14 years of Mars' atmosphere monitoring by SPICAM on Mars Express

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Introduction: The SPICAM experiment onboard Mars Express has accumulated over the last 14 years a wealth of observations in different wavelength ranges [1, 2]. This suite of spectrometers has been utilized to characterize the atmospheric composition of Mars and its activity from the near-surface to above the exosphere. Despite the intermittent problems of the signal amplification in the ultraviolet channel, SPICAM has been able to record millions of spectra with an observational baseline planned to study the temporal and spatial variabilities of the atmosphere, allowing in particular the exploration of each specie's seasonal and decadal cycle (Figure 1).

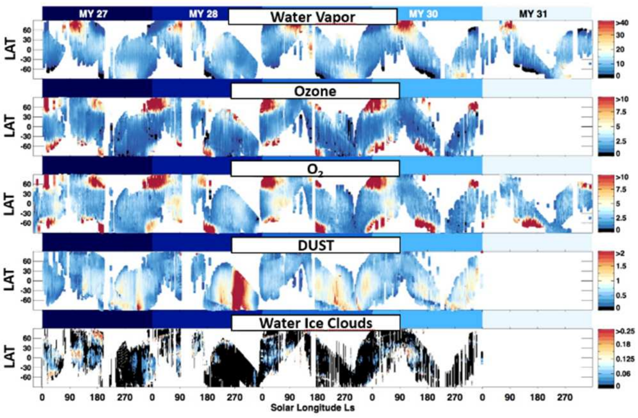

Figure 1: The multi-annual monitoring made by SPICAM water vapor, ozone, molecular oxygen singlet delta daytime emission in the near infrared, and dust as well as water ice opacity at 250 nm in nadir looking mode. (From [3])

Target and observation plans: SPICAM has the distinct capability of observing with a variety of geometrical configurations [1]; monitoring the column-integrated abundances of ozone, water vapor as well as aerosols in a nadir-looking mode, characterizing their vertical distribution in either stellar occultation (Figure 2) or solar occultation modes (Figure 3) and in some dedicated limb staring mode, SPICAM can infer the density of hydrogen atoms from 200 up to 10 000 km of altitude. In addition to Mars, SPICAM has also observed and characterized the surface of Phobos [4] and Deimos.

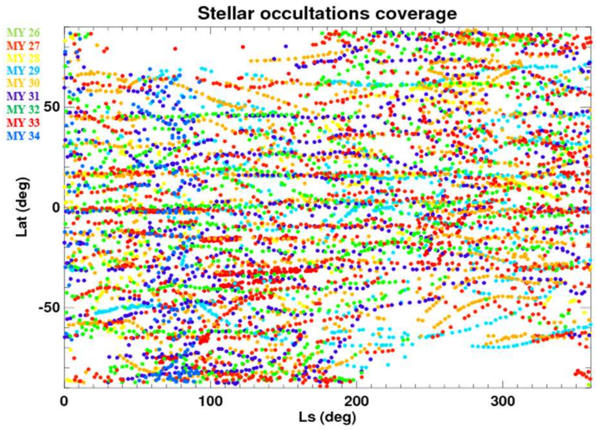

Figure 2: Locations of all stellar occultations made by SPICAM.

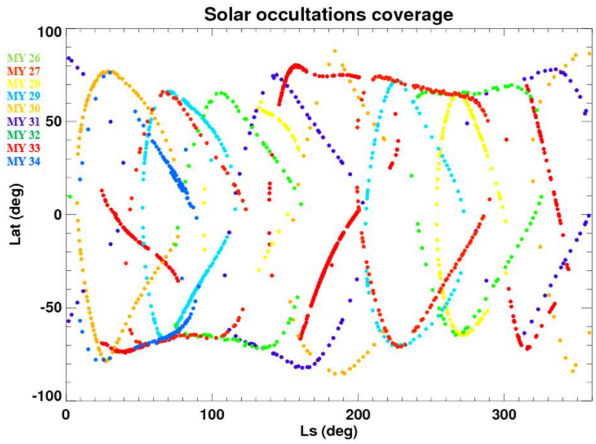

Figure 3: Locations of all solar occultations made by SPICAM.

SPICAM evolution: As of December 2014, SPICAM UV channel has ceased returning science data, sending only dark frames instead. This situation is the outcome of a progressive demise of the UV channel whose origin was first identified back in 2006. Then, the SPICAM UV channel started to exhibit an anomalous image intensifier behaviour, characterized by multiple sporadic and spurious changes of the high voltage setting (gain) during a sequence of observation.

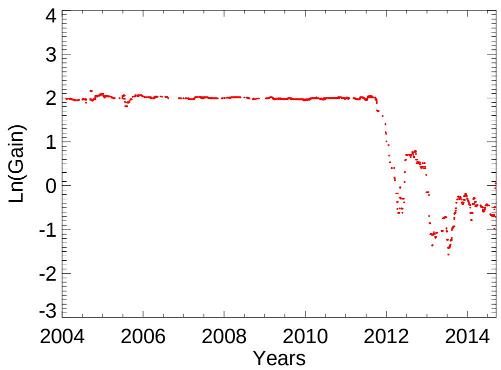

Figure 4: *Gain (in logarithmic scale) evolution with time for a fixed value of high voltage. This figure highlight the relatively stable behavior from 2004 to 2011, and the significant loss of sensitivity that occurred in November 2011 (from [3]).*

This degradation remained stable from 2006 to 2011 and the post-treatment process including a specific cleaning stage allowed to retain more than 90% of recorded spectra. The spurious gain changes suddenly increased in November 2011 while the mean gain of the intensifier simultaneously started to decrease (Figure 4). Combined effects could not be handled by post-treatment and data collected thereafter have so far not been analysed. However, new improvements are being implemented, permitting us to expect that the full dataset post-11/2011 will eventually be recovered. These improvements consist in a neat separation of the various signal components (straylight vs. signal) in combination with a deconvolution process that optimizes the rendered spectral resolution. Also, UV calibration is the topic of current efforts aimed to provide a revisited solar spectrum in a range of interest for SPICAM. These improvements are being tested to understand and quantify their impact on the production of the highest data levels.

Meanwhile, the infrared channel has exhibited a stable behavior throughout the MEX mission, and no noticeable degradation of the IR spectra quality has to be reported at this point.

SPICAM's science: With his dual ultraviolet (UV)-near Infrared channels, SPICAM observes spectral ranges encompassing signatures created by a variety atmospheric gases, from major (CO_2) to trace species (H_2O, O_3). Here, we present a synthesis of the observations collected for water vapor, ozone, clouds and dust, carbon dioxide, exospheric hydrogen and airglows.

The main scientific results have been collected thanks to the multi-annual monitoring made by SPICAM. Several results described in this poster are presented in greater depth in companion articles that specifically address a particular theme of the SPICAM observations [4, 5, and 6]. This article is organized around the following topics:

- **Lower atmosphere** sounding including observations and mapping of water vapor, ozone, O_2 and aerosols;
- **Middle atmosphere** sounding with a characterization of the CO_2, O_2, O_3 and aerosols from 50 to 150 km as well as NO emissions subsequent to N and O atoms recombination;
- **Upper atmosphere** sounding to infer the concentration of hydrogen and oxygen atoms above the exobase. (200 to 10000 km altitude)

Conclusion: SPICAM is entering his 8th Martian year around Mars and continues to collect measurements with its infrared channel. This dataset is unique insofar as it comes from the same calibrated instrument, continuously over the course of 14 years. Hence, it allows to probe different physical phenomena with multi-annual and seasonal timescale, as well as episodic events (e.g dust storms). SPICAM contributed to the improvement of the understanding of Mars's climate in several areas including lower atmosphere composition, chemical processes and the structure of the atmosphere.

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References:

[1] Bertaux, J.-L., et al., (2006), JGR 111, E10S09
[2] Korablev, O., et al., (2006), JGR, 111, E09S03
[3] Montmessin, F., et al., (2017), ICARUS, 297
[4] Bertaux, J-L., et al., (2018), submitted
[5] Trokhimovskiy, A., et al., (2015), ICARUS, 251
[6] Guslyakova, S., et al., (2015), ICARUS, 122