Time-energy correlations as a hallmark of different branching processes

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Several biological and natural systems appear to operate close to a critical point, as evidenced by the absence of a characteristic size in the phenomenon. Indeed, the existence of power law distributions has been detected in several contexts, as different as earthquakes, solar flares or spontaneous brain activity, and, surprisingly, with similar scaling behaviour. We propose that the specific features of each phenomenon are imbedded in the temporal organization of events in time. A detailed analysis of time-energy correlations detrending statistical noise is able to enlighten the difference between the physical mechanisms controlling different phenomena, as for instance earthquakes and solar flares. Conversely, the temporal organization of neuronal avalanches in the rat cortex in vitro exhibits a distribution of waiting times between successive events with a non-monotonic behavior, not usually found in other natural processes. Numerical simulations provide evidence that this behavior is a consequence of the alternation between states of high and low activity, leading to a dynamic balance between excitation and inhibition. This behavior is also detected at a larger scale, i.e., on fMRI and MEG data from resting patients. Indeed, by monitoring temporal correlations we confirm that the system is able to self-regulate the activity level tuning the size of successive events according to their temporal distance.