Direct measurement of optical constants of interstellar ice analogs

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Overview: motivation

Investigate properties of dust with ice mantles from interstellar medium to comets

V1331 Cyg, credit: NASA/ESA

LH 95, credit: NASA/ESA

LDN 483, credit: ESO

L1544, credit: ESA

67P, credit: NASA

T Tauri, credit: NASA

Overview: motivation

Our model accounts for drastic CO depletion at the center of pre-stellar cores or in protoplanetary disk midplanes:

- how do dust opacities change in case of thick icy mantles?
- Comparison with data from ALMA and NOEMA.

Overview: outline

Project:

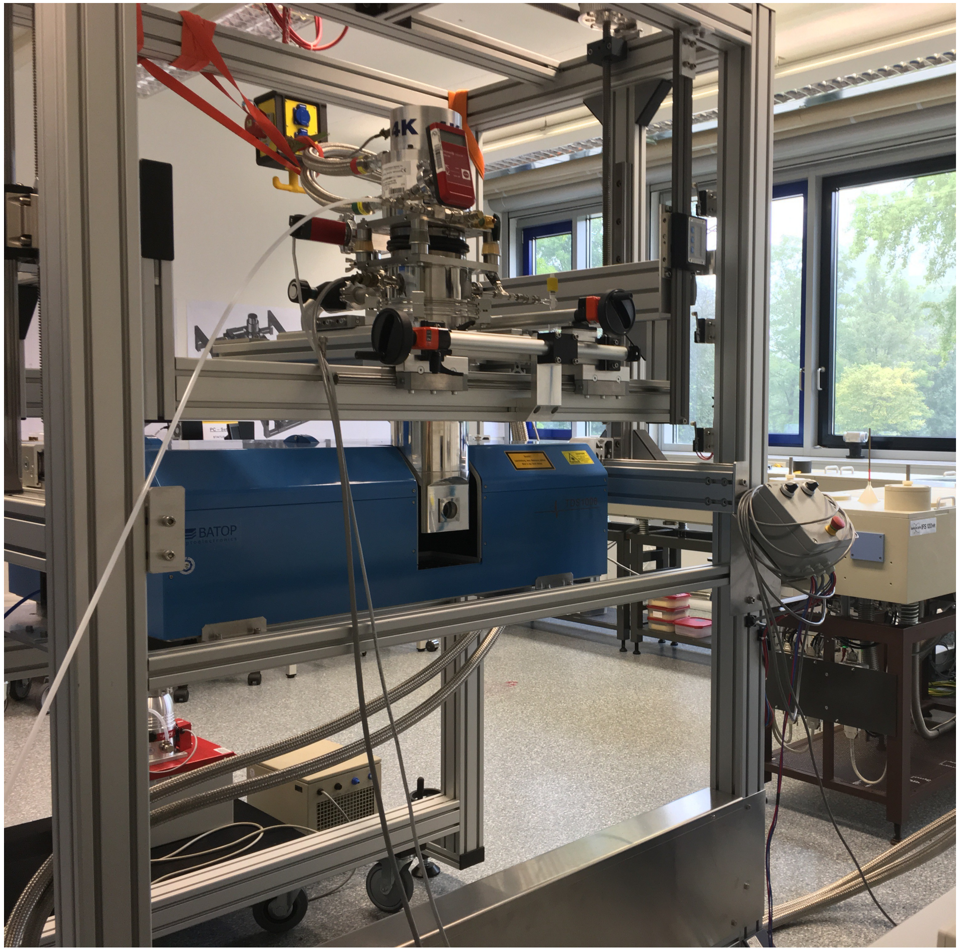
- Step 1: grow CO ice samples and thickness estimation
- Step 2: use the THz spectra to derive the optical constants
- Step 3: calculate the opacities

Experimental Setup

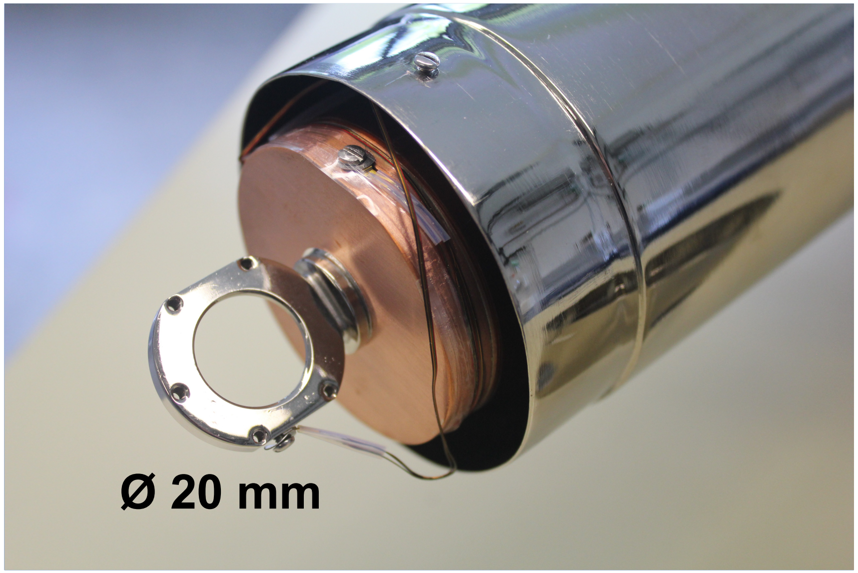
designed and developed at CAS@MPE

ARS DE-210 Cryostat
T = 4.2 K, P = 10^{-6} mbar
GMX-20 interface:
sample isolated from vibration

Batop TDS 1008 Spectrometer
0.05 – 4 THz, res. ≥ 2 GHz
(6000-75 μm)

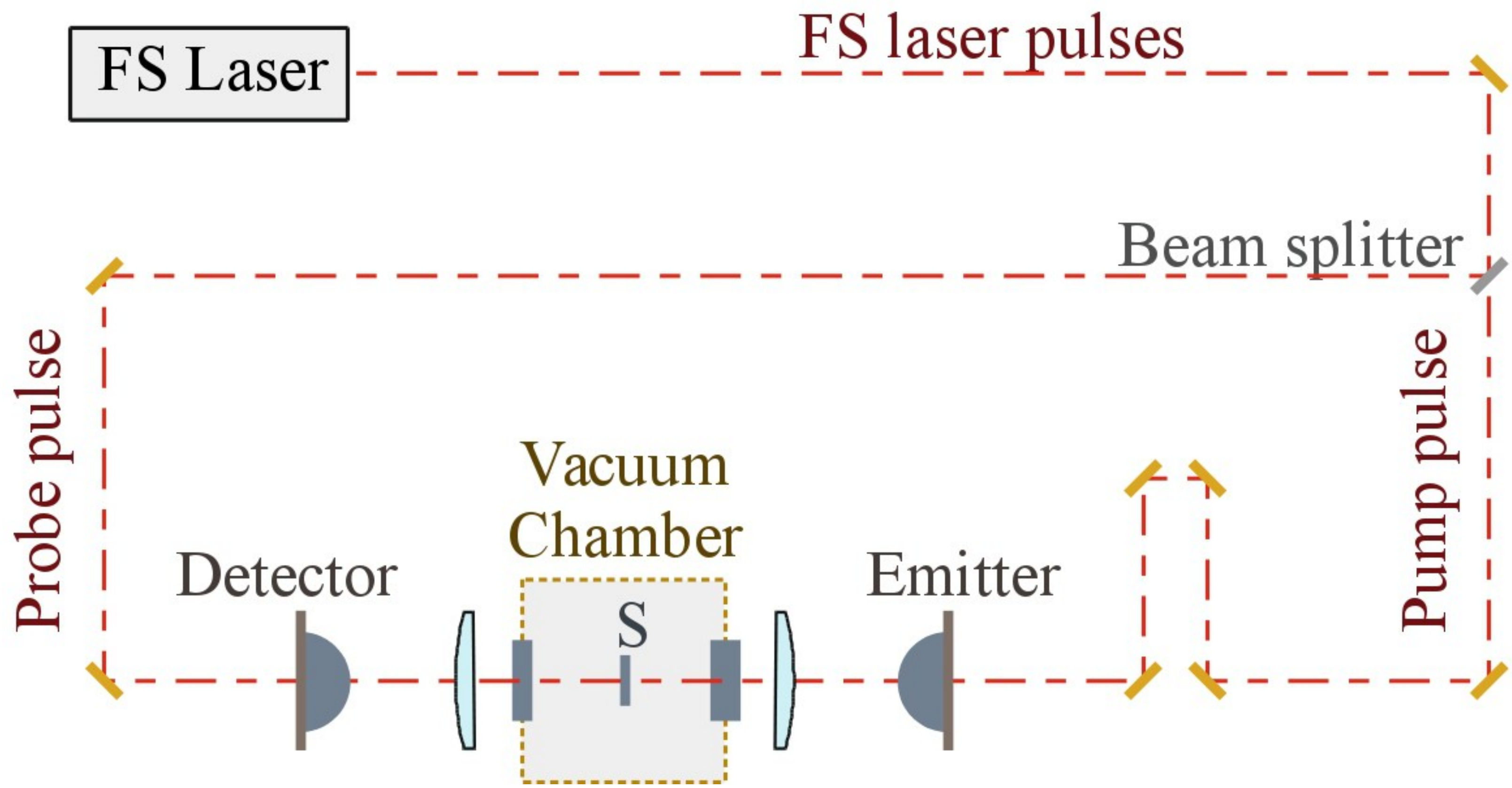


Experimental Setup

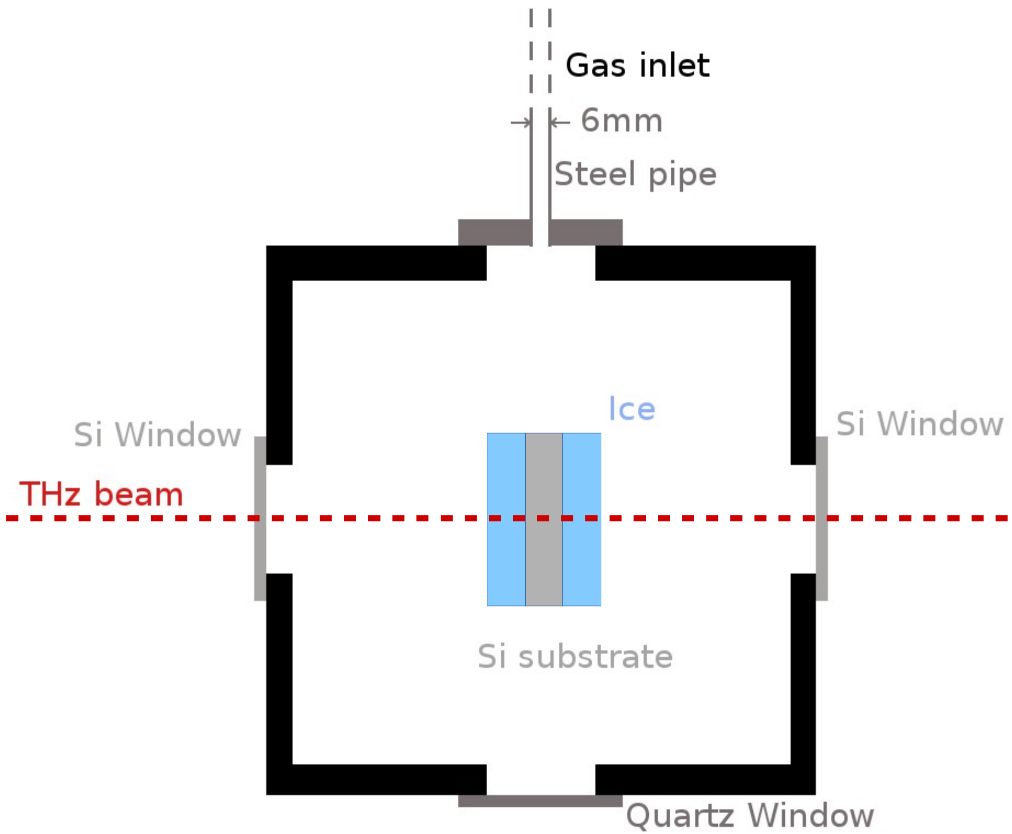


Substrate and optical windows:
high-resistivity float-zone silicon
(HRFZ-Si)

Experimental Setup



Experimental Setup



Ice morphology depends on the deposition conditions:

- gas inlet orientation
- temperature→

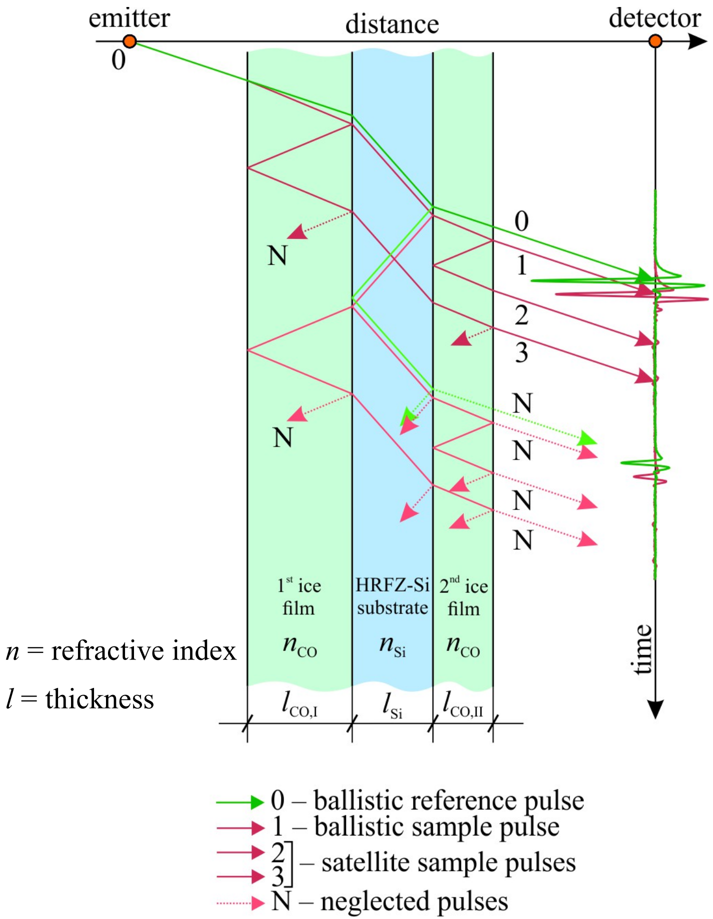
during deposition:

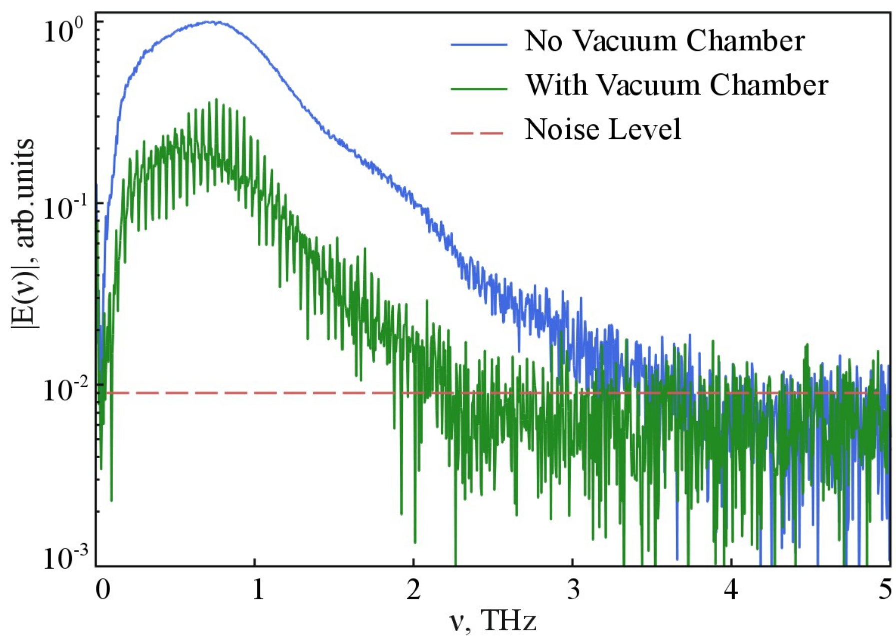
T = 28.5, 31.2, 33.1 K

(reference and sample spectra: T = 14 K)

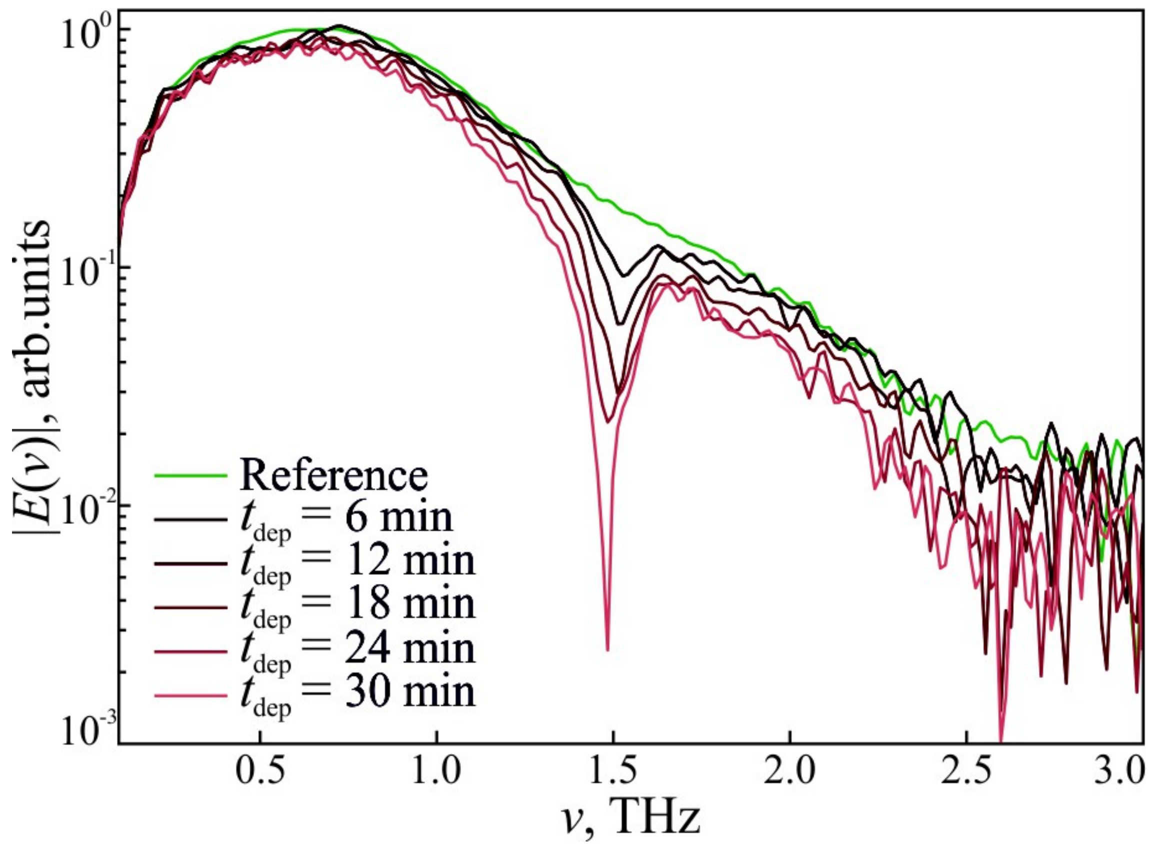
Ice uniform within 10%

Experimental Setup

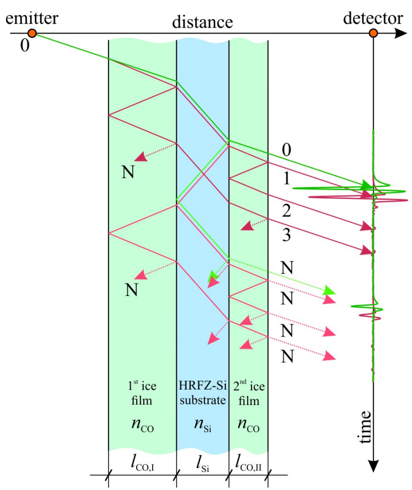


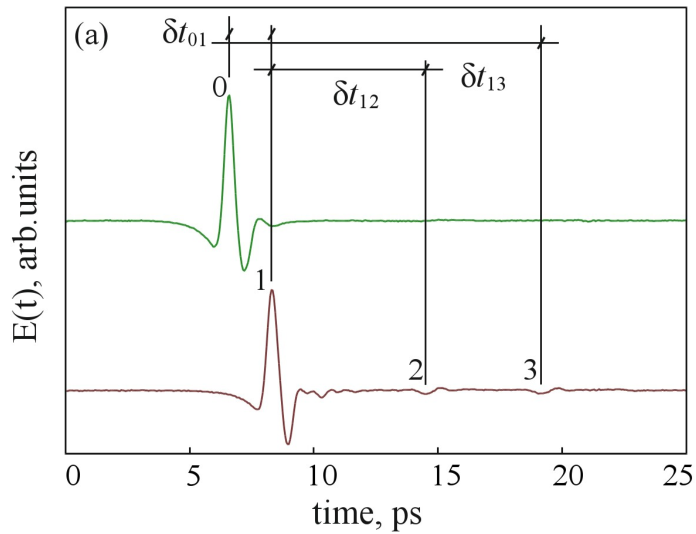


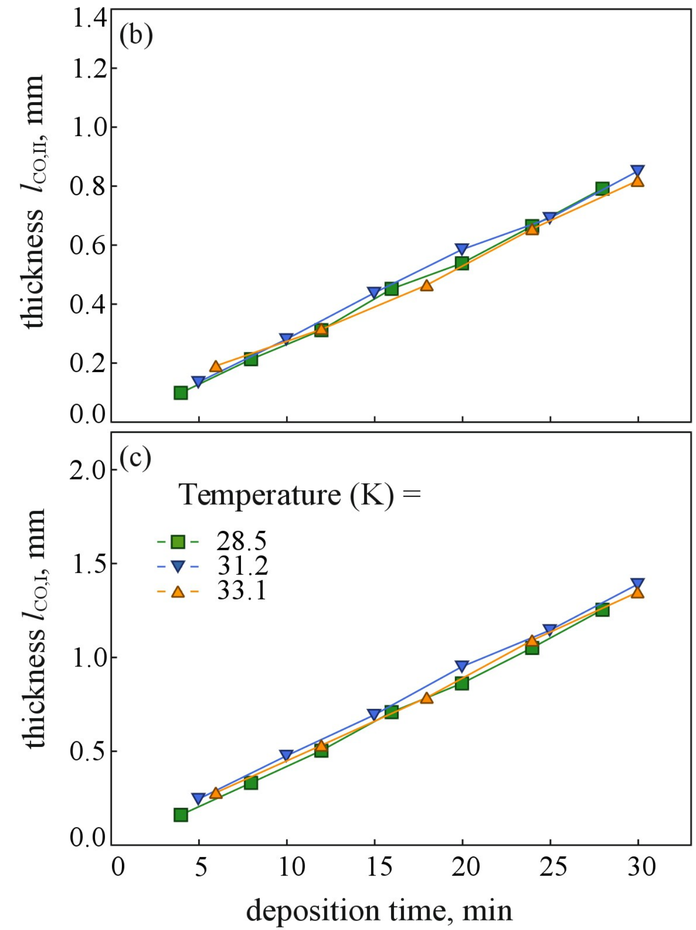
CO ice THz spectra



Step 1: ice thickness estimation







(a) Time delays between the ballistic pulses of the reference (0) and sample (1) waveforms, the first satellite pulse (2), and the second satellite pulse (3).

(b,c) Estimates for the thicknesses of the two ice films as a function of the total deposition time for the different temperatures.

Step 2: optical properties determination

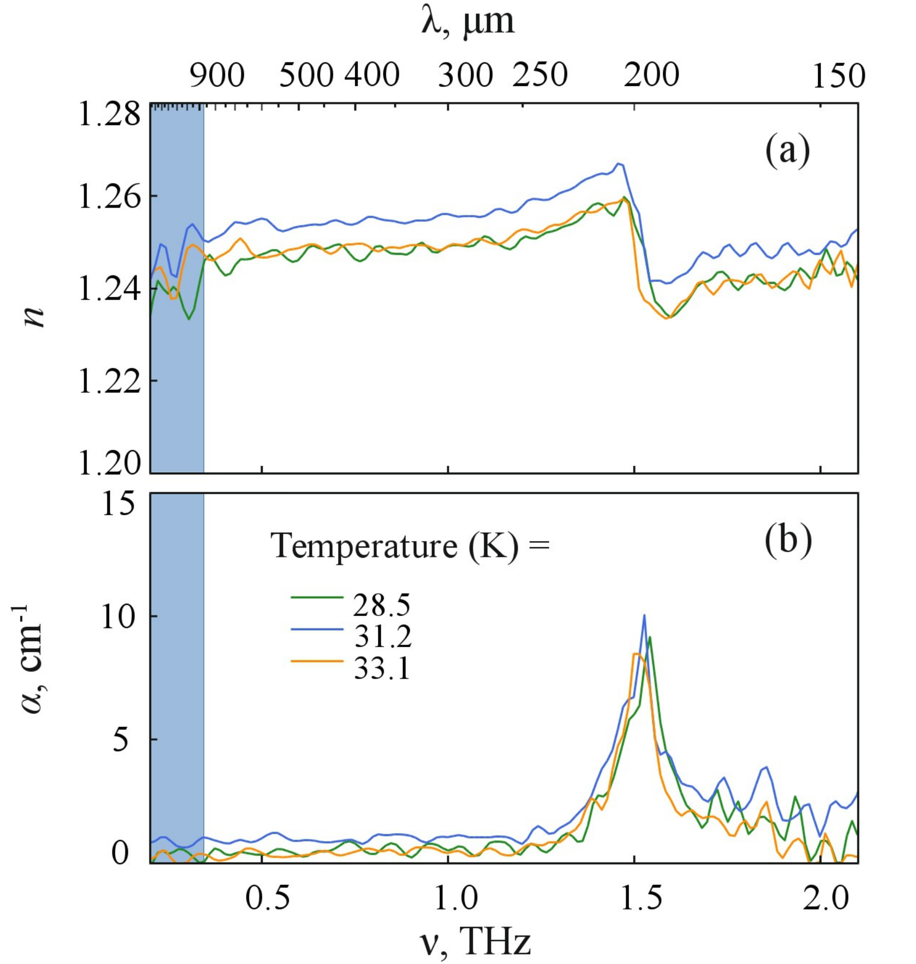
(a) Real part of the refractive index, *n*

(b) amplitude absorption coefficient, α

Previous study:

n = 1.28 in the MIR range

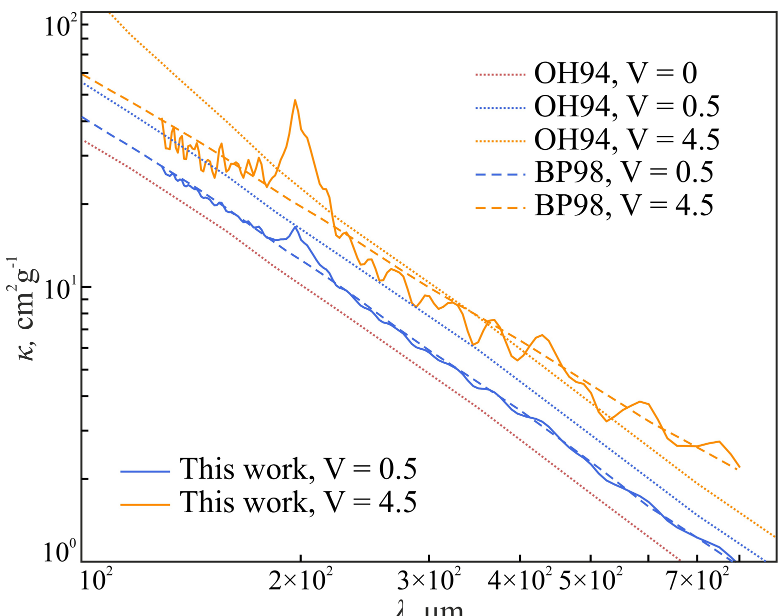
Baratta & Palumbo (1998).



Step 3: opacity calculation

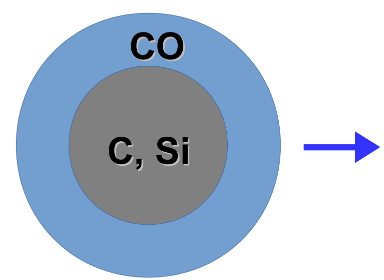
We want to compare our data with one of the most cited paper on computing dust opacities: Ossenkopf & Henning (1994), who calculated opacities for bare grains and water based ice mantles.

Opacities and parameters of the fitting function $\kappa \propto \lambda^{\beta}$; β : spectral index.



BP98: Baratta & Palumbo (1998).

Volume ratio	β
V = 0.5	-1.85
V = 4.5	-1.65



Spherical dust grain model:
V = volume ratio between the ice layer and the bare dust grain

Next

- Complex refractive index measurements for pure ices and ice mixtures (H_2O, CO_2, N_2, ...)

  →analysis ongoing for CO_2

- Extension of the spectroscopic data in the IR using a FTIR spectrometer

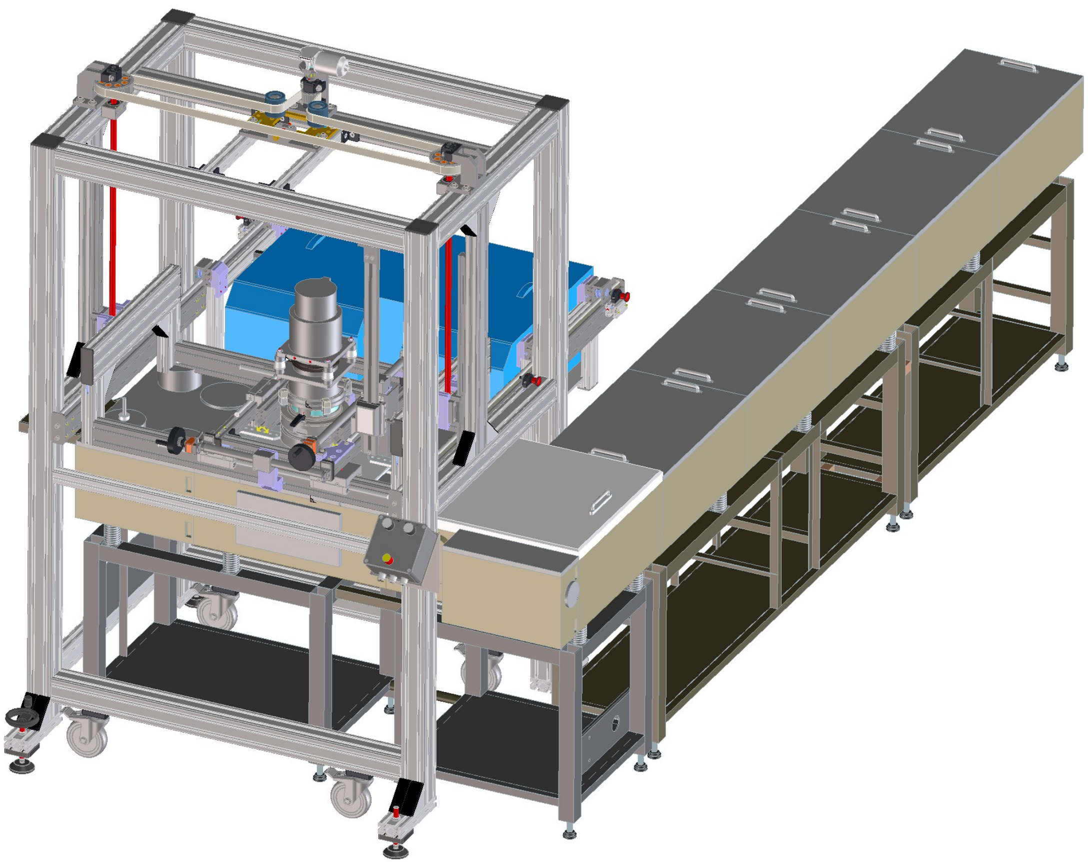
  → analysis ongoing for CO

Experimental Setup

Bruker IFS 125 HR FTIR

(also in preparation for JWST)

- NIR 14000-1850 cm^{-1} (0.7-5.4 μm)
- MIR 4800-450 cm^{-1} (2.1-22.2 μm)
- FIR 450-5 cm^{-1} (22.2-2000 μm)



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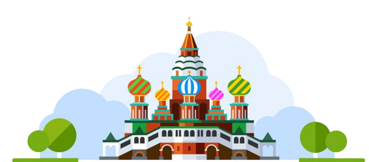

Thanks for your attention!