Solicitation: MAVEN Critical Data Products Request for Proposal MFS-269-212010

Date of Submission: 2010 February 28

Proposal Title: SPICAM support for aerobraking at Mars

Short Title: SPICAM support for aerobraking at Mars

Applicant Organization:
Trustees of Boston University, 881 Commonwealth Avenue, Boston, MA 02215

Type of Proposing Institution: Educational Institution

Submission: By email to michele.f.schneider@jpl.nasa.gov by 2010 March 1, 3pm local time

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Researcher Signature and Date:

Paul Withers — 2010.02.24

Signature — Date

Institutional Endorsement:

Steve Singer — 2/24/2010

Signature — Date

Steven Singer
Comptroller

Goal: To support MAVEN operations (125/150 km periapsis) by providing empirical data products on thermospheric variability from observations by the SPICAM UV spectrometer on Mars Express.

SPICAM stellar occultations produce vertical profiles of atmospheric density, pressure and temperature from 50 km to140 km with a vertical resolution of 1-2 km. Typical uncertainties at 125 km are 10-25% in density, 10-25% in pressure, and 20 K in temperature. SPICAM has obtained >2,000 profiles so far and is expected to obtain >1,000 more by 1 May 2012. These profiles span a wide range of Ls, latitude, longitude, and LST. They also encompass significant variations in dust conditions and solar irradiances.

Task 0: Regeneration of atmospheric profiles for Mars Year 26
(Bertaux, supported by Montmessin; 0-6 months)

After several years of operations, the SPICAM team's understanding of their instrument has significantly improved. New data processing techniques have recently been validated and will be used to generate the atmospheric profiles that will be used here: including an iterative process to eliminate stray light, which is often apparent in the field of view of the spectrometer and is mostly connected to a night time emission of nitric oxide (NO). This affects 50% of the profiles. An example of the raw data is shown in Fig. 1. An example atmospheric profile is shown in Fig. 2. For each stellar occultation, a header will be produced containing date, Mars Year, Ls, F10.7, latitude, longitude, and LST. Each header will be accompanied by a file containing a vertical profile of density and uncertainty between 50 km to 140 km interpolated onto regular altitude levels with 2 km spacing. It will also contain pressure and temperature, with error bars. These files will be delivered to JPL.

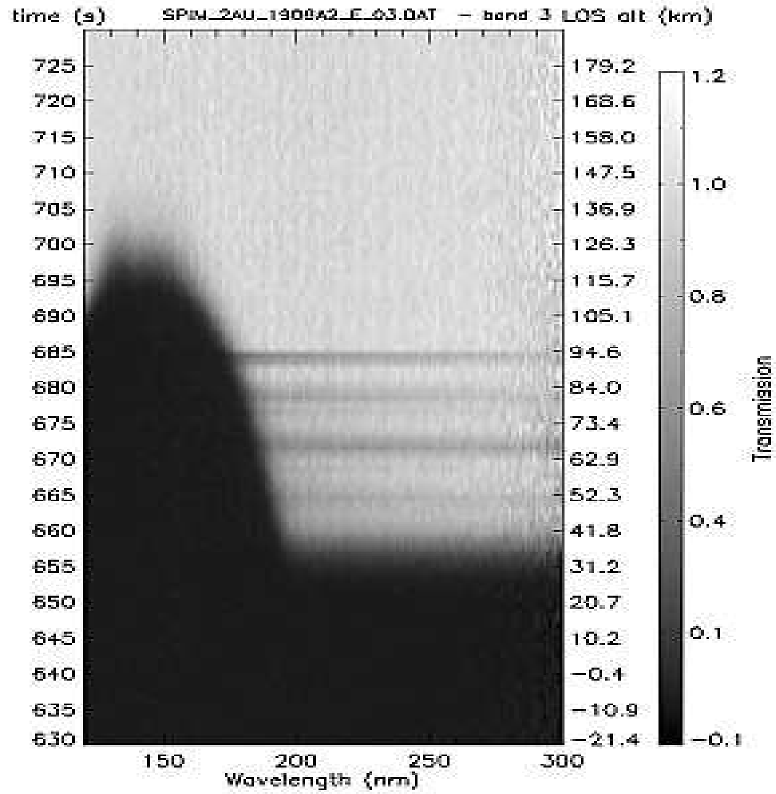

Fig. 1. SPICAM transmission measurements from a stellar occultation (Fig. 38 of Bertaux et al. (2006))

Task 1: Generation of atmospheric profiles for subsequent Mars Years
(Montmessin, supported by Bertaux; 6-9 months)

Beginning in MY 27, the instrument suffered from sporadic gain changes on a 1 second basis. The SPICAM team has prepared, tested, and validated new correction algorithms to clean the data. These algorithms will be applied to stellar occultations in MY 27 and later years. Deliverables for Task 1 are the same as defined for Task 0.

Task 2: Climatology
(TBD; 9-12 months)

Variations in atmospheric properties with time of day are shown in Fig. 3. First, we shall define a grid of Ls, latitude, and LST such that the boxes of this grid are small enough that martian climate should not vary greatly within each box, yet large enough that a reasonable fraction of boxes contain a reasonable number of SPICAM profiles. Then, for each Ls, latitude and LST box, we shall record the number of SPICAM profiles in the box, a vertical profile of average density and uncertainty between 50 km to 140 km interpolated onto regular altitude levels with 2 km spacing, a similar pressure profile, and a similar temperature profile. These files will be delivered to JPL.

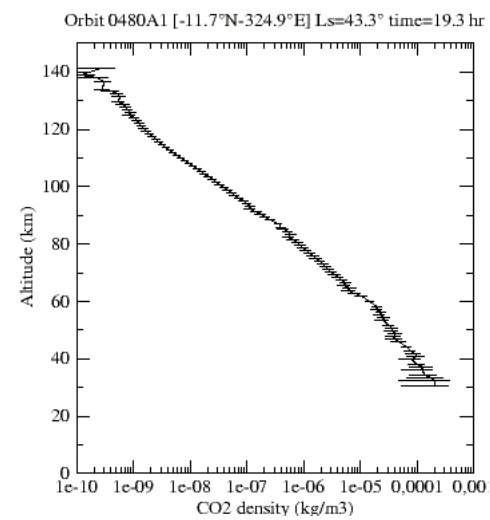

Fig. 2. Example SPICAM density profile from orbit 0480A1 (12S, Ls=43, LST=19 hr) with 1-sigma errors (Fig. 3 of Forget et al. (2009)).

Task 3: Solar variations
(TBD, supported by Bertaux, Montmessin; 12-18 months)

Predictions of how thermospheric temperatures depend on solar conditions are shown in Fig. 4. Using the previously defined Ls, latitude, and LST grid, we shall identify boxes that contain profiles with a wide range of F10.7. Our efforts will focus on extreme variations in F10.7 in order to characterize the worst-case scenarios MAVEN might experience, rather than a less-focused analysis of all profiles. This ensures that the scope of this Task is commensurate with the assigned effort. For each of the selected boxes, we shall record the number of SPICAM profiles in the box. For each of 100 km, 105 km, 110 km, 115 km, ... and each of density, pressure, and temperature, we shall fit variations in the given atmospheric property at the given altitude to F10.7 considering the measurement uncertainties. We shall report the fitting function (eg linear, quadratic), a goodness of fit metric such as reduced chi-squared, the fitted coefficients, and the uncertainty in the fitted coefficients. Each of these fits will be accompanied by a plot of the atmospheric properties versus F10.7. These files and images will be delivered to JPL.

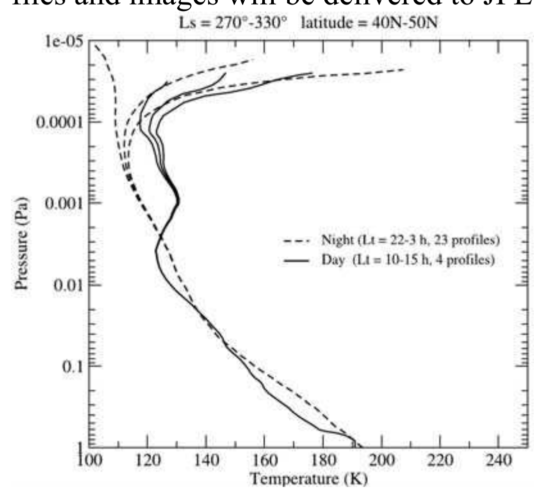

Fig. 3. Day-night temperature variations observed by SPICAM in the winter northern mid-latitudes. Curves are averages of multiple profiles (Fig. 9 of Forget et al. (2009)).

Task 4: Effects of dust
(TBD, supported by Bertaux, Montmessin; 18-24 months)

The atmospheric response to changes in dust opacity is illustrated in Fig 5. Using the previously defined Ls, latitude, and LST grid, we shall identify boxes that contain profiles from a single Mars Year and reflect a wide range of atmospheric dust conditions. The grid will be modified if necessary. As in Task 3, we shall focus on extreme, worst-case events to keep this Task commensurate with the assigned effort. Dust data are available from the MGS TES, ODY THEMIS and MER Mini-TES instruments. We shall investigate the effects of global-scale, regional-scale and local-scale dust opacities on atmospheric density, pressure and temperature at 100 km, 105 km, 110 km, 115 km, ... We shall fit variations in the given atmospheric property at the given altitude to the given dust opacity considering the measurement uncertainties. We shall report the fitting function (eg linear, quadratic), a goodness of fit metric such as reduced chi-squared, the fitted coefficients, and the uncertainty in the fitted coefficients. Each of these fits will be accompanied by a plot of the atmospheric properties versus dust opacity. These files and images will be delivered to JPL.

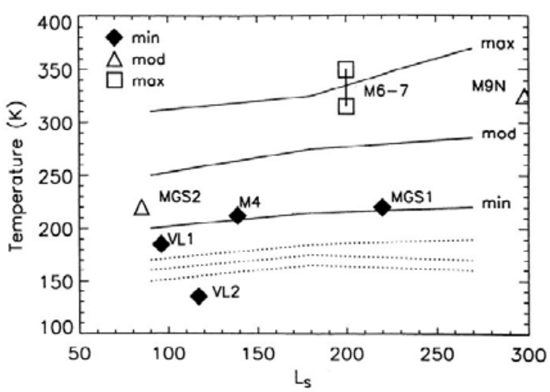

Fig. 4. Predicted exospheric (solid lines) and homopause (dotted lines) temperatures as a function of season for minimum, moderate, and maximum solar conditions. Selected spacecraft observations are indicated by symbols. Results apply at LST=15 hrs near the equator (Fig. 2 of Bougher et al. (2000)).

Timeline

Deliverables from each Task will be delivered to JPL by email at the end of the time period assigned to the Task.

Personnel and Responsibilities

Withers (5% FTE) project management.
Bertaux (15% FTE) lead Task 0, support Tasks 1, 3, and 4.
Montmessin (15% FTE) support Task 0, lead Task 1, support Tasks 3 and 4.
TBD (15% FTE) lead Task 2 unsupported, perform Tasks 3 and 4 with support.
The position identified as "TBD" will be filled by a young scientist with SPICAM experience. Bertaux will select this individual, whose activities commence in Month 9 of this effort.

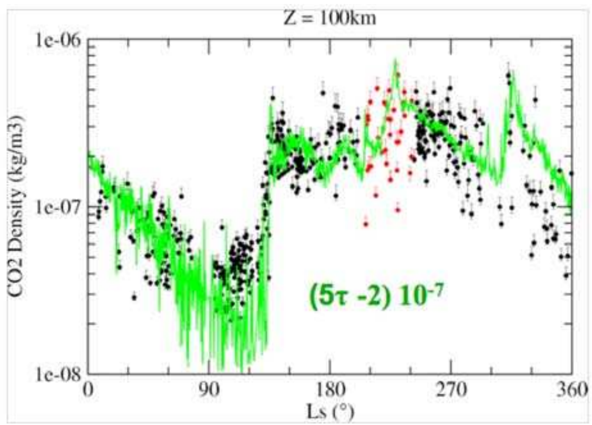

Fig. 5. SPICAM atmospheric density measurements at 100 km and equatorward of 50 deg (black points with error bars) from MY 26. Red points are densities from MY 27. The green curve is derived from MER dust opacity data and shows $(5\tau-2)\ 10^{-7}$. The sudden increase in density between Ls=120 deg and Ls=150 deg is coincident with a doubling of the dust opacity τ observed by Spirit and Opportunity (Smith et al., 2006) (Modified from Fig. 4 from Forget et al., (2009)).

References

- Bertaux et al. (2006) JGR, 111, doi:10.1029/2006JE002690
- Bougher et al. (2000) JGR, 105, 17669-92
- Forget et al. (2009) JGR, 114, doi:10.1029/2008JE003086
- Smith et al. (2006) JGR, 111, doi:10.1029/2006JE002770

Budget Narrative

Two year effort, starting 1 May 2010, ending 30 April 2012

Effort of PI Withers	5% FTE per year for two years
Effort of Co-I Bertaux	15% FTE per year for two years
Effort of Co-I Montmessin	15% FTE per year for two years
Effort of TBD	15% FTE per year for two years

The position identified as "TBD" will be filled by a young scientist with SPICAM experience. Bertaux will select this individual, whose activities commence in Month 9 of this effort. See Statement of Work from Bertaux.

Treating some personnel as consultants in the proposed budget greatly simplifies institutional interfaces and reduces red tape that would otherwise delay the start of this time-critical effort. Bertaux and Montmessin consider that substantial delays would be introduced by the requirement to develop and implement a sub-contracting arrangement at LATMOS in France. This would introduce unnecessary risk into this effort.

Domestic Travel
1 person-trip (Withers) in Year 2 to 2-day MAVEN team meeting

Justification: Have in-depth discussions with broad range of MAVEN scientists and engineers to ensure activities are responsive to project needs. Attending MAVEN team meetings is a valuable supplement to telecons with the MAVEN project scientist and a small subset of other MAVEN personnel. Face-to-face discussions will also enhance the productivity of subsequent telecons.

International Travel
1 person-trip (Withers) in Year 1 to 2-day collaboration meeting in France

Justification: Verify progress on Tasks 0 and 1, discuss detailed implementation plans for Tasks 2, 3, and 4. A face-to-face meeting will be more effective than a series of telecons at achieving these objectives. It will also ensure a prompt initiation of this effort.

Other basic research costs, such as travel for foreign participants, supplies, computational expenses, possible publication costs, will be covered by the foreign participants or their institutions.