A Continuous-Time Dynamical System Describing both Rate Encoding and Spiking Neurons

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Introduction

- We introduce a two-dimensional nonlinear system, modeling a wide range of dynamic properties of spiking neurons.
- By altering key parameters of this system, its dynamics become identical to those of a time-continuous rate-encoding model.
- Differences of the dynamical properties of single units as well as of network structures under these two regimes can be treated within the same mathematical framework.

Neuron Model

A two-dimensional non-linear system given by

$$\tau_x \dot{x} = f(x) - y \qquad f(x) = s\sigma\left(a\left(x - s/4\right)\right)$$
$$\tau_y \dot{y} = g(x) - y \qquad g(x) = g_0\sigma\left(a_g\left(x - I\right)\right) - \Delta_y$$
$$\sigma(x) = \left(1 + \exp(-x)\right)^{-1}$$

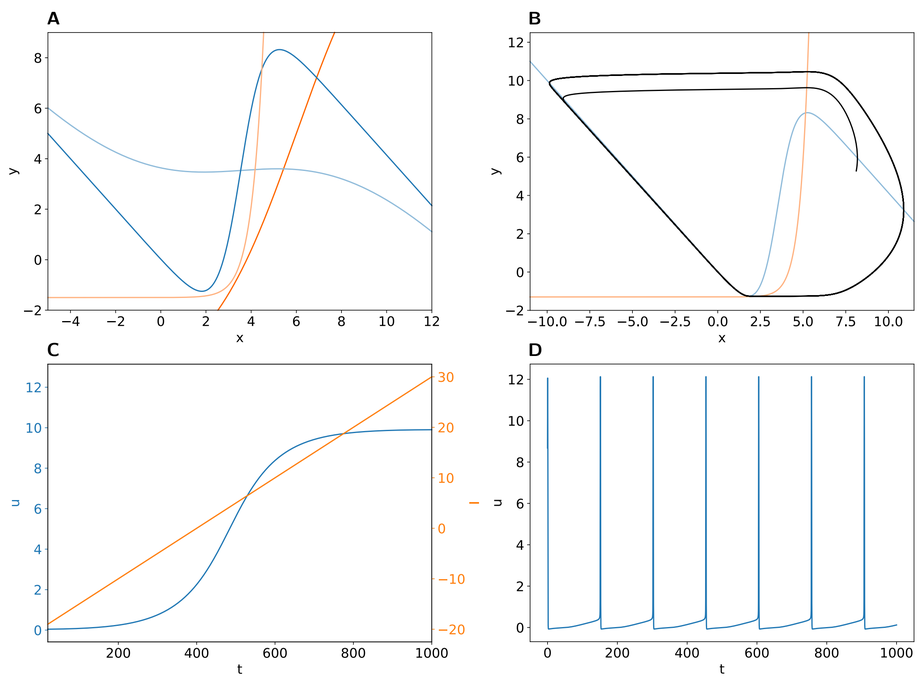

Figure 1: A: x/y-nullclines (blue/red) of the dynamical system for parameter sets generating spiking/non spiking behavior. B: Phase plane trajectory for the spiking dynamics. C/D: Dynamics of readout variable u for the spiking/non-spiking case.