# *Slow-frequency oscillations of synaptic activity in the neocortex*

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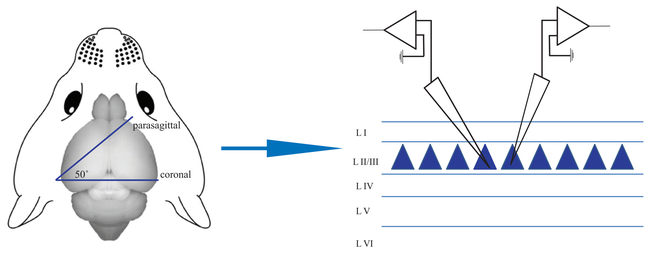
## *Introduction*

The recurrent connectivity of the neocortex endows it with the remarkable ability to generate and maintain ongoing activity even in the absence of sensory drive. This activity percolates through both the excitatory and inhibitory circuits, manifests as **excitatory or inhibitory postsynaptic currents (EPSCs/IPSCs)** and influences the voltage trajectory of the neuronal membrane. Previous work on ongoing cortical activity has mostly focused on the generation of rhythmic UP/DOWN states, which are characterized by a substantial depolarization of the membrane driven by a high synaptic conductance [1,2]. However, little attention has been given to the presence of low-conductance ongoing synaptic activity. Here we explore the spatiotemporal structure of these postsynaptic currents using whole cell recordings in the voltage-clamp configuration in mouse cortical slices.




## *Methods*

We used single and dual patch-clamp recordings in the voltage-clamp configuration to record excitatory and inhibitory post-synaptic currents in layer 2/3 **pyramidal cells (PC)** and **somatostatin-positive interneurons (IN)** from acute coronal and thalamocortical slices of mouse somatosensory cortex. Thalamocortical slices were prepared in accord with a previously established protocol [3]. EPSCs and IPSCs were disentangled by biasing the membrane potential to the reversal potential for IPSCs and EPSCs, respectively. Events were mean-subtracted and low-pass filtered before passing for further analysis. Time-resolved autocorrelation analysis was performed for single-cell recordings, while pairs of neurons (PC-PC) were subjected cross-correlation analysis.

## *Results*

### 1. Layer 2/3 pyramidal cells and somatostatin-positive interneurons receive barrages of spontaneous excitatory and inhibitory synaptic inputs *in vitro*

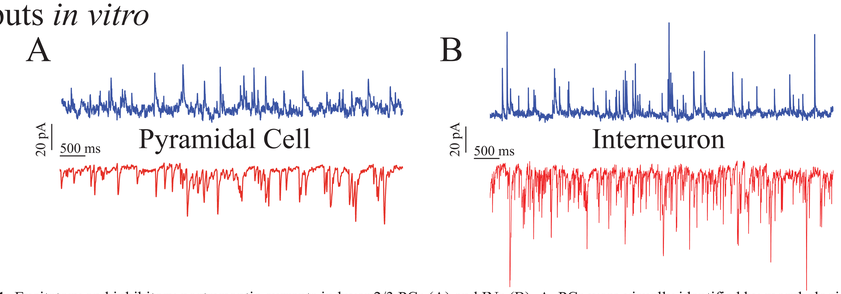



**Figure 1:** Excitatory and inhibitory postsynaptic currents in layer 2/3 PCs (A) and INs (B). **A.** PCs were visually identified by morphological criteria and sampled at random from the layer 2/3 neuronal population. EPSCs (red) were recorded at the reversal potential for IPSCs ($E_{IPSC}$ = -82 mV), while IPSCs (blue) were recorded at the reversal potential for EPSCs ($E_{EPSC}$ = +17mv). **B.** INs experessing EGFP driven by the GAD67 promoter were identified using flourescence microscopy and sampled at random from layer 2/3. As in **A**, EPSCs were recorded at $E_{IPSC}$. IPSCs were recorded at the reversal potential for EPSCs in INs ($E_{EPSC}$ = 0 mV). All postsynaptic currents were low-pass filtered on-line using a Bessel filter at 1 kHz and band-pass filtered off-line between 0.1 and 100 Hz prior to analysis.

### 2. EPSCs and IPSCs in pyramidal cells and somatostatin-positive interneurons exhibit a slow (0.5-5 Hz) non-stationary oscillatory component

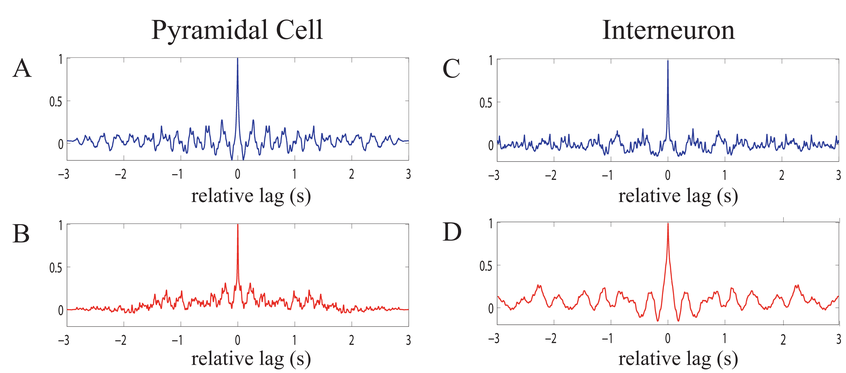



**Figure 2:** Autocorrelation analysis of EPSCs and IPSCs from layer 2/3 PCs and INs. **A,B.** Autocorrelogram for IPSCs (blue) and EPSCs (red) from PCs. **C,D.** Autocorrelogram for EPSCs and IPSCs from INs. Recorded signals were low-pass filtered before passing for auto-correlation analysis. Autocorrelograms were generated for 3-second intervals across the duration of the whole signal (60-seconds), some of which are shown here.

Poster available at: http://neurosciences.case.edu/labs/galan/publications.html

### 3. Cross-correlograms of pyramidal cell inputs are comparable in amplitude but not in frequency

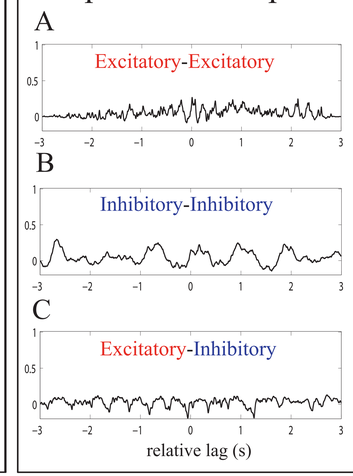



**Figure 3:** Cross-correlograms of PC inputs. PC pairs were visually identified in a focal plane of 200 μm² in layer 2/3 and selected randomly for patch-clamp recordings. **A.** Cross-correlogram of simultaneously recorded EPSCs. Note the cross-correlation between the pair has a preferred frequency of ca. 5 Hz. **B.** Cross-correlogram of simultaneously recorded IPSCs. The preferred frequency between inhibitory inputs across pairs is around 2 Hz. **C.** Cross-correlogram of simultaneously recorded EPSCs and IPSCs. Excitatory and inhibitory inputs across PC pairs shared an oscillatory component in the frequency of ca.3 Hz. Also note that although the preferred frequency across combinations of excitatory and inhibitory inputs are different, the amplitude is preserved across pairs.

### 4. Amplitude of EPSCs but not IPSCs in layer 2/3 pyramidal cells is TTX-insensitive

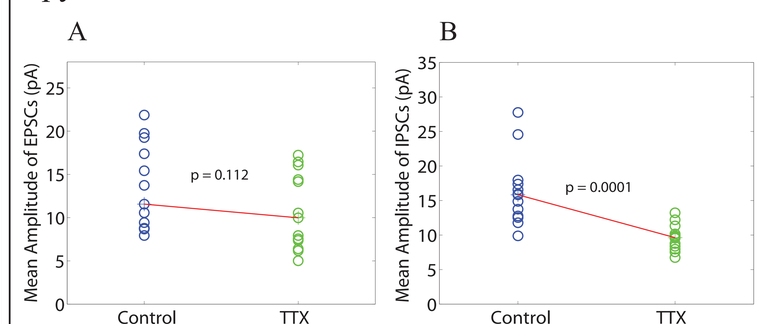



**Figure 4:** Effects of tetrodotoxin (TTX) on amplitude of EPSCs in PCs. 1 μM TTX was added to the artificial cerebrospinal fluid (ACSF) and continuously perfused throughout the duration of the recording. Recordings were carried out at least 15 minutes after addition of TTX into the perfusate. **A.** Plot of mean amplitude of EPSCs under control and TTX conditions (n = 13). **B.** Plot of mean amplitude of IPSCs under control and TTX conditions (n = 13).

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**References**

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