



A Massive 500 m Diameter Lightning Leader Ionization Front

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We have recently [1] reported on a new mode of negative leader propagation, seen using the LOFAR lightning imaging capability, that distinguishes itself from the more common stepped negative leaders. This new mode, called Intensely Radiating Negative Leaders (IRNL), begins as a normal negative leader that accelerates in a fraction a millisecond to reach a velocity of about 10^6 m/s and emits copious amounts of broad-band radiation, including VHF. The radiation is so intense that it is difficult for our impulsive imager (based on a time-of-flight-difference method) to locate sources. This IRNL mode typically lasts for 1 to 3 ms, while it covers a distance of several kilometers, after which a few dozen more normal negative leaders are emerging propagating at more normal speeds, of the order of 10^5 m/s. This mode occurs during the initial stage of all lightning flashes we have mapped but it is also seen in the middle of a well developed flash and is not propagating along an existing leader channel and thus is clearly distinct from a recoil or a dart leader.

To obtain a better insight in the dynamics of the IRNL mode we have imaged it with our TRI-D imager [2] that is based on a beam-forming technique, coherent addition of the signals of about 400 individual LOFAR antennas. This allowed us to 'see' inside the IRNL where we find [3] that it propagates with a very extended ionization wave front that has diameters ranging from 100 to even 500 m. This is in sharp contrast with normal negative leaders where the ionization front is of the order of 1 meter.

[1] O. Scholten, et al., Scientific Reports 11, 16256 (2021).

[2] O. Scholten, B. M. Hare, J. Dwyer, N. Liu, C. Sterpka, S. Buitink, T. Huege, A. Nelles, and S. ter Veen, Phys. Rev. D 104, 063022 (2021).

[3] O. Scholten, et al., arXiv:2110.02547.