SIX MARS YEARS OF ATMOSPHERIC ARGON MEASUREMENTS WITH THE MARS EXPLORATION ROVER ALPHA PARTICLE X-RAY SPECTROMETERS.

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Introduction: Since landing in 2004, the Mars Exploration Rover (MER) Opportunity (MER-B) has been exploring Meridiani Planum. Part of its scientific payload is the Alpha Particle X-ray Spectrometer (APXS), designed for determining the chemistry of solid samples, such as rocks and soils, when deployed to near contact [1]. After landing, atmospheric measurements using the APXS on MER-B and its twin Spirit (MER-A) were proposed [2] to study the long-term variation in the abundance of argon in the near-surface equatorial atmosphere of Mars.

The atmosphere of Mars is dominated by CO_2 (95% v/v) with minor amounts of Ar (<2%) and N_2 (<3%) and other trace gases [3]. Of the elements that compose the atmosphere of Mars, the APXS is only able to directly detect Ar (see Figure 1). At the winter pole, especially during southern winter, much of the CO_2 freezes out of the atmosphere generating a global pressure gradient. Non-condensable gases, like Ar, are affected by this gradient and accumulate at the winter poles - confirmed by orbital measurements [4]. Atmospheric measurements with the MER-B APXS have been acquired with a semi-regular cadence over a span of 6 Mars years. This dataset provides insights into seasonal behavior of near-surface non-condensable gases near the equator of Mars. This work presents the most thorough analysis of this data set and is complemented by recent measurements with instruments on the Mars Science Laboratory (MSL) rover Curiosity. In addition to atmospheric analyses, the study provides the best statistics to date on the ubiquitous MER APXS background.

Method: The APXS was not designed to measure the atmosphere of Mars. As such, no calibration was conducted pre-flight to characterize the instrument response to a variable atmosphere. Limited lab testing under Mars-like conditions (10 mbar CO_2) suggests a <1% difference in Ar peak area compared to vacuum. Absent calibration, the analysis method relied on Mars data. A near-ideal calibration data set is provided by MER-A through several long-duration atmospheric measurements with the APXS conducted almost daily while the rover was stuck. The short timescale implies little change in atmosphere should be observed and thus the analysis methods tested should in turn be stable. The most-stable model with the least relative errors was applied to the abundance of MER-B atmospheric spectra. Spectra acquired during warmer temperatures and early in the mission (due to the increased background associated with gammas from the Mössbauer instrument) were filtered out of the MER-B analysis.

Results: After filtering MER-B atmospheric spectra, over 1,600 hours of data remained. When properly summed, the resulting spectrum provides an unprecedented level of statistics to characterize the APXS spectral background present in every APXS measurement (see Figure 2).

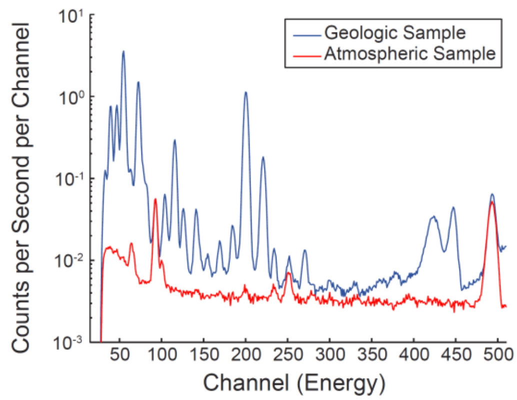

Figure 1: Comparison of MER-B spectra from a solid sample (blue, 11.5h duration) and atmospheric sample (red, 16h duration). The Ar K_α peak is situated around channel 100.

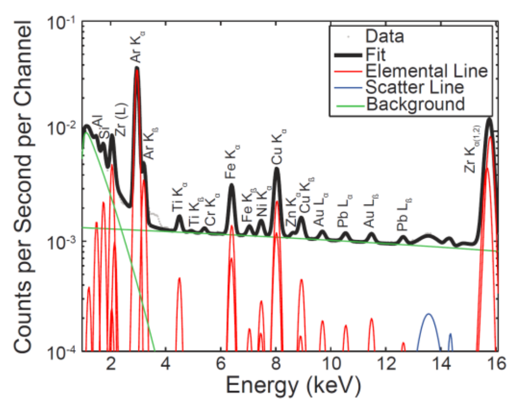

Figure 2: Least-squares fit of MER-B atmospheric spectra totaling 1614.5 hours in duration. With the exception of the Ar K_α and K_β peaks, all elemental signals originate from the APXS instrument.

Individual atmospheric measurements with the APXS do not provide the level of confidence of other surface-based atmospheric composition analysis instruments. However, the frequency at which measurements are taken with the APXS is much higher. Coupled with the 6 Mars years and counting of data obtained, the data set presented is of significant scientific value and complementary to the higher accuracy but lower frequency quadrupole mass spectrometer (QMS) measurements with the Sample Analysis at Mars (SAM) instrument on MSL.

The 1,600+ hours of filtered MER-B atmospheric data were sol-summed for improved statistics. The best analysis method, as determined through analysis of MER-A data, was applied and the relative argon peak areas scaled by temperature to yield the argon partial pressure (p_{Ar}). Plotted chronologically with proper source-decay compensation applied, an annual periodicity in the argon partial pressure was observed.

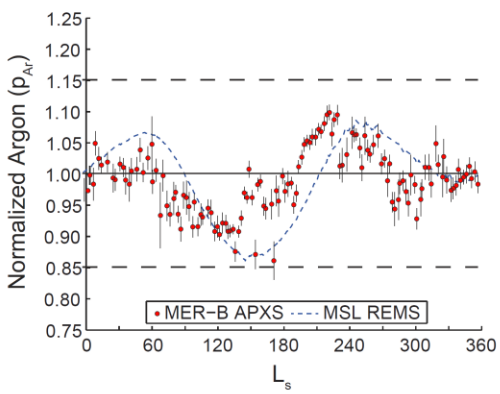

Figure 3: MER-B normalized p_{Ar} from L_s-binned sum spectra. Normalized pressure from MSL overlaid for comparison.

Plotted against solar longitude (L_s), the year-to-year variation in the sol-summed spectra was minimal, supporting further improved statistics through summing by L_s. Qualitatively, the p_{Ar} from MER-B are in agreement with pressure measurements from Viking and MSL in both the relative timing and magnitude of the variability (see Figure 3). A sharp rise in p_{Ar} was observed around L_s 150 coinciding with start of the northward migration of the southern polar air mass at the onset of southern spring. The MSL pressure sensor on the Rover Environmental Monitoring Station (REMS) instrument observed a short-lived change in pressure consistent with a 10% increase in non-condensable gases. A similar rise in p_{Ar} is possibly seen ~180 L_s later from a north-sourced air mass moving south. Future measurements targeting these two L_s periods will improve detection confidence and statistics.

Due to the absence of a pressure monitoring instrument on either MER rover, the argon mixing ratio can be estimated as a ratio of the MER-B-measured p_{Ar} to the MSL-measured pressure [5], each normalized to L_s 0. The argon mixing ratio observed by the MER-B APXS is consistent with QMS measurements from SAM on MSL [6].

Summary: At over 1,600 hours of good-resolution atmospheric spectra, extremely low count rate signals were resolved permitting the study of the ubiquitous APXS background to an unprecedented level of detail. Through model testing using the MER-A APXS, a calibration was conducted and the ideal analysis method for analyzing p_{Ar} was determined. The p_{Ar} variation observed matched the expected as predicted by current models and offers a significant reduction in uncertainty compared to previous work.

For the first time, an annual short-lived equatorial enrichment (~10%) in argon was observed, centered around L_s 150. The location of MSL inside Gale Crater may inhibit measuring this short-lived increase in p_{Ar} with SAM. However, current argon mixing ratio measurements with the SAM QMS are in agreement and complement each other nicely given the high frequency of APXS measurements and the high accuracy of QMS. The authors propose, in collaboration with the MSL SAM, and REMS teams, to increase the frequency of measurements around L_s 150 (and L_s 325) to attempt to further characterize this (these) short-lived increase(s) in non-condensable gas abundance at the equator using spacecraft on opposite sides of Mars.

References:

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