BP 43: Neurosciences

Time: Friday 9:30–11:45 Location: ZEU 250

Topical Talk BP 43.1 Fri 9:30 ZEU 250

The Dynamics of Neuronal Circuits — •Fred Wolf — Max Planck Institute for Dynamics and Self-Organization — Bernstein Center for Computational Neuroscience, Göttingen University — Faculty of Physics, Göttingen University

Current advances in photonic live imaging, the ability to *instrument* living cells with genetically encoded sensors and effectors, and emerging techniques for the large-scale mapping of neuronal micro-circuits are currently driving a revolutionary change in the science of biological nervous systems. These advances are opening up exciting avenues for studying the collective dynamics and cooperative phenomena underlying the function of neuronal systems. This talk will first provide a condensed survey of emerging experimental techniques for observing and perturbing neuronal circuits. I will then present examples from our own theoretical and experimental work[1-8] on the dynamics of neocortical circuits that exemplify challenging dynamical systems and statistical physics problems that need to be solved to understand biological neuronal circuits.

[1]M. Kaschube et al., Science 330, 1113 (2010). [2]T. Tchumatchenko et al., Phys Rev Lett 104, 58102 (2010). [3]W. Wei and F. Wolf, Phys Rev Lett 106, 88102 (2011). [4]T. Tchumatchenko et al. J Neurosci 31, 12171 (2011). [5]M. Monteforte and F. Wolf, Phys Rev Lett 105, 1 (2010). [6]M. Monteforte and F. Wolf, Phys. Rev. X 2, 041007 (2012). [7]V. Ilin et al., Neurosci 33, 2281 (2013). [8]W. Keil et al., Science 336, 413 (2012).

BP 43.2 Fri 10:00 ZEU 250

The neuronal action potential as a nonequilibrium first order phase transition — •Benjamin Schäfer[1,3], Bernhard Altaner[2], Federico Faraci[1], and Marc Timme[1,4] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Ogranization, 37077 Göttingen, Germany — [2]Dynamics of Complex Fluids, Max Planck Institute for Dynamics and Self-Ogranization, 37077 Göttingen, Germany — [3]Otto-von-Guericke University Magdeburg, 39106 Magdeburg, Germany — [4]Bernstein Center for Computational Neuroscience (BCCN) Göttingen

Neuroscience has become one of the fastest growing topics in science, with aims ranging from understanding brain function to medical applications. Foundational assumptions underlying theoretical and modeling approaches are rarely questioned, in particular if they are already "long-estabilished". For example the excitation of a single nerve was explained in 1952 with a mathematical model by Hodgkin and Huxley and this model was since then modified and supplemented with overwhelming success in characterizing experimental data.
Is this the only way to explain neuronal excitation? This talk addresses the question whether models based on a complementary perspective of phase transitions can consistently explain nerve excitation. We start with a short review on the Hodgkin-Huxley model and several experiments performed on nerves. The idea of the neuronal action potential modeled as a phase transition is presented and the relation to existing models is shown. The talk ends by giving an exemplary biological mechanism that could realize the phase transition in biological nerve cells.

BP 43.3 Fri 10:15 ZEU 250

Asymmetric two-trace model for STDP — •Rodrigo Echeveste and Claudius Gros — Institut für Theoretische Physik, Johann Wolfgang Goethe Universität, Max-von-Laue-Str. 1, Frankfurt am Main, Germany

In the present work we propose a simple model formulating synaptic potentiation and depression in terms of two interacting traces, representing the fraction of open NMDA receptors and the Ca^{2+} concentration in the post-synaptic neuron, respectively. These two traces then determine the evolution of the synaptic weight. We first test that the standard STDP curve for low frequency trains of pairs of pre- and post-synaptic spikes is obtained and we then evaluate high frequency effects. Secondly, we study triplets. In this case, we are interested in non-linear effects and, in particular, in possible asymmetric response to pre-post inversion.

Having a low number of parameters and composed of only polynomial differential equations, the model is able nonetheless to reproduce key features of LTP and LTD. Moreover, since the parameters of the model are easily related to the dynamical properties of the synapse, it permits to make a connection between the observed synaptic weight change and the behaviour of the underlying traces.

BP 43.4 Fri 10:30 ZEU 250

Including intrinsic thalamic currents in a population model of the thalamo-cortical system during deep sleep — Michael Schellenberger Costa[1], Arne Weigenand[1], Thomas Martinetz[1], and •Jens Christian Claussen[2,1] — [1]INB, Universität zu Lübeck, Germany — [2]Computational Systems Biology Lab, Research II, Jacobs University Bremen, Germany

Sleep has been shown to be beneficial for the consolidation of memories [1, 2]. As the thalamocortical interaction is important for both the processing of sensory stimuli and the generation of slow waves a detailed understanding of its dynamical properties is needed, to reveal the influence of one on the other. Population models have been used to investigate the behaviour of awake brain networks [3,4,5]. These models lack the hallmarks of a sleeping thalamus e.g. rebound bursts and waxing/waning of spindles [6]. Therefore we adapt a cortical population model proposed [7] and extend it with the respective intrinsic properties specific in the RE and TC neurons.
[1] L. Marshall et al, Nature, 444, 610 (2006) [2] H V V Ngo et al, J Sleep Res (2013), Neuron (2013). [3] M. Ursino et al, NeuroImage, 52, (2010). [4] R. C. Sotero et al, Neur Comp 19, 478 (2007) [5] B S Bhattacharya et al, Neural Networks 24, 631 (2011). [6] A Destexhe, T J Sejnowski, Physiol Rev 83, 1401 2003) [7] D. Steyn-Ross et al, J Biol Phys 31, 547 (2005)

BP 43.5 Fri 10:45 ZEU 250

Statistics of neural spiking under non-Poissonian stimulation — •Tilo Schwalger[1] and Benjamin Lindner[2,3] — [1]EPFL, Lausanne, Switzerland — [2]Humboldt-Universität zu Berlin, Berlin, Germany — [3]Bernstein-Center for Computational Neuroscience, Berlin, Germany

Nerve cells in the brain generate sequences of spikes with a complex statistics. To understand this statistics, the synaptic input received from other neurons is often modeled by temporally uncorrelated input (Poissonian shot noise), which possesses a flat (white) power spectrum. However, realistic input is temporally correlated because presynaptic neurons exhibit refractoriness, bursting or adaptation, carry a time-dependent signal in their spikes and are subject to short-term synaptic plasticity. The effect of such "colored noise" input is poorly understood theoretically because the the associated first-passage-time problem with colored noise is generally a hard problem. Based on a weak-noise expansion of a multi-dimensional Fokker-Planck equation, we derive simple analytical formulas for essential spike train statistics for a tonically firing neuron driven by arbitrarily correlated synaptic input. We show that synaptic input with power-law correlations also leads to power laws in the interspike interval correlations and the Fano factor. Furthermore, input spikes that are more regular than Poisson, as well as neurons with short-term synaptic depression, cause negative interval correlations similar to neurons with adaptation. Our results provide a framework for the interpretation of spiking statistics measured in vivo.

BP 43.6 Fri 11:00 ZEU 250

Asymmetric neural coding in the honeybee brain — Elisa Rigosi[1,2], Gianfranco Anfora[3], Renzo Antolini[4], Paul Szyszka[5], Giorgio Vallortigara[2], and •Albrecht Haase[2,4] — [1]BIOtech center, Dep. of Industrial Engineering, University of Trento, Mesiano (TN), Italy — [2]Center for Mind/Brain Sciences, University of Trento, Mattarello (TN), Italy — [3]Research and Innovation Center, Fondazione Edmund Mach, San Michele a/A (TN), Italy — [4]Department of Physics, University of Trento, Povo (TN), Italy — [5]Department of Biology, Neurobiology, University of Konstanz, Konstanz, Germany

Left-right asymmetric processing of symmetric stimuli is a common property of sensory systems, yet little is known about asymmetric neuronal coding. We studied this aspect in the honeybee using various methods to trace asymmetries along the olfactory pathway. Electron microscopy was used to image the odour receptor sensilla and electroantennography for the olfactory receptor neurons to characterize the input to the primary processing centers, the antennal lobes (ALs). Two photon microscopy visualizes the AL morphology and in vivo

functional imaging of the projection neurons describes the output of the ALs. We identified for the first time a left-right asymmetry in the neural coding during odour processing. Neurophysiological distances between odours in the right antennal lobes are higher than in the left ones. Moreover, mixture processing differs between sides. Behavioural experiments support the brain imaging results. The implementation of different neuronal coding strategies in the left and right brain side may serve to increase coding capacity by parallel processing.

BP 43.7 Fri 11:15 ZEU 250

Computer simulation of the distribution of histone deacetylases 1 and 3 in the brain — •Davoud Pouladsaz — Department of Biological Physics, Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Since their abnormal activities have been implicated in various neurological disorders, including oncogenesis, neurodegenerative and psychiatric disorders, histone decaetylases (HDACs), a class of enzymes that alter the chromosome structure and affect the gene expression, are potential targets for therapeutic development. Therefore, understanding the distribution of HDACs in the brain can serve as a valuable tool in this regard. We perfom Monte Carlo simulations in order to calculate the distribution of HDAC1 and HDAC3 in the brain based on previous experimental results of patterns of histone acetylation in the brain in response to MS-275, a benzamide derivative with in vivo antitumor activity and selectivity against HDAC1 and HDAC3. The results show significant correlation to experimental measurements.

BP 43.8 Fri 11:30 ZEU 250

The fly on a swing- Generation of complex locomotor pattern through nonlinear coupling to a prototypical dynamic environment — •Jan Bartussek[1,2,3], Hannah Haberkern[3], and Martin Zapotocky[2] — [1]Department of Animal Physiology,University of Rostock, Albert-Einstein-Str. 3, 18059 Rostock, Germany — [2]Institute of Physiology, Academy of Sciences of the Czech Republic, Videnska 1083, 14220 Praha 4, Czech Republic — [3]Institute of Neuroinformatics, ETH/Uni Zurich, Winterthurerstr. 190, 8057 Zurich, Switzerland

We investigated the mutual, dynamic coupling of flying flies with their environment. By gluing single fruit flies to a steel tether with defined mechanical properties, we replaced the dynamics of the natural world by a prototypical environment, which can be modelled as a simple harmonic oscillator. We used an interferometer to measure the vibrations of the tether induced by the flying fly. Depending on the tether resonance frequency, the forces from the fly were inducing a large cumulative motion of the tether and activation of the fly's mechanosensors. The fly therefore received delayed feedback dependent on its previous activity. This lead to a variety of observed dynamical locomotor patterns, including locking of the wingbeat to the tether resonance frequency. We were able to reproduce most of the observed dynamical features in a simple nonlinear model of two mutually coupled oscillators. Aerodynamic calculations indicate that even in natural free flight, the wingbeat might be continuously locked to mechanosensory feedback due to body oscillations. We argue how this locking can improve flight control on fast time scales.