

# A New Type of Transient Luminous Events Produced by Terrestrial Gamma-ray Flashes

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Discovered in 1994 by the Burst and Transient Source Experiment (BATSE) detector aboard the Compton Gamma-Ray Observatory [Fishman *et al.*, Science, 264, 1313, 1994], Terrestrial Gamma-ray Flashes (TGFs) are high-energy photon bursts originating from the Earth's atmosphere in association with thunderstorm activities. Since their discovery, TGFs have also been observed by the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) [Smith *et al.*, Science, 307, 1085, 2005], the Fermi Gamma-ray Space Telescope [Briggs *et al.*, JGR, 115, A07323, 2010], and the Astrorivelatore Gamma a Immagini Leggero (AGILE) satellite [Marisaldi *et al.*, JGR, 115, A00E13, 2010]. Space-borne measurements have revealed some temporal and spectral features of TGFs: typically lasting from fractions of to a few milliseconds, having a fluence of fractions of photons/cm<sup>2</sup>, and exhibiting a hard energy spectra extending up to a few tens of MeVs [Dwyer *et al.*, Space Sci. Rev., 173, 133, 2012]. Moreover, detailed analyses of radio emissions have pointed out the close correlation between TGFs and the initial development stages of normal polarity intra-cloud lightning that transports negative charge upward (+IC) [e.g., Lu *et al.*, GRL, 37, L11806, 2010; JGR, 116, A03316, 2011].

In this work, we show that, while TGFs pass through the atmosphere, the large quantities of energetic electrons knocked out during collisions of gamma-rays with air molecules can generate significant amount of excited species of neutral and ionized nitrogen molecules, thereby leading to production of a new type of transient luminous events (TLEs). The spectroscopic and morphological features of this predicted luminous phenomenon have been theoretically quantified in the framework of Monte Carlo simulations. Considering the measurability of this type of events and its close relation with TGFs, corresponding measurements would provide a novel perspective to investigate TGFs, as well as lightning discharges that produce them.