Magnetism of 2D van der Waals systems : a theoretical study

Director : **Andrés Saúl** (andres.saul@cnrs.fr)
Tutor académico : **Alfredo Levy-Yeyati** (a.l.yeyati@uam.es)

A large amount of compounds are formed by the stacking of layers of strongly bound atoms while the layers are weakly attached between them by a weak *van der Waals* interaction (Fig. 1(a)). Some van der Waals compounds are magnetic showing a large diversity of magnetic orders at low temperatures (Fig. 1(b)). The weakness of the van der Waals interaction is at the origin of the discovery of graphene, that was followed by the development of experimental techniques allowing the exfoliation of other van der Waals systems opening the possibility of studying the thickness dependence of the physical properties of quasi two-dimensional systems down to a bilayer or even a single layer.

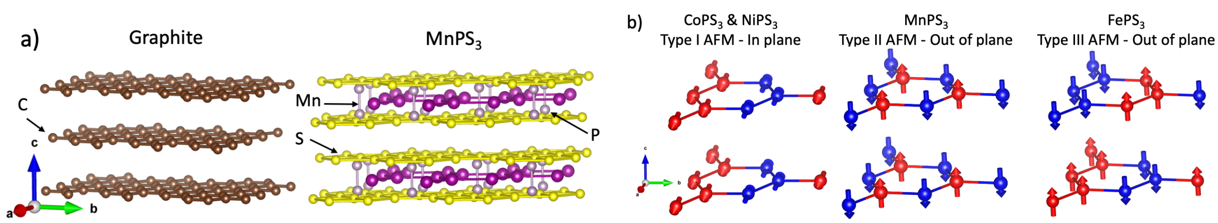

FIG. 1. a) Example of van der Walls systems. b) Example of diversity in the anti-ferromagnetic order of van der Walls systems of the same *family*, here the metal phosphorus tri-chalcogenides MPX_3 (M = Fe, Co, Ni, Mn). Only the magnetic atoms Co, Ni, Mn or Fe are shown. The arrows show the preferential orientation of the magnetic moments.

Interestingly, despite the existence of a theorem (Mermin-Wagner) saying that a magnetic Heisenberg Hamiltonian can not show long range order in two dimensions, experimental studies have shown that some van der Waals systems remain magnetically ordered at low temperature in the limit of a single monolayer [1-4]

In this internship we will use state of the art theoretical methods to understand the reasons for the existence of magnetic order in these quasi two-dimensional systems and study in detail their magnetic excitations (magnon's band structure) and their interactions with light (Raman and Infra-red spectroscopy), electromagnetic fields (Electron Spin Resonances), and lattice vibrations (magneto-elastic interactions).

Practical details:

The research project will be performed under the supervision of Andrés Saúl (Marseille, France). The intern would be able to apply for a financial stipend in France. Funds are available for visits to Marseille. The scientific project could be continued in the doctorate program.

[1] B.Huang, et. al., *Layer-dependent ferromagnetism in a van der Waals crystal down to the monolayer limit*, Nature 546, 270 (2017).

[2] C. Gong, et. al., *Discovery of intrinsic ferromagnetism in two-dimensional van der Waals crystals*, Nature 546, 265 (2017).

[3] N. Samarth, *Magnetism in flatland*, Nature 546, 216 (2017).

[4] K. Kim, et. al., *Antiferromagnetic ordering in van der Waals two-dimensional magnetic material MnPS3 probed by Raman spectroscopy*, 2D Materials 6, 041001 (2019).