Contribution ID: **42** Type: **Parallel Talk**

FIMP Dark Matter in Bulk Viscous Non-Standard Cosmologies

Thursday, 3 December 2026 16:00 (20 minutes)

Feebly Interacting Massive Particles (FIMPs) provide a well-motivated dark matter scenario in which the observed relic abundance is generated through the freeze-in mechanism. Since this production takes place in the early universe, it can be significantly affected by non-standard cosmological histories, in which the expansion history prior to Big Bang nucleosynthesis is modified. In this work, we study FIMP dark matter production in a non-standard cosmology containing an additional field ϕ that decays into the Standard Model radiation bath and experiences dissipative processes described by a bulk viscous pressure within the Eckart formalism. We numerically solve the coupled evolution equations for the ϕ field, the thermal bath, and the dark matter number density, and compare the classical non-standard cosmology with its bulk viscous extension. We find that bulk viscosity enhances the energy density of the ϕ component and increases the subsequent entropy injection into the thermal bath, leading to a greater dilution of the FIMP abundance. As a consequence, new regions of the cosmological parameter space $(T_{\rm end}, \kappa)$ and of the dark matter parameter space $(m_\chi, \langle\sigma v\rangle)$ can reproduce the observed relic abundance. These results illustrate how dissipative effects in the early universe, before Big Bang nucleosynthesis, can have significant implications for dark matter phenomenology.

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Session Classification: Parallel Talks-SD:704

Track Classification: Dark Matter