Exotic magnetism on the quasi-FCC lattices of the $d^3$ double perovskites $La_2NaB'O_6$ ($B' = Ru, Os$)

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B-site ordered double perovskites with quantum spins $S = 1/2$ ($d^1$) and $S = 1$ ($d^2$) on the B$'$ site have attracted a great deal of recent interest, due to the possibility of studying 4d and 5d magnetism combined with magnetic frustration on the face-centered-cubic (FCC) lattice. There has been less focus on $d^3$ systems, as they are generally expected to behave more classically and yield simple, commensurate magnetic ground states. In contrast, we find evidence for long-range and short-range ($\xi = 70$ Å at 4 K) incommensurate magnetic order on the quasi-FCC lattices of the monoclinic double perovskites $La_2NaRuO_6$ and $La_2NaOsO_6$ respectively. Incommensurate magnetic order on the FCC lattice has not been predicted by mean field theory, but may arise via a delicate balance of inequivalent nearest neighbor and next nearest neighbor exchange interactions. Furthermore, in the Ru system with long-range order, inelastic neutron scattering reveals a spin gap $\Delta = 2.75$ meV. Magnetic anisotropy is generally minimized in the more familiar octahedrally-coordinated $3d^3$ systems, so the large gap observed for $La_2NaRuO_6$ may result from the significantly enhanced value of spin-orbit coupling in this $4d^3$ material.