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HCl in the atmosphere of Mars: first detection of a halide gas

Kevin S. Olsen et al.

The ExoMars Trace Gas Orbiter (TGO) mission was sent to Mars in 2016 to make the most sensitive measurements of the atmosphere to date and to hunt for any trace gases diagnostic of active geologic or biogenic processes (Vago et al., 2015). After the first full Mars year of observations, we are able to report the first such discovery: gaseous hydrogen chloride (HCl) has been detected by the Atmospheric Chemistry Suite mid-infrared channel (ACS MIR).

ACS science operations commenced at a crucial time for Mars observations. The first solar occultation spectra were recorded on solar longitude (Ls) 163 (late April 2018) at a time of changing seasons on Mars. The northern hemisphere was entering winter, while the southern hemisphere was beginning to warm towards summer season. Around Ls 190, we witnessed a global dust storm of unprecedented severity, with dust remaining in the atmosphere through Ls 250 (Montabone et al., 2020).

HCl was observed by ACS simultaneously in both hemispheres after the main phase of the global dust storm. It remained detectable to ACS MIR for several months, while the impact of the dust was still being felt in the atmosphere, before vanishing. The dust lofted and mixed into the atmosphere caused the atmosphere to warm resulting in an expansion of the lowest layers, increasing the water vapour content, elevating the hygropause to 50-60 km, and enhancing meridional Hadley cell circulation (Fedorova et al., 2020).

Fig. 1 shows a model of the absorption spectrum contributions of the Martian atmosphere as seen by ACS MIR. The HCl branches, shown in the lower panel, partially overlap with the region of interest used to investigate methane (CH₄). So far, TGO instruments have found no evidence of the absorption signature of methane, but in its place ACS MIR has made two surprising discoveries: we have identified a previously unknown CO₂ absorption-rotation band (Trokhimovskiy et al., 2020); and we were able to resolve the spectral signature of ozone at low altitudes in the north polar region at the start of northern winter (Olsen et al., 2020a).

Methods

ACS MIR is a cross-dispersion spectrometer operating in solar occultation mode (Korablev et al., 2018). This geometry provides high signal-to-noise ratios, excellent sensitivity to the vertical structure of the atmosphere, and a very long optical path, amplifying trace gas absorption. The instrument consists of a primary echelle diffraction grating to disperse infrared radiation, followed by a secondary, steerable diffraction grating to separate diffraction orders. The secondary grating position changes the instantaneous spectral range. The full coverage is 2300-4500 cm⁻¹, and the spectral resolution achieved is 0.040-0.045 cm⁻¹ in the region of interest for HCl. The spectral range shown in Fig. 1 covers two secondary grating positions, labelled 11 and 12.

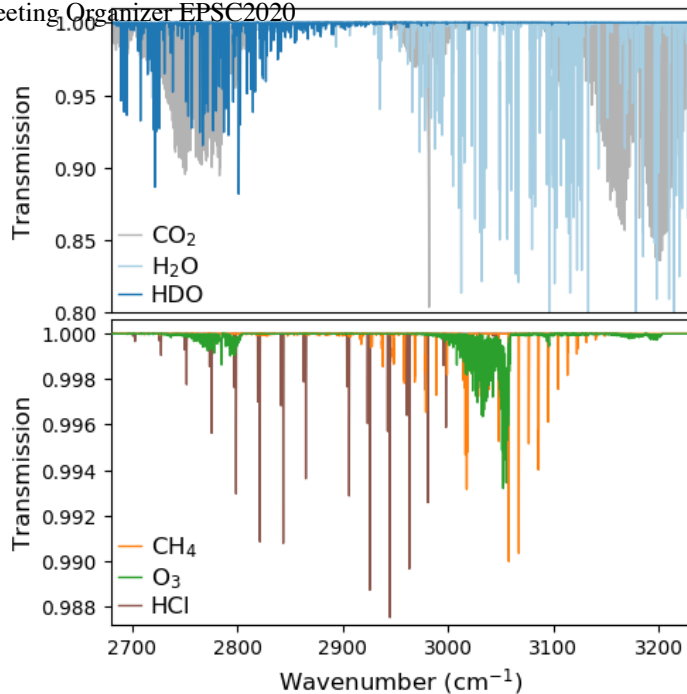


Fig. 1. Modelled gas absorption contributions as seen in the lower atmosphere by ACS MIR during solar occultation. The top panel shows contributions from major species: CO₂, H₂O, and HDO. The bottom panel shows contributions from HCl at 1.5 ppbv, ozone at 140 ppbv, and methane at 1 ppbv. HCl and O₃ signatures at these mixing ratios have been observed, while CH₄ has not.

Spectral fitting was done using the JPL Gas Fitting Software Suite (GFIT) (Irion et al., 2002; e.g., Sen et al., 1996). GFIT computes volume mixing ratio scaling factors for each spectral window and at each altitude. A retrieved profile of gas abundance is derived by inverting the matrices of optical paths and the estimated column abundances. Temperature and pressure profiles are retrieved from coincident observations made with the ACS near infrared channel (ACS NIR) (Fedorova et al., 2020; Vandaele et al., 2019). A full description of the retrieval method can be found in (Olsen et al., 2020b).

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