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Electron interactions and gap nodes in FeAs superconductors

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Objectives:

⇒ Raman scattering

⇒ FeAs compounds

⇒ $Ba(Fe_{0.931}As_{0.069})_2As_2$

Funded by the DFG via Research Unit FOR538

http://for538.wmi.badw.de/

Collaborators FeAs

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Experiments:	Theory:	Samples:
•B. Muschler •W. Prestel	•T.P. Devereaux (Stanford)	• Jiun-Haw Chu (Stanford) • James G. Analytis (Stanford) • Ian R. Fisher (Stanford)

The WMI team

Bernhard

Wolfgang

Leonardo

Hans

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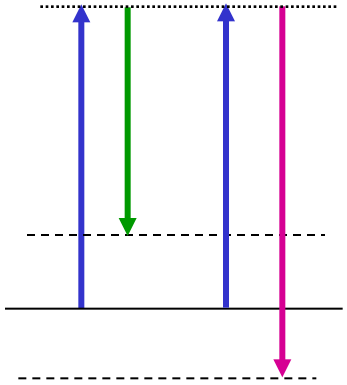
Raman scattering

FeAs compounds

normal state

superconductivity

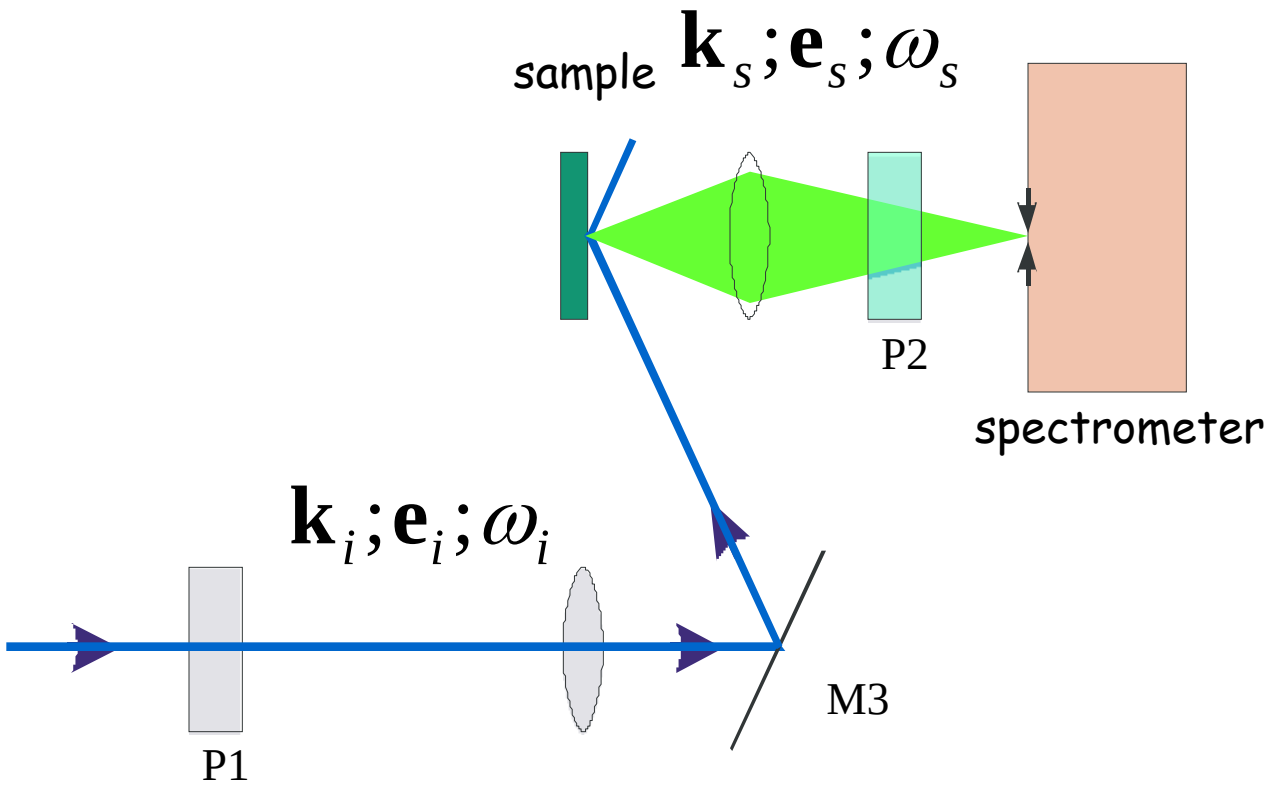
Inelastic scattering



Phonons
Electrons
Fluctuations
Magnons
Orbitons
.....

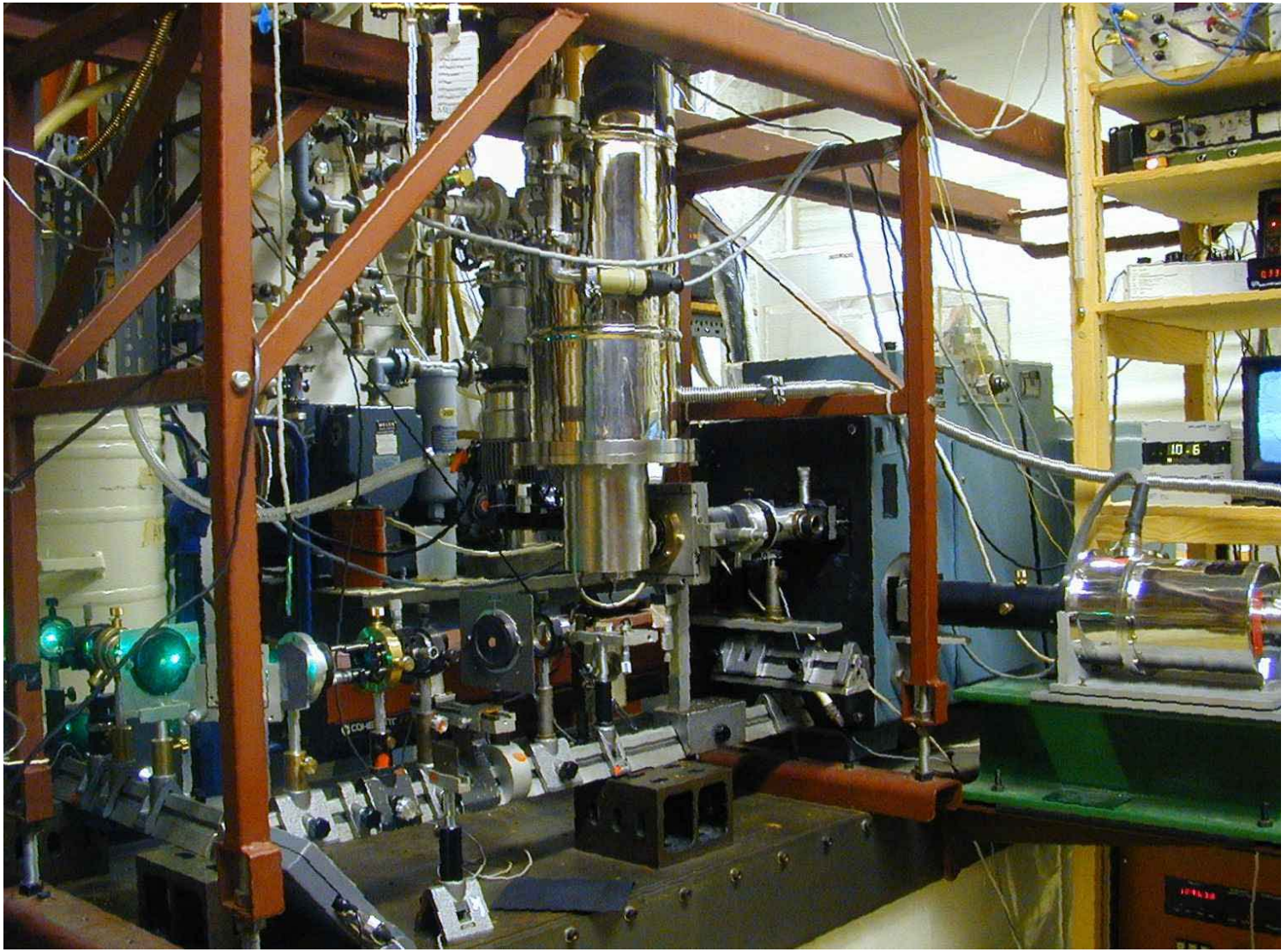
$$S_{\mu}(q=0,\Omega) \propto \{1+n(\Omega,T)\}\,\mathrm{Im}\,\chi_{\mu}(\Omega,T)$$

Raman Experiment

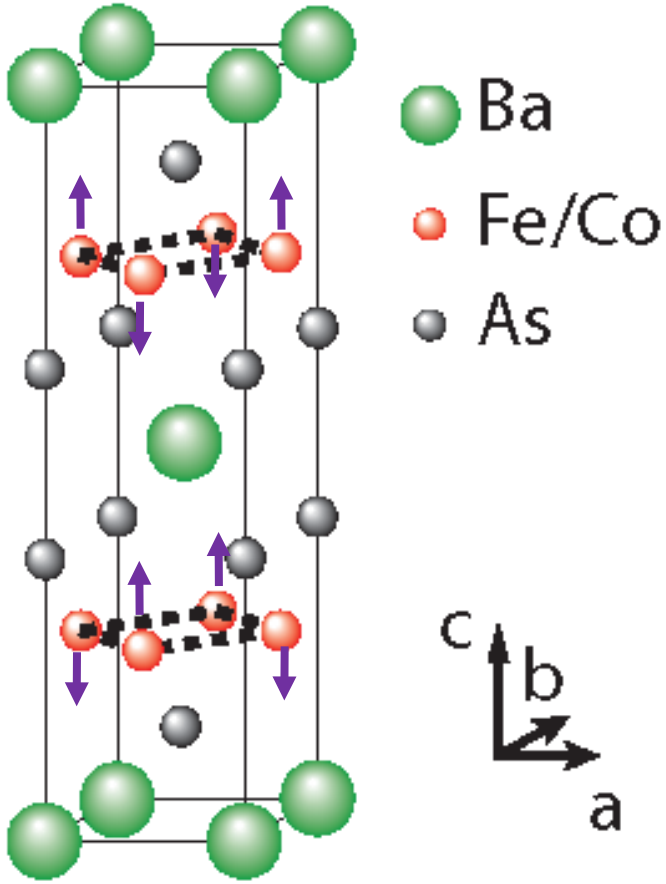


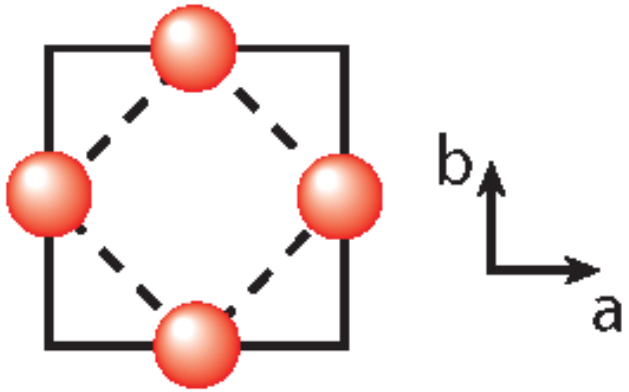
$$\Omega = \omega_i - \omega_s$$

Setup

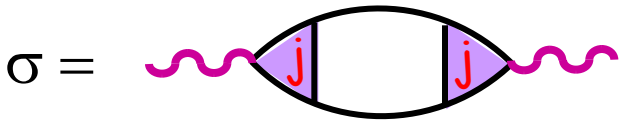


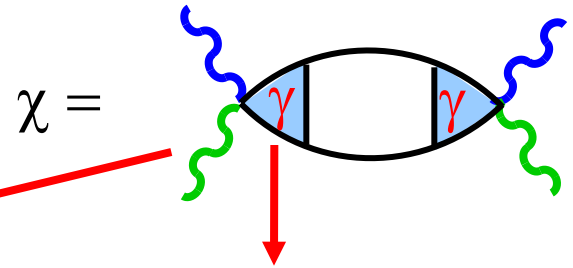
$BaFe_2As_2$ selection rules





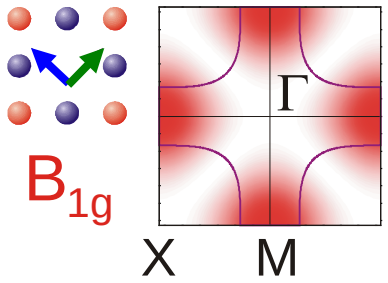
Conductivity, Raman, and selection rules for electrons

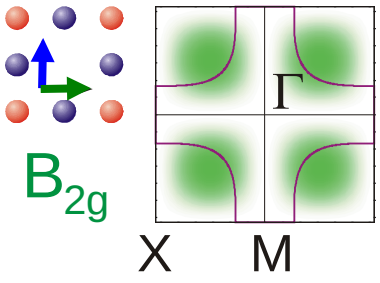


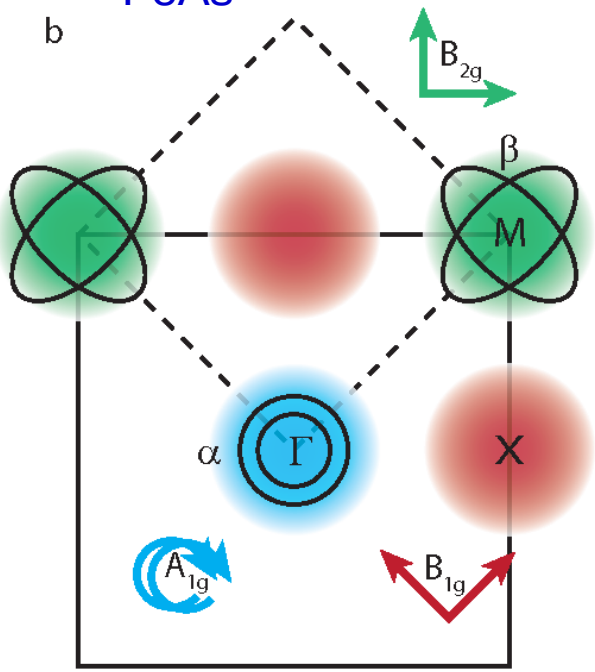


cuprates

FeAs



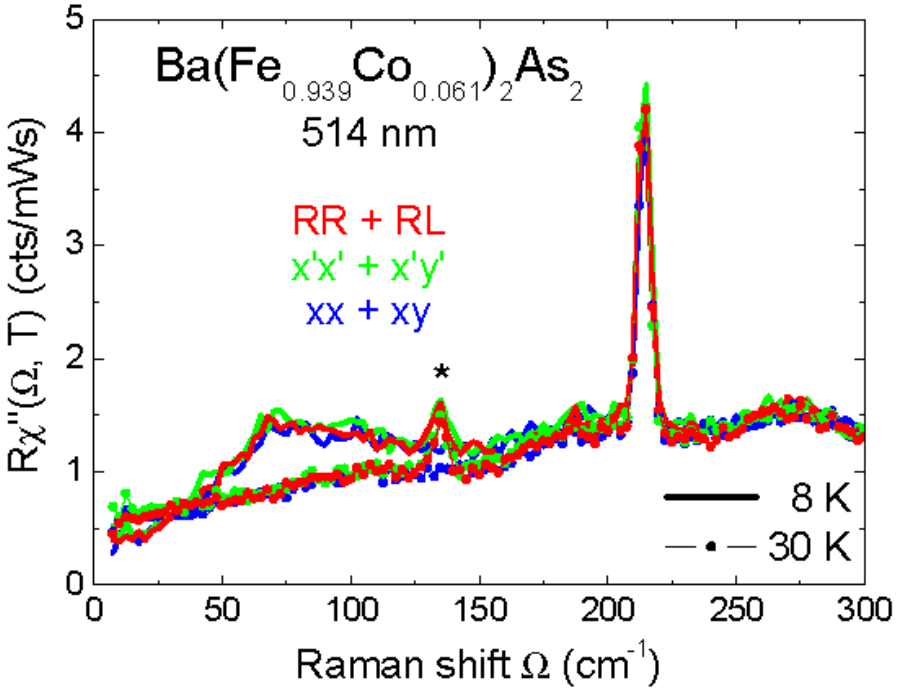




T.P. Devereaux and R.H.,
Rev. Mod. Phys. **79**, 175 (2007)

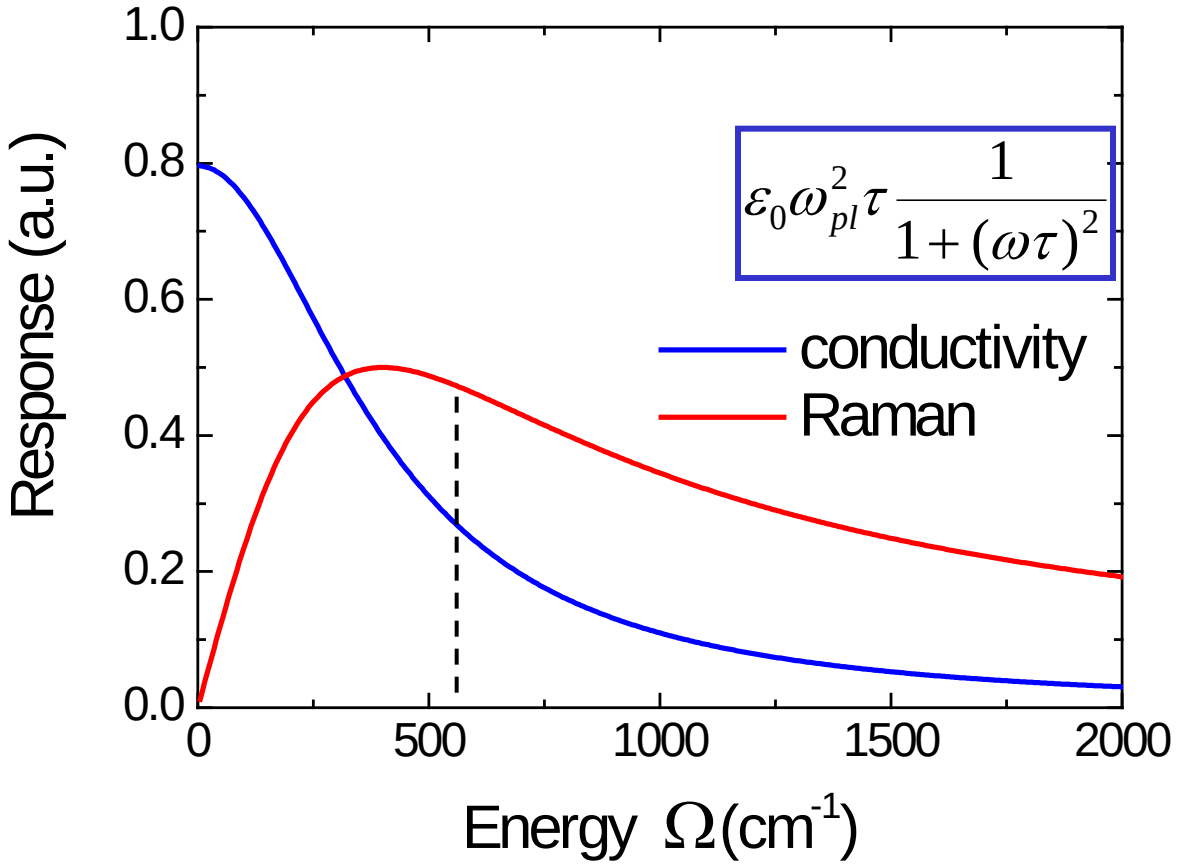
More on selection rules (FeAs)

Geometry	$\hat{e}_i$	$\hat{e}_s$	Symmetry
xx	$\hat{x}$	$\hat{x}$	$A_{1g} + B_{1g}$
xy	$\hat{x}$	$\hat{y}$	$B_{2g} + A_{2g}$
$x'y'$	$\frac{1}{\sqrt{2}}(\hat{x} + \hat{y})$	$\frac{1}{\sqrt{2}}(\hat{x} - \hat{y})$	$B_{1g} + A_{2g}$
$x'x'$	$\frac{1}{\sqrt{2}}(\hat{x} + \hat{y})$	$\frac{1}{\sqrt{2}}(\hat{x} + \hat{y})$	$A_{1g} + B_{2g}$
RR	$\frac{1}{\sqrt{2}}(\hat{x} - i\hat{y})$	$\frac{1}{\sqrt{2}}(\hat{x} + i\hat{y})$	$A_{1g} + A_{2g}$
RL	$\frac{1}{\sqrt{2}}(\hat{x} - i\hat{y})$	$\frac{1}{\sqrt{2}}(\hat{x} - i\hat{y})$	$B_{1g} + B_{2g}$



Phonons: Litvinchuk, Lemmens, Sacuto

Conductivity vs. Raman (Momentum Scattering)



$$\mathrm{Im}\,\chi(\Omega) \propto \Omega\,\mathrm{Re}\,\sigma(\Omega)$$

Shastry and Shraiman
PRL **65**, 1068 (1990)

$$\chi_\mu(\Omega) = \frac{M_\mu(\Omega)}{\Omega + M_\mu(\Omega)}$$

Opel,…, Tüttö et al.
PRB **61**, 9752 (2000)

Electronic RS in the superconducting state

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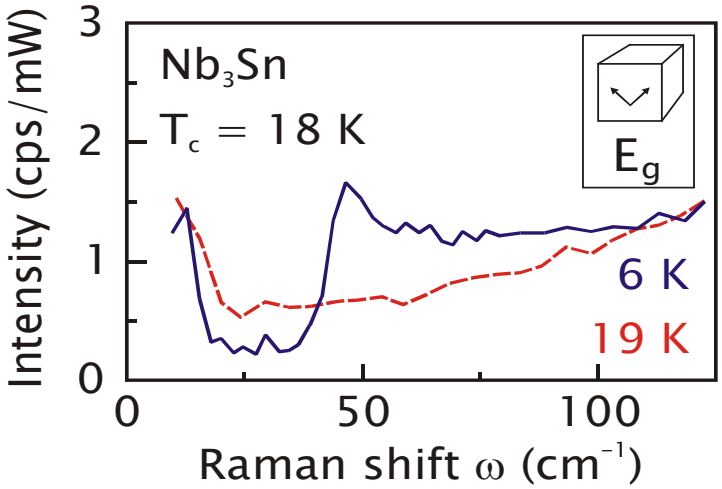
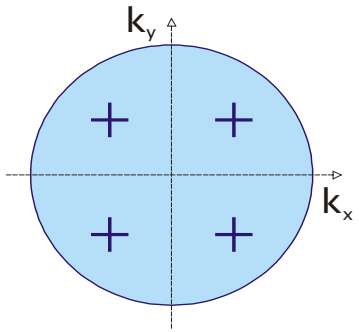
Conventional superconductors

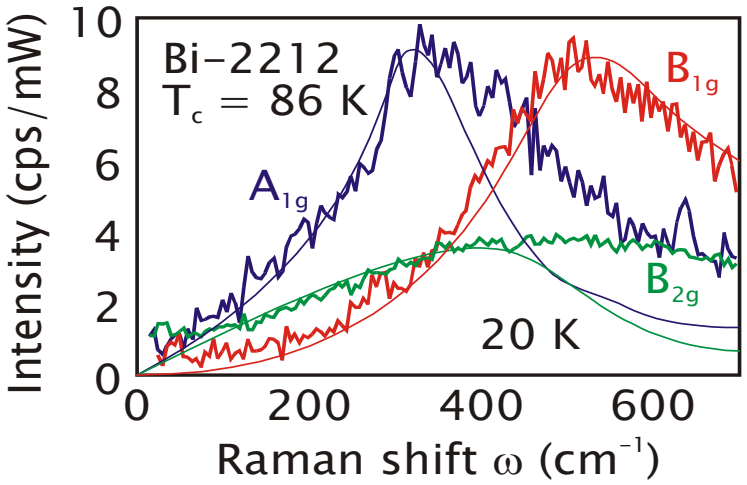


Hackl et al., Physica C **162-164**, 431 (1989)

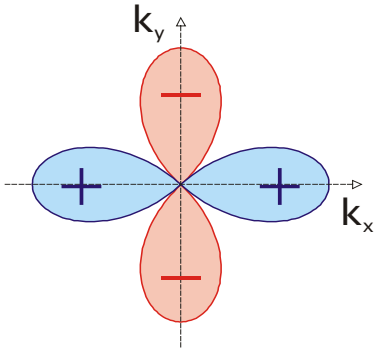


s-wave

Cuprate superconductors



Devereaux et al., PRL **72**, 3291 (1994)



$d_{x^2-y^2}$-wave

Raman scattering

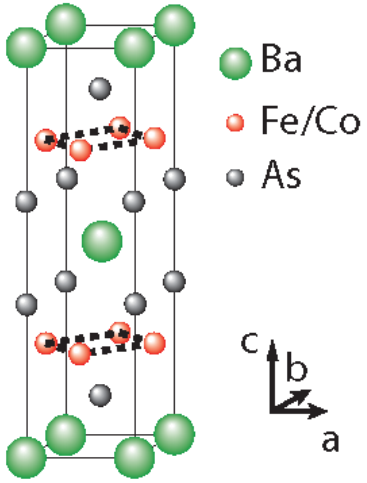
FeAs compounds

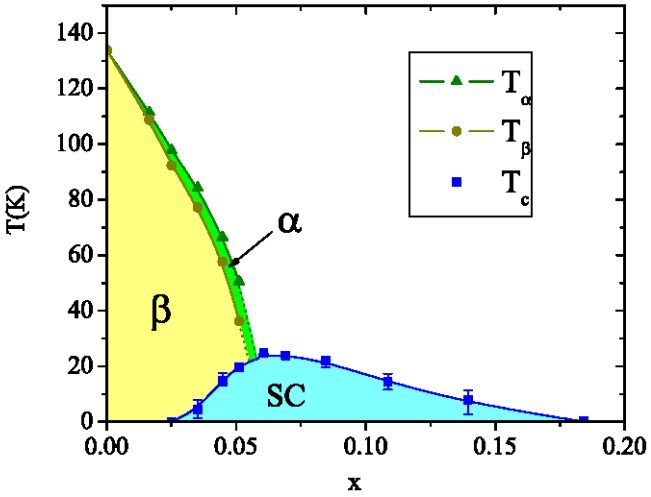
normal state

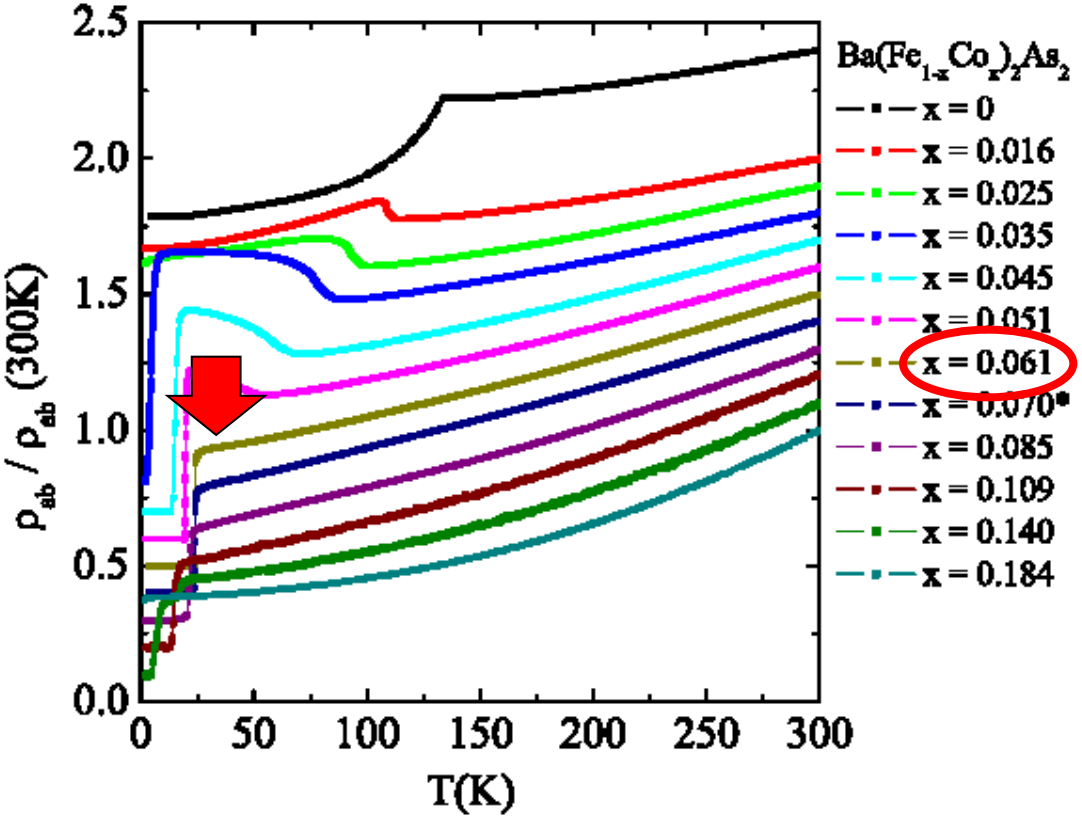
superconductivity

$BaFe_2As_2$

Kamihara et al.
J.Am.Chem.Soc.
130, 3296 (2008)
Rotter et al. PRL
Sefat et al. PRL







Chu et al. PRB **79**, 014506 (2009)

Mandrus, Canfield, Büchner, Klauss, Dai,….

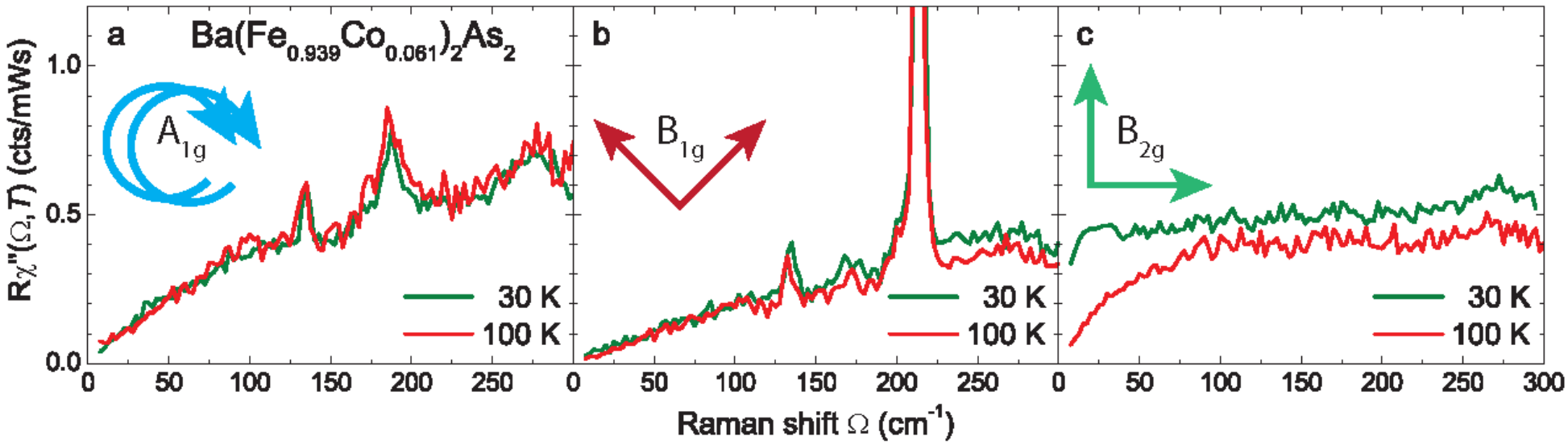
Raman scattering

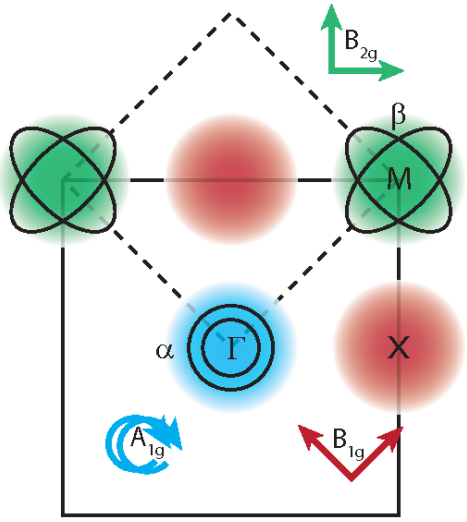
FeAs compounds

normal state

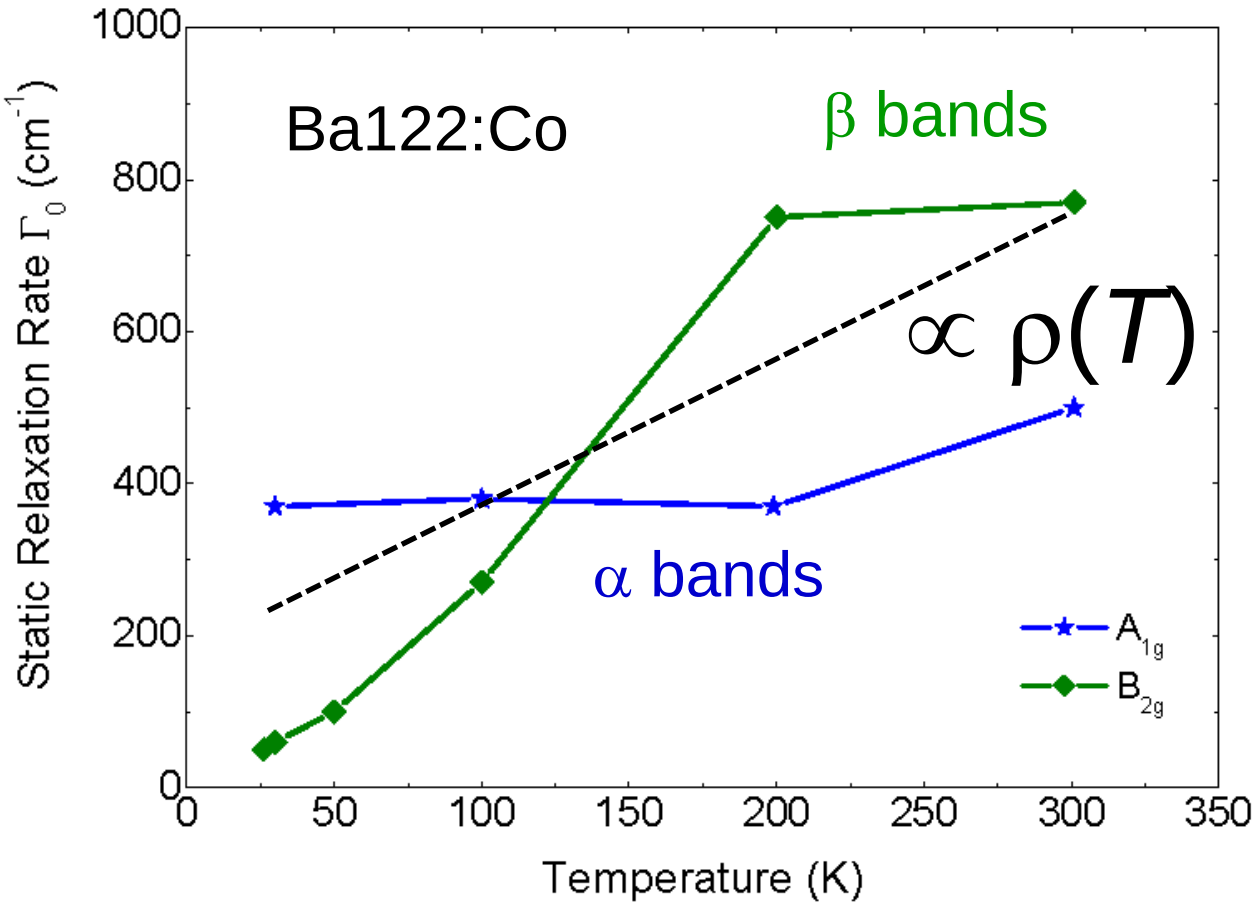
superconductivity

Ba122 normal state – Raman scattering

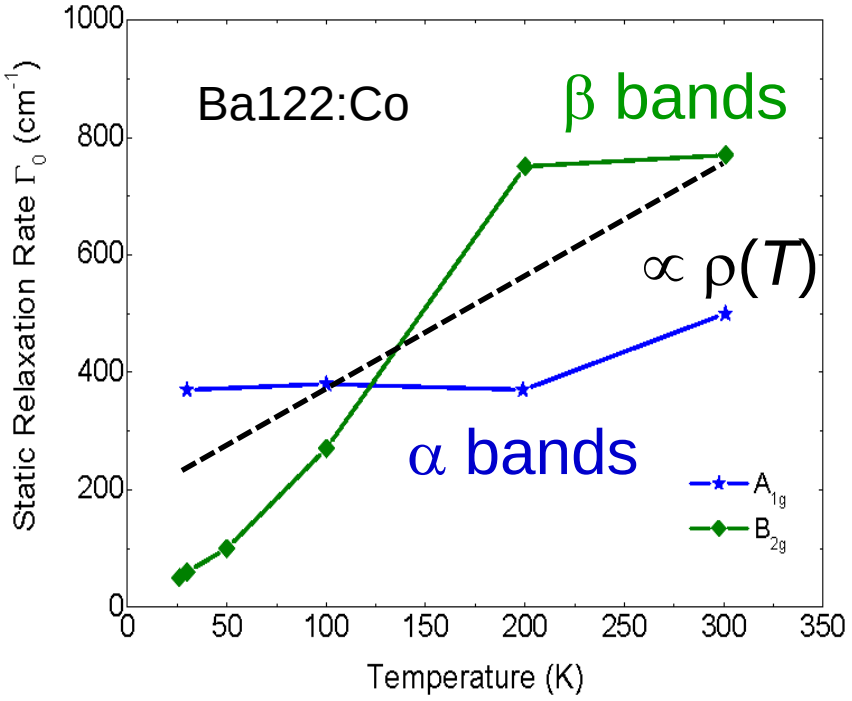


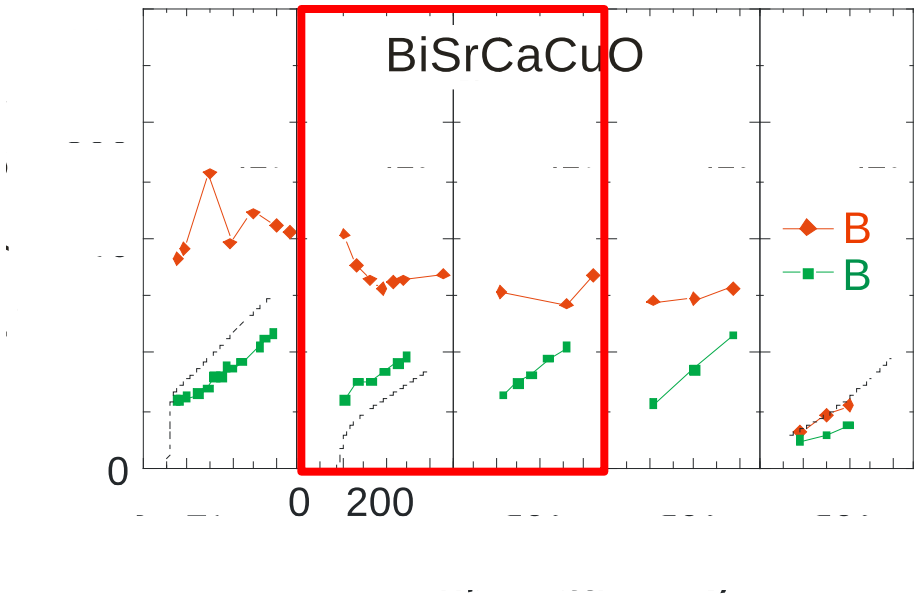


Memory function analysis

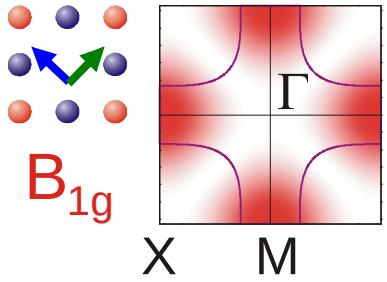


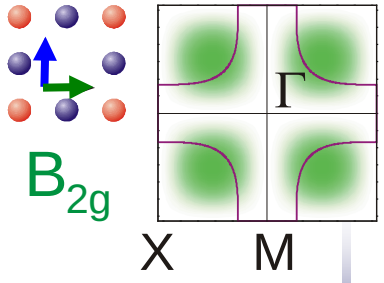
Ba122:Co – Bi2212





Opel et al.
PRB **61**, 9752 (2000)





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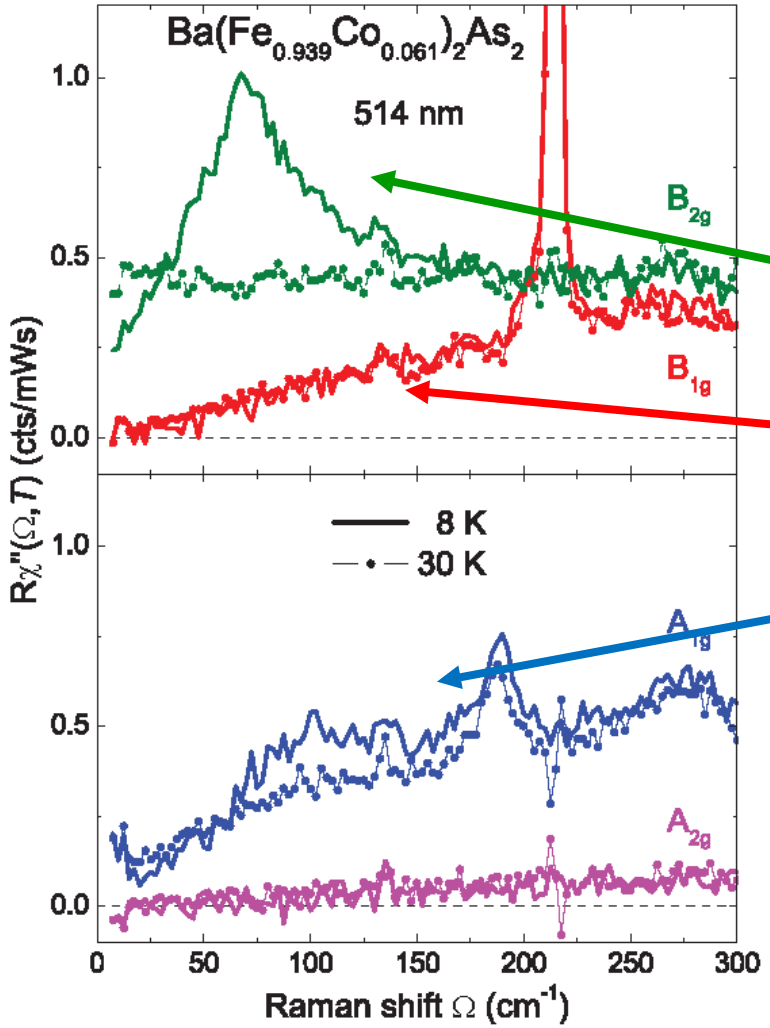
Raman scattering

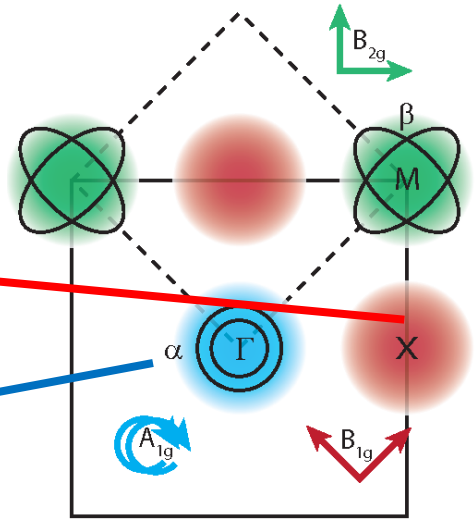
FeAs compounds

normal state

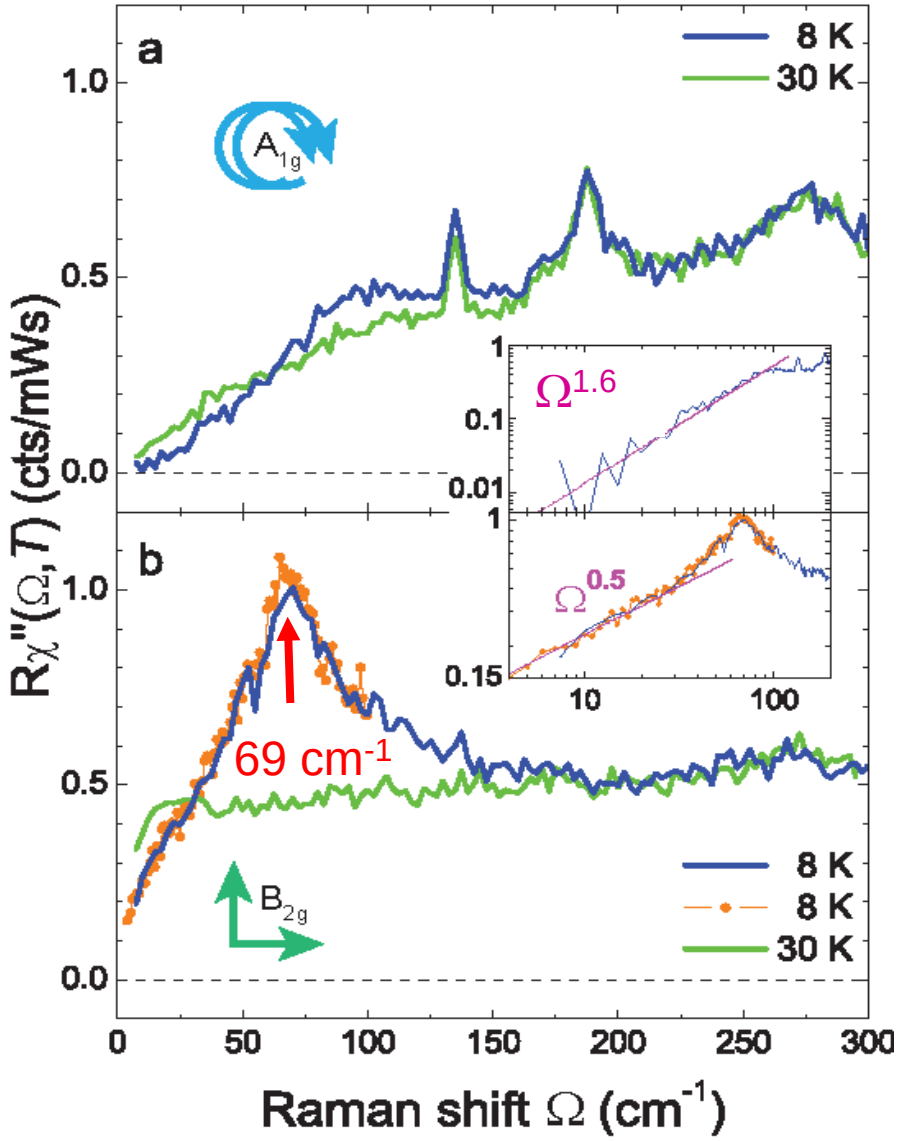
superconductivity

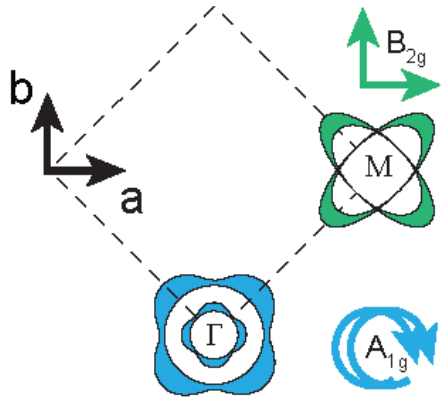
Ba122 superconducting state

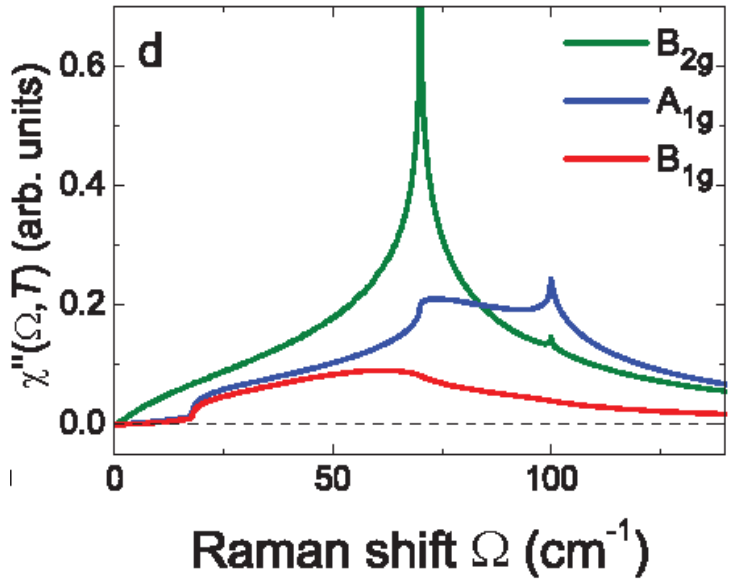




Ba122:Co – Raman spectra





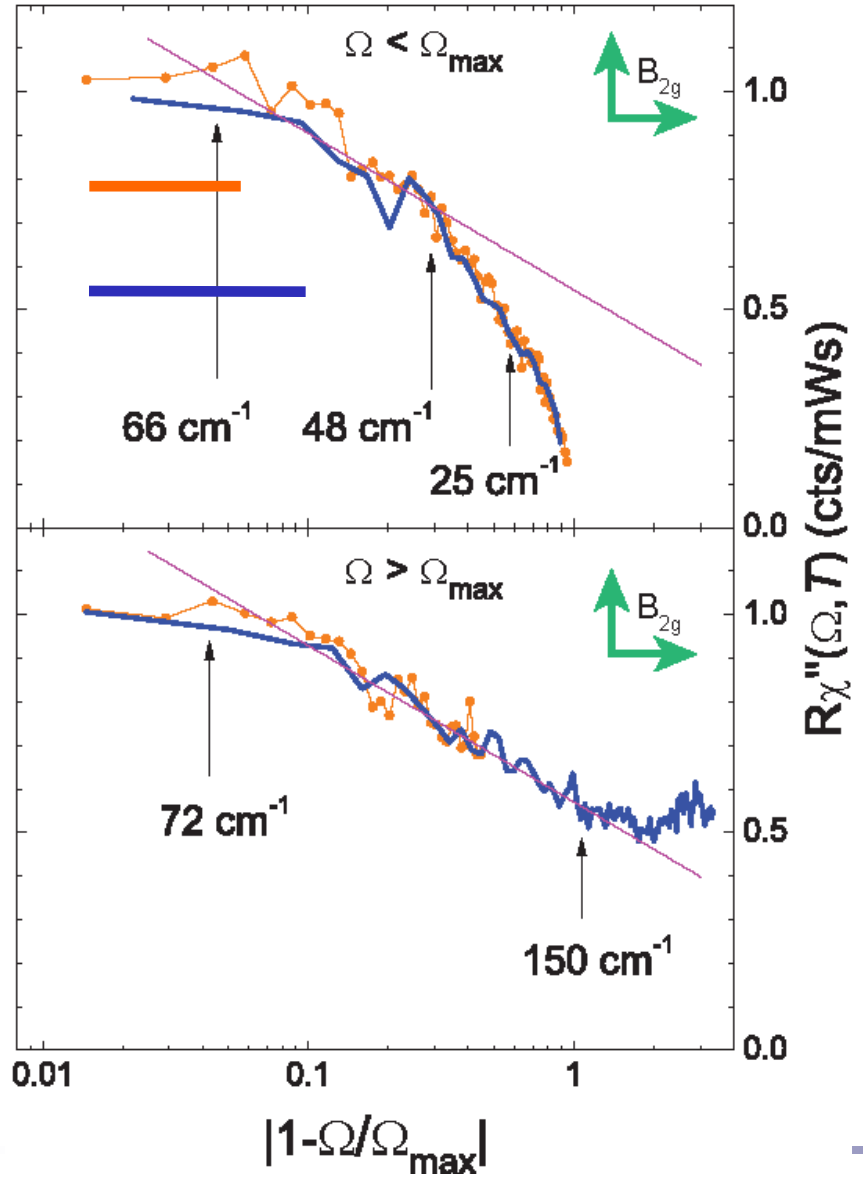


Ba122:Co - gap maximum

$\Delta\Omega$ = 3 cm^{-1}

resolution

$\Delta\Omega$ = 6 cm^{-1}



very narrow sc transition

indication of a strong **k**-dependence around the maximal gap

2D-like behavior

Ba122 ARPES

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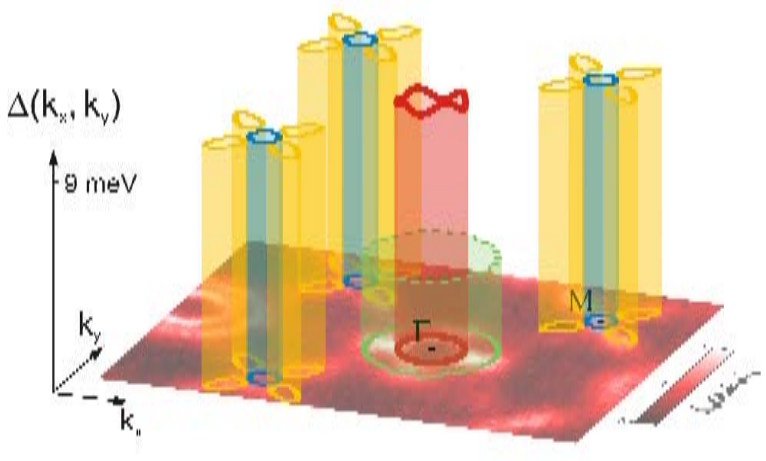
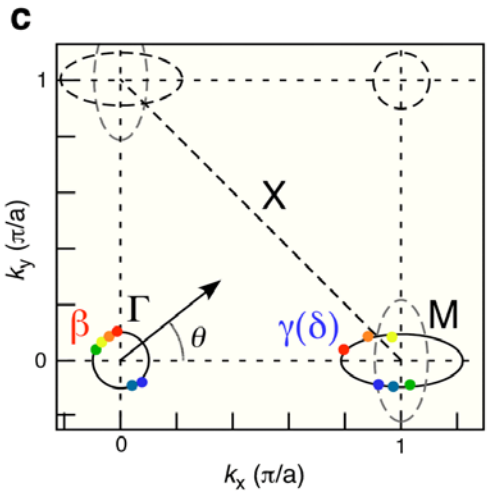
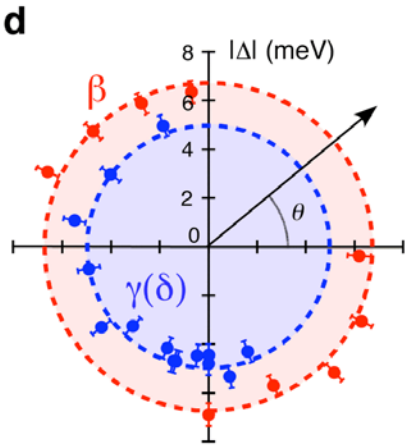
Ba122:K



Evtushinski et al. PRB

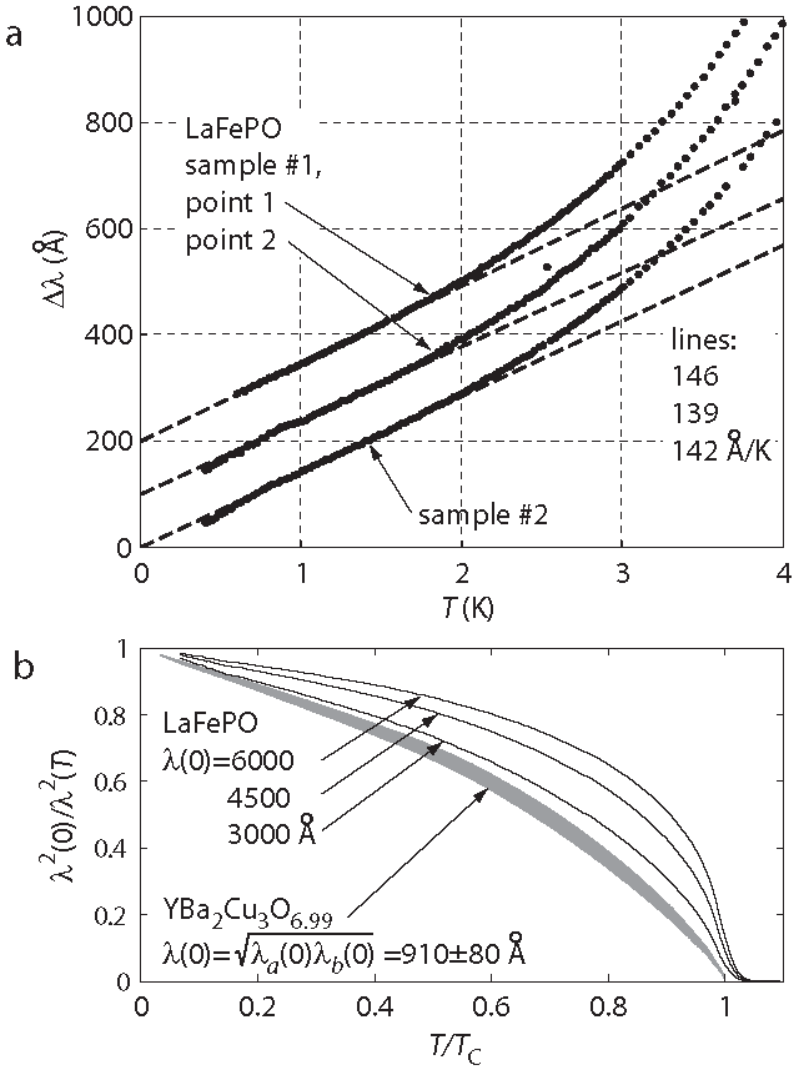
Ba122:Co

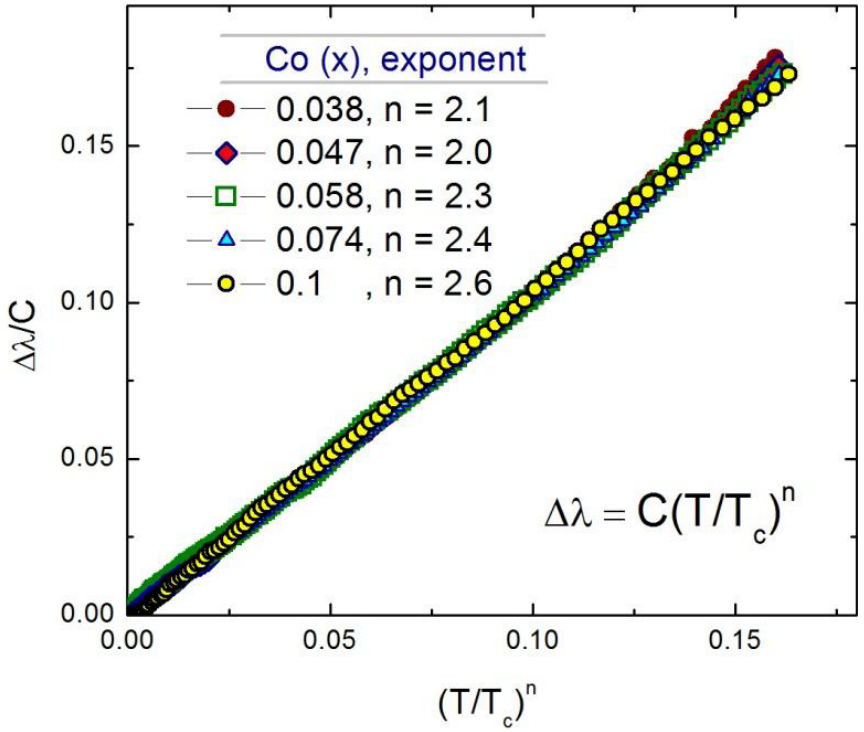




Terashima et al. arXiv:0812.3704

LaFePO and Ba122:Co - penetration depth





Prozorov et al. arXiv:0901.3698

Hicks et al. arXiv:0903.5260

FeAs Summary

- Electronic Raman scattering projects the different bands in FeAs
- Strong **k** anisotropy of the carrier properties
- Evidence for nodes (or near nodes) in the gap of $Ba(Fe_{0.931}As_{0.069})_2As_2$