SUPERCONDUCTIVITY WS 15-16

Monday 10:00-11:30

SR Exp. physics II

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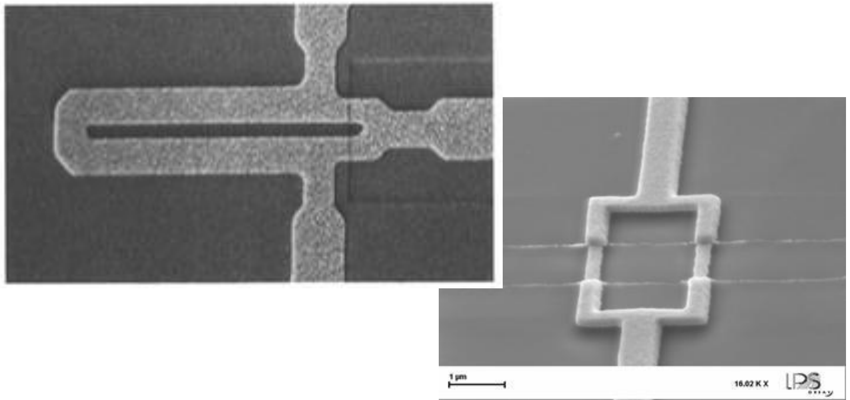
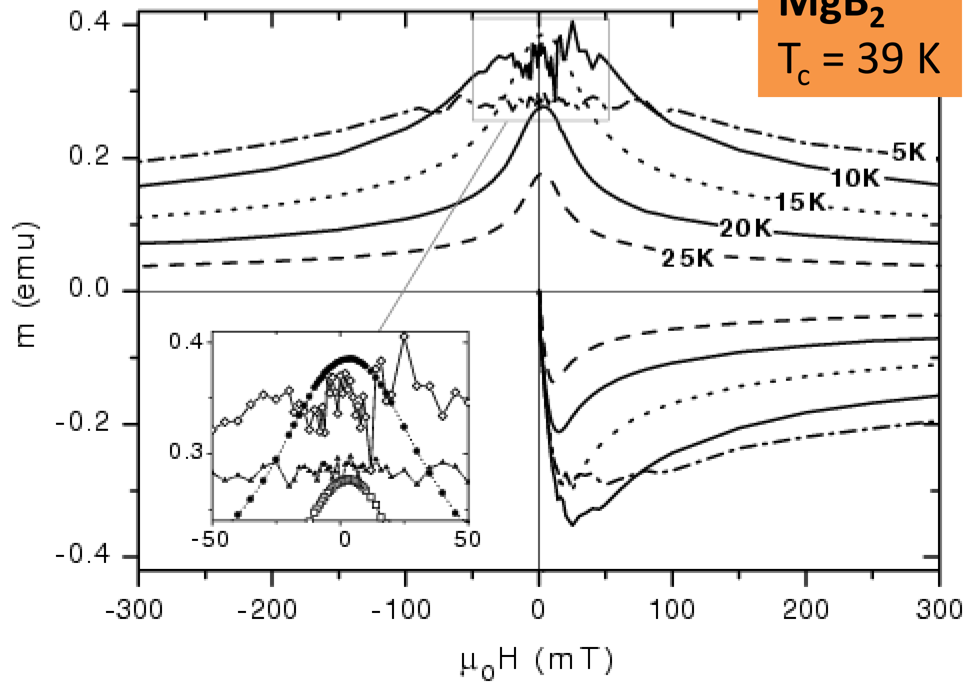
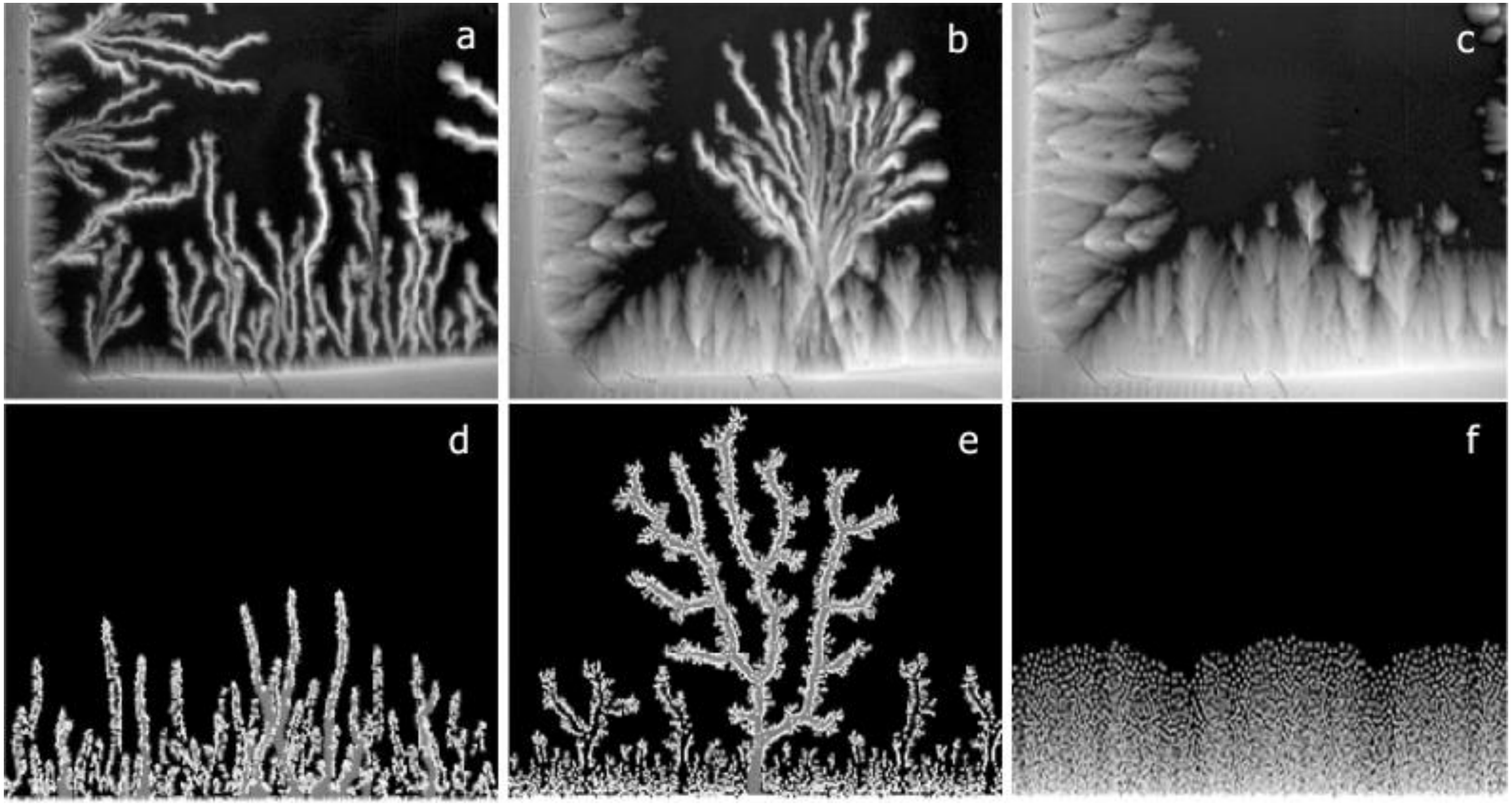
SQUID magnetometer



MgB_2
T_c = 39 K

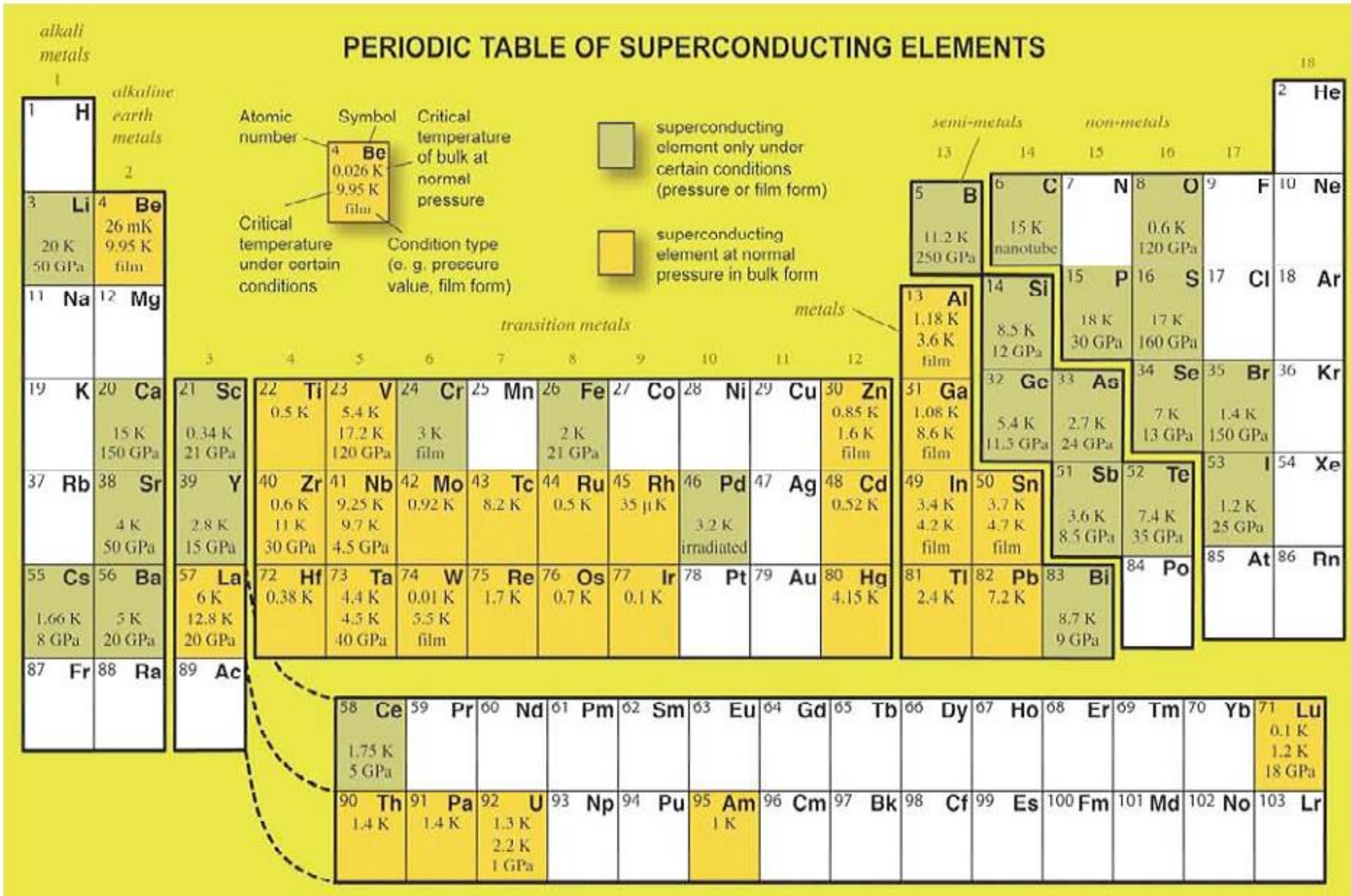


Magnetization hysteresis loops for a **MgB_2** thin film. The measurements were done after zero-field cooling down to different temperatures using a SQUID magnetometer (Quantum Design MPMS). Pronounced fluctuations in the magnetization are evident at T = 10 and 5 K, while only regular behaviour is seen at the higher temperatures. The fluctuations indicate that numerous flux jumps are taking place. Their magnitude as well as the accompanying effect of cutting off (flattening) the central peak vary with the temperature. [Johansen et al. *Europhys. Lett.*, **59** (4), p. 599 (2002)]



MgB_2 films: Different types of flux pattern morphology at various temperatures. a)-c) MO images taken for T = 3.3, 9.9 and 10.5 K at applied fields of 13, 17 and 19 mT, respectively. At low T the dendrites are numerous and with few branches, while just below 10 K only large tree-like structures are formed. Above 10 K the film behaves traditionally according to the critical-state model. d)-f) Results of computer simulations largely reproducing the observed types of flux penetration patterns. Individual vortices are indicated by white dots, and gray indicate elevated temperature due to heat dissipated by the most recent vortex motion.
[Johansen et al. *Europhys. Lett.*, **59** (4), p. 599 (2002)]

Materials: The elements



Typically $T_c < 5$ K

Pb: 7.2 K, Nb: 9.25 K; Rh: 35 μK

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Inducing SC in the elements

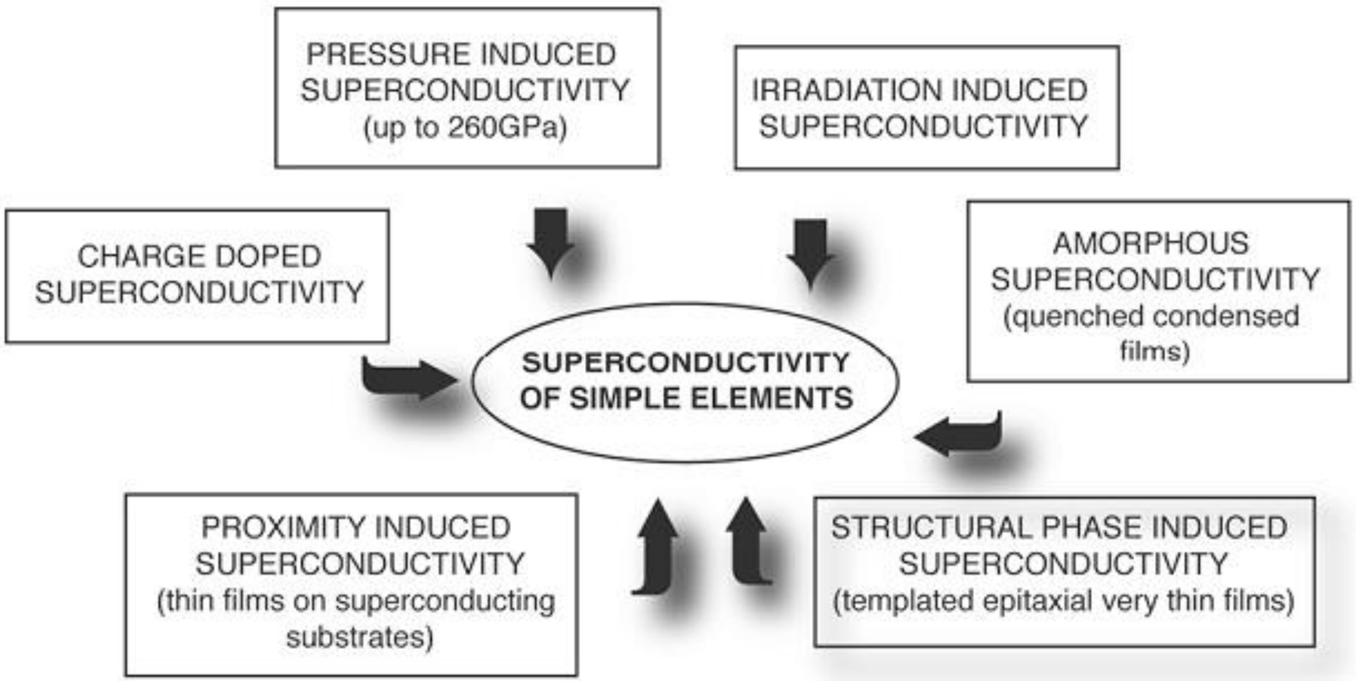

Figure 3. *Techniques used to transform normal elements into superconductors*

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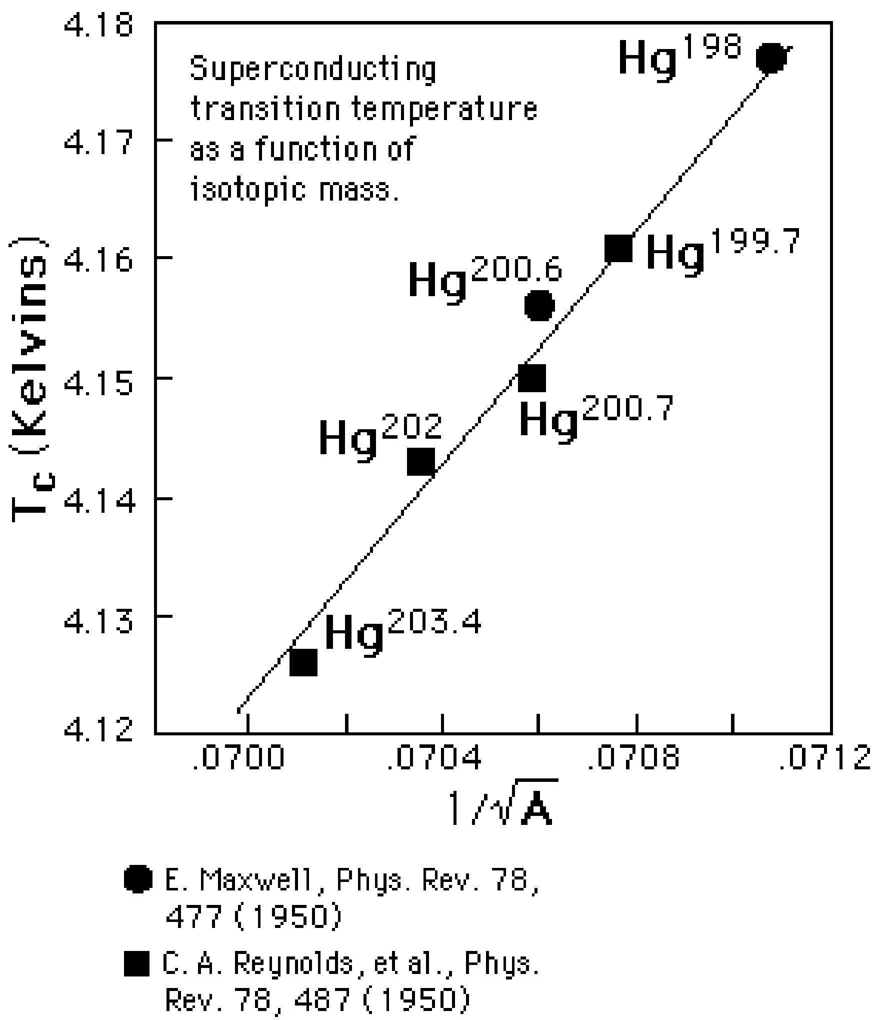
What gives superconductivity?

What give ‘good’ superconductivity
(High Tc, High Jc, High Hc)?

- High density of states?
- Strong electron-phonon coupling?
- High phonon frequencies (Debije frequency)?
- Diamagnetic?
- Heat capacity (sommerfeld coefficient)?
- Good normal conductivity?
- Other? Compressibility?, Sound velocity?, etc.?

Isotope effect



$$T_c \sim M^{-\alpha}$$
$$\alpha \sim 0.5$$

➔ Phonons $\Omega \sim 1/\sqrt{M}$

Debye frequency good predictor?

Isotope effect

	Hg	Sn	Pb	Zn	Cd	Tl		Mo	Os	Ru	Zr
α	0.5	0.47	0.48	0.45	0.5	0.5		0.33	0.2	0.0	0.0
θ_{Debye}	72	200	105	329	210	79		423	467	555	290
T_c	4.2	3.7	7.2	0.9	0.6	2.5		0.9	0.7	0.5	0.7

α only sometimes 0.5, sometimes even 0!

- k,ω-dependent coupling, bandstructure

Debye temperature does not seem to have much predictive power

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Correlations between normal-state properties and superconductivity

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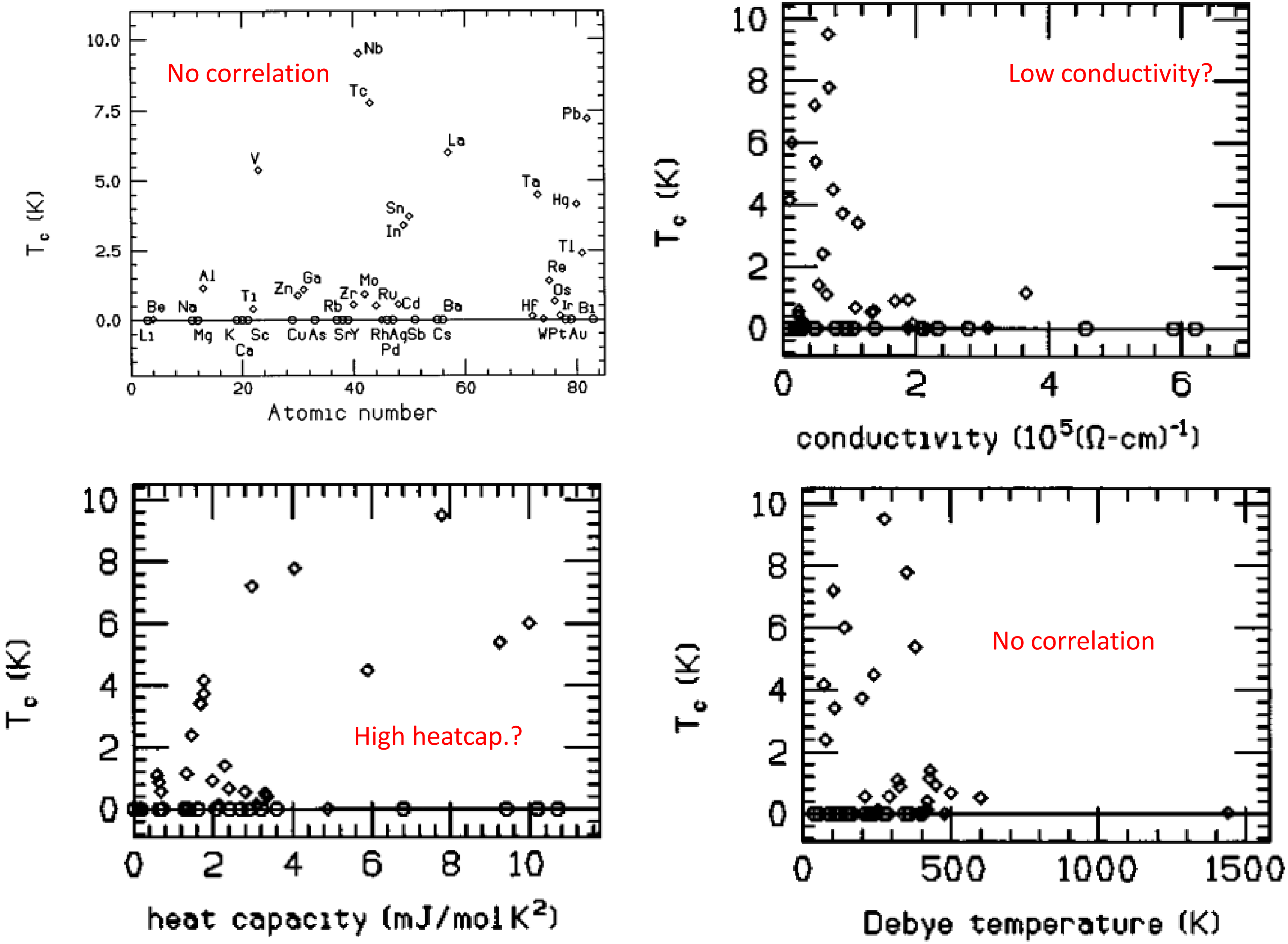
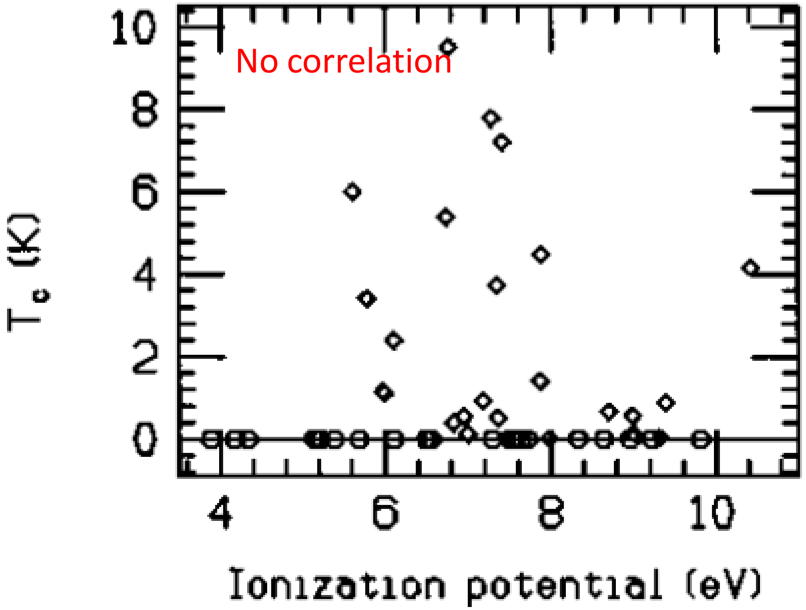
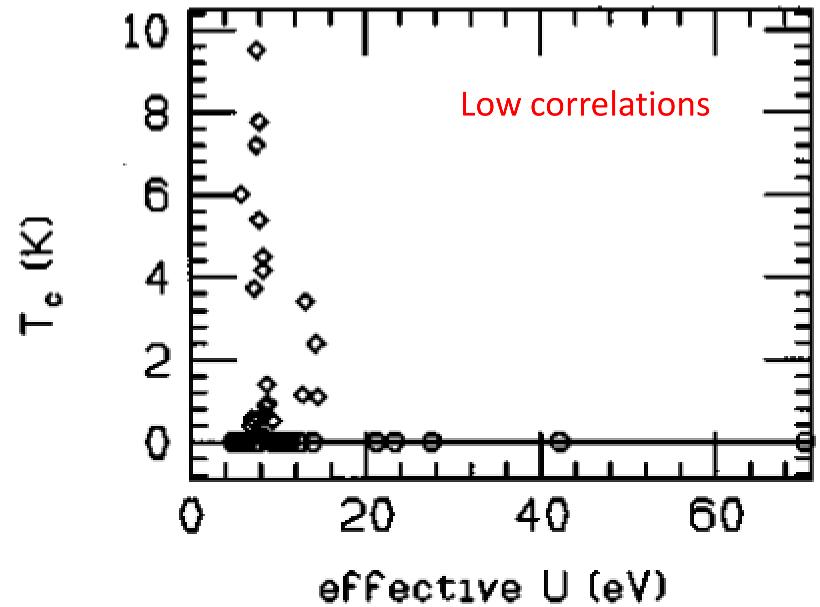
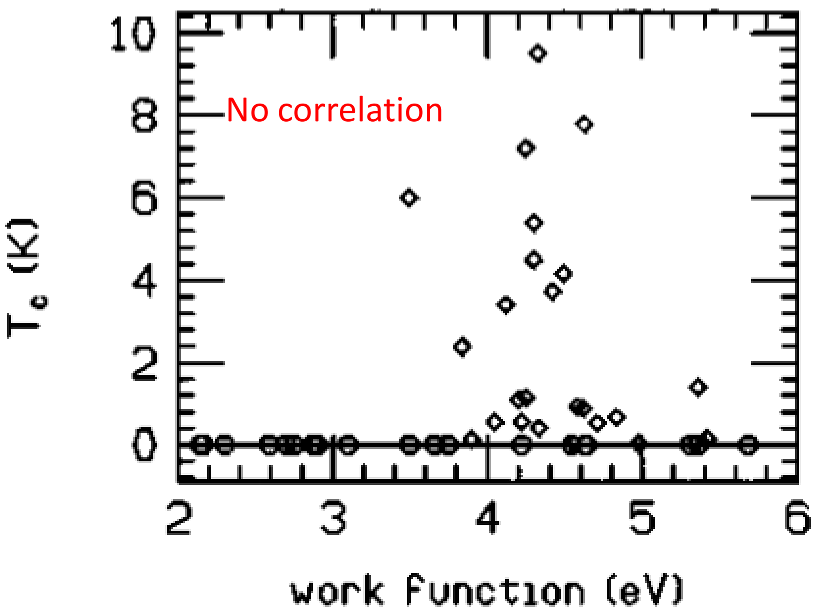
Despite many years of intense theoretical effort it is still not possible to predict whether a material will be superconducting or not at low temperatures by measurement of its physical properties at higher temperatures. Nor is it possible in general to estimate the magnitude of the superconducting critical temperature T_c from measurements of normal-state properties. Here we address these questions from a statistical point of view. The metallic elements in the first six rows of the periodic table are assumed to be a ''representative sample'' drawn from a larger set of materials, and various statistical measures of correlations between the magnitude of T_c and a normal-state property, as well as between a normal-state property and the fact whether the material is or is not a superconductor, are considered. Thirteen normal-state physical properties are studied, some of which are believed to be important to determine superconducting properties within conventional BCS theory and others not. It is found that properties assumed to be important within BCS theory rank lowest in predictive power regarding whether a material is or is not a superconductor. Instead, properties with highest predictive power in this respect are found to be bulk modulus, work function and Hall coefficient. With respect to the magnitude of T_c, it is found to be positively correlated with electronic heat capacity, magnetic susceptibility, and atomic volume, and negatively correlated with electrical and thermal conductivity and Debye temperature. No significant correlations with ionic mass and ionization potential are found. Consequences of these findings for the theoretical understanding of superconductivity are discussed. [S0163-1829(97)01314-3]

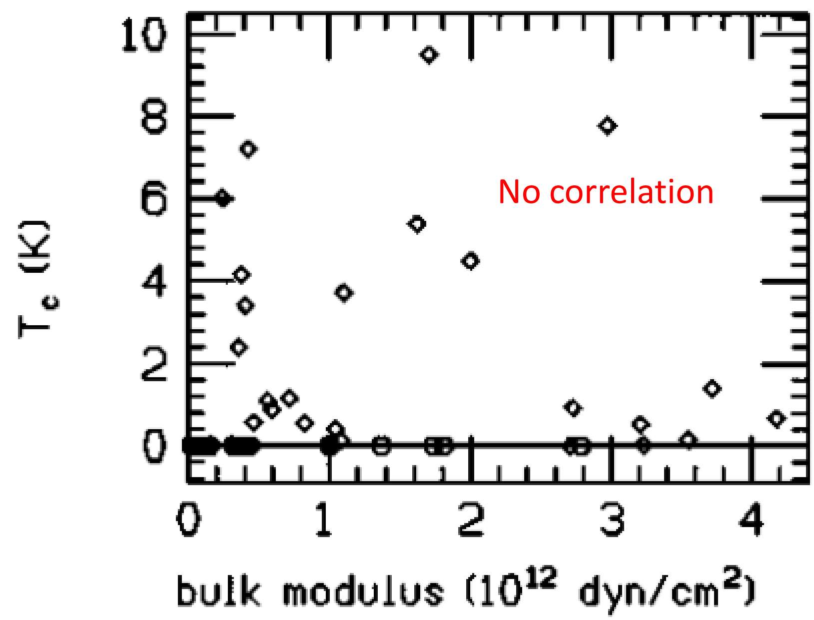


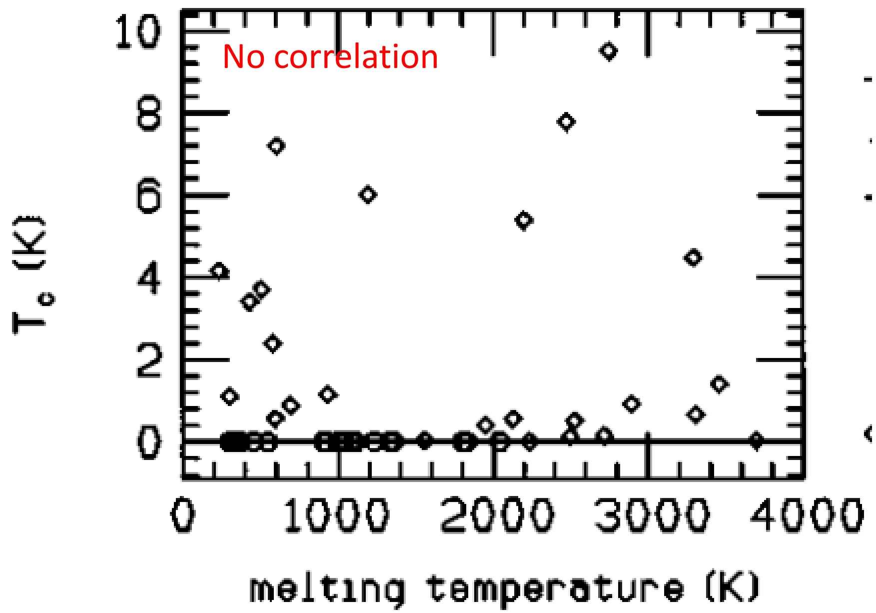
Circles: not superconductings. Squares: superconducting

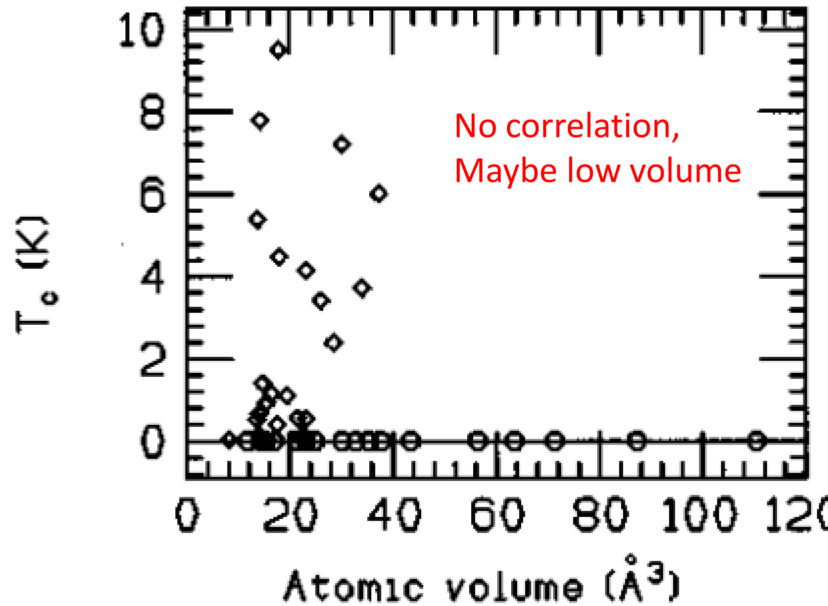

No correlation
10
8
6
4
2
0
Tc (K)
4
6
8
10
Ionization potential (eV)

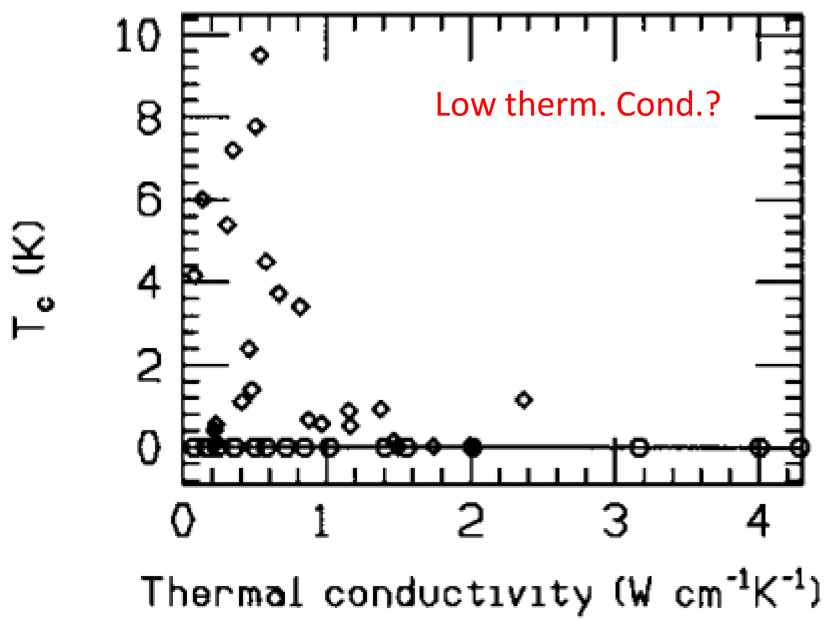

Low correlations
10
8
6
4
2
0
Tc (K)
0
20
40
60
effective U (eV)

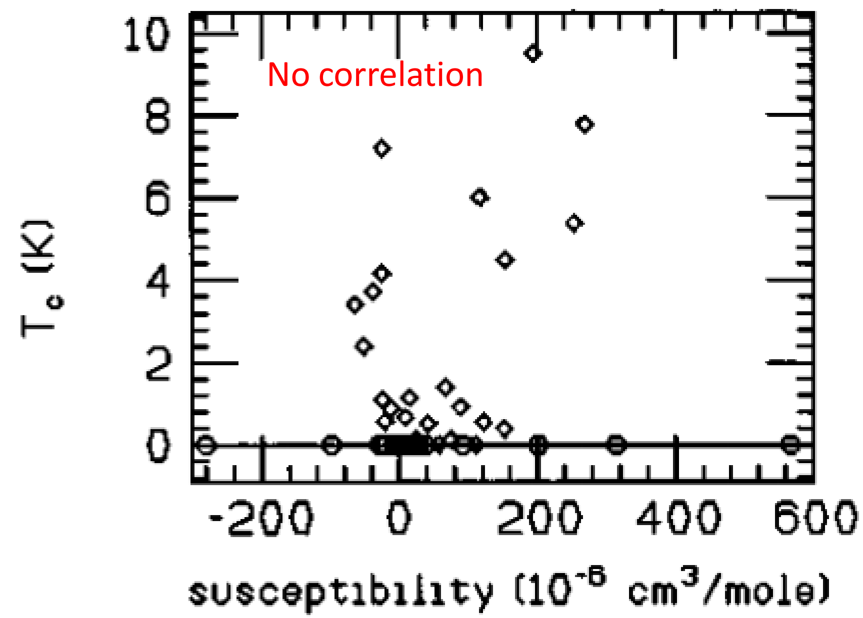

No correlation
10
8
6
4
2
0
Tc (K)
2
3
4
5
6
work function (eV)

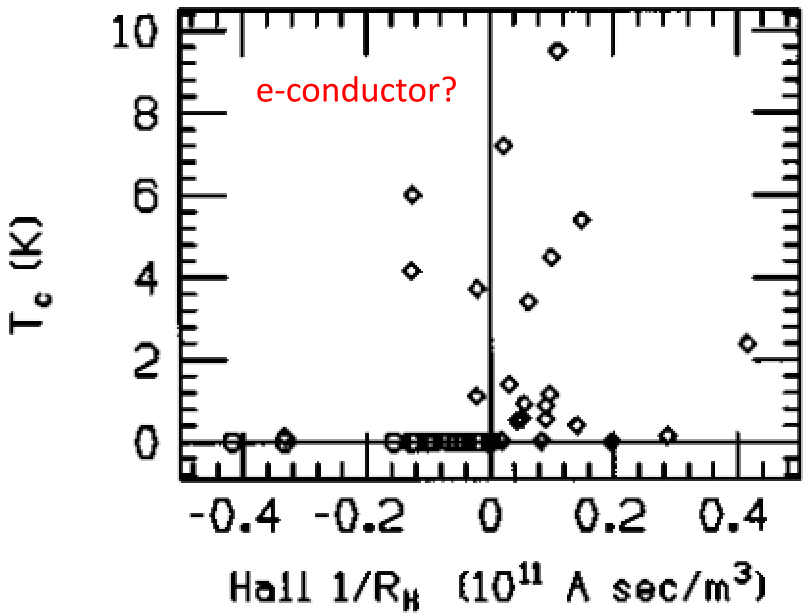

No correlation
10
8
6
4
2
0
Tc (K)
0
1
2
3
4
bulk modulus (10^12 dyn/cm^2)

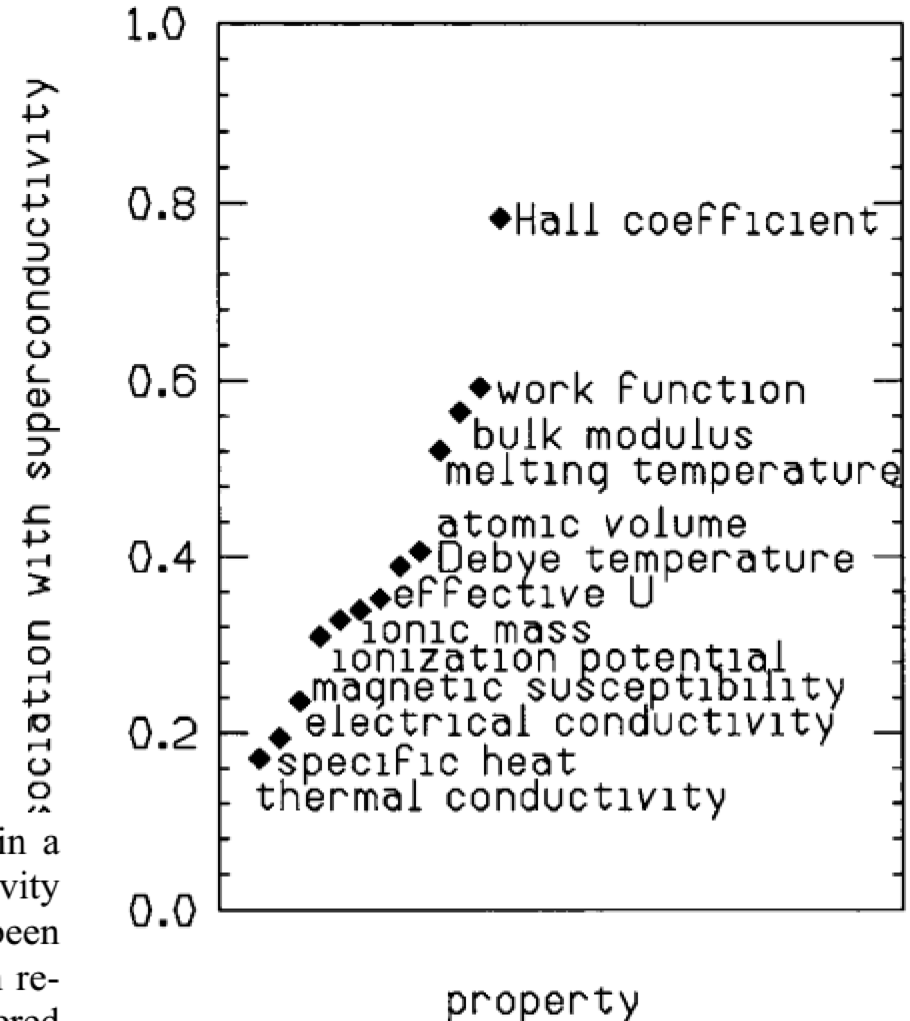

No correlation
T_c (K)
melting temperature (K)


No correlation,
Maybe low volume
T_c (K)
Atomic volume (Å^3)


Low therm. Cond.?
T_c (K)
Thermal conductivity (W cm^{-1}K^{-1})


No correlation
T_c (K)
susceptibility (10^{-6} cm^3/mole)





The understanding of superconductivity in solids is in a peculiar state. The conventional theory of superconductivity has been firmly in place for several years, and had been thought to describe superconductivity in all materials. In recent years, new families of materials have been discovered that do not seem to fit the conventional framework, and scientists have been working in developing new theoretical frameworks to describe the new materials. However, the applicability of the conventional theory to the ''conventional'' materials has not been called into question. Perhaps this is the time to do so.

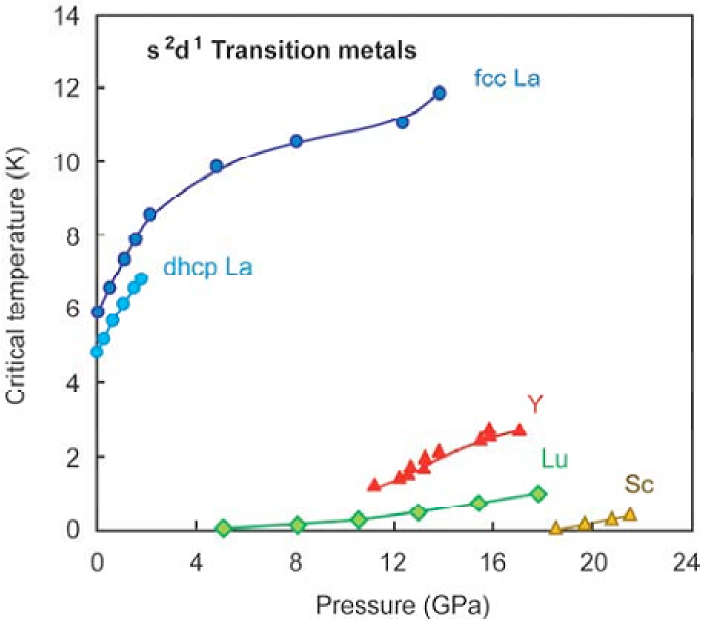


Figure 5. Critical temperature dependence on pressure for s^2d^1 transition metals, La [16], Lu [44], Sc [44], Y [30].

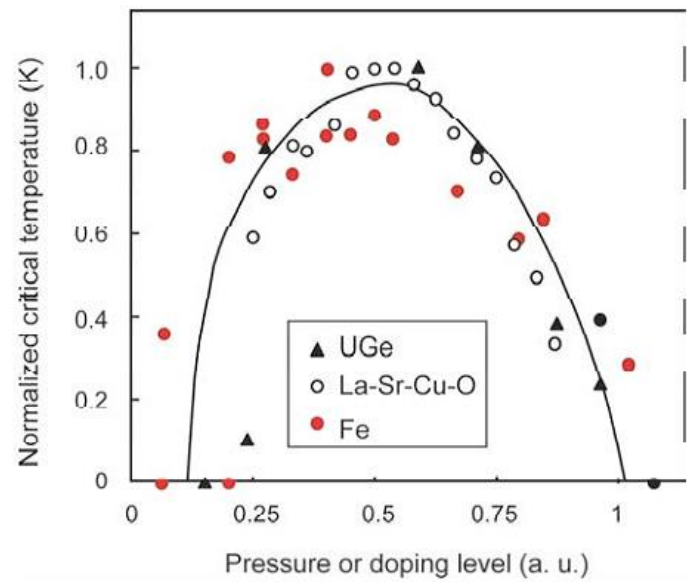


Figure 7. *Normalized critical temperature variation with pressure and doping level for materials with ferromagnetic or antiferromagnetic behavior. Data are taken from references [59], [58] and [7] for UGe2, La-Sr-Cu-O, and Fe, respectively.*

Overlap integrals, bandwidth, $D(E_F)$ atomic volume

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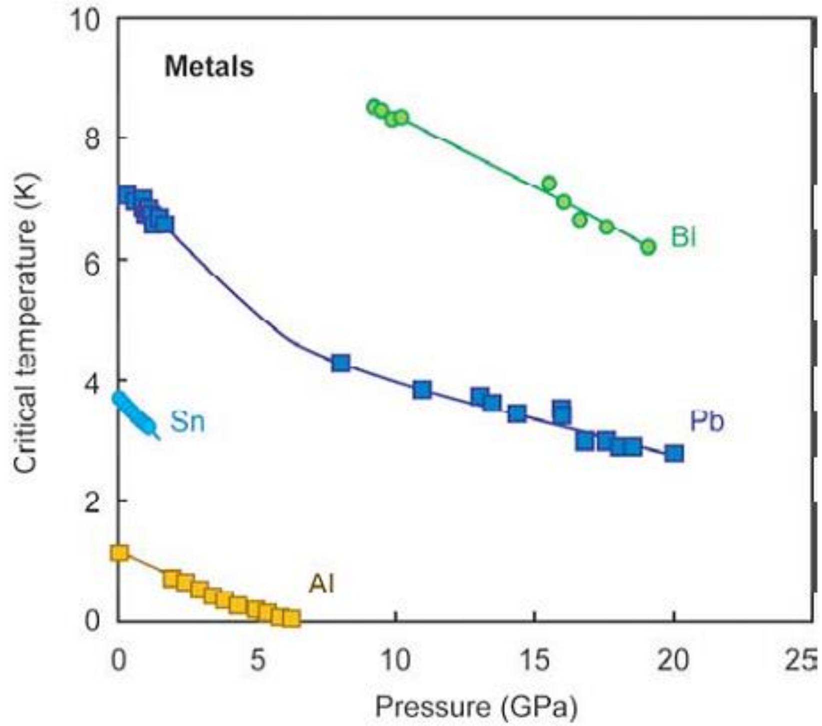

Figure 8. *Critical temperature dependence on pressure for metals, Al [62], Sn [63], Pb [40, 64-67], Bi [39, 40].*

There are no predicting physical properties
At this point best still seems high DOS at E_F

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