Towards nodal-antinodal dichotomy in high-Tc superconductors from the holographic perspective

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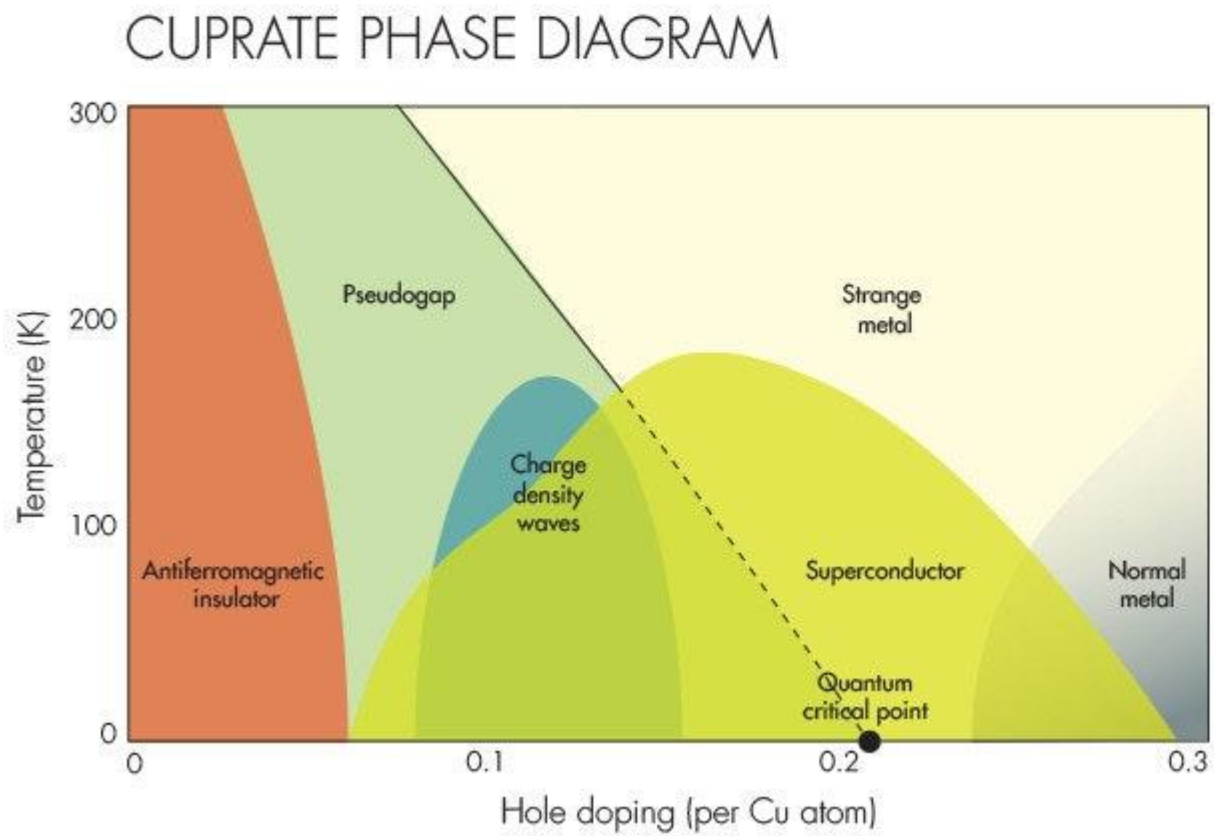
Quantum critical point

- Dense entanglement
- No quasiparticles (therefore no Fermi-liquid)
- Diagrammatic approach works poorly



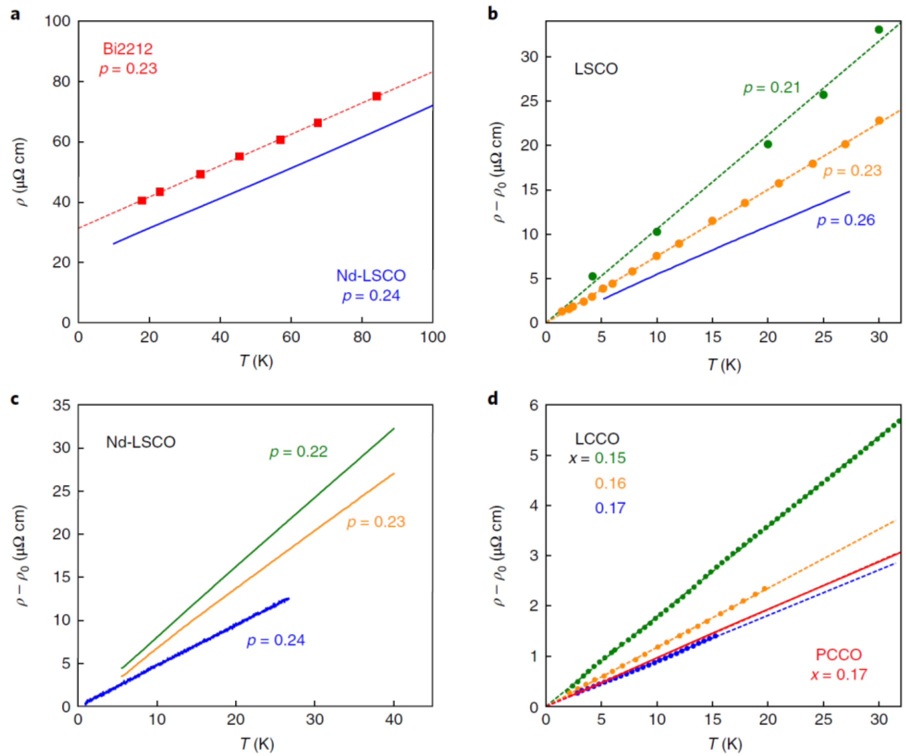
AdS/CFT for High-Tc superconductors

- Linear T-scaling of DC-conductivity

Davison, Schaalm, Zaanen, PRB 89 (2014)

It follows from hydrodynamic properties of systems with minimal viscosity proportional to the thermodynamic entropy

$$\rho_{DC}(T) = \frac{A\hbar}{\omega_p^2 m_e l^2} \frac{S_e(T)}{k_B}$$

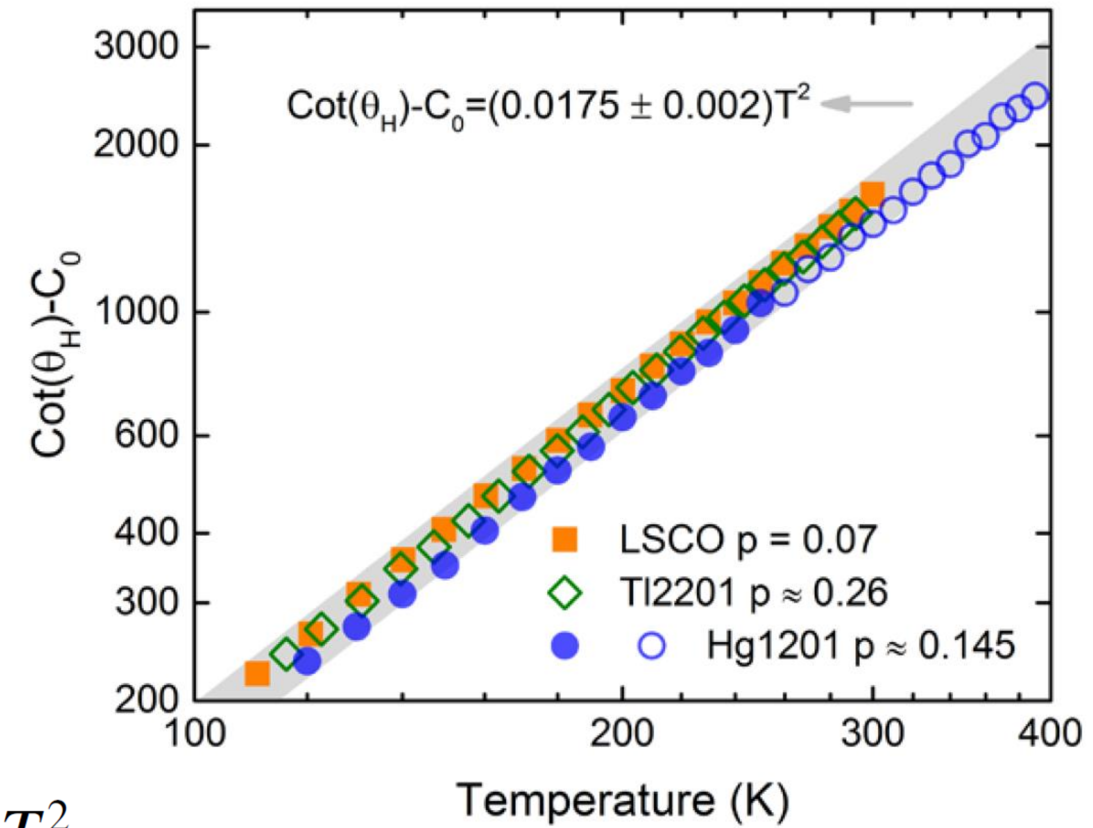


T-linear resistivity in five overdoped cuprates (Legros etal. Nature Physics 2018)

AdS-CFT in High-Tc superconductors

- T-dependence of the Hall angle

Blake, Donos, PRL 114 (2015)

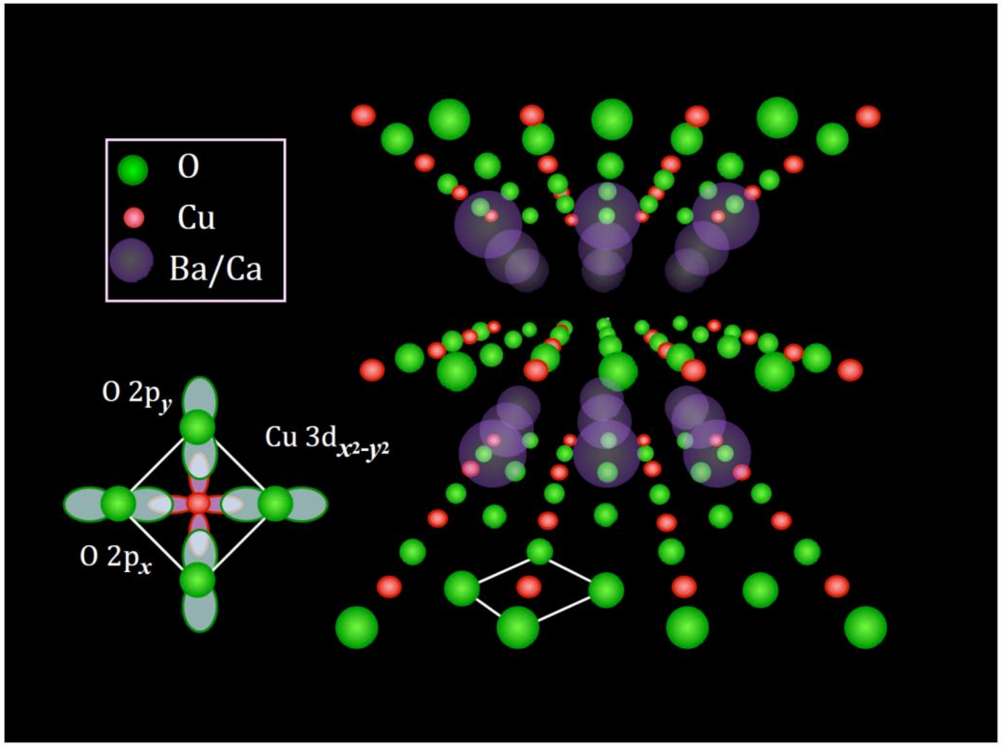


Hall angle can be naturally interpreted in terms of a two-constituent quantum liquid, with regular quasiparticles and the critical sector, which gives the dependence

$$\tanh\theta_H = \sigma_{xy}/\sigma_{xx} \sim 1/T^2$$

AdS-CFT in High-Tc superconductors

- Localization in two-dimensional CuO planes

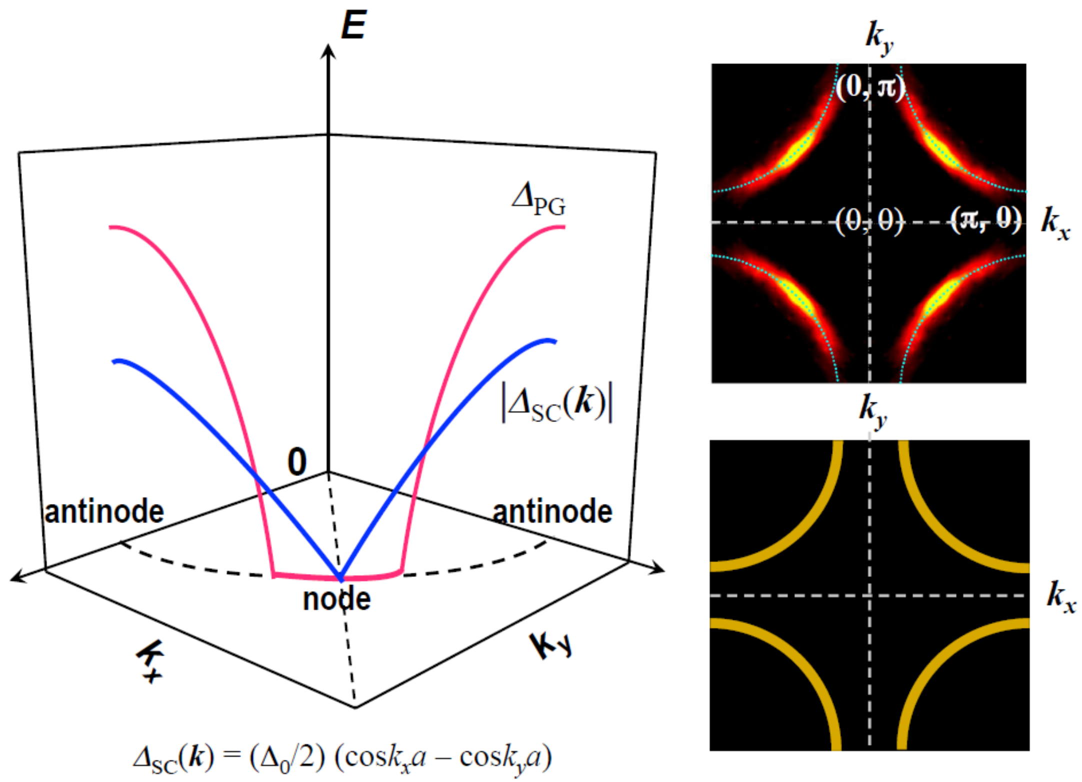


Donos, Hartnoll, Nature Physics (2013)

The interaction-driven metal-insulator transition that causes anisotropic localization: current can flow along the plane but not in the direction orthogonal to them.

Nodal-antinodal dichotomy

Once the pseudogap sets in, the antinodal regions of the Fermi surface are gapped out, giving rise to Fermi arcs.



Holographic setup

- We need finite chemical potential, therefore the background should be a deformed charged black hole (we need gauge field)
- Periodic structure is given by scalar fields
- Fermions are not coupled directly to gravity-matter equations

Holographic setup

- Consider system of coupled gravity-matter equations on periodic lattice
- Solve Dirac equations on the obtained background
- Study asymptotic behavior of spinors to obtain Green function

Einstein-Maxwell equations

$$S = \frac{1}{16\pi G}\int d^4x\sqrt{-g}\left[R + \frac{6}{L^2} - \partial_\mu\phi\partial^\mu\phi - \partial_\mu\chi\partial^\mu\chi - \frac{1}{2}F^{\mu\nu}F_{\mu\nu} - 2V(\phi,\chi)\right]$$

$$V(\phi,\chi) = -(\phi^2+\chi^2)/L^2$$

$$\phi(x,z)\Big|_{z\to 0} = z\phi^{(1)}(x) + z^2\phi^{(2)}(x) + \ldots$$

$$\chi(x,z)\Big|_{z\to 0} = z\chi^{(1)}(x) + z^2\chi^{(2)}(x) + \ldots$$

Crystal lattice is modeled by boundary conditions.

$$\phi^{(1)}(x) = \cos(\theta)V_0\cos(k_0x)$$

$$\chi^{(1)}(x) = \sin(\theta)V_0\sin(k_0x)$$

Dirac equations

$$\Gamma^{\underline{a}} e^{\mu}_{\underline{a}} \left(\partial_\mu + \frac{1}{4}\omega_{\underline{ab}\mu}\Gamma^{\underline{ab}} - iqA_\mu \right) \zeta - m\zeta = 0$$

Green function is given by spinor behaviour on the conformal boundary.

$$\Psi_\alpha(x) = a_\alpha(x)(1-r)^{-mL}\begin{pmatrix}0\\1\end{pmatrix} + b_\alpha(x)(1-r)^{mL}\begin{pmatrix}1\\0\end{pmatrix} + \ldots$$

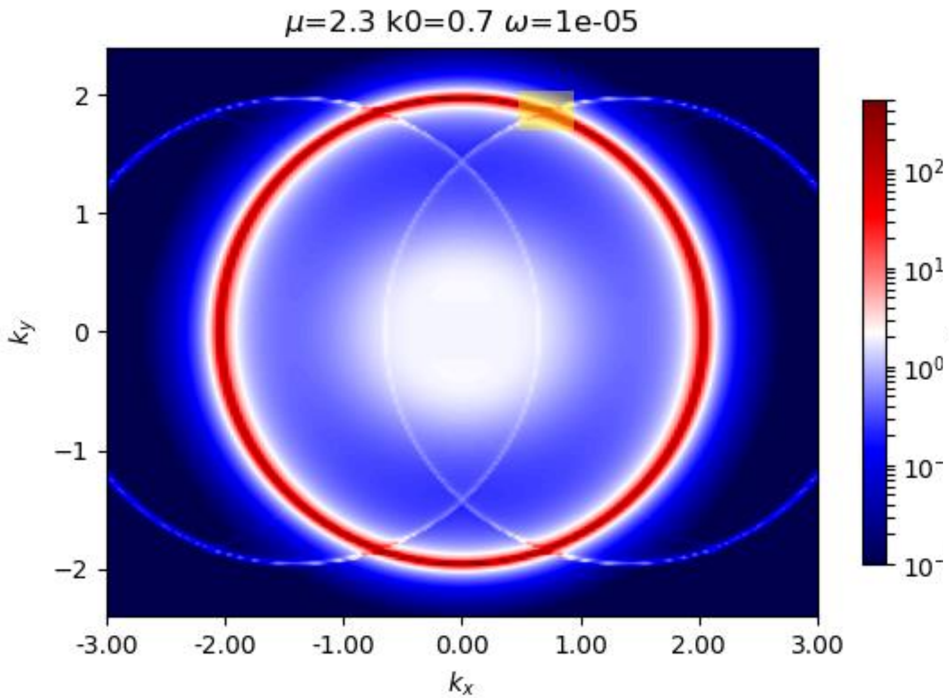
$$\begin{pmatrix}b_1(x)\\b_2(x)\end{pmatrix} = \int dx'\ G^R(\omega, k_x, k_y|x, x')\begin{pmatrix}a_1(x')\\a_2(x')\end{pmatrix}$$

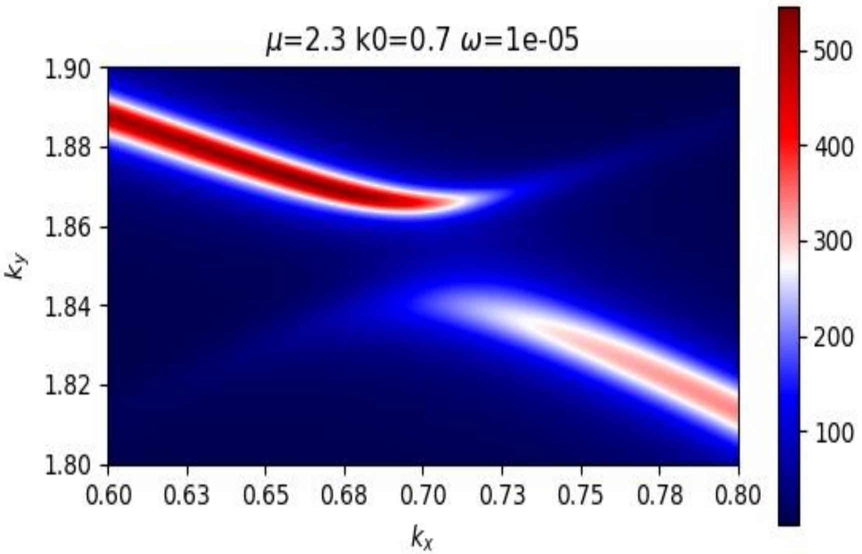
Spectral function $A(\omega, k) = \mathrm{Im}\,\mathrm{Tr}\,G^R(\omega, k)$

2 regimes

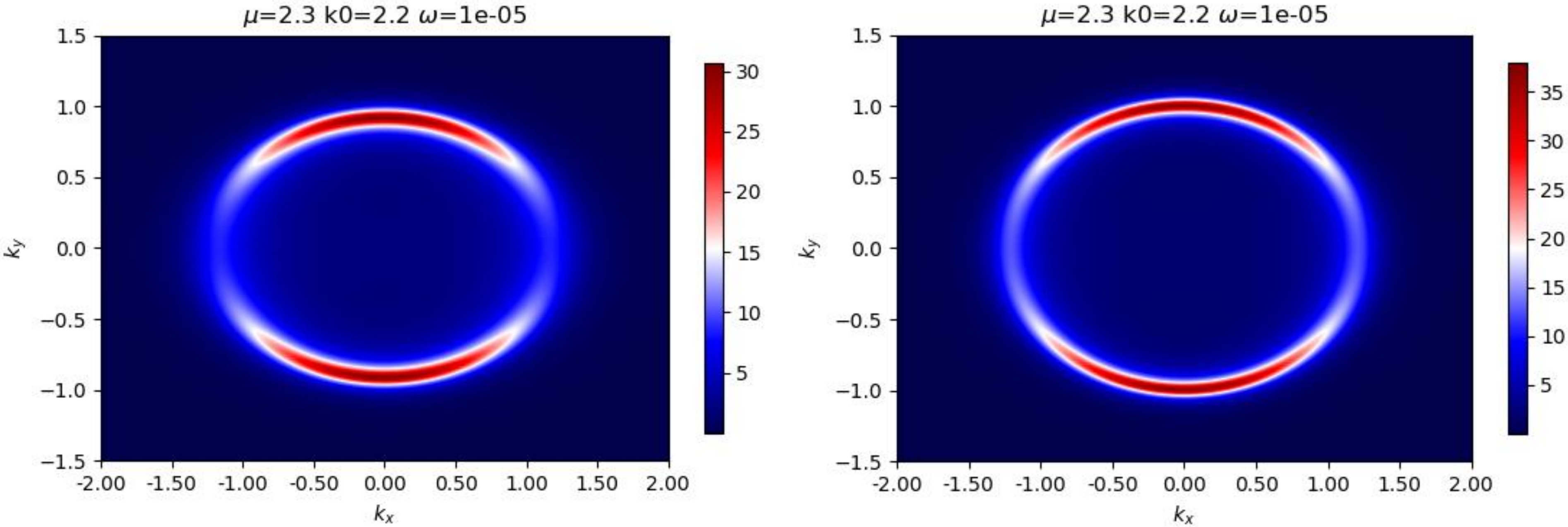
- Umklapp scattering due to interaction between Brillouin zones
- Anisotropy due to infrared physics captured by holographic approach
- The comparison can be achieved by different solutions of Einstein equations

Umklapp scattering





Emergence of Fermi arcs



Summary

- AdS-CFT correspondence allows to explain anisotropy of Fermi surfaces
- Anisotropy is related with strong correlations but not with one-particle scattering
- In the following we can consider modulations in 2 directions
- or include time into the equations, which would correspond to time-resolved ARPES