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To whom it may concern,

The doctoral dissertation entitled *"Three-Body Physics of Ultracold Gases: Theory of Weakly Bound Quantum States in Strongly Interacting Systems"* presents an original contribution to one of the most relevant and challenging problems in cold molecular physics: ion–atom–atom three-body recombination. The work extends theoretical tools previously developed for three-body recombination in neutral systems to systems composed of one charged particle and two neutral atoms. Owing to the substantially different length and energy scales associated with ion–atom and atom–atom interactions, the corresponding three-body scattering problem is particularly demanding. Nevertheless, the dissertation presents pioneering results for the recombination of a single ion with two atoms and provides evidence for universal behavior in this new class of few-body systems.

In general, the dissertation is well written, clearly organized, and easy to follow. It should serve as a useful reference for students and researchers entering the field. The author provides a careful explanation of the underlying theory and has clearly devoted considerable effort to presenting a comprehensive account of the solution of the three-body Schrödinger equation within the adiabatic hyperspherical framework. The relevant literature is appropriately cited, and due credit is given to the previous theoretical developments on which the present work is based. The chapter devoted to computational details is particularly valuable, and I commend the author for including such a thorough and practical discussion.

The physics addressed in the dissertation is interesting, timely, and potentially important for future studies of ultracold ionic systems. The discussions are generally thoughtful and physically well motivated. Some of the broader conclusions, however, would benefit from further investigation. Here are a few points that could be worth looking into:

- In the discussion of the role of the atom–atom scattering length, the author demonstrates that variations in this quantity affect the three-body scattering length. However, the nature of this dependence is not explored in detail. Can the author provide a more quantitative or qualitative explanation of how the atom–atom scattering length influences the three-body scattering length and the corresponding recombination observables?
- The dissertation contains relatively little comparison with predictions based on classical trajectory approaches or with models in which ion–atom–atom recombination is treated as a sequential two-step process. Such comparisons could help clarify which features of the reported results are genuinely quantum mechanical and which may follow from more general dynamical considerations. Could the author discuss how the present predictions compare with those expected from classical or sequential-capture models?

- The propensity rules governing the binding energies of the product dimers appear to be similar in neutral atom–atom–atom and ion–atom–atom recombination. The author states that "the same physical process found for neutral homonuclear systems applies to ionic heteronuclear systems." This is an interesting and potentially important conclusion. However, the evidence supporting it should be discussed more carefully. Can the author identify specific observables, scaling relations, or dynamical mechanisms that provide strong evidence for this claim? It would also be useful to clarify which aspects of the recombination process remain different because of the long-range ion-induced-dipole interaction.

The dissertation is based primarily on one published paper and one manuscript in preparation, which might ordinarily be regarded as a somewhat limited publication basis for a doctoral thesis. In the present case, however, the technical difficulty, scope, and quality of the work compensate for the relatively small number of publications. The dissertation represents a substantial and coherent research effort and demonstrates the author's strong command of few-body physics, quantum scattering theory, and computational methods.

In conclusion, I consider this dissertation to constitute an original and valuable contribution to the study of few-body phenomena in ultracold systems. The author demonstrates the ability to conduct independent scientific research and possesses the theoretical knowledge required in the discipline.

I therefore conclude that the dissertation meets the scientific requirements for the award of a doctoral degree, and I recommend that the candidate be admitted to the public defense.

Sincerely,

Sincerely yours,
Jesús Pérez Ríos
Assistant Professor