**Global maps of the Moon neutron flux from LEND instrument onboard LRO** M.L. Litvak[1], I. G. Mitrofanov[1], A. B. Sanin[1], W. V. Boynton[2], G. Chin[3], J. B. Garvin[3], D. Golovin[1], G. Droege[2], L. G. Evans[4], K. Harshman[2], A.S. Kozyrev[1], A. Malakhov[1], T. McClanahan[3], G. Milikh[5], M. Mokrousov[1], R. Sagdeev[5], R. Starr[6], J. Trombka[5], [1]**Space Research Institute, RAS, Moscow, 117997, Russia, litvak@mx.iki.rssi.ru,** [2]University of Arizona, Tucson, AZ USA **,** [3]NASA Goddard Space Flight Center, Greenbelt, MD USA, [4]Computer Science Corporation, Greenbelt, MD USA, [5]University of Maryland, College Park, MD USA, [6]Catholic University, Washington DC, USA,

**Introduction:** Latest neutron spectroscopy observations made by Lunar Exploration Neutron Detector (LEND) onboard Lunar Reconnaissance Orbiter (LRO) during more then 1 year of mapping phase started at September, 15 2009 are used to create global maps of lunar neutron fluxes in different energy ranges with various spatial resolution. In our analysis we have created global maps showing regional variations in flux of thermal (energy range < 0.015 eV) and fast neutrons (>0.5 MeV), compared those fluxes to variances in soil elemental composition and compared our results to previous results obtained by Lunar Prospector Neutron Spectrometer (LPNS).

Regional variations of neutron flux in the thermal energy range (neutrons with energies below 0.4 eV) correlate with concentrations of major and minor lunar soil forming elements (like Fe, Ti, Gd, Sm) having large macroscopic absorption cross sections. For example, the distribution of Fe and Ti is highly "non-homogeneous" between the nearside mare basins and farside highlands and as result produces the significant regional variations of thermal neutrons across the lunar surface [4,7]. The epithermal neutrons with energies from 0.4 eV up to 10 keV is another key subsurface composition marker because the intensity of neutron flux in this energy range is sensitive to the abundance of hydrogen. Even a small amount (~100 ppm) of H causes significant depression of epithermal neutron flux [1,2,3,6]. Finally, fast neutrons with energies from 100 keV up to 15 MeV may be used to analyze the average composition of lunar soil via correlation of intensity of fast neutron flux and average atomic mass of the lunar soil [4,5,8] .

**Map of thermal neutron flux:** The thermal neutron flux intensity shown on the LEND map (Figure 1) has significant dynamic range with a factor 3.5-4 and is reasonably well correlated with main patterns of lunar soil composition. The major effect is seen on the nearside of the Moon in mare basaltic terrains where there are significant depressions of thermal neutron flux. In contrast, the highlands on the farside of the Moon show significantly higher intensities of thermal neutron flux. These regional variations have been observed in previous experiments and were analyzed in details using data from LPNS and Lunar Prospector Gamma-Ray Spectrometer (LPGRS) instruments. The correlation of lunar maria with considerable reductions in thermal neutron flux intensity has been interpreted as an enhanced abundance of such primary soil forming elements as Fe and Ti and minor and trace elements like Gd, Sm which have large absorption cross sections (see for example 4,7,9). The direct correlation (pixel to pixel) between LPNS and LEND maps of thermal neutron flux shows very high linear correlation coefficient 0.98.

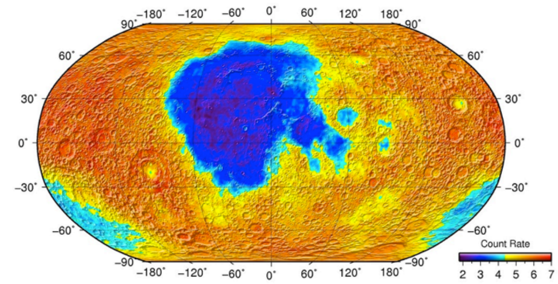


**Figure 1.** Smoothed map 1°x1° of thermal neutron flux from lunar surface measured as a difference in counting rate between the pair of LEND Doppler detectors.

**Map of epithermal neutron flux:** The resulting corrected global map of LEND epithermal counting rate is shown on Figure 2. It is done with a 1°x1° grid and smoothed with a Gaussian filter with FWHM equal to 60 km (compared with omnidirectional spatial resolution). Several large crater basins both in the farside and nearside show increasing intensity of epithermal neutron flux in comparison with neighboring areas. For example, one can see a significant increase of epithermal neutron flux in the southern hemisphere in such crater basins as Clavius, Maginus, Longomontanus and Tycho (marked on the figure 2). At the equatorial latitudes within [-30S, 30N] high epithermal flux is observed at Mare Orientale, Mare Fecunditatis, Mare Nectaris, Mare Crisium and Mare Moscowience.

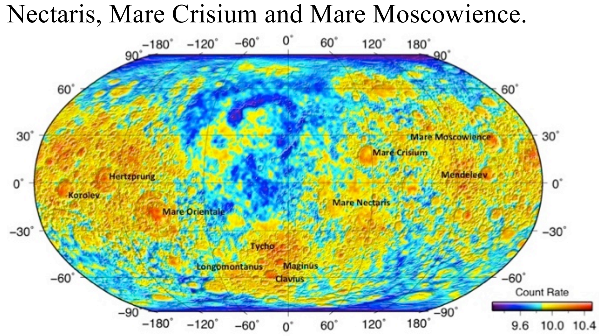


**Figure 2.** Smoothed map 1°x1° of epithermal neutron counting rate measured by LEND SETN detector.

LEND/LPNS pixel to pixel correlation shows fairly good linear correlation coefficient is about 0.73. The best agreement between LEND and LPNS data is in the southern hemisphere poleward of ~50S for all longitudes. The significant correlation is also found poleward of 60N within [-180$^o$, -120$^o$] and [60$^o$, 180$^o$] longitude sectors. The same pattern of distribution of low values of epithermal flux is seen at moderate and near equatorial latitudes in the vicinity of Mare Imbrium basin. The largest discrepancies between LEND and LPNS are seen in the northern hemisphere at Mare Frigoris where LPNS has significantly higher values of epithermal flux than LEND and at equatorial latitudes [-30S, 30N] in the highlands on farside (with longitudes from -180$^o$ up to -120$^o$ and from 120$^o$ up to 180$^o$) of the Moon where in contrast LEND is counting more epithermal neutrons than LPNS. The largest discrepancies between LEND and LPNS are seen in the northern hemisphere at Mare Frigoris where LPNS has significantly higher values of epithermal flux than LEND and at equatorial latitudes [-30S, 30N] in the highlands on farside (with longitudes from -180$^o$ up to -120$^o$ and from 120$^o$ up to 180$^o$) of the Moon where in contrast LEND is counting more epithermal neutrons than LPNS.

**Map of fast neutron flux:** The fast neutron flux measured by LEND changes by 25% across the lunar surface from maria to the highlands, with the maximum of fast neutron flux observed in mare terrains (see figure 3). This result is consistent with the LPNS argument that mare basalts are rich in Fe (producing more fast neutrons in comparison with Al-rich soils). The latitude band profile of fast neutron flux does not show so significant a polar extended neutron suppression effect as observed in the epithermal neutron range. One may distinguish only small areas around poles with neutron suppression less than 1%. The pixel to pixel correlation between LEND and LPNS maps shows that linear correlation coefficient is equal to ~0.6. It is significantly high value taking into account low statistic of counts and small regional variations of neutron flux everywhere except Fe enriched areas.

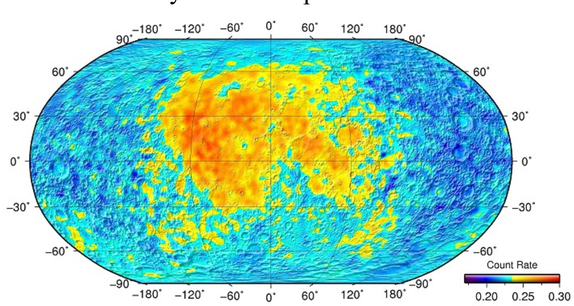


**Figure 3.** Smoothed map 1$^o$x1$^o$ of fast neutron flux from the lunar surface measured by LEND fast neutron sensor.


**References:**
[1] Mitrofanov I.G., et al., (2008) Astrobiology, 8, 4, 793-804. [2] Mitrofanov I.G. et al., (2010), Space Science Reviews, 150, 1-4, 183-207. [3] Mitrofanov I.G. et al., (2010), Science, 330, 6003, 483. [4] Feldman, W.C., et al., (1998) Science, 281, 1489–1493. [5] Feldman, W.C., et al., (1998), Science, 281, 1496–1500. [6] Feldman, W.C., et al., (2001), J. Geophys. Res., 106(E10), 23,231–23,252. [7] Elphic R.C., et al, (1998), Science, 281, 1493– 1496. [8] Gasnault O., et al., (2001), Geophys. Res. Let, 28, 19, 3797-3800. [9] Lawrence D.J., et al., (2002, J. Geophys. Res., 107(E12), 5130, doi:10.1029/2001JE001530.