REPORT

on competition for an academic position

"associate professor"

in professional direction 4.1. Physical Sciences (General Theory of Relativity and Relativistic Astrophysics) for the needs of Sofia University "St. Kliment Ohridski" (SU), Faculty of Physics (FzF), announced in SG no. 30/15/04/2022 and on the websites of FzF and SU

The review was prepared by: Professor DSc Vladimir Krastev Dobrev, BAS, in his capacity as a member of the scientific jury for the competition in professional direction 4.1. Physical sciences (General theory of relativity and relativistic astrophysics) according to Order No. RD-38-260/27.05.2022. of the Rector of Sofia University.

Only one candidate submitted documents for participation in the announced competition:

Chief Assistant Dr. Kalin Vilianov Staykov, FzF of SU

I. General description of the presented materials

1. Application details

The documents submitted by the candidate in the competition correspond to the requirements of the ZRASRB, PPZRASRB and the Regulations for the terms and conditions for acquiring scientific degrees and occupying academic positions at SU "St. Kliment Ohridski" (PURPNSZADSU).

To participate in the competition, candidate Kalin Vilianov Staykov submitted a list of 13 publications, all in foreign scientific journals with impact factor. The articles are also presented as files, which makes it possible to get to know them in detail.

Also presented are 8 other publications (5 of them with IF), as well as other documents detailed in the candidate's Application for admission to the competition and supporting the candidate's achievements. Among these documents, I will note that the candidate has submitted a Sample Certificate showing the fulfillment of the minimum national requirements for the relevant scientific field and the additional requirements of SU.

2. Applicant data

The candidate was born in March 1990. He received a Bachelor's degree in 2013 at the Faculty of Science and Technology. He also received a Master's degree there in 2014, with this degree being his first publication (No. 13 in the list of his publications, with IF and Q1). He obtained PhD degree in 2016 at the FzF of SU. His thesis is based on 2 IF publications (#14 and 17 in the general list, and which are not included in the current application). After that, since 2017, he has been Chief Assistant at FzF of SU, and for the last competition he participated with 2 publications with IF (No. 11 and 18 from the general list, and which are not included in the current application). During these years, he also acted as a teacher and supervisor of students in the FzF of SU.

He participated with reports in 5 international conferences. He had 3 one-month specializations in Germany. He acted as a reviewer for 3 authoritative international journals. He received the most prestigious national award "Pythagoras" for a young scientist in 2022, also an award of the FzF of SU for the best PhD dissertation. He managed a project at FNI, and was also a participant in 4 other projects at FNI. He was Deputy delegate in the management board of COST action CA16214, "The multi-messenger physics and astrophysics of neutron stars (PHAROS)", 2017 - 2021. He was member of the organizing committee of NewCompStar School 2017 - "Neutron stars: theory, observations and gravitational waves emission", Sofia, Bulgaria, 2017. He is Associate member in LISA Consortium since November 2021.

3. General characteristics of the scientific works and achievements of the candidate

The scientific activity of the candidate is scientific research. The scientific field consists of advanced sections of modern theoretical and mathematical physics, and more specifically of general relativity and relativistic astrophysics, which meets the competition specification.

Conformity of the scientific works and achievements to the minimum national requirements (according to Art. 2b, paras. 2 and 3 of ZRASRB) and, accordingly, to the additional requirements of SU "St. Kliment Ohridski" for occupying the academic position of "associate professor" in the scientific field and professional direction of the competition:

The candidate collects the following points: group A: 50 points for the acquired PhD degree; group B (habilitation thesis or equivalent publications): 100 points from 4 papers with IF and Q1 - see papers 1-4 from the list of his publications (also Appendix 1); group D (publications outside those of group B): 210 points from 9 works with IF (of which 7 are Q1, one each Q2 and Q3 - see works 5-13 of his list of publications (also Appendix 1); (note: the candidate gives the number from the general list). group D (citations): 162 points (required 50) for works No. 1-13 (see Appendix 2); group E (scientific management and participation in projects) : 44 points (actually not required for associate professor).

Total scores 522 (А-Д) points, with 430 points required in the national requirements.

The requirement of the FzF that points collected from the 13 scientific works presented by the candidate for the competition, which do not repeat those from previous procedures for acquiring a scientific title and academic position, has been met. In the total list of 18 works, these 13 are numbered 1-3, 5-10, 12,13,15,16. (The candidate cites other numbers, but this is not essential.)

The other requirements of the FzF have also been met: Successfully defended diploma students - 3; number of publications from group I in the last 3 years – there are 3 of them with a minimum requirement of 1; number of publications from group I in groups of indicators B and D - there are the required 7; h-factor = 10 with a minimum of 5 required.

I am not aware of any proven plagiarism in the scientific works submitted for the competition. Here it can be said that all his works are in most reputed international journals and cited in such journals, so the question of plagiarism loses its meaning!

4. Characteristics and assessment of the candidate's teaching activity

The candidate as a teacher at the FzF has 1912 hours with a minimum of 540 hours according to the requirements of the FzF.

5. Content analysis of the candidate's scientific achievements contained in the materials for participation in the competition (The numbering of the works is according to the candidate's list.)

The scientific results presented for the competition are concentrated on the modeling of compact objects (black holes and neutron stars) and the study of their parameters and properties in modified theories of gravity. Quasi-normal modes (gravitational waves) of these objects and of the space-time around them have also been investigated. Considerations are made in various modified gravitational theories, with comparison with the corresponding considerations in Einstein's general theory of relativity (GTR).

Paper 13 studies how fast rotation affects the relation between the normalized moment of inertia I and the quadrupole moment Q for scalarized neutron stars. The work shows that the I−Q relation is almost independent of the equation of state for scalarized rapidly rotating stars, but the differences with GTR increase when compared to the slowly rotating case. In general, smaller negative values of the scalar field coupling parameter β lead to larger deviations. An important note is that although the normalized I−Q relation is quite similar for the scalar-tensor theories and OTO, the unnormalized moment of inertia and the quadrupole moment can be very different in the two theories.

Paper 12 studies the oscillations of neutron and quark stars in R2 gravity. More precisely, the non-radial f modes are investigated and the differences with GTR are investigated. Using these results, several asteroseismological gravitational wave relations are constructed. The results show that the differences coming from R2 gravity are up to 10%, which will be difficult to observe in the near future. On the other hand, small deviations in some of the asteroseismological ratios show that they are not only independent of the equation of state, but also quite insensitive to gravitational theory.

In paper 11 universal relations between different normalizations of the moment of inertia and the compactness of neutron and quark stars are investigated. Slow-rotating as well as fast-rotating models are studied in GTR, R2 gravity, and scalar-tensor theories of gravity. The moment of inertia-compactness relationships for various normalizations of the moment of inertia are considered. It is shown that for all studied cases the deviations from the universality of the equation of state are small for the studied equations of state. It turns out that in some of the cases the relations under consideration are largely independent of the theory.

Paper 10 examines a phenomenon called the glitch in young pulsars, which is a sudden increase in the pulsar's rotation. It is thought to arise from the exchange of angular momentum between the crust and the interior of the star. The crust of the neutron star has a space-time curvature 14 orders of magnitude greater than that probed in tests of the Solar System. This makes gravity the weakest constrained physical parameter in crustal processes. The work calculates the ratio of the moment of inertia of the crust to the total moment of inertia of the neutron star in scalar-tensor theory and non-perturbative R+aR^2 gravity. For the first theory, it is shown that the ratio of the moment of inertia of the crust to that of the core does not change significantly from that derived in GTR. For the second theory, it is shown that the ratio increases significantly from what is expected in GTR in the case of high-mass objects.

Paper 9 investigates the axial quasi-normal modes of neutron stars in f(R) gravity using a large set of equations of state. The numerical calculations are done using two different approaches: performing a time evolution of the perturbation equations and solving the time-independent equation as a boundary value problem. According to the results, the mode frequencies and decay times decrease with the increase of the free parameter in the theory compared to the GTR case. While the frequencies deviate significantly from Einstein's theory for all realistic neutron star masses, the decay times reach negligibly small differences only for the more massive models.

In paper 8 a scalar-tensor theory of gravity with a massive scalar field with self-action in the potential is considered. Thus, significant deviations from GTR in neutron star models are obtained, which are in agreement with observations of binary pulsars.

Paper 7 examines the quasi-normal modes of compact objects in several alternative theories of gravity, in particular black holes and scalar hair neutron stars are considered. Black holes in dilaton-Einstein-Gauss-Bonnet theory and in the generalized scalar Einstein-Gauss-Bonnet theory are considered. In the latter case, scalarized black holes arise, for which the stability of various solutions is studied. The existence of an (effective) minimum mass in these models is discussed, and how the spectrum of modes becomes richer compared to GTR when a scalar field is present. The effect of scalar hair for realistic neutron star models is discussed. Here, R2 gravity, scalar-tensor theory, a specific subsector of Horndesky theory with a non-minimal derivative connection, and dilaton-Einstein-Gauss-Bonnet theory are considered.

In paper 6 universal relations between different normalizations of the moment of inertia and the compactness of neutron stars are investigated in the slow-rotation approximation. The relations in a particular class of theories for massive scalar-tensor theories with self-action are investigated, for which significant deviations from TOR are allowed for parameter values that are in agreement with observations. The moment of inertia-compactness relationships for different normalization of the moment of inertia are considered. It is shown that for all studied cases the deviations from the universality of the equation of state are small.

Paper 5 studies orbital and epicyclic frequencies in massive scalar tensor theories (STT) with a self-acting scalar field. The radius of the innermost stable circular orbit (ISCO) was studied, the orbital and epicyclic frequencies of a particle moving in a circular orbit around neutron stars in such theories. It is shown that significant deviations from GTR are possible for parameter values consistent with observations. It is shown that the radius of the ISCO is always larger than the corresponding one in GTR, and that the orbital and epicyclic frequencies are smaller than those in GTR. The maximum deviations of the free parameters in STT compared to GTR were found.

In paper 4, extended scalar tensor-Gauss-Bonnet gravity with a massive scalar field is considered. The existence of Gauss-Bonnet black holes is numerically demonstrated for three different forms of the coupling function, including the case of spontaneous scalarization. A systematic study of black hole characteristics such as horizon area, entropy and temperature for these coupling functions has been carried out and these characteristics have been compared with Schwarzschild solutions. Introducing mass to the scalar field suppresses the scalar field, and increasing this mass brings black holes closer to the Schwarzschild case. For linear and exponential coupling functions, the nonzero mass of the scalar field extends the region of existence of black hole solutions. Larger deviations from the Schwarzschild solution are observed only at small masses, and these differences decrease with increasing scalar field mass. The largest deviation from the case of a massless scalar field is observed at black hole masses near the bifurcation point.

Paper 3 considers a multi-scalar extension of Einstein-Gauss-Bonnet gravity with a three-dimensional target space, namely S^3, H^3 or R^3, and in the case where the image from spacetime to the target space is non-trivial. The existence of black holes in this class of models is numerically shown for several Gauss-Bonnet coupling functions, including the scalarization case. Various characteristics of black holes and the space-time around them, such as the area of the horizon, the entropy and the radius of the photon sphere, have also been systematically studied. For one of the coupling functions, scalarized black holes have been found that have a non-trivial structure.

In paper 2 new non-topological, spontaneously scalarized neutron stars are constructed in multi-scalar Gauss-Bonnet gravity with a maximally symmetric target space and a non-trivial mapping from spacetime to target space. The theory is characterized by the fact that for some classes of coupling functions, the field equations allow solutions with a trivial scalar field that coincide with those in GTR. For a certain range of parameters, these solutions lose stability and new branches of solutions with a non-trivial scalar field bifurcate from the trivial branch.

Paper 1 studies the axial quasi-normal modes of scalar hair black holes in Gauss-Bonnet gravity with a massive self-acting scalar field. Two functions coupling the scalar field to the Gauss-Bonnet invariant are considered, and one of them leads to the scalarization of black holes. Axial perturbations are studied by time evolution of the perturbation equation, and the effect of the scalar field mass and self-action constant on the oscillation frequency and decay time is investigated. We also investigate the effect of the non-zero scalar field potential on the critical point where the perturbation equation loses hyperbolicity for scalarized black holes. The results show that the scalar field potential extends the range of parameters where such a loss of hyperbolicity is observed, thereby shrinking the region of existence of stable black holes.

Conclusion: All contributions can be classified as obtaining and proving new facts. The results definitely enrich existing knowledge, correspond to modern achievements and represent an original contribution to science. I should stress that all results are supported by difficult numerical calculations presented in detail in corresponding figures. The results are widely reflected in the works of other authors - there are 162 citations for papers #1-13, and a total of 416 citations for all works according to the INSPIRE-HEP page!

The candidate's works are collective: there is 1 work with 1 co-author, 3 works with 2 co-authors each, 5 works with 3 co-authors each, 2 works with 4 co-authors each, 1 work with 5 co-authors, 1 work with 6 co-authors. For 9 out of 13 works submitted for the competition, the candidate assesses his contribution as significant, the latter being confirmed by Corresponding member of BAS. Prof. DSc. Stoytcho Yazadjiev.

6. Critical notes and recommendations

I have no critical comments on the scientific nature of the works. I have a minor critical note only on the design of the competition materials – the numbering of the 13 works for the competition in the total list of 18 works is incorrect.

7. Personal impressions of the candidate

I do not know the candidate personally.

8. Conclusion on the application

After having familiarized myself with the materials and scientific works presented in the competition and based on the analysis of their significance and the scientific and scientific-applied contributions contained in them, I confirm that the scientific achievements meet the requirements of ZRASRB, the Regulations for its application and the relevant Regulations of SU "St. Kliment Ohridski" for the candidate to occupy the academic position of "associate professor" in the scientific field and professional direction of the competition. In particular, the candidate satisfies the minimum national requirements in the professional direction and no plagiarism has been found in the scientific works submitted for the competition.

I give my positive assessment to the application.

II. GENERAL CONCLUSION

Based on all above, I strongly recommend the scientific jury to propose to the competent authority for the selection of the Faculty of Physics at SU "St. Kliment Ohridski" to choose Kalin Vilianov Staykov to occupy the academic position of "associate professor" in professional direction 4.1. Physical Sciences (General Theory of Relativity and Relativistic Astrophysics) for the needs of the Faculty of Physics at Sofia University "St. Kliment Ohridski".

28.8.2022 Prepared the report: .....

(Professor, DSc, Vladimir Krastev Dobrev)