Griffiths phases in infinite-dimensional modular networks

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Recent experimental evidences suggest that the brain operates near criticality, where spatial and temporal correlations diverge. In this region information processing capabilities, sensitivity, and the dynamic range of stimuli over which there is significant variation in the collective response of the network are optimal. In condensed matter physics, quenched disorder can lead to the so-called Griffiths phases (GPs) with dynamical criticality in an extended parameter space exhibiting high sensitivity to external stimuli. GP is the consequence of rare regions (RRs), consisting of locally supercritical (also called active or endemic states in epidemics) domains that occur with small probability but that last for very long times. GP generated by the heterogeneities on modular networks has recently been suggested to provide a mechanism, rid of fine parameter tuning, to explain the critical behavior of the brain. A hypothesis based on activity spreading models claims that the heterogeneity effects become irrelevant in the thermodynamic limit, in case of infinite-dimensional random graphs. We investigate the dynamical behavior of an activity spreading model evolving in heterogeneous random networks with highly modular structure, organized non-hierarchically. We observe that loosely coupled modules act as effective RRs slowing down the extinction of activation. As a consequence, we find extended control parameter regions with continuously changing dynamical exponents for single network realizations in the thermodynamic limit, as in a real GP. The avalanche size distributions of spreading events exhibit robust power-law tails. Our findings relax the requirement of a hierarchical organization of the modular structure, which can help to rationalize the criticality of modular systems in the framework of GPs.

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