The main objectives of this PhD project are to investigate the mathematical modeling of Cortical Spreading Depression (CSD). This involves the modeling and analysis of systems with multiple time and space scales, as well as stochastic effects. We look both at single-cell models, microcircuits, and large networks. In terms of neuroscience, we are mainly interested in questions related to synaptic plasticity, neuronal excitability and memory. In particular, we focus on modelling efforts towards questions related to pathological states such as migraine and epileptic seizures, and neurodegenerative diseases such as Alzheimer.

The team evolves in a rich scientific environment with six permanent members, three postdocs, four PhD students, and one junior chair, as well as a large network of international collaborators regularly visiting us and giving talks. More info on our team webpage [here](#). The successful candidate will be given access to a wide range of computing facilities (laptop computer, an account on the local cluster) and will receive training from the supervisory team as well as from dedicated summer and winter schools that he/she will be encouraged to attend.

### Assignment

**Summary of the project.** Cortical Spreading Depression (CSD) refers to a wave of depolarized electrical activity that is generated in specific brain regions and propagates through large parts of the cortex (see e.g. [here](#)). This is associated with pathological states of the brain that can correspond, depending on the case, to migraines or strokes. Our team for this project consists of three mathematicians/modelers and one electrophysiologist. We have already derived a model accounting for the initiation of CSD, following a biological hypothesis for which the experimentalist of the team has preliminary data. This is a micro-circuit composed of two neural populations (each of which is represented by one average neuron), one excitatory and one inhibitory. We also consider evolution equations for pump dynamics and slowly-varying ionic concentrations, which are known to play an important role in this ignition process. The successful candidate will have the task to investigate numerically the current model and derive a mathematical reduction under the form of a slow-fast dynamical system. This will then enable a full time-scale analysis of the model and its bifurcation structure. The second part of the PhD will be devoted to extend the model to a spatially-extended system taking the form of a slow-fast neural field model, where both a theoretical analysis and link with experimental data will be part of the work.

**Team.** This PhD will be co-supervised by Mathieu Desroches (Inria Sophia Antipolis, mathneuro team, [website](#)) and Martin Krupa (UCA, JAD laboratory, [website](#)). The work will be done in close collaboration with electrophysiologist Massimo Mantegazza (IPMC, Sophia Antipolis, [website](#)). The project will benefit from an interaction with our collaborator Daniele Avitabile from the University of Nottingham (UK).

### Main activities

The main objectives of this PhD project are

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**Context**

The MathNeuro team at the Inria centre of Sophia Antipolis Méditerranée focuses on applications of multi-scale dynamics to neuroscience. This involves the modelling and analysis of systems with multiple time and space scales, as well as stochastic effects. We look both at single-cell models, microcircuits, and large networks. In terms of neuroscience, we are mainly interested in questions related to synaptic plasticity, neuronal excitability and memory. In particular, we focus on our modelling efforts towards questions related to pathological states such as migraine and epileptic seizures, and neurodegenerative diseases such as Alzheimer.

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### Main activities

The main objectives of this PhD project are
1. to study computationally a network model based on our preliminary work (here),
2. to reduce the model to a minimal dynamical systems for a thorough bifurcation analysis,
3. to derive and study a multi-timescale neural field version of the model,
4. to compare both the local ODE model and the spatially-extended model with experimental data from the Mantegazza lab, in link with both healthy and pathological states, so as to further enlighten the mechanisms underpinning CSD in the case of certain forms of migraine.

Skills
Candidates should be familiar with dynamical systems theory: differential equations, equilibria, stability, limit cycles, invariant manifolds, etc. Some notions of bifurcation theory are desirable but could be learnt during the early phase of the project. A background knowledge in neuronal modeling (conductance formalism) will be seen as very positive, as well as some notions of programming (e.g. in matlab, C++, python, julia, etc.). In any case, candidates should be interested in deepening their preliminary knowledge in all the above topics.

Benefits package
- Subsidised catering service
- Partially-reimbursed public transport
- Social security
- Paid leave
- Flexible working hours
- Sports facilities

Remuneration
Duration: 36 months
Location: Sophia Antipolis, France
Gross Salary per month: 1982€ brut per month (year 1 & 2) and 2085€ brut/month (year 3)