Week 6 – part 1 : Escape noise

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Neuronal Dynamics:
Computational Neuroscience of Single Neurons

Week 6 – Noise models:
Escape noise

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6.1 Escape noise
- stochastic intensity and point process

6.2 Interspike interval distribution
- Time-dependend renewal process
- Firing probability in discrete time

6.3 Likelihood of a spike train
- likelihood function

6.4 Comparison of noise models
- escape noise vs. diffusive noise

6.5. Rate code vs. Temporal Code
- timing codes
- stochastic resonance

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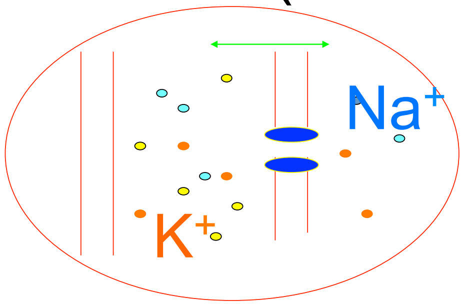
Neuronal Dynamics – Review: Sources of Variability

- Intrinsic noise (ion channels)

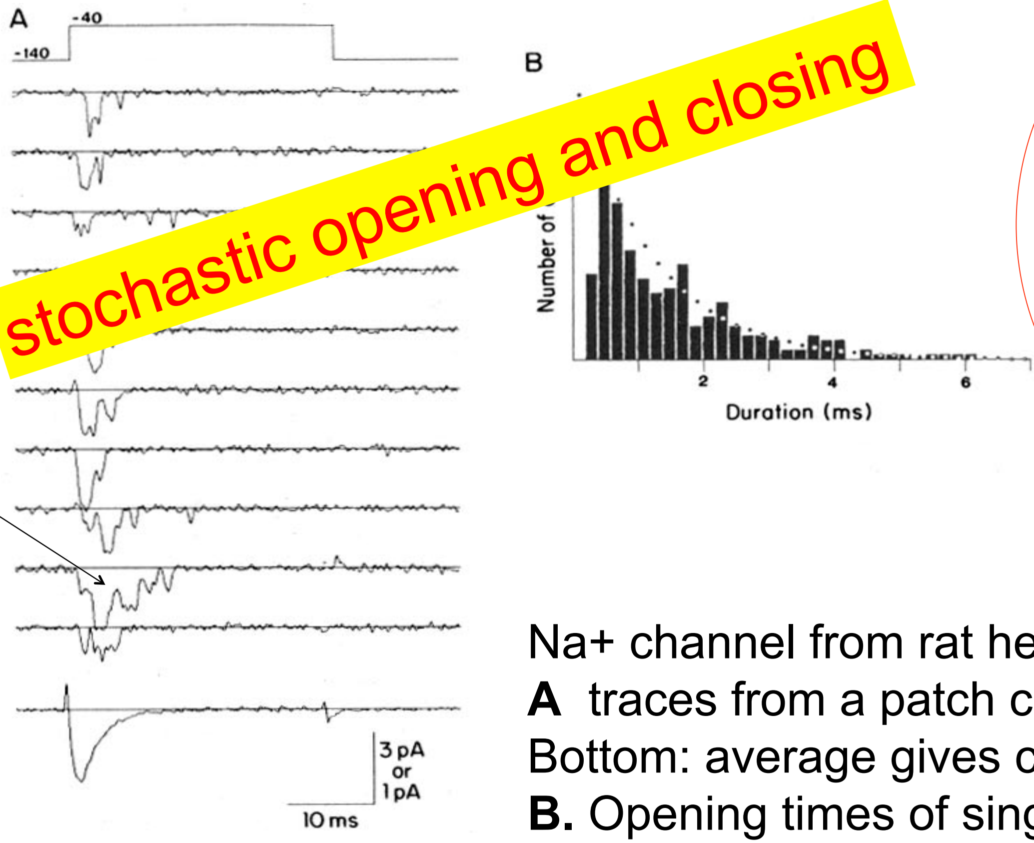


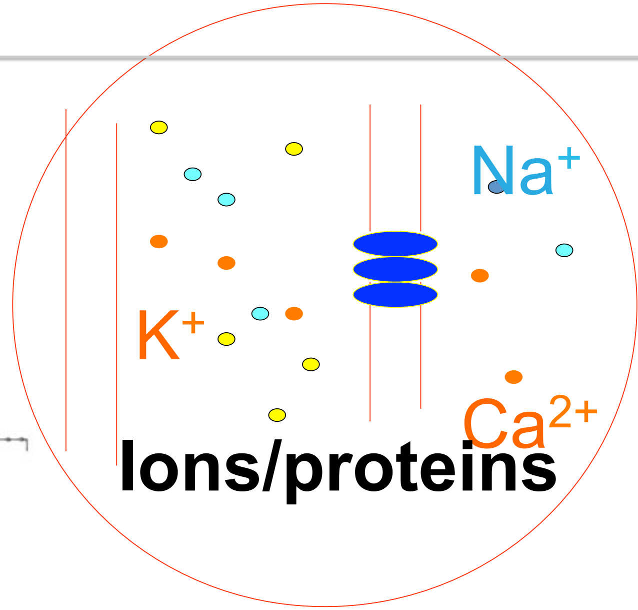
-Finite number of channels
-Finite temperature

Review from 2.5 Ion channels

stochastic opening and closing

Steps:
Different number of channels

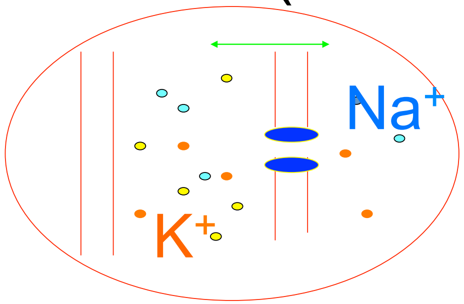




Na+ channel from rat heart *(Patlak and Ortiz 1985)*
A traces from a patch containing several channels.
Bottom: average gives current time course.
B. Opening times of single channel events

Neuronal Dynamics – Review: Sources of Variability

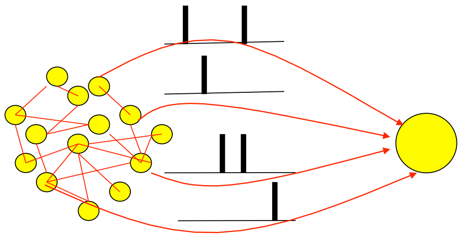
- Intrinsic noise (ion channels)



-Finite number of channels
-Finite temperature

small contribution!

-Network noise (background activity)



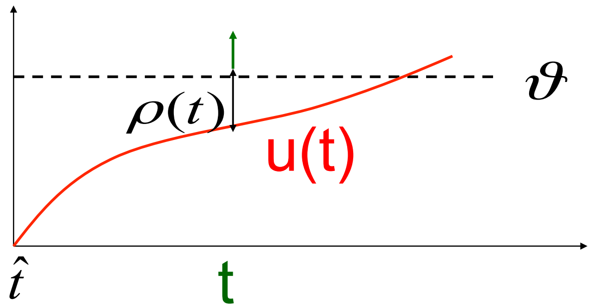
-Spike arrival from other neurons
-Beyond control of experimentalist

Noise models?

big contribution!

Noise models

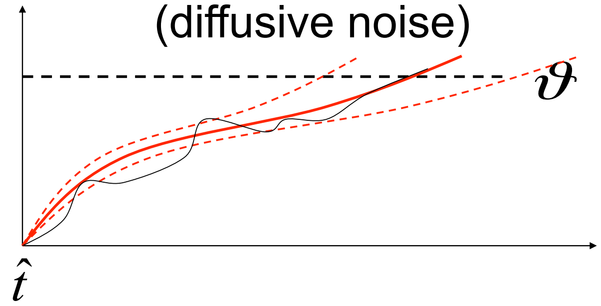
escape process,
stochastic intensity



escape rate

$$\rho(t) = f(u(t) - \vartheta)$$

stochastic spike arrival
(diffusive noise)



noisy integration

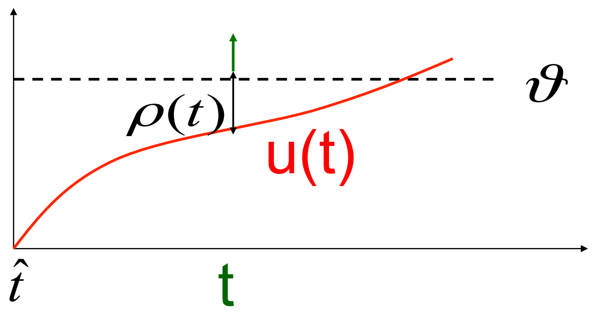
$$\tau \cdot \frac{du_i}{dt} = -u_i + RI + \xi(t)$$

Now:
Escape noise!

Relation between the two models:
later this week (lecture 6.4)

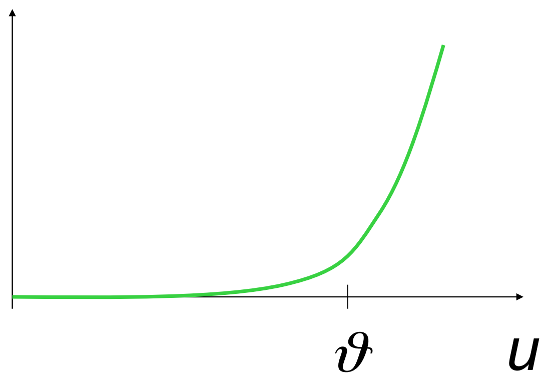
Neuronal Dynamics – 6.1 Escape noise

escape process



escape rate

$$\rho(t) = f(u(t) - \vartheta)$$



escape rate

$$\rho(t) = \frac{1}{\Delta} \exp\left(\frac{u(t) - \vartheta}{\Delta}\right)$$

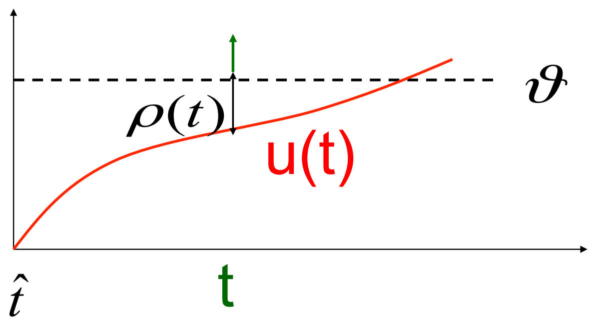
Example: leaky integrate-and-fire model

$$\tau \cdot \frac{d}{dt} u = -(u - u_{rest}) + RI(t)$$

$$\text{if spike at } t^f \Rightarrow u\left(t^f + \delta\right) = u_r$$

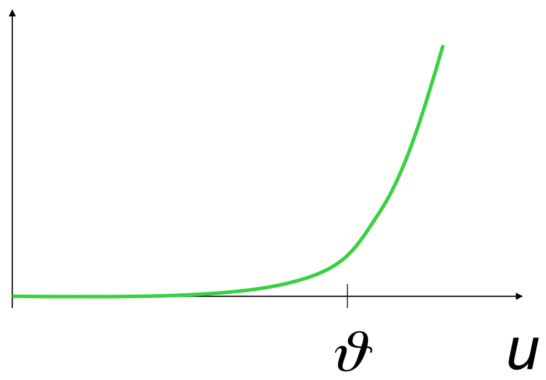
Neuronal Dynamics – 6.1 stochastic intensity

escape process



escape rate

$$\rho(t) = f(u(t) - \vartheta)$$



Escape rate = stochastic intensity of point process

$$\rho(t) = f(u(t))$$

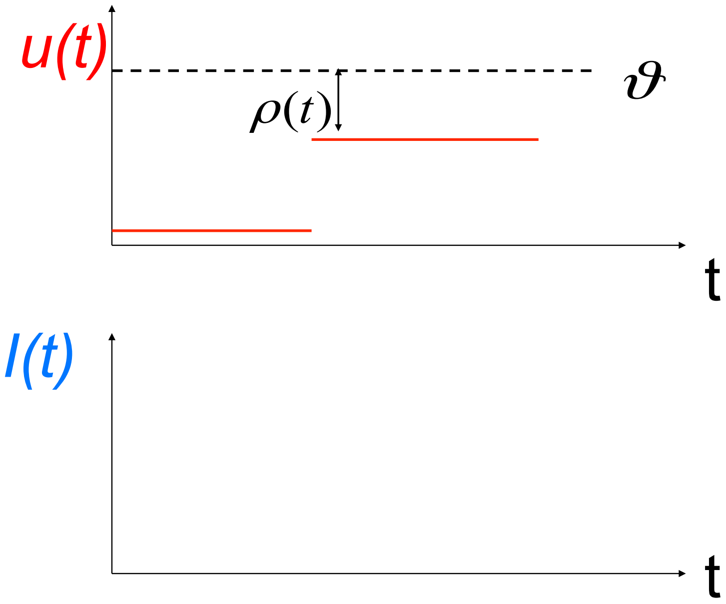
examples

$$\rho(t) = \frac{1}{\Delta}\exp\left(\frac{u(t) - \vartheta}{\Delta}\right)$$

$$\rho(t) =$$

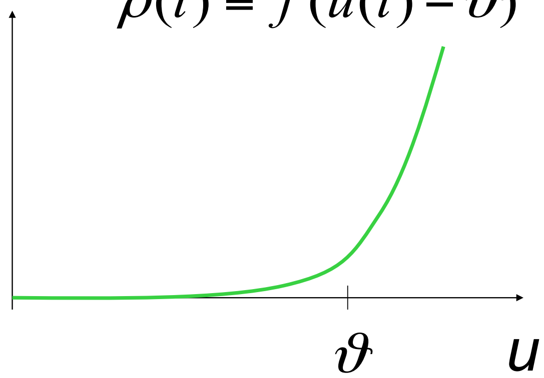
Neuronal Dynamics – 6.1 mean waiting time

$$\tau \cdot \frac{d}{dt} u = -(u - u_{rest}) + RI(t)$$



escape rate

$$\rho(t) = f(u(t) - \vartheta)$$

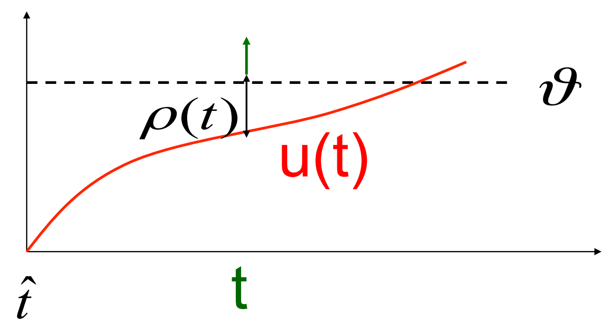


mean waiting time, after switch

Neuronal Dynamics – 6.1 escape noise/stochastic intensity

Escape rate = stochastic intensity
of point process

$$\rho(t) = f(u(t))$$



Neuronal Dynamics – Quiz 6.1.

Escape rate/stochastic intensity in neuron models

[ ] The escape rate of a neuron model has units one over time

[ ] The stochastic intensity of a point process has units one over time

[ ] For large voltages, the escape rate of a neuron model always saturates at some finite value

[ ] After a step in the membrane potential, the mean waiting time until a spike is fired is proportional to the escape rate

[ ] After a step in the membrane potential, the mean waiting time until a spike is fired is equal to the inverse of the escape rate

[ ] The stochastic intensity of a leaky integrate-and-fire model with reset only depends on the external input current but not on the time of the last reset

[ ] The stochastic intensity of a leaky integrate-and-fire model with reset depends on the external input current AND on the time of the last reset