MARTIAN GAMMA ALBEDO.

O. Gasnault[1], S. Maurice[2], C. d'Uston[1], and W.V. Boynotn[3], [1]Centre d'Etude Spatiale des Rayonnements (9, avenue Roche, 31028 Toulouse, France. Olivier.Gasnault@cesr.fr), [2]Laboratoire d'Astrophysique (14, avenue Belin, 31400 Toulouse, France), [3]Lunar and Planetary Laboratory (Tucson, AZ).

Introduction: Chemical measurements of Martian surface are currently made using γ-ray and neutron spectrometers onboard Odyssey [1-6]. The high-quality γ-ray detector reveals spectral lines representative of bulk elements at the surface of the planet [7]. However, interpreting these spectra is challenging because of the low signal-to-background ratio.

Here, to better handle the overall γ emission from Mars, we analyze the total number of counts measured by the γ-ray spectrometer. From these measurements, we derive a γ-albedo parameter, which reveals information on Martian atmosphere through spatial and time variations.

γ-Albedo Definition: By extension of the well-known concept of albedo in visible wavelengths, we define the γ-albedo as the ratio between the number of photons emitted by Mars at energy higher than 100 keV, and a value representative of γ source.

This definition implies that (1) we can make the difference between photons coming from Mars and any other events in the detector; (2) we have a measurement of γ source activity. The first point is resolved by selecting a spectral window corresponding mostly to Martian emissions. The second point can be overcome with the detector counting rate at the highest energies, called ULD for Upper Level Discriminator. Indeed, we will illustrate in the following text that ULD counting rate is a measurement of Galactic Cosmic Ray activity, which in turn is the major source of γ-photons [8].

Observations and Simulations: We processed all available spectra between February 20, 2002, and September 22, 2002. A total of 693,329 spectra cumulated over 19.6 s have been analyzed. The mean number of counts between 100 keV and 10 MeV is 176 counts s^{-1} (170 after boom deployment), with a standard deviation of about 20 counts s^{-1}.

On the other hand, we developed a full numerical model of the instrument [9]. Expected background counting rate has been evaluated. Figure 1 shows the various components forming the background in the detector, and their relative levels. For an average Sun activity, we predicted a total background level at about 160 counts s^{-1}. As shown on Figure 1, the actual measurement is higher (10 %) due to discrepancies at high-energy, but in the following we concentrate on the low-energy band where the agreement is good between measurement and numerical calculations.

Figure 1 reveals that Martian flux of γ photons (other than rays contributing to spectral lines) is dominant between 0.5 and 1,1 MeV, as more than 90 % of the background. We therefore use that spectral window to define the γ-albedo thereafter. This is a conservative definition: the energy window could be ex-

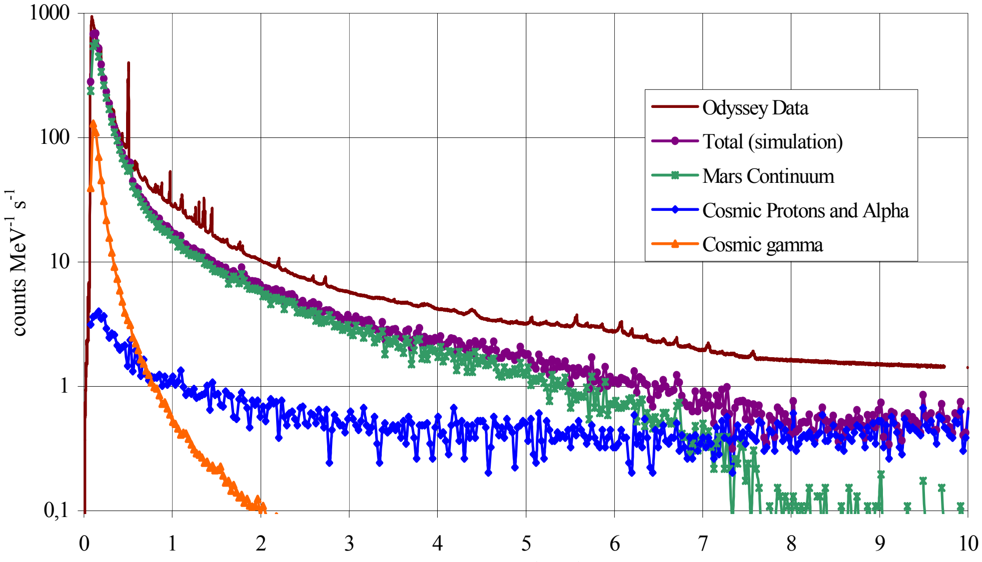

Figure 1: Odyssey Gamma-Ray Spectrometer observation at Mars, and the decomposition of its background into various components as predicted by numerical simulations. Cosmic electrons (not shown) are included. Actual measurements include spectral lines representative of soil composition.

tended up to 4 MeV, where signal from Mars still contributes for 80 % of the total.

Note that we also see in Figure 1 the dominant effect of Galactic Cosmic Rays (proton and alpha particles) at high-energy, justifying the use of the counting rate at high-energy (ULD) to normalize the γ-albedo.

Time Variations: The γ-albedo changes as a function of time. Figure 2 shows the γ-albedo for the successive orbits of Odyssey. Large gaps in Figure 2 match the two annealing operations (orbits 220-414, and 939-1131) and the boom deployment (orbits 1252-1299). The strong decrease after orbit 1870 is a residual effect of a Solar Particle Event in July 2002 that impacted the measurements for a long time [10]. Discontinuities are not fully understood today and will be addressed in future works. A periodical variation with a 6-orbit frequency has been identified, which reveals longitudinal variations. These spatial variations are interpreted as atmospheric effects in the next paragraph. At last, an additional recurrent variation with a frequency of about 150 orbits (12.5 days) might be present, but need to be confirmed.

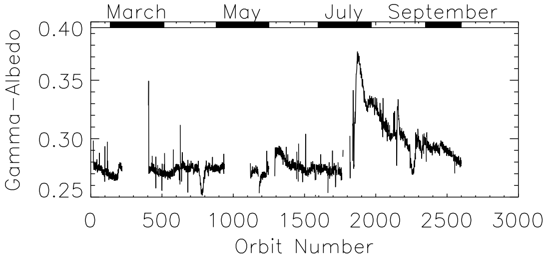

Figure 2: Time variation of Martian γ-albedo.

Spatial Variations: Figure 3 shows the correlation between the γ-albedo and the topography of the surface. Obviously, the lower is the surface, the thicker is the atmosphere and more photons are lost before reaching the spacecraft.

Figure 3 reveals a significant difference between polar and equatorial latitudes. The γ-albedo is 5 % lower in polar regions than in equatorial regions. Previous results demonstrate the presence of light elements (hydrogen and carbon) in high concentrations in the near subsurface at both poles [11-13]. We know that the presence of light elements strongly diminish the neutron production in the soil [14], and consequently the number of γ-photons produced. Realistic simulations are planned to confirm this interpretation.

Equatorward, the relationship between the γ-albedo and topography looks linear with an excellent correlation coefficient (Figure 3). This relationship holds for energy ranges other than [0.5, 1.1] keV, but the slope of the linear regression changes. This result was expected since the transparency of the atmosphere is function of the photon energy. Preliminary results demonstrate that the slope, correlating the γ-continuum to the topography, follows a law as $E^{-1.6}$, where E is the γ-photon energy.

Conclusion: Defining and using the Martian γ-albedo measured by Odyssey, we hope to derive some information on the Martian atmosphere. Because of a large counting rate, the γ-albedo presents a good statistics. This parameter is also mostly independent on soil compositions, and therefore it is more appropriate to study atmospheric effects than spectral lines.

A first result is the fact that the γ-albedo is representative of atmospheric attenuation. From there, we should be able to derive the atmospheric scale or/and attenuation coefficient. If this technique is sensitive enough, we might be able to monitor some changes with time or seasons. Note that this study can be supported by neutron spectroscopy, which is also sensitive to the mass of the atmosphere [15]

Spatial variations must also be investigated in details to help in extracting spectrum lines that represent Martian soil compositions.

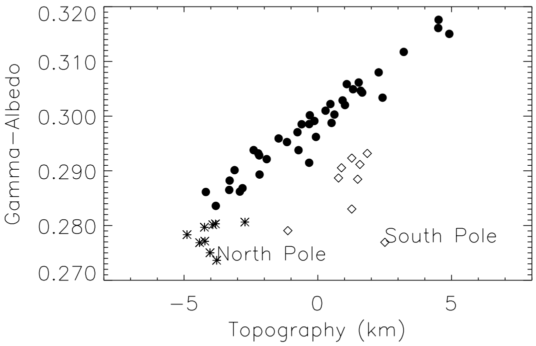

Figure 3: Correlation between the γ-albedo and the topography. Diamonds are south of -45° latitude, asterisks are north of +45° latitude, and plain circles are equatorward. Spatial resolution is 30° at the equator.

References: [1] Boynton W.V. et al. (2003) *LPSC 34*. [2] Keller J.M. et al. (2003), *LPSC 34*. [3] Taylor G.J. et al. (2003) *LPSC 34*. [4] Mitrofanov I.G. et al. (2003) *LPSC 34*. [5] Feldman W.C. et al. (2003) *LPSC 34*. [6] Litvak M.L. et al. (2003) *LPSC 34*. [7] Reedy R.C. et al. (2003) *LPSC 34*. [8] Evans L.G. et al. (1993) *Remote Geochemical Analysis,* C. Pieters and P.A.J. Englert (ed.), 167-198. [9] Gasnault O. (1999) *PhD thesis #3531*, Université Paul Sabatier, France, pp.167. [10] Evans L.G. et al. (2003) *LPSC 34*. [11] Boynton W.V. et al. (2002) *Science*, *297*, 81-85. [12] Feldman W.C. et al. (2002) *Science, 297,* 75-78. [13] Mitrofanov I.G. et al. (2002) *Science, 297,* 78-81. [14] Gasnault O. et al. (2001) *GRL, 28, 19,* 3797. [15] Prettyman T.P et al. (2003) *LPSC 34*.