Experimental set up used to characterize the optical properties of gases at typical planetary conditions

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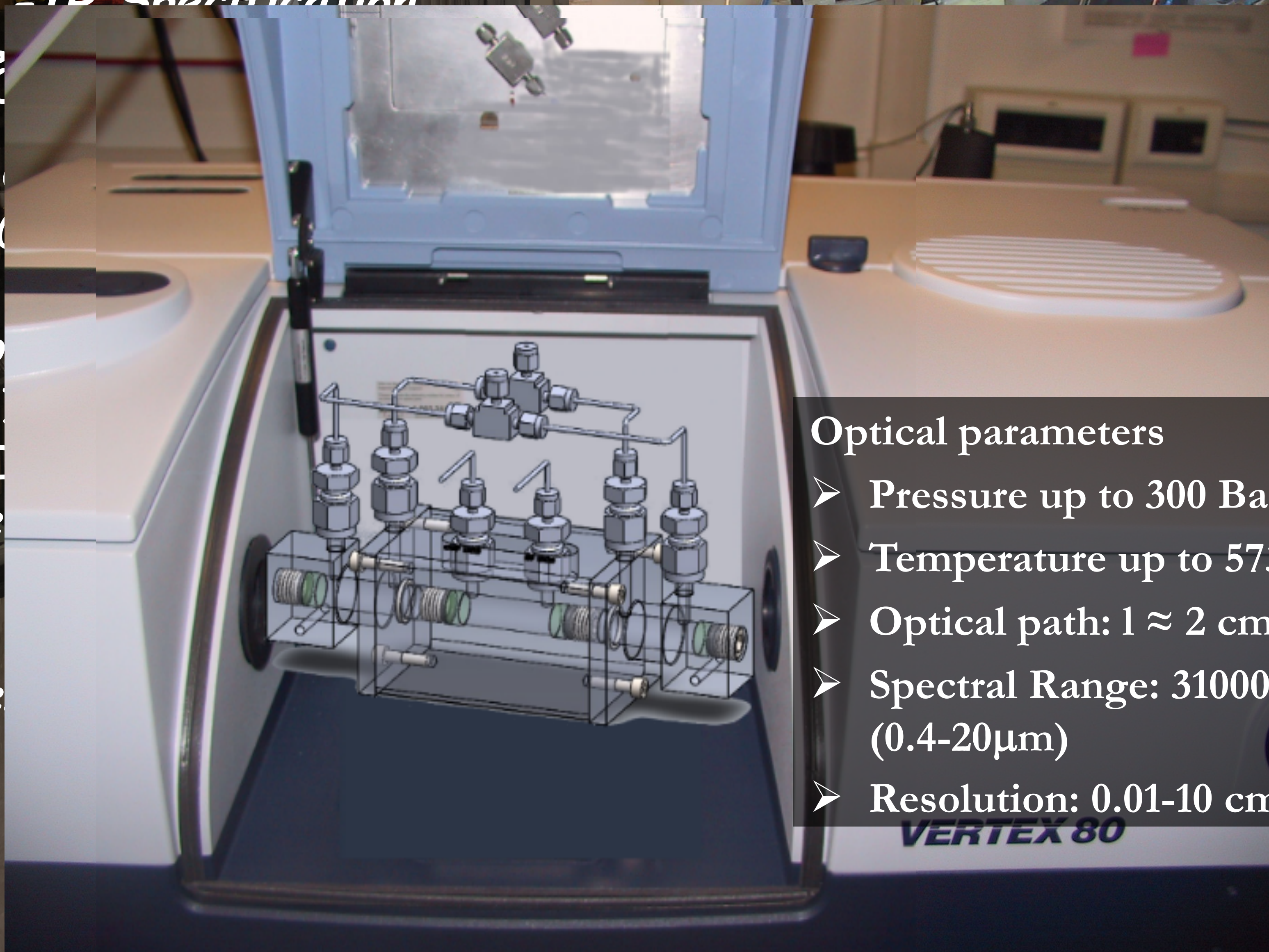
OUTLINE

- **Experimental setup:**
  - **High Pressure-High Temperature gas cell**
  - **Measurements of properties of gases at high pressure and high temperature**

    (as an example Venusian real vertical profile)
  - **CRD System**
  - **Study of the continuum and very weak absorptions**

    (as an example the atmospheric windows of Venus)
  - **Multi Pass gas cell**
  - **Collision Induced Absorption (CIA) bands of H_2, H_2&CO_2 and H_2&CO_2&CO**
  - **Working progress**
- **Summary**

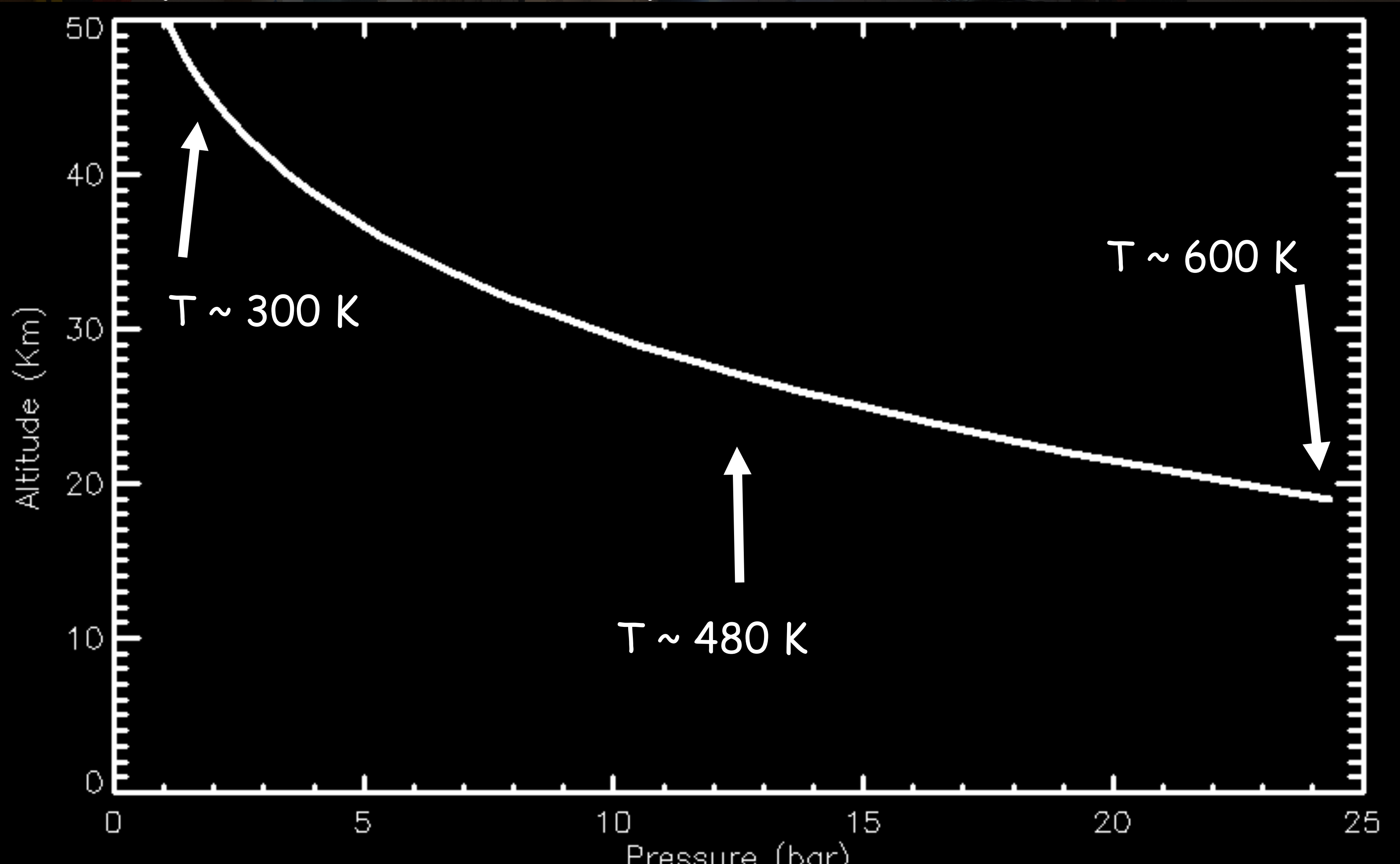
Experimental setup (HP-HT)



Optical parameters

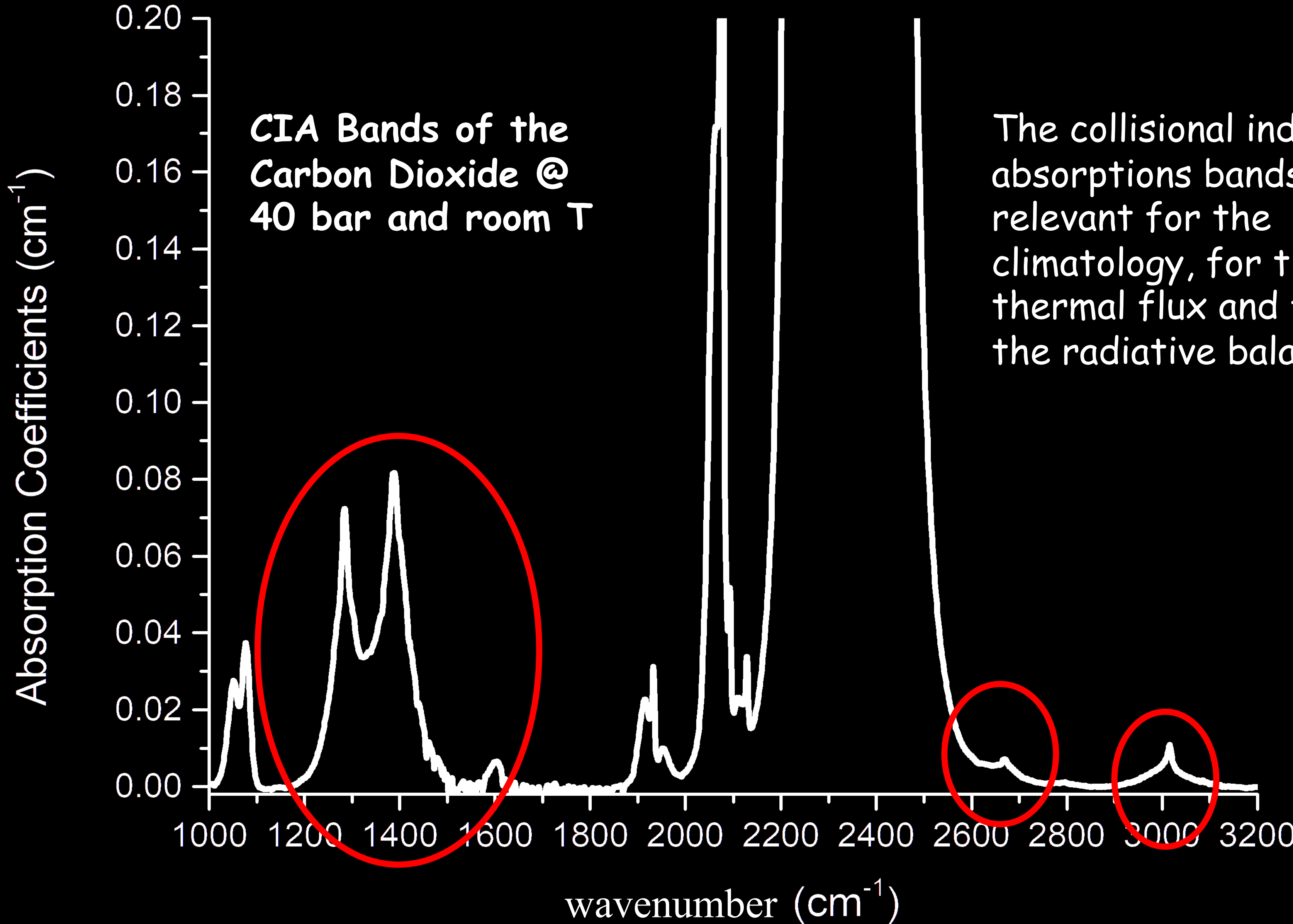
- Pressure up to 300 Bar
- Temperature up to 573 K
- Optical path: l ≈ 2 cm
- Spectral Range: 31000-700 cm^{-1} (0.4-20μm)
- Resolution: 0.01-10 cm^{-1}

For example: the Venus International Reference Atmosphere (VIRA): Models of the Structure from the Surface up to the deep atmosphere of Venus (Moroz V.I. et al. 1997) is shown: [1]

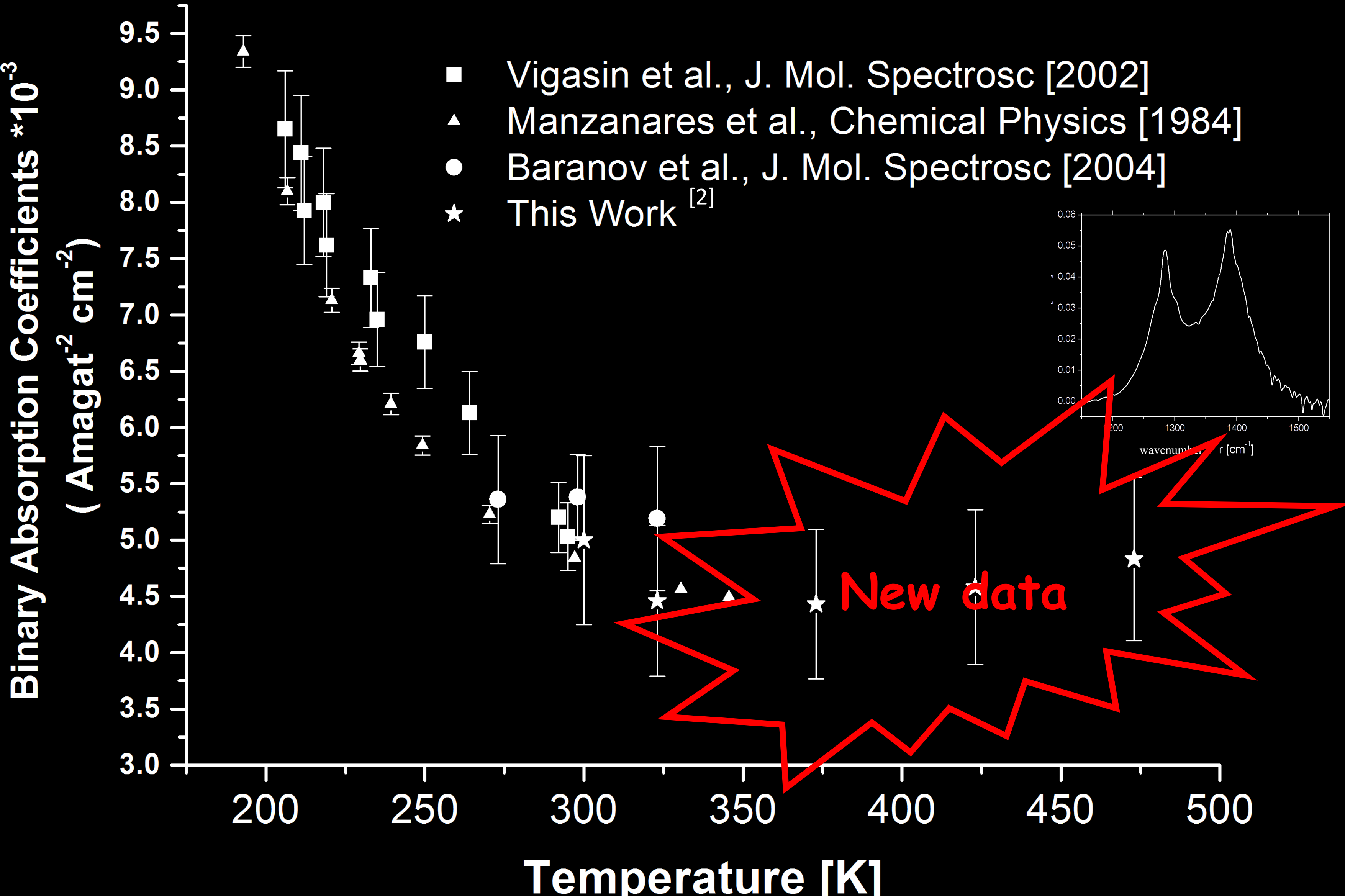


[1]Experimental CO_2 absorption coefficients at high and pressure and high temperature (Journal of Quantitative Spectroscopy and Radiative Transfer 2013)

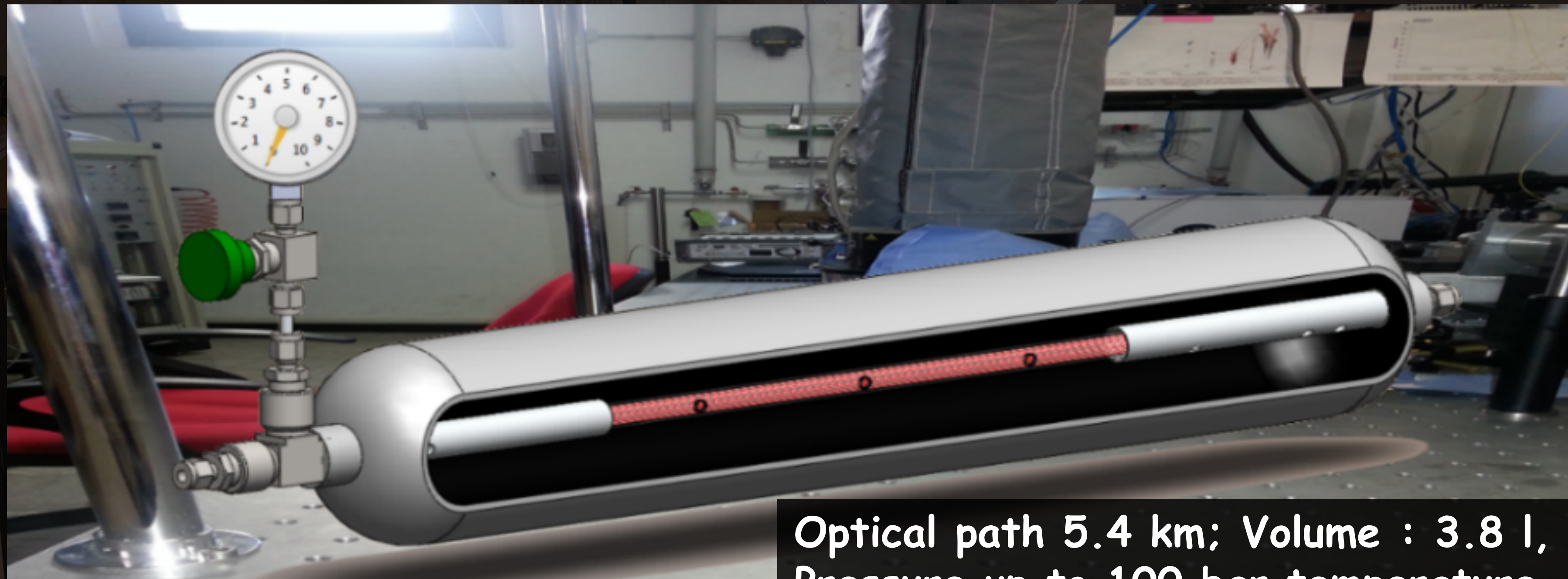
Collisional Induced absorptions (CIA) bands: due to the collision between a pair of molecules of carbon dioxide



The collisional induced absorptions bands is relevant for the climatology, for the thermal flux and for the radiative balance



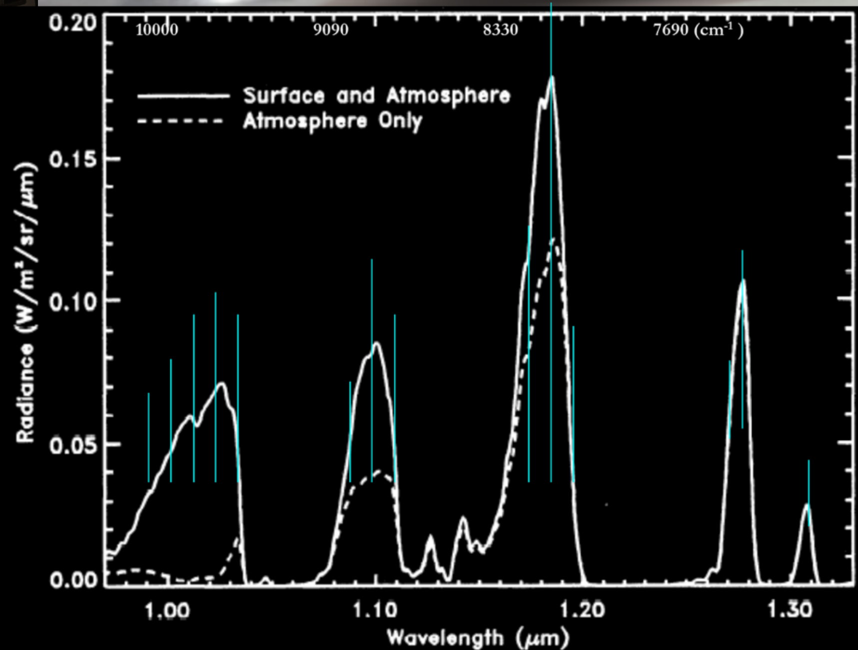
[2]Temperature dependence of collisional induced absorption (CIA) bands of CO_2 with implications for Venus' atmosphere (Journal of Quantitative Spectroscopy and Radiative Transfer 2018)



Optical path 5.4 km; Volume : 3.8 l, Pressure up to 100 bar temperature up to about 420 K

Thanks to the high reflectivity of the mirrors we can measure the total absorption of about 10^{-6}

Spectral range depends on the laser tunability.



Atmospheric Venus's windows: narrow spectral regions which allow probing the lower atmosphere and surface

CO_2 Loss rate @ high pressure at 1.18 μm

[3]Loss rate = $1.93 \cdot 10^{-6} + 1.17(5) \cdot 10^{-8}\, D + 5.47(14) \cdot 10^{-10}\, D^2$

We have three different contributions:

- Constant due to the loss of the mirrors: $1.93 \cdot 10^{-6}$ (cm^{-1})
- Linear contribution due to Rayleigh scattering :
  1.17(5)*10^{-8} cm^{-1}Amagat^{-1} (calculated **1.23(8)* 10^{-8}** cm^{-1}Amagat^{-1}**)
- Quadratic contribution due to the wings + CIA + continuum:
  5.47(14)*10^{-10} cm^{-1}Amagat^{-2}

Refer to B. Bézard et al. (Icarus, 2011 and JOURNAL OF GEOPHYSICAL RESEARCH, 2009)

Continuum: **7(2)*10^{-10}** cm^{-1}Amagat^{-2}

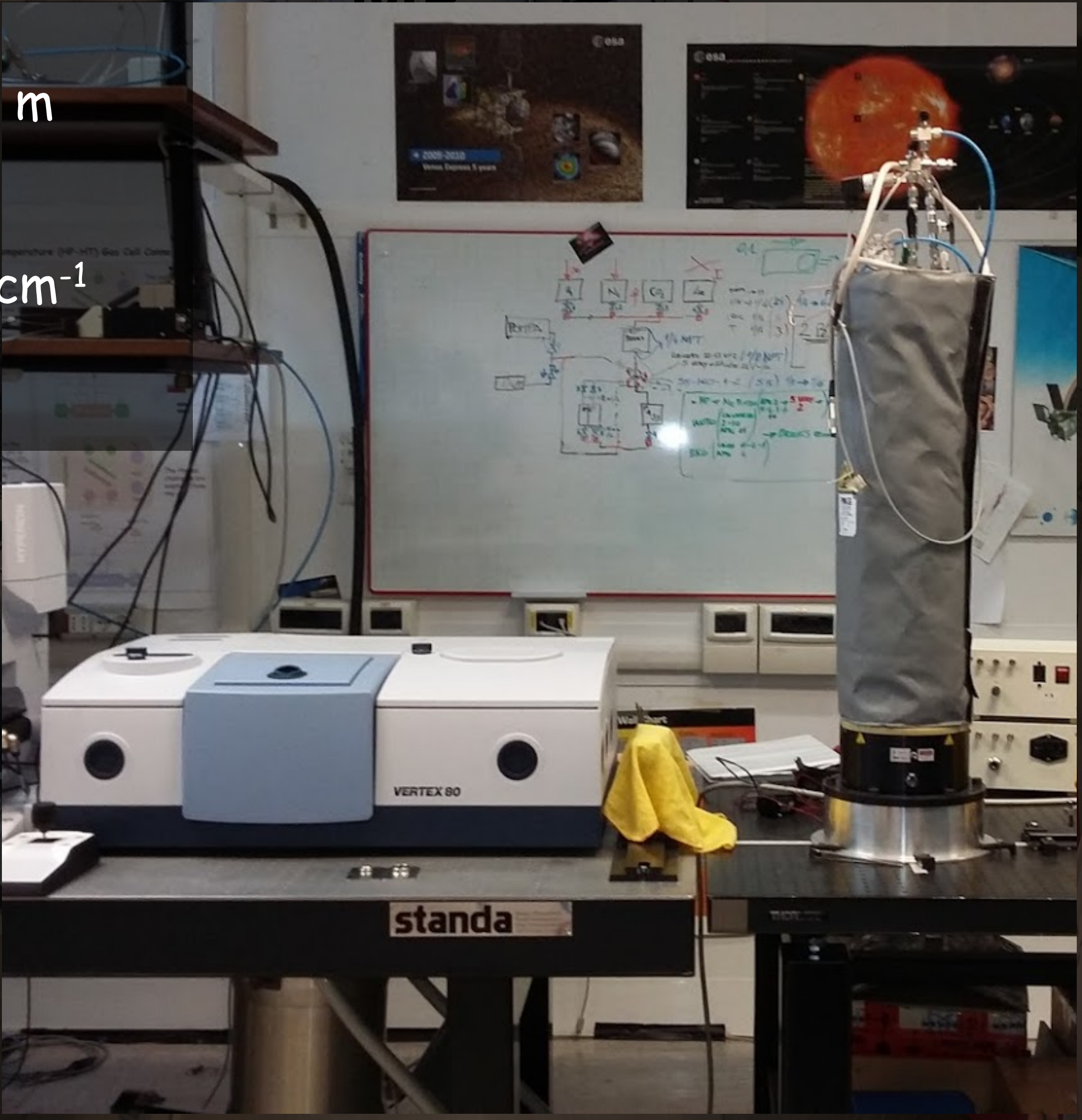
Far wings: **2*10^{-10}** cm^{-1}Amagat^{-2}

[3]Carbon dioxide absorption at high densities in the 1.18 mm nightside transparency window of Venus M. Snels, S.Stefani, G.Piccioni and B. Bzard (Journal of Quantitative Spectroscopy and Radiative Transfer, 2013)

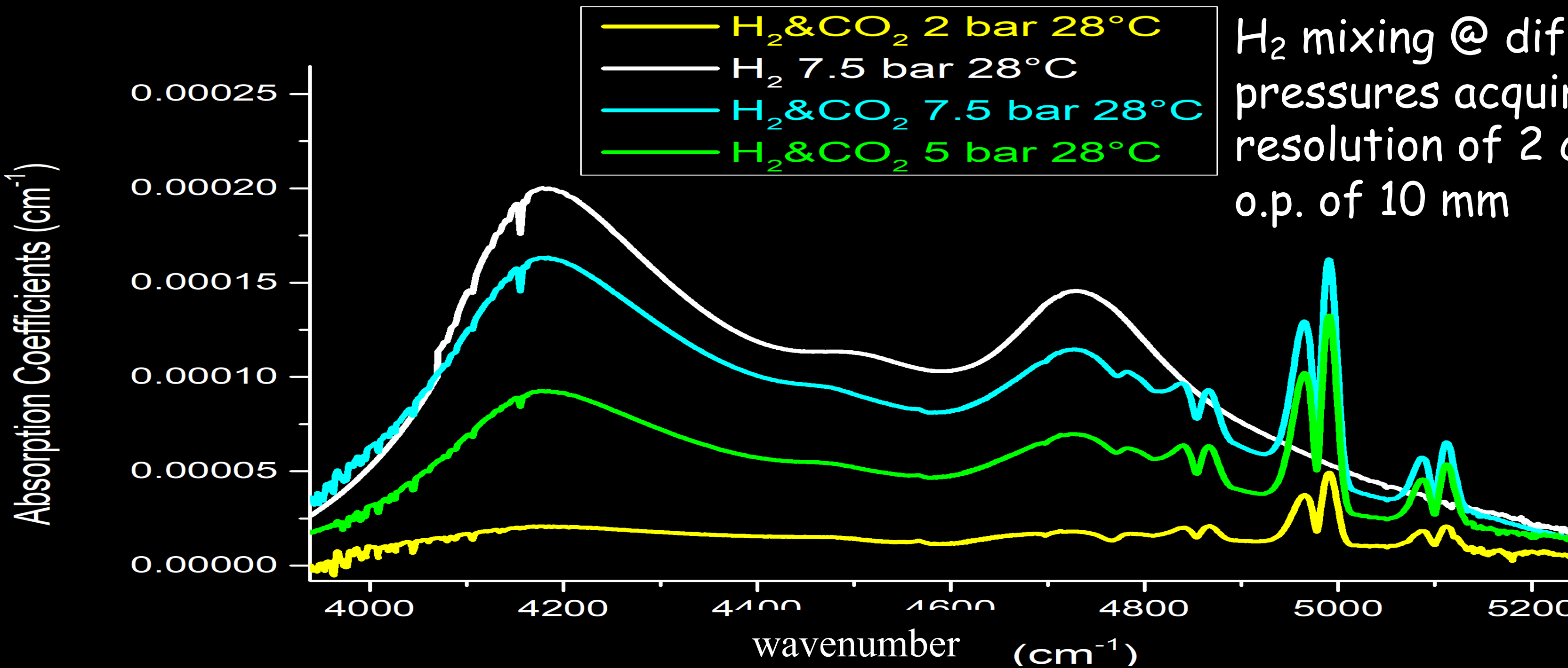
**Direct measurement of the Rayleigh scattering cross section in various gases. Sneep M and Ubachs W. (Journal Of Quantitative Spectroscopy and Radiative

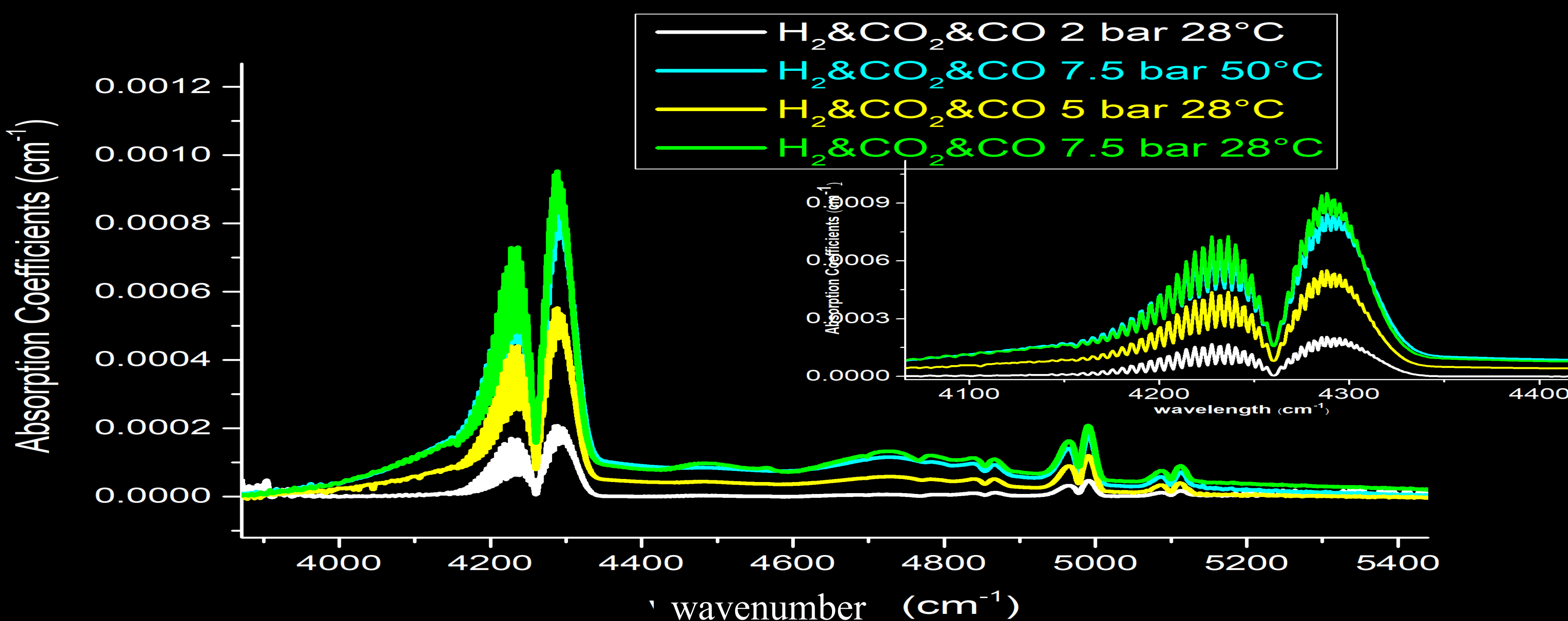
Multi pass (MP) gas cell @ intermediate pressure and high temperature

Optical parameters:
O.P. variable from 2.5 to 30 m
Pressure: 1-10 bar
Temperature : 294-400 K
Spectral Range: 31000-700 cm^{-1} (0.4-20μm)
Resolution : 0.01- 10 cm^{-1}



H$_2$ mixing @ different pressures acquired with a resolution of 2 cm^{-1} and an o.p. of 10 mm

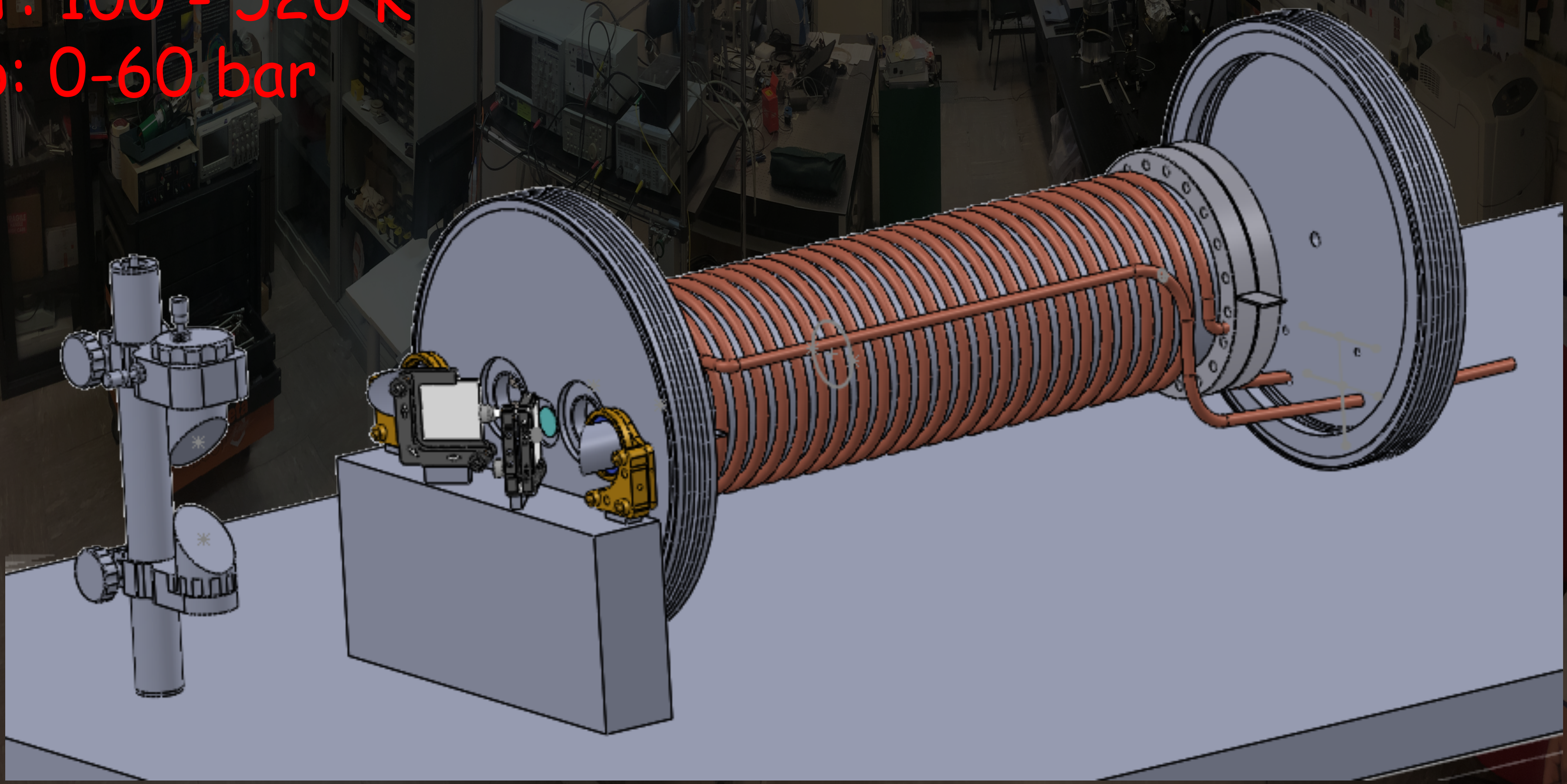




Working progress

In order to extend further the temperature and pressure range, and to overcome some present limitations, we designed a new chamber which consists of a heatable\coolable cell placed inside of a vacuum chamber

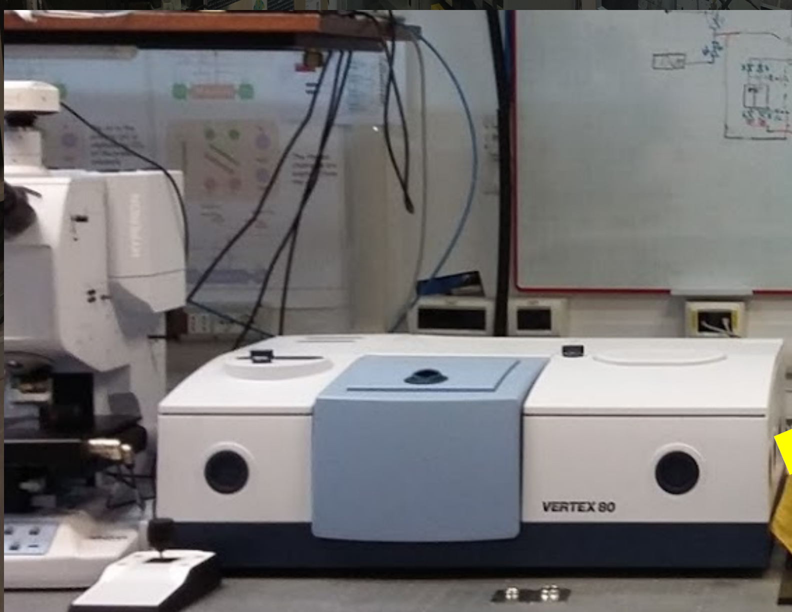
T: 100 - 520 K
p: 0-60 bar

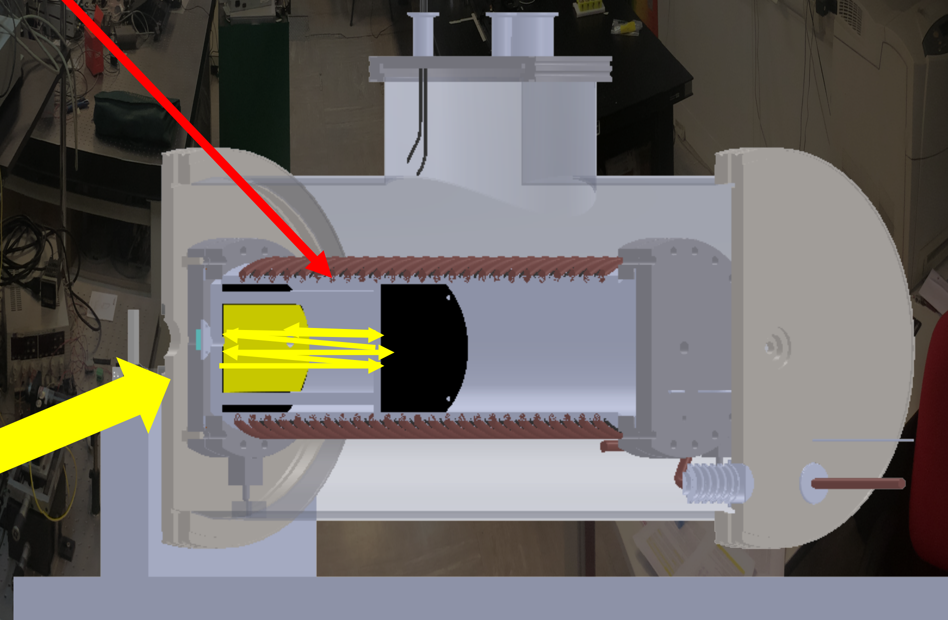


PASS (Planetary Atmosphere Simulation System)

Coolable/heatable MP gas cell O.P. ≈ 10 m aligned with the FT-IR

Spectral range 31000-700 cm^{-1} (0.4 - 20 μm)
Resolution 0.01 - 10 cm^{-1}





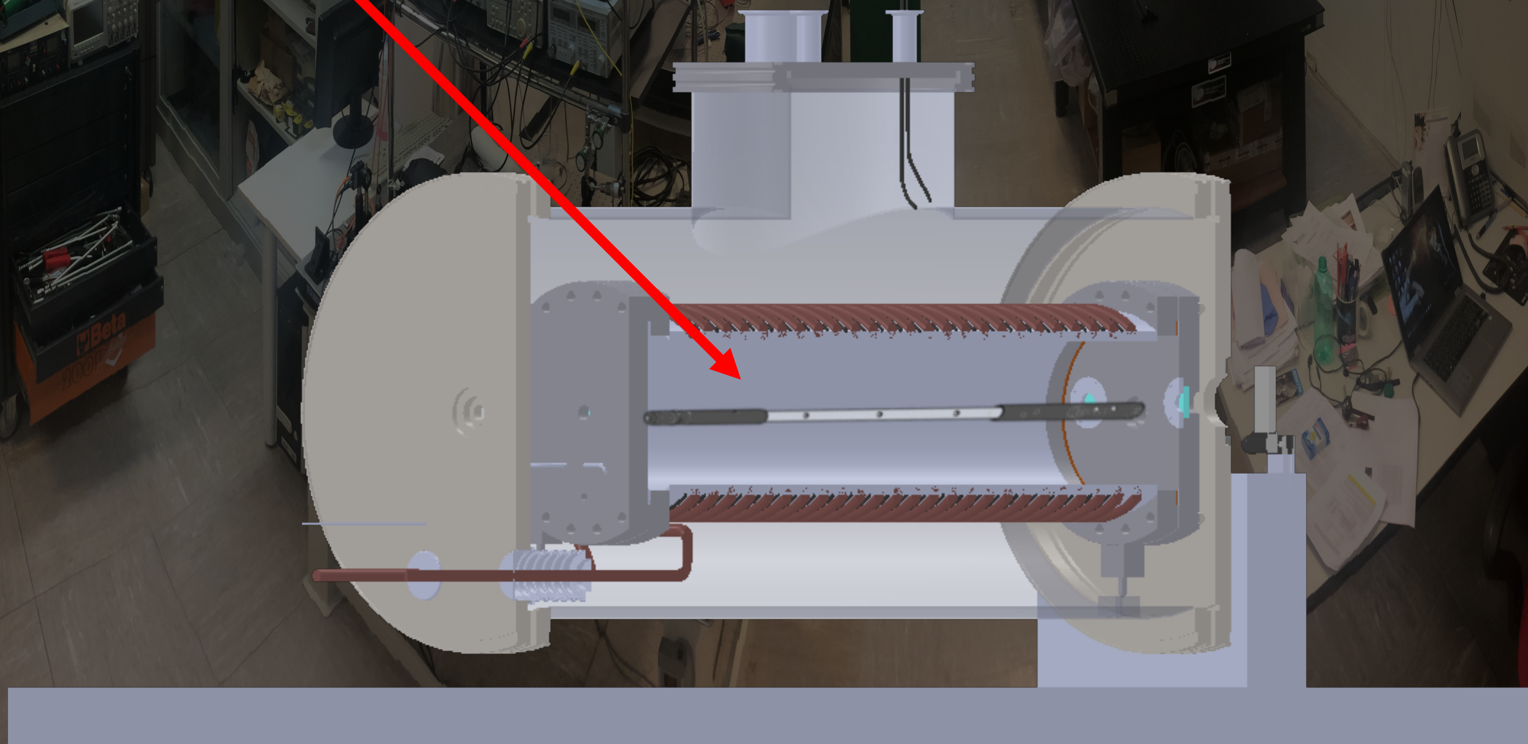
PASS (Planetary Atmosphere Simulation System)

Coolable/heatable **Cavity Ring Down (CRD) System**

O.P. ≈ 5 Km

Spectral range: depends on the laser tunability and on the mirrors (we worked in the range 1.79- 1.81 μm)

Resolution about 0.1 nm



Summary

- The HP-HT set up provide information about the absorption coefficients of gases at high pressure and high temperature important for both interpreting remote sensing data and supporting the theoretical models (LMM) (an important implication for the CO_2 at typical Venusian conditions)
- The CRD set up provide information about the absorption in narrow spectral regions, in particular about the atmospheric windows of Venus @ 1.18 mm
- The MP gas cell allow us to study weak absorption with a moderate long optical path in particular the H_2, H_2&CO_2&CO CIA band.
- Collision Induced Absorption (CIA) can be characterized in our lab using both different gases and different conditions (High/Low Pressure-High/Low Temperature)

What we can do for ARIEL:

- in our lab we can measure the absorption coefficients of different gases at high/low pressure and high/low temperature using both MP and CRD set up
- we can create a dedicated data base in order to implement the input parameters of the radiative transfer models
- our lab is part of a network of facilities which are involved in the "atmosphere in a test tube" project (see the R. Claudi presentation)

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References

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- Carbon dioxide opacity of the Venus' atmosphere (https://doi.org/10.1016/j.pss.2014.08.002)
- Experimental CO_2 absorption coefficients at high and pressure and high temperature (https://doi.org/10.1016/j.jqsrt.2012.11.019)
- Molecular dynamics simulations for CO_2 spectra. IV. Collisional line-mixing in infrared and Raman bands (https://doi.org/10.1063/1.4811518)
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- Carbon dioxide absorption at high densities in the1:18 μm nightside transparency window of Venus (https://doi.org/10.1016/j.jqsrt.2013.09.009)
- Near-infrared Rayleigh scattering of SF_6 (https://doi.org/10.1080/00268976.2013.807365)