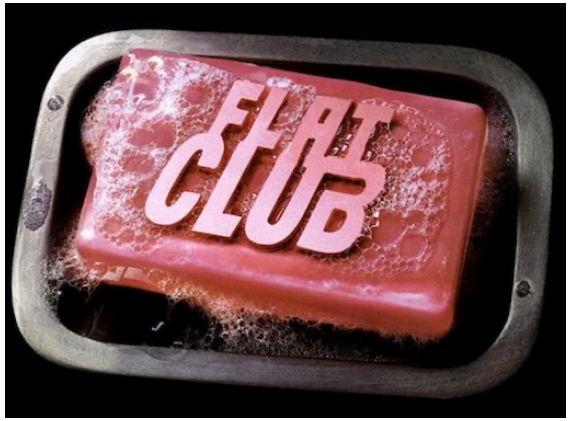
FAST & FURIOUS quasiparticles

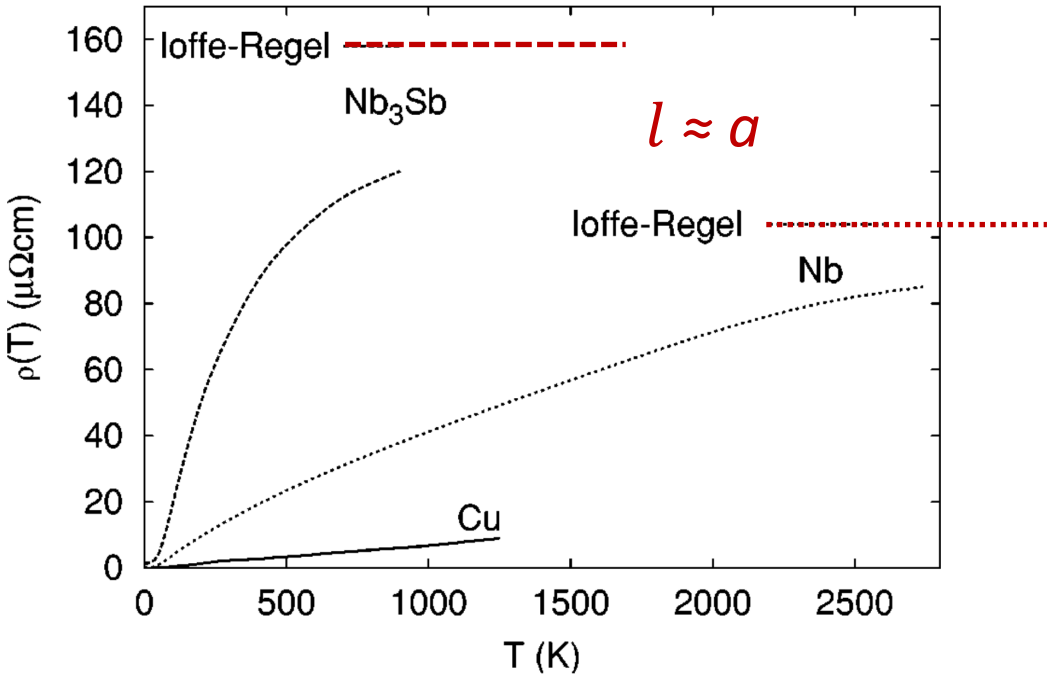
Anna Tamai

DQMP



October 20, 2023

Metals at high temperature

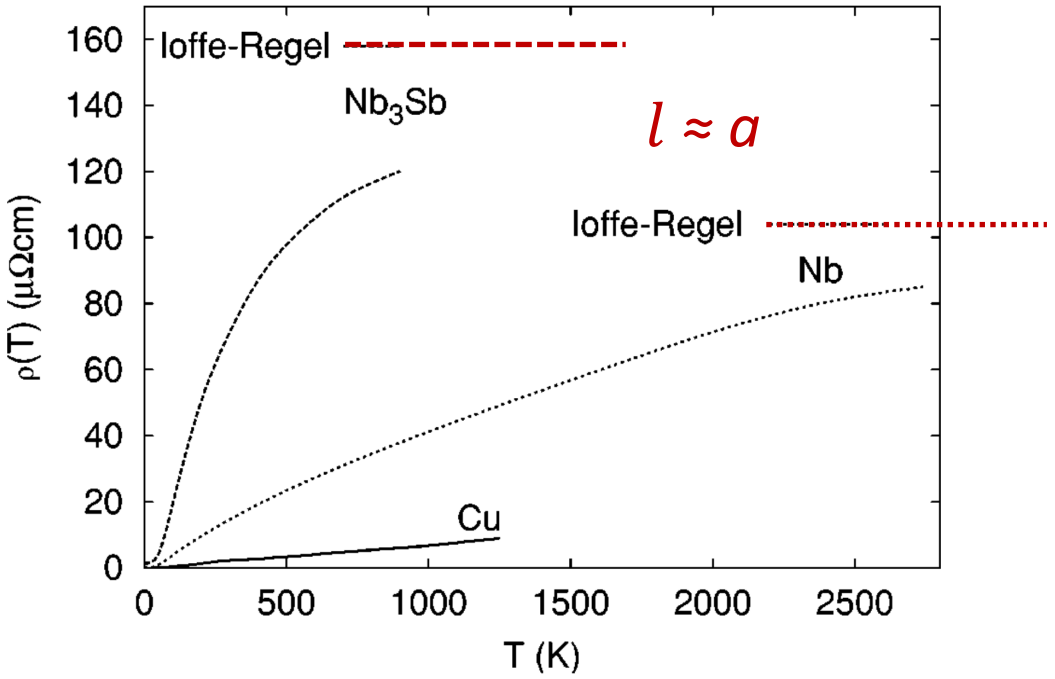


Gunnarsson, RMP 2003

$$\rho = \frac{3\pi^2\hbar}{e^2 {k_F}^2 l}$$

Semiclassical Boltzmann theory
3D metal

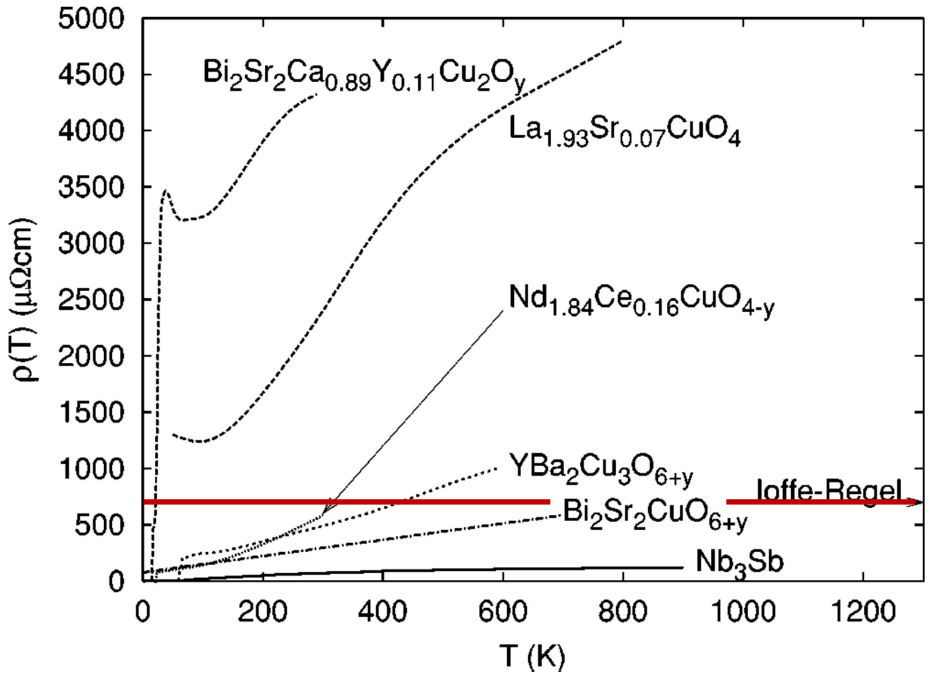
Metals at high temperature



Gunnarsson, RMP 2003

bad metals

Non saturating resistivity → $l < a$

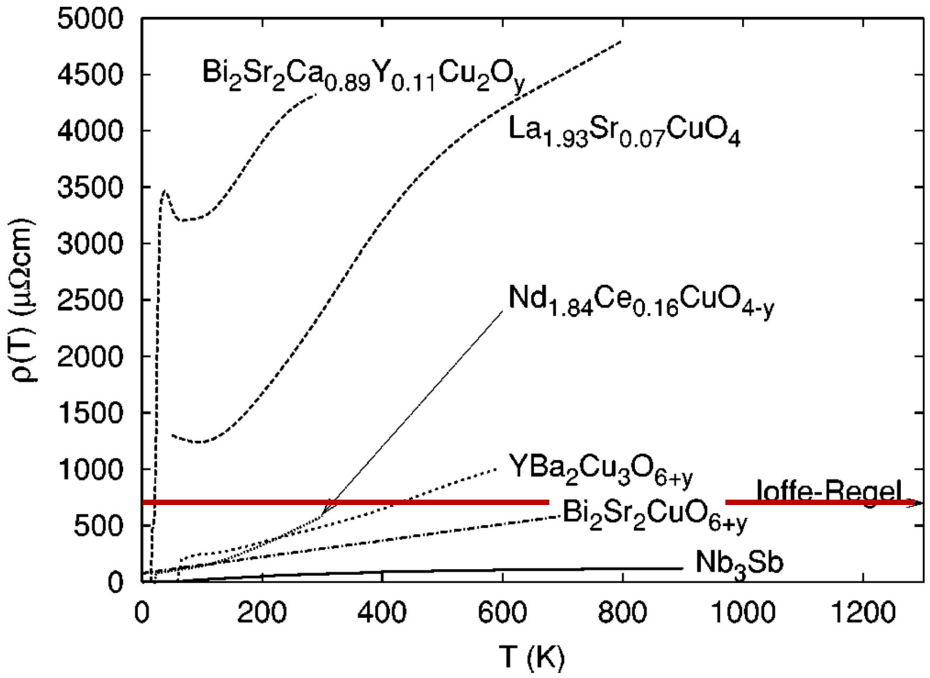


also *iron-pnictides, ruthenates, manganites, C60, organics,…*

(Bad metals vs strange metals)

bad metals

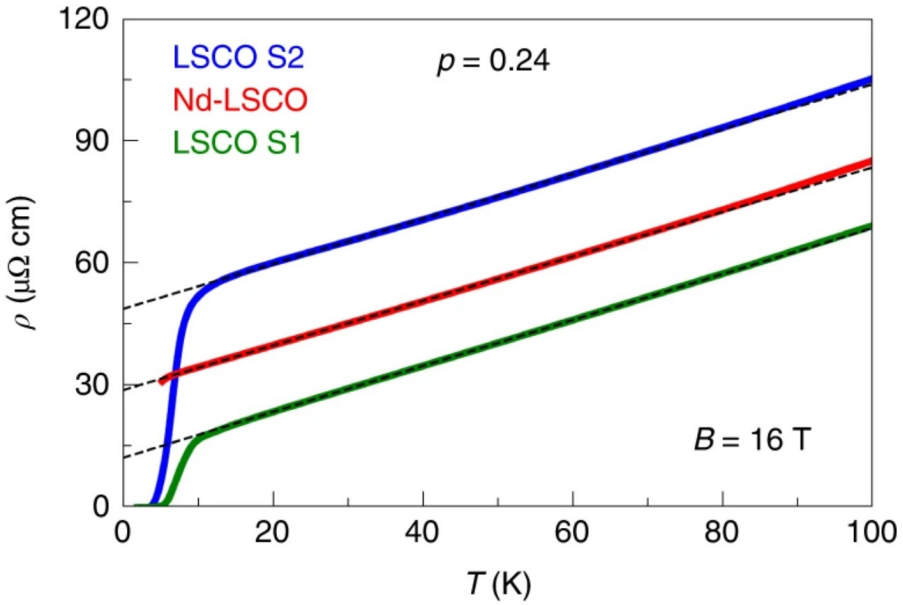
Non saturating resistivity → $l < a$



also *iron-pnictides, ruthenates, manganites, C60, organics,…*

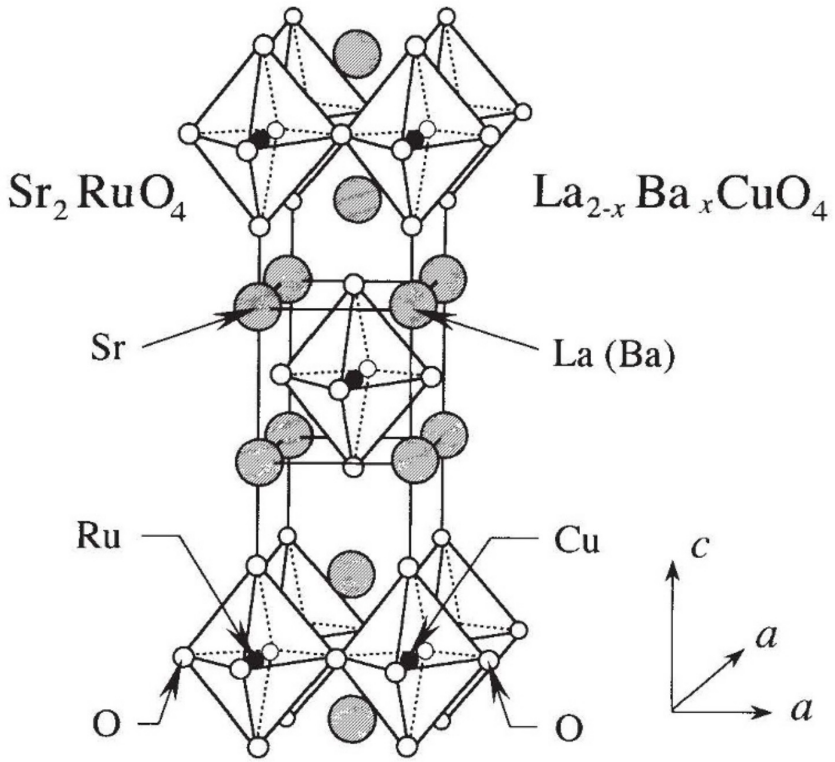
strange metals

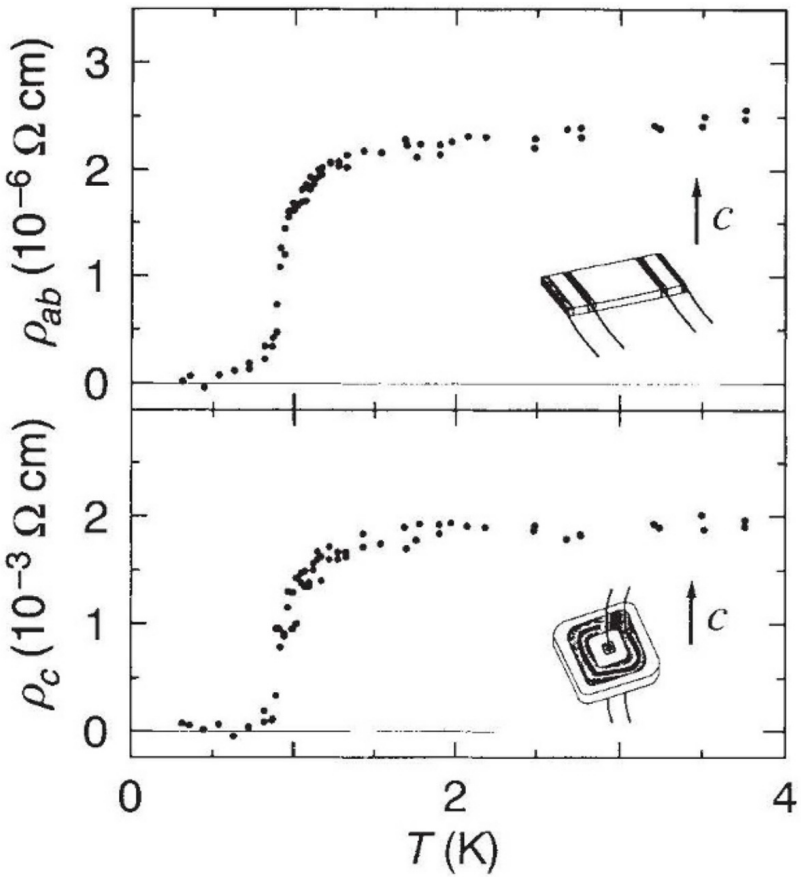
Linear resistivity $\frac{1}{\tau} = \frac{k_B T}{\hbar}$



also *iron-pnictides, ruthenates, MATBG ….*

Sr_2RuO_4

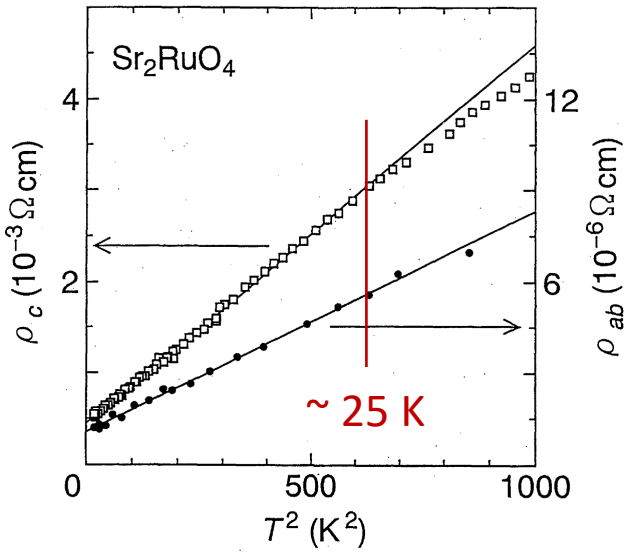




Y. Maeno, Nature 1994

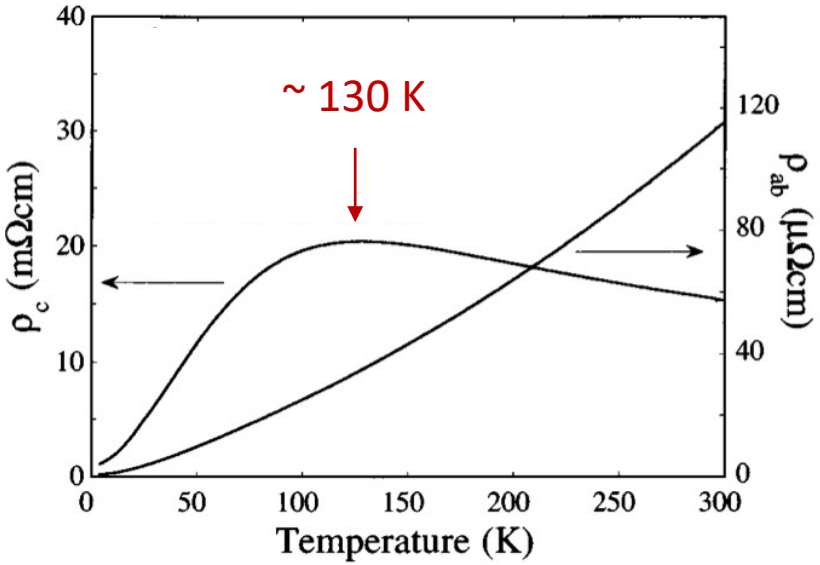
Sr_2RuO_4 - resistivity

low - T



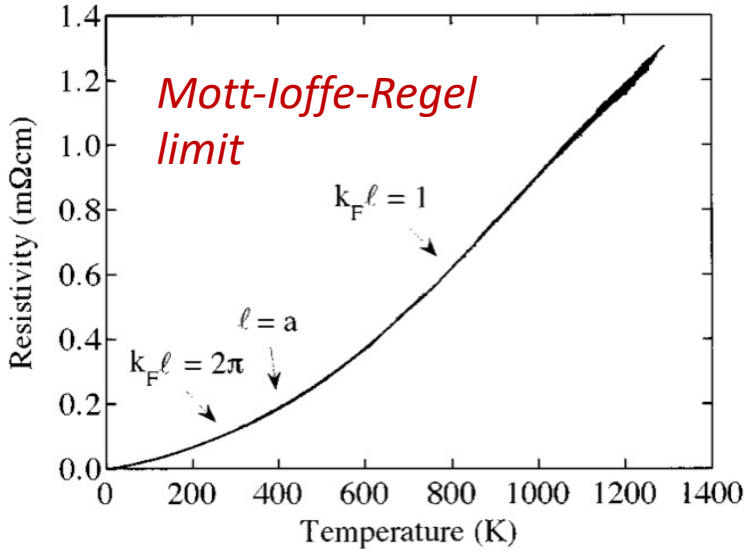
Y. Maeno, JPSJ 1997

c-axis crossover



N.E. Hussey, PRB 57, 5505 (1998)

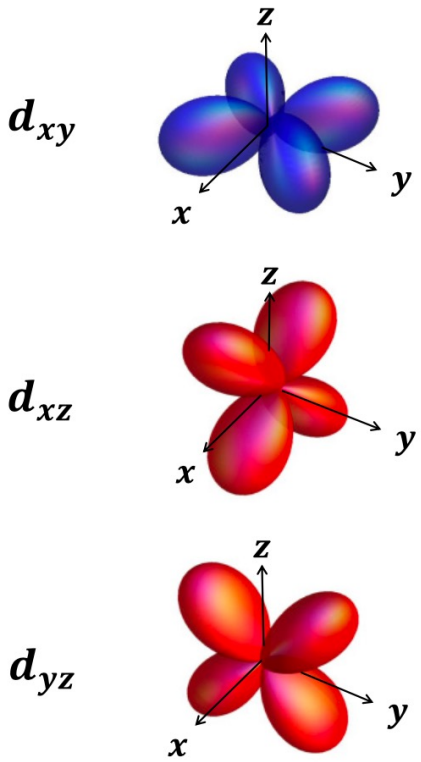
high - T

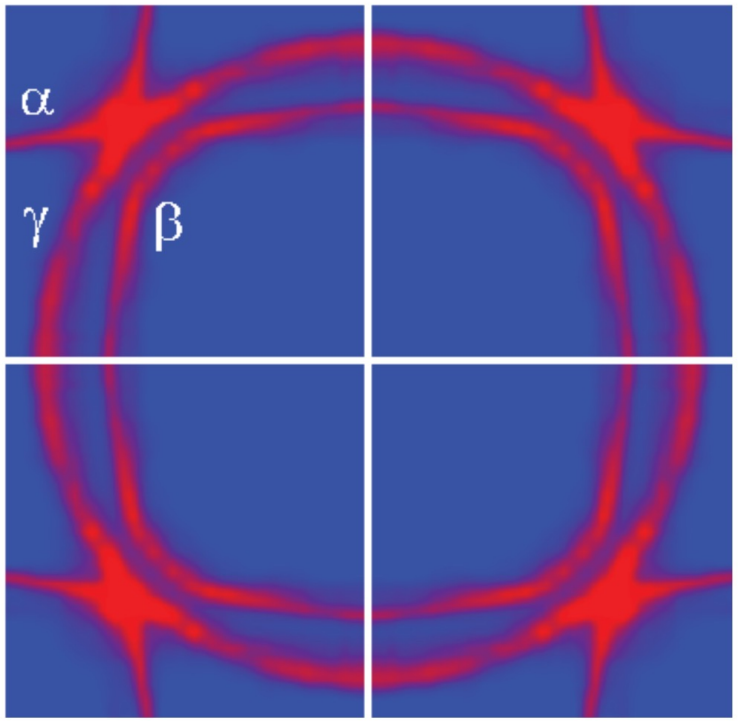


A. W. Tyler, PRB 58, R10107 (1998)

Electronic structure

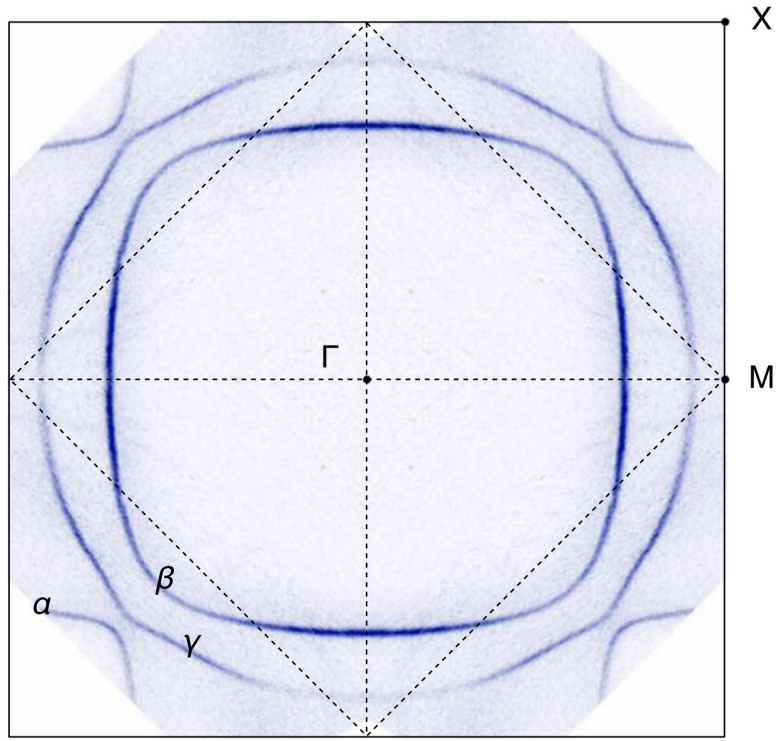
Ru^{4+} : **4** 4*d* el./Ru





A. Damascelli et al., PRL 85, 5194 (2000)

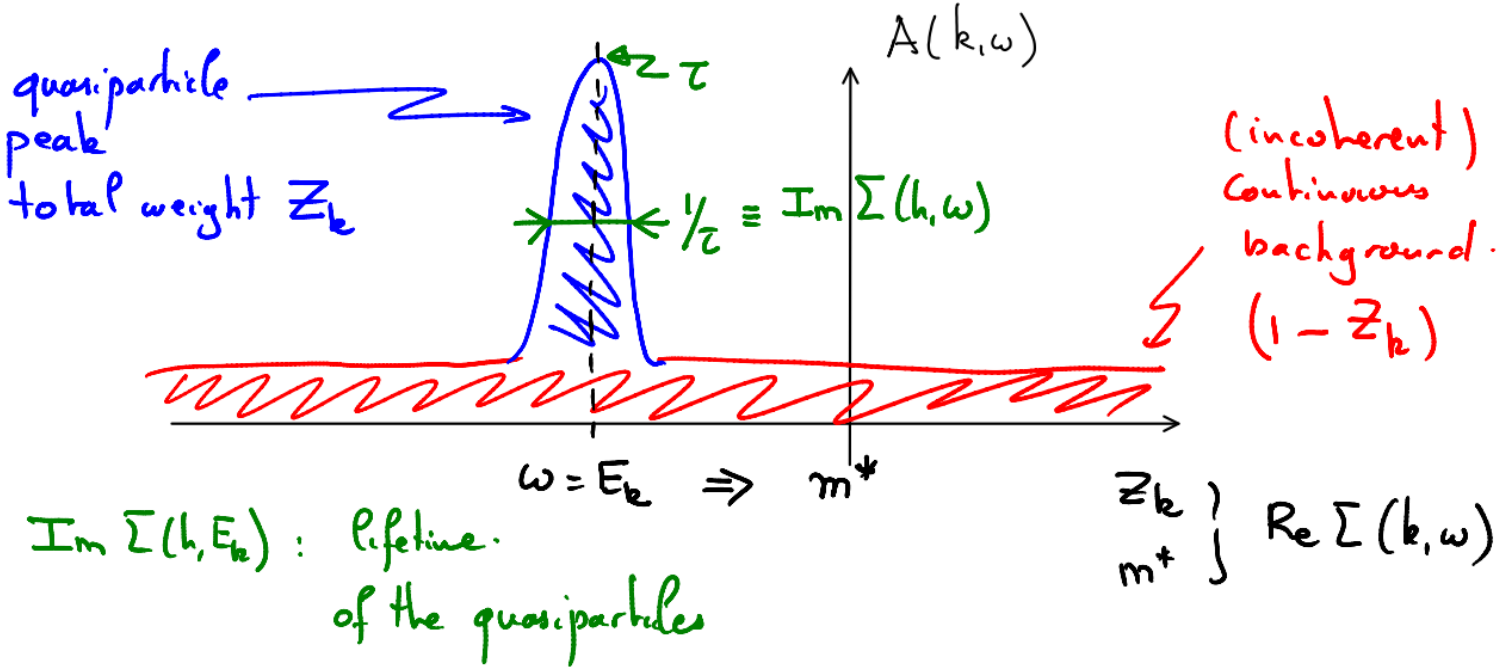
laser ARPES



A. Tamai, PRX 2019

Correlations in a Fermi liquid

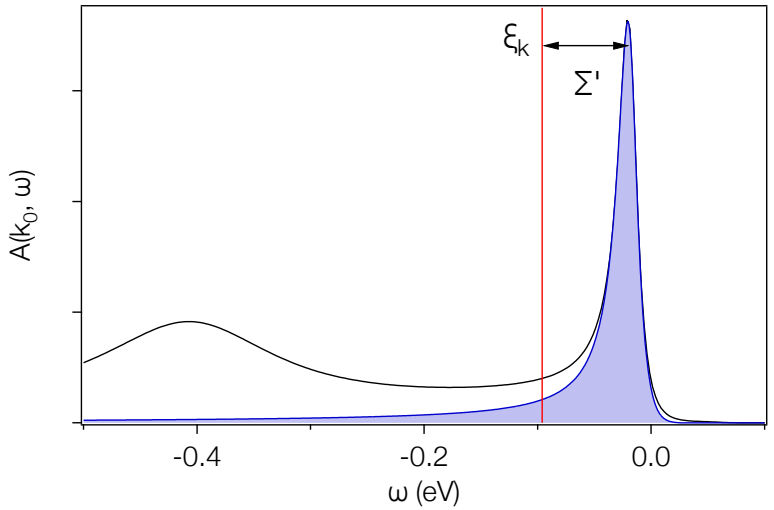
$$\frac{dI^{SA}}{d\Omega d\epsilon} \propto A(\vec{k},\omega) = \frac{-\frac{1}{\pi}\Sigma''(\omega)}{[\omega - \xi_{\vec{k}} - \Sigma'(\omega)]^2 + [\Sigma''(\omega)]^2}$$



T. Giamarchi, C. Berthod, Many Body Physics, Lecture notes (2013)

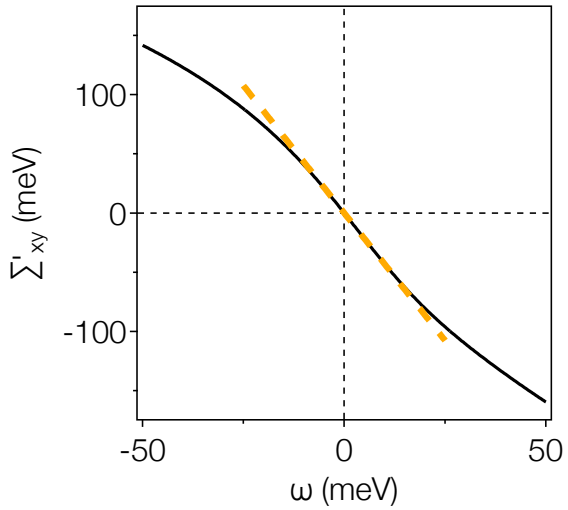
Quasiparticle residue: Z

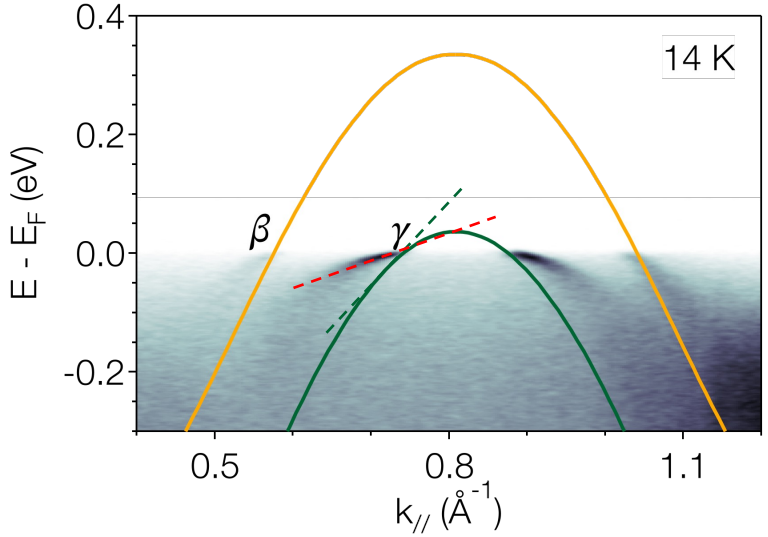
spectral weight



$$Z = \int A_{ch}(\omega) d\omega$$

mass enhancement

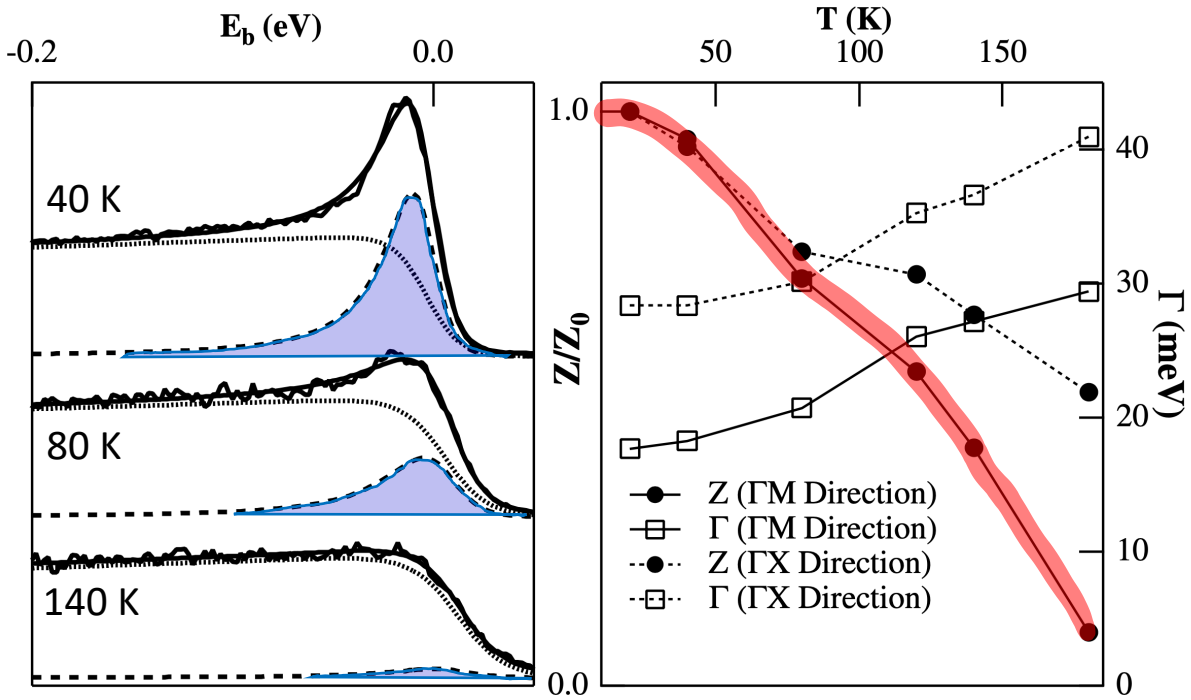




$$Z = \left(1 - \left.\frac{\partial \Sigma'}{\partial \omega}\right|_{\omega=0}\right)^{-1}$$

$$Z = \frac{v_F^*}{v_0} = \frac{m_0}{m^*}$$

Temperature dependence - previous studies

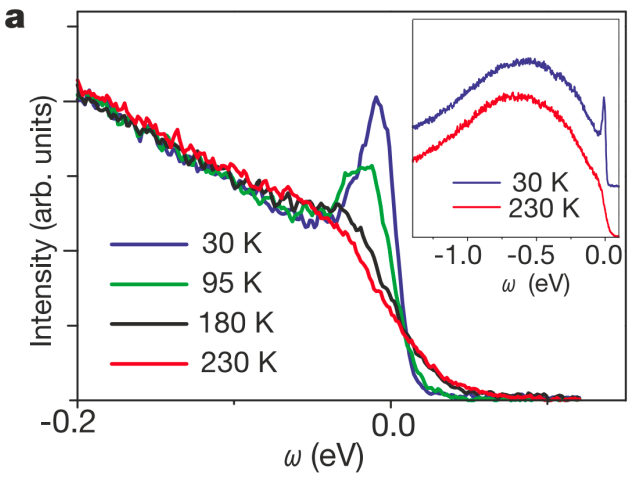


Sr_2RuO_4, Wang et al. 2004 :

- QPs disappear near 130 K (ρ_c crossover)
- $Z \rightarrow 0$ around 200 K

Wang, PRL 92, 137002 (2004)

Temperature dependence - previous studies

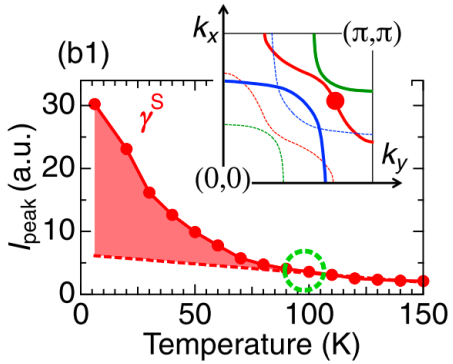


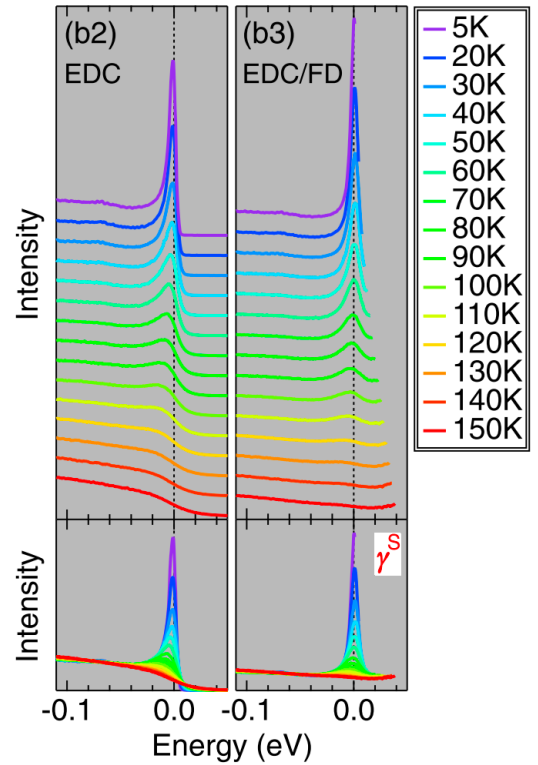
Cobaltates

Valla,
Nature 417 (2003)

Sr_2RuO_4 Surface states

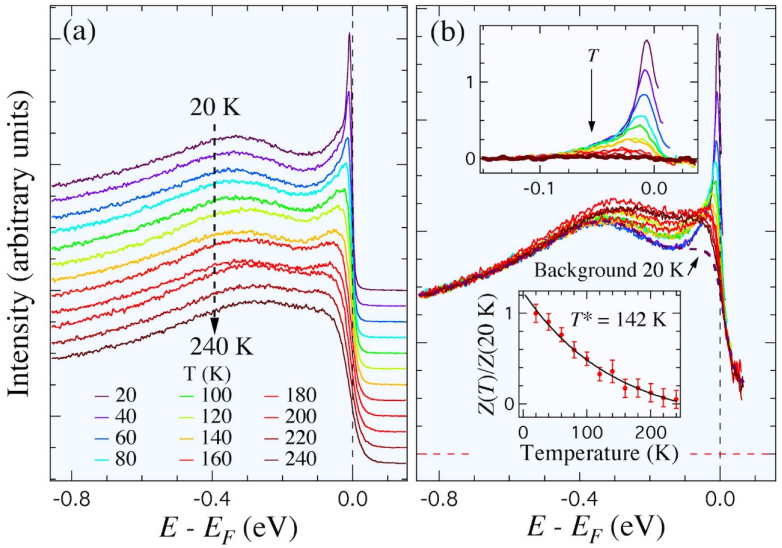
Kondo,
PRL 117, 247001 (2016)





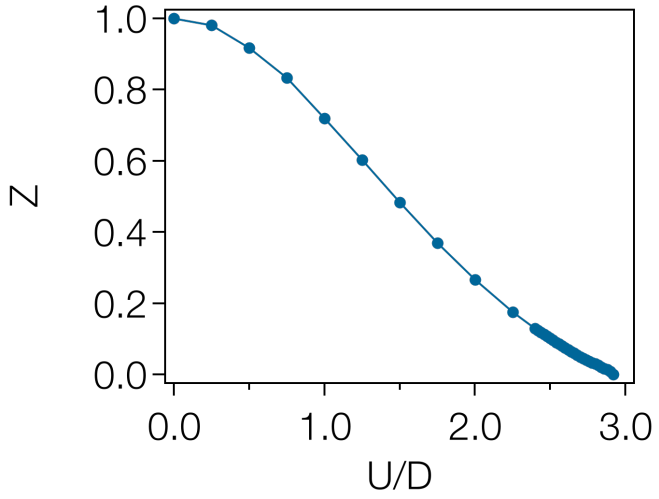
KFe_2As_2

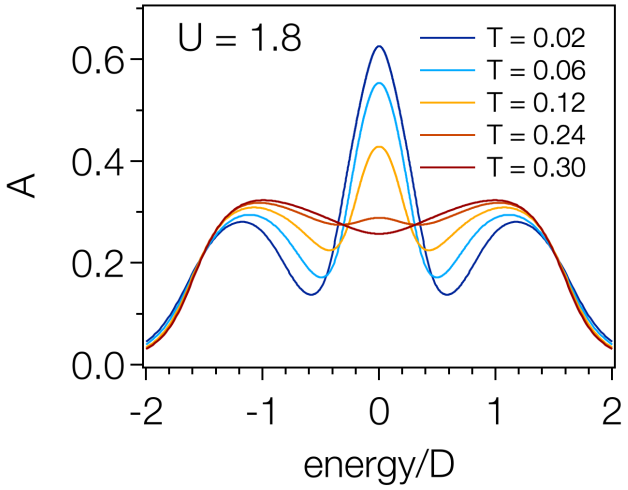
Richard,
arXiv:1807.00193

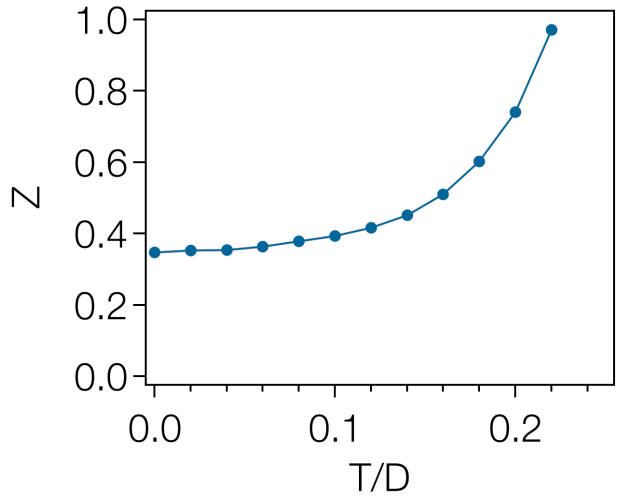


Temperature dependence – DMFT

Hubbard model - half filling

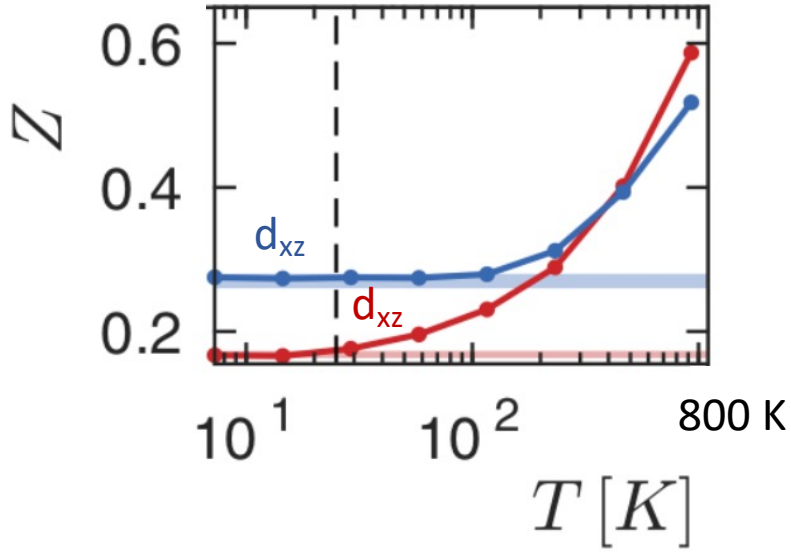






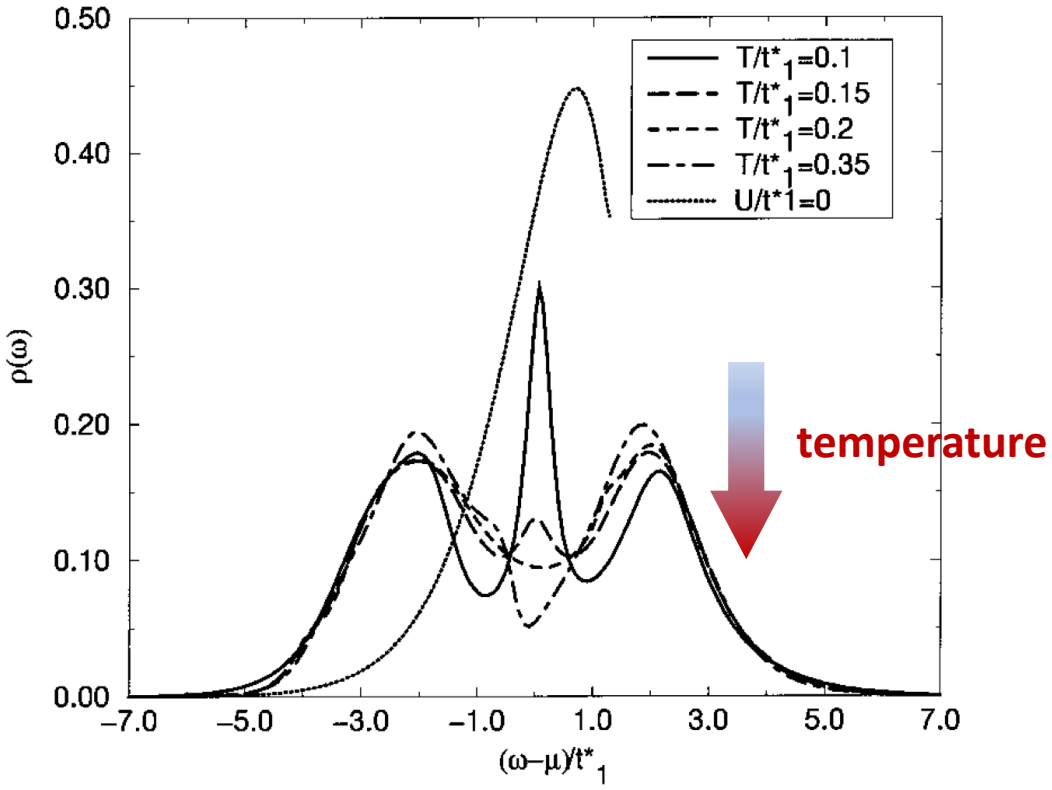
Jernej Mravlje (2023)

Sr_2RuO_4



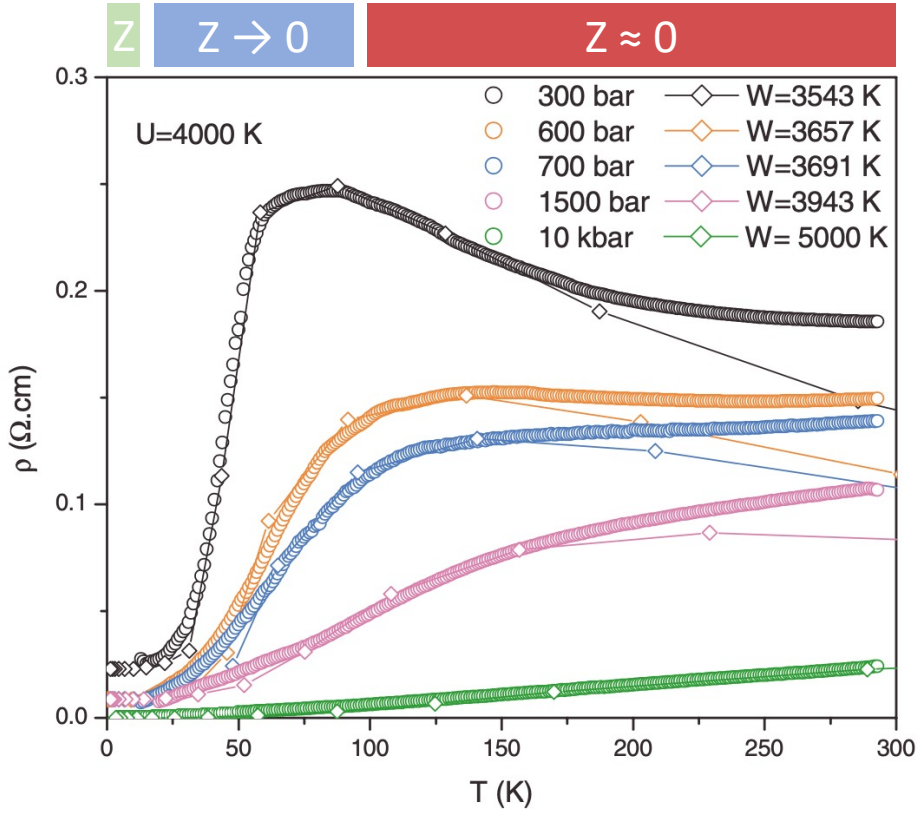
F. Kugler, PRL 124 16401 (2020)
J. Mravlje, PRL 106 096401 (2011)

Temperature dependence - previous studies



Half-filled Hubbard model, moderate U

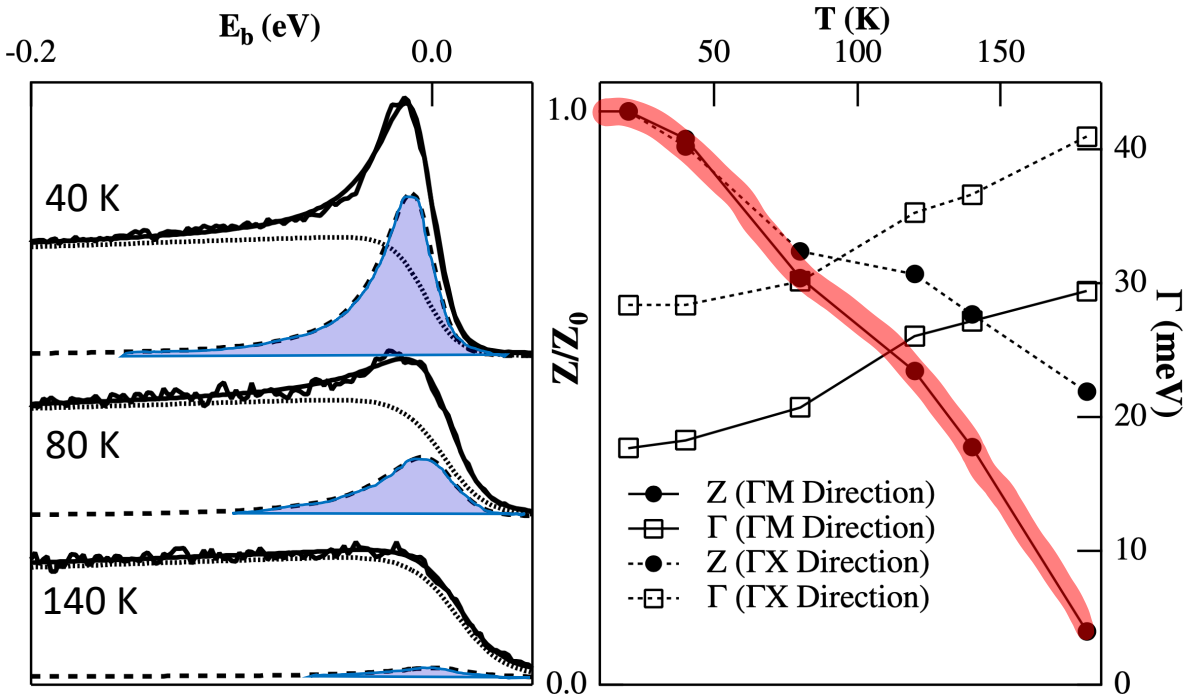
Merino and McKenzie, PRB 61 7996 (1999)



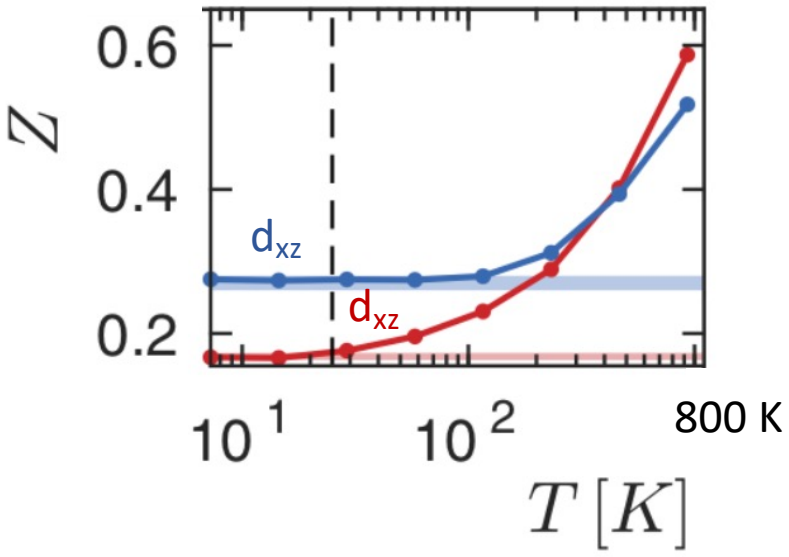
κ –(BEDT-TTF)$_2$Cu[N(CN)$_2$]Cl

Limelette et al., PRL 91 016401 (2003)

Temperature dependence - previous studies



DMFT



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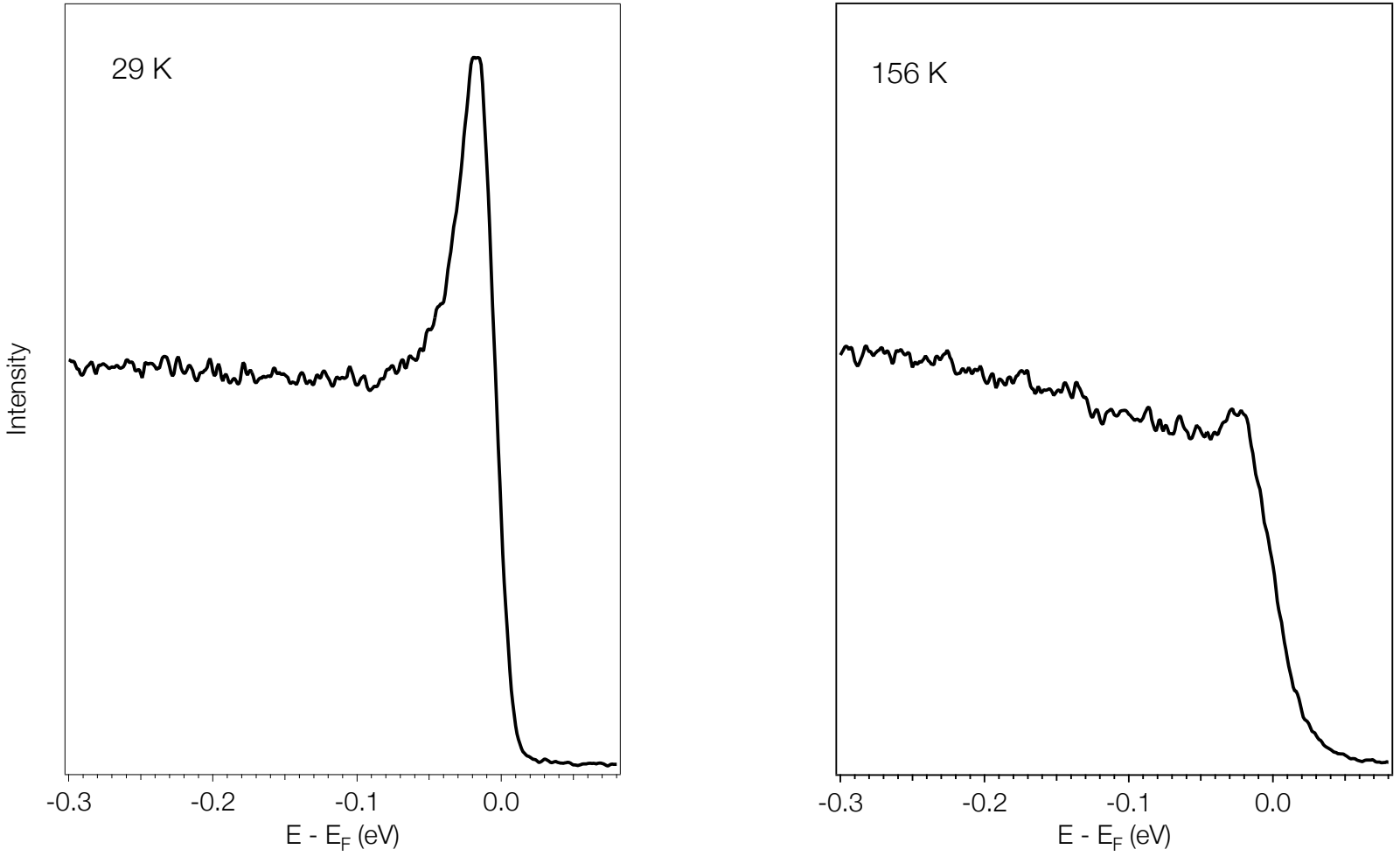
Wang, PRL 92, 137002 (2004)

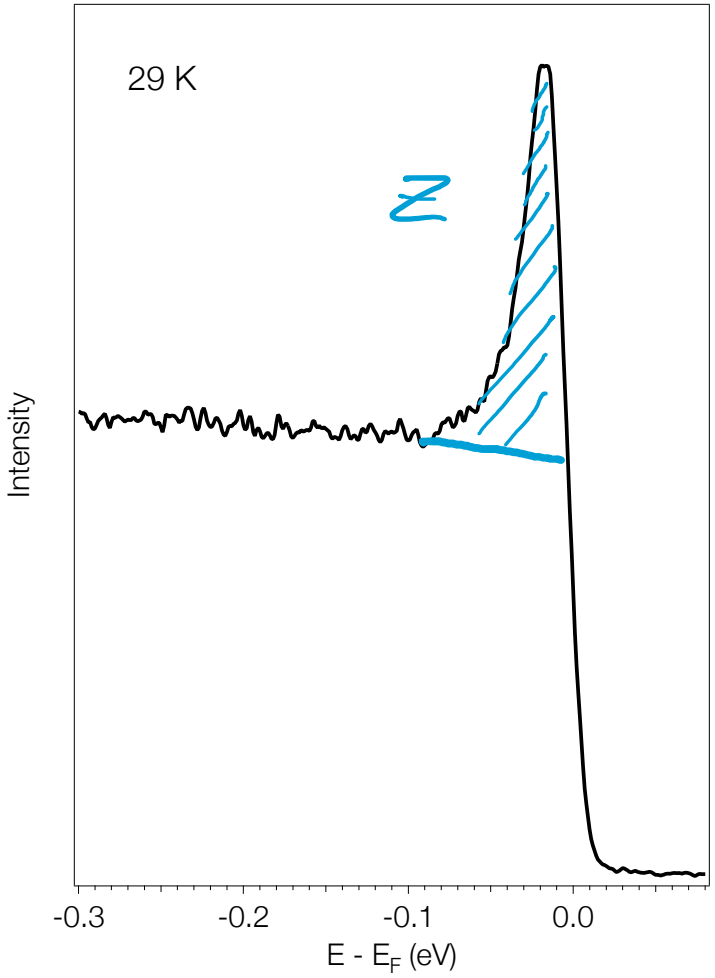
???

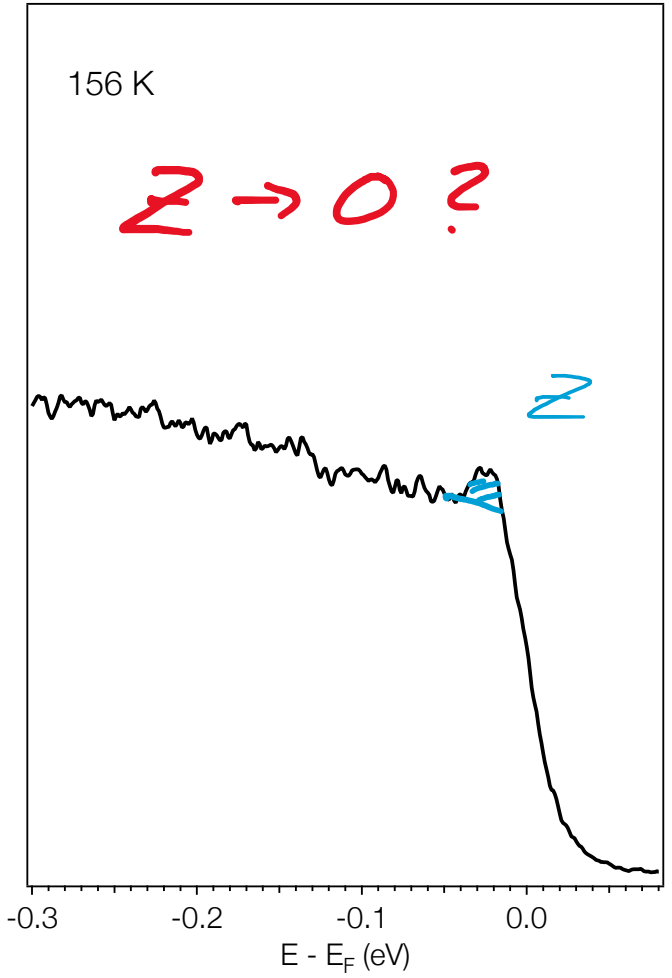
F. Kugler, PRL 124 16401 (2020)
J. Mravlje, PRL 106 096401 (2011)

New data

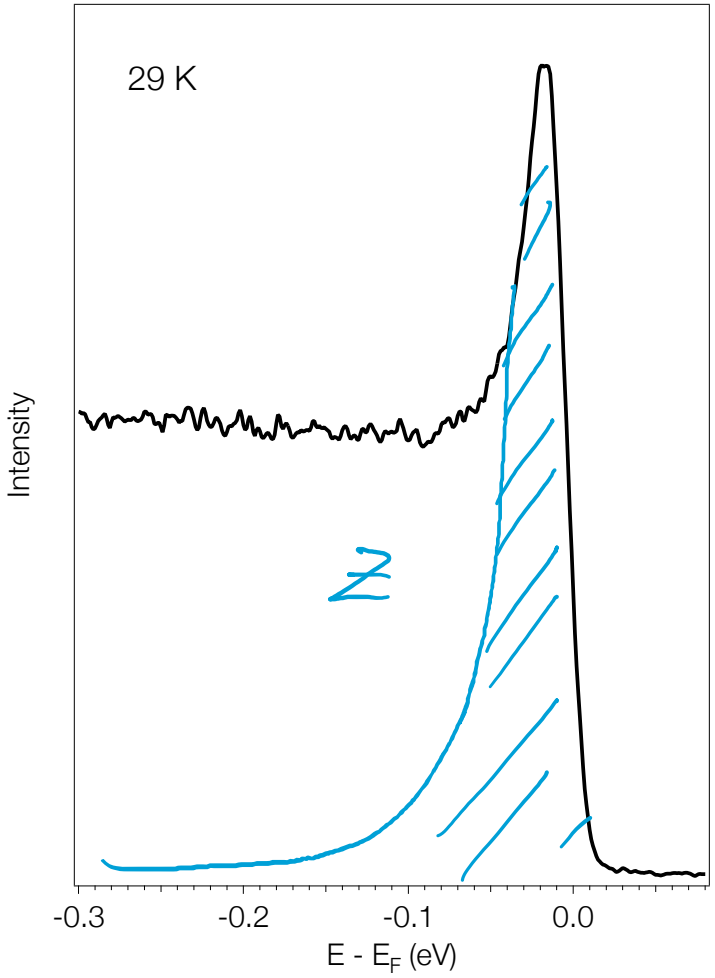


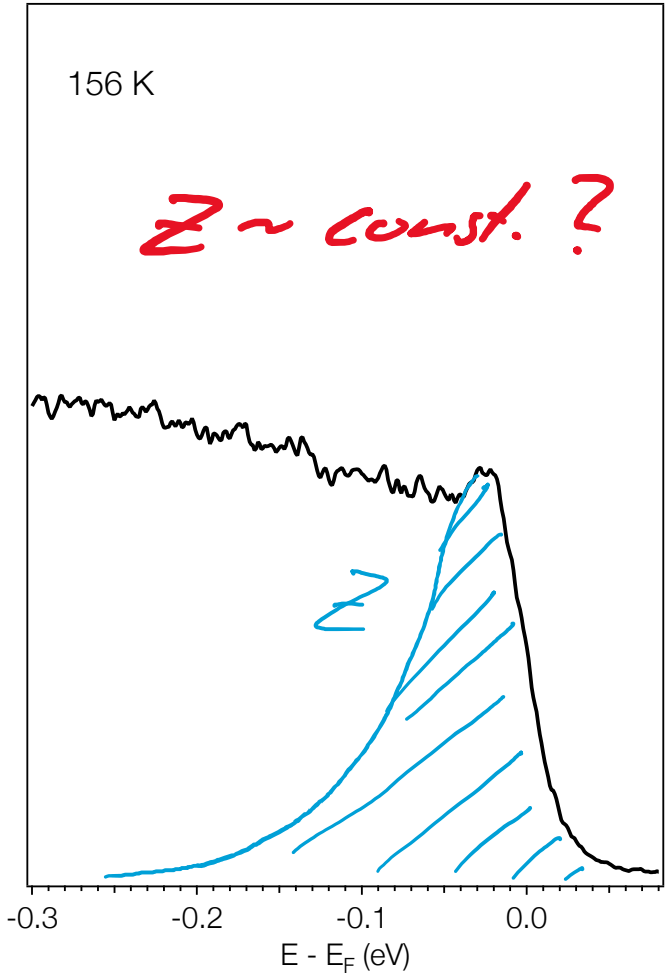
Spectral weights



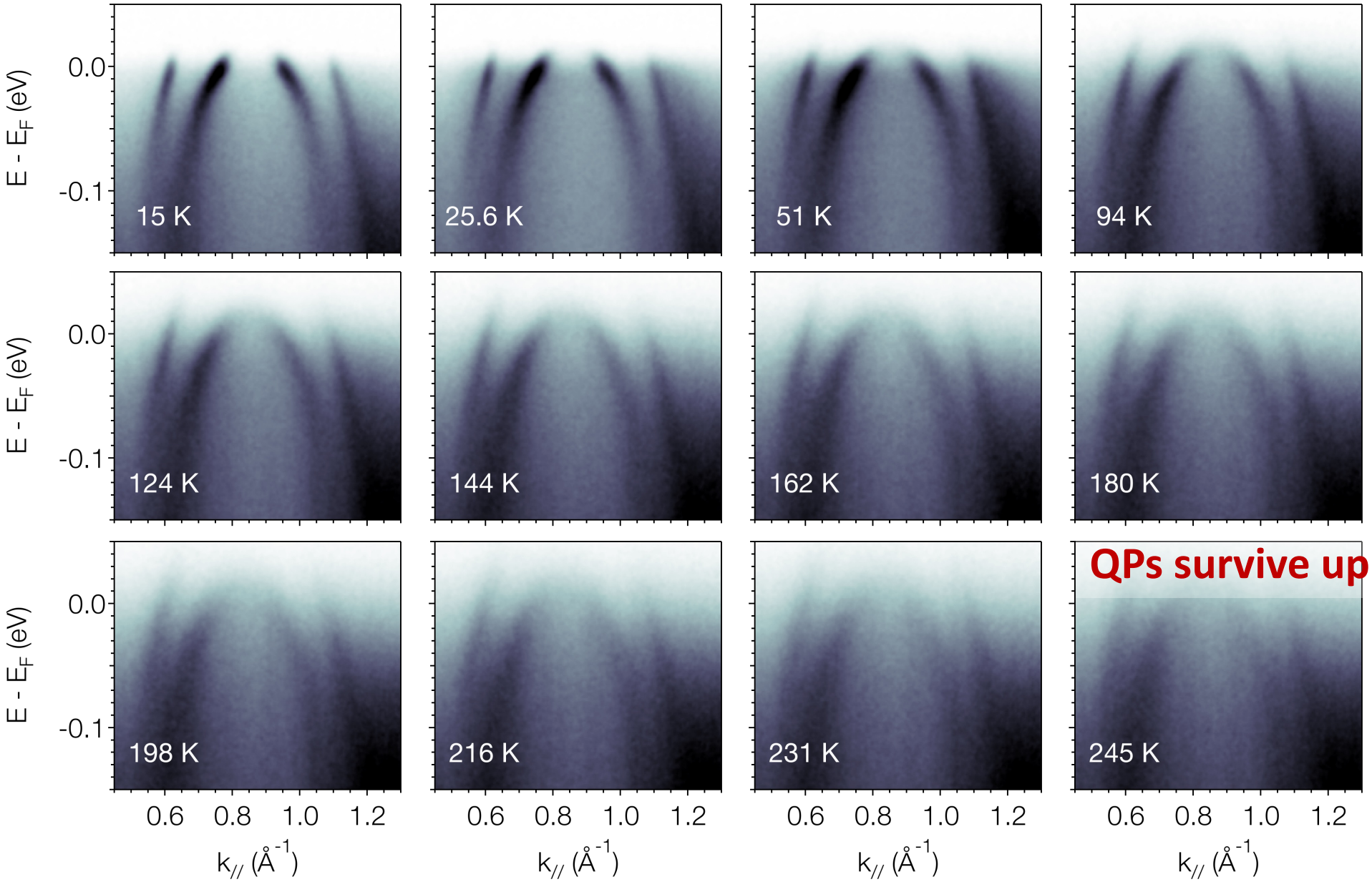


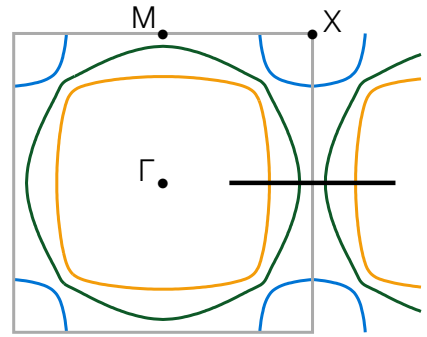
Spectral weights





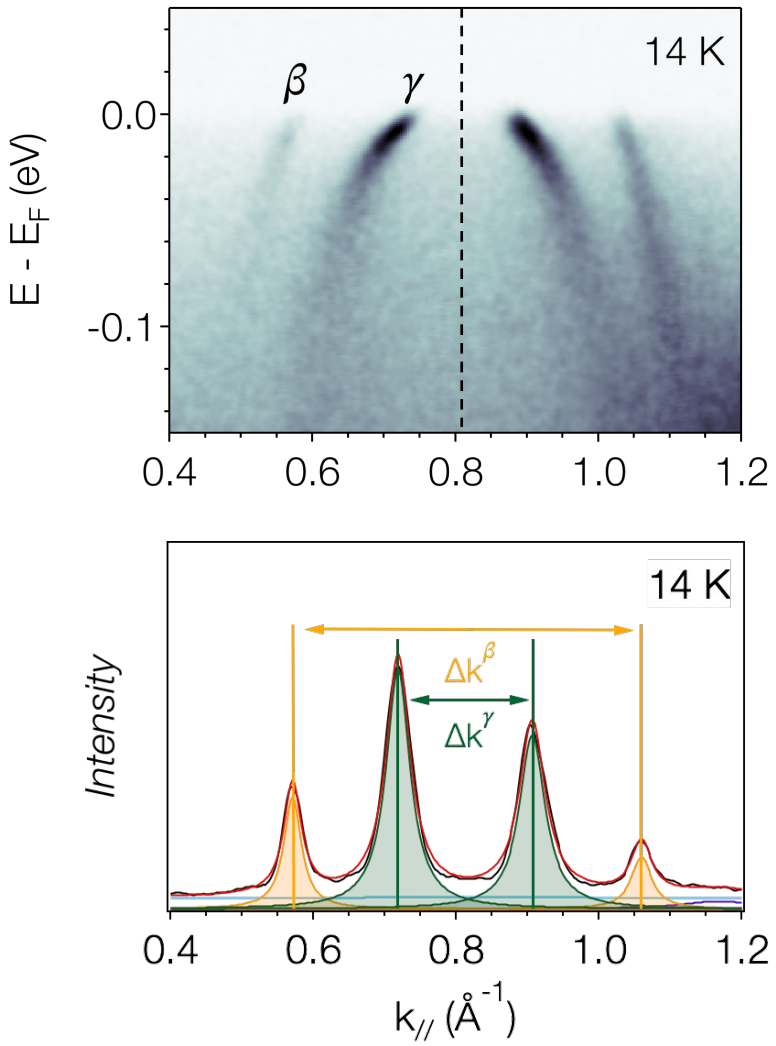
Temperature dependent ARPES

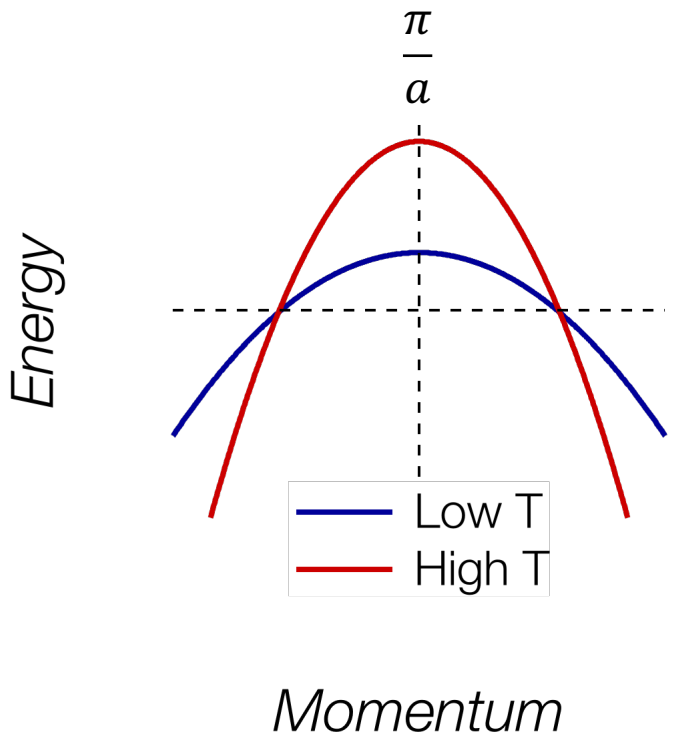




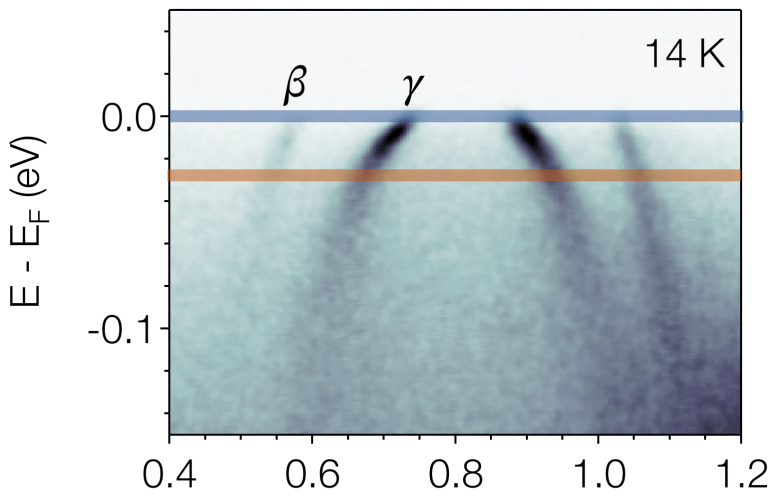
QPs survive up to high temperature !

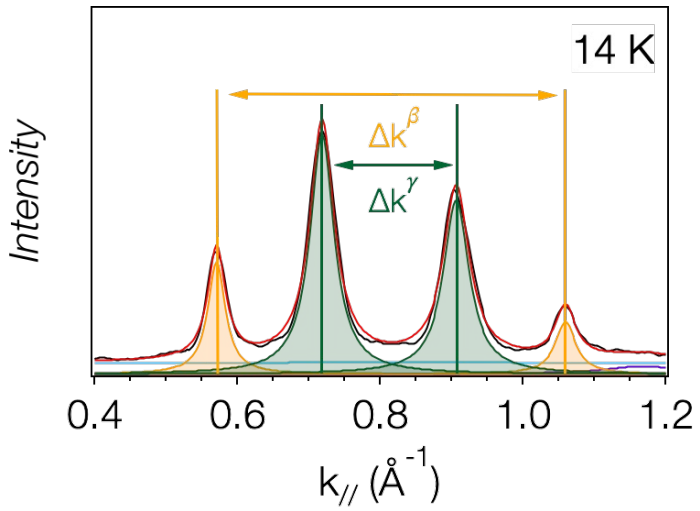
Temperature dependent ARPES



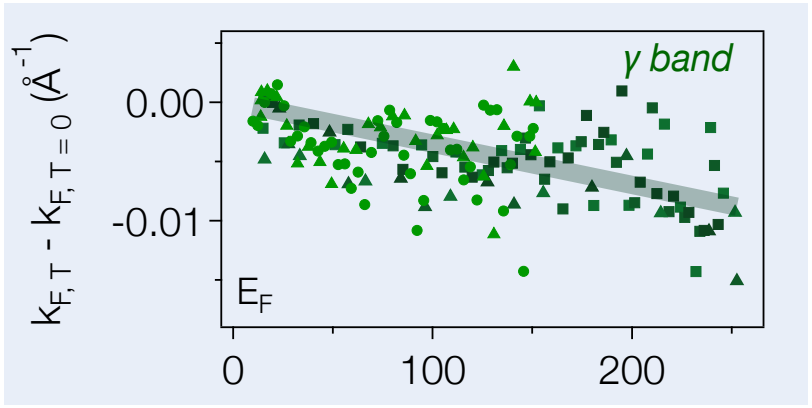


Temperature dependent ARPES

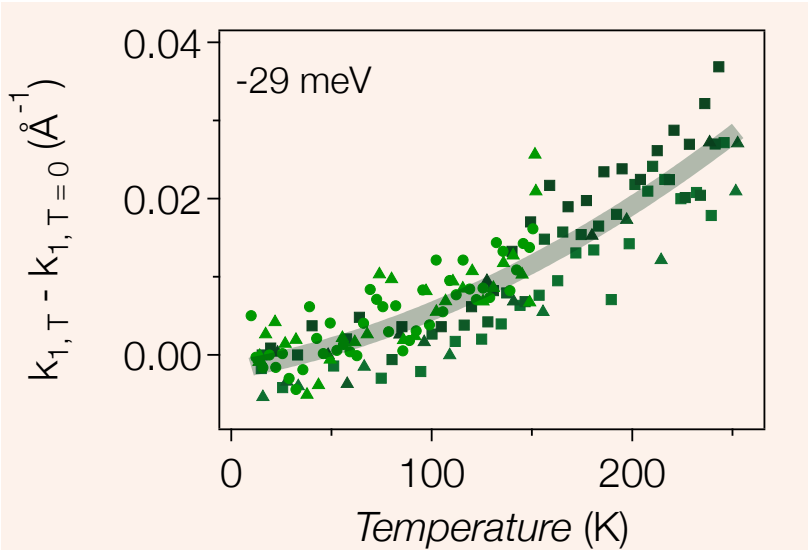


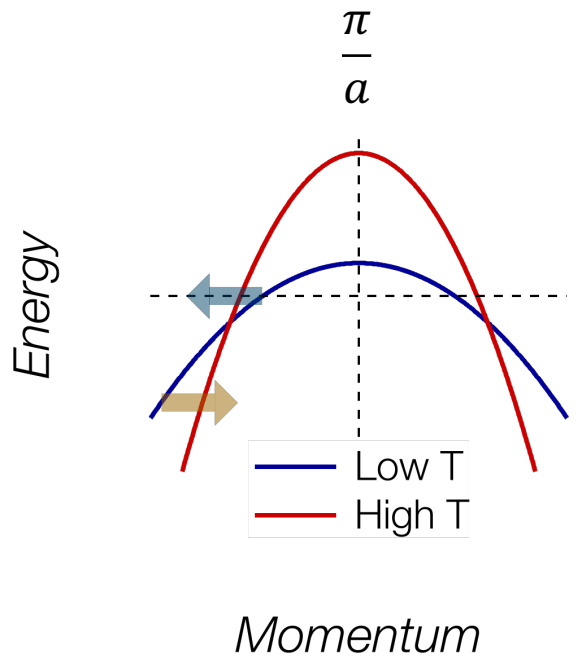


@ E_F



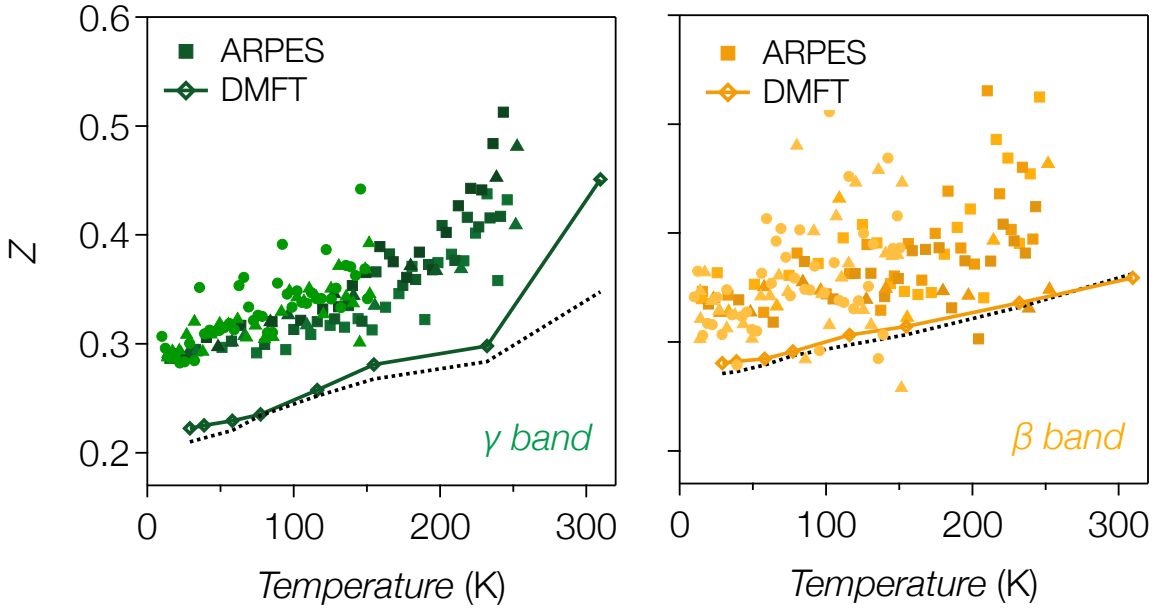
below E_F

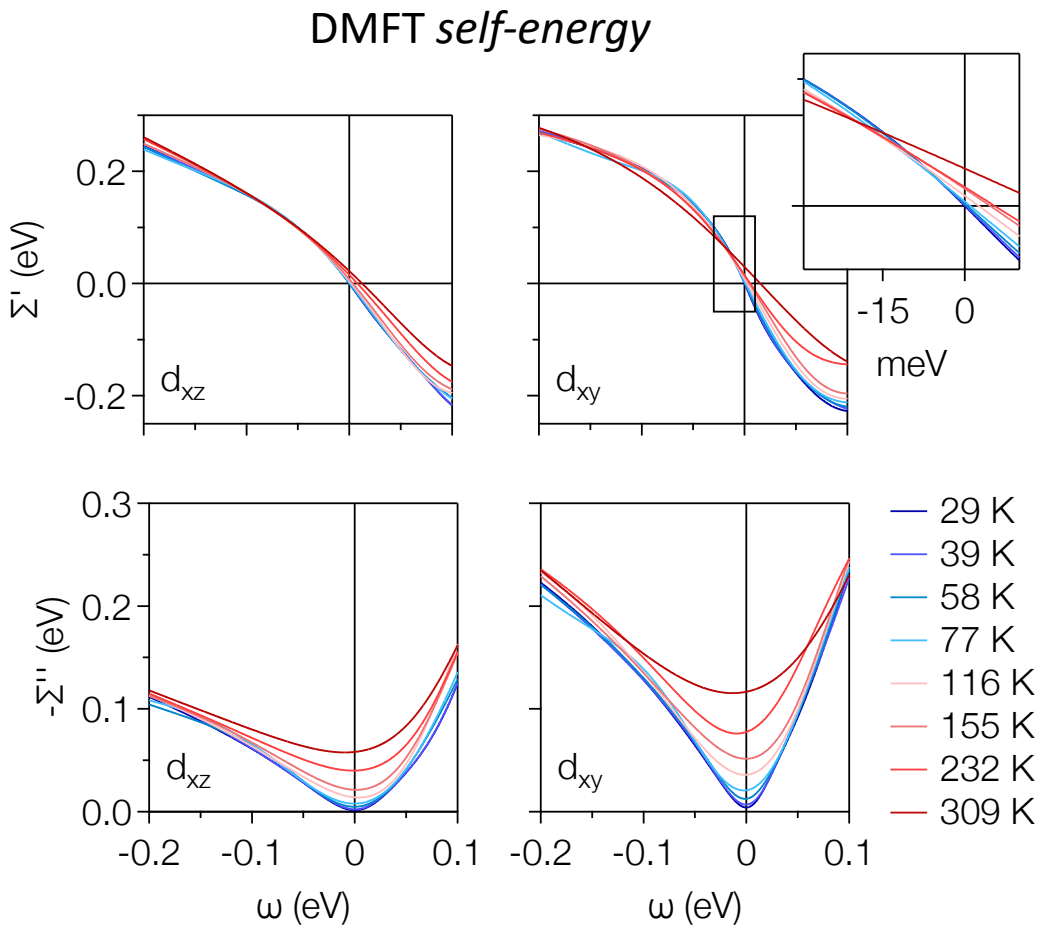




QP residue Z

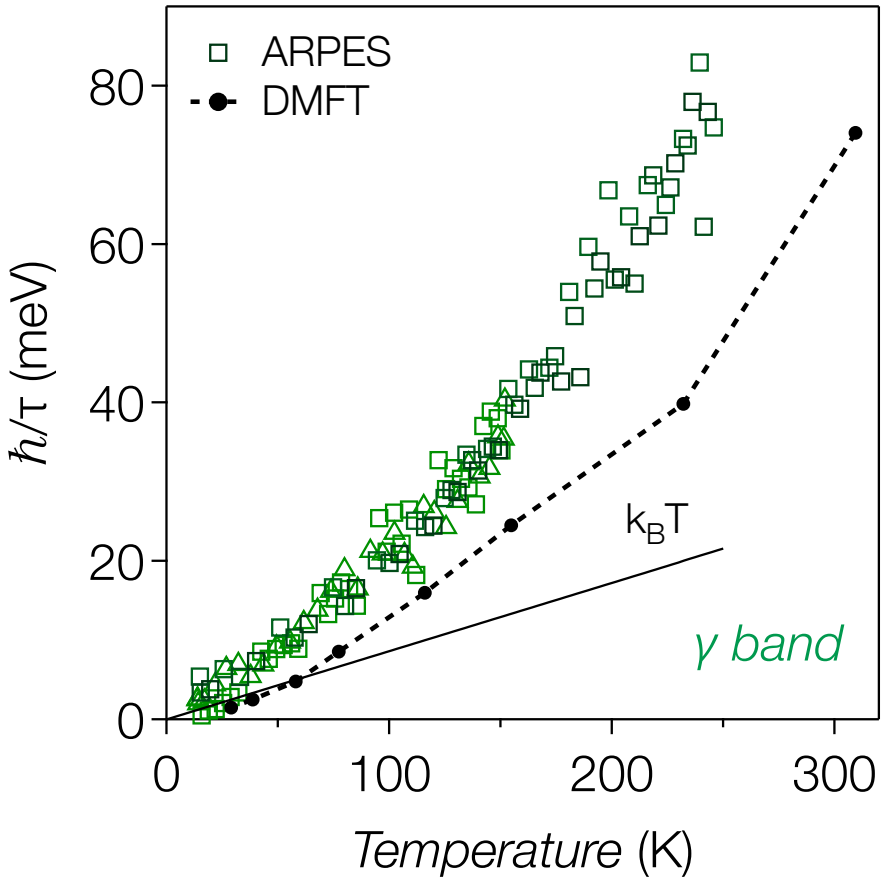
$$Z = \frac{v_F^*}{v_0} = \frac{m_0}{m^*}$$

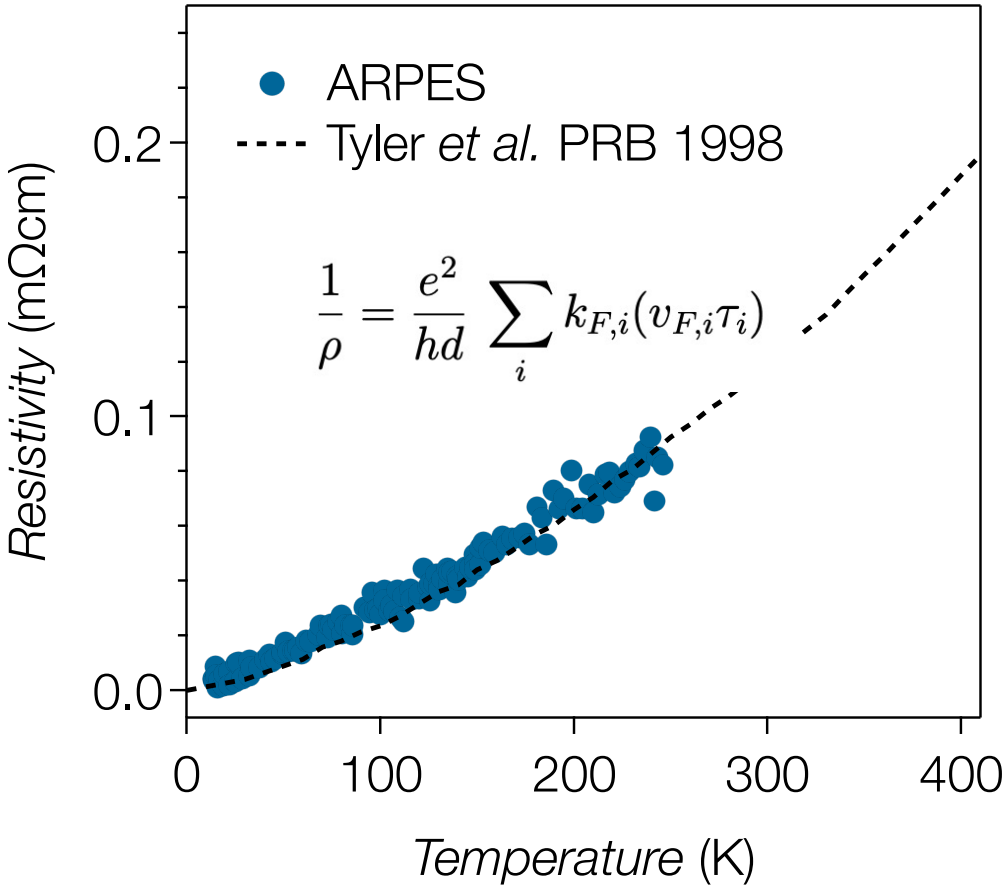




Hunter, arXiv:2308.02313

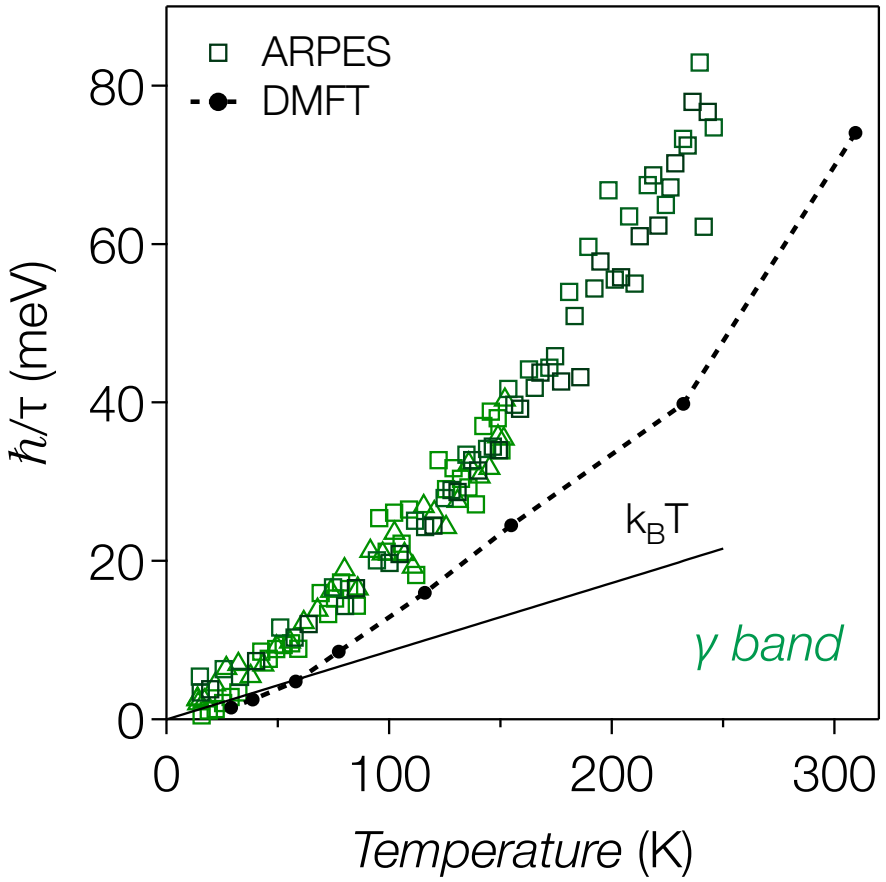
QP scattering & resistivity





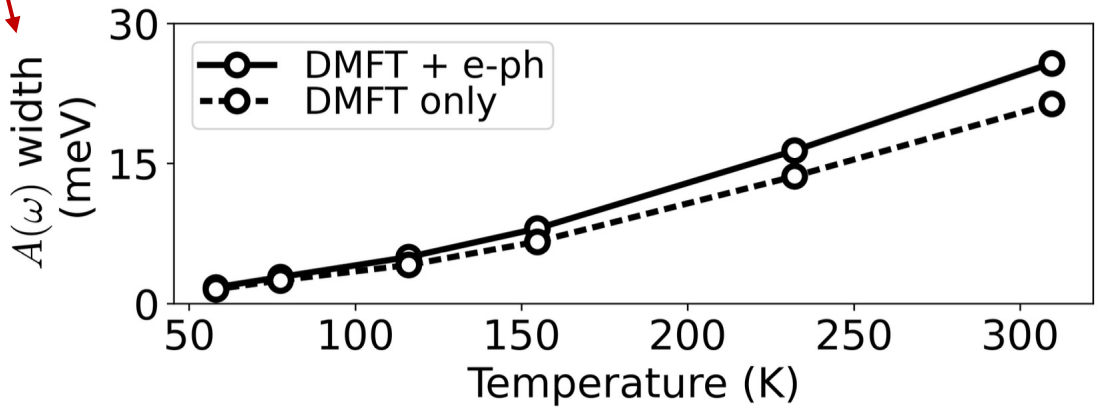
Hunter, arXiv:2308.02313

QP scattering & resistivity



el. – ph contribution is small

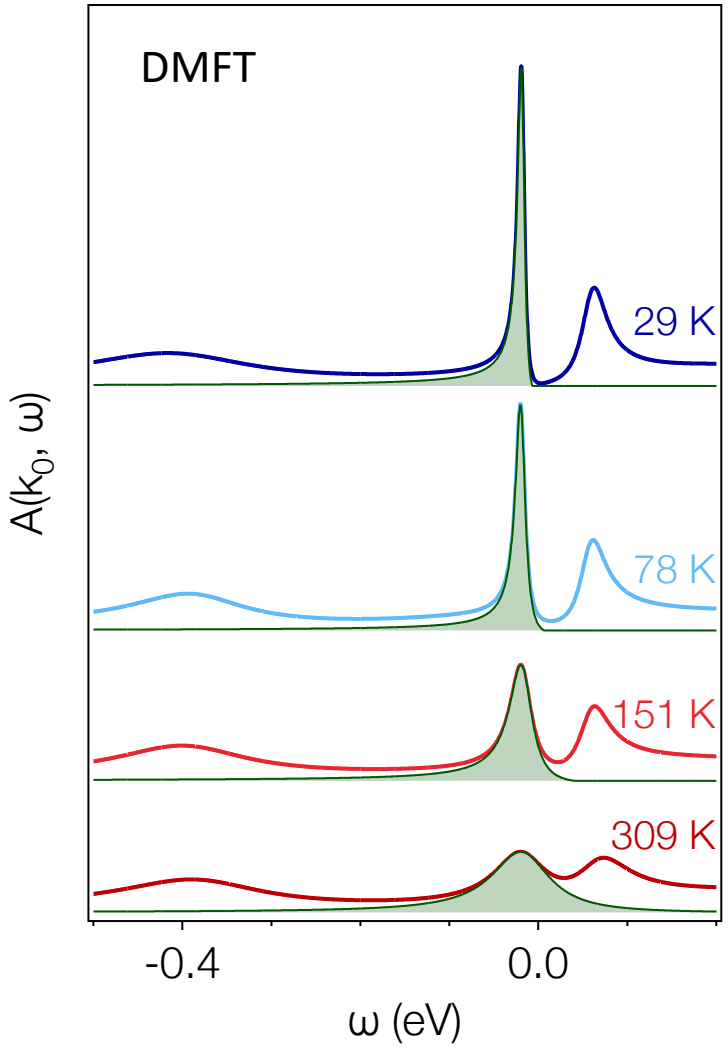
HWHM



Abramovich, arXiv:2304.06771

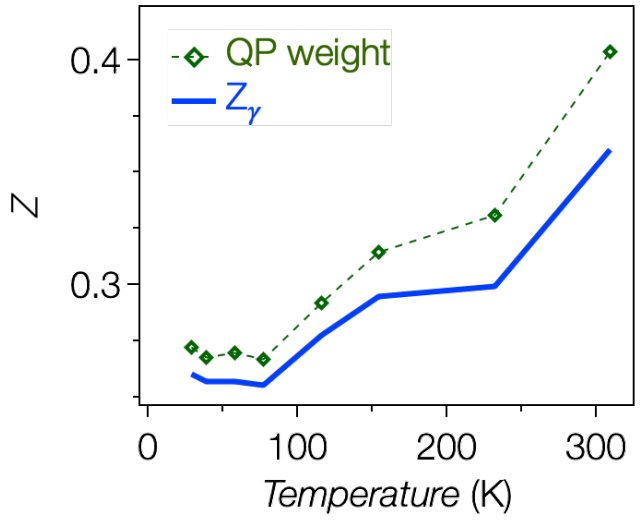
Hunter, arXiv:2308.02313

Spectral weight vs temperature



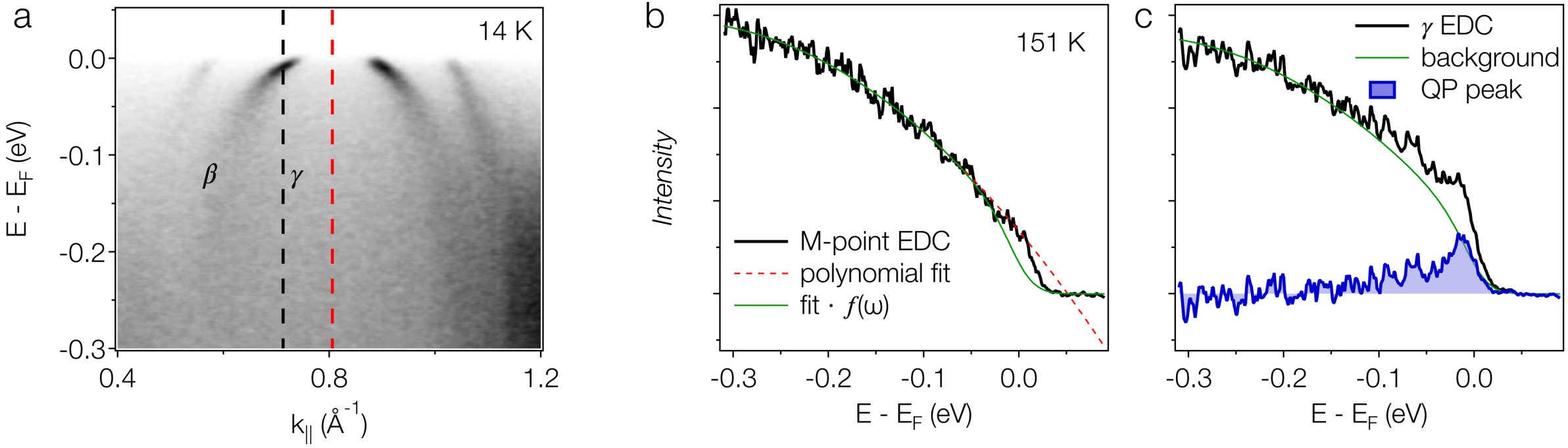
QP weight $= \int A_{ch}(\omega) d\omega$

$$\frac{1}{Z_\gamma} = \sum_m \frac{1}{Z_m} |U_{m\nu}(\theta)|^2$$

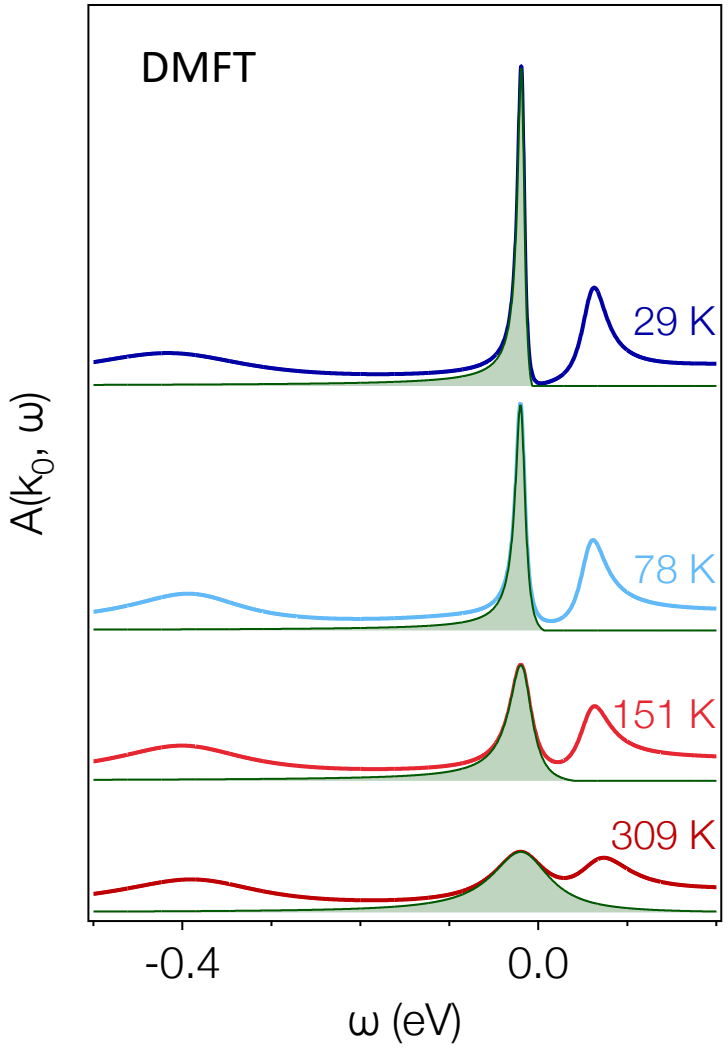


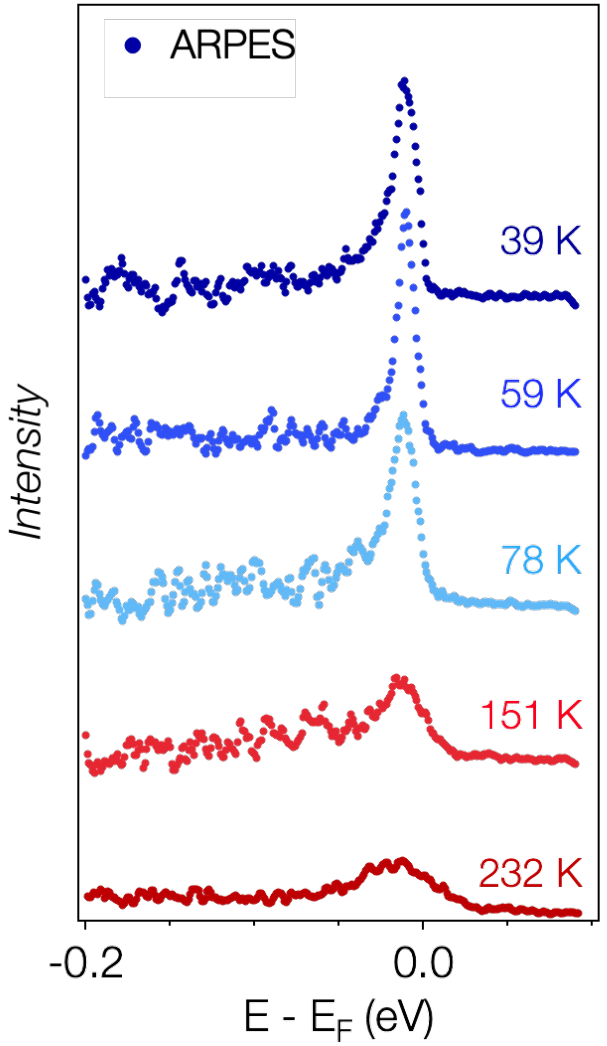
Hunter, arXiv:2308.02313

ARPES spectral weights



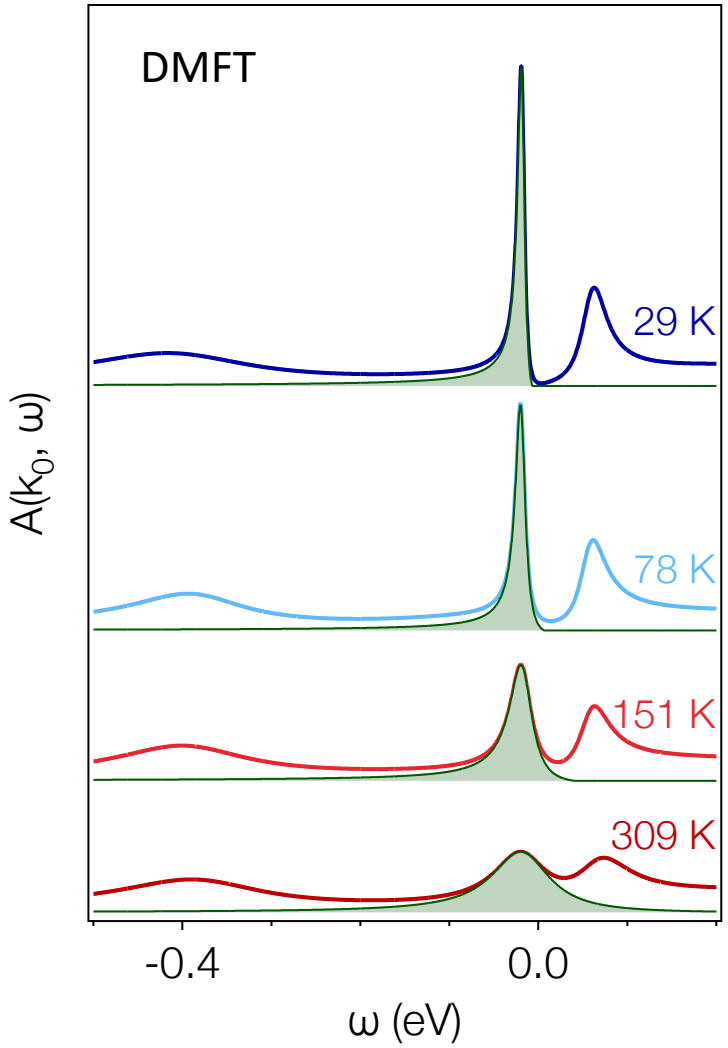
Spectral weight vs temperature

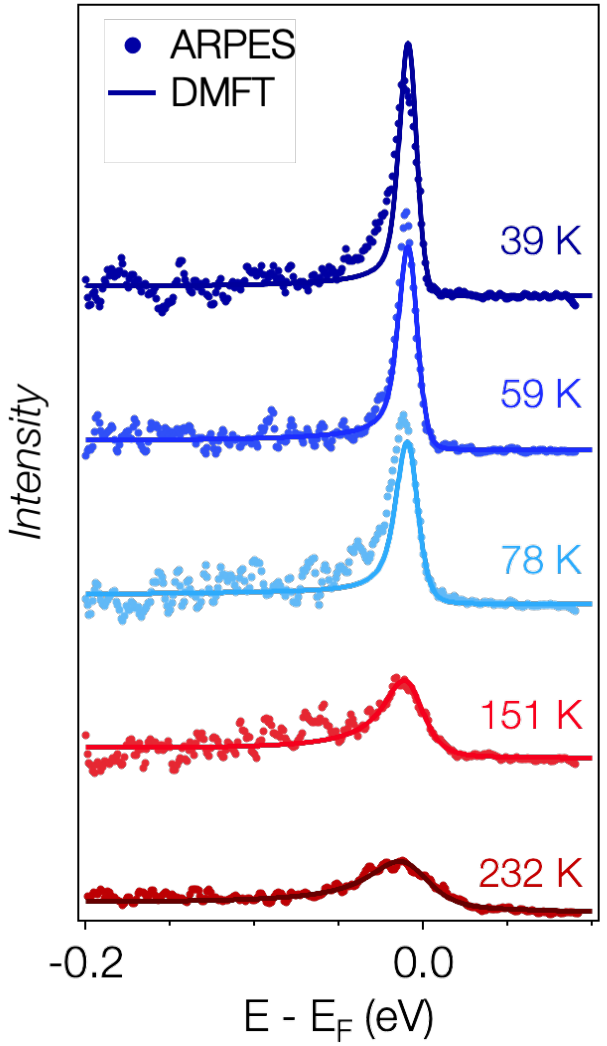




Hunter, arXiv:2308.02313

Spectral weight vs temperature





Hunter, arXiv:2308.02313

The fate of QP at high temperature

- QP – like excitations in non-FL regime
- Dispersion: *Z* increases and lifetime decreases with temperature; *fast and furious*
- Spectral weights unreliable