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Relaxations of spin chains in molecular magnets: experimental investigations of the role of anisotropy

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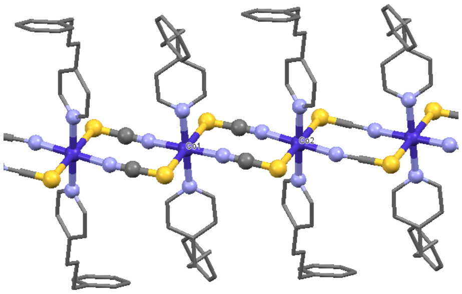
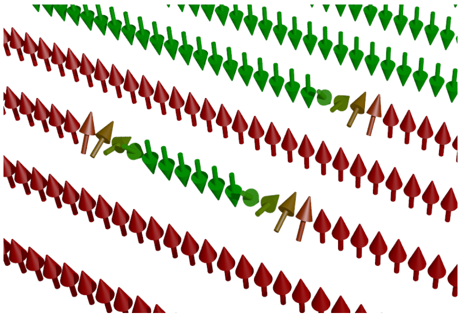
The dynamics of spin chains is a subject that covers a range of interesting phenomena. A reminder is the last Nobel prize for Duncan Haldane, awarded for, among other topics, a theory of spin chains that incorporated effects of topology. The newest topic that hit the headlines in March 2017 was a *discrete time crystal* observed in the spin chain of atomic ions, trapped and periodically perturbed.

The project concerns studies of the dynamics of experimental realization of spin chains: crystals in which metal ions linked together with non-magnetic ligands. An example of such a crystal structure is shown in the figure on the right. Co(II) ions are connected by $(\mathrm{NCS})_2$ bridges into chains. Spins are localized at metal ions, while the bridges mediate the exchange interaction between spins.



In such systems, at very low temperature, the spin dynamics slows down. In extreme cases, this leads to the appearance of magnetic hysteresis, despite the absence of long-range order. More precisely, a slow magnetic relaxation occurs, i.e. the system reacts to changing magnetic field with a certain delay. This phenomenon, foreseen by Roy Glauber in the 1960s, waited for experimental confirmation till 2002. Only a dozen of different single chain magnets has been found, because it is difficult to meet in one crystal all the necessary conditions: (i) large spin anisotropy, (ii) strong exchange interaction along the chains, and (iii) negligible interaction between the chains. In 2009, it was discovered that the analogous phenomenon of slow relaxation also occurs in quasi-one-dimensional crystals in a magnetically ordered phase.

The relaxation of spin chains depends on processes that can flip all spins in a chain (in the figure: up to down or *vice versa*). If a single spin flips inside a chain, then its neighbours also can flip, and such wave propagates in both directions to both ends. Such processes can be studied by measuring the energy barrier required for the process to start and continue. If this barrier is small in comparison to the thermal energy, the chain flips spontaneously, which is called the superparamagnetic effect. The same process limits the density of magnetic recording in hard disk drives.



The project includes preparation of a family of crystals $M(\mathrm{NC}X)_2L_2$ ($M = \mathrm{Co}$, Fe, $X = \mathrm{S}$, Se, L = different ligands) that comprise spin chains, the study of their magnetic properties and processes related to superparamagnetic behaviour. The modifications of the chain by rational design of the crystal structure will allow us to optimize various parameters that influence the energy barrier, and thus, the whole relaxation process.