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Diffusion of relativistic runaway electron avalanches

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Diffusion of relativistic runaway electron avalanches

One of the unsolved problems in atmospheric physics is the construction of a model of Terrestrial Gamma-ray Flashes (TGFs). This phenomenon was first discovered in 1994 by Compton Gamma Ray Observatory [1] and was observed by other space gamma-ray observatories such as Fermi [2], which were created for observing gamma radiation from astrophysical sources. It has been established that avalanches of relativistic runaway electrons avalanches (RREA) accelerated by an electric field in thunderclouds are the sources of these bursts [3]. However, research shows that the existence of RREA is not sufficient to generate a TGF [4]. In an attempt to settle this issue a model of relativistic feedback mechanism was suggested by Joseph Dwyer. The Dwyer model does not take into account diffusion of RREAs and the finite transverse size of the accelerating region. RREAs of new generations resulting from feedback may be created outside the acceleration region, which may lead to a decrease in the number of new avalanches and an increase in the requirements for self-sustaining RREA production by the feedback.

In this work the transverse propagation of avalanches was described using a modified two-dimensional diffusion equation. A correction to the criterion for self-sustaining production of RREAs was obtained:

$\Gamma_d = \Gamma \cdot \exp(-\left(\frac{2.403}{R}\right)^2 D\tau)$

Here Γ is a feedback coefficient without correction, R is the transverse size of the accelerating area and $D\tau$ is the diffusion coefficient multiplied by the average time of creation of new generation. Monte Carlo simulation using GEANT4 was also performed to calculate the correction to feedback coefficient. For example, for an air density corresponding to an altitude of 10 km above sea level for an acceleration zone with a size of 400 m in the longitudinal direction and 500 m in the transverse direction $\Gamma_d \approx 0.99 \cdot \Gamma$. It can be seen that taking into account the transverse size does not make a significant contribution to the feedback coefficient and therefore almost does not distort the criterion for self-sustaining RREA production.

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