Summary

The Grüneisen parameter has been shown to be a powerful detection tool for quantum criticality, shortly after Zhu *et al.* [23] predicted its divergence $\Gamma(T) \propto T^{-\nu z}$ at every QCP. The temperature exponent νz of the diverging Γ provides important information regarding the type of quantum criticality, giving the product of ν, the critical exponent of the correlation length, and z, the critical exponent of the correlation time. Therefore the goal of this thesis was to focus on different types of QCPs, such as FM and AFM QCPs. Moreover, the discovery of superconductivity coexisting with ferromagnetism in UCoGe [29] and the evidence of FM QCPs in systems with Si-doping [40] or under pressure [42] gave the possibility to study other FM QCPs with the help of the Grüneisen ratio. Here we reported the thermal properties of pure UCoGe at ambient pressure, which presented the first evidence of bulk SC and FM.

In *chapter 3* different experimental techniques are presented. In particular the dilatometry technique is implemented over a wide temperature range (30 mK -150 K) for two different cells. Cell-1 was calibrated to be used in the Heliox and Kelvinox systems (30 mK-20 K) and cell-2 for the glass-dewar system (2-150 K). At very low temperatures ($T < 100$ mK) a minimum in the calibration function is found. Its origin is still unclear, but it is possibly related to a two level Schottky system. Experiments carried out in field corroborated this hypothesis.

Chapter 4 is devoted to the AFM QCP in $Ce(Ru_{0.24}Fe_{0.76})_2Ge_2$. The single crystalline sample is shown to have a Fe-concentration $x \sim 0.75$, which is lower than the nominal one, and $T_N \sim 1.2$ K, therefore AFM order is still present in the sample. The AFM was suppressed by applying a small magnetic field. From magnetostriction and magnetoresistance measurements, we consider $B_c \sim 0.8$ T. The resistivity exponent n from the data fitted by $\rho(T) = \rho_0 + aT^n$ showed a minimum $n = 1.3$ at $B \sim B_c$. The result is lower than the one predicted for a SDW AFM QCP, which is n=3/2, possibly due

to crystallographic disorder.

Thermal expansion and specific heat were studied in several applied magnetic fields and the Grüneisen ratio was calculated. The thermal expansion data fitted by a power law function $\beta = aT^n$ present a minimum $n = 1$ for $B \sim B_c$. For the specific heat divided by the temperature c/T at $T = 0.5$ K we reported the highest value $\gamma = 0.83$ J/mol K^2 for $B \sim B_c$. Both parameters deviate from the prediction for a SDW AFM QCP. At the critical field, the Grüneisen ratio reaches high values at low temperatures ($\Gamma_{mag} = 50$ at 0.5 K). Nevertheless the specific heat and the thermal expansion at $B \sim B_c$ are not compatible with the prediction for a SDW AFM QCP and Γ does not diverge. This was not unexpected since (i) the system presents competing local and long-range fluctuations at the QCP, (ii) the system is above the upper critical dimension and (iii) if different Γ ratio's do not couple due to the presence of more than one energy scale, only Γ_{mag} is predicted to diverge when the magnetic field is used as control parameter.

The thermal expansion and specific heat experiments on a FM SDW QCP are reported in *chapter 5*. The thermal expansion data on the polycrystalline U(Rh,Ru)Ge series ($x = 0.10, 0.20$ and $x_c = 0.38$) are combined with specific heat data taken previously on the same samples in order to obtain the Grüneisen ratio Γ towards the QCP. The transition temperatures obtained by thermal expansion are in very good agreement with the ones of the previously reported phase diagram. Although no diverging Γ is reported for $x = 0.38$, a steady rise of the Grüneisen ratio is observed in the paramagnetic regime on approach of the FM transition.

We then investigated the thermal properties of single crystalline samples of $URh_{0.62}Ru_{0.38}Ge$. AC-susceptibity revealed that the samples under study were still ferromagnetic and therefore the Ru-concentration was lower than x_{cr}. Moreover, a typical variation of 2% in the Rh/Ru ratio was observed along the crystal pulling direction applied during the Czochralski growth. The thermal expansion results of one $URh_{0.62}Ru_{0.38}Ge$ sample (nominal critical concentration) are compared with the specific heat data on the same sample. In both data sets the FM transition is observed. The calculated Grüneisen ratio presents a large plateau to drop at $T \sim 1$ K due to FM. We showed that this behaviour is not inconsistent with the theory proposed by ref. [23].

In *chapter 6* we reported thermal expansion measurements on polycrystalline UCoGe, which provided the first evidence of coexistence of SC and FM in the bulk of the sample. This was concluded since the steps at the transitions were large and the total length associated to SC was small compared to the one associated to FM. High temperature thermal expansion revealed the formation of a Kondo lattice state for $T < 80$ K. The FM and SC transition temperatures, $T_C = 3$ K and $T_{sc}^{bulk} = 0.45$ K, are in good agreement with resistivity and ac-susceptibility data and the SC transition in thermal expansion and the specific heat appears when the resistivity drops to zero.

An annealing study of the single crystalline samples was performed in order to improve their quality. The single crystals with the highest quality that were previously obtained were two bar-shaped samples with $RRR = 30$ and 40. From our study it is clear that the SC transition temperature will not increase much further when increasing the RRR, but the width of the SC transition can decrease with improving samples quality. The thermal expansion data confirmed bulk FM and SC at $T_C = 2.6$ K and $T_{sc}^{bulk} = 0.42$ K. An additional contribution is present below ~ 1.5 K, just before superconductivity sets in, as it was already observed in other SCFMs. This shoulder-like feature indicates the presence of a second energy scale, most likely related to an enhancement of the spin fluctuations. A qualitative analysis using the Ehrenfest relation showed that T_{sc} increases while T_C decreases when pressure is applied along the b axis, and vice-versa for pressures applied along the a and c axes. Thermal expansion on single crystalline UCoGe revealed a very anisotropic response to magnetic field. For an external magnetic field $B \| \Delta L$, T_C is suppressed in a small magnetic field when $B \| m_0$ while T_C stays around the same value up to a magnetic field of 8 T when $B \perp m_0$. The step size considerably increased when a field $B \perp m_0$ was applied. It would be of high interest to use these results in order to study the Grüneisen parameter in a field tuned QCP in UCoGe.