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The quantum phases of ultracold dipolar gases near a Roton excitation

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Discovered in liquid helium about 80 years ago, superfluidity is a counterintuitive phenomenon, in which quantum physics and particle-wave duality manifest at the macroscopic level. Since then, it has yielded many advances in understanding quantum matter, yet leaving mysterious some of its features. A hallmark of superfluidity is the existence of so-called quasi-particles, i.e. elementary excitations dressed by interactions. Laudau predicted two type of quasi-particles, the first ones being the well-known phonon mode. The second ones, much more bizarre and intriguing, are massive quasi-particles named rotons. They have large momenta, and, contrarily to ordinary (quasi)particles with energy increasing with the momentum, the roton dispersion relation exhibits a minimum at a finite momentum. This unusual behavior expresses the tendency of the fluids to build up short-wavelength density modulation in space, precursor of a crystallization instability and eventually to the elusive and highly-debated supersolid quantum phase. In 2003, theoreticians suggested that a similar rotonic excitation might also occur in dipolar Bose- Einstein condensates because of the special properties of the long-rang and anisotropic dipole- dipole interaction. We here report on the observation of roton quasiparticles in a dipolar gas of high magnetic Er atoms and first studies, demonstrating hallmarks of long-lived supersolid behavior, using a Bose-Einstein condensate of Dy atoms.