Brief information about the project

Name of the project	AP19175613 «Variational Methods in the Quantum Problem of Several Particles with Coulomb Interaction as Applied to Modern Problems of Physics» (0123PK00290).
Relevance	The project is dedicated to a current topic, and in addition to its undoubted theoretical value, it has great practical significance, for example, for experiments to test changes in fundamental constants. The results of the work will be of great importance in metrology, namely for clarifying fundamental physical constants, primarily for improving the value of the electron-to-proton mass ratio, m_e/m_p.
Purpose	The goal of the project is to develop a variational method for three-particle quantum mechanical systems with an arbitrary value of quantum angular momentum, based on the representation of the Schrödinger equation in Breit-Hilleraas symmetry in spheroidal coordinates, as well as to carry out high-precision energy calculations.
Objectives	1. Calculate non-relativistic ionization energies of exotic atoms with high accuracy. 2. Calculate higher corrections of order $m\alpha^8$ in the adiabatic approximation for the antiproton helium atom. 3. Study of the spin structure of the order $m\alpha^6$ and $m\alpha^7\ln(\alpha)$ in antiproton helium atoms. Calculation of the sensitivity of binding energy to particle masses in an antiproton helium atom.
Expected and achieved results	In this project, nonrelativistic ionization energies of exotic atoms are calculated with high accuracy. Data on magnetic dipole transitions in the molecular H_2^+ ion were obtained for a wide range of v and L, quantum numbers of vibrational and total orbital momentum. The results of the work were published in the highly rated journal Physical Review A. (Q1 by scopus). The spin structure of order $m\alpha^6$ and $m\alpha^7\ln(\alpha)$ in antiproton helium atoms will be calculated. Higher order corrections $m\alpha^8$ will be calculated in the adiabatic approximation for the antiproton helium atom with very high accuracy. The leading relativistic corrections will be calculated, in particular, systematic calculations of relativistic corrections in the antiproton helium atom will be determined. The results obtained will have a significant impact on the development of metrology to improve physical fundamental constants, astrochemistry, and the space industry. In particular, to create atomic clocks that are used for a space navigation system, which in turn can provide greater accuracy of parameters for determining the astrochemical characteristics of substances, as well as the

	movement of cars automatically via satellite communications, which in turn are scientific and technological needs.
Research team members with their identifiers (Scopus Author ID, Researcher ID, ORCID, if available) and links to relevant profiles	1.Aznabayev Damir Talgatovich, PhD, Hirsch index – 6, ORCID: 0000-0001-5065-1299, Scopus author ID: 55621187200.
List of publications with links to them	D. T. Aznabayev, A. K. Bekbaev, and V. I. Korobov. Magnetic dipole transitions in the H 2 + ion // Physical Review A. DOI: https://doi.org/10.1103/PhysRevA.108.052827 (2023).
Patents	-