Today's technology evolves permanently, the capacity, the speed of writing and reading, the speed of computation is increasing, resulting also in an increase in energy consumption. However, it seems that it is inevitably approaching the physical limits of further miniaturization, increasing speed and the density of packing. To overcome these limits we need to look forward for new generation of data processing and storage technologies. Spintronic devices have received attention as alternative going beyond CMOS technologies that promise to reduce power consumption over conventional charge based computing schemes. To enable low power operation, we should find possibility to operate in the spin domain and avoid spin-charge conversion[1]. Recent years have witnessed a rapidly growing interest in exploring the use of **spin waves**, it is a fundamental wave excitation of ferromagnets which can transfer spin without the charge. Therefore, spin wave based interconnects can be considered as a basic building block of future spintronic circuits.

The main objective of the **SpinSky Project** is to acquire the knowledge necessary to understand the physics of the two important application-related topics of modern magnetism: a) efficient generation of propagating short wavelength spin waves (SWs), and b) synchronization of the magnetization oscillations in nano-dots. The one of advantages of the SW technology is low energy consumption at nanoscale operation length and at microwave frequencies. Thus the Project advances the fields of magnonics and spintronics and attempt to pave the way for application of magnetic nano-oscillators and magnonic logic elements. Moreover, the Project will give deep insight into topological properties of waves in periodic structures, and evaluate a possibility of utilizing those properties. Both goals are critical for further development of the magnonics and spintronics fields of research, and SW-based devices.

To reach those ambitious goals, we propose to test new approach, it is to employ non-collinear topologically protected stable magnetic states coupled to the ferromagnetic film with the imprinted magnetization texture, i.e., a heterostructure composed of the array of **magnetic skyrmions** (see Fig. 1) and thin magnetic film, i.e., artificial skyrmionic crystal. Magnetic skyrmions are small swirling topological defects in the magnetization texture. Their stabilization and dynamics depend strongly on their topological properties. In most cases, they are induced by chiral interactions between atomic spins in non-centrosymmetric magnetic compounds or in very thin ferromagnetic films with broken inversion symmetry[2].

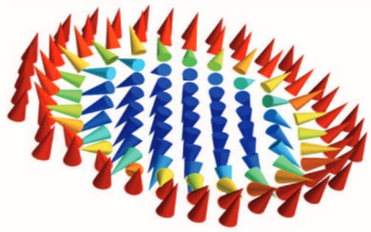

Figure 1. 3D visualization of Néel-type skyrmion.

We assume, that the topological properties of SWs in skyrmionic crystal will support synchronization of magnetization oscillations between skyrmions, as well as generation of short wavelength SWs. This hypothesis will be tested through intensive numerical simulations and developed theoretical models. In order to realize the objectives, we organized the research into four main tasks: A) Study conditions for stabilization of the skyrmion state in nano-dots in contact with ferromagnetic films with imprinted magnetization texture; B) Optimization of the dynamical coupling between excitations in nano-dots and SW dynamics in ferromagnetic film; C) Study the SW dynamics and their topological properties in an array of interacting nano-dots deposited on the ferromagnetic films; D) Evaluation of coupled skyrmion dynamics and their topological properties heterostructure for applications: synchronization and SW excitations.

The above mentioned tasks will be realized by employing and developing several numerical or analytical methods. Our joint project endeavors to study the topological SW characteristics of artificial skyrmionic crystals and their corresponding interaction through a synergistic collaboration between the groups from China and Poland. By combining the expertise of the China side on micromagnetic simulation and the Poland side on magnonic band structure calculation, we will investigate topological and nonlinear effects in structures incorporating magnetic skyrmions, antiferromagnets and even frustrated magnetic systems. With the acquired knowledge, we can design spintronic logic devices utilizing SW propogation in skyrmionic crystals, in particular employ the topological properties of SWs to manipulate the skyrmion state and synchronizing the skyrmionic oscillators. The results of this joint Project will push forward the frontiers of our understanding of the topological properties of the magnonic bands, and provide deep insight into the possibility and functionality of magnonic devices utilizing those properties.

1. Ciubotaru, F. *et al.* Spin waves for interconnect applications. *2017 IEEE Int. Interconnect Technol. Conf.* **1,** 1–4 (2017).
2. Fert, A., Reyren, N. & Cros, V. Magnetic skyrmions: Advances in physics and potential applications. *Nat. Rev. Mater.* **2,** 17031 (2017).