Universal temperature dependence of the magnetization in gapped spin chains

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Since the discovery of the Haldane gap, studies of gapped spin chains have been attractive to both theoreticians and experimentalists. Moreover, recent rapid progress in high magnetic field measurements is providing various fascinating data for the gapped spin systems under the high magnetic field. On the other, due to lack of exact methods, theoretical studies of general gapped spin systems even for static properties have been difficult compared to that of $S = 1/2$ chain. However, very recent development of new numerical algorithms (e.g. SSE) has made detailed data even in high field regime available.

Given by this situation, we study the temperature dependence of the magnetization in $S = 1$ Haldane chain under a wide range of magnetic fields, $\mathcal{H} = \sum_j J\vec{S}_j \cdot \vec{S}_{j+1} - hS^z_j$, in detail by using QMC. Especially we discuss the cases where the magnetic fields h exceed the gap Δ. Although the excitation of the system in this regime is gapless and the low energy effective theory is the Tomonaga-Luttinger (TL) liquid as with the $S = 1/2$ Heisenberg chain, the behavior in the Haldane chain is qualitatively different from that of the $S = 1/2$ Heisenberg chain; the data is dipicted in Figure. This results are discussed from the viewpoint of dilute boson and the TL liquid and compared to the three dimensional magnon Bose-Einstein condensation. We believe that this results is universal for almost gapped spin systems in quasi one dimension because the above discussion is independent of details of systems. We also believe that this behavior is relevant to experiments.

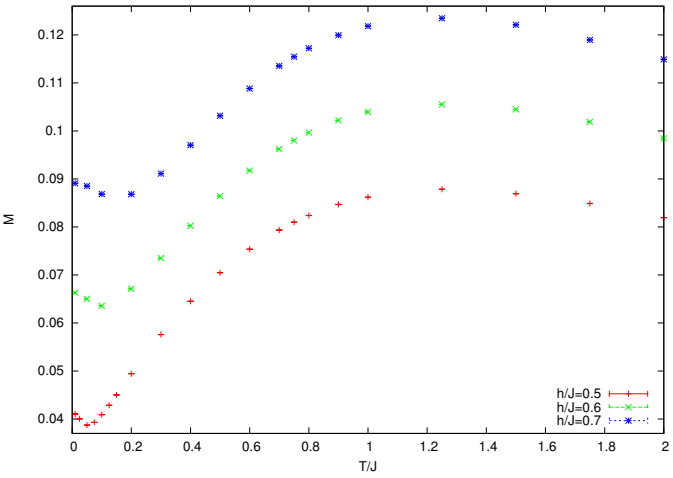

FIG. 1: The tepmerature dependence of the magnetization for $h/J = 0.5, 0.6$ and 0.7, respectively.