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Optical Observations of Terrestrial Gamma-ray Flashes

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Research Mentor

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Project Summary

Terrestrial Gamma-ray Flashes (TGFs) were discovered in the early 1990's in Huntsville with the Burst and Transient Source Experiment (BATSE) on NASA's Compton Gamma-ray Observatory. TGFs are very brief (sub-ms) and extremely intense pulses of gamma rays emitted by thunderstorms, closely associated with intra-cloud lightning. Electric fields in thunderstorms accelerate free electrons upward. Electrons that gain sufficient energy collide with atomic electrons and generate additional free electrons, which repeat the process, creating an upward cascade. The energetic electrons, when they pass near nuclei, emit gamma rays via bremsstrahlung, thereby producing TGFs.

Huntsville TGF research has continued with the Gamma-ray Burst Monitor (GBM) on NASA's Fermi Space Telescope, which was launched in 2008 and continues operation. We have related TGFs to lightning using the radio waves that are emitted by lightning. So far we have extremely few gamma-ray and optical co-observations of TGFs because the gamma-ray and optical instruments have small fields of view and were made by satellites in different orbits so that the same thunderstorm was rarely simultaneously observed. We found one TGF that was co-observed in gamma-rays / optical by GBM and NASA's Lignting Imaging Sensor (LIS). Several other TGFs were co-observed by the solar gamma-ray instrument Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) and LIS. For the TGF detected by both GBM and LIS, the optical emission appears after the gamma-ray emission. This is difficult to understand since the lightning likely initiated the TGF.

The next generation weather satellite GOES-R is scheduled for launch on 2016 November 16th. GOES-R will include the Geostationary Lightning Mapper (GLM) instrument, which will for the first time detect optical flashes from lightning over a large area. Instead of having very rare co-observations of TGFs, nearly every TGF detected by GBM in the Western hemisphere will be observed with GLM, so that by August we will have approximately 100 co-observations. This will provide us with an unprecedented opportunity to study the relationships between the gamma-ray, radio and optical signals emitted by TGFs and their associated lightning. We can answer questions such as: Do all TGFs have optical flashes? Does the optical emission occur simultaneous to, or after the gamma-ray emission? How many flashes are seen in conjunctions with TGFs?

The mentor will adapt an existing program that correlates GBM TGF data with radio data to additionally correlate with GLM optical data. Common events are identified by positional and temporal coincidence. The student will assist by running the program, creating a sample of co-observed events, and analyzing the characteristics of that sample.

Student Prerequisites

The successful applicant will have a good academic record and should have taken physics classes. While not essential, experience with computer programming is highly desirable.

Student Duties

The student will download data files and run the analysis program to generate a sample of co-observed TGFs. The student will analyze the characteristics of the sample, e.g., What fraction of TGFs of have optical signals? How many optical signals? Timing relations between the signals? Using methods such as scatter plots, the student will search for patterns in the sample. With guidance from the mentor, the student will apply statistical tests to determine whether possible patterns are statistically significant or could be due to chance.

The student will learn exploratory data analysis and selected statistical tests. They will learn programming for data analysis, graphing data, and the science of TGFs and lightning.

The GBM TGF collaboration holds bi-weekly telecons; during the course of the project the student will have the opportunity to make several informal progress reports to these meetings. Other Huntsville GBM Team research scientists and graduate student working on TGFs will be available for assistance. The telecons and group discussions will expose the student to additional perspectives. The end result, due by the end of the 12 weeks, will be a summary report of the research results.

Mentor Supervision and Interaction

The Mentor (Dr. Briggs) leads the GBM TGF research program, a collaboration of GBM Team members in Huntsville, and scientists at other US and international universities. During the first week of the project the student and mentor will work together approximately 3 hours per day to show the student how to access the data and to guide the student in the exploration of the data. When the project is past the initial setup, the student will work more independently, consulting with the mentor approximately 30 minutes daily, with one longer weekly meeting. Office space for the student will be provided in Cramer Hall, near to the mentor and other GBM Team members. If the mentor should be absent for several days or a week to attend a conference, other GBM team scientists will be available as substitute mentors (e.g., UAH researcher Dr. Jenke or UAH postdoctoral researchers Drs. Cramer and Mailyan).