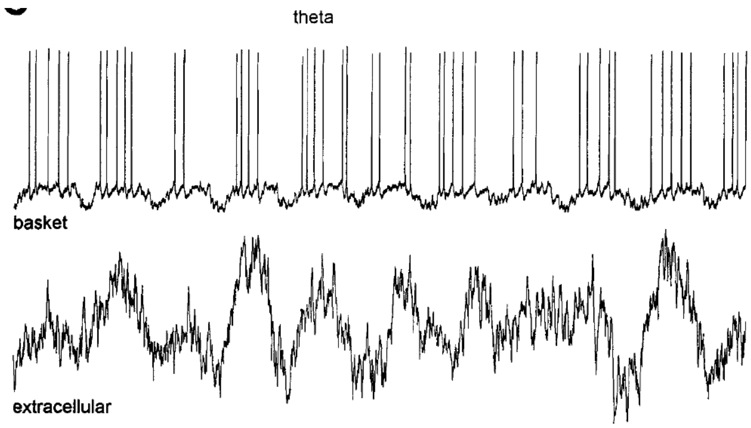
Synchrony



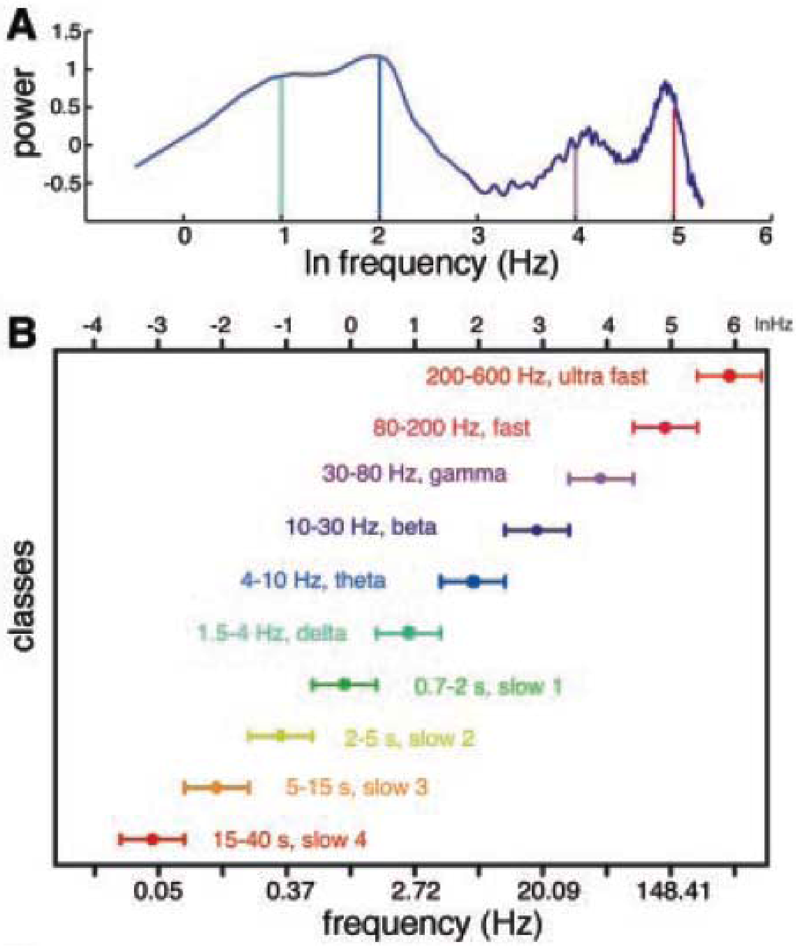
Rhythmic firing (30-80Hz, *gamma*) and silence (4-8Hz, *theta*) in basket cell (hippocampus) [Buzsaki 95].

Rhythmic activity is common in hippocampus and neocortex

Rhythms are nested: slower ones modulate faster ones

Basket-cell network synchronizes in the gamma band

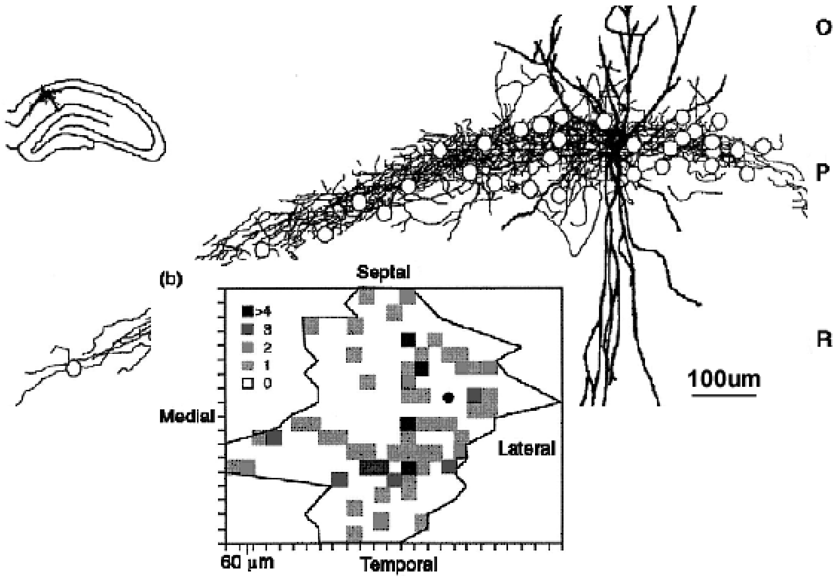
Brain rhythms



A, Spectrum of hippocampal EEG shows peaks. **B**, Frequency peaks in rat cortex. [Buzsaki 04].

3 of 10

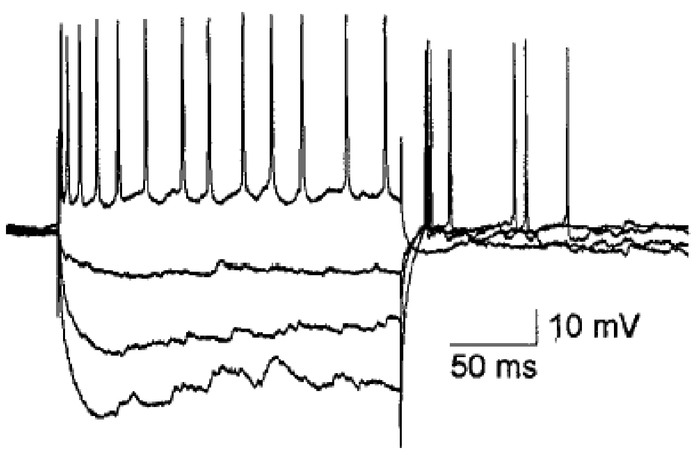
Basket cells in hippocampus



Basket cells (parvalbumin +ve) make connections (circles) to other basket cells locally [Buzsaki 95].

4 of 10

Basket cell electrophysiology



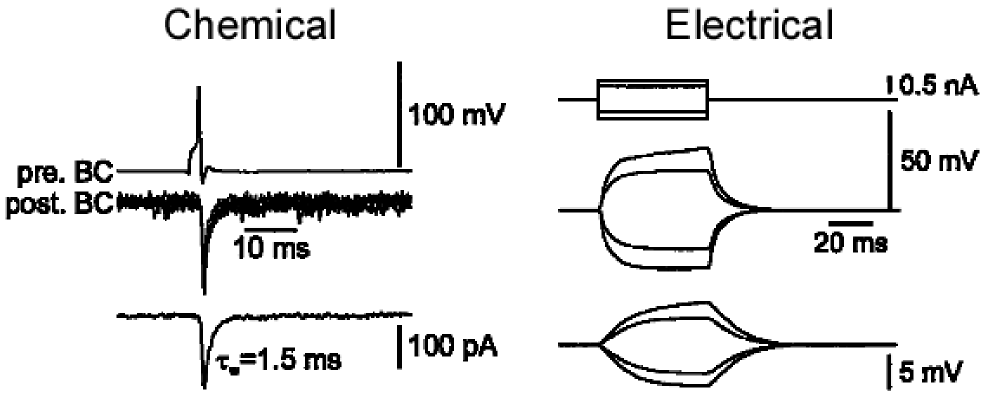
Basket cells show frequency adaptation and rebound spikes [Buzsaki 95]

For gamma synchrony, we model basket cell with positive-feedback neuron plus M-current.

It's reasonable to ignore the rebound current; it requires prolonged hyperpolarization (theta inhibition).

5 of 10

Synaptic physiology



Hippocampal BCs are chemically ($GABA_A$) and electrically (gap junctions) coupled [Jonas 02]

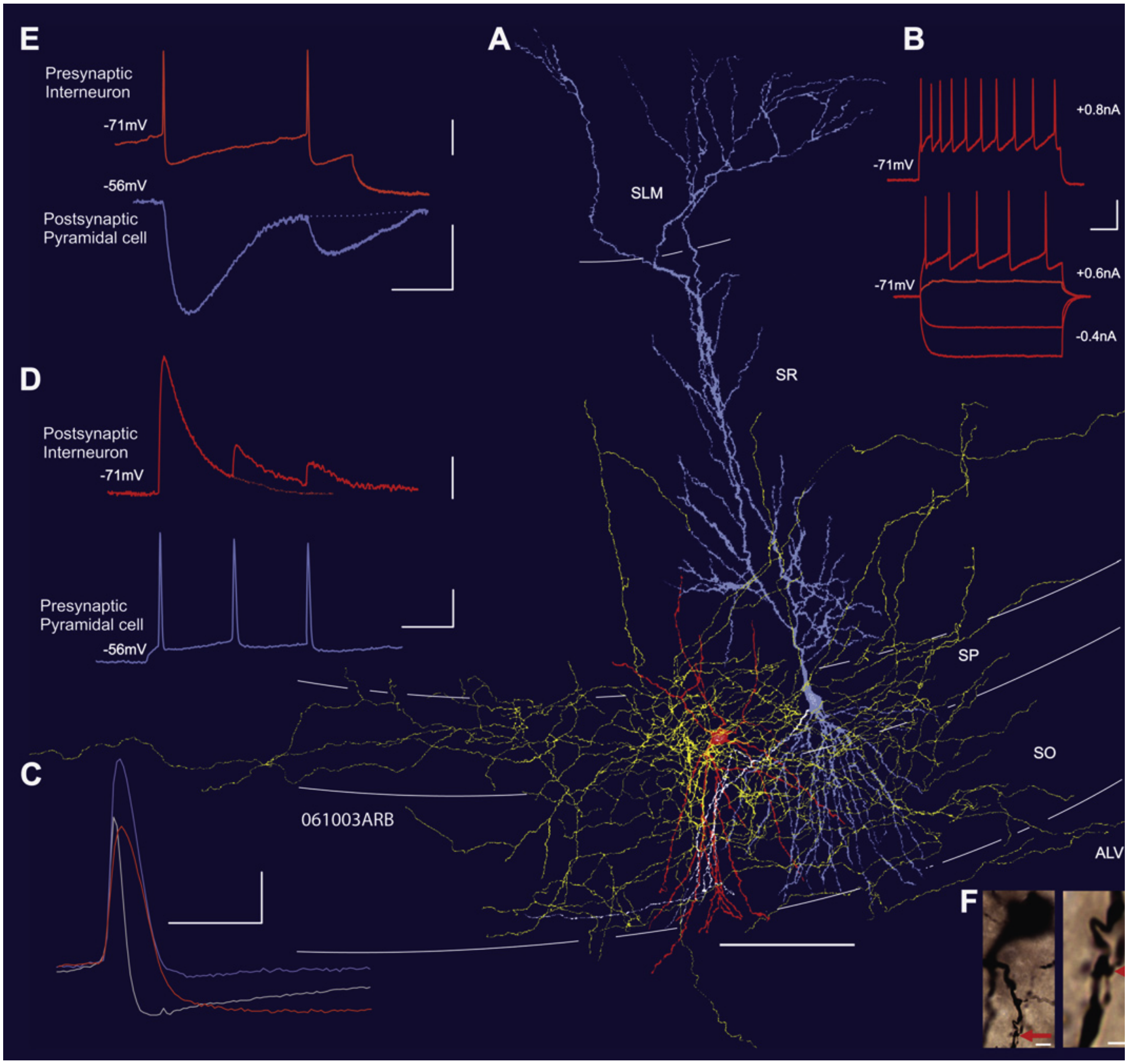
Post-synaptic currents rise fast ($\tau = 0.16$ms) and decay rapidly ($\tau = 1.2$ to 2.5ms; slower in pyramidal cells).

Delay arises from axonal conduction (0.25m/s) and synaptic latency (0.5ms).

Nearby basket-cells are coupled by gap-junctions; coupling ratio is 0.1 (fraction of voltage).

We use rise-time as a surrogate for delay and ignore electrical coupling.

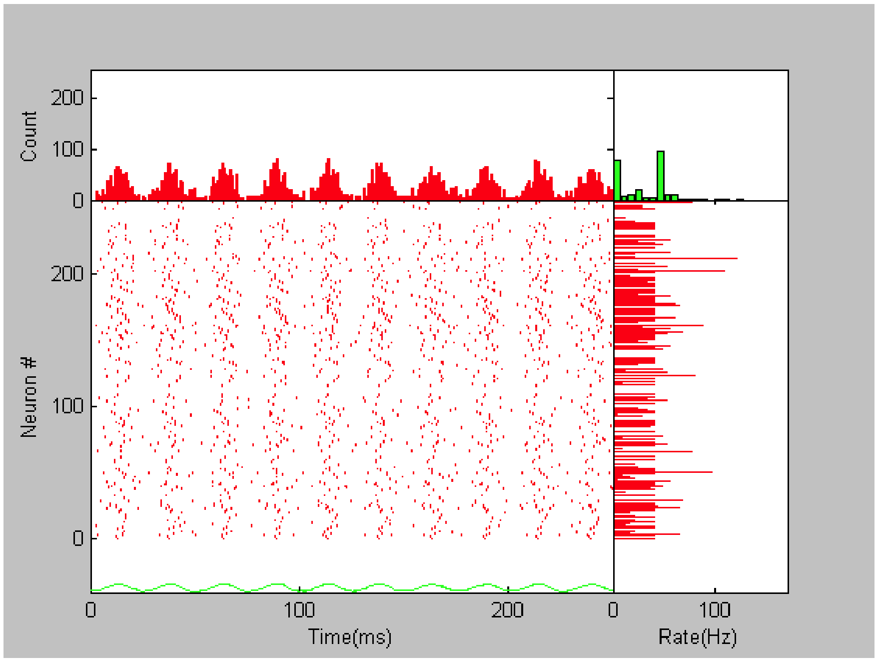
Ivy Cells



A Ivy cell (soma/dendrites in orange, axon in yellow) and the pyramidal cell (soma/dendrites in light blue, axon in white) (100um). **B** Responses of the Ivy cell to injected current pulses (20mV,40ms). **C** Action potentials in the pyramidal (mauve), Ivy (orange), and a bistratified cells (gray) (20mV,2ms). **D** Composite averages of excitatory postsynaptic potentials (EPSPs) elicited by pyramidal cell in Ivy cell (2mV,20mV,20ms) and **E** inhibitory postsynaptic potentials (IPSPs) elicited by Ivy cell in pyramidal cell (20mV,1mV,50ms). **F** Putative synaptic input from pyramidal cell to interneuron (red arrows) [Klausberger08].

7 of 10

Interneuron network model: Mutual Inhibition



Interneurons synchronize in gamma band.

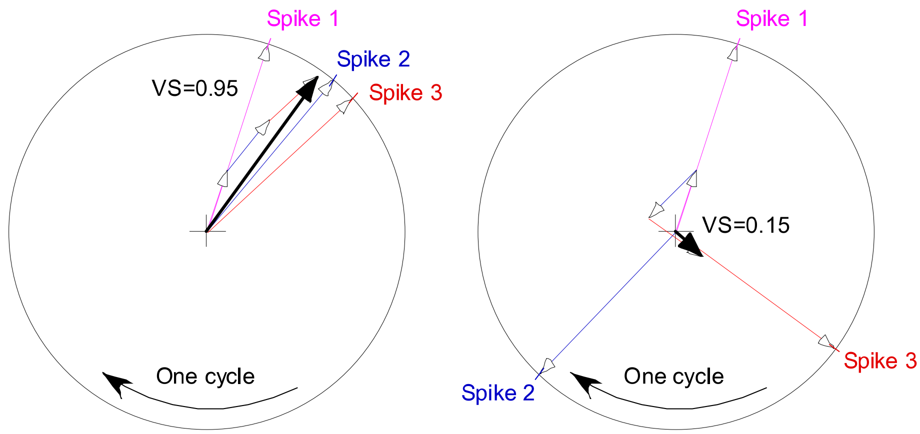
About half of the neurons are silenced; these are the least excitable neurons.

The rest fire once per cycle, except for a few that skip cycles or fire twice per cycle.

Spike-rates have a CV (standard-deviation/mean) of 0.24 when the neurons are unconnected.

This variability is introduced by fabrication process.

Quantifying synchrony: Vector strength



Each spike is assigned a vector by mapping the period onto a circle

Each spike is represented by a unit-length vector:

$$\vec{U}_i = (\mathrm{Cos}[\theta_i], \mathrm{Sin}[\theta_i]) \quad \text{where} \quad \theta_i = 2\pi \left(\frac{t_i \bmod T}{T}\right)$$

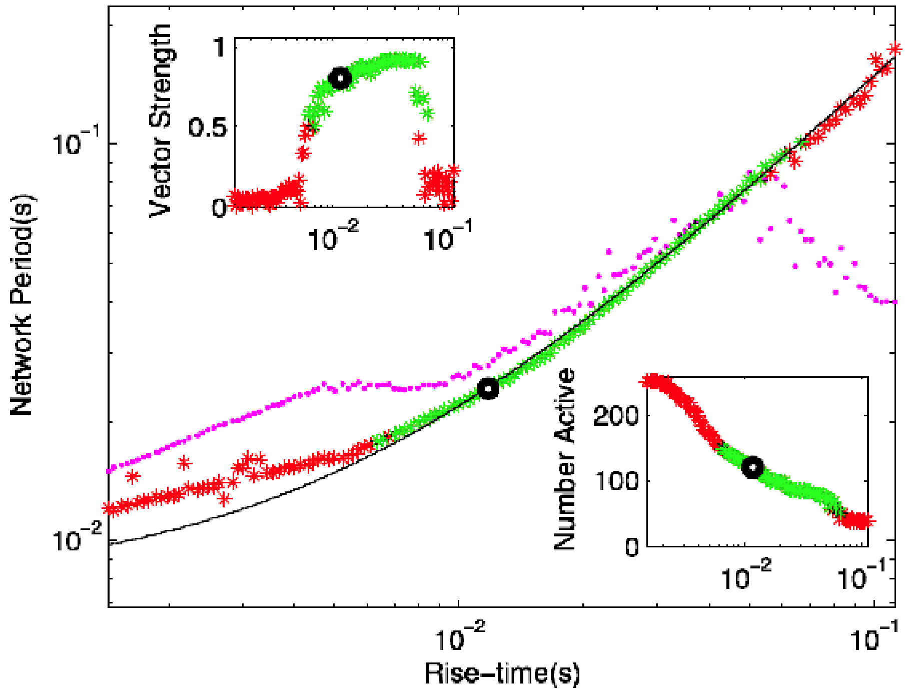
t_i is the spike-time; T is the rhythms period. The normalized vector sum

$$\vec{V} = \frac{1}{N}\sum_{i=1}^{N} \vec{U}_i$$

is computed: Its magnitude ranges from 0 (independent spiking) to 1 (coincident spiking).

9 of 10

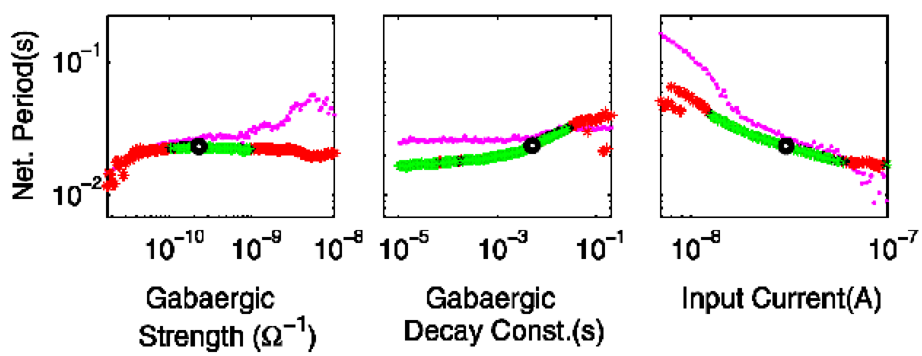
Synaptic rise-time determines rhythms period



Period is proportional to rise-time (linear fit includes offset); *purple*–mean interneuron period

10 of 10

Strength, decay-constant and excitation modulate period



The other parameters hardly change the period