REVIEWER´S ASSESSMENT OF FINAL WORK

I. IDENTIFICATION DATA

Title:	Extended theories of gravity and their cosmological and astrophysical applications
Author´s name:	Kamil Mudrunka
Type of assignment:	Master Thesis
Faculty:	Faculty of Nuclear Sciences and Physical Engineering (FNSPE)
Department:	Department of Physics (DP)
Reviewer:	Dr Giuseppe Gaetano Luciano
Reviewer´s affiliation:	Department of Chemistry, Physics, Environmental and Soil Siences, Escola Politecninca Superior, Universidad de Lleida, Av. Jaume II, 69, 25001 Lleida, Spain

II. ASSESSMENT OF CRITERIA

Work assignment — **demanding**

Assess how demanding the work topic is.

Quantum gravity is one of the most challenging tasks in theoretical physics, both conceptually and technically. For higher-dimensional quantum gravity, the complexity increases further due to conceptual and technical challenges. For these reasons, my assessment is that the work topic is demanding.

Fulfilling the assignment — **fulfilled**

Consider whether the work submitted meets the assignment. If necessary, give your comments on items of the assignment not fully answered, or judge whether the scope of the assignment has been broadened. If student failed to fully treat the assignment, try to assess the importance, impact and/or the reasons for the failings.

In my view the author fulfilled the assignment very well. He covered all required points in a sufficient depth and with proper mathematical rigor. Particularly, Section 4 (Perturbations in Weyl conformal gravity) substantially broadens the scope of the assignment. Similarly, Section 5 (Quantum field corrections to black holes) contains a number of new derivations, e.g. black hole horizon corrections (in Section 5.5), which would certainly deserve to be published.

Chosen approach to solution — **appropriate**

Assess whether student applied a correct approach or method of solution.

The student uses a mixture of exact analytical techniques (some quite sophisticated), such as gravitational perturbation theory (both classical and quantum) or Newman-Penrose formalism, as well as advanced numerical simulations in Python developed directly for the purpose of the thesis. The methods that are used all seem to be appropriate for the tasks that are required.

Professional standard — **excellent**

Assess the professional standard of the work, application of course knowledge, references, and data from practice.

I have found the professional standard of the thesis pretty high. The thesis work demonstrates that the student has gained a good knowledge of the material and knows how to use it effectively. I did not notice any specific issues with references. All the most pertinent references on the subject have been correctly mentioned, although it would not be a problem to add more citations, as the subject of higher-derivative gravity is a rather vast topic.

Level of formality and of the language used — **excellent**

Assess the use of scientific formalism, the typography and language of the work.

Apart from a few typos at places (e.g., the first sentence in Appendix B seems to be unfinished and the second does not have much sense), I could not spot any essential grammar problems. The author's command of the

English language is excellent. Similarly, scientific formalism is written correctly. Since there are a large number of long equations in the text, I would personally include even more of them in the Appendix.

Choice of references, citation correctness **excellent**

Assess student´s effort in finding and using study sources for completing their work. Give characteristics of the references chosen. Assess whether student made use of all the relevant sources. Verify whether all items used are properly distinguished from the results obtained by student and their deliberations, whether there are no violations of citation ethics, and whether the bibliography presented is complete and complies with the citation usage and standards.

The thesis is rich on sources. The references are well chosen and I could not find any essential reference missing. On the other hand, one could certainly enlarge citation list by including a number relevant papers on higher-order quantum gravity (e.g. K. Stelle or M. Duff seeding papers) or even more papers on conformal gravity from Mannheim group.

Further comments and assessment

Give your opinion on the quality of the main results obtained in the work, e.g. the theoretical results, or the applicability of the engineering or programming solutions obtained, publication outputs, experimental skills, and the like.

As can be seen from my previous comments, I really appreciate the thesis's depth and extent. It is rare to see so complete MSc work. It is just a pity that I had a rather limited time for my review, so I could not check all the mathematical derivations carefully (and many could not be checked without the assistance of advanced software tensor packages). However, all the derivations I could verify sound correct and physically consistent. The thesis is well structured and written in a mature style, and it also contains a number of interesting historical connections. In addition, it contains a wealth of material that would be very useful to publish in such topical journals as Physical Review D or Classical and Quantum Gravity. Here, in particular, I would emphasize the “Wormhole solution” of Weyl conformal gravity in Section 3 and the “Quantum corrections to black hole horizons“ in Section 5.5.

III. OVERALL ASSESSMENT, QUESTIONS TO BE ASKED DURING THE WORK DEFENCE, SUGGESTED GRADE

Summarize those aspects of the work that were significantly influential for your overall assessment. Suggest questions to be answered by student during the defence of the work before the examination board.

All in all, the thesis is certainly exceptional, both in the scope and depth of the material. The student was able to handle the difficult (and often counterintuitive) material well. He demonstrated proficiency in working with both sophisticated analytical techniques (e.g., Newman-Penrose formalism) and showed the ability to formulate his own software tensor packages to tackle lengthy computations. I have perhaps only few comments the author may wish to clarify:

a) The student employs the metric signature convention (West Coast convention), which is not typically used in the gravity community, where Pauli's or East Coast convention is more common. Working with the opposite metric tensor convention can be tricky because it may be difficult to keep the signs under control in computations. How did the student ensure that his results are free from sign errors? In some formulas, such as eq. (2.16), I found it challenging to reconstruct all the signs. I ask the author to please comment on this point.

b) I was unable to discern the origin of equation (4.36). Could the student briefly comment on its derivation? Additionally, the paragraph following the equation could be cosmologically significant. What signatures, if any, could be expected in the Cosmic Microwave Background (CMB)? I suggest elaborating on this aspect, as the thesis

work could benefit in terms of implications and physical relevance.

Suggested grade: **A - excellent.**

Date: 24/05/2024

Signature

GIUSEPPE GAETANO LUCIANO - DNI YB9359922

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