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Effective field theories for dark matter pairs in the early universe

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We consider threshold effects of thermal dark matter (DM) pairs (fermions and antifermions) interacting with a thermal bath of dark gauge fields in the early expanding universe. Such threshold effects include the processes of DM pairs annihilating into the dark gauge fields (light d.o.f.) as well as electric transitions between pairs forming a bound state or being unbound but still feeling non-perturbative long range interactions (Sommerfeld effect). We scrutinize the process of bound-state formation (bsf) and the inverse thermal break-up process (bsd), but also (de-)excitations, providing a thermal decay width due to the thermal bath. We compute the corresponding observables by exploiting effective-field-theory (EFT) techniques to separate the various scales (the mass of the particles M, the momenta Mv, the energies Mvˆ2, as well as thermal scales: the temperature T, the Debye mass m_D), which are intertwined in general. To do so we make use of the so-called non-relativistic EFT (NREFT) as well as potential non-relativistic EFT (pNREFT) at finite T. These processes play an important role for a quantitative treatment of the dynamics of the relevant d.o.f. at the thermal freeze-out regime and the corresponding observables appear in the relevant evolution equations, from which we eventually determine the relic energy density of DM.

Submitted on behalf of a Collaboration?

Yes

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