Response to referee report
"Towards a Quantum Fluid Theory of Correlated Many-Fermion Systems from First Principles"

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1 Response Letter

Dear Editors,

we thank both referees for their constructive review. We have revised the paper by taking into account all comments raised by the referees.

We believe our revised manuscript is now suitable for publication.

Sincerely,
Attila Cangi

2 Response to Referees

Comments by Referee #2

> The authors addressed all the points that I raised in my previous report improving the manuscript. I think that the paper can be now published.

We thank the referee for reviewing our manuscript and for recommending publication.

Comments by Referee #1

> The authors have addressed the majority of my points satisfactorily. However, I believe there are still a small number of issues that deserve to be addressed more thoroughly before I can recommend the paper for publication.

We thank the referee for reviewing our manuscript and for providing valuable feedback. We address the individual points below.

> The paper convincingly shows that the MFBP produces significantly different forces compared to the SBP. This is well explained e.g. at the start of Section 3. However, as suggested in my earlier comment 5, the wording of the manuscript should reflect the fact that the authors \claim" that the dynamics will significantly differ for the MFBP compared to the SBP, rather than actually showing it (which would require actually computing and comparing the dynamics in the two cases). For example, as mentioned in my first report, the wording in the abstract \This enables more accurate QHD simulations beyond its common application domain in the presence of strong perturbations at scales unattainable with first-principles methods" is rather strong, given that no dynamics achieving previously unattainable accuracy has actually been shown. A similar consideration applies to the wording \In conclusion, the many-fermion Bohm potential leads to a substantially different quantum dynamics" at the end of Section 3.

We agree with these suggestions and have changed the wording in the revised manuscript.

In the revised manuscript, the sentence in the abstract now reads:
"This may lead to more accurate QHD simulations beyond its common application domain in the presence of strong perturbations at scales unattainable with first-principles methods."

In the revised manuscript, the sentence at the end of Section 3 now reads:
"In conclusion, the many-fermion Bohm potential may lead to a substantially different quantum dynamics which will be explored in our future work."

> In the conclusion, I find the sentences \Particularly, the effect of the standard Bohm potential has very recently been assessed in hydrodynamics simulations (45). These clearly demonstrate the different dynamics obtained and indicate the importance the many-fermion Bohm potential might have on the dynamics of the shock formation" to be unclear. Since the new preprint (45) only shows the dynamics computed using the SBP, the authors should explain how this by itself shows that the dynamics obtained from the two potentials differs. In their reply to my first report, the authors note they \already discussed the expected effects of the MFBP on the shock propagation in WDM". However, their discussion is based on \the presence of higher-order spatial derivatives of the density". Such higher-order spatial derivative is already present in the SBP, Eq. (1). So, this by itself does not explain the expected difference.

We agree that our statement was unclear. In Ref. (45), the significance of quantum diffraction effects in hydrodynamics simulations provided by the common SBP are demonstrated for shock propagation in WDM. As we show in Figure 2, the magnitudes of the SBP and the many-fermion Bohm potential differ significantly. In particular, the use of the many-fermion Bohm potential leads to stronger forces in region of strong density perturbations (Figure 3). We, therefore, argue in the Conclusion of our manuscript that the shock propagation in WDM is further influenced when the many-fermion Bohm potential is used in hydrodynamics simulations.

We have revised our manuscript to clarify this point [see page 7, end of paragraph 3]:
"As demonstrated in Figures 2 and 3, the many-fermion Bohm potential yields significantly different forces in regions of strong density perturbation than the standard Bohm potential. We therefore expect the many-fermion Bohm potential to further impact the dynamics of shock formation."

> In their reply, the authors argue that the manuscript's results are expected to be general since any perturbation can be expressed as a linear combination of harmonic perturbations. This is true of the perturbation term of the Hamiltonian. However, the force due to the Bohm potential does not depend linearly on the Hamiltonian. Thus, it is not immediately clear to me that the finding that forces are significantly different for harmonically perturbed Hamiltonians implies that this holds for any perturbation. In any case, I think that the manuscript should explicitly mention any arguments the authors have in favour of the general validity of their results, here shown for a particular example.

We have softened our language regarding this point. We now explicitly mention that the presented findings are obtained by considering harmonic perturbations [see conclusion, second paragraph]: "Considering a harmonic perturbation in the Hamiltonian defined by Eq. (7), we showed that the standard Bohm potential..."

> As mentioned in my first report (comment 6), the wording of the final part of Section 1 could make it sound like the authors first show in general that the SBP and MFBP significantly differ, and subsequently turn to a specific example. I would suggest reformulating this for clarity. For example, saying upfront that they focus on a specific example of physical relevance and then that they \(1) generate an exact [...]", or simply changing \We highlight the practical importance of this result by turning our attention to..." to something along the lines of \Throughout the manuscript, we consider the practically important example of...".

We take up the referee's suggestion and revise the text passage in question accordingly: "Throughout the manuscript, we consider the practically important example of the harmonically perturbed, interacting electron gas at finite temperature which is a challenging many-fermion system and is a relevant for modeling high-energy density experiments conducted facilities around the globe."

We believe, this now should clearly communicate that the results presented in this manuscript are based on the harmonically perturbed, interacting electron gas at finite temperature.