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Firing patterns in model networks of hippocampal persistent firing neurons

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Motivation

- Persistent firing has long been thought to be the neural mechanism underlying short-term memory encoding and storage [1]
- We analyse the dynamics of networks of persistent firing hippocampal neurons
- We hypothesise that these circuits could contribute to the emergence of theta oscillations in the hippocampus

Neuron Model

- Neuron Model [4]:
  \[ \frac{dV}{dt} = -I_{syn} - I_{K} - I_{M} - I_{C} - I_{CAN} - I_{REM} \]
- Hodgkin-Huxley and M Currents:
  \[ I_{syn} = f(V_{m}, \theta) \]
  \[ I_{K} = f(V_{m}, m^2) \]
  \[ I_{M} = f(V_{m}, \theta^2) \]
  \[ I_{C} = f(V_{m}, m) \]
- Excitatory Postsynaptic Current:
  \[ I_{CAN} = -g_C (V_{m} - E_{C}) \]

Calcium Dynamics

- Calcium Dynamics:
  \[ \frac{d[Ca^{2+}]}{dt} = \gamma(I_{Ca}) \frac{[Ca^{2+}]_{o}}{[Ca^{2+}]_{i}} \]

Fitting Model to In-Vitro Data

The persistent firing frequency is modulated by the activation of CAN receptors in the model (right) in accordance with in vitro recordings [5] (448)

Results

Results – Network Firing Regimes

Results – CAN-Mediated Theta Oscillations

The CAN current activation allows in vitro cells to display persistent firing in biophysiologically plausible frequency bands. Conversely, a pyramidal network without CAN current (bottom line) does not display such a rich firing regime.

Conclusion

- Networks of CAN-equipped neurons display a rich array of firing regimes
- Self-sustained theta oscillations emerge from the interaction between CAN-mediated persistent firing and synaptic activity

References