**Inelastic Neutron Scattering: A technique to probe the soul of magnetic nanoparticles.**

**E. M Jefremovas**[1,2*], M. de la Fuente[1], B. Fåk[3], A. Michels[4], J. A. Blanco[5] and L. F. Barquín[1]

[1]Institute for Physics. Johannes Gutenberg University of Mainz, Germany

[2]Dpto CITIMAC, Faculty of Science, University of Cantabria, Spain

[3]Insitute Laue-Langevin, France

[4]Department of Physics and Materials Sciences, University of Luxembourg, Luxembourg

[5]Department of Physics, University of Oviedo, Spain

During the last decades, we have dived into the fascinating pool of 4*f* intermetallic ensembles of nanoalloys. With a strong magnetic moment, these ensembles constitute the best case examples alloys to unveil modifications in RKKY interactions and crystalline electric field (CEF) driven by the size reduction to the nanoscale. Chiefly focused in binary alloys, in the form $RM_2$, being $R$ = Tb, Nd, Gd (magnetic), and $M$ = Cu, Al, Y, La (non-magnetic), we have been able to elucidate the existence of two different symmetry environments, one ascribed to the magnetic moments located within the core, which mostly retain the bulk-like properties, and a second one, connected to the surface magnetic moments, where the less-symmetric and more distorted environment alters the magnetic coupling [1], [2]. Indeed, the existence of two different symmetry environments leads to a dual spin dynamics, with also a possible modification of the actual role of the CEF at the mesoscopic scale, both essential matters, as they determine the energy levels, i.e., the basic support of the material properties. As a matter of fact, the streamlined experimental technique capable of probing such excitations is inelastic neutron scattering (INS), which imposes a limitation to magnetic nanoparticles (NPs), as large amounts (≈10g) are needed to get a reliable signal-to-noise ratio. Using ball-milling, we mastered the production of crystalline $RCu_2$ NPs, where the antiferromagnetic bulk state is retained at the core, being lost at the surface. Equipped with these NPs, we dived, for the first time, into their soul.

In this talk, we will address how we depicted the energy level splitting in both $TbCu_2$ and $NdCu_2$ nanoalloys using INS [3], [4]. By varying the temperature, we surveyed the different magnetic regions of those NPs, probing both crystalline electric field and collective magnon excitations. Our results show how neutrons can be a game changer in the investigation of spin dynamics in magnetic NPs, as a powerful tool to depict their underlying physics.

[1] E. M. Jefremovas et al., Nanomaterials **10**, 6 (2020) and 11 (2020).

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[3] E. M. Jefremovas et al. Phys. Rev. B **104**, 134404 (2021)

[4] E. M. Jefremovas et al. Comm. Mater. **4**, 1 (2023).

*martinjel@unican.es