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The Impulsive Nature of Lightning Initiation

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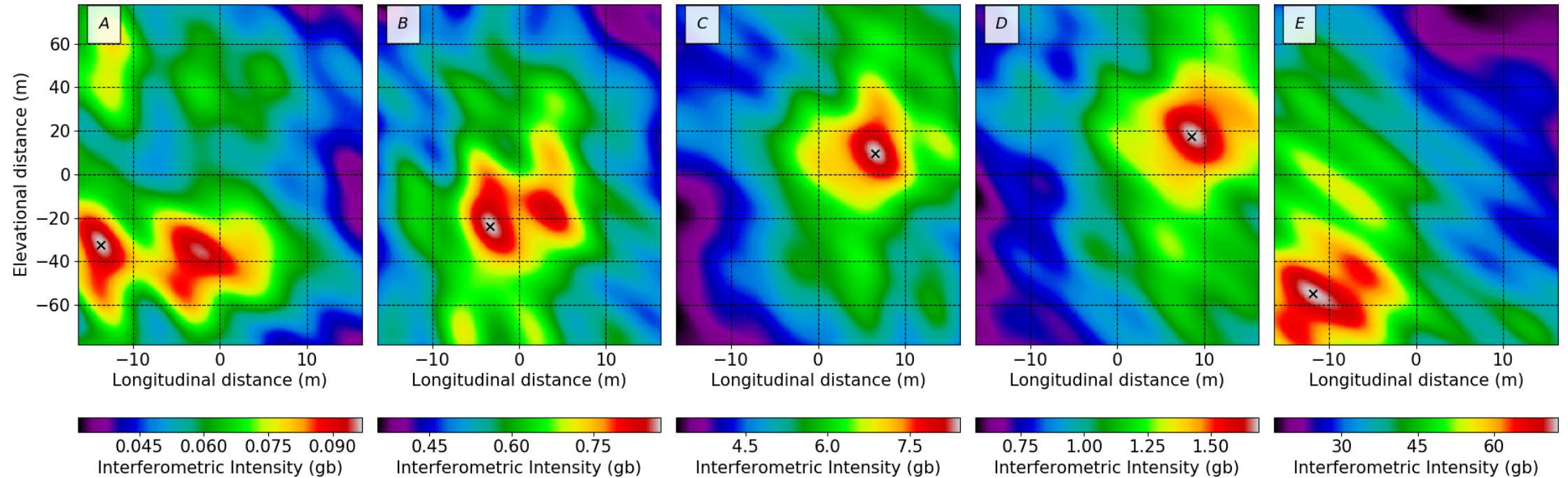
The Spontaneous Nature of Lightning Initiation

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CR KSP

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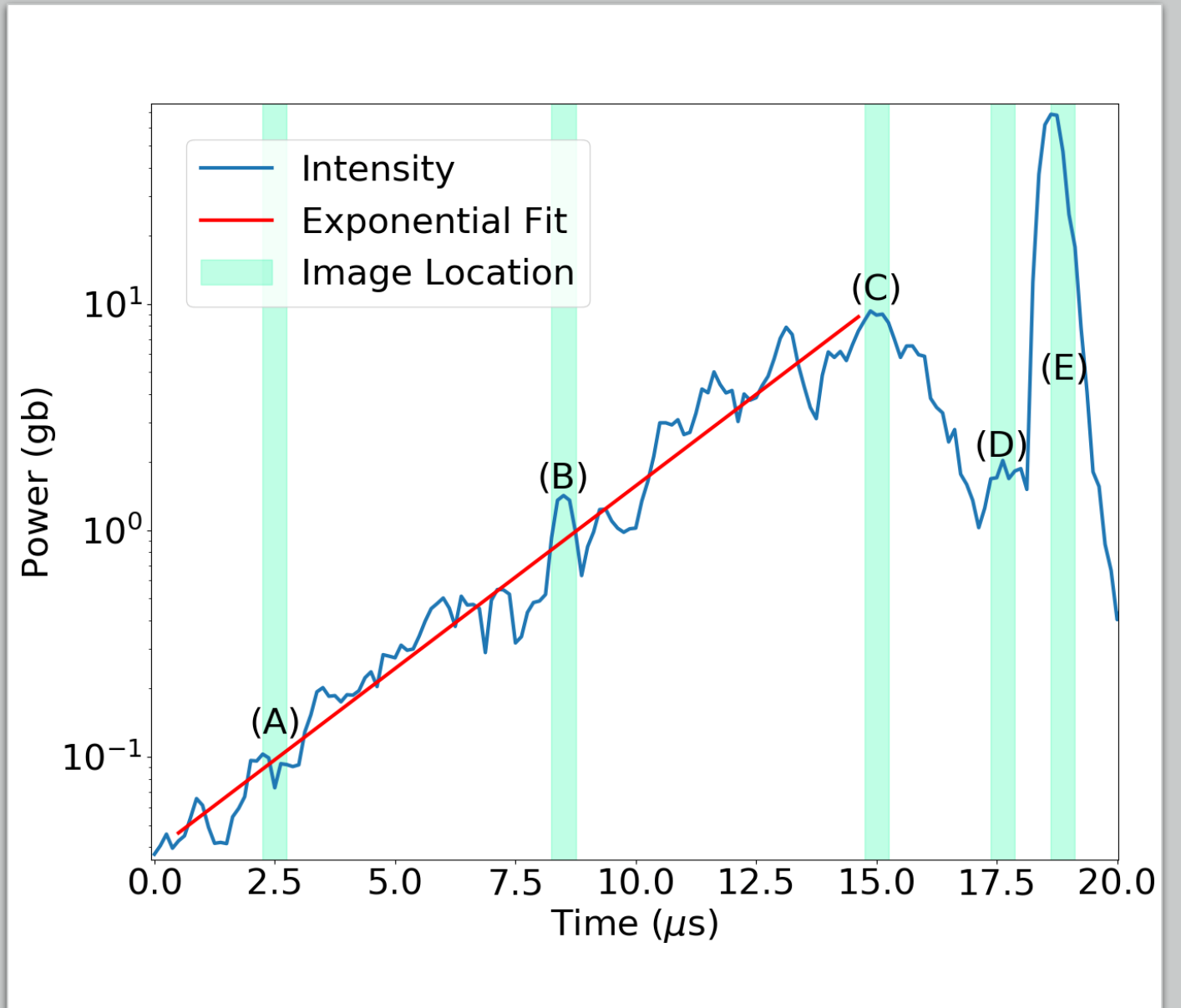
Precision Imaging Through Interferometric Beamforming



- Sub-meter precision imaging of lightning initiation via interferometric beamforming with LOFAR.
- First imaged pulse is 22 μ s prior to first IBP.
- Galactic background units (gb) are derived from the normalized noise level on single antenna.
- (A-D) Source moves at constant velocity approximately 100 m while increasing in intensity.
- (E) Source vanishes and new source appears at the inception point of negative leader.

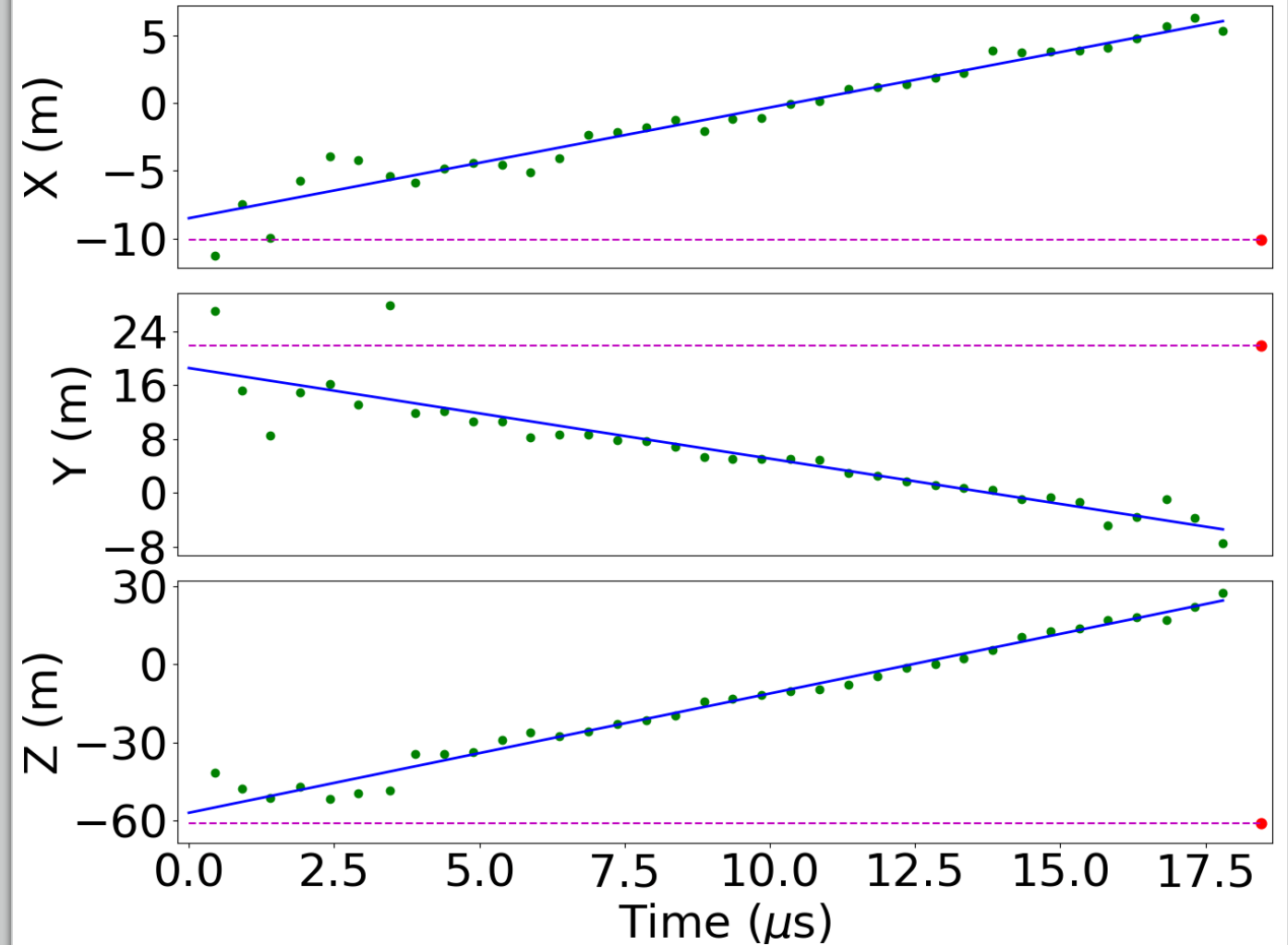
Exponential Ramp-up

- VHF power versus time showing exponential ramp-up.
- e-folding rate: $2.7 \pm 0.4 \mu\text{s}$
- $15 \mu\text{s}$ two order of magnitude rise followed by $2 \mu\text{s}$ order of magnitude drop, but velocity remains constant.
- Pulse at end (E) is the inception point of the negative leader, $4 \mu\text{s}$ later.

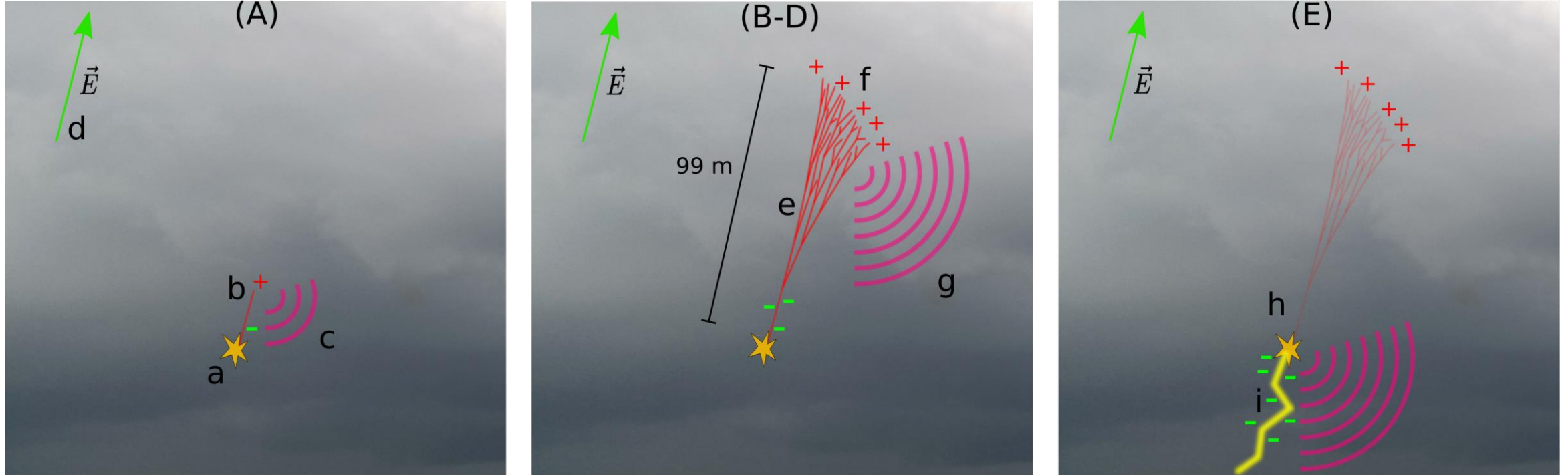


Velocity Fit

- Initiation discharge starts and ends within 10 m of the inception point of the negative leader (red dot and dashed line)
- Propagation speed of avalanche discharge is $4.8 \pm 0.1 \times 10^6$ m/s (green dots are VHF source locations and blue line is a linear fit)
- Velocity is constant throughout the entire ramp-up (time aligns with ramp-up in previous slide)



Proposed Discharge Mechanism



- (A) Initiation starts with a single streamer, producing first VHF signal.
- (B-D) Streamer branches multiple times, producing significant charge separation and larger VHF signal.
- (E) Hot leader channel forms near the start of the avalanche due to accumulation of negative charge at tip.
- *First source is a rapidly propagating and intensifying group of streamers that subsequently produces a hot leader channel near the initiation point, similar to original Griffiths and Phelps 1976.*

* A-E align with images shown in slide 2