## Title

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# Unconventional Flux Dynamics in the Heavy Fermion Superconductors $UPt_3$ and $UBe_{13}$

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We have investigated flux creep in single crystals of $UPt_3$ (H//c) and $UBe_{13}$ (H//$c_4$) in the temperature range 5 mK < T < $T_c$ and for magnetic fields H < 0.2 T. The relaxation curves for both of these heavy fermion superconductors show novel behaviours, with decay laws which depend strongly on the applied field. At all temperatures, we observe contributions to the decays which seem to arise from different processes with different time dependences, namely logarithmic and stretched exponential.

Recently we reported on a novel behaviour of the relaxation of the magnetization in the heavy electron compound $UPt_3$ [1]. We present here some new results which show that two clearly different relaxation mechanisms are responsible for the decay of the magnetization from a metastable configuration in $UPt_3$: i) the well known thermally activated flux creep and ii) a temperature independent, complex relaxation which follows the stretched exponential form:

$$M(t)-M(\infty)=[M(0)-M(\infty)]\exp\left[-(t/\tau)^{\beta}\right] \quad (1)$$

with $0.6 < \beta < 0.9$. Two relaxation mechanisms are also responsible for the decay of the magnetization of $UBe_{13}$, although with a much weaker contribution of the temperature independent process.

The $UPt_3$ specimen is a single crystal (1.7x3x 0.9 $mm^3$) with a transition temperature $T_c$ = 528 mK and a transition width $\Delta T_c$ = 11 mK. The magnetic field was applied parallel to the c-axis of the crystal. The $UBe_{13}$ single crystal (1.7x1.8x4.9 $mm^3$) has $T_c$ = 880 mK and $\Delta T_c$ = 60 mK. The specimens were placed inside the mixing chamber in direct contact with the $^3He$-$^4He$ solution. We discuss here relaxation of the remanent magnetization at a constant temperature after having cycled the zero field cooled specimen in a field $H_i$.

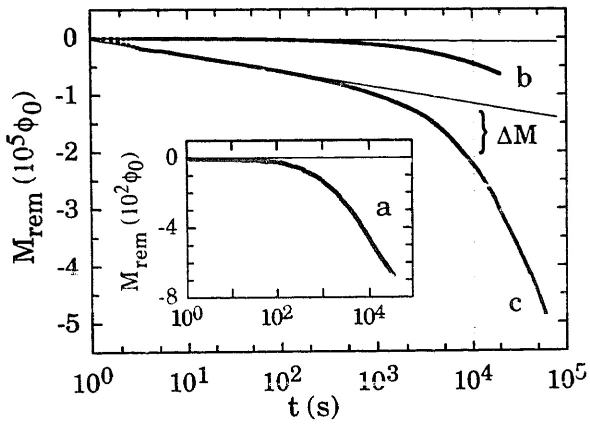


*Fig.1: Relaxation curves of $M_{rem}$ for the $UPt_3$ sample at 450 mK for different cycling fields $H_i$: 3.4 Oe (a), 28 Oe (b) and 680 Oe (c). For comparison we have chosen $M_{rem}(t=1s) = 0$.*

Decays of the remanent magnetization $M_{rem}$ at T = 450 mK for three different cycling fields $H_i$ are shown in Fig. 1. It is clear from this figure that, for high values of $H_i$, two types of decays are present. The curves can be described as a superposition of a logarithmic and a stretched exponential decay. For low values of $H_i$ (of the order of 1 Oe) on the other hand, we observe a decay that can be well fitted with *only* a stretched exponential law as shown by us previously for another $UPt_3$ crystal with H ⊥ c-axis [1]. If we try to quantify the anomalous decay we find out that, for example for $H_i$ = 3.4 Oe (Fig. 1a)

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the remanent magnetization at the specimen is about $M_{rem} \cong 1100\ \phi_0$ and its decay in the first $10^4$ seconds is $\Delta M \cong 420\ \phi_0$. As the flux front penetrates deeper into the crystal for bigger cycling fields $H_i$, we find that the ratio $\Delta M\ [10^4\ s]\ /M_{rem}$ decreases from about 38% (Fig. 1a) to 1.3% (Fig. 1c), where $\Delta M\ [10^4\ s]$ represents only the stretched exponential part, i.e. the logarithmic part of the decay has been subtracted (lines in Fig. 1). This behaviour is displayed in Fig. 2 for data at T = 450 mK and different cycling fields $H_i$. Undoubtedly, the closer the flux front is to the surface of the specimen, the stronger its decay is in a given time interval.

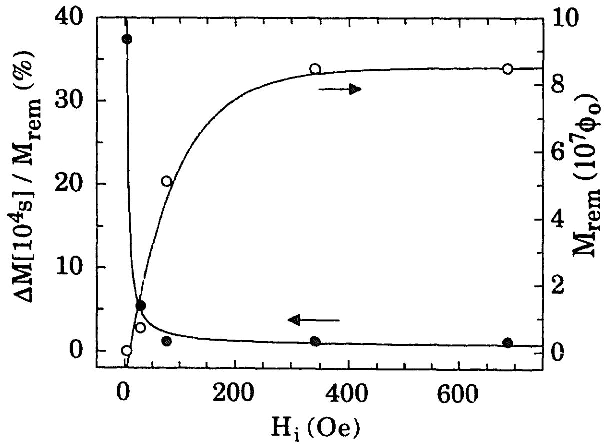


*Fig.2: Remanent Magnetization $M_{rem}$ (open symbols) and ratio $\Delta M\ [10^4\ s]/M_{rem}$ (full symbols) for the $UPt_3$ sample at 450 mK.*

In Fig. 3 we give the normalized logarithmic decay rates obtained from the slopes of the lines as the ones shown in Fig. 1, for $UPt_3$ and $UBe_{13}$. At each temperature, the cycling field $H_i$ is above the field $H^*$ necessary to establish the critical state with the exception of the data at T = 5 mK. We notice that the logarithmic decay rate in $UBe_{13}$ is considerably stronger than in $UPt_3$. It follows the temperature dependence predicted by Kim-Anderson and it extrapolates to about zero for $T \to 0$. For $UPt_3$ on the other hand, we observe very weak, conventional flux creep only at high temperatures and no thermally activated creep for $T \leq 400$ mK.

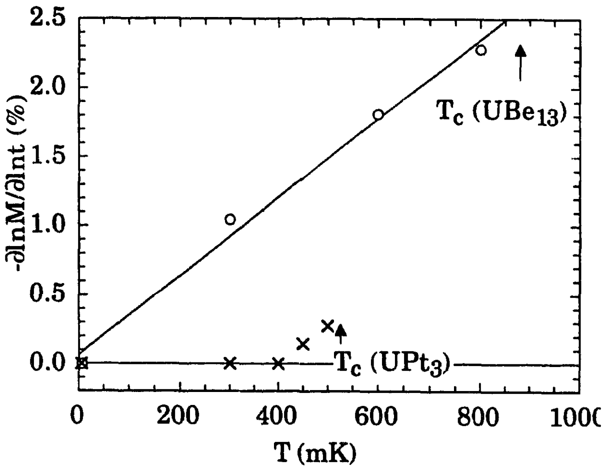


*Fig.3: Normalized decay rates of the logarithmic part of the decay for both samples.*

It is tempting to relate the strong pinning at $T \leq 400$ mK to the existence of fractional vortices [2, 3]. In the low field, low temperature phase of $UPt_3$ with a multicomponent order parameter, domain walls can act as strong pinning centers reducing the creep rate to unobservable low levels [4].

Below 400 mK, only the stretched exponential type of decay is observed in $UPt_3$. We also observe a stretched exponential contribution to the relaxation of $M_{rem}$ in $UBe_{13}$ but its magnitude is at least a factor of 10 weaker than in $UPt_3$ at all temperatures. The anomalous flux dynamics discussed here for $UPt_3$ and $UBe_{13}$ is not found in $CeCu_2Si_2$ [5]

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