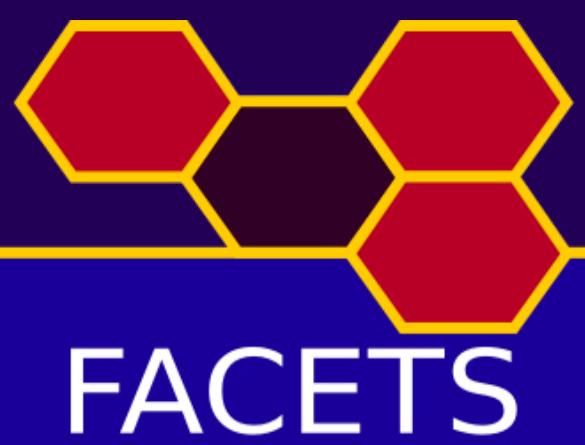


687.16 A biophysical cortical column model to study the multi-component origin of the VSD signal



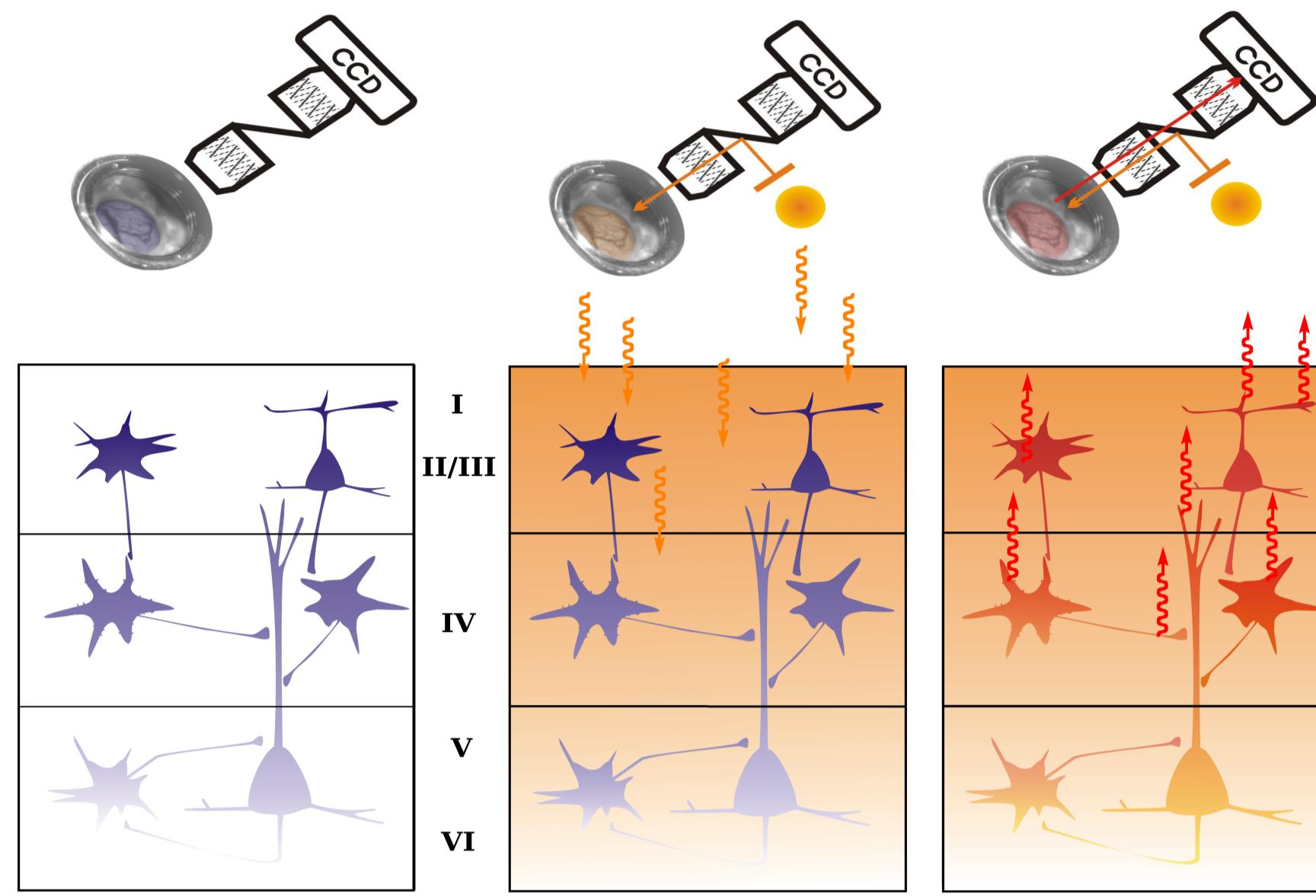
Sandrine Chemla^{1,2} and Frédéric Chavane²

(1) NeuroMathComp Project, INRIA Sophia-Antipolis

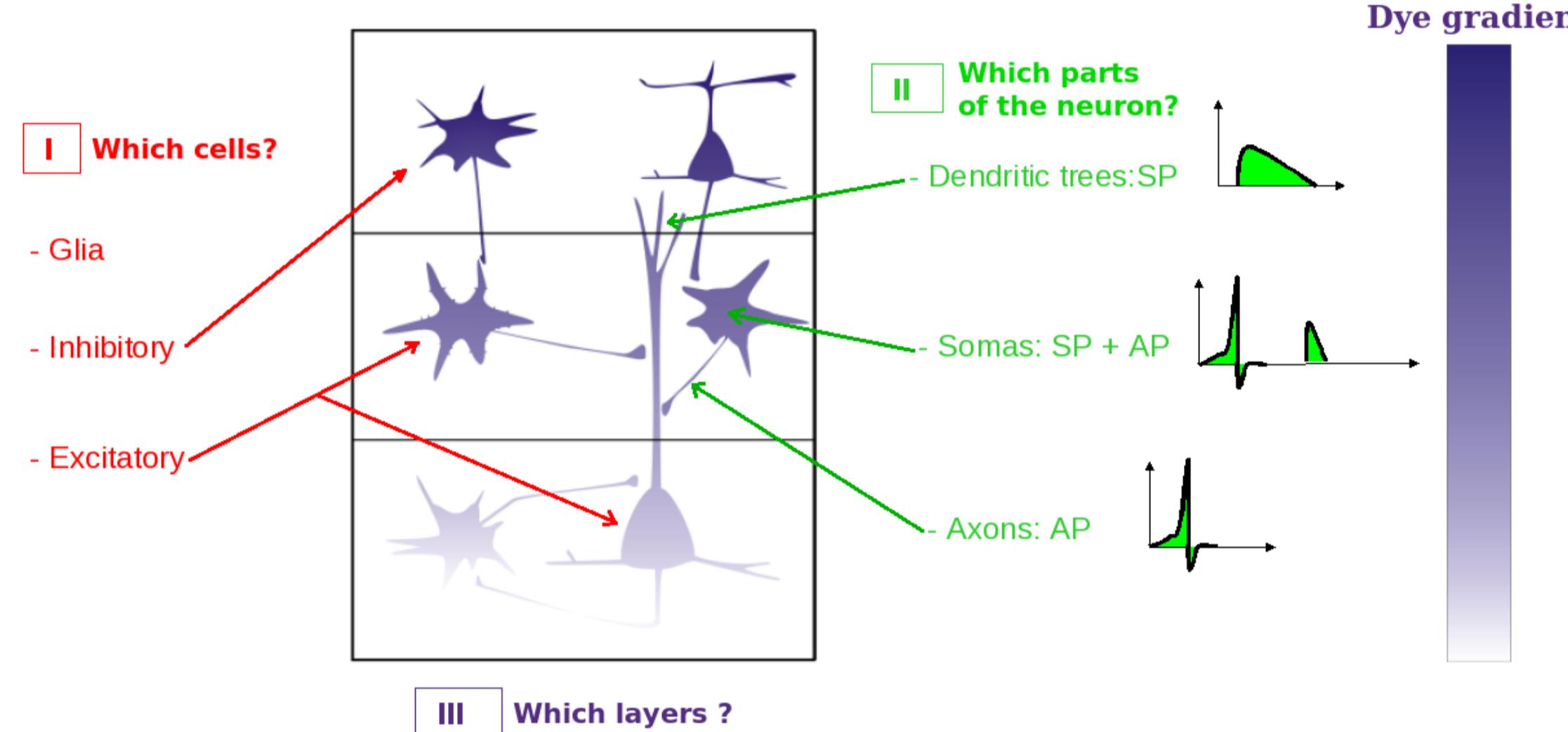
(2) DyVA Team, CNRS - INCM

We propose a biological cortical column model of voltage-sensitive dye imaging signal (VSD signal). With this model, we confirm and quantify the fact that the VSD signal is the result of an average from multiple components, with **excitatory dendritic activity of superficial layers** as the main contribution. It also suggests that **inhibitory cells, spiking activity and deep layers** are contributing differentially to the signal **dependently on time and response strength**.

Voltage-Sensitive Dye Imaging (VSDI)



The origins of the optical signal?

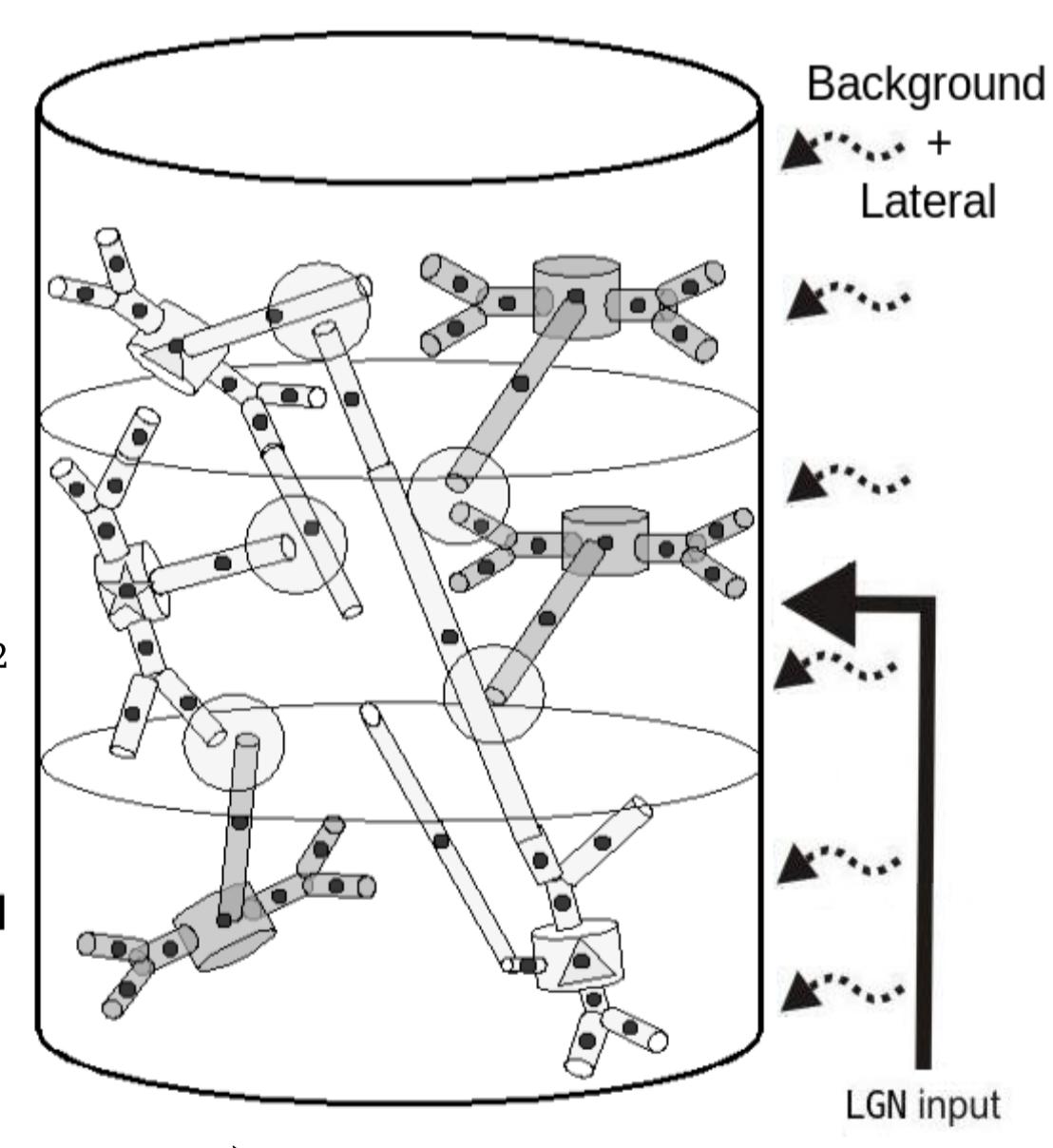


The answer is: Modelling!

Single neuron model

- Reduced **compartmental** description (soma, axon, several dendrites)

- Conductance-based **Hodgkin-Huxley** neuron model (soma, axon)



Network architecture

- Synaptic connections are made between six specific populations of neurons, according to Binzegger et al. (2004)¹

- Background activity (Destexhe et al., 2001)²

- Lateral interactions (Buzas et al., 2006)³

Simulation tools

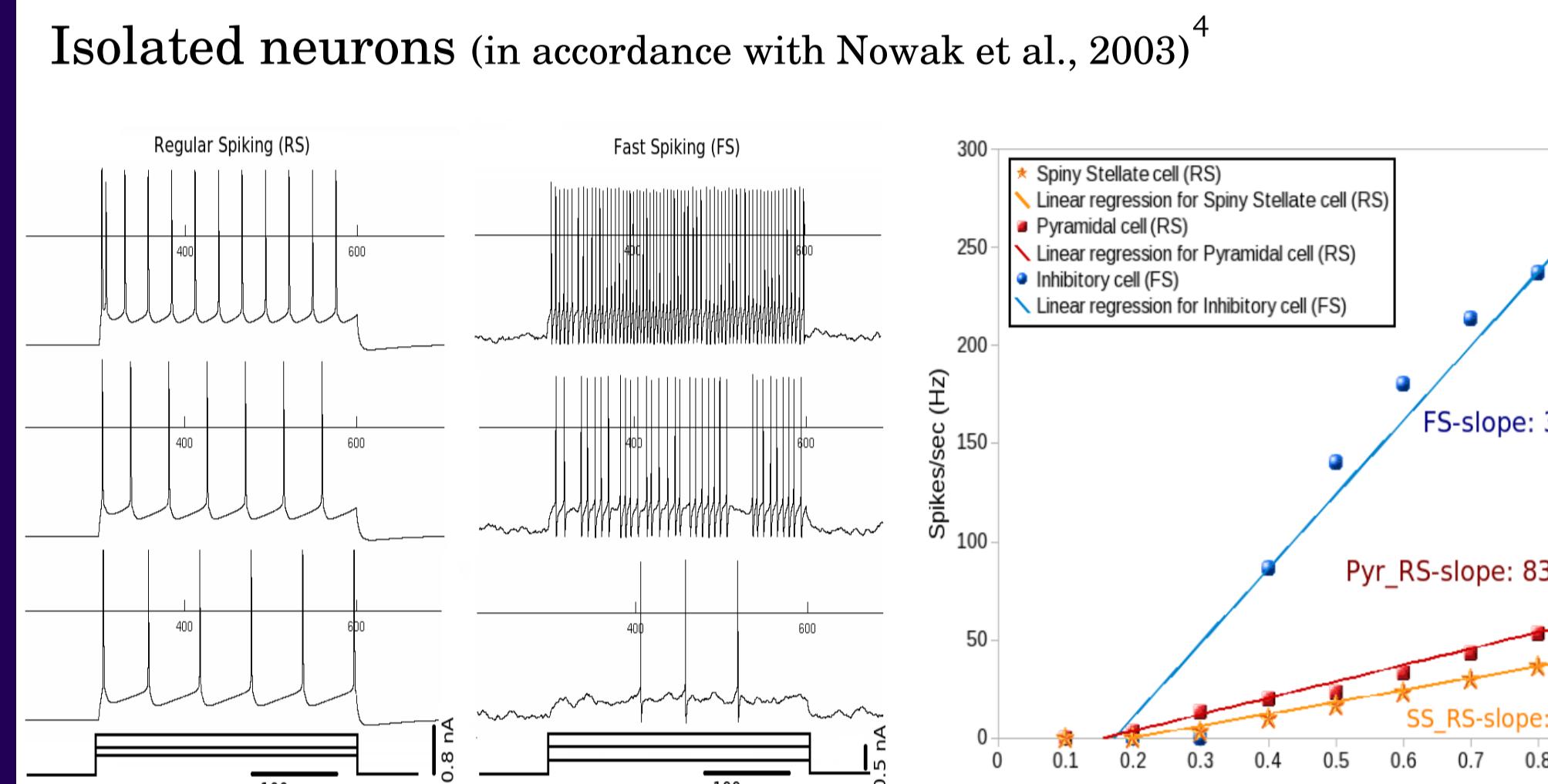
- NEURON (<http://neuron.duke.edu>)

- NEUROCONSTRUCT (<http://www.neuroConstruct.org>)

Rationale

To tease apart the **different contributions of the various compartments** introduced, one strategy is to dynamically explore one parameter that is known to affect differentially those compartments: **activity level (contrast)**. These manipulations were applied within functional regimes that are known to affect differentially excitatory and inhibitory components of the network, but also the relative contribution of membrane depolarization and spiking output.

Model behavior



Computation of the VSD signal

Linear integration on membrane surface

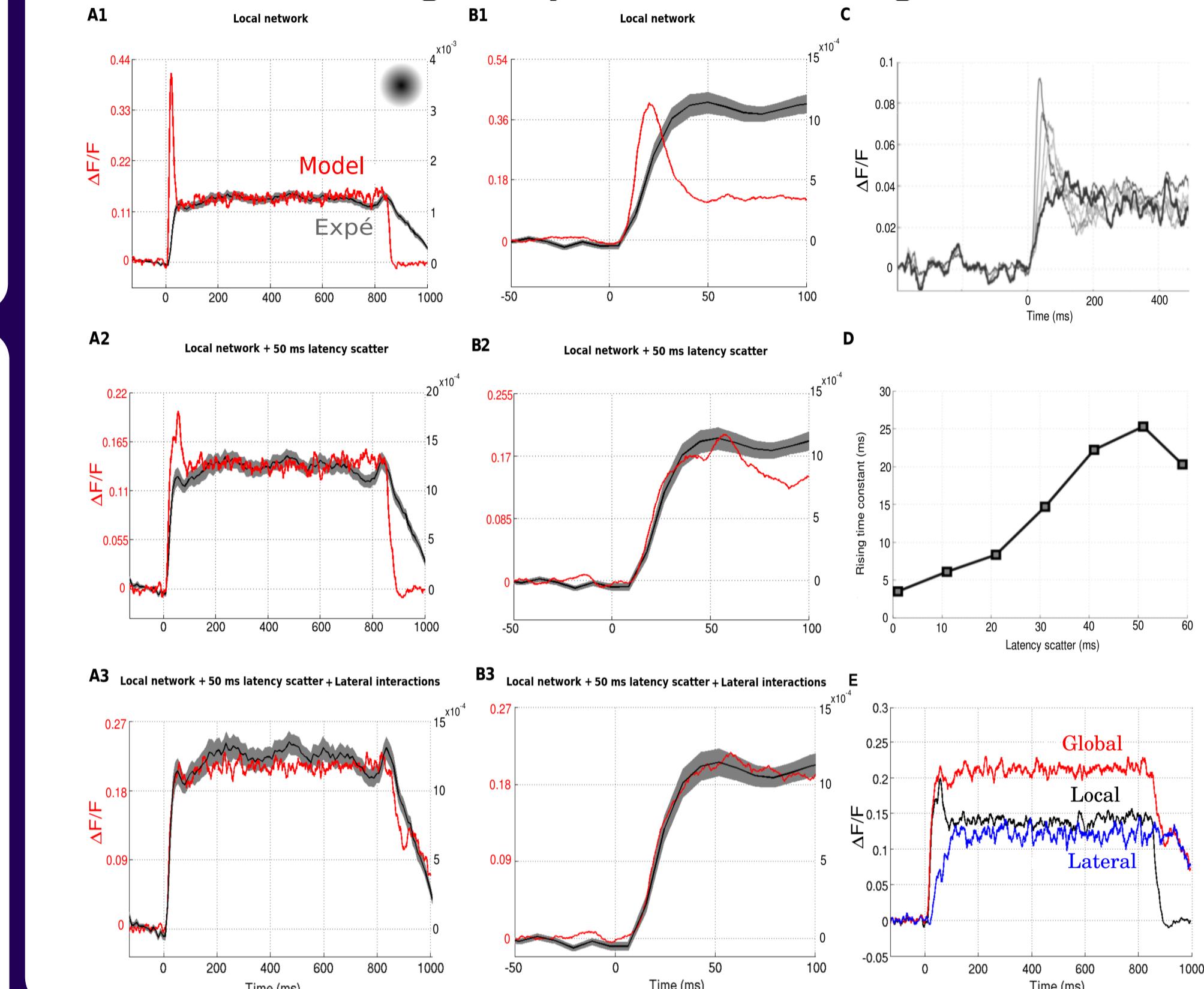
$$OI^L = \lambda^L \sum_{i=0}^{N^L} V_i(0.5) S_i \rightarrow OI = \sum_{L \in \{ \text{Layers} \}} OI^L$$

References

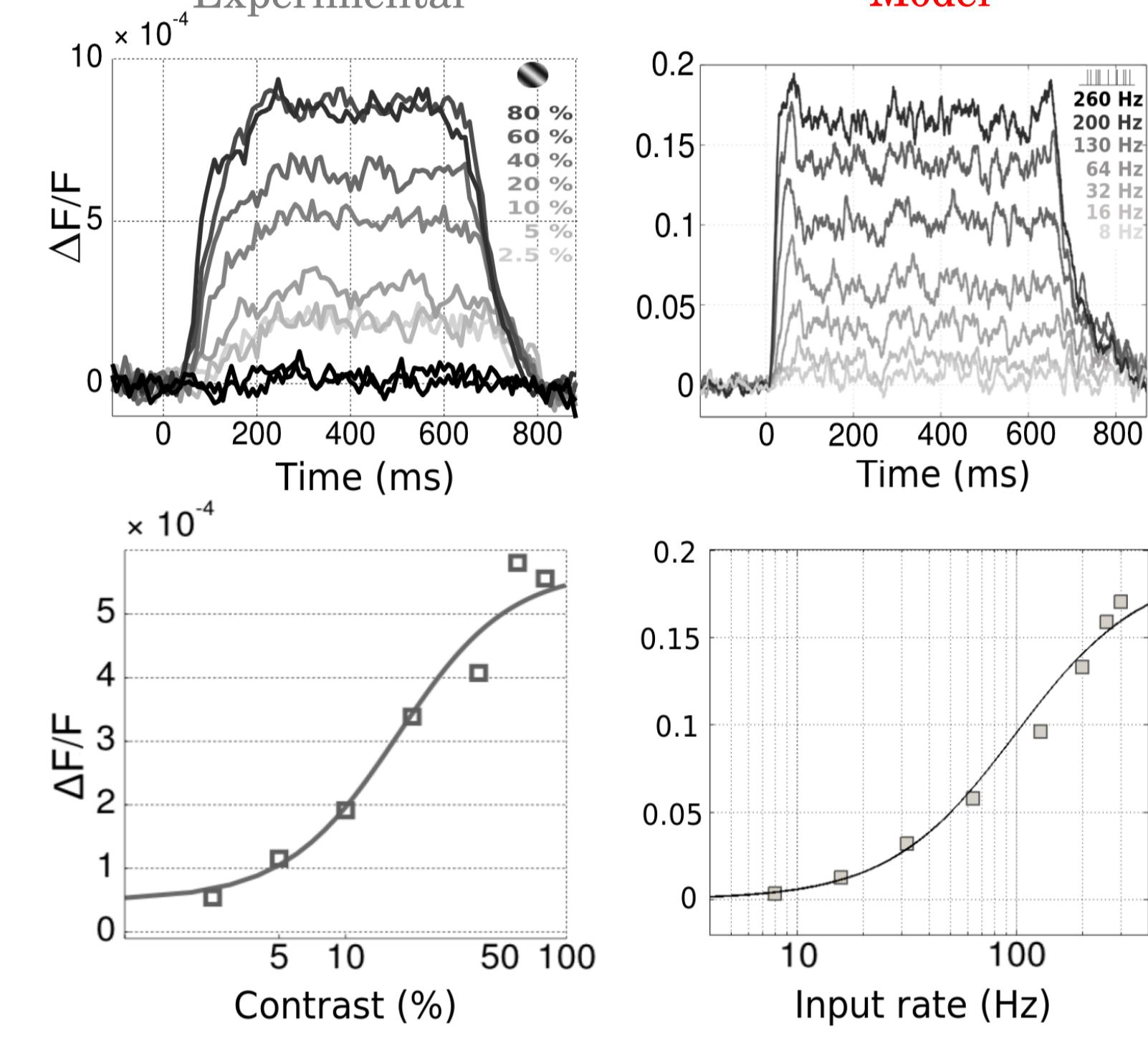
- [1] Binzegger T., Douglas R., Martin K., 2004. A quantitative map of the circuit of cat primary visual cortex. *The Journal of Neuroscience* 24(39): 8441-8453.
- [2] Destexhe A., Rudolph M., Fellous J., Sejnowski T., 2001. Fluctuating synaptic conductances recreate in-vivo-like activity in neocortical neurons. *Neuroscience* 107(1): 13-24.
- [3] Buzas P., Kovacs K., Ferecsko A.S., Budd J.M., Eysel U.T., Kisvarday Z.F., 2006. Model-based analysis of excitatory lateral connections in the visual cortex. *The Journal of Comparative Neurology* 499(6): 861-881.
- [4] Nowak L.G., Azouz R., Sanchez-Vives M.V., Gray C., McCormick D., 2003. Electrophysiological classes of cat primary visual cortical neurons in vivo as revealed by quantitative analyses. *J. Neurophysiol.* 89(3): 1541-1566.
- [5] Contreras D., Palmer L., 2003. Response to contrast of electrophysiologically defined cell classes in primary visual cortex. *The Journal of Neuroscience* 23(17): 6936-6945.
- [6] Reynaud A., Barthelemy F., Masson G., Chavane F., 2007. Input-output transformation in the visuo-oculomotor network. *Arch. Ital.Biol.* 145(3-4): 251-262.

Validation by fitting experimental data

Temporal evolution of the VSD signal:
Fitting the dynamics of VSD signal



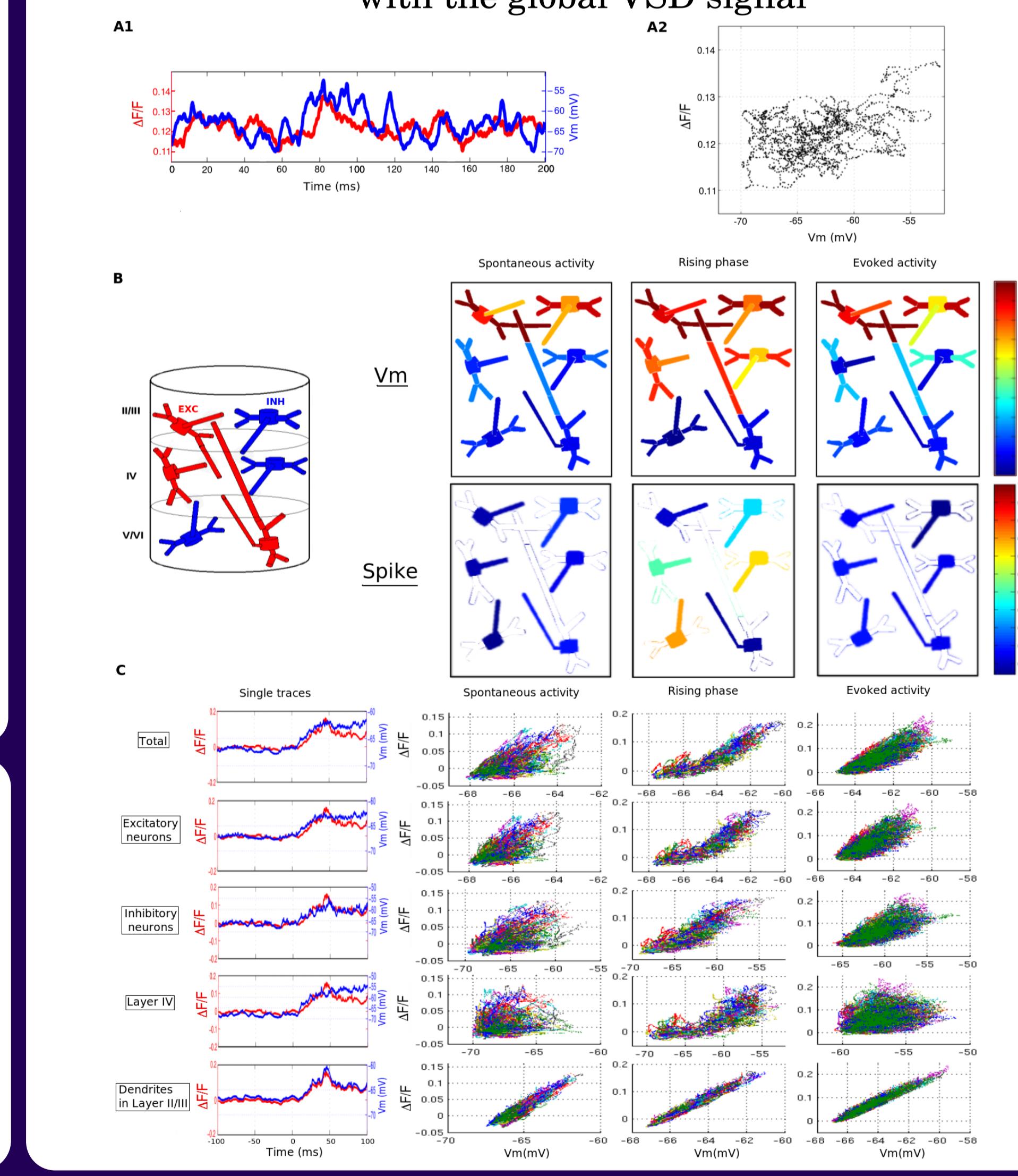
Response to increasing level of input activity:
Fitting the contrast response function of the VSD signal*



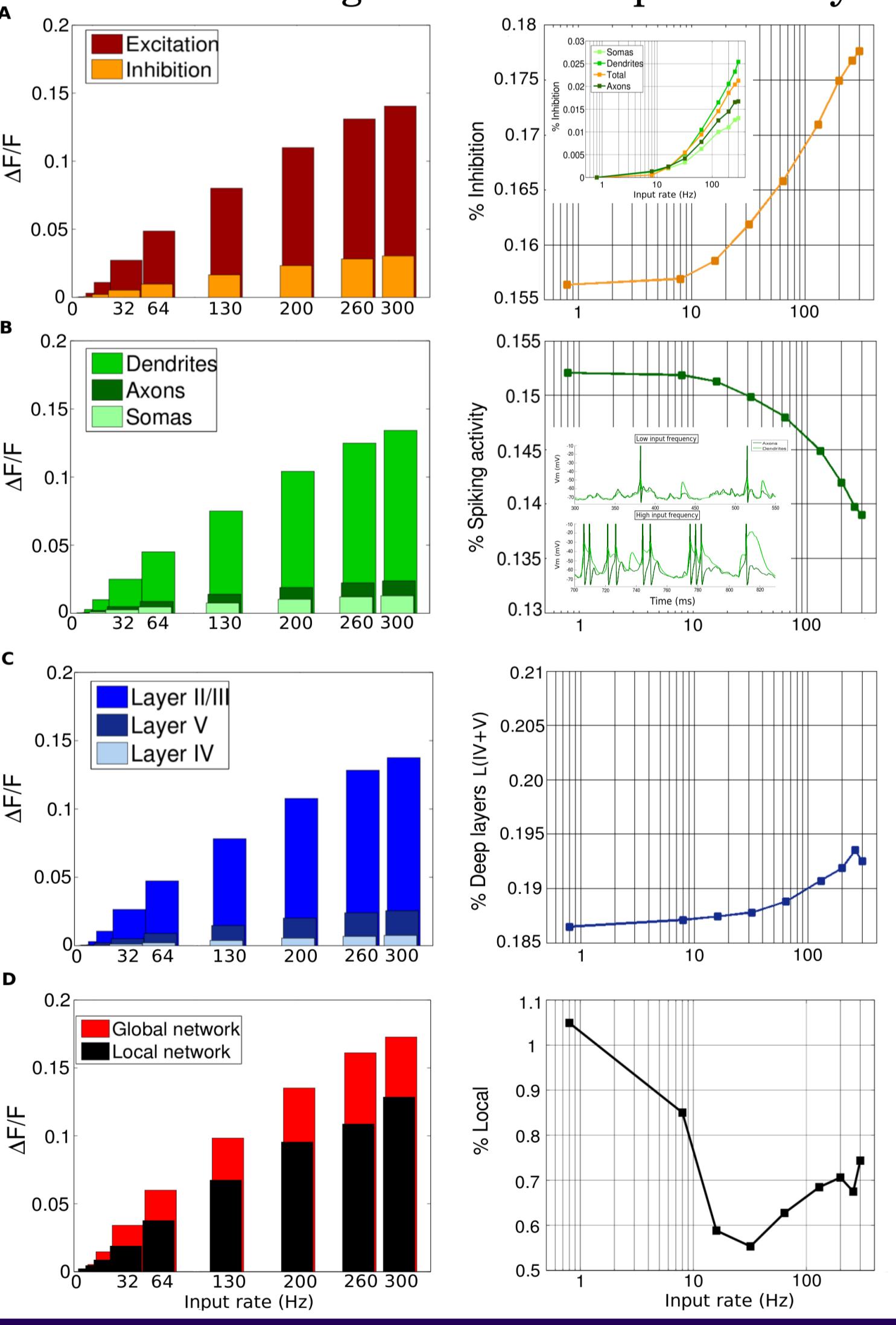
* The stimuli used in the experiment are drifting gratings while we used spike trains of increasing frequency for the model, resulting in different time courses between the modeled and the experimental responses.

Contributions of the VSD signal

Correlating the various components with the global VSD signal



Contributions of the VSD signal when increasing the level of input activity



Conclusion

The model predicts that the VSD signal has a multi-composite origin and provides an exact estimation of the relative contribution of each component (excitation 83%, inhibition 17%, synaptic activity 77%, spiking activity 14%, superficial layers 81%, deep layers 19%).

The various contributions are not only a function of contrast, but also of time, transient and sustained input having different impact on the recurrent cortical column.

Perspectives: Is reverse engineering feasible? Is the biophysical model realistic enough?