26 - 30 June 2023
Belgrade, Serbia

21. СИМПОЗИЈУМ ФИЗИКЕ КОНДЕНЗОВАНЕ МАТЕРИЈЕ

THE 21st SYMPOSIUM ON CONDENSED MATTER PHYSICS

BOOK OF ABSTRACTS

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Vinca Institute of Nuclear Sciences
University of Belgrade, Faculty of Physics
Serbian Academy of Sciences and Arts
Ministry of Science, Technological Development and Innovation

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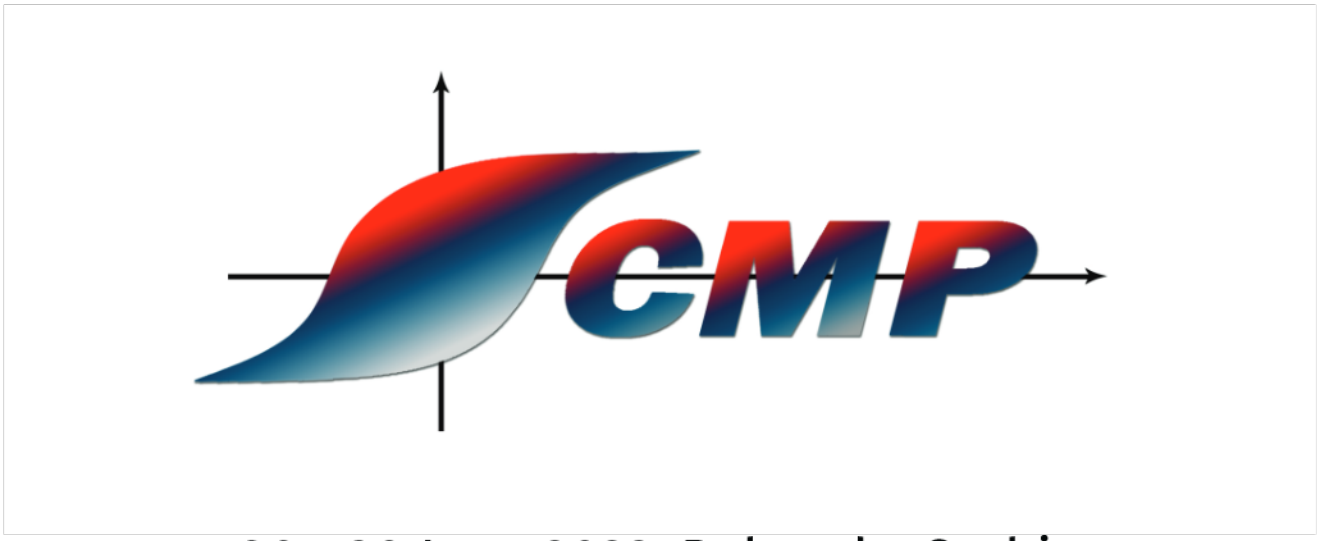

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Higher-order Connectivity Patterns in the Correlation Structure of Complex Systems

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Abstract. Detecting pertinent patterns in the collective behavior of complex system elements is challenging for the practical, as well as theoretical, understanding of a system's dynamics. To date, complex network research set a convenient framework for modeling the complexity of systems formed by elements linked through pairwise interactions. However, this approach may neglect the effects of non-pairwise interactions [1], which produce higher-order structures that underlie complex systems [2], and higher-order interactions among large groups of elements are essential in the system's functioning and dynamics. On the other hand, one of the ways to capture pairwise weighted interactions of system elements is the formation of the cross-correlation matrix. Nevertheless, extracting grouped interactions of elements as higher-order correlations from pairwise is a rather challenging task [3] due to the nonlinearity of collective behavior which characterizes the system. Toward overcoming this problem, and as an approximation, we propose a framework for extracting collective behavior embedded in connectivity patterns based on pairwise interaction by aggregating elements into higher-order structures called simplices. These objects build non-trivial, complex, layered structures and display rich structural properties. In a nutshell, the development of a system reconstruction from correlations between its elements, using the algebraic topological approach, begins by mapping the system onto a multidimensional object called a simplicial complex [4]. We use the case of the financial system to exemplify the outcomes of the approach. Within this context, the k-order connected clusters of elements within the correlation structure represent aggregations of system elements (i.e., firms) under the criteria of induced multidimensional similarity, hence transcending the binary correlations. For example, 2nd order connected clusters of correlation structure represent groups of firms that form connected chains of elements where two successive firms are significantly correlated to three common firms. The interpretation of the results of these aggregations suits the qualitative classification of firms into groups due to the industry they belong. Furthermore, the novel and mixed collections of firms are revealed based on the algebraic topological approach applied. Our approach sheds light on the higher-order organization of interactions embedded in the cross-correlation matrix and, as a consequence, extracts patterns of collective behavior within a complex system.

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