SENSITIVITY TO FINE STRUCTURE OF NEUTRON SUPRESSION IN LUNAR POLAR REGIONS

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Introduction: Hydrogen-bearing volatiles such as water or hydroxyl in the Moon's cold polar regolith can be detected by the suppression of epithermal neutron flux (energy just above thermal) from the Moon's surface. Neutrons are difficult to manipulate and cannot be focused in the fashion of photons, but an opaque collimator can be used to eliminate neutrons from outside a narrow field of view and thus improve spatial discrimination. Detected neutron-capture events from lunar sources will include neutrons from within the targeted narrow FOV and a diffuse low spatial-resolution component of lunar neutrons from outside the FOV that penetrate the finite opacity of the collimator, resulting in a bimodal point-spread function (PSF) mapping out the actual distribution of neutron leakage from the lunar surface. The Lunar Exploration Neutron Detector (LEND) instrument on the Lunar Reconnaissance Orbiter (LRO) spacecraft incorporates exactly this sort of collimator. Making use of LEND enhanced angular sensitivity from the narrow collimator FOV requires the application of deconvolution techniques suited for the bimodal PSF of the collimator.

The detector PSF must reflect the share of collimated neutrons that enters through the opening of the collimator within angle from nadir of about 12^{o}. This part of the bimodal PSF is responsible for high spatial resolution. Detected neutrons in the collimated population cover the energy range from just above the energy cutoff at ~0.4 eV due to a cadmium window on the detector, to the sensitivity cutoff of the detector at ~10 keV. Lower resolution contributions to the measured count rate, in the "wings" of the PSF, are attributed to neutrons penetrating through the walls of the collimator. This population of detected neutrons originates from the lunar surface at higher energy than those that are detected in collimation, from 10keV to several MeV. Penetration through the collimator degrades the energy of these energetic neutrons sufficiently to make them detectable.

We evaluate neutron transport from the Moon's surface to detection within the LEND instrument to determine the angular sensitivity of the detector to lunar neutron populations as a function of energy. The angular sensitivity of the collimated detector projects to the lunar surface as a PSF that can be used to deconvolve the measured distribution of neutron flux to recover the fine structure of neutron suppression on the surface.

We demonstrate the results of such deconvolution applied to reconstruct the fine structure of neutron suppression within permanent shadowed regions (PSR) in the craters Cabeus and Shoemaker [1,2] near the lunar south pole. We also apply this technique to other neutron suppression regions (NSR) that have been identified in the polar regions but which are not necessarily connected to PSRs.

The spatial profile of the neutron leakage derived from deconvolution is used then to emulate the convolution process of the LEND CSETN detector, forward-modeling the transport of lunar neutrons to the detector. This is an essential cross-check for self-consistency in applying the deconvolution technique on chosen areas of the lunar surface. Since the combined features of the instrument PSF act to dilute spatial features and reduce the actual contrast between localized NSRs and the surrounding terrain, the results from deconvolution enhance the level of neutron leakage suppression that can be detected in fine scale structures, consequently indicating higher concentrations of hydrogen than would appear in the raw LEND data.

Reference: [1]. Boynton, W. V., et al. (2012), High spatial resolution studies of epithermal neutron emission from the lunar poles: Constraints on hydrogen mobility, J. Geophys. Res., 117, E00H33. [2] T.P. McClanahan et al. Comparison of image restoration methods for lunar epithermal neutron emission mapping Computers & Geosciences 36 (2010)1484–1493.