

Whole Brain Dynamics and Modeling

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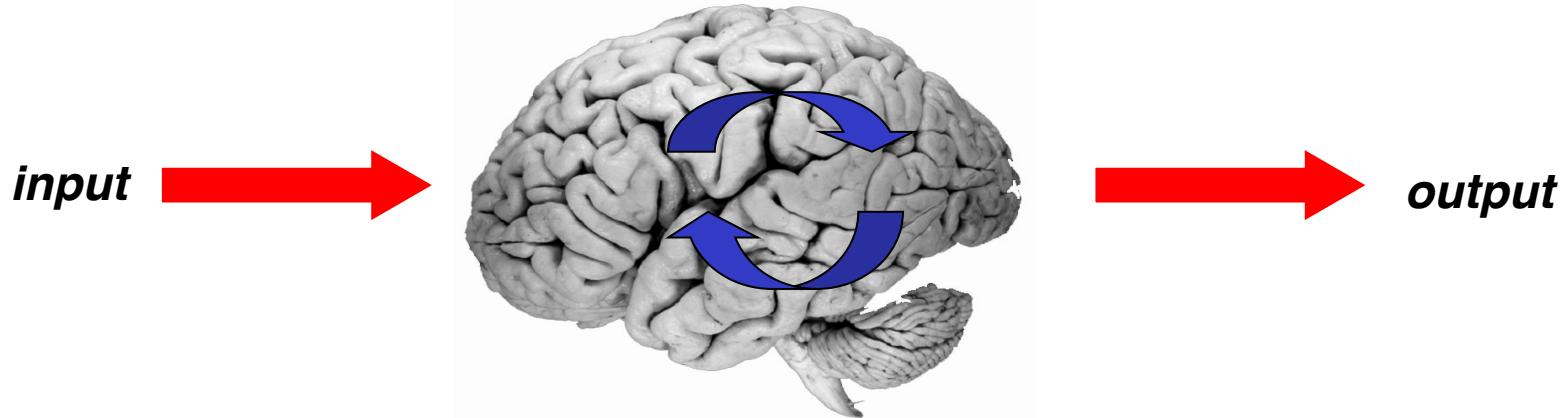
Barcelona

www.gustavodecolab.com



Basal and Evoked States

Evoked activity: Task, Stimuli

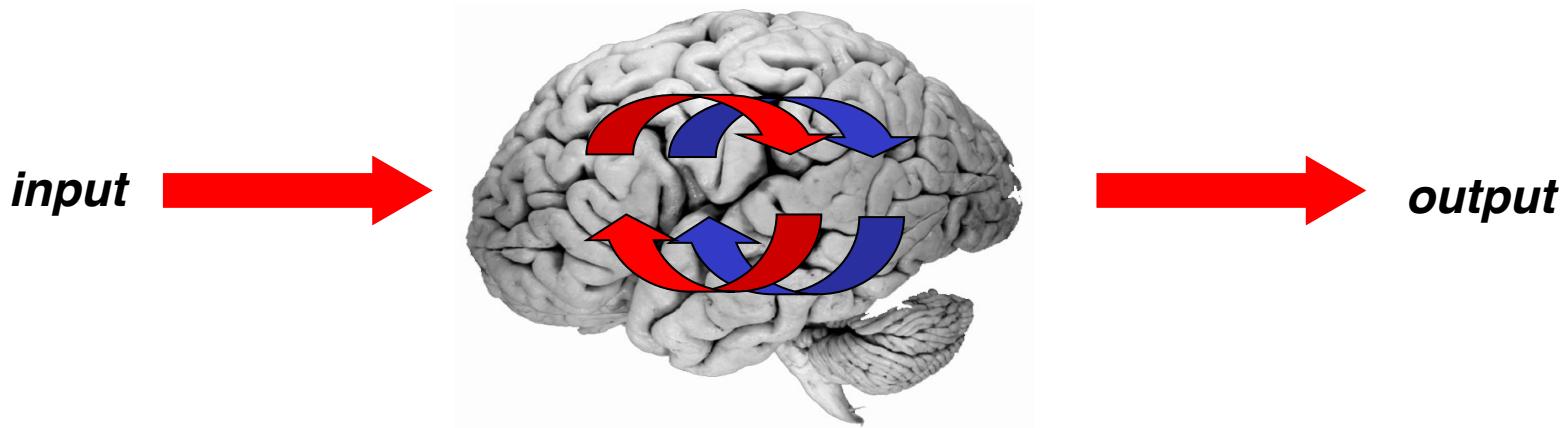


Resting Brain



Basal and Evoked States

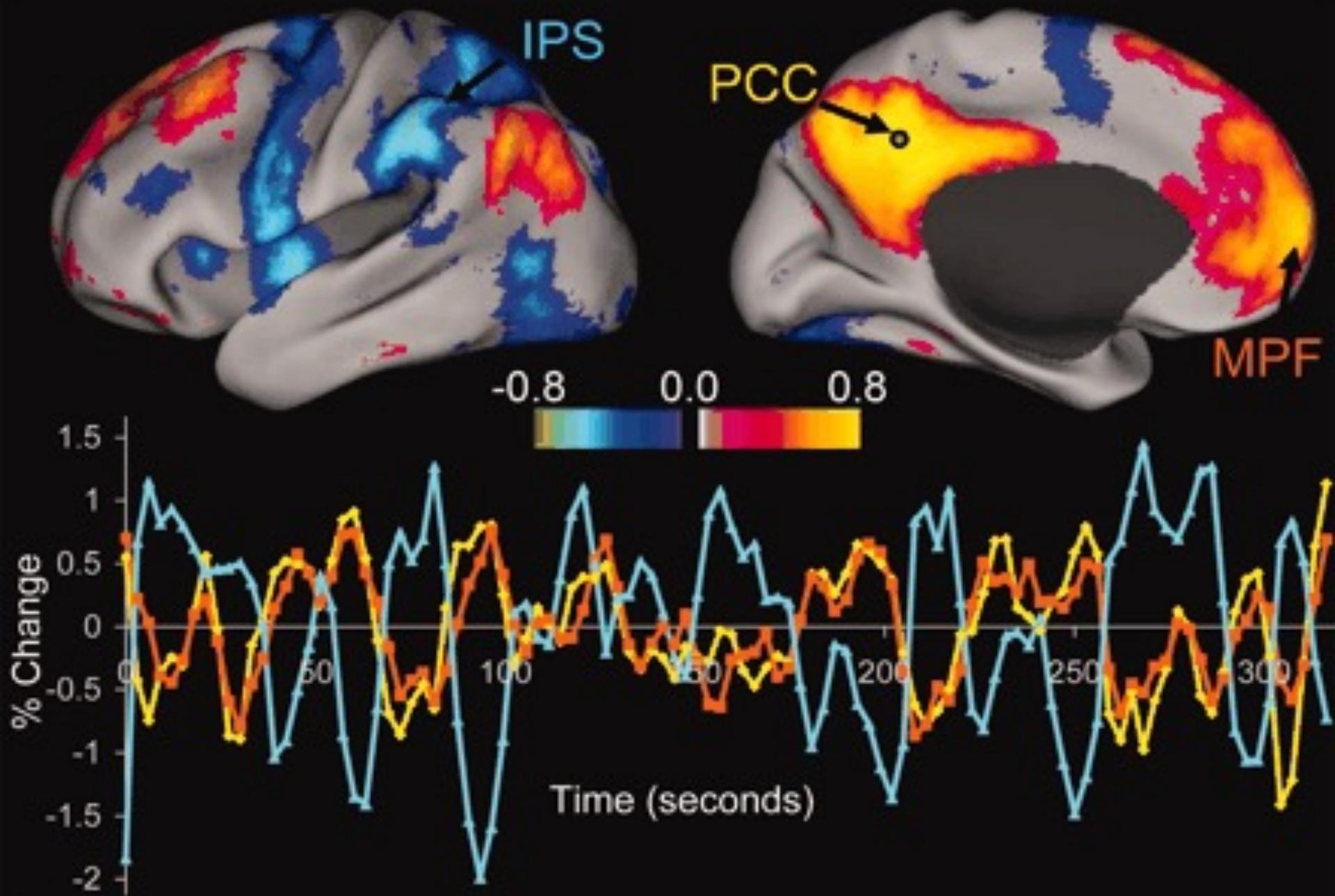
Evoked activity: Task, Stimuli



Resting Activity



Resting State: Fox et al., 2005, PNAS



Spontaneous Brain Activity: Spatial Resting State Networks

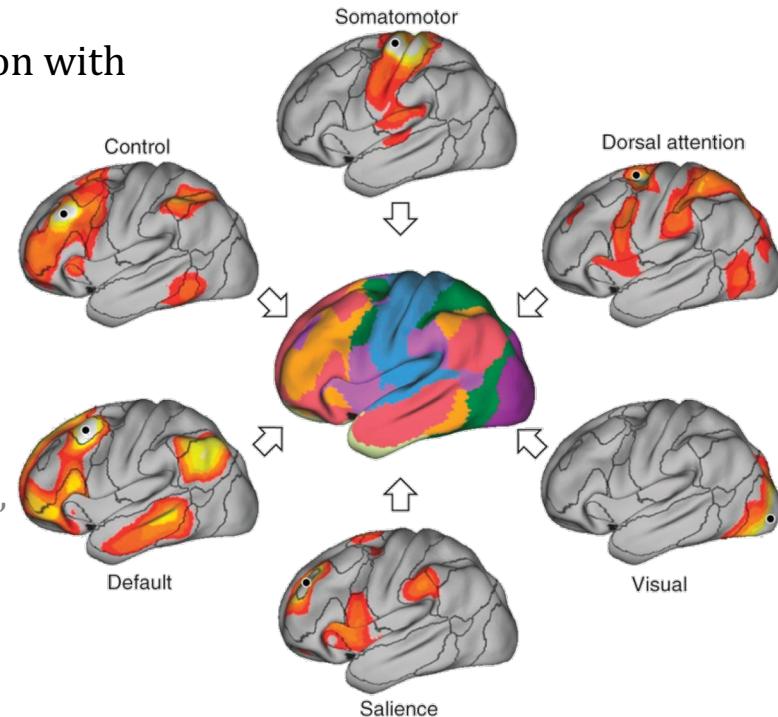
Baseline (or spontaneous) states are active states.

- Early studies reported systematic patterns of de-activation with increasing cognitive demands.
(Andreasen et al., 1995; Shulman et al., 1997)

- The brain at rest displays spatial patterns of correlated activity across different brain areas known as 'Resting State Networks' (RSNs).

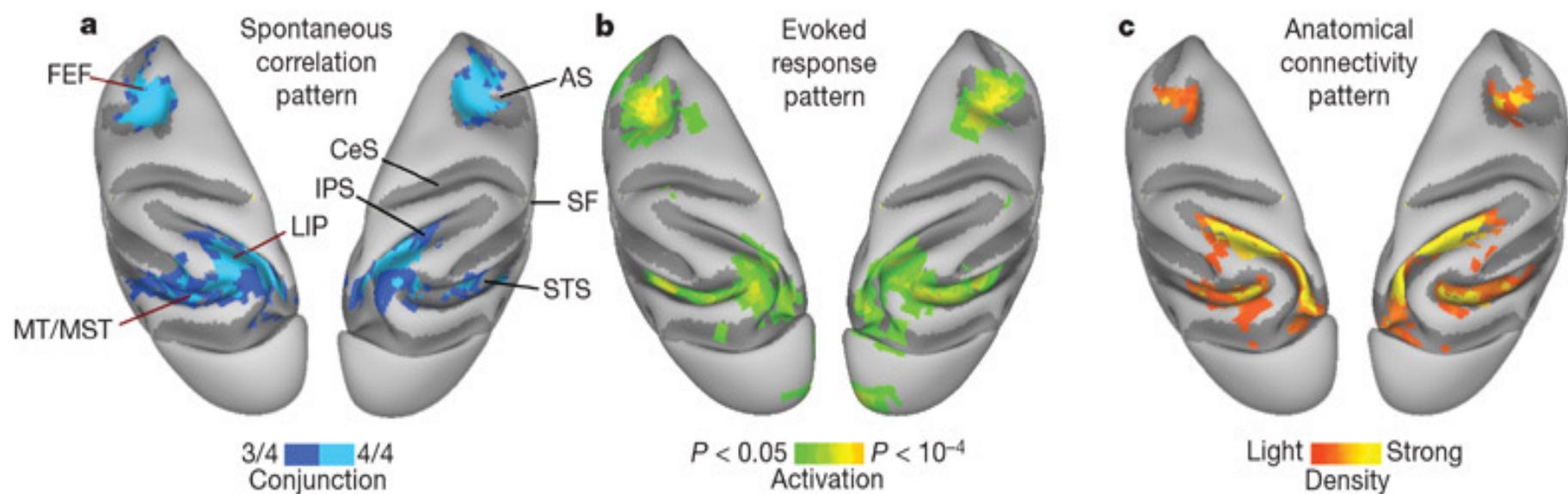
(Biswal et al., 1995; Greicius et al., 2003; Fransson, 2005; Fox et al., 2005)

- The RSNs resemble the pattern of activation observed during cognitive tasks, suggesting an intrinsic link between spontaneous and evoked activity.
(Biswal et al., 1995; Greicius et al., 2003; Fox et al., 2005)



Buckner et al., 2013

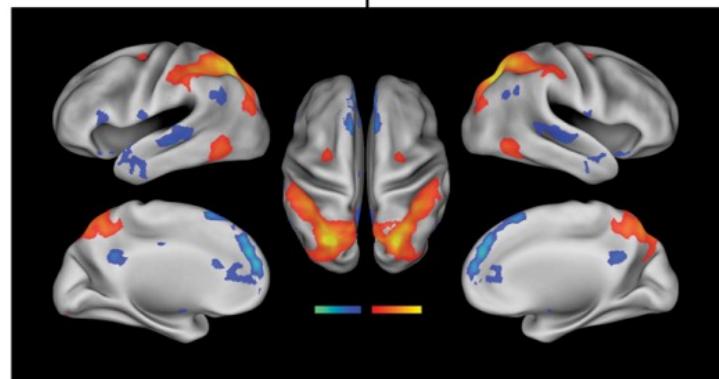
Resting State: Vincent et al., 2007, Nature



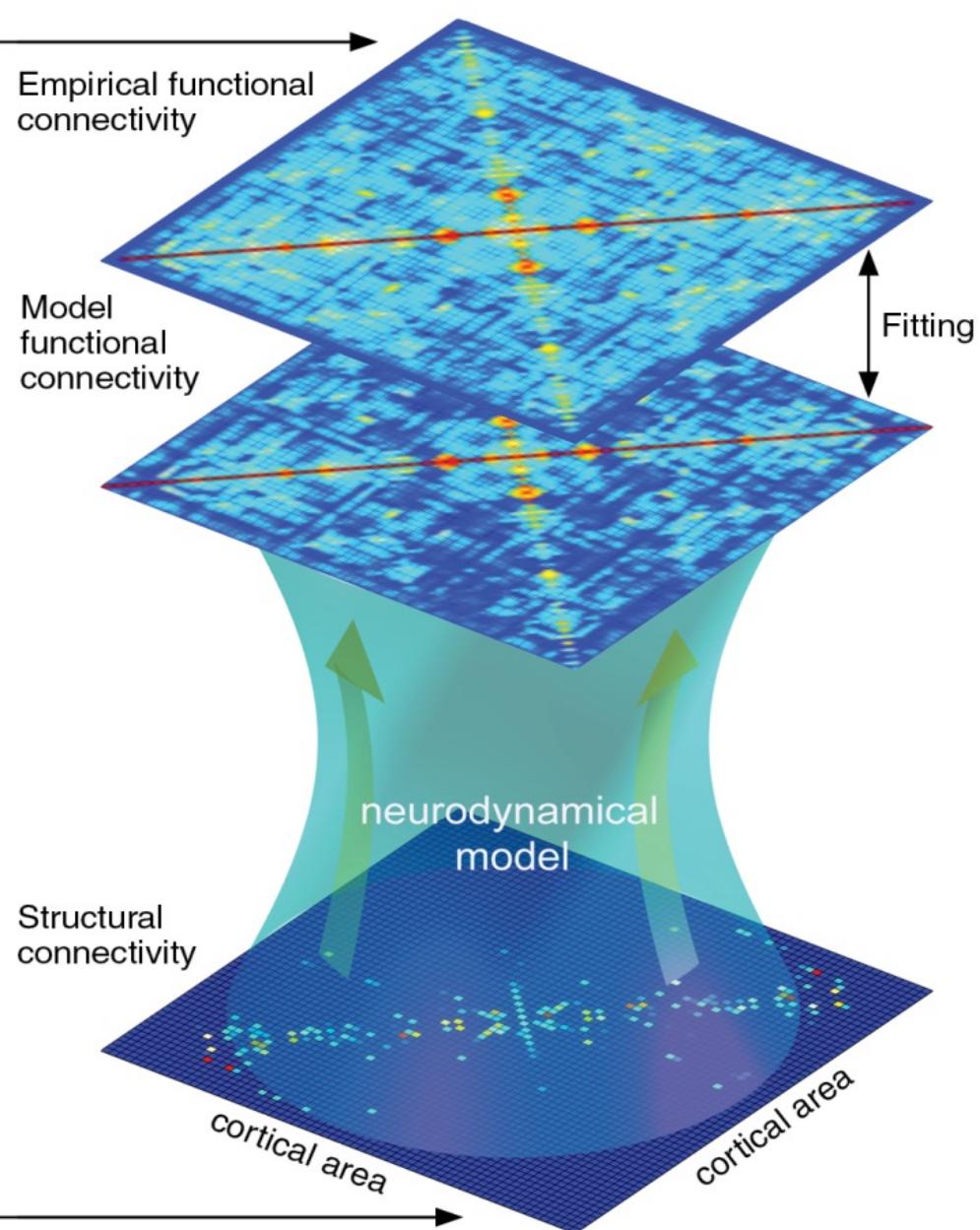
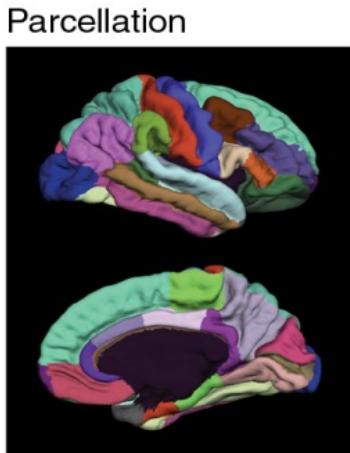
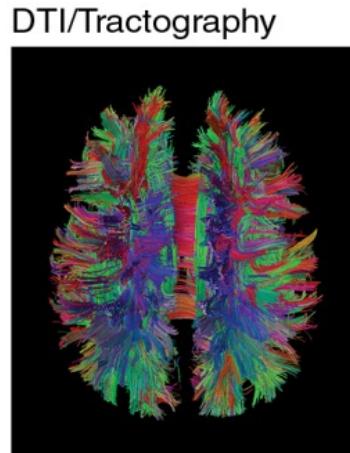
Strudtural Connectome: DTI



Linking structure and dynamics



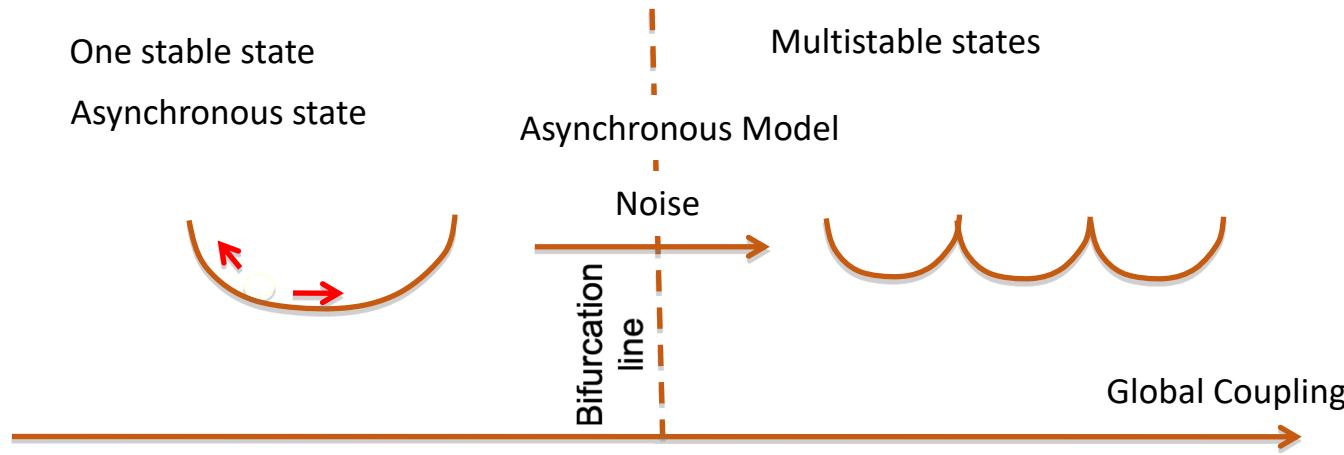
Empirical Resting-State Functional Connectivity
Correlation of BOLD signals



Resting State Scenarios and Models

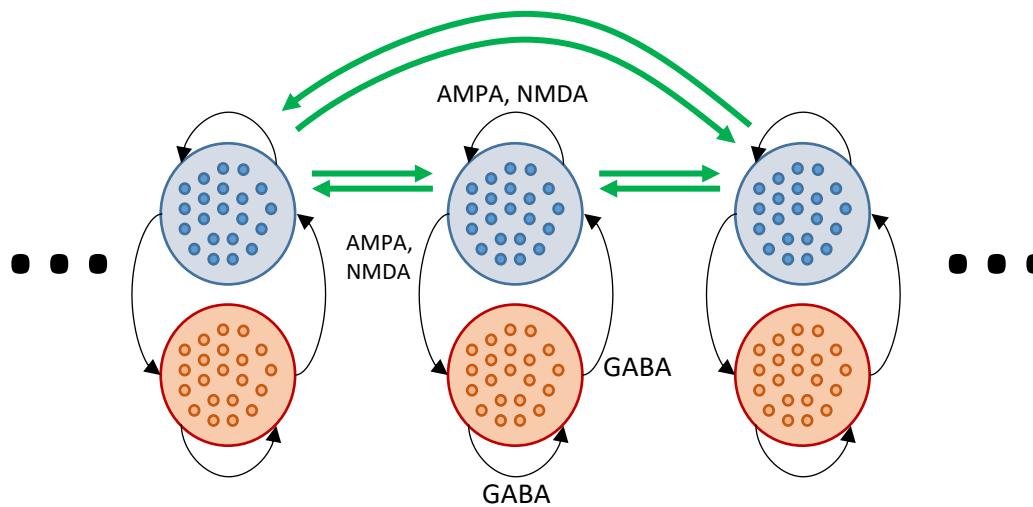
Scenario I: Dynamical Excursions in Multistable States at the Brink of a Bifurcation

(Deco and Kringelbach, Neuron 2014; Deco et al; TINS 2014; Rev. Nat. Neu. 11;Deco et al. JNS 2012, 2013,2014)

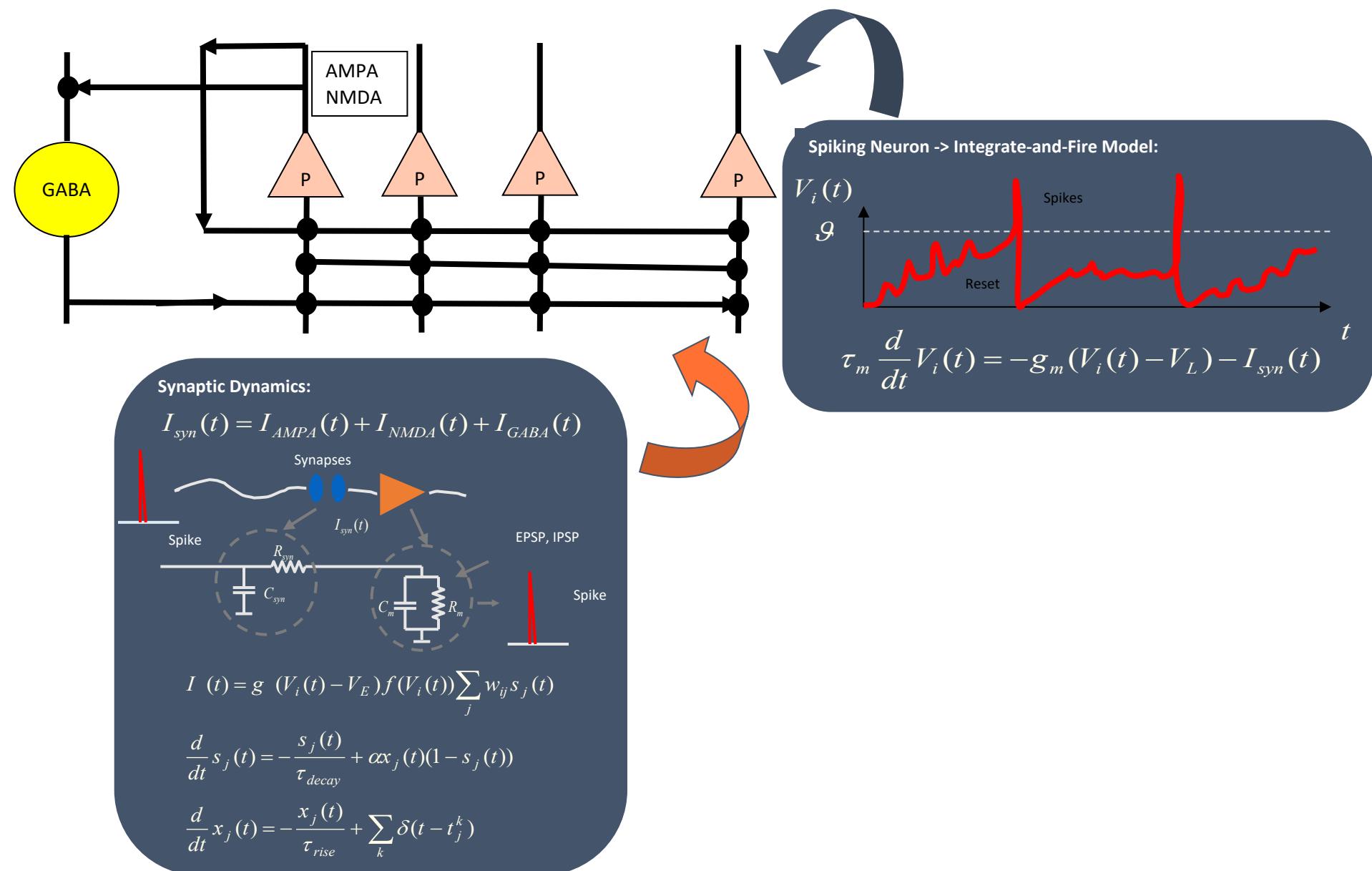


Spiking Networks for Local Brain Areas

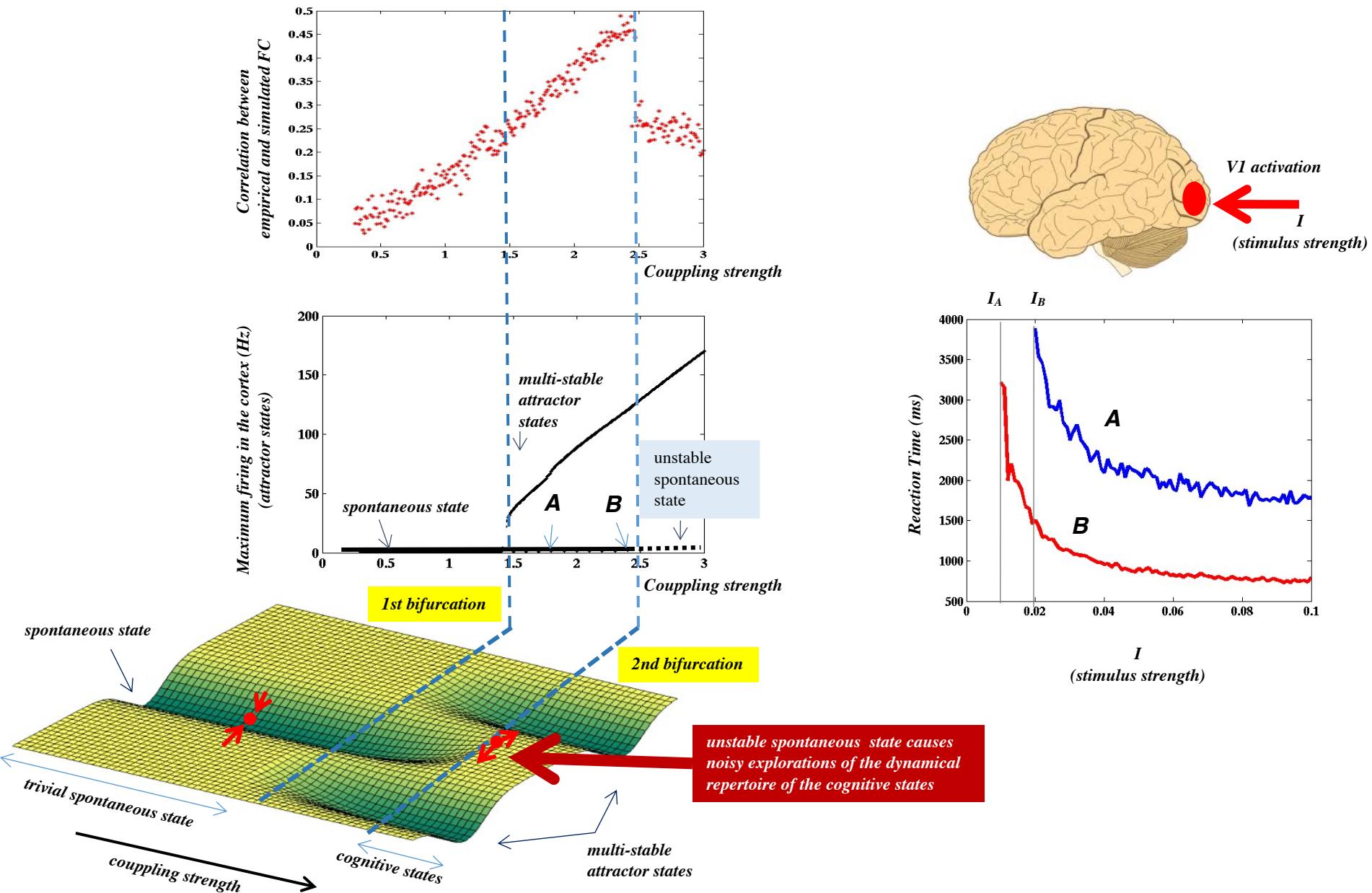
Realistic
spiking
network



Spiking Networks for Local Brain Areas

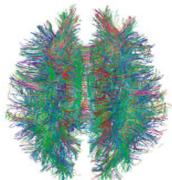


Resting-State: Exploration of the Dynamical Repertoire



Whole-Brain Models

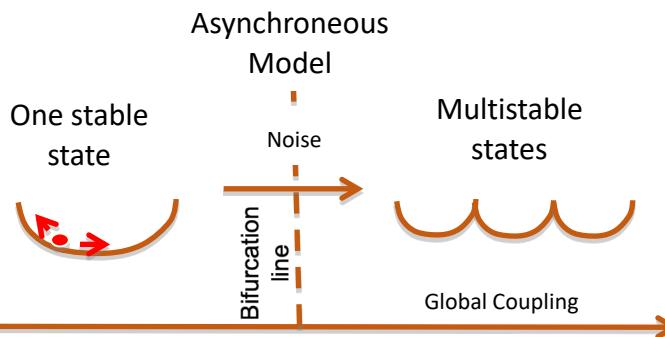
I Scenario: Linear Fluctuations



+ Noise → FC

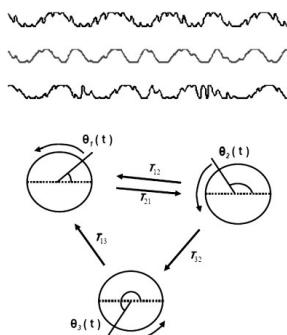
- Simple Autoregressive, SAR (Messé et al., 2014, 2015)
- Mean-Field Linearization (Deco et al. 2014)

II Scenario: Dynamical Excursions in Multistable States at the Brink of a Bifurcation



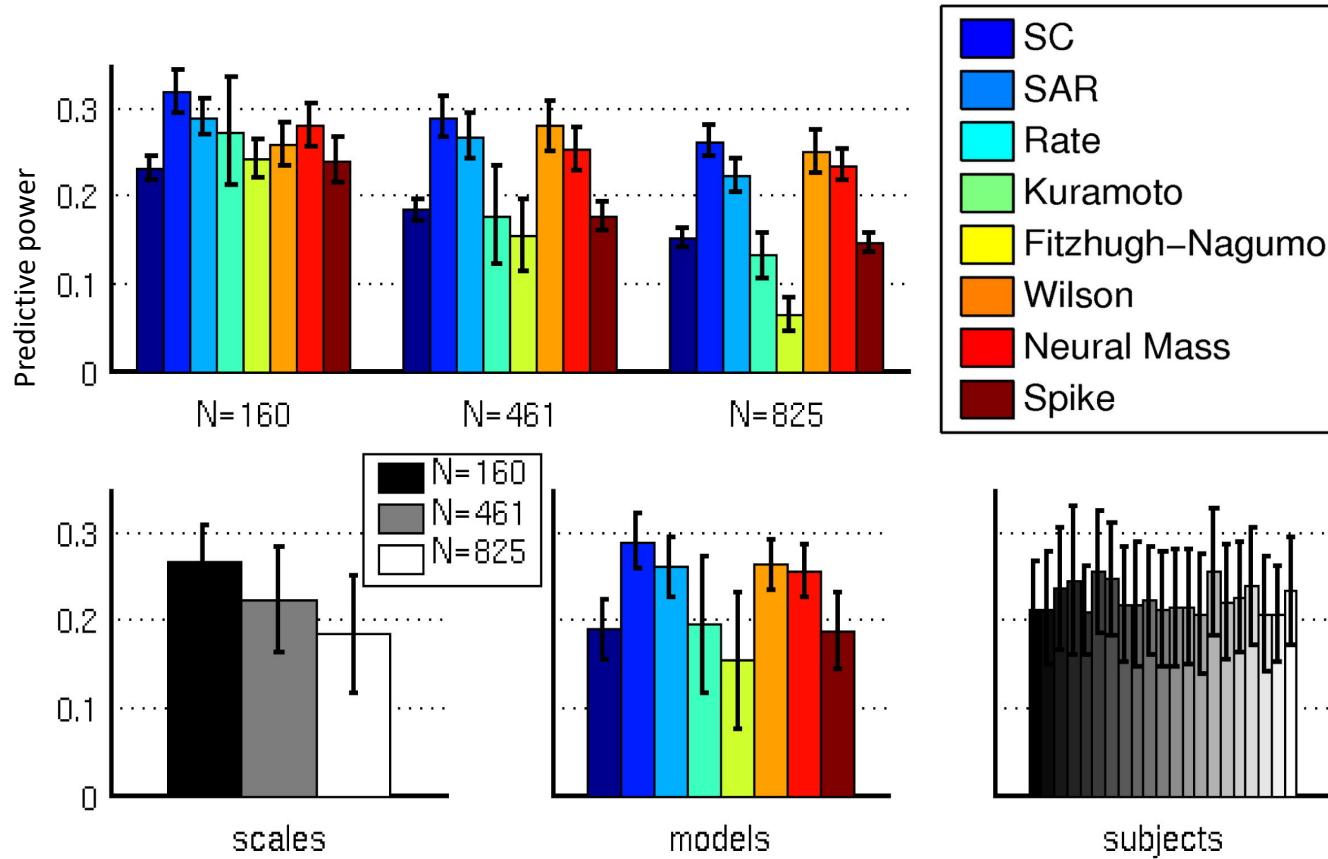
- Spiking Networks (Deco & Jirsa, 2012)
- Mean-Field (Deco et al., 2013, 2014, 2015, 2016)
- Neural-mass (Breakspear et al. 2003, Honey et al. 2009)

III Scenario: Transitions Between Metastable Synchronous States



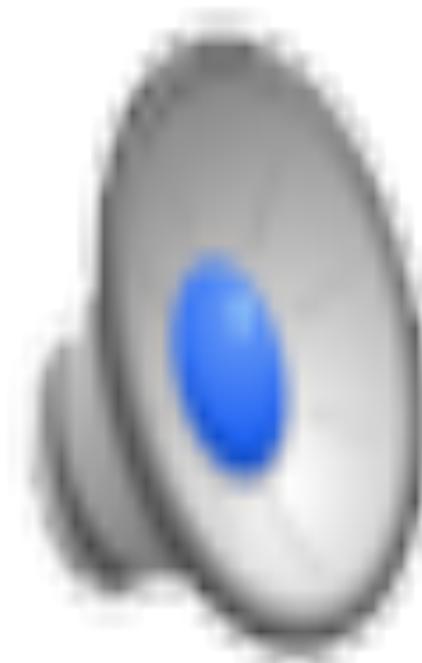
- Kuramoto (Cabral et al 2011, 2012, 2014)
- Wilson-Cowan (Deco et al. 2009)
- Fitzhugh-Nagumo (Gosh et al. 2008, Stefanescu & Jirsa, 2008)

Functional Connectivity (FC)



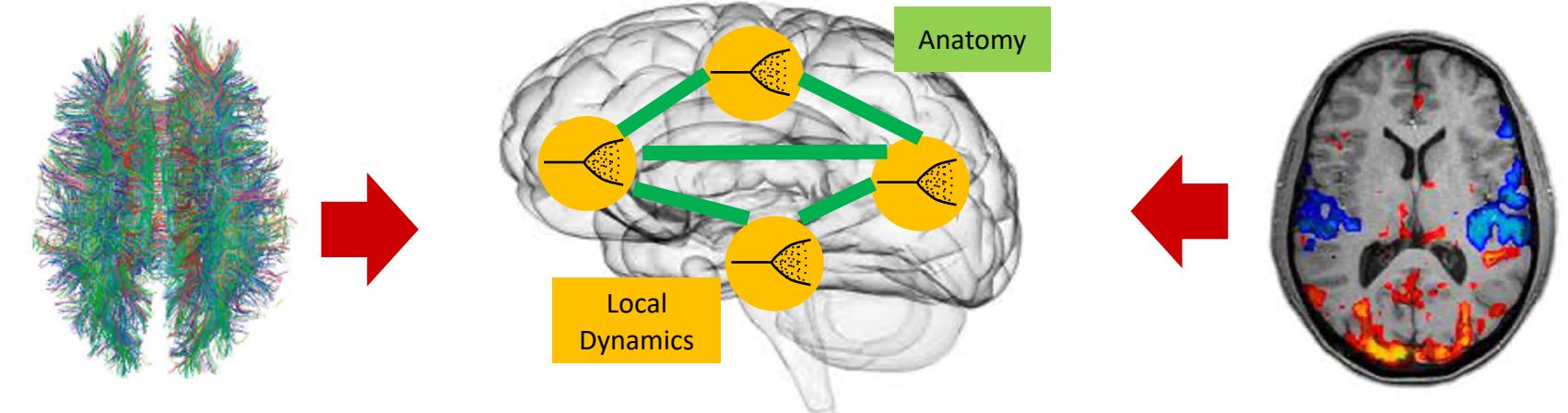
Messé et al., 2014, 2015

FCD



Allen et al., 2013; Hansen et al. 2015;.....

Hopf Model: Noise/Oscillations; Multistability/metastability



Structural Connectivity
DTI/DSI

Functional Connectivity
fMRI

Hopf Normal Form:

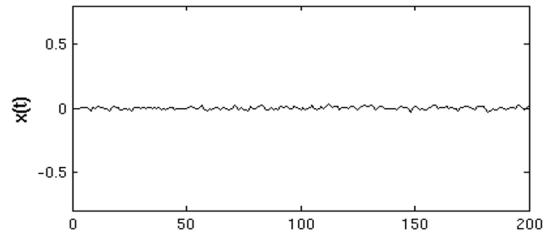
$$\frac{\partial x}{\partial t} = ax - \omega y - x(x^2 + y^2) + v(t)$$

$$\frac{\partial y}{\partial t} = ay - \omega x + y(x^2 + y^2) + v(t)$$

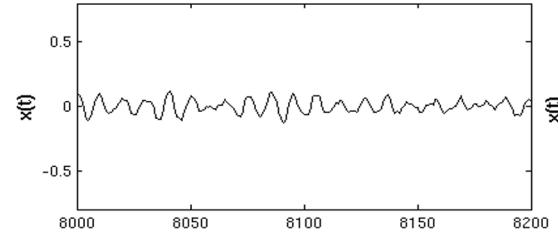
Bifurcation Parameter a

**Mesoscopic
Model**

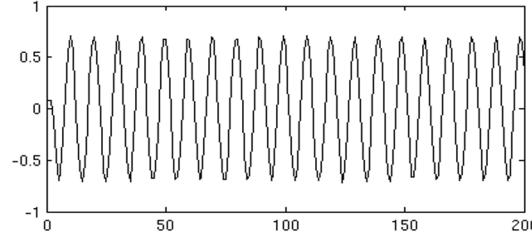
Noise



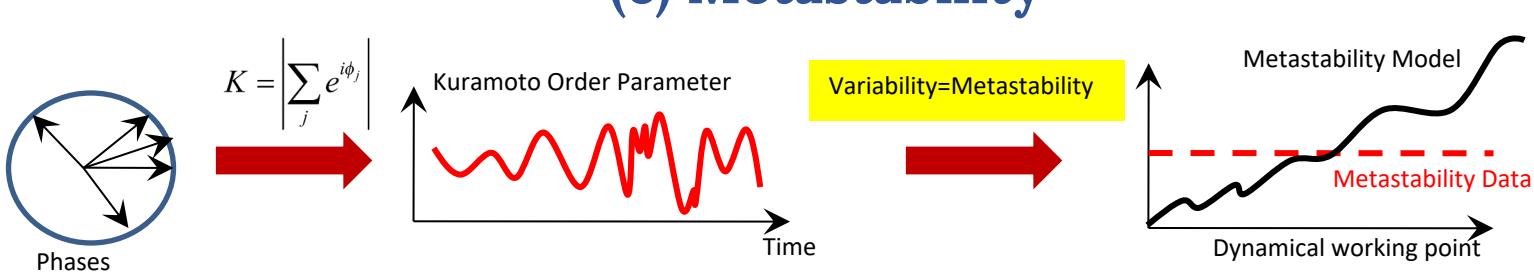
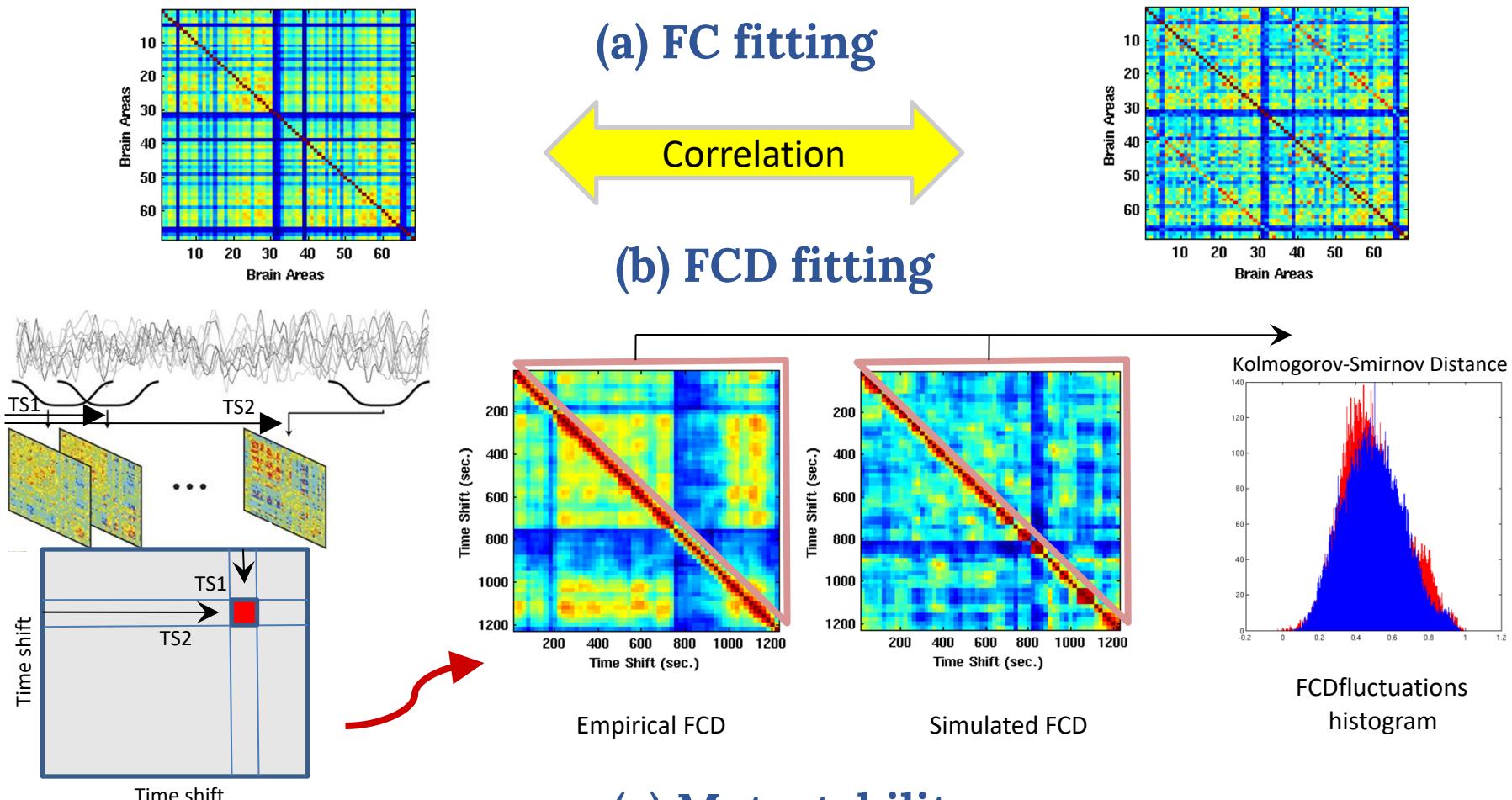
Noise + Oscillations



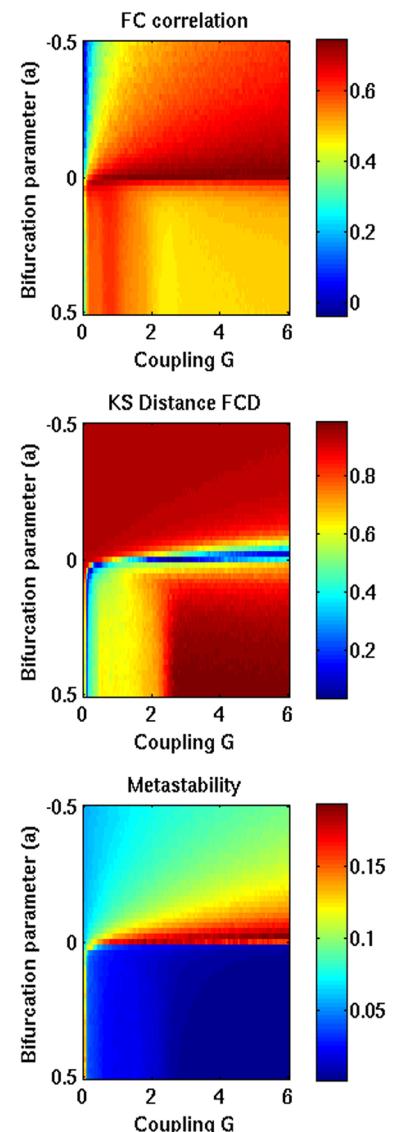
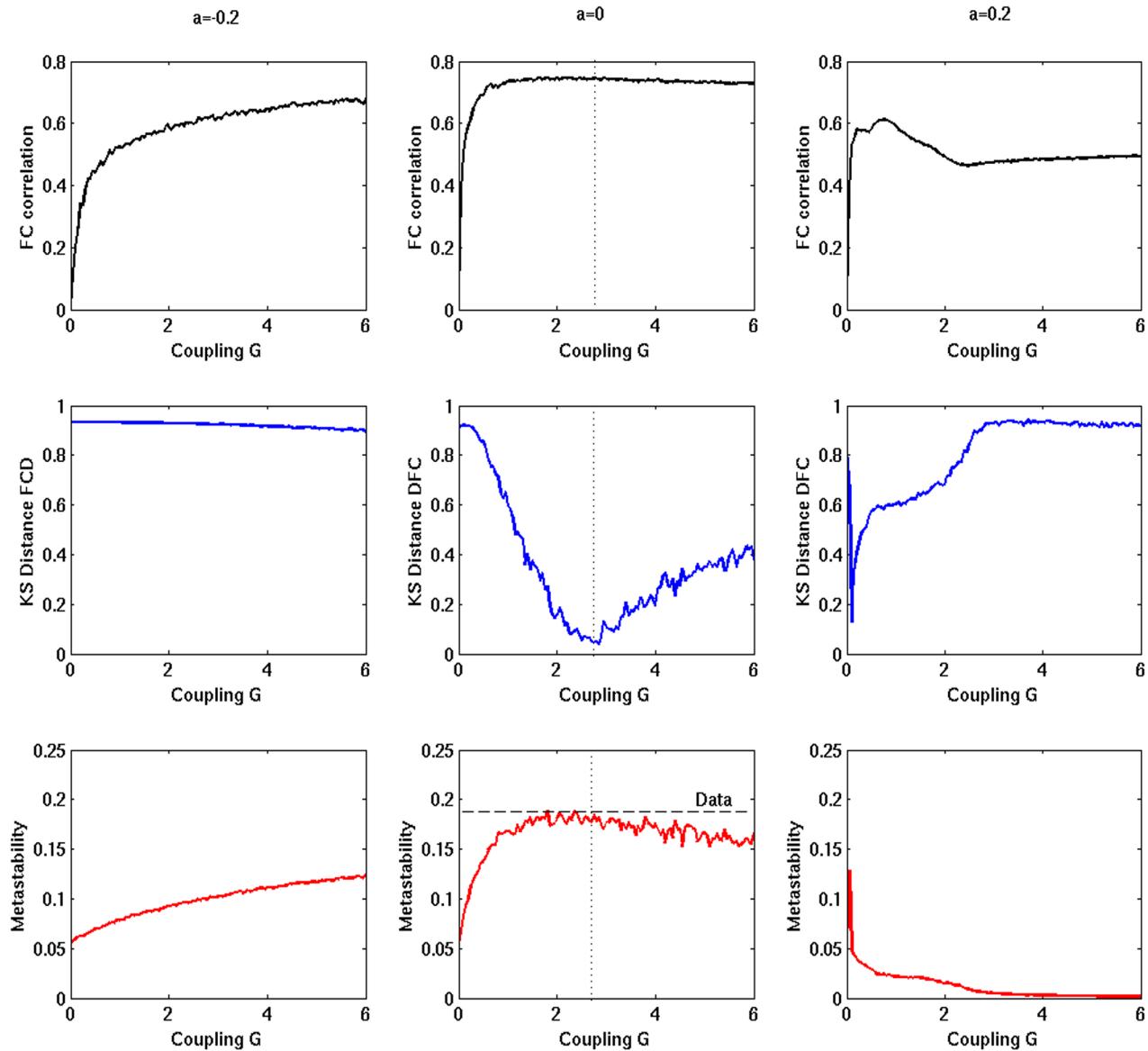
Oscillations



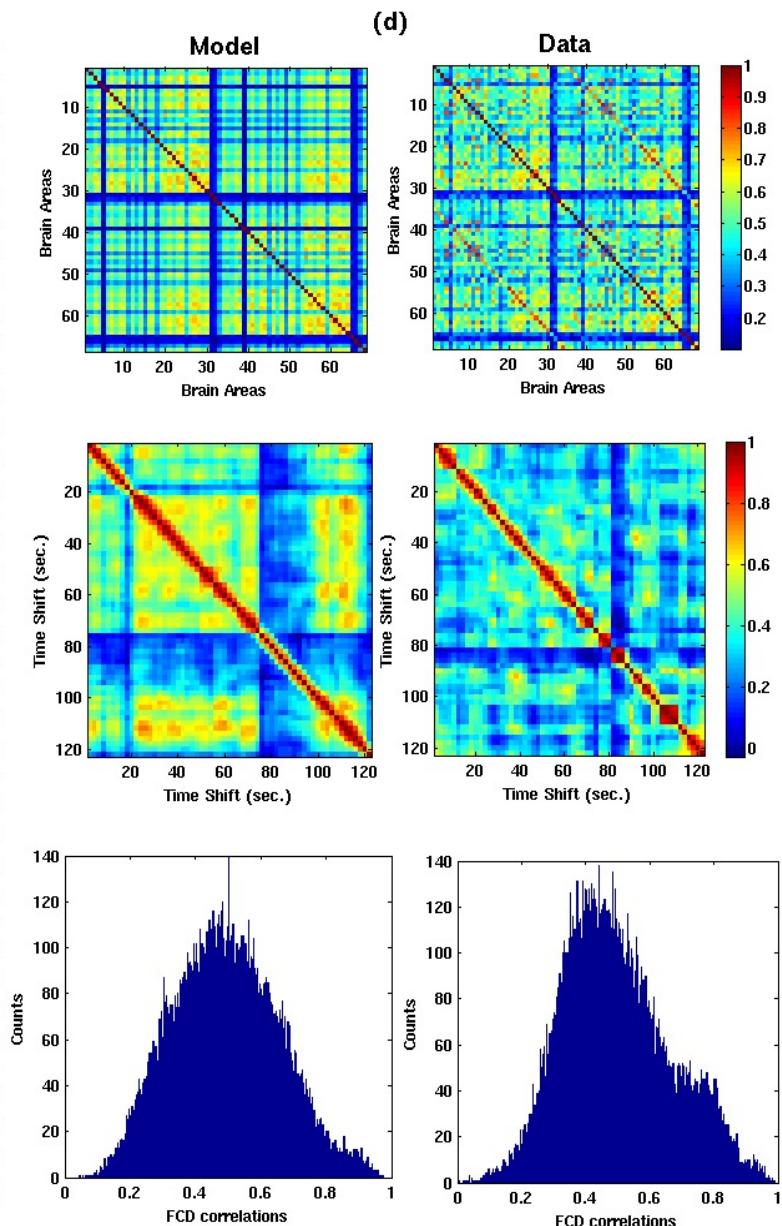
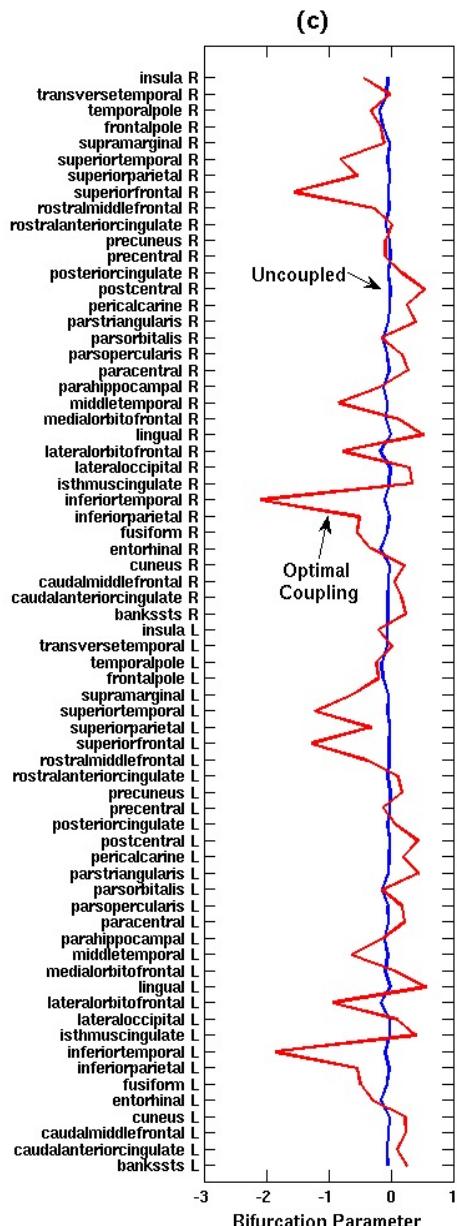
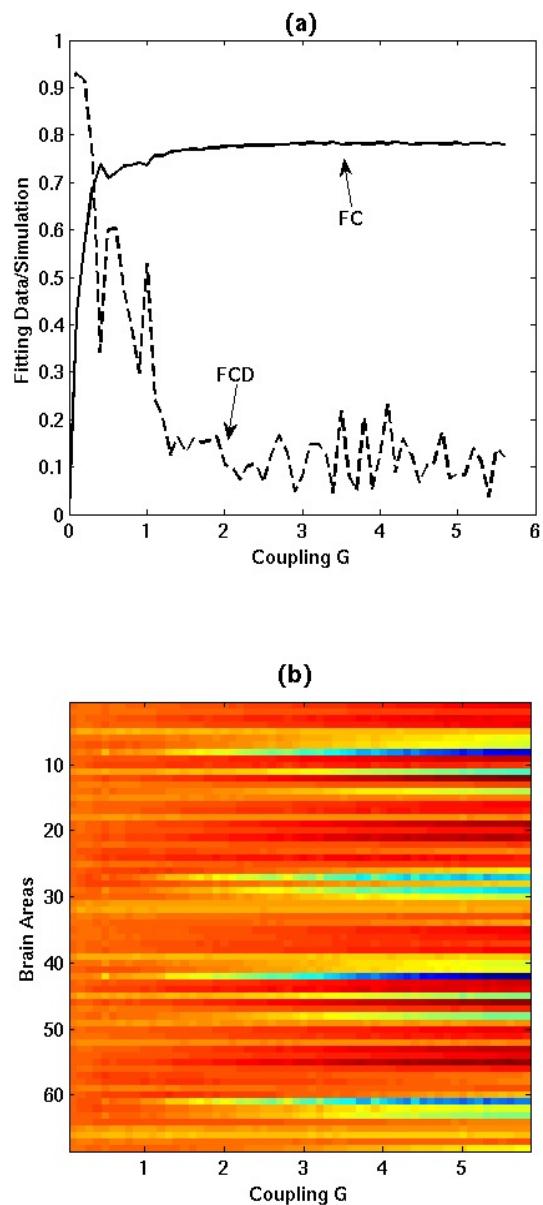
Experiments vs. Models Comparisons



Optimal Working Point: At the brink of Hopf (Oscillations) Bifurcation



Intrinsic Characterization of the Dynamical Core



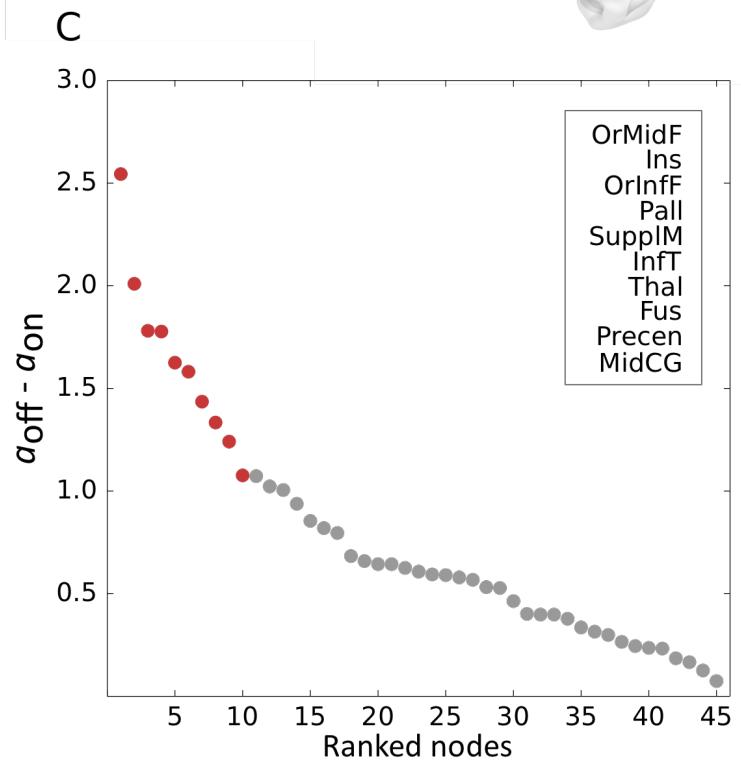
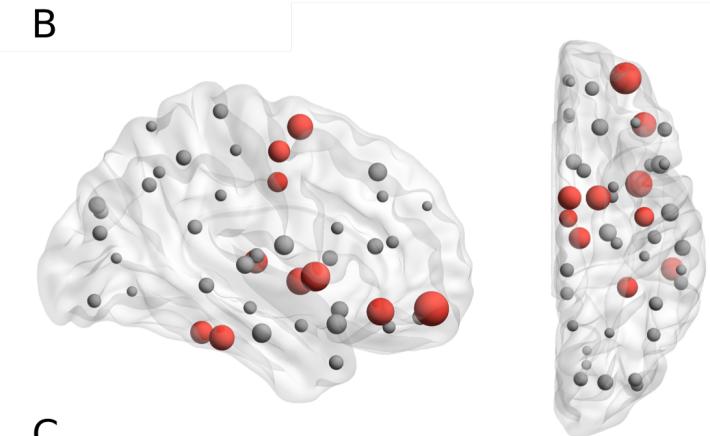
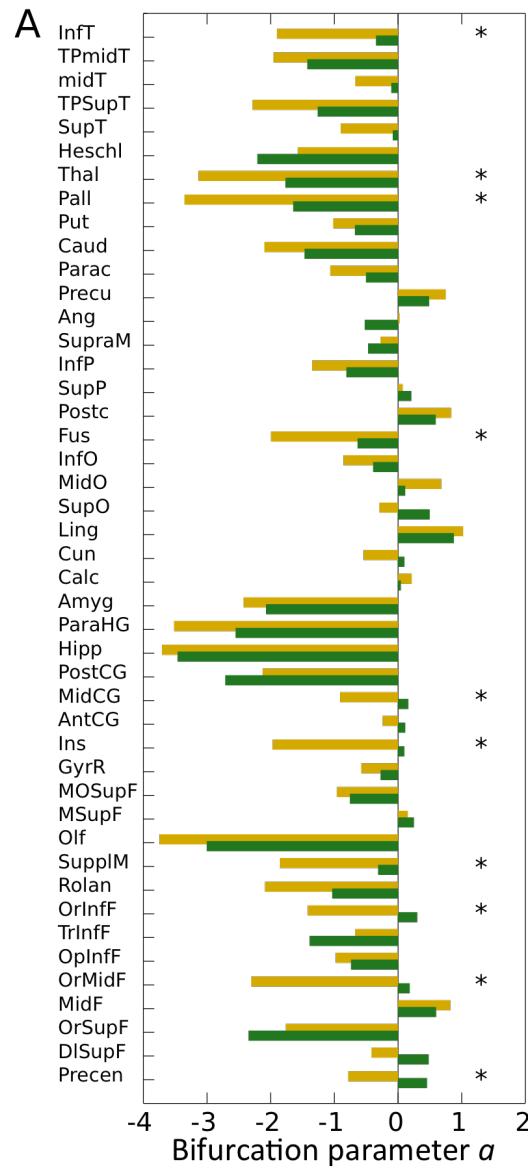
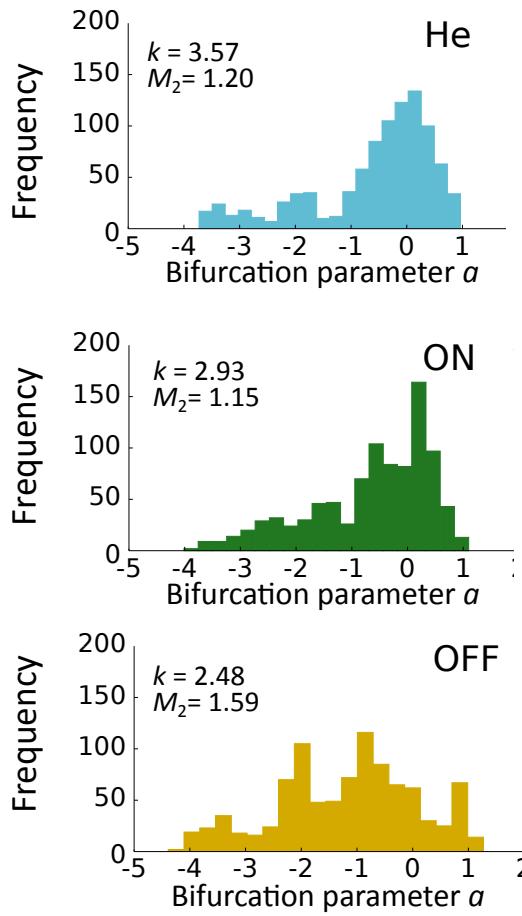
Parkinson



Parkinson: DBS ON vs DBS OFF

- 10 Parkinsonian Patients with DBS implantation in STN
- 10 Healthy controls
- 2 sessions resting fMRI of 10 min. with DBS on and DBS off

Parkinson: DBS ON vs DBS OFF



Conclusions

1. **Whole-brain modelling** opens up for causal understanding of neuroimaging data
2. Perspective: **Prediction of best treatment** for disorders of consciousness and patients with neuropsychiatry disorders

Thank You!