

# Negative Absolute Temperature for Motional Degrees of Freedom

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Absolute temperature is one of the central concepts in statistical mechanics and is usually described as being strictly non-negative. However, in systems with an upper energy bound, also negative temperature states can be realized. In these states, the occupation probability of each basis state increases with energy. So far, they have been demonstrated only for localized degrees of freedom such as the spin of nuclei or atoms [1, 2]. By using a Feshbach resonance in bosonic  $^{39}\text{K}$ , we implemented the attractive Bose-Hubbard model in a three-dimensional optical lattice. Following a recent proposal [3, 4], we were able to create a negative temperature state for motional degrees of freedom, strikingly resulting in a condensate at the upper band edge of the lowest band. This attractively interacting bosonic superfluid is thermodynamically stable, i.e. stable against mean-field collapse for arbitrary atom numbers. We additionally investigated the characteristic timescale for the emergence of coherence in the ensemble, and found an intriguing symmetry between the negative temperature and positive temperature state.

## References

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