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Magnetic Soft Modes in the Distorted Triangular Antiferromagnet α-$CaCr_2O_4$

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We have explored the phase diagram and excitations of a distorted triangular lattice antiferromagnet. The unique two-dimensional distortion considered here is very different from the "isosceles"-type distortion that has been extensively investigated. We show that suprisingly it is able to stabilize the 120° spin structure (typical of the undistorted triangular antiferromagnet) for a large range of exchange interaction values, with new structures found only for extreme distortions. A physical realization of this model is α-$CaCr_2O_4$. Despite its highly symmetric 120° spin structure, the magnetic excitation spectrum of α-$CaCr_2O_4$ is very complex. The unique pattern of nearest-neighbor exchange interactions as well as the substantial next-nearest-neighbor interactions place it close to the phase boundary of the 120° structure as is clearly revealed by the presence of low energy modes acting as soft modes of the neighboring structure. Indeed, fitting to linear spin-wave theory favors a set of exchange parameters within the nearby multi-k phase in contradiction to the observed 120° order, and quantum fluctuations may be necessary to stabilize α-$CaCr_2O_4$ within the 120° phase.