Aalto University

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A Song of Order and Disorder in Critical Systems: Characterizing Phase Transitions Using Fluctuations and Partition Function Zeros

Title of the dissertation	Lee-Yang theory and large deviation statistics of interacting many-body systems
Contents of the dissertation	The collective behavior of large numbers of interacting particles may give rise to a phase transition. Consider, for example, a macroscopic gas in contact with a heat reservoir. If the temperature is slowly reduced, the gas will abruptly condense into a liquid at the critical point. However, how do the molecules 'know' that they should suddenly form a liquid rather than a gas? This is a fascinating question that arises in many important systems in nature, from superconductors to black holes. An ongoing challenge is to identify the underlying principles of phase transitions and to characterize their features that constitute the source of exotic phenomena, such as topological, quantum, and non-equilibrium phases of matters. In this thesis, we present a novel theoretical and methodological framework for predicting phase properties of a macroscopic system based on the behavior of just a few of its constituents. First, we determine the partition function zeros in the complex plane from the thermodynamic fluctuations that are inherent to critical regions. We then exploit these complex zeros to characterize the criticality and large deviation statistics in interacting many-body systems. We can thereby predict the features of large complex systems from remarkably small system sizes. Our approach combines ideas and concepts from the finite-size scaling analysis with the Lee-Yang formalism and theories of high cumulants and large deviations. It can be used in a wide range of critical systems from physics, chemistry, and biology, both in theory and experiment.
Field of the dissertation	Statistical Physics
Doctoral candidate	Aydin Deger, M.Sc.
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Opponent	Professor Ralph Kenna, Coventry University, United Kingdom
Custos	Professor Christian Flindt, Aalto University School of Science, Department of Applied Physics
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