PhD Report – First year

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Cycle: XXXVIII
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1 Research activities

During the first year of PhD, my research activity has focused on the study of magnetoelectric multiferroics, hosting both magnetism and ferroelectric polarization. They enable switching of magnetic order by electric fields, which is of pressing interest for improved information storage devices. Discovery of ferroelectric polarization induced in spiral magnets [1] fueled the explosion of interest in multiferroics and non-collinear magnets over the past 20 years [2, 3, 4, 5], however some fundamental properties of these systems are still not understood.

These are the two main projects I have worked on:

- **Modelling thermal transport in non-collinear magnets**. This work is motivated by recent ultrafast experiments that observed strong change of thermal conductivity upon the phase transition from ferromagnetic to spiral and skyrmion states in GaV_4S_8 [6]. One possible explanation is the scattering of magnons and phonons off the domain walls formed in abundance in non-collinear states, but the origin of the effect is still debated. Another possible explanation is that non-collinearity of spins leads to cubic anharmonic terms [7], that are absent in collinear structures, and limits the magnon mean free path. Moreover, considering magnons as heat carriers is a poor approximation in the non-collinear state and leads to an underestimation of thermal conductivity, since energy relaxation time is much longer than the scattering time for magnons. We started this work for my Master thesis, computing the amplitudes of these scattering events involving three magnons, developing a description of thermal transport using Boltzmann transport equation, and writing a C++/OpenMP code that diagonalizes the collision matrix and computes thermal conductivity. The convergence of the numerical calculations requires a dense k-grid, which is a consequence of the rich structure of the scattering matrix. During this year, we had to optimize the code and its parallelization to be able to use denser k-grids and reach the convergence. We also implemented the computation of effective magnon viscosity [8], and started to explore the possibility of a vorticity in a magnon flow.
- **Non-local electric field-induced domain wall motion in spin spiral multiferroics**. Here we studied switching in spiral magnets – fundamental for technological applications, and still poorly understood. We find that electric field can induce unconventional non-local dynamics of domain walls (DWs) in spiral magnets. There are two principal types of low-energy walls in cycloidal spiral magnets. The walls that have coplanar spins (type I) exhibit

non-local motion, *i.e.* spins far from the wall rotate. In type II DWs, the spin rotation plane is twisting continuously, so that spins leave the easy plane within the wall. The motion of these walls only requires spins within the walls to rotate, similarly to ferromagnetic DWs. Non-local dynamics of type I walls leads to unconventional equations of motion, zero contribution to dielectric constant in thermodynamic limit and a much stronger pinning compared to type II walls, as well as a peculiar breakdown at high electric fields.

2 Schools and conferences

- **The 15th International Meeting on Ferroelctricity**, March 26-30, 2023, Tel Aviv, Israel. I contributed with a talk: "*Motion of multiferroic domain walls*"
- **School on Quantum Many-Body Phenomena out of Equilibrium: from Chaos to Criticality**, 21 August - 1 September, 2023: Trieste, Italy (in person). I presented a poster: "*Modelling thermal transport in non-collinear magnets*"

3 Courses and exams

- **Crystalline solids: electronic correlations, instabilities and order**, Prof. Sergey Artyukhin – passed
- **Energetics in the quantum regime**, Prof. Dario Ferraro – exam to be taken soon
- **Crash course on theoretical condensed matter physics**, Prof. Niccolò Traverso Ziani – exam to be taken soon

4 Publications

- F. Foggetti, M. Parodi, N. Nagaosa, S. Artyukhin, *Non-local electric field-induced domain wall motion in spin spiral multiferroics* – in preparation
- M. Parodi, S. Artyukhin, *Thermal conductivity of non-collinear magnets* – in preparation

References

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[6] Fumiya Sekiguchi, Kestutis Budzinauskas, Prashant Padmanabhan, Rolf B Versteeg, Vladimir Tsurkan, István Kézsmárki, Francesco Foggetti, Sergey Artyukhin, and Paul HM van Loosdrecht. Slowdown of photoexcited spin dynamics in the non-collinear spin-ordered phases in skyrmion host gav4s8. *Nature Communications*, 13(1):1–8, 2022.

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