Dark solitons in superfluid Fermi gases: Dispersion relation and snaking instability

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Abstract:

A great puzzle is presented by recent experimental results on the oscillation frequency of dark solitons in a trapped superfluid Fermi gas [1] that differ by an order of magnitude from earlier theoretical predictions [2,3]. This highlights the problem of describing a strongly correlated quantum fluid by mean-field theory. In this talk we present theoretical studies of the dispersion relation and the transverse snaking instability of dark solitons for a superfluid Fermi gas with tunable interaction strength in the crossover regime between Bose-Einstein condensation of atom pairs and BCS-type superfluidity.
For the strongly interacting unitary Fermi gas, scaling arguments permit the derivation of very general and exact statements about the soliton dispersion relation that link several experimentally accessible observables [2]. In a second part of the talk, we report numerical results using Bogoliubov-de Gennes mean field theory for the dispersion relation and discuss the implications for the soliton oscillations in a trapped gas [2] and a high-velocity instability [4]. In order to study the dynamical instability to transverse modulation (snaking instability) that leads to the decay of dark solitons into vortices, we have implemented a calculation of the linear-response function in the RPA approximation. Complex poles of the response function provide information about the time scale of the snaking instability and give an indication about a suppression of the snaking instability for narrow transverse samples. Again, our numerical results indicate significant deviations from experimental observations reported in Ref. [1] and highlight the puzzle of understanding a strongly correlated quantum fluid.

References:

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