Cosmic rays and high energetic particles at Venus: Analysis of triggered pulse events detected by Akatsuki/LAC

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Cosmic rays and high energetic particles from astrophysical sources outside the solar system are an important contributor to planetary radiation environments. On Venus, cosmic rays cause ionization in the atmosphere, and this effect is considered as a dominant ionization source. We have known that some bodies within the solar system shine to X-rays, and in the case of Venus, charge exchange interactions between highly charged ions in the solar wind and the Venusian atmosphere would be one of the X-ray sources. However, our understanding of the environment of the high energetic particles around the Venus orbit is quite limited. Therefore, the detection of cosmic rays by the instrument onboard Venus orbiter provides us precious information.

Lightning and Airglow Camera (LAC), which is one of the onboard instruments of Akatsuki, is a new type of lightning detector equipping 8×8 pixels (16×16 mm) APD (avalanche photodiode) detector and enables detecting optical lightning flash with 30 kHz sampling rate. LAC adopts the pre-trigger sampling method to record pulsed signals by using half of 64 pixels. Despite no detection of flashes attributable to lightning, LAC recorded over 500 cosmic ray events during the 49 observation sessions of LAC from August 2016 to January 2020. The estimated average event rate of LAC was 0.44 events min^{-1}. Considering the director size, the previous detection report of Pioneer Venus star sensor [Burucki et al., 1981; 1991] was 38 (or 12 during quiet sun) events min^{-1}, and this low event rate might be caused by the LAC shielding is less susceptible to cosmic ray triggers. The output peak values of the pulsed signals have covered almost from 6 digits to 80 digits, and intense events having large peak value (>80 digits) seem to be randomly recorded. Since the energy of cosmic rays is high enough to excite photoelectron inside the detector, this wide range of the peak values can be caused by the incidence angle of cosmic rays to the face of the APD detector. Under this assumption, the possibility of the incidence angle (θi) is proportional to sin2 θi when we expect the isotropic cosmic ray incidence, where θi is the angle measured from the normal vector of the sensor plane. We conducted a statistical analysis with 501 recorded cosmic ray events and found that detected events roughly follow the assumed isotropic incidence relation. However, there was minor disagreement, and one of the possible explanations is that we should consider the energy distribution of cosmic rays and/or the complex structure of LAC shielding. On the other hand, we could find the event rate has some dependence on Venus–Spacecraft distance, and our result indicates a slightly higher rate of around 6000 km and almost monotonical increase of event rate from 9000 to 12000 km from the Venus surface. If they are some high energetic particles from the sun, then these observation distances correspond to the refraction angle of ~30° and 24°–19°. Hoever, we currently do not have any plausible explanation for this.

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