OPINION

on a PhD Thesis for the educational and scientific degree

Doctor in specialty 4.1 Physical Sciences

on: *"Constraining strong regime gravity through analysis*

of compact astrophysical objects"

Author: **Victor Ivaylov Danchev**

The opinion is prepared by:
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Victor Ivaylov Danchev was born on 3.08.1995 in Teteven. In 2019 he graduated
with full honors the Faculty of Physics of Sofia University "Kl. Ohridski" in Physics
with a master's degree. In 2020 he was accepted as a PhD student at the Faculty of
Physics of Sofia University with scientific adviser Stoytcho Yazadjiev,
Corresponding member of BAS, and a scientific consultant Dr. Daniela Doneva. He
completed his PhD in early 2023.

The Thesis contains 150 pages, with list of cited literature of 157 titles. The first 3
chapters are introductory, the fourth is devoted to a detailed exposition of the various
numerical methods, a basic apparatus in this research. The last 3 chapters contain an
exposition of the original results. Finally, the main contributions are systematized.

Danchev's thesis is based on results presented in three articles, co-authored with
S. Yazadjiev (in 2 of them) and with D. Doneva in all three. They are published in
prestigious Q1 quartile journals: Phys. Rev. D and Eur. Phys. J. C. More than 20
independent citations of the three articles are noted in the databases to date.

The extended abstract correctly reflects the content of the thesis and concisely and
succinctly presents the background of the research in the field, as well as the setting
of the tasks and the specific results obtained.

This research is in the field of so-called alternative theories of gravity, involving
additional scalar fields in the action of the standard theory of General Relativity
(GR). While their predictions based on perturbation theory do not differ significantly
from those of GR, this is not the case in the strong gravitational interaction regime for
compact objects of high density matter, such as white dwarfs, neutron stars or black
holes. The consistency of these theories is checked in such a regime, comparing
with data from astrophysical observations. Numerical simulations were used to

exploit universal relations in different classes of alternative theories - Scalar-Tensor and Gauss-Bonnet type theories.

The main problem is that there is a large uncertainty in the equation complementing the system of structural equations, the equation of state, which in principle is determined by the microscopic theory for the types of particles in the matter. Therefore, some universal relations for the basic quantities characterizing the compact objects are studied. They involve a set of parameters, weakly dependent on the type of the equation of state. Conversely, fitting the parameters in the universal relations for the given theory and accounting for the observational data, poses constraints on the form of the equation of state itself. Particularly interesting are the results for slow-rotating topological neutron stars in the framework of Tensor - Multi-Scalar theories allowing non-trivial topological charge. A certain class of such theories leads to results significantly different from GR.

Solving the equations for strong gravitational interactions is possible only numerically, with a variety of non-trivial numerical algorithms and techniques. V. Danchev demonstrates in-depth knowledge in this area as well as develops his own approaches to the calculations, which is key to solving the tasks in the thesis.

My general impression from the materials presented, as well as from the information about Victor Danchev on the web, is that he is a capable young man with diverse interests. Danchev is a co-author of several publications other than those for the thesis, in other areas of theoretical and experimental physics. At the same time, since 2017, he has been a participant, with his scientific competences, in the high-tech Bulgarian company EnduroSat. He is also active in promoting physics as can be seen from his impressive presentations available on YouTube at the Ratio site. In these performances he shows a thorough understanding of a range of physical phenomena and theories - not only in the field of his thesis, as well as an ability to present them comprehensibly and inspiringly for a wide audience.

Danchev's thesis fully fulfills the requirements for the educational and scientific degree "Doctor", accepted by the Faculty of Physics of Sofia University. I strongly suggest to the scientific jury to award the degree "doctor" to Victor Ivaylov Danchev.

Sofia, 4.05.2023

/ Valentina Petkova /