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On the master equation approach to stochastic neurodynamics

We consider a master equation formulation of stochastic neurodynamics for a recurrent network of synaptically coupled homogeneous neuronal populations each consisting of N identical neurons. The state of the network is specified by the fraction of active or spiking neurons in each population, and transition rates are chosen so that in the thermodynamic or mean-field limit we recover standard rate-based models. We derive the lowest order corrections to these rate equations for large but finite N using the Van Kampen system-size expansion, and show how this is related to the path-integral approach of Buice and Cowan. We also describe applications of the master equation approach to (i) studying the noise amplification of neural oscillations and (ii) calculating exit times from metastable states.