NEURAL DATA ANALYSIS

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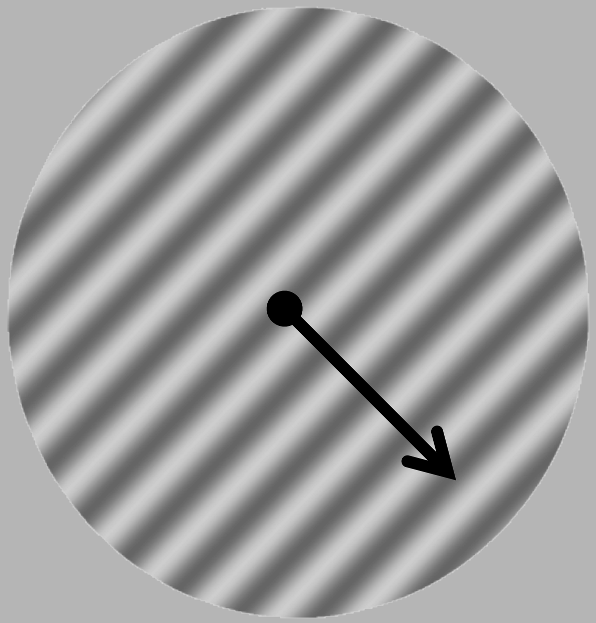
COMPUTATIONAL VISION AND NEUROSCIENCE GROUP

STIMULUS

Drifting gratings presented in trials

Parameters:

- 2 sec per trial
- 16 directions of motion
- Diameter: 2 deg
- Eccentricity: ~2-3 deg
- Speed: 3.4 cycles / sec
- Spatial frequency: 3 cycles / deg



Recordings:

- Anesthetized monkey V1

STRATEGIES FOR ANALYZING DATA

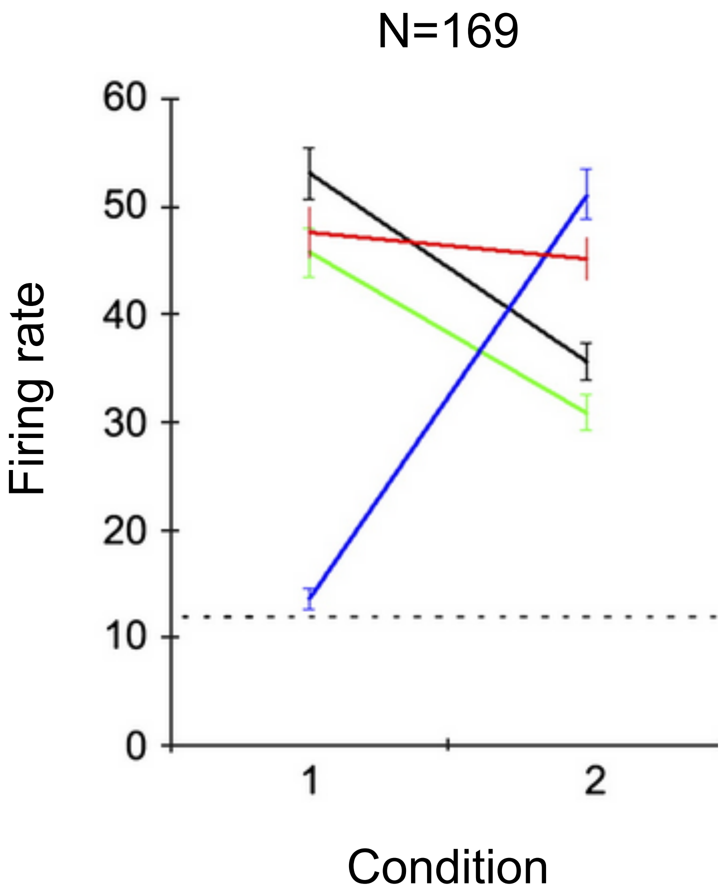
Look at raw data

Visualize spikes

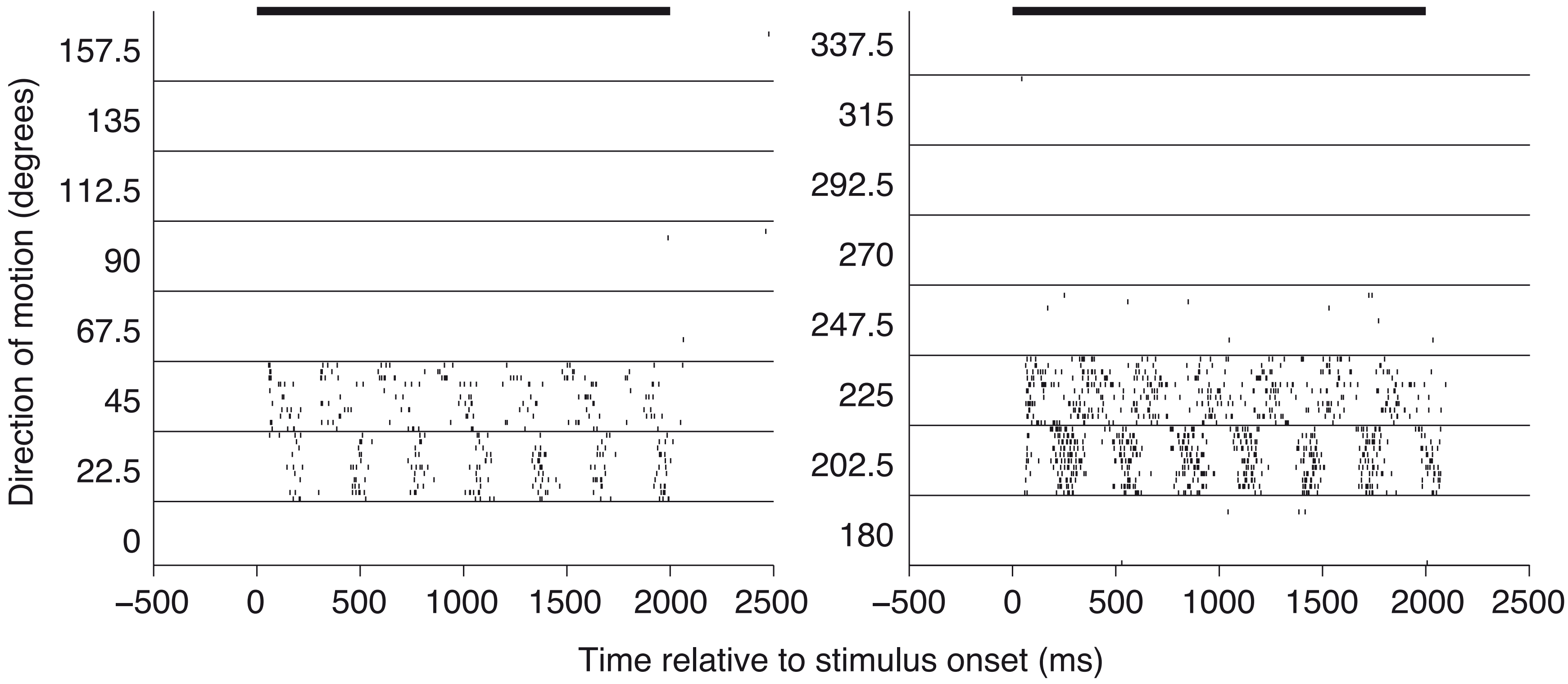
Do not look at

- Fitted tuning functions
- Adaptation indices
- Population averages
- Population histograms

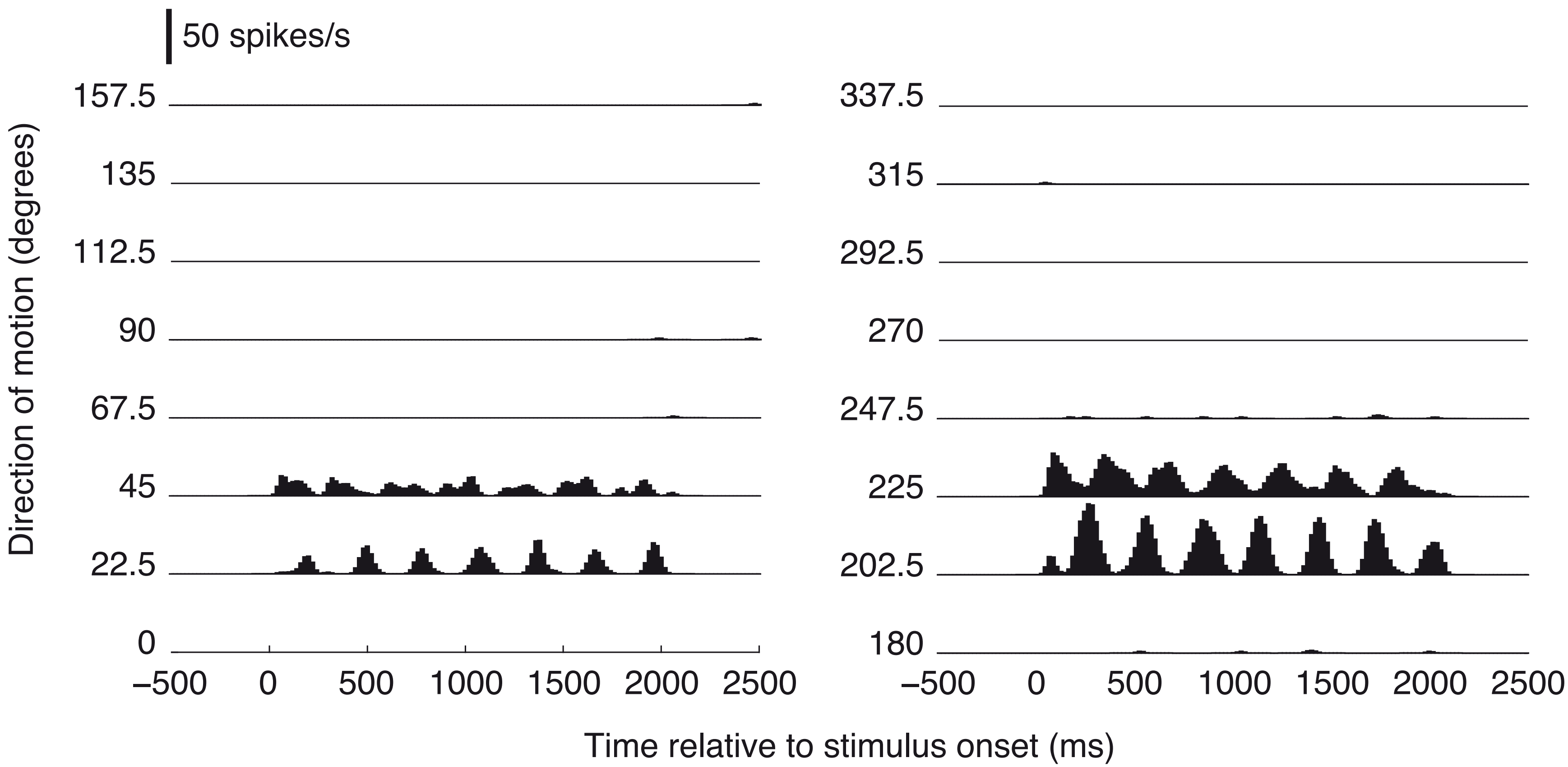
until you spent considerable time looking at raw data and examples



SPIKE RASTERS

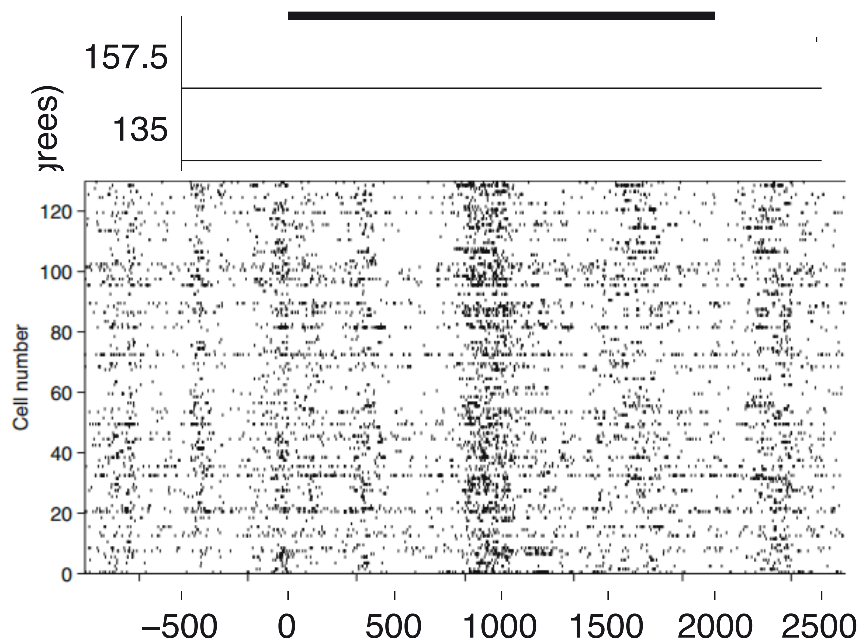


PERI-STIMULUS TIME HISTOGRAM



PSTH & SPIKE RASTERS

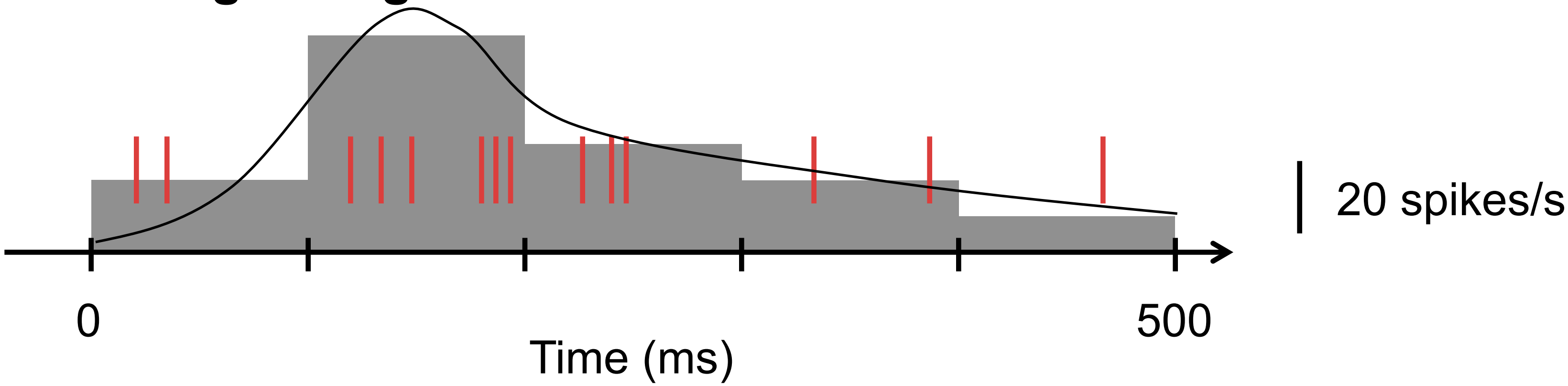
- **Repeated measurements of spike trains with a reference time to align on**
  - Stimulus
  - Onset of Movement/Saccade
- **Event-related single neuron rate dynamics**
- **Population raster plot**
  - population dynamics
- **Align on LFP phase?**



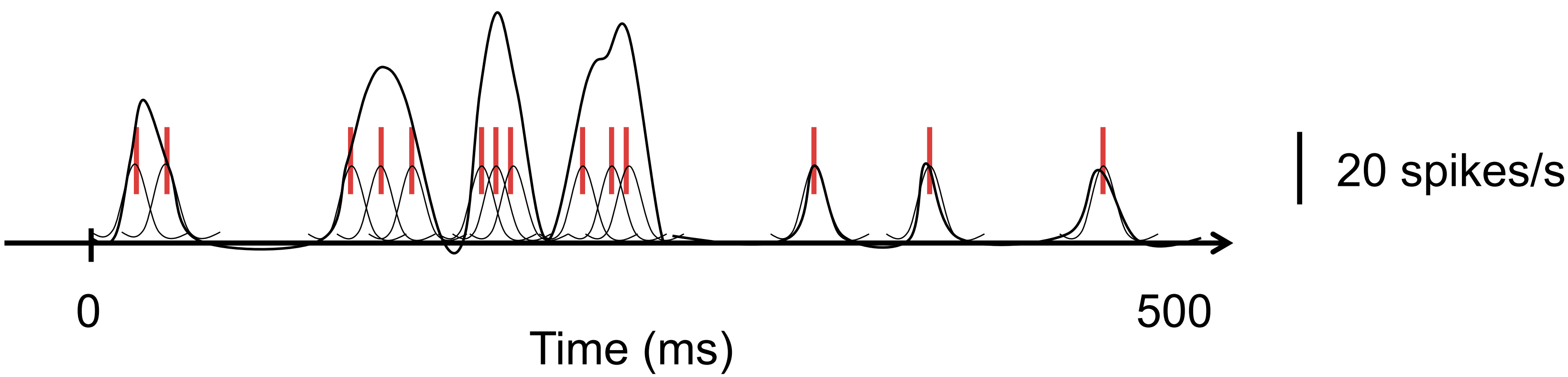
Kelly et al 2010

PSTH/SDF – HOW TO

1. **Average firing rate in a bin**



2. **Directly estimate spike density**



WINDOW SIZE

Optimal bin width / Gaussian window size
(Shimazaki & Shinimoto 2007)

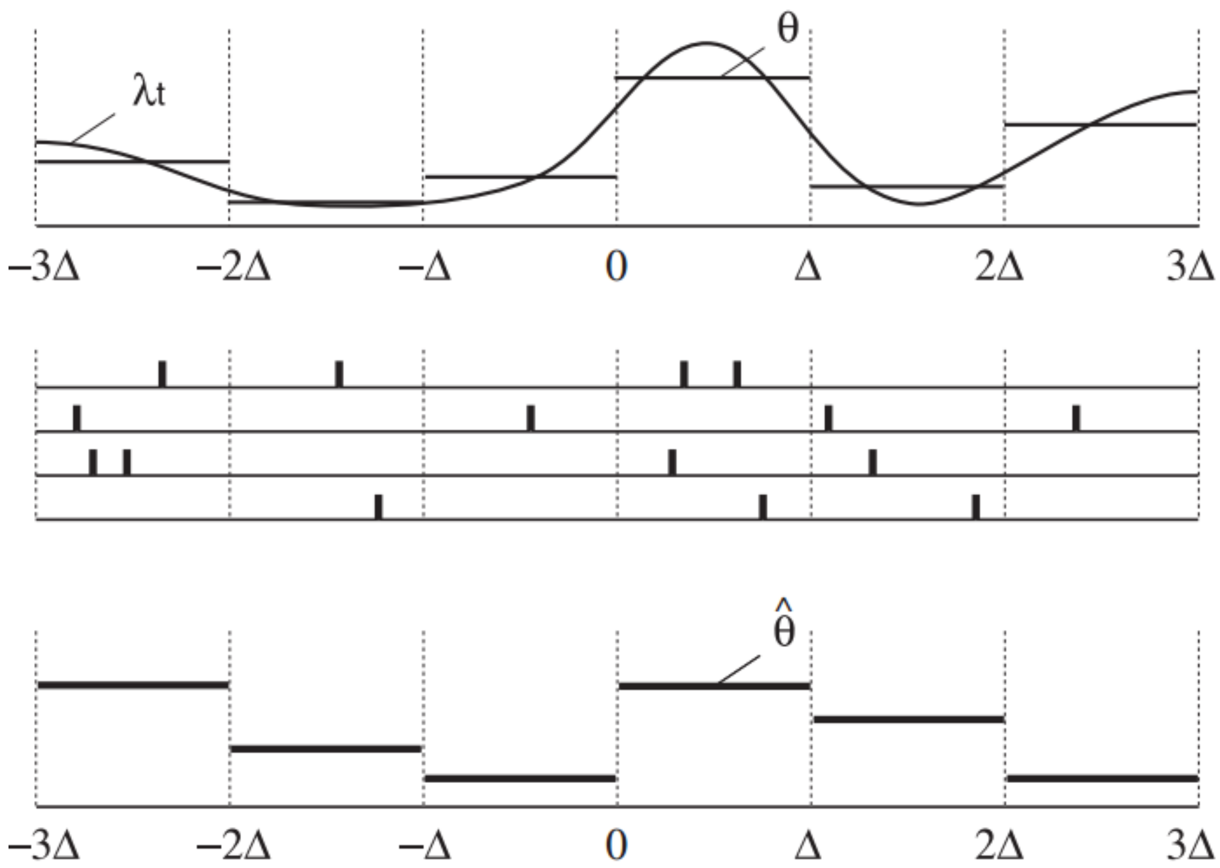
Gaussian process (Cunningham, Yu, Shenoy 2007)

BARS (DiMatteo et al. 2001)

Bayesian binning (Endres et al. 2008)

Reviewed by Cunningham et al. 2009

BIN SIZE SELECTION



$$\theta = \frac{1}{\Delta}\int_0^{\Delta} \lambda_t dt$$

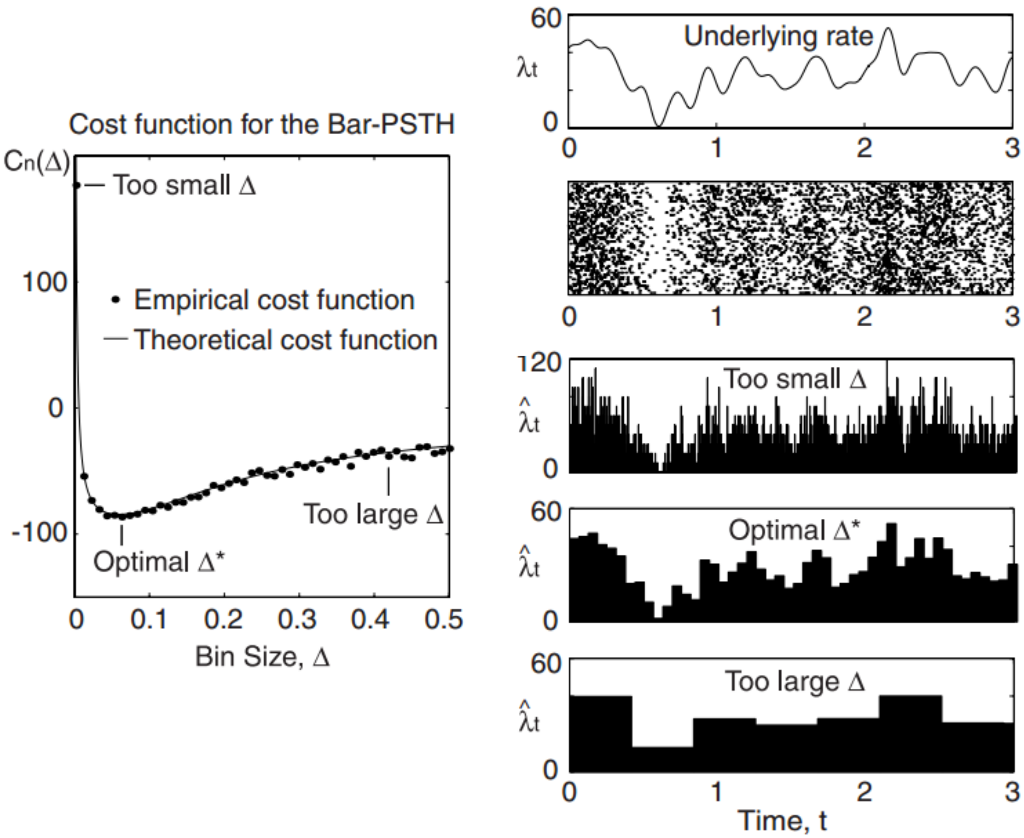
$$\hat{\theta} = \frac{k}{n\Delta}$$

BIN SIZE SELECTION

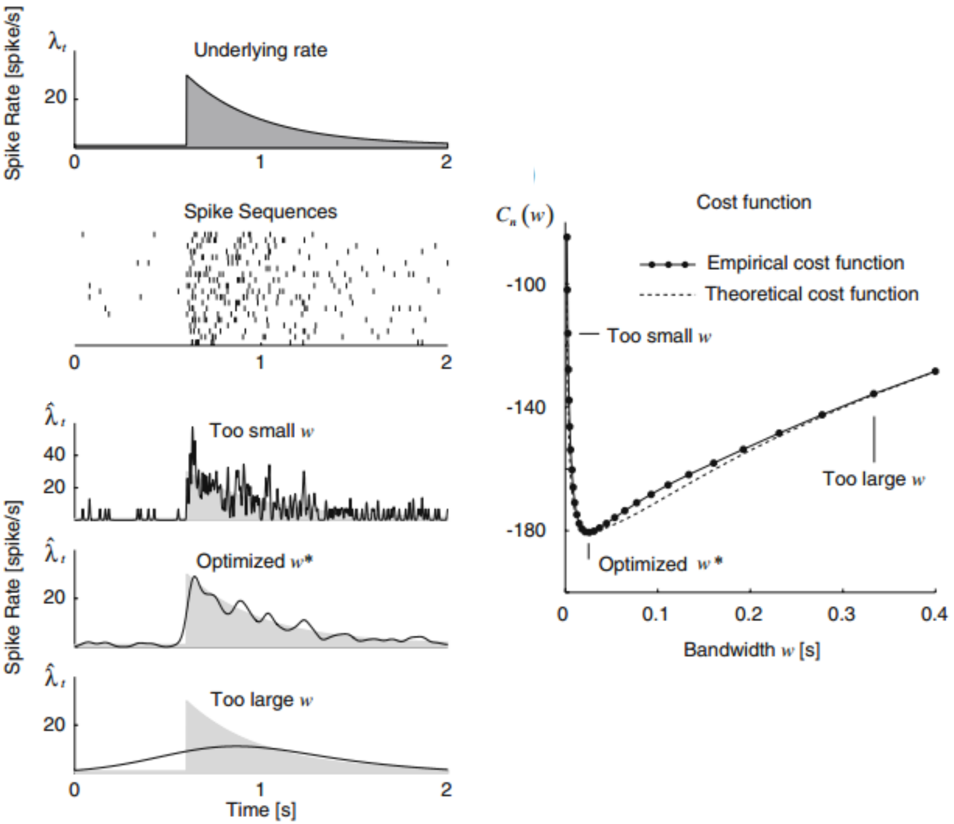
- **Divide the observation period T into N bins of width Δ.**
- **Count the number of spikes k_i from all n trials that fall into i-th bin**
- **Compute $k = \frac{1}{N}\sum_i^N k_i$ and $v = \frac{1}{N}\sum_i^N \left(k_i - \bar{k}\right)^2$**
- **Compute $C_n(\Delta) = \frac{2\bar{k} - v}{(n\Delta)^2}$**
- **Search for Δ^* that minimizes $C_n(\Delta)$**

Shimazaki & Shinomoto 2007

BIN SIZE SELECTION



OPTIMAL KERNEL WIDTH



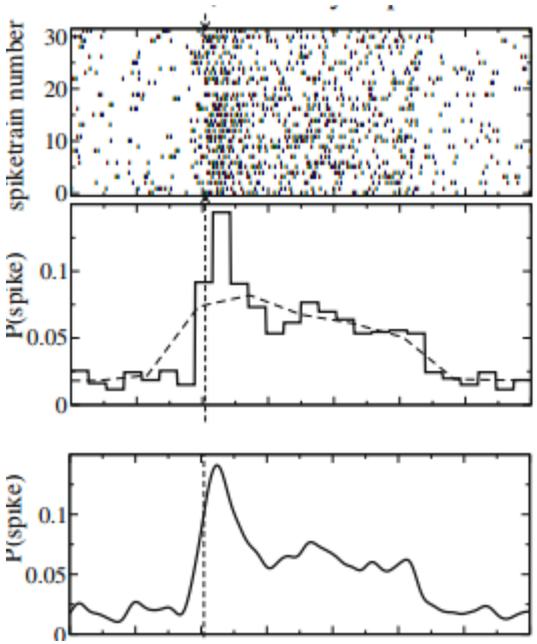
$$n^2 C_n(\omega) = \frac{N}{\omega} + \frac{2}{\omega} \sum_{i<j} \left[\exp\left(-\frac{(t_i - t_j)^2}{4\omega^2} \right) - 2\sqrt{2} \exp\left(-\frac{(t_i - t_j)^2}{2\omega^2} \right) \right]$$

Shimazaki & Shinimoto 2010

PROBLEMS WITH PSTH/SDF

- **Problems with PSTH approaches**
  - Sharp transients
  - Many bins where rate is constant

- **Problems with SDFs**
  - Sharp transients are blurred

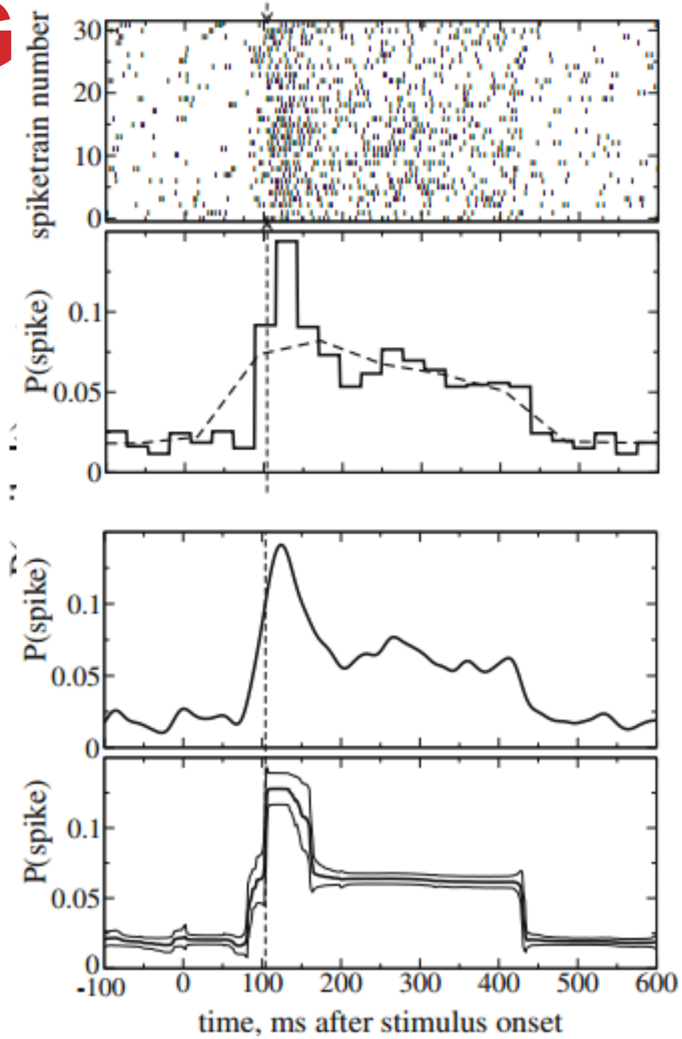


BAYESIAN BINNING

- **Model PSTH as sequence of intervals with constant firing probability**

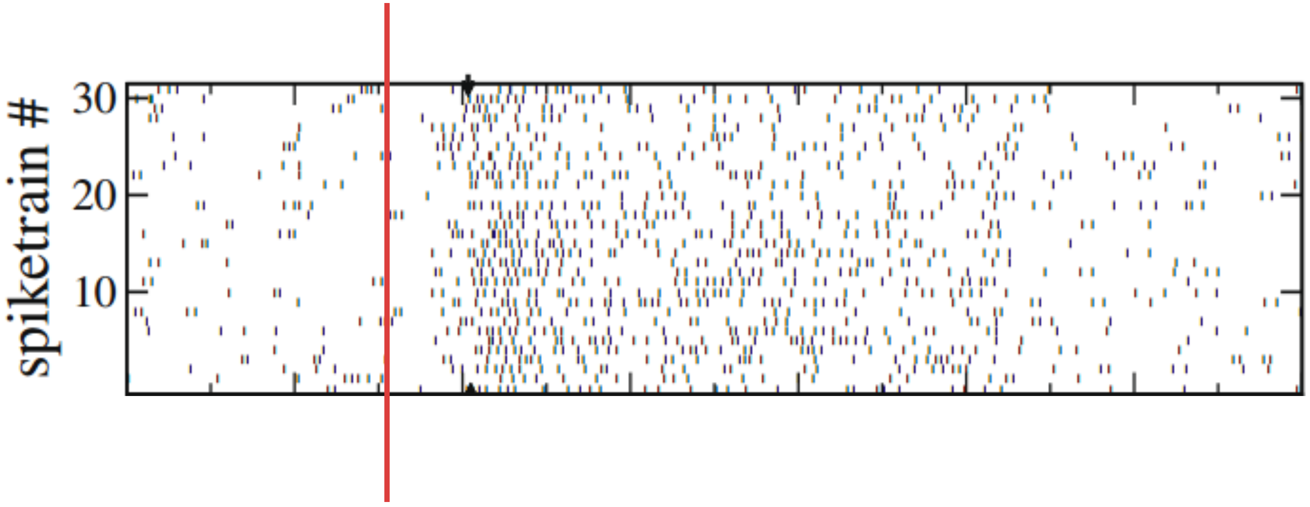
$$P(\vec{z}^i|\{f_m\},\{k_m\},M)=\prod_{m=0}^{M} f_m^{s(\vec{z}^i,m)}(1-f_m)^{g(\vec{z}^i,m)}$$

- **Bayesian inference for model parameters by computing posterior**
- **Dynamic programming**
- **Code online: http://mloss.org/software/view/67/**



Endres et al. 2008/2010

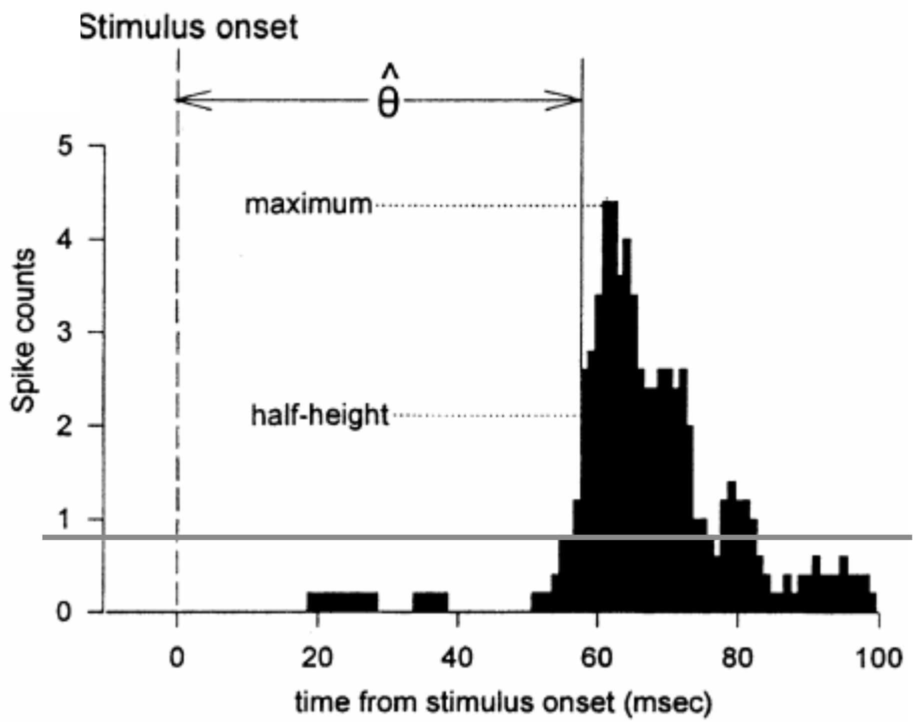
LATENCY DETECTION



„Latency is where is the signal starts“

LATENCY DETECTION

- **Non-parametric estimation as half height of peak firing rate**
- **Threshold criterion above spontaneous firing**



Friedman & Priebe 1998

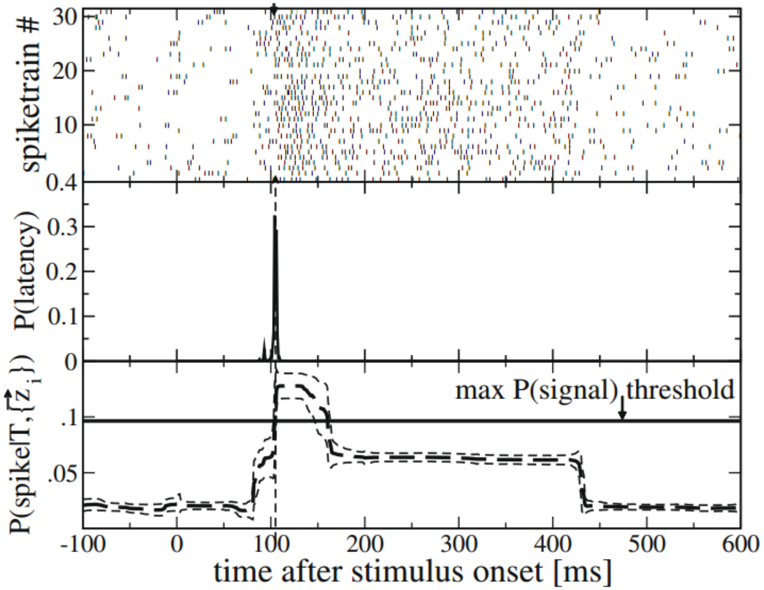
LATENCY DETECTION

- **Change point detection**

$$s(t) = \ Poisson(\lambda_1), t \in [0, \theta)$$

$$s(t) = \ Poisson(\lambda_2), t \in [\theta, \kappa)$$

- **Bayesian binning**



SIMPLE OR COMPLEX CELL?

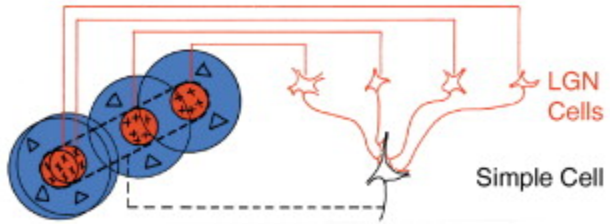
Simple cells:

- Selective for spatial frequency and orientation
- Modulated by phase of a grating

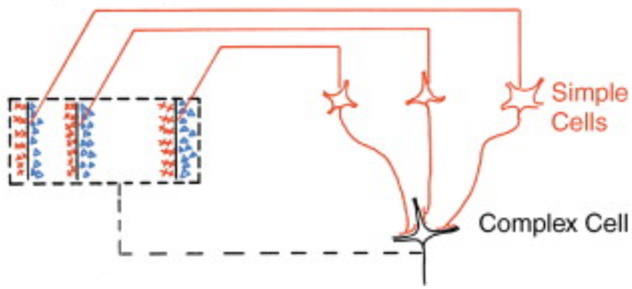
Complex cells:

- Selective for spatial frequency and orientation
- Invariant to phase of the grating

Circuit Building a Simple Cell from LGN Cells



Building a Complex Cell from Simple Cells



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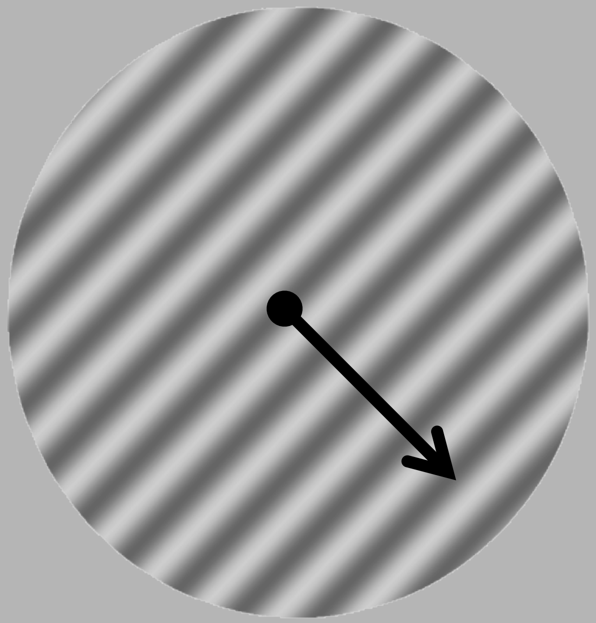

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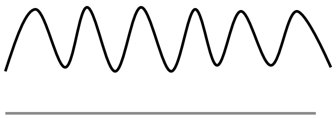
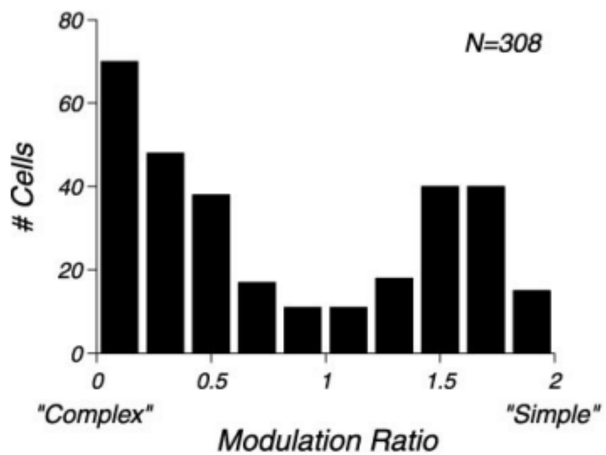
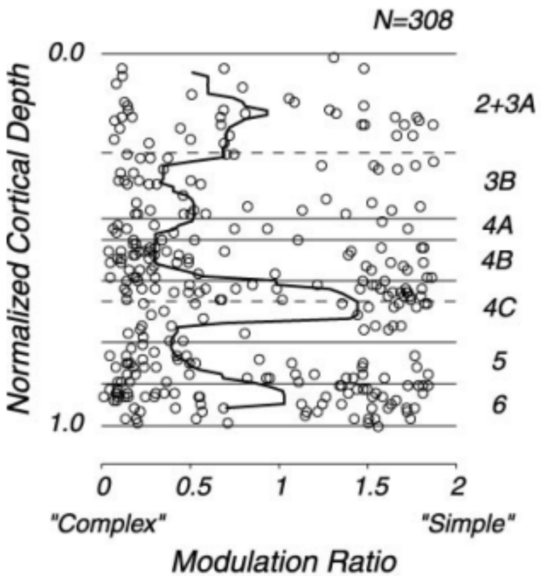
LINEARITY INDEX

Compare oscillation at stimulus frequency to DC component

$$LI = \frac{F_1}{F_0}$$







Ringach et al. 2002

SIMPLE OR COMPLEX?