R E F E R E E   R E P O R T

on the contest for the academic position of "Associate Professor" in the scientific domain 4.1 "Physical Sciences" ("Gravitation, Relativity Theory") according to the official opening published in the "State Newspaper", issue 65 of August 08, 2019, with a single participating contestant **Dr. Petya Georgieva Nedkova**, Assistant Professor at the Faculty of Physics, Department of Theoretical Physics, Sofia University "St. Kliment Ohridski"

Referee: Prof. (Ret.) Dr.Sc. Svetlana Jordanova Pacheva, Institute of Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences

I. General Description of the Submitted Documents

The contestant has submitted all the documents required by the contest procedure. Specifically, the following relevant documents, from the scientific point of view, have been supplied:

(a) A list of **20** scientific publications together with a **monograph** "*Mathematical aspects of static and stationary higher-dimensional spacetimes"*(to appear soon) - for the purpose of the contest evaluation; also supplied is the full list of all **25** contestant's publication plus the **monograph**   (b) Electronic copies of all publications as well as of the monograph;

(c) A list of **159** independent citations so far on the works by the contestant.

Among the papers by the contestant **17 are publications in leading international journals of Q1 class** with high impact-factors (with total IF=79 and h-index=6), as well as **8** publications in proceedings of international conferences with impact-ranks. An official certificate by the Sofia University's Publishing House has been submitted for the monograph, co-authored with Prof. Dr.Sc. Stoycho Yazadjiev, confirming its forthcoming publication. The contestant has leading contributions in most of her coauthored publications, in particular, she has a leading contribution in a substantial part of the monograph, confirmed by a special written statement by Prof. Dr.Sc. S. Yazadjiev.

The contestant has presented also a list of her participations with invited talks in 12 authoritative international conferences, among them the most renowned ones – the 12th, 13th and 14th „*Marcel Grossmann Meetings on Recent Developments in Theoretical and Experimental General Relativity, Astrophysics, and Relativistic Field Theories*".

The contestant has submitted an official certificate about her participation in 14 national and international projects, in particular – participations in large projects financed by the National Science Fund as well as participations in two prominent multinational

European COST networks - COST Action MP1210 "*The String Theory Universe*" (2013-2017) and COST Action CA16214 (PHAROS) " *The Multi-Messenger Physics and Astrophysics of Neutron Stars*" (2017-2021) (in the latter the contestant is a member of the Action's Management Committee).

II. Timeliness of the Scientific Topics

The principal topics of the contestant's scientific research are:

(a) Systematic derivation of new exact solutions in black hole physics in space-times with one extra space dimension and detailed study of their relevant physical characteristics;

(b) Study of the physical properties of compact astrophysical objects in modified gravity theories – beyond Einstein's general relativity.

In the last 100 years or so – since the time of the celebrated Th. Kaluza and O. Klein works on unification of gravity and electromagnetism in space-times with more than 4 dimensions – a revolutionary progress has been achieved in the proper understanding of the fundamental laws governing the physical processes in the world of elementary particles at (ultra) high energies, as well as of the matter objects at galactic and cosmological scales. The main motivation for studying gravity in multi-dimensional space-times nowadays stems from its crucial role in several interrelated areas in modern elementary particle physics and theoretical astrophysics:

(a) Grand unified theories of Kaluza-Klein type;

(b) String theory which unifies fundamental interactions among elementary particles at ultrahigh energies, and in particular – the "holographic" duality between gravity in space-times with an extra space dimension, on the one hand, and strongly coupled gauge field theories in flat Minkowski space-time, on the other hand;

(c) The concept of gravity at low energy scales (low with respect to the Planck scale) possessing relatively large extra space dimensions (much larger than those in the standard Kaluza-Klein-type models) – the so called "TeV gravity", and the modern cosmological "braneworlds" scenarios.

Let us note that in the context of the "holographic" gauge-gravity duality, the compact objects – black holes in the 5-dimensional "dual" space-time play a decisive role for the adequate "dual" description of the strongly coupled physical processes in 4 dimensions, where there exist no working non-perturbative methods at strong couplings: for instance in quantum chromodynamics for the description of quark-gluon plasma in ultra-relativistic heavy ion collisions, as well as in condensed matter physics for description of superconductivity and superfluidity.

On the other hand, many authors nowadays think that Einstein's theory should be modified already at the classical level (in addition to the fundamental problem of the theory to describe quantum gravity effects due to the non-renormalizable ultraviolet divergences). The principal motivation of the modern modifications/extensions of Einstein's theory comes from:

(a) Adequate description of the cosmological dynamics of the early Universe, as well as of the late Universe – its accelerated expansion;

(b) The "mysterious" dark energy and dark matter in the cosmological evolution;

(c) Explanation of the large scale structure of the Universe;

(d) Study of physical processes in very strong gravitational fields.

III. Short Outline of the Research Activity and the Main Scientific Contributions

The principal research topics in the works of the contestant and her main scientific contributions may be categorized as follows:

III-A Derivation of new exact solutions of the gravitational equations in space-time manifolds with extra dimensions and their thermodynamic properties

The results on this topic are contained in the majority of the contestant's publications. Among the most important ones we point out the following:

(a) A new class of exact solutions in D=5 Einstein-Maxwell-dilaton gravity describing systems of black holes and Kaluza-Klein "bubbles" with an asymptotically non-vanishing magnetic vector potential along the compact Kaluza-Klein extra space dimension.

(b) New exact solutions describing configurations of chain-wise ordered 5-dimensional Kaluza-Klein "bubbles" and 5-dimensional magnetic dipole black rings in the presence of self-gravitating electromagnetic field.

(c) A new stationary axially-symmetric solution of 5-dimensional Einstein theory in vacuum is found, which describes a rotating black ring with one angular momentum in the presence of two Kaluza-Klein "bubbles".

(d) New exact solutions for static black holes located on locally flat gravitational instantons of Taub-bolt and Taub-NUT types are found in the 5-dimensional Einstein and Einstein-Maxwell-dilaton gravitiy.

(e) A new exact solution for deformed black holes is obtained – this is the first in the literature explicit solution for a rotating deformed black hole in the presence of an extra space dimension.

(f) A detailed study is performed of the thermodynamic properties of the above listed solutions describing compact astrophysical objects possessing event horizons and of gravitational instantons in the generalized multi-dimensional Einstein-Maxwell-dilaton gravity.

III-B Classification of the solutions describing wormholes in Einstein-Maxwell-dilaton gravity

Here the most significant result is the formulation and the proof for the first time in the literature of a uniqueness theorem for the static traversable wormhole solutions in the presence of phantom (scalar and/or electromagnetic) fields within the framework of Einstein-Maxwell-dilaton gravity.

III-C Scalarized black holes in generalized scalar-tensor gravitational theories

The main new result here are finding numerical solutions which describe scalarized black holes (i.e., black holes with a nontrivial "scalar hair") in the scalar-tensor gravity coupled to the topological Gauss-Bonnet invariant. Their thermodynamic entropy is studied and an interesting connection is revealed between the bifurcation of the above mentioned solutions and different regions in parametric space.

III-D "Shadows" and relativistic images of accretion disks of compact astrophysical objects

The results here contain deriving and investigating the properties of the "shadow" images of black holes, wormholes and naked space-time singularities, in particular, for the first time in the literature – "shadows" of rotating wormholes are found. The latter result quickly acquired international recognition by the multinational astrophysical collaboration "*Event Horizon Telescope*".

III-E Monograph: "*Mathematical aspects of static and stationary higher-dimensional spacetimes*". The book represents a quintessence of a significant portion of the most important and remarkable results in the journal publications of the contestant.

The exposition in the book is streamlined, systematic and self-contained, in a form suitable both for active graduate and Ph.D. students, as well as for professionals in the same or in closely related areas of theoretical physics. The fact that the book is written in English undoubtedly will attract significantly broader reader interest. I am confident that this book could surely be accepted for publication by any leading international science publishing house, for instance – by Springer.

IV. Short Characteristics of the Teaching Activities

The contestant possesses a significant teaching experience, in addition to her successful research activity:

(a) She was a lecturer in 6 undergraduate and 2 advanced graduate courses at the Department of Theoretical Physics;

(b) She has been also a teaching assistant for 6 undergraduate courses at the Department of Theoretical Physics.

According to her CV the contestant has been entrusted throughout her carrier at the Physics Department with an equivalent of 7 years full lecturing duties. Along with this the contestant was a supervisor of two successfully defended B.A. theses (one of them supervised during her visit in Germany and subsequently published with her foreign B.A. student in Physical Review D).

V. Impact of the Scientific Contributions

The character of the main scientific contributions of the contestant may be defined as **acquiring of new knowledge** about the fundamental laws in gravitational physics – cosmology and astrophysics. In a broader aspect the scientific results in the contestant's works contribute to the long-term program of the global community of scientists in the areas of high-energy elementary particle physics, the astrophysicists and cosmologists in their search for answers to such difficult conceptual problems as the true nature of "dark energy" and "dark matter" in Universe's evolution, searching for extra dimensions of space-time, deeper understanding of the nature of black holes and various other compact astrophysical objects.

VI. Personal Impressions

I personally know the contestant as one of the most zealous and diligent young scientists from her participation in two large joint projects of the theoretical groups in the Institute for Nuclear Research and Nuclear Energy (Bulg. Acad. Sci.) and the Department of Theoretical Physics of Sofia University (Projects DO-257/18.12.2008 and DFNI-T02_6/14.12.2014, financed by the Bulgarian National Science Fund). I have excellent impressions from her professional expertise and thoroughness demonstrated during her several talks on advanced topics of her ongoing research at the seminar in Theoretical and Mathematical Physics in our Institute.

VII. Conclusions

- The principal results in the works of the contestant are novel and represent significant contribution to a hot advanced area of modern theoretical and mathematical physics.
- The published works contain solutions of essential and deeply non-trivial problems of great impact on the advancement of the pertinent scientific area and on the accumulation of new knowledge under the conditions of strong international competition.
- The contestant demonstrates an excellent acquaintance with the relevant literature, a thorough understanding of the principal difficulties to be resolved.
- The contestant has mastered advanced mathematical and theoretical tools and demonstrates impressive capabilities to effectively apply these tools to solve complicated problems.
- Contestant's works are published in the most elite international journals and proceedings of most authoritative international conferences. The number of independent citations of the contestant's works exceeds the usual average value of citations in the domain of modern theoretical and mathematical physics. This shows that they have been recognized and highly appreciated by the international scientific community.

Based on the above evaluations, which undoubtedly prove that the contestant satisfies higher criteria than the standard requirements for the contested academic position, I recommend without hesitation to the deeply respected Faculty Council of the Department of Theoretical Physics in the Faculty of Physics of Sofia University to award Dr. Petya Georgieva Nedkova with the academic position "Associate Professor", which she, in my opinion, truly deserves.

29.11.2019   Referee:
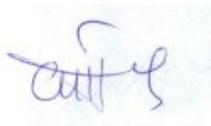
(Prof. Dr.Sc. Svetlana Pacheva)