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Loss of synchrony in an inhibitory network of type-I oscillators

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Understanding the dynamics and synchronization of inhibitory neurons is a question of fundamental importance in neuroscience, since inhibitory networks play a crucial role in rhythmogenesis, both in invertebrate motor pattern generators [1] and in the mammalian hippocampus and neocortex [2]. Invertebrate CPGs in particular often contain simple two-cell inhibitory sub-networks that play a crucial role in the control of rhythmic motor behaviors. Therefore, characterizing the dynamics of two-cell inhibitory networks is relevant for a better understanding of the rhythmic dynamic activity produced by central pattern generators and other inhibitory circuits.

Here we describe the activity states in a network of two cells with type-I excitability coupled by reciprocal inhibition. Weak coupling analysis is very successful in the study of phase-locked activity in such a network, and predicts synchronous or anti-synchronous dynamics, depending on the time scale of inhibition and the intrinsic cell properties [3]. However, it is known that an increase in coupling strength can destabilize synchrony in many neural circuits [4]. In particular, recent work by Maran and Canavier [5] has shown that non-weak coupling leads to alternating-order firing (termed "leap-frog" spiking by G.B. Ermentrout) in an inhibitory network of two Wang-

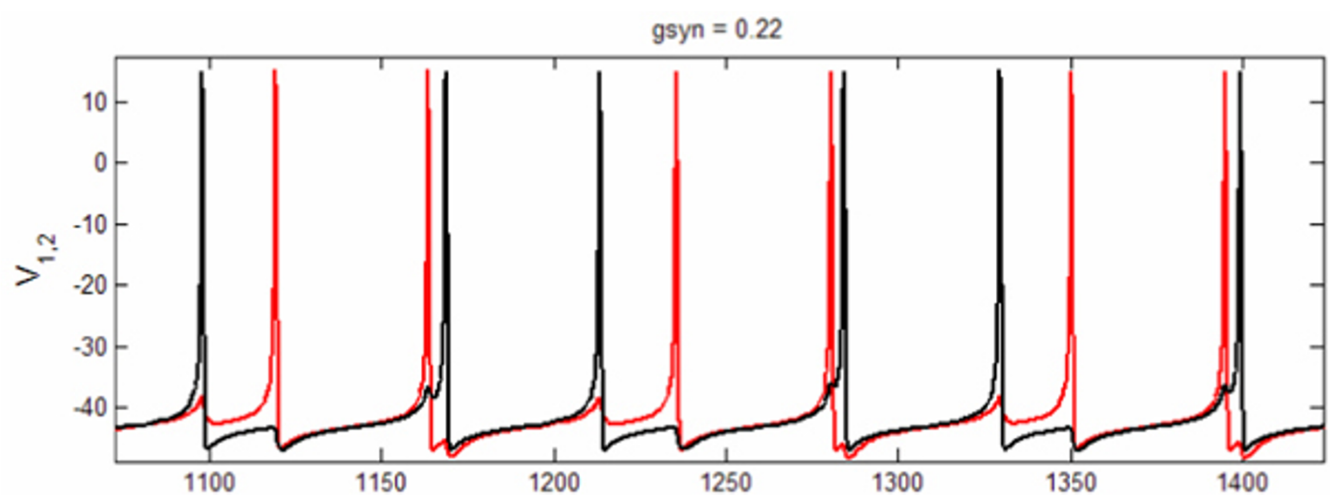

Figure 1
Alternating-order (leap-frog) activity in an inhibitory network of two Morris-Lecar cells with type-I excitability. The membrane potentials of the two model cells are shown as black and red traces, respectively.

Buzsáki model neurons, whereby the order of spiking of the two cells alternates in each cycle of the oscillation. Here we show that such activity is a generic property of an inhibitory network of oscillators of type-I excitability class. In particular, we demonstrate that leap-frog spiking can also be obtained in a two-cell network of simpler Morris-Lecar model cells, as shown in Figure 1.

We examine the phase-plane geometry of such order non-preserving dynamics, and find that it arises when the inhibition is sufficiently strong to allow a presynaptic cell to transiently suppress the postsynaptic cell below its excitability threshold (saddle-node on an invariant cycle bifurcation) in each cycle of the oscillation. Therefore, non-zero synaptic decay time is crucial for obtaining leap-frog spiking in a continuous system. However, we show that alternating-order spiking can also be obtained in an appropriately modified pulse-coupled integrate-and-fire network. Following the approach of Maran and Canavier [5], we show that the entire activity state bifurcation profile of the two-cell Morris-Lecar network can be completely characterized using the phase-resetting properties of each of the two cells, and describe the conditions on the phase resetting curve that lead to the loss of synchrony and the emergence of leap-frog spiking.

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