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Non-singular solutions to the Boltzmann equation with a fluid Ansatz

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Cosmological phase transitions can give rise to intriguing phenomena, such as baryogenesis and stochastic gravitational wave backgrounds, due to nucleation and percolation of vacuum bubbles in the primordial plasma. A key parameter for predicting the amount of these relics is the bubble wall velocity, whose computation relies on solving the Boltzmann equations of the various species in the plasma along the bubble profile. One approach to this task relies on adopting a fluid Ansatz for the non-equilibrium distribution function, which greatly simplifies the collision terms and makes the system more tractable when a linearization is performed on the non-equilibrium fluctuations. In this Ansatz one typically performs a separation of what is called the background properties of the plasma, and the non-equilibrium fluctuations around this background. Clearly, an appropriate choice of background is essential to ensure that the non-equilibrium fluctuations will remain sufficiently small to grant the application of the linearization procedure. However, the recent literature on this approach typically modelled the background as constant, leaving all the spatial-dependence arising from equilibrium effects to be described as fluctuations of the light species. This led to a breakdown of the linear approximation when the wall approached the speed of sound, making the solutions singular. In this work we solve this issue by reparameterizing the fluid Ansatz to include these equilibrium fluctuations into the background (which then becomes spatially-dependent), rather than in the fluctuations. This leads to a modification of the Boltzmann equation, and we show that all terms that would give rise to a singularity now vanish. We recalculate the different contributions to the counter-pressure of the plasma on the expanding wall, and discuss their relative importance. The Standard Model with a low cutoff is chosen as benchmark model and results are shown for different values of the cutoff scale. Our finding indicate that non-equilibrium effects are typically non-negligible for the computation of the wall velocity.

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