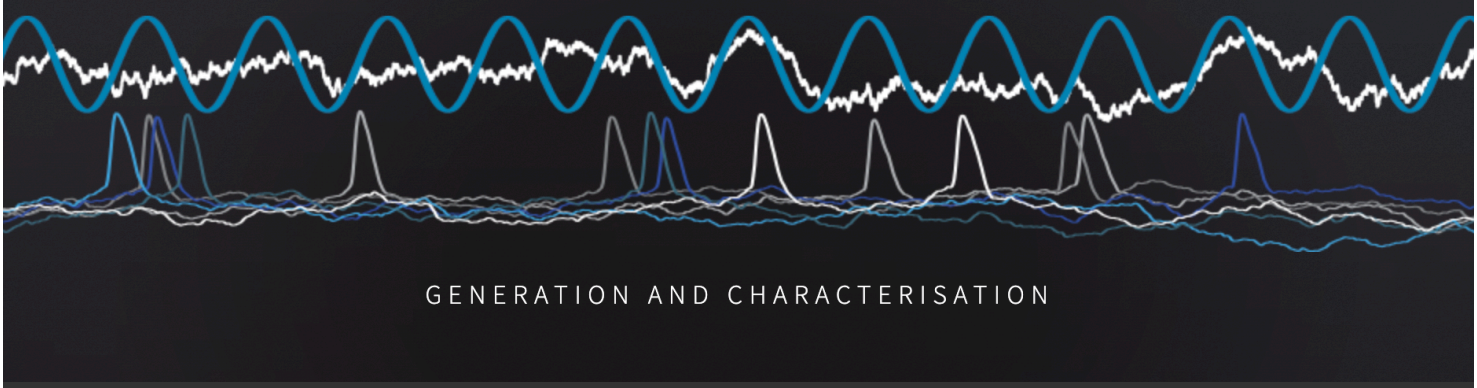
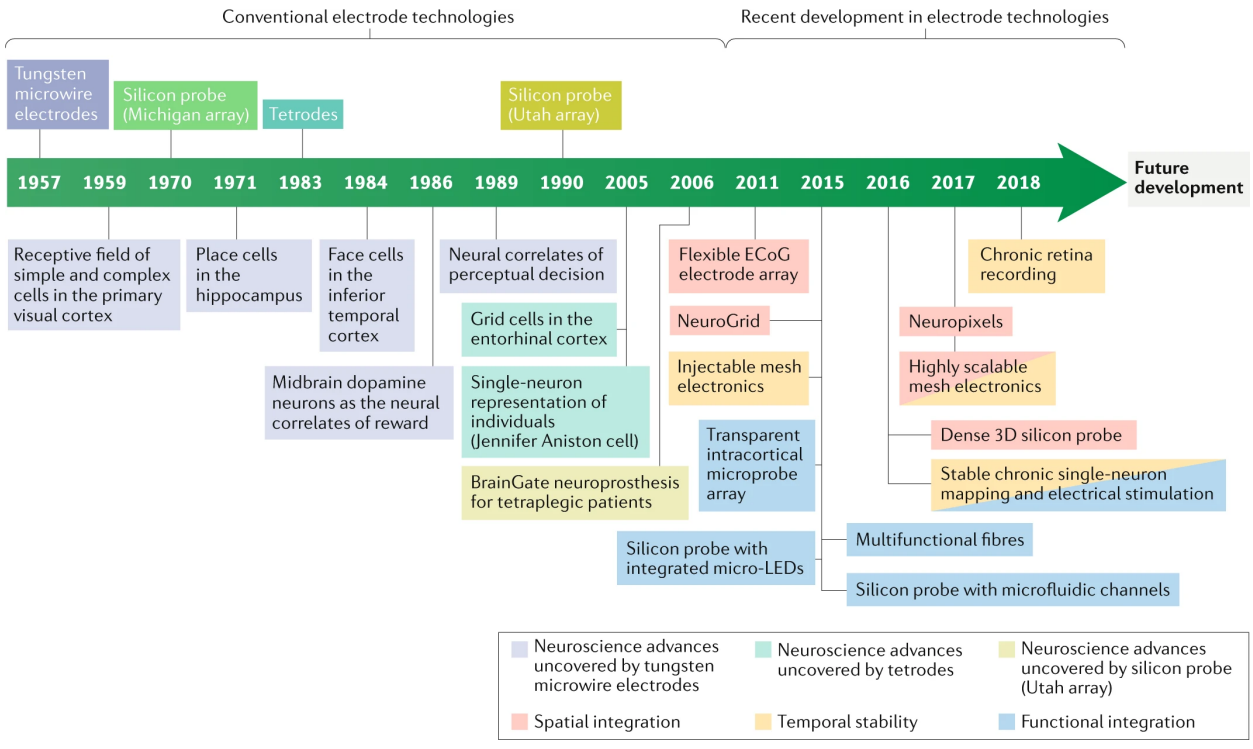
ELECTROPHYSIOLOGICAL SIGNALS



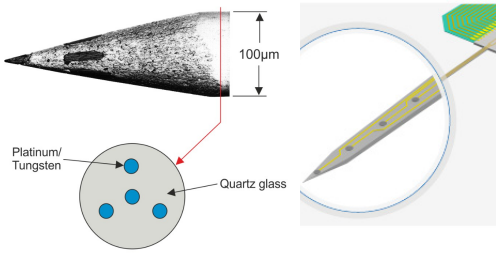
GENERATION AND CHARACTERISATION

Michele GIUGLIANO

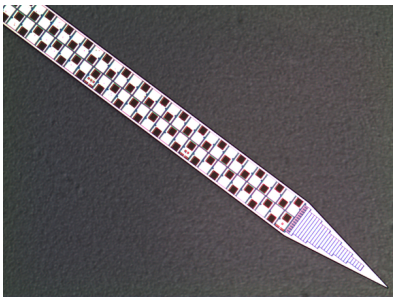
Analysis of Electrophys. Signals

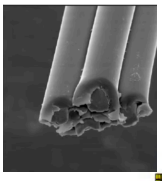


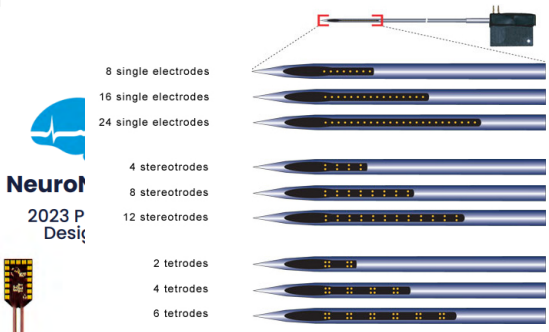
Hong & Lieber, *2019*

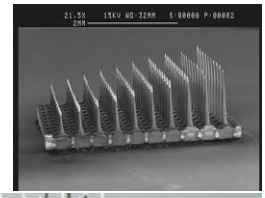


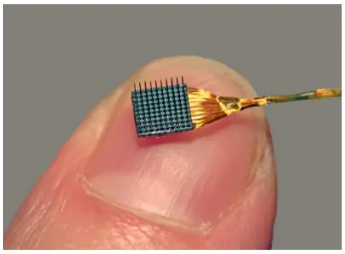
Tetrodes, Silicon Probes, Neuropixels, Utah Arrays

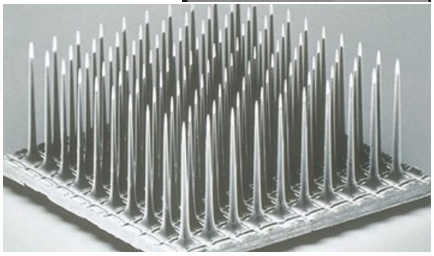




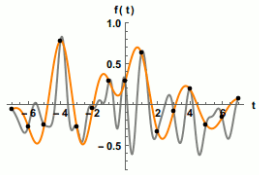


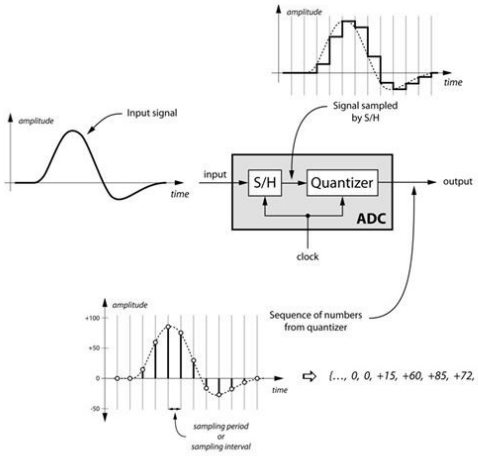


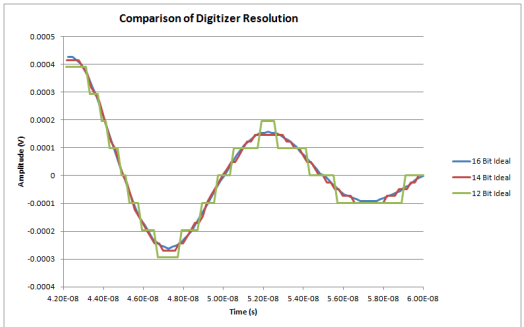




Sampling and Analog-to-Digital (A/D) Conversion (after amplification! e.g. x100)

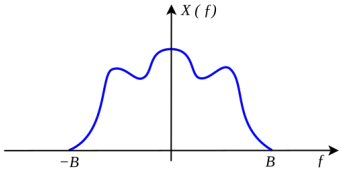






Nyquist-Shannon Theorem

$f_s > 2\ B$



$100\mu V \times 100 = 10mV$

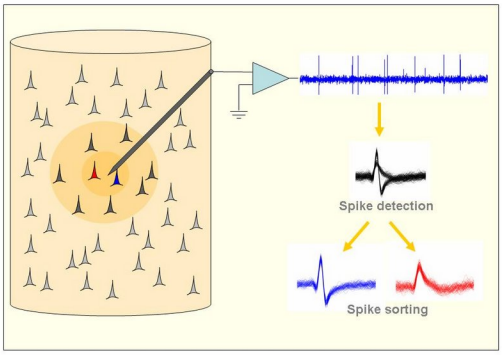
Range of A/D and Resolution of A/D

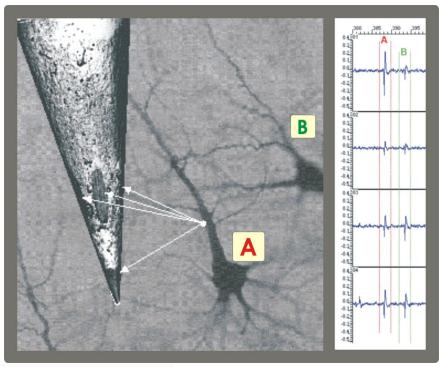
$\pm 5V \quad \pm 10V$

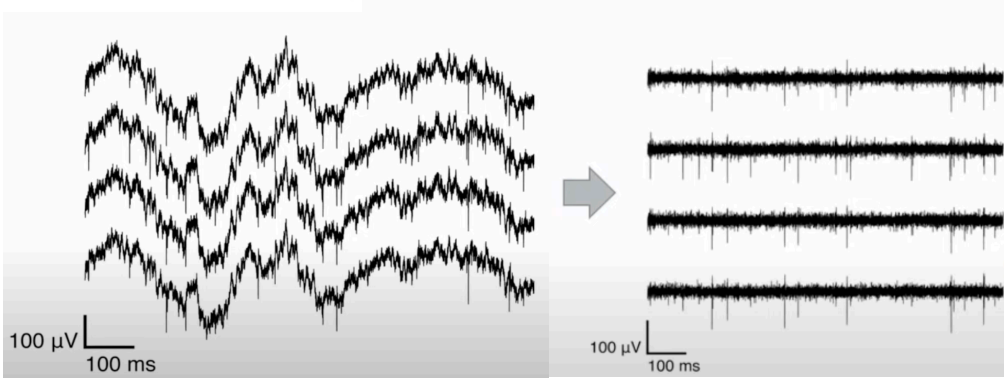
$2^N \quad 2^{12} = 4096 \quad 2^{14} = 16384 \quad 2^{16} = 65536$

$2.4mV \quad 0.6mV \quad 0.15mV$

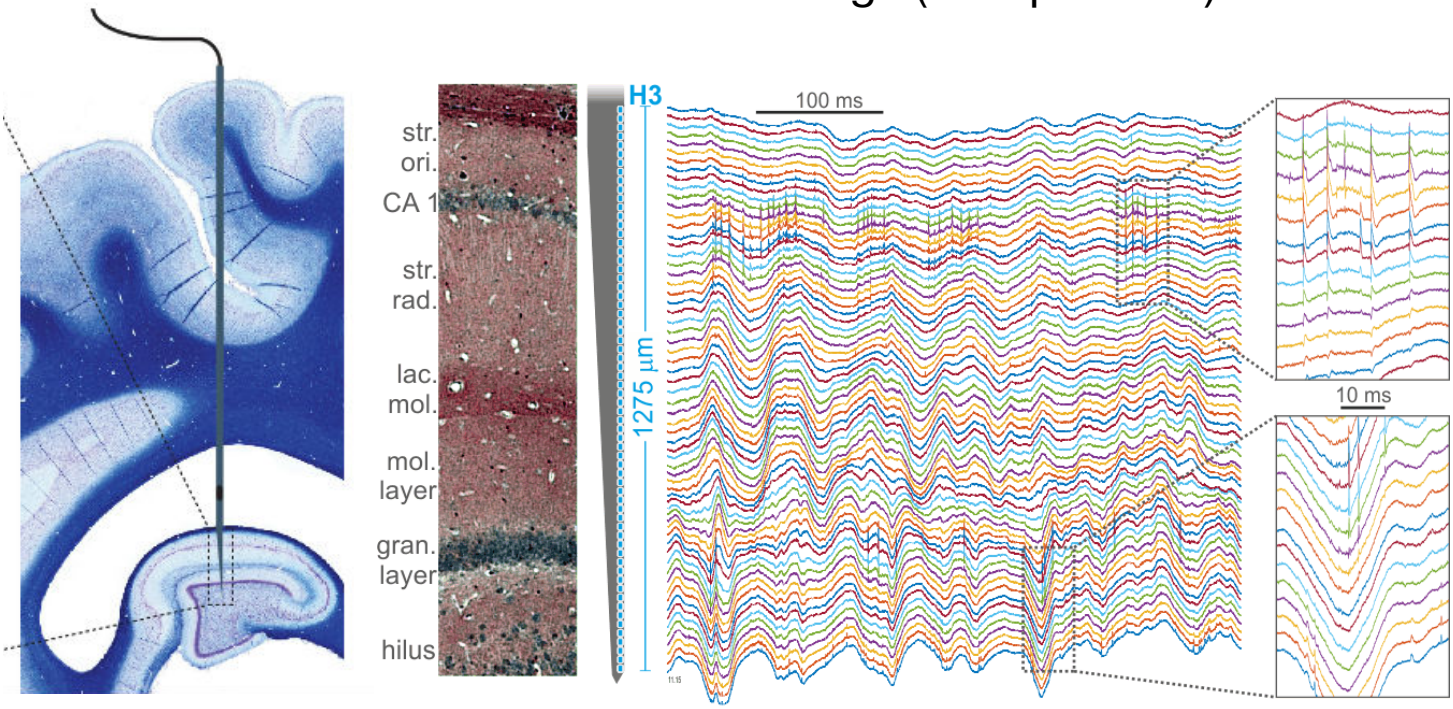
Spike detection and spike sorting





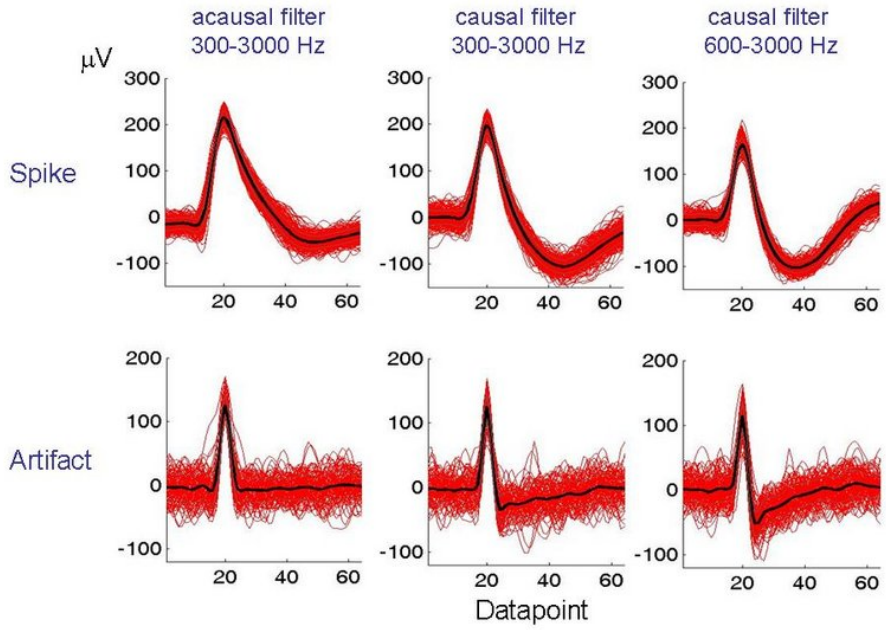


Raw extracellular recordings (multiple sites)



Wolf's lab, UPenn

Beware of filtering: a-causal is preferred



Peak-detection / Threshold crossings: estimates of the "baseline" noise level (from data itself!)

- **median:** the value separating the higher half from the lower half of a data sample… $\tilde{X}$

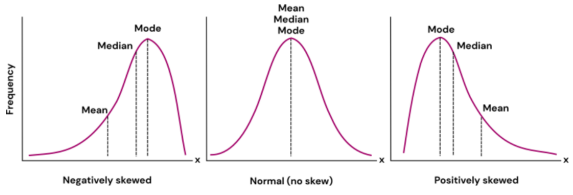
1, 3, 3, **6**, 7, 8, 9

Median = 6

1, 2, 3, **4**, **5**, 6, 8, 9

Median = (4 + 5) ÷ 2

= 4.5



- **MAD (median absolute deviation):** the *median* of the absolute deviations from the data's median…

$$MAD = median(|X_i - \tilde{X}|)$$

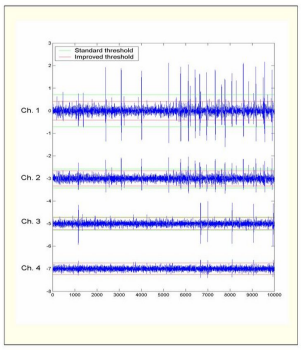
$$\hat{\sigma} = k\ MAD$$

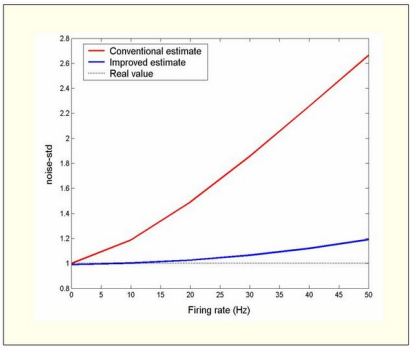
It is related to an *unbiased estimator* of the standard deviation (i.e. converge in probability to the true value)

For normal distribution, the scaling factor is **1/0.6645**.

$$\hat{\sigma} = \frac{MAD}{0.66449}$$

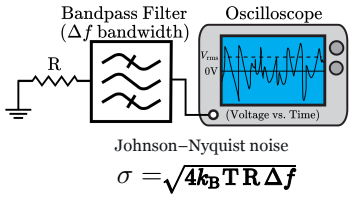
Peak-detection / Threshold crossings: estimates of the “baseline” noise level (from data itself!)





$$Thr = 5\,\sigma_n$$

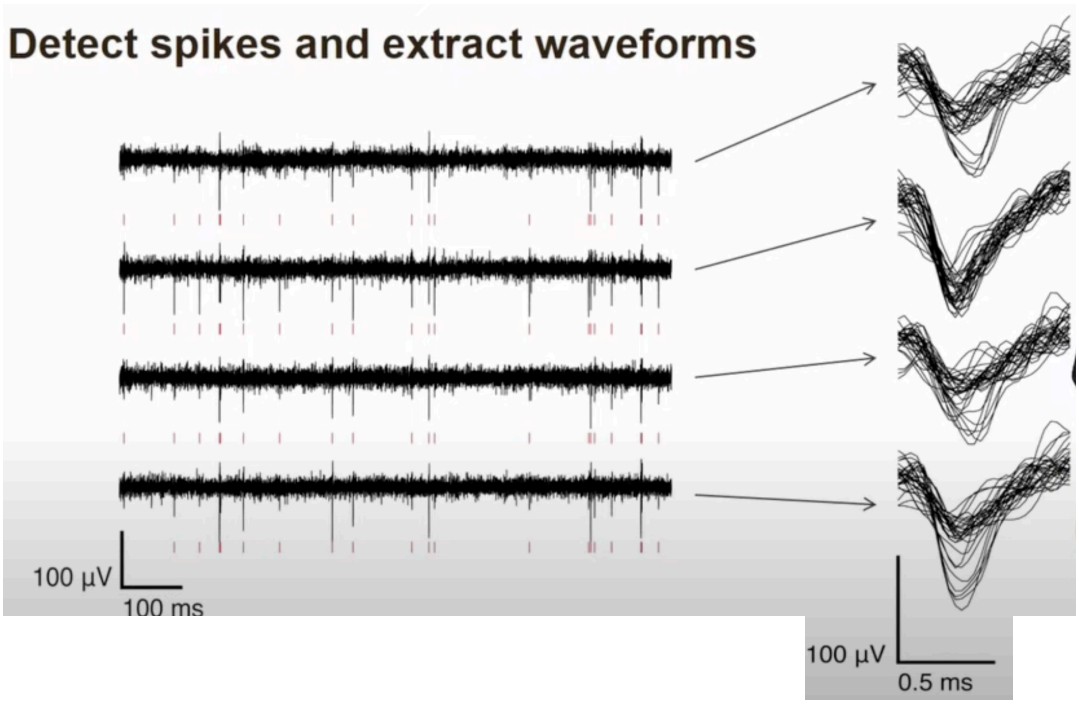
$$\sigma_n = \frac{median\,(|x|)}{0.6745}$$



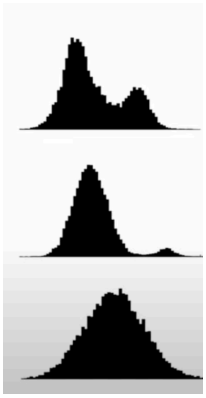
Johnson–Nyquist noise

$$\sigma = \sqrt{4k_B T R \Delta f}$$

- adaptive *versus* fixed threshold for the detection
- based on the hypothesis that *data = signal + noise* (noise has unknown statistical properties!)
- amount of noise estimated from the data itself, hopefully not altered by the signal itself (e.g. lot of spikes)
- robust estimators of the standard deviation: e.g. based on median of the band-pass filtered data.

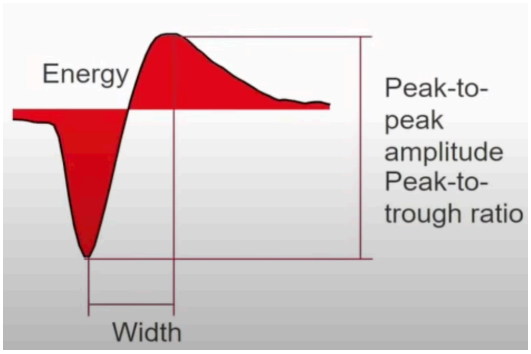


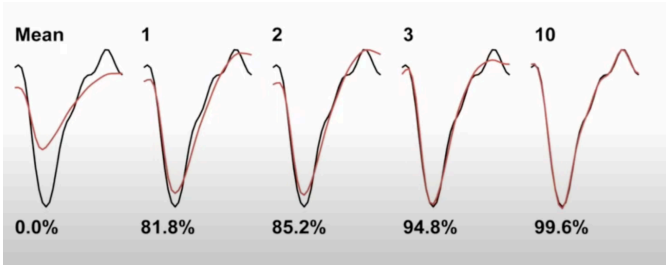
Feature extraction



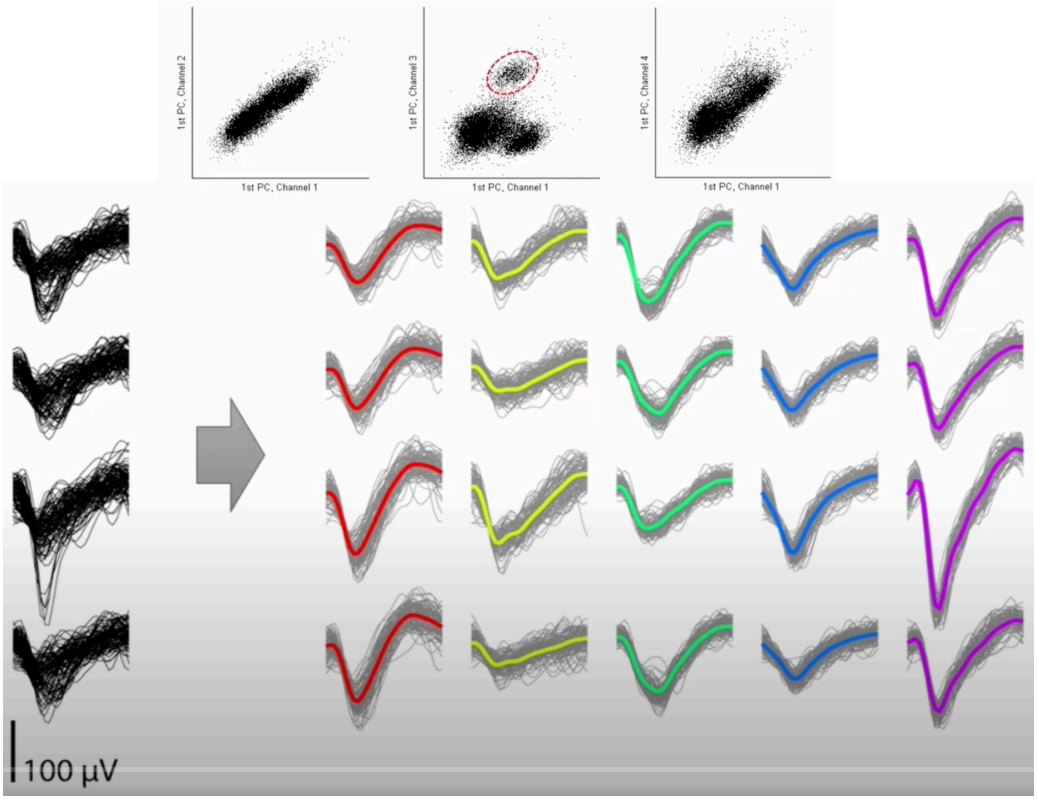
- smallest set of features, as possible
- best set of features to discriminate spike waveforms, robust against noise
- might depend on the choice of the classification algorithm

PCA - Principal Component Analysis

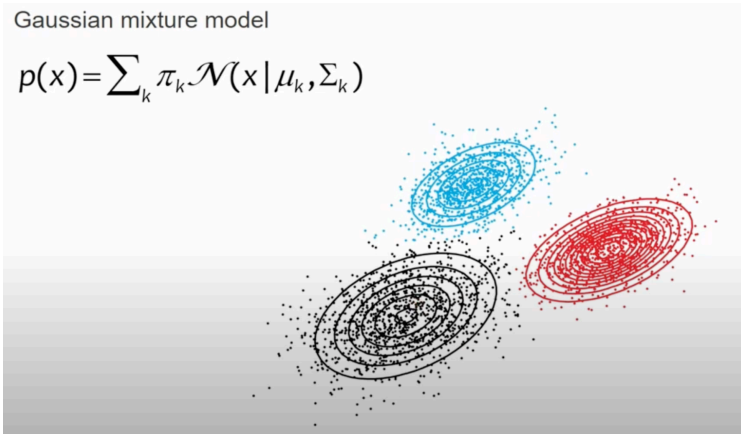


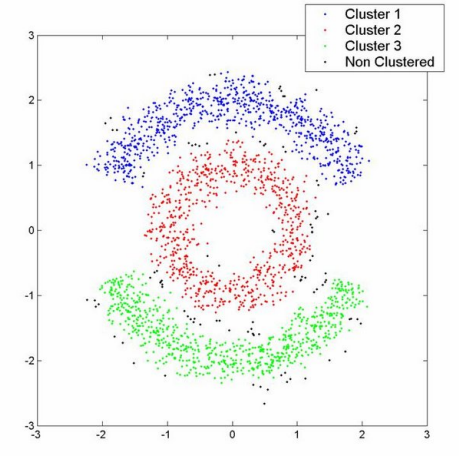


- Finds an orthonormal basis for the data
- First PC = direction of the largest variance
- very few components describe well the data
- (alternatives: non-linear PCA, autoencoder networks,



Clustering: manual *vs* unsupervised



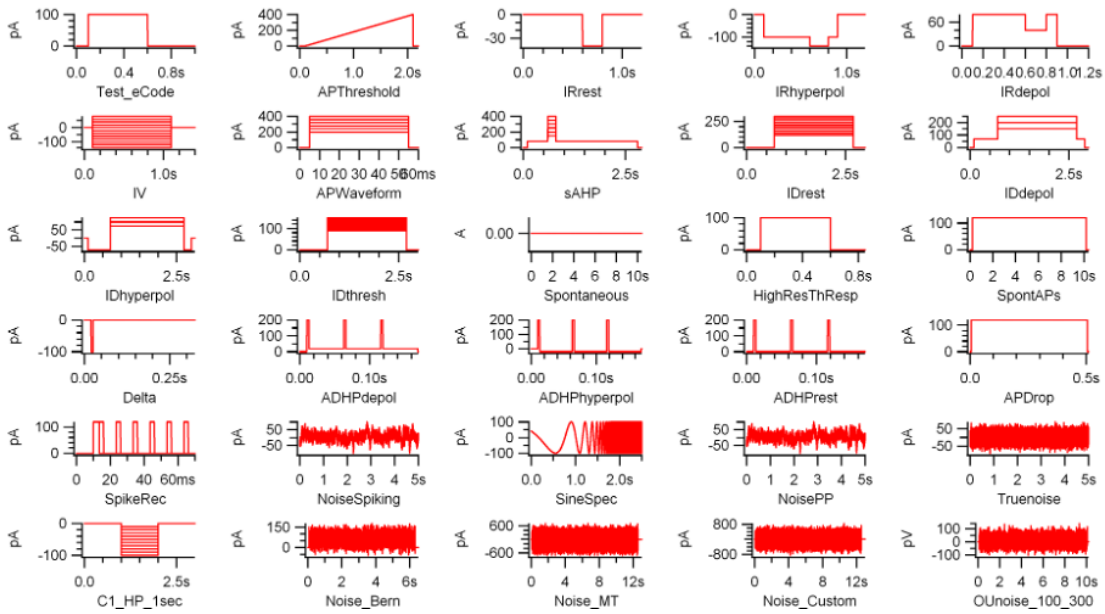


- manual (subjective, high error rate, not reproducible, time consuming)
- unsupervised/automatic clustering: k-Means, Mixture of Gaussian, super paramagnetic clustering, etc.

- tetrodes? bursting neurons? overlapping spikes?

Extracting features

Intracellular recordings - stimulus/response for extracting the *e-Code* of a cell



Intracellular recordings - stimulus/response for extracting the *e-Code* of a cell