Dynamical phase transitions in two-dimensional Fermi liquids with quadrupolar interactions

Rui Aquino, Daniel G. Barci

Departamento de Física Teórica - Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier 524, 20550-013, Rio de Janeiro, RJ, Brazil.

Quantum nematic phases of Fermi liquids have been observed in several highly correlated systems, such as high $T_c$ superconductors, heavy fermions and quantum Hall systems\textsuperscript{a}. The isotropic-nematic quantum phase transition can be understood as a Fermi surface instability, driven by attractive quadrupolar interactions. Using bosonization, the non-Fermi liquid character of this transition has been explicitly shown\textsuperscript{b}.

In this work, we focus on the dynamics of the isotropic phase when the isotropic-nematic transition is approached. For this purpose, we study collective excitations of a two-dimensional Fermi surface considering density-density, as well as quadrupolar interactions.

Using a semiclassical approximation in the bosonized theory, we write an evolution equation for Fermi surface fluctuations, analog to the Landau Fermi liquid formalism\textsuperscript{c}. By expanding the Fermi surface deformations in an angular momentum basis, the system is reduced to a set of infinitely coupled harmonic oscillators. Each oscillator describes a Fermi surface deformation mode with a specific symmetry.

Focusing on the isotropic and the quadrupolar modes, we integrate out all other higher angular momentum components to compute the exact Green’s functions. To do this, we use a “decimation” technique\textsuperscript{d}. Truncating the system to $n$ modes, we are able to compute a recurrence relation in which the $n$th-order Green’s function is written in terms of the $(n-1)$th-order one. Then, by carefully taking the limit $n \to \infty$, we compute the exact Green’s function. The normal frequencies are computed from $G^{-1}(\omega, \vec{q}) = 0$.

The dispersion relation of the normal modes depends on two Landau parameters, $F_0$ and $F_2$, that codify the density and the quadrupolar interactions respectively. We compute the dynamical fase diagram, where we display the normal modes in the $(F_0, F_2)$ plane. We show that, in specific regions of the $(F_0, F_2)$ plane, the dynamics of the Fermi surface fluctuations changes abruptly, signalling a dynamical phase transition.

We acknowledge financial support to CNPq and FAPERJ. R.A. is a FAPERJ IC fellow.

\textsuperscript{a}E. Fradkin, S. Kivelson, et. al., Annual review of Condensed Matter Physics, 1, 153 (2010)
\textsuperscript{c}Daniel G. Barci and D. Reyes, Phys. Rev. B87, 075147 (2013)
\textsuperscript{d}H. L. Calvo and H. M. Pastawski, Braz. J. of Physics 36, 963 (2006)