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Seminaires du LPTM , Universite de Cergy Pontoise

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Domaines : physics.bio-ph

Titre : *Statistical mechanics of correlated neuronal variability*

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Résumé : *Neuronal networks are many particle systems with interesting physical properties : They operate far from thermodynamic equilibrium and show correlated states of collective activity that result from the interaction of large numbers of relatively simple units [1]. We here present recent progress towards a quantitative understanding of such systems by application of non-equilibrium statistical mechanics.*

Mean-field theory and linear response theory capture many qualitative properties of the "ground state" of recurrent networks [2]. A fundamental quantity required is the single neuron transfer function. Formally, it constitutes an escape problem driven by colored noise. We recently applied boundary layer theory to obtain a reduction to the technically much simpler white noise problem [3]. It allows us, for example, to formulate a theory of finite-size fluctuations in layered neuronal networks [4]. Verification of such theoretical predictions is fundamentally hindered by sub-sampling : We only see a tiny fraction of all neurons within the living brain at a time. Employing tools from disordered systems (spin glasses) combined with an auxiliary field formulation, we overcome this issue by deriving a mean-field theory that is valid beyond the commonly-made self-averaging assumption. It predicts that the heterogeneity of the network connectivity enables a novel sort of critical dynamics which unfolds in a low-dimensional subspace [5]. The functional consequences are analyzed by importing tools from field theory of stochastic differential equations. We obtain closed-form expressions for the transition to chaos and for the sequential memory capacity of the network by help of replica calculations [6]. We find that cortical networks operate in a hi-

therto unreported regime that combines instability on short time scales with asymptotically non-chaotic dynamics ; a regime which has optimal memory capacity.

As an outlook we present two directions in which field-theoretical methods enable insights into network dynamics : First, a novel diagrammatic expansion of the effective action around non-Gaussian solvable theories [7]; we exemplify this method by finally providing the long-searched for diagrammatic formulation of the Thouless-Anderson-Palmer mean-field theory of the Ising model. Second, the application of the functional renormaliztion group to neuronal dynamics [8]. It enables the systematic study of second order phase transitions in such networks.
