Transitions from tonic firing to bursting in model neurons with synaptic input and bi-directional coupling

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Tonic-bursting transitions are of high functional significance for the release of neurotransmitters and hormones and also facilitate neural synchronization which can become of particular physiological and pathophysiological relevance e.g. for Parkinson's disease or the induction of epileptic seizures.

We have investigated tonic-to-bursting bifurcations in a slightly modified model of a flexible neural pattern generator (Sosnovtseva et al. 2004). Figure 1 shows the modifications of the impulse pattern when such a neuron is subjected to an external current I_{syn}, according to an unspecific synaptic input, and when a calcium-dependent potassium current $I_{K,Ca}$ is changed, according to synaptic modulation of a specific ion channels.

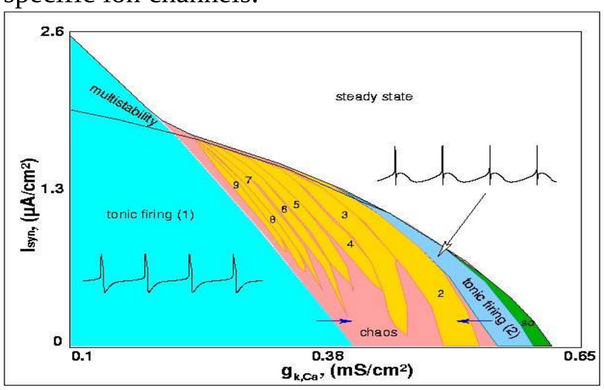

Figure1 Map of different activity patterns of a single neuron plotted as function of the calcium dependent potassium current ($g_{K,Ca}$, abscissa) and current injection (I_{syn}, ordinate): Bursting regimes (yellow, numbers indicate spikes per bursts) are surrounded by chaotic regimes (pink) and different types of tonic firing (blue, see voltage traces). SO: subthreshold oscillations; Multistability means coexistence of different regimes. Blue arrows show transitions from tonic firing regimes to bursting.

Our computer simulations demonstrate that bursting activity is surrounded by chaotic regimes and different regimes of tonic firing as well as stable membrane potential (steady state). Accordingly, different routes to bursting behavior can be observed, e.g. via period doubling and homoclinic or Hopf bifurcations.

Bi-directional coupling of two of such neurons can induce bursting activity where the single neurons show tonic firing but can also completely suppress spike-generation. Our data show that the activity of coupled neurons strongly depends not only on the coupling strength but also on the position in the above map, i.e. the single neuron's dynamics.

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References

Hans A. Braun, Karlheinz Voigt, Martin T. Huber: Oscillations, resonances and noise: basis of flexible neuronal pattern generation. BioSystems 71, 39-50 (2003).