

Composition and Spectral Characterization of Space Radiation in LEO Orbit onboard JoeySat Satellite with MiniPix-Timepix3

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Knowledge and measurements of the space radiation field in outer space are valuable for science and applied research (space weather, earth-solar physics) as well as satellite industry engineering and spacecraft operations. Radiation effects on spacecraft components and electronics [1] are becoming increasingly sensitive to the varying characteristics and large gradients of the harsh space radiation field in space. Measurements of the complex and highly dynamic mixed-radiation field in space require particle-type discrimination and wide-dynamic range response of radiation field intensity, particle energy distributions, directionality, spatial (satellite orbit location) and time. For this purpose, the semiconductor pixel detector Timepix3 has been deployed in LEO orbit onboard OneWeb JoeySat (launched May 2023, 600-1200 km polar orbit). Timepix3 provides detailed wide-range data on the complex space radiation field in the satellite environment. Payload implementation with miniaturized COTS electronics [2] of low mass and reduced power consumption provides deployment advantages and reduced cost. The MiniPix-TPX3 Space (Fig. 1) is operated and readout to the satellite SOCAN bus interface by a customized control and readout computer. Intended for operation in high intensity radiation environment, the detector is behind a 5 mm thick aluminum shield the intense plasma and EV field and suppress the low-energy radiations (electrons below ≈ 1 MeV, protons below ≈ 30 MeV, low-energy X rays below ≈ 10 keV). The radiation field is measured continuously and registered at selected intervals (ranging from ms up to 25 sec) overall nearly every minute. The total raw data rate is up to 24 MB/day which is downlinked to ground to be processed offline.

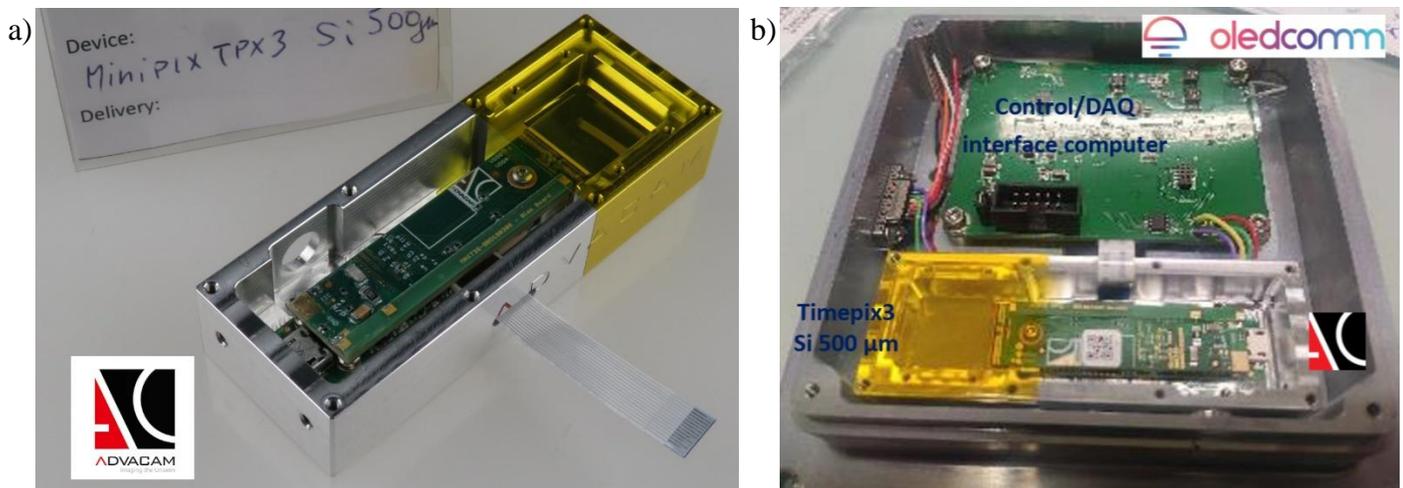


Figure 1: (a) The miniaturized MiniPix-Timepix3 Space detector (Advacam) onboard JoeySat. Size 95 mm \times 28 mm \times 21 mm, mass \approx 100 g (with casing). Power consumption \approx 2 W. The detector is controlled and readout by serial flexi connector (shown on the side). (b) The MPX payload with the control/readout computer (Oledcomm) and interface to JoeySat satellite SOCAN bus (OneWeb/Eutelsat).

The registered radiation is processed and analyzed along the satellite orbit with particle-type resolving power [3-5]. Total and partial particle fluxes (Fig. 2) and dose rates are accurately produced in wide range of radiation field intensity. Detailed time-stamped data (Fig. 2a,b) are produced for further physics analysis. In the data shown, the large spikes observed on the first hours correspond to the satellite crossings of the polar horns. Distinct variations

are observed according to particle type with specific correlation to orbit and time. The proton component is closely correlated to the storm onset period. Other components – electrons, low-energy gamma rays and X rays (not shown) – exhibit partly overlapping and also distinct orbit-time dependence. Corresponding results are produced for particle dose rates (total, partial), deposited energy distributions, linear-energy-transfer (LET) spectra and directional fluxes. The derived data products are evaluated also along the satellite orbit. Fig. 2c,d shows results of particle flux (all particles) over several day periods prior and after a geomagnetic storm. The evaluated quantity (particle flux, all particles) spans many, nearly 6, orders of magnitude (displayed by the color bar, in log scale). Large gradients and dynamic changes are observed over the specific orbit-time patterns. Systematic and extensive results including post-processing physics evaluation will be presented over the satellite varying orbit (600 km, 1200 km, transfer intervals) and periods of solar-geomagnetic activity.

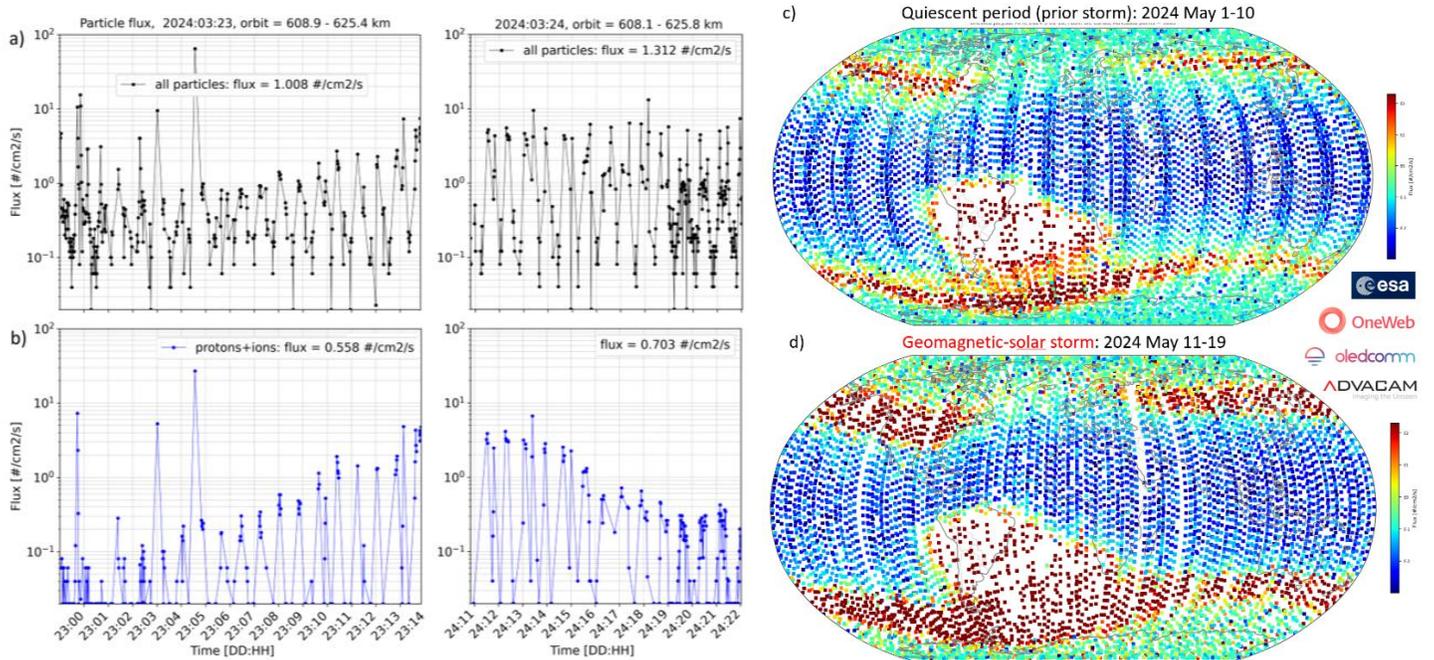


Figure 2: (left panel) Time dependence of particle flux (displayed in log scale) of space radiation measured by Timepix3 in LEO orbit at 600 km onboard the JoeySat OneWeb satellite: a) all particles, b) protons. Data are given for a 14-hour interval on 23 March 2024 (left) and an 11-hour interval on 24 March (middle) 2024. (right panel) Earth maps of particle flux (a) prior and (b) during the 11 May 2024 solar storm. Particle flux data are displayed by the color bar (log scale) for all particles in log scale (color bar) acquired in interval of 9 days: (c) 1-10 May 2024 and (d) 11-19 May 2024.

Acknowledgments:

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