

Topology and dynamics in biological neural networks

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BNN Course, March 11, 2019

Outline

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Measure of Network dynamics

- Firing rate

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 - Inter-spike intervals (CV)

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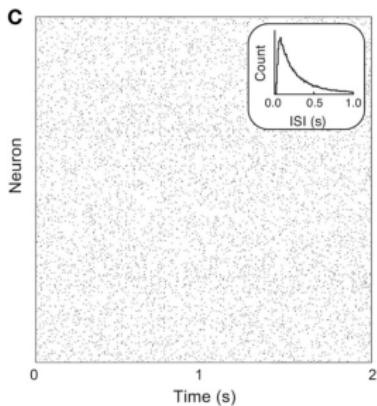
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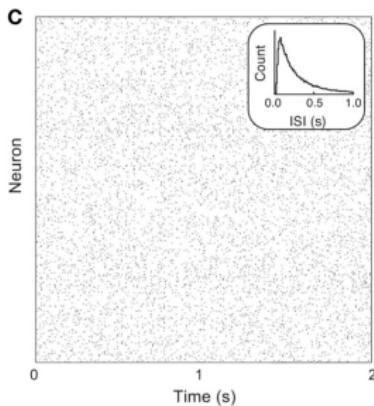
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 - Power spectrum (frequency domain)

Is random good enough? (I): Cortical activity



[Doiron & Litwin-Kumar, 2014]

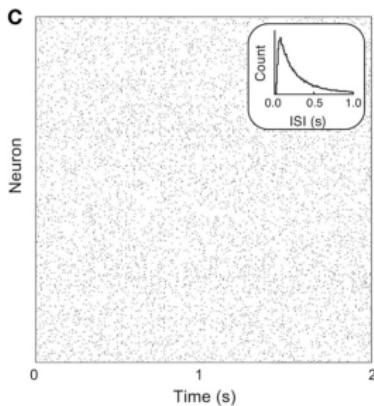
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Cortical activity in awake behaving animals:

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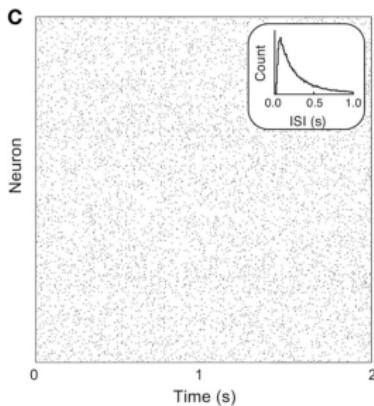


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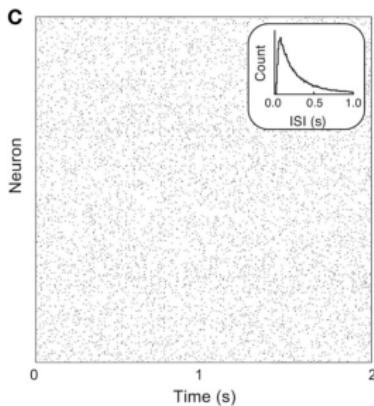


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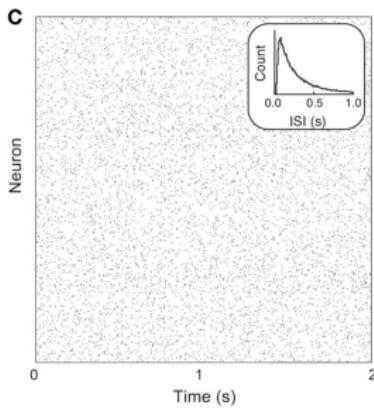


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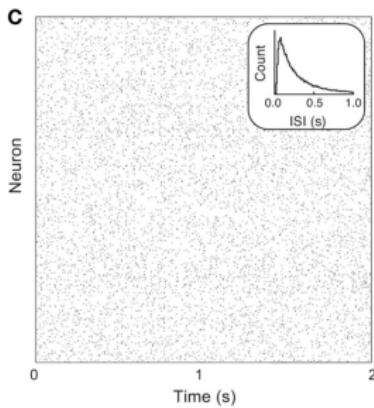


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Is random good enough? (II): Cycle skipping

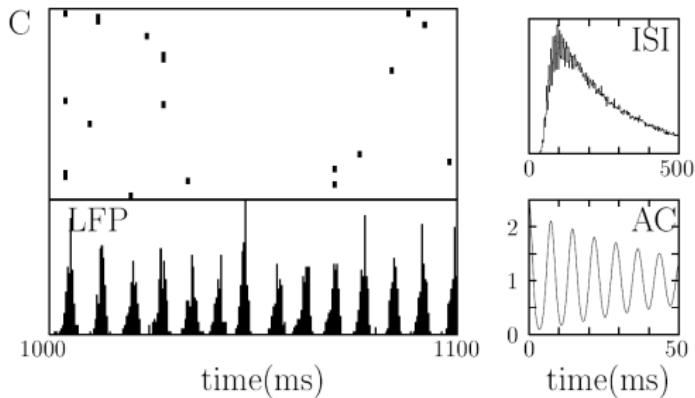
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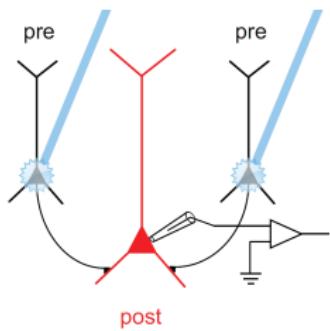
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Brunel & Hakim 1999

Random is not enough (I)

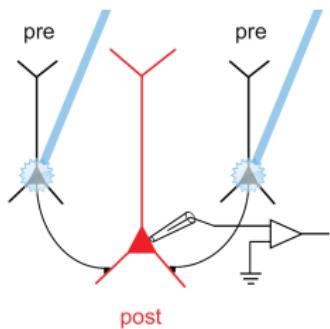
- Distance dependent connectivity



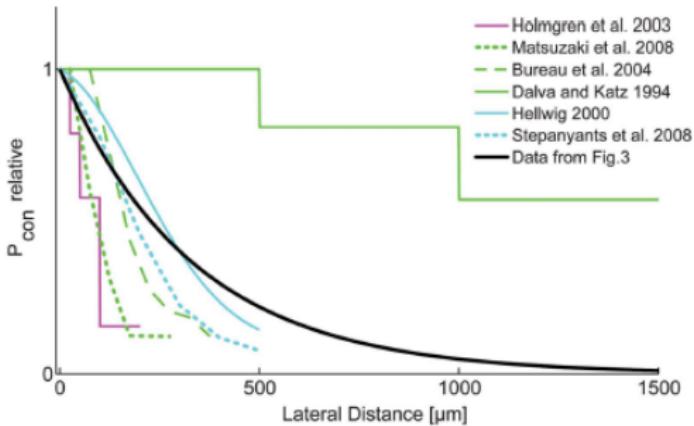
[Boucsein et al. 2011]

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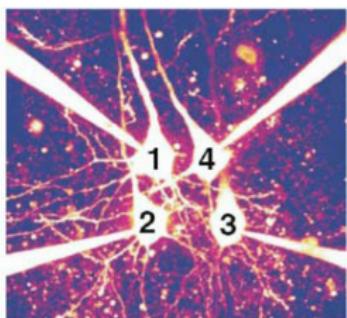


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Random is not enough (II)

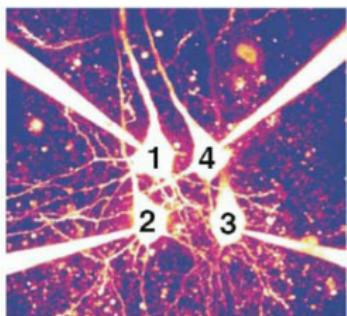
- Highly non-random distribution of connectivity motifs



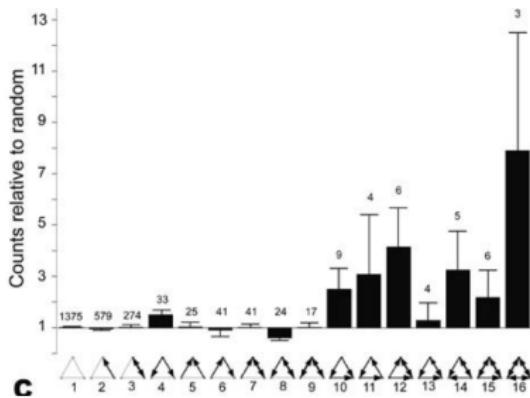
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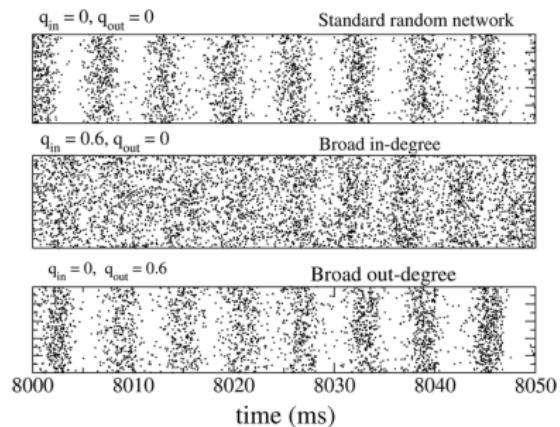
Degree distribution

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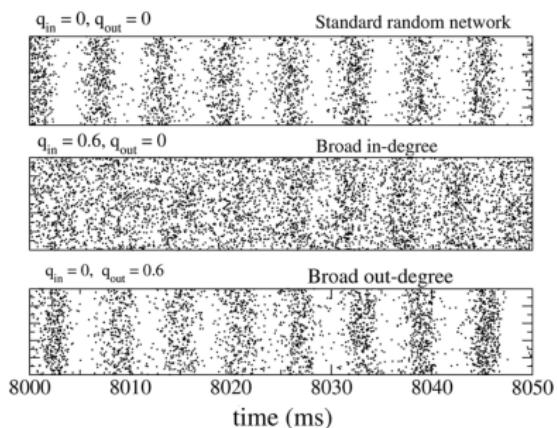
Inh



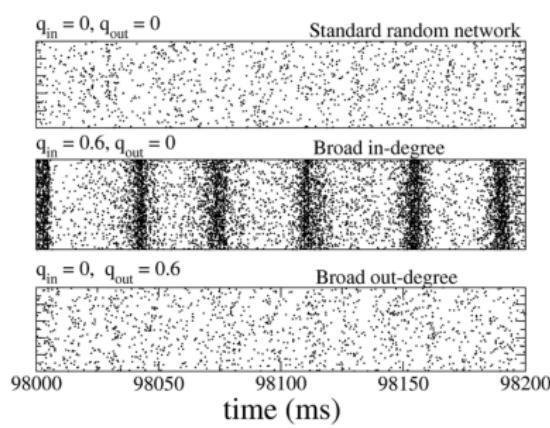
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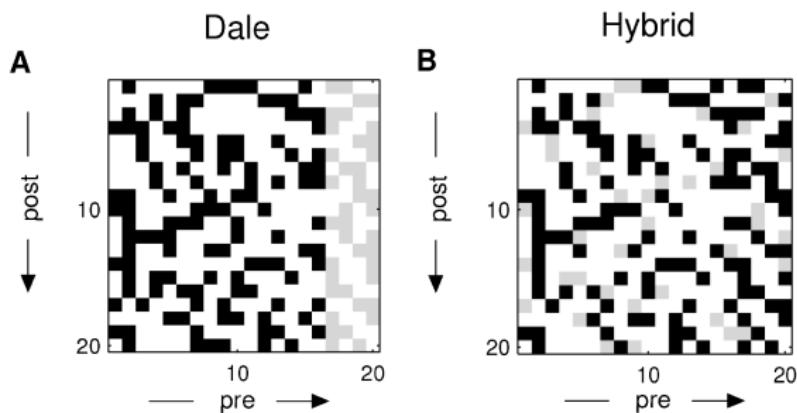


Exc-Inh



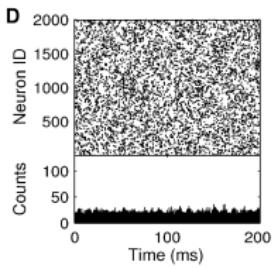
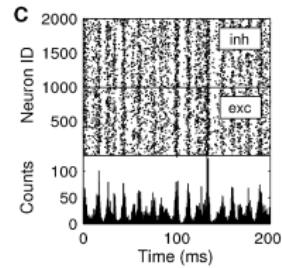
[Roxin, 2011]

Dale versus hybrid connectivity

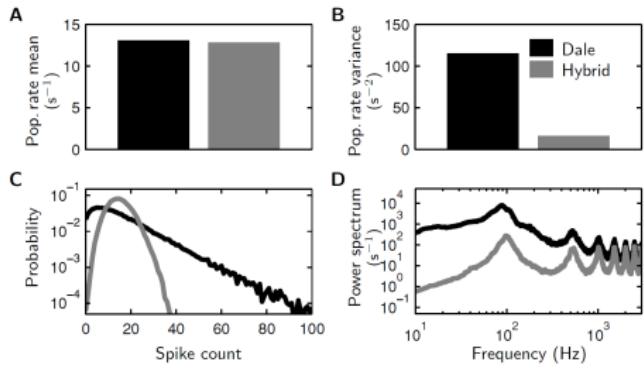
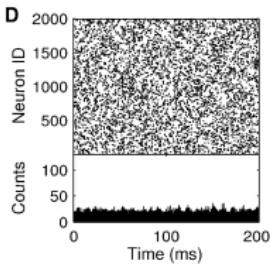
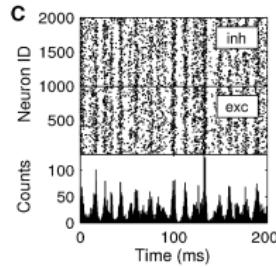


[Kriener et al., 2008]

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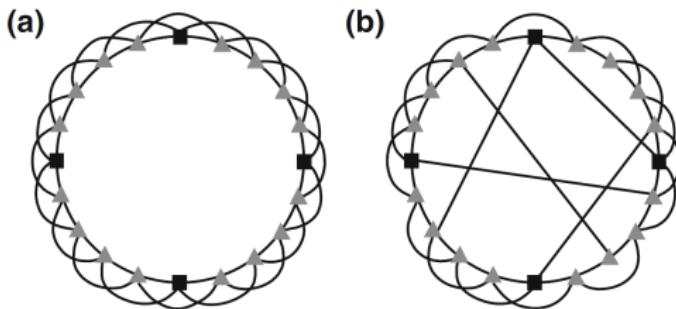
Dale versus hybrid connectivity



[Kriener et al., 2008]

- Same mean firing rate
- Hybrid less synchronous than Dale

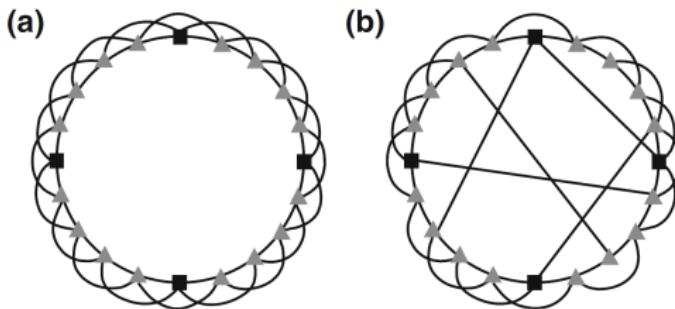
Distance dependent connectivity



[Kriener et al., 2009]

- Probability of rewiring p_r

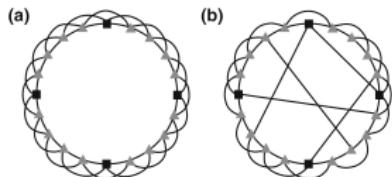
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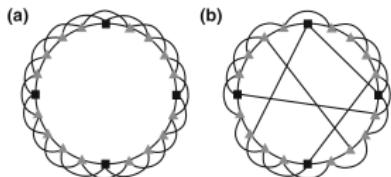
- Probability of rewiring p_r
- $0 < p_r < 1 \rightarrow$ “small-world” network ([Watts & Strogatz, 1998])

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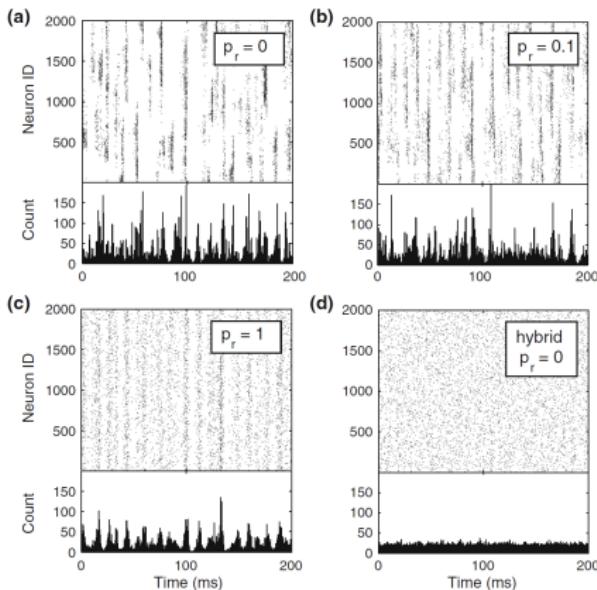


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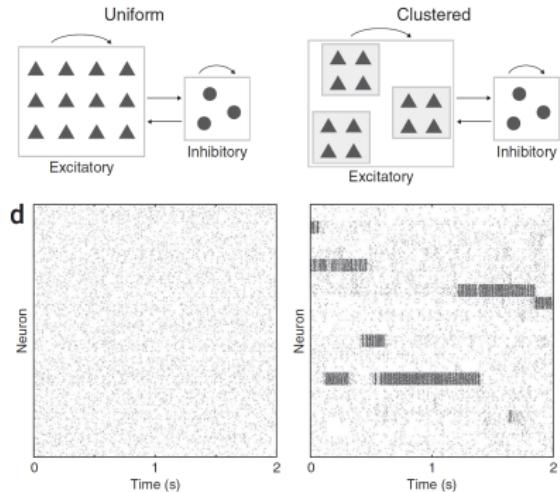


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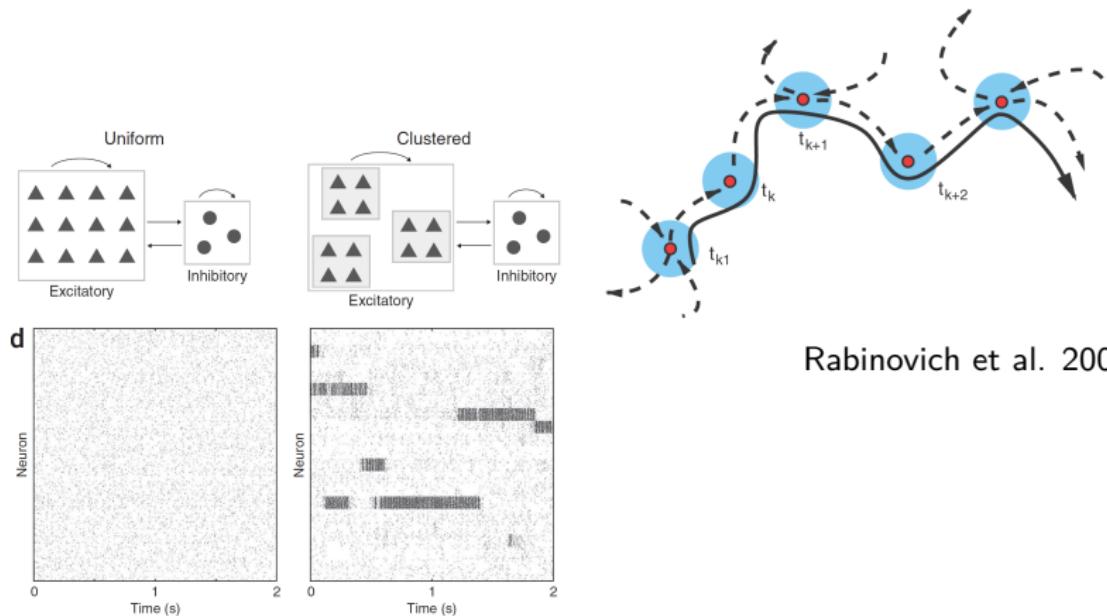
- Clustered networks are “locally” more synchronous.
- Hybrid beats local connectivity!

Clustered networks and metastability



[Litwin-Kumar & Doiron, 2012]

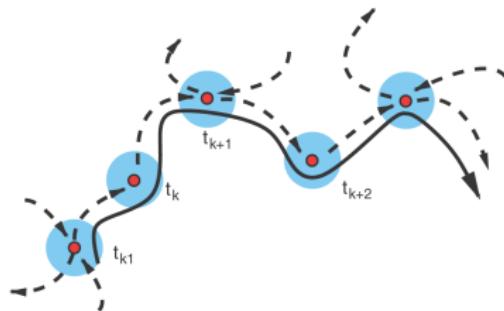
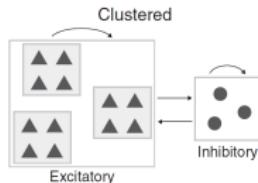
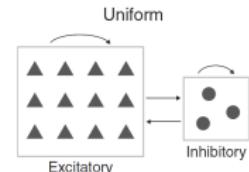
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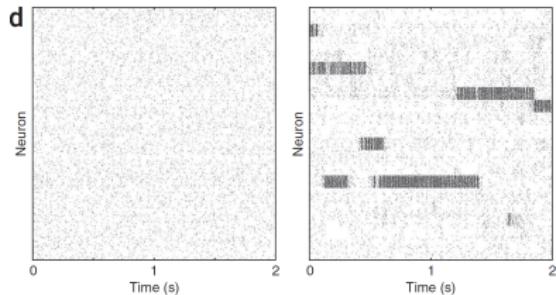
Rabinovich et al. 2008

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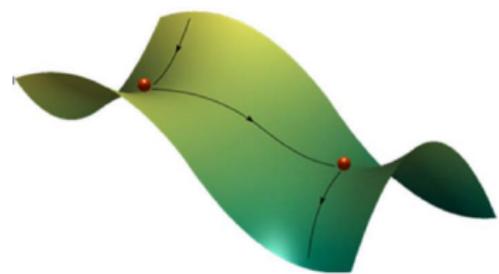
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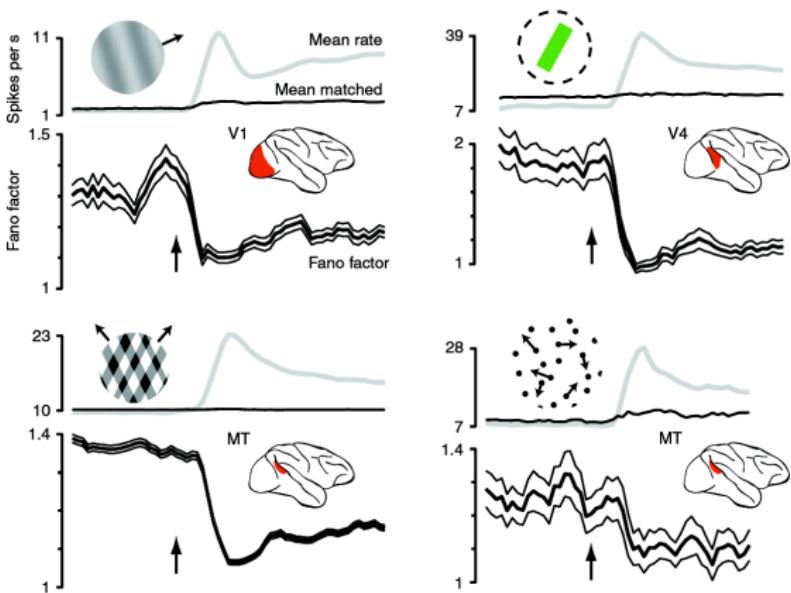
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Rabinovich & Varona 2011

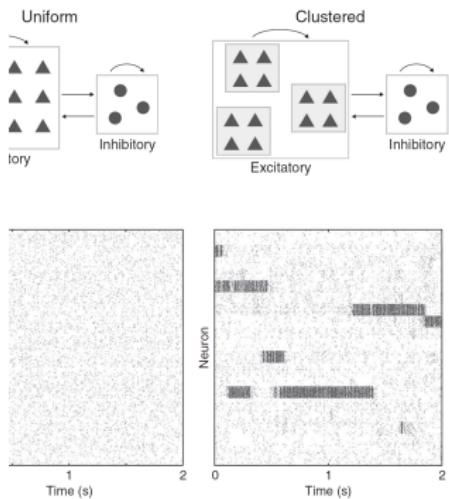
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Stimulus-induced variability reduction

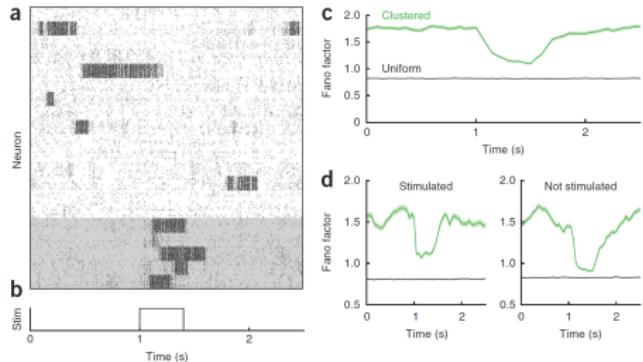
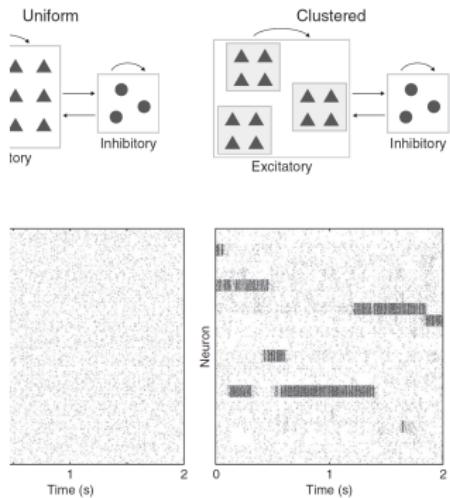


[Churchland et al. 2010]

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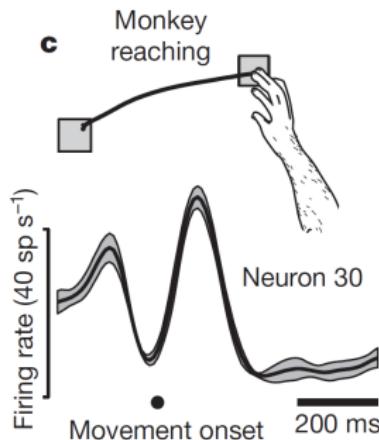
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Neural dynamics during reaching

- Neurons in motor cortex produce complex spatio-temporal patterns during reaching movements.

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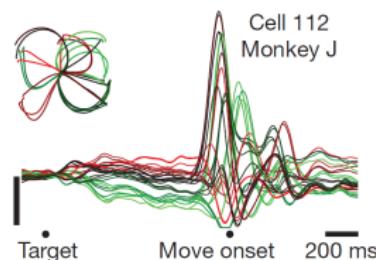
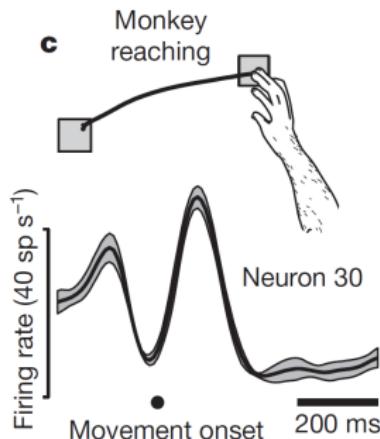
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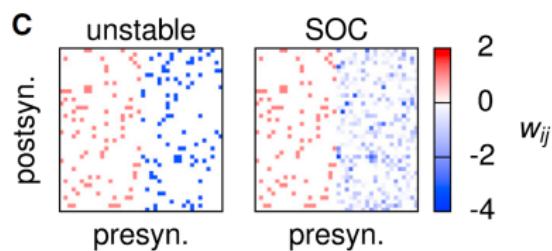
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Detailed balance connectivity

- “Detailed balance” connectivity stabilizes the network dynamics.

Detailed balance connectivity

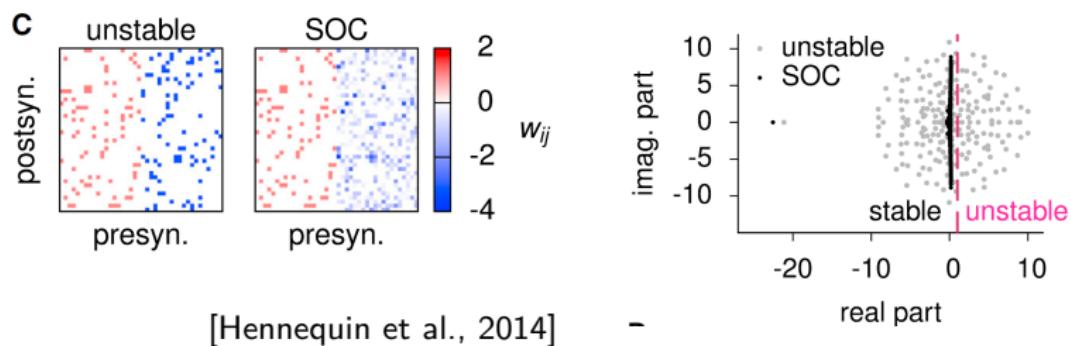
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[Hennequin et al., 2014]

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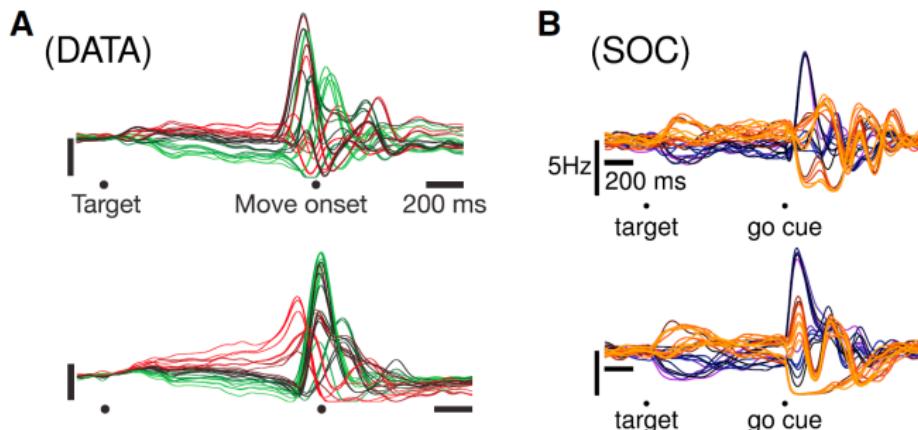


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- “Detailed balance” networks can reproduce the complex spatio-temporal neural activity patterns found in motor cortex.

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- The stimulation of a cluster in a clustered network can reproduce the stimulus-induced drop in firing rate variability.
- A detailed balance connectivity can reproduce the complex spatio-temporal neural activity patterns found in motor cortex.

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