From 500 K to 0.0000000005 K: Cooling an Atomic Vapor towards Absolute Zero

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The temperature difference between a hot summer day (100 °F) and a cold winter night (0 °F) certainly feels like a lot, but it only corresponds to a 20% difference in the thermal energy of the molecules in the air. In the laboratory, we are able to reduce the thermal energy of an atomic vapor by a factor of one trillion! Starting with a room temperature metal, we first vaporize the solid to form a gas with atoms moving around randomly at speeds of a few football field lengths per second. By applying a combination of laser beams and magnetic fields, the atoms are slowed down to speeds of just a few human hair thicknesses per second. These low speeds correspond to a temperature that is just one half a billionth of a degree above absolute zero. At these low temperatures, the atoms quit behaving like individual billiard balls bouncing around randomly and start behaving like waves that can overlap with each other. In particular, they undergo a phase transition to form a new state of matter called a Bose-Einstein condensate. This talk will describe novel properties of the condensate phase and the beautiful experiments that have explored these properties.