Report Scipost “Self-stabilized Bose polarons” by Richard Schmidt and Tilman Enss.

In the present work the authors elaborate on the stabilization mechanism of Bose polarons occurring for strong local attractions. Indeed, it is known that using conventional approaches, e.g. the Fröhlich model, an instability emerges in this strongly attractive interaction regime and the bosons of the medium accumulate towards the impurity. To tackle this problem a variational type approach is constructed that operates beyond the standard Bogoliubov approximation including the local boson repulsion which acts against the impurity’s attractive potential excluding binding. As argued this additive term is able to stabilize the Bose polaron in the vicinity of the respective scattering resonance. For instance, it is demonstrated that the polaron energy is bounded from below across the resonance while the polaron dressing cloud remains sizable. Moreover, at resonance, the polaron energy shows a universal behavior on the effective range and the impurity contact is finite exhibiting a peaked structure at positive scattering lengths.

I find the results and ideas presented intriguing with direct experimental relevance and most likely will inspire similar theoretical investigations in the future. The manuscript is also well written. However, I have some questions regarding the findings and also the applicability of the used method. Thus, if the authors provide convincing answers to my comments, summarized below, and perform the respective minor revisions then I would certainly recommend this work for publication in Sci post.

1) I have some conceptual questions regarding the applicability of the used model, e.g. described by Eqs. (1) or (2).

a) As far as I understand it holds for both mobile and immobile impurities (Figure 3(b)). However, I am not able to clearly judge its applicability for finite impurity masses, meaning that in the latter case impurity-medium correlations is possible to become important. Can the authors briefly comment on this issue?

b) Is it possible the present formalism to be extended for larger impurity concentrations, e.g. more than a single one? Would then its reliability be restricted?

c) Can it be extended to account also for long-range interactions e.g. dipoles?

I imagine that the emergent physics especially in c) will be fundamentally different than the one described in the manuscript but I wonder what is the authors opinion here.

2) On page 3, first paragraph of the left column, it is stated that “For bosons in the vicinity … leads to induced interactions between bosonic particles ...”. What type of induced interactions are meant here? Also, are they always attractive or is it possible to engineer also repulsive ones?

3) Is it possible to compare or translate the modified quasiparticle dispersion to the one obtained for particle-balanced mixtures e.g. introduced in Phys. Rev. Lett. **117**, 100401 (2016) by Petrov? I can understand that this might be well beyond the scope of the present work but

if the authors are able to provide any relevant hint would be extremely useful not only for advancing the impact of their work but also for the community.

4) On page 3, first paragraph of the right column, I would suggest besides Ref. [40] to include also Refs. New J. Phys. **21**, 103026 (2019), New J. Phys. **22**, 043007 (2020), that also refer to the one-dimensional case and elaborate on the effect of attractive impurity-boson interactions while relying on a variational treatment.

5) It is also not clear to me how the present model accounts for impurity-medium correlations. Please comment. I would expect that such effects would become particularly important in the nonequilibrium polaron dynamics which the authors claim to be a next step to apply their formalism.

6) Regarding the dynamical instability appearing in the GPE. Is it related to the presence of Bogoliubov modes with complex eigenfrequencies leading to the instability of the corresponding stationary solution of the GPE solution? Or is it one of the so-called thermodynamic ones as introduced e.g. by Castin in arXiv:cond-mat/0105058?

7) I wonder what is the behavior of the polaron residue in the interaction region of the bound state? Is it finite? If no, how then the polaron picture should be interpreted?

8) I am bit preplexed regarding the results shown in figure 3 (b). On the one hand in the caption it is argued that the polaron binding energy is presented when equal mass of boson and impurity is considered and for two different gas parameters. However, in the text it is written that “...we present the energy for a mobile impurity of arbitrary mass...”. Please comment. Also, why the authors do not show the polaron binding energy for a heavier impurity and one of the scattering lengths used for the equal mass case? This will enable to judge also the the impact of the mass on the binding energy.