The Canadian contribution to the MATMOS instrument

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Abstract: MATMOS is a solar-occultation FTS part of the Exomars mission. It will measure the transmittance of the Martian atmosphere to characterize its chemical composition. We present an overview of the Canadian hardware contribution to MATMOS.

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1. Introduction

The 2016 ExoMars Trace Gas Orbiter (TGO) [1, 2], formally known as the Mars Science Orbiter (MSO), is the name for a NASA-ESA mission that will send an Orbiter and demonstration lander to Mars in 2016 [2, 3].

ESA leads mission operations and is responsible for providing the orbiter bus and lander, NASA leads science operations and will provide the launch vehicle. The orbiter will carry five science instruments, a demonstration lander and telecommunication hardware to provide deep space link and relay functionality from Earth to both the demonstration lander and potential future landed assets on Mars [9].

Over the last years, the MSO - SAG (Science Analysis Group) of the MEPAG (Mars Exploration Program Analysis Group) and the MSO – SDT (Science Definition Team) have produced a series of reports describing scientific objectives for TGO and potential payloads. In all reports, a Fourier transform spectrometer (FTS) operating in solar occultation mode was proposed as a high priority instrument for the atmospheric objectives of the mission [6, 7, 8]. The goal for this instrument is to detect trace gases at parts per trillion sensitivity and characterise the chemical composition of the Martian atmosphere through vertical profile measurements of gases, cloud and aerosol. An Announcement of Opportunity was released in January 2010 by NASA and ESA for ExoMars Trace Gas Orbiter Science Instruments. [4, 5]. The California Institute of Technology, in partnership with the Canadian Space Agency and NASA’s Jet Propulsion Laboratory, submitted a proposal for a solar-occultation FTS called MATMOS (Mars Atmospheric Trace Molecule Occultation Spectrometer) that was selected in August 2010. The Canadian hardware contribution to MATMOS includes the input optics, the interferometer and its control electronics and a multi-spectral solar imager.

The MATMOS science team is co-led by Paul Wennberg (CalTech) and Victoria Hipkin (CSA). Membership includes prominent Canadian atmospheric and planetary researchers from Dalhousie University in Halifax (Dr. James Drummond); the University of Toronto (Drs. Jonathan Abbatt, Barbara Sherwood-Lollar, Kimberly Strong, and Kaley Walker), York University (Dr. Jack McConnell) and the University of Winnipeg (Dr. Ed Cloutis).

The MATMOS instrument builds on the expertise Canada has acquired from the CSA's Scisat mission, which has been using a similar technique and technology to study ozone depletion in Earth's atmosphere since 2003 [10]. CSA has selected ABB Bomem as the prime contractor for the Canadian elements of MATMOS - the same company that built the ACE-FTS for the Scisat mission.

The presentation will focus on the description of the Canadian hardware contributions to the MATMOS FTS. The project, funded by the Canadian Space Agency, is now in Phase A.

2. The MATMOS instrument

MATMOS is a solar-occultation FTS with several similarities to the American ATMOS instrument that flew on four Space Shuttle missions and to the ACE-FTS that flies on the Canadian Scisat satellite. MATMOS will measure the atmosphere transmittance of Mars using the Sun as a source of background illumination. Twice per orbit, as the Sun rises or sets beyond the edge of Mars, MATMOS will acquire spectra of the infrared sunlight at different tangent heights. The ratio of these spectra with the spectrum of the Sun acquired over the atmosphere will yield transmittance spectra at different altitudes. The concentration of various chemicals can be retrieved from the transmittance spectra. Because of the high radiance from the Sun, the instrument can measure with a fine spectral resolution (0.02 cm⁻¹) with a high signal to noise ratio (exo-atmospheric SNR > 250). The instrument will acquire approximately 70 spectra per sunrise or sunset.
The data from MATMOS will be used to derive the composition of the atmosphere of Mars at a level of details finer that what previous missions have achieved. The results will be used to understand the photochemistry of the Martian atmosphere (H₂O₂, O₃, CO) and the transport of CO and H₂O, to study the isotopic fractionation in the atmosphere (in particular H₂O and CO₂ and their isotopologues), to study exchange of CH₄ and H₂O with the surface, and to make the inventory of the chemical species in the Martian atmosphere with accuracy levels between 100 and 1 ppt.

Figure 1: Left: Artist representation of the Exomars TGO satellite. Right: Schematic of the MATMOS instrument on the satellite

3. Overview of the Input Optics and Interferometer module

The input optics includes a telescope to reduce the beam size and to collimate the input radiance before sending it into the interferometer. The telescope is made of two off-axis parabolic mirrors. The total magnification is 4.0. A field stop is located at the intermediary focal point of the telescope. The field of view of the instrument is 1.56 mrad corresponding to a spatial resolution of about 3 km at the tangent plane.

Contrary to ACE, the input optics of MATMOS does not include a Sun-tracker to perform active tracking of the Sun. The pointing is done by the satellite.

The interferometer is based on the design of the ACE-FTS that is flying on Scisat since 2003. The interferometer is a Michelson interferometer based on cube corners mounted on a “V-shaped” rotary arm. The optical beam is folded to achieve a total optical path difference of ±25 cm in a relatively small volume. The folding is done by a flat mirror inserted in one “arm” of the interferometer and by fully reflective coatings on portions of the beamsplitter plate (see Figure 2). This configuration not only extends the optical path difference, it also ensures that misalignments between the recombining beams are compensated. The scanning speed can be commanded: depending on the selected speed, it will take between 2 and 6 seconds to record an interferogram at the full optical path difference.

The coatings of the beamsplitter and compensator are optimized for a spectral range going from 850 cm⁻¹ to 4320 cm⁻¹. That range is slightly wider than for the ACE-FTS.

The interferometer uses a 1550 nm distributed feedback laser diode as the metrology source to provide real-time feedback on the position and speed of the scan arm for the servo-control of the scanning mechanism. A scanning speed instability of no more than 0.5% (RMS) is expected. The signal from the laser is also used for the resampling of the science data on a regular optical path difference grid (time sampling). The laser launcher and the laser detection are part of the interferometer. The temperature and the current of the laser diode are regulated to stabilize its wavelength.
Both the input optics and the interferometer are currently completing their Phase A.

4. Overview of the Solar Imager

The MATMOS solar imager is a small sub-system designed to be integrated with the input optics and bore-sighted with the FTIR field of view. The imager will be able to observe the full solar disk with pixel resolution designed to resolve thin cloud and aerosol layers within the FTIR FOV. It will serve to validate the pointing of the FTS on the Sun centre and to estimate the optical extinction due to aerosols in the Martian atmosphere. The imager will have four bands distributed in the ultra-violet, the visible and the near infrared. The Solar Imager scientific definition is led by Professor James Drummond (Dalhousie University). The imager concept is being developed by ABB and has just completed its conceptual development phase (Phase 0).

5. References