

FeMn₃Ge₂Sn₇O₁₆ : a Spin-liquid Candidate with a Perfectly Isotropic 2-D Kagomé Lattice

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The compound Fe₄Si₂Sn₇O₁₆ has a hitherto unique crystal structure, consisting of ionic oxide layers based on edge-sharing FeO₆ and Sn⁴⁺O₆ octahedra alternating with layers of intermetallic character based on FeSn₆²⁺ octahedra, separated by covalent SiO₄ tetrahedra. The ionic layers contain kagomé lattices of magnetic Fe²⁺ cations (octahedral crystal field, high-spin [HS] d⁶, $S = 2$) with perfect trigonal symmetry; while the intermetallic layers are non-magnetic because the Fe²⁺ is in the low-spin ($S = 0$) state. The formula is more correctly written as Fe₄Si₂Sn₇O₁₆ to differentiate the one LS-Fe²⁺ per formula unit in the intermetallic layer from the three HS-Fe²⁺ per formula unit in the kagomé oxide layer.

Fe₄Si₂Sn₇O₁₆ also has a unique magnetic ground state below a Néel ordering temperature $T_N = 3.5$ K, in which the spins on 2/3 of the Fe²⁺ sites in the kagomé oxide layers order antiferromagnetically, while 1/3 remain disordered and fluctuating down to at least 0.1 K. The nature and origin of this unique “striped” partial spin-liquid state is unclear. The fact that it breaks trigonal symmetry, which the more conventional $q = 0$ or $\sqrt{3} \times \sqrt{3}$ kagomé states would not, raises the possibility that the anisotropic distribution of the 6 unpaired spins on HS-Fe²⁺ ($t_{2g}^4 e_g^2$) plays a role. To test this possibility, we have now synthesised an isotropic analogue with a kagomé lattice of HS Mn²⁺ ($t_{2g}^3 e_g^2$), by co-substituting Ge⁴⁺ for Si⁴⁺ in the bridging/stannite layers to match the lattice dimensions between layers.

We found that FeMn₃Ge₂Sn₇O₁₆ has the same “striped” magnetic ground state as Fe₄Si₂Sn₇O₁₆, in the same temperature range, ruling out this explanation. However, the zero-field striped structure is collinear for FeMn₃Ge₂Sn₇O₁₆ vs. non-collinear for Fe₄Si₂Sn₇O₁₆, which may indeed be a consequence of the change in anisotropy on the magnetic kagomé site, and suggests that FeMn₃Ge₂Sn₇O₁₆ is an even more ideal spin-liquid candidate than Fe₄Si₂Sn₇O₁₆. We also found that an external applied magnetic field lifts the degeneracy on the disordered site, giving rise to another ordered magnetic structure never before observed nor predicted on a kagomé lattice.

Level of Expertise

Experienced Researcher

Do you wish to take part in the poster slam

No

Travel Funding

No

Speakers Gender

Male

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