Hidden symmetries and exotic quantum magnetism of large-spin alkali and alkaline-earth fermions (LT26)

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The recent experimental progress on the large-spin ultracold Fermi gases provides an exciting opportunity to investigate exotic many-body physics which does appear in usual solid state systems. Conventionally, large values of spin suppresses quantum spin fluctuations in solid state systems. On the contrary, spin fluctuations in large-spin cold fermion systems are enhanced and become even stronger than those in spin-$\frac{1}{2}$ electron systems. Under certain conditions, the large-spin cold fermion systems possess large symmetries of $SU(2N)$ and $Sp(2N)$. In the simplest case with hyperfine spin $F = \frac{3}{2}$, a generic hidden symmetry of $Sp(4)$, or isomorphically, $SO(5)$ is proved without fine-tuning, which may be realized with alkali and alkaline-earth atoms of ^{132}Cs, ^{9}Be, ^{135}Ba, ^{137}Ba, and ^{201}Hg. This high symmetry has important effects on the competitions among antiferro-spin-quadruple ordering, charge-density-wave ordering, and singlet Cooper pairing, which can be unified under even larger exact symmetries of $SO(7)$ and $Sp(4) \otimes SU(2)$. Exotic quantum magnetism includes dominant multiple-site spin correlations in analogy to the baryon-type color-singlet states in quantum chromodynamics. Furthermore, the existence of the quartetting phase, a four-fermion counterpart of the Cooper pairing phase, and its competition with other orders are also studied.