Similarities in appearance between natural sprites and pilot systems in the lab.

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Detailed nanosecond-fast high-resolution photography of negative meter-scale laboratory discharge unveiled similarities between pilot systems and high-altitude sprites. Both phenomena have similar development behaviour and possess unique features like bright isolated dots and reconnection.

1. Introduction

Sprites are high-altitude kilometre-scale electrical discharges that happen above thundercloud. It is generally assumed that sprites are triggered by positive lightning [1].

In Eindhoven University of Technology we investigate meter-scale laboratory discharges looking for similarities with natural lightning and lightning-related phenomena. Negative lightning possesses step-like propagation behaviour which is associated with space leader formation in front of its main leader. Meter-scale laboratory sparks also develop via formation of a space stem that transforms into a pilot system that finally develops into a space leader in longer gaps. With ns-fast photography we investigated the pilot system formation and found striking similarities with high-altitude sprites. But sprites are different in size, environment and polarity. Laboratory pilot barely reaches 70 cm and develops in STP air, while high-altitude sprites reaches ionosphere stretching for dozens of kilometres. Also sprites are assumed to be of opposite to the pilot system polarity.

During the TEA-IS summer school we want to discuss differences and similarities between high-altitude sprites and pilot systems in negative laboratory discharges.

2. Experiments

We use 1 MV Marx generator to create meter-scale laboratory sparks between two cone-shaped electrodes. A ns-fast ICCD camera is located at 4 m distance from the spark and it takes pictures of the discharge at various time slots. For better visibility we applied a linear colour-coding scheme to black and white images from the camera. In more detail the experimental setup is described in [2] and [3].

2.1. Pilot system formation and development

The formation and development of a pilot system is shown in Figure 1. Negative streamers (ns) leave isolated dots behind during its propagation (image (a)). Later, the dots become starting points for positive streamers (ps). The positive streamers move upwards and connect to negative streamer/leader. The amount of dots and positive streamers can be different. The entire bipolar structure – negative streamers – dots – positive streamers is the pilot system. The free space in between negative and positive streamers is the space stem.

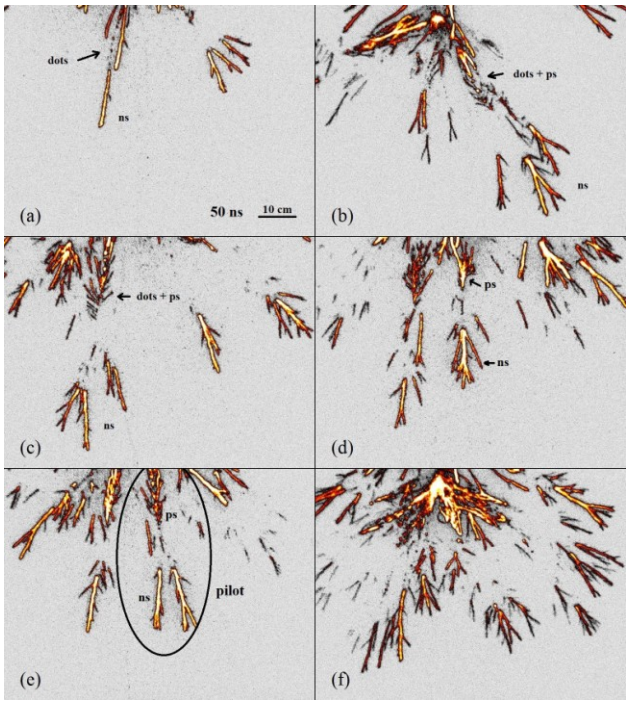

Figure 1. Pictures of six different discharges. (a) Negative streamers (ns) leave isolated dots behind

which then give rise to positive streamers (ps) that move towards the HV cathode (located above and not shown here). (e) Exposure time is 50 ns.

Often the dots are branching points of negative streamers. According to [4], the sprites possesses the similar developing process. An original black and white image of 100 ns exposure time is shown in Figure 2.

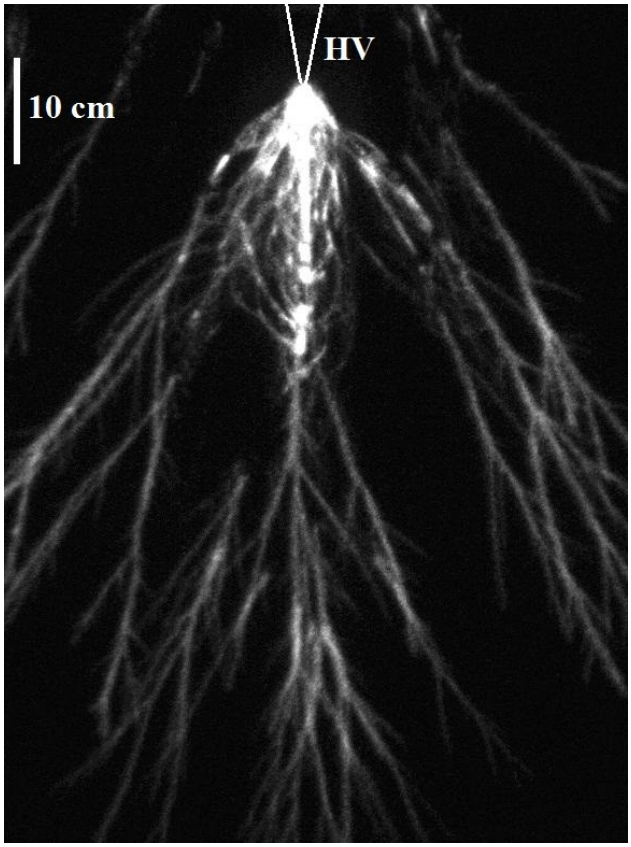

Figure 2. Pilot systems captured with 100 ns exposure. The image can be compared with those represented in [4]. Original black and white image, no colour coding is applied.

Remarkably, the upper part of the pilot system (including the isolated dots) is brighter than its bottom part. The same is valid for sprites. It is also clear that the pilots are directed towards the point-like HV electrode, whereas the ionosphere acts as a diffuse electrode for natural sprites.

2.2. Pilots reconnection

One of the unique and important features of the sprites is their reconnection. The phenomenon is described in detail in [4]. Laboratory pilots show the similar reconnection. Even though the image is only a 2D representation of the phenomenon, the uncharacteristic curvature of the negative streamer allow us to claim that the reconnection between the pilot systems occurs as well. Detailed pictures of the process will be presented in the workshop.

3. Discussion and conclusions

With detailed ns-fast photography we investigated a formation and development of pilot systems in negative long laboratory discharge. It is shown that the pilot formation begins with a negative streamer propagation, which leaves isolated periodic bright dots behind. Sometimes, the dots are splitting points of the negative streamer. Later, the dots behave as starting points for positive streamers that move in opposite direction. A similar development process was observed in high-altitude sprites. Moreover, the laboratory pilots can reconnect with each other in the same way as sprites do. Although the polarity of the sprites known to be opposite to the observed pilots, striking visual similarities between two phenomena must be discussed within scientific community.

4. Acknowledges

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5. References

[1] D. J. Boccippio, E. R. Williams, S. J. Heckman, W. A. Lyons, I. T. Baker, R. Boldi, *Science*,1995, **269** (5227), pp. 1088-1091

[2] P. Kochkin, A. P. J. van Deursen, and U. Ebert, *J. Phys. D: Appl. Phys*., 2012, **45**, 425202

[3] P. Kochkin, A. P. J. van Deursen, and U. Ebert, *J. Phys. D: Appl. Phys*., 2014, **47**, 145203

[4] S. A. Cummer, N. Jaugey, J. Li, W. A. Lyons, T. E. Nelson and E. A. Gerken, *Geophys. Res. Lett*., 2006, **33**, L04104