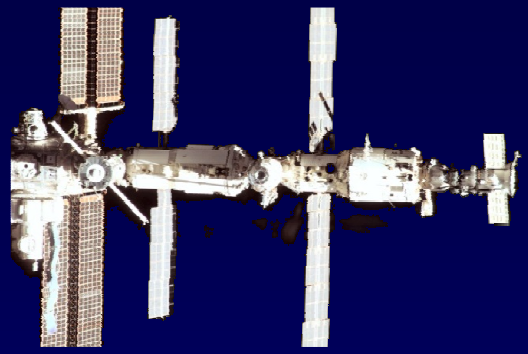
Fifth workshop "Solar influences on the magnetosphere, ionosphere and atmosphere"
Nesebar, Bulgaria June 3-7, 2013



RADIATION ENVIRONMENT ON THE INTERNATIONAL SPACE STATION DURING SPE IN 2012

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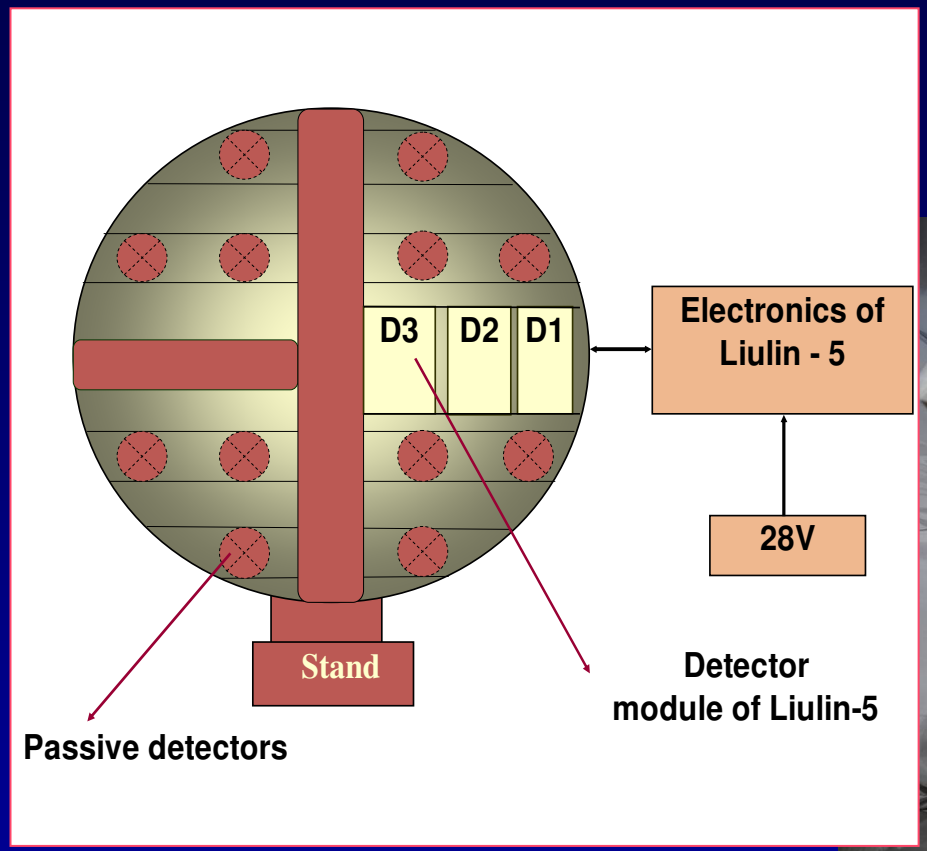
LIULIN – 5

- **Experiment Liulin-5 for investigation of the radiation environment within the spherical tissue-equivalent phantom on ISS is conducted on RS of ISS since July 2007. It is a part of the international project MATROSHKA-R.**
- **We present results of analysis of the data obtained from 2012 to April 2013 and during SPEs in March and May 2012.**

MOTIVATION

- Ionizing radiation is a main health concern to the astronauts in long duration space flights. Radiation exposures to BFO should be kept below 0.5 Sv/year for LEO missions.
- Complex ISS radiation environment –GCR, trapped radiation, SEP, albedo particles from Earth's atmosphere and the secondary radiation produced in the shielding materials of the spacecraft and in human body .
- Dose characteristics in LEO depend also on the solar cycle phase, spacecraft orbit parameters, helio – and geophysical parameters.
- For human flights both absorbed doses and the biologically significant dose equivalents should be controled.

Llulin -5 in the Spherical Phantom on ISS in MIM1 module



Block diagram of Liulin - 5 in the phantom

Phantom in MIM1 module of ISS

Goals

- 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.

Quality factor

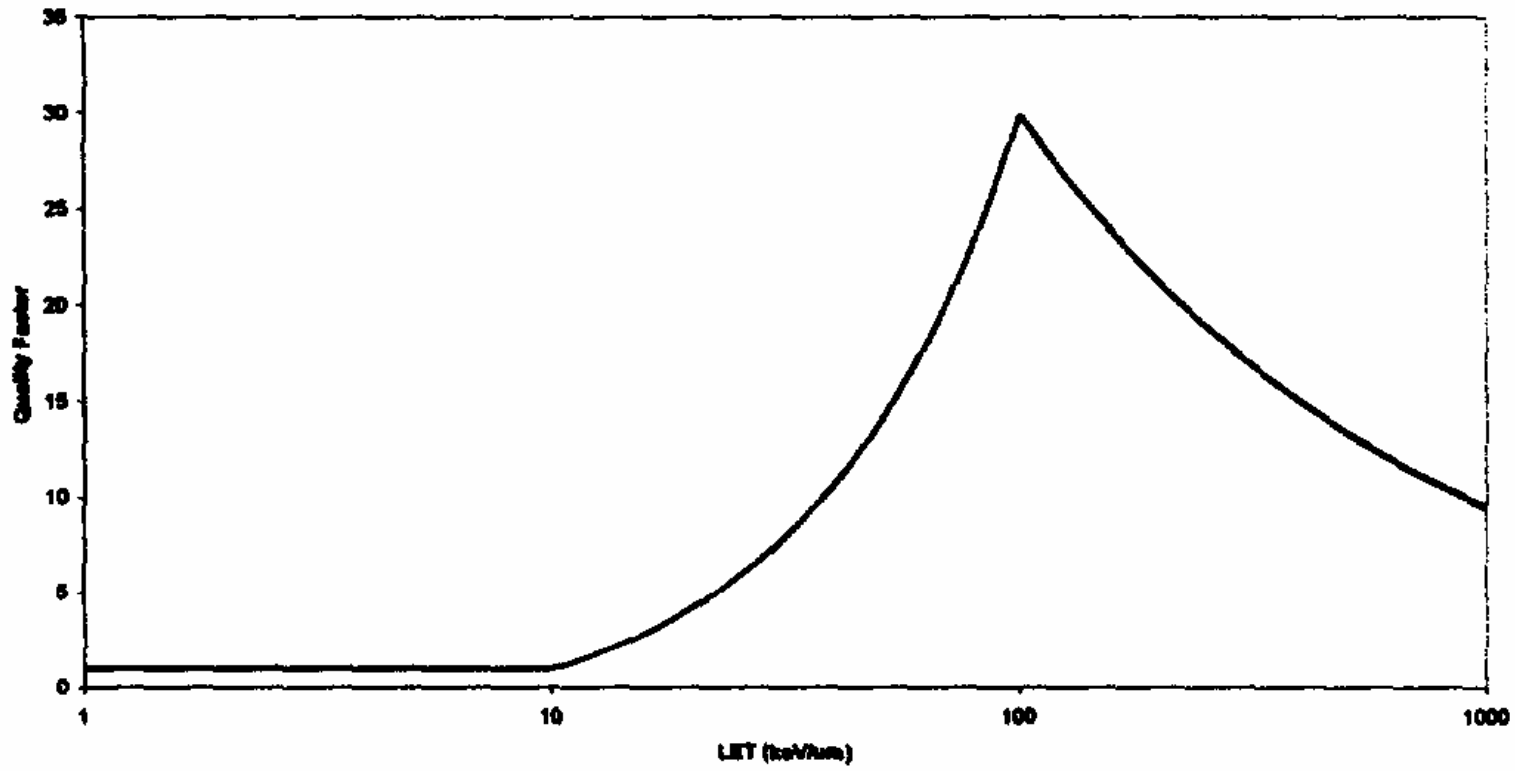
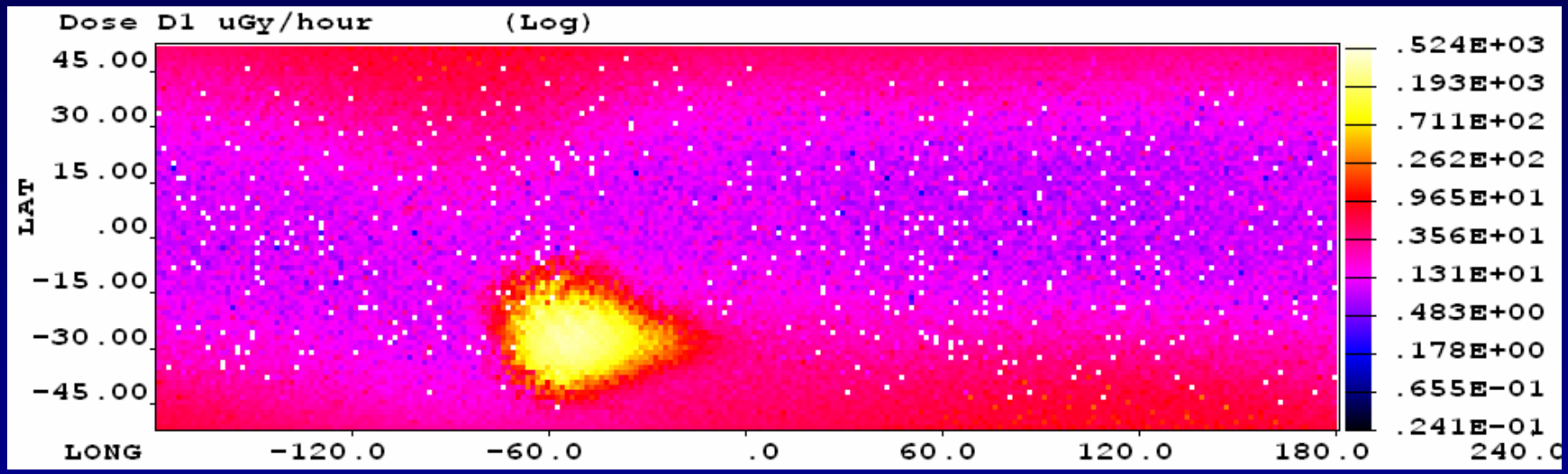


Fig. 3. Quality Factor as a Function of LET as Defined in ICRP-60

Results

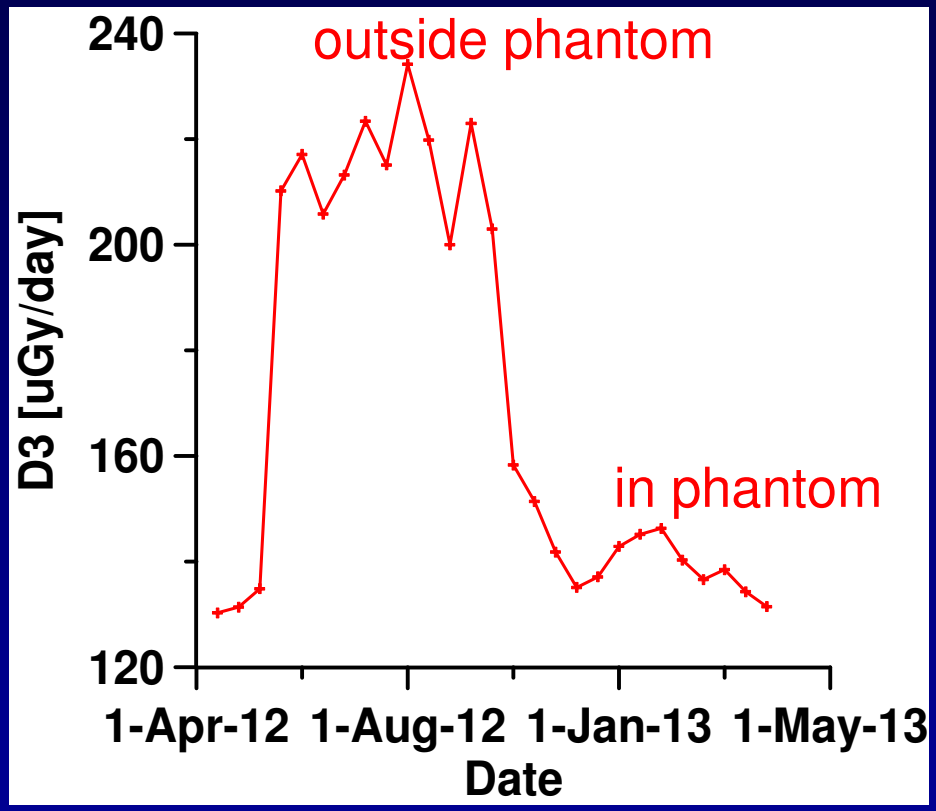
- Dose rate and particle flux during quite periods and SPE.
- LET spectra and Q during quite periods and SPE.

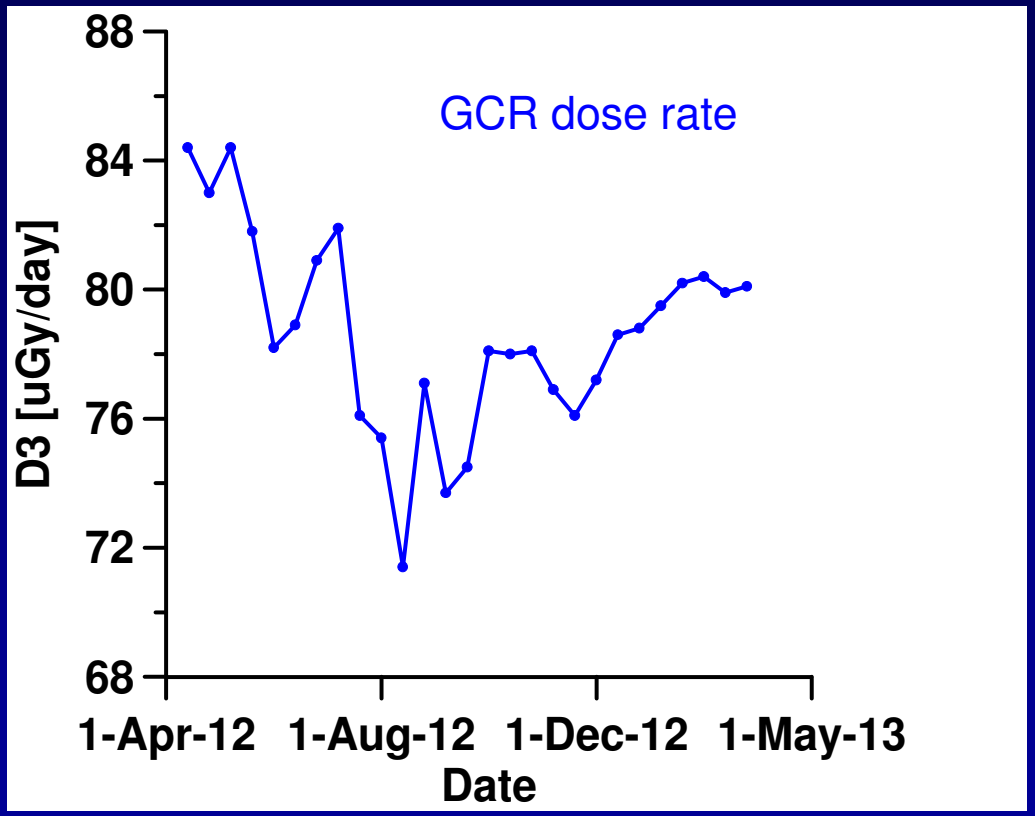
Dose rate along the ISS trajectory



Dose rate (40 mm depth) 27.12.2011 - 17.04.2012.

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





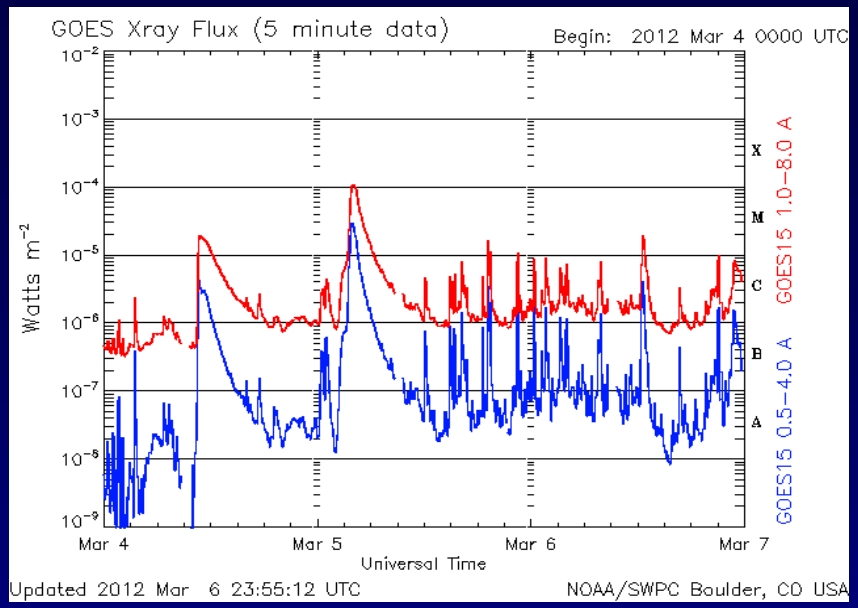
Total dose rate. Dose at the center of the phantom is 1.8 less than outside it

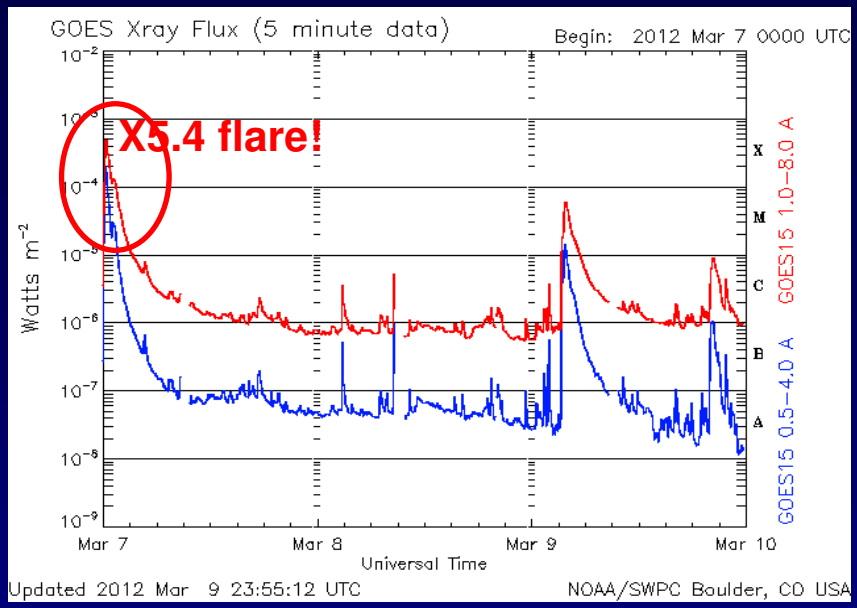
GCR dose rate

SPE observations

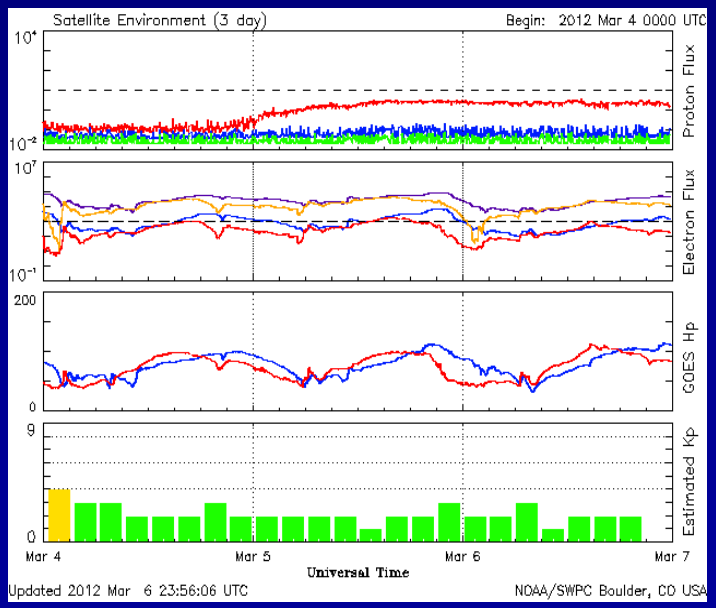
On 07.03.2012 GOES -13 registered beginning of two SPE associated with Earth-directed CMEs. >100 MeV event began at 04:05 UT , >10 MeV event began at 05:10 UT.

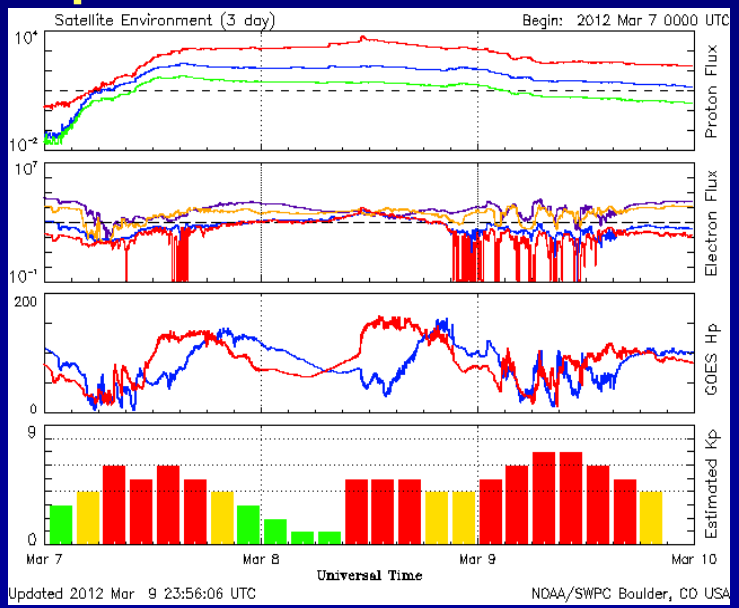
GOES-13 satellite X-ray flux 4-10 March 2012



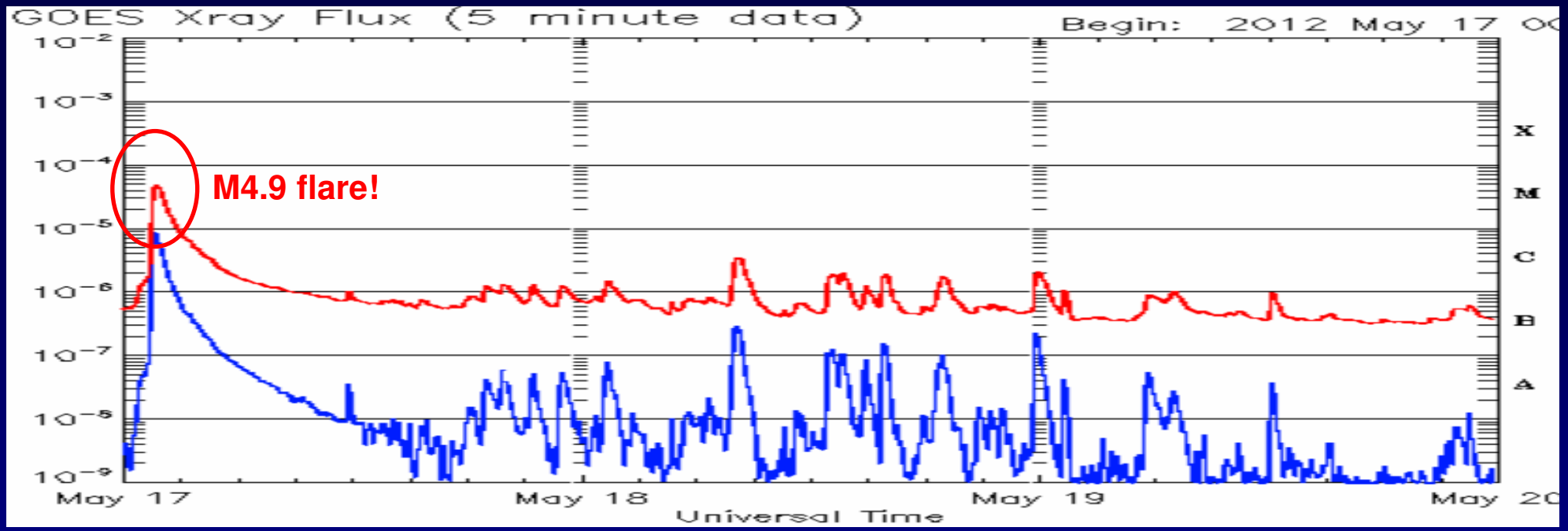


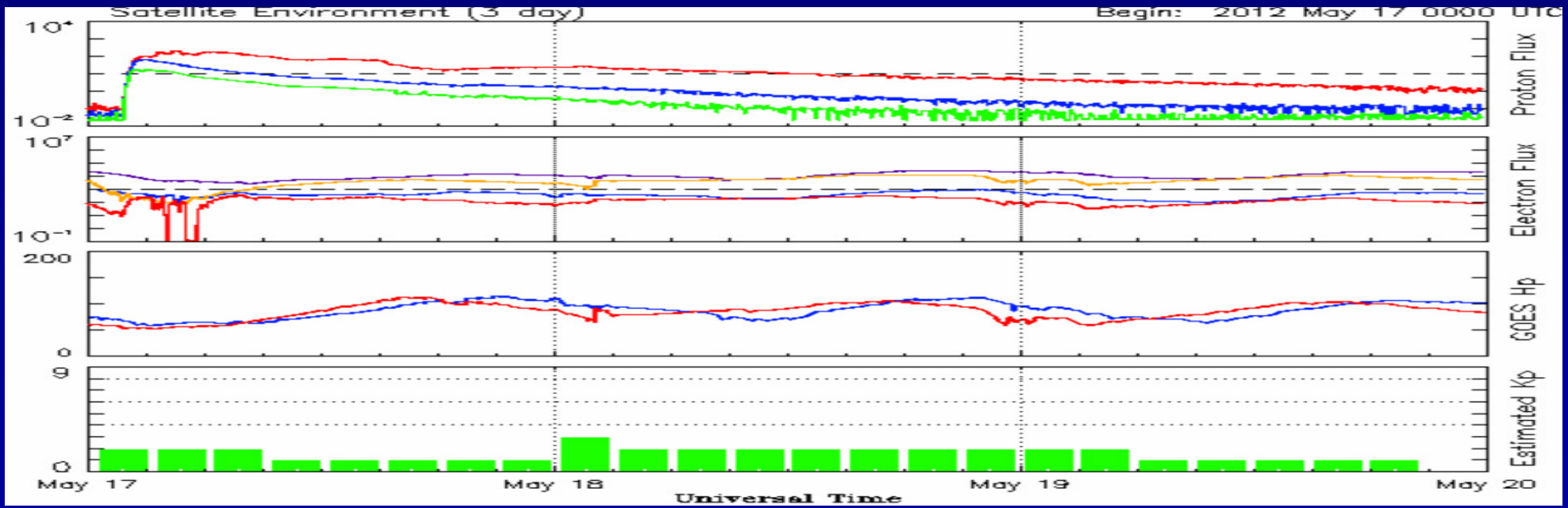
GOES-13 satellite environment plot 4-10 March 2012



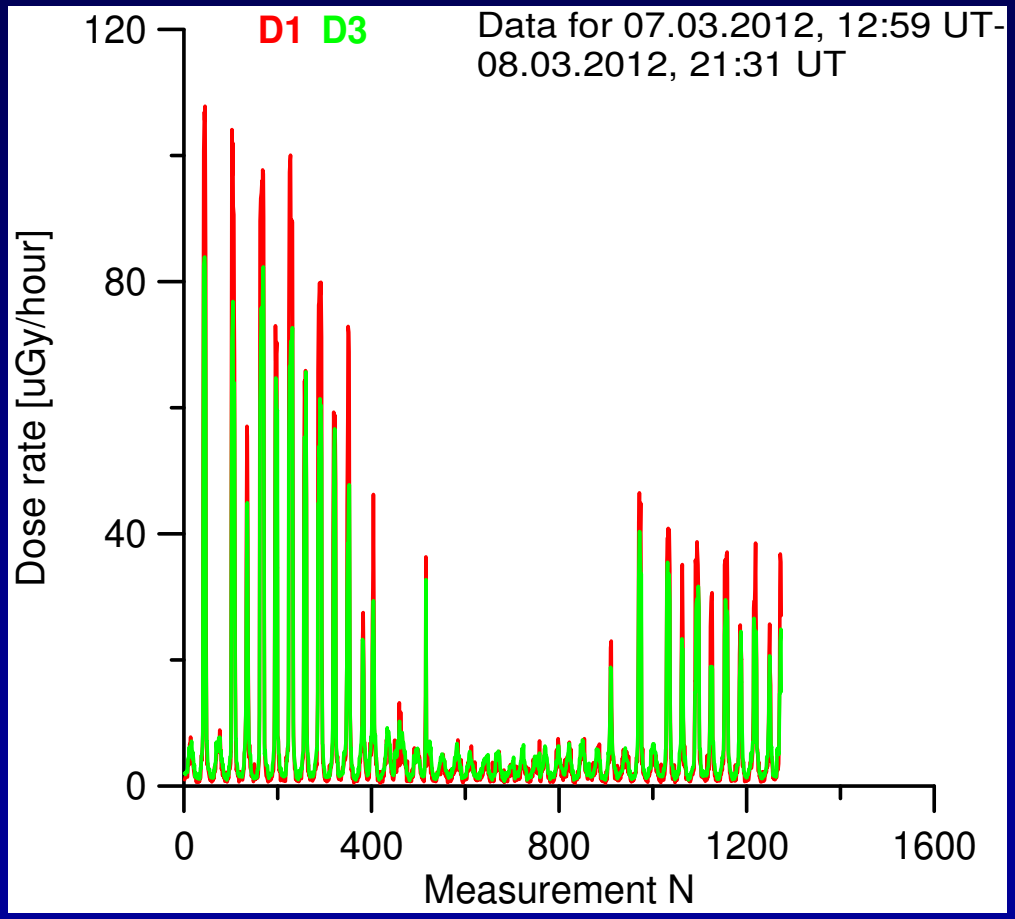


GOES-13 satellite X-ray flux 17-20 May 2012



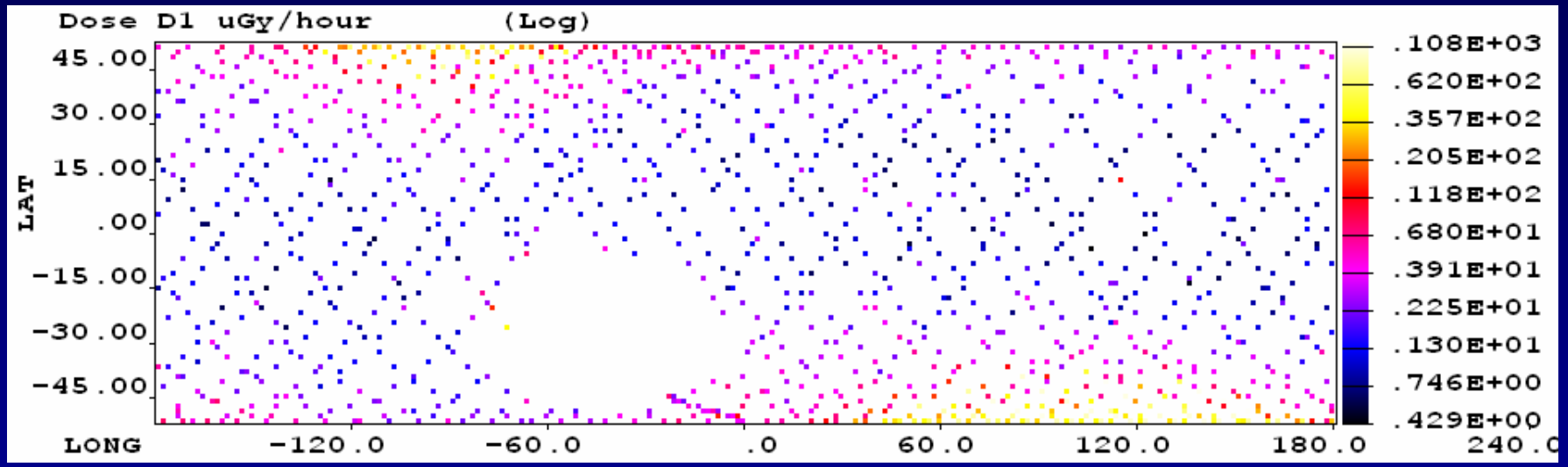


Dose rate distribution during March 2012 SPE (outside SAA) (1)



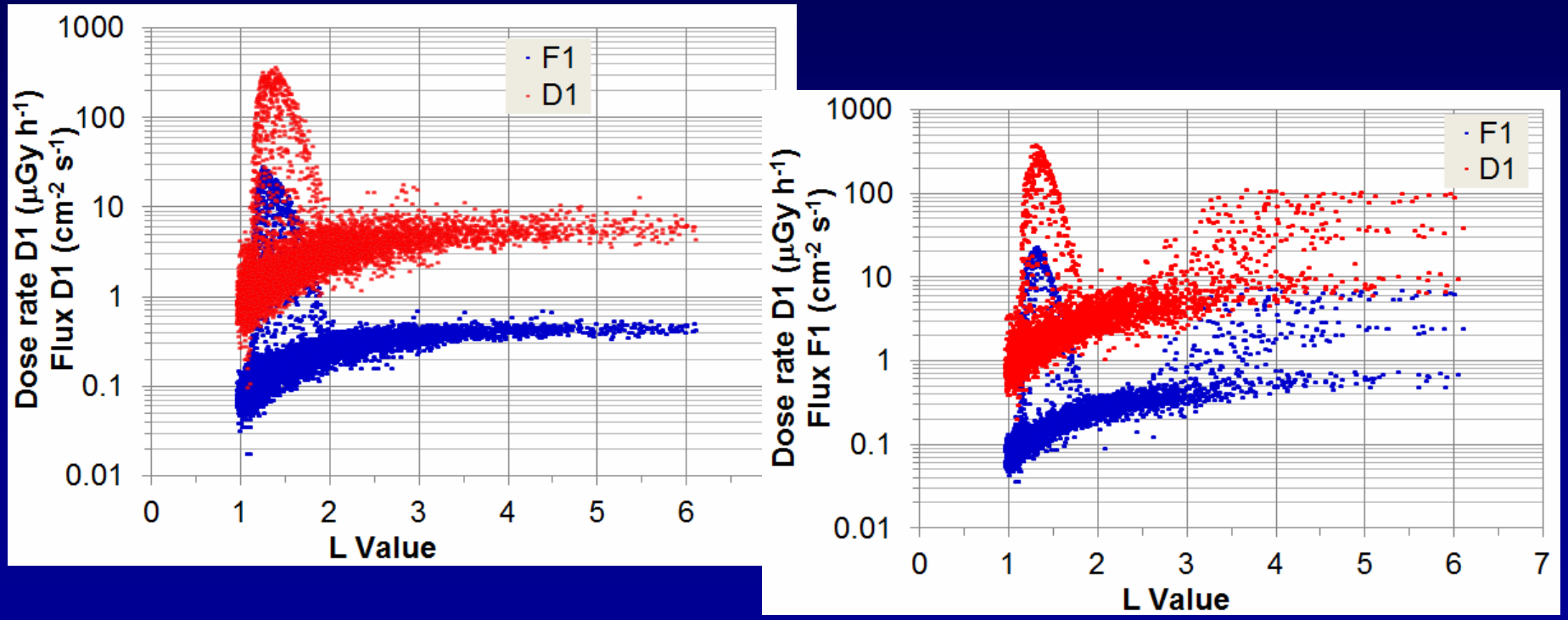
Successive measurements at 40 mm depth (red) and at 165 mm depth (green) outside SAA during SPE. **The first registration of particle flux and dose rate increase in Liulin-5 data was on 07.03.2012, at 13:01 UT, at L=3, Lat =-42.3^0, Long =136.6^0, Alt= 421.7 km. The last registration of flux and dose rate increase was on 08.03.2012, at 21:31 UT at L=3.8, Lat=-48.8^0, Long=71.3^0, Alt=421.7 km.**

Dose rate outside SAA during SPE in March 2012



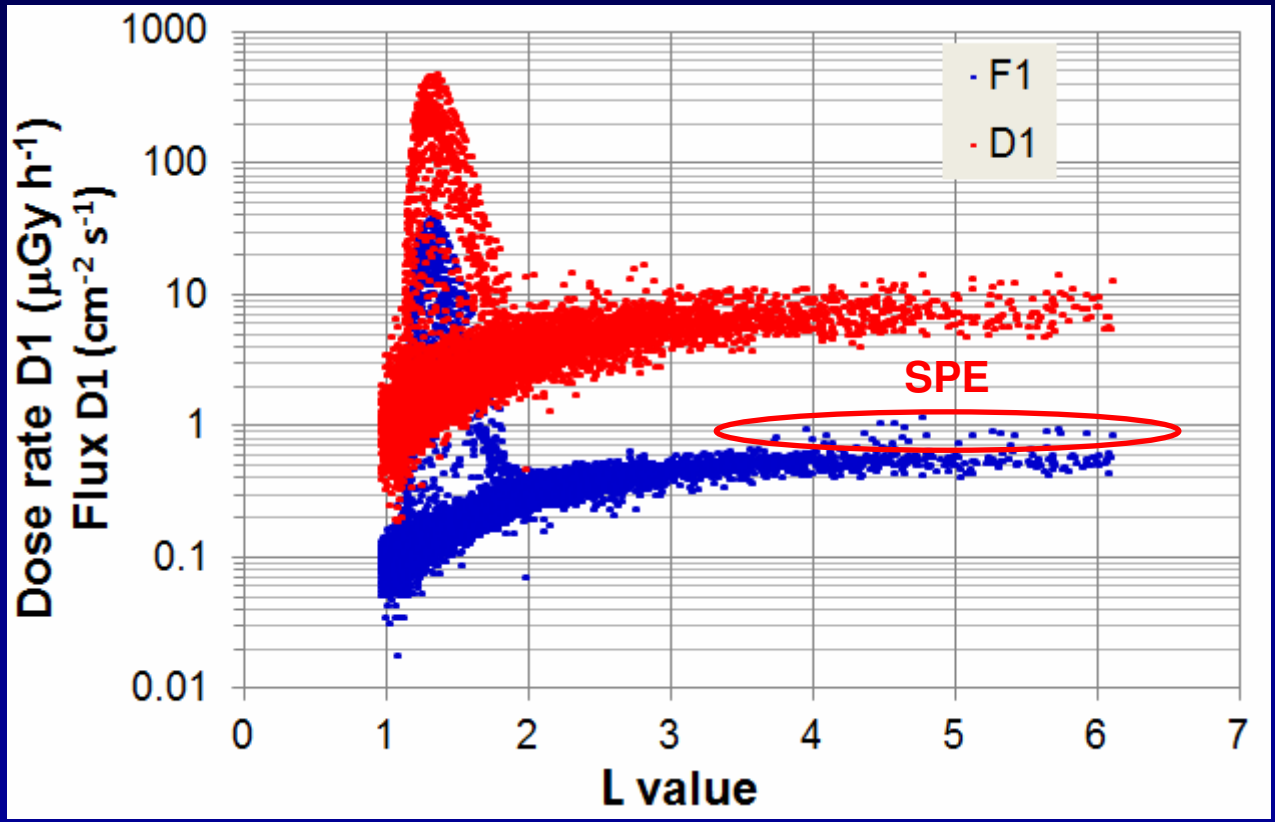
Dose rate D1 outside SAA during SPE from 07.03.2012, 12:59 UT to 08.03.2012, 21:31 UT. Increase of dose rate from solar protons is observed at high geographic latitudes in the region of the south and north magnetic poles.

Particle flux and dose rate during quite conditions and SPE in March 2012



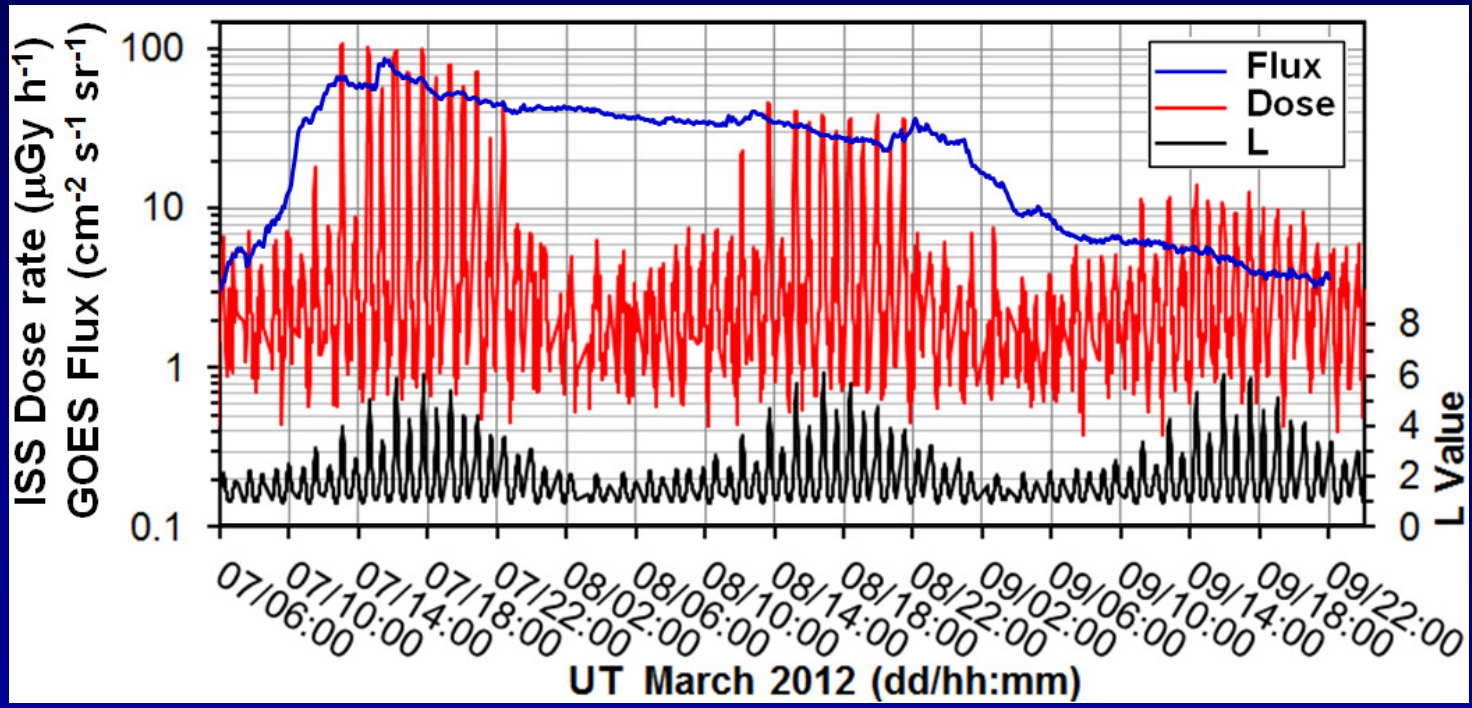
Particle flux F1 and dose rate D1 at 40 mm phantom's depth before (left) and during SPE (right) , March 7-12 2012. **The maximum flux observed outside SAA during SPE reached 7.2 part/cm^2.s and the dose rate reached 107.8 µGy/hour on 07.03.2012, 13:06 UT at L = 4, Lat = - 51.1^0, Long =166.8^0, Alt= 422 km. The averaged dose rate D1 outside SAA during SPE was 8.43 µGy/h and averaged flux was 0.59 part/cm^2.s. The total dose outside SAA received during SPE was 259.9 µGy.**

Particle flux and dose rate during quite conditions and SPE in May 2012



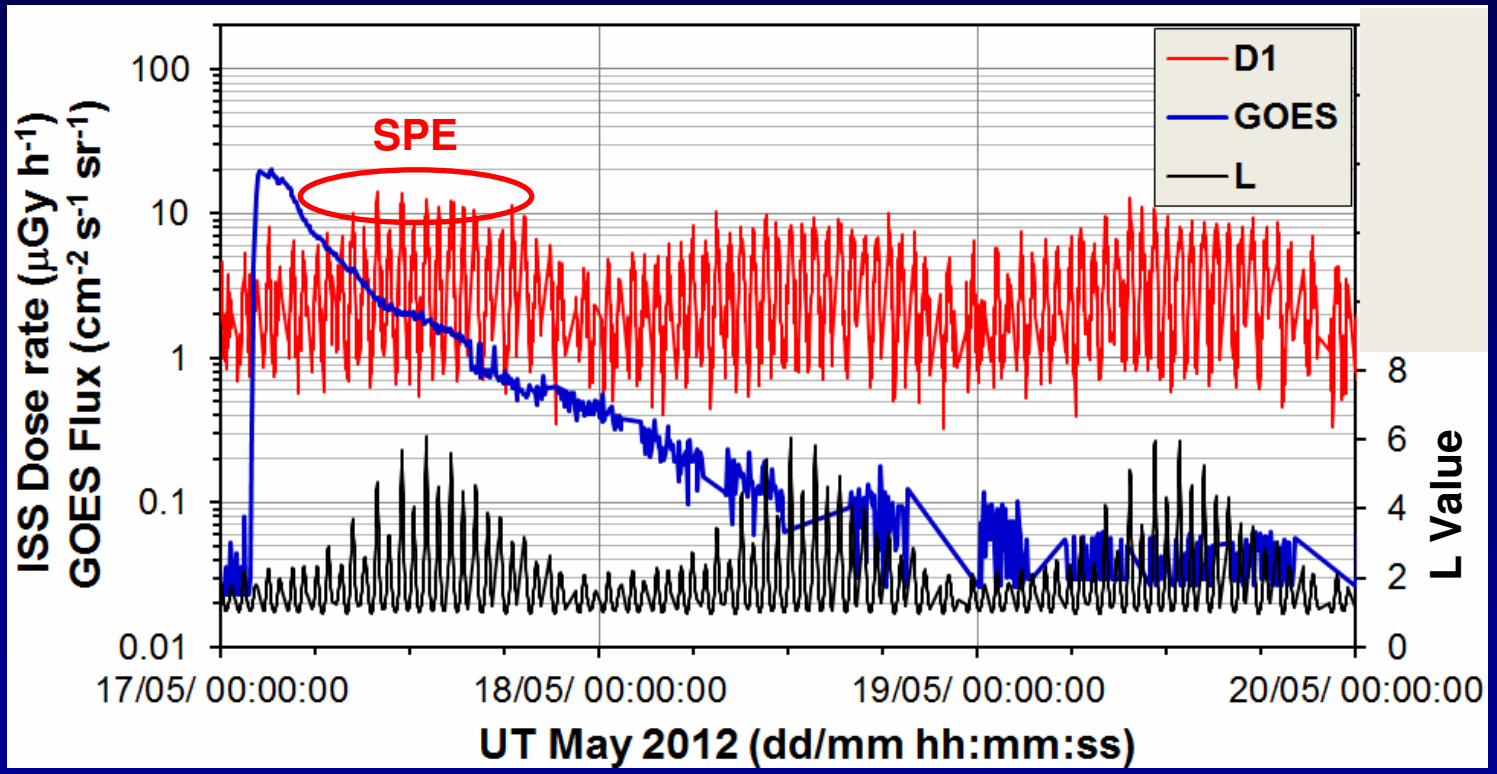
14-21.05.2012

Comparison of the GOES-13 100 MeV proton flux data with Liulin-5 dose rate during March 2012 SPE



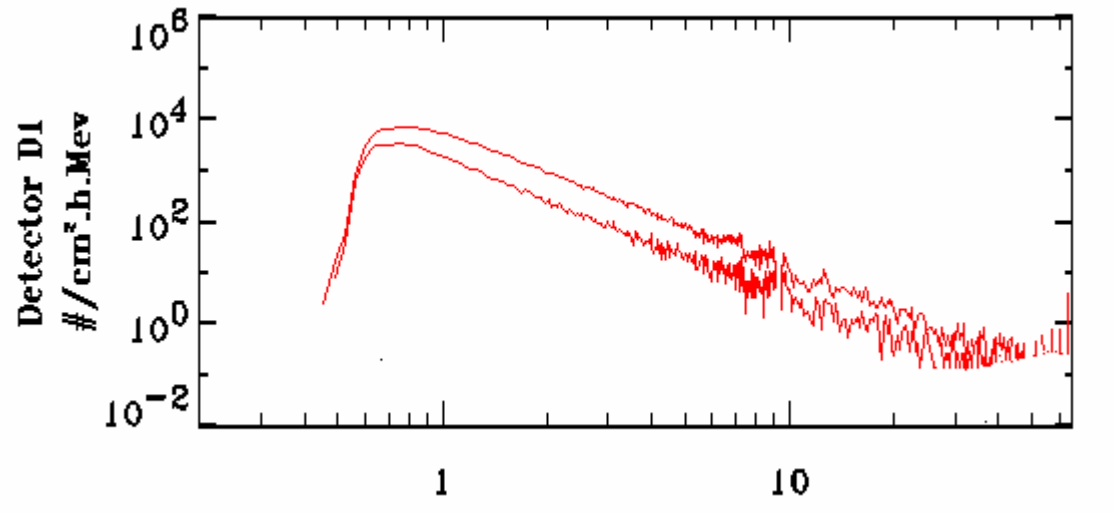
GOES-13 flux data of protons with energies >100 MeV (blue), Liulin-5 dose rate measured outside SAA (red) and the corresponding L values (black) versus time during SPE.

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

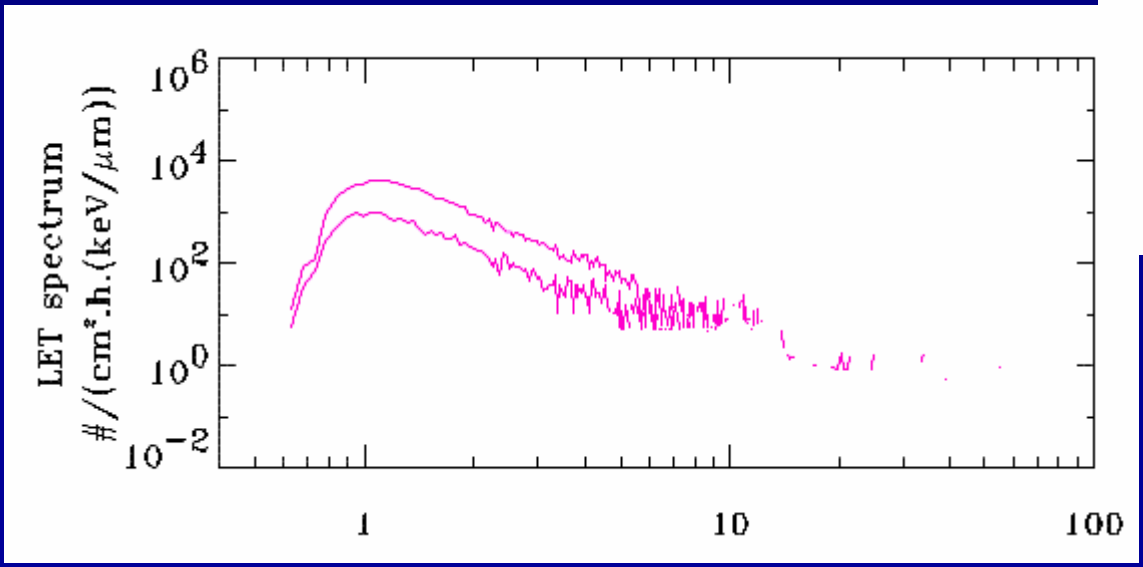


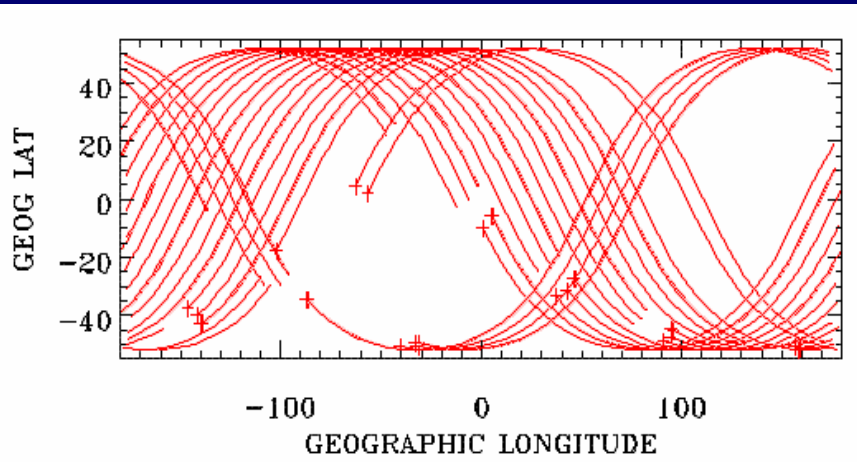
GOES-13 flux data of protons with energies >100 MeV (blue), Liulin-5 dose rate measured outside SAA (red) and the corresponding L values (black) versus time during SPE.

LET spectra and Qav



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





Conclusion

- Doses outside the phantom are ~ 1.8 higher than at the center of the phantom.
- The minimum of GCR dose rate was in Sept.-Oct. 2012 – max of SA.
- During SPEs of 7-12 March 2012 at 3 < L the particle flux and dose rates increased in all depths along the radius of the tissue-equivalent spherical phantom on ISS.
- The additional absorbed dose to BFO 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.
- Slight increase of dose rate and particle flux during May 2012 SPE.
- Good agreement of Liulin-5 dose rates trend at 3 < L during the SPEs with the 100 MeV proton flux measured by GOES – 13.

Acknowledgements

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

- NIRS - Japan.

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