

# Oscillatory dynamics in networks of brain activity during rest

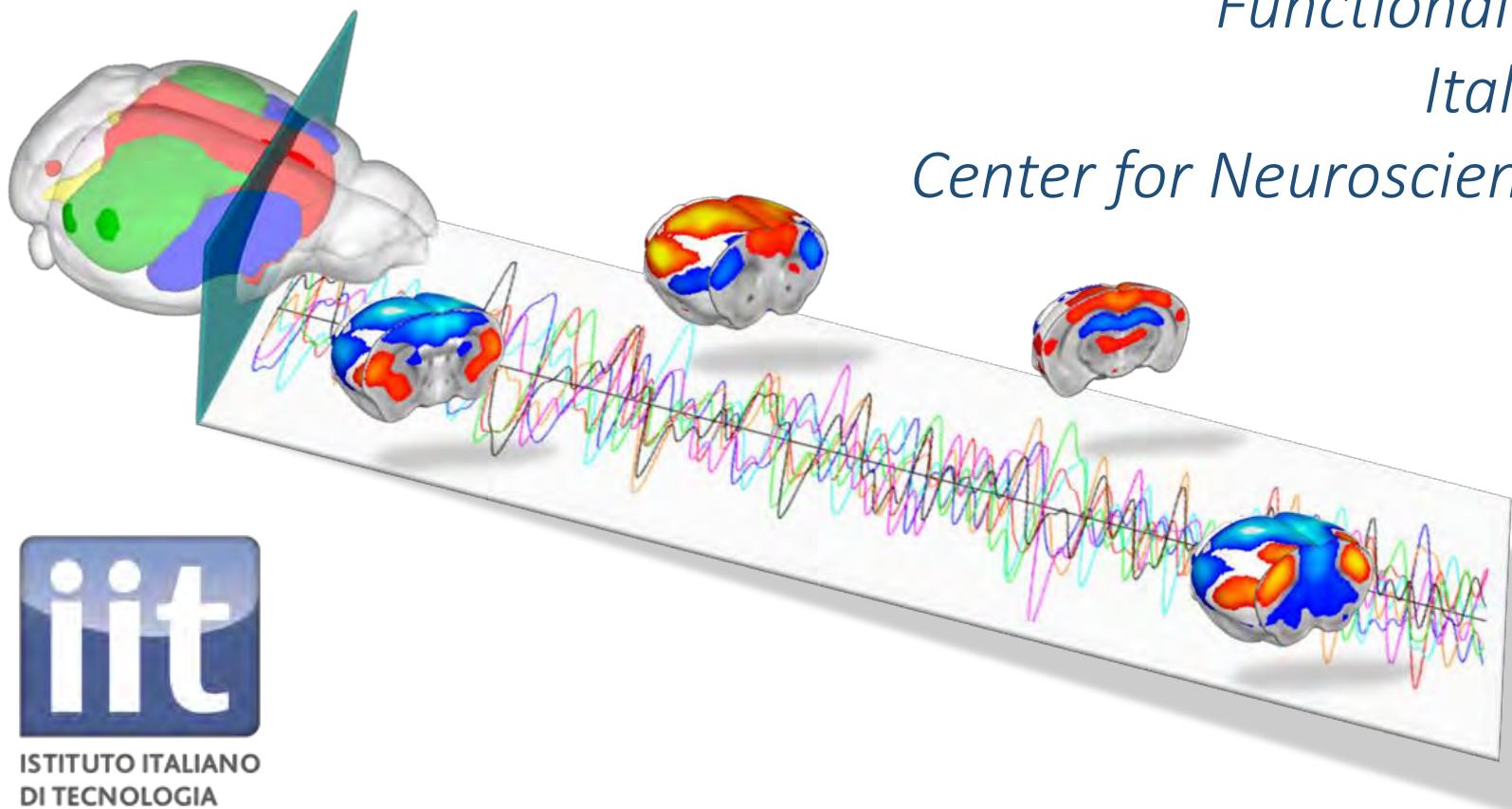
Alessandro Gozzi, PhD

Functional Neuroimaging Laboratory

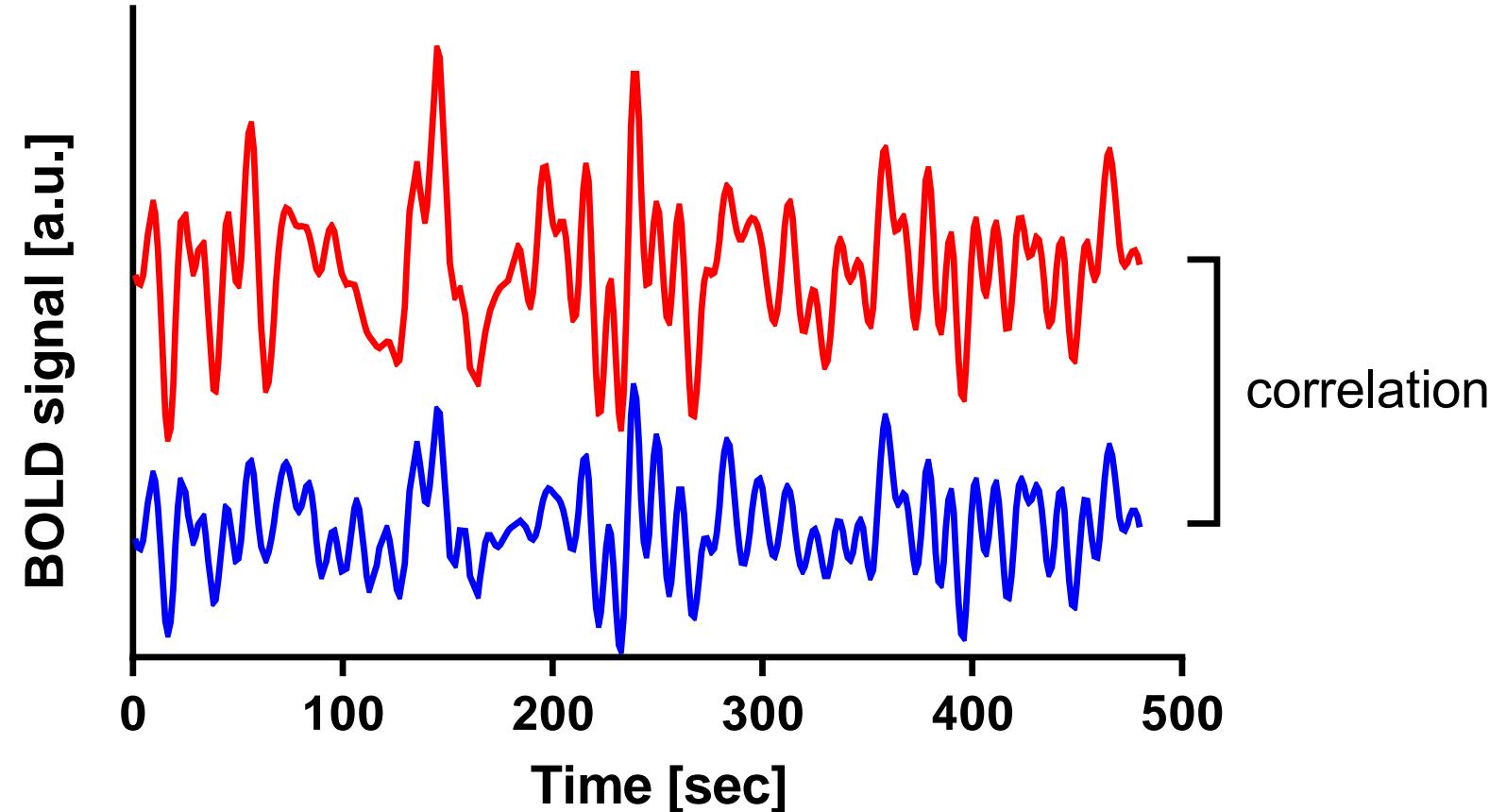
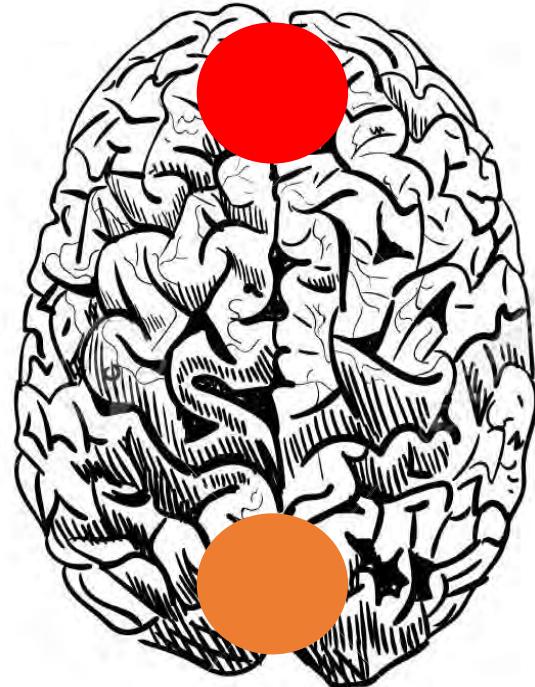
Italian Institute of Technology

Center for Neuroscience and Cognitive Sciences

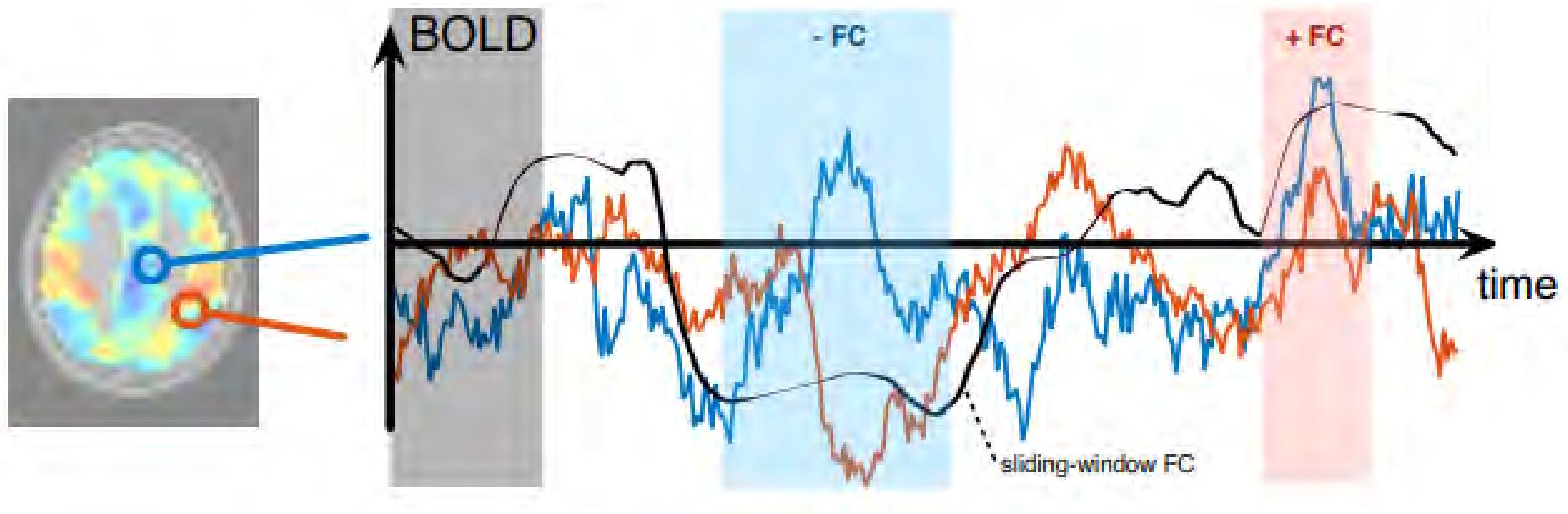
Rovereto,  
Italy



# Resting state fMRI (rsfMRI) and “functional connectivity”

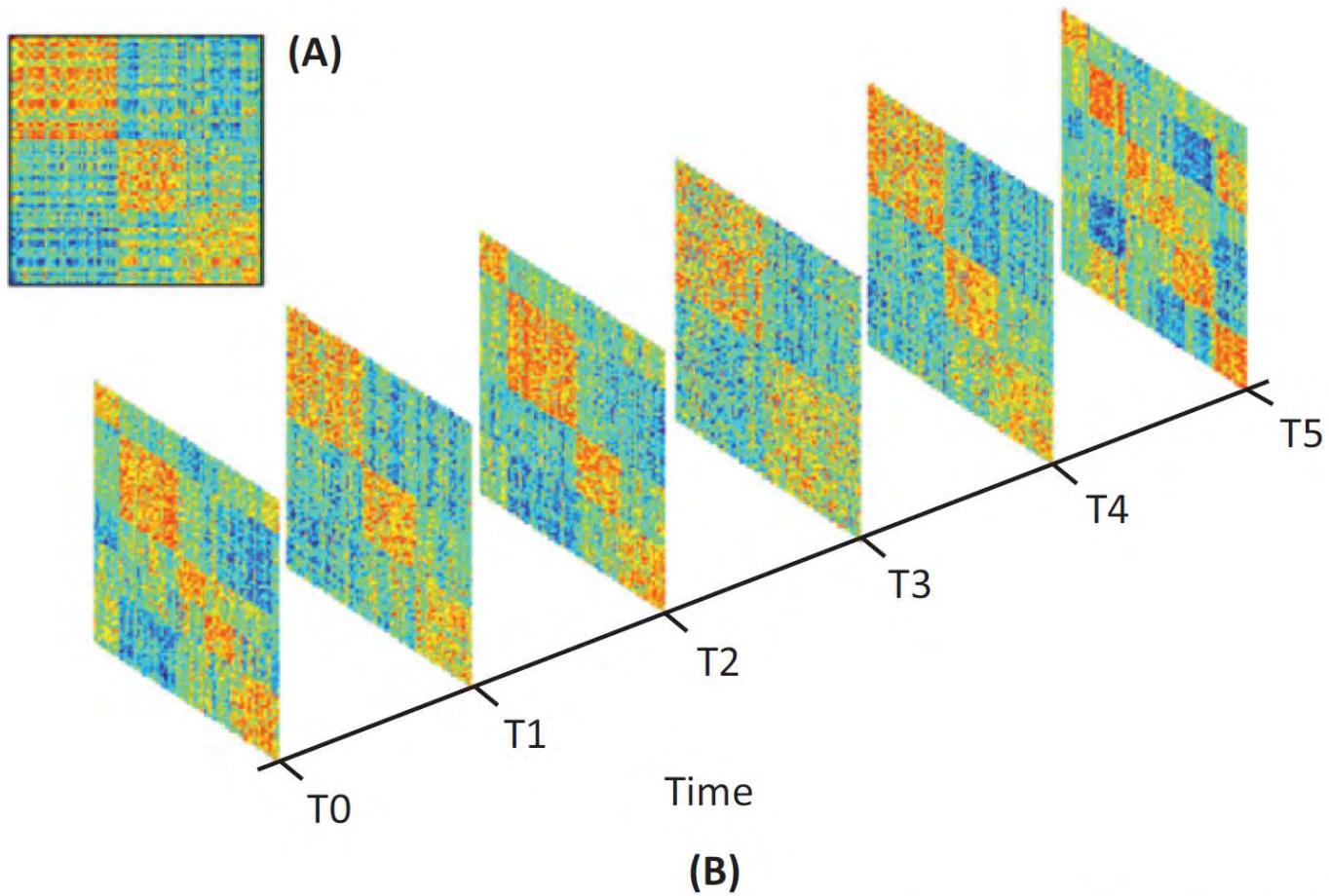


# ....however the brain is a dynamic system

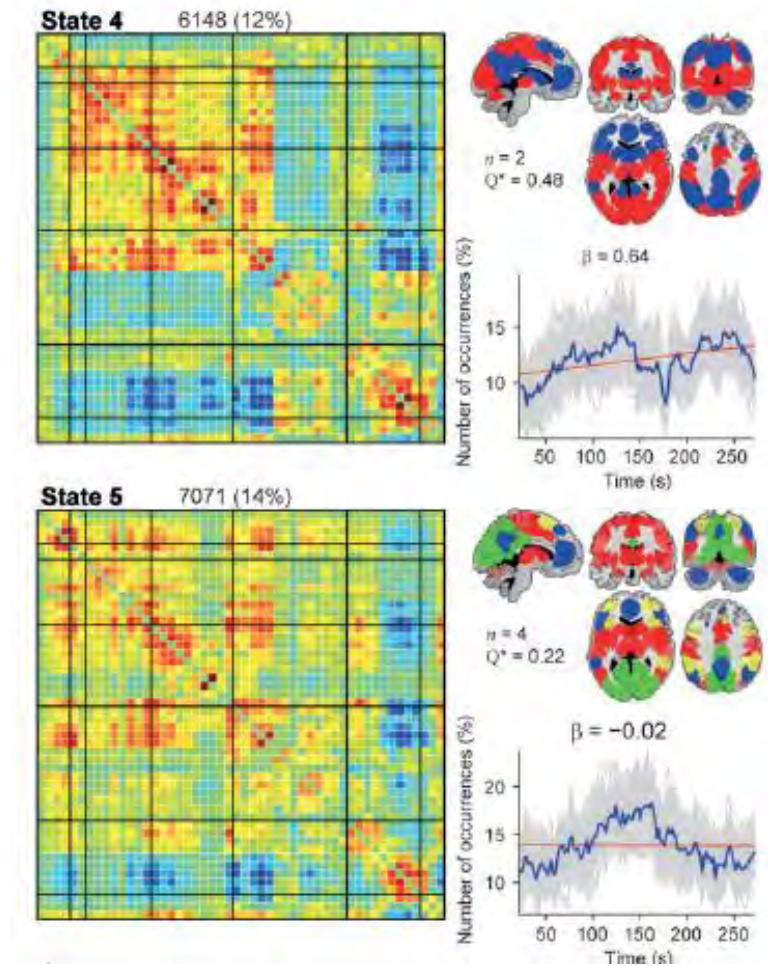


Allen et al., 2014

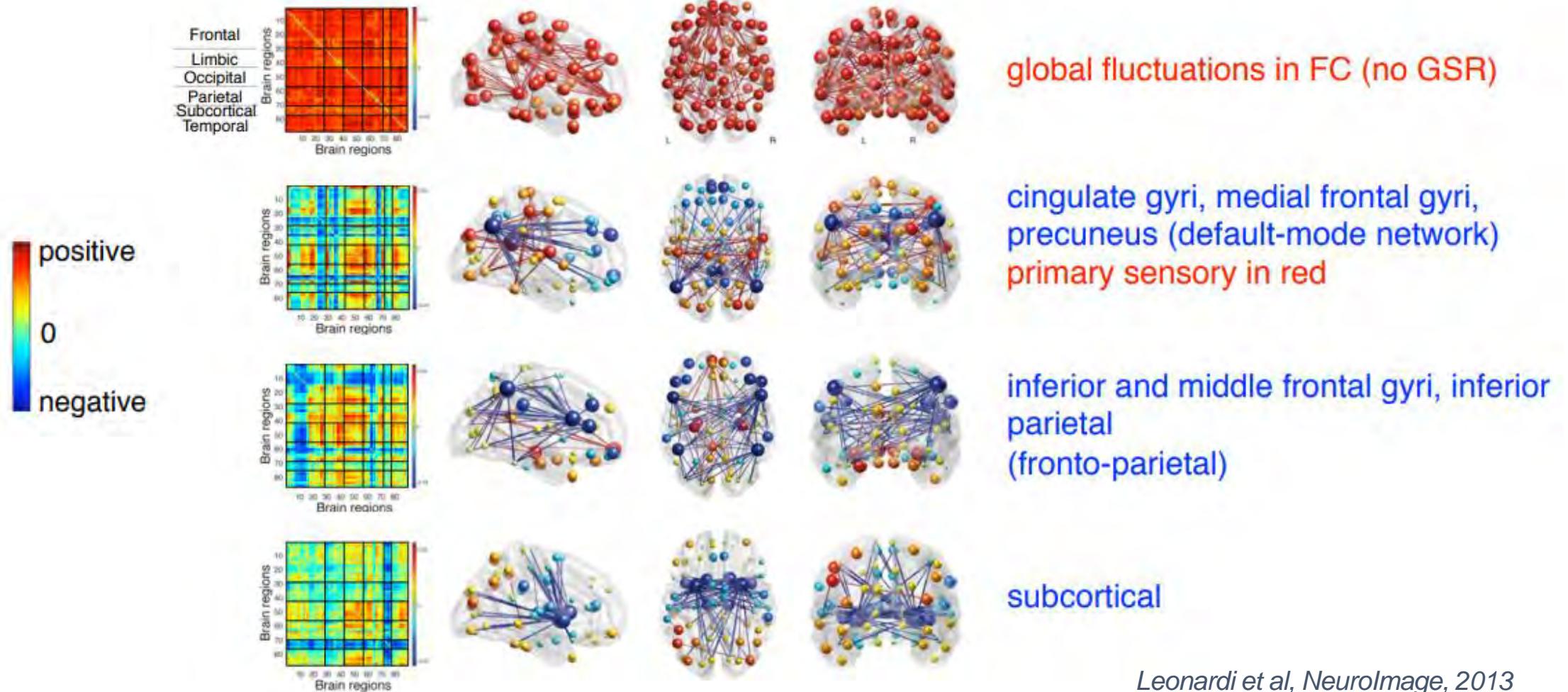
# Time-varying functional connectivity mapping



TRENDS in Neurosciences



Allen et al., 2014



*Leonardi et al, NeuroImage, 2013*

# rsfMRI networks undergo dynamic configurations

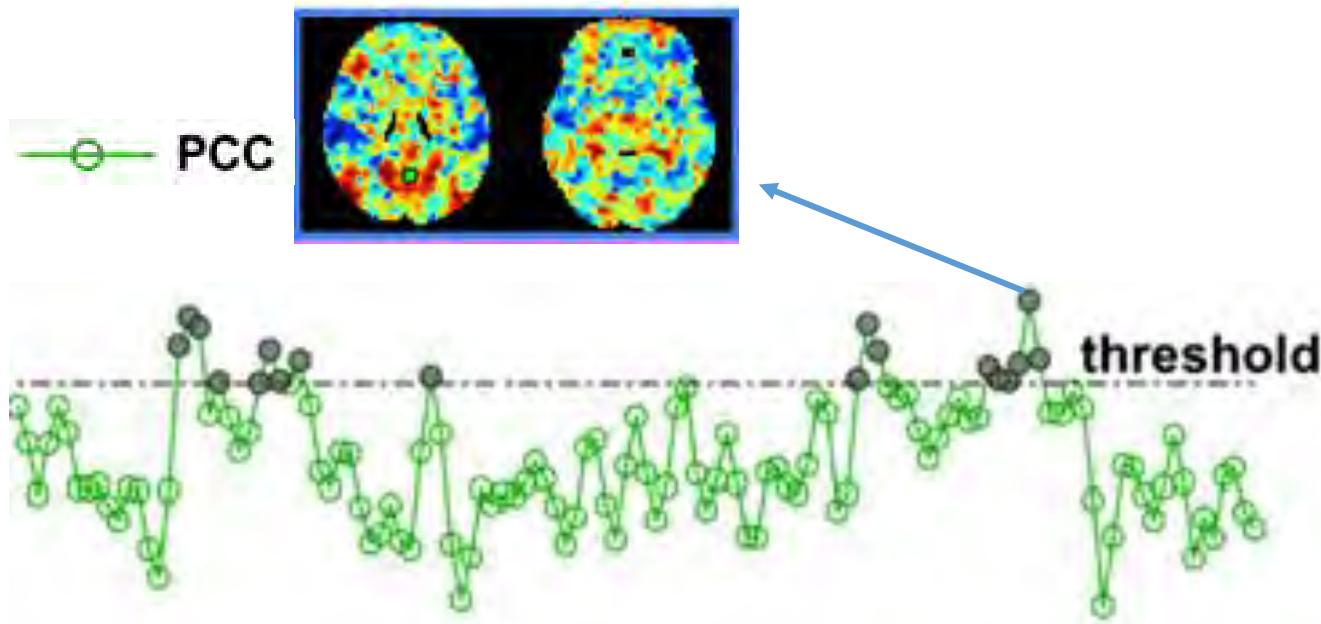
# Limitations of sliding-window approaches

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- Computational demanding – brain parcellations
- Arbitrary choice of window length and overlap
- Correlation based measures

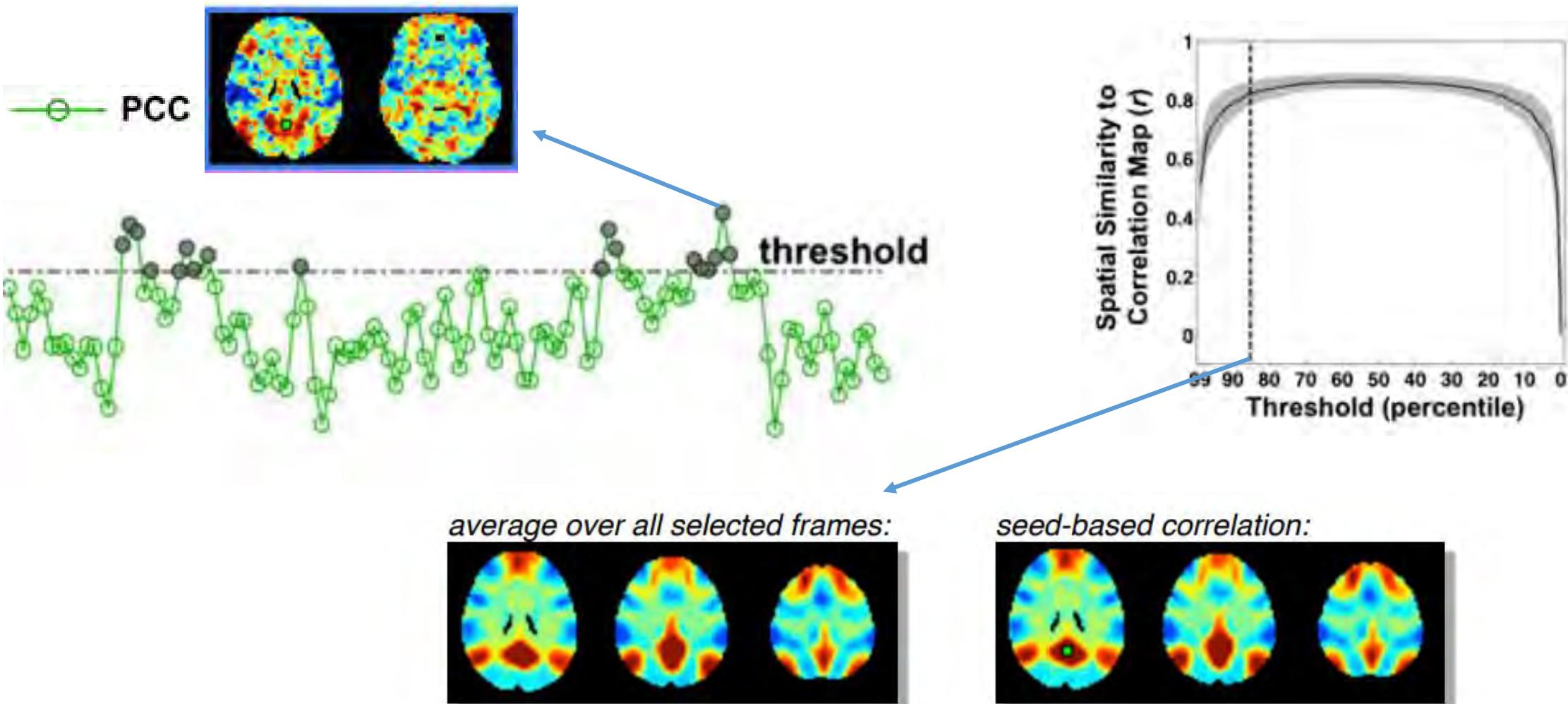
Can we map rsfMRI dynamics  
without using correlation?

# Point-processes analyses



Relevant network features can be observed from single fMRI frames at local extrema of key regions

# Selective fMRI frame averaging reconstitutes rsfMRI network activity

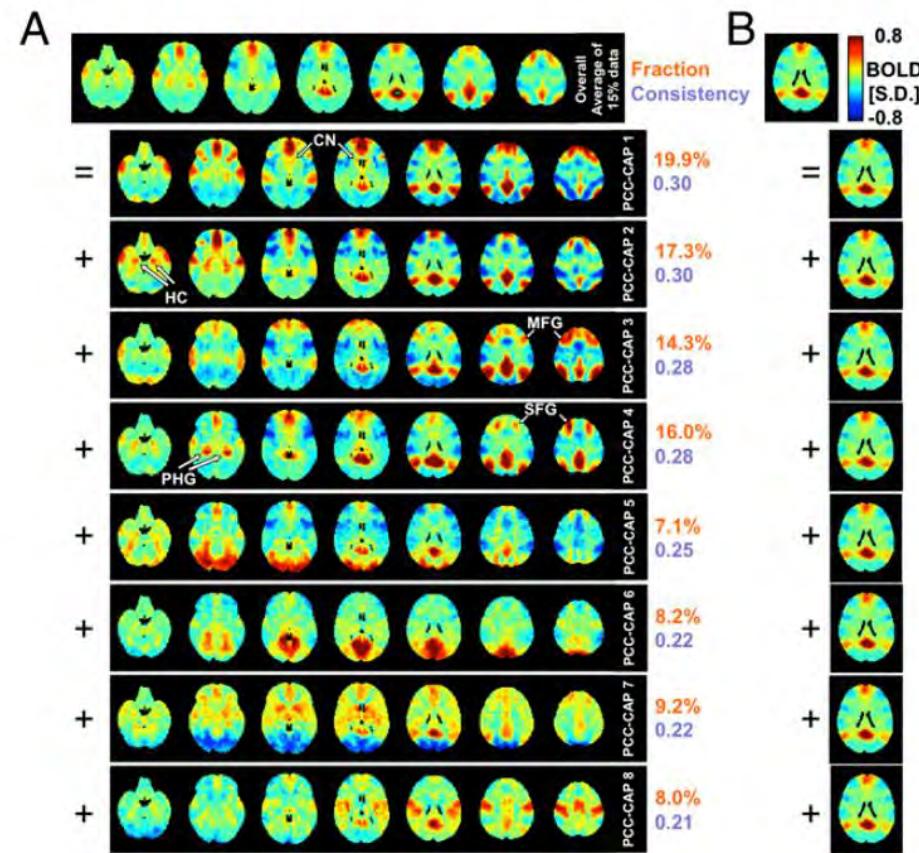
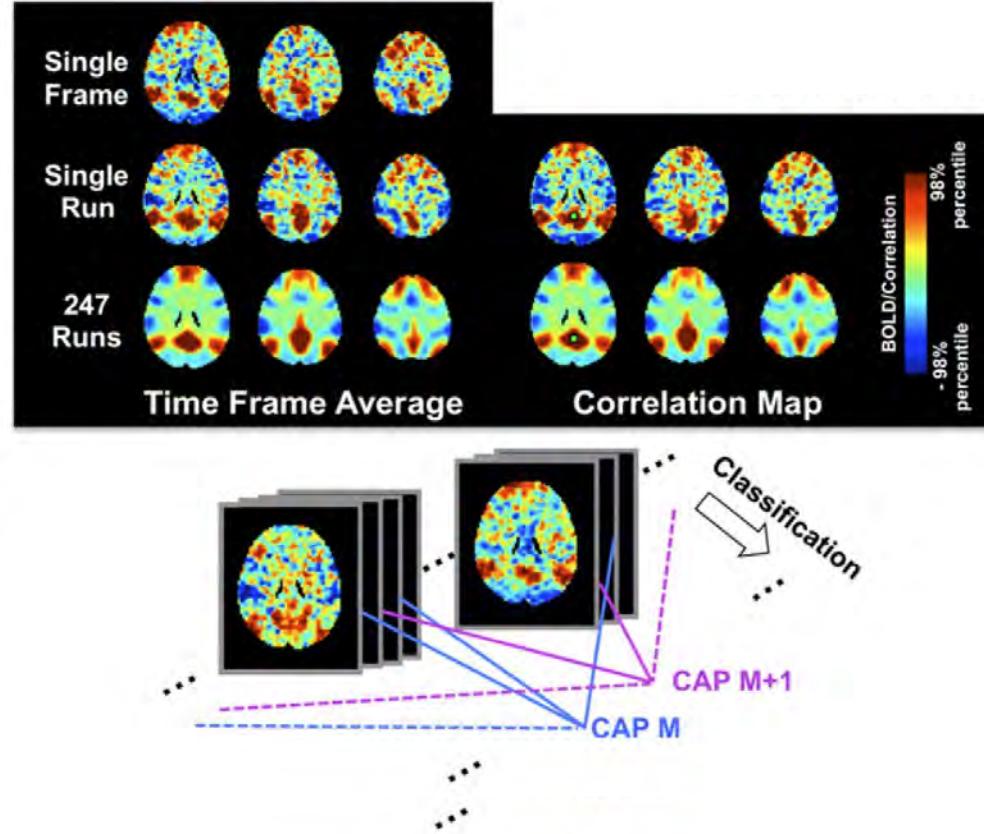


Co-Activation Patterns (CAPs) → mean BOLD signal

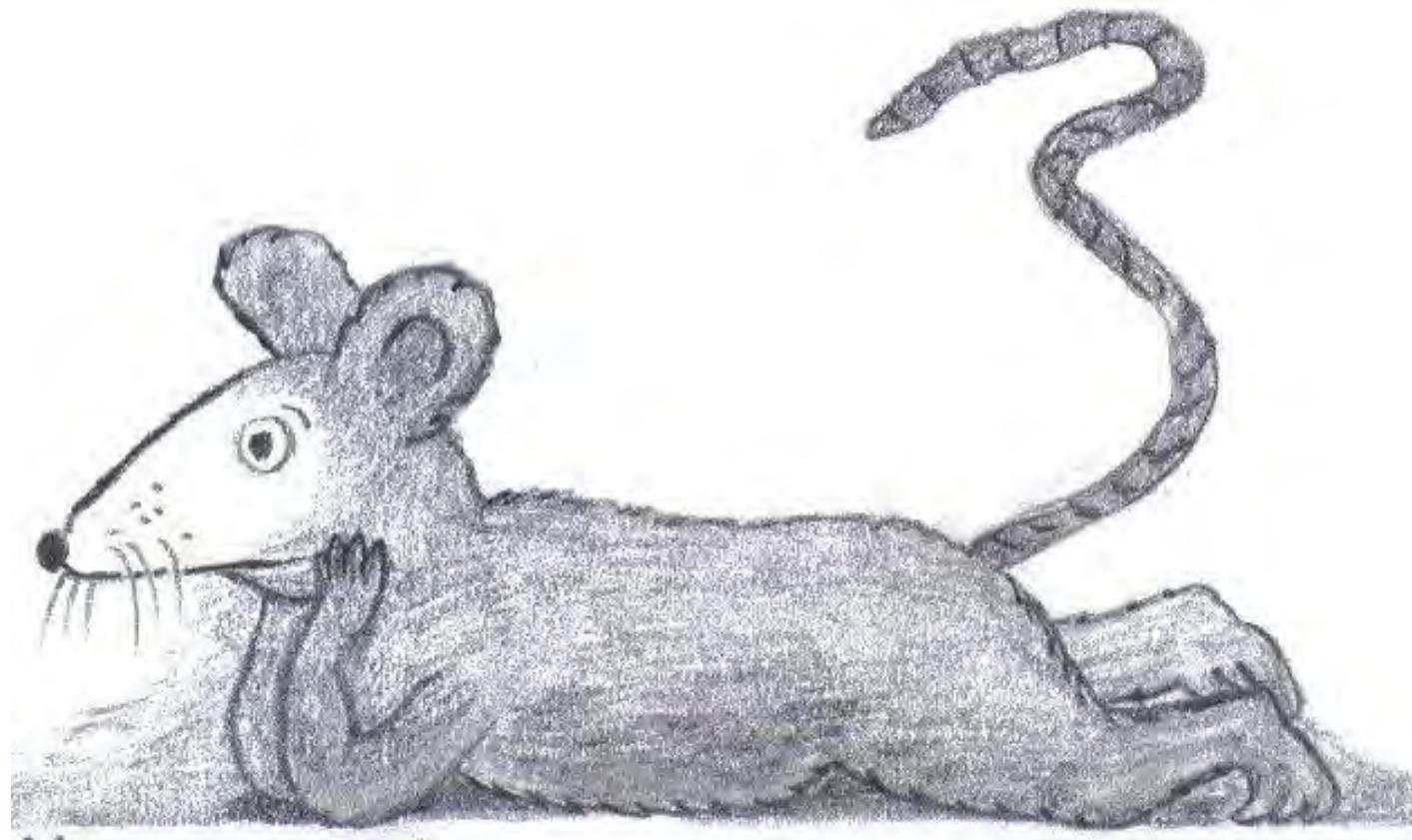
# Time-varying functional network information extracted from brief instances of spontaneous brain activity

Xiao Liu<sup>1</sup> and Jeff H. Duyn

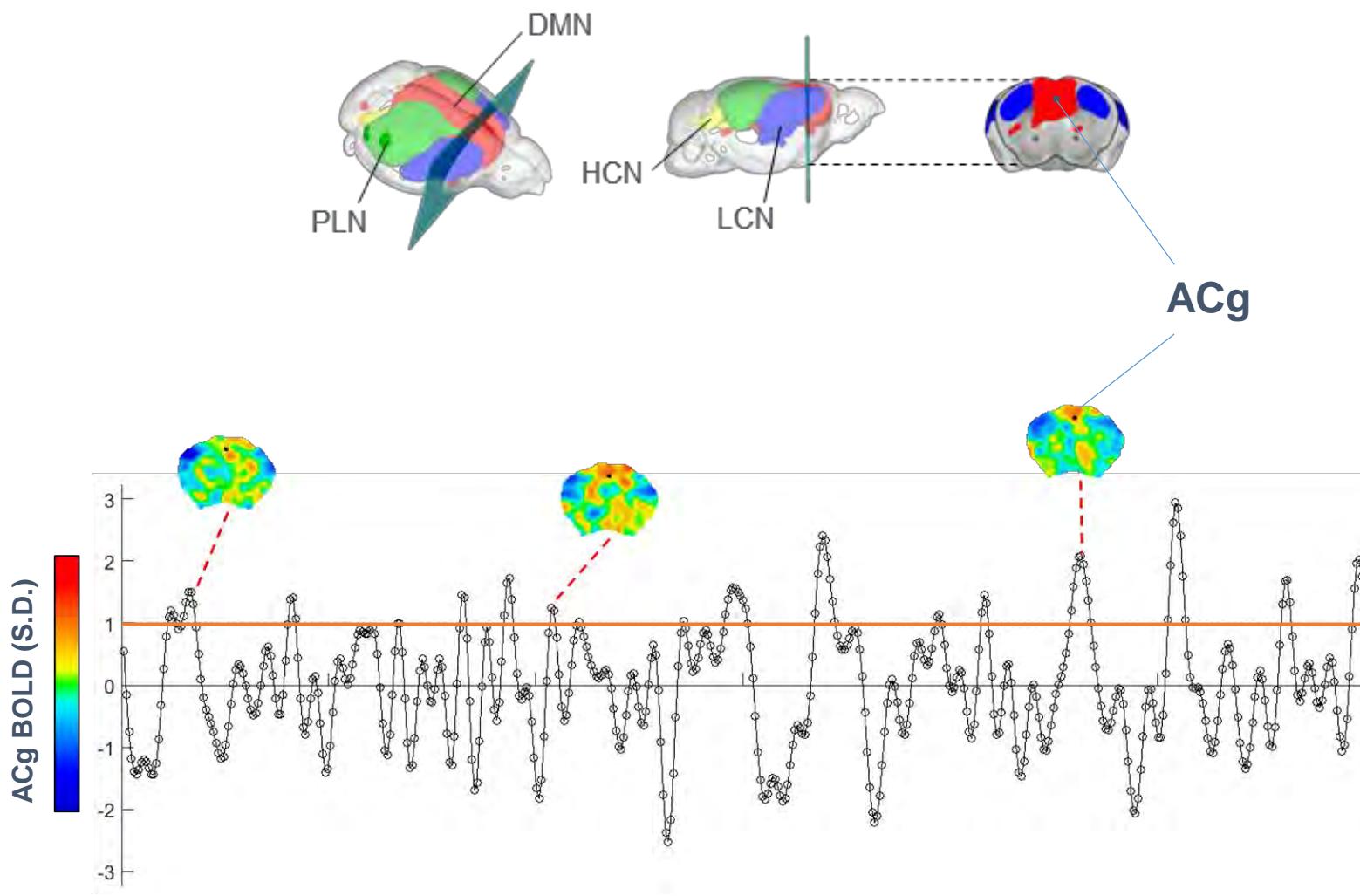
Advanced Magnetic Resonance Imaging Section, Laboratory of Functional and Molecular Imaging, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Bethesda, MD 20892



# *Can we map mouse rsfMRI dynamics with voxel resolution?*

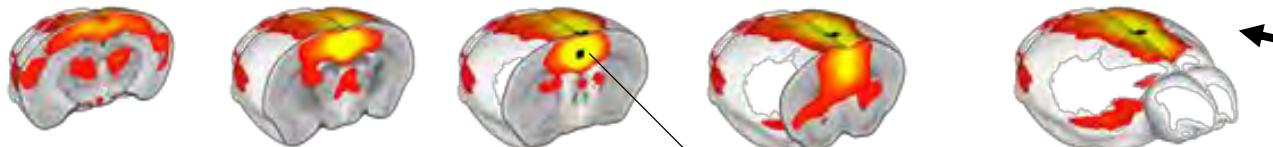


# Selective fMRI frame averaging recapitulates networks of correlated activity

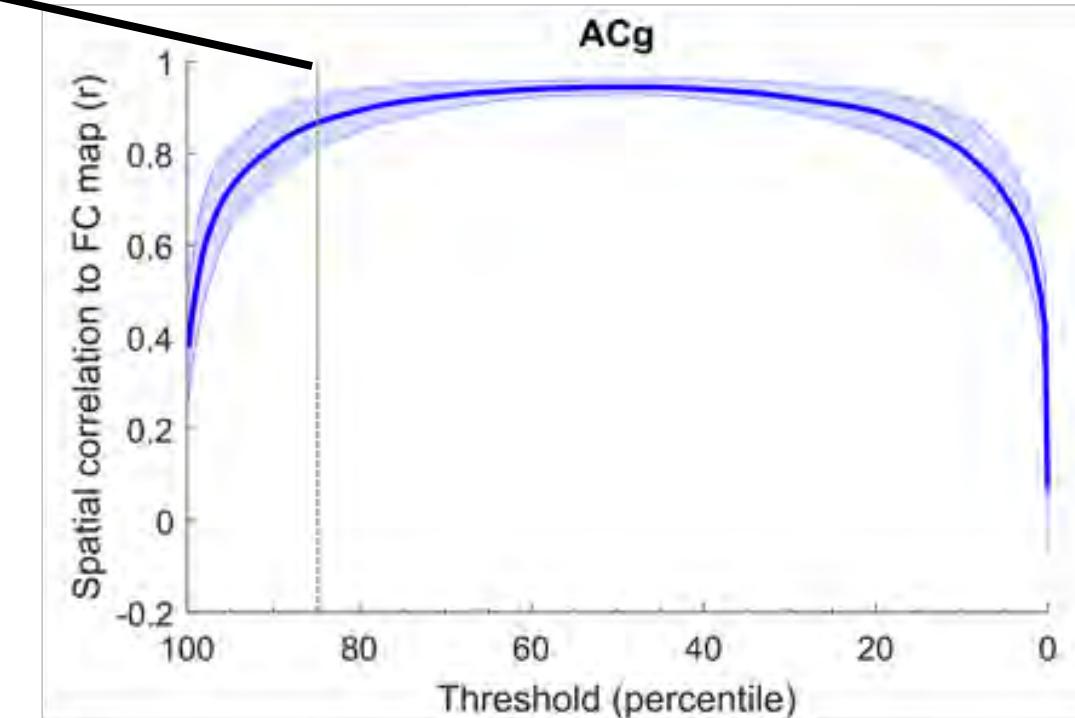
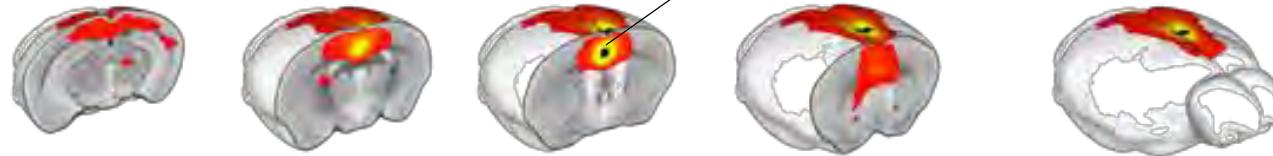


# Selective fMRI frame averaging recapitulates rsfMRI network activity

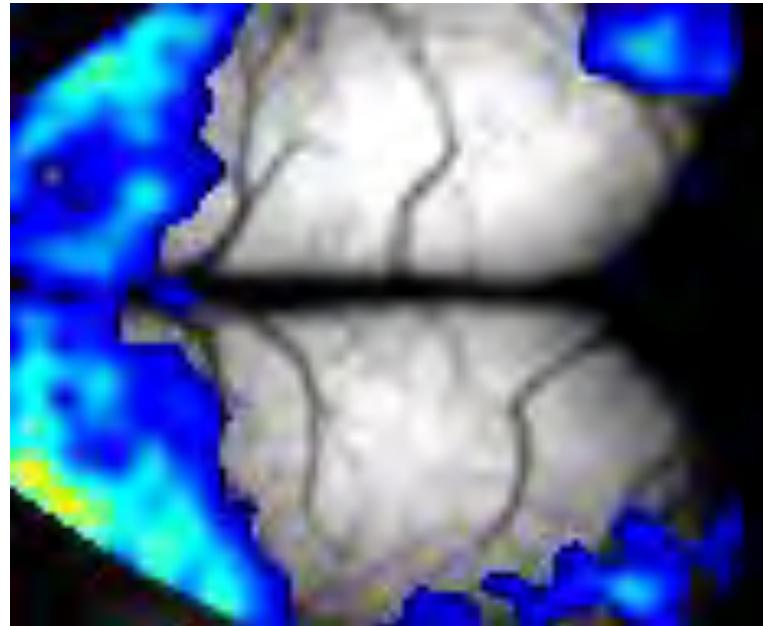
*Mean CAP (ACg)*



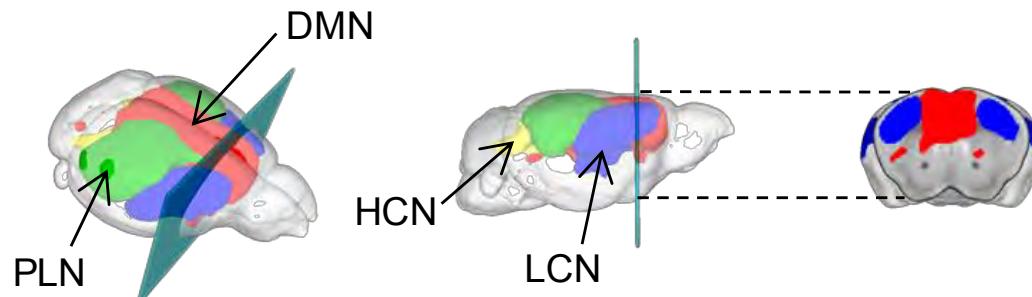
*Seed-based correlation map (ACg)*



# Optical imaging show wave-like hemodynamic activity in the mouse dorsal cortex

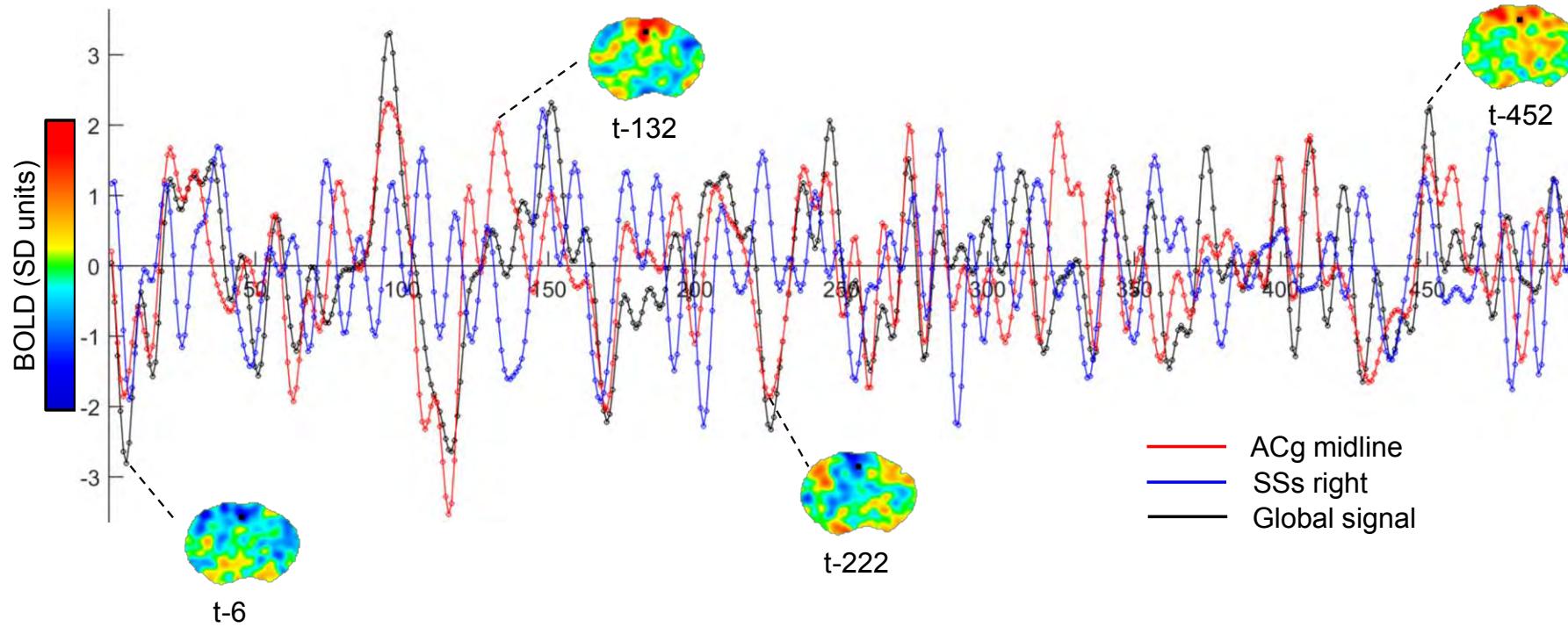


Matsui et al., 2017, 2018

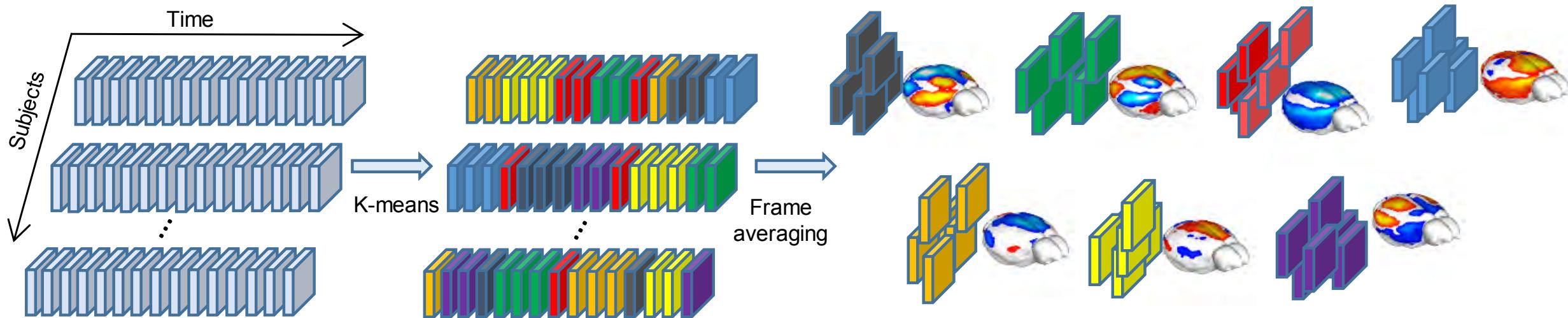


*Stefano Panzeri*

*Daniel Gutierrez-Barragan*

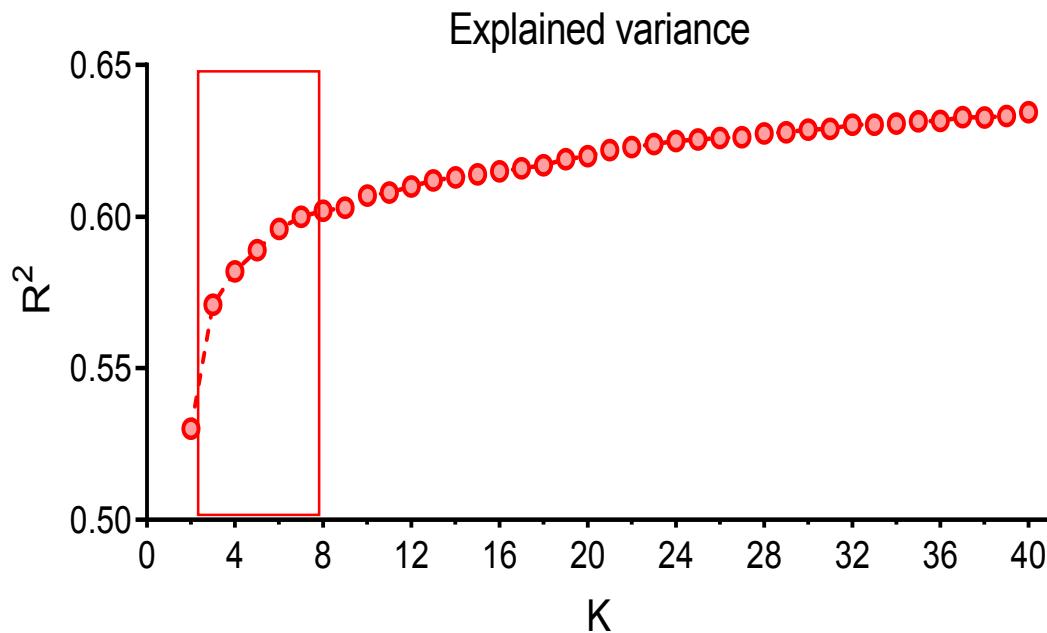


# Identification of recurring brain states through whole-brain fMRI frame clustering

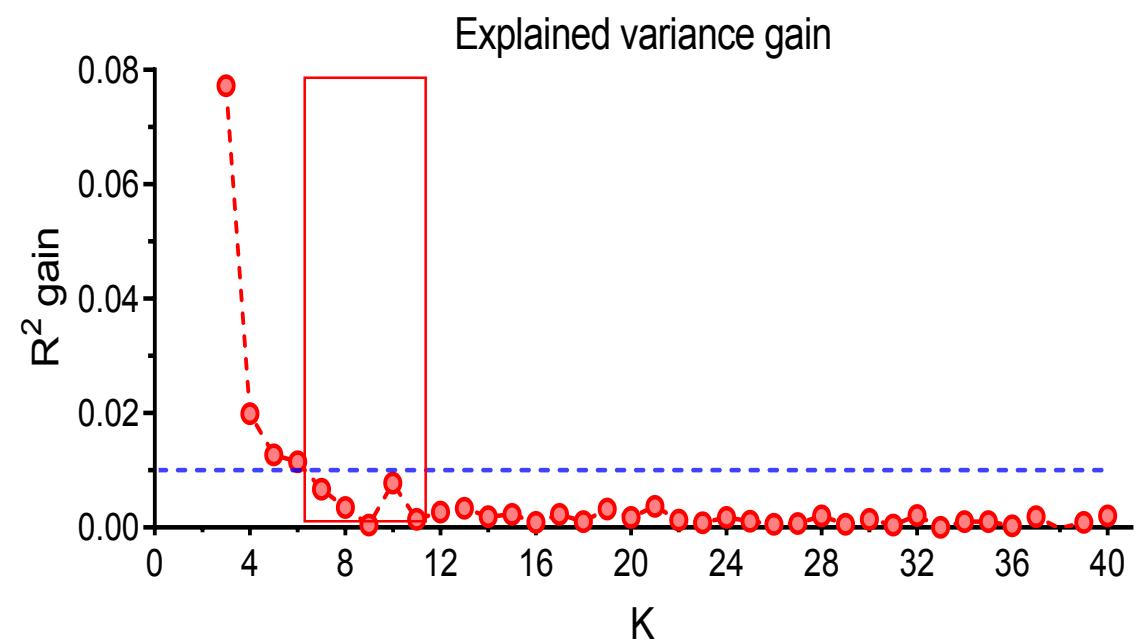


# A few recurring states govern mouse rsfMRI dynamics

B

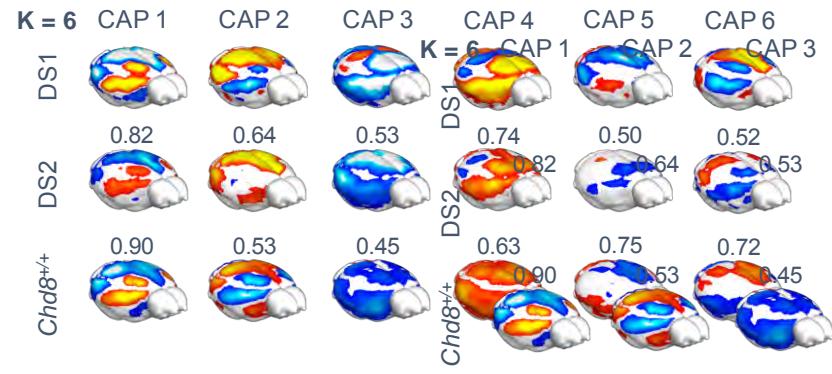


BC



**K = 6** CAP 1 CAP 2 CAP 3 CAP 4 CAP 5 CAP 6

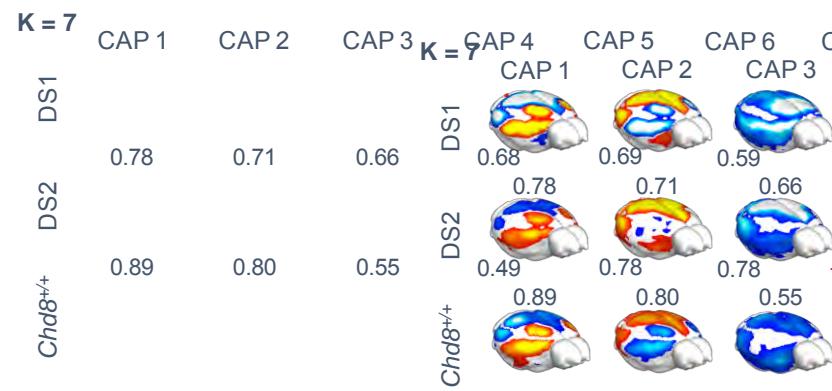
# Cluster number selection



**K = 6**

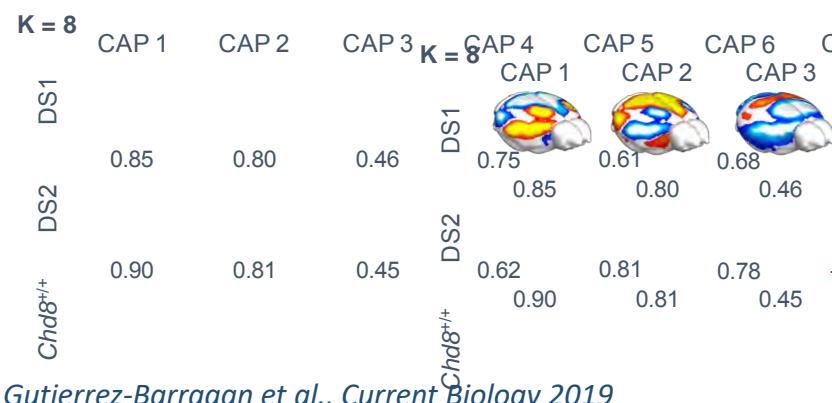
	CAP 5	CAP 6	CAP 1	CAP 2	CAP 3	CAP 4
DS1						
	0.50	0.50	0.74	0.74	0.75	0.75
DS2						
	0.52	0.52	0.82	0.64	0.53	0.74
<i>Chd8<sup>+/+</sup></i>						
	0.53	0.53	0.90	0.53	0.45	0.63

Dataset 1, n = 40, 500 volumes  
 Dataset 2, n = 41, 300 volumes  
 Dataset 3, n = 23, 500 volumes



**K = 7**

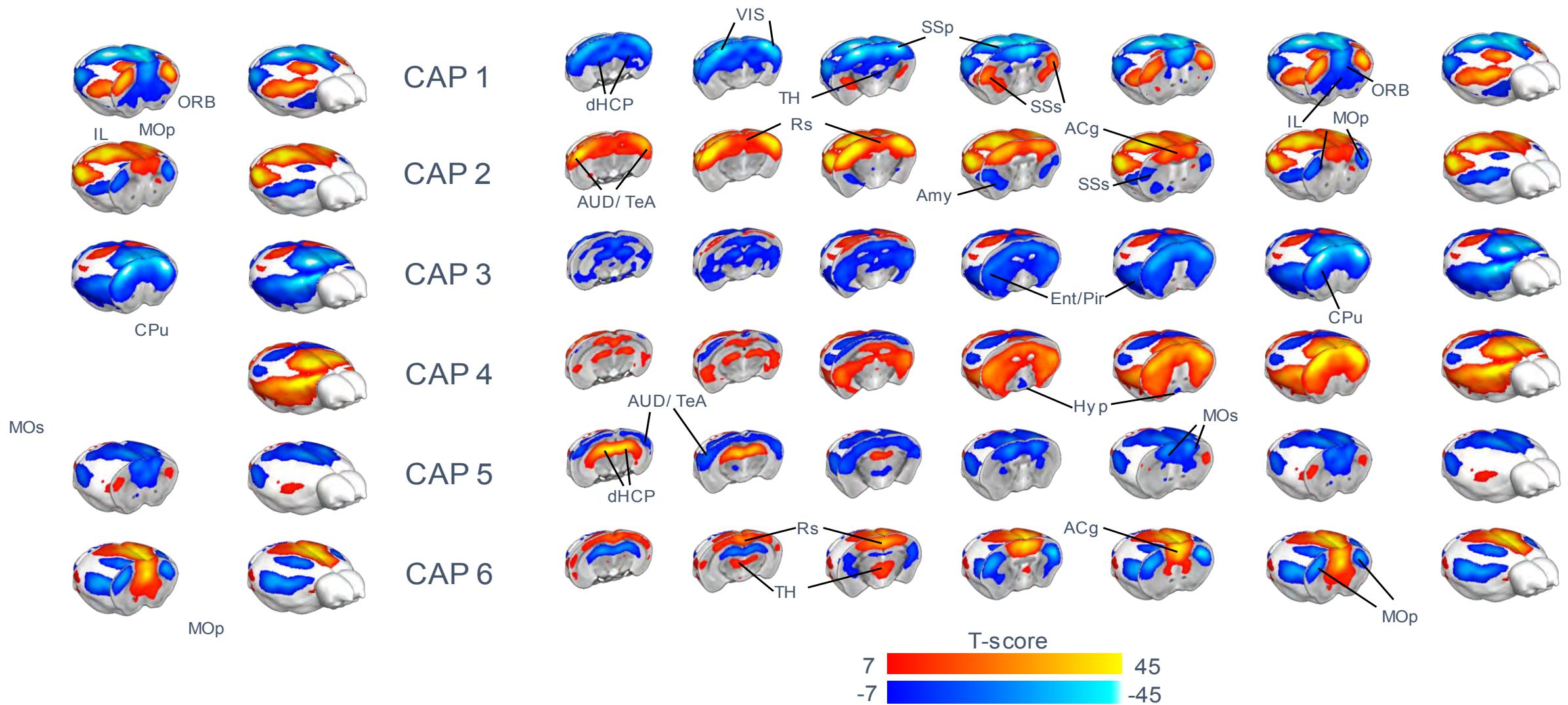
	CAP 5	CAP 6	CAP 1	CAP 2	CAP 3	CAP 4	CAP 7
DS1							
	0.59	0.59	0.59	0.76	0.66	0.68	0.66
DS2							
	0.66	0.66	0.68	0.68	0.69	0.69	0.59
<i>Chd8<sup>+/+</sup></i>							
	0.55	0.55	0.78	0.78	0.78	-0.01	0.78



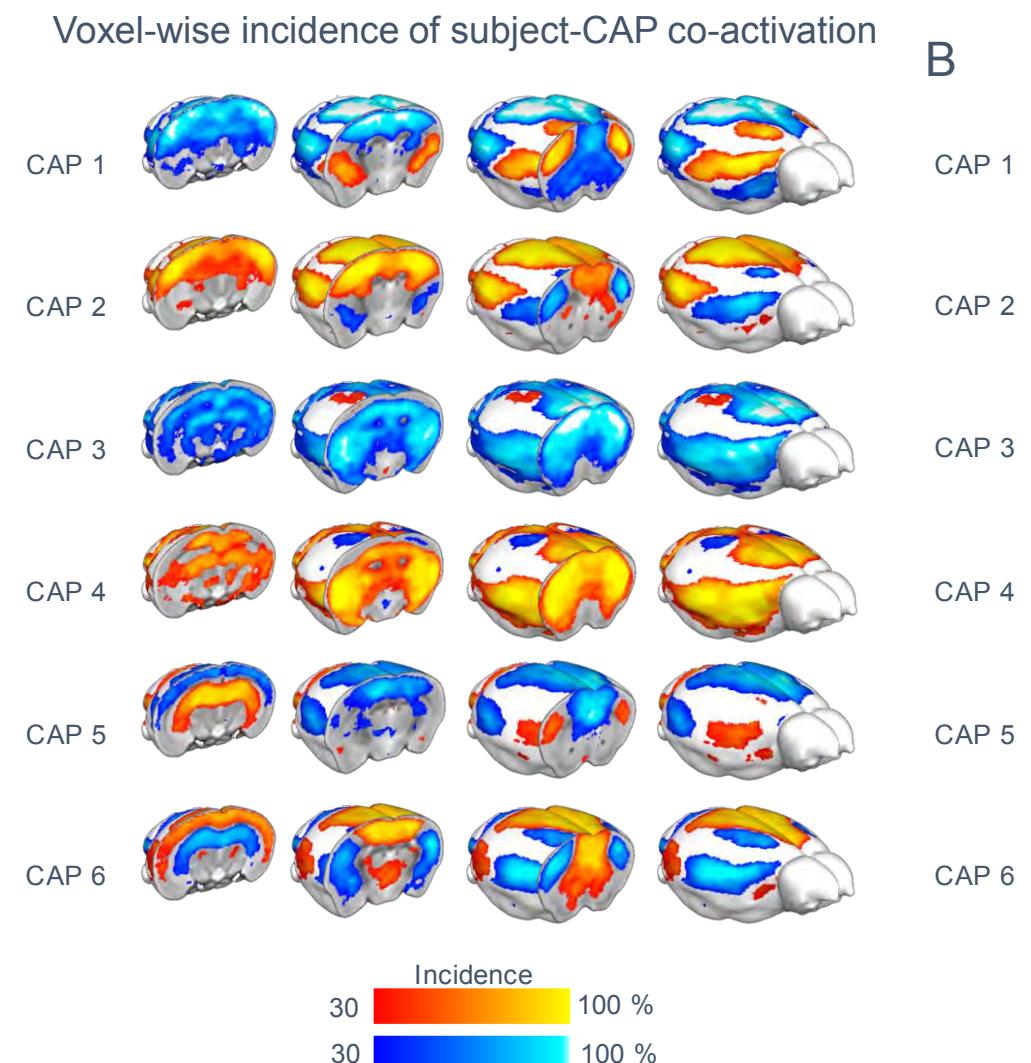
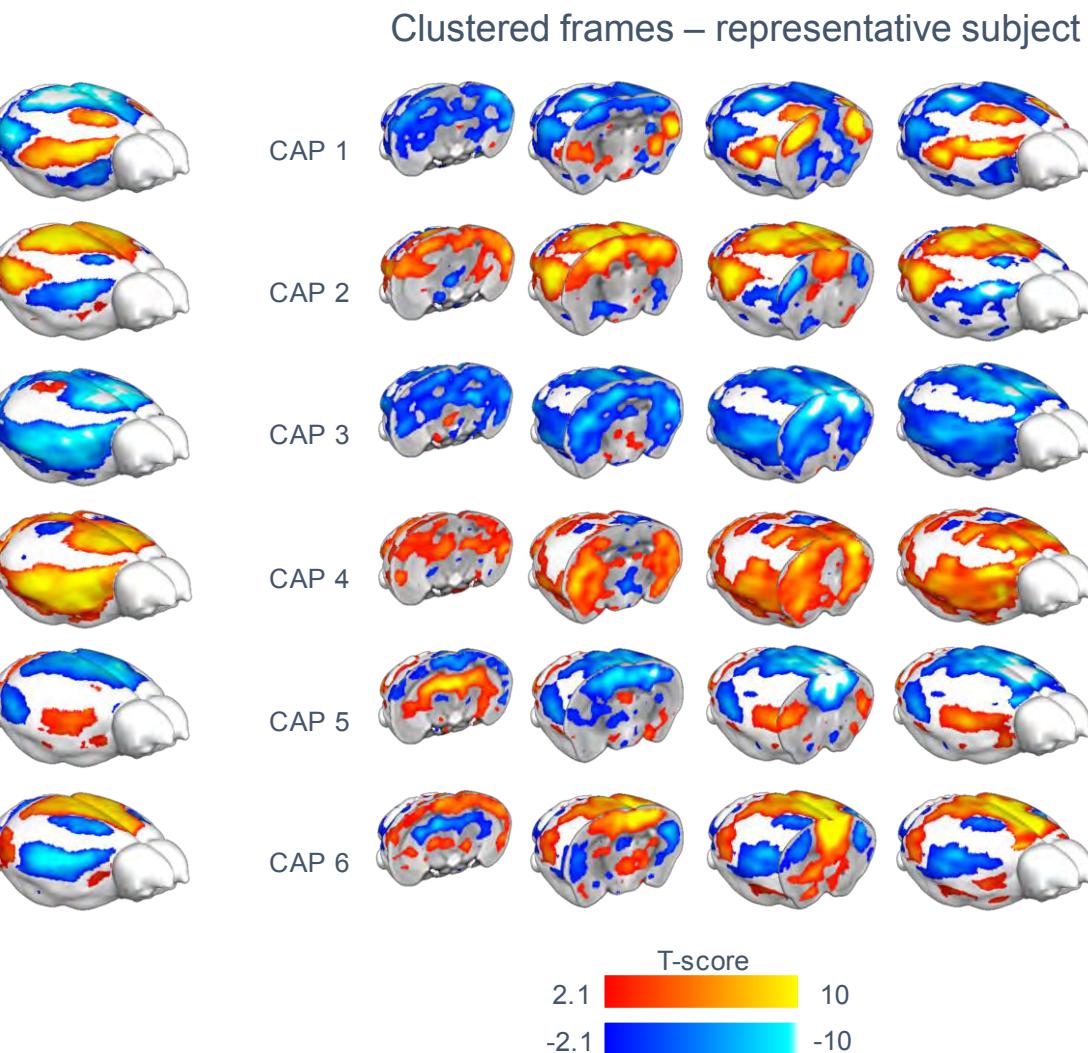
**K = 8**

	CAP 6	CAP 7	CAP 8	CAP 1	CAP 2	CAP 3	CAP 4	CAP 5	CAP 6	CAP 7	CAP 8
DS1											
	0.61	0.61	0.61	0.68	0.66	0.66	0.68	0.68	0.66	0.66	0.68
DS2											
	0.81	0.81	0.81	0.78	0.78	0.78	0.81	0.81	0.78	0.78	0.81
<i>Chd8<sup>+/+</sup></i>											
	0.90	0.90	0.90	0.81	0.81	0.45	0.62	0.81	0.68	-0.14	-0.82

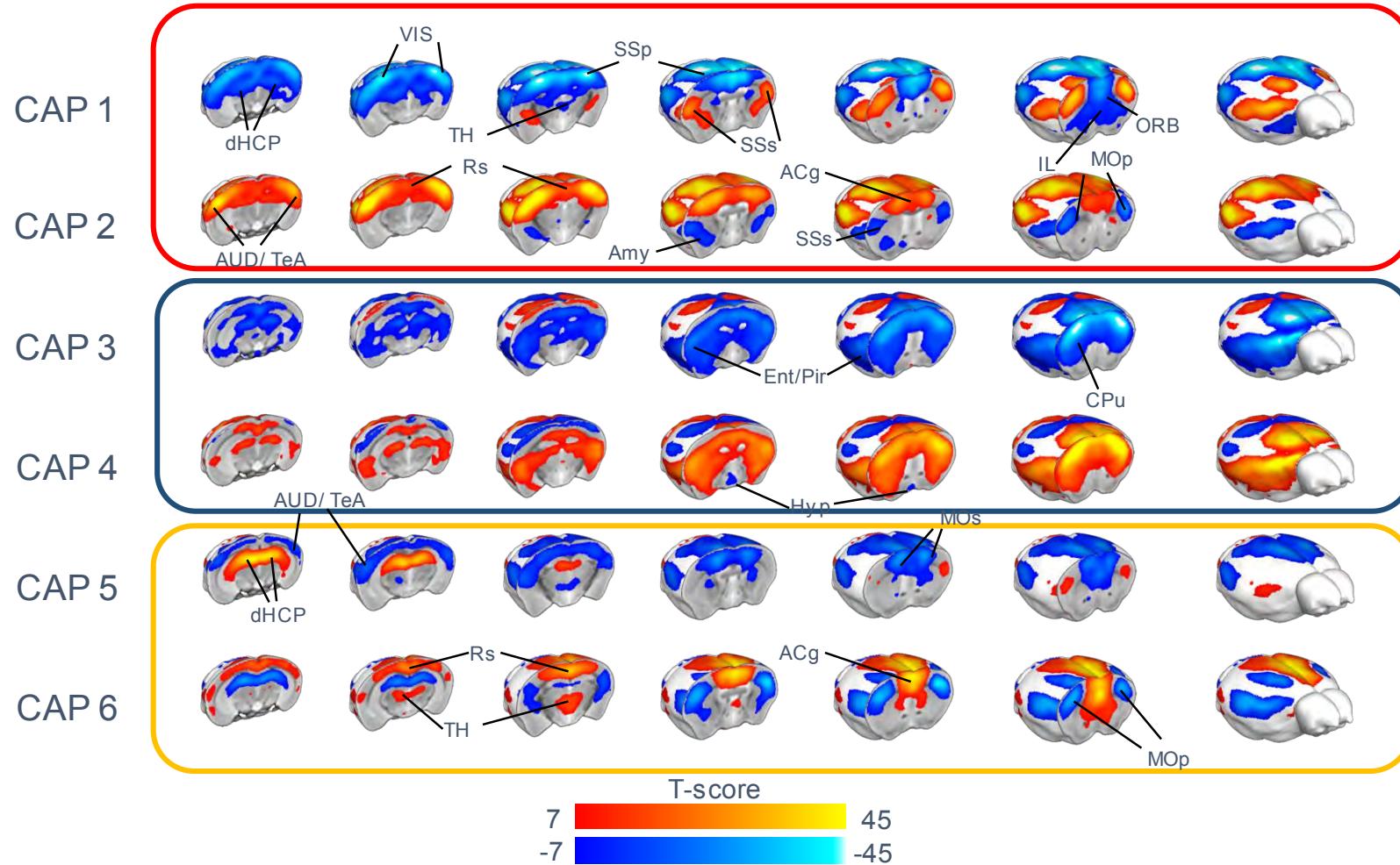
# Recurring functional states of the mouse brain



# Brain states can be reliably mapped at the single subject level



# Mouse brain states can be grouped into “state” and “anti-state” pairs



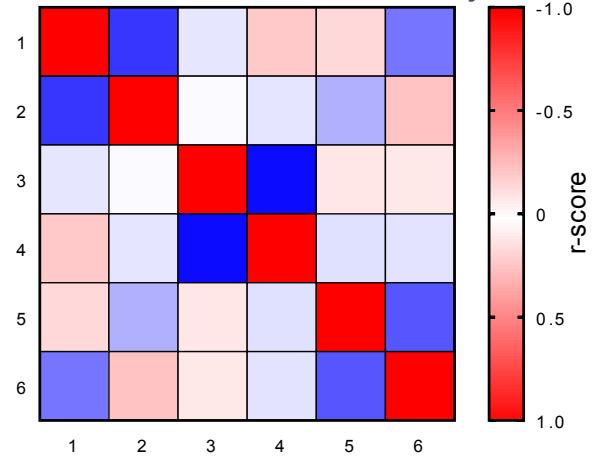
B Between CAP similarity

Gutierrez-Barragan et al., Current Biology 2019

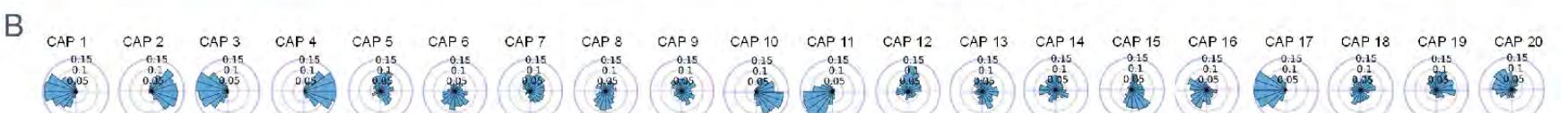
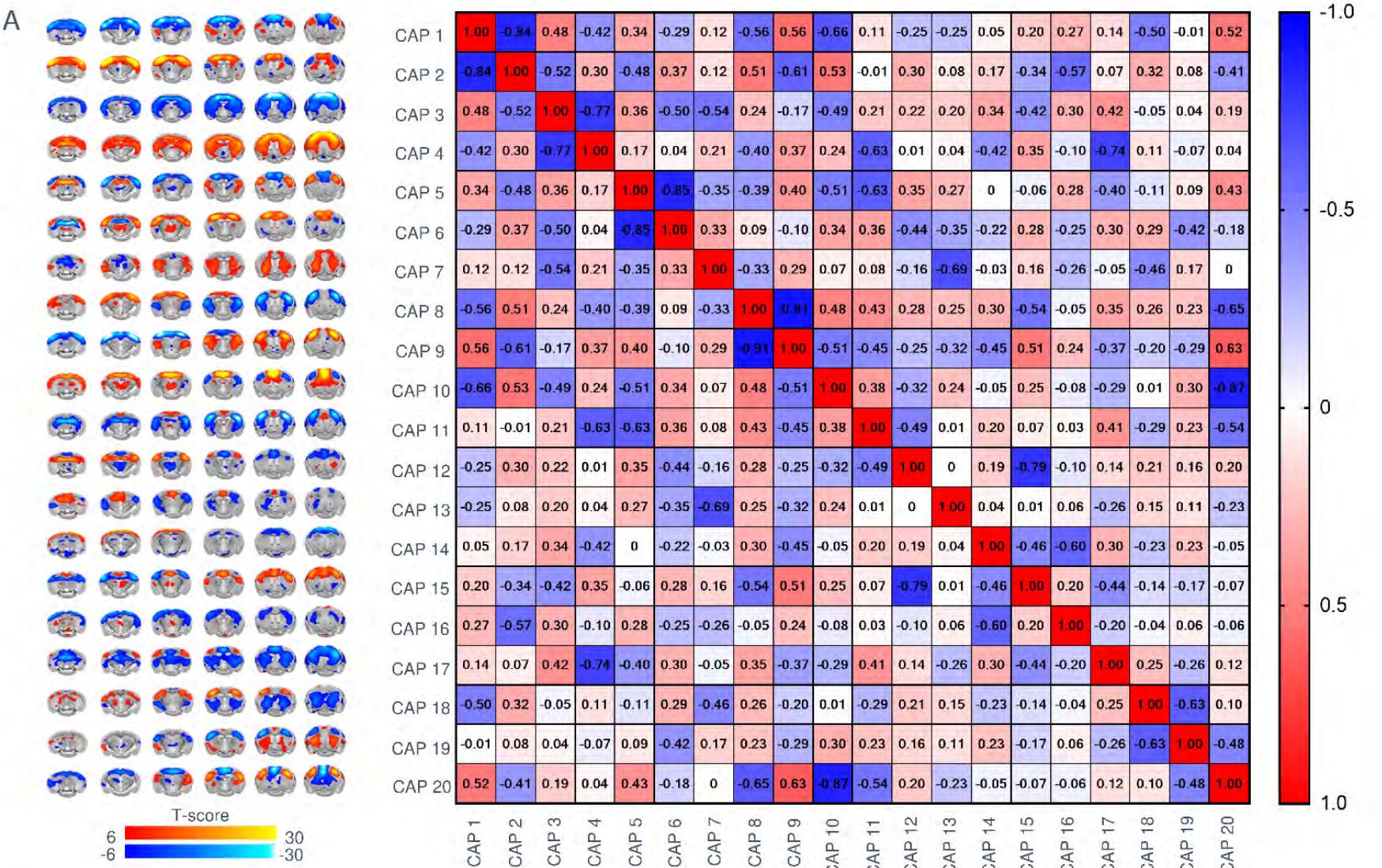
C CAP occurrence

D CAP durations

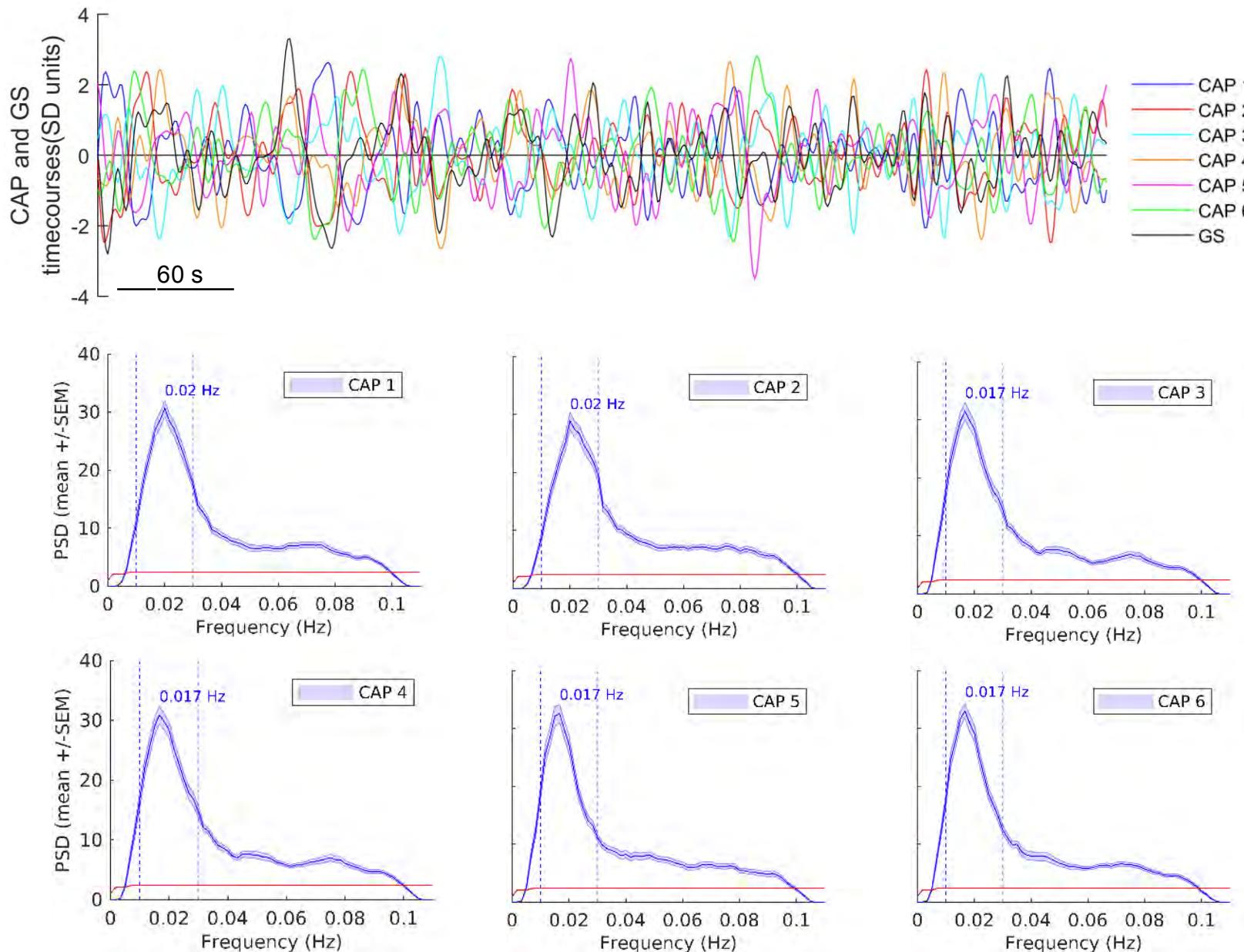
Between CAP similarity



Do fMRI brain state exhibit oscillatory activity?

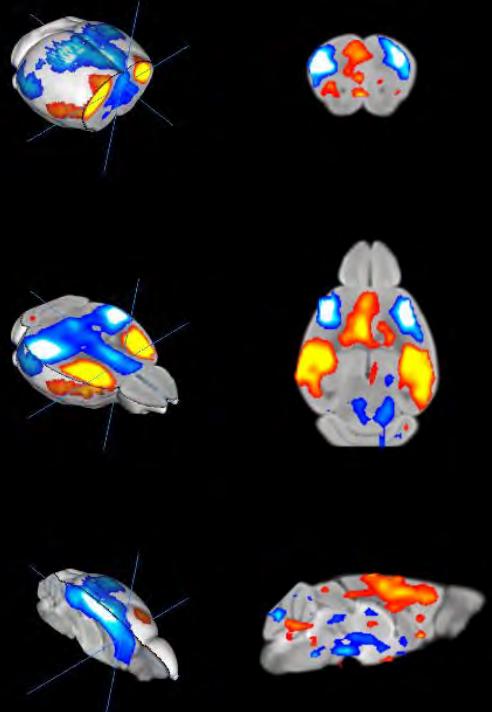


# Brain state exhibit oscillatory dynamics

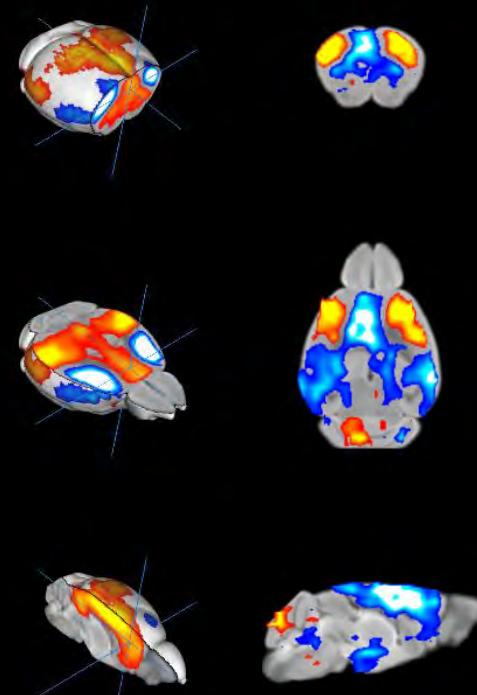


# fMRI states exhibit gradual assembly and disassembly

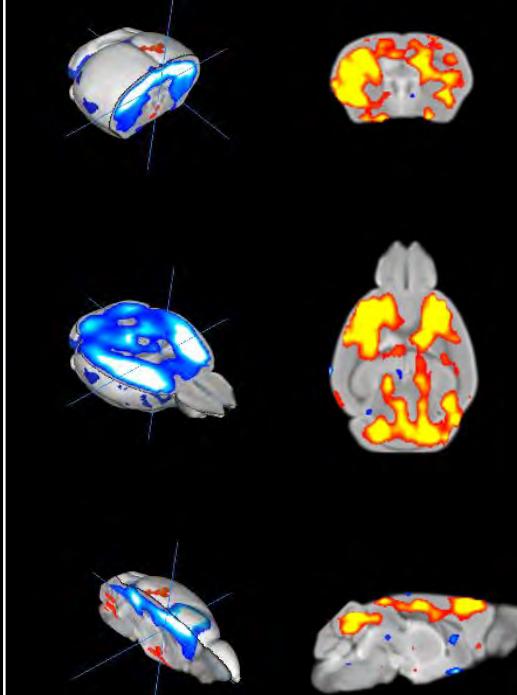
CAP 1



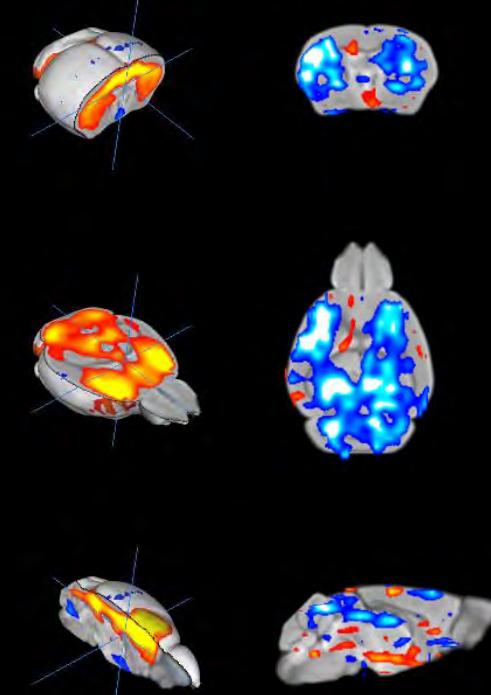
CAP 2



CAP 3

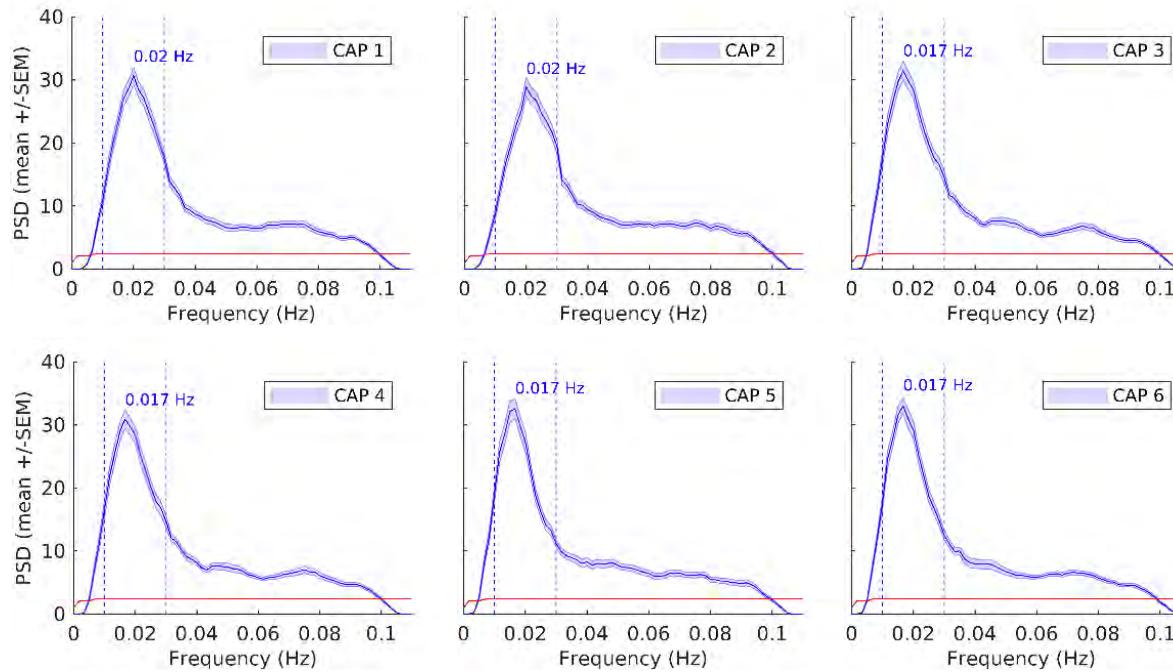


CAP 4

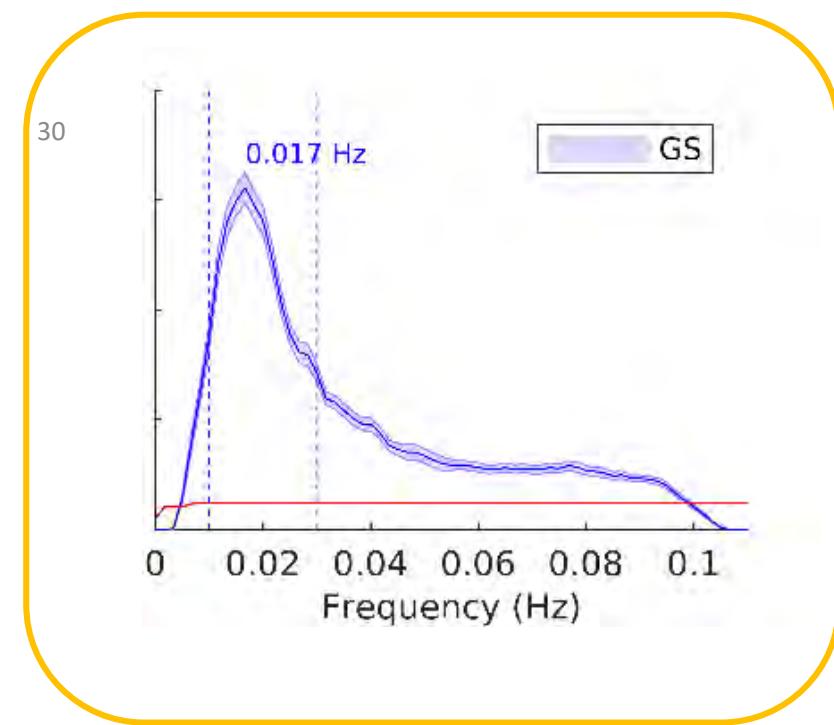


1 frame = 1,2 s

# Brain state exhibit oscillatory dynamics

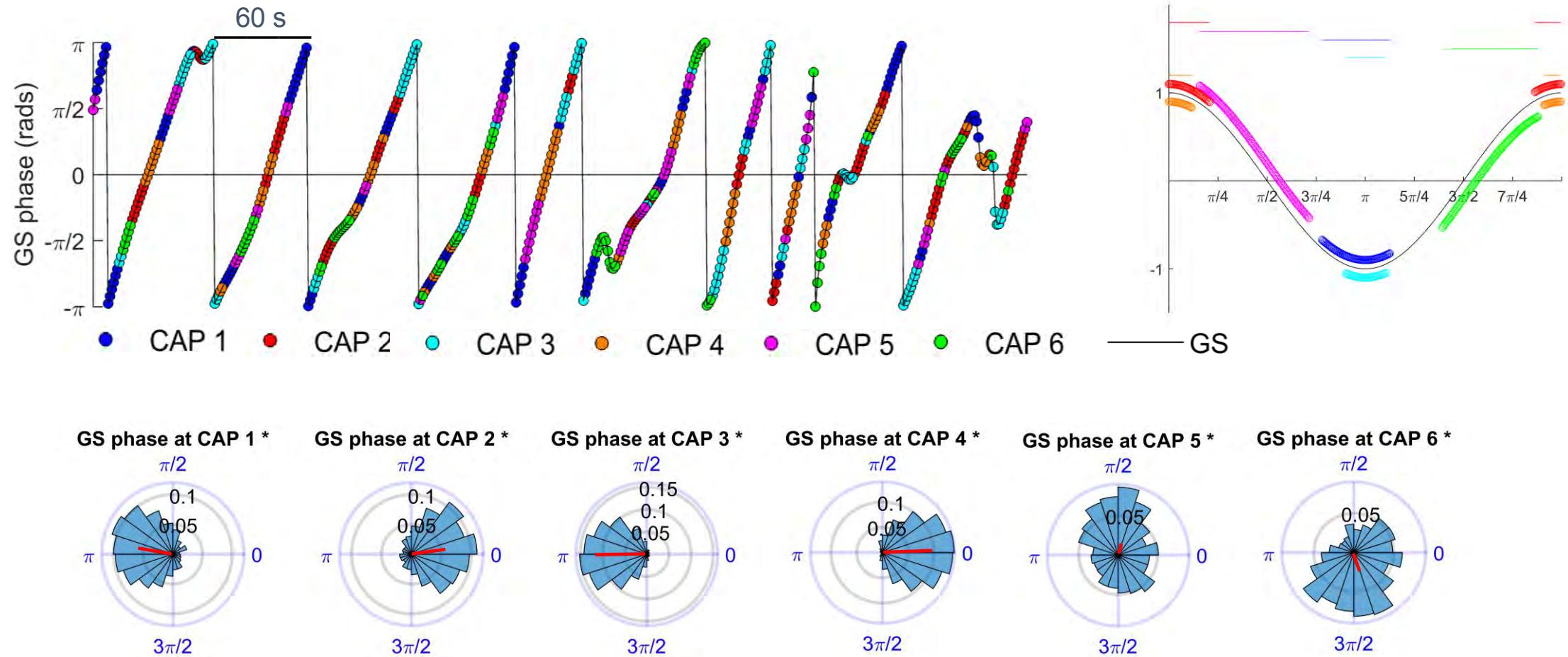


**CAP power spectra**

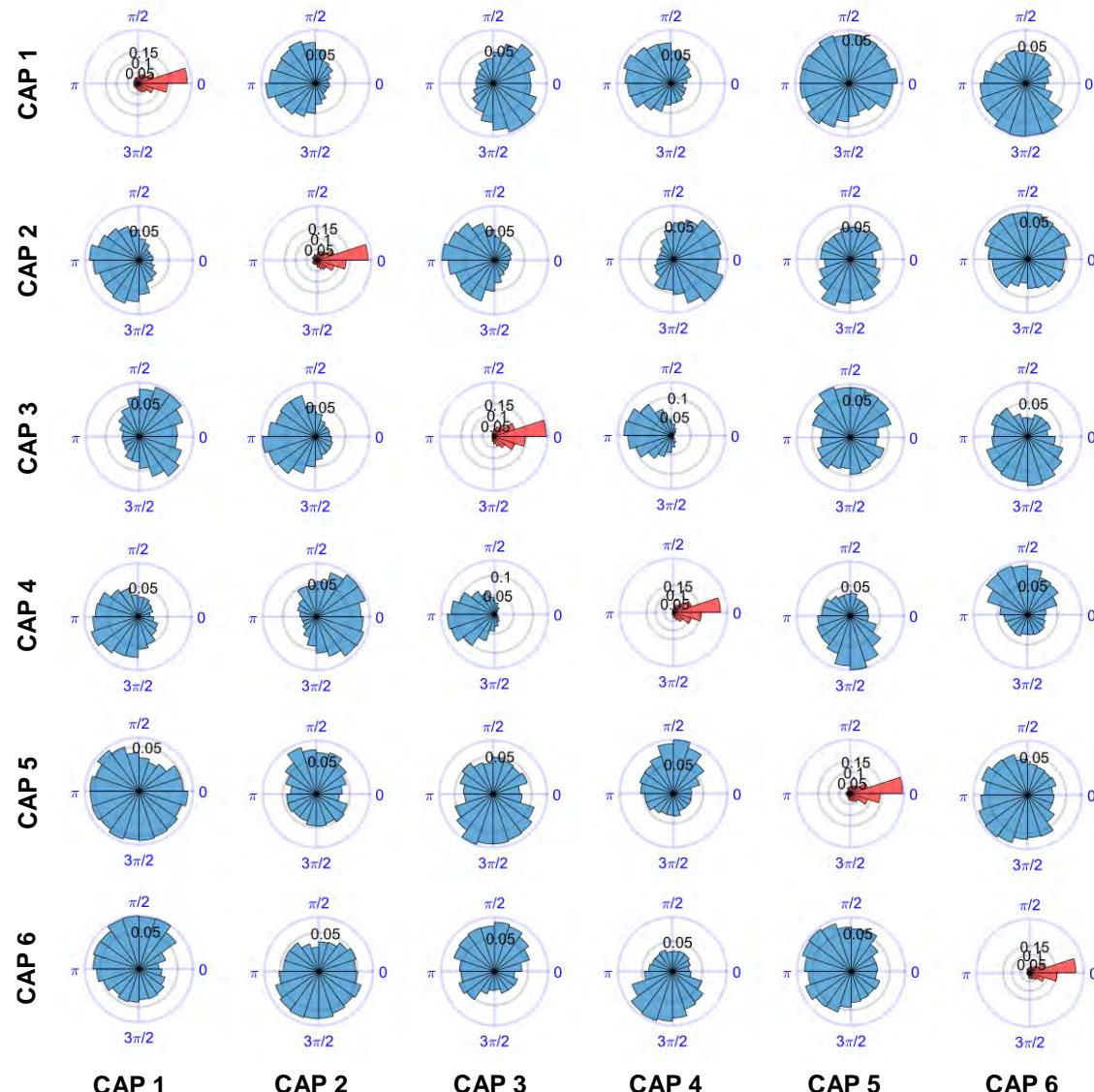


**Global fMRI signal power spectra**

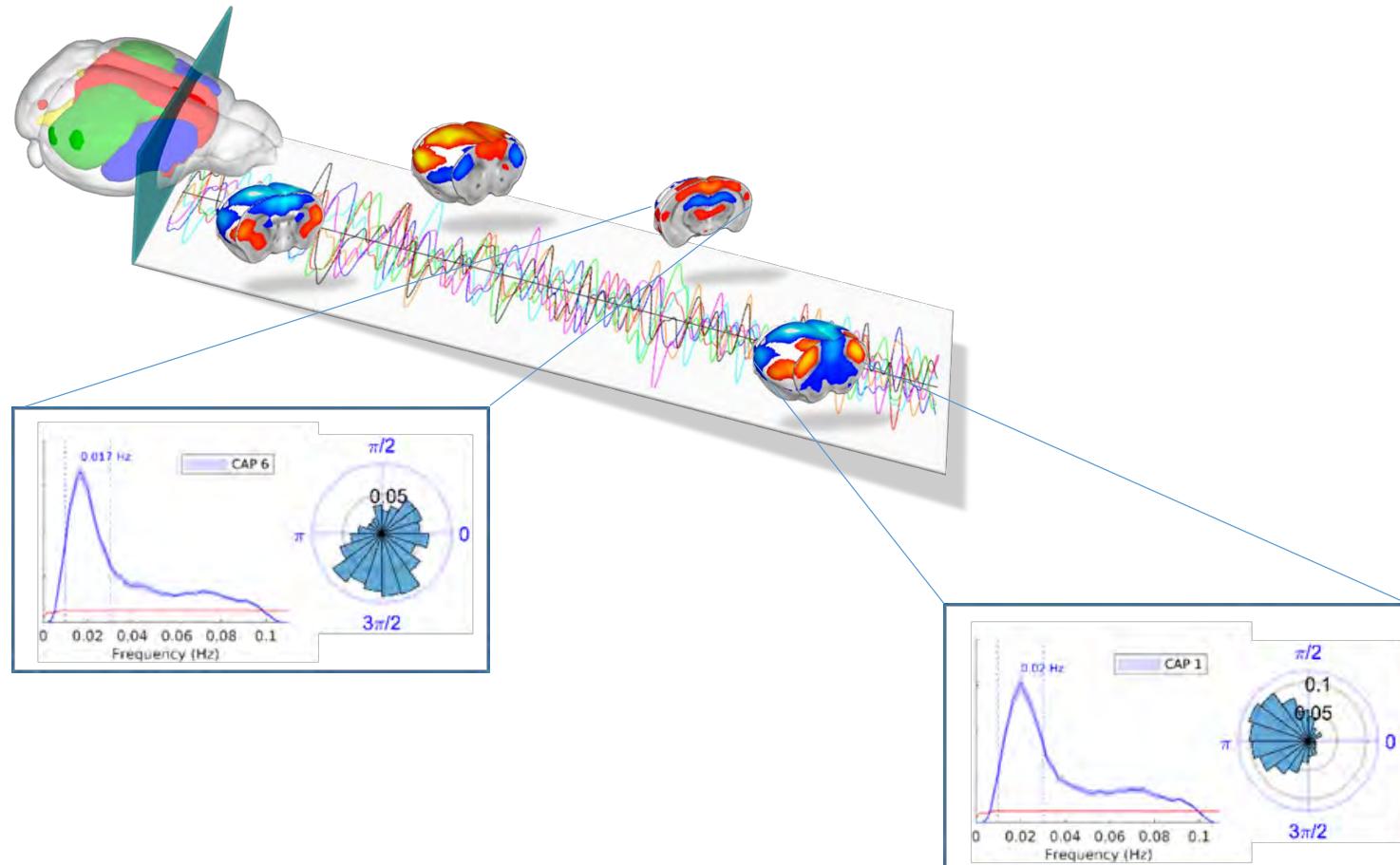
# Mouse brain states occur at specific phases of global fMRI signal oscillation



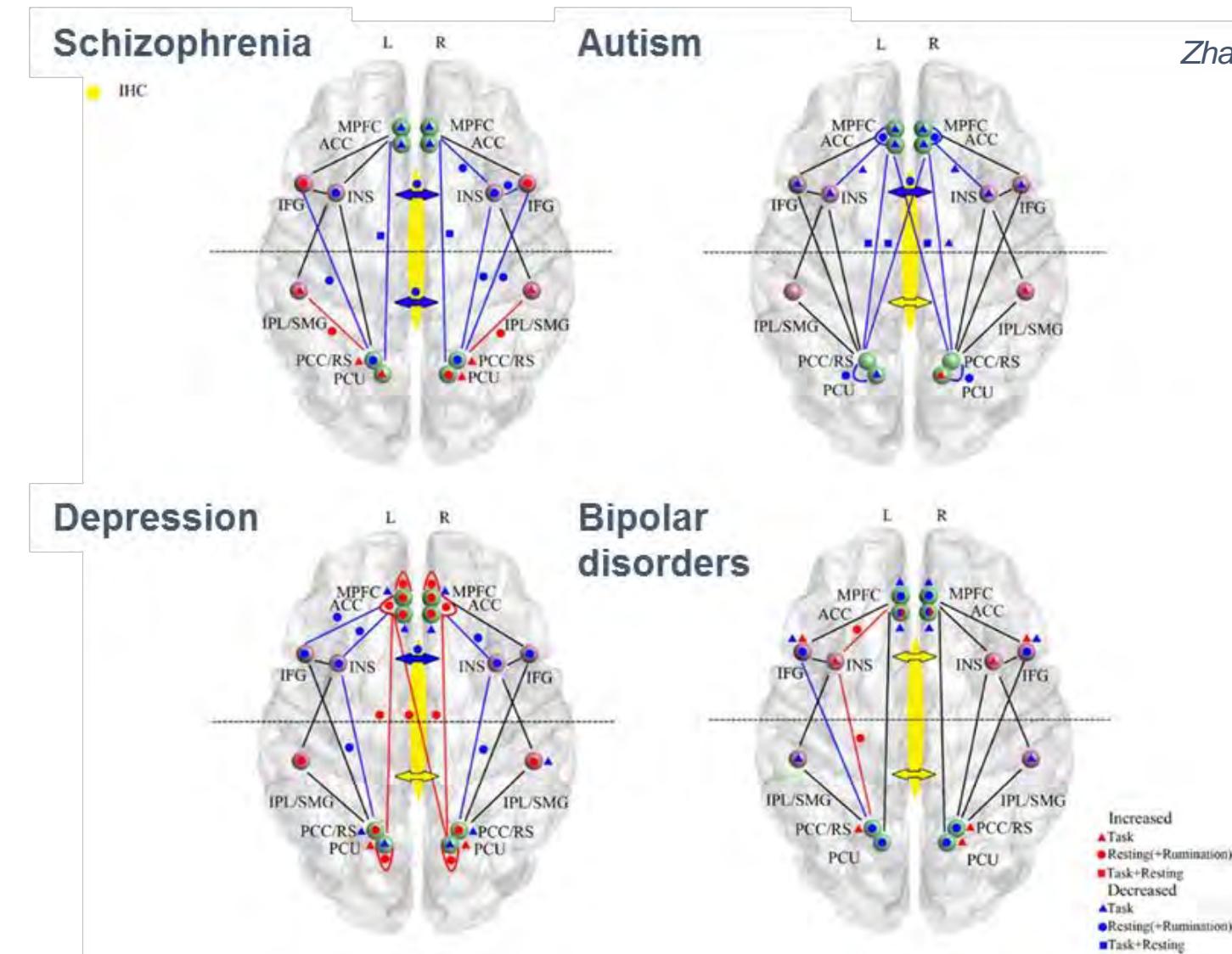
# fMRI functional states act as coupled oscillators



## Oscillatory brain states govern spontaneous rsfMRI network dynamics



# rsfMRI network activity is disrupted in brain disorders



Zhao et al., *frontiers nhum*, 2013

# rsfMRI overconnectivity in a genetic models of autism (CHD8 haplo-insufficiency)

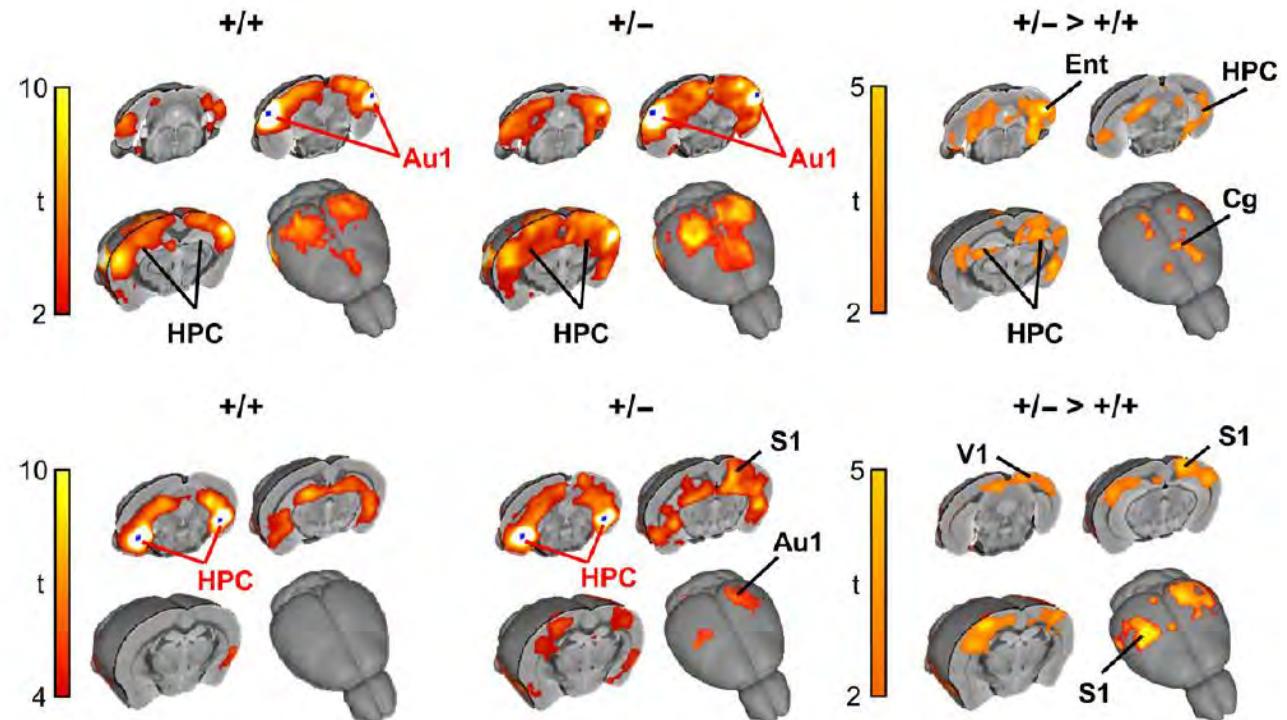


Cerebral Cortex, 2018; 1-15  
doi: 10.1093/cercor/bhy058  
Original Article

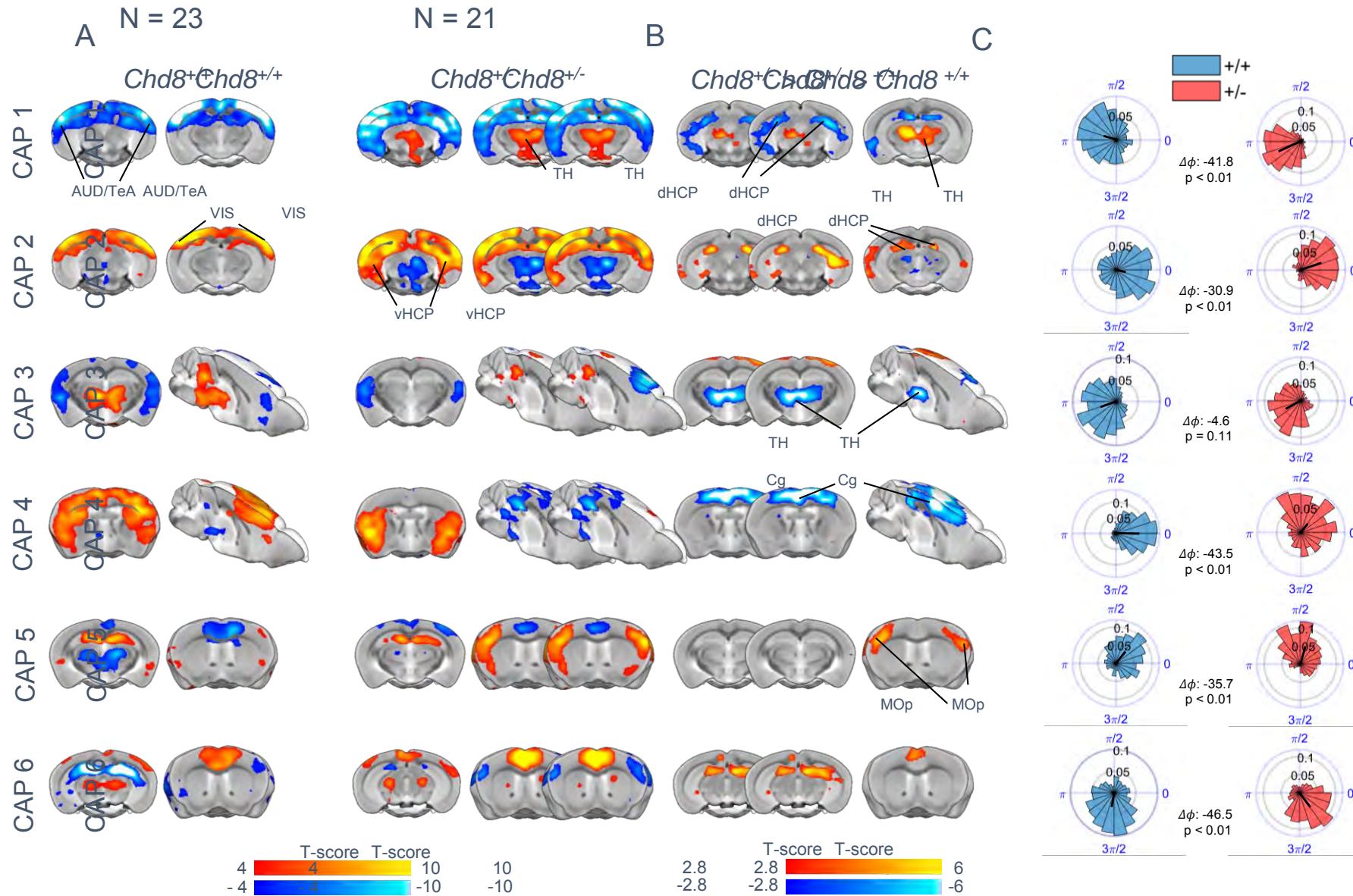
## ORIGINAL ARTICLE

### Altered Neocortical Gene Expression, Brain Overgrowth and Functional Over-Connectivity in *Chd8* Haploinsufficient Mice

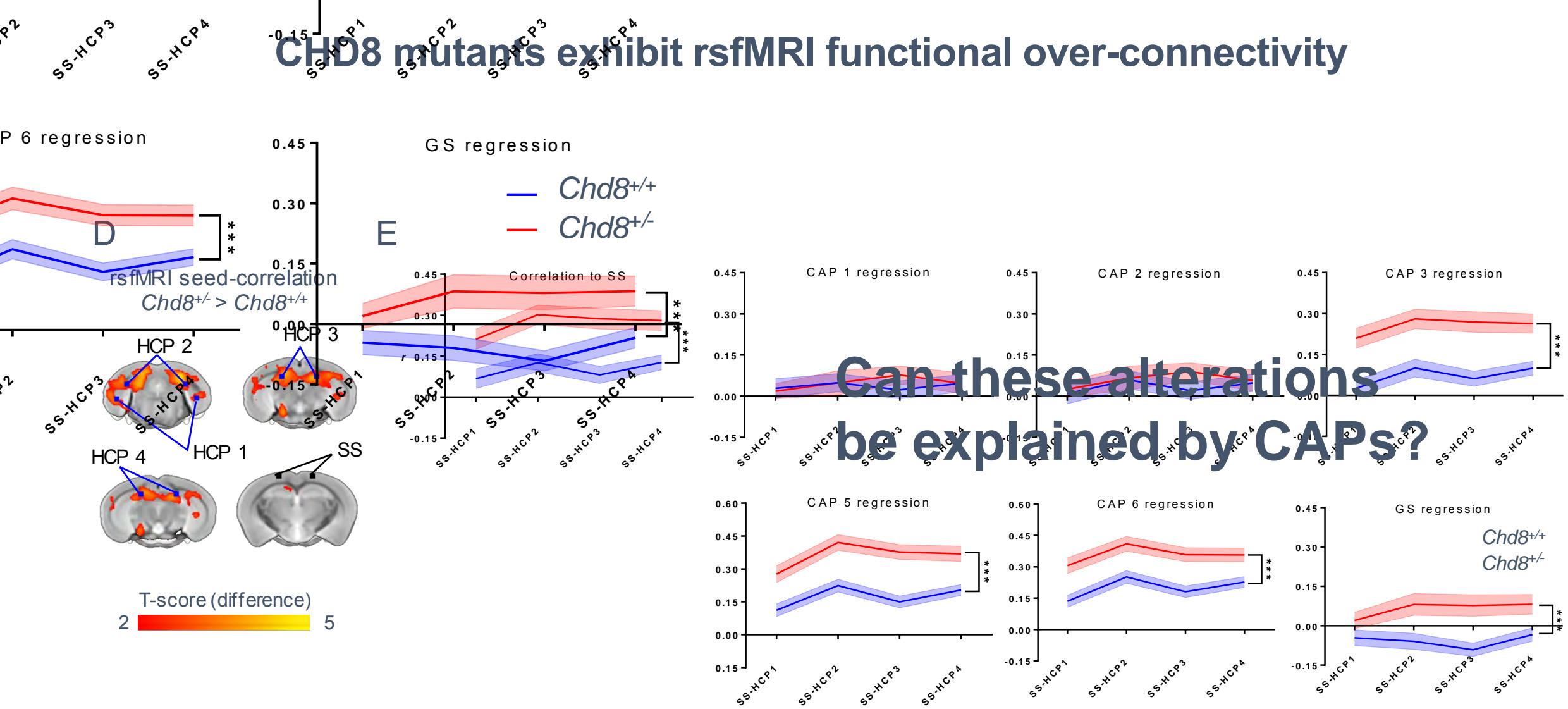
Philipp Suetterlin<sup>1,†</sup>, Shaun Hurley<sup>1,†</sup>, Conor Mohan<sup>1,†</sup>, Kimberley L. H. Riegman<sup>1,†</sup>, Marco Pagani<sup>2</sup>, Angela Caruso<sup>3</sup>, Jacob Ellegood<sup>4</sup>, Alberto Galbusera<sup>2</sup>, Ivan Crespo-Enriquez<sup>1</sup>, Caterina Michetti<sup>5</sup>, Yohan Yee<sup>4</sup>, Robert Ellingford<sup>1</sup>, Olivier Brock<sup>6</sup>, Alessio Delogu<sup>6</sup>, Philippa Francis-West<sup>1</sup>, Jason P. Lerch<sup>4</sup>, Maria Luisa Scattoni<sup>3</sup>, Alessandro Gozzi<sup>2</sup>, Cathy Fernandes<sup>7,8</sup> and M. Albert Basson<sup>1,8</sup>



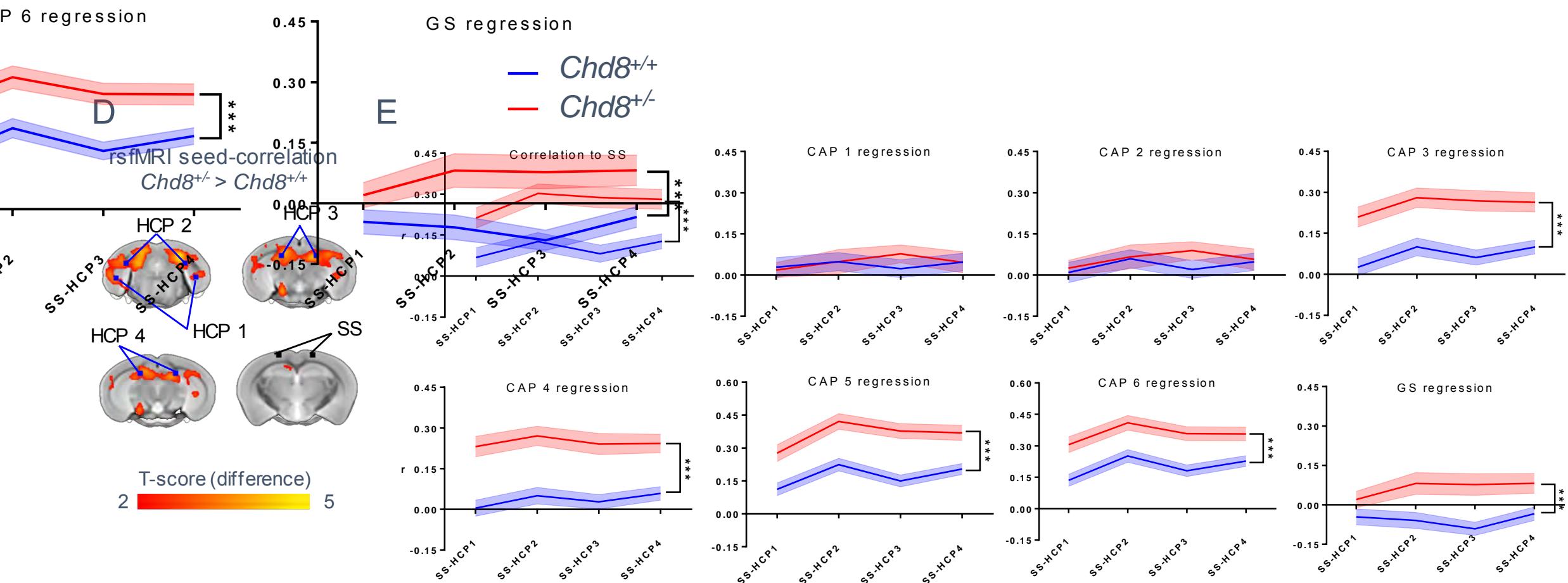
# Altered brain state topography in a genetic mouse model of autism



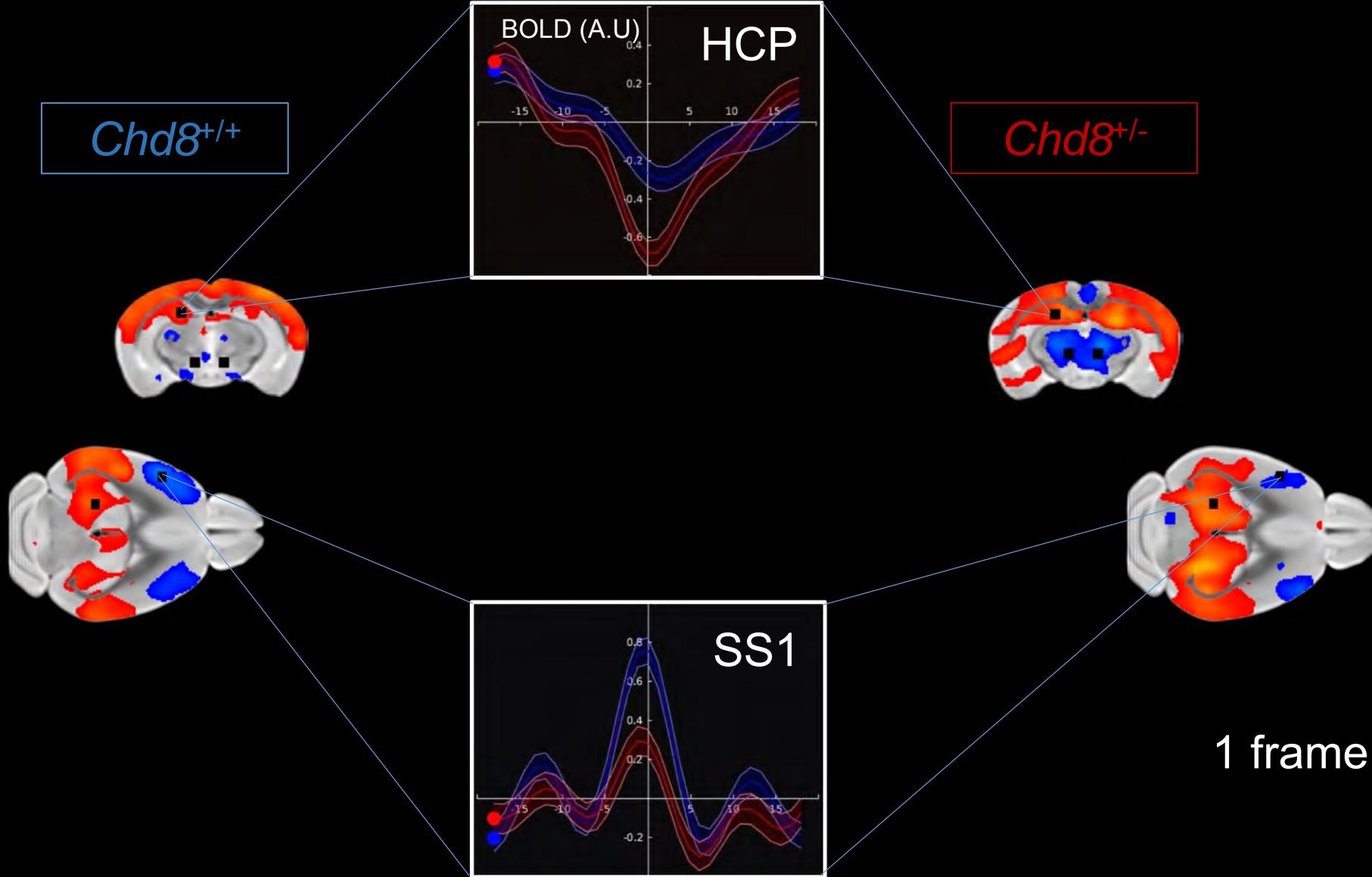
# CHD8 mutants exhibit rsfMRI functional over-connectivity



# Atypical brain states may be implicated in rsfMRI over-connectivity in CHD8 mutants

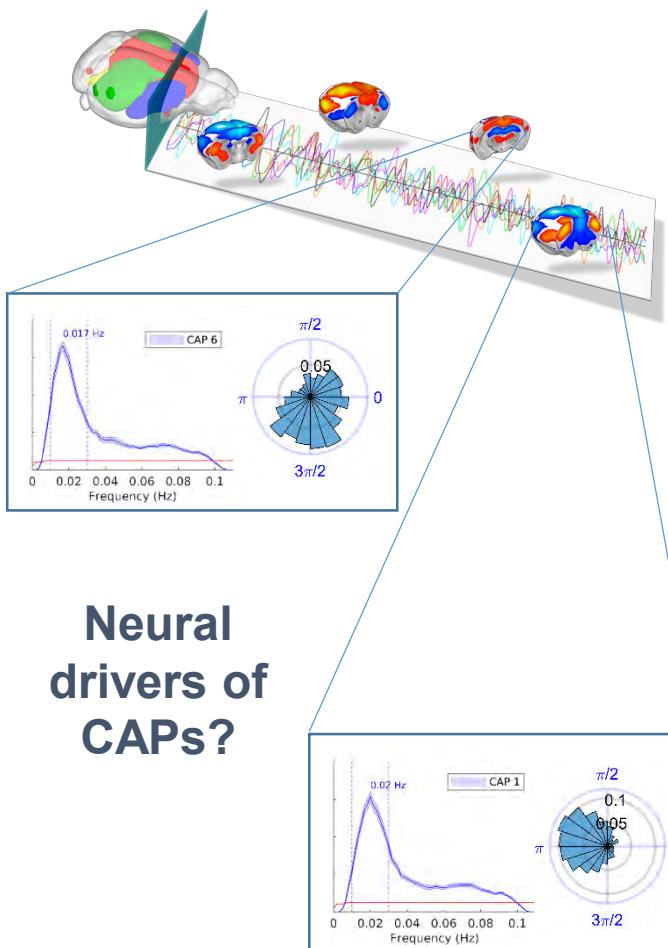


# Altered regional BOLD dynamics in CHD8 mice at specific states

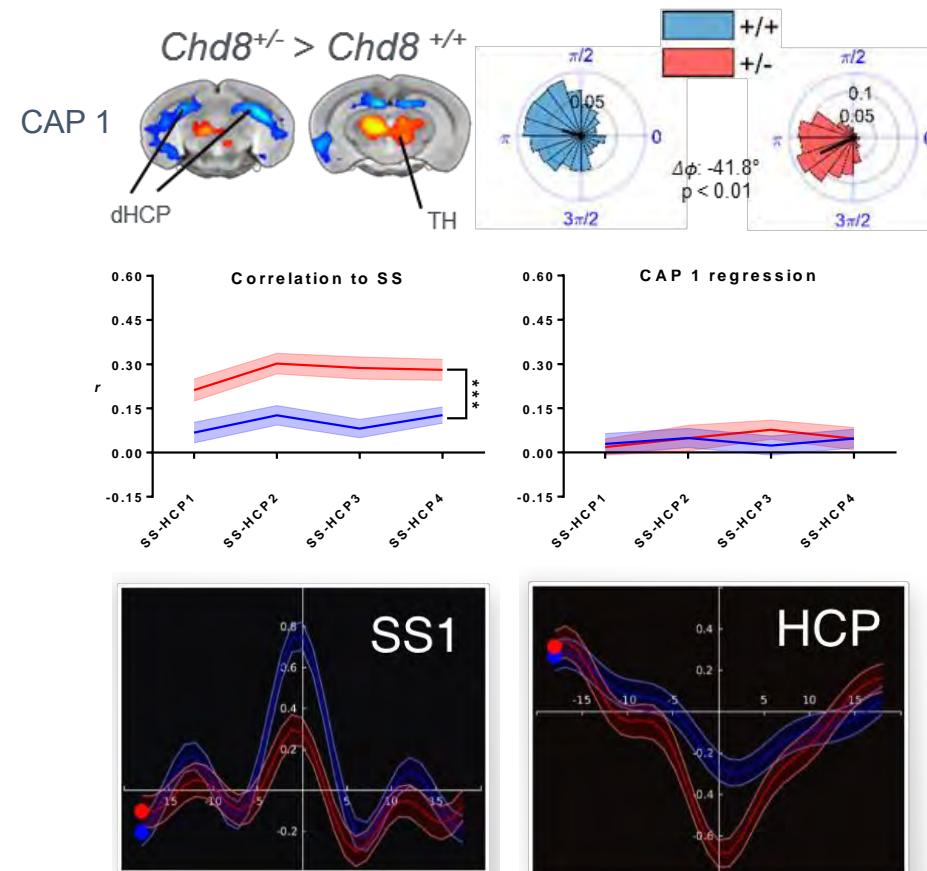


# Interim conclusions (2)

Oscillatory brain states govern spontaneous rsfMRI network dynamics

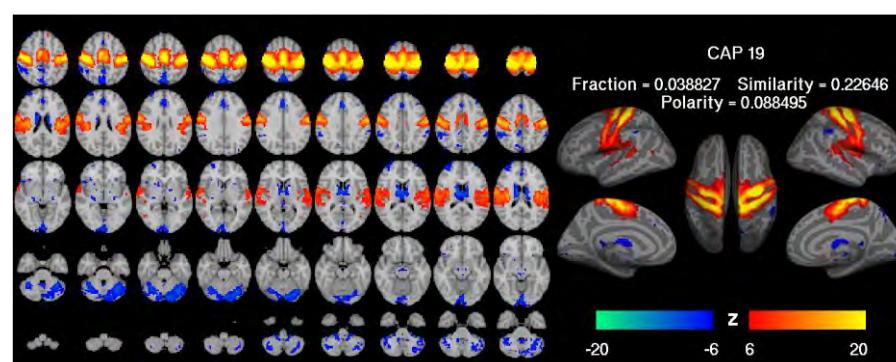
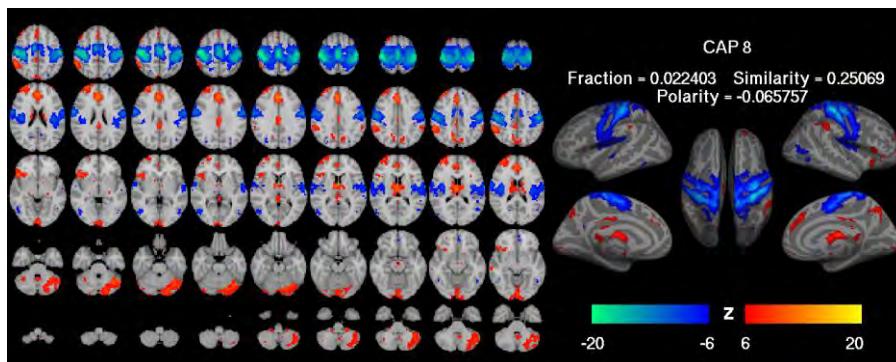
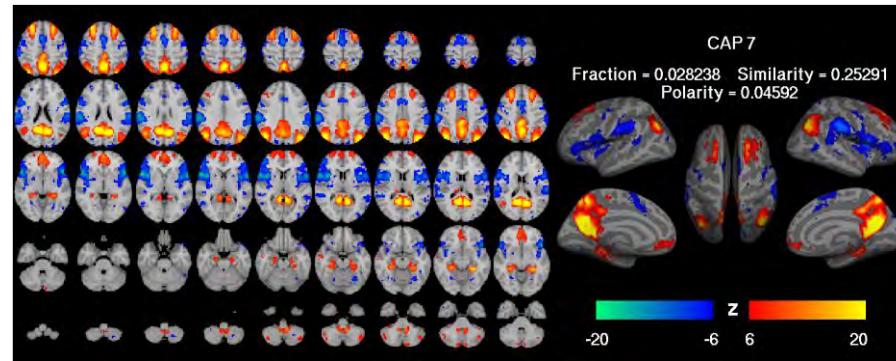
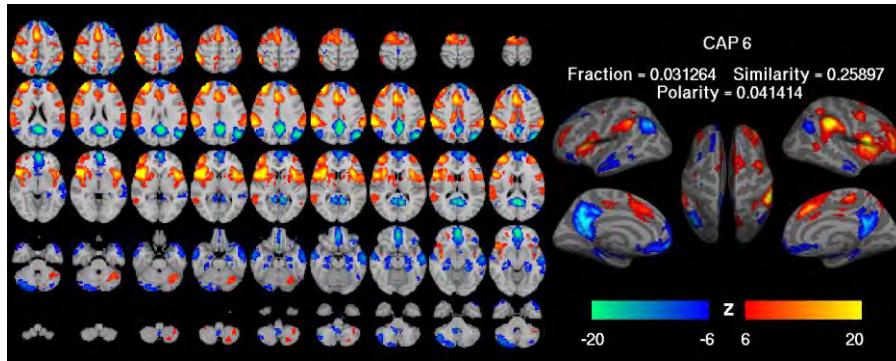
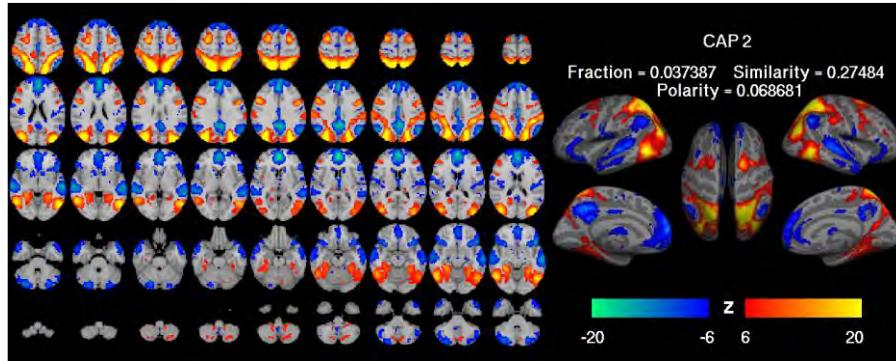
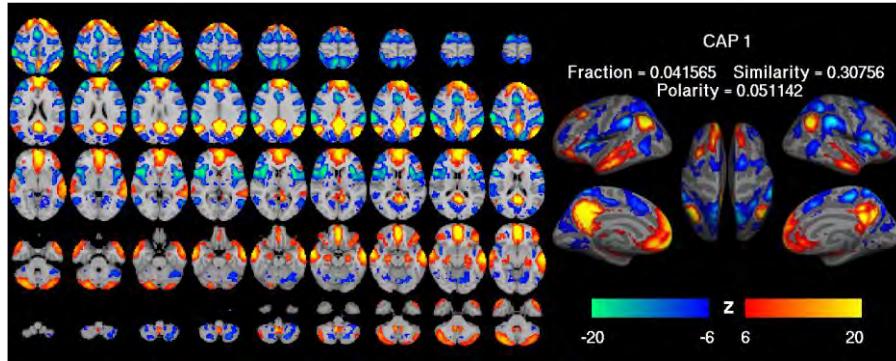


Atypical brain states can explain FC aberrancies in models of ASD



Where, When, and How FC differences in ASD occur?

# Comparable state anti-State configuration also found in the human brain



# Conclusions

- fMRI dynamics can be mapped with voxel-resolution in the mouse
- Oscillatory fMRI states govern rsfMRI dynamics and can explain rsfMRI “connectivity” disruption
- States topography shaped by ascending modulatory activity

# Thanks!

➤ Istituto Italiano di Tecnologia  
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  - Maria Luisa Scattoni
- ETH Zurich
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