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# STUDYING THE OPTICAL EMISSION OF LIGHTNING ASSOCIATED WITH TERRESTRIAL GAMMA RAY FLASHES

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## ABSTRACT

Terrestrial gamma-ray flashes (TGF) are emissions of gamma rays in the earth's atmosphere during thunderstorms. In this investigation, we delve into the optical emissions of lightning linked with TGF's. The TGF's are observed by the Telescope Array Surface Detector (TASD) in conjunction with lightning detectors including an INTF, a fast antenna, a high-speed camera, and a slitless spectroscopic system. This study will present preliminary findings from a photometer array, installed at the site in 2023, that provides a higher timing resolution, offering insights into optical emissions from atmospheric electrical discharge processes in the ultraviolet and infrared spectra.

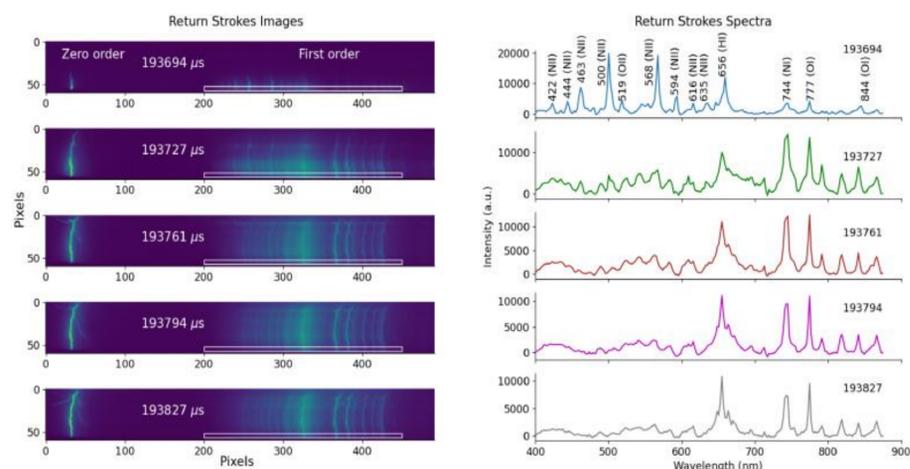
## INSTRUMENTATION



**Figure 1:** The Telescope Array Surface Detector together with the suit of lightning instruments installed at the TA site including the spectroscopic system and photometer array from which the data discussed in this work is collected.

## SPECTROSCOPY

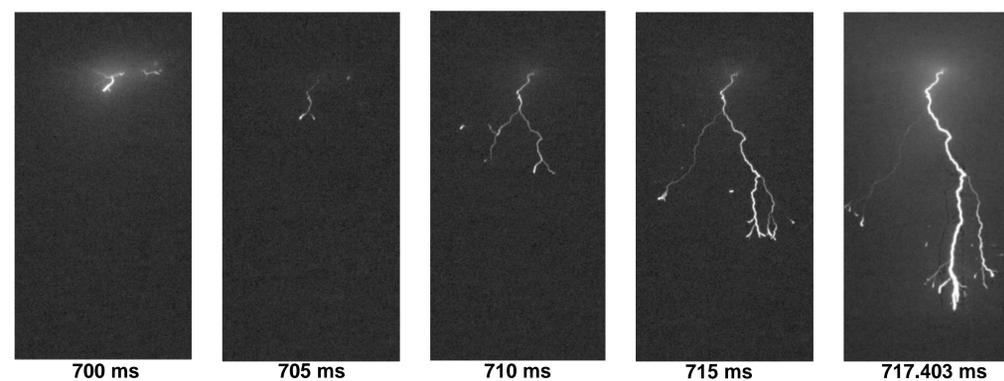
One way to analyze the optical component associated with TGFs is to study the spectra of the lightning associated with a TGF. Lightning spectroscopy is one of the most powerful tools in lightning research since this method allows us to identify the chemical components inside the channel and measure quantitative physical features of the optical emissions.



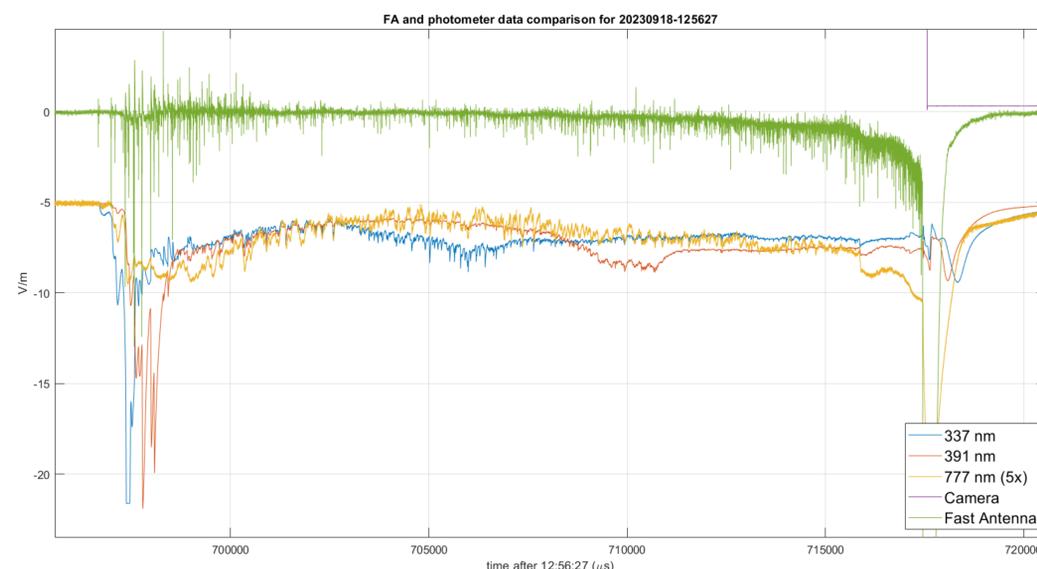
**Figure 2:** Time-resolved spectra of the return stroke that produced TGFs. The left panel shows a sequence of the first five images of the return stroke, and white rectangles represent the trimmed areas from which we extracted the spectra. The right panel displays the time-resolved return stroke spectra in chronological order from top to bottom. The range of spectra is 400-900 nm

## PHOTOMETER ARRAY

To study the ultraviolet emissions of lightning associated with TGF's, a photometer array was developed and installed at the TASD site. The photometer array is designed to capture lightning in the UV (337 and 391 nm) and infrared (777 nm) emissions. The photometer array was digitized at a sampling rate of 30 MS/s and was triggered by the Phantom v2012 high-speed camera (1). The system incorporated the ability to remotely adjust the circuitry gain, allowing us to change the sensitivity of the instrument. Initially, we observed only return stroke emissions but after making changes to the gain we were able to observe our first Initial Breakdown Pulse (IBP). This work investigates lightning events observed in September 2023 by the suite of lightning detectors at the TASD site.



**Figure 3:** Lightning images captured by Phantom v2012 high speed video camera from start of event to return stroke.



**Figure 4:** The Fast Antenna and the photometer data for the observed lightning flash from the beginning to the time of the first return stroke.

## SUMMARY AND OUTLOOK

We present the first observation of the IBP in the ultraviolet emission. We continue to investigate other events observed in the same storm. A clearer signal below the cloud will allow us to investigate the streamer to leader transition in lightning phenomena. We will also continue to use this instrument to attempt to capture lightning events associated with TGF this year. This will allow us to understand the TGF initiation mechanism.

## REFERENCES:

(1) Abbasi, R. U., Saba, M. M. F., Belz, J. W., Krehbiel, P. R., Rison, W., Kieu, N., et al. (2023). First high-speed video camera observations of a lightning flash associated with a downward terrestrial gamma-ray flash. *Geophysical Research Letters*, 50, e2023GL102958