

## Three-dimensional Structure of Sprite Streamers by Aircraft observation

KOBAYASHI, Nui<sup>1\*</sup>, SATO Mitsuteru<sup>1</sup>, TAKAHASHI Yukihiko<sup>1</sup>, KUDO Takeshi<sup>1</sup>, SANMIYA Yusuke<sup>1</sup>, YAMADA Taishi<sup>1</sup>, NHK Cosmic Shore Project<sup>2</sup>, STENBAEK-NIELSEN, Hans C.<sup>3</sup>, MCHARG, Matthew G.<sup>4</sup>, HAALAND Ryan<sup>5</sup>, KAMMAE Takeshi<sup>3</sup>, CUMMER, Steve A.<sup>6</sup>, YAIR yoav<sup>7</sup>, LYONS Walter<sup>8</sup>

<sup>1</sup>Dept. of CosmoSciences, Hokkaido Univ., <sup>2</sup>NHK, <sup>3</sup>Univ. of Alaska, Fairbanks, AK, United States, <sup>4</sup>US Airforce Academy, Colorado Springs, CO, United States, <sup>5</sup>Fort Lewis College, Durango, CO, United States, <sup>6</sup>Duke University, Durham, NC, United States, <sup>7</sup>Open University of Israel, Ra'anana, Israel, <sup>8</sup>FMA Research, Ft Collins, CO, United States

The spatial distributions and the three-dimensional structures of sprite streamers are the key parameters to reveal the occurrence conditions and the development mechanisms of them. However the three-dimensional structures of sprite streamers have never been identified, because it is difficult to capture images from multiple ground-based observation sites simultaneously. Moreover, since the time constant of sprite emissions is about a few milliseconds, it is difficult to capture detailed spatial and time evolution of sprite streamer without using high-speed cameras.

In this study, we study the characteristic of the spatial and time evolution of sprite streamers, especially three-dimensional structures which have never been revealed, by analyzing the data of sprite images observed by high-speed cameras from jet aircraft.

On November 28 and December 3, 2010 in winter Japan, we have carried out optical observations using a high-speed camera and a high-vision CCD camera from a jet aircraft under collaboration between Japan Broadcasting Corporation (NHK) and Hokkaido University. Using the high-speed camera, it is possible to capture images with a sampling rate of 8,300 frames per second (fps). Using the high-vision CCD camera, it is possible to capture true color images of sprites with a sampling rate of 30 fps. During the two observation flights, we have succeeded to capture 28 sprite events. We have analyzed a columniform sprite observed at 13:12:35UT on November 28, 2010 and revealed the spatial and time evolution of the sprite streamers. This sprite consists of 4 distinct sprite elements. Each element begins as a bead between 66 and 78 km altitude and moved downward with a speed of  $0.8 \times 10^7$ - $1.1 \times 10^7$  m/s and a remnant emission stayed at the region where the bead passed through. The altitudes of upper and lower edge of columns are estimated to be 85-90 km and 65-70 km, respectively. It is found that these results are comparable with previous results derived from the sprite observations in North America.

On the other hand, we have carried out simultaneous optical observations using the high-speed cameras and high-vision cameras and WATEC CCD cameras from two jet aircrafts in summer US. In the period of June 27-July 10, 2011, aircraft observations were conducted in 8 nights totally, and succeeded to capture sprite images for over 40 events by the high-speed cameras in each aircraft simultaneously. Using these images, we have performed triangulation analysis for two sprite events observed at 05:20:49UT on July 3, 2011 and at 08:54:13UT on July 5, 2011, and estimated the spatial distributions. It was found that sprites were occurred with a horizontal shift from the location of the parent CG discharge with distance from 60 to 80 km. This result may suggest that there are certain occurrence conditions produced by not only a vertical current of the parent CG discharge but also other factors such as horizontal lightning currents, atmospheric gravity waves and micro meteors. We also studied a columniform sprite with upward streamers observed at 05:20:49UT from July 3, 2011 and performed triangulated analysis to identify the three-dimensional structures. It was found that upward streamers grew radially from a bottom part of the downward streamer. It was also found that the altitudes of upper and lower edge of upward streamers are 76-78 km and 72-73 km, respectively, and that diameter and the velocity of the upward streamers are about 0.3 km and  $5.5 \times 10^6$  -  $5.6 \times 10^6$  m/s. On the other hand, the altitude of upper and lower edge of downward streamer is estimated to be 81 km and 71 km, respectively. The diameter and the velocity of downward streamer were estimated to be about 0.7 km and  $4.7 \times 10^6$  m/s, respectively.

At the presentation, we will show the characteristic of the spatial and time evolution of sprite streamers observed in winter Japan and in summer US more in detail.

Keywords: sprite, Three-dimensional structure of sprite streamers, spatial distributions of sprite