BP 8: Neurophysics II

Time: Monday 14:30–17:00 Location: H 1058

BP 8.1 Mon 14:30 H 1058

Born to be critical: Spontaneous activity in early cortex and its role in shaping sensory representations — •Bettina Hein[1], Klaus Neuschwander[1], David E. Whitney[2], Gordon B. Smith[2], David Fitzpatrick[2], and Matthias Kaschube[1] — [1]Frankfurt Institute for Advanced Studies, Frankfurt am Main, Germany — [2]Max Planck Florida Inst., Jupiter, FL, USA

The cortex is spontaneously active from the first moments that circuits form and there is ample evidence indicating that early cortical maturation relies on spontaneous activity. Yet, we know very little about how the pattern of spontaneous activity prior to visual experience impacts circuit formation. Here we took advantage of the robust columnar representation of orientation preference in ferret visual cortex to determine how patterns of spontaneous activity before eye-opening are related to stimulus evoked patterns in the same animal later in development. By using the calcium indicator GCaMP6 we revealed population activity on a single trial basis in chronic recordings of the developing visual cortex. Novel analysis approaches allowed us to uncover interpretable statistical relations from these data. We found that events of spontaneous activity varied in size over several orders of magnitude. Large events displayed robust columnar patterns that resembled the mature organization of the orientation preference map, several days prior to the time when this map was evoked by visual stimulation. We conclude that early spontaneous activity patterns exhibit a rich dynamics and an orderly columnar structure that forms the basis for building sensory evoked representations during cortical development.

BP 8.2 Mon 14:45 H 1058

Input spike trains suppress chaos in balanced target circuits — •Rainer Engelken, Michael Monteforte, and Fred Wolf — MPI for Dynamics and Self-Organization, Bernstein Center for Comp. Neurosc., Göottingen, Germany

A longstanding hypothesis claims that structured input in neural circuits enhances reliability of spiking responses. While studies in single neurons well support this hypothesis [Mainen, Sejnowski 1995] the impact of input structure on the dynamics of recurrent networks is not well understood. Studies in rate chaotic networks suggest a suppression of chaos by structured input [Molgedey 1992], but in spiking input, this has not yet been thoroughly analyzed. Previous studies of the dynamic stability of the balanced state used a constant external input [v.Vreeswijk 1996; Monteforte 2010] or white noise [Lajoie 2013, 2014].

We generalize the analysis of dynamical stability for balanced networks driven by input spike trains. An analytical expression for the Jacobian enables us to calculate the full Lyapunov spectrum. We solved the dynamics in numerically exact event-based simulations and calculated Lyapunov spectra, entropy production rate and attractor dimension. We examined the transition from constant to stochastic input in various scenarios.We find a suppression of chaos by input spike trains. We also find that both independent bursty input spike trains and common input more strongly reduces chaos in spiking networks. Our study extends studies of chaotic rate models [Molgedey et al. 1992] to spiking neuron models and opens a novel avenue to study the role of sensory streams in shaping the dynamics of large networks.

BP 8.3 Mon 15:00 H 1058

A Frequency-resolved Mutual Information Rate — •Davide Bernardi[1,2] and Benjamin Lindner[1,2] — [1]Bernstein Center for Computational Neuroscience, Berlin — [2]Humboldt-Universität zu Berlin, Institut für Physik

The information spike trains encode about an external time-dependent stimulus is quantified by Shannon's mutual information rate. However, the numerical estimation of the mutual information rate is demanding and does not reveal which features of the stimulus are encoded. Several studies have identified mechanisms at the cellular and network level leading to low- or high-pass filtering of information, i. e. the selective coding of low- or high-frequency components of the time-dependent stimulus. However, these findings rely on an approximation, specifically, on the qualitative behavior of the coherence function, an approximate frequency-resolved measure of information flow, whose quality is generally unknown.

We developed a numerical procedure to directly calculate a frequency-resolved version of the mutual information rate. This can be used to study how different frequency components of a Gaussian stimulus are encoded in neural models without invoking a weak-signal paradigm or making undue assumptions on the nature of the neural encoding. We demonstrate its application for paradigmatic descriptions of neural firing like an integrator neuron and a simple setup mimicking a coincident detector cell receiving input from two leaky integrate-and-fire neurons.

BP 8.4 Mon 15:15 H 1058

Spike timing reliability and information transfer under noisy juxtacellular stimulation — Experiment and theory — •Jens Doose[1,2], Guy Doron[1,2], Michael Brecht[1,2], and Benjamin Lindner[1,2] — [1]Bernstein Center for Computational Neuroscience — [2]Humboldt University of Berlin, Berlin, Germany

We used nanostimulation, a technique which allows stimulation of identified single neurons in vivo, in order to drive pyramidal cells in anesthetized rat motor cortex. Using this method we find that stimulating with fluctuating stimuli (frozen bandpass-limited white noise) results in increased spike timing reliability. Specifically, we report that parametrically increasing the stimulus variance results in increased spike train synchronization. We also explore how well the spike train as well as statistics like the power spectrum or the spectral coherence function, in response to this stimulus can be captured by a model neuron. In particular we use the exponential integrate-and-fire neuron, a simple model that has been successfully applied for reproducing spike times of pyramidal cells under noisy current stimulation in vitro.

BP 8.5 Mon 15:30 H 1058

Synaptic unreliability facilitates information transmission in balanced cortical populations — •Leon A. Gatys[1], Alexander S. Ecker[1], Tatjana Tchumatchenko[2], and Matthias Bethge[1] — [1]Centre for Integrative Neuroscience and Institute for Theoretical Physics, Tuebingen, Germany — [2]Max Planck Institute for Brain Research, Frankfurt, Germany

Synaptic unreliability is one of the major sources of biophysical noise in the brain. In the context of neural information processing, it is a central question how neural systems can afford this unreliability. Here we examined how synaptic noise affects signal transmission in cortical circuits, where excitation and inhibition are thought to be tightly balanced. Surprisingly, we found that in this balanced state synaptic response variability actually facilitates information transmission, rather than impairing it. In particular, the transmission of fast-varying signals benefits from synaptic noise, as it instantaneously increases the amount of information shared between presynaptic signal and postsynaptic current. This finding provides a parsimonious explanation why cortex can afford to operate with noisy synapses.

15 min break

BP 8.6 Mon 16:00 H 1058

Electro-physiological characterization of the ultra-fast Channel-Rhodopsin Chronos — •Ulrich Fromme[1], Andreas Neef[2,3], and Christoph F. Schmidt[1] — [1]Faculty for Physics, George August University, Goettingen, Germany — [2]Bernstein Center for Computational Neuroscience, Goettingen, Germany — [3]MPI for Dynamics and Self-Organization, Goettingen, Germany

The light-gated ion channels Channel-Rhodopsins (CHRs) have become a major tool in experimental neuro science due to their low invasiveness and the possibility of genetically targeting specific cell types. To address specific issues, various ChRs with a wide array of different properties have been introduced. Here we characterize Chronos an especially light sensitive ChR with improved opening and closing speeds compared to traditional ChRs such as the widely used ChR2. This ChR shows great promise in various applications, such as the creation of neural implants, where good time resolution and low light intensities are favorable. We used patch-clamp recordings to characterize the kinetics of the ensemble of channels, which dictate the performance in applications. We also created Markov models representing the light cycle of Chronos, which enables the extraction of single-molecule properties from the electro-physiological measurements.

BP 8.7 Mon 16:15 H 1058

Assessing network states from subsampled activity — •Anna Levina[1,2,3], Theo Geisel[1,3], and Viola Priesemann[1,3] — [1]BCCN Göttingen, Germany — [2]MPI MIS, Leipzig, Germany — [3]MPI DS, Göttingen, Germany

Experimental studies suggest that neural activity self-organizes close to criticality, as various preparations have shown signatures of it. At criticality, the neural network may profit from the optimal information processing associated with a critical state.

The appeal of the criticality hypothesis for the brain lies in its potential to unveil a fundamental principle of collective neural dynamics and offers an opportunity to relate neuronal circuits to well studied physical systems. When testing for criticality in simulated systems the full information about their activity can be used. Data obtained from brain recordings are limited by subsampling, however, since to date it is impossible to assess the activity of every single neuron in the brain.

Here we discuss how subsampling changes avalanche size distributions, and how it is possible to recover information of the actual network state even under subsampling. To this end, we extend methods from statistical physics and analyse scaling laws for subsampled systems. To demonstrate the generality of our novel approach, we evaluate models from different universality classes and support our results by analytical considerations.

BP 8.8 Mon 16:30 H 1058

Estimating branching parameters from subsampled systems — •Jens Wilting[1], Theo Geisel[1,2], and Viola Priesemann[1,2] — [1]Max-Planck-Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]BCCN, Göttingen, Germany

Branching processes are frequently used to model time-varying data in economics, finance, epidemiology, population dynamics, physics, and neuroscience. Depending on the expected number of offspring ϵ , the process shows either stationary fluctuations (sub-critical) or transient growth (super-critical), and has a deep connections to self-organized criticality. Methods to infer ϵ from fully sampled systems are well established. In real-world systems, however, often only a subset of all agents can be sampled. Since under subsampling classical approaches to infer ϵ fail, we have developed a novel approach based on the autocorrelation function that for the first time allows to robustly infer ϵ even under subsampling. Importantly, our method generalizes to autoregressive processes with both additive and multiplicative noise, making it widely applicable. We demonstrate that our method correctly estimates ϵ under sub-sampling in simulated branching processes, and also in the purely deterministic Bak-Tang-Wiesenfeld model. Moreover, applying our method to necessarily subsampled neuronal population dynamics from macaque monkeys, we show that spiking dynamics reflects a sub-critical regime ($\epsilon = 0.95$)

BP 8.9 Mon 16:45 H 1058

Self-consistent spectra in recurrent spiking networks — •Stefan Wieland[1,2] and Benjamin Lindner[1,2] — [1]Bernstein Center for Computational Neuroscience Berlin, Germany — [2]Humboldt University Berlin, Germany

Firing patterns in cortical networks are often modeled with Poissonian spike trains. Demanding self-consistency at the level of firing rates, i.e. that spike trains driving a neuron possess the same firing rate as the spike train they evoke, then yields a tractable analytic description of network dynamics. However, output spike trains are usually observed to be non-Poissonian, something a more coherent framework should account for. Here we present iterative schemes that yield self-consistent statistics in recurrent neural networks at the level of spike-train correlations.