SEARCHING FOR WATER ICE IN THE MOON COLD TRAPS BY LEND INSTRUMENT ONBOARD THE NASA LRO MISSION

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Introduction: The Lunar Exploration Neutron Detector (LEND) has been selected for the NASA Lunar Reconnaissance Orbiter (LRO) mission to determine hydrogen distribution through lunar subsurface of 1 – 2 meters depth with high sensitivity and high spatial resolution [1]. It is known that presence of hydrogen nuclei in lunar soil significantly influences on the epithermal neutron leakage flux allowing measurements of hydrogen content.

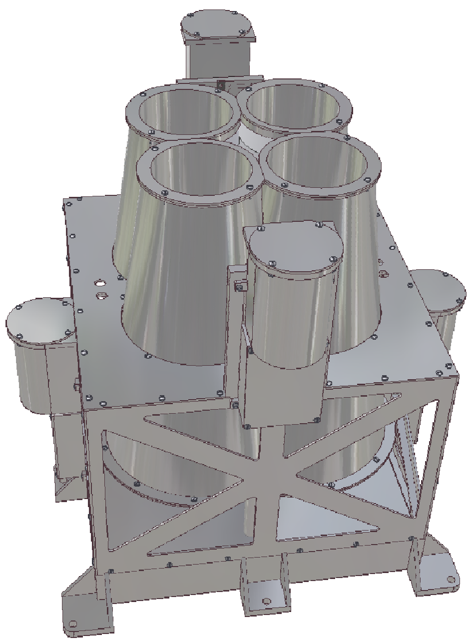

Fig. 1. The concept view of LEND instrument for NASA LRO mission

For neutron detectors without imaging capabilities the surface footprint of such measurements is defined by the orbit's altitude and may be as large as 100 km in diameter, provided 50 km would be an averaged LRO altitude. That is why a set of four collimators for epithermal neutrons is suggested for the LEND in order to improve the spatial resolution [1,2] (Fig. 1). Due to the efficient collimation of epithermal neutrons and high efficiency of their detection, LEND is able to provide an estimate of hydrogen content with spatial resolution up to 5 km and detection limit better then 100 ppm in the vicinity of lunar poles.

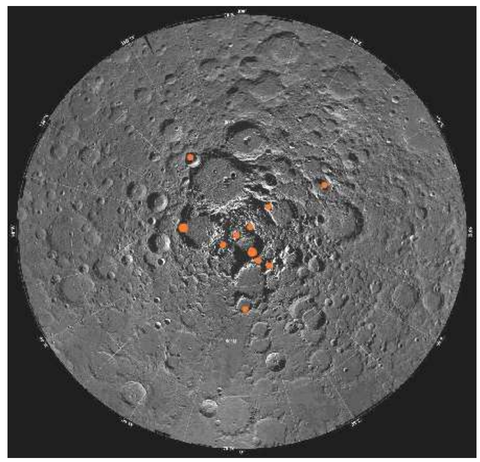

Fig. 2. The cold traps candidates in the northern hemisphere of Moon.

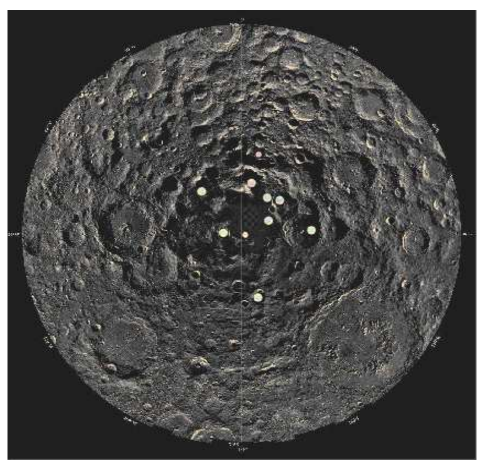

Fig. 3. The cold traps candidates in the southern hemisphere of Moon.

In this paper we focus on identification of prospective lunar polar cold traps, as targets for LEND investigation. We also present the results of numerical studies of the LEND instrument detection limits of Hydrogen deposits for these selected traps. The aspects concern improving of spatial resolution of the surface neutron flux maps are also presented based on super resolution technique, which is successfully used for the processing of astronomy images.

Data Analysis: To perform such analysis, the two sets of prospective cold traps were selected for the northern and southern polar regions of Moon (Fig. 2 – 3).

The center positions of prospective southern cold traps situated within 83.3ºS – 89.9ºS latitude belt. Their shadowed surfaces range from 30 up to 575 km^2. The prospective northern cold traps have centers located within 81.5ºN – 89.2ºN latitude belt and their shadowed surface range from 30 up to 300 km^2.

The optimized shape of epithermal neutron collimator (see [2]) has been used to perform numerical estimations of counting rate in the LEND collimated sensor for epithermal neutrons. Suggested collimator's shape allows to reach as low as 82.5 ppm hydrogen detection limit (3 sigma) for the hypothetical circular spot area with radius 5 km and located at the pole.

The detection limit for hydrogen at each given prospective cold trap is estimated as 3σ level difference between counting rate from the target (cold trap with given surface area and exposure time for LRO spacecraft) and from the surrounding dry area with 0% of hydrogen content.

Results: Numerical simulations have shown that there are 3 "perfect" cold traps around poles, where detection limit of hydrogen content is estimated below 100 ppm. It was also found that 6 other cold traps can be considered as very perspective targets for testing of water ice. Detection limit for these prospective traps is estimated in the range 100 – 200 ppm. Finally, another 14 candidates have detection limit for hydrogen between 200 and 600 ppm. These "probable" candidates can be used for farther statistical analysis together with the data from another LRO instruments to improve our knowledge about distribution of hydrogen in vicinity of lunar polar regions.

There is also the possibility to estimate hydrogen detection limit for "probable" candidates by combining data from individual cold traps. The results of such analysis for "probable" northern and southern cold traps are shown at figures 4 and 5 correspondingly. For this analysis the following algorithm has been used: the first bin on each figure is defined from neutron counting statistic and exposure time for the best "possible" candidate, the second bin is defined from the sum of counting statistic and exposure time for the first and second good "possible" candidate, the third bin is result of combination of the first, second and third candidate, and so on.

One sees from Figures 4 and 5, that collective estimations allow to test Hydrogen content with accuracy about 100 ppm even for "possible" cold traps candidates, when all accumulated data for them are used together.

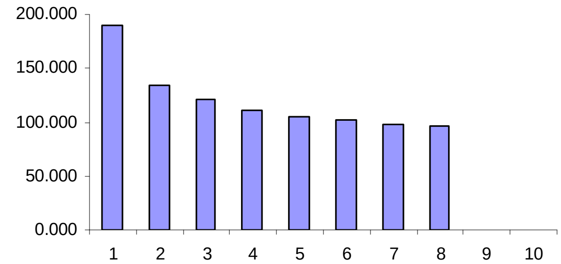

Fig. 4. Collective estimation of Hydrogen content for northern "possible" cold traps candidates

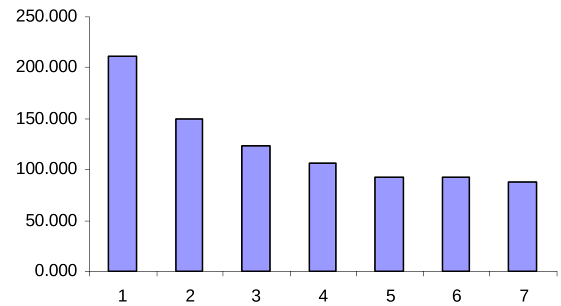

Fig. 5. Collective estimation of Hydrogen content for southern "possible" cold traps candidates

Future analysis: In order to improve spatial resolution of the neutron mapping by LEND, the further efforts will be made using the modern super resolution technique [3]. This procedure is being successfully used in astronomy to deconvolve details of blurry images of extended sources. Data processing with super resolution technique is based on the conjugate gradient method (CGM). Each orbit provides a snapshot shifted by a small share of pixel, horizontally and vertically. Signal processing over the multiple orbits is shown to lead to a significant increase of the image resolution of the neutron emission.

References:

[1] Mitrofanov I.G. et al., LEAG-2005, Abstract #2035, 2005. [2] Sanin A.B. et al., LEAG-2005, Abstract #2034, 2005. [3] R. Z. Sagdeev, private communications.