Two types of asynchronous activity in networks of excitatory and inhibitory spiking neurons

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Balanced networks of excitatory and inhibitory neurons are believed to play the role of fundamental units of computation in the cortex. Asynchronous activity in such networks constitutes the primary medium for the propagation and the processing of information. Here we show that an unstructured, sparsely connected network of integrate-and-fire neurons can display two fundamentally different types of asynchronous activity. For weak synaptic couplings, the network at rest is in the well-studied, classical asynchronous state in which individual neurons fire irregularly at constant rates. For strong couplings, we find that the network at rest displays a novel type of heterogeneous asynchronous activity, in which the firing rates of individual neurons fluctuate strongly in time and across neurons. The two types of asynchronous resting states possess vastly different computational properties. In the classical asynchronous state, temporally varying inputs lead to a highly redundant response of different neurons that favors information transmission but strongly limits the computational capacity of the network. In the heterogeneous asynchronous state, the incoming stimulus interacts with the internal dynamics, so that the response of different neurons to the input strongly vary. This variability in the population deteriorates the transmission of information, but provides a rich substrate for non-linear processing of the stimuli as performed in decision-making and categorization.