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Magnetic Excitations in Spinor Bose-Einstein Condensates

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The quantum degenerate spinor Bose gas is a new material characterized by both magnetic and superfluid order. Like other ordered magnetic materials, the gas supports magnon excitations, which are the Nambu-Goldstone bosons associated with the spontaneous breaking of rotational symmetry. We have developed techniques to create and image magnon excitations in ferromagnetic rubidium spinor condensates. At short times after their creation, magnons are observed to propagate coherently, allowing us to measure their energy dispersion with high precision through interferometry. Using high-resolution spin-sensitive imaging, we measure the magnon spectrum to be gapped due to magnetic dipole interactions (as it often is in magnetic solids). At longer times, the magnons thermalize. We show that this thermalization allows one to measure the temperature of highly degenerate gases, and to reduce this temperature further by a new form of evaporative cooling.