GALACTIC COSMIC RAY INDUCED NEUTRON ENVIRONMENT ON MARS.

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Introduction:

The main sources of space radiation are the continuous background of galactic cosmic rays (GCRs) and sporadic energetic solar particle events (SPEs). On Earth, in an effort to understand and monitor this space radiation, a network of neutron monitors is deployed throughout the entire world. By measuring the counts per second continuously at different locations, the intensity of GCR and SPE particles reaching the Earth can be obtained (so-called ground level enhancement, or GLE). It also provides a record of the long term variation of the ground neutron environment for more than six decades [1]. Similarly, in this study we present an approach for using measurements of neutron background counts taken by different instruments to extract information of the GCR and SEP radiation environment at Mars.

When charged particles reach the top of the Martian atmosphere, a shower of secondary particles is created and transported through the atmosphere. Once they reach the surface, nuclear interactions happen more frequently, generating even more secondary particle. 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 to deeper layers until they reach thermal equilibrium. Eventually, neutrons are absorbed in the atmosphere or regolith, or leak away from the medium (i.e., albedo neutrons or leakage neutrons).

The background neutron energy spectrum induced by GCR on the Mars surface is dependent on the regolith composition at the given location and the intensity of the GCR at any given time. Regolith components such as water (for scattering) and chlorine (for absorption) are of particular importance. We define Water Equivalent Hydrogen (WEH) to account for all the moderating elements and Absorption Equivalent Chlorine (AEC) to represent all neutron-absorbing elements.

Understanding the radiation environment at Mars is important to provide accurate estimates of exposure for future robotic or crewed missions that 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. Currently there are multiple neutron instruments in orbit and on the surface of Mars:

- MSL DAN (Dynamic Albedo of Neutrons): Neutron detector for thermal and epithermal neutrons, on Mars Science Laboratory (MSL). Sensitive to background neutrons [2]
- MSL RAD (Radiation Assessment Detector): Radiation telescope using solid state detector for charged particles combined with scintillators sensitive to neutral radiation [3].
- Mars Odyssey HEND (High Energy Neutron Detector): Neutron spectrometer able to detect a wide range of energetic neutrons (0.4 eV to15 MeV) [1].
- ExoMars FREND (Fine Resolution Epithermal Neutron Detector): Neutron detector to detect neutrons with energies from 0.4 eV to 500 keV for high spatial resolution [4].

These instruments are in unique positions to measure the background neutron environment from multiple locations and at different energies. We continue to explore how we can use different data sets to reconstruct the neutron background environment at the surface of Mars.

Previous and current work:

Previous simulations of how the GCR particles reacted to different regolith compositions were presented in [5]. We can infer what the neutron spectrum should look like when varying the hydrogen and chlorine content. Figure 1 shows a few simulated neutron spectra (normalized to 1 source neutron) for different chlorine and water content. Contributions from both the atmosphere and the regolith are included. The blue vertical lines represent the energy boundaries between thermal ($E<0.025$ eV) , epithermal (0.25 eV $< E < 0.01$ MeV) and fast neutrons ($E > 0.01$ MeV).

From Figure 1 it can be seen that by increasing the chlorine content, only the thermal neutrons are affected because there are more absorbers interacting with the thermal neutrons as seen from the decrease of the intensity of thermal neutron peak. On the other hand, when the water content is increased, the entire spectrum shifts down due to more scattering interactions, and the intensity of thermal peak increases. As a result, it can be concluded that epithermal neutron generation depends on water content , and not on chlorine content.

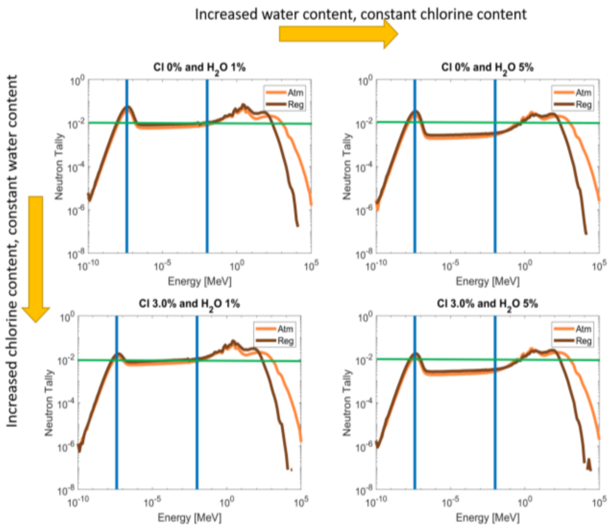

Figure 1. Simulated GCR-induced neutron spectrum coming from the atmosphere and the regolith for different chlorine and water content in the composition of the regolith.

In passive mode, DAN not only measures background radiation generated by GCR, but also by the Multi-Mission Radioisotope Thermal Generator (MMRTG) onboard the rover. Measurements from DAN are distributed in two different channels: the total neutron counts (CTN) and epithermal neutron counts (CETN).

Serval attempts have been made to find possible correlations between the MMRTG-corrected DAN passive thermal data (GCR-only) and the radiation measurements from RAD and HEND [6].

Because GCRs are not the only source of the background radiation that DAN measures, a methodology to decouple the two sources was implemented. For each location where the MSL rover stopped, a simulation estimated the neutron contribution from the MMRTG by using the regolith composition model estimated by the DAN active mode at that location. Then these MMRTG-only counts were subtracted from the total counts at given locations. The results from this is supposed to be the GCR-only neutron count at the surface. However, it has been somewhat difficult to find possible correlations between DAN GCR neutrons and the measurements by other instruments. On the other hand, RAD and HEND comparison present a good agreement as illustrated in Figure 2.

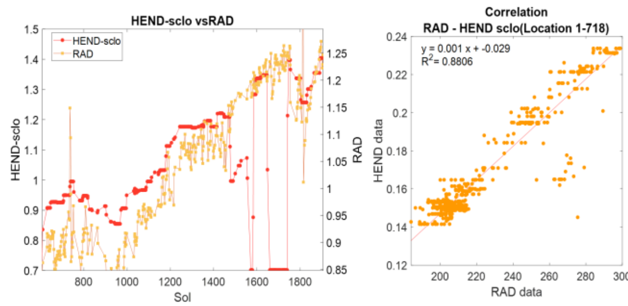

Figure 2. RAD and HEND preliminary comparison, Left present a time plot for RAD and HEND data between sol 0 and 200. Right plot shows a scatter plot with a linear fit to show correlation between RAD and HEND measurements.

Future work:

The next step will be to correct in a similar manner the DAN epithermal data to obtain the GCR-only counts. Epithermal count analysis seems more promising because of the small dependence on the chlorine content of the regolith. Once the data is corrected, direct comparisons with HEND and RAD data can be made to investigate possible correlations.

Additionally, by looking at MMRTG parametric simulations we can understand the behavior of the neutrons to changes in the soil composition, similar to what is presented in Figure 1.

With these two new analyses we will be able to finalize the DAN data analysis and come up with a conclusion about the usability of the DAN passive data for the background neutron radiation. Next, we can focus on different data sets such as the RAD neutral counts and the newer data set collected by FREND since 2016.

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