Polarized Neutron Scattering Reveals Preferred Spin Excitations in the Bilayer Iron-Based Superconductor $CaK(Fe_{0.96}Ni_{0.04})_4As_4$

In unconventional superconductors, the major challenge on the mechanism research is to reveal how the electrons form Cooper pairs and collectively condense to a superconducting state under both interactions from charge and spin. The iron-based superconductors are similar to those copper oxide and heavy fermion superconductors; they also exhibit strong spin fluctuations, which likely promote the superconducting pairing by acting as the bosonic "pairing glue". Such argument is supported by a spin resonance mode with a peak energy universally linear scaling with T_c. However, it is still unknown whether in such multi-orbital systems the spin system may have some preferred fluctuating directions that is coupled to the orbital degree of freedom.

Neutron scattering is a direct probe to measure the spin fluctuations in materials, and thus a powerful tool in the mechanism research of unconventional superconductivity. With spatial resolution in polarized neutron scattering, it will give us detailed information about the spin-orbit coupling and the spin anisotropy in iron-based superconductors. So far, there are three confirmed magnetic orders in iron pnictide superconductors: the collinear stripe-type order with in-plane moments so-called as stripe spin-density wave (SSDW); the collinear biaxial order with c-axis polarized moments so-called as charge-spin-density wave (CSDW); and the noncollinear, coplanar order with in-plane moments so-called as spin-vortex crystal (SVC) phase. Accumulating evidence suggests the spin

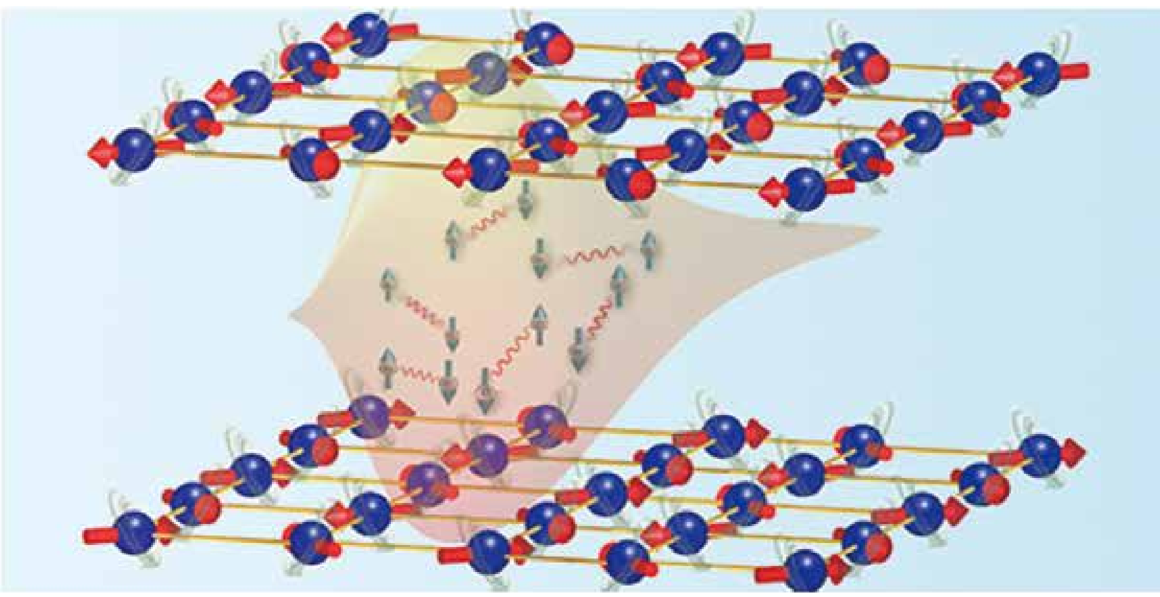

Figure 1. The c-axis preferred magnetic excitations in the spin resonance mode at the superconducting state coexisting with a spin-vortex crystal order. (Image by IOP)

resonance is preferentially polarized along c-axis in the superconducting state coexisting with the SSDW or CSDW orders.

Recently, LIU Chang *et al*. with the group led by Profs. LUO Huiqian and LI Shiliang at the Institute of Physics, Chinese Academy of Sciences, have revealed the spin resonance mode and the spin anisotropy in the SVC ordered superconductor $CaK(Fe_{0.96}Ni_{0.04})_4As_4$, in collaboration with BOURGES Philippe and SIDIS Yvan from the Laboratoire Leon Brillouin, Universite Paris-Saclay, HE Guanghong and LI Yuan from the School of Physics, Peking University, and other colleagues,

The researchers have discovered two spin resonance modes with odd and even L-symmetries with respect to the reduced distance within the Fe-As bilayer unit. Polarization analysis suggests that the odd mode is highly anisotropic, manifesting a strong c-axis component and two weakly anisotropic in-plane components. Such c-axis preferred spin excitations already show up in the SVC phase and even continue to the paramagnetic phase until the spin anisotropy finally disappears at high temperature (Figure 1). These results provide the last missing piece of the puzzle on the spin-orbit coupling effect in iron-pnictide superconductors, and suggest that the c-axis magnetic excitations are universally preferred by the presumably orbital-selective superconducting pairing. Meanwhile, the form of magnetic order depends on material-specific symmetry characteristics in addition to spin-orbit coupling, leading to a rich variety of interplay between superconductivity and magnetism in the iron-based superconductors.

This study entitled "Preferred spin excitations in the bilayer iron-based superconductor $CaK(Fe_{0.96}Ni_{0.04})_4As_4$ with spin-vortex crystal order" was published in *Physical Review Letters* and highlighted in the Editors' Suggestion. It is also reported by the *Physics Magazine* entitled "Spin Fluctuations May Drive Iron-Based Superconductivity" as a Synopsis.

The study was supported by the National Key R&D project of China, the National Natural Science Foundation of China, the Chinese Academy of Sciences and grants from US, Europe and India.

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