The 2023 Shanghai Symposium on Particle Physics and Cosmology: Phase Transitions, Gravitational Waves, and Colliders (SPCS 2023)

Contribution ID: 11

Type: not specified

## Hydrodynamic sound shell model and bubble wall velocity

Saturday, 23 September 2023 19:00 (20 minutes)

For a cosmological first-order phase transition in the early Universe, the associated stochastic gravitational wave background is usually dominated by sound waves from plasma fluid motions, which have been analytically modeled as a random superposition of freely propagating sound shells but with the force by the scalar field that produces the self-similar profile removed. Recently, we proposed a new analytic sound shell model by focusing on the forced propagating contribution from the initial collision stage of sound shells while the moving bubble walls still maintain their self-similar profiles. We reproduce the causal  $k^3$  scaling in the infrared consistent with numerical simulations, and also recover the broad dome in the power spectrum first observed in numerical simulations. We also provided a new method to estimate the bubble wall velocity from the junction condition given by the conservation of particle number density flow.

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Session Classification: Parallel 1