Phase Transitions towards Self-Organized Criticality in Neuronal Systems

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In recent work we have demonstrated the existence of genuine self-organized criticality (SOC) in neuronal networks [1] caused by depressing dynamical synapses, i.e., where the synaptic coupling exhibits fatigue under repeated presynaptic firing. This adaptation mechanism drives the network into a self-organized critical regime by adjusting the average coupling strengths to a critical value. The size distribution of critical avalanches exhibits an inverse power law, which has been observed in the same form experimentally in neuronal cultures as well as in awake monkeys.

We have now generalized this study to include facilitating besides depressing synaptic dynamics as found in biological systems. We show analytically that the generalized model attains SOC in an extended region of parameter space that is reached through phase transitions. The critical region of the connectivity parameter is sandwiched between a sub- and a supercritical regime which also can be reached experimentally by a manipulation of the synaptic strengths. The system exhibits a rich dynamical behaviour including a hysteresis between critical and noncritical dynamics, switching of the dynamics in dependence of external inputs, and first- and second-order phase transitions that form a cusp bifurcation [2]. This is the first observation of a complex classical bifurcation scenario combined with a SOC phase.

*work in collaboration with A. Levina and M. Herrmann

References:

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[2] A. Levina, J. M. Herrmann, and T. Geisel, Phase Transitions towards Criticality in a Neural System with Adaptive Interactions, Phys. Rev. Lett. 102, 118110 (2009).