Irregular persistent activity in a model of a local cortical network

(Francesca Barbieri)

Recent neuro-physiological experiments on monkeys (Compte et al. 2003) have reported highly irregular persistent activity during the performance of an oculomotor delayed-response task. These experiments show that during the delay period the ISI's coefficient of variation (CV) of prefrontal neurons is above 1, on average, and larger than during the fixation period, regardless of whether the cue is preferred or nonpreferred.

Previous models (Amit and Brunel 1997, Brunel 2000) of spontaneous and selective persistent activity in the cortex based on excitatory synaptic feedback do not reproduce this feature because the excitatory feedback during persistent activity brings neurons in a region of the f-I curve in which the firing is relatively independent from fluctuations and hence the CV is small.

To overcome this problem, we introduced two ingredients: (1) a high post-spike reset potential (close to threshold) , (2) a non-linear relationship between synaptic efficacy and pre-synaptic firing rate via a short-term depression (STD) mechanism.

We show that when the reset potential is close enough to the threshold, the CV-I curve has a maximum above 1 for a sub-threshold mean current. The range of the mean synaptic input values for which the CV is greater than 1 is always in the sub-threshold regime in which firing is dominated by fluctuations of the mean synaptic input. With short-term depression, synaptic efficacies saturate at a certain limiting value of the presynaptic frequency; this is turn provokes a saturation of the mean synaptic current to a neuron at the same limiting presynaptic frequency. This allows the persistent state solution to reach the region of the f-I curve which corresponds to high values of the CV.

We tested this idea both with numerical simulations and analytical techniques. For the analytical studies we used mean-field techniques, recently extended in presence of STD (Romani et al. 2006), that involves the use of the distribution of the interspikes intervals of an integrate-and-fire neuron receiving a Gaussian current in input; this permits to obtain an accurate estimate of the statistic of the postsynaptic current in presence of STD and hence to find the stationary states in a self-consistent way. We simulated a fully connected excitatory network of leaky integrate-and-fire neurons endowed with STD and we found a very good agreement with theoretical prediction for a large range of synaptic efficacies.