Week 5 – part 4 :Stochastic spike arrival

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Neuronal Dynamics:
Computational Neuroscience of Single Neurons

Week 5 – Variability and Noise:
The question of the neural code

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Week 5 – part 4 :Stochastic spike arrival

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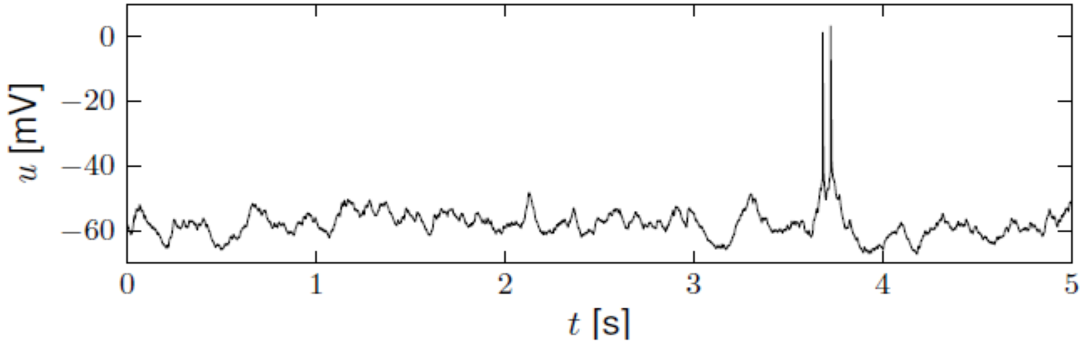
Neuronal Dynamics – 5.4 Variability in vivo

Spontaneous activity *in vivo*

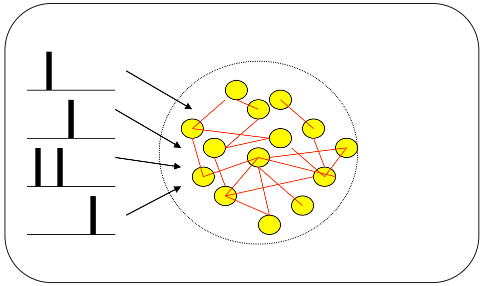
Variability
of membrane potential?

awake mouse, freely whisking,

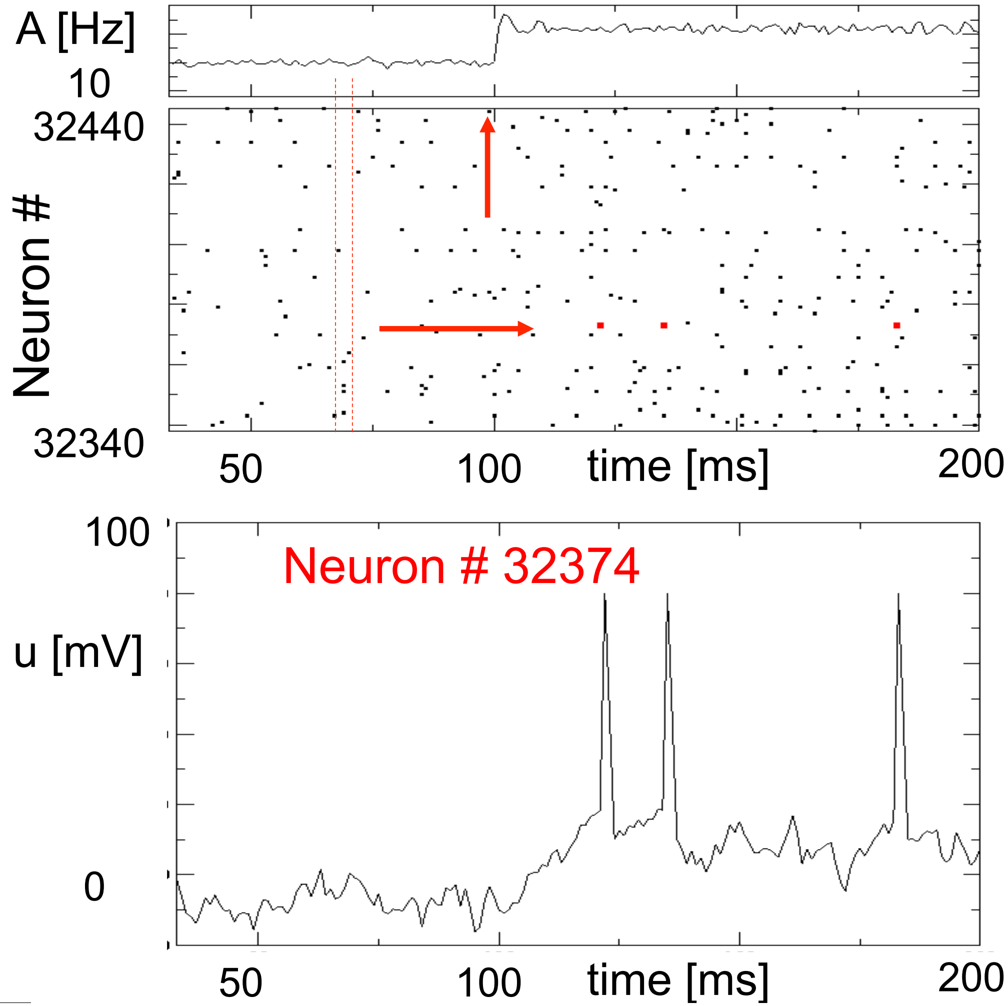


Crochet et al., 2011

Random firing in a population of LIF neurons

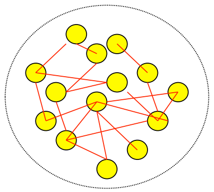


input {low rate
high rate



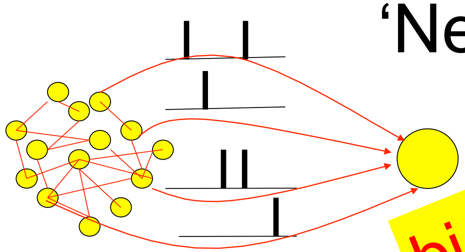
Population
- 50 000 neurons
- 20 percent inhibitory
- **randomly connected**

Neuronal Dynamics – 5.4 Membrane potential fluctuations



from neuron's point
of view:
stochastic spike arrival

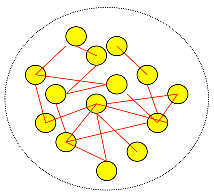
Pull out one neuron



'Network noise'

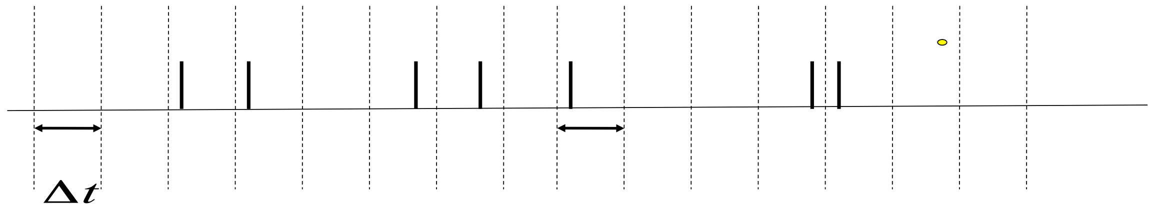
big contribution!

Neuronal Dynamics – 5.4. Stochastic Spike Arrival



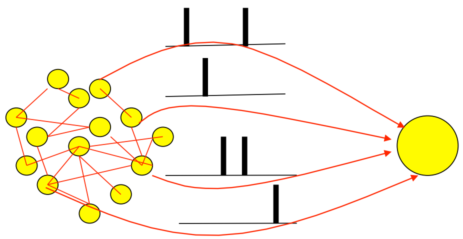
math detour now!

Total spike train of K presynaptic neurons



spike train

Pull out one neuron



Probability of spike arrival:

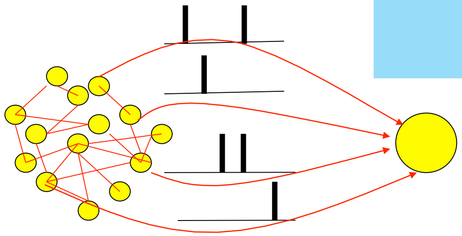
$$P_F = K\rho_0\,\Delta t$$

Take $\Delta t \to 0$

expectation

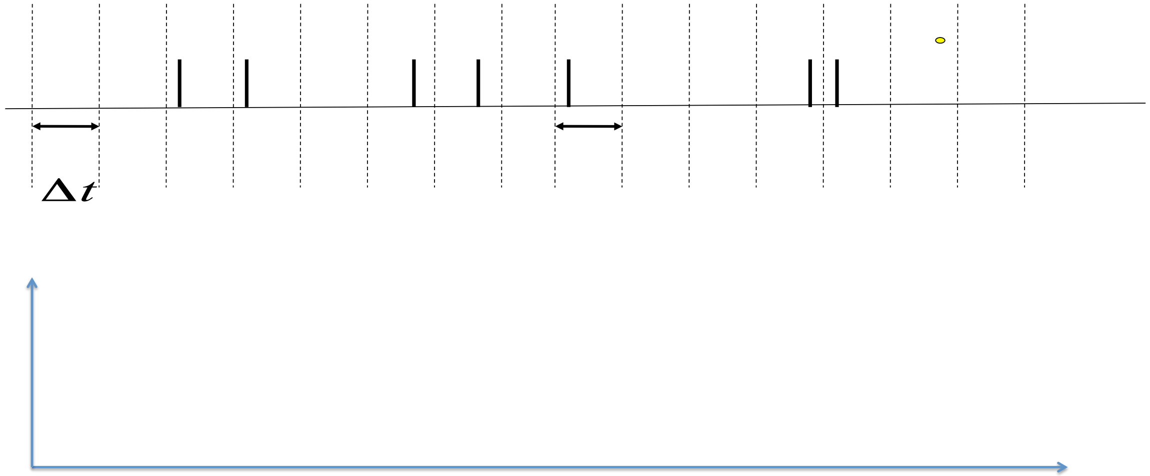
$$S(t) = \sum_{k=1}^{K}\sum_{f}\delta(t - t_k^f)$$

Neuronal Dynamics – 5.4. Fluctuation of input current

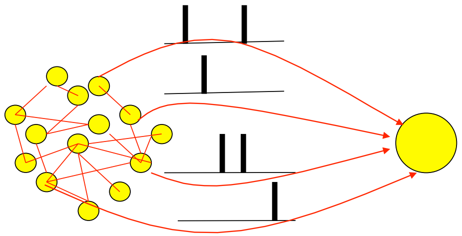


math detour now!

Total spike train of K presynaptic neurons



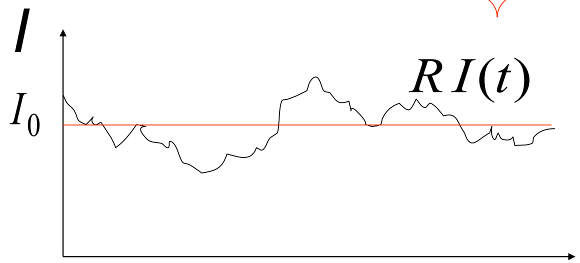
Neuronal Dynamics – 5.4. Fluctuation of current/potential



Synaptic current pulses of shape α

$$RI^{syn}(t) = \sum_k w_k \sum_f \alpha(t - t_k^f)$$

EPSC

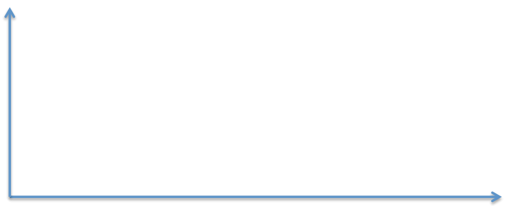


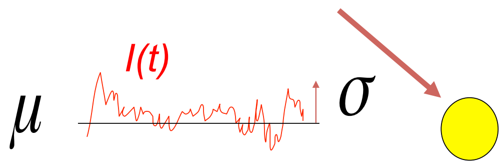
Passive membrane

$$\tau \frac{d}{dt} u = -(u - u_{rest}) \quad + R\,I^{syn}(t)$$

$$I^{syn}(t) = I_0 + I^{fluct}(t)$$

→ Fluctuating potential

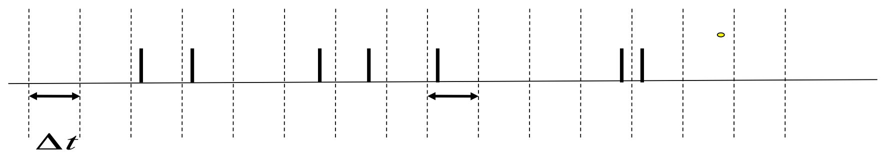




Fluctuating input current

Neuronal Dynamics – 5.4. Calculating the mean

$$RI^{syn}(t) = \sum_k w_k \sum_f \alpha(t - t_k^f)$$



$$I^{syn}(t) = \tfrac{1}{R} \sum_k w_k \sum_f \int dt' \alpha(t-t')\,\delta(t' - t_k^f)$$

$$x(t) = \sum_f \int dt'\, f(t-t')\,\delta(t' - t_k^f)$$

mean: assume Poisson process

use for assignment/ homework!

$$I_0 = \langle I^{syn}(t) \rangle = \tfrac{1}{R} \sum_k w_k \int dt' \alpha(t-t') \Big\langle \sum$$

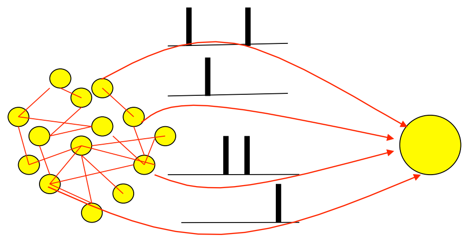
$$\langle x(t) \rangle = \int dt'\, f(t-t') \Big\langle \sum_f \delta(t' - t_k^f) \Big\rangle$$

$$I_0 = \tfrac{1}{R} \sum_k w_k \int dt' \alpha(t-t')\ \nu_k$$

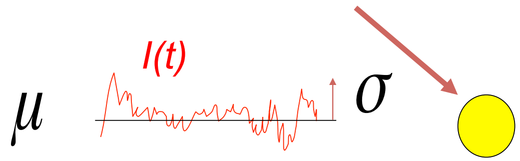
$$\langle x(t) \rangle = \int dt'\, f(t-t')\ \rho(t')$$

rate of inhomogeneous Poisson process

Neuronal Dynamics – 5.4. Fluctuation of current/potential

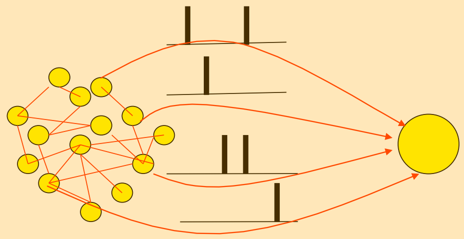


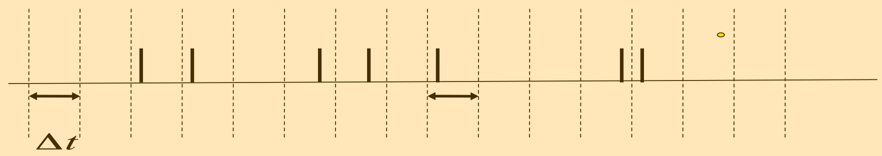
fluctuating input current



fluctuating potential

Neuronal Dynamics – Assignment/homework





$$u(t) = \sum_f \int dt' \, f(t-t') \, \delta(t' - t_k^f)$$

A leaky integrate-and-fire neuron receives stochastic spike arrival, described as a homogeneous Poisson process.

Calculate the mean membrane potential. To do so, use the above formula.