Radiation Environment on ISS in 2012- April 2013 According the Data from Liulin-5 Particle Telescope

J.V. Semkova[a],T.P. Dachev[a], R.T. Koleva[a], St. Malchev[a], N. G. Bankov[a], V. Benghin[b], V. Shurshakov[b], V. Petrov[b], S. Drobyshev[b]

[a]*Space Research and Technology Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria*

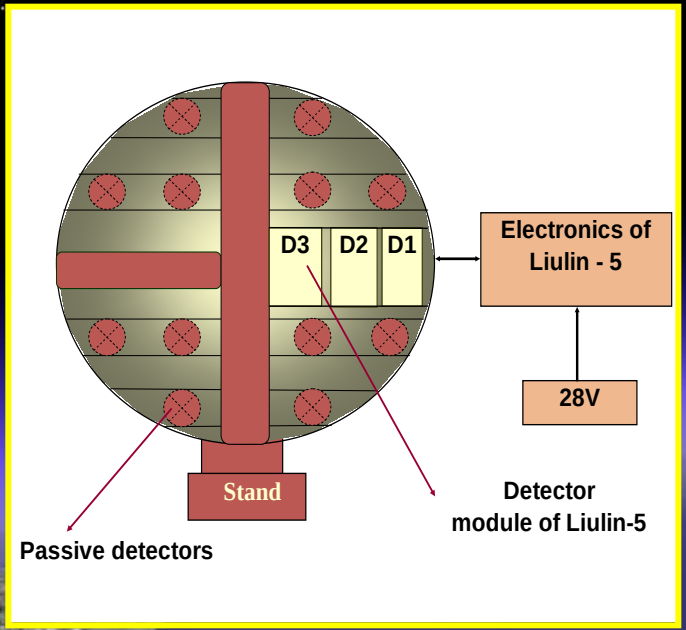
[b]State Research Center Institute of Biomedical problems, Russian Academy of Science, Moscow, Russia

Introduction

Experiment Liulin-5 for investigation of the radiation environment within the spherical tissue-equivalent phantom on ISS is conducted on RS of ISS. It is a part of the MATROSHKA-R project. Data available for July 2007-April 2010 and for end 2011-April 2013.

- Liulin-5 measures simultaneously at 3 different depths of the radial channel of the spherical phantom: Energy Deposition Spectra, Dose Rate & Particle flux - then Absorbed Dose D.
- Measurement of the Linear Energy Transfer (LET) spectra in silicon – then assessment of LET(H_2O), Q=f(LET), given in ICRP-60 and Dose Equivalent H; H=DxQave.
- We present results for dose rates and particle fluxes in and outside the phantom from end 2011 to April 2013 during increasing of SA in 24 cycle;
- Compared are Liulin-5 data during SPEs in 2012 and data from Liulin dosimeter-radiometer on Mir Space station during SPEs in 1989-1991.

Location of Liulin -5 instrument in the Spherical Phantom on ISS in MIM1 module

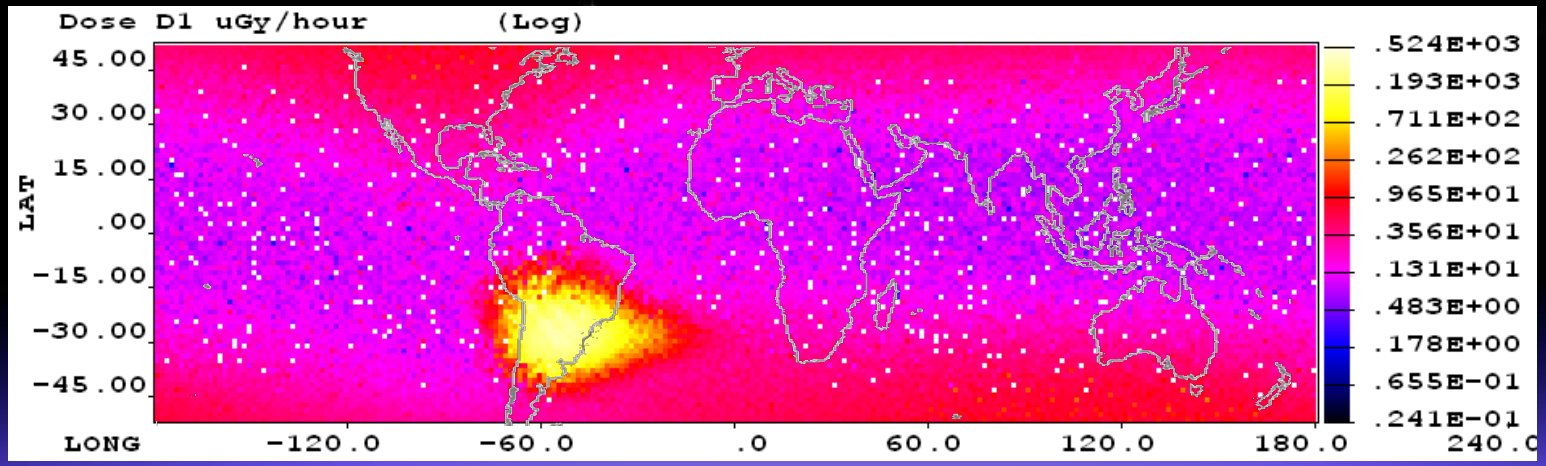


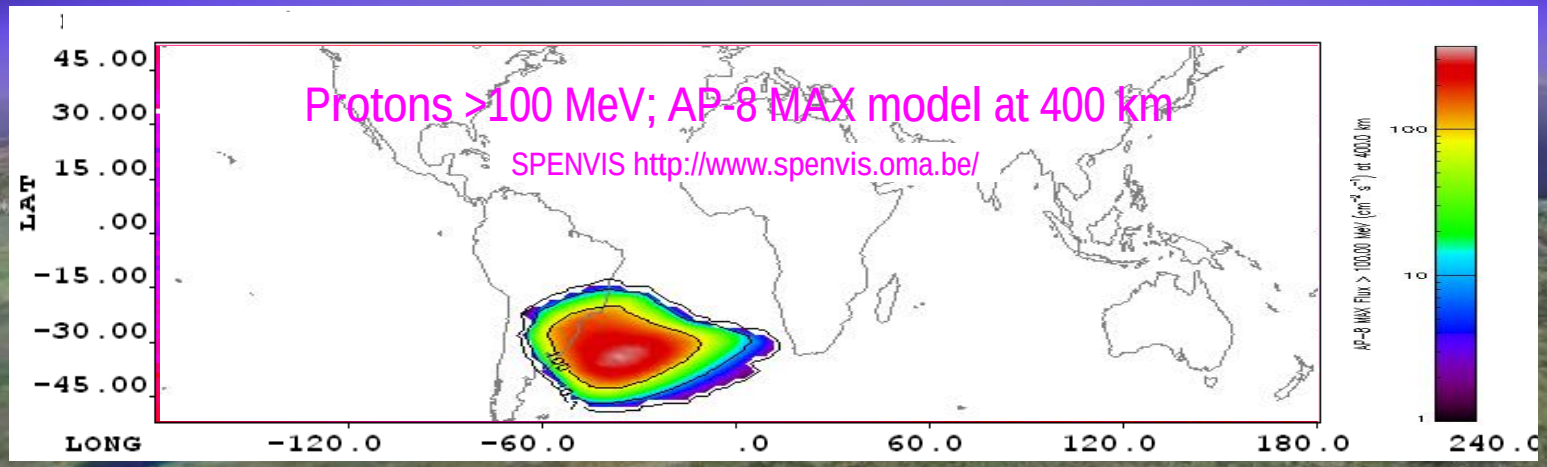
Block diagram of Liulin - 5 in the phantom

From 27 December 2011 to April 2013 measurements were conducted in and outside the phantom located in the MIM1 module of ISS.

Liulin-5 results for the period April 2012-April 2013

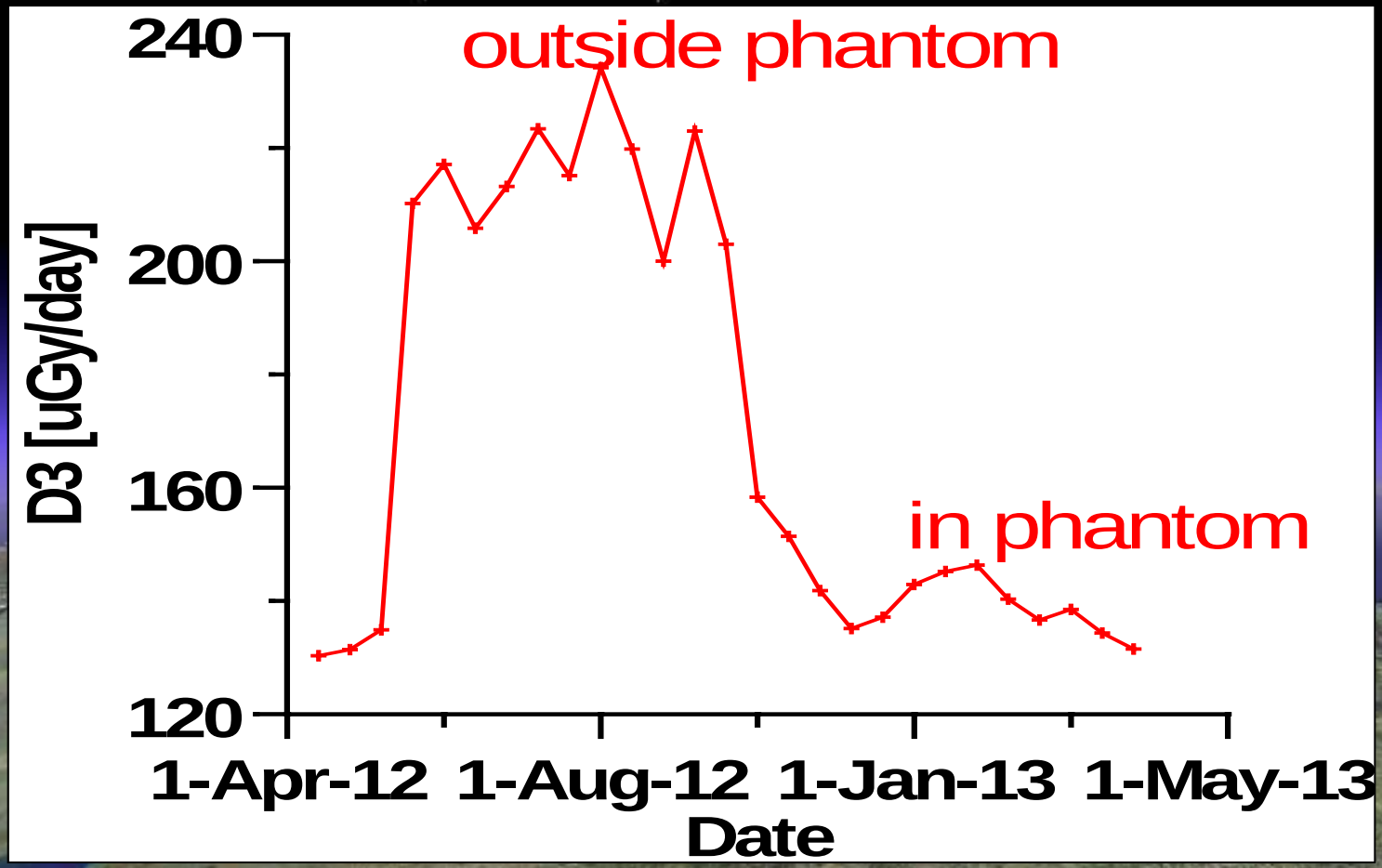
Mapping the dose rate along the ISS orbit





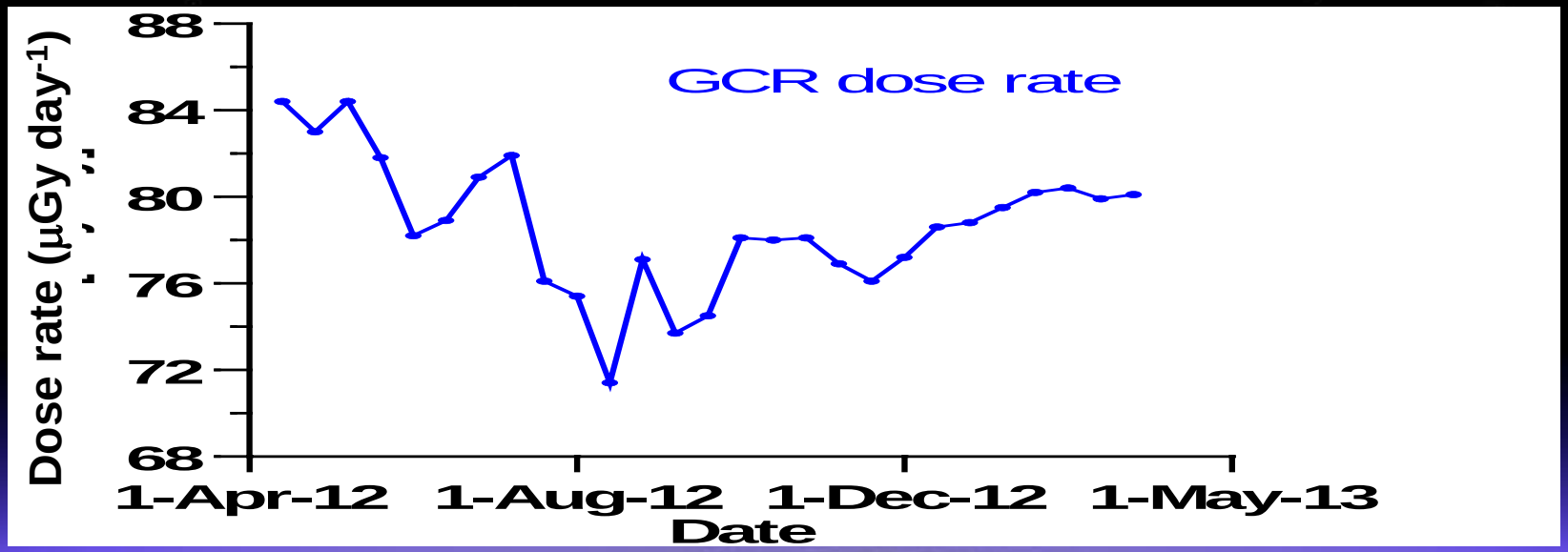
Dose rate (40 mm depth) 27.12.2011 - 17.04.2012. The SAA dose rate reached maximum of 524 μGy/h on 27.01.2012 at -22.3^0 lat, -54.25^0 long. and 401 km alt. at L =1.2 and B=0.194 Gs. Outside SAA lowest doses of ~1 μGy/h –near the equator, highest of ~9.5 μGy/h at high latitudes.

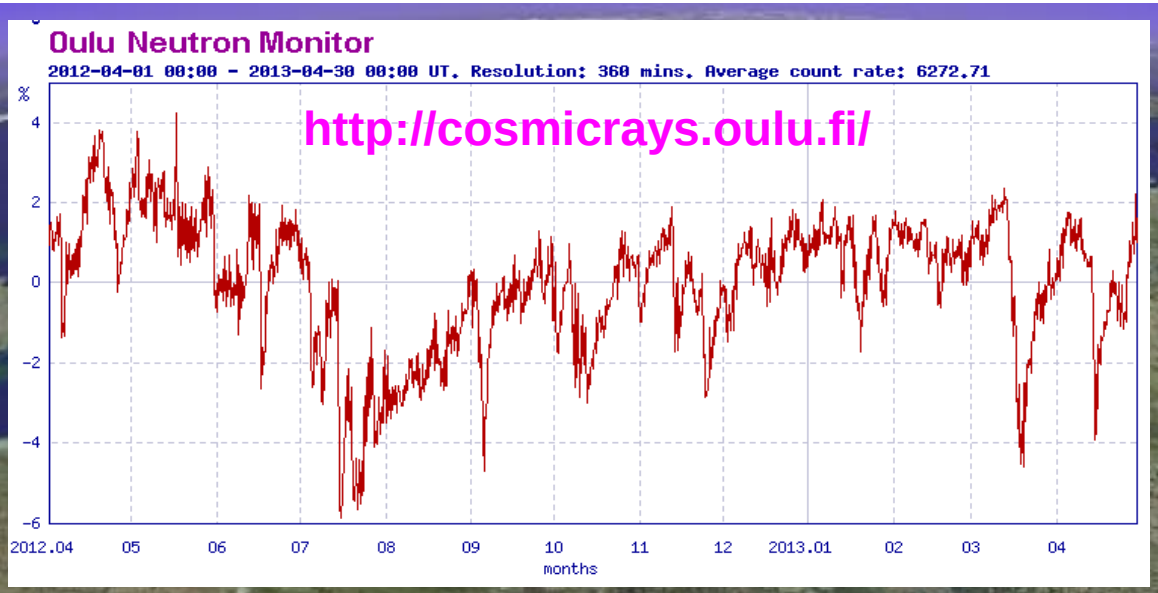
Dose rate at 160 mm depth in the phantom and outside phantom from April 2012 to April 2013



Total dose rate. Doses outside phantom are 1.7 higher than at the phantom' s center – due to self shielding of the phantom against SAA trapped protons.

GCR dose rate from April 2012 to April 2013



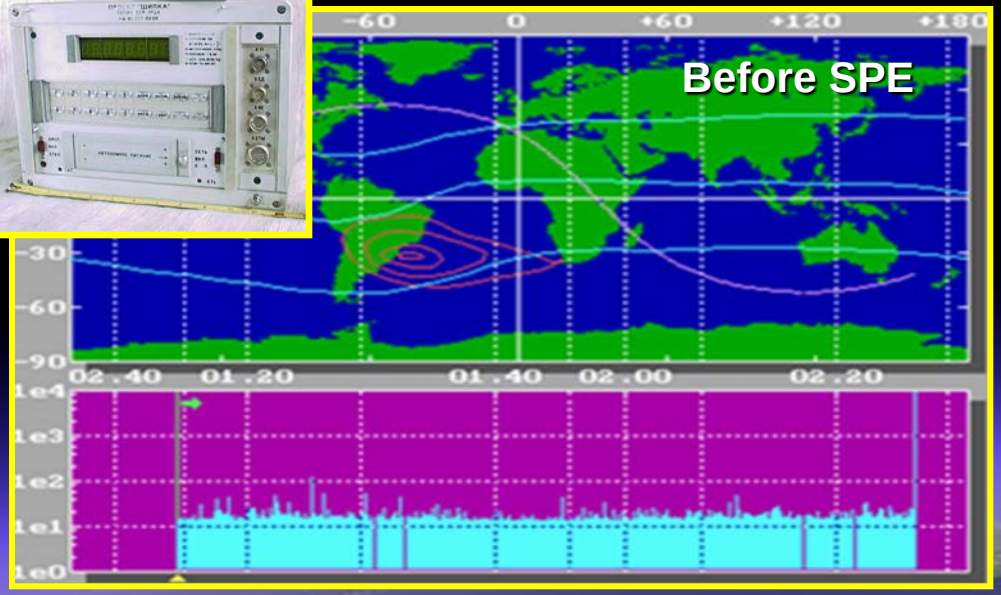


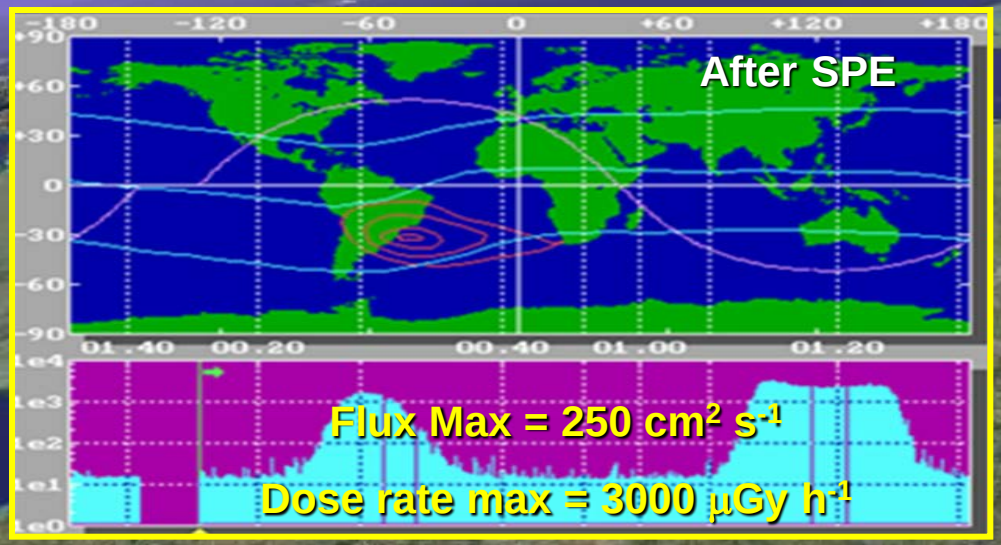
GCR dose rate minimum is in July-August 2012 – consistent with Oulu NM count rate below.

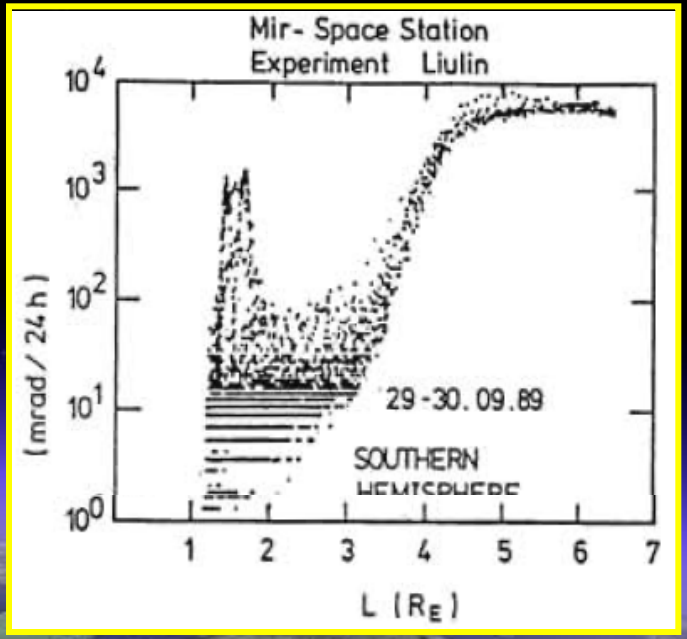
SPEs results

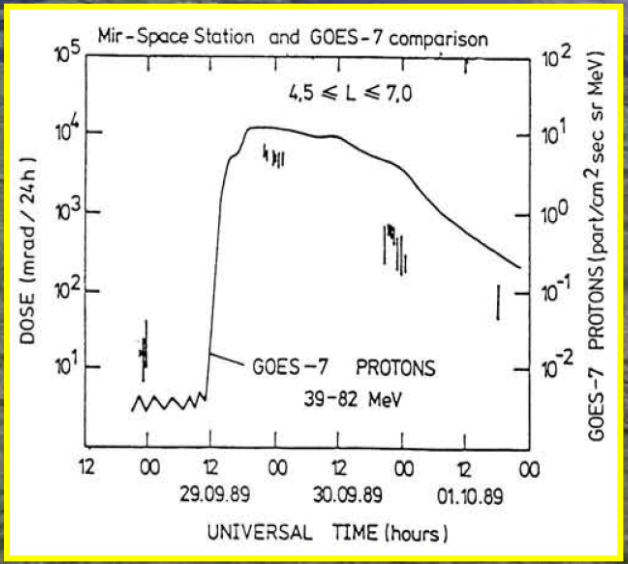
Historical LIULIN on Mir results

Solar Particle Event observation on Mir space station on 29.09.1989 by LIULIN instrument*



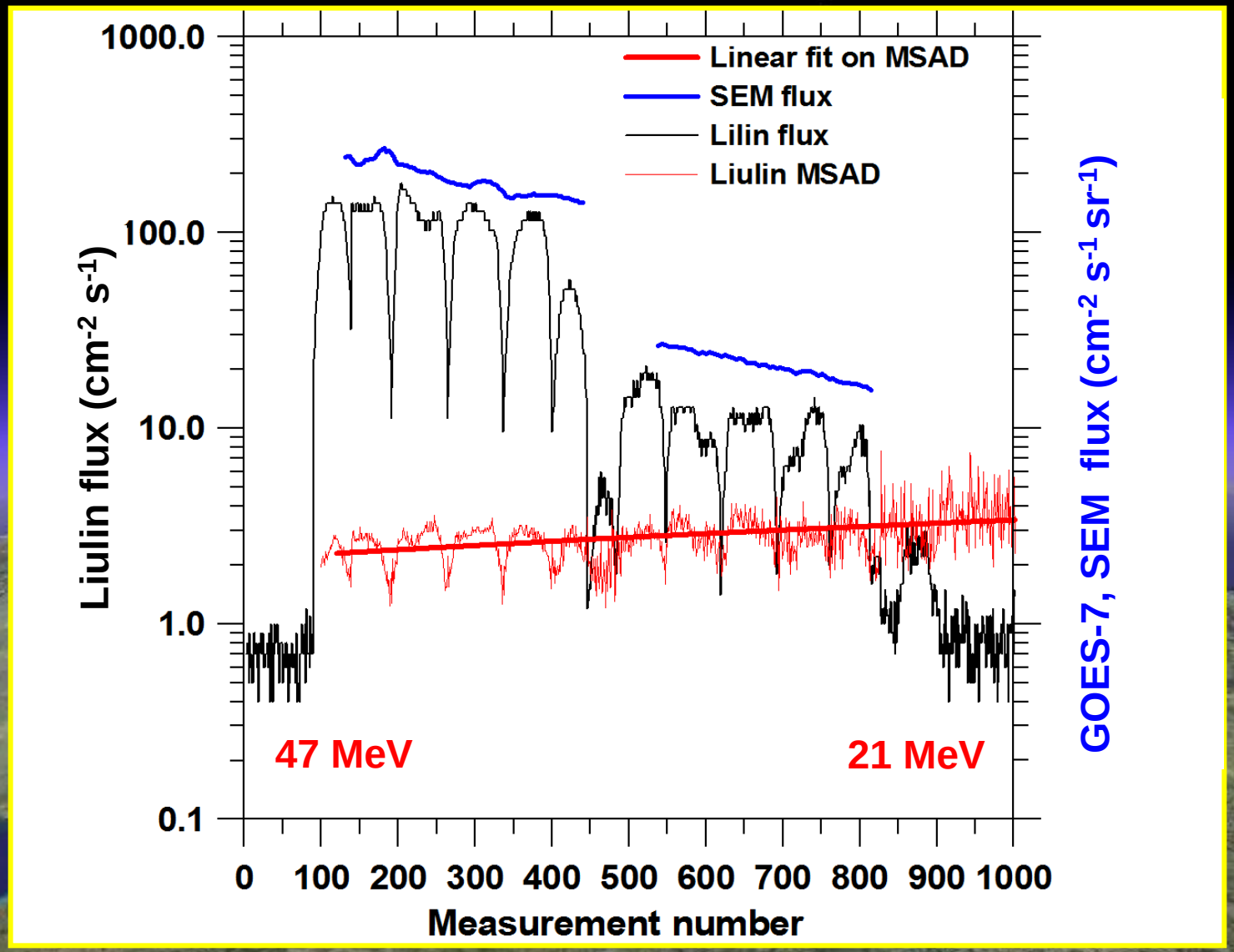




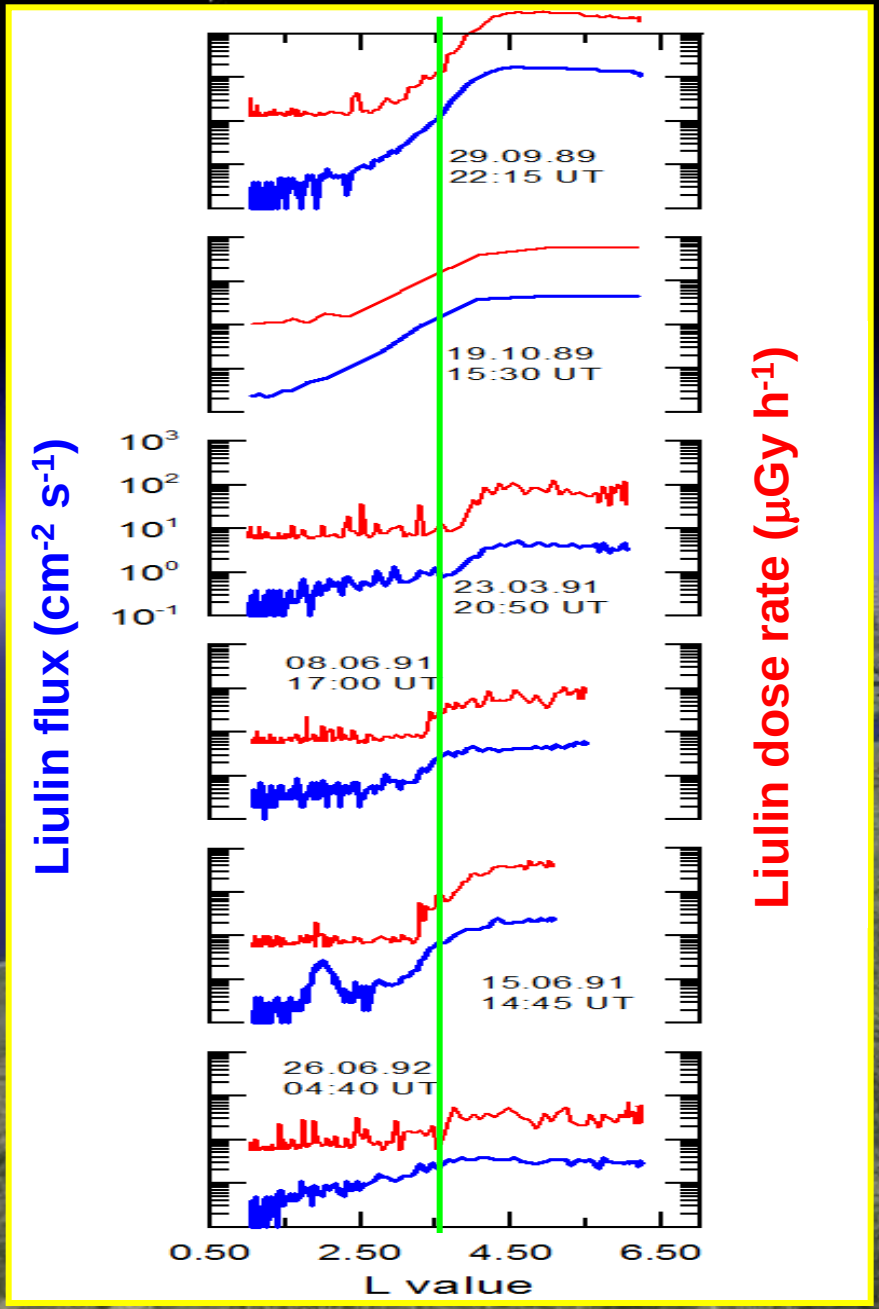


*Dachev et al., MIR dosimetry…, ASR, 321-324, 1991.

The proton energy decrease during the SPE

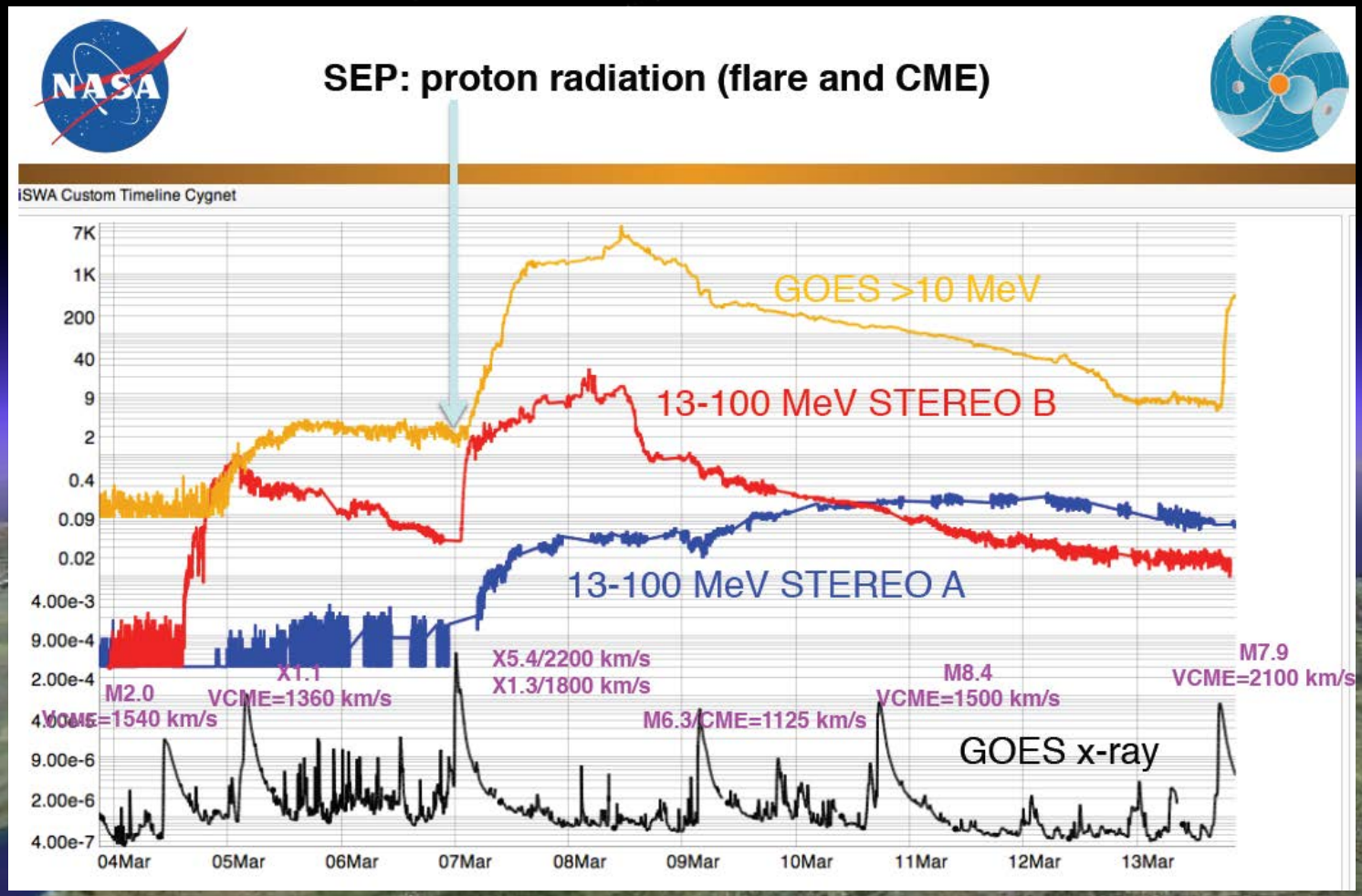


6 different SPE observations by LIULIN on Mir



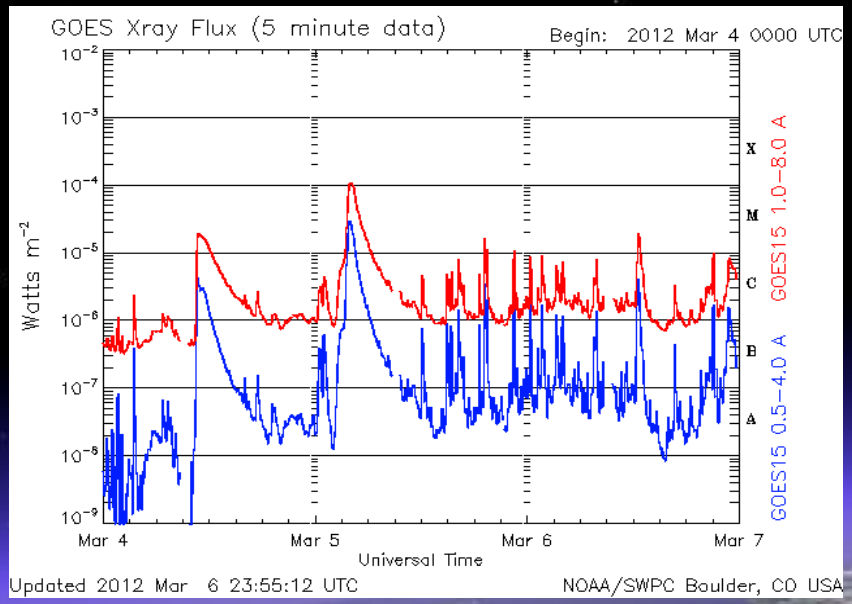
Liulin-5 results for SPEs in March and May 2013

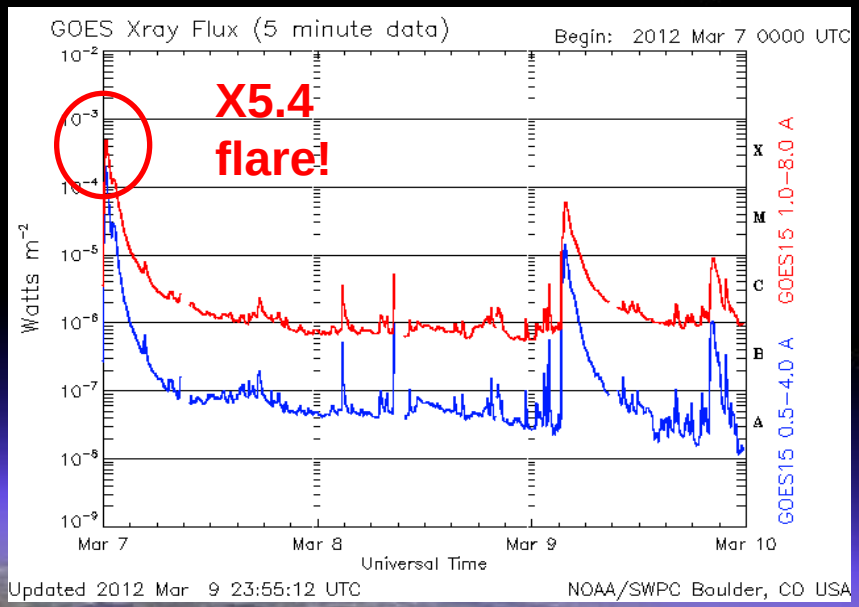
On 07.03.2012 GOES -13 registered beginning of two SPE associated with Earth-directed CMEs. More than 100 MeV event began at 04:05



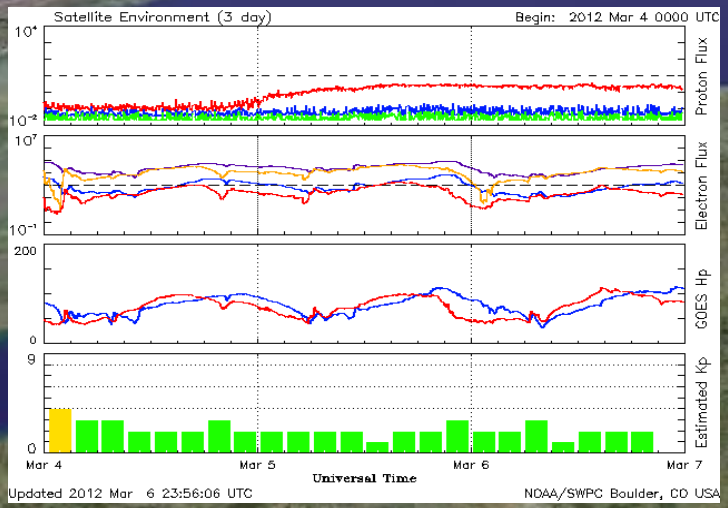
Zheng, Y., NASA GSFC Space Weather Center operational Experiences over the past several major solar Events, ESWW9-Session4A, November 2012.
http://www.spaceweather.eu/en/repository/show?id=379

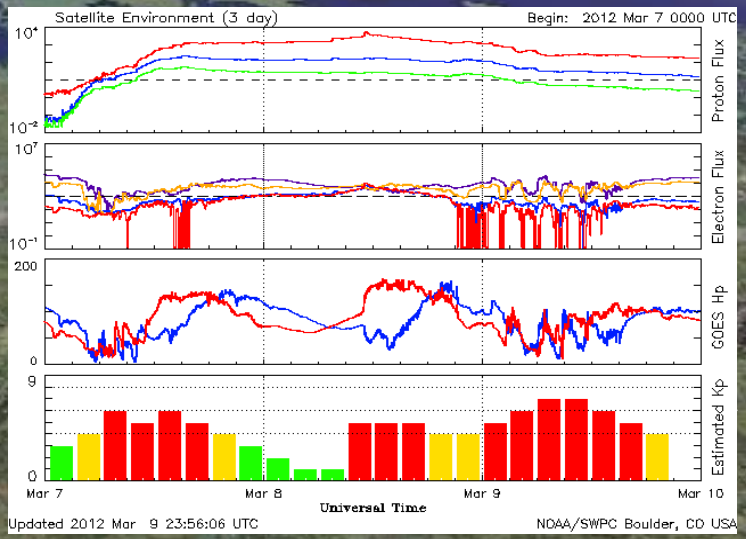
GOES-13 satellite X-ray flux



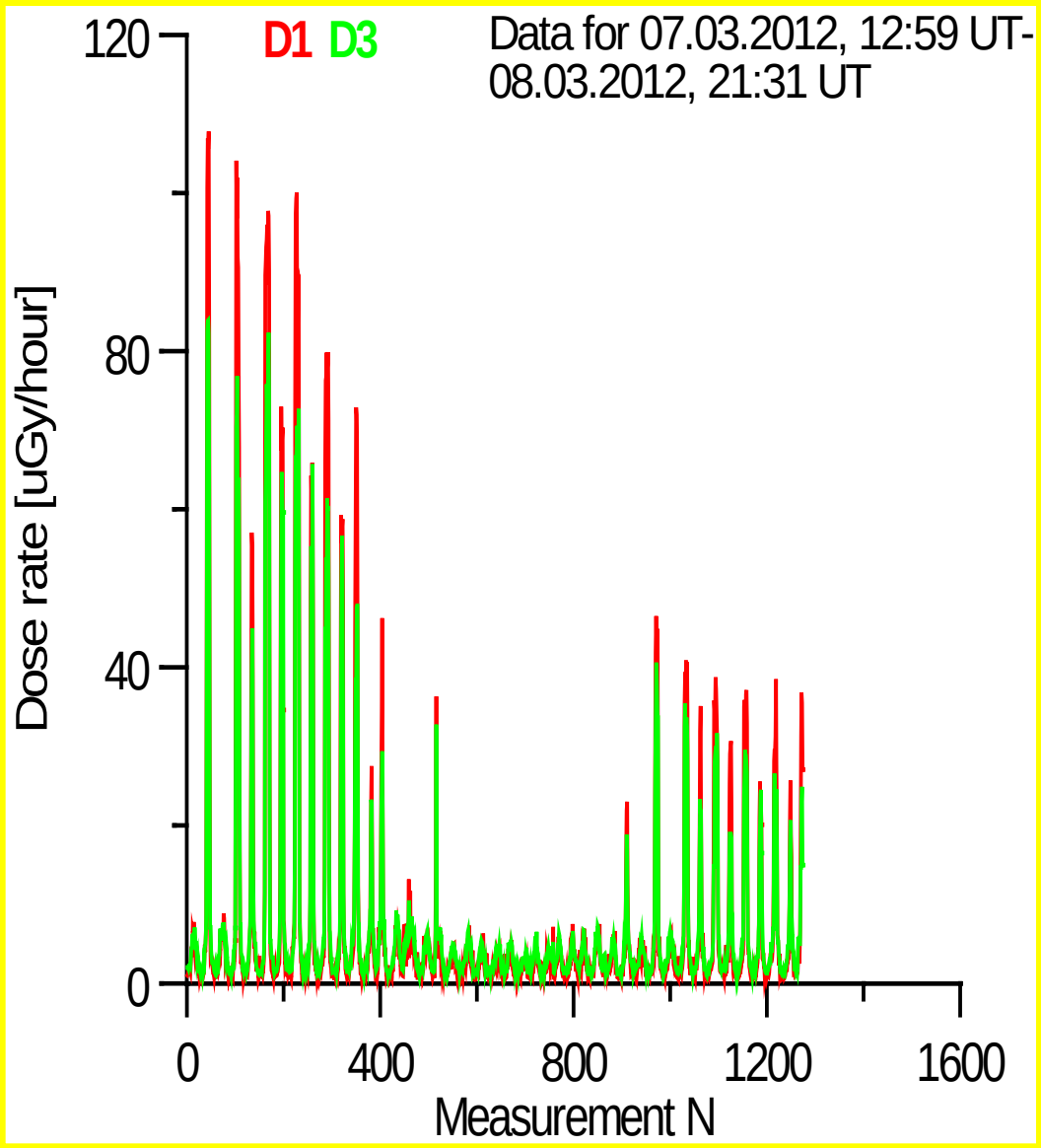


GOES-13 satellite environment plot



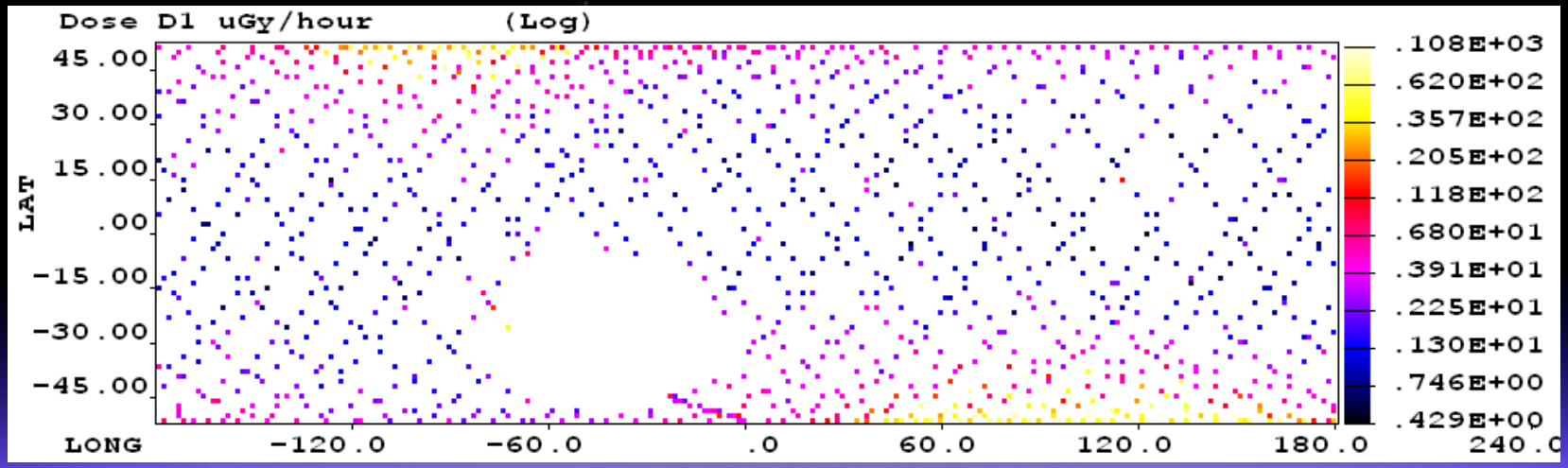


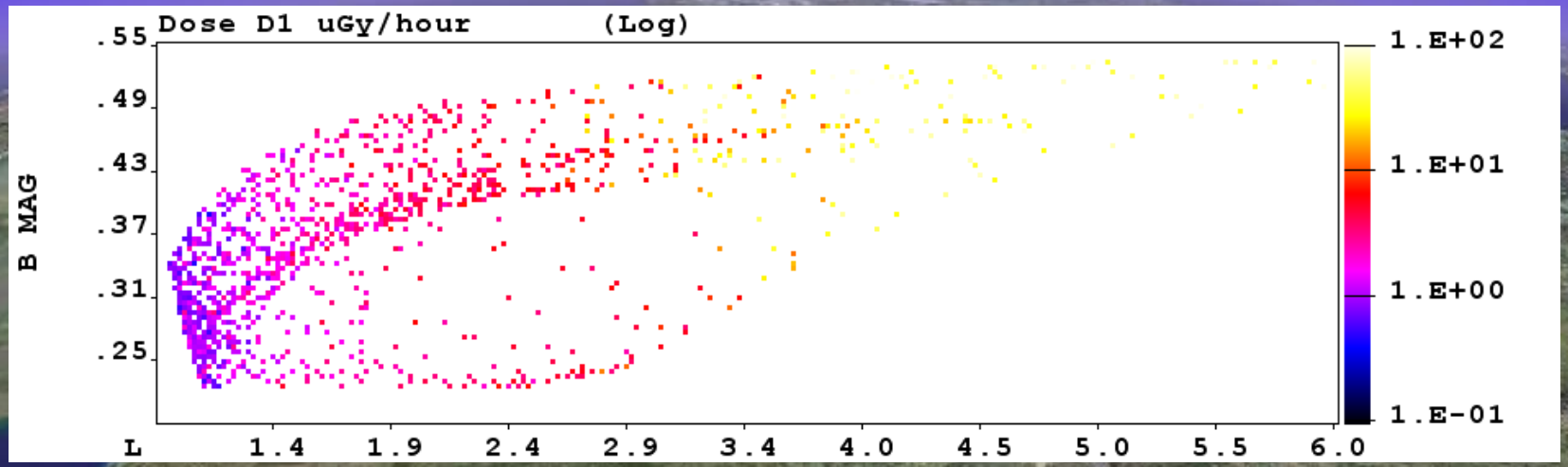
Dose rate distribution during March 2012 SPE (outside SAA) (1)



Successive measurements at 40 mm depth (red) and at 165 mm depth (green) outside SAA during SPE. The first registration of particle flux and dose rate increase in Liulin-5 data was on 07.03.2012, at 13:01 UT. The last registration of flux and dose rate increase was on 08.03.2012, at 21:31 UT.

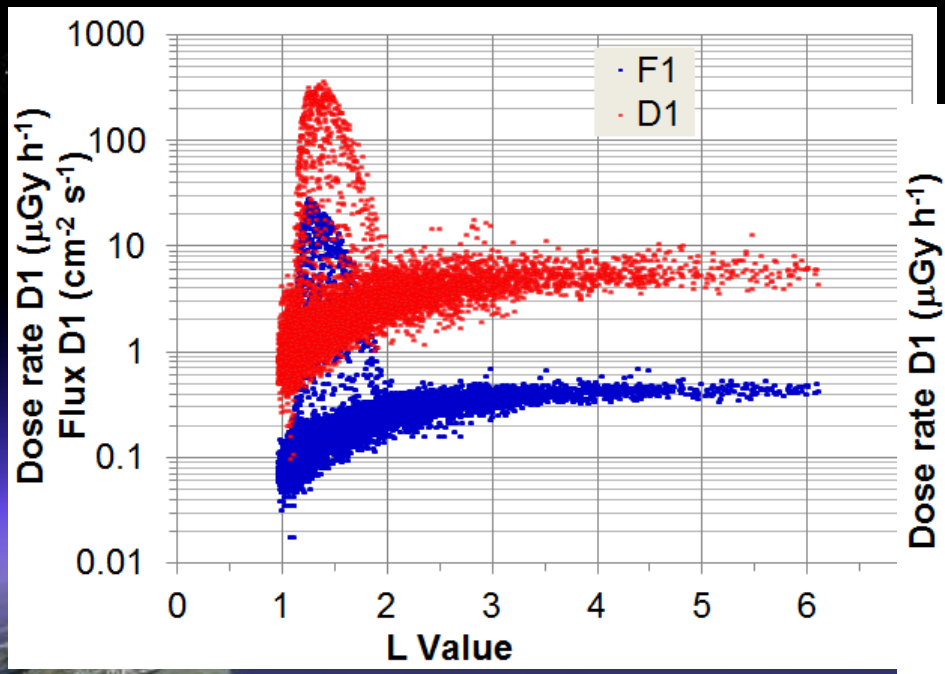
Dose rate in the first detector (D1) outside SAA during SPE in March 2012

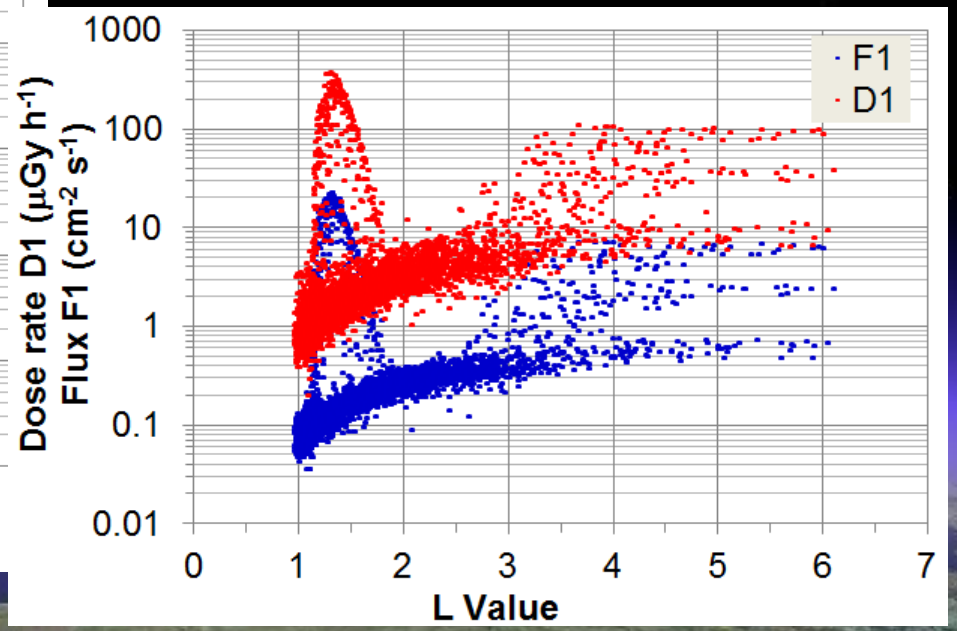




Data from 07.03.2012, 12:59 UT to 08.03.2012, 21:31 UT. Increase of dose rate from solar protons is observed at high geographic latitudes in the region of the south and north magnetic poles at L>3.

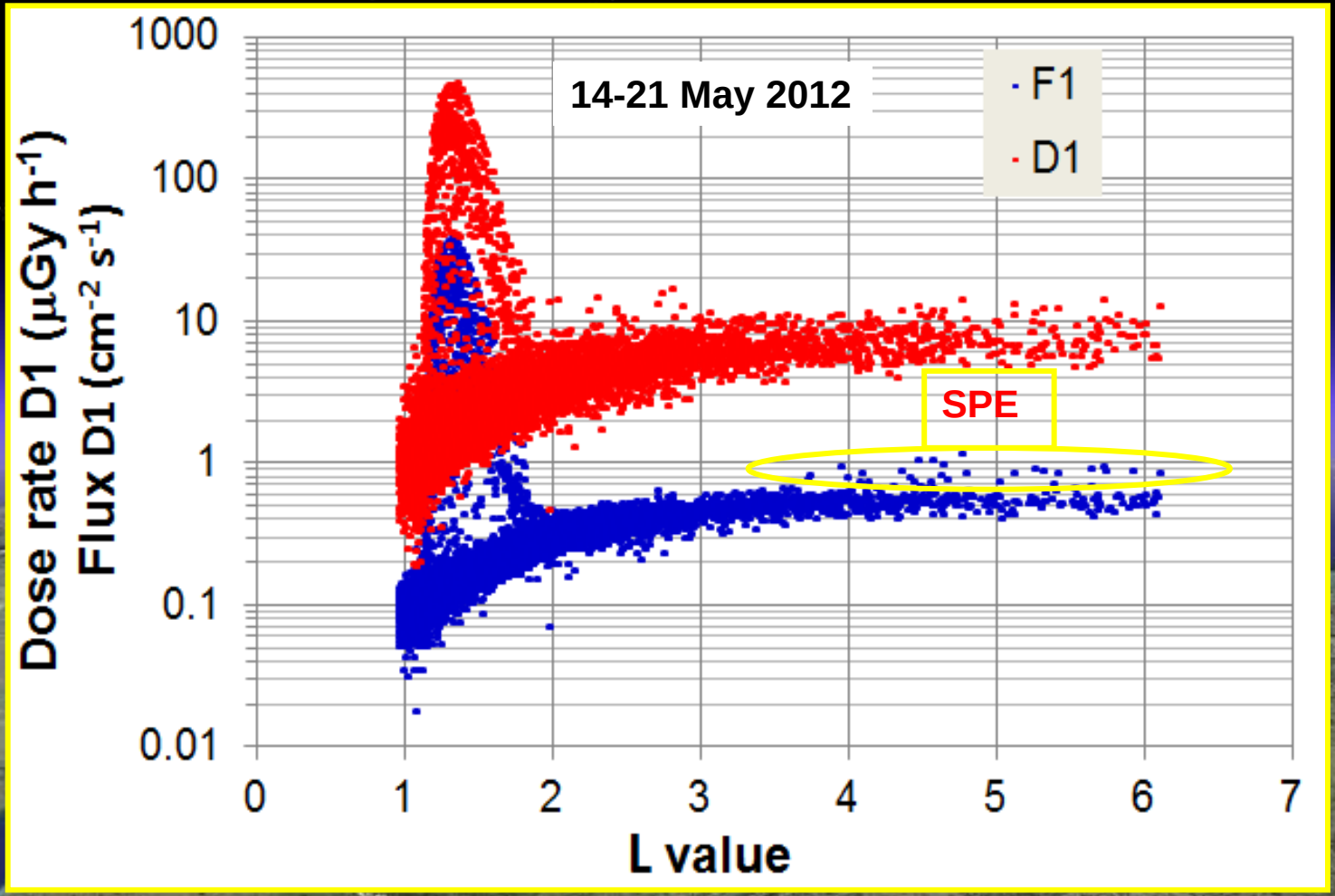
Particle flux and dose rate during quite conditions and SPE in March 2012. The total dose outside SAA received during SPE was 260 µGy.



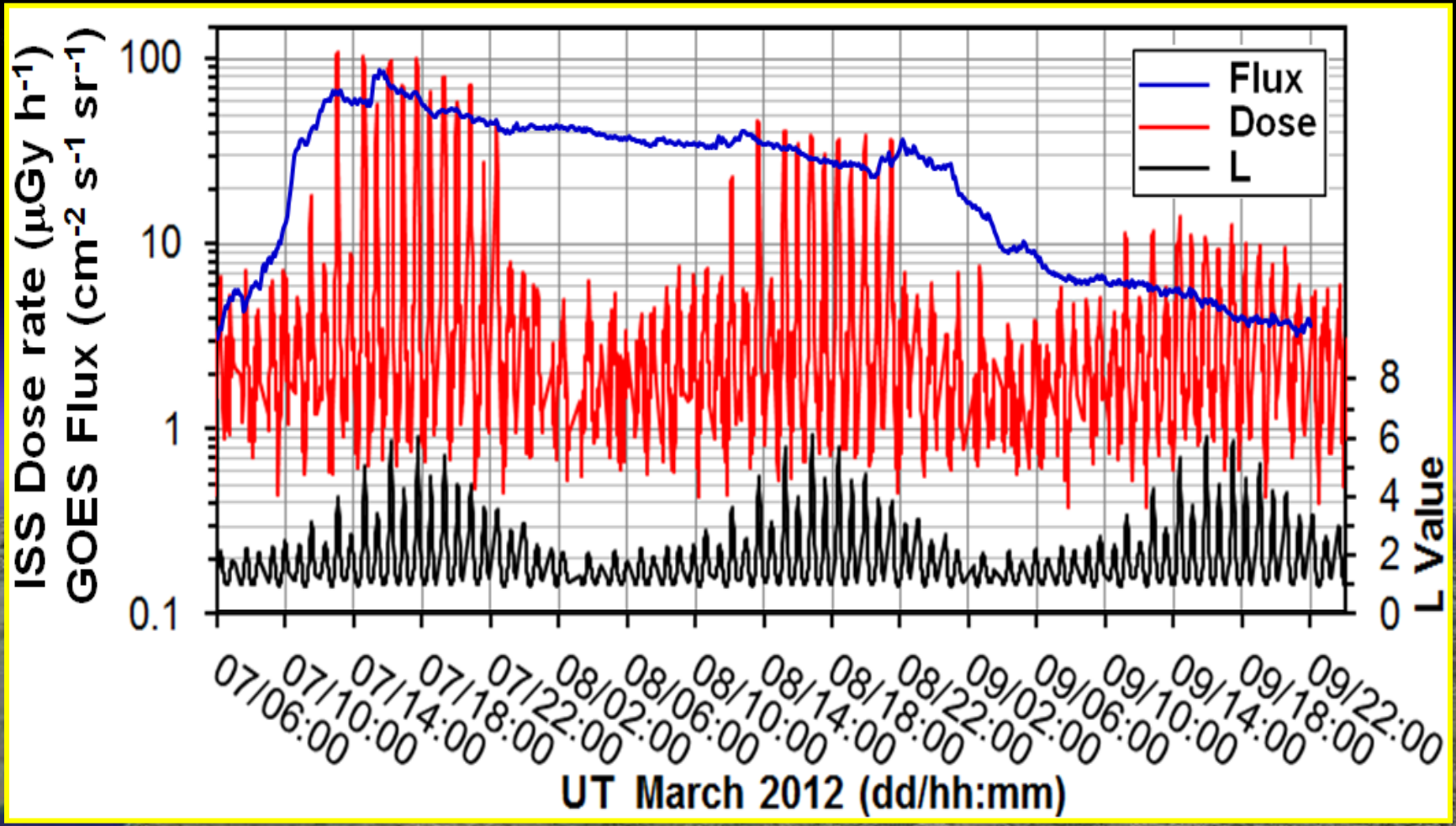


Particle flux F1 and dose rate D1 at 40 mm phantom's depth before (left) and during SPE (right) , March 7-12 2012. The maximum flux observed outside SAA during SPE reached 7.2 cm^{-2} s^{-1} and the dose rate reached 108 µGy h^{-1} at L = 4, Lat = - 51.1^0, Long =166.8^0, Alt= 422 km. The averaged dose rate D1 outside SAA during SPE was 8.43 µGy h^{-1} and averaged flux was 0.59 cm^{-2} s^{-1}

Particle flux and dose rate during SPE in May 2012

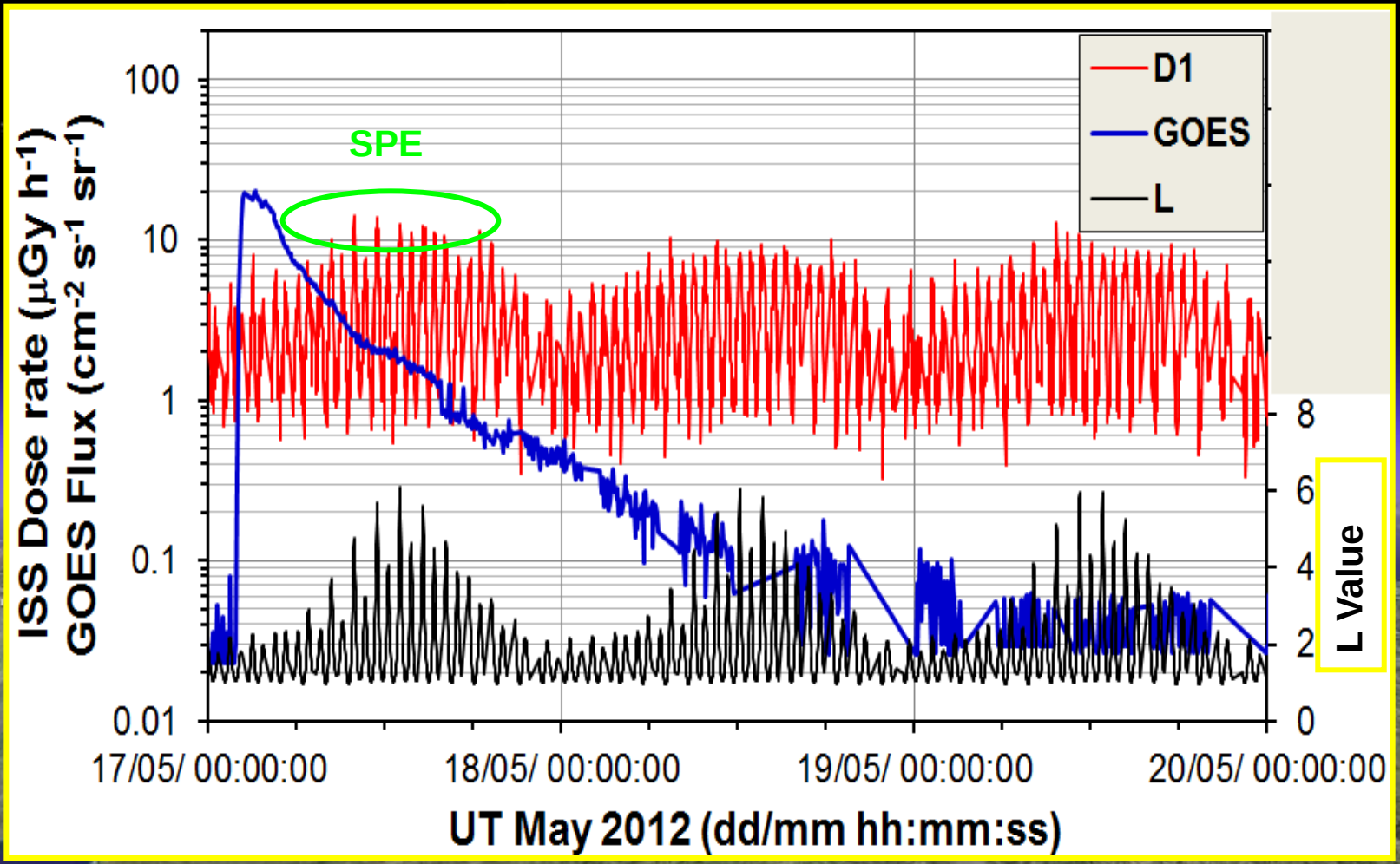


Comparison of the GOES-13 flux data with Liulin-5 dose rate during the March 2012 SPE



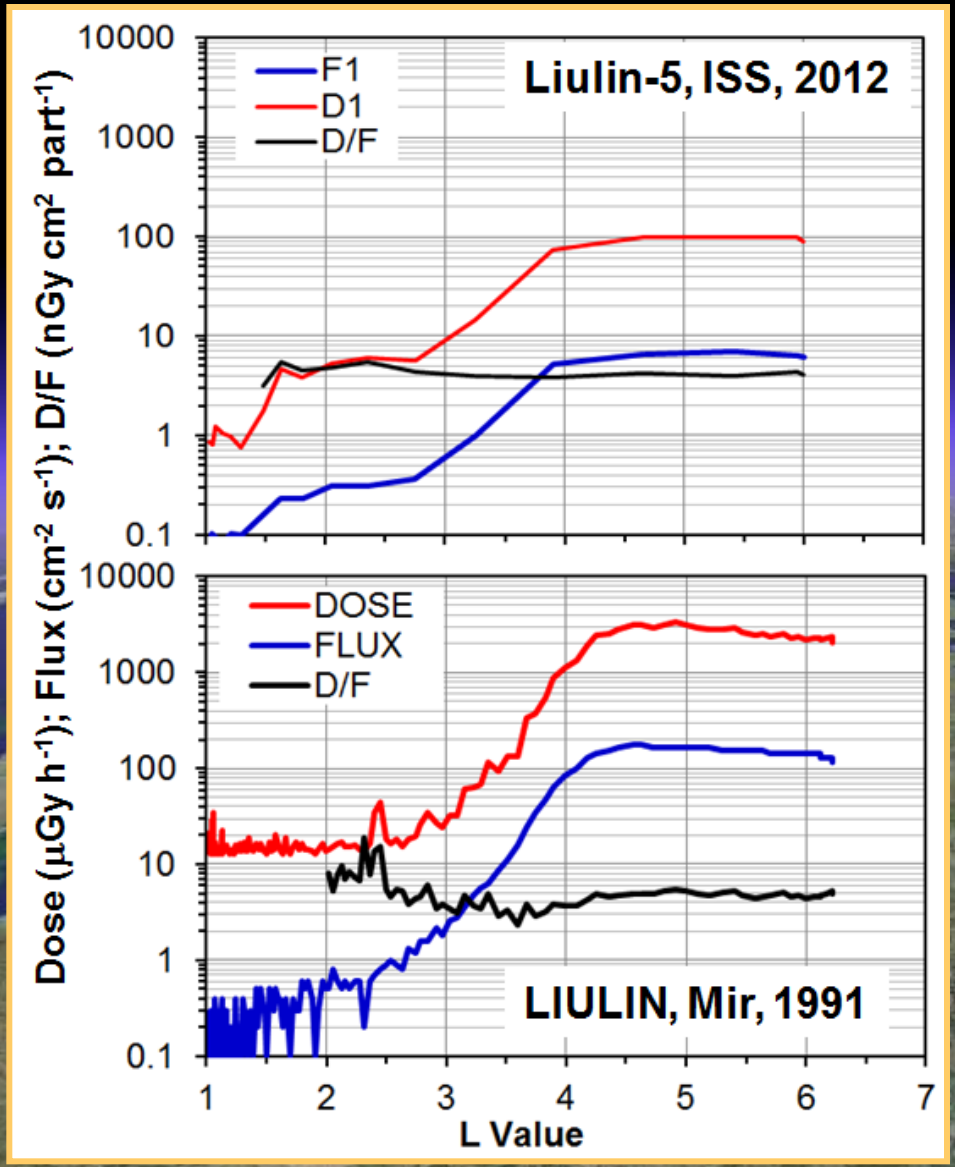
GOES-13 flux data of protons with energies >100 MeV (blue), Liulin-5 dose rate measured outside SAA (red) and the corresponding L values (black) versus time during SPE.

Comparison of the GOES-13 flux data with Liulin-5 dose rate during the May 2012 SPE



GOES-13 flux data of protons with energies >100 MeV (blue), Liulin-5 dose rate measured outside SAA (red) and the corresponding L values (black) versus time during SPE.

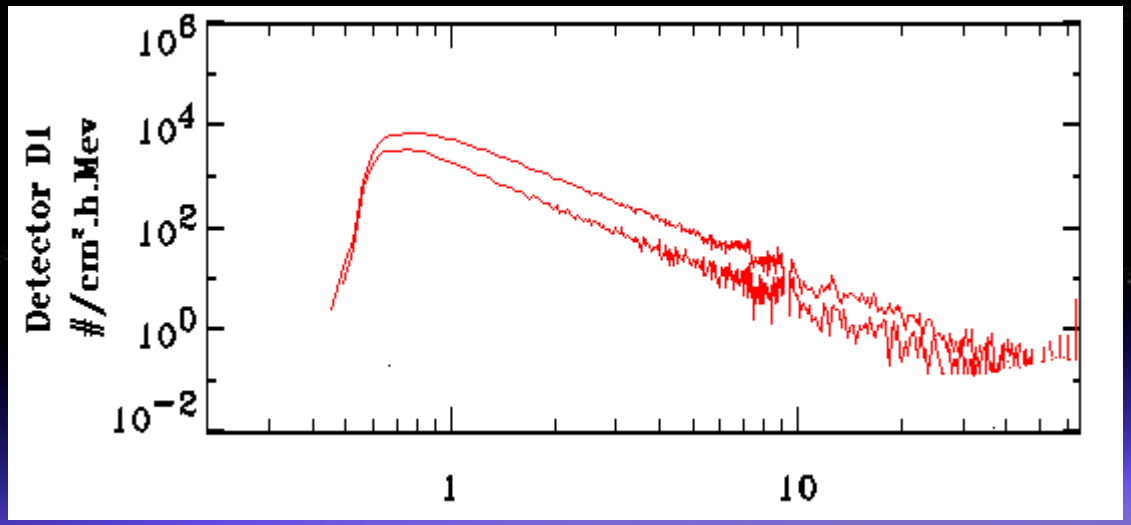
Comparison of the L value profiles of the SPEs in 1989-1991 and 2012



7 March 2012
17:20:08-17:46:30

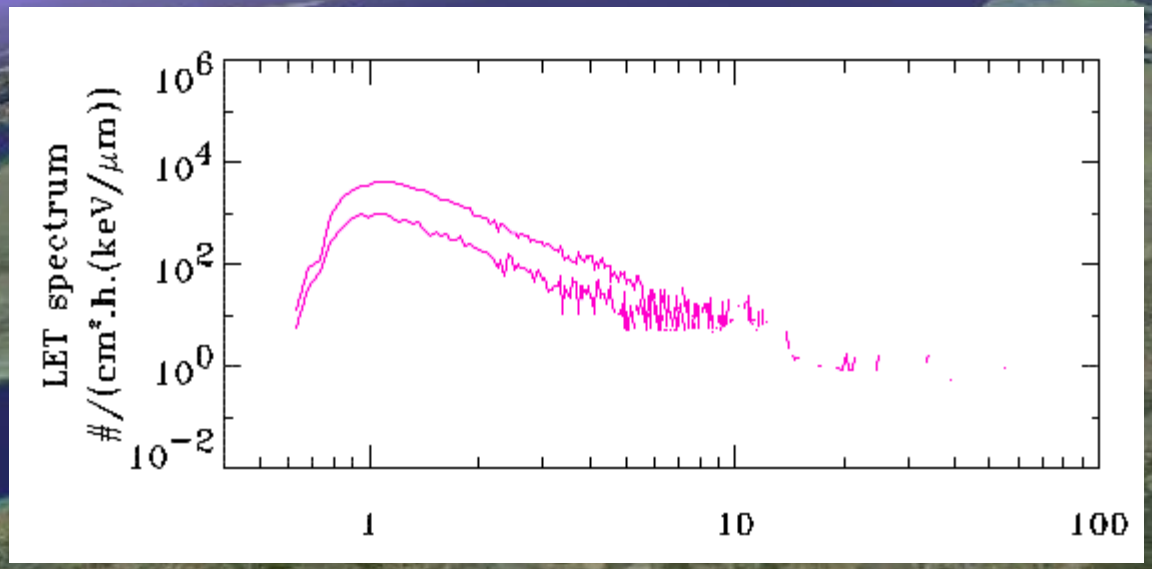
30 September 1991
00:54:10-01:18:40

LET spectra and Qav

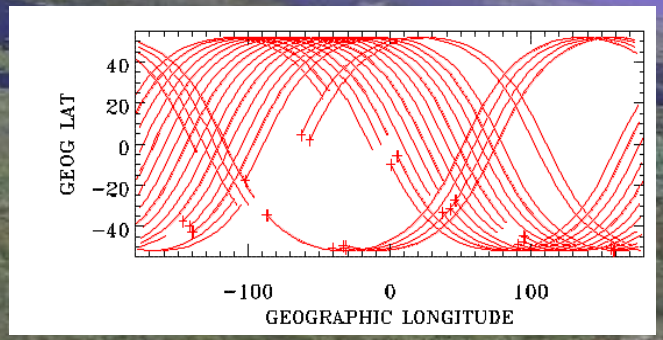


Deposited energy [MeV]

Deposited energy and LET spectra on orbits not crossing SAA. Upper curve in both spectra- during SPE –Q=2.5, DR= 10.09 μGy h^{-1} , lower curve –after SPE -Q=4.147, DR= 2.81 μGy h^{-1}.



LET [keV/μm]



CONCLUSIONS

- In MIM1 module the doses outside phantom (210-230 μGy/day) are 1.7 higher than at the phantom' s centre;
- The GCR dose rate decreased from ~ 85 μGy/day in April 2012 to ~ 70 μGy/day in September-October 2012. From September –October 2012 the GCR dose rate increases. The behavior is consistent with Sunspot Number R_i;
- During SPEs of 7-12 March 2012 at 3 < L the particle flux and dose rates increased in all three depths of 40, 60 and 165 mm along the radius of the tissue-equivalent spherical phantom in MIM1 module of ISS. The additional absorbed dose at 40 mm depth in the phantom from SPEs is ~ 180 μGy, the additional dose equivalent is ~ 450 μSv - comparable to the averaged daily absorbed dose and dose equivalent in the spherical phantom in ISS during quite periods. Outside SAA during SPE Q is 2.5, dose equivalent rate at 40 mm depth is 21.1 μSv/h . After the SPE Q is ≈ 4.15, dose equivalent is 11 μSv/h .
- No significant increase of dose rate and particle flux during SPE in May 2012;
- Good agreement of Liulin-5 dose rates trend during the SPEs with the proton flux ≥ 100 MeV measured by GOES – 13;
-
- Dose rates and particle fluxes observed at 3 < L during SPE on Mir station in 1989-1991 are higher than those in 2012 on ISS.

Acknowledgements

- Agreement between RAS and BAS on space research and grant DID-02/8 from the Bulgarian Science Fund;

- NIRS – Japan;

- RKK “Energia” and the cosmonauts for the operation of Liulin-5 instrument aboard ISS.


Thank you for your attention