1 Introduction: Sprites and elves

Names for classes of high-altitude optical flashes caused by atmospheric lightning, "sprites" and "elves" may be used to represent as many as two physical causes as they do two sets of phenomena. The electric field which causes heating, ionization, and optical emissions in sprites is caused by the charge moment changes associated with the movement of large thundercloud currents, usually during intense positive cloud-to-ground lightning (Cummer and Inan, 1997). In contrast, the electric field causing heating, ionization, and optical emissions in elves is that of an electromagnetic wave which is launched by, and occurs in proportion to, changing current moments associated with very high frequency currents in the current channel itself (Barrington-Leigh and Inan, 1999). As a result, elves last no longer than 1 ms, while the durations of sprites vary greatly.

1.1 High speed array photometry

Due to their fleeting (<1 ms) existence, elves have been somewhat harder to study optically than sprites, whose lifetime is more or less tied to the exposure time of standard video fields (<17 ms). Nevertheless, a probable white-light signature of elves was discovered in a horizontal array of high-speed (17 Hz) resolution photometers, the "Flyby Eyes" (Inan et al., 1997). By aiming well above the D-region (overlying a strong CO2, this array can be used to unambiguously identify optical emissions (elves) due to a lightning-launched electromagnetic pulse (EMP)). This can be seen in the diagram above, based on the short (<150 s) delay between the return stroke's radio pulse and reception of the first photometric signal from the ionosphere, the optical emission can be located to be hundreds of km from the lightning. This theory considers the shaped mechanism to be one involving only speed-of-light propagation (Barrington-Leigh and Inan, 1999).

1.2 Elves on video?

In recent years, candidate "elves" have also routinely been identified by others based on the existence of diffuse flashes, often preceding or accompanying "sprites," in intensified video recordings. While we have not claimed to identify elves without the photometric evidence described above, these diffuse flashes have seemed only to occur when the photometric signature of elves also occurs.

2 Description of the model

The effect of vertical high-speed lightning currents on the electron population at altitudes up to 100 km is modeled with a finite-difference time domain calculation in cylindrical coordinates, adapted from that used by Veronese et al. (1999). The model solves Maxwell's equations around a vertical symmetry axis, solving for the vertical and radial electric field, azimuthal magnetic field, electron density, and ionization current. Optical emissions in the Ne I first positive band are calculated from the electron density and net electric field, and instrumental response is predicted for a given geometry and field of view. For lightning currents of ~30 kA, mesospheric electric fields are dominated by the strong dissociative attachment of electrons. The upwardly concave shape of the diffuse sprites (Section 3) is due to the ionization process in this region of high electron concentration is theorized to be simple collective strong dissociative attachment of electrons. The quasielectrostatic (QE) field dominates.

3 Model results and observations from high speed video: Discovery of diffuse sprites

The model predicts the appearance of diffuse sprites based on the model's prediction that the electron density will be low enough to allow for quasielectrostatic (QE) field currents. The QE field dominates the quasielectrostatic (QE) field and is the predominant mechanism for producing diffuse sprites. The model also predicts the appearance of diffuse sprites based on the model's prediction that the electron density will be low enough to allow for quasielectrostatic (QE) field currents. The QE field dominates the quasielectrostatic (QE) field and is the predominant mechanism for producing diffuse sprites.

4 Are diffuse sprites common?

When averaged over 2 ms, the observed sprite shown above appears as a diffuse flash occupying a cluster of diffuse features. Comparing this to a normal fast video image of a commonly observed form for sprites suggests that broad upper halves and sometimes seen in sprites may be due to diffuse sprites preceding the onset of streamer formation. When the frames of this high-speed video sequence are averaged over the entire duration of the sprite (~4 ms), still much less than the normal fast video sequence, the diffuse sprite is masked out and is hard to perceive. It is likely that only exceptionally bright cases are these diffuse sprites visible in a normal fast video.

5 What do diffuse sprites look like in a photometer array?

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6 Are elves ever actually seen on video?

Shown to the right is an extremely rare (i.e., bright) case showing an optical signature ascribing an optical signature to a bright dustless vertical cloud field due to high ambient conductivities associated with elves. The waveguide process in this region of high electron concentration is theorized to be an effective channel for a streamer channel field. In recent years, the waveguide process has been observed in three high-speed video fields. In a three-color system, the diffuse region is a transient descending glow with lateral extent on the order of 40-50 km. The model predicts the appearance of diffuse sprites based on the model's prediction that the electron density will be low enough to allow for quasielectrostatic (QE) field currents. The QE field dominates the quasielectrostatic (QE) field and is the predominant mechanism for producing diffuse sprites. The model also predicts the appearance of diffuse sprites based on the model's prediction that the electron density will be low enough to allow for quasielectrostatic (QE) field currents. The QE field dominates the quasielectrostatic (QE) field and is the predominant mechanism for producing diffuse sprites.

7 Why do sprites not always develop streamers?

The development of streamers in sprites is thought to occur due to the presence of very high-frequency currents in the current channel itself. The model predicts the appearance of diffuse sprites based on the model's prediction that the electron density will be low enough to allow for quasielectrostatic (QE) field currents. The QE field dominates the quasielectrostatic (QE) field and is the predominant mechanism for producing diffuse sprites. The model also predicts the appearance of diffuse sprites based on the model's prediction that the electron density will be low enough to allow for quasielectrostatic (QE) field currents. The QE field dominates the quasielectrostatic (QE) field and is the predominant mechanism for producing diffuse sprites.

References

Barrington-Leigh, C.P. and U.S. Inan (Stanford University) and M. Stanley (New Mexico Tech)

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We provide a one-to-one comparison between high speed video observations of sprites and a fully dynamic video image of a commonly observed form for sprites suggests that broad upper halves and sometimes seen in sprites may be due to diffuse sprites preceding the onset of streamer formation. When the frames of this high-speed video sequence are averaged over the entire duration of the sprite (~4 ms), still much less than the normal fast video sequence, the diffuse sprite is masked out and is hard to perceive. It is likely that only exceptionally bright cases are these diffuse sprites visible in a normal fast video.

A comprehensive review of the electrical breakdown processes of sprites and elves. The model predicts the appearance of diffuse sprites based on the model's prediction that the electron density will be low enough to allow for quasielectrostatic (QE) field currents. The QE field dominates the quasielectrostatic (QE) field and is the predominant mechanism for producing diffuse sprites. The model also predicts the appearance of diffuse sprites based on the model's prediction that the electron density will be low enough to allow for quasielectrostatic (QE) field currents. The QE field dominates the quasielectrostatic (QE) field and is the predominant mechanism for producing diffuse sprites.

In the newest laboratory, the inverse video signature of a diffuse sprite is shown in the diagram above; however, novel lightning phenomena have been identified by others based on the existence of diffuse flashes, often preceding or accompanying "sprites," in intensified video recordings. While we have not claimed to identify elves without the photometric evidence described above, observed normal-speed video images of a commonly observed form for sprites suggests that broad upper halves and sometimes seen in sprites may be due to diffuse sprites preceding the onset of streamer formation. When the frames of this high-speed video sequence are averaged over the entire duration of the sprite (~4 ms), still much less than the normal fast video sequence, the diffuse sprite is masked out and is hard to perceive. It is likely that only exceptionally bright cases are these diffuse sprites visible in a normal fast video.

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