Seminar 12/6/2021

Jessi Cisewski Kehe

Title: Topological Data Analysis That's Out of This World

Abstract: Data exhibiting complicated spatial structures are common in many areas of science (e.g., cosmology, biology), but can be difficult to analyze. Persistent homology is an approach within the area of Topological Data Analysis (TDA) that offers a framework to represent, visualize, and interpret complex data by extracting topological features which may be used to infer properties of the underlying structures. For example, TDA is a beneficial technique for analyzing intricate and spatially complex web-like data such as fibrin or the large-scale structure (LSS) of the Universe. LSS is known as the Cosmic Web due to the spatial distribution of matter resembling a 3D web. The accepted cosmological model presumes cold dark matter but discriminating LSS under varying cosmological assumptions is of interest. In order to understand the physics of the Universe, theoretical and computational cosmologists develop large-scale simulations that allow for visualizing and analyzing the LSS under varying physical assumptions. Each object in the 3D data set can represent structures such as galaxies, clusters of galaxies, or dark matter haloes, and topological summaries ("persistence diagrams") can be obtained for these simulated data that summarize the different ordered holes in the data (e.g., connected components, loops, voids). The topological summaries are interesting and informative descriptors of the Universe on their own, but hypothesis tests using the topological summaries provide a way to make more rigorous comparisons of LSS under different theoretical models. We present several possible test statistics for two-sample hypothesis tests using the topological summaries, carry out a simulation study to investigate the performance of the proposed test statistics using cosmological simulation data for inference on distinguishing LSS assuming cold dark matter versus a different cosmological model which assumes warm dark matter.