Taking magnetic hyperthermia and magnetogenetics to the next level: key aspects to address from a basic-physics point of view

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Magnetic fluid hyperthermia is an alternative approach for cancer treatment that uses the heat released by magnetic nanoparticles when subjected to a magnetic field, to controllably damage the tumour cells – which are more sensitive to a temperature increase than the healthy ones. Its key aspects are the fact that the human body is essentially insensitive to moderate magnetic fields, and that common magnetic compounds are very biocompatible; thus, undesired secondary effects are prevented, what motivated much research attention during the last years. However, and in spite of the promising capabilities, the success in reaching routine clinical practice has been very scarce. The aim of the talk is to highlight some crucial aspects that, in my opinion and from the theoretical point of view, need to be addressed in order to achieve further biomedical success using the heat released by nanomagnets under AC fields. I will focus on magnetic hyperthermia but also on a related novel approach: the thermally-triggered remote control of cellular activities, the so-called *magnetogenetics*.

From the physics point of view, a main difficulty is the lack of theoretical models able to describe not only the heating performance itself, but in general the behaviour of the MNPs in the viscous biological environment under AC magnetic fields. This results in the absence of accurate tools able to guide the experiments. The failure in the current models involves several key factors, including procedural (complete impossibility to explain successful heating effects on cells when the global heating is negligible); interpretative (current heating mechanisms cannot account for accurate heat-triggering experiments – other mechanisms at play?); and descriptive ones (available models are limited to short timescales, far from those of the experiments). The complex nature of the problem requires a multiphysics approach to go beyond the state-of-of-the art and overcome the above limitations, able to; simultaneously embrace superparamagnetic and Brownian processes; provide alternatives to current heat generation mechanisms; and efficiently deal with the different timescales involved. During the talk I will summarize the limitations and possible ways to overcome them, with the objective of developing a general framework for the heating performance of magnetic nanoparticles in viscous media under AC magnetic fields.