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Eternal Freeze-Out from Bound State Effects

My talk will show how the presence of highly excited bound states changes the common assumption of Freeze-Out taking place at $T \approx M/25$. Instead of a decoupling at finite-time, particle densities deplete continuously until additional physical effects occur, e.g. phase transitions or lifetime constraints. We have applied our framework to a t-channel mediator model yielding $\mathcal{O}(1)$ corrections to the DM relic abundace.

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Publication Abstract:
We explore the impact of highly excited bound states on the evolution of number densities of new physics particles, specifically dark matter, in the early Universe. Focusing on dipole transitions within perturbative, unbroken gauge theories, we develop an efficient method for including around a million bound state formation and bound-to-bound transition processes. This enables us to examine partial-wave unitarity and accurately describe the freeze-out dynamics down to very low temperatures. In the non-Abelian case, we find that highly excited states can prevent the particles from freezing out, supporting a continuous depletion in the regime consistent with perturbativity and unitarity. We apply our formalism to a simplified dark matter model featuring a colored and electrically charged t-channel mediator. Our focus is on the regime of superWIMP production which is commonly characterized by a mediator freeze-out followed by its late decay into dark matter. In contrast, we find that excited states render mediator depletion efficient all the way until its decay, introducing a dependence of the dark matter density on the mediator lifetime as a novel feature. The impact of bound states on the viable dark matter mass can amount to an order of magnitude, relaxing constraints from Lyman-α observations.

Would you be interested in presenting a poster? (this will not impact the decision on your talk)

yes

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