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Anomalously fast cooling and heating in a colloidal system

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Since the temperature of an object that cools decreases as it relaxes to thermal equilibrium, naively a hot object should take longer to cool than a warm one. Yet, some 2300 years ago, Aristotle observed that "to cool hot water quickly, begin by putting it in the sun."In the 1960s, this counterintuitive phenomenon was rediscovered as the statement that "hot water can freeze faster than cold water"and has become known as the "Mpemba effect."While many specific mechanisms have been proposed, no general consensus exists as to the underlying cause. Here we demonstrate the Mpemba effect in a controlled setting, the thermal quench of a colloidal system immersed in water, which serves as a heat bath. Our results are reproducible and agree quantitatively with calculations based on a recently proposed theoretical framework. By carefully choosing parameters, we observe cooling that is exponentially faster than that observed using typical parameters, in accord with the recently predicted strong Mpemba effect. We then show that similar phenomena can be observed when heating—these are the first observations of an inverse Mpemba effect. In this case, a cold system placed in a hot bath will reach equilibrium more quickly than a warm one placed in identical conditions. Our experiments give a physical picture of the generic conditions needed to accelerate relaxation to thermal equilibrium and support the idea that the Mpemba effect is not simply a scientific curiosity concerning how water freezes into ice—one of the many anomalous features of water—but rather the prototype for a wide range of anomalous relaxation phenomena that may have significant technological application.

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