Emergence of a quantum coherent state at the border of ferroelectricity

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Keywords: High pressure, Piston-cylinder cell, Dielectric properties, Quantum criticality, Ferroelectricity, Instrumentation

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The quantum paraelectric $SrTiO_3$ exists on the border of ferroelectricity in the vicinity of a quantum critical point. It is this proximity to a quantum critical point and the fluctuations associated with it which are responsible for SrTiO3's strikingly non-classical dielectric susceptibility [1]. The lack of itinerant electrons and the simplicity of the system make it an attractive model system for investigation of the underlying physics of quantum criticality.

Here we show by means of high precision measurements of the temperature and pressure dependence of the dielectric susceptibility [2] that quantum melting of this displacive ferroelectric leads to an unconventional quantum paraelectric state exhibiting the phenomenon of 'order by disorder', namely a fluctuation induced enhancement of electric polarization extending up to a characteristic coherence temperature T*. T* vanishes at the ferroelectric quantum critical point and the square of T* increases with a characteristic linear dependence on the applied pressure. We show that in the vicinity of T* this thermal activation phenomenon can be understood quantitatively, without the use of adjustable parameters, in terms of the hybridization of the critical electric polarization field and the volume strain field of the lattice. We argue that this coherent optical-acoustic phonon state emerges from and as a result of the ferroelectric quantum critical point and is critical to our understanding of the mechanisms behind the quantum criticality and the phenomena resulting from it in $SrTiO_3$ and more generally in quantum critical ferroelectric compounds.

At still lower temperatures, well below T*, we observe a breakdown of this unconventional form of quantum paraelectricity and the emergence of a still more exotic state characterized by slowly fluctuating micro-domains of the lattice structure. We suggest that this low temperature state may be viewed as a type of instanton liquid arising from anisotropic strain induced long-range correlations of the electric polarization field.

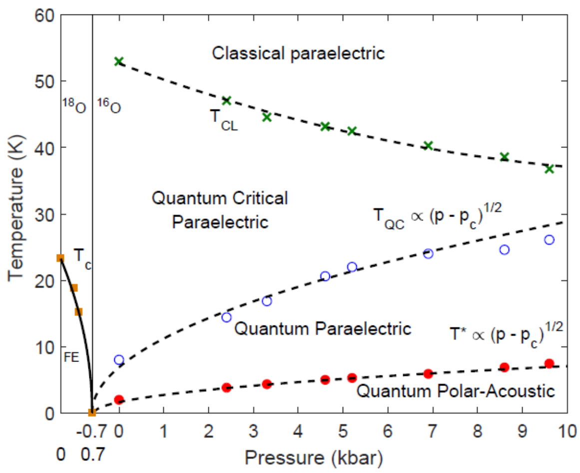

Figure 1. Extracted phase diagram for $SrTi^{16}O_3$ from -0.7 to 10 kbar (right) and for $SrTi^{18}O_3$ from 0 to 0.7 kbar (left, [3]), overlayed to match up the positions of proposed QCPs. Closed circles give the positions of the low minimum in the inverse susceptibility. Open circles and crosses denote crossover temperatures into and out of the quantum critical regime.

Acknowledgments: This work was carried out with support from Jesus and Trinity Colleges of the University of Cambridge, the EPSRC, IHT KAZATOMPROM and the CHT Uzbekistan programme. The work was carried out with financial support from the Ministry of Education and Science of the Russian Federation in the framework of Increase Competitiveness Program of NUST MISiS (№ K2-2017-024).

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