Weyl semimetals have received significant attention in recent years because they extend the classification of topological phases beyond insulators, host exotic Fermi arc surface states, demonstrate unusual transport phenomena and provide an emergent condensed matter realization of Weyl fermions [2,3,7-12]. Such kind of topologically non-trivial semimetals are believed to open a new era in condensed matter physics. In contrast to topological insulators, where only the surface states are interesting, a Weyl semimetal features unusual band structure in the bulk and on the surface, leading to novel phenomena and potential applications. This opens up unparalleled research opportunities, where both bulk- and surface-sensitive experimental probes can measure the topological nature and detect quantum phenomena. In the bulk, a Weyl semimetal has a band structure with band crossings, Weyl nodes, which are associated with definite chiral charges. Unlike the Dirac points, the degeneracy associated with a Weyl node does not require any symmetry for its protection, other than the translation symmetry of the crystal lattice. The low-energy quasiparticle excitations of a Weyl semimetal are chiral fermions described by the Weyl equation, well known in high- energy physics, which gives rise to a condensed matter analogue of the chiral anomaly. On the surface, the non-trivial topology guarantees the existence of surface states in the form of Fermi arcs, which are open curves that connect the projections of the bulk Weyl nodes on the surface. These Fermi arcs are by themselves of great interest, because Fermi surfaces have to be closed contours in any purely two-dimensional band structure. The chiral anomaly is further interesting because it leads to novel spin polarization textures, unusual quantum interference effects in tunneling spectroscopy, and a new type of quantum oscillation, where electrons move in real space between different surfaces of a bulk sample when executing a constant-energy orbit in momentum space under an external magnetic field.

The discovery of topological Weyl semimetals not only provides a rich material base for exploring unusual physical phenomena, it also opens the door for novel future applications. Massless Weyl fermions hosted by WSM crystal could give rise to faster and more efficient electronics. This opens the opportunity for new technologies to be develop. "The physics of the Weyl fermion are so strange, there could be many things that arise from this particle that we're just not capable of imagining now" said M. Zahid Hasan, a Princeton professor of physics who led the research team.

There are aims in the research proposal that are intended to find experimental signature(s) of Weyl fermions in exotic three-dimensional semimetals via their thermoelectric properties at ultra-low temperatures and in strong magnetic fields. We plan to measure Nernst and Seebeck coefficients for topologically nontrivial phases that are realized in certain transition metal pnictides. To our best knowledge, we plan to perform first-ever measurements of the Nernst effect and thermopower in the presence of nontrivial Berry curvature. It is expected that oscillating Nernst effect in Weyl semimetal across the quantum limit gives rise to deep insight into band structure and hence, could disclose unusual features and novel properties. First and foremost, however, investigations in the quantum limit are crucial to determine a degeneracy of intersecting bands with linear dispersion. In other words, results of a study of the Nernst effect at ultra-low temperatures may bring the answer to the question: can be indeed used the Weyl Hamiltonian to describe exotic quasiparticles in topological semimetals?

Second objective of measurements of the Nernst effect and thermopower in the presence of a non-trivial Berry curvature is aimed at comparative study of Weyl and Dirac semimetals. Nernst and Seebeck coefficients obtained in small magnetic fields and in the limit $T = 0$ will be analyzed in terms of existing theoretical models. Specifically, one expects qualitatively different anomalous Nernst response of massless Weyl and Dirac fermions. Complementary study of topological crystalline isolators should be a valuable result of the research program because in these unique non-trivial topological phases massive bulk Dirac fermions are expected to coexist with massless surface Dirac fermions.

Search for a signature of Adler-Bell-Jackiw-like anomaly in thermoelectric power is the third objective. We speculate that an unusual thermomagnetic response may be observed for non-orthogonal orientation gradient – field. This could be a smoking gun experiment for Weyl fermions and a great success of our project.

All experiments intended to determine unusual physical properties of topological Weyl and Dirac semimetals will be performed at home utilizing resources of the Ultra-Low Temperature Laboratory at the ILTSR PAS in Wroclaw which is equipped with two ^{3}He-^{4}He dilution refrigerator (T_{base} = 75 mK + B = 14.5/16 T; T_{base} = 35 mK + $B \leq 7.7$ T). The research program includes topics suitable for a complete doctoral dissertation, and the part associated with measurements of oscillatory phenomena will be a very important extension of the second dissertation. Some experiments will be carried out within student placements.