NEGATIVE STEPPED LEADERS AS A SOURCE OF RUNAWAY ELECTRONS

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In the presence of sufficiently strong electric fields $\sim 10E_k$ in a weakly ionized plasma, where E_k is the conventional breakdown threshold field defined by the equality of the ionization and dissociative attachment coefficients in air, a fraction of initially low energy ($\sim$several eV) electrons can be directly accelerated over the peak of the dynamic friction force of electrons in air and become thermal runaway electrons [Gurevich, Sov. Phys. JETP, 12, 904, 1961]. Streamers are filamentary plasmas, which are driven by highly nonlinear space charge waves. The enhancement of electric fields around tips of streamers is one of the unique naturally occurring circumstances in which fields $\sim 10E_k$ can be dynamically produced and sustained for relatively extended periods of time. The ability of these streamer tip fields to generate runaway electrons was identified and discussed in the literature over two decades ago [Babich, Sov. Phys. Dokl., 263, 76, 1982, and references therein]. Streamers are known to act as building blocks of streamer zones of conventional lightning leaders. It is also believed that the filamentary plasma structures observed in blue jets and gigantic jets, which emanate from the tops of thunderclouds, are directly linked to the processes in streamer zones of lightning leaders. In this talk we will discuss a probable scenario of events in which non-relativistic thermal runaway electrons emitted from the tips of streamers in the streamer zones of lightning leaders can be accelerated to relativistic energies. With total potential differences on the order of tens of MV available in streamer zones of lightning leaders, it is proposed that during a highly transient negative corona flash stage of the development of negative stepped leader, electrons with energies 2-8 keV ejected from streamer tips near the leader head [Moss et al., Eos. Trans. AGU, 85(47), Fall Meeting Suppl., Abstract AE31A-0158, 2004; JGR, in review, 2005; Liu et al., 2005 Seminar Series on TGFs, SSL, UC Berkeley, February 15, 2005] can be further accelerated to energies of hundreds of keV and possibly to several tens of MeV, depending on particular magnitude of the leader head potential. It is proposed that these energetic electrons may be responsible (through the *bremsstrahlung* process) for the generation of hard X-rays observed from ground and satellites preceding lightning discharges, or with no association with lightning discharges in cases when the leader process does not culminate in a return stroke [e.g., Fishman et al., Science, 264, 1313, 1994; Inan et al., GRL, 23, 1017, 1996; Moore et al., GRL, 28, 2141, 2001; Dwyer et al., GRL, 32, L01803, 2005; Smith et al., Science, 307, 1085, 2005; Cummer et al., GRL, 32, L08811, 2005; and references therein]. For a lightning leader carrying a current of 100 A, an initial flux of $\sim$2-8 keV thermal runaway electrons integrated over the cross sectional area of the leader is estimated to be 10^{20} s^{-1} [Moss et al., JGR, in review, 2005], with the number of electrons accelerated to relativistic energies depending on the particular field magnitude and configuration in the leader streamer zone during the negative corona flash stage of the leader development. The duration of the negative corona flash and associated energetic radiation is estimated to be in the range from ~ 1 μs to ~ 1 ms depending mostly on the pressure dependent size of the leader streamer zone.

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2. H - Waves in Plasma

3. (a) S-H/G2

4. C - Contributed Paper, Program chair: Elizabeth Gerken

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