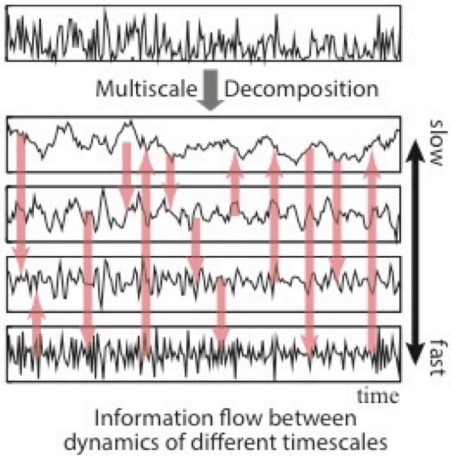
Study of Causality and Information Flows in Multivariate Time Series from Real Complex Systems

Background: Is it possible to detect causal relations/information flows in a complex system only based on the observed time series? Can we identify which elements/components in the system affect or are affected by the others during the time course? What can the causal relations tell us about the system-level properties that conventional correlation analyses cannot tell? By employing the concept of transfer entropy (Phys. Rev. Lett., 85, 461 (2000)) developed in the context of information theory, this project provides an opportunity for the students to answer these questions by directly investigating multivariate time series from real complex systems in biophysics or finance.



To have a more concrete idea about the project, the figure on the right illustrates, for instance, a possible outcome of the study where a multiscale time series (e.g. a time series of protein dynamics) is decomposed into a hierarchy of time series each with a well defined but distinct dynamical timescale. Indicated by the red arrows in the figure, the information flows among the multiscale time series that are directional and in general time varying can be identified. The construction of such chart of information flow allows us to understand, e.g., how dynamics at different timescales talk to each other, how specific events in one time series are triggered by another, how the effects from fluctuations at different scales propagate inside the system, etc.

Project goals: 1) To understand, apply and generalize the concept of transfer entropy to detect time dependent driving/response components from multivariate time series in "real" biophysical or financial systems; 2) To practice various statistical techniques to analyze and model stochastic time series data; 3) To exercise trainings in logical thinking and scientific communication skills.

Remarks: Depending on the interests of the student, the time series to be studied can be chosen from a wide variety of disciplines, such as from molecular systems, neural systems, financial systems, etc.

Keywords: Information theory, transfer entropy, dynamical system, multivariate time series analyses.

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