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 2020 academic year include:

- **Superconductivity/superfluidity**
  - — Superconductivity in a new cuprate $Ba_2CuO_{3+\delta}$ [1], see Fig.1.1.1
  - — Superconductivity in a nickelate (Nd,Sr)NiO_2[2], see Fig.1.1.2
  - — Design of flat bands and flat-band superconductivity[3, 4], see Fig.1.1.3
  - — BCS-BEC crossover in superconductivity/superfluidity in incipient 2-band systems
- **Topological systems**
  - — Zero modes in Kekule-ordered honeycomb systems[5]
  - — Valley and spin polarisation in bilayer graphene and transition-metal dichalcogenides
- **Non-equilibrium and non-linear phenomena**
  - — "Imprinting" of topological states by spatially-periodic circularly-polarised light[6]

[1] Kimihiro Yamazaki, Masayuki Ochi, Daisuke Ogura, Kazuhiko Kuroki, Hiroshi Eisaki, Shinichi Uchida, and Hideo Aoki: Superconducting mechanism for a new-type cuprate $Ba_2CuO_{3+\delta}$ based on a multiorbital Lieb lattice model, *Phys. Rev. Research* **2**, 033356 (2020).

[2] Hirofumi Sakakibara, Hidetomo Usui, Katsuhiro Suzuki, Takao Kotani, Hideo Aoki, and Kazuhiko Kuroki: Model construction and a possibility of cuprate-like pairing in a new d^9 nickelate superconductor (Nd,Sr)NiO_2, *Phys. Rev. Lett.* **125**, 077003 (2020) (Editors' suggestion).

[3] 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, *Phys. Rev. B* **101**, 014501 (2020).

[4] Hideo Aoki: Theoretical possibilities for flat-band superconductivity, *Journal of Superconductivity and Novel Magnetism* **33**, 2341 (2020).

[5] Tohru Kawarabayashi, Yuya Inoue, Ryo Itagaki, Yasuhiro Hatsugai and Hideo Aoki: Robust zero modes in disordered two-dimensional honeycomb lattice with Kekulé bond ordering, *Annals of Physics*, doi.org/10.1016/j.aop.2021.168440 (Proc. "Localization 2020").

[6] Hwanmun Kim, Hossein Dehghani, Hideo Aoki, Ivar Martin, and Mohammad Hafezi: Optical imprinting of superlattices in 2D materials, *Phys. Rev. Research* **2**, 043004 (2020).

Gallery

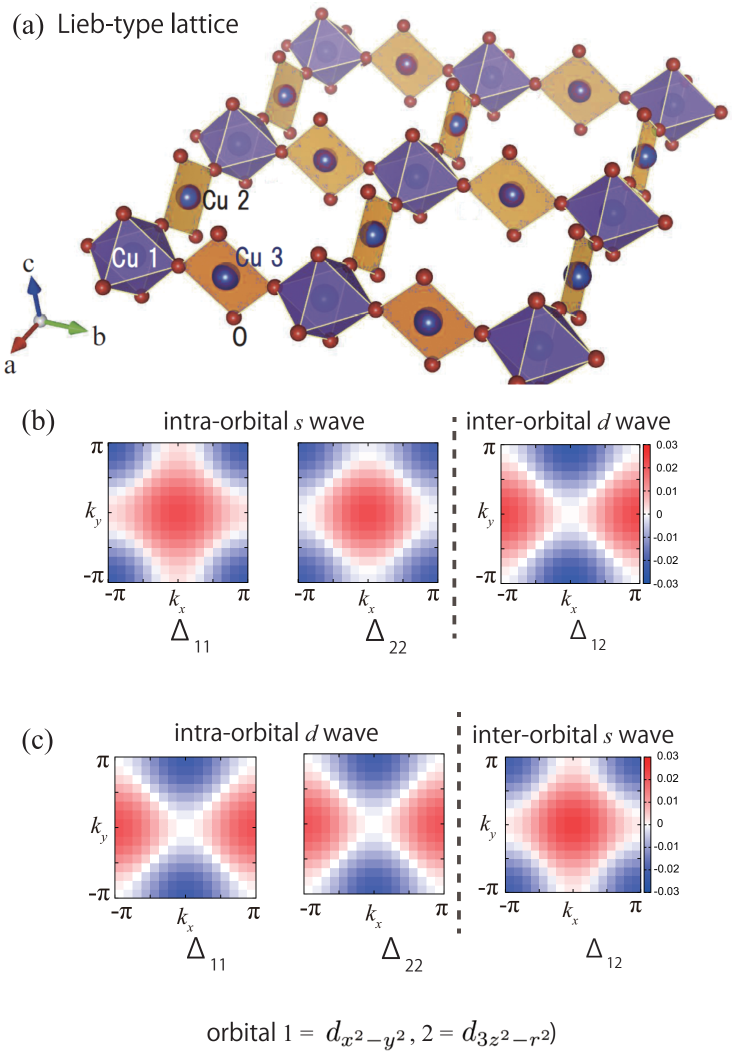

図 1.1.1: (a) A theoretically proposed Lieb-lattice type crystal structure for a new cuprate superconductor $Ba_2CuO_{3+\delta}$. (b) Gap function Δ_{ij} in the orbital (i, j) representation is shown for the intra-orbital s-wave, inter-orbital d-wave pairing, and (c) the intra-orbital d-wave, inter-orbital s-wave.[1]

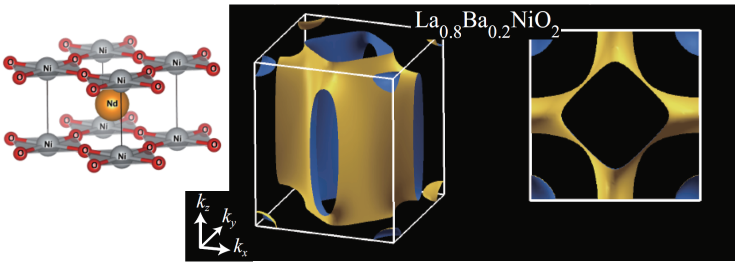

図 1.1.2: A theoretical Fermi surface in the nickelate superconductor, with a crystal structure in the left inset.[2]

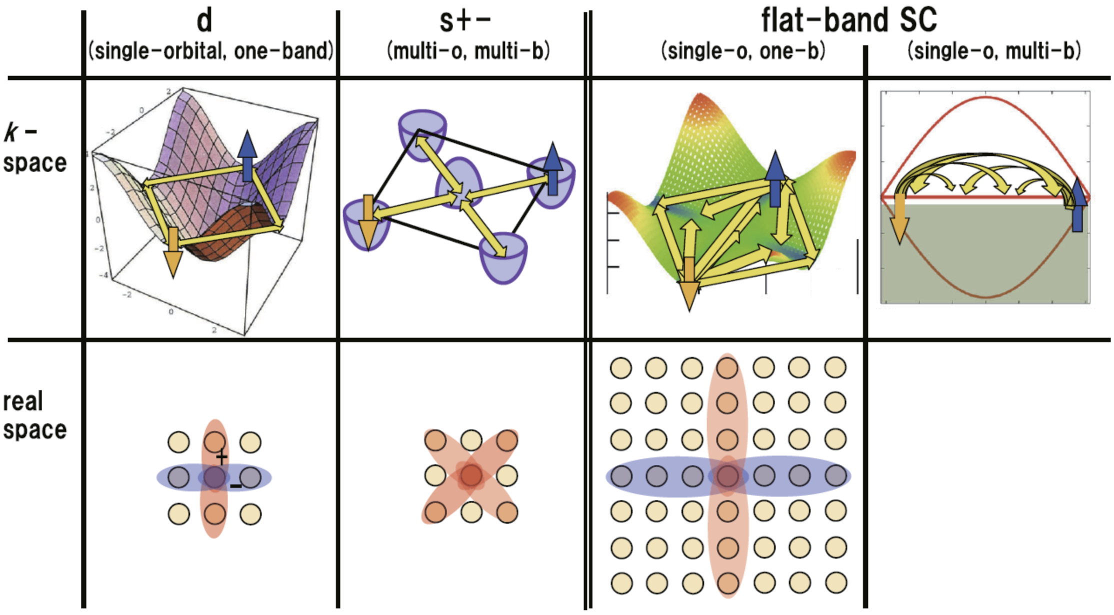

図 1.1.3: Schematic models for superconductivity. [4] Left column: Ordinary one-orbital, one-band systems, as exemplified here for a d-wave pairing. Second from left: Ordinary multi-orbital, multi-band systems, here for an $s_{\pm}$-wave pairing. Yellow arrows represent main pair-scattering channels with nesting vectors between the “hot spots”. These are contrasted with flat-band systems — Second from right: one-orbital, one-band flat-band systems. Right: one-orbital, multi-band flat-band systems. In the flat-band systems the pair scattering occurs over a “bunch” of nesting vectors. The bottom panels depict the pairs in real space.

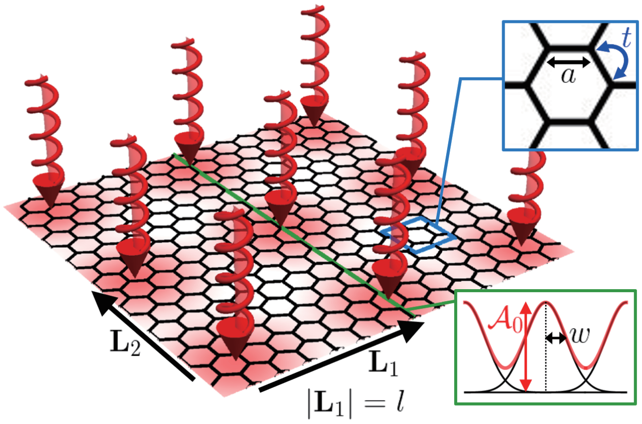

図 1.1.4: Two-dimensional systems (as exemplified by graphene) illuminated by a spatially-periodic, circularly-polarised light is schematically shown. [6]