We have shown how a network composed of globally connected heterogeneous neurons produces intermittent or stable chimera-like states.

Based on the isolated neuron dynamics, we infer how aspects from the individual dynamics like the difference in natural frequencies, bifurcation, and bistability promote the states of synchronization observed in the network’s dynamics.

The allocation of heterogeneity around the bifurcation promotes the bi-stable configuration with coexistence of chimera-like and unsynchronized states because neurons from one side of the bifurcation have different propensity to synchronize than from the other.

As the stability of each state depends on the synaptic current features, setups that present certain degree of dispersion in the input signal neurons receive enable intermittent ejections from one state to the other (the intermittent dynamics).

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References

The Network of non-identical Izhikevich Neurons

The Izhikevich neuronal model can reproduce several neuronal dynamical features [4]. Spikes are fast increase and subsequent decrease of membrane potential, while sequence of fast membrane potential spikes are known as bursts [5]. Here we study a complete connected network of Izhikevich neurons with distinct parameters uniformly distributed around a bifurcation, which is demarcated by the number of spikes in each burst of the periodic dynamics.

Fig. 2: Inter-Spike Interval (ISI) and Inter-Burst Interval (IBI) of a single izhikevich neuron varying the parameter α through the bifurcation value α0.

Neuron dynamics for α < α0

Fig. 1: Dynamics of the uncoupled neuron, for (a) a neuron before the bifurcation: (b-c) a neuron in the bifurcation (each from one basin of attraction for the bistable dynamics) and (d) a neuron after the bifurcation.

Intermittent Transitions to Chimera Patterns of Synchronization

For the complex system to remain in a bi-stable configuration, the synaptic current of the unsynchronized state has to force the neurons with a low amplitude signal in contrast with high amplitude forcing signal of the synchronized state. In this way the desynchronized state requires the heterogeneity to not be suppressed by the collective dynamics, while the synchronized one requires the neurons to lose their individual dynamics over a collective one. Particularly in this model, the uniformity in the synaptic current is attached with the number of elements that compound the network, due to the mean field approximation used for the global connection. Therefore the parameter distribution provides the background for the neurons to perform more than one state of synchronization, and the features of the synaptic current enable neurons to match frequencies or to retain their distinct natural frequencies.

Fig. 6: Mean field of the network for the two states of synchronization, its uniformization indicates how the stability of the two states originates.

Fig. 7: Time evolution of the network order for a configuration with intermittent transitions. We show the Kuramoto order parameter in time for (a) several transitions in a larger time scale, (b) a amplification of two transitions and (c) the raster plot of one transition, the black regions demarcate bursts while white regions demarcate quiescent periods.