

Warsaw, 10th of March 2025

Quantum control of collisions beyond ultralow temperatures

At ultracold temperatures, interatomic collisions are relatively simple, and their outcome can be controlled using a magnetic field. However, research by scientists led by Prof. Michał Tomza from the Faculty of Physics of the University of Warsaw and prof. Roee Ozeri from the Weizmann Institute of Science shows that this is also possible at higher temperatures. The scientists published their observations in the scientific journal “Science Advances”.

At ultracold temperatures, near absolute zero, interatomic collisions show simple behaviour, and researchers can control and alter their effects. As the temperature increases, so does the kinetic energy, which radically complicates the collision mechanism. As a result, controlling the collisions becomes difficult. At least that is what has been thought so far.

Getting the quanta under control

Prof. Michał Tomza's research group from the Faculty of Physics of the University of Warsaw, in collaboration with Prof. Roee Ozeri's experimental group from the Weizmann Institute of Science, studied collisions between rubidium atoms and strontium cations at temperatures far above the ultracold regime. Interatomic collisions can be controlled at ultracold temperatures by changing a magnetic field using so-called Feshbach resonances. 'Unfortunately, it's hard to use this tool in ion-atom collisions because of a complex interaction between the ion and the trap used to hold it in place. This interaction tends to accelerate the colliding pair during the collision and prevent it from being cooled, says Maks Walewski, the first author of the paper.

Unexpected order

At high temperatures, a larger kinetic energy of the colliding particles can be distributed in many different ways, making the collision mechanism complex and hard to control. However, researchers from the University of Warsaw discovered an unexpected order in collisions between rubidium atoms and strontium cations, which allows collisions to be controlled in much warmer conditions.

The scientists' calculations focused on rubidium and strontium, studied experimentally at the Weizmann Institute of Science. However, similar structure may also exist in other combinations of elements. 'At first, we just wanted to reproduce the experimental results using our theoretical model to verify its underlying assumptions. However, we found that our results did not merely agree with experimental data – they also suggested that the ion-atom collisions could be controlled in a surprisingly warm environment, says Dr. Matthew D. Frye.

Further experimental studies are needed to confirm these findings, just as they were at earlier stages of research. The theoretical results of the scientists from the University of Warsaw build on ground-breaking research by an experimental group from the Weizmann Institute of Science, who investigated single collisions between rubidium atoms and strontium cations.

Discovery in practice

‘The ability to achieve quantum control at higher, apparently classical, temperatures may significantly simplify future experimental realizations and suggests that similar phenomena may also occur in other systems. Moreover, the discovery may shed light on fundamental questions concerning the boundary between quantum and classical worlds and the significance of quantum effects in seemingly classical conditions, says Prof. Michał Tomza.

The results may impact not only the fundamental research, but also the development of advanced technologies. ‘The discovery could be important for the development of quantum technologies, in which controlled atom-ion interactions play a key role. The state-of-the-art quantum computers rely on cooling atoms or ions to ultralow temperatures, so any approach that allows quantum control at higher temperatures could pave the way to more efficient quantum devices, says Prof. Tomza.

The research has been supported by the European Union (ERC, QuantMol, 101042989), the National Science Center, Poland (grant no. 2020/38/E/ST2/00564), Poland’s high-performance computing infrastructure PLGrid (HPC Centers: ACK Cyfronet AGH; computational grant no. PLG/2023/016115), and the Israeli Science Foundation (grant no. 1385/19).

Faculty of Physics of the University of Warsaw

Physics and astronomy at the University of Warsaw appeared in 1816 as part of the then Faculty of Philosophy. In 1825, the Astronomical Observatory was established. Currently, the Faculty of Physics at the University of Warsaw consists of the following institutes: Experimental Physics, Theoretical Physics, Geophysics, the Department of Mathematical Methods in Physics, and the Astronomical Observatory. The research covers almost all areas of modern physics on scales from quantum to cosmological. The Faculty’s research and teaching staff consists of over 250 academic teachers. About 1,100 students and over 170 doctoral students study at the Faculty of Physics UW. The University of Warsaw is among the 300 best universities in the world, educating in the field of physics according to Shanghai’s Global Ranking of Academic Subjects.

SCIENTIFIC PUBLICATION:

M. Z. Walewski, M. D. Frye, O. Katz, M. Pinkas, R. Ozeri, M. Tomza, *Quantum control of ion-atom collisions beyond the ultracold regime*, „Science Advances” 11, eadr8256 (2025):
<https://doi.org/10.1126/sciadv.adr8256>

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From left, researchers from the UW Faculty of Physics: Dr Matthew Frye, Prof Michał Tomza, Maks Walewski, Photo: Mirosław Kaźmierczak/UW