Journée d'équipe PS-MAASAI

Programme

SESSION 1

09:00 – 09:30	**Maya Guy** *Revealing Asteroid Families with a Mixture Model*
09:30 – 10:00	**Yuxiu** *Heterogeneous synaptic motifs bridge microscale structure and macroscale nonlinear dynamics*
10:00 – 10:30	**Simon Queric** *Bridging Maximum Likelihood and Optimal Transport in Stochastic Block Models*
10:30 – 11:00	**Coffee break**

SESSION 2

11:00 – 11:30	**Lukas Wessels** *Uniqueness by Common Noise for 1D Mean Field Games*
11:30 – 12:00	**Matteo Cagnotti** *Numerical approximation of the skew fractional Brownian motion*
12:00 – 13:00	**Poster session & lunch buffet**

Each talk: 25 minutes followed by 5 minutes of questions.

Abstracts

09:00 – 09:30

Revealing Asteroid Families with a Mixture Model

Maya Guy

Identification of asteroid families is a key question in planetary sciences, offering crucial insights into the collisional and dynamical history of the asteroid Main Belt (MB). These families, originating from the fragmentation of a parent body, form dense clusters in orbital proper elements space. Over time, the non-gravitational Yarkovsky effect induces a drift, producing the characteristic V-shaped patterns in the (semi-major axis, absolute magnitude) plane. Current techniques for families identification suffer from several limitations. We propose a new machine learning model, a probabilistic clustering method, for identifying asteroid families. We model the observed population of the MB as a mixture that captures the Yarkovsky-driven evolution. We will present the method, a validation based on a numerical simulation of the inner Main Belt that highlights the performance and advantages of our approach, and preliminary results on real asteroids.

09:30 – 10:00

Heterogeneous synaptic motifs bridge microscale structure and macroscale nonlinear dynamics

Yuxiu

Recent breakthroughs in synaptic-resolution network connectomics have revealed that brain circuits feature fine-scale structural connectivity, such as pairs of correlated synaptic couplings known as second-order motifs. Large-scale recordings of neuronal activity in networks containing nonlinear neurons reveal macroscopic heterogeneous population dynamics throughout cortices. These findings rekindle the inquiry into an intriguing question: may microscale synaptic structures contribute to macroscopic heterogeneous dynamics and computations in ways that canonical brain circuit models cannot?

To answer this question, we create random RNNs with various cell types, nonlinear non-negative neural responses, and arbitrary marginal and second-order correlated synaptic statistics. We derive mean-field low-rank equations for P-population networks in which the pre- and postsynaptic neuronal population identities determine the synaptic and motif strengths. Our framework requires $2P$ latent dynamic variables, with P variables describing mean population activity and P variables capturing within-population variability. Theoretical and simulation results demonstrate that chain motifs induce correlations in synaptic variability, enabling microscopic fluctuations to be integrated and to influence mesoscopic mean population dynamics. We apply this framework to reverse engineer network connectivity that recapitulates the heterogeneous activity across the population in the mouse primary visual cortex. By bridging the gap between synaptic organisation and nonlinear heterogeneous population dynamics, these findings offer a principled approach and verifiable predictions regarding the relationship between fine-scale connectivity, heterogeneous dynamics, and functional computations.

10:00 – 10:30

Bridging Maximum Likelihood and Optimal Transport in Stochastic Block Models

Simon Queric

We study inference in stochastic block models (SBMs) through the lens of optimal transport (OT). We first establish that maximum likelihood variational inference (MLVI) can be interpreted as a semi-relaxed Gromov–Wasserstein (srGW) projection with entropic regularization. While this formulation yields accurate clustering, the entropic regularization prevents transport plans from being sparse, hindering intrinsic model selection. Consequently, we investigate unregularized srGW estimators, and prove that they consistently recover both the SBM connectivity matrix and latent cluster assignments in the asymptotic regime. However, this asymptotic property does not translate into reliable model selection in finite samples, and calls for additional mechanisms to promote sparsity in the inferred cluster proportions. We empirically show that such a regularized formulation yields estimators that simultaneously recover model parameters and select the number of clusters in a single optimization problem, thereby avoiding costly grid search or heuristic model selection procedures.

11:00 – 11:30

Uniqueness by Common Noise for 1D Mean Field Games

Lukas Wessels (joint work with F. Delarue)

Mean field games (MFGs) provide a probabilistic framework for studying large populations of interacting, actively optimizing agents. A fundamental challenge in this theory is that equilibria are generally non-unique in the absence of monotonicity assumptions. This talk will begin with an accessible introduction to the MFG framework, requiring no prior expertise in the area. We will then explore how shared randomness can resolve this non-uniqueness problem. Specifically, we establish that introducing an infinite-dimensional multiplicative common noise restores the uniqueness of equilibria for generic MFGs in one spatial dimension. Our approach is based on Girsanov's theorem, which allows us to decouple the forward-backward structure in the MFG system describing these equilibria. Along the way, we will also discuss a novel higher regularity result for backward stochastic Hamilton–Jacobi–Bellman equations.

11:30 – 12:00

Numerical approximation of the skew fractional Brownian motion

Matteo Cagnotti (joint work with Rémi Catellier)

Skew Brownian motion behaves like Brownian motion away from the origin, but its excursions are positive with prescribed probability. We study the fractional analogue in which the noise has correlated increments. The interaction at the origin makes numerical simulation difficult. In this talk we will discuss the definition of solution, alternative approximation schemes and their convergence.