Complex Dynamics in Large-Scale Interacting Brain systems: Towards Physical Models of Sleep and Consciousness

Workshop and Seminar

Scientific coordinators: P. Achermann, E. Olbrich, and T. Wennekers

The **workshop** was attended by 65 participants and brought together scientists working in multiple disciplines as diverse as experimental brain research, medicine, psychology, complex systems science, data analysis, and large-scale computational modeling of the nervous system. The main goal was to advance an integrated understanding of the complex dynamics of the brain that underly different brain states like sleep and consciousness. The 5-day workshop contained 21 invited and nine contributed talks. It featured world-leading experts in experimental sleep and cognition research (e.g., P. Maquet, V. Crunelli, S. Bressler), modelers (e.g., A. Destexhe, M. Bazhenov, P. Robinson, M. Wilson, S. Hill), theoreticians (e.g., J. Kurths, J. Jost), and data analysts (e.g., P.A. Valdes Sosa).

A major topic was the physical origin of the slow oscillation, a most fundamental process characterising sleep. It was covered by presentations of new experimental results (V. Crunelli, I. Ulbert) and different modelling approaches (J.-C. Claussen, M. Bazhenov, S. Hill). Sleep has further been suggested to be involved in memory consolidation for many years. Several talks addressed recent experiments investigating this hypothesis (J. Fell, R. Huber). Complexity physics provides a major novel direction in sleep research because the brain can be considered a complex network of cells and their connections. Presentations in this area explored network topologies of neural networks and their impact on network dynamics, especially synchronisation phenomena (J. Kurths, J. Jost, C. Zhou). A further strand of research covered in the workshop was large-scale modeling of the brain as very detailed models of biological neural networks can now be simulated on high performance computers. This enables detailed studies of neurophysiological processes related to sleep control and sleep oscillations (D. Forger, P. Robinson, M. Bazhenov, S. Hill). One current challenge in the field of sleep research and neuroscience is the integration of different experimental approaches like macroscopic measurements such as EEG and fMRI with more microscopic data such as local field potentials or multi-unit recordings. To combine these techniques mathematical models based on statistical inference can be used. These topics were addressed in the contributions of P.A. Valdes Sosa, I. Bojak and R.D. Pascual Marqui.

As part of the workshop a public evening lecture "Why do we sleep?" was given by P. Achermann. The lecture was attended by approximately 200 visitors and was followed by a lively discussion. K. Friston, one of the leading theorists on cortical function, furthermore gave a colloqium talk entitled "Free-energy, perception and learning" to the members of the Max Planck Institute for the Physics of Complex Systems.

A special discussion session during the workshop addressed problems regarding communication and epistemological barriers between the different disciplines. The workshop was a significant step to bridge such gaps and to initiate interactions between the different contributing disciplines.

Young researchers (PhD students and postdoctoral fellows) presented their work in a poster session (19 posters) or as speaker in the main program (S. Postnova). Posters were at display during the entire workshop.

A **seminar** complemented the workshop. This aimed at supporting immediate research work by the participants as well as setting up of new collaborations. The seminar lasted for 10 days and was attended by 13 participants, mainly young researchers. It included five tutorial lectures that provided introductions into complexity measures, state space models, sleep, neural assemblies and large scale simulation models. Three additional morning sessions targeted on open discussions with foci on challenges in time series analysis, a calculus of cognition, and the future of large-scale modeling. Beside these arranged talks and discussions, participants worked on collaborative projects of which some will continue in the future.