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Quadrupolar Spin Orders in FeSe ZHENTAO WANG, ANDRIY NEVIDOMSKYY, Department of Physics and Astronomy, Rice University — Motivated by the absence of long-range magnetic order and the strong spin fluctuations observed in the Fe-based superconductor FeSe, we study spin-1 model on a square lattice up to next-nearest neighbor Heisenberg and biquadratic spin exchanges. The zero-temperature variational phase diagram gives the conventional antiferromagnetic order and also more exotic quadrupolar spin phases. These quadrupolar phases do not host long-range magnetic order and preserve time-reversal symmetry, but break the spin SU(2) symmetry. In particular, we observe a robust ferroquadrupolar order (FQ) in immediate proximity to the columnar AFM phase. We envision that FeSe may be positioned within the FQ phase close to the phase boundary. Using the flavor-wave technique, we calculate the structure factor inside the FQ phase and find a Goldstone mode emerging from $Q = (0, 0)$, which however bears zero spectral weight at $\omega = 0$ due to time reversal symmetry. At the same time, we observe strong spin fluctuations near $(\pi, 0)/(0, \pi)$, which agrees with the recent neutron scattering experiments. Further, we calculate the higher order interactions between the $(\pi, 0)$ and $(0, \pi)$ spin fluctuations inside the FQ phase, which may shed light on the C_4 symmetry breaking in the nematic phase of FeSe.

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