Giant spin-lattice coupling in a paraelectric antiferromagnet EuTiO$_3$ studied by neutron scattering

Mutual control and detection of magnetic and electric orders are of great interest in many fields for their applications in novel devices and therefore have attracted long period attentions. However, in most cases, magnetic and electric orders either have largely different energy scales or weakly coupled. Giant spin-lattice coupling in EuTiO$_3$ was first revealed by Katsufuji and Takagi in 2001. The dielectric constant in EuTiO$_3$ shows a significant change at the magnetic ordering temperature and also responds to a magnetic field. Incipient ferroelectricity was expected for EuTiO$_3$ for its plenty of similarities to SrTiO$_3$ and it has the same energy level as the magnetic order. The discovery of ferroelectric ferromagnet in its film matter further excited the attentions in EuTiO$_3$. In this talk I will introduce the neutron scattering work on the isotope $^{153}$EuTiO$_3$ crystal. Taking the advantages of neutron scatterings in terms of detecting phonons, magnons, and their couplings, we have discovered a “flat” hybrid phonon-magnon mode at ~ 10 meV at temperature below ~ 100 K, which interacts with the soft ferroelectric transvers optical phonon (TO) mode at low temperature and repulses the TO mode to higher energy. Our results reveal the hidden mechanism of spin-lattice coupling in EuTiO$_3$ and for the first time shows a hybrid phonon-magnon mode that survives at above the magnetic ordering temperature. The polarized neutron diffraction further confirms that 3d-4f orbital hybridization makes an important role in strong spin-lattice coupling in EuTiO$_3$. 