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High-speed, high-fidelity radio imaging of lightning using the Long Wavelength Array at Sevilleta, New Mexico (LWA-SV)

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Lightning can be an impulsive broadband emitter at radiofrequencies (RF) and is often approximated as a point source over short periods of time, particularly for lightning detection networks operating above 1 MHz. For instance, lightning mapping arrays locate individual 3-D RF sources in successive $\sim$10 μs intervals [1], three-antenna interferometers locate individual 2-D RF sources in successive $\sim$1 μs intervals [2], and very large antenna arrays have been used to locate individual 3-D RF sources in successive $\sim$1 μs intervals [3]. However, treating lightning as a point source can produce ambiguous or even misleading results, as in the case of bidirectional breakdown during lightning initiation [4]. In this case, each source location is likely a superposed location of two or more sources, with the brightest of the sources mapped more accurately. Beyond lightning initiation, multi-source emission occurs in heavily branched lightning leader systems – such as those approaching ground – and during attachment – when an upward propagating leader (from ground or a tall grounded structure) connects to a downward propagating leader from the cloud.

Multi-source lightning RF emission can be resolved using large radio arrays consisting of tens of sensing elements and operating in a purely interferometric imaging mode, as used in radio astronomy [5]. Here we demonstrate multi-source imaging of bidirectional and branched lightning leaders using the Long Wavelength Array in Sevilleta, New Mexico (LWA-SV), which consists of 256 dual-polarization antennas arranged within a roughly 100-meter diameter, covering the frequencies 3-88 MHz. Designed to study transient radio events, the LWA-SV has a lightning trigger that can instantaneously capture all 256 dual-polarization measurements for 250 ms and 40 MHz bandwidth. Our newly-developed algorithm produces high-fidelity images of lightning at 3 million frames per second (300 ns exposure per image).

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