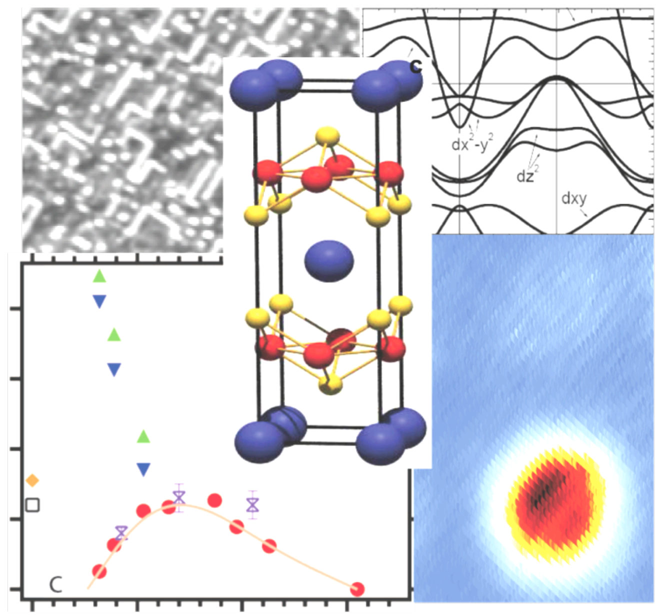
Boosting the critical temperature in Co-doped Ba122: a spectroscopic view.

Erik van Heumen
van der Waals - Zeeman institute
Universiteit van Amsterdam



Collaborators

Optical spectroscopy

Alona Tytarenko

Crystal growth

Yingkai Huang

transport properties

Anne de Visser

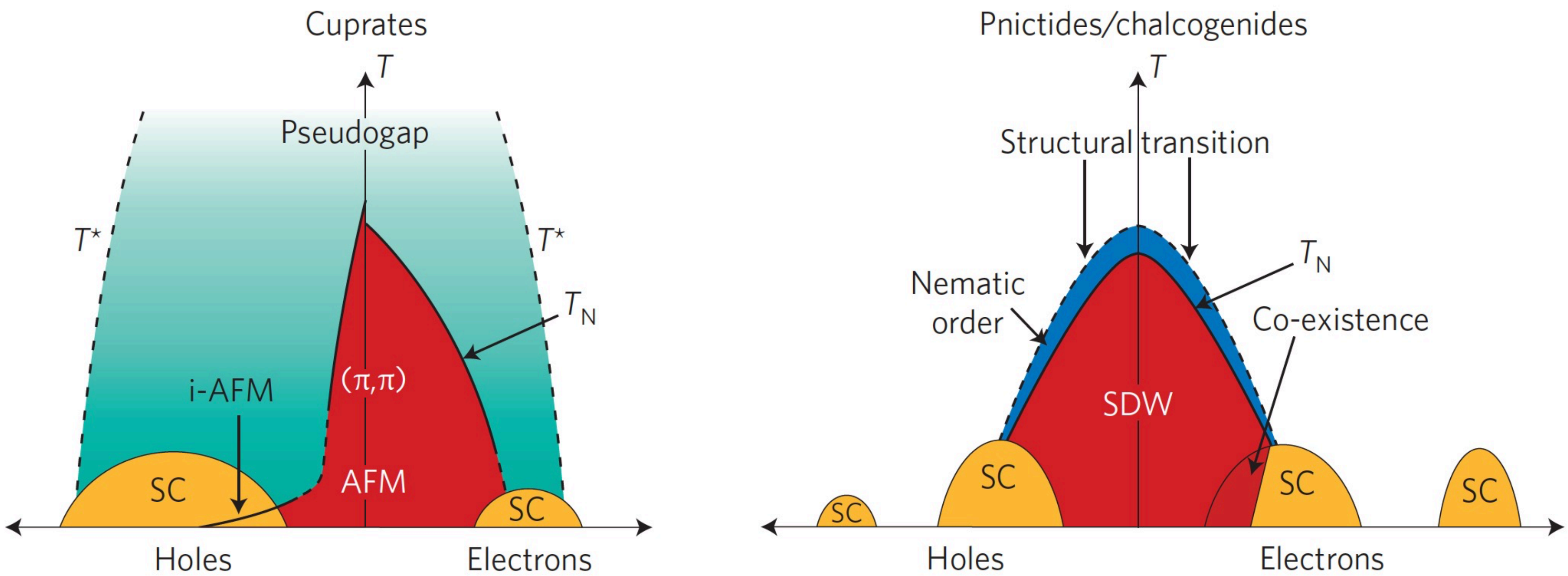
Poster: contains all details of the data analysis

Outline

- Unconventional SC & local Fermi liquids
- Optical spectroscopy of Iron pnictide SC's
- Is the normal state of iron pnictides Fermi liquid like?
- Summary

Unconventional superconductors

Basov, D. N. & Chubukov, A. V., Nature Physics **7**, 272 (2011).



- Do similar looking phase diagrams suggest a common origin?
- Understanding the non-SC state holds the key.

Intraband optical response of charge carriers

$$\hat{\sigma}(\omega) = \frac{i\omega_p^2}{4\pi}\frac{1}{\omega + \hat{M}(\omega, T)}$$

Drude Model

$$\hat{M}(\omega, T) = i\Gamma_D$$

'local' Fermi Liquid

$$\hat{M}(\omega, T) = M_1(\omega, T) + iM_2(\omega, T)$$

$$M_2(\omega, T) = C\left[(\hbar\omega)^2 + (p\pi k_B T)^2\right]$$

Götze, W. & Wölfle, P, Phys. Rev. B **6**, 1226–1238 (1972).
Maslov, D. L. & Chubukov, A. V, Phys. Rev. B **86**, 155137 (2012).
Berthod, C. et al. Phys. Rev. B 87, 115109 (2013).

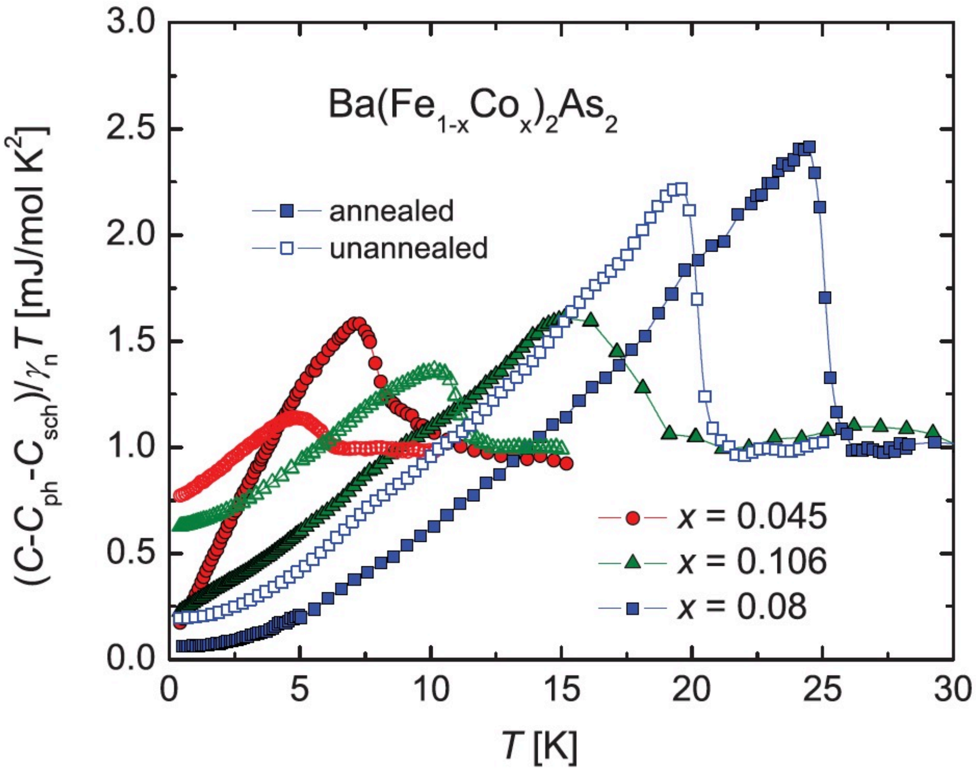
Experimental observations of local Fermi liquids

Correlated electron systems

Material	p	Reference
Organic conductors	2.38	Dressel, J. Phys. Condens. Mat. **23**, 293201 (2011).
Sr_2RuO_4	2	Stricker, D. et al. Phys. Rev. Lett. **113**, 087404 (2014).
$HgBa_2CuO_{4+\delta}$	1.5	Mirzaei, S. I. et al. Proc. Natl. Acad. Sci. **110**, 5774 (2013).
$Pb_{0.5}Bi_{1.55}Sr_{1.2}La_{0.8}CuO_{6+\delta}$	1.5	Mirzaei, S. I. et al. Proc. Natl. Acad. Sci. **110**, 5774 (2013).
ortho-II $YBa_2Cu_3O_{6.5}$	1.5	Mirzaei, S. I. et al. Proc. Natl. Acad. Sci. **110**, 5774 (2013).
$Ce_{0.95}Ca_{0.05}TiO_{3.04}$	1.31	Katsufuji, T. & Tokura, Y. Phys. Rev. B **60**, 7673–7676 (1999).
$Nd_{0.905}TiO_3$	1.03	Yang, J. et al., Phys. Rev. B **73**, 195125 (2006)
URu_2Si_2	1	Nagel, U. et al., Proc. Natl. Acad. Sci. **109**, 19161 (2012).
Pnictides	?	

Annealing iron pnictides

- Annealing increases $T_{c.}$
- Reduces residual scattering.
- Spectroscopic data is lacking
- 1 crystal: cut in 2 pieces
- 1 piece annealed



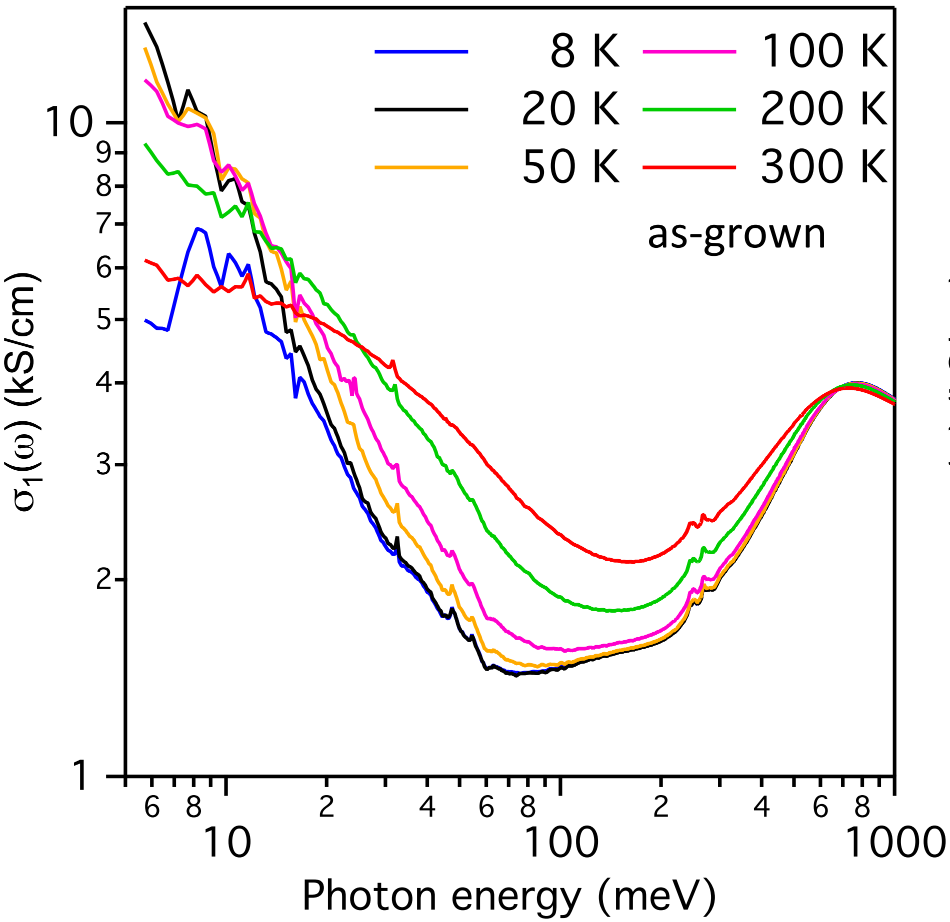
Gofryk, K. et al., Phys. Rev. B **83**, 064513 (2011).

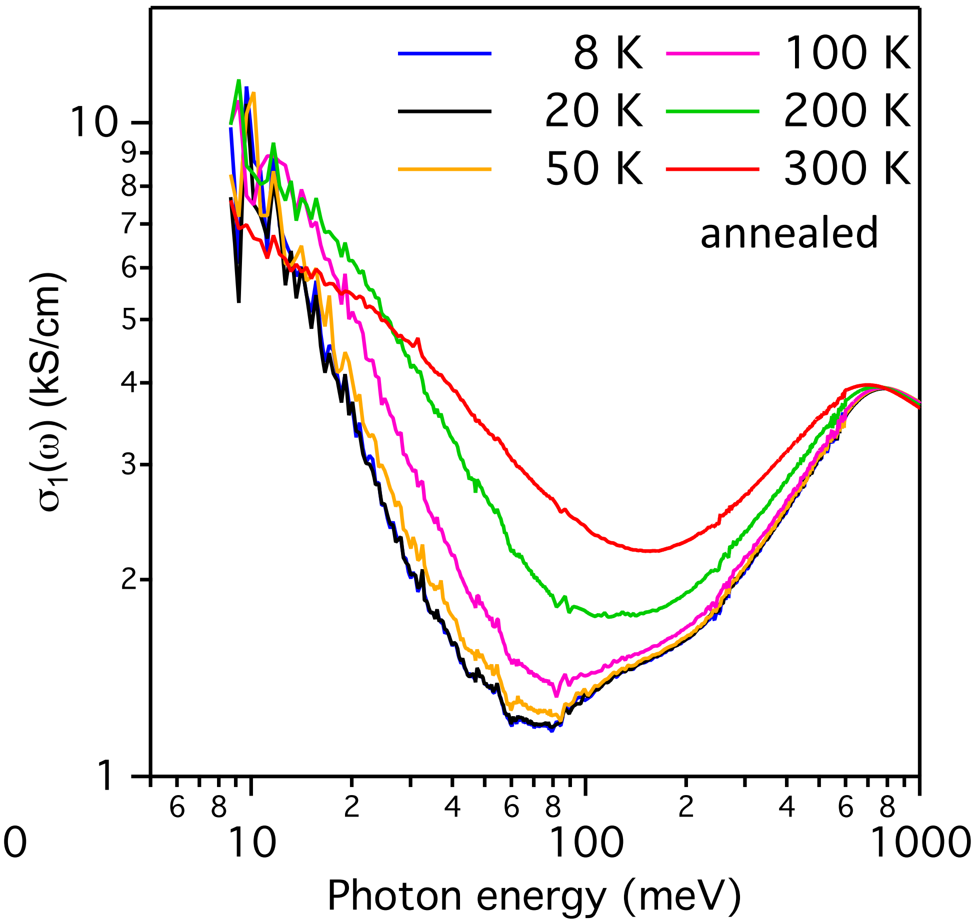
Outline

- Unconventional SC & local Fermi liquids
- Optical spectroscopy of Iron pnictide SC's
- Is the normal state of iron pnictides Fermi liquid like?
- Summary

Optical conductivity

- Interband transitions similar.
- Intraband conductivity subtly changed





Outline

- Unconventional SC & local Fermi liquids
- Optical spectroscopy of Iron pnictide SC's
- Is the normal state of iron pnictides Fermi liquid like?
- Summary

Extended Drude Model

$$\hat{\sigma}(\omega) = \frac{i\omega_p^2}{4\pi} \frac{1}{\omega + \hat{M}(\omega)}$$

$$M_1(\omega, T) = \omega \left(\frac{\omega_p^2}{4\pi} Im \left[\frac{1}{\omega \hat{\sigma}(\omega, T)} \right] - 1 \right) \qquad M_2(\omega, T) = \frac{\omega_p^2}{4\pi} Re \left[\frac{1}{\hat{\sigma}(\omega, T)} \right]$$

- Important: this assumes *no* interband transitions.
- Can this be applied to pnictides?

not without taking interband processes into account

EvH et al., Europhysics Letters 90, 37005 (2010).

Benfatto, L. et al., Phys. Rev. B **83**, 224514 (2011).

Marsik, P. et al, Phys. Rev. B 88, 180508 (2013).

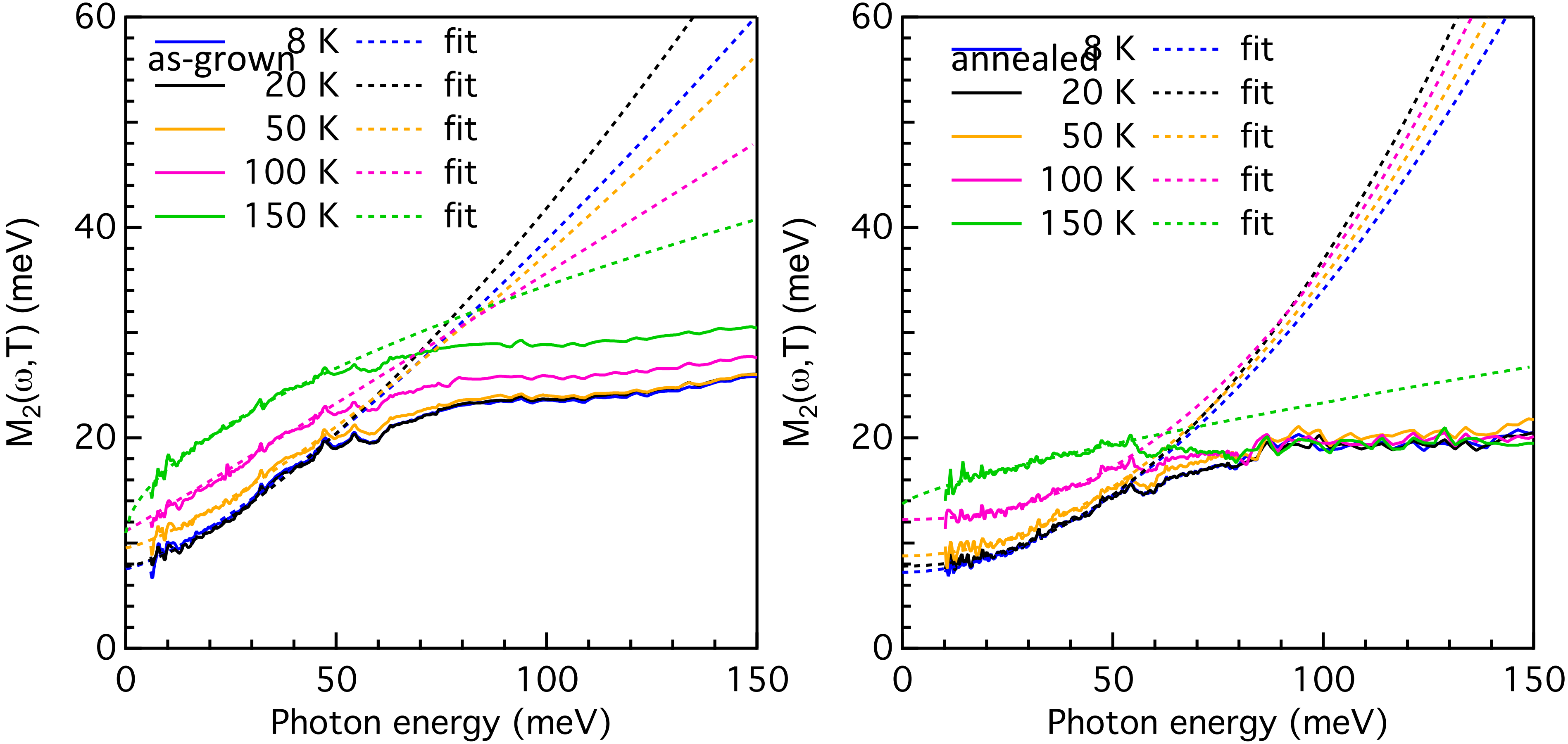
Extended Drude analysis

Two methods:

- Calculate $M(\omega)$, correct for non-zero interband contribution to σ. (i.e. $\varepsilon_\infty \approx 100$) For details: see poster
- Subtract $\sigma_{inter}(\omega)$, calculate $M(\omega)$.

Memory function

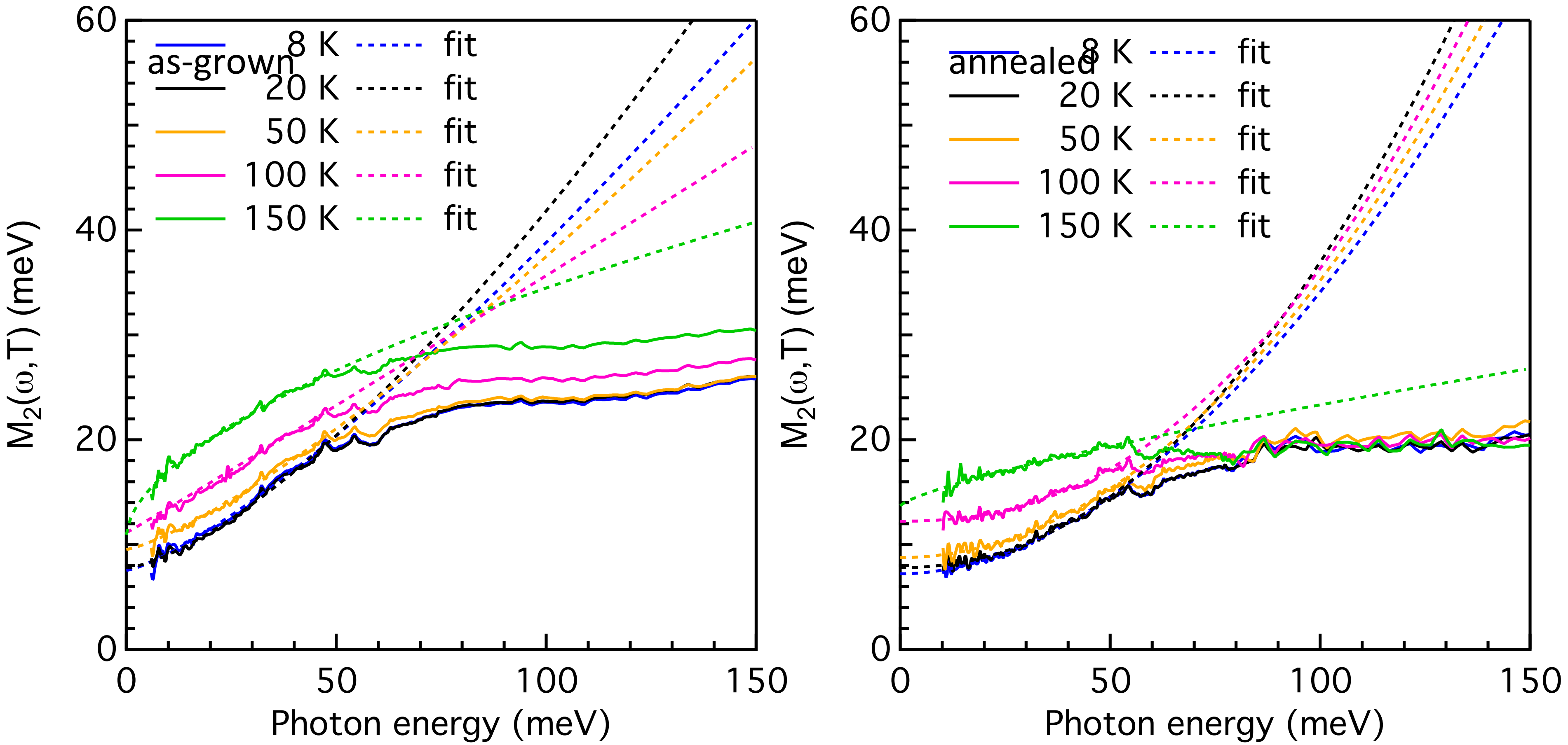
- Lower scattering rate for annealed sample.
- Different frequency/temperature dependence ?



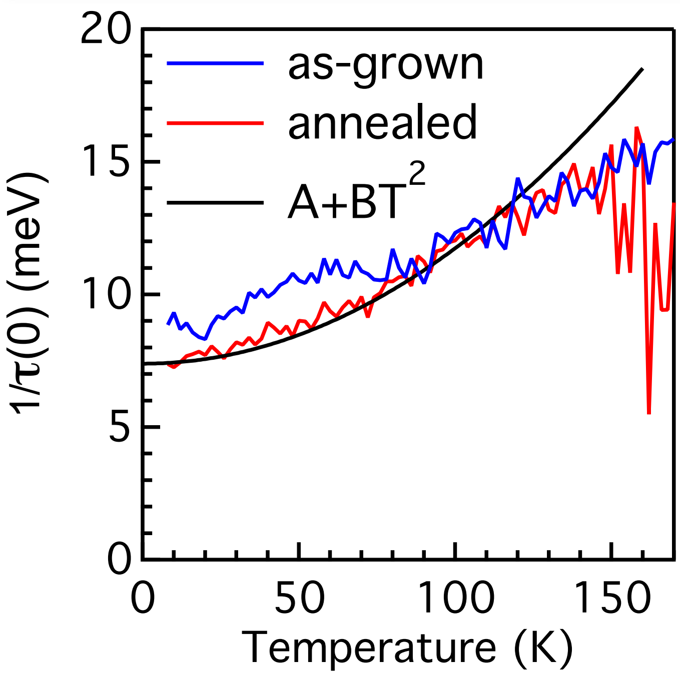
Frequency dependence

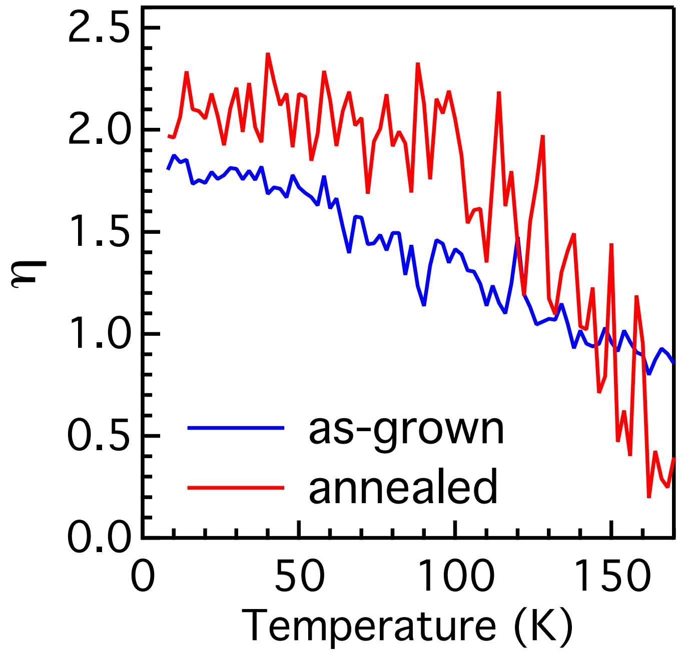
- Fit $M_2(\omega)$ with power-law function (10 – 50 meV):

$$M_2(\omega) = \frac{1}{\tau}(0) + B\omega^\eta$$



Power law fit results

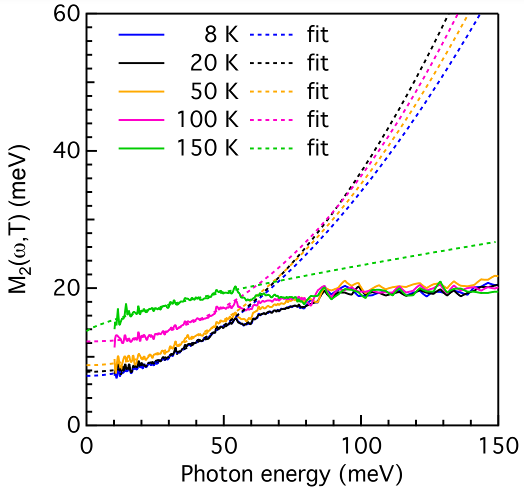


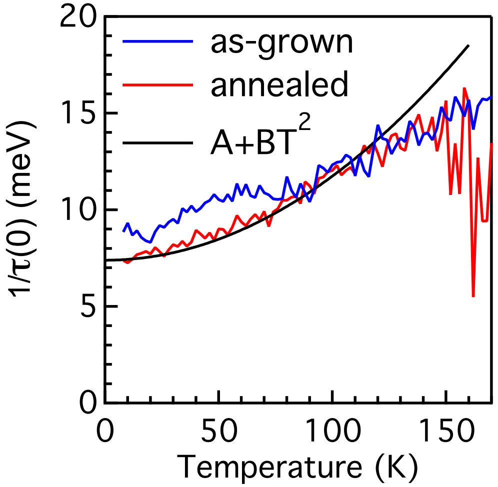


$$M_2(\omega) = \frac{1}{\tau}(0) + B\omega^{\eta}$$

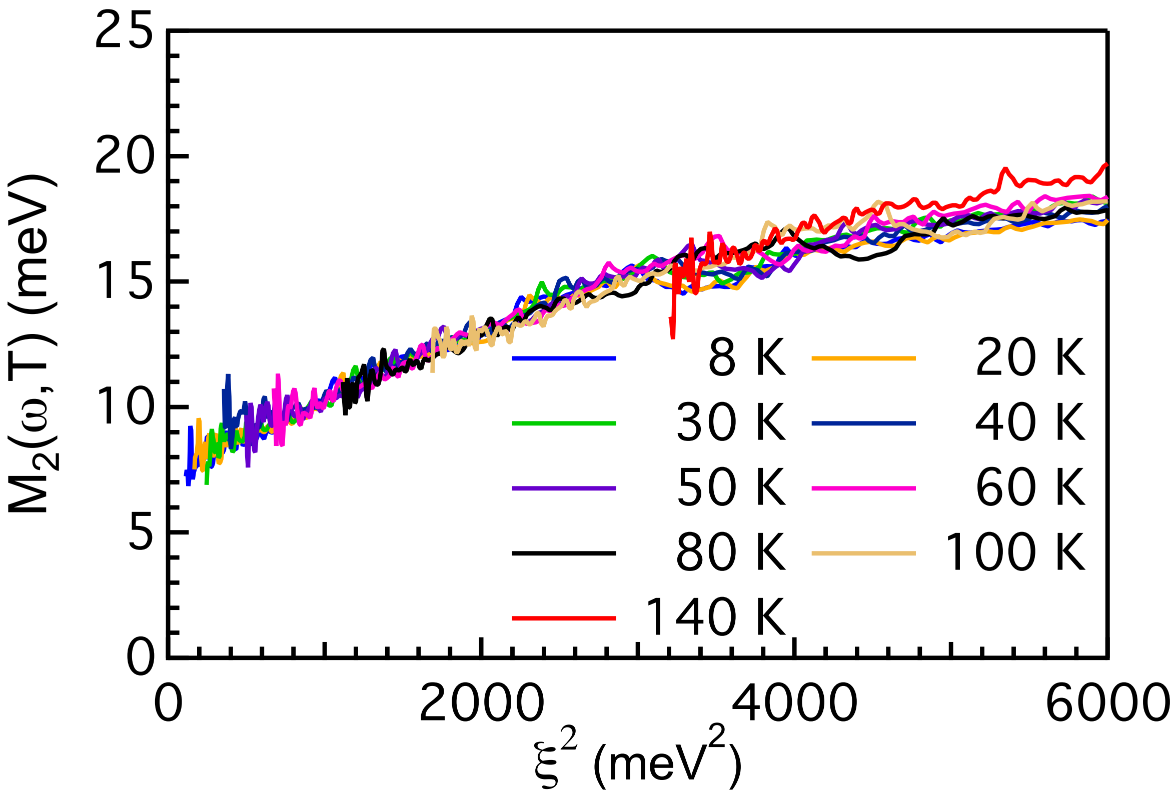
- $1/\tau(0)$ has different T dependence for T < 120 K
- Frequency power ≈ 2 between 0 – 120 K for annealed sample
- Temperature power ≈ 2 between 0 – 120 K for annealed sample

ω,T scaling in annealed pnictides





$$M_2(\omega, T) = C\left[(\hbar\omega)^2 + (p\pi k_B T)^2\right]$$



$$\xi^2 = \left[\omega^2 + (p\pi k_B T)^2\right]$$

- Best scaling for p = 1.5

Outline

- Unconventional SC & local Fermi liquids
- Optical spectroscopy of Iron pnictide SC's
- Is the normal state of iron pnictides Fermi liquid like?
- Summary

Summary

- $M_2(\omega,T)$ is a function of ω^2 and T^2 after annealing.
$$M_2(\omega, T) \propto \left[(\hbar\omega)^2 + (1.5\pi k_B T)^2\right]$$
- The normal state of iron pnictides is Fermi liquid like.

Thanks for your attention