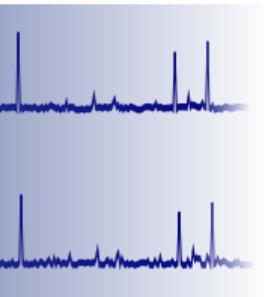
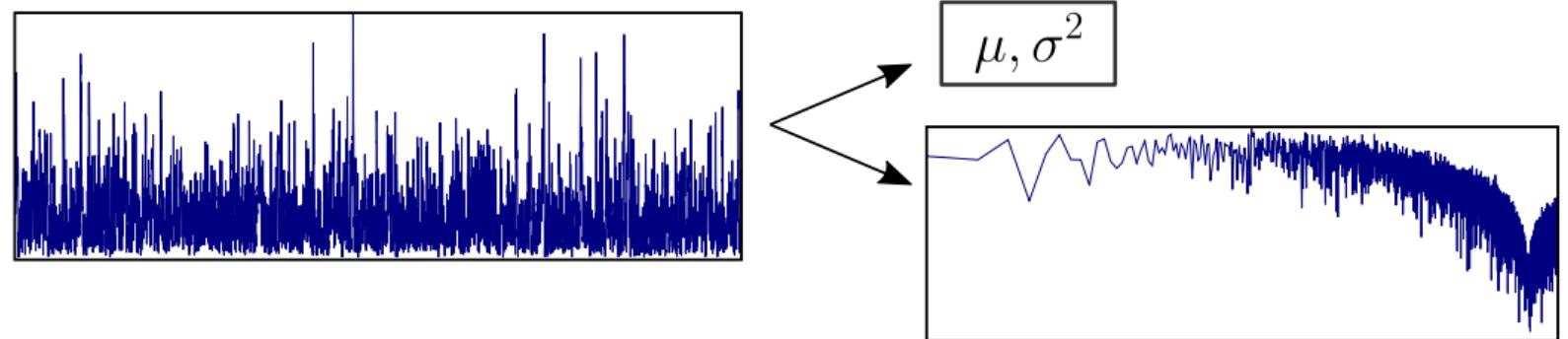
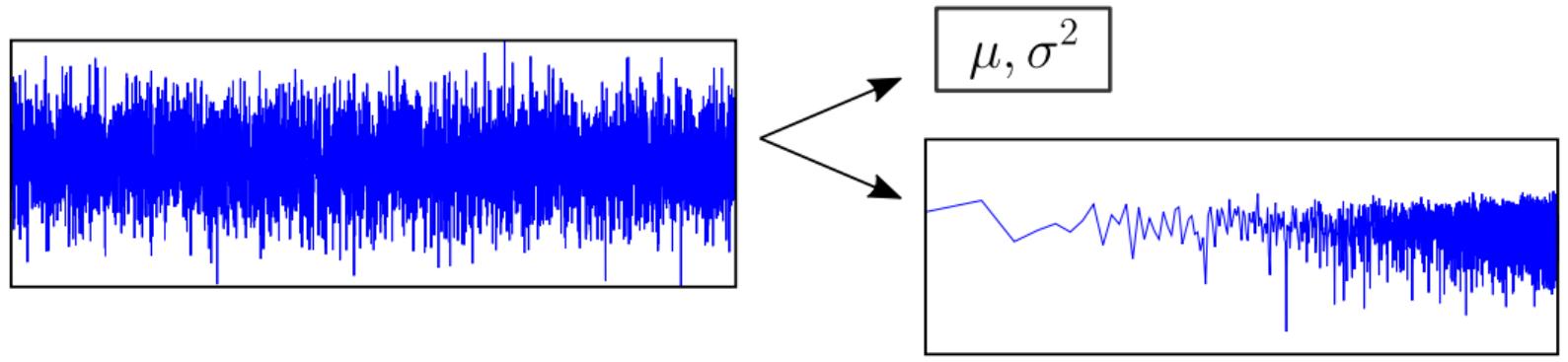


Physics PhD Workshop
December 2nd 2020



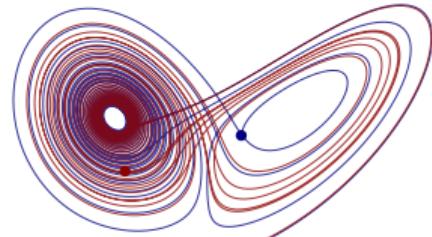
Michele Castelluzzo
Chasing nonlinearity in experimental time series

Why nonlinear analysis?



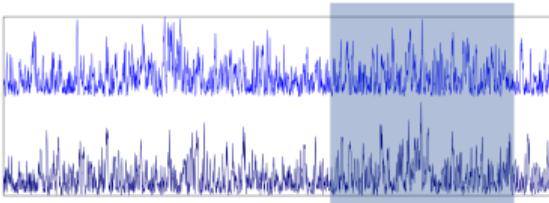
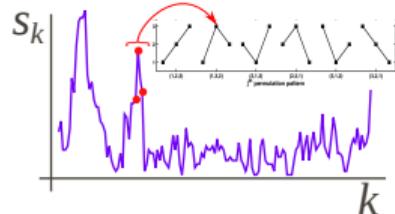
Two sides of the coin

Methods



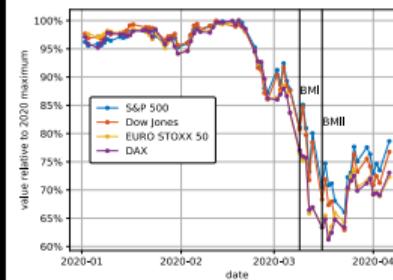
Lyapunov Exponent

Permutation Entropy

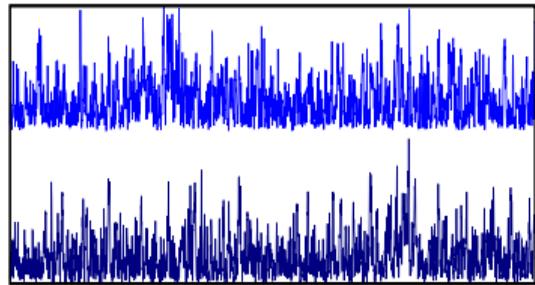


Cross-correlation

Applications



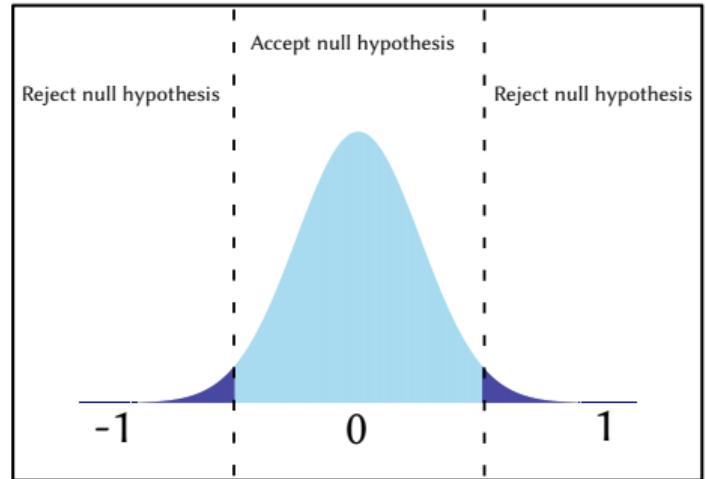
Assessing significance of a statistic



Pearson
correlation
coefficient

$$\rightarrow \rho \rightarrow$$

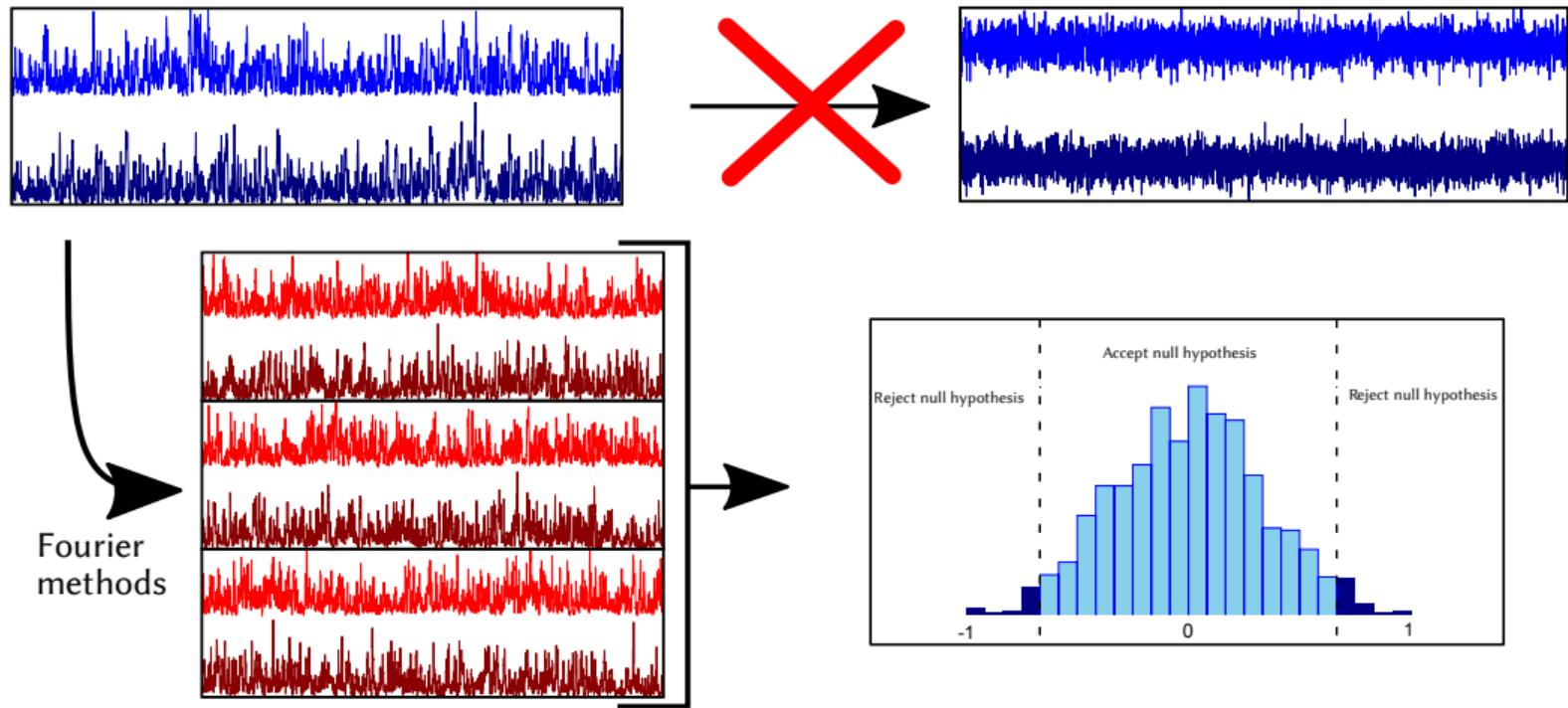
@ normality:



$$\rho(\tau) = \frac{C_{nm}(\tau)}{\sqrt{C_{nn}(0) C_{mm}(0)}}$$

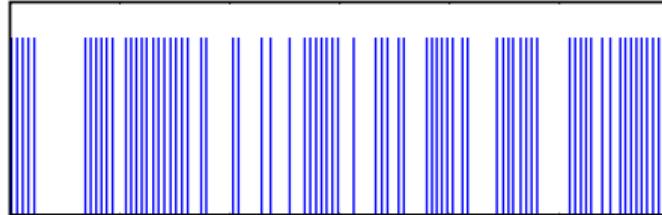
$$C_{nm}(\tau) = \delta x_n[i] \delta x_m[i + \tau]$$

Method of surrogates

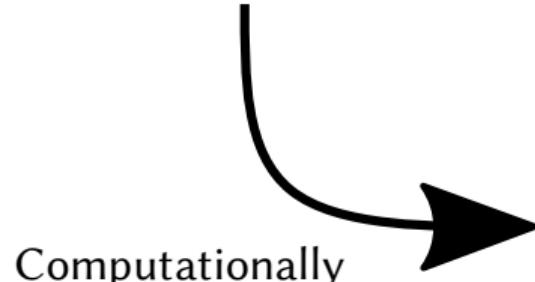
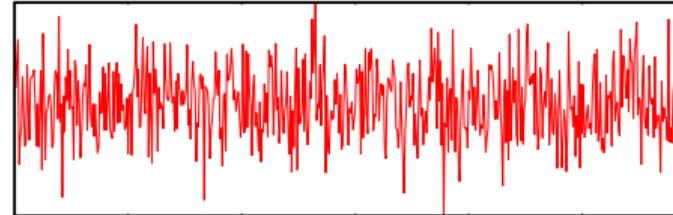


Fourier
methods

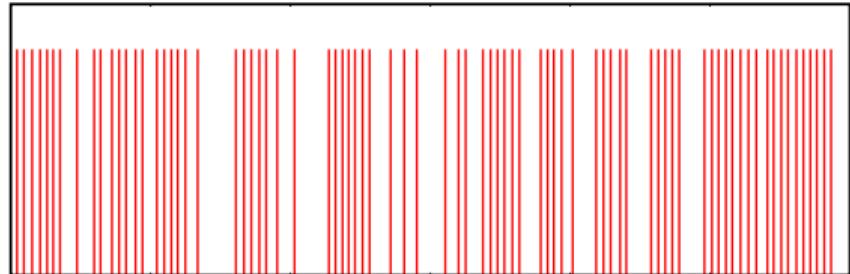
Issue: surrogates of IEI



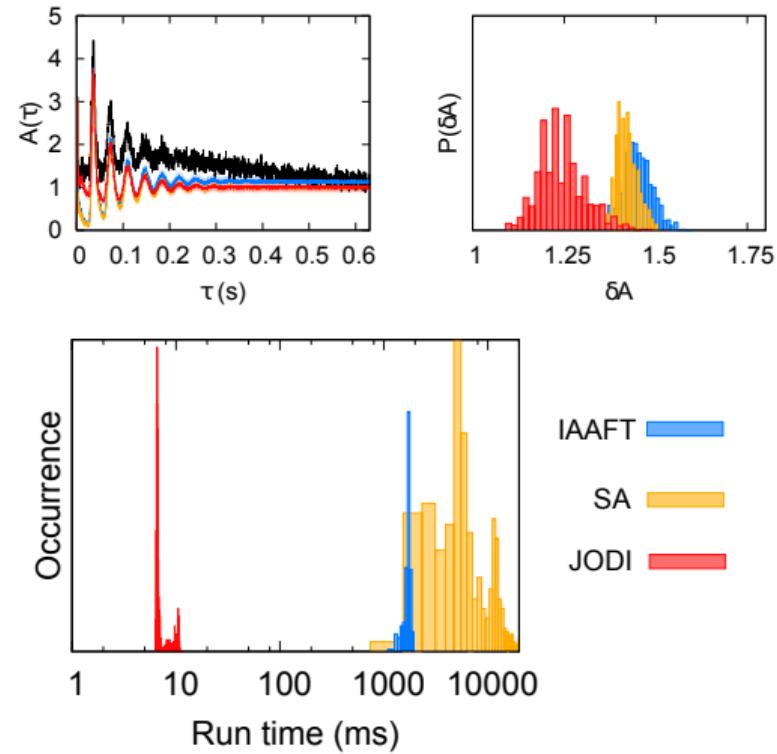
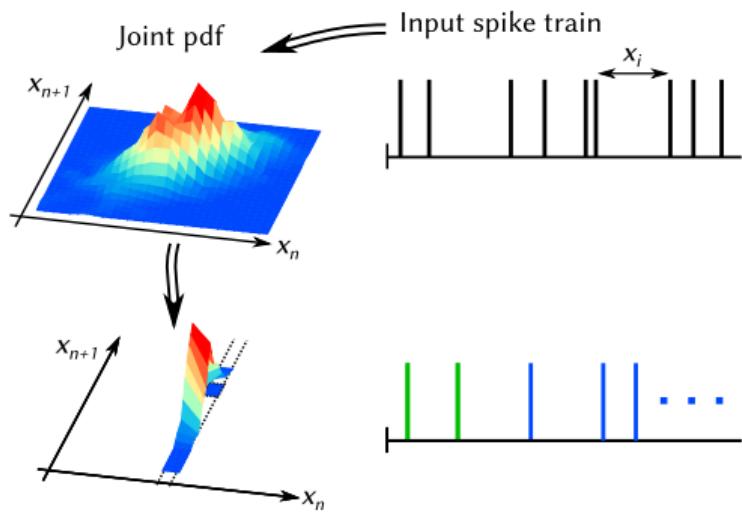
~~Fourier
methods~~



Computationally
expensive methods

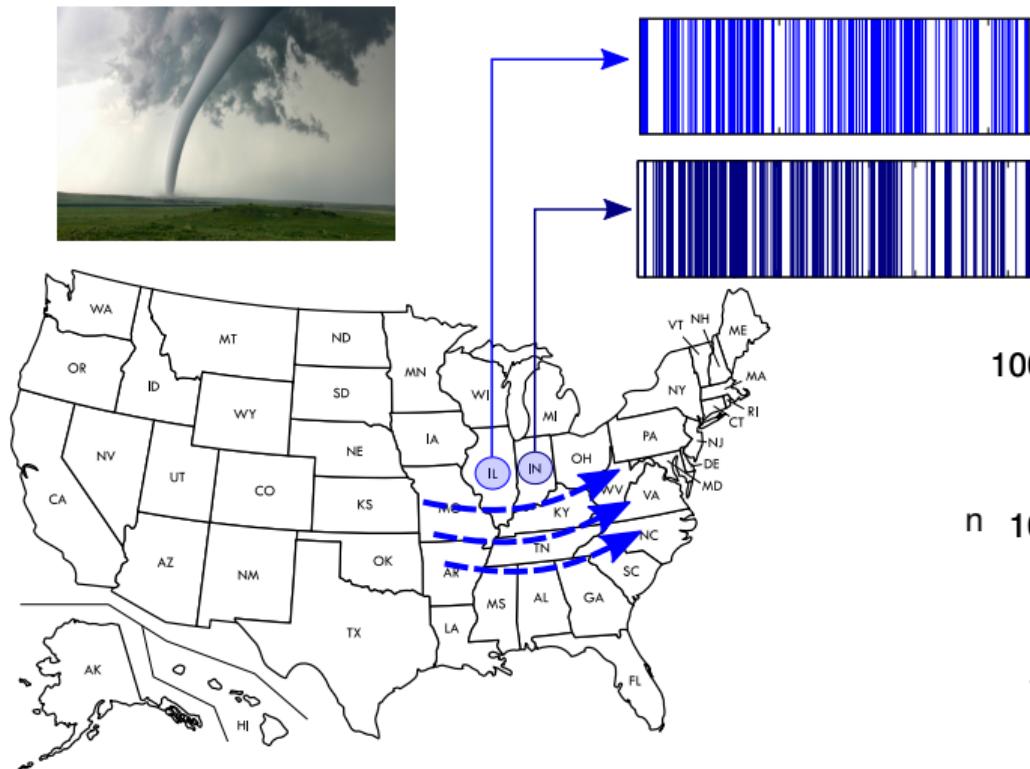


Our solution: JODI¹



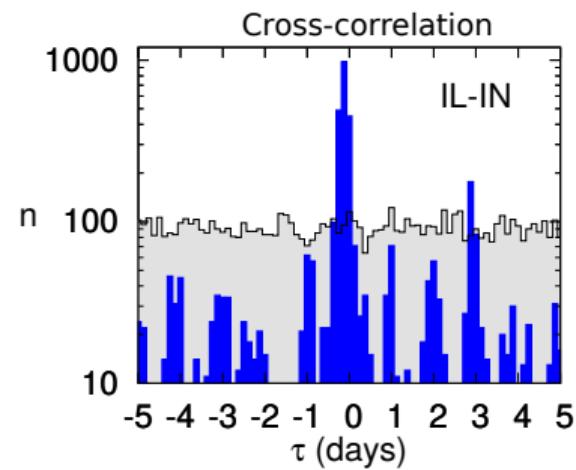
¹L. Ricci, M. Castelluzzo, L. Minati, A. Perinelli, in *Chaos*, 29, 121102 (2019)

Using JODI: tornadoes²



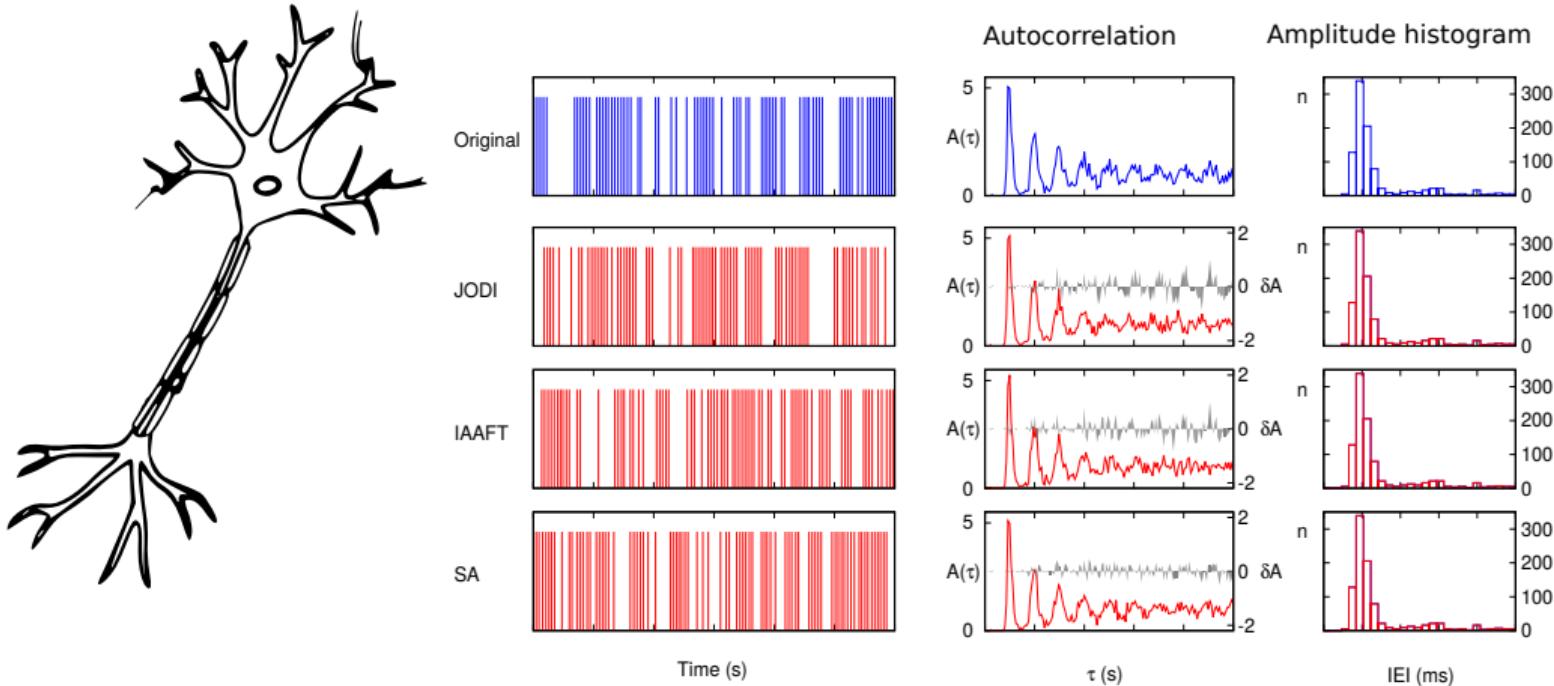
2h-delay correlation between
tornadoes in Illinois and Indiana states

Compatible with **50-100 km/h**
weather fronts speed



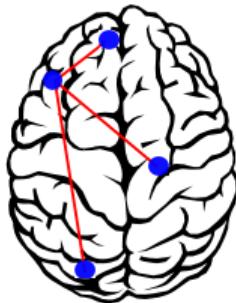
² A. Perinelli, M. Castelluzzo, L. Minati, L. Ricci, in *Chaos*, 30, 073120 (2020)

Using JODI: giant squid axon firing³



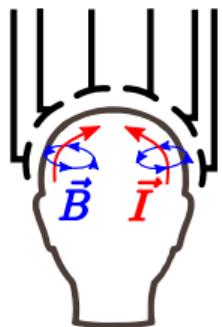
³ A. Perinelli, M. Castelluzzo, L. Minati, L. Ricci, in *Chaos*, 30, 073120 (2020)

One application: brain networks

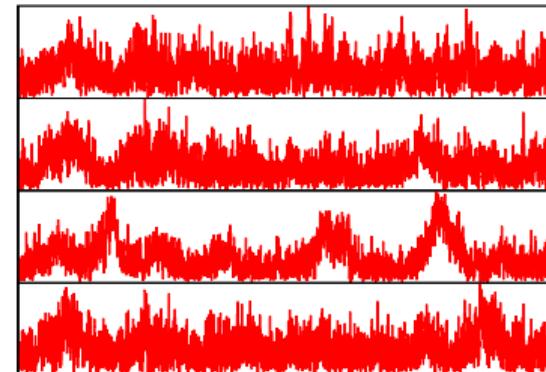


Correlation between
brain regions

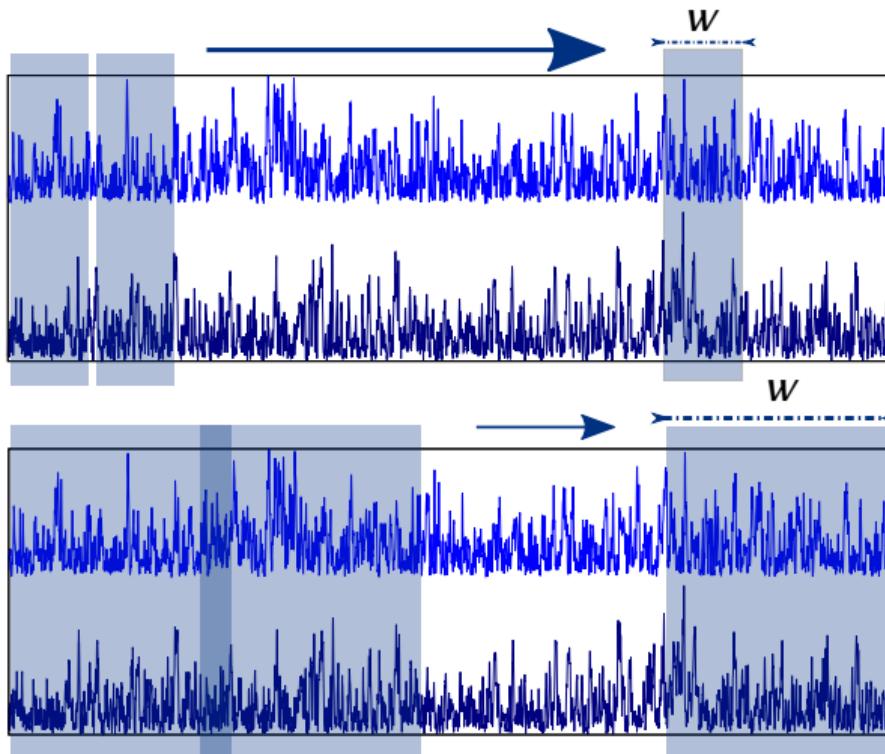
MEG recording



Source
reconstruction

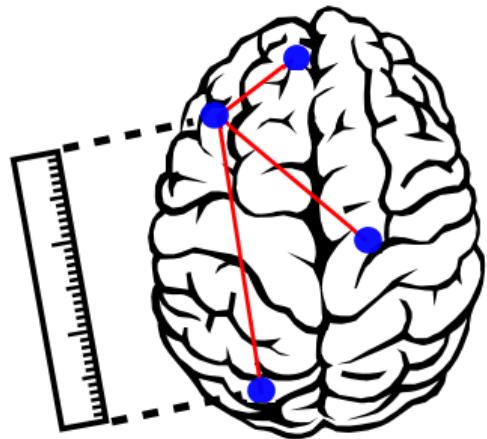


Time scale of observation

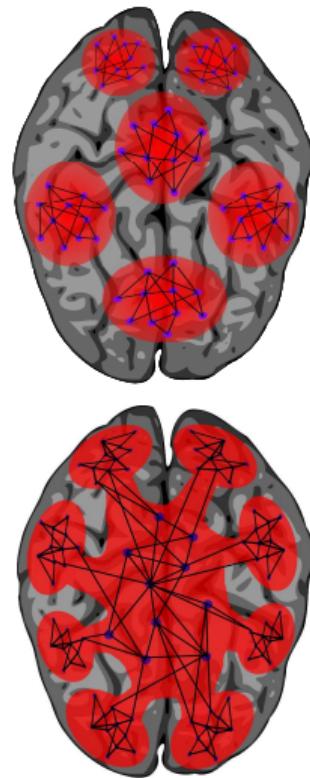


Time scale of observability W :
minimum w with >50% of
significantly correlated
windows

Significance evaluated
via surrogates method



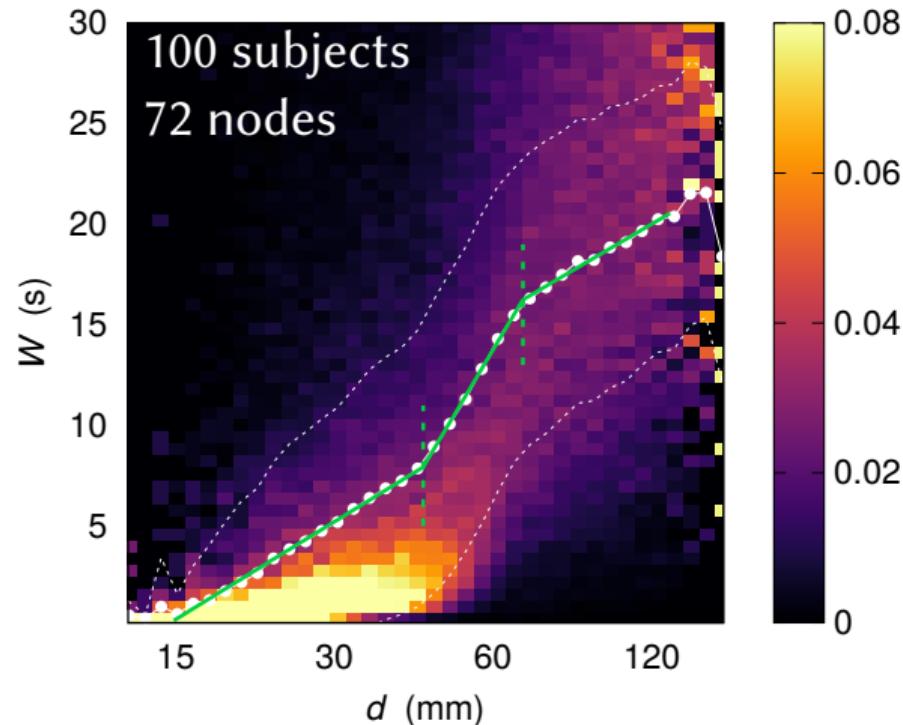
Geometric distance



Metabolic cost of
sustaining links:
wiring cost

Complexity,
needed to perform
cognitive tasks

Time scale vs. log(Distance)



Future development:

- intra- vs cross-hemispheric communication;
- age and neurodegenerative diseases

M. Castelluzzo, A. Perinelli, D. Tabarelli, L. Ricci,
in *Frontiers in Physiology, Special Issue: Fractal and Network Physiology*
(under revision)

Thank you!



My partners in crime:



Leonardo Ricci
Alessio Perinelli



Davide Tabarelli