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# Theory of Pressure Effects and Possible Zero-field Quadrupolar Phase in $PrOs_4Sb_{12}$

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The skutterudite superconductor $PrOs_4Sb_{12}$ has attracted a growing interest due to the unique $h$-$T$ phase diagram. In the past few years, we have developed a theory of the field-induced order in this material, and have clarified that the effect of predominant AFQ interaction should appear in the following three aspects in the experimental observations: (1) anisotropy of the phase diagram, (2) momentum dependence of neutron inelastic scattering spectra, (3) field direction dependence of the induced antiferromagnetism. Recent experiments all indicate the consistency with the AFQ model, and rule out the possibility of predominant magnetic interaction.

Here, we shall report some new results of recent theoretical investigations on the possible zero-field AFQ order that can be realized by hydrostatic and uniaxial pressures, as a continuation of the previous studies. This study is clearly related with a recent experiment by Tayama et al., which shows through magnetization measurements that the hydrostatic pressure reduces the level splitting with the interaction strength being almost unchanged.

Making use of a new pseudo-spin description suitable for the AFQ state at zero field, we show that the AFQ model is well approximated as the four-state AF Potts model in the uniform transverse field, known as the quantum Potts model. This mapping immediately clarifies the following aspects of the AFQ model: When the singlet-triplet gap becomes zero, a macroscopic degeneracy of the ordered phase appears. The magnetic susceptibility shows a divergent increase with decreasing the crystal field, reflecting the degeneracy. A type of the uniaxial strains can stabilize the AFQ order at zero field, where an analogy with the magnetic field effect on $CeB_6$ can be found.

Based on these findings in the Potts limit, we have studied the mean-field solutions of the original AFQ model as a function of the magnetic field. The evolutions from the field-induced order to the zero-field one have been elucidated by changing the crystal field and the uniaxial strain. In particular, we point out that the effect of the strain directions on the AFQ order is very anisotropic, and discuss its origin in relation with the competing interaction in the Potts limit. Possibilities of new phase transitions with the pressure effects are discussed.

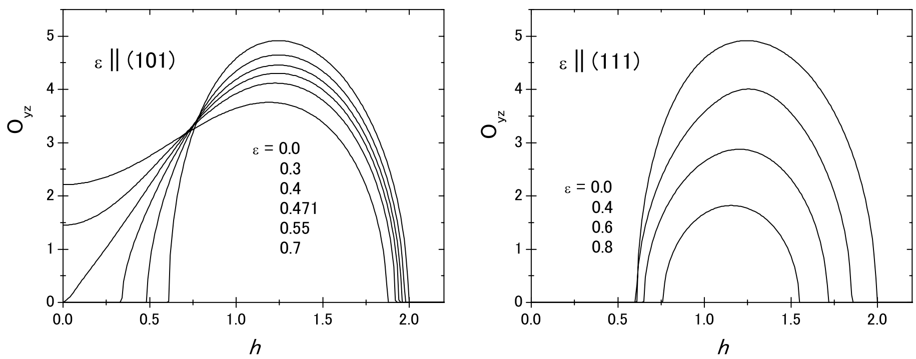


Figure 1: The AFQ moment as a function of the magnetic field $h||(001)$, under the strains $\epsilon||(101)$ and (111).