1 Aoki Group

Subject: Theoretical condensed-matter physics

Our main interests are many-body and topological effects in electron and cold-atom systems, i.e., **superconductivity, magnetism and topological phenomena**, for which we envisage **materials design** and novel **non-equilibrium** phenomena should be realised. Studies around the 2018 academic year include:

- **Superconductivity**
  — Electron correlation and High-Tc superconductivity
    Dynamical vertex approximation (DΓA)[1], see Fig.1.1.5
    DMFT with a slave-particle impurity solver [2]
    High-Tc superconductivity in multi-layer cuprates [3], see Fig.1.1.6
    Design of high-Tc superconductors in hidden-ladder compounds[4]
  — Design of flat bands and flat-band superconductivity[5], see Fig.1.1.7
- **Topological systems**
  — Chiral symmetry in graphene-related systems[6]
  — Electron propagation in bilayer graphene[7]
- **Non-equilibrium and non-linear phenomena**
  — Relaxation dynamics of doped repulsive Hubbard model[8], see Fig.1.1.8
  — Higgs modes in high-Tc, d-wave superconductors[9]

[1] Motoharu Kitatani, Thomas Schäfer, Hideo Aoki and Karsten Held: Why T_c is so low in high-T_c cuprates: importance of the dynamical vertex structure, *Phys. Rev. B* **99**, 041115(R) (2019).

[2] Sharareh Sayyad, Naoto Tsuji, Massimo Capone and Hideo Aoki: SO(4) FLEX+DMFT formalism with SU(2)⊗SU(2)-symmetric impurity solver for superconductivity in the repulsive Hubbard model, submitted (arXiv:1903.05800).

[3] Kazutaka Nishiguchi, Shingo Teranishi, Koichi Kusakabe and Hideo Aoki: Superconductivity arising from layer-differentiation in multi-layer cuprates, *Phys. Rev. B* **98**, 174508 (2018).

[4] Daisuke Ogura, Hideo Aoki and Kazuhiko Kuroki: Possible high-T_c superconductivity due to incipient narrow bands originating from hidden ladders in Ruddlesden-Popper compounds, *Phys. Rev. B* **96**, 184513 (2017).

[5] Sharareh Sayyad,Edwin W. Huang, Motoharu Kitatani, Mohammad-Sadegh Vaezi, Zohar Nussinov, Abolhassan Vaezi and Hideo Aoki: Pairing and non-Fermi liquid behavior in partially flat-band systems, submitted (arXiv:1903.09888).

[6] Tohru Kawarabayashi, Hideo Aoki and Yasuhiro Hatsugai: Topologically protected doubling of tilted Dirac fermions in two dimensions, *Proc. 34th Int. Conf. on Physics of Semiconductors*, Montpellier, France, July 2018 [*Phys. Status Solidi* B, 2019, 1800524].

[7] P.A. Maksym and H. Aoki: Fast split operator method for computation of time-dependent qantum states of bilayer graphene in a magnetic field, *Physica E* **112**, 66 (2019).

[8] Sharareh Sayyad, Naoto Tsuji, Abolhassan Vaezi, Massimo Capone, Martin Eckstein and Hideo Aoki: Momentum-dependent relaxation dynamics of the doped repulsive Hubbard model, *Phys. Rev. B* **99**, 165132 (2019).

[9] Kota Katsumi, Naoto Tsuji, Yuki I. Hamada, Ryusuke Matsunaga, John Schneeloch, Ruidan D. Zhong, Genda D. Gu, Hideo Aoki, Yann Gallais, Ryo Shimano: Higgs mode in the d-wave superconductor $Bi_2Sr_2CaCu_2O_{8+x}$ driven by an intense terahertz pulse, *Phys. Rev. Lett.* **120**, 117001 (2018) (Editor's suggestion).

Gallery

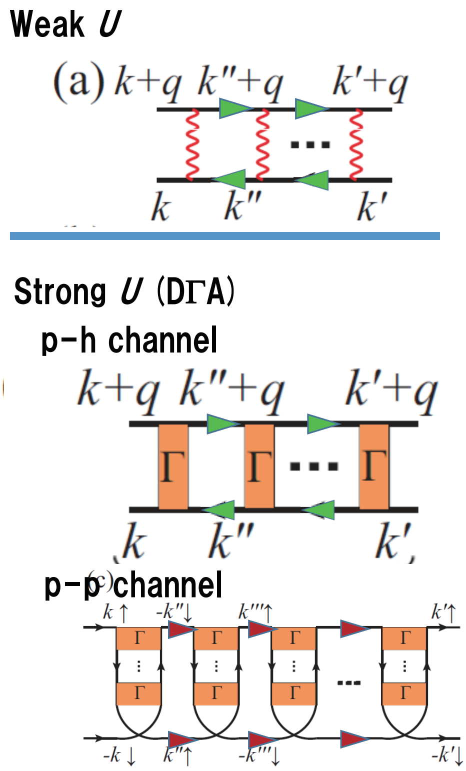

図 1.1.5: Top: Antiferromagnetic spin fluctuations for weak interaction U (red wiggled lines) in terms of particle-hole ladder diagrams (solid line: Green's function). Middle: DΓA diagrams describe similar spin fluctuations but now for strong correlation, with ladders (in the particle-hole channel; green arrows) of the vertex Γ which is non-perturbative and frequency-dependent. Bottom: DΓA further incorporates the diagrams in the particle-particle channel (red arrows).[1]

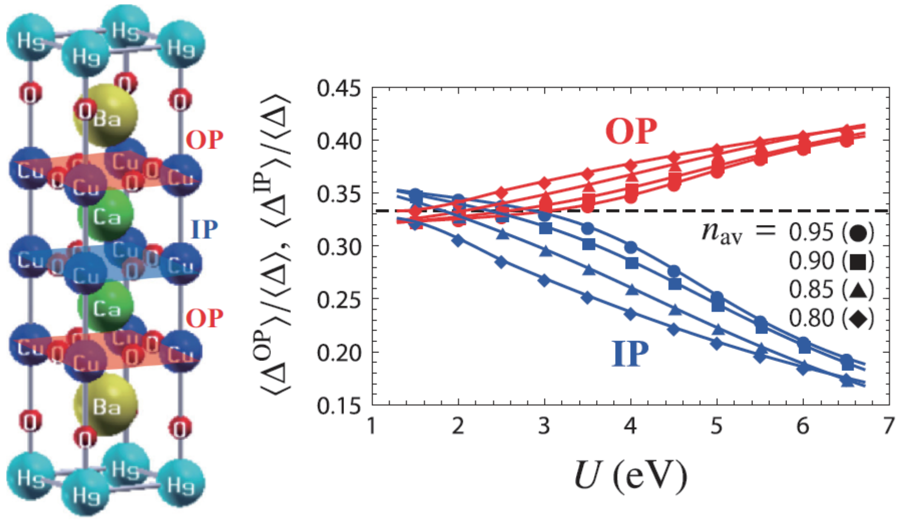

図 1.1.6: Left: Crystal structure of a Hg-based three-layer cuprate Hg-1223 with two outer planes (OPs) and one inner plane (IP) in a unit cell. Right: The gap function Δ against the repulsive interaction U is displayed for various values of the average band filling n_{av}.[3]

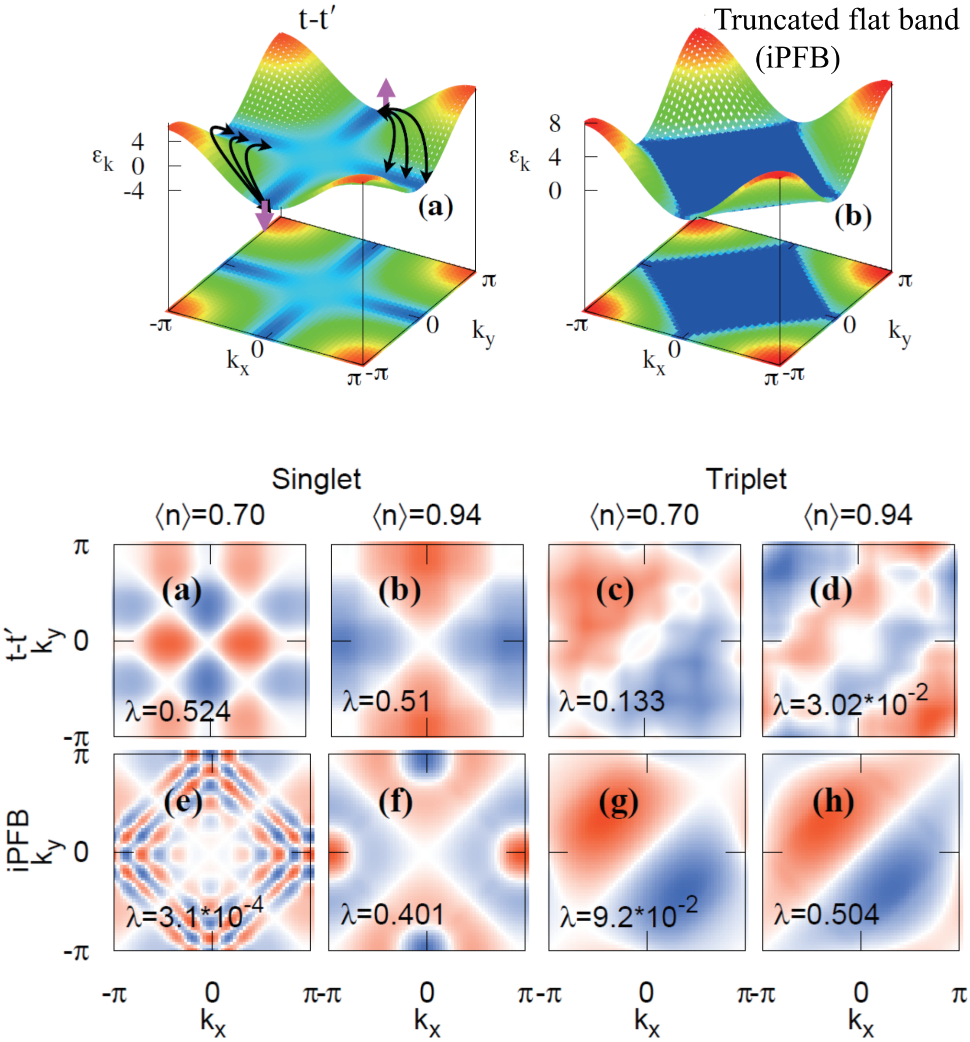

図 1.1.7: Top: One-electron band dispersions for the t-t' model and flattened-bottom model (iPFB). Arrows represent pair hopping processes. Bottom: Singlet (left four panels) and triplet (right four) gap functions in momentum space for the t-t' (first row) and iPFB (second row) models for $U = 3$, $1/T = 33$. Colour code for the gap function is red: positive, blue: negative, and the band filling is $n = 0.7$ (a,c,e,g) or 0.94 (b,d,f,h). Maximum eigenvalue, λ, of the Eliashberg equation is indicated in each panel. [5]

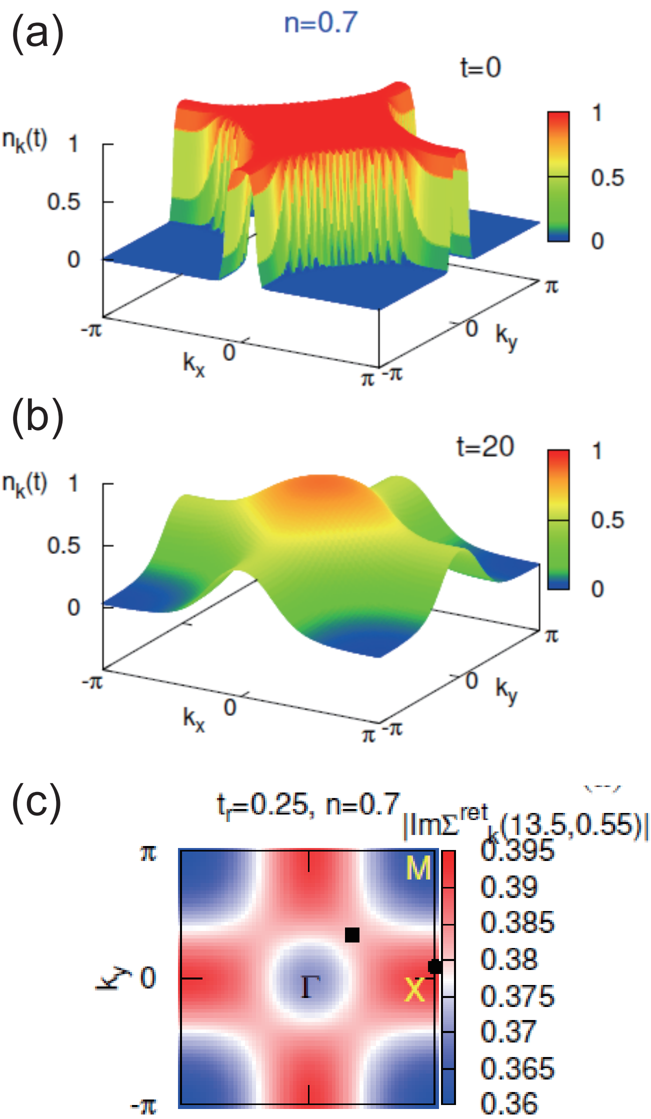

図 1.1.8: For a hole-doped filling $n = 0.7$ the momentum-dependent distribution functions, $n_k(t)$, at initial $t = 0$ (a) and final $t = 20$ (b) are plotted for the repulsive interaction changed from zero to $U = 3$ in the Hubbard model. (c) Momentum dependence of the self-energy, $\mathrm{Im}|\Sigma_k(t)|$, after the ramp. [9]