Vacancy-induced spin textures and their interactions in a classical spin liquid

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Abstract

Motivated by experiments on the archetypal frustrated magnet $SrCr_{9p}Ga_{12-9p}O_{19}$ (SCGO), we study the classical Heisenberg model on the pyrochlore slab (Kagomé bilayer) lattice with site-dilution $x = 1 - p$. This allows us to address generic aspects of the physics of non-magnetic vacancies in a classical spin liquid. We explicitly demonstrate that the pure ($x = 0$) system remains a spin-liquid down to the lowest temperatures, with an unusual *non-monotonic* temperature dependence of the susceptibility, which even turns diamagnetic for the apical spins between the two kagome layers. For $x > 0$ but small, the low temperature magnetic response of the system is most naturally described in terms of the properties of spatially extended spin textures that cloak an "orphan" $S = 3/2$ Cr^{3+} spin in direct proximity to a pair of missing sites belonging to the same triangular simplex. In the $T \to 0$ limit, these orphan-texture complexes each carry a net magnetization that is exactly half the magnetic moment of an individual spin of the undiluted system. Furthermore, we demonstrate that they interact via an entropic *temperature dependent pair-wise exchange interaction* $J_{eff}(T, \vec{r}) \sim T\mathcal{J}(\vec{r}\sqrt{T})$ that has a logarithmic form at short-distances and decays exponentially beyond a thermal correlation length $\xi(T) \sim 1/\sqrt{T}$. The sign of J_{eff} depends on whether the two orphan spins belong to the same Kagome layer or not. We provide a detailed analytical account of these properties using an effective field theory approach specifically tailored for the problem at hand. These results are in quantitative agreement with large-scale Monte Carlo numerics. [with Arnab Sen and R. Moessner]