GDR MEETICC
Réunion thématique Supraconductivité
07/12/2021

Interplay between superconductivity and nematicity in Co-doped $BaFe_2As_2$: an elasto-Raman study

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Collaborators

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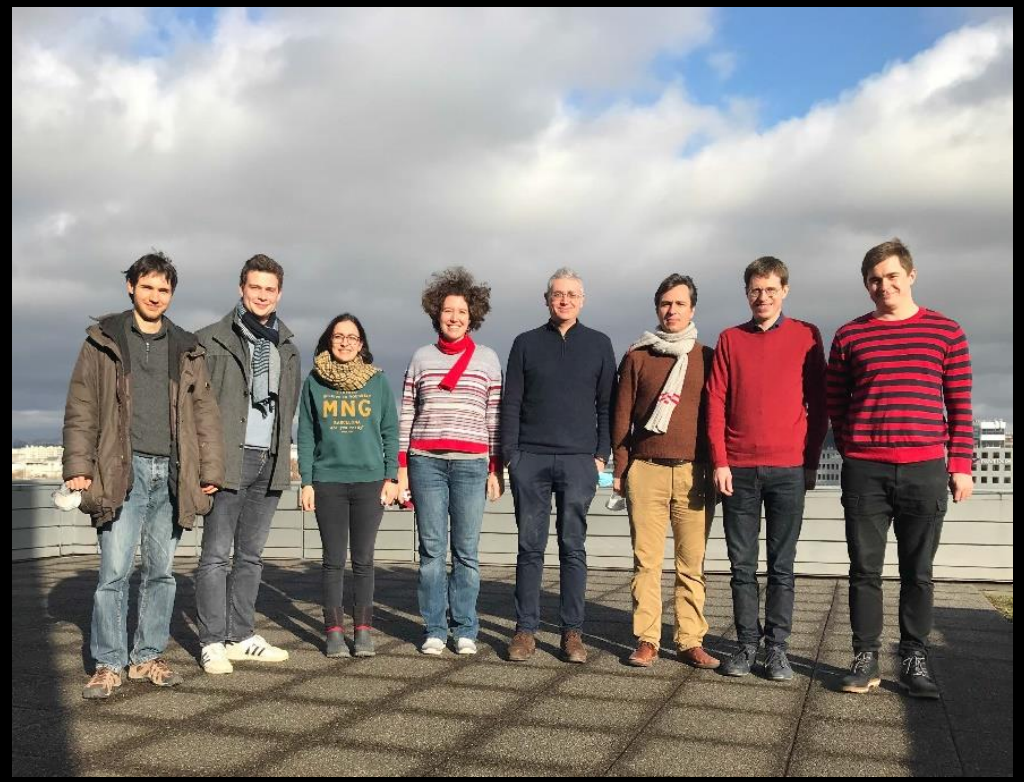

Materials synthesis:

Dorothée Colson
Anne Forget

Co-Ba122: key points and strain effects

Elasto-Raman spectroscopy

Strain activation of As phonon

Suppression of nematic fluctuations under strain

Co-Ba122: key points and strain effects

Elasto-Raman spectroscopy

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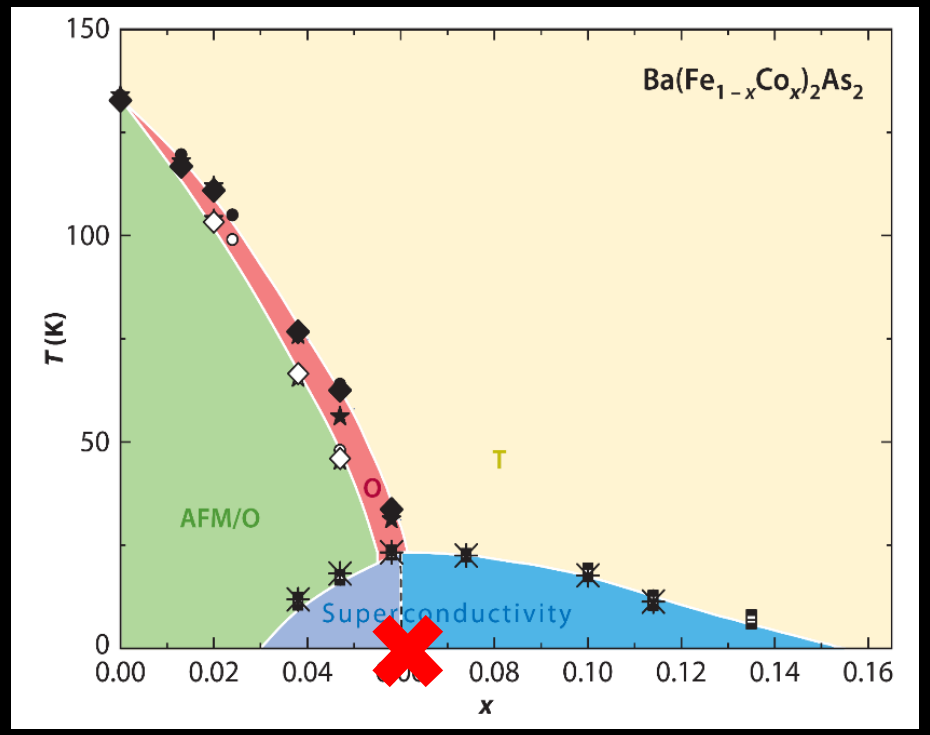
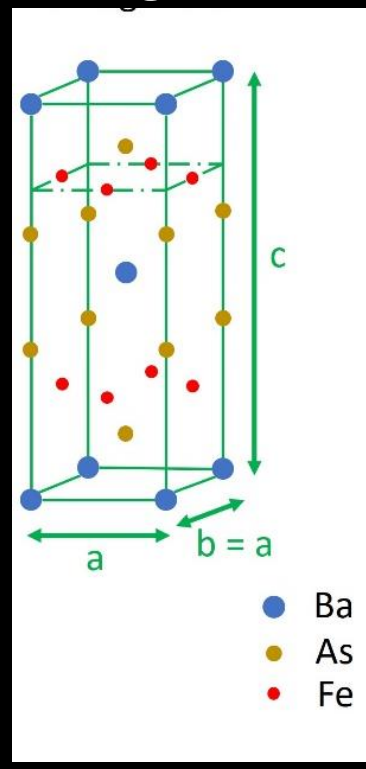
Nematicity and superconductivity in Co-Ba122

Canfield et Bud'ko, *Ann. Rev. Cond. Matt.* (2010)

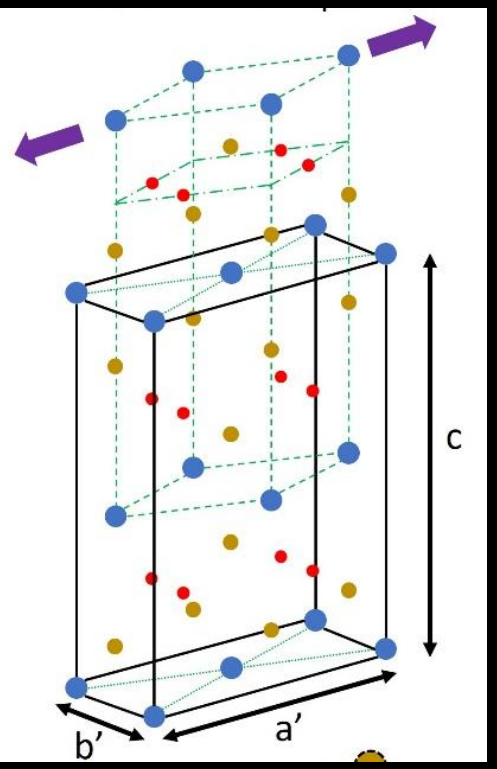


Nematic quantum critical point (NQCP)

Tetragonal

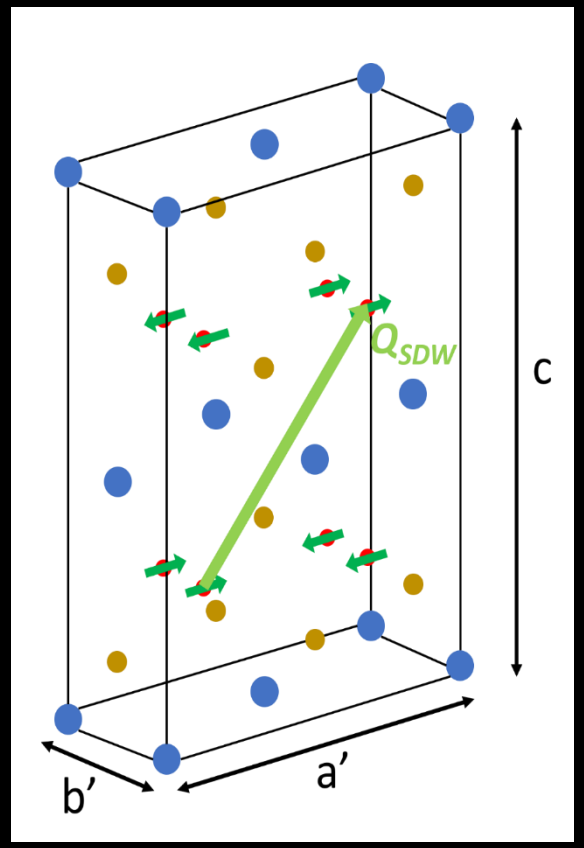


Orthorhombic



B_{2g} distortion

AFM ordering



Effect on T_c ? (Lederer et al. *PRL* 2015, Labat et Paul, *PRB* 2017)

Nematicity and superconductivity in Co-Ba122

Free energy

Structural OP

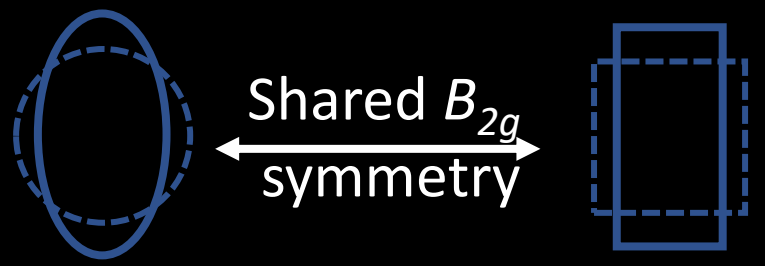
Nematic susceptibility

$$F = F_0 + \frac{1}{2}C_0\epsilon^2 + \frac{1}{2}\chi^{-1}\phi^2 - \lambda\epsilon\phi$$

Nemato-structural coupling

Structural coefficient

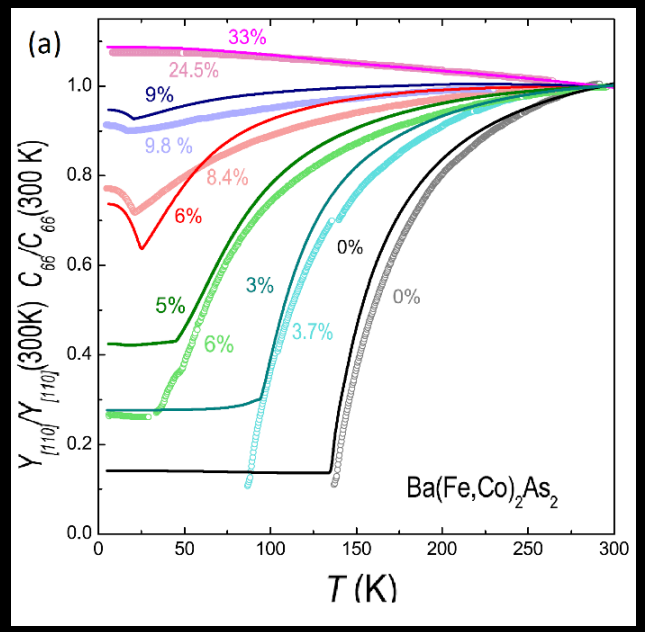
Nematic OP



ϕ
Electrons

ε_{B2g}
Lattice

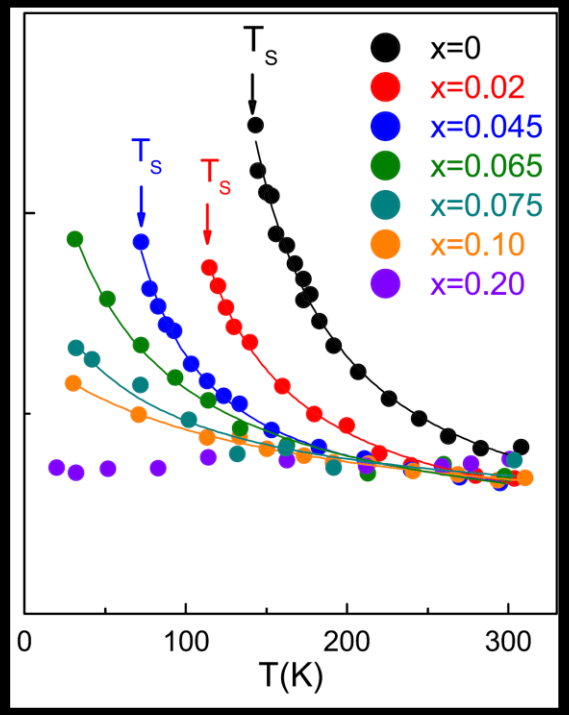
Structural coefficient



Böhmer et Meingast, *CR Physique* (2016)

Raman spectroscopy

χ_{B2g}



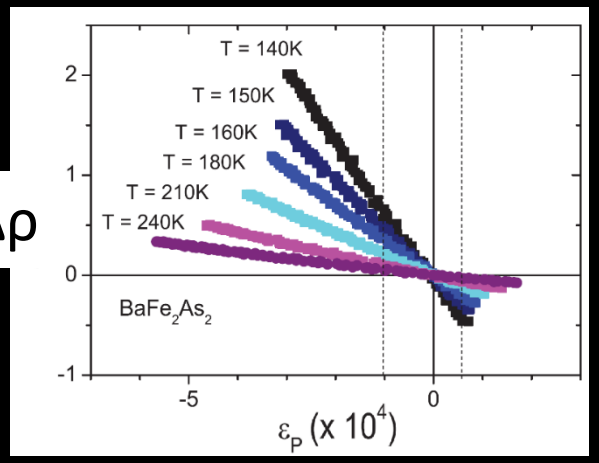
Gallais et Paul, *CR Physique* (2016)

Nematicity and superconductivity in Co-Ba122

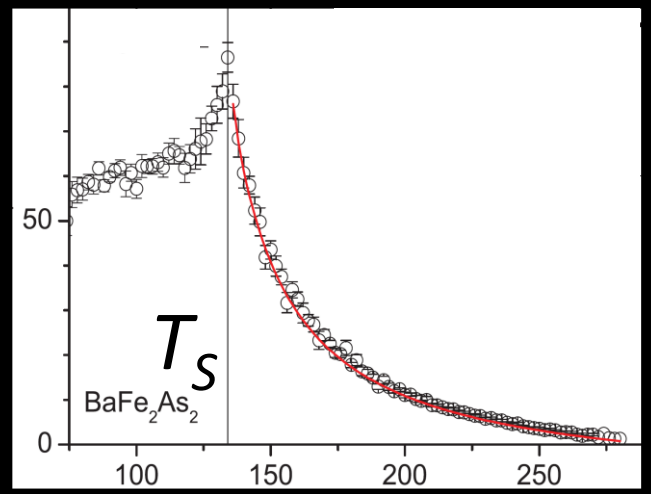
Apply strain

Elastoresistivity

Δρ



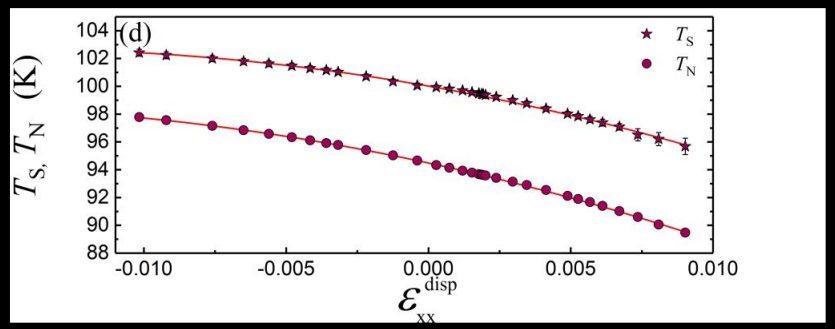
χ



Chu et al. *Science* (2012)

Probe of nematic fluctuations

Effect on nemato-magnetic transition

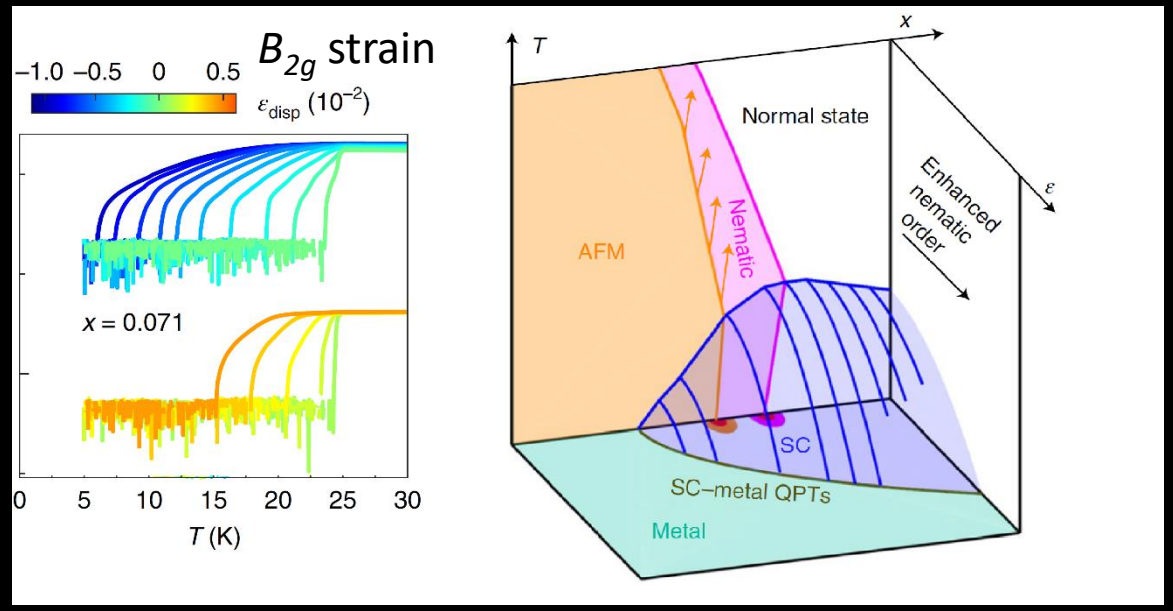


Transverse B_{1g} strain

Ikeda et al. *PRB* (2018)

Effect on superconductivity

ρ



Malinowski et al. *Nat. Phys.* (2020)

Probe of NQCP (Worasaran et al. *Science* 2021)

Elasto-X-Ray diffraction (Sanchez et al. *Nat. Mat.* 2021)

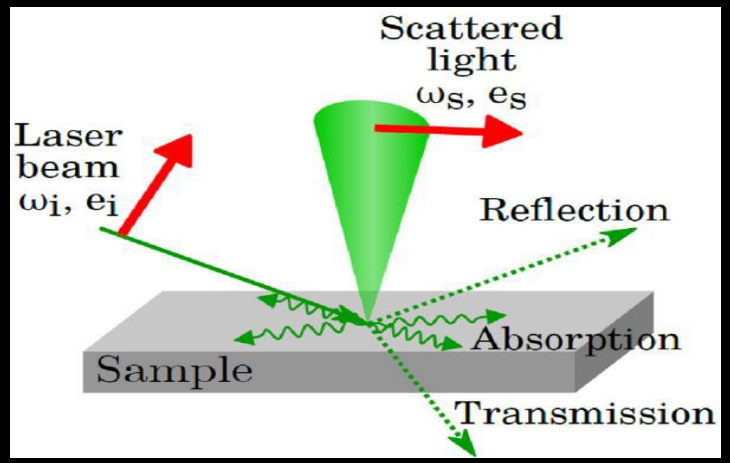
Co-Ba122: key points and strain effects

Elasto-Raman spectroscopy

Strain activation of As phonon

Suppression of nematic fluctuations under strain

Raman spectroscopy

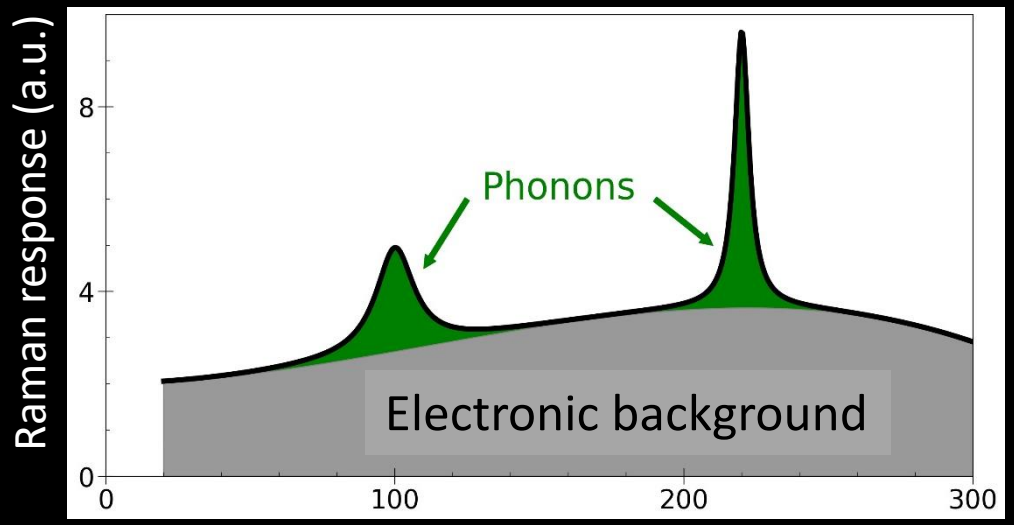


Probe of ***inelastic*** light scattering

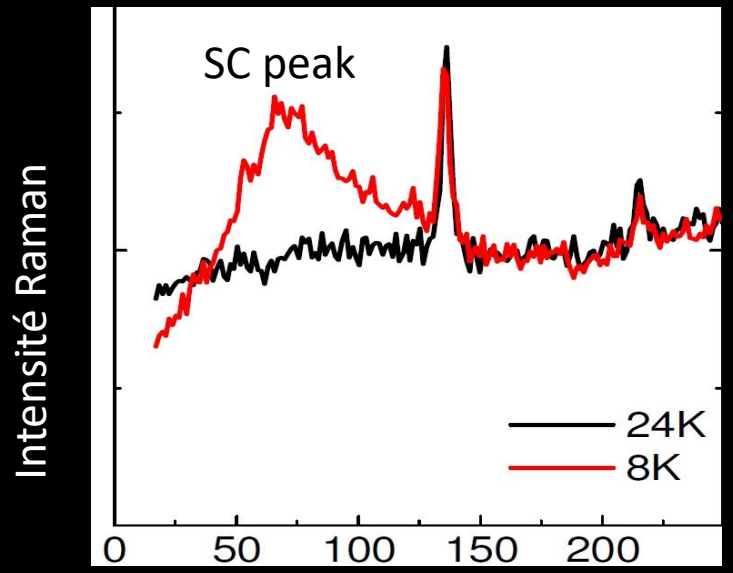
Spectrum : Intensity of scattered light vs. $\omega = \omega_i - \omega_s$

Raman response χ''

Raman spectrum



Raman shift $\omega = \omega_i - \omega_s$ (energy unit)

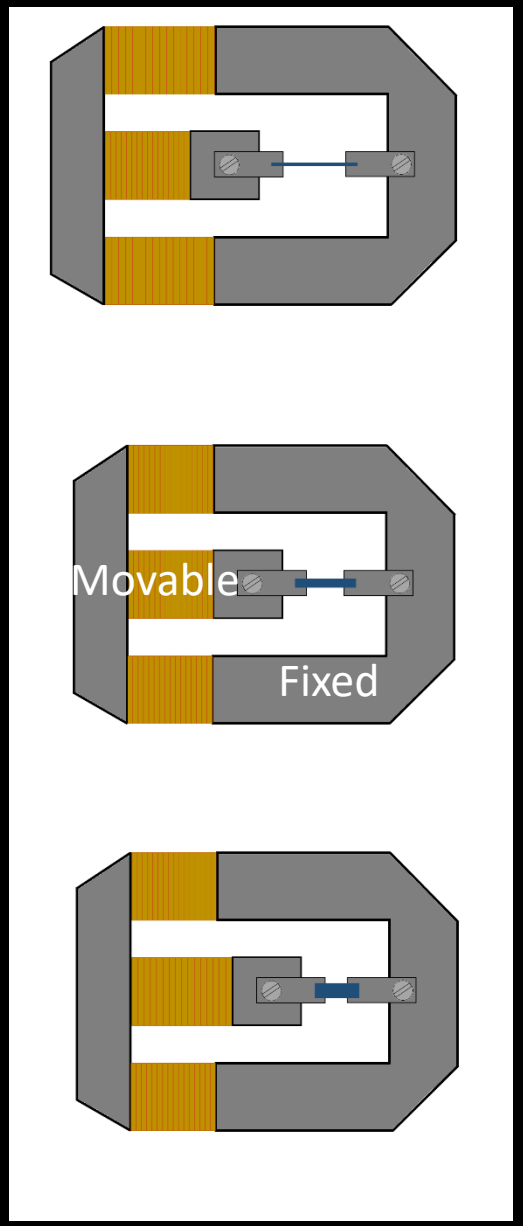


ω (cm^{-1})

Choice of polarizations → Probe different symmetries (B_{1g}, B_{2g}...)

Strain device

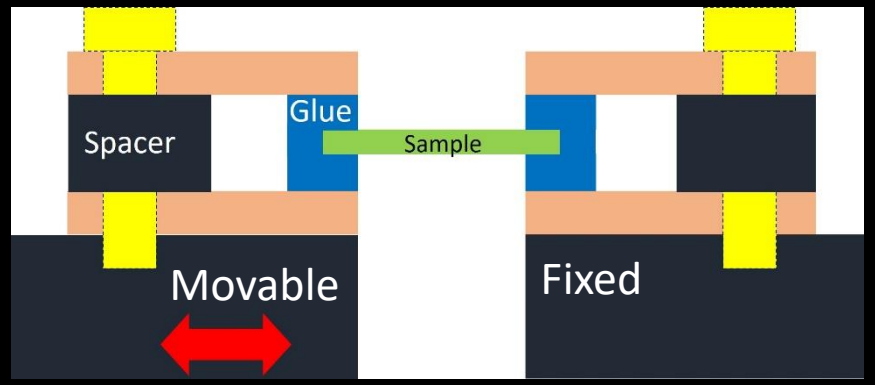
Hicks et al. *Rev. of Sci. Inst.* (2014)
Razorbill Instruments



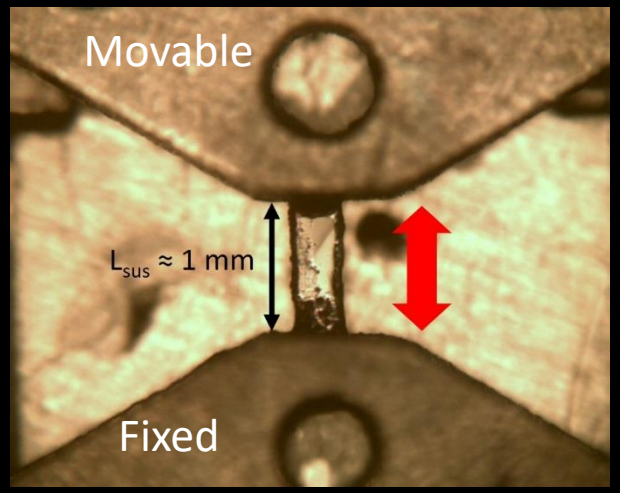
Tensile

Neutral point

Compressive



Side view



Top view

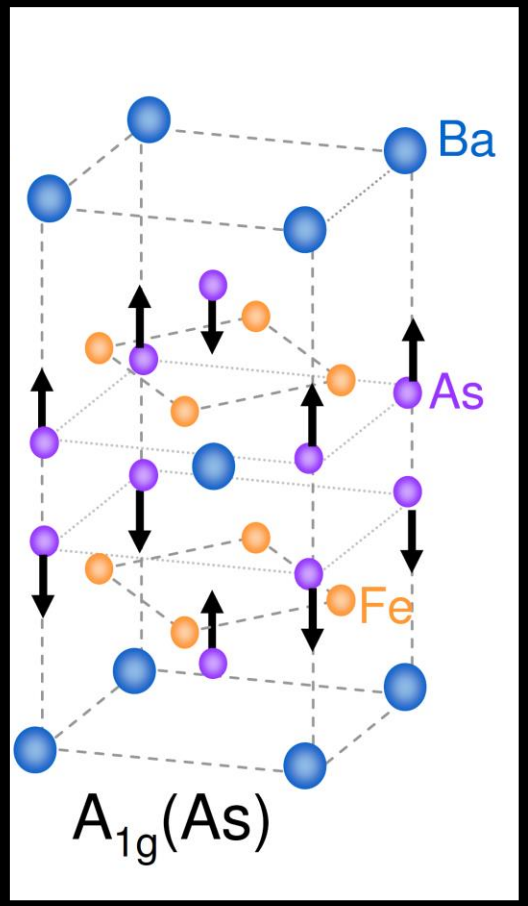
Co-Ba122: key points and strain effects

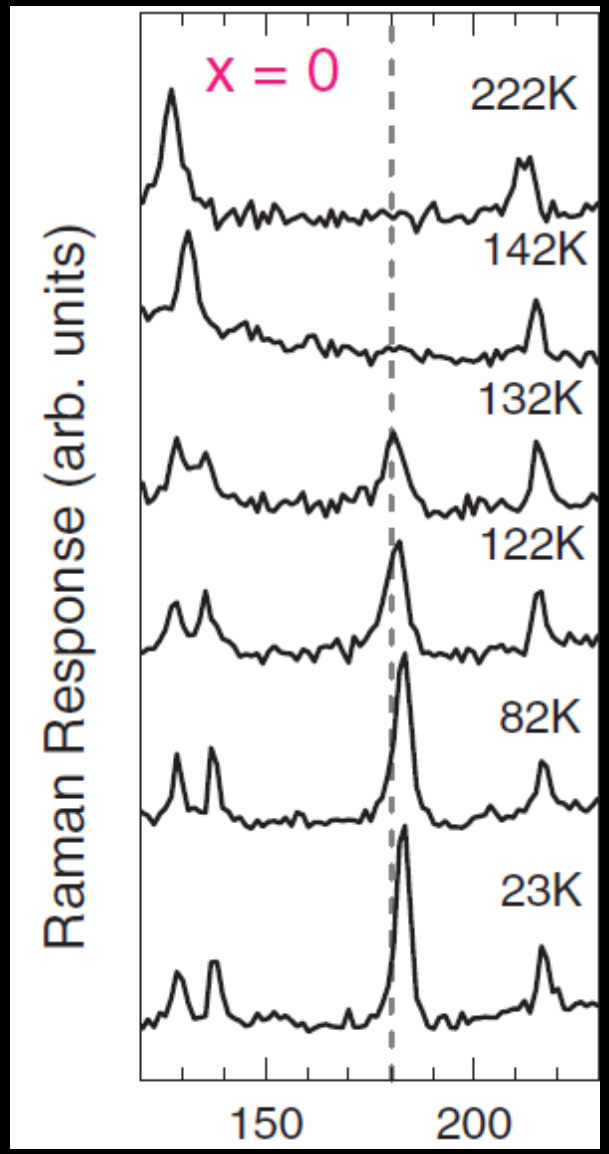
Elasto-Raman spectroscopy

Strain activation of As phonon

Suppression of nematic fluctuations under strain

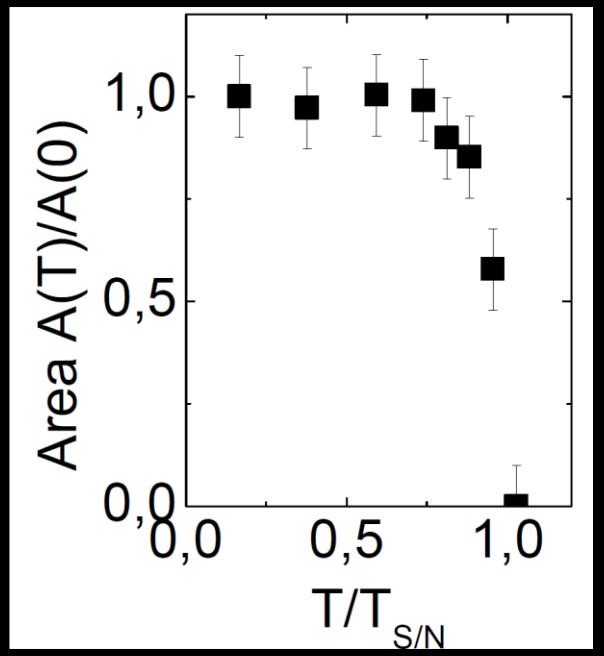
Nemato-structural effect of strain on As phonon





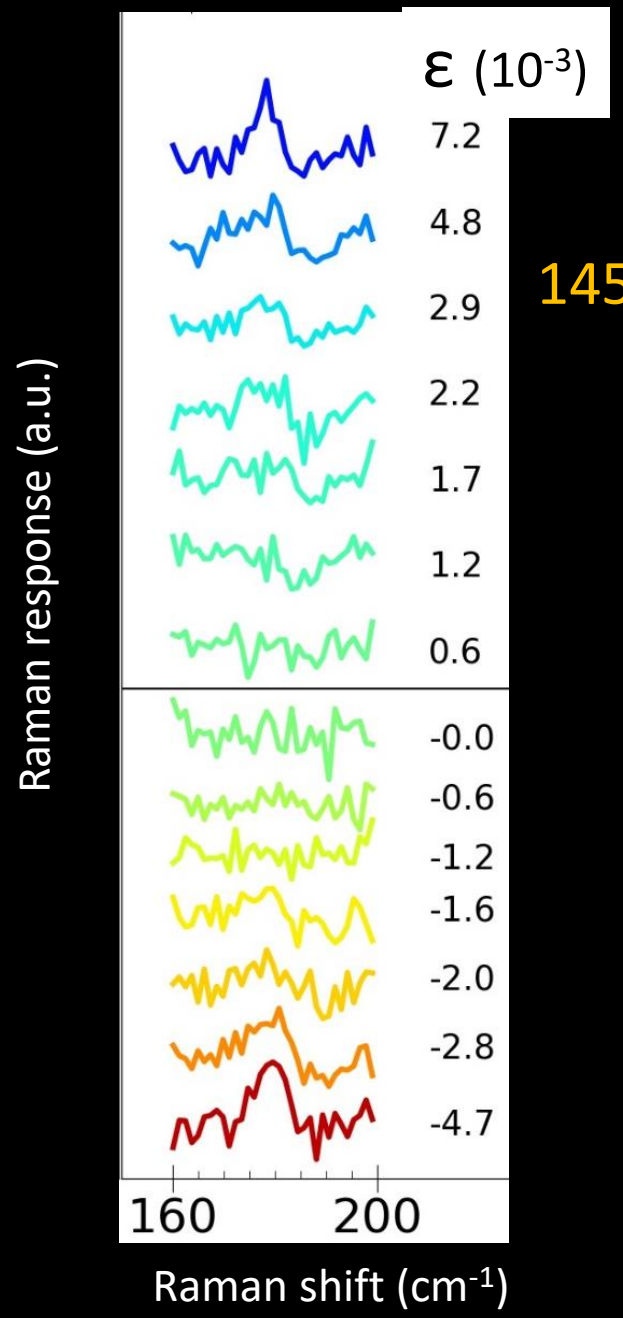
Chauvière et al. *PRB* (2011)

As phonon activated in B_{2g} symmetry below T_s = 138 K

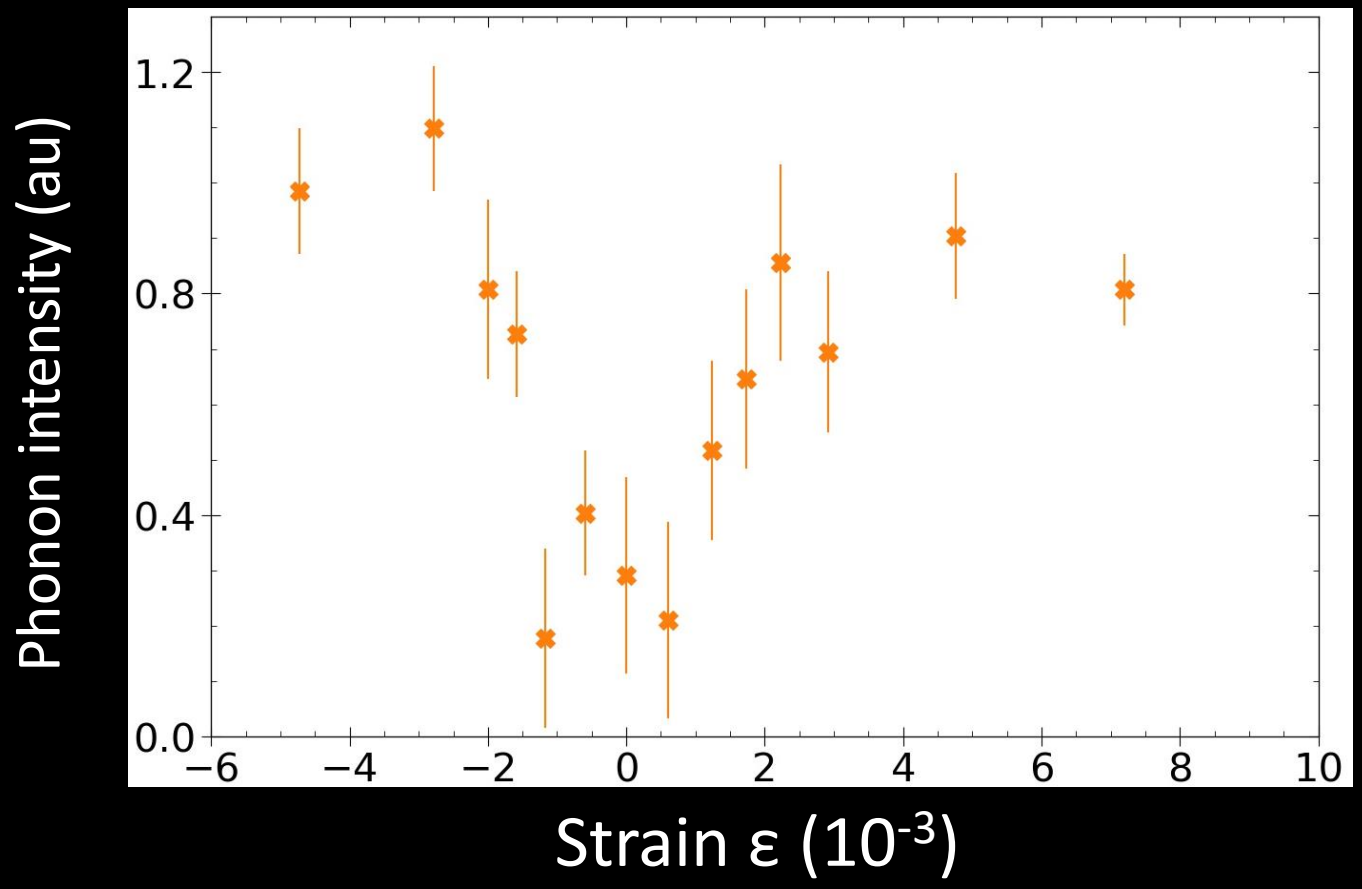


Phonon intensity = Nemato-structural OP

Strain activation of As phonon



145 K > T_S = 138 K



Validation of set-up : B_{2g} strain induced through applied stress

See arxiv:2110.06175

Co-Ba122: key points and strain effects

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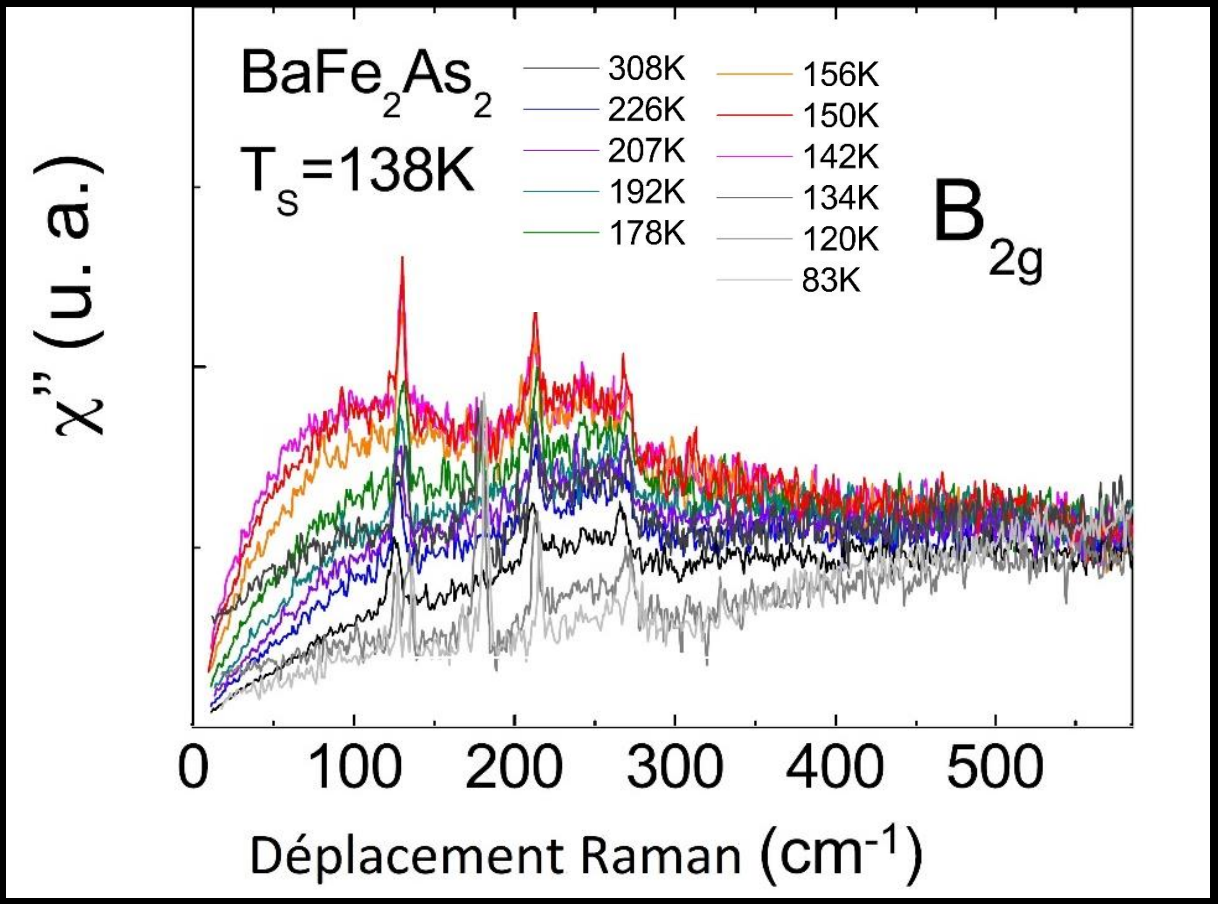
Suppression of nematic fluctuations under strain

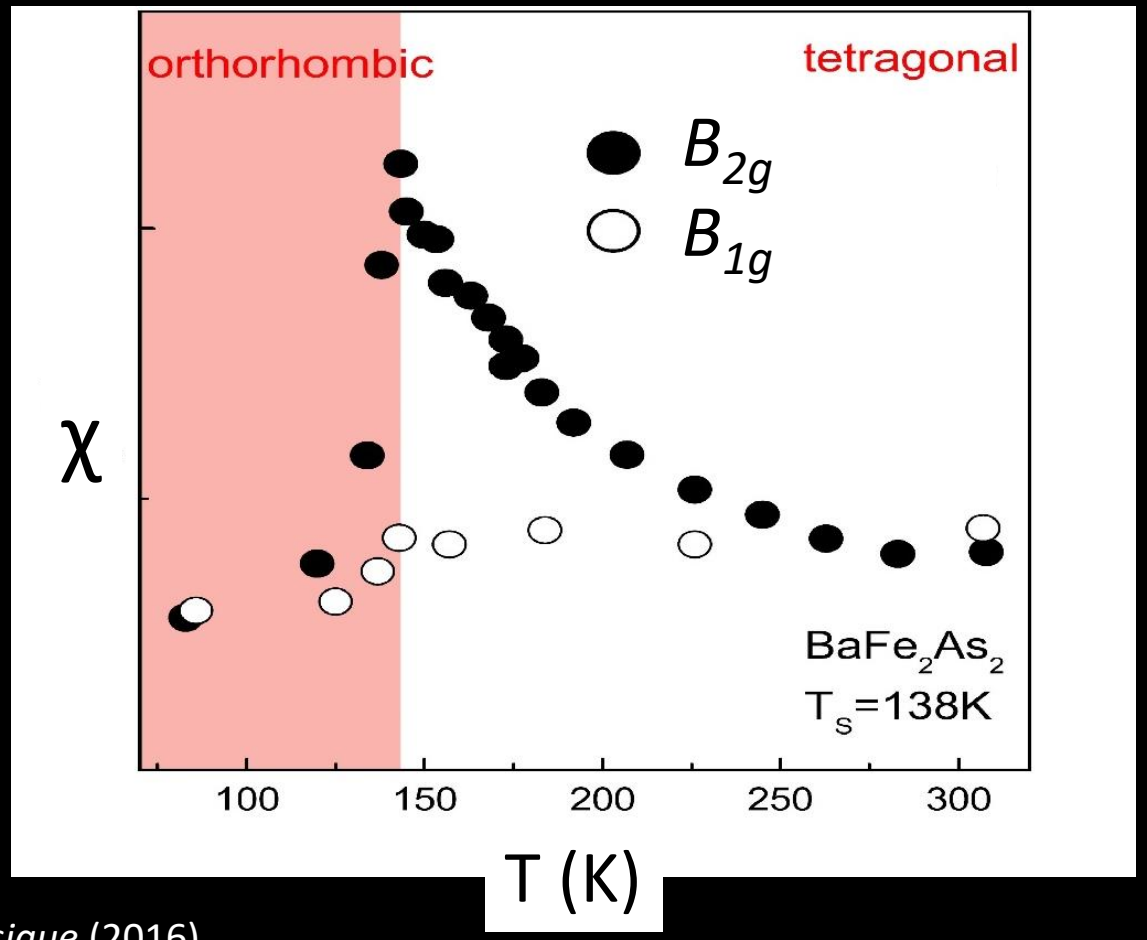
Nematicity in Raman

Measured Raman response

Nematic susceptibility

$$\chi = \int \frac{\chi''(\omega)}{\omega} d\omega$$



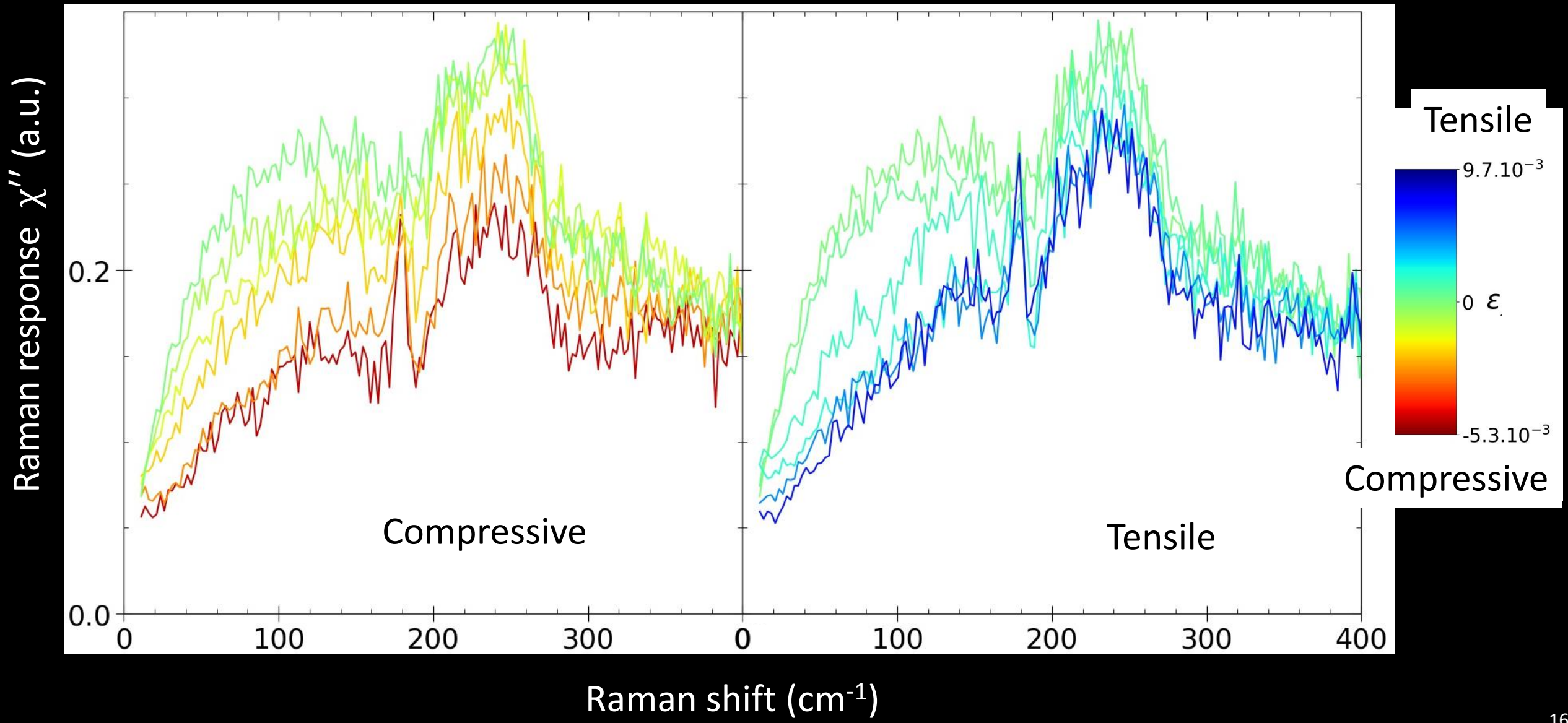


Gallais et Paul, *CR Physique* (2016)

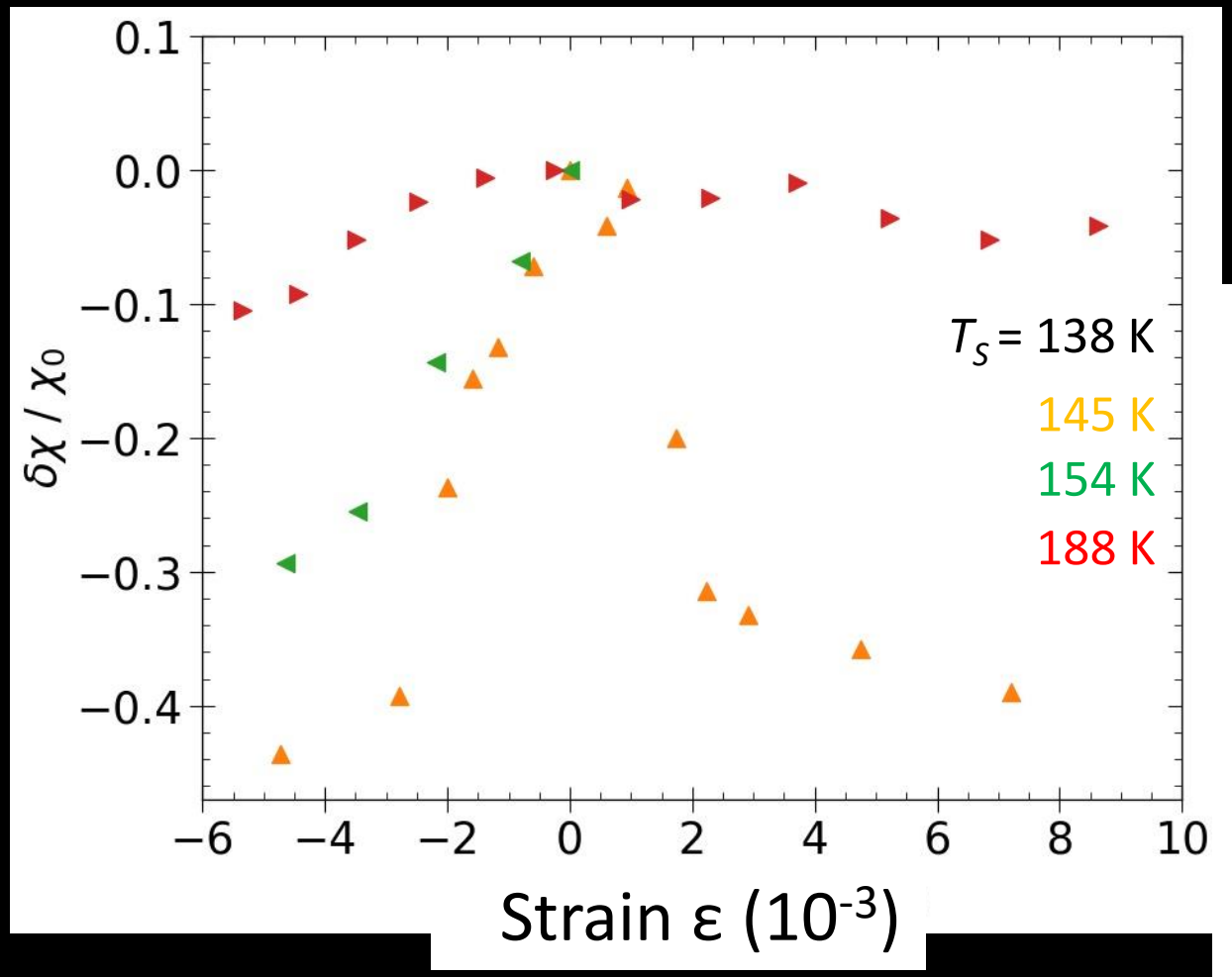
Continuum in metallic state under strain

$BaFe_2As_2$ 145 K > T_S = 138 K

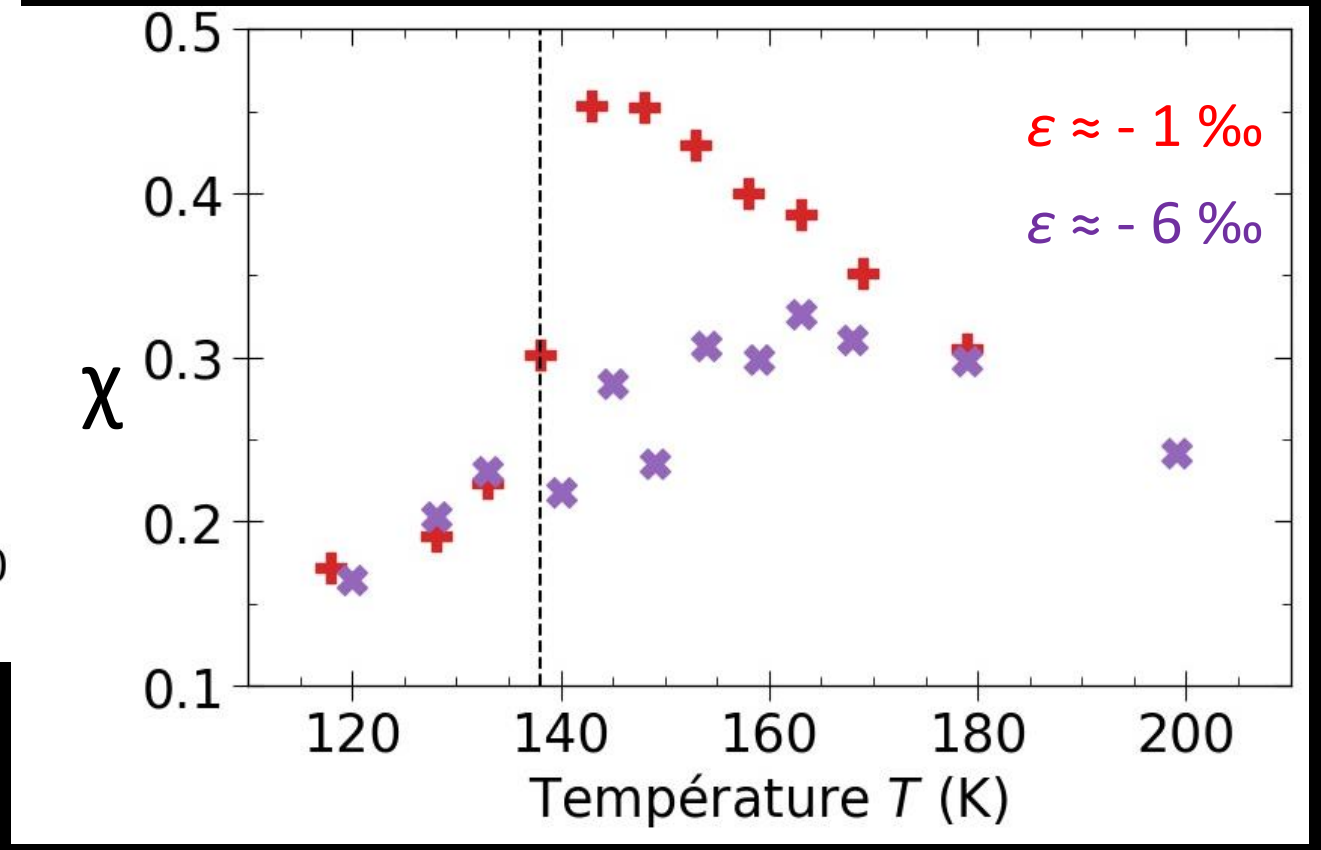
$$\chi = \int \frac{\chi''(\omega)}{\omega} d\omega$$



Continuum in metallic state under strain



$$\frac{\delta\chi}{\chi_0} \propto -\chi_0^3 \epsilon_{B_{2g}}^2$$

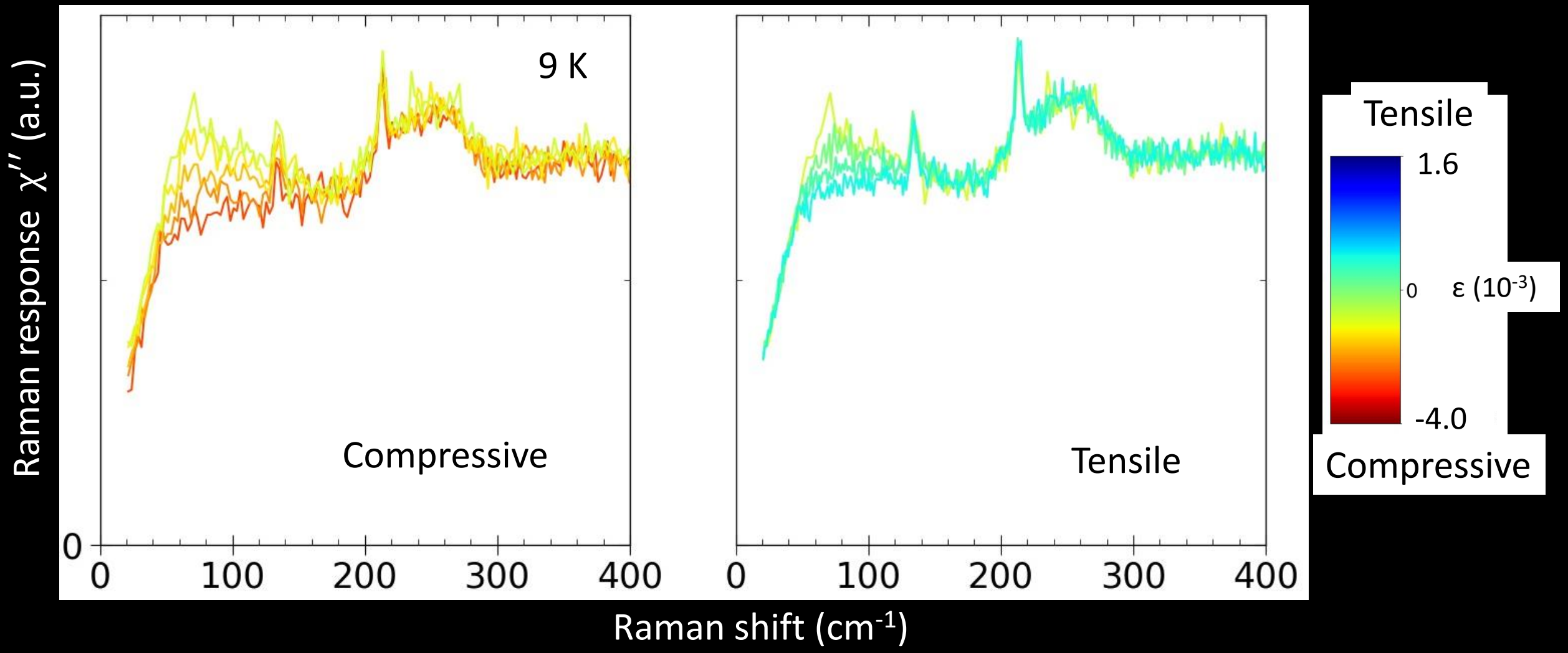


Suppression of nematic fluctuations under strain

Continuum in superconducting state under strain

x = 7 % (close to optimal, T_c = 25 K)

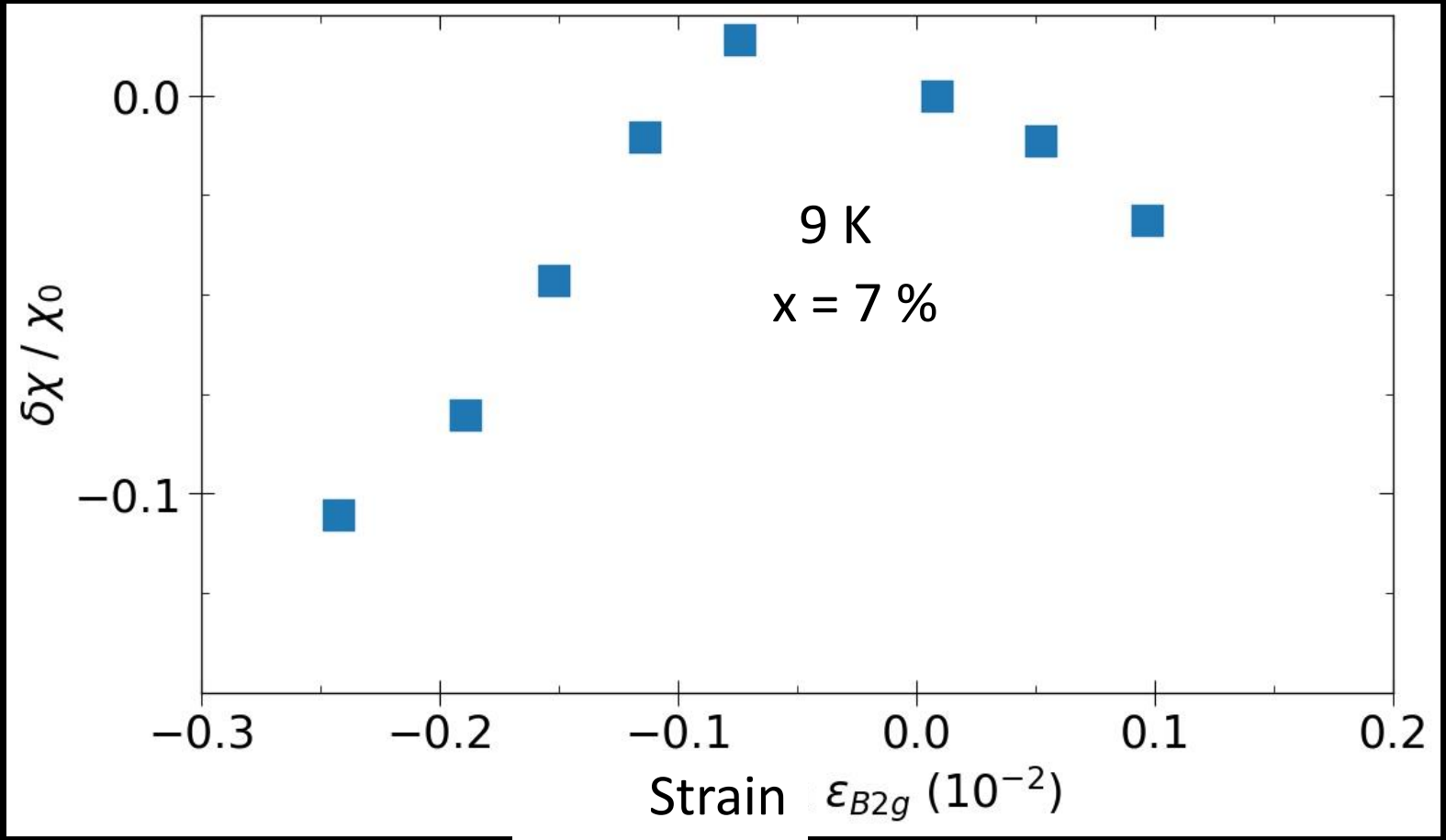
$$\chi = \int \frac{\chi''(\omega)}{\omega} d\omega$$



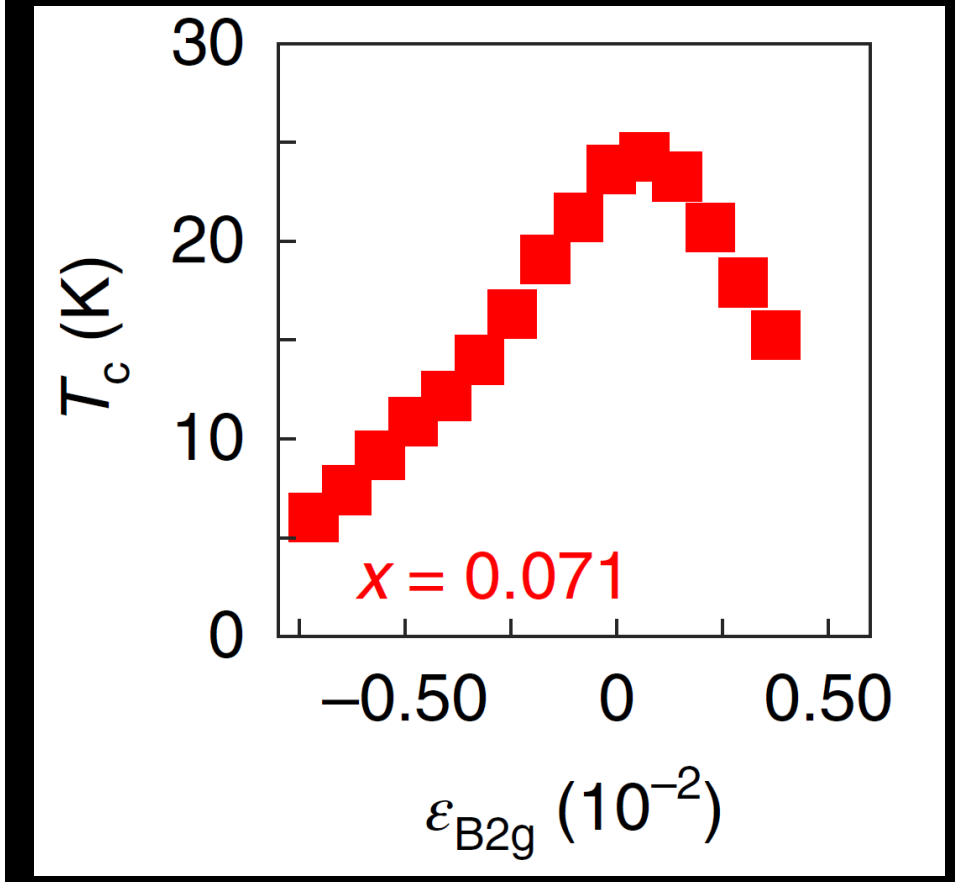
Suppression of nematic fluctuations

Continuum in superconducting state under strain

Suppression of nematic fluctuations



Suppression of T_c

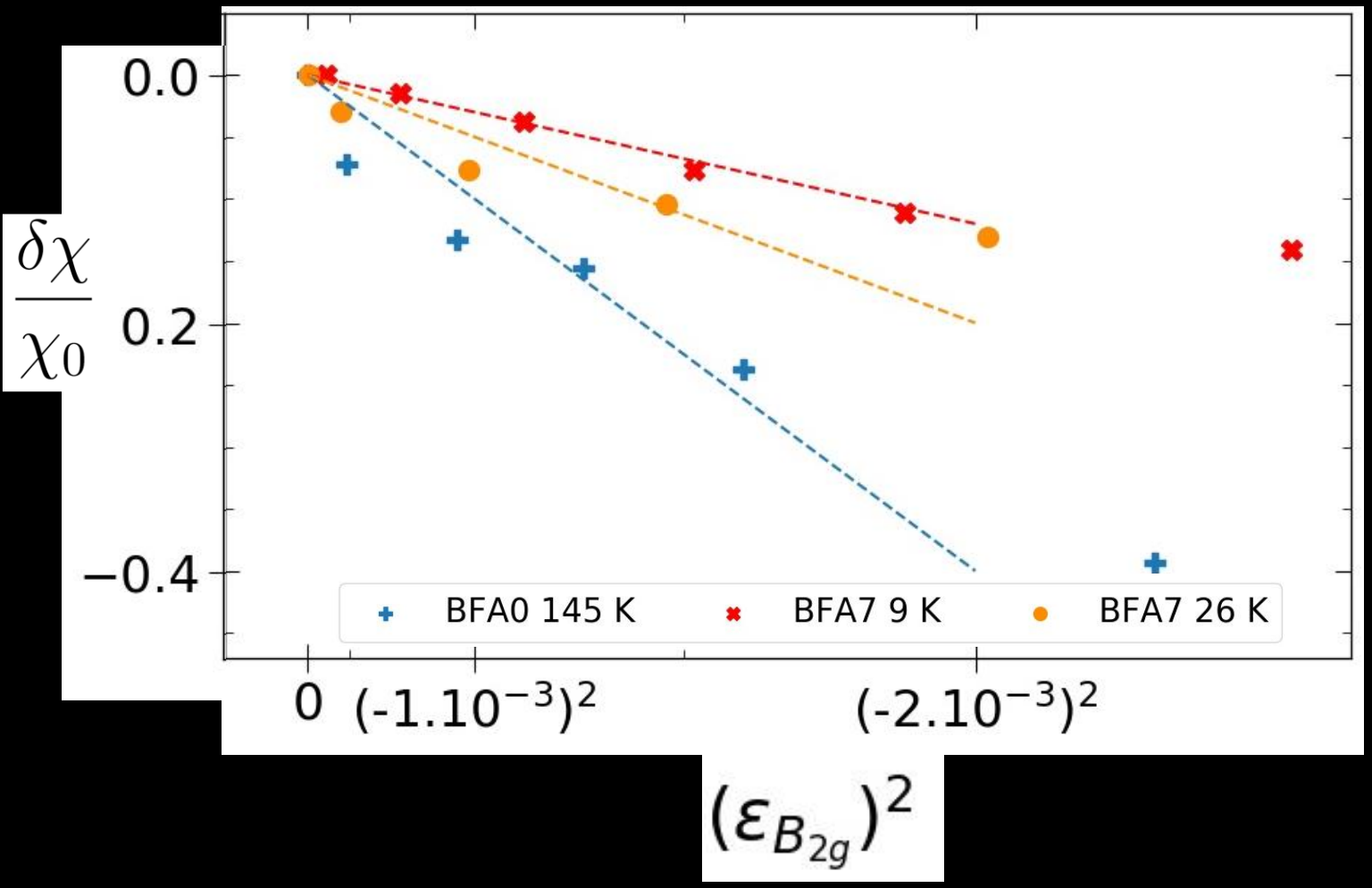


Malinowski et al. *Nature Physics* (2020)

Nemato-elastic coupling

$$\frac{\delta\chi}{\chi_0} = -3u\lambda^2\chi_0^3\epsilon_{B_{2g}}^2$$

$$F = \frac{1}{2}C_0\epsilon^2 + \frac{1}{2}\chi_0^{-1}\phi^2 + \frac{1}{4}u\phi^4 - \lambda\epsilon\phi$$



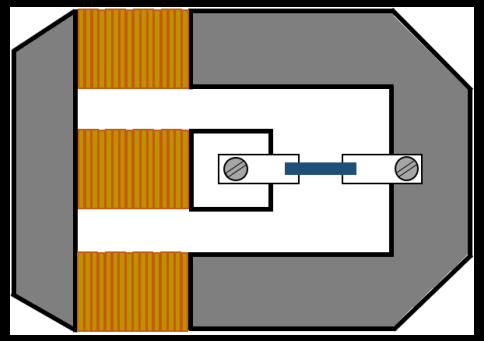
$$\frac{\lambda\,(x = 7\,\%)}{\lambda\,(x = 0\,\%)} = [0{,}7\ ;\ 2]$$

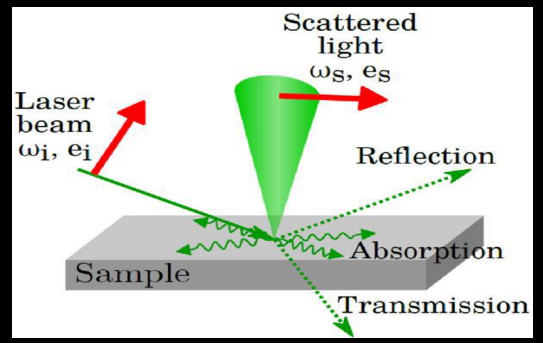
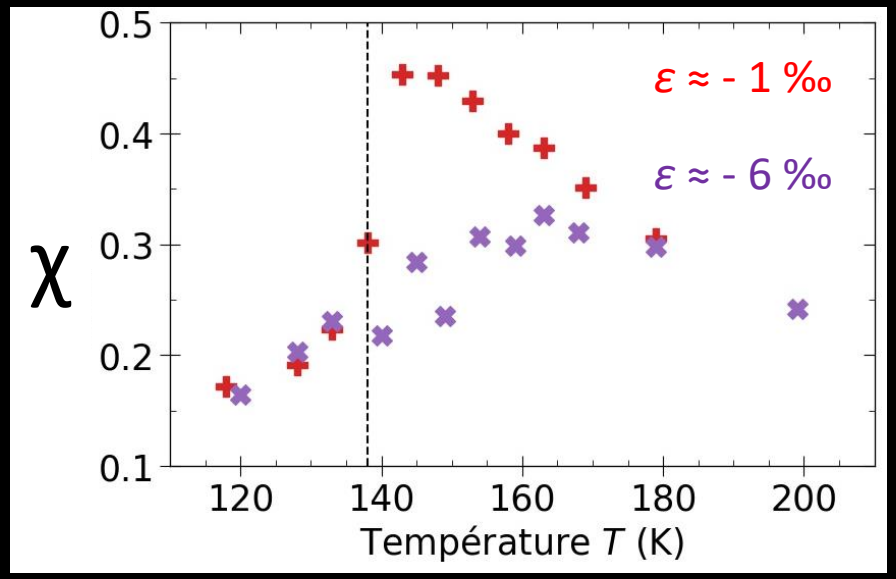
$= 0{,}2$

Élastocalorimetry (Ikeda et al. *PNAS* 2021)

Conclusions

- Elasto-Raman : new tool to study nematicity





- Suppression of nematic fluctuations under strain
  - Both in metallic and superconducting state
  - Possible explanation of fall of T_c