# Common, Long-Duration Gamma-ray Glows in Thunderclouds

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γ -ray glows have been observed for the first time as a common, long duration phenomenon from the tops of thunderclouds. The Airborne Detector for Energetic Lightning Emissions (ADELE) observed 12 γ-ray glows during its Summer 2009 flight campaign. Comparing our glows to nearby lightning activity, we show that lightning activity decreases during the onset of a glow. Since glows have a very hard spectrum, with many counts above 5 MeV, they may be evidence of a continual relativistic runaway process with positron feedback. From simulations, we hope to show that some glows are a relativistic avalanche that is most likely downward facing, (opposite of the normal TGF direction) between the upper positive and the screening layer, with the bremsstrahlung from the upward positron beam producing the hard spectrum of the glow.

## 1. Introduction to Glows

Long duration γ-ray glows are continual high-energy emission that is seen coming from thunderclouds. They have been observed by balloon [1], plane [2], and from the ground [3]. Glows last anywhere from a few seconds to several minutes [4] and have been associated with both storm cells active with lightning [2] and those with no lightning [5]. Glows may compete with lightning so as to limit the overall charge in a thunderstorm and could provide a current opposite to the charging current. Glows may constitute evidence that continuous relativistic runaway with feedback limits the total electric field in air [6]. This would support observations that the electric field remains near the runaway threshold [7].

## 2. Data

### 2.1. Instrument

The Airborne Detector for Energetic Lightning Emissions (ADELE) is an array of six γ-ray detectors. It consists of two sets, each containing a NaI crystal (5”X5”) and two plastic scintillators (5”X5” and 1”X1”), with each set having lead shielding on one-half of the detector to get above/below directionality. ADELE flew during the summer of 2009 out of Boulder, Colorado and Melbourne, Florida on a Gulfstream V operated by NCAR. During its nine flights, one terrestrial γ-ray flash (TGF) [8,9] and twelve γ-ray glows were observed.

### 2.2. ADELE’s Glows

The 12 glows varied in length, intensity and spectral hardness. Glows lasted anywhere from a few seconds to several tens of seconds. From simulations we can tell that for most of our glows, the duration appears to be due to plane motion past an active glowing cell. At least one glow appears to be “shorted out” by something, possibly lighting as it has very similar structure to McCarthy and Park’s 1983 glow [2] in which the instantaneous end of the glow was coincident with the plane being struck by lighting. Figure 1 shows the ADELE glow that abruptly ends (top panel) with the McCarthy and Parks glow (bottom panel).

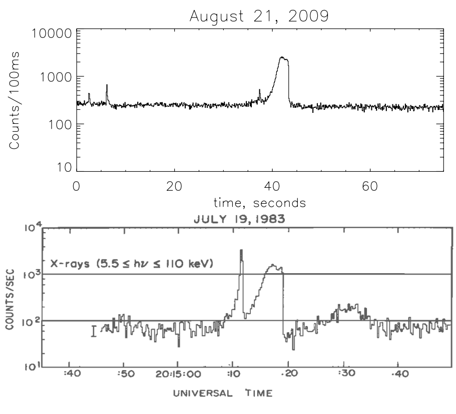


**Figure 1.** [Top panel] Glow seen by ADELE on August 21, 2009. Each data point is a summed 2-second bin >300 keV from both large plastic scintillators. [Bottom panel] Glow seen on July 19, 1983 by McCarthy & Parks [2].

The ADELE glow in Figure 1 is fifty times brighter than any other glow seen by ADELE, and has a much softer spectrum. A possible explanation is that we flew between the upper positive and screening layer directly through the electron beam coming from a downward facing relativistic avalanche.

All glows seen near Florida are related to active lightning cells while the only glow seen near Colorado is associated with no lighting activity.

## 3. Models

Since the spectra of glows are harder than those of a TGF, we believe that one of two possibilities is happening. It could be an upward RREA avalanche with feedback happening very deep in the cloud where the higher plane cannot capture most of the low energy photons that have been scattered away. The other possibility is that it is a downward facing avalanche between the upper positive charge region and the negative shielding layer above the cloud where ADELE is detecting bremsstrahlung directly from the upward directed positron beam. The plane is expected to mostly be above the screening layer and out of the high-field region.

In order to distinguish between different avalanche possibilities, we use a three-stage Monte-Carlo simulation. The first stage consists of the model discussed in Dwyer [10] which models energetic “seed” electrons entering an electric field and correctly shows them undergo avalanche multiplication with backscattered γ-rays or positrons beginning new avalanches (relativistic feedback). This simulation is left in general units of g/cm so using a model of the atmosphere allows us to get altitude distributions for upward/downward facing avalanches.

The next two stages are modelled using GEANT3, a Monte Carlo simulation package used to describe particle interactions in matter. The output spectrum for photons from stage 1 is then inserted into our model of the atmosphere at various source altitudes. The output from stage 2 is recorded at 14 km, the Gulfstream V’s cruising altitude. We also use two different source/detector region geometries: a point source being detected by a large region with the size determined by our data and a large extended size source, comparable to that of a cloud, being detected by a much smaller region.

Stage 3 consists of placing a model of the instrument inside the plane at various radii away from the source at the detector altitude and finding the instrument’s response from inside an airplane as it moves past a glow region.

## 4. Results

Figure 3 shows a comparison of several different models from our original version of our simulations that only involved modelling photons, described above.

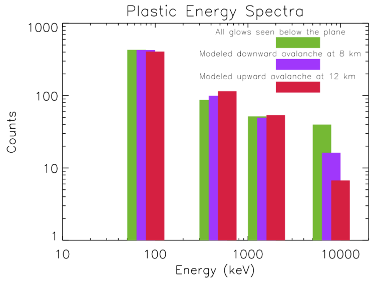


**Figure 3.** Summed spectra for all glows besides the very bright, soft glow on August 21 (green). The spectra of the best-fit model (purple). The spectra of a modelled TGF producing avalanche (red).

The best-fit model, a downward facing avalanche at 8 km, is unphysical because the expected electric field at this altitude should produce an upward avalanche. None of the different models were hard enough which compelled us to include positrons and electrons in all three stages. Electrons are modelled with a 7.2 MeV folding energy with the same angular and height distribution as the photons in stage 1. Positrons are inserted with a 30 MeV folding energy directly up/down along a uniform altitude distribution along the same regions of altitudes from stage 1.

At the writing of this abstract, the simulations have not finished. By the time of the TEA-IS summer school, all simulations will be finished and we will hopefully have some exciting new results!

## 5. References

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