The detection of ultra-relativistic electrons in low Earth orbit by the LYRA instrument on board the PROBA2 satellite

A.C. Katsiyannis*(1), M. Dominique(1), V. Pierrard(2), G. Lopez Rosson(2)
(1) Solar Influences Data Center, Royal Observatory of Belgium, Avenue Circulaire -3- Ringlaan, B-1180, Belgium.
(2) Belgian Institute for Space Aeronomie, Avenue Circulaire -3- Ringlaan, B-1180, Belgium.
e-mail: Katsiyannis@oma.be, website: http://proba2.oma.be/about/LYRA

Abstract

The Large Yield RAdiometer (LYRA) is an ultraviolet radiometer on-board ESA's PROBA2 micro-satellite. Since its 2009 launch it observes the Sun in four different pass-bands, chosen for their relevance to solar physics, aeronomy and space weather. Flying on an altitude of 725 km, LYRA proved to be an excellent flare monitor and is involved in the analysis of the atmospheric composition of the Earth.

We present the analysis of energetic particles, indirectly detected by LYRA in the form of microbursts of <10 ms, with a phenomenon duration of 100 s. Combining Energetic Particle Telescope (EPT) observations with LYRA data for an overlapping period of time, we identified these particles as electrons with an energy range of 2 to 8 MeV. The observed events are strongly correlated to geo-magnetic activity and appear even during modest disturbances. Additionally, they are well confined geographically within the L=4-6 McIlwain zones, and they show prominent dawn-dusk and day-night asymmetries. A combination of wave-particle interaction mechanisms is proposed as a starting point towards a full quantitative explanation.

1 The LYRA detections

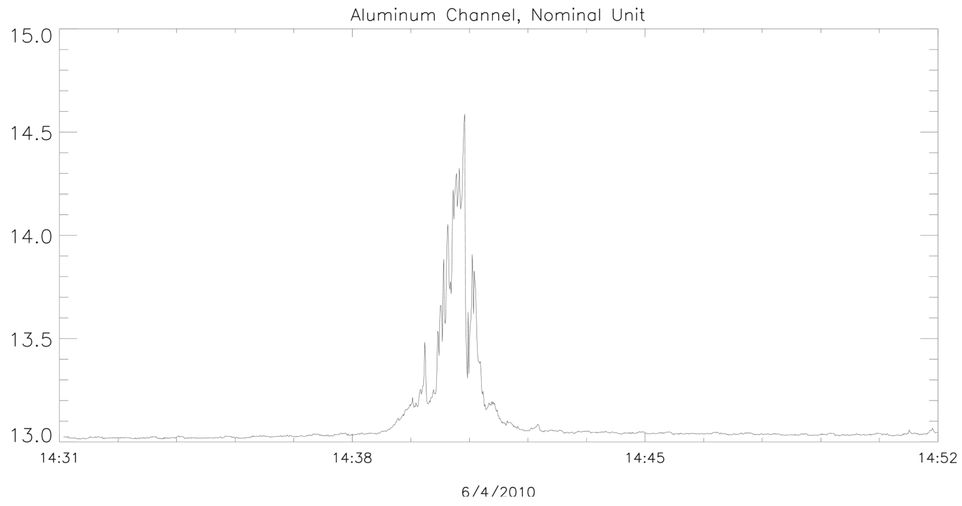

Figure 1: An example of a disturbance as it appears on the Aluminum channel of LYRA/PROBA2.

2 Disturbances vs Ap Index

The authors correlated the 3-hour, geomagnetic Ap index with the likelihood of detection of a disturbancy for the period of April 2010 to December 2014 and found as strong correlation with the a_p Index. Figure 2 illustrates the dependance between the likelihood of detection of those events with the geomagnetic activity on Earth's surface. The wide spread of points for high a_p values can be explained by the small numbers of samples used for those points. The drop in the likelihood observed for $a_p = 180$ is due to the detections lost as the signal from the events is much weaker than the signal from solar flares (during geomagnetic storms the possibility of solar flares is also very high).

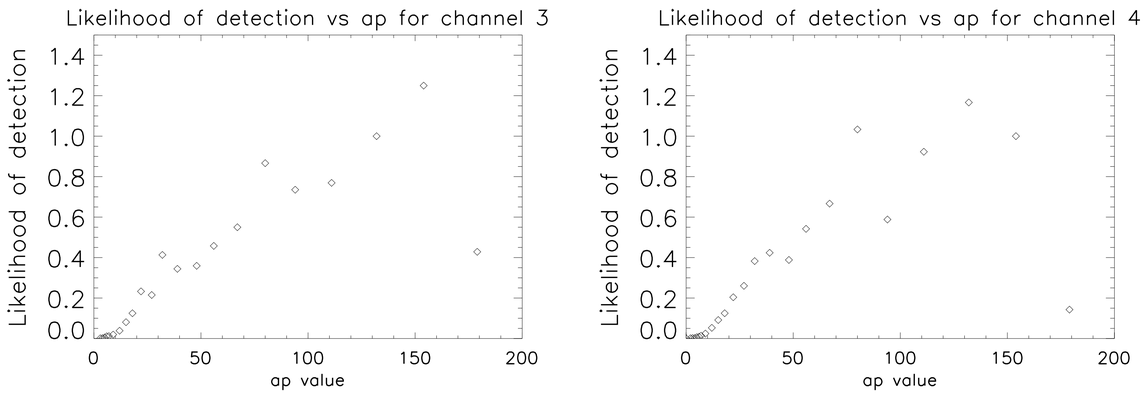

Figure 2 The likelihood of occurrence of a disturbance in the Aluminum (left) and Zirconium (right) channels of LYRA versus the Ap index for the same 3-hour window.

3 Geographical distribution of the disturbances

An independent confirmation of the correlation between the disturbances observed by LYRA and Earth's magnetic activity can be achieved by plotting the positions of the satellite when the detections were obtained.

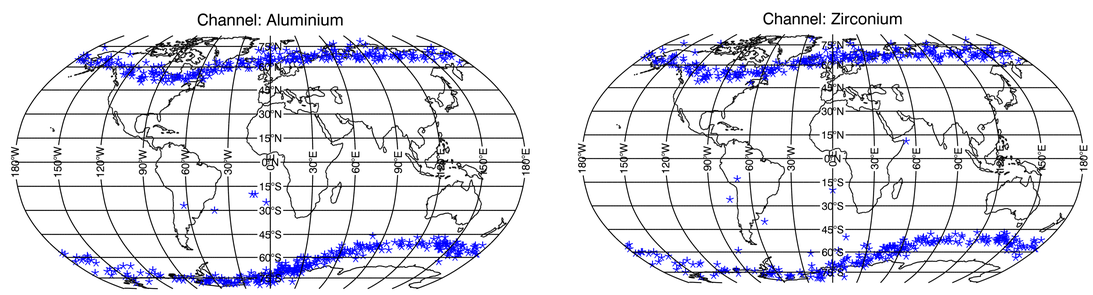

Figure 3. Maps of the geographical locations of the satellite during all the detections that occurred between April 2010 and December 2014. Left is channel 3 (Al) and right is channel 4 (Zr).

4 The LYRA detections in magnetic coordinates

Since this phenomenon is obviously magnetic, the Magnetic Local Time (MLT) and invariant latitude (Λ) of the detections for both LYRA channels was calculated and plotted in polar coordinates (see Figure 4). As obvious from the plot, the detections are divided to two different populations, which suggests a different physical mechanism for each population.

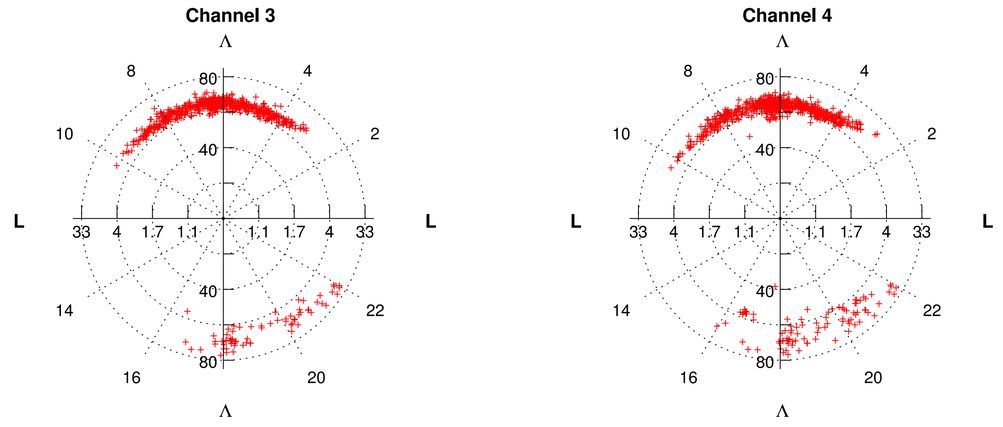

Figure 4. A polar map of the detections in the MLT vs Λ coordinates.

5 The EPT fluxes

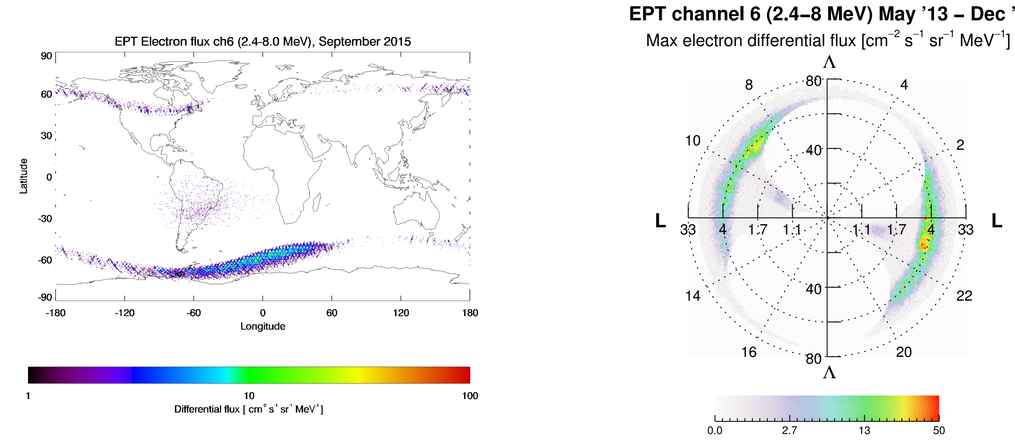

Figure 5. Map of EPT detections of channel 6 for September 2015. Channel 6 is sensitive to electrons of the 2.4-8 MeV energy range. The map on the left is on geographical coordinates, while on the right the Magnetic Local Time (MLT) versus the Invariant Latitude (Λ) in polar coordinates.

ESA's PROBA-V mission is dedicated to Earth's observation and in-situ measurements of space weather. EPT is an instrument designed for the detection of barionic charged particles of various energy ranges. Figure 5a shows a map of the detections made by channel 6 of EPT that is sensitive to electrons of energy range 2.4-8 MeV. This map is in agreement with the maps of Figure 3 with the only exception of the detections of the South Atlantic Anomaly (SAA) made by EPT. As such, it confirms the identification of the reported observations as electrons of the range of 2.4-8 MeV. The lower part of the range (ie 2.4 MeV) is a conservative estimation as the detections of the SAA made by EPT do not have LYRA counterparts and lower energy particles are know to penetrate the atmosphere in the SAA area more easily. Thus the energies of the electrons detected by LYRA are probably significantly higher than 2.4 MeV.

Bibliography: A.C. Katsiyannis et al., J. Space Weather Space Clim. 2018, 8, A01