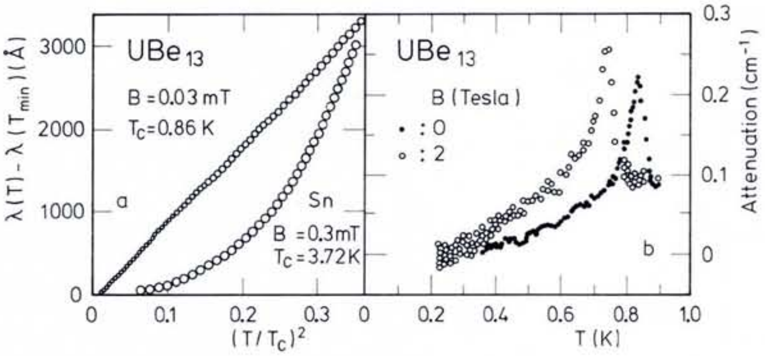

Fig. 5 — UBe_{13}: (a) increment of the magnetic field penetration depth as a function of $(T/T_c)^2$. For comparison, data for the BCS superconductor Sn are also shown (Einzel D. *et al.*, *Phys. Rev. Lett.* **56** (1986) 2513). (b) Longitudinal ultrasonic attenuation data taken as a function of temperature at 1.7 GHz for $B = 0$ and 2 T display the superconducting phase transition (Golding B. *et al.*, *Phys. Rev. Lett.* **55** (1985) 2479).

complex T-dependencies are predicted theoretically [4]. Simple power-law dependencies have been established also for classical superconductors. For example, the specific heat of HfV_2 ($T_c = 9$ K) is well described by a T^3 dependence over a large temperature regime.

Anisotropies of the order parameter should be smeared out by potential scattering. In fact, non-magnetic dopants like Th, La and Y partially substituted for the f-ions in $CeCu_2Si_2$ and UBe_{13} act qualitatively in a way similar to magnetic dopants in a BCS superconductor. On the other hand, the "pair breaking" by non-magnetic scatterers is surprisingly weak if estimated on the assumption of an isotropic potential scattering. This difficulty adds to another serious problem: for both $CeCu_2Si_2$ and UBe_{13}, the mean free path of the heavy fermions estimated from the measured normal-state resistivities are considerably shorter than the superconducting coherence lengths. These observations highlight a strong anisotropy of the scattering rate in Kondo lattices [3] which has to be unravelled by future work.

As with the shape of the superconducting order parameter, the nature of the pairing interaction is presently not known. Arguments in favour of magnetic coupling, in addition to the seeming analogy to superfluid ^3He, were provided by the Los Alamos group who noticed that superconductivity in UPt_3 "possibly coexists" with the pronounced spin-fluctuation phenomena that had been previously discovered for this compound by Jaap Franse and his colleagues. In the meantime, it has been found using sensitive microscopic probes like muon-spin rotation, nuclear magnetic resonance and neutron-diffraction measurements that magnetic correlations dominate the low-T "Fermi-liquid" properties of certain heavy-fermion compounds like $CeCu_6$ and $CeRu_2Si_2$ and even give rise to a cooperative antiferromagnetic state in others like URu_2Si_2, UPt_3 and $U_{1-x}Th_xBe_{13}$ ($0.01 < x < 0.05$). Since for these systems the ordered moments are usually extremely small ($\lesssim 10^{-2}\mu_B$/f-ion), a magnetic instability of the coherent heavy-fermion band seems to lead to "band magnetism" in the Fermi liquid; this effect should be distinguished from the "local-moment ordering" in heavy-fermion systems like $CeAl_2$. The coexistence between this form of band antiferromagnetism and superconductivity is illustrated in Figs. 4b and 6 for both UPt_3 and URu_2Si_2. More than one superconducting phase transition seem to occur in UPt_3 (Fig. 4a) and in $U_{1-x}Th_xBe_{13}$ and they have been associated with both unconventional and conventional order parameters.

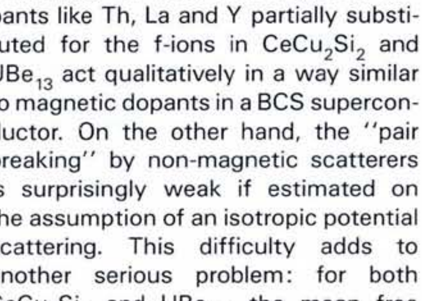

Fig. 6 — URu_2Si_2: ρ *vs* T (on a logarithmic scale). Arrows mark the onsets of antiferromagnetism (T_N) and superconductivity (T_C). Both phenomena are coexisting at low temperatures (Schlabitz W. *et al.*, *Z. Phys.* **B62** (1986) 171).

Alternatively, an electron-phonon coupling unique for Kondo lattices had been proposed to explain superconductivity with $T_c \lesssim 1$ K in $CeCu_2Si_2$ [2, 3]. It is based upon a pronounced volume dependence of k_BT^*, the characteristic energy or heavy-fermion band width and can be expressed by a giant "Grüneisen parameter", $\Gamma = -d\ell n\,(k_BT^*)/d\ell nV \cong 100$. Therefore, the "breathing mode" of the lattice, which is associated with large volume changes, couples strongly to the heavy fermions.

Experimental evidence for this particular electron-phonon coupling is found in striking anomalies of the elastic constants (as determined in Bruno Lüthi's group), thermal expansion and longitudinal sound absorption (see Fig. 5b).

Outlook

Heavy-fermion systems have provided a number of exciting phenomena which were quite unexpected within traditional concepts of metal physics. They allow us to investigate, for example, how band magnetism develops in a material characterized at elevated temperatures by a dense array of local moments. In addition, they are ideal testing grounds for models concerned with superconductivity in strongly correlated electron systems and they may have some impact on the future understanding of the phenomenon of high-T_c superconductivity in Cu-oxides.

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