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FRANK CAPRA

The end of the tyranny of copper

Iron Arsenic Based Superconductors:

Six months with reduced sleep....(and counting).

Paul C. Canfield

Senior Physicist, Ames Laboratory

Distinguished Professor, Dept. Physics

Iowa State University

October 23, 2008

National Research Council
The National Academies

Sergey Bud'ko Ni Ni, Matt Tillman, Eun-Deok Mun

At a gross level, the past couple of decades of research in superconductivity have been a process of shedding (or destroying) prejudices.

Discovery	Prejudice countered
High T_c	Superconductivity in oxides will not rival intermetallics
RT_2B_2C	Superconductivity in intermetallics is dead
MgB_2	Superconductivity in intermetallics cannot exceed $T_c \sim 30$, $N(E_F)$ vital for high T_c in intermetallics

The recent work in FeAs based superconductors continues this trend.

FeAs compounds	"Really high T_c" superconductivity is found in oxides and specifically copper oxides

At a gross level, the past couple of decades of research in superconductivity has confirmed (or at least preserved) one old prejudice: extremes in superconductivity are found near (often in competition with) other phase transitions.

High T_c	Cu-based magnetism
RT_2B_2C	Strong phonon softening / structural phase transitions
MgB_2	At the extreme of the AlB_2 structure's stability (i.e. structural phase transition)

The recent work in FeAs based superconductors continues this trend.

FeAs compounds	Structural / antiferromagnetic transition

Fe-As based superconductors part I

The end of the tyranny of copper

$RFeAs(O_{1-x}F_x)$ T_c up to 55 K

$RFeAsO_{1-x}$ T_c up to ~50 K

Hard to make, is this oxide physics, intermetallic physics, both, neither…?????

What is role of O / F?

What is the nature of the superconductivity, what is the symmetry of the gap?

Superconductivity in FeAs compounds was years in the making….

Journal of Alloys and Compounds 302 (2000) 70–74

Quaternary rare earth transition metal arsenide oxides *RT*AsO (*T*=Fe, Ru, Co) with ZrCuSiAs type structure

P. Quebe, L.J. Terbüchte, W. Jeitschko*

Anorganisch-Chemisches Institut, Universität Münster, Wilhelm-Klemm-Straße 8, D-48149 Münster, Germany

Received 18 November 1999; accepted 1 December 1999

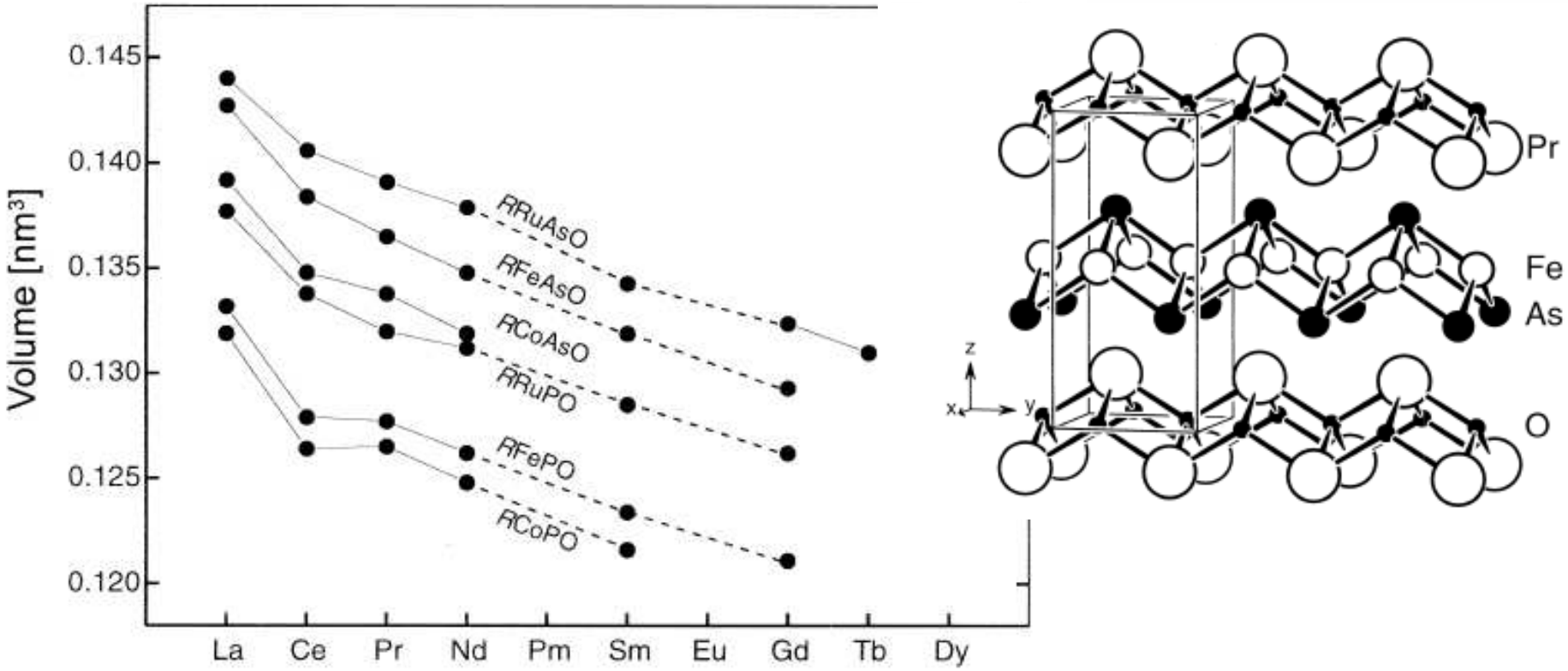


Fig. 1. Cell volumes of compounds *RTPn*O (*T*=Fe, Ru, Co; *Pn*=P, As) with ZrCuSiAs type structure.

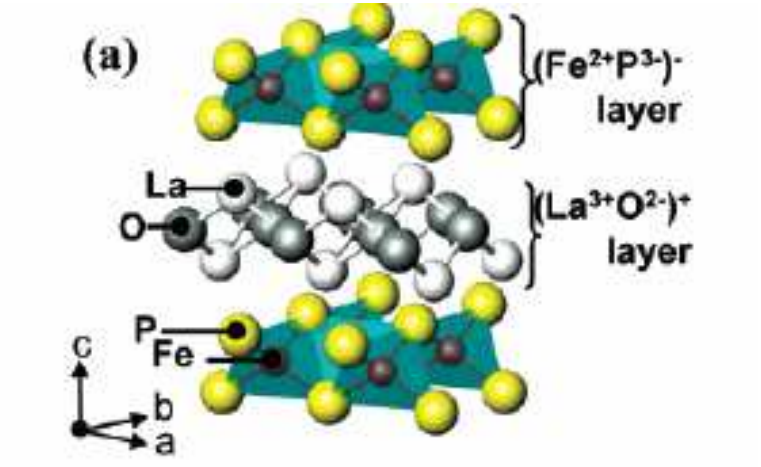
Received May 15, 2006; E-mail: hosono@msl.titech.ac.jp

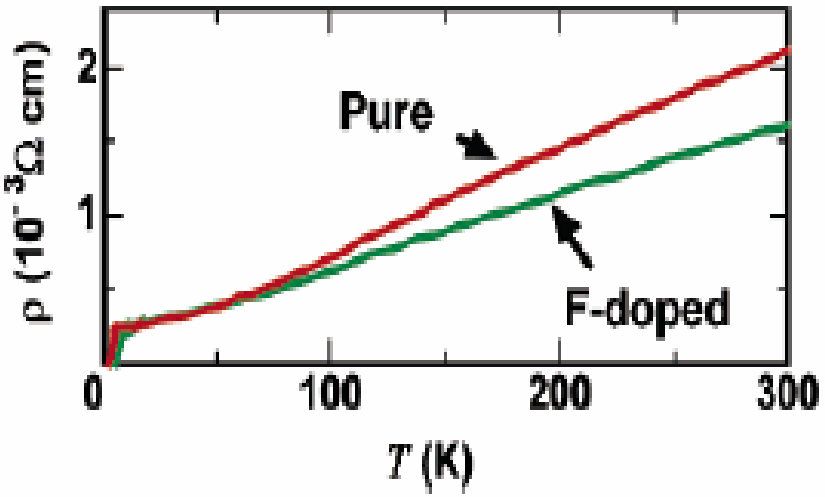
J|A|C|S COMMUNICATIONS

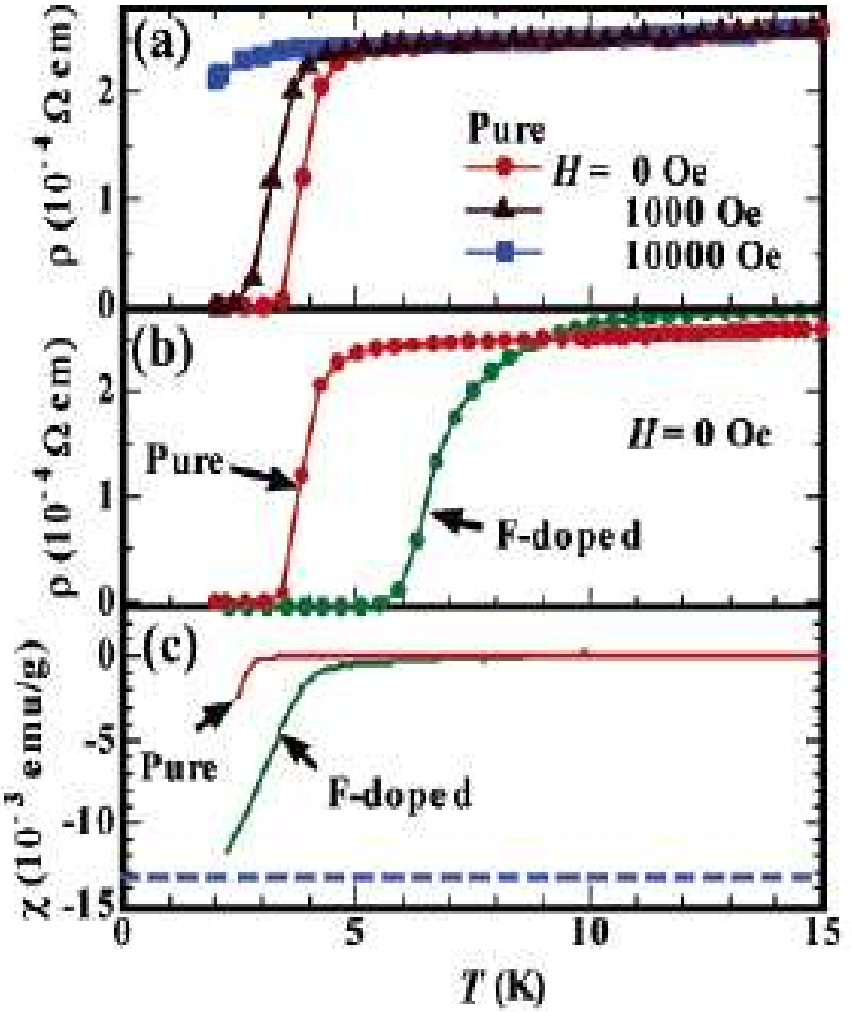
Published on Web 07/15/2006

Iron-Based Layered Superconductor: LaOFeP

Yoichi Kamihara,† Hidenori Hiramatsu,† Masahiro Hirano,†,‡ Ryuto Kawamura,§ Hiroshi Yanagi,§ Toshio Kamiya,†,§ and Hideo Hosono*,†,‡





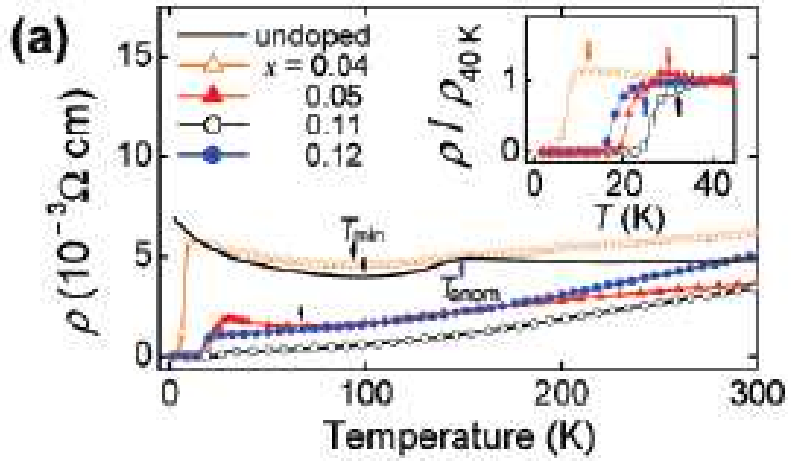


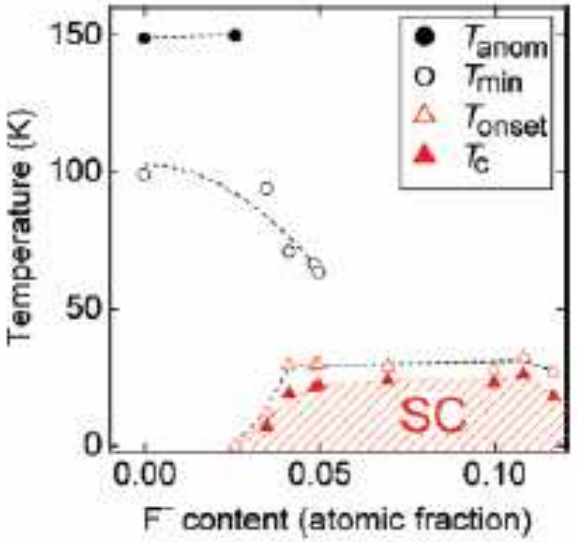
J|A|C|S
COMMUNICATIONS

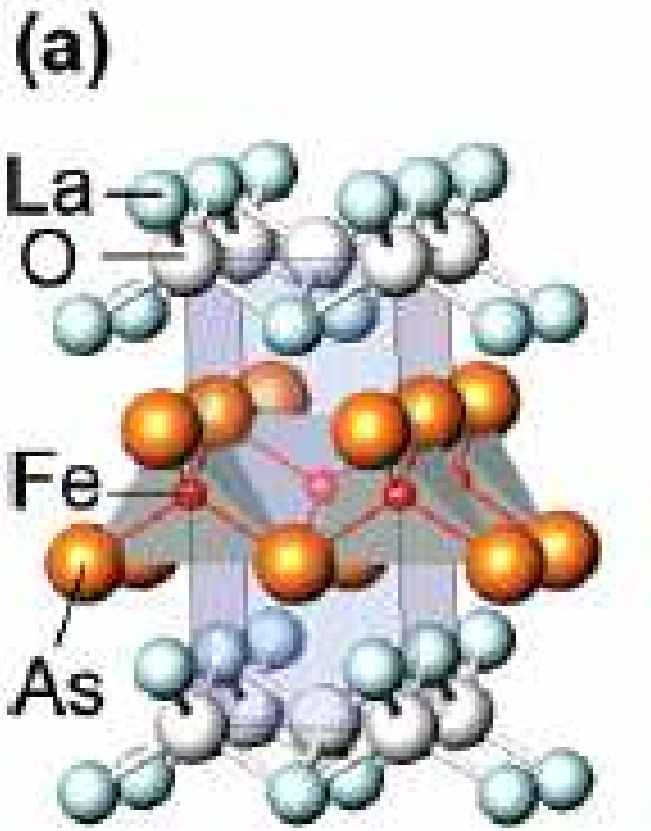
Published on Web 02/23/2008

Iron-Based Layered Superconductor La[$O_{1-x}F_x$]FeAs (x = 0.05−0.12) with T_c = 26 K

Yoichi Kamihara,*,† Takumi Watanabe,‡ Masahiro Hirano,†,§ and Hideo Hosono†,‡,§







VITAL POINT TO MAKE:

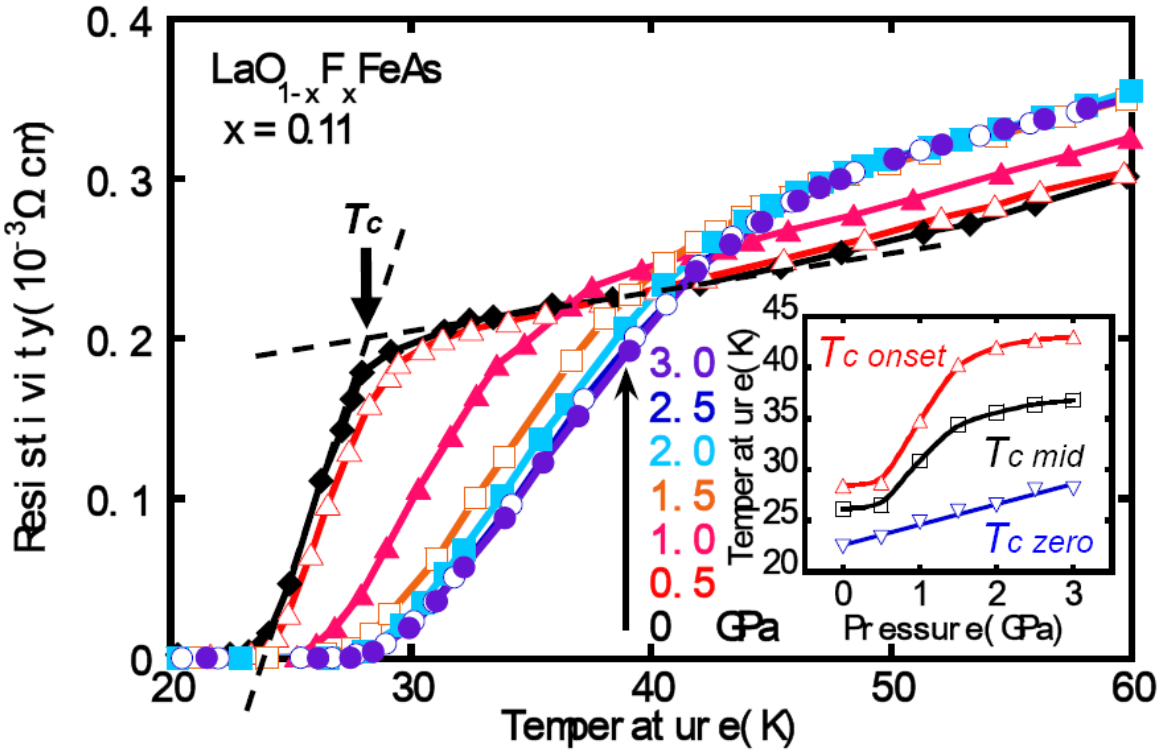
New materials with wonderful properties do not "just appear by accident".

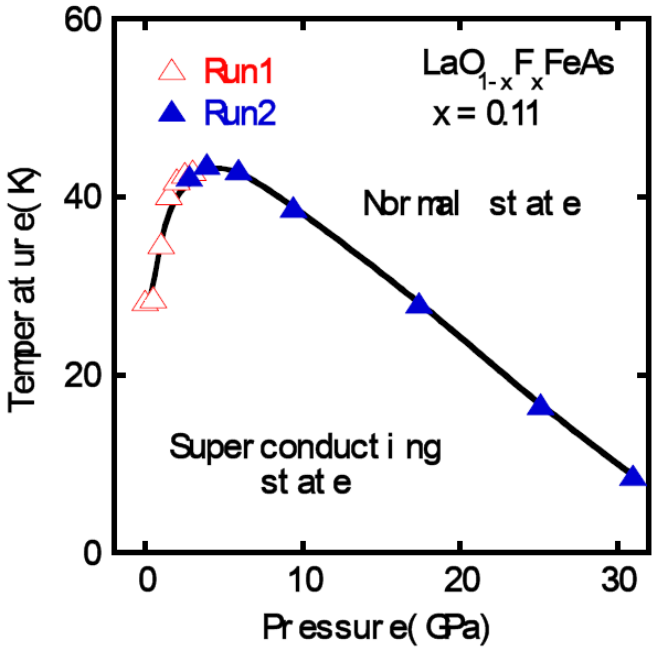
Superconductivity in $LaFeAs(O_{1-x}F_x)$ was the result of a career of new materials discovery (Jeitschko) and a several year campaign of looking for superconductivity in compounds with square-planar Fe (Hosono).

As will be discussed below, the extension to square planar members of the $ThCr_2Si_2$ was made simple by decades worth of work on this well known family of ternary intermetallics.

FeAs superconductivity is another example of basic research at its finest. Long term efforts to extend our knowledge of novel and complex materials, coupled with focused searches for specific properties, result in important discoveries.

With the basic discovery made, the question becomes can the properties be improved?





T_C can be tuned with pressure…A LOT!!

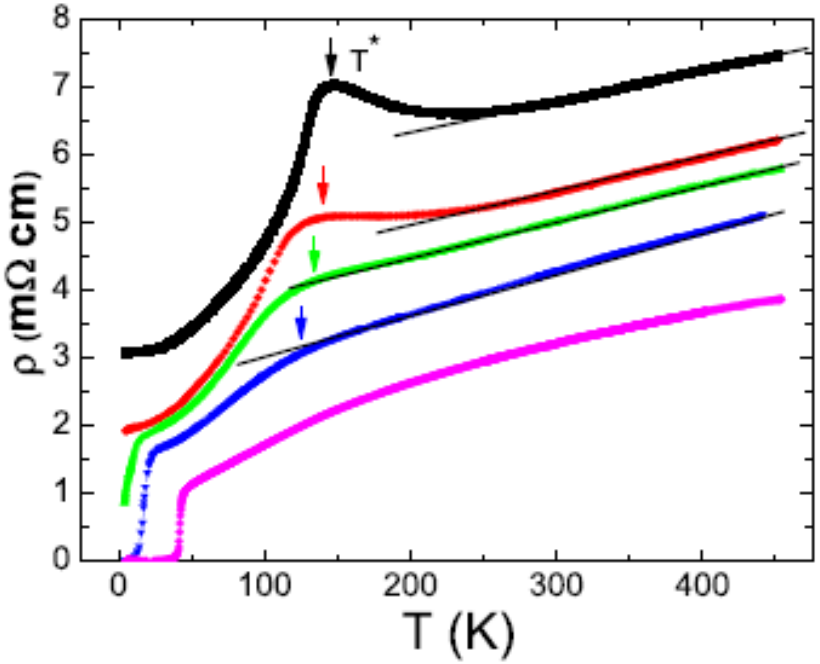
Superconductivity at 43 K in an iron-based layered compound $La[O_{1-x}F_x]FeAs$

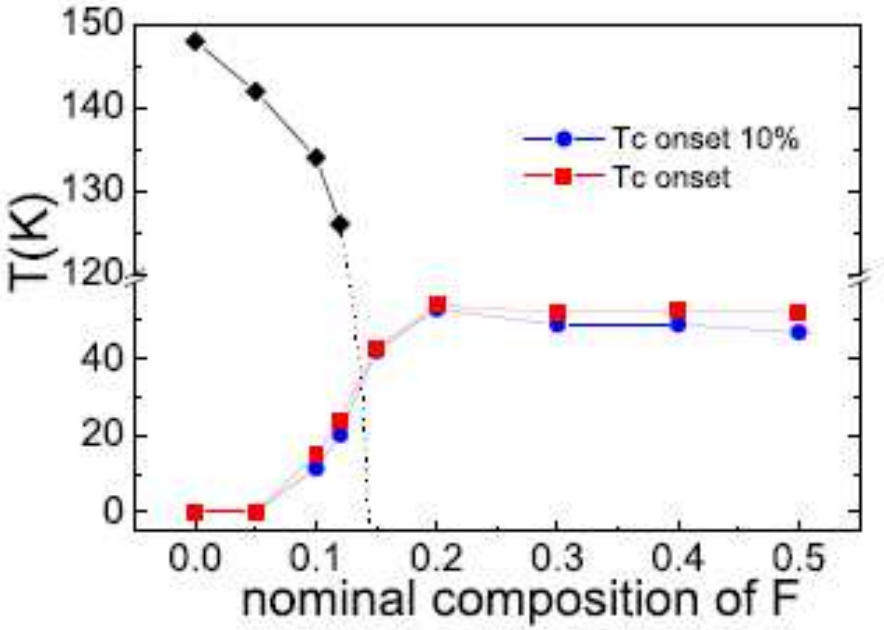
Hiroki Takahashi[1], Kazumi Igawa[1], Kazunobu Arii[1], Yoichi Kamihara[2], Masahiro Hirano[2,3], & Hideo Hosono[2,3]

An other way to change the volume of a RXY compound's unit cell is to change R….Use the lanthanide contraction.

Phase Diagram and Quantum Critical Point in Newly Discovered Superconductors: $SmO_{1-x}F_xFeAs$

R. H. Liu[1], G. Wu[1], T. Wu[1], D. F. Fang[1], H. Chen[1], S. Y. Li[2], K. Liu[1], Y. L. Xie[1], X. F. Wang[1], R. L. Yang[1], C. He[2], D. L. Feng[2] and X. H. Chen[1]*



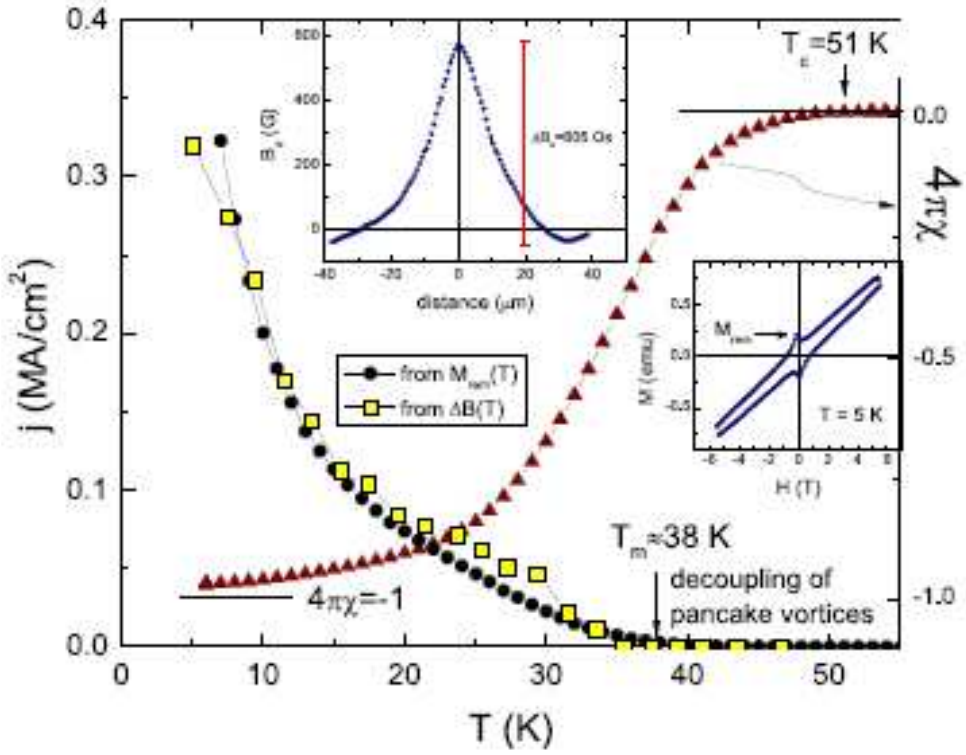


$NdFeAs(O_{0.9}F_{0.1})$

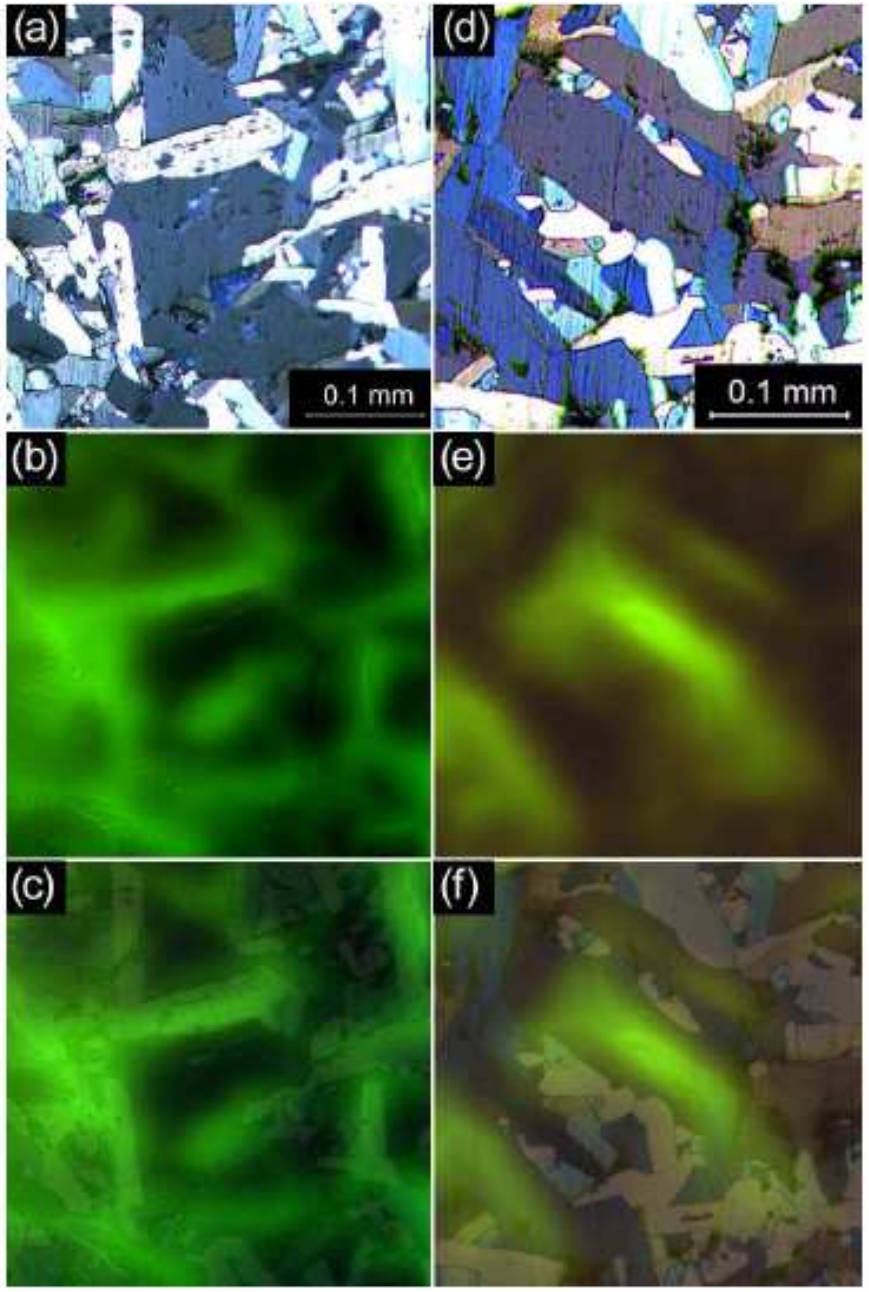
High pressure synthesis

T_C ~ 51-53 K

NOT single phased



R. Prozorov,* M. E. Tillman, E. D. Mun, and P. C. Canfield
arXiv:0805.2783v2 [cond-mat.supr-con] 4 Jun 2008

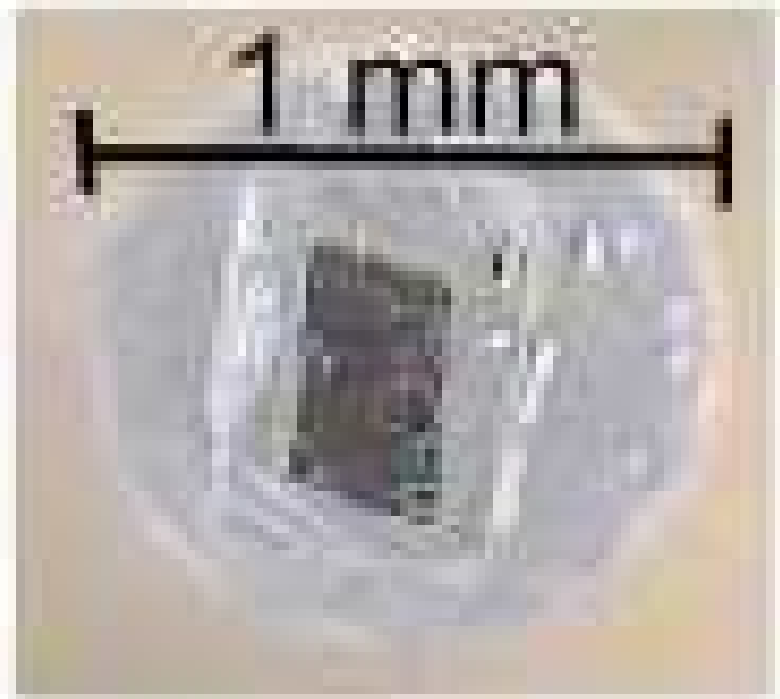


Can find and isolate ~400 μm on a side plates/ grains

$NdFeAs(O_{1-x}F_x)$ single crystals

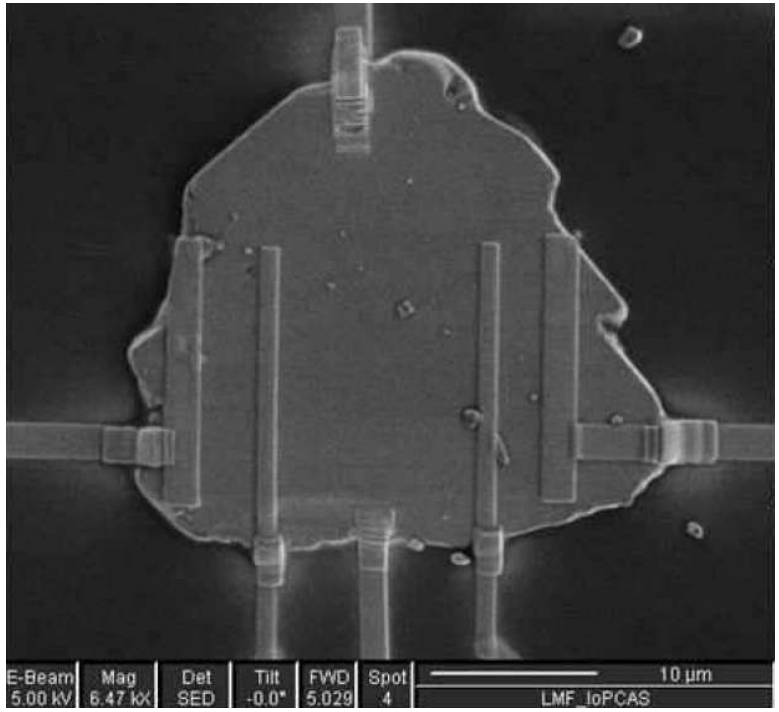
Small single crystals (but actually the biggest currently around) can be extracted from the pellets. At this point we are getting linear dimensions near 1 mm (larger than the photo from July below)

arXiv:0807.0876v1 [cond-mat.supr-con] 5 Jul 2008



Single crystals have also been grown out of molten salts (high pressure as well as ambient pressure). Size is very small. Below is ~25 μm linear dimension.

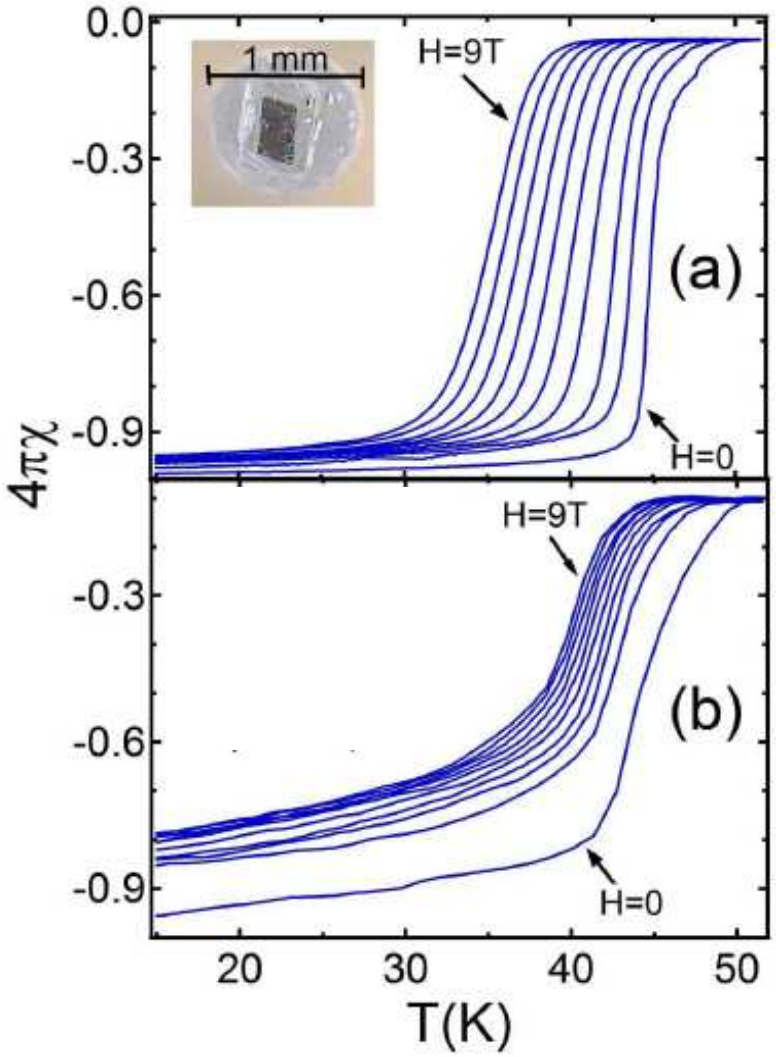
arXiv:0810.2469v1 [cond-mat.supr-con] 14 Oct 2008



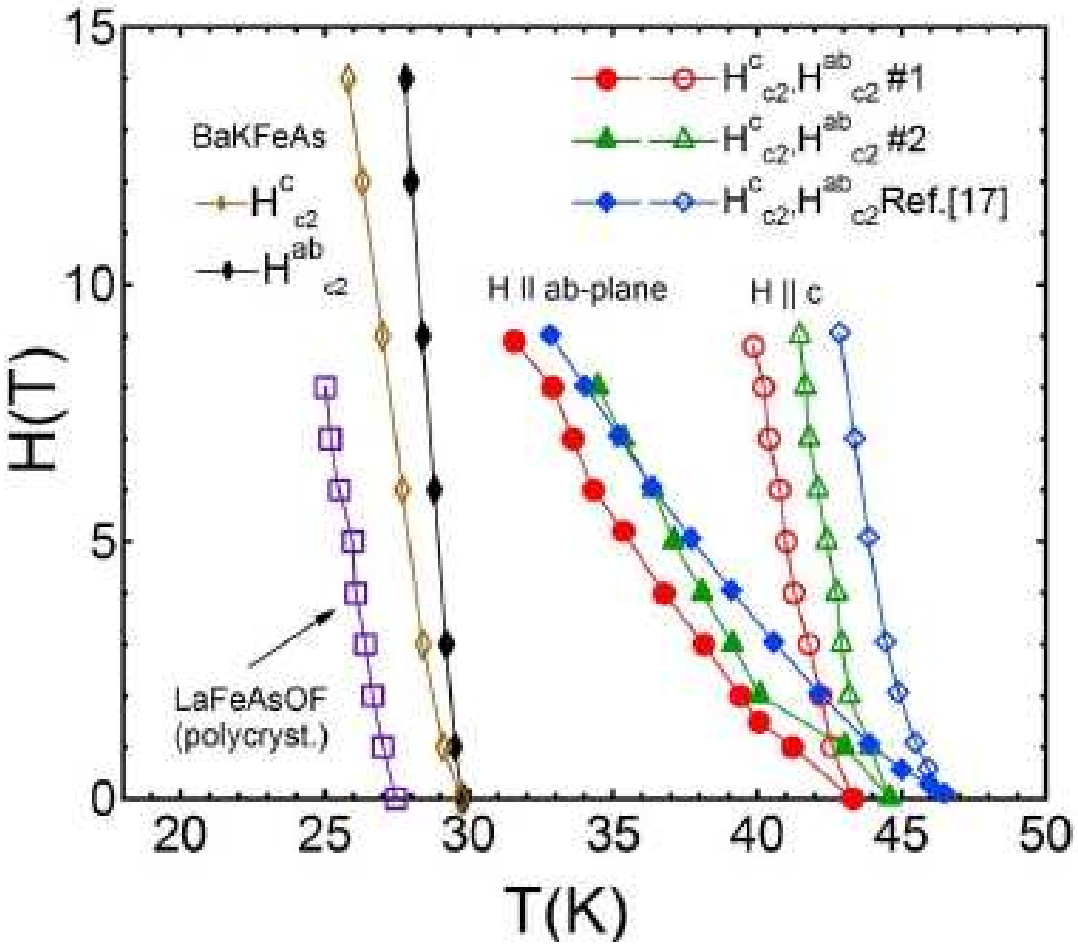
Nodeless superconducting gap in $NdFeAsO_{0.9}F_{0.1}$ single crystals from anisotropic penetration depth studies

C. Martin, R. T. Gordon, M. A. Tanatar, M. D. Vannette, M. E. Tillman, E. D. Mun,
P. C. Canfield, V. G. Kogan, G. D. Samolyuk, J. Schmalian, and R. Prozorov*

arXiv:0807.0876v1 [cond-mat.supr-con] 5 Jul 2008



Extract $H_{c2}(T)$ close to T_c

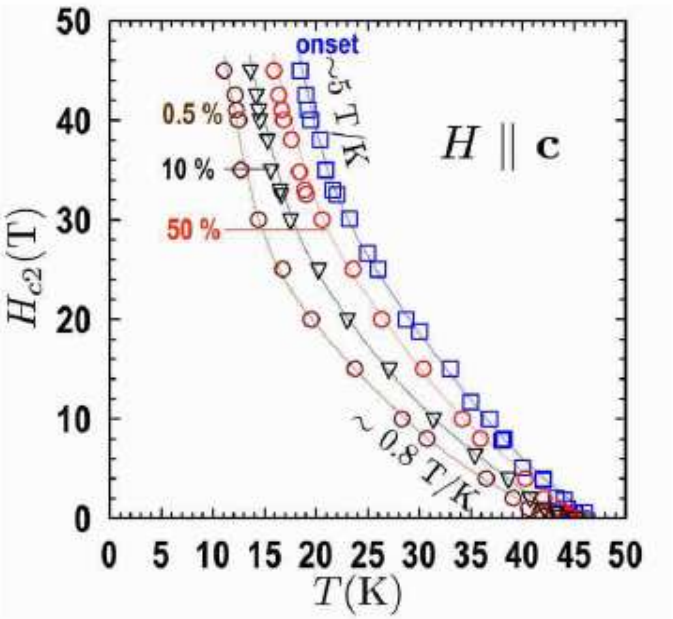


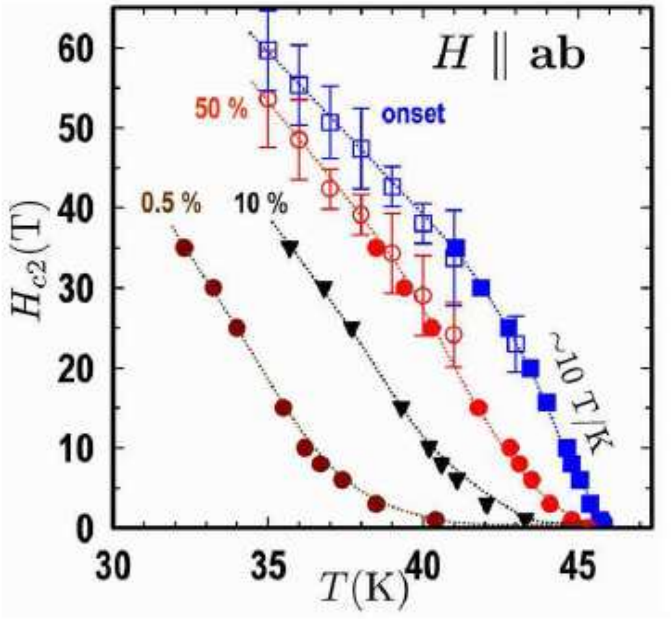
Upper critical fields and thermally-activated transport of $Nd(O_{0.7}F_{0.3})FeAs$ single crystal.

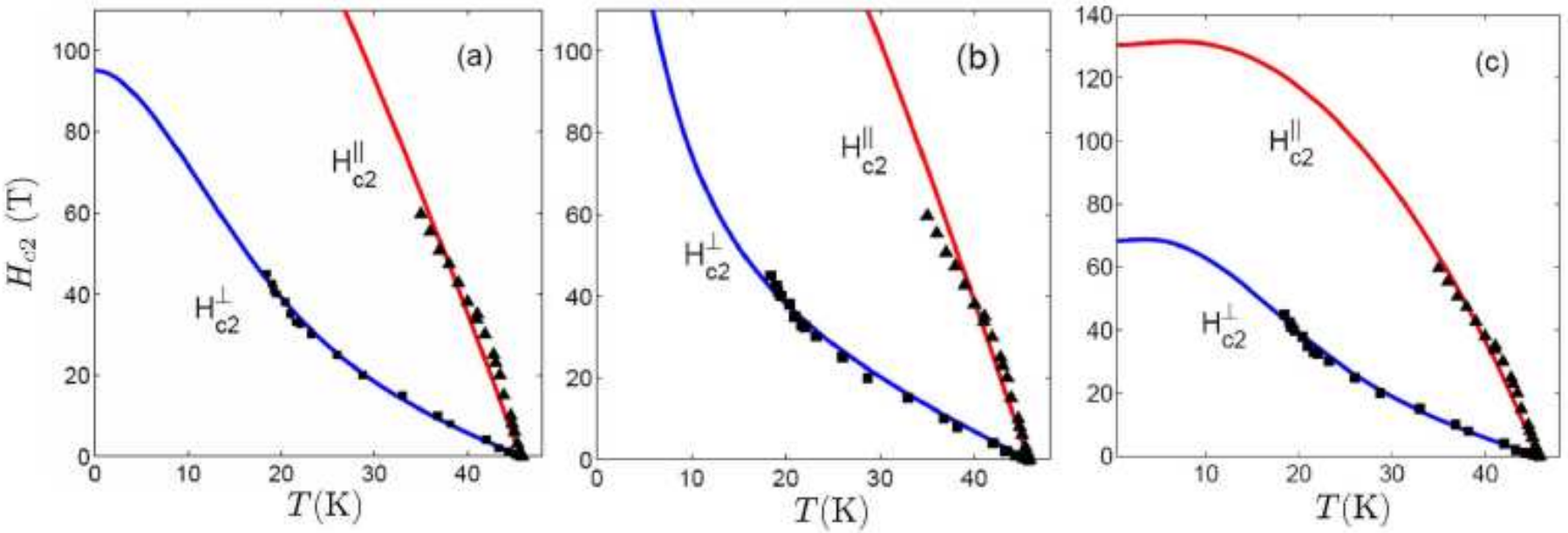
arXiv:0810.2469v1 [cond-mat.supr-con] 14 Oct 2008

J. Jaroszynski, et al.

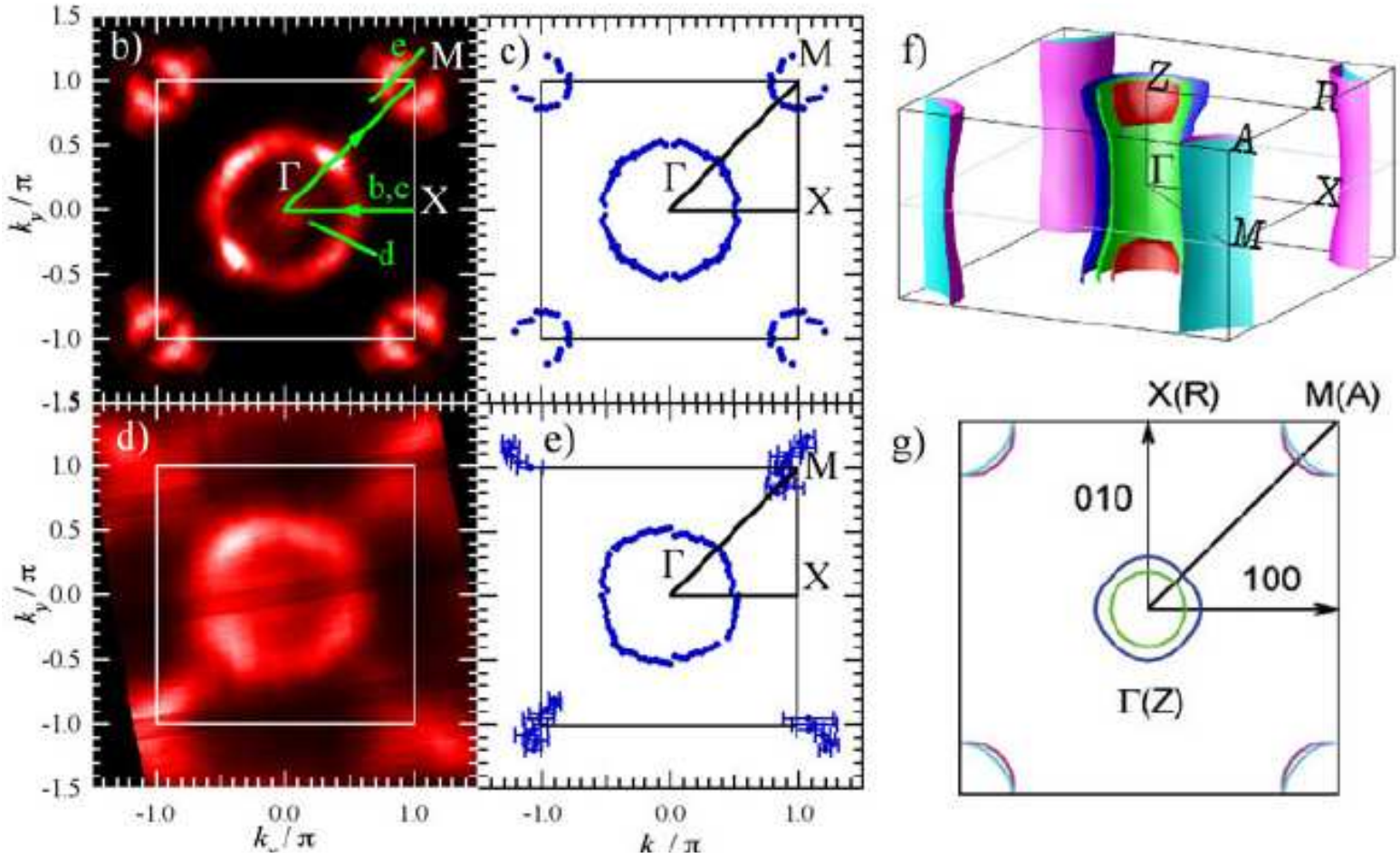
H_{c2}(T) is anisotropic, but not too large. Both directions show very large values.







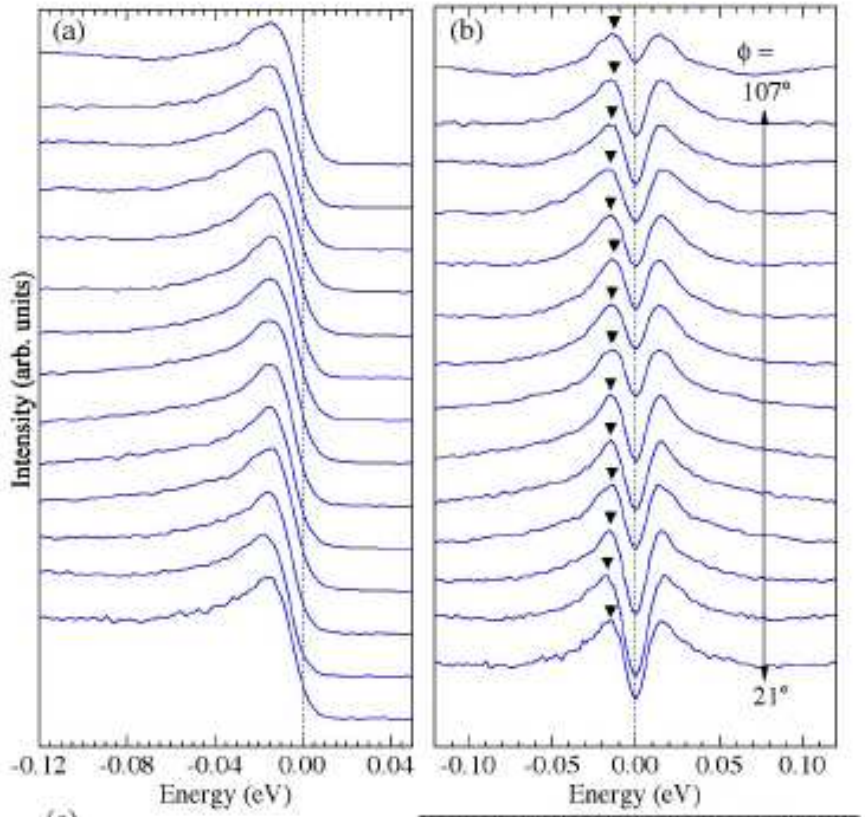
Using single grains we can perform ARPES and find Fermi surface and compare with band structure calculations....

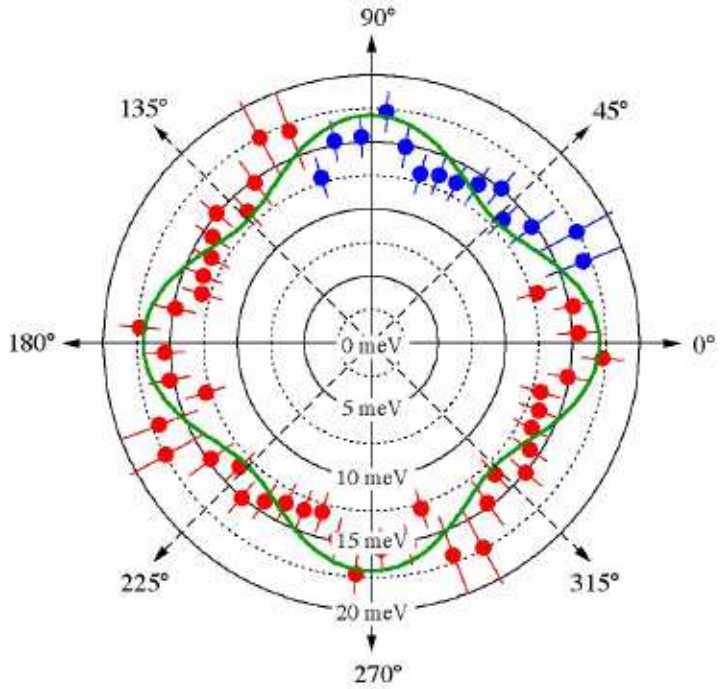


arXiv:0806.2147v3 [cond-mat.supr-con] 17 Jun 2008

C. Liu,[1] T. Kondo,[1] M. E. Tillman,[1] R. Gordon,[1] G. D. Samolyuk,[1] Y. Lee,[1] C. Martin,[1] J. L. McChesney,[2] S. Bud'ko,[1] M. A. Tanatar,[1] E. Rotenberg,[2] P. C. Canfield,[1] R. Prozorov,[1] B. N. Harmon,[1] and A. Kaminski[1]

Using single grains we can perform ARPES and find the superconducting gap and study its (lack of) anisotropy





arXiv:0807.0815v1 [cond-mat.supr-con] 6 Jul 2008

PRL **101,** 147003 (2008)

Takeshi Kondo,[1] A. F. Santander-Syro,[2,3] O. Copie,[4] Chang Liu,[1] M. E. Tillman,[1]
E. D. Mun,[1] J. Schmalian,[1] S. L. Bud'ko,[1] M. A. Tanatar,[1] P. C. Canfield,[1] and A. Kaminski[1]

Nodeless superconducting gap in $NdFeAsO_{0.9}F_{0.1}$ single crystals from anisotropic penetration depth studies

arXiv:0807.0876v1 [cond-mat.supr-con] 5 Jul 2008

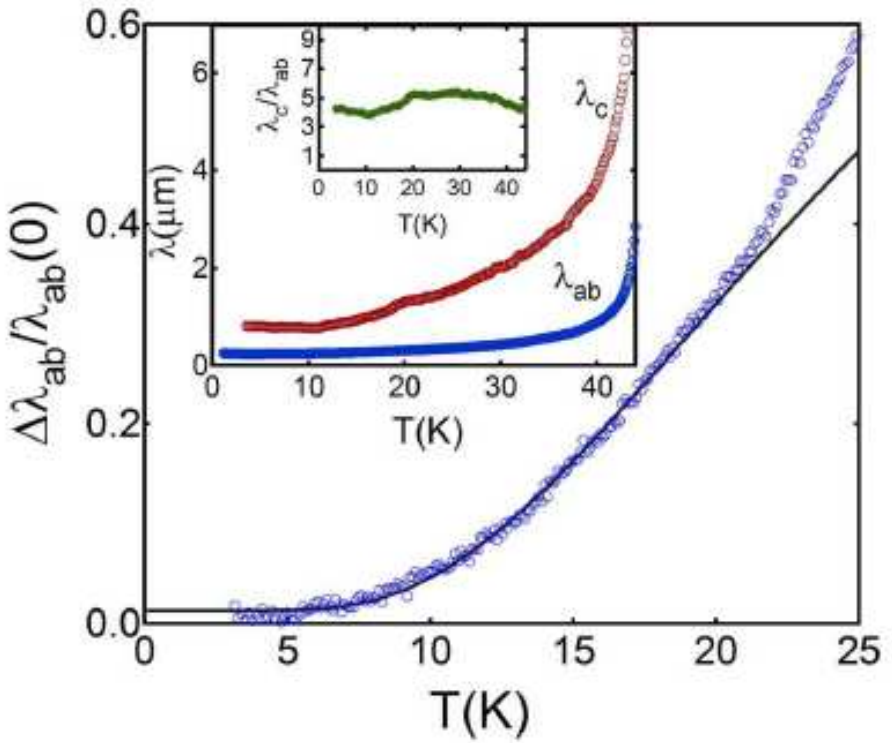


FIG. 3: (Color online)Low temperature region of $\Delta\lambda_{ab}/\lambda_0$. The solid line is the best fit to Eq. (1). The inset shows $\lambda_{ab}(T)$ and $\lambda_c(T)$. The smaller inset shows the ratio $\gamma_\lambda = \lambda_c(T)/\lambda_{ab}(T)$.

$$\frac{\Delta\lambda(T)}{\lambda(0)} = \sqrt{\frac{\pi\Delta_0}{2T}}\exp\left(-\frac{\Delta_0}{T}\right). \qquad (1)$$

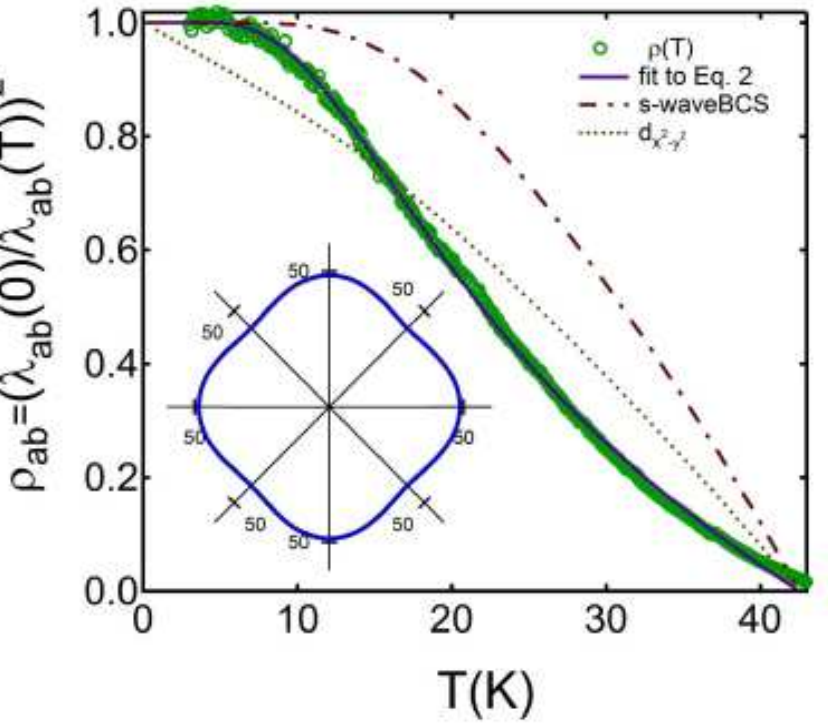


FIG. 4: (Color online)The in-plane superfluid density vs. temperature (symbols). Solid line is a fit to an anisotropic gap described by Eq. 3. The inset shows the angular dependence of the fitting gap. The s-wave BCS (lines and dots) and pure d-wave (dotted line) superfluid densities are plotted for comparison.

$$\Delta(\varphi,T) = \Delta(T)\,\frac{1+\varepsilon\cos(4\varphi)}{1+\varepsilon}, \qquad (3)$$

Final comments on current state of RFeAsO samples and data.

Exact knowledge of how much F goes in or how much O is missing are qualitative, or semi-quantitative at best.

All polycrystalline samples are mixed phase to some extent (in many cases to a very large extent).

Grow of the RFeAsO compounds is very complicated and controlling O or F exacerbates this problem.

Largest single crystals / single grains are on the order of 600 μm.

A lot of work needs to be done to get samples "under control".

There may be an intrinsic O-deficiency in these materials.

But T_c is the highest so far for these FeAs based compounds and gap appears to be without nodes, (at least for some measurements).

Fe-As based superconductors part II

Not even oxides!!!!

$(AE_{1-x}A_x)Fe_2As_2$ $T_C \sim 40$ K

AE = Ba, Sr, Ca A = K, Na, Li

$AE(Fe_{1-x}T_x)_2As_2$ $T_c \sim 30$ K

AE = Ba, Sr, Ca T = Co, Ni, …

Much easier to make (these are not oxides but true intermetallics)

What is role of A and T doping?

What is the nature of the superconductivity, what is the symmetry of the gap?

Superconductivity at 38 K in the iron arsenide $(Ba_{1-x}K_x)Fe_2As_2$

Marianne Rotter, Marcus Tegel and Dirk Johrendt*

arXiv:0805.4630v1 [cond-mat.supr-con] 29 May 2008

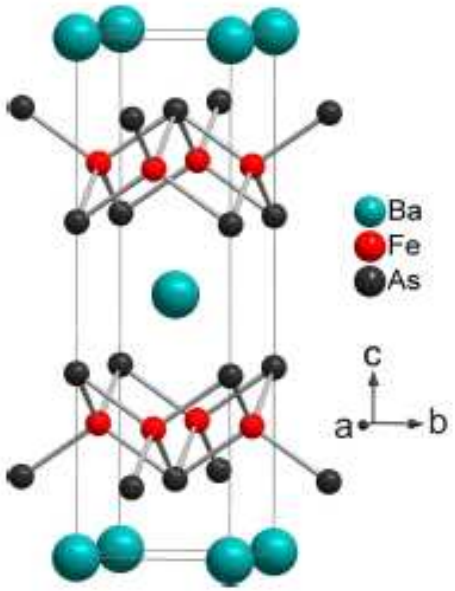
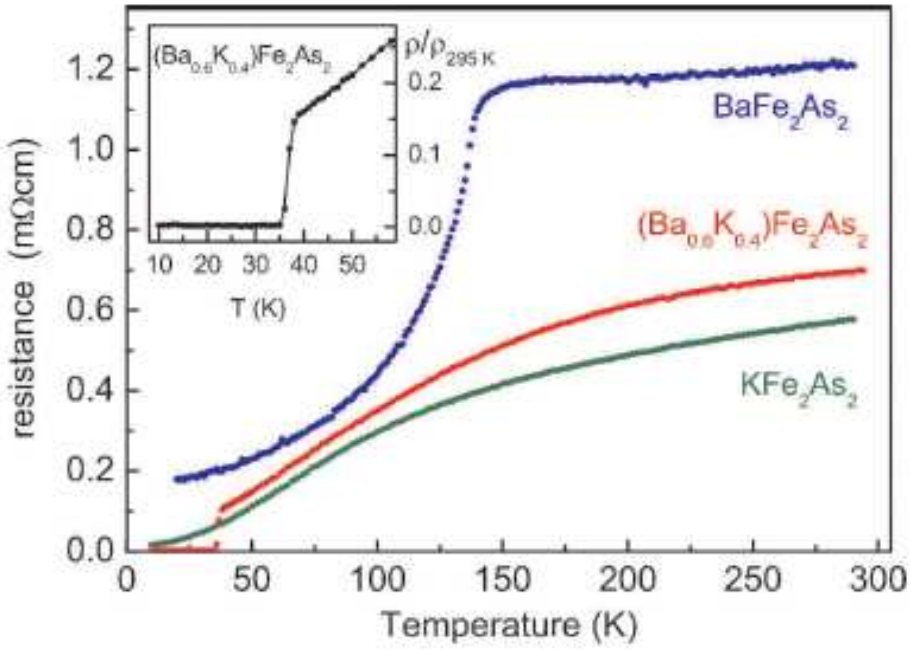


FIG. 1: Crystal structure of $BaFe_2As_2$.



For $BaFe_2As_2$ there is a structural/AF transition that is suppressed with K-doping

In both of these structures there is a square planar sheet of Fe that is capped top and bottom with As. The A or RO layers separate these FeAs units.

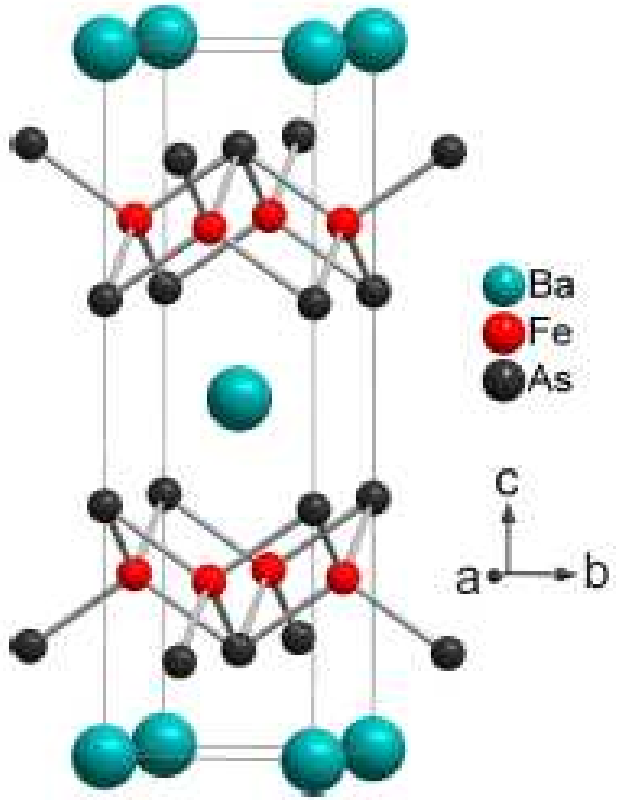
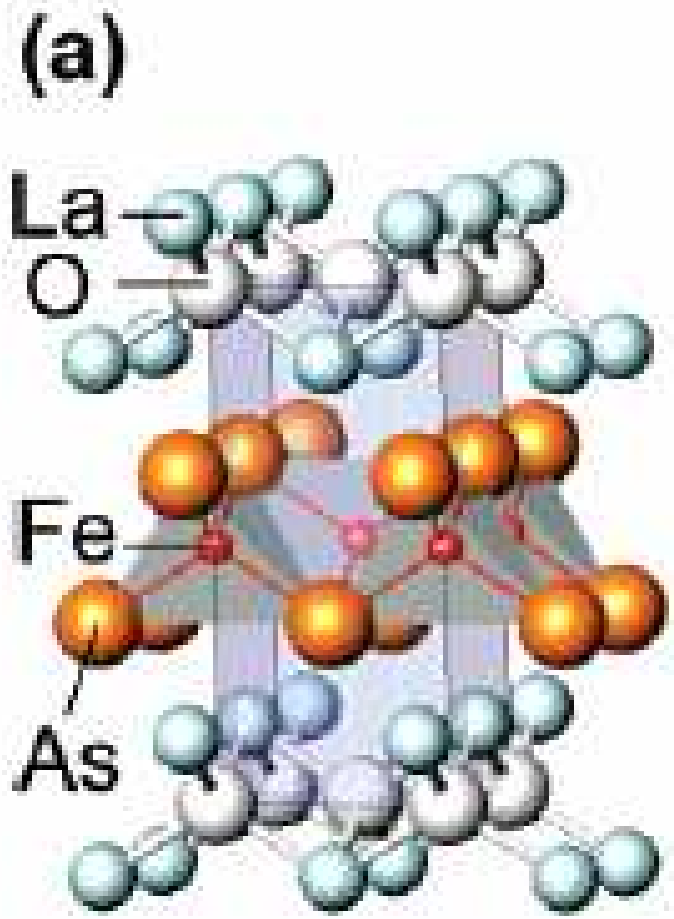


FIG. 1: Crystal structure of $BaFe_2As_2$.



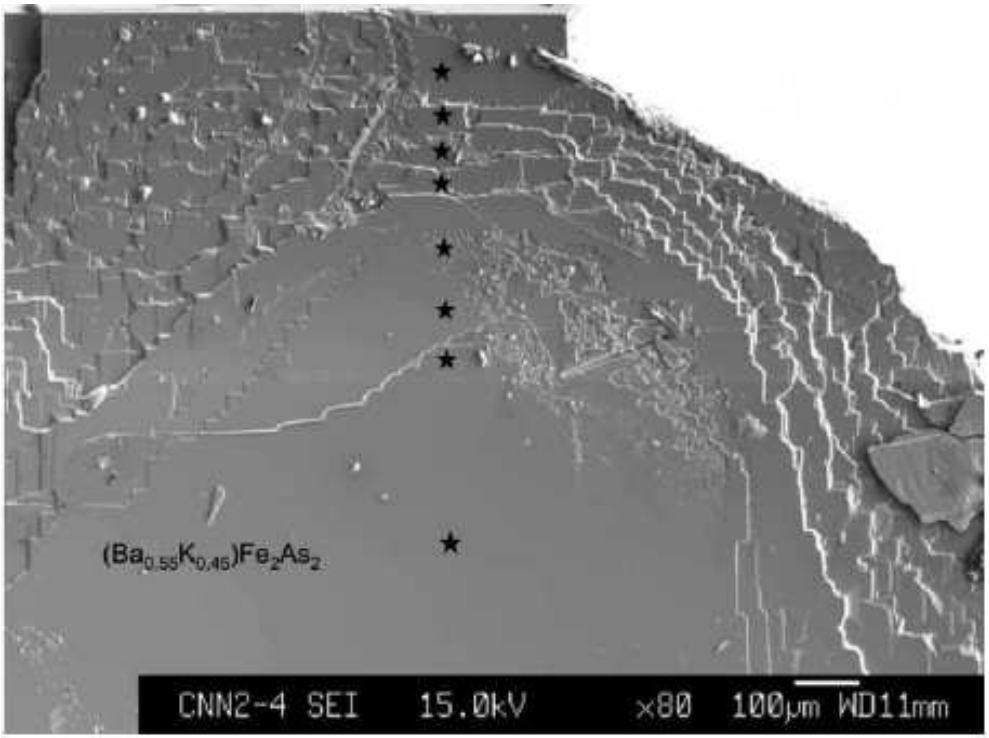
Within two days of reading Rotter's discovery we had grown large single crystals. Now single crystal work can really begin.

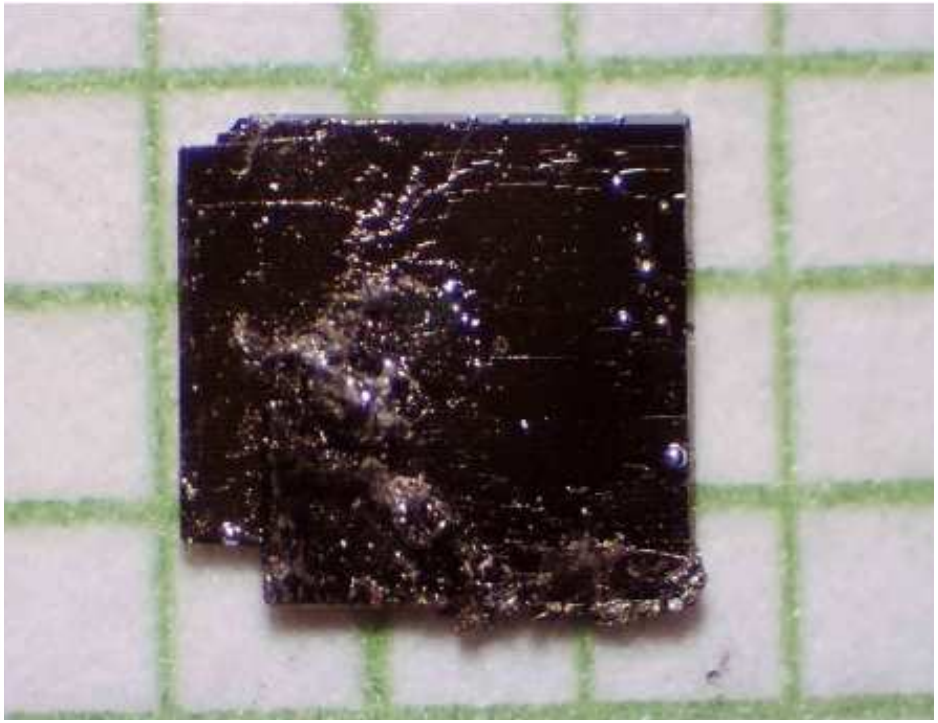
PHYSICAL REVIEW B **78**, 014507 (2008)

Anisotropic thermodynamic and transport properties of single-crystalline $Ba_{1-x}K_xFe_2As_2$ ($x=0$ and 0.45)

N. Ni,[1,2] S. L. Bud'ko,[1,2] A. Kreyssig,[1,2] S. Nandi,[1,2] G. E. Rustan,[1,2] A. I. Goldman,[1,2] S. Gupta,[1,3] J. D. Corbett,[1,3] A. Kracher,[1] and P. C. Canfield[1,2]

(Received 11 June 2008; revised manuscript received 18 June 2008; published 10 July 2008)

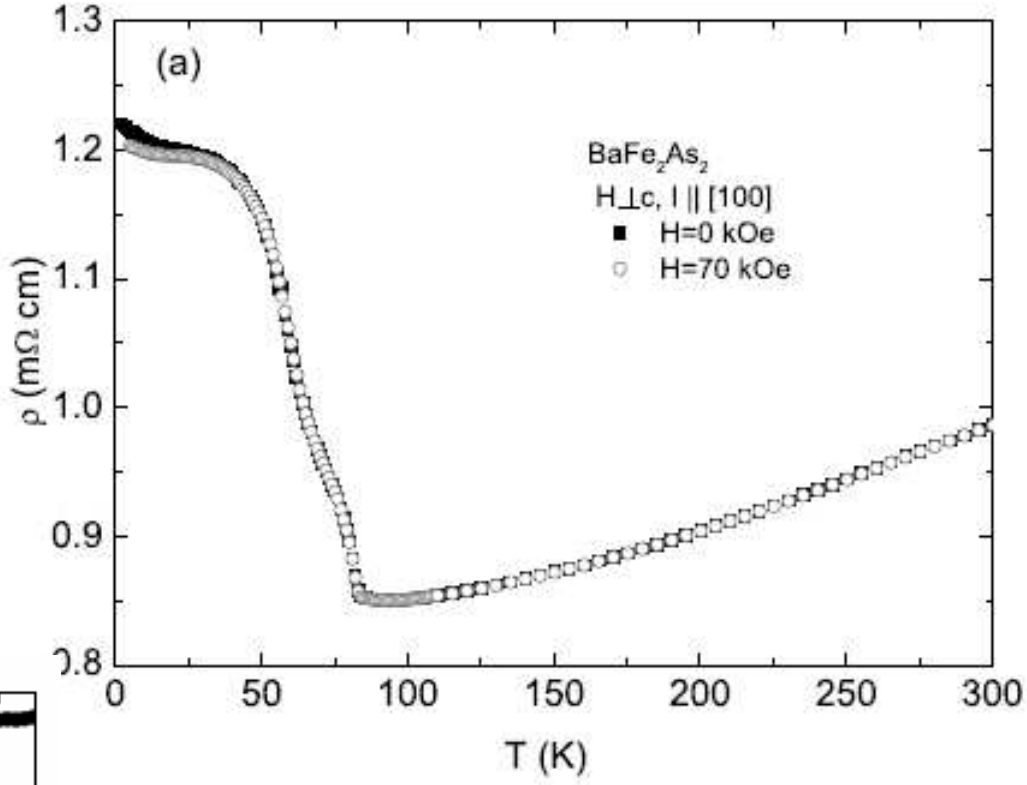


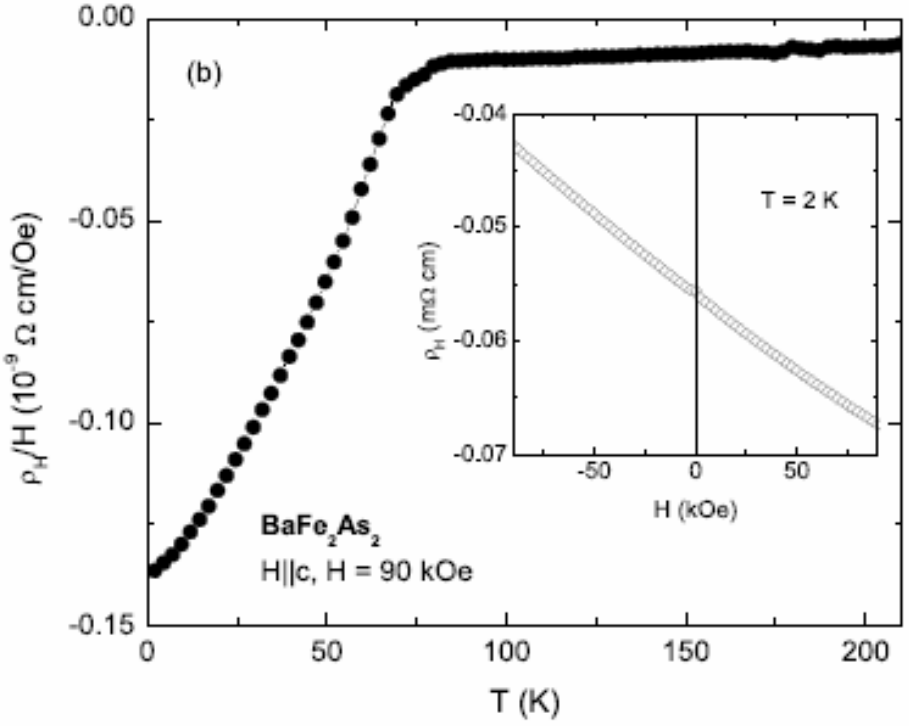


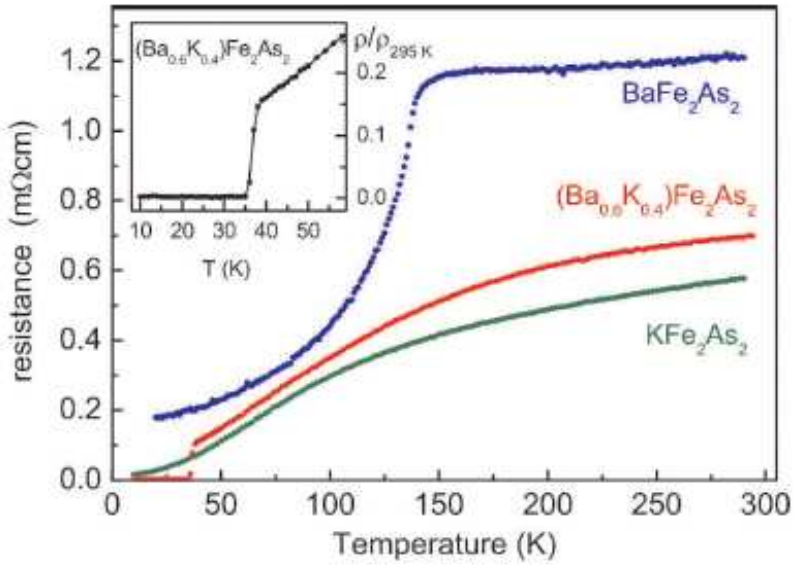
PHYSICAL REVIEW B **78**, 014507 (2008)

$Ba_{1-x}K_xFe_2As_2$ ($x = 0$ and 0.45)

$BaFe_2As_2$ has ~1% Sn substituted for As. Phase transition at ~ 80 K



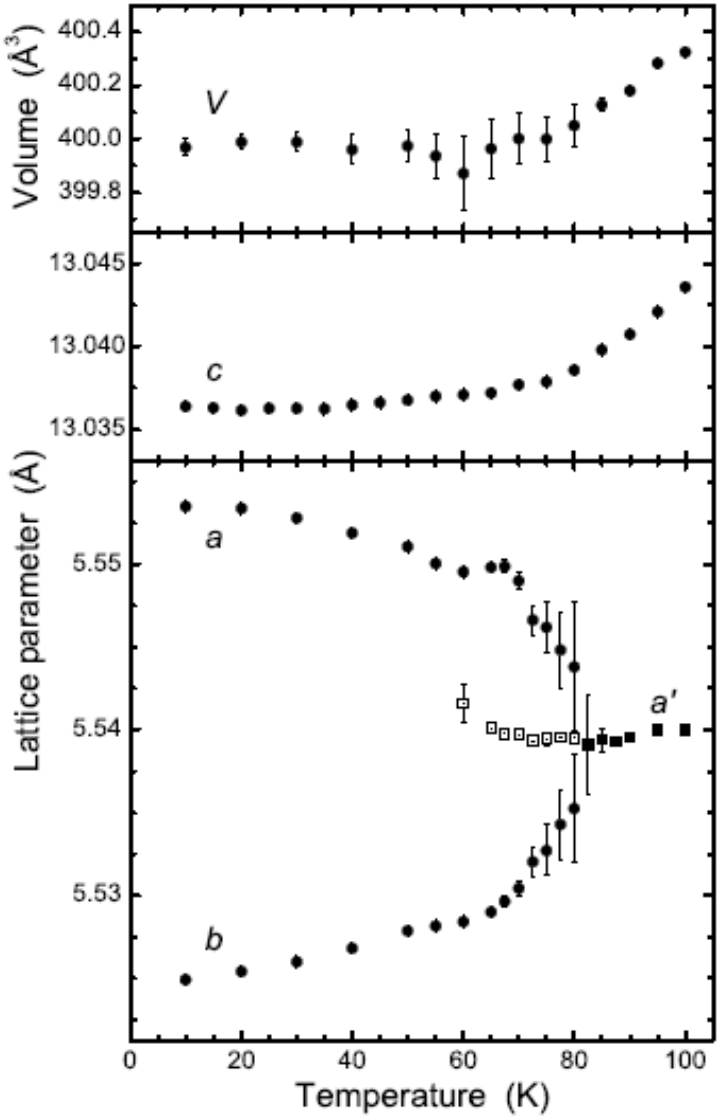


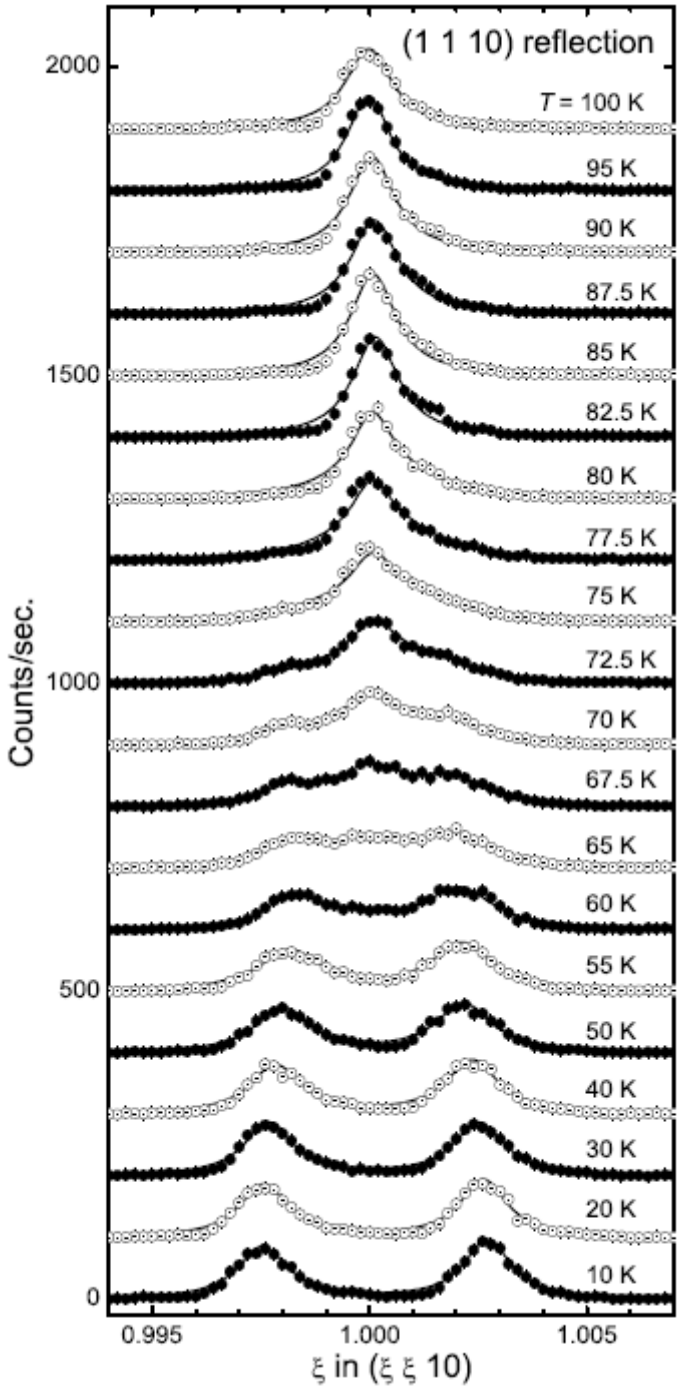


Clear tet –ortho transition and probably first order

PHYSICAL REVIEW B 78, 014507 (2008)

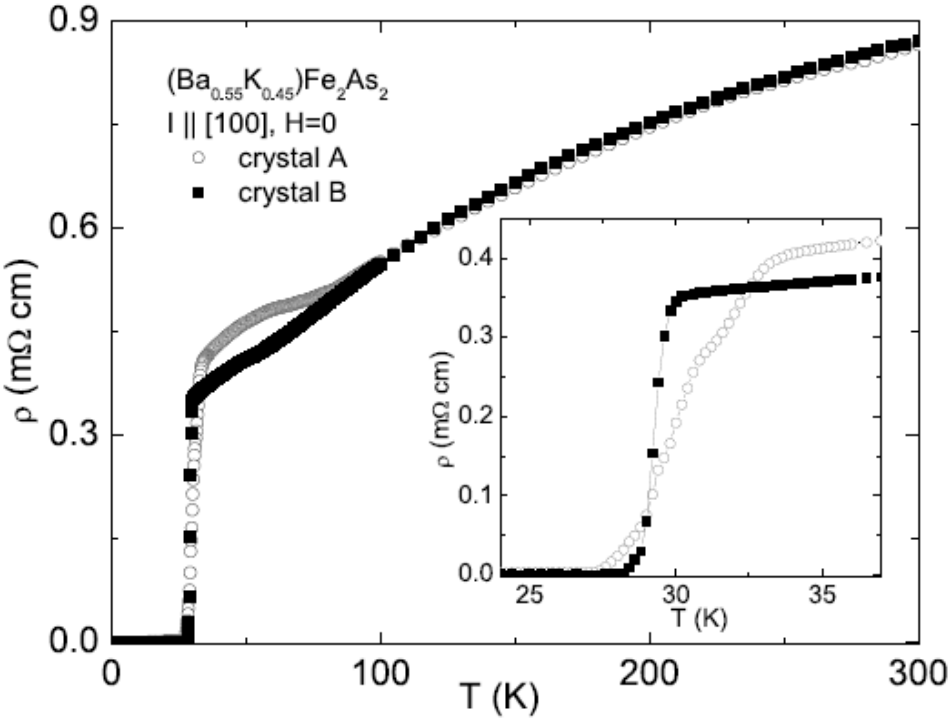
$Ba_{1-x}K_xFe_2As_2$ ($x = 0$ and 0.45)

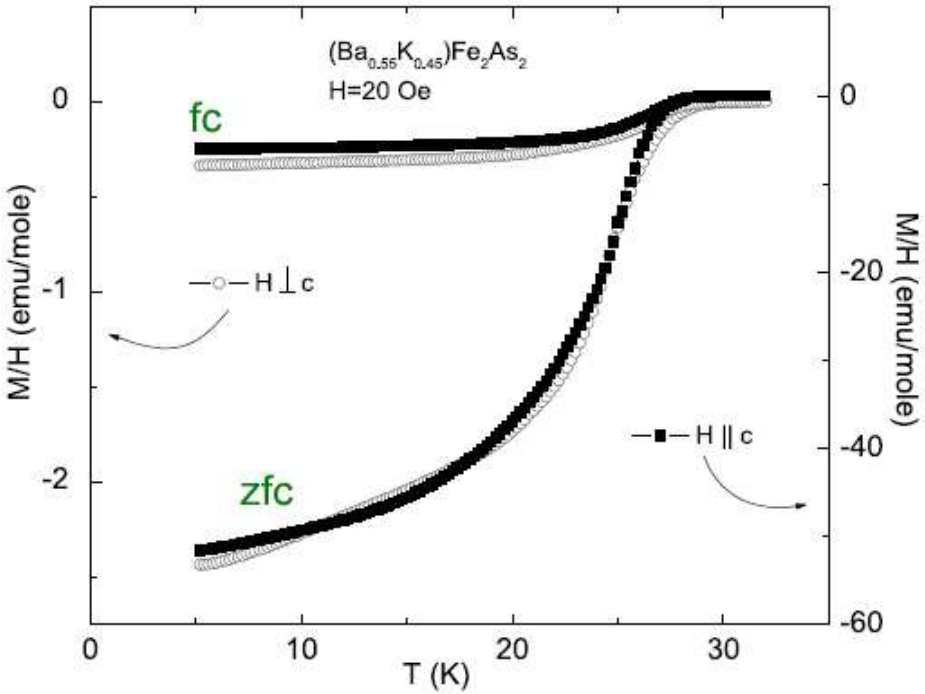




PHYSICAL REVIEW B **78**, 014507 (2008)

$Ba_{1-x}K_xFe_2As_2$ ($x=0$ and 0.45)



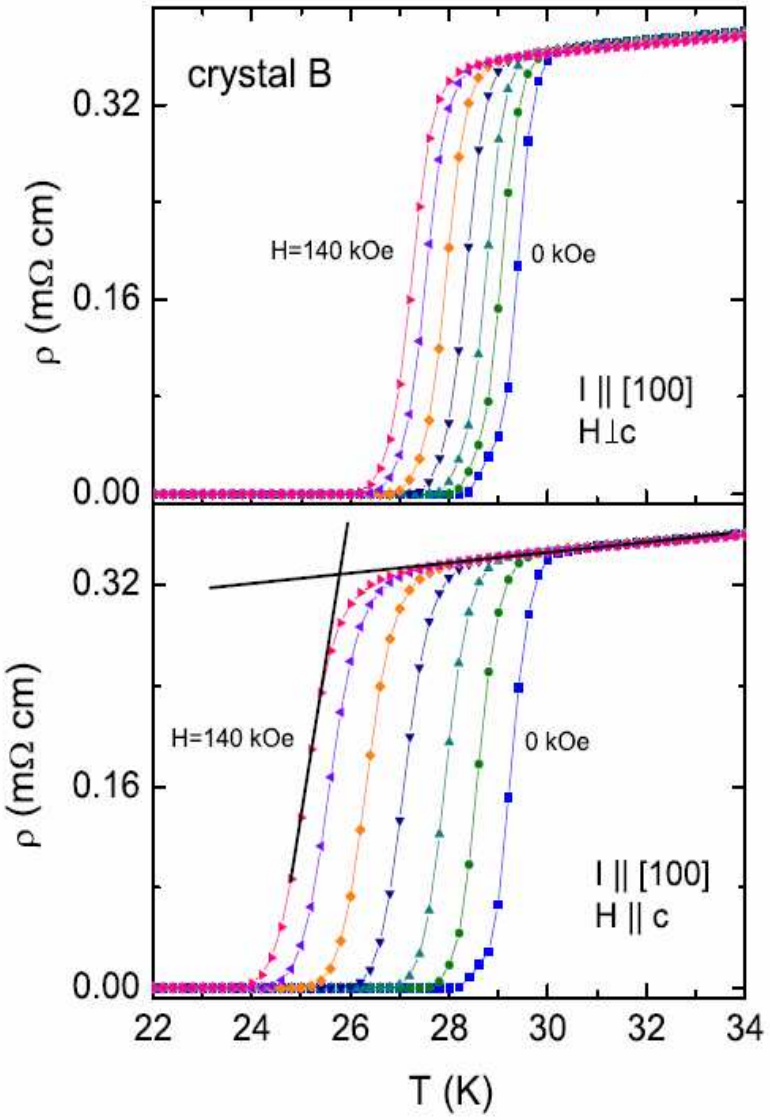


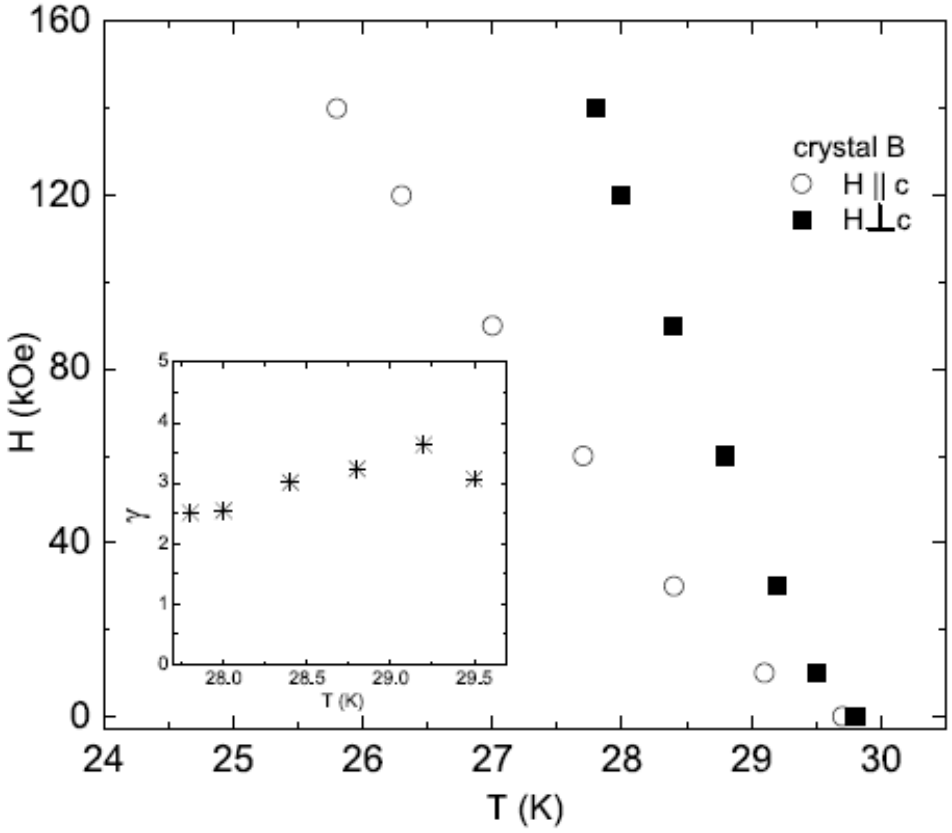
When K is substituted for Ba we get T_C of 30 K for ~40% K.

NOTE: from elemental analysis K values vary from plane to plane 40 +- 7 %

PHYSICAL REVIEW B **78**, 014507 (2008)

$Ba_{1-x}K_xFe_2As_2$ ($x = 0$ and 0.45)



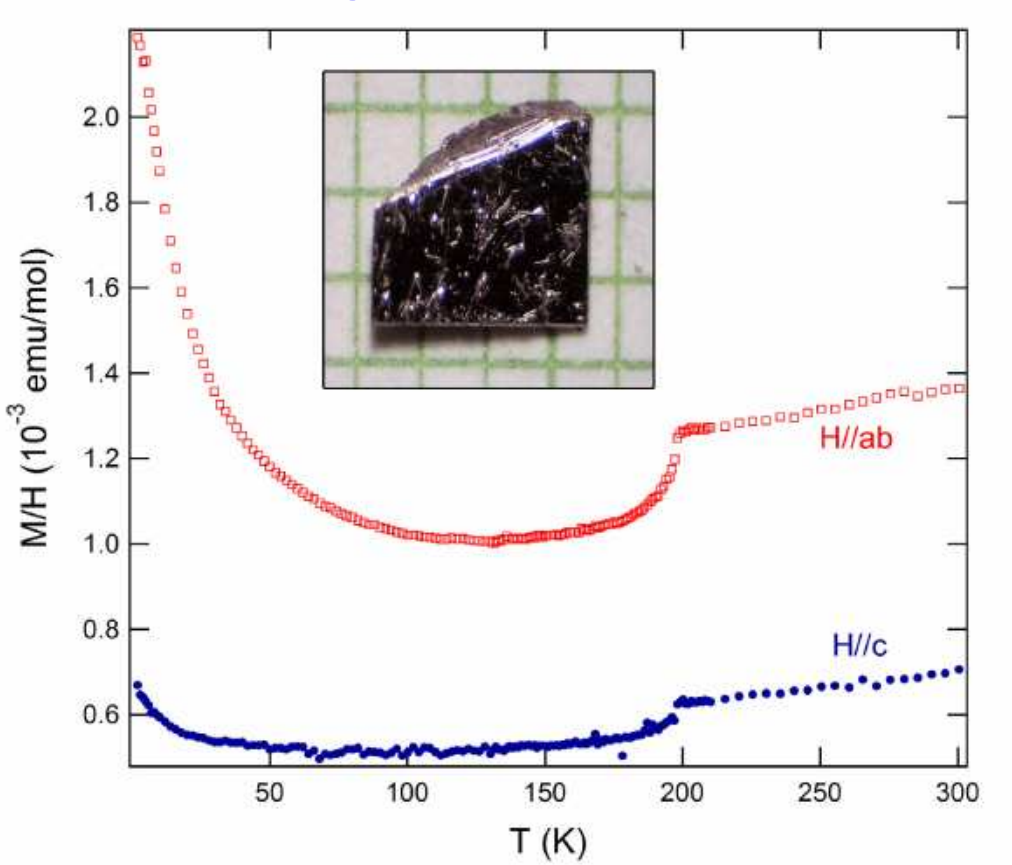


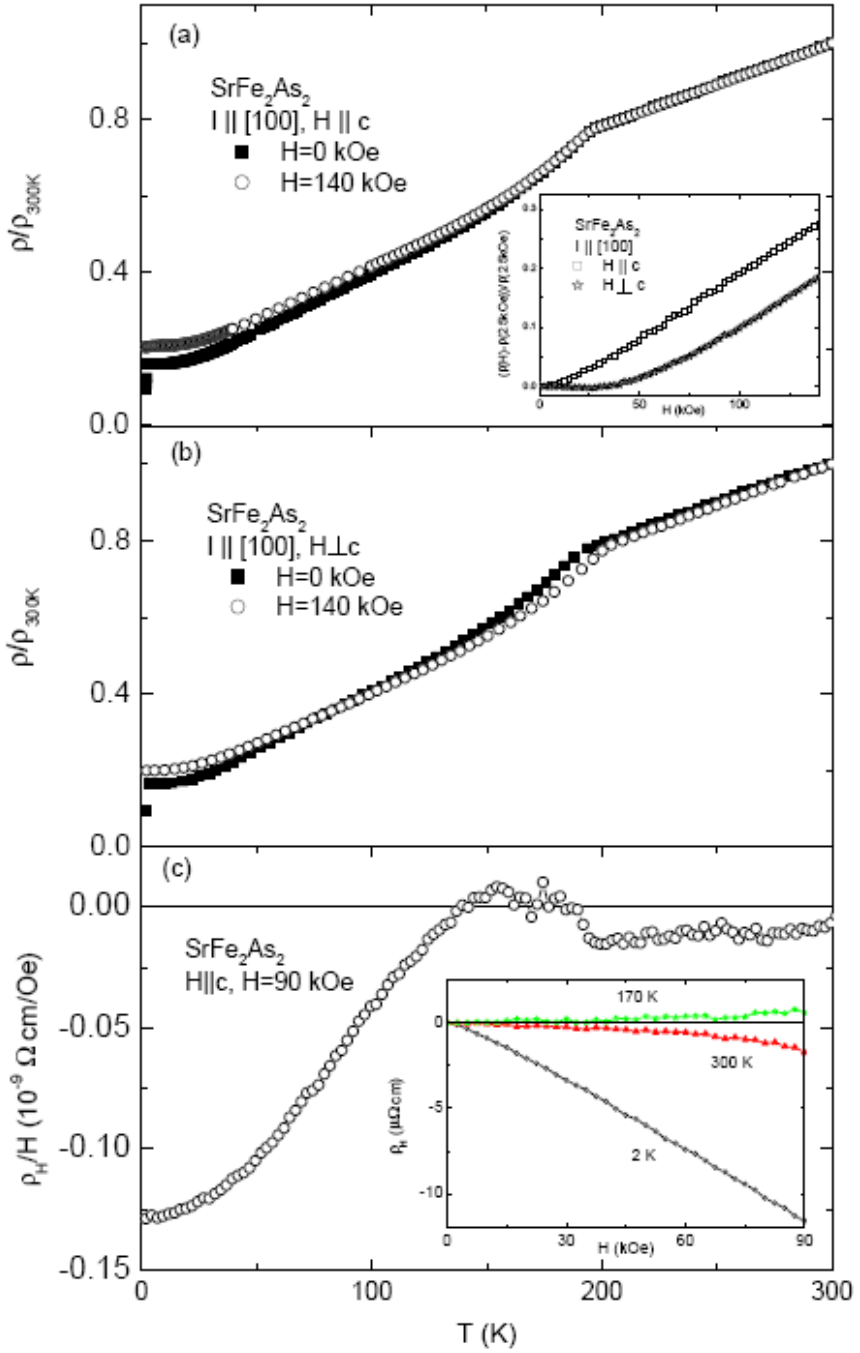
H_{c2}(T= 0 K) values as high as 70 or 100 T are not unreasonable….

Structural transition and anisotropic properties of single-crystalline $SrFe_2As_2$

PHYSICAL REVIEW B 78, 024516 (2008)

$SrFe_2As_2$ was another know member of the $ThCr_2Si_2$ structure that was shown to superconduct with alkali-doping as well. Single crystals showed less Sn-uptake and clearer, first order signatures.

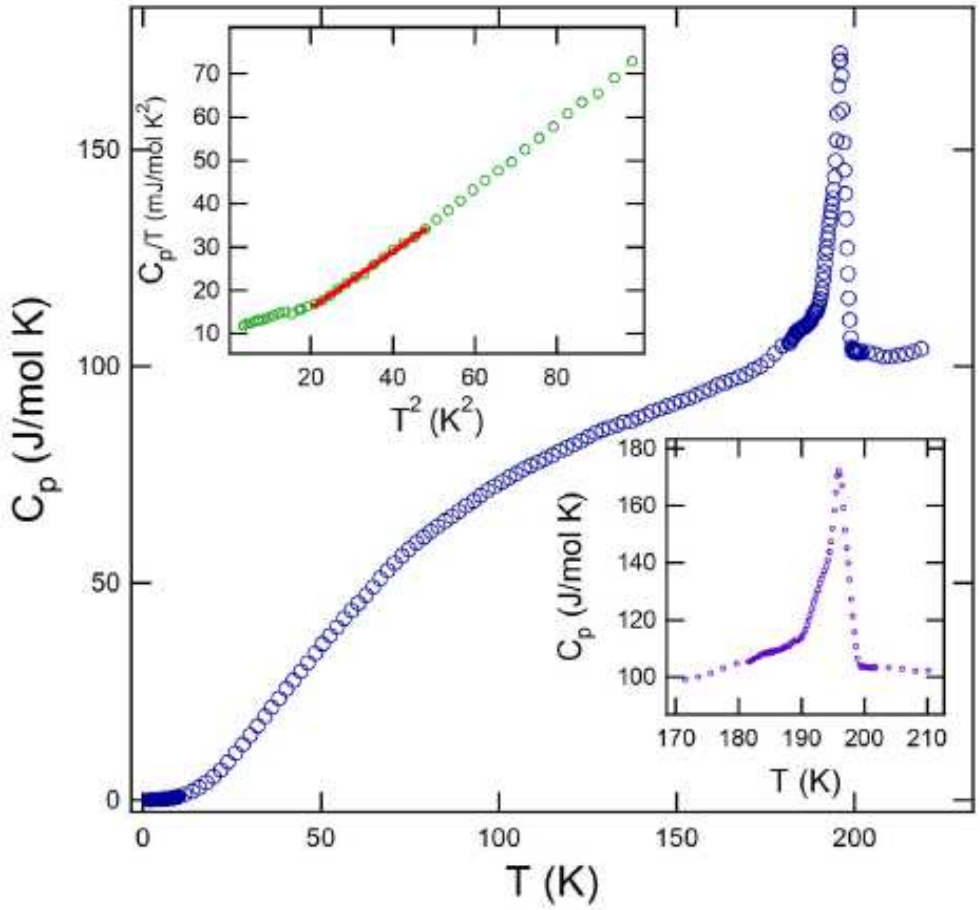


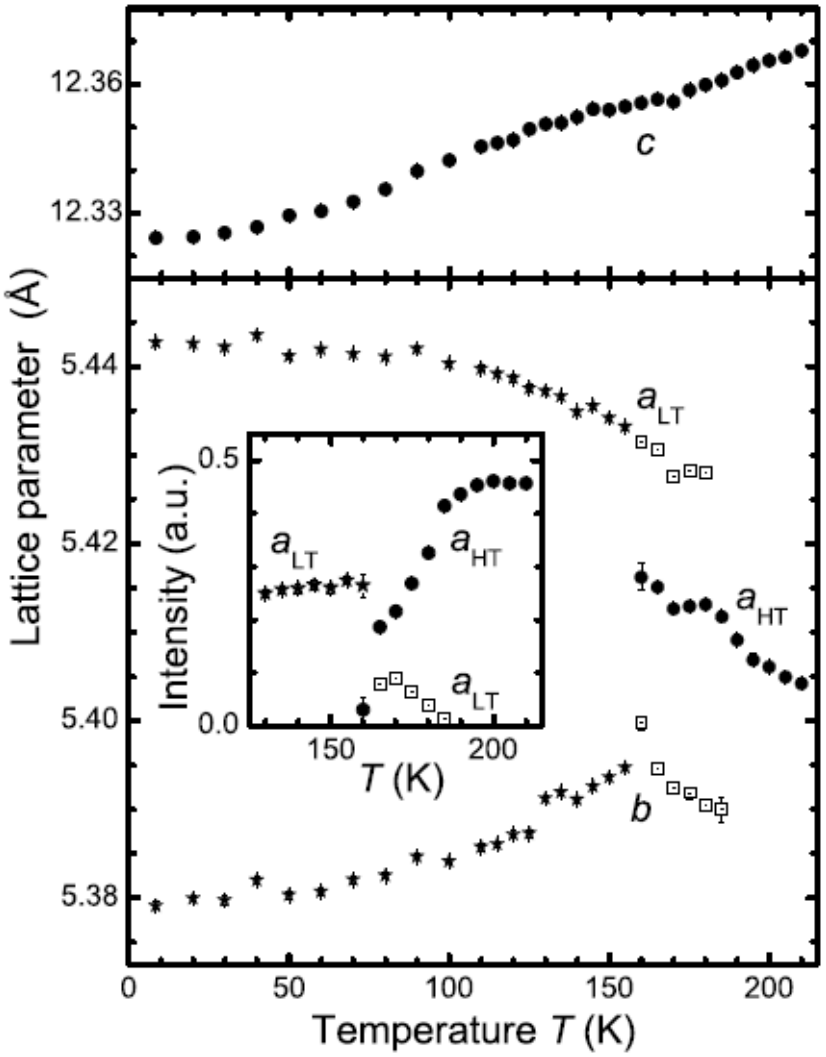


PHYSICAL REVIEW B 78, 024516 (2008)

Structural transition and anisotropic properties of single-crystalline $SrFe_2As_2$

J.-Q. Yan,[1] A. Kreyssig,[1,2] S. Nandi,[1,2] N. Ni,[1,2] S. L. Bud'ko,[1,2] A. Kracher,[1] R. J. McQueeney,[1,2] R. W. McCallum,[1,3] T. A. Lograsso,[1] A. I. Goldman,[1,2] and P. C. Canfield[1,2]





The substitution of K for Ba or Sr in the $(AE)Fe_2As_2$ materials is difficult, due to a combination of vapor pressure and reactivity, and can lead to compositional inhomogeneities. This is a problem for crystal grown from Sn as well as those grown from FeAs.

PHYSICAL REVIEW B 78, 014507 (2008)

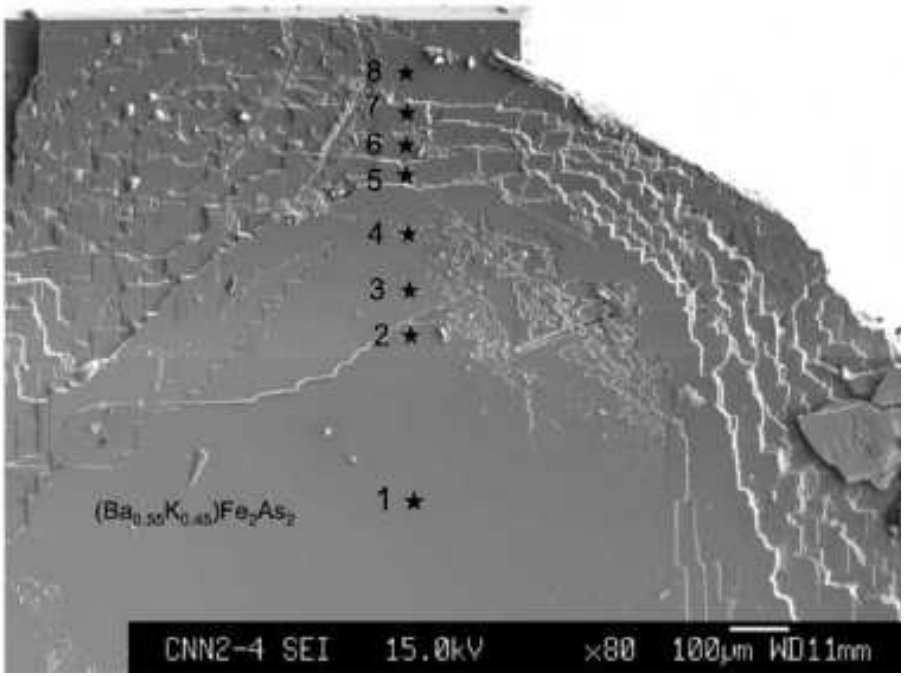


TABLE I. WDS elemental analysis (in atomic %) for $Ba_{0.55}K_{0.45}Fe_2As_2$ single crystal shown in Fig. 2.

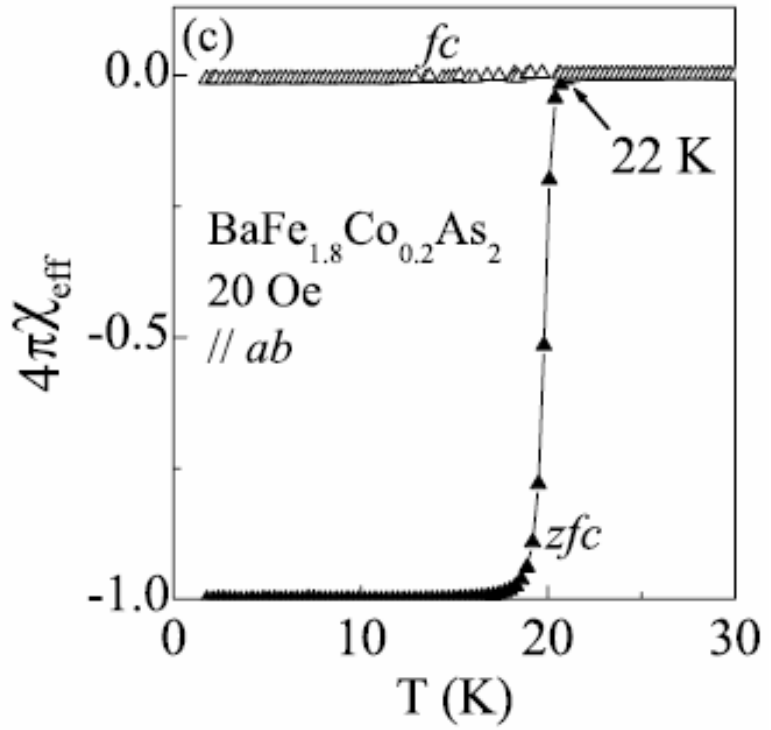
Point	As	Sn	K	Fe	Ba	K/(K+Ba)
1	37.6	0.53	10.2	41.7	9.9	0.51
2	38.5	0.74	8.1	40.3	12.3	0.40
3	38.3	0.89	6.8	42.1	12.0	0.36
4	38.1	0.93	7.0	41.5	12.6	0.36
5	38.4	0.48	10.3	40.6	10.3	0.50
6	38.3	0.48	10.7	40.9	9.7	0.53
7	38.5	0.74	8.8	41.4	10.6	0.45
8	38.2	0.71	9.4	41.4	10.2	0.48

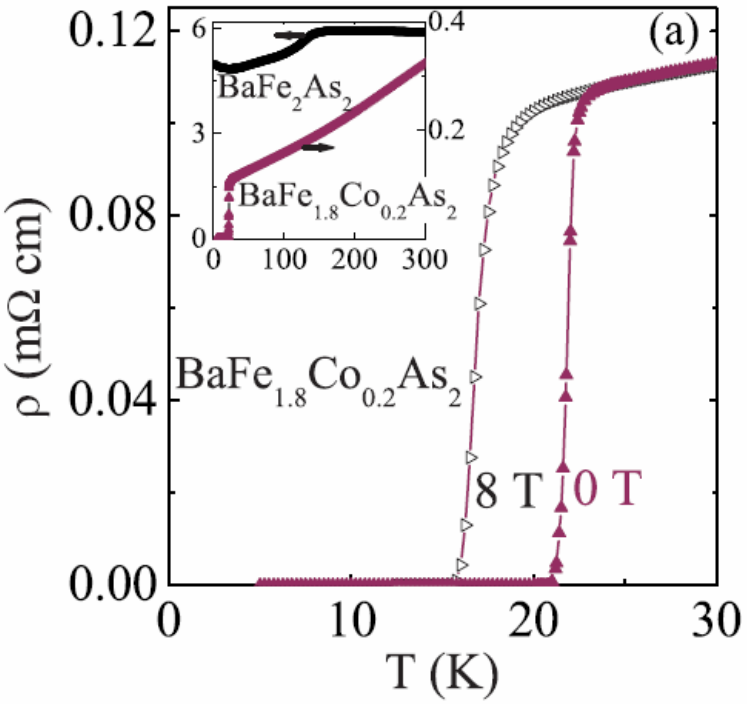
Several groups found that substitution of Co for Fe could stabilize superconductivity….This is *very* different from the copper oxide materials.

PRL **101,** 117004 (2008) PHYSICAL REVIEW LETTERS week ending 12 SEPTEMBER 2008

Superconductivity at 22 K in Co-Doped $BaFe_2As_2$ Crystals

Athena S. Sefat, Rongying Jin, Michael A. McGuire, Brian C. Sales, David J. Singh, and David Mandrus
Materials Science & Technology Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA
(Received 25 July 2008; published 11 September 2008)





The Co-doped samples have lower maximum T_c values (compared to the K-doping) but are easier to make and appear to be more homogeneous.

Superconductivity in $SrFe_{2-x}Co_xAs_2$: Internal Doping of the Iron Arsenide Layers

A. Leithe-Jasper, W. Schnelle, C. Geibel, and H. Rosner
Max-Planck-Institut für Chemische Physik fester Stoffe, Nöthnitzer Str. 40, 01187 Dresden, Germany

arXiv:0807.2223v1 [cond-mat.supr-con] 14 Jul 2008

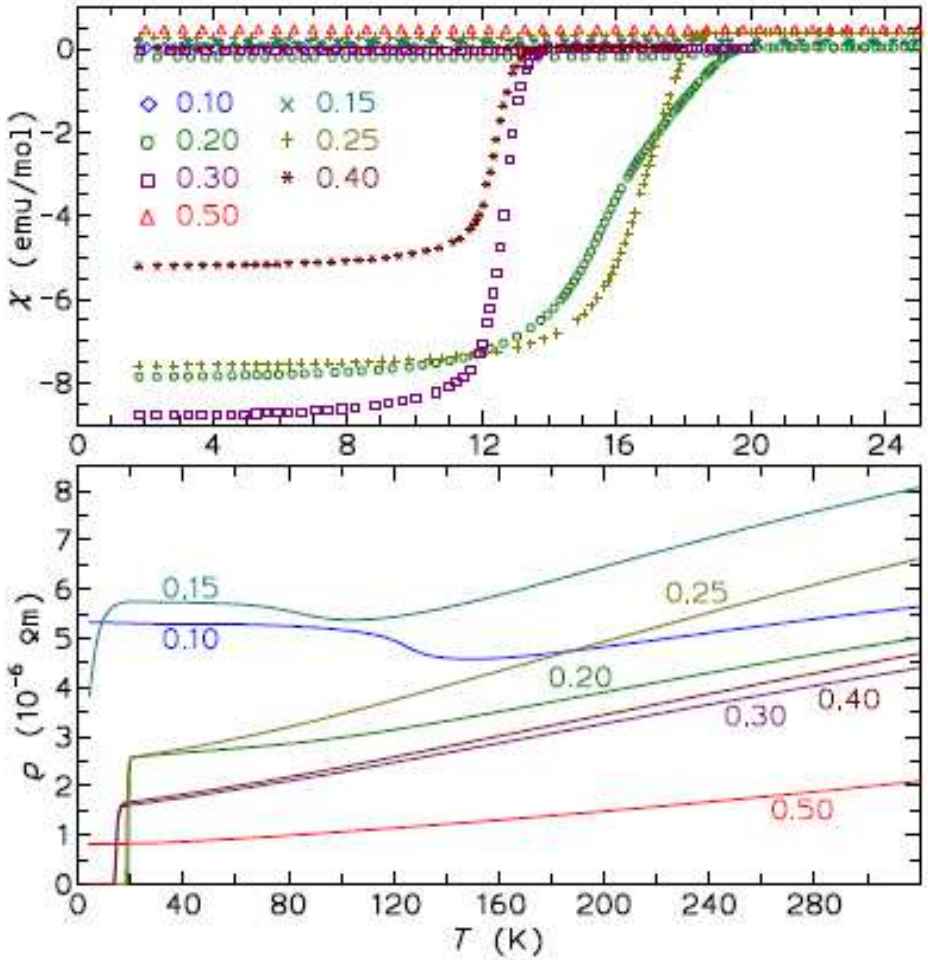
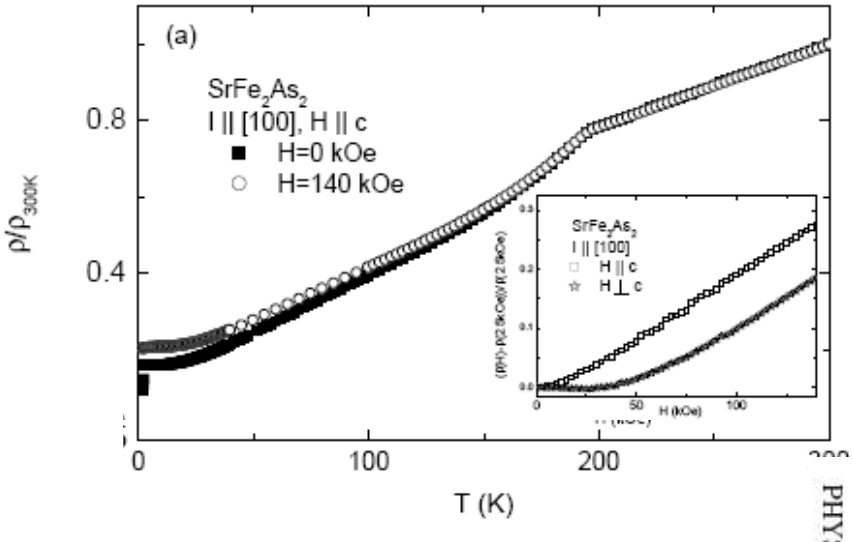


FIG. 1: (Color online) Top: magnetic susceptibility $\chi(T)$ of $SrFe_{2-x}Co_xAs_2$ samples in a nominal field of $\mu_0 H = 2\,\mathrm{mT}$. Bottom: electrical resistivity of the same samples.



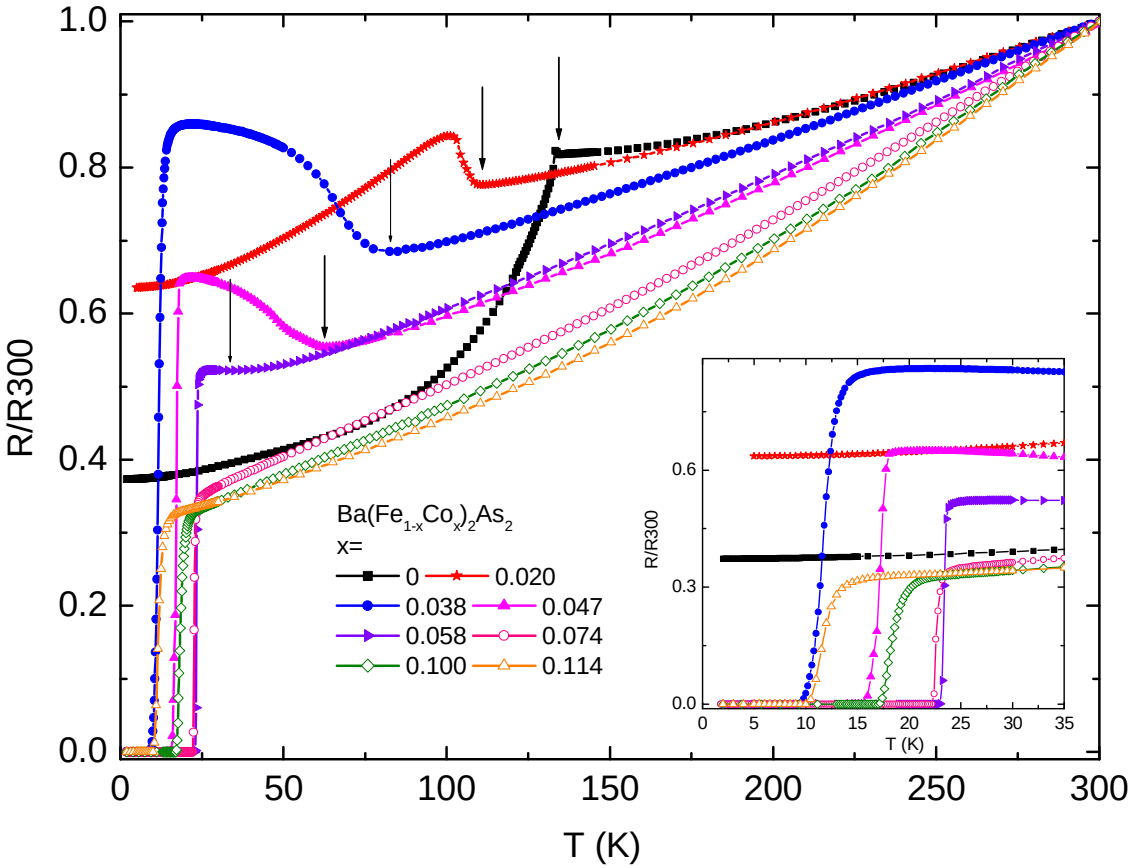
Note that suppression of the upper transition with Co affects the resistive anomaly in a manner similar to our initial Sn doping.

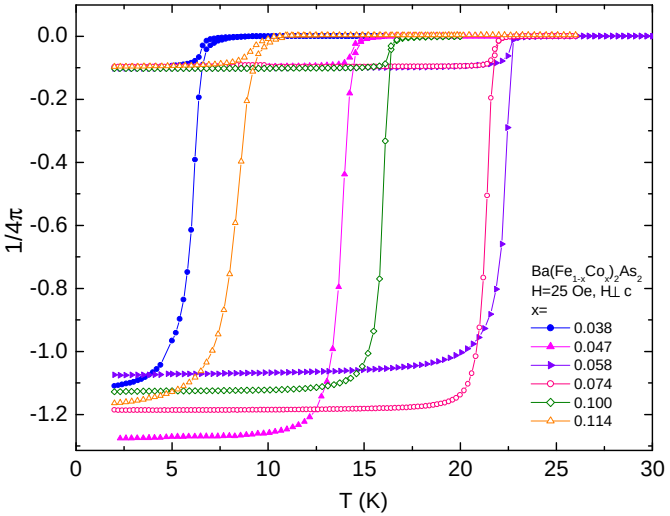
Structural transition and anisotropic properties of single-crystalline $SrFe_2As_2$
PHYSICAL REVIEW B 78, 024516 (2008)

We have performed an extensive study of the $Ba(Fe_{1-x}Co_x)_2As_2$ series

Note: ---evolution of high temperature resistive anomaly

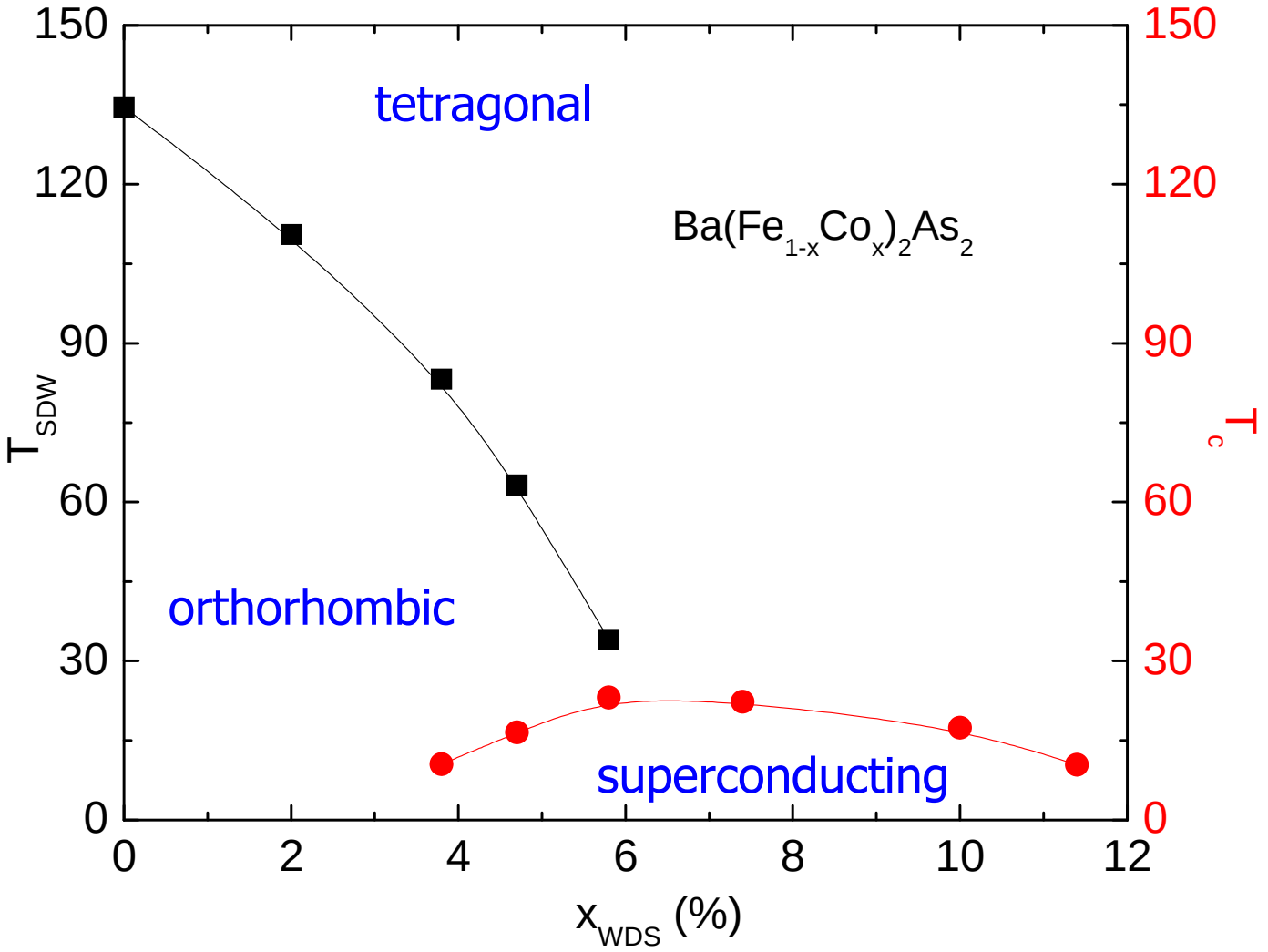
Note: ---well defined and fairly broad region of superconductivity





Ni Ni et al, unpublished

For $Ba(Fe_{1-x}Co_x)_2As_2$ we again see superconductivity emerge as we suppress the structural (antiferromagnetic) transition



BUT we do see supercond. clearly existing in the ortho / antiferro phase as well as in the tetragonal one....*Assuming a homogeneous sample.*

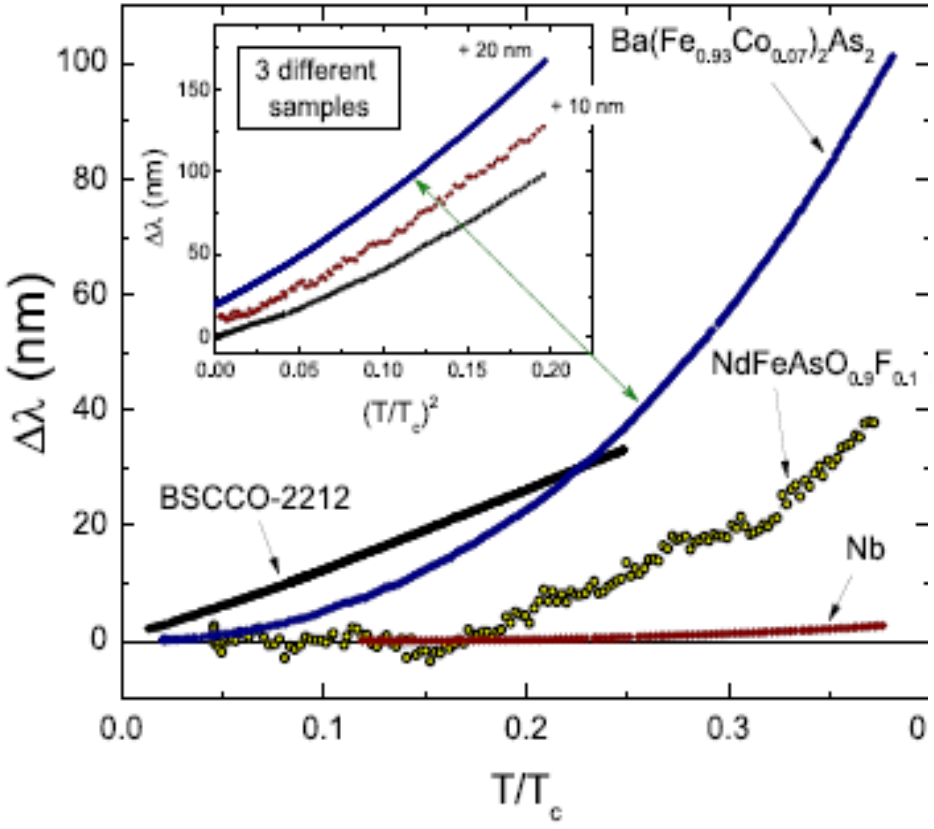
Ni Ni et al, unpublished

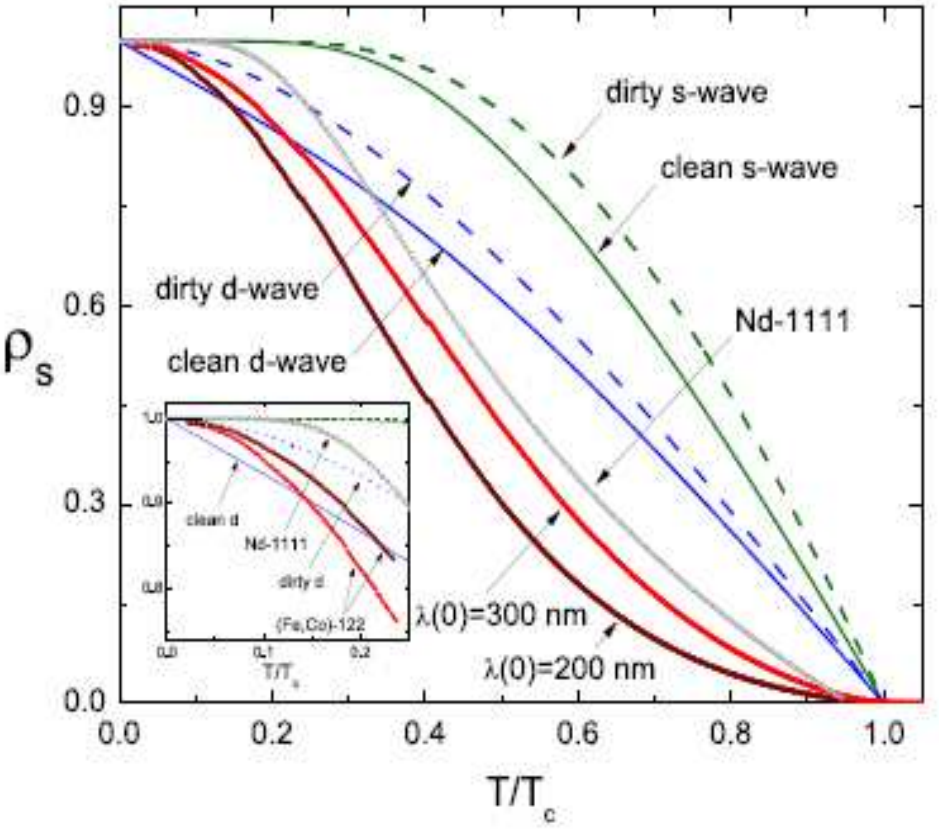
Unconventional London penetration depth in $Ba(Fe_{0.93}Co_{0.07})_2As_2$ single crystals

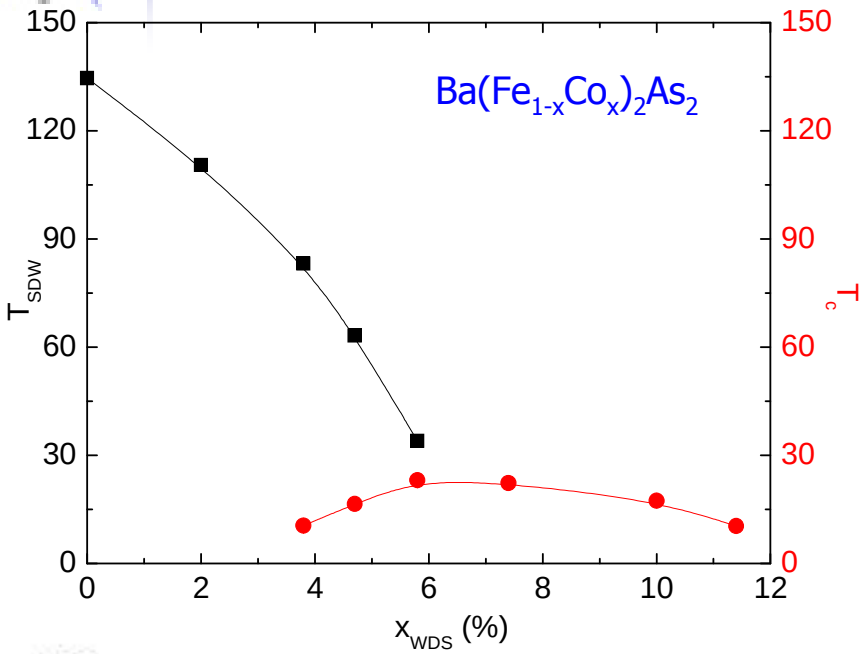
R. T. Gordon, N. Ni, C. Martin, M. A. Tanatar, M. D. Vannette, H. Kim, G. Samolyuk, J. Schmalian, S. Nandi, A. Kreyssig, A. I. Goldman, J. Q. Yan, S. L. Bud'ko, P. C. Canfield, and R. Prozorov*
Ames Laboratory and Department of Physics & Astronomy, Iowa State University, Ames, IA 50011
(Dated: 11 October 2008)

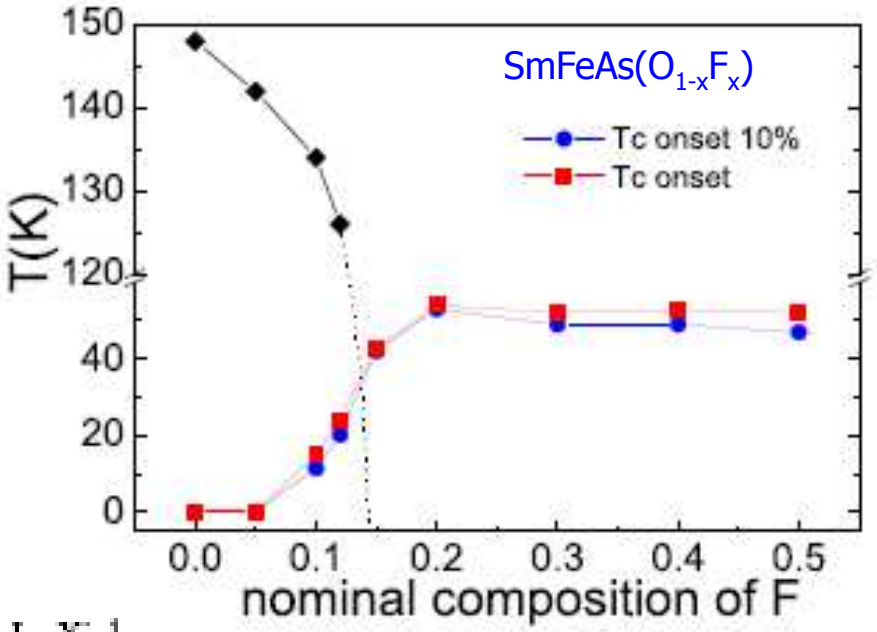
arXiv:0810.2295v1 [cond-mat.supr-con] 13 Oct 2008

Unlike $NdFeAs(O_{1-x}F_x)$, $Ba(Fe_{1-x}Co_x)_2As_2$ appear to have nodes….









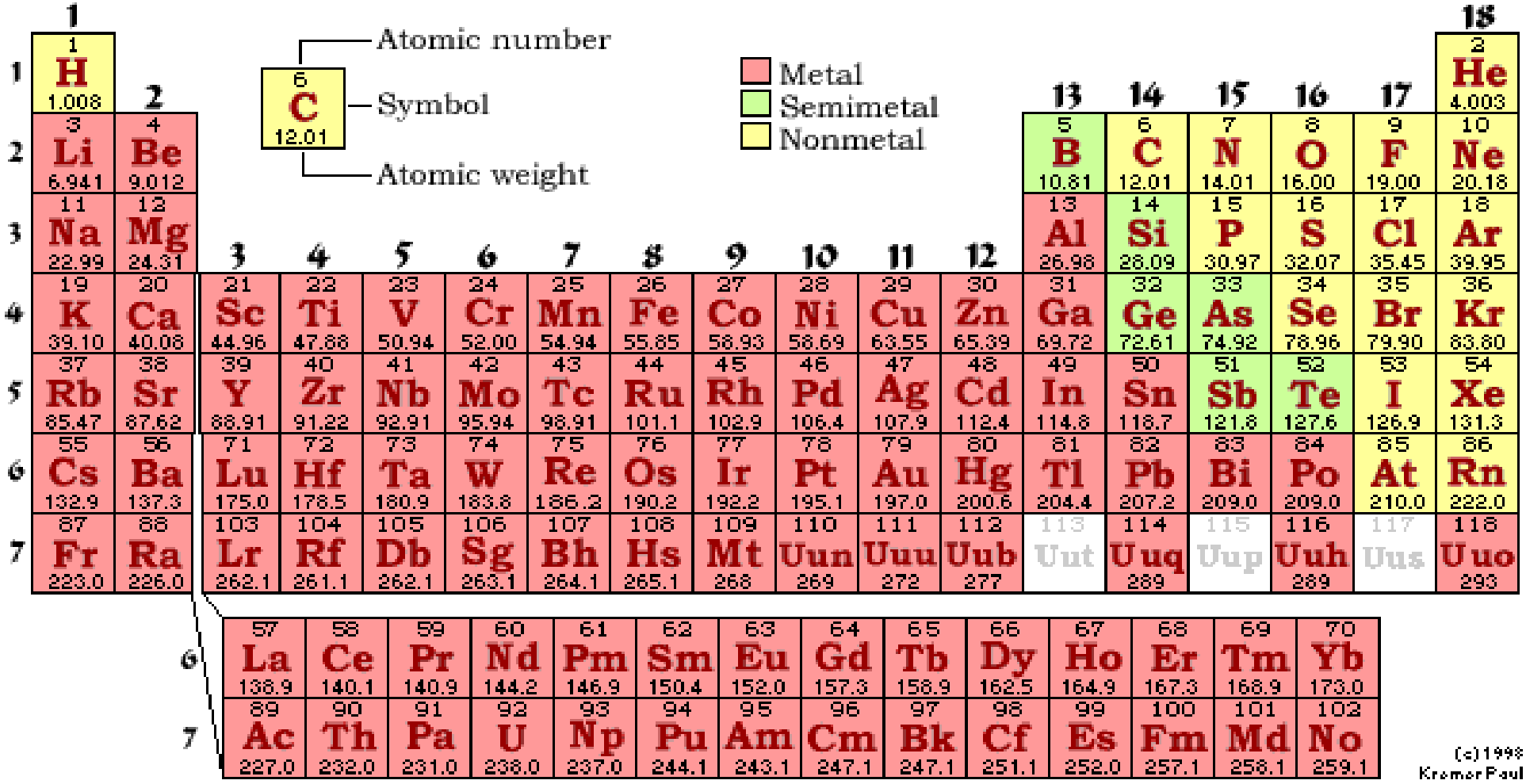
L. Xie[1],

The doping dependence of the structural / antiferromagnetic phase transition, as well as the doping dependence of T_c are very similar between the different families. Superconductivity appears when the structural / antiferromagnetic phase is either partially or fully suppressed.

Similar phase diagrams are found for virtually all examples of the 1111 and 122 compounds.

Both $BaFe_2As_2$ and $SrFe_2As_2$ were both know members of this structure….We decided to see if a new member could be found (and explored)

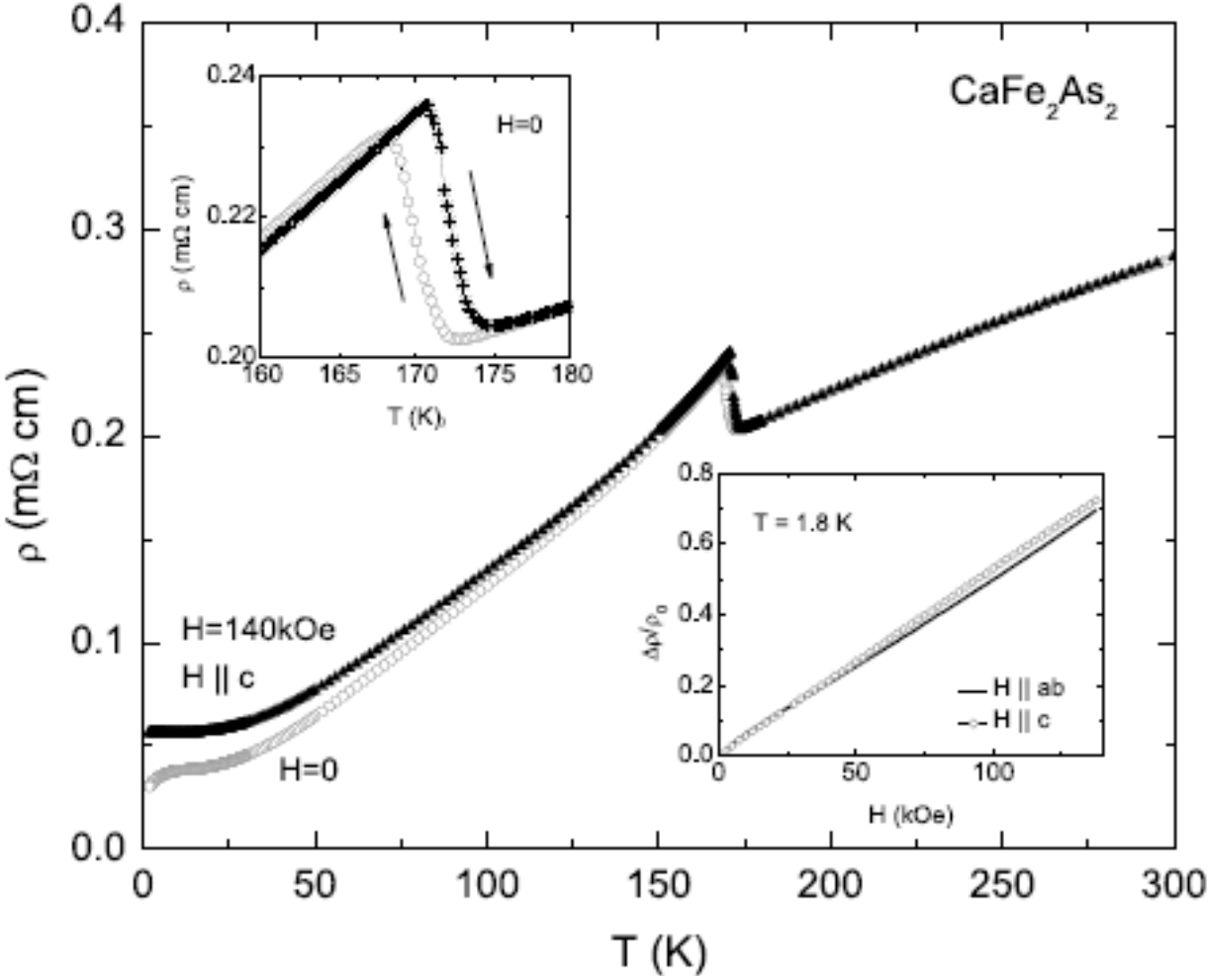
Both Ba and Sr members, when substituted with K suppressed the high temp, structural (magnetic) phase transition and became superconductors….

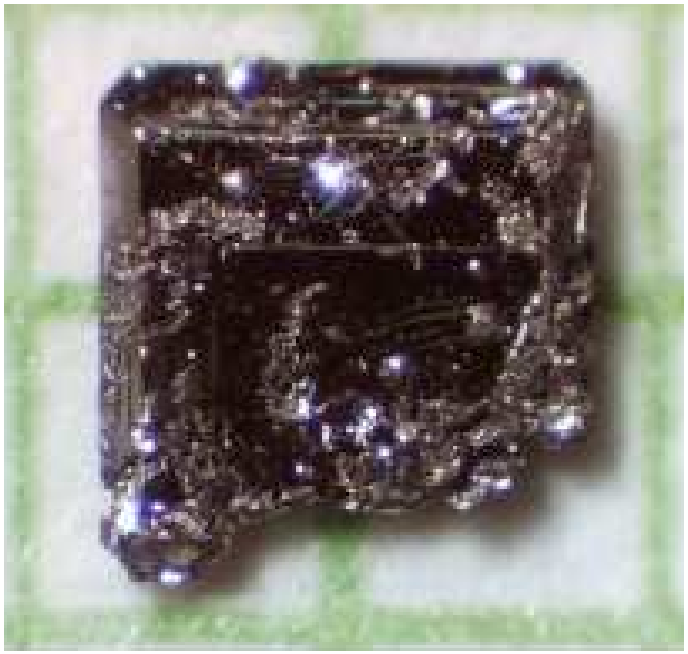


PHYSICAL REVIEW B 78, 014523 (2008)

First-order structural phase transition in $CaFe_2As_2$

N. Ni, S. Nandi, A. Kreyssig, A. I. Goldman, E. D. Mun, S. L. Bud'ko, and P. C. Canfield





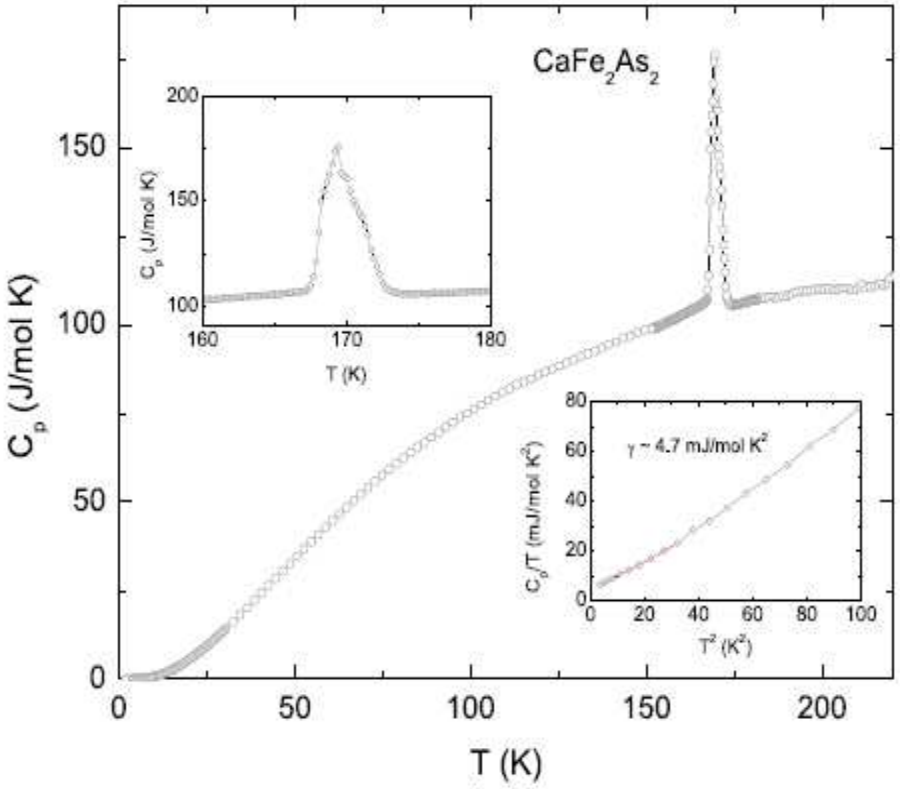
PHYSICAL REVIEW B 78, 014523 (2008)

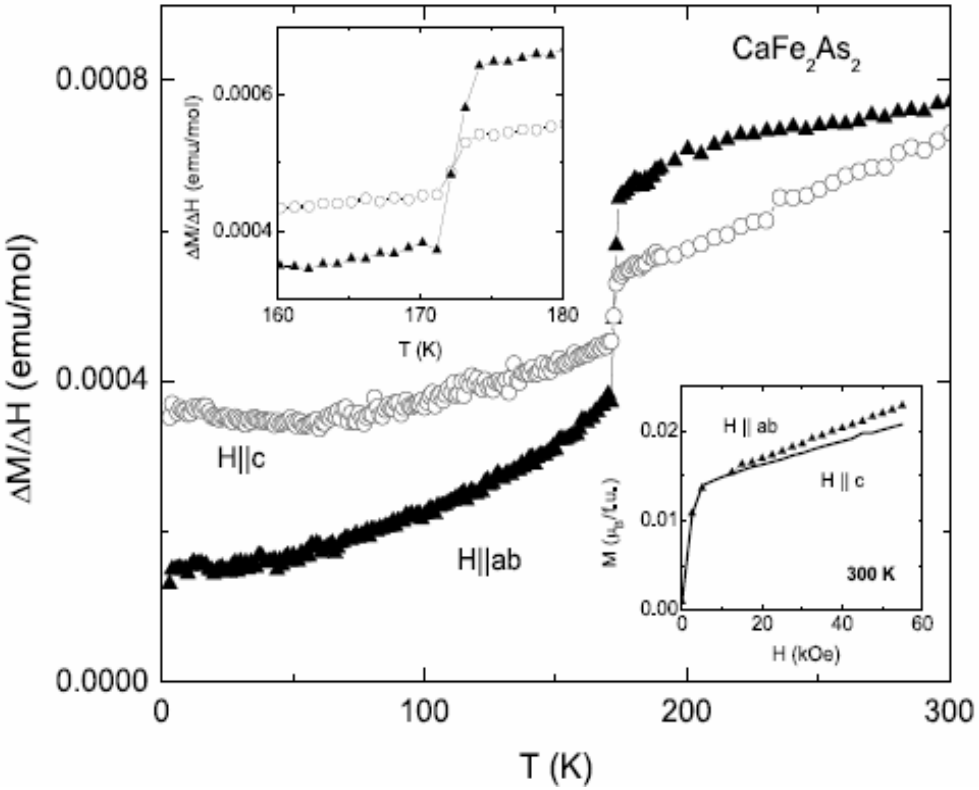
First-order structural phase transition in $CaFe_2As_2$

N. Ni, S. Nandi, A. Kreyssig, A. I. Goldman, E. D. Mun, S. L. Bud'ko, and P. C. Canfield

No detectable Sn uptake into crystal

Striking manifestation of first order phase transition in thermodynamic and transport measurements.

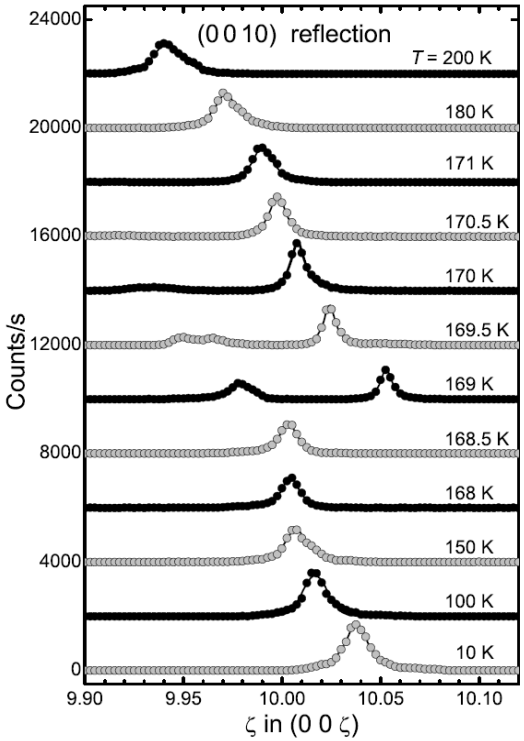


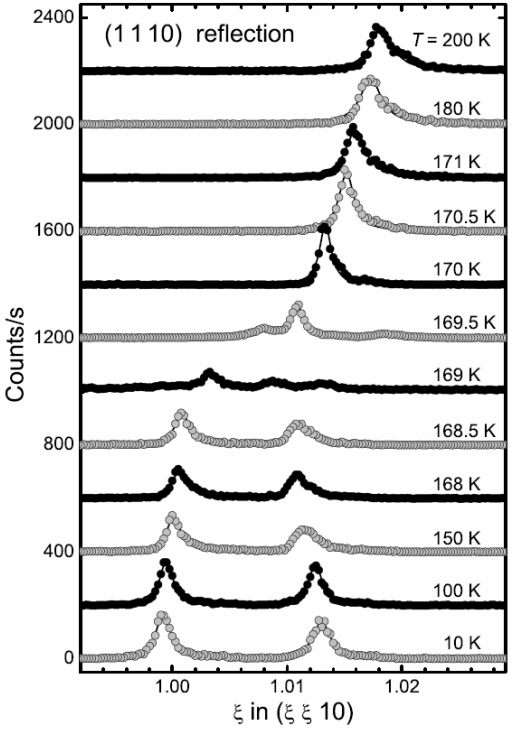


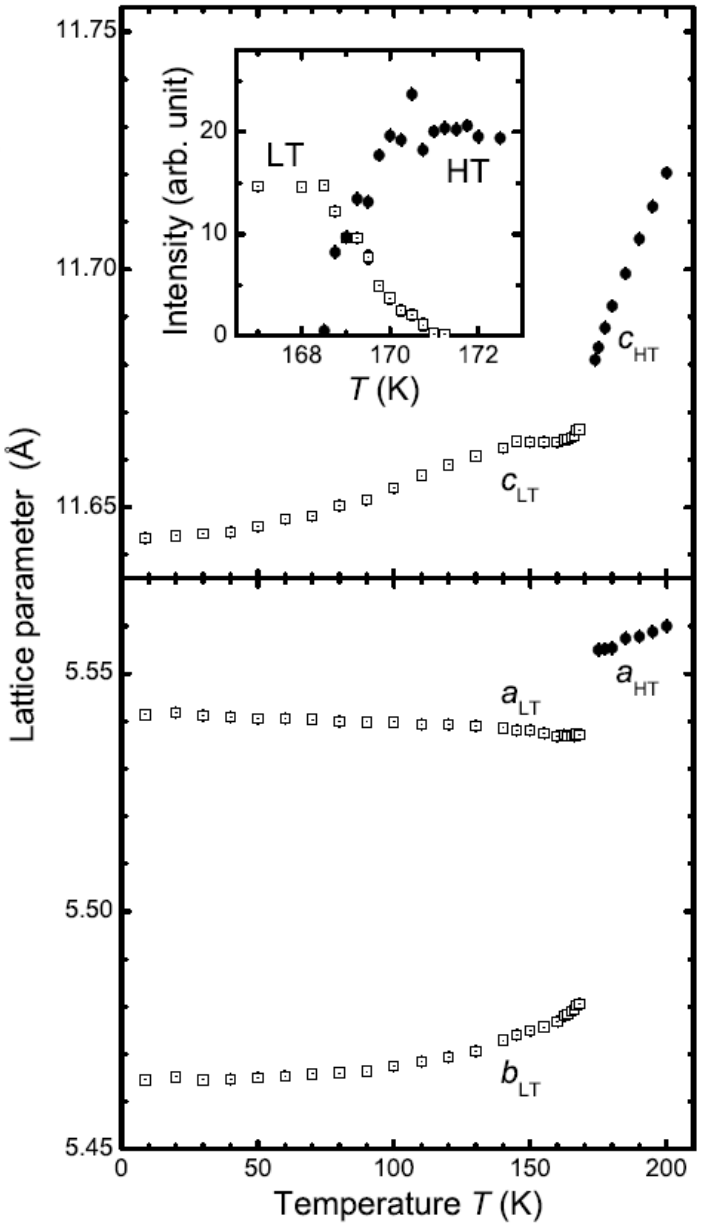
PHYSICAL REVIEW B 78, 014523 (2008)

First-order structural phase transition in $CaFe_2As_2$

Dramatic changes in unit cell parameters and narrow co-existence region.



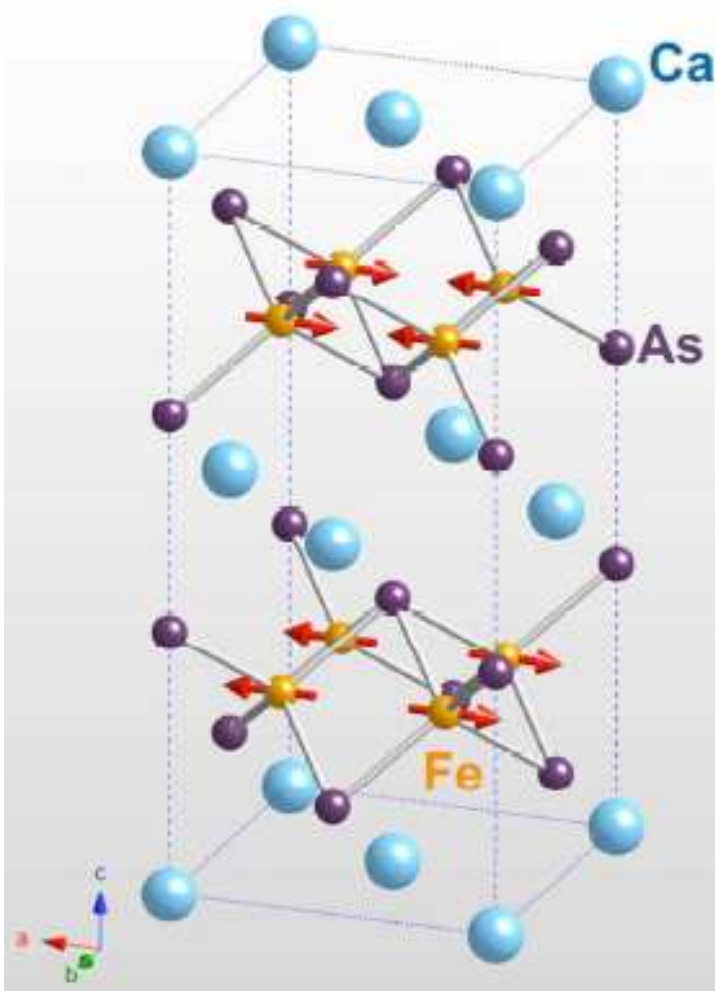




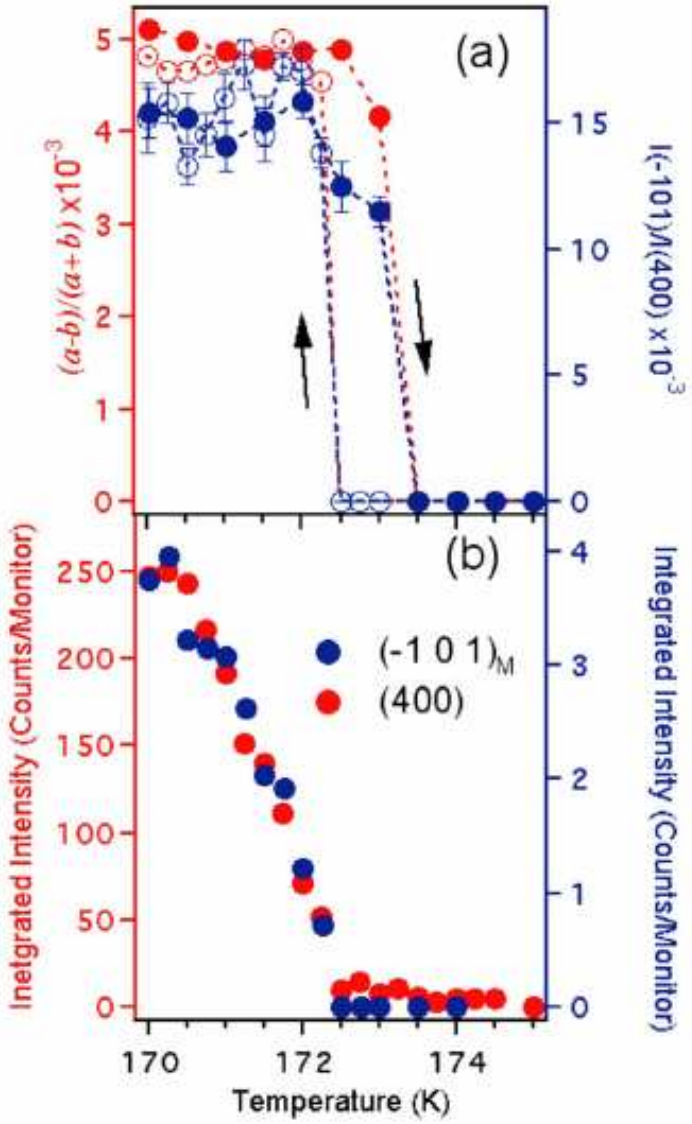
PHYSICAL REVIEW B 78, 100506(R) (2008)

Lattice and magnetic instabilities in $CaFe_2As_2$: A single-crystal neutron diffraction study

A. I. Goldman,[1,2] D. N. Argyriou,[3] B. Ouladdiaf,[4] T. Chatterji,[5] A. Kreyssig,[1,2] S. Nandi,[1,2] N. Ni,[1,2] S. L. Bud'ko,[1,2] P. C. Canfield,[1,2] and R. J. McQueeney[1,2]



Strongly coupled, first order, antiferromagnetic and structural phase transitions



Observations and wishes about $CaFe_2As_2$

$CaFe_2As_2$ appears to be similar to $SrFe_2As_2$ and $BaFe_2As_2$.

It is much softer

It has a smaller lattice parameter (Ca is smaller than Sr or Ba)

Pressure was useful in enhancing T_C in LaFeAs(O/F)

It would be wonderful to have a pure compound that could manifest all of the salient features of this system.

Pressure Induced Superconductivity in $CaFe_2As_2$

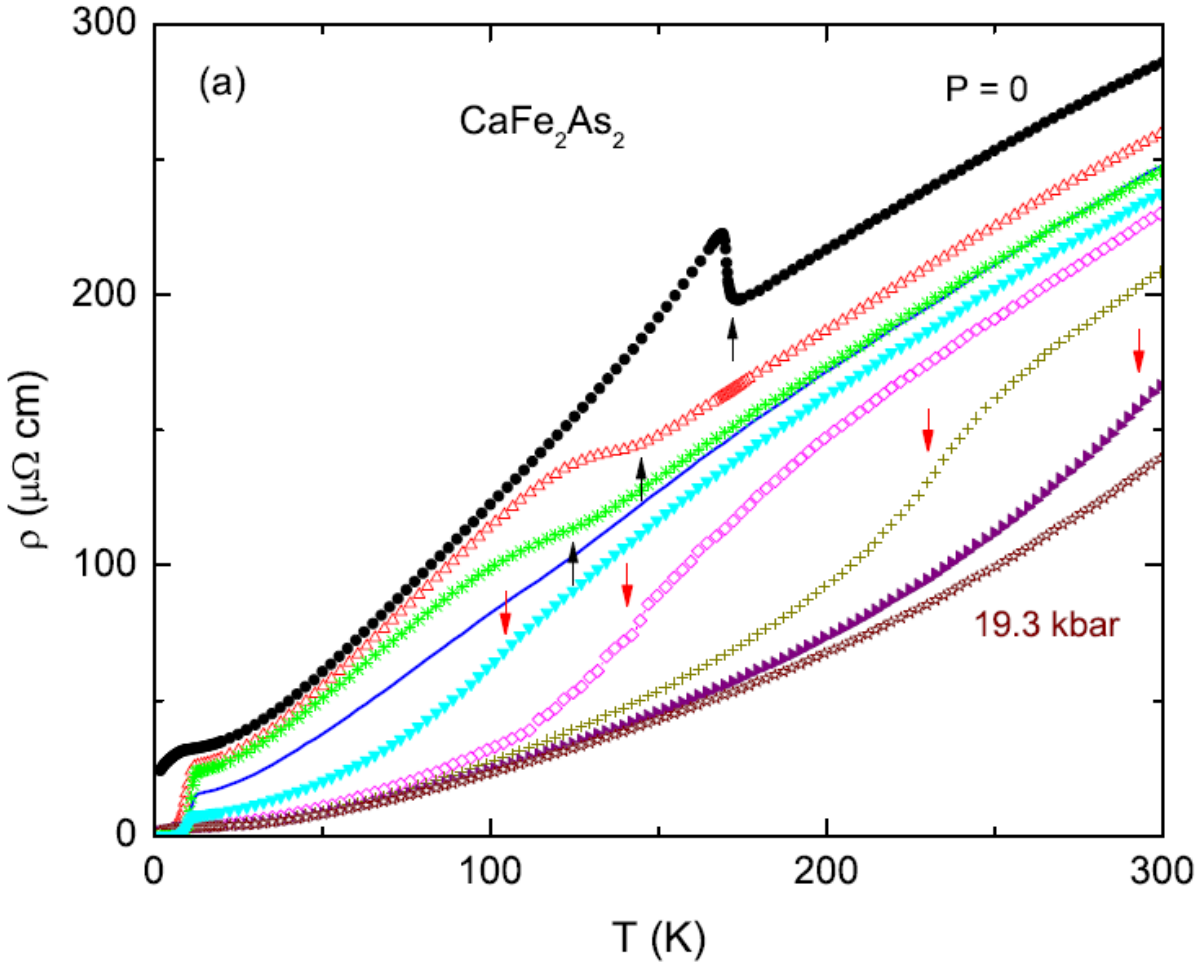
Milton S. Torikachvili
Department of Physics, San Diego State University, San Diego, California 92182-1233, USA

Sergey L. Bud'ko, Ni Ni, and Paul C. Canfield
Ames Laboratory, U.S. DOE and Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA
(Received 3 July 2008; published 31 July 2008)

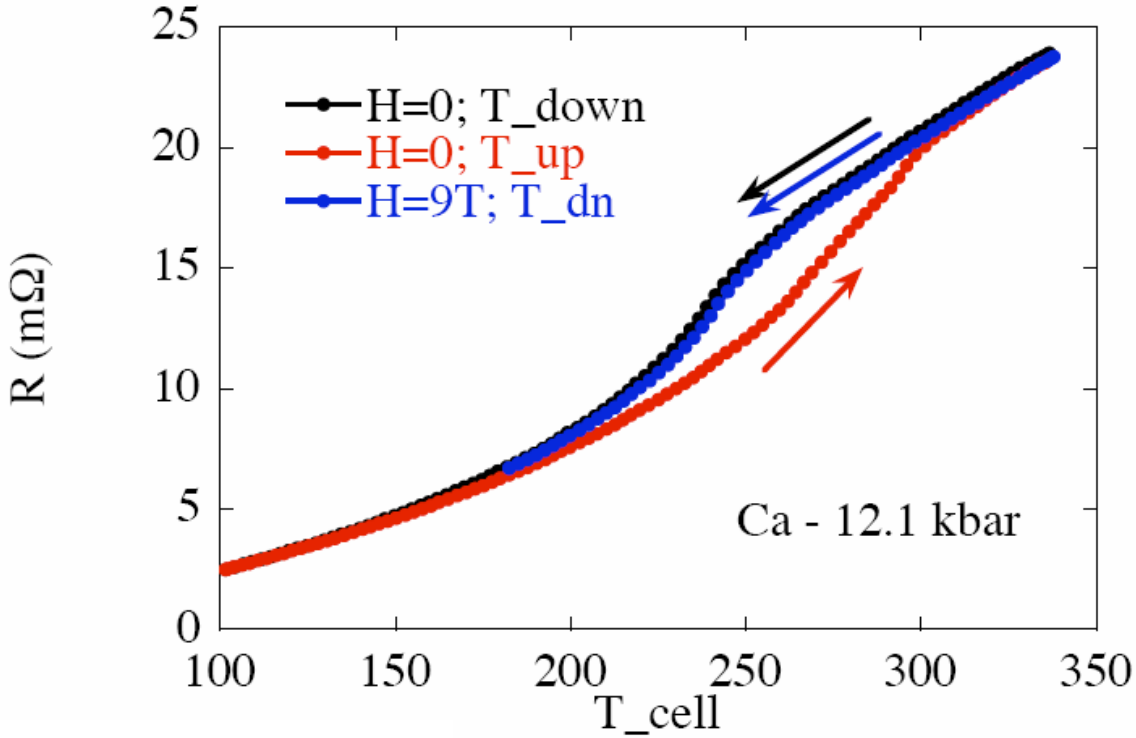
Pure compound

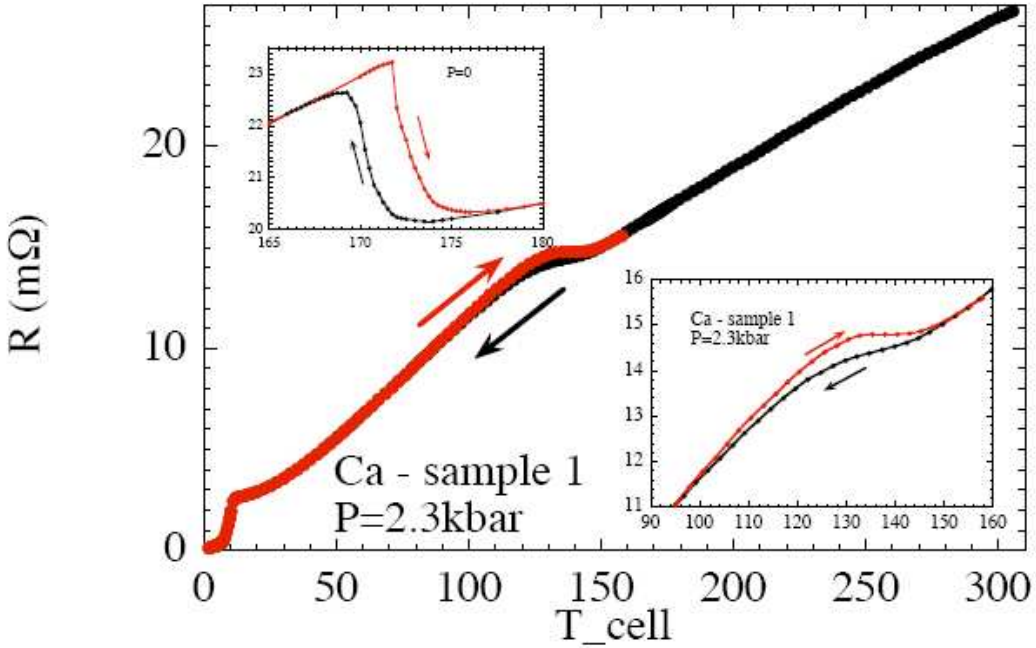
No doping

No disorder



$CaFe_2As_2$ under pressure

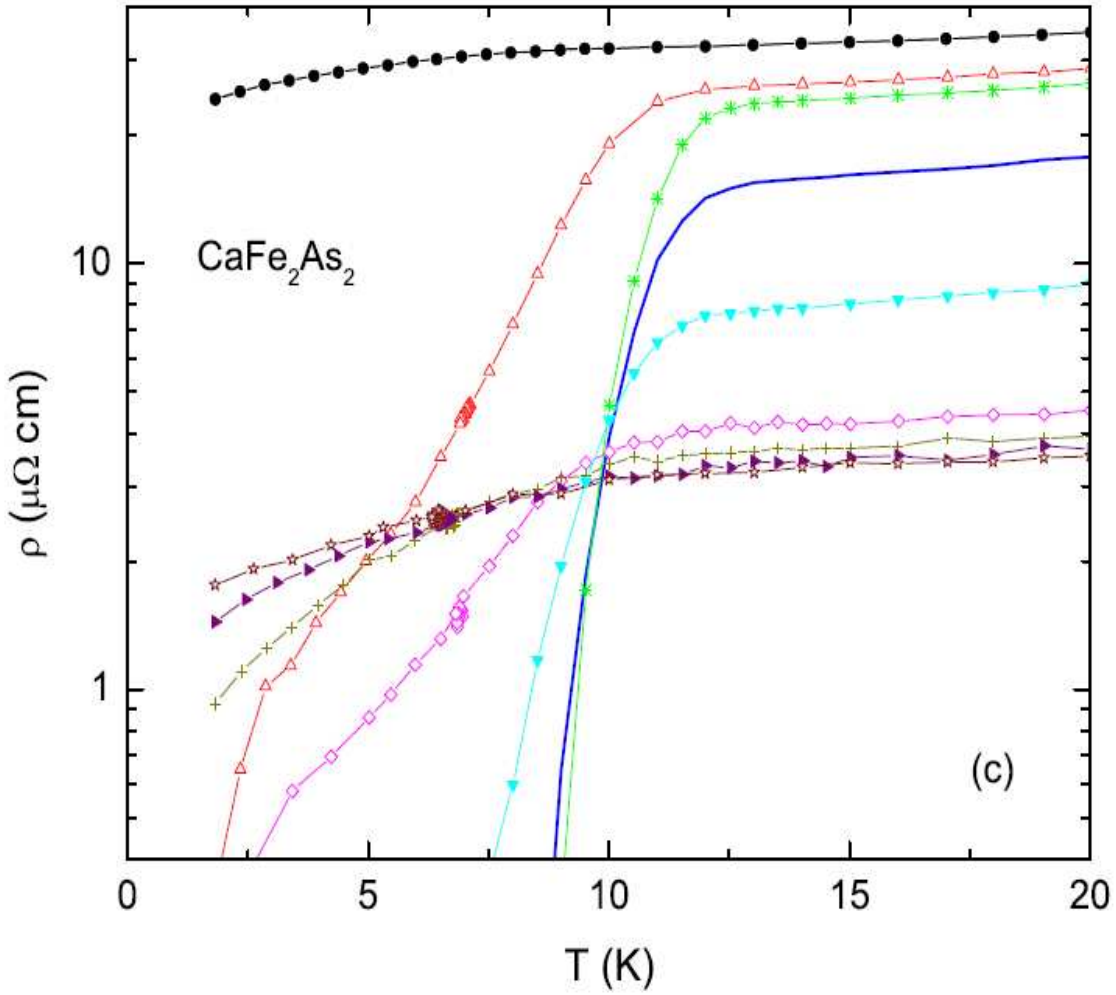




Both of these high temperature transitions are first order in nature (as assessed via hysterisis in transport data).

PRL 101, 057006 (2008) PHYSICAL REVIEW LETTERS week ending 1 AUGUST 2008

Pressure Induced Superconductivity in $CaFe_2As_2$



For low and high pressures there is no detectable superconductivity

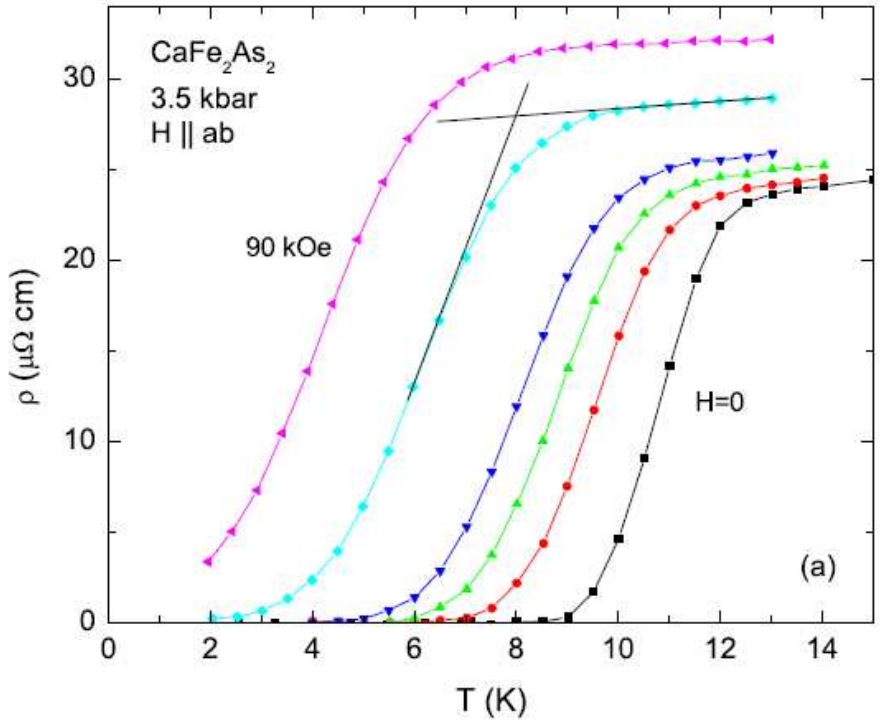
For pressures centered about 5 kbar there are sharp SC transitions

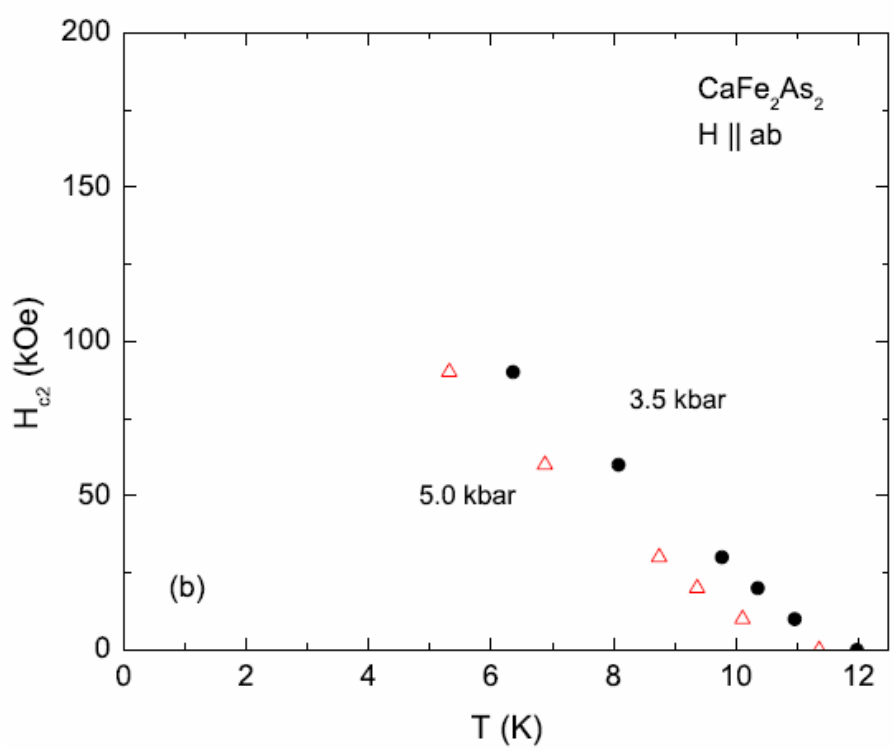
There is a dramatic reduction of residual resistivity, ρ(15K), as pressure passes through the 5 kbar region.

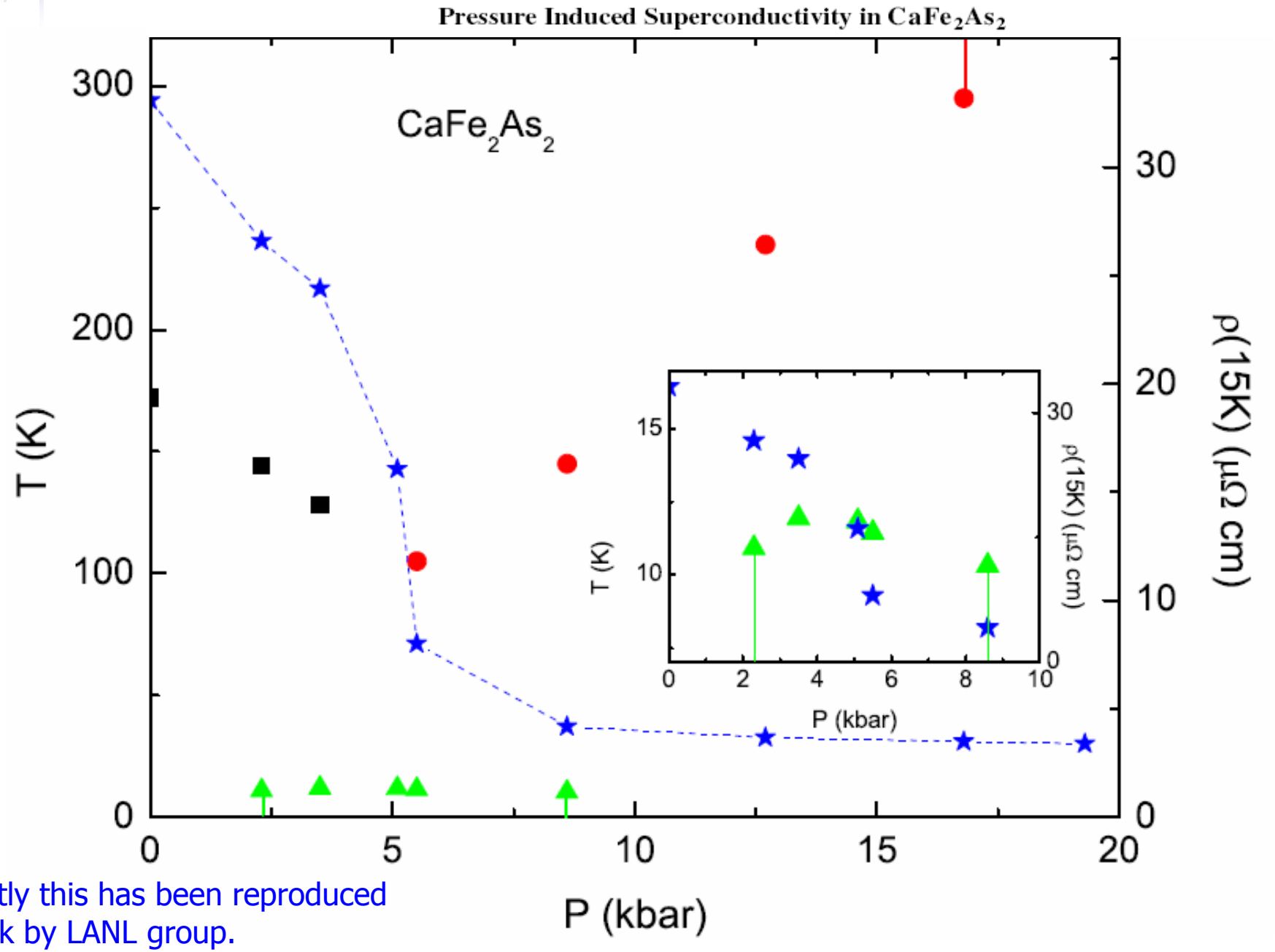
PRL 101, 057006 (2008) PHYSICAL REVIEW LETTERS week ending 1 AUGUST 2008

Pressure Induced Superconductivity in $CaFe_2As_2$

Reasonable H_{c2} curves for SC region.







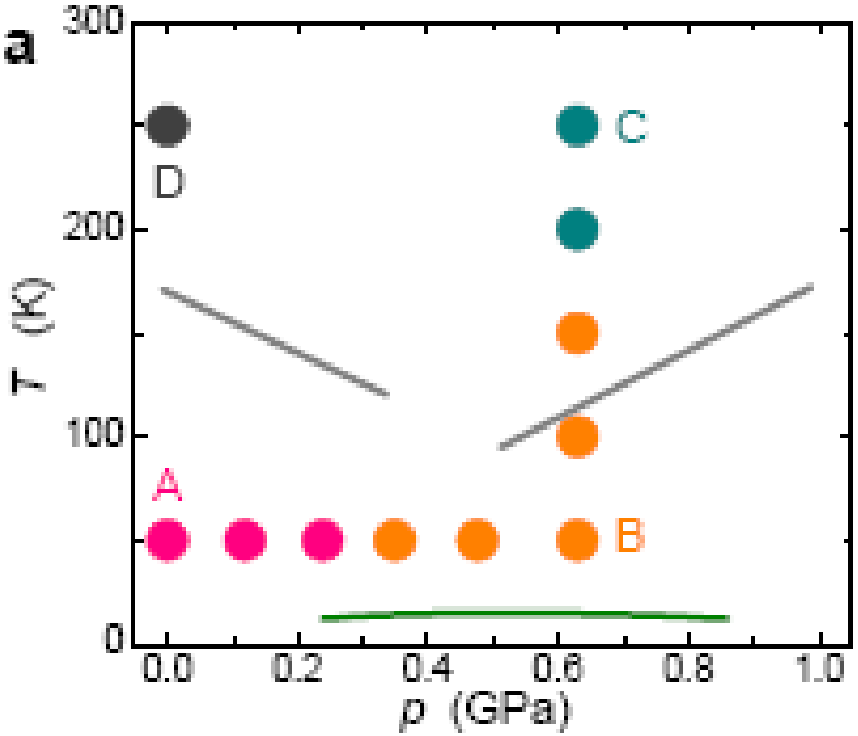
Recently this has been reproduced in work by LANL group.

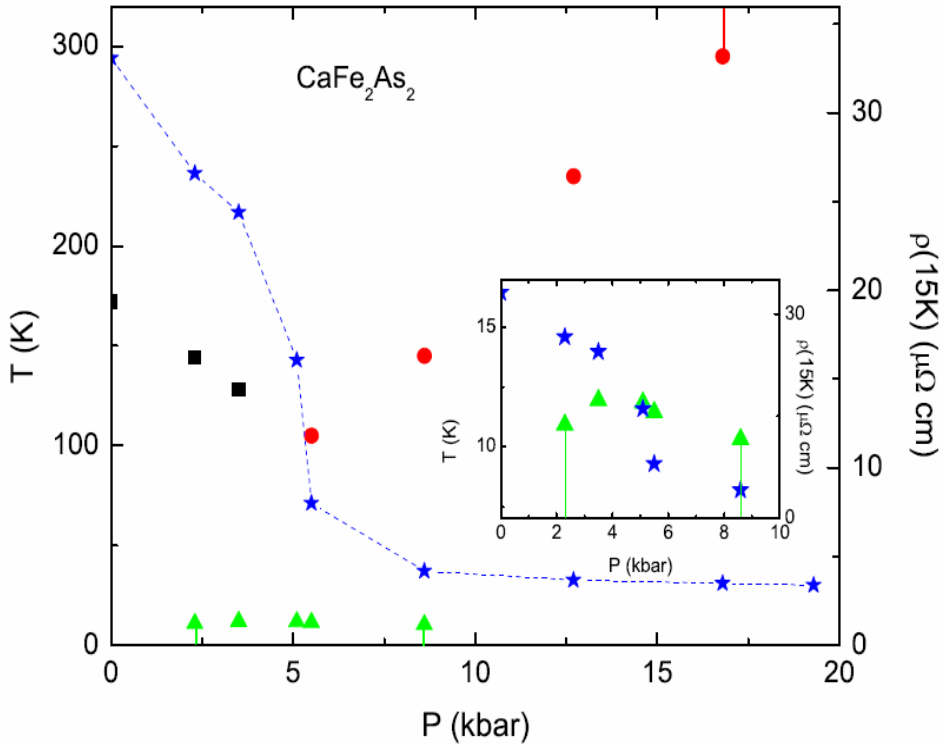
The P-T phase diagram of $CaFe_2As_2$ can be studied further via neutron diffraction work using He-pressure cells

A. Kreyssig *et al.* arXiv:0807.3032

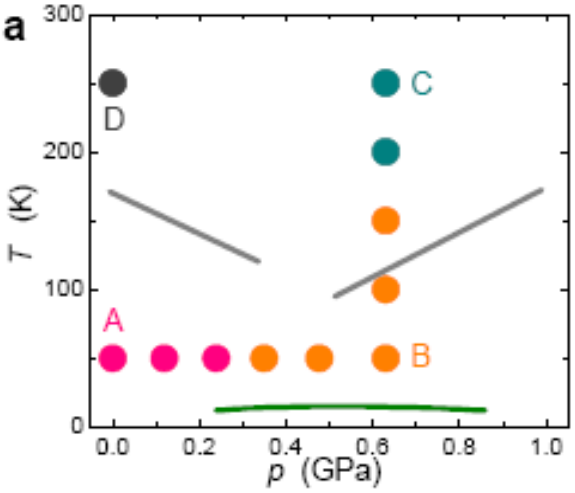
Squeezing the magnetism out of superconducting $CaFe_2As_2$

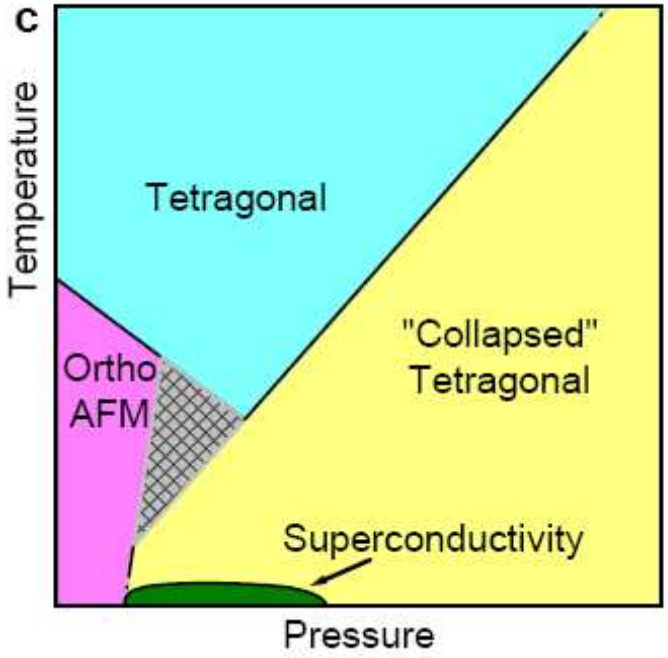
A. Kreyssig[1,2], M. A. Green[3,4], Y. Lee[1,2], G. D. Samolyuk[1,2], P. Zajdel[3,5], J. W. Lynn[3], S. L. Bud'ko[1,2], M. S. Torikachvili[6], N. Ni[1,2], S. Nandi[1,2], J. Leão[3], S. J. Poulton[3,4], D. N. Argyriou[7], B. N. Harmon[1,2], P. C. Canfield[1,2], R. J. McQueeney[1,2] & A. I. Goldman[1,2]

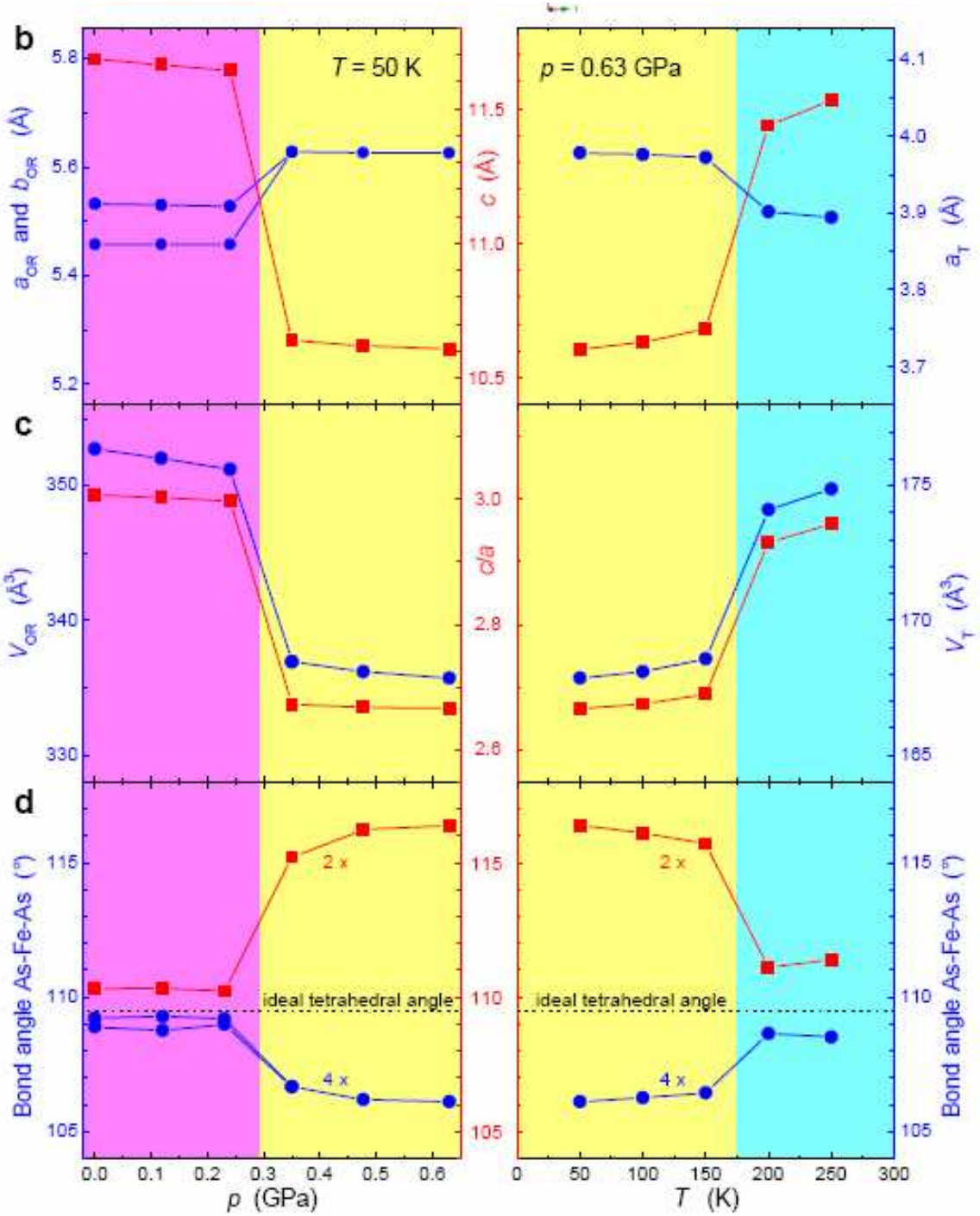


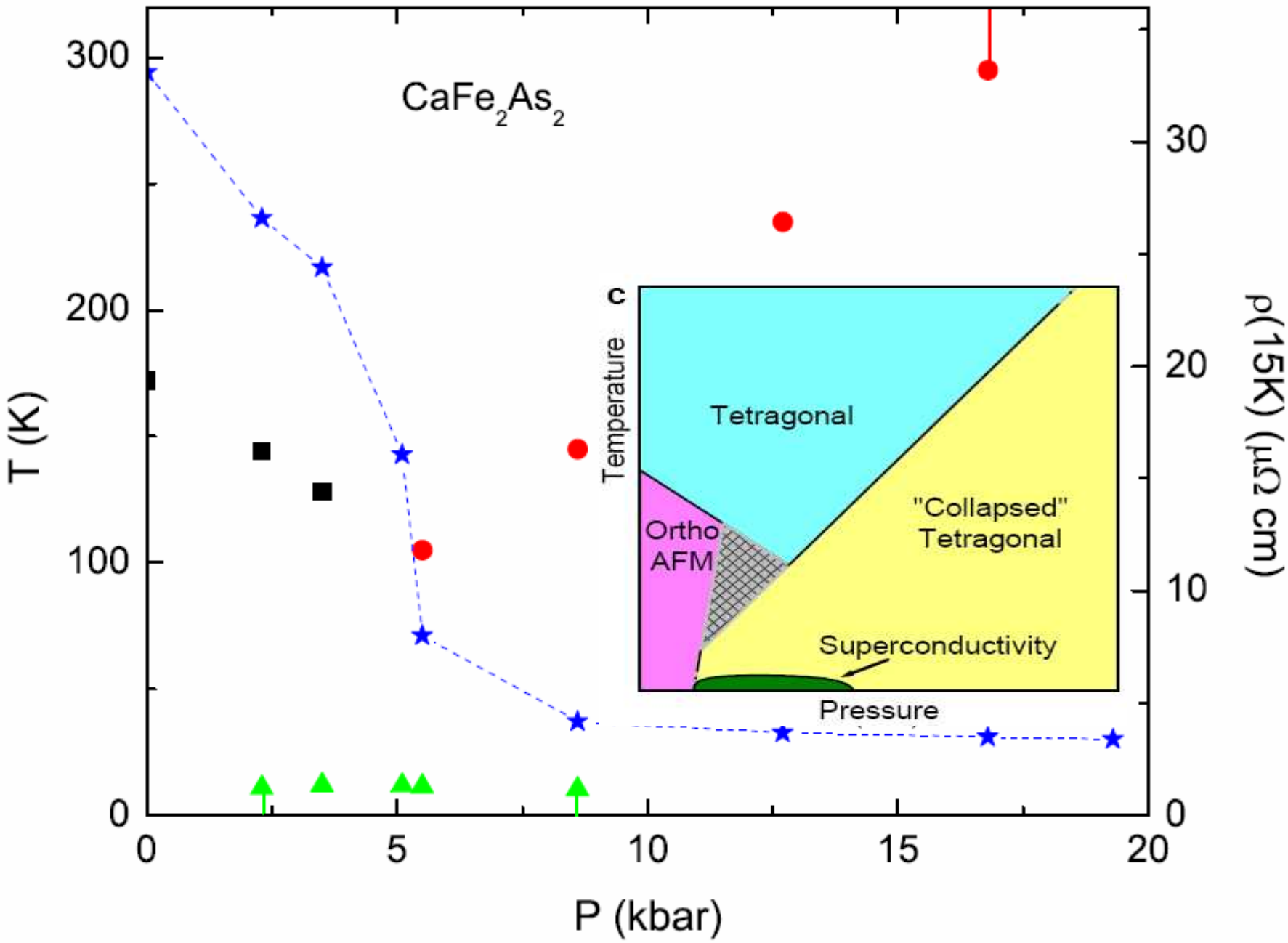


A. Kreyssig *et al.* arXiv:0807.3032



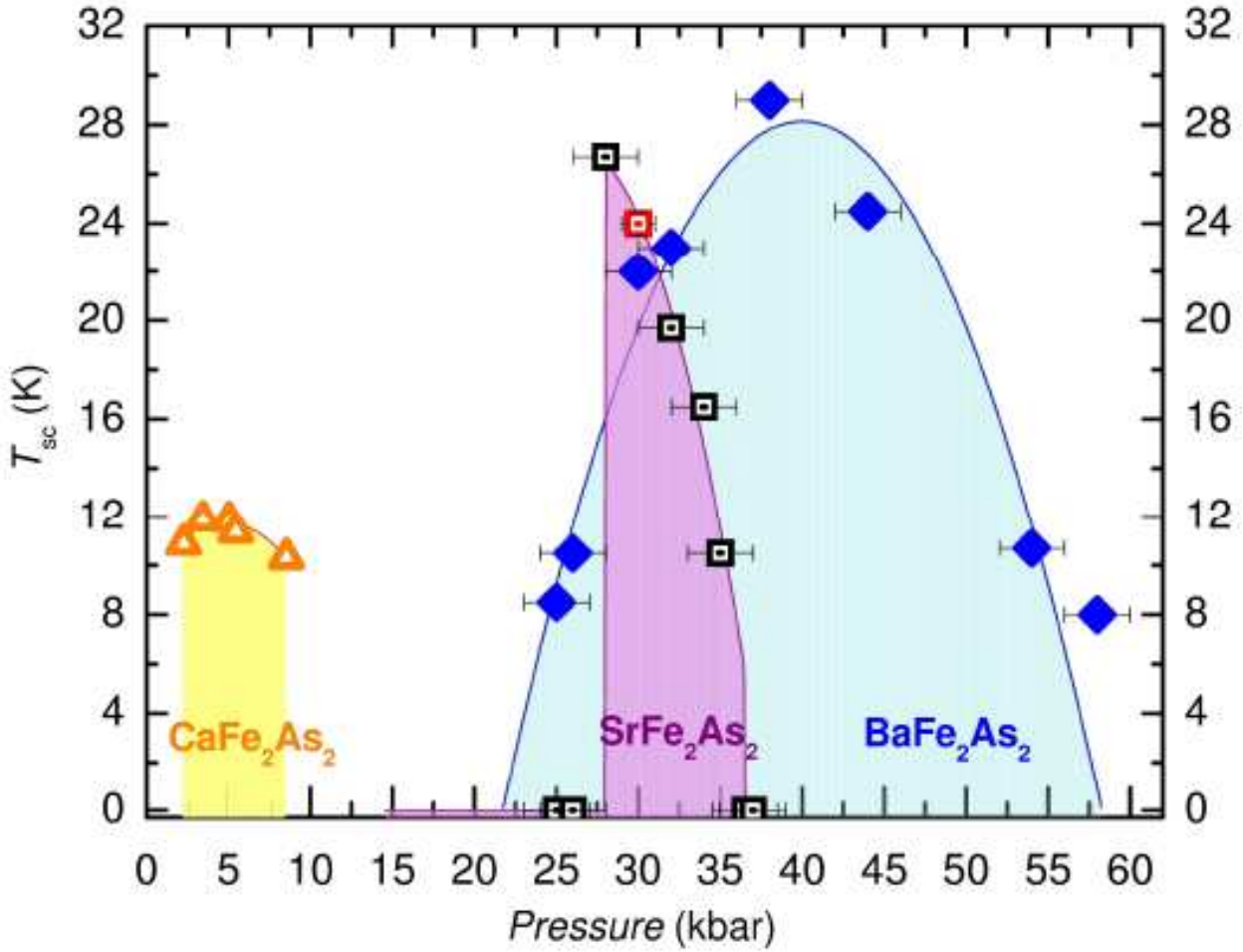





CaFe2As2
T (K)
P (kbar)
ρ(15K) (μΩ cm)
300
200
100
0
0
5
10
15
20
30
20
10
0
c
Temperature
Tetragonal
Ortho
AFM
"Collapsed"
Tetragonal
Superconductivity
Pressure

Superconductivity up to 29 K in $SrFe_2As_2$ and $BaFe_2As_2$ at high pressures

[1] Patricia L. Alireza, Jack Gillett, Y. T. Chris Ko, Suchitra E. Sebastian, and Gilbert G. Lonzarich, arXiv:0807.1896, J. Phys.: Condens. Matter (to be published).



$BaFe_2As_2$ and $(Ba_{0.55}K_{0.45})Fe_2As_2$ are far less pressure dependent.

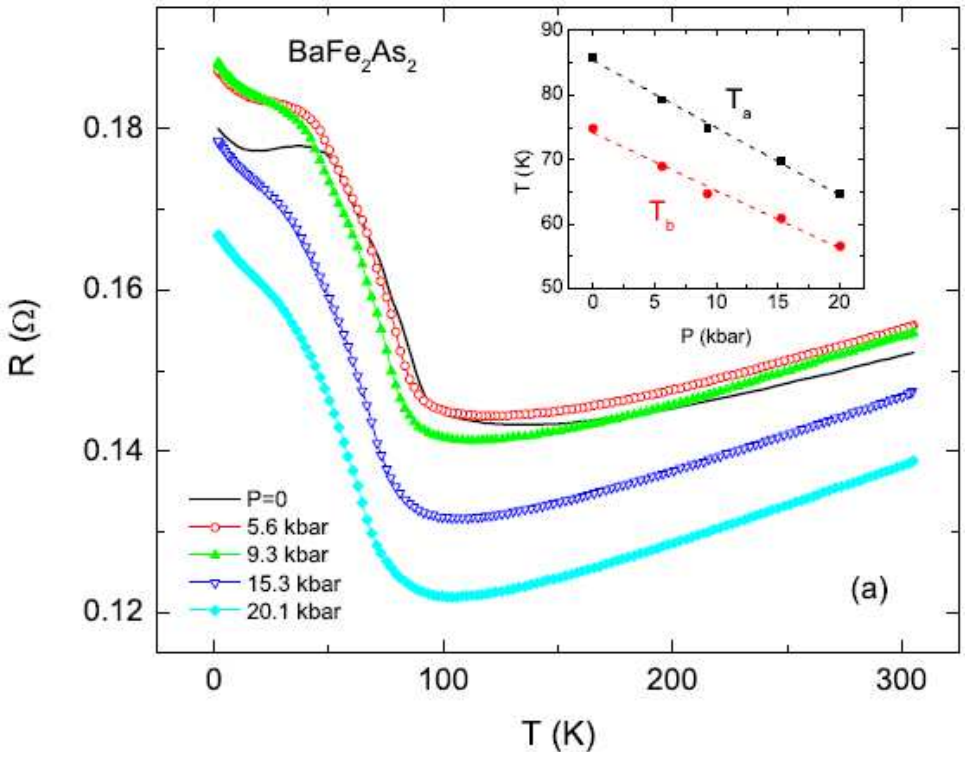
PHYSICAL REVIEW B **78**, 104527 (2008)

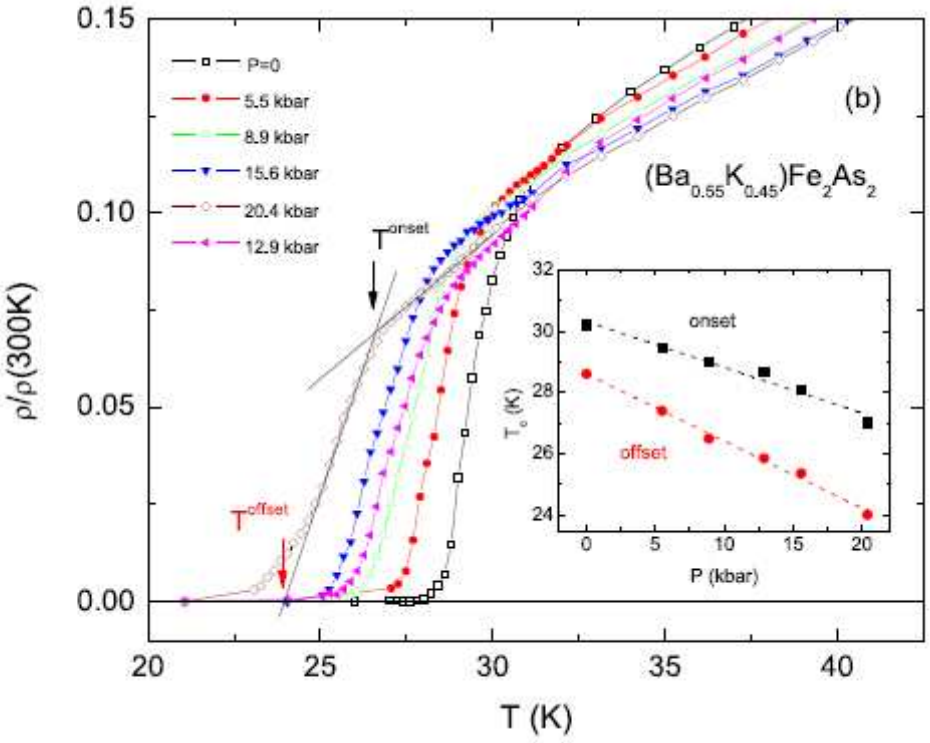
Effect of pressure on the structural phase transition and superconductivity in $(Ba_{1-x}K_x)Fe_2As_2$ ($x=0$ and 0.45) and $SrFe_2As_2$ single crystals

M. S. Torikachvili
Department of Physics, San Diego State University, San Diego, California 92182-1233, USA

S. L. Bud'ko, N. Ni, and P. C. Canfield
Ames Laboratory, US DOE and Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA

(Received 7 July 2008; published 29 September 2008)





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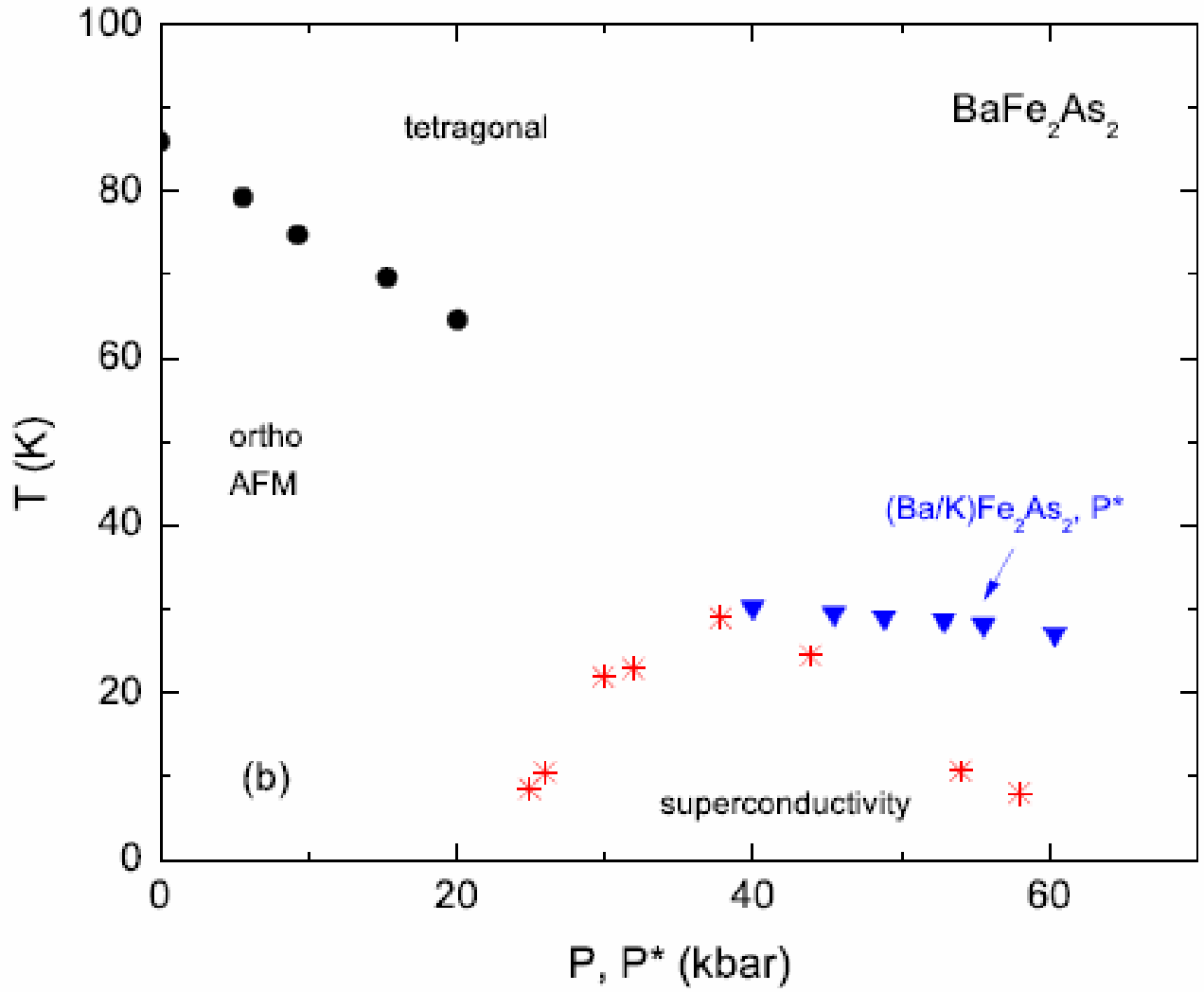
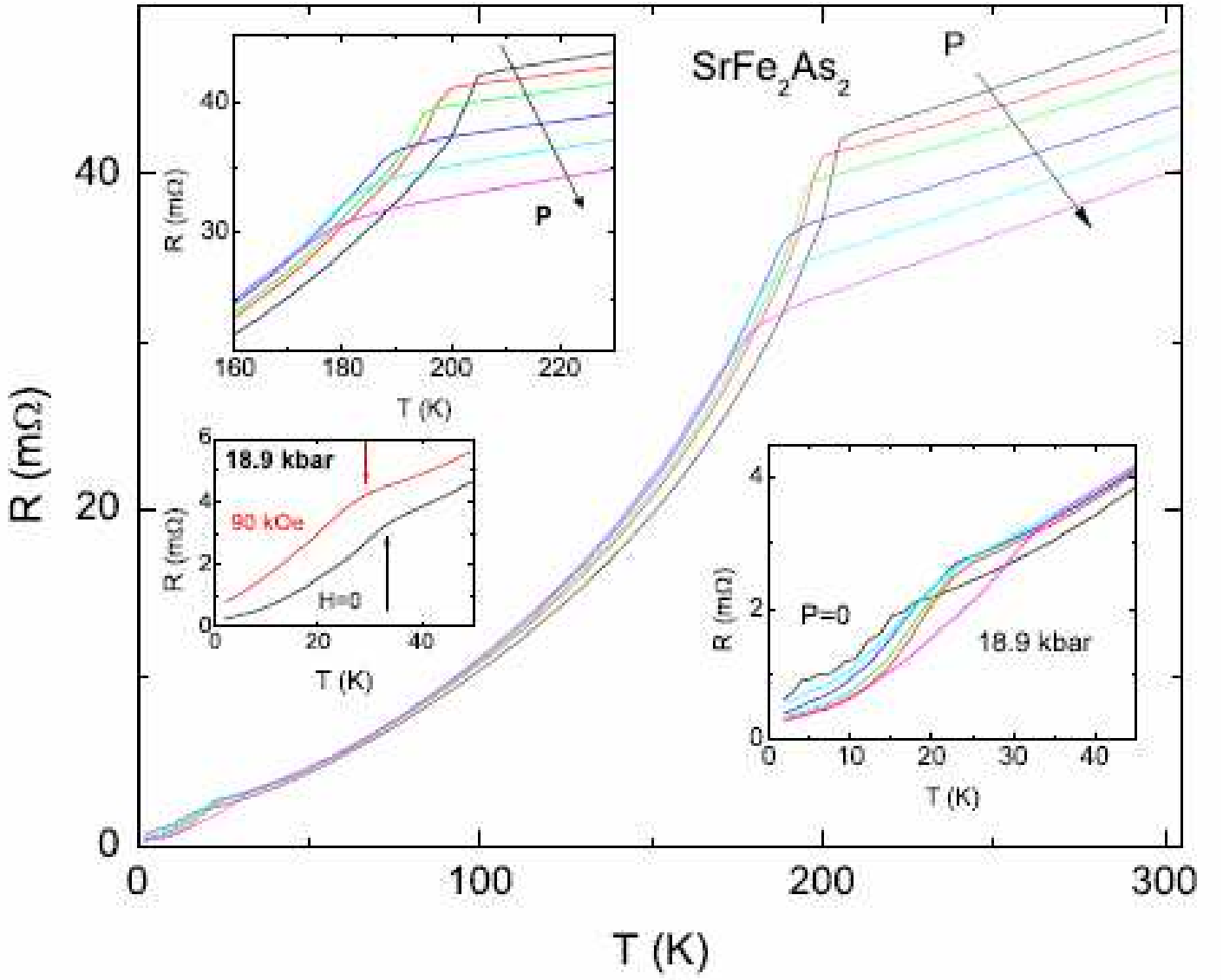
Effect of pressure on the structural phase transition and superconductivity in $(Ba_{1-x}K_x)Fe_2As_2$ ($x=0$ and 0.45) and $SrFe_2As_2$ single crystals



What is missing here is transport measurements at the salient pressures. Stay tuned….

PHYSICAL REVIEW B 78, 104527 (2008)

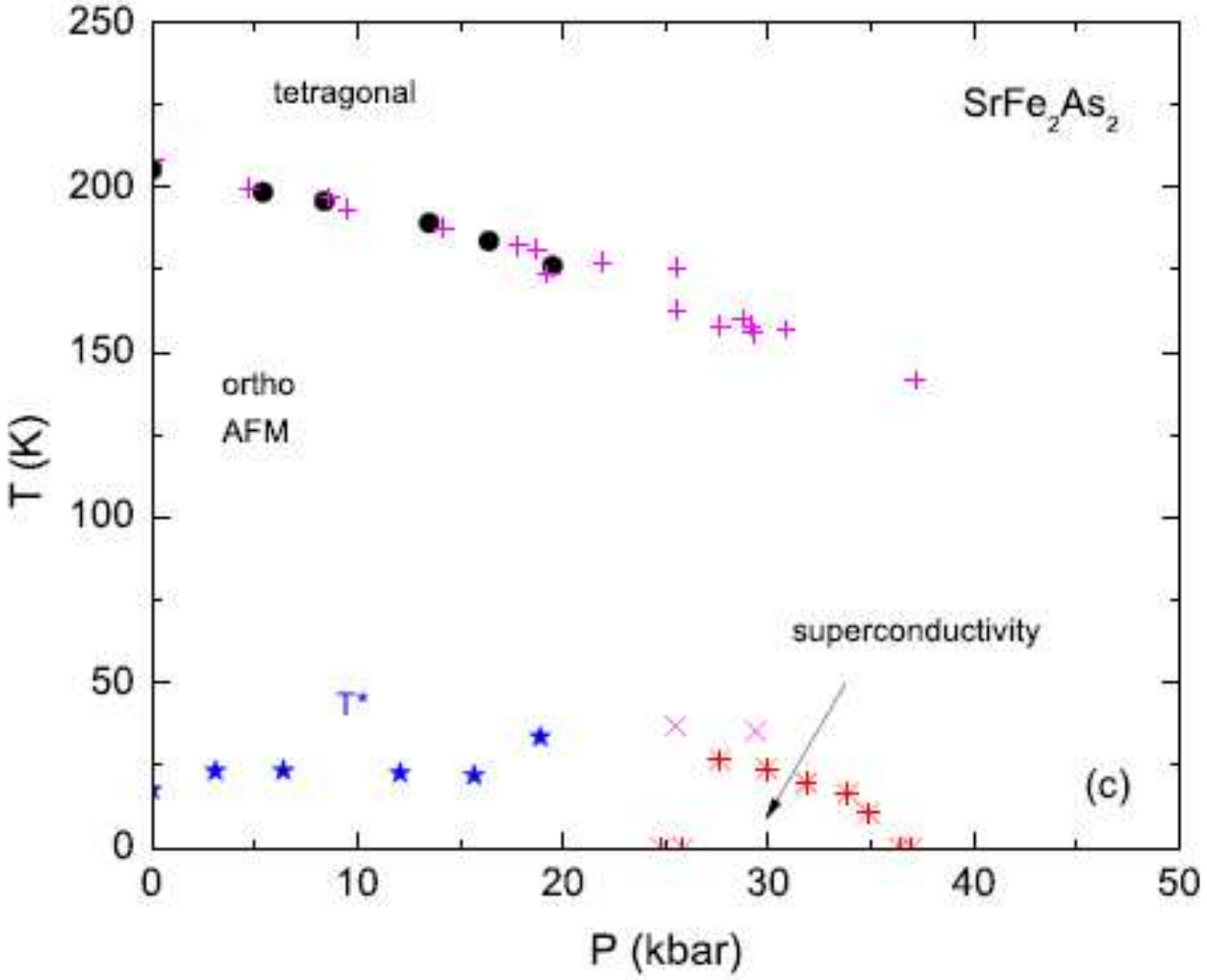
Effect of pressure on the structural phase transition and superconductivity in $(Ba_{1-x}K_x)Fe_2As_2$ ($x=0$ and 0.45) and $SrFe_2As_2$ single crystals



The lower temperature feature is not easily associated with bulk superconductivty. On the other hand, it is clearly present.

PHYSICAL REVIEW B 78, 104527 (2008)

Effect of pressure on the structural phase transition and superconductivity in $(Ba_{1-x}K_x)Fe_2As_2$ ($x=0$ and 0.45) and $SrFe_2As_2$ single crystals

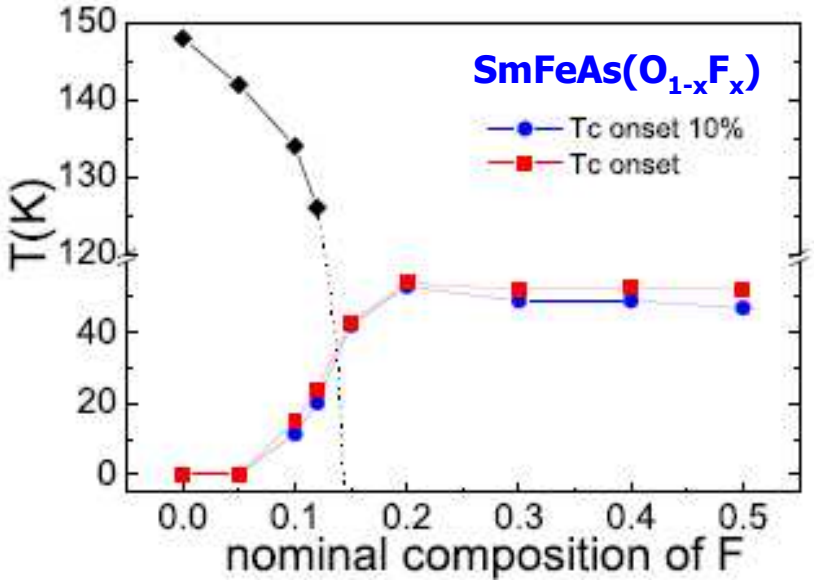


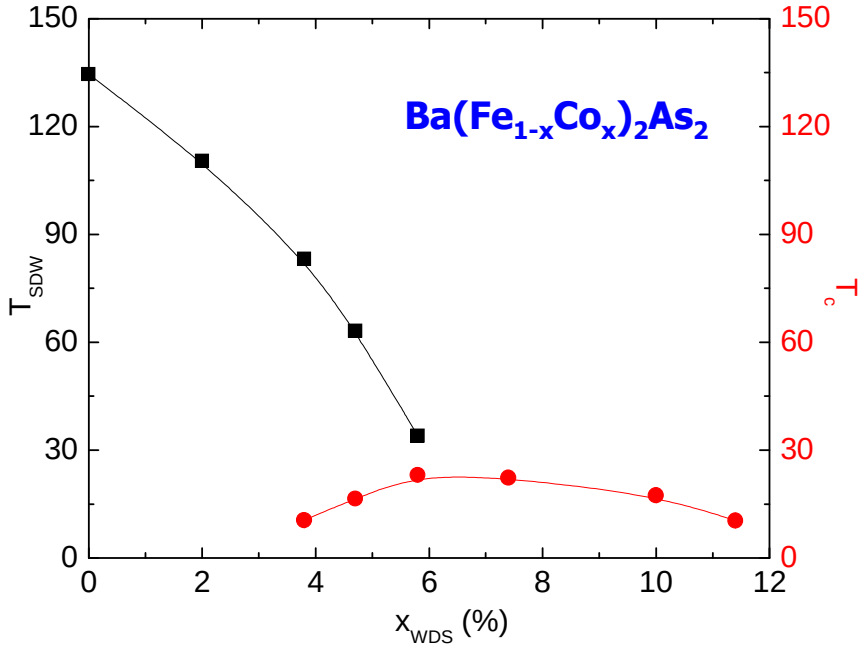
For $SrFe_2As_2$ under pressure there is some question about nature or range of superconductivity

For both $BaFe_2As_2$ and $SrFe_2As_2$ the quality of the hydrostatic pressure may result in problems….

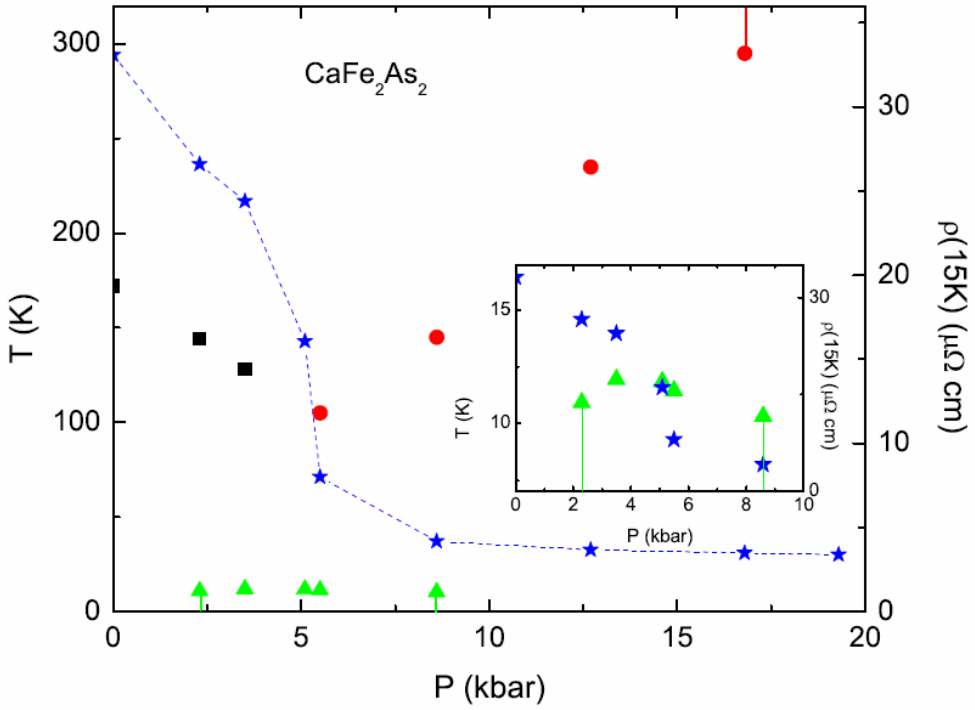
M. Kumar, M. Nicklas, A. Jesche, N. Caroca-Canales, M. Schmitt, M. Hanfland, D. Kasinathan, U. Schwarz, H. Rosner, and C. Geibel, arXiv:0807.4283 (unpublished). + X

[1] Patricia L. Alireza, Jack Gillett, Y. T. Chris Ko, Suchitra E. Sebastian, and Gilbert G. Lonzarich, arXiv:0807.1896, J. Phys.: Condens. Matter (to be published). **





Similar phase diagrams have been mapped out for F-doped SmFeAs(O/F), for Co-doped $BaFe_2As_2$ and for pure $CaFe_2As_2$ under very accessible pressures. T_c emerges as the structural / antiferromagnetic transition is suppressed.



Common features and hints from the data so far

Several classes of FeAs compounds with square planar Fe capped top and bottom with As and with Fe^{2+} via gross / formal counting.

In cases of RFeAsO and AFe_2As_2 a (combined) structural and magnetic phase transition needs to be suppressed for SC to emerge. This transition seems to disappear quite suddenly.

Single crystals of the AFe_2As_2 compounds are VERY soft. The $CaFe_2As_2$ can be rolled into a spiral with fine tweezers. Not at all hard.

All of the salient features associated with these compounds can be found in pure $CaFe_2As_2$ under pressure. This may allow for a clean sorting out of what is going on.

More FeAs compounds are being found and more ways of "doping" them are being developed.

Current "Big" questions:

Operational / empirical questions

Is Fe special or can this be generalized to 3d transition metals?

Is $T_c < 60$ K the maximum T_c for this class of superconductors or is there a quantum leap to 100 K lurking near by?

Physical questions

What is symmetry of gap? Can it be different in 1111 and 122 compounds?

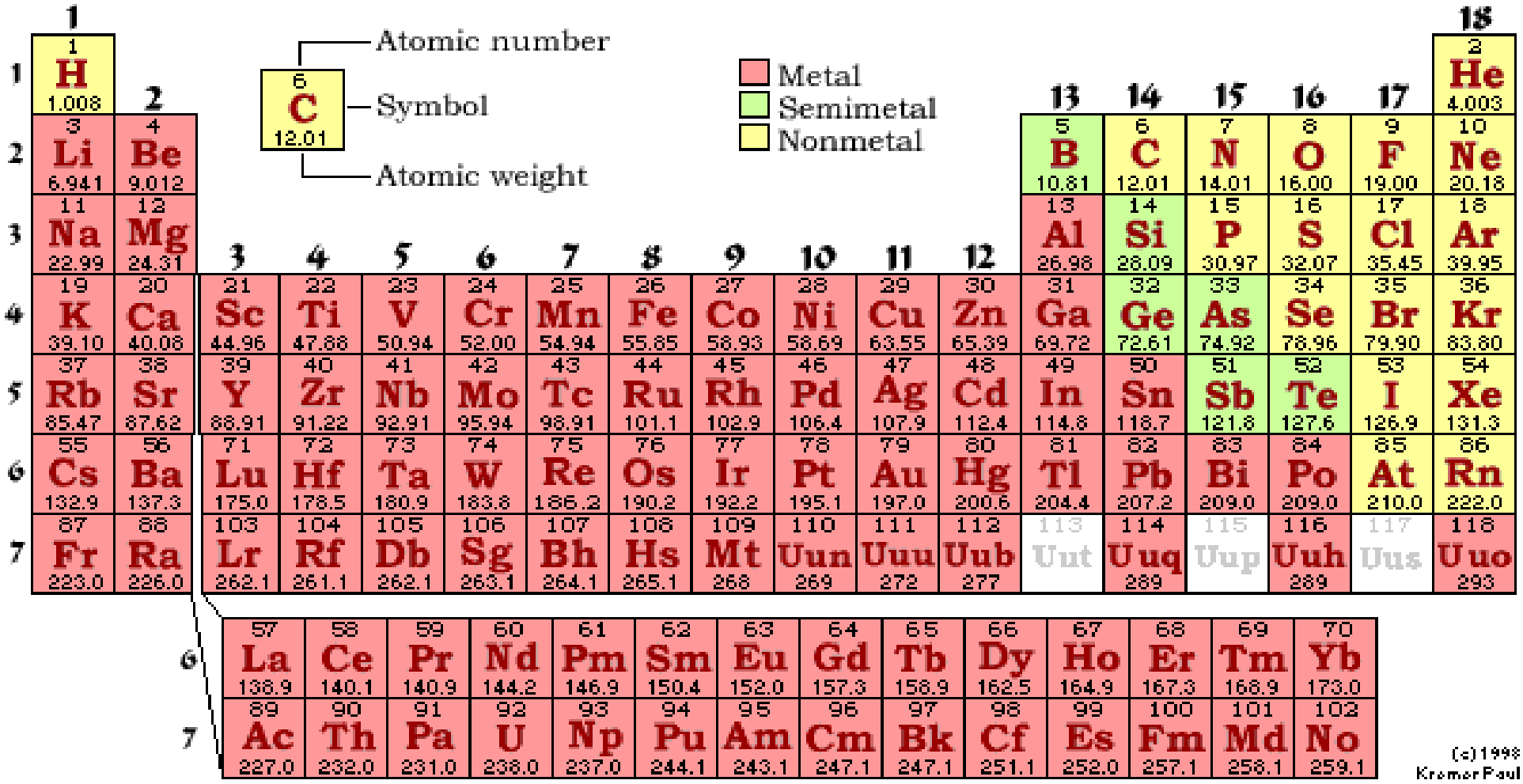
What is mechanism for pairing: what is important, proximity to AF transition, proximity to structural transition, both, neither?

Engineering questions

Can good PIT wires be made easily?

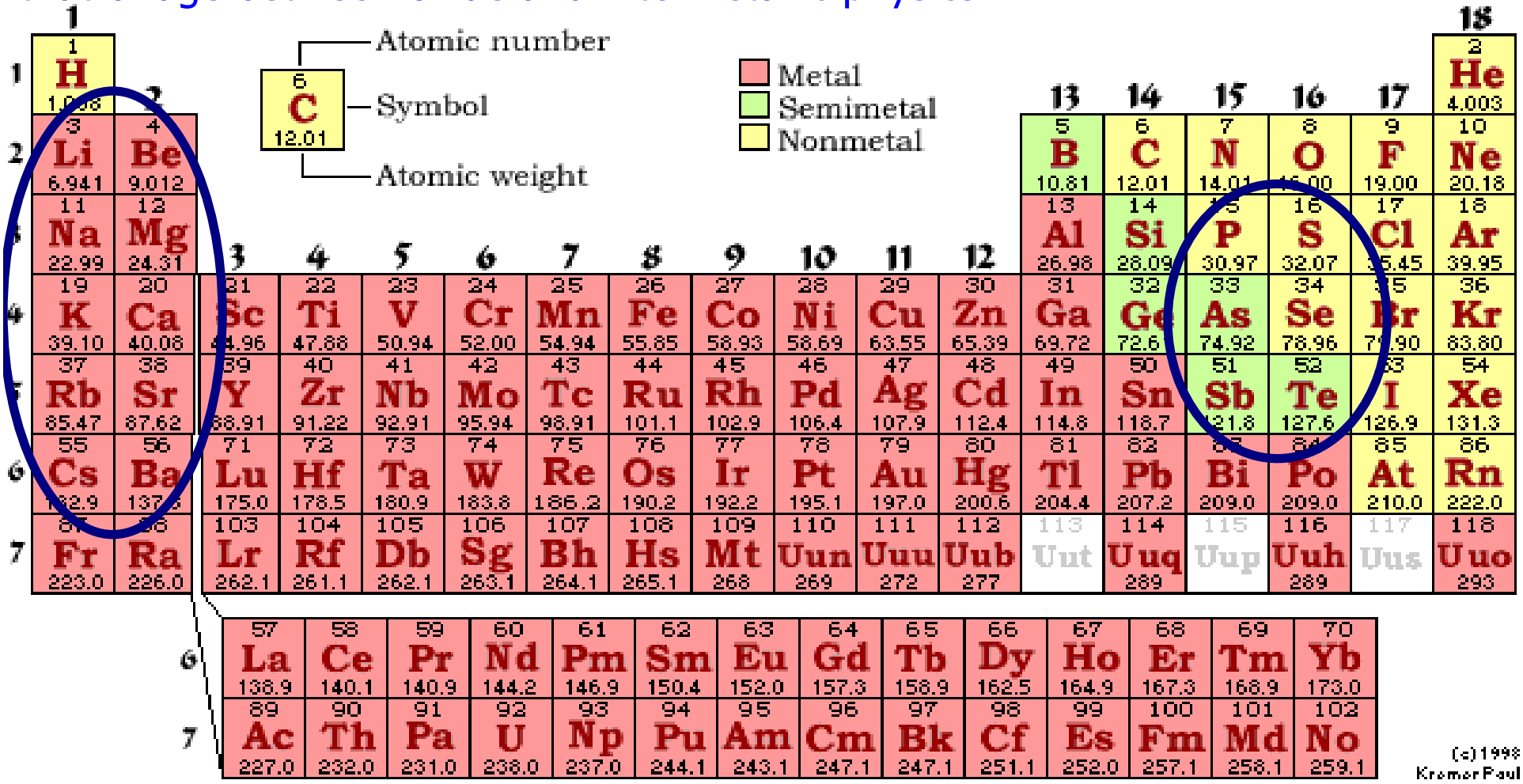
How high can J_c be pushed?

With H-T_c's, RT_2B_2C, MgB_2, and now FeAs materials we are seeing that compounds that live between traditional oxide physics and intermetallic physics are the ones that offer exciting and potentially useful superconductivity.



With H-T_c's, RT_2B_2C, MgB_2, and now FeAs materials we are seeing that compounds that live between traditional oxide physics and intermetallic physics are the ones that offer exciting and potentially useful superconductivity.

Compounds with these elements have been avoided due to the difficulty in making them. These are precisely the compounds that will show properties that bridge between oxide and intermetallic physics.



Much More to Come