M2 INTERNSHIP PROPOSAL

Laboratory name: **Institut de Biologie de l'ENS**
CNRS identification code: **UMR 8197**
Internship director : **Jonas RANFT**
e-mail: **jonas.ranft@ens.psl.eu** Phone number: **01 44 32 37 31**
Web page: **https://qbio.ens.psl.eu/en/people/jonas-ranft**
Internship location: **46 rue d'Ulm, 75005 Paris**

Thesis possibility after internship: **TBD**
Funding: **internship**

Self-consistent theory of recurrent networks with correlated inputs

Keywords: theoretical neuroscience, dynamic mean-field theory, rotator networks, Dale's law

Despite the incredible complexity of our brains' neural networks, simplified theoretical descriptions of neural activity can be a powerful tool to study their dynamics. In particular statistical physics inspired approaches have led to profound insights, ranging from the balanced state of excitatory-inhibitory spiking networks to the emergence of chaos in recurrent rate networks. However, many of these results have been obtained for biologically unrealistic limiting cases such as infinitely large networks and/or vanishing connection probability between neurons (the so-called sparse limit), because even for relatively simple network models it becomes quickly too complicated to obtain analytical solutions of their dynamics. It remains challenging to develop theories that apply to spiking networks and allow one to characterize the dynamic properties of biologically more realistic networks, e.g. with a finite connection probability. Here, to overcome some of the difficulties we propose to study ``rotator networks,'' which are considerably simpler than real spiking networks and therefore more amenable to mathematical analysis, but can nevertheless capture dynamical properties of networks of spiking neurons [1]. A typical problem is to understand the self-generated fluctuations of neural activity, which are due to the quenched disorder of random synaptic connections and can show a rich temporal correlation structure shaped by the network dynamics. They need to be determined self-consistently, as in recurrent networks typical inputs (a priori unknown) equal typical outputs (also unknown) (see Fig. 1a,b). For rotator networks with Gaussian connectivity matrices, dynamic mean-field theory has allowed to obtain a semi-analytical expression for the power spectra of the network noise [1]. In the more realistic setting of networks composed of excitatory and inhibitory units with finite connection probability p, this solution ceases to be exact (see Fig. 1c). In a recent work, we have shown that using a cumulant expansion, the theory can be extended to account for non-Gaussian fluctuations that are cause by correlated external inputs [2], but finding the correct expression for the case of purely excitatory or inhibitory connections, also known as Dale's law, remains an open problem. Subsequent work could exploit the result to study information transmission across such recurrent networks, e.g. addressing how the mutual information between an input signal and the network output depends on the network parameters, or whether the intrinsic network dynamics gives rise to optimal frequency bands in terms of channel capacity.

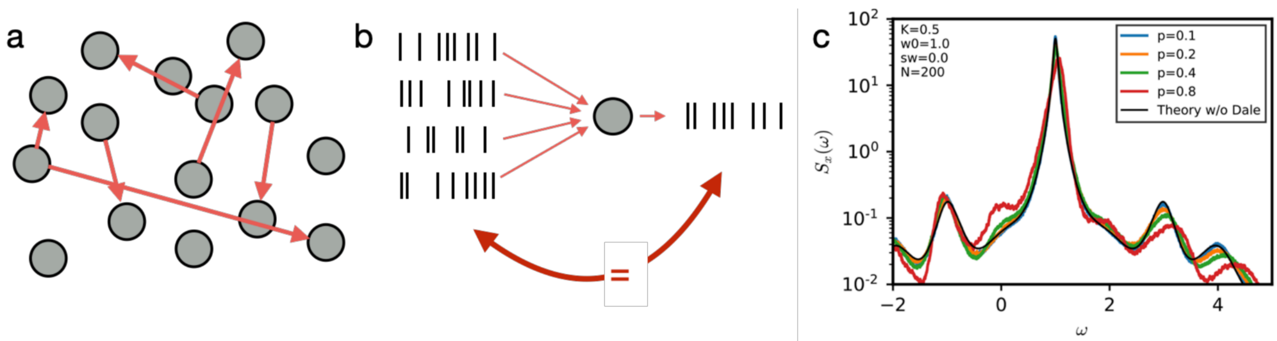

Figure 1: Self-consistent network noise power spectra. (a) Sketch of a recurrent network with random connectivity between units. (b) The stochastic activity of a typical unit has the same statistics as the inputs the unit receives. (c) Power spectra of a rotator network for varying connection probability p (colored lines) vs. the solution for Gaussian connectivity (black line).

[1] A. van Meegen & B. Lindner, Phys Rev Lett (2018). [2] J. Ranft & B. Lindner, Chaos (2022).