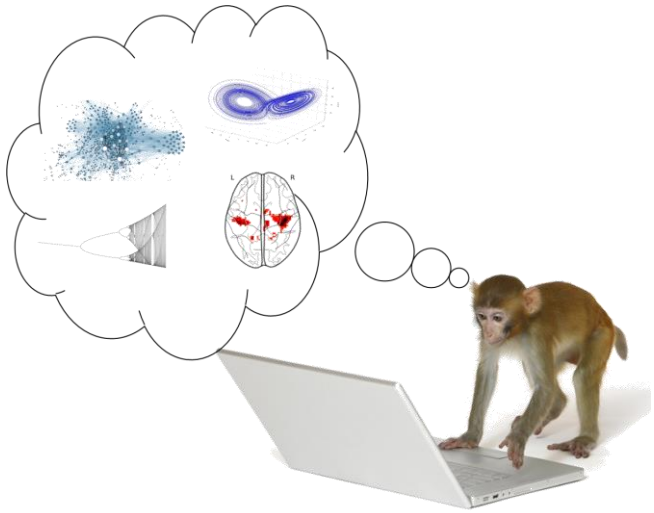
Modelling large scale brain dynamics with networks of neural masses and neural fields



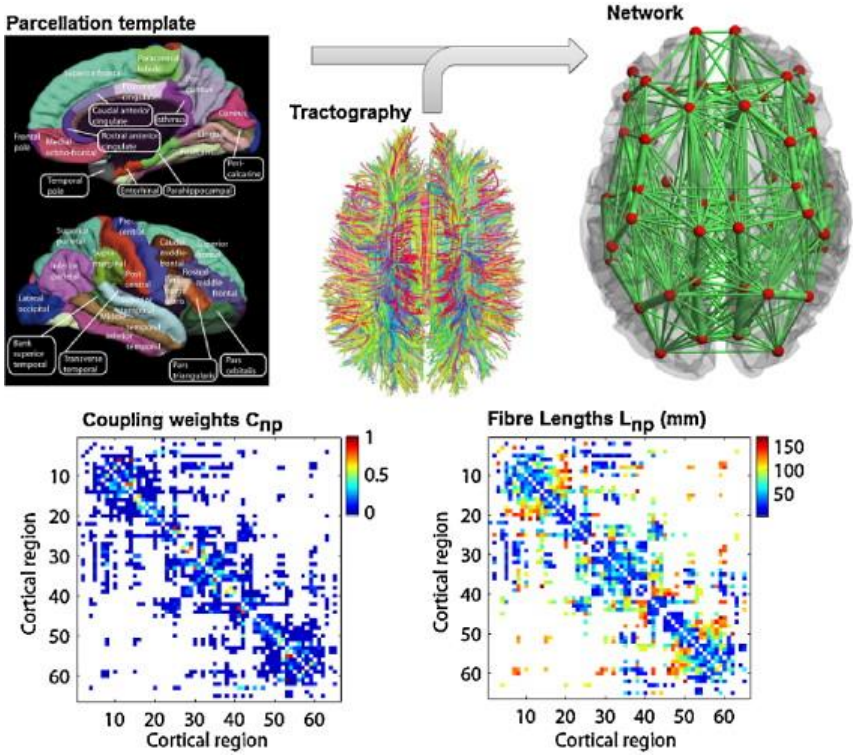
Dr. John D. Griffiths

Rotman Research Institute

Baycrest, Toronto

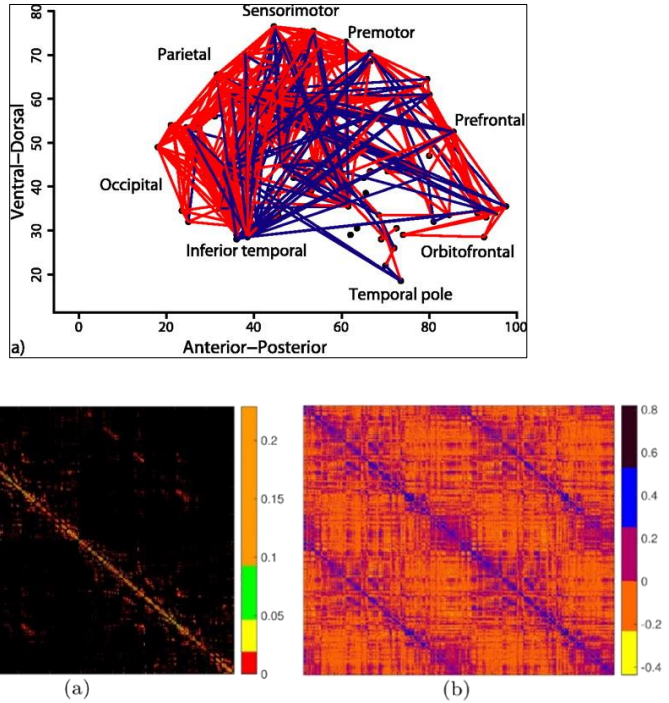
Connectomics

Structural connectome



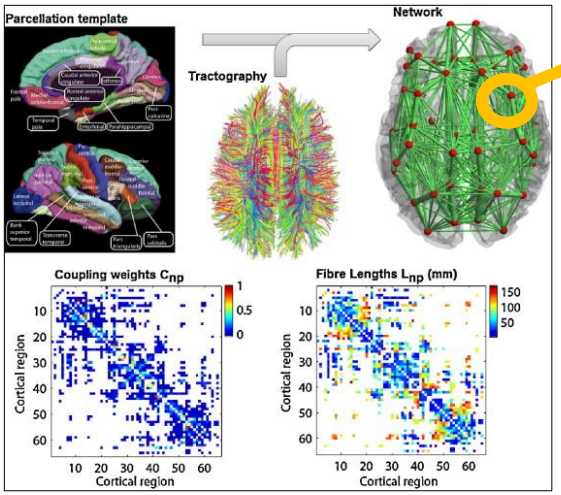
Daducci et al. 2012

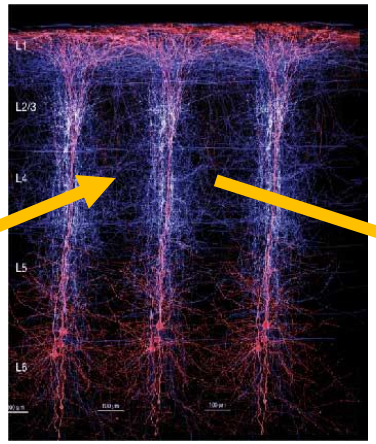
Functional connectome

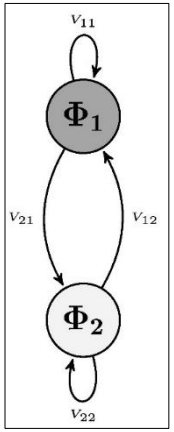


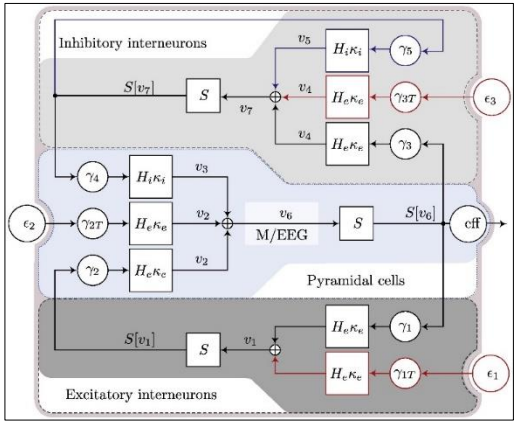
Achard et al. 2006

Modelling neuroimaging data with networks of neural masses

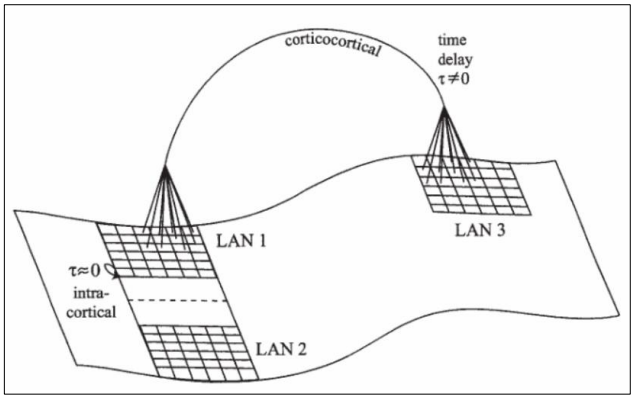




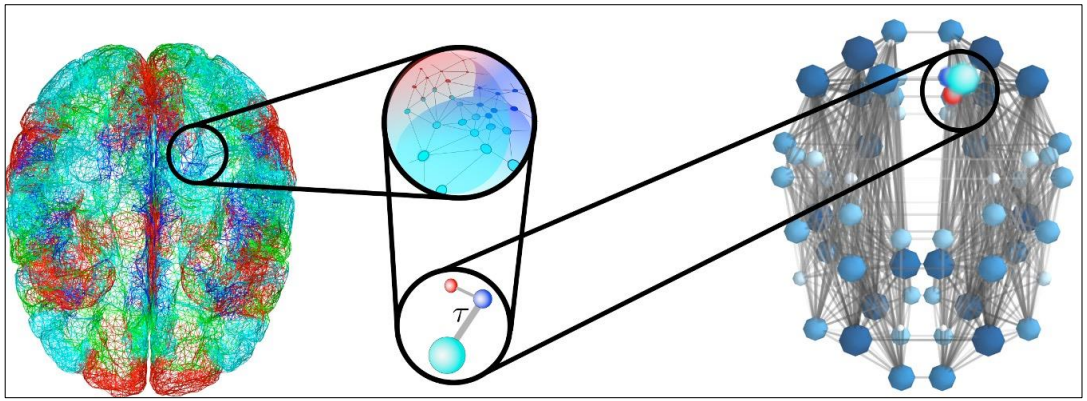




Modelling neuroimaging data with networks of neural masses



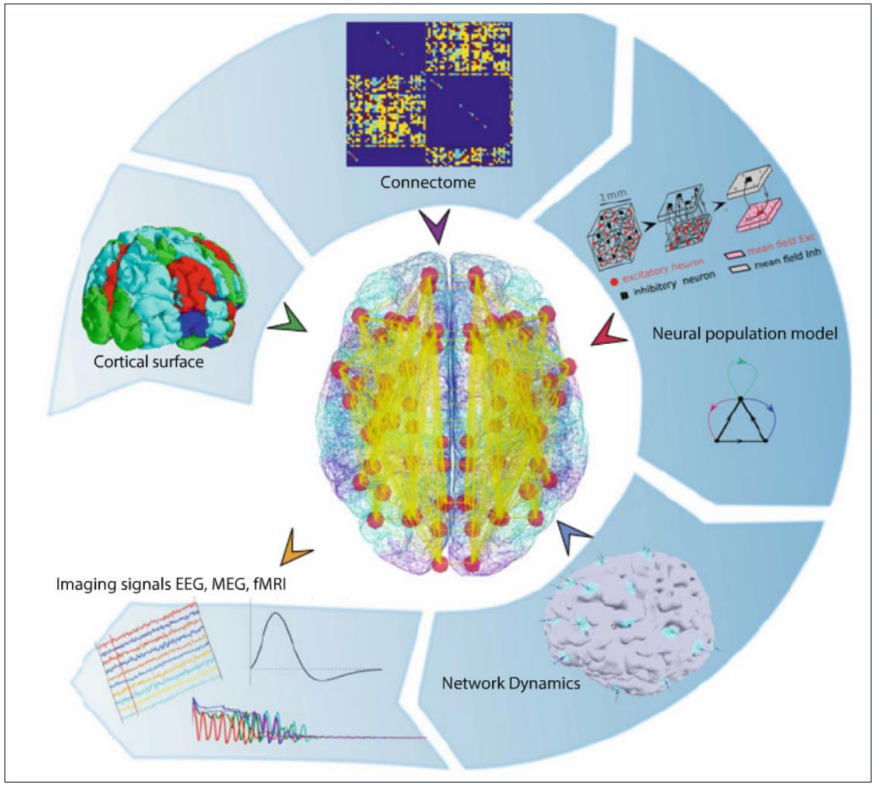
Jirsa (e.g. 2004; 2009) – local neural fields with 'two-point' long-range connection

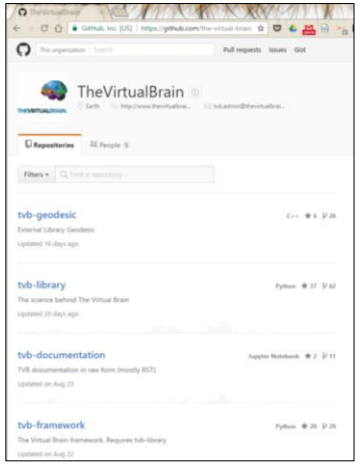


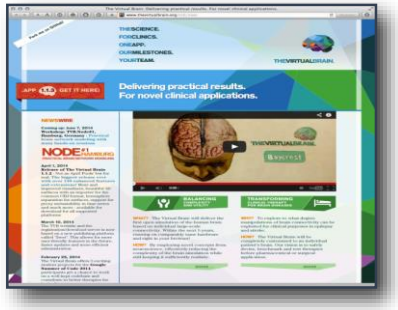
Jirsa & Spiegler 2011 – systematic approximation of neural fields with local networks of neural masses

The Virtual Brain Platform (TVB)

- Global (heterogenous) coupling: connectome
- Local (homogeneous) coupling: surface-based modelling
- Forward models for all imaging modalities
- Construct individualized LSBNMs from structural neuroimaging data
- Comprehensive neuroinformatics ontology
- Free (as in speech)







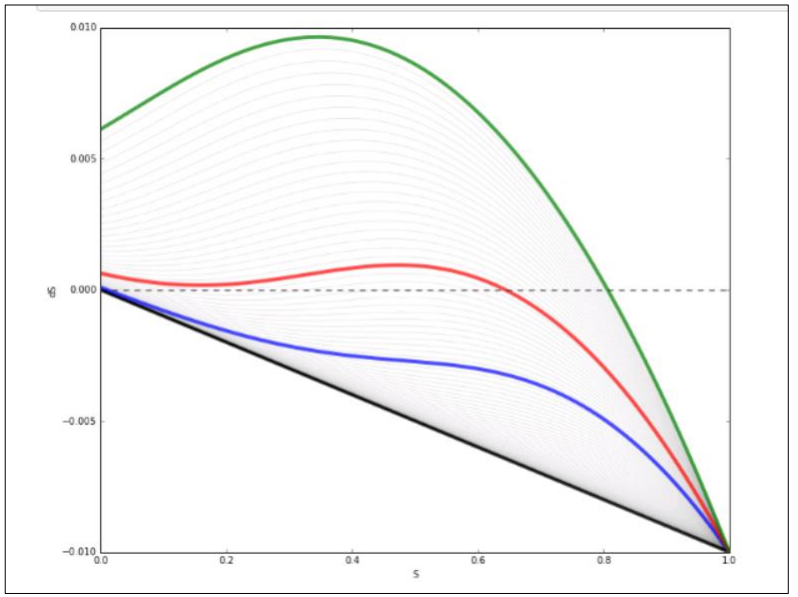
Deco-Jirsa RSBD Bifurcation Theory

Local model

$$\frac{dS_i(t)}{dt} = -\frac{S_i}{\tau_S} + (1 - S_i)\gamma H(x_i) + \sigma v_i(t)$$

$$H(x_i) = \frac{ax_i - b}{1 - \exp\left(-d(ax_i - b)\right)}$$

$$x_i = wJ_N S_i + GJ_N \sum_j C_{ij} S_j + I_0.$$



Phase plane

S = Synaptic gating variable

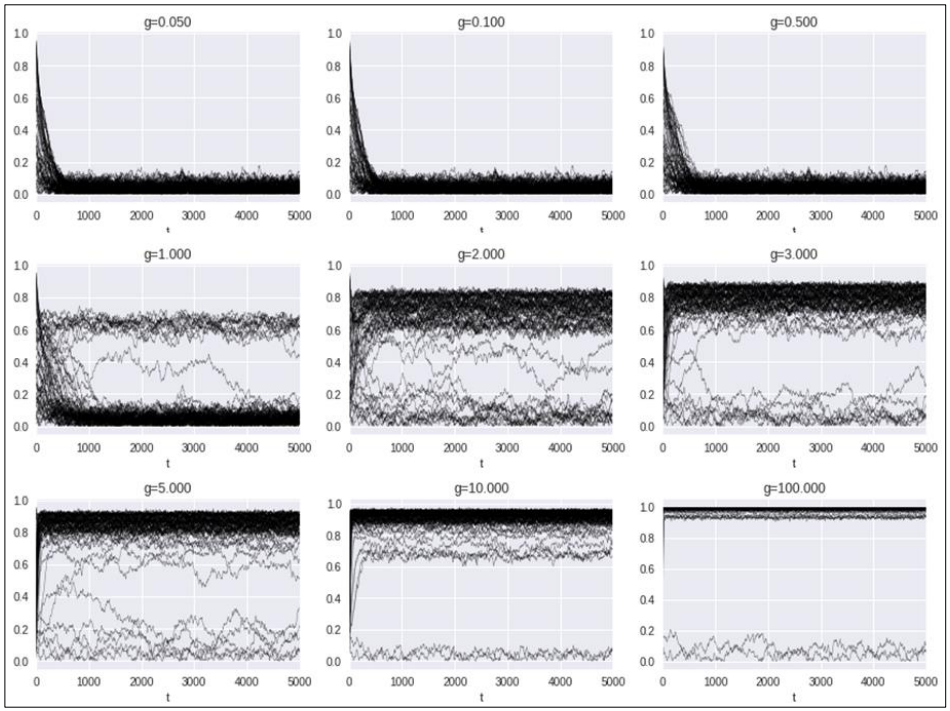
x = population firing rate

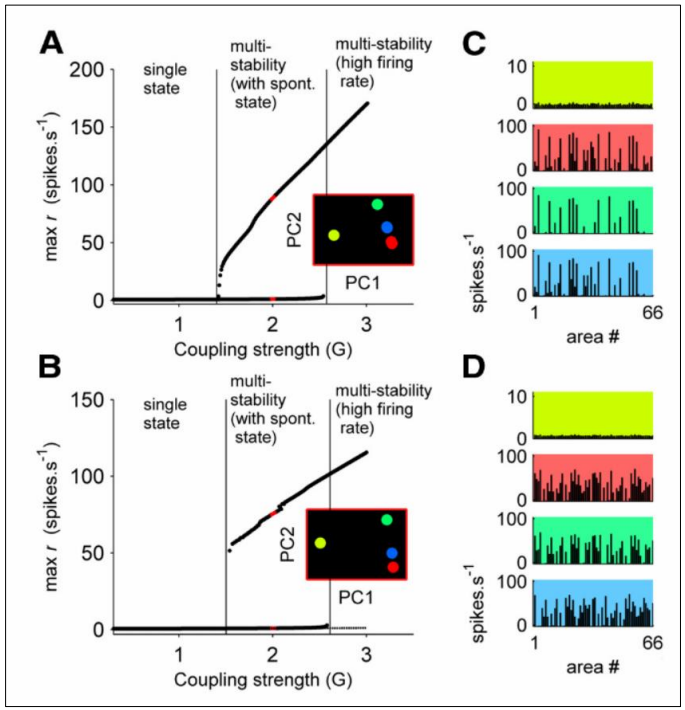
H = transfer function

Deco et al. JN 2013

Deco-Jirsa RSBD Bifurcation Theory

Bifurcation Structure of full & reduced models

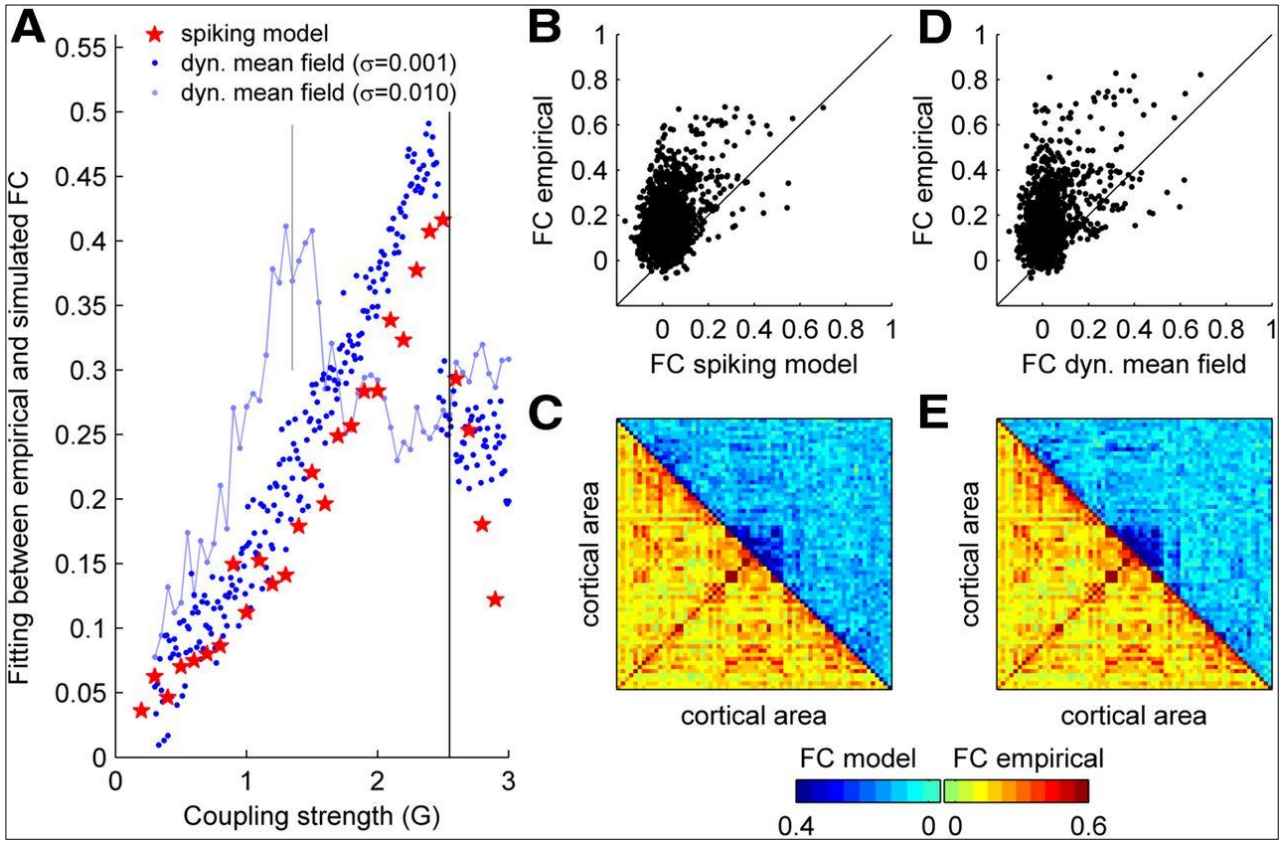




Deco et al. JN 2013

Deco-Jirsa RSBD Bifurcation Theory

SC-FC Fit is maximal at the second bifurcation



Deco et al. JN 2013

Deco-Jirsa RSBD Bifurcation Theory

Summary

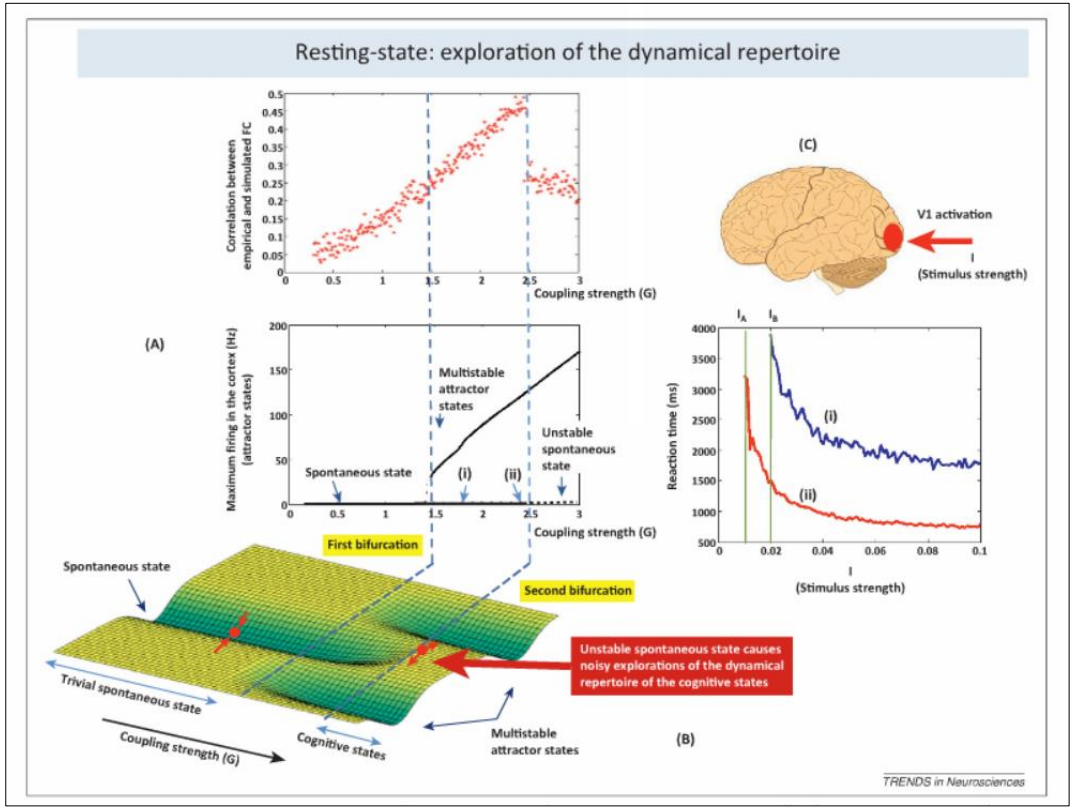
Low global coupling: spontaneous low firing rate is stable

First bifurcation: multistability

Second bifurcation: spontaneous state loses stability

Resting state FC structure is at edge of second bifurcation

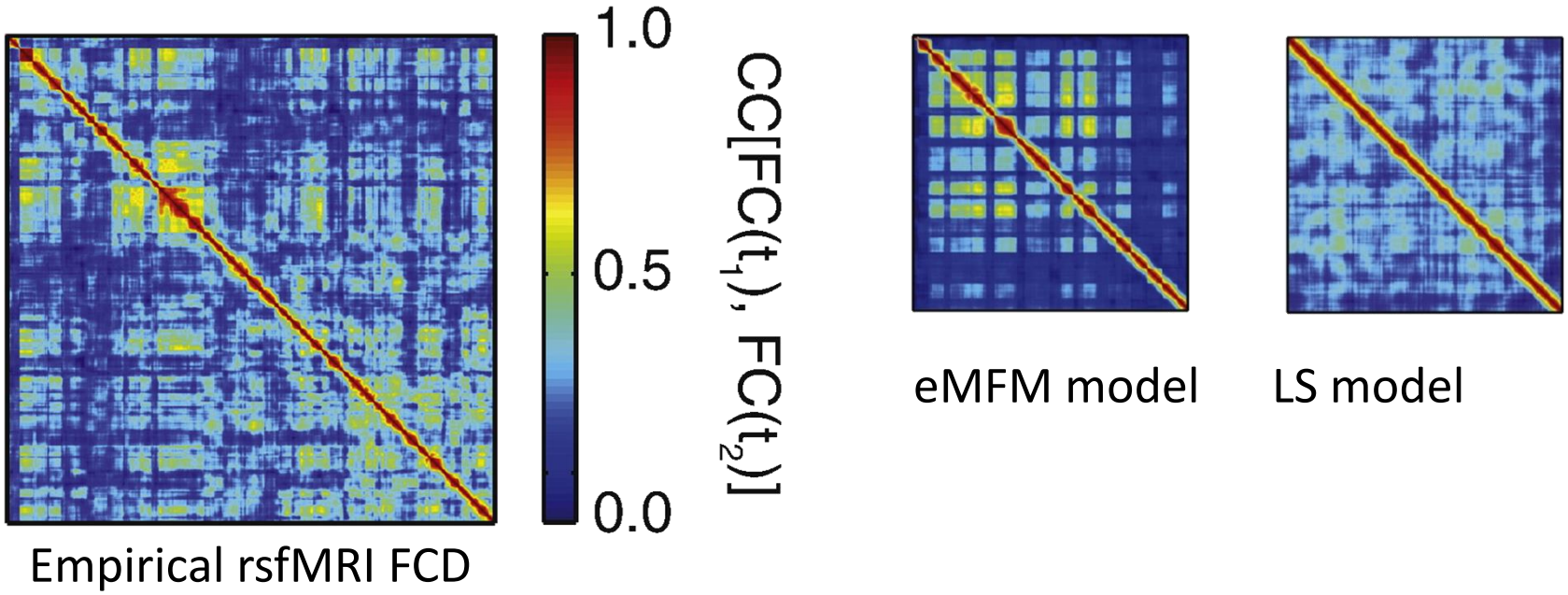
This is optimal for information processing



Deco et al. TINS 2013

Deco-Jirsa RSBD Bifurcation Theory

Extensions: non-stationary covariance structure



Hansen et al. 2015

What Ho TDA…

Questions for algebraic topologists:

What can we learn about the 'dynamic repertoire' of macroscopic neural states using tools from topological data analysis?

- Data features
- Theoretical insights
- ..?

Thank You ☺