TÉCNICO LISBOA

Prof. Vitor Cardoso
Head of IST Physics Department
Instituto Superior Técnico

Assessment of Mieszko Rutkowski thesis

To the PhD committee,

The PhD thesis on "Linear and nonlinear perturbations of Einstein equations with matter" by Mieszko Rutkowski deals with the response of perturbed black hole spacetimes. Gravitational wave astronomy is now in full bloom, and the next years will test regions of strong, dynamical gravity with unprecedented accuracy. In parallel, long baseline interferometry is giving us access to imaging and motion close to supermassive black holes, a truly tantalizing achievement. The thesis deals with state-of-the-art topics and makes important contributions to the field of study. The document is concise, well-written and clear. The thesis should be accepted.

Chapter 1 is a (rather dry) introduction and motivation to the work and to the formalism used. It is technically correct, although it is well-known material.

Chapter 2 discusses the linearized Einstein field equations, on a charged black hole background. Although a fraction of this material is not new, this Chapter is very well-written and thorough. It discusses gauge modes and coordinates very carefully, as well as gauge-invariant quantities. This exposition is very interesting and could be useful to a number of researchers wishing to learn more about the content of Einstein equations.

Chapter 3 is a very original contribution to our understanding of nonlinear perturbations in General Relativity. It discusses the tower of excitations and how one can handle the full set of perturbations order by order. This is original, and in my opinion very relevant work which will likely find applications in the future, once the community learns about this study. It is one of the outstanding contributions of this thesis.

Chapter 4 changes gears slightly, to discuss possible rotating configurations and the vacuum limit. The gist of the idea is to apply the nonlinear formalism developed in Chapter 3 to study if one can approach the Kerr limit from a sequence of rotating stars – in particular certain configurations called gravastars. The candidate provides strong evidence that such a matching to the Kerr limit is not possible, contradicting previous

claims in the literature. I followed this controversy (in fact I was one of the referees of several of some of the works in question), and am very happy to see this discussion (and its corresponding published version), since it helps to shed light on the issue. It is hard to over-emphasize the importance that this work can have in the field, specially now that data relating to strong-field gravity is available.

Overall, the document is very well written, it forms a consistent and coherent view on the topic. There is a substantial amount of novel material and a good and sound discussion of the literature. The written english is of high quality and most of the material is either new (published recently by the candidate) or presented in an interesting way. It's an exciting line of research. The document is, in my opinion, ready to be defended.

Yours sincerely, Vitor Cardoso Lisbon, January 11, 2022