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# Collapse of ordered spatial pattern in neuronal network

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## HIGHLIGHTS

- Correlation function from sampled signals is calculated to predict the collapse.
- Possible mechanism of breakdown of spatial regularity is investigated.
- The results could be further used to discern forthcoming instability and desynchronization.

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## ABSTRACT

Spatiotemporal systems can emerge some regular spatial patterns due to self organization or under external periodical pacing while external attack or intrinsic collapse can destroy the regularity in the spatial system. For an example, the electrical activities of neurons in nervous system show regular spatial distribution under appropriate coupling and connection. It is believed that distinct regularity could be induced in the media by appropriate forcing or feedback, while a diffusive collapse induced by continuous destruction can cause breakdown of the media. In this paper, the collapse of ordered spatial distribution is investigated in a regular network of neurons (Morris–Lecar, Hindmarsh–Rose) in two-dimensional array. A stable target wave is developed regular spatial distribution emerges by imposing appropriate external forcing with diversity, or generating heterogeneity (parameter diversity in space). The diffusive invasion could be produced by continuous parameter collapse or switch in local area, e.g, the diffusive poisoning in ion channels of potassium in Morris–Lecar neurons causes breakdown in conductance of channels. It is found that target wave-dominated regularity can be suppressed when the collapsed area is diffused in random. Statistical correlation functions for sampled nodes (neurons) are defined to detect the collapse of ordered state by series analysis.



## 1. Introduction

Spatiotemporal system can present complex dynamical behaviors and spatial distribution. The collective behavior of networks could be investigated on networks of coupled oscillators, neurons [1–5]. The multi-agent systems and neuronal network can present regular spatial distribution due to self-organization or appropriate forcing [6,7]. Indeed, a powerful pacemaker is effective to keep the regularity of the media by generating continuous pulse or target wave [8,9]. It is found that powerful target wave in two-dimensional space or pulses in chain network can regulate the collective behaviors of nervous system completely [10–12]. Spiral wave is self-sustained and also effective to regulate the collective behaviors of

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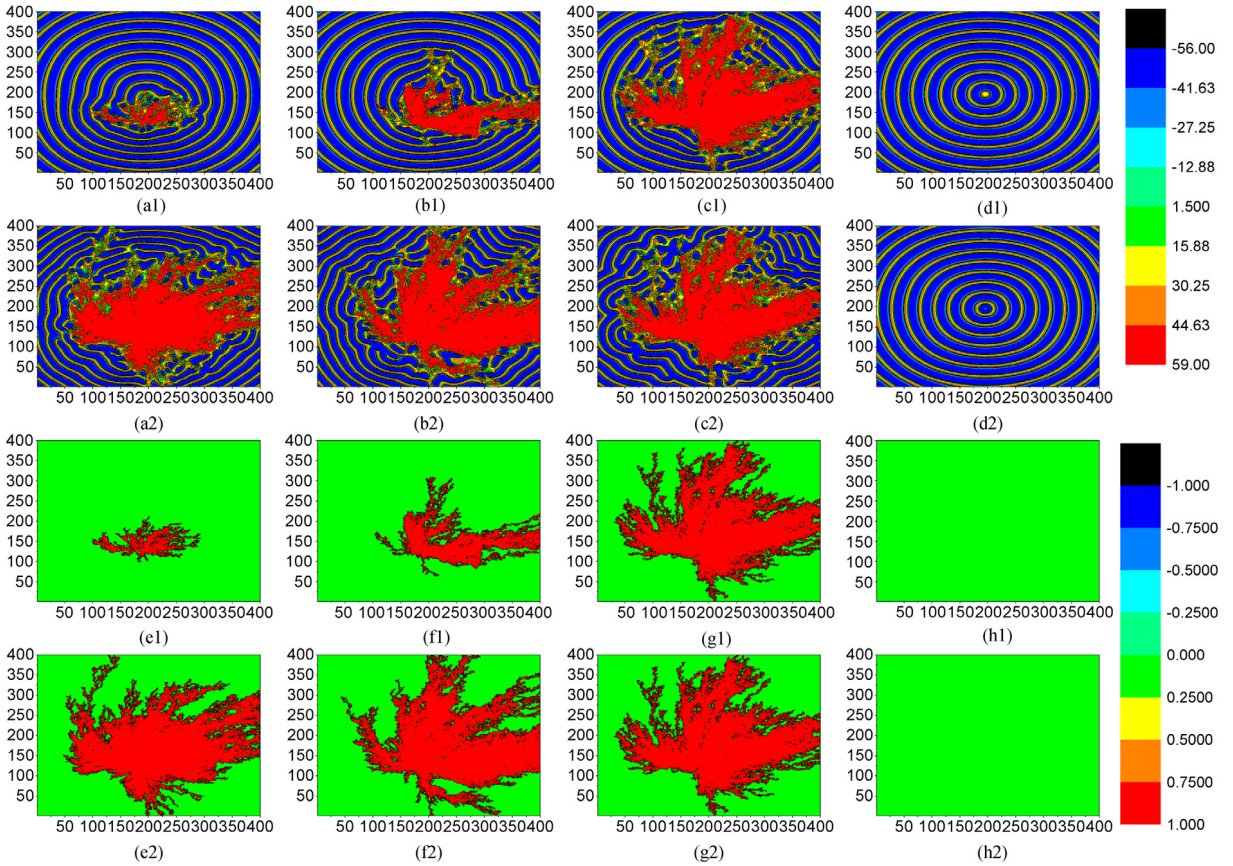


**Fig. 1.** Developed spatial pattern suffered from diffusive collapse in parameter and diffusion of poisoned area under different diffusion period $\Delta t$. The first row (a1, b1, c1, d1) and the second row (a2, b2, c2, d2) in the panel represent the developed patterns at $t = 710$, 1400 time units, respectively. The third row (e1, f1, g1, h1) and the fourth row (e2, f2, g2, h2) in the panel represent the collapse or poisoning diffusion, respectively. For the first column (a1, a2, e1, e2) $\Delta t = 0.5$; the second column (b1, b2, f1, f2) $\Delta t = 0.3$; the third column (c1, c2, g1, g2) $\Delta t = 0.15$ and the fourth column in the panel (d1, d2, h1, h2) show the state without collapse or channels poisoning.

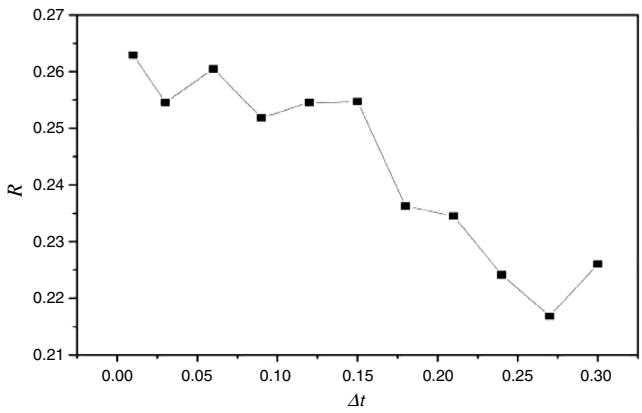


**Fig. 2.** Dependence of synchronization factor on the period of collapse diffusion $\Delta t$ (0.01–0.30).

network. Spiral wave in cortex finds its functional role as a continuous pacemaker [13–15], and it is believed that spiral wave can be developed from broken target waves [16,17]. Heterogeneity associated with diversity in parameter [18], periodical forcing, self-feedback, and autapse driving [19] in local area could be effective to develop stable target waves in the media. As a result, the collective behaviors of the media could be regulated by the pacemaker-like wave source completely. However, the ordered state or regular spatial distribution in the media can be destroyed by diffusive collapse induced by external attack or internal breakdown. For example, blocking in ion channels [20,21] can change the excitability of neurons, and then the electrical activities of neurons are changed greatly.