# DY 38: Partial Synchronization Patterns in Neuronal Networks I (Focus Session joint with DY / SOE / BP) (joint session SOE/DY)

Understanding the dynamics of the human brain is one of the main scientific challenges today. Synchronization is important for information transmission in the brain and also plays a central role in various neurological diseases, such as Alzheimer's disease and epilepsy, for example. It is therefore crucial to develop and analyze models of brain circuits in which various synchronization patterns appear. In this focus session we show how these patterns emerge in models of neuronal networks, with particular attention to chimera states, solitary states but also with a broader outlook on partial synchronization in general. We aim to bring together scientists from different backgrounds to share ideas, in particular on analogies between partial synchronization in model systems and physiological processes in the brain. (Session organized by Giulia Ruzzene and Iryna Omelchenko)

Time: Wednesday 15:00–17:15 Location: GÖR 226

**Invited Talk** DY 38.1 Wed 15:00 GÖR 226

**Cross frequency coupling in next generation inhibitory neural mass models** — •Simona Olmi[1], Andrea Ceni[2], David Angulo Garcia[3], and Alessandro Torcini[4] — [1]Inria Sophia Antipolis Mediterranee Research Centre, 2004 Route des Lucioles, 06902 Valbonne, France — [2]Department of Computer Science, College of Engineering, Mathematics and Physical Sciences, University of Exeter, UK — [3]Grupo de Modelado Computacional - Dinamica y Complejidad de Sistemas. Instituto de Matematicas Aplicadas, Universidad de Cartagena, Colombia — [4]Laboratoire de Physique Theorique et Modelisation, Universite de Cergy-Pontoise, 95302 Cergy-Pontoise cedex, France

Coupling among neural rhythms is one of the most important mechanisms at the basis of cognitive processes in the brain. In this study we consider a neural mass model, rigorously obtained from the microscopic dynamics of an inhibitory spiking network with exponential synapses, able to autonomously generate collective oscillations. Furthermore, we show that two inhibitory populations in a master-slave configuration with different synaptic time scales can display various collective dynamical regimes: namely, damped oscillations towards a stable focus, periodic and quasi-periodic oscillations, and chaos. Finally, when bidirectionally coupled, the two inhibitory populations can exhibit different types of $\theta$-$\gamma$ cross-frequency couplings: namely, phase-phase and phase-amplitude cross-frequency couplings.

**Topical Talk** DY 38.2 Wed 15:30 GÖR 226

**Brain functional connectivity asymmetry** — •Jaroslav Hlinka — Institute of Computer Science of the Czech Academy of Sciences, Prague, Czech Republic

The brain is one of the iconic complex systems with a very intricate structure of interconnections and interactions among its many parts. It is also commonly studied via application of graph-theoretical approaches [1], while the representative graph can be defined using the functional connectivity approach: two brain regions are considered connected to an extent given by the strength of their activity synchronization, assessed by the statistical dependence between their activity as sampled over time, typicaly by linear correlation [2]. The human brain is organized into two almost symmetrical hemispheres, with the hemispheres containing further subdivision into key subnetworks/modules. However, there is some level of asymmetry that is known to be functionally relevant; in the current contribution we provide evidence that the left hemisphere functional connectivity, experimentally observed in resting state by functional magnetic resonance imaging, has more modular structure. We further discuss the origin of this asymmetry in structure or dynamics [3], its functional relevance and robustness with respect to methodological choices.

[1] Bullmore, E. et al. Nature Reviews Neuroscience, 2009, 10, 186-198

[2] Hlinka, J. et al. NeuroImage, 2011, 54, 2218-2225

[3] Hlinka, J. & Coombes, S., European Journal of Neuroscience, 2012, 36, 2137-2145

**Topical Talk** DY 38.3 Wed 16:00 GÖR 226

**Partial Synchronization Patterns in the Brain** — •Eckehard Schöll — Institut für Theoretische Physik, Technische Universität Berlin

Partial synchronization patterns play an important role in the functioning of neuronal networks, both in pathological and in healthy states. They include chimera states, which consist of spatially coexisting domains of coherent (synchronized) and incoherent (desynchronized) dynamics. We show that partial synchronization scenarios are governed by a delicate interplay of local dynamics, network topology, and time delay. Our focus is in particular on applications of brain dynamics like unihemispheric sleep [1], epileptic seizure [2], and relay synchronization between distant areas of the brain.

[1] Ramlow, L., Sawicki, J., Zakharova, A., Hlinka, J., Claussen, J. C. and Schöll, E., Partial synchronization in empirical brain networks as a model for unihemispheric sleep, EPL 126, 50007 (2019), highlighted in phys.org https://phys.org/news/2019-07-unihemispheric-humans.html and Europhys. News 50 no.5-6 (2019).

[2] Chouzouris, T., Omelchenko, I., Zakharova, A., Hlinka, J., Jiruska, P. and Schöll, E., Chimera states in brain networks: empirical neural vs. modular fractal connectivity, Chaos 28, 045112 (2018).

DY 38.4 Wed 16:30 GÖR 226

**Coexistence of fast and slow gamma oscillations in one population of inhibitory spiking neurons** — Hongjie Bi, Marco Segneri, Matteo di Volo, and •Alessandro Torcini — Laboratoire de Physique Théorique et Modélisation, Université de Cergy-Pontoise, CNRS, UMR 8089, Cergy-Pontoise, France

Oscillations are a hallmark of neural population activity in various brain regions with a spectrum covering a wide range of frequencies. Within this spectrum gamma oscillations have received particular attention due to their ubiquitous nature and to their correlation with higher brain functions. Recently, it has been reported that gamma oscillations in the hippocampus of behaving rodents are segregated in two distinct frequency bands: slow and fast. These two gamma rhythms correspond to different states of the network, but their origin has been not yet clarified. We show that a single inhibitory population can give rise to coexisting slow and fast gamma rhythms corresponding to collective oscillations of a balanced spiking network. The slow and fast gamma rhythms are generated via two different mechanisms: the fast one being driven by the coordinated tonic neural firing and the slow one by endogenous fluctuations due to irregular neural activity. Furthermore, to make a closer contact with the experimental observations, we consider the modulation of the gamma rhythms induced by a slower (theta) rhythm driving the network dynamics. In this context, depending on the strength of the forcing and the noise amplitude, we observe phase-phase coupling with different theta-phases preferences for the two coexisting gamma rhythms.

DY 38.5 Wed 17:00 GÖR 226

**Solitary States in Neural Networks** — •Leonhard Schülen and Anna Zakharova — Institut für theoretische Physik, Technische Universität Berlin, Deutschland

Understanding mechanisms of desynchronization plays a significant role in the study of neural networks. Dynamical scenario of transition from pathological neural synchrony to a healthy state can involve partial synchronization patterns, such as chimera states or solitary states. The term "solitary" comes from the Latin "solitarius" and can be understood as "alone", "lonely", or "isolated". In the case of chimera states, a network spontaneously splits into coexisting domains of synchronized and desynchronized behavior, which are localized in space. For solitary states, on the contrary, it is typical that individual "solitary" oscillators split off from the synchronized cluster at random positions in space. Here we discuss the formation of solitary states and, in particular, the conditions under which these patterns occur in one-layer and two-layer networks of oscillatory FitzHugh-Nagumo neurons. Furthermore, we present a technique that allows to engineer solitary states. By delaying links of selected nodes we are able to control their position and displacement with respect to the synchronized cluster.