Efficient sampling in spiking neural networks
(Funded Master internship and PhD via selective funding)

Motivation: To adapt and thrive in uncertain environments, animals rely on their brains to estimate uncertainty across sensory and motor timescales. Sampling-based inference offers a robust theoretical framework for understanding probabilistic computation in neural circuits, but it remains unclear how spiking neural networks can implement these algorithms in a biologically plausible and computationally efficient way. Recent studies highlight the critical role of population geometry – shaped by neural codes and dynamics – in enabling fast and accurate sampling [1]. Moreover, novel non-reversible approaches, inspired by Piecewise Deterministic Markov Processes (PDMP) [2, 3, 4], could further enhance efficiency and offer a biologically realistic path to scalable sampling. Exploring these ideas could provide new insights into neural computation and inspire advances in neuromorphic systems.

Goal: This internship will investigate biologically plausible mechanisms for rapid sampling in spiking neural networks by leveraging both population geometry and non-reversible dynamics. In particular, we will explore new approaches inspired by PDMP-based processes, which hold promise for dramatically improving convergence rates while maintaining biological relevance. By integrating numerical simulations and theoretical insights, this project aims to establish design principles for fast and scalable sampling, bridging the gap between computational efficiency and neural plausibility.

Environment: The project is embedded in a interdisciplinary research collaboration bridging mathematics and computational neuroscience between Paul Masset (Mc Gill Uni), Manon Michel (Université Clermont-Auvergne) and Jacob Zavatone-Veth (Harvard Uni). The internship can be principally located either in Mc Gill University (Canada) or Université Clermont-Auvergne (France).

This opportunity is open to Master's students, including first-year students (Master 1). For Master 2 students, the internship will aim at laying the groundwork for an interdisciplinary PhD project centered on a quantitative analytical and numerical study of biologically-plausible sampling algorithms in spiking neural networks.

Please note that for internships taking place in Canada, administrative formalities (such as obtaining a visa) can take significant time and should be initiated as early as possible.

Profile: We are seeking an enthusiastic candidate with a strong background in probability, statistics, statistical physics, and/or computational neuroscience. Experience in programming and an interest in sampling or biologically-inspired algorithms would be beneficial. For more details, please contact Paul Masset (paul.masset@mcgill.ca), Manon Michel (manon.michel@uca.fr) and Jacob Zavatone-Veth (jzavatoneveth@g.harvard.edu).

References:

[1] P. Masset, J.A. Zavatone-Veth, P.J. Connor, V.N. Murthy, and C. Pehlevan. *Natural gradient enables fast sampling in spiking neural networks*, *Advances in Neural Information Processing Systems (NeurIPS)* 35, (2022).

[2] M. H. Davis, *Piecewise-Deterministic Markov Processes: A General Class of Non-Diffusion Stochastic Models*, *JRSS B*, 46 (3): 353–388, 1984.

[3] M. Michel, S. Kapfer, and W. Krauth. *Generalized event-chain Monte Carlo: Constructing rejection-free global-balance algorithms from infinitesimal steps*, *J. Chem. Phys*, 140, 054116, 2014.

[4] A. Monemvassitis, A. Guillin and M. Michel. *PDMP characterisation of event-chain Monte Carlo algorithms for particle systems*, *Journal of Statistical Physics* 190, 66 (2023).