



Title of the Talk

Myfirstname A. Myname¹, Herfirstname B. Hername², Hisfirstname C. Hisname^{1,2}

¹Sample institute, sample city, sample country

²Sample institute, sample city, sample country

The study of emergent collective phenomena in interconnected systems lies at the heart of modern nonlinear science, bridging complex networks, dynamical systems, and statistical physics. In this work, we investigate the interplay between intra-layer and inter-layer coupling strengths in a multiplex network of nonlocally coupled phase oscillators. The governing dynamics for the i -th oscillator in layer α is given by

$$\dot{\theta}_i^\alpha = \omega_i^\alpha + \lambda \sum_{\beta=1}^L \sum_{j=1}^N \sigma_{\alpha\beta} A_{ij}^{\alpha\beta} \sin(\theta_j^\beta - \theta_i^\alpha - \alpha),$$

where $A_{ij}^{\alpha\beta}$ denotes the adjacency matrix representing connections within and across layers, λ is the overall coupling strength, and $\sigma_{\alpha\beta}$ modulates the relative coupling between layers. We systematically explore how the multiplex topology influences the emergence of chimera states - fascinating hybrid patterns where synchronized and desynchronized domains coexist.

Using the Master Stability Function (MSF) formalism, we derive the linear stability conditions for the fully synchronized state. The variational equation reduces to a set of decoupled eigenvalue problems in the eigenspace, allowing us to compute the maximum transverse Lyapunov exponent as a function of the inter-layer coupling. Our analytical predictions are validated through extensive numerical simulations on diverse network architectures, including scale-free, Erdős–Rényi, and small-world topologies. We find that the inter-layer coupling can both suppress and promote synchronization, depending on the spectral properties of the supra-adjacency matrix.



Figure 1: Figure caption here.

A striking observation is the re-entrant transition to synchronization: for intermediate values of the inter-layer coupling, the system loses synchrony and exhibits multi-clustered chimera patterns, while strong coupling restores global coherence. This non-monotonic behavior is rooted in the competition between the intra-layer coupling that favors local order and the inter-layer coupling that introduces heterogeneity. We further characterize the chimera states using the local order parameter and the strength of incoherence, identifying regimes where the chimera is stationary versus breathing (oscillatory). Our results provide a robust framework for understanding asymmetrical dynamical patterns in real-world multiplex systems, ranging from neuronal networks to power grids and social contagion processes.

Bibliography

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