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# PhD defense day on July 7

Sophie Jaffard

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On the occasion of Sophie Jaffard's PhD defense on July 7, 2025, we have invited four members of the jury, Eva Löcherbach, Thomas Moreau, Vincent Rivoirard and Rebecca Willett, to present their research work. You are all invited to attend this event, which will begin in the morning with the various presentations and end in the afternoon with the defense. Presentations will take place in the LJAD conference room.

## Planning of the day

Horaire	Intervenant	Sujet
9h30 - 10h00	Eva Löcherbach	Nonparametric estimation of the jump rate in mean field interacting systems of neurons.
10h05 - 10h35	Vincent Rivoirard	PCA for point processes.
		Coffee break
11h00 - 11h30	Rebecca Willett	TBA
11h35 - 12h05	Thomas Moreau	Event-based representations for Electromagnetic Brain Signals.
		Lunch buffet
14h00 - 17h00	Sophie Jaffard	<i>PhD defense.</i> Spiking neural networks: learning as point processes.
17h00 - 18h00		PhD defense buffet

## Abstracts of the talks

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**Eva Löcherbach.** Nonparametric estimation of the jump rate in mean field interacting systems of neurons.

**Abstract:** We consider finite systems of  $N$  interacting neurons described by non-linear Hawkes processes in a mean field frame. Neurons are described by their membrane potential. They spike randomly, at a rate depending on their potential. In between successive spikes, their membrane potential follows a deterministic flow. We estimate the spiking rate function based on the observation of the system of  $N$  neurons over a fixed time interval  $[0, t]$ . Asymptotic are taken as  $N$ , the number of neurons, tends to infinity. We introduce a kernel estimator of Nadaraya-Watson type and discuss its asymptotic properties with help of the deterministic dynamical system describing the mean field limit. We compute the minimax rate of convergence in an  $L^2$ -error loss over a range of Hölder classes and obtain the same rate of convergence as for density estimation in the classical iid setting. This is a joint work with Aline Duarte (USP), Kadmo Laxa (USP) and Dasha Loukianova (Evry).

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**Vincent Rivoirard.** PCA for point processes.

**Abstract:** We introduce a novel statistical framework for the analysis of replicated point processes that allows for the study of point pattern variability at a population level. By treating point process realizations as random measures, we adopt a functional analysis perspective and propose a form of functional Principal Component Analysis (fPCA) for point processes. The originality of our method is to base our analysis on the cumulative mass functions of the random measures which gives us a direct and interpretable analysis. Key theoretical contributions include establishing a Karhunen-Loève expansion for the random measures and a Mercer Theorem for covariance measures. We establish convergence in a strong sense, and introduce the concept of principal measures, which can be seen as latent processes governing the dynamics of the observed point patterns. We propose an easy-to-implement estimation strategy of eigenelements for which parametric rates are achieved. We fully characterize the solutions of our approach to Poisson and Hawkes processes and validate our methodology via simulations and diverse applications in seismology, single-cell biology and neurosciences, demonstrating its versatility and effectiveness. Joint work with Victor Panaretos (EPFL), Franck Picard (ENS de Lyon) and Angelina Roche (Université Paris Cité).

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**Rebecca Willett.** TBA

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**Thomas Moreau.** Event-based representations for Electromagnetic Brain Signals

**Abstract:** The quantitative analysis of non-invasive electrophysiology signals from electroencephalography (EEG) and magnetoencephalography (MEG) often boils down to the

identification of certain types of events and their distribution in the signal. The events are characterized by their temporal patterns, such as evoked responses, transient bursts of neural oscillations, but also blinks or heartbeats for data cleaning. Given these events and patterns, a natural question is to estimate how their occurrences are modulated by certain cognitive tasks and experimental manipulations.

In this talk, I will present contributions to the analysis of event-related neural responses using point-process models. While PP has been used in neuroscience in the past, in particular for single cell recordings (spike trains), techniques such as CDL make them amenable to human studies based on EEG/MEG signals. A particular focus will be on the development of methods that scale to the large dimensionality of the data in the neuroscience context, with efficient optimization procedures and robustness to noisy observation, with early results on M/EEG datasets.

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**Sophie Jaffard.** Spiking neural networks: learning as point processes.

**In front of a jury, composed of:**

François Delarue, PR, Université Côte d'Azur

Eva Löcherbach, PR, Université Paris 1 Panthéon Sorbonne

Thomas Moreau, CR, INRIA Saclay

Patricia Reynaud-Bouret, DR, Université Côte d'Azur

Vincent Rivoirard, PR, Université Paris Dauphine

Ivo Sbalzarini, PR, Technische Universität Dresden

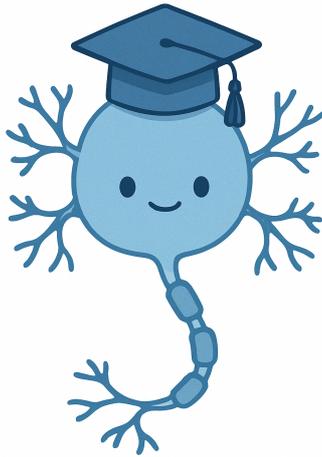
Samuel Vaiteř, CR, Université Côte d'Azur

Rebecca Willett, PR, University of Chicago

**Abstract:** This thesis focuses on the development and theoretical analysis of mathematical models of neural learning, complemented by the statistical analysis of experimental data, to gain insights into the brain's learning processes and their role in shaping specific behaviors. The work is inherently interdisciplinary, bridging mathematics, biology, machine learning, and cognition. During task learning, neurons adjust their synaptic connections through local mechanisms, enabling them to fire together in response to specific concepts, forming what are known as neuronal assemblies and driving global behaviors. These processes have inspired early machine learning algorithms and continue to yield increasing empirical results in biologically inspired neural networks. However, a gap remains between the empirical findings and the underlying theory, and the transition from neuronal mechanisms to cognitive behavior remains poorly understood.

To address this issue, I designed a simple biologically inspired neural network and mathematically proved that it can achieve global learning while relying solely on learning rules local to the synapse. Then, I extended these results by introducing hidden layers into the network, demonstrating that it naturally forms neuronal assemblies and can successfully learn complex tasks. Finally, I established strong approximation results between cognitive models reknown to accurately model behavior, and spiking neural models including my own, providing evidence on how neural dynamics lead to specific behaviors. These theoretical

findings are supported by the analysis of neuronal recordings from rats and data from human participants performing a categorization task we designed.



**We hope to see many of you!**