DETECTION OF ADDITIONAL ELEMENTS FROM THE MARS ODYSSEY GRS MEASUREMENTS.

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Introduction: Analysis of data from Mars by the Odyssey Gamma-Ray Spectrometer (GRS) has produced maps for 6 elements (H, Si, Cl, K, Fe, and Th) [1]. K and Th gamma rays are produced by natural radioactivity. Gamma rays from the other elements are produced by neutron interactions in the martian surface. These elements have either a high concentration on Mars (Si, Fe) or a high-cross section for neutron interactions (Cl, H).

Other elements on Mars can also be detected. Due to a lower abundance, a significant background, or a smaller cross section, longer observing times are required to determine their concentrations. We report here preliminary results for several additional elements, some of which can be mapped at poorer spatial resolution and others that can only be analyzed for large regions on Mars. One method to validate the results for these weaker elements is to determine the composition independently for two or more gamma rays and to compare the results. The results shown below are all from the analysis of a large belly-band region (~ 45° S to ~45° N) accumulated over the first three years of the mission [1].

Sulfur: Sulfur has two significant gamma-rays [2]; one due to neutron capture at 5420 keV and one due to neutron scatter at 2230 keV, which has a Doppler broadened width of about 10 keV. The results of analyzing these two peaks are shown in Figure 1.

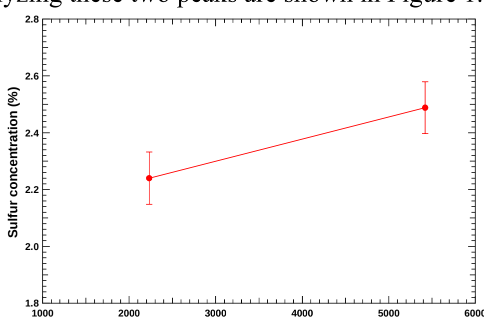

Figure 1 –Belly-band composition results for two different Sulfur gamma rays. The weighted mean of these values is 2.4% .

The belly-band value for Cl is 0.5% [1]; this gives a S/Cl ratio of about 5, similar to the lander results [3].

Uranium: Uranium composition is more difficult to determine than the other two major radioactive elements (K and Th) due to the low gamma-ray fluxes compared to the others and interferences the most prominent Uranium gamma-rays. For example, the 1764.5 keV Uranium peak is close to a 1762 keV Ti peak; the GRS cooler contains a large amount of Ti [2]. There was also a measurable amount of Uranium from the local material that has to be subtracted. The results of an analysis of three prominent gamma rays from Uranium are shown in Figure 2.

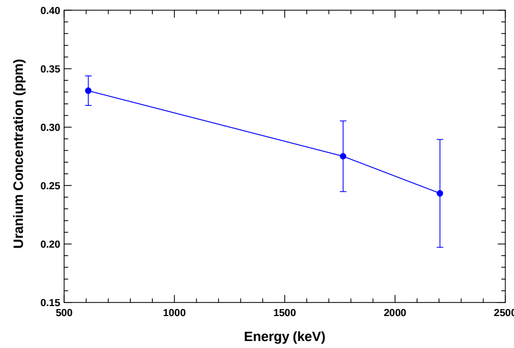

Figure 2 – Belly-band results for three Uranium peaks. The weighted mean for these peaks is 0.32 ppm.

Aluminum: Aluminum has three prominent gamma rays; two due to neutron scatter and one due to neutron capture. One of the inelastic scatter gamma rays is a Doppler broadened peak at 2211 keV. This is part of a complicated region around the 2223 keV Hydrogen peak that also includes a Uranium peak at 2204 keV and a Sulfur peak at 2230 keV, as described in [2]. Since that analysis, constraints on the peak width of the Doppler broadened lines were obtained from laboratory measurements. There was a measurable and significant signal from Aluminum during times over thick polar caps when the carbon dioxide attenuates most surface gamma rays [1,2]. These background gamma rays from the local material are not constant, but depend on the fast and thermal neutron flux at the detector. Titanium peaks were used as neutron monitors to determine the Aluminum background count rates. Results of analysis of the three Aluminum peaks for the belly-band are shown in Figure 3.

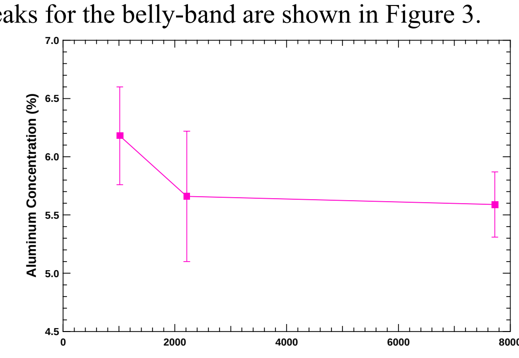

Figure 3 – Belly-band composition results for three Aluminum gamma rays. The weighted mean for these peaks is 5.8% .

Calcium: Calcium has both a prominent neutron capture gamma ray at 1943 keV and a neutron scatter gamma ray at 3736 keV. The scatter gamma ray is in a very complicated region dominated by the very strong Doppler broadened gamma ray from Oxygen and Carbon at 3927 keV [2], and about a third of the signal is from a Ti gamma ray. The analysis of that gamma ray has a fairly large uncertainty. The capture gamma ray has a much smaller uncertainty, and only that gamma ray will be used to map Ca. The results for the belly-band are shown in Figure 4.

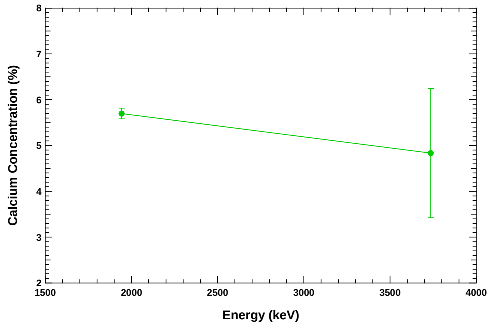

Figure 4 – Belly-band results for two Calcium peaks. The weighted mean is 5.6% .

Other Elements: Typical count rates for the well-determined Silicon 1779 keV gamma ray were 0.034 counts/s [2]. Typical count rates for the Aluminum 2211 keV gamma ray were 0.0045 counts/s. There are other elements that can be analyzed, but they have even lower count rates, typically down by factors of 2-3. These elements cannot be mapped with the current statistics, but can only be analyzed for the belly-band and perhaps some other large regions on Mars. Improvement in the uncertainty for these elements will require significantly longer accumulation times.

Sodium: Sodium has three prominent gamma rays at 3587 keV, 3981 keV, and 6395 keV, all produced by neutron capture. The fit to the 3587 keV peak is shown in Figure 5.

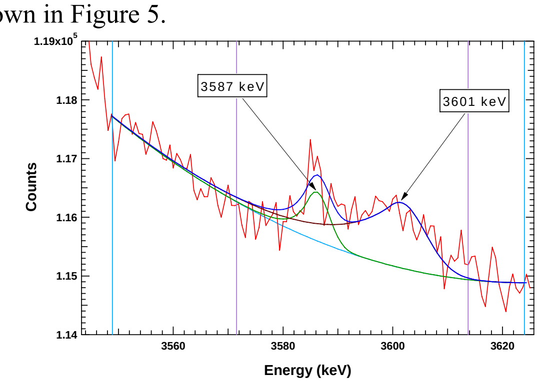

Figure 5 - Fit to the 3587 keV Sodium peak in the belly-band spectrum. The broadened peak at 3601 keV is from $^{56}Fe(n,n\gamma)$.

Chromium: The best peak for analyzing Chromium is the 8884 keV neutron capture gamma ray. Due to the relatively low efficiency of the detector at this high energy, the count rate from the single escape peak will be 1.5 times higher than from the full-energy peak. The fit to the 8373 keV peak is shown in Figure 6.

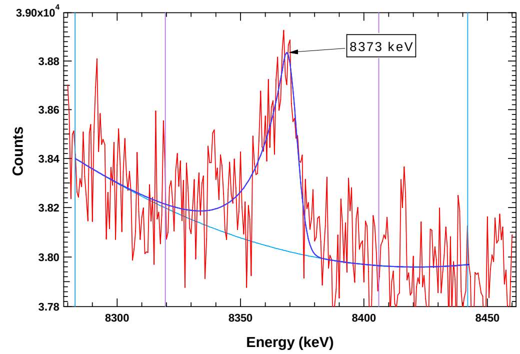

Figure 6- Fit to the 8373 keV Chromium single escape peak in the belly-band spectrum.

Manganese: The most prominent Manganese peak is the 7244 keV neutron capture gamma ray. The full-energy peak and the single escape peak have similar count rates. However, these peaks are close to large escape peaks from Chlorine gamma rays at 7790 keV. The difficulty in analyzing this Manganese peak is shown in Figure 7.

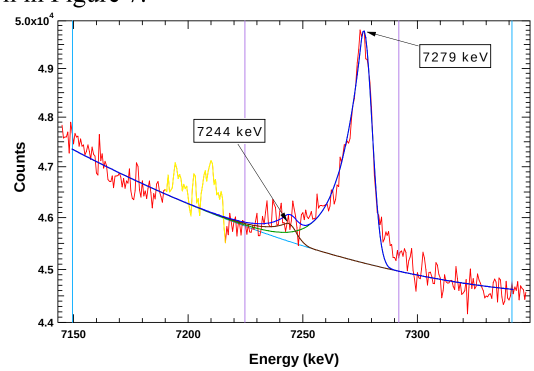

Figure 7 – Fit to the 7244 keV Manganese peak in the belly-band spectrum.

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References: [1] Boynton W. V. et al. (2007), *JGR, 112, E12S99*, doi:10.1029/2007JE002887. [2] Evans, L. G. et al. (2007), *JGR, 112, E03S04*, doi:10.1029/2005JE002657. [3] Karunatillake S. et al. (2007) *JGR, 112, E08S90*, doi:10.1029/2006E002859.