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To,
The Editors,
Journal of Physics: Condensed Matter. 15th January, 2023

Dear Madam/Sir,

We are writing to submit the manuscript titled "Frustration shapes multi-channel Kondo physics: a star graph perspective" for your consideration towards publication in Physical Review B. This work is devoted towards understanding how various important properties of multi-channel Kondo (MCK) physics (e.g., the nature of its criticality and the emergence of gapless local non-Fermi liquid excitations) arise from the frustration of spin-singlet order and ground state degeneracy in the system. We recall that the absence of Fermi liquid excitations, an imperfect screening of impurity local moment, and a T=0 divergence of the impurity susceptibility are some of the defining features that make the MCK problem different from its single-channel counterpart. However, the structure of the ground-state manifold of this problem, and the quantum entanglement encoded therein, remain unknown in general. This is due to the lack of an effective Hamiltonian at the intermediate-coupling critical fixed point that defines the low energy physics of the problem. This elicits the question: can features of the ground state Hilbert space be used to obtain fresh insights on the criticality and emergence of non-Fermi liquids in the MCK? How is the entanglement of the ground state and lowest-lying excited states different from the single-channel case? Does the orthogonality catastrophe of the ground state show up in any of these measures? Answering such important questions is the primary goal of our work.

We begin by employing the unitary renormalisation group (URG) formalism developed recently by us to derive the low energy intermediate coupling fixed point effective Hamiltonian of the MCK with N conduction channels. In the zero-bandwidth limit, the effective Hamiltonian corresponds to a star graph model of the impurity moment interacting with N spin-½ moments via Heisenberg antiferromagnetic exchange. This makes apparent the frustration inherent in the problem, and reveals the fact that the start graph model possesses a N-fold degenerate ground-state manifold. The critical behaviour of the effective Hamiltonian is captured via a zero-temperature discontinuity in the impurity magnetization and a related divergence in the impurity susceptibility. The topological feature of the ground state manifold is also captured through spectral flow arguments. We also find that a local Mott liquid is formed from the conduction bath moments that couple to the impurity, and formed by inter-channel interactions (induced by the impurity).

Upon the addition of electronic dispersion to the zero-bandwidth model, we have derived the effective Hamiltonian for two-channel and three-channel (shown in the Supplementary Materials provided along with the main manuscript). These effective Hamiltonians clearly show the absence of local Fermi liquid due to the exact cancellation of terms associated with degenerate ground states, and the emergence of non-Fermi liquid (NFL) excitations arising from the related orthogonality catastrophe. Importantly, the RG equation is seen to be guided by the scattering phase shift arising from those members of the degenerate ground state manifold of the star graph that cause the maximal impurity magnetisation; the intermediate coupling fixed point of the MCK is seen to correspond to a function of this scattering phase shift. The algebraic behaviour of the impurity contribution to the specific

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heat and magnetic susceptibility, as well as the fractional value of the impurity entropy at T=0, are also observed to be related to this scattering phase shift. Thus, our results establish the central role played by ground state degeneracy in governing the physics of the MCK, including the emergence of the NFL phase and various thermodynamic properties associated with it.

The availability of an effective Hamiltonian has further enabled the study of the ground state wavefunction of the MCK. For example, we have been able to display the inter-channel and intra-channel entanglement structure, unveil a discontinuity in various entanglement measures such as the N-partite information (for N>1), and employed the Bures distance measure to capture the orthogonality catastrophe in the MCK system. We have also identified two kinds of duality transformations in the MCK models, and show how they constrain the nature of the RG flows as well as connect between the overscreened and underscreened versions of the problem. We end by studying the effect of channel-anisotropic perturbations on the Kondo couplings: the impurity phase transitions here are shown to be related to changes in the ground state degeneracy structure of the model. While the main results are presented in the manuscript, we have provided various detailed derivations and additional results in the Supplementary Materials.

Thus, our work offers a host of new results on the entanglement features of the multi-channel Kondo problem, and the central role of quantum frustration in describing its signature properties. We strongly believe that our work will significantly interest the community of researchers working on quantum impurity problems as well as the quantum information to many-particle systems, and that it is likely to motivate further research. We request you, therefore, to kindly initiate the review process.

Yours sincerely,
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