Schedule

Events for:
Monday, January 27th - Friday, January 31st

Monday, January 27th

9:30am **Opening Remarks - SCGP 102**

Title: Opening Remarks

9:45am **Tali Tishby - SCGP 102**

Speaker: Tali Tishby

Title: The dynamics that lead to generalization in Deep learning

10:30am **Coffee Break - SCGP cafe**

11:00am **Dmitri Chklovskii - SCGP 102**

Speaker: Dmitri Chklovskii

Title: TBA

11:45am **Nicolas Brunel - SCGP 102**

Speaker: Nicolas Brunel

Title: TBA

12:30pm **Lunch - SCGP cafe**

2:00pm **Braden Brinkman - SCGP 102**

Speaker: Braden Brinkman

Title: A non-perturbative renormalization group analysis of strongly-coupled spiking networks

Abstract: TBA

2:45pm **Giancarlo La Camera - SCGP 102**

Speaker: Giancarlo La Camera

Title: Temporal stimulus segmentation by reinforcement learning in populations of spiking neurons

Abstract: Stimulus identification is the process of picking out a particular stimulus among many other stimuli which may be present in the environment, for the purpose of performing a task. In the most interesting yet demanding scenario, the problem amounts to extracting action-relevant segments out of a noisy input stream, thus also involving the extrapolation of the beginning and the end of relevant stimulus features, not known a priori. In a typical framework, the identity and timing of the relevant stimuli are known to the learning agent. Departing from this view, I introduce an autonomous learning system able to identify action-relevant stimuli without prior knowledge of them, while learning to ignore stimuli that are not behaviorally relevant. The model is based on ensembles of spiking neurons able to handle spatiotemporal patterns of spike trains reminiscent of those recorded in alert animals performing decision tasks. It uses a biologically plausible learning rule for maximizing the average reward obtained for correct decisions taken at the right time. Performance of the model on surrogate and cortical datasets is robust to stimulus noise and multiple coding strategies, providing an example of a spiking network model able to solve multi-choice decision tasks in the absence of prior information on the relevance and timing of input stimuli.

3:30pm **Coffee Break - SCGP cafe**

4:00pm **Jin Wang - SCGP 102**

Speaker: Jin Wang

Title: Nonequilibrium neural network dynamics and thermodynamics revealed by the global landscape and flux quantifications

Abstract: The brain map project aims to map out the neuron connections of the human brain. Even with all the wirings mapped out, the global and physical understandings of the function and behavior are still challenging. Hopfield quantified the learning and memory process of symmetrically connected neural networks globally through equilibrium energy. The energy basins of attractions represent memories and the memory retrieval dynamics is determined by the energy gradient. However, the realistic neural networks are asymmetrically connected and oscillations cannot emerge from symmetric neural networks. Here, we developed a non-equilibrium landscape-flux theory for realistic asymmetrically connected neural networks [1]. We uncovered the underlying potential landscape and the associated Lyapunov function for quantifying the global stability and function. We found the dynamics and oscillations responsible for cognitive processes and physiological rhythm regulations are determined not only by the landscape gradient but also by the flux. We found that the flux is closely related to the degrees of the asymmetrical connections in neural networks and is the origin of the neural oscillations. The neural oscillation landscape shows a closed ring attractor topology. The landscape gradient attracts the network down to the ring. The flux is responsible for coherent oscillations on the ring. We suggest the flux may provide the driving force for associations among memories. We applied our theory to rapid eye movement (REM) sleep cycle. We identified the key regulation factors for function through global sensitivity analysis of landscape topography against wirings. Our predictions are consistent with experimental observations. For decision making in the brain, a quantitative description of global attractor landscapes has not yet been completely given. Here, we developed a theoretical framework to quantify the landscape associated with the steady state probability distributions and associated steady state curl flux, measuring the degree of non-equilibrium through the degree of detailed balance breaking for decision making [2]. We quantified the decision-making processes with optimal paths from the undecided attractor states to the decided attractor states, which are identified as basins of attractions, on the landscape. Both landscape and flux determine the kinetic paths and speed. The kinetics and global stability of decision making are explored by quantifying the landscape topography through the barrier heights and the mean first passage time. Our theoretical predictions are in agreements with the experimental observations: more errors occur under time pressure. We quantitatively explored two mechanisms of the speed-accuracy tradeoff with speed emphasis and further uncovered the tradeoffs among speed, accuracy, and energy cost. Our results imply that there is an optimal balance among speed, accuracy, and the energy cost in decision making. We uncovered the possible mechanisms of changes of mind and how mind changes improve performance in decision processes. Our landscape approach can help facilitate an understanding of the underlying physical mechanisms of cognitive processes and identify the key factors in the corresponding neural networks. [1] H. Yan, L. Zhao, L. Hu, X. Wang, E.K. Wang, J. Wang*. Nonequilibrium landscape theory of neural networks. Proc. Natl. Acad. Sci. USA.110 , E4185–E4194 (2013). [2] H. Yan, K. Zhang, J. Wang*. Physical mechanism of mind changes and tradeoffs among speed, accuracy, and energy cost in brain decision making- Landscape, flux, and path perspectives. Chinese Phys. B. 25(7), 078702. (2016)

4:45pm **Ari Pakman - SCGP 102**

Speaker: Ari Pakman

Title: Neural Clustering Processes

Tuesday, January 28th

9:45am **Arianna Maffei - SCGP 102**

Speaker: Arianna Maffei

Title: Circuit mechanisms for learning in sensory cortex

10:30am **Coffee Break - SCGP cafe**

11:00am **Carina Curto - SCGP 102**

Speaker: Carina Curto

Title: Dynamically relevant motifs in inhibition-dominated networks

Abstract: Many networks in the nervous system possess an abundance of inhibition, which serves to shape and stabilize neural dynamics. The neurons in such networks exhibit intricate patterns of connectivity whose structure controls the allowed patterns of neural activity. In this work, we examine inhibitory threshold-linear networks whose dynamics are constrained by an underlying directed graph. We develop a set of parameter-independent graph rules that enable us to predict features of the dynamics, such as emergent sequences and dynamic attractors, from properties of the graph. These rules provide a direct link between the structure and function of these networks, and may provide new insights into how connectivity shapes dynamics in real neural circuits.

11:45am **Lunch - SCGP cafe**

1:00pm **SCGP Weekly Talk: Misha Tsodyks**

Speaker: Misha Tsodyks

Title: Mathematical models of human memory

Abstract: Human memory is a multi-staged phenomenon of extreme complexity, which results in highly unpredictable behavior in real-life situations. Psychologists developed classical paradigms for studying memory in the lab, which produce easily quantifiable measures of performance at the cost of using artificial content, such as lists of randomly assembled words. I will introduce a set of simple mathematical models describing how information is maintained and recalled in these experiments. Surprisingly, they provide a very good description of experimental data obtained with internet-based memory experiments on large number of human subjects. Moreover, more detailed mathematical analysis of the models leads to some interesting ideas for future experiments with potentially very surprising results.

2:00pm **Jim DiCarlo - SCGP 102**

Speaker: Jim DiCarlo

Title: Reverse Engineering Visual Intelligence

2:45pm **Stefano Fusi - SCGP 102**

Speaker: Stefano Fusi

Title: The geometry of abstract neural representations

3:30pm **Coffee Break - SCGP cafe**

4:00pm **Ken Miller - SCGP 102**

Speaker: Ken Miller

Title: TBA

4:45pm **Memming Park - SCGP 102**

Speaker: Memming Park

Title: Stimulus-choice population code (mis)alignment in the middle temporal cortex during perceptual decision-making

Abstract: For stimuli near perceptual threshold, the trial-by-trial activity of single neurons in many sensory areas is correlated with the animal's perceptual report. This phenomenon has often been attributed to feedforward readout of the neural activity by the downstream decision-making circuits. The interpretation of choice-correlated activity can be better understood in the light of population-wide correlations among sensory neurons. Using a statistical nonlinear dimensionality reduction technique on single-trial ensemble recordings from the middle temporal area during perceptual-decision-making, we extracted low-dimensional neural trajectories that captured the population-wide fluctuations. We dissected the particular contributions of sensory-driven versus choice-correlated activity in the low-dimensional population code. We found that the neural trajectories strongly encoded the direction of the stimulus in single dimension with a temporal signature similar to that of single MT neurons. If the downstream circuit were optimally utilizing this information, choice-correlated signals should be aligned with this stimulus encoding dimension. Surprisingly, we found that a large component of the choice information resides in the subspace orthogonal to the stimulus representation inconsistent with the optimal readout view. This misaligned choice information allows the feedforward sensory information to coexist with the decision-making process. The time course of these signals suggest that this misaligned contribution likely is feedback from the downstream areas. We hypothesize that this non-corrupting choice-correlated feedback might be related to learning or reinforcing sensory-motor relations in the sensory population.

Wednesday, January 29th

9:45am **Bruce Cumming - SCGP 102**

Speaker: Bruce Cumming

Title: Disparity as a tool to understand how cortical neurons exploit the statistics of the natural environment

10:30am **Coffee Break - SCGP cafe**

11:00am **Chuck Stevens - SCGP 102**

Speaker: Chuck Stevens

Title: A maximum entropy combinatorial code for two quite different neural systems

Abstract: In this talk I describe the fly olfactory encoding of odors, and the monkey encoding of human faces. These quite different systems will be shown to use the same maximum entropy combinatorial code. Roughly speaking, a maximum entropy combinatorial code will encode the largest number of objects with the smallest number of neurons. Fly olfaction. The fly's nose has multiple copies of each of about 50 genetically different types odorant receptors. Each odorant receptor type converges on one of each of 50 different types of glomeruli in the antenna lobe of the fly olfactory system, and each glomerulus type supplies odorant information to one type of projection neuron that removes concentration dependence of the odor response and sends the odor information to 2000 Kenyon cells in the mushroom body of the fly. Most odors activate most of the 50 types of odorant receptors and projection neurons. If the firing rates of activated projection neurons are measured and the average firing rate is calculated, every odor gives the same average value. And if the distribution of firing rates is estimated, the distribution is the same exponetial for every odor. What is different from one odor to the next is which projection neurons are firing at which rates. That is, the odor identity is encoded by which projection neurons are firing at the highest rates for that odor. This type of combinatorial code is known to be maximum entropy. Monkey face code. Visual information is sent to six distinct face patches in the monkey inferior temporal cortex, and the information is distributed between the different patches. The anterior medial face patch provides outputs for the face systems. Most of the neurons in a face patch respond specifically to faces, and Doris Tsao presented 2000 human faces in two monkeys, and recorded from about 100 neurons in the output face patch. Most of the 100 neurons responded to most faces, and non-responding neurons were just silent. The average firing rate for responding neurons was the same for all 2000 faces, and when the cumulative distributions for all 2000 faces are superimposed, they are found to be exponentially distributed with the same mean far all faces. Thus, the fly olfactory system and the monkey face system both encode their objects with just the same maximum entropy code.

11:45am **Brent Doiron - SCGP 102**

Speaker: Brent Doiron

Title: Information flow in excitatory and inhibitory cortical circuits

12:30pm **Lunch - SCGP cafe**

2:00pm **Surya Ganguli - SCGP 102**

Speaker: Surya Ganguli

Title: TBA

2:45pm **Luca Mazzucato - SCGP 102**

Speaker: Luca Mazzucato

Title: Metastable attractors explain the variable timing of stable behavioral action sequences

Abstract: Natural animal behavior displays rich lexical and temporal dynamics, even in a stable environment. This implies that behavioral variability arises from sources within the brain, but the origin and mechanics of these processes remain largely unknown. Here, we focus on the observation that the timing of self-initiated actions shows large variability even when they are executed in stable, well-learned sequences. Could this mix of reliability and stochasticity arise within the same circuit? We trained rats to perform a stereotyped sequence of self-initiated actions and recorded neural ensemble activity in secondary motor cortex (M2), which is known to reflect trial-by-trial action timing fluctuations. Using hidden Markov models we established a robust and accurate dictionary between ensemble activity patterns and actions. We then showed that metastable attractors, with the requisite combination of reliable sequential structure and high transition timing variability, could be produced by reciprocally coupling a high dimensional recurrent network and a low dimensional feedforward one. Transitions between attractors were generated by correlated variability arising from the feedback loop between the two networks. This mechanism predicted a specific structure of low-dimensional noise correlations that were empirically verified in M2 ensemble dynamics. This work suggests a robust network motif as a novel mechanism to support critical aspects of animal behavior and establishes a framework for investigating its circuit origins via correlated variability.

3:30pm **Coffee Break - SCGP cafe**

4:00pm **David Hansel - SCGP 102**

Speaker: David Hansel

Title: Theory of orientation selectivity in rodent primary visual cortex

4:45pm **Anitha Pasupathy - SCGP 102**

Speaker: Anitha Pasupathy

Title: TBA

Thursday, January 30th

9:45am **Barry Richmond - SCGP 102**

Speaker: Barry Richmond

Title: What is being computed where in the ventral visual stream and beyond

10:30am **Coffee Break - SCGP cafe**

11:00am **Tatiana Engel - SCGP 102**

Speaker: Tatiana Engel

Title: Discovering interpretable models of neural population dynamics from data

Abstract: Significant advances have been made recently to develop powerful machine learning methods for finding predictive structure in neural population recordings. However, most these techniques compromise between flexibility and interpretability. While simple ad hoc models are likely to distort defining features in the data, flexible models (such as artificial neural networks) are difficult to interpret. We developed a flexible yet intrinsically interpretable framework for discovering neural population dynamics from data. In our framework, population dynamics are governed by a non-linear dynamical system defined by a potential function. The activity of each neuron is related to the population dynamics through unique firing-rate functions, which account for heterogeneity of neural responses. The shapes of the potential and firing-rate functions are simultaneously inferred from data to provide high flexibility and interpretability. Using this framework, we find that good data prediction does not guarantee accurate interpretation of the model, and propose an alternative strategy for deriving models with correct interpretation. We demonstrate the power of our approach by discovering metastable dynamics in spontaneous spiking activity in the primate area V4.

11:45am **William Marshall - SCGP 102**

Speaker: William Marshall

Title: Causal Emergence: Can Macro Beat Micro?

12:30pm **Lunch - SCGP cafe**

2:00pm **David Schwab - SCGP 102**

Speaker: David Schwab

Title: TBA

2:45pm **Misha Tsodyks - SCGP 102**

Speaker: Misha Tsodyks

Title: TBA

3:30pm **Coffee Break - SCGP cafe**

4:00pm **Paul Miller - SCGP 102**

Speaker: Paul Miller

Title: Multistable, metastable, and quasi-stable attractor states in cognitive processing

4:45pm **Mike Douglas - SCGP 102**

Speaker: Mike Douglas

Title: How will we do mathematics in 2030?

Abstract: We make the case that over the coming decade, computer assisted reasoning will become far more widely used in the mathematical sciences. This includes interactive and automatic theorem verification, symbolic algebra, and emerging technologies such as formal knowledge repositories, semantic search and intelligent textbooks. After a short review of the state of the art, we survey directions where we expect progress, such as mathematical search and formal abstracts, developments in computational mathematics, integration of computation into textbooks, and organizing and verifying large calculations and proofs. For each we try to identify the barriers and potential solutions.

Friday, January 31st

9:45am **Bruno Averbeck - SCGP 102**

Speaker: Bruno Averbeck

Title: Dimensionality, Information and Learning in Prefrontal Cortex

10:30am **Coffee Break - SCGP cafe**

11:00am **Cengiz Pehlevan - SCGP 102**

Speaker: Cengiz Pehlevan

Title: Statistical Mechanics of Generalization in Kernel Machines and Deep Networks in the Infinite-Width Limit

11:45am **Tilo Schwalger - SCGP 102**

Speaker: Tilo Schwalger

Title: Mesoscopic mean-field models for spiking neural networks

12:30pm **Lunch - SCGP cafe**

2:00pm **Final Remarks and Farewell - SCGP 102**

Title: Final Remarks and Farewell