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# Reply to “Comment on Generalized Exclusion Processes: Transport Coefficients”

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We reply to the comment of Becker, Nelissen, Cleuren, Partoens, and Van den Broeck [1] on our article [2] about transport properties of a class of generalized exclusion processes.

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Stochastic lattice gases with symmetric hopping are described, on a coarse-grained level, by diffusion equation with density-dependent diffusion coefficient. Density fluctuations additionally depend on the local conductivity (which also describes the response to an infinitesimal applied field). A hydrodynamic description therefore requires the determination of these two transport coefficients. Generally for lattice gases even with rather simple hopping rules, analytic results are unattainable; however, when an additional feature, known as the *gradient condition*, is satisfied, the Green-Kubo formula takes a simple form [3] and computations of the transport coefficients become feasible. For a number of lattice gases of gradient type, e.g., for the Katz-Lebowitz-Spohn model with symmetric hopping [4], for repulsion processes [5], for a lattice gas of leap-frogging particles [6, 7], the diffusion coefficient has been rigorously computed. The gradient property is also true for the misanthrope process, a class of generalized exclusion processes [8, 9].

For gradient type lattice gases, an exact expression for the diffusion coefficient can also be obtained by a perturbation approach: one writes the formula for the current at the discrete lattice level and then performs a continuous limit assuming that the density field is slowly varying.

Generalized exclusion processes with multiple occupancies [10–13], in general, do not obey the gradient condition. However, we argued in [2] that the perturbation approach should, nevertheless, lead to an exact prediction for the diffusion coefficient. For the class of generalized exclusion processes which we studied [2] simulation results were indeed very close to the predictions by perturbative calculation. The comment [1] by Becker *et al.* prompted us to perform more simulations and to analyze our results more carefully.

Becker *et al.* computed numerically the diffusion coefficient  $D(\rho)$ . They performed simulations for various system sizes  $L$  and various density differences  $\delta\rho$  between the boundary reservoirs. In order to extract  $D(\rho)$  from simulations they needed to take [1] two limits:  $L \rightarrow \infty$  and  $\delta\rho \rightarrow 0$ . We considered a system with a large density difference and measured the stationary current through the system: the advantage is that we have to take only one limit,  $L \rightarrow \infty$ . We analyzed the generalized exclusion process GEP(2) with maximal occupancy  $k = 2$  particles per site and extreme densities at the boundaries:  $\rho(0) = 2$  and  $\rho(L) = 0$ . According to our expectations

[2], the average current should vanish as  $(1 + \frac{\pi}{2})/L$  when  $L \gg 1$ . Simulation results (Fig. 1) demonstrate that the error is smaller than 0.9%, but this discrepancy does not seem to disappear in the  $L \rightarrow \infty$  limit.

The numerical results of Ref. [1] and our simulations (Fig. 1) show that the perturbation approach does not lead to the correct analytical results for the GEP(2). We emphasize that the perturbation approach is *not* a naive mean-field theory where correlations are obviously neglected as argued by Becker *et al.* In dense lattice gases, the equilibrium state itself is usually highly correlated; e.g., in the repulsion process  $\langle \tau_i \tau_{i+1} \rangle = 0 \neq \rho^2$  for  $0 \leq \rho \leq \frac{1}{2}$ , where  $\tau_i \in \{1, 0\}$  denotes the occupation number of site  $i$ : the mean-field assumption is completely wrong. Yet, a careful use of the perturbation approach leads to the correct result [5].

The gradient condition is thus crucial for the applicability of the perturbation approach. For GEP( $k$ ) with maximal occupancy  $k$ , the gradient condition is obeyed in extreme cases of  $k = 1$  which reduces to the simple exclusion process and  $k = \infty$  which reduces to random walks. Presumably because GEP( $k$ ) is sandwiched between two extreme cases in which the perturbation approach works, this method provides a very good approximation when  $1 < k < \infty$ .

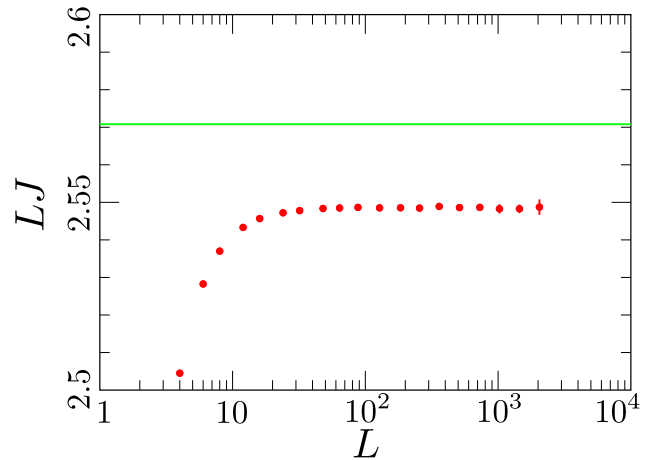


FIG. 1. Stationary current multiplied by the system size: simulation results (dots) and the prediction from our previous approach. The latter holds for  $L = \infty$ , but is shown as a line.

We now clarify the underlying assumptions behind the perturbation approach and suggest some tracks to improve our results. For the GEP(2), the current reads

$$J_i = \langle \tau_i f(\tau_{i+1}) - f(\tau_i) \tau_{i+1} \rangle, \quad (1)$$

where  $\tau_i \in \{0, 1, 2\}$  and  $f(n) = 1 - \frac{1}{2}n(n-1)$ . In our computation of the diffusion coefficient [2], we used two assumptions. The first one concerns one-point functions. Let  $\mathbb{P}[\tau_i = m]$  be the probability of finding  $m$  particles at site  $i$ . The density at  $i$  is

$$\rho_i = \langle \tau_i \rangle = \mathbb{P}[\tau_i = 1] + 2\mathbb{P}[\tau_i = 2]. \quad (2)$$

We assumed that one-site probabilities satisfy

$$\mathbb{P}[\tau_i = m] \simeq X_m(\rho_i) \quad (3)$$

where the  $X_m$ 's represent the single-site weights in an infinite lattice or on a ring:

$$X_0(\rho) = \frac{1}{Z}, \quad X_1(\rho) = \frac{\lambda}{Z}, \quad X_2(\rho) = \frac{\lambda^2}{2Z} \quad (4)$$

with the fugacity  $\lambda$  and the normalization  $Z$

$$\lambda(\rho) = \frac{\sqrt{1+2\rho-\rho^2} + \rho - 1}{2-\rho}, \quad Z = 1 + \lambda + \frac{1}{2}\lambda^2. \quad (5)$$

The second assumption was to rewrite the current as

$$J_i \simeq \langle \tau_i \rangle \langle f(\tau_{i+1}) \rangle - \langle f(\tau_i) \rangle \langle \tau_{i+1} \rangle. \quad (6)$$

This, indeed, is a mean-field type assumption [1]. The assumptions (3), (6) are asymptotically *true* in the stationary state of a large system ( $L \rightarrow \infty$ ): We have checked these facts by performing additional simulations.

Our numerical results suggest more precise expressions for (3) and (6) with some scaling functions  $\kappa$  and  $\mu$ :

$$\mathbb{P}[\tau_i = m] = X_m(\rho_i) + \frac{1}{L} \kappa_m\left(\frac{i}{L}\right), \quad (7)$$

$$J_i = \langle \tau_i \rangle \langle f(\tau_{i+1}) \rangle - \langle f(\tau_i) \rangle \langle \tau_{i+1} \rangle + \frac{1}{L} \mu\left(\frac{i}{L}\right), \quad (8)$$

where we omitted  $o(L^{-1})$  terms. Performing the perturbation approach with the refined expressions (7), (8), we obtain

$$J = -\frac{1}{L} \frac{d\rho}{dx} \left( 1 - X_2(\rho) + \rho \frac{dX_2(\rho)}{d\rho} \right) + \frac{1}{L} \mu(x) \quad (9)$$

where we have switched from the discrete variable  $i$  to  $x = i/L$ . The functions  $\kappa_m$  do not appear in (9), but  $\mu(x)$  does, and it was missing in our paper [2] leading to the wrong expressions for the current and for the stationary density profile. In order to calculate  $\mu(x)$ , we are presently examining nearest-neighbor correlation functions for the GEP(2). Numerically at least, these nearest-neighbor correlations exhibit a neat scaling behavior and simple patterns; detailed results will be reported in [14].

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- [1] T. Becker, K. Nelissen, B. Cleuren, B. Partoens, and C. Van den Broeck, Phys. Rev. E **93**, 046101 (2016).  
[2] C. Arita, P. L. Krapivsky, and K. Mallick, Phys. Rev. E **90**, 052108 (2014).  
[3] H. Spohn, *Large Scale Dynamics of Interacting Particles* (New York: Springer-Verlag, 1991).  
[4] S. Katz, J. L. Lebowitz, and H. Spohn, J. Stat. Phys. **34**, 497 (1984).  
[5] P. L. Krapivsky, J. Stat. Mech. P06012 (2013).  
[6] J. M. Carlson, J. T. Chayes, E. R. Grannan, and G. H. Swindle, Phys. Rev. Lett. **65**, 2547 (1990).  
[7] D. Gabrielli and P. L. Krapivsky, in preparation.  
[8] C. Coccozza-Thivent, Z. Wahrscheinlichkeitstheorie verw. Gebiete **70**, 509 (1985).  
[9] C. Arita and C. Matsui, arXiv:1605.00917.  
[10] C. Kipnis, C. Landim, and S. Olla, Commun. Pure Appl. Math. **47**, 1475 (1994).  
[11] C. Kipnis, C. Landim, and S. Olla, Ann. Inst. H. Poincaré **31**, 191 (1995).  
[12] T. Seppäläinen, Ann. Prob. **27**, 361 (1999).  
[13] T. Becker, K. Nelissen, B. Cleuren, B. Partoens, and C. Van den Broeck, Phys. Rev. Lett. **111**, 110601 (2013).  
[14] C. Arita, P. L. Krapivsky, and K. Mallick, in preparation.