THE MARS ATMOSPHERIC TRACE MOLECULE OCCULTATION SPECTROMETER: SCIENCE OBJECTIVES

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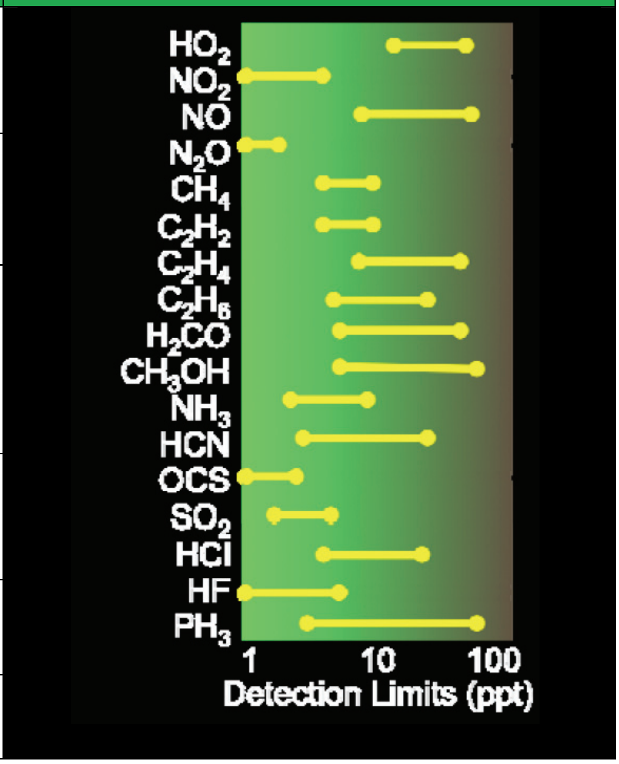
Introduction:

The Mars Atmospheric Trace Molecule Occultation Spectrometer (MATMOS) is described in a companion paper. Here, we describe the six scientific objectives of the MATMOS investigation. These are designed to respond to the ExoMars Trace Gas Orbiter (EMTGO) Joint Instrument Definition Team priorities. The MATMOS investigation seeks evidence for— or places strict upper limits on—life and volcanic activity on Mars by exploring the atmosphere for a wide range of diagnostic gases. MATMOS directly addresses the two highest priority objectives of EMTGO: (1) detecting trace gases and (2) characterizing their 3-D distribution in the context of the atmospheric state.

Objective 1: Search for atmospheric chemical tracers of geological and biogenic activity MATMOS will make coincident measurements of diagnostic gases and their isotopic distribution at ultra high sensitivity. A review of possible source processes generates the list of diagnostic trace gases targeted. Reduced carbon (C), sulfur (S), and nitrogen (N) containing gases are biomarkers on Earth and may be detectable on Mars [1-3]. Shallowly buried organic material from putative past life could also be thermally decomposed during impact events or by igneous intrusions[4]. Based on terrestrial analogs, detection of gases such as SO_2, CH_4, H_2S, and NH_3 may also be suggestive of magmatism, hydrothermal activity, or low temperature water-rock reactions [5,6].

Objective 2: Quantify the lifetimes of diagnostic gases and establish the role of heterogeneous chemistry The MATMOS investigation provides a comprehensive understanding of the loss processes (chemical sinks) for diagnostic gases required to

EMTGO	MATMOS objectives	MATMOS target trace gases
JIDT #1: Trace Gas Detection	1. Search for atmospheric chemical tracers of geological and biogenic activity.	
	2. Quantify the lifetimes of diagnostic gases and establish the role of heterogeneous chemistry.	
JIDT #2: Characterisation	3. Quantify the exchange of water, CO_2 and their isotopologues with the surface and cloud providing unique insight into atmospheric cycles of CO_2, dust and water.	
	4. Understand upper atmosphere coupling toward improving the description of atmospheric escape.	
JIDT #3: Localisation	5. Provide essential support to localization campaigns.	
	6. Solve the mystery of Mars methane.	

relate their abundances to the size of their sources. Measurement of the vertical distribution of oxidants, cloud, and dust are needed to distinguish the two leading mechanisms for the observed variability of CH_4 and other trace gases: the adsorption-evaporation cycle driven by temperature variation [7] and non-standard chemistry associated with H_2O_2 produced in dust storms [8]. MATMOS data will be analyzed using a combination of chemical transport models: a 2-D Lagrangian model based on the Caltech model [9], and a 3-D MATMOS Chemistry-Climate Model (MCCM) based on an improved version of GM3 [10]. The chemistry mechanisms used within this hierarchy will be consistent and benefit from new laboratory studies into heterogeneous reactions.

Objective 3: Quantify the exchange of water, CO_2 and their isotopologues with the surface and cloud providing unique insight into atmospheric cycles of CO_2, dust and water Mars volatile reservoirs may have an isotope signature measurably different from the current atmosphere which may contribute to variability in the ratio of HDO to H_2O in the Mars atmosphere with latitude and season [11-13]. MATMOS will provide co-located dust, cloud, temperature, and volatile isotopologue profiles and place these in the context of concurrent visible limb images contributing information about the spatial extent of cloud and dust layers. Measurements at sunrise and sunset will focus on a significant local time that is poorly addressed by current Mars climatology. At sunset, atmospheric water vapor content will still be significant, while sunrise follows the coldest part of the night, when water can be expected to be in the condensed phase.

Objective 4: Understand upper atmosphere coupling toward improving the description of atmospheric escape MATMOS will retrieve temperature and pressure profiles from the surface to ~200 km, complementing the 2013 MAVEN aeronomy investigation.

Objective 5: Provide essential support to localization campaigns With EMTGO nominal orbit parameters, MATMOS solar occultation data will provide global coverage of trace gas profiles at ~4 degrees latitude x 8 degrees longitude in ~8 weeks. This is adequate to resolve seasonal sources and guide mapping instruments. MATMOS line-resolving spectral resolution can also aid in improving trace gas retrievals from Mars infrared mapping instruments, allowing data mining of past data sets.

Objective 6: Solve the mystery of Mars methane A broad investigation of atmospheric chemical composition sensitive enough to measure $^{12}CH_4$ and $^{13}CH_4$ together with cogenerated species—for example, C_2H_6, H_2S, SO_2, HCN, and NH_3—would provide the best opportunity for identifying the source of CH_4 [14]. The mystery of its reported short chemical lifetime [15-17] is addressed through comprehensive characterization of its chemical context (Objective 2).

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