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Calibration of the Nomad SO Channel on ExoMars Trace Gas Orbiter

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Introduction

NOMAD is a three-channel spectrometer on the ExoMars 2016 Trace Gas Orbiter. The NOMAD solar occultation (SO) channel has been operating around Mars since April 2018 [1]. In the past three years of science operations, we have performed many calibrations and have taken millions of spectra. This huge dataset allows us to continue to refine the calibration, through additional characterisation of the optical elements, detector performance and temperature-induced effects.

SO channel

By using an Acousto-Optic Tunable Filter (AOTF) in combination with an echelle grating spectrometer, the SO channel is able to operate at unprecedented spectral resolution – typically 0.15 to 0.25 cm^{-1} [2] – and is therefore able to measure trace gases and set stringent upper limits on the presence (or non-presence) of organic molecules in the Martian atmosphere [3].

In solar occultation mode, the Sun is used as the illumination source, meaning that very high Signal-to-Noise Ratios (SNRs) can be achieved, typically up to 2,000 for a single spectrum at the top of the atmosphere. The SO channel records 24 spectra per second in solar occultation mode, with a typical vertical sampling resolution (i.e. altitude difference between consecutive spectra) of around 50-150m [4]. Therefore, by binning multiple spectra together, the SNR can be increased significantly whilst still keeping a high vertical sampling resolution.

Calibration

However the AOTF-grating combination also presents additional challenges, as the optical properties

of both elements must be independently characterised in order to correctly retrieve atmospheric gas concentrations. Analysis of the AOTF shape and sidelobes, and the Instrument Line Shape (ILS), are ongoing in several of the groups within the NOMAD team. Additional systematic effects have also been identified in the spectra e.g. [5] which hamper efforts to further increase SNR and thus reduce detection limits via binning. Whilst much calibration work on this has already been performed [2, 4], the calibration can still be improved and work is ongoing to understand these effects and how to remove them from the data.

Applications

Since the beginning of the mission, a particular emphasis has been placed on making observations of CH_4 around Gale Crater, in both nadir and solar occultation modes. HCl detections observations are now also made regularly, following the discovery of HCl in the atmosphere [7, 8] and its isotopologue [5], which are close to the detection limit of the channel. Calibration improvements will allow us to further constrain the CH_4 upper detection limit, observe lower concentrations of HCl, and further constrain the isotopic ratio.

References

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