RESULTS OF LEND HIGH-RESOLUTION EPITHERMAL NEUTRON MEASUREMENTS: EVIDENCE FOR TWO HYRODGEN EMPLACEMENT MECHANISMS. W. V. Boynton[1] G.F. Droege[1] K. Harshman[1] I Mitrofanov[2] and the LEND Science team. [1]University of Arizona, Tucson AZ 85718, wboynton@LPL.Arizona.edu, [2]Institute for Space Research of Russian Academy of Science, 117997 Moscow, Russia, mitrofanov@l503.iki.rssi.ru

Introduction: The possibility of volatiles, and particularly ice, being concentrated in permanently shadowed regions (PSRs) was suggested long ago [1,2]. The first evidence of this possibility was found by an analysis of radar reflection data from the Clementine Mission [3], but others have raised questions concerning this result [4,5]. Data from the Lunar Prospector Neutron Spectrometer (LPNS) showed a significant reduction in the flux of epithermal neutrons in the vicinity of both lunar poles [6] indicating an enhancement of hydrogen, but the spatial resolution of the instrument was not sufficient to associate the hydrogen with the PSRs.

More recently, the Lunar Exploration Neutron Detector (LEND) collected data with much better spatial resolution than that of LPNS [7]. With higher resolution, the data showed that the areas of depressed epithermal neutron flux, called neutron suppressed regions (NSRs) were not spatially consistent with the PSRs. In this work we shall show the results of a more detailed analysis of the LEND data that show clear evidence of two distinct populations of hydrogen enrichment in the lunar poles.

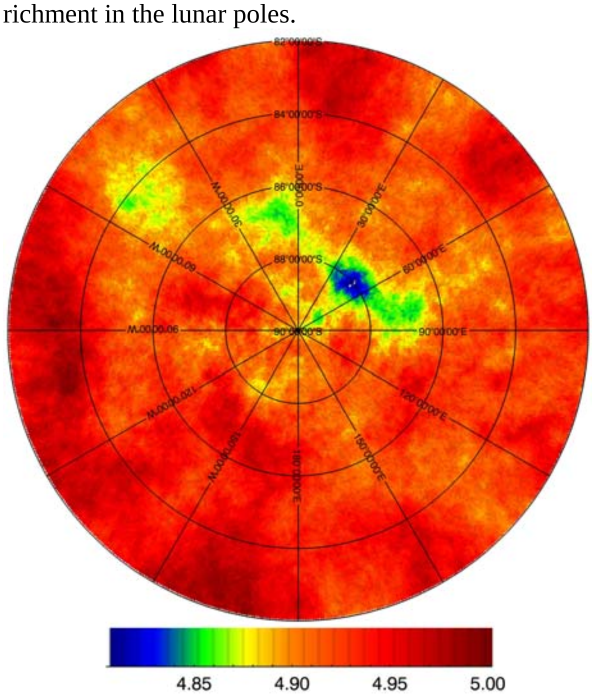

Fig. 1 Map of LEND collimated epithermal count rates in the south polar region south of -82° latitude.

Results: The data from the four collimated sensors are first corrected for changes in efficiency during warm up following each ~14-day on/off cycle and for variations in the cosmic-ray flux with time: cosmic rays are the excitation source for the neutrons. Occassionally one or two sensors were shut off, and the count rates of the working sensors were adjusted upward to the equivalent four-sensor rate with counting uncertainties adjusted appropriately.

Figure 1 shows the counting rates in the South Polar Region. It can be seen that the counting rate is fairly uniform at just less than 5.0 counts/sec, but there are a few areas with significantly lower count rates. The collimated sensors have a field of view (FOV) of 5.6° HWHM [8], which corresponds to 5 km on the surface at 50 km altitude.

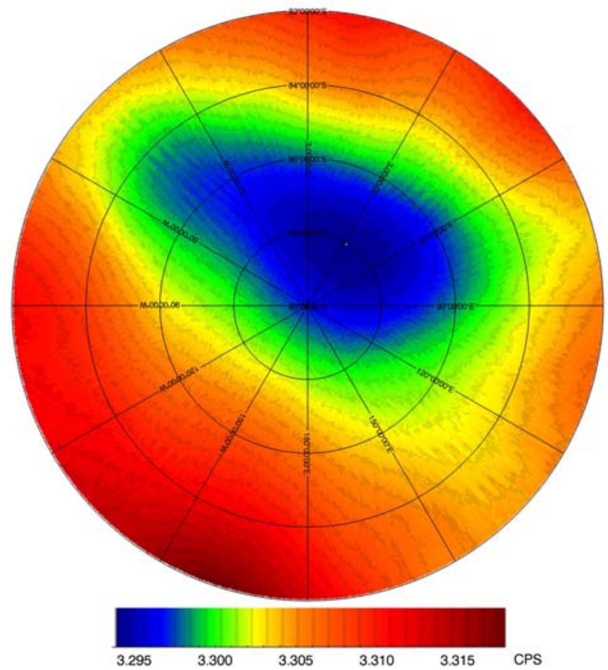

Fig. 2. Background counting rate shows only a very small variation with location.

Some neutrons from outside the FOVare also counted. These neutrons come from three sources: lunar neutrons leaking through the walls of the collimator, lunar neutrons scattered off the spacecraft, and cosmic-ray produced neutrons from the spacecraft. The counting rates from the first two sources depend on the emission of neutrons within view of the spacecraft, but since the spacecraft sees an area so much larger than that of the collimated sensors, the counting rate from this source is averaged over a very large area and does not change much over the polar region. Figure 2 shows a map of the background signal calculated based on the emission rate of neutrons from all regions within view of the spacecraft. It can be seen that the background counting rate is nearly independent of location within the polar region.

Difference maps. In this work we are interested in finding places of hydrogen enrichement, so we make a map of count rate differences. As will be shown, there are two populations of hydrogen distribution. One is shown by a linear decrease in counting rate with latitude in both polar regions (fig. 3), and the other is due to the NSRs.

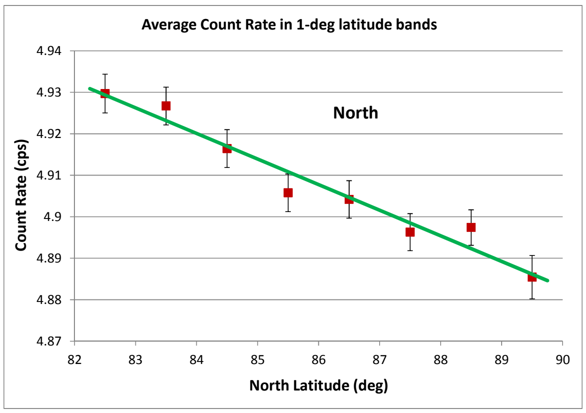

Fig 3. The epithermal count rate (North Pole) decreases linearly with latitude showing an increase in hydrogen concentration. (South is nearly identical.)

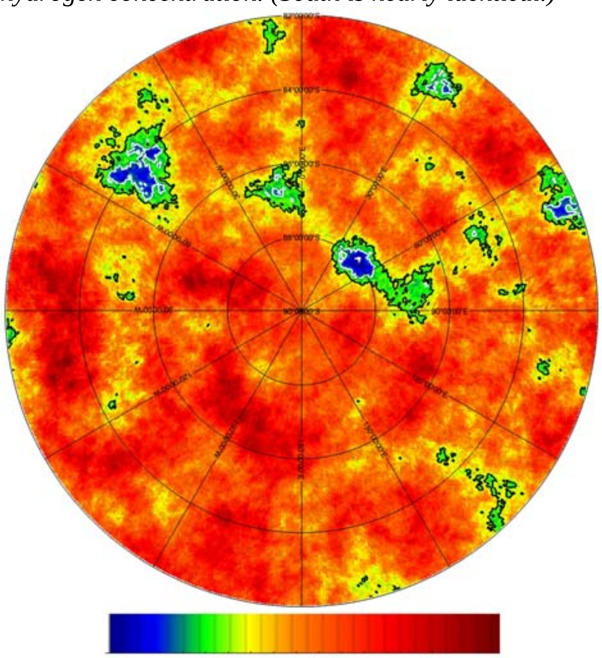

Fig 4. Count-rate difference map in the South Polar Region. Contours are drawn at a difference -0.04 cps.

We make a difference map by subtracting the count rate determined from the linear fit in fig. 3. The difference maps are shown in fig. 4. It is obvious there are some regions with count rates significantly lower than most of the rest of the map. It is not clear just by looking at the map if these regions are just the tail of a normal distribution, or if they represent a different population of hydrogen enrichement.

We examine this question by making a histogram of all of the points (HEALPix bins) in the maps separately for each pole. The results for the South Pole are shown in figure 5. It is very obvious that we have a bimodal distribution of count rates (and thus hydrogen distribution).

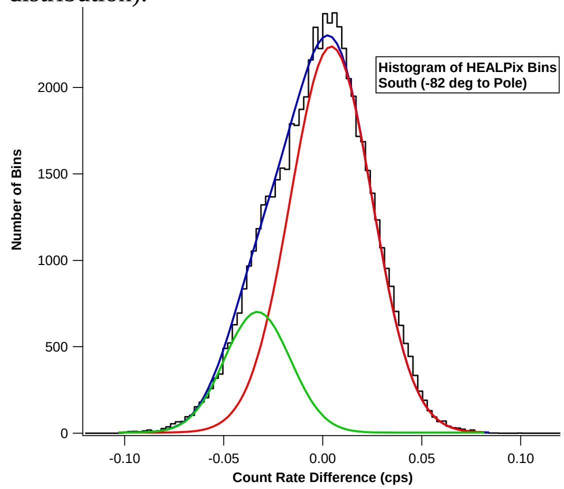

Fig 5. Histogram of HEALPix bins in fig 4 shows a clear bimodal distribution of count rates. The smooth blue line is the sum of the two Gaussian shown in red and green.

Discussion: It is clear from figure 5 that there are two distinct populations of hydrogen distribution, which suggests that two different mechanisms are responsible for the observed distribution. The smaller population has lower count rates and clearly corresponds to the NSRs. It is perhaps not surprising that the NSRs are represent a different mechanism, but prior to obtaining these LEND data, the mechanism was thought to be associated with the PSRs, but we now know that is not the case.

The other distribution is represented by the very regular increase in hydrogen toward the pole. This distribution is not likely to be due to the primary emplacement of hydrogen if it comes from the solar wind because the cosine of the angle would have a higher flux at lower latitudes. This distribution is almost certainly due to average surface temperatures being lower toward the pole, hence volatile migration is suggested.

The implications of these distributions will be discussed in more detail at the meeting.

References: [1] Watson et al. (1961), [2] Arnold (1971), [3] Nozette et al., (1996), [4] Stacey et al. (1997) [5] Simpson and Tyler (1999), [6] Feldman et al. (1998). [7] Mitrofanov et al. (2011), [8] Mitrofanov et al. (2008).