Multi-stable pattern formation in the visual cortex

F. Wolf[1]*, M. Kaschube[1], M. Schnabel[1], S. Löwel[2], K.-F. Schmidt[2], H. Dinse[3], K. KreikemeIer[3]

[1] Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany
[2] Leibniz Institute for Neurobiology, Magdeburg, Germany
[3] Ruhr University, Bochum, Germany
* Electronic Address: `fred@chaos.gwdg.de`

Dynamical pattern formation in the primary visual cortex of the brain is studied using pattern formation theory, computer simulation, optical brain imaging, and brain stimulation experiments. In the visual cortex, as in most areas of the cerebral cortex information is processed in a 2-dimensional array of functional modules, called cortical columns. Individual columns are groups of neurons extending vertically throughout the entire cortical thickness and sharing many functional properties. Orientation columns in the visual cortex are composed of neurons preferentially responding to visual contours of a particular stimulus orientation. In a plane parallel to the cortical surface, neuronal selectivities vary systematically, so that columns of similar functional properties form highly organized 2D patterns, known as functional cortical maps. Experimental evidence suggests that the formation of so called orientation maps in the visual cortex is a dynamical process guided by neuronal activity and sensitive to visual experience and external electrical stimulation. We will discuss an analytically tractable class of dynamical models for the formation of the orientation maps. In this class of models an inner permutation symmetry guarantees the emergence of contour detectors for all stimulus orientations. By the same symmetry a large number of dynamically degenerate solutions exist, that quantitatively reproduce the experimentally observed patterns. Long-range interactions are found essential for the stability of such realistic solutions. A combination of optical brain imaging and brain stimulation experiments is used to experimentally test the predicted multi-stability of visual cortical pattern formation.