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At your request, I am reviewing the habilitation dissertation of **David Kubizňák**, entitled "Selected problems in theoretical gravitational physics".

The subject of the thesis is very close to my own research, so I have known most of the work that is presented here since the moment that the articles that comprise this dissertation appeared in arXiv. I have indeed invited Dr. Kubizňák to present his work to our group at University of Barcelona. Thus, I consider that, even before reading this dissertation, I have been well acquainted with its contents.

I want to emphasize what I regard as the main aspect of Dr. Kubizňák's research: it is not only of very high international quality, but much of it has been seminal and original – that is, it is not the work of an able follower of the latest trends in the field, but of the person who initiates new lines. This has been notably the case not only once but in two different occasions, namely, the development of 'black hole chemistry', and the study of hidden symmetries of rotating black holes. In the latter case, he has even coauthored a major review monograph on the topic, published by the main journal in the field, *Living Reviews in Relativity*. In other lines of research that he has pursued, his contributions have been consistently solid. By now he has become a well-known and respected member of the community working on modern aspects of black hole theory, and one of the leading experts on black hole thermodynamics.

I will now discuss the different contributions to this field that are presented in the dissertation.

The notions of black hole chemistry, extended black hole thermodynamics, and thermodynamic volume of black holes, were introduced through the work of Dr. Kubizňák and his collaborators, developing an intriguing suggestion to consider the cosmological constant – a parameter that defines a theory, not a state – as an intensive quantity in black hole thermodynamics. I think it is fair to say that the ultimate import of this rather unconventional idea is still not clear; in particular, its interpretation within the framework of AdS/CFT holography has been a matter of debate since the beginning. I have always known Dr. Kubizňák to show a keen appreciation of these issues, much more deeply than many other contributors to the subject. In my opinion, whatever the final verdict is, what has been found so far – most significantly through the findings of Dr. Kubizňák – indicates that there is something of lasting value here.

On the subject of hidden symmetries of rotating black holes and their consequences, I can raise no objections nor concerns, but only a sincere appreciation and admiration of the work done by Dr. Kubizňák. This is mathematical physics at its best. It has resulted in a surprising and important result: the separability of massive vector perturbations, which has an impact on the current modelling of gravitational wave signals from black hole ringdown, aimed at detecting new light fields that are possibly present around astrophysical black holes.

Dr. Kubizňák's dissertation also includes his diverse contributions to black hole thermodynamics in an impressive number of different directions. The ones I find most interesting are the analysis of the role of string tension in the first law. Black holes attached to cosmic strings have been studied for many years (including by myself), but somehow the role of the string in the thermodynamics had only been discussed in specific situations and never been thoroughly examined and clarified. The analysis that is presented in the dissertation, based on an article that appeared a few years ago, is likely to become the main reference for this topic.

Another problem that I am very familiar with – how a vortex can be supported on a rotating black hole – had remained open for well over two decades. The difficulties here lie in the behavior of the fields as they straddle across the ergosphere. I find it satisfying to see that they have been satisfactorily resolved by Dr. Kubizňák and his collaborators, with new properties being uncovered along the way, most notably that the string cannot be described by a simple conical defect, and that the flux expulsion in the extremal limit can be more drastic than in the absence of rotation.

I will be briefer in my comments on the work that is presented on theories of gravity modified by higher curvature terms, since I am a little less knowledgeable about it. The quality of work in this prolific field of research is very variable, but Dr. Kubizňák's is among the best motivated and most sound. I will highlight in particular his contribution to the subject of 'the $D \to 4$ limit of Gauss-Bonnet theory', which has attracted a good deal of attention in the last couple of years, but which, I must honestly say, has mostly been of appallingly low quality. Remarkably, the article that Dr. Kubizňák coauthored on it clarified, in a very physical sense, what this limit actually entails, and is among the handful of truly reliable papers that have made sense of the subject.

I would like to raise a point where I find that this otherwise superb dissertation might have been clearer. It refers to the discussion in pp. 15-16 about black hole thermodynamics when Euclidean regularity is not imposed. I find that the discussion unnecessarily mixes examples which are different in fundamental ways. The issue of the conical singularities along the symmetry axes of a black hole is an unproblematic one, once these timelike defects are properly regarded as limits of field-theory string vortices. This is different than the absence of regularity in the Euclidean time direction when two horizons of different temperature are present – as occurs generically in the case of accelerating black holes, or black holes in deSitter space. The absence of Euclidean regularity in these cases has different implications than in the case of a cosmic string, and the two situations should not be lumped together. Additionally, in the same section, the issue of formulating magnetic black hole thermodynamics is mentioned giving the impression that it belongs in a similar class as the previous ones. But it does not: this is

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not problematic since it is known how to deal with it by the addition of appropriate boundary terms. I would suggest that this relatively brief part of the dissertation might be discussed during the defense, to clear up any possible confusion.

To conclude my assessment, *I have no doubt that this dissertation more than amply satisfies the requirements for acceptance by the habilitation committee. It is the work of an international top-class scientist, which constitutes an original, deep, and durable contribution to a topical, difficult, and important subject in gravitational theory*.

Plagiarism check

I have examined the results of the plagiarism check performed by the *Turnitin* system and have found nothing objectionable. The dissertation is a compilation of several published papers, some of which are co-authored by Dr. Perche. It seems obvious to me that this is no plagiarism; moreover, from what I know of Dr. Kubizňák through my reading of his work and my personal interaction with him over the years, I have no doubts that he has been a main contributor to these papers, both in the originating ideas and in their technical development. I have no concerns whatsoever in this respect.

Yours sincerely,

[redacted]

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