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Using a Population Rate Model of the CA1 Hippocampus to examine cell-type specific contributions to theta-gamma coupled rhythms

The rodent hippocampus is an extensively studied brain region expressing well-defined rhythmic activities with functional and behavioural correlates. The co-expression of theta (3-12 Hz) and gamma (20-100 Hz) rhythms may represent a general coding scheme and particular changes in these coupled rhythms occur in disease states.

We develop a population rate model of the CA1 hippocampus that combines excitatory pyramidal cells and three distinct inhibitory cell types (bistratified cells, PV-expressing and CCK-expressing basket cells), that were found to be essential for theta-gamma coupled rhythms. We use a combination of theoretical and numerical analyses to examine specific contributions by cell types and subcircuits.

We find CCK-expressing basket cells initiate coupled rhythms and regularise theta; PV-expressing basket cells enhance both theta and gamma rhythms; pyramidal and bistratified cells govern the generation of theta rhythms, and PV-expressing basket and pyramidal cells play dominant roles in controlling theta frequencies. We use these insights to predict a two-stage process by which theta-gamma coupled oscillations may arise in generalisable circuit motifs of excitatory and inhibitory cell types.