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Thermodynamic signature of quantum criticality: universally diverging Grüneisen ratio

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At a generic quantum critical point where pressure acts as (or couples to) the zero-temperature control parameter, the Grüneisen ratio Γ (the ratio of thermal expansion to specific heat) is *divergent*[1]. This property provides a novel probe to quantum criticality from thermodynamics. When scaling applies, $\Gamma \sim 1/T^x$ at the critical pressure $p = p_c$, where the exponent x measures the scaling dimension of the most singular operator coupled to pressure; in the alternative limit $T \to 0$ and $p \neq p_c$, $\Gamma = G_r/(p - p_c)$, where G_r is a universal combination of critical exponents. The predicted divergence has been observed near the quantum critical points of several heavy fermion metals[2]. Analyses based on specific models relevant to these experiments are also presented. [1] L. Zhu, M. Garst, A. Rosch, and Q. Si, Phys. Rev. Lett. **91**, 066404 (2003). [2] R. Küchler *et al.*, Phys. Rev. Lett. **91**, 066405 (2003); *ibid.* **93**, 096402 (2004).