Sonic black holes and thermal phonons

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We have created an analogue of a black hole in a Bose-Einstein condensate. A step-like potential accelerates the flow of the condensate to velocities which cross and exceed the speed of sound by an order of magnitude. The Landau critical velocity is therefore surpassed. The predicted Hawking temperature is given by the gradient of the velocity at the horizon, and is thus determined from the measured profiles of the velocity and speed of sound. A simulation finds negative energy excitations, which are required for Hawking radiation. Furthermore, we observe the Planck distribution of thermal phonons in a 3D Bose-Einstein condensate. This observation provides an important confirmation of the basic nature of quantized excitations in the condensate. In contrast to the bunching effect, the density fluctuations are seen to increase with increasing temperature. This is due to the non-conservation of the number of phonons. When the quench time drops below the measured thermal equilibration time, the phonon temperature is out of equilibrium with the surrounding thermal cloud. Thus, for rapid cooling rates, a Bose-Einstein condensate is not as cold as previously thought. These measurements are enabled by our in situ k-space technique.