# BP 2: Neurophysics I

Time: Monday 9:30–13:00 Location: H 1058

BP 2.1 Mon 9:30 H 1058

**The vertebrate retina as an optical image processor** — •Moritz Kreysing — Max Planck Institute of Molecular Cell Biology and Genetics, 01307 Dresden, Germany

The neuronal processing capabilities of the vertebrate retina are increasingly well understood. These processes are thought to be initiated by the detection of light by the photoreceptors as projected by the lens. However, recent findings show that cells inside the light path give rise to fine changes in these projected images prior to the detection event. Using the concept of modulation transfer function analysis, we firstly describe the neuronal retina as a frequency domain, optical image processor. Based on direct measurements we discuss to which extend demodulation of transmitted image frequencies must be understood as the result of simple contrast loss due to scattering. We further analyze transmitted light fields for newly generated image frequencies, and discuss these in relation to the retina's optical architecture and possible benefits for vision under low light conditions.

BP 2.2 Mon 9:45 H 1058

**General Anaesthesia: From experiments to theory** — •Axel Hutt — INRIA Nancy, Frankreich

The talk will introduce into general anaesthesia, starting from a clinical perspective in human medicine showing the link to animal experiments. Anaesthetic effects on the microscopic scale of single synapses and the macroscopic scale of electroencephalogram (EEG) and Local Field Potentials elucidates the complexity of the neural mechanism originating from the interaction bridge between single neurons and populations and networks of populations. In the last part, the talk will introduce to recently developed neural population models involving nonlinear delayed interactions. This model permits to reproduce the major anaesthetic effects on a macroscopic scale. A final reduced model proposes an interaction mechanism explaining few signals features in EEG.

BP 2.3 Mon 10:00 H 1058

**Up and down states in top-down input may be advantageous to the transmission of information about weak signals** — •Felix Droste and Benjamin Lindner — HU Berlin & Bernstein Center for Computational Neuroscience Berlin, Berlin, Germany

How a single neuron transmits information about a sensory stimulus is heavily dependent on the state of the embedding network. This allows higher cortical areas, providing so-called top-down input, to influence the processing of a bottom-up signal. Cortical networks may be in asynchronous-irregular states, where the population firing rate is roughly constant in time. In this case, analytical approaches to signal transmission are well established. However, the firing rate may also be time dependent. It may, for instance, jump between so-called up and down states (observed under anesthesia, during sleep, or quiet wakefulness). While the effect of such input on information transmission has been studied in experiments, theoretical approaches have so far been lacking.

Here, we model up/down input to a leaky integrate-and-fire neuron by dichotomous noise, a simple stochastic two-state process. We derive exact results for the spike train power spectrum and the susceptibility for pure two-state input and expand this to incorporate additional fluctuations around the states, which take into account the shot-noise nature of the input. This allows us to compare signal transmission with an asynchronous-irregular background to that in the presence of up/down state input. We find that if the overall input firing rate is low, up/down states may be beneficial for information transmission.

BP 2.4 Mon 10:15 H 1058

**How does addition, deletion, or shifting of spikes by intrinsic noise affect signal transmission in spiking neurons?** — •Sergej Voronenko[1,2], Wilhelm Stannat[1,3], and Benjamin Lindner[1,2] — [1]Bernstein Center for Computational Neuroscience, Berlin, Germany — [2]Humboldt University, Berlin, Germany — [3]TU Berlin, Berlin, Germany

We study analytically how different effects of intrinsic noise on the output of a spiking neuron influence signal transmission. To this end, we consider populations of neurons driven by a strong common time-dependent signal, where each neuron is subject to independent intrinsic noise. In this setup the intrinsic noise degrades the transmission of information by single neurons. On the population level, however, the intrinsic noise can lead to enhancement of the information transmission, an effect known as suprathreshold stochastic resonance. The strength and the robustness of the stochastic resonance effect is determined by whether the output spikes of the single neurons are shifted by the intrinsic noise, or whether the intrinsic noise adds and deletes output spikes. Our investigation is one of the first analytical studies of the transmission of information by neurons with highly correlated input.

BP 2.5 Mon 10:30 H 1058

**Information filtering by partial synchronous spikes in a neural population** — •Alexandra Kruscha — Bernstein Center for Computational Neuroscience, Berlin, 10115, Germany — Institute for Physics, Humboldt-Universität zu Berlin, Berlin, 12489, Germany

Synchronous firing of neurons is a prominent feature in many brain areas. Here, we are interested in the information transmission by the synchronous spiking output of a noisy neuronal population, which receives a common time-dependent sensory stimulus. Experimental and theoretical work revealed that synchronous spikes encode preferentially fast components of the stimulus, i.e. synchrony acts as an information filter. In these studies a rather strict measure of synchrony was used: all neurons in the population have to fire within a short time window. Here, we generalize the definition of the synchronous output, for which only a certain fraction $\gamma$ of the population has to fire in synchrony. We present an analytical approach to characterize the information transfer in dependence of this fraction and the population size, by deriving the cross-correlation and the coherence function between the stimulus and the partial synchronous output. We show that there is a critical synchrony fraction, namely the probability at which a single neuron spikes within the predefined time window, which maximizes the information transmission of the synchronous output. At this value, the partial synchronous output acts as a low-pass filter, whereas deviations from this critical fraction lead to a more and more pronounced band-pass filtering effect. We confirm our analytical findings by numerical simulations for the leaky integrate-and-fire neuron.

BP 2.6 Mon 10:45 H 1058

**Synthetic Neuronal Networks on Glass Using Topological and Chemical Cues** — •Andreas Schlegel[1], Aune Koitmäe[1], Paul Gwozdz[1], Jann Harberts[1], Christian Heusinger[1], Gabriele Loers[2], and Robert H. Blick[1] — [1]Center for Hybrid Nanostructures (CHYN) and Institute of Nanostructure and Solid State Physics, University of Hamburg, Germany — [2]Center for Molecular Neurobiology Hamburg, University Medical Center Hamburg-Eppendorf, Germany

The understanding of neuronal signal transduction is of interest for research of biological networks. We present a method to achieve directional guidance of neurite outgrowth with the goal of providing synthetic neuronal circuits.

We use glass microstructured with an excimer laser (geometrical confinement). In a second step patterns of Poly-L-Lysine (PLL) are printed onto the glass (chemical guidance). The topological pattern consists of lines with alternating units of containers (diameters $\sim 20\,\mu$m) and channels (width $\sim 4\,\mu$m, length $30 - 200\,\mu$m). The distance between the lines varies between 10 and 200 $\mu$m. The depth of the structures is $4\,\mu$m. PLL is printed inside the containers to promote cell adhesion.

The neurites prefer to grow within the microstructures over several hundred $\mu$m. Neurons situated inside containers grow neurites along channels and connect to multiple neurons in line over a millimeter range. Crosslinking of neurites between separated lines becomes less common with increasing distance. A transition from partially random behavior to controlled growth is observed.

BP 2.7 Mon 11:00 H 1058

**Spatiotemporal imaging of neurotransmitter release using near infrared fluorescent carbon nanotube probes** — •Sebastian Kruss — Institut für Physikalische Chemie / Universität Göttingen

Neurotransmitters are central for chemical communication between (neuronal) cells. So far there are no analytical tools available to spatially detect or image neurotransmitters. Therefore, the chemical events in synapses and neural circuits remain largely unexplored. Optical nanoscaled sensors/probes could provide non-invasive, fast, high-resolution and parallel imaging of neurotransmitters. Nanomaterials are promising building blocks for such probes. For example, semiconducting single-walled carbon nanotubes (SWCNTs) are hollow cylinders of one-atom-thick sheets of carbon. They provide an intrinsic bandgap, which results in near infrared (nIR) fluorescence (900-1600 nm) that is beneficial for biomedical applications. The molecular environment of SWCNTs strongly affects their nIR-fluorescence, which can be used for molecular recognition and signal transduction. We have developed carbon nanotube-based label-free fluorescent sensors/probes for neurotransmitters. These probes change their fluorescence in the presence of neurotransmitters. Parallel imaging of many of those probes provides an image that corresponds to the neurotransmitter concentration. We also demonstrate spatiotemporal imaging of dopamine release from cells during exocytosis. In summary, this method enables chemical imaging in biological systems and can provide completely new insights into communication between cells.

**15 min break**

BP 2.8 Mon 11:30 H 1058

**Probing a quantum mechanical model of olfaction in insects** — Marco Paoli[1,2], Elisa Rigosi[1,2], Gianfranco Anfora[3], Giorgio Vallortigara[1], Renzo Antolini[1,4], and •Albrecht Haase[1,4] — [1]Center of Mind/Brain Sciences, University of Trento, Rovereto, Italy — [2]BIOtech center, University of Trento, Trento, Italy — [3]Research and Innovation Centre, Fondazione Edmund Mach, S.Michelle all'Adige, Italy — [4]Department of Physics, University of Trento, Trento, Italy

One of the first examples for a possible manifestation of quantum effects in biological systems is the vibration theory of olfaction. In contradiction to the widespread assumption that smell is a purely chemical sense, it proposes phonon assisted electron tunneling as the trigger mechanism for signal transduction. This would induce a sensitivity of olfactory receptors not only to molecular shape and binding properties, but also to the vibrational spectrum of the odorants. Here we present first *in vivo* functional imaging experiments in the honeybee brain showing evidence for the bees' ability to distinguish isotopes by smell. A possible correlation of these results with the odorants' vibrational spectra is discussed.

BP 2.9 Mon 11:45 H 1058

**Dynamic changes in network synchrony reveal resting-state functional networks** — •Vesna Vuksanovic[1,2] and Philipp Hövel[1,2] — [1]Institute für Theoretische Physik, Technische Universität Berlin, Germany — [2]Bernstein Center for Computational Neuroscience Berlin, Humboldt-Universität zu Berlin, Germany

Experimental studies of the human brain activity at rest i.e. without any overt-directed behavior have revealed patterns of correlated activity, so called resting-state networks. The neural mechanisms contributing to the formation of these networks are largely unknown. We use modeling approach to interpret these experimental findings, looking at the brain as the dynamical system. We characterize brain network dynamical properties by synchrony and variability in synchrony. We demonstrate that functional brain interactions may arise from the network dynamics which allow flexible changes between different network configurations. We show that these changes reflect almost periodic alternations between network synchronized and desynchronized state.

BP 2.10 Mon 12:00 H 1058

**Discrimination, correlation and prediction of collective neural responses to natural sounds in the auditory midbrain** — •Dominika Lyzwa[1,2] and Michael Herrmann[2] — [1]Dept. Nonlinear Dynamics, MPI for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for Perception, Action and Behavior, School of Informatics, University of Edinburgh, U.K.

The main structure in the auditory midbrain, the inferior colliculus (IC) is the central converging station for all sound information and important for processing complex sounds, such as speech. How complex sounds are encoded by groups of neurons across the IC is an open question. In order to better understand the processing of this nucleus, we investigated the separability of multi-unit responses. To explore the spatial extent of the neural representation, we computed noise correlations between neural groups across the IC. The analysis is based on spiking multi-unit activity which had been simultaneously recorded from 32 positions along and across isofrequency laminae of the ICC while presenting 11 species-specific vocalizations to guinea pigs. Using neural discrimination and cross-correlation it was found that small groups of neurons reliably encode the spectrotemporally rich set of vocalizations. Combination of a few multi-units yielded improved discrimination over an individual unit, but temporal correlations between the units did not improve discrimination. The findings suggest that encoding of vocalizations in the mammalian inferior colliculus is shaped by the input and organization of receptive fields and not by neural interactions within this nucleus.

BP 2.11 Mon 12:15 H 1058

**anomalous transport in complex dendrites - geometrical considerations** — m reza shaebani, •anne e hafner, and ludger santen — Department of Theoretical Physics, Saarland University, Saarbrucken, Germany

Dendritic spines, which are small membranous protrusions emerging from the dendrites, serve as the main recipients of exitatory inputs in the mammalian brain. The spines undergo dynamic structural changes, which is regulated by neuronal activity and is believed to be a cellular basis of neural functions such as cognition, memory, and learning. The density, morphology, and spatial distribution of spines vary at different cortical areas or due to neurodegenerative diseases or aging. Morphological changes of spines influences the transport characteristics of ions and other molecules in dendrites, since they are frequently trapped in the spines which slows down their propagation in the dendritic channel. Anomalous diffusion of tracer particles has been reported in dendrites, which is strongly dependent on spines morphological properties. Here we analytically study a diffusive motion composed of two different modes of motility, a motion and a waiting mode. We investigate how the overall transport properties depend on the structural properties of the dendrites and spines, and on the fraction of time spent in each state. The analytical predictions are in agreement with available experimental data as well as the results of extensive Monte Carlo simulations.

BP 2.12 Mon 12:30 H 1058

**The effects of positive interspike interval correlations on neuronal information filtering properties.** — •Sven Blankenburg[1,2] and Benjamin Lindner[1,2] — [1]Department of Physics Humboldt University Berlin, Germany — [2]Bernstein Center for Computational Neuroscience Berlin, Germany

Neurons encode time-dependent stimuli in sequences of action potentials (spike trains). The neuron can encode either preferentially slow components of the stimulus (low-pass filter), high frequency components (high-pass filter), or a specific frequency band (band-pass filter) depending on the characteristics of the stimulus as well as the intrinsic neuronal dynamics. The standard integrate-and-fire model acts as a low-pass filter of information, irrespective of the firing regime (regular, Poisson-like, or bursting) of the neuron. However, experiments reveal band-pass filtering in some neurons, requiring theoretical explanation. In this study, intrinsic stochastic adaptation is identified as a possible mechanism. For our analytically tractable model system we show that positive ISI correlations, such as those caused by stochastic adaptation can result in a pronounced band-pass filtering of information for time-dependent stimuli.

BP 2.13 Mon 12:45 H 1058

**Nonlinear population dynamics for finite-size spiking neural networks with adaptation – Non-Gaussian fluctuations and information filtering** — •Tilo Schwalger, Moritz Deger, and Wulfram Gerstner — Brain Mind Institute, École polytechnique fédérale de Lausanne, CH-1015 Lausanne

Bridging the scale from the microscopic dynamics of single neurons to the global population activities of pulse-coupled neurons is crucial for multi-scale modeling of the nervous system. Current theories mostly consider the limit of large networks. However, this approach is limited to the mean activity and neglects fluctuation effects. In realistic neural circuits, the number of neurons of a given type can be rather small (N=50–1000), which requires a theory for the fluctuating population dynamics. Existing finite-size theories are either based on rather simplified neuron models or rely on heuristic assumptions. Using mean field theory and a quasi-renewal approximation [1,2], we present stochastic population equations for the large class of generalized integrate-and-fire neurons with spike-frequency adaptation. Our theory goes beyond the Gaussian approximation and thus applies to rather small populations. We study spontaneous transitions between up and down states in a bistable network induced by finite-size noise. Furthermore, for the asynchronous state, we analytically calculate the power spectrum of the fluctuations. This allows us to investigate information filtering by coupled populations of adapting neurons [2].

References: [1] R. Naud, W. Gerstner, PLoS Comp. Biol. (2012); [2] M. Deger, T. Schwalger, R. Naud, W. Gerstner, Phys. Rev. E (2014)