

PhD Thesis

Effective theories for many-body systems with nonuniform symmetries

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Abstract

The low-energy dynamics of many-body systems is governed by gapless modes whose properties are dictated by symmetry. Their existence follows from Goldstone's theorem, while their effective description at zero temperature is determined by the pattern of symmetry breaking. At finite temperature, an analogous role is played by hydrodynamics, which describes the universal collective behavior of many-body systems over long times and large distances.

These principles are well understood for *uniform* symmetries, which act homogeneously in spacetime and lead to a correspondence between massless Goldstone modes and broken generators, as well as gapless hydrodynamic modes and conserved charges. However, this simple picture changes in the presence of *nonuniform* symmetries, whose generators do not commute with spacetime translations. The low-energy implications of these symmetries remain less understood, as they do not introduce additional gapless modes but instead constrain the dynamics of the existing degrees of freedom.

In this thesis, we develop a unified framework for many-body systems with nonuniform symmetries and show that their effects can be understood in terms of additional fields that are not independent at low energies and can be eliminated, leading to kinematic constraints that reshape the infrared dynamics. In systems with spontaneous symmetry breaking, this mechanism modifies the effective theory and often softens the dispersion relations of the remaining modes. At finite temperature, it manifests in hydrodynamics as constraints on macroscopic currents. As a result, nonuniform symmetries give rise to qualitatively new physical phenomena, including modified spectra of collective excitations, exemplified by transverse Tkachenko oscillations in quantum vortex crystals, and unconventional transport phenomena, such as anomalously slow diffusion and softened sound modes in dipole-conserving systems.