SMARC - Soliton non-stationary dynamics for Spintronic-MAgnonic Reservoir Computing

Imagine a computer that functions like the human brain: energy-efficient, capable of learning from experience, and processing data in real-time. This vision is becoming increasingly attainable through neuromorphic technologies inspired by the workings of biological neural networks. Our project aims to create an innovative computational system based on the magnetic properties of solitons, such as skyrmions and vortices—remarkable, stable magnetic structures at the nanoscale that resemble water vortices or smoke rings. Solitons are unique in their ability to maintain their structure under challenging conditions, making them ideal candidates for next-generation computational technologies.

Our research lies at the intersection of two cutting-edge fields: spintronics and magnonics. Spintronics focuses on controlling the magnetic properties of electrons for information transmission and processing, while magnonics explores spin waves—collective oscillations of magnetization—that enable highly energy-efficient signal processing.

A central aspect of our work is investigating the non-stationary dynamics of magnetic solitons. Unlike stabilized states, where the system oscillates predictably at a fixed frequency, non-stationary dynamics exhibit complex and often unpredictable temporal behaviours. These behaviours are especially intriguing for neuromorphic computing, as they mimic the dynamic processes observed in biological neurons. In this project, we aim to harness these non-stationary oscillations to simulate learning and enable advanced data processing in next-generation neural networks.

The project has three main objectives:

1. **Understanding and controlling the non-stationary dynamics of magnetic solitons** to enable their application in computational tasks.
2. **Design and test neuromorphic reservoir computing** systems that exploit these non-trivial dynamics.
3. **Conducting experiments to validate simulation** results and demonstrate the practical application of these systems.

During this project, we will collaborate with Prof. Philipp Pirro's team in Germany, renowned experts in magnonics and spintronics. This partnership provides access to cutting-edge laboratories and experimental techniques, allowing us to conduct research at the forefront of the field

Our goal is to develop a groundbreaking computational system that leverages the speed, energy efficiency, and unique properties of magnetic solitons. This innovation has the potential to transform information processing technologies and advance artificial intelligence by providing a new paradigm for neuromorphic computing.

In addition to its technological implications, the project will make a significant contribution to fundamental research by deepening our understanding of magnetism and spin-wave dynamics. By investigating the non-stationary behaviour of magnetic solitons, we aim to uncover new principles that could shape future research in magnonics and spintronics.