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Relationships between HCl, H₂O, aerosols, and temperature in the Martian atmosphere

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One of the main objectives of the ExoMars Trace Gas Orbiter (TGO) mission is to hunt for any gases that may be diagnostic of active geological or biogenic processes. Of key interest was methane (CH₄) due to its link to biological production mechanisms on Earth. While this has so far not been observed (Montmessin et al., 2021), the discovery of hydrogen chloride (HCl) was announced after the first full Martian year of observations (Korablev et al., 2021). Like CH₄, HCl will photolyze readily in the Martian atmosphere and have a short lifetime, requiring an active source. One of the dominant sources on Earth is active volcanism, making its characterization a high priority for TGO.

HCl was discovered using data from the mid-infrared channel of the TGO's Atmospheric Chemistry Suite (ACS MIR). This is a cross-dispersion spectrometer operating in solar occultation geometry. The instrument consists of a telescope and foreoptics, a primary echelle grating to access the mid-infrared spectral region, and a secondary diffraction grating to separate overlapping diffraction orders. The solar occultation method is self-calibrating, provides a very long optical path length, and very high signal-to-noise ratios.

It was quickly revealed that HCl was linked to water vapour and had its own seasonal cycle, possibly associated with dust activity (Korablev et al., 2021; Olsen et al., 2021). In this presentation, we will present the results of our work to further characterize HCl and explore its possible origins and seasonality. We present a direct comparison over altitude between the volume mixing ratios (VMR) of HCl with: the water vapour VMR, temperature, water ice extinction, and dust extinction. Water vapour is measured simultaneously with ACS MIR, temperature is measured simultaneously with the near-infrared channel of ACS (Fedorova et al., 2020; 2023), and aerosol extinctions are taken from co-located measurements made with the Mars Climate Sounder (MCS) on Mars Reconnaissance Orbiter (Kleinböhl et al., 2009; 2017).

Our results reveal that regardless of the photochemical origins of HCl, seasonal dust activity very strongly controls its behaviour. At the start of southern spring, dust is lifted into the atmosphere and warms the vertical extent over which dust is present. Temperature strongly controls water vapour,

and HCl is tightly correlated with water vapour over altitude. We do not find direct evidence that the abundance of dust aerosols impacts the HCl VMR, but observed a pronounced difference between the altitude range where HCl (and water vapour) is present and where water ice forms (controlled by temperature).

We have explored, and will discuss, the likelihood of several hypothesized HCl formation and destruction mechanisms. These include heterogeneous reaction on chloride-bearing dust aerosols, emissions from the surface, year-round atmospheric residence (low altitudes? alternative form of chloride?), the formation of perchlorate and surface deposition, and the adhesion of HCl on aerosol surfaces and eventual deposition.

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