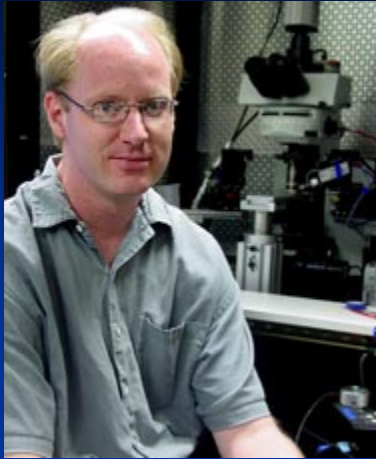


Reliability, *discriminability* and noise-induced synchrony in olfactory neurons

Roberto Fernández Galán, Bard Ermentrout & Nathaniel Urban

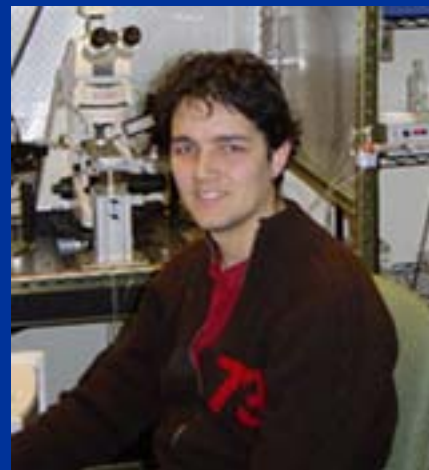




Nathan Urban,
Principal Investigator



Bard Ermentrout,
Professor of Mathematics



Nicolas Fourcaud-Trocmé,
Postdoc

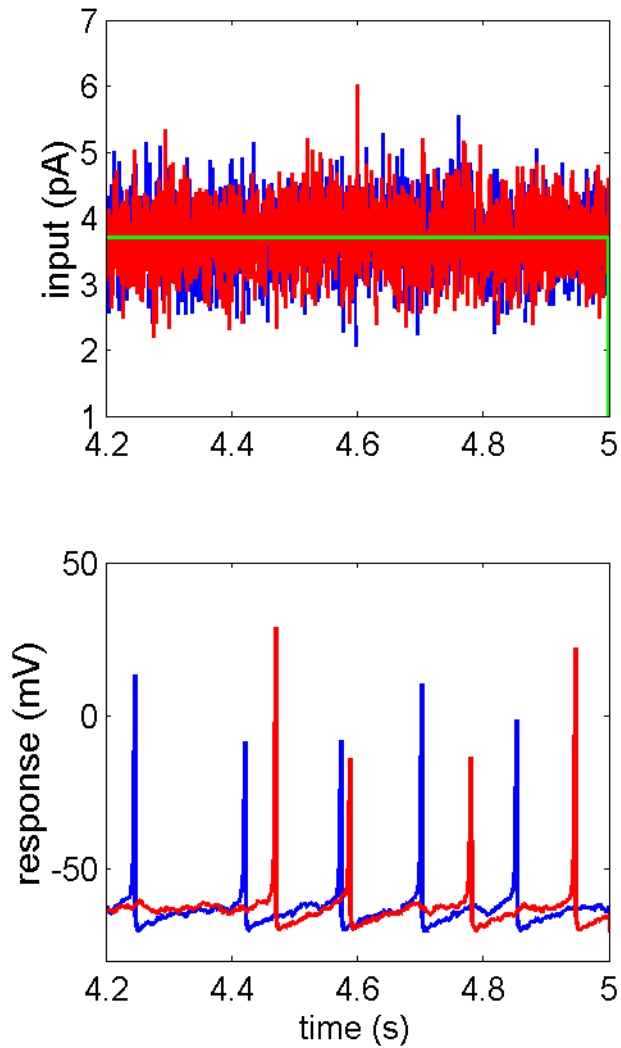
Neural reliability

- Sensory systems, both natural and artificial, must reliably respond to the same stimulus in different and variable environments.
- Stimulus transduction and coding of sensory information operate in low signal-to-noise regimes
- The understanding of the mechanisms for neural coding and information processing may inspire the design of artificial sensor technologies that optimally operate with high levels of background noise.

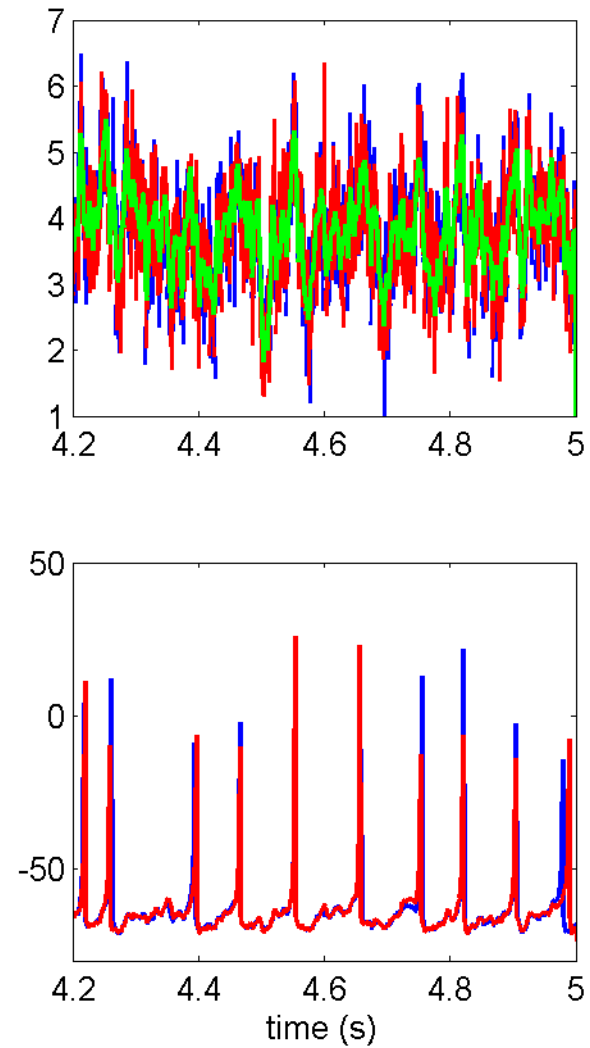
Neural reliability

- In the presence of background noise the neural response to a constant stimulus varies with repetitive stimulation...
- but the neural response to a fluctuating stimulus can be highly reliable! (Bryant & Segundo 1976; Mainen & Sejnowski 1995)
- There is no biophysical explanation for this phenomenon so far

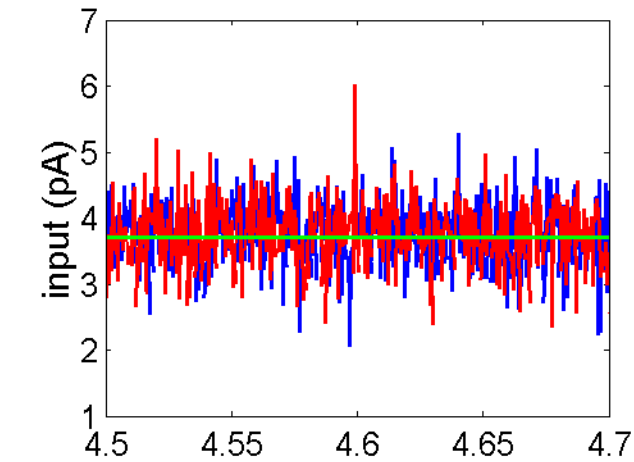
Constant input signal plus background noise



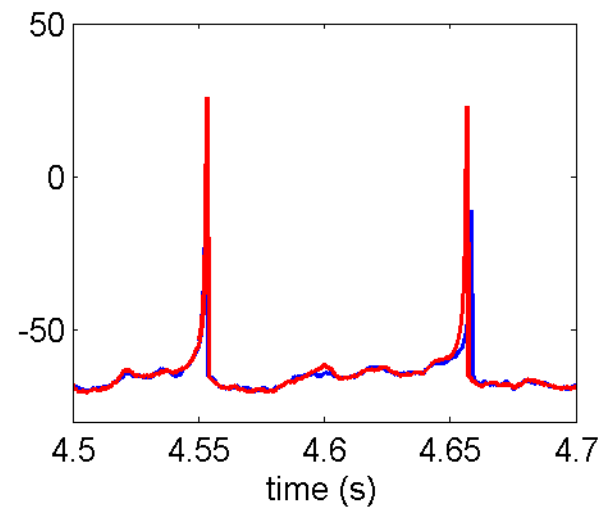
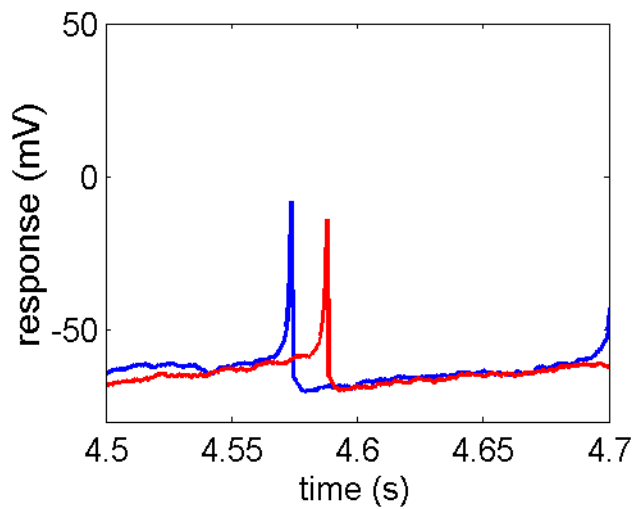
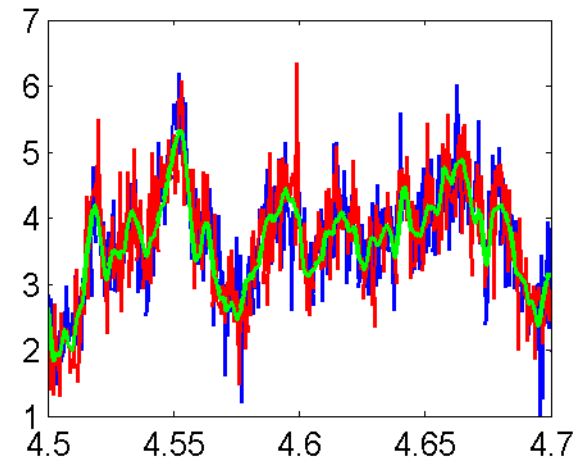
Fluctuating input signal plus background noise



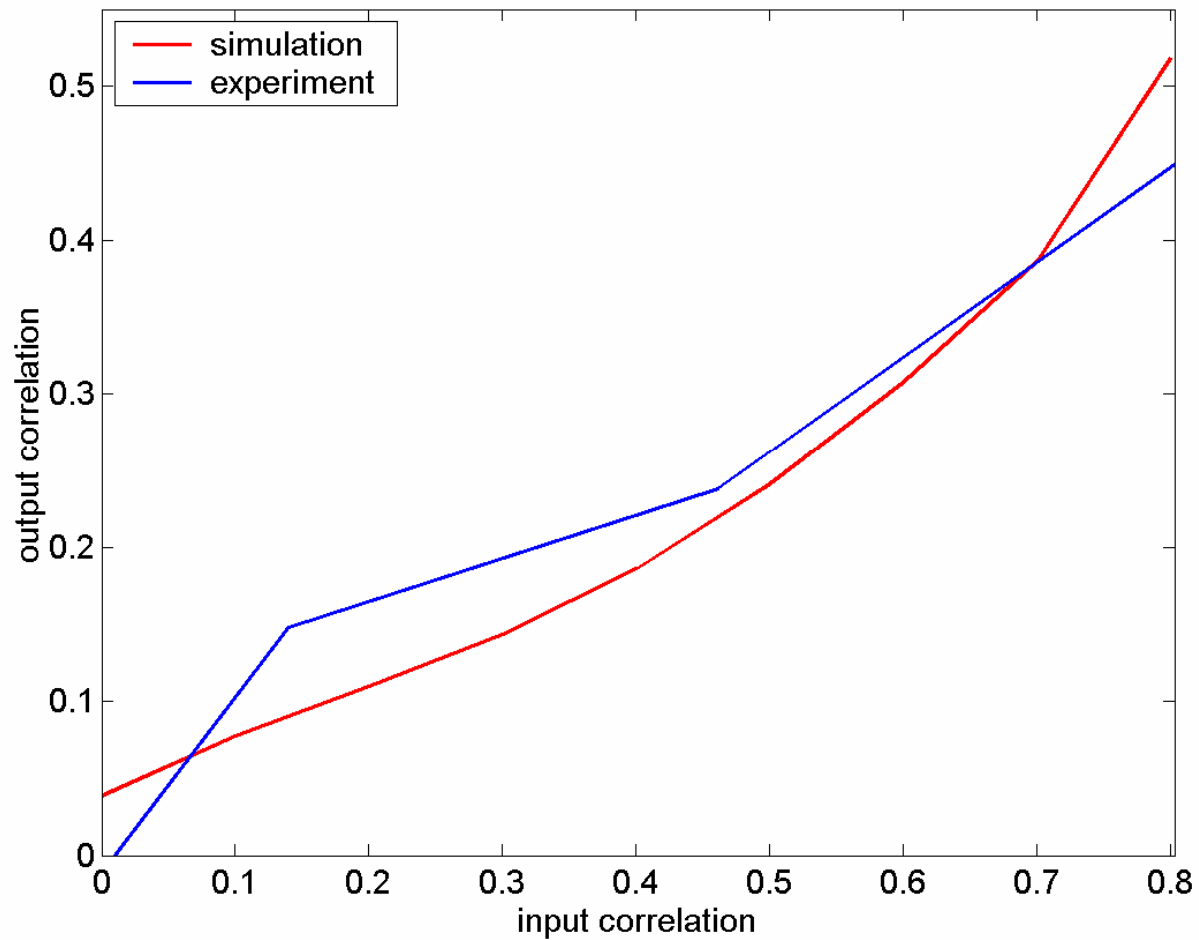
Constant input signal
plus background noise



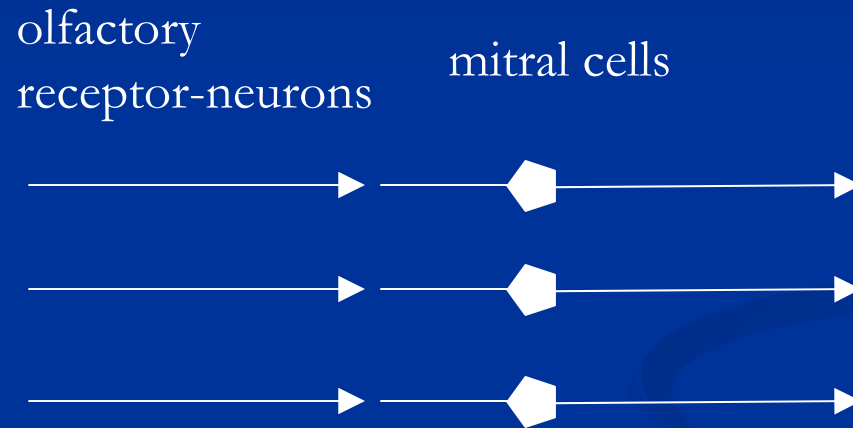
Fluctuating input signal
plus background noise



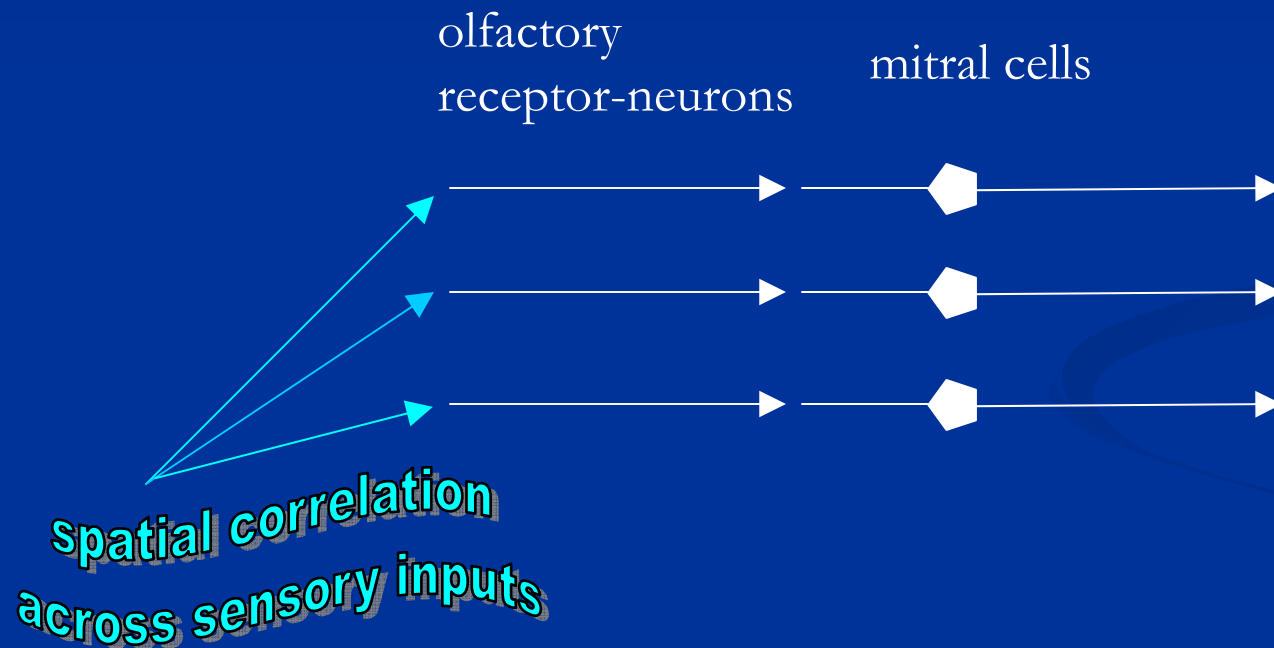
Discriminability



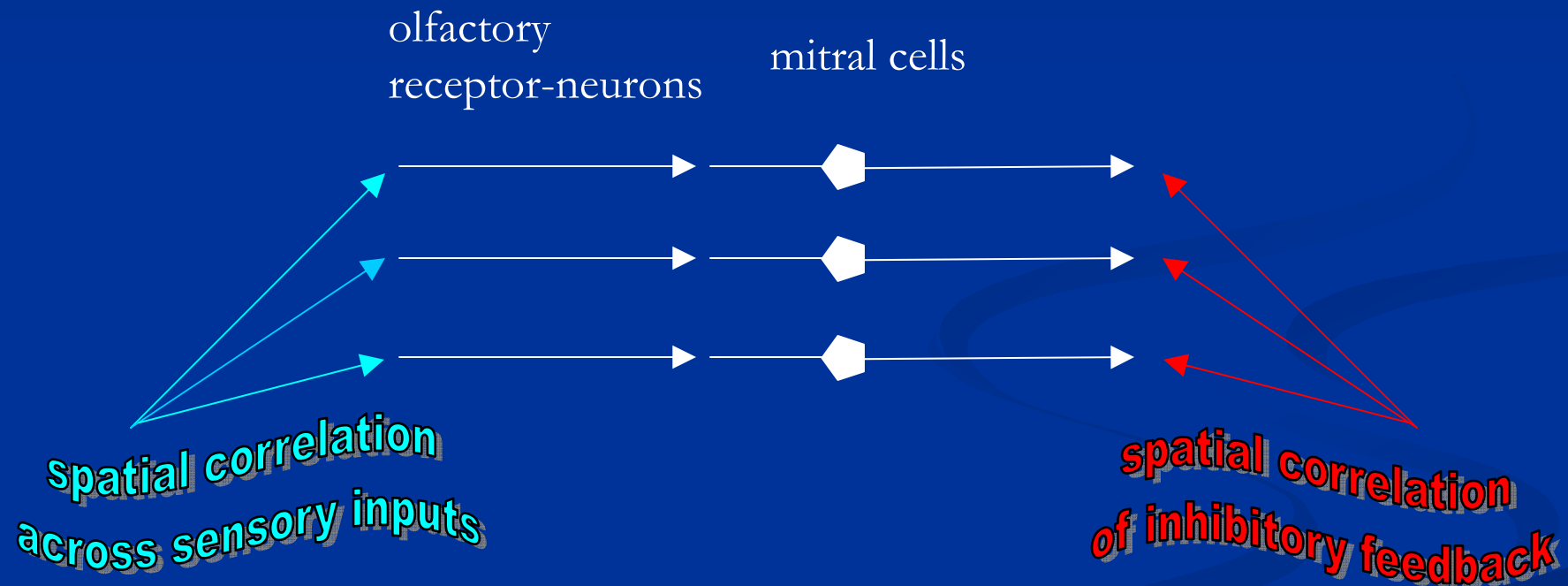
Stochastic synchronization in the olfactory system



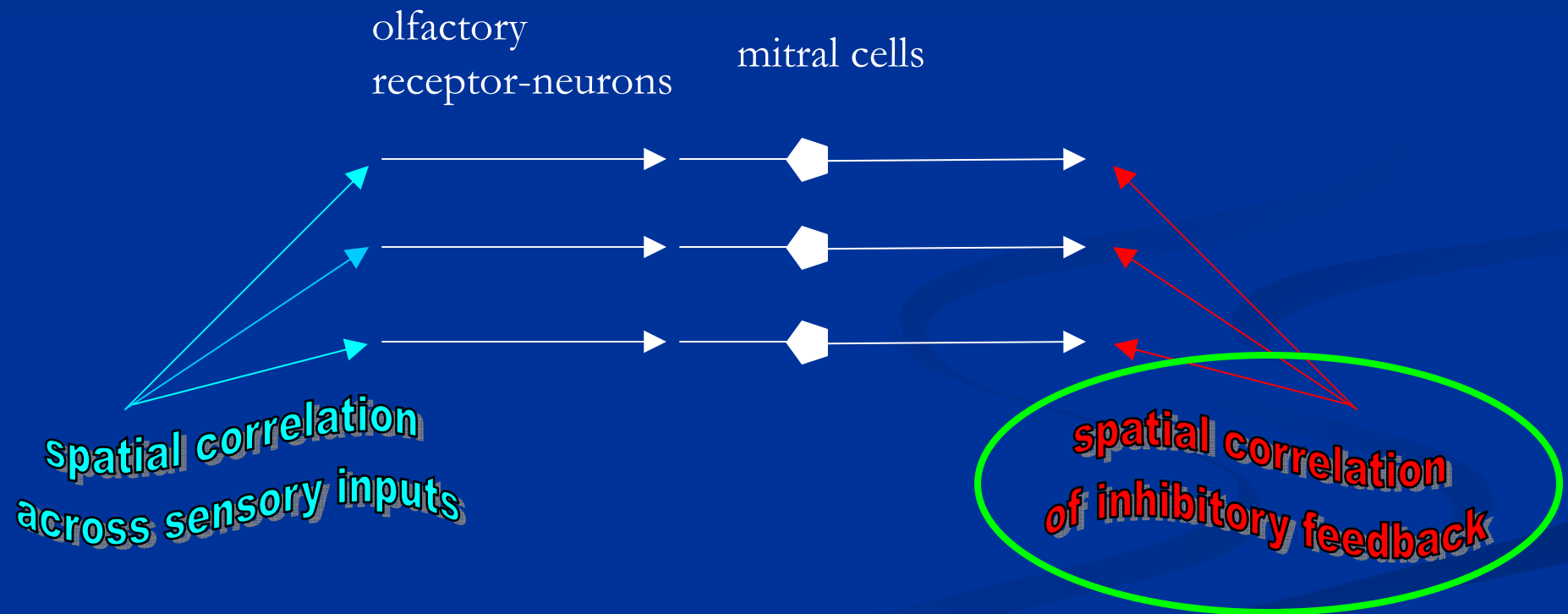
Stochastic synchronization in the olfactory system



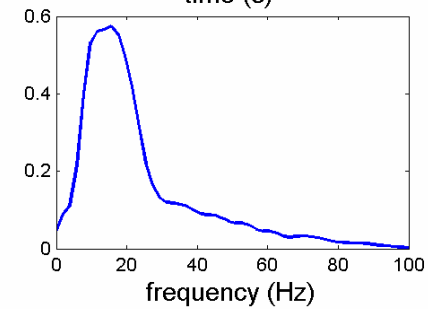
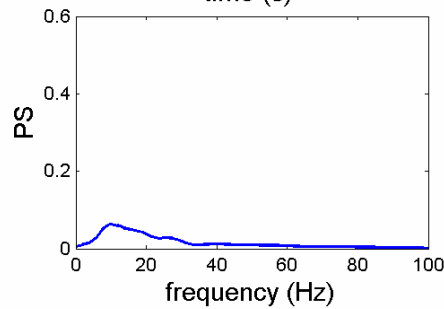
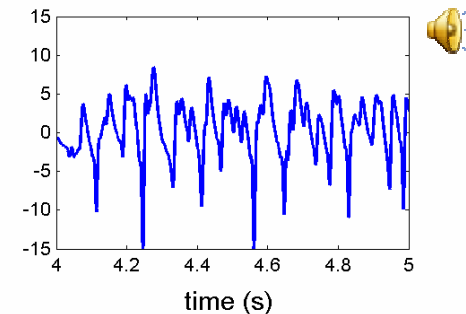
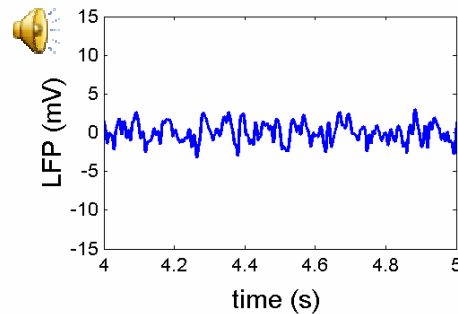
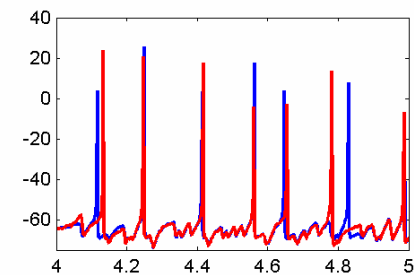
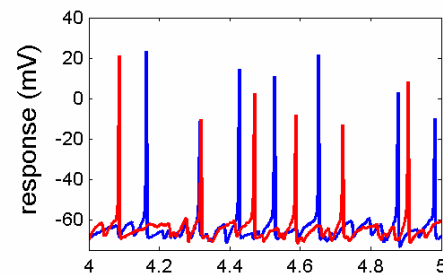
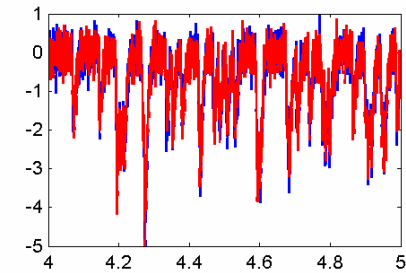
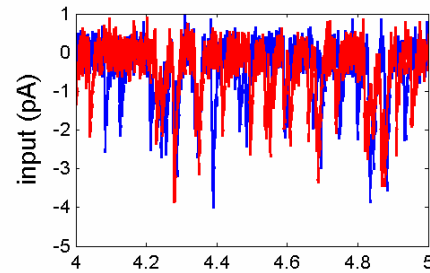
Stochastic synchronization in the olfactory system



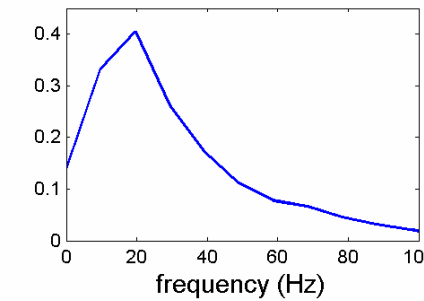
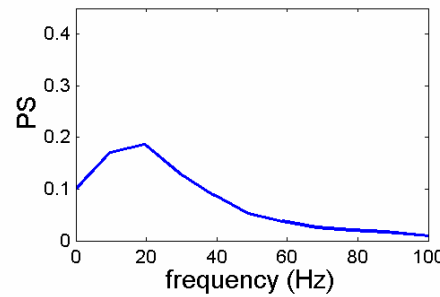
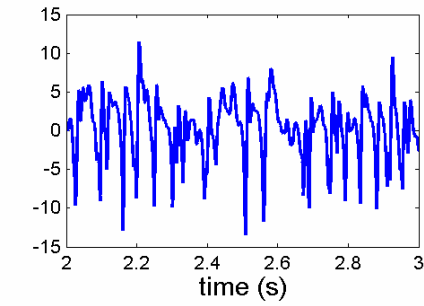
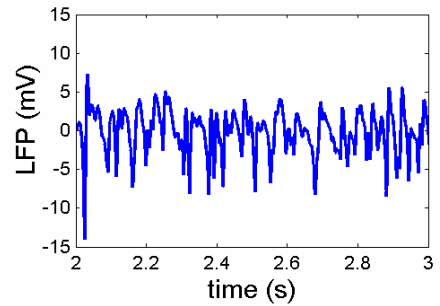
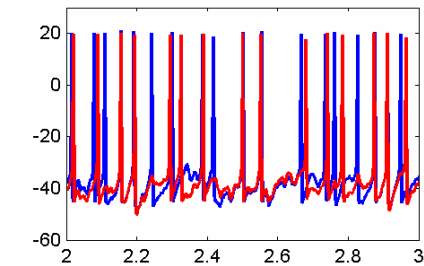
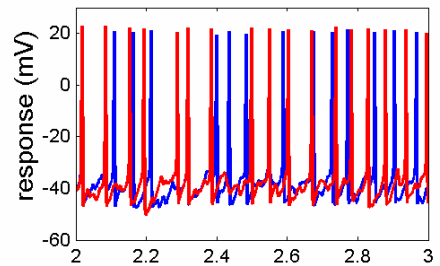
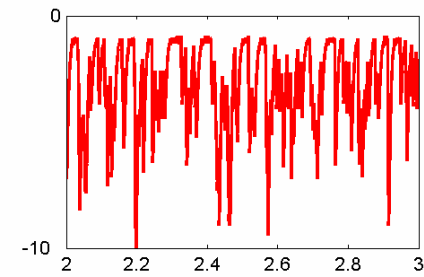
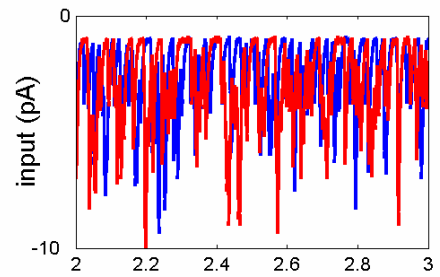
Stochastic synchronization in the olfactory system



Reliability, *discriminability*,
and stochastic synchrony
(computer simulations)



Reliability, *discriminability*,
and stochastic synchrony
(experiments)



Optimizing the device's design

General single-neuron model (e.g. Hodgkin-Huxley)

$$\frac{d\vec{x}}{dt} = F(\vec{x}) + I_0 + I(t)$$



Linearization
around a steady state

$$\frac{d\vec{u}}{dt} = L\vec{u} + I(t)$$



Fourier transform
(frequency domain)

$$u_1(\omega) = Z(\omega)I(\omega)$$

$|Z(\omega)|^2$ monotonously
decreasing function



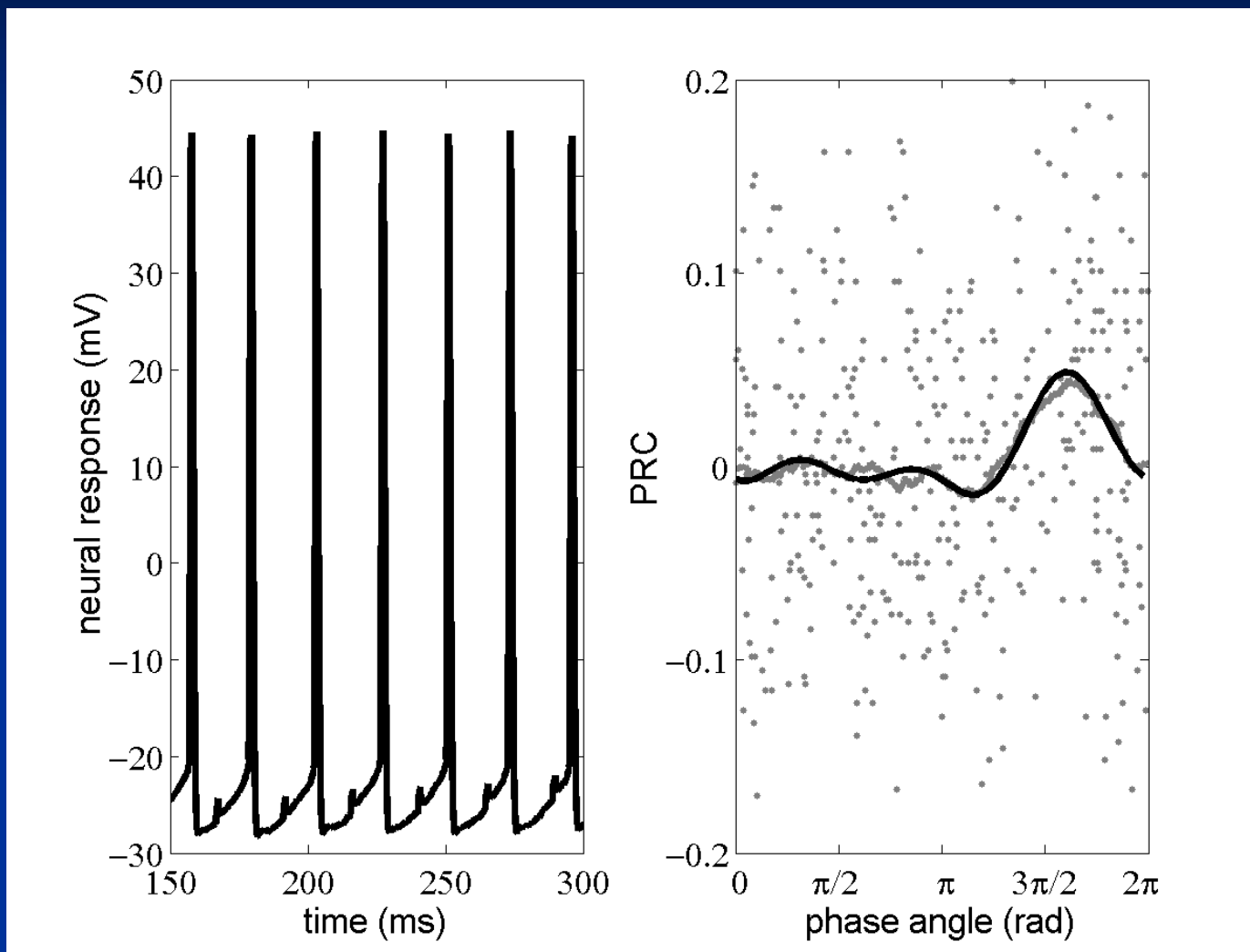
Low-pass filter, type I or
INTEGRATOR

$|Z(\omega)|^2$ function with a peak



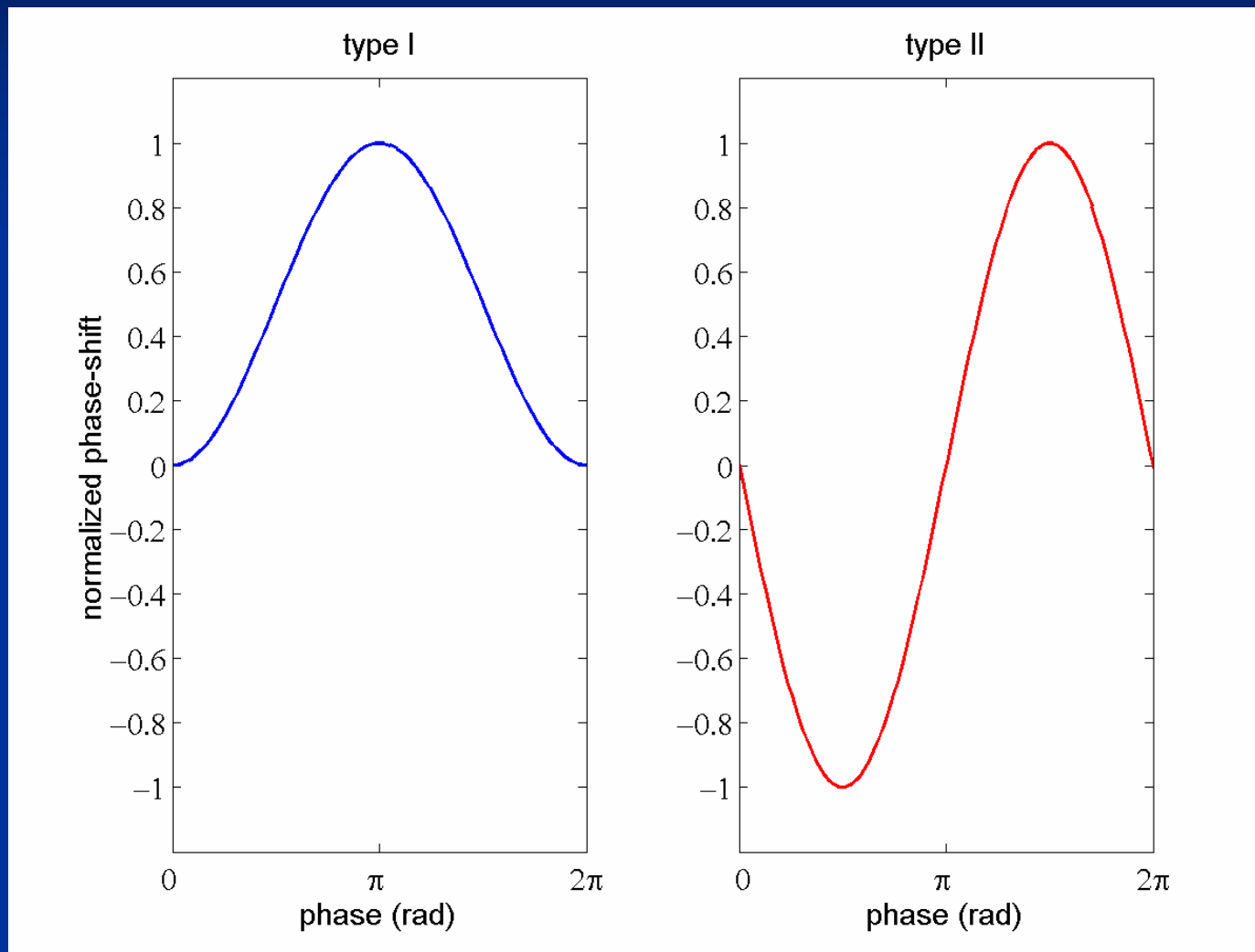
Band-pass filter, type II or
RESONATOR

Phase-response curves in real neurons

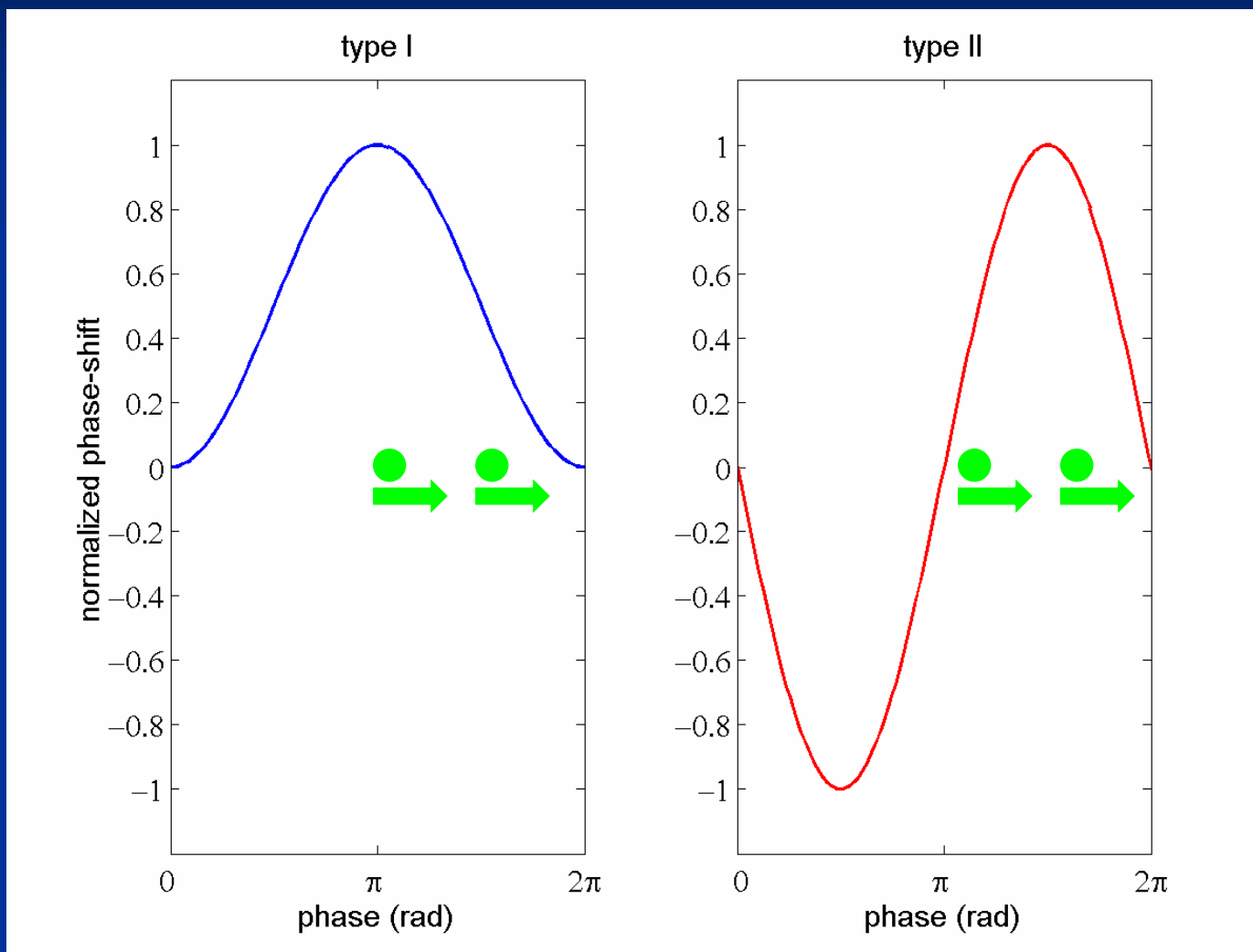


Galán et al (2005) Phys. Rev. Lett.

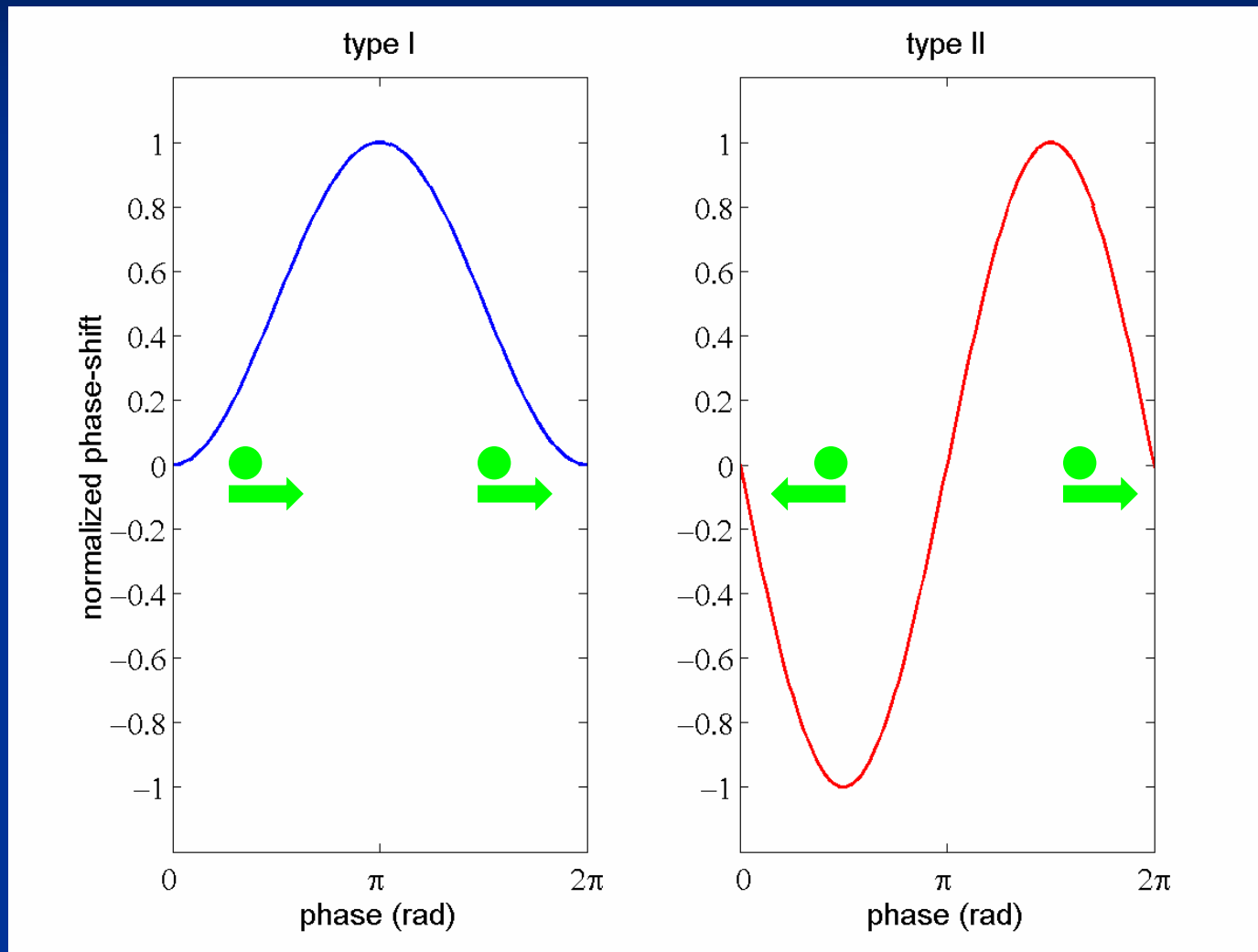
Optimizing the device's design



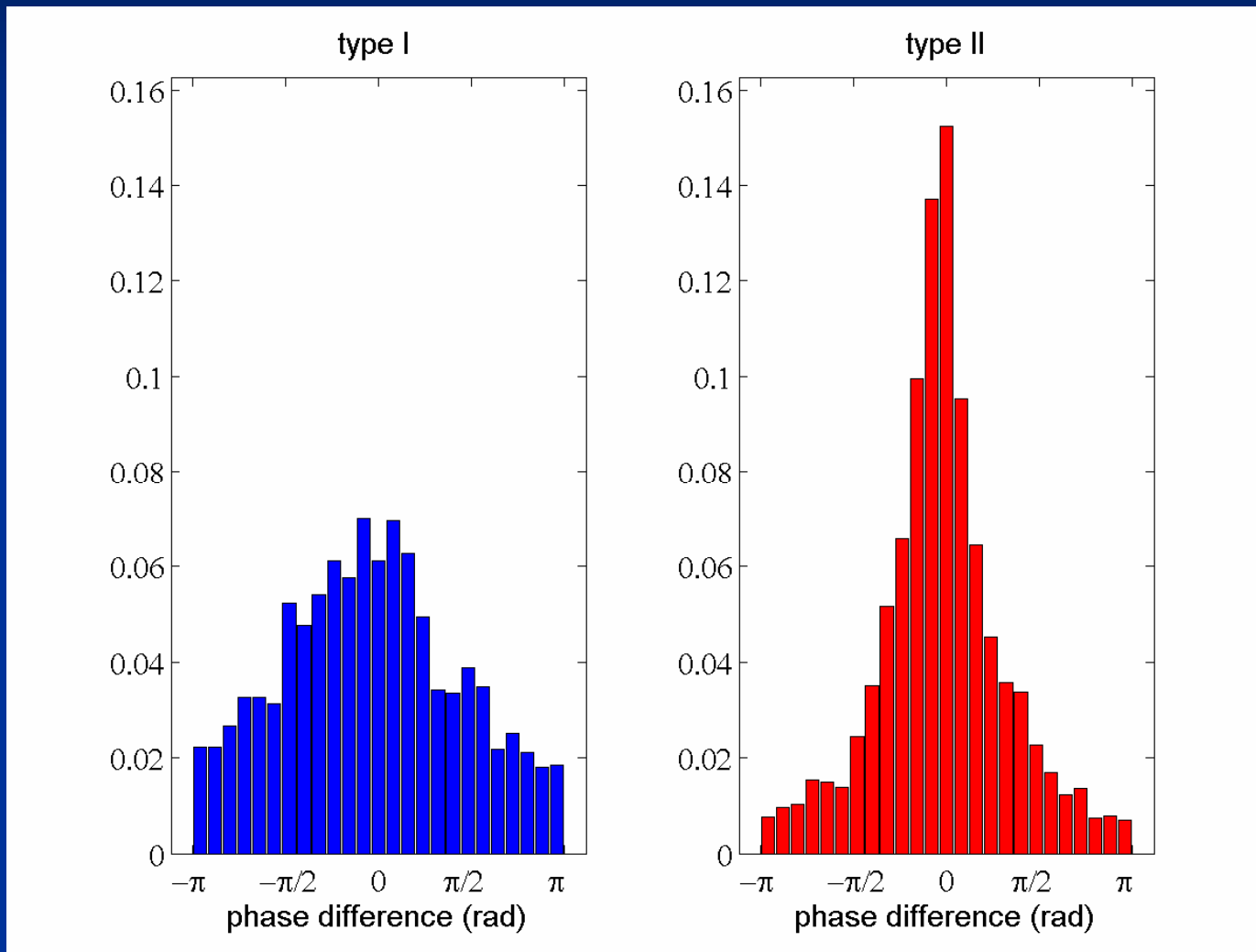
Optimizing the device's design



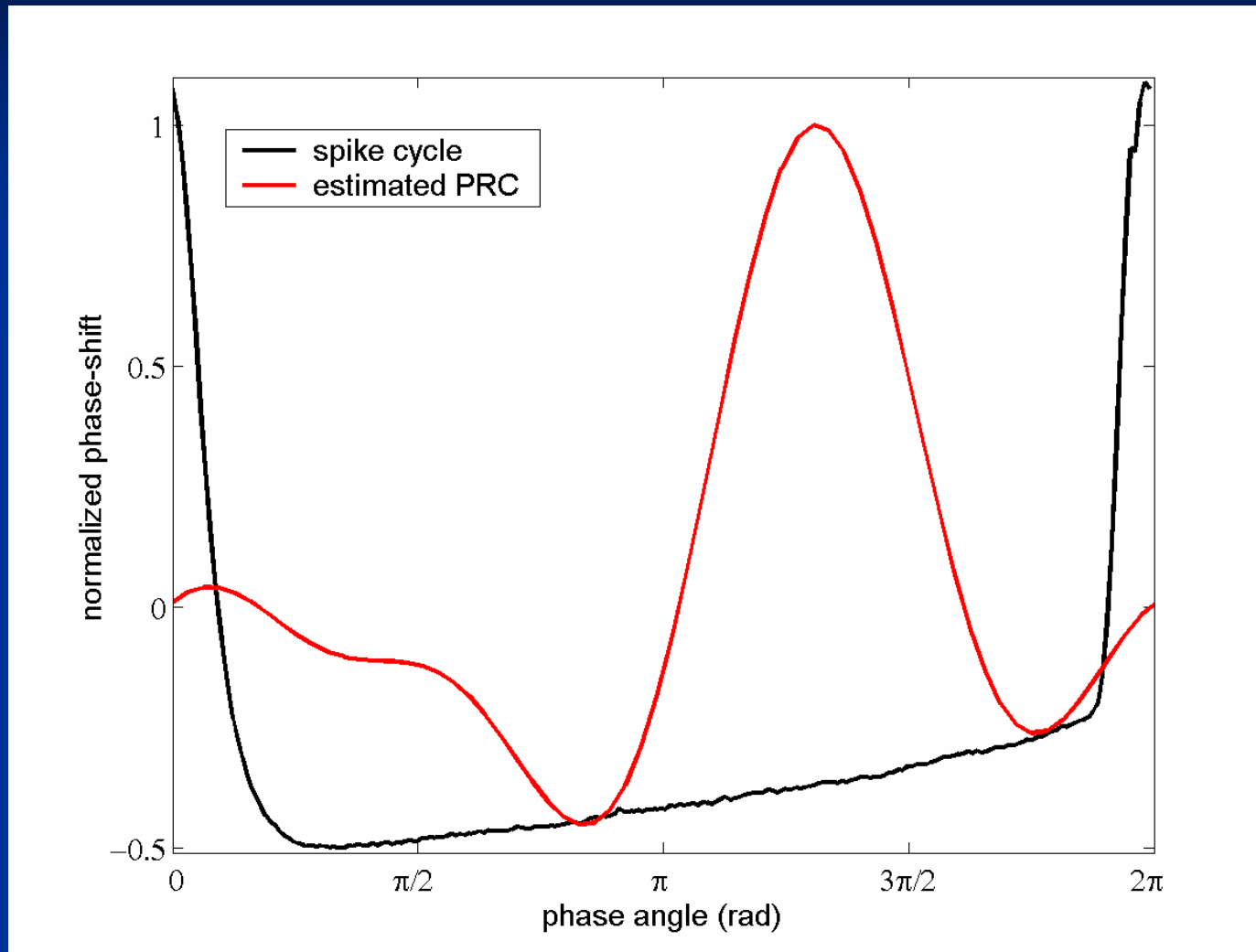
Optimizing the device's design



Optimizing the device's design



Phase-response in a mitral cell



Galán et al (2005) Phys. Rev. Lett.

Conclusions

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- Real neurons, as any device with a resetting threshold, reliably respond to fluctuating inputs in the presence of background noise

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- Olfactory neurons generate similar responses to similar fluctuating stimuli
- Correlated fluctuating inputs induce coherent oscillations in assemblies of olfactory neurons
- Resonators are better suited for a hardware implementation of artificial devices with a resetting threshold than are integrators

Thanks for your attention

www.andrew.cmu.edu/user/rfgalan/home.htm