The project focuses on describing selected fundamental aspects of systems (and compounds) of strongly correlated fermions (electrons). By such fundamental properties selected, we mean three issues:

(i) Modeling the transition from indistinguishable particles to their distinguishable counterparts and the related emergence of quasiparticles with spin-dependent heavy effective masses of electrons in applied magnetic field. This case is interesting because the distribution of such particles arises as a combination of the classical Boltzmann partition with respect to the spin direction and the quantum distribution due to their (quasi)momentum. As a result, this leads to a strong alterations of Fermi-Dirac or Bose-Einstein type distributions for those particles.

(ii) Accurate consideration of inter-electron correlations in the theory of chemical bonding and in nanosystems. The source of our interest was our recent exact solution of the Heitler-London model, which in turn is a fundamental contribution to quantum chemistry. This solution allowed to highlight inaccuracies in the standard definition of covalency and precisely define true covalency and the degree of atomicity in simple molecules and nanosystems. In the current project, we intend to extend this approach from electron bonding to hydrogen (proton) bonding case, which beautifully binds, for example, purine bases in the DNA helix. The approach will compared with that for nanosystems.

(iii) As the third part of the project, we propose a revision of the types of exchange interactions in correlated multi-orbital systems. It turns out that in addition to the superexchange (kinetic exchange) or Kondo interactions, there is also a purely electronic Dzialoshinskii-Moriya-type interaction, the importance of which we realized quite recently. This new interaction completes the earlier two and constitutes yet another original contribution of fundamental importance, especially to the theory of specific magnetic properties (e.g., the non-collinear magnetism). In this part we also analyze an original description of the spectral properties of dynamic excitations for the introduced effective models.

As a crowning of the proposed project and two previous OPUS grants (2019-2026), we will apply for a special permission to complete a monograph *(Concepts in Strongly Correlated Fermions).* Such an undertaking is also intended to incorporate in it our earlier original achievements: The derivation of the so-called t-J model (1977-80), the first thermodynamic theory of the Mot (metal-insulator) transition (1986-90), the theory of high-temperature superconductivity beyond mean-field theory (2017-22), the introduction of spin-dependent masses (1990-2006), new quantum-classical statistics, as well as a precise discussion of correlations in molecules and nanophysical systems.

As an illustration of our approach we draw in Fig.1. two examples of nonstandard properties od strongly correlated systems (explanation is provided as the Figure Caption).

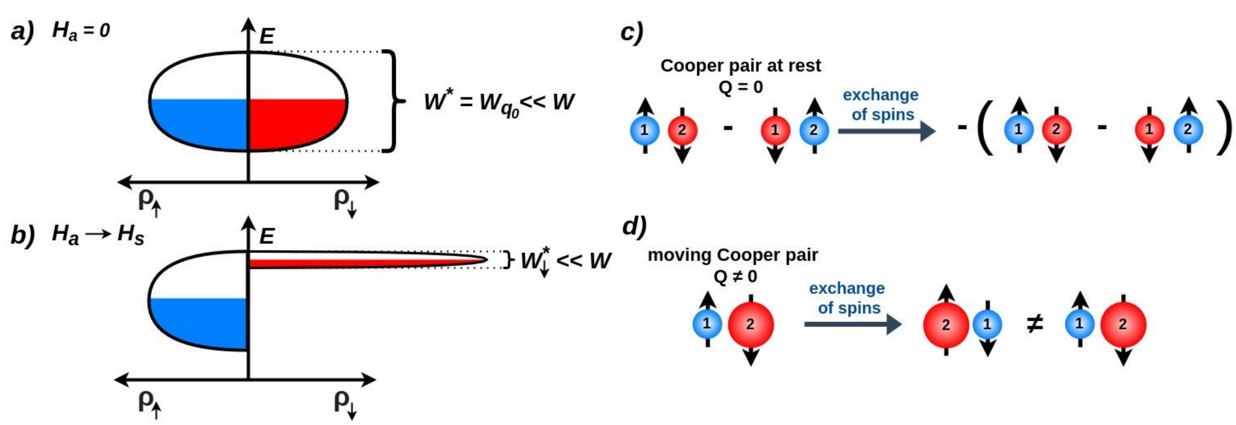

Fig.1. **Left**: Undistorted (a) and distorted (b) spin subbands in the polarized state of correlated electrons. **Right**: Illustration of Cooper pair with equal (c) and nonequal (d) masses, depending on spin direction of component particles.