Long-range magnetic order in the quasicrystals and approximants

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Existence or absence of a long-range magnetic order in quasiperiodic spin systems has been one of the central controversies in quasicrystal research since its discovery in 1982 [1]. Historically, magnetic quasicrystals found in early stage all show spin-glass-like behaviour, suggesting that long-range order is somehow prohibited in quasiperiodic materials. On the other hand, more and more magnetic long-range order has been found in quasicrystal “approximants”, in which local atomic (and consequently magnetic) clusters, being identical to those in quasicrystals, form spatially periodic network. Representative examples of such magnetic approximants are Cd6RE [2], Au-Si-Tb [3], and Au-Al-Tb [4], just to note a few. We have studied magnetic structures in the ordered phase of those approximants, and found intriguing non-collinear non-coplanar arrangement of spins, named “whirling spin order”. Representative magnetic structure, found in the Au-Al-Tb 1/1 approximant, is shown in Fig. 1. Systematic study on the magnetic order in the approximants further suggests that the condition for the establishment of the long-range order is indeed related to electron density [5]. Encouraged by this inspiring idea, Tamura et al. designed a new quasicrystalline phase in Au-Ga-RE (RE = Gd and Tb) alloy system [6]. Bulk magnetic characterization combined with neutron diffraction clearly shows formation of ferromagnetic order in the Au-Ga-Gd and Au-Ga-Tb quasicrystals, the first confirmation of the long-range magnetic order in quasicrystals. We have recently extended the higher dimensional crystallography to magnetic structure analysis. Using an irreducible representation table for the six-dimensional Pm-3-5 space group, higher-dimensional magnetic representation method has been developed, and implemented in the home-made powder Rietveld analysis code. Preliminary Rietveld fitting has been tried to the data obtained in the Au-Ga-Tb magnetic quasicrystal. In this talk, present status of the development of the analysis method will be presented, along with various magnetic structures found in the approximants.


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