LEND instrument onboard LRO:

the first year of observations in space

Igor Mitrofanov,

on behalf of the LEND Team

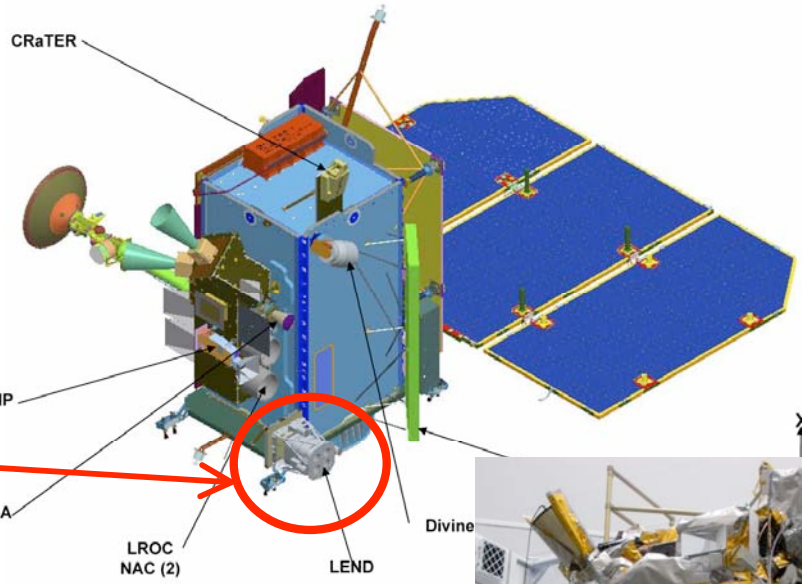
July 20, 2010

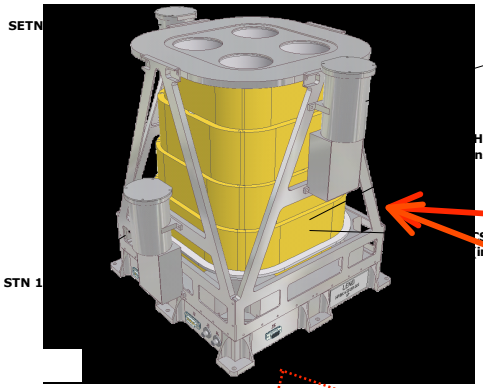
Lunar Exploration Neutron Detector

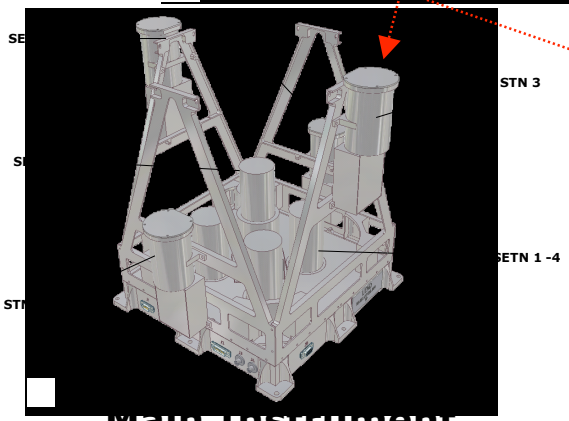
Congratulations with the 35th anniversary of the first Russian-US joint step to space!
Go LRO! Go LEND!

LEND Instrument Overview

LEND consists of nine detectors to measure fluxes of thermal, epithermal, and fast neutrons.



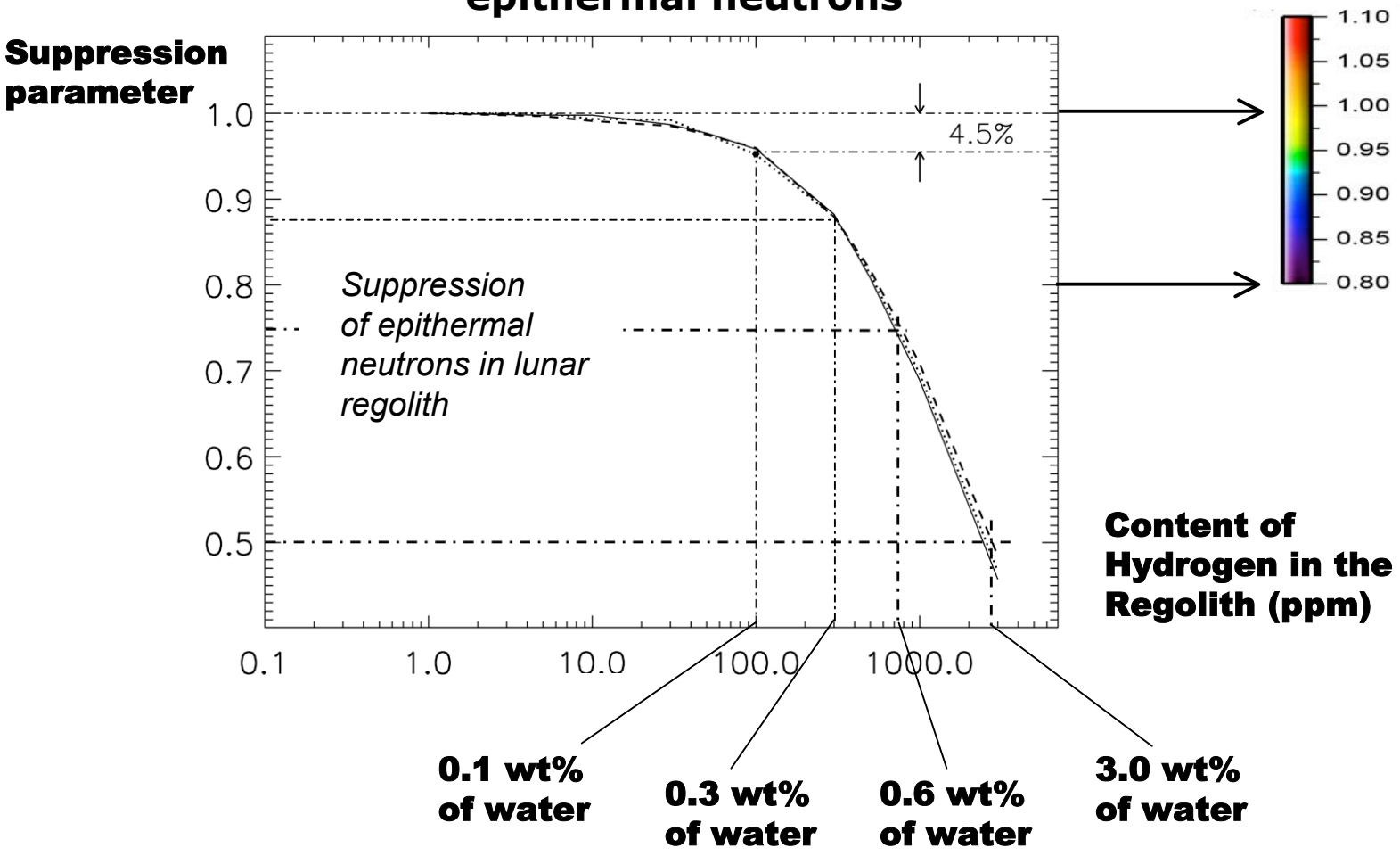




Main Instrument

Collimator

Relationship between content of Hydrogen (or water) and suppression of epithermal neutrons



Lunar Exploration Neutron Detector

Radiation Data Product (III): ***Neutrons***

SETN

Radiation Data Product (III): ***Neutrons***

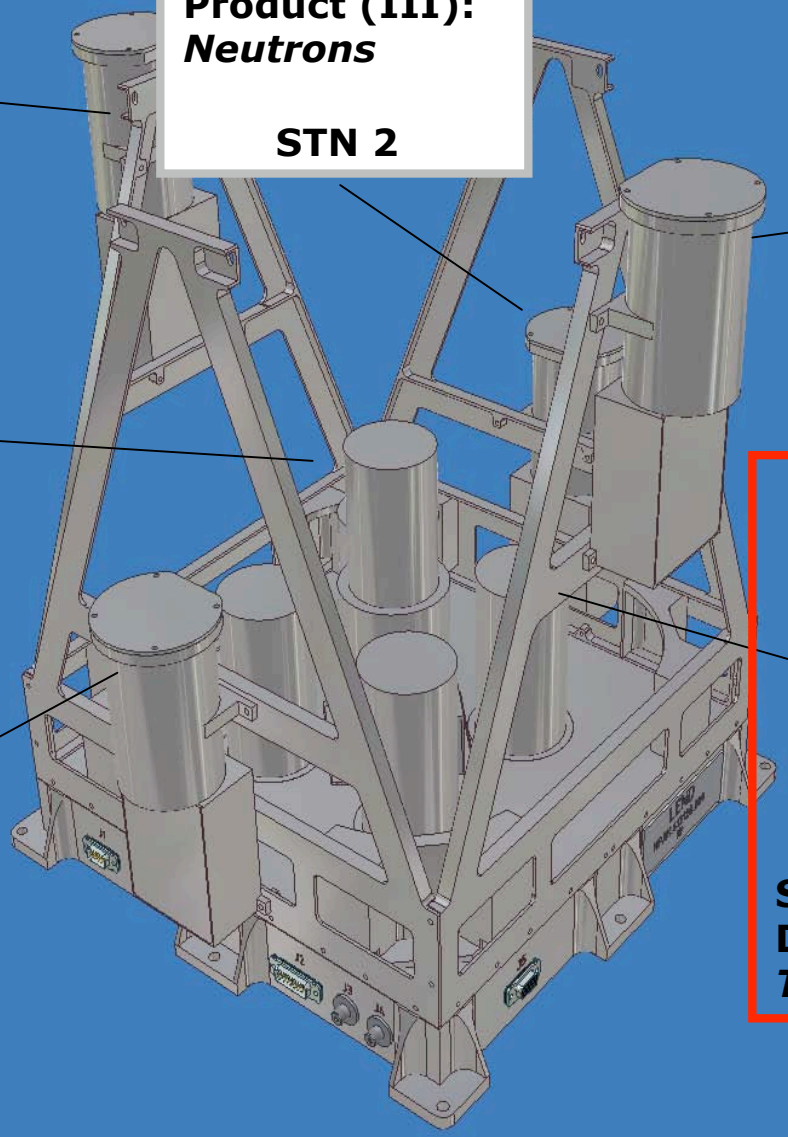
STN 2

Radiation Data Product (III): ***Neutrons***

STN 3

Surface Composition Data Product (II): ***Testing Water Ice***

SHEN (inside)



Surface Composition Data Product (I): ***Hydrogen***

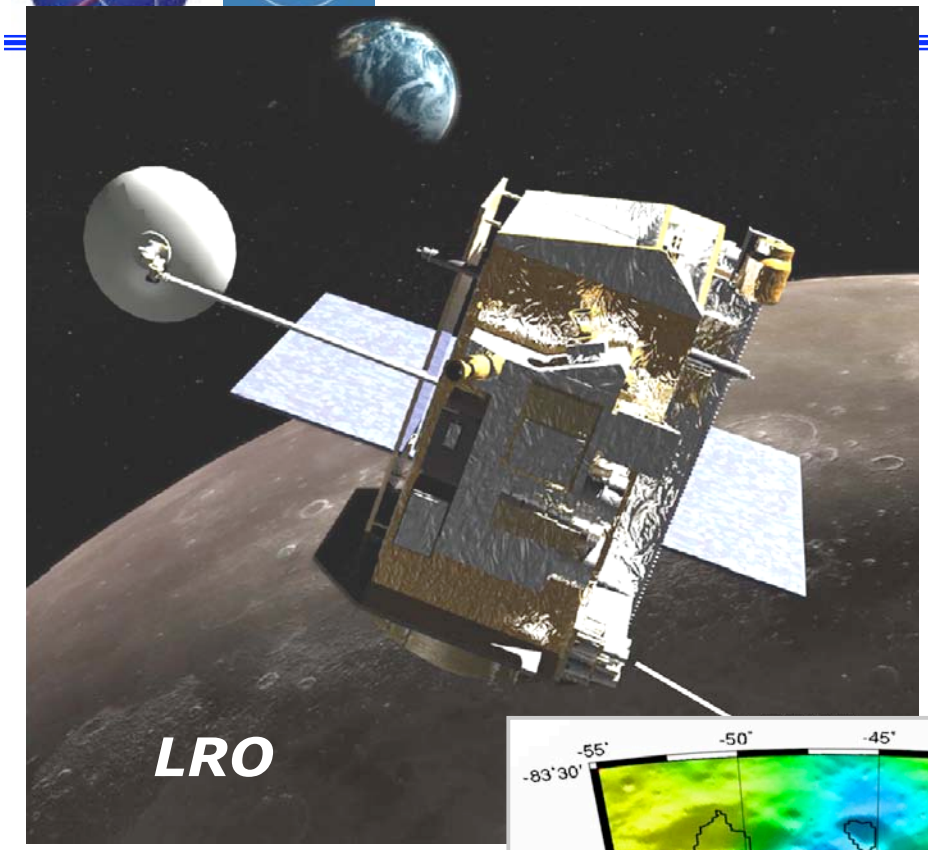
CSETN 1-4

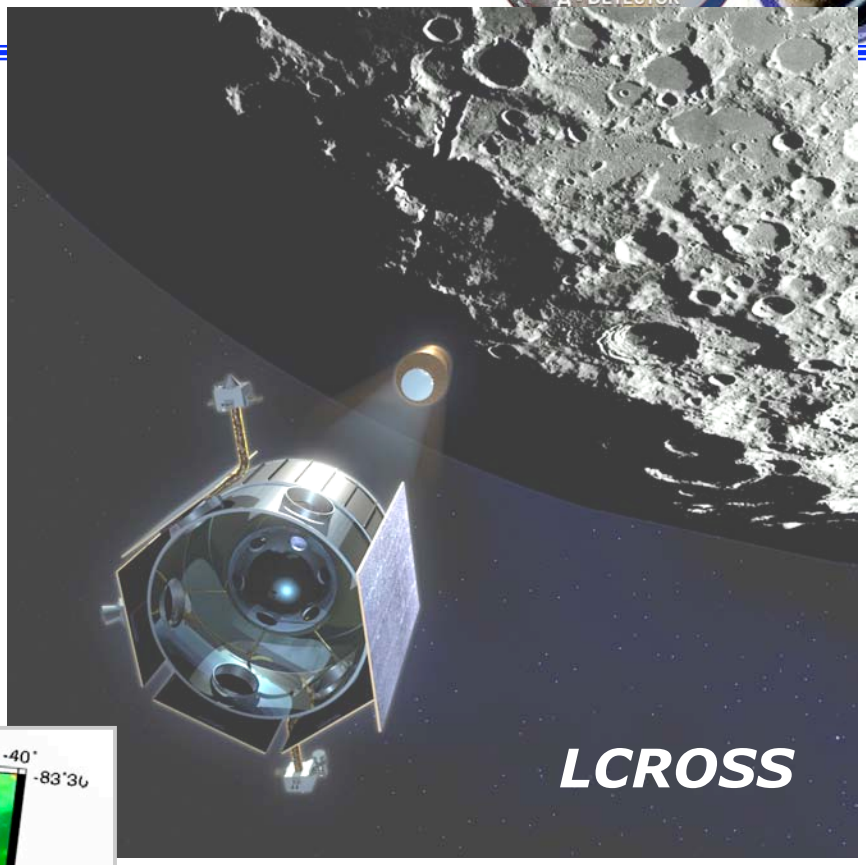
Radiation Data Product (III): ***Neutrons***

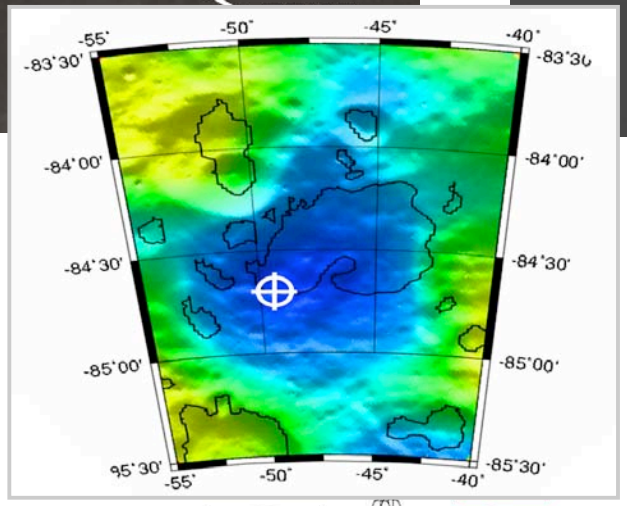
STN 1

Surface Composition Data Product (II): ***Testing Water Ice***

Lunar Exploration Neutron Detector







Cabeus was suggested by LEND, as the best impact target for LCROSS

Suppression of neutron emission in Cabeus was found to be 0.4 ± 0.1 cts/s.

It corresponds to the average enhancement of hydrogen in Cabeus region about 550 ppm

Since LEND selection was done in 2004 by NASA peer review process, there were numerous public statements and publications by David Laurence, William Feldman, Richard Elphic and others that LEND *is not capable to perform measurements of lunar neutrons with high special resolution*.

The most recent example is in the program of this Forum:

Lunar Compositional Information Provided by Orbital Neutron Data from the Lunar Reconnaissance Orbiter (LRO)

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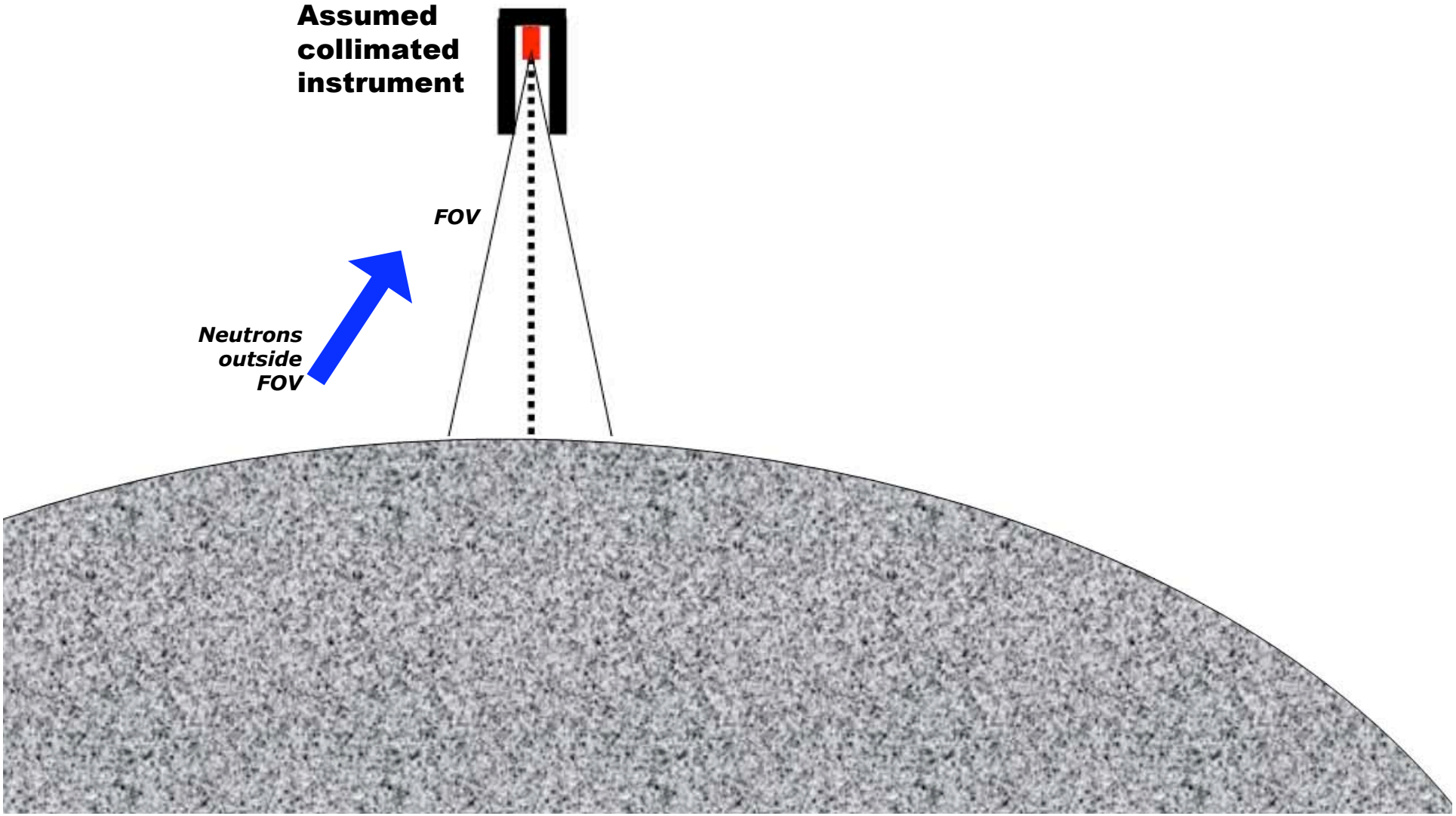
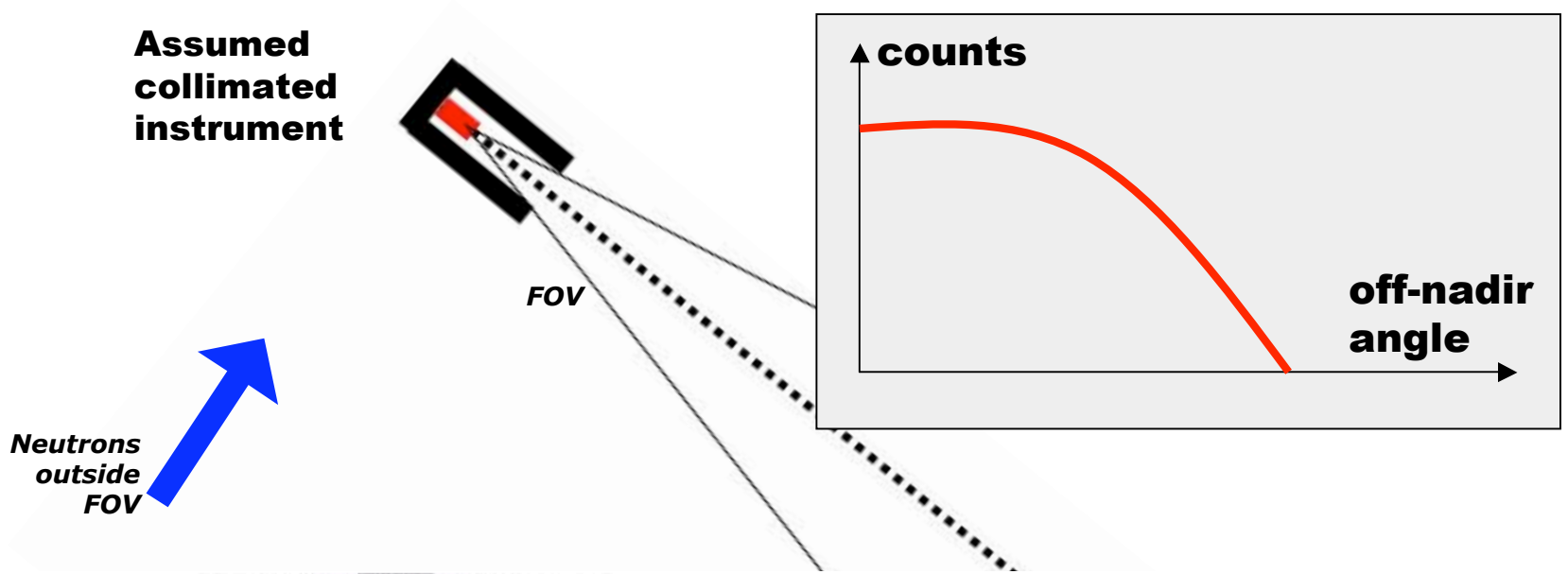
First Name: David
Last Name: Lawrence
Institution: Johns Hopkins University Applied Physics Laboratory
Co-authors: D. Ben Bussey, Johns Hopkins University Applied Physics Laboratory, USA
Joshua T. Cahill, Johns Hopkins University Applied Physics Laboratory, USA
Vincent R. Eke, Department of Physics, Durham University, UK
Richard C. Elphic, NASA Ames Research Center, US
William C. Feldman, Planetary Science Institute, US
Hebert O. Funsten, Los Alamos National Laboratory, US
Thomas H. Prettyman, Planetary Science Institute, US
Luis, F. A. Teodoro, Eloret Corporation, NASA Ames Research Center, US

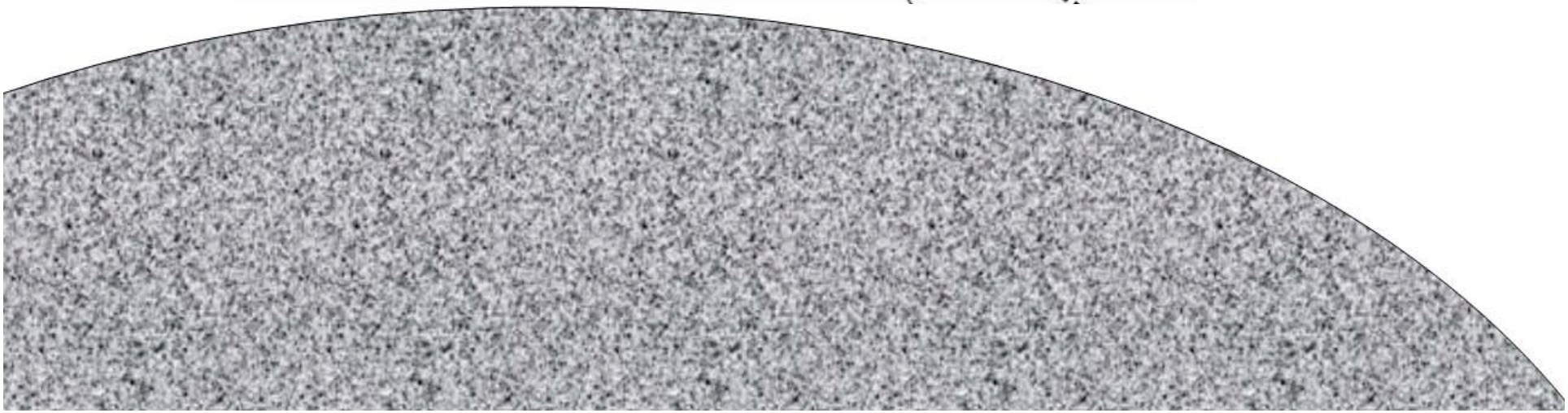
As part of the "Scientific and Exploration Potential of the Lunar Poles" project, we are studying neutron spectroscopy and the use of this technique for understanding hydrogen abundances on the Moon. Here, we have applied the same analysis techniques used for Lunar Prospector (LP) neutron data to those obtained with the Lunar Exploration Neutron Detector (LEND) recently made available from the Planetary Data System (PDS). We have confirmed that the data from the uncollimated neutron sensors, which have a large spatial footprint, provide clear composition information and are consistent with LP neutron data. We also analyzed the LEND high-spatial-resolution collimated data by determining the counting rates for nadir and off-limb pointing conditions. Our analysis shows that the summed counting rate of all collimated sensors has no change to within a 2-σ uncertainty between the nadir and off-limb pointing. We are investigating what these results imply for the statistical significance of lunar polar hydrogen abundances at high spatial resolution.

Lunar Exploration Neutron Detector



Lunar Exploration Neutron Detector





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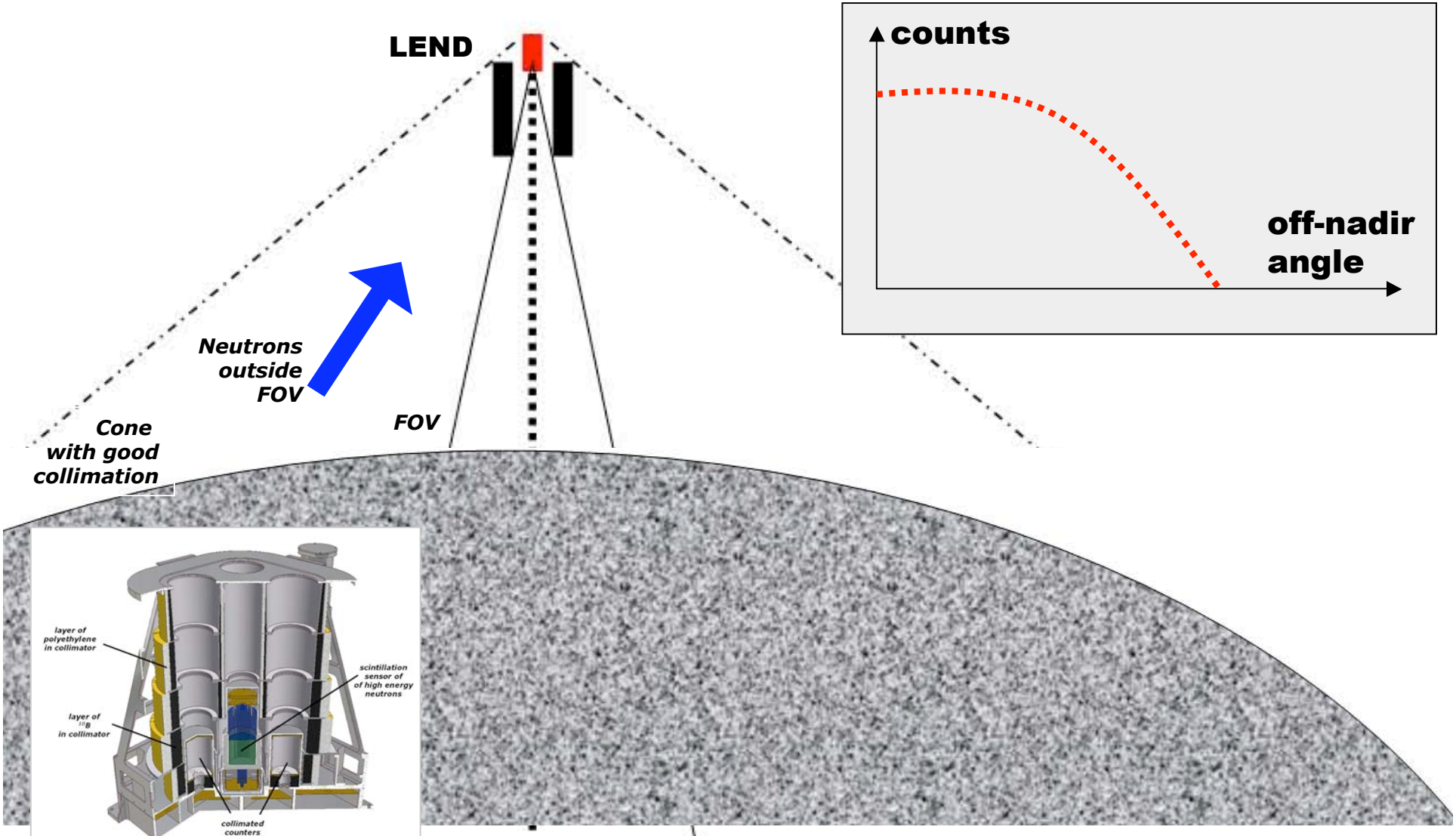

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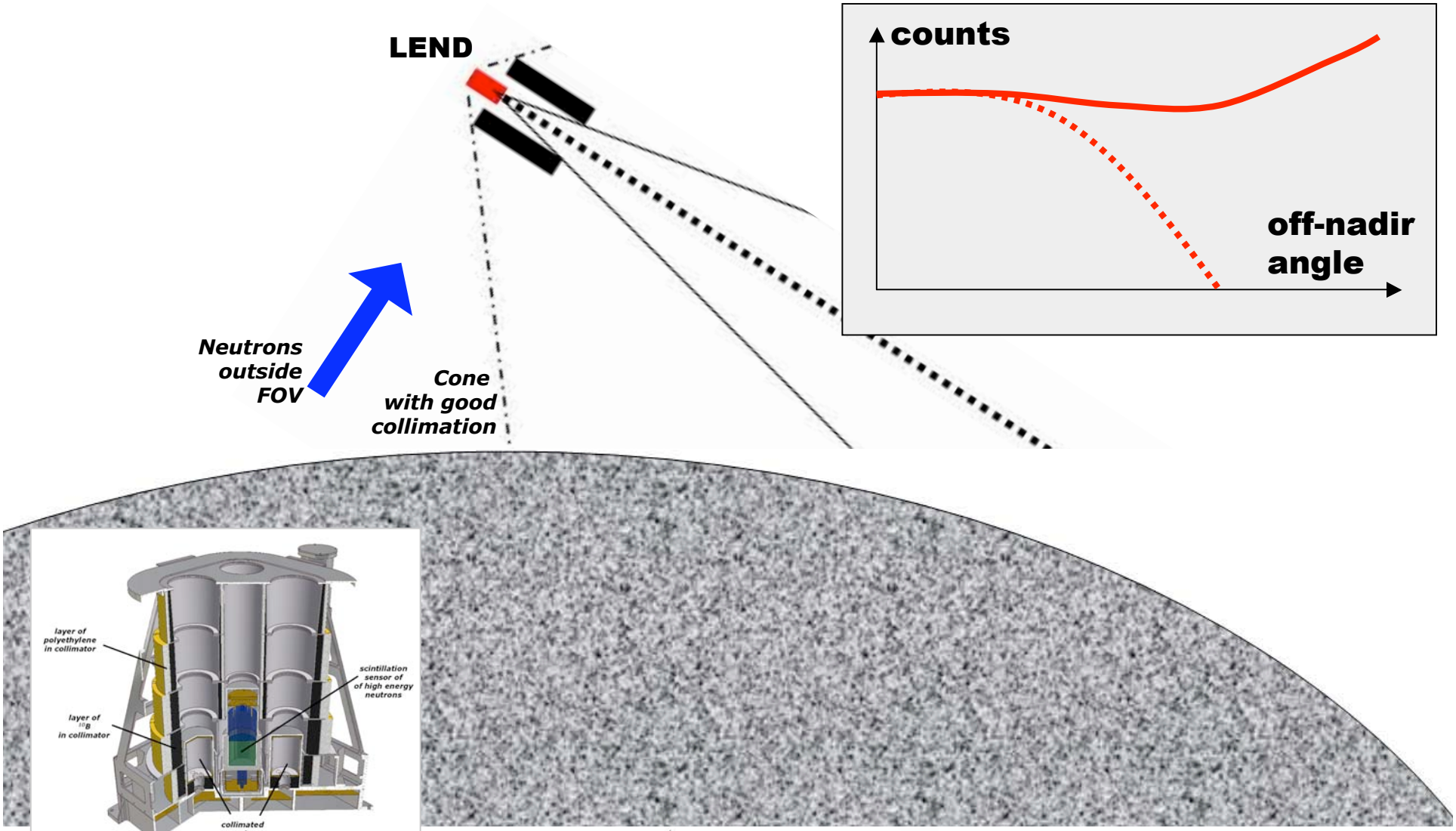
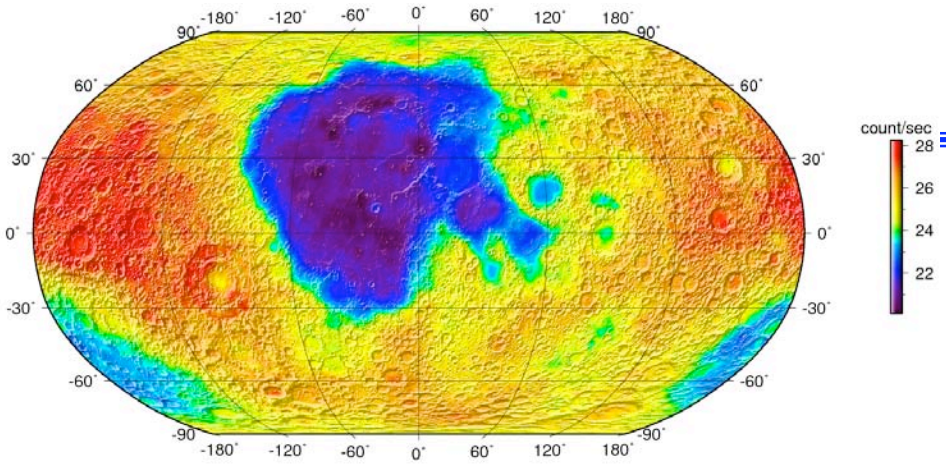
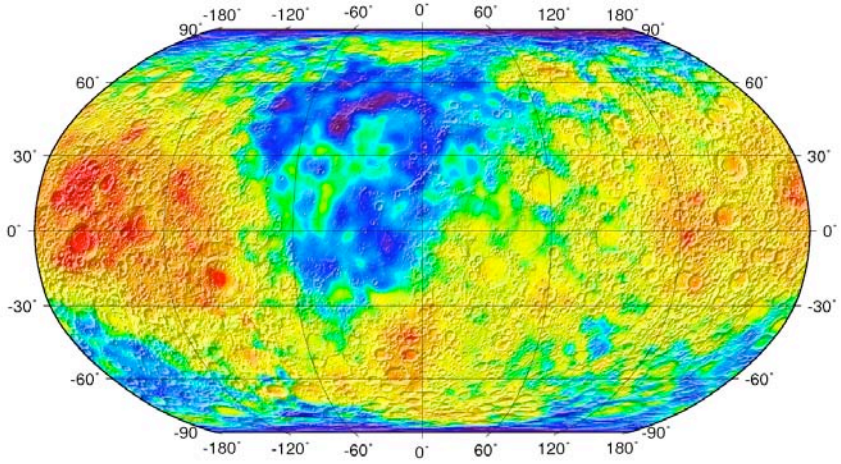
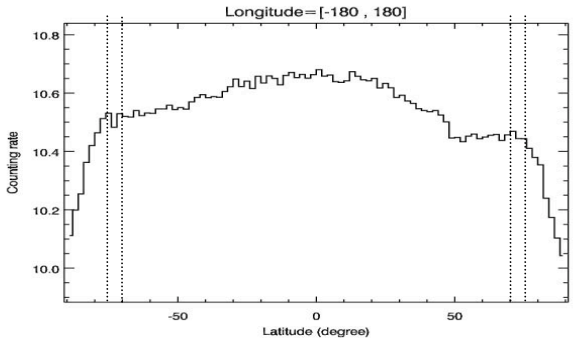


LEND global mapping for thermal neutrons



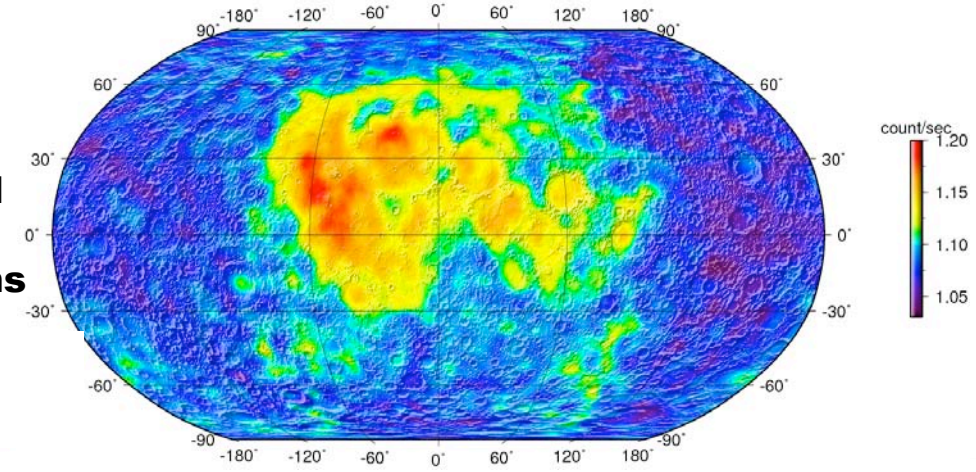
LEND global mapping for epi-thermal neutrons





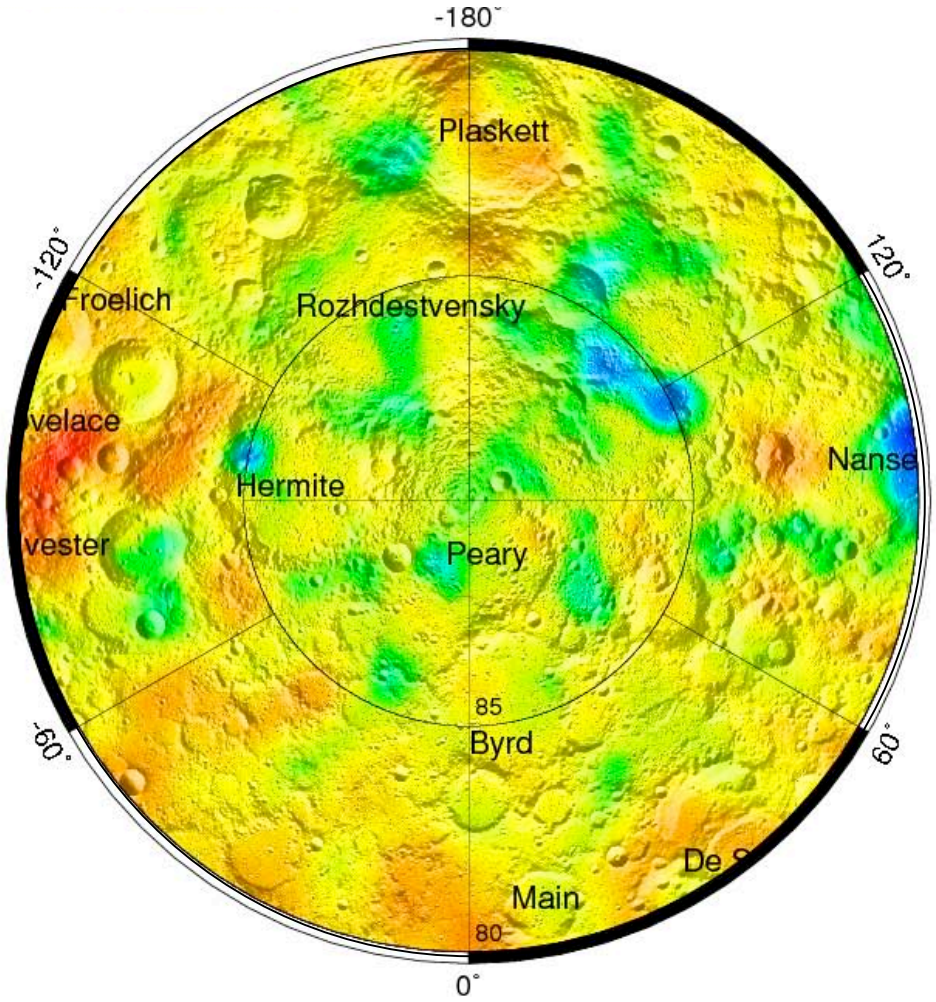
Effect of polar suppression of epi-thermal neutrons

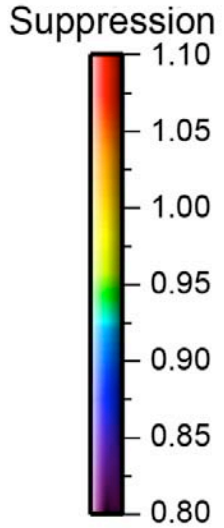
LEND global mapping for fast neutrons



Lunar relief is shown from LOLA altimetry

LEND map of epithermal neutrons at North pole above 80° latitude





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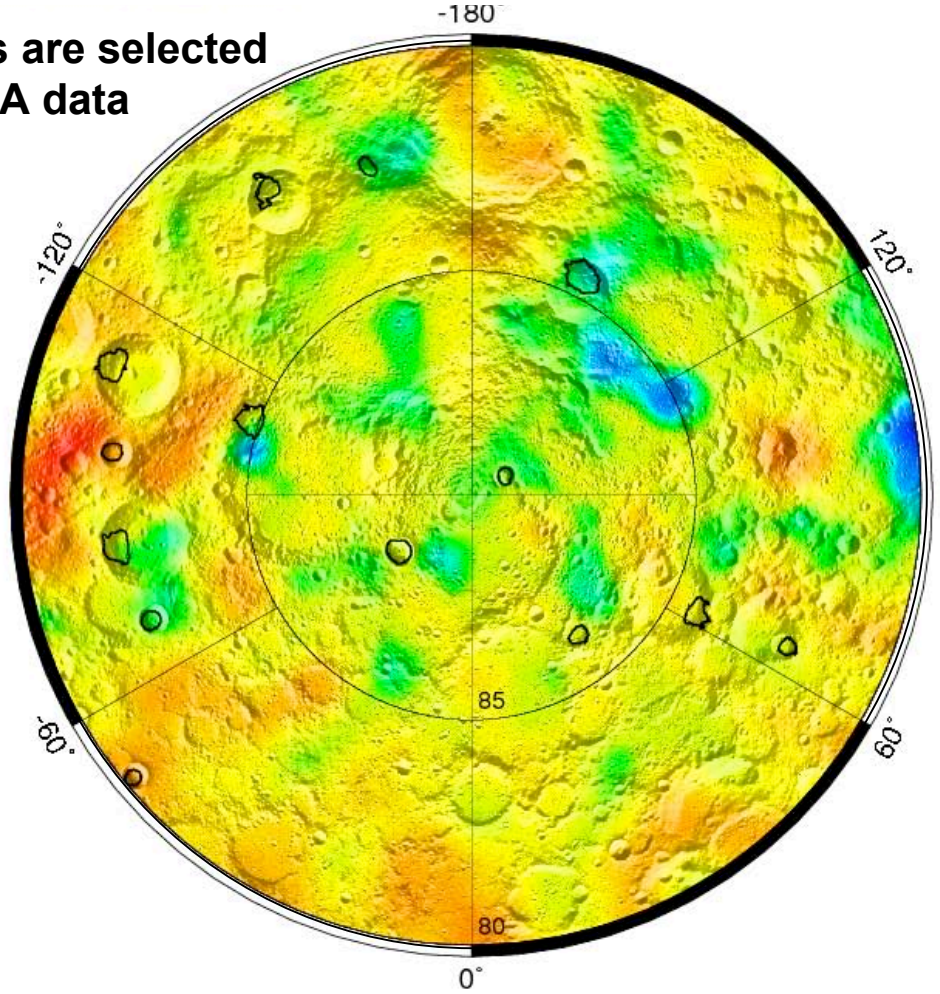
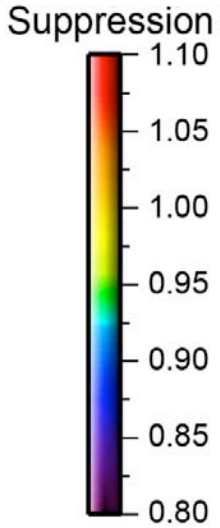
LEND map of epithermal neutrons at North pole above 80° latitude

14 Northern PSRs are selected according to LOLA data with area > 75 km^2





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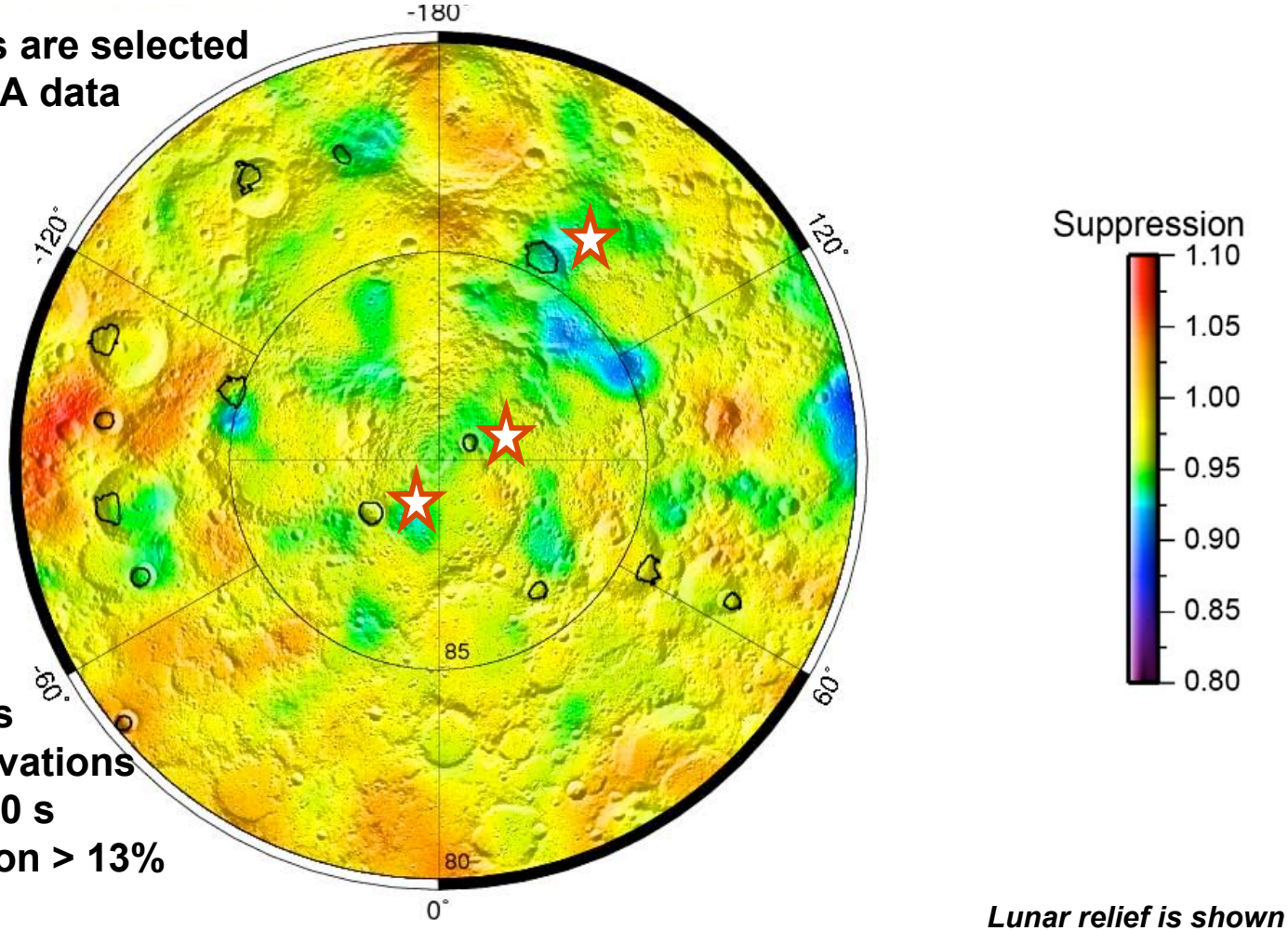
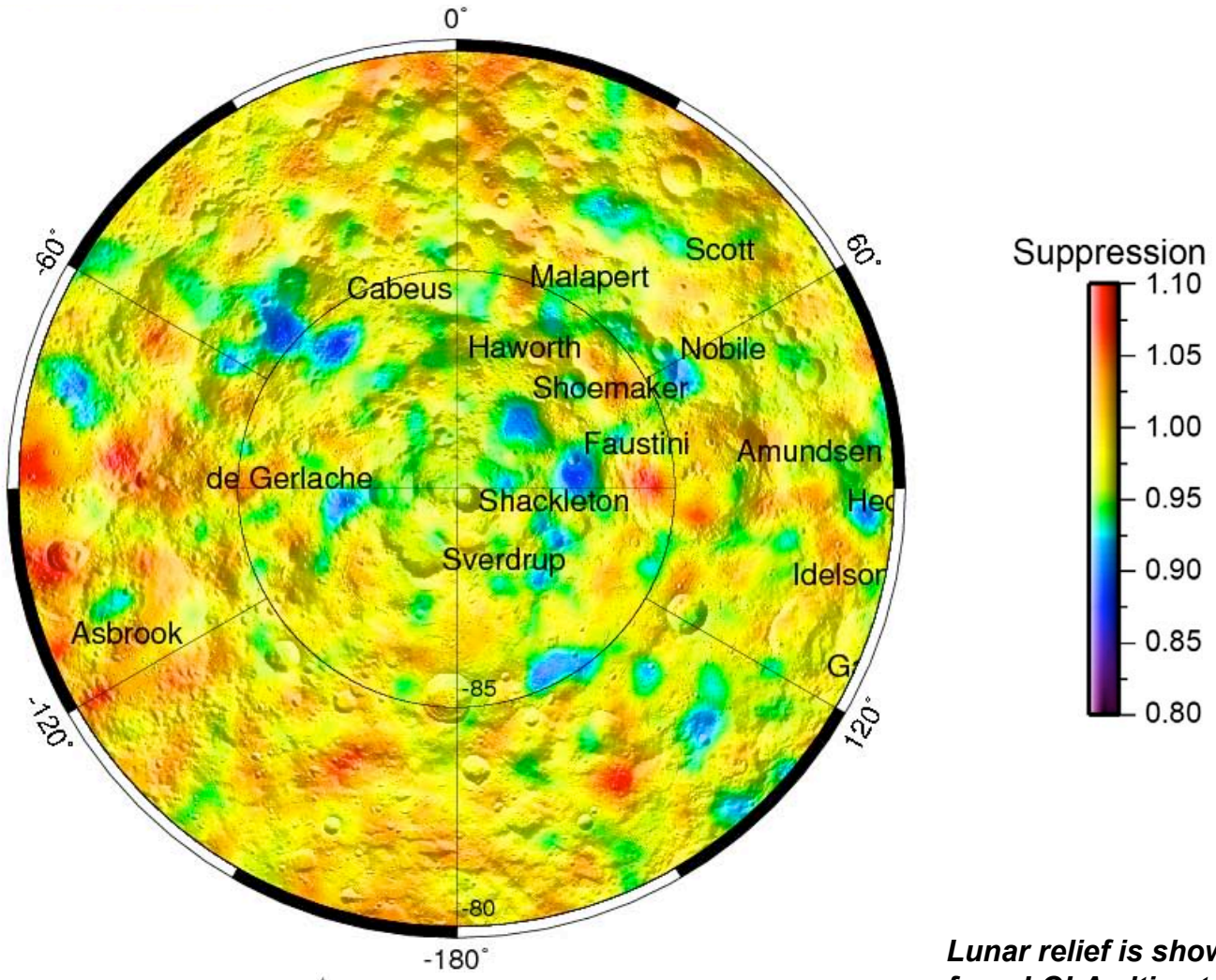


For 3 northern PSRs LEND time of observations is large enough >700 s to detect suppression > 13% (water > 0.3 wt%)

Lunar relief is shown from LOLA altimetry

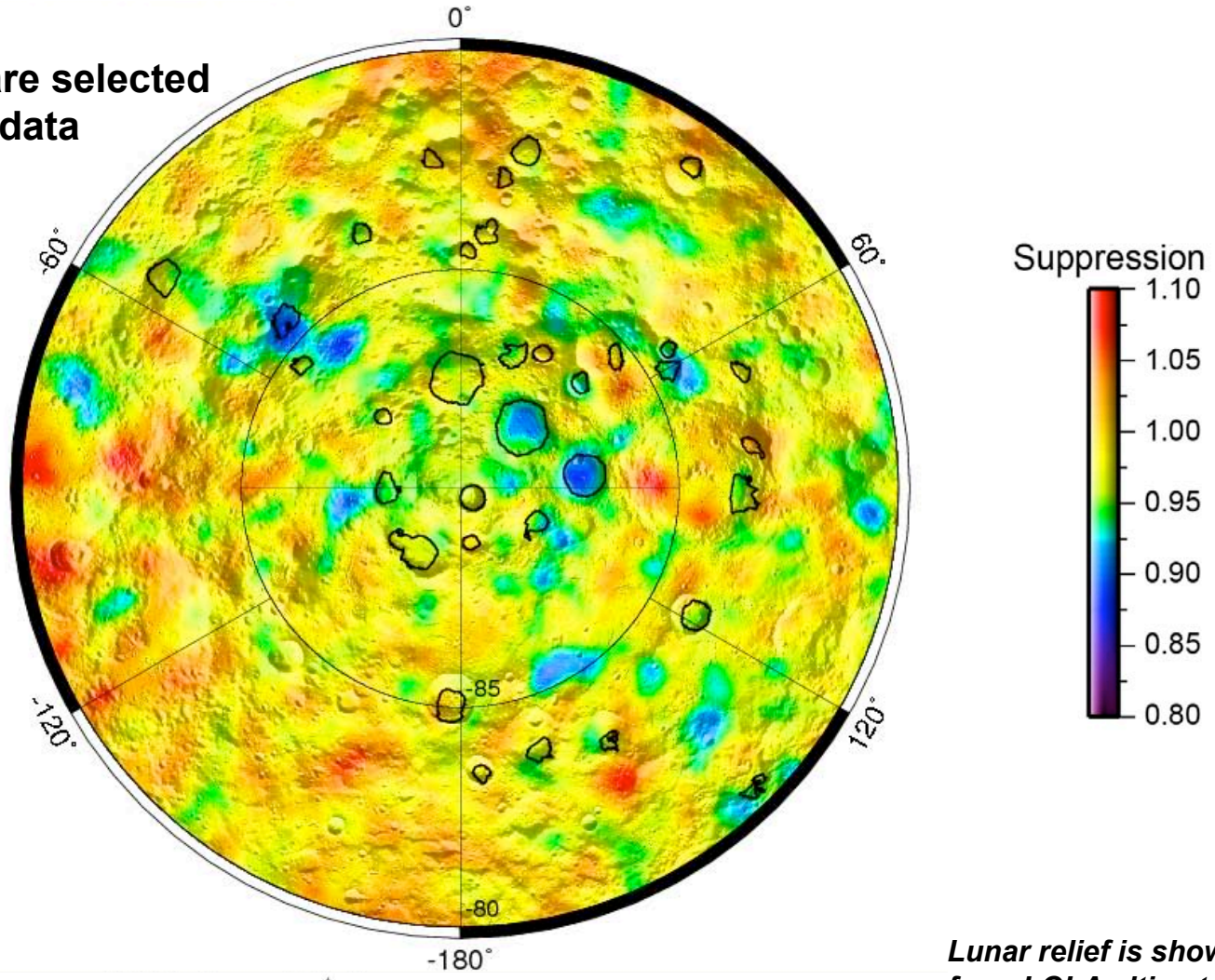
LEND map of epithermal neutrons at South pole above 80° latitude



Lunar relief is shown from LOLA altimetry

LEND map of epithermal neutrons at South pole above 80° latitude

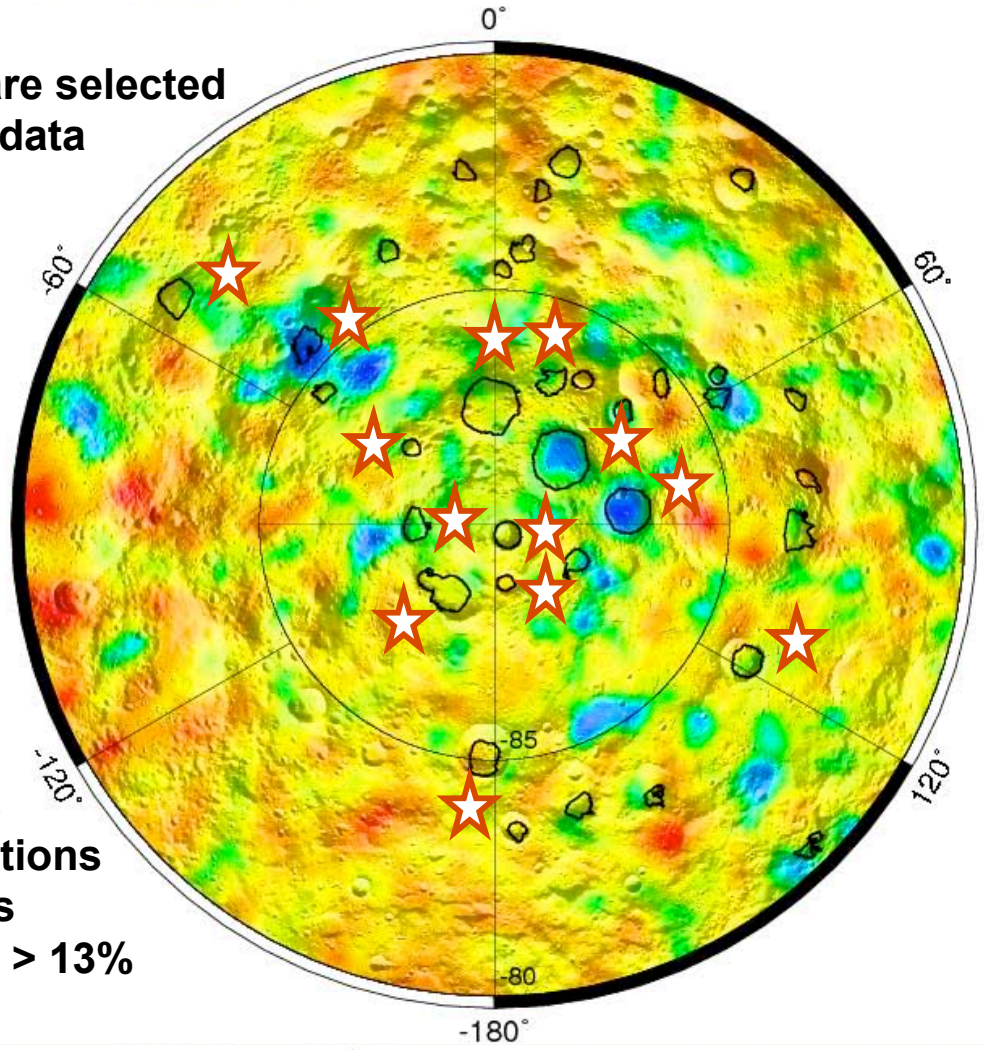
35 southern PSRs are selected according to LOLA data with area > 75 km^2



Lunar relief is shown from LOLA altimetry

LEND map of epithermal neutrons at South pole above 80° latitude

35 southern PSRs are selected according to LOLA data with area > 75 km^2

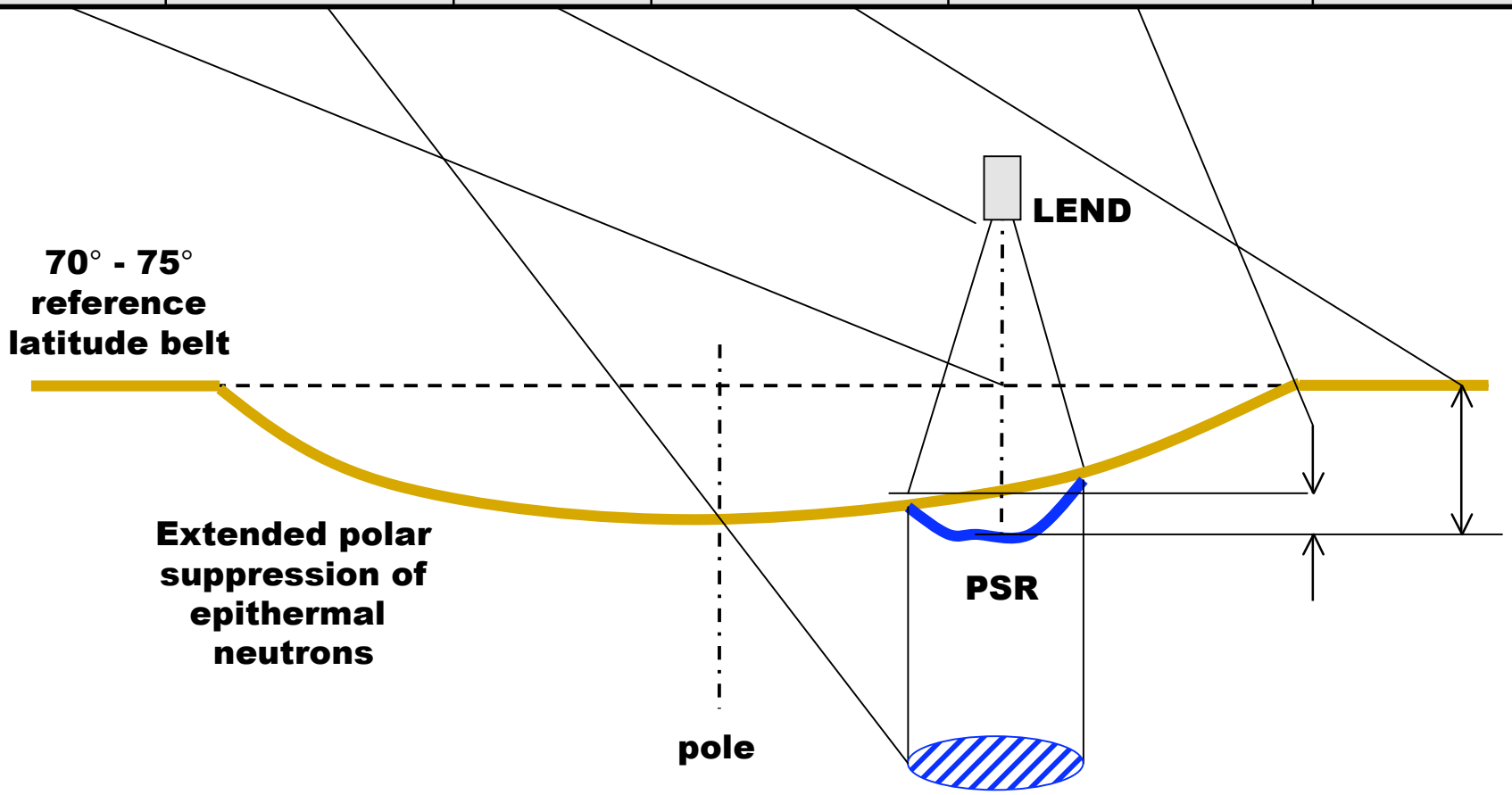


For 13 southern PSRs LEND time of observations is large enough >700 s to detect suppression > 13% (water > 0.3 wt%)

Lunar relief is shown from LOLA altimetry

Testing PSRs with area > 75 km^2 and total observation time >700 s

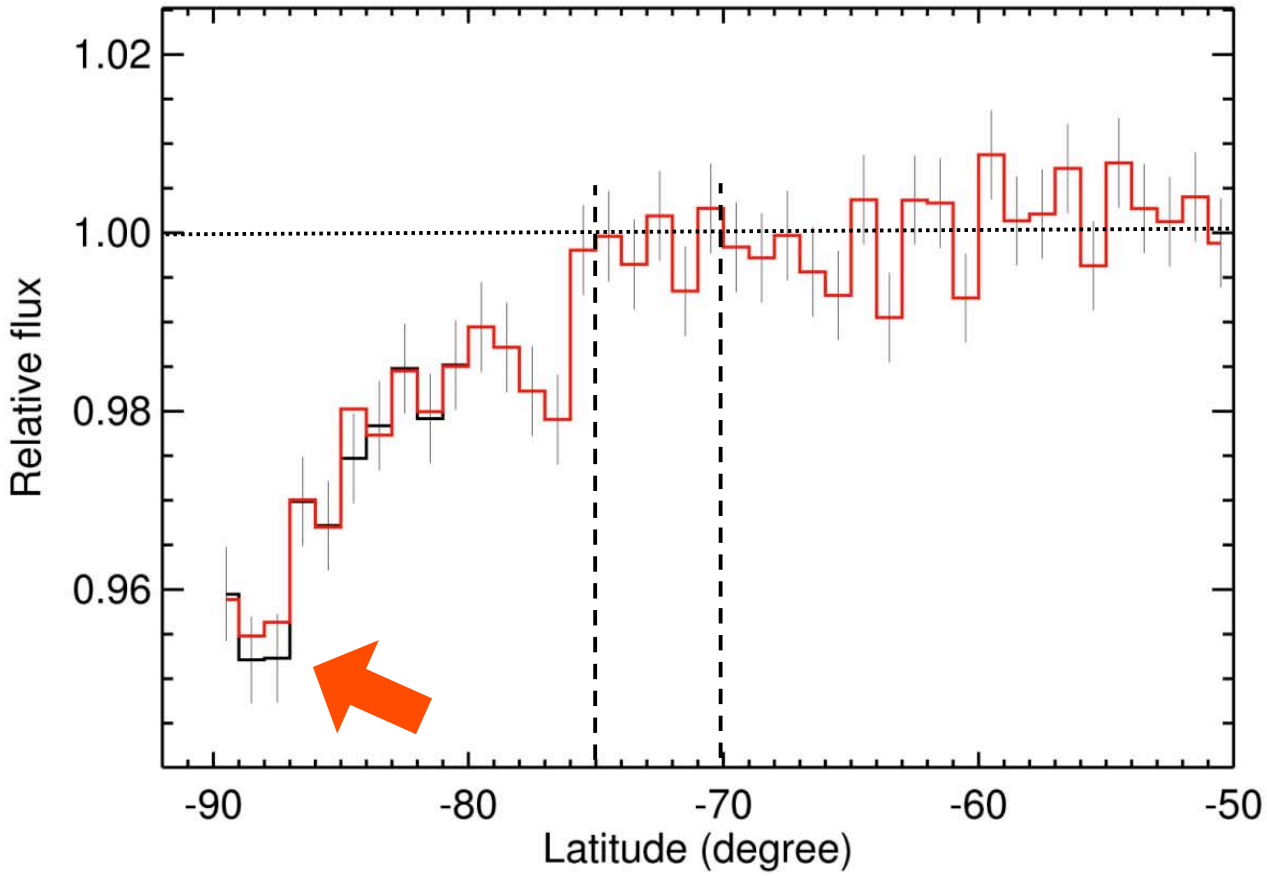
Latitude of PSR	Area of PSR (km^2)	Total observation time (sec)	Observed absolute suppression of PSR	Observed local suppres-sion in PSR in companion with its vicinity	Remarks



Testing PSRs with area > 75 km^2 and total observation time >700 s

Latitude of PSR	Area of PSR (km^2)	Total observation time (sec)	Observed absolute suppression of PSR	Observed local suppres-sion in PSR in companion with its vicinity	Remarks
+ 87.97	196	2060	0.98 ± 0.03	1.01 ± 0.03	
+ 89.12	79	1410	0.95 ± 0.04	0.99 ± 0.04	
+ 84.5	345	840	0.82 ± 0.05	0.84 ± 0.05 (4 σ)	
- 88.00	1048	14180	0.92 ± 0.01	0.95 ± 0.01 (4 σ)	Shoemaker
- 87.47	972	9450	0.96 ± 0.01	0.99 ± 0.01	Haworth
- 89.64	220	8120	0.98 ± 0.01	1.02 ± 0.01	Shacklton
- 88.23	520	6470	0.98 ± 0.02	1.01 ± 0.02	Sverdup
- 87.13	635	2370	0.89 ± 0.03	0.92 ± 0.03 (~3 σ)	Faustini
- 88.35	223	1410	0.91 ± 0.03	0.94 ± 0.03	De Gerlache
- 85.02	319	1300	1.01 ± 0.03	1.06 ± 0.03	
- 88.74	79	1100	1.02 ± 0.04	1.07 ± 0.04	
- 88.08	163	800	0.87 ± 0.04	0.91 ± 0.04	
- 87.6	90	790	0.95 ± 0.05	0.99 ± 0.05	
- 86.7	195	760	0.92 ± 0.05	0.95 ± 0.05	
- 81.67	342	720	0.98 ± 0.05	1.00 ± 0.05	
- 83.88	290	720	0.95 ± 0.05	0.98 ± 0.05	
- 84.44	242	700	0.83 ± 0.05	0.85 ± 0.05 (~3 σ)	Cabeus

Contribution of tested PSRs with area > 75 km^2 into polar suppression of epithermal neutrons

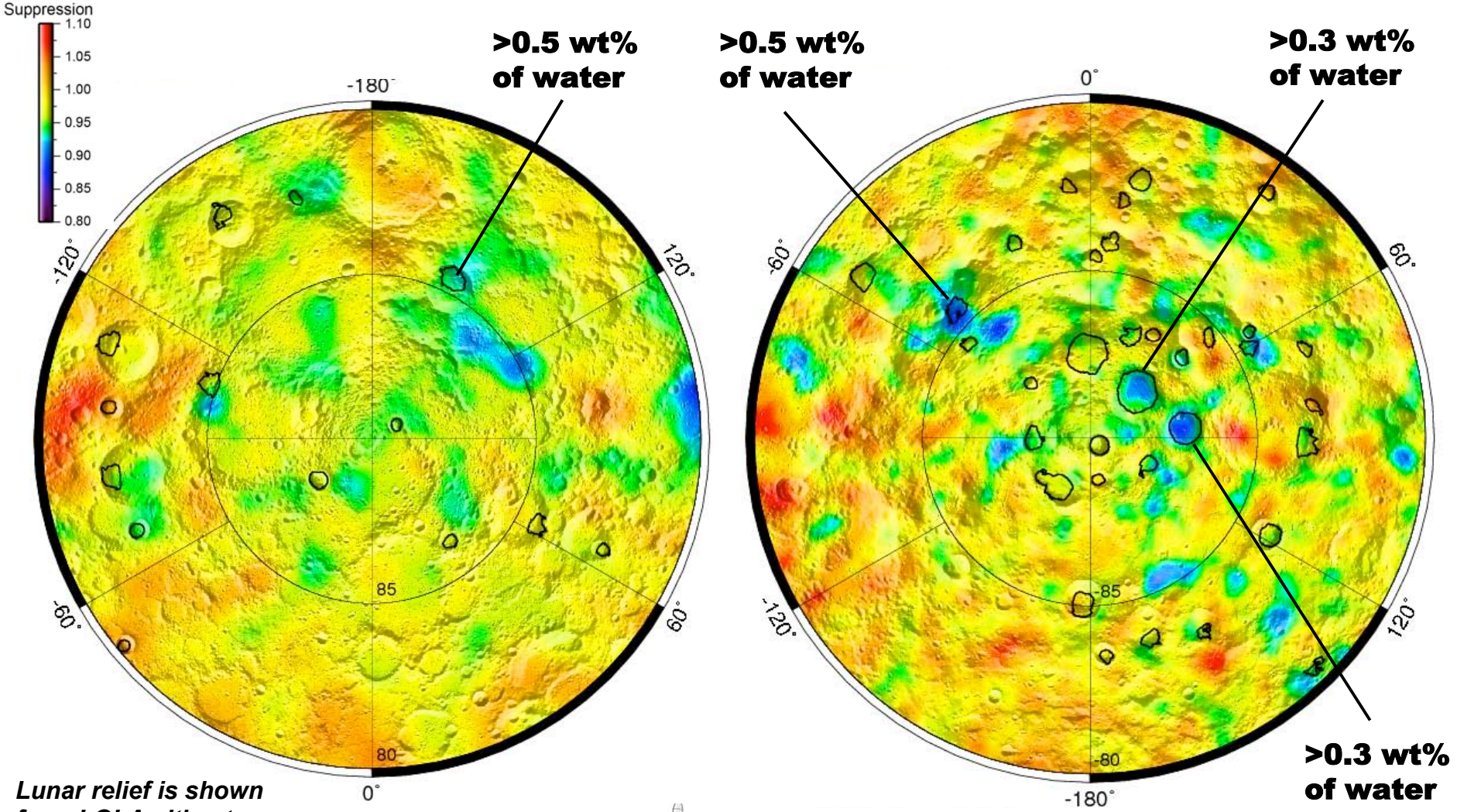


Average suppression at latitude belt

Average suppression at latitude belt with excluded contributions of large PSRs

Lunar Exploration Neutron Detector

LEND maps of epithermal neutrons at North and South poles above 80° latitude



Lunar relief is shown from LOLA altimetry

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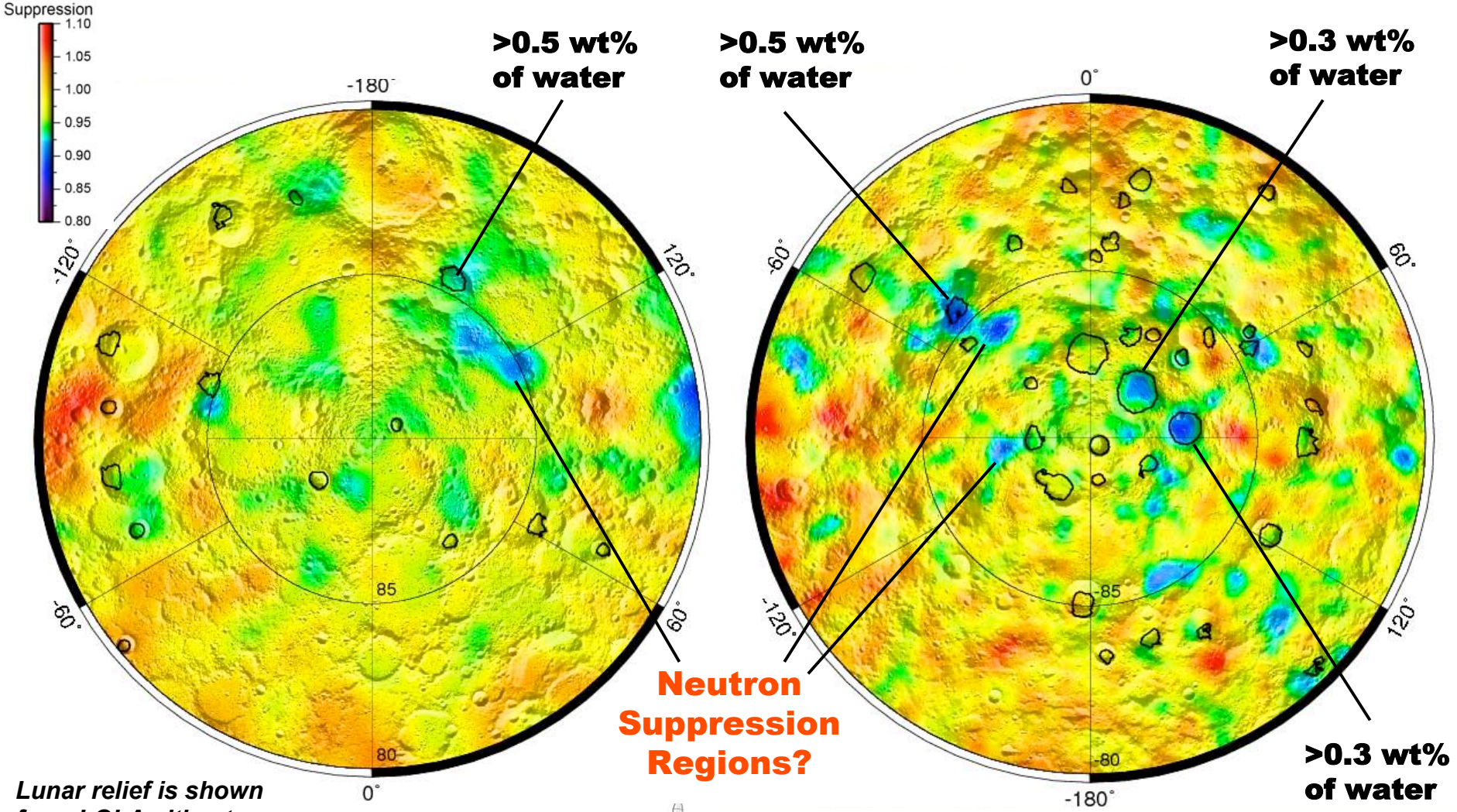
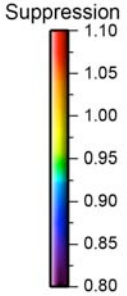
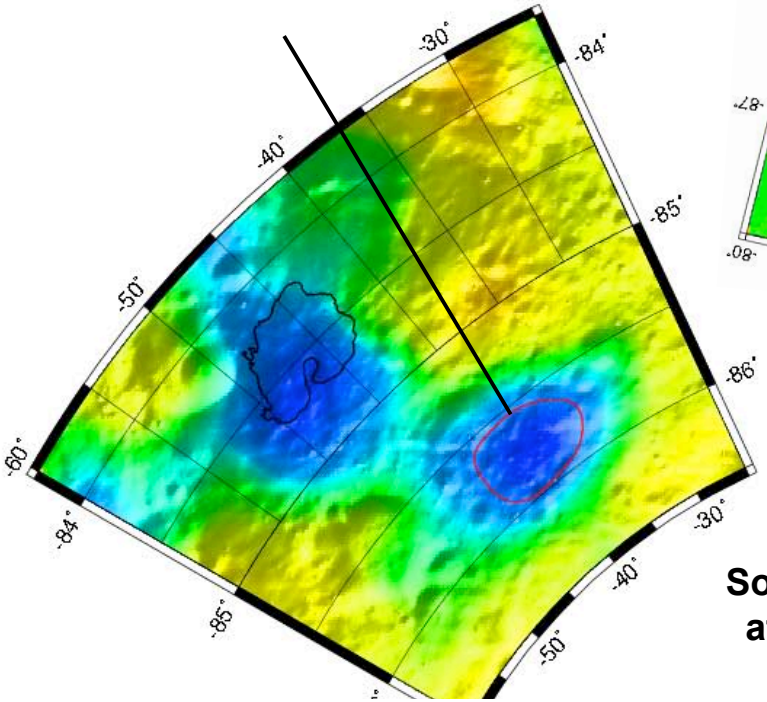


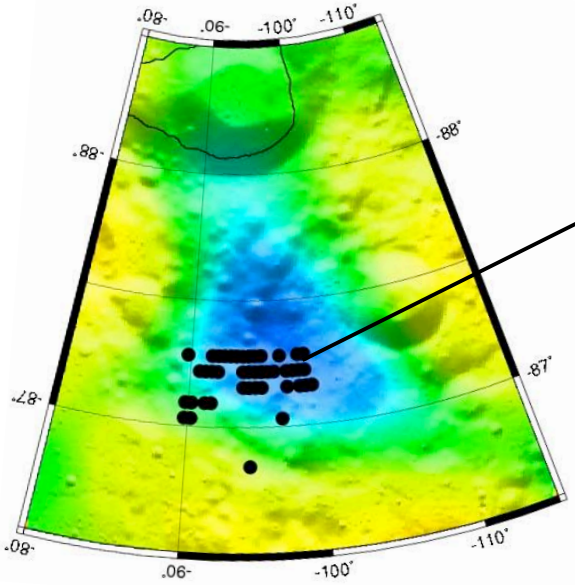
Lunar relief is shown from LOLA altimetry

NSRs may become the main subjects for LEND studies at space science stage

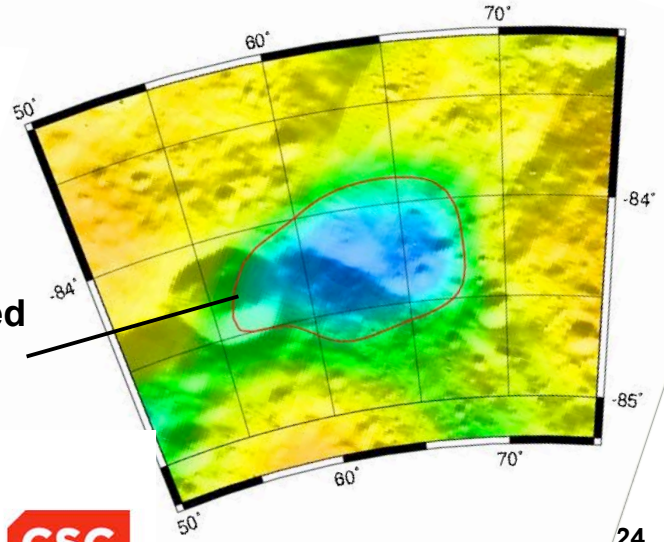


Twin NSR in Cabeus have deeper suppression than one of PSR





Some pixels of this NSR have very high temperature (Diviner) and very high Incident flux (LOLA) for this latitude



Some NSRs are located at hills with opposite slopes

CONCLUSIONS:

Analysis of LEND data points out that observable effect of extended polar suppressions of emission of lunar epithermal neutrons is not produced by integrated contributions of large *Permanently Shadowed Regions* (PSRs) with deep local suppressions.

LEND data shows that *Permanently Shadowed Regions* with areas >75 km^2 have no appreciable enhancement of Hydrogen in regolith in comparison with illuminated areas at the same latitudes. Many PSRs are shown to have practically the same content of Hydrogen, as the surrounding illuminated areas. The largest enhancement of Hydrogen Δ > 0.5 wt% of water equivalent is detected for PSR in Cabeus.

Several local *Neutron Suppression Regions* (NSRs) were resolved by LEND at illuminated polar area of the Moon, which manifest the deepest detected suppression of neutrons about 70% (in comparison with the average flux of neutrons at the latitude belt 70 ° – 75°).