Erratum: Interacting lattice systems with quantum dissipation: A quantum Monte Carlo study [Phys. Rev. B 97, 035148 (2018)]

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Recently, the concept of an incoherent transverse quantum fluid (iQTF) [1,2] was introduced, which calls for a radical reexamination of our data in the superfluid phase. We agree with the authors of Refs. [1,2] that our system in the superfluid phase in the thermodynamic limit is described by the theory of iQTFs. As we show below, the equal time Green's functions appear to be reasonably well fitted by power laws on mesoscopic length scales, as in Luttinger liquid theory, which we erroneously used as a sufficient criterion to explain the superfluid phase. Here, we clarify the crossover between the Luttinger liquid and the iQTF regimes, which may extend well beyond the system sizes one can routinely study in quantum Monte Carlo simulations.

We analyze the iQTF and Luttinger liquid scenarios for the leftmost data point of Fig. 2(a) of the paper, which is the data point with the best chances of observing the iQTF behavior. It consists of hard-core bosons at half filling and has system parameters $J = J_b = 1$, $J' = 0.2$, $V = 2.4$, and $L_x = L_y = \beta = 64$. The revisited quantum Monte Carlo data shows that the system compressibility κ scales linearly with L_y. This in turn implies that the "Luttinger parameter" K (defined as extracted from the asymptotic decay $x^{-1/2K}$ of the equal-time correlation function; note that the relation $K = \pi\sqrt{\Lambda_s \kappa}$ with Λ_s the superfluid stiffness certainly does not hold because the system density is not the canonically conjugate variable to the superfluid phase) scales with the square root of L_y and that the "speed of sound" c scales with the inverse square root of L_y. This is incompatible with the standard Luttinger liquid scenario. However, the scaling of the system compressibility is such that it remains very small, $\sim L_y/100$, which is masking the iQTF behavior. As shown in Fig. 1, the equal time density matrix seems well approximated by a power law behavior [$\sim \sin(\pi x/L)^{-1/2K}$]. It is only the density matrix of the $L = 64$ data (and larger system sizes) that is unusual because it is higher (outside the error bars, which are of the order $\sim 10^{-5}$) than the $L = 48$ curve. Yet, this signals the crossover to the iQTF regime, characterized by a finite but small condensate density, $n_0 \approx 0.0165$. Conformal invariance is also broken. This is further illustrated in Fig. 2 where the $L = 64$ data are well fitted by the generalized Bogoliubov relations of the iQTF theory [2].

That the equal-time density matrices on mesoscopic scales show certain features of both theories is not a coincidence: imagine that we have a parameter set deep in the iQTF phase and take a finite but small $L_x = L_y = \beta$, where its properties are already apparent. If we, on the one hand, perform a finite size scaling in $L_x = L_y = \beta$ the iQTF theory remains valid and those properties

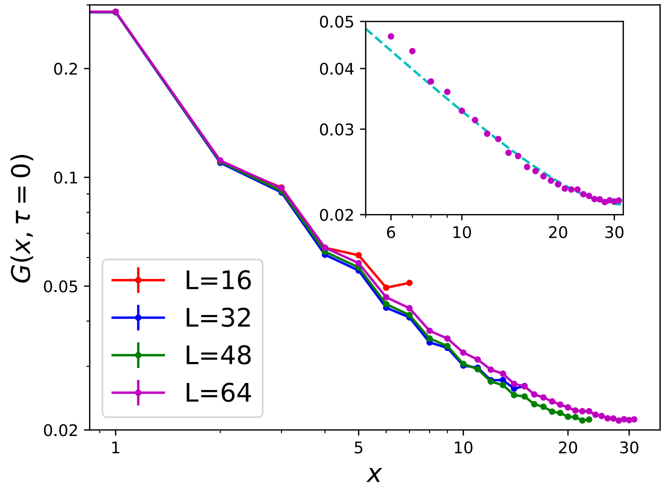

FIG. 1. Equal time density matrix $G(x, \tau = 0)$ for the system consisting of hard-core bosons at half filling with $J = J_b = 1$, $J' = 0.2$, $V = 2.4$, and various $L_x = L_y = \beta$. Monte Carlo simulations ran for 100 different seeds for each curve, necessary to obtain smaller error bars than in the paper. The inset shows a fit of the $L = 64$ curve with a power law $\sim \sin(\pi x/L)^{-1/2K}$, resulting in $K = 0.85(2)$.

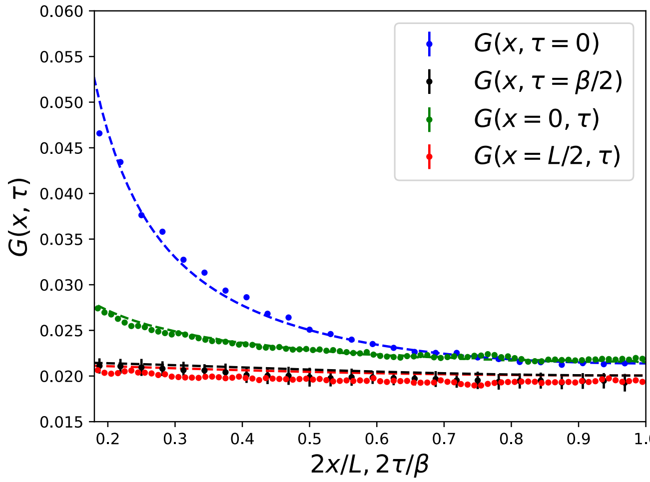

FIG. 2. Fitting the generalized Bogoliubov relations to the four Green's functions for $J = J_b = 1$, $J' = 0.2$, $V = 2.4$, and $L_x = L_y = \beta = 64$. Fit results are $n_0 = 0.0165(1)$ and $\gamma = 3.06(4)$.

will become more pronounced with increasing $L_x = L_y = \beta$. If, on the other hand, we keep L_y fixed and scale $L_x \sim \beta$, then the system will flow to an effective one-dimensional system and recover crucial aspects of Luttinger liquid behavior.

The main finding of our paper was the establishment of an insulating density wave with infinite compressibility, which we can confirm. It is now seen that the compressibility diverges on either side of the transition. The transition between the insulating density wave phase and the iQTF phase breaks the $U(1)$ symmetry as well as lattice translational invariance and is therefore of first order. In this density wave phase, the revisited quantum Monte Carlo data shows that increasing the length L_y is not influencing the compressibility nor the system's equal-time density matrix at low enough temperatures. The behavior of the superfluid stiffness near the transition, vanishing in the same fashion as in the Kosterlitz-Thouless transition, has therefore its origins in the Luttinger-liquid to iQTF crossover that we described above.

The absence of a strong dependence on L_y in the ordered phase also forces us to reanalyze the claim of a finite temperature transition of the density wave phase. The new data shows that the compressibility does not diverge at finite temperature. The conjecture of a finite temperature phase transition cannot be maintained. At low temperature, the system has an exponential correlation length, which the linear extrapolation $1/L$ as shown in the inset of Fig. 3(a) failed to capture. We compare the finite temperature behavior of our model to that of a pure classical one-dimensional Ising model and they are qualitatively the same despite the infinite extent in the y direction. At finite temperature there is therefore a crossover instead of a phase transition.

We thank the authors of Refs. [1,2] for stimulating discussions.

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[2] A. Kuklov, L. Pollet, N. Prokof'ev, L. Radzihovsky, and B. Svistunov, Universal correlations as fingerprints of transverse quantum fluids, arXiv:2310.19875 [cond-mat.other].