uncovering the links between biophysics and cognition. In this project we propose to develop methods such as local network structure, neuronal excitability and local network dynamics. We believe that it is possible to develop data analysis techniques that can be applied to brain activity measured non-invasively with imaging techniques, yet are difficult to connect quantitatively with specific neuronal models. These models quickly become unwieldy, difficult to understand beyond observation of simulated results and next to impossible to analyse. Alternative approaches are reduced models of population neural circuits to large scale networks. This complex architecture poses serious challenges to the modelling of neuronal activity and its relationship to cognitive function. In fact, direct simulations of biophysically based spiking neurons, while becoming technically possible due to increased computing power and programming techniques, quickly become unwieldy, difficult to understand beyond observation of simulated results and next to impossible to analyse. Alternative approaches are reduced models of population neural activity studied to address large scale data, such as brain activity measured non-invasively with imaging techniques. These can be analysed, yet are difficult to connect quantitatively with specific neuronal data such as local network structure, neuronal excitability and local network dynamics. We believe that it is precisely such quantitative connection between the different levels that is critical to further progress uncovering the links between biophysics and cognition. In this project we propose to develop a

About the research centre or Inria department

The Inria Sophia Antipolis - Méditerranée center counts 37 research teams and 9 support departments. The center's staff (about 600 people including 400 Inria employees) is composed of scientists of different nationalities (250 foreigners of 50 nationalities), engineers, technicians and administrators. 1/3 of the staff are civil servants, the others are contractual. The majority of the research teams at the center are located in Sophia Antipolis and Nice in the Alpes-Maritimes. Six (6) teams are based in Montpellier and a team is hosted by the computer science department of the University of Bologna in Italy. The Center is a member of the University and Institution Community (ComUE) "Université Côte d'Azur (UCA)". 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 [https://team.inria.fr/mathneuro](https://team.inria.fr/mathneuro). 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

**Assignments:**

**Summary of the project.** This project aims, by developing a powerful mathematical theory, to investigate how large-scale brain dynamics and function may arise from collective behavior of the underlying neuronal circuits. It goes without saying that network organization of the brain is complex at almost every scale: from small neuronal circuits to large scale networks. This complex architecture poses serious challenges to the modelling of neuronal activity and its relationship to cognitive function. In fact, direct simulations of biophysically based spiking neurons, while becoming technically possible due to increased computing power and programming techniques, quickly become unwieldy, difficult to understand beyond observation of simulated results and next to impossible to analyse. Alternative approaches are reduced models of population neural activity studied to address large scale data, such as brain activity measured non-invasively with imaging techniques. These can be analysed, yet are difficult to connect quantitatively with specific neuronal data such as local network structure, neuronal excitability and local network dynamics. We believe that it is precisely such quantitative connection between the different levels that is critical to further progress uncovering the links between biophysics and cognition. In this project we propose to develop a

General Information

- **Theme/Domain:** Computational Neuroscience and Medicine
- **Scientific computing (BAP E)**
- **Town/city:** Sophia Antipolis
- **Inria Center:** CRI Sophia Antipolis - Méditerranée
- **Starting date:** 2018-10-01
- **Duration of contract:** 3 years
- **Deadline to apply:** 2018-05-06

Contacts

- **Inria Team:** MATHNEURO
- **Recruiter:** Simona Olmi / simona.olmi@inria.fr

The keys to success

Candidates should be motivated by a multi-disciplinary project involving statistical physics and applied mathematics (dynamical systems), scientific computing (numerical simulation) and computational modeling at various temporal and spatial scales (multi-scale networks, field models, cross-frequency coupling). Candidates should be interested in applying mathematical theories and techniques to a given biological problem, interact with a biologist and manipulate experimental data.

Conditions for application

**Defence Security:**

This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST). Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

**Recruitment Policy:**

As part of its diversity policy, all Inria positions are accessible to people with disabilities.

**Warning:** you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.
mathematical formalism, Exact Reduced Methodology (ERM) that takes exactly this step and further validate and apply it to critical questions. In particular, we will employ ERM to mimic the dynamics of realistic neuronal ensembles. Using this powerful formalism we will develop mesoscopic models that are able to summarize quantitatively the large scale collective dynamics, while taking into account properties of the constituent neurons and circuits. Notably we will focus on the ubiquitously observed brain oscillations and particularly on theta-gamma cross frequency coupled dynamics that have been linked to cognitive function.

**Team.** This PhD will be co-supervised by Simona Olmi (Inria Sophia Antipolis, Starting Research Position) and Mathieu Desroches (Inria Sophia Antipolis, mathneuro team, http://www-sop.inria.fr/members/Mathieu.Desroches/). The work will be done in close collaboration with Martin Krupa (UCA, JAD laboratory, http://math.unice.fr/laboratoire/fiche&id=803). The project will benefit from the ongoing collaborations with the Fédération Hospitalo-Universitaire ‘`Epilepsy and Disorders of Neuronal Excitability’’ (EPINEXT) in Marseille.

**Main activities**

Main activities (5 maximum):

(1) Extension of the Exact Reduced Methodology (ERM) to sparse networks

(2) Derivation of ERM for neural networks with realistic synapses.

(3) Implementation of architectures able to sustain functionally relevant multi-frequency oscillations and identification of the mechanisms behind the emergence of θ-γ rhythms

(4) Extension of neural mass models to neural field models, thus taking into account spatially extended systems. In particular we will consider multi scale networks reproducing the main features of human brain circuits (connectomes) at various level of resolution.

**Skills**

Candidates should be familiar with dynamical systems theory: differential equations, equilibria, stability, limit cycles, linear stability analysis, Lyapunov exponents etc. Some notions of Ott-Antonsen Ansatz are desirable but could be learnt during the early phase of the project. A background knowledge in neuronal modeling (Θ-neuron) will be seen as very positive, as well as some previous work on modelling networks of phase oscillators. Strong programming skills are required, specially deep knowledge of programming in C, C++ and/or python. 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)