



# Functional Connectome Dynamics; Slow, Fast, or Both?

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# Whole-brain connectomes in EEG/MEG

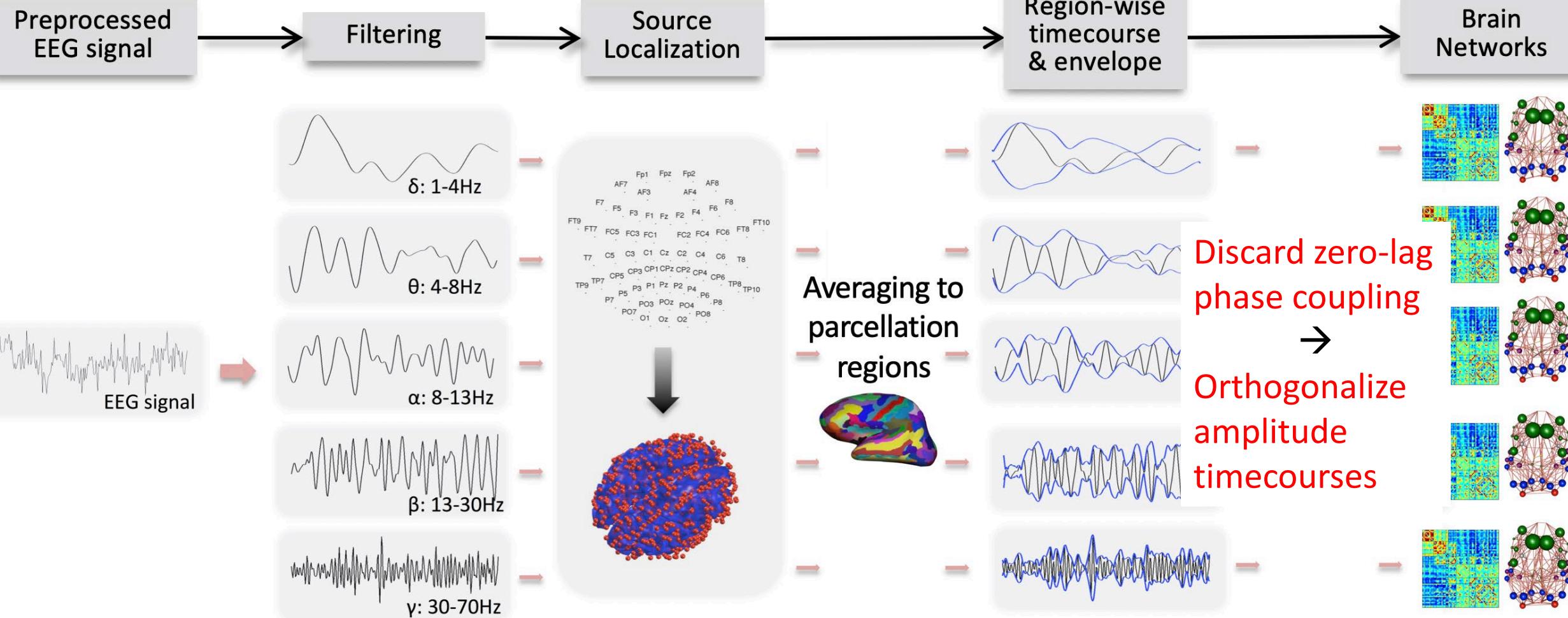


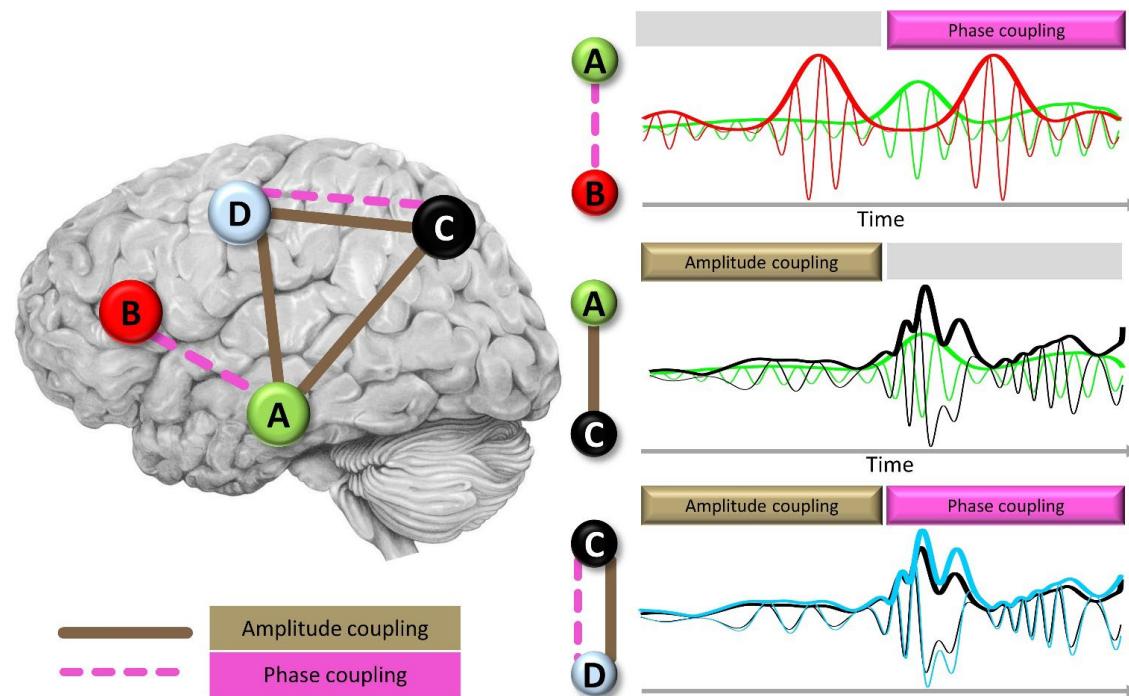
Illustration modified from Deligianni et al., *Frontiers Neurosci* 2014

Reviews: Sadaghiani & Wirsich, *Netw Neurosci* 2020

Sadaghiani, Brookes & Baillet, *NeuroImage* 2022

# Electrophysiological connectivity: technical considerations

## Connectivity measures



Mostame & Sadaghiani 2020, *NeuroImage*

## Timescales

Four orders of magnitude:

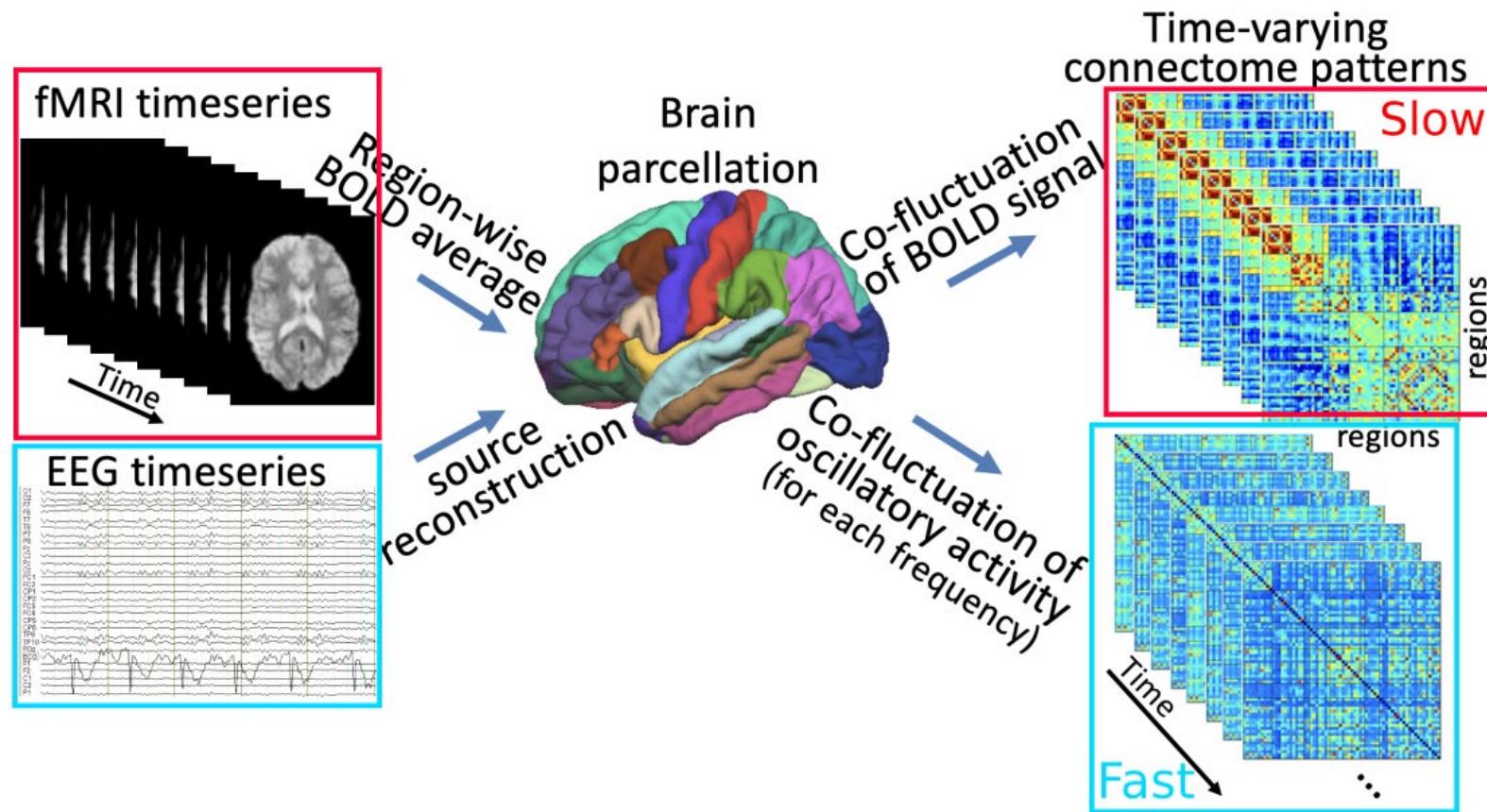
Infraslow (<0.1Hz)

to

Canonical oscillations range  
(~1-100Hz)



# Multi-modal whole-brain connectome dynamics

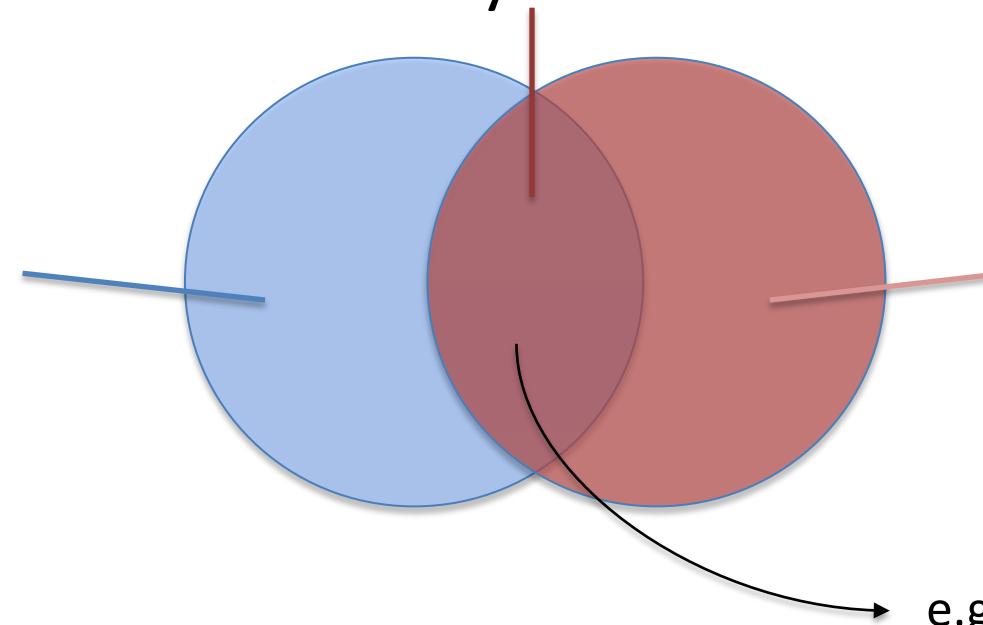




Connectivity dynamics  
measured by EEG *and* fMRI

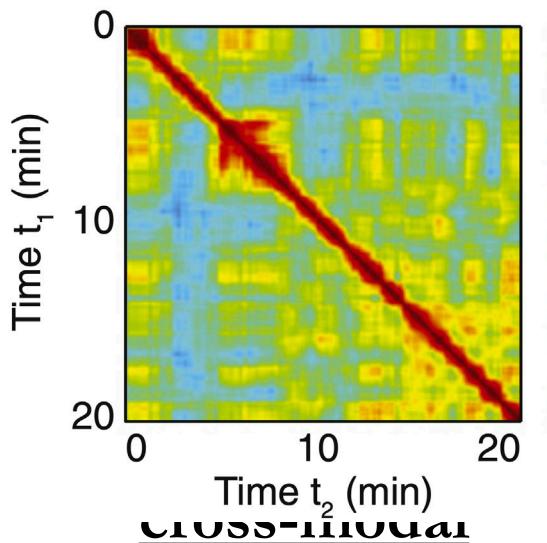
Connectivity dynamics  
measured in EEG  
+ Noise in EEG

Connectivity dynamics  
measured in fMRI  
+ Noise in fMRI

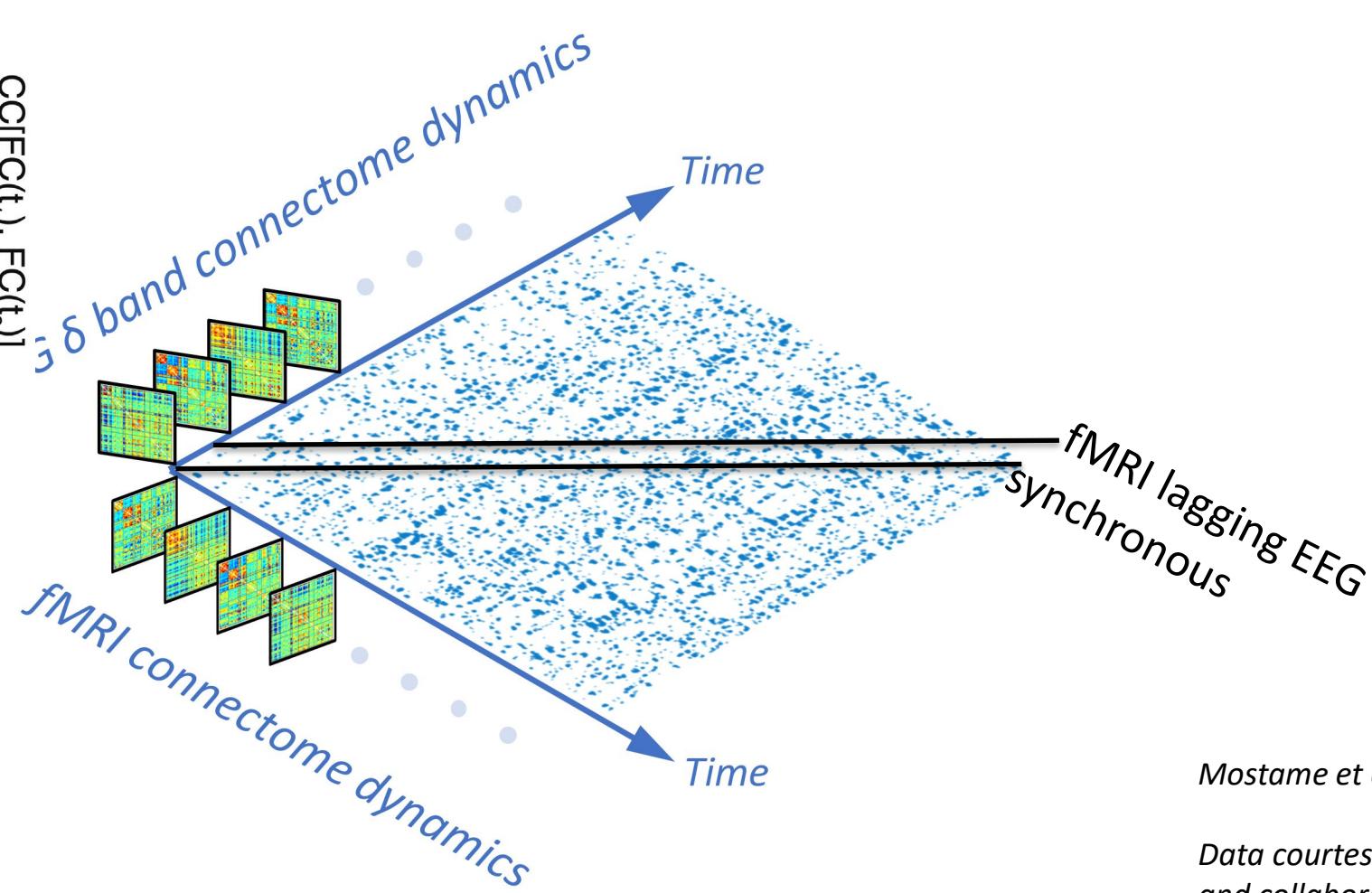


e.g. Wirsich et al. *NeuroImage* 2020

# Similar connectome states occur *asynchronously* in concurrent intracranial EEG and fMRI



Hansen et al., *NeuroImage*, 2015



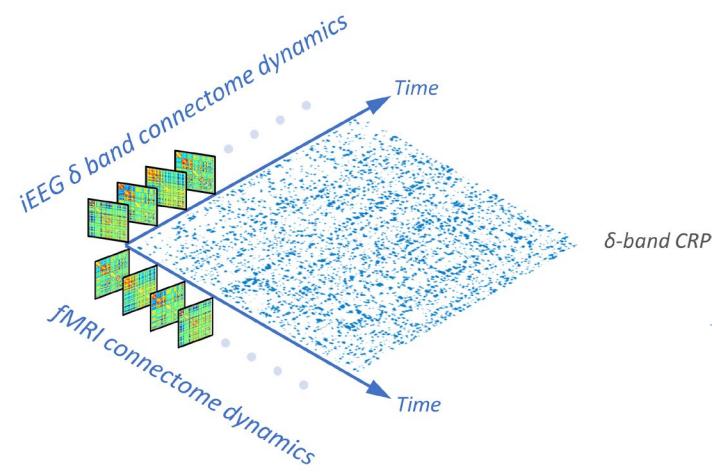
Mostame et al., *in prep*

Data courtesy of Lemieux (UCL) and collaborators



# Similar connectome states occur *asynchronously* in concurrent intracranial EEG and fMRI

Time-lagged  
cross-modal  
spatial correlation



Replicated in  
scalp EEG-fMRI

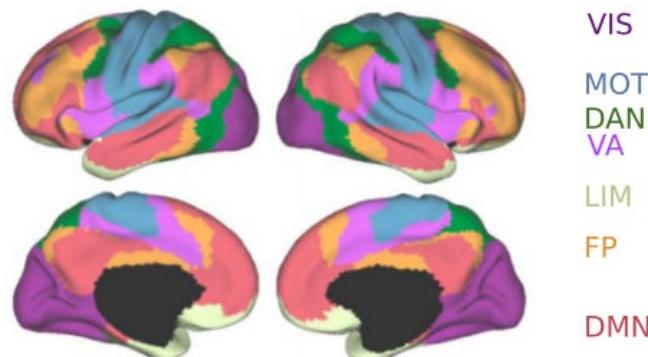
*Mostame et al., in prep*

*Data courtesy of Lemieux (UCL)  
and collaborators*



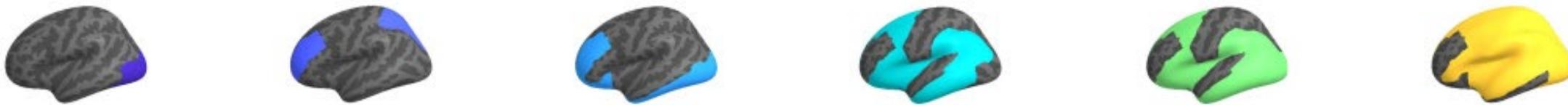
# Combinations of intrinsic connectivity networks as state “blueprints”

## Intrinsic connectivity networks



→ Determine which blueprint fits the activity pattern\* at each time frame

\* Instantaneous BOLD signal or EEG band-limited amplitude in 68 regions

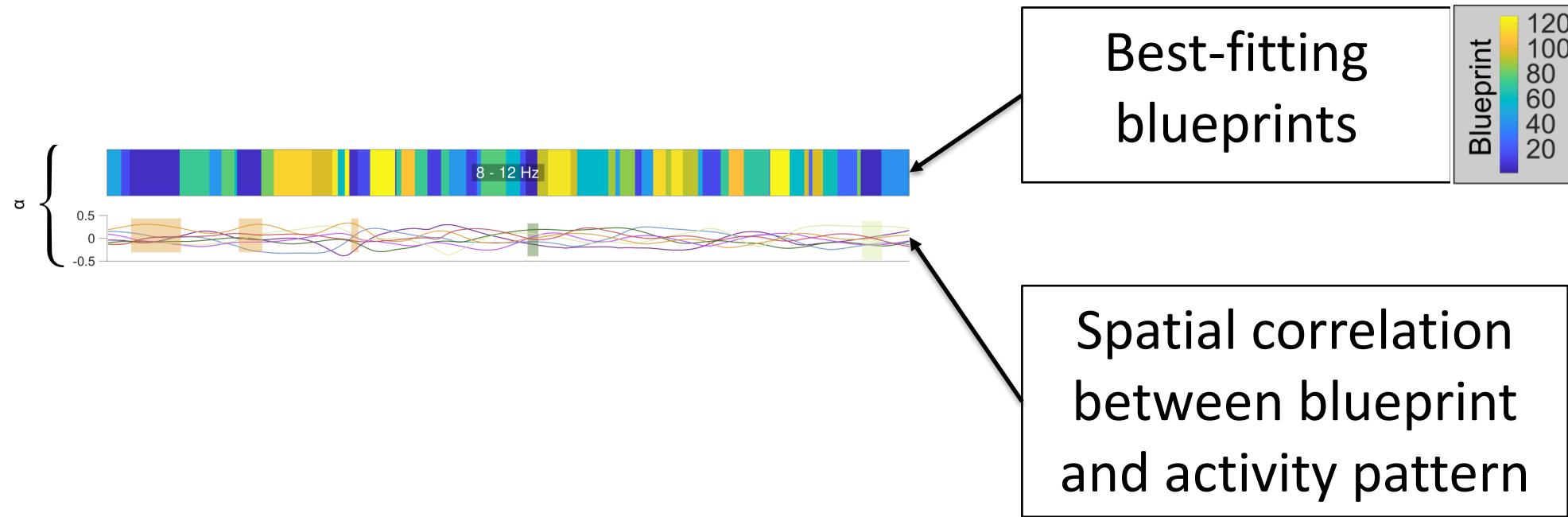


Alderson et al., in prep

For blueprints (fMRI) see Sporns et al., Netw Neurosci 2021



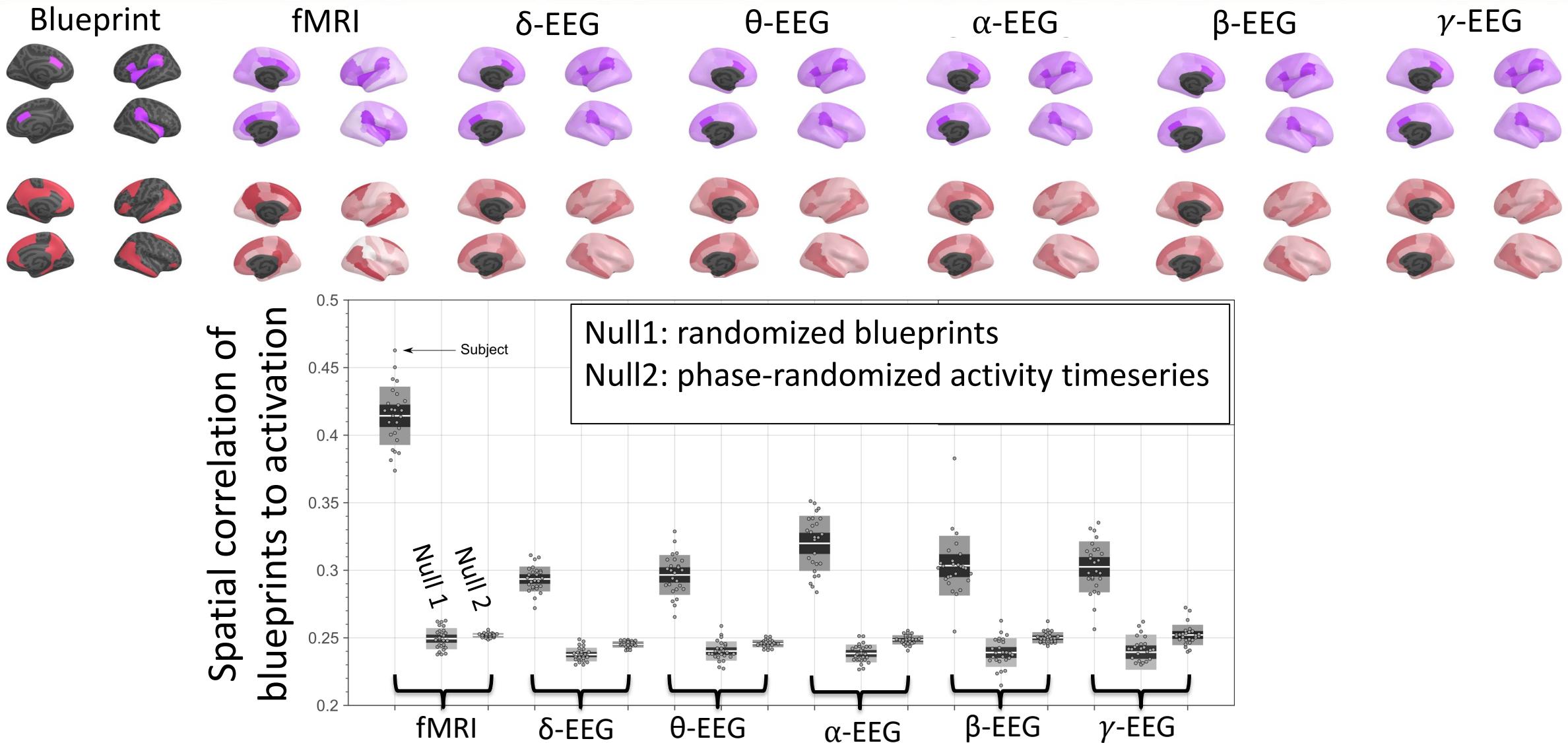
# State blueprints (ICN combinations) fit activation patterns at all timescales



Alderson *et al.*, in prep

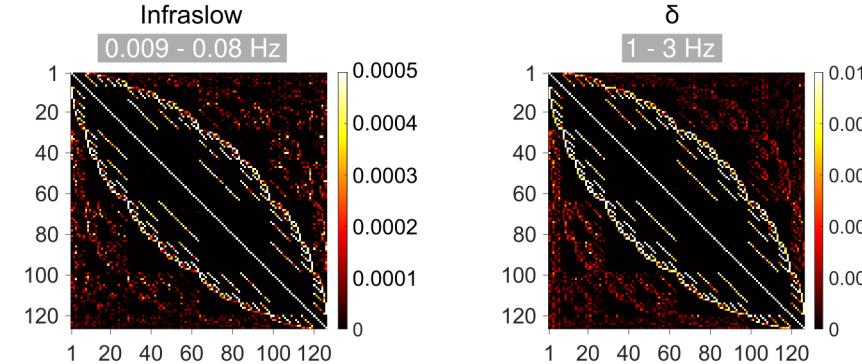


# State blueprints (ICN combinations) fit activations patterns at all timescales

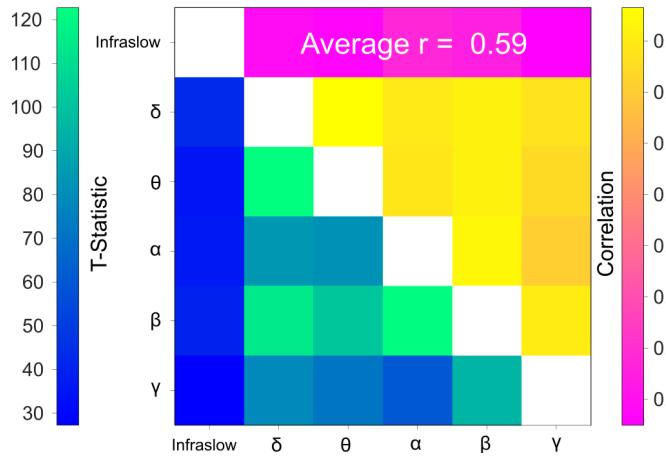


# Sequences of states share temporal properties over timescales

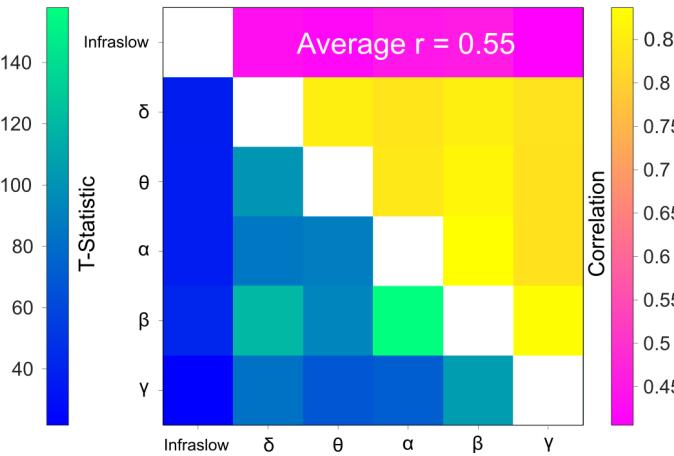
Transition probabilities



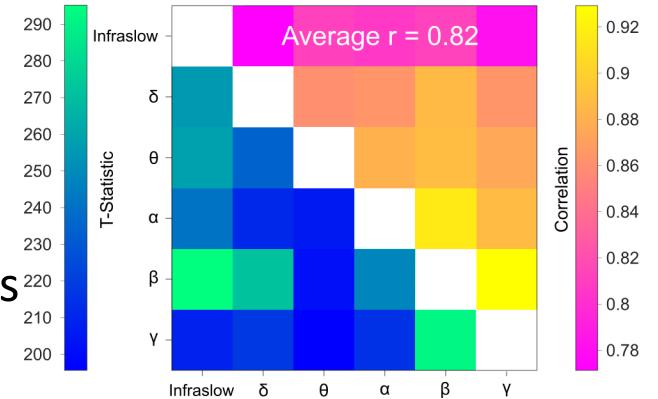
Similarity of  
fractional occupancy distribution



Similarity of  
dwell time distribution



Similarity of  
Transition probabilities



**But at different speeds:**

Mean dwell time fMRI: ~2500ms

Mean dwell time δ-EEG: ~100ms

Mean dwell time γ-EEG: ~20ms

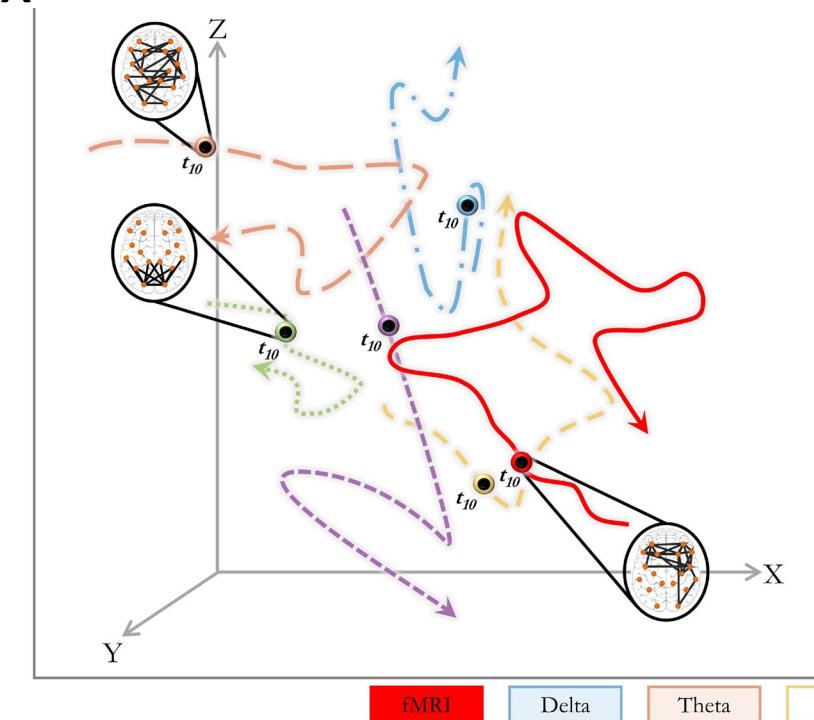
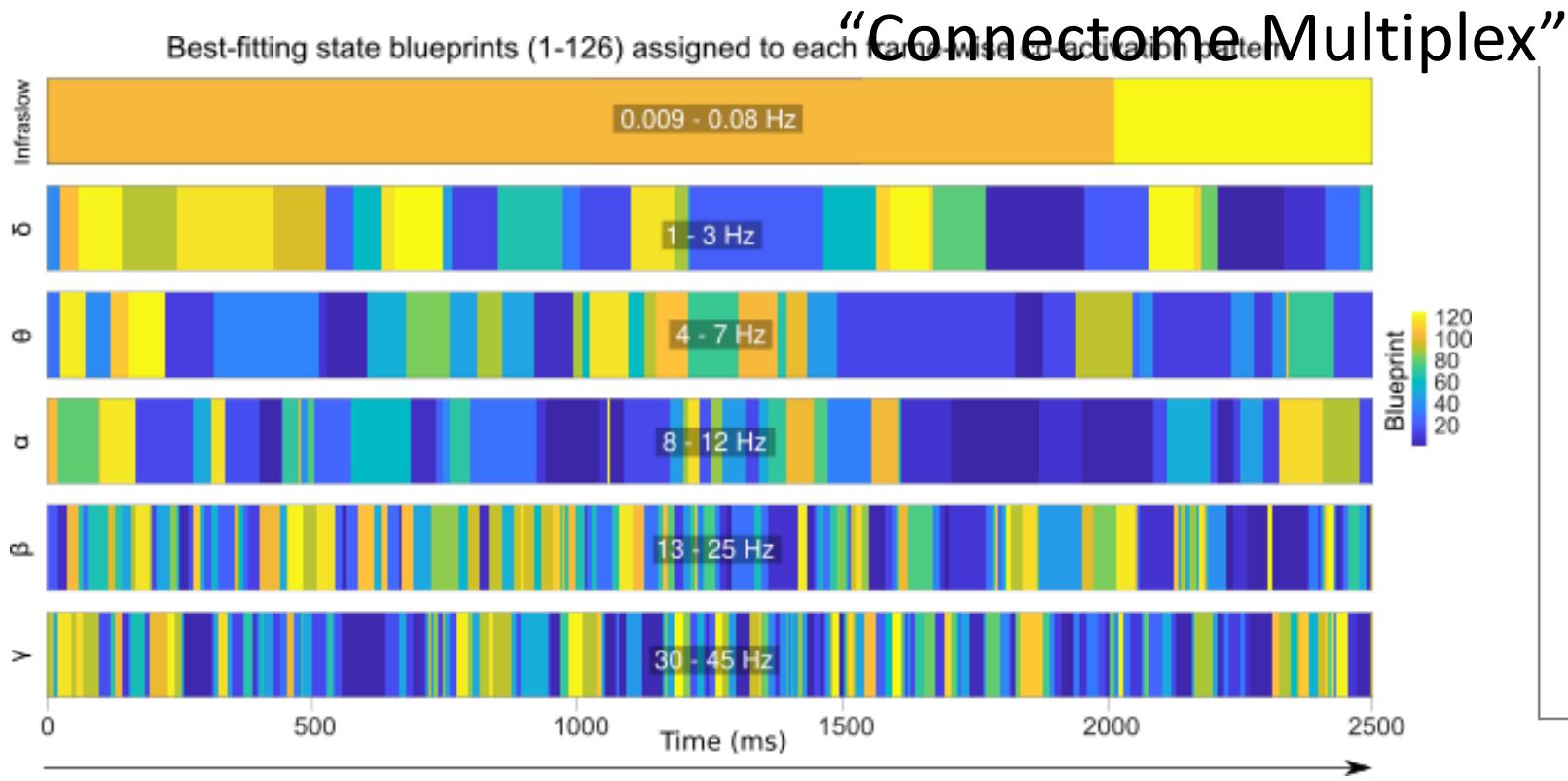
# Take-Home Message

Functional connectome dynamics comprise  
**multiple parallel streams**

with spatially similar states  
and temporally similar state sequences  
but at **different speeds**



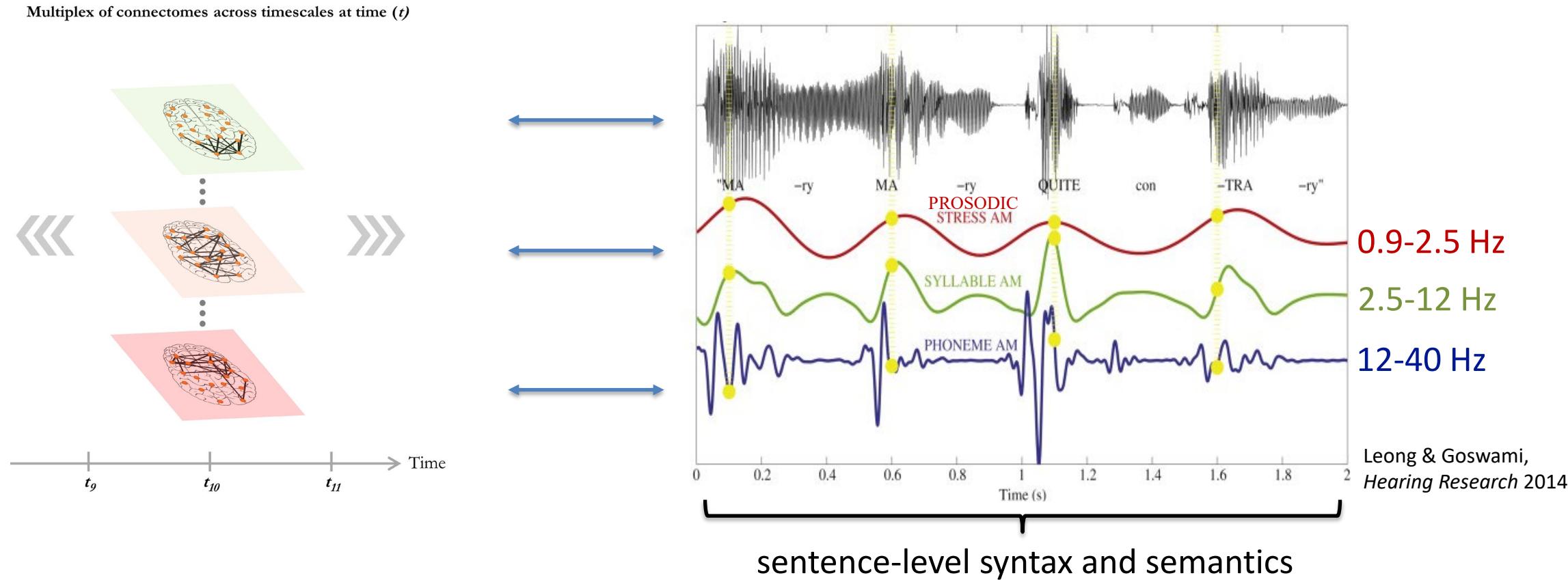
# Functional connectome dynamics comprise multiple parallel streams



# Conclusions

The brain is a multi-timescale system, because cognitive processes unfold at different speeds.

This extends to whole-brain connectome organization, creating a dynamic multiplex.



# Acknowledgements



Thomas Alderson  
Parham Mostame

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Funding for  
multi-modal work:

NIH/NIMH R01MH116266  
NSF CAREER 2237285

## Intracranial EEG-fMRI:

Maxime Guye (Aix-Marseille)  
Louis Lemieux (UCL)  
Ben Ridley (Cochrane)  
Serge Vulliémoz (Geneva)  
Jonathan Wirsich (Geneva)

## Scalp EEG-fMRI:

Anne-Lise Giraud (Institut Pasteur, Paris)  
Katia Lehongre (ICM, Paris)  
Benjamin Morillon (Aix-Marseille)

Multi-department strategic hire in Neuroinformatics

<https://publish.illinois.edu/neuro-cluster/>



## Proportion of Each Type of Transition

