STREAMER AND DIFFUSE GLOW DYNAMICS OBSERVED IN SPRITES

E. A Gerken[(1)], U. S. Inan[(2)]

[(1)]Space, Telecommunications and Radioscience Laboratory, Stanford University, STAR laboratory, Stanford University, Stanford, CA 94305-9515; E-mail egerken@.stanford.edu

[(2)]As (1) above, but E-mail inan@nova.stanford.edu

ABSTRACT

Telescopic imaging shows that decameter-scale structure in sprites covers a wide range of morphologies and time scales. Hundreds of sprites have been observed by the Stanford University telescopic imager. Certain categories of structures have been found to occur such as upward and downward branching, beading, propagating diffuse glow striations and streamer/diffuse glow transition regions. In this paper we use selected cases of fine structure observed by the telescopic imager on July 13, July 19, and August 6, 1998 to illustrate these morphologies and then compare these structures to that predicted by existing streamer and sprite models.

EXPERIMENT DESCRIPTION

During the months of July and August 1998, Stanford University deployed a telescopic imaging system, consisting of a ~41 cm diameter, f/4.5 Dobsonian-mounted Newtonian reflecting telescope with an intensified CCD camera attached to its eyepiece and a bore-sighted wide field of view (FOV) camera mounted on its top. The system was deployed at the Langmuir Laboratory (LL), located in the Magdalena mountains of central New Mexico and operated by the New Mexico Institute of Mining and Technology. The FOV of the telescope (0.5 in CCD) was ~0.7 degrees by ~0.92 degrees while that of the bore-sighted camera (.33 in CCD, 50 mm lens, f/1.4) was ~9 degrees by ~12 degrees. The narrow FOV camera was field-selected, creating images exposed for ~17ms while the wide FOV camera was in interlaced frame mode creating images exposed for ~33ms. GPS video time-stamping and IRIG-B code were used for timing. National Lightning Detection Network (NLDN) data and starfields were used for altitude determination. Electromagnetic signatures of causative lightning discharges known as radio atmospherics (or sferics) were recorded using crossed-loop magnetic antennas and an ELF/VLF receiving system located at Stanford University.

PREVIOUS OBSERVATIONS AND CURRENT MODELS OF FINE STRUCTURE

Other video observations have previously revealed fine structure in sprites, including upward and downward branching [1], [2], [3], [4]. High speed imaging of sprites has captured the temporal development of some of the fine structures seen in sprites such as the upward and downward branching and slowly moving beads [5], [6] revealing that in general sprites are initiated as columns with downward branching at their bases followed by upward branching from the column. A theoretical explanation of observed spatial fine structures in sprites was put forth in the context of a streamer-based model of electrical breakdown above thunderstorms [7], [8]. Characteristic structure widths for each altitude have been predicted, ranging from ~10 m at 70km to ~100 m at 85 km [8] Sprite models have also been developed using fractal techniques which predict general shapes of bulk sprite volumes [9], [10].

STREAMER AND DIFFUSE GLOW DYNAMICS OBSERVED TELESCOPICALLY

Using the telescopic imaging system we find that sprite structure can assume a wide variety of shapes, sizes, and time scales, but certain structures such as beading, faint downward branching, propagating diffuse glows, and columns appear repeatedly. We observe that within some sprite events, several different types of structural features appear while in others only one morphology occurs. Propagating diffuse glow striations are observed to move slowly and are broader than predicted for streamer formation. While many streamers move at velocities greater than the time resolution of regular video rate imaging, some have been found to move as slowly as 10^4 m/s. Fine beading exists in many negative streamers and may possibly be a result of meteoric dust particles in the upper atmosphere. Columniform sprites may originate from positive branching streamers. Beads at the base of columns can glow for over 100ms while slowly drifting upward. Faint positive streamers are observed at the base of large bright sprites. Some sprites having branching positive streamers and non-branching negative streamers may be double-headed streamers initiated from plasma enhancements such as vaporized meteoric dust. A transition region between streamer formation and diffuse glow is

observed at ~ 80km altitude. No structure is observed in telescopic images of the diffuse glow at the tops of sprites, termed "sprite halos" [11].

[1] Sentman, D. D., E. M. Wescott, M. J. Heavner, and D. R. Moudry, "Observations of sprite beads and balls", *EOS Trans. AGU*, 77, Fall Meet. Suppl., F61, 1996.
[2] Taylor, M. J., and S. Clark, "High resolution CCD and video imaging of sprites and elves in the N2 first positive band emission", *EOS Trans. AGU*, 77, Fall Meet. Suppl., F60, 1996.
[3] Stanley, M., P. Krehbiel, W. Rison, C. Moore, M. Brook, and O. H. Vaughn, "Observations of sprites and jets from Langmuir Laboratory, New Mexico", *EOS Trans, AGU*, 77, Fall Meet. Suppl., F69, 1996.
[4] Fukinishi, H., Y. Takahashi, M. Fujito, Y. Wanatabe, and S. Sakanoi, "Fast imaging of elves and sprites using a framing/streak camera and a multi-anode array photometer", *EOS Trans. AGU*, 77, Fall Meet. Suppl., F60, 1996.
[5] Stanley, M. P., P. Krehbiel, M. Brook, C. Moore, and W. Rison, "High speed video of initial sprite development", *Geophys. Res. Lett*., vol. 26, p. 3201, 1999.
[6] Stenbaek-Nielsen, H. C., D. R. Moudry, E. M. Wescott, D. D. Sentman, and F. T. Sao Sabbas, "Sprites and possible mesospheric effects", *Geophys. Res. Lett*., vol. 27,p. 3829, 2000.
[7] Raizer, Y. P., G. M. Milikh, M. N. Shneider, and S. V. Novakovski, Long streamers in the upper atmosphere above thundercloud, *J. Phys. D: Appl, Phys.,*vol. 31, p. 3255, 1998.
[8] Pasko, V. P., U. S. Inan, and T. F. Bell, "Spatial structure of sprites", *Geophys. Res. Lett*., vol. 25, p. 2123, 1998.
[9] Pasko, V. P., U. S. Inan, and T. F. Bell, "Fractal structure of sprites", *Geophys. Res. Lett*., vol. 27, p. 497, 2000.
[10] Petrov, N. I. and G. N. Petrova, "Physical mechanisms for the development of lightning discharges between a thundercloud and the ionosphere", *Tech. Phys*., vol. 44, p. 472, 1999.
[11] Barrington-Leigh, C. P. and U. S. Inan, "Identification of sprites and elves with intensified video and broadband array photometry", *J. Geophys. Res*., vol. 106, p. 1741, 2001.