FORMOSAT-2/ISUALによるスプライトの多波長観測：理論との整合性と矛盾点

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Multi-spectral measurements of sprites with FORMOSAT-2/ISUAL: consistency and inconsistency with theories

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In order to clarify the applicability of quasi-electrostatic field model and streamer model, which constitute the main frame of the conventional sprite theory, we comprehensively analyze the multi-spectral data of sprites obtained with the ISUAL payload on FORMOSAT-2 satellite.

The ISUAL observes various types of optical phenomena such as lightning, TLEs (Transient Luminous Events: sprites, elves, and blue jets), airglow, and aurora, while flying on a sun-synchronous (09:30 to 21:30 LT) polar-orbit at a height of ~891 km. It consists of an imager with a selectable six-color filter wheel, a six-color spectrophotometer, and a dual-color array photometer. For sprite measurements, the imager usually observes N2 first positive band emission with a broadband (633 - 751 nm) red filter, but sometimes observes O2 atmospheric band emission with a narrowband 762-nm filter. The spectrophotometer measures six-wavelength ranges: 150-280, 337, 391.4, 623-750, 777.4, and 250-390 nm, while the array photometer observes two broadband emissions of 340-480 nm and 510-750 nm. Consequently, the ISUAL provides us a plenty amount of spectral, spatial, and temporal information of sprites, which are essential to discuss the consistency/inconsistency between the observations and theories.

During the period from July 4, 2004 to June 25, 2006, the ISUAL observed 482 sprite events. In order to derive the electric fields and electron energies in sprites on the basis of local field approximation, 22 sprite events were analyzed by combining the array photometer data with the Monte Carlo swarm experiments. The estimated initial peaks of reduced electric fields and electron energies in sprite streamers were 98-380 Td and 4.4-8.9 eV, respectively, and were roughly consistent with the theoretical expectations in a streamer head under applied thundercloud electric field. At the later stage (~0.5 ms after the initiation), the estimated values were significantly lower than those expected in the numerical calculations. Similar discrepancies were also found between the spectrum obtained from spectrophotometer measurements and those found in a modeled streamer head. Past high-speed imaging observations have revealed that sprite streamers initially propagate downward branching into multiple channels and decay with a lifetime of ~0.8 ms, which is comparable to the time scale of initial stage where the conventional models agree well with the experimental results. Subsequently, streamers propagate upward from the branching altitude and finally form the later bright stage with stationary structures which continue glowing in the trails of streamers. Therefore, we conclude that the discrepancy of the spectrum between the observation and theory primarily comes from the stationary structures in their trails which are totally different from the dynamic nature of streamers. For the full consistency, chemical reactions in these long-lived stationary features might be one of the most essential keys.