

## Simultaneous Optical and Electrical Observations for One Downward Bipolar Flash Simultaneous Optical and Electrical Observations for One Downward Bipolar Flash

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A downward bipolar flash, containing a positive first return stroke and 5 negative subsequent return strokes, was simultaneously recorded by two high-speed cameras, two Lightning Attachment Process Observation Systems (LAPOS), one fast antenna and one slow antenna at 17:54:14, 29 July 2010 (local time) in Guangzhou, Guangdong, China. The analysis shows that:

(1) The overall flash duration is about 864 ms and all 6 strokes occur and propagate along a single channel. The interval between the first stroke (positive) and the first subsequent stroke (negative) is 279 ms, apparently bigger than those between the subsequent strokes, which are 76, 111, 78 and 149 ms. The average inter-stroke interval is about 138 ms. The peak current of the first positive stroke is 142.6 kA, much larger than those 5 negative ones, 4 of which are recorded by lightning location system with peak current values of from -22.9 kA to -32.0 kA.

(2) The downward positive leader exhibits quite smooth channel without any branch in the view range of high-speed camera. The 2D velocity of the positive leader ranges from 2.1 to  $3.4 \times 10^6$  m/s, with a median value of about  $2.5 \times 10^6$  m/s. The positive leader propagates downward with a rising velocity trend. The 1D velocity of the positive return stroke is estimated to be about  $1.2 \times 10^8$  m/s. The 20% to 90% rising time of luminosity pulse of the positive stroke is about 2.5 us, and the duration from 20% front to 50% tail is about 55.4 us. The first positive stroke is followed by about 100 ms continuing current superposed with multiple pulse events.

(3) The 2D velocities of subsequent dart-leaders range from about  $4.0 \times 10^6$  m/s to more than  $12.4 \times 10^6$  m/s. The 1D velocities of the subsequent negative return strokes range from about 1.2 to  $1.3 \times 10^8$  m/s. The 20% to 90% rising time values of luminosity pulses of the subsequent negative strokes range from 1.3 to 2.2 us, and the durations from 20% front to 50% tail range from 64.8 to 82.3 us. Continuing current process with duration ranging from 3 to 11 ms as well as 2 to 4 evident M-components is observed following each negative stroke.

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