ATMOSPHERIC CHEMISTRY EXPLORER FOR MARS, ACE-M.

P. Bernath, *[bernath@sciborg.uwaterloo.ca],* **C. Boone, K. Walker, S. McLeod,** *Department of Chemistry, University of Waterloo, Waterloo, Canada,* **M.-A. Soucy, J. Giroux, H. Buijs,** *ABB, Quebec City, Quebec, Canada,* **J. Drummond,** *Department of Physics, University of Toronto, Canada,* **Y. Moudden, J. C. Mc-Connell, John Caldwell**, *Centre for Earth and Space Science, York University, Toronto, Canada,* **C. T. McElroy**, *Meteorological Service of Canada, Toronto,* **R. Colin,** *Univ. Libre Bruxelles, Belgium;* **P. Simon,** *BIRA, Belgium*.

Introduction

Work is proceeding in Canada on the design of an experiment that could be used for sensitive detection of molecules in the atmosphere of Mars by occultation, airglow and scattered light from an orbiter. The science objective of the ACE-M experiment is the global study of the atmospheric composition of Mars, with a focus on trace species, particularly those that are related to possible life-signatures. The instruments that make up the experiment are an infrared Fourier transform spectrometer (FTS) and three grating spectrometers with spectral coverage from the near UV to the near infrared. ACE-M will be capable of making a sequence of measurements in solar occultation, limb scattering and emission, and nadir modes. Spectral-global algorithms will provide height profiles and total columns of atmospheric gases as well as the meteorological variables of temperature and pressure. Martian dayglow and nightglow will also be monitored. The composition of dust clouds and aerosols will be strongly constrained from their infrared spectra much as PSCs on Earth. Particle size distributions will be deduced from the visible and near infrared atmospheric extinction.

The FTS will be based on the ABB-Bomem ACE-FTS and SOFIS instrument designs, with a maximum spectral resolution of about 0.1 cm^{-1}. The grating spectrographs will be based on the design of the MAESTRO instrument on the ACE mission [Bernath et al., 2005]. Thus, the technology and algorithms developed for ACE will form the basis of ACE-M. Small detector arrays and dichroic optics will be used with the FTS to improve the signal-to-noise ratio. As in the ACE mission, at least one bore-sighted filtered imager is planned. An on-board computer will provide semi-autonomous operation and carry out massive data compression in the time, spatial and spectral domains to match the limited bandwidth available for data transmission back to Earth.

The study of isotopic ratios of atmospheric molecules provides important information on Martian geological history [Krasnopolsky et al. 1996, 1997]. The isotopic ratios (as measured by ACE-M) for atmospheric molecules such as H_2O, CO_2, CO, etc., will place severe constraints on the models of Martian planetary evolution and the history of volatile species. Also a detailed understanding of Martian atmospheric chemistry is required to distinguish abiological signatures (e.g., methane and sulphur dioxide from volcanism) from gases generated by putative Martian "bacteria".

In solar occultation mode, the long observation path length will lead to the detection [or certainly more stringent upper limits] of many new trace species by ACE-M. The presence of dust, clouds and aerosols with possible concomitant heterogeneous reactions may modify change the gas phase chemistry [Krasnopolsky, 1993]. Detection of these species are important ACE-M capabilities.

The vertical resolution planned would yield an improvement on the Thermal Emission Spectrometer (TES] on the Martian Global Surveyor orbiter [Smith et al. 2001] with, however, fewer profiles per orbit. The ACE-M instrument will have a much higher spectral resolution ("more channels"] and will provide temperature and pressure profiles of higher vertical resolution in the nadir direction. By looking at the limb in solar occultation, profiles of trace gases (e.g., O3 and H2O), dust and clouds can also be measured by ACE-M. These trace species, as well as dust and clouds have a profound effect on the atmospheric chemistry and on the radiative balance.

The bore-sighted imager will provide diagnostic information about the ACE-M scene, particularly about dust clouds in the field of view. The design details for the field of view, spectral range, spectral resolution and instrument performance are part of this proposed concept study.

The infrared detectors will require cooling to ~80 K, and current proposals are to adopt passive cooling. The FTS instrument will also need to be cooled to eliminate most of the thermal self-emission from the instrument. The benefits of instrument cooling are being studied and the optimum instrument temperature for nadir operations will be assessed. Modest cooling of the spectrographs to 250 K is also beneficial because it decreases the detector noise. The extensive use of passive coolers complicates satellite operations because the radiators need to avoid Martian and solar views. However, passive radiators have minimal power requirements, no moving parts and long lifetimes.

An important part of the instrument is the telescope that determines the size of the field of view. In the occultation geometry, the telescope and scan time determine the spatial resolution of the atmospheric profiles. The goal is to have a resolution better than 1/2 the atmospheric scale height, i.e., less than 5 km. In the nadir direct this results in a field of view of less than 1 km. The scientific goal is to have a signal-to-noise ratio higher than 50 for nadir measurements and higher than 300 for solar occultation measurements.

The ACE-M FTS may use small arrays of InSb and HgCdTe detectors. It will include at least one solar imager. The primary operating mode will be solar occultation but nadir and limb emission will also be possible but at lower resolution. This latter mode implies a filter wheel, plus changes in telescope and field stop. The spectral coverage would be from 650-3800 cm-1 (set by CO2 *v*2, 667 cm-1, and *v*1+*v*3, 3716 cm-1, and H_2O). The maximum spectral resolution would be 0.02 cm^{-1} (25 cm optical path difference) but with the possibility of a lower resolution ~ 0.1 cm^{-1} may be desirable. The external field of view would be about 1 mrad. The long pathlength for solar occultation (500 km) leads to sub-ppb detection limits for trace species including NO, CO, H_2O, SO_2, CH_4, N_2O, O_3, H_2O_2, HDO, etc. The FOV leads to a vertical resolution of 3-5 km from the surface to 120 km (limited at lower end by dust and clouds). Clouds and dust can be monitored through IR extinction while pressure and temperature profiles can be determined using CO2 lines. The mass of the complete package of instruments would be less than 40 kg, and the average power use would be 40 W. The nadir viewing would be useful for source identification. Potentially, the data rate is high so it will need extensive compression. However, there is a very strong heritage based on the ACE-FTS.

The detailed hardware design is being carried out by ABB-Bomem, with some support provided by C. T. McElroy and co-workers for the spectrographs. ABB-Bomem are currently evaluating the optimum resolution (spectral and spatial), signal-to-noise ratio, number of detectors, imager size, telescope parameters and instrument design. ABB-Bomem will also evaluate the instrument data rate and options for data compression.

Martian atmospheric modelling will play an important role in instrument design and analysis and GM3 [Moudden and McConnell, 2005; 2006] with chemistry and further improvements will be used.

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