First atmospheric results produced by the SuperCam instrument on Mars2020

Franck Montmessin[1], Timothy McConnochie[2], Thierry Fouchet[3], Olivier Forni[4], Paolo Pilleri[4], Clément Royer[3], Elise Knutsen[5], Tanguy Bertrand[6], Olivier Gasnault[4], Jeremie Lasue[7], Carey Legett[8], Mark Lemmon[9], Raymond Newell[10], Dawn Venhaus[10], Sylvestre Maurice[4], and Roger Wiens[11]

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[11]Space Science and Applications

November 21, 2022

Abstract

The SuperCam instrument [1,2] onboard Mars2020 disposes of a variety of active and passive techniques, including passive spectroscopy in the 0.40-0.85 (VIS) and 1.3 to 2.6 microns (IR, [3,4]) wavelength ranges. Since the landing on Mars of Perseverance in February 2021, Supercam has acquired numerous observations of its near and distant environment, exploring the geological and mineralogical context of Jezero crater. In addition, several measurements were devoted to probing the atmosphere surrounding the Perseverance rover. The technique of using sky spectra in passive mode, known as "passive sky", has already been demonstrated with ChemCam on the Mars Science Laboratory (MSL) rover [4]. SuperCam provides a superset of the ChemCam capabilities used in [4], and in particular adds a near-infrared component that includes absorption and scattering characteristics of key gases and aerosols/clouds. "Passive sky" measurements have typically been performed every other week to allow a consistent monitoring of the seasonal evolution of the main quantities (CO_2, O_2, H_2O, CO, aerosols/clouds). Particular attention was given to joint measurements of O_2 and CO, as they appear as key components of the Martian chemical cycle and have never been measured together at the same time on the surface of Mars. As the 2 µm wavelength region is used for the first time at the surface of Mars, it enables the detection of CO (around 2.35 µm). CO possesses a small absorption that has made it difficult to identify in SuperCam spectra so far. An overview of SuperCam's progress to date in its attempt to characterize the Martian atmosphere at Jezero will be presented. References : [1] Wiens, R.C., et al. , 2021. Space Sci Rev 217, 4, [2] Maurice, S., et al., 2021. Space Sci Rev 217, 47, [3] Royer, C., et al.., 2020. Review of Scientific Instruments 91, 063105, [4] Fouchet, T., et al., 2021, Icarus, submitted. [5] McConnochie T. H et al., 2018. Icarus 307, 294

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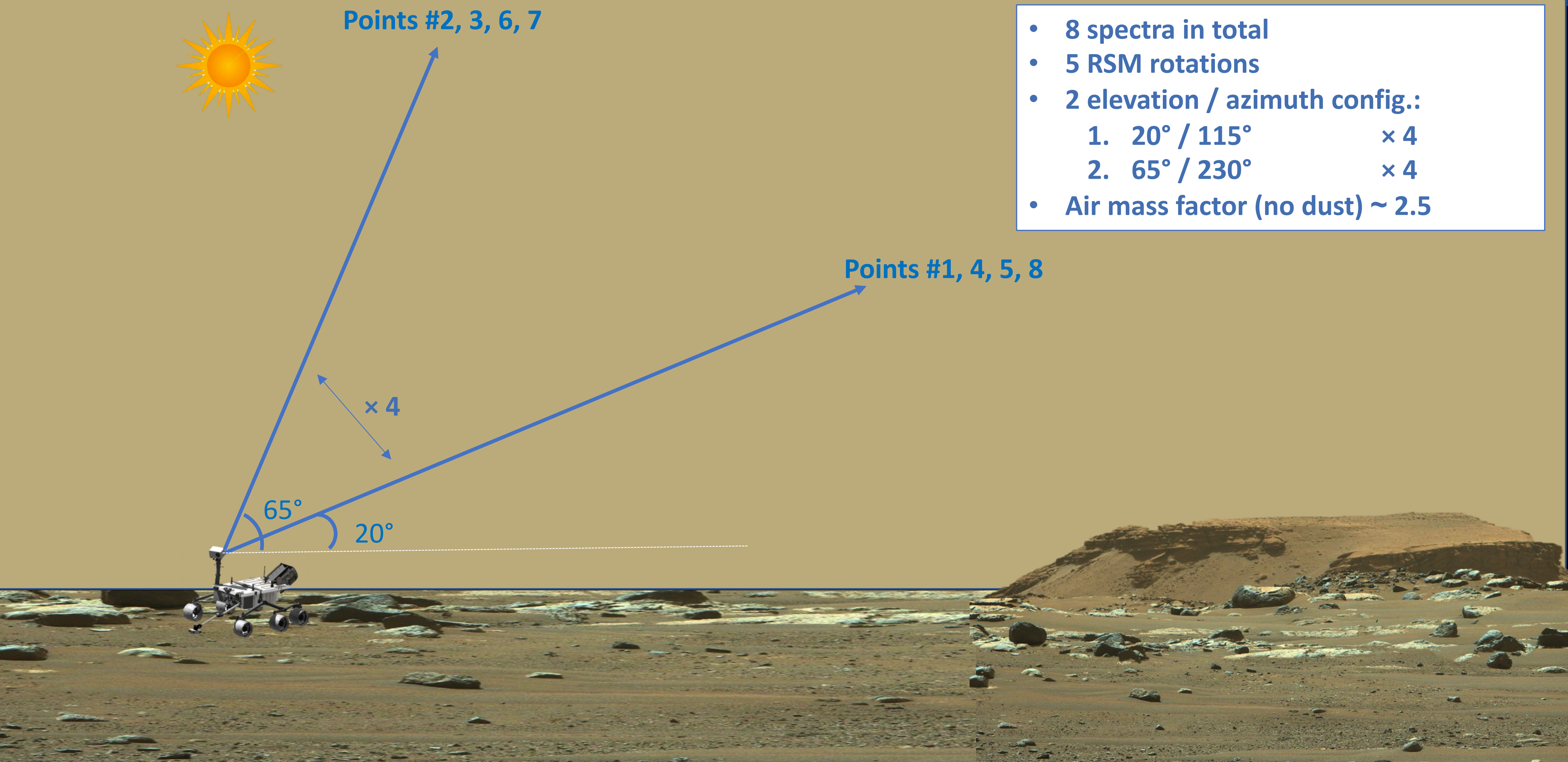
SCAM Passive v1 (Sol 67)

- 8 spectra in total
- 5 RSM rotations
- 2 elevation / azimuth config.:
  1. 20° / 115° × 4
  2. 65° / 230° × 4
- Air mass factor (no dust) ~ 2.5



SCAM Passive v2 (Sol 104+)

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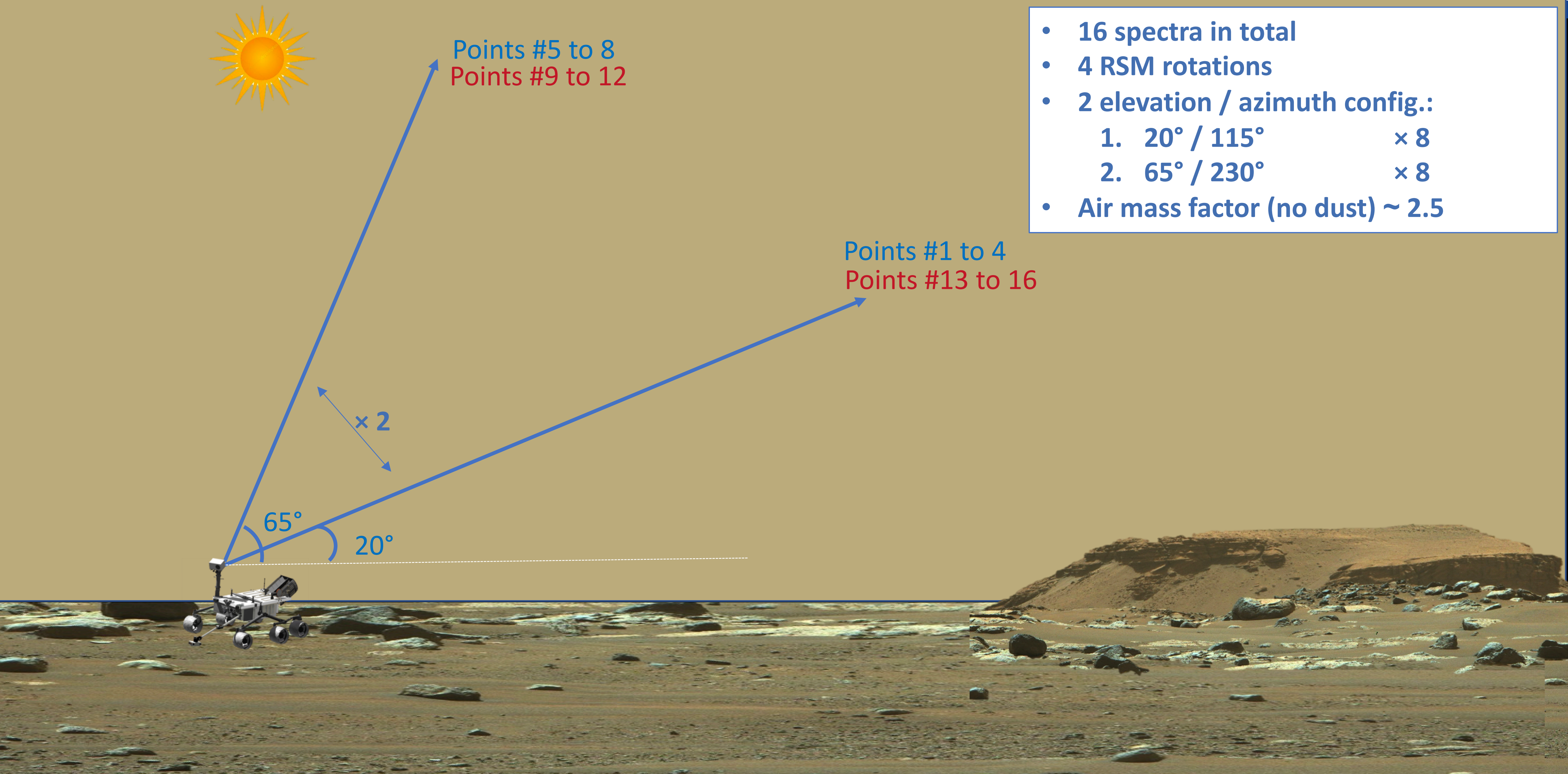
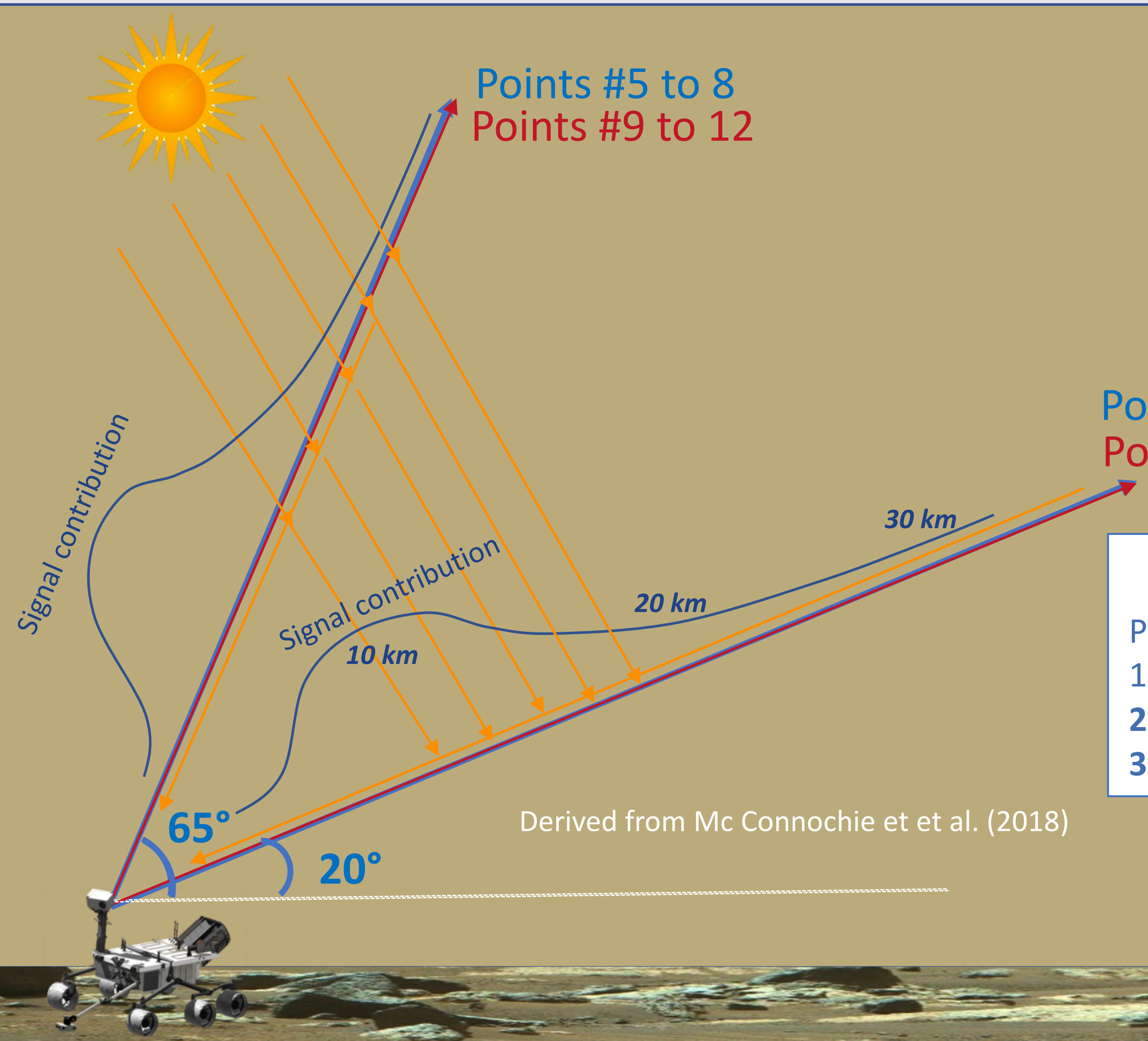
- 16 spectra in total
- 4 RSM rotations
- 2 elevation / azimuth config.:
  1. 20° / 115° × 8
  2. 65° / 230° × 8
- Air mass factor (no dust) ~ 2.5



Passive sky observations



Derived from Mc Connochie et et al. (2018)

- **16 spectra in total**
- **4 RSM rotations**
- **2 elevation / azimuth config.:**
  1. **20° / 115° × 8**
  2. **65° / 230° × 8**
- **Air mass factor (no dust) ~ 2.5**

Ratioing spectra at 2 different elevations:

Provides an atmospheric **Transmission**, which

1. allows infering **physical quantities from relative measurements**
2. **alleviates the need for calibration**
3. **subtracts the absorption** of the High Elevation from Low Elevation

Altitude contribution to PS measurement

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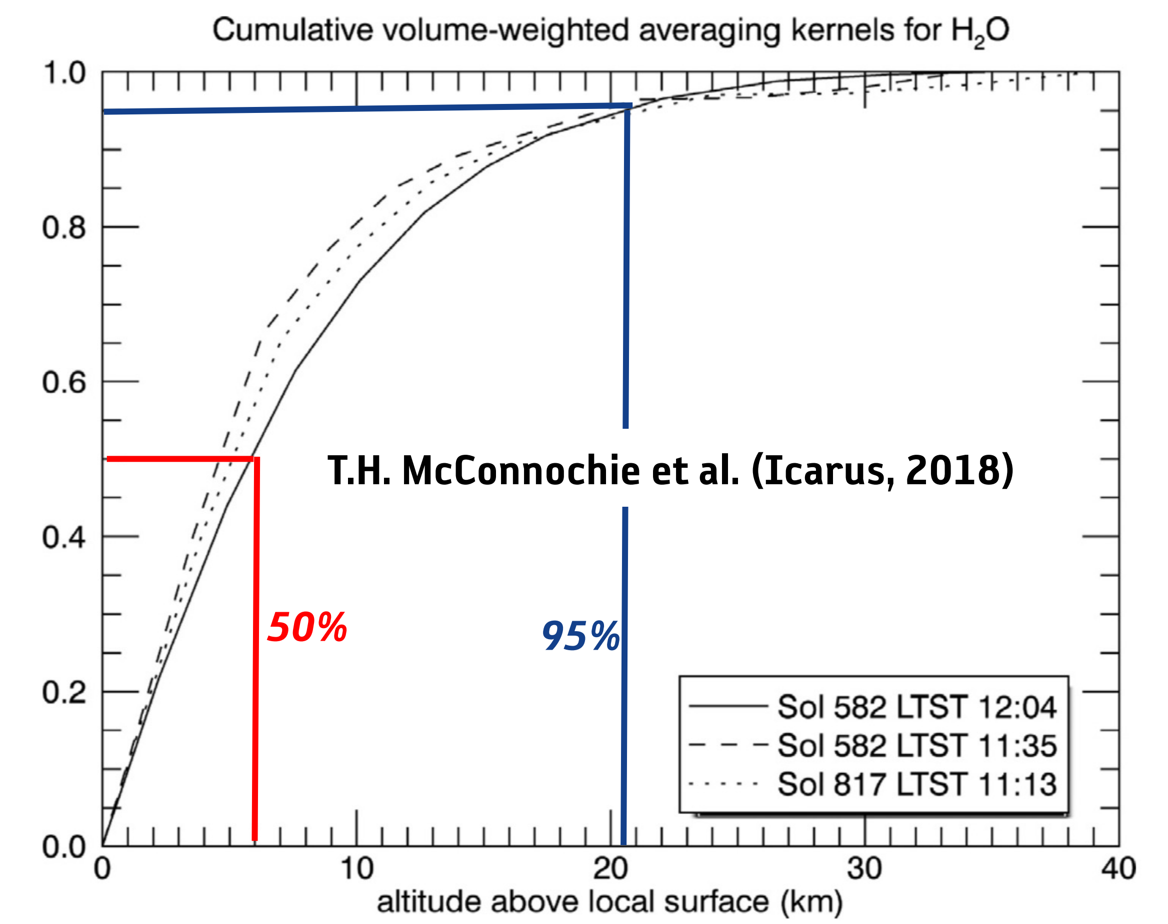


Fig. 7. Cumulative volume-weighted vertical averaging kernels for water vapor for three different ChemCam passive sky observations. The *y*-axis is unitless cumulative response. These observations are a typical high-opacity ($\tau = 1.19$) case—sol 817 LTST; a typical low-opacity ($\tau = 0.46$) case—sol 582 @ 11:35 LTST; and a case with low opacity ($\tau = 0.46$) but also westward-looking geometry and unusually low near-surface scattering, i.e. unusually low H'—sol 582 @ 12:04.

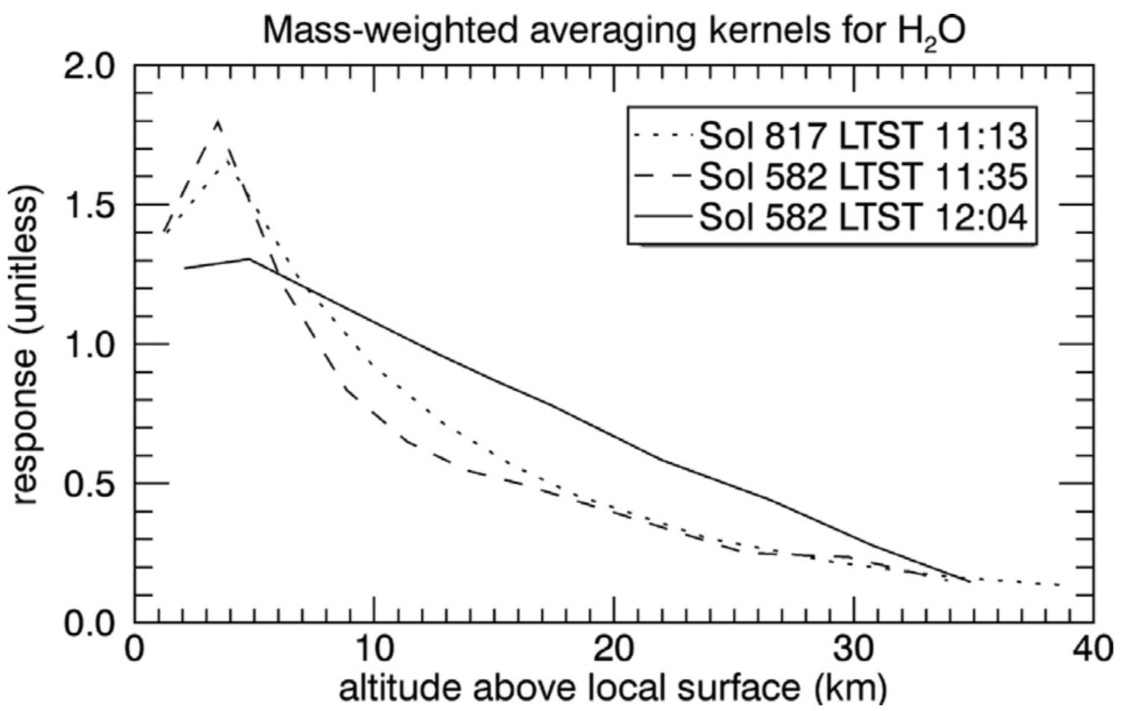
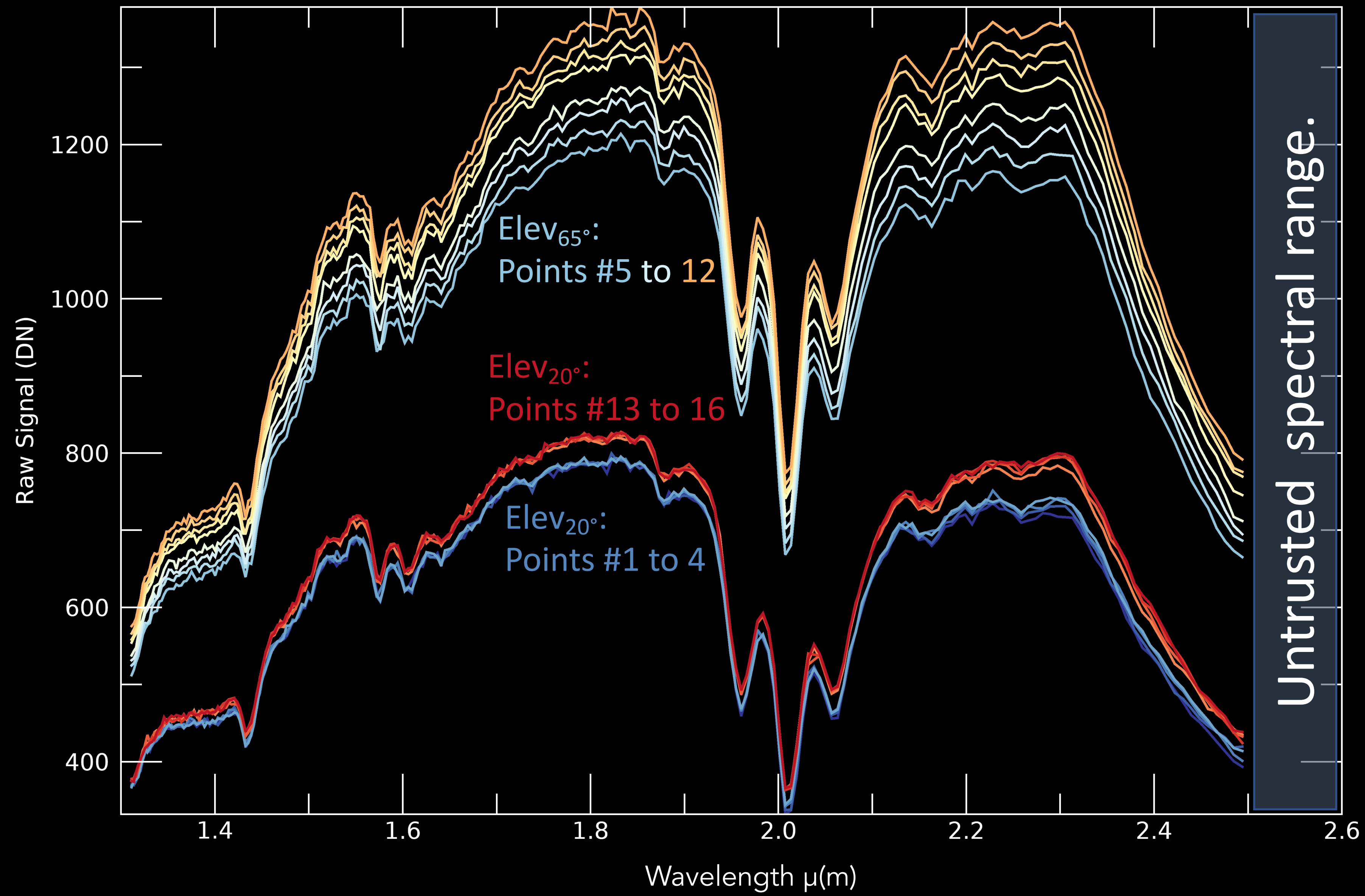


Fig. 8. Mass-weighted vertical averaging kernels for water vapor for three different ChemCam passive sky observations. The three cases plotted are identical to those in Fig. 7.

50% of the signal is theoretically produced by the first 6 km.

45% is contributed by the 6 to 20 km layer .

Raw Signal (Good example) – Sol 111



Elev$_{65°}$ spectra are brighter and have less CO_2 absorption (lower air mass factor).

Elev$_{20°}$ spectra are darker and exhibits stronger CO_2 absorption.

Raw Signal (Bad example: glitches) – Sol 104

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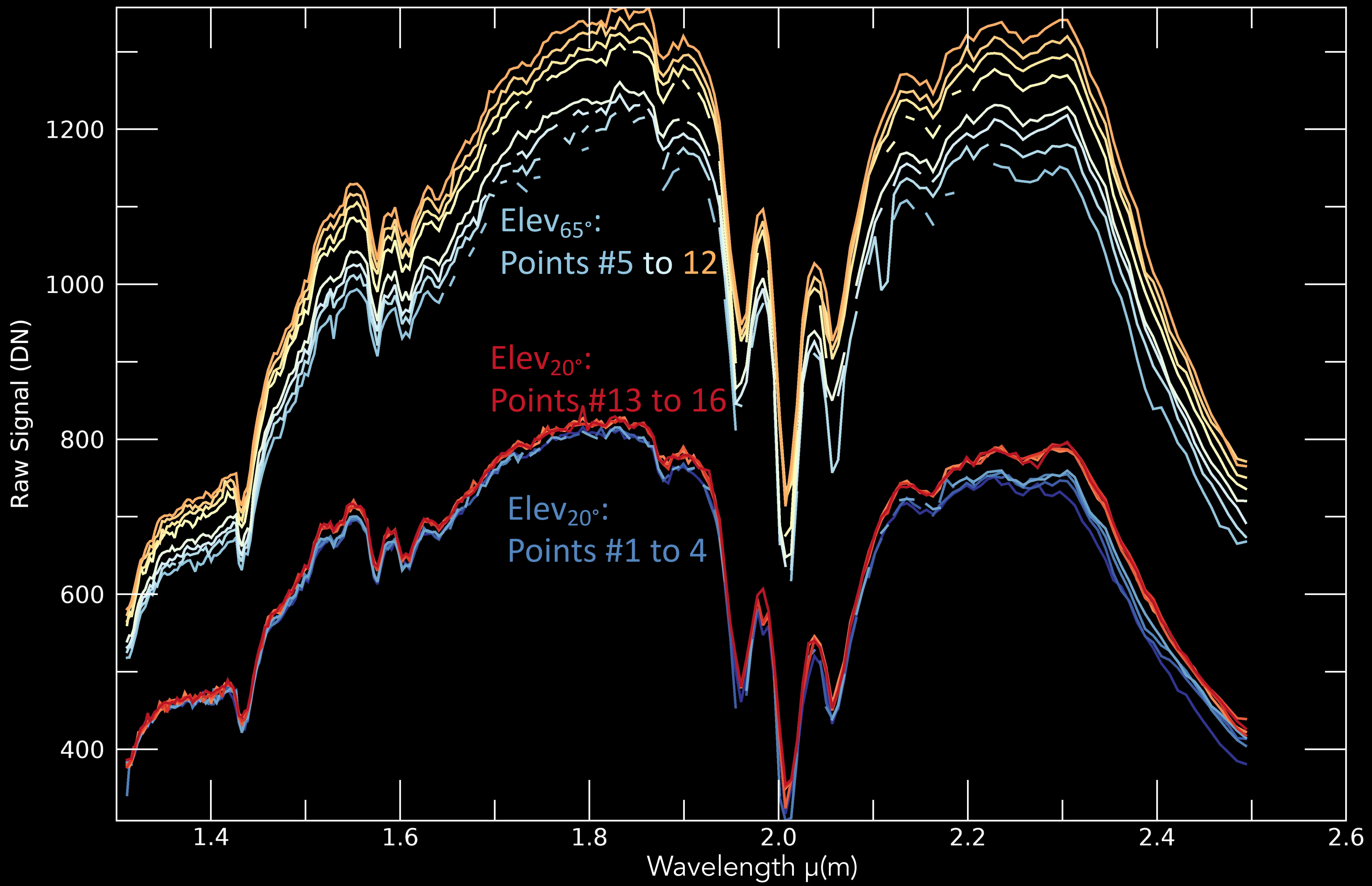

Elev$_{65°}$ spectra are brighter and have less CO_2 absorption (lower air mass factor).

Elev$_{20°}$ spectra are darker and exhibits stronger CO_2 absorption.

Holes in the spectra represent AOTF glitches where AOTF throughput is decreased by some factor.

$\text{Elev}_{20°}$ / $\text{Elev}_{65°}$ ratio (Good Example) Sol 67

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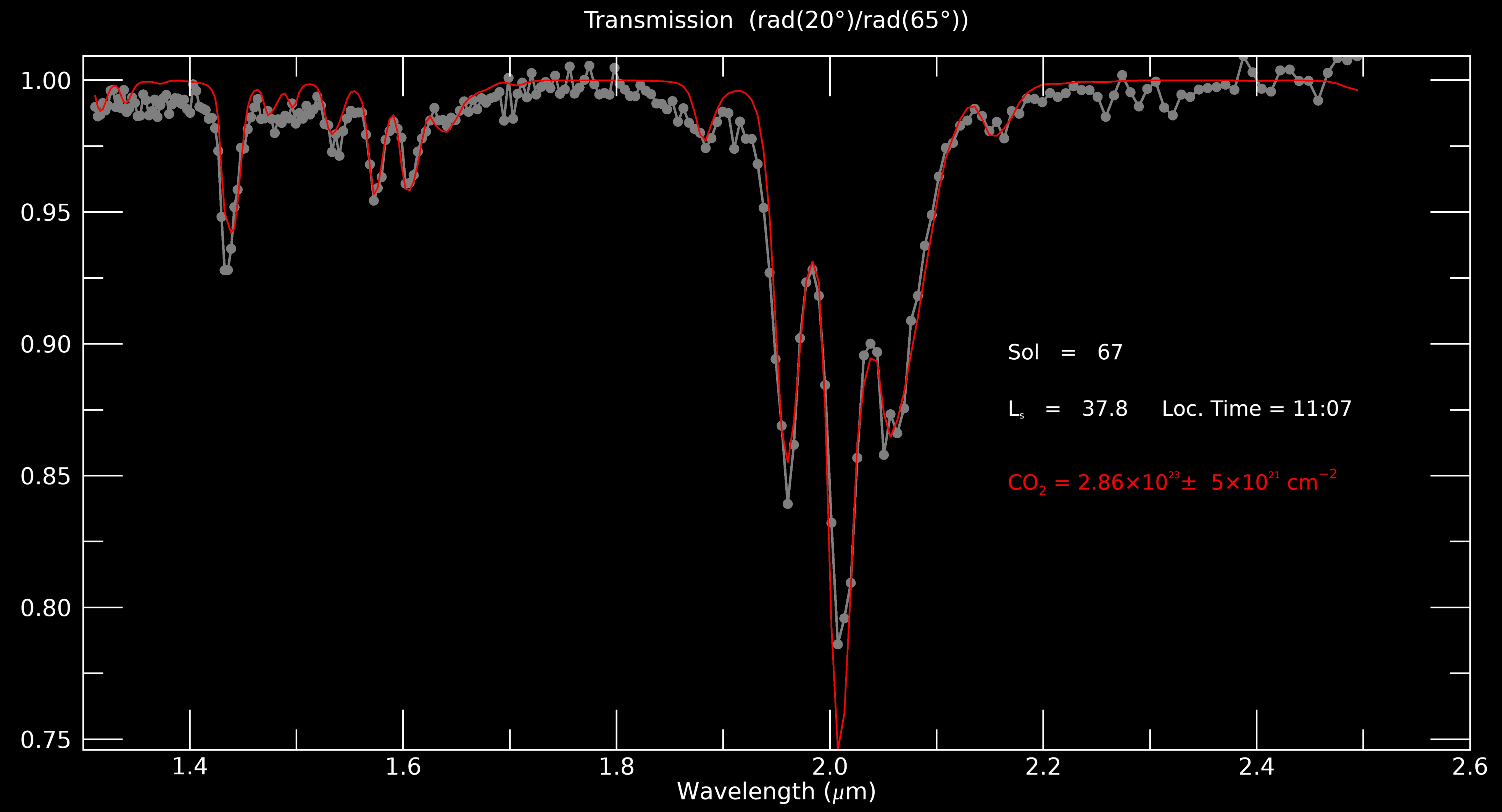
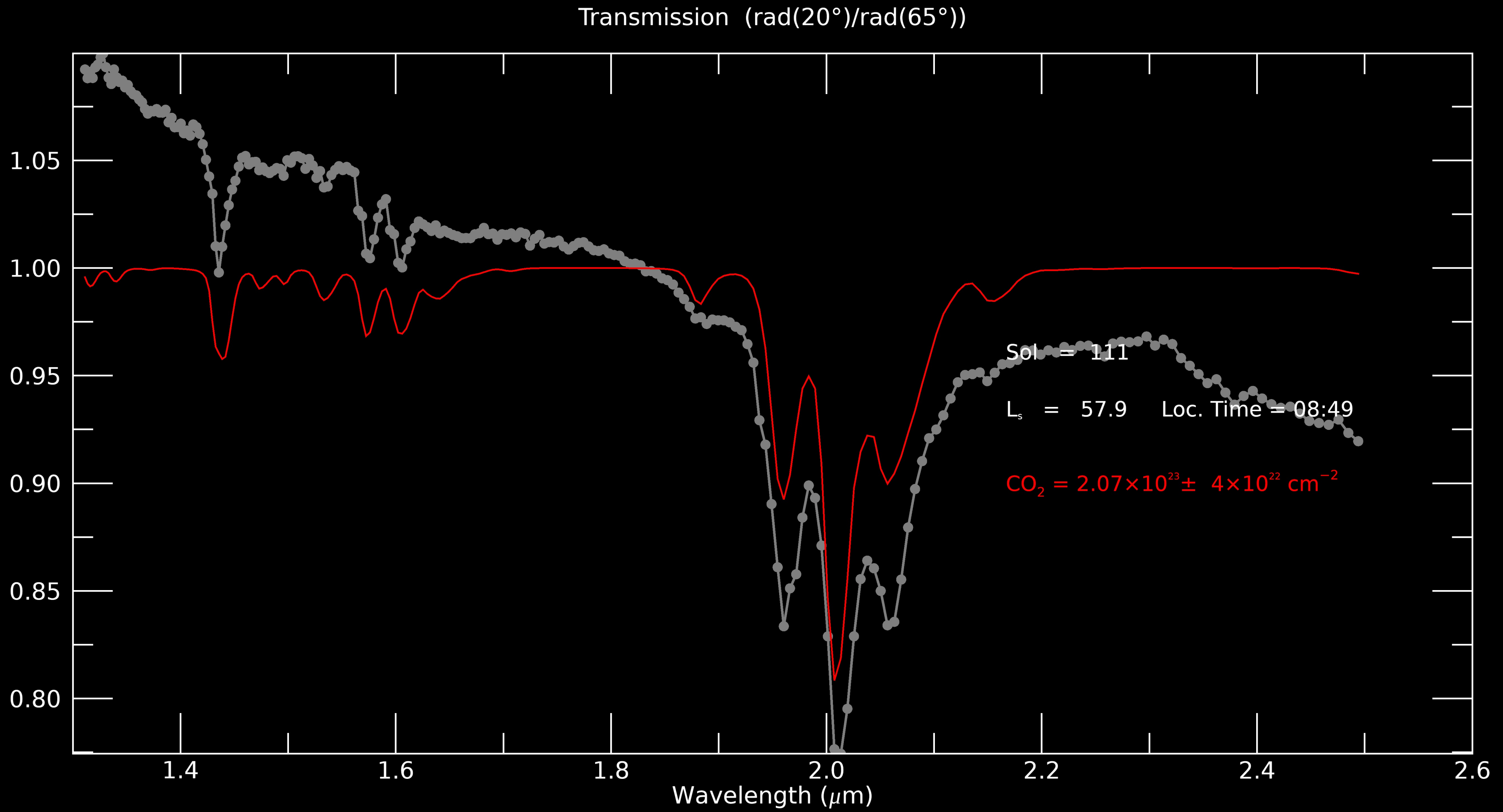


Elev$_{20°}$ / Elev$_{65°}$ ratio (Bad Example) Sol 104



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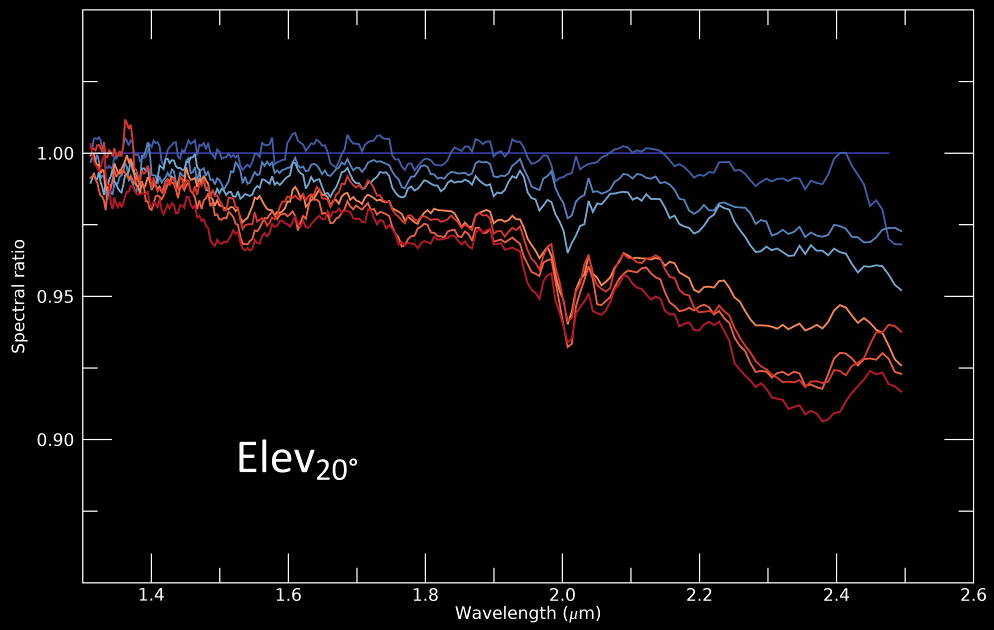
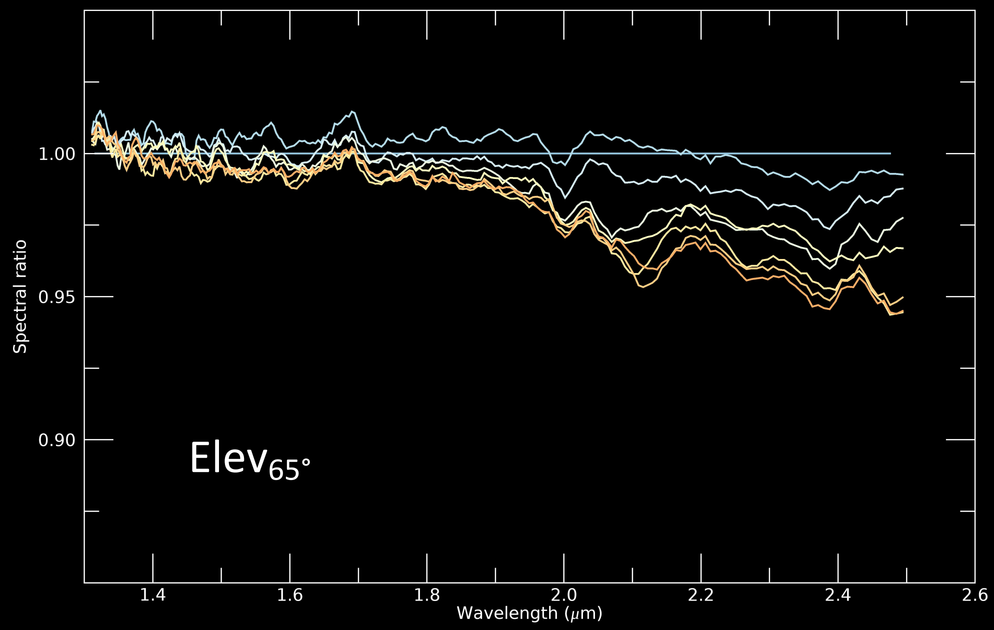
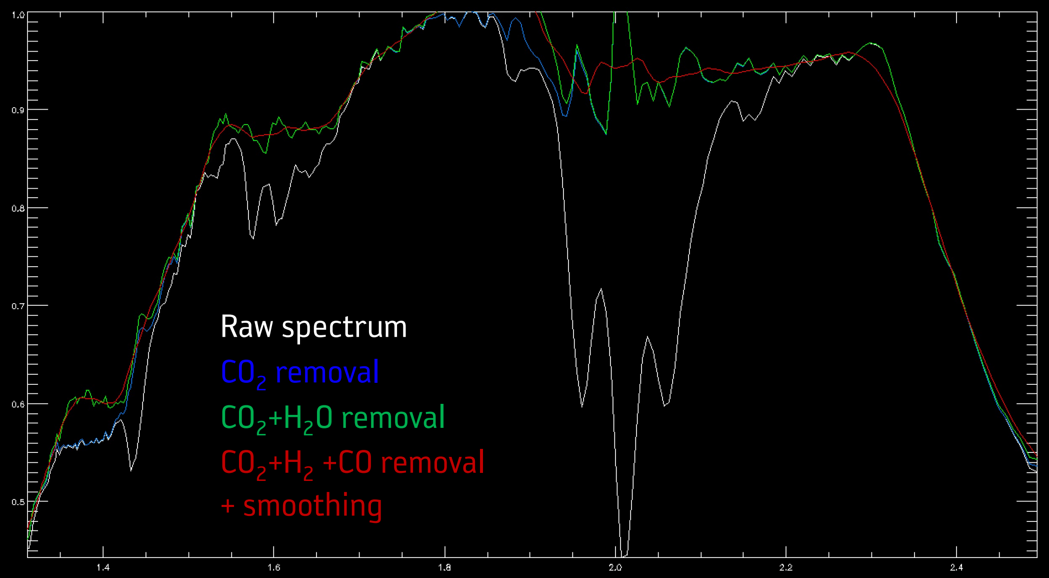
The Baseline syndrome

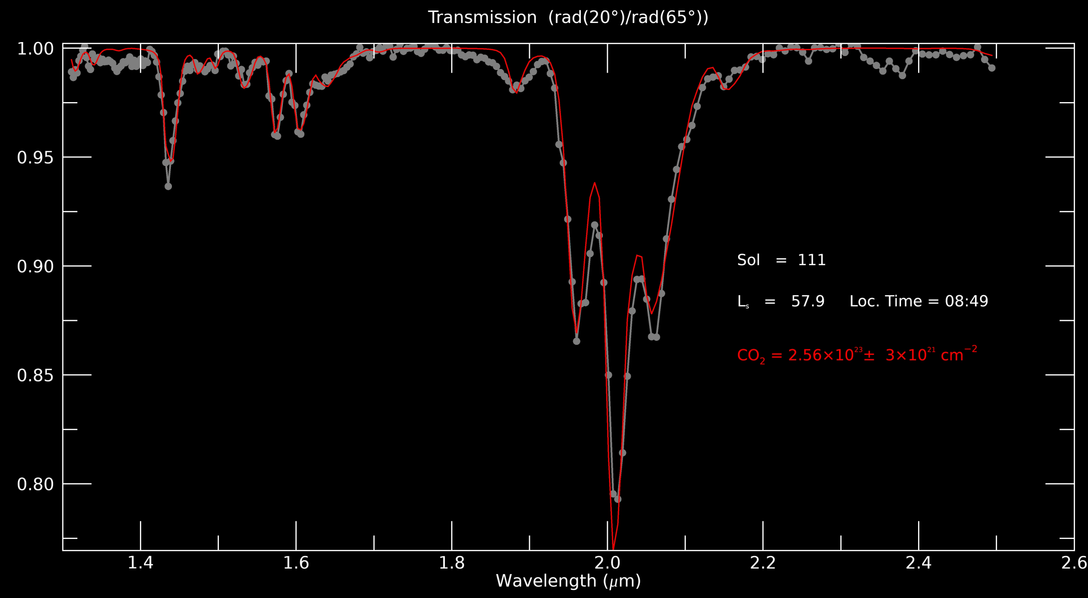




- Spectral ratio between acquisitions performed at the same elevation reveals a bending trend likely associated with a loss of AOTF throughput as temperature increases in the IRS-board.
- Some hard-to identify features also appear.
- Ratio of the mean spectra between elevations is insufficient for a reliable retrieval.
- The approach adopted considers isolating the baseline of each individual spectrum and use it do dovide the raw spectrum.

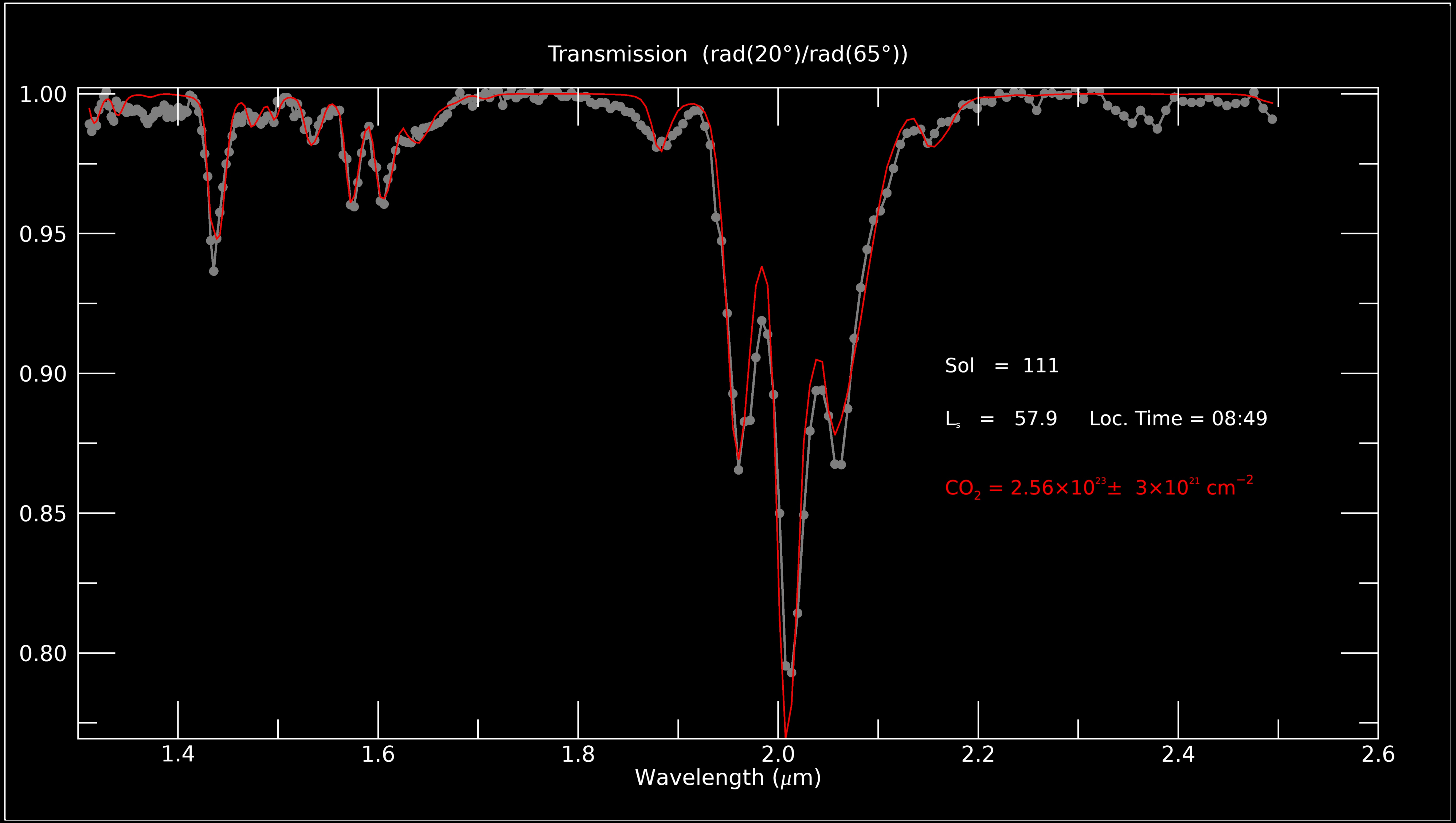
The Baseline syndrome



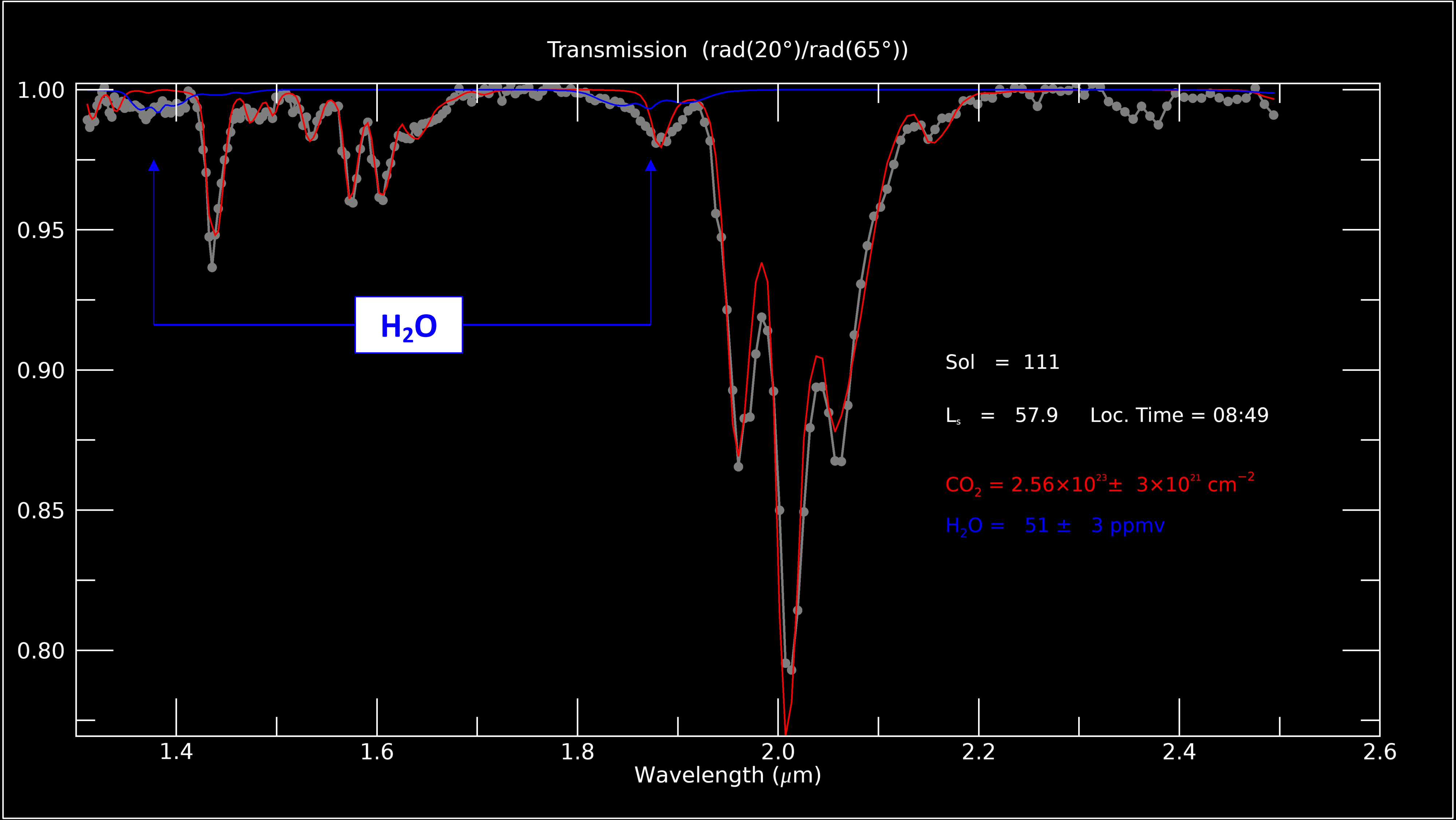


- The approach adopted considers isolating the baseline of each individual spectrum and using it do divide the raw spectrum.
- Baseline isolation relies on successive removal of gaseous features by dividing raw spectrum with adjusted amounts of synthetic CO_2, H_2O and CO absorption to minimize variance.
- While it allowed to salvage some measurements, several remained too difficult to correct.

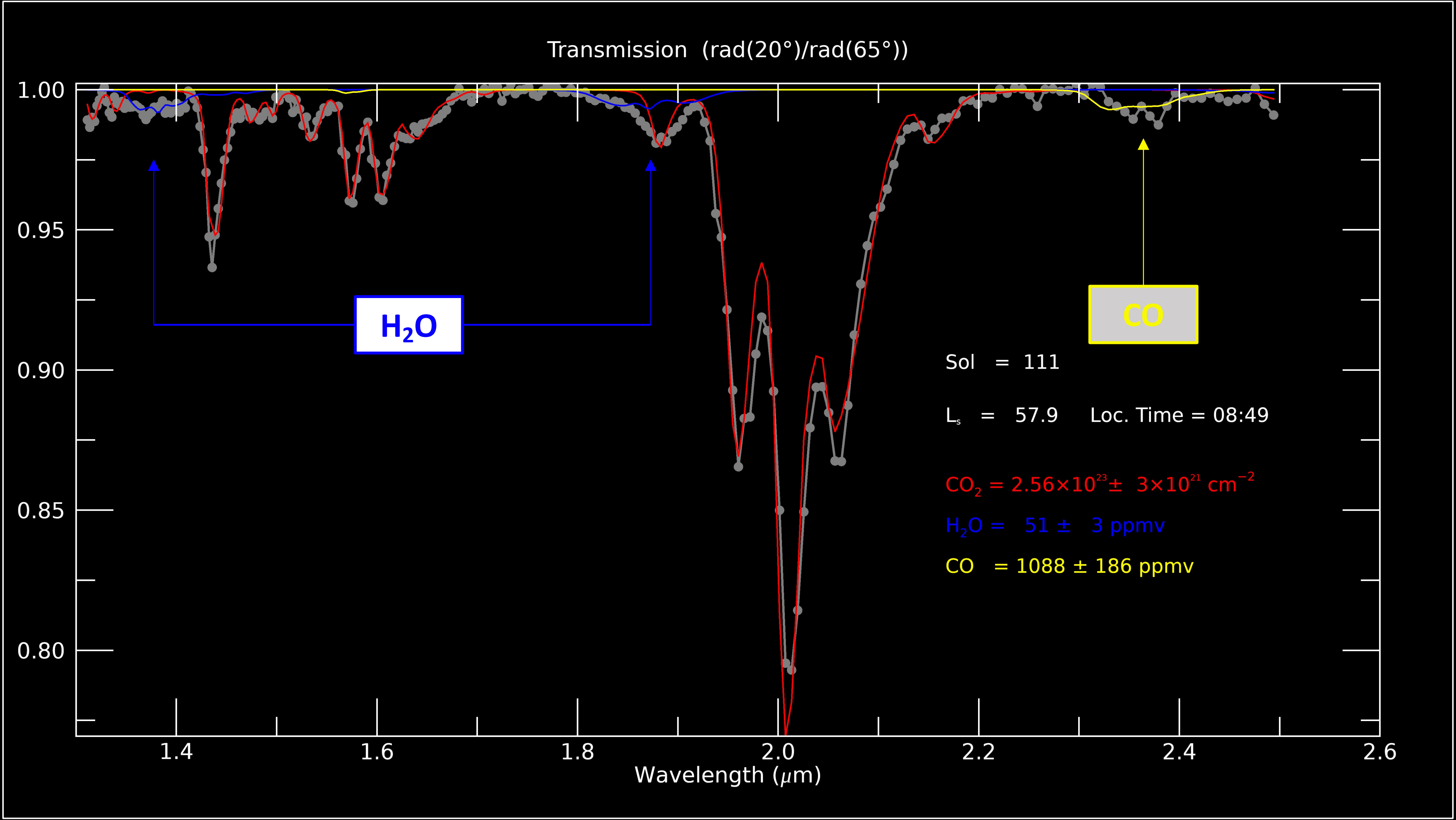
Fitting attempt (Sol 111) – CO_2 only



Fitting attempt (Sol 111) – CO_2 & H_2O



Fitting attempt (Sol 111) – CO_2, H_2O & CO



Fitting attempt (Sol 111)

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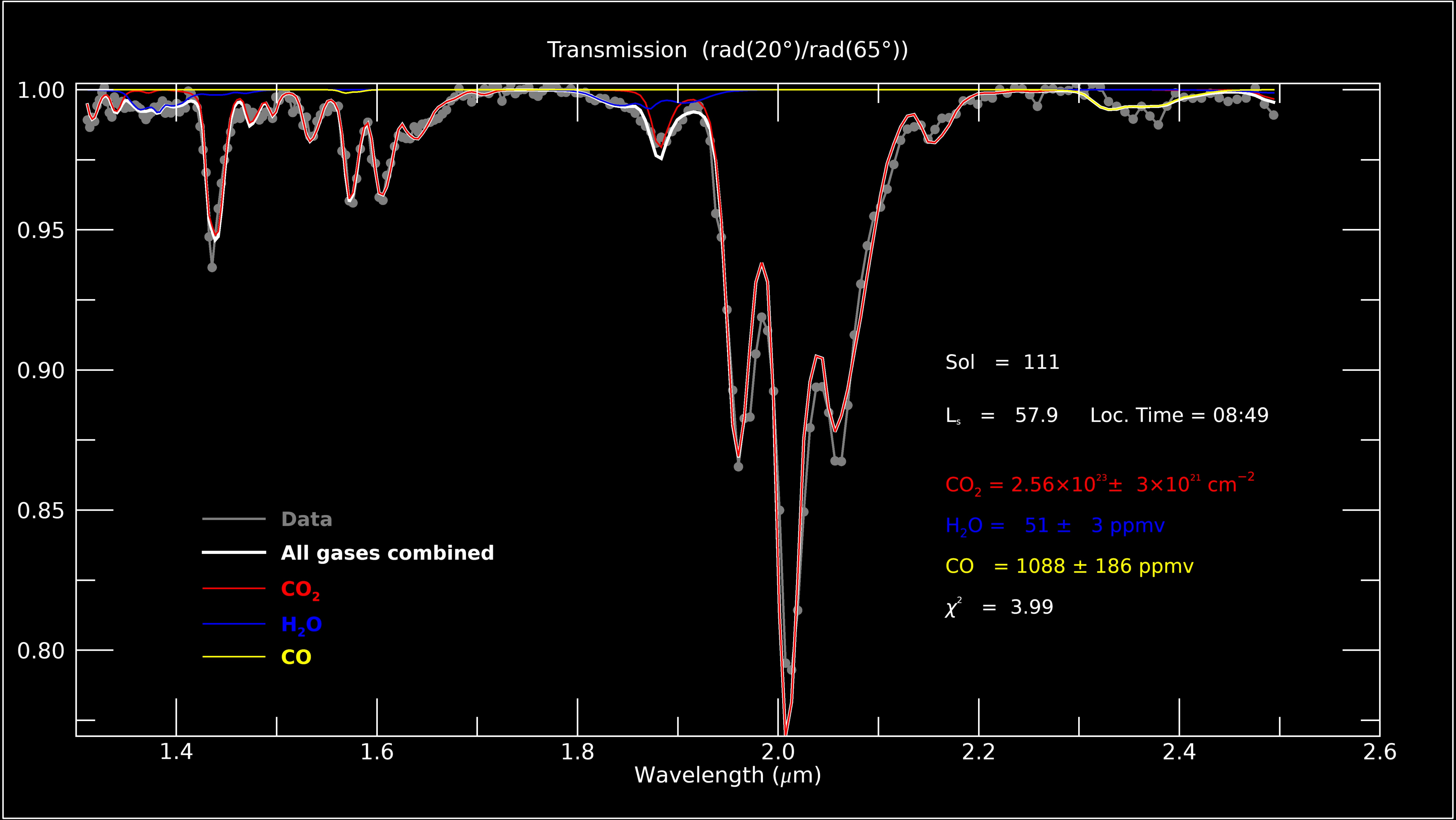

Fitting attempt (Sol 67)

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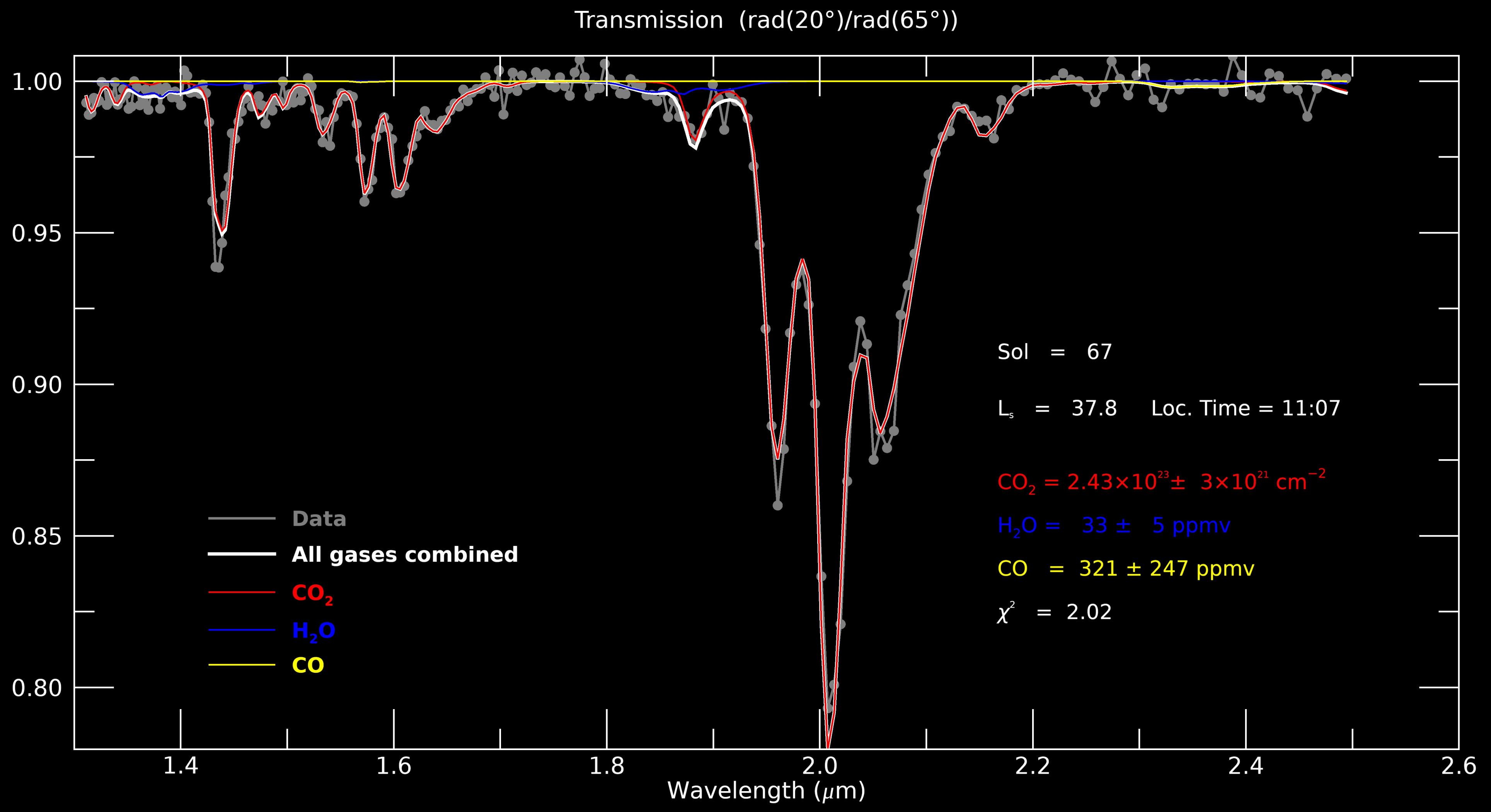

Fitting attempt (Sol 133)

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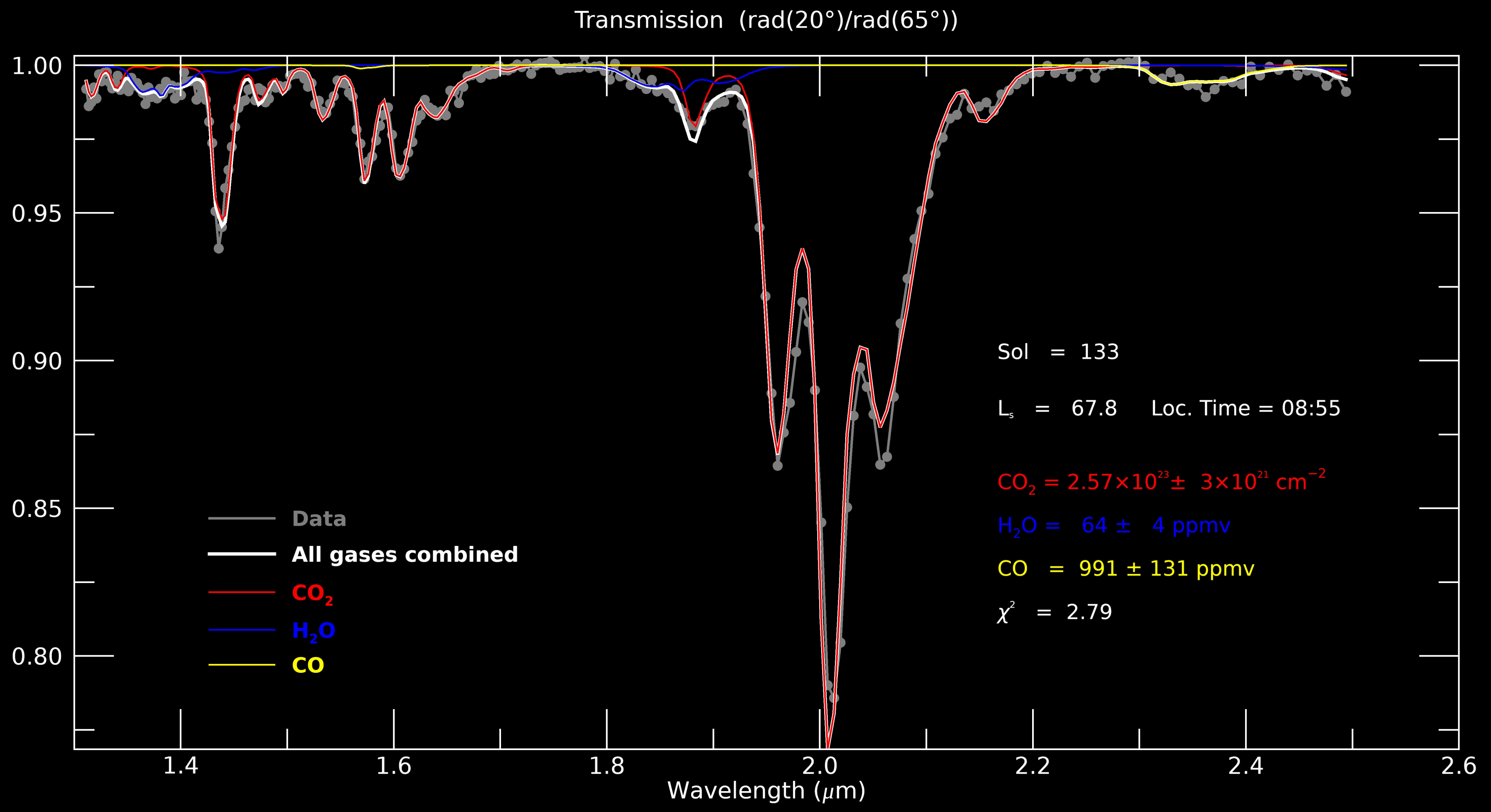
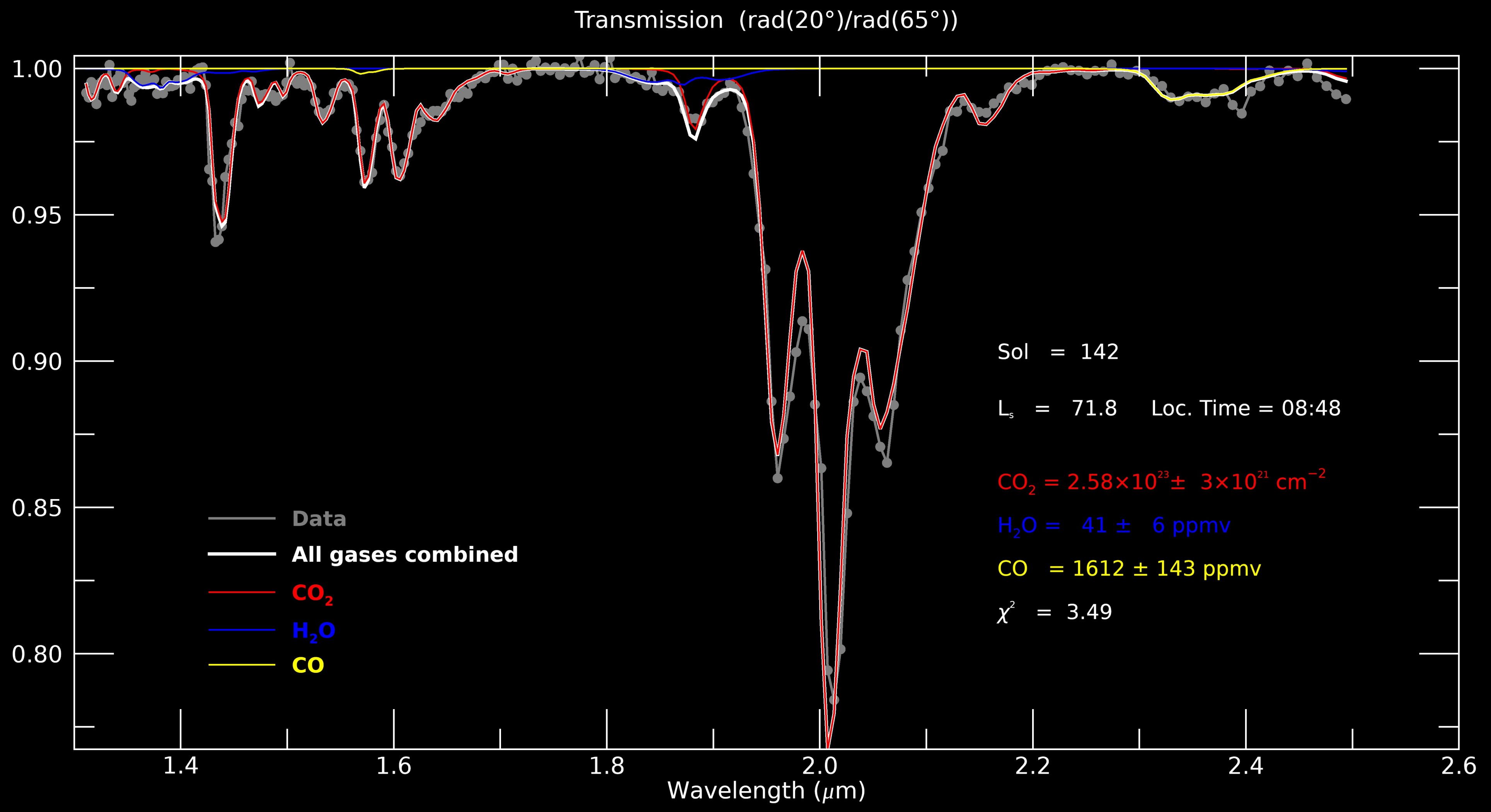


Fitting attempt (Sol 142)



MEDA Rel. Humidity data (courtesy of L. Tamppari)

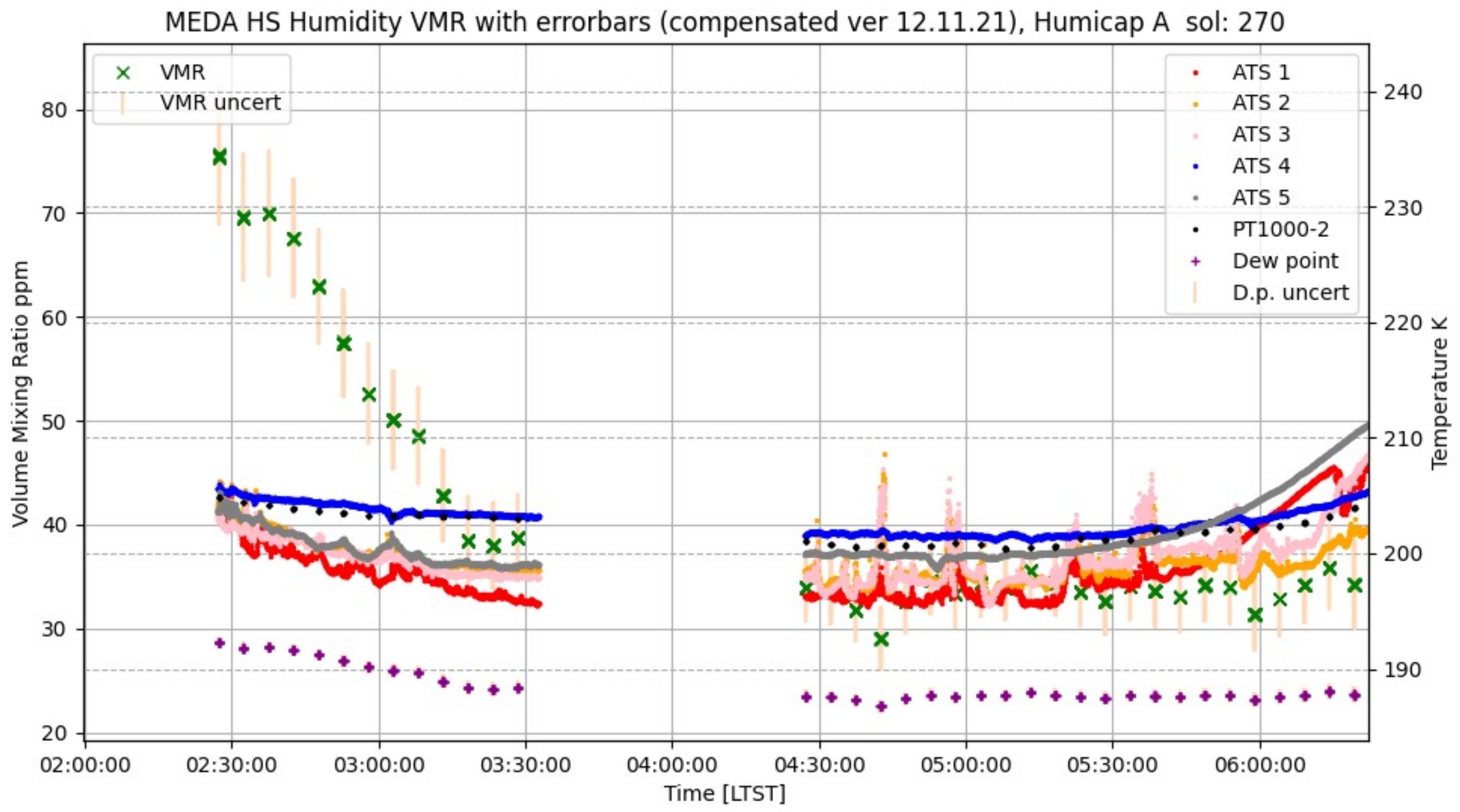


Figure 2. Example data with uncertainties (relative humidity collected using HRIM mode converted to volume mixing ratio, VMR, using the RH sensor board temperature) using the new compensation algorithm. Also shown are data from the 5 MEDA Air Temperature Sensors (ATS), the TIRS ground temperature, and the calculated frost point. Frost point calculation assumes the VMR at the sensor (1.6 m) and the ground temperature sensor from the TIRS.

RH measurements suggest a H_2O VMR of **40 ppmv** at 1.6 m with little diurnal change.

P251-2253

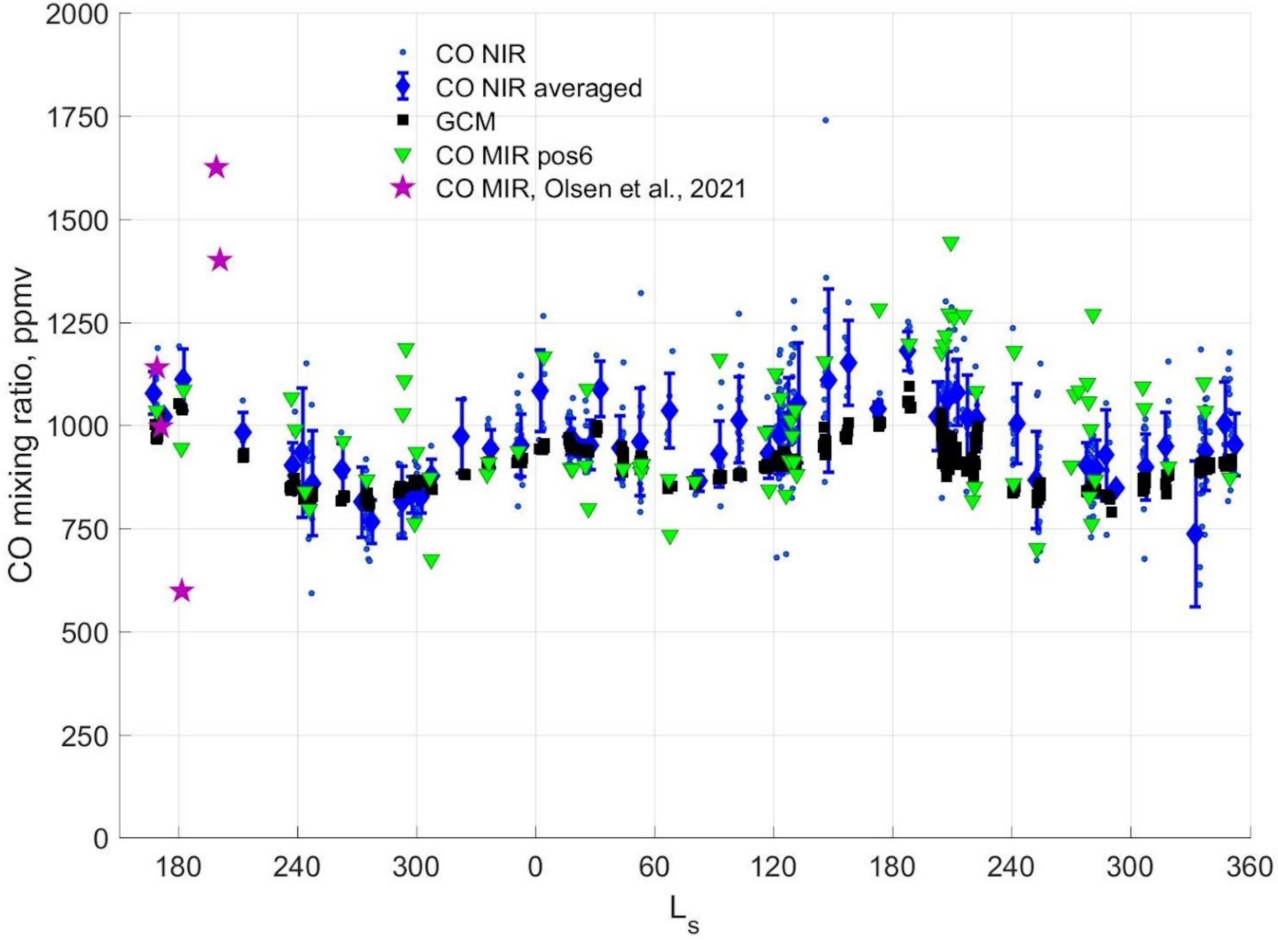
First results of the Perseverance environmental station's (MEDA's) Relative Humidity Sensor

Tuesday, 12/14

Convention Center Poster Hall, D-F

ACS CO measurements (courtesy of A. Fedorova)

Fedorova et al. (2022), in preparation



Averaged values of CO from ACS profiles measured within ±45° latitude range and below 30 km. Blue points, purple and green triangles are individual NIR, MIR and TIRVIM occultations, respectively. Black squares are GCM model results corresponding to the NIR averages.

Measurement overview

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Sol	L_s (°)	Local Time	CO_2 (cm^{-2})	H_2O (ppmv)	CO (ppmv)	Remarks
67	37.8	11:07	2.43×10^{23}	33 ±5	321 ± 247	H_2O low, (too) low CO
86	46.6	10:56	2.17×10^{23}	127 ±5	negative	Unreliable (baseline defects)
104	54.7	08:24	2.64×10^{23}	24 ±5	1555 ± 154	H_2O low, high CO
111	57.9	08:49	2.56×10^{23}	51 ±5	1088 ± 186	No glitch - H_2O and CO ok
121	62.4	11:16	2.40×10^{23}	negative	345 ± 176	Untrusted (baseline defects)
133	67.8	08:55	2.57×10^{23}	64 ±4	991 ± 131	H_2O and CO ok
142	71.8	08:48	2.58×10^{23}	41 ±5	1612 ± 143	H_2O ok, high CO
157	78.5	08:47	2.72×10^{23}	36 ±4	1091 ± 145	H_2O and CO ok
166	82.7	15:33	2.75×10^{23}	147 ±6	negative	H_2O (too) high, negative CO
179	88.6	16:12	2.96×10^{23}	negative	369 ± 253	Unreliable (baseline defects)
192	94.4	12:57	2.46×10^{23}	negative	90 ± 100	Unreliable (baseline defects)
205	100.3	09:04	2.60×10^{23}	39 ±4	1700 ± 151	H_2O ok, high CO
214	104.5	08:40	2.56×10^{23}	negative	2112 ± 204	Unreliable (baseline defects)
237	115.2	09:00	2.39×10^{23}	22 ±4	1305 ± 172	H_2O low, high CO
249	121.1	12:38	2.06×10^{23}	negative	42 ± 200	Unreliable (baseline defects)
263	127.9	1:31	2.23×10^{23}	negative	156 ± 209	Unreliable (baseline defects)

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Measurement overview

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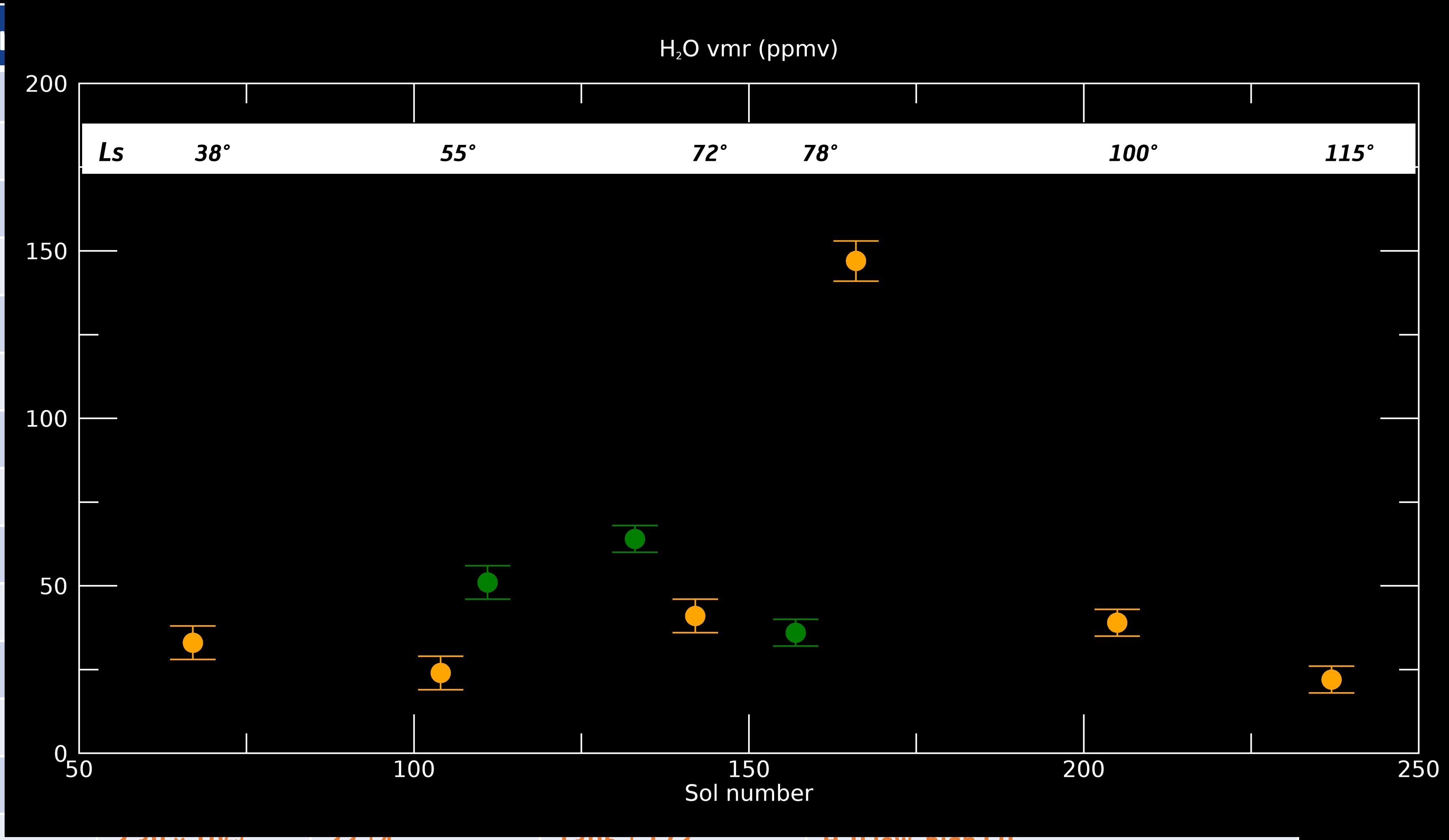

Summary

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- 16 Passive sky performed so far
- P, T deduced from absorption features suggest significant contribution from 20 km

- 4 Measurements (only) trustable for H_2O and CO vmr
- 6 Measurements trustable for H2O and not CO (can be improved)
- Mean H_2O vmr retrieved between L_s 37.8 and 127.9° is 50 ppmv
- Mean CO vmr retrieved between L_s 37.8 and 127.9° is 1000 ppmv

- Difficulty to produce reliable results at noon time and PM
- Main difficulty arises from handling glitches and baseline distorsion

- Preliminary results to be consolidated thanks to:

a) better handling of AOTF T-dependence

b) selection of spectra (outliers, too many glitches)

c) better extraction of the baseline

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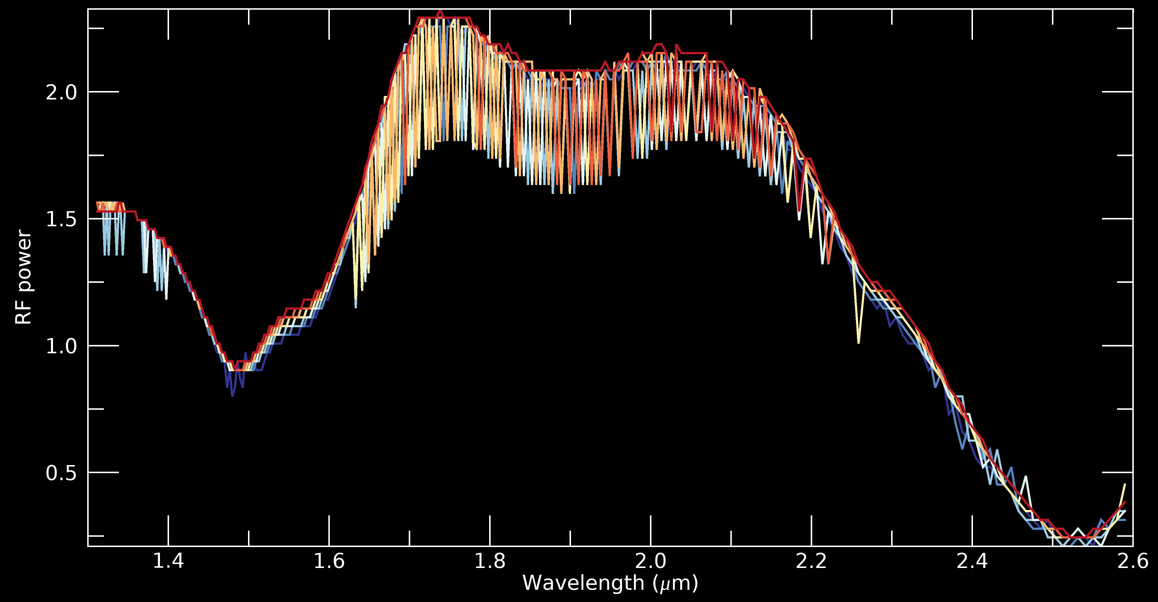
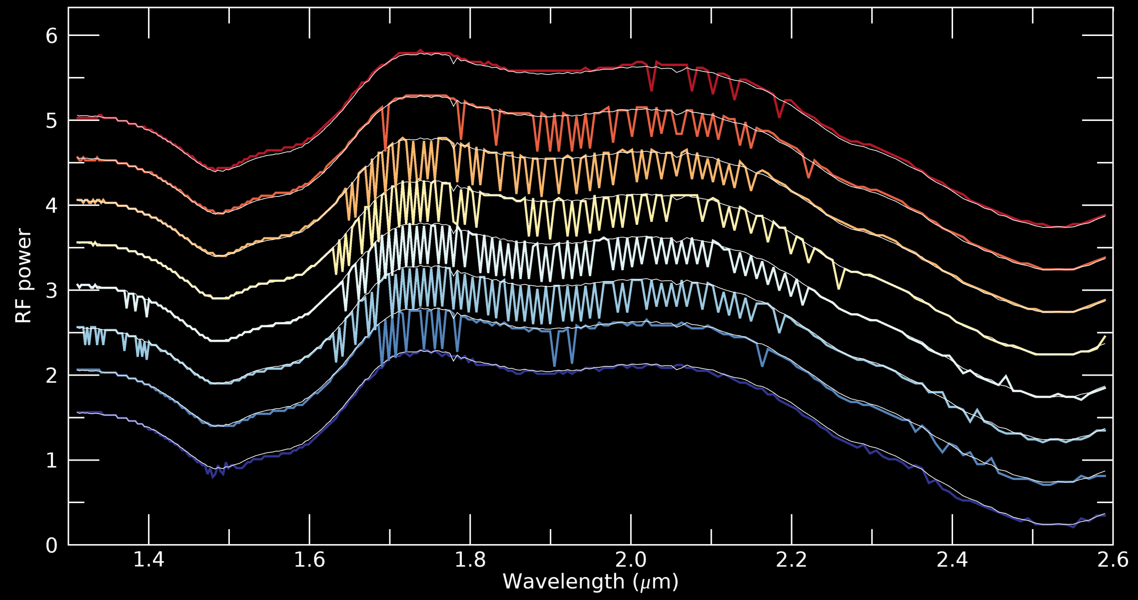
Résultats RF & Glitches (Sol 67)





- **Table 4**
- **t_int 80 ms**
- **203 glitches (29 / spectre)**
- **4 spikes**