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 2017 academic year include:

- **Superconductivity**
  - Electron correlation and High-Tc superconductivity
    - Dynamical vertex approximation (DFA)[1]
  - Design of flat bands and flat-band superconductivity[2, 3]
  - Tc dome and Pomeranchuk instability[4]
  - Design of ladder compounds[5]

- **Topological systems**
  - Quantum Hall effect and chiral symmetry in graphene[6]
  - Designed ferromagnetic and topological organic material[7]
  - Three-dimensional graphene[8, 9, 10]
  - Electronic birefringence in bilayer graphene

- **Non-equilibrium and non-linear phenomena**
  - Higgs modes in superconductors
    - Conventional, s-wave superconductors[11, 12, 13]
    - High-Tc, d-wave superconductors[14]
  - Collective excitations in two-band superconductors[15]
  - Superconductivity in non-equilibrium[16]
  - Floquet topological phase transitions[17, 18]

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Gallery
1.1.8: (a) Dynamical vertex approximation (DVA) result for the eigenvalue $\lambda$ (a measure of $T_c$, for the $d$-wave pairing in the present case) of the Eliashberg equation against the band filling $n$ for the repulsive interaction $U = 6t$ at temperatures $T/t = 0.010, 0.013$ in the Hubbard model for a high-$T_c$ cuprate. (b) The local vertex correction $\delta \Gamma_m(\nu_n, \nu_{n'}, \omega = 0) \equiv \Gamma_m(\nu_n, \nu_{n'}, \omega = 0) - (-U)$ is plotted against frequencies $\nu_n, \nu_{n'}$ (blue: positive; red: negative). (c) The magnetic vertices that appear in the Bethe-Salpeter equation. Left: a typical diagram as in RPA with $U$ (red wavy line) as an irreducible building block, connected by $\chi_0$ (two blue Green’s functions with fermionic frequencies $\nu_1$ and $\nu_1 + \omega$. Right: Local (here second-order) vertex corrections with a particle-particle bubble. They lead to a suppression of $T_c$. After Ref.[1].

1.1.9: A Ruddlesden-Popper compound $\text{Sr}_3\text{TM}_2\text{O}_7$ (TM: transition metal) may seem to be a simple double layer (black lattice), but is a two-leg ladder in fact if we consider the d orbitals of TM, here $d_{xz}$ (left panel) and $d_{yz}$ (right). After Ref.[5].
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図 1.1.10: (a) A flat-band model in which we can control the energy position of the flat band. There, the flat band is in general different from zero (an arrow). (b) A newly constructed model in which the flat band pierces a dispersive one. After Ref.[3].

図 1.1.11: (a) A typical example of flat-band models (here Lieb lattice). (b) Band structure when we “deform” the model, in which we can see that the flat band pierces the Dirac point of a tilted Dirac cone. After Ref.[6].
図 1.1.12: Various families of carbon structures. After Ref.[10].
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1.1.13: (a) An oscillating d-wave superconductivity order parameter when a high-Tc cuprate is illuminated by a THz laser pulse is schematically shown. (b) Experimental result for the change in the reflectivity (which corresponds to the third-order nonlinear optical response $\chi^{(3)}$) induced by the laser pulse is plotted for various temperatures, here for the $A_{1g}$ component among various irreducible representations for the cuprate crystal. A horizontal dashed line indicates $T_c$. (c) Theoretical result for the third-order nonlinear optical response $\chi^{(3)}$ is plotted against temperature, here resolved into various irreducible representations for each of the charge-density fluctuations (CDF) contribution and the Higgs mode contribution. After Ref.[14].
图 1.1.14: A chiral spin structure can be induced when a circularly-polarised light is illuminated to a strongly-correlated electron system. After Ref.[18].