LOW-LATITUDE NEAR-ANTIPODE MEASUREMENTS OF ATMOSPHERIC ARGON WITH THE MARS EXPLORATION ROVER AND MARS SCIENCE LABORATORY ALPHA PARTICLE X-RAY SPECTROMETERS. S. J. VanBommel[1,2], R. Gellert[2], B. C. Clark[3], D. W. Ming[4], C. Schröder[5], A. S. Yen[6], J. A. Berger[2], N. I. Boyd[2], V. A. Flood[2], J. U. Hanania[2], C. D. O'Connell-Cooper[7], L. M. Thompson[7], and B. J. Wilhelm[2], [1]Washington University in St. Louis, St. Louis, MO, [2]University of Guelph, Guelph, ON, Canada, [3]Space Science Institute, Boulder, CO, [4]Johnson Space Center, Houston, TX, [5]University of Stirling, Stirling, UK, [6]California Institute of Technology, Pasadena, CA, [7]University of New Brunswick, Fredericton, NB, Canada.

Introduction: The Mars Exploration Rover (MER) *Opportunity* and the Mars Science Laboratory (MSL) rover *Curiosity* are both equipped with an Alpha Particle X-ray Spectrometer (APXS) [1, 2]. Though designed for chemical analyses of solid samples such as rocks, soils, and unconsolidated material, the APXS is also capable of detecting argon in the atmosphere of Mars [3].

Argon (Ar) constitutes approximately 2% by volume of the Martian atmosphere which is dominated (~95%) by CO_2 [4]. Noncondensable gases in the atmosphere of Mars (e.g., Ar, N_2) accumulate over the winter pole as CO_2 is deposited onto the frost cap [5]. The following spring, CO_2 sublimates from the winter polar cap and a global pressure gradient drives circulation to lower latitudes.

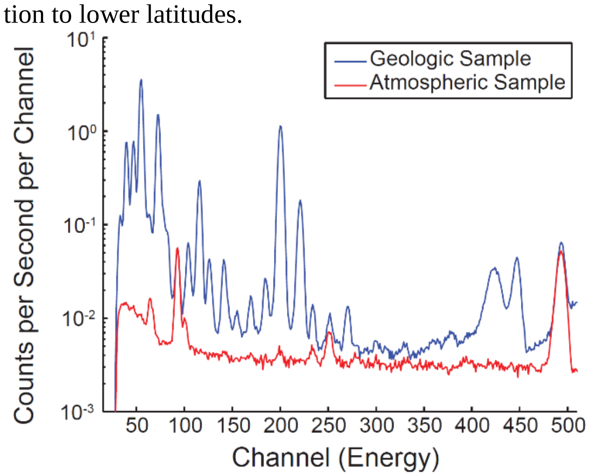

Figure 1: APXS spectra acquired by the MER rover Opportunity. Atmospheric spectrum (red) corresponds to a measurement duration of 16 hours. Geologic spectrum (blue) corresponds to a measurement duration of 11.5 hours. The argon peak is visible around channel 100, especially in the atmospheric (red) spectrum. Figure from [3].

In APXS atmospheric spectra, Ar is the only signal that originates from the atmosphere – the remaining peaks are sourced from the instrument itself (e.g., Figure 2). Figure 1 offers a comparison of atmospheric (red) and geologic (blue) spectra acquired by the MER APXS. The Ar peak is visible around channel 100 with most of the signal associated with the column of air inside the MER APXS instrument [3, 6]. Peaks present in a MER APXS atmospheric spectrum are presented in Figure 2. Due to a different instrument configuration, a smaller minimum atmospheric column can be obtained with the MSL APXS. This results in the Ar peak appearing as a mere shoulder between the chlorine and potassium peaks of MSL APXS geologic spectra acquired in contact with the surface.

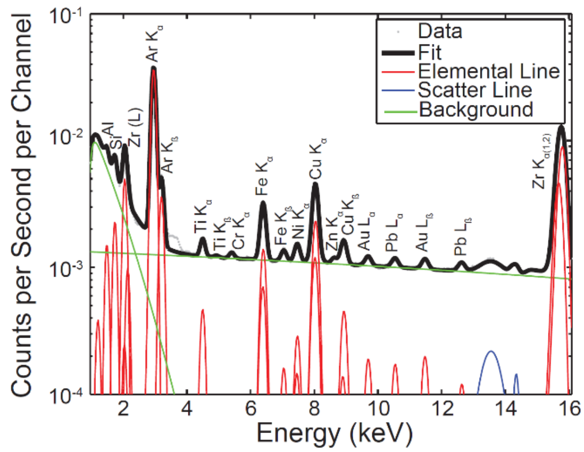

Figure 2: Least-squares fit of a sum spectrum of 1,600+ hours of Opportunity atmospheric spectra. Figure from [3].

The MER and MSL APXS instruments have operated as three atmospheric Ar monitoring stations distributed thousands of kilometers apart in the lower latitudes of Mars. The instruments have acquired thousands of hours of atmospheric spectra over several Martian years. These measurements provide information in regards to variation in the density of argon in the atmosphere. Argon is an effective tracer for global atmospheric circulation. Measurements of Ar with the APXS instruments provide ground-based observations for global climate models (e.g., [7, 8]).

Method and Results: Continued analyses of *Opportunity*'s APXS atmospheric spectra follow that of [3]. The same method was modified for analyses of spectra acquired by *Curiosity*'s APXS.

Previous work (i.e., [3]) demonstrated that the observed annual argon partial pressure (p_{Ar}) cycle (Figure 3) is consistent with the expected condensation flow driven by the deposition and subsequent sublimation of atmospheric CO_2 at the winter pole. The resulting variation in the argon volume mixing ratio (VMR) observed by *Opportunity* is in agreement with global climate models (e.g., [8]).

Through data reduction, statistical noise is reduced resulting in an annual p_{Ar} cycle that is periodic and varies smoothly. An exception arises around solar longitude (L_s) 155, where a short-duration enrichment in argon is observed [3]. The enrichment is attributed to the leading-edge of a northward-migrating air mass that was enriched in Ar over the southern polar cap as CO_2 was deposited during southern autumn and winter. A ~10% enrichment in noncondensable gases at low-latitudes would manifest as a <1% increase in overall pressure, and is consistent with pressure observations on the other side of Mars by MSL REMS (Figure 3, inset, from MY 32) [3, 9]. A potential detection of a weaker argon-enriched southward migrating air mass is observed around L_s 325, roughly 180° L_s after its northward counterpart.

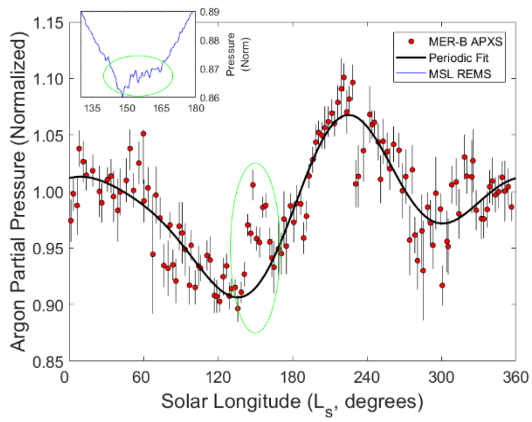

Figure 3: Opportunity APXS argon partial pressure measurements reduced through summation by similar L_s. A periodic least-squares fit is applied. A short-term deviation is observed around L_s 155. A parallel observation was made by MSL REMS on MY 32.

A coordinated effort was undertaken to monitor the atmosphere on opposite sides of Mars at similar latitudes with the *Curiosity* and *Opportunity* rover APXS instruments. *Opportunity* APXS measurements were limited by an ongoing investigation of Perseverance Valley that included several APXS geochemical analyses. *Curiosity*'s APXS acquired roughly 90 hours of atmospheric integration time between sol 1981 and sol 2084 (~L_s 137 to L_s 195). The *Opportunity* APXS acquired roughly 80 hours of atmospheric spectra over a similar timeframe.

During the joint observational campaign, a large global dust storm (GDS) rapidly enveloped Perseverance Valley (and *Opportunity*) and later Gale Crater (and *Curiosity*). *Curiosity*'s APXS atmospheric observational cadence continued through the GDS. A comparison of atmospheric spectra acquired under nominal (no GDS) conditions and during the MY 34 GDS is provided in Figure 4.

Peaks associated with Mars dust are not visible in GDS MSL APXS atmospheric spectra, even when the data are reduced for improved statistics. The LOD for both SO_3 and Cl, signature elements in Mars dust [10, 11], is 0.2 wt% per [2], for a geologic matrix. The MSL APXS sensitivity to SO_3 and Cl in the atmosphere can be characterized through the application of [6]. As S and Cl peaks are not visible in Figure 4 (between the Zr L line at channel ~75 and the Ar K_α line at channel ~110), the determined sensitivity offers an upper limit on the abundance of dust in the volume of atmosphere interrogated by the APXS during the GDS.

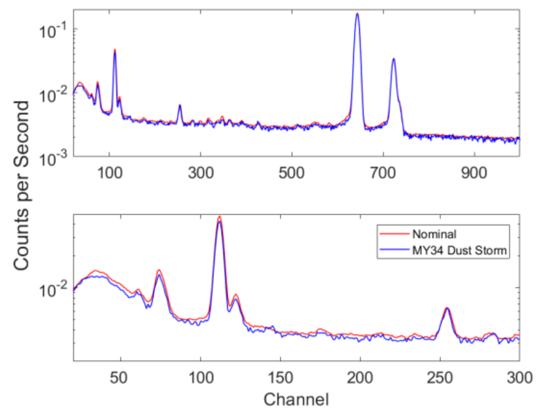

Figure 4: MSL APXS atmospheric spectra acquired during the MY global dust storm (blue) and under nominal conditions (red). The lack of peaks associated with Mars dust is consistent with the expected low-density of dust in the atmosphere. Spectra are a sum of all measurements in the corresponding acquisition conditions.

Conclusions: The MSL and MER APXS instruments are capable of high-frequency atmospheric monitoring. Future APXS measurements on *Opportunity* and *Curiosity* will continue to monitor the condensation flow of argon on Mars from opposite sides of the planet. Measurements of the atmosphere during the MY 34 GDS did not contain spectral features signature to dust.

Acknowledgments: 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.

References: [1] Gellert et al., (2006), JGR, 111. [2] Gellert et al., (2015), Elements, 11. [3] VanBommel et al., (2018), JGR, 123. [4] Franz et al., (2017), PSS, 138. [5] Sprague et al., (2012), JGR, 117. [6] VanBommel et al., (2019), NIM:B, 441. [7] Lian et al., (2012), Icarus, 218. [8] Forget et al., (1999), JGR, 104. [9] Martínez et al., (2017), SSR, 212. [10] Yen et al., (2005), Nature, 436. [11] Berger et al., (2016), GRL, 43.