# Aspects of dark matter coannihilations

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# 論文の内容の要旨

# Aspects of dark matter coannihilations
# (暗黒物質の共対消滅について)

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This thesis deals with particle physics of dark matter, particularly emphasizing the importance of particle physics phenomena in the early universe. Dark matter is one of the biggest mysteries in modern physics. Despite convincing evidence of its existence, its properties as a particle remain largely unknown.

Dark matter is a relic of the early universe if standard big bang cosmology applies. Understanding the behavior and interactions of dark matter in the early universe allows us to predict the present abundance of dark matter. Understanding how dark matter interacts also allows us to map constraints from dark matter detection experiments to the viable parameter space of the dark matter model in consideration.

In particular, this thesis deals with a specific type of dark matter production mechanism called coannihilation, where there exists, in addition to dark matter, a particle mediating the dark sector and the visible sector, and its mass is very close to that of the dark matter particle. We go through the calculations of coannihilation involving a particle carrying color (Quantum Chromodynamics, or QCD) charges, and emphasize the effects of the formation of colored bound state on the prediction of dark matter relic abundance on top of the better-known Sommerfeld effects. In addition, we study the case where the particle is also electrically charged.

Furthermore, we discuss other cosmological implications of colored bound states. If the colored particle's lifetime is long, it could affect the theoretical predictions of the big bang nucleosynthesis. It is known that the standard calculation (without including effects of exotic particles) of processes of big bang nucleosynthesis matches well with experimental observations, placing a stringent limit on the abundance of the long-lived particle. The formation of colored bound state in the early universe can change the prediction of the abundance of such a long-lived particle. If dark matter is super weakly interacting, the decay of the frozen-out colored particle can contribute to the relic abundance of dark matter as well. Finally, we study how the Large Hadron Collider can probe scenarios of coannihilation and long-lived colored particles.

Summarizing our results, we find that for most cases, on top of the Sommerfeld enhancement, bound-state effects can further significantly increase the largest possible DM masses which can give the observed DM relic abundance, by $\sim 30 - 100\%$ with

respect to values obtained by considering the Sommerfeld effect only while considering DM coannihilating with color triplet or octet exotic particles. In particular, it indicates that the Bino DM mass in the right-handed stop-Bino coannihilation scenario in the Minimal Supersymmetric extension of the Standard Model (MSSM) can reach 2.5 TeV.