MESOSCOPIC THEORY FOR COUPLED STOCHASTIC OSCILLATORS

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The celebrated Ott-Antonsen ansatz for coupled oscillators provides a useful framework for working with deterministic systems in the thermodynamic limit, but it fails to capture many features of stochastic systems. Several solutions have been recently proposed to accurately describe the behaviour of the order parameters in coupled oscillator systems. However, a fluctuating description of such order parameters has been still elusive. I constructed for the first time a general mesoscopic description of finite-size populations of oscillators subject to white noise. The theory allows one to derive Langevin equations for the Kuramoto-Daido order parameters, opening the door to study features of synchronization phase transitions and finite-size effects, which were inaccessible before. The analysis of the fluctuations in the stochastic Kuramoto model uncovered highly accurate, closed analytical expressions for the average Kuramoto order parameter which outperforms previous approaches. In this talk, I will show how to derive the exact fluctuating theory for systems of coupled oscillators and its implications for theoretical neuroscience, from individual neurons to whole-brain neural mass models.

[1] V. Buendía, Mesoscopic theory for coupled stochastic oscillators, *Phys. Rev. Lett.* **134**, 197201 (2025).

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