

Systematically comparing properties of local dynamics and pairwise coupling in the brain

Annie G. Bryant
31 May 2024

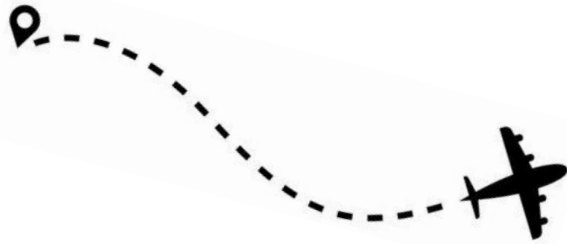


THE UNIVERSITY OF
SYDNEY





Boston, MA

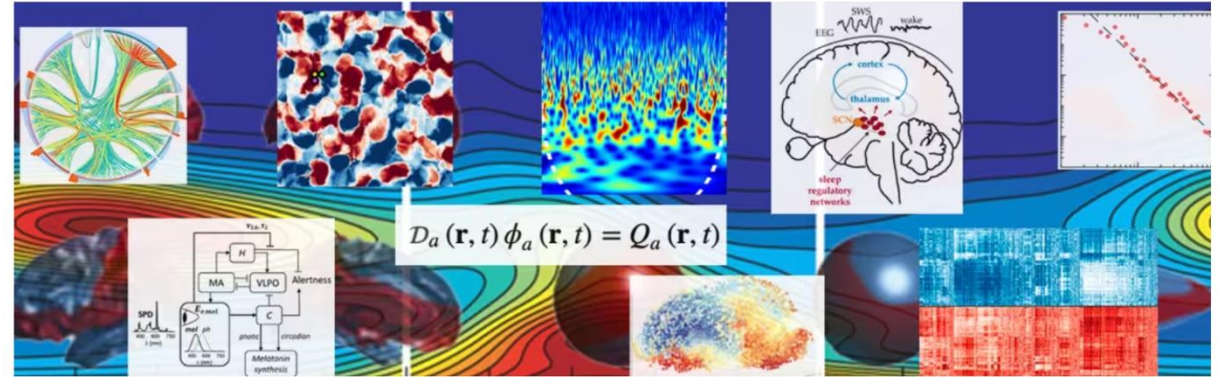


2022

 Sydney, NSW



Faculty of Science



← Home

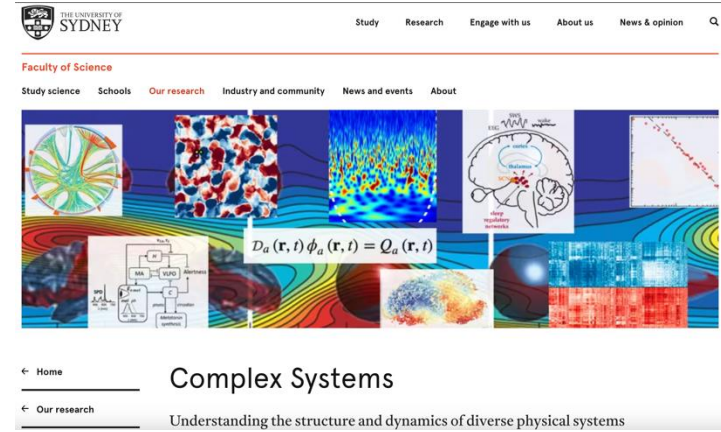
Complex Systems

← Our research

Understanding the structure and dynamics of diverse physical systems



Boston, MA



Sydney, NSW



- ← Home

- ← Our research

- ← Research centres
institutes and groups

- Institute of Agriculture

- Sydney Institute for
Astronomy ▶

Centres and institutes_

Centre for Complex Systems

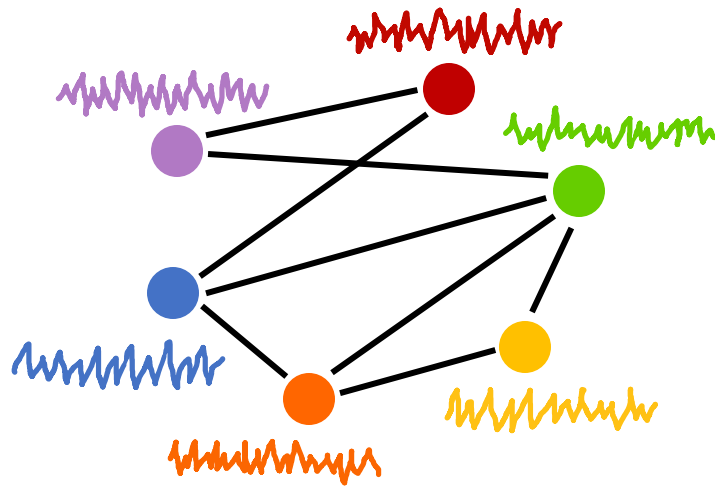
Exploring complex natural and artificial systems

We study collective behaviours and critical phenomena in various contexts: brain dynamics, computational epidemiology, urban and social dynamics, swarm intelligence, distributed computation, systems biology and nanoscience.

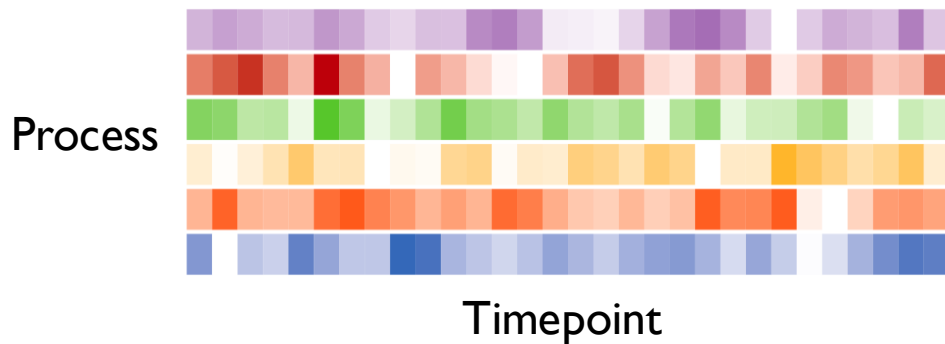
[Our symposia](#)
→

Complex systems are all around us!

Example complex system



Multivariate time series (MTS) representation



Fluid dynamics



Fluid dynamics: vortices, turbulence

Economics



National economy: economic growth, recession

Biology



Perception, movement

Complex systems

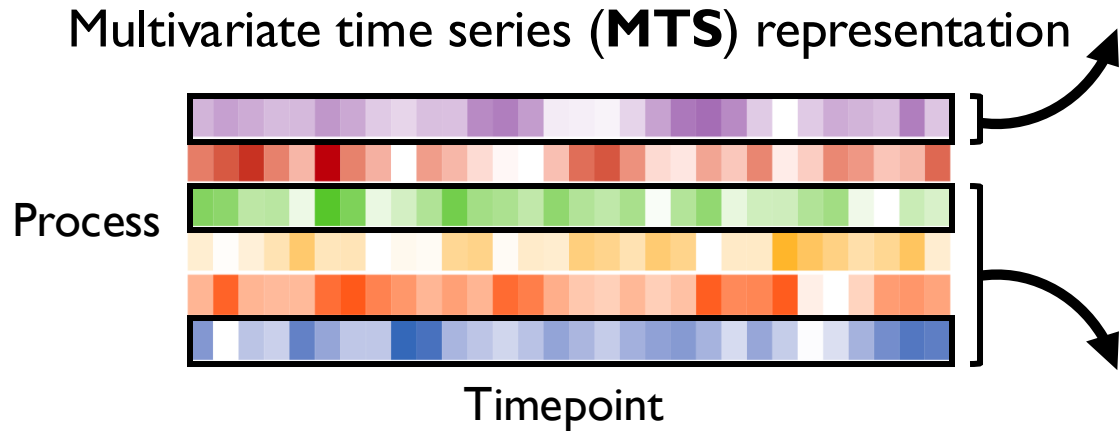


Many-body quantum systems: superconductivity, quantum entanglement

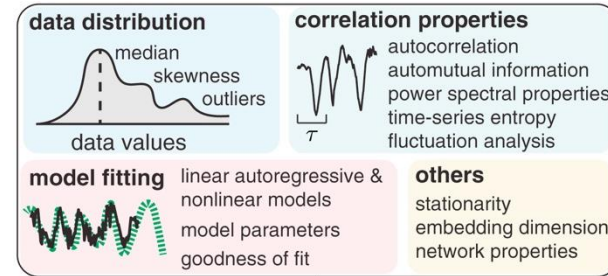


What does this **generalized MTS** representation offer us?

Localized dynamics of one process



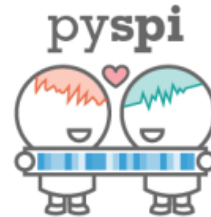
hctsa



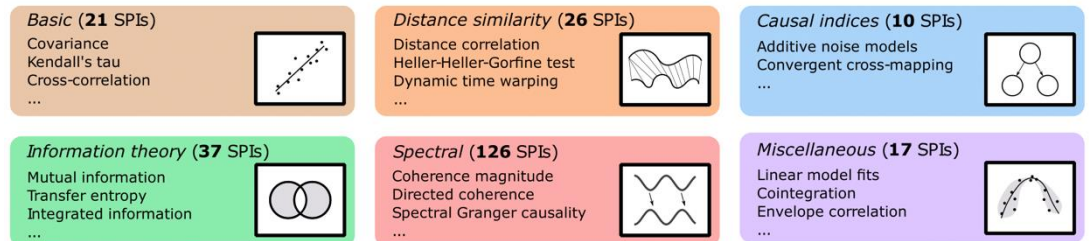
catch22

- 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)

What does this generalized MTS representation offer us?

Localized dynamics of one process



hctsa

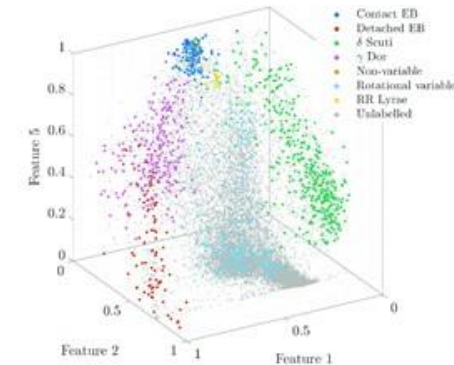
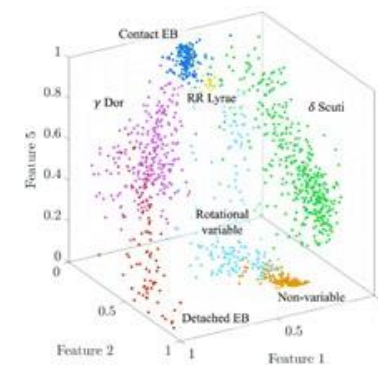
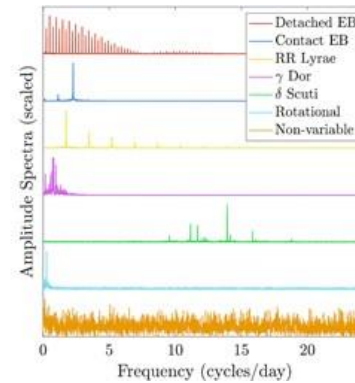
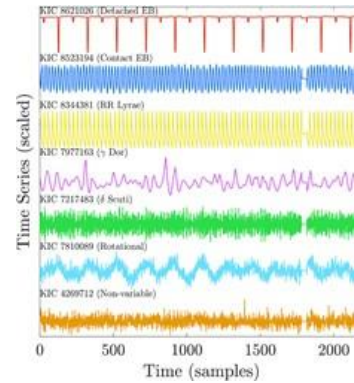
JOURNAL ARTICLE

Classifying *Kepler* light curves for 12 000 A and F stars using supervised feature-based machine learning

Nicholas H Barbara, Timothy R Bedding, Ben D Fulcher, Simon J Murphy, Timothy Van Reeth

Monthly Notices of the Royal Astronomical Society, Volume 514, Issue 2, August 2022, Pages 2793–2804, <https://doi.org/10.1093/mnras/stac1515>

Published: 02 June 2022 Article history



Statistical dependencies between pairs of processes



Article | Published: 25 September 2023

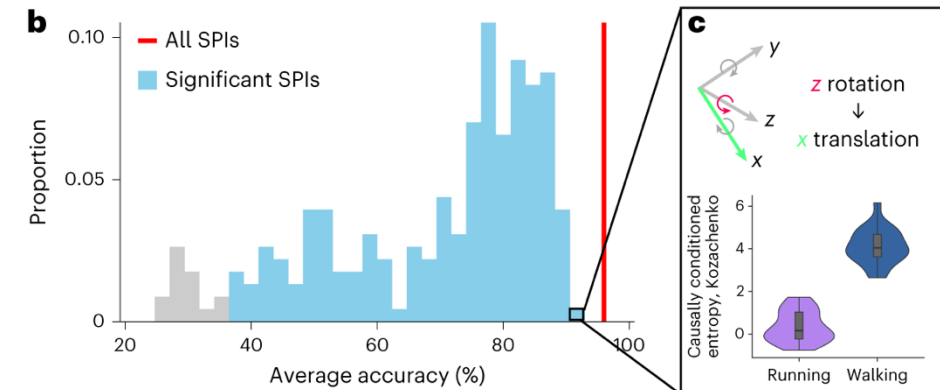
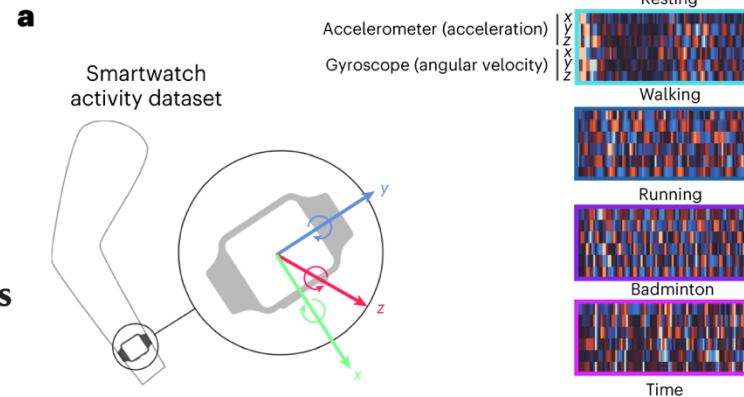
Unifying pairwise interactions in complex dynamics

Oliver M. Cliff, Annie G. Bryant, Joseph T. Lizier, Naotsugu Tsuchiya & Ben D. Fulcher

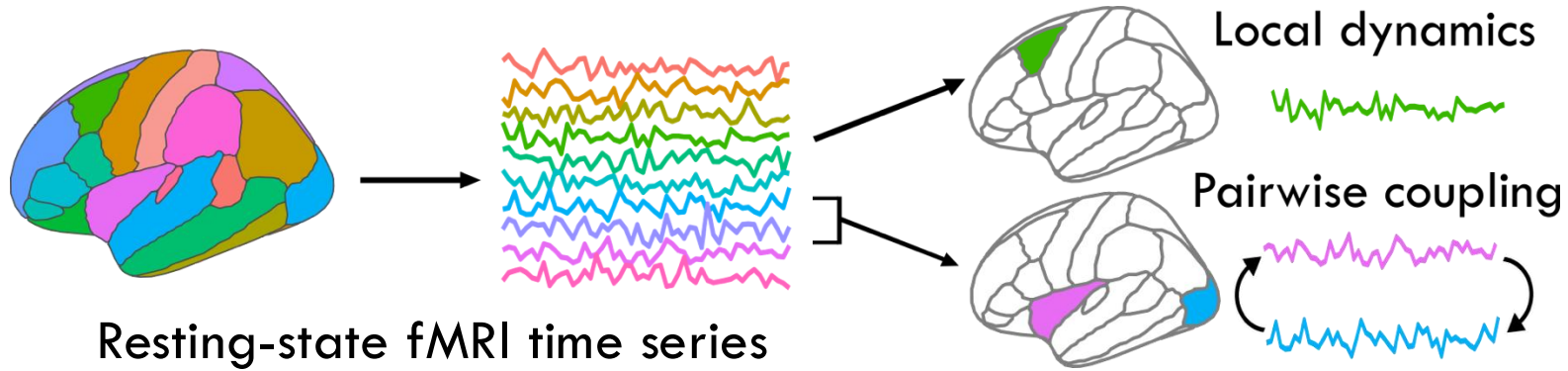
Nature Computational Science 3, 883–893 (2023) | [Cite this article](#)



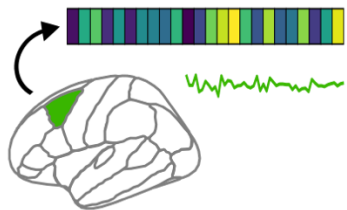
phyphox



Analyzing brain dynamics as a complex system

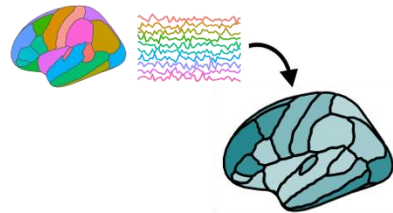


i. Local dynamics in an individual region



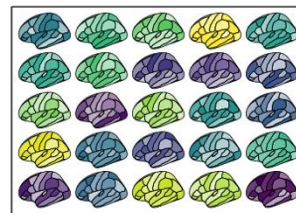
(A_{region})

ii. Whole-brain maps of an individual feature



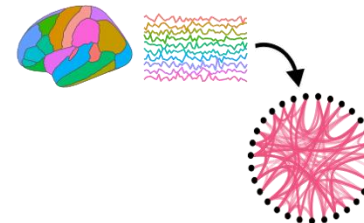
(A_{feature})

iii. Whole-brain maps of all features



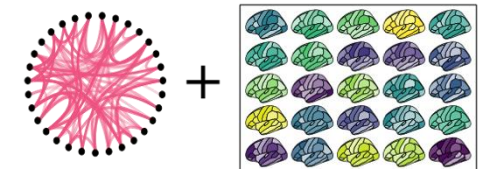
($A_{\text{uni_combo}}$)

iv. FC across all region pairs with one SPI



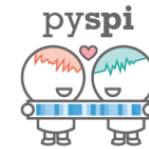
(A_{FC})

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

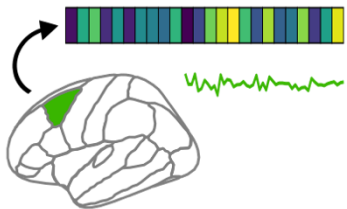


($A_{\text{FC_combo}}$)

Case study: classifying neuropsychiatric disorders

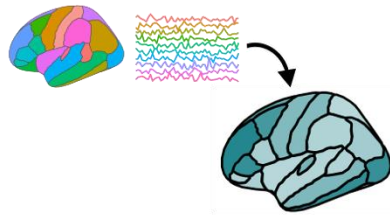


i. Local dynamics in an individual region



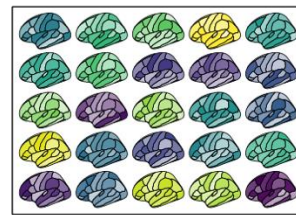
(A_{region})

ii. Whole-brain maps of an individual feature



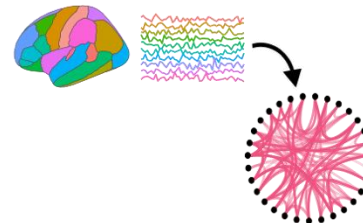
(A_{feature})

iii. Whole-brain maps of all features



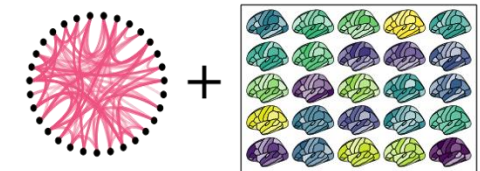
($A_{\text{uni_combo}}$)

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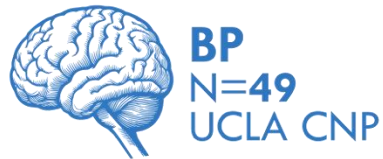


(A_{FC})

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



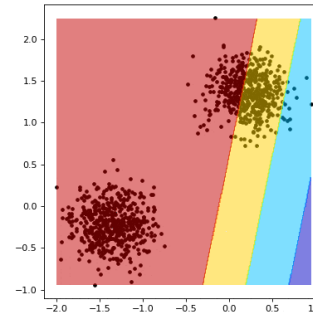
($A_{\text{FC_combo}}$)



Controls



Cases



Source: scikit-learn

Linear support vector machine (SVM)

- Balanced accuracy
- Inverse probability weighting

× 10-fold CV

× 10 repeats



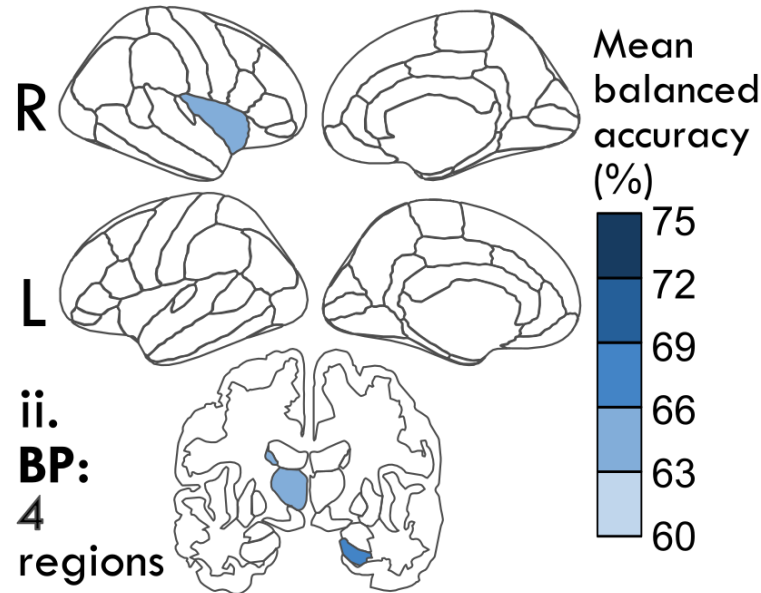
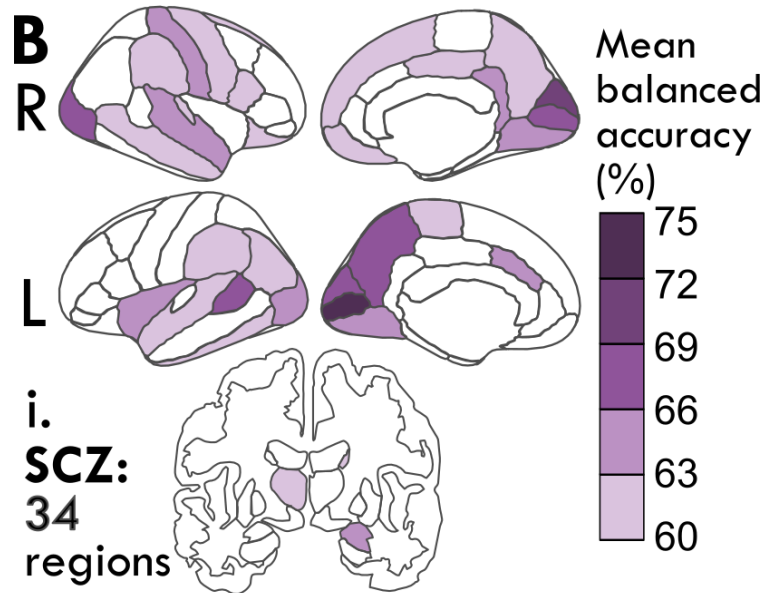
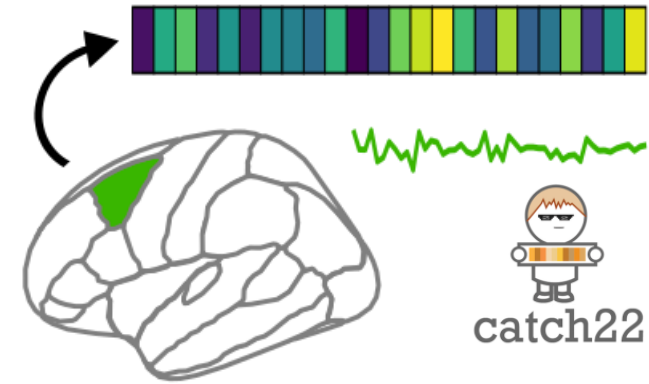
Data preprocessed by Traut et al. *NeuroImage* (2022)


Data preprocessed by Dr Kevin Aquino


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

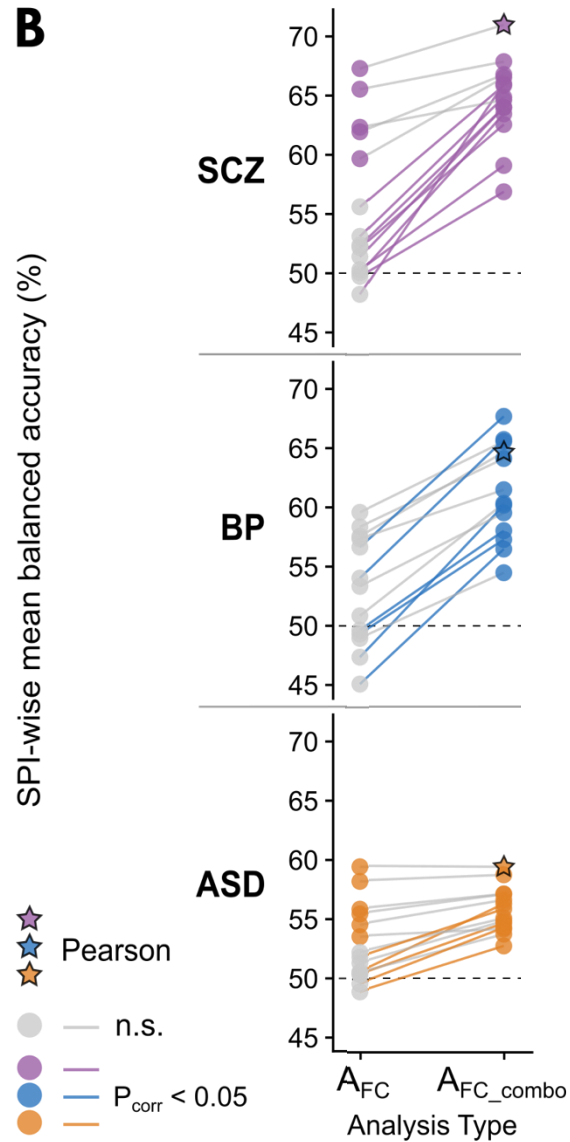


Gene expression 

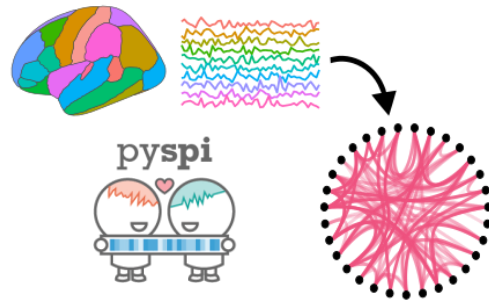
Anatomical changes 

Stimulation analysis 

The benefit of integrating local dynamics and pairwise coupling

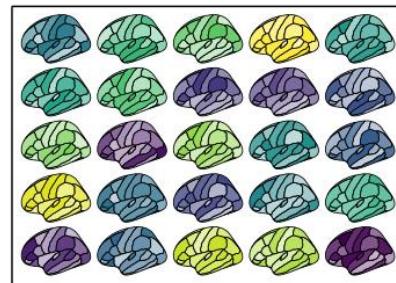


iv. FC across all region pairs with one SPI



+

iii. Whole-brain maps of all features



Most linear pairwise
functional connectivity metrics
are more informative
with the inclusion of
brain-wide maps of
local regional
dynamics

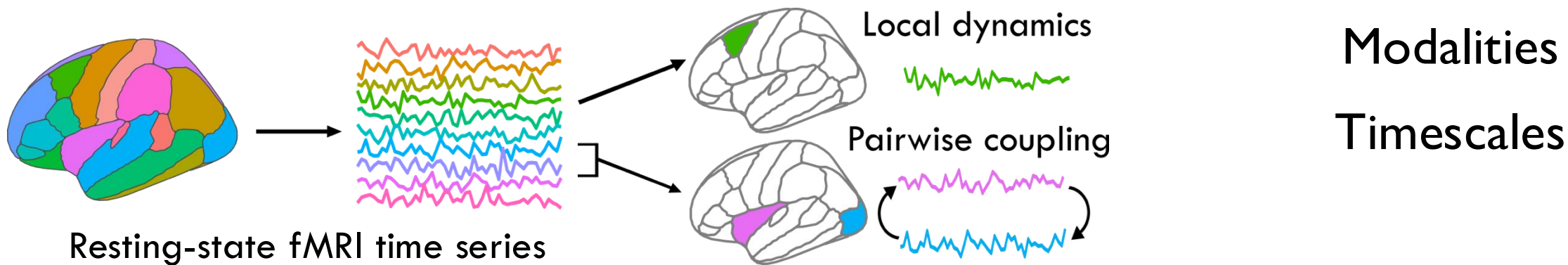


Bryant et al. *bioRxiv* (2024)

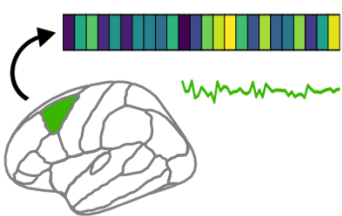
And for this reason.... my Shark Tank pitch 🤪



A flexible, generalizable framework for MTS data

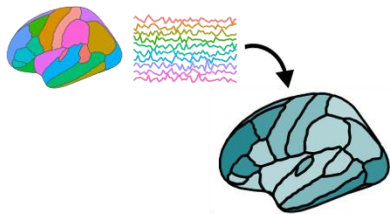


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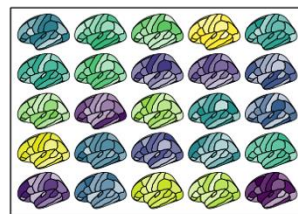
(A_{region})

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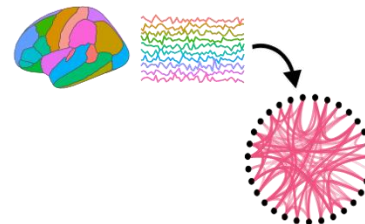
(A_{feature})

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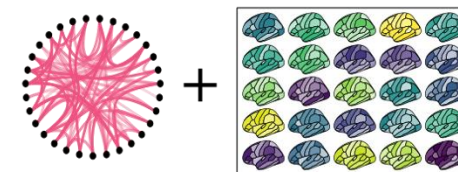
($A_{\text{uni_combo}}$)

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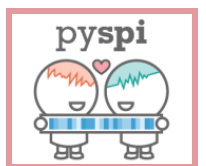
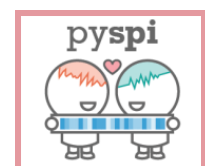
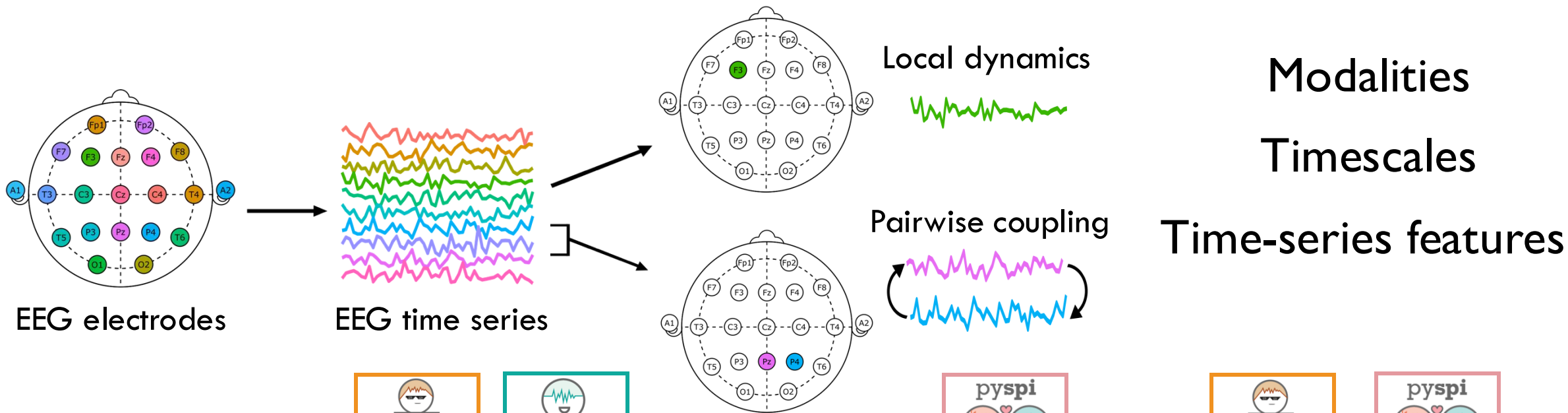
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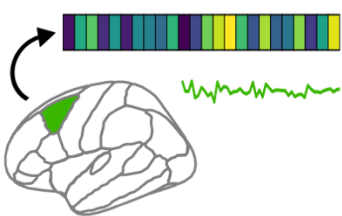


($A_{\text{FC_combo}}$)

A flexible, generalizable framework for MTS data

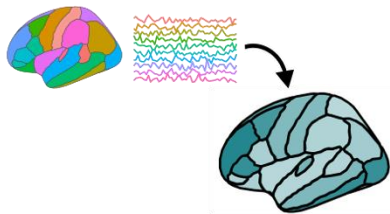


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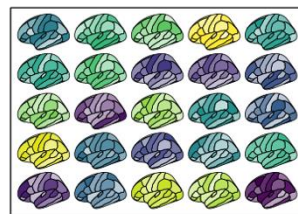
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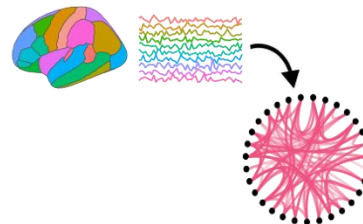
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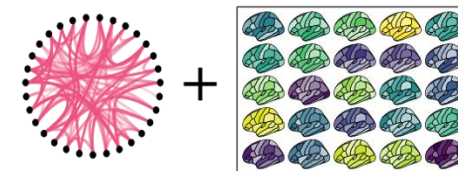
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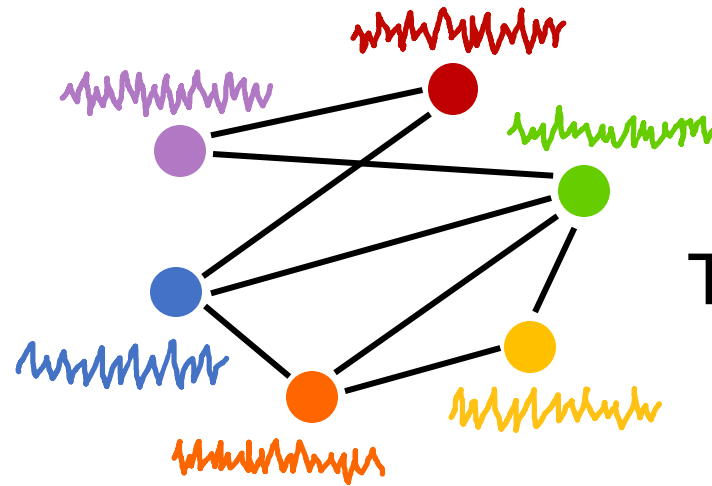
A flexible, generalizable framework for MTS data



How does the **local spin** of each atom relate to **exchange interactions** between neighbouring spins, in the context of **magnetic ordering**?



How does the **movement of individual fluid particles** relate to pressure and viscous forces between pairs of particles, in the context of fluid dynamics like turbulent flows?



Modalities

Timescales

Time-series features

Domains



How does the **movement of individual colloidal particles** relate to van der Waals and electrostatic forces between pairs of particles, in the context of phase behaviour in colloidal systems?

Thank you for the invitation & for your time 😊



Check out our preprint if ya keen



Fulcher Lab, The University of Sydney

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Trent Henderson Brendan Harris
Kieran Owens Joshua Moore

Systems Neuroscience & Psychopathology Lab, Rutgers University

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Brain Key Inc.

Kevin Aquino

NSB Lab, Monash University

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Brandon Munn Gabriel Wainstein Chris Whyte
Eli Mueller Bella Orlando

Systems Neuroscience Group, The University of Newcastle

Prof Michael Breakspear Joseph Giorgio

PhD funding support from:



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The American Australian
Association Graduate
Education Fund