



UNIVERSITA' DEGLI STUDI DI PAVIA

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RE: Opponent Report on the Habilitation Thesis

"Exact spacetimes in theories beyond general relativity"
candidate: Robert Švarc

Broadly speaking the research programme of the candidate habilitation thesis is framed within the class of gravitational theories that extend standard general relativity by considering modifications of the Einstein-Hilbert action functional with higher order curvature terms. They are generically known as $f(R)$ theories, where f is a curvature function of choice. These theories are indeed a viable alternative to general relativity, with solid foundations in the geometry of gauge theories and in the analysis of the renormalization group for the gravitational interaction. Connections with string theory are strong and they provide a relevant playground for discussing modifications of general relativity that may help in addressing the dark matter and dark energy conundrum. $f(R)$ theories are quite more complex than general relativity because the associated field equations are typically of order higher than the second, and their analysis require much geometrical and physical ingenuity. This ingenuity has been put to work by Dr. Švarc in the research programme, argument of his habilitation thesis, by addressing a number of very difficult technical problems, ranging from the analysis of the geodesic deviation equation in higher dimensional spacetimes, to the study of the exact solutions to quadratic gravity in four dimensions, to the properties of the Einstein-Gauss-Bonnet theory. The results of this research programme are detailed in 9 original and very interesting papers published in leading high-impact journals, during the years 2012-2021. It is important to stress that these are all co-authored papers. They are all of great originality (I do not think that it is necessary to mention the control made by the plagiarism checker Turnitin software! These are really original and relevant papers!)

That said, I think that the present habilitation thesis is really poorly written and does not make justice to the collection of published works presented by Dr. Švarc nor to their coauthors. Reasons for such a statement are multiple and intertwined. In my opinion, both the presentation and the content of the thesis can and must be vastly improved to comply with the high physical and mathematical standards required in order to receive habilitation. Without further ado, let me point out some of the (many) aspects that should be addressed, in my opinion, for reaching such

standards. I must stress that some of these points are quite annoying since the level of the 30 pages that introduce Dr. Švarc's research programme is quite low:

- i) A comparison between the quality of the published papers presented and the level of the introduction had my eyebrows raising. I felt surprised by the superficial and sketchy presentation of the arguments, a presentation often written in a rather poor English, and bashed it out quickly as not really important.
- ii) The consequence of this attitude is that, at face value, one cannot help feeling dubious as to the quality of Dr. Švarc contribution to the papers presented. I understand that this is a hard statement, and I am strongly confident that what I am saying is simply a superficial and wrong impression.
- iii) On the other hand, I do think that the utmost attention must be given to writing a habilitation thesis when the papers presented are in collaboration. Since there are no single-authorship published paper among those presented, an opponent can appreciate the candidate's contribution to the presented papers and the corresponding research programme only if the presentation of this programme is written with extreme care. The candidate's mastery of the subject and his contributions must be evident, everything must be well-motivated and explained and put in a proper perspective in order to evaluate the candidate attitude to research.
- iv) The mere presentation of a sketchy list of formulas is quite detrimental if these formulas and the accompanying results are introduced, as is the case here, without any form of serious derivation and physical motivation. An example, among many, is the extremely superficial way of introducing and discussing, both from the physical and mathematical point of view, the various action functionals that feature in the thesis. Typically this sort of formalism allows for a rich narrative, gives room to a varied landscape for introducing key research findings, and put them in a proper perspective. Here a badly missed opportunity.
- v) Most of all, what is missing is a careful and detailed analysis by the candidate of the physical motivations for going beyond general relativity in the direction of $f(R)$ theories and/or in the higher-dimensional case. Using curiosity as a motivation, in a decade-long research programme, is not a good justification if you do not explain it to me.

To summarize:

The introductory section of this habilitation thesis is poorly organized and badly written. The physical motivations of the co-authorship research programme presented are not appropriately discussed by the habilitation candidate, nor put in a proper perspective for what concerns his career. As a consequence, it is extremely difficult, at least from what I read, to assess the actual contribution of the candidate to the list of published papers presented, none of which is single-authored by him. This is a habilitation thesis and the proper physical and mathematical language should be used with care and clarity; mastery of the subject, both physical and mathematical, must be made clear at every step. The candidate should have taken the outmost care in describing his key research findings, emphasizing his personal role in carrying out the research programme described. Here, quite to the contrary, the habilitation thesis has been handled in a very superficial way, to the point that the reader may cast the extremely dangerous doubt I described above. As it stands, the very poor quality of the introductory chapter jeopardizes the relevance, for awarding habilitation, of the collection of the co-authored papers presented. On the positive side, I wish to emphasize that the research papers co-authored by Dr. Švarc are of high quality and I am confident that if the points I have stressed are addressed with due care, a revised version of the habilitation thesis of the candidate will reach the high standards of quality that will amply remove any reserve to awarding habilitation.

Best regards,

Mauro Carfora

