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Opponent's report on doctoral thesis

Stars moving in gaseous medium near a galactic center

submitted by **Marcel Štolc**

Doctoral thesis Stars moving in gaseous medium near a galactic center, developed within the framework of the doctoral study program Theoretical Physics, Astronomy and Astrophysics at the Astronomical Institute of the Charles University, Faculty of Mathematics and Physics, and the Astronomical Institute of the Czech Academy of Sciences, Prague, focuses on the study of the radiation emitted by the fluid orbiting and forming accretion discs around compact objects (namely supermassive black holes at centers of galaxies), especially on the thermal optical and UV parts of the electromagnetic spectrum; for a good reason, the accretion disc is modeled by the Shakura-Sunyaev thin-disc model. The aim of this work is to investigate whether and how the perturbations of this thin disc model, such as the presence of an optically thin hot plasma component in the form of an advection-driven fluid flow in the inner part of the discs (also alternating with the surrounding dust component), and the presence of another ("small") black hole component orbiting further away and breaking the thin disc into two parts with the associated gap in the disc, or a combination of both the effects, would manifest themselves in the observed spectrum (compared to the common spectrum coming from the unperturbed disc). The thesis is divided into five main sections, which very well describe the necessary theoretical background, the comparison with observations, and the related discussion of the obtained results.

As required, the thesis is also based on results published in peer-reviewed journals such as the Monthly Notices of the Royal Astronomical Society and the Space Science Reviews. It is more than obvious from the results presented in the thesis that the writing of the thesis required a lot of effort, which clearly demonstrates the author's expertise in the given field, both in the theoretical relativistic astrophysics and in the observational data handling and required modeling to solve the given problem, as well as his ability to think analytically, and his care and sense of clarity. I consider the thesis to be of high quality, also very well and clearly written and supplemented by a number of appropriate illustrative figures, graphs and tables. In addition, to being clear, this allows the reader to verify the results presented.

From a scientific point of view, the thesis presents new, very interesting and valuable results. I did not find any errors in the thesis. Conceptually and terminologically, the thesis seems to me in order. Although it is not my responsibility to make any detailed linguistic judgments, the thesis seems to me grammatically correct and well understood. There are a certain number of typing errors and inaccuracies, but in the number that is quite common for this type of work. Let me mention the following as examples:

page 25 – eg. (1.51 -> eg. (1.51), **page 25** – dR -> {\rm d}R, **page 27** – within the star (in italic shape), **page 37** – seee -> see, **page 52** – In Figure 3.11 and 3.11 -> In Figures 3.10 and 3.11, **page 70** – ranging from ultraviolet over optical up to X-ray domain -> ranging from optical over ultraviolet up to X-ray domain, or, **in the text**, we can find xR_g (without the space) in some places, sometimes x R_g (with the space), etc. In **figures starting from Figure 3.3.**, I would appreciate to use physical quantities to label the vertical axes, instead of using "SED_perturbed/SED_unperturbed" (or to define quantities "SED_perturbed" and "SED_unperturbed"). Similarly, in **Figure 3.2**, it would be OK not to use "rel. ratio", but a quantity. In **Figure 3.4** concerning the scenario I with ADAF disc (no secondary black hole component), the caption contains information on the secondary black hole.

As for the discussion within the thesis defense, I would suggest the following issues.

1) The thesis considers the gap in the thin disc caused by the secondary black hole orbiter. Given the rotating primary black hole in the center, we could, in principle, obtain the "gap in the disc" by considering two discs - one co-rotating with the primary black hole, the other counter-rotating, with the gap in between them. Could this scenario be similarly reflected in the emitted radiation in a similar way? I mean, would it be possible to distinguish between this kind of "perturbed configuration" from the one studied in the thesis?

2) The disc rotating around the central black hole is considered to be thin. Would it be possible to say something about the thick disc, instead of the thin one, with respect to the studied perturbation (hot plasma ADAF disc perturbing the inner part of the thick disc, secondary black hole orbiting far away).

3) (Also related to Point 1) There is a series of papers by Pugliese, et al. on the so-called Ringed accretion discs, i.e. co-rotating and counter-rotating thick discs (toroidal structures). Would it be possible to use (or modify) the method presented in the thesis to be applicable to this kind of scenario as well?

In light of the aforementioned, it is my conclusion that the submitted thesis fulfils all the criteria for a doctoral thesis and that it should be admitted to the defense. I recommend that Marcel Šolc be awarded the degree of Ph.D.

Opava, August 1, 2024

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doc. RNDr. Jiří Kovář, Ph.D.

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