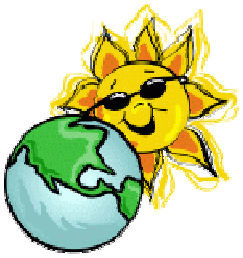


Monitoring of GCRs and SPE observation by neutron data obtained in different planetary missions

Dmitry Golovin

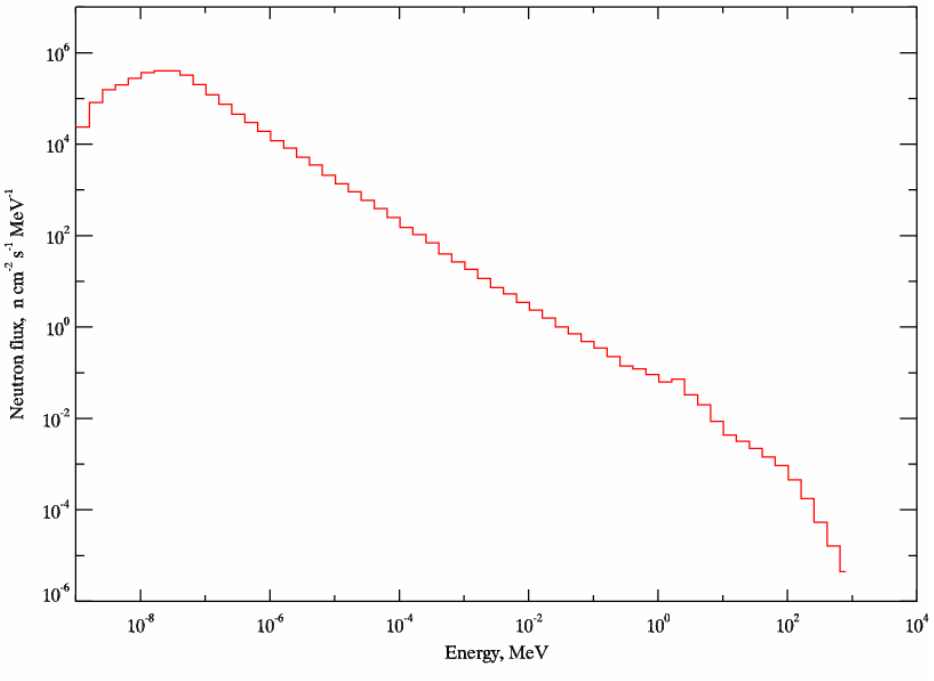
Igor Mitrofanov, Maxim Litvak, Anton Sanin, Alexey Malakhov, Igor Nuzhdin, Fedor Fedosov, and Sergey Nikiforov

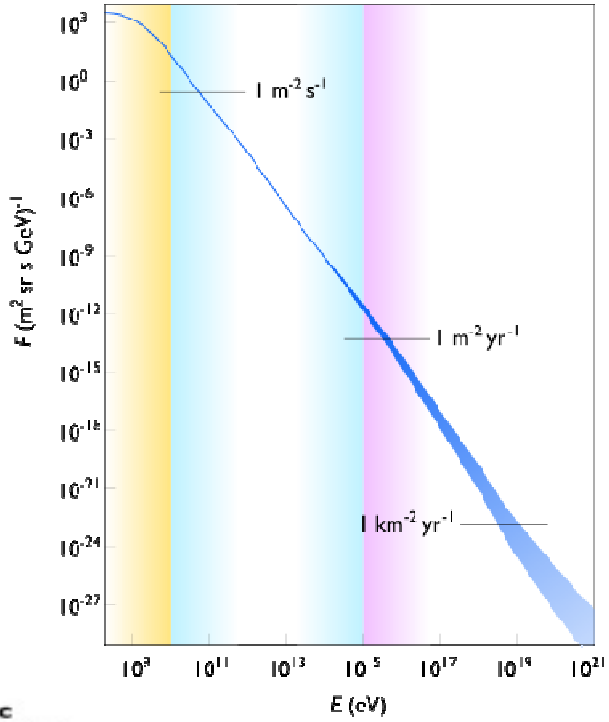
on behalf of HEND, LEND and DAN teams

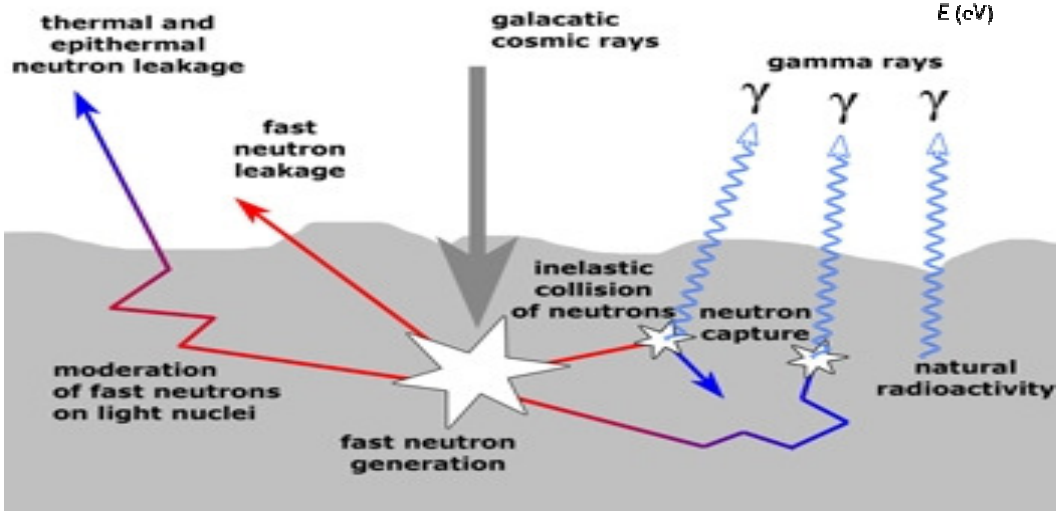
Space Research Institute (IKI), Russia

Solar Workshop 2013
June 03-07, Nessebar

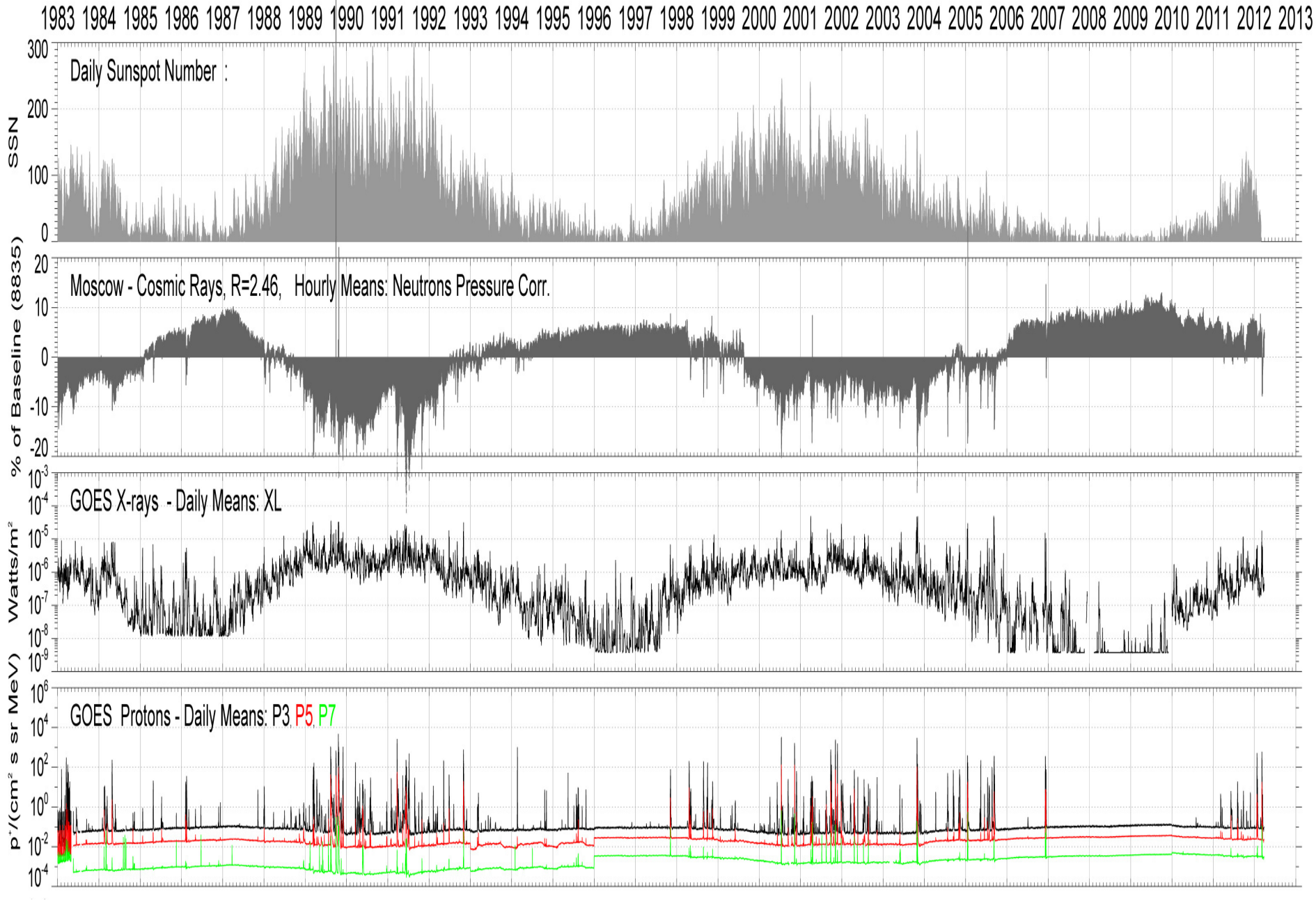
Interaction of GCR protons with planets and neutrons production





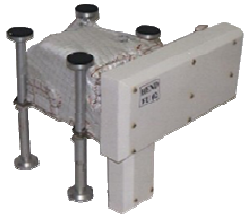


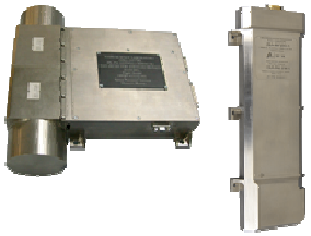
Space Environment Overview: 1983-01-01 00h - 2012-12-31 24h

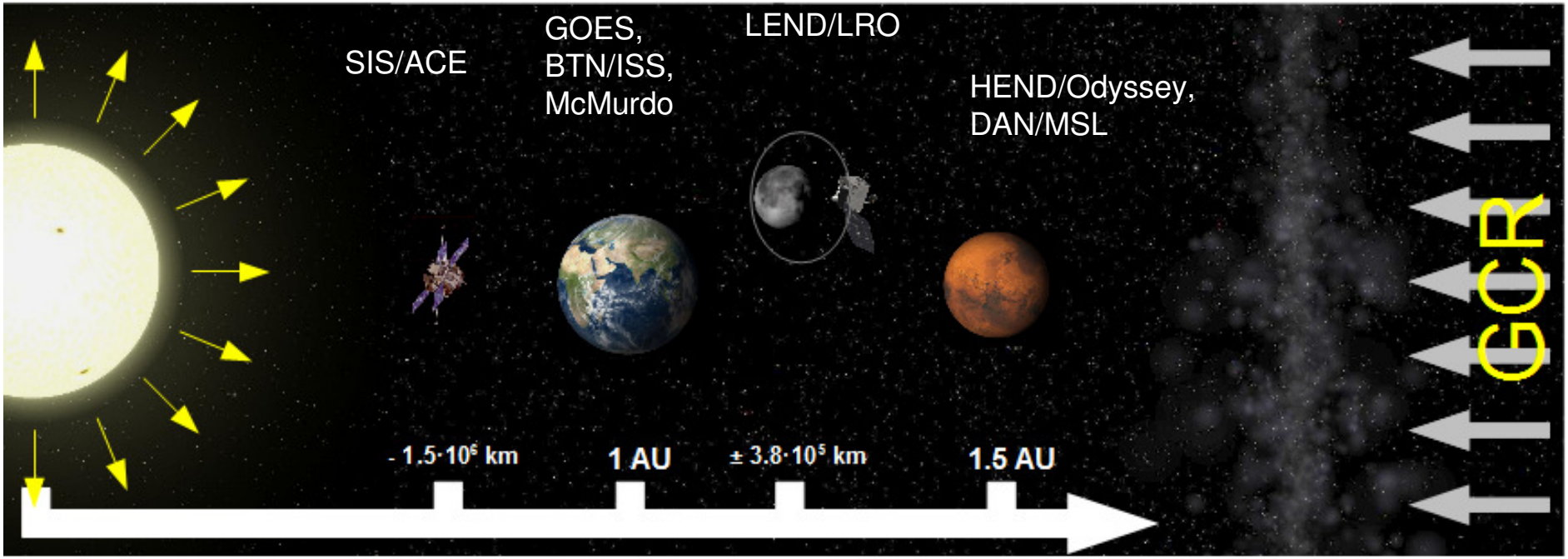


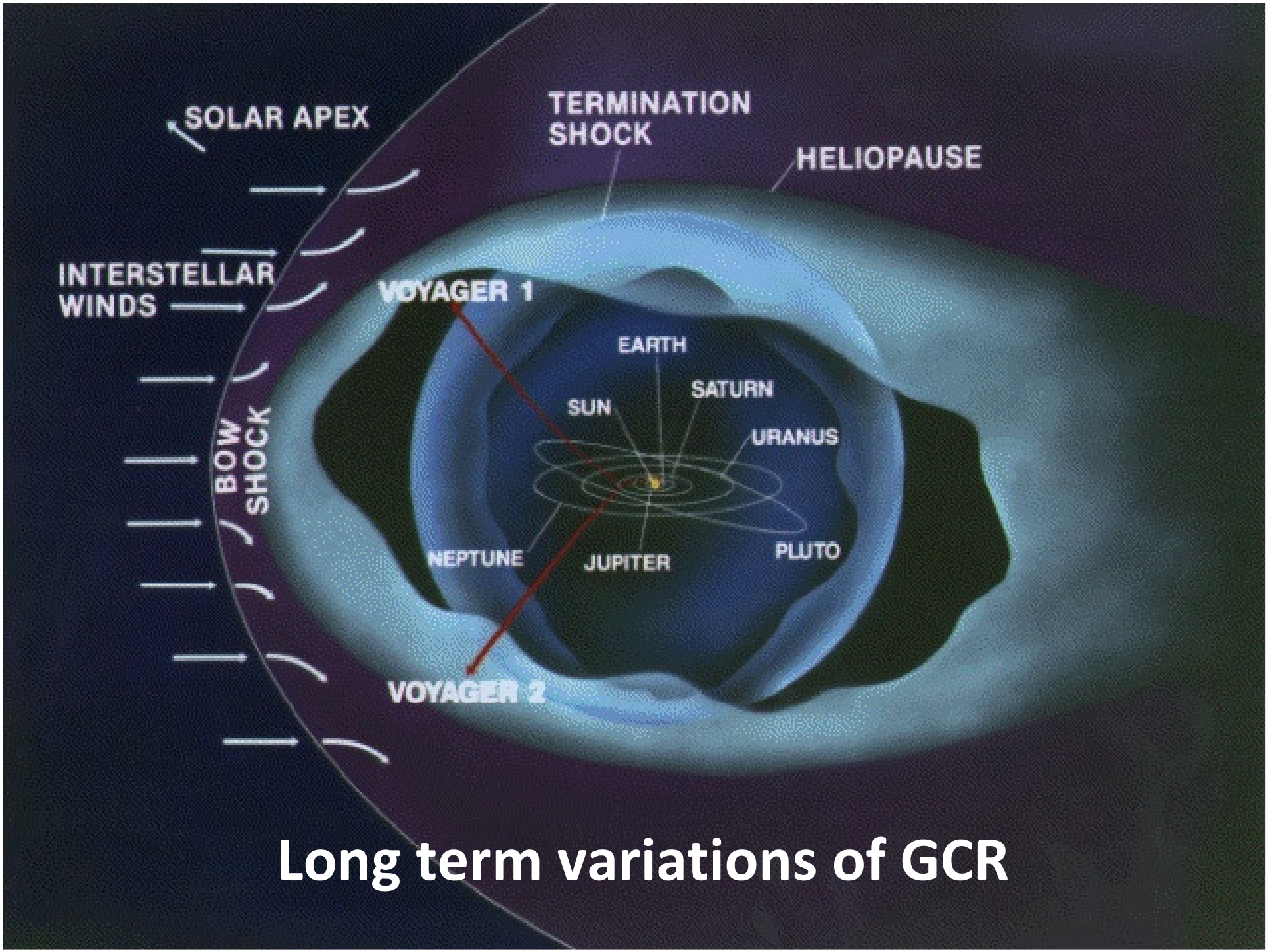
Instruments for GCRs and SPE detecting

HEND (2001) - neutrons 0.4 eV -15 MeV;
X-rays and Gamma-rays 30 keV – 1 MeV
BTN (2007) - neutrons 0.4 eV -15 MeV;
X-rays and Gamma-rays 30 keV – 1 MeV
LEND (2009) - protons E>30 MeV,
neutrons <15 MeV
DAN (2012) - neutrons <100 keV



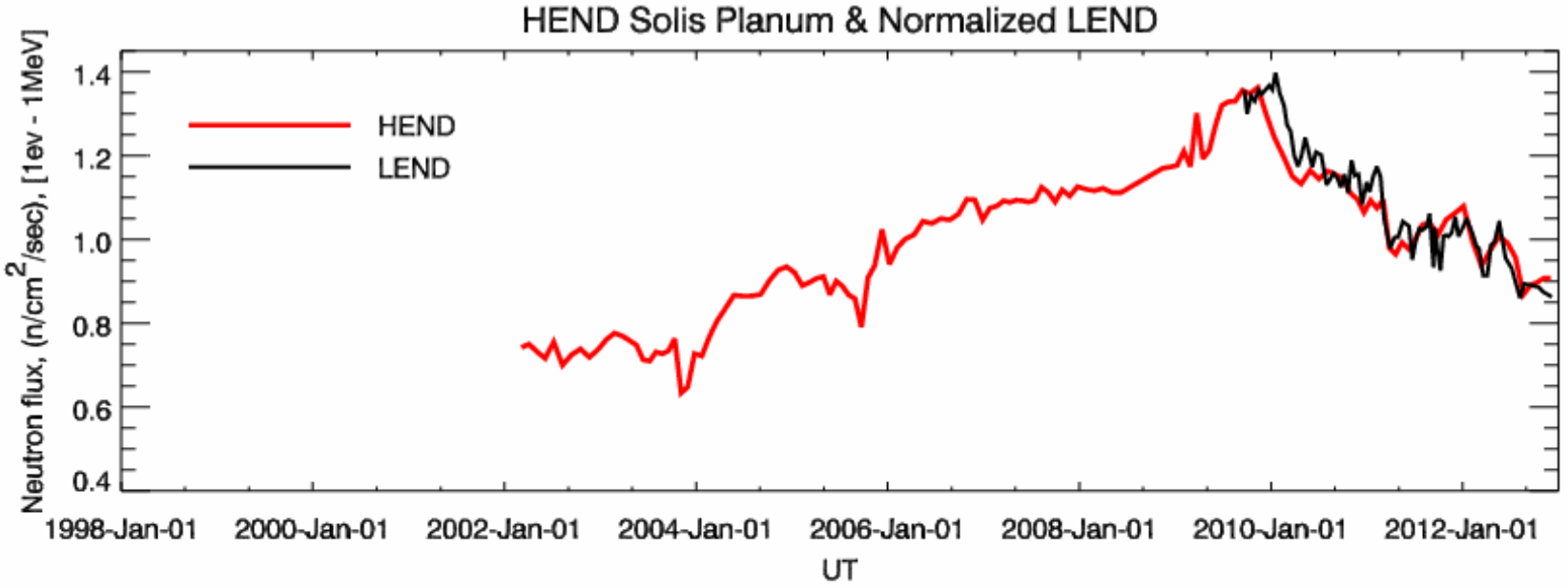


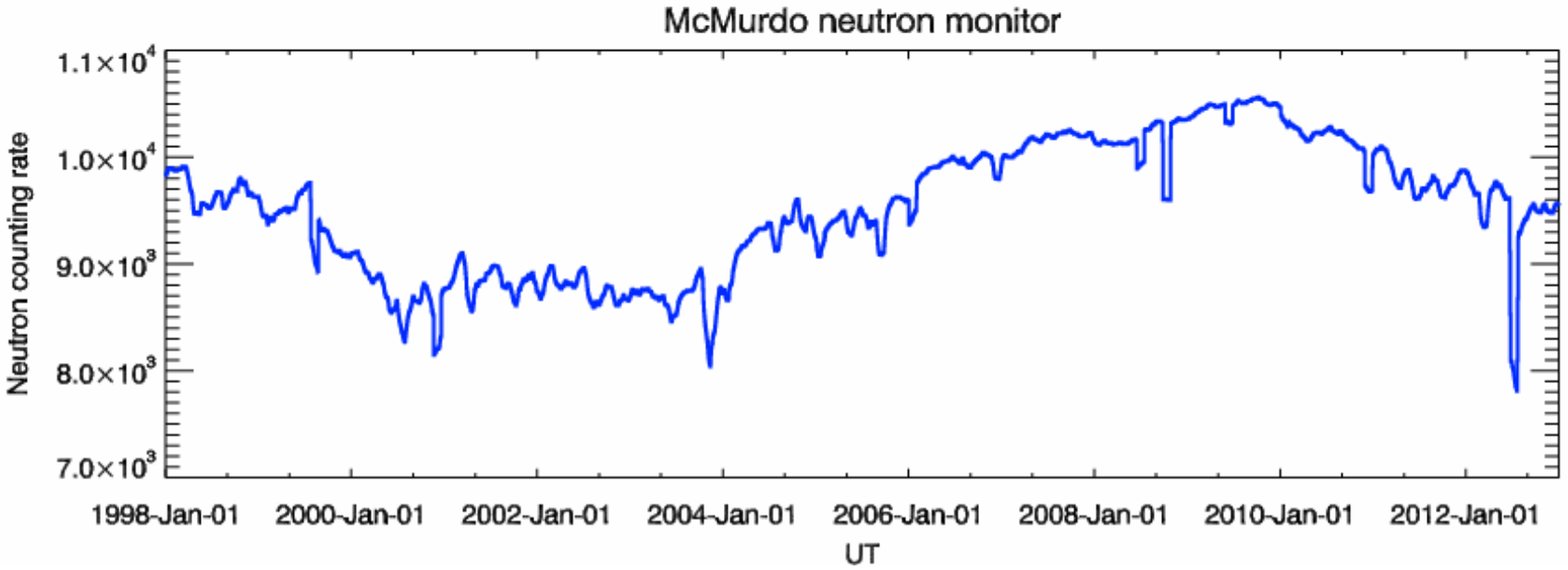




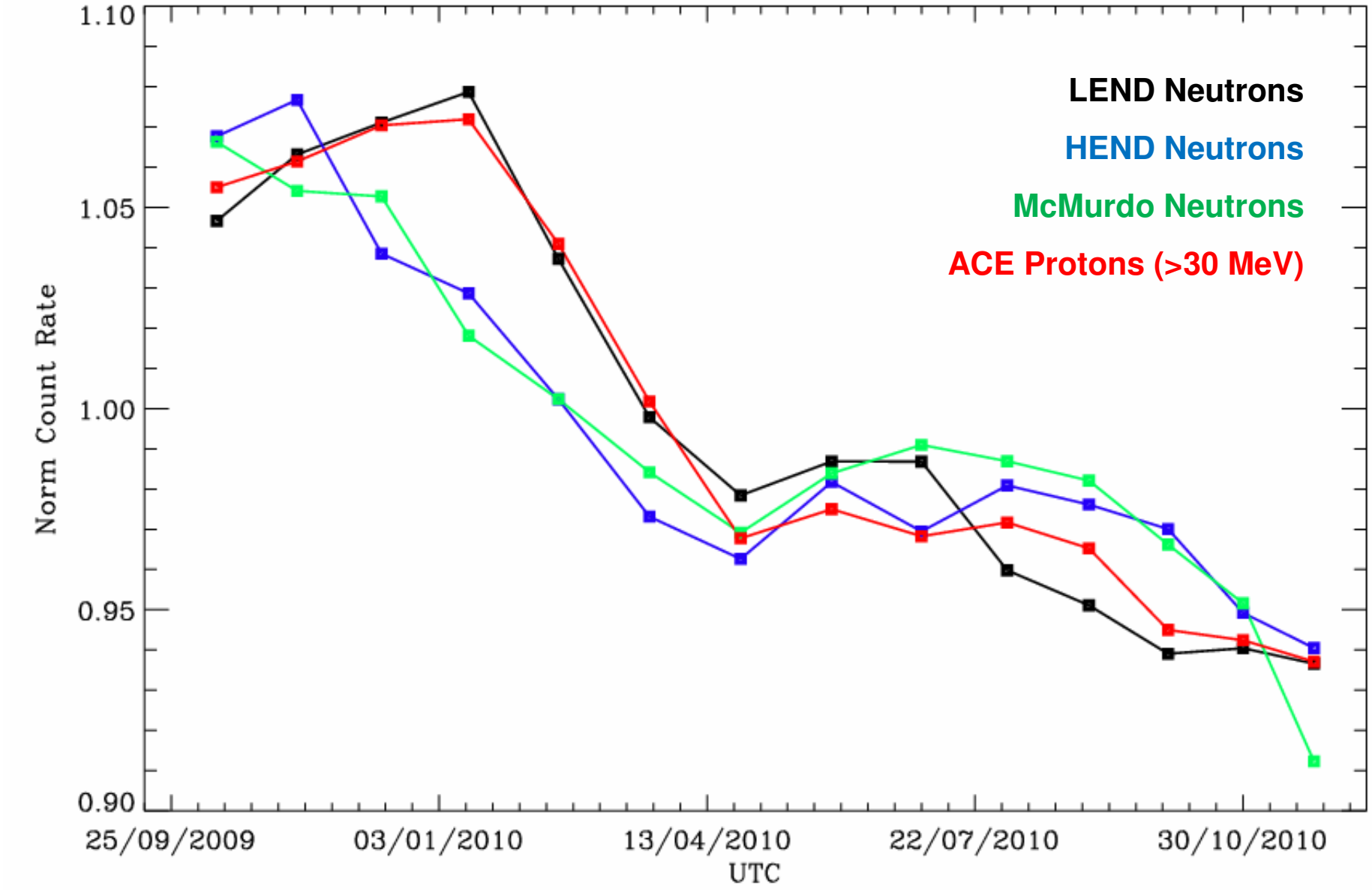
Long term variations of GCR

Long-Term Trends of GCR



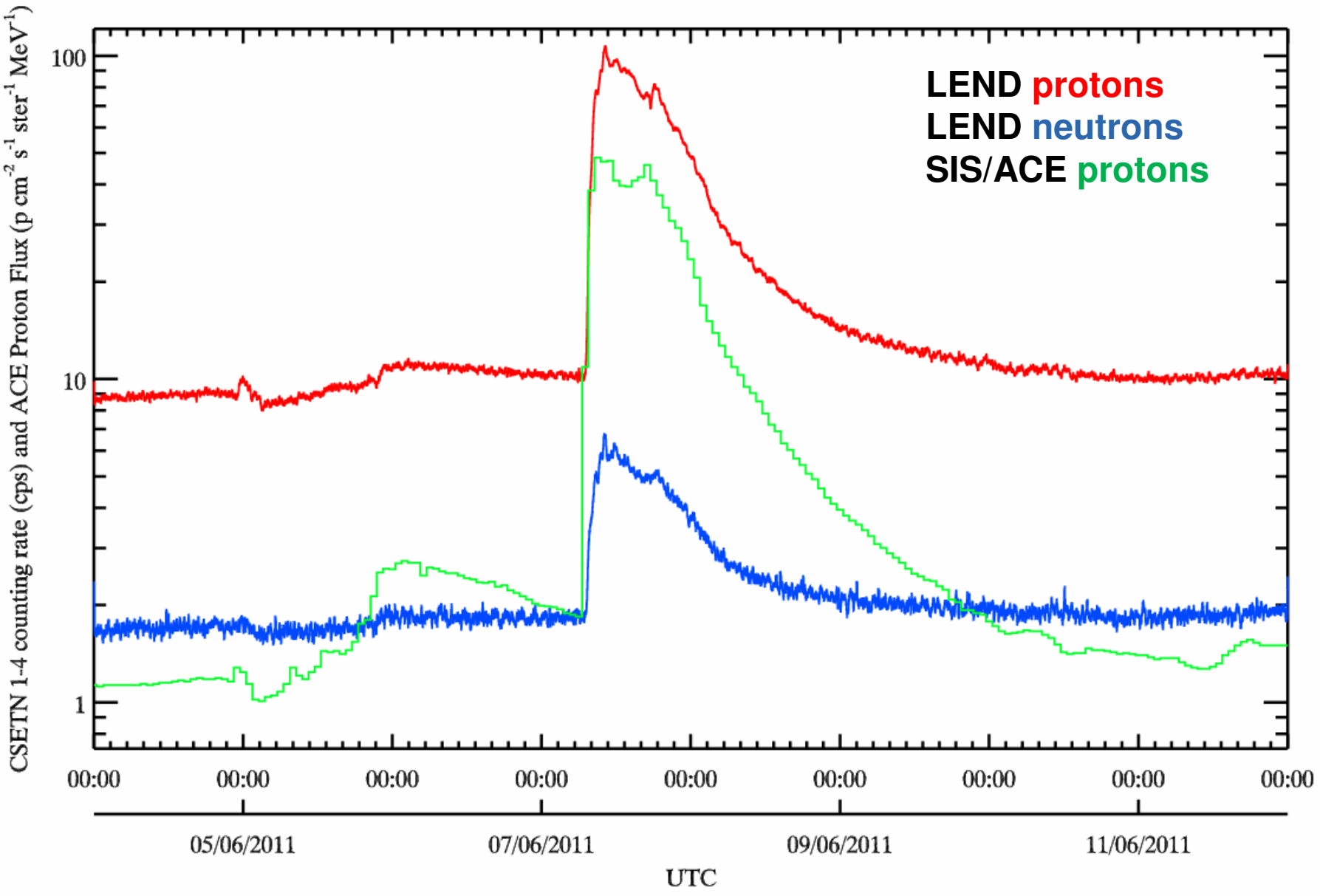


Trends of GCR in the beginning of 24 solar cycle

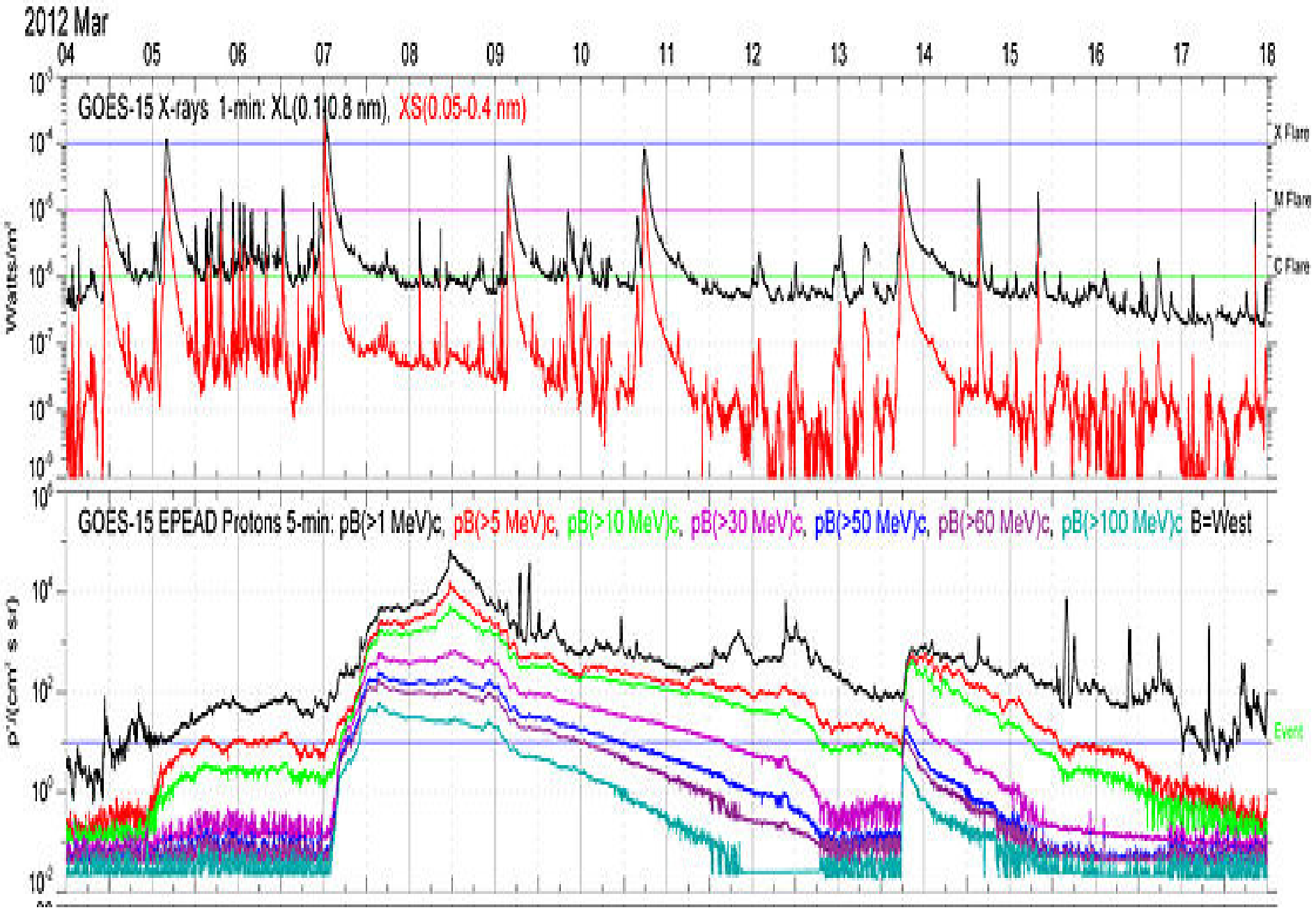


SPE and X-ray Registration

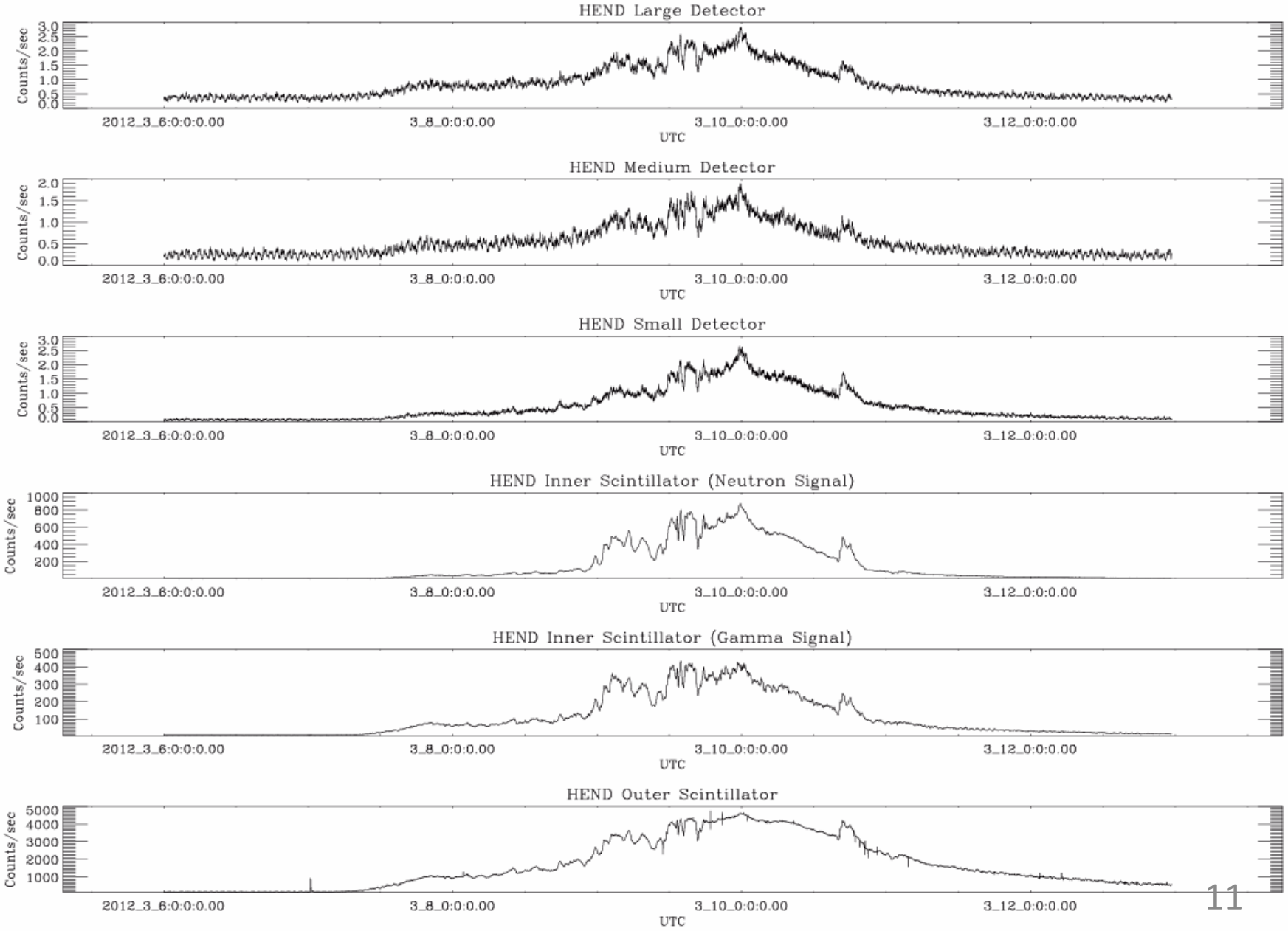
Detecting SPE by LEND



Extreme Event: 2012-03-04 00h - 2012-03-17 24h



SPE (2012 March) by HEND



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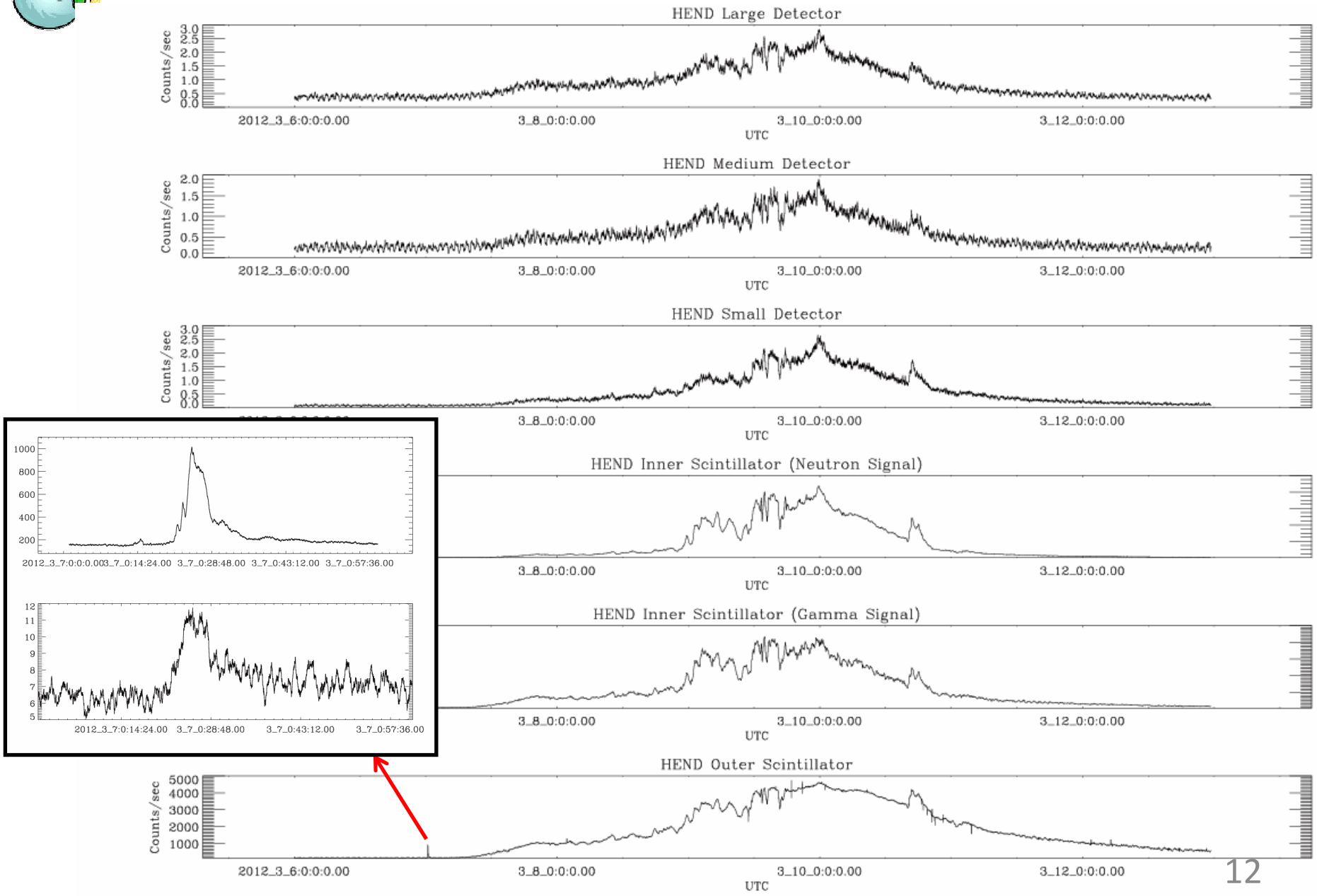
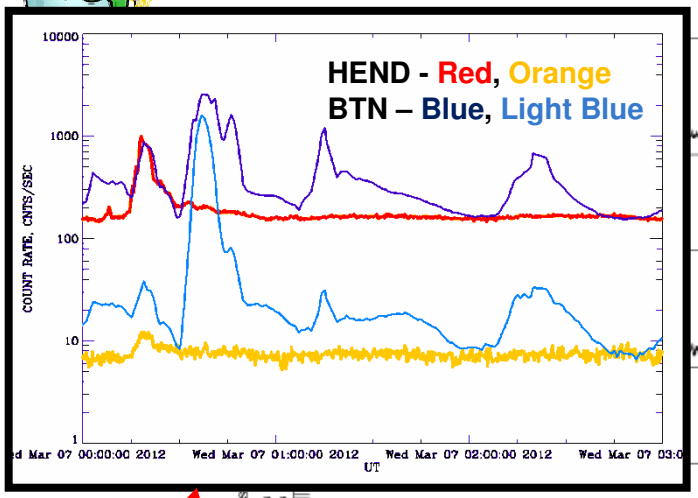
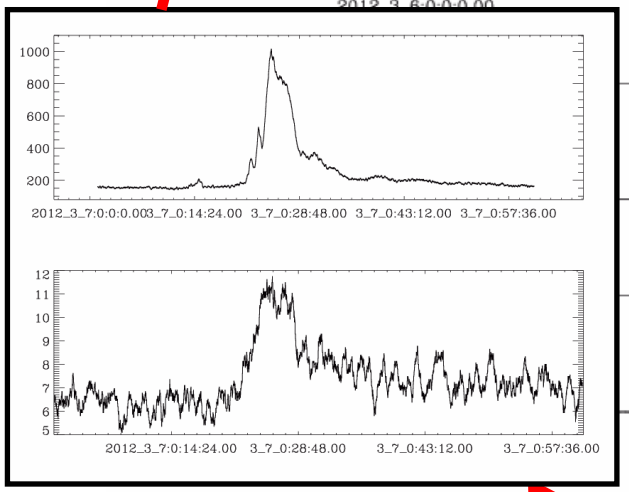
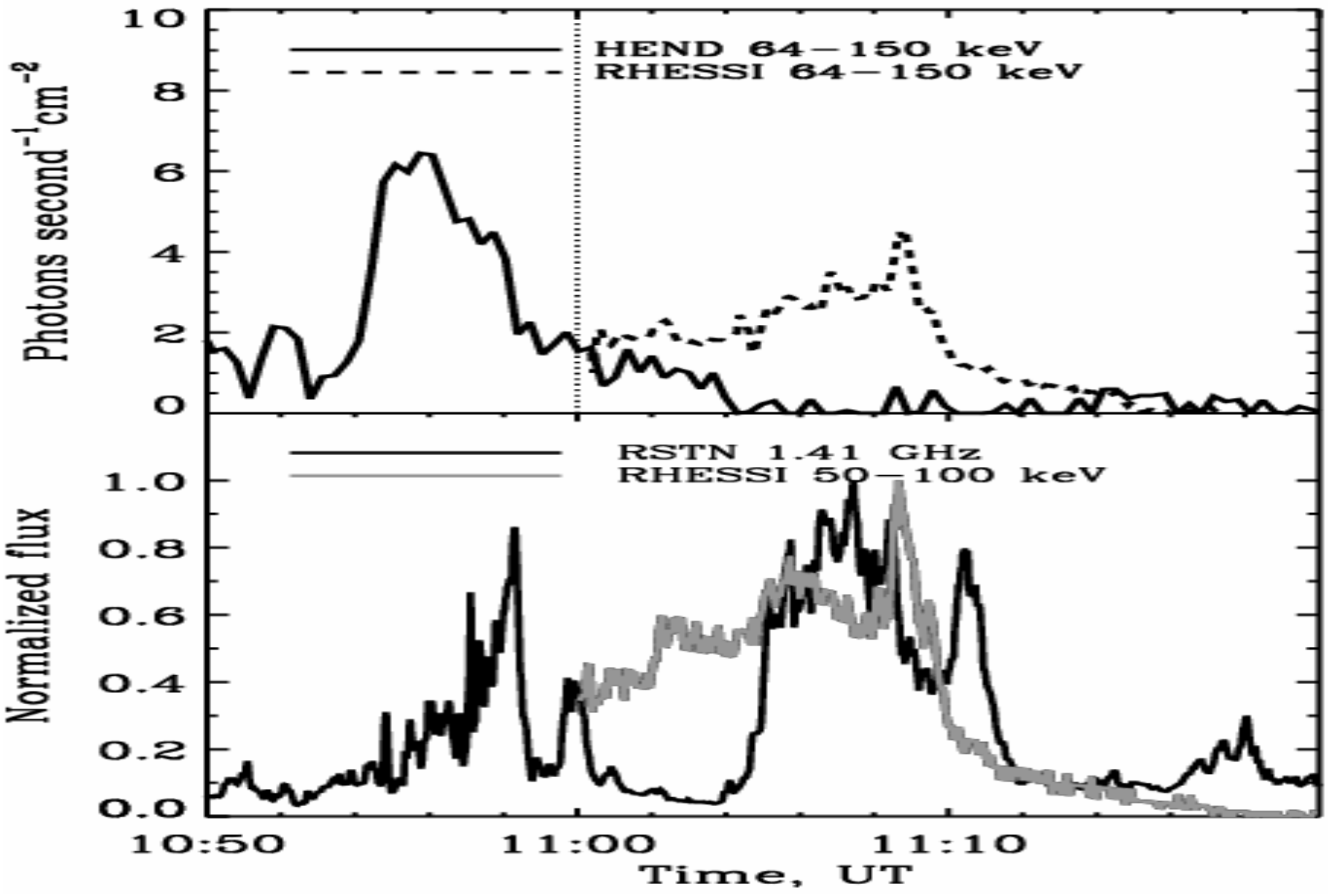


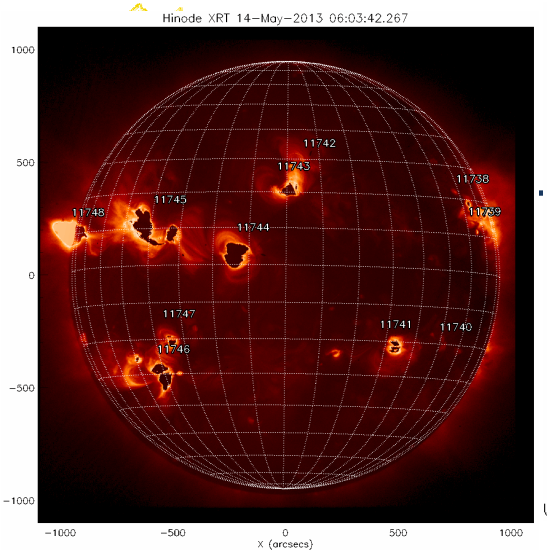
SPE (2012 March) by HEND

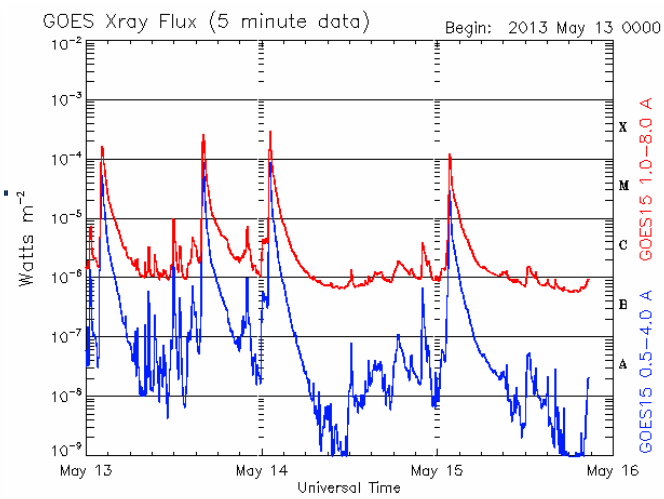




Stereoscopic observations of Sun (14.07.05)

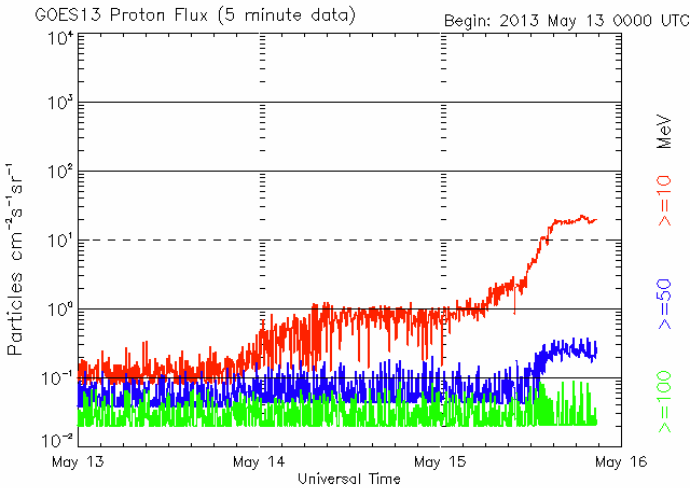






Updated 2013 May 15 20:55:12 UTC

NOAA/SWPC Boulder, CO USA



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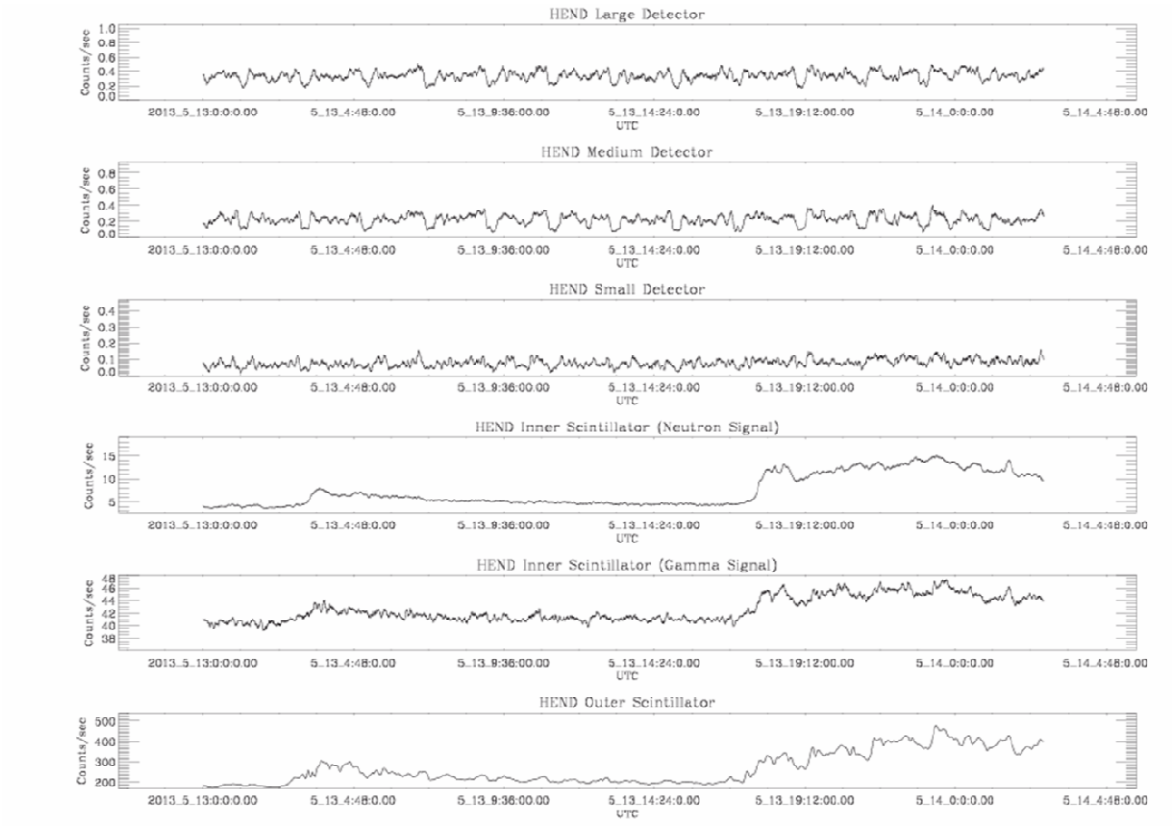
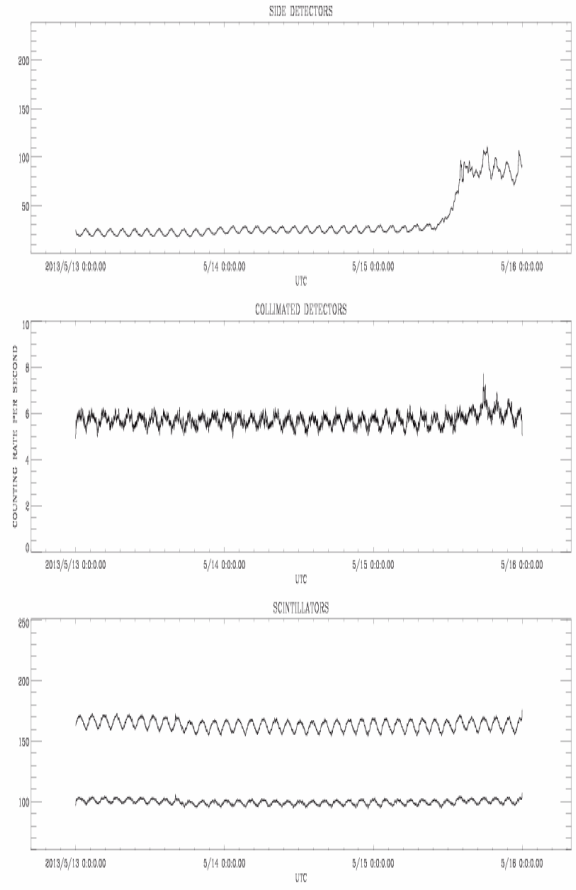
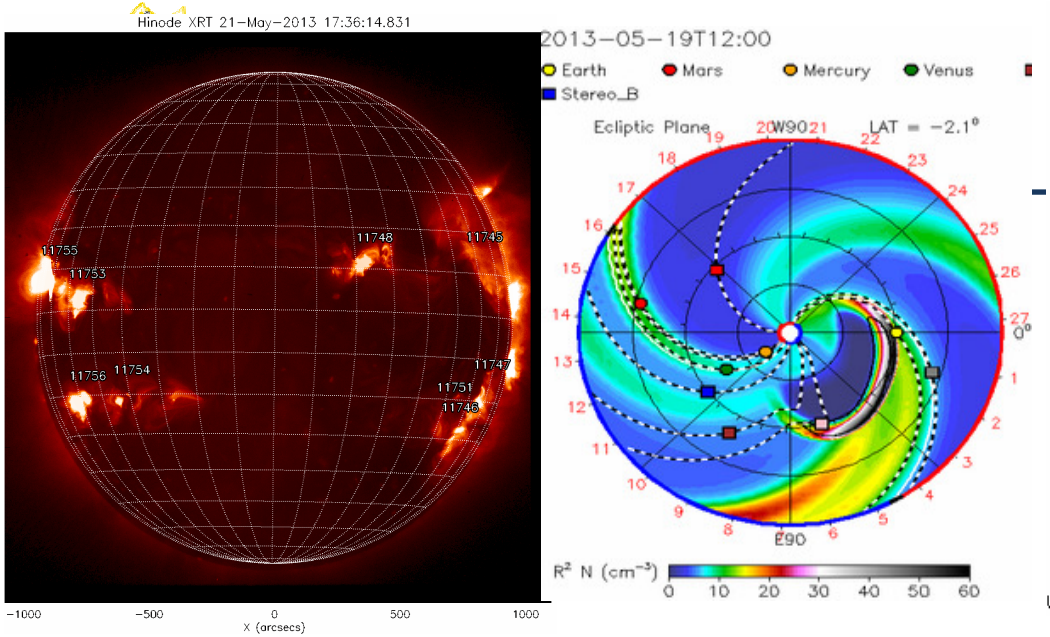
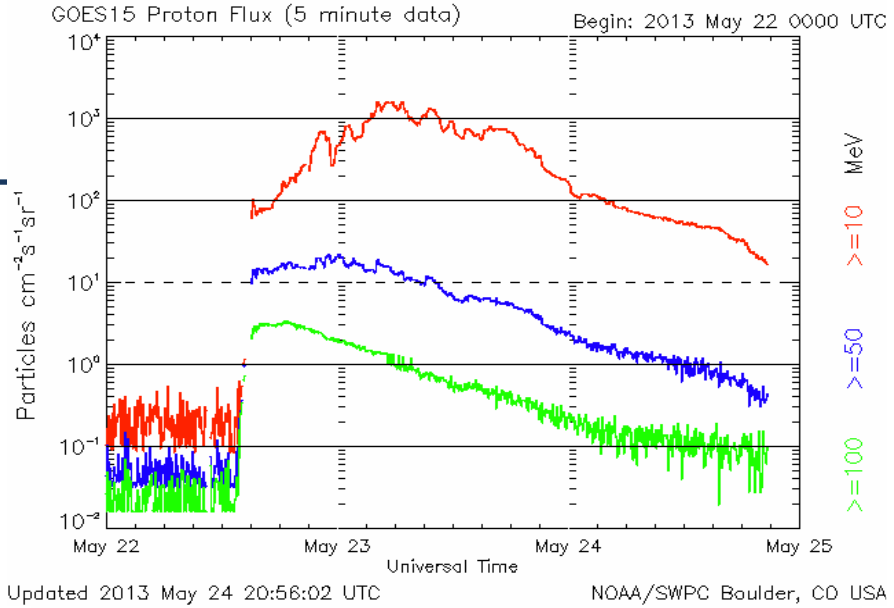
NOAA/SWPC Boulder, CO USA

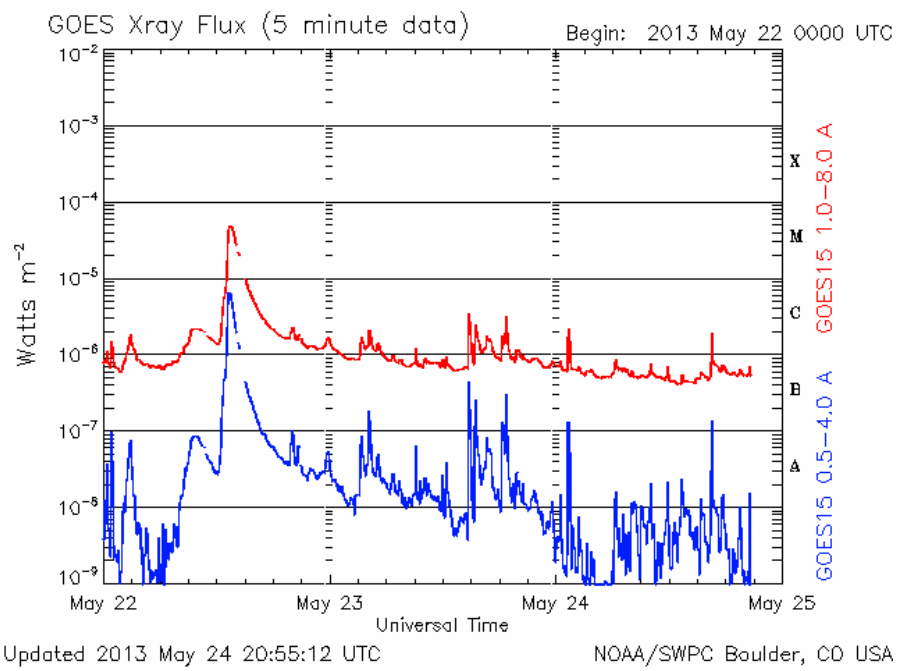


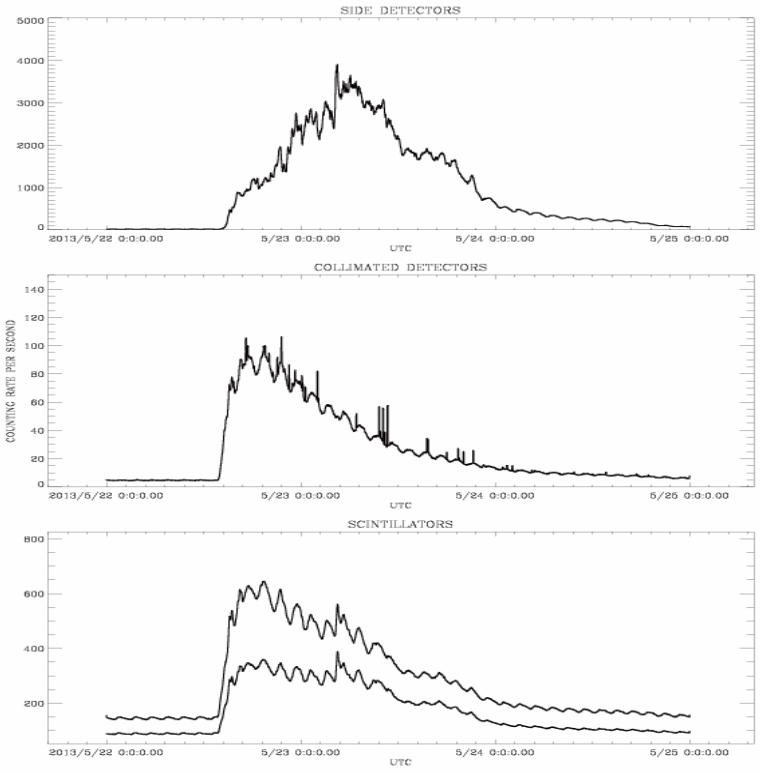


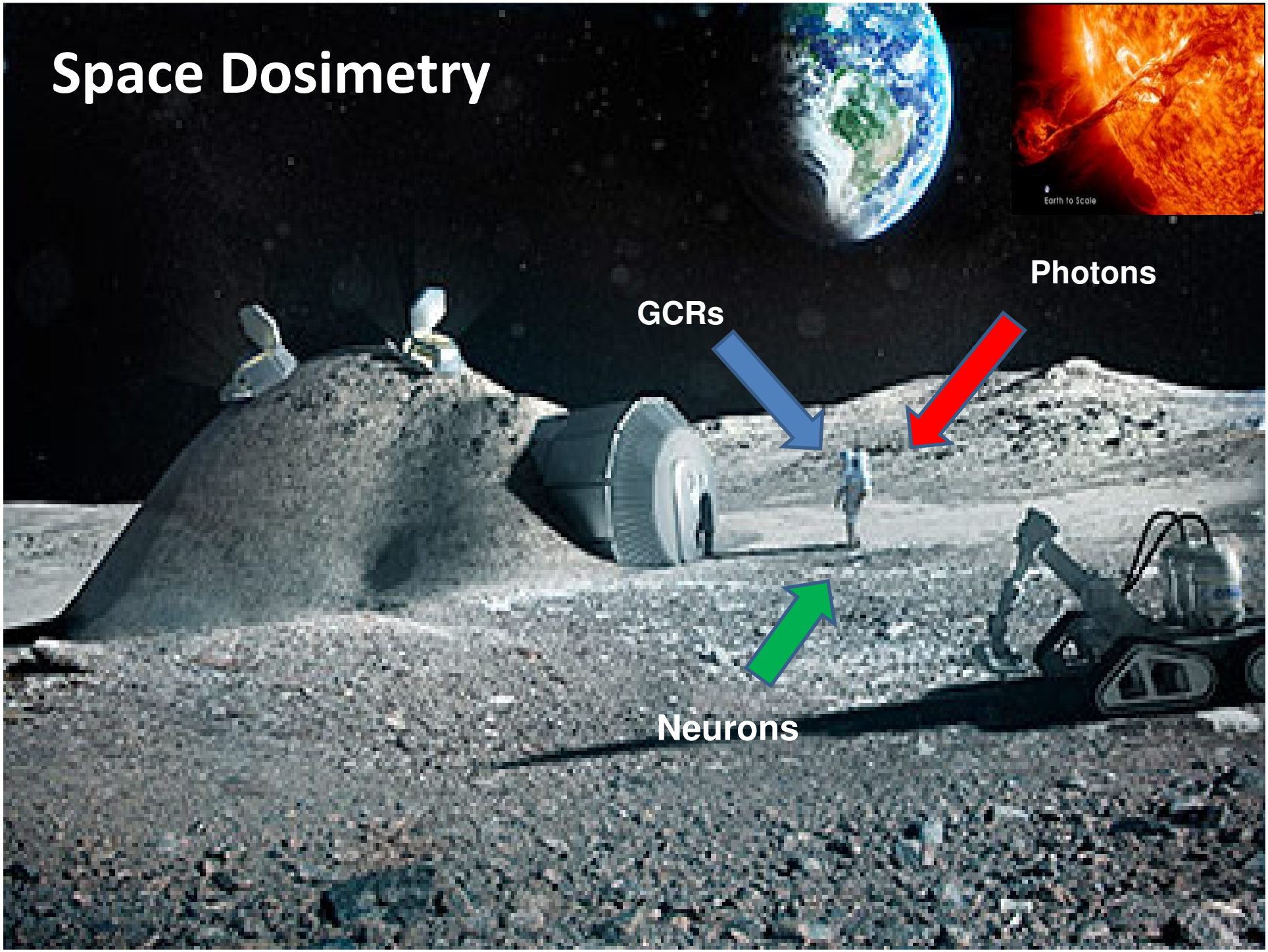

Hinode XRT 21-May-2013 17:36:14.831
11755
11753
11748
11745
11756
11754
11747
11751
11748
-1000
-500
0
500
1000
X (arcsecs)

2013-05-19T12:00
Earth
Mars
Mercury
Venus
Stereo_B
Ecliptic Plane
LAT = -2.1°
R² N (cm⁻³)
0
10
20
30
40
50
60


GOES15 Proton Flux (5 minute data)
Begin: 2013 May 22 0000 UTC
Particles cm⁻²s⁻¹sr⁻¹
>=10 MeV
>=50
>=100
May 22
May 23
May 24
May 25
Universal Time
Updated 2013 May 24 20:56:02 UTC
NOAA/SWPC Boulder, CO USA

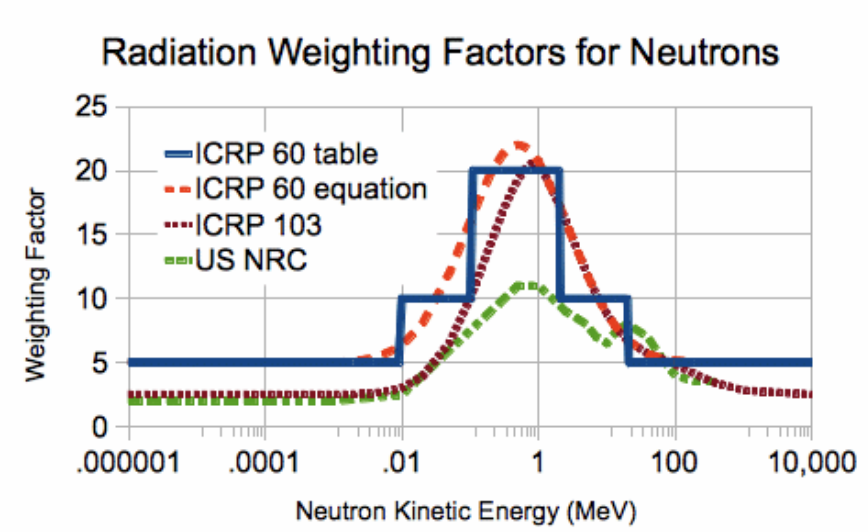

GOES Xray Flux (5 minute data)
Begin: 2013 May 22 0000 UTC
Watts m⁻²
X
M
C
B
A
GOES15 1.0-8.0 A
GOES15 0.5-4.0 A
May 22
May 23
May 24
May 25
Universal Time
Updated 2013 May 24 20:55:12 UTC
NOAA/SWPC Boulder, CO USA


SIDE DETECTORS
COLLIMATED DETECTORS
COUNTING RATE PER SECOND
SCINTILLATORS
2013/5/22 0:0:0.00
5/23 0:0:0.00
5/24 0:0:0.00
5/25 0:0:0.00
UTC

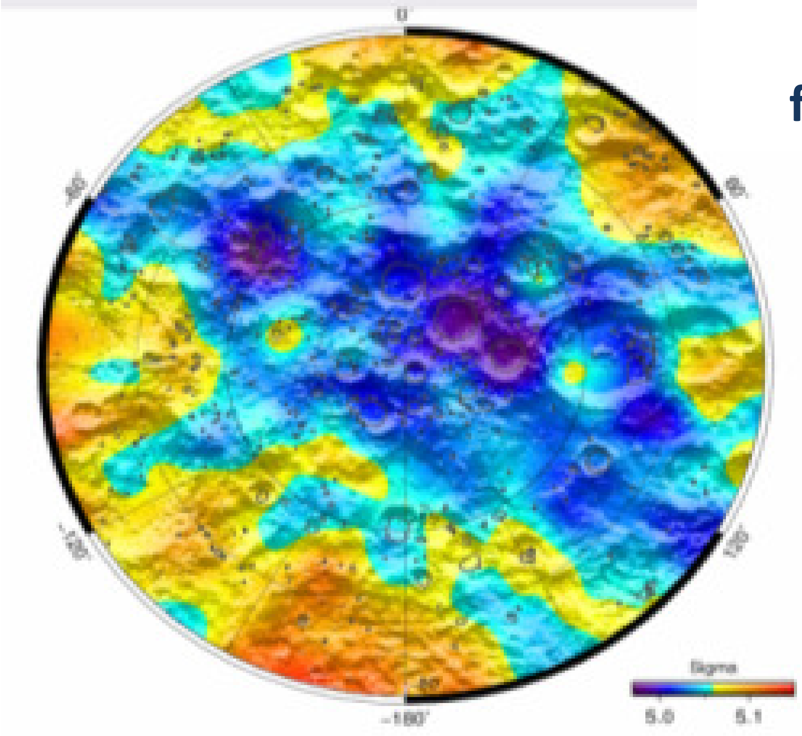

Space Dosimetry
Earth to Scale
Photons
GCRs
Neurons

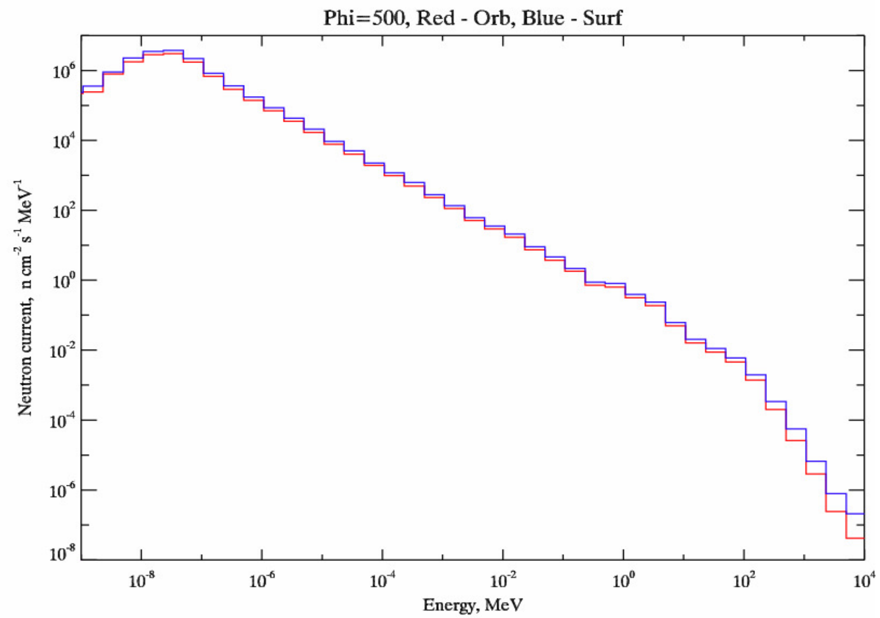
Neutron doze rate equivalent

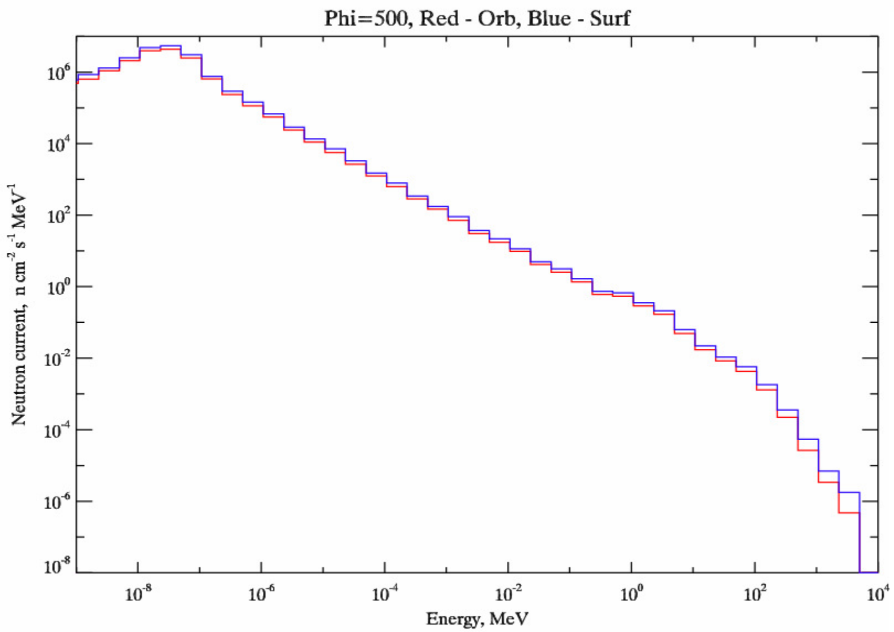
Radiation weighting factors WR (formerly termed Q factor) used to represent relative biological effectiveness according to ICRP report 103		
Radiation	**Energy**	**W_R (formerly Q)**
x-rays, gamma rays, beta rays, muons		1
neutrons	< 1 MeV	$2.5 + 18.2 \cdot e^{-[\ln(E)]^2/6}$
	1 MeV - 50 MeV	$5.0 + 17.0 \cdot e^{-[\ln(2 \cdot E)]^2/6}$
	> 50 MeV	$2.5 + 3.25 \cdot e^{-[\ln(0.04 \cdot E)]^2/6}$
protons, charged pions		2
alpha rays, Nuclear fission products, heavy nuclei		20

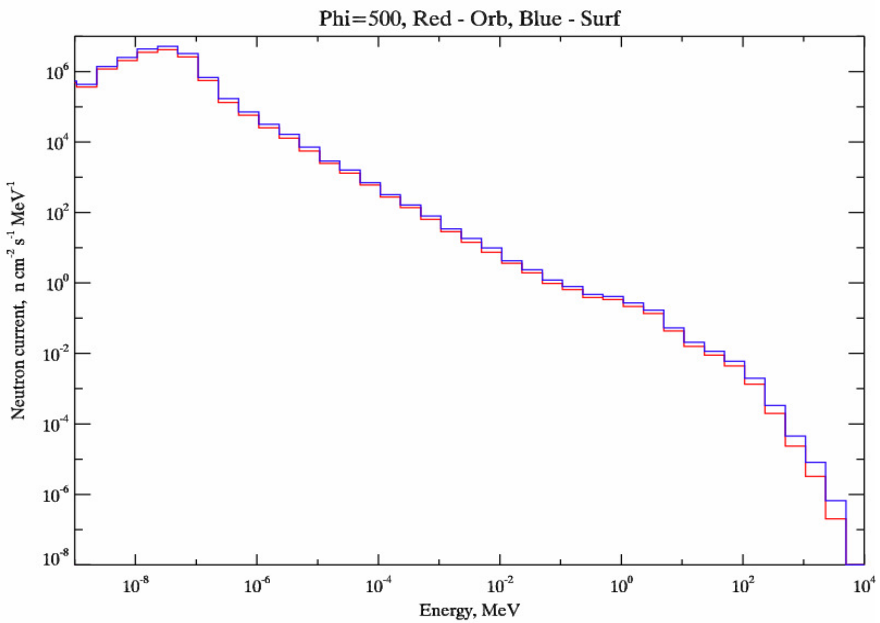


MCNPC calculations of spectra and doses for dry (0.1%) and wet (1%, 5%) lunar regolith



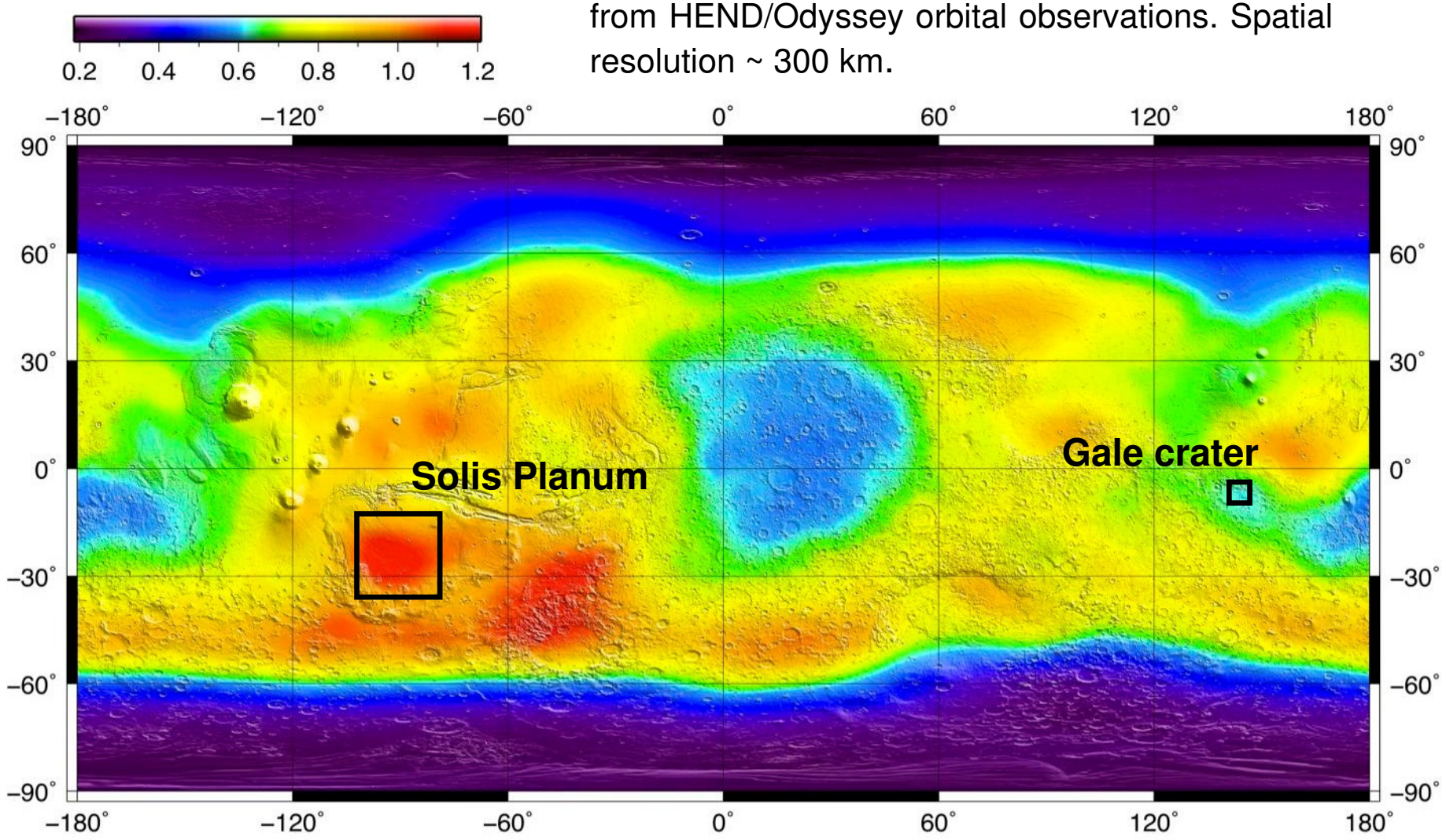




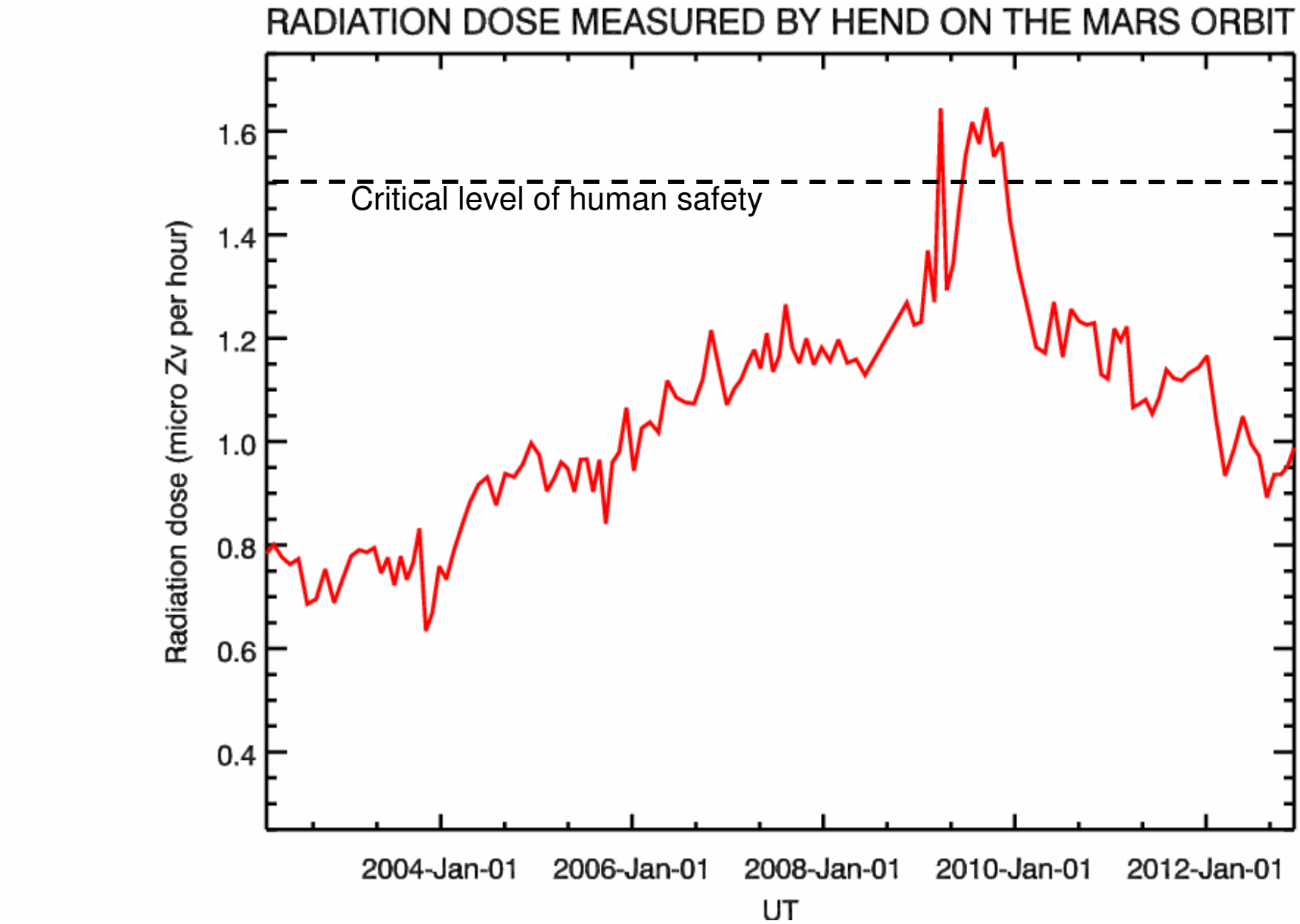


Neutron dose on Mars by HEND and DAN

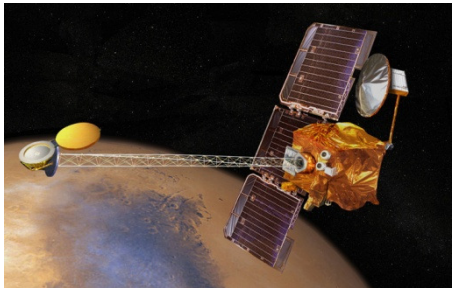
Global Marian map of normalized neutron flux from HEND/Odyssey orbital observations. Spatial resolution ~ 300 km.



Neutron dose equivalent rate above Solis Planum

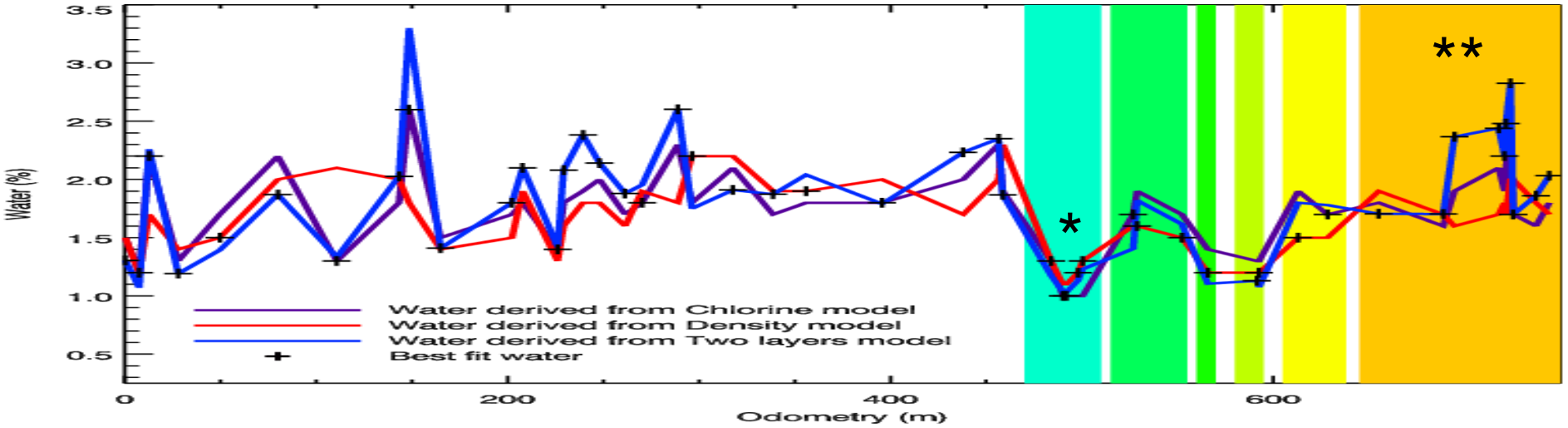


Dose rate equivalent from neutrons



Location	Orbit µSv/hour	Surface µSv/hour
Moon, 0.1% H2O	3.0	3.9
Moon, 5.0% H2O	2.5	3.2
Mars, Gale crater: HEND/Mars Odyssey for phi=547 MV of GCR	0.66	2.6
Mars, Gale crater: DAN, Yellowknife (water ~3 wt%) **	0.70	2.8
Mars, Gale crater: DAN, Rocknest (water ~1 wt%) *	0.74	3.0
Low Earth Orbit ISS, BTN-1	Equator SAA	0.2 5.0

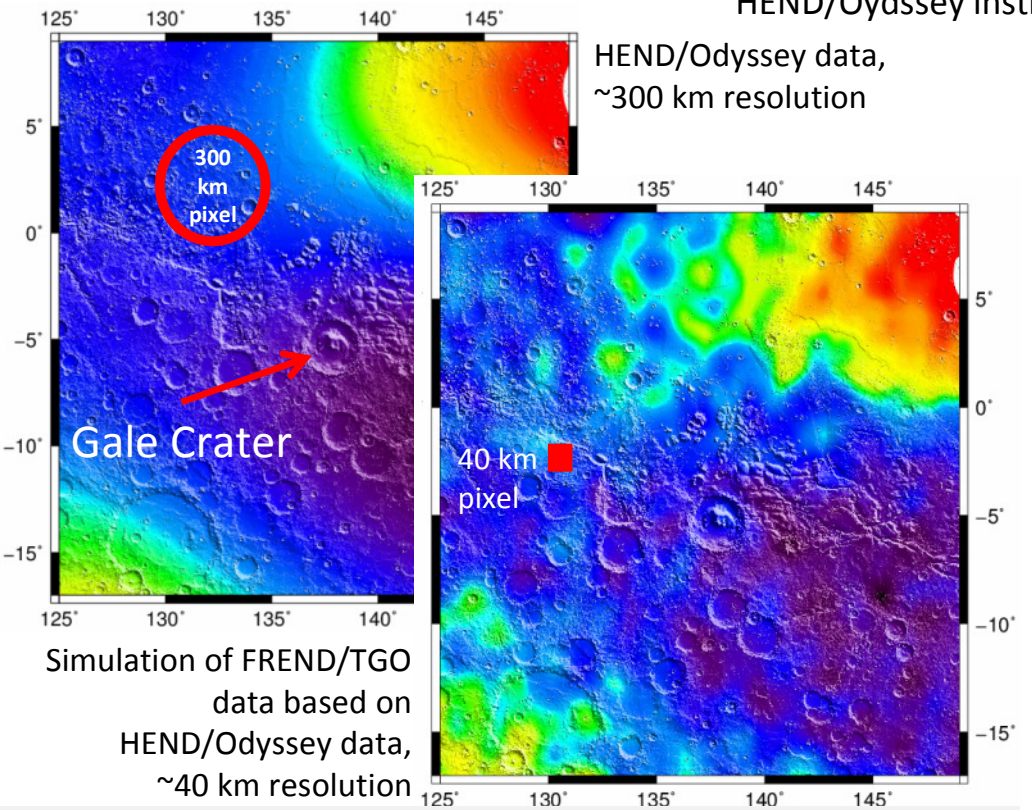
Variations of water content in the soil along the Curiosity traverse



Future investigations

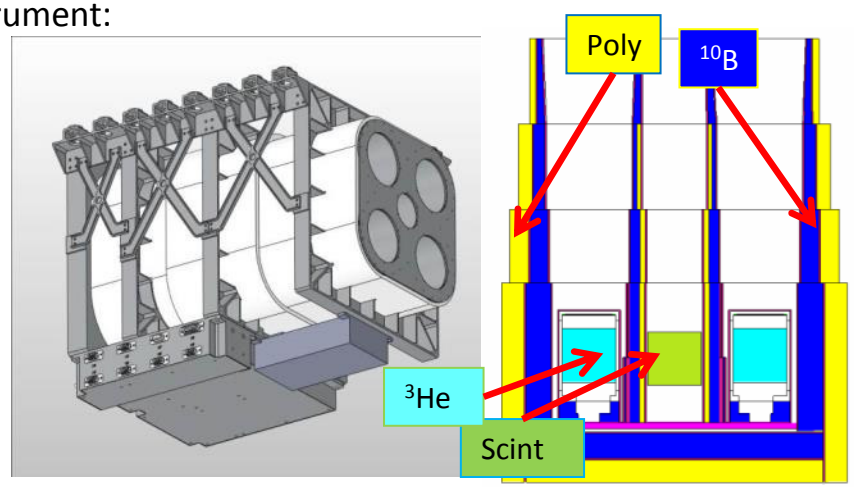
FREND: Fine Resolution Epithermal Neutrons Detector

FREND is a neutron detector with a collimation module that significantly narrows the field of view of the instrument, thus allowing to create higher resolution maps of hydrogen-abundant regions on Mars and improve current data from HEND/Oydssey instrument:



HEND/Odyssey data, ~300 km resolution

Simulation of FREND/TGO data based on HEND/Odyssey data, ~40 km resolution



FREND design *FREND Collimator*

Energy ranges:
Epithermal (^{3}He counters): 0.4 eV – 500 keV
Fast (Stylbene Scintillator): 0.5 – 10 MeV
Spatial resolution: ~ 40 km from 400 km orbit
Mass: 36 kg, **Power:** 11W operational

Dosimetry module
Silicon based semi-conductor detector
Resolution: < 100 keV for 100 keV – 10 MeV r;
< 350 keV for 10 MeV – 80 MeV

Measured values:
Absorbed dose: 10^{-5} – 10^{1} Gy
Absorbed dose rate: 10^{-6} – 10^{-1} Gy/h
Flux of particles: 1 – 1000 particles·cm^{2}/s
Time resolution of absorbed dose and flux: 1 min
Time resolution of ionization losses spectr: 1 hr

Conclusion

• GCR neutron and proton trends were measured by different instruments.

• Instruments with different locations in solar system allow to make stereoscopic observing of solar events

• Neutron radiation dose equivalent was evaluated for MSL location and for 400 km orbit using HEND orbital data