Evidence for Diurnally-Varying Hydration at the Moon's Equator from the Lunar Exploration Neutron Detector (LEND)

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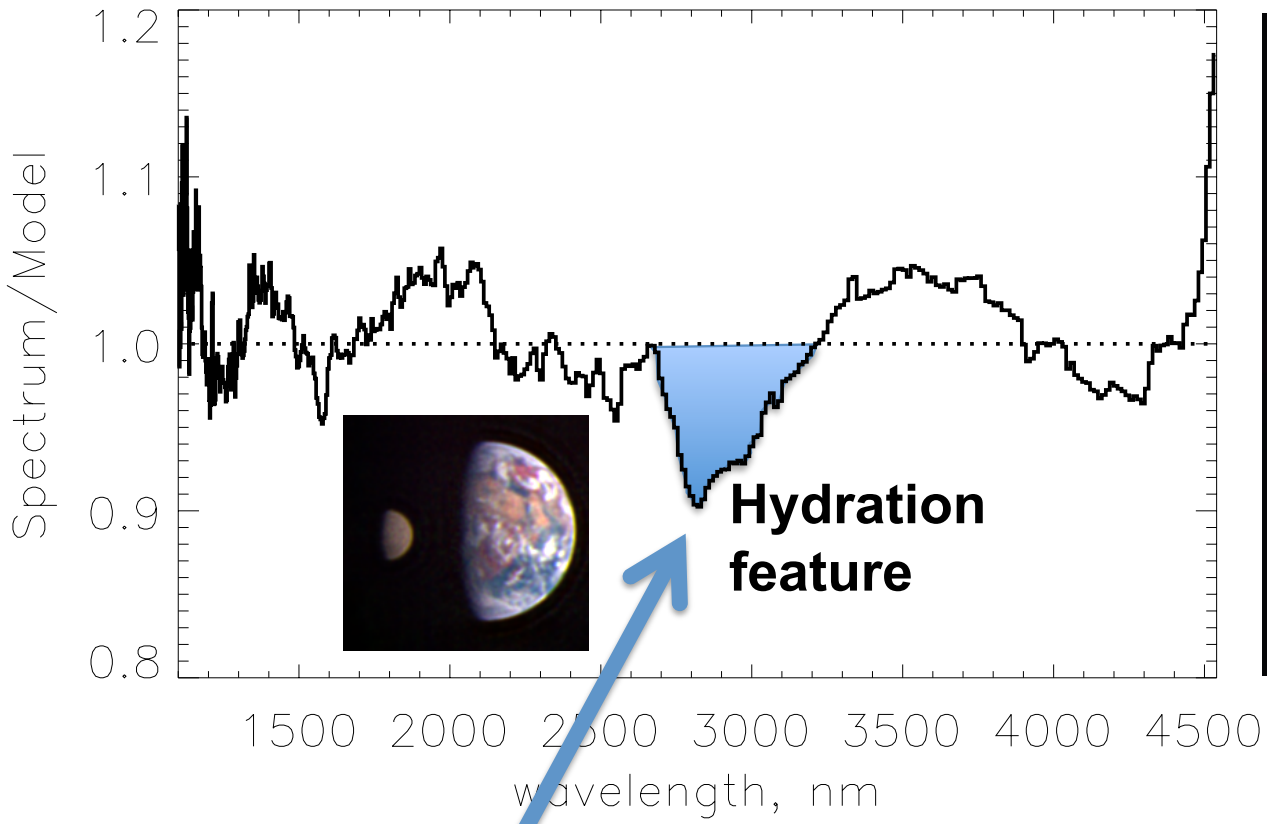

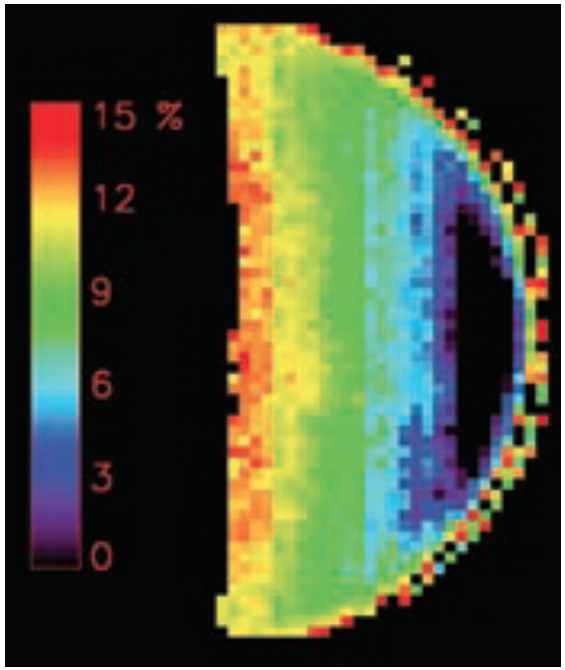

Livengood *et al. Astrobiology* **11**, 2011

Sunshine *et al.*, *Science* **326**, 565–568, 2009

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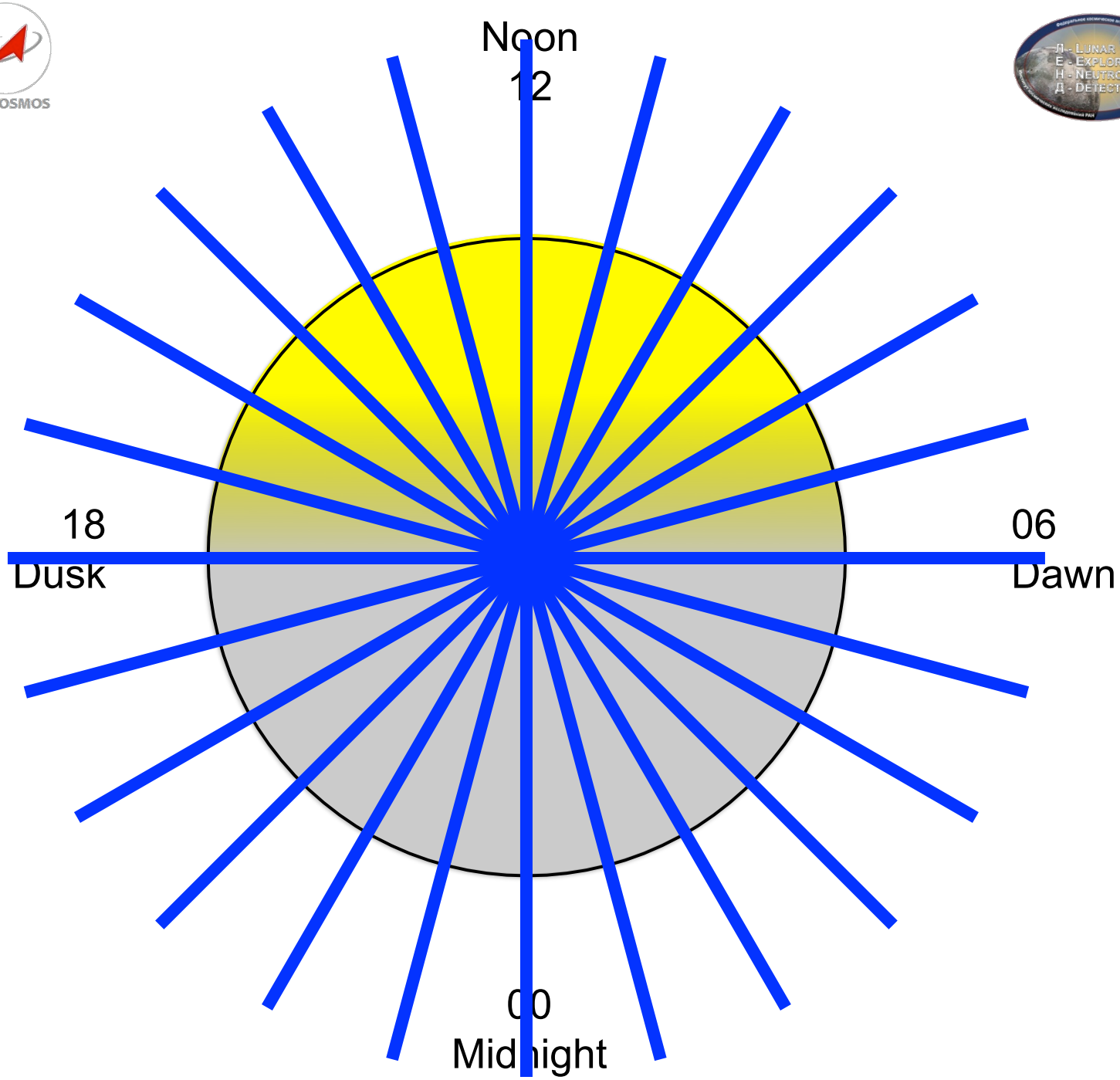
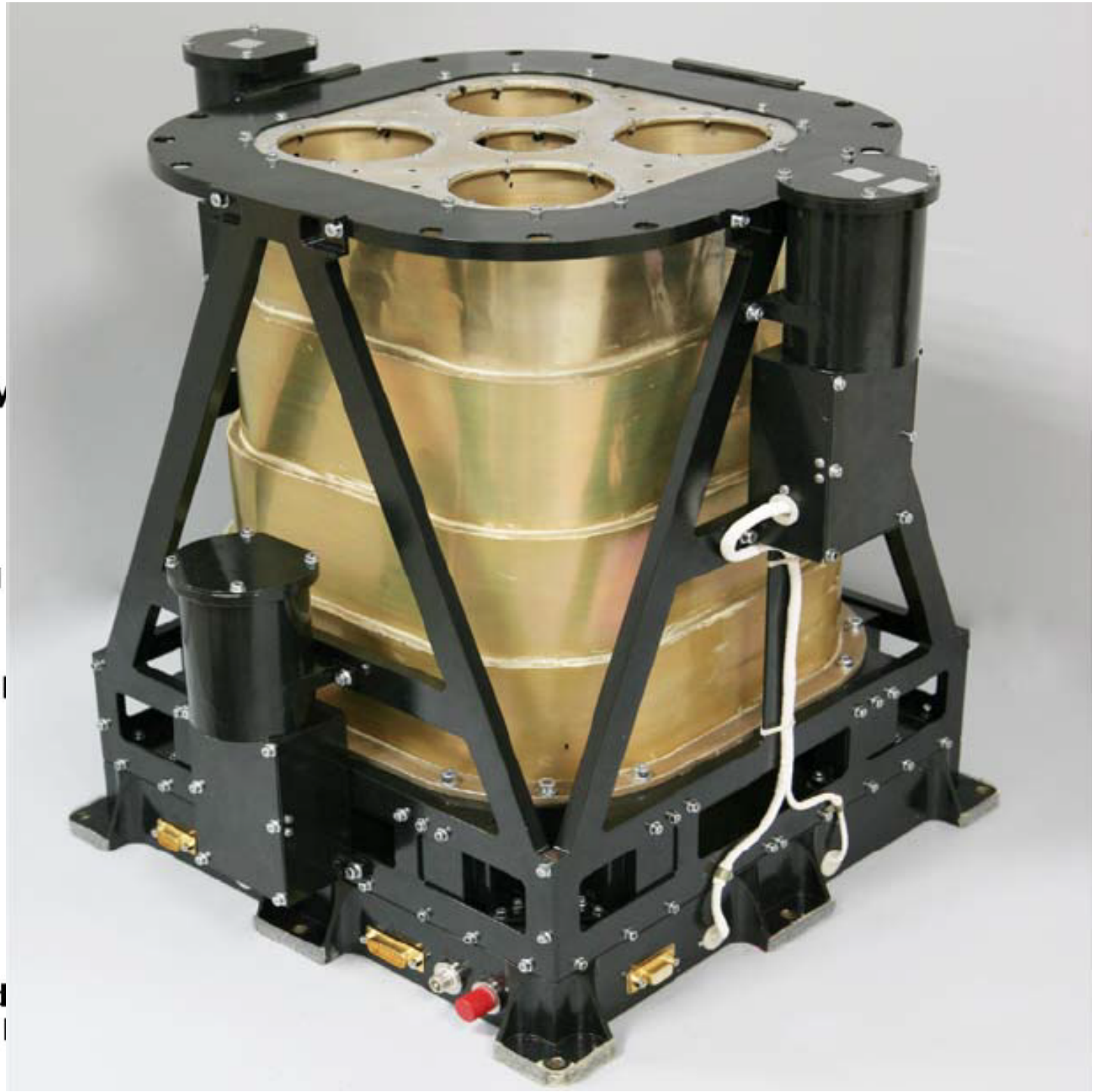
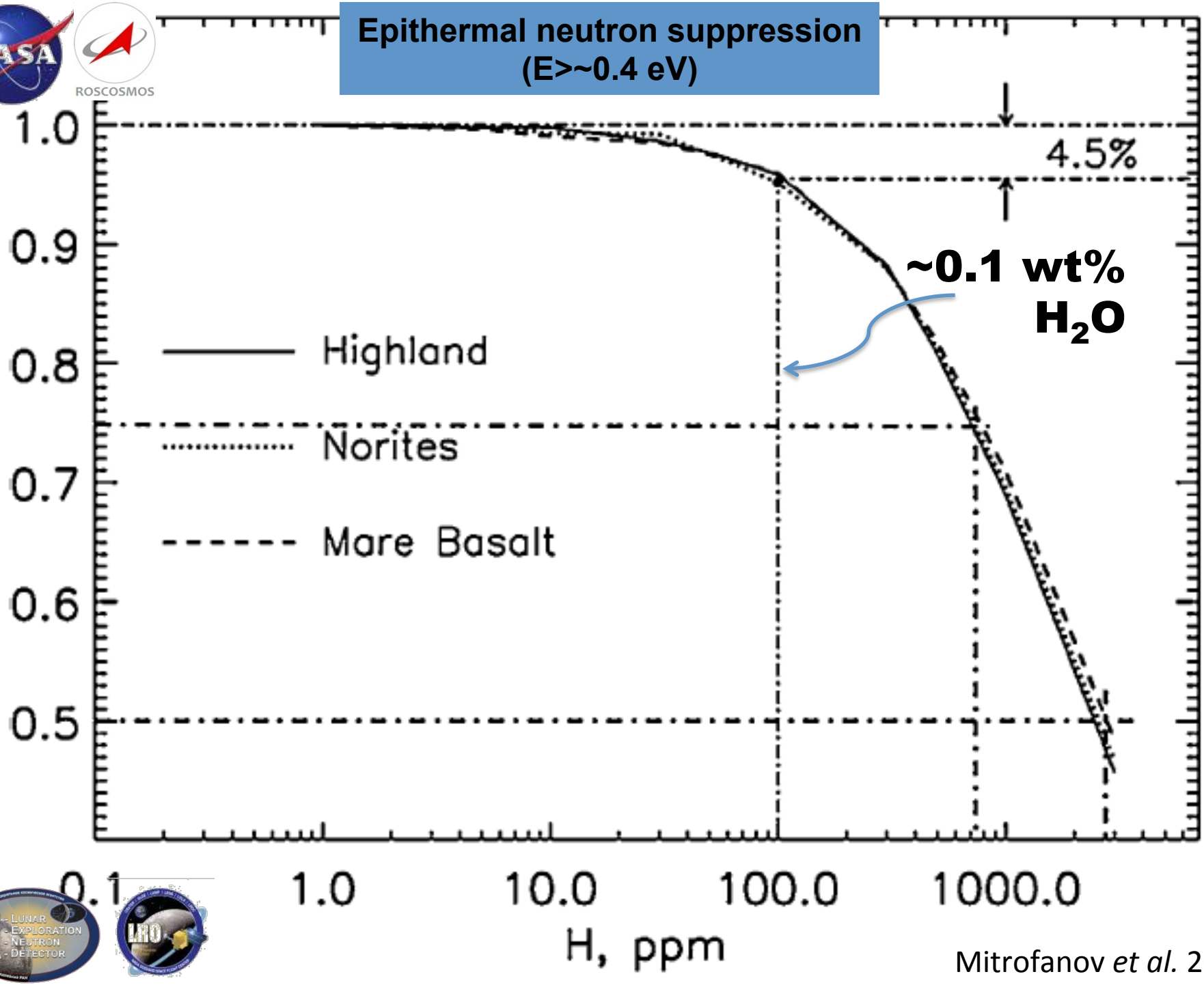
- Hydrated minerals observed at lunar terminator in reflected light: EPOXI, M^3, Cassini VIMS
- How much H_2O/OH is there?
- LRO LEND instrument sensitive to total water abundance within upper meter of regolith.
- Use LEND data from low latitudes (30°S to 30°N), discriminated by local time.


Noon
12
18
Dusk
06
Dawn
00
Midnight

LEND
Lunar
Exploration
Neutron
Detector

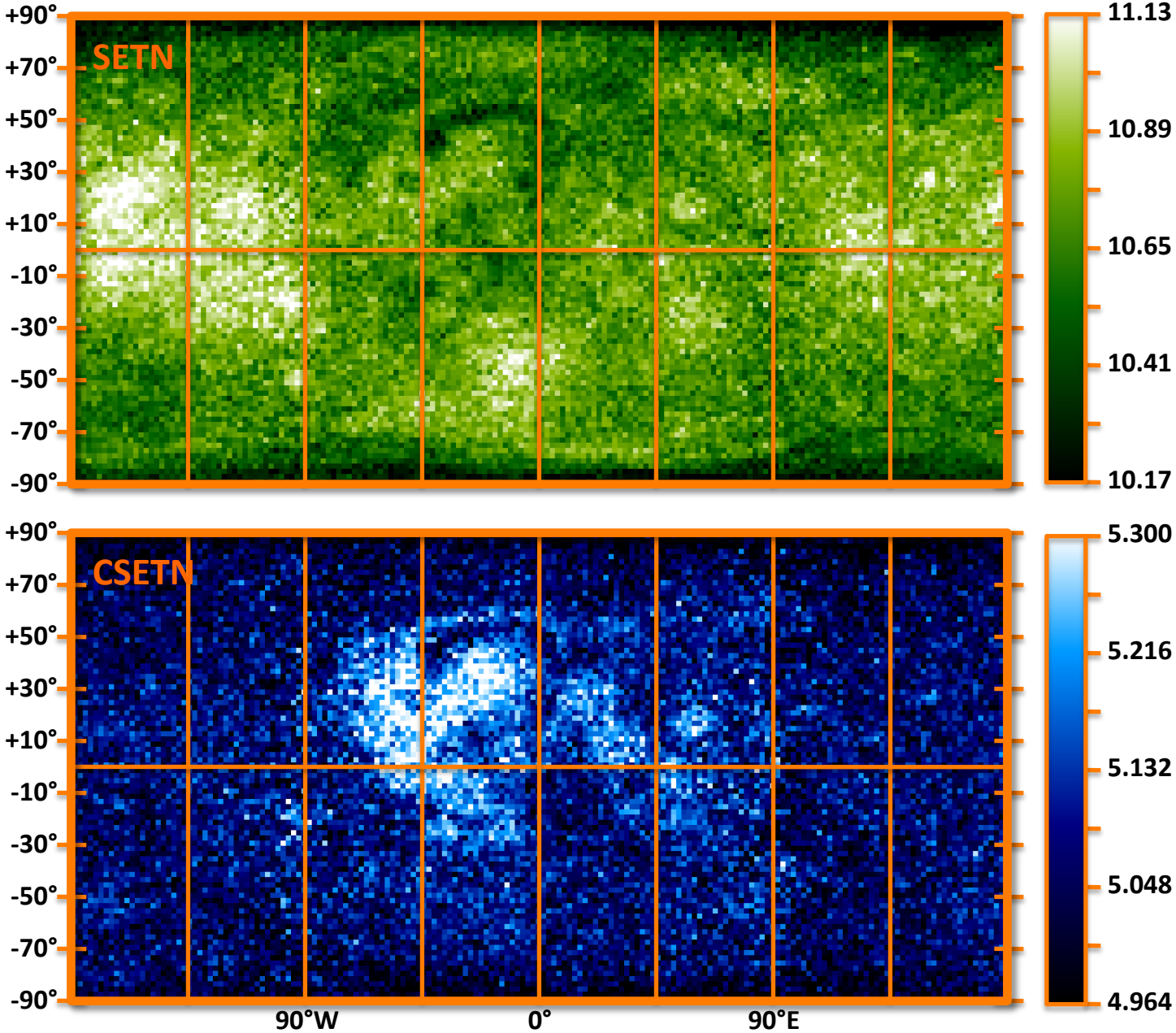


Epithermal neutron suppression (E>~0.4 eV)



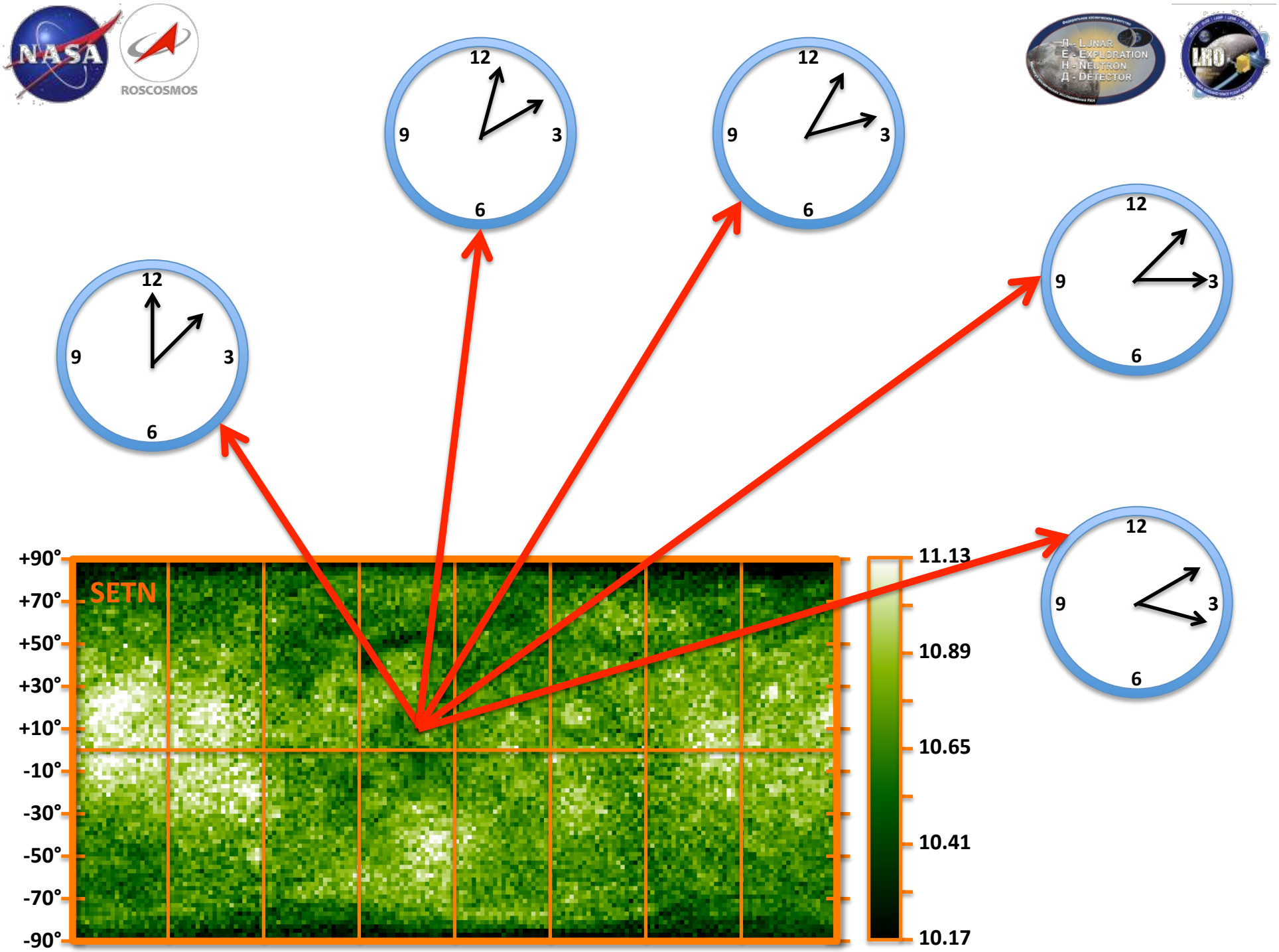
Mitrofanov *et al.* 2010

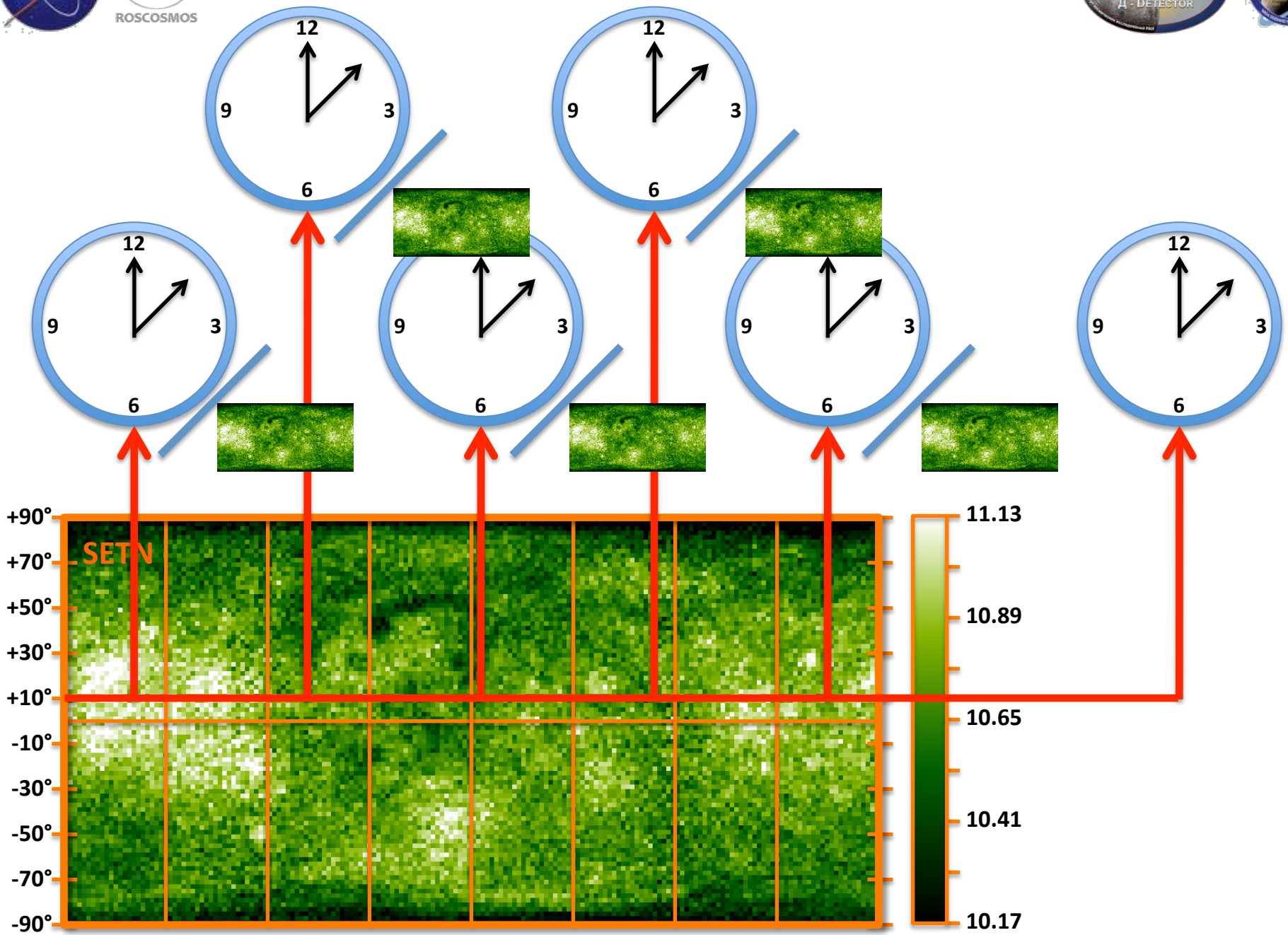
Cylindrical maps of Lunar Neutron Flux



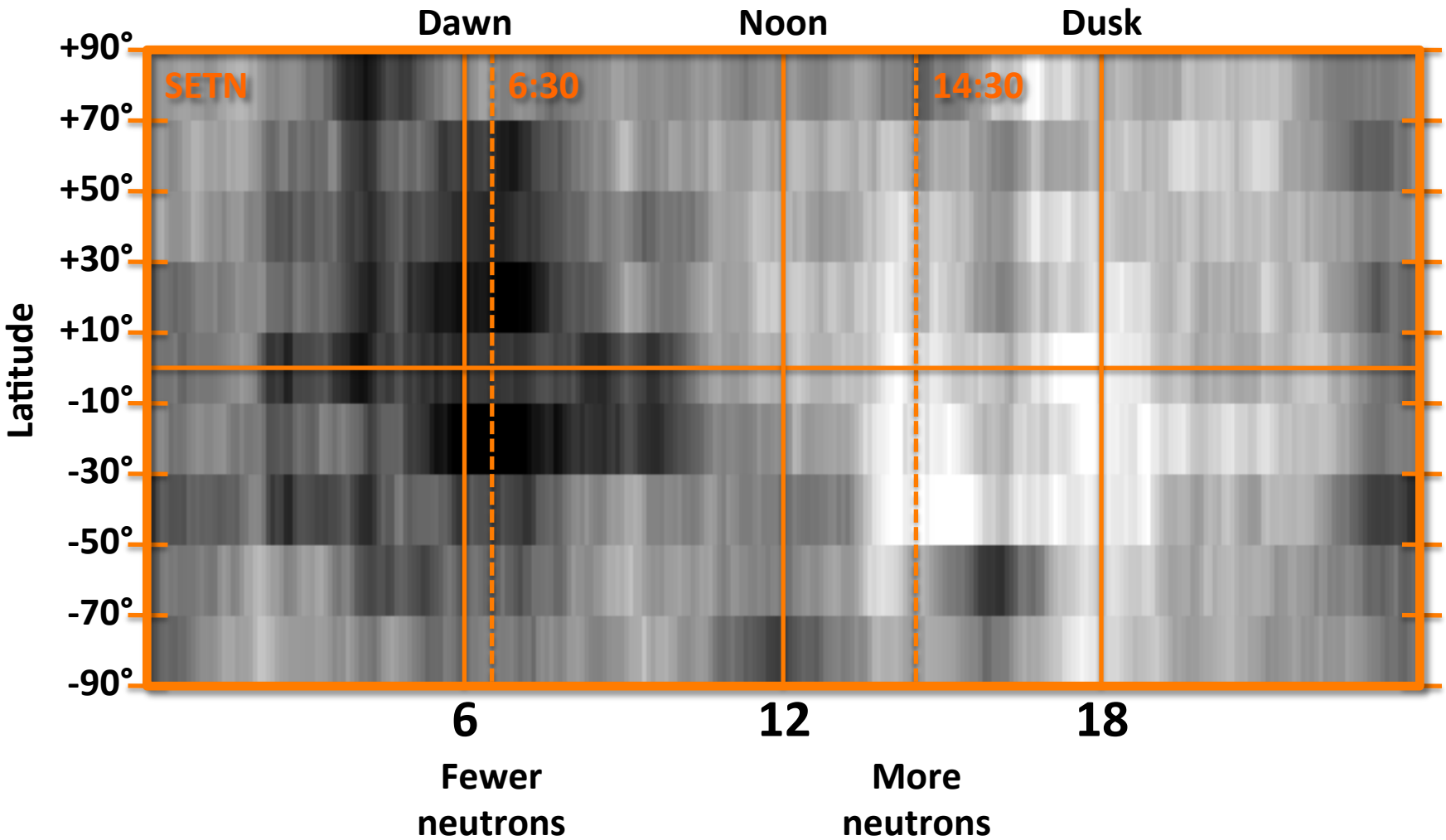
Uncollimated Epithermal = E>0.4 eV

Collimated Epithermal = E>0.4 eV
+
Out-of-collimation component at higher energy

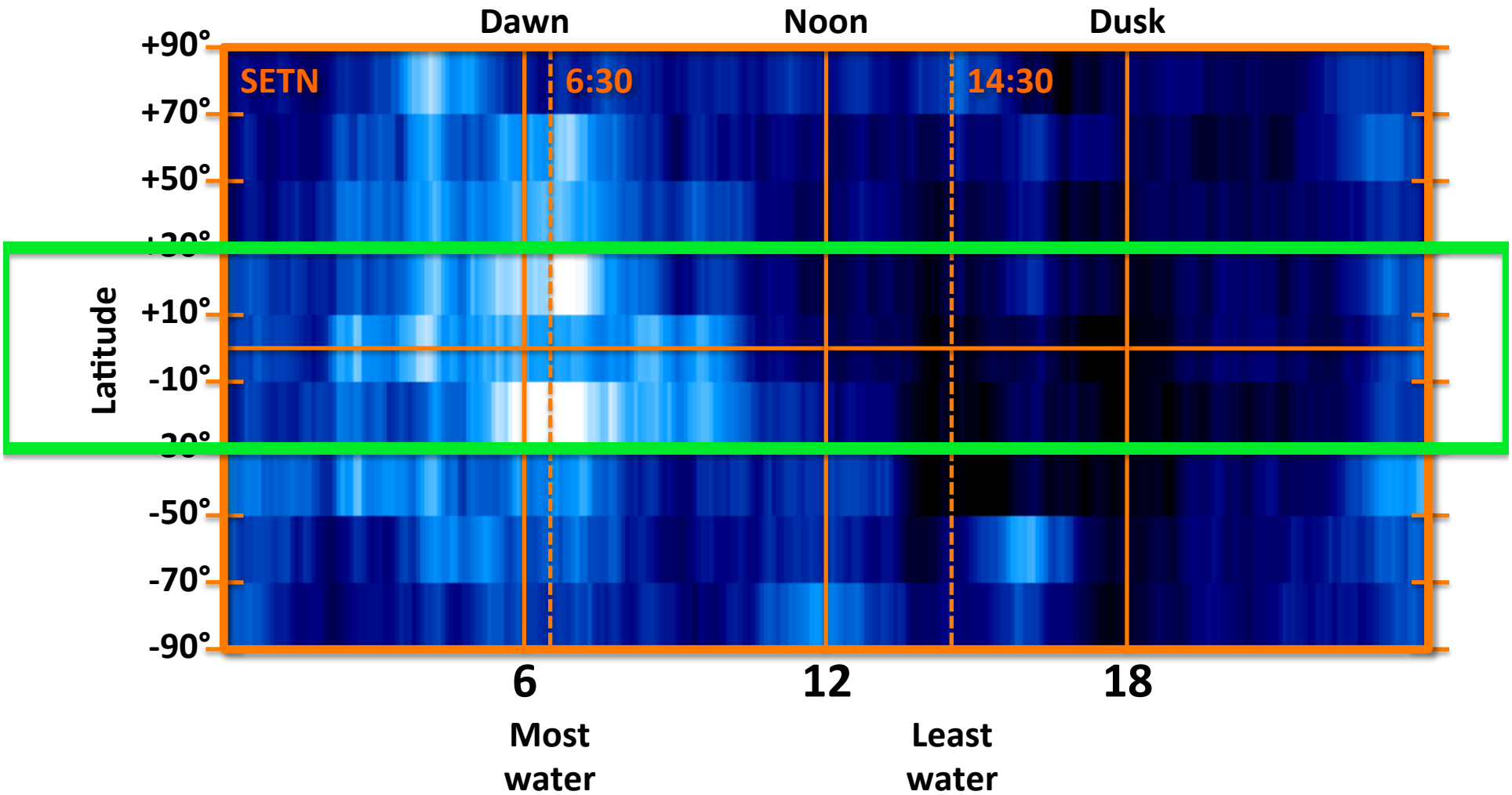

NASA
ROSCOSMOS
Л - LUNAR
E - EXPLORATION
H - NEUTRON
Д - DETECTOR
LRO
SETN
+90°
+70°
+50°
+30°
+10°
-10°
-30°
-50°
-70°
-90°
11.13
10.89
10.65
10.41
10.17
12
3
6
9

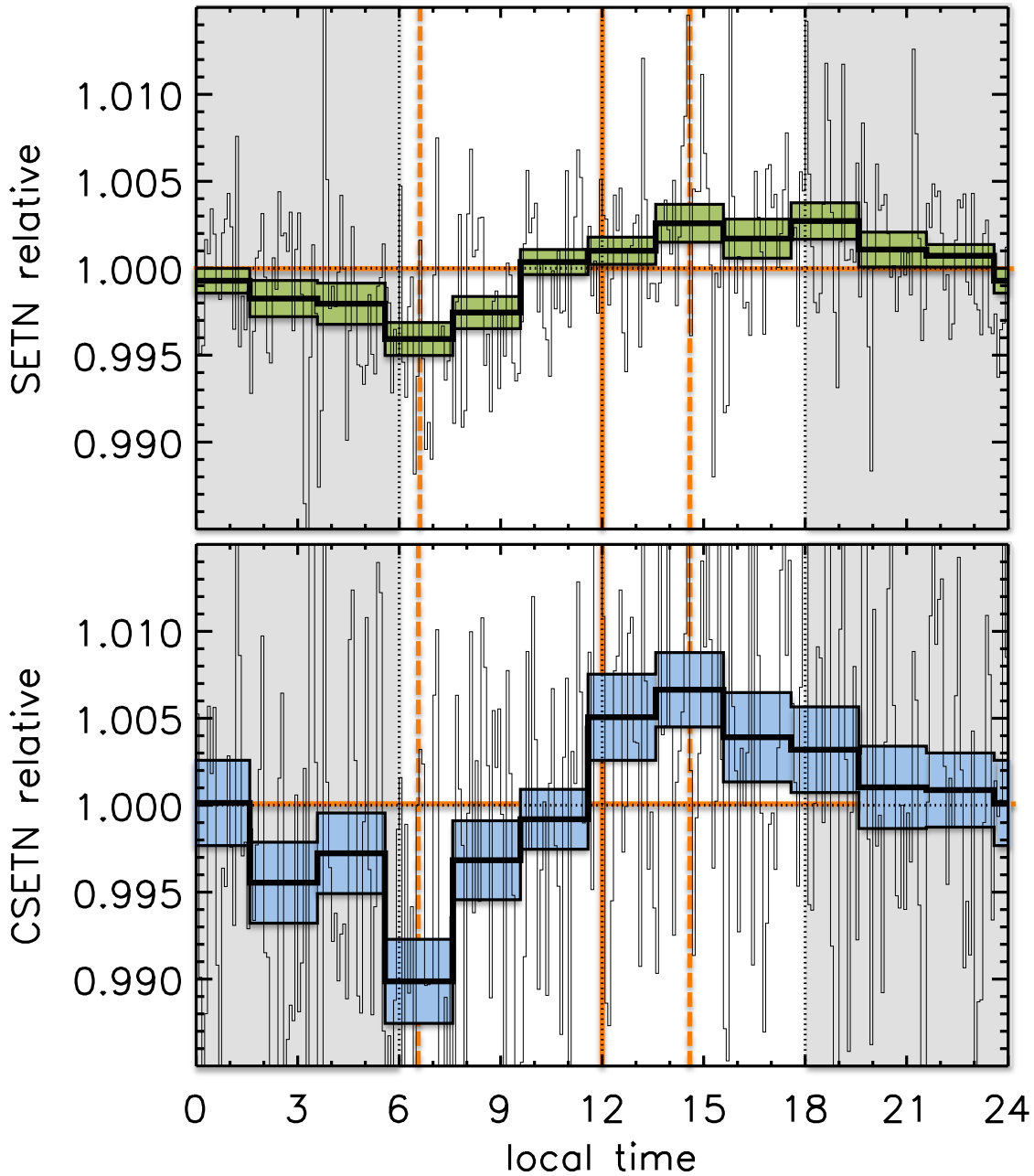

12
9
3
6
SETN
+90°
+70°
+50°
+30°
+10°
-10°
-30°
-50°
-70°
-90°
11.13
10.89
10.65
10.41
10.17

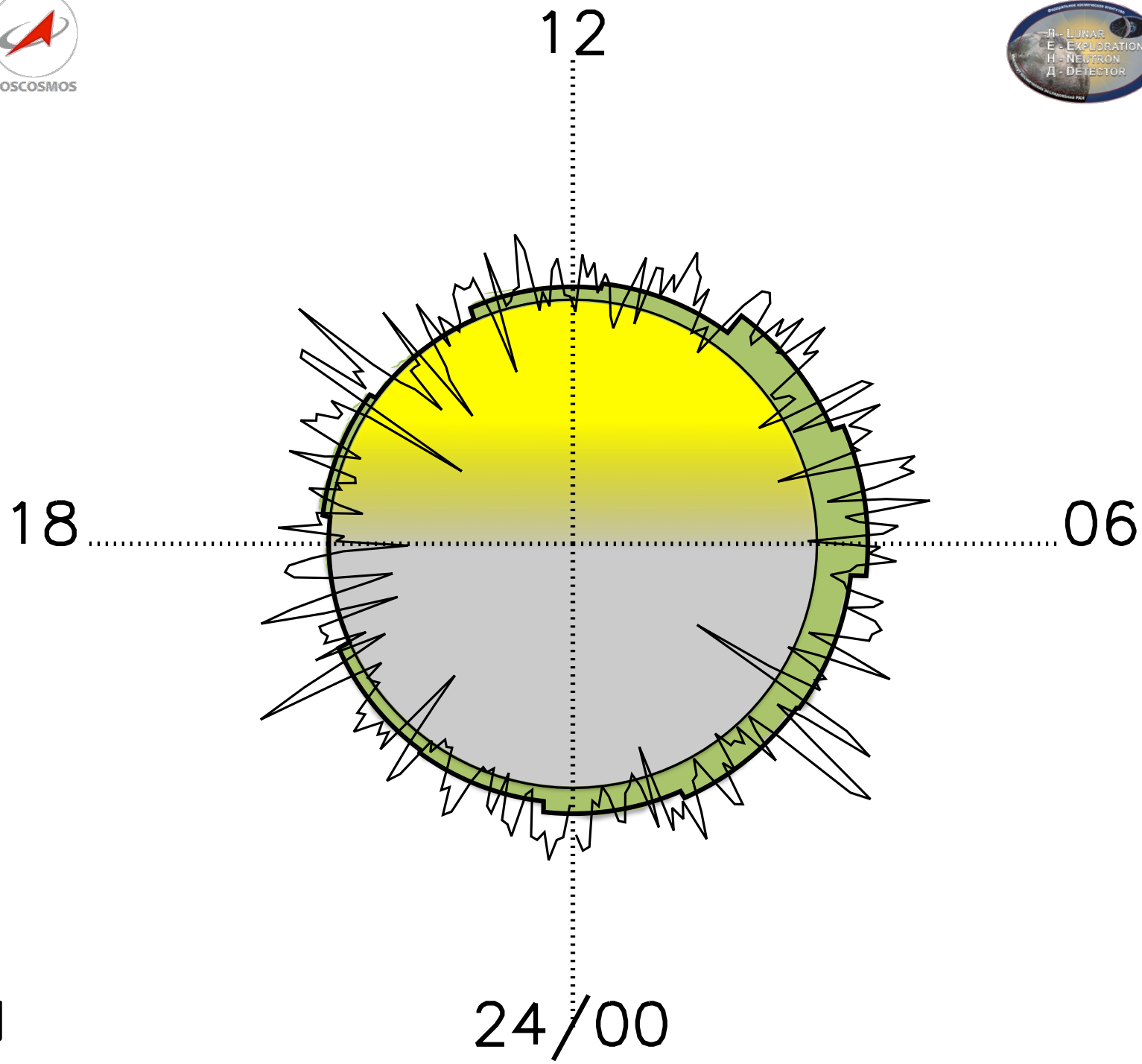
SETN


Dawn
Noon
Dusk
SETN
6:30
14:30
+90°
+70°
+50°
+30°
+10°
-10°
-30°
-50°
-70°
-90°
Latitude
6
12
18
Fewer neutrons
More neutrons

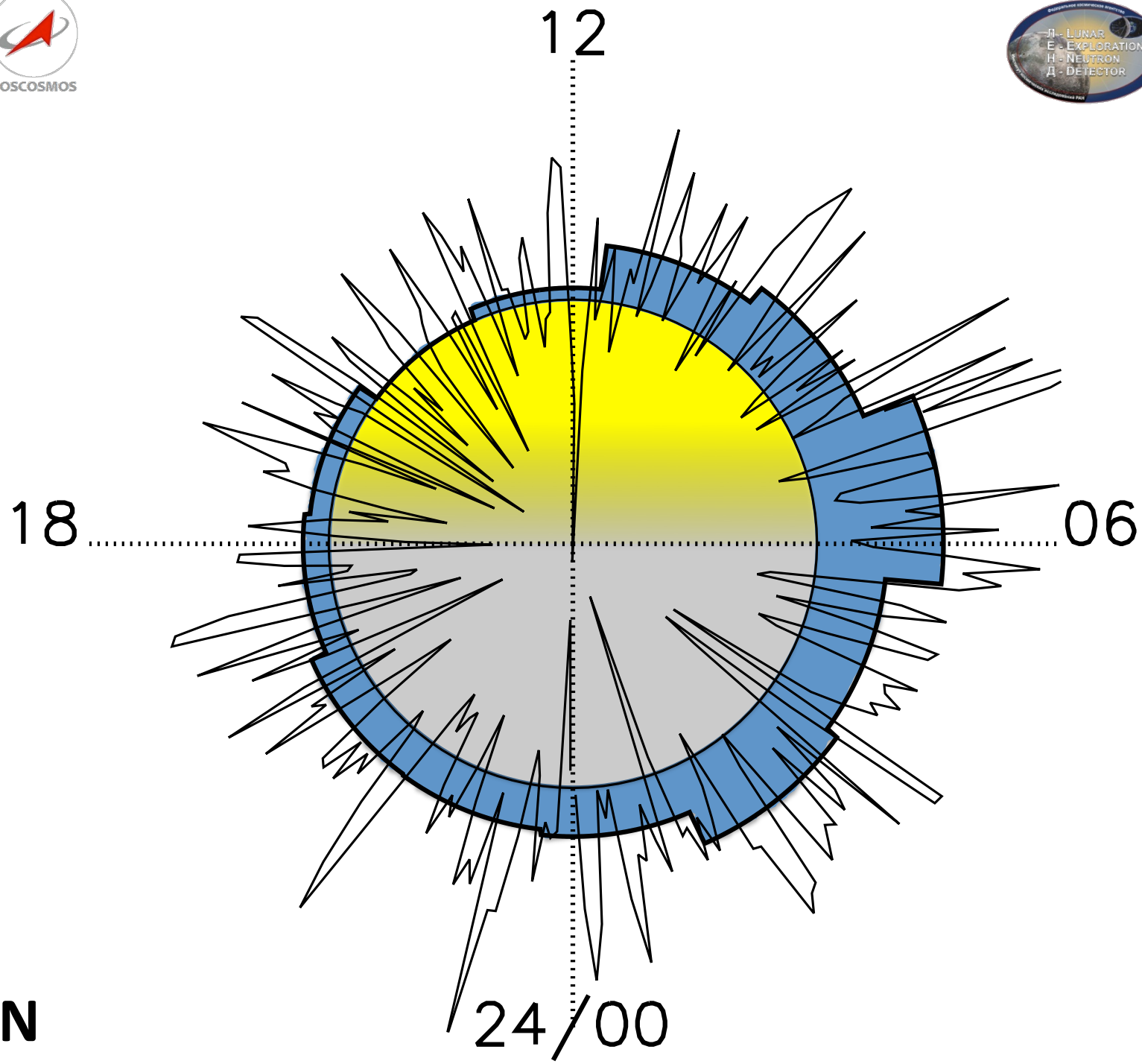
SETN


Dawn
Noon
Dusk
SETN
6:30
14:30
+90°
+70°
+50°
+30°
+10°
-10°
-30°
-50°
-70°
-90°
Latitude
6
12
18
Most water
Least water

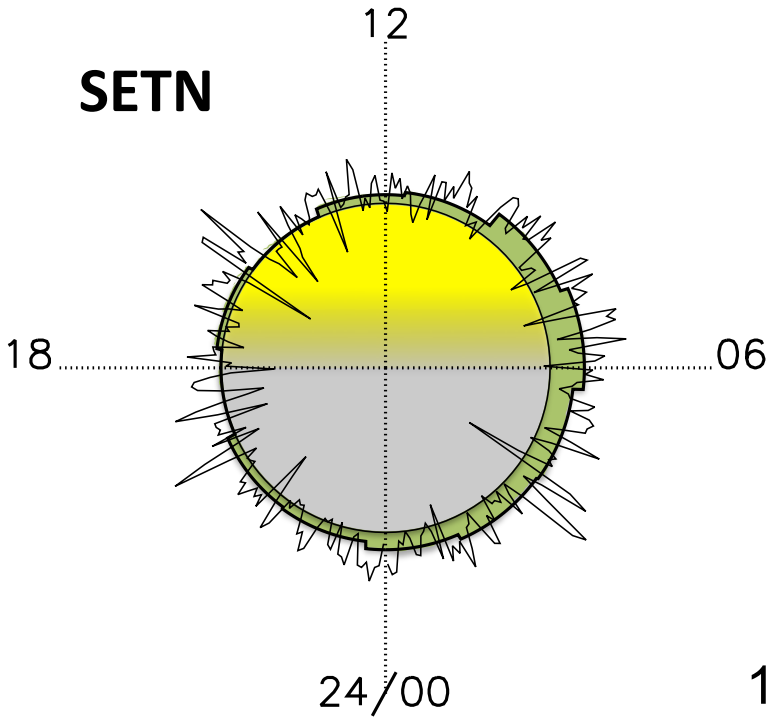

SETN relative
1.010
1.005
1.000
0.995
0.990
CSETN relative
1.010
1.005
1.000
0.995
0.990
0
3
6
9
12
15
18
21
24
local time

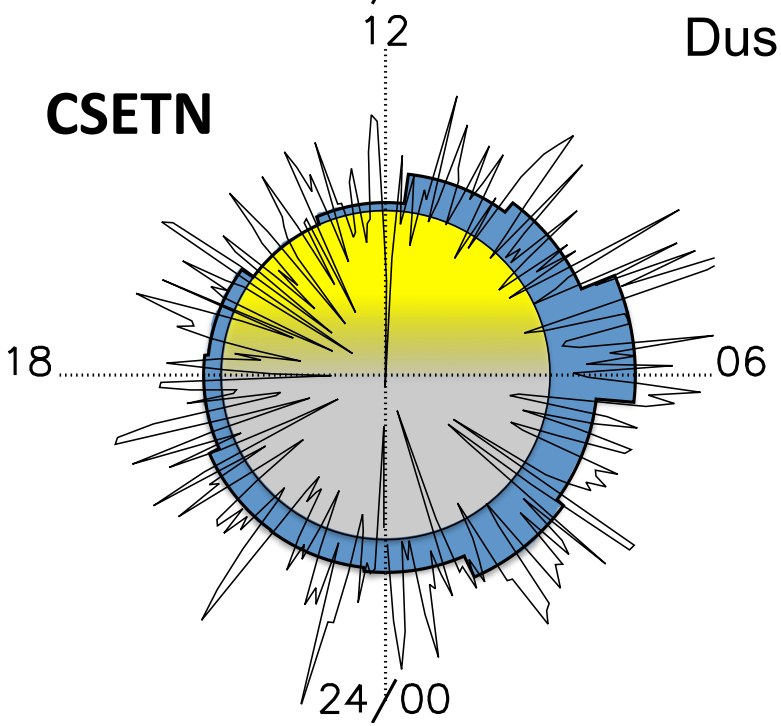


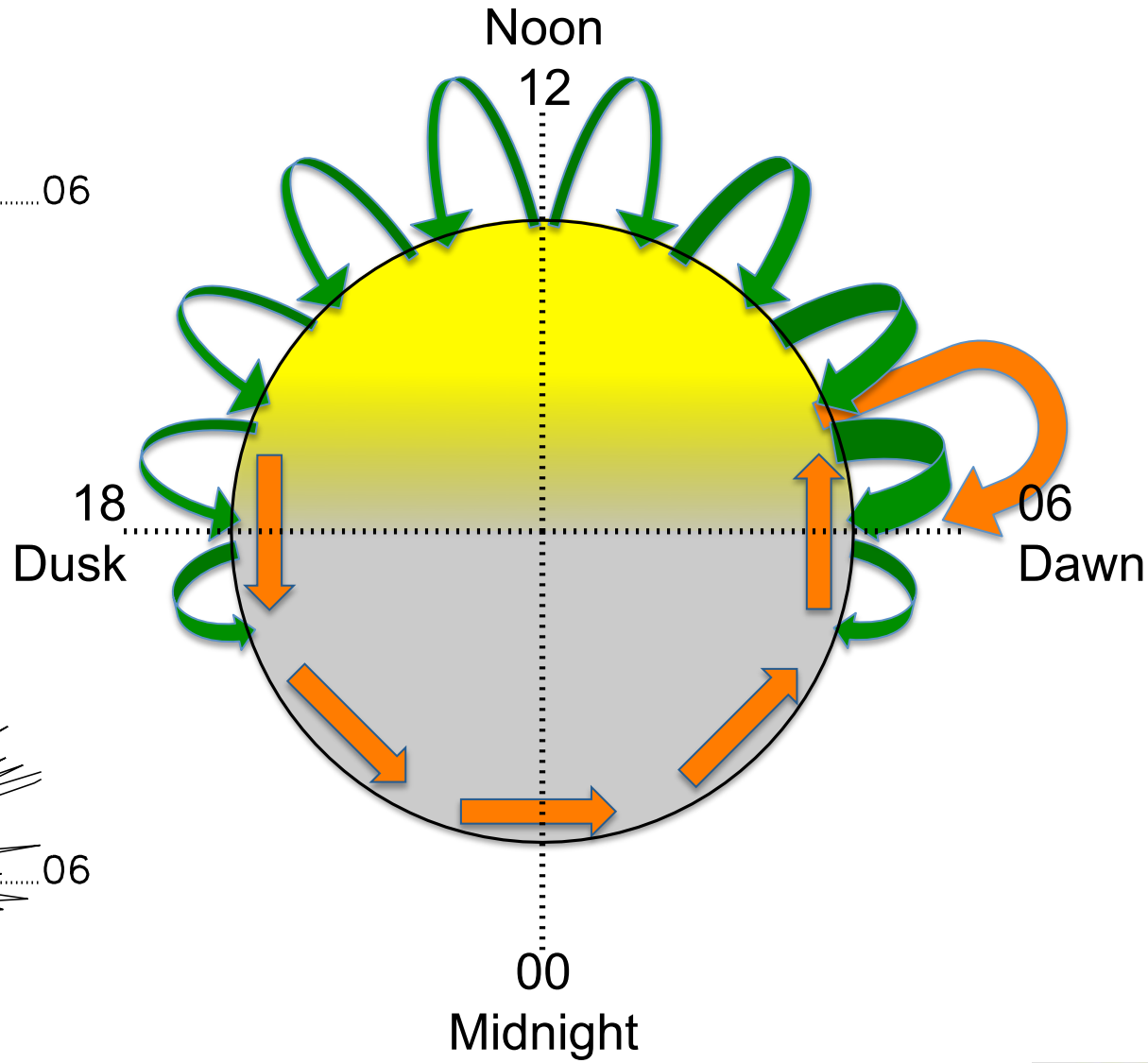
SETN



CSETN


SETN
12
18
06
24/00


CSETN
12
18
06
24/00


Noon
12
18
Dusk
06
Dawn
00
Midnight

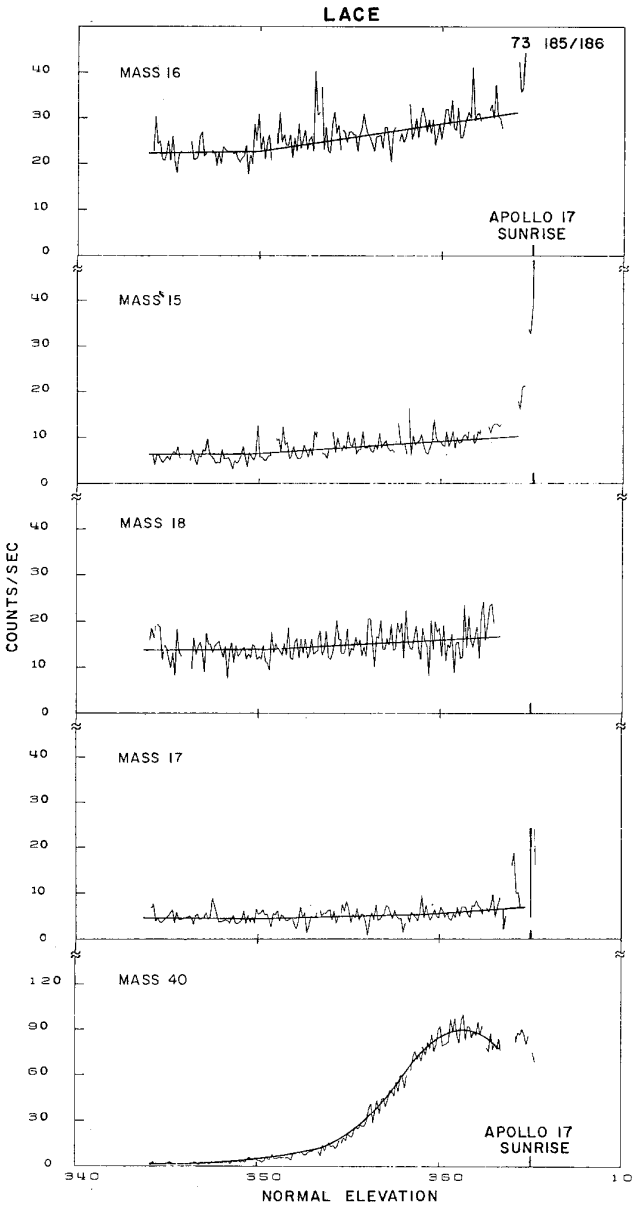


Fig. 2. Counting rate of 5 gas species as a function of normal elevation of the Sun where 0° is at the terminator crossing of the Apollo 17 landing site. Sunrise occurs nearly 5° after terminator crossing. Pre-dawn enhancement (see text) is indicated by positive slope of lines fitted to data.

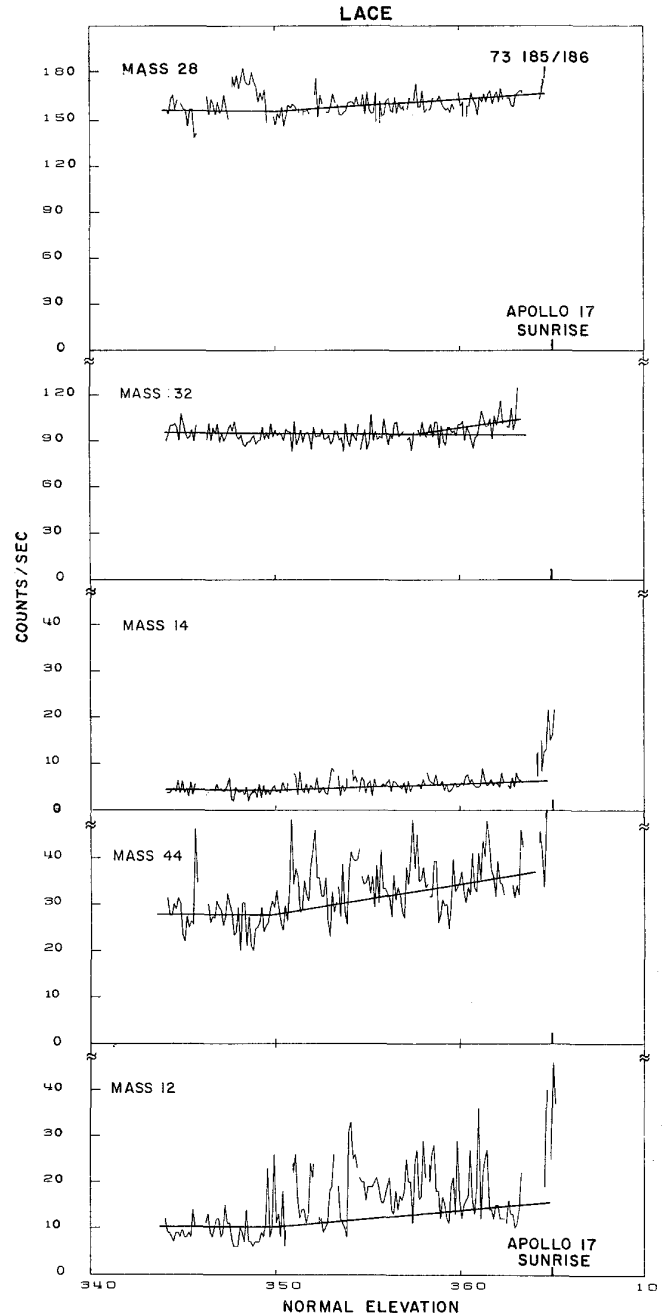


Fig. 3. Similar to Figure 2 except for 5 different gas species.

TABLE I

Pre-Dawn Enhancement

Mass (amu)	Counts[a]	Parent molecule							Total
		CH_4	NH_3	H_2O	N_2	CO	O_2	CO_2	
12	2±2	0.2	–	–	–	0	–	0.3	0.5
14	2±1	0.5	0.02	–	0.3	0	–	–	0.8
15	5±2	5	0.07	–	–	–	–	–	5
16	8±2	6	0.8	0.3	–	0	0.4	0.5	8
17	2+2 −1		1	1	–	–	–	–	2
18	3±3	–	–	3	–	–	–	–	3
28	4±4	–	–	–	4	0	–	0.6	4.6
32	5±5	–	–	–	–	–	5	0	5
40	90±10	–	–	–	–	–	–	–	90
44	7±5	–	–	–	–	–	–	7	7

[a] Counting rate increase at sunrise.

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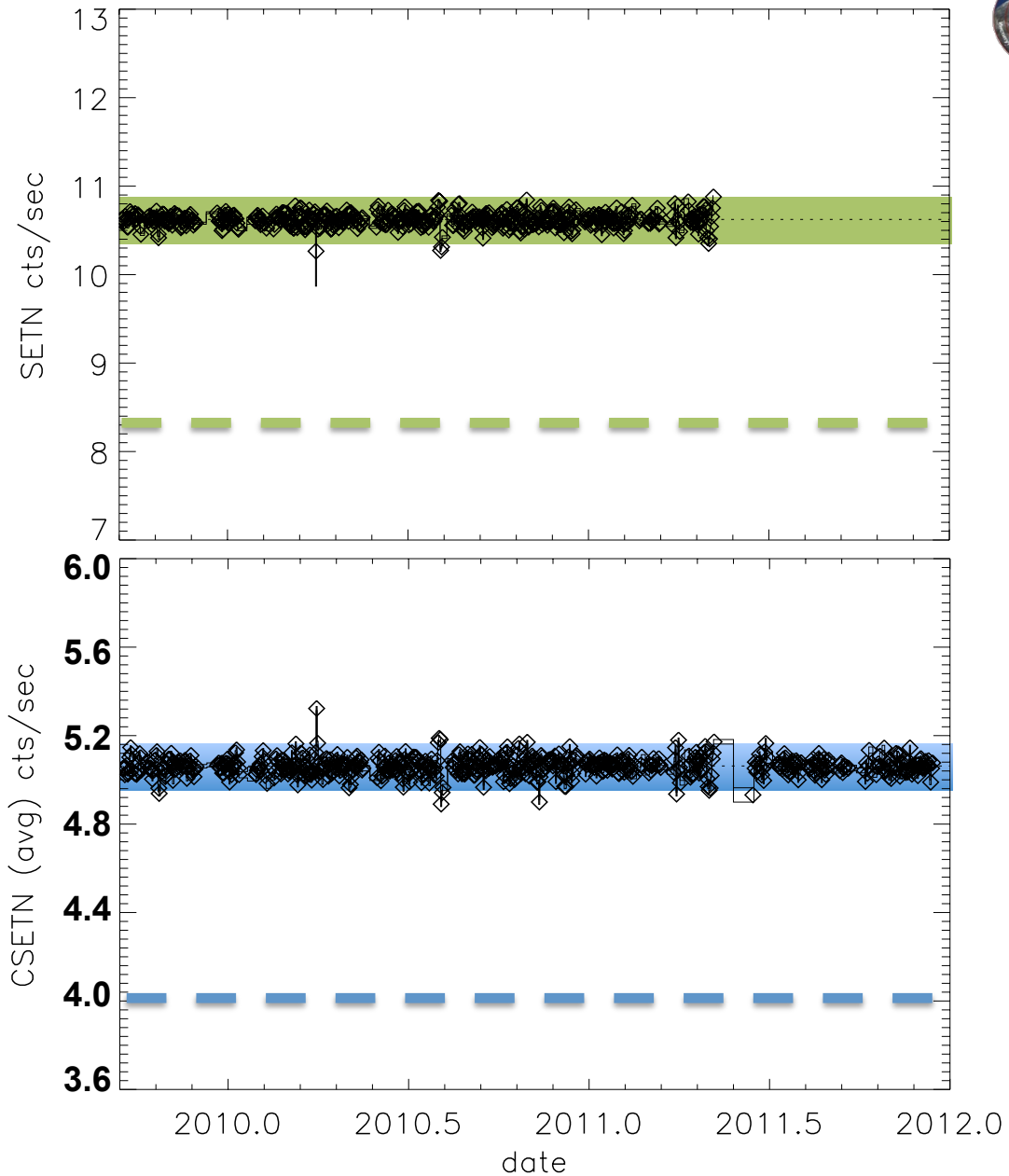
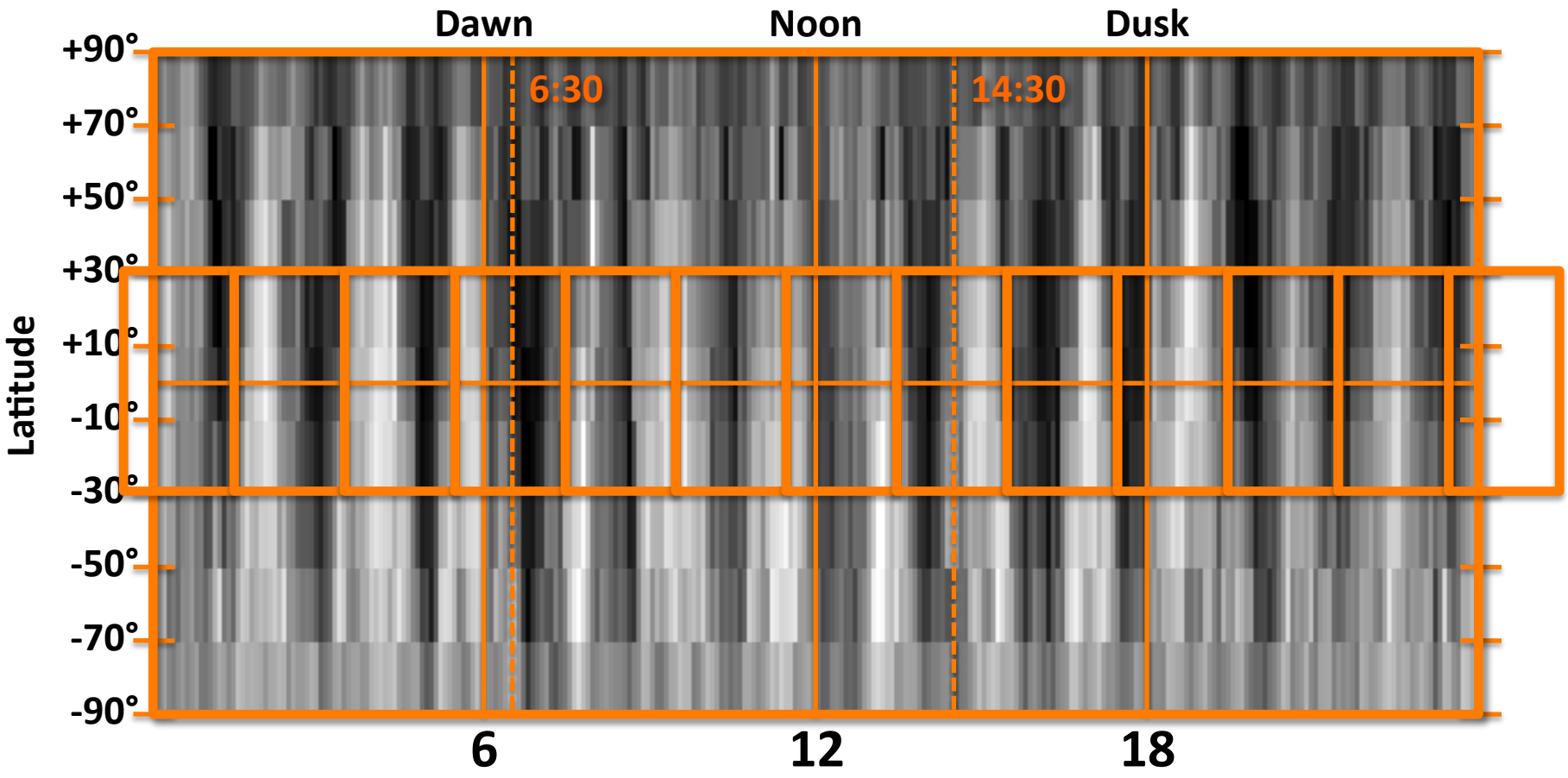
- Maximum epithermal neutron emission in mid-afternoon
  = least hydrogen moderation
  = "driest" regolith.
- Minimum epithermal neutron emission at dawn terminator/early morning
  = most hydrogen moderation
  = "wettest" regolith.

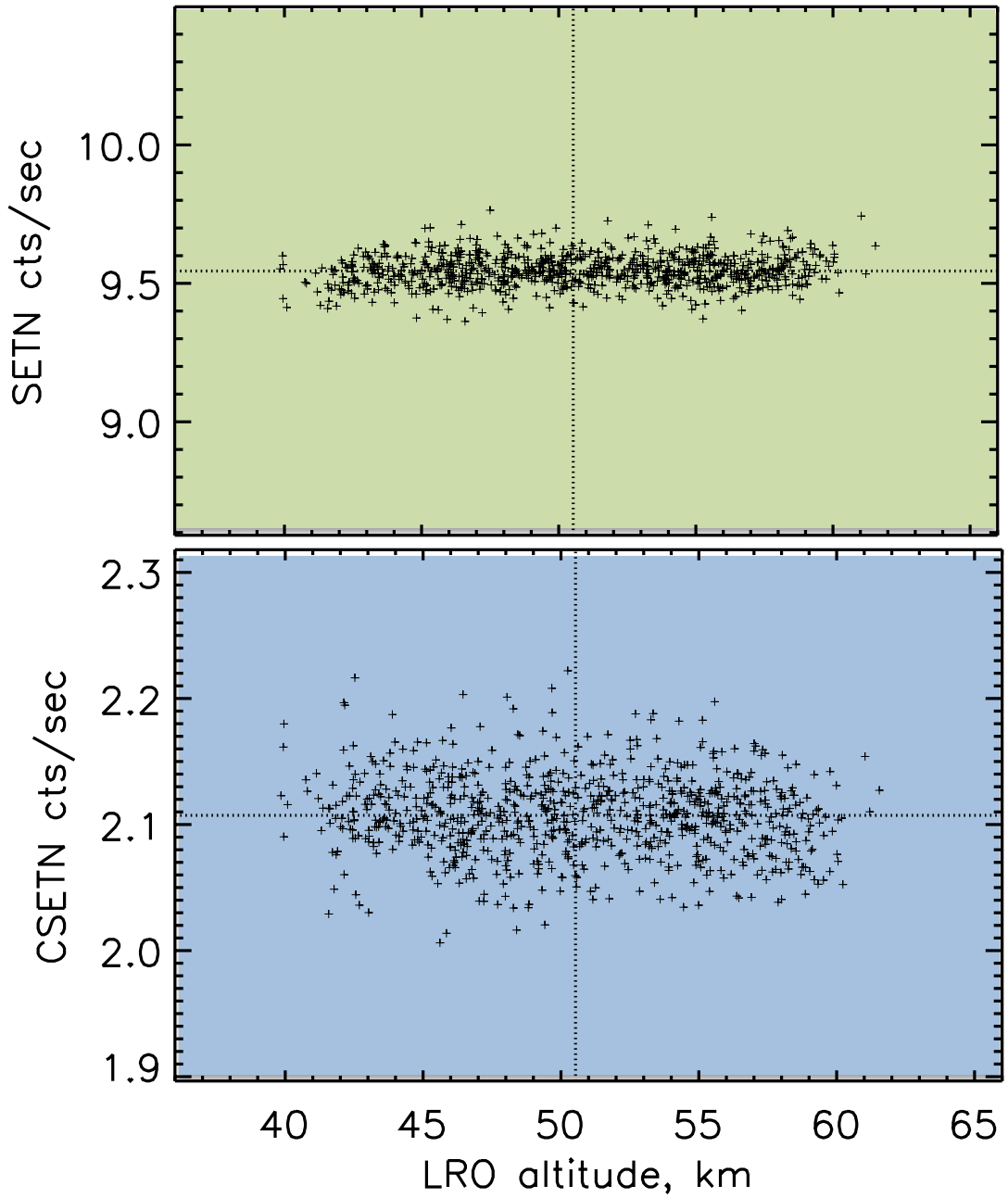
Additional slides follow.

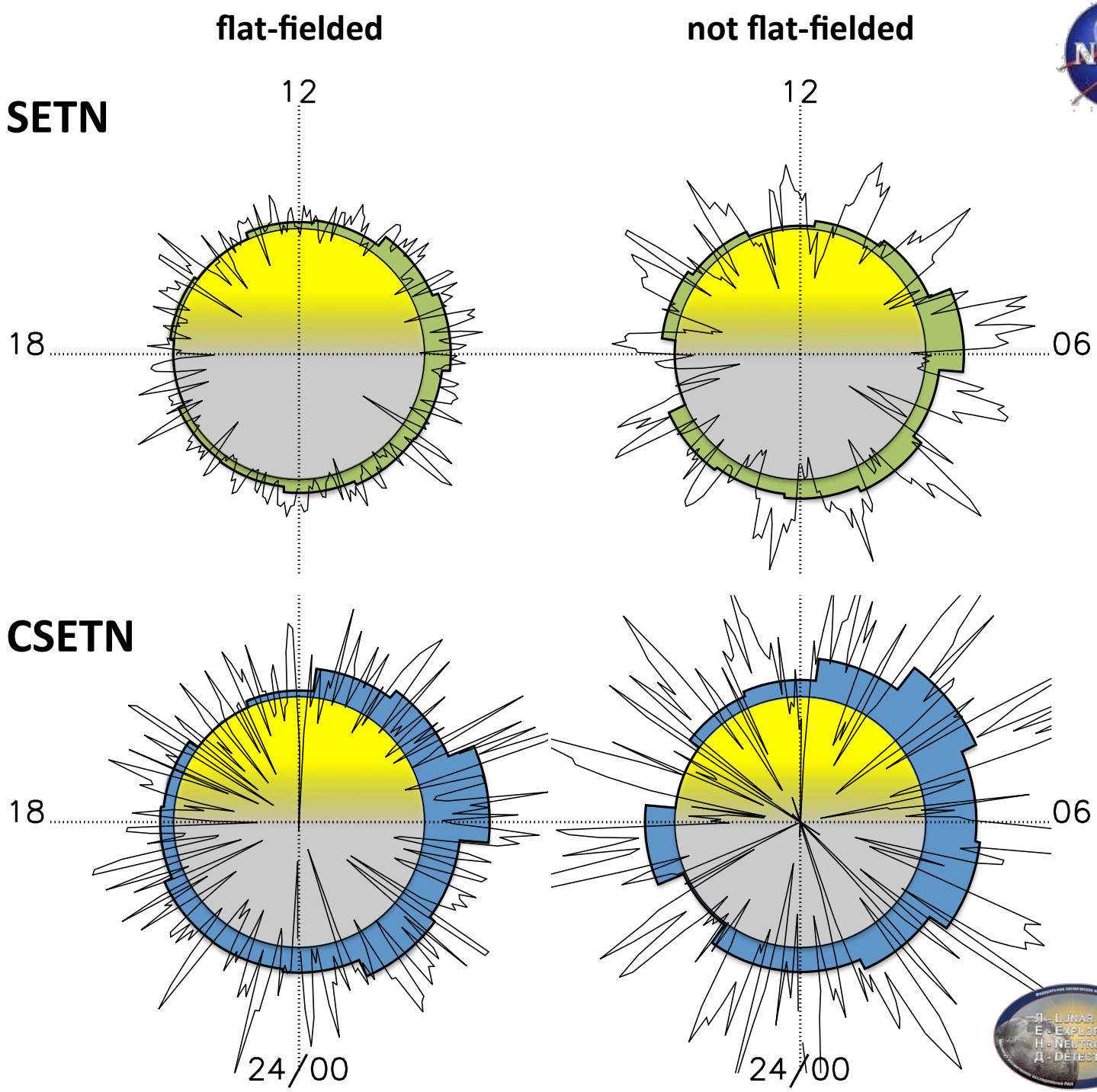
LEND Detectors, after correction for sensitivity and GCR-flux variations.

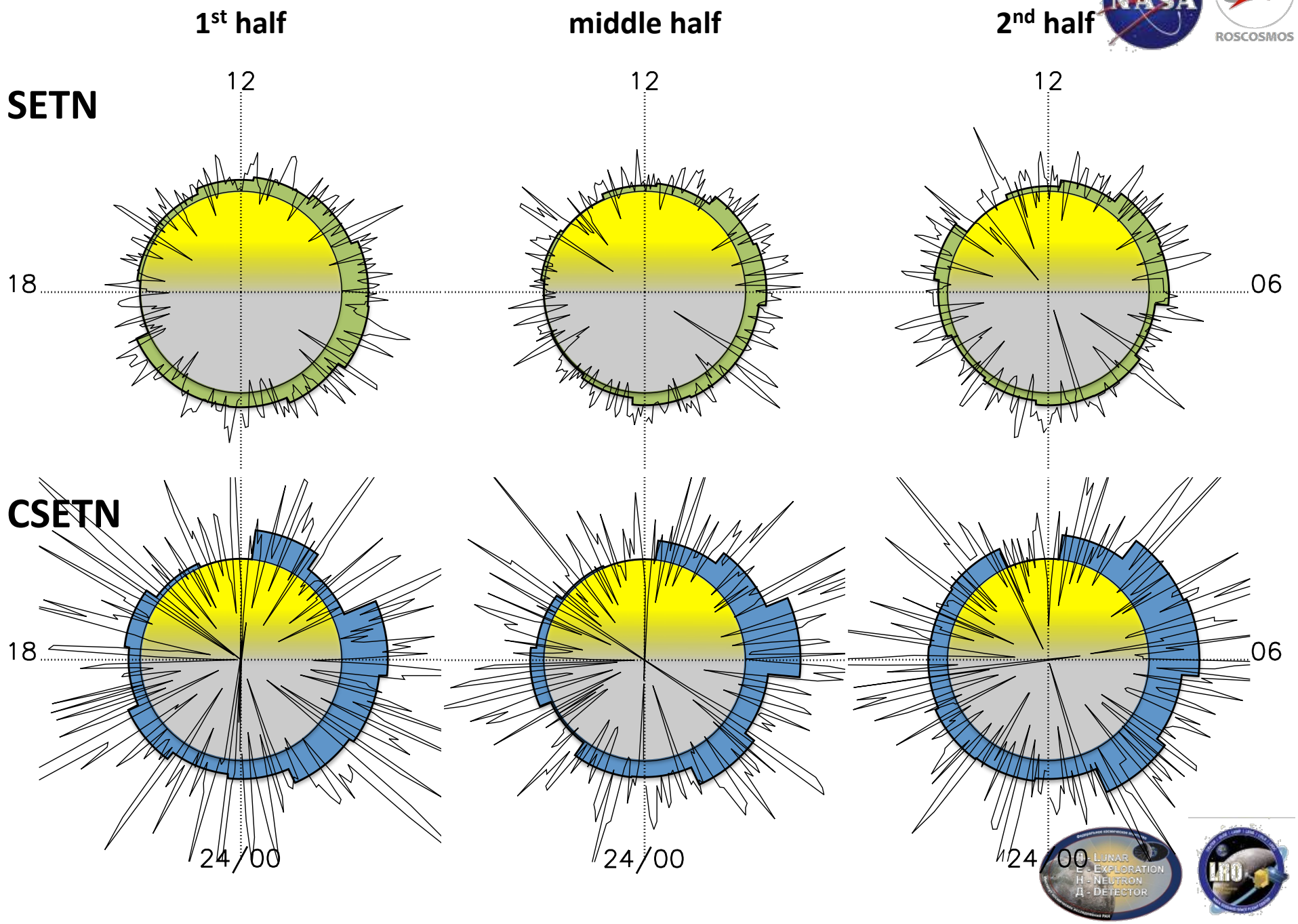


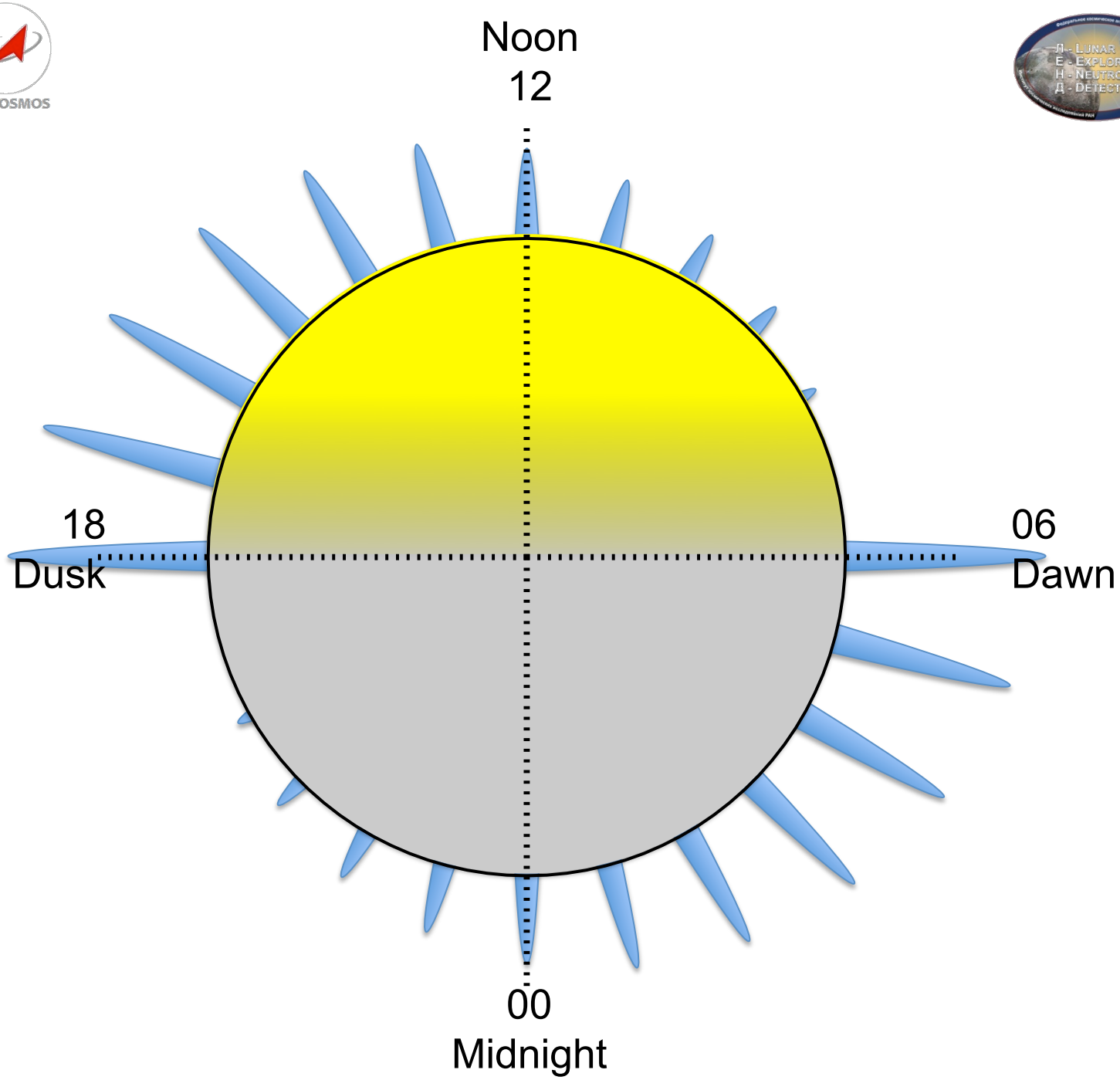
Altitude

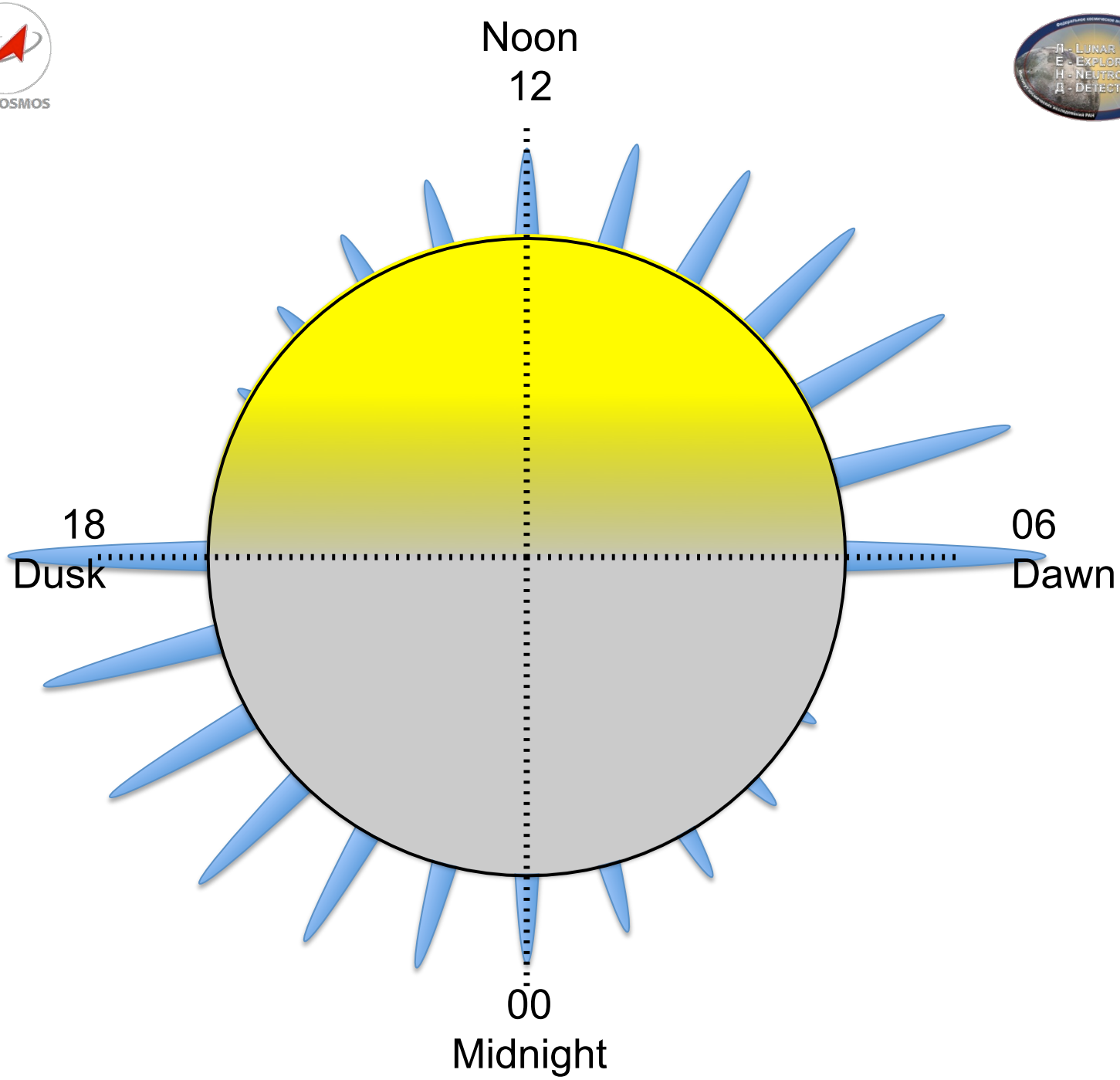

Dawn
Noon
Dusk
6:30
14:30
+90°
+70°
+50°
+30°
+10°
-10°
-30°
-50°
-70°
-90°
Latitude
6
12
18

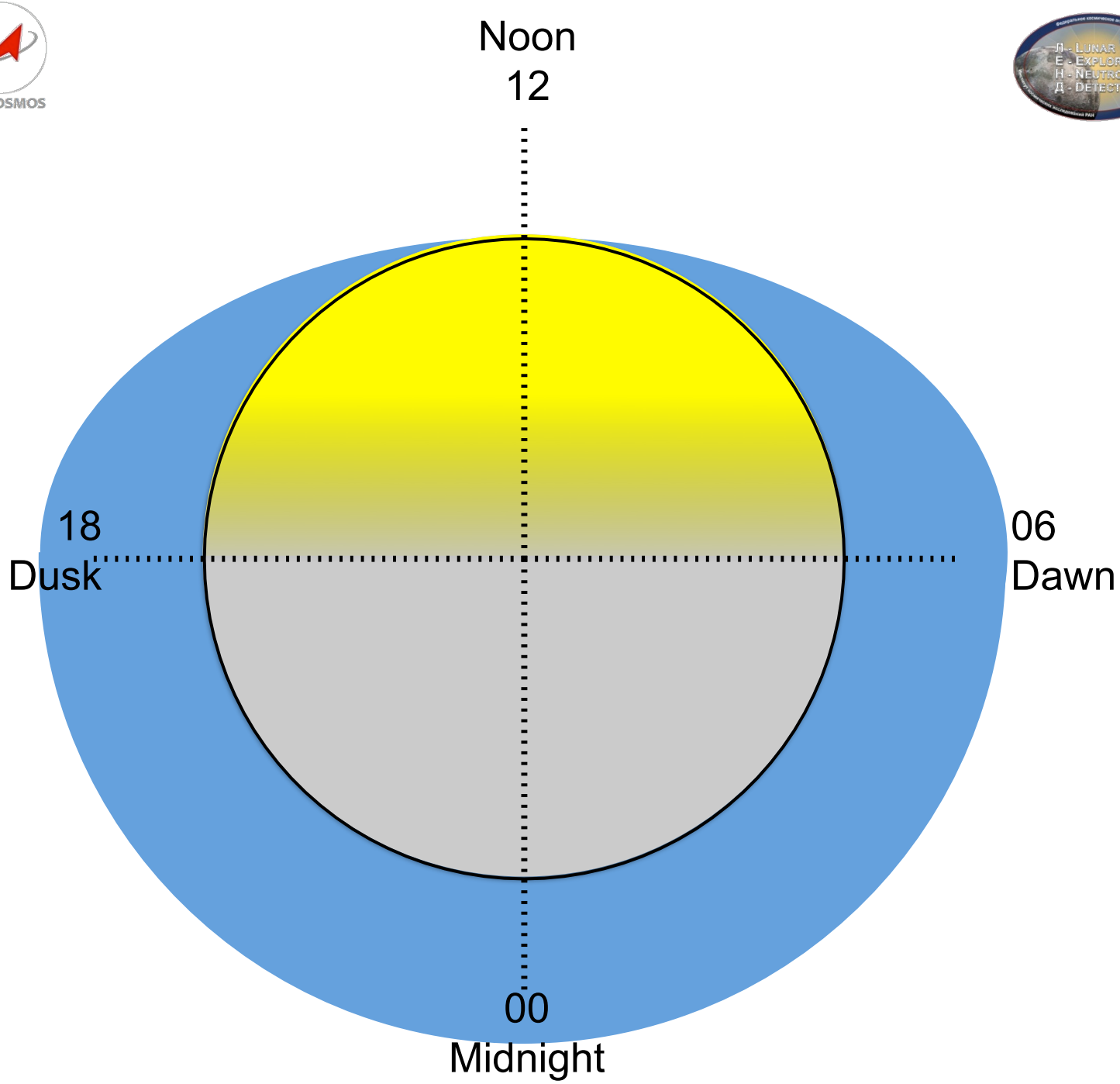

SETN cts/sec
10.0
9.5
9.0
CSETN cts/sec
2.3
2.2
2.1
2.0
1.9
40
45
50
55
60
65
LRO altitude, km


flat-fielded
not flat-fielded
SETN
CSETN
12
18
06
24/00

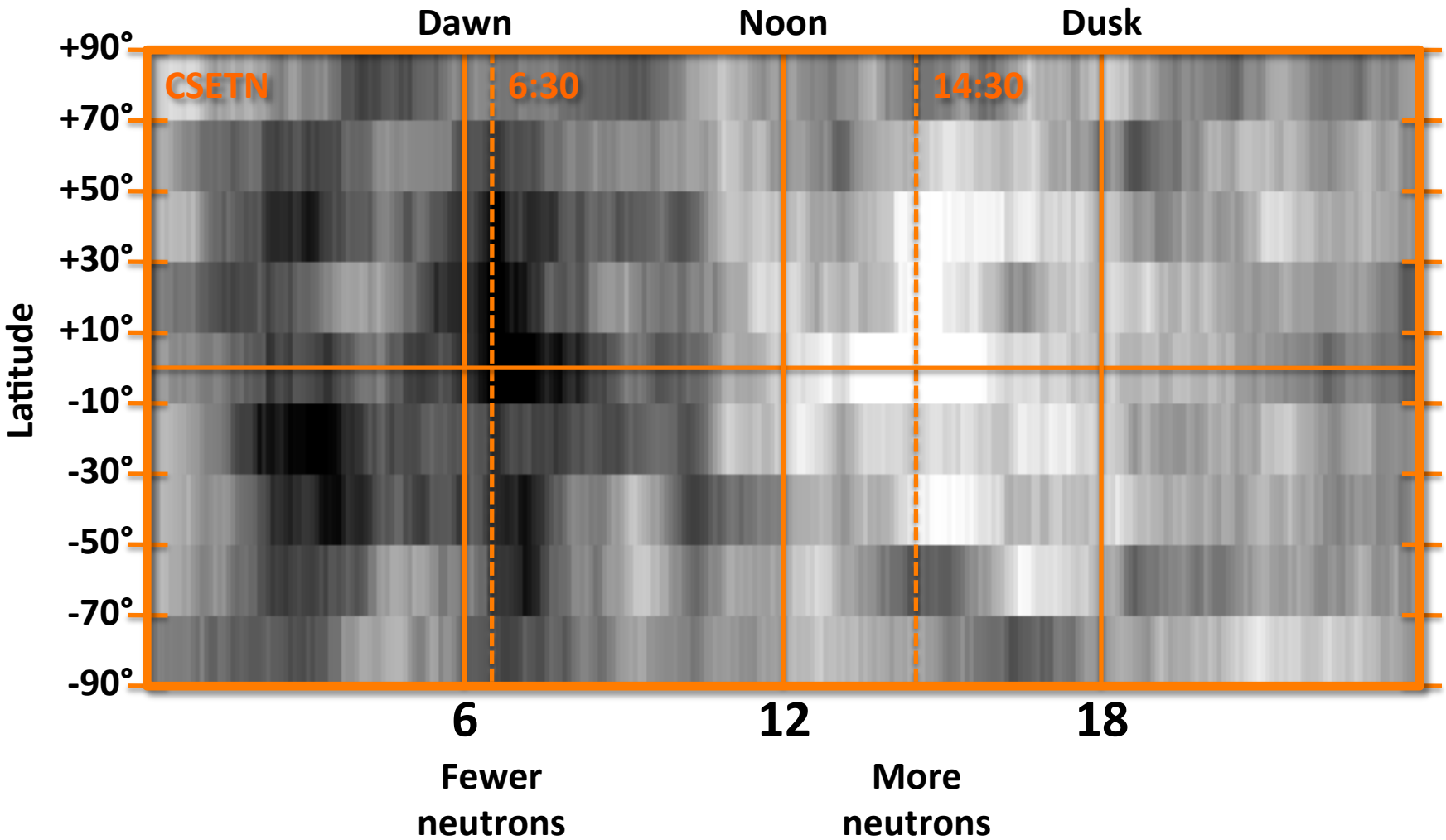

1st half
middle half
2nd half
SETN
CSETN
12
18
06
24/00


Noon
12
18
Dusk
06
Dawn
00
Midnight

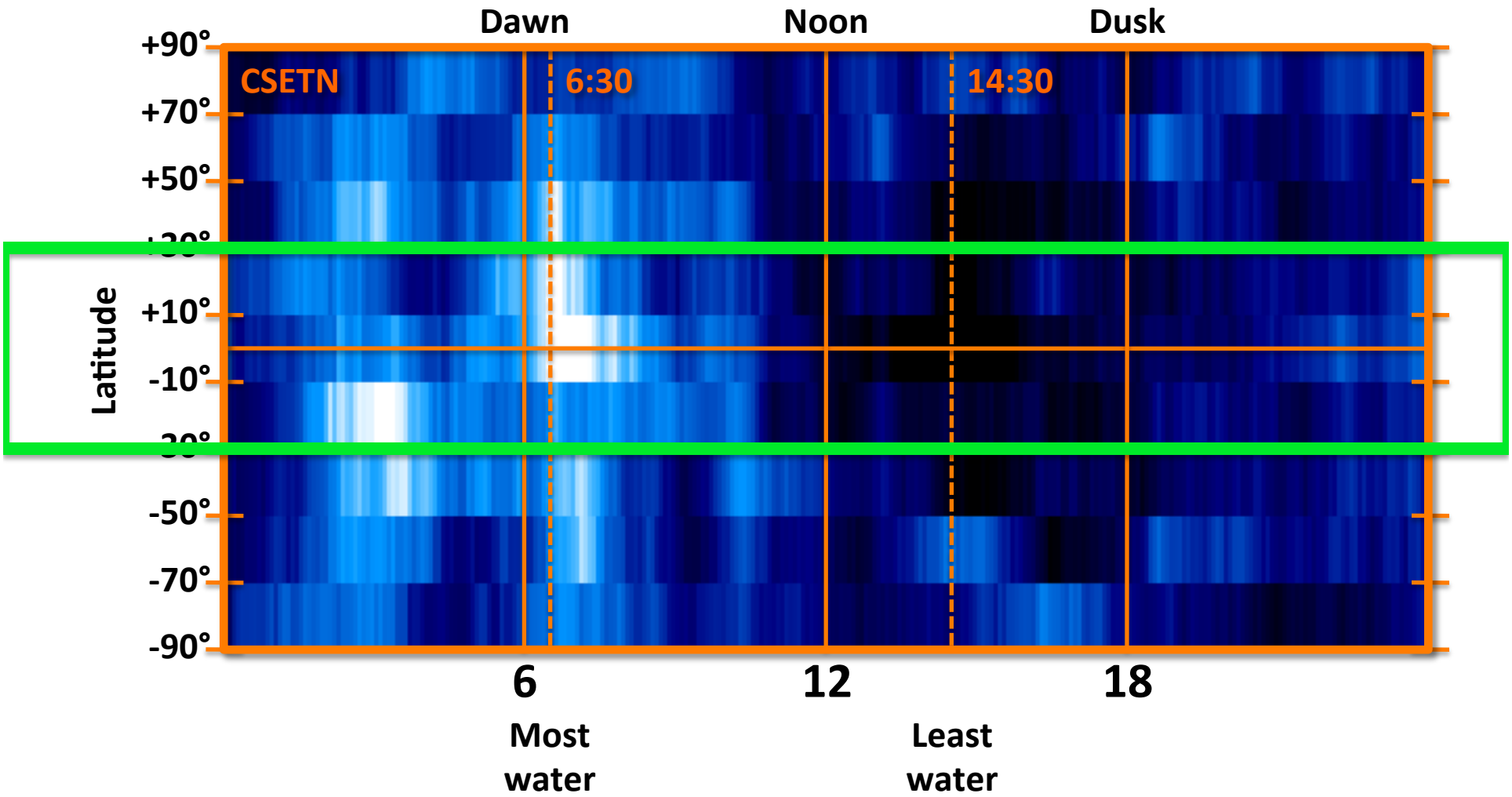

Noon
12
18
Dusk
06
Dawn
00
Midnight


Noon
12
18
Dusk
06
Dawn
00
Midnight

CSETN


Dawn
Noon
Dusk
CSETN
6:30
14:30
+90°
+70°
+50°
+30°
+10°
-10°
-30°
-50°
-70°
-90°
Latitude
6
12
18
Fewer neutrons
More neutrons

CSETN


Dawn
Noon
Dusk
CSETN
6:30
14:30
+90°
+70°
+50°
+30°
+10°
-10°
-30°
-50°
-70°
-90°
Latitude
6
12
18
Most water
Least water