Stochastic Wilson-Cowan equations for networks of excitatory and inhibitory neurons

Jack Cowan
Mathematics Department
University of Chicago

Not long ago we found a way to describe the large-scale statistical dynamics of neocortical neural activity in terms of (a) the equilibria of the mean-field Wilson-Cowan equations, and (b) the fluctuations about such equilibria due to intrinsic noise, as modeled by a stochastic version of such equations. Major results of this formulation include a role for critical branching, and the demonstration that there exists a non-equilibrium phase transition in the statistical dynamics which is in the same universality class as directed percolation (DP).

Here we show how the mean-field dynamics of interacting excitatory and inhibitory neural populations is organized around a Bogdanov-Takens bifurcation, and how this property is related to the DP phase transition in the statistical dynamics. The resulting theory can be used to explain the origins and properties of random bursts of synchronous activity (avalanches), population oscillations (quasi-cycles), synchronous oscillations (limit-cycles) and fluctuation-driven spatial patterns (quasi-patterns).

If time permits we will also show how such a system of interacting neural populations can be made to self-organize to a state near the Bogdanov-Takens bifurcation, if the coupling constants (synaptic weights) are activity-dependent, and follow approximately, a generalization of the Vogels et al. version of spike-time dependent synaptic plasticity (STDP).