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**The H₂O–CO₂ continuum around 3.1, 5.2 and 8.0 μm :
New measurements and validation of a previously
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Highlights

The H₂O – CO₂ continuum around 3.1, 5.2 and 8.0 μm: New measurements and validation of a previously proposed χ factor

Wissam Fakhardji, Ha Tran, Olivier Pirali, Jean-Michel Hartmann

- H₂O – CO₂ continuum measurements at room temperature
- Confirmation of previous measurements for the 1400 – 1500 cm⁻¹ spectral region
- New measurements in the 1800 – 2000 and 3100 – 3300 cm⁻¹ regions
- Validation of a previous χ factor model

1 The H₂O – CO₂ continuum around 3.1, 5.2 and 8.0
2 μm: New measurements and validation of a previously
3 proposed χ factor

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12 **Abstract**

13 The H₂O – CO₂ continuum has been measured, at room temperature, at
14 discrete spectral points in the 1100 – 1500, 1800 – 2000, and 3100 – 3300
15 cm⁻¹ intervals. Our results are in good agreement with previous experimental
16 values in the low frequency wing of the ν_2 band of H₂O when the associated
17 uncertainties are taken into account. Furthermore, they confirm the quality,
18 in this region, of a χ factor previously adjusted on measurements in the 100
19 – 1500 cm⁻¹ range, and prove its validity in the blue side of the ν_2 band as
20 well as in the region around 3.1 μm, which have been experimentally studied
21 for the first time in this work. Together with recent measurements in the 1.6
22 μm, 2.3 μm and far infrared regions, our results contribute to the progressive
23 building-up of a data set for the modeling of the absorption by CO₂ + H₂O
24 mixtures throughout the infrared, which is needed for studies of CO₂-rich
25 planetary atmospheres.

26 *Keywords:* CO₂ – H₂O continuum, measurements, χ -factor model,
27 CO₂-rich atmospheres

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28 1. Introduction

29 The accurate knowledge and modeling of spectra of $\text{H}_2\text{O} + \text{CO}_2$ mixtures
30 for various temperature and pressure conditions is required for planetary
31 science. In particular, the effect of CO_2 on the water vapor greenhouse effect
32 must be known to model the atmospheres of Venus and Early Mars and it
33 will likely be soon needed for some exoplanets [see, e.g. (Lebonnois et al.,
34 2015; Turbet et al., 2021; Turbet et al., 2020; Pluriel et al., 2019)].

35 The absorption by gas samples containing water vapor is generally split into
36 several contributions, which, in the present case of $\text{H}_2\text{O} + \text{CO}_2$ mixtures,
37 are those of the local lines of the H_2O and CO_2 monomers, and those
38 of the so-called continua associated with intermolecular interactions within
39 $\text{H}_2\text{O} - \text{H}_2\text{O}$, $\text{CO}_2 - \text{CO}_2$ and $\text{H}_2\text{O} - \text{CO}_2$ pairs. This separation, which was
40 introduced many years ago [see, e.g. (Burch, 1982; Burch and Alt, 1984)]
41 and kept since then (Mlawer et al., 2012), has a practical interest since the
42 continua are proportional to the product of the densities of the molecules
43 involved (provided that the local transitions contributions are computed up
44 to a distant to the line centers significantly larger than the pressure broadened
45 widths). Recall that the continua potentially include contributions of the
46 far wings of the pressure-broadened absorption lines of the monomers, of
47 collision-induced absorption, and of bound and quasi-bound bi-molecular
48 complexes.

49 In a pioneer study carried three decades ago, a quasistatic theoretical
50 approach was developed (Ma and Tipping, 1992; Pollack et al., 1993) for
51 the prediction of the $\text{H}_2\text{O} - \text{CO}_2$ continuum due to the far wings of the
52 CO_2 -broadened lines of H_2O . In the absence of any experimental results,
53 the associated calculated spectra and line-shape correction-factor $\chi_{\text{H}_2\text{O}-\text{CO}_2}$
54 provided the very first data throughout the infrared. Twenty five years
55 later came the first measurements of the $\text{H}_2\text{O} - \text{CO}_2$ continuum, which
56 investigated the $1100\text{--}1300\text{ cm}^{-1}$ region (Baranov, 2016). Then, Tran et
57 al. (2019) produced new data from 100 to 1500 cm^{-1} , which confirmed
58 the results of Baranov (2016) and extended the investigated spectral range.
59 Note that this latter study also provided a line-shape factor $\chi_{\text{H}_2\text{O}-\text{CO}_2}$ for
60 CO_2 -broadened H_2O transitions, obtained by adjusting the measured values
61 between 100 and 1500 cm^{-1} , with which the calculated continuum agrees
62 well with the experiments. For the H_2O -broadened wings of CO_2 lines,
63 the situation is somehow similar, with first results and data obtained only
64 recently. These include measurements in the high frequency wing of the CO_2

65 ν_3 band (Baranov, 2016; Tran et al., 2018) from which a $\chi_{\text{CO}_2-\text{H}_2\text{O}}$ absorption
66 factor was deduced (Tran et al., 2018), and direct predictions using molecular
67 dynamics simulations (Hartmann et al., 2018a). Finally, recall that another
68 process participating to the continua is collision-induced absorption (CIA)
69 (Frommhold, 1993). In the particular case of $\text{H}_2\text{O} + \text{CO}_2$ mixtures such a
70 contribution was pointed out recently by a cavity ring down spectroscopy
71 study (Fleurbaey et al., 2022a). This investigation, which provided values of
72 the continuum of $\text{H}_2\text{O} + \text{CO}_2$ mixtures at some points around 1.60, 2.3 and
73 3.5 μm , also evidenced the presence of a CIA peak around 6000 cm^{-1} . The
74 latter was soon after attributed (Fleurbaey et al., 2022b) to the simultaneous
75 transitions involving the ν_3 -band dipole of CO_2 and the ν_1 -band polarizability
76 of H_2O .

77 In the present work, we continue the efforts made to build up a $\text{H}_2\text{O} +$
78 CO_2 continuum throughout the infrared by measuring the absorption, at
79 room temperature, on both sides of the ν_2 band as well as around 3.1 μm .
80 The experimental procedure is presented in Section 2 and the data analysis
81 is described in Section 3. Finally, the results are shown in Section 4 and
82 compared to previous experiments and predictions based on the line-shape
83 factor $\chi_{\text{H}_2\text{O}-\text{CO}_2}$ proposed in Tran et al. (2019).

84 2. Measurements

85 The spectra were measured using the facilities at the AILES beam line
86 of the SOLEIL synchrotron, previously used for similar experiments (Tran
87 et al., 2019; Fakhardji et al., 2022). A high resolution Fourier transform
88 spectrometer (FTS, Bruker IFS 125 HR) was used, equipped with a globar
89 source and a KBr beam splitter. The light exiting the FTS passed through
90 a 2.5 m long multi-pass cell with diamond windows, set for an optical path
91 of 101.3 m. The transmitted intensity was then measured with a liquid
92 nitrogen-cooled HgCdTe detector. For each spectrum, whose usable part lies
93 between about 700 and 4600 cm^{-1} , an average of 1000 scans was made with
94 an unapodized resolution of 0.5 cm^{-1} . In the measurements of the absorption
95 by $\text{H}_2\text{O} + \text{CO}_2$ mixtures, all carried at 295 K, the cell was first filled with
96 purified water vapor at a pressure of $\sim 15 \text{ mb}$ (measured using a 0-1000
97 mb Pfeiffer model CMR361 capacitive gauge which has a stated accuracy
98 of 0.2%). Then CO_2 was introduced step by step, progressively increasing
99 the total pressure from $\sim 500 \text{ mb}$ to $\sim 1000 \text{ mb}$ (measured using the same
100 capacitive gauge) and a spectrum was recorded after each step (awaiting

101 about 10 to 15 min each time to allow the gas mixture to reach equilibrium).
 102 In addition to this "ascendant" procedure, we also recorded spectra using a
 103 "descendant" procedure, i.e. starting from the highest pressure of ~ 1000 mb
 104 and progressively reducing it down to ~ 500 mb. Note that these two ways of
 105 collecting data are not equivalent since the mole fractions of H_2O ($\sim 1.5\%$)
 106 and CO_2 ($\sim 98.5\%$) are kept constant in the descendant procedure while they
 107 vary in the ascendant one (the proportion of water vapor then decreasing from
 108 $\sim 3\%$ down to $\sim 1.5\%$). In order to obtain the 100% transmittance levels,
 109 reference spectra were also recorded with the cell filled with pure argon at \sim
 110 1 bar, before and after each of the series with $H_2O + CO_2$ mixtures described
 111 above.

112 3. Data analysis

113 In a first step, the transmission associated with each $H_2O + CO_2$ sample
 114 was obtained by dividing the corresponding recording by the reference
 115 spectrum (recorded with argon). Then, various contributions to the
 116 absorption needed to be removed in order to obtain the targeted continuum
 117 due to the CO_2 -broadened far wings of the H_2O lines. Indeed, for a CO_2+H_2O
 118 mixture at temperature T with densities d_{CO_2} and d_{H_2O} , the total absorption
 119 coefficient α_{tot} at wavenumber σ can be written as:

$$\begin{aligned}
 \alpha_{tot}(\sigma, d_{CO_2}, d_{H_2O}, T) = & \alpha_{loc}^{CO_2}(\sigma, d_{CO_2}, d_{H_2O}, T) + \alpha_{loc}^{H_2O}(\sigma, d_{CO_2}, d_{H_2O}, T) \\
 & + \alpha_{CA}^{CO_2-CO_2}(\sigma, d_{CO_2}, T) + \alpha_{CA}^{H_2O-H_2O}(\sigma, d_{H_2O}, T) \\
 & + \alpha_{CA}^{H_2O-CO_2}(\sigma, d_{CO_2}, d_{H_2O}, T)
 \end{aligned}
 \tag{1}$$

120 where $\alpha_{loc}^{CO_2}$ and $\alpha_{loc}^{H_2O}$ are the contributions of local lines of the two molecules,
 121 computed including all transitions within a given interval (see below) around
 122 the current wavenumber. The coefficient $\alpha_{CA}^{CO_2-CO_2}$ and $\alpha_{CA}^{H_2O-H_2O}$ denote
 123 the continuum absorptions by pure CO_2 and H_2O respectively. Finally
 124 $\alpha_{CA}^{H_2O-CO_2}$ is the continuum absorption due to interacting $H_2O + CO_2$ pairs.
 125 In order to deduce $\alpha_{CA}^{H_2O-CO_2}$ we have computed all the other contributions
 126 as described below.

127

128 *1 - Computation of the local lines absorption ($\alpha_{loc}^{CO_2}$, $\alpha_{loc}^{H_2O}$)* - The
 129 calculation of the associated absorption coefficients was carried using Voigt
 130 profiles [truncated ± 5 cm^{-1} for CO_2 , for consistency with Perrin and

131 Hartmann (1989) and $\pm 25 \text{ cm}^{-1}$ for H_2O , for consistency with Mlawer et
132 al. (2012) and Clough et al. (1989), away from their centers] with line
133 positions and intensities taken from the HITRAN database (Gordon et al.,
134 2022). Since the latter provides only self- and air-broadening coefficients,
135 the needed values of the broadenings of H_2O lines by CO_2 were taken from
136 Brown et al. (2007), while we used the data of Sung et al. (2009) for the H_2O
137 broadenings of CO_2 transitions, as done in Tran et al. (2019). The pressure
138 shifts of the CO_2 lines induced by collisions with H_2O and those of H_2O lines
139 by CO_2 being not available, they are considered to be the same as the ones
140 with air. The impact of this approximation is expected to be negligible given
141 the small value of the line shift in comparison to the spectral resolution of
142 the recorded spectra. The partial pressure of H_2O for each recording was
143 also determined by fitting some absorption lines. The obtained results are
144 consistent (with a difference around only $\sim 2\%$) with the values deduced
145 from the H_2O mole fraction and the total pressure of the mixture (both a
146 priori known through the pressure readings during the making of the mixture
147 and the successive recordings).

148 *2 – Computation of the pure CO_2 continuum* ($\alpha_{CA}^{CO_2-CO_2}$) – $\alpha_{CA}^{CO_2-CO_2}$ was
149 computed taking into account two contributions. The first, due to the wings
150 of CO_2 lines broadened by collisions with CO_2 , was computed using the
151 $\chi_{\text{CO}_2-\text{CO}_2}$ factor from Perrin and Hartmann (1989). Note that this model was
152 preferred to a line-mixing model because it leads to much better agreement
153 with the measurements in the line-wings (Tran et al., 2011). The second,
154 due to two collision-induced absorption bands around 1350 cm^{-1} (Baranov
155 and Vigasin, 1999) was taken from Karman et al. (2019).

156 *3 – Computation of the pure H_2O continuum* – Finally, the contribution
157 of the H_2O self-continuum was computed using the version v3.2 (available
158 at http://rtweb.aer.com/continuum_frame.html) of the MT_CKD model
159 (Mlawer et al., 2012).

160 Note that, since data are available for its computation, the contribution of
161 the H_2O -broadened wings of CO_2 lines were computed using the $\chi_{\text{CO}_2-\text{H}_2\text{O}}$
162 from Tran et al. (2018), and removed from $\alpha_{CA}^{H_2O-CO_2}(\sigma, d_{\text{CO}_2}, d_{\text{H}_2\text{O}}, T)$. Note
163 that it makes a practically negligible contribution in the investigated spectral
164 regions.

165 Once all these contributions have been calculated, the associated spectral
166 transmission $\tau_{Calc}(\sigma)$ is predicted and convolved by the FTS instrument
167 function $F_{inst}(\sigma)$. The targetted continuum due to the far wings of the
168 CO_2 -broadened H_2O monomer lines was then obtained from the measured

169 transmission $\tau_{Meas}(\sigma)$ by using:

$$\alpha_{CA}^{H_2O-CO_2}(\sigma) = -\ln [\tau_{Meas}(\sigma)/(\tau_{Calc}(\sigma) * F_{inst}(\sigma))] / L \quad (2)$$

170 where L is the optical path in cm and $*$ denotes a convolution. Note that
 171 for consistency with the usual definition of the H₂O continua (Mlawer et al.
 172 2012; Clough et al., 1989), the values of $\alpha_{CA}^{H_2O-CO_2}(\sigma, d_{CO_2}, d_{H_2O}, T)$ provided
 173 by this procedure are corrected by adding the "pedestal" (since it was not
 174 subtracted from $\alpha_{loc}^{H_2O}$) defined by:

$$P(\sigma, d_{CO_2}, d_{H_2O}, T) = \frac{d_{CO_2} d_{H_2O}}{\pi} \sum_{l \text{ if } |\sigma - \sigma_l| < 25} \frac{S_l(T) \gamma_l(T)}{(25)^2} \quad (3)$$

175 where the sum extends over all H₂O lines centered within $\pm 25 \text{ cm}^{-1}$
 176 around the current wavenumber. $S_l(T)$ is the the integrated intensity of
 177 line l in $\text{cm}^{-2}/\text{amagat}$, and $\gamma_l(T)$ (in $\text{cm}^{-1}.\text{amagat}^{-1}$) is the CO₂-broadening
 178 coefficient of the line. Note that the amagat density unit is used here as in
 179 previous studies, 1 amagat corresponding to $2.687 \times 10^{19} \text{ molec}/\text{cm}^3$.

180 Using the above described procedure, the $\alpha_{CA}^{H_2O-CO_2}$ continuum can
 181 potentially be retrieved for each wavenumber where the absorption by H₂O
 182 is measurable under our experimental conditions. However, the values
 183 obtained are very uncertain when the computed absorption that has been
 184 removed represents a very large part of the total absorption. Hence, as
 185 done in Tran et al. (2019), we selected only the spectral points located
 186 in troughs between lines and sufficiently distant from the latter. In order
 187 to determine the density-normalized $CA^{H_2O-CO_2}(\sigma, T)$ continuum from the
 188 values of $\alpha_{CA}^{H_2O-CO_2}(\sigma, d_{CO_2}, d_{H_2O}, T)$, we used the fact that, for binary
 189 collisions (an assumption valid at the pressures of our measurements), they
 190 are related through:

$$\alpha_{CA}^{H_2O-CO_2}(\sigma, d_{CO_2}, d_{H_2O}, T) = d_{CO_2} d_{H_2O} CA^{H_2O-CO_2}(\sigma, T) \quad (4)$$

191 We thus performed a linear fit of $\alpha_{CA}^{H_2O-CO_2}$ versus the product of the densities
 192 $d_{CO_2} d_{H_2O}$ for each retained spectral point. Some examples of this exercise
 193 are displayed in Fig. 1, which shows that our measured values do quite well
 194 follow the proportionality law of Eq. (4). Note that, in order to obtain
 195 these results, the level of the reference spectrum (corresponding to the 100%
 196 transmittance recorded with the cell filled with argon) was also adjusted by
 197 multiplying it by a linear function of wavenumber assumed independent of
 198 the pressure.

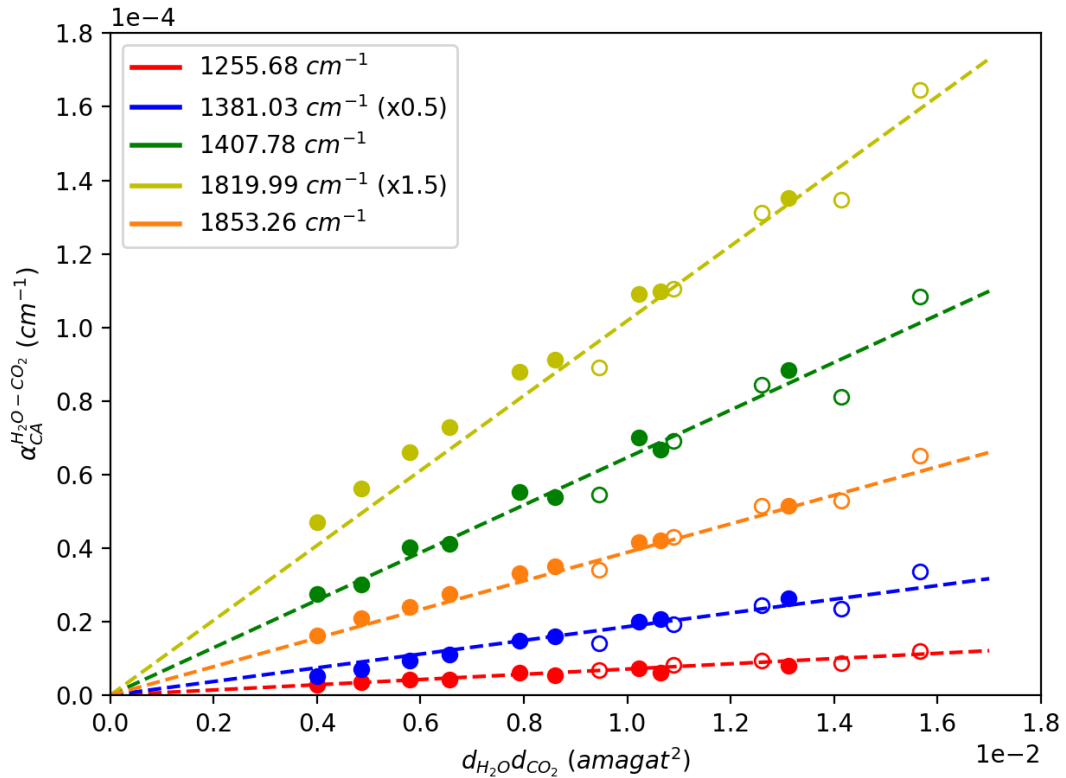


Figure 1: Examples of linear fits (dashed lines) of the measurements (represented with filled and empty dots respectively for increasing and decreasing pressure ramps) for fixed values of the wavenumber. The value of the $\text{H}_2\text{O} - \text{CO}_2$ continuum $C A^{\text{H}_2\text{O}-\text{CO}_2}(\sigma)$ is directly given by the slope of the line.

199 4. Results and discussion

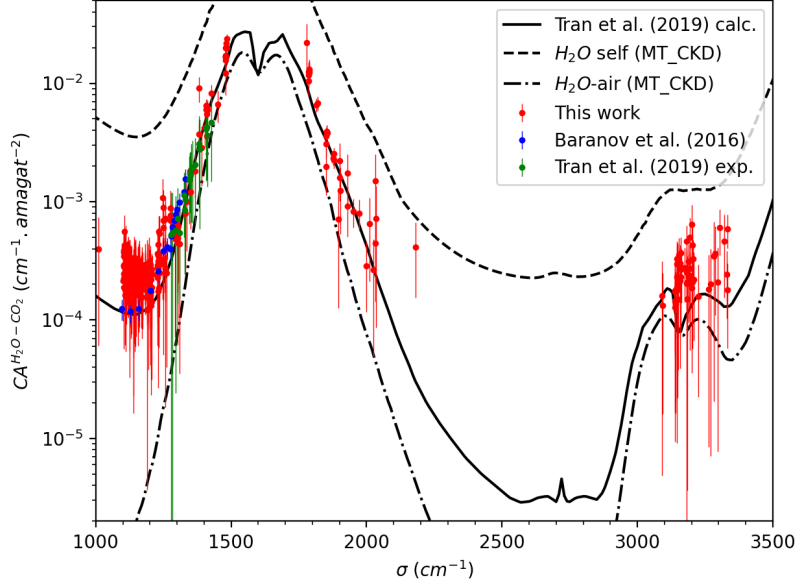
200 Figure 2 displays a comparison of our experimental values (provided in
 201 the supplementary material) for the $\text{H}_2\text{O} - \text{CO}_2$ continuum with the other
 202 measurements available in the considered spectral region (Baranov, 2016;
 203 Tran et al., 2019). The uncertainties on our determinations, shown by the
 204 error bars in Fig. 2, were obtained taking into account three major sources
 205 of error. The first one comes from the dispersion of the measurements and
 206 it was obtained from the 1σ statistical error in the linear fits exemplified
 207 in Fig. 1. In addition, the calculations of the other contributions to the
 208 absorption (presented in Sec. 3) that have been removed propagate errors

209 due to uncertainties on the spectroscopic parameters used (in particular
 210 for the contribution of the H₂O local lines). This additional source of
 211 errors was computed using the uncertainties on the H₂O line intensities
 212 and air-broadening coefficients provided, for each line, by the HITRAN
 213 database (Gordon et al., 2022) [we thus assumed the same values for the
 214 CO₂-broadening coefficients of Brown et al. (2007)]. Even though they
 215 are not expected to play a major role, the uncertainties on the intensities
 216 and self-broadening coefficient for CO₂ are also taken in account. For both
 217 H₂O and CO₂ lines, we disregarded the uncertainties on their positions since
 218 the associated uncertainties are negligible. The third source of error is the
 219 uncertainty on the self H₂O continuum that we estimated by comparing the
 220 MT_CKD model with the measurements made by Ptashnik et al., (2019).
 221 The difference observed was on average about $\sim 10\%$ and we then supposed
 222 this level for the uncertainties and added them to the error bars. Note
 223 that the first and the two other sources of error mentioned above behave
 224 differently according to the spectral region of interest. Indeed, the dispersion
 225 of the measurements becomes less important as the absorption increases,
 226 and the associated statistical error decreases. In contrast, the uncertainties
 227 on the spectral parameters and those on the self H₂O continuum naturally
 228 play a larger role near the center of the ν_2 band, while their impact is less
 229 pronounced in the far wings regions. Hence the first source of error dominates
 230 in the weak absorption regions, while the uncertainty associated with the
 231 calculation of the removed absorption is predominant near the band center.
 232 Finally, in our results we have selected only the values of the continuum
 233 which are larger than their associated uncertainty.
 234 The first thing to be noticed is that, between 1100 and 1200 cm⁻¹, our
 235 continuum values are on average larger than the previous measurements
 236 (Baranov, 2016; Tran et al., 2019) (although all are compatible when
 237 uncertainties are taken into account) while at higher frequencies in the
 238 red wing of the ν_2 band the agreement is better. The center of the ν_2
 239 absorption band being saturated it is not possible to extract information on
 240 the continuum but, in the 1800 – 2000 cm⁻¹ range we were able to determine
 241 it, providing the first determination of the H₂O – CO₂ continuum, which is
 242 also the case for the 3100–3300 cm⁻¹ interval.
 243 As is well known, the self and foreign H₂O continua include four
 244 contributions, all proportional to the product of densities of the species
 245 involved: (i) What is left of the wings of the pressure-broadened monomer
 246 lines after the removal of the contribution of the transitions within ± 25

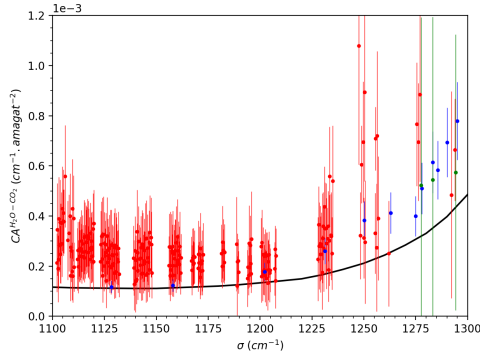
247 cm^{-1} . (ii) The absorption due to the interaction-induced dipole within free
 248 colliding pairs (see e.g. Fleurbaey et al., 2022a,b). The participation of
 249 (iii) bound and (iv) meta-stable or quasi-bound dimers. In the case of the
 250 water vapor continua the related importance of these four contributions has
 251 been a controversial and still open issue for decades (see e.g. Hartmann et
 252 al., 2018b and references therein), whose discussion is largely beyond the
 253 scope of the present study. However, an empirical approach was proposed
 254 by Tran et al. (2019) to compute the $\text{H}_2\text{O} - \text{CO}_2$ continuum. The authors
 255 rightly or wrongly assumed that the continuum in the $100\text{-}1500 \text{ cm}^{-1}$ region,
 256 is entirely due to the far wings of the monomer lines. They consequently
 257 adjusted a $\chi_{\text{CO}_2-\text{H}_2\text{O}}$ correction factor on the experimental data as was done
 258 many years ago for the self- and air-broadened H_2O continua (Clough et
 259 al, 1989). In the absence of any other theoretical approach for comparison
 260 with our measurements, we used this model, with results displayed in Fig.
 261 2. As can be seen, the agreement between calculations and experiments in
 262 the newly studied regions is quite good, which demonstrates the predictive
 263 capabilities of the χ factor approach. However, note that concluding from
 264 this that the continuum in whole studied regions is only due to the monomer
 265 far wings would be highly hazardous.
 266 Finally, the top panel in Fig. 2 enables to compare the $\text{H}_2\text{O} - \text{CO}_2$ continuum
 267 with those, taken from Mlawer et al. (2012), for pure H_2O and H_2O -air. As
 268 can be seen the values for $\text{H}_2\text{O} - \text{CO}_2$ are slightly larger than those for H_2O -air
 269 and significantly smaller than those for $\text{H}_2\text{O} - \text{H}_2\text{O}$ (Brown et al., 2007). This
 270 is consistent with the quasi static predictions of Ma and Tipping (1992) and
 271 with the fact that the broadening coefficients of H_2O lines by CO_2 (Brown et
 272 al., 2007) are slightly larger than those by air and significantly smaller than
 273 those for pure H_2O (Gordon et al., 2022).

274 5. Conclusion

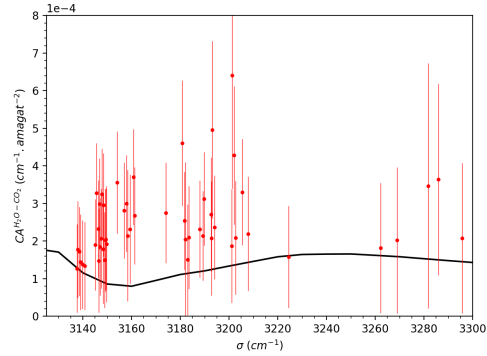
275 We measured the $\text{H}_2\text{O} - \text{CO}_2$ continuum on both sides of the ν_2 absorption
 276 band, as well as around $3.1 \mu\text{m}$. The data obtained in the spectral range 1100
 277 $- 1400 \text{ cm}^{-1}$ are consistent with previous measurements (Baranov, 2016; Tran
 278 et al., 2019) when their respective uncertainties are taken into account. For
 279 the first time, the continuum has been measured on the high frequency side
 280 of the ν_2 band from 1800 cm^{-1} to 2000 cm^{-1} as well as between 3100 and
 281 3300 cm^{-1} . In addition to providing new measured data, this study also
 282 enabled a successful further test of the $\chi_{\text{H}_2\text{O}-\text{CO}_2}$ factor model proposed in



(a)



(b)



(c)

Figure 2: $\text{H}_2\text{O}-\text{CO}_2$ continuum – The data measured in this study are shown with red dots and are compared to the results of previous experiments (Baranov, 2016; Tran et al., 2019) respectively displayed in blue and green. The black line represents the values predicted using the $\chi_{\text{H}_2\text{O}-\text{CO}_2}$ factor model developed by Tran et al. (2019). For comparison, we also show the self- and air-broadened H_2O far line wings continuum [computed using the latest version available at http://rtweb.aer.com/continuum_frame.html of the MT_CKD model (Mlawer et al., 2012)] with dashed and dashdotted lines, respectively. The top panel (a) displays the results in log scale while the two bottom plots (b) and (c) show respectively the 1100–1300 cm^{-1} and 3100–3300 cm^{-1} regions in linear scale.

283 Tran et al. (2019). This demonstration of the predictive capabilities of a
284 line-shape correction-factor fitted to experimental results below 1500 cm^{-1} is
285 of considerable interest, particularly for spectral regions where measurements
286 have not yet been made. However recall that our experimental data have
287 been collected at room temperature only, which stresses the crucial need of
288 investigations at various temperatures.

289 It is worth mentioning that our knowledge of the continua associated with
290 $\text{H}_2\text{O} - \text{CO}_2$ pairs has significantly increased in the last four years, and
291 that much progress has been made after the first computations of Ma et
292 al. (1992) and measurements of Baranov (2016). Many new experimental
293 data have been provided which confirmed the latter data and considerably
294 extended the spectral range in which values of the continuum are available.
295 In addition, the original $\chi_{\text{H}_2\text{O}-\text{CO}_2}$ factor of Ma et al. (1992) has been
296 significantly improved (Tran et al., 2019). This provides a computational
297 approach with which a satisfactory agreement with measurements is obtained
298 at almost all experimentally investigated wavelengths, provided that it
299 is complemented, around 6000 cm^{-1} , by a description (Fleurbaey et al.,
300 2022b) of the collision-induced simultaneous transitions. However, much
301 still remains to be done: First, new measurements are needed to test the
302 model in so far unstudied regions, e.g. $2200 - 3000\text{ cm}^{-1}$, while experiments
303 of improved precision are desirable around $3.1\text{ }\mu\text{m}$. Last but not least, the
304 temperature dependence, for which the only information available comes from
305 the early theoretical study of Pollack et al. (1993) must be investigated
306 experimentally.

307 **Declaration of Competing Interest**

308 The authors declare no conflicts of interest

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313 absorption coefficient using the $\chi_{\text{H}_2\text{O}-\text{CO}_2}$ factor model.

314 **Supplementary material**

315 The measured data of the $\text{H}_2\text{O} - \text{CO}_2$ continuum presented in this work
316 are available in the supplementary material

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