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Terrestrial Gamma-Ray Flashes Initiated by Positive Lightning Leaders

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1. Extended Abstract

Terrestrial gamma ray flashes (TGFs) are powerful, sub-millisecond bursts of gamma rays that originate from thunderstorms [1]. TGFs are known to be associated with +IC lightning, occurring when the upward negative leaders travel between the negative and positive charge centers. One model for explaining TGFs involves the relativistic feedback discharge mechanism initiated by negative lightning leaders. During a relativistic feedback discharge, the production of relativistic runaway electron avalanches (RREAs) [2] becomes self-sustaining via a feedback mechanism caused by backward propagating relativistic positrons and backscattered x-rays [3, 4, 5]. As a negative lightning leader moves up through the thundercloud electric field, it enhances the electric field in front of it, sometimes pushing the system over the feedback threshold, above which the number of RREAs grows exponentially. The numbers of runaway electrons and emitted gamma rays then increase until the electric field collapses due to the large amount of ionization, resulting in a TGF. Simulations of relativistic feedback discharges initiated by negative leaders have been able to account for several TGF properties including the TGF pulse widths, gamma-ray fluences and the size and shapes of the multiple pulses that appear in some TGFs.

Recent ground-based observations of TGFs associated with upward positive leaders show that not all TGFs are associated with negative leaders [6]. It is possible that positive leaders enhance the electric fields, pushing the systems over the feedback thresholds, similar to negative leaders, resulting in TGFs. Unlike the case for negative leaders, for positive leaders the runaway electrons are steered towards the leader tip, resulting in larger fluences of runaway electrons at the source. In addition, for positive leaders, most of the discharge current resulting from the runaway electrons and their ionization is located near the leader tip, allowing the TGF to inject current into the lightning channel. In this presentation, we will present TGF simulations of relativistic feedback discharges initiated by positive lightning leaders in thunderclouds, and we will compare these simulations with space-based and ground-based TGF observations.

2. References

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