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Hidden Maxwell's Demon in Cosmological First Order Phase Transition

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We discuss the application of information thermodynamics to cosmological first-order phase transitions. When the bubble wall can distinguish particles in the plasma based on their physical properties—such as their mass, CP charge, etc.—its interaction with the plasma can be interpreted as a "measurement"of those properties and a subsequent "feedback"based on the outcomes. Therefore, the system consisting of the bubble and the plasma is expected to be regarded as an information thermodynamic system, in particular from the wall-rest frame perspective. In such systems, the distinguishability of particles in the plasma plays a crucial role, but this importance has been neglected in previous studies on hydrodynamics across the bubble wall. In this work, we extend the conventional hydrodynamical framework to incorporate the distinguishability of plasma particles, and we discover solutions exhibiting negative entropy production, which is impossible in ordinary thermodynamic systems. Furthermore, by solving the energy-momentum conservation equations at the bubble wall, we find that this negative entropy production leads to novel solutions for the temperature and velocity profile during the first-order phase transition, which are distinct from the known detonation and deflagration regimes. We also discuss the lower bound on the negative entropy production derived from the second law of information thermodynamics.

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