Development of orbital and spin fluctuations in Fe-based superconductors based on the self-consistent vertex correction (SC-VC) method
HIROSHI KONTANI, Nagoya University

To achieve unified understanding of the whole phase diagram of Fe-based superconductors, we analyze the multiorbital Hubbard model going beyond the random phase approximation (RPA). The 2nd-order non-magnetic structure transition at $T_S(> T_N)$, nematic order as well as large softening of shear modulus $G_{66}$ indicate the strong orbital fluctuations in the normal state. However, only the spin fluctuations develop within the RPA. To resolve this discrepancy, we develop the self-consistent vertex correction (SC-VC) method beyond the RPA, and find the mutual development of orbital and spin fluctuations due to the Aslamazov-Larkin VC, which describes the Kugel-Khomskii type spin-orbital coupling [1]. We find that (i) both the antiferro-orbital and ferro-orbital (=nematic) fluctuations develop for $J/U > 0.17$ by including the self-energy correction (=SC-VΣ method): Both fluctuations contribute to the s-wave superconductivity, and the nematic fluctuations are the origin of the structure transition and the softening of $G_{66}$. (ii) The coexistence of orbital and spin fluctuations can induce the loop-shape nodes on the electron-pockets in BaFe$_2$(As,P)$_2$, as well as (impurity-induced) smooth $s_+ \rightarrow s_+$ crossover with high $T_c$ [2,3]. Also, the horizontal node on the $z^2$-orbital hole-pocket predicted by RPA is filled by the inter-orbital fluctuations due to the VC, consistently with laser ARPES and other bulk experiments of 122 compounds. (iii) The same orbital nematic fluctuations are obtained in a simple two-orbital model for Sr$_3$Ru$_2$O$_7$, not only by the SC-VC method [4] but also by the two-dimensional RG method [5]. Therefore, the VC is expected to be the origin of novel orbital physics in various multiorbital $d$- and $f$-electron systems.