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Report on habilitation thesis of Dr Robert Švarc

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Dear Professor Hlavatý, dear members of the committee,

it is my pleasure to provide in the following a report on the habilitation thesis presented by Dr. Robert Švarc. It should be noted that the candidate is not personally known to me. My review is solely based on the submitted evaluation material, namely the habilitation thesis and the originality check, and publicly avaliable data on his publications.

The submitted habilitation thesis by Robert Svarc entitled „Exact spacetimes in theories beyond general relativity" is based on the scientific work of the author in the area of theoretical physics, more specifically solution to gravitational field equations. It comprises nine original research articles published in the most respected professional journals of the field, among them Physical Review Letters, during the last decade in his scientific career.

Modifications or extensions of General Relativity are an important research topic in contemporary theoretical physics. They are related to the most challenging open questions, as the unification of gravity with the other fundamental forces or the nature of dark matter and dark energy. Recent breakthroughs in astrophysical observations, like the new gravitational wave window to the universe and the first images of black holes might open up possibilities to test our understanding of gravity on new levels. Dr. Švarc's scientific work, presented in this thesis and in 25 peer reviewed publications and some conference proceedings since 2010, significantly contributes to these open questions.

One can identify four different areas of research where the candidate has actively contributed to the progress of our knowledge in the field of gravitational physics. These are, respectively: (i) mathematical methods and general concepts, (ii) spherically symmetric solutions to quadratic gravity, (iii) decreasing entropy of dynamical black holes in critical gravity, and (iv) Kundt spacetimes in the Einstein–Gauss–Bonnet theory. Regarding the first area, the candidate started the investigations already in his PhD thesis completed in 2012, and continued this research direction in two more papers that are part of this thesis. The other areas correspond to the candidate's evolving research interests from about the last four years, and very nicely exploit and evolve the basic concepts developed before.

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The above mentioned research directions are reflected by the candidate's contributions in the selected papers and are summarized in a concise (32 pages plus references) overview, summary and brief but very useful outline of the future research. The thesis starts with a general introduction to gravity theories and reasons to consider extensions or modifications of General Relativity. This is followed by an overview of modified gravity theories classified according to Lovelock's theorem, with an emphasis on quadratic theories of gravity in four and higher dimensions, that are most relevant for the following discussions. A complementary view on general spacetimes, that is independent of the underlying field equation, is presented in the third chapter. The candidate discusses here the specific algebraic structure of the involved tensors and, based on that, the non-twisting and shear-free geometries. Additional tools to analyze spacetimes are presented in chapter four. First, the generalization of the Newman-Penrose formalism for 4-dimensional quadratic gravity is discussed. This work is also already available on arXiv and surely will be published in a peer-review journal soon. Second, an invariant form of the geodesic deviation equation in higher dimensional spacetimes is derived. The basic ingredients presented in chapters 3 and 4 have been used extensively in the publications related to research areas (ii) to (iv) mentioned above. This impressively demonstrates the power of the general methods developed by Dr Švarc, that enables the high impact results included in the thesis, and will trigger many more research results in the future.

The main expertise of the candidate and the focus of the habilitation thesis are laid in the area of exact solutions and rigorous mathematical approaches, which I very much appreciate especially in the context of testing the gravitation theories and constraining their parameters and consistency. From the thesis it becomes clear that Dr Švarc is not only able to derive involved, rigorous mathematical results, but also to apply the develop methods in various ways, that are very relevant for the future development of the theory of gravity as well as for data analysis of observations in astrophysics. Therefore, while the candidate's work in this thesis is impressive, there remains a great potential for future continuation and further exploration.

Regarding the originality check that have been provided along with the thesis, first I have to mention that, apart from the titles and abstracts of the included original publications, I could not find even a single complete sentence that was not original to the thesis. Therefore, it is immediately clear that the result of 33% directly emerges from the original publications that are part of the thesis. Anyway, I went carefully through the marked points, and indeed almost all link to the papers published by the candidate. Exceptions are a student paper (marked as point 4) that is not available due to data privacy, but is probably ref. [62], and a lecture by Prof Podolský (marked as point 8). These two I checked even more carefully. It turns out that point 4 contains the titles of the original papers, some parts of the general formulas from the original publications, a half sentence, and some references. Point 8 contains the title and larger parts of the abstract of the original paper A1.1, that is co-authored by

the candidate. Therefore, all points are surely to be considered original to Dr. Švarc.

Finally, besides the original research and the scientific results exhibited in the papers and included in this thesis, it seems that Dr. Svarc has been very active in regular teaching duties at the university.

I conclude that the candidate clearly demonstrates the competence and readiness to accept duties associated with the Habilitation at Charles University. I thus recommend accepting the submitted thesis and awarding the qualifications.

Please feel free to contact me if any further clarification is needed.

Eva Hackmann