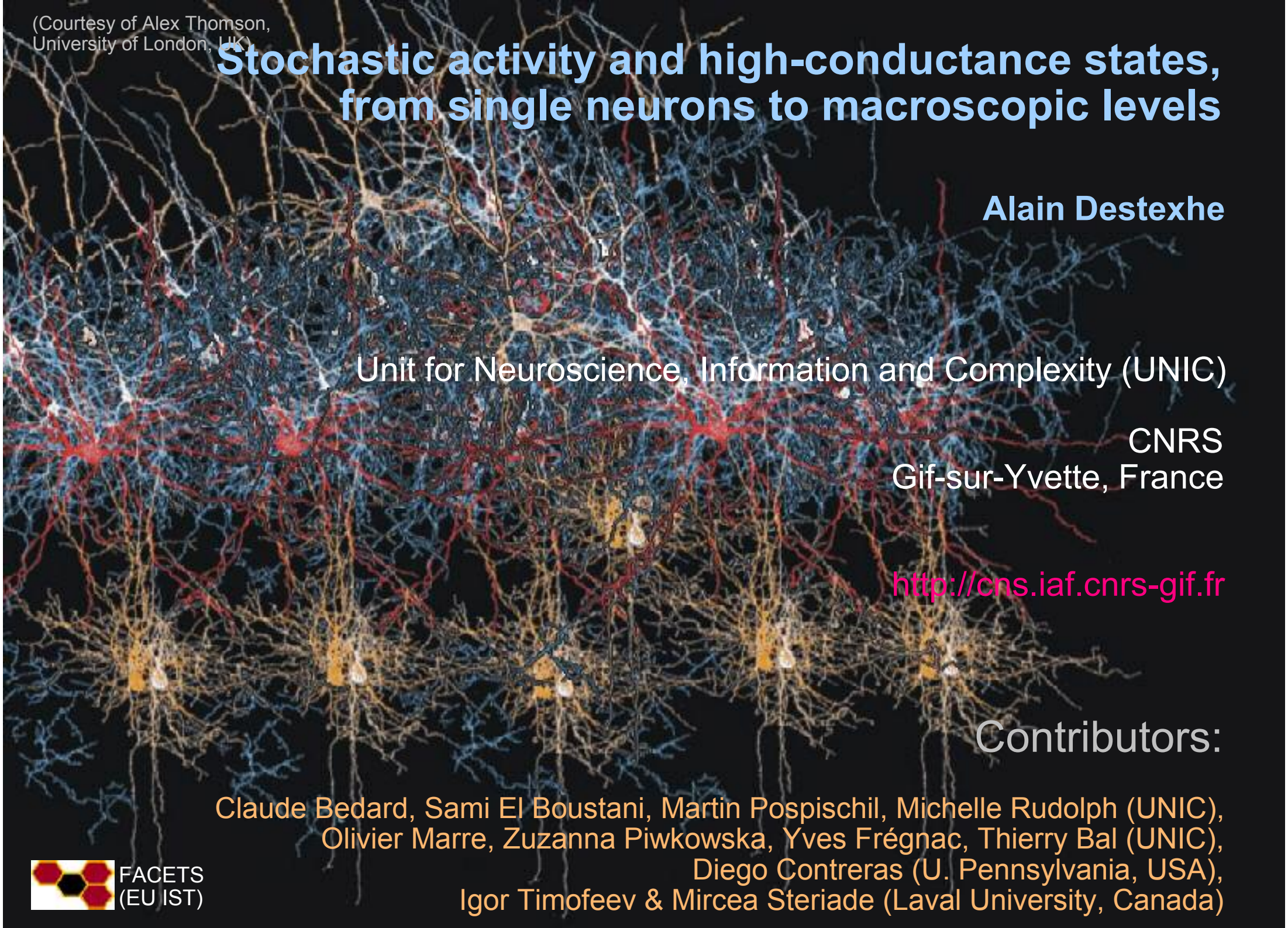


(Courtesy of Alex Thomson, University of London, UK)

Stochastic activity and high-conductance states, from single neurons to macroscopic levels

Alain Destexhe

Unit for Neuroscience, Information and Complexity (UNIC)

CNRS
Gif-sur-Yvette, France

http://cns.iaf.cnrs-gif.fr

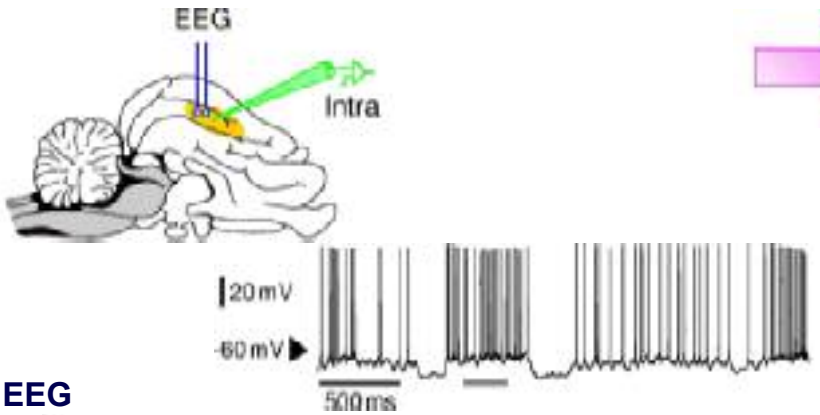
Contributors:

Claude Bedard, Sami El Boustani, Martin Pospischil, Michelle Rudolph (UNIC),
Olivier Marre, Zuzanna Piwkowska, Yves Frégnac, Thierry Bal (UNIC),
Diego Contreras (U. Pennsylvania, USA),
Igor Timofeev & Mircea Steriade (Laval University, Canada)

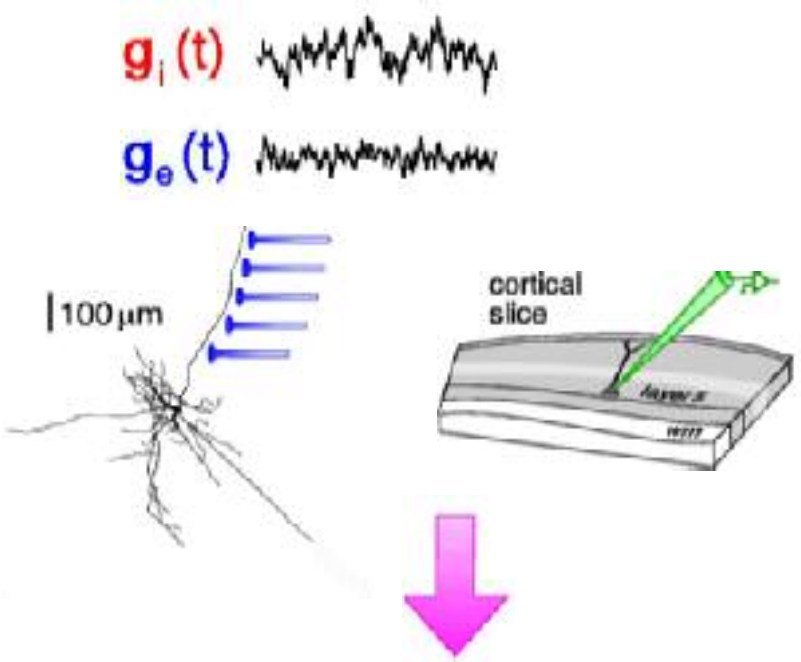
FACETS
(EU IST)

Multiscale analysis

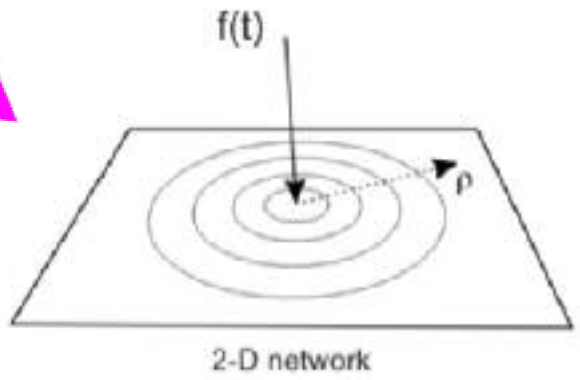
Characterization of "noisy" network activity in vivo: *High-conductance states*

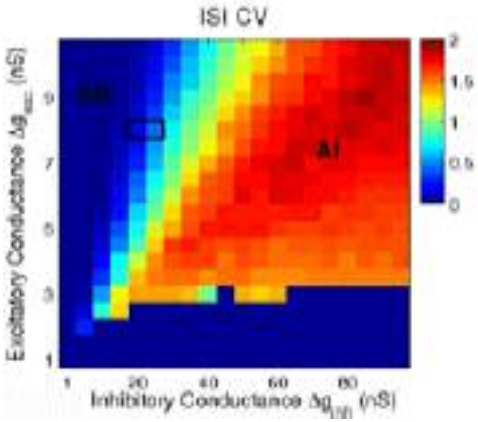


Integrative properties of single neurons during *High-Conductance states*



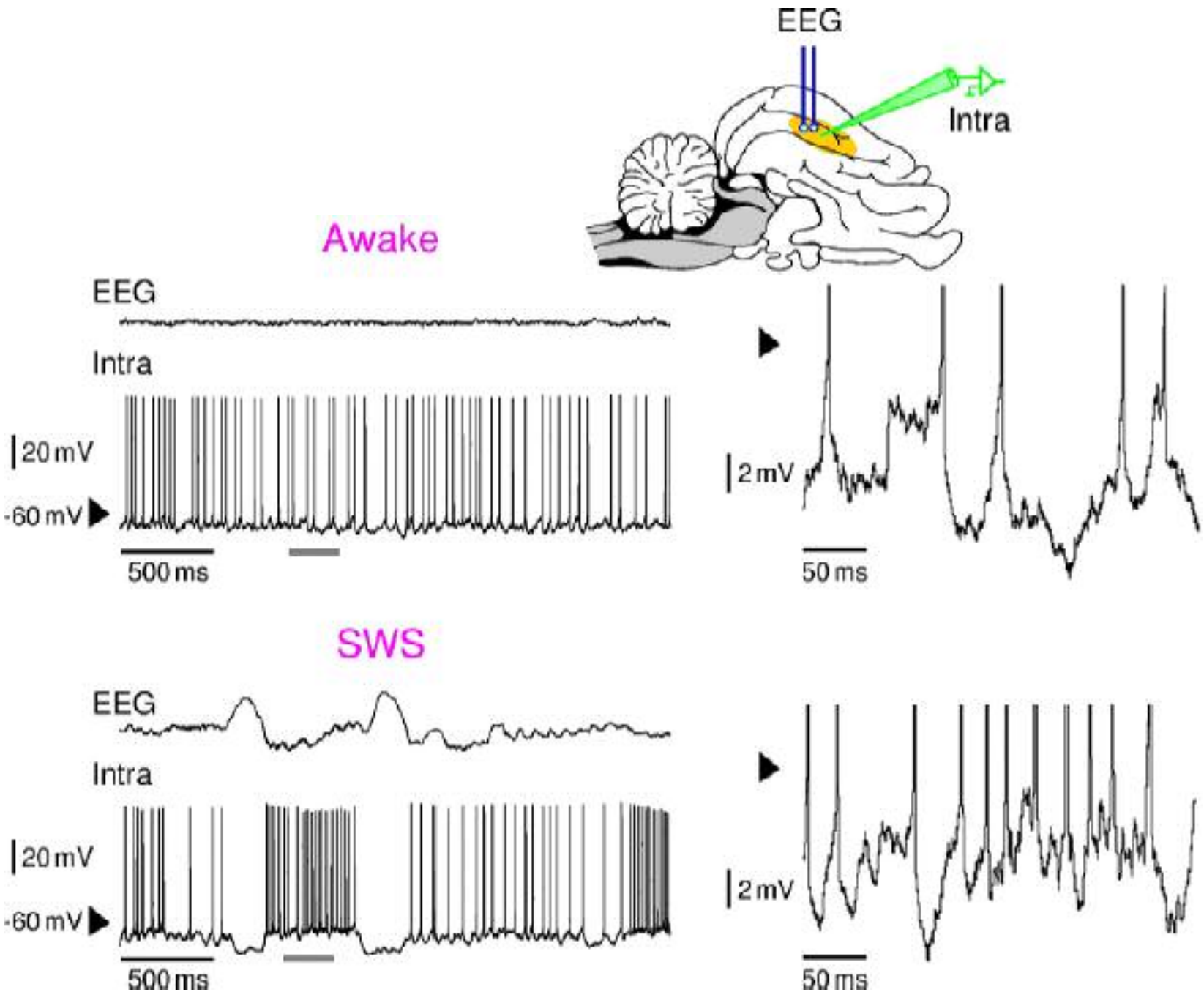
High-conductance states at the network level



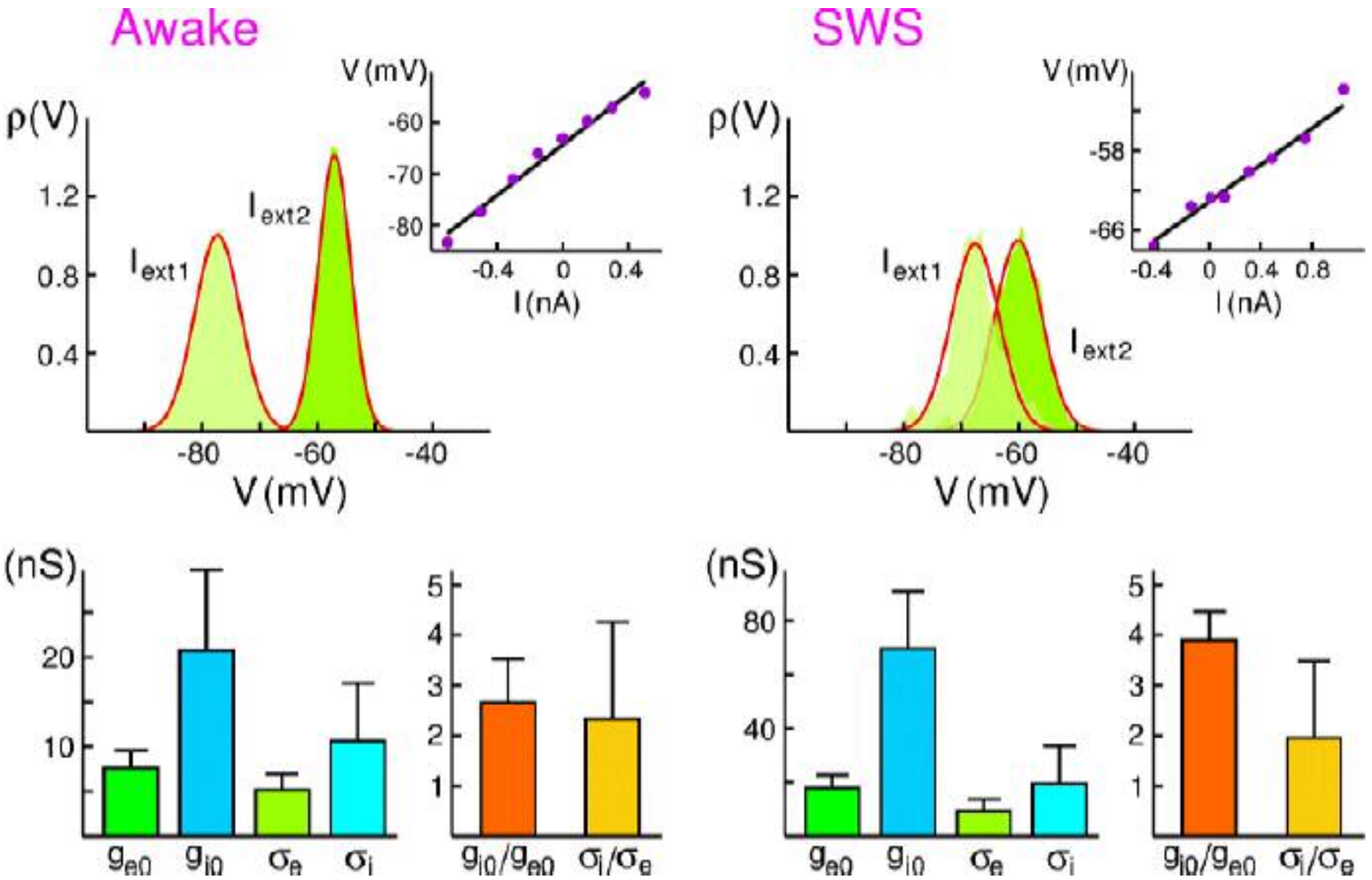


Integrative properties at the level of single neurons

Extracting conductances from *in vivo* activity



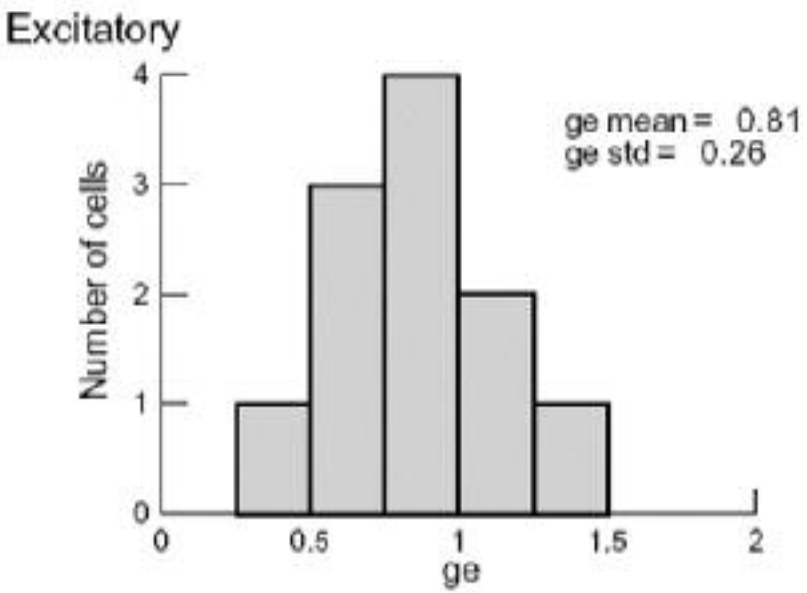
Extracting conductances from *in vivo* activity

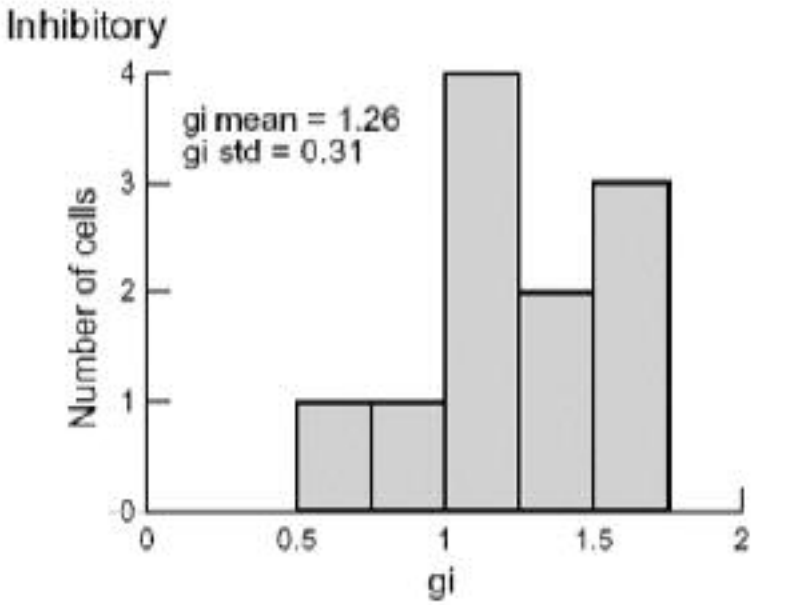


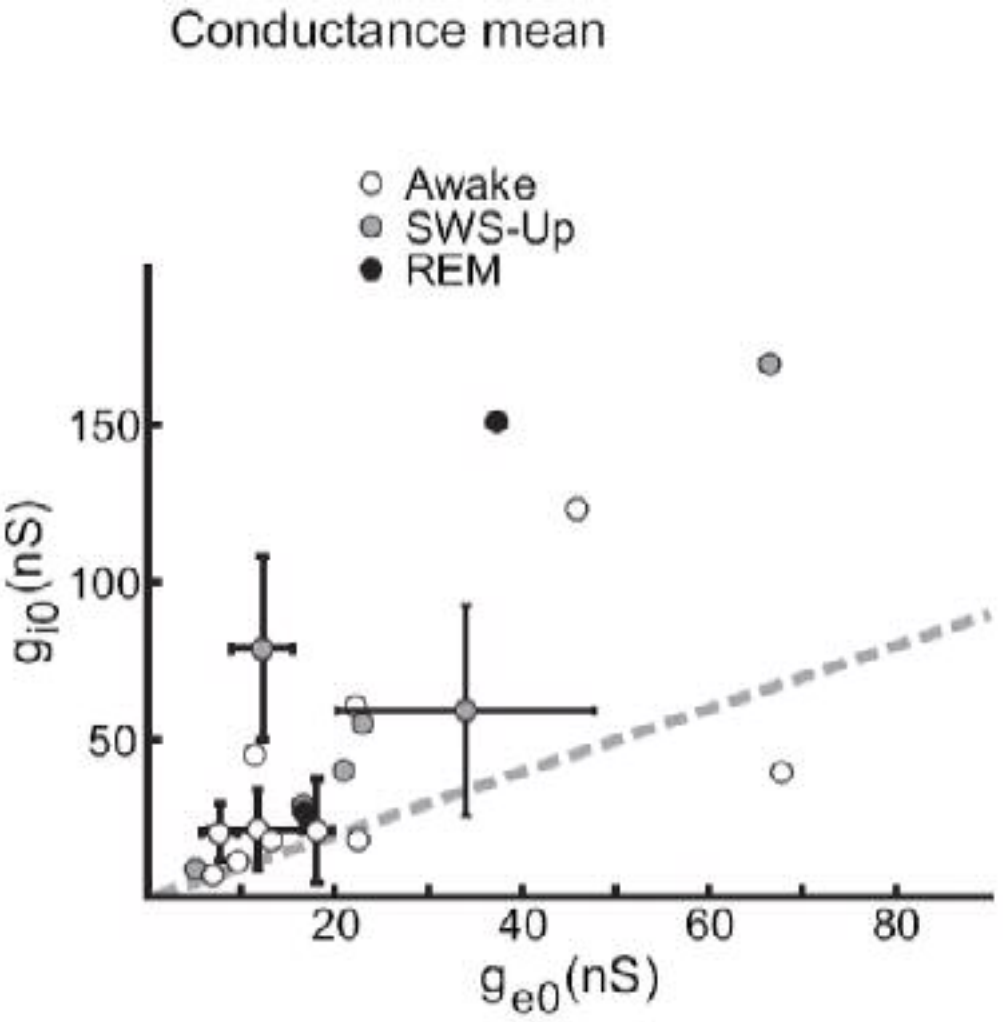
Rudolph, Pospischil, Timofeev & Destexhe, *J. Neurosci*, 2007

Extracting conductances from *in vivo* activity

Conductance measurements
in awake cats





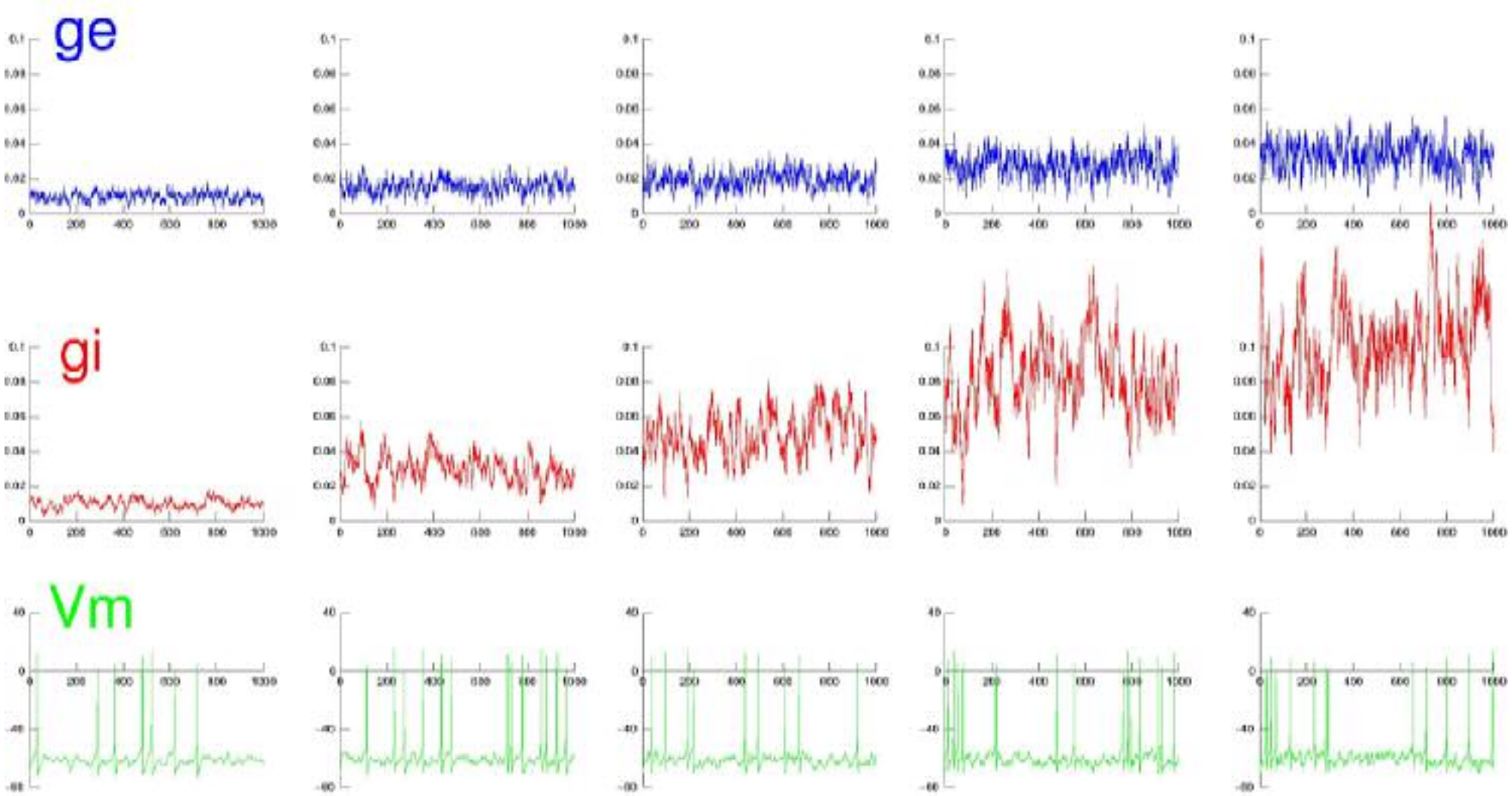


Rudolph, Pospischil, Timofeev &
Destexhe, *J. Neurosci*, 2007

Contrasting low and high conductance states

Low-conductance states
(excitation ~ inhibition)

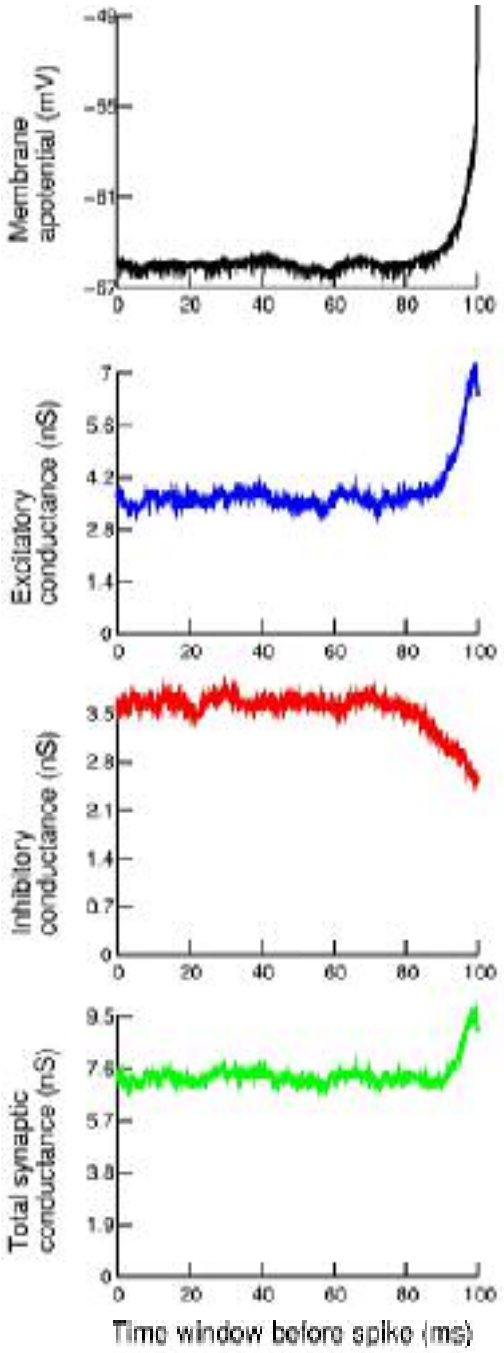
High-conductance states
(inhibition >> excitation)



Spike-triggered averages of conductances

Dynamic-clamp

Low-conductance

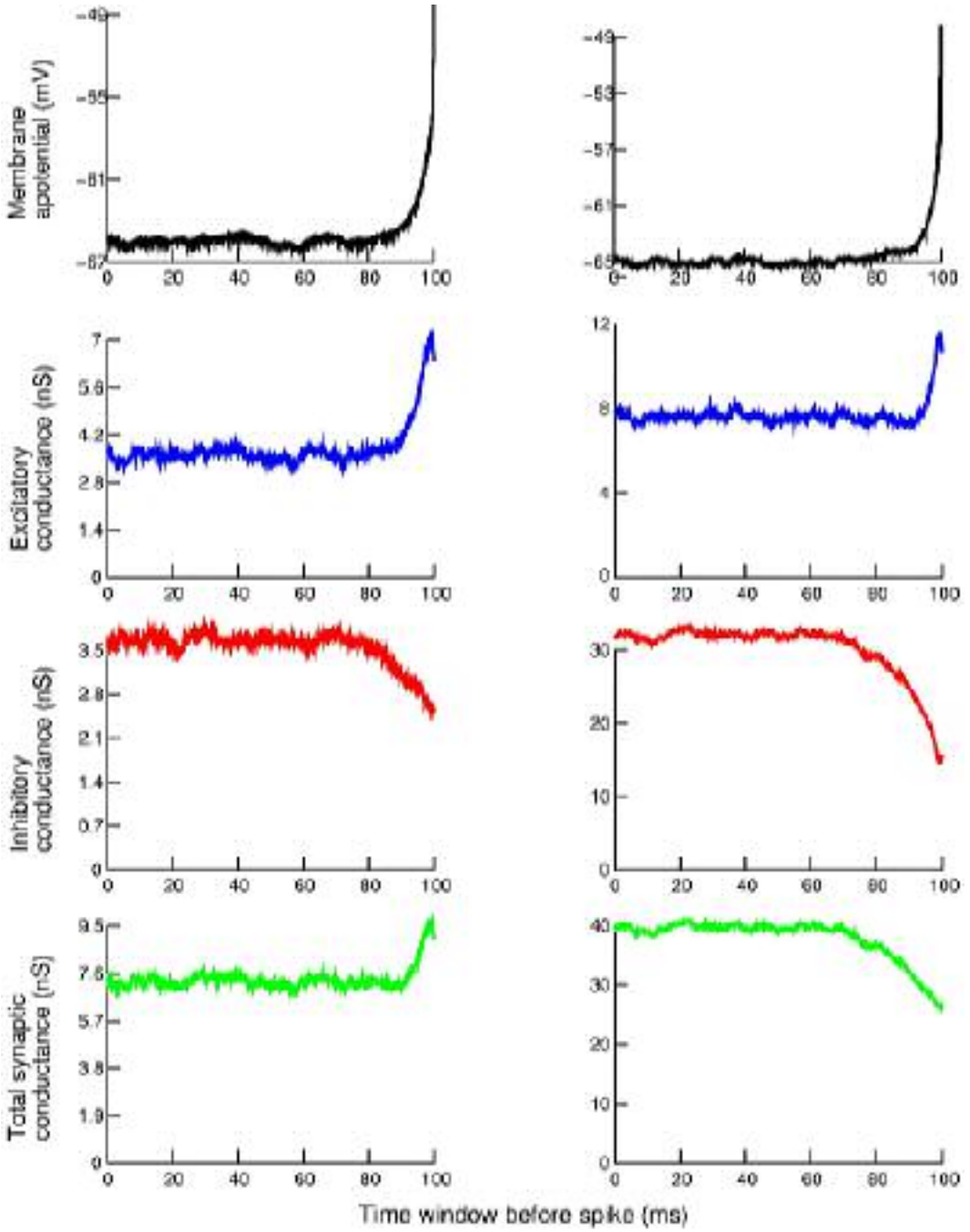


Spike-triggered averages of conductances

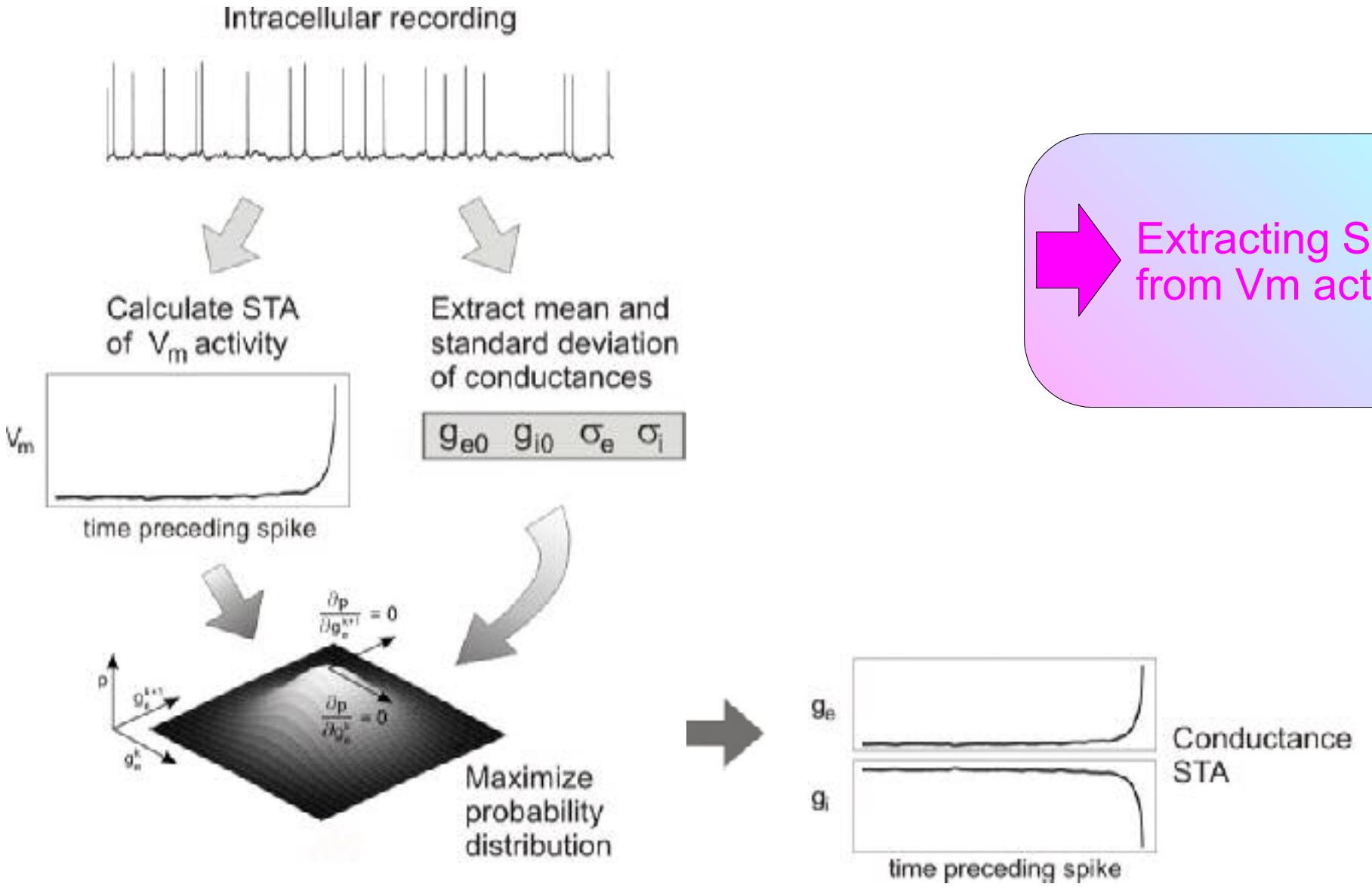
Dynamic-clamp

Low-conductance

High-conductance



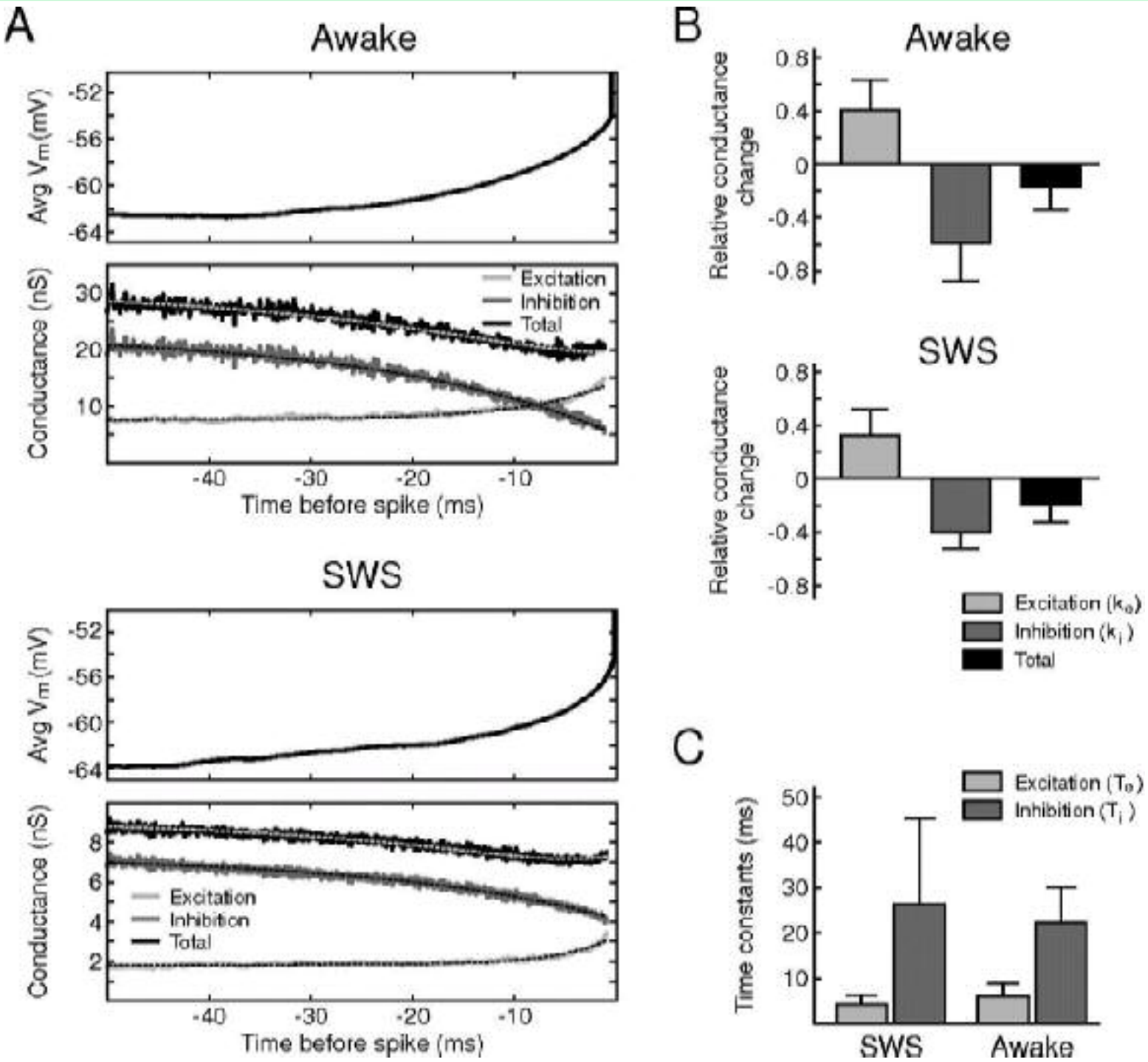
Spike-triggered averages of conductances



Extracting STA from Vm activity

Pospischil, Piwkowska, Rudolph, Bal & Destexhe, *J Neurophysiol* 2007

Spike-triggered averages of conductances



Rudolph et al., *J. Neurosci*, 2007

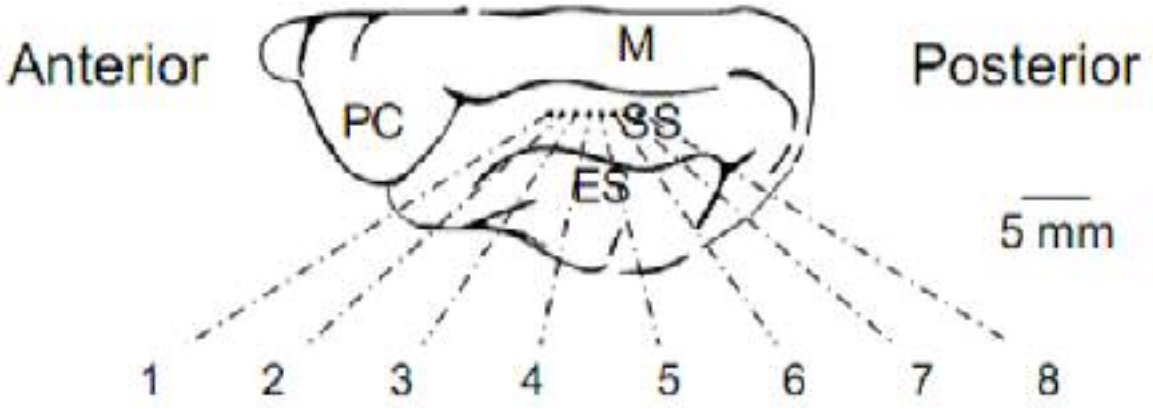
Stochastic analysis of single cortical neurons *in vivo*

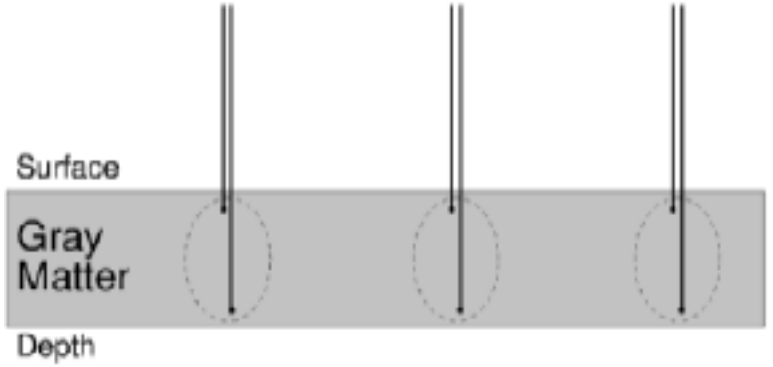
Summary of the stochastic analysis of High-conductance States

- Stochastic analysis of Vm fluctuations reveals dominant inhibitory conductances
- Two ways to evoke spikes: by excitation (rare) or release of inhibition (more generally seen)
- Considerable cell-to-cell variability (diversity)

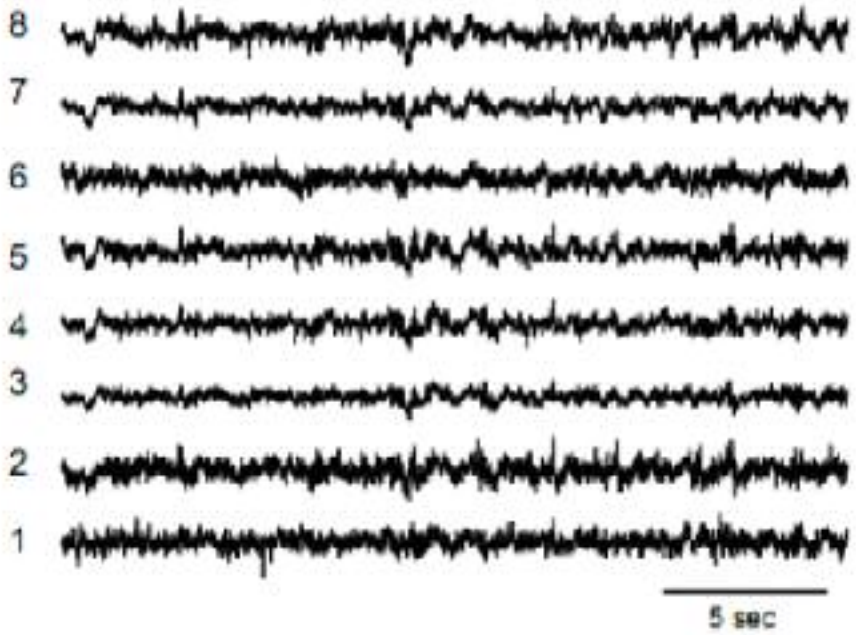
Integrative properties at the level of networks of neurons

Multisite recordings in awake cats

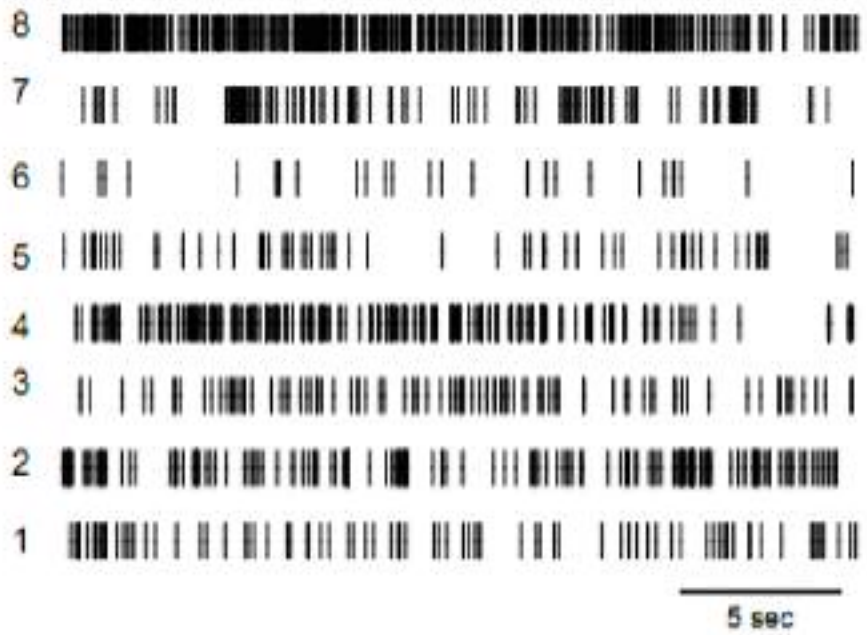




LFPs (macroscopic)

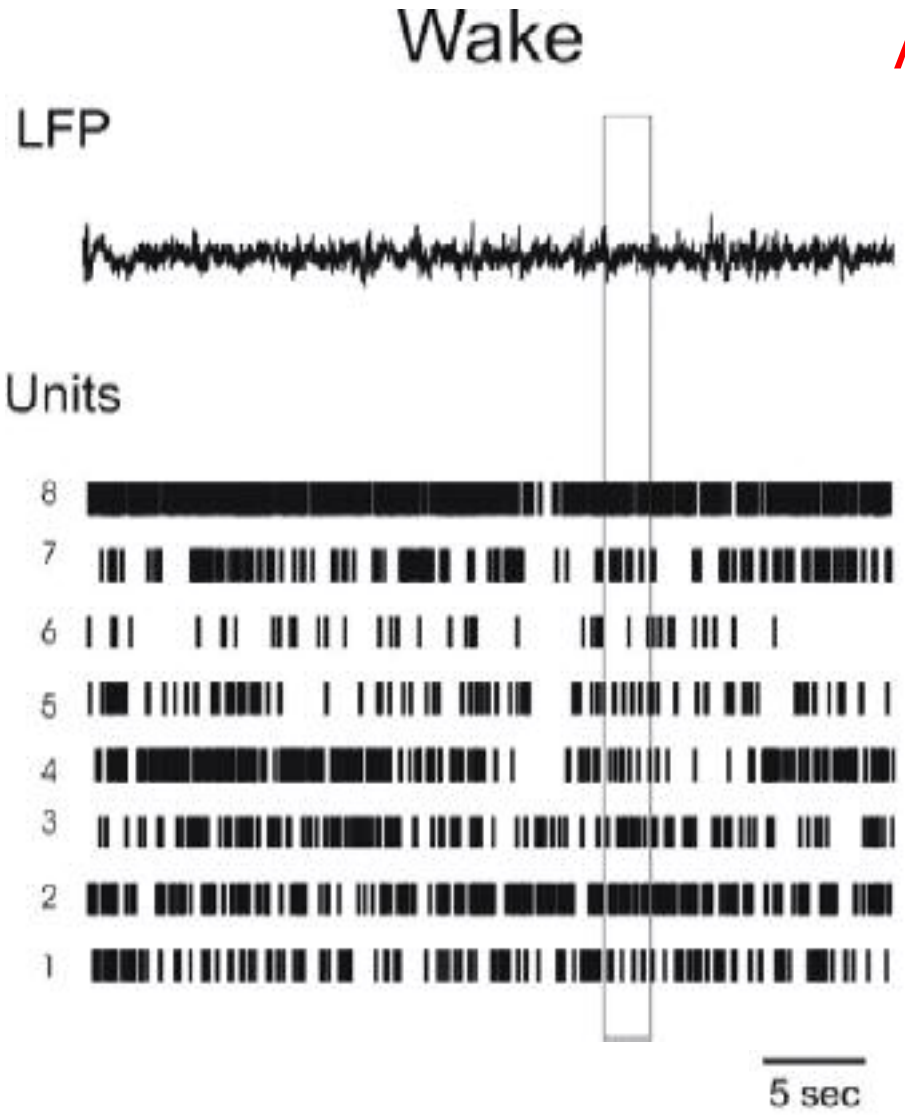


Units (microscopic)

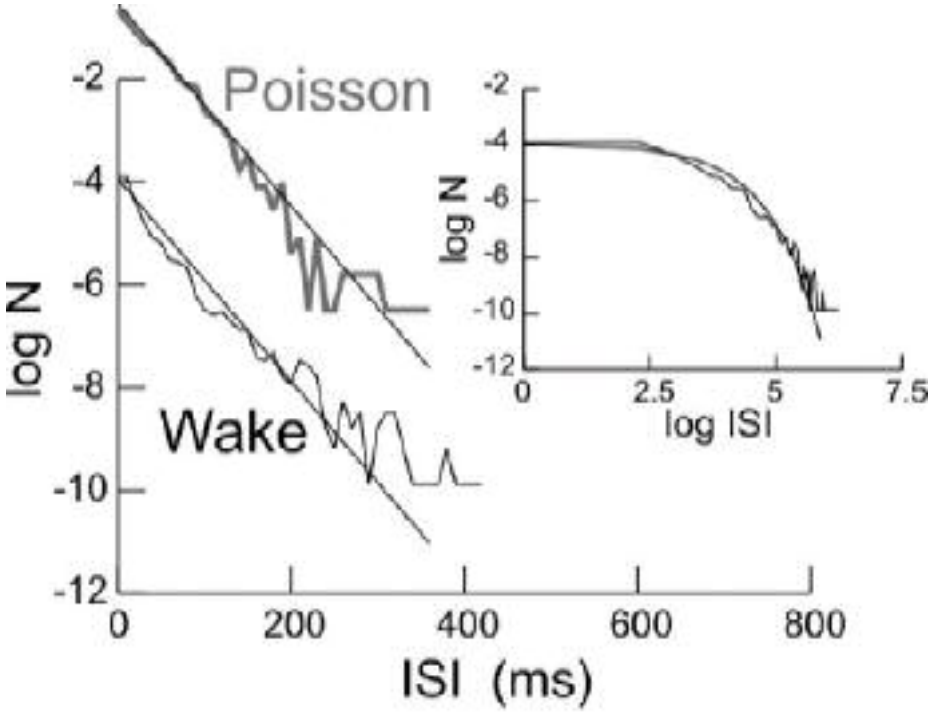


Destexhe et al., J. Neurosci.,1999

Multiunit extracellular recordings in awake cats

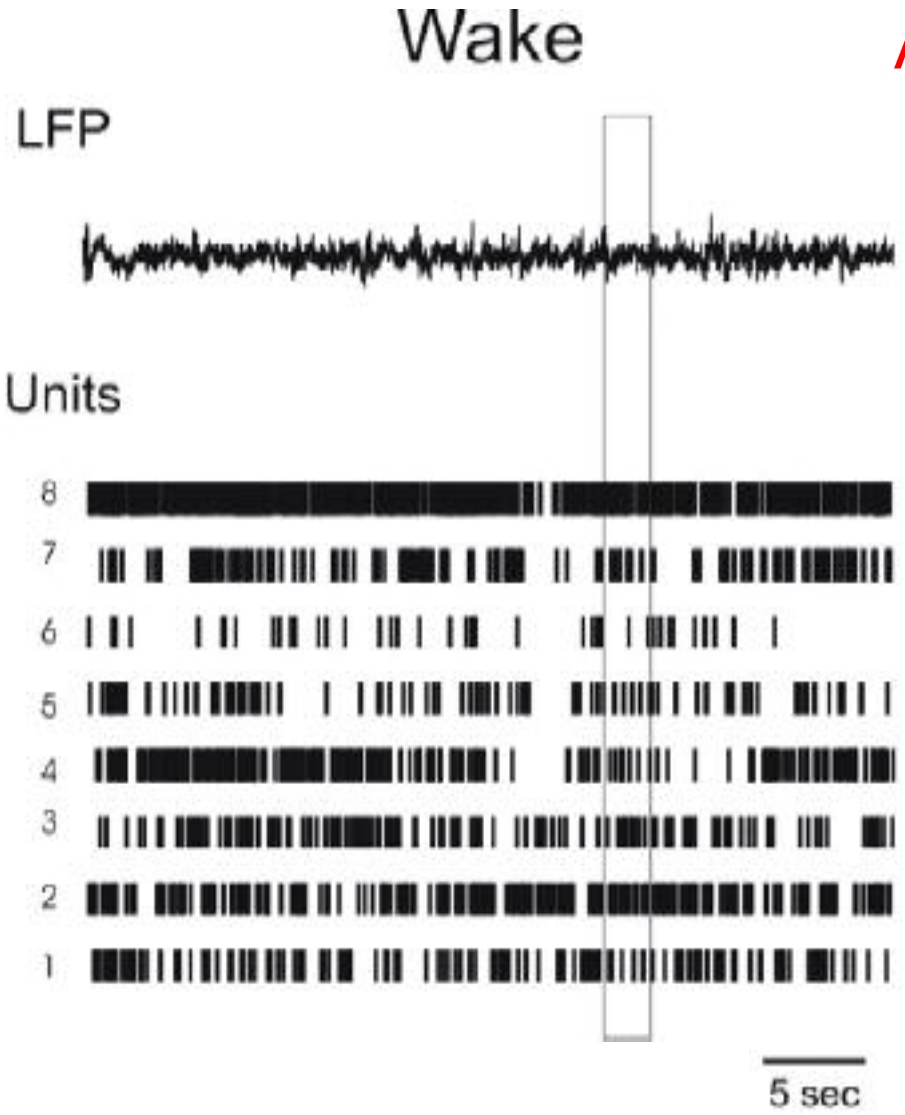


Apparent stochastic dynamics!

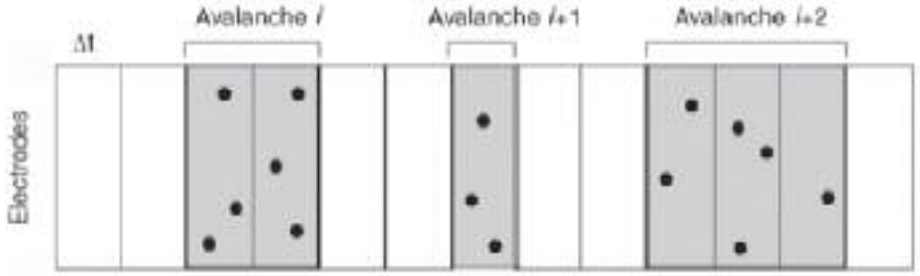


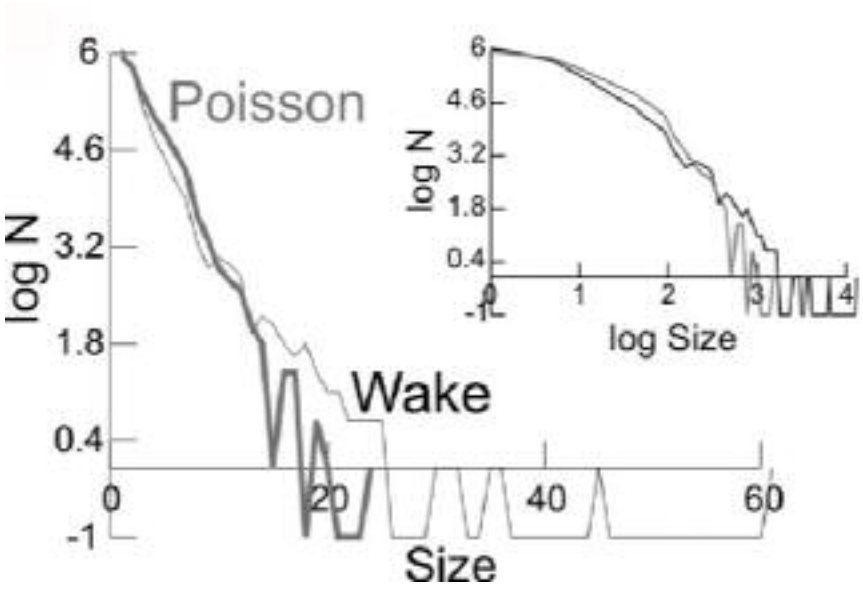
Softky & Koch, *J Neurosci.* 1993
Bedard, Kroger & Destexhe, *Phys Rev Lett* 2006

Multiunit extracellular recordings in awake cats



Apparent stochastic dynamics!



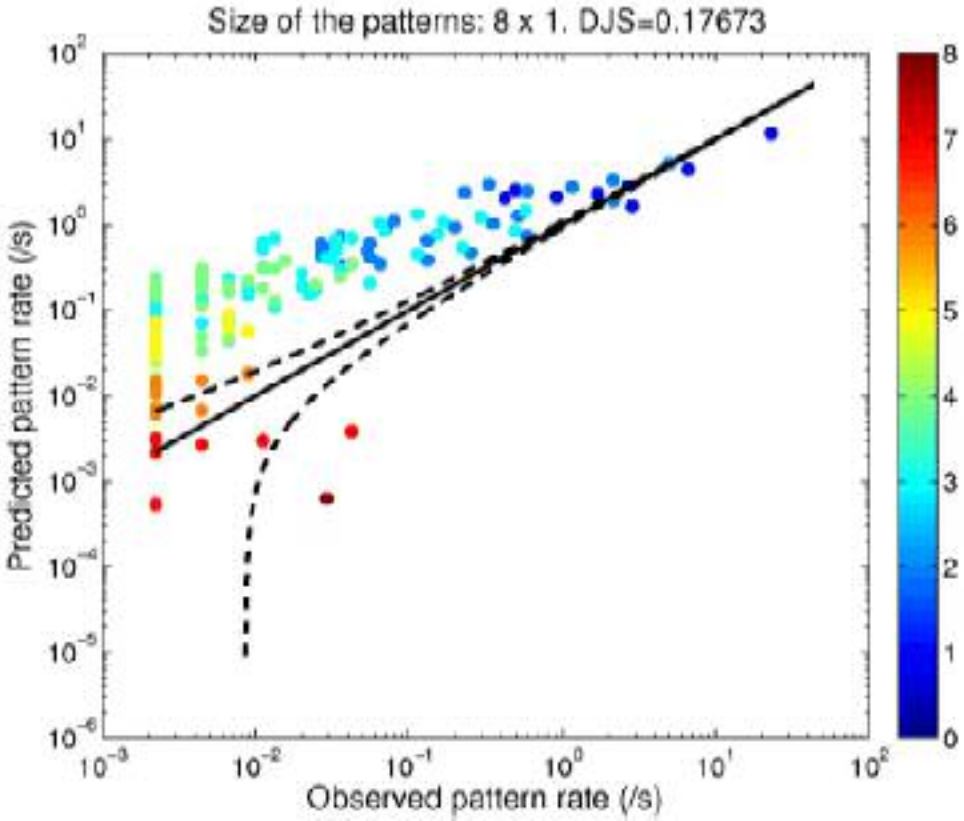


Bedard, Kroger & Destexhe, *Phys Rev Lett* 2006

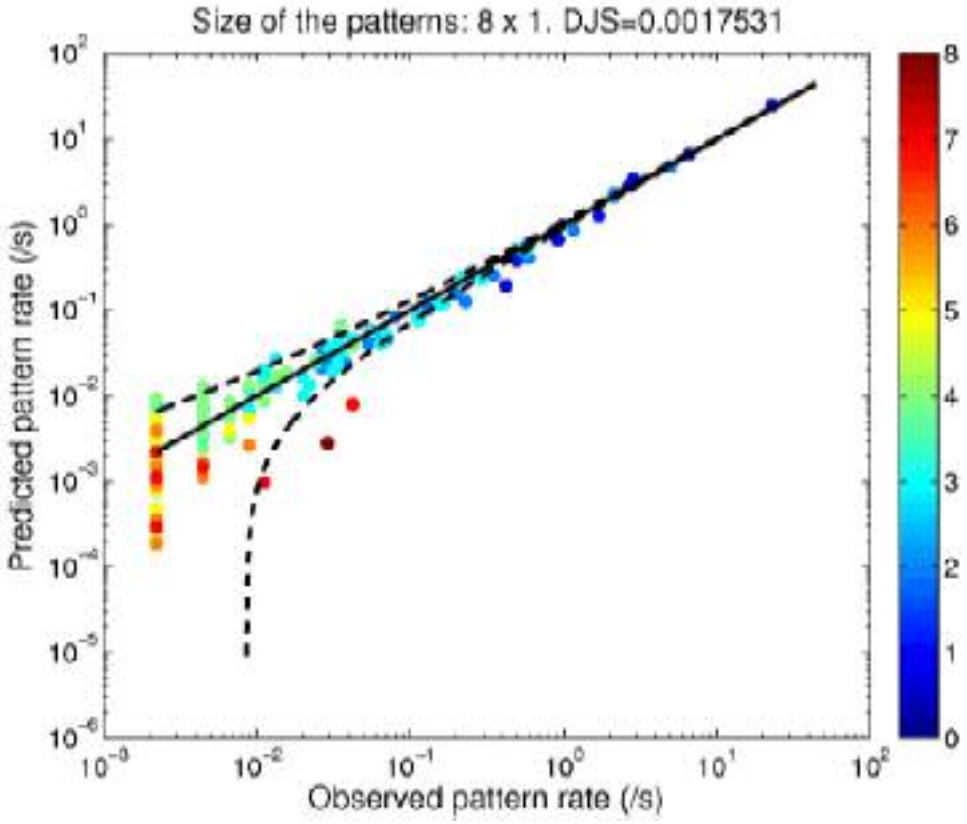
Multiunit extracellular recordings in awake cats

Statistics of spike patterns in cat parietal cortex

Uncorrelated



Correlated

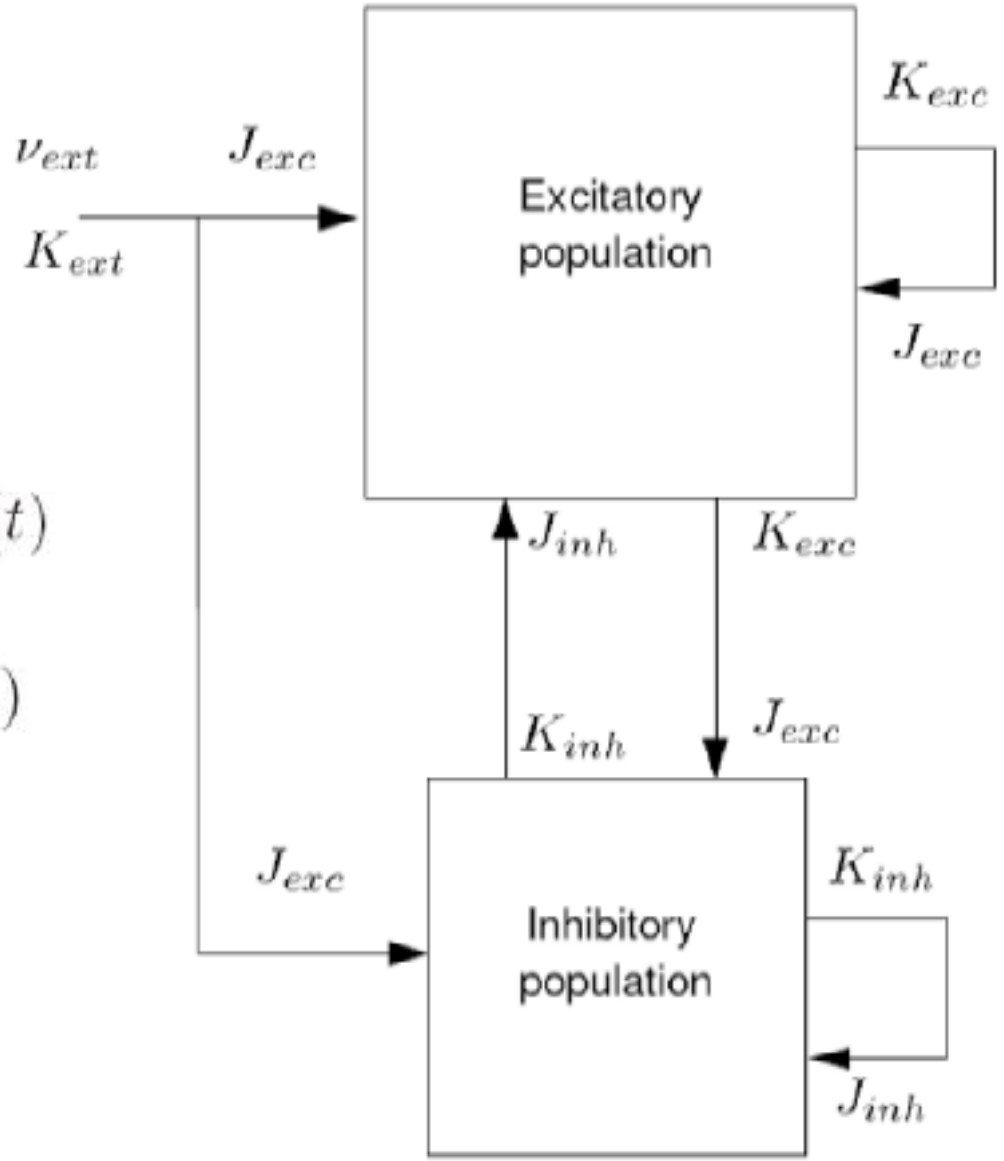


Marre, El Boustani, Fregnac & Destexhe
Physical Review Letters, 2009

Network models of self-sustained irregular states

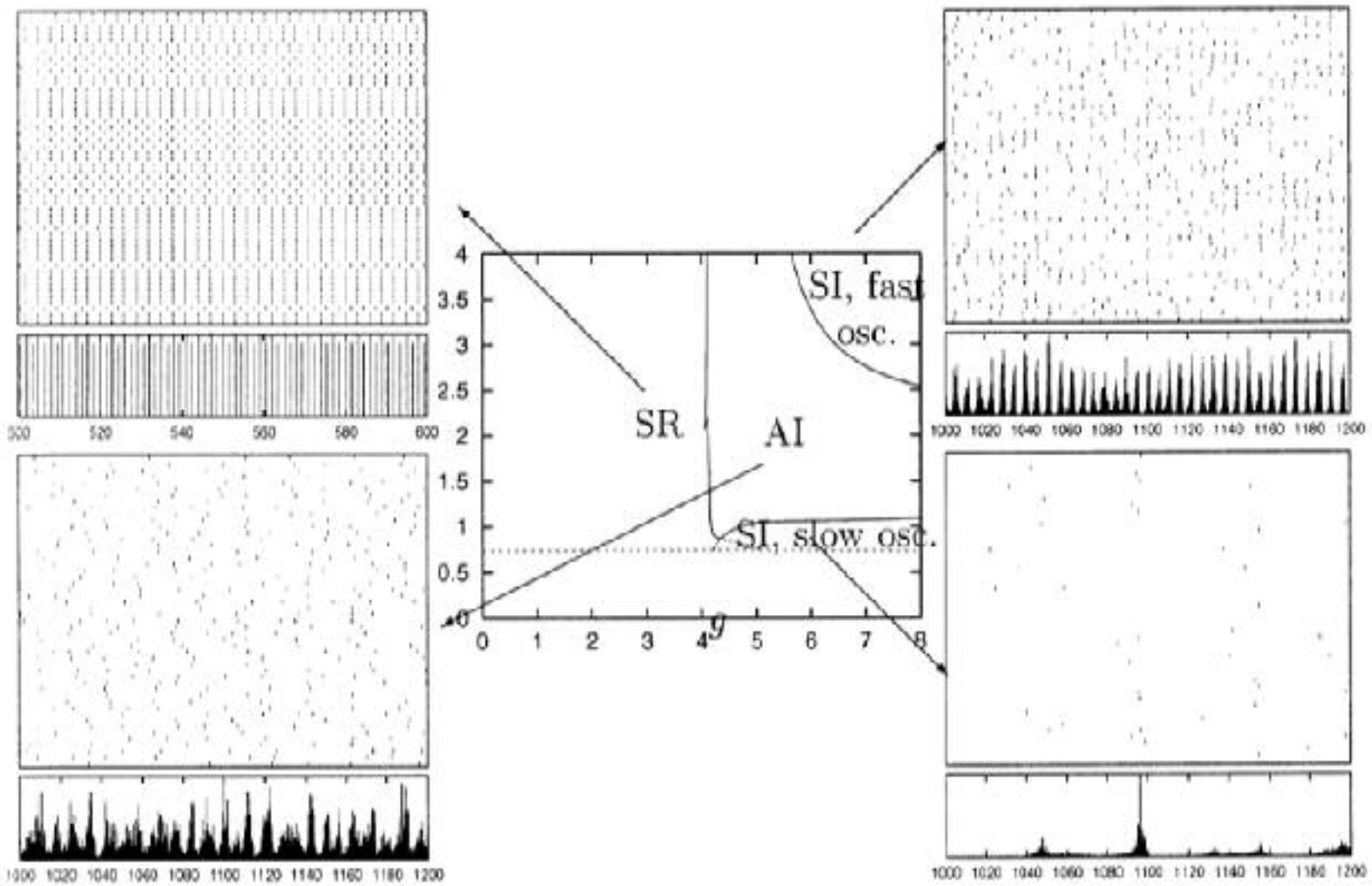
Networks of IF neurons

$$C_m \frac{dV_i}{dt} = -g_L(V_i - E_L) + S(t) - \sum_j g_{ji}(t)(V_i - E_j)$$



Network models of asynchronous irregular states

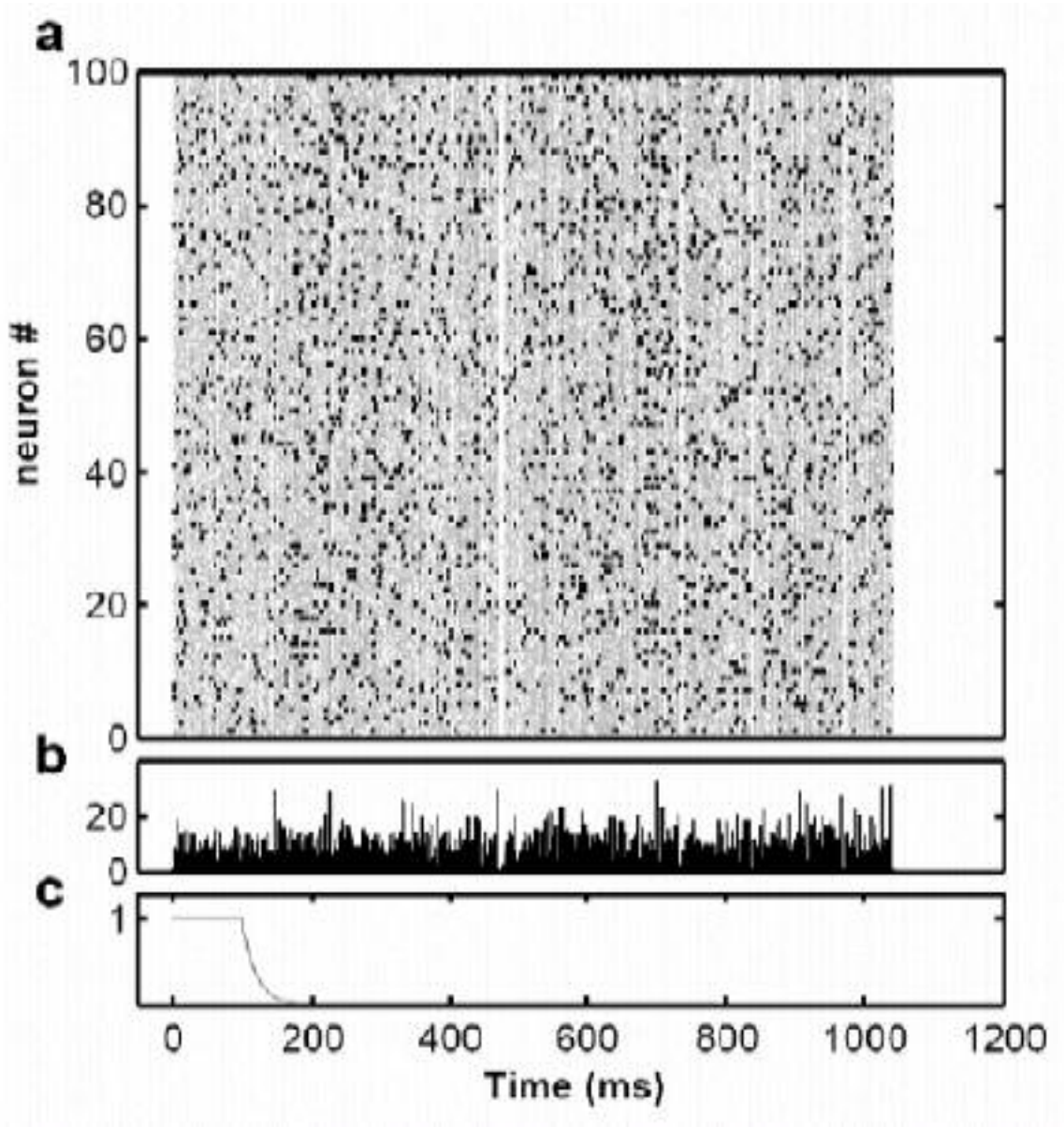
Networks of IF neurons



Brunel, *J Physiol Paris*, 2000

Self-sustained asynchronous irregular states

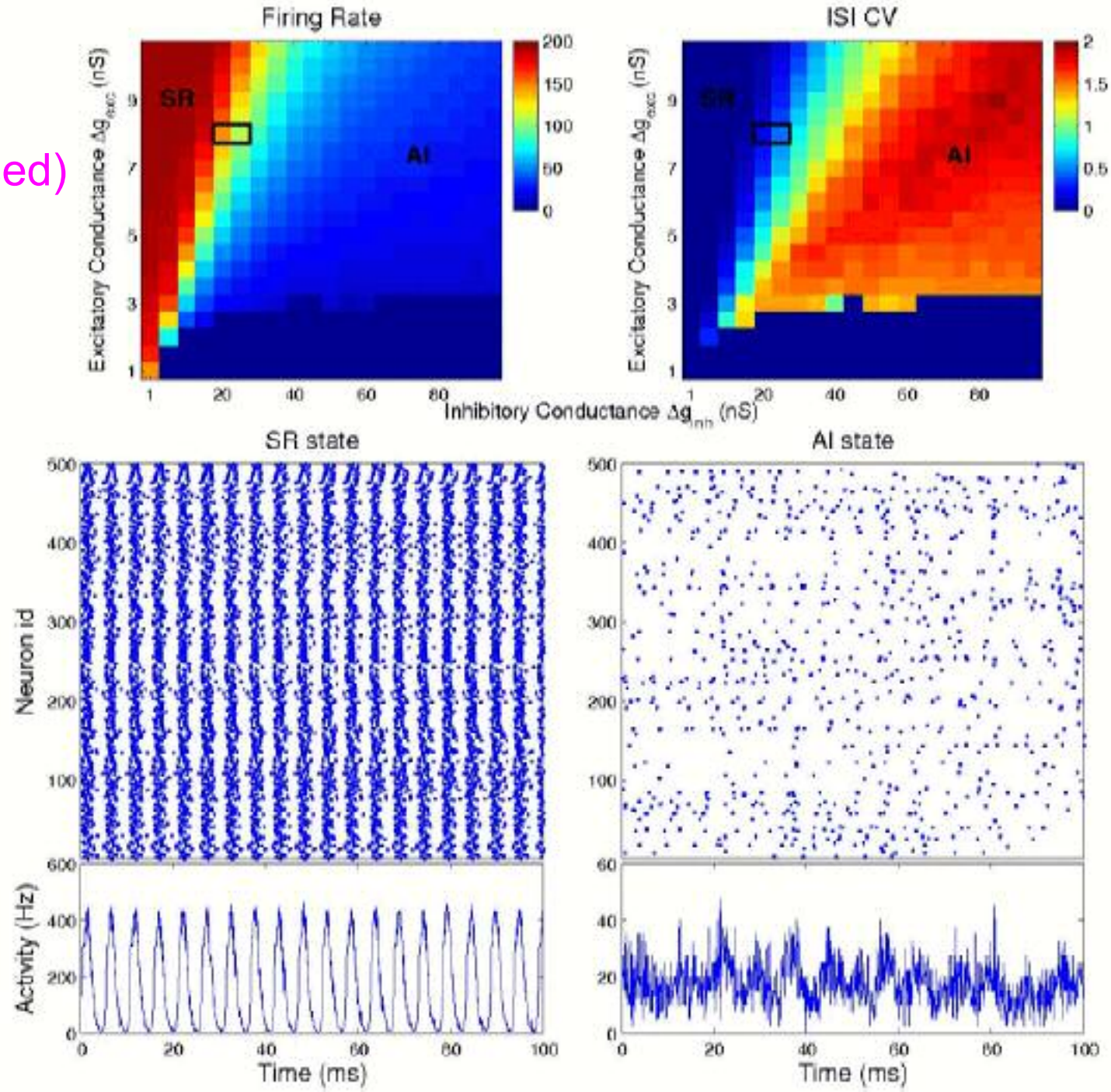
Networks of
IF neurons
(conductance-based)



Kumar et al.
Neural Computation 2008

Self-sustained asynchronous irregular states

Networks of
IF neurons
(conductance-based)

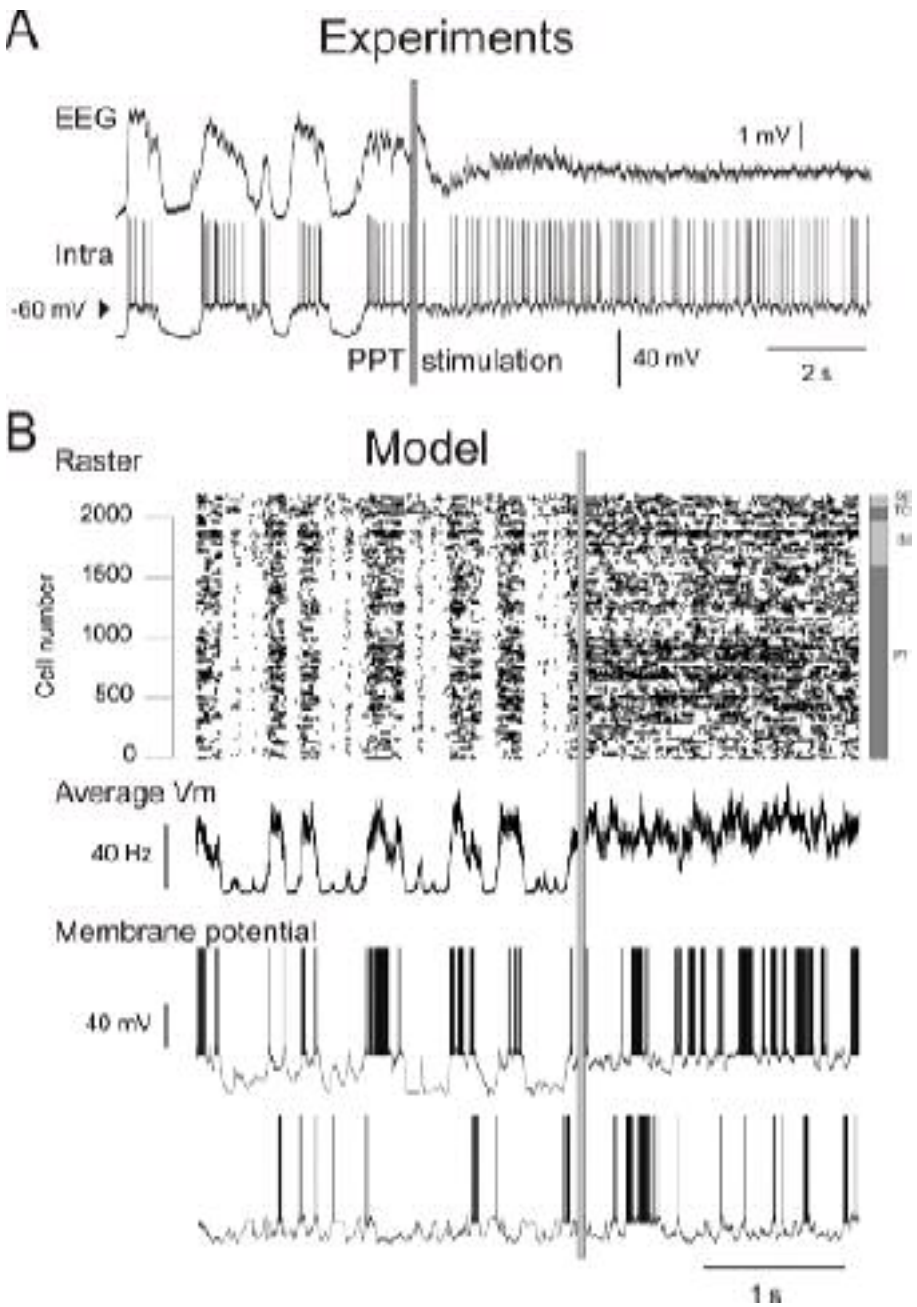


Vogels & Abbott,
J Neurosci 2005

El Boustani & Destexhe,
Neural Computation 2009

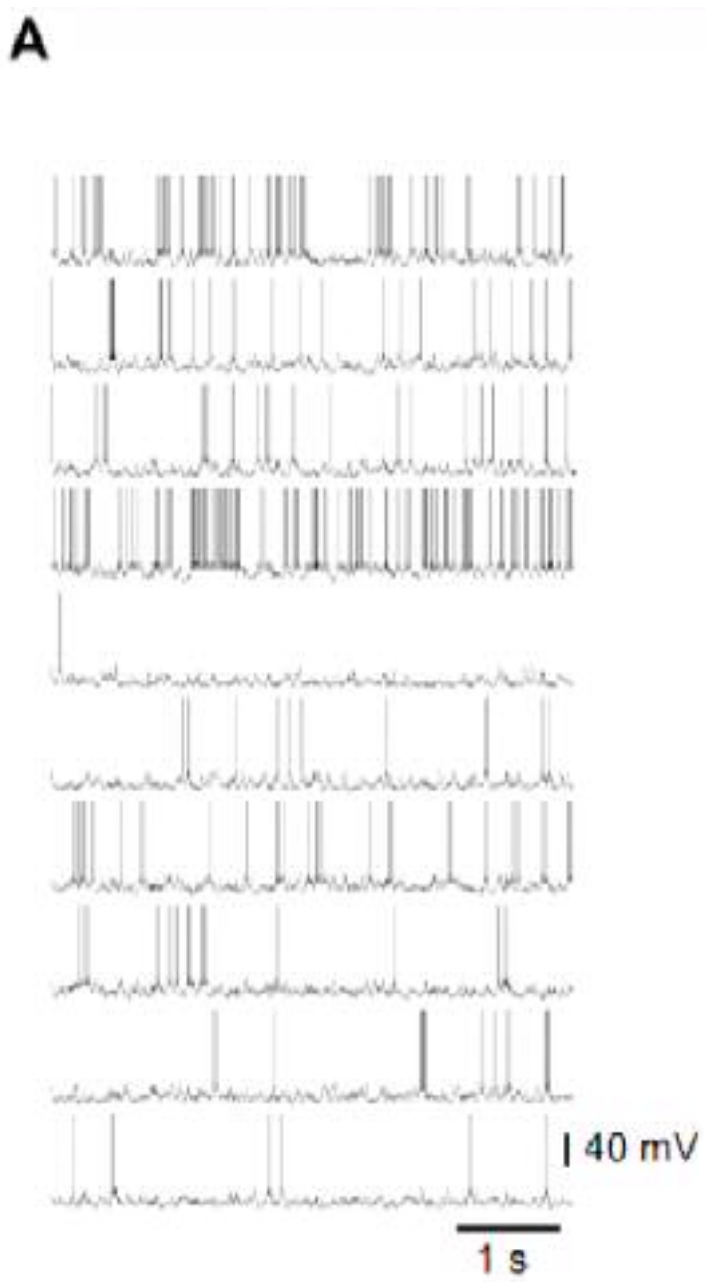
Self-sustained asynchronous irregular states

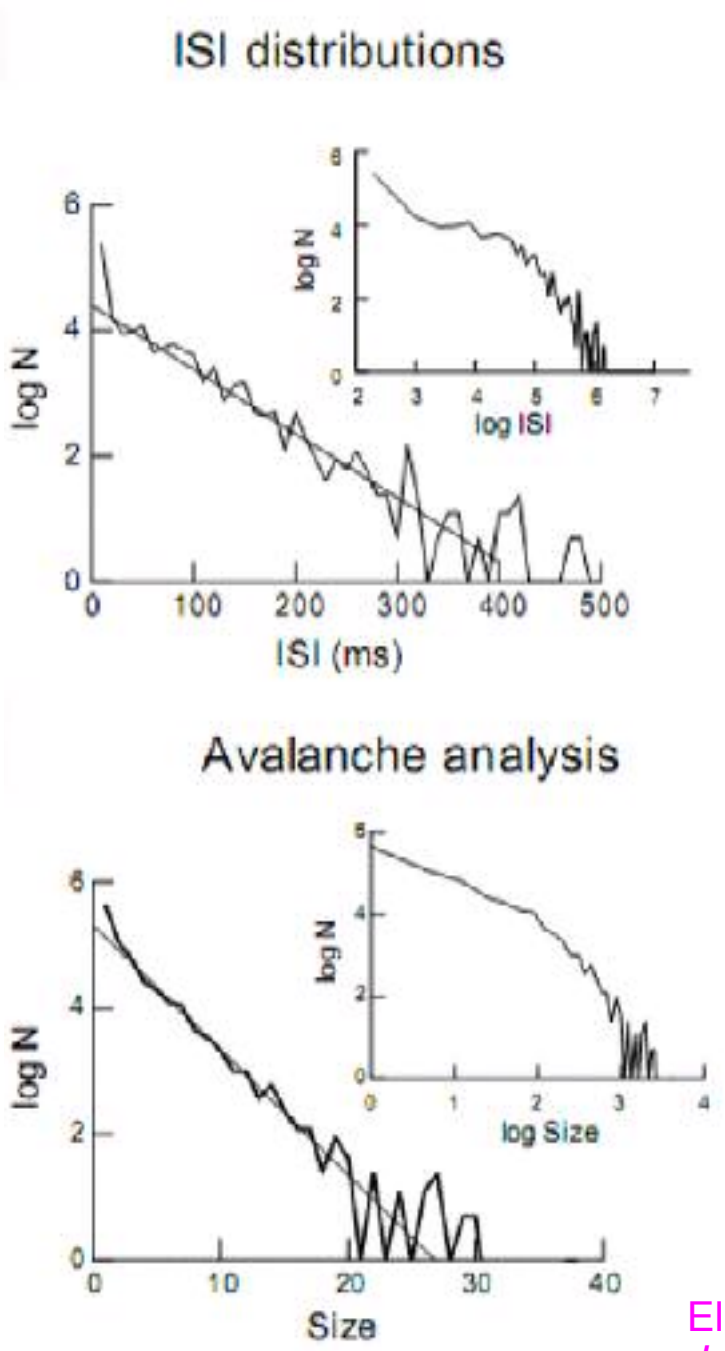
Networks of adaptative exponential IF neurons (conductance-based)



Destexhe
J Computational Neurosci
2009

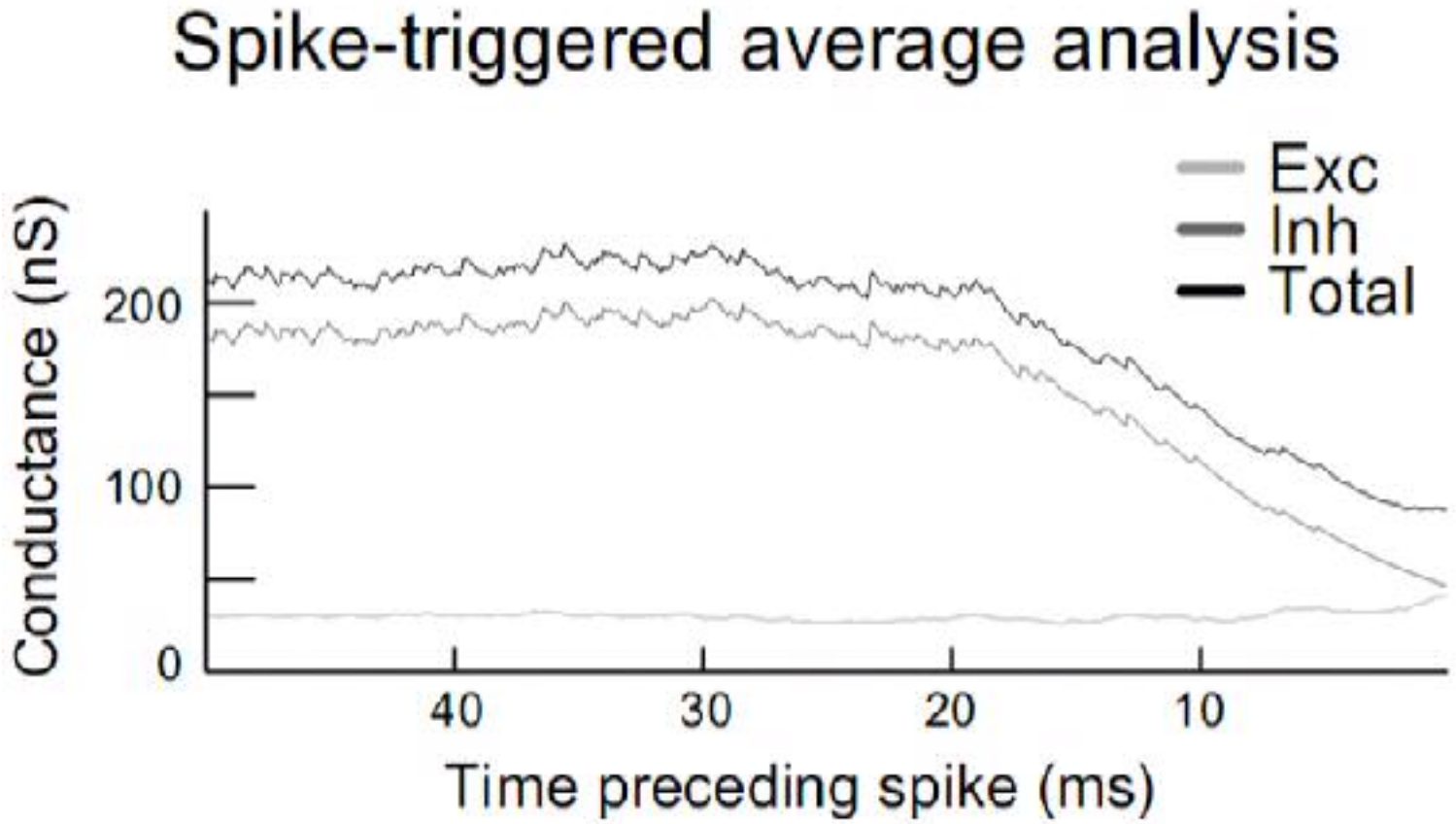
Analysis of AI states





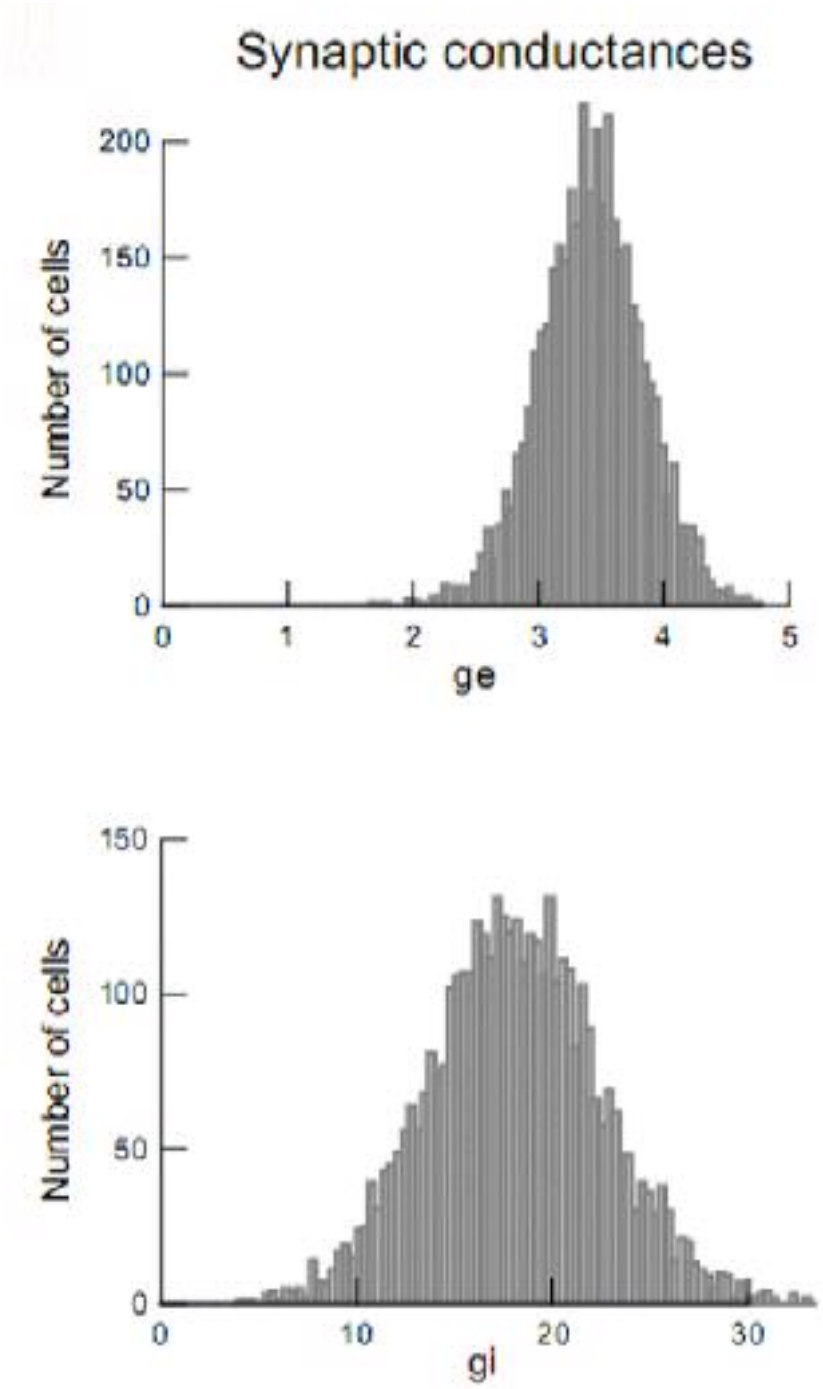
El Boustani et al.,
J Physiol Paris, 2007

Analysis of AI states



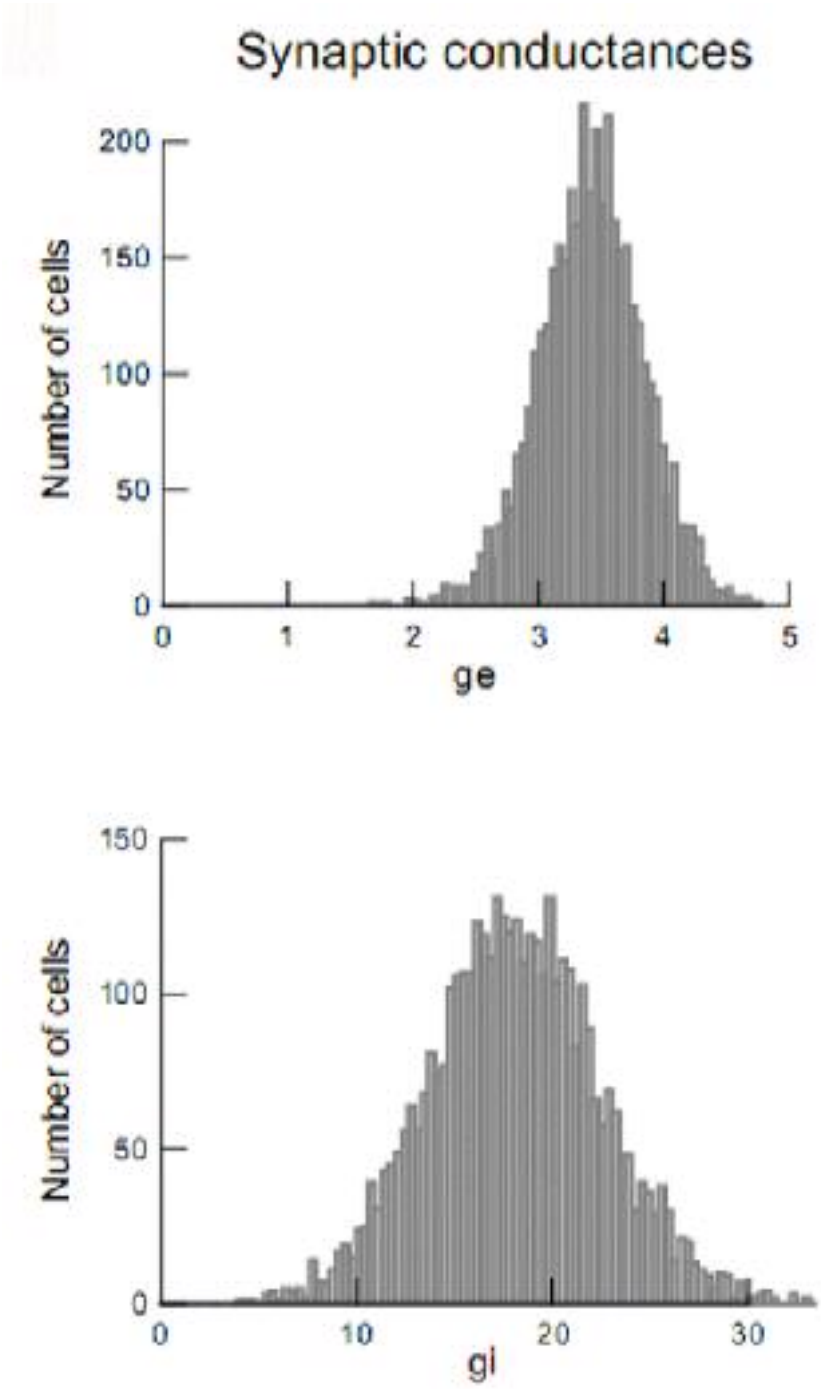
El Boustani et al.,
J Physiol Paris, 2007

Analysis of AI states



El Boustani et al.,
J Physiol Paris, 2007

Analysis of AI states



20 times
too many!

El Boustani et al.,
J Physiol Paris, 2007

Modulation of information transfer by network activity

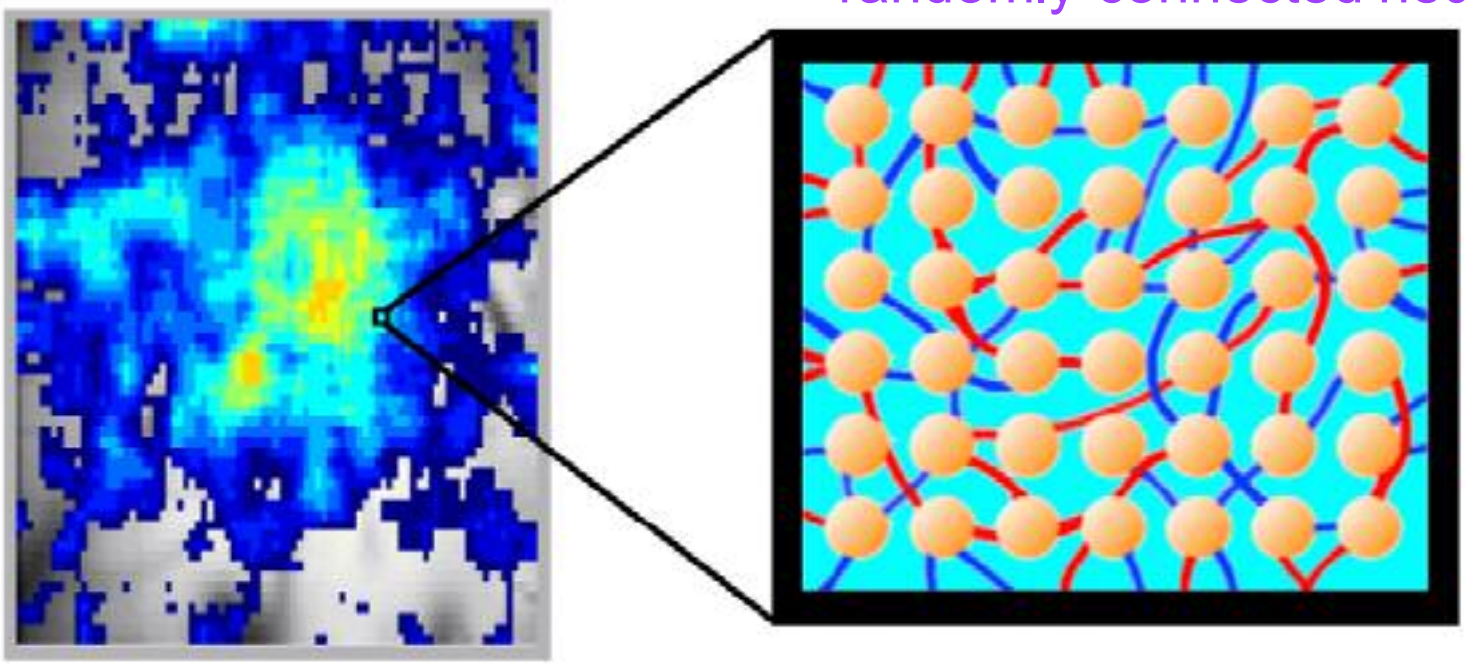
How to obtain models consistent with conductance measurements ?

Mean-field model of AI states

Macroscopic modeling of AI states in spiking networks

Optical imaging

1 pixel = network of randomly-connected neurons

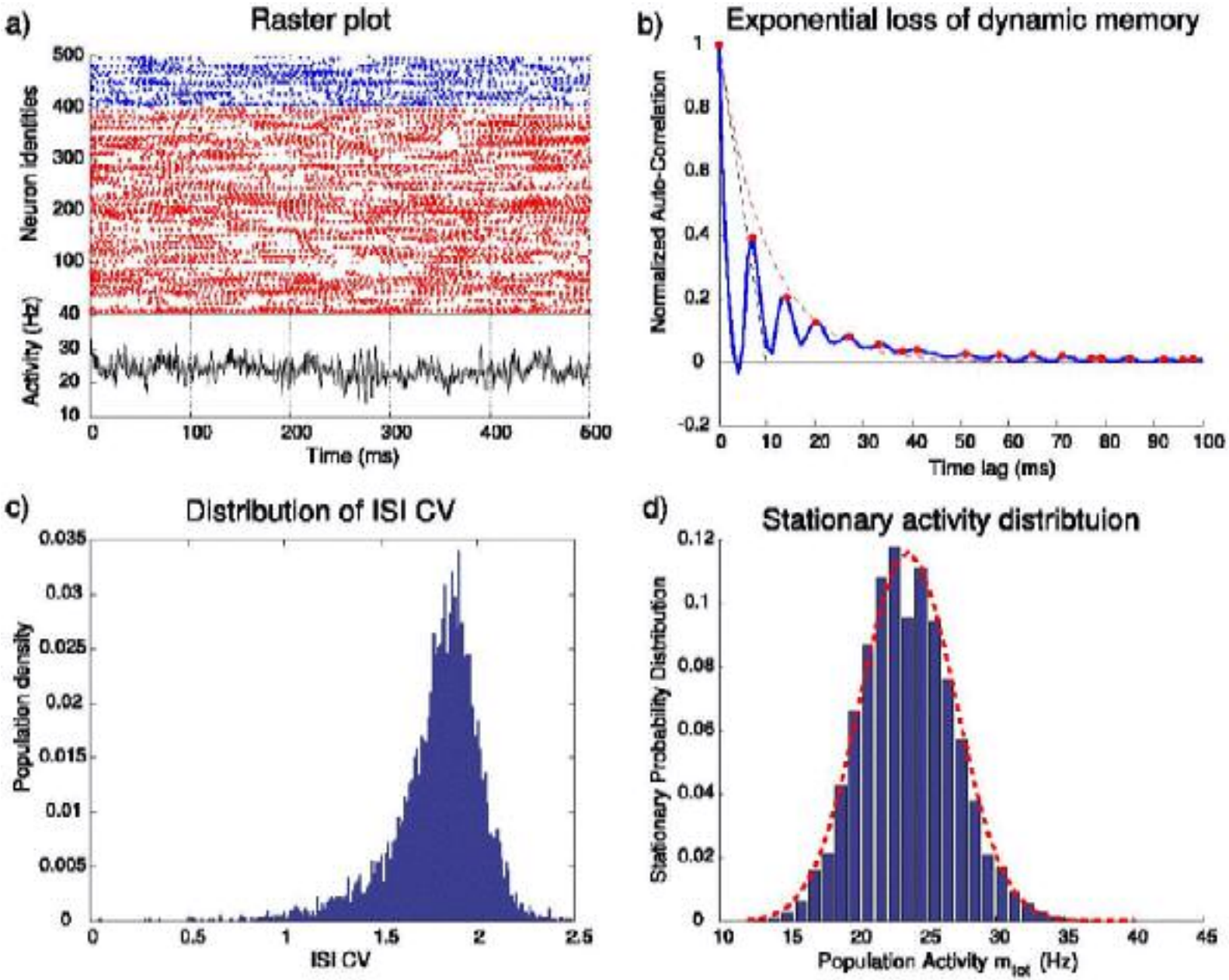


$$T\partial_t < m_\mu > = (\nu_\mu - < m_\mu >) + \frac{1}{2}\partial_\lambda\partial_\eta\nu_\mu c_{\lambda\eta}$$

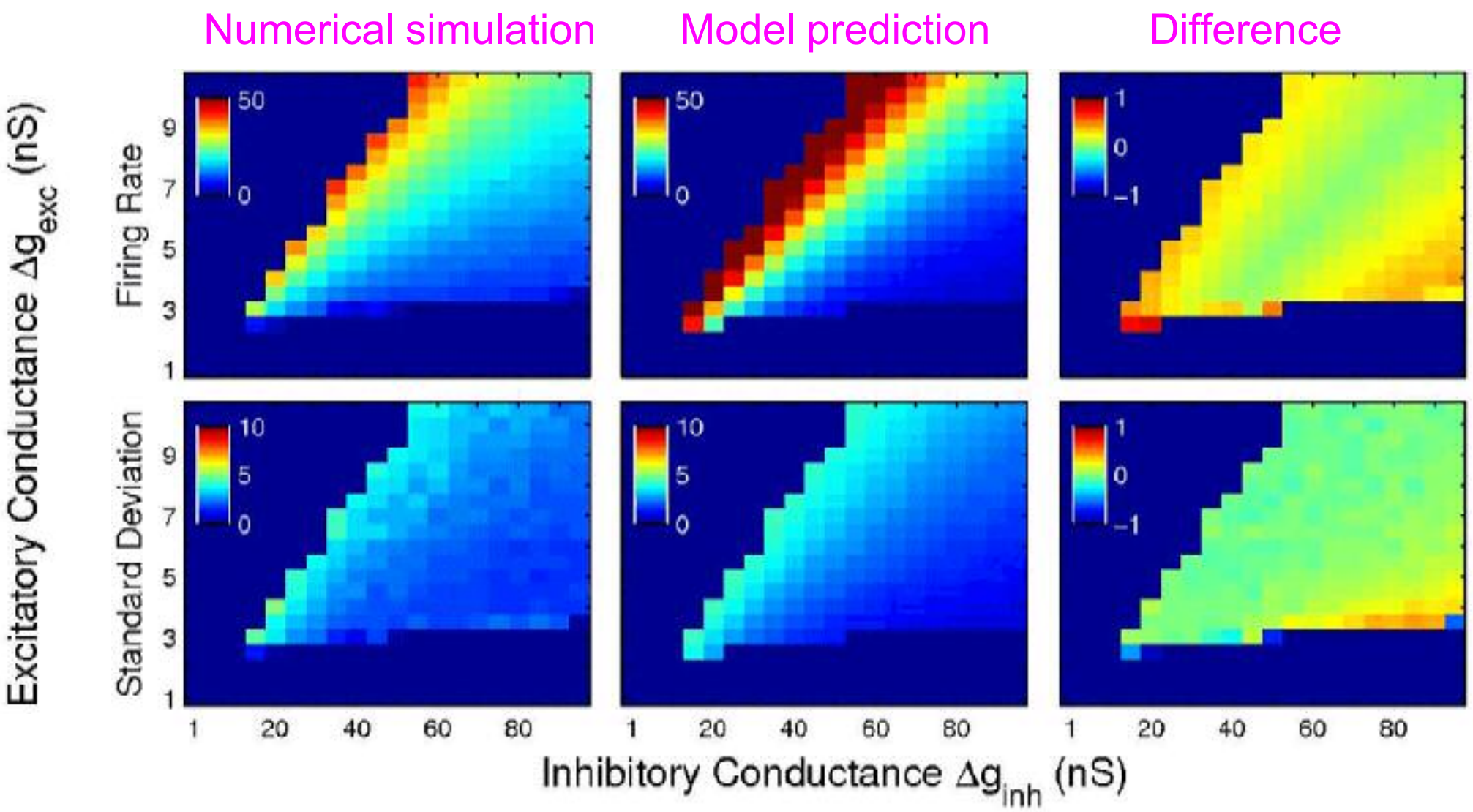
$$T\partial_t c_{\mu\nu} = \delta_{\mu\nu}A_{\mu\mu}^{-1} + (\nu_\mu - < m_\mu >)(\nu_\nu - < m_\nu >) + \partial_\lambda\nu_\mu c_{\nu\lambda} + \partial_\lambda\nu_\nu c_{\mu\lambda} - 2c_{\mu\nu}$$

El Boustani & Destexhe,
Neural Computation 2009

Mean-field model of AI states

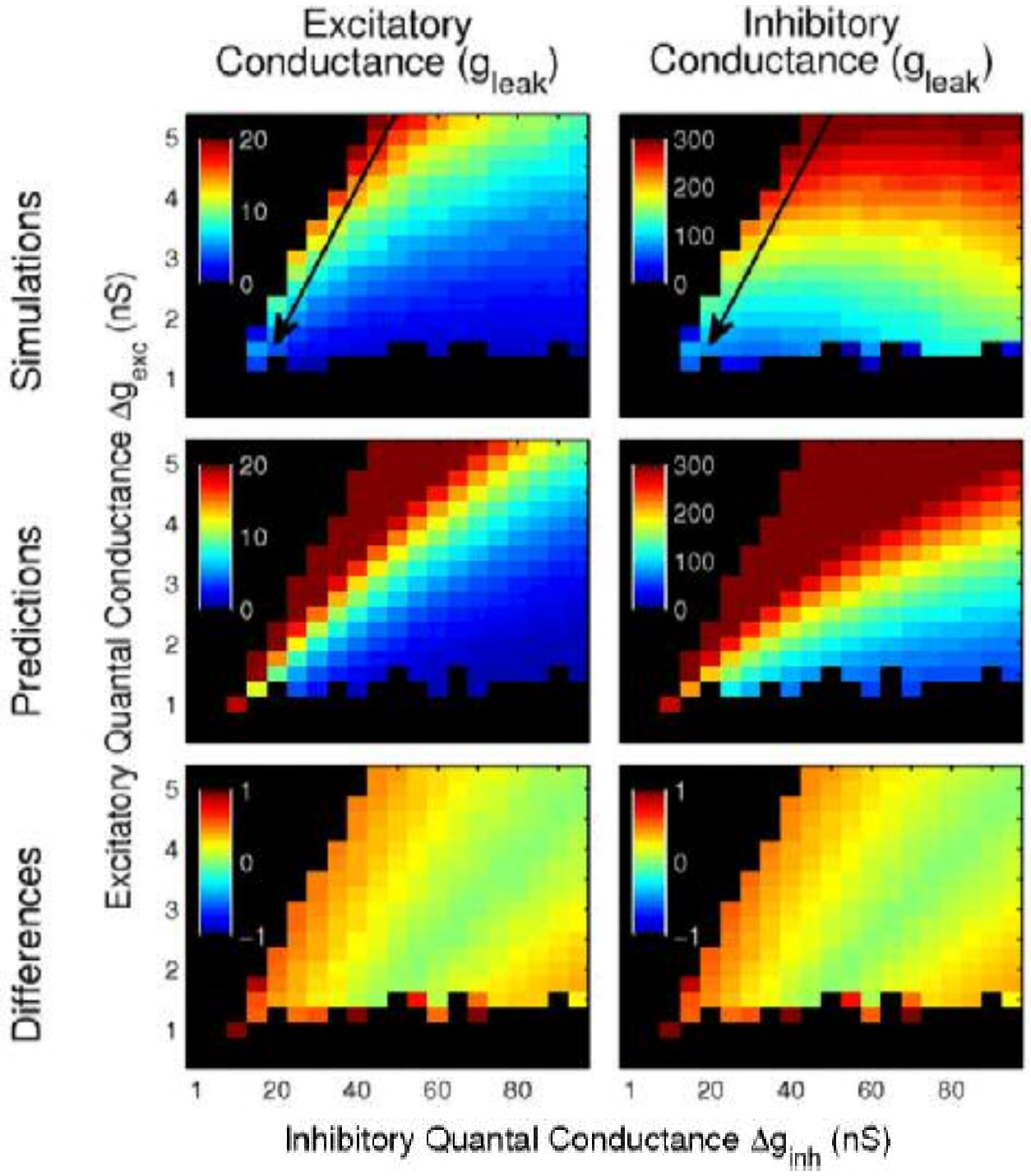


Mean-field model of AI states



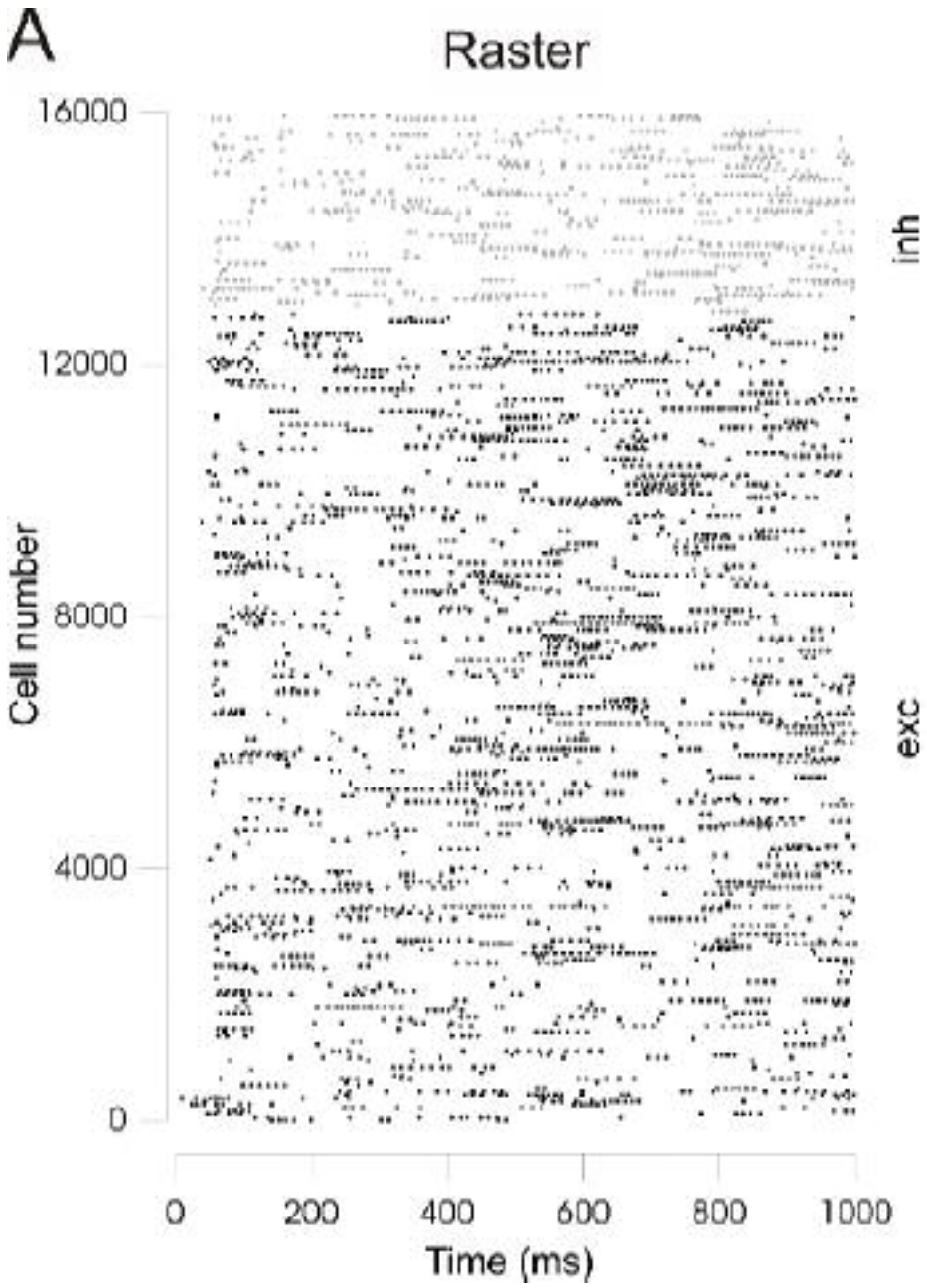
Mean-field model of AI states

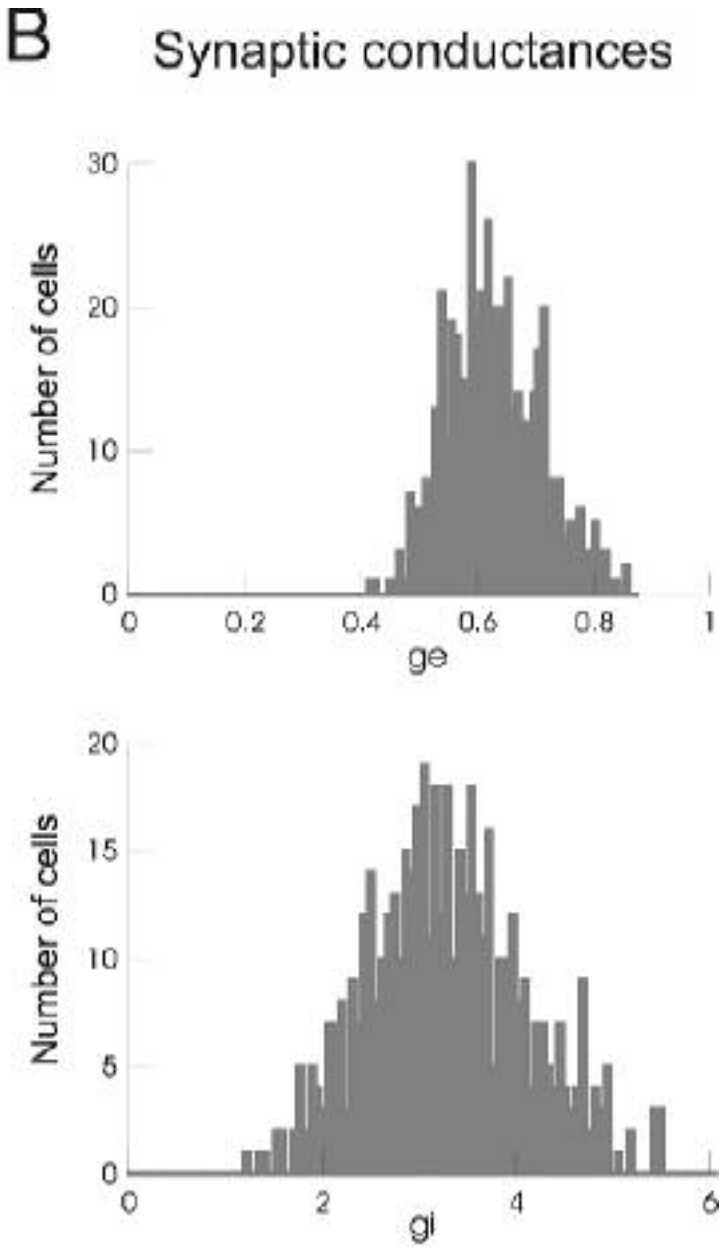
Conductance maps



Network models with realistic conductance patterns

Best model: N=16000, 320 synapses/neuron

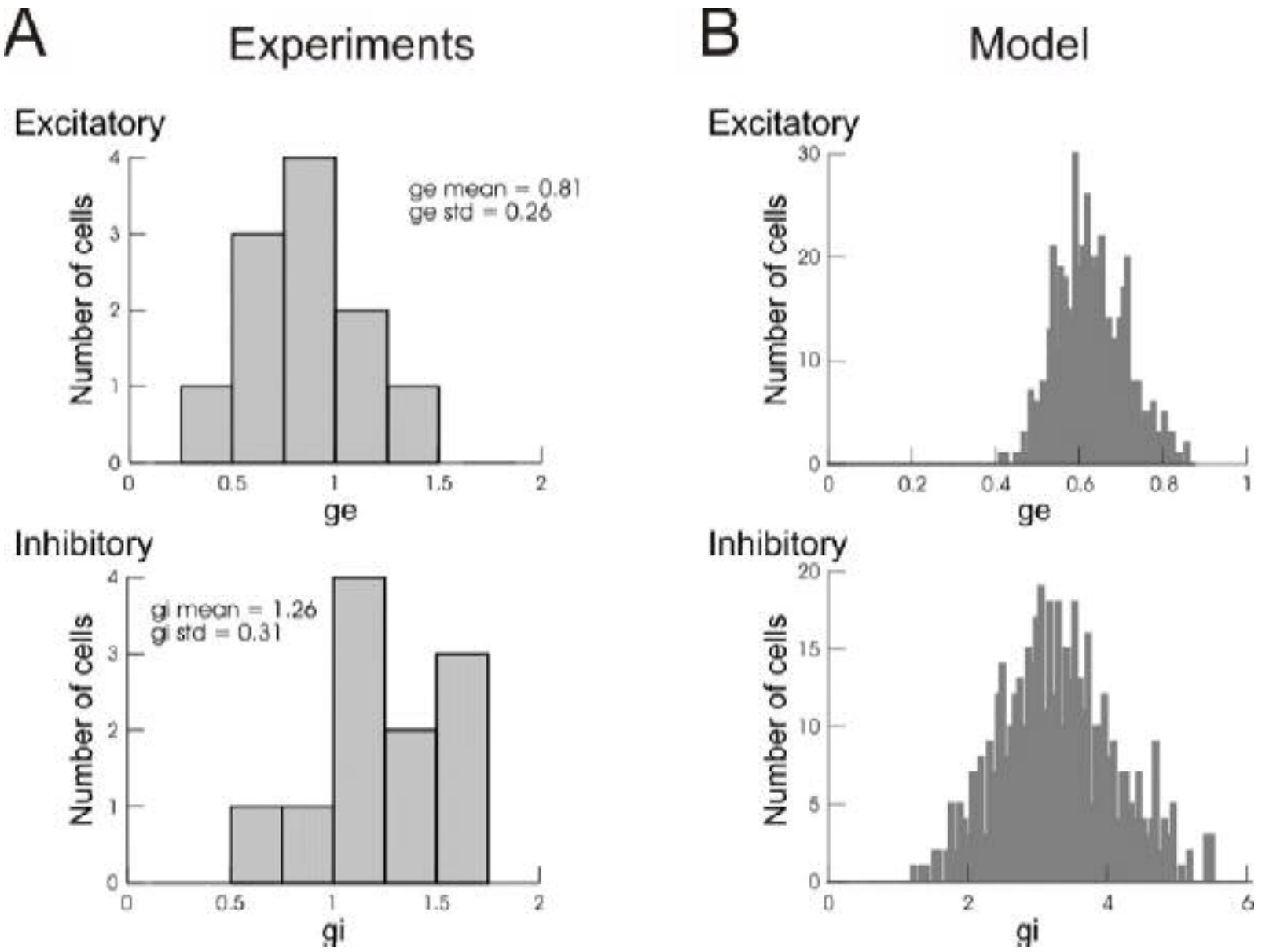




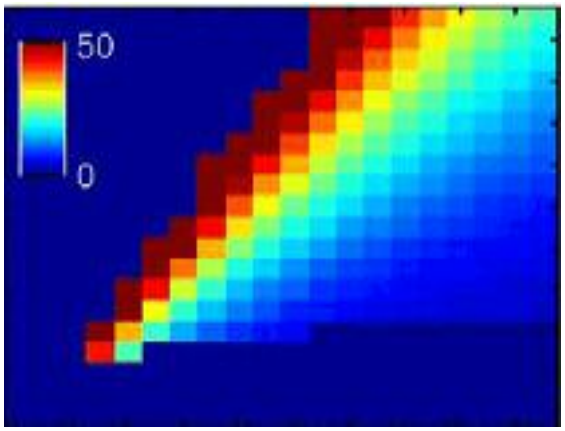
Vogels & Abbott, *J Neurosci*, 2005

Network models with realistic conductance patterns

Comparison



Impact of network activity on populations of neurons

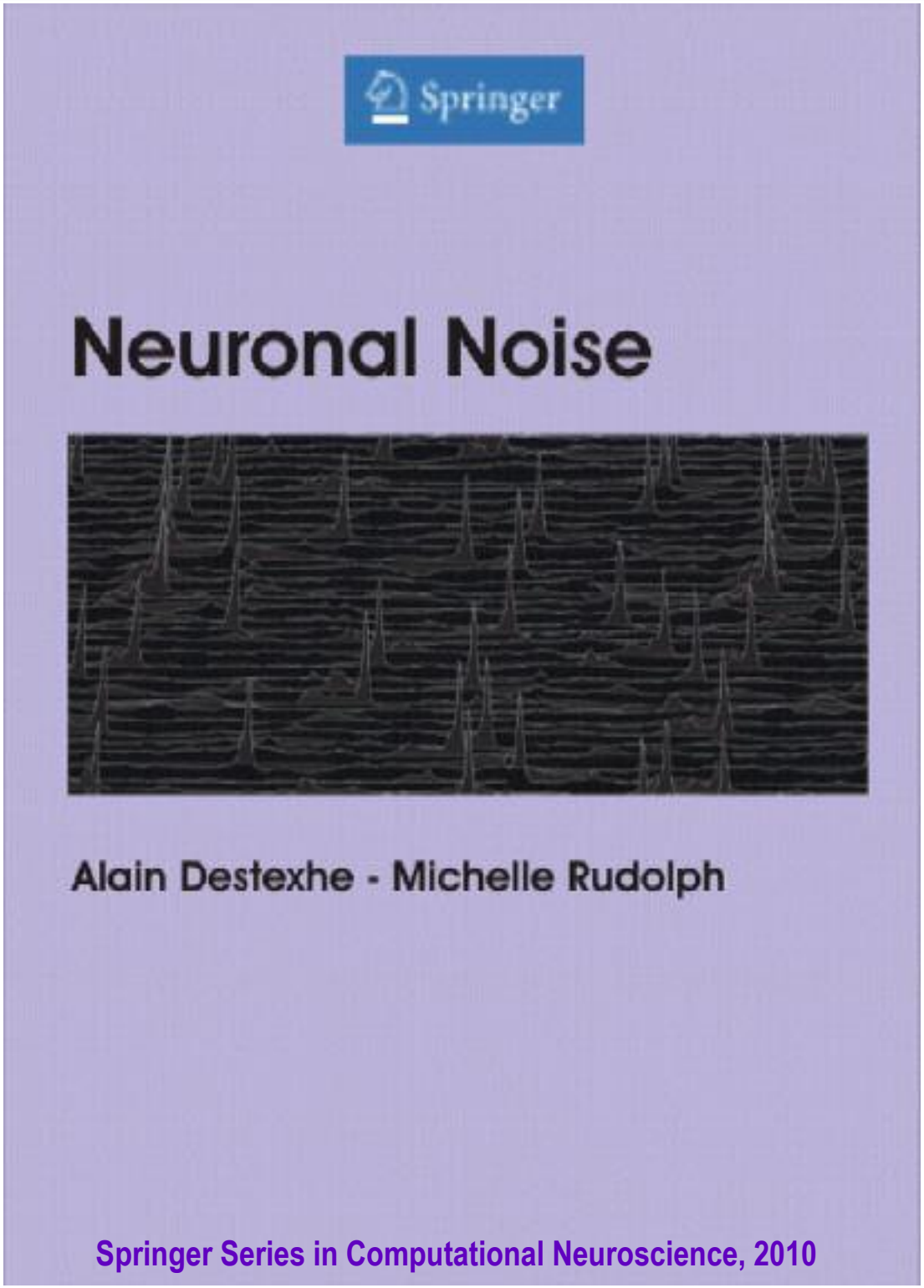


Conclusions

- Randomly connected networks of IF neurons can easily generate dynamics which reproduce experimental observations...
- ... except for conductances measurements!
- Mean-field models can be used to identify network configurations with correct conductance state

Thanks to the team...

http://cns.iaf.cnrs-gif.fr


Springer
Neuronal Noise
Alain Destexhe - Michelle Rudolph
Springer Series in Computational Neuroscience, 2010