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Partial Magnetic Order in $Fe_3PO_4O_3$

The magnetic frustration brought about by triangular motifs and competing antiferromagnetic interactions in $Fe_3PO_4O_3$ (spacegroup R3m) have been shown to lead to an unusual magnetic state below T_N = 163 K. Below T_N, antiferromagnetic order is restricted to nanosized needle-like domains oriented along the c-axis, with the correlation length restricted to ξ= 7nm in the *ab* plane. Here we present single crystal neutron diffraction results, which reveal that this state does not select a preferred ordering wavevector in the *ab* plane, resulting in continuous rings of scattering rather than well-defined satellite Bragg peaks. The lack of a preferred incommensurate ordering wavevector can be understood in terms of the competition between J_1 (nearest neighbor) and J_2 (next nearest neighbor) interactions in a Heisenberg model, which produces a quasi-degenerate manifold of ordering wavevectors. The inability to form long range coherent structure remains unexplained, however the restriction to small domain sizes in the *ab* plane implies the presence of a high density of topological defects. Determining the nature of these defects and the mechanism of their formation is an avenue for further research.