Statistical methods for understanding neural codes:

Multineuronal spike coding in primate retina

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August 1, 2007

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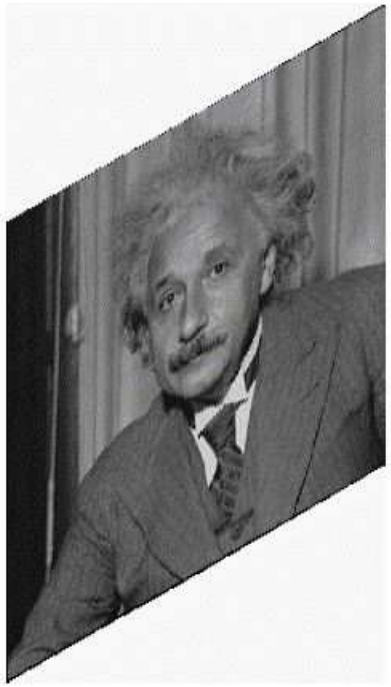
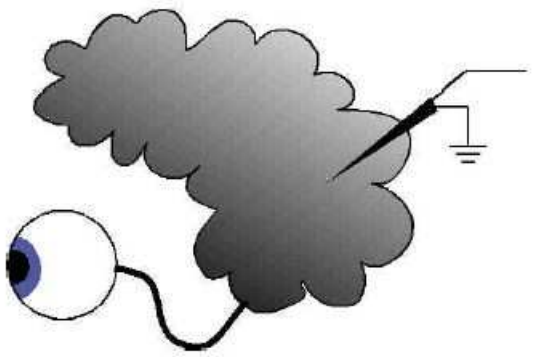
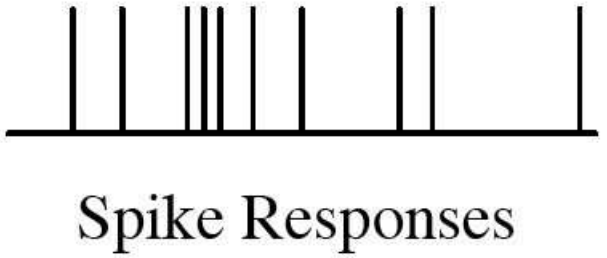
Support: NIH CRCNS award, Sloan Research Fellowship, NSF CAREER award.

The neural code







Input-output relationship between

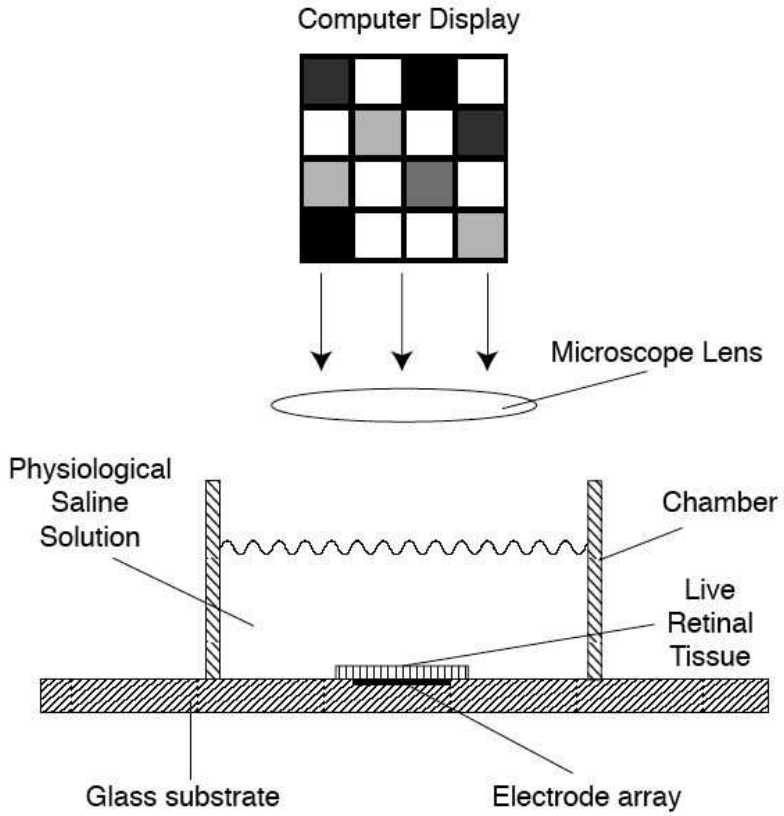
- External observables x (sensory stimuli, motor responses...)
- Neural variables y (spike trains, population activity...)

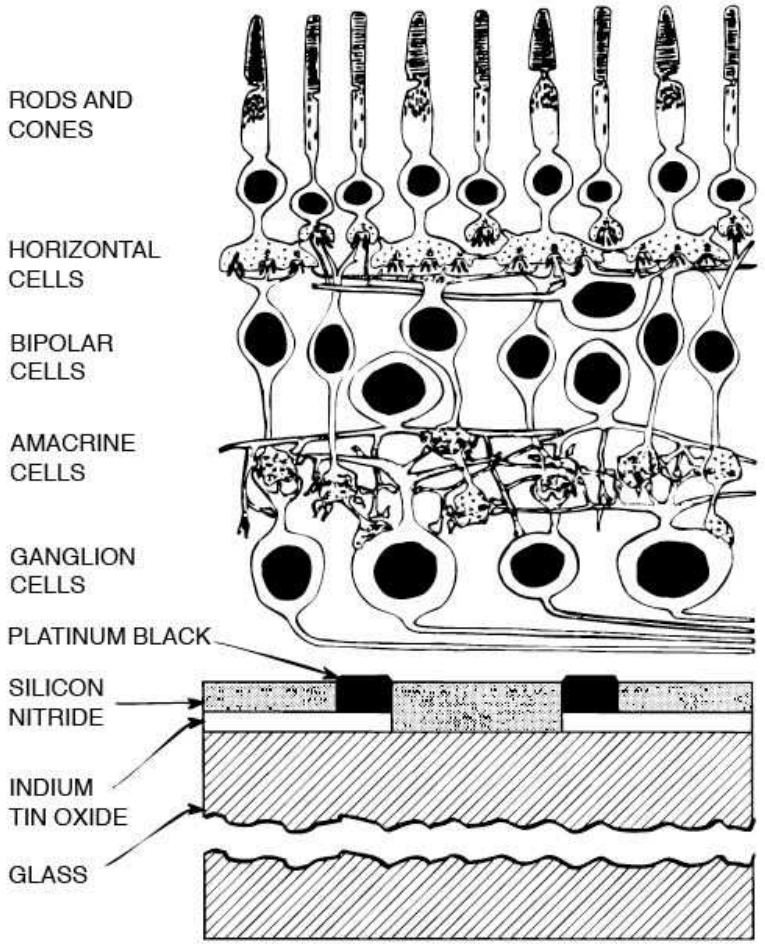
Probabilistic formulation: $p(y|x)$

Retinal ganglion neuronal data

Preparation: dissociated salamander and macaque retina

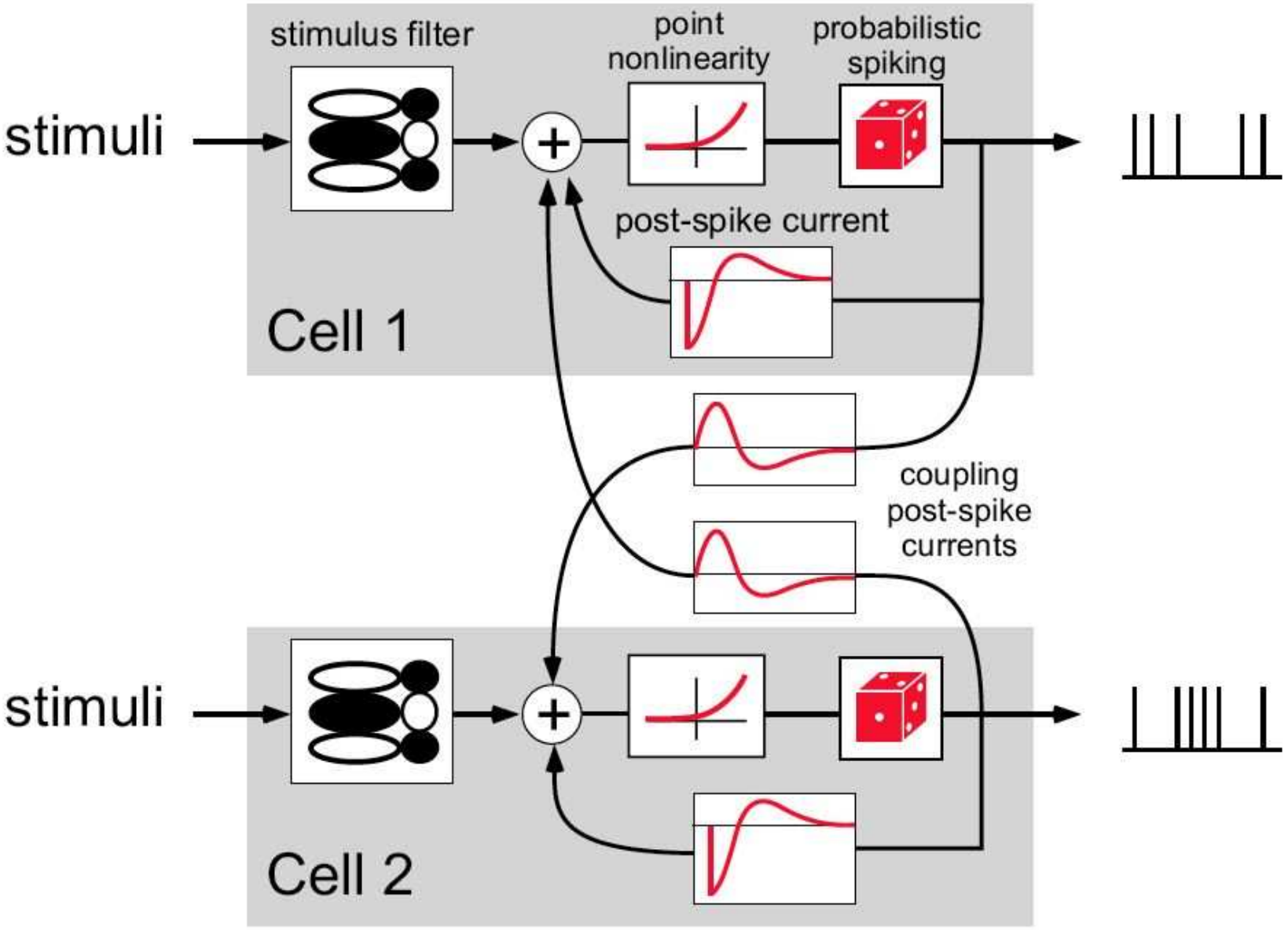
— extracellularly-recorded responses of populations of RGCs





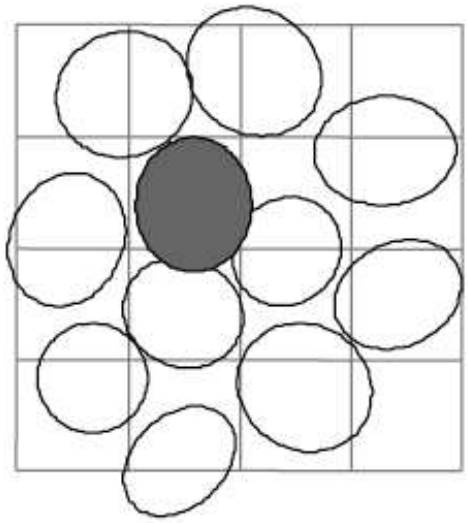
Stimulus: random spatiotemporal "flicker" visual stimuli

Multineuronal generalized linear model

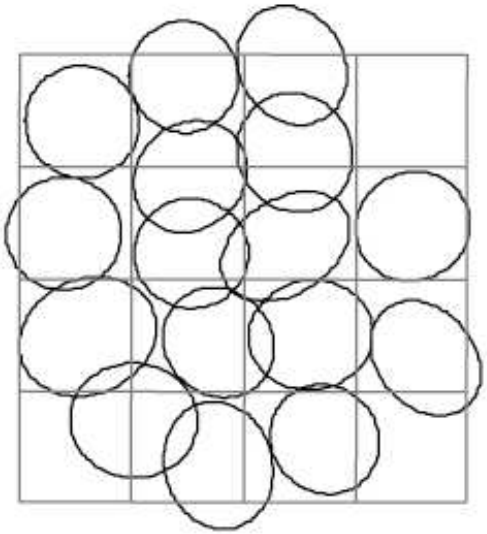


— Fit by L1-penalized max. likelihood (concave optimization)

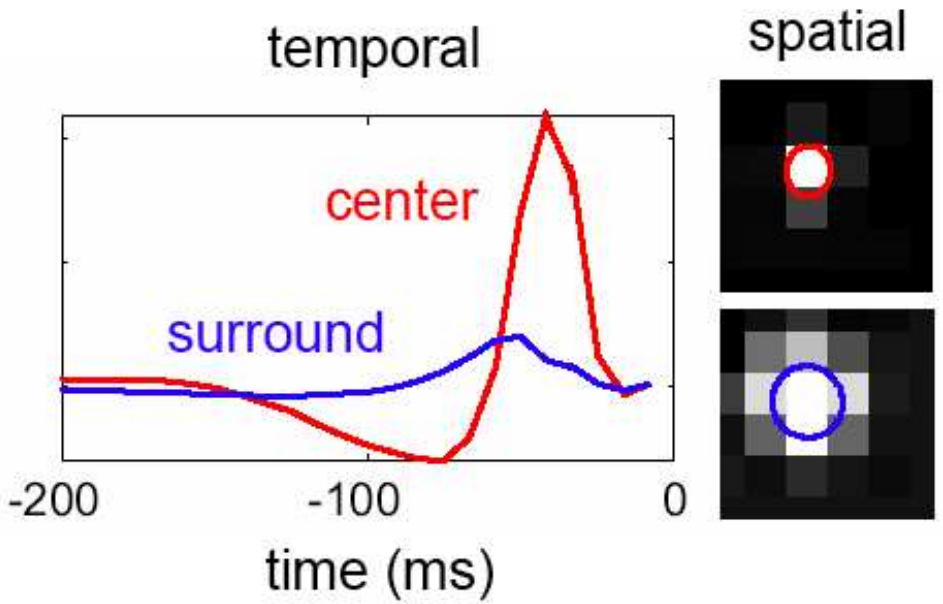
ON cells



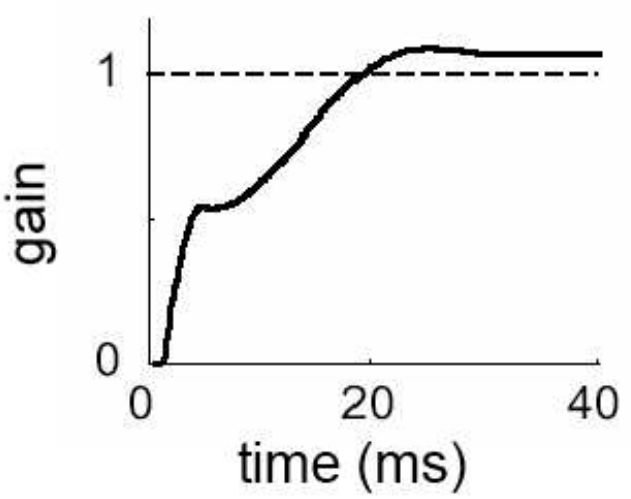
OFF cells



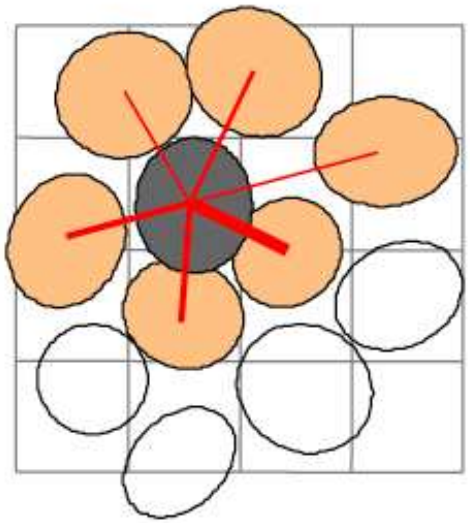
stimulus filter



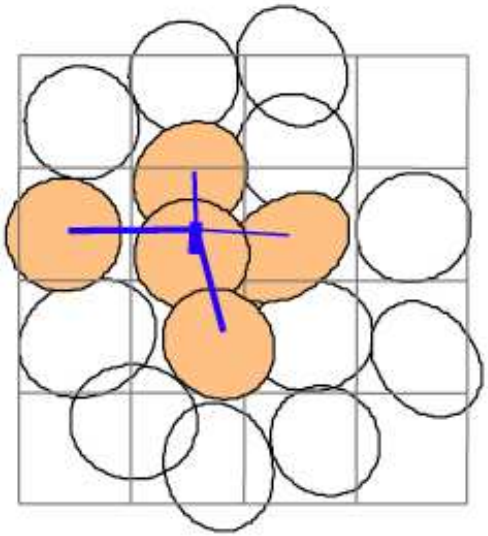
post-spike filter



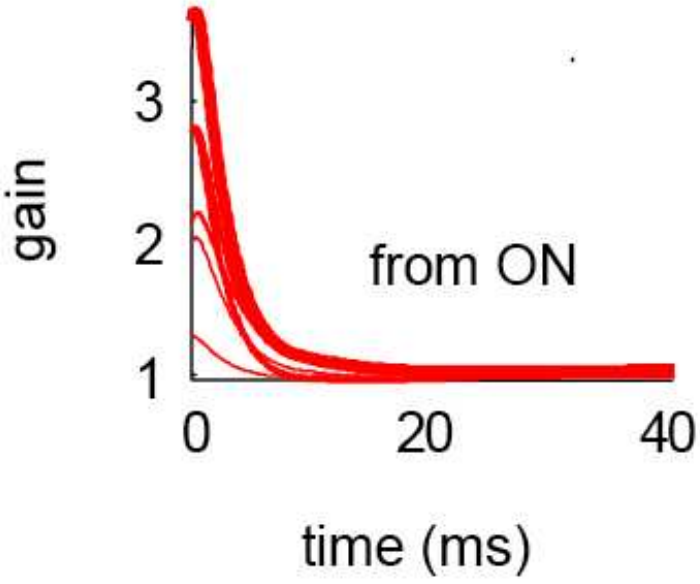
ON cells

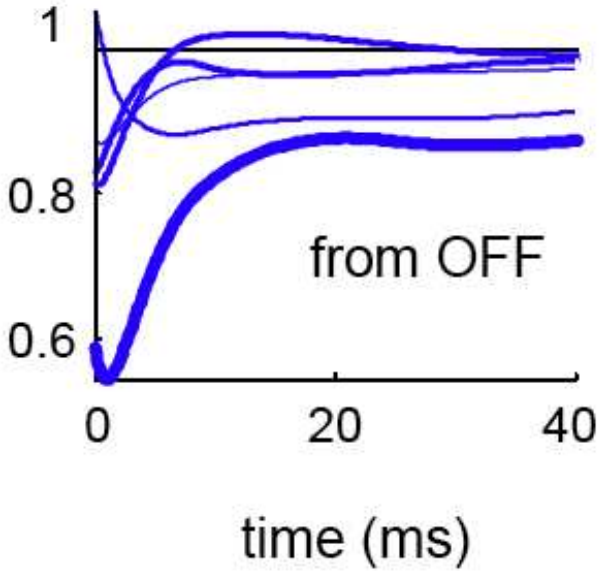


OFF cells

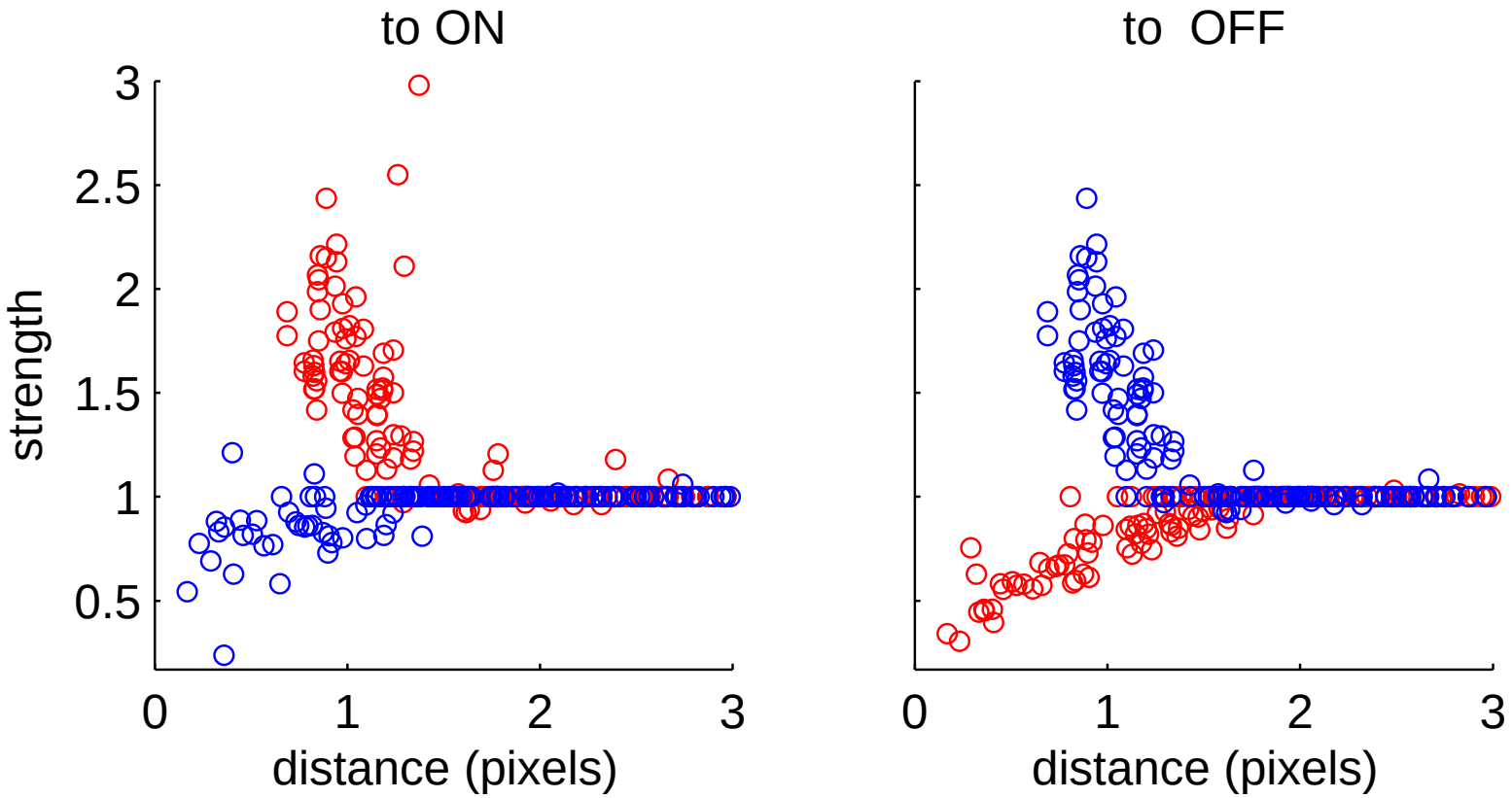


coupling filters

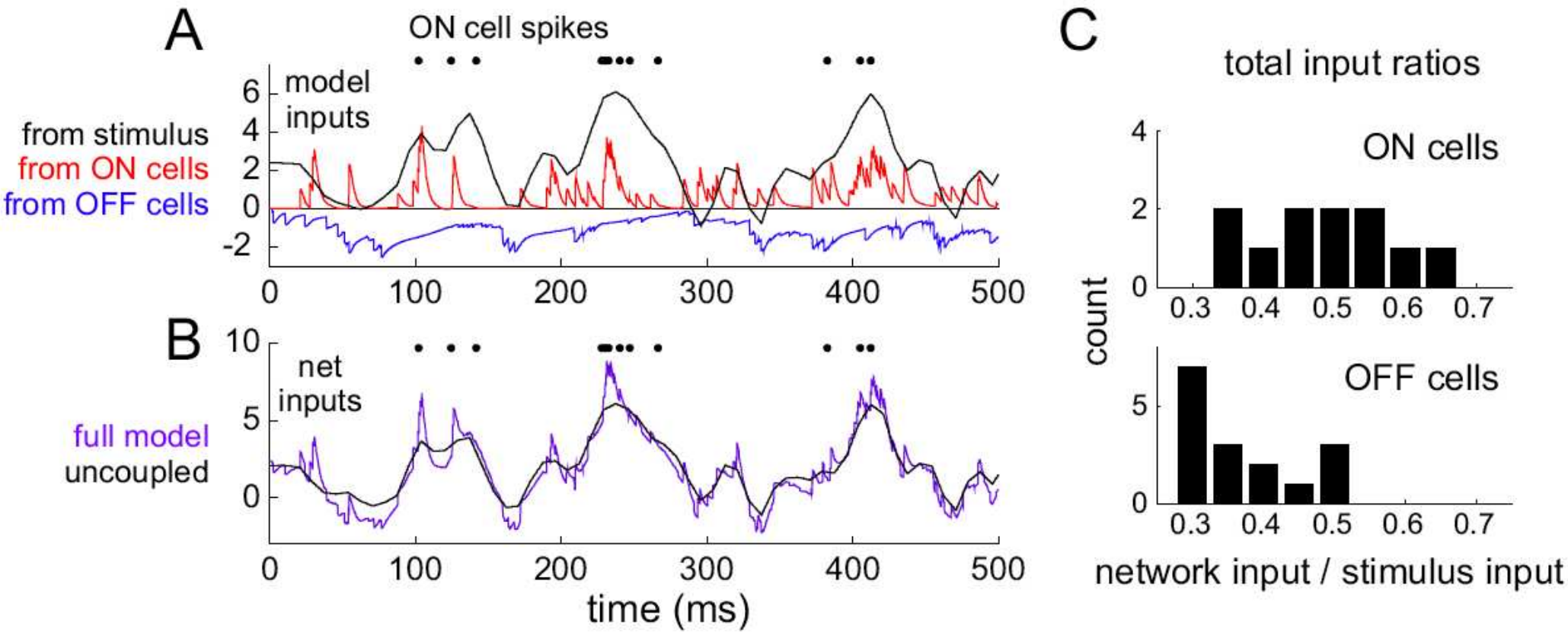




Nearest-neighbor connectivity



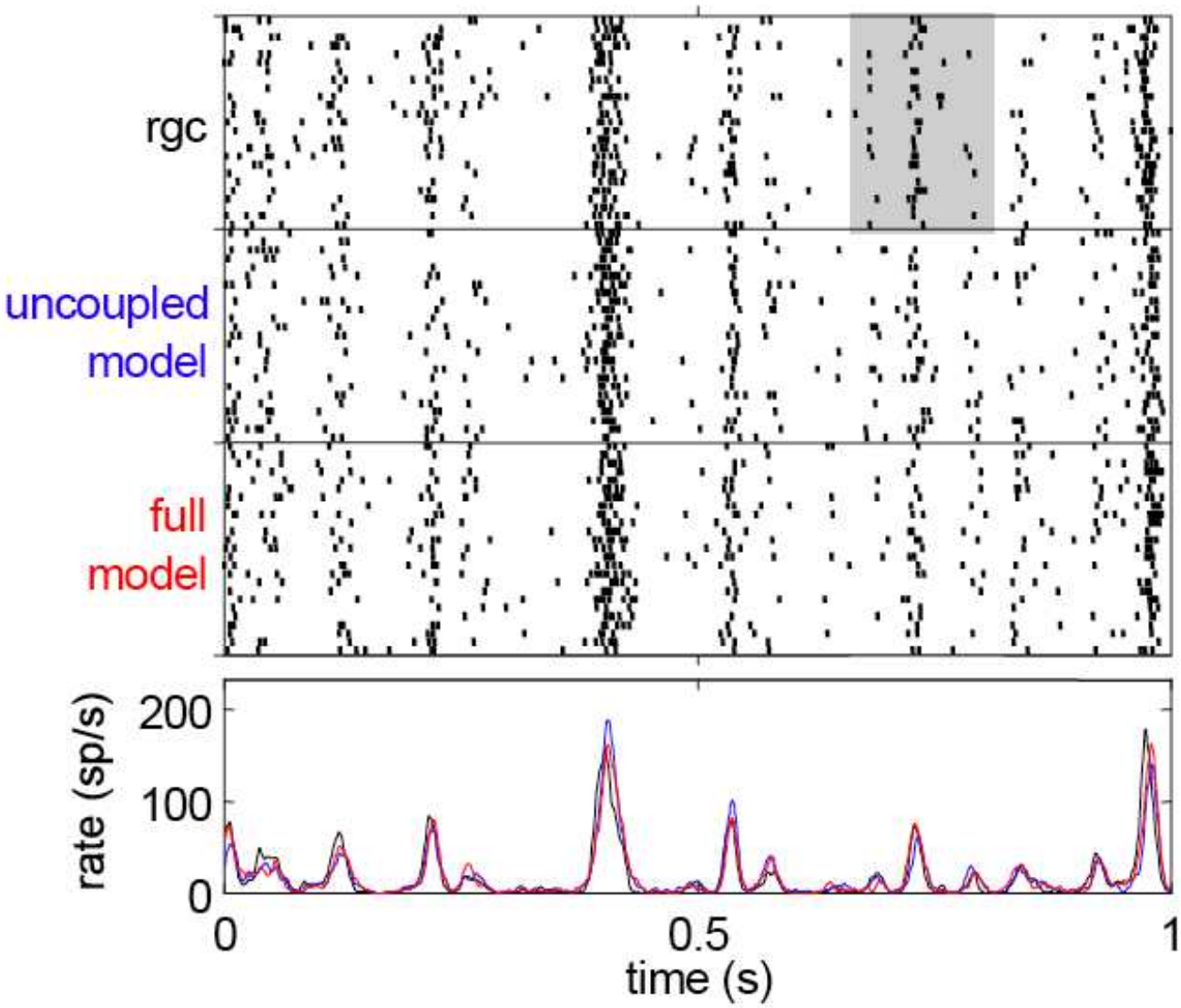
Network vs. stimulus drive

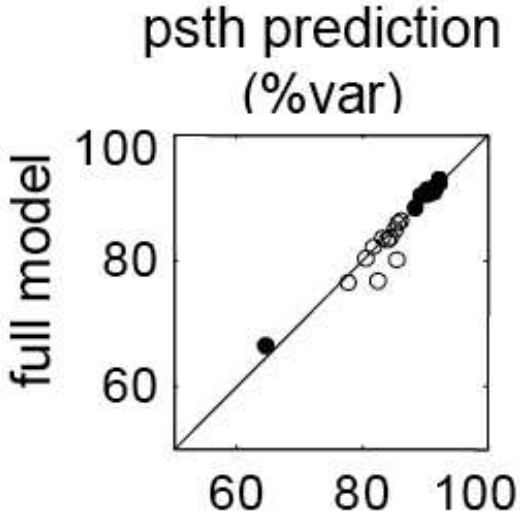


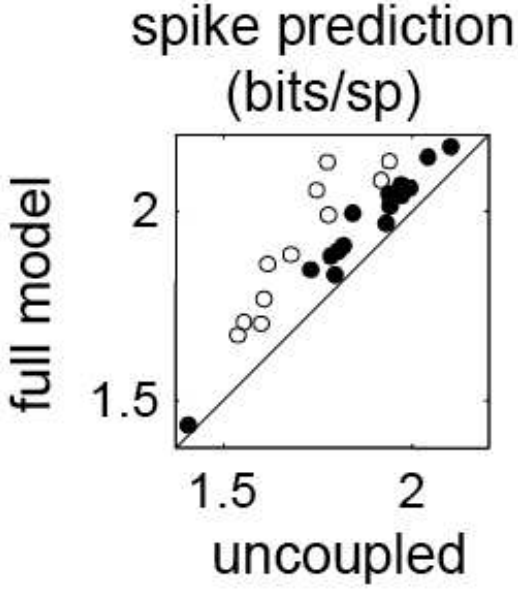
— Network effects are $\approx 50\%$ as strong as stimulus effects

Spike Train Prediction

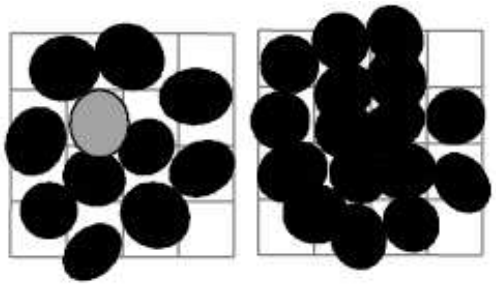
- improved prediction, but not of mean rate!



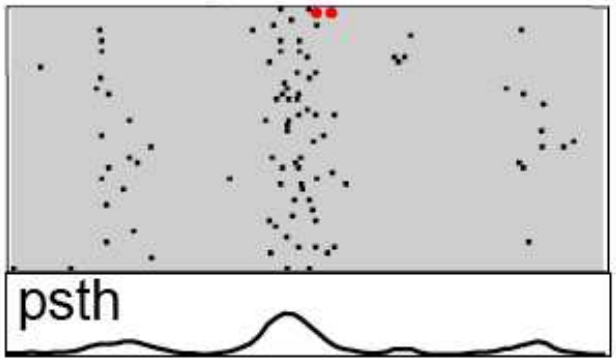




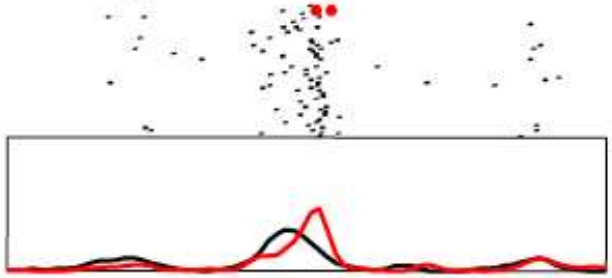
Network predictability analysis



rgc raster

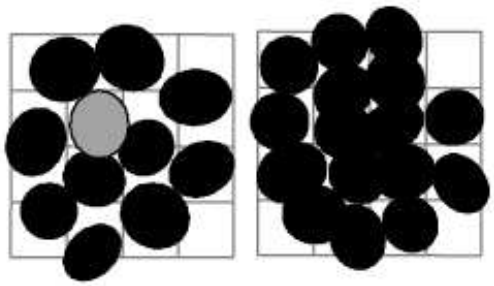


single-trial prediction

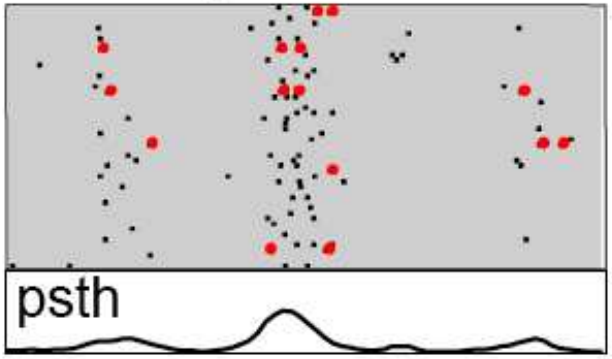


- fix all other neurons for a single trial

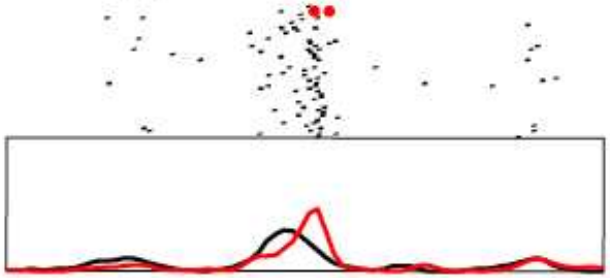
- draw single-trial predictions of this cell's spike train

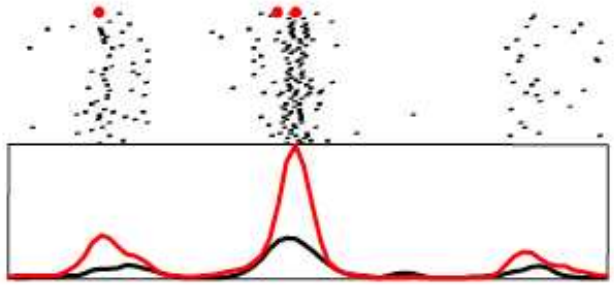


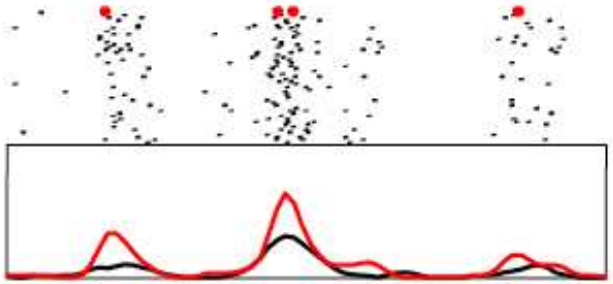
rgc raster

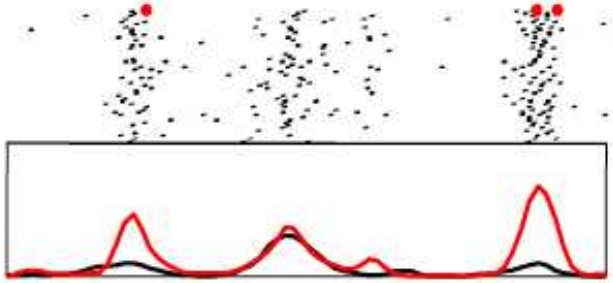


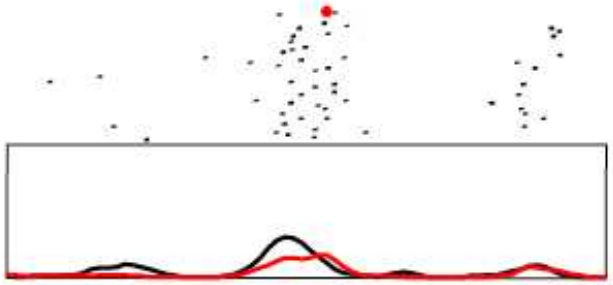
single-trial prediction

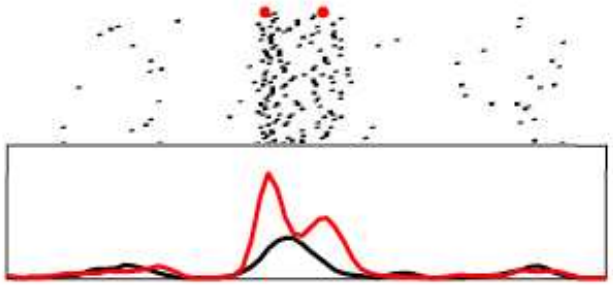


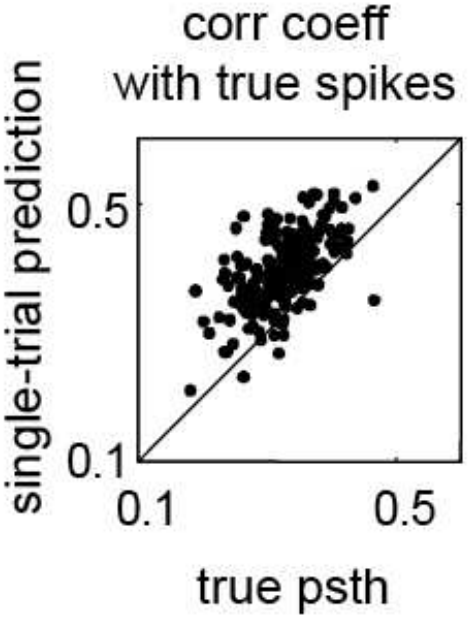






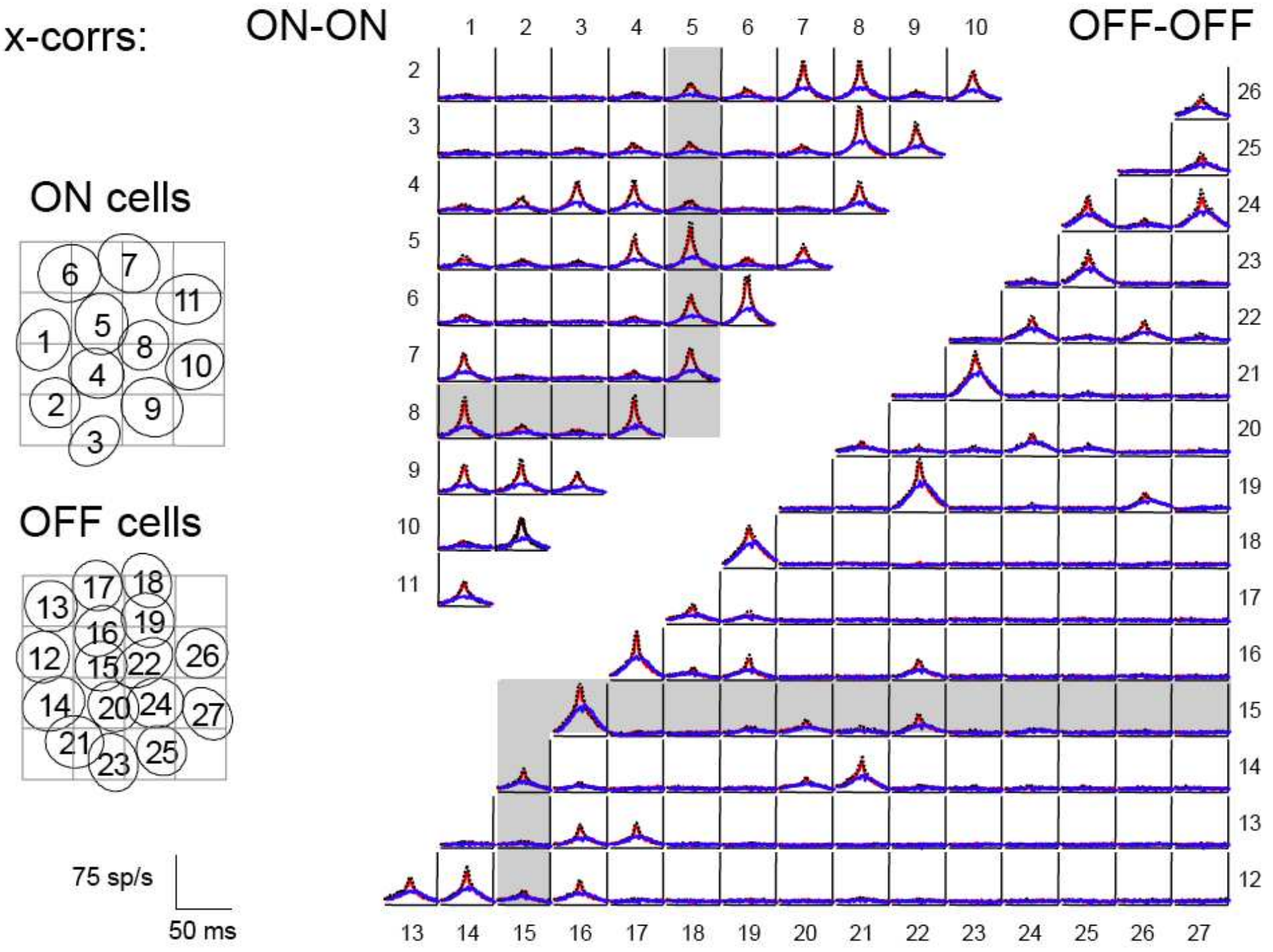






- single-trial variability predicted by local network activity

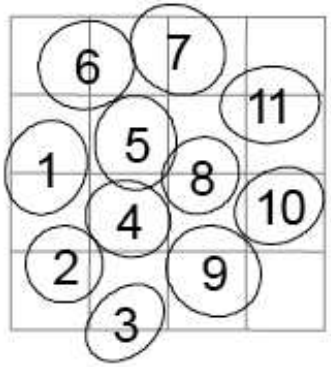
Model captures spatiotemporal cross-corrs



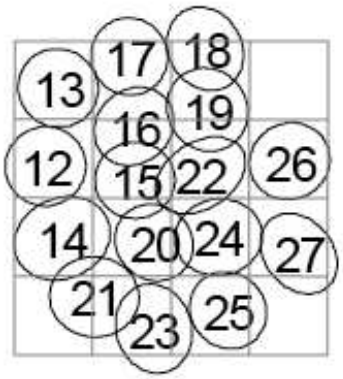
x-corrs:

ON-OFF

ON cells

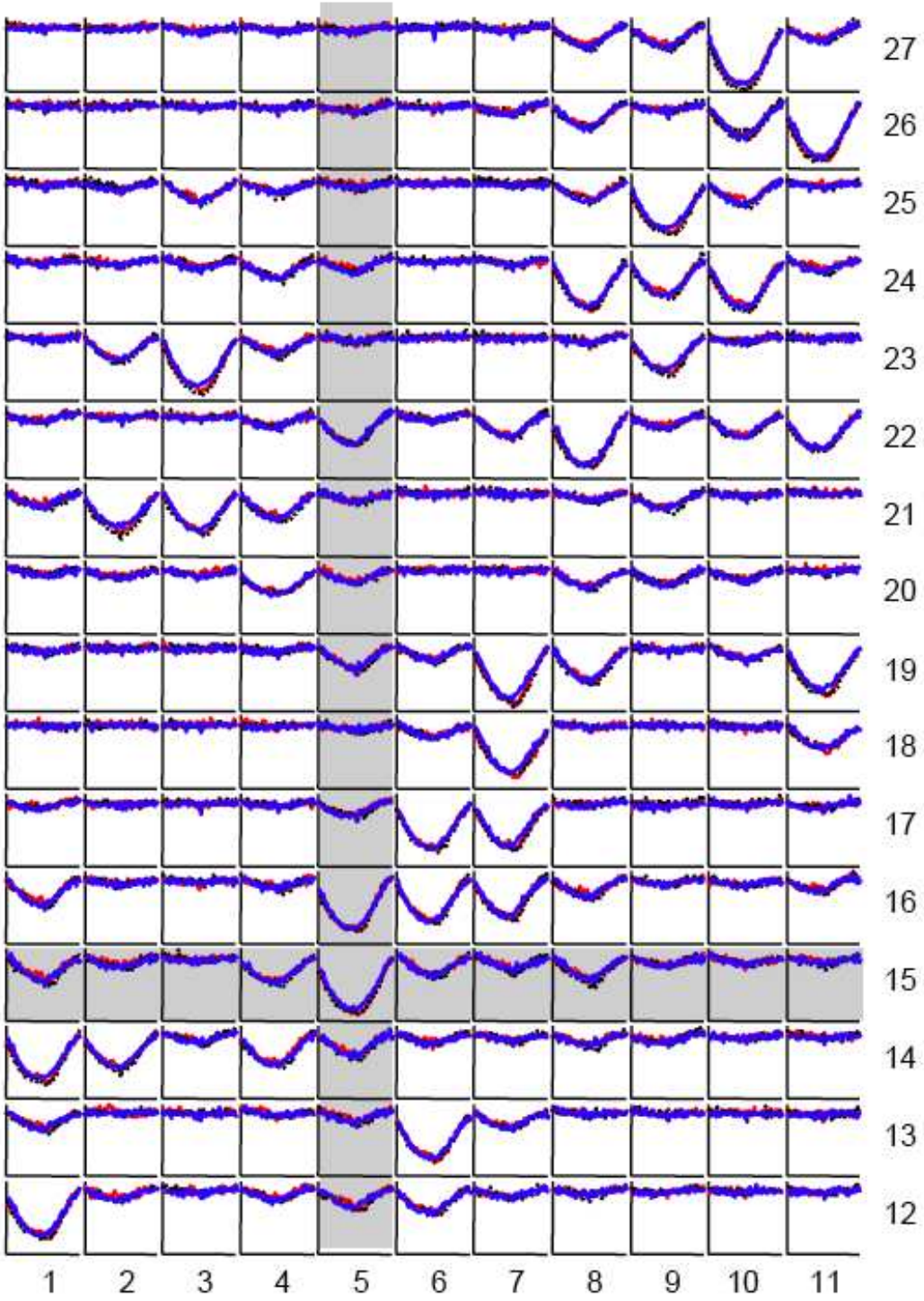


OFF cells

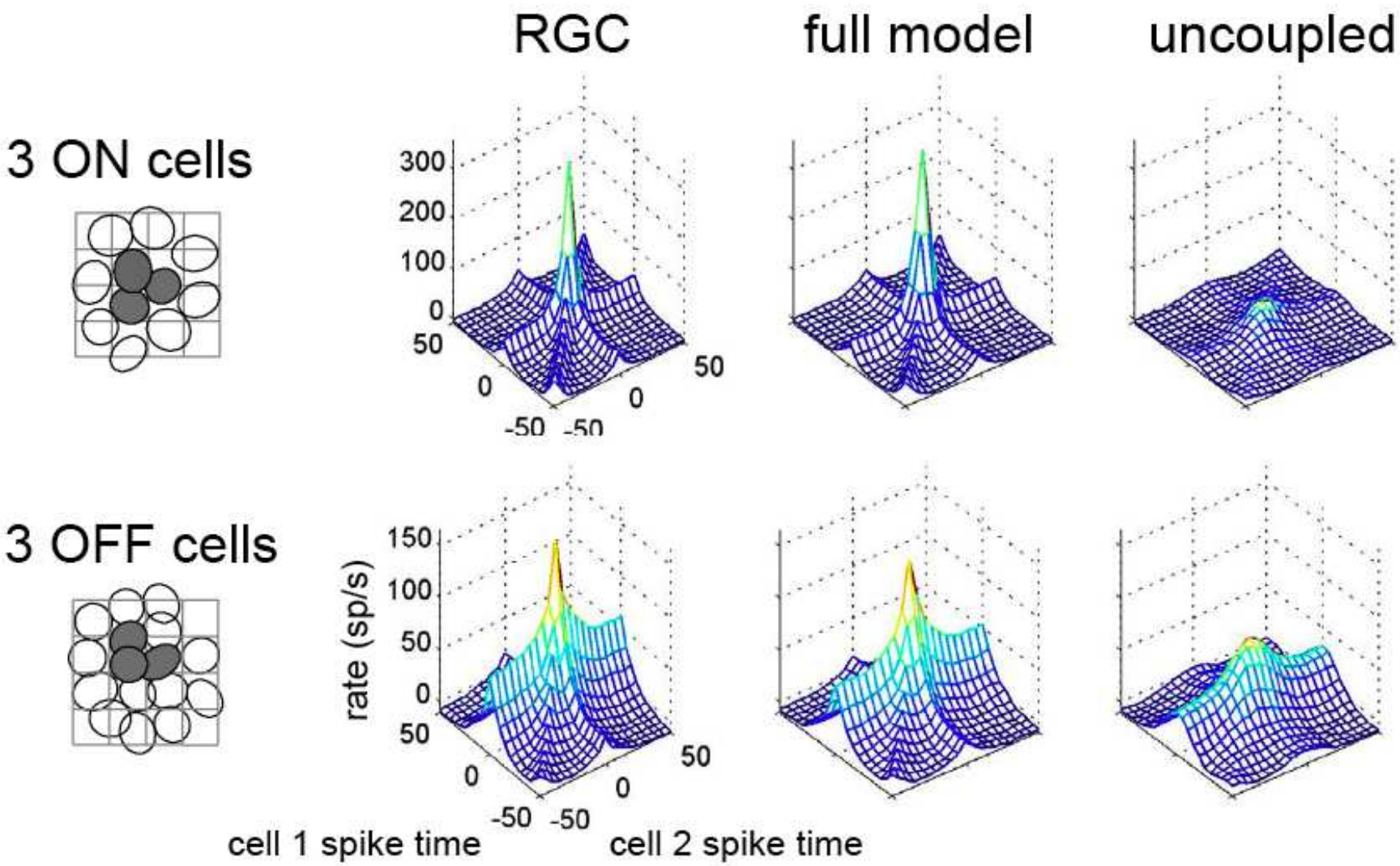


37 sp/s

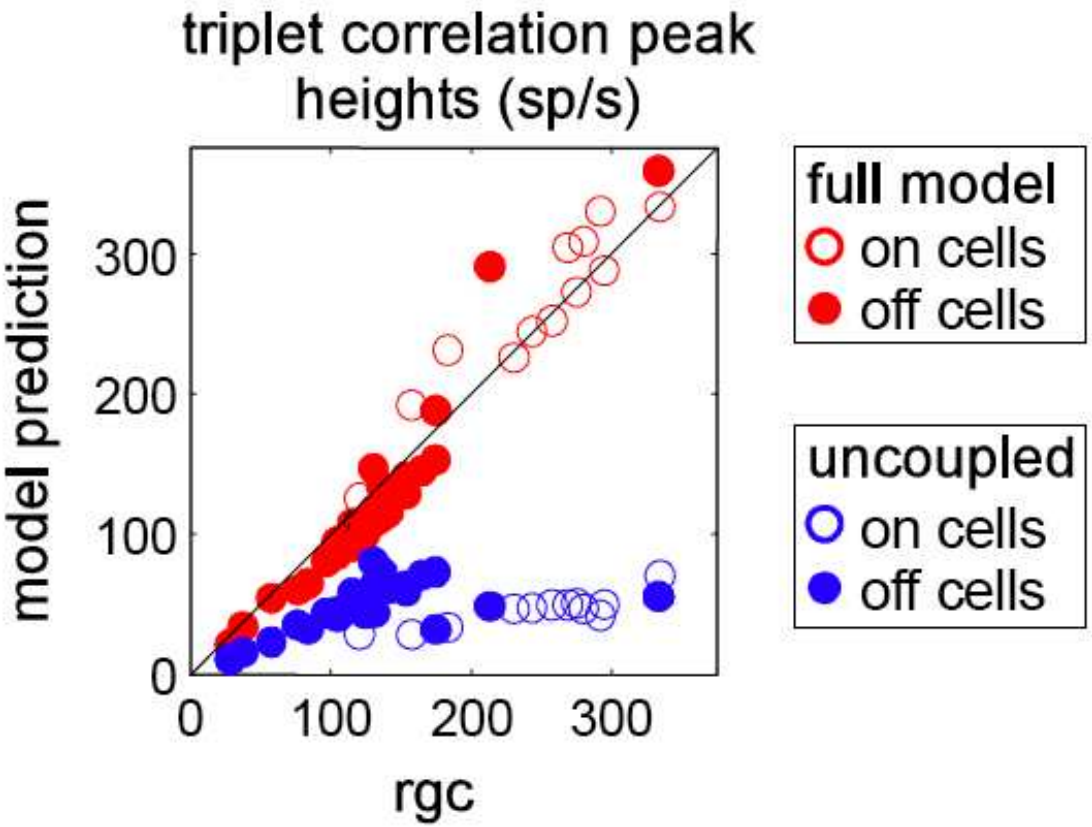
50 ms



Triplet correlations

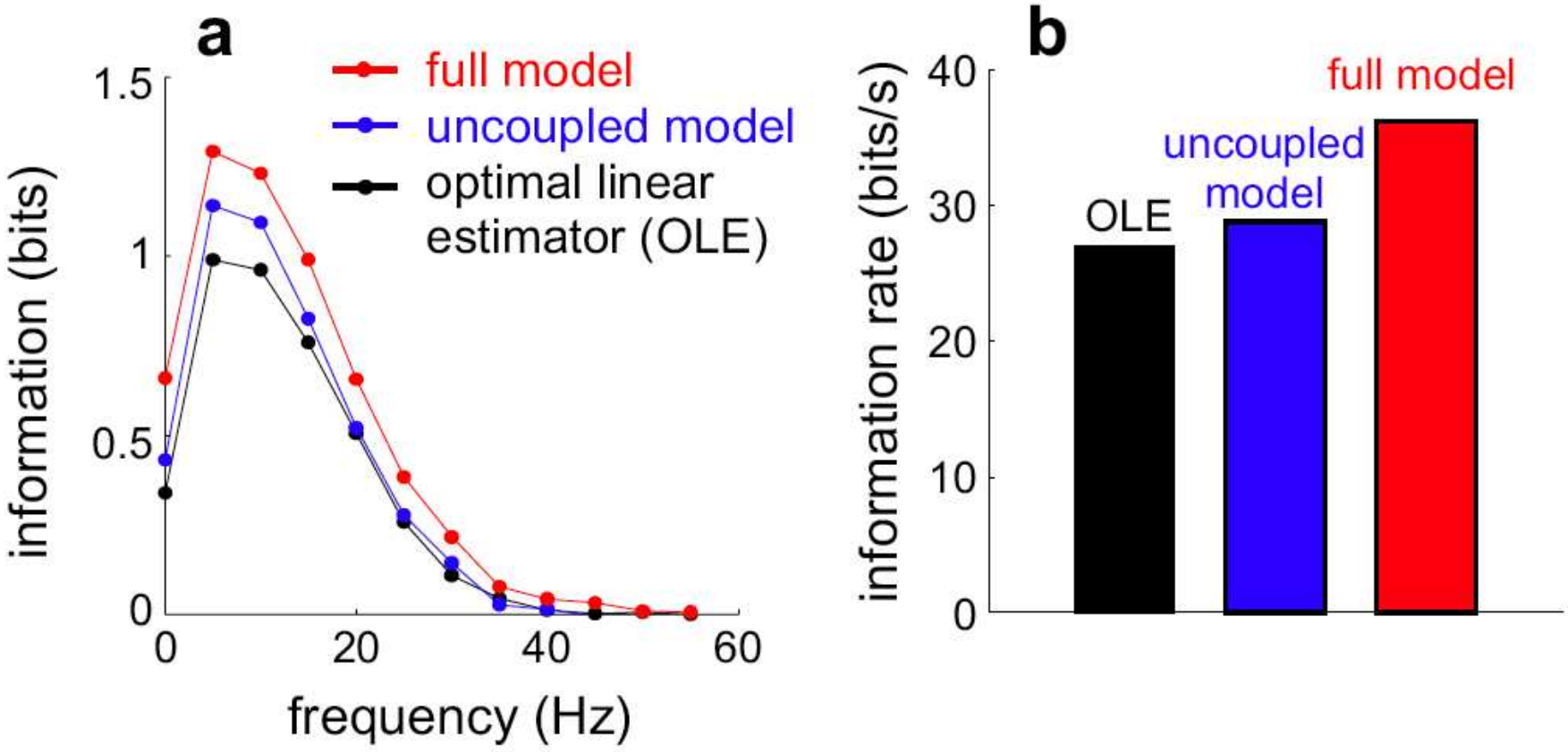


Triplet correlations



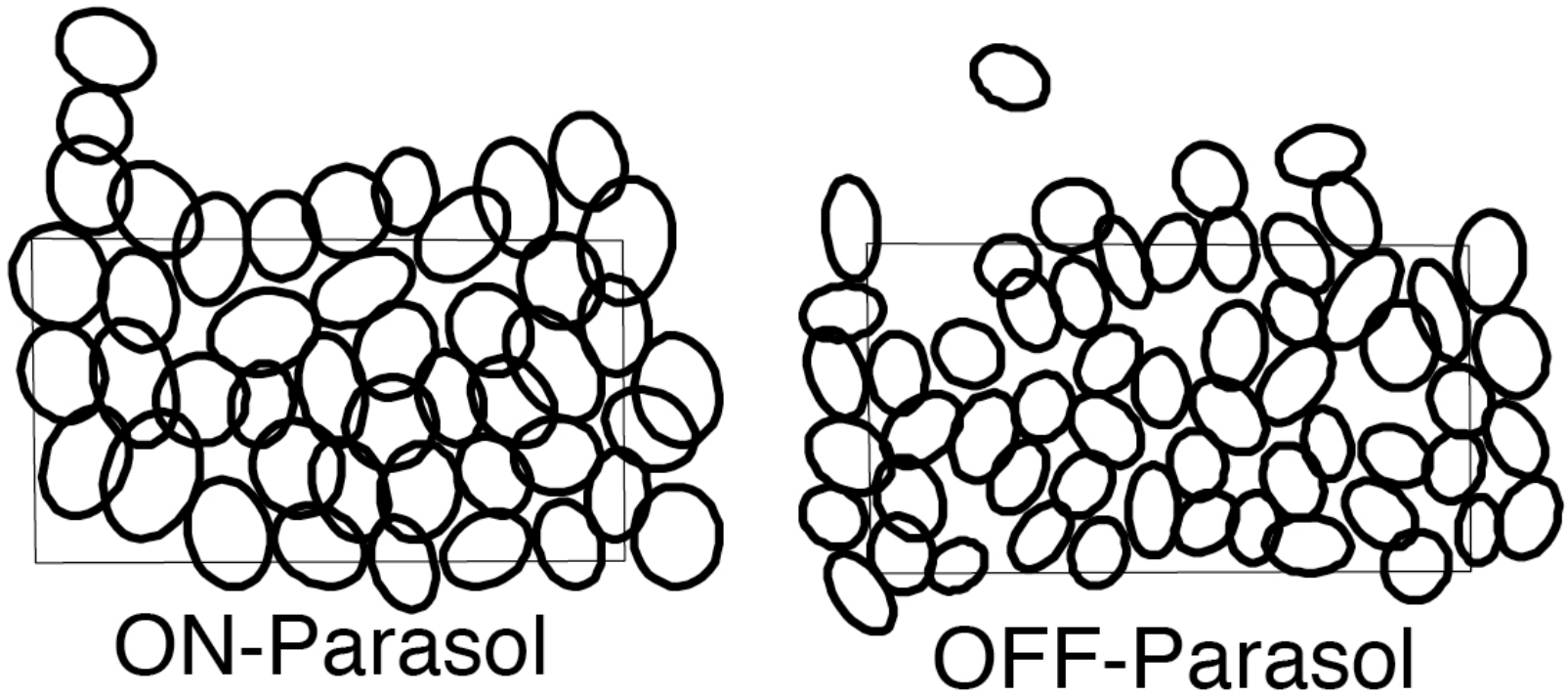
Optimal Bayesian decoding

— Compute $E(stim|resp)$ via MCMC under each model



— Including network terms mproves decoding accuracy.

Next: Large-scale network modeling



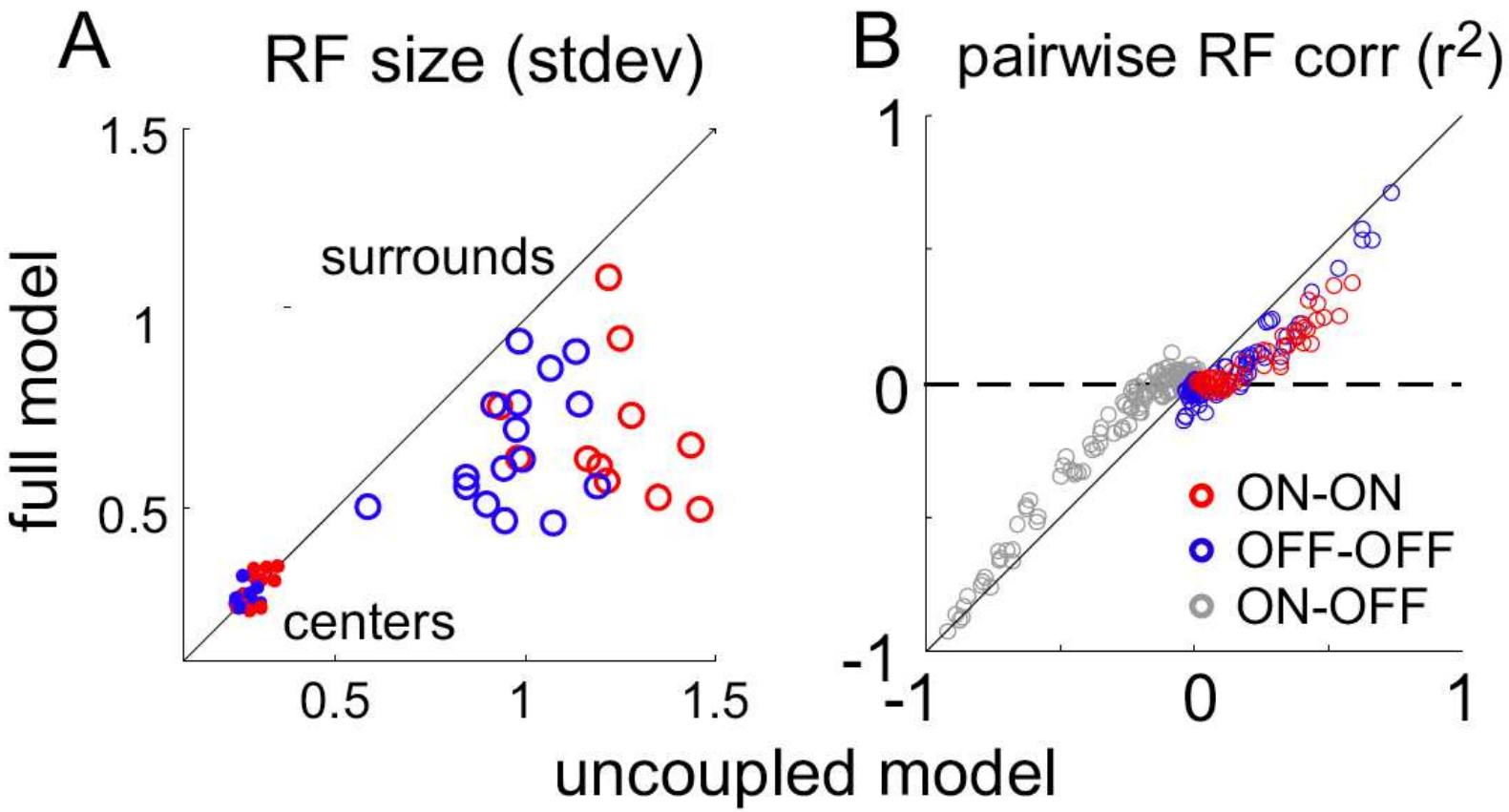
— Do observed local connectivity rules lead to interesting network dynamics? What are the implications for retinal information processing?

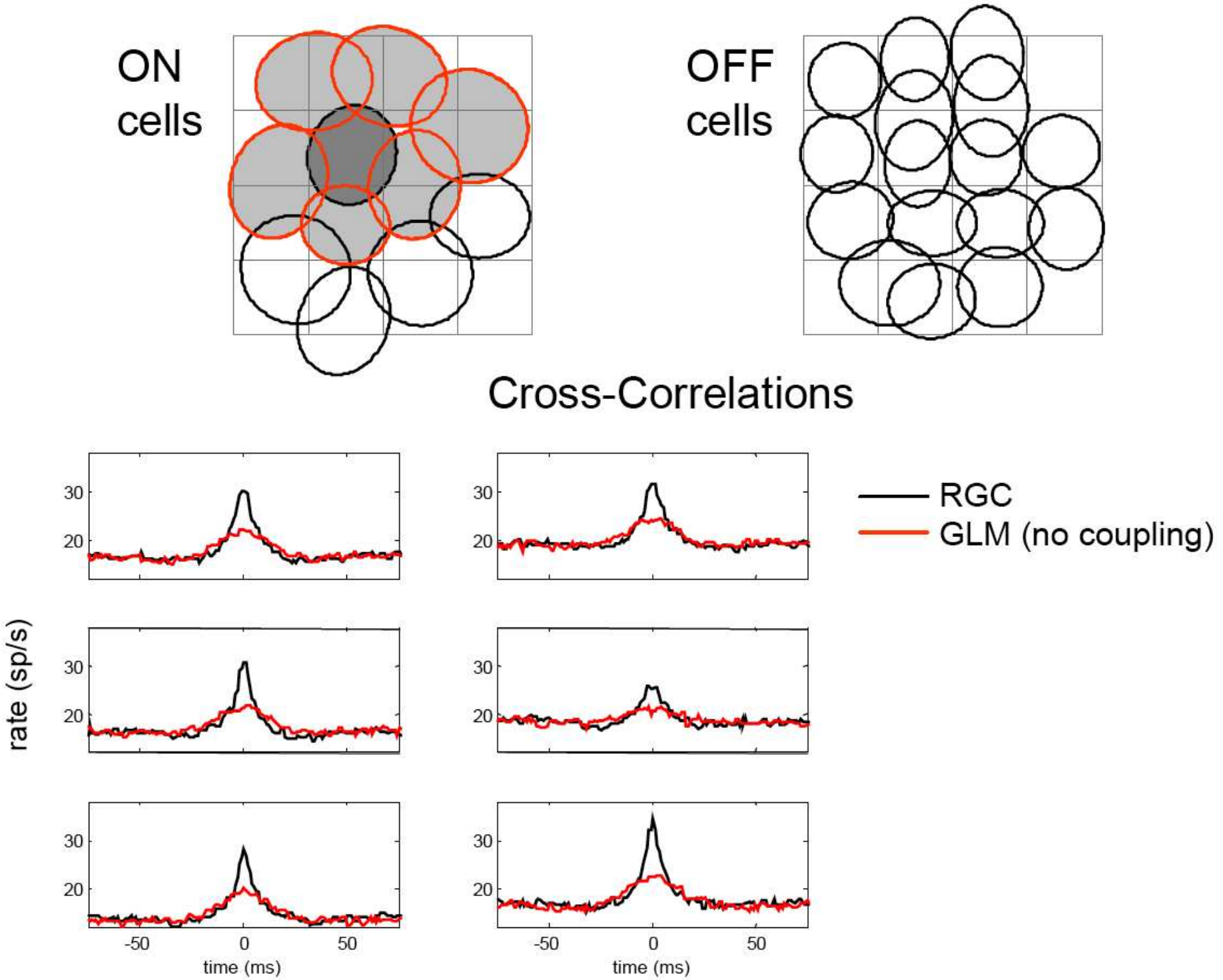
References

Pillow, J. and Paninski, L. (2007). Model-based decoding, information estimation, and change-point detection in multi-neuron spike trains. *Submitted*.

Pillow, J., Paninski, L., Shlens, J., Simoncelli, E., and Chichilnisky, E. (2005). Modeling multi-neuronal responses in primate retinal ganglion cells. *Comp. Sys. Neur. '05*.

Fitting coupling terms exposes smaller receptive fields




ON
cells
OFF
cells
Cross-Correlations
RGC
GLM (no coupling)
rate (sp/s)
30
20
-50
0
50
time (ms)