

2025 Activity Report

RESEARCH CENTRE: Inria Branch at the University of Montpellier
IN PARTNERSHIP WITH: CNRS, Université Côte d'Azur

Project-Team

MATHNEURO

Mathematics for Neuroscience

In collaboration with Laboratoire Jean-Alexandre Dieudonné (JAD)



Project-Team MATHNEURO

Creation of the Project-Team: 2019 January 01

Each year, Inria research teams publish an Activity Report presenting their work and results over the reporting period. These reports follow a common structure, with some optional sections depending on the specific team. They typically begin by outlining the overall objectives and research programme, including the main research themes, goals, and methodological approaches. They also describe the application domains targeted by the team, highlighting the scientific or societal contexts in which their work is situated. The reports then present the highlights of the year, covering major scientific achievements, software developments, or teaching contributions. When relevant, they include sections on software, platforms, and open data, detailing the tools developed and how they are shared. A substantial part is dedicated to new results, where scientific contributions are described in detail, often with subsections specifying participants and associated keywords. Finally, the Activity Report addresses funding, contracts, partnerships, and collaborations at various levels, from industrial agreements to international cooperations. It also covers dissemination and teaching activities, such as participation in scientific events, outreach, and supervision. The document concludes with a presentation of scientific production, including major publications and those produced during the year.

Keywords

Computer sciences and digital sciences

- A6. – Modeling, simulation and control
 - A6.1. – Methods in mathematical modeling
 - A6.1.1. – Continuous Modeling (PDE, ODE)
 - A6.1.2. – Stochastic Modeling
 - A6.1.4. – Multiscale modeling
 - A6.2. – Scientific computing, Numerical Analysis & Optimization
 - A6.2.1. – Numerical analysis of PDE and ODE
 - A6.2.2. – Numerical probability
 - A6.2.3. – Probabilistic methods
 - A6.3. – Computation-data interaction
 - A6.3.4. – Model reduction

Other research topics and application domains

- B1. – Life sciences
 - B1.2. – Neuroscience and cognitive science
 - B1.2.1. – Understanding and simulation of the brain and the nervous system
 - B1.2.2. – Cognitive science

Contents

Project-Team MATHNEURO	1
1 Team members, visitors, external collaborators	5
2 Overall objectives	5
3 Research program	6
3.1 Excitability	6
3.1.1 Neuronal networks dynamics	7
3.1.2 Mean-field and stochastic approaches	7
3.1.3 Neural fields	7
3.1.4 Slow-fast dynamics in neuronal models	7
3.2 Ageing	8
3.3 Cognition	8
3.3.1 Modeling associative memory	8
3.3.2 Decision-making	9
3.3.3 Visual perception	9
4 Application domains	9
5 Highlights of the year	10
6 Latest software developments, platforms, open data	10
6.1 Open data	10
6.1.1 Data sciences for MathNeuro	10
6.1.2 EBRAINS-EITN Fall School in Computational Neuroscience 2025	10
7 New results	10
7.1 Excitability	10
7.1.1 Neuronal networks and neural fields	10
7.1.2 Multiple-timescale dynamics at the level of single neurons	12
7.1.3 Multiscale modeling of Dravet Syndrome	13
7.1.4 Neuronal excitability: Interface with electrophysiological experiments	13
7.1.5 Corticogenesis and exposome	14
7.2 Ageing	14
7.3 Cognition	15
7.3.1 Memory	15
7.3.2 Decision-making	16
7.3.3 Visual perception	17
8 Partnerships and cooperations	17
8.1 National initiatives	17
8.1.1 ANR projects	17
8.1.2 Inria Exploratory Action	18
8.2 Regional initiatives	18
8.2.1 Unmute	19
9 Dissemination	19
9.1 Promoting scientific activities	19
9.1.1 Scientific events: organization	19
9.1.2 Scientific events: selection	19
9.1.3 Journal	20
9.1.4 Invited talks	20
9.1.5 Leadership within the scientific community	21

9.1.6	Scientific expertise	21
9.1.7	Research administration	21
9.2	Teaching - Supervision - Juries - Educational and pedagogical outreach	21
9.2.1	Teaching	21
9.2.2	Supervision	21
9.2.3	Juries	22
10	Scientific production	22
10.1	Major publications	22
10.2	Publications of the year	24
10.3	Cited publications	25

1 Team members, visitors, external collaborators

Research Scientists

- Mathieu Desroches [Team leader, INRIA, Senior Researcher, HDR]
- Emre Baspinar [INRIA, Researcher]
- Fabien Campillo [INRIA, Senior Researcher, HDR]
- Pascal Chossat [CNRS, Emeritus, HDR]

Post-Doctoral Fellow

- Louisiane Lemaire [INRIA, Post-Doctoral Fellow]

Interns and Apprentices

- Natalie Elena Cernei [INRIA, Intern, from Dec 2025]
- Camilla Nouveau [INRIA, Intern, until Feb 2025]

Administrative Assistant

- Sandrine Boute [INRIA]

Visiting Scientist

- Natalie Elena Cernei [University of Bologna (Italy), from Oct 2025 until Nov 2025]

External Collaborator

- Serafim Rodrigues [BCAM and Ikerbasque Research Professor, Bilbao, Spain]

2 Overall objectives

MathNeuro specializes in multiscale computational modeling of neural dynamics, with a strong emphasis on experimental validation and finalized applications, particularly in pathological behaviors. Our work includes the modeling, analysis, and simulation of systems operating across multiple temporal and spatial scales, ranging from single-cell models to microcircuits and large-scale networks.

In neuroscience, we focus on phenomena such as synaptic plasticity and neuronal excitability, with particular attention to pathological conditions including epileptic seizures, migraines, and neurodegenerative diseases like Alzheimer's.

In terms of methodology, the team brings together specialists in dynamical systems theory, stochastic processes, and data analysis, with a strong emphasis on computational expertise.

We have made a clear commitment to collaborate closely with experimental neuroscience groups, staying as connected to the data as possible, and we aim to strengthen our expertise in this area.

The research in MathNeuro is organized around key thematic and questions coming from Neuroscience, around the prominent concepts of **neuronal (hyper)excitability**, **synaptic plasticity**, **ageing** and **cognition**. Then, we work on these questions in collaboration with experimentalists, in link with experimental data, using mathematical modeling, analysis and simulation. We analyze these questions for both healthy and pathological brain states. The recruitment of Emre Baspinar in the team, in 2023, has brought two novel research topics, on *neurogeometry* (transversal to excitability and plasticity) and on *decision-making* (as part of our research line on cognition).

3 Research program

We have chosen to structure the MathNeuro research program around two main axes: excitability and cognition. Questions related to plasticity arise within both axes, while aging and memory can be encompassed under cognition.

3.1 Excitability

Excitability refers to the all-or-none property of neurons [51, 55]. That is, the ability to respond nonlinearly to an input with a dramatic change of response from “none” — no response except a small perturbation that returns to equilibrium — to “all” — large response with the generation of an action potential or spike before the neuron returns to equilibrium. The return to equilibrium may also be an oscillatory motion of small amplitude; in this case, one speaks of resonator neurons as opposed to integrator neurons. The combination of a spike followed by subthreshold oscillations is then often referred to as mixed-mode oscillations (MMOs) [47]. Slow-fast ordinary differential equation (ODE) models of dimension at least three are well capable of reproducing such complex neural oscillations. Part of our research expertise is to analyze the possible transitions between different complex oscillatory patterns of this sort upon input change and, in mathematical terms, this corresponds to understanding the bifurcation structure of the model. In particular, we also study possible combinations of different scenarios of complex oscillations and their relevance to revisit unexplained experimental data, e.g. in the context of bursting oscillations [48]. In all case, the role of noise [43] is important and we take it into consideration, either as a modulator of the underlying deterministic dynamics or as a trigger of potential threshold crossings. Furthermore, the shape of such time series (i.e., with a given oscillatory pattern) can be analyzed within the mathematical framework of dynamic bifurcations; see section 3.1.4. The main example of abnormal neuronal excitability is hyperexcitability and it is important to understand the biological factors which lead to such excess of excitability and to identify (both in detailed biophysical models and reduced phenomenological ones) the mathematical structures leading to these anomalies. Hyperexcitability is one important trigger for pathological brain states related to various diseases such as chronic migraine [63], epilepsy [65] or even Alzheimer’s Disease [59].

A central axis of research within our group is to revisit models of such pathological scenarios, in relation with a combination of advanced mathematical tools and in partnership with biological labs.

In particular, we started in 2024 an Inria Exploratory Action whose PI is Fabien Campillo. It is focused on the multiscale modeling of Dravet Syndrome (DS) [50], which is a severe encephalopathy that affects children, has a strong genetic component and is characterized, amongst other adverse symptoms, by epileptic crises. Our exploratory action is called 2MDS and it aims to develop mathematical models of neuronal activity in the context of DS, focusing on a specific mutation of a Sodium ion channel present in the majority of patients affected by this disease [60]. Namely, we are developing Markov-state models of ion channels with this mutation, at various population scales, as well as macroscopic models of Hodgkin-Huxley type in order to compare the outputs of our models to experimental data from our partners. This project involves a collaboration with the Inria Project-Team Astral (Pierre Del Moral), as well as, partners in Spain: MathNeuro’s external collaborator Serafim Rodrigues, who leads the research group MCEN on mathematical, computational and experimental neuroscience at the Basque Center for Applied Mathematics (BCAM, Bilbao, Spain), and Juan Manuel Encinas, an experimentalist at Achucarro Basque Center for Neuroscience, who leads a research group interested in neurogenesis with a particular focus on DS. Through the 2MDS exploratory action, we have recruited Louisiane Lemaire as a postdoc for 24 months (April 2024-March 2026). She is a specialist on biophysical modeling and she is in charge of the macroscopic model of DS that we are developing. This project caught the attention of the Spanish Dravet Foundation, which invited the team to participate in a COST action proposal aimed at bridging the gap between research on *developmental and epileptic encephalopathies* (DEE). This collaborative network will develop computational models and improve diagnostic tools to better understand and treat DEE.

Around the questions of neuronal excitability and hyperexcitability, we have a number of subprojects, which are listed below.

3.1.1 Neuronal networks dynamics

The study of neuronal networks is certainly motivated by the long term goal to understand how brain is working. But, beyond the comprehension of brain or even of simpler neural systems in less evolved animals, there is also the desire to exhibit general mechanisms or principles at work in the nervous system. One possible strategy is to propose mathematical models of neural activity, at different space and time scales, depending on the type of phenomena under consideration. However, beyond the mere proposal of new models, which can rapidly result in a plethora, there is also a need to understand some fundamental keys ruling the behavior of neuronal networks, and, from this, to extract new ideas that can be tested in real experiments. Therefore, there is a need to make a thorough analysis of these models. An efficient approach, developed in our team, consists of analyzing neuronal networks as dynamical systems. This allows to address several issues. A first, natural issue is to ask about the (generic) dynamics exhibited by the system when control parameters vary. This naturally leads to analyze the bifurcations [2] occurring in the network and which phenomenological parameters control these bifurcations. Another issue concerns the interplay between the neuron dynamics and the synaptic network structure.

3.1.2 Mean-field and stochastic approaches

Modeling neural activity at scales integrating the effect of thousands of neurons is of central importance for several reasons. First, most imaging techniques are not able to measure individual neuron activity (microscopic scale), but are instead measuring mesoscopic effects resulting from the activity of several hundreds to several hundreds of thousands of neurons. Second, anatomical data recorded in the cortex reveal the existence of structures, such as the cortical columns, with a diameter of about $50 \mu\text{m}$ to 1mm , containing of the order of 10^2 to 10^5 neurons belonging to a few different species. The description of this collective dynamics requires models which are different from individual neurons models. In particular, when the number of neurons is large enough, averaging effects appear, and the collective dynamics is well described by an effective mean-field, summarizing the effect of the interactions of a neuron with the other neurons, and depending on a few effective control parameters. This vision, inherited from statistical physics requires that the space scale be large enough to include a large number of microscopic components (here neurons) and small enough so that the region considered is homogeneous.

Our group is both using and developing mathematical methods allowing to study neural activity at multiple temporal [19] and spatial scales [4], reproducing and predicting brain states in both healthy [14] and pathological conditions [25, 26].

3.1.3 Neural fields

Neural fields are a phenomenological way of describing the activity of a population of neurons by integro-differential equations. This continuous approximation turns out to be very useful to model large brain areas such as those involved in migraine and visual perception. The mathematical properties of these equations and their solutions are still imperfectly known, in particular in the presence of delays, different time scales and noise.

Our group is developing mathematical and numerical methods for analyzing these equations. These methods are based upon techniques from functional analysis, bifurcation theory, equivariant bifurcation analysis, delay equations, and stochastic partial differential equations. We have been able to characterize the solutions of these neural fields equations and their bifurcations, apply and expand the theory to account for such perceptual phenomena as edge, texture [44], and motion perception. We have developed a neural field model to study migraine-related phenomena [30]. We have also developed a theory of singular perturbations for neural fields equations [3], based in particular on center manifold and normal forms ideas [4].

3.1.4 Slow-fast dynamics in neuronal models

Neuronal rhythms typically display many different timescales, therefore it is important to incorporate this slow-fast aspect in models. We are interested in this modeling paradigm where slow-fast point models, using Ordinary Differential Equations (ODEs), are investigated in terms of their bifurcation structure and the patterns of oscillatory solutions that they can produce. To gain insight into the dynamics of such systems, we use a mix of theoretical techniques — such as geometric desingularization and centre manifold

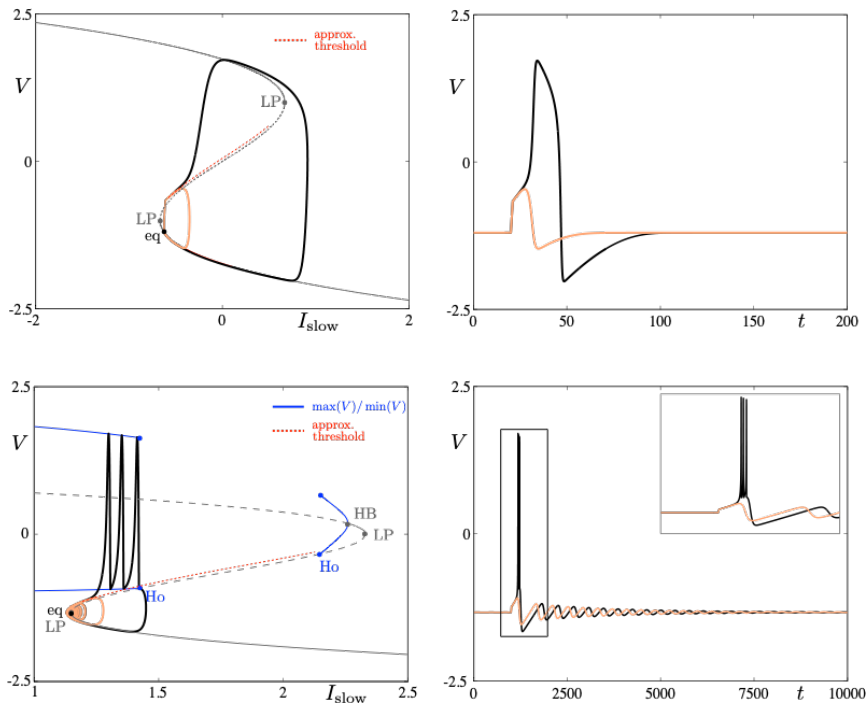


Figure 1: Excitability threshold as slow manifolds in a simple spiking model, namely the FitzHugh-Nagumo model, (top panels) and in a simple bursting model, namely the Hindmarsh-Rose model (bottom panels). This figure is unpublished.

reduction [57] — and numerical methods such as pseudo-arclength continuation [49]. We are interested in families of complex oscillations generated by both mathematical and biophysical models of neurons. In particular, so-called *mixed-mode oscillations (MMOs)* [16], [47, 56], which represent an alternation between subthreshold and spiking behavior, and *bursting oscillations* [48, 54], also corresponding to experimentally observed behavior [45] (see Figure 1). We are working on extending these results to spatio-temporal neural models [3].

3.2 Ageing

Ageing is both a major issue of public health, and a very rich and active multi-disciplinary research area. The work done within the MathNeuro team aims to better model and understand certain pathological states of brain activity, such as cortical spreading depression or epilepsy, but also certain age-related diseases (e.g., Alzheimer’s Disease, Parkinson’s Disease). More generally, we have ongoing collaborations with experimentalists and clinicians in order to tackle key questions related to identifying new biomarkers of healthy and pathological aging.

Within this context, our approach is twofold. First, incorporating tools from data science (e.g., AI, machine learning, topological data analysis [20]) in order to decipher large multiscale multimodal longitudinal datasets related to aging, like the [Baltimore longitudinal Study of Aging](#). Second, using modeling approaches (e.g., hidden Markov models [42]) in order to investigate more specific questions and data related to aging, like the sensitivity to dopamine in patients suffering from Parkinson’s Disease.

3.3 Cognition

3.3.1 Modeling associative memory

The processes by which memories are formed and stored in the brain are multiple and not yet fully understood. What is hypothesized so far is that memory formation is related to the activation of certain groups of neurons in the brain. Then, one important mechanism to store various memories is to associate certain groups of

memory items with one another, which then corresponds to the joint activation of certain neurons within different subgroup of a given population. In this framework, plasticity is key to encode the storage of chains of memory items. Yet, there is no general mathematical framework to model the mechanism(s) behind these associative memory processes. We are aiming at developing such a framework using our expertise in multi-scale modeling, by combining the concepts of heteroclinic dynamics, slow-fast dynamics and stochastic dynamics.

The general objective that we wish to pursue in this project is to investigate non-equilibrium phenomena pertinent to storage and retrieval of sequences of learned items. In previous works by team members [13, 1, 22], it was shown that with a suitable formulation, heteroclinic dynamics combined with slow-fast analysis in neural field systems can play an organizing role in such processes, making the model accessible to a thorough mathematical analysis. Multiple choice in cognitive processes require a certain flexibility in the neural network, which has recently been investigated in the article [23].

Our goal is to contribute to identify general processes under which cognitive functions can be organized in the brain.

3.3.2 Decision-making

Decision-making refers to making a choice between multiple alternatives. It is important to make the choice by taking into account short- and long-term consequences of each alternative. This requires complex interactions between intricate neural mechanisms. These mechanisms are far from being fully understood.

Our goal is to contribute to a better understanding of the neural mechanisms relevant to decision-making. For this, we develop computational models based on mean-field approximations of large dimensional neuronal networks. We test our models on experimental data at behavioral level [6]. Finally, these mean-field models can be integrated to brain simulators. This is useful to study decision-making processes at the whole-brain scale.

3.3.3 Visual perception

Visual perception in human, non-human primates and in many other mammalian species is achieved throughout several cortical processes. The primary visual cortex (V1) is the part of the brain which is responsible for the first step in the processing of visual input [53, 67]. This processing allows to identify local features of the objects in a visual scene and integrating these features to provide a global representation of the objects in V1. This is crucial for a complete visual perception of the objects.

Our goal is to contribute to the understanding of V1 functional architecture [61, 62]. To achieve it, we use a neurogeometric approach. We develop geometric models of V1 by using tools from differential geometry and partial differential equations [5]. We apply our geometric models to visual perception phenomena and pathological dynamics generating visual hallucinations [41]. This will effectively embed the topic of neurogeometry within the thematics of (hyper)excitability [37].

4 Application domains

The first focus area involves studying various pathologies, their initiation, and propagation. Our research particularly addresses epilepsies [25] and Dravet syndrome; cortical spreading depression in connection with certain types of migraine with aura [30] as well as their visual symptoms [37]; Alzheimer's Disease [7] and Parkinson's Disease. Additionally, our work on cognition has the potential to contribute to the study of mental disorders such as schizophrenia [66] and obsessive-compulsive disorders [64].

A second key aspect of our work is the development of an independent research focus on experimental approaches, carried out in close collaboration with Serafim Rodrigues' experimental laboratory at BCAM Bilbao. This initiative has been supported by Inria's direction, including contributions toward funding specialized equipment. In particular, MathNeuro has been allowed to purchase electrophysiology and optogenetics equipments and put them at the disposal of the Rodrigues lab in Bilbao via the signature of agreement letters.

5 Highlights of the year

Since the relocation of MathNeuro to Montpellier, we have made a substantial effort to establish new strategic local collaborations. As a result, **within a very short time frame, we have initiated five local collaborations involving all members of the team**, with (1) the [Institute for Regenerative Medicine and Biotherapy](#) (see Section 7.2), (2) the [Institute of Functional Genomics \(IGF\)](#) (see Sections 7.1.1 and 7.3), (3) the [Institute for Neurosciences of Montpellier](#) (see Section 7.1.5), (4) [Euromov](#) (see Section 7.2), and finally (5) the Laboratory of [Physiology and Experimental Medicine of the Heart and Muscles \(PHYMEDEXP\)](#).

Collaborations (1) and (4) address questions related to ageing; collaboration (2) focuses on cognition; collaboration (3) investigates the effects of pollution on corticogenesis; and collaboration (5) is dedicated to the modeling of channelopathies. This last collaboration is very recent and is therefore not yet presented in this report.

Fabien Campillo was promoted to first-grade senior researcher (DR1) in January 2025.

6 Latest software developments, platforms, open data

6.1 Open data

6.1.1 Data sciences for MathNeuro

Participants: Fabien Campillo, Mathieu Desroches, Serafim Rodrigues (*BCAM, Spain*).

MathNeuro aims to develop a more systematic ‘Data Science’ approach to data acquisition and analysis. In this context, we developed two tools this year.

First, a Jupyter Book entitled **“Data Science and Spikes”**, designed as a practical and accessible entry point into data science through the exploration of electrophysiological data, in particular spike train recordings [[GitHub](#), [online book](#), [PDF](#)].

Second, the tool called **PEPYNA** for “Python-based Electrophysiology Neuron Yield & Analysis” [[GitHub](#)] focuses on the analysis of electrophysiological data, initially targeting [Axon Binary Format \(ABF\)](#) files and with the potential to extend to other data formats. It involves the processing, visualization, and basic statistical analysis of single-neuron datasets using Python scripts and notebooks. The long-term objective of this tool is to evolve into a reusable and extensible software library.

6.1.2 EBRAINS-EITN Fall School in Computational Neuroscience 2025

Participant: Emre Baspinar.

Emre Baspinar prepared the Jupyter notebooks **“TVB-AdEx-Tutorial-EBRAINS-EITN-Fall-School”** for the hands-on session entitled “The Virtual Brain environment for whole-brain models”, which he organized in [EBRAINS-EITN Fall School in Computational Neuroscience 2025](#), Marseille, on November 24, 2025.

7 New results

This section is organized according to the three main neuroscience thematics currently treated in MathNeuro, namely: **excitability**, **ageing** and **cognition** (which includes memory and decision-making).

7.1 Excitability

7.1.1 Neuronal networks and neural fields

Participants: Emre Baspinar, Fabien Campillo, Mathieu Desroches.

Collaboration: Daniele Avitabile (*VU Amsterdam*), Damien Depannemaecker (*INS, AMU*), Massimo Mantegazza (*IPMC, Inserm, Sophia Antipolis*).

*This research theme is developed in close collaboration with **Daniele Avitabile**, Professor at VU Amsterdam, a renowned specialist in mathematical models in neuroscience, as well as in numerical analysis and numerical implementation.*

Multiple-timescale dynamics of neuronal networks

We have initiated about one year ago a new collaboration with the *Institut de Neurosciences des Systèmes* in Marseille, in particular with Damien Depannemaecker and Viktor Jirsa, on multiple-timescale dynamics of neuronal networks. We have already one article accepted for publication, described next.

To model the dynamics of neuron membrane excitability, many models can be considered, from the most biophysically detailed to the highest level of phenomenological description. Recent works at the single neuron level have shown the importance of taking into account the evolution of slow variables such as ionic concentration. A reduction of such a model to models of the integrate-and-fire family is interesting to then go to large network models. In this paper, we introduce a way to consider the impairment of ionic regulation by adding a third, slow, variable to the adaptive Exponential integrate-and-fire model (AdEx). We then implement and simulate a network including this model. We find that this network was able to generate normal and epileptic discharges. This model should be useful for the design of network simulations of normal and pathological states. The manuscript [31] has been accepted for publication in *Journal of Computational Neuroscience*.

Cortical spreading depolarization (CSD)

We are also pursuing our long-term project on the modeling of hyperexcitability, in particular in the context of Cortical spreading depolarization (CSD). This collaboration is historical in MathNeuro and it continues to be the subject of a strong collaboration with Massimo Mantegazza (IPMC, Inserm, Sophia Antipolis). Recently, we have extended our temporal model for the initiation of CSD (topic of the PhD thesis of Louisiane Lemaire in MathNeuro, defended in 2021) towards spatially-extended activity to account for the propagation of the phenomenon throughout the cortex. Emre Baspinar is now actively participating to the project, which constituted a part of his research program for his recruitment at Inria. The latest work [30], recently published in the journal *PLoS Computational Biology*, is described below.

CSD is a wave of neural depolarization that initiates locally and then slowly spreads across the cortex. It is characterized by (i) initial neural hyperexcitability, (ii) prolonged neural silence following the hyperexcitability. CSD is implicated in several pathologies, particularly in migraine. Although there is an extensive literature on the role of excitatory neurons in CSD, much less is known about the role of inhibitory neurons.

In this work, we study the role of inhibitory neurons in migraine-related CSD initiation and propagation, at both experimental and computational levels. We perform experiments in mouse brain slices and develop a novel computational model to unveil the mechanisms underlying the experimental results. In the experiments, we test the role of inhibitory neurons in CSD propagation by modulating their activity with optogenetic and pharmacological tools. In the modeling part, we simulate the activity of large excitatory and inhibitory populations of neurons by using a neural field model. The model is based on an excitatory-inhibitory population pair which is coupled to a potassium concentration variable. Our experimental and simulation results show that the decrease of the synaptic activity of inhibitory neurons can enhance CSD propagation, because of the reduction of the inhibitory synaptic weight, whereas their spiking activity can enhance CSD propagation because of increased extracellular potassium.

We are currently exploring the role of astrocytes in the propagation of CSD, which was the topic of the internship of Camilla Nouveau in MathNeuro, which started in September 2024 and ended in February 2025. A manuscript is in preparation, it should be submitted in the winter 2026. This work induced a collaboration on the role of astrocytes in CSD, with Etienne Audinat, DR CNRS from *Institute of Functional Genomics (IGF)*, Montpellier. We applied for an ANR JCJC 2026 research grant in the context of this collaboration.

Mean-field limits of inhibitory neuronal networks

We have also initiated a collaboration with Boris Gutkin and Alex Cayco-Gajic from the **Group for Neural Theory** at the École Normale Supérieure of Paris on mean-field limits of inhibitory neuronal networks connected by gap junction, in link with the electrical activity of the cerebellum. This collaboration took shape within the PhD project of H el ene Todd (**Group for Neural Theory**) and it gave rise to one joint article published this year in the journal **Physical Review E**, available as [36].

In this work, we study networks of inhibitory interneurons, which are essential for regulating the activity of principal neurons, especially by inducing temporally patterned dynamic states. We aim to understand the dynamic mechanisms that allow for synchronization to arise in networks of electrically and chemically coupled interneurons. To this end, we use the ‘exact’ mean-field reduction, using the Ott-Antonsen ansatz already studied in the MathNeuro team (see [2] and [28]) to derive a neural mass model for both homogeneous and clustered networks. We first analyze a single population of neurons to understand how the two couplings interact with one another. We demonstrate that the network transitions from an asynchronous to a synchronous regime either by increasing the strength of the gap junction connectivity or the strength of the background input current. Conversely, the strength of inhibitory synapses affects the population firing rate, suggesting that electrical and chemical coupling strengths act as complementary mechanisms by which networks can tune synchronous oscillatory behavior. Next, inspired by the existence of multiple interconnected interneuron subtypes in the cerebellum, we analyze networks consisting of two clusters of cell types defined by differing chemical versus electrical coupling strengths. We show that breaking the electrical and chemical coupling symmetry between these clusters induces bistability, so that a transient external input can switch the network between synchronous and asynchronous firing. Together, our results show the variety of cell-intrinsic and network properties that contribute to synchronization of interneuronal networks with multiple types of coupling.

7.1.2 Multiple-timescale dynamics at the level of single neurons

Participants: Fabien Campillo, Mathieu Desroches, Serafim Rodrigues (*BCAM, Spain*).

Collaboration: Piotr Kowalczyk (*University of Wroclaw, Poland*), Joaquin Piriz (*Achucarro Basque Center for Neuroscience, Spain*).

Integrate-and-fire model of single neuron activity

We have an ongoing collaboration with Piotr Kowalczyk (Wroclaw University, Poland) on integrate-and-fire model of single neuron activity. Over the past year, we have finalized and published a second article on the topic, following [18]. In this new work, we present a computational study of the Conductance-Based Adaptive Exponential (CADEX) integrate-and-fire neuronal model, focusing on its multiple timescale nature, and on how it shapes its main dynamical regimes. In particular, we show that the spiking and so-called delayed bursting regimes of the model are triggered by discontinuity-induced bifurcations that are directly related to the multiple-timescale aspect of the model, and are mediated by canard solutions. By means of a numerical bifurcation analysis of the model, using the software package **Coco** [46], we can precisely describe the mechanisms behind these dynamical scenarios. Spike-increment transitions are revealed. These transitions are accompanied by a fold and a period-doubling bifurcation, and are organized in parameter space along an isola of periodic solutions with resets. Finally, we also unveil the presence of a homoclinic bifurcation terminating a canard explosion which, together with the presence of resets, organizes the delayed bursting regime of the model. This work has been partially done during stays of Serafim Rodrigues in MathNeuro, and the manuscript [32] has been published in the **Bulletin of Mathematical Biology**.

Multiscale mathematical model of recordings of LHb neural data

This year, we have pursued our new collaboration with an experimental group in Bilbao, at Achucarro the Basque Center for Neuroscience, together with our close collaborator Serafim Rodrigues (BCAM). Namely, we are now working with the lab of Joaquin Piriz, a specialist of mood disorder, in particular in link with a specific brain region, the lateral Habenula (LHb). Mathieu Desroches and Fabien Campillo, together with Serafim Rodrigues, are working on a multiscale mathematical model of recordings of LHb neural data

collected by Joaquin Piriz. LHB neurons have general bursting activity and there are already a number of studies modeling these. The novelty here is the presence of two different bursting patterns observed in the data from the Piriz lab. We have made a phenomenological multiple-timescale model generating these two bursting patterns based upon the behavior of two slow processes, which we suspect are related to slow potassium and calcium currents. The model reproduces the collected data, both in a deterministic and in a stochastic environment. We are also developing a burst-detection algorithm in order to be able to automatically analyze the data from our collaborator. A manuscript has been submitted for publication and it is currently in revision in *The Journal of Physiology* and it is available as [40].

We are currently working on building up a biophysical model reproducing these bursting patterns and that will allow us to zoom into the biological mechanisms underpinning this coexistence of activity patterns in LHB neurons. This work is at the core of the Master internship project of Natalie Elena Cernei (University of Bologna), which started in October 2025 and will end in February 2026.

7.1.3 Multiscale modeling of Dravet Syndrome

Participants: Fabien Campillo, Mathieu Desroches, Louisiane Lemaire, Serafim Rodrigues (*BCAM, Spain*).

This project started in early 2024, and is funded by the Exploratory action **2MDS**. In particular, we recruited Louisiane Lemaire as postdoc to work on this project. She is an expert in the modeling of hyperexcitability, in particular in the context of ion channel mutations. She had done her **PhD** in MathNeuro on the CSD project. She joined our team in Montpellier in April 2025.

Dravet syndrome is a developmental and epileptic encephalopathy (DEE) that typically begins in the first year of life. This complex pathology is characterized by drug-resistant seizures, various comorbidities such as cognitive delay, and a risk of early death. Most cases are due to mutations of Nav1.1, a voltage-gated sodium channel expressed in fast-spiking (FS) inhibitory neurons. The pathological mechanism in the initial stage of the disease involves impaired function of those neurons, leading to network hyperexcitability. However, the details remain unclear.

Mutations of Nav1.1 may result in non-functional channels or channels with altered gating properties. We focus on the less studied case of altered gating, by investigating how it impairs neuronal activity in the case of a specific mutation (A1783V). Using recordings in cell lines, Layer *et al.* [58] showed that A1783V alters the voltage dependence of channel activation, as well as the voltage dependence and kinetics of slow inactivation. Slow inactivation is a mechanism distinct from the fast inactivation of sodium channels at each spike, developing much more slowly, during prolonged trains of depolarization. Implementing the three effects of the mutation in a conductance-based model, Layer *et al.* predict that altered activation has the largest impact on channel function, as it causes the most severe reduction in firing rate.

Using conductance-based models tailored to the dynamics of FS inhibitory neurons, we examine how the three alterations affect susceptibility to depolarization block, another firing deficit aside from frequency reduction. We look deeper into slow inactivation, exploiting the timescale difference with the rest of the system. We find that slow inactivation of mutant channels at lower voltage values than wild type channels favors depolarization block upon sustained stimulation. More precisely, shifting the steady-state voltage dependence of slow inactivation destroys the stable limit cycle of the full system corresponding to tonic spiking, and creates a stable equilibrium corresponding to depolarization block. The accelerated kinetics of slow inactivation in mutant channels hastens the transition from tonic spiking to depolarization block. These findings suggest that alterations of Nav1.1 slow inactivation should not be neglected as they might play an important pathological role, adding to the conclusions of Layer *et al.* on the consequences of altered Nav1.1 activation.

This work was published in 2025 in the journal *Scientific Reports*, and it is available as [35].

7.1.4 Neuronal excitability: Interface with electrophysiological experiments

Participants: Fabien Campillo, Mathieu Desroches, Serafim Rodrigues (*BCAM, Spain*).

Collaboration: Jan Sieber (*University of Exeter, UK*).

Since 2024, several key developments have occurred in the experimental laboratory project at BCAM, the so-called *NeuroMATH lab*. A dual protocol was implemented to study neuronal excitability dynamics. The “voltage-clamp” (VC) protocol with a slow ramp on the target stabilized membrane potential to reveal the excitability structure of neurons, while the “current-clamp” (CC) protocol with slow ramp on the target confirmed the separation between slow and fast components of the neuronal model. As a result, we are currently investigating the bifurcation structure of real neurons directly from experimental data, which is a great tool to validate models as well as explore the parameter space of neurons. These initial results were published in 2025 in the journal *PLOS Computational Biology* and available as [29].

We are currently using a *dynamic-clamp* protocol to adjust the neuron’s behavior, transforming an integrator neuron into a resonator neuron; we are effectively confirming experimental and theoretical predictions obtained in the PhD project of Guillaume Girier (successfully defended in September 2024) and published in 2023 [21]. These experiments were initiated during a one-month stay in Bilbao by Fabien Campillo and Mathieu Desroches in the winter 2024, and they are still running in order to obtain enough trials and material prior to writing a research article.

7.1.5 Corticogenesis and exposome

Participants: Fabien Campillo, Mathieu Desroches.

In 2025, we have started a collaboration with the *Institute for Neurosciences of Montpellier (INM)*, namely with the team of *Karine Loulier* (Inserm). The collaboration is on the effect of pollution on cortico-genesis. Loulier has obtained funds from the *ExposUM Institute* of Montpellier, to make progress on this topic. We have been included to the project and will co-supervise with her a Master internship in 2026 to start deciphering her data.

7.2 Ageing

Participants: Emre Baspinar, Fabien Campillo, Mathieu Desroches, Serafim Rodrigues (*BCAM, Spain*).

*This research theme is developed in close collaboration with Professor *Tamas Fülöp* (MD) a geriatrician at the University of Sherbrooke (Canada) and an internationally recognized expert in the field of ageing.*

We have continued our research activities on pathological ageing, in particular in the context of Alzheimer’s Disease (AD). We have been part for a few years of an international consortium investigating these questions with biological experiments, data-scientific approaches and some modeling. The consortium brings together medical doctors, biologists, data scientists and modelers. Within this context, our core collaboration involves Tamas Fülöp (a geriatrician) and his team at the University of Sherbrooke (Canada) and our close collaborator Serafim Rodrigues (BCAM, Bilbao, Spain) and his team *MCEN*. We have already published a number of articles, both on data-scientific approaches to ageing studies [20] and also on the so-called *infection hypothesis* of AD [7]. In 2024, we have published a book chapter (see description below) on this hypothesis, and we have also obtained access to a major database on aging, *BLSA*, via a data transfer agreement (DTA) signed by Inria and the National Institute on Aging (NIA, NIH, USA). We plan to study it using variable data-scientific approaches (AI, machine learning and topological data analysis) in order to identify new biomarkers of pathological ageing and inform future models that we wish to build up. In 2025, we secured an international ANR grant, in direct partnership with the University of Luxembourg (Prof. Jorge Goncalves, an expert in AI and machine learning to analysis multi-omics data, co-investigator of the ANR grant) and Prof. Tamas Fülöp (MD, University of Sherbrooke, Canada). In 2026, we will start to analyze the *BLSA* data using

a mix of tools from data science (AI, machine learning, topological data analysis) with two postdoctoral researchers, one at Inria, the other one at UL.

For years, the understanding of AD has been shaped by the amyloid hypothesis, which suggests that pathological markers like amyloid-beta ($A\beta$) and phosphorylated Tau are the primary drivers of the disease. This hypothesis has guided the development of major treatment strategies, including monoclonal antibodies targeting $A\beta$. However, most of these treatments have failed to produce clinically significant results, highlighting the urgent need for a new therapeutic approach. It is now evident that AD is a complex, multifactorial disease that develops over decades, ultimately leading to $A\beta$ and Tau accumulation. Therefore, addressing the underlying causes of these depositions is crucial. One well-supported yet underrecognized theory is the infection hypothesis, which links infections to AD pathology. Despite substantial scientific evidence, this perspective has faced significant resistance. Together with our colleagues from the international consortium to which we belong, on this topic, we have just published a review article describing how chronic infections contribute to AD by triggering neuroinflammation and $A\beta$ accumulation. We also explore the barriers to accepting the infection hypothesis and the steps necessary for its integration into drug development and early-stage treatment strategies. Persisting with an amyloid-centric approach will only exacerbate the societal burden. Embracing the infection hypothesis could transform AD research, diagnosis, and treatment, bringing new hope to millions. This review was accepted for publication in *Journal of Alzheimer's Disease* in late 2025 and it is available as [33].

We have also initiated two collaborations in Montpellier.

The first is with Jean-Marc Lemaitre, DR Inserm and head of the *Institute for Regenerative Medicine and Biotherapy (IRMB)* in Montpellier. With him as PI, we participate to the *CENTAURE* project, also involving the CHU of Toulouse, just funded from the *Mécénat Santé AXA 2025* and aiming at deciphering the secrets behind the exceptional longevity of centenarians. The role of MathNeuro will be to provide data-analytical expertise on deciphering data from several cohorts of centenarians, in Montpellier, Toulouse and from Martinique, which has been identified as a *blue zone*, that is, a zone with an abnormally high rate of centenarians. We will recruit a postdoc in 2026 to advance on this project.

The second collaboration is with *Euromov*, with whom we have initiated a study in partnership with the *Beau Soleil Clinic* on a project that proposes an innovative and less invasive approach to assess dopaminergic responsiveness in Parkinson's Disease. This approach relies on prolonged actigraphy and wearable sensor data, rather than exclusively on the burdensome L-dopa test.

7.3 Cognition

7.3.1 Memory

Participants: Fabien Campillo, Pascal Chossat, Mathieu Desroches.

Collaboration: Frédéric Lavigne (*BCL, Université Côte d'Azur, Nice*).

We have continued along the year 2025 our research line on modeling memory processes with different strategies, both with dynamical systems and Bayesian inference.

Associative memory

In the context of the *ANR project HEBBIAN* (PI: Arnaud Rey, CNRS, Marseille), we are working on modeling associative memory using multiple-timescale dynamical systems and heteroclinic dynamics in the context of attractors networks. This research line has given a number of articles [1, 13, 22, 24], all of them mostly focused on abstract mechanism and computations. In the context of this ANR project, we are working on data collected in the lab of Arnaud Rey, and we are adapting the model and its plasticity rules to be able to reproduce the data.

In 2025, the manuscript [34] by Pascal Chossat, Elif Köksal Ersöz and Frédéric Lavigne (BCL lab, Univ. Côte d'Azur) was published in the journal *PLOS one*. This work focuses on gain modulation of

actions selection without synaptic relearning. Adaptation of behavior requires the brain to change goals in a changing environment. Synaptic learning has demonstrated its effectiveness in changing the probability of selecting actions based on their outcome. In the extreme case, it is vital not to repeat an action to a given goal that led to harmful punishment. The present model proposes a simple neural mechanism of gain modulation that makes possible immediate changes in the probability of selecting a goal after punishment of variable intensity. Results show how gain modulation determine the type of elementary navigation process within the state space of a network of neuronal populations of excitatory neurons regulated by inhibition. Immediately after punishment, the system can avoid the punished populations by going back or by jumping to unpunished populations. This does not require particular credit assignment at the “choice” population but only gain modulation of neurons active at the time of punishment. Gain modulation does not require statistical relearning that may lead to further errors, but can encode memories of past experiences without modification of synaptic efficacies. Therefore, gain modulation can complement synaptic plasticity.

Bayesian brain and the free energy principle

The *Principle of Free Energy* (FEP) is a mathematical and conceptual framework proposed by Karl Friston [52]. This principle posits that living organisms (their organs, brains, and the neurons therein) aim to minimize surprise or uncertainty about their environment. According to this theory, this minimization is achieved by creating internal models of their environment to predict sensory inputs. By reducing the discrepancy between predicted and actual sensory data—referred to as free energy or surprise—organisms adapt effectively, learn, and make predictions. This principle extends beyond the Bayesian brain hypothesis; it underpins theories of perception, action, and cognition while offering insights into how biological systems maintain stability and navigate complex environments through predictive processing. Although proposed nearly two decades ago, this theory has gained significant traction in recent years, spreading far beyond neuroscience and into other scientific fields. Furthermore, experimental validations have begun to confirm its premises. While this approach generates excitement, it also faces criticism for its abstract and ambitious nature.

This year, we have started to address this topic through the lens of *nonlinear filtering (NLF)* [8]. Bayesian NLF, an area of expertise for Fabien Campillo (who leads this research line in Mathneuro), is a fundamental yet underexplored component of the FEP. This novel research direction within MathNeuro has benefited from a new collaboration with Jérémie Naudé, a CNRS senior researcher at the **Institute of Functional Genomics (IGF)** in Montpellier. This collaborative effort aims to provide a deeper understanding of the Free Energy Principle (FEP) and its applications, particularly in neuroscience.

7.3.2 Decision-making

Participant: Emre Baspinar.

Collaboration: Alain Destexhe (*NeuroPsi, CNRS, Saclay*).

This is a new research line in MathNeuro, led by Emre Baspinar and for which he has brought to the team novel collaborations, in particular with Alain Destexhe (CNRS, Paris-Saclay) and Rubén Moreno-Bote (UPF, Barcelona, Spain). This year, one project is finalized and accepted for publication. It is described below.

Decision-making refers to choosing one of the existing alternatives. A decision is often made based on a strategy which maximizes long term benefits of the chosen alternatives. Neural mechanisms underlying strategy-based decision-making are far from fully understood. In this work, we propose a strategy-based decision-making model to contribute to better understanding of relevant neural mechanisms in human and macaque. The model is based on two neural populations. Each population is composed of a pair of excitatory-inhibitory subpopulations in cortical layer 2/3. The model is biophysically plausible since it is based on long-range cortico-cortical connections between the layer 2/3 populations. These connections are excitatory. This long-range excitation is conflicted by an inhibition based on local connections within the populations. This configuration introduces a competition between the layer 2/3 populations, sufficient for making a decision to choose between two alternatives shown on the monitor. We integrate the model with a

learning mechanism. This allows the model to learn the optimal decision-making strategy which maximizes the long term benefits. We test the model on two decision-making tasks applied on human and macaque. This model elaborates certain biophysical details, which were not considered by the previous models proposed for similar decision-making tasks. Finally, it can be embedded in a brain simulator such as The Virtual Brain to study large-scale brain dynamics. The manuscript [6] has been accepted for publication in journal [PLoS One](#).

7.3.3 Visual perception

Participant: Emre Baspinar.

This is a new research line in MathNeuro, led by Emre Baspinar and for which he has brought to the team novel collaborations, in particular with Giovanna Citti (University of Bologna, Italy) and Alessandro Sarti (EHESP, Paris). We participate to a Marie-Curie Horizon Europe Grant 2026 application as collaborator, where Giovanna Citti and Alessandro Sarti are the main PIs of the project. Our collaboration in the project is based on numerical methods for neurogeometric models of visual perception.

Neural fields refer to integro-differential equations which model the average neural activity of a neural population at a coarse-grained limit. In classical neural fields the neural interactions are modeled based on a distance-based connectivity, without taking into account the modulatory effects of functional properties of neurons on the connectivity. Such effects are observed in particular in the primary visual cortex (V1) and can be modeled by using neurogeometric approach. In this work, we consider a neural field which takes into account these effects in the connectivity by focusing on the functional architecture of V1. We discuss the potential of this neural field to an extension towards pathological cortical activity. This work was presented in Geometric Science of Information 2025, Saint-Malo and published as a conference paper [37].

8 Partnerships and cooperations

8.1 National initiatives

Participants: Fabien Campillo, Mathieu Desroches.

8.1.1 ANR projects

HEBBIAN

Title: Apprentissage hebbien de séquences

Duration: From October 1, 2023 to September 30, 2027

Inria contact: Mathieu Desroches

Coordinator: Arnaud Rey (CNRS, Marseille)

Summary: This project is articulated around three main research questions that are central to better understand sequence learning mechanisms: Q1) What is the relationship between the spacing between two repetitions of the same sequence and the development of a memory trace of that sequence? Q2) How does sequence encoding vary with sequence size, number, and learning context? Q3) How are small, regular sequences that are embedded in larger sequences, encoded (i.e., the parts and whole problem)? Our project is also based on two main research hypotheses. We first assume that the mechanisms supporting the learning of sequential information are based on elementary associative learning mechanisms that are evolutionarily ancient and shared by humans and non-human primates (Rey et al., 2012, 2019a, 2022). Our second main hypothesis assumes that these associative learning mechanisms are mainly supported by Hebbian learning principles (Brunel & Lavigne, 2009; Köksal Ersöz et al., 2020, 2022; Tovar & Westermann, 2023).

AUDACITIES

Title: Revealing fundamental invariants and transitions of complex multiscale patient data: life-span study

Duration: From November 1, 2025 to October 31, 2029

Inria contact: Mathieu Desroches

Coordinator: Mathieu Desroches

Summary: Physical theories are based on stable mathematical structures, based on regularities and symmetries. In these theories, objects are defined and understood thanks to invariants and transformations preserving the invariants. These invariants allow the synthesis of physical laws, useful for making predictions. In contrast, biological organisms exhibit variability, contextuality, memory effects, where their unique trajectories involve a cascade of changes in their symmetries and a continuous 'reshaping' of existing phenotypes and genotypes, a process that depends on rare events (i.e. a change of rules). The present proposal hypothesizes that quasi-invariant laws and associated transitions exist in multi-omics multi-phenotypic multi-scale data. We postulate that biological quasi-invariants should be synthesized via a systems approach, not only by numerical summaries (e.g., statistical quantifiers), but also in crucial combination with dynamic summaries, as well as with topological and geometric invariants simultaneously. We will search for quasi-invariant biological laws, their transitions and the emergence of aging contained in unique anonymized human lifespan data (i.e., longitudinal, from 20 years to centenarians) that combine multi-omics and multiple scales. Indeed, we have unique access to two complementary databases: **BLSA** (Baltimore Longitudinal Study of Aging, NIH, USA) and **SLAS** (The Singapore Longitudinal Aging Studies, National University of Singapore), which offer us a privileged place to advance this research. We will analyze this data using several tools: geometric and topological data analysis, machine learning, deep learning and structural recurrence analysis.

8.1.2 Inria Exploratory Action

2MDS

Title: Multiscale Modeling of Dravet Syndrome

Duration: From May 1, 2024 to April 30, 2026

Inria contact: Fabien Campillo

Coordinator: Fabien Campillo

Webpage : [Inria Exploratory Action 2MDS](#)

Summary: The Inria Exploratory Action 2MDS is being co-directed by Fabien Campillo (EPI MathNeuro), and Pierre Del Moral (EPI Astral). Mathieu Desroches, head of MathNeuro project, and Serafim Rodrigues, head of the "Mathematical, Computational and Experimental Neuroscience" MCEN research group at BCAM (Bilbao, Spain) are also participating in this project. The aim of 2MDS is to develop a multiscale modeling framework for channelopathies, a group of diseases caused by the dysfunction of ion channels or their interacting proteins. These pathologies include the Dravet Syndrome (DS), a severe form of child epilepsy. This project will also have a substantial experimental component, conducted by our collaborator Serafim Rodrigues in his experimental laboratory (The "NeuroMath" lab, University of the Basque Country campus, Leioa.), also in collaboration with Juan Manuel Encinas of the Basque center for neuroscience, an expert in DS (Martín-Suárez et al., 2020).

8.2 Regional initiatives

Participants: Emre Baspinar, Fabien Campillo, Mathieu Desroches.

8.2.1 Unmute

Title: Unraveling and Modeling the aggravation of ASD symptoms following in Utero exposure to Environmental pollutant residues

Duration: From September 1, 2025 to August 31, 2027

Inria contacts: Fabien Campillo & Mathieu Desroches

Coordinator: Karine Loulier (Institute of Neurosciences of Montpellier, Inserm)

Summary: Autism spectrum disorders (ASD) arise from a complex interplay of genetic and environmental factors, and are characterized by stereotyped behaviors, social interaction deficits and frequent comorbidities such as drug-resistant epilepsy. The multiplicity of causative factors and phenotypic manifestations hinder the development of targeted diagnostic or therapeutic tools that would reduce or reverse the growing incidence of ASD and improve patients' quality of life. Our preliminary results obtained in a genetic mouse model of ASD with drug-resistant epilepsies show aggravated social interaction deficits and heterogeneous Focal Cortical Dysplasia (FCD)-type cortical malformations in heterozygous newborn animals exposed prenatally to a cocktail of three anilinopyrimidine fungicide residues. Our project aims to link the structural features of fungicide-induced FCD, such as the cell composition, occurrence frequency, size, location in distinct cortical areas and biochemical signature, with their effects on neuronal network activity and behavioral deficits. We will investigate how these malformations, exacerbated by environmental exposure in a genetically susceptible background, contribute to the severity of ASD and epilepsy. Our findings will help establish predictive biomarkers to anticipate ASD severity and guide therapeutic strategies. By bridging structural, functional, and behavioral insights, this research will improve our understanding of gene-environment relationship between ASD and fungicide exposure and offer novel avenues for personalized intervention.

9 Dissemination

9.1 Promoting scientific activities

9.1.1 Scientific events: organization

Organizer

Emre Baspinar was the organizer of the minisymposium [Modeling Neural Dynamics](#) that took place at the [SIAM Conference on Applications of Dynamical Systems](#), Denver, USA, May 11-15, 2025.

Mathieu Desroches was co-organizer of the two-part minisymposium [Patterns of Neural Activity](#) that took place at the [SIAM Conference on Applications of Dynamical Systems](#), Denver, USA, May 11-15, 2025.

9.1.2 Scientific events: selection

Member of the conference program committees

Mathieu Desroches has been board member of the International Conference on Mathematical Neuroscience since September 2024.

Reviewer

Emre Baspinar was a reviewer for the [Geometric Science of Information](#) conference, Saint Malo, October 29-31, 2025.

9.1.3 Journal

Member of the editorial boards

Fabien Campillo is editorial board member of [Arima](#).

Mathieu Desroches is co-founder and co-Editor-in-Chief of the [SIAM series on Mathematical Neuroscience](#).

Reviewer - reviewing activities

Emre Baspinar acted as a reviewer for [Journal of Computational Neuroscience](#).

Mathieu Desroches acted as a reviewer for [Bulletin of Mathematical Biology](#), [Chaos: An International Journal of Nonlinear Science](#), [Journal of Physics A](#), [PLoS Computational Biology](#), [Scientific Reports](#), [SIAM Journal on Applied Dynamical Systems](#) and [SIAM Journal on Mathematical Analysis](#).

9.1.4 Invited talks

Fabien Campillo and **Mathieu Desroches** gave an invited seminar talk entitled “Présentation de l’équipe-projet Inria MathNeuro : *Mathematics for Neuroscience*” at the [Institut de Génomique Fonctionnelle](#), Montpellier, April 18, 2025.

Pascal Chossat gave an invited Keynote Lecture entitled “Models for sequential association of learned concepts in the cortex” at the [Coupled 80](#) online conference, October 9, 2025.

Mathieu Desroches gave an invited presentation entitled “Multiscale modeling of differential neurotransmitter release” at the “[Brain Plasticity & Modelisation](#)” workshop, Montpellier, January 24, 2025.

Mathieu Desroches gave an invited presentation entitled “Observing hidden neuronal states in experiments” at the [Applied Mathematics Webinar](#), LAMSIN (Tunisie), February 5, 2025.

Mathieu Desroches gave an invited online presentation entitled “Classifying bursting oscillations using slow-fast dynamics” in the [minisymposium ‘Patterns of Neural Activity’ - Part 1 of 2, SIAM Conference on Application of Dynamical Systems](#), Denver (USA), May 12, 2025.

Mathieu Desroches gave an invited online presentation entitled “Complex neuronal bursting oscillations: the role of slow variables” at the [Virtual SMB MathNeuro Mini-Conference](#), June 13, 2025.

Mathieu Desroches gave an invited online presentation entitled “Complex neuronal bursting oscillations: the role of slow variables” at the [Secondes journées maths-bio de la fédération OcciMath](#), Institut de Mathématiques de Toulouse, September 18, 2025.

Mathieu Desroches gave an invited online presentation entitled “Complex neuronal bursting oscillations: the role of slow variables” at the [Coupled 80](#) online conference, October 10, 2025.

Emre Baspinar gave an invited minicourse entitled “Neural fields as population models” at [EBRAINS-EITN Fall School in Computational Neuroscience](#), Marseille, November 24, 2025.

Emre Baspinar gave an invited hands-on session entitled “The Virtual Brain environment for whole-brain models” at [EBRAINS-EITN Fall School in Computational Neuroscience](#), Marseille, November 24, 2025.

Emre Baspinar gave an invited talk entitled “Geometric neural fields for cortical activity” at [Geometric Science of Information](#), Saint Malo, October 29, 2025.

Emre Baspinar gave an invited talk entitled “A biologically plausible decision-making model based on interacting neural populations” at [NeuroMod meeting](#), Antibes, July 9, 2025.

Emre Baspinar gave an invited talk entitled “A computational model for cortical spreading depression” at [SIAM Conference on Applied Dynamical Systems](#), Denver, USA, May 11, 2025.

9.1.5 Leadership within the scientific community

Fabien Campillo is a founding member of the African scholarly Society on Digital Sciences (ASDS).

9.1.6 Scientific expertise

Emre Baspinar has been reviewing grant proposals for **Natural Sciences and Engineering Research Council of Canada**.

Mathieu Desroches was reviewer of the PhD manuscript entitled “Emergence of complex dynamics in neuronal and glial cells of the CNS” by Matteo Martin at the University of Bologna (Italy).

9.1.7 Research administration

Emre Baspinar is mentoring the PhD seminar of the Inria Branch at the University of Montpellier.

Fabien Campillo is member of the “Formation Spécialisée de Site” (FSS).

Fabien Campillo is member of the “Inria Evaluation Committee” (CE). In particular, he has been member of:

- the committee for the advancement of the ISFP Researchers’ Career,
- the working group “Reflections on the Use of Generative AI for Research Professions” (see [38]),
- the working group “Individual evaluation of researchers”,
- the working groups for the creation of 3 team-projects (COPHY, POPOPOP, NECTARINE),
- the working groups for the evaluation of the 3 team-projects (ERMINE, MIND, MNEMOSYNE).

9.2 Teaching - Supervision - Juries - Educational and pedagogical outreach

9.2.1 Teaching

Master: Emre Baspinar, Computational modeling of neural populations (Lectures, example classes and computer labs), 24 hours (Nov.-Dec. 2025), M1 (Mod4NeuCog), Université Côte d’Azur, Sophia Antipolis, France.

Master: Mathieu Desroches, Multiple Timescale Dynamics in Neuroscience (Lectures, example classes and computer labs), 9 hours (Jan. 2025), M1 (Mod4NeuCog), Université Côte d’Azur, Sophia Antipolis, France.

Master: Mathieu Desroches, Modèles Mathématiques et Computationnels en Neuroscience (Lectures, example classes and computer labs), 8 hours (Feb. 2025), M1 (BIM), Sorbonne Université, Paris, France.

Master: Mathieu Desroches, Modeling using Dynamical Systems (Lectures, example classes and computer labs), 10 hours (Sep.-Oct. 2025), M1 (IEAP), Université de Montpellier, Montpellier.

Master: Louisiane Lemaire, Modèles Mathématiques et Computationnels en Neuroscience (Lectures, example classes and computer labs), 10 hours (Feb. 2025), M1 (BIM), Sorbonne Université, Paris, France.

9.2.2 Supervision

Master 2 internship: Camilla Nouveau, University of Bologna (Italy), has done a Master 2 internship on “Modeling of astro-neural population dynamics and its application to cortical spreading depression”, supervised by Emre Baspinar, September 2024 - February 2025.

Master 2 internship: Natalie Elena Cernei, University of Bologna (Italy), is doing a Master 2 internship on “Multiscale modeling of Lateral Habenula neurons”, supervised by Mathieu Desroches, October 2025 - February 2026.

9.2.3 Juries

Fabien Campillo was a member of the jury for the recruitment of a Junior Chair at the Inria Branch at the University of Montpellier.

Fabien Campillo was a member of the jury for the recruitment of directors of research (grade DR2) at Inria.

Fabien Campillo was a member of the jury for the recruitment researchers (CRCN & ISFP) at the Inria centre at the University Grenoble Alpes.

Fabien Campillo was a member of the habilitation thesis jury (HDR, see [this page](#)) of Coralie Fritsch at the Université de Lorraine, December 15, 2025.

Pascal Chossat was a member of the Comité de Suivi Individuel (CSI) of PhD student Martin Jalard at the Inria Center at Univ. Côte d'Azur (Sophia Antipolis).

Mathieu Desroches was president of the jury (and reviewer of the thesis manuscript) of the PhD defense of Matthieu Aud'hui at the [LTSI lab](#) of the University of Rennes, December 8, 2025.

Mathieu Desroches was jury member of the PhD defense of H el ene Todd in the [Group for Neural Theory](#), Ecole Normale Sup erieure, Paris, June 30, 2025.

Mathieu Desroches was a member of the Comit e de Suivi Individuel (CSI) of PhD student Sarah Gaubi at Institut Pasteur (Inserm, Paris).

Mathieu Desroches was a member of the Comit e de Suivi Individuel (CSI) of PhD student Gabriele Casagrande at Institut de Neurosciences des Syst emes (Aix-Marseille Universit e, Marseille).

Emre Baspinar was a member of the Comit e de Suivi Individuel (CSI) of PhD student Jawad Ali at Sorbonne Universit e,  cole doctorale de Sciences Math ematiques de Paris Centre.

10 Scientific production

10.1 Major publications

- [1] C. Aguilar, P. Chossat, M. Krupa and F. Lavigne. ‘Latching dynamics in neural networks with synaptic depression’. In: *PLoS ONE* 12.8 (Aug. 2017), e0183710. DOI: [10.1371/journal.pone.0183710](https://doi.org/10.1371/journal.pone.0183710). URL: <https://hal.inria.fr/hal-01402179> (cit. on pp. 9, 15).
- [2] D. Avitabile, M. Desroches and G. Bard Ermentrout. ‘Cross-scale excitability in networks of quadratic integrate-and-fire neurons’. In: *PLoS Computational Biology* 18.10 (3rd Oct. 2022), e1010569. DOI: [10.1371/journal.pcbi.1010569](https://doi.org/10.1371/journal.pcbi.1010569). URL: <https://inria.hal.science/hal-03326530> (cit. on pp. 7, 12).
- [3] D. Avitabile, M. Desroches and E. Knobloch. ‘Spatiotemporal canards in neural field equations’. In: *Physical Review E* 95.4 (Apr. 2017), p. 042205. DOI: [10.1103/PhysRevE.95.042205](https://doi.org/10.1103/PhysRevE.95.042205). URL: <https://hal.inria.fr/hal-01558887> (cit. on pp. 7, 8).
- [4] D. Avitabile, M. Desroches, R. Veltz and M. Wechselberger. ‘Local theory for spatio-temporal canards and delayed bifurcations’. In: *SIAM Journal on Mathematical Analysis* 52.6 (18th Nov. 2020), pp. 5703–5747. DOI: [10.1137/19M1306610](https://doi.org/10.1137/19M1306610). URL: <https://hal.science/hal-02412921> (cit. on p. 7).
- [5] E. Baspinar, A. Sarti and G. Citti. ‘A sub-Riemannian model of the visual cortex with frequency and phase’. In: *The Journal of Mathematical Neuroscience* 10.1 (Dec. 2020). DOI: [10.1186/s13408-020-00089-6](https://doi.org/10.1186/s13408-020-00089-6). URL: <https://hal.archives-ouvertes.fr/hal-03130244> (cit. on p. 9).
- [6] E. Baspinar, G. Cecchini, M. Depass, M. Andujar, P. Pani, S. Ferraina, R. Moreno-Bote, I. Cos and A. Destexhe. *A biologically plausible decision-making model based on interacting neural populations*. 10th Jan. 2025. DOI: [10.1101/2023.02.28.530384](https://doi.org/10.1101/2023.02.28.530384). URL: <https://hal.science/hal-04012636> (cit. on pp. 9, 17).

- [7] K. Bourgade, E. Frost, G. Dupuis, J. Witkowski, B. Laurent, C. Calmettes, C. Ramassamy, M. Desroches, S. Rodrigues and T. Fülöp. ‘Interaction Mechanism Between the HSV-1 Glycoprotein B and the Antimicrobial Peptide Amyloid- β ’. In: *Journal of Alzheimer’s Disease Reports* 6.1 (24th Sept. 2022), pp. 599–606. DOI: [10.3233/ADR-220061](https://doi.org/10.3233/ADR-220061). URL: <https://hal.science/hal-03805857> (cit. on pp. 9, 14).
- [8] F. Campillo. *The Gauss-Galerkin approximation method in nonlinear filtering*. 13th Feb. 2023. URL: <https://inria.hal.science/hal-03985941> (cit. on p. 16).
- [9] F. Campillo, N. Champagnat and C. Fritsch. ‘Links between deterministic and stochastic approaches for invasion in growth-fragmentation-death models’. In: *Journal of mathematical biology* 73.6-7 (2016), pp. 1781–1821. URL: <https://hal.archives-ouvertes.fr/hal-01205467>.
- [10] F. Campillo and C. Fritsch. ‘Weak convergence of a mass-structured individual-based model’. In: *Applied Mathematics & Optimization* 72.1 (2015), pp. 37–73. URL: <https://hal.inria.fr/hal-01090727>.
- [11] F. Campillo, M. Joannides and I. Larramendy-Valverde. ‘Analysis and approximation of a stochastic growth model with extinction’. In: *Methodology and Computing in Applied Probability* 18.2 (2016), pp. 499–515. URL: <https://hal.archives-ouvertes.fr/hal-01817824>.
- [12] F. Campillo and C. Lobry. ‘Effect of population size in a predator–prey model’. In: *Ecological Modelling* 246 (2012), pp. 1–10. URL: <https://hal.inria.fr/hal-00723793>.
- [13] P. Chossat and M. Krupa. ‘Heteroclinic cycles in Hopfield networks’. In: *Journal of Nonlinear Science* (14th Jan. 2016). DOI: [10.1007/s00332-015-9276-3](https://doi.org/10.1007/s00332-015-9276-3). URL: <https://hal.inria.fr/hal-01096505> (cit. on pp. 9, 15).
- [14] J. M. Cortes, M. Desroches, S. Rodrigues, R. Veltz, M. A. Munoz and T. J. Sejnowski. ‘Short-term synaptic plasticity in the deterministic Tsodyks–Markram model leads to unpredictable network dynamics’. In: *Proceedings of the National Academy of Sciences of the United States of America* 110.41 (2013), pp. 16610–16615. URL: <https://hal.inria.fr/hal-00936308> (cit. on p. 7).
- [15] M. Desroches, O. Faugeras, M. Krupa and M. Mantegazza. ‘Modeling cortical spreading depression induced by the hyperactivity of interneurons’. In: *Journal of Computational Neuroscience* (Oct. 2019). DOI: [10.1007/s10827-019-00730-8](https://doi.org/10.1007/s10827-019-00730-8). URL: <https://hal.inria.fr/hal-01520200>.
- [16] M. Desroches, A. Guillamon, E. Ponce, R. Prohens, S. Rodrigues and A. Teruel. ‘Canards, folded nodes and mixed-mode oscillations in piecewise-linear slow-fast systems’. In: *SIAM Review* 58.4 (Nov. 2016). accepted for publication in *SIAM Review* on 13 August 2015, pp. 653–691. DOI: [10.1137/15M1014528](https://doi.org/10.1137/15M1014528). URL: <https://hal.inria.fr/hal-01243289> (cit. on p. 8).
- [17] M. Desroches, T. J. Kaper and M. Krupa. ‘Mixed-Mode Bursting Oscillations: Dynamics created by a slow passage through spike-adding canard explosion in a square-wave burster’. In: *Chaos* 23.4 (Oct. 2013), p. 046106. DOI: [10.1063/1.4827026](https://doi.org/10.1063/1.4827026). URL: <https://hal.inria.fr/hal-00932344>.
- [18] M. Desroches, P. Kowalczyk and S. Rodrigues. ‘Spike-adding and reset-induced canard cycles in adaptive integrate and fire models’. In: *Nonlinear Dynamics* 104 (3rd May 2021), pp. 2451–2470. DOI: [10.1007/s11071-021-06441-z](https://doi.org/10.1007/s11071-021-06441-z). URL: <https://inria.hal.science/hal-03129713> (cit. on p. 12).
- [19] M. Desroches, J. Rinzel and S. Rodrigues. ‘Classification of bursting patterns: A tale of two ducks’. In: *PLoS Computational Biology* 18.2 (24th Feb. 2022), e1009752. DOI: [10.1371/journal.pcbi.1009752](https://doi.org/10.1371/journal.pcbi.1009752). URL: <https://inria.hal.science/hal-03589815> (cit. on p. 7).
- [20] T. Fülöp, M. Desroches, F. A. N. Santos, S. Rodrigues and A. A. Cohen. ‘Why we should use topological data analysis in ageing: Towards defining the “topological shape of ageing”’. In: *Mechanisms of Ageing and Development* 192 (Dec. 2020), p. 111390. DOI: [10.1016/j.mad.2020.111390](https://doi.org/10.1016/j.mad.2020.111390). URL: <https://inria.hal.science/hal-03661283> (cit. on pp. 8, 14).
- [21] G. Girier, M. Desroches and S. Rodrigues. ‘From integrator to resonator neurons: A multiple-timescale scenario’. In: *Nonlinear Dynamics* (24th June 2023). DOI: [10.1007/s11071-023-08687-1](https://doi.org/10.1007/s11071-023-08687-1). URL: <https://hal.science/hal-04108504> (cit. on p. 14).

- [22] E. Köksal Ersöz, C. Aguilar Melchor, P. Chossat, M. Krupa and F. Lavigne. ‘Neuronal mechanisms for sequential activation of memory items: Dynamics and reliability’. In: *PLoS ONE* 15.4 (2020), pp. 1–28. DOI: [10.1371/journal.pone.0231165](https://doi.org/10.1371/journal.pone.0231165). URL: <https://hal.archives-ouvertes.fr/hal-02879964> (cit. on pp. 9, 15).
- [23] E. Köksal Ersöz, P. Chossat, M. Krupa and F. Lavigne. ‘Dynamic branching in a neural network model for probabilistic prediction of sequences’. In: *Journal of Computational Neuroscience* 50.4 (10th Aug. 2022), pp. 537–557. DOI: [10.1007/s10827-022-00830-y](https://doi.org/10.1007/s10827-022-00830-y). URL: <https://inria.hal.science/hal-03532787> (cit. on p. 9).
- [24] E. Köksal Ersöz, M. Desroches, A. Guillamon and J. Tabak. ‘Canard-induced complex oscillations in an excitatory network’. working paper or preprint. Nov. 2018. URL: <https://hal.inria.fr/hal-01939157> (cit. on p. 15).
- [25] L. Lemaire, M. Desroches, M. Krupa, L. Pizzamiglio, P. Scalmani and M. Mantegazza. ‘Modeling NaV1.1/SCN1A sodium channel mutations in a microcircuit with realistic ion concentration dynamics suggests differential GABAergic mechanisms leading to hyperexcitability in epilepsy and hemiplegic migraine’. In: *PLoS Computational Biology* 17.7 (27th July 2021), e1009239. DOI: [10.1371/journal.pcbi.1009239](https://doi.org/10.1371/journal.pcbi.1009239). URL: <https://inria.hal.science/hal-03191275> (cit. on pp. 7, 9).
- [26] E. Pavlidis, F. Campillo, A. Goldbeter and M. Desroches. ‘Multiple-timescale dynamics, mixed mode oscillations and mixed affective states in a model of Bipolar Disorder’. In: *Cognitive Neurodynamics* (2022). DOI: [10.1007/s11571-022-09900-4](https://doi.org/10.1007/s11571-022-09900-4). URL: <https://inria.hal.science/hal-03640331>. In press (cit. on p. 7).
- [27] S. Rodrigues, M. Desroches, M. Krupa, J. M. Cortes, T. J. Sejnowski and A. B. Ali. ‘Time-coded neurotransmitter release at excitatory and inhibitory synapses’. In: *Proceedings of the National Academy of Sciences of the United States of America* 113.8 (Feb. 2016), E1108–E1115. DOI: [10.1073/pnas.1525591113](https://doi.org/10.1073/pnas.1525591113). URL: <https://hal.inria.fr/hal-01386149>.
- [28] H. Taher, M. Desroches and D. Avitabile. ‘Bursting in a next generation neural mass model with synaptic dynamics: a slow-fast approach’. In: *Nonlinear Dynamics* (19th Apr. 2022). DOI: [10.1007/s11071-022-07406-6](https://doi.org/10.1007/s11071-022-07406-6). URL: <https://inria.hal.science/hal-03530186> (cit. on p. 12).

10.2 Publications of the year

International journals

- [29] D. Amakhin, A. Chizhov, G. Girier, M. Desroches, J. Sieber and S. Rodrigues. ‘Observing hidden neuronal states in experiments’. In: *PLoS Computational Biology* 21.12 (8th Dec. 2025), e1013748. URL: <https://inria.hal.science/hal-05408631> (cit. on p. 14).
- [30] E. Baspinar, M. Simonti, H. Srour, M. Desroches, D. Avitabile and M. Mantegazza. ‘GABAergic neurons can facilitate the propagation of cortical spreading depolarization: experiments in mouse neocortical slices and a novel neural field computational model’. In: *PLoS Computational Biology* 21.6 (4th June 2025), e1013099. DOI: [10.1101/2024.10.24.620012](https://doi.org/10.1101/2024.10.24.620012). URL: <https://hal.science/hal-04008117> (cit. on pp. 7, 9, 11).
- [31] D. Depannemaecker, F. Tesler, M. Desroches, V. Jirsa and A. Destexhe. ‘Modeling impairment of ionic regulation with extended Adaptive Exponential integrate-and-fire models’. In: *Journal of Computational Neuroscience* 53.1 (3rd Mar. 2025), pp. 1–8. DOI: [10.1007/s10827-025-00893-7](https://doi.org/10.1007/s10827-025-00893-7). URL: <https://hal.science/hal-04885229> (cit. on p. 11).
- [32] M. Desroches, P. Kowalczyk and S. Rodrigues. ‘Discontinuity-induced dynamics in the Conductance-Based Adaptive Exponential Integrate-and-Fire Model’. In: *Bulletin of Mathematical Biology* 87.1 (2nd Jan. 2025), pp. 1–23. DOI: [10.1007/s11538-024-01384-z](https://doi.org/10.1007/s11538-024-01384-z). URL: <https://inria.hal.science/hal-04665937> (cit. on p. 12).
- [33] T. Fülöp, A. Cohen, E. Frost, S. Lévesque, A. Khalil, S. Rodrigues, M. Desroches, M. Alami, H. Berrougui, C. Ramassamy, K. Hirokawa, J. Witkowski and B. Laurent. ‘Unmasking the hidden catalyst: how infections trigger Alzheimer’s disease’. In: *Journal of Alzheimer’s Disease* (18th Dec. 2025). URL: <https://inria.hal.science/hal-05460207>. In press (cit. on p. 15).

- [34] E. Köksal-Ersöz, P. Chossat and F. Lavigne. ‘Gain modulation of probabilistic selection without synaptic relearning’. In: *PLoS ONE* 20.9 (30th Sept. 2025), e0333350. DOI: [10.1371/journal.pone.0333350](https://doi.org/10.1371/journal.pone.0333350). URL: <https://hal.science/hal-04418804> (cit. on p. 15).
- [35] L. Lemaire, M. Desroches, S. Rodrigues and F. Campillo. ‘Depolarization block induction via slow NaV1.1 inactivation in Dravet syndrome’. In: *Scientific Reports* 15.1 (24th Sept. 2025), p. 32749. DOI: [10.1038/s41598-025-17468-2](https://doi.org/10.1038/s41598-025-17468-2). URL: <https://inria.hal.science/hal-05408721> (cit. on p. 13).
- [36] H. Todd, M. Desroches, A. Cayco-Gajic and B. Gutkin. ‘The role of gap junctions and clustered connectivity in emergent synchronisation patterns of inhibitory neuronal networks’. In: *Physical Review E* 112 (14th July 2025), p. 014405. URL: <https://inria.hal.science/hal-05408706> (cit. on p. 12).

Conferences without proceedings

- [37] E. Baspinar. ‘Geometric Neural Fields for Cortical Activity’. In: *Geometric Science of Information*. Vol. 16035. Lecture Notes in Computer Science. Saint Malo (Palais du Grand Large), France: Springer Nature Switzerland, 20th Oct. 2025, pp. 183–193. DOI: [10.1007/978-3-032-03924-8_19](https://doi.org/10.1007/978-3-032-03924-8_19). URL: <https://hal.science/hal-05384972> (cit. on pp. 9, 17).

Reports & preprints

- [38] S. Arias, M. Bergmann, F. Campillo, M.-A. Enard, C. Fabre, F. Garcia, B. Guedj, E. Jeannot, G. Neglia, D. Peurichard, D. Racoceanu, B. Sagot and G. Tworkowski. *Reflections on the Use of Generative AI for Research Professions*. Inria, 9th July 2025. URL: <https://inria.hal.science/hal-05188001> (cit. on p. 21).
- [39] S. Arias, M. Bergmann, F. Campillo, M.-A. Enard, C. Fabre, F. Garcia, B. Guedj, E. Jeannot, G. Neglia, D. Peurichard, D. Racoceanu, B. Sagot and G. Tworkowski. *Réflexions sur l’usage de l’IA générative pour les métiers de la recherche*. Inria, 2025, pp. 1–10. URL: <https://inria.hal.science/hal-05187992>.
- [40] D. Fedorov, F. Campillo, M. Desroches, E. Soria-Gómez, S. Rodrigues and J. Piriz. *Multiple bursting patterns in Lateral Habenula neurons: experiments and computational model*. 23rd Jan. 2025. DOI: [10.1101/2025.01.23.634464](https://doi.org/10.1101/2025.01.23.634464). URL: <https://inria.hal.science/hal-05458905> (cit. on p. 13).

10.3 Cited publications

- [41] P. C. Bressloff, J. D. Cowan, M. Golubitsky, P. J. Thomas and M. C. Wiener. ‘Geometric visual hallucinations, Euclidean symmetry and the functional architecture of striate cortex’. In: *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* 356.1407 (2001), pp. 299–330 (cit. on p. 9).
- [42] F. Campillo, R. Rakotozafy and V. Rossi. ‘Bayesian numerical inference for hidden Markov models’. In: *International Conference on Applied Statistics for Development in Africa Sada’07*. 2007, 6–p (cit. on p. 8).
- [43] B. Cessac and D. Matzakou-Karvouniari. ‘The non linear dynamics of retinal waves’. In: *Physica D: Nonlinear Phenomena* 439 (2022), p. 133436 (cit. on p. 6).
- [44] P. Chossat and O. Faugeras. ‘Hyperbolic planforms in relation to visual edges and textures perception’. In: *PLoS Computational Biology* 5.12 (2009), e1000625 (cit. on p. 7).
- [45] M. O. Cunningham, M. A. Whittington, A. Bibbig, A. Roopun, F. E. LeBeau, A. Vogt, H. Monyer, E. H. Buhl and R. D. Traub. ‘A role for fast rhythmic bursting neurons in cortical gamma oscillations in vitro’. In: *Proceedings of the National Academy of Sciences of the United States of America* 101.18 (2004), pp. 7152–7157 (cit. on p. 8).
- [46] H. Dankowicz and F. Schilder. *Recipes for continuation*. SIAM, 2013 (cit. on p. 12).

- [47] M. Desroches, J. Guckenheimer, B. Krauskopf, C. Kuehn, H. M. Osinga and M. Wechselberger. ‘Mixed-Mode Oscillations with Multiple Time Scales’. In: *SIAM Review* 54.2 (May 2012), pp. 211–288. DOI: [10.1137/100791233](https://doi.org/10.1137/100791233). URL: <https://hal.inria.fr/hal-00765216> (cit. on pp. 6, 8).
- [48] M. Desroches, T. J. Kaper and M. Krupa. ‘Mixed-Mode Bursting Oscillations: Dynamics created by a slow passage through spike-adding canard explosion in a square-wave burster’. In: *Chaos* 23.4 (Oct. 2013), p. 046106. DOI: [10.1063/1.4827026](https://doi.org/10.1063/1.4827026). URL: <https://hal.inria.fr/hal-00932344> (cit. on pp. 6, 8).
- [49] M. Desroches, B. Krauskopf and H. M. Osinga. ‘The geometry of slow manifolds near a folded node’. In: *SIAM Journal on Applied Dynamical Systems* 7.4 (2008), pp. 1131–1162 (cit. on p. 8).
- [50] C. Dravet. ‘Dravet syndrome history’. In: *Developmental Medicine & Child Neurology* 53 (2011), pp. 1–6 (cit. on p. 6).
- [51] G. B. Ermentrout and D. H. Terman. *Mathematical foundations of neuroscience*. Vol. 35. Springer, 2010 (cit. on p. 6).
- [52] K. Friston. ‘The free-energy principle: a unified brain theory?’ In: *Nature Reviews Neuroscience* 11.2 (2010), pp. 127–138 (cit. on p. 16).
- [53] D. H. Hubel. ‘Exploration of the primary visual cortex, 1955–78’. In: *Nature* 299.5883 (1982), pp. 515–524 (cit. on p. 9).
- [54] E. M. Izhikevich. ‘Neural excitability, spiking and bursting’. In: *International Journal of Bifurcation and Chaos* 10.06 (2000), pp. 1171–1266 (cit. on p. 8).
- [55] E. M. Izhikevich. *Dynamical systems in neuroscience*. MIT press, 2007 (cit. on p. 6).
- [56] M. Krupa, N. Popović, N. Kopel and H. G. Rotstein. ‘Mixed-mode oscillations in a three time-scale model for the dopaminergic neuron’. In: *Chaos: An Interdisciplinary Journal of Nonlinear Science* 18.1 (2008), p. 015106 (cit. on p. 8).
- [57] M. Krupa and P. Szmolyan. ‘Relaxation oscillation and canard explosion’. In: *Journal of Differential Equations* 174.2 (2001), pp. 312–368 (cit. on p. 8).
- [58] N. Layer, L. Sonnenberg, E. Pardo González, J. Benda, U. B. Hedrich, H. Lerche, H. Koch and T. V. Wuttke. ‘Dravet Variant SCN1A A 1783 V Impairs Interneuron Firing Predominantly by Altered Channel Activation’. In: *Frontiers in cellular neuroscience* 15 (2021), p. 754530 (cit. on p. 13).
- [59] R. Mileusnic, C. L. Lancashire and S. P. Rose. ‘Amyloid precursor protein: from synaptic plasticity to Alzheimer’s disease’. In: *Annals of the New York Academy of Sciences* 1048.1 (2005), pp. 149–165 (cit. on p. 6).
- [60] J. C. Mulley, I. E. Scheffer, S. Petrou, L. M. Dibbens, S. F. Berkovic and L. A. Harkin. ‘SCN1A mutations and epilepsy’. In: *Human mutation* 25.6 (2005), pp. 535–542 (cit. on p. 6).
- [61] J. Petitot. *Neurogéométrie de la vision: modèles mathématiques et physiques des architectures fonctionnelles*. Editions Ecole Polytechnique, 2008 (cit. on p. 9).
- [62] J. Petitot, Petitot and Hiripi. *Elements of neurogeometry*. Springer, 2017 (cit. on p. 9).
- [63] D. Pietrobon and M. A. Moskowitz. ‘Pathophysiology of migraine’. In: *Annual review of physiology* 75 (2013), pp. 365–391 (cit. on p. 6).
- [64] E. T. Rolls. ‘Glutamate, obsessive–compulsive disorder, schizophrenia, and the stability of cortical attractor neuronal networks’. In: *Pharmacology Biochemistry and Behavior* 100.4 (2012), pp. 736–751 (cit. on p. 9).
- [65] F. H. L. da Silva, W. Blanes, S. N. Kalitzin, J. Parra, P. Suffczynski and D. N. Velis. ‘Dynamical diseases of brain systems: different routes to epileptic seizures’. In: *IEEE transactions on biomedical engineering* 50.5 (2003), pp. 540–548 (cit. on p. 6).
- [66] M. Spitzer, U. Braun, L. Hermle and S. Maier. ‘Associative semantic network dysfunction in thought-disordered schizophrenic patients: direct evidence from indirect semantic priming’. In: *Biological psychiatry* 34.12 (1993), pp. 864–877 (cit. on p. 9).
- [67] F. Tong. ‘Primary visual cortex and visual awareness’. In: *Nature reviews neuroscience* 4.3 (2003), pp. 219–229 (cit. on p. 9).