

Multiferroicity, magneto-lattice coupling, superconductivity, metal-insulator transition: the richness of iron-based spin-ladder compounds BaFe_2X_3

Manganese-based compounds have long served as prototypical systems for magnetoelectricity with improper ferroelectricity. Their multiple stable valence states and high magnetic moments (typical of 3d ions) make them ideal candidates for Type II multiferroicity, where ferroelectricity arises from magnetic ordering. The RMnO_3 and RMn_2O_5 families (with R being a rare-earth element) exemplify this behavior, exhibiting strong magnetoelectric coupling. However, their functional properties are generally limited to low temperatures, typically below 50 K. To overcome this limitation, recent research has turned to iron-based compounds, which offer similar advantages—multiple valence states and large magnetic moments—along with higher magnetic ordering temperatures (often above 100 K), due to stronger magnetic exchange interactions.

In this context, we have investigated the quasi-one-dimensional iron spin ladder systems BaFe_2X_3 ($X = \text{Se}, \text{S}$). Using a combination of infrared spectroscopy, X-ray and neutron diffraction, and spectroscopy, we have mapped the complex pressure–temperature phase diagram of BaFe_2X_3 . At ambient pressure, BaFe_2Se_3 is polar at room temperature, and upon cooling below 250 K, a magnetic transition induces a multiferroic state. The underlying magnetic structure exhibits significant frustration, driven by competing magnetic interactions and anisotropy. Above 4 GPa, we observe the emergence of a new magnetic phase coinciding with a structural transition, yet without significant changes in the local electronic structure or magnetic moment. The system's metallicity increases in two distinct stages: first at 4 GPa and then again at higher pressures, eventually plateauing prior to the onset of superconductivity. Notably, the superconducting phase is associated with a non-centrosymmetric crystal structure, providing new insight into possible pairing mechanisms. A parallel, ongoing study on BaFe_2S_3 further explores magneto-elastic coupling in this system, highlighting the intricate interplay between magnetism, structure, and superconductivity.

References:

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Victor Balédent began his career in physics with a PhD at the Laboratoire Léon Brillouin (LLB, CEA-Saclay / Université Paris-Sud, 2010), focused on magnetic order in the pseudogap phase of high-Tc cuprate superconductors (PhD Prize 2012). He then completed a postdoc on the GALAXIES beamline at Synchrotron SOLEIL (2010–2012), specializing in XAS, XES, and RIXS spectroscopy under extreme conditions. He joined the Laboratoire de Physique des Solides (LPS, CNRS / Université Paris-Saclay) as an Associate Professor (Maître de Conférences) in 2013, and obtained his Habilitation à Diriger les Recherches in 2024, dedicated to the multiferroic physics of RMn_2O_5 compounds. He is also an associated researcher at LLB since 2021 and at the GALAXIES beamline, Synchrotron SOLEIL since 2017. Since 2025, he holds a Junior Chair at the Institut Universitaire de France (Fundamental Chair).



An experimental physicist specializing in quantum materials and strongly correlated electron systems, Victor Balédent explores how remarkable phenomena such as magnetism, superconductivity, multiferroicity, and metal–insulator transitions coexist or compete. To probe the organization of atoms, charges, and spins at the quantum scale, he combines elastic and inelastic neutron and X-ray scattering techniques, pushing materials to extreme conditions — ultralow temperatures, high pressures, and intense magnetic or electric fields.

Key topics: Magnetism · Superconductivity · Multiferroicity · Metal–insulator transitions (Mott physics)

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