TOTO-Cheyenne: Ionizing Radiation from Thunderstorms on Cheyenne Mountain

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BACKGROUND:

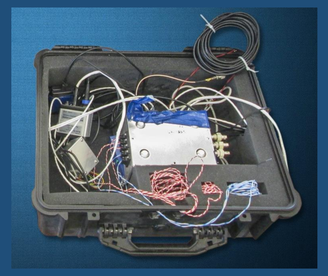
- Year 2 of study of high-energy radiation from thunderstorms in Colorado
- Put detector up close and personal to the charge layers, on top of isolated mountain
- Cheyenne Mountain is 9570 ft (2917 m), southern end of extended mountain range
- Radiation detector at base of radio towers at 9440 ft (2877 m), cinder block building
- High speed camera watching from afar to correlate radiation data with actual strike
- Camera on mountain sees lightning and changes color (pink) with close strike

2019 RECAP

- 23 days of storms during summer 2019 (1 Jun to 1 Oct)
- 158 total NLDN strikes within 5 km, 141 -CG, 17 +CG
- 74 total camera strikes: 20 strikes within 5 km of detector
- 1 positive strike at 0.14 km away on 22 Jul at 22:17:57 Z
  - No excess radiation recorded in detector on mountain
  - Camera already full from local storms that day, no data

DETECTOR:

- Two 3x3” cylindrical NaI (Tl) crystals (with Bridgeport)
- Two 2x2x2” plastic scintillator cubes (with Bridgeport)
- One 1x1x1” plastic cube (readout by a silicon PMT (SiPM) and Bridgeport)
- Beagle Bone Black running Ubuntu Linux 14.04
- Pressure, temperature sensors, Trimble Copernicus II GPS
- Housekeeping data to SQLite database every second
- Effective energy range of 100 keV to 12 MeV
- Pulse-per-second (PPS) from GPS to all modules
- Records internal oscillator time at arrival of PPS
- Beagle Bone to USB hub, readout few per second
- System clock time plus PPS time allows the signals from all 5 detectors to be time-aligned (1 ms accuracy) to look for coincident events



HIGH SPEED CAMERA:

- Phantom V2011 - 1 MP digital camera
  - Widescreen CMOS sensor up to 22 GP/sec at full resolution of 1280 x 800, > 22,000 fps
  - Used 60,000-67,000 fps for field of view
  - Exposure 4 μs every ~15 μs
  - Auto-triggering feature (set and forget)
  - Maximum of 20 events per day (without reset)
- Located on 5th floor of Fairchild Hall, facing south
- Approximately 18.5 miles (30 km) away from detector
- Time synchronized to GPS (accuracy ~ 5 ns)

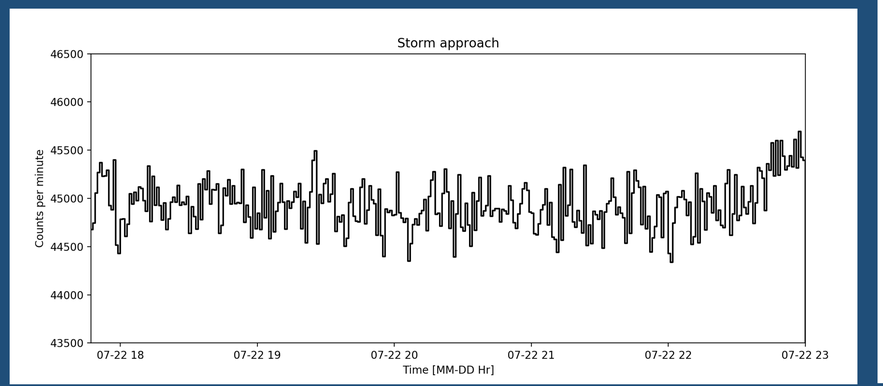


Figure 1: Total background count rate in the five scintillators during the approach of a thunderstorm on 22 July 2019. The time series starts shortly before a strong but distant +CG reported by NLDN at 22:17:57Z (145 kA, 7.4 km away) and ends after a moderate +CG at 22:46:51Z (38 kA, 0.14 km away), when radon washout is visible as an increase in background count rate. No excess counts were detected from the very close +CG. Count rates are dominated by the 3x3” NaI(Tl) detectors.

NLDN positive CG strike list for 22 July 2019

TIME	ms	kA	LAT	LONG	km
22:17:57Z	691	145.2	38.766	-104.944	7.39
22:38:35Z	188	78.6	38.757	-104.921	5.17
22:43:50Z	695	60.6	38.748	-104.909	3.91
22:46:51Z	454	37.9	38.743	-104.866	0.14
22:49:03Z	735	26.7	38.682	-104.950	10.00

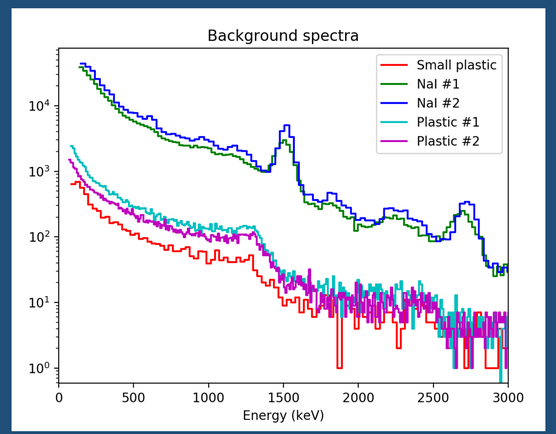


Figure 2: Sample background spectrum in each of the five scintillators. Prominent background lines are visible in the NaI(Tl) detectors at 1460 keV from ^{40}K and 2614 keV from decay of ^{232}Th. Compton back-scatter peaks from the two lines are visible in the plastic scintillators.

Mountain strike (-CG) on 16 July at 21:10:22Z

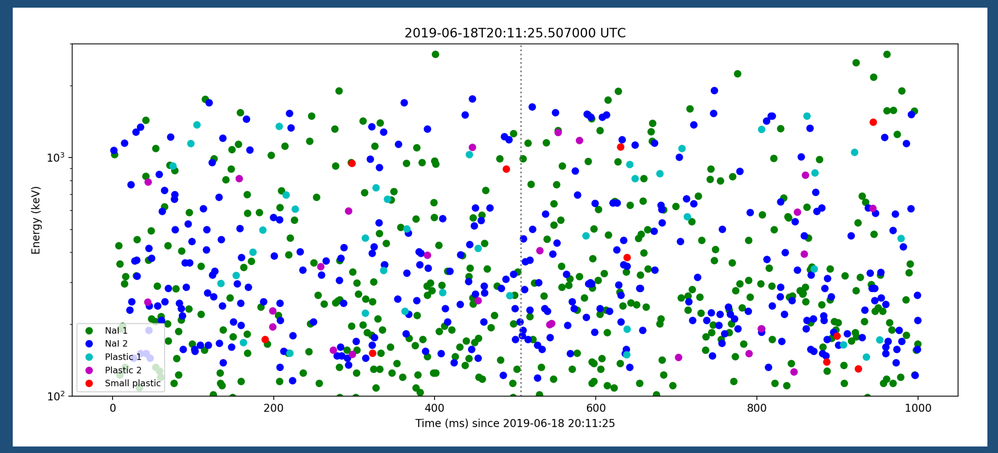


Figure 3: Scatter plot of photon energy as a function of time for events surrounding the 92 kA -CG that struck ~1.8 km away on 18 June 2019 at 20:11:25Z. Events are color-coded by scintillator. No excess events from the approaching stepped leader are visible. Attenuation of hard X-rays is expected in the intervening atmosphere and materials of the building in which the detectors are housed.