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Complex earthquake directivity during the 2009 L'Aquila mainshock

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The normal faulting rupture characteristics of the 2009 L'Aquila earthquake have been deeply studied by several authors by using different data set (broad-band and strong-motion seismic data, and surface deformation measurements, such as GPS and InSAR). Most of the published source models have highlighted the complexity of the rupture process and have shown a clear south-eastward rupture directivity. Besides, the key feature of the source process retrieved by Cirella et al. (2012) reveals two distinct stages of rupture history. The rupture initially propagates up-dip from the hypocenter at relatively high rupture velocity and with a modest moment release. Successively, nearly two seconds after nucleation, the rupture proceeds towards SE, along the strike direction, breaking the largest and deeper asperity. The up-dip and along-strike rupture propagation are separated in time and associated with a Mode II and a Mode III crack, respectively.
There are clues suggesting a second, less evident, near-source up-dip directivity occurring before the well known south-eastward directivity. For this reason we investigate in detail the first seconds of the rupture to unravel the up-dip propagation.
The near-fault strong motion data show a remarkably short duration of strong shaking. In particular, the comparative energy (calculated with a cumulative sum of square acceleration) computed for the three components of the closest stations at frequencies below 0.4 Hz are not well reproduced by using the available kinematic models, suggesting that the complexity of the rupture process has been not completely understood.
We first study the effect of the source-to-receiver geometry on comparative energy, through several forward modeling of point sources located on the fault, up-dip from the hypocenter. Therefore, we perform a non-linear inversion of strong motion and CGPS data with an epicentral distance less than 30 km; then we use the retrieved model to compute the dynamic rupture parameters.
We found that the up-dip directivity characterizing the first seconds of the rupture is responsible of the short duration of strong shaking and of the prominent velocity pulses observed at the closest stations (e.g., AQU, AQK).