Pseudoelectron Excitation in the Luttinger Liquid

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The concept of spin-charge separation plays a central role in describing the low-energy physics near Fermi points in one-dimensional (1D) interacting electron gas, a typical example of the Luttinger liquid (LL). This concept may be confirmed in real materials by the recent high-resolution angular resolved photoemission spectroscopy (ARPES) in which the one-electron spectral function $A(p,\omega)$ can be directly measured in the wide range of momentum p and energy ω.

If $|p|$ is not restricted to the region near the Fermi momentum p_F, the linear dispersion approximation, usually adopted in the LL theory, is not sufficient in appropriately obtaining $A(p,\omega)$. In fact, the effect of the nonlinearity in the electron dispersion on $A(p,\omega)$ has been intensively studied in recent years [1]. According to those studies on integrable systems, $A(p,\omega)$ has singularities for arbitrary p at $\omega=\varepsilon_s(p)$ and $\omega=\varepsilon_c(p)$, where $\varepsilon_s(p)$ and $\varepsilon_c(p)$ are the spectra of the spinon and holon modes, respectively. In the usual LL theory, the exponents characterizing these singularities are independent of p, but the nonlinearity in $\varepsilon_s(p)$ and $\varepsilon_c(p)$ makes them depend on p. Their actual p dependences can be calculated with use of the Bethe-ansatz method. For nonintegrable systems, the threshold singularity, which is located at $\omega=\varepsilon_s(p)$, remains intact, but the singularity at $\omega=\varepsilon_c(p)$ is smeared into a broad peak.

In those preceding works, only the singularities at $\omega=\varepsilon_s(p)$ and $\omega=\varepsilon_c(p)$ are discussed on the belief that the electron nature will not sustain in the spin-charge separated system. For p far away from p_F, however, the effect of interactions becomes so weak that we would naively expect that the nature of an injected electron to measure $A(p,\omega)$ manifests itself as a main peak in $A(p,\omega)$. Then a natural question arises: *Does an electron-like excitation mode actually exist in the 1D interacting electron gas for* $|p|\gg p_F$*?* If yes, a related and more intriguing question is: *How does the electron-like mode reconcile with the physics of spin-charge separation for* $|p|\sim p_F$*?*

In this study, by employing both analytical and numerical methods, we have reexamined $A(p,\omega)$ in the Luttinger liquid with both linear and nonlinear electron dispersion at zero temperature. Irrespective of dispersion, we have discovered a conspicuous peak structure between two singularities at $\omega=\varepsilon_s(p)$ and $\omega=\varepsilon_c(p)$. The structure is featured by a decay mode of an electron-like particle (*pseudoelectron*) which may be regarded as an electron dressed with a "cloud" of spinons and holons. This pseudoelectron exists even for $|p|\sim p_F$, is considered as the 1D counterpart of the Landau's quasiparticle in higher dimensions, and appears in $A(p,\omega)$ as a peak with a cusp in addition to the well-known double-peak divergences representing the low-energy spin-charge separation. For $|p|\gg p_F$, on the other hand, it becomes a main contribution to $A(p,\omega)$ and behaves as a nearly free electron. This 1D nearly free electron does not, however, manifest itself in $A(p,\omega)$ as a Lorenzian (as in the case of higher dimensions) but divergent peak. Those results answer the questions posed in the previous paragraph. In our talk, we also give a full picture of $A(p,\omega)$ in 1D interacting electron gas, including a transition between the spin-charge separated and nearly-free electron regimes.

[1] For a review, see A. Imambekov T. L. Schmidt, and L. I. Glazman, Rev. Mod. Phys. **84**, 1253 (2012).