DY 9: Focus Session: Dynamical Patterns in Neural Systems: From Brain Function to Dysfunction (joint session DY/ BP)

Pattern formation in biological systems is at the forefront of current cross-disciplinary research; scientists are striving across disciplines to understand detailed activity patterns in neural systems and their role in brain function.This focus session will outline the potential of modern imaging and network approaches for revealing collective mechanisms underlying normal and pathophysiological activity in the brain. (Organizers St. C. Müller and Th. Geisel)

Time: Tuesday 9:30–11:30 Location: HÜL 186

Invited Talk DY 9.1 Tue 9:30 HÜL 186

From epilepsy to migraine to stroke: A unifying framework. — •Markus A Dahlem — Department of Physics, Humboldt-Universität zu Berlin

We seek to understand in terms of quantitative mathematical models the dynamics of ion imbalances in three pathological conditions: epileptiform activity during seizures, cortical spreading depression in migraine, and anoxic depolarizations after stroke or traumatic brain injury. A family history of epilepsy increases the chances of having severe migraines and certain patients with migraine are at greater risk for stroke. The multiplicity of potential links include common genetic risk factors and indirect links like common triggers outside the brain. In the present approach, however, we will focus on basic electrophysiological mechanisms of neural excitability and the transitions between different activity forms related to ion imbalances in the brain. The change of both membrane potential and—due to reduced ion gradients—Nernst potentials together cause in varying degrees a release of Gibbs free energy, that is, the thermodynamic potential that measures the energy available to the neurons for normal functioning. We hence describe the three states related to epilepsy, migraine, and stroke in terms of their free energy starvation and stress. The mathematical description of such phenomena requires a broader thermodynamical perspective, as it goes beyond the original Hodgkin-Huxley description based on equivalent electrical circuits in membrane physiology.

Invited Talk DY 9.2 Tue 10:00 HÜL 186

Non-standard Interactions in Networks: Synchrony and the Emergence of Neural Activity Patterns — •Marc Timme[1], Sven Jahnke[1], Raoul-Martin Memmesheimer[2], Wen-Chuang Chou[1], and Christian Tetzlaff[1] — [1]Network Dynamics, MPI for Dynamics and Self-Organization — [2]Donders Institute for Neuroscience, University of Nijmegen

Patterns of spatio-temporally distributed neural activity have been experimentally observed in different systems and are intimately related to network function. How spatial and temporal specificity emerge dynamically in neural circuits, however, remains unclear.

Here we demonstrate how non-standard interaction mechanisms such as non-additive coupling and inhibitory feedback co-acting with heterogeneities may generate apparently disordered patterns that yet are precise in space and time and selectively respond to specific inputs only. The results may contribute towards an explanation of sensory processing in olfactory systems and processes involved in memory consolidation.

References: PLoS Comput. Biol. 8:e1002384 (2012); Phys. Rev. X 2:041016 (2012); PLoS Comput. Biol. 9:e1003307 (2013); Chou et al., in prep.

Invited Talk DY 9.3 Tue 10:30 HÜL 186

Towards a dynamic map of neuronal circuits — •Alipasha Vaziri — Research Institute of Molecular Pathology (IMP), — Center for Molecular Biology, University of Vienna — Research Platform for Quantum Phenomena and Nanoscale Biological Systems, University of Vienna

Knowledge on structural connectivity in neuronal circuits is necessary for understanding information representation and processing in local circuits. Addressing this challenge has been hampered by lack of appropriate tools and methods that allow parallel and spatiotemporally specific application of excitation patterns onto neuronal populations while capturing the dynamic activity of the entire network at high spatial and temporal resolution. The combination of new optical excitation techniques, optogenetics and high speed functional imaging are providing new opportunities to address this question and move towards a dynamic map of neuronal circuits. Compared to standard two-photon microscopy exploiting the spectral properties of femtosecod lasers provide an additional degree of freedom whereby alternative spatial light distributions can be "sculpted" in a biological sample. We have developed such a two-photon technique for brain-wide calcium imaging in C. elegans. The combination of this microscope with a nuclear-localized, genetically encoded calcium indicator, NLS-GCaMP5K, has allowed us to capture the activity of individual neurons within the densely packed head ganglia of C. elegans. We demonstrate near-simultaneous recording of activity of up to 70% of all head neurons.

DY 9.4 Tue 11:00 HÜL 186

Fast reconfiguration of high-frequency human brain networks in response to surprising changes in auditory input — •Sandra Chapman[1,2,3], Ruth Nicol[4], Petra Vertes[5], Pradeep Nathan[5,6], Marie Smith[7], Yury Shtyrov[8], and Edward Bullmore[5,6] — [1]CFSA, Physics, Univ. of Warwick, UK — [2]MPIPKS, Dresden, Germany — [3]Mathematics and Statistics, UIT, Norway — [4]University Hospitals Coventry and Warwickshire NHS Trust, Coventry, UK — [5]Behavioral and Clinical Neuroscience Institute, Dept. of Psychiatry, Univ. of Cambridge, UK — [6]GSK Clinical Unit, Addenbrooke's Hospital, Cambridge, UK — [7]Dept. of Psychological Sciences, Birkbeck, Univ. of London, UK — [8]MRC Cognition and Brain Sciences Unit, Cambridge, UK

We measured rapid changes in functional brain network organization in response to brief, discrete, changes in auditori stimulii. We estimated network topology and distance parameters in the immediate response, < 1 s, following auditory presentation of standard, repeated tones interspersed with occasional 'surprising' tones, using MEG to measure synchronization of high frequency (gamma band 33-64 Hz) oscillations in healthy volunteers. We found that global small-world parameters of the networks were unchanged between the standard and surprising tones. However, auditory surprises were associated with local changes in clustering of connections between temporal and frontal cortical areas, and with increased interlobar, long-distance synchronization. This work maps the dynamic network response that corresponds to the well known evoked response to this mismatch-negativity paradigm.

DY 9.5 Tue 11:15 HÜL 186

The Cerebral Cortex as an Excitable Medium: Spiral Dynamics in Cortical Models of Epilepsy — •Kentaroh Takagaki — Leibniz Institut für Neurobiologie, Magdeburg, Germany

Epilepsy affects up to 50 million people worldwide, each year. Although much research has focused on the genetic and pharmacological aspects of this disorder, little is known about how the population activity patterns of neurons initiate and stabilize within the epileptic cortex. Our work in cortical slice models of epilepsy shows that spatially organized, dynamically stable spiral patterns may contribute to such epileptogenesis. We have also recently recorded such phenomena in vivo, in the Mongolian Gerbil.

We hypothesize that such spiral dynamics may serve a role similar to the well-known reentrant spirals in ventricular fibrillation of the heart. To explore this hypothesis and brain population dynamics in general, we have been applying transcranial DC stimulation to modulate the excitability of the cortex, and observing the resulting population dynamics via voltage-sensitive dye imaging.