JOHANNES GUTENBERG UNIVERSITÄT MAINZ

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Report on the Habilitation Thesis by Dr. Vojtěch Patkóš

"Precision calculations of light atomic spectra"

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Dear Colleagues

It is with great pleasure that I recommend the Habilitation Thesis "Precision calculations of light atomic spectra" by Dr. Vojtěch Patkóš for acceptance and congratulate the candidate for his beautiful work.

I am an experimental physicist in the field of precision spectroscopy of light atoms, and I consider the work of Dr. Patkóš extremely useful for my field. I have met him on several occasions at workshops and conferences, and he is clearly an excellent physicist.

Precision physics of so-called "simple atoms" is a very demanding field, and I consider Dr. Patkóš one of the leading figures in the extremely difficult theory calculations required here. These "simple" atoms are atoms and ions with only one or two electrons, which is the reason that one can actually perform precision calculations on them. On the experimental side, many of these atoms are amenable to high-precision laser spectroscopy, and the confrontation between theory and experiment at a level parts in 10^{12} allows for tests of our fundamental theory (QED and the Standard Model), and the determination of fundamental physical constants such as the Rydberg constant, fine structure constant, or parameters of the atomic nuclei such as charge and magnetization radii, or the dynamics nuclear polarizability.

Indeed, for decades, only one-electron systems such as hydrogen, or the exotic atoms of muonium, positronium, muonic hydrogen, etc. could be calculated sufficiently precisely, and they are still forming the backbone of the CODATA Least Squares Adjustment of Fundamental Physical Constants. Very recently, and because of the work by Dr. Patkóš and his colleagues the two-electron atoms such as helium, and the ions of Li^{+}, Be^{2+}, B^{3+}, C^{4+} have entered this vibrant field of precision physics. For example, a comparison of two-electron systems from He to C allows for precision isotope shift measurements to be interpreted as precise nuclear charge radii, which also allow for searches of exotic physics.

The present Habilitation Thesis is concerned with all these aspects. The introductory chapters give a survey of techniques used by Dr. Vojtěch Patkóš which have lead to significant advances in the field. The advanced NRQED calculations to α^6 in two-body hydrogen-like systems are the most advanced and most precise calculations in this system to date. The calculated P state fine splittings in muonic helium-3 and -4 show excellent agreement with our experimental values. The calculated hyperfine splittings for point-like nuclei serve as extremely important benchmarks for ab initio nuclear theory of the Zemach radii and polarizabilities, as well as for the experimental determination of these nuclear properties from experiments in ordinary and muonic atoms and ions.

The second branch of the work of Dr. Patkóš is concerned with two-electron helium-like systems. These calculations have previously been much less precise than the one-electron hydrogen-like systems, because of electron-electron correlations which complicate the calculations tremendously.

Dr. Patkóš and his colleagues have advanced this field by an impressive amount, allowing for the first time to match the precision of laser spectroscopy experiments. Indeed, because of his new calculations, the field has flourished, providing a leap in the field and a second corner stone to the CODATA adjustment. These results, reported on in the second part of Dr. Patkós' outstanding Habilitation, make precision studies amenable to a hugely increased number of atomic systems:
For one-electron hydrogen-like systems, only hydrogen has been investigated with lasers. Soon, hopefully, helium-ions, will be measured, too. For higher Z, no laser sources exist, and progress is expected to be small.
For He-like systems, on the other hand, the metastable states in both ortho- and para-atoms allow for a large number of atoms and ions to be studied. So far, transitions have been measured in He, Li^{+}, Be^{2+}, B^{3+}, C^{4+}, and significant progress is expected in the coming years. This is only due to the work of Dr. Patkóš and his coworkers.

Some recent examples of his calculations include the $^{3}He/^{4}He$ isotope shift, where long-standing experimental discrepancies on the level of 25σ (!) exist. Our recent measurements in muonic helium, and the comparison with the most recent measurements from Amsterdam, using the complete theory in He-like systems, seem to have at least partially resolved this problem. This is very reassuring, given the large amount of experiments on He-like ions with larger Z. The work of Dr. Patkóš has already transformed the field, and I expect that his work will soon lead to accurate and very reliable determinations of nuclear structure and fundamental constants from these "more difficult simple atoms".

In summary, there can be no doubt that the work by Vojtěch Patkóš is original and of highest quality. He is a world-leading theorist in the field of precision theory in one- and two-electron atoms, providing extremely useful calculations for the interpretation of precision atomic physics measurements needed to advance our understanding of fundamental physics, determine improved values of fundamental physical constants within the CODATA Determination of the Fundamental Physical Constants, and for searches of physics beyond the Standard Model. This is demonstrated by the large publication count of Vojtěch Patkóš, and the very large citation count.

I propose to accept this Habilitation, grading it with highest grades.

Sincerely

Prof. Dr. Randolf Pohl