A model of the V1 network, and cortical oscillations

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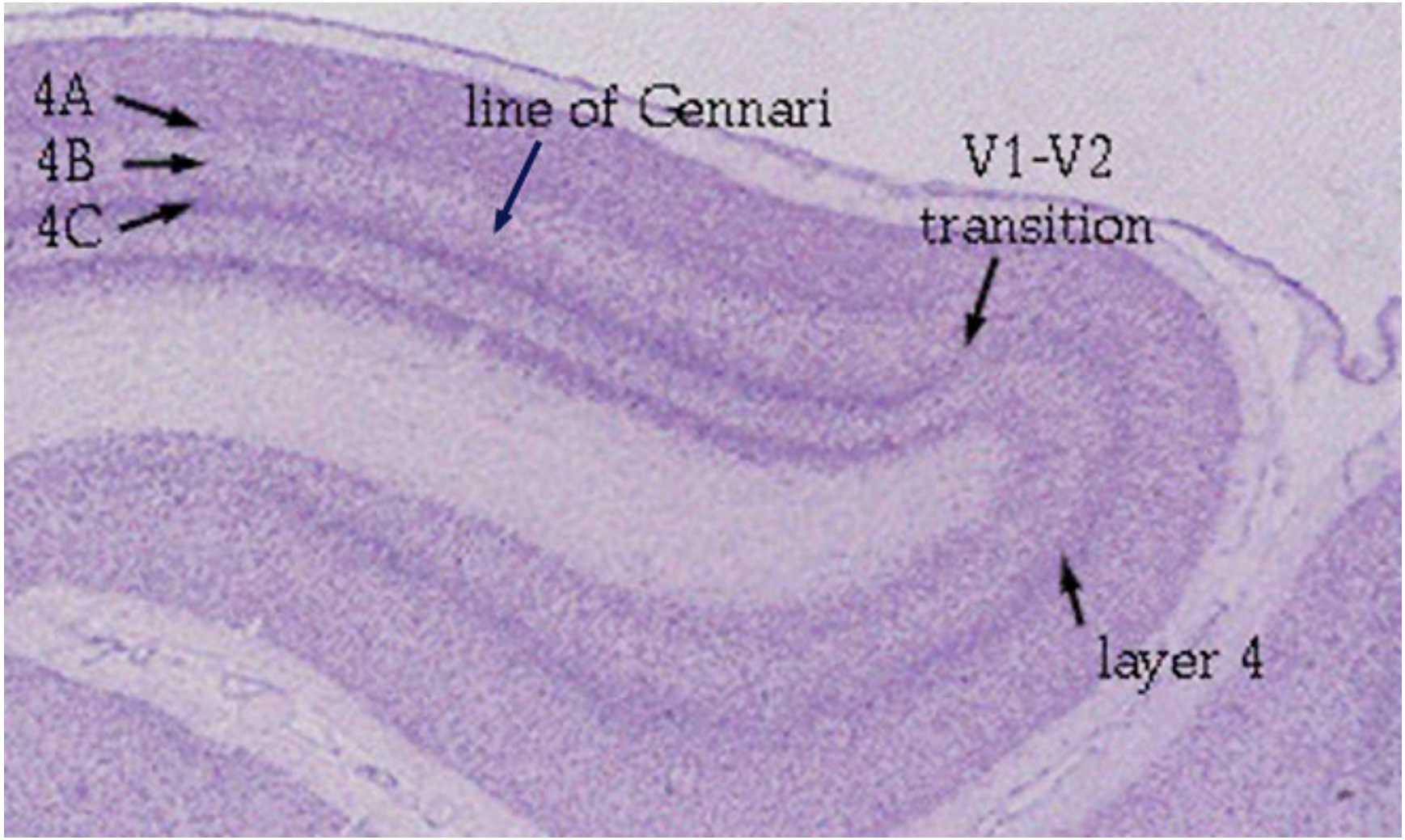
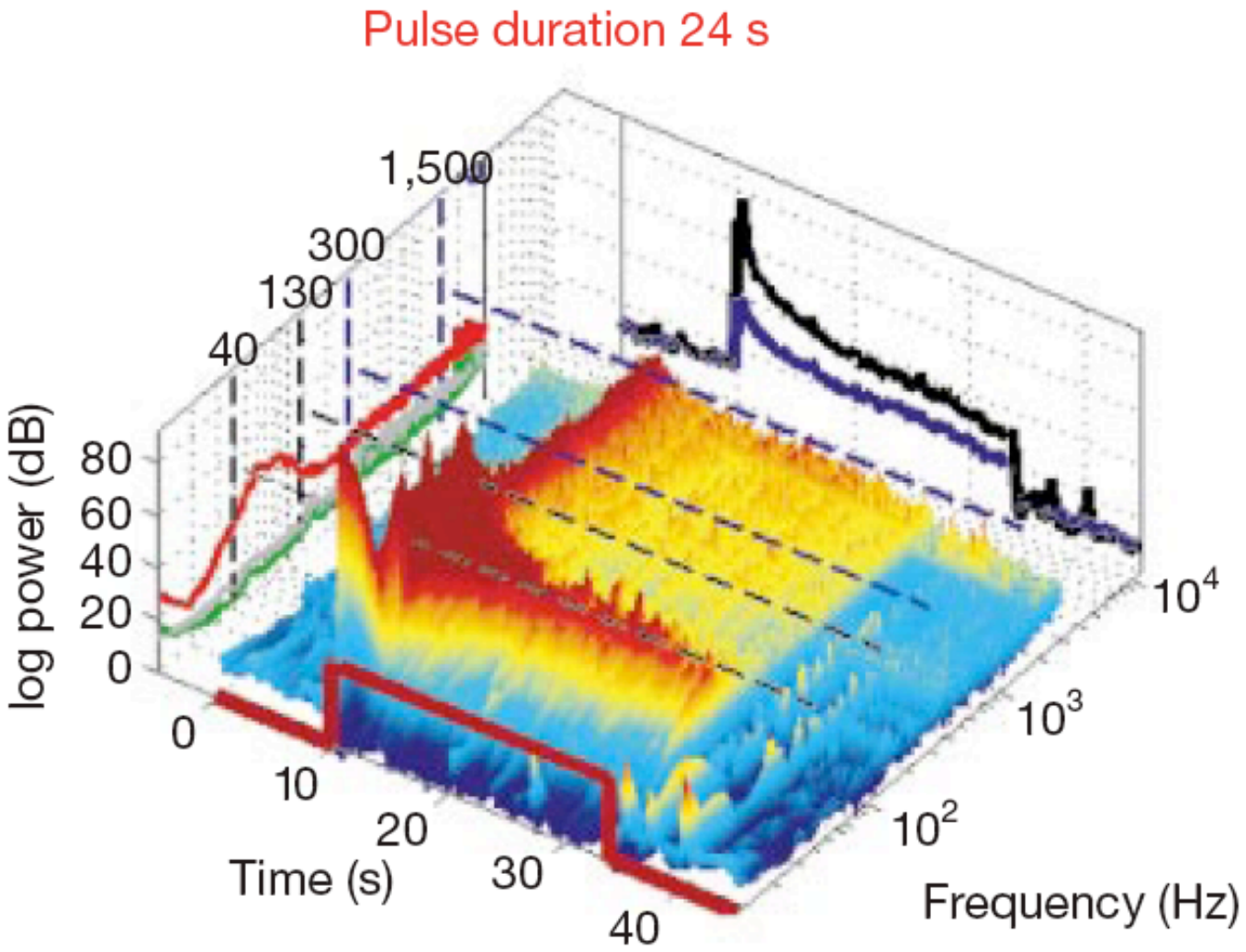
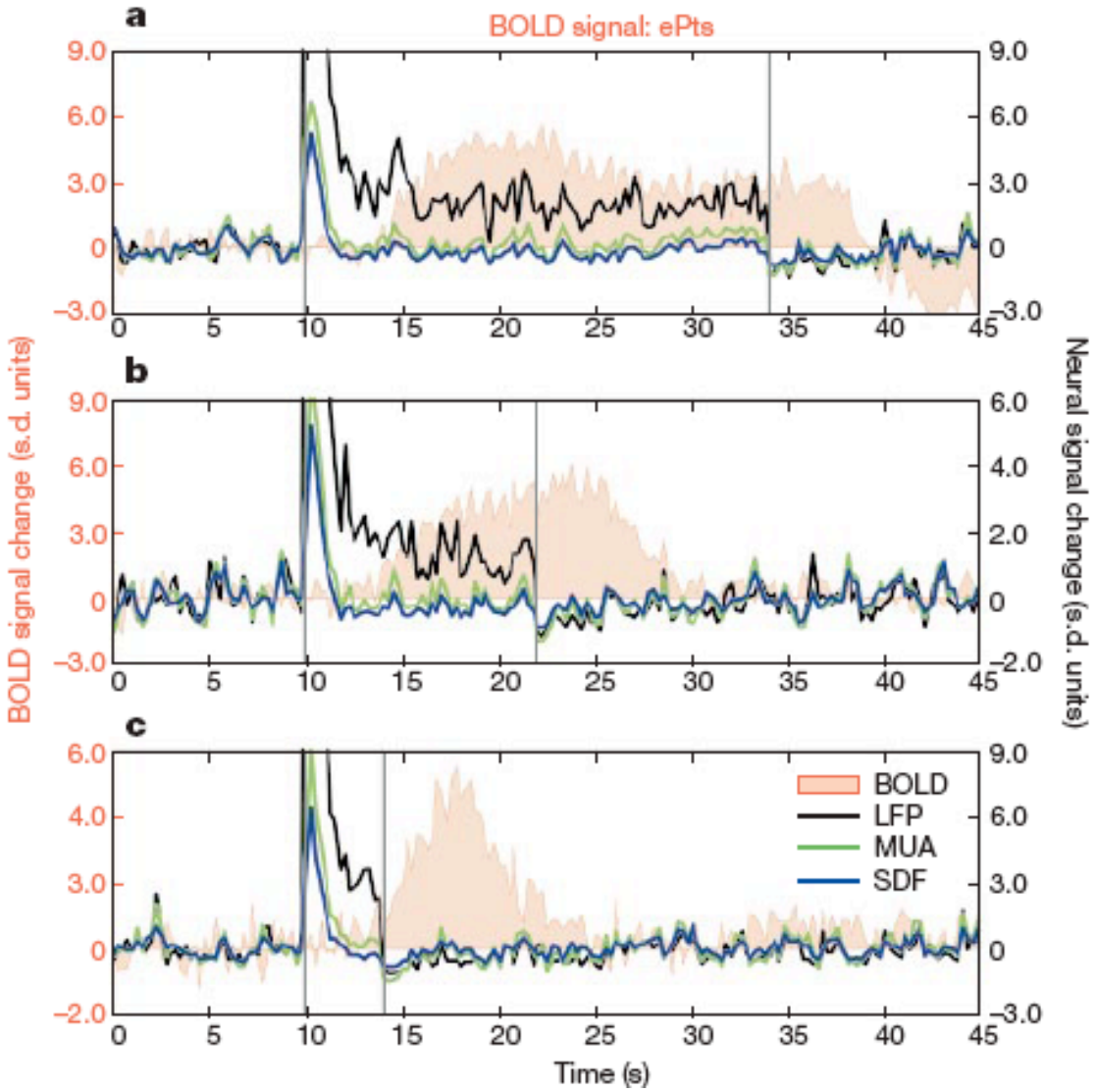
V1 cortex



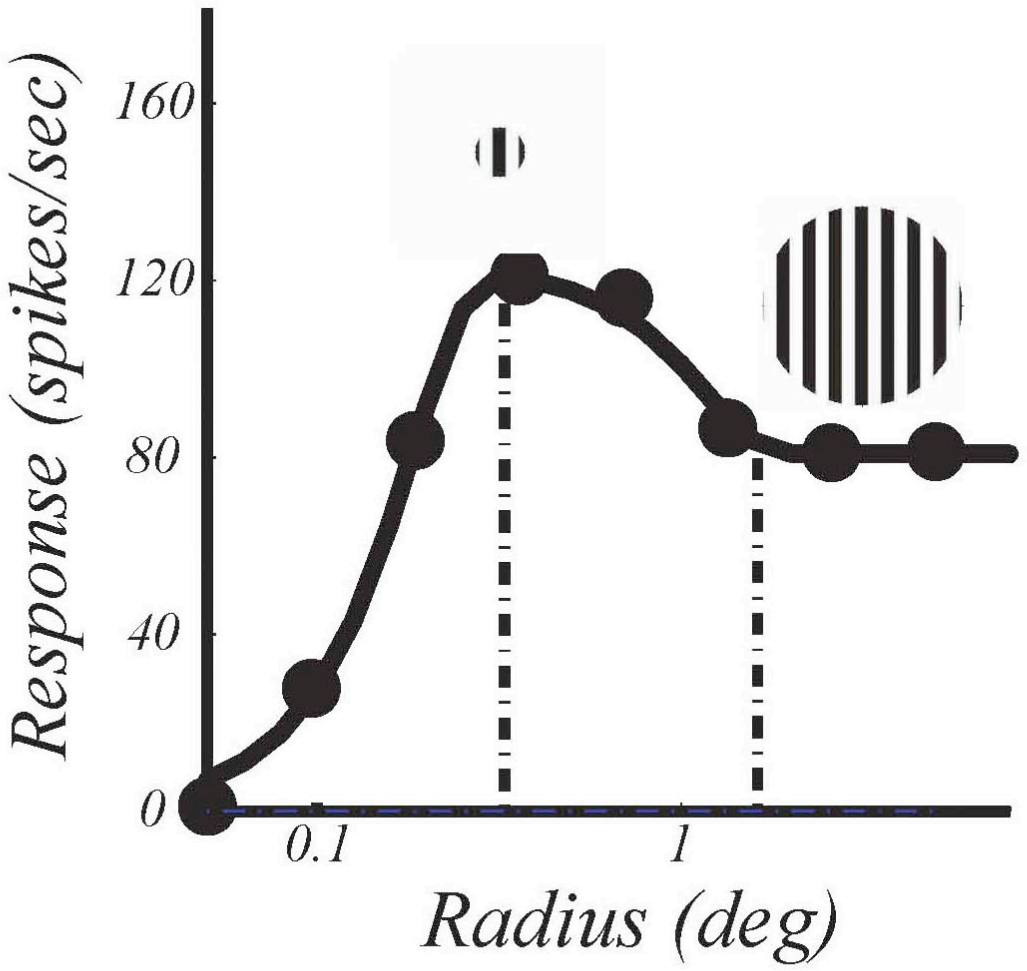
V1 Local Field Potential (LFP)spectrograms, from Logothetis et al. 2001

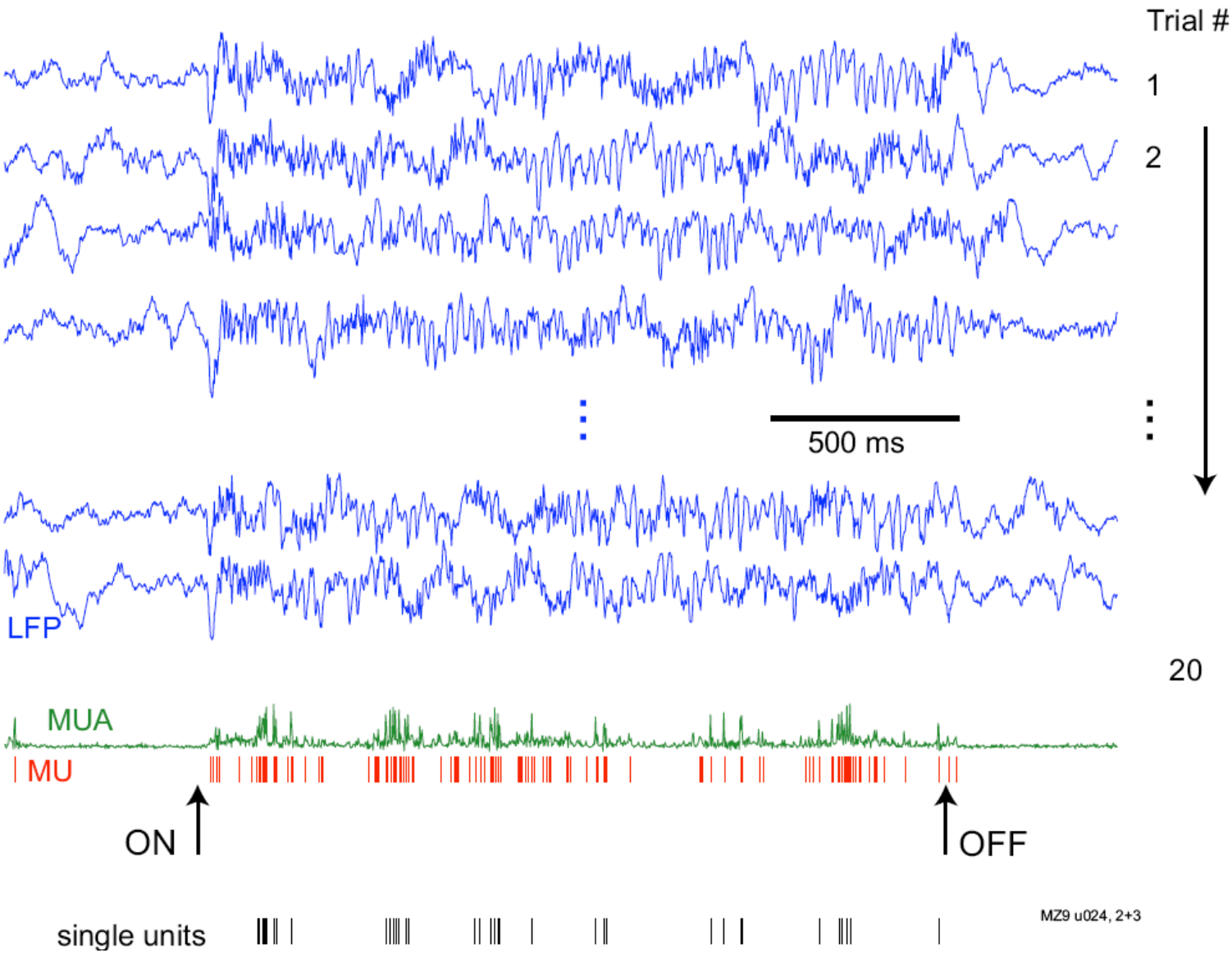


Response dynamics, from Logothetis et al. (2001)

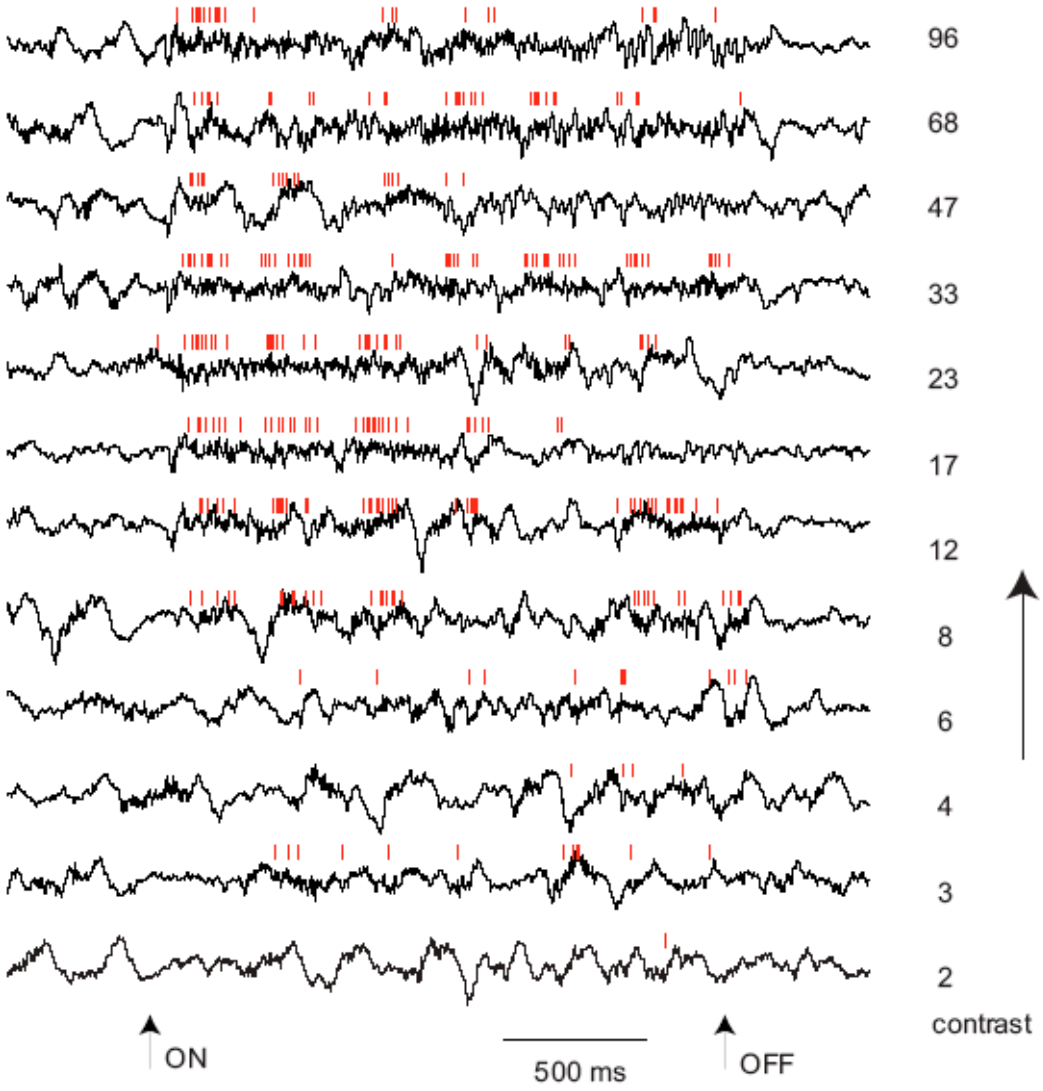


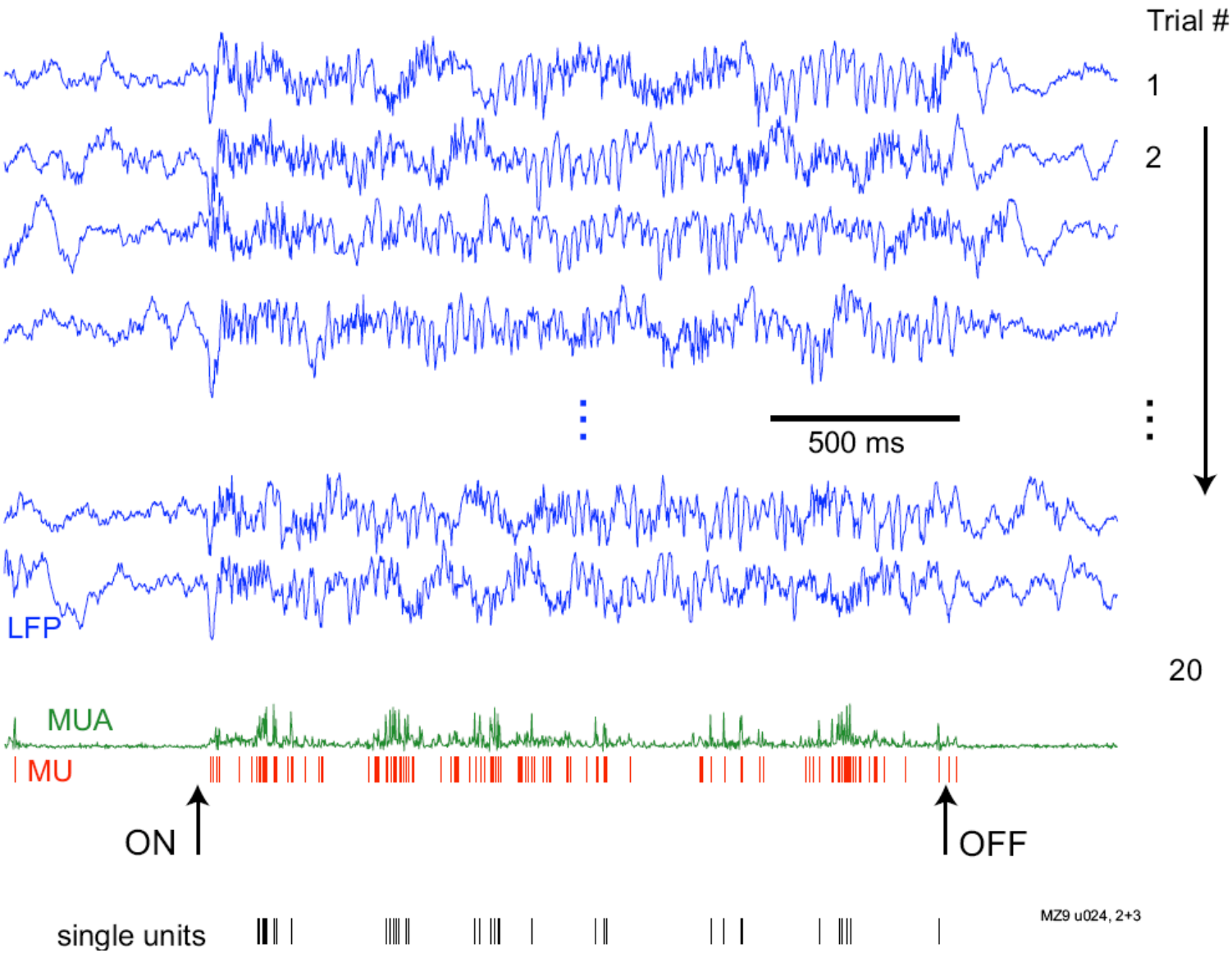
Optimum size for V1 cells



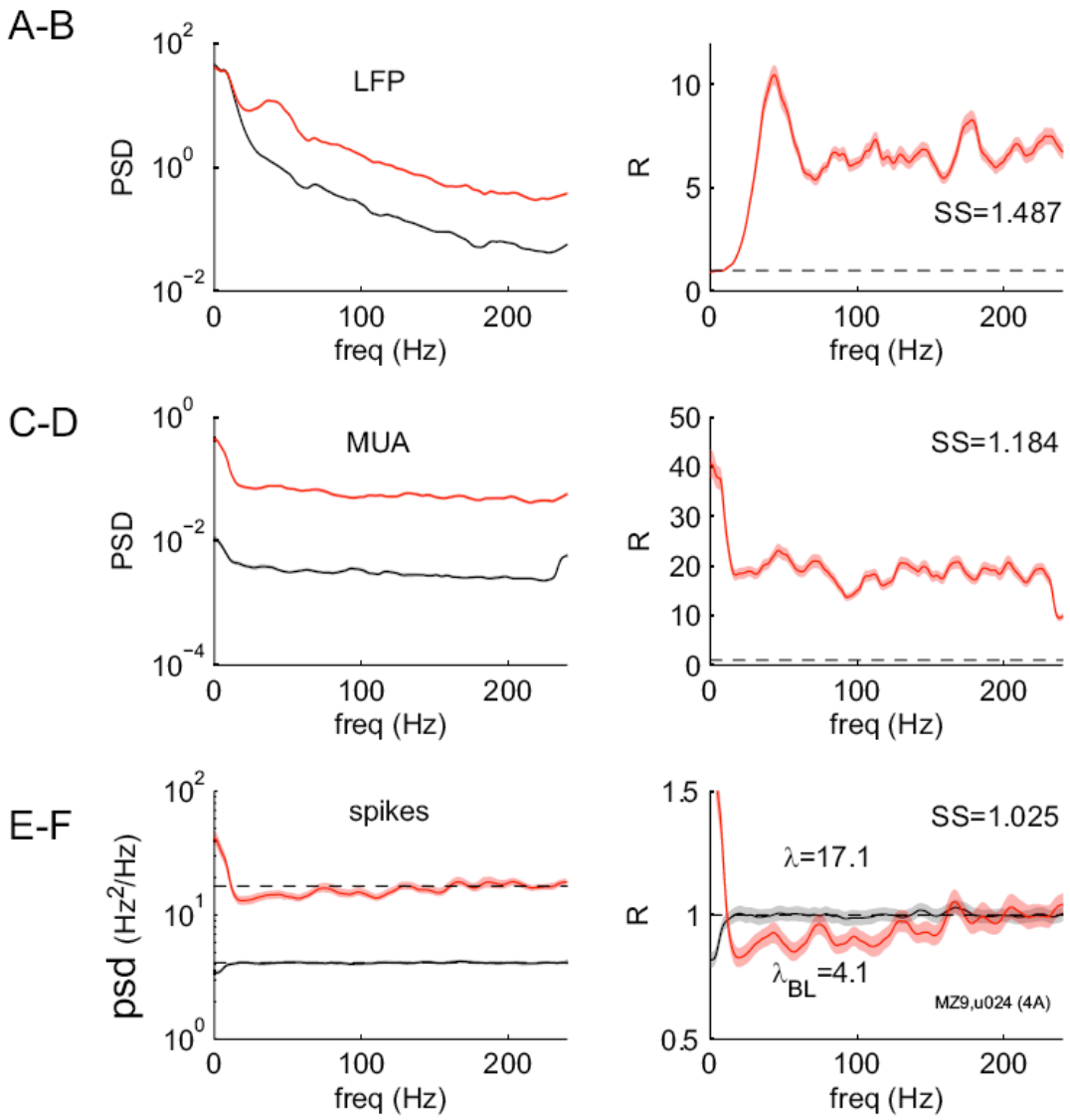

Trial #
1
2
20
500 ms
LFP
MUA
MU
ON
OFF
single units
MZ9 u024, 2+3

Dependence of the LFP on contrast

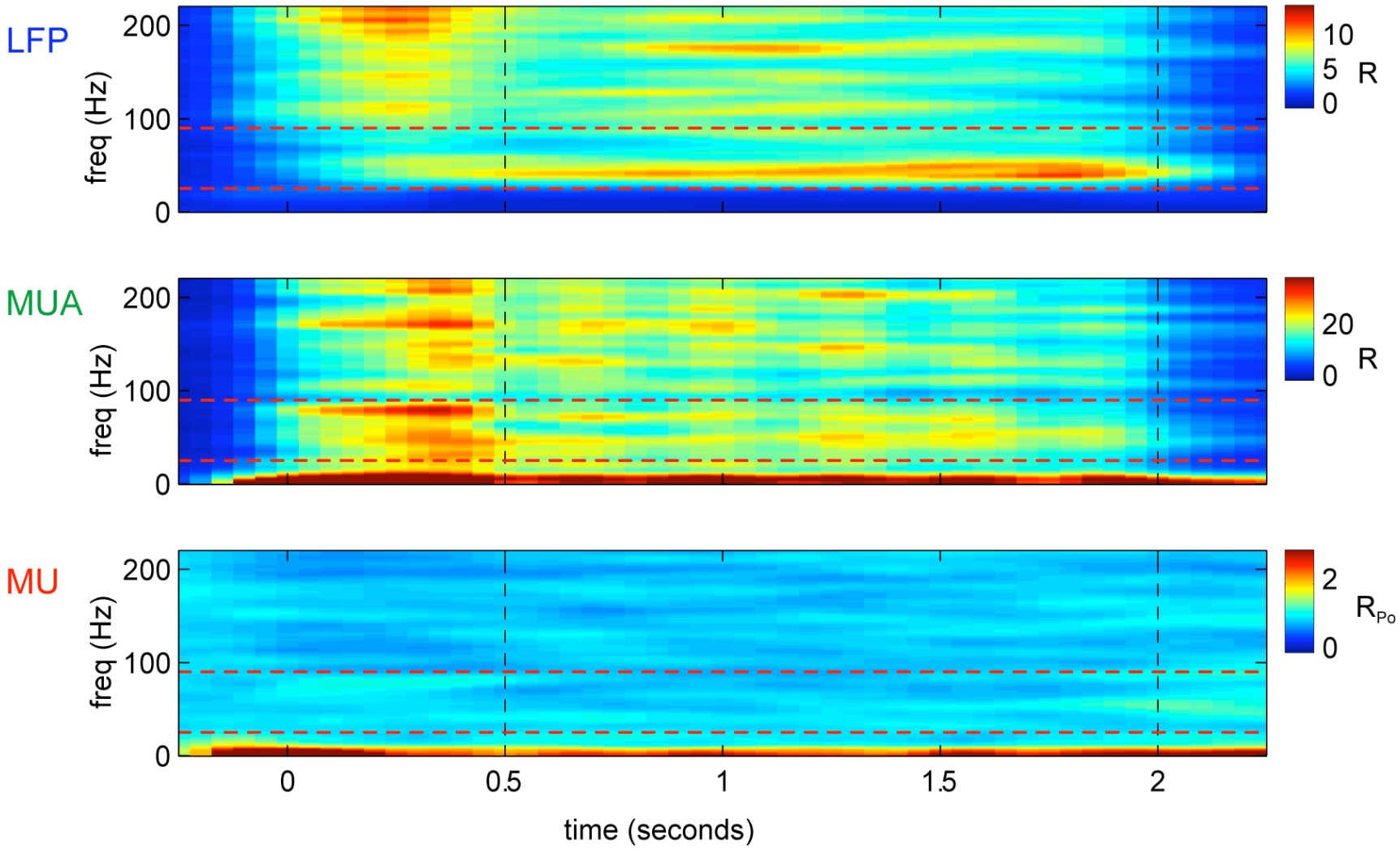



Trial #
1
2
20
500 ms
LFP
MUA
MU
ON
OFF
single units
MZ9 u024, 2+3

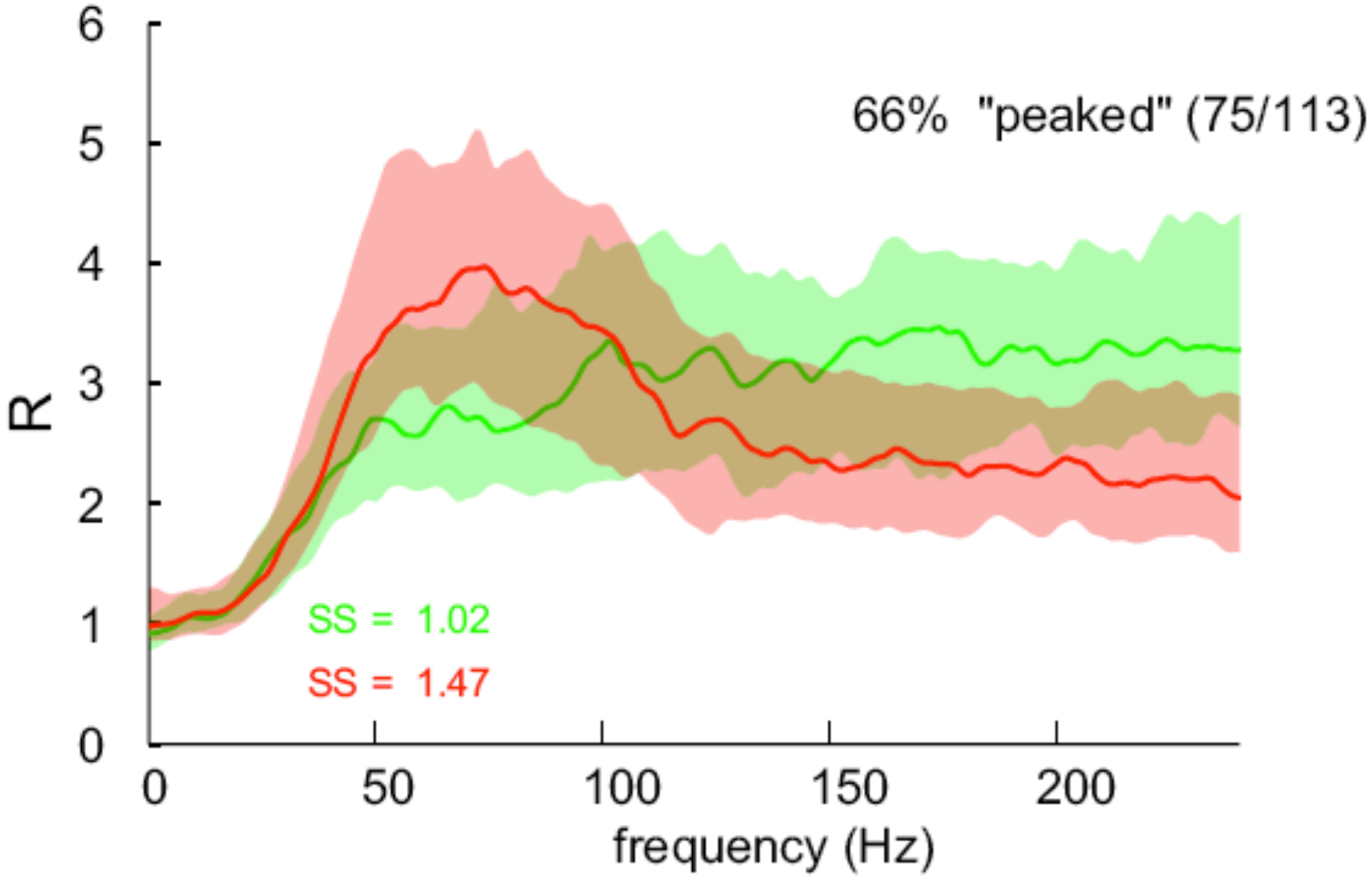
Spectral analysis of the LFP, MUA, and spikes



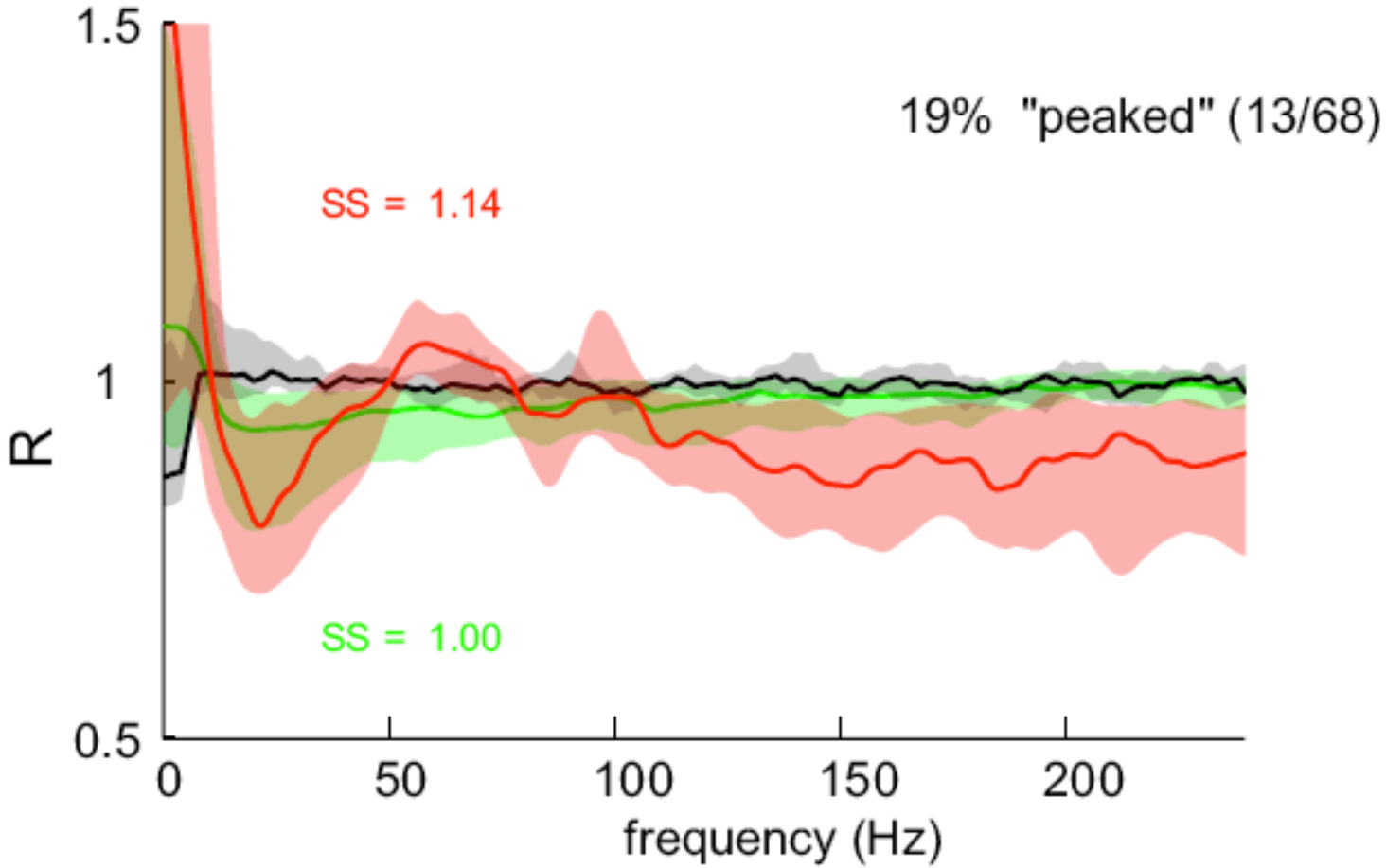
Spectrograms of the LFP, MUA, spikes in our experiment



Average LFP R-spectra



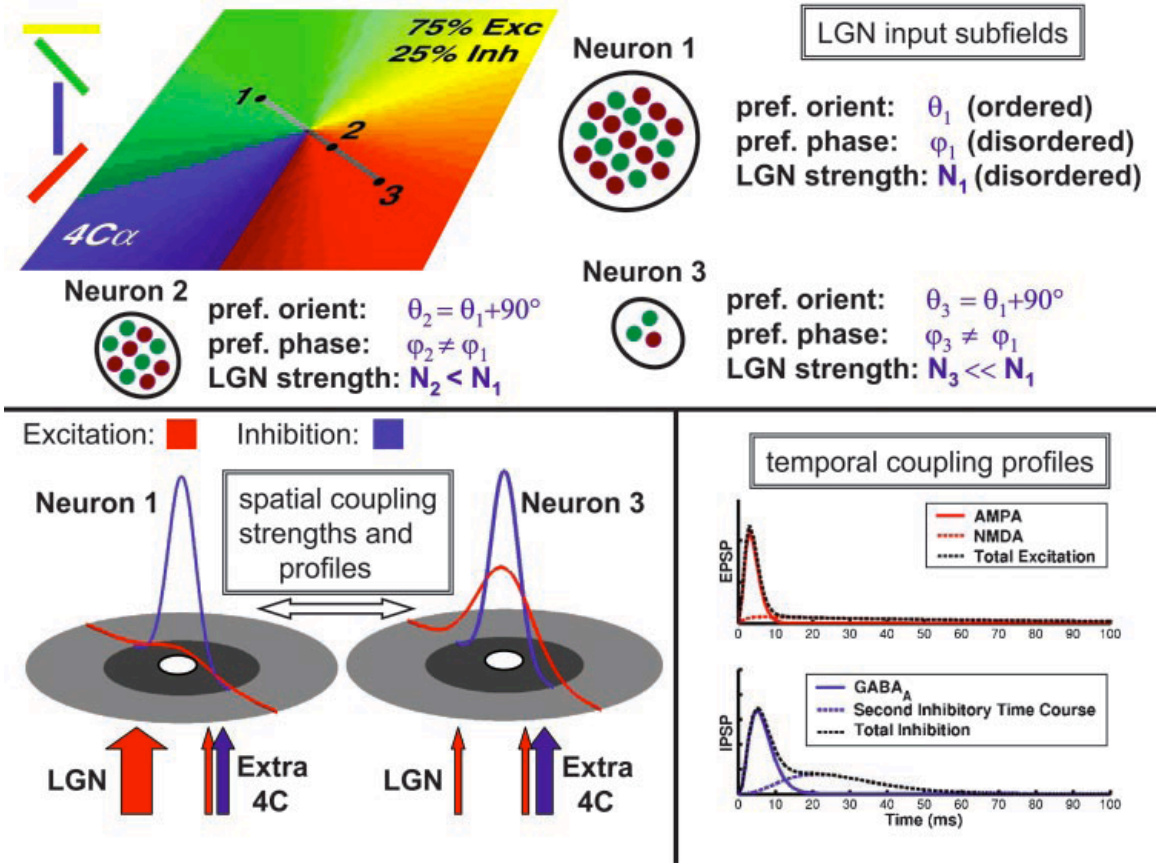
Average Spike spectra



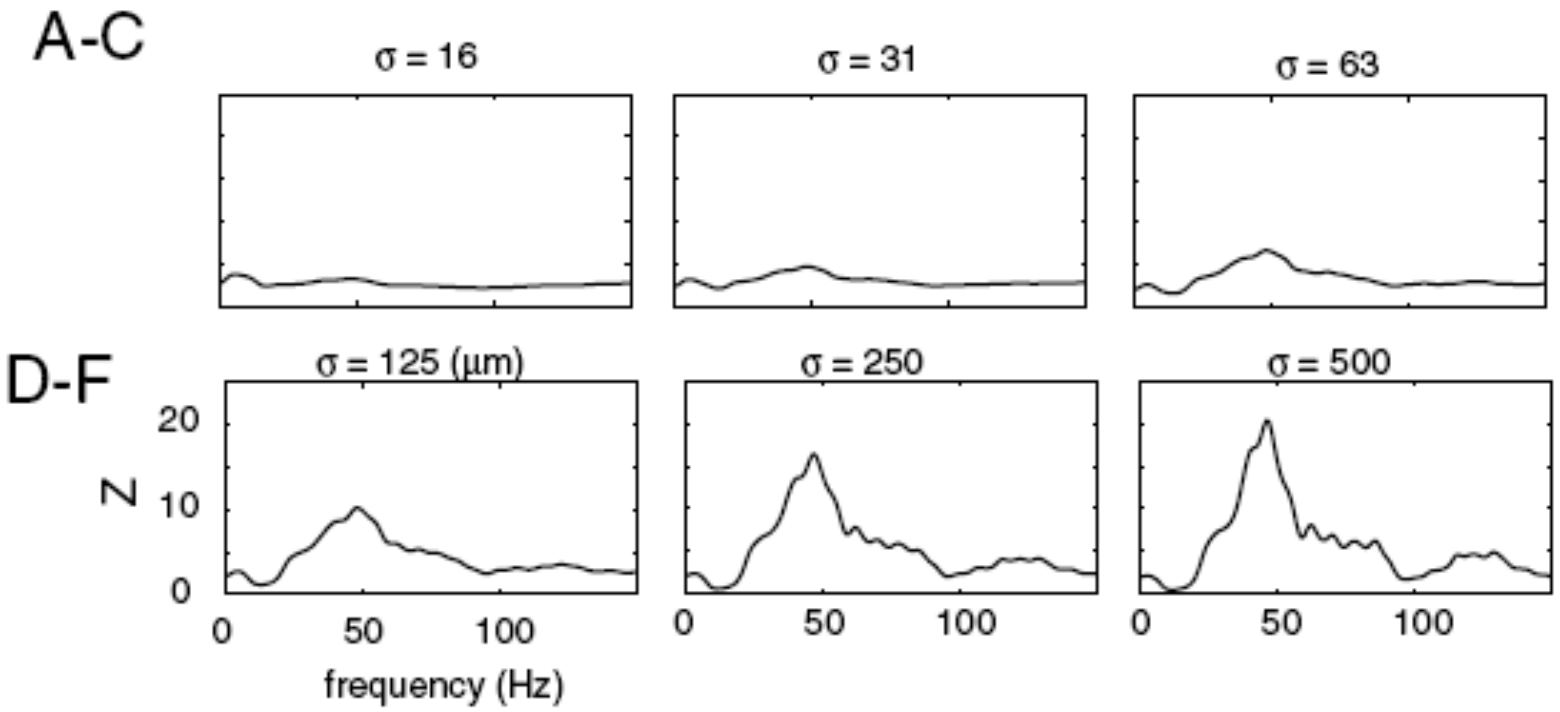
Steady state behavior of V1

- LFP sustained, single-unit spikes more transient
- LFP power spectrum becomes peakier at high contrast
- LFP peak is in gamma band of frequencies (25-90Hz)
- Spike power spectrum usually not peaked with the stimuli we used here (optimal for single cell spike rate)

V1- egalitarian model



R-spectra of V1-egalitarian model for different population sizes

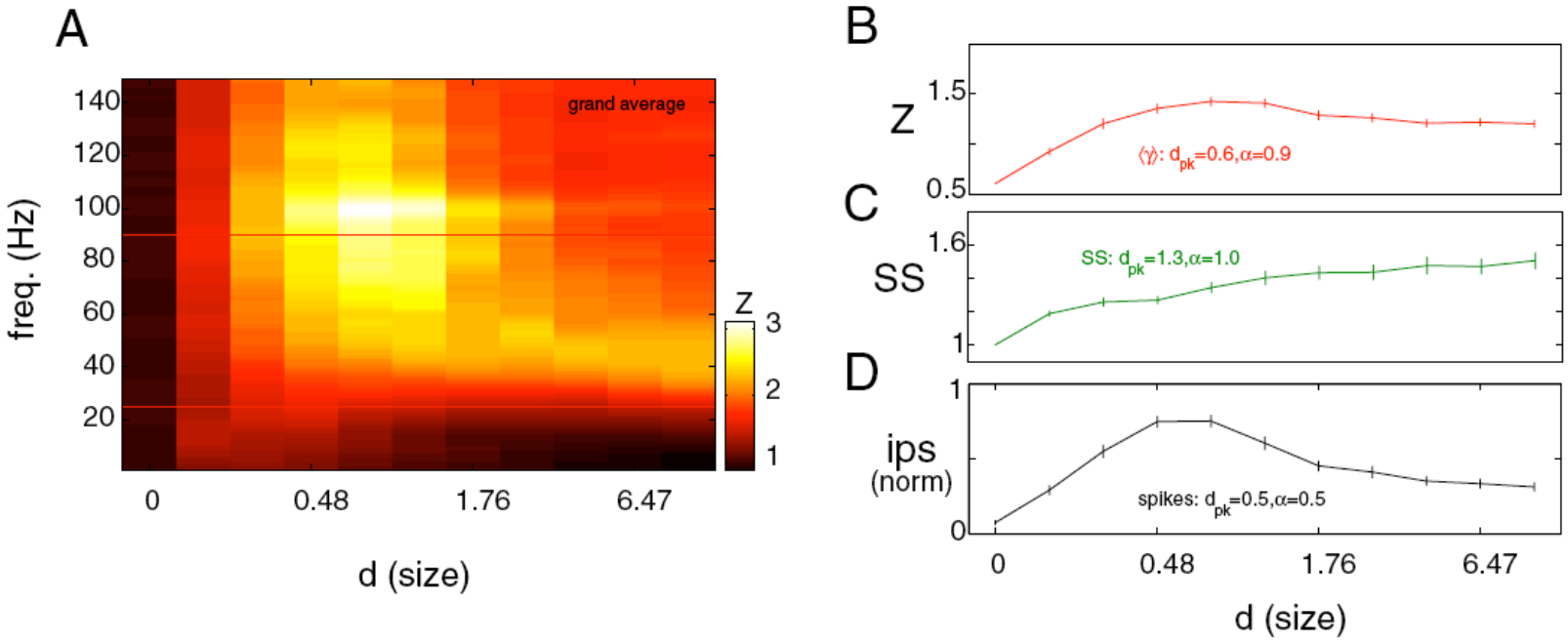


Egalitarian model and LFP data

- Single cells do not have peaked spectra.
- Ensembles of cells do have gamma band peaks.
- In the model, spectral peak is a consequence of the strong excitatory-inhibitory cortico-cortical interactions, and the time constants of E and I.

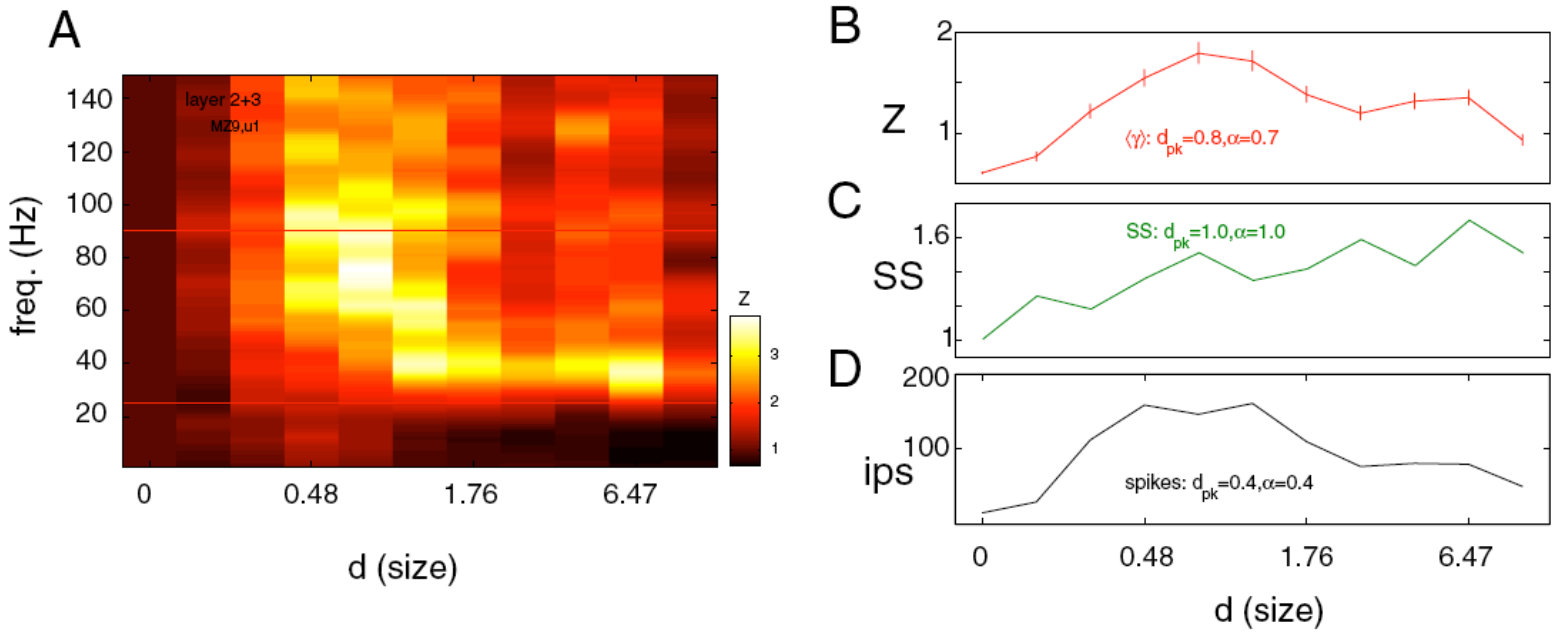
LFP:dependence on stimulus size

average across all recording sites

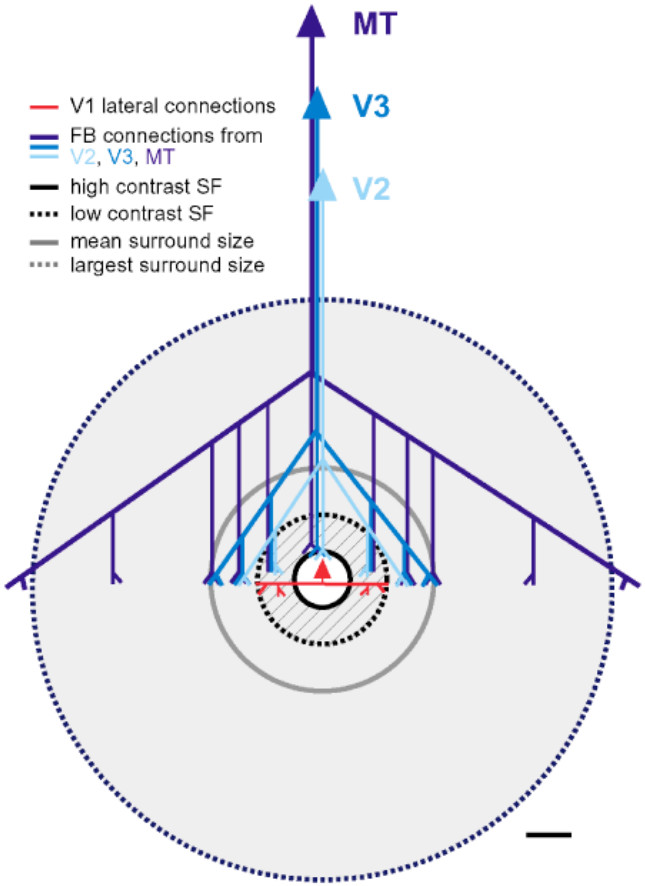


LFP dependence on size

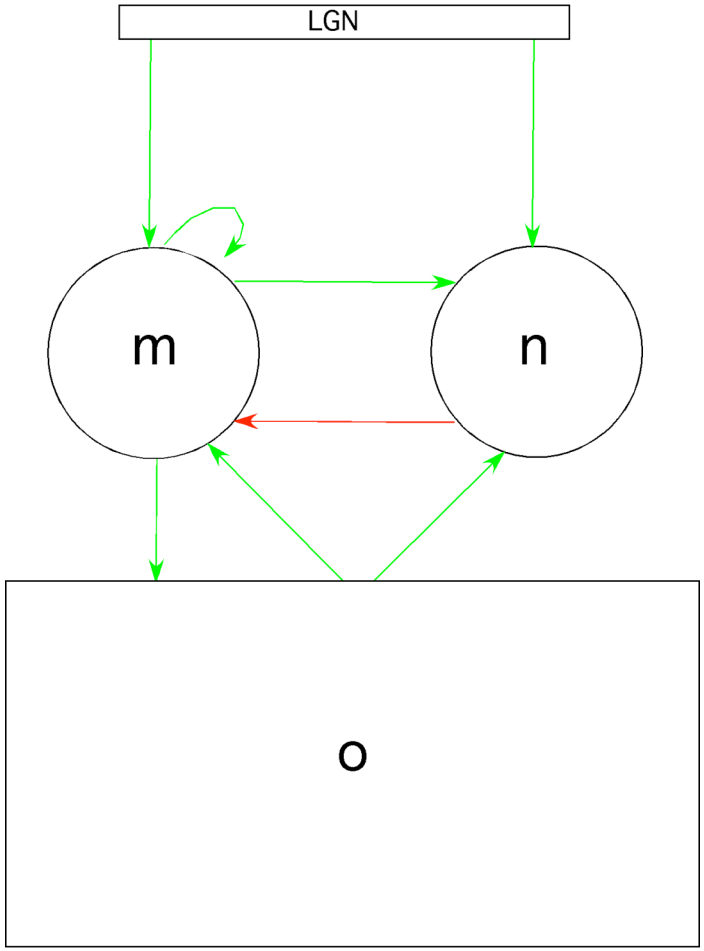
single site, layer 2/3



Feedback connectivity(from Angelucci et al 2002)



3-population model schematic



m, excitatory neurons

n, inhibitory neurons

o, Extra-striate feedback

Three population model

$$\tau_E \frac{dm(r,t)}{dt} = -m(r,t) + \left[I_{LGN}(r,t) + S_{EE}K_E * m(r,t) - S_{EI}K_I * n(r,t) + U_{EF}Q * o(r,t)\right]_+ \quad (1)$$

$$\tau_I \frac{dn(r,t)}{dt} = -n(r,t) + \left[\psi I_{LGN}(r,t) + S_{IE}K_E * m(r,t) + U_{IF}Q * o(r,t)\right]_+ \quad (2)$$

$$\tau_E \frac{do(r,t)}{dt} = -o(r,t) + \left[U_{FE}F * m(r,t)\right]_+ \quad (3)$$

ψ is a constant giving the strength of LGN drive to inhibitory population relative to excitatory population

Stationary states of the model

Stationary profile of the excitatory population, $m(r,\theta)$ has the form

$$m(r,\theta) = Aa + Bb(r)\cos(\theta - 2\theta_0)$$

A and B are the mean and modulation amplitudes of the LGN input

$$a = \frac{1-\psi S_{ei}}{1-D(0)}$$

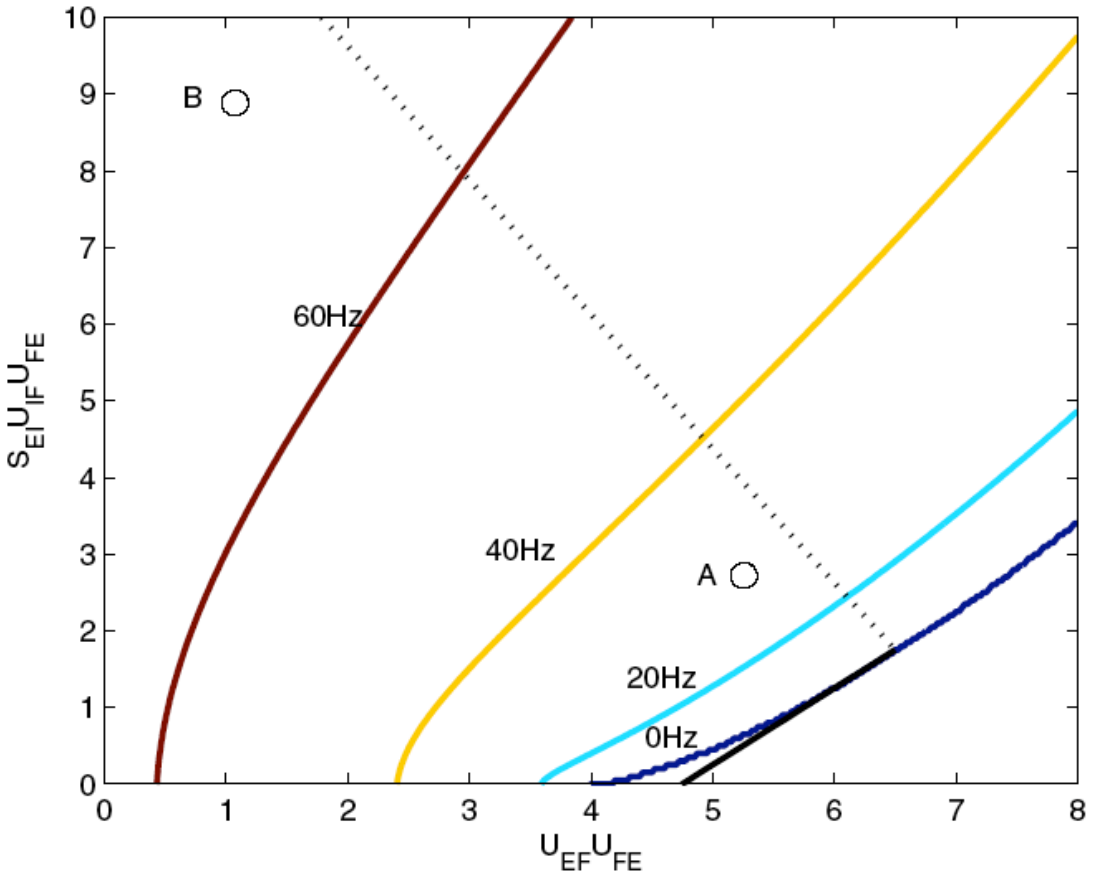
$$b(r) = \int_0^\infty \frac{dk}{k}\left[\frac{1-\psi S_{ei}\widetilde{K}_I(k)}{1-D(k)}\right]J_1(kr)$$

$$D(k) = S_{ee}\widetilde{K}_E(k) - S_{ei}S_{ie}\widetilde{K}_E(k)\widetilde{K}_I(k) + U_{ef}U_{fe}\widetilde{F}(k)\widetilde{Q}(k) - S_{ei}U_{if}U_{fe}\widetilde{K}_I(k)\widetilde{F}(k)\widetilde{Q}(k)$$

Oscillation frequency as a function of feedback

An expression for the change in resonance frequency when feedback is added

$$\Delta\omega^2\tau_E\tau_I = (S_{EE} - g - 1)(S_{EE} - g - 5)/4g - U_{EF}U_{FE}/g$$



Models and oscillations in V1

- Gamma band oscillations are expected in strongly coupled cortical networks, as in the egalitarian model (see Brunel and Wang, 2003)
- The effect of net-inhibitory feedback is to decrease the oscillation frequency within the gamma band, consistent with the 3-population model
- Speculation: the LFP signal may be reflecting inhibitory interneuron activity (based on dynamics, space scale).