EPSC Abstracts
Vol. 13, EPSC-DPS2019-283-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

The Mars Year 34 Global Dust Storm and Atmospheric Measurements with Multiple Generations of Alpha Particle X-ray Spectrometers

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Abstract

The Alpha Particle X-ray Spectrometer (APXS) on the Mars Science Laboratory (MSL) rover *Curiosity* utilizes the principles of X-ray spectroscopy to determine the composition of rocks and unconsolidated material on Mars. Its predecessors, the Mars Exploration Rover (MER) APXS instruments, routinely acquired spectra of the Martian atmosphere. These spectra measure the abundance of argon (Ar) in the atmosphere, providing ground-truthed data for Mars climate models through the use of Ar as a tracer. Here we present these results alongside atmospheric measurements with the MSL APXS that include spectra acquired during the Mars Year (MY) 34 global dust storm (GDS).

1. Introduction

The APXS utilizes complementary particle-induced X-ray emission and X-ray fluorescence techniques to determine the composition of Martian materials [2,3,5]. Due to the unavoidable cm-scale separation between the APXS sensor head and the sample being interrogated, a column of CO_2-dominated air exists in every APXS analysis on Mars. This not only results in the attenuation of low-energy X-rays induced within the sample (e.g., sodium), but also results in the presence of an atmospheric Ar peak in every spectrum of a solid target (e.g., Fig. 1, blue).

The atmosphere of Mars does not directly produce any observable peaks in APXS spectra, with the exception of the aforementioned Ar (K_α and K_β) peaks [6]. The Martian atmosphere is ~2% argon v/v [1]; the remaining constituents are not directly detected with the APXS due to their sub-keV characteristic X-ray line energies.

APXS atmospheric spectra (e.g., Fig. 1, red) also contain peaks associated with instrument components in addition to the Ar peaks from the atmosphere. The magnitude of the Ar peaks in atmospheric spectra depends on the density of Ar in the atmosphere. Correcting for thermal variation, the observed variation in Ar peak area over time is a proxy for varying Ar partial pressure (p_{Ar}). These data provide the only high-frequency ground-truthed low-latitude data for Mars global climate modelers (e.g., [4]).

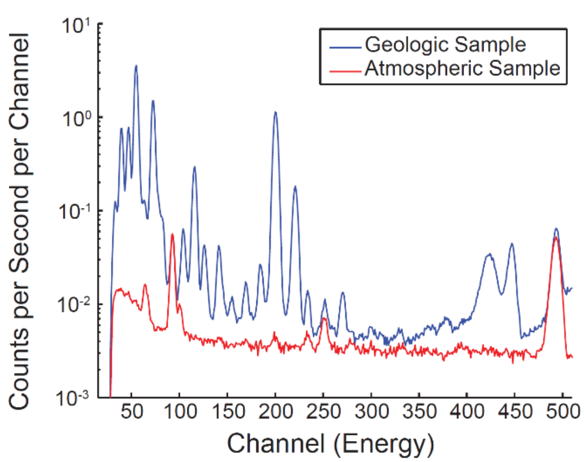

Figure 1: APXS spectra acquired by the MER rover *Opportunity*. Atmospheric spectrum (red) corresponds to a measurement duration of 16 hours. Geologic spectrum (blue) corresponds to a measurement duration of 11.5 hours. The argon peak is visible around channel 100, especially in the atmospheric spectrum [6].

As the APXS instruments were not designed nor calibrated for analyses of the Martian atmosphere, a calibration was conducted using high-frequency, long-duration, and ideal-resolution atmospheric spectra acquired by the MER rover *Spirit* while it was stuck and had power to spare. The best performing model was applied to the 1764.8 hours of quality *Opportunity* rover APXS atmospheric spectra as well as the ~270 hours of quality atmospheric spectra acquired by *Curiosity*'s APXS prior to May 2019, including ~30 hours during the MY 34 GDS.

2. Results and Conclusions

The APXS atmospheric spectra acquired by the *Opportunity* rover demonstrate a rather consistent p_{Ar} cycle [6] that is in agreement with global climate models [4] and low-frequency high-accuracy measurements by SAM on the *Curiosity* rover. Short-term enrichments are observed on top of the smooth periodic curve. A possible explanation for the short-lived enrichment in Ar is provided by [6]. Work in collaboration with the authors of [4], who see a similar feature in their climate models, will investigate the source of the enrichment further.

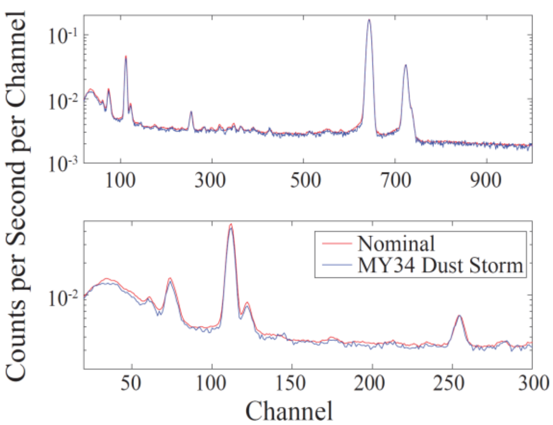

Figure 2: MSL APXS atmospheric spectra acquired during the MY global dust storm (blue) and under nominal conditions (red). The lack of peaks associated with Mars dust is consistent with the expected low density of dust in the atmosphere. Spectra are a sum of all measurements in the corresponding acquisition conditions.

A GDS swept Mars in MY 34 ultimately resulting in the end of the *Opportunity* rover mission. The *Curiosity* rover, powered by a nuclear ^{238}Pu source, is not dependent on solar illumination to generate power and thus was relatively unencumbered by the significant increase in atmospheric opacity.

During the MY 34 GDS, *Curiosity* acquired ~30 hours of atmospheric measurements with its APXS. A direct comparison of MY 34 GDS atmospheric spectra with those acquired under nominal conditions does not show any signals associated with dust (see Fig. 2). While atmospheric opacity at *Curiosity*'s landing site was at record levels for the mission, the density of dust in the atmosphere was not significant enough for the APXS to detect. The only differences observed when comparing MY 34 GDS APXS atmospheric spectra with their nominal counterparts are associated with instrument effects (e.g., source decay). The APXS would require ~100x more dust in the atmosphere than was estimated optically in order to detect airborne dust spectrally.

Acknowledgements

This work was supported by NASA/Caltech/JPL and by the Canadian Space Agency. Much appreciation goes to NASA/JPL for their support, dedication, and invaluable expertise during development and operations of both the MER and MSL missions.

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