What is the LEND collimated detector really measuring?

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The flux of epithermal, i.e. intermediate energy, neutrons leaking from the lunar surface provides information about the abundance of hydrogen in the top ~ 70 cm of the regolith. Hydrogen nuclei moderate neutrons knocked from their nuclei by energetic cosmic rays, and decrease the epithermal neutron leakage flux. This technique was first used for the Lunar Prospector (LP) neutron spectrometer to indicate hydrogen concentrations near to the lunar poles [1]. The Lunar Exploration Neutron Detector (LEND) Collimated Sensors for EpiThermal Neutrons (CSETN) on LRO are an attempt to improve the spatial resolution of the lunar hydrogen map inferred using neutron spectroscopy [2].

Serious questions have been raised concerning the effectiveness of the LEND CSETN for actually returning a sharper map of the lunar neutron flux [3, 4, 5]. This work uses the LP results in combination with data from the LEND CSETN to demonstrate that less than 5% of the LEND CSETN counts come from within the field-of-view (FOV) of the collimator.

A preliminary consideration of the data

The LEND uncollimated Sensor for EpiThermal Neutrons (SETN), which is strapped to the outside of the collimator, gives an obvious first check of the data from the CSETN. Whole-Moon maps are shown in figures 1 and 2. The CSETN map is very evidently not a sharper version of that from the SETN, which implies that these are largely maps of different quantities. The lunar variation is clearly driven by neutrons with different energies in the SETN and CSETN cases.

The neutrons counted by the LEND CSETN originate through cosmic rays striking either the spacecraft (‘spacecraft-generated neutrons’) or the Moon. The lunar neutrons can be split into components that are collimated, i.e. from within the collimator FOV, and uncollimated, i.e. from outside the FOV, but with sufficient energy to reach the detector after scattering from material in the spacecraft. To assess how well the LEND CSETN is performing, one must determine what fraction of the counts come from these three components: lunar collimated, lunar uncollimated and spacecraft-generated neutrons. Only the first of these three components comes from the small patch within the collimator FOV.

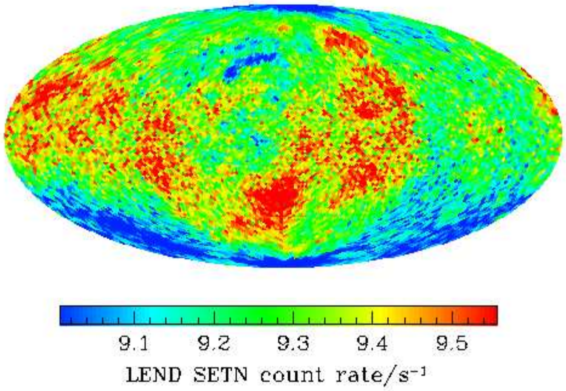

Figure 1: A Mollweide projection of the (omni-directional/uncollimated) LEND SETN count rate map.

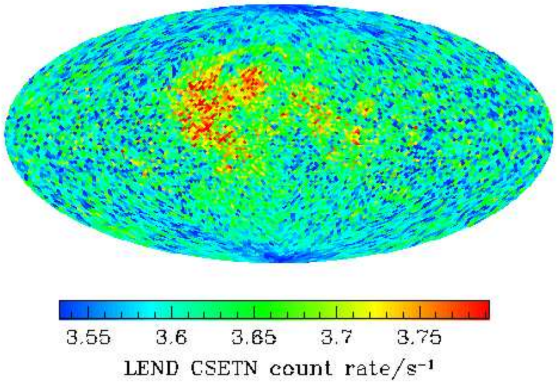

Figure 2: A Mollweide projection of the (collimated) LEND CSETN count rate map.

Method

The three different components vary differently with longitude, latitude and altitude. The lunar collimated flux should be dominated by low energy epithermal neutrons and have a dependence similar to that seen in LP results, albeit at slightly higher spatial resolution. It should not depend significantly upon LRO altitude, because the Moon is approximately constant surface brightness in neutrons, and the collimator angular FOV is fixed. The lunar uncollimated flux decreases with increasing altitude as the solid angle subtended by the lunar disc decreases, and it will vary with longitude and latitude in a way that reflects the high energy epithermal neutrons with sufficient energy to reach the detector indirectly. The spacecraft-generated neutrons will be independent of longitude or latitude, but will increase with LRO altitude as the Moon blocks out fewer cosmic rays.

Using LP results and Monte Carlo modelling, templates for the spatial variation of the lunar components were constructed [5]. For any choice of the overall component fractions comprising the LEND CSETN data, a model count rate can then be calculated and compared with the observed data. The overall component fractions were varied to determine the best fit to the LEND CSETN time series data.

Results

The best-fitting fractions contain less than 5% of the LEND CSETN flux in the lunar collimated component, $42 - 46\%$ in the lunar uncollimated component, and $51-55\%$ in spacecraft-generated counts. The ranges represent systematic uncertainties associated with details of the model (see [5] for more details). These fractions contrast starkly with those asserted by the LEND team [2, 6], who claim that the lunar collimated component exceeds the lunar uncollimated one. Given the different variation of these components with LRO altitude, one might imagine that the LEND CSETN data should clearly discriminate between these possibilities. That it does can be seen in figure 3, which shows how the most likely model found here, with very little lunar collimated flux, provides by far the best description of the LEND CSETN data. The LEND team decompositions of the CSETN count rate provide a qualitatively wrong trend of increasing flux with altitude.

Conclusions

The LEND CSETN count rate is comprised of just over half coming from extra-lunar sources (charged cosmic ray particles and neutrons produced by cosmic ray interactions with LRO) and the rest from the Moon itself. Over 90% of the flux from the Moon comes from outside the collimator FOV and is comprised of high energy epithermal and some fast neutrons rather than the low energy neutrons that originate within the FOV. These conclusions contradict the assertions of the LEND team, whose decompositions of the total count rate are grossly inconsistent with the altitude dependence of the LEND CSETN data. Given that the detector is effectively an uncollimated Sensor for High Energy Epithermal Neutrons, it would be more appropriate if the LEND CSETN were known as the LEND SHEEN.

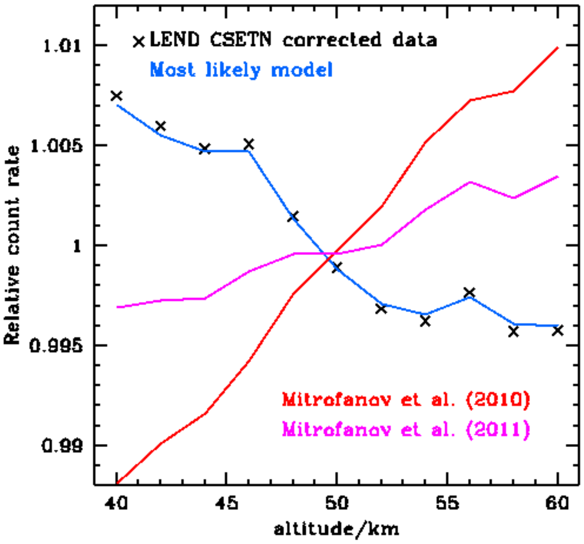

Figure 3: The relative count rate as a function of altitude. Points show the LEND CSETN data. The blue, red and magenta lines show the trends from the most likely model found here and the asserted component fractions of [2] and [6] respectively.

References

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