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Magnetism, rotons, and beyond: engineering atomic systems with lattice shaking[1]

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Conventional methods of quantum simulation rely on kinectic energy determined by free particle dispersions or simple sinusoidal optical lattices. Solid state sytems, by contrast, exhibit a plethora of band structures which differ quantitatively, qualitatively, and even topologically. To what extent does this variety explain the many electronic phenomena observed in these materials? Here we address this question by subjecting an otherwise simple Bose superfluid to a customized band structure engineered by dynamically phase modulating (shaking) an optical lattice. The engineered dispersion contains two minima which we associate to a pseudospin degree of freedom. Surprisingly, in such a system the Bose superfluid exhibits many new behaviors. The psuedospin develops a ferromagnetic order, which can lead to polarization of the entire sample or to sub-division into polarized domains. The excitations of the system also exhibit the roton-maxon structure associated with strong interactions in superfluid helium.

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