REPORT

on a competition for occupying the academic position "Associate Professor" in the professional field 4.5. Mathematics (Mathematical Modelling and Application of Mathematics to Mechanics and Robotics), for the needs of Sofia University "St. Kliment Ohridski" (SU), Faculty of Mathematics and Informatics (FMI), announced in State Gazette, Issue 21/15.03.2022 and on the websites of FMI and SU

The report (review) has been written by: Tihomir Ilchev Valchev, PhD, Assoc. Prof. at the Institute of Mathematics and Informatics, Bulgarian Academy of Sciences. I was appointed a member of the scientific jury by order No РД 38-234/11.05.2022 of the Rector of Sofia University for the competition for occupying the academic position "Associate Professor" in the professional field 4.5. Mathematics (Mathematical Modelling and Application of Mathematics to Mechanics and Robotics), announced in State Gazette, Issue 21/15.03.2022 and on the websites of FMI and SU.

The only applicant for the competition thus announced is Dr. Aleksander Aleksiev Stefanov, Chief Assist. Prof. at the Faculty of Mathematics and Informatics, Sofia University "St. Kliment Ohridski"/Institute of Mathematics and Informatics, Bulgarian Academy of Sciences.

I. General Description of the Submitted Documents

1. Information about the competition documents

All documents submitted for the competition are in compliance with the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations on the Application of the Law on the Development of the Academic Staff in the Republic of Bulgaria, and the Regulations on the Conditions and Procedure for Obtaining Academic Degrees and Occupying Academic Positions at Sofia University "St. Kliment Ohridski".

The applicant Dr. Aleksander Stefanov has submitted 16 publications for participation in the competition: 9 papers published in Bulgarian or foreign scientific journals and 7 reports published in conference proceedings. The following documents required by the Regulations on the Conditions and Procedure for Obtaining Academic Degrees and Occupying Academic Positions at Sofia University "St. Kliment Ohridski" have been submitted: application form for accessing the competition, CV, copies of Bachelor's, Master's and PhD diplomas, a copy of the annex agreement for appointment to the academic position "Chief Assistant Professor", certificate for length of service, documents on satisfying the requirements of Art. 105, Par. 1, P. 2 (a copy of the PhD diploma and a copy of the annex agreement), a complete list of publications and a list of publications for participation in the competition, information about minimal national requirements, a list of citations, author's signed

statement on the original scientific contributions in the publications for participation in the competition, a list of courses for undergraduate students in SU delivered by the applicant, a list of co-organized high school Olympiads, copies of the scientific publications for participation in the competition, abstracts of the scientific publications for participation in the competition in English and Bulgarian, and a copy of the announcement of the competition in State Gazette.

2. Short biographical record of the applicant

The applicant Chief Assist. Prof. Dr. Aleksander Aleksiev Stefanov completed a Bachelor's degree in Engineering Physics at the Faculty of Physics, Sofia University in 2010. One year later he finished a Master's degree in Theoretical and Mathematical Physics at the same faculty. In 2016 the applicant earned a PhD degree in the professional field 4.1 Physical Sciences (Physics of Atoms and Molecules) at the Faculty of Physics, Sofia University by defending the thesis "Nonlinear Dynamical Systems Related to Infinite Dimensional Lie Algebras". In the period 2015 to 2017 the applicant occupied the academic position "Assistant Professor" at the Faculty of Mathematics and Informatics, Sofia University. Later, in 2017 he was appointed a chief assistant professor at the same faculty. Meanwhile Dr. Stefanov has been working as an (part-time) assistant professor at the Institute of Mathematics and Informatics, Bulgarian Academy of Sciences since 2015 now.

The applicant's scientific interests range over a variety of areas of mathematics and physics, e.g. theory of integrable systems, differential equations, analytical mechanics, optics, quantum information, and robotics.

3. General characterization of the applicant's scientific works and achievements

Dr. Stefanov's complete list of scientific works consists of 24 publications: 12 papers in scientific journals and 12 reports in conference proceedings. There are no independent (single-authored) papers – all of them have at least one coauthor. Most papers are published in reputable journals with impact factor, e.g. *Scientific Reports*, *Optics Communications*, *Journal of Mathematical Physics*, *European Journal of Physics* etc. The scientific results obtained by the applicant are reported at international conferences, whose proceedings in most cases are published within respected conference series like *AIP Proceedings* and *Springer Proceedings in Physics*. All this is a clear manifestation of a very good scientific activity.

The applicant has picked up 16 works to participate in the competition: 9 papers in scientific journals and 7 reports in conference proceedings. The papers are published as follows: 1 paper in *Scientific Reports* (Q1), 1 paper in *Optics Communications* (Q2), 1 paper in в *Journal of Mathematical Physics* (Q2), 1 paper in *Theoretical and Mathematical Physics* (Q3), 2 papers in *European Journal of Physics* (Q3), 1 paper in *Journal of Geometric Mechanics* (Q4), 1 paper in *Journal of Physics Communications* (no impact factor but with SJR), and 1 paper in *Journal of Geometry and Symmetry in Physics* (no impact factor but with SJR). The conference reports are published in conference proceedings being part of the series: *AIP Proceedings* (3 reports), *Springer Proceedings in Physics* (1

report), *Pliska Studia Mathematica* (2 reports), as well as in the proceedings of *27th International Conference on Software, Telecommunications and Computer Networks, SoftCOM 2019* (1 report). The series *Pliska Studia Mathematica* is indexed in the database *zbMATH Open*, while the rest of the series are indexed in the database *Scopus* too. Information on the fulfillment of the minimal national requirements under Art. 2б of the Law on the Development of the Academic Staff in the Republic of Bulgaria is given in the table below:

Group of indicators	**Indicator**	**Minimal points**	**Points of the applicant**
А	1. PhD thesis	50	50
Б	2. Doctor of Sciences thesis	-	-
В	4. Habilitation thesis – scientific publications, that are indexed and reviewed in world-renowned databases of scientific information	100	165
Г	7. Scientific publications, that are indexed and reviewed in world-renowned databases of scientific information, not included in the habilitation thesis	200	435
Д	11. Citations in scientific publications, monographs, collection volumes, and patents, that are indexed and reviewed in world-renowned databases of scientific information	50	56
Е		-	-

The indicator **В**4 and **Г**7 points as given above are slightly understated compared to those evaluated by the applicant for the following reasons. First, according to the Regulations on the Application of the Law on the Development of the Academic Staff in the Republic of Bulgaria journal quartiles are solely determined by the database *Web of Science* in the case of the professional field 4.5 Mathematics. On the other hand, the applicant has used the two databases *Web of Science* and *Scopus* then he has picked up the higher quartile, which is allowed only in the case of the professional fields 4.1 Physics, 4.2 Chemistry, and 4.3 Biology. For instance, *Journal of Geometric Mechanics* is rated with a quartile Q4 for 2019 by *Web of Science*, while *European Journal of Physics* is rated with a quartile Q3 for 2018 and 2019. Second, *Journal of Physics Communications* and *Journal of Geometry and Symmetry in Physics* have SJR but no impact factor has been assigned to them, which determines fewer points (3x10) for both journals. Third, the Proceedings of *Softcom2019* are indexed in *Scopus* but there is no SJR assigned to it for the publication year of the report (2019), so the corresponding points should be 3x6.

Regarding indicator **Д**11, I have checked that the listed citations of publications are sufficient for the minimal national requirements to be fulfilled, moreover there are some omitted citations indexed in *Scopus*.

In view of the remarks made so far, it is seen that the scientific works presented in the competition fulfill and even much exceed the minimal national requirements under Art. 2б, Par. 2 and 3 of the Law on the Development of the Academic Staff in the Republic of Bulgaria and all additional requirements of Sofia University for occupying the academic position “Associate Professor” in the professional field of the competition.

The publications submitted for the completion have not been presented in earlier procedures for obtaining academic positions.

No plagiarism has been found in the scientific works submitted for the competition.

4. Characterization and assessment of the applicant's teaching activity

I do not have personal impressions of the applicant's teaching activity. According to the information presented in the documents submitted for the competition Dr. Stefanov has delivered lectures or exercises in various mathematical subjects to full-time or part-time undergraduates from the Faculty of Mathematics and Informatics, Faculty of Physics, and Faculty of Biology at Sofia University. There is no information about supervision of undergraduate students. All this demonstrates that the applicant has sufficient experience in teaching.

5. Analysis of the applicant's scientific achievements given in the documents submitted for the competition

Dr. Stefanov's scientific publications can be classified into the following fields (topics): integrable models, robotics, physics of measurement and electronics, optics, and quantum information. All the works are written in collaboration with other scholars. Since the applicant has not submitted a statement of personal contributions in the publications, I assume that his contribution is equal to the rest of co-authors. The numbering of publications used below follows the one of the applicant.

Nearly half of the competition publications belong to the field of integrable models. The works in this group are purely theoretical and deal with constructing and studying of systems of partial differential equations of two independent variables that are integrable in the sense of the method of inverse scattering transform (IST). Certain generalizations of the nonlinear Schrödinger equation (NLS), the modified Korteweg-de Vries equation (mKdV), and the Gerdjikov-Ivanov equation (GI) are considered here as representative examples. A major trend in modern theory of integrable systems is finding some generalizations of classical integrable equations, which means that the topic of those publications is relevantly chosen.

IST is based on the property of some nonlinear equations to be represented as the compatibility condition of two linear differential operators (Lax operators), thanks to which the nonlinear problem can be reduced to a linear problem that is simpler to study in principle. Lax operators depend on some additional external parameter, called spectral parameter, which allows one to formulate and solve the corresponding scattering problem. Generally speaking, completely integrable systems to find application in physics or mathematics possess Lax pairs which fulfill certain additional algebraic symmetry condition (reductions). Reductions are determined by the action of some finite group (reduction group) that preserves auxiliary linear problems. All the nonlinear equations under consideration in that group of publications have Lax operators related to simple complex Lie algebras with some additional reductions imposed. For example, in the work [B4-C.4] two pairs of NLS related to symmetric spaces of the type *D.III* are constructed. For that purpose one imposes reductions induced by the

reduction group $\mathbb{Z}_2 \times \mathbb{Z}_4$ on the Lax operators with coefficients in the Lie algebra *so(8)* while reductions induced by $\mathbb{Z}_2 \times \mathbb{Z}_5$ are imposed on those operators related to *so(10)*. The corresponding scattering problem is considered in detail and the symmetries induced by the imposed reductions are described.

New GI-type nonlinear equation is derived in the report [B4-C.3]. The corresponding Lax representation is a rational bundle related to the Lie algebra *sl(2)* with reduction induced by the dihedral group D_2. The scattering problem and the spectral properties of the scattering operator are studied.

Lax operators with coefficients in simple complex Lie algebras and reduced by the dihedral group D_h , where h is the Coxeter number for the corresponding Lie algebra, are considered in the paper [B4-J.2]. The interrelation between the corresponding scattering problem and local Riemann-Hilbert problem in the complex plane is deeply studied. A detailed derivation of two new integrable systems associated with rational bundles for *sl(2)* with D_2-reductions imposed is also presented. One of those integrable systems represents a deformation of the classical GI, while the other is an equation of the Landau-Lifshitz type.

The papers [B4-J.1, Γ7-J.6, Γ7-J.7, Γ7-C.3] contain new examples of mKdVs, associated with affine algebras. 2-component mKdVs whose Lax representations are related to the affine algebras $A_4^{(2)}$ and $B_2^{(1)}$ are derived in the report [Γ7-C.3]. For that purpose, the Lax pair is reduced by using a Coxeter automorphism or order 10 and 4 respectively. Moreover, the integrable hierarchies of those mKdVs are described in terms of recursion operators. These considerations are continued in the paper [Γ7-J.7] where new 3-component mKdVs associated with the affine algebra $A_5^{(2)}$ are added to the list of the above-mentioned mKdVs. Moreover, the spectral properties of the scattering operator for all the three affine algebras $A_4^{(2)}$, $A_5^{(2)}$ and $B_2^{(1)}$ are described. Similar detailed studies are done in the paper [Γ7-J.6] in the case of the affine algebra $A_n^{(1)}$, and in [B4-J.1] – in the case of $D_4^{(k)}$, *k=1,2,3*. An explicit construction of the Coxeter automorphism for the affine algebra $D_4^{(3)}$ obtained herein can also be attributed to the original contributions in [B4-J.1].

The works in this group are cited in papers published in reputable journals like *Nonlinear Analysis: Real World Applications*, indexed in the databases *Scopus* and *Web of Science*.

The reports [B4-C.1, B4-C.2] are classified to the second area, "Robotics". In the work [B4-C.2], new original design of a walking robot with two degrees of freedom is presented. Constructing robots with similar minimalistic design represents a current trend in modern robotics. Considing the robot a rigid body, which is a standard assumption in robotics, kinematical and dynamical description of its motion is presented. The mathematical model here is based on the following additional assumptions: the base of the robot does not split during its movement, the robot does not tip during its movement and friction at the gears and the motor is negligible. The numerical simulation of the motion of the robot hints on how its main motor can be controlled to ensure a more effective regime of work. The publication [B4-C.1] represents a conceptual continuation of [B4-C.2]. Taking into account the energy dissipation due to friction and heat loss in the main motor, a more general mathematical model

of the motion of the same robot is considered. Using a 3D-printed prototype of the robot, the numerical simulation based on that mathematical model is experimentally tested. The research presented in this group of publications can be characterized as applied in nature. 3D-printed prototypes of such a robot could find applications in training undergraduate students or for work with children with special educational needs. The report [B4-C.1] is cited in a proceeding report published in *Journal of Physics: Conference Series*.

The topic "Physics of measurement and electronics" includes the works [Г7-J.3, Г7-J.4, Г7-J.5, Г7-C.2]. In the publications [Г7-J.3, Г7-J.5], new experimental set-ups for determining some physical constants are presented. Those set-ups are aimed to be accessible to high-school students and undergraduate students, i.e. those publications are mainly of methodological importance. The paper [Г7-J.3] describes a detailed methodology to evaluate the Boltzmann constant by measuring the voltage between the electrodes of a capacitor for various values of the temperature. For this to be done, one uses a version of the well-known equipartition theorem from thermodynamics, that is adapted to capacitors. In the paper [Г7-J.5], a new method for determining the electron charge through the so-called Schottky noise in a photodiode, which originates from the discrete nature of electron charge, is considered. The method is based on the Schottky equation that represents a simple linear interrelation between the spectral density of the Schottky noise and the average value of the electric current in the photodiode. The factor appearing in the Schottky equation is, in fact, doubled value of the electron charge. The advantage of the experimental set-up proposed here compared to the known ones is that it does not require a complicated and expensive electronic equipment, that is it could find applications in high-school physical laboratory.

In the publications [Г7-J.4, Г7-C.2], a mathematical model describing the behaviour of an operational amplifier like the one employed in the set-ups in [Г7-J.3, Г7-J.5] is derived and studied. The model is based on an ordinary differential equation interrelating the input and output voltages, called by the authors of these papers Manhattan equation. The research that is done in those papers can be classified as applied in nature.

The publications in that group are cited in papers published in reputable journals with impact factor like *Measurement*, as well as in two PhD theses.

The publications [Г7-J.1, Г7-J.2, Г7-C.1] are classified to the topic "Optics and quantum information". The works [Г7-J.1, Г7-J.2] are dedicated to a current trend in modern optics – generation of Bessel beams. Those are non-diffracting beams, i.e. they recover their profile after passing by some obstacle. The electric field amplitude of a Bessel beam is described mathematically in terms of cylindrical Bessel functions of the first kind. Since they do not diffract, Bessel beams or appropriately produced approximations of those find application in optical traps, laser acceleration of elementary particles, microscopy, laser eye surgery and so on. In the two papers under review here, a new method for generation of Bessel beams, which uses a special type of beams with singular light fields, so-called optical vortices, is developed. The experimental set-up, proposed here, is based on the idea of employing two spatial light modulators to produce optical vortices from an initial Gauss beam. The

optical vortices, thus created, have prescribed characteristics, called topological charges, so that after they interfere a Gauss-Bessel beam with a decreased or even zero topological charge is produced. In the latter case we have annihilation of vortices. The advantage of that approach is that it allows for the generation of long-range Bessel beams – their range can be about 2.5 m. The usual methods for generation of Bessel beams, e.g. those employing axicons, produce beams having centimeter ranges. The results obtained in the two papers can be classified as applied in nature. The publication [Г7-J.2] is cited in a paper published in *Journal of the Optical Society of America B: Optical Physics*.

In the report [Г7-C.1], a quantum system of two non-interacting two-level subsystems (qubits) is considered. From mathematical point of view, this means that the state space of the bigger system is a tensor product of the state spaces of the two qubits. A new parametrization of the unitary group *SU(4)*, based on its Cartan decomposition, is derived. That decomposition is analogous to the Cartan decomposition of the orthogonal group, acting in three-dimensional Euclidean space, which leads to introducing Euler angles. This is the reason why the parametrization for *SU(4)* introduced in the report is called by the authors Euler angle parametrization. The Euler angle parametrization is used to evaluate the von Neumann entropy which characterizes the entanglement of the states of the two-qubit system. The result presented in the report has theoretical significance.

As a conclusion of the analysis of the applicant's scientific works made so far, my impression is that they are dedicated to relevant topics of the corresponding areas of contemporary science. The approaches and methods employed in the works are entirely relevant to the problems discussed therein. The scientific results presented in the publications are important which is confirmed by the fact that a major part of the applicant's publications appear in reputable journals with impact factor or proceedings with SJR, indexed in world-renowned databases like *Web of Science* or *Scopus*. The writing style applied in the works allows the average reader to understand the basic ideas in the text, i.e. the exposition is accessible not only to experts in the corresponding field but to a broader audience. In view of the way the references in the applicant's publications are selected, my impression is of very good acquaintance with the literature on the subjects under consideration.

6. Critical remarks and recommendations

In view of the concluding remarks in the previous paragraph I have no substantive objections to the applicant's works. However, I would like to pay attention to the following small defects. First, as it is seen from the lists of publications, obviously the applicant has sufficiently well-developed teamwork skills. On the other hand, the lack of independent publications is somewhat striking, which is certain shortcoming of the application. So I recommend the applicant to try to do at least part of his research on his own in the future. In my opinion, this is the clearest way a scholar can show that they are capable of proposing and solving scientific problems at the same time, which is an essential ability when supervising undergraduates as well as PhD students in the future.

Second, I noticed use of incorrect terms in some publications. In the abstract of the paper [B4-J.2] the authors have written "… depends on the realization of the G_R-action …". This is an example

of tautology since word "realization" has basically the same meaning as term "action". So one should write either "realization of the group G_R", or more appropriately "action of the group G_R" instead. Another example appears in the paper [B4-J.1]. Therein the authors call mKdVs equations of fifth order which does not seem appropriate to me. MKdV is a third order equation that has a dispersion law different from the one of the derived equations.

Third, while in general the results in the publications are correctly depicted in the statement on the original scientific contributions, the applicant could have explained in more detail what research had been done and what results had been obtained in the papers included in the topic "Optics". For example, he could have explained in a few words what experiments had been conducted.

Finally, I would like to point out that it would be more appropriate to use a simpler, fully numerical numbering of the publications, which would avoid making errors and confusion. I think the form of numbering used by the applicant is too complicated.

7. Personal impressions of the applicant

I know the applicant personally since the beginning of 2015 when he was appointed an assistant professor in the Department "Differential Equations and Mathematical Physics" at the Institute of Mathematics and Informatics, Bulgarian Academy of Sciences. From the very beginning Dr. Stefanov made an impression on me as an energetic young man who is highly motivated to do science and teaching undergraduate students at a later time. Dr. Stefanov's wish to extend his scientific activity from the theory of integrable systems to other areas of science, e.g., analytical mechanics or robotics, also produces a strongly positive impression on me. In my opinion, this requires rather nontrivial efforts to make.

8. Application conclusion

After getting acquainted with all documents and scientific works presented in the competition and based on the analysis of their significance and the scientific and applied contributions contained in them, I **do confirm** that all scientific achievements fulfill the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations on the Application of that Law, and the corresponding Regulations at Sofia University "St. Kliment Ohridski" for occupying by the applicant the academic position "Associate Professor" in the scientific domain and the professional field of the competition. In particular, the applicant fulfills the minimal national requirements in the professional field. No plagiarism has been found in the scientific works submitted for the competition.

I express my **positive** assessment to the application.

II. GENERAL CONCLUSION

Taking into account the above stated, I **will confidently join** a decision of the Scientific Jury to propose to the competent body of the Faculty of Mathematics and Informatics, Sofia University "St. Kliment Ohridski" to elect Chief Assist. Prof. Dr. Aleksander Aleksiev Stefanov for the academic position "Associate Professor" in the professional field 4.5 Mathematics (Mathematical Modelling and Application of Mathematics to Mechanics and Robotics).

Sofia,

6.07.2022 Jury member:

/Assoc. Prof. Dr. Tihomir Valchev/