GALACTIC COSMIC RAY INDUCED NEUTRONS ON AND AROUND MARS. L.M. Martinez-Sierra[1] (lmsierra@jpl.nasa.gov), I. Jun[1], B. Ehresmann[2], D. Hassler[2], M.L. Litvak[3], I.G. Mitrofanov[3], C. Zeitlin[4]. [1]The Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA. [2]Southwest Research Institute, Space Science and Engineering Division, Boulder, CO. [3]Space Research Institute, RAS, Moscow, 117997, Russia. [4]Leidos, Exploration and Mission Support, Houston, TX.

Introduction:

The primary sources of space radiation at Mars are the continuous background of galactic cosmic rays (GCRs) and sporadic energetic solar particle events (SPEs). On Earth, to understand and monitor this space radiation, a network of neutron monitors is deployed throughout the entire world. Continuous measurements at different locations indirectly describe the intensity of GCR and SPE particles reaching the surface of Earth (so-called ground level enhancement, or GLE). The long-term variation of the ground neutron environment for more than six decades has been also recorded [1]. Similarly, in this study, we present an approach for using measurements of neutron background counts taken by different instruments to extract information about the GCR environment at Mars.

The charged particles first interact with the Martian atmosphere, creating a shower of secondary particles. At the surface, the nuclear interactions happen with the regolith, generating even more secondary particles. Protons, alpha particles, and neutrons are among the particles created. Protons and other charged particles are often stopped by ionization interactions in the medium, while neutrons can continue traveling and penetrating deeper layers until they reach thermal equilibrium. Eventually, neutrons are absorbed in the regolith or leak away from the medium (i.e., albedo neutrons or leakage neutrons).

Understanding the radiation environment at Mars is important to provide accurate estimates of exposure for future robotic or crewed missions that will explore the red planet. There are two possible approaches to understanding the radiation environment, either by direct measurements or by simulations. Both are needed to improve models of the GCR and SPE environments and validate the proper use of radiation transport codes for simulating surface exposure.

The neutron environment has not been studied in detail by in-situ measurements on Mars (neither orbital or surface fluxes). By using different instruments currently measuring radiation on the surface and on orbit around Mars. we could understand the neutron background environment and how it responds to different environmental conditions such as atmospheric density changes and fill the gap in our understanding of the neutron background environment at Mars. Here we used: (1) The MSL RAD (Radiation Assessment Detector), which is a radiation telescope using solid state detector for charged particles combined with scintillators sensitive to neutral radiation [3] and (2) The Mars Odyssey HEND (High Energy Neutron Detector), which is a neutron spectrometer able to detect a wide range of energetic neutrons (0.4 eV to15 MeV) [4].

These instruments are in unique positions to measure the background neutron environment from multiple locations (RAD on the surface of Mars and HEND on orbit) and at different energies. The neutrons, after being generated at the surface of Mars, travel through the atmosphere interacting with the nuclei until they are detected on Orbit by HEND. In this study, we intend to investigate this possible correlation between the surface and the orbit neutron flux by finding an atmospheric transfer function and recreating the first complete neutron flux spectrum. We continue to explore how we can use different data sets to reconstruct the GCR induced neutron background flux at given time and location considering the atmospheric conditions of Mars.

Previous and current methodologies:

Previous studies had tried to link the GCR environment with neutron albedo as measured by the Dynamic Albedo Neutron instrument onboard MSL. Unfortunately, the instrument and the measurements are not sensitive enough to detect significant changes in the GCR environment. Instead, the neutron albedo responds strongly to sub-surface content variations as they affect the thermal and epithermal neutron fluxes. GCR particles reactions to different regolith compositions were presented in [5].

HEND has been taking measurements for almost two decades now. Designed to detect water content on the Martian subsurface, the measurements respond in short term to the seasonal variations and subsurface content, but the long-term counts recorded by HEND respond to the long-term evolution of the GCR. We can indirectly use the neutron measurements at different energy bins to extract the neutron flux for given periods and understand its time variations.

On the other hand, RAD has been on the surface of Mars since 2012 onboard the MSL rover. The RAD instruments have been measuring the dose rate from all the GCR and SPE induced secondary particles. The measurements from RAD also include neutral counts recorded by the scintillator detectors caused by gammas and neutrons. When the RAD dose rate and HEND neuron counts are compared, we can see a good agreement as illustrated in Figure 1.

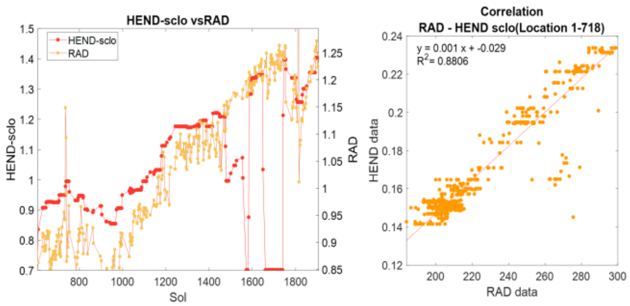

Figure 1. RAD and HEND preliminary comparison, Left present a time plot for RAD and HEND data between sol 0 and 200. Right plot shows a scatter plot with a linear fit to show correlation between RAD and HEND measurements.

This correlation is the first step into looking at long term trends for the GCR induced neutron flux on Mars's surface and orbit.

Independent neutron fluxes had been obtained from HEND and RAD measurement previously [7,8]. By using the detectors response function (efficiency functions) for HEND and RAD, we find the two-parameter power-law approximation of the flux using the least-square methodology. The counts from RAD and HEND can lead to different energy ranges of the neutron flux spectra and, when corrected for atmospheric variation during a given period (when the measurements overlap for both instruments) we could reconstruct a wide energy range neutron flux by joining both spectrums.

References: [1] Boynton W.C., et al (2004) [2] Mitrofanov I.G., et al. (2012) Space Science Reviews. [3] Hassler, D. M., et al. (2012), Space science reviews 170. [4] Mitrofanov, I.G., et al (2018) Space Science Reviews. [5] Jun, I. et al. (2013) JGR: Planets, 118. [7] Livtak, M. L. et al. (2020) Planetary Space Science, #118. [8] Guo, J. et al (2017) Life Sciences in Space Research, #14.

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