**Contribution Prospectives 2020**

**Dark Matter and Early Universe**

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**Abstract**:

The properties of the very early Universe before Big-Bang Nucleosynthesis, while being at the origin of several very important questions, such as the origin of the baryon asymmetry in the Universe, the nature of the electroweak phase transitions, the possibility of grand unification, the mechanism for inflation, etc. are only very little known and as of today we have no direct observations of the period before recombination. Nevertheless, cosmological constraints based on assumptions for the early Universe properties and simplistic models are frequently used to constrain particle physics scenarios.

We propose an “inverse” methodology. Given the current and future advanced technology employed for particle physics experiments in clean and reliable environments, we propose to use understanding of the properties of dark matter particles obtained from particle physics to obtain constraints on the properties of the very early Universe, providing an observational access to the dark era before Big-Bang nucleosynthesis.

The interplay between dark matter direct and indirect detection experiments, measurements of the dark matter abundance and searches for new physics (NP) at colliders is particularly important for the discovery and interpretation of scenarios beyond the Standard Model (BSM). Their complementarity has been thoroughly studied for thermal relics, in particular in the case of the minimal supersymmetric extension of the Standard Model (MSSM). However, such analyses generally rely on simplifying assumptions on the cosmological and astrophysical models, leading to large biases and uncertainties [1,2,3]. In particular, it is assumed that:

* the expansion is dominated by
* relics are in thermal equilibrium in the early Universe, then freeze out
* no phase transition affected the Universe after the relic freeze-out
* the dark matter halos follow simple profiles to interpret limits from indirect detection
* the local dark matter density is obtained from dark matter halo profiles in direct detection
* dark matter is composed of one type of particle.

In case of discovery of new phenomena in dark matter experiments or at the LHC, these assumptions will render difficult or impossible the interpretation of the discovery in order to unravel the underlying particle physics scenario. A solution is to consider that the interpretation of data has to be performed within both a specific particle physics scenario and a consistent cosmological and astrophysical context, where the hypotheses are explicit.

In [4] we have illustrated this concept in the framework of the MSSM with a neutralino dark matter relic, using only the relic density measurements. In particular, we showed that the presence of cosmological scalar fields at the freeze-out time can affect the calculation of the relic density by orders of magnitude, and that a discrepancy between the measured dark matter density and the calculated one can set constraints on the primordial scalar field models.

Such studies should be performed in a broader context using all the dark matter data, and for this it is of utmost importance that direct and indirect detection experiments find common astrophysical contexts when converting their results in terms of particles physics scenarios, and that the community develops tools not only to precisely compute dark matter observables in a given a particle physics model, but which also features different cosmological and astrophysical scenarios. It can be noted that two such tools are currently developed in France: micrOMEGAs [5] and SuperIso Relic [6], but additional work and collaborations with the experimental community are needed.

[1] A. Arbey, F. Mahmoudi, Phys.Lett. B669 (2008) 46-51, arXiv:0803.0741.

[2] A. Arbey, F. Mahmoudi, JHEP 1005 (2010) 051, arXiv:0906.0368.

[3] A. Arbey, M. Boudaud, F. Mahmoudi, G. Robbins, JHEP 1711 (2017) 132, arXiv:1707.00426.

[4] A. Arbey, J. Ellis, F. Mahmoudi, G. Robbins, JHEP 1810 (2018) 132, arXiv:1807.00554.

[5] G. Belanger, F. Boudjema, A. Pukhov, A. Semenov, http://lapth.cnrs.fr/micromegas/

[6] A. Arbey, F. Mahmoudi, G. Robbins, http://superiso.in2p3.fr/relic/