Dark Sectors for Dark Matter and Cosmology

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Standard Cosmology today is based on the so-called ΛCDM model, according to which the energy budget of the Universe is given by three main components [1]: ordinary matter ($\Omega_B \sim 0.04$), dark matter ($\Omega_D M \sim 0.26$) and dark energy ($\Omega_\Lambda \sim 0.70$).
When we talk about ordinary matter we mean baryons (and a small fraction of radiation) which are today well described by the Standard Model. The dark energy is, instead, an unknown form of energy that exerts a negative pressure (a sort of repulsive gravity) and that should explain why our Universe is undergoing an accelerated expansion. Its nature is still a puzzle in physics, even if is often linked to the Cosmological Constant Λ or Vacuum energy. What is dark matter, then? This is another open and puzzling question today. We know that this is a kind of matter that does not interact with the electromagnetic force, therefore we aren't able to see it and it is really difficult to detect. We know about its existence only indirectly, thanks to the effects that it exerts on ordinary matter through gravitational interactions (rotation curves, X-rays halos, weak lensing, etc. See for example [2]). While experimental physicists are trying to find a way to detect dark matter, theoretical physicists are proposing new models that can describe its nature. In fact, the indirect evidences of dark matter give us some bounds that we know it has to respect; for example, we know its abundance ($\Omega h^2 \sim 0.12$) and that if we consider it as a particle beyond the Standard Model, its mass has to be in the range $10^{-22}\ eV \lesssim M_{DM} \lesssim\ TeV$.
In this context, what I aim to study during my PhD is a possible candidate of dark matter (or of a fraction of dark matter): in particular, I will focus on Dark sectors with purely gravitational couplings to the Standard Model [3].

This dark sector can be described, for instance, by a pure gauge Yang-Mills theory which is composed of pure dark gluons when the temperature of the dark sector is above the confinement scale Λ. When the temperature reaches Λ there is a confinement first order phase transitions with resulting formation of dark glueballs. Many interesting phenomena happens in this context, for example Cannibalism: particles of dark matter can "eat" themselves (in $3 \to 2$ processes) in order to warm up and keep thermal equilibrium even in a non-relativistic regime. How long does this effect last or when does it start are all important questions to be asked, together with which role this kind of dark matter has in structure formation. The building of such models requires, beside analytical calculations, the use of the code CLASS (Cosmic Linear Anisotropy Solving System) [4].

References

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[4] D. Blas, J. Lesgourgues, and T. Tram, *The Cosmic Linear Anisotropy Solving System (CLASS) II: Approximation schemes*, arXiv:1104.2933 [astro-ph.CO]