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Intensely Radiating Negative Leaders Observed by LOFAR and their possible connection to TGFs

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Multiple recent works by the LOFAR lightning team have established the existence of a type of negative leader that emits extremely intense radio radiation. In addition, these leaders propagate about ten times faster than normal negative leaders (10^6 m/s vs 10^5 m/s). We refer to this phenomena as Intensely Radiating Negative Leaders or IRNLs; it is plausible they could be related to previously described beta leaders. We have observed IRNLs during the initial stage of every lightning flash, but they can also occur later in the lightning flash; possibly whenever a negative leader propagates through a small high-field region. During the beginning of the lightning initial stage an IRNL starts out as one branch which has powerful corona bursts at its tip. These corona bursts play a role in producing initial breakdown pulses (IBPs) observed by a lower-frequency magnetic loop antenna. However, unlike other observations, we do not see any evidence for fast breakdown (propagation speed is always well below 10^7 m/s). The IRNL quickly branches into an uncountable number of densely packed channels such that the radio emission can no longer be separated into individual IBPs. Once the IRNL hits the positive cloud charge region it expands out in a ring of uncountable number of plasma channels that can only be described as a multi-kilometer sized plasma explosion. Since this phenomena is so energetic and closely linked to both the lightning initial stage and initial breakdown pulses, it is a very strong candidate for TGF emission.

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