Persitent activity of neural dynamics on hierarchical networks

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The brain exhibits many levels of neural activity, from quiescent phases to large-scale burstings and synchronization, with intermediate states often called states of persitent activity. Recent developments in connectomics have attributed this functionality to the hierarchical organisation of the neural network [1].
We explore the relation between hierarchichy and the level of activity on the network. Two types of network structures are examined: hierarchical modular networks [1] and hierarchical preferential attachment networks [2]. We study a binary neural dynamics on these networks. We parametrize the dynamics to model refractory periods, spontaneous activations and energy limitations.
We find, both numerically and analytically, that a modular structure is sufficient to support different levels of activity, including the persistent activity. The hierarchical organisation futher enhances the diversity of the dynamics. In addition, persistent activity is found to emerge in a narrow window of parameters, where the dynamics is both limited and supported by the structure. Our work established a rigorous framework for neural dynamics on hierarchical networks and brings new light on persistent activity.

[1] KAISER M., GORNER M. ET HILGETAG C.C., *Criticality of spreading dynamics in hierarchical cluster networks without inhibition*, New J. Phys., 9 (2007), p. 110.
[2] HÉBERT-DUFRESNE L., LAURENCE E., ALLARD A., YOUNG J.-G. AND DUBÉ L.J., *Complex networks as an emerging property of hierarchical preferential attachment*, Phys. Rev. E, 92 (2015), p. 062809.

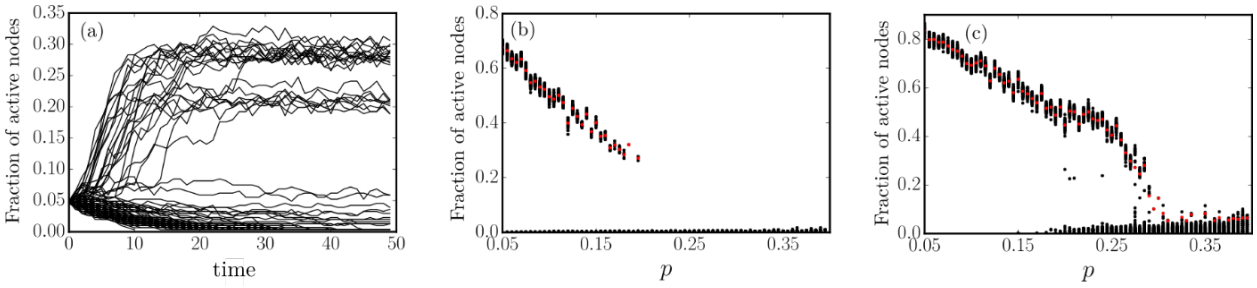

Figure 1: (a) Fraction of active nodes under neural dynamics in hierarchical modular networks. Each line represents a different realisation of the dynamics. In (b) and (c), fraction of active nodes at equilibrium as a function of p, a construction parameter of the hierarchical structure. In (b), the network supports a single endemic state of activity. In (c), the dynamical parameters are modified to highlight the emergence of intermediate regimes near the continuous transition. Red dots are the average activation and black dots are single realisations.