Sparse synchronization in networks of Excitatory and Inhibitory oscillators

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Networks of interacting excitatory (E) and inhibitory (I) neurons robustly generate fast collective oscillations (>40 Hz) [1]. Remarkably, in vivo and in vitro studies indicate that during such episodes of "E-I-based oscillations", the spiking activity of individual E cells is often highly irregular and significantly slower than the global oscillation frequency. Analytical and computational studies revealed that such synchronous states —often referred to as as “sparsely synchronized states”—, generically arise in large networks of spiking neurons with strong noise (in external inputs and/or due to sparse network connectivity) and strong inhibitory coupling [2], and are traditionally considered to be at odds (see [1]) with the classical synchronization scenarios emerging in globally coupled ensembles of self-sustained oscillators [3].

Here we implement an E-I network consisting of simple pulse-coupled phase-oscillators derived from a model of spiking neurons [4], and we show how such network is capable of generating sparsely synchronized states in conditions of sparse connectivity. Furthermore, we study how the dynamics of the ensemble change as we vary the connectivity from sparse to fully connected. Remarkably, as the network reaches all-to-all coupling, sparsely synchronized states smoothly transition into a novel type of partially synchronous states where E cells fire quasiperiodically at a slower frequency than the global oscillation [5]. Lastly, we make use of the fully connected configuration to study the exact low-dimensional dynamics of the population [6, 7], allowing us to provide a complete theoretical analysis of such partially synchronous states.

In summary, our results offer a novel theoretical perspective on the origin, nature and properties of sparsely synchronized states in E-I networks.
