

Lightning-related transient luminous events at high altitude in the Earth's atmosphere

Victor P. Pasko

Department of Electrical Engineering, Communications and Space Sciences Laboratory (CSSL), The Pennsylvania State University, 211B Electrical Engineering East, University Park, PA 16802-2706, USA, ph. 814-865-3467, fax 814-865-7065, e-mail: vpasko@psu.edu

Transient luminous events are large-scale electrical discharges occurring at high altitude in the Earth's atmosphere, which are directly related to the electrical activity in underlying thunderstorms, and which represent a newly discovered mechanism for coupling the lower atmosphere with the ionosphere. Several different types of transient luminous events have been documented and classified. These include relatively slow-moving fountains of blue light, known as 'blue jets', that emanate from the top of thunderclouds up to an altitude of 40 km; 'sprites' that develop at the base of the ionosphere and move rapidly downwards at speeds up to 10,000 km/s; 'elves', which are lightning induced flashes that can spread over 300 km laterally, and upward moving 'gigantic jets', which establish a direct path of electrical contact between thundercloud tops and the lower ionosphere.

The total electrostatic energy associated with charge separation inside of a thundercloud is on the order of 1-10 GJ and substantial fraction of this energy is released in one lightning discharge on time scales less than 1 sec. One of the important aspects of the lightning phenomena at low altitudes is that the energy release is happening in highly localized regions of space leading to formation of spark channels with dense plasma and temperatures exceeding 25000 K. Due to the exponential decrease in the atmospheric neutral density as a function of altitude even a small fraction of the thundercloud energy released at mesospheric/lower ionospheric altitudes often results in bright transient luminous events with the total affected volume of atmosphere typically measured in thousands of cubic kilometers at mesospheric/lower ionospheric altitudes above thunderstorms. The recently discovered infrasonic waves from sprites represent one of the least understood energy dissipation channels related to this phenomenon.

The goal of this talk is to provide an overview of the history of discovery of different types of transient luminous events, and some of the recent modeling efforts related to elves, sprites and jets directed on interpretation of experimentally observed features of these events. We will discuss a physical mechanism proposed for explanation of sprites, which is build on original ideas advanced many decades ago by the Nobel Prize winner C. T. R. Wilson. We will also discuss similarity properties of electrical discharges as a function of gas pressure in the context of a selected set of results from the recent laboratory and modeling studies of streamers, which are directly applicable for understanding of recent high spatial and temporal resolution imagery of sprites revealing many internal filamentary features with transverse spatial scales ranging from tens to a few hundreds of meters.