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Critical features in electromagnetic anomalies detected prior to the L'Aquila earthquake

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Earthquakes (EQs) are large-scale fracture phenomena in the Earth's heterogeneous crust. Fracture-induced physical fields allow a real-time monitoring of damage evolution in materials during mechanical loading. Electromagnetic (EM) emissions in a wide frequency spectrum ranging from kHz to MHz are produced by opening cracks, this can be considered as the so-called precursors of general fracture. We emphasize that the MHz radiation appears earlier than the kHz on both laboratory and geophysical scales. An important challenge in this field of research is to distinguish characteristic epochs in the evolution of precursory EM activity and identify them with the equivalent last stages in the EQ preparation process. Recently, we proposed the following two-stage model. (i) The first epoch, which includes the initial emergent MHz EM emission, is thought to be due to the fracture of a highly heterogeneous system that surrounds a family of large high-strength asperities distributed along the activated fault sustaining the system. (ii) The second epoch, which includes the emergent strong impulsive kHz EM radiation, is due to the fracture of the asperities themselves. A catastrophic EQ of magnitude Mw=6.3 occurred on 6 April, 2009 (06/04/09) in central Italy. The majority of the damage occurred in the city of L'Aquila. Clear kHz_MHz EM anomalies had been detected prior to the L'Aquila EQ. Here, we investigate the seismogenic origin of the MHz part of the anomalies. The analysis, which is in terms of intermittent dynamics of critical fluctuations, reveals that the candidate EM precursor (i) can be described as analogous to a thermal continuous phase transition and (ii) has anti-persistent behavior. These features suggest that this candidate precursor was triggered by microfractures in the highly disordered system that surrounded the backbone of asperities of the activated fault. A criterion for underlying strong critical behavior is introduced. In this field of research, reproducibility of results is desirable; and is best done by analyzing a number of precursory MHz EM emissions. We refer to previous studies of precursory MHz EM activities associated with nine significant EQs that have occurred in Greece in recent years. We conclude that all the MHz EM precursors studied, including the present one, can be described as analogous to a continuous second-order phase transition having strong criticality and anti-persistent behavior.