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Poster presentation

Pattern selection, pinwheel stability and the geometry of visual space

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Symmetries are critical for the dynamics of spatially extended systems. In the visual cortex, spontaneous symmetry breaking is believed to underlie the formation of orientation maps and pinwheel defects [1]. It has been proposed that the dynamical stability of these topological defects in the visual cortex reflects the Euclidean symmetry of the visual world [2]. We present a comprehensive analysis of the impact of Euclidean symmetry on the phase diagram of orientation map models [3]. In particular, we analyze defect stability and pattern selection in a Swift-Hohenberg model of visual cortical development, which is symmetric under the Euclidean group $E(2)$ and compare the results to a previous model exhibiting a higher $E(2)$ $U(1)$ symmetry (shift symmetry) [1].

We find three classes of stationary solutions, which all exist independently of the degree of broken shift symmetry:

(1) Stripe patterns without any pinwheels, (2) pinwheel crystals with pinwheels regularly arranged on a rhombic lattice and (3) aperiodic patterns containing a large number of irregularly positioned pinwheels. We calculate the stability boundaries of these solutions in dependence of the degree of broken shift symmetry as well as of the nonlocal long-range interactions. With increasing strength of symmetry breaking pinwheel free patterns are progressively replaced by pinwheel crystals in the phase diagram while both pinwheel free patterns and pinwheel crystals remain stable. Phases of aperiodic, pinwheel rich patterns, however, remain basically unaffected. A critical strength of symmetry breaking exists above which multistable aperiodic patterns collapse into a single aperiodic state. Euclidean symmetry strongly influences the geometry and multistability of model solutions but does not directly impact on defect stability.

We conclude that pattern formation in the visual cortex is very sensitive to the presence of interactions imposed by Euclidean symmetry. The dynamical stability of realistic defect arrangements, however, is closely related to the fundamentally non-local nature of neuronal interactions in the brain.

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