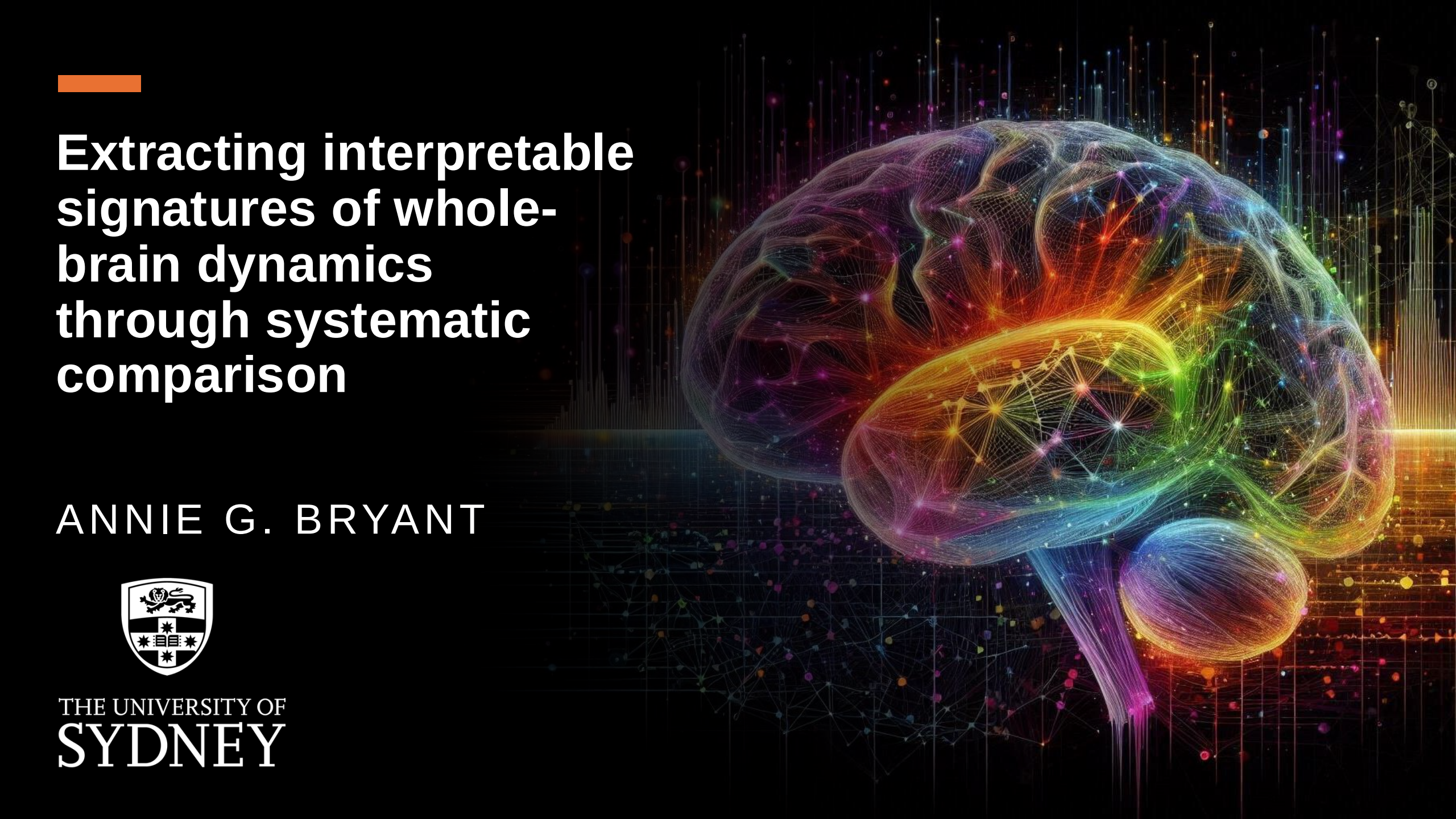
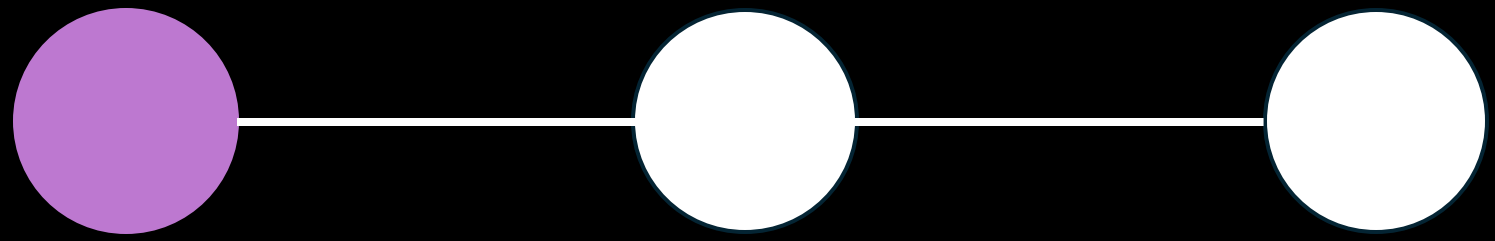
Extracting interpretable signatures of whole-brain dynamics through systematic comparison

ANNIE G. BRYANT

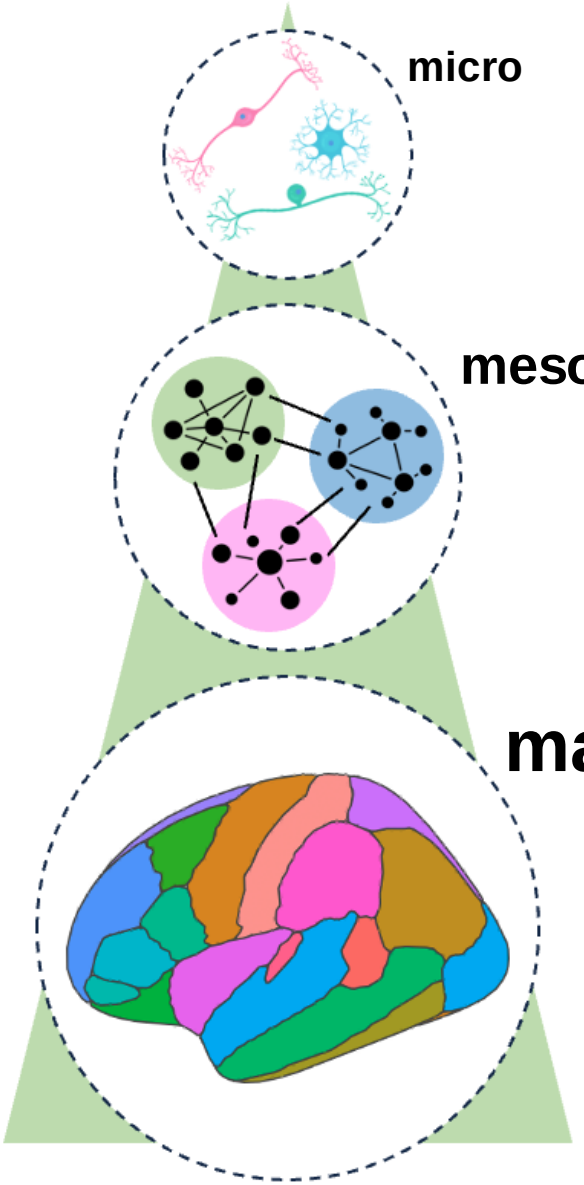
THE UNIVERSITY OF SYDNEY

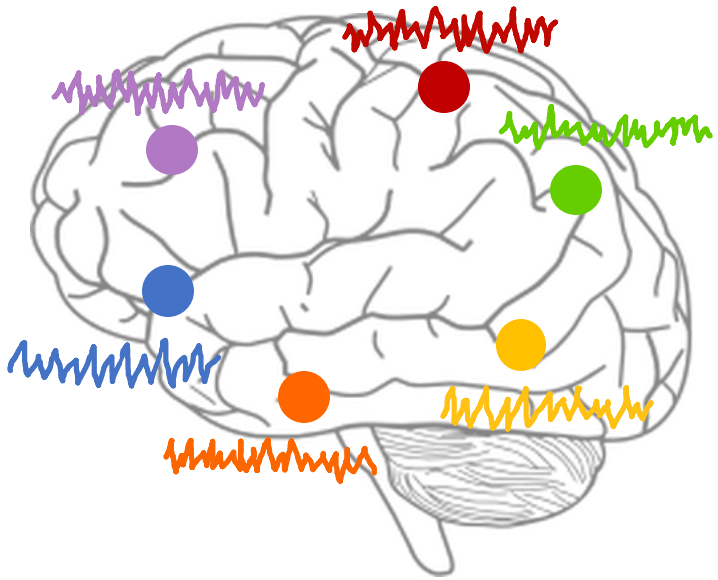


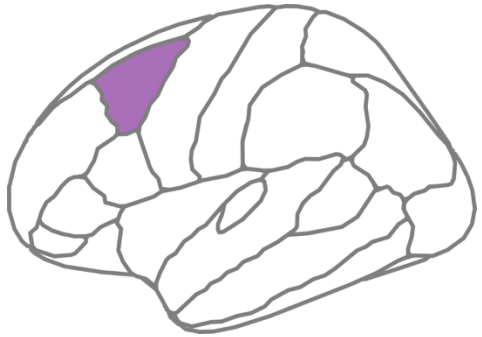
Why should we consider **venturing beyond standard metrics** for quantifying brain activity from structural and/or functional neuroimaging?



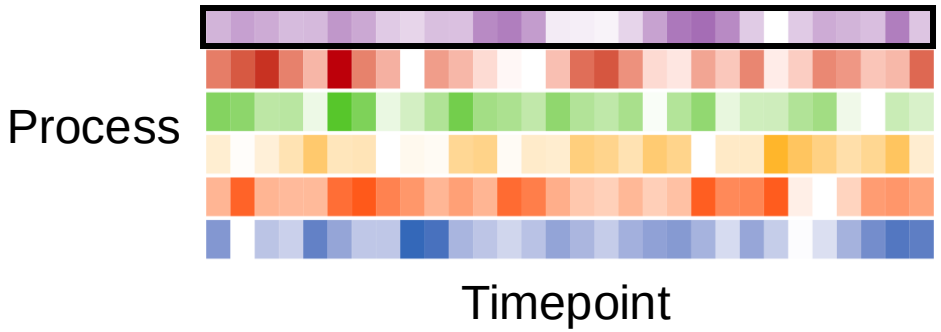
Brain dynamics can be measured at **multiple scales**



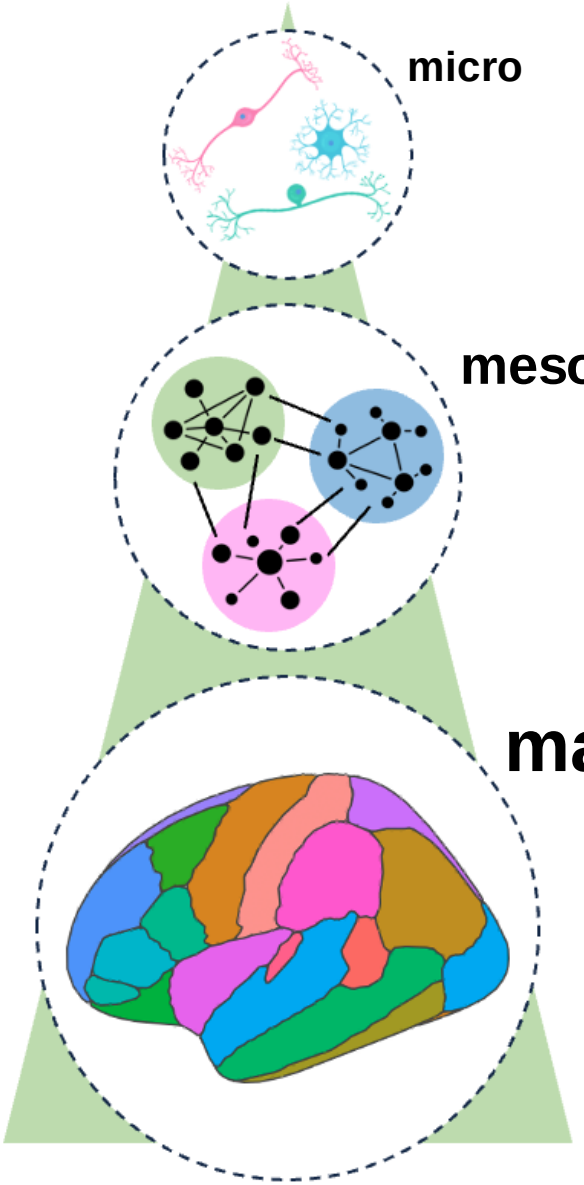


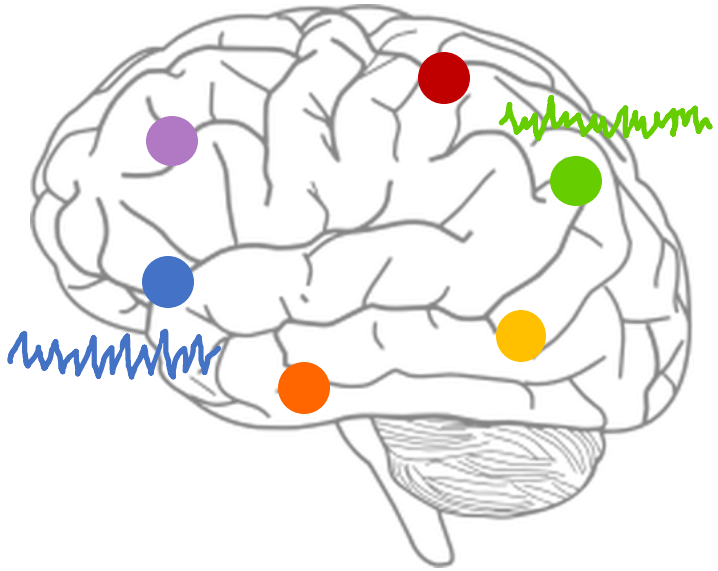


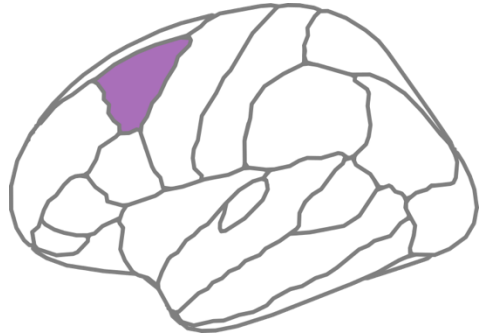
Multivariate time series (**MTS**)

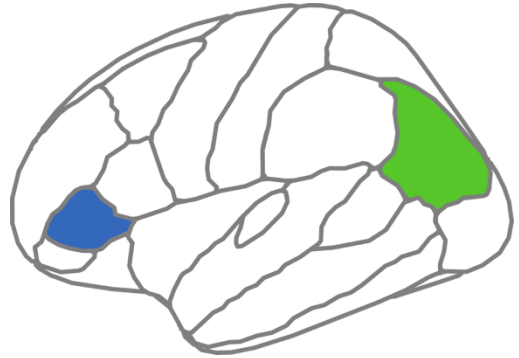


Brain dynamics can be measured at **multiple scales**

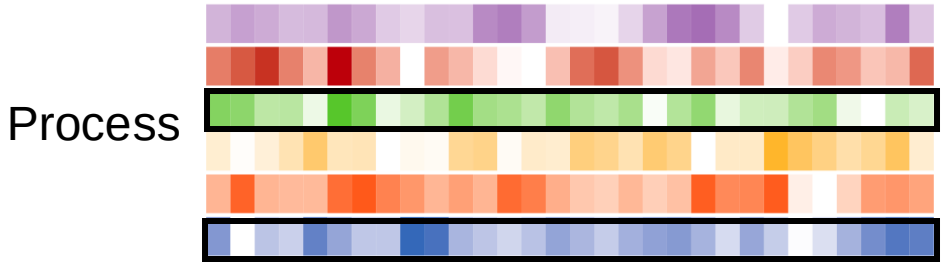




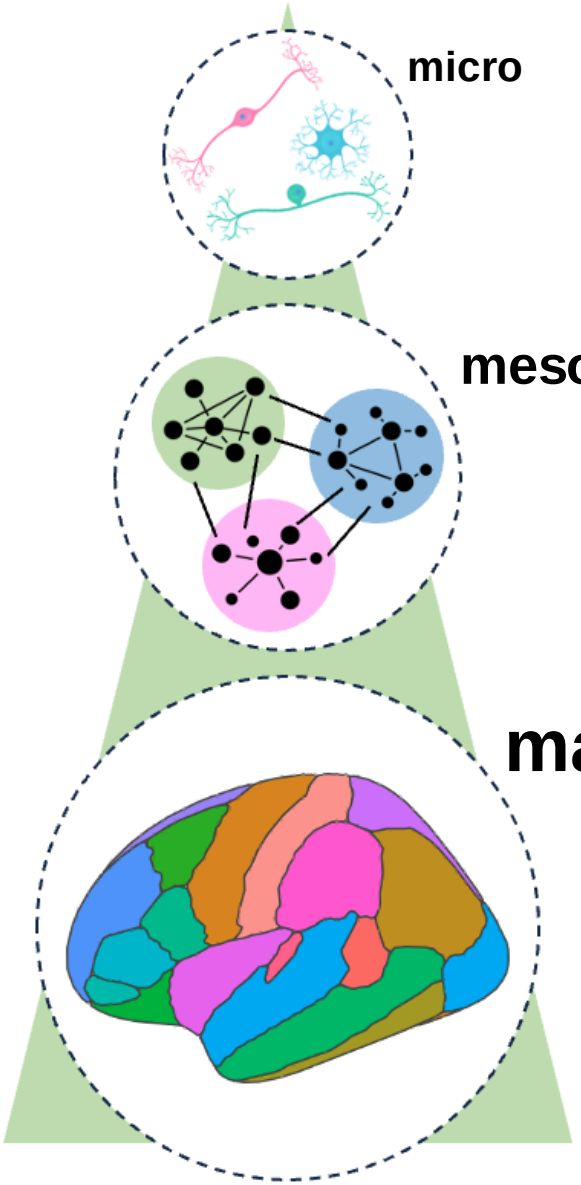


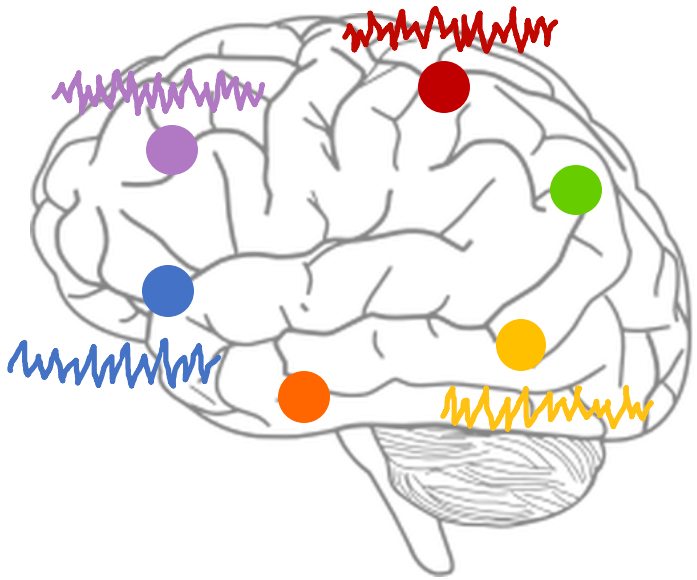


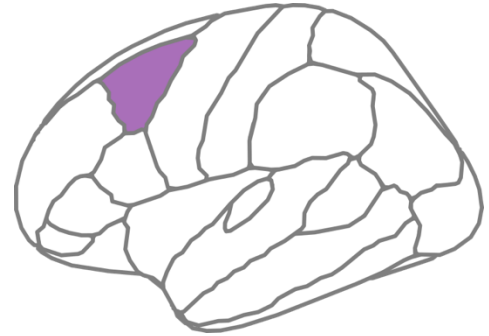
Multivariate time series (**MTS**)

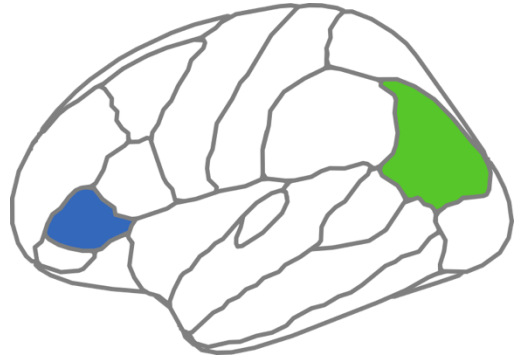


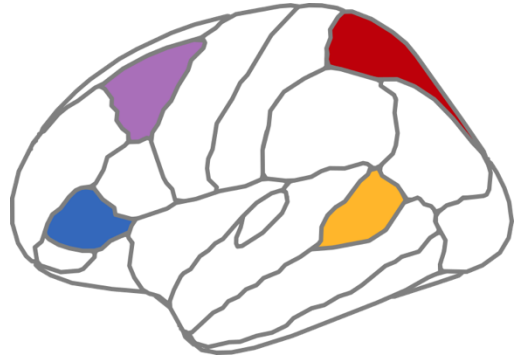
Brain dynamics can be measured at **multiple scales**

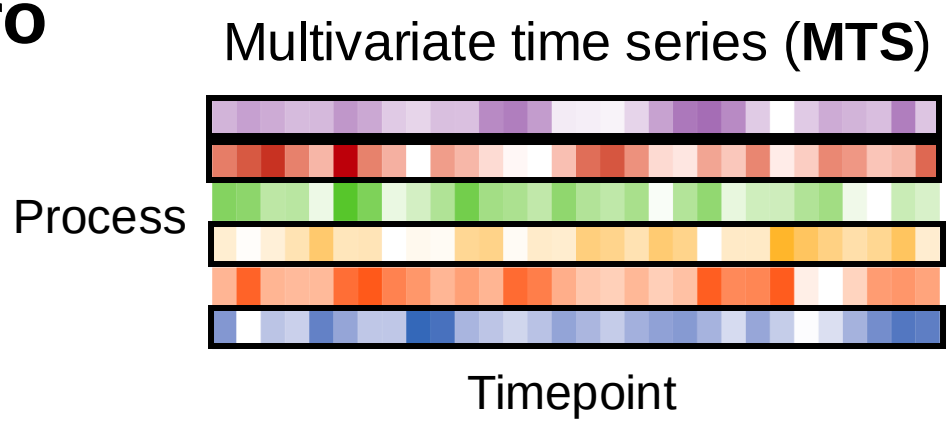




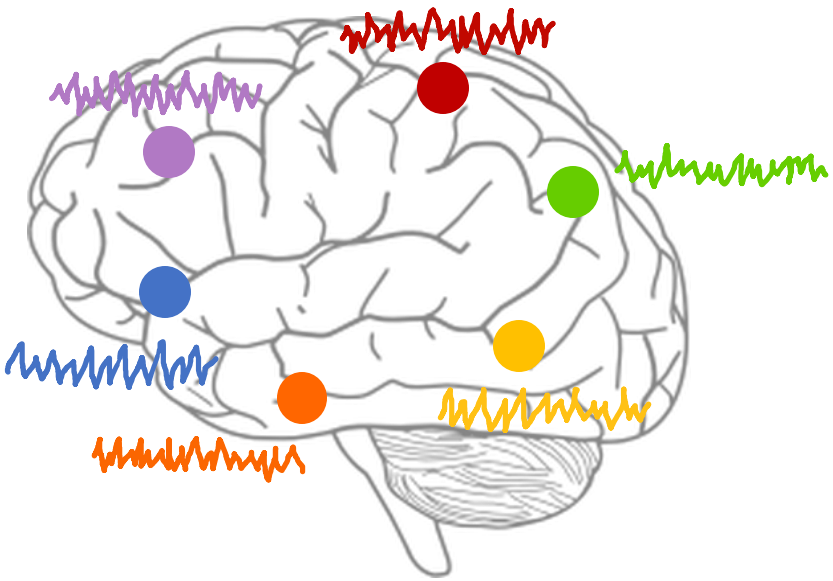


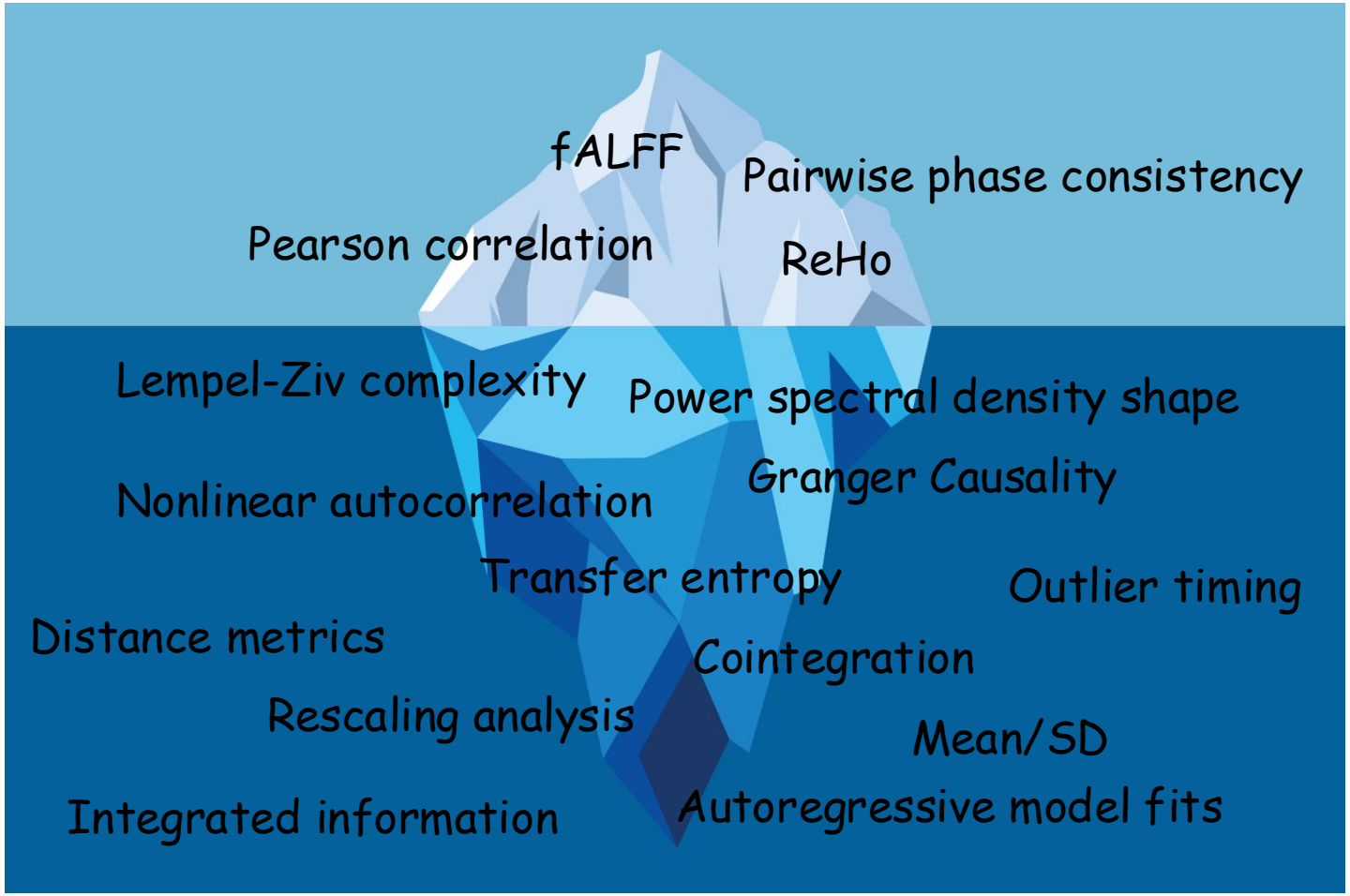




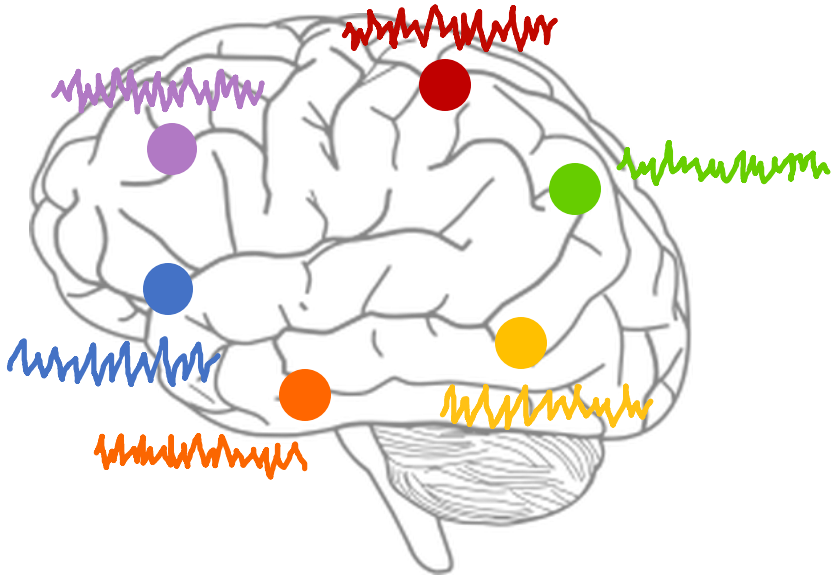


How might we begin to **quantify** brain dynamics?

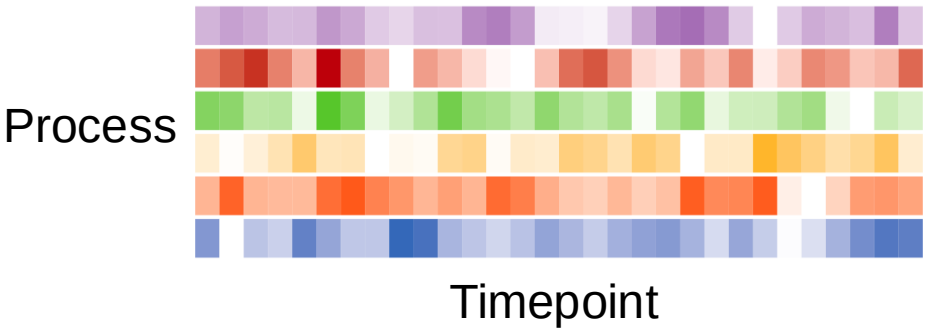




The **brain** is a **complex system** of great **biological interest**



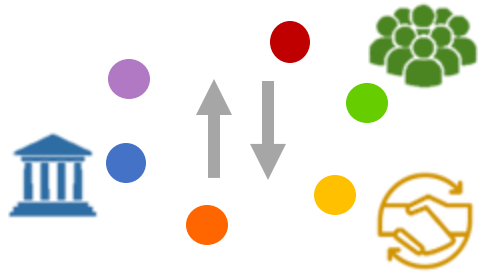
Multivariate time series (**MTS**)



City structure

City properties: density, traffic patterns, crime rates, culture

Economics



National economy: economic growth, recession

Physics

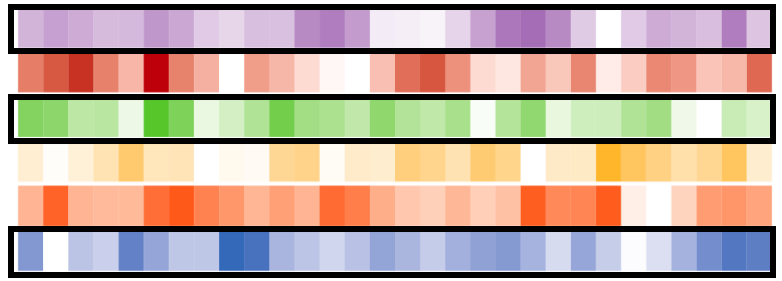
Fluid dynamics: vortices, turbulence

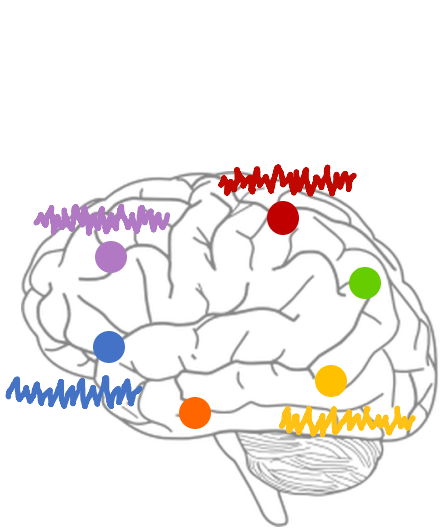
Social networks

Facebook friends: community formation

What does this **generalized representation** offer us?

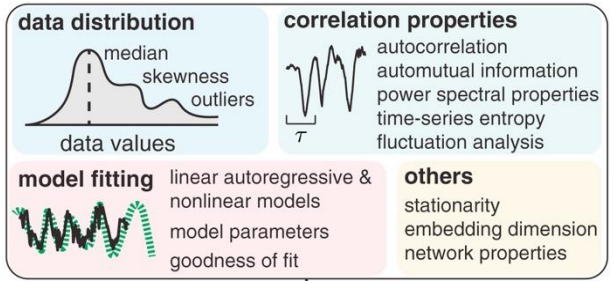
Multivariate time series (**MTS**)





Localized dynamics of one process

hctsa

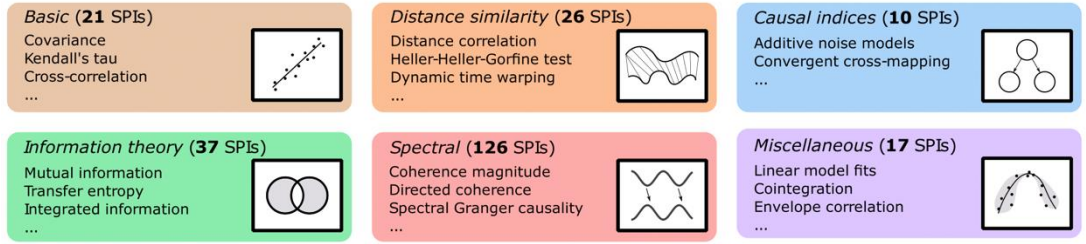


catch22

Fulcher et al. *J R Soc* (2013), *Cell Systems* (2017)
Lubba et al. *Data Mining and Knowledge Discovery* (2019)

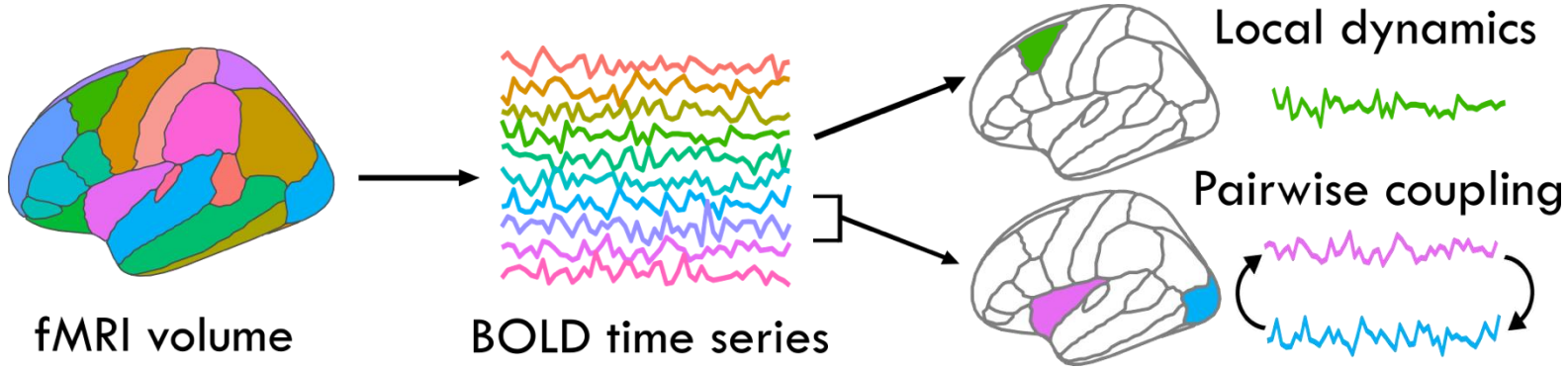
Statistical dependencies between **pairs** of processes

pyspi

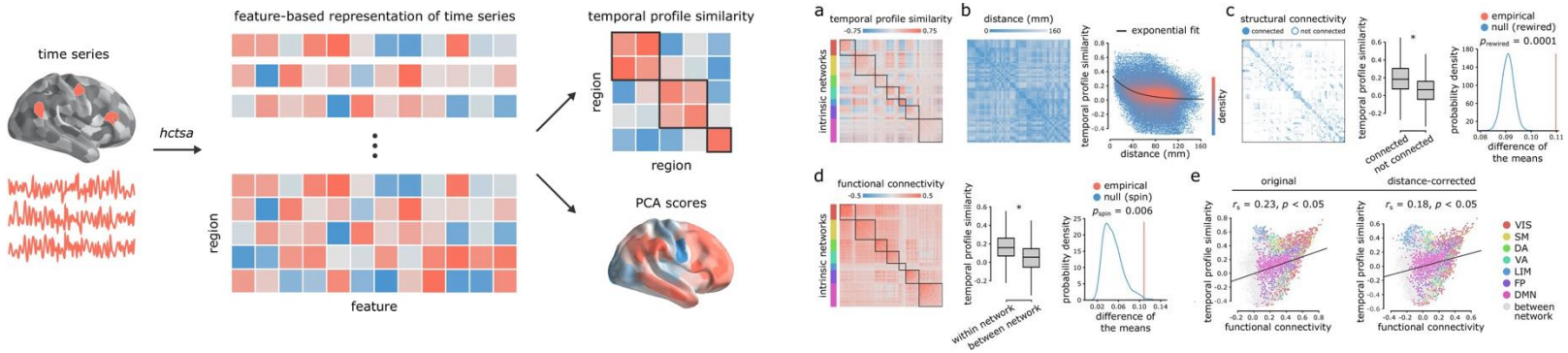


Cliff et al. *Nat Comp Sci* (2023)

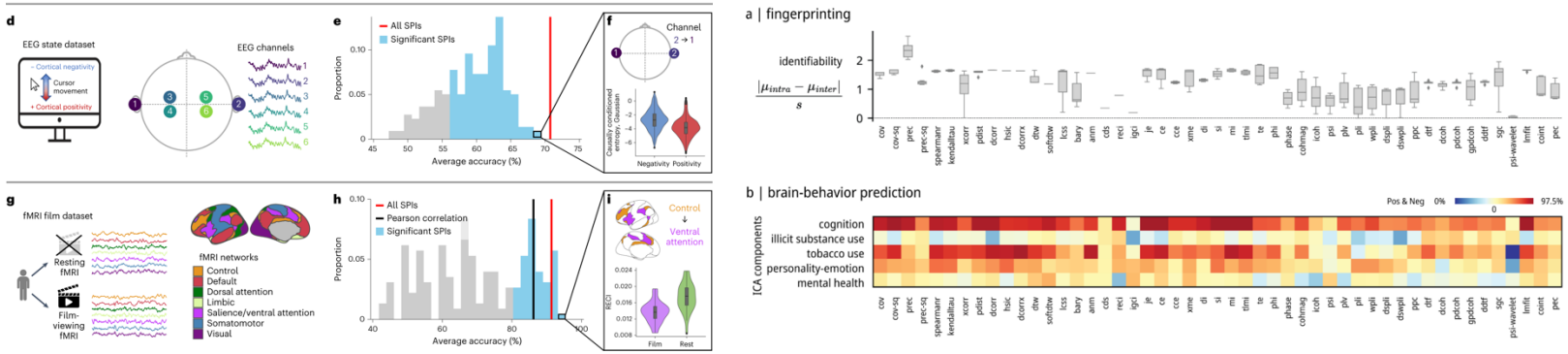
Measuring **local dynamics + pairwise coupling** in the brain



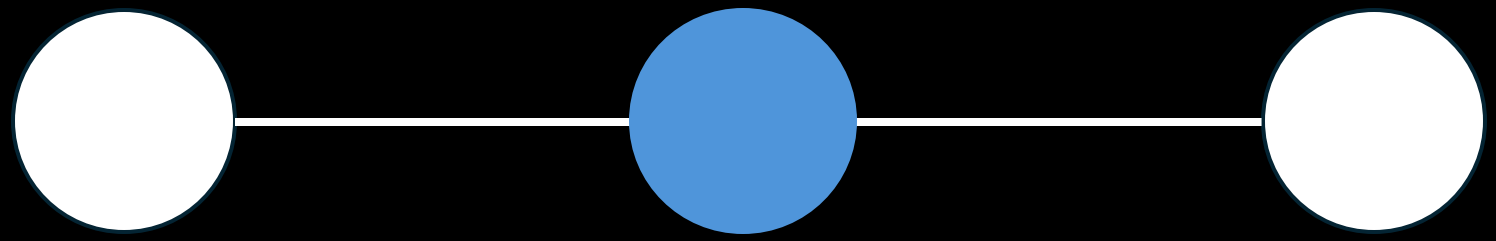
Shafiei et al. *eLife* 2020 (pictured),
Nat Comms 2023



Cliff et al. *Nat Comp Sci* 2023 (left)
Liu et al. *bioRxiv* 2024 (right)



How can this systematic method be applied in a **comprehensive** yet **interpretable** way to real functional neuroimaging problems?



Case study: classifying **neuropsychiatric disorders**

catch22

pyspi

catch22 + pyspi

i. Local dynamics in an individual region

ii. Whole-brain maps of an individual feature

iii. Whole-brain maps of all features

iv. FC across all region pairs with one SPI

v. FC across all region pairs by SPI plus all whole-brain maps of local dynamics

SCZ
N=48
UCLA CNP

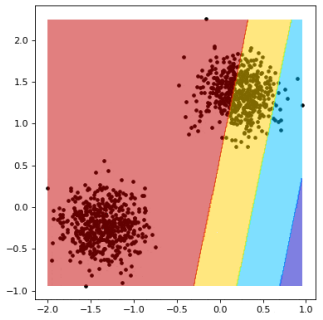
BP
N=49
UCLA CNP

ADHD
N=39
UCLA CNP

ASD
N=513
ABIDE

Controls

Cases



Source: scikit-learn

Linear support vector machine (SVM)

- Balanced accuracy
- Inverse probability weighting

× 10-fold CV
× 10 repeats

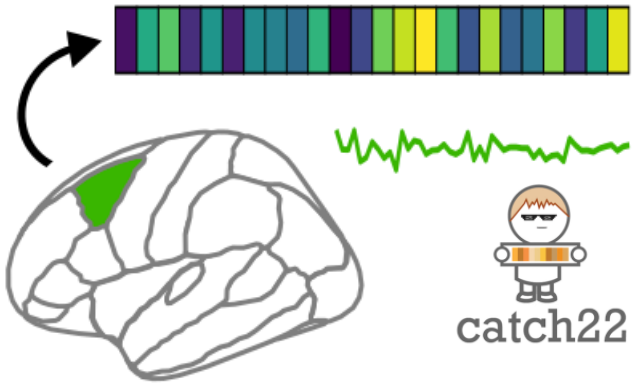
Data preprocessed by Traut et al. *NeuroImage* (2022)

Data preprocessed by Kevin Aquino & Linden Parkes

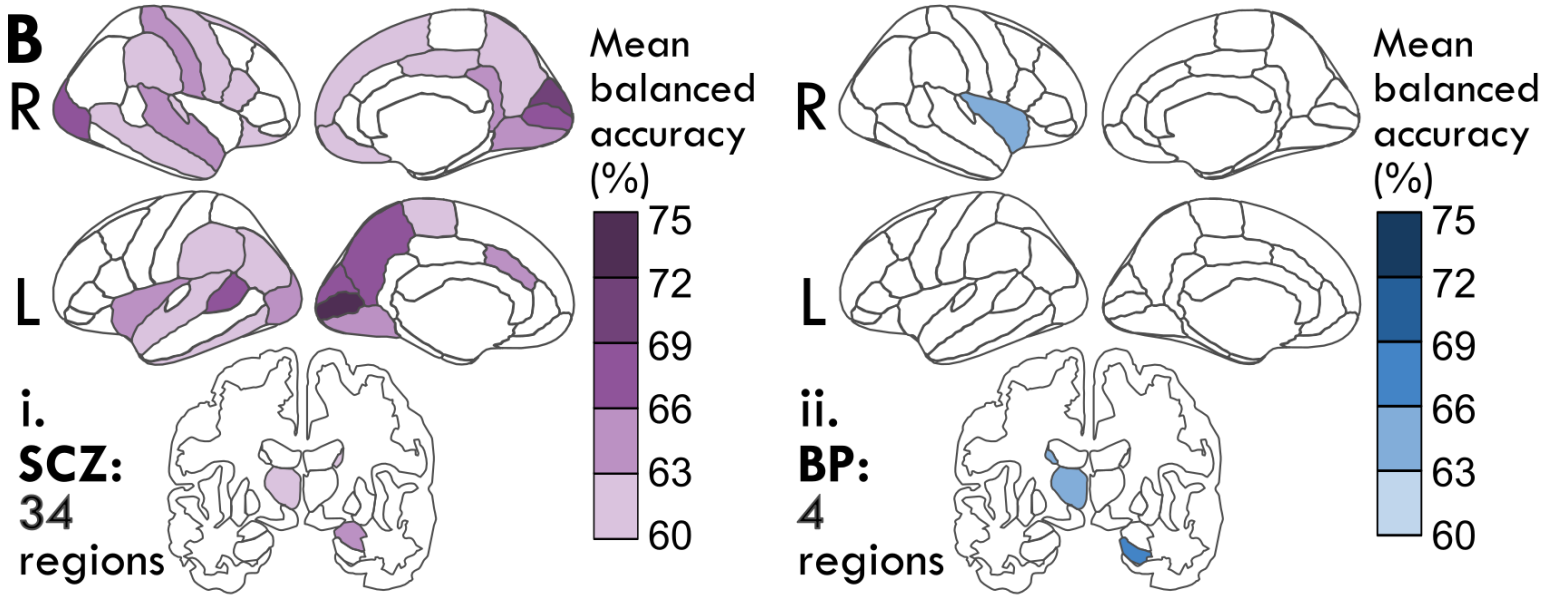
Bryant et al. *bioRxiv* (2024)

Interpretable **spatial maps** of **region-specific dysfunction**

Dynamical signatures of resting-state activity in **individual brain regions** can distinguish patients from controls in schizophrenia and bipolar disorder



aparc+aseg FreeSurfer atlas



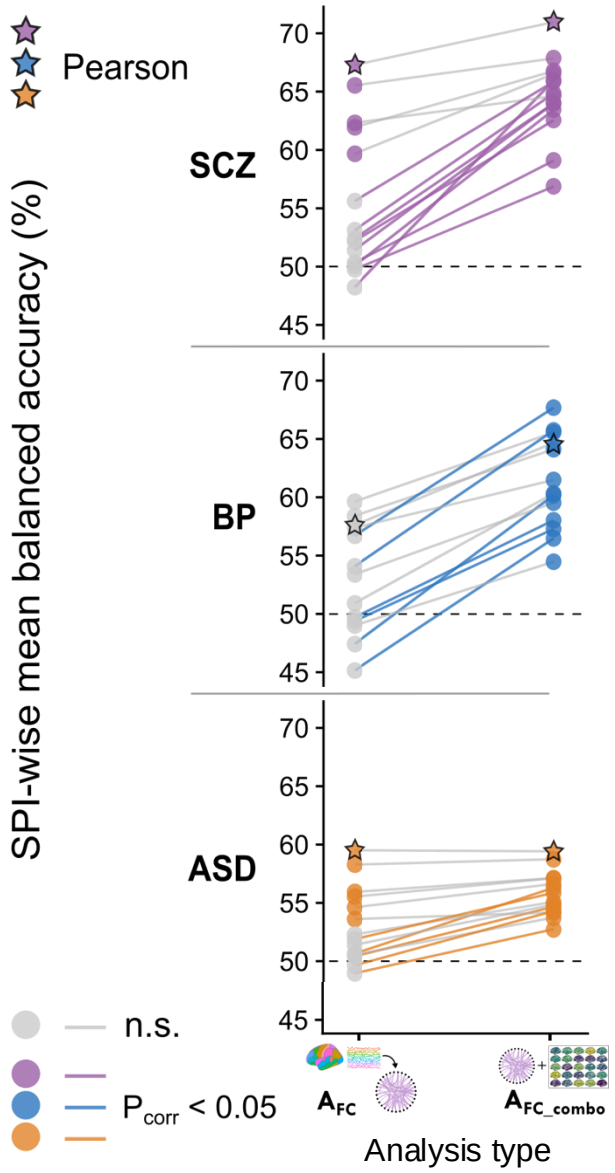
Gene expression

Anatomical changes

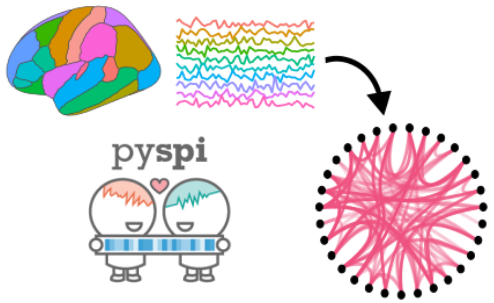
Stimulation analysis

Bryant et al. *bioRxiv* (2024)

The benefit of **integrating** local dynamics **and** pairwise coupling

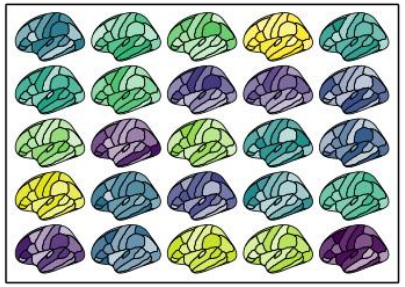


iv. FC across all region pairs with one SPI



+

iii. Whole-brain maps of all features

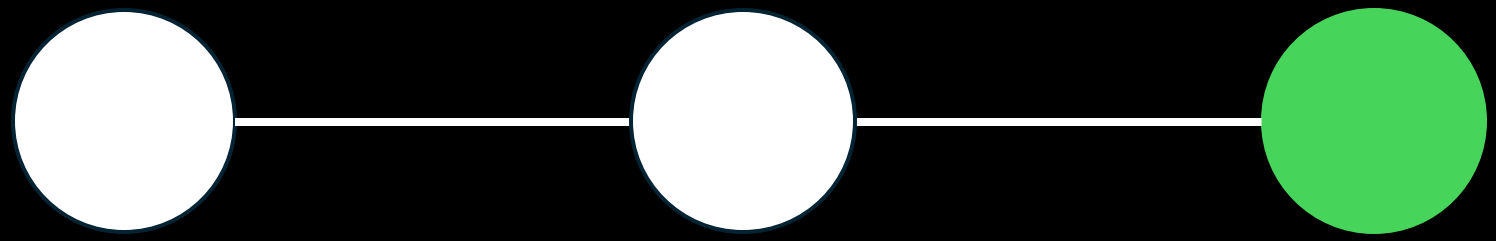


Most pairwise **functional connectivity** metrics are more informative with the inclusion of **brain-wide maps** of **local regional dynamics,** and the **Pearson correlation** coefficient is the top performer

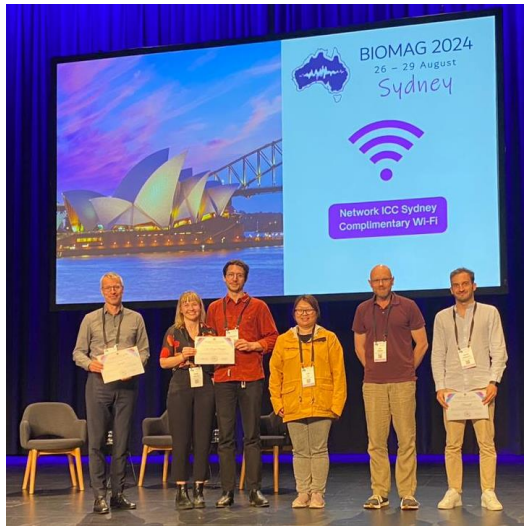
✨synergy✨

Bryant et al. *bioRxiv* (2024)

What other types of neuroimaging-focused insights can this comprehensive approach offer?

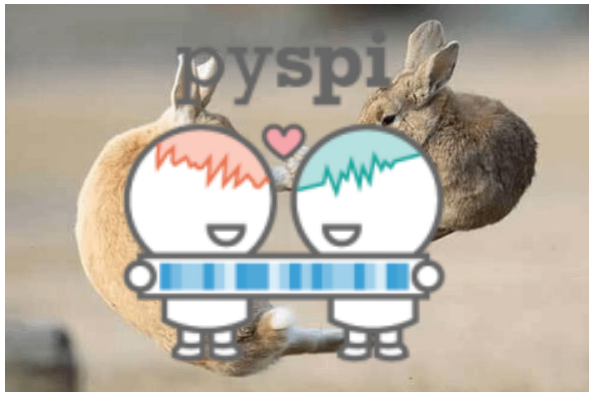


Quantifying properties **inter-areal coupling** to evaluate **competing hypotheses of consciousness**

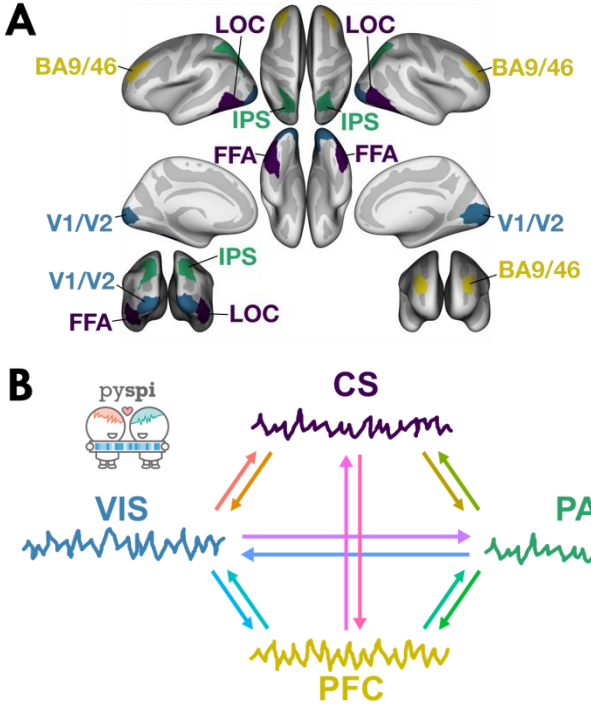


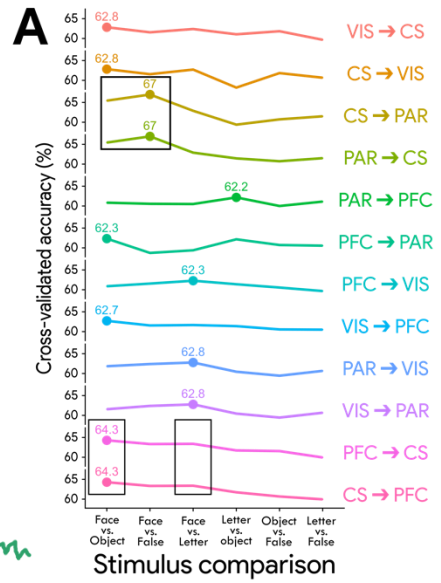
Christopher Whyte

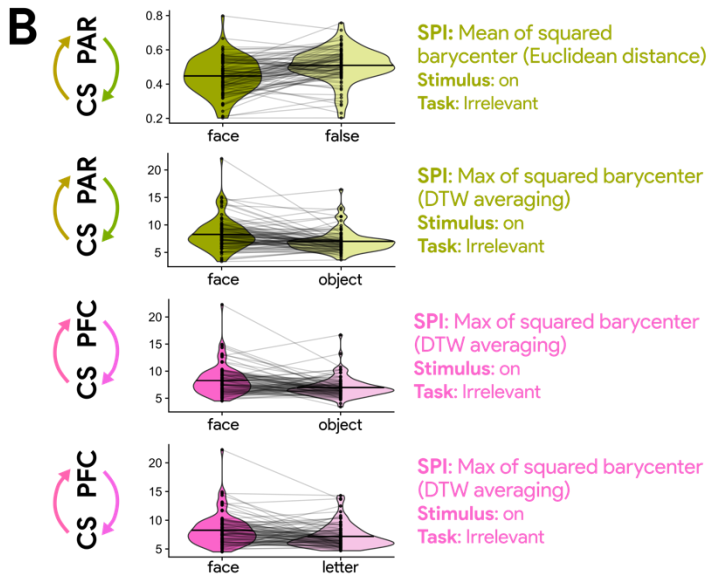
🐰[1]: Integrated information theory (IIT)



🐰[2]: Global neuronal workspace theory (GNWT)

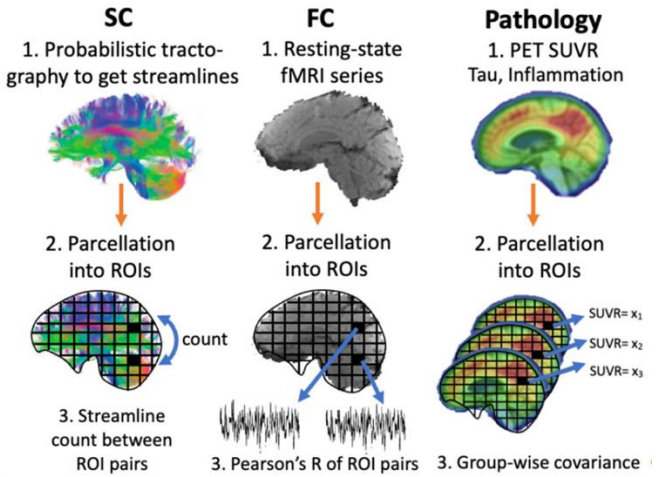




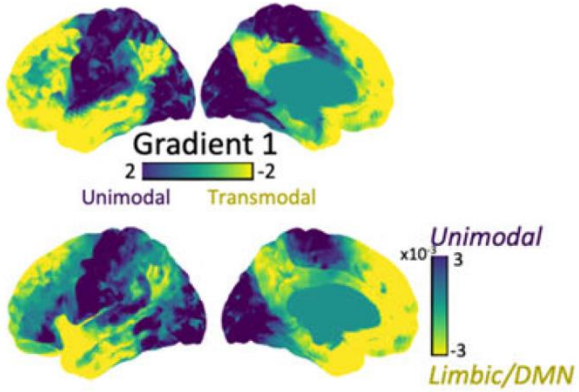


Bryant & Whyte, *In Preparation*

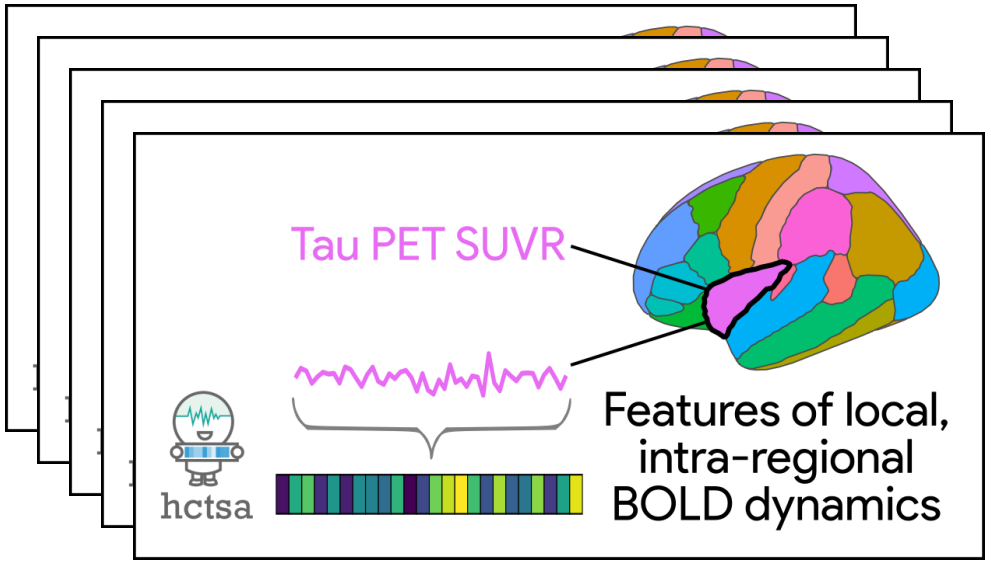
My final PhD project: Comparing **spatially-resolved** associations between **resting-state brain activity** and **AD neuropathology**



FC + Tau Gradients



Ottoy et al. *Nat Comms* (2024)

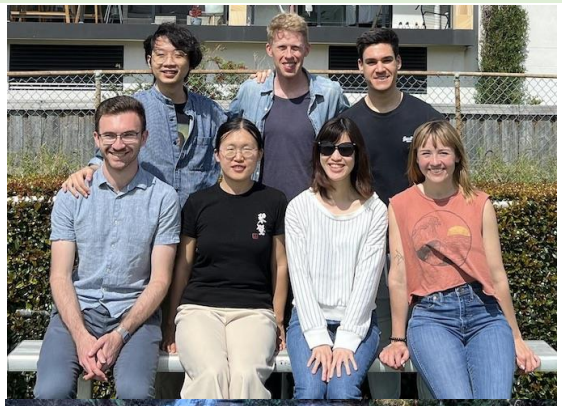


N=346 participants from the Anti-Amyloid Treatment in Asymptomatic Alzheimer's **(A4) study**

💡How does the accumulation of Alzheimer's disease **neuropathology** relate to **region-specific alterations** to **brain dynamics**?

Bryant et al., *In Preparation*

Thank you to the organizers and to my research groups 😊

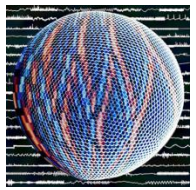


Dynamics & Neural Systems Group

Dr Ben Fulcher
Trent Henderson
Brendan Harris
Rishi Maran
Kieran Owens
Teresa Dalle Nogare
Aria Nguyen
Joshua Moore

Shine Lab

A/Prof Mac Shine
Eli Müller
Brandon Munn
Giulia Baracchini
Natasha Taylor
Gabriel Wainstein
Bella Orlando
Joshua Tan
Christopher Whyte
Chetan Gohil



THE UNIVERSITY OF SYDNEY

shinelab

PhD Funding Support from:

Australian Government

Australian Government Research Training Program

THE UNIVERSITY OF SYDNEY

The University of Sydney Physics Foundation

AMERICAN AUSTRALIAN ASSOCIATION Established 1948

The American Australian Association Graduate Education Fund

Annie G. Bryant
annie.bryant@sydney.edu.au
@anniegbryant