Topology, dynamics and coding in neuronal networks

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Outline

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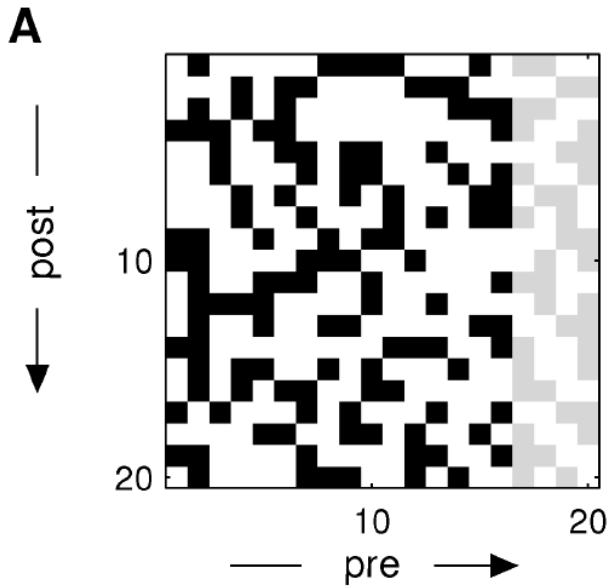
What is topology?

- Graph: nodes and vertices, directed and undirected.
- Adjacency matrix.
- In-degree and out-degree distributions.



Kriener et al. 2008

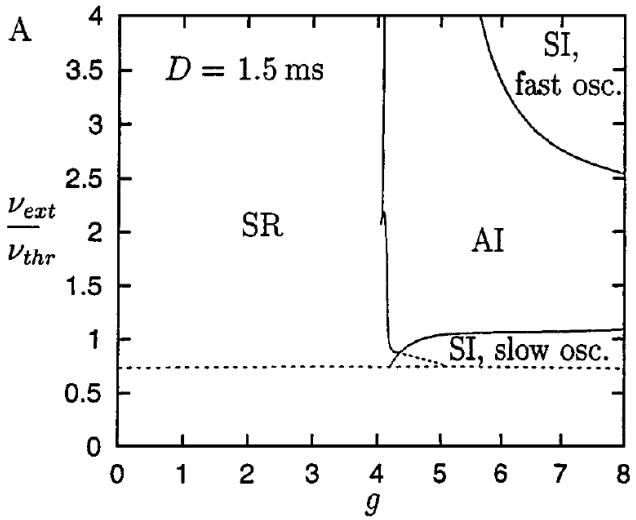
What do we care about?

- Distribution of mean output firing rates.
- Cellular variability:
  - within a trial: CV of the ISI distribution.
  - between trials: Fano factor of the spike count distribution
- Co-variability between activity of different cells:
  - Fano factor of the PSTH.
  - Distribution of pairwise correlations coefficients.
  - Higher order correlations.
  - Power spectrum.

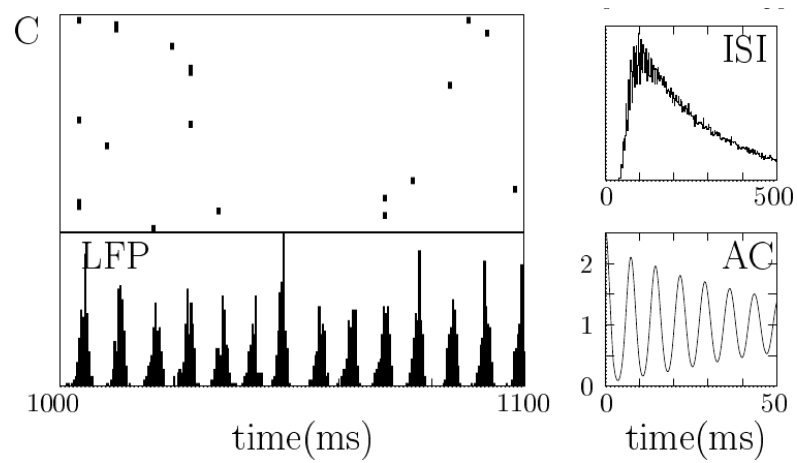
Outline

Is random good enough?

- Sparse randomly connected balanced EI networks can produce activity:
  - Skewed and long-tailed firing rate distributions.
  - High single cell variability (irregularity).
  - Very low co-variability between pairs of cells (asynchrony).
- While also offering a variety of other dynamical states.
- Fast and slow oscillations where individual neurons fire irregularly skipping cycles are also possible.
- Mean-field techniques can be used.



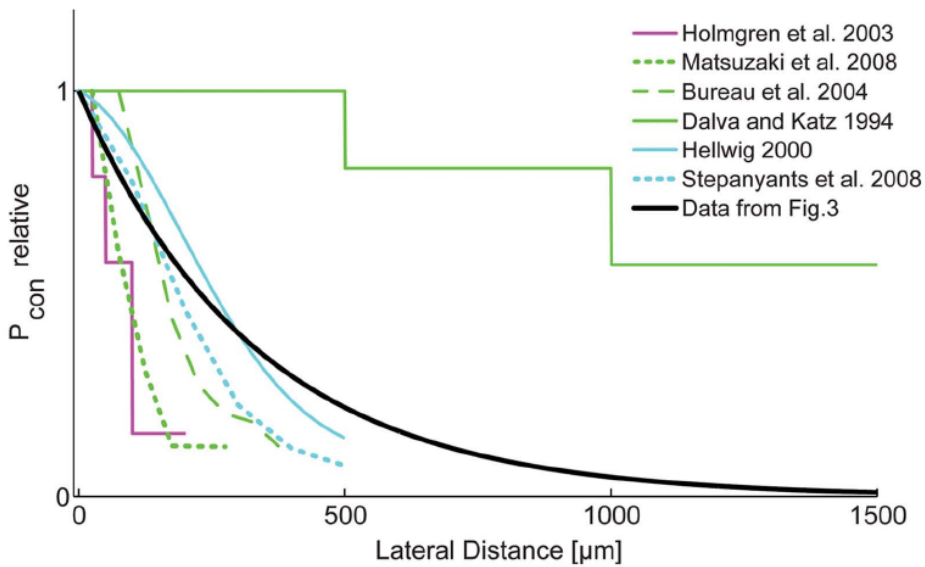
Brunel 2000



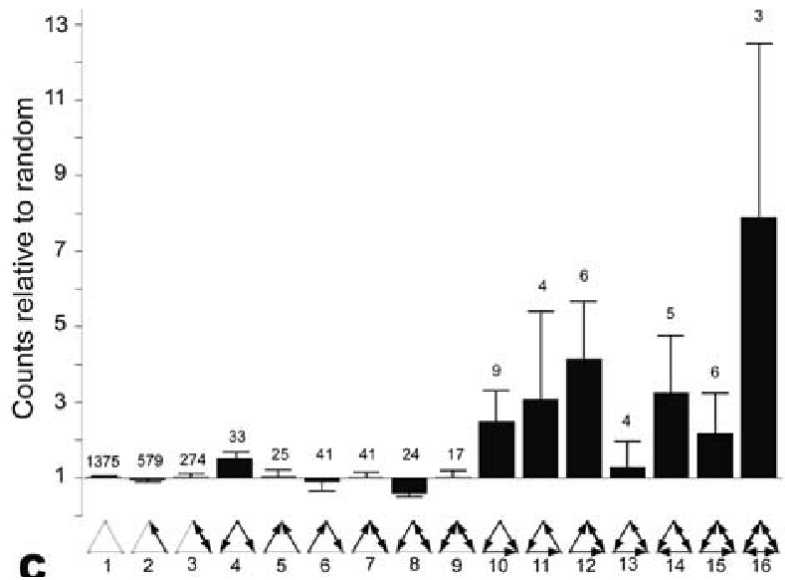
Brunel and Hakim 1999

Random is not enough

- Random connectivities can't explain different phenomena that are observed in the brain.
- Recent experimental studies have shown that the wiring in the brain is far from random.



Boucsein et al. 2011



Song et al. 2005

Outline

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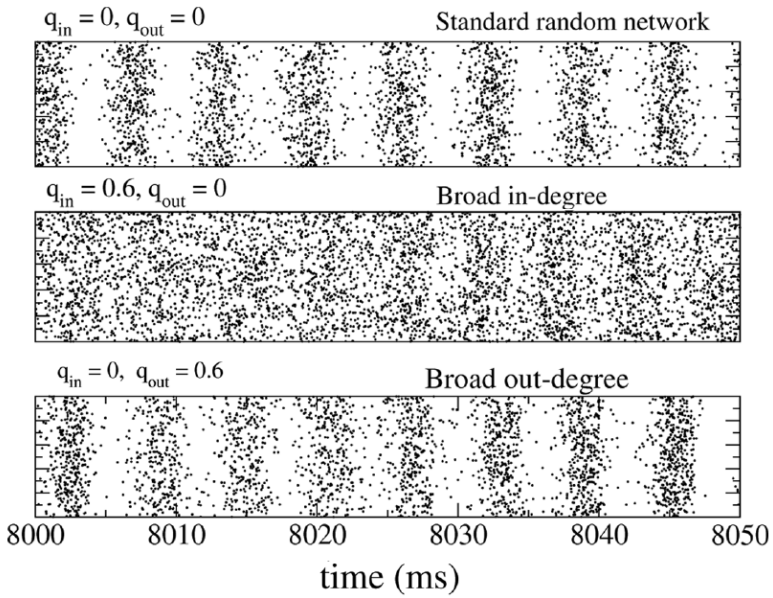
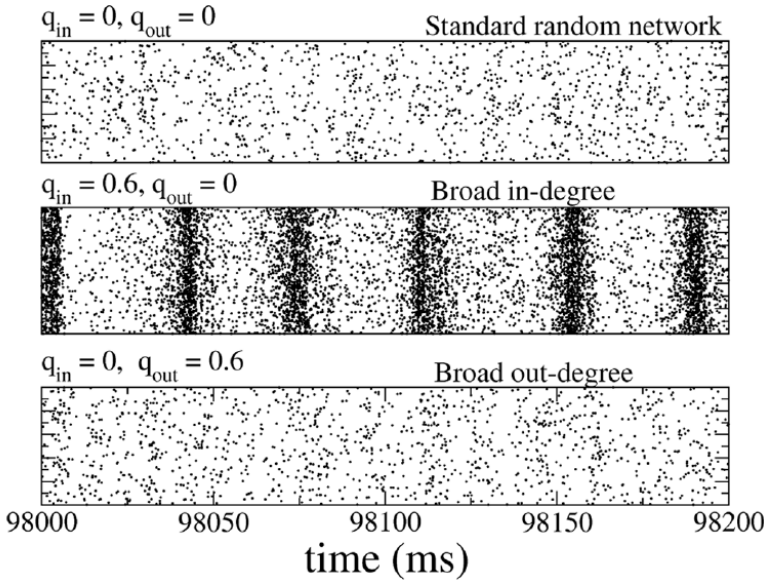
The effect of degree distributions

- Increasing the width of the in-degree distribution affects the global state of the network by driving transitions between asynchronous behavior and oscillations.

Inh



Exc-Inh

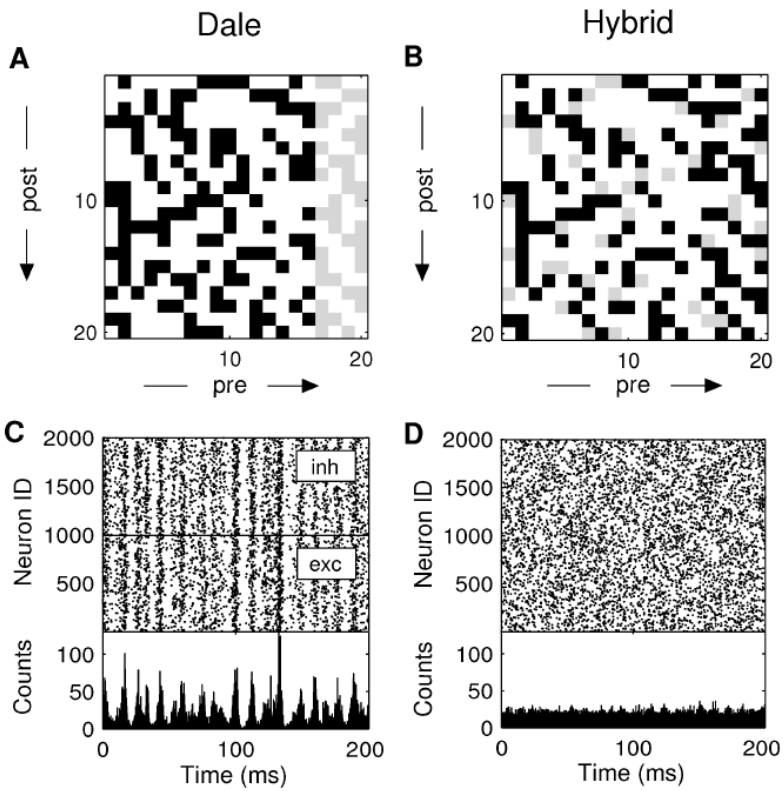


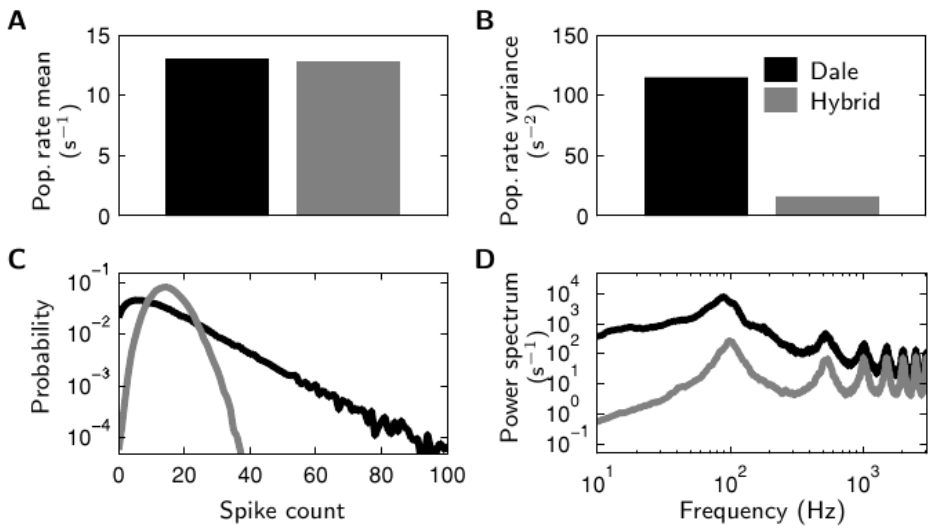
Roxin 2011

Outline

Hybrid topologies

- Mean inputs are identical in hybrid and Dale spiking networks.
- Correlations vanishes when randomizing weights even for densely connected networks.





Kriener et al. 2008

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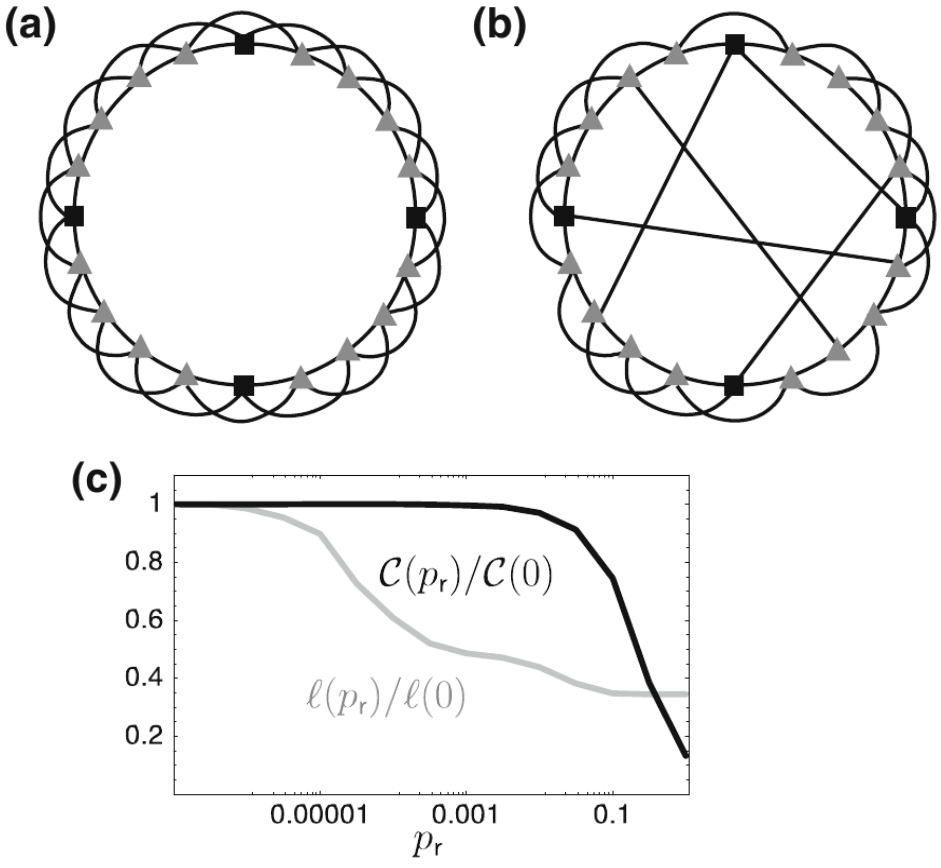
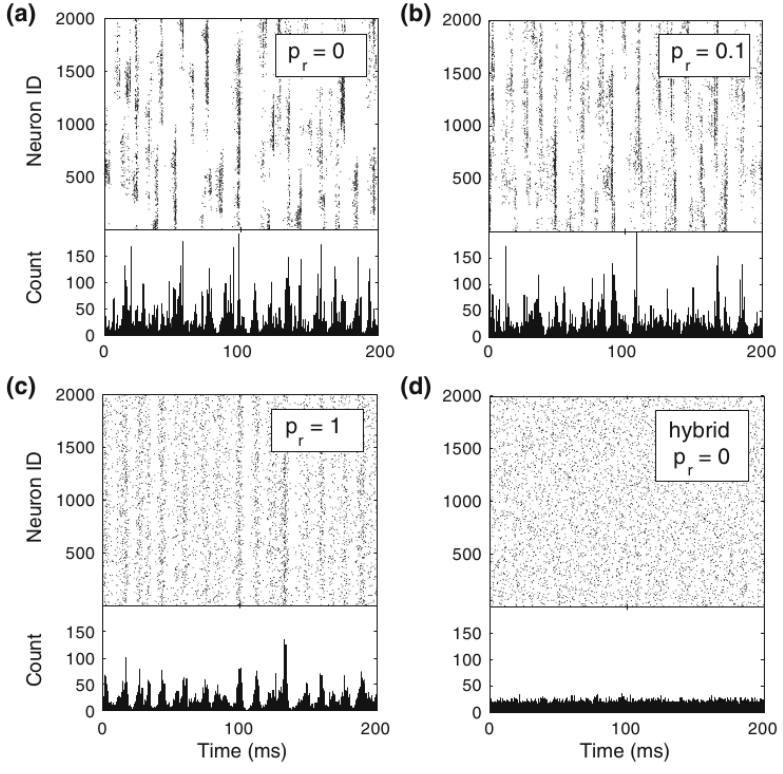
Distance dependent connectivity

- The Fano Factor of the PSTH is higher in networks with higher clustering coefficient but only locally.
- Dale beats topology!

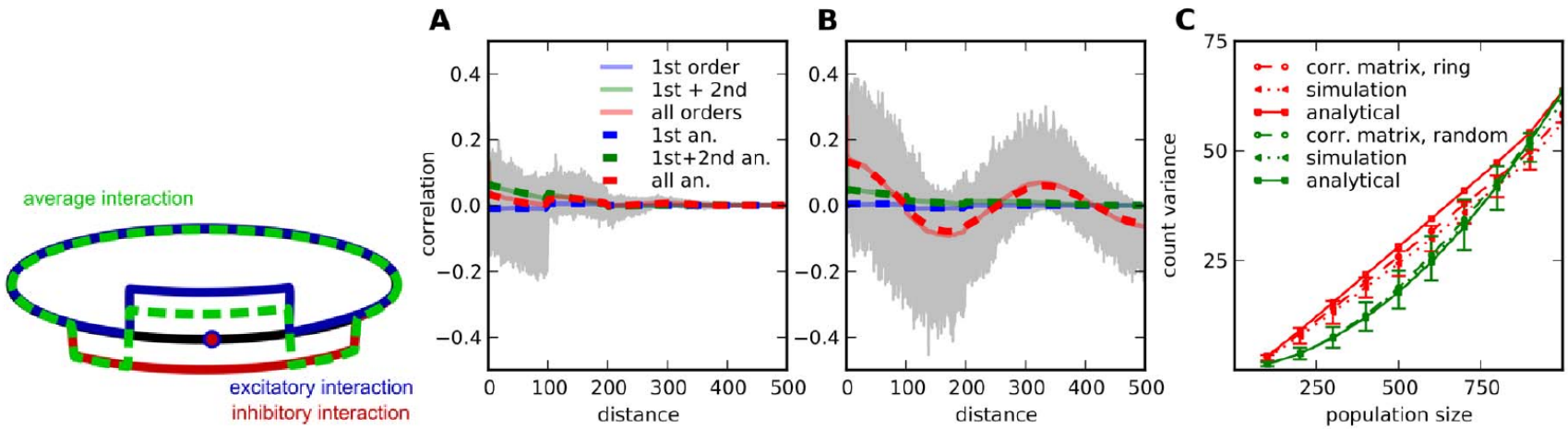




Kriener et al. 2009

Distance dependent connectivity

- In networks with local connectivity, the distribution of correlation coefficients (cc) is broader, while average correlations remain similar compared to the random case.
- In EI networks broader inhibitory connectivity broadens the cc distribution.
- Locally fluctuations increase faster in the ring network than in the random case.

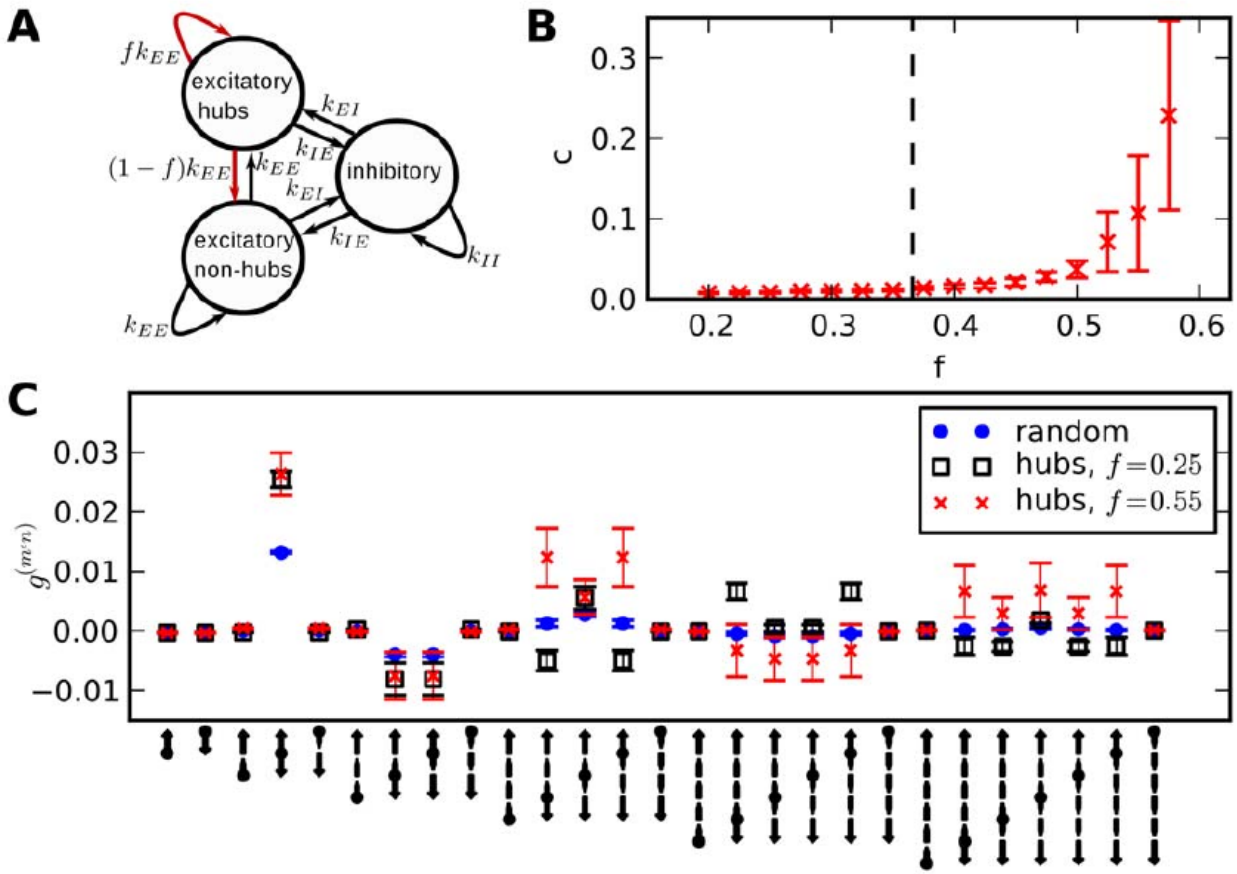


Pernice et al. 2011

Outline

Networks with hubs

- Making the out-degree distribution broader and favoring connections between neurons within similar out-degree increases average correlations.



Pernice et al. 2011

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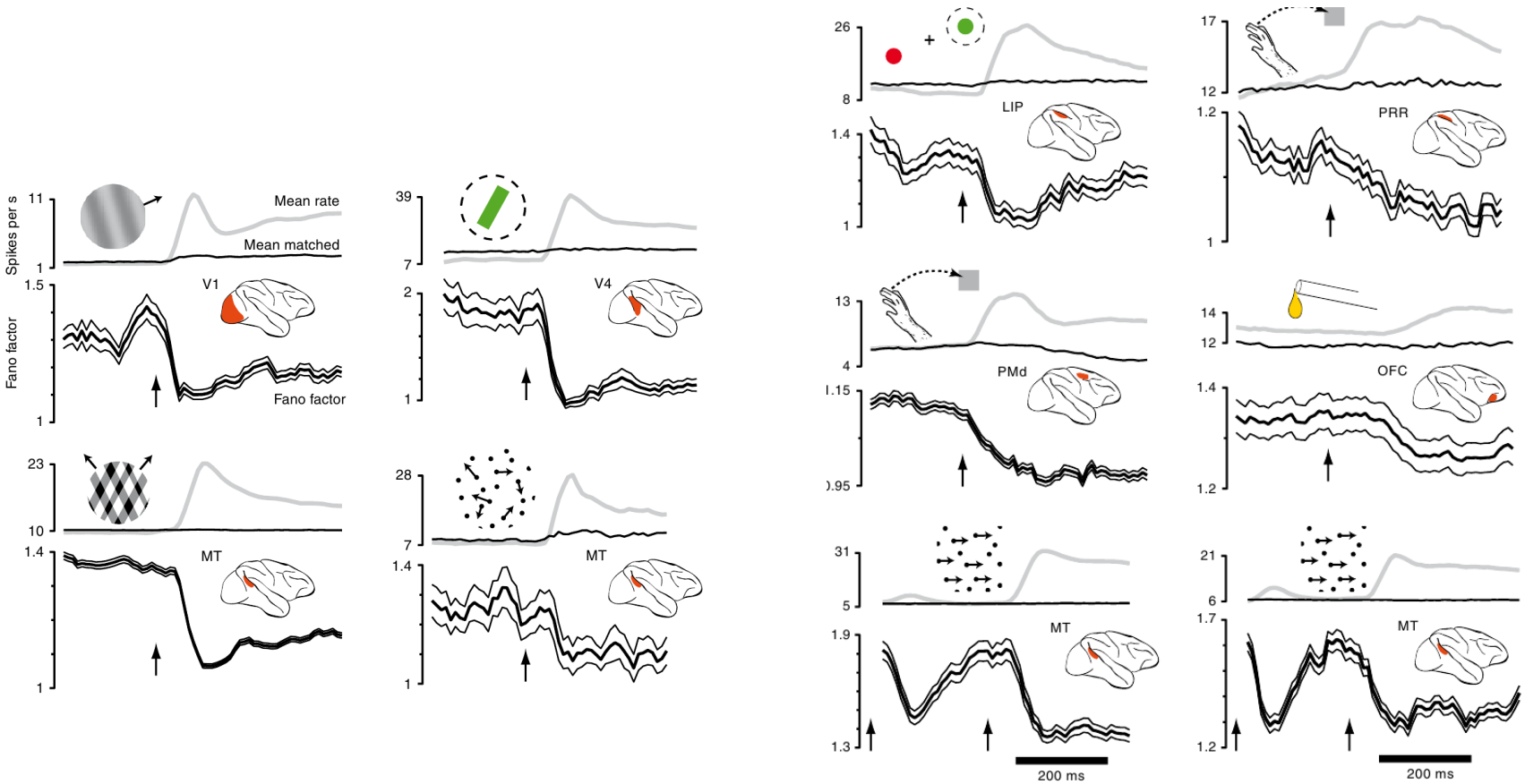
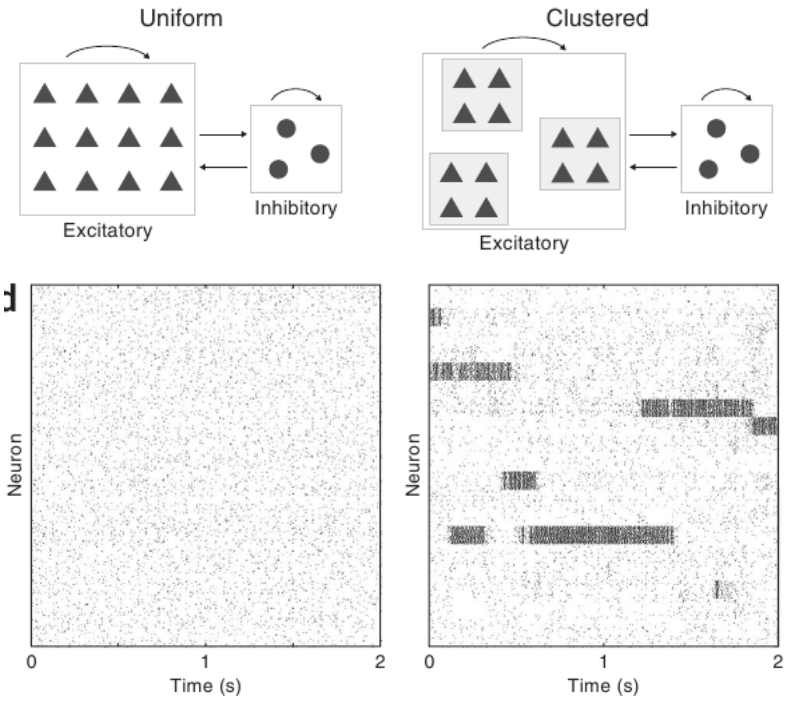
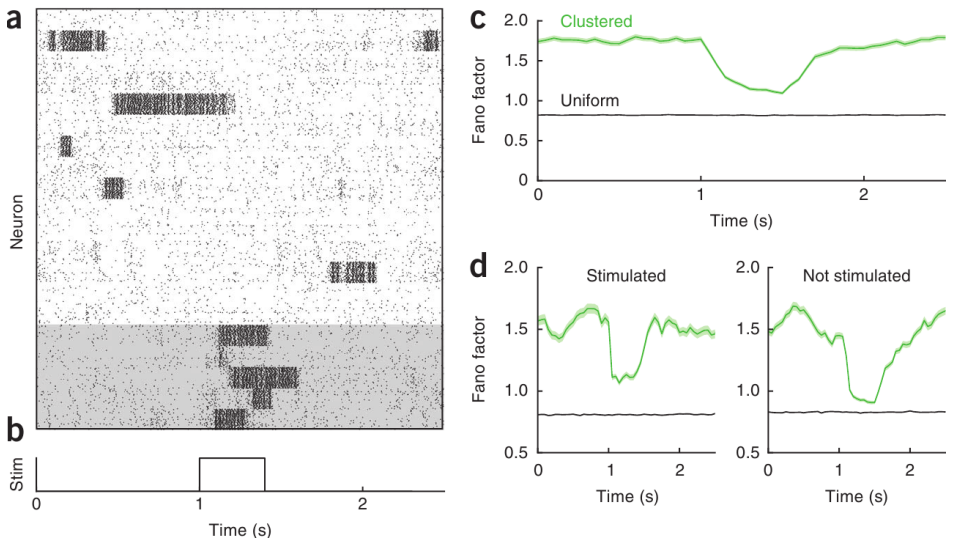
Stimulus induced variability reduction



Churchland et al. 2010

Stimulus induced variability reduction



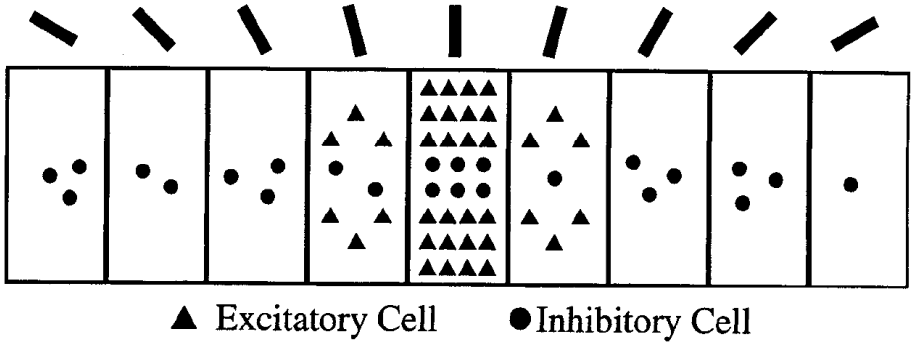


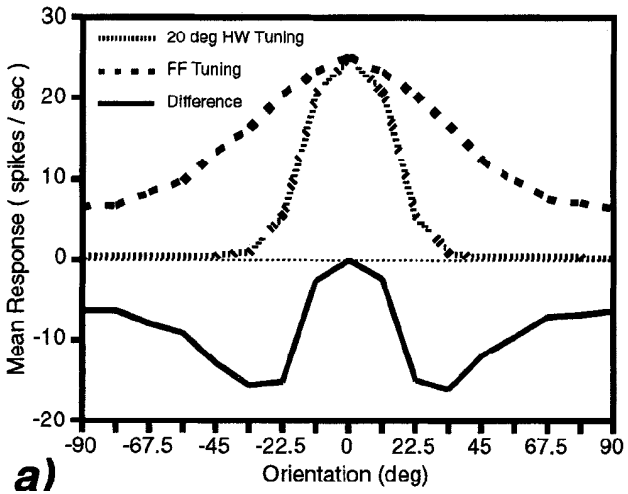
Litwin-Kumar et al. 2012

Outline

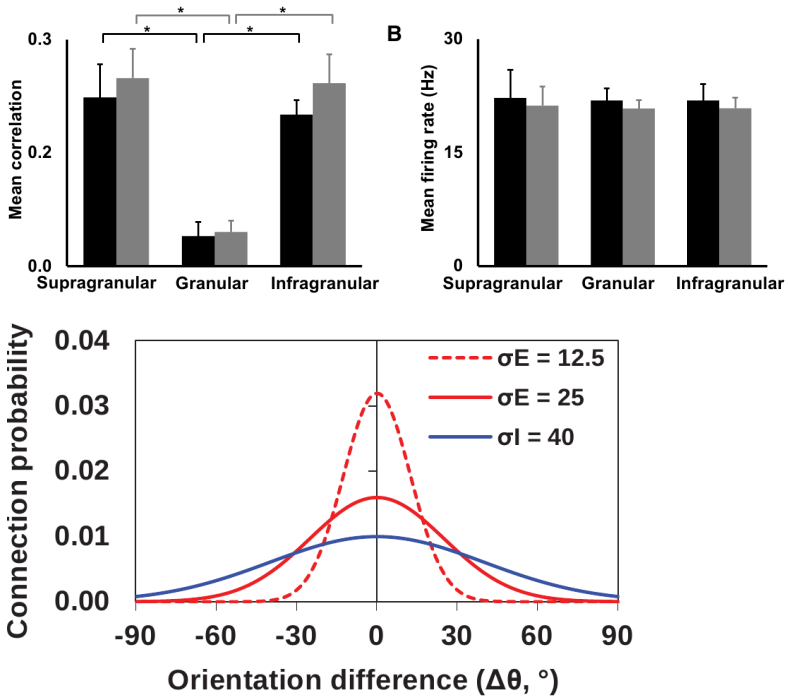
Topology in *feature* space

- Useful to get sharpening of tuning curves.
- Also to get contrast invariance.
- To reduce noise correlations?





Somers et al. 1995



Hansen et al. 2012

Summary

- Random connectivity is a good model but it is not enough.
- Degree distributions have a strong impact in the activity of the network.
- The presence of hub neurons can increase the amount of correlated activity in the network.
- Local connectivity can explain the reduction of inter-trial variability, as well as sharpening of tuning curves and contrast invariance.