17 February 2025 · CC-BY 4.0

Qeios

Peer Review

Review of: "Fermionic Casimir Effect at Finite Temperature in Hořava-Lifshitz Theories"

Adrian E. Rubio López[1]

1. Physics department, Universidad de Santiago de Chile, Chile

In this manuscript, the author addresses the study of the finite temperature Casimir effect for a family of fermionic field theories, known as Hořava-Lifshitz theories. These theories are characterized by having the form of a typical massless Dirac field but with the modification that the spatial terms can appear with an arbitrary integer power. For higher powers, the fermionic fields violate Lorentz invariance. However, for any power, field modes are found by imposing MIT bag boundary conditions, which the author summarizes in a clear manner. In these conditions, the author proceeds to the calculation of the Casimir free energy by exploiting the mode solutions found in some other reference but showing the implementation of the Zeta functions for the calculations. Then, the author proceeds to show the results at finite temperature for both even and odd integer powers, separating them into low- and high-temperature regimes. For even powers, the author shows that the Casimir free energy vanishes, giving no pressure/force; while for odd powers, the author works out the expressions for the corresponding non-vanishing pressures.

In terms of results, the work looks like an extension of the ones obtained in Ref.[15] to the scenario of finite temperature for the field. In terms of techniques, the author applied the zeta function technique, which allows for carrying out the calculations differently from the one employed in Ref.[15]. Considering these points, the work is solid. However, I find that the context or the interest of the work performed needs to be strengthened in order to make it more attractive. In a similar way, I find that there is a lack of physical insights derived from the obtained results. I believe this can also be improved, and it would make the work more attractive too. I would try to raise some comments with the aim of helping along these lines:

 doi.org/10.32388/E1ZQSY

1 - In the introduction, in the first two paragraphs, the contexts of Casimir effect results and the Hořava-Lifshitz theories are explained and summarized. This sets the context of the work, which will be a combination of these two concepts. But the novelty comes because of the inclusion of temperature in the calculation. Then, the third paragraph is basically to motivate that. The author claims that no one includes the temperature for this type of theory, which is good. But I think it will strengthen the work to also state why that matters because, for other types of field theories, the inclusion of temperature is typically associated with experimental conditions, for instance. Is there any general reason (apart from the general argument that nobody did it before) to justify the interest in knowing the thermal result? Another alternative is to suggest a scenario where thermal corrections might take place or a crucial role. Maybe it is possible to add something of this to the third paragraph of the introduction.

2 - Eqs.(III.8) and (III.9), regarding Poisson sums, seem unnecessary at that point in the work and kind of out of place. Given the fact that even and odd power cases are split below, maybe it would be better to locate each equation when they are specifically required in the calculation.

3 - In Sect.III.A, the free energy and the Casimir pressure for even values of the critical exponent are worked out. During the section, the author analyzes the low- and high-temperature limits. The author shows that both are 0, so at the end of the section concludes stating that both the free energy and the Casimir pressure vanish. I have a few points here:

3 - a - Suppose that you take a value of temperature that is not either low or high; it is intermediate. In other words, take $\beta\sim a$. What happens to the free energy and the pressure in this scenario? Is there any mathematical or physical argument (or both) that makes it clear? If that is the case, it should be included in the manuscript. If there is no reason, then it would be good to try some numerics and see what happens and if it deserves a plot or just a mention in the text. I can imagine that if, in the intermediate regime, there is a non-vanishing behavior of the free energy (and also of the pressure), there will be substantial modifications to perform. Maybe a plot might be useful if non-vanishing results are obtained.

3 - b - Related also to the previous point, is there any physical explanation of why the free energy is 0 for even values of the critical exponent? I see in the text that this is the conclusion of the section because of the mathematical results, but I do not see any physical insight into why these confined field theories are giving that result. It would be good if the author could elaborate on this. I believe this will strengthen the work on physical grounds.

4 - Section III.B. is similar to the previous one but for odd values of the critical exponent and with the difference that the results are not 0. Again, I think it would be good if the author could elaborate on why these cases are different from 0, if there is any physical insight that makes that clear or is physically expected. The author can also compare the two situations, results for odd values with respect to even values. What does it change at the very basic level? Why, in the odd values' scenario, does the temperature seem to make a difference, but for even values, it does not? Also, the fact that some of the cases give attractive forces and some others repulsive seems to be interesting. What are the physical insights that allow us to understand that?

5 - Regarding the conclusions, I do not understand the necessity of showing the full expressions of the free energy and pressure for different (odd) values of the critical exponent if the only comment refers to some numerical factor in front of the leading contributions. Maybe this can be argued in the text. Otherwise, it would be appropriate to elaborate more on the dependences and the differences in each case. By now, I am not sure the full expressions are needed, but maybe there is something that I am not getting correctly. Also, in addition to listing the results as they are now, it would be good if the physical insights referring to the inclusion of the temperature could be summarized in this section. In that sense, the author can compare the present results with the one shown in Ref.[15].

6 - A general writing style comment would be to not write in the first person (singular). "Impersonal style" or "objective writing" might be better for conveying ideas and concepts. It is understandable that the first person was employed since this work has a single author, but the passages sound subjective and might be confusing. For instance, sometimes it is not clear if the author is giving an impression/interpretation or pointing out a result. In that regard, "objective writing" might help to reduce or vanish those ambiguities. Then, I suggest modifying the writing in such a way.

All in all, I consider that answering the above points is required and also making modifications accordingly to the work. This might improve the quality of the work and complete it as a more solid scientific work.

Declarations

Potential competing interests: No potential competing interests to declare.