Thesis supervisor's report on the doctoral dissertation by Dr. Barbora Bezděková

"Propagation and transfer of electromagnetic radiation in refractive and dispersive media in relativistic spacetimes"

Barbora Bezděková stands out among her peers by having studied two branches of physics at the Master's and doctoral levels. She already earned a Ph.D. in plasma physics in 2020, when she defended her thesis on "Multipoint Observations of Magnetospheric Wave Phenomena". The currently presented thesis finalizes her Ph.D. study of theoretical physics.

In the course of this study, the late professor Jiří Bičák had been Barbora's thesis supervisor from 2020 till his passing in January 2024. During this period, Barbora collaborated on her thesis research with several scientists from the University of Bremen (Volker Perlick, Christian Pfeifer and Oleg Tsupko) and Comenius University (Vladimír Balek). In addition, she started an independent research project on cosmological applications of gravitational lensing by galaxy clusters with Roger Blandford (Stanford University). I took over the supervision responsibilities for the last few months of Barbora's studies, in the final stages of thesis writing and submission.

Barbora's two specializations come together in her thesis. The study of photon propagation in a plasma in a black-hole spacetime is highly relevant for deciphering the recently observed "black-hole shadows". While most other researchers concentrate on highly involved numerical simulations, she selects specific well-defined scenarios and utilizes analytical methods to derive the general properties of photon trajectories. This approach provides the opportunity to gain more physical insight into the nature of these complex systems.

The first chapter of the thesis gives an overview of the Hamiltonian approach and Synge's formalism, which are particularly useful for studying light rays in a medium around a compact gravitating source (such as a black hole) in the geometrical optics limit. In the second chapter Barbora derives general analytical results for axially symmetric stationary spacetimes, in particular, the generalized Carter constant, the photon region, the black-hole shadow and the light-deflection angle.

The third chapter includes applications to specific spacetimes, among others the deflection and its weak-field approximation in the Kerr and the Hartle-Thorne metrics, or the plasma effect on photon trajectories. The role of plasma motion is studied in Chapter 4, in the case of spherically symmetric metrics and a radially falling or rotating plasma. The fifth and sixth chapters describe the identification of allowed (and forbidden) regions for light rays in the Kerr metric in a cold plasma.

The results of Barbora's thesis research appear in four published first-author articles (three in impact-factor journals; one in conference proceedings) and in one second-author preprint submitted to an impact-factor journal. In addition, she has nine other articles in impact-factor journals from her plasma / space physics research not related to the present thesis.

Barbora has reported on her current research results at eight conferences, where she presented 6 talks and 2 posters. She has attended 3 summer schools and travelled for research visits to Comenius University (Slovakia), University of Bremen (Germany) and Stanford University (USA). She secured a Charles University Grant Agency grant (as a PI) for her research, and she was awarded a stipend from the Karel Urbánek Fund for her stay at Stanford University. Most recently, she was selected as a young scientist participant of the 2024 Lindau Nobel Laureate Meeting.

Even though I have not been in as close contact with Barbora as professor Bičák had been, I can comment only positively on her work ethic. She is active and inquisitive, hard-working, diligent and driven, tackling advanced theoretical topics without hesitation. In addition, she has a strong personality and a good sense of direction.

Not only the submitted thesis and related publications, but also her active approach to research clearly demonstrate Barbora's capability of independent creative work.

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