# OPPONENT REVIEW

Competition for holding of academic position "Associate Professor", gazetted on 22 December 2020, No 108

**One candidate:** Tikhomir Valchev

**Procedure Notifier**: Institute of Mathematics and Informatics, BAS - Sofia

**Professional Direction:** 4.5 Mathematics

**Scientific Subject:** Equations of Mathematical Physics

**Opponent**: Prof. Michail Todorov, PhD, Dept of Mathematical Modeling and Numerical Methods, Faculty of Applied Mathematics and Informatics by the Technical University of Sofia, Bulgaria, by order 29/19.02.2021 of the Director of Institute of Mathematics and Informatics, BAS - Sofia

## 1. Short biographical record of the applicant

Dr Tikhomir Valchev was born in 1979. He undergraduated Faculty of Physics by the St. Kliment Ohridski University of Sofia in 2002 and one year later in 2005 he graduated the same faculty, subject Theoretical and Mathematical Physics. He was physicist and Assistant Professor (2004-2012) in the Institute of Nuclear Research and Nuclear Energy – BAS. Since 2012 till 2014 he had been postdoc in the Dublin Institute of Technology, Ireland, specialty Integrable systems. Mean-while he took his PhD degree in Physics in 2009, thesis title "Reduction of Nonlinear Equations of Soliton kind over Homogeneous and Symmetric Spaces. Since 2015 he has been a Senior Assistant Professor in the Institute of Mathematics and Informatics – BAS, section on Differential Equations.

## 2. General description of the competition documents

The applicant filled following compulsory documents: CV, copies of Bachelor, Master and PhD diplomas, document for academic position, certificate for a length of service, a certificate showing no previous conviction, information about minimal national requirements (NCID), 2 lists of citations, author information for the scientific contributions related to the given competition supplied by PDF copies of all the articles, list of research competitions, abstracts of refereed publications, advertisement in the official gazette.

## 3. General characterization of the research, teaching and applied activities

The results are presented in complement conferences and seminars in BG and abroad. The total scientific contribution of Dr Valchev consists of 42 works (11 journal papers with total IF = 8.228, 25 papers in conference proceedings with SJR). Sixteen works are self-dependent and the else with two or three co-authors. The applicant does not present a confirmation for equivalent co-authorship and this is the reason to suppose that his participation is at least of equal value.

Twenty journal works are cited many times like works, Refs. [11, 25, 26] from the list of publications are cited 10, 12, and 15 times, respectively – totally 104 citations (no autocitations), *h*-index = 7. Let me emphasize that all the citations are in journals and publications with IF and/or SJR.

The applicant presents 15 works for the competition including 8 journal papers, 7 of them with IF belonging to quartiles *Q2* and *Q3*, other 5 - with SJR, 1 – reviewed in Zentralblatt, 1 – in Mathrev, and 1 – published in the e-base *arXiv*. All of them are published in the period 2010-2019, i.e. they are not included in any previous competitions. The journal works are published in high ranked issues (*J. Physics A, Pliska Studia Mathematica, Nonlinear Mathematical Physics, Physics Letters A, etc.*) The proceedings works are in AIP CP with SJR. More details can be seen in the following

***Table:*** Information about the works

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|---|---|
| Works – 8+6+1 numbers | Abroad<br><br>*Physics Letters A – 1 number, Pliska Studia Mathematica – 1 number, J. Nonlinear Mathematical Physics – 1 number, Journal of Physics A and Conference Proceedings – 2numbers, Theoretical and Mathematical Physics – 1 number, Symmetry, Integrability and Geometry: Methods and Applications – 1 number, American Institute of Physics Conference Proceedings –2 numbers, etc.* |
| Reports on national and international scientific events > 15. | *American Institute of Mathematical Sciences – 2 times, Conferences on Geometry, Integrability and Quantification – 2 times, NTADES – 1 time, 10th International Workshop on Complex Structures, Integrability and Vector Fields – 1 time, International Conference "Physics and Mathematics of Nonlinear Phenomena"- 1 time, etc.* |

The applicant announces about 28 independent citations of the works included in this competition. Dr Valchev is a scientific leader of a big project with the National Science Fund of Republic of Bulgaria. Also, he has taken part in 4 projects more: 2 granted by National Science Fund of Republic of Bulgaria, 1 – by the UK, and 1 – by Ireland. Dr Valchev realized 2-year postdoc specialization in the School of Mathematics by the Dublin Institute of Technology.

Having in mind the said above and according the Regulations in BAS and in particular those in the Institute of Mathematics and Informatics I can conclude that the applicant covers the

requirements to hold the academic position of Associate Professor in the professional subject 4.5 Mathematics. Also, he covers and exceeds the minimal national regulations of LDASRB and has not any plagiarism in his works.

## 4. Analysis of the scientific and applied contributions

Dr Valchev presents comprehensive author information where he claims his scientific and applied contributions. The investigations are mainly directed to the so-called S-integrable dynamical systems, i.e. integrable in sense of the method of inverse scattering problem (MISP). The problems into consideration can be grouped in 3 directions:

- *Quadratic bundles*

In works [7, 10, 11] an investigation of scattering operators, which are quadratic polynomials with respect to the spectral parameter and coefficients in Lie algebra is conducted. Such kind of operators known as quadratic bundles are subject of interest because of the physical interpretation of fully integrable equations admitting Lax pairs with these operators. A principal question here is how to develop the formalism of the direct scattering problem for vanishing boundary condition? To this end Jost's solutions and fundamental analytic solutions are introduced and the relationship between MISP and the local Riemann-Hilbert problem is discussed. The effect of the reduction conditions on the solutions and the scattering data is considered. The latter allows to describe the spectral properties of the scattering operator – the spectrum consists of two parts: continuous and discrete. The continuous part contains the real and imaginary axes in the Gaussian plane, while the discrete eigenvalues are grouped by fours symmetrically placed with respect to the axes. Diagonalizing the Lax pair one can obtain explicitly the conserving densities and their integrals of motion for the whole integrable hierarchy subject to the quadratic bundle. General recurrent relationships between the conserving densities are derived. Reflectionless potentials of the quadratic bundles and the corresponding soliton-like solutions are built and it is demonstrated that they are the simplest potentials, for which the matrix is block-diagonal. The fundamental analytic solutions actually are solutions of Riemann-Hilbert's problem associated with Zakharov-Shabat dressing method. Having built by dressing reflectionless potentials we easily can get the particular integrals of a given nonlinear evolutionary equation (NEU) belonging to the respective integrable hierarchy. The study conducted in [7] shows that depending on the location of poles in Gaussian plane different kinds of potentials (solutions) can exist. In case of complex-valued poles one obtains reflectionless soliton-like solutions. Otherwise if the poles are real or imaginary numbers, the spectrum degenerates and one obtains quasi-rational solutions (potentials). In these cases the derived solutions cannot be running waves.

- *Equations of magnetic kind*

This series of works is devoted to multicomponent NEU considered as analogs of the known Heisenberg NEUs, that are S-integrable. Kind of NEU possesses a scattering operator depending linearly on the spectral parameter. The main difference consists in the Lax presentation, which is associated with Hermitian symmetric spaces and which requires general algebraic relationship. Another kind of studied NEU possesses a Lax presentation like a rational bundle again related to

Hermitian symmetric spaces. These NEU can be considered as S-integrable deformations of the coupled to linear bundle NEU.

Linear bundles polarly calibrated and the related analogs of the Heisenberg equation are considered in works [1-6], [12], [13], and [15]. In particular, in work [15] a new matrix NEU is introduced the latter representing the zero curvature condition of the Lax pair. The result is generalized for linear bunds with imposed local pseudo-Riemannian reduction in [1], and with a nonlocal and without any reduction in [1]. The non-reduced system of two matrix NEUs in work [1] can be interpreted as a particular case of a more general system, related to the original Heisenberg ferromagnetic equation. In work [13] the direct scattering problem in the Hermitian case and for constant boundary conditions is studied in detail. Jost's solutions and scattering matrix are defined and fundamental analytic solutions subject to a local Riemann-Hilbert problem are built. The recursion operators describing the respective integrable hierarchy in few alternative ways are built. It is proved that the eigenfunctions of the recursive operators are full set and the potential and its variation are expanded. The above result allows MISP to interpret as a generalized Fourier transformation and to linearize the NEU system. By using the dressing technics explicitly particular solutions (integrals) of the NEU pair in question are derived. Depending on the location of the poles in the Gaussian plane one can get soliton-like solutions, associated with 4 symmetrically placed with respect to the real and imaginary axes poles (quadruplet) and soliton solutions of doublet kind (corresponding to pairs of complex conjugated poles). The results from work [13] are generalized in works [5] and [6], where a linear bundle with more general pseudo-Hermitian reduction and constant boundary conditions is introduced. NEUs whose Lax operators are rational functions of the spectral parameter are investigated in work [15]. After the zero curvature condition of the considered Lax pair a vector NEU is derived. Next, for it the formalism of the direct scattering problem for constant boundary conditions is developed. For given boundary condition the continuous spectrum of the scattering operator can be consist of either the real axis, similarly to the already considered linear bundles or the real axis and the unit circle. In work [14] recursion operators for the same rational bundle in two alternative ways are built: the Gurses-Carasu-Sokolov method and the squared solution. In work [1] a rational bundle without any additional reduction is introduced and after the zero curvature condition a system of vector NEU is obtained. The system in question can be interpreted as a local integrable deformation of the vector system in [1] and [4] related to a linear bundle. It turned out that such kind of a local deformation does exist only in the case of vector NEU. Local as well nonlocal reductions of the above mentioned deformed system of vector NEU are considered.

- *Others*

The fully integrable NEUs usually admit Lax presentation subject of some additional algebraic conditions and reductions. The latter is a question of paramount significance in the theory of integrable systems – to study and to describe the reductions. A good example for that are the Lax

operators with coefficients pseudo-Hermitian matrices. In work [9] for the first time is considered a possible generalization of the reduction in A.Mikhailov's sense. The ordinary (local) reductions of this kind by a finite group (known as a group of reductions) are described. The group of reductions is a finite group concerning the symmetries in the scattering problem, which act on the set of fundamental solutions of this auxiliary problem keeping unchanged the independent variables. In work [9] a generalization admitting some transform of these variables is proposed. Such kind of approach allows to apply a group formalism to study by using of MISP some classes of nonlocal NEU, for example the nonlocal Schroedinger equation derived by M. Ablowitz and Z. Musslimani in 2013.

Another advantage of the above generalization consists in the methodical approach to construct solutions of fully integrable equations having prior given discrete pointwise symmetries. Many fully integrable systems like KdV, nonlinear Schroedinger, etc., admit quasi-rational solutions. This due to a spectral degeneration of the scattering operator and they can be derived from the soliton solutions by appropriate limit (longwave approach). In work [8] an approach to construct quasi-rational solutions for multicomponent NEU integrable by MISP is realized. It is based on the Zakharov-Shabat dressing method with a dressing multiplier - meromorphic function with simple poles. To illustrate this approach the applicant considers how to get quasi-rational solutions with flat asymptotics for multicomponent nonlinear Schroedinger equation as well as quasi-rational solutions with constant asymptotics for a two-component magnetic system. The solutions obtained are not running waves and generally speaking they are not globally determined, i.e. they have singularities.

## 5. Importance and contribution to the science and practice. Citations by other authors

The works of the applicant clearly indicate the achievements and accents in his scientific production. Beyond question they give directions to next important studies. All the publications contain original and useful results. The conducted investigations possess mainly theoretical significance. Undoubtedly Dr Valchev holds and can apply effectively the mathematical methods, which he complements by profound physical knowledge so needed for the successful research. The results obtained definitely got publicity and recognition clearly seen from the impressive number of citations as well as from the journal rank where they are cited.

## 6. Critical remarks and recommendations

I have not any remarks and criticisms. The documents are prepared diligently and give a real imagination about the scientific activity of the applicant. The statement demonstrates a deep understanding of the studied matter. Yet, he demonstrates deep understanding on abstract algebras. The reference to the regulations for holding of academic positions demonstrate explicitly that Dr Valchev covers and even exceeds the minimal scientific criteria for associate professor in mathematical sciences: Group A – 50 points, required 50; Group B – 100 points, required 100; Group Г – 254 points, required 220; Group Д - 153 points, required 70, group E – 64 points, required 20. The works are published in journals with IF and/or SJR, and are belonging to quartiles *Q2* and *Q3*. The number of citations is

considerable – 104 (28 of them for this competition) in qualitative issues. In my opinion, the applicant is well qualified and can teach specialized classes on integrable dynamical systems and this is my main recommendation to his future activity. Yet, the gained level of knowledge requires Dr Valchev to keep developed this research topic attracting postgraduated students to train.

**7. Personal impression**

I have known Tikhomir Valchev since 2007. He regularly took part in the seminars on integrability and mathematical physics in INRNE and IMI-BAS as well as in AIMS conferences held in Madrid (2014) and Taipei (2018). He strikes me as a modest but high had level and motivated young professional deeply penetrated in complicated field of study requiring equally profound knowledge both in mathematics and physics.

## Conclusion

Gaining an impression for the all-round scientific and research activity of the applicant and having in mind the legal rules and criteria (LDASRB and its regulations in the BAS) as well as the specific rules in IMI I **rate positively** the entire activity. On the strength of virtue of the law **I propose Dr Tikhomir Valchev** for academic position Associate Professor in the Institute of Mathematics and Informatics, Professional Direction 4.5 Mathematics, Scientific Subject: Equations of Mathematical Physics.

Opponent

(Prof. Michail Todorov)

Sofia, April 15th 2021