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Towards a unified study of extreme events using universality concepts and transdisciplinary analysis methods

George Balasis (1), Reik V. Donner (2), Jonathan F. Donges (2,3,4), Alexander Radebach (2,5), Konstantinos Eftaxias (1), Jürgen Kurths (2,4,6)

(1) National Observatory of Athens, Greece, (2) Potsdam Institute for Climate Impact Research, Potsdam, Germany, (3) Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden, (4) Department of Physics, Humboldt University, Berlin, Germany, (5) Mercator Research Institute on Global Commons and Climate Change, Berlin, Germany, (6) Institute for Complex Systems and Mathematical Biology, University of Aberdeen, Aberdeen, United Kingdom

The dynamics of many complex systems is characterized by the same universal principles. In particular, systems which are otherwise quite different in nature show striking similarities in their behavior near tipping points (bifurcations, phase transitions, sudden regime shifts) and associated extreme events. Such critical phenomena are frequently found in diverse fields such as climate, seismology, or financial markets. Notably, the observed similarities include a high degree of organization, persistent behavior, and accelerated energy release, which are common to (among others) phenomena related to geomagnetic variability of the terrestrial magnetosphere (intense magnetic storms), seismic activity (electromagnetic emissions prior to earthquakes), solar-terrestrial physics (solar flares), neurophysiology (epileptic seizures), and socioeconomic systems (stock market crashes).

It is an open question whether the spatial and temporal complexity associated with extreme events arises from the system's structural organization (geometry) or from the chaotic behavior inherent to the nonlinear equations governing the dynamics of these phenomena. On the one hand, the presence of scaling laws associated with earthquakes and geomagnetic disturbances suggests understanding these events as generalized phase transitions similar to nucleation and critical phenomena in thermal and magnetic systems. On the other hand, because of the structural organization of the systems (e.g., as complex networks) the associated spatial geometry and/or topology of interactions plays a fundamental role in the emergence of extreme events.

Here, a few aspects of the interplay between geometry and dynamics (critical phase transitions) that could result in the emergence of extreme events, which is an open problem, will be discussed.