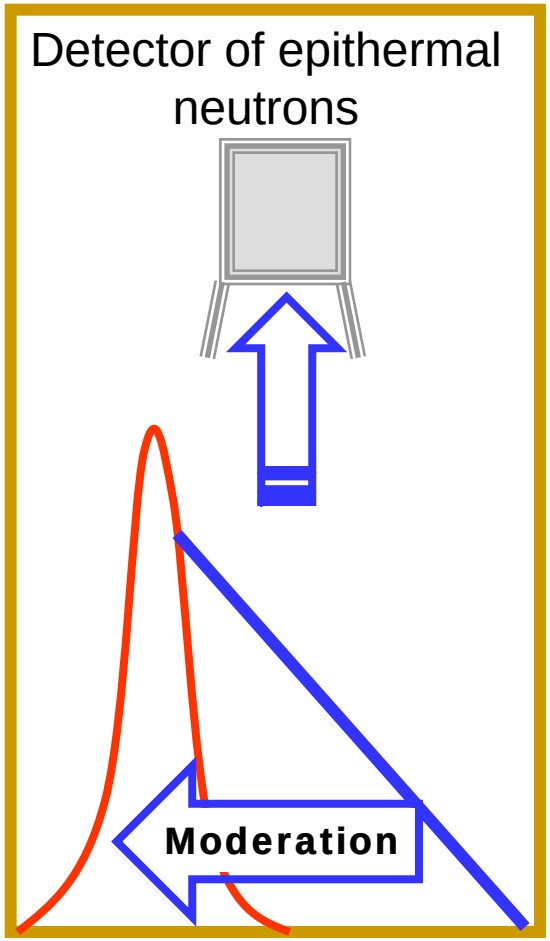
Main results from LEND instrument after 1 year of lunar mapping onboard NASA's LRO Mission

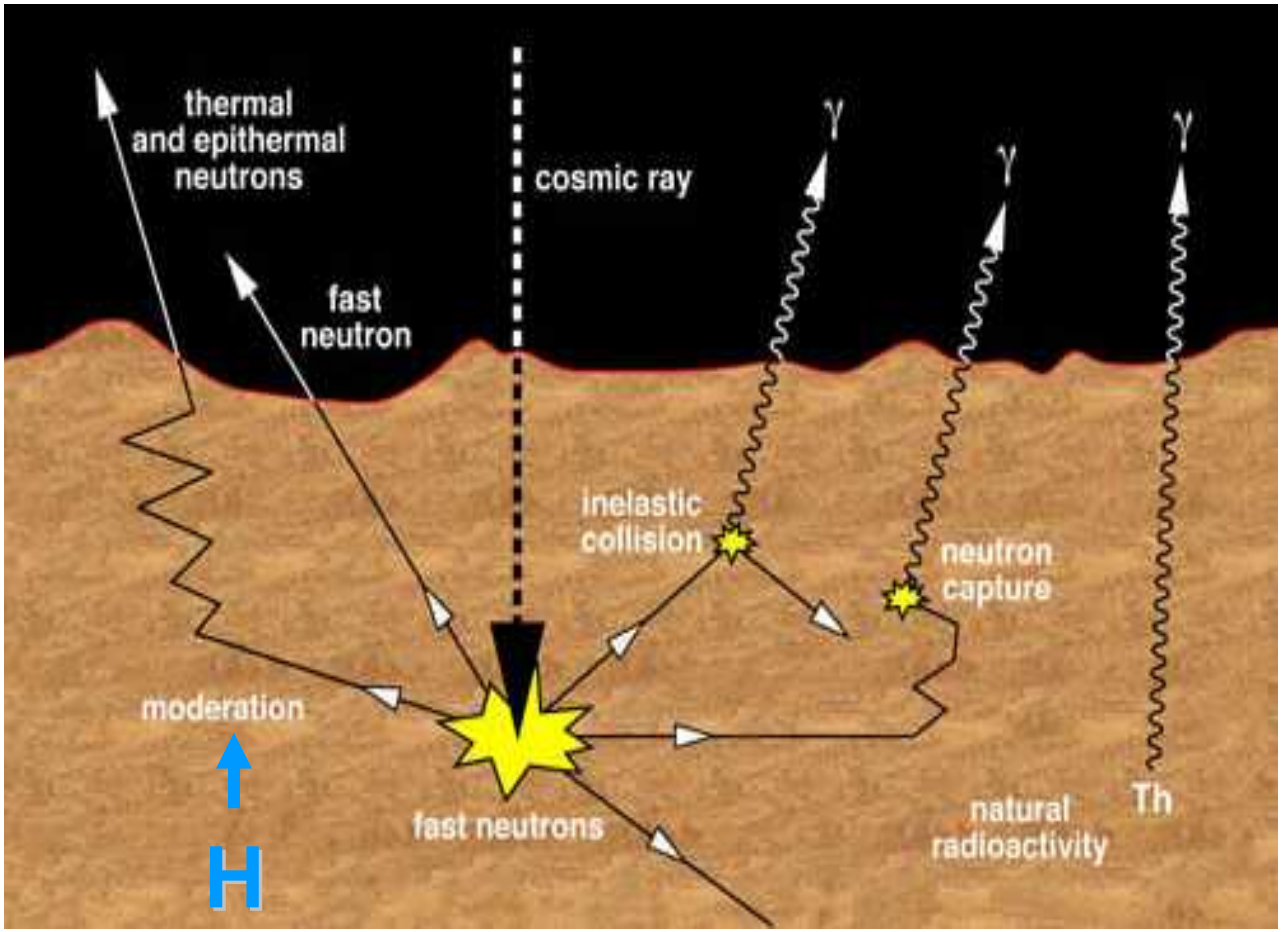
Igor Mitrofanov,

on behalf of LEND Team

September 15, 2010

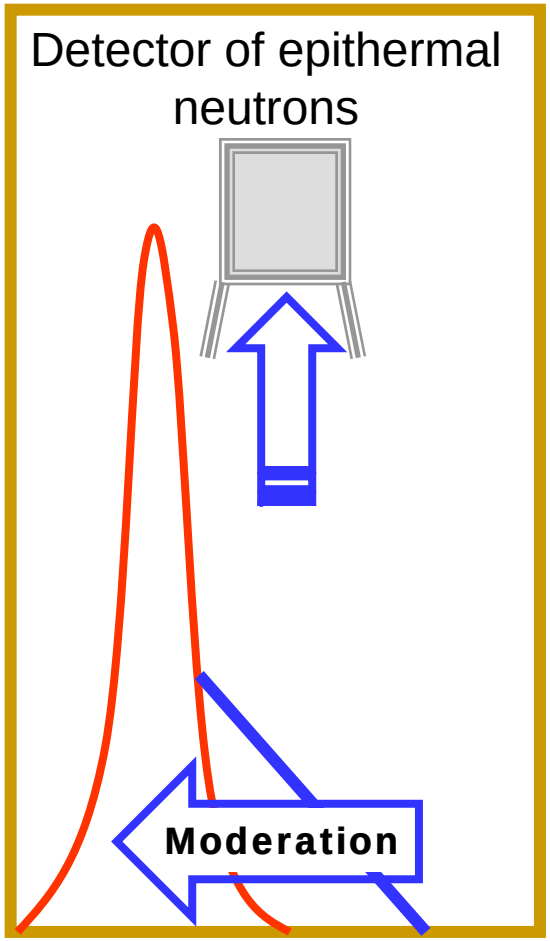
Physics of neutron method of measurement of hydrogen (water) in Lunar regolith

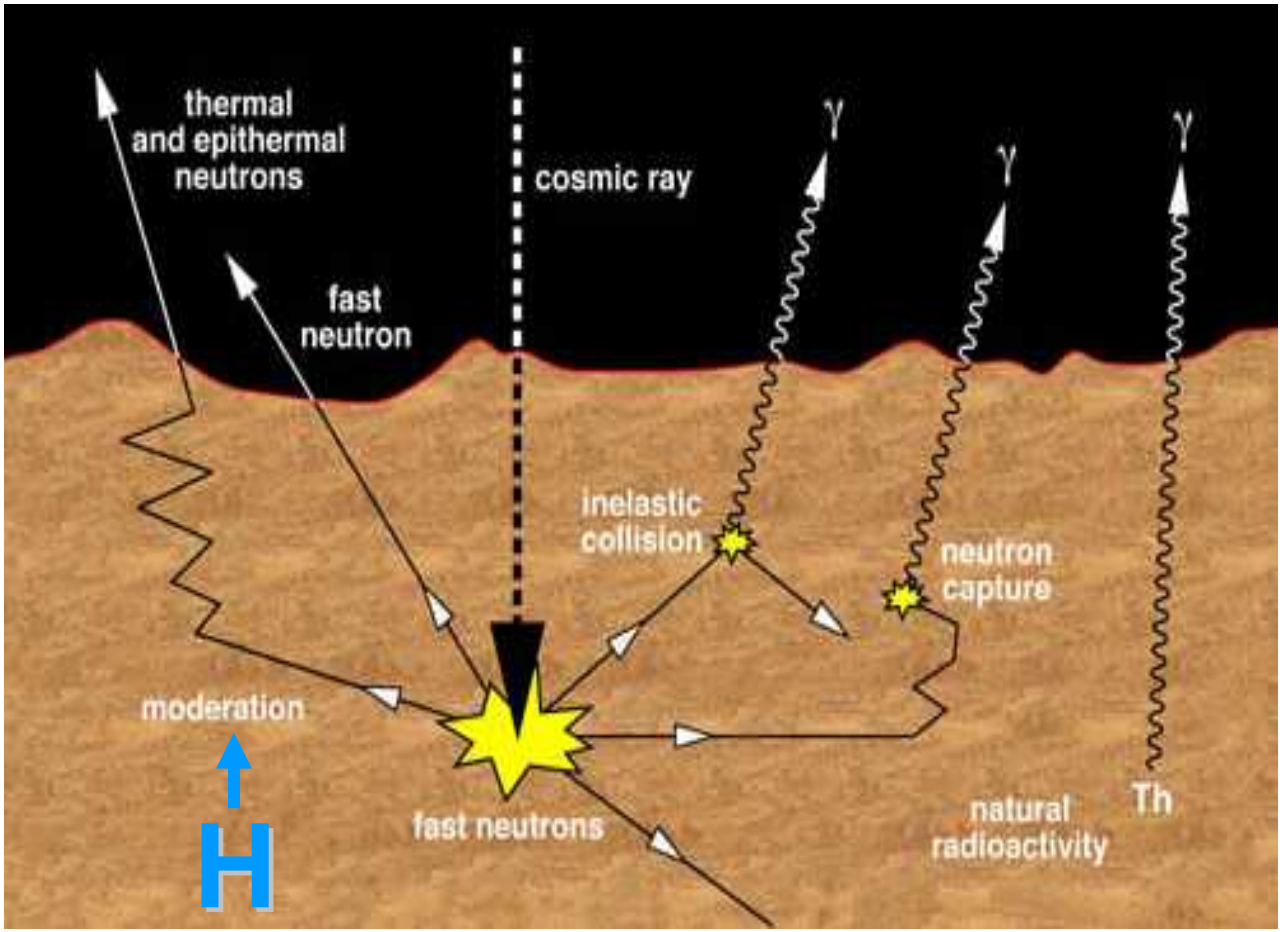




Energy spectrum of neutrons

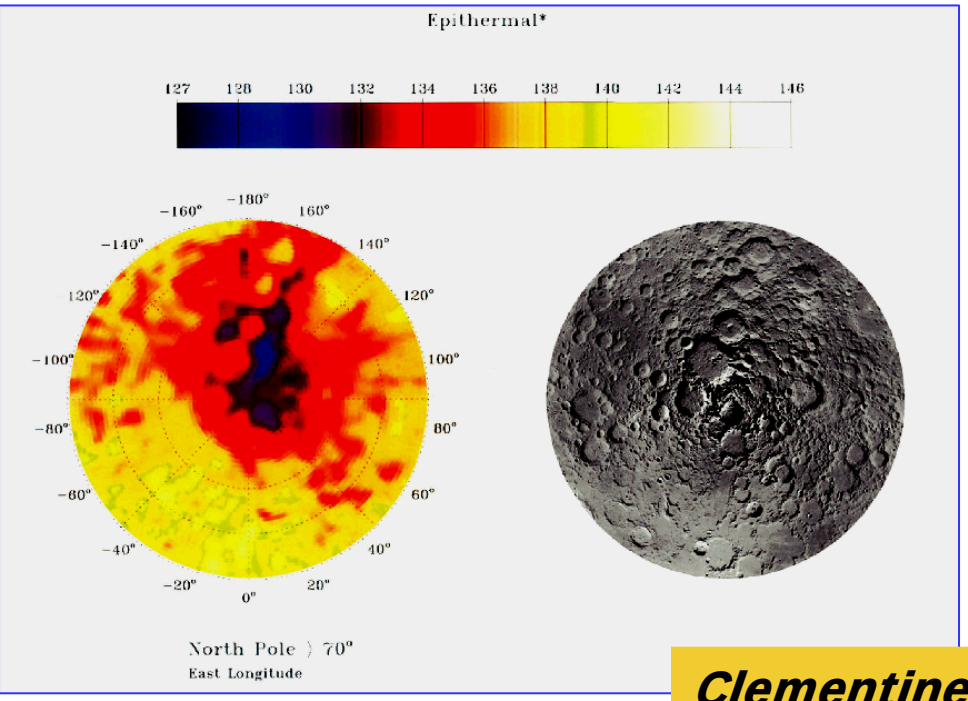
Physics of neutron method of measurement of hydrogen (water) in Lunar regolith

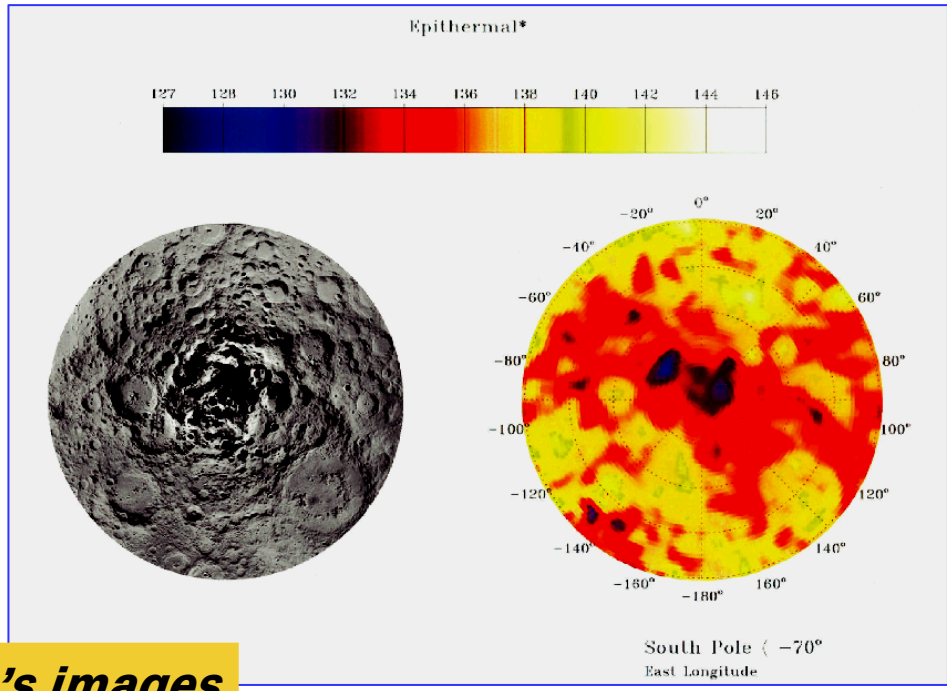




Energy spectrum of neutrons

PSRs – RADIO DATA - COLD TRAPS – DEPRESSION OF NEUTRONS – WATER ICE DEPOSITS





Clementine's images

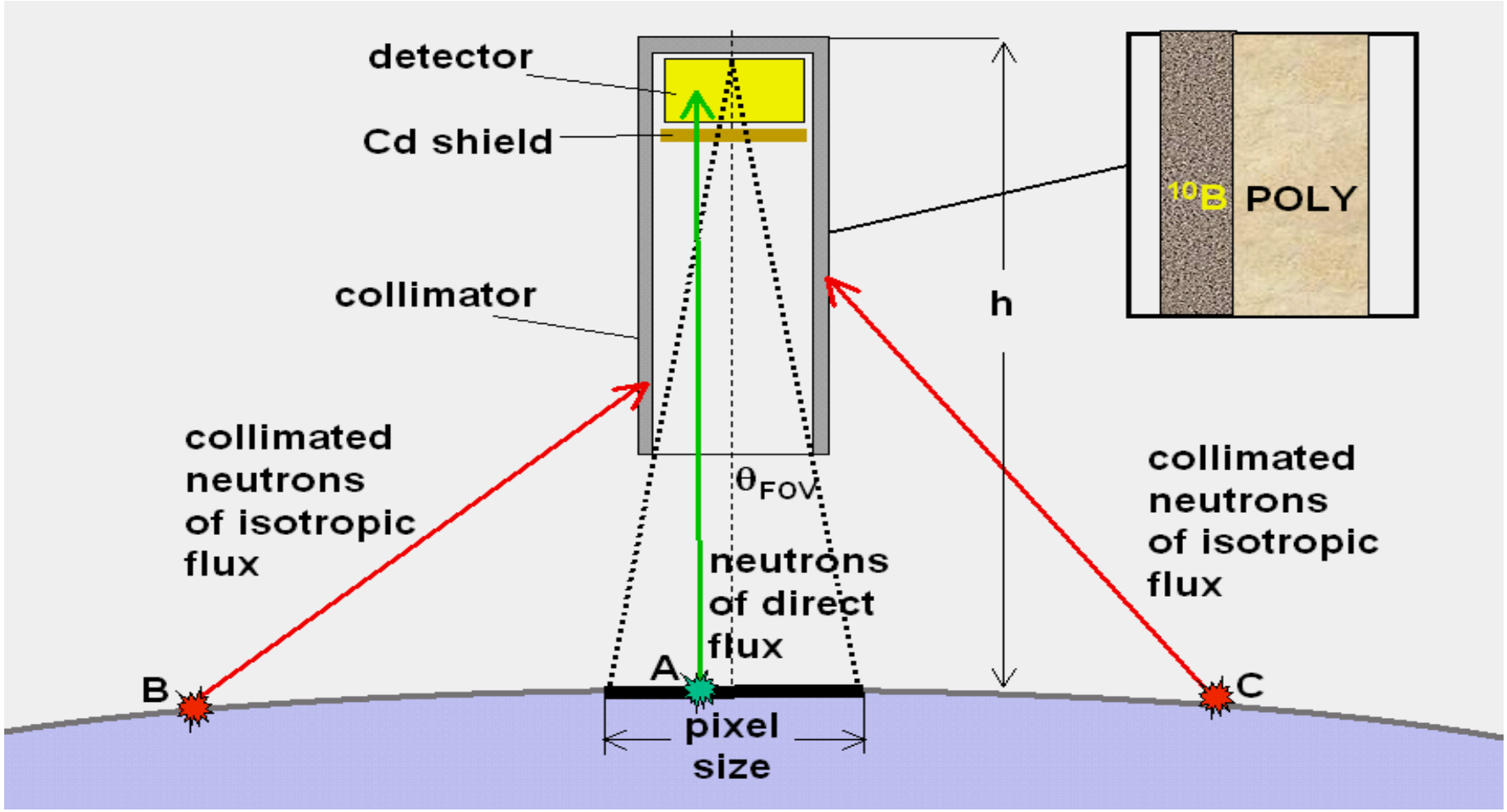
Lunar Procpector

Lunar Procpector

Lunar Exploration Neutron Detector

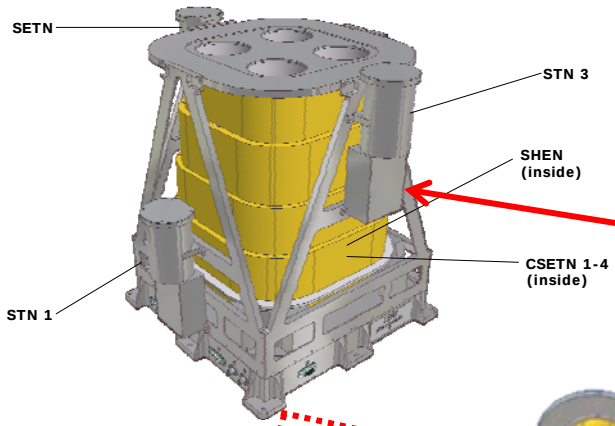
Objectives of NASA LEP	LRO solicited measurements and LEND Tasks	LEND performance requirements
Characterization of neutron component of global lunar radiation environment	*Task 1*: Characterization of deep space radiation environment, including neutron albedo in particular at energies in excess of 10 MeV	Measurements of thermal neutrons with flux variation >1% and altitude-dependent spatial resolution about 50 km(*
Determination of hydrogen resources on the Moon with high spatial resolution	*Task 2*: Creation of high resolution maps of hydrogen distribution with sensitivity about 100 ppm of Hydrogen weight and with horizontal spatial resolution of 5 km	Measurements of epithermal neutrons >0.4 eV with flux variations about 2% (pole) and 10% (equator) and spatial resolution HWHM=5 km (pole) and 15 km (equator) at orbit of 50 km(*
Evaluation of water ice deposits in the Moon's polar regions	*Task 3*: Characterization of surface distribution and column density of possible near-surface water ice deposits in the Moon's polar cold traps	Measurements of high energy neutrons 0.3-15.0 MeV with flux variations 4% (pole) and 10% (equator) and spatial resolution 15 km (pole) and 50 km (equator) at orbit of 50 km(*

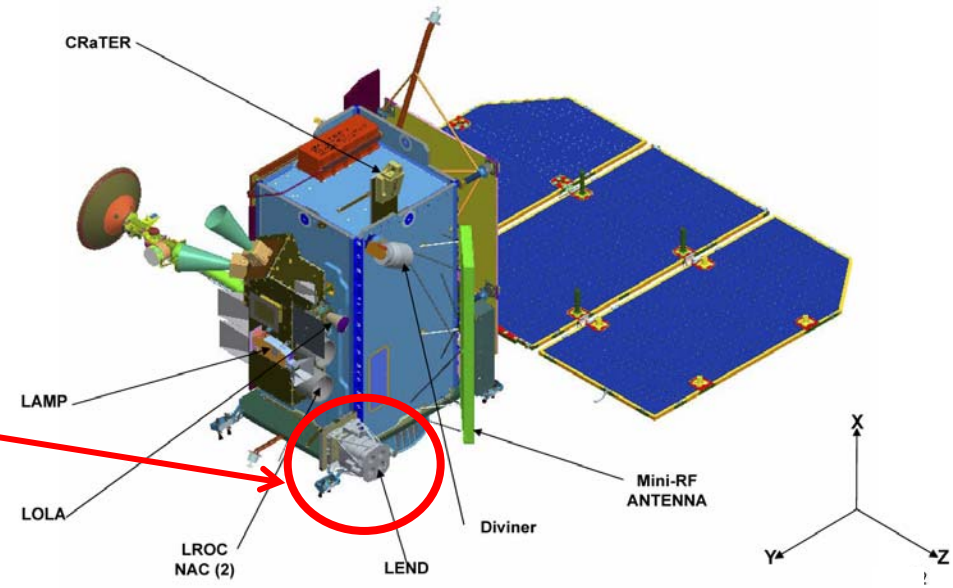
New key Technology: Collimation of Neutrons from Lunar Surface

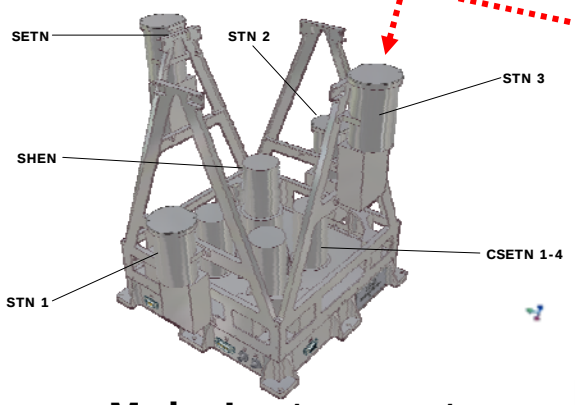


LEND Instrument Overview

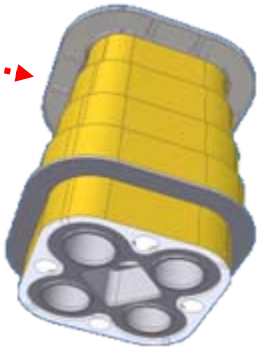
LEND consists of nine detectors to measure fluxes of thermal, epithermal, and fast neutrons.



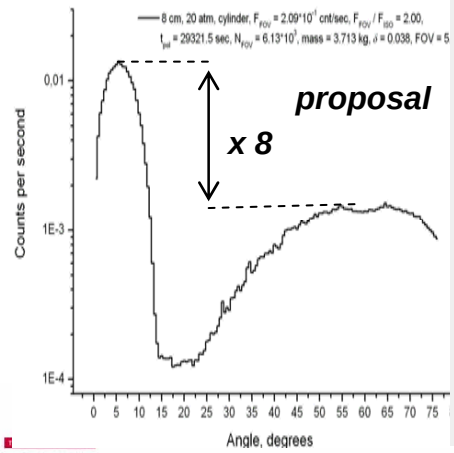


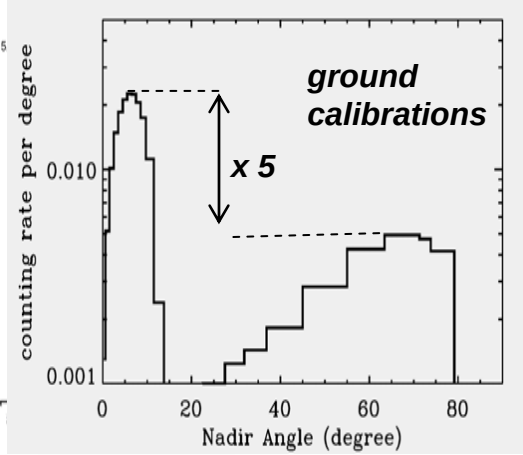


Main Instrument

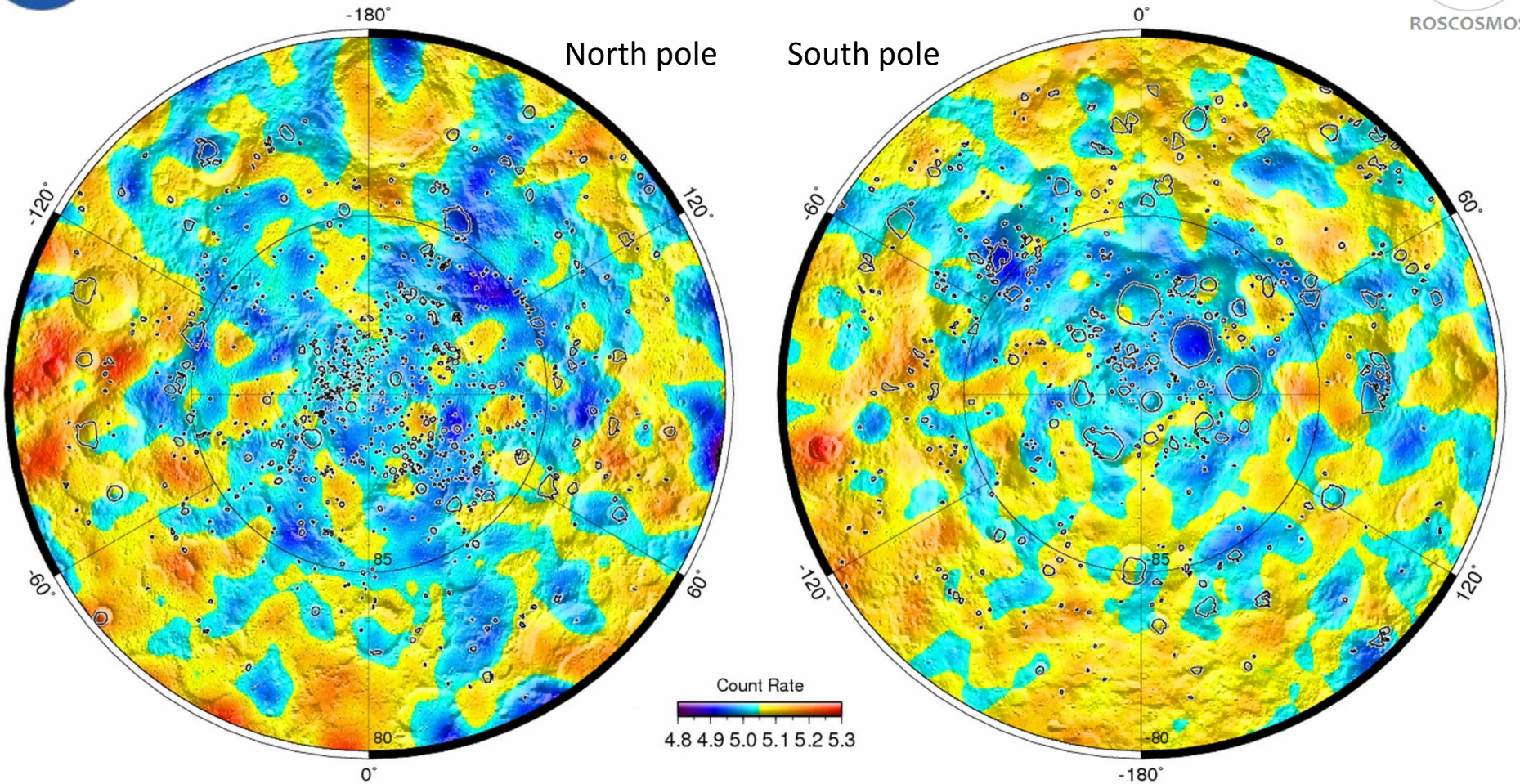


Collimator

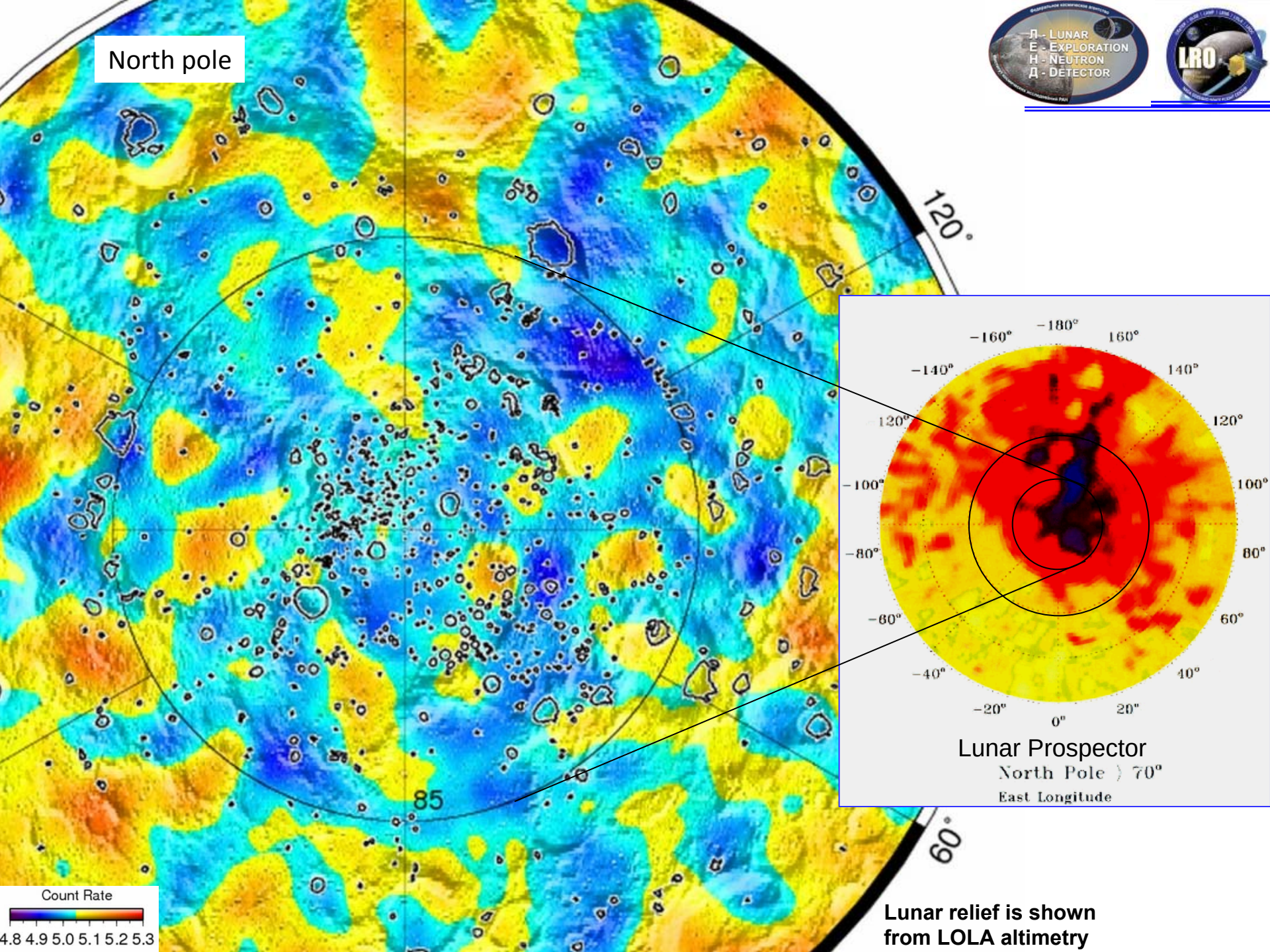




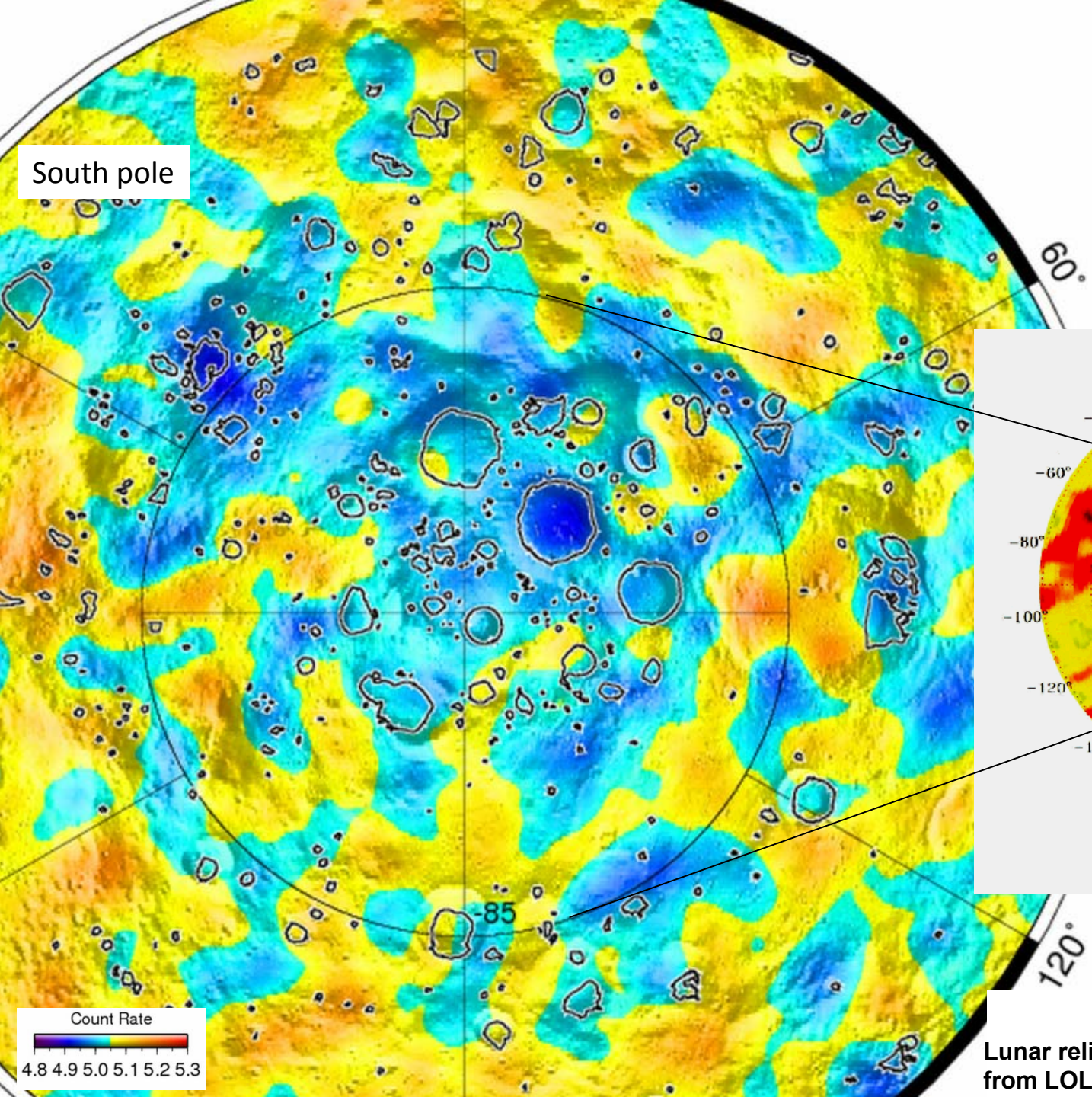
Lunar Exploration Neutron Detector Polar Map

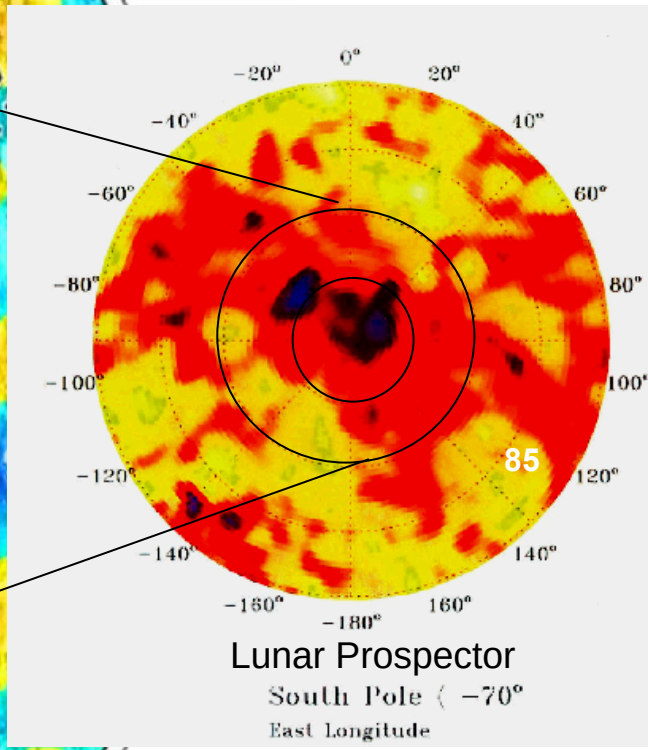


Lunar Exploration Neutron Detector (LEND) is one of the instruments aboard NASA's Lunar Reconnaissance Orbiter (LRO). It is the first collimated neutron instrument to ever fly in space allowing it to achieve high spatial resolution for mapping neutron emission from the Moon. The map above shows neutrons count rate at the Moon's poles, where a decrease of counts means higher content of hydrogen in regolith. Gray color and black contours represent surface relief and permanently shadowed regions. LEND is a contribution of the Russian Federation to the LRO mission developed under an Agreement between NASA and Roscosmos in Space Research Institute (IKI), Moscow.



Lunar relief is shown from LOLA altimetry





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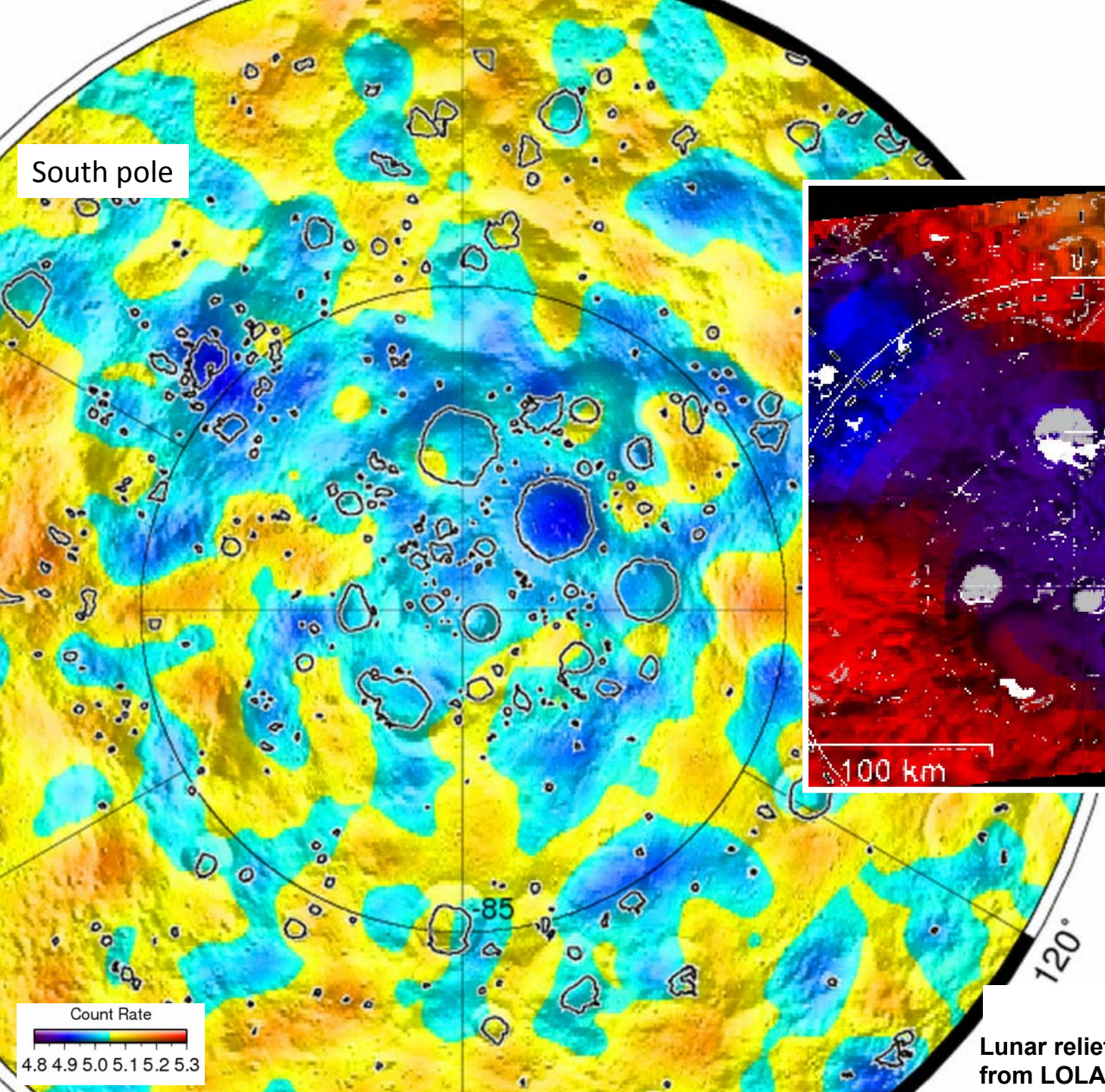
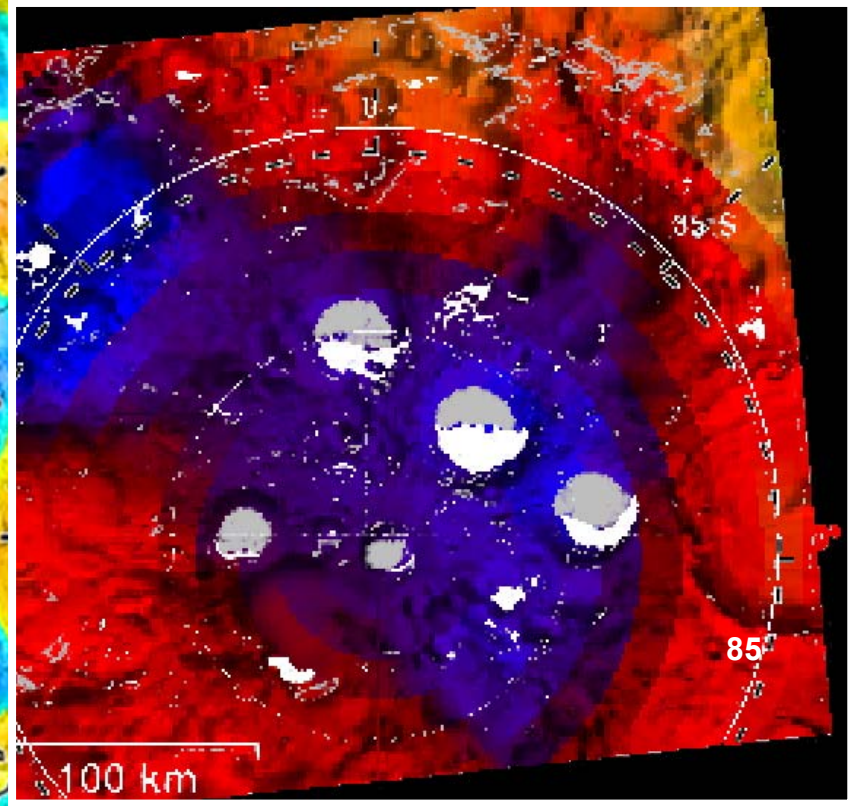
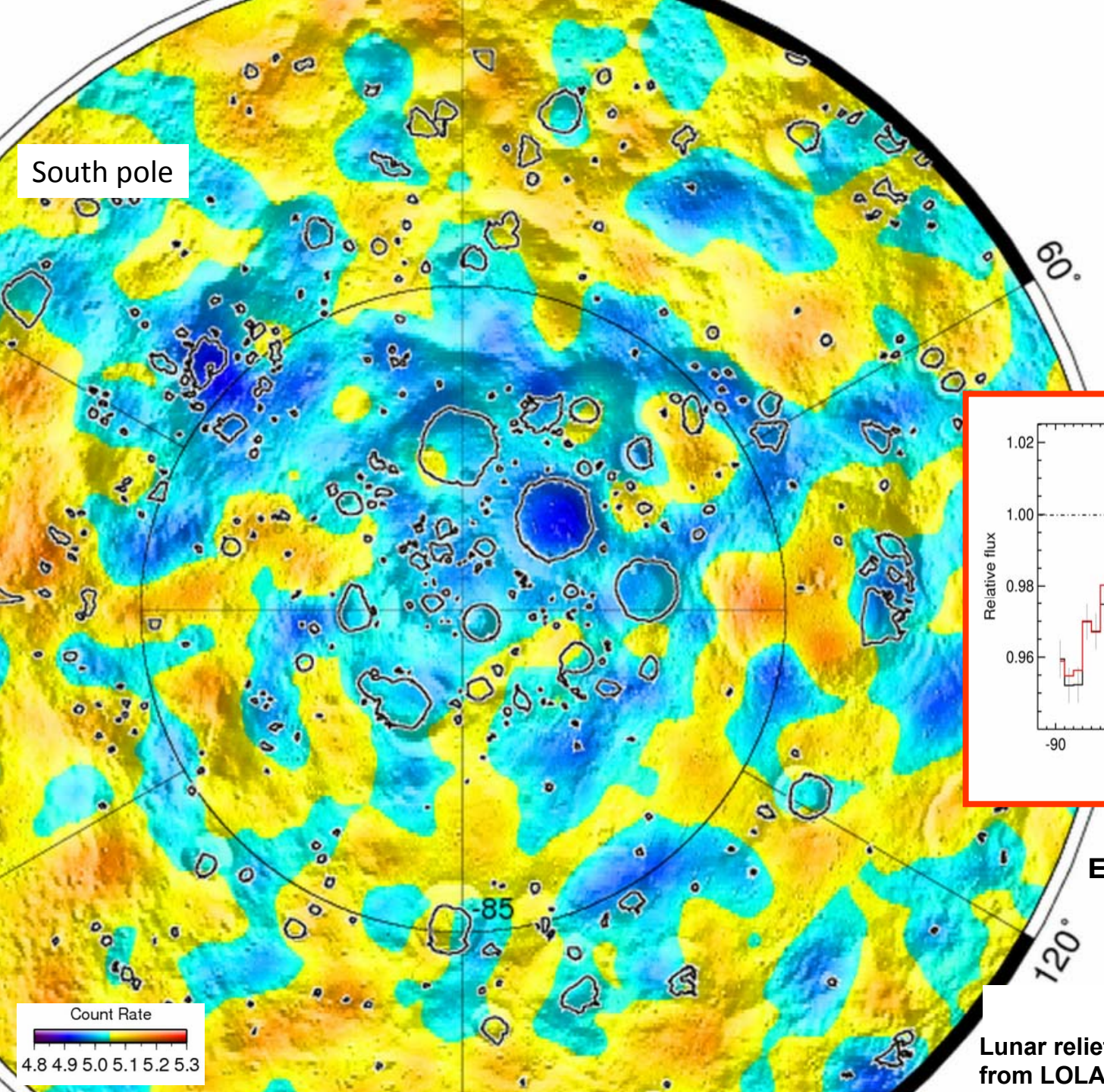
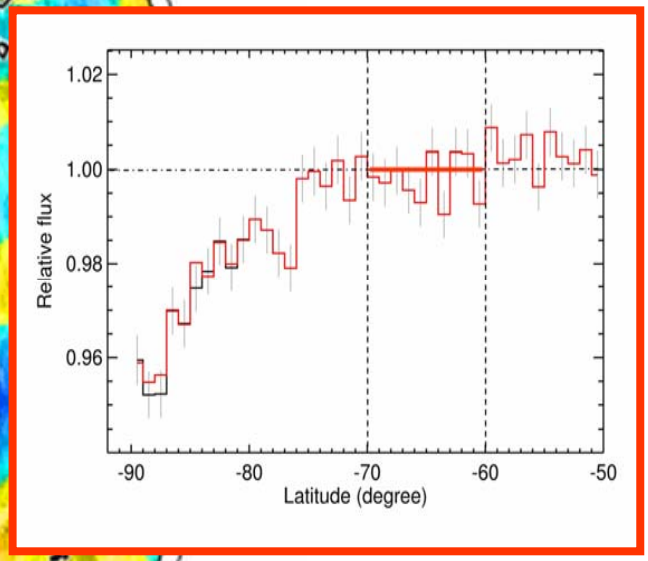




Testing the Model of ice in "cold traps" of PSRs, as the origin of polar neutron suppression

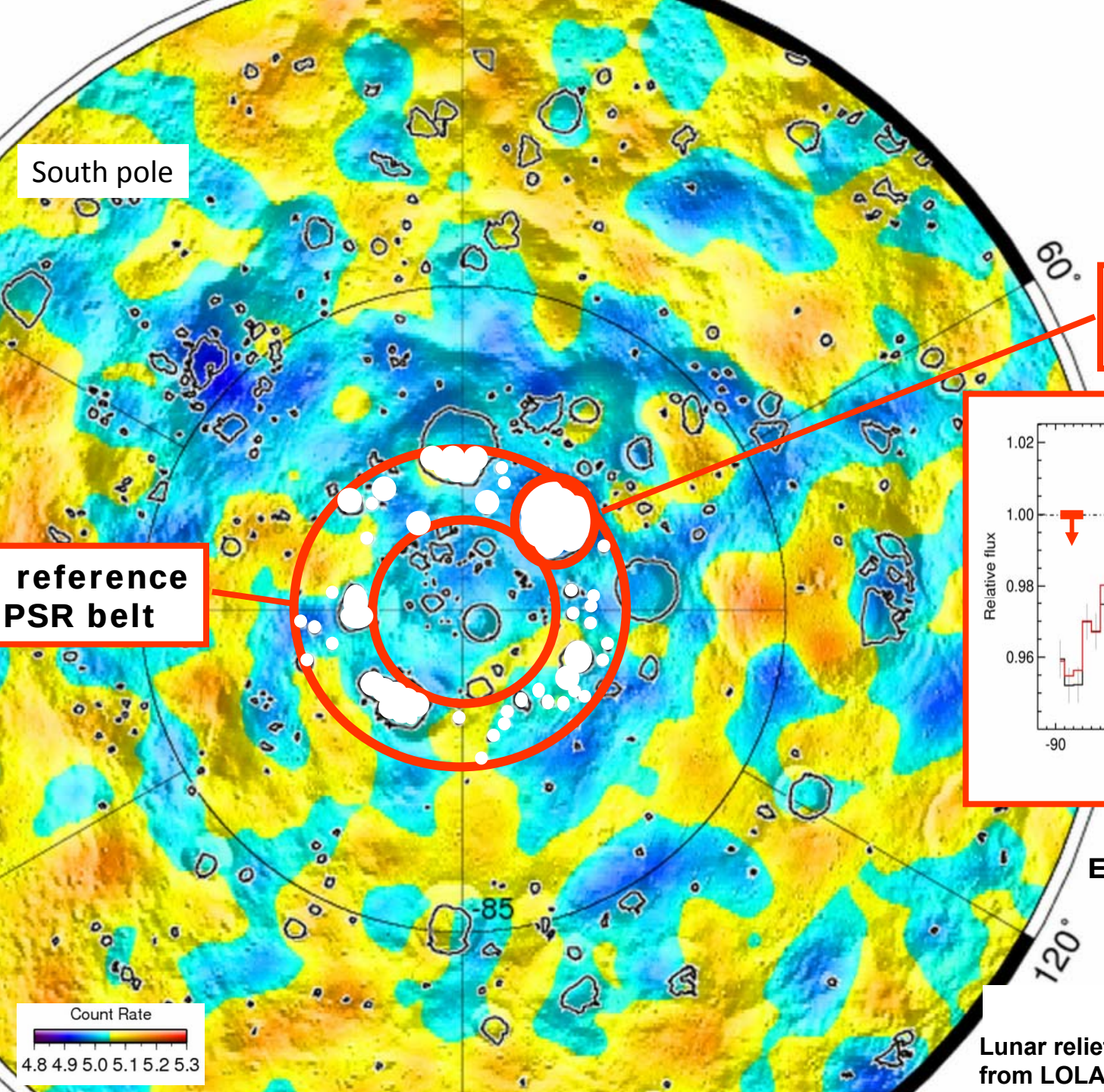
Lunar relief is shown from LOLA altimetry



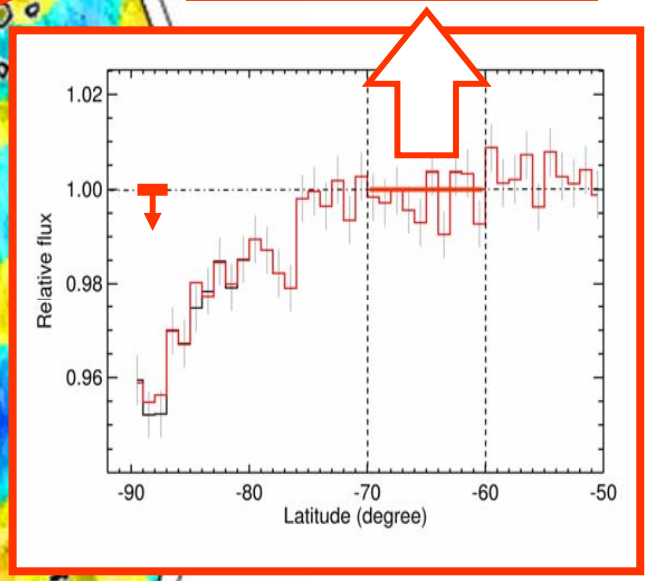


Effect of polar neutron suppression, as seen by LEND

Lunar relief is shown from LOLA altimetry



Reference Flux at 60° - 70° S



Effect of polar neutron suppression, as seen by LEND

Lunar relief is shown from LOLA altimetry

Testing PSRs with area > 75 km^2 and total observation time >800 s

Latitude of PSR	Area of PSR (km^2)	Total observation time (sec)	Absolute suppression in comparison with 60° - 70° latitude belt	Suppression in PSR in companion with no-PSR belt at the same latitudes	Remarks
+ 87.97	196	2353	0.98 ± 0.03	1.01 ± 0.03	
+ 89.12	79	1463	0.96 ± 0.04	1.00 ± 0.04	
+ 84.5	345	1099	0.89 ± 0.04 (2.8 σ)	0.91 ± 0.04 (2.2 σ)	
- 88.00	1048	16832	0.92 ± 0.01 (7.3 σ)	0.95 ± 0.01 (4.0 σ)	Shoemaker
- 87.47	973	10876	0.96 ± 0.01	0.99 ± 0.01	Haworth
- 89.64	220	10092	0.96 ± 0.01	1.01 ± 0.01	Shackltton
- 88.23	518	8281	0.97 ± 0.02	1.00 ± 0.02	Sverdup
- 87.13	635	3122	0.94 ± 0.03 (2 σ)	0.97 ± 0.03	Faustini
- 88.35	223	1563	0.93 ± 0.03 (2 σ)	0.96 ± 0.03	De Gerlache
- 85.02	319	1468	1.01 ± 0.03	1.05 ± 0.03	
- 88.74	79	1403	1.00 ± 0.04	1.04 ± 0.04	
- 88.08	163	964	0.89 ± 0.04 (2.8 σ)	0.91 ± 0.04 (2.2 σ)	
- 87.6	90	1149	0.95 ± 0.04	1.00 ± 0.04	
- 86.7	195	866	0.92 ± 0.05	0.95 ± 0.05	
- 81.67	342	848	0.99 ± 0.05	1.00 ± 0.05	
- 83.88	290	869	0.96 ± 0.05	0.98 ± 0.05	
- 84.44	242	904	0.82 ± 0.05 (3.7 σ)	0.86 ± 0.05 (3 σ)	Cabeus

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+ 84.5	345	1099	0.89 ± 0.04 (2.8 σ)	0.91 ± 0.04 (2.2 σ)	
- 88.00	1048	4h 42 min	0.92 ± 0.01 (7.3 σ)	0.95 ± 0.01 (4.0 σ)	Shoemaker
- 87.47	973	8h 07 min	0.96 ± 0.01	0.99 ± 0.01	Haworth
- 89.64	220		0.96 ± 0.01	1.01 ± 0.01	Shackltion
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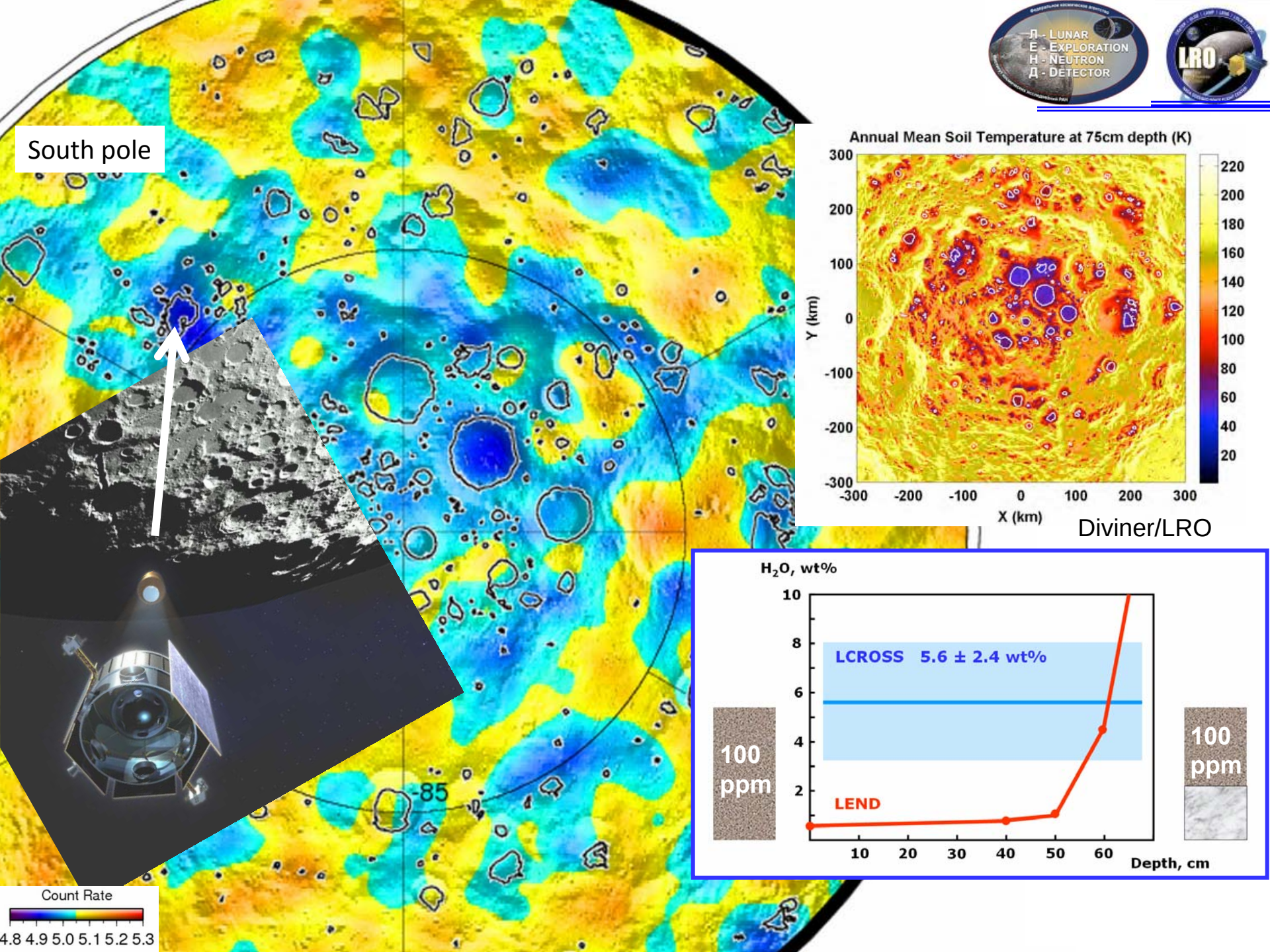
South pole
Л - LUNAR
E - EXPLORATION
H - NEUTRON
Д - DETECTOR
LRO
Annual Mean Soil Temperature at 75cm depth (K)
Y (km)
X (km)
300
200
100
0
-100
-200
-300
220
200
180
160
140
120
100
80
60
40
20
Diviner/LRO
H_2O, wt%
LCROSS 5.6 ± 2.4 wt%
LEND
100 ppm
100 ppm
Depth, cm
10
8
6
4
2
10
20
30
40
50
60
-85
Count Rate
4.8 4.9 5.0 5.1 5.2 5.3

CONCLUSIONS after ESMD mapping stage of LEND investigations:

(1) LEND confirmed discovery by ***Lunar Prospector*** of extended neutron polar suppression areas above 70° N and S latitudes

(2) LEND found that ***Permanently Shadowed Regions*** (PSRs) should not be identified with local spots of the largest neutron suppression at poles:

- some PSRs have significant enhancement of hydrogen in comparison with sunlit vicinity at the same polar latitude,
- but many of them do not have any contrast of neutron suppression in comparison with illuminated neighborhood (+ **talk by W.Boynton**)

(3) LEND discovered several ***Neutron Suppression Regions*** (NSRs), which are thought to have the largest content of hydrogen on the Moon and which are not necessarily located in the permanent shadow; southward segment of Cabeus has the strongest signature of water, estimated as 0.5 – 4.0 wt% **(+ talk by A.Sanin**)