Comparison of Measured Thermal/Epithermal Neutron Flux and Simulation Predictions for the Odyssey Neutron Spectrometer in Orbit about Mars.
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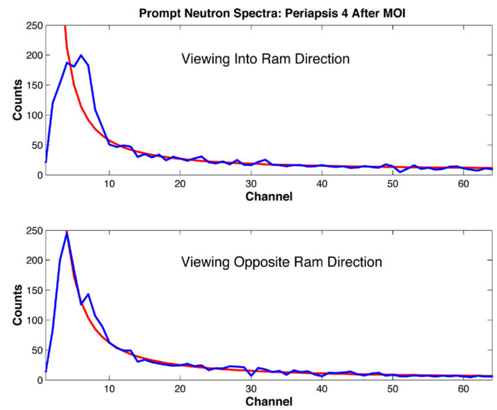
Introduction: One of the scientific objectives of the neutron spectrometer (NS) component of the gamma ray spectrometer (GRS) subsystem onboard Mars Odyssey is to map the near surface abundance and stratigraphy of H and CO_2 and its variation with season. This instrument was activated on May 2, 01, and during the cruise phase to Mars the NS measured the energy spectrum of fast neutrons (~0.7 to 6 MeV) produced by interactions of galactic cosmic rays and the spacecraft [1]. After Mars orbit insertion in late October, 01, the NS remained on for a few orbits before the aerobraking phase commenced. The instrument is scheduled to be activated again on about Jan. 23, 01, at which time the spacecraft will be close to an optimum mapping configuration. Feldman et al. [2] report results of an initial pass of the NS over the Martian surface that suggests the presence of a large polar terrene rich in hydrogen. In this study, results are presented from end-to-end simulations of the NS system as it passes over the Martian surface. The results are compared with the data from the early pass after MOI given in [2] and, it is anticipated, with early mapping data.

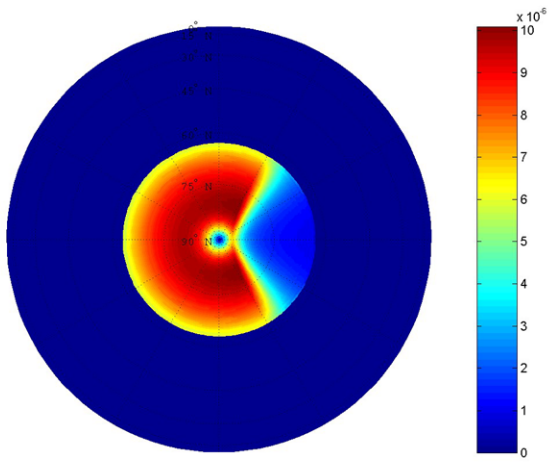
The NS employs borated plastic scintillator to detect thermal (E < ~0.3 eV) and epithermal (~0.3 eV < E < ~600 keV) neutrons, in addition to fast neutrons. There are four independent detector prisms that view nominally in: 1-the nadir direction, 2-the spacecraft velocity direction, 3-the zenith direction, which is toward the spacecraft and 4-opposite the spacecraft velocity. Under ideal conditions, the forward looking prism 2 will detect more neutrons than the backward looking prism 4 due to a kinematical ram effect [3]. This effect is strongest at energies near and lower than the energy of a neutron moving at the spacecraft speed, ~0.06 eV.

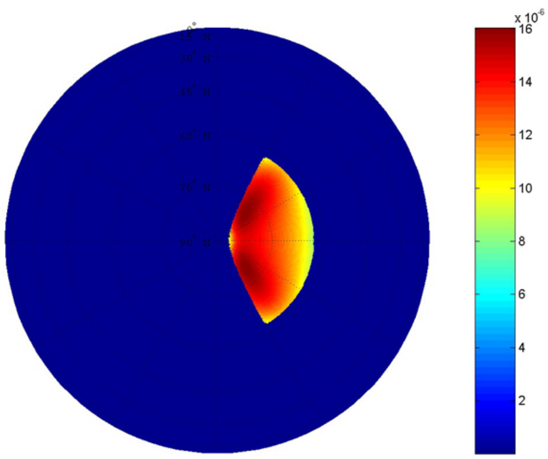
This effect was observed for the first time in space during the first few orbits of Odyssey at Mars, as is shown in the following figure. Plotted are neutron counts per 19.2 s as a function of channel measured by the NS near a periapsis pass (pass 4). Although the viewing direction was not optimum during this pass because Odyssey was oriented for aero braking, which differs from the mapping orientation, the data does illustrate enhanced counts in the forward looking prism (top panel) when compared to the backward looking prism (bottom panel). The red curves are fits to the detector background (primarily gamma rays from Mars and the spacecraft) and the counts above this background in channels 6-9 are identified as the signature of a thermal or epithermal neutron.



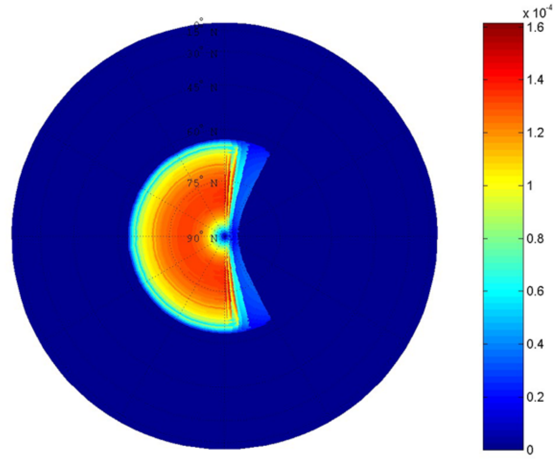
In order to interpret this data in terms of surface composition at Mars, an end-to-end simulation of the neutron sensor in orbit about Mars is under development at Los Alamos. In the simulation, the neutron phase space velocity distribution function either at the Martian surface or at the atmosphere boundary is assumed known for all points in the Odyssey NS field of view. These distribution functions are obtained for assumed Martian surface and atmosphere compositions using Monte Carlo neutron transport codes. These same codes are also used to calculate the NS efficiency-area products as a function of incident neutron energy and direction. In the simulation, the accessible phase space for neutron orbits in the Martian gravitational field that connect the NS on Odyssey and the ground is mapped. Using the fact that the phase space density is constant along the neutron dynamical trajectory, the contribution of each source parcel to the measured counts is mapped onto the Martian surface for the assumed surface compositions.

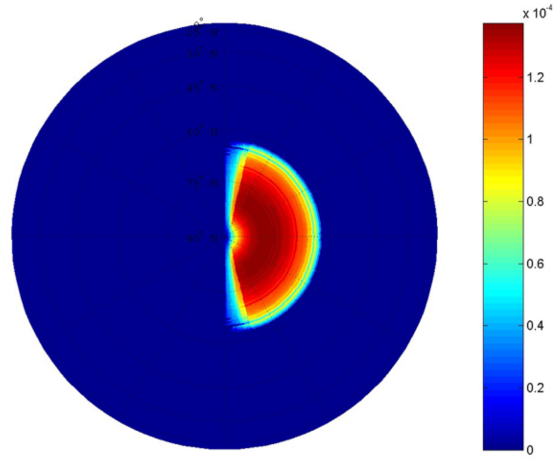
The next four figures illustrate results for this procedure, assuming the Martian surface neutron flux is homogenous and representative of ferroan anorthositic composition that contains 1 percent H_2O by mass. A 16 g/cm^2 atmosphere is included in the simulation. In the first two figures the thermal neutron energies < 0.3 eV are treated. The top illustrates the distribution of counts in 19.2 s multiplied by fractional surface area as observed by the detector looking into the ram direction. The bottom figure is the same quantity for the prism looking in the backward direction. All four of the following figures have identical surface grids, so the count rates magnitudes can be compared to each other. Odyssey is at an altitude of 400 km and assumed to be in the ideal mapping configuration for these simulations. The spacecraft nadir is the North Pole (the origin of the maps) and the spacecraft velocity is toward the left in the figures. It is clear from these figures that the counting rate measured in the forward direction will exceed that measured in the backward direction. In this case, the ratio of the integrated counts per 19.2 s for the forward looking prism to that for the backward prism is 1.8 This illustrates the kinematical ram effect for low energies.





Simulations for the epithermal energy range from 0.3 eV to 600keV are shown in the next two figures. The top is the forward looking prism, the bottom the backward prism.





In this case the ratio of the integrated counts for 19.2 s for the forward looking prism to that for the backward prism is 1.3, lower than that for the thermal range as expected. Indeed at high energies this ratio must go to unity [3].

The ratio of the forward to backward total counts integrated over all energies is about 1.4. We note that this ratio is very close to the ratio of counts measured during the fourth periapsis pass above the northern hemisphere of Mars [2]. Although this agreement can only be considered preliminary at the present time, it promises an eventual quantitative understanding of NS data that will be returned during the mapping portion of the Mars Odyssey mission.

Reference: [1] Feldman, W.C., et al. *JGR, 2002, in press*, [2] Feldman, W.C. et al., LPSC XXXIII, (2002), [3] Feldman, W.C. and D. M. Drake, Nucl. Instr. Meth., A245, 182-190 (1986).