Joint analysis of SphinX and STEP-F instruments data on magnetospheric electron flux dynamics at low Earth orbit

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Introduction

The **S**olar **ph**otometer **in X**-rays SphinX and the **S**atellite **T**elescope of **E**lectrons and **P**rotons STEP-F operated from February to November 2009 in the course of scientific space mission *CORONAS-PHOTON*. On top of intended solar X-ray measurements an additional particle related signal has been recorded by SphinX. In order to determine the energies and particle types contributing to the SphinX records the STEP-F data have been used for joint analysis as both instruments were placed in close proximity to each other on the satellite (Figure 1).

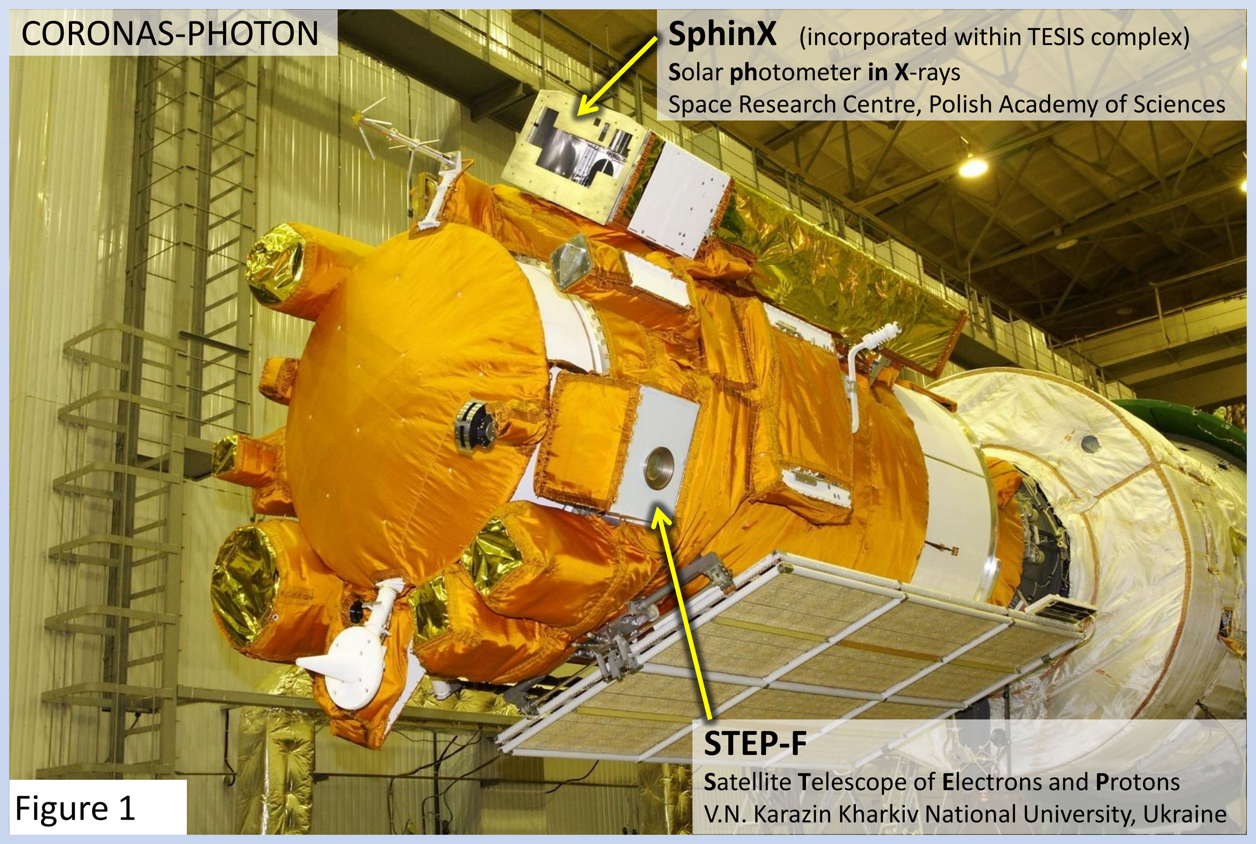

Figure 1

Geophysical conditions in May 2009

For joint data analysis the time period from May 1 to May 31, 2009 has been selected. The geophysical conditions in May 2009 varied from quiet to weak geomagnetic storm ($D_{st} \approx -25$ nT) with a maximum on May 8. Such changing conditions allows to analyse response of SphinX detectors to particle flux by comparison of time series data from both instruments. In addition the selected time period provides very interesting data for studies of electron flux dynamics. The selected indices: AA (a), a_p (b), D_{st} (c), velocity (d) and density (e) of solar wind by measurements on SOHO satellite as well as particle fluxes (f, g) at geostationary orbit by measurements on GOES11 satellite in May, 2009 are shown in Figure 2.

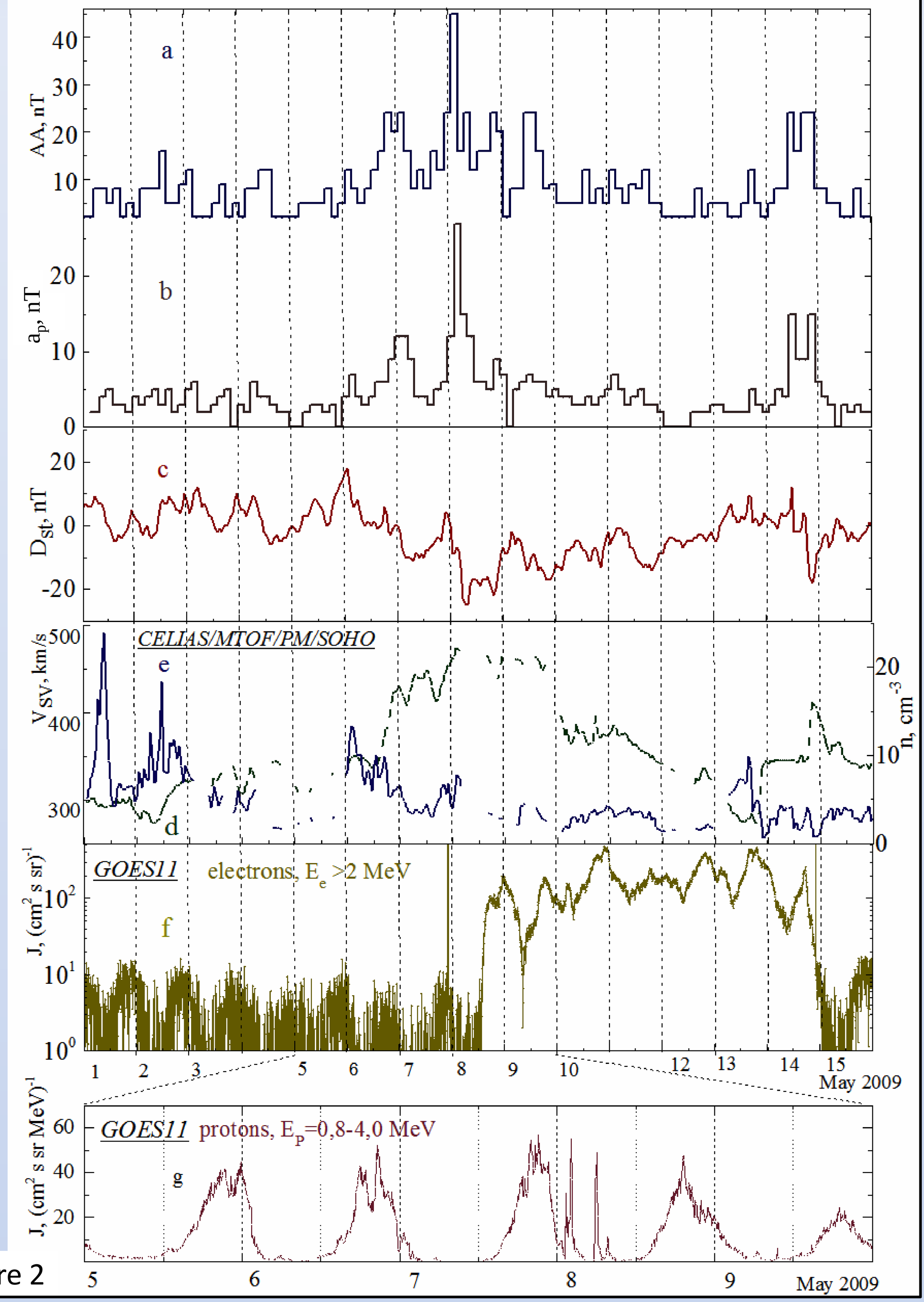

Figure 2

SphinX energy thresholds

SphinX instrument was equipped with large area silicon PIN photodiodes intended to measure soft X-rays emission from the Sun in the energy range of 1.2 – 15 keV. In order to determine species of particles recorded by SphinX and effective energy thresholds a dedicated analysis was performed using calibrated STEP-F data. The energy thresholds for electrons registration within South Atlantic Anomaly (SAA) were determined by analysis of flux intensity distribution in L-shell domain. Based on dependence of particles energy on L-shell positions of maximum flux intensity the SphinX energy thresholds were found (Figure 3). They amount to ~500 keV and ~475 keV for detector D1 and D2 respectively. The energy thresholds for electrons registration within Radiation Belts (RB) were determined by analysis of ΔL displacement of maximum flux intensity during geomagnetic storm from the initial position for quiet conditions. By the comparison with STEP-F data where the energy thresholds for particular channels are well known the SphinX energy thresholds were found as ~5 keV and ~60 keV for detector D1 and D2 respectively [1].

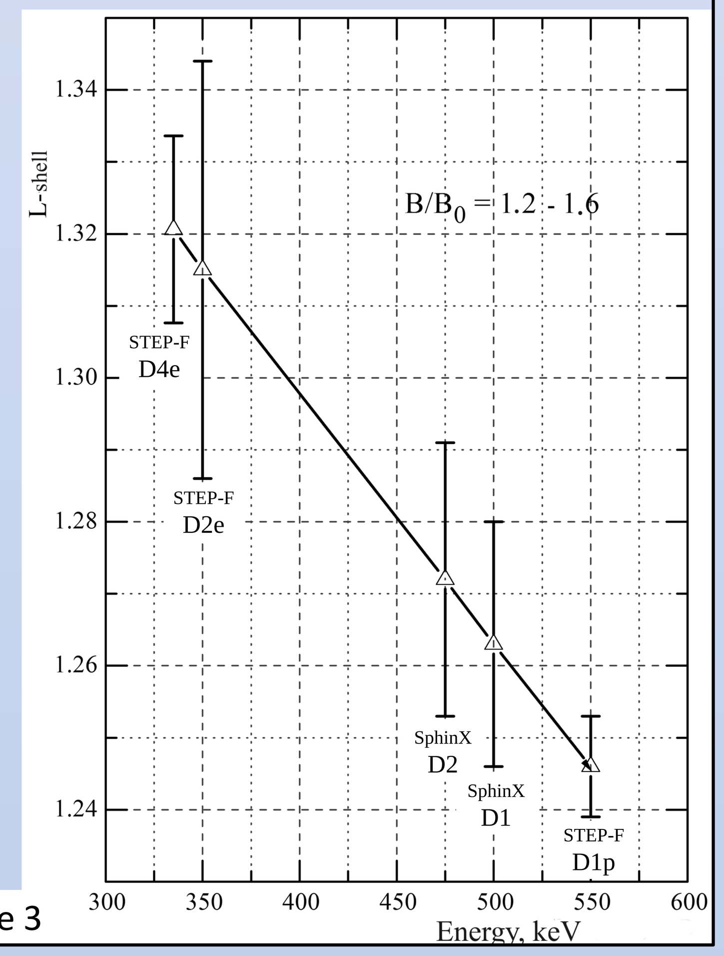

Figure 3

Electron flux dynamics

The dynamics of electron flux as seen at low Earth orbit has been studied based on STEP-F and SphinX data. All measurements were taken at orbit altitude of ~560 km and inclination of 82.5°. For each day of May a first orbit was selected for the analysis. Each of them starts from equator at near the same longitude. First part of the orbit from 0th to 48th minute corresponds to northern hemisphere while the second part from 48th to 96th minute corresponds to the southern hemisphere. These 31 orbits have been composed into single plot of the characteristic RB and SAA pattern evolving in time. Figures 4 and 5 show the electron flux dynamics as seen by SphinX detectors D2 and D1 respectively. Figure 6 was obtained from STEP-F electron registration channel. As the STEP-F has relatively wide angle of view the RB pattern in Figure 6 is distinctive regardless of satellite orientation. SphinX did not register entire RB at ~30th and ~75th minute most likely due to anisotropy of particles in RB and relatively narrow field of view (Figure 5). Beginning from May 7 both SphinX and STEP-F instruments registered increase of particle intensity within RB caused by geomagnetic storm. It can be seen in Figure 5 that SphinX was also able to register inner belt in southern hemisphere at ~60th minute. The SAA pattern is distinct in all figures, however it rather doesn't change due to geomagnetic storm.

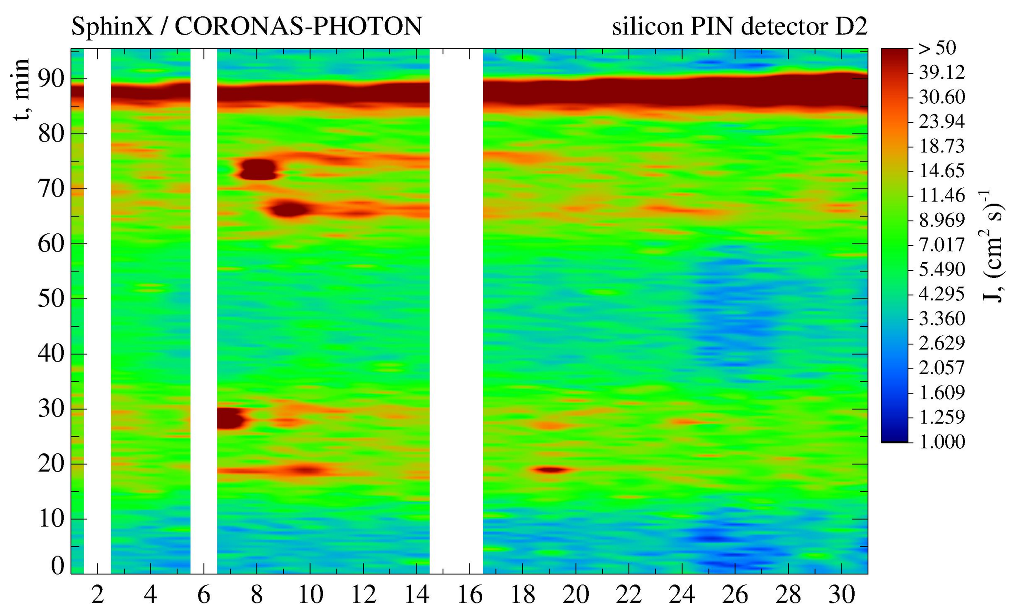

Figure 4

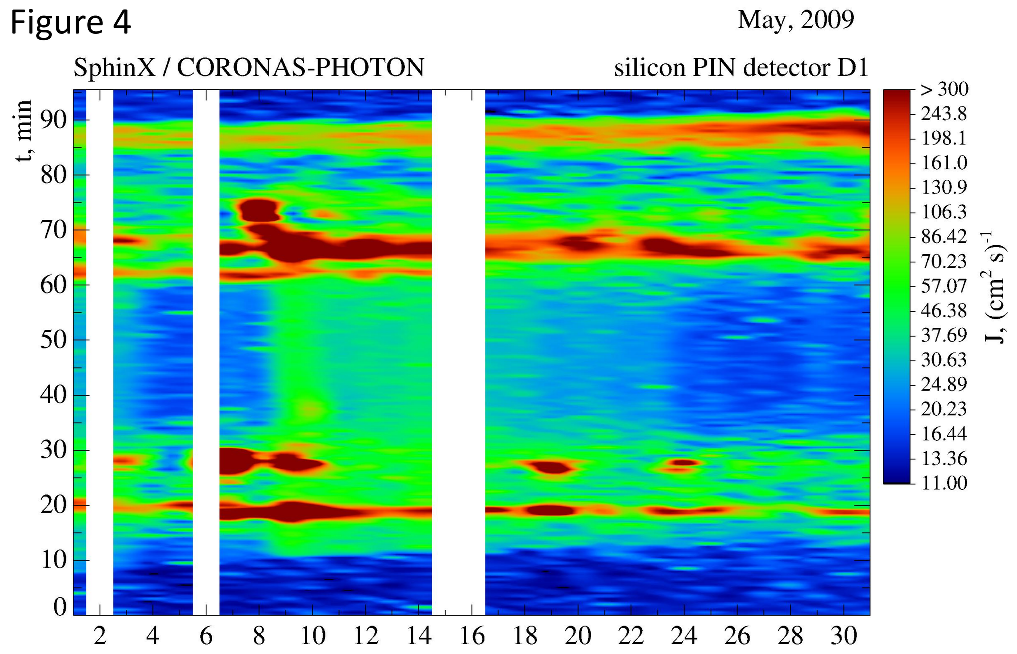

Figure 5

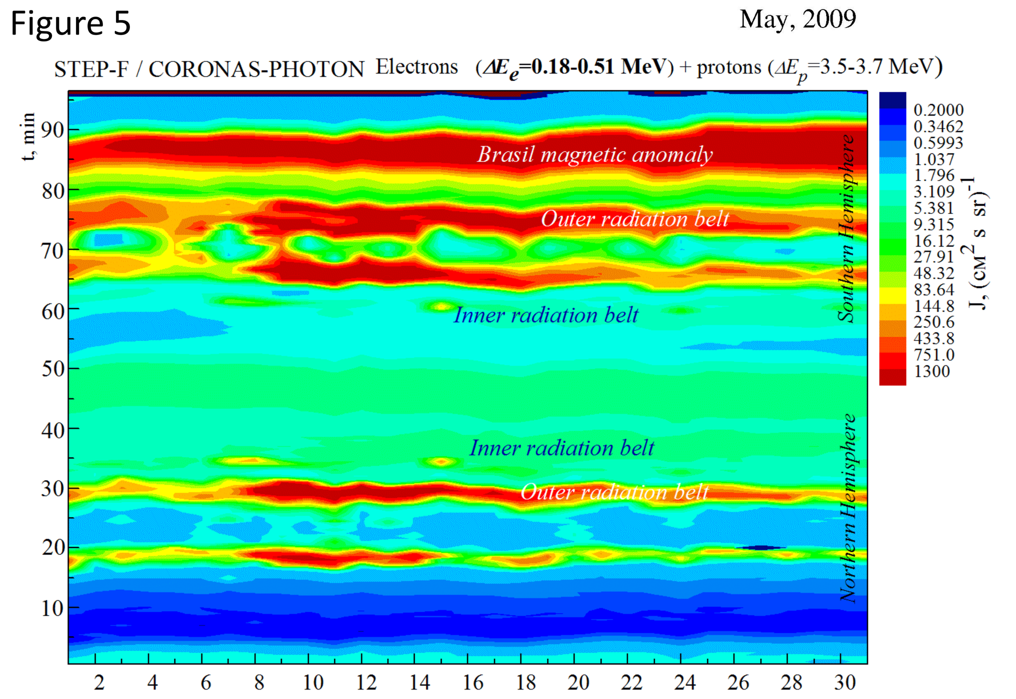

Figure 6

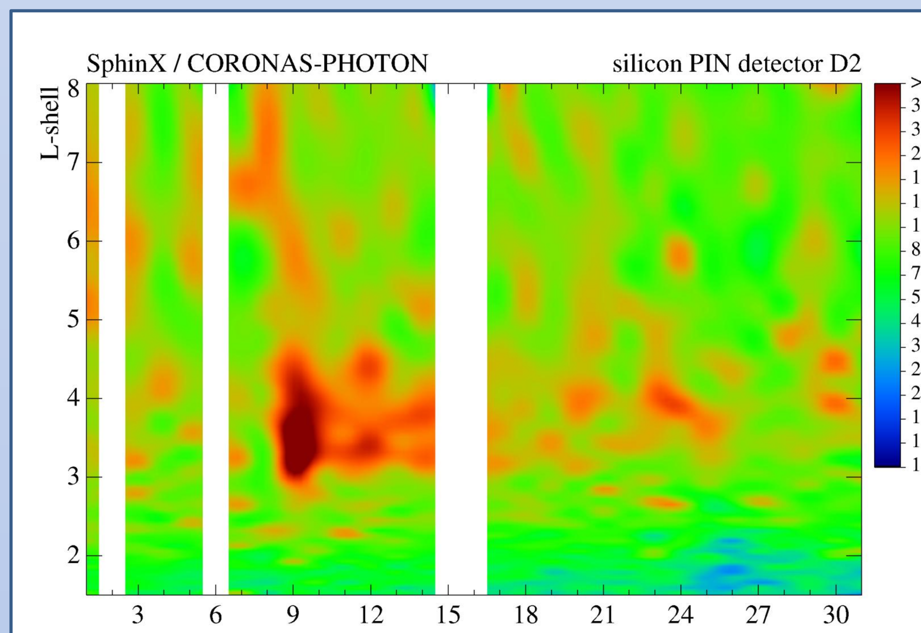

Figure 7

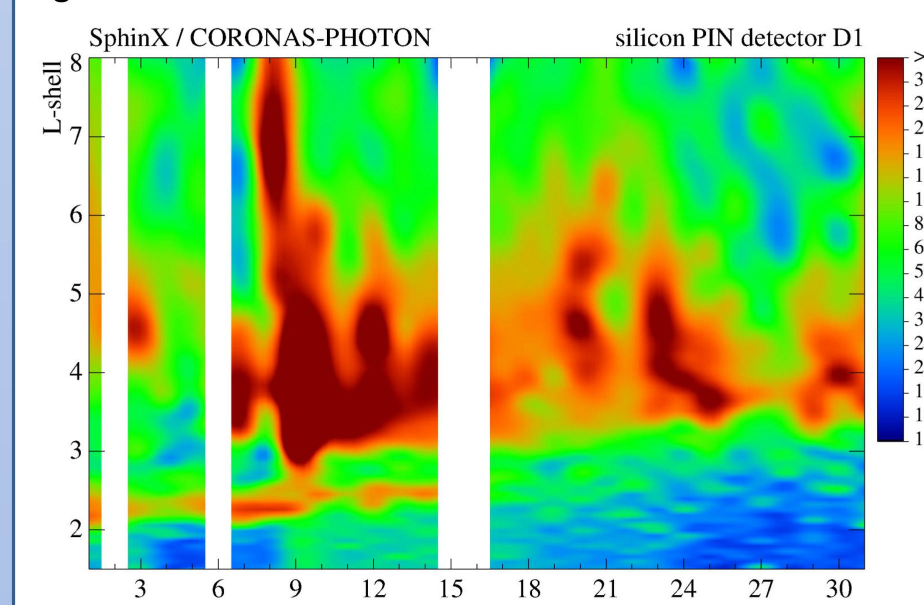

Figure 8

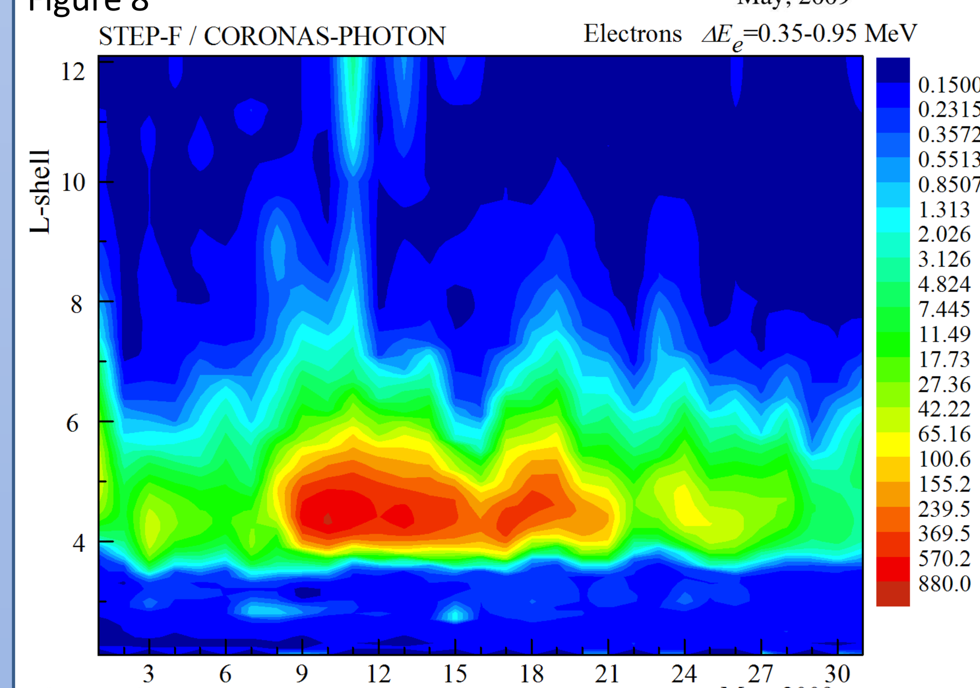

Figure 9

Distribution of electron fluxes on drift L-shells

For the analysis of electron flux dynamics on drift L-shells a series of figures have been made using part of first orbits for selected L range. Figures 7 and 8 show distribution of electron fluxes and secondary gamma radiation recorded by SphinX on drift L-shells for first orbits of each day for southern hemisphere, descending node.

It is clearly seen on Figure 8 that the distribution of particle intensity within outer RB was affected by geomagnetic storm on May 8. The main changes within outer RB were significant increase of particle intensity with maximum observed on May 9 and slight displacement toward lower L values. In addition the inner RB can be also seen for few days in vicinity of geomagnetic storm at L ~2.5. These changes are less visible in Figure 7 as the detector D2 has lower sensitivity to particles than D1. However, the observed patterns obtained from both SphinX detectors seem to match each other very well.

Figure 9 shows distribution of electron fluxes recorded by STEP-F in energy range of 0.35 – 0.95 MeV on drift L-shells for the first orbits of each day for northern hemisphere, descending node. The figure exhibits rapid decrease of particle intensity on May 7 and 15 at L ~2.5 followed by increase of particle intensity at higher L values. The dynamics of electron flux as seen by SphinX and STEP-F reflects a typical process of radial diffusion in RB.

[1] O. V. Dudnik, P. Podgorski, J. Sylwester, et. al. X-Ray Spectrophotometer SphinX and Particle Spectrometer STEP-F of the Satellite Experiment CORONAS-PHOTON. Preliminary Results of the Joint Data Analysis, Solar System Research, 2012, Vol. 46, No. 2, pp. 160–169. © PleiadesPublishing, Inc., 2012. DOI: 10.1134/S0038094612020025.

ACKNOWLEDGEMENT

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