REVIEW

regarding the competition for the academic position

"Associate Professor"

in specialty 4.5. Mathematics, Scientific Specialty "Equations of Mathematical Physics" (Mathematical Modeling in General Relativity and Quantum Physics)

at the Institute of Mathematics and Informatics (IMI) at the Bulgarian Academy of Sciences

according to the announcement in the SN No. 82/27.09.2024

with only candidate: Hamed Pejhan, PhD, Researcher (R3) at IMI-BAS

Reviewer: Nikolay M Ni.kolov, PhD, Associate Professor at INRNE-BAS

1. General description of the submitted materials

Dr. Hamed Pejhan has presented all the necessary materials in accordance with the Law on the Development of the Academic Staff in the Republic of Bulgaria, which fully satisfies the requirements of both the law and all additional provisions. In particular, according to the submitted reference for the fulfillment of the minimum requirements by a candidate in a competition for the academic position of "Associate Professor" at IMI-BAS, he participates in this competition, with 3 publications in section "C" and 9 publications in section "D", all in indexed journals of rank Q1, except for only two, which are of rank Q2. In section "E" are presented 21 independent citations. The total number of publications of Dr. Pejhan includes one monograph in two editions, 21 publications in refereed journals, 2 publications in conference proceedings.

2. Curriculum vitae of the candidate

Dr. Pejhan obtained his Bachelor's and Master's degrees in Iran, respectively at the University of Urmia (2007) and Azad University in Tehran (2010). In 2015, Dr. Pejhan

obtained his PhD from Azad University with a dissertation on " Krein Quantization Approach to the Vacuum Energy Problem". Dr. Pejhan's postdoctoral period includes a 3-year specialization at Azad University (until 2018), 3 years postdoctoral stay at Zhejiang University of Technology, Hangzhou, China (until 2021), 2 years research position at Azad University, Tehran (until 2023) and from 2023 until now he is at the Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences.

3. Pedagogical activity

There is information that Dr. Pejean was the scientific supervisor of Dr. Surena Rahbardehgha, who successfully defended his PhD thesis in 2018.

4. Main scientific contributions in the publications submitted by the candidate for the competition

The scientific papers presented by Dr. Pejhan are in the field of mathematical Quantum Field Theory (QFT) in curved space-time and in particular, in de Sitter spaces.

At the beginning, I will briefly sketch the general problems of the field. It should be clarified that the mathematical QFT in curved space-time has two main directions, relatively separated from each other: the first is QFT over general space-time manifolds, mostly global-hyperbolic, but without any supposed symmetry. In this case, instead of the individual symmetry of the manifolds (which is generally absent), universal "functional covariancece" is used. Dr. Pejhan's research relates to the second direction, where models are studied in special curved space-time manifolds with high symmetry, which in this case is de Sitter space. It should be noted that both of these directions are especially timely and concern important fundamental issues for the mathematical structure of QFT. In QFT over de Sitter's space, such an important issue is, for example, the problem with the axiom of the so-called "energy positivity", which

has a fundamental interpretation in physics related to the stability of matter and the existence of the vacuum. The group of isometries of de Sitter space, which is actually the Lorentz group, SO(1,4), does not have a positive cone of generators in its Lie algebra, like the Poincaré group, and this makes it impossible to directly transfer the axiom of positive energy from the flat case of Minkowski space to the case of de Sitter space. Fortunately, however, there are alternative "substitutes". In addition, the high symmetry of de Sitter space allows the application of the Wigner paradigm, for the introduction of "elementary particles" or, more abstractly, "elementary quantum systems", as irreducible unitary (projective) representations of the symmetry group. For the further application of this concept in QFT it is also necessary to construct special two-point kernels of the Hilbert scalar product, called "two-point functions". The papers presented by Dr. Pejhan address this problem for the case of the linearized equation for gravitational field fluctuations around the de Sitter background. This is, in short, the problem of the two-point function of the graviton. It should also be clarified that these studies of Dr. Pejhan refer only to the class of the so called "free quantum fields", in this case, it is the linearized gravity.

After the above general description of the area, I move on to the scientific contributions in the works presented by Dr. Pejhan. They are briefly in the following directions:

- In works [6], [4] the type and properties of two-point functions of a (linearized) graviton over de Sitter space are investigated. The general covariance of the gravitational field reflects, after linearization of the Einstein graviton fluctuations around the de Sitter background, a special gauge symmetry. For the construction of quantum fields in the presence of gauge symmetry, an approach with an indefinite scalar product is proposed - this is a generalization of the Krein-Gupta-Bleiler (KGB) approach for the quantization of the free electromagnetic field. Based on this, a model of a free graviton field is built in work [2]. The constructed graviton field has a certain gauge and conformal symmetry and in this sense is called "massless". These works, as well as others,

are based on a thorough group-theoretic analysis of the emergent representations, in the present case of the connected component of the unit of the SO(1,4) group.

- Works [12] and [10] investigate the two-point graviton function for conformal gravity, again from a group-theoretic point of view.
- In work [3] the possible vacuum states of the graviton field are investigated with respect to the SO(1,4) invariance. The existence of such invariant states was found to be impossible. As a consequence, the authors explore the possibility of lower invariant states, but with still sufficiently high symmetry, such as SO(4).
- In work [9], the issue of correspondences of field models with spin 2 at the limit to a flat space-time, depending on the arising irreducible unitary representations, is addressed.
- Work [1] has an "applied character", in the sense that, based on the results of the above works, possible explanations for the so-called "problem of the cosmological constant" are presented. This is also the latest work proposed for the current competition.
- Works [7], [8] and [11] also refer to certain applications of the studied graviton models, such as their relation to "black hole radiation" and the "Casimir effect".

5. Reflection of the candidate's scientific publications

Dr. Pejhan has presented 21 independent citations. He is recommended by 5 internationally renowned scientists in his field, among whom is Prof. Ivan Todorov (BAS) and Prof. Jean-Pierre Gazette (Universite Paris Cite, CNRS, France).
I have no information about plagiarism.

6. Critical remarks of the reviewer on the submitted materials for the competition

Since the candidate has no independent works among those presented in the competition, I expected the candidate's individual scientific contributions to be more clearly outlined. However, based on my additional acquaintance, I believe that Dr. Peihan possesses the necessary individual scientific contribution and qualities that are required in this competition.

7. Personal impressions of the reviewer about the candidate and other data

I know the candidate and I have good impressions.

8. Reasoned and clearly formulated conclusion

According to the above, Dr. Hamed Pejhan unquestionably satisfies all the criteria for this competition. That is why I strongly recommend that he be elected as an associate professor at the Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences.

Date: 26, January, 2025 Reviewer:

/Assoc. Prof. Dr. Nikolay M. Nikolov/