

Modeling Terrestrial Gamma-ray Flashes

Joseph R. Dwyer

Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne FL

Terrestrial gamma-ray flashes (TGFs) are intense, multi-MeV bursts of gamma-rays that originate from within the Earth's atmosphere [Fishman et al., 1994]. Because gamma-rays experience rapid attenuation in the air, it was initially hypothesized that the source of TGFs was sprites. However, it was later found by RHESSI that most TGFs originate from thundercloud altitudes, 15 - 21 km, and not from sprites [Dwyer and Smith, 2005; Cummer et al., 2005; Carlson et al., 2007]. Indeed, it is now established that many TGFs are associated with positive intra-cloud lightning and occur when an upward leader is propagating between negative and positive charge regions within the cloud [Stanley et al., 2006; Lu et al., 2010; Shao et al., 2010; Cummer et al., 2011].

There are currently two valuable mechanisms for explaining TGFs [Dwyer, 2008]: the relativistic feedback mechanism and the lightning leader mechanism. For relativistic feedback, relativistic runaway electron avalanches become self-sustaining through the generation of backward propagating runaway positrons and back-scattered x-rays [Dwyer, 2003; 2007]. For lightning leader mechanism, relativistic runaway electron avalanches are seed by lightning leaders, presumably via the cold runaway electron mechanism [Dwyer, 2004; Moss et al., 2006; Dwyer, 2008; Carlson et al., 2010; Dwyer et al., 2010].

TGFs have recently been modeled by the relativistic feedback discharge (RFD) model [Dwyer 2012]. This model includes the production, propagation, diffusion and avalanche multiplication of runaway electrons, the production and propagation of x-rays and gamma-rays, and the production, propagation and annihilation of runaway positrons. The large-scale electric fields are calculated self-consistently from the charge motion of the drifting low-energy electrons and ions, produced from the ionization of air by the runaway electrons. Simulation results show that when relativistic feedback is considered, bright gamma-ray flashes are a natural consequence of upward +IC lightning propagating in large-scale thundercloud fields. Furthermore, these flashes have the same time structures, including both single and multi-pulses, intensities, angular distributions, current-moments, and energy spectra as terrestrial gamma-ray flashes (TGFs), and produce large current moments that should be observable in radio waves.

A new TGF observed at ground level is also reported [Dwyer et al., 2012]. It was detected by the 19-station Thunderstorm Energetic Radiation Array (TERA) at the University of Florida/Florida Tech International Center for Lightning Research and Testing (ICLRT) at Camp Blanding, Florida. The gamma-ray flash, which had a duration of 52.7 μ s, occurred on June 30, 2009 during a natural negative cloud-to-ground lightning return stroke, 191 μ s after the start of the stroke. This event is the first definitive association of a gamma-ray flash with natural CG lightning and is among the most direct links to a specific lightning process so far.

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