Spin excitation spectrum in coexistent phase of AFM+dSC

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The strongly correlated electron system shows a rich phase diagram around an antiferromagnetic quantum critical point, which consists of a paramagnetic phase with a non-Fermi liquid behavior, an antiferromagnetic phase, and *d*-wave superconducting phase. Further, several heavy fermion compounds UPd_2Al_3, $CeIn_3$, $CePd_2Si_2$, $CeRh_2Si_2$, $CeRhIn_5$ are known to show a coexistent phase of antiferromagnetism and superconductivity. In Ce-compounds among these, the same electron will contribute to both order parameters of antiferromagnetism and superconductivity.

In order to clarify the low energy excitation in the coexistent phase of antiferromagnetism and *d*-wave superconductivity, we have studied dynamical spin susceptibility within RPA, recently, based on Hubbard model with two mean-field terms of antiferromagnetism and *d*-wave superconductivity [1]. In the antiferromagnetic phase of the calculated phase diagram, there are Fermi surfaces when carriers are doped in the half-filled system. As the low energy excitation, the antiferromagnetic spin wave is shown at the ordering wave vector. In addition, as the temperature is decreases to the transition temperature to the coexistent phase, different low energy spin excitations are enhanced at an incommensurate wave vector corresponding to the nesting vector connecting Fermi surfaces in the antiferromagnetic state. The additional low energy mode will play a role of a glue to form Cooper pairs in the antiferromagnetism. Actually, corresponding resonance mode appears in the coexistent phase. We have also calculated the NMR relaxation rate, whose temperature dependence is consistent with the experimental data of $CeRhIn_5$ [2].

[1] H.-J. Lee and T. Takimoto, arXiv:1204.5032.

[2] M. Yashima *et al.*, Phys. Rev. B **79**, 214528 (2009).