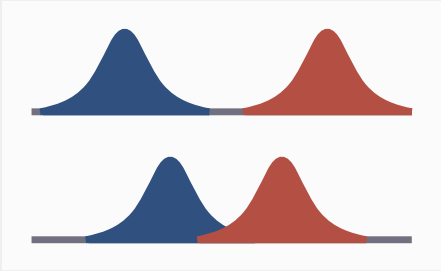
EXACTLY SOLVABLE MODEL OF CORRELATED METAL-INSULATOR TRANSITION

Insights on Non-Fermi Liquid and Mott Insulator

Abhirup Mukherjee

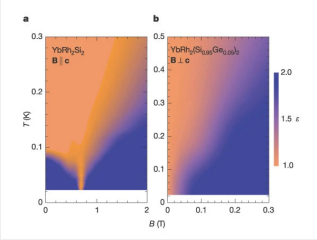
EPQM Seminar

February 1, 2025

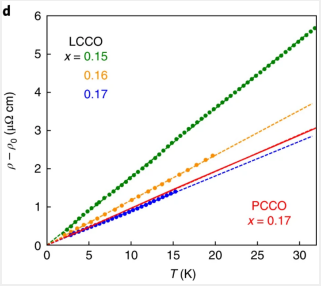


Why Are Non-Fermi Liquids Interesting ?

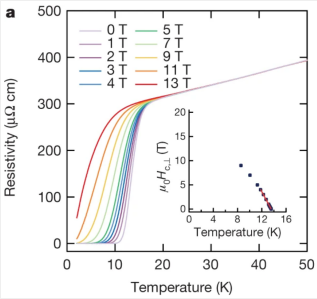
- New Phase Of Matter. Beyond Landaus' theory
- Found in several materials, proximate to **quantum critical** points.
- The normal state of **unconventional superconductors**.



Ge-doped $YbRh_2Si_2$



$La_{2-x}Ce_xCuO_4$



$NdNiO_3$, $Nd_{0.8}Sr_{0.2}NiO_3$

Custers et al. 2003; Legros et al. 2019; Greene et al. 2020.

The Hatsugai-Kohmoto Model

Consider **infinite-ranged** interaction in real-space.

$$H = -t \sum_{\langle i,j \rangle,\sigma} c^{\dagger}_{i,\sigma} c_{j,\sigma} + \frac{U}{L^d} \sum_{i_1,i_2,r} c^{\dagger}_{i_1+r,\uparrow} c^{\dagger}_{i_2-r,\downarrow} c_{i_2,\downarrow} c_{i_1,\uparrow}$$

Hatsugai-Kohmoto Interaction

Hatsugai et al. 1992; Baskaran 1991.

The Hatsugai-Kohmoto Model

Consider **infinite-ranged** interaction in real-space.

$$H = -t \sum_{\langle i,j \rangle, \sigma} c^{\dagger}_{i,\sigma} c_{j,\sigma} + \frac{U}{L^d} \sum_{i_1, i_2, r} c^{\dagger}_{i_1+r,\uparrow} c^{\dagger}_{i_2-r,\downarrow} c_{i_2,\downarrow} c_{i_1,\uparrow}$$

Fourier transform to k-space. **Decouples** into 2x2 Hamiltonians!

$$H = \sum_{\vec{k}} H_{\vec{k}}; \quad H_{\vec{k}} = \varepsilon_{\vec{k}} \sum_{\sigma} n_{\vec{k},\sigma} + U n_{\vec{k}\uparrow} n_{\vec{k}\downarrow}$$

Hatsugai-Kohmoto Interaction

Hatsugai et al. 1992; Baskaran 1991.

The Hatsugai-Kohmoto Model

Consider **infinite-ranged** interaction in real-space.

$$H = -t \sum_{\langle i,j \rangle, \sigma} c^{\dagger}_{i,\sigma} c_{j,\sigma} + \frac{U}{L^d} \sum_{i_1, i_2, r} c^{\dagger}_{i_1+r,\uparrow} c^{\dagger}_{i_2-r,\downarrow} c_{i_2,\downarrow} c_{i_1,\uparrow}$$

Fourier transform to k-space. **Decouples** into 2x2 Hamiltonians!

$$H = \sum_{\vec{k}} H_{\vec{k}}; \quad H_{\vec{k}} = \varepsilon_{\vec{k}} \sum_{\sigma} n_{\vec{k},\sigma} + U n_{\vec{k}\uparrow} n_{\vec{k}\downarrow}$$

Contrast with the completely **local** Hubbard interaction.

$$H_{\text{int}} \sim \sum_{i} n_{i,\uparrow} n_{i,\downarrow} = \sum_{k_1, k_2, q} c^{\dagger}_{k_1+q,\uparrow} c^{\dagger}_{k_2-q,\downarrow} c_{k_2,\downarrow} c_{k_1,\uparrow}$$

Hatsugai-Kohmoto Interaction

Hatsugai et al. 1992; Baskaran 1991.

Hubbard Interaction

THANK YOU

- Baskaran, G. (1991). **“AN EXACTLY SOLVABLE FERMION MODEL: SPINONS, HOLONS AND A NON-FERMI LIQUID PHASE”.** In: *Modern Physics Letters B* 05.09, pp. 643–649.
- Custers, J. et al. (2003). **“The break-up of heavy electrons at a quantum critical point”.** In: *Nature* 424.6948, pp. 524–527.
- Greene, Richard L. et al. (2020). **“The Strange Metal State of the Electron-Doped Cuprates”.** In: *Annual Review of Condensed Matter Physics* 11.Volume 11, 2020, pp. 213–229. issn: 1947-5462.
- Hatsugai, Yasuhiro and Mahito Kohmoto (1992). **“Exactly Solvable Model of Correlated Lattice Electrons in Any Dimensions”.** In: *Journal of the Physical Society of Japan* 61.6, pp. 2056–2069.
- Legros, A et al. (2019). **“Universal T-linear resistivity and Planckian dissipation in overdoped cuprates”.** In: *Nature Physics* 15.2, pp. 142–147.