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Ground-Based Observations of Terrestrial Gamma Ray Flashes Associated with Downward-Directed Lightning Leaders

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Terrestrial gamma-ray flashes (TGFs) are bursts of gamma-rays initiated in the Earth's atmosphere. TGFs were serendipitously first observed over twenty years ago by the BATSE gamma ray satellite experiment. Since then, several satellite experiments have shown that TGFs are produced in the upward negative breakdown stage at the start of intracloud lightning discharges. In this talk, we present the ground-based first observation of TGFs, and show that TGFs are also produced by the downward negative breakdown occurring at the beginning of negative cloud-to-ground flashes.

The Terrestrial gamma-ray flashes discussed in this work were detected between 2014-2017 at ground level by the Telescope Array surface detector (TASD) together with Lightning Mapping Array (LMA) and the slow electric field antenna (SA).
The TASD detector is a ~700~km^2 ultra high energy cosmic ray detector in the southwestern desert of Utah. It is comprised of 507 (3~m^2) plastic scintillator detectors on a 1.2~km square grid. The LMA detector, a three-dimensional total lightning location system, is comprised of nine stations located within and around the array. The slow electric field antenna records the electric field change in lightning discharges.

The observed Gamma ray showers were detected in the first 1-2 ms of downward negative breakdown prior to cloud-to-ground lightning strikes. The shower sources were observed by the LMA detector at XSaltitudes of a few kilometers or less above ground level. The detected energetic burst showers have a footprint on the ground typically $\sim$ 3–5~km in diameter. The bursts comprise of several (2-5) individual pulses, each of which have a span of a few to tens of microseconds and an overall duration of several hundred microseconds. Using a forward-beamed cone of half-angle of 16^{circle}, GEANT simulation studies indicate that the showers are consistent with gamma rays of $10^{12} - 10^{14}$ primary photons. We hypothesize that the observed terrestrial gamma-ray flashes are similar to those detected by satellites, but that the ground-based observations are closer to the source and therefore are able to observe weaker sources and report on the structure of the temporal distribution at the source. This result and future studies will enable us to better identify and constrain the mechanisms of downward TGF production.

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