Charge Motion and Altitude of Terrestrial Gamma-Ray Flashes

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Abstract

We describe recent coordinated observations of radio emissions and terrestrial gamma ray flashes (TGFs) that provide new insight into the detailed processes that generate this thunderstorm-driven high-energy radiation. These observations include lightning mapping array measurements of the structure and development of a lightning flash that produced a TGF, and high time resolution observations of the specific lightning processes associated with three TGFs.

1. Summary

Radio emissions continue to provide a unique view into the electrodynamics of terrestrial gamma-ray flash (TGF) production. It is generally agreed that most and perhaps all TGFs are produced during the early, upward-propagating leader stage of normal polarity IC lightning flashes [1, 2]. Observations have shown that at least some TGFs are effectively simultaneous with a distinct low frequency pulse, indicating production of that pulse by the TGF-generating electron acceleration process itself [3]. Additional observations of an anti-correlation between the TGF-radio association rate and TGF duration [4], and detailed comparisons of simulation and measurement [5] strongly support this picture.

A subset of TGF events detected over the past several years by the GBM instrument on the Fermi satellite, and also measured by our network of low frequency radio sensors, produced radio emissions that are sufficiently distinct to estimate the TGF source altitude from multiple ground-ionosphere reflections. By combining the gamma ray measurements, radio measurements, and Monte Carlo modeling, the self-consistency of the source altitude, gamma ray flux, and radio emission duration and magnitude can be rigorously and quantitatively tested in the context of TGF generation theories. These TGFs are also sufficiently close to the radio sensors to reliably measure the charge motion in the upward leader that occurs before the gamma ray production, which is a critical parameter in TGF modeling. We will present several of these observations and associated analysis, and attempt to draw some firm conclusions about the physics behind TGFs.

2. References

1. Shao, X.-M., T. Hamlin, and D. M. Smith, A closer examination of terrestrial gamma-ray flash-related lightning processes, *J. Geophys. Res*., **115**, 2010, A00E30.

2. Lu, G., R. J. Blakeslee, J. Li, D. M. Smith, X.-M. Shao, E. W. McCaul, D. E. Buechler, H. J. Christian, J. M. Hall, and S. A. Cummer, Lightning mapping observation of a terrestrial gamma-ray flash, *Geophys. Res. Lett*., **37**, 2010, L11806.

3. Cummer, S. A., G. Lu, M. S. Briggs, V. Connaughton, S. Xiong, G. J. Fishman, and J. R. Dwyer, The lightning-TGF relationship on microsecond timescales, Geophys. Res. Lett., **38**, 2011, L14810.

4. Connaughton, V., et al., Associations between Fermi Gamma-ray Burst Monitor terrestrial gamma ray flashes and sferics from the World Wide Lightning Location Network, *J. Geophys. Res*., **115**, , 2010, A12307.

5. Dwyer, J. R. and S. A. Cummer, Radio emissions from terrestrial gamma-ray flashes, *J. Geophys. Res*., **118**, doi:10.1002/jgra.50188.

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