Modeling sprite streamer initiation from an unstable sprite halo front

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High-speed videos have shown that sprite streamers either form out of dark background in the lower ionosphere or appear to be initiated from inhomogeneities at the bottom of a sprite halo [e.g., Cummer et al., GRL, 33, L04104, 2006; McHarg et al., GRL, 34, L06804, 2007; Stenbaek-Nielsen et al., GRL, 34, L11105, 2007]. On the other hand, modeling studies have concluded that inhomogeneities in the lower ionosphere are required for sprite streamer initiation at both overbreakdown [e.g., Qin et al., JGR, 116, A06305, 2011] and subbreakdown conditions [e.g., Liu et al., PRL, 109, 025002, 2012; Kosar et al., JGR, 117, A08328, 2012].

However, it is unknown what is the source of the ionospheric inhomogeneity that initiates sprite streamers. The sprite halo modeling results presented in [Liu, JGR, 117, A03308, 2012] indicate that the lightning and halo field exceeds the conventional breakdown threshold field only briefly as the halo front descends downward. However, the halo front can propagate through some distance because of the electron density growth at subbreakdown conditions enabled by the electron detachment from O^- ions. Both the peak field and speed of the halo front decrease, while the front becomes sharper and sharper. The halo front can be viewed as a planar ionization wave to the observed structures initiating sprite streamers. It is known that a steepening planar ionization wave front tends to be unstable.

In this talk, we present simulation results showing that a planar ionization wave front in the lower ionosphere subject to a lightning field is unstable. The instabilities lead to the development of structures similar to those initiating sprite streamers on high-speed videos. We also show that positive sprite streamers eventually form from those structures.