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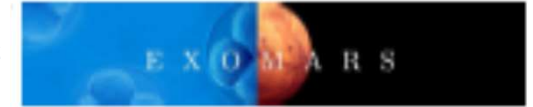
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# *Temperature and CO<sub>2</sub> density distribution in Mars upper atmosphere from the ACS-MIR / TGO solar occultations at 2.7 μm absorption band*

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Franck Montmessin (2), Juan Alday (3), Kevin Olsen (3),  
and Miguel Lopez-Valverde (4)  
and ACS team

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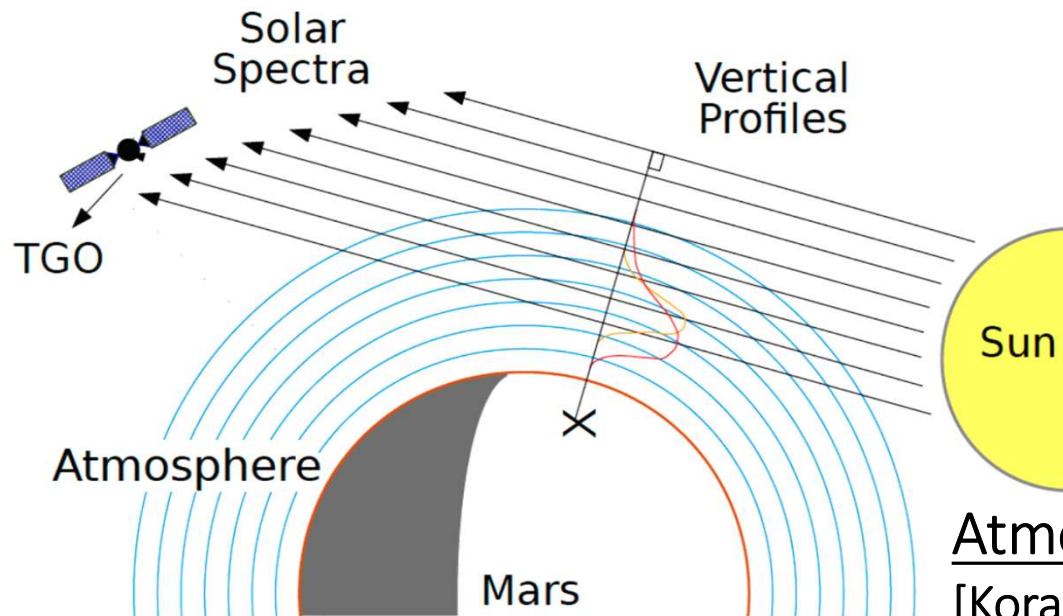
(3) University of Oxford

(4) IAA, Granada, Spain

EGU 2020 (remotely), 4-8 May 2020, Virtual World



# Solar occultation by ExoMars Trace Gas Orbiter (April 2018 – nowadays)



Measured atmospheric transmission spectrum:

$$J_A(\nu, z) = \frac{F(\nu, z)}{F_0(\nu)}$$

$F_0(\nu)$  – pure solar spectrum;  
 $F_0(\nu, z)$  – solar spectrum, transmitted through atmosphere at tangent altitude  $z$ .

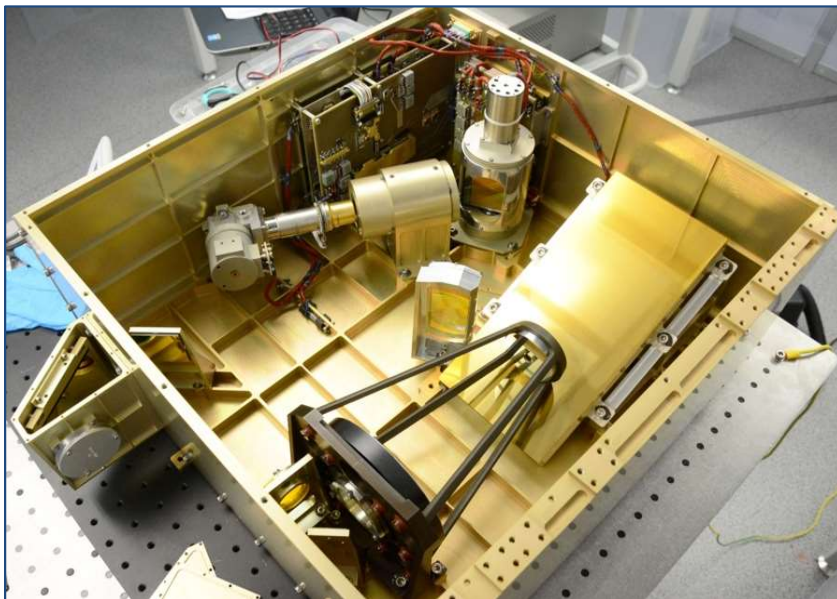
## Atmospheric Chemistry Suite (ACS)

[Korablev et al., 2018, Sp. Sci. Rev.]

Science goals: altitude sensitive profiling of atmospheric temperature, density, minor species (CO, H<sub>2</sub>O, HDO, CH<sub>4</sub> etc.)

### ACS-MIR channel:

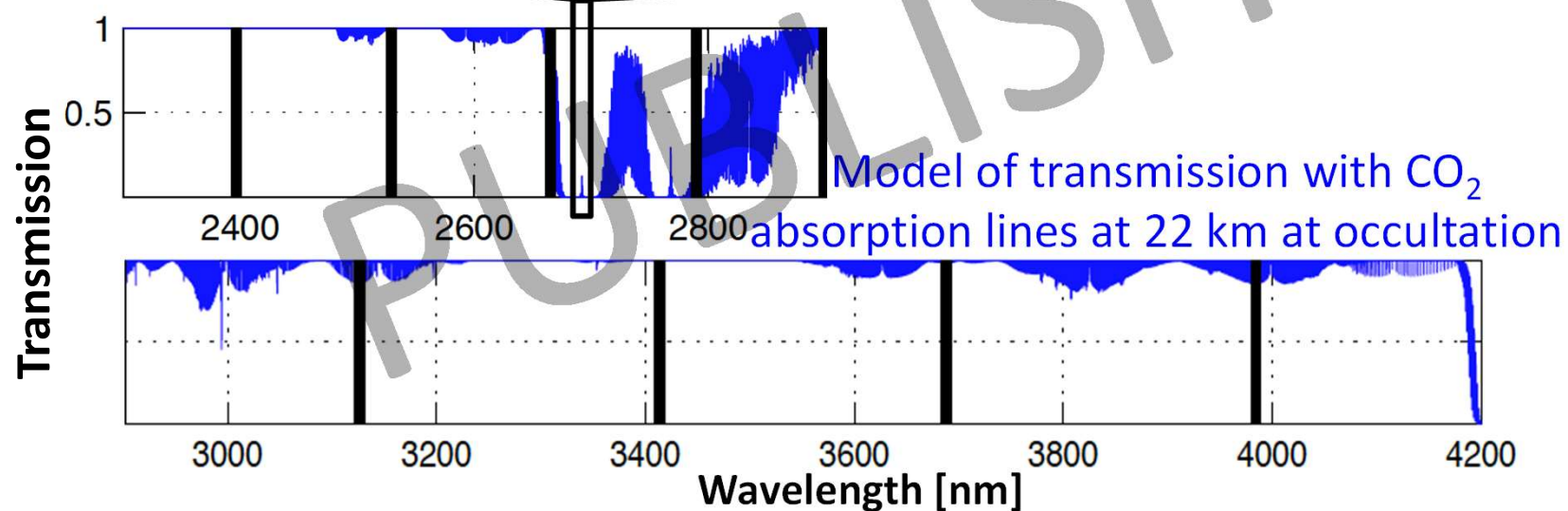
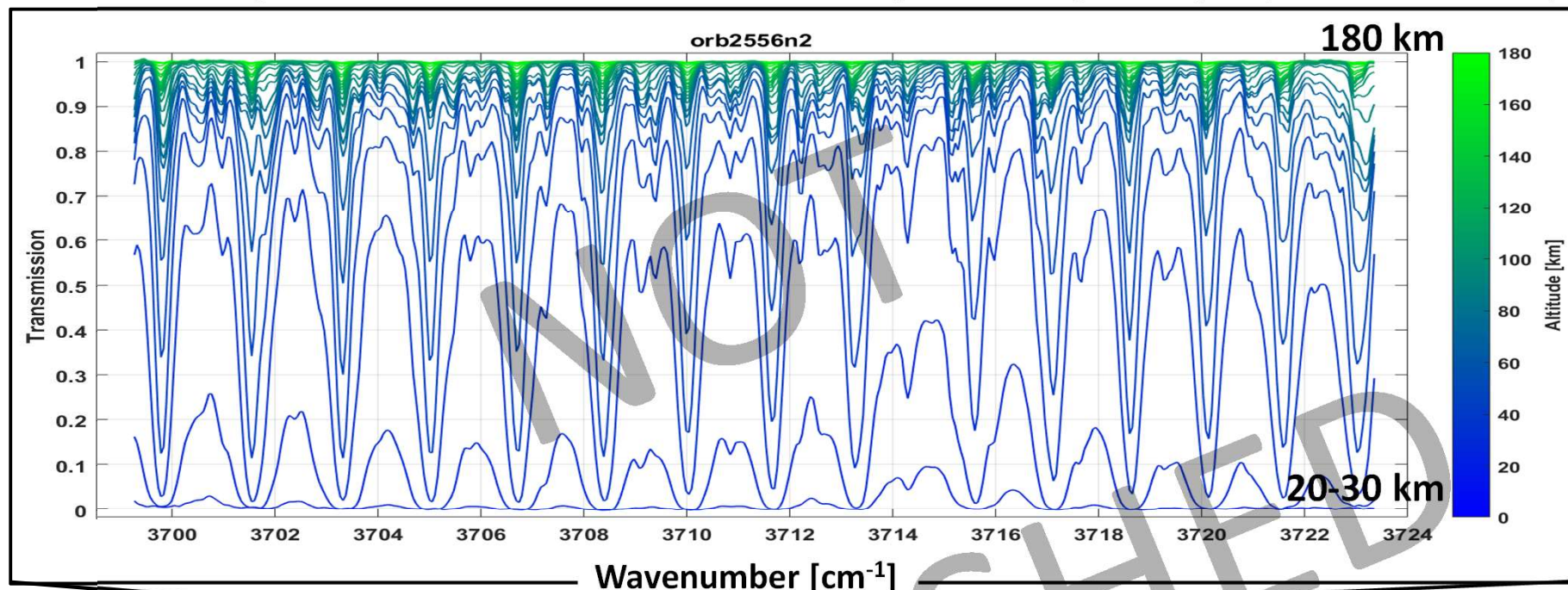
- Echelle spectrometer
- Cross-dispersion system
- Spectral range 2.3 – 4.2  $\mu\text{m}$
- Resolving power  $\lambda/\Delta\lambda \sim 30\,000$
- FOV:  $0.23^\circ \times 0.02^\circ$  (0.2-2 km)





# CO<sub>2</sub> spectroscopy around 2.7 $\mu\text{m}$

Transmission spectra measured at one occultation in spectral range  $\sim 2.7 \mu\text{m}$  (echelle order 221)



## Concept of temperature and density retrievals from transmission spectra

$$J(z) = \exp\left[-\int \left(\sigma_{CO_2}(T, p)n_{CO_2}(z) + \sigma_{H_2O}(T, p)n_{H_2O}(z) + 5F_{SMOW}\sigma_{HDO}(T, p)n_{H_2O}(z)\right)dz - \tau_{aer}\right]$$

$J(z)$  - transmission,  $\sigma(T, p)$  -  $CO_2$  and  $H_2O$  absorption cross sections,  $n$  -  $CO_2$  and  $H_2O$  number densities,  $F_{SMOW} = 1.3 \cdot 10^{-4}$ ,  $\tau_{aer}$  - aerosol slant opacity.

1) Spectroscopic database HITRAN 2016 for  $\sigma(T, p)$  and  $CO_2$  broadening for  $H_2O$  lines [Gordon et al., 2017; Gamache et al., 2016; Devi et al., 2017];

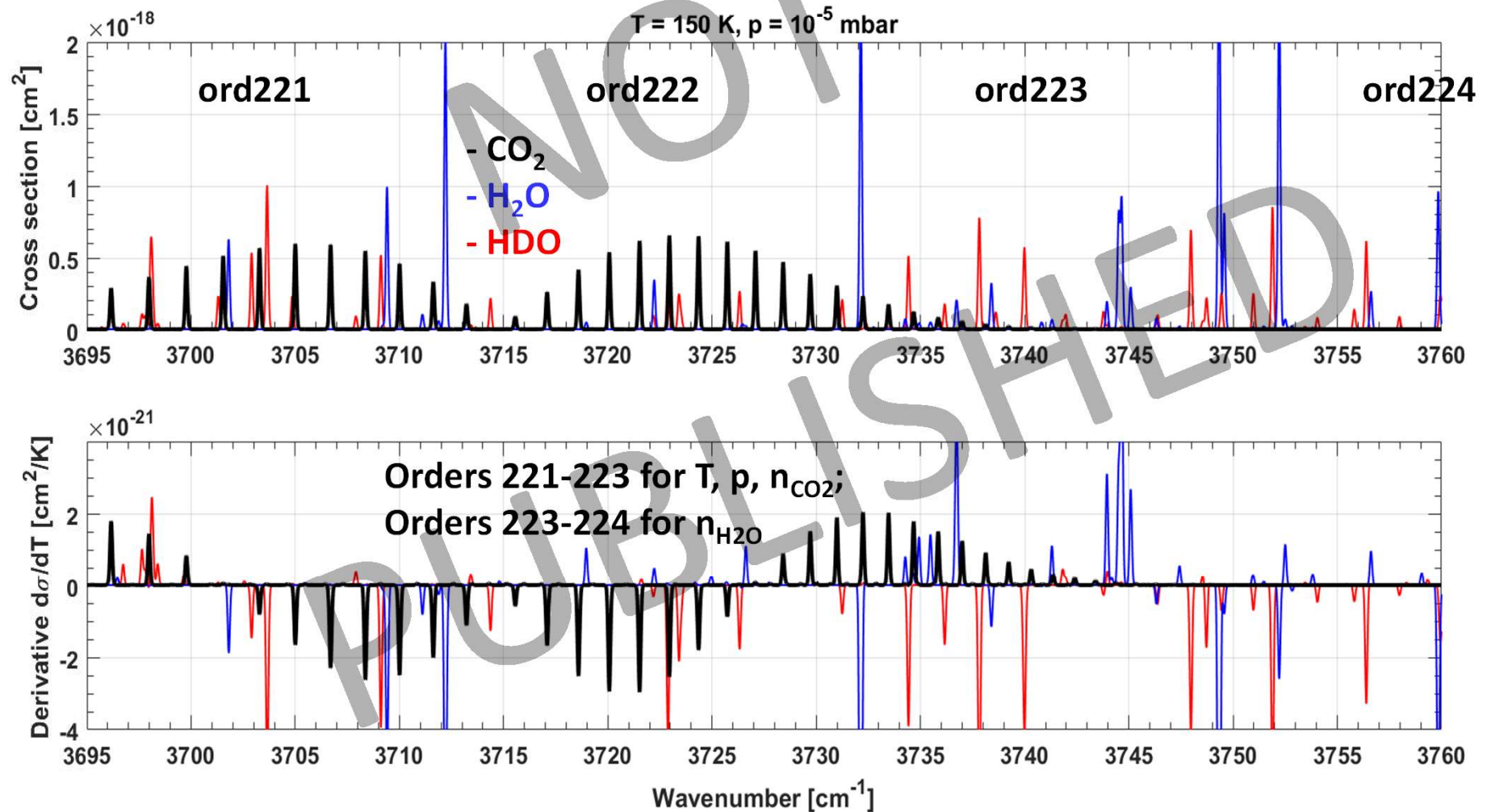
2) 1<sup>st</sup> guess for  $(T, p)$ ,  $n_{CO_2}$  and  $n_{H_2O}$  profiles from the MCD5.3 (climatology);

3) Direct retrievals of  $T(z)$ ,  $n_{CO_2}$  and  $n_{H_2O}$  at a multi iteration scheme while hydrostatic pressure:  $p(z) = p_o \exp\left(-\int \frac{m(z)g(z)}{kT(z)} dz\right)$

## Concept of temperature and density retrievals from transmission spectra

4) Use Levenberg-Marquardt algorithm with an Jacobian based on cross-section derivatives  $d\sigma/dT$ :

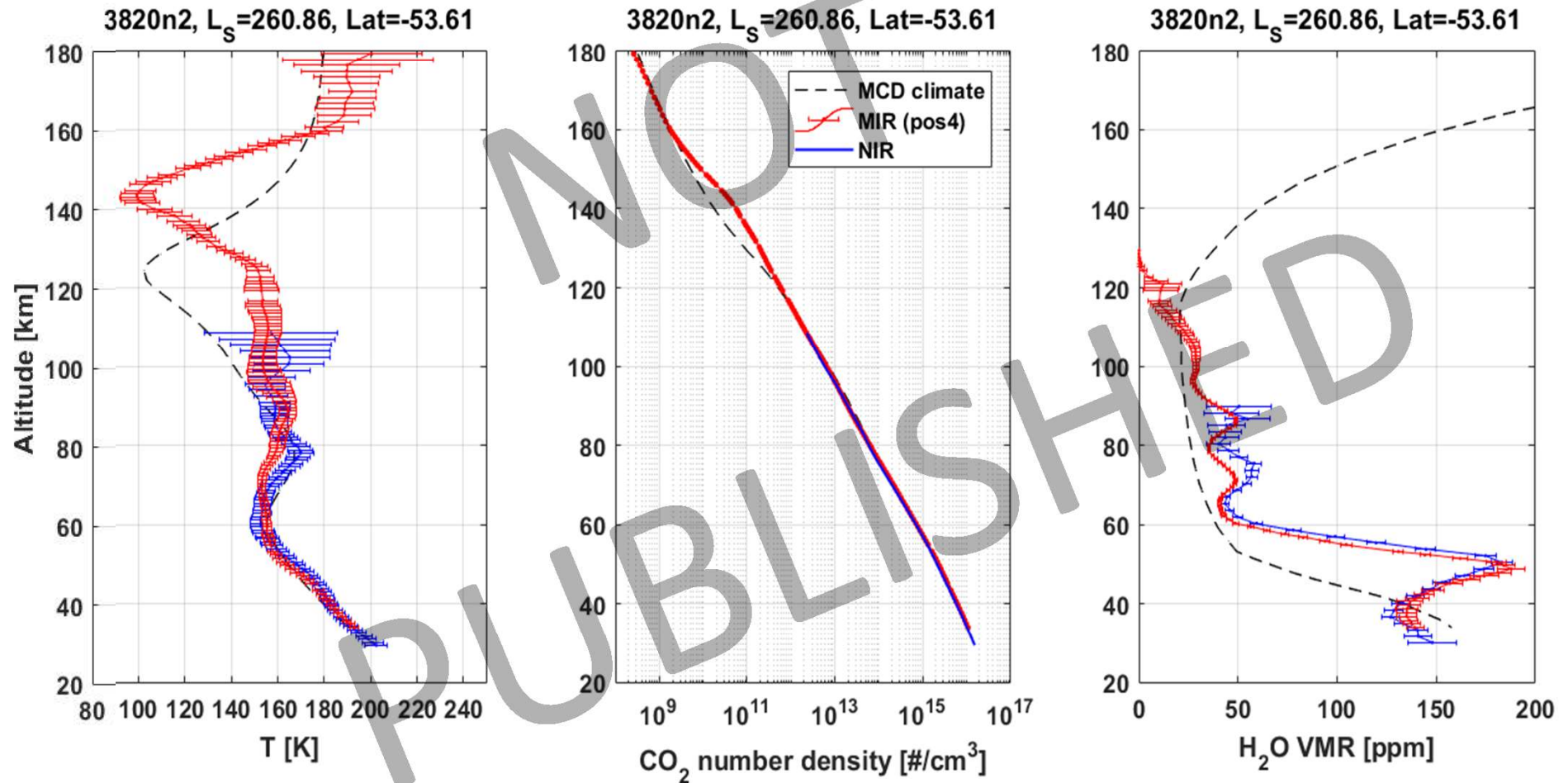
$\text{CO}_2$ ,  $\text{H}_2\text{O}$  and  $\text{HDO}$  spectroscopy at 2.65-2.7  $\mu\text{m}$  range (MIR echelle orders from 221 to 224)





## Example of one profile retrievals (average of orders 221, 222, 223):

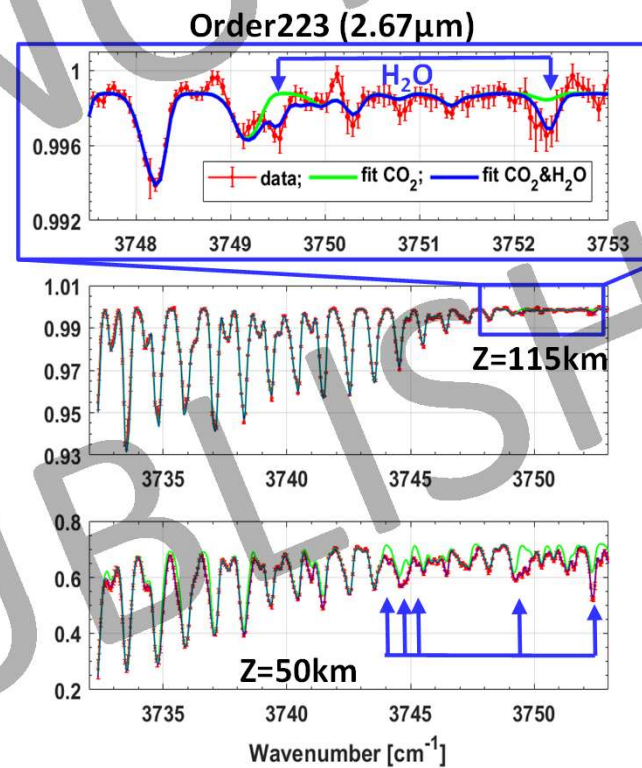
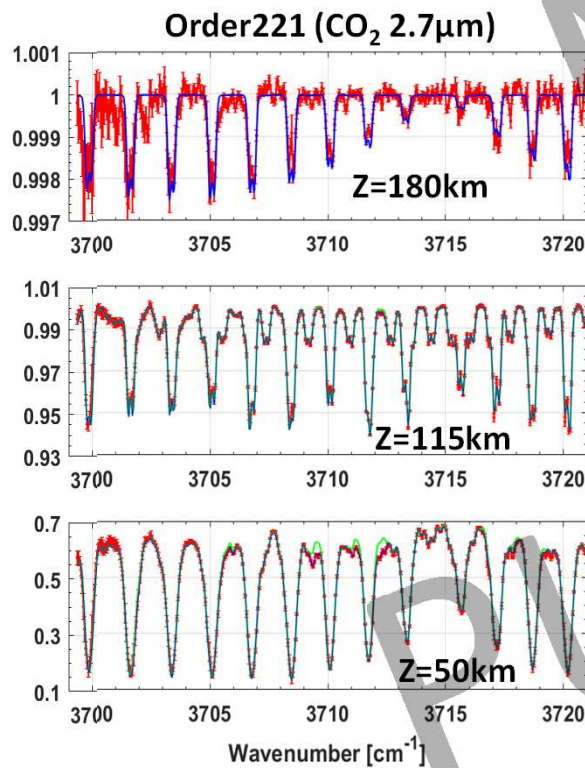
- sensitivity to CO<sub>2</sub> absorption up to 180 km;
- sensitivity to very high water abundance (1-10 ppm at 110-120 km)



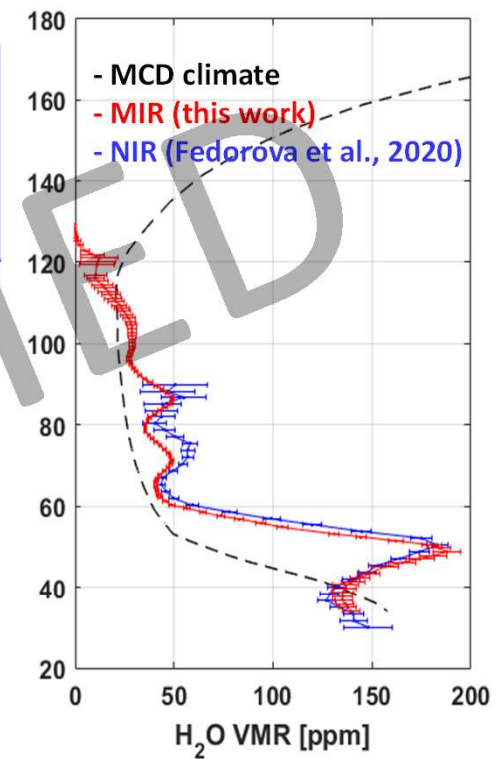
- MCD climatology; - MIR (this work); - NIR (Fedorova et al., 2020, SCIENCE)

## Example of one profile retrievals (average of orders 221, 222, 223):

- sensitivity to CO<sub>2</sub> absorption up to 180 km;
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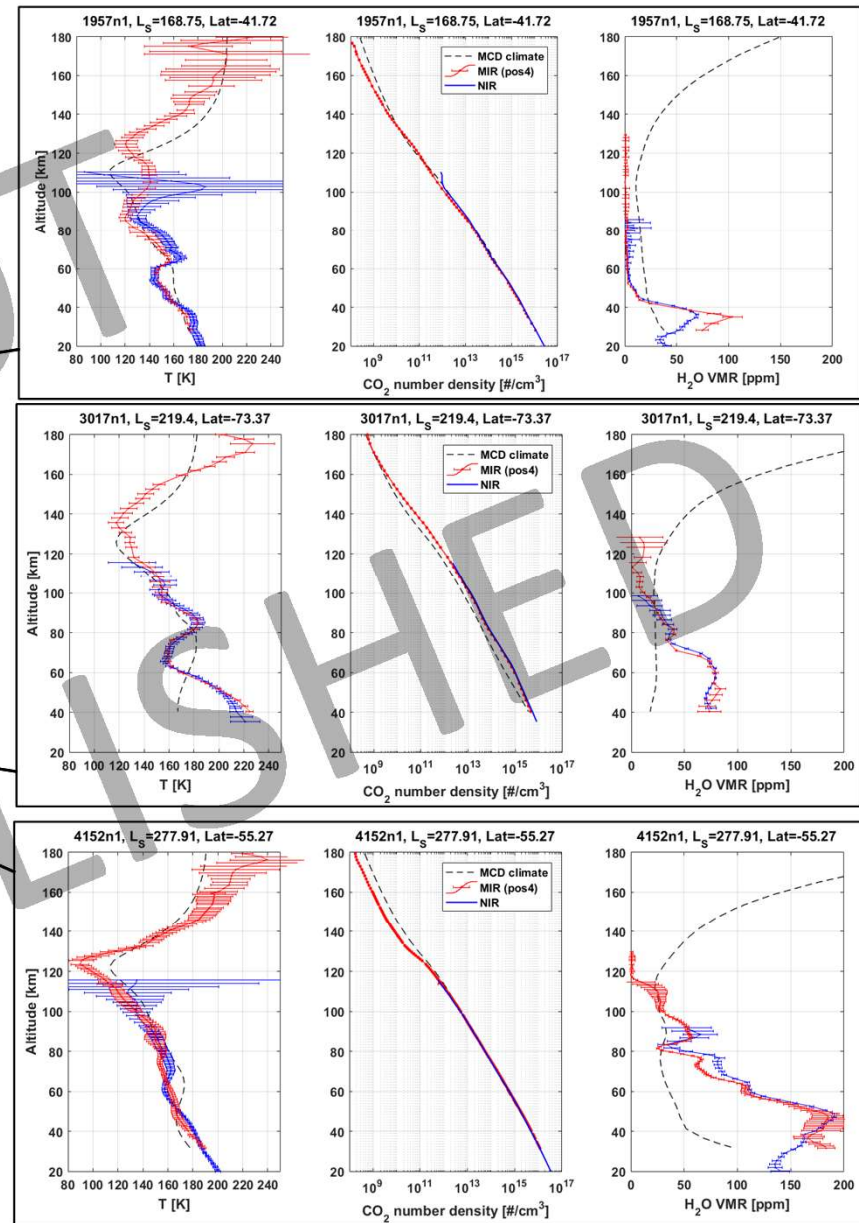
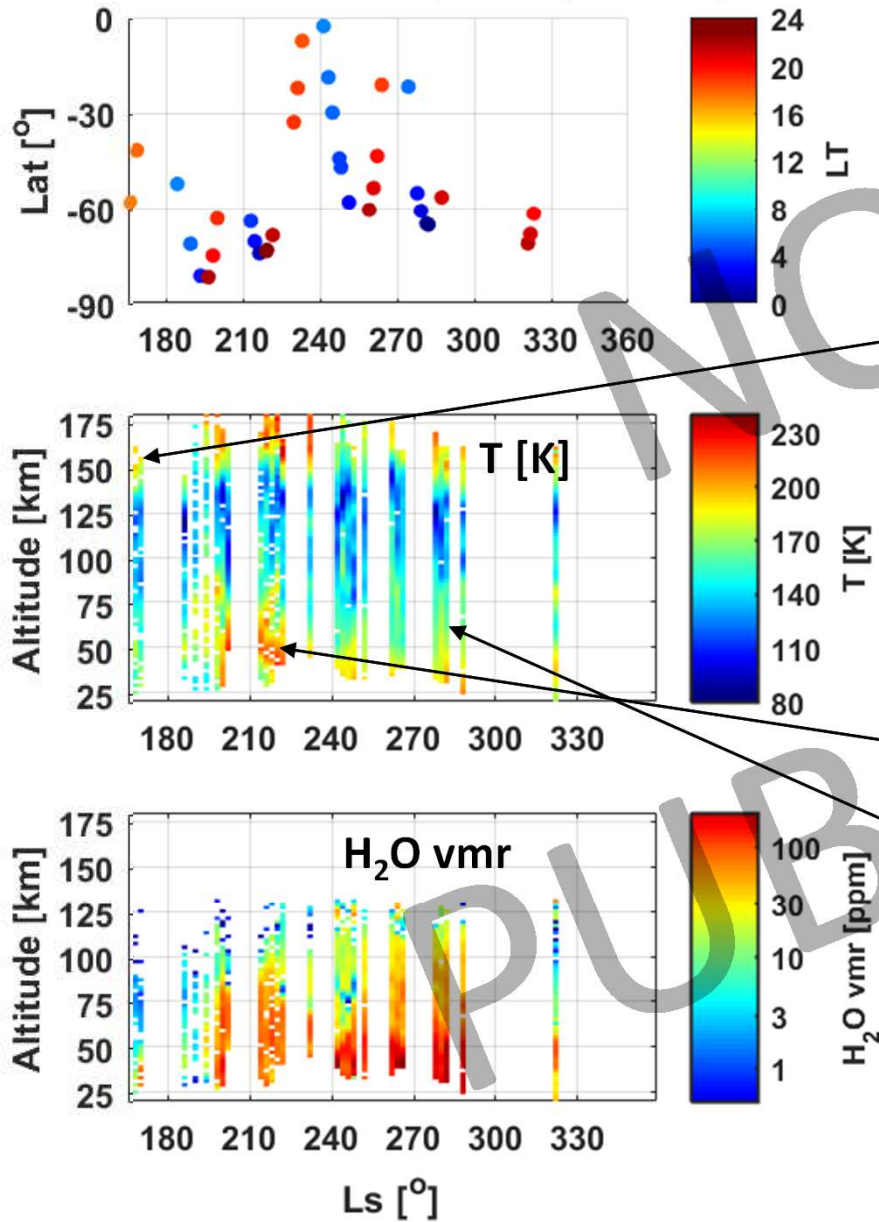
Orb 3820n2, Ls = 260.86, Lat = -53.6





# Profiles variability with Martian seasons in MY34 (Ls from 165)

## Southern hemisphere (not full)



## Summary

- 1) After recent transmission improvements for ACS-MIR spectra new temperature, CO<sub>2</sub> and H<sub>2</sub>O density retrievals in the mesosphere/thermosphere are in good progress at 2.65-2.7 μm from 20 to 180 km of altitude;
- 2) Good coincidence with ACS-NIR (Fedorova et al., 2020) retrievals below 100 km;
- 3) Abundance of 1-10 ppm H<sub>2</sub>O vmr at 110-120 km on perihelion Southern hemisphere, MY34.
- 4) Mesospheric+thermospheric comparison with IUVS/MAVEN and with GCM MY34 is needed.
- 5) ~350 calibrated occultations at Southern and Northern hemispheres are ready for farther retrievals in MY34 and MY35.

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