

UV Rayleigh scattering as a source of seed electrons for initiation of streamers in the system of two approaching hydrometeors

Victor P. Pasko¹ and Jaroslav Jansky²

¹School of Electrical Engineering and Computer Science, Penn State University, 227 Electrical Engineering East, University Park, PA 16802-2706, USA

²Department of Mathematics and Physics, University of Defense, Brno, Czechia

Photoionization processes due to extreme ultraviolet emissions are important for understanding lightning induced plasma irregularities and lightning initiation processes at higher [e.g., Liu and Pasko, *Journal of Geophysical Research*, 109, A04301, 2004] and lower [e.g., Jansky and Pasko, *Journal of Geophysical Research*, 125, e2019JD031337, 2020] altitudes in the Earth's atmosphere. The lightning initiation in low thundercloud fields, in particular, represents an unsolved problem in lightning discharge physics. One of the initial conditions required for formation of a hot leader channel is initiation of non-thermal streamer discharges that naturally can develop from electron seeds undergoing avalanche multiplication in high electric fields. The maximum electric field in thunderstorms measured by balloons is typically 3-4 kV/cm/atm, that is significantly smaller than the breakdown electric field needed for avalanche multiplication of electrons $E_k=28.7$ kV/cm/atm. Hydrometeors can greatly intensify the local electric field and that stimulated renewed interest to accurate numerical modeling of related gas discharge processes [Dubinova et al., *Physical Review Letters*, 115, 015002, 2015; Sadighi et al., *Journal of Geophysical Research*, 120, 3660, 2015; Babich et al., *Journal of Geophysical Research*, 121, 6393, 2016]. In the present work we use Monte Carlo modeling to quantitatively investigate an idea that Rayleigh scattering of ultraviolet photons in the range 98-102.5 nm, that are responsible for photoionization in air [e.g., Janalizadeh and Pasko, *Plasma Sources Science and Technology*, 28, 105006, 2019, and references therein], can lead to production of seed electrons for initiation of gas discharges (i.e., streamers) in regions of space that normally would be shielded by opaque objects and would not have direct line of sight exposure to ultraviolet photons produced by gas discharges occurring at other locations. This problem has relevance to initiation of streamers during collisions of two hydrometeors when the initial discharge in the gap between two hydrometeors can stimulate the subsequent streamer discharges developing on the outer periphery of two hydrometeors [e.g., Cooray et al., *Proceedings of 24th International Conference on Lightning Protection*, Birmingham UK, 1998; Jansky and Pasko, 2020; and references therein]. We note that the measured Rayleigh scattering cross section in deep-UV spectral region [Ityaksov et al., *Molecular Physics*, 106, 2471, 2008] when extrapolated to 98-102.5 nm is orders of magnitude lower than the photoabsorption cross section of molecular oxygen. However, our results demonstrate that this process can lead to production of seed electrons for initiation of streamers.