THE MARS ATMOSPHERIC TRACE MOLECULE OCCULTATION SPECTROMETER

P.O. Wennberg, *California Institute of Technology, Pasadena, CA, USA (Wennberg@caltech.edu),* **V.J. Hipkin,** *Canadian Space Agency, Montreal, Quebec, Canada (Victoria.Hipkin@asc-csa.gc.ca),* **J.R. Drummond**, *Dalhousie U., Halifax, NS, Canada,* **G.C. Toon, M. Allen, J.-F. Blavier, L.R. Brown, A. Kleinböhl**, *NASA Jet Propulsion Laboratory, Pasadena, CA, USA,* **J.P.D. Abbatt, B. Sherwood Lollar, K. Strong, K.A. Walker**, *U. Toronto, Toronto, ON, Canada*, **P.F. Bernath**, *U. of York, York, U.K.,* **R.T. Clancy**, *SSI, NC, USA*, **E.A. Cloutis,** *U. Winnipeg, Winnipeg, MB, Canada,* **D.J. DesMarais**, *NASA Ames, Moffitt Field, CA, USA*, **J.M. Eiler, Y.L. Yung**, *California Institute of Technology, Pasadena, CA, USA*, **T. Encrenaz**, *LESIA, Paris, France*, **J.C. McConnell**, *York U., Toronto, ON, Canada.*

We describe the Mars Atmospheric Trace Molecule Occultation Spectrometer (MATMOS) investigation, selected for the 2016 Mars Trace Gas Orbiter (TGO). The MATMOS instrument is a Solar occultation Fourier Transform InfraRed spectrometer (SFTIR) with a co-aligned solar imager that will detect, profile, and map with parts per trillion sensitivity a large suite of trace gases. The investigation, a partnership between the California Institute of Technology (Caltech), the Canadian Space Agency (CSA), and NASA's Jet Propulsion Laboratory (JPL), directly addresses key goals of the 2016 ExoMars Trace Gas Orbiter mission.

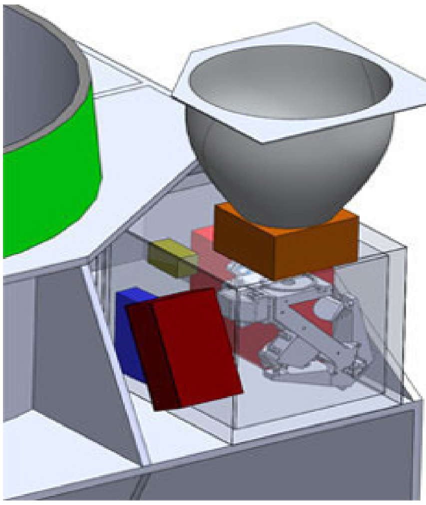

Figure 1. MATMOS will be located on the Sun Deck of the 2016 Exomars Trace Gas Orbiter.

MATMOS will be situated on the "Sun Deck" of the TGO spacecraft (Figure 1). As the orbiter enters and exits the shadow of Mars, four color visible images and FTIR spectra will be acquired as the sun sets (or rises) by approximately 3 km tangent altitude. The spectra will be obtained from 850 – 4300 cm^{-1} with S/N greater than 200 and with a spectral resolution of 0.02 cm^{-1}. For the expected inclination of the TGO orbit, spectra will be obtained at both high latitudes and in the tropics in each season. Shown in Figure 2 are the expected locations of the occultations for aerocentric longitude L_s 0 – 90.

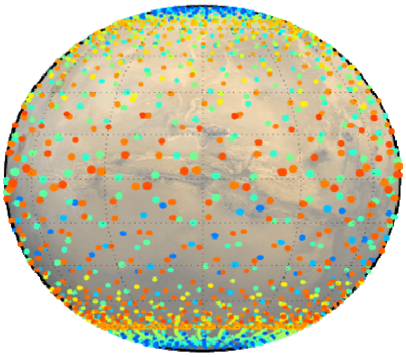

Figure 2. As the beta-angle changes, occultations drift across the planet. Shown in this figure are the sub solar points for the occultations calculated to occur as L_s varies from 0 (blue) to 90 (red).

The images and spectra from MATMOS will be processed at the California Institute of Technology by the science team. The spectra and retrieved products will be made available to the public rapidly from the MATMOS web site at Caltech and its mirror at the Canadian Space Agency.

The high S/N and high spectral resolution allow precise and accurate measurements of a large suite of compounds. Shown below are examples of the limits of detection for trace gas profiles from an average of 100 occultations obtained under high (dotted) and low (solid) dust loading (Figure 3). Averaging of the data obtained below 20 km reduce the limit of detection by approximately 3. Thus, it is expected that MATMOS will be able to quantify the abundance of methane, for example, down to concentrations as low as 3 ppt.

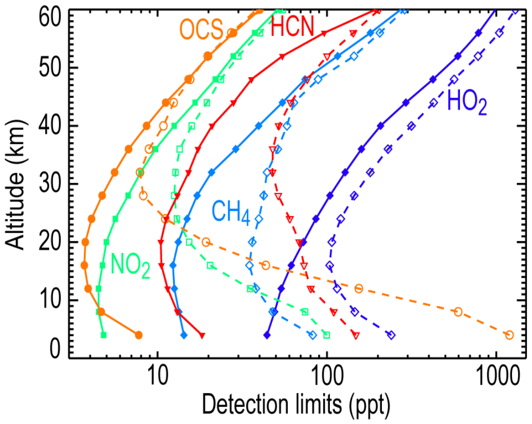

Figure 3. MATMOS has detection limits in the range 1−100 parts per trillion. Shown is the expected performance for several gases for an average of 100 occultations under low ($\tau = 0.1$, solid line) and high ($\tau = 0.6$, dashed) dust opacities at 1075 cm^{-1}.

MATMOS will also provide precise retrievals of the isotopic ratios of oxygen and carbon in major and minor gases. Examples of the expected precision are shown below for both low and high dust conditions (Figure 4).

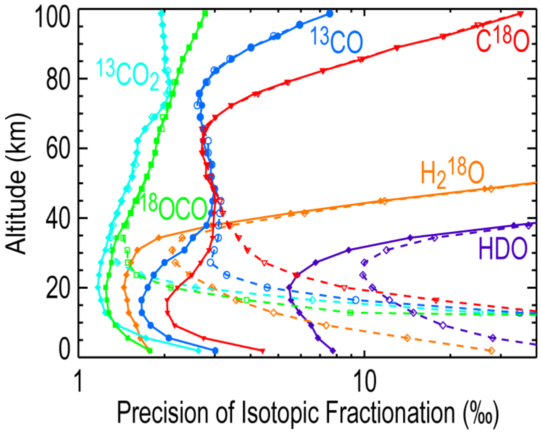

Figure 4. MATMOS will produce precise profiles of the isotopic abundance of CO, CO2, and H2O. Shown is the expected performance for 100 occultation average under low ($\tau = 0.1$, solid) and high ($\tau = 0.6$, dashed) dust opacity.

Operations of MATMOS are quite simple. A small telescope is used to bring sunlight into the interferometer. MATMOS itself has no active pointing capability and so relies completely on the spacecraft to couple radiation from the center of the sun into the instrument. Following the FTS modulator, the sunlight is directed onto two detectors mounted on the cold stage of a passive radiator. The raw interferograms are converted to spectra on board for transmission to Earth. Such extensive onboard processing is required to reduce the data volume (by 100 fold) as the MATMOS downlink is limited to ~1.9 Mbits / day.

The MATMOS imager, bore-sighted with the FTS resolves structure within the extended FTS FOV (~3 km). Such thin cloud layers were observed, for example, by Phoenix for ~30 min. near dawn. Colors represent LIDAR backscatter (Figure 5). Each spectrum will be accompanied by an image of the extended field of view. With four colors, the imager in combination with the IR spectra will allow the optical properties of dust and cloud to be determined.

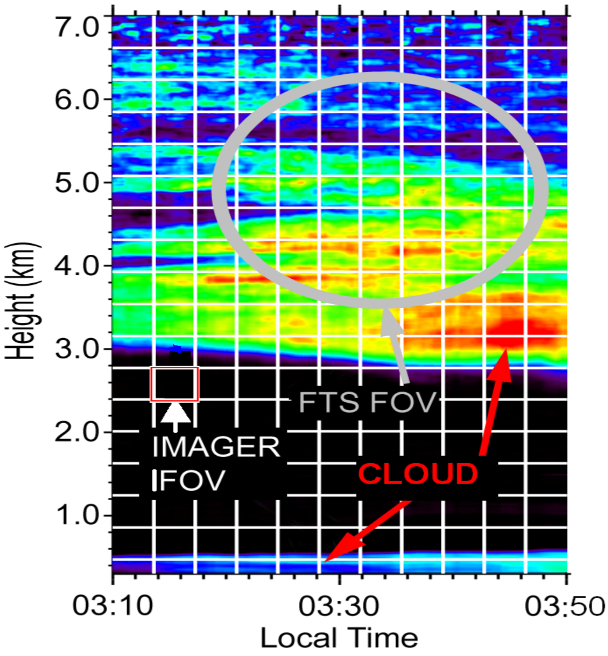

Figure 5. The MATMOS imager resolves structure within the FTS FOV. These thin cloud layers were observed by Phoenix for ~30 min. near dawn.85 Colors represent lidar backscatter.

MATMOS brings to Mars an observational technique that has been instrumental in discovery of the trace gas chemistry of Earth. Shortly after science operations begin, the MATMOS investigation will provide global, vertically resolved measurements of a large suite of trace gases that will provide important new constraints on the exchange of volatiles across the surface of the planet.