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Rapid bound-state formation of Dark Matter via inelastic Standard Model particle scattering

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The thermal decoupling description of multi-TeV scale dark matter (and co-annihilating partners) is reconsidered. In several works it has been pointed out that the inclusion of quantum mechanical effects in the computation of the thermal relic abundance is in certain cases required in order to make a precise determination of the upper bound on the DM mass. One of these quantum mechanical effects is the existence of meta-stable bound-state solutions in the two-particle spectrum of the WIMPs, caused by attractive (SM) force-carriers. The formation of these bound states and their subsequent decay into SM particles gives a significant effect in the relic density computation on top of the Sommerfeld enhancement, typically allowing for heavier DM masses. So far, only the single mediator emission (W, Z, H, g, photon or exotic) was considered as the formation process of the bound states. In this talk, I show that bound-state formation via inelastic bath particle scattering, i.e. the mediator instead in the t-channel and connected to the SM plasma particles, can be the dominant conversion process. For a vector mediator we find that bound-state formation via bath particle scattering at the freeze-out temperature exceeds the single mediator bound-state formation cross-section by several orders of magnitude. More generally, bound-state formation via inelastic bath particle scattering has obviously no kinematical block if the mediator is massive (e.g. W, Z, H), whereas the single mediator emission is highly suppressed for temperature smaller than the mediator mass. The implications of these findings are that bound-state effects become more pronounced and consequently dark matter could be even more heavier than expected.

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