



Contribution ID: 34

Type: **Contributed talk**

Rapid bound-state formation of Dark Matter in the Early Universe

Tuesday, 12 November 2019 15:45 (20 minutes)

The thermal decoupling description of multi-TeV scale dark matter (DM) and co-annihilating partners is reconsidered. In such a high-mass region, even the electroweak force carriers could act as long-range forces, leading to the existence of meta-stable DM bound states. The formation and subsequent decay of the latter further depletes the relic density on top of the Sommerfeld enhancement, allowing for heavier DM masses. So far, only the on-shell 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 bath particle scattering, i.e. the mediator instead in the t-channel and connected to the SM plasma, can be the dominant conversion process. For a simplified setup we find that bound-state formation via bath particle scattering exceeds the single mediator bound-state formation cross-section by several orders of magnitude at the freeze-out temperature. The implications of these findings are that bound-state effects become more pronounced during chemical decoupling and consequently DM could be heavier than previously expected, eventually informing indirect and collider searches.

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Presenter: Dr BINDER, Tobias

Session Classification: Young Scientists session

Track Classification: DM theory