Mechanisms of interneuronal control of spontaneous oscillations in a full-scale parallel computer model of the CA1 network

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The CA1 region of the hippocampus displays several well-characterized oscillations, such as theta oscillations, gamma oscillations, and sharp wave-ripples, characteristic of different behavioral states and associated with different functions in learning and memory. The behavior of the various interneuron types has been found to differ across types and also across states (Varga et al., 2012; Lapray et al., 2012; Klausberger and Somogyi, 2008). The relative importance of the network and cell properties, including connectivity, intrinsic cell properties, and relative number of each cell type, in driving and maintaining these differences is unknown.

Here, we set out to quantify the roles of various properties in enabling and driving the variation across interneuron types and states, using a detailed, full-scale model of the rat CA1, run on a parallel supercomputer. Our network model exhibits spontaneous theta and gamma oscillations (Figure 1). The model includes 8 interneuron types in addition to pyramidal cells. We include biologically realistic proportions of each interneuron type, as well as realistic connectivity between each neuron type (Bezaire and Soltesz, 2013). These numbers are now available in our recent, quantitative assessment of the CA1, which systematically examines the prevalence of each interneuron type and its divergence, as well as compares the estimated convergence onto pyramidal cells and interneurons with experimentally observed input synapses on each neuron class (Bezaire and Soltesz, 2013). In addition, we employ specialized models of each interneuron type, using experimental data to constrain their intrinsic properties and synaptic connections with other neuron types. We highlight the different environments experienced by each type of model interneuron to make experimentally testable predictions about the mechanisms by which interneurons achieve the variety of experimentally observed behaviors.

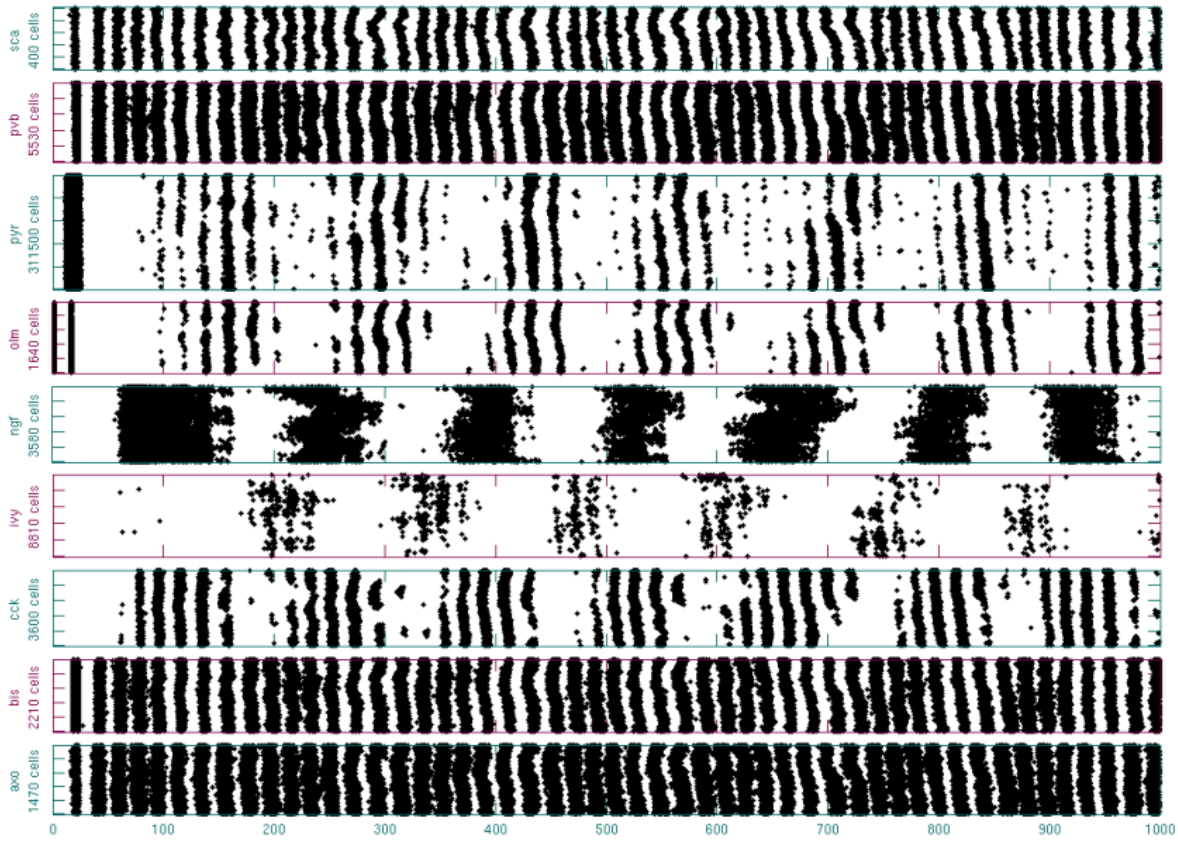

Figure 1: Full scale CA1 network model produces spontaneous theta and gamma oscillations. This spike raster plots the spike times of each neuron in the network (x-axis: simulation time, 0 – 1000 ms; y-axis: each neuron's spikes are displayed in a separate row, with neurons grouped by type; pyramidal cells are 3rd row from the top). Dominant theta frequency is 7.3 Hz, gamma is 51.7 Hz.