# Large-scale synchronization of cortical oscillations on the human connectome

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## **Noise** can counterintuitively **synchronize** dynamics on the **human connectome**, driven by the brain's **hierarchy of activity timescales** and **heterogeneous connectivity**

## CORTICAL SYNCHRONIZATION

- Mechanism for communication of functionally specific brain regions from mutual interactions between local oscillatory units
- Excess or deficit results in pathologies (e.g., epilepsy, Parkinson's disease)

## STRUCTURE–FUNCTION

- How does the unique structure of the human connectome shape neural dynamics (function)?

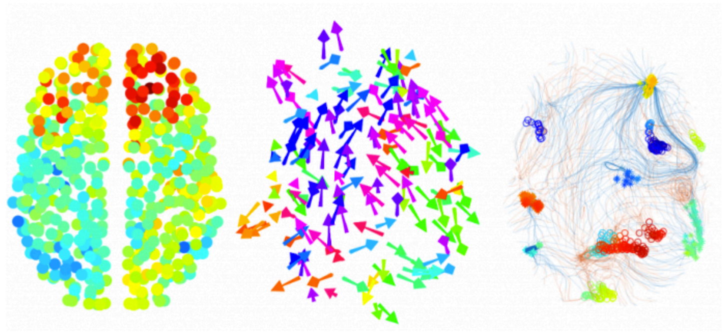


Figure 1: Example of how the brain's structure-function coupling leads to global brain waves (Roberts et al. 2019).

## STOCHASTIC EFFECTS

- Studies have found a counterintuitive effect, called stochastic resonance, where global perturbations can improve system performance

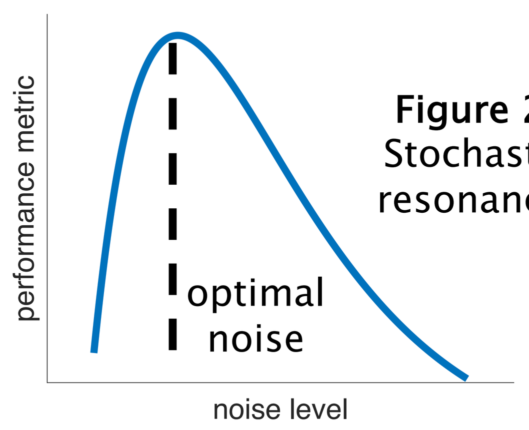



Figure 2: Stochastic resonance.

## OBJECTIVES

- Develop a computational model to study how the brain's structure-function coupling leads to patterns of large-scale cortical synchronization
- Investigate stochastic synchronization on the human connectome and tease out its driving mechanisms

## METHODS

- Each brain region has a local oscillatory phase with dynamics governed by the Kuramoto model

*phase* — *coupling strength* — *white noise strength*

$$d\theta_j = \left[\omega_j + c\sum_{k=1}^{N} C_{jk}\sin\left(\theta_k - \theta_j\right)\right]dt + \sigma\eta_j(t)$$

*natural oscillation frequency* — *structural connectivity matrix*

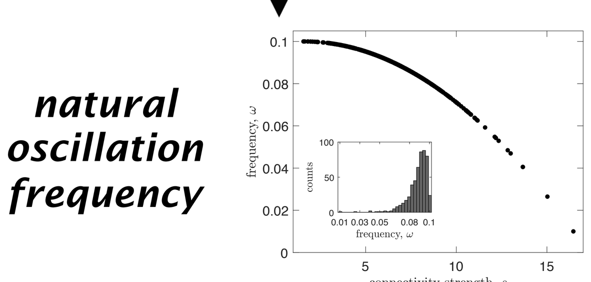


Figure 3: Hierarchy of timescales (Cocchi et al. 2016).

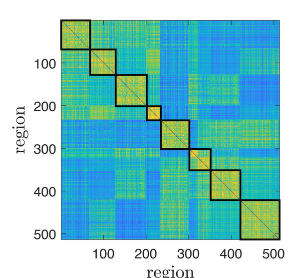
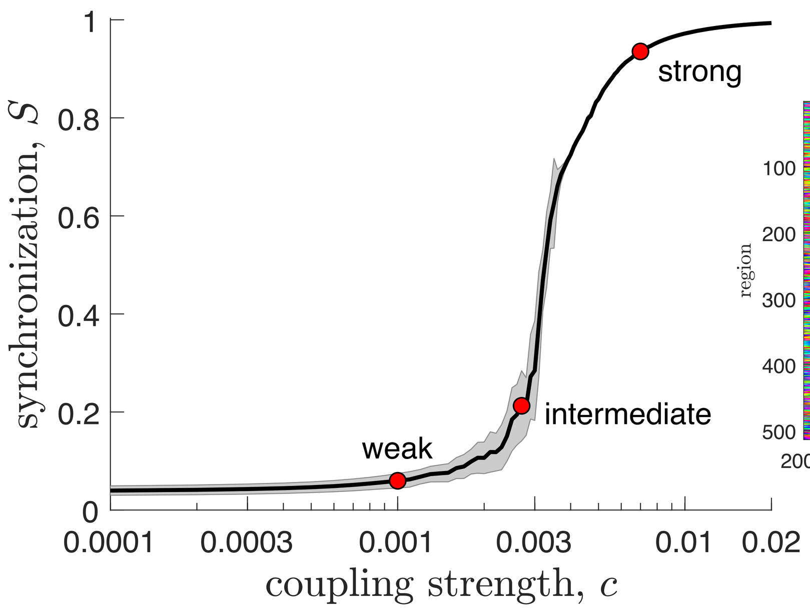


Figure 4: Healthy connectome (Roberts et al. 2016).

## RESULTS: *SYNCHRONIZATION PATTERNS*



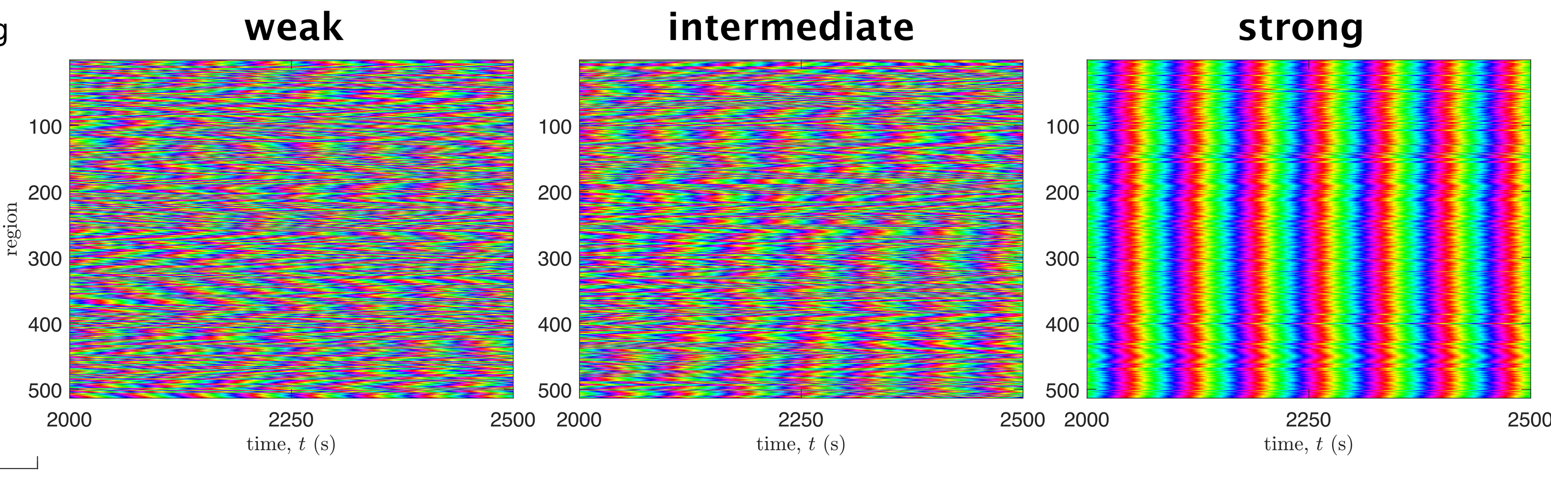
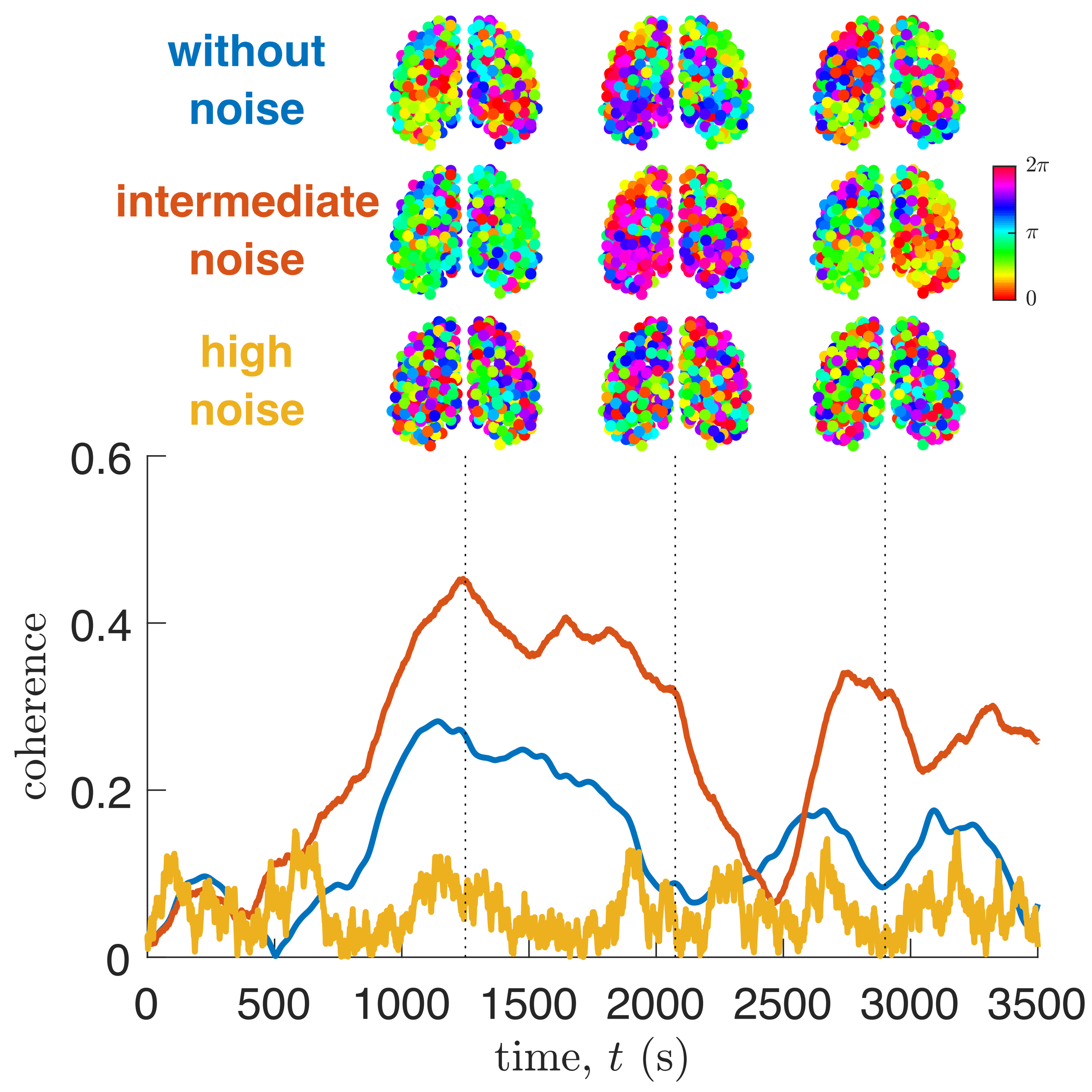




Figure 5: Synchronization for different coupling strengths.

## RESULTS: *STOCHASTIC SYNCHRONIZATION*



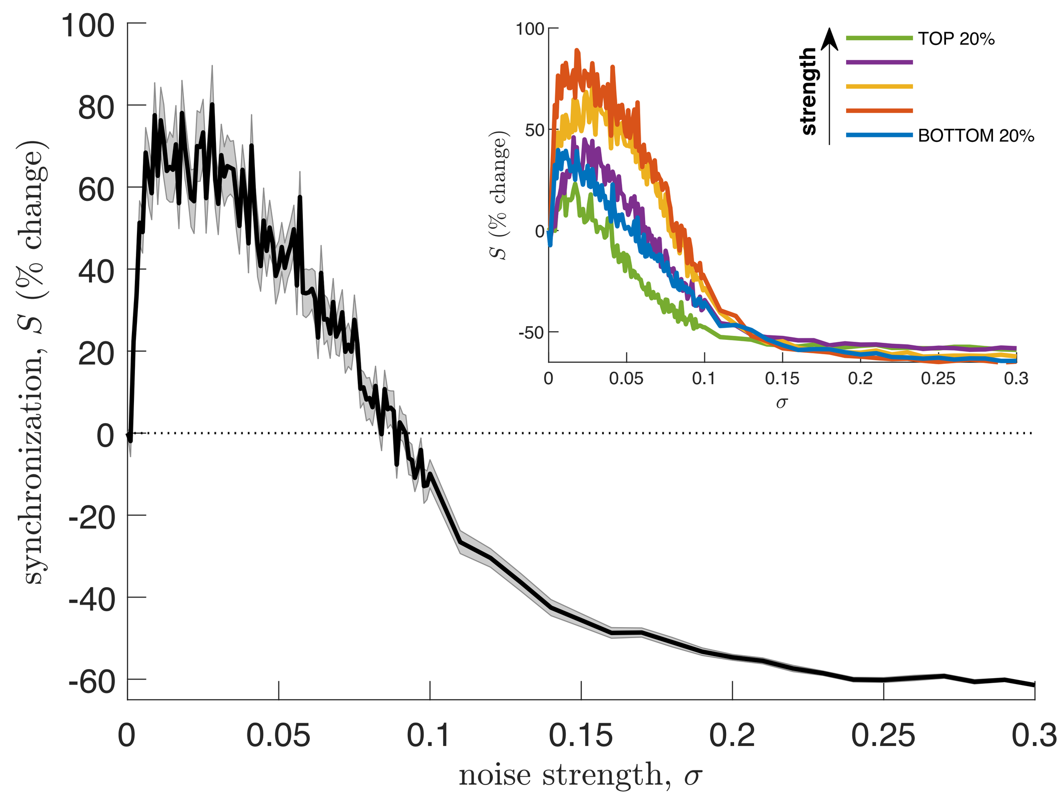




Figure 6: (Left) Global coherence for three noise regimes. (Right) Percent change of synchronization [global and locally within networks partitioned according to connectivity strength].

## RESULTS: *MECHANISMS*

### 1. Role of hierarchy of timescales

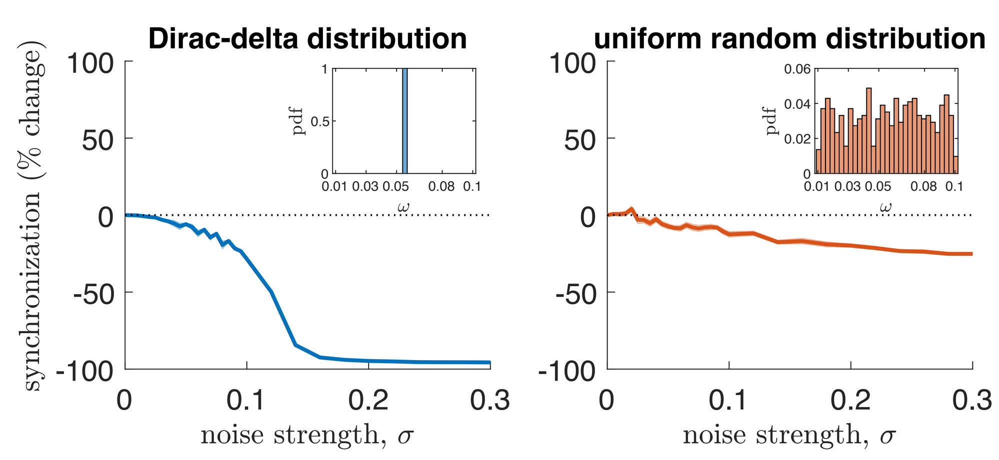



Figure 7: Synchronization for other distributions of frequency.

### 2. Role of connectome's heterogeneity

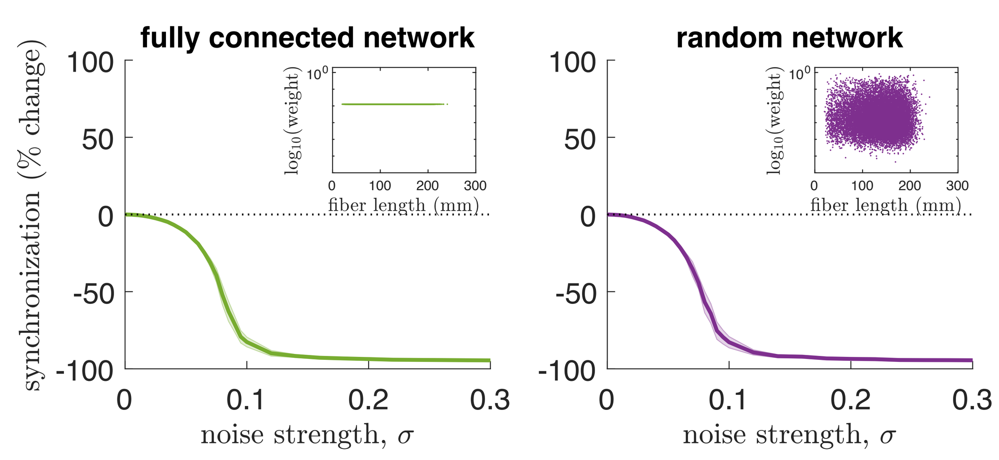



Figure 8: Synchronization for other connectivities.

### 3. Amalgamation of phase clusters

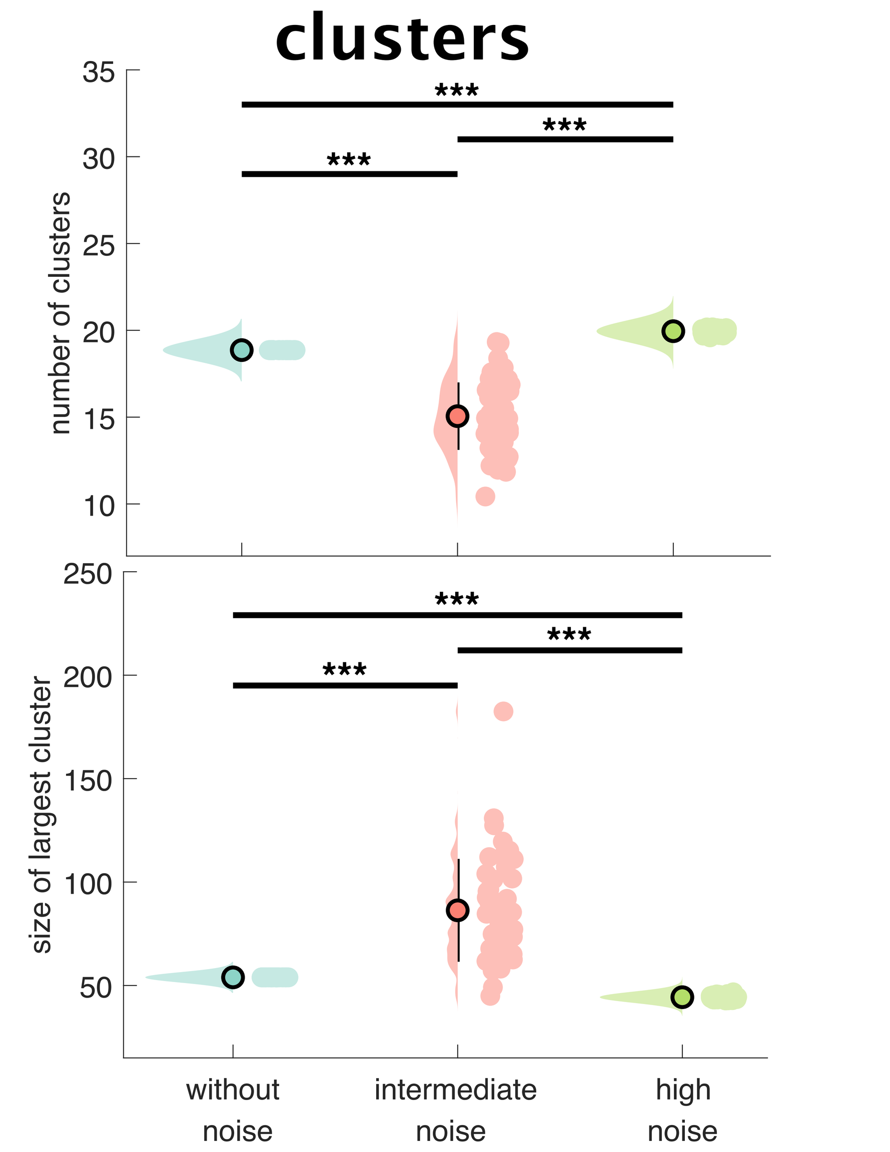



Figure 9: Cluster formations for three noise regimes.

References:
[1] Roberts et al., *Nature Communications*, vol. 10, 2019.
[2] Cocchi et al., *eLife*, vol. 5, 2016.
[3] Roberts et al., *NeuroImage*, vol. 124, 2016.

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