4-1 Observation of Collective Behavior of Strongly Interacting Electrons
—Study of Collective Charge Excitations of Charge Stripes—

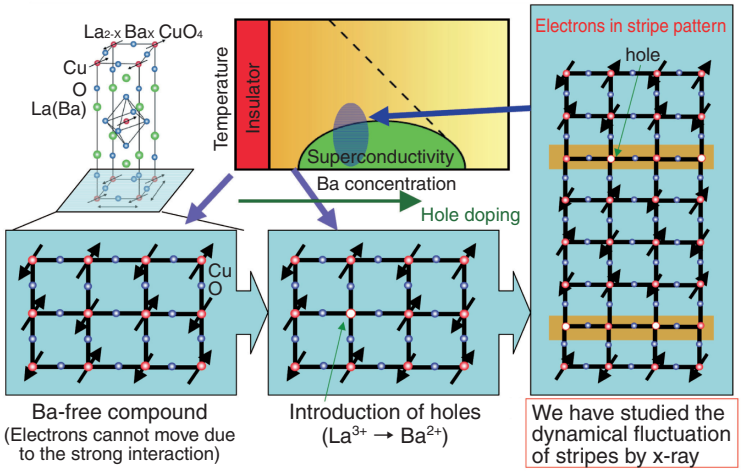

Fig.4-2 An example of strongly interacting electrons in case of cuprate $La_{2-x}Ba_xCuO_4$
The system varies from an insulator to a superconductor by the hole doping achieved by Ba substitution. The arrows represent the magnetic properties of electrons. Electrons order in the stripe form in the superconducting regime. We observed the collective excitation of the charge stripes.

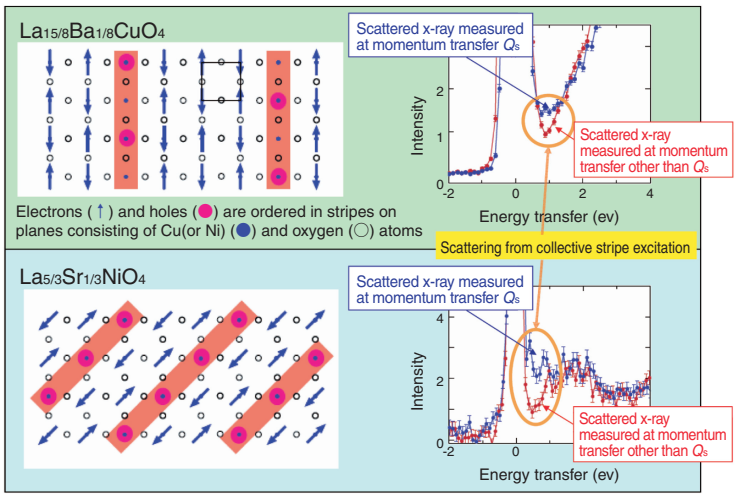

Fig.4-3 Observation of collective charge stripe excitations
Comparison between scattered x-ray intensity measured at momentum transfer Q_s corresponding to the spatial period of charge stripes (blue data) and at momentum transfer other than Q_s (red data). In both materials, additional signals of collective charge stripe excitation were observed at momentum transfer Q_s.

We succeeded in observing the collective fluctuation (collective excitation) of electrons that strongly interact with each other in a material, in collaboration with Tohoku University and Argonne National Laboratory.

In the scheme of today's physics, the behavior of electrons that do not interact with each other, such as conduction electrons in metals, is well understood, whereas the behavior of electrons that behave collectively as a result of strong interaction is not well understood because of the difficulty of theoretical interpretation. However, materials with strongly interacting electrons are known to exhibit various new functional features, notably high temperature superconductivity.

We investigated the collective behavior of electrons in high-temperature cuprate superconductor and a related nickelate compound which are typical examples of materials with strongly interacting electrons. In these materials, electrons order themselves in stripes as shown in Fig.4-2 due to their strong interaction.

In resonant inelastic x-ray scattering experiments done at the synchrotron radiation facilities "SPring-8" and "Advanced Photon Source", we succeeded in directly observing the collective charge stripe excitations in cuprate and nickelate which correspond to the periodic alignments of the electrons into a stripe pattern. As shown in Fig.4-3, the two materials used for this study have different charge stripe geometries. The charge stripes align vertically in the cuprate but diagonally in the nickelate. The observation of the collective charge stripe excitations in both materials verified the universal collective fluctuation of charge stripes, suggesting that collective charge fluctuation resulting from strong interaction between electrons is necessary for high temperature superconductivity.

This success will open up a new research field in materials science for exploration, namely, the collective excitation of electrons. It is highly expected that the mechanism behind high-temperature superconductivity of target materials will be clarified by further research in collective excitation.

Reference

Wakimoto, S. et al., Charge Excitations in the Stripe-Ordered $La_{5/3}Sr_{1/3}NiO_4$ and $La_{2-x}(Ba,Sr)_xCuO_4$ Superconducting Compounds, Physical Review Letters, vol.102, issue 15, 2009, p.157001-1-157001-4.