Elucidating the Electronic Structure of Magnetite using X-ray Magnetic Dichroism

H. Elnaggar[1], A. Juhin[1], A. Rogalev[2], Ch. Brouder[1], F. M. F. de Groot, F. Wilhelm[2], M-A. Arrio[1], M. Sikora[3], M. W. Haverkort[4], Ph. Sainctavit[1], P. Glatzel[2], R. Wang, S. Lafuerza[2] and T. Schmitt[5]

Debye Institute for Nanomaterials Science, Utrecht University, [1]Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie, CNRS, Sorbonne Université, [2]European Synchrotron Radiation Facility, [3]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, [4]Institut für Theoritiche Physik, Universität Heidelberg, [5]Photon Science Division, Paul Scherrer Institut *.
H.M.E.A.Elnaggar@uu.nl

Transition metal oxides have gained a lot interest due to their unique properties most famous of which are: super-conductivity, multiferroicity, magnetism, catalysis et cetera. The rich physics offered by these systems arises from the intricate interplay of the various degrees of freedom (*e.g.* spin, orbital, charge and lattice. X-ray spectroscopy has become an established tool that can uncover element- and site-specific information offering an ideal toolbox to study strongly correlated systems. In particular, carefully designed experiments with optimized scattering geometries can reveal subtle spectral features that are typically indistinguishable. However, the challenge to optimize and interpret data from such experiments persists and has hindered the full exploitation of dichroic techniques.

In this talk, I will discuss a series of X-ray magnetic dichroism measurements on the prototypical Mott insulator, magnetite (Fe_3O_4). This illusive system remains a widely debatable subject ever since the phenomenal work of Verwey in 1939 [1] due to its complexity: Fe_3O_4 is a mixed valence, strongly correlated system where many interactions such as Jahn-Teller (dynamical and static), spin-orbit, Kugel-Khomskii and phonons are very close in energetics. As a matter of fact, the origin of the metal to insulator transition and the magnitude of the orbital magnetic moment in Fe_3O_4 are contentious [2-5]. I will show here that X-ray magnetic dichroism measurements in combination with theoretical simulations can offer a unique perspective on these open questions. I will focus on the following two aspects:

(a) Investigation of non-collinear ordering of the orbital magnetic moments in the high temperature phase of Fe_3O_4 using a combination of X-ray linear and circular magnetic dichroism measurements in the hard X-ray regime [6].
(b) Investigation of trimeron correlations in the high temperature phase of Fe_3O_4 using resonant inelastic X-ray scattering in the soft X-ray regime [7].

References

[1] - Verwey, Nature **144**, 327 (1939).
[2] - E. Goering, M. Lafkioti, S. Gold, and G. Schütz, J. Magn. Magn. Mater. **310**, e249 (2007).
[3] - D. J. Huang, C. F. Chang, H.-T. Jeng, G. Y. Guo, H.-J. Lin, W. B. Wu, H. C. Ku, A. Fujimori, Y. Takahashi, and C. T. Chen, Phys. Rev. Lett. **93**, 077204 (2004).
[4] - M. Coey, Nature **430**, 155EP (2004).
[5] - M. S. Senn, J. P. Wright, and J. P. Attfield, Nature 481, 173 (2012).
[6] - H. Elnaggar *et. al.*, Submitted to Phys. Rev. Lett.
[7] - H. Elnaggar *et. al.*, Submitted to Phys. Rev. Lett.

* Co-authors are presented in alphabetical order