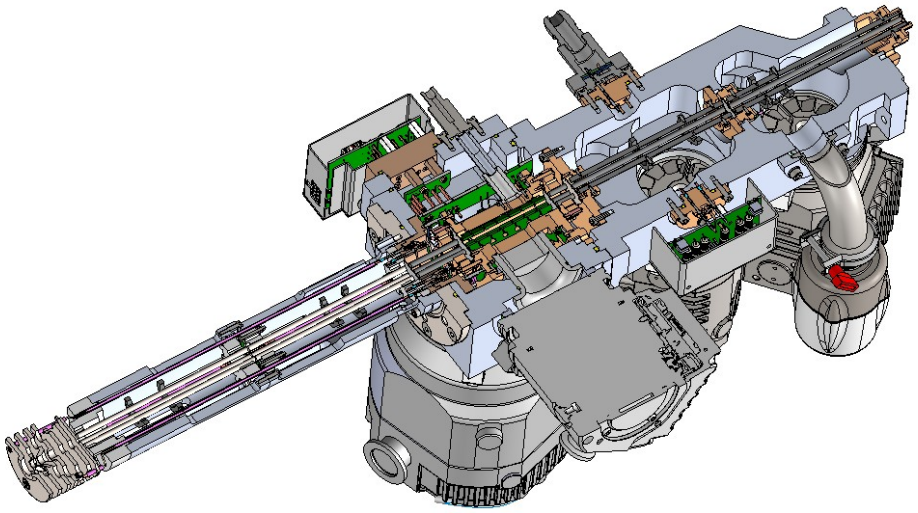
- Electrons or UV processing of ice mixtures at ~10K
- In situ measurement of ice composition using FTIR
- Measure desorbed molecules using QMS
- Laser desorption ionization (IR + UV lasers)
- Sample replacing without breaking vacuum of main chamber
- Very high sensitivity and mass resolution using Orbitrap mass spectrometer.

Laser desorption ionization + Orbitrap

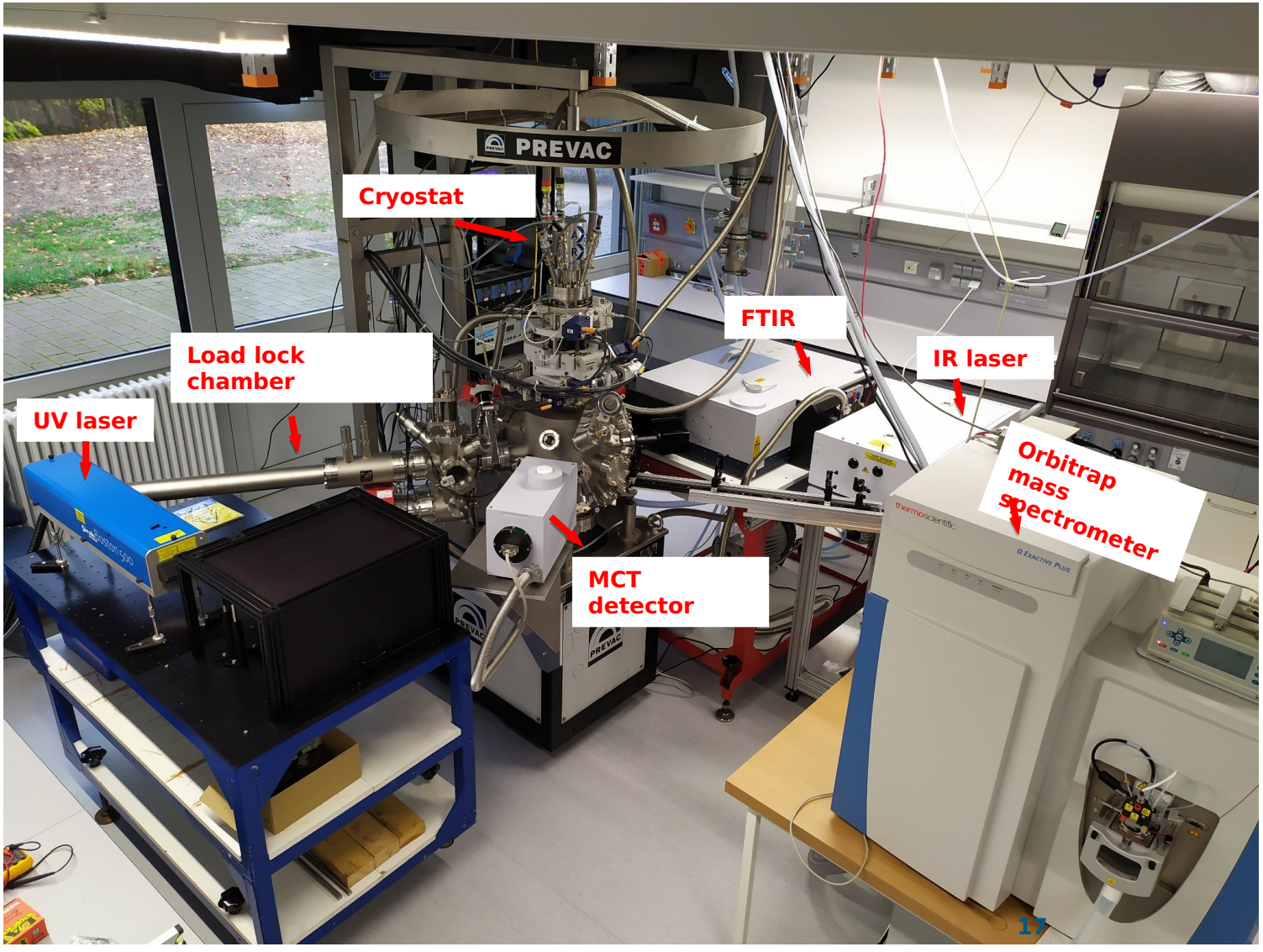


3D drawing of the setup

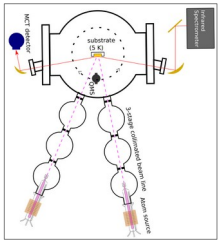




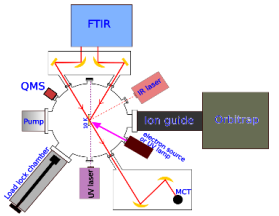
Ion guiding system (coming soon!)


PREVAC
Cryostat
FTIR
IR laser
Load lock chamber
UV laser
Orbitrap mass spectrometer
MCT detector
thermoscientific
Q Exactive Plus

Comparison between two setups



Setup-1

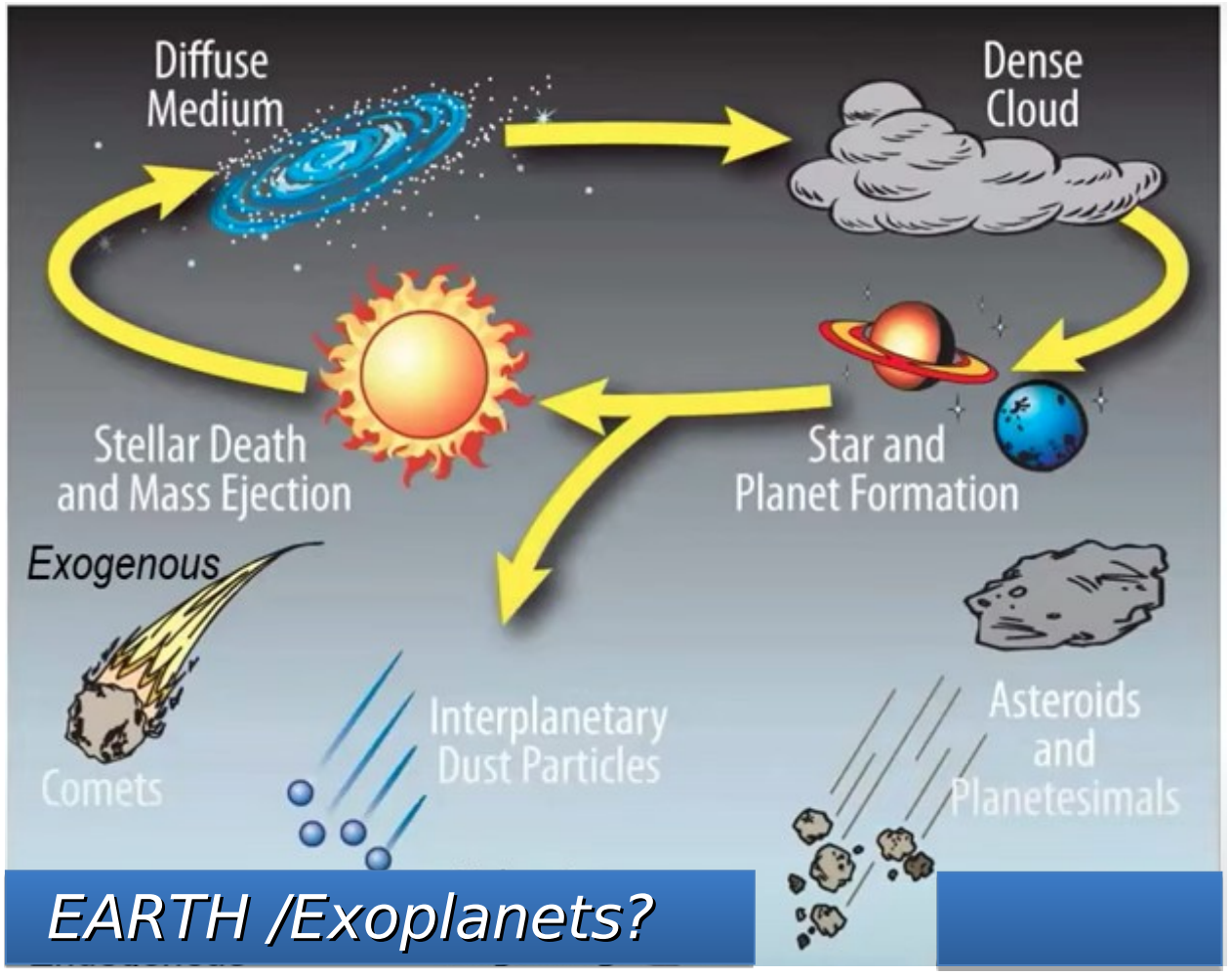


Setup-2

Atom addition and thermally induced reactions	Irradiation (electron/UV photons) induced reactions
Reactions with simple molecules and atoms	Complex reactions with larger size molecule(s)
Identification and quantification (QMS and FTIR)	Identification (FTIR and high resolution Orbitrap MS)
Good synergy with astronomical observations and modeling	Closer to astrobiology and Origin of Life

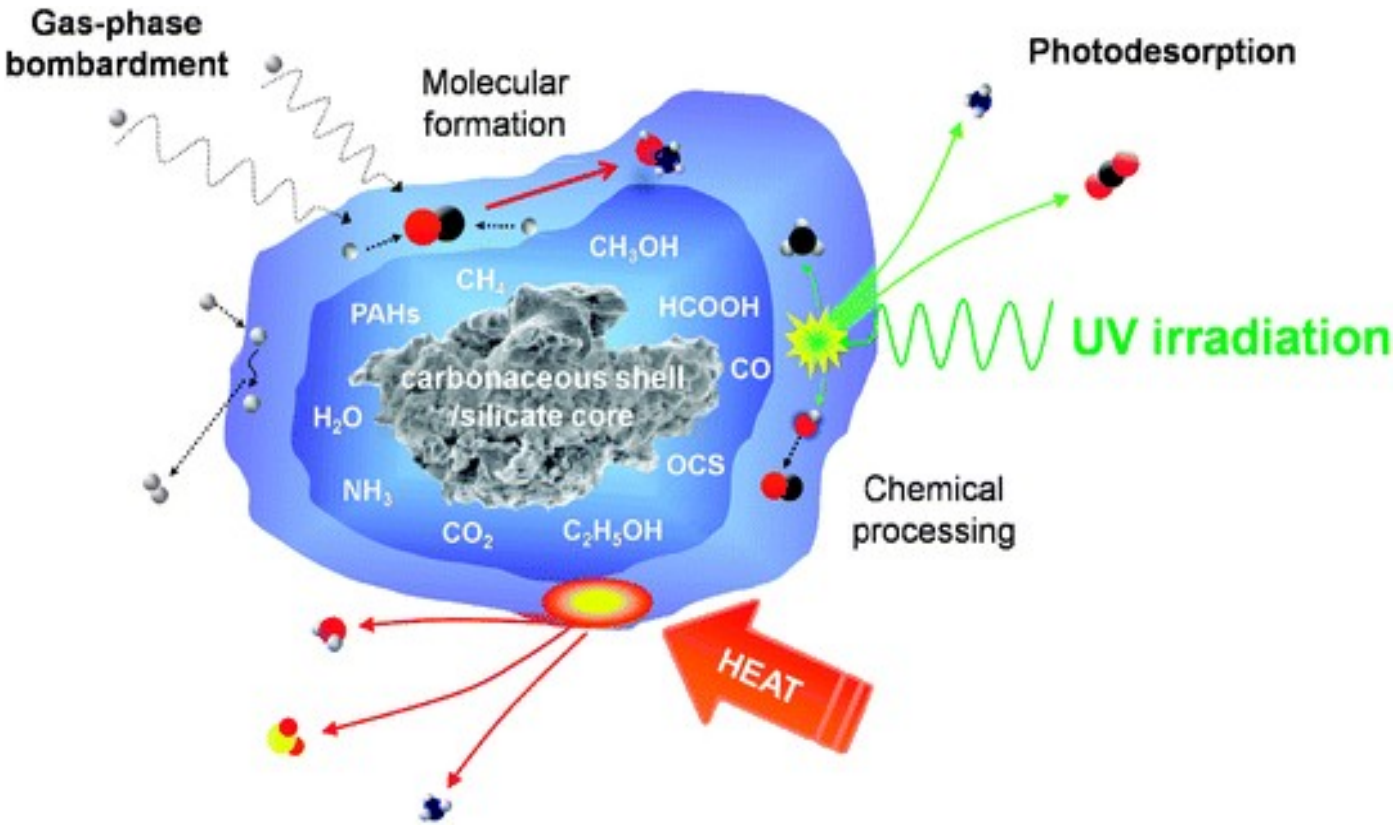
Part-II

Origins of life



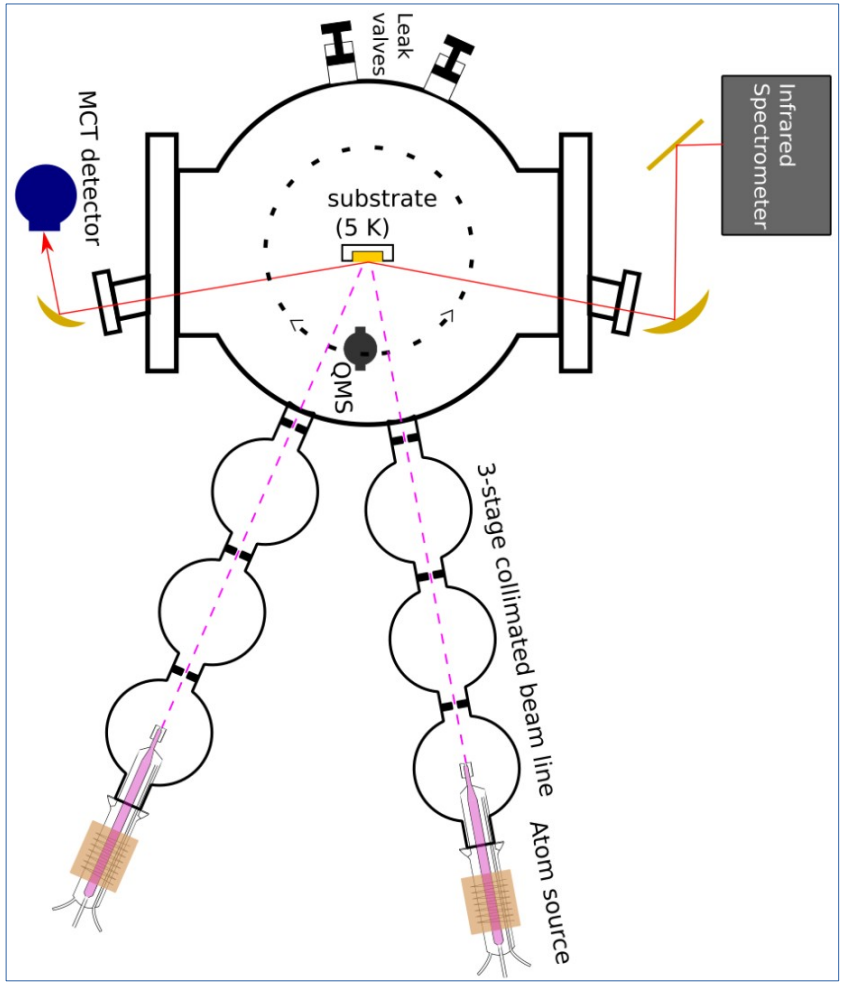
After Deamer et al. 2002

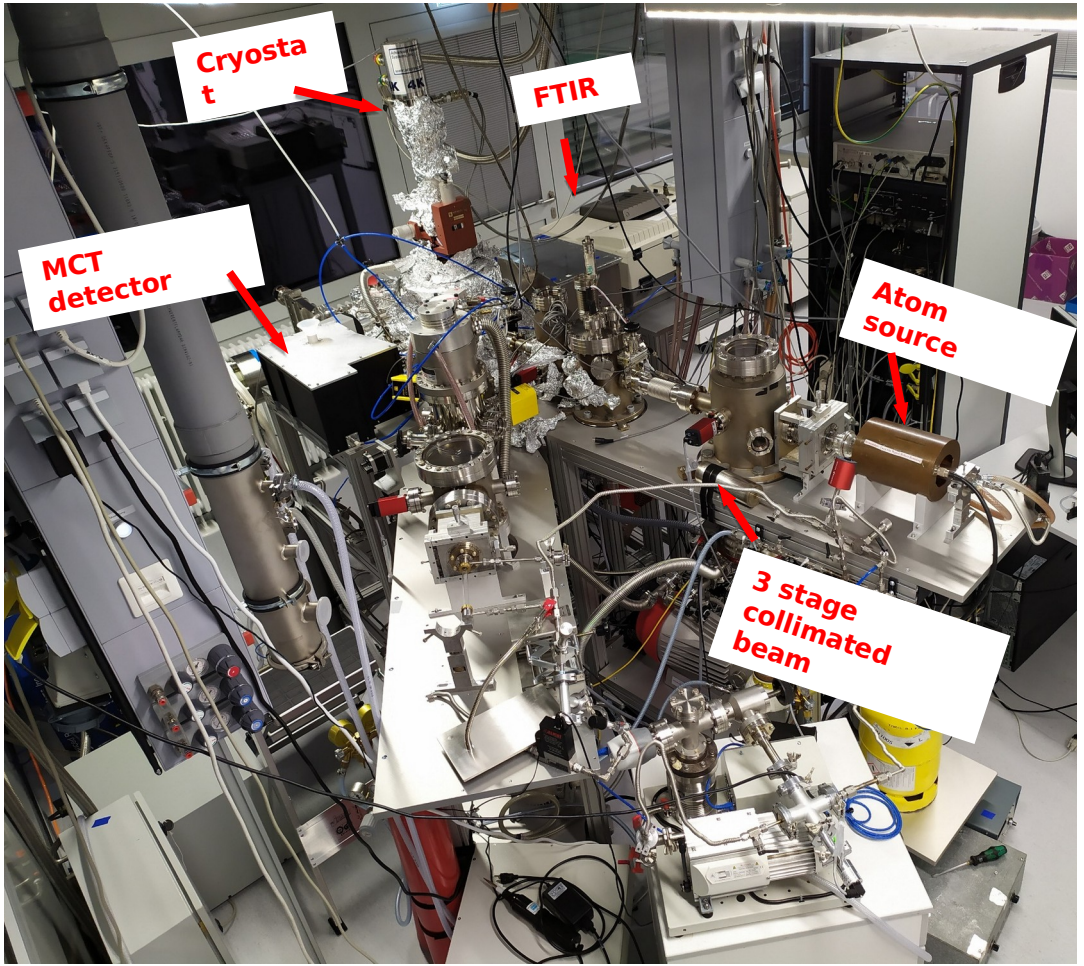
Processing of interstellar ices



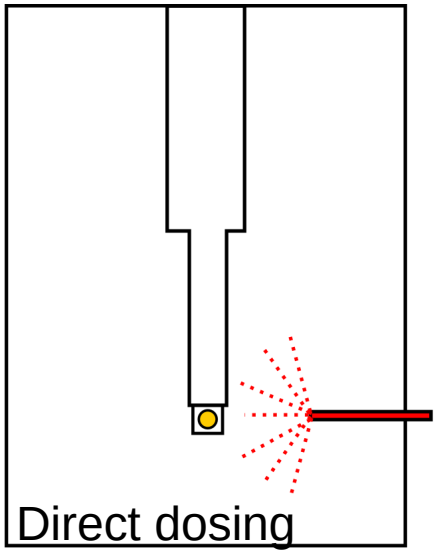
Burke & Brown 2010

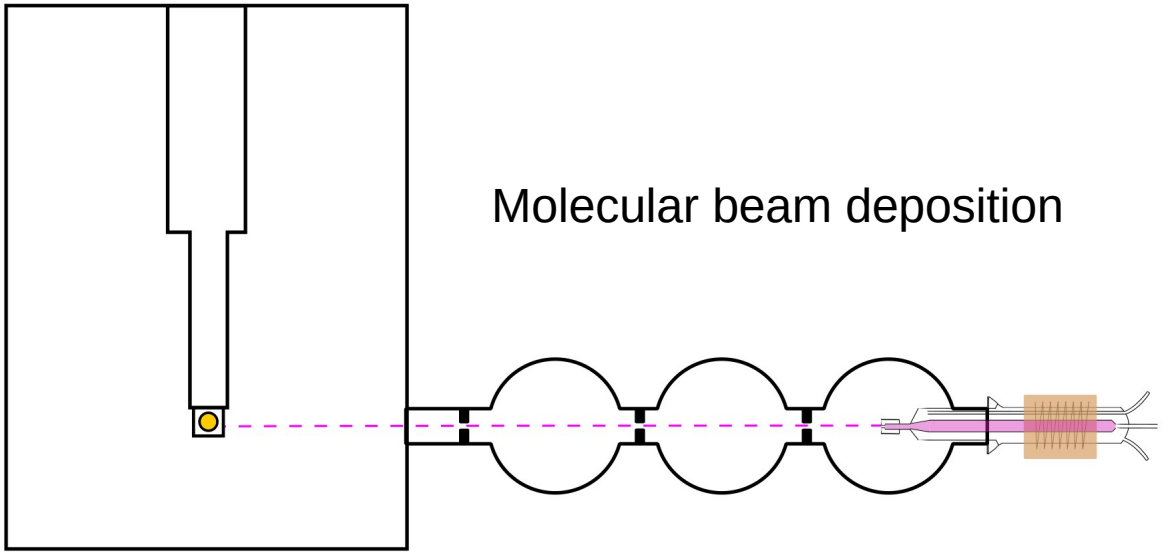
Setup-1

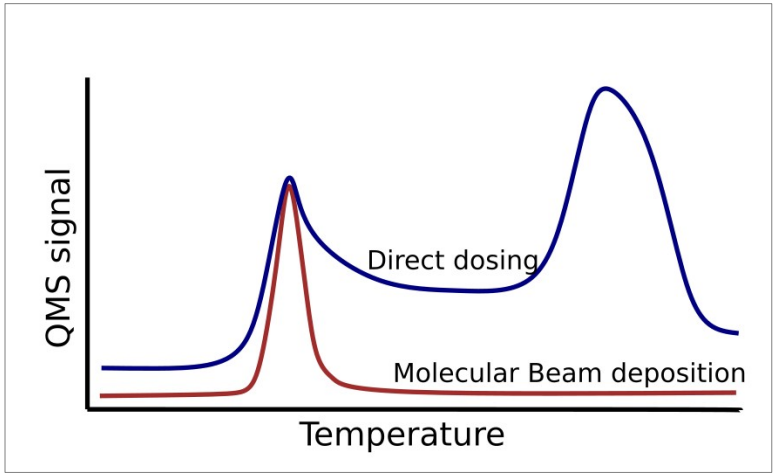

Leak valves
MCT detector
substrate
(5 K)
Infrared Spectrometer
QMS
3-stage collimated beam line
Atom source


Cryosta t
FTIR
MCT detector
Atom source
3 stage collimated beam

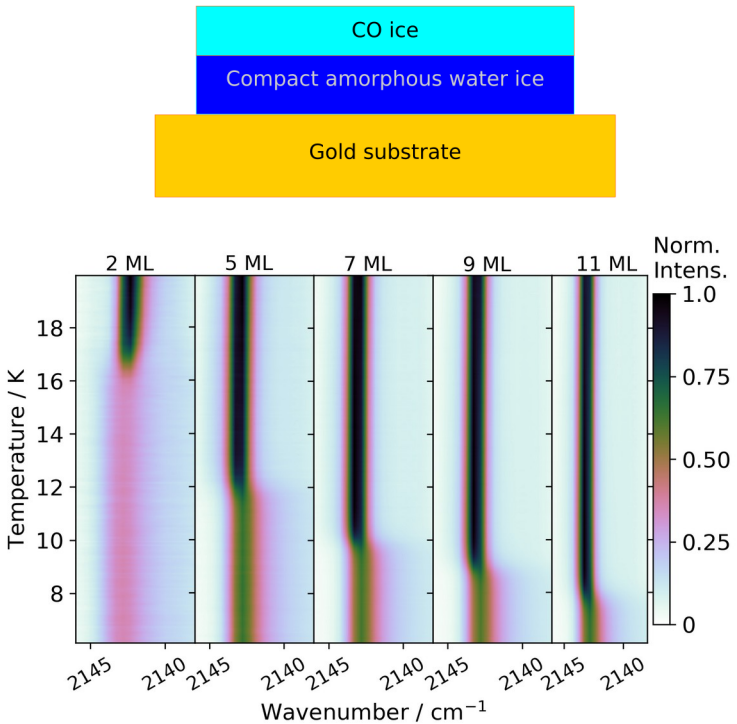
Advantage of molecular beam

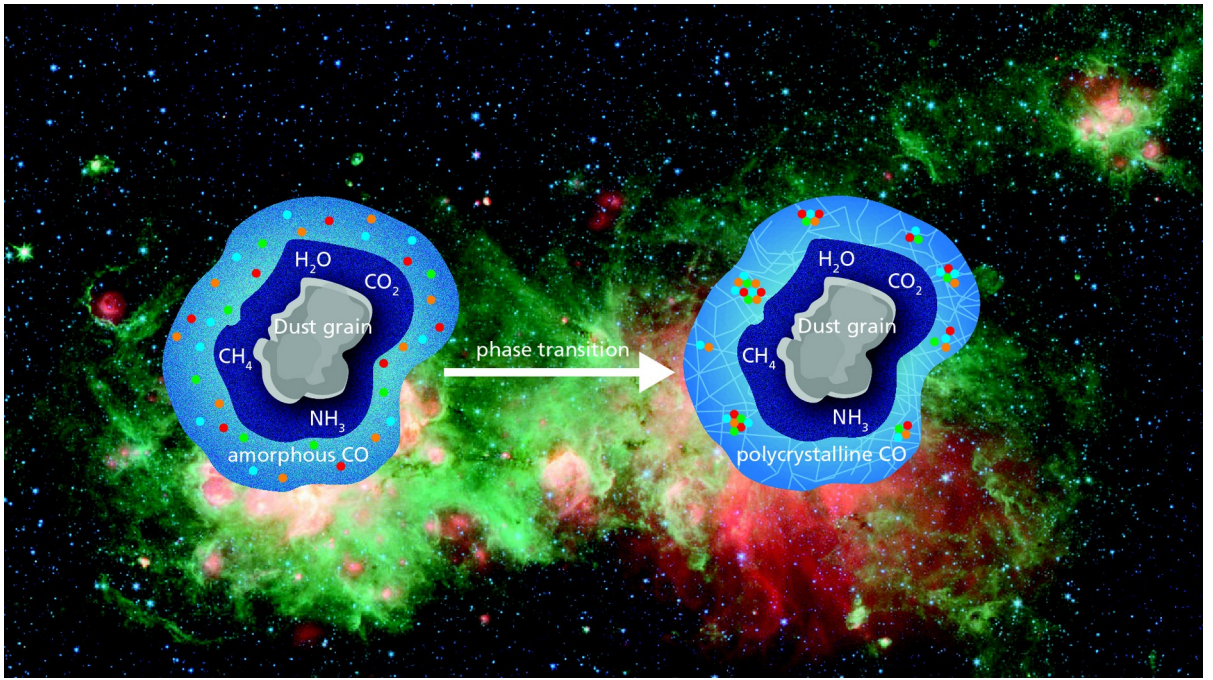






Phase transition of interstellar CO ice

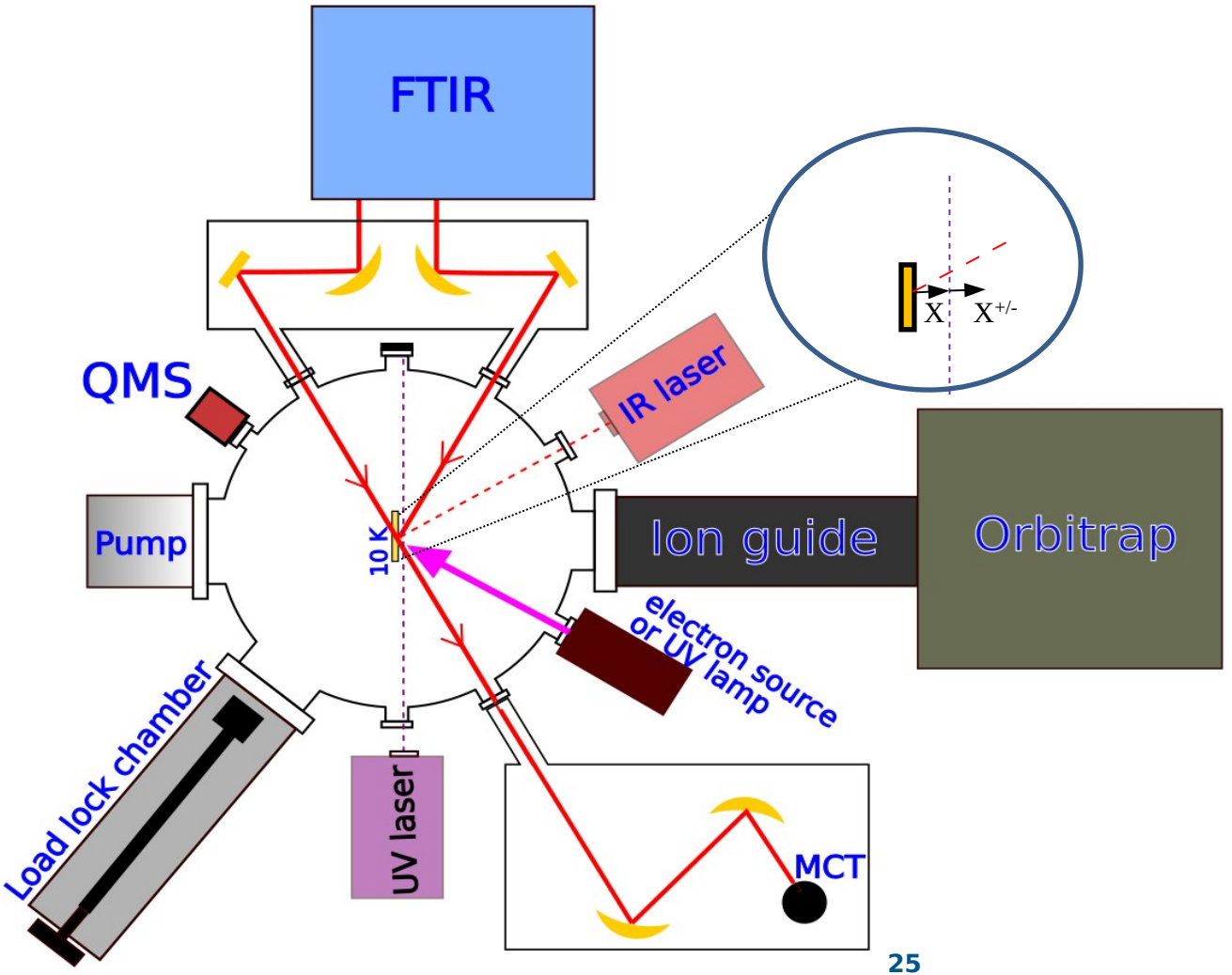




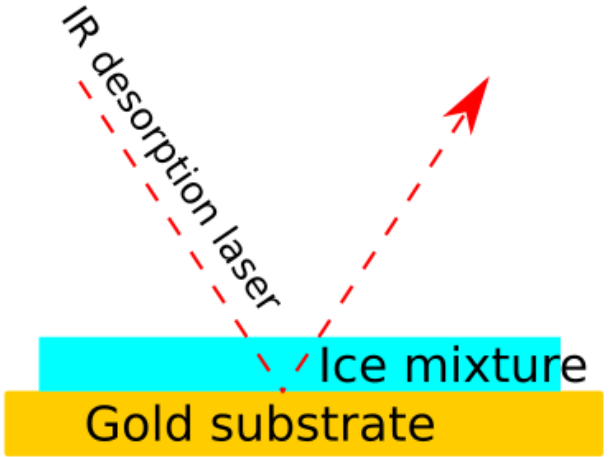
An important mechanism to form complex organic molecules in the ice

He+, 2021

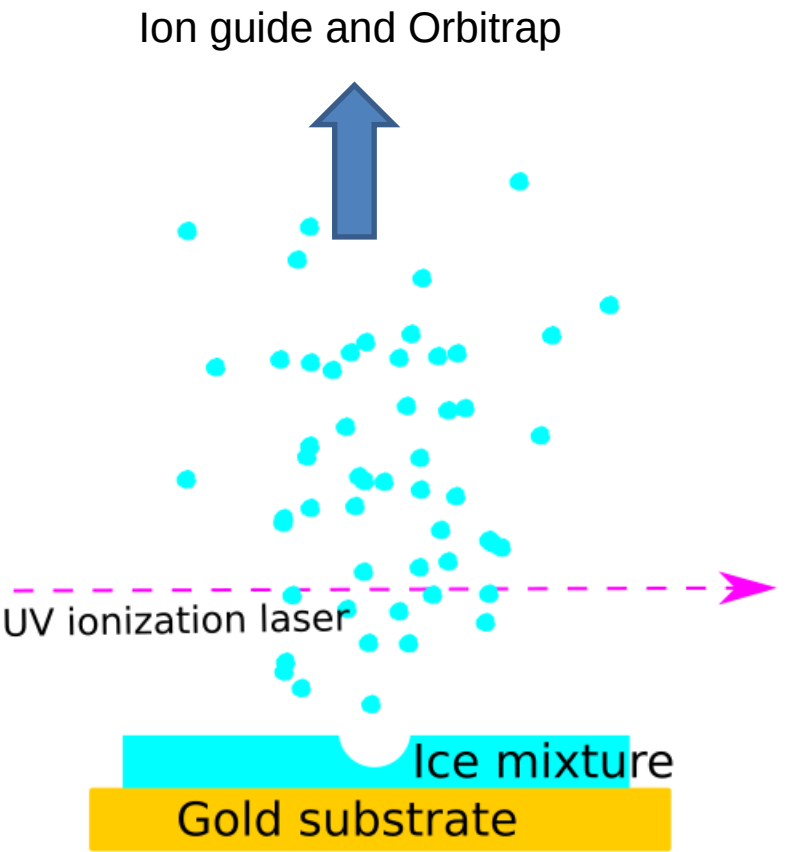
Setup-2


FTIR
QMS
IR laser
X
X+/-
Pump
10 K
Ion guide
Orbitrap
electron source
or UV lamp
Load lock chamber
UV laser
MCT

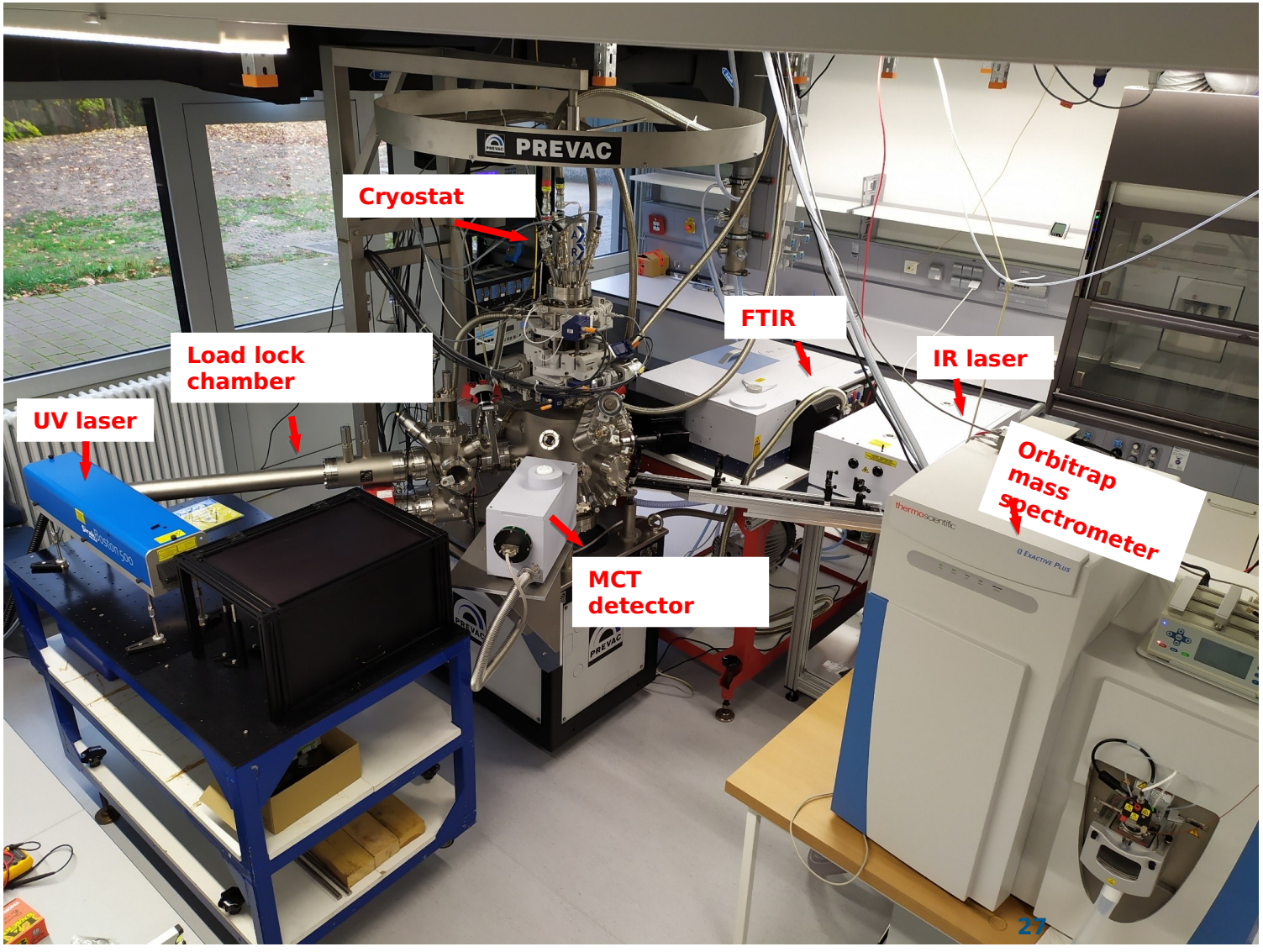
Desorption+ionization (2 steps)



Desorption



Ionization


Cryostat
Load lock chamber
UV laser
FTIR
IR laser
Orbitrap mass spectrometer
MCT detector
PREVAC
thermoscientific

Laser systems

ns pulsed-UV

Specifications

Pulse Energy	10 Hz
1064 nm	500 mJ
532 nm	270 mJ
355 nm	150 mJ
266 nm	50 mJ

Pulse Width	5-8 ns
Divergence	0.5 mrad
Beam Diameter [1]	< 8 mm
Timing Jitter	0.5 ns
Energy Stability (rms)	0.7 %
Pointing Stability	± 50 mrad

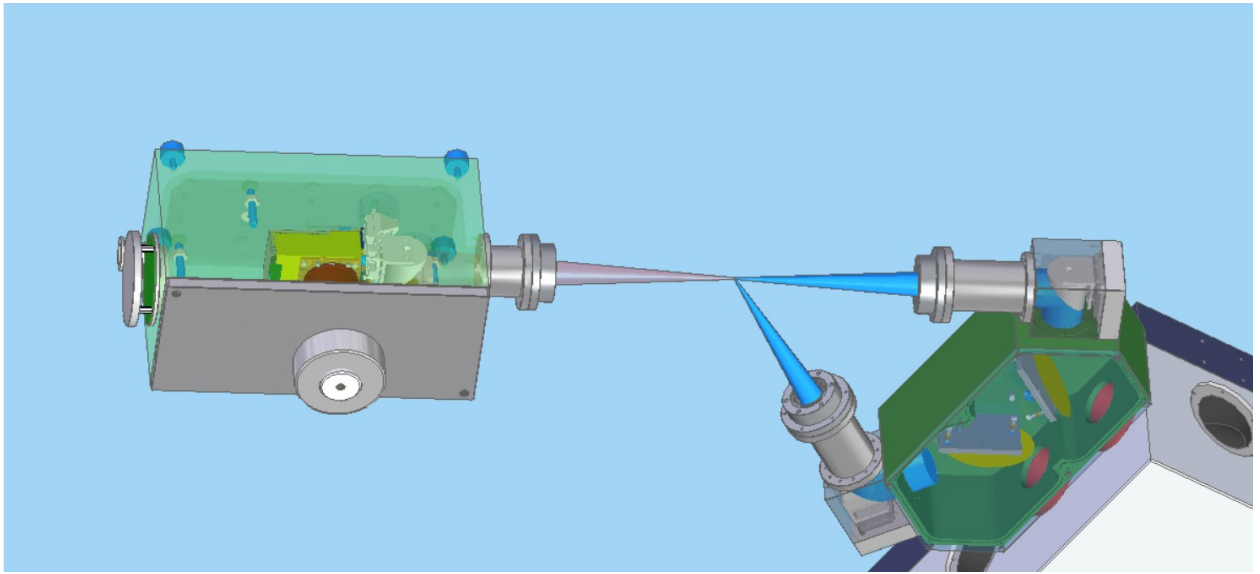
[1] at beam exit

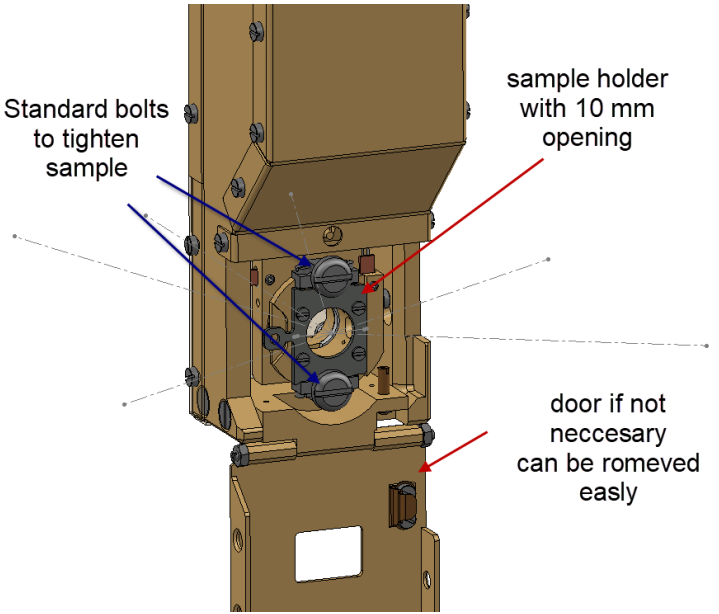
ns pulsed tunable IR laser

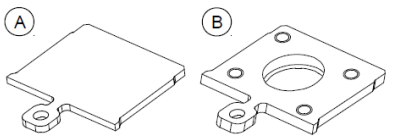
SPECIFICATIONS [1]

Model	NT377
OPO	
Wavelength range	2500–4400 nm
Output pulse energy [3]	12.5 mJ
Linewidth [4]	< 10 cm^{-1}
Scanning step	1 nm
Typical pulse duration [5]	3–5 ns
Typical beam diameter [6]	6 mm
Polarization	horizontal
PUMP LASER [7]	
Pump wavelength	1064 nm
Max pump pulse energy	300 mJ
Pulse duration	4–6 ns
Beam quality	"Hat-Top" in near field
Beam divergence	< 0.5 mrad
Pulse energy stability (StdDev)	< 1 %
Pulse repetition rate	10 or 20 Hz

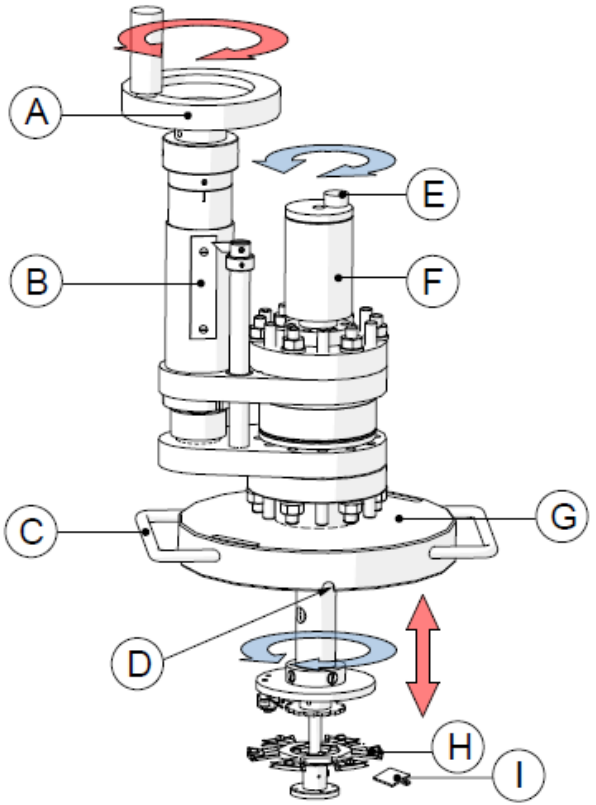
IR spectroscopy

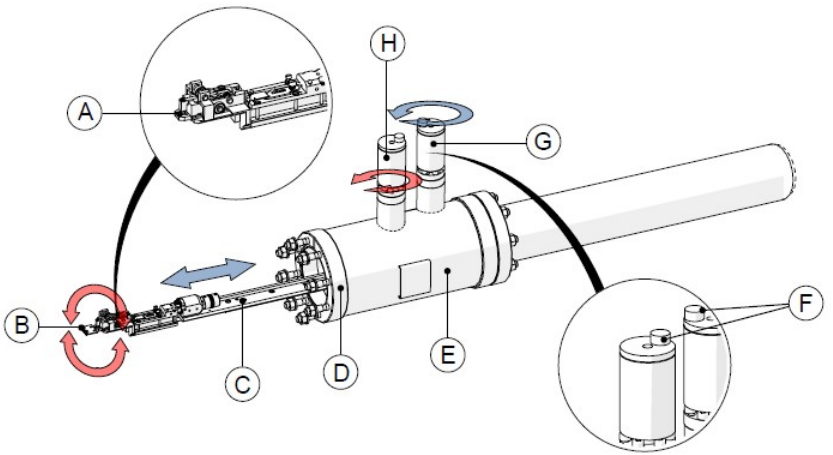




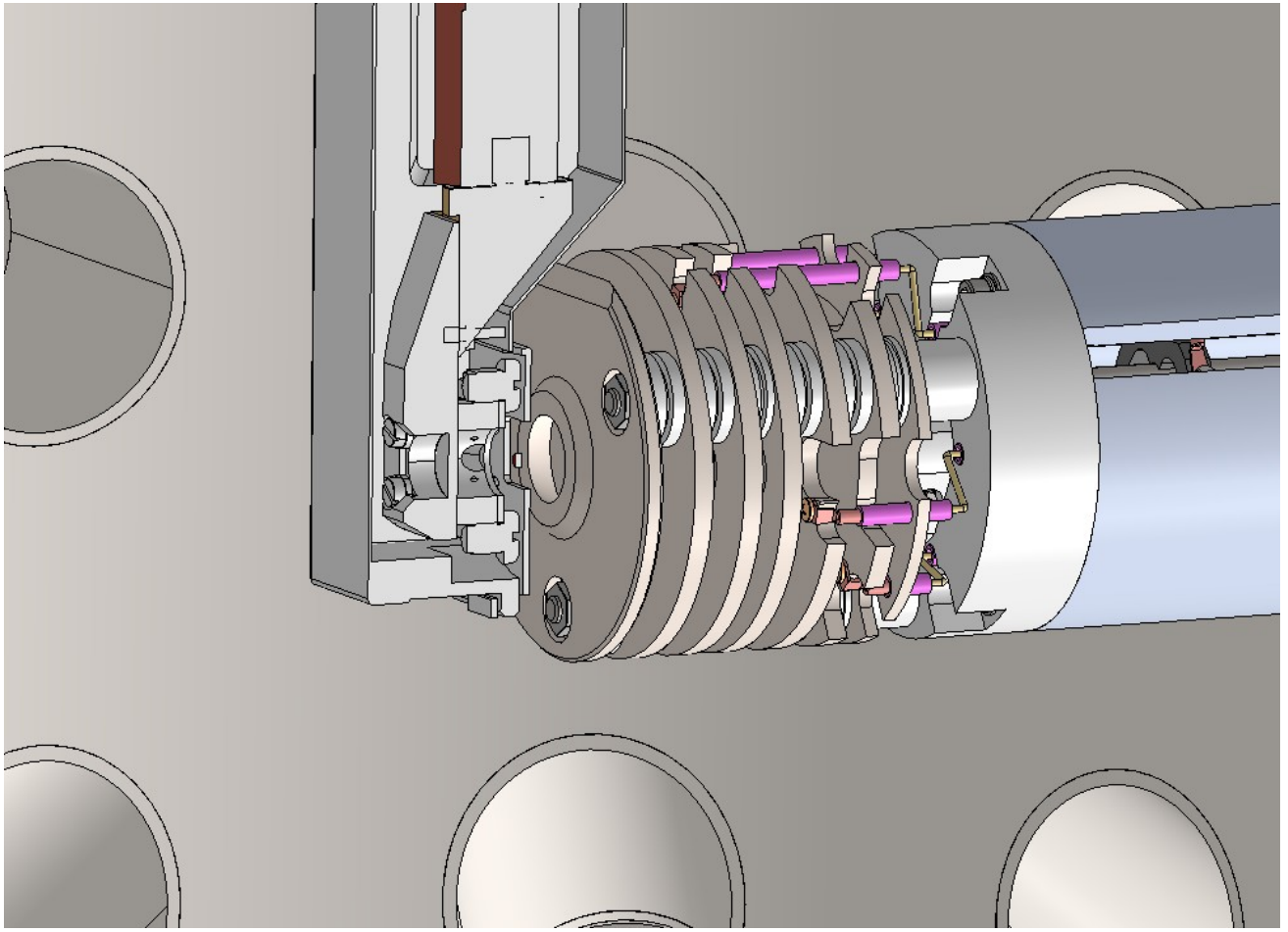


Load lock chamber

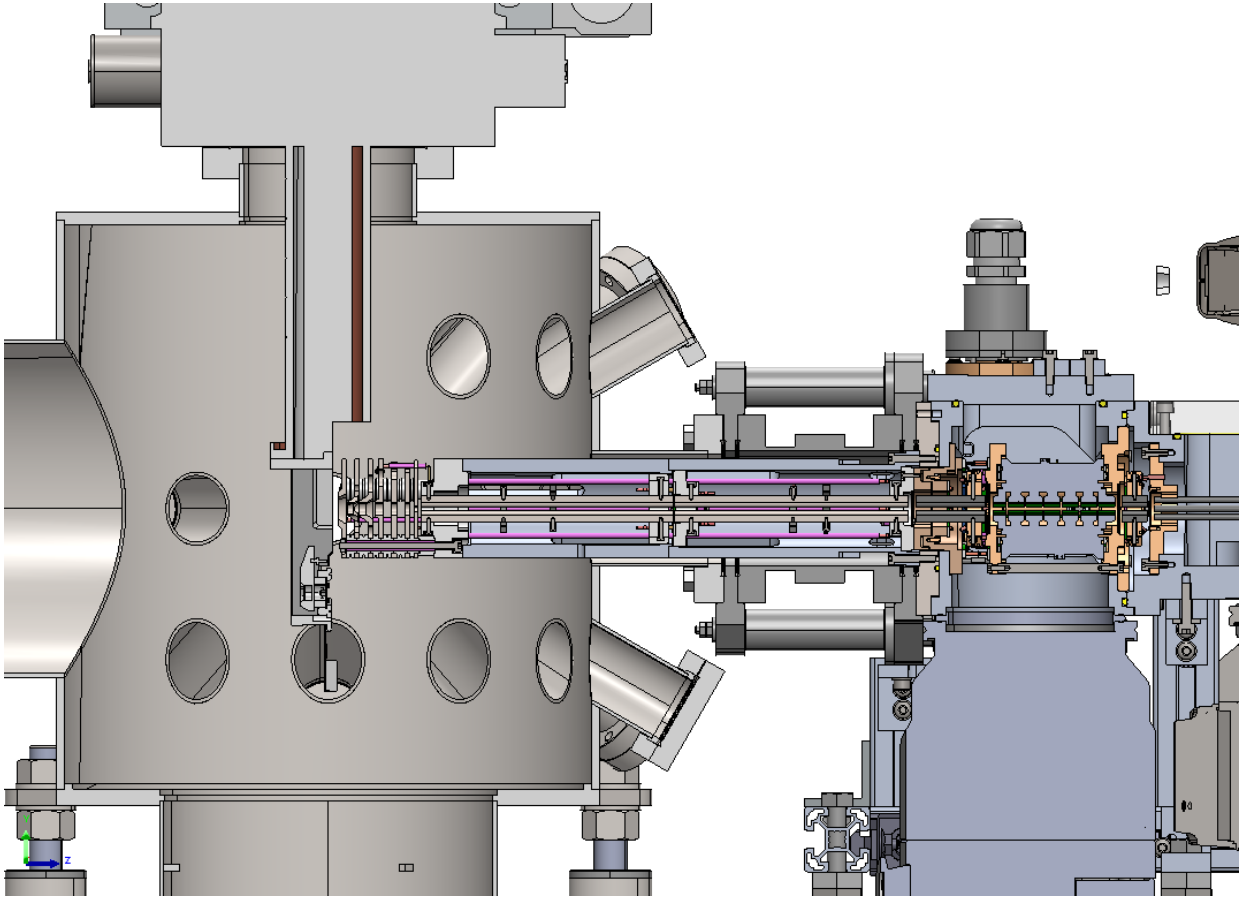




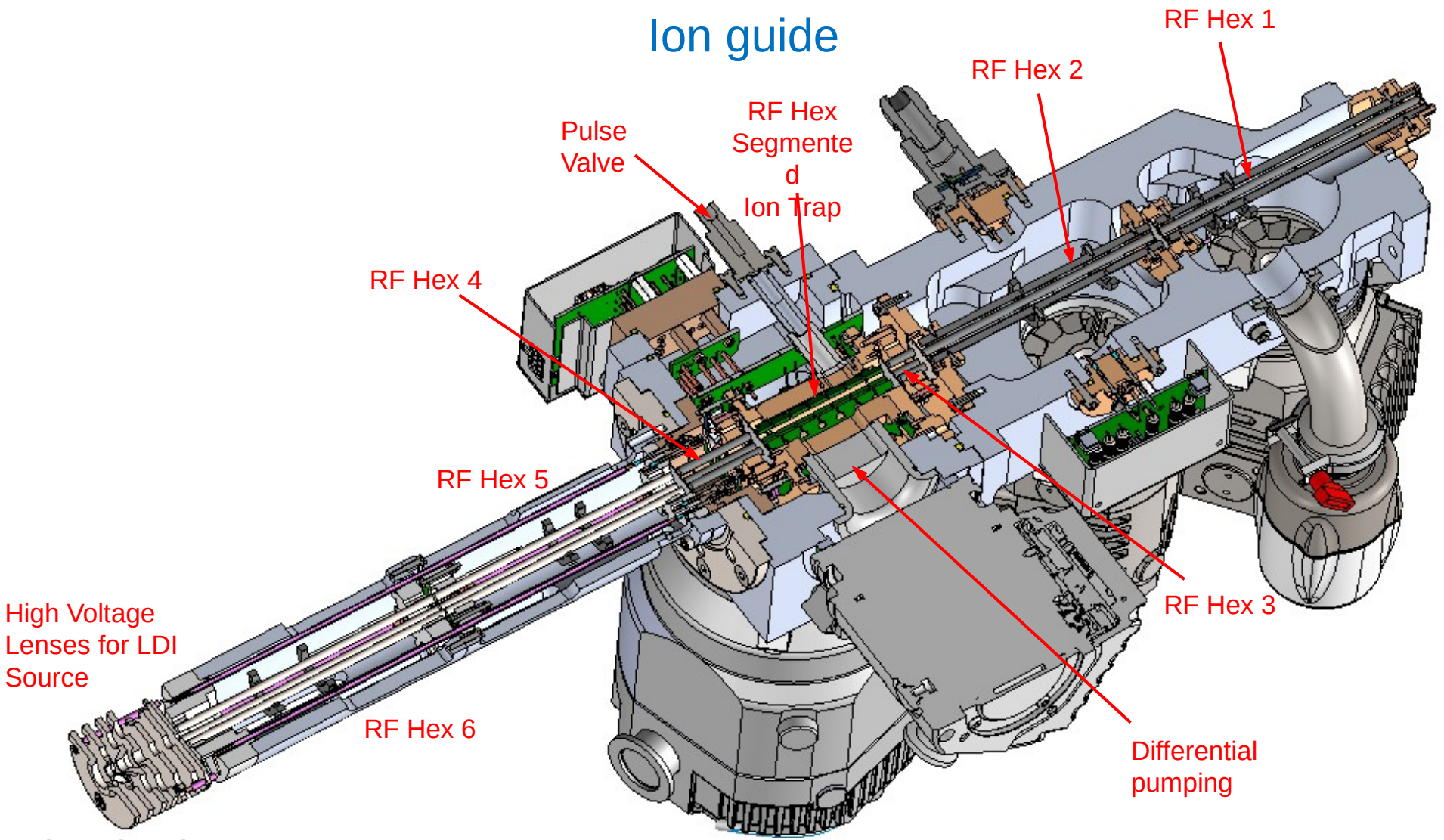
Ion guide

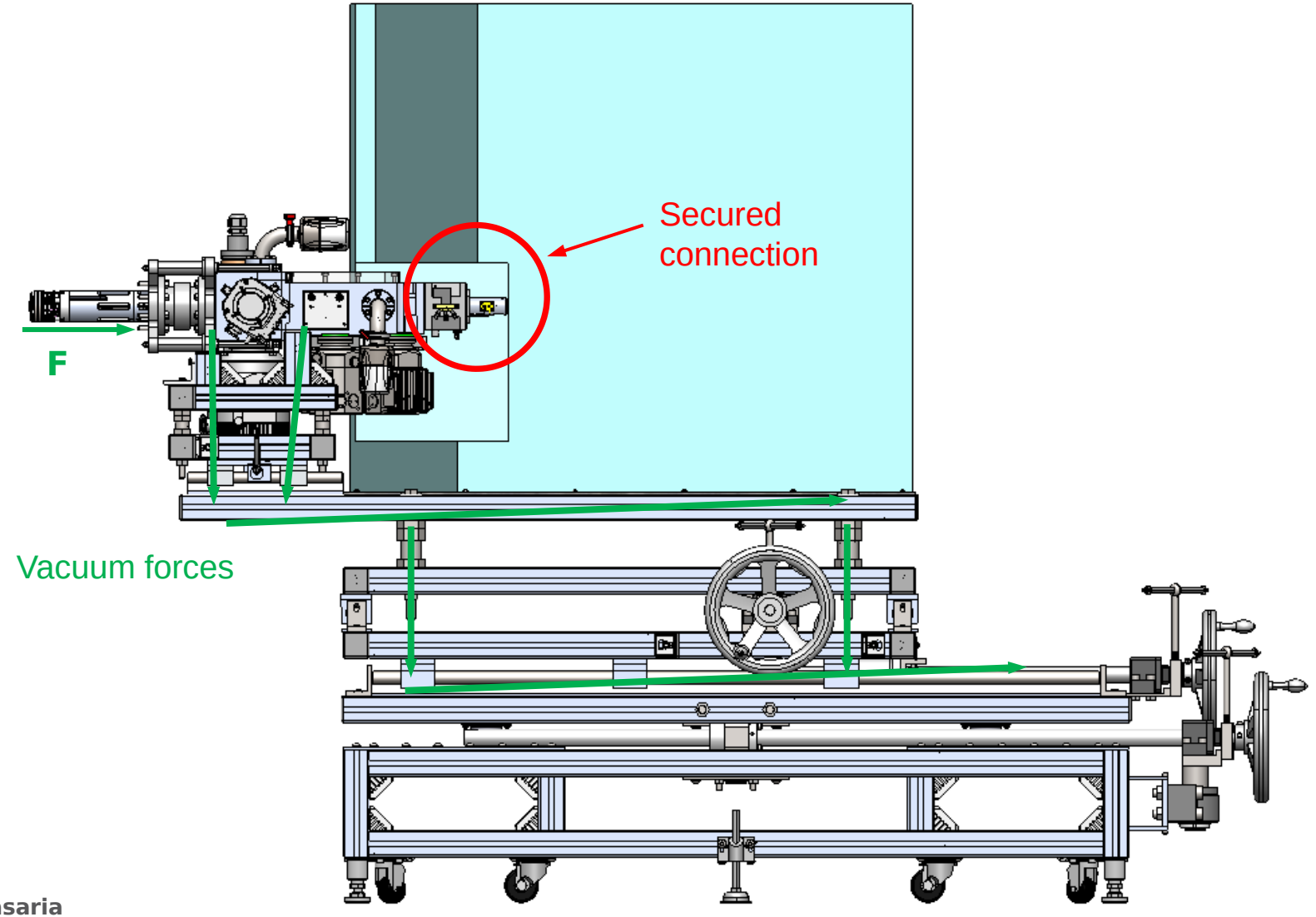


Ion guide

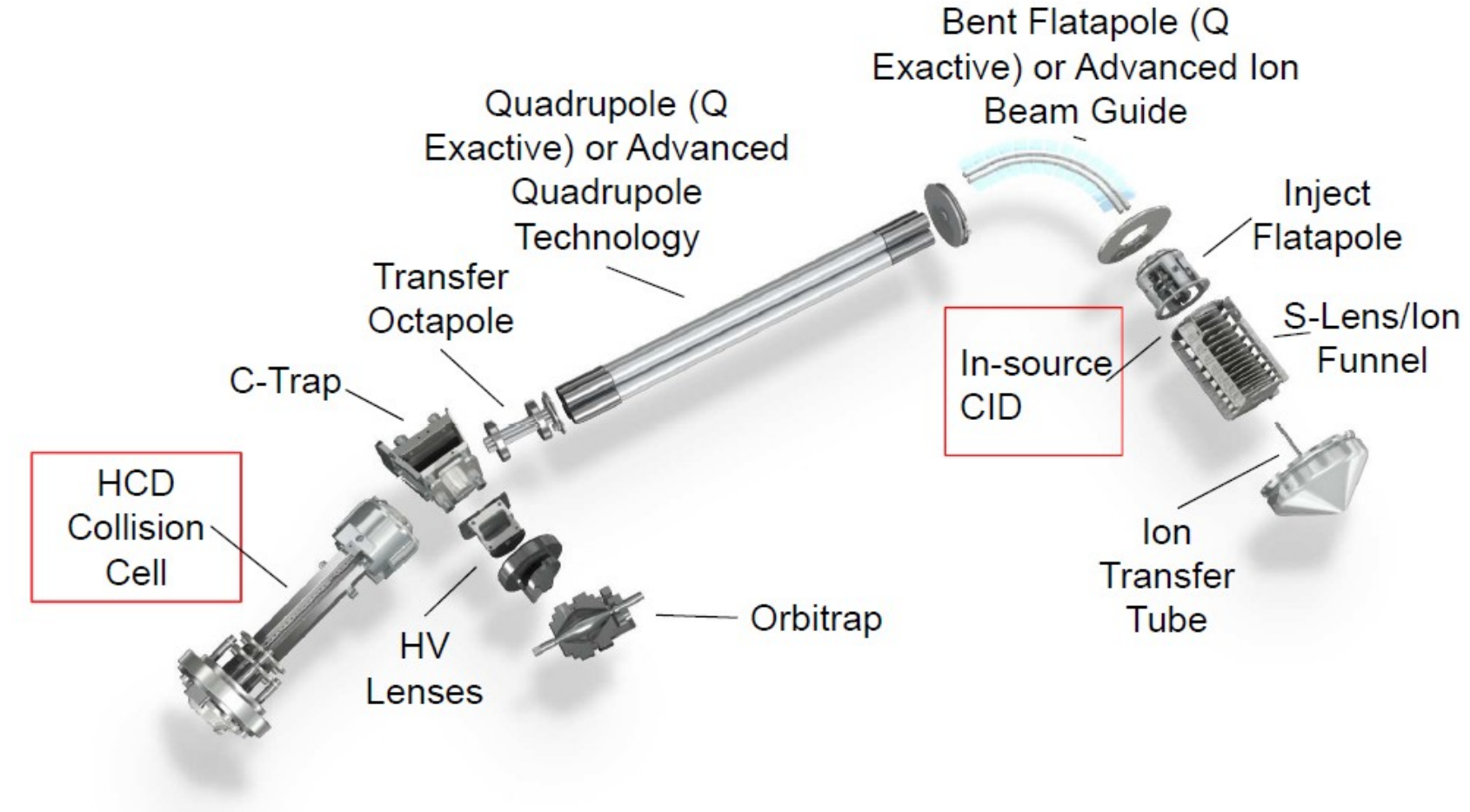


Ion guide

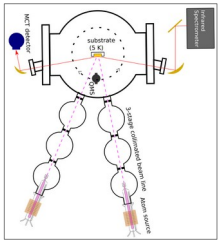

RF Hex 1
RF Hex 2
RF Hex Segmented Ion Trap
Pulse Valve
RF Hex 4
RF Hex 5
RF Hex 3
High Voltage Lenses for LDI Source
RF Hex 6
Differential pumping


Secured
connection
F
Vacuum forces

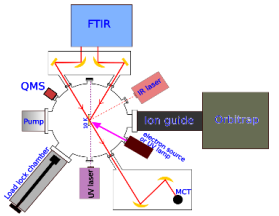
Orbitrap MS


Bent Flatapole (Q Exactive) or Advanced Ion Beam Guide
Quadrupole (Q Exactive) or Advanced Quadrupole Technology
Inject Flatapole
Transfer Octapole
S-Lens/Ion Funnel
C-Trap
In-source CID
HCD Collision Cell
Ion Transfer Tube
HV Lenses
Orbitrap

Comparison between two setups



Setup-1



Setup-2

Atom addition and thermally induced reactions	Irradiation (electron/UV photons) induced reactions
Reactions with simple molecules and atoms	Complex reactions with larger size molecule(s)
Identification and quantification (QMS and FTIR)	Identification (FTIR and high resolution Orbitrap MS)
Good synergy with astronomical observations and modeling	Closer to astrobiology and Origin of Life

Thank you!