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Self-organized quantization and oscillations on continuous fixed-energy sandpiles

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Atmospheric self-organization and activator-inhibitor dynamics in biology provide examples of checkerboard-like spatio-temporal organization. We study a simple model for local activation-inhibition processes. Our model, first introduced in the context of atmospheric moisture dynamics, is a continuous-energy and non-Abelian version of the fixed-energy sandpile model. Each lattice site is populated by a non-negative real number, its energy. Upon each timestep all sites with energy exceeding a unit threshold re-distribute their energy at equal parts to their nearest neighbors. The limit cycle dynamics gives rise to a complex phase diagram in dependence on the mean energy μ: For low μ, all dynamics ceases after few re-distribution events. For large μ, the dynamics is well-described as a diffusion process, where the order parameter, spatial variance σ, is removed. States at intermediate μ are dominated by checkerboard-like period-two phases which are however inter-spersed by much more complex phases of far longer periods. Phases are separated by discontinuous jumps in σ or $\partial\sigma/\partial\mu$ —akin to first and higher-order phase transitions. Overall, the energy landscape is dominated by few energy levels which occur as sharp spikes in the single-site density of states and are robust to noise.

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