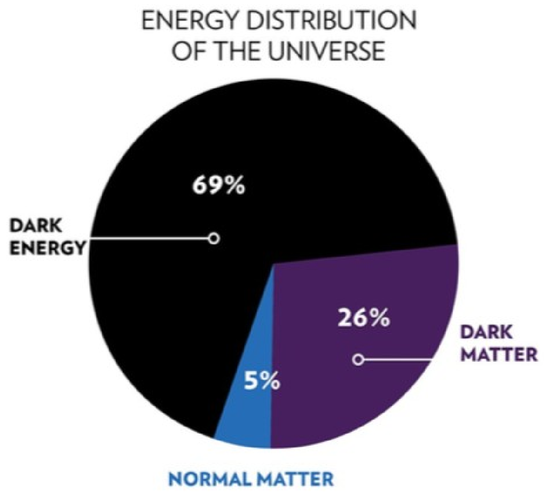
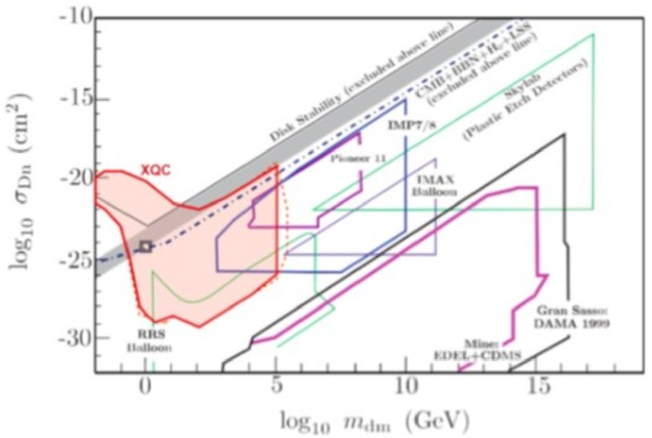
Cosmological analysis of possibility to constrain SIMP-like dark matter models

Autors: Kamaletdinov Airat, Ekaterina Esipova



The problem of Dark matter, which according to modern estimates is about 25 percent of the total density of the Universe, is one of the central problems in cosmology and particle physics.



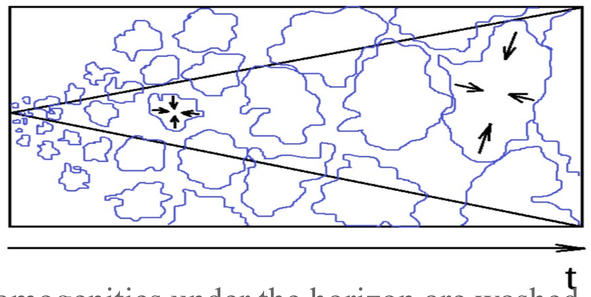
The limits on the spin- independent scattering cross section of Dark Matter on nucleons, for DM in the 300 MeV – 100 GeV mass range, based on the DAMIC, XQC and other experiments.

There was many direct experiments to search for strong interacting dark matter (SIMP), which put constraints on the cross sections for its interaction with baryonic matter

Besides direct constraints there can be indirect ones coming from cosmology.

Large scale structure of the Universe strongly depends of the moment when DM decouples from ambient relativistic plasma.

According to [1], [2], due to the Silk damping effect, the minimum size of inhomogeneities which the Dark matter forms will be determined by the horizon size at the decoupling moment. So we can put a lower limit on the decoupling temperature. Decoupling temperature $T_{dec} < 1 — 5$ keV is forbidden



Inhomogenities under the horizon are washed out according to Silk damping effect

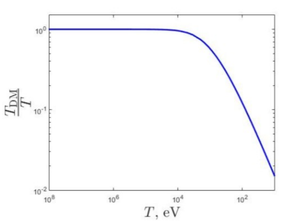
To determine the moment of dark matter decouples from baryonic matter, it is necessary to know the equation of SIMPs temperature evolution.

Temperature evolution of the SIMP component is described by the equation

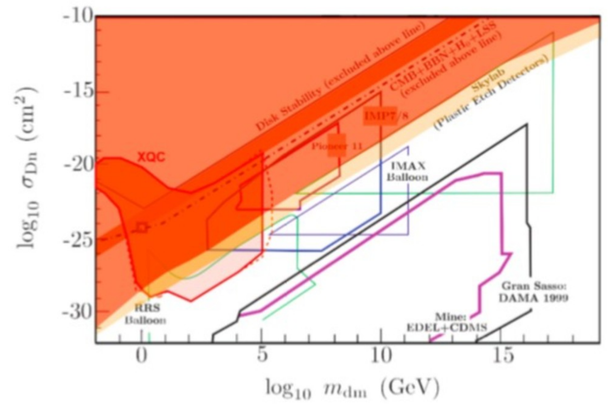
$$\frac{dT_s}{dT} = -\frac{2}{3T}\left(\frac{1}{H}\langle\overline{\Delta E}\sigma v\rangle_{sp} n_p - 3T_s\right)$$

The decoupling temperature of DM particles from nucleons should be

$T_{dec} < 5$ keV



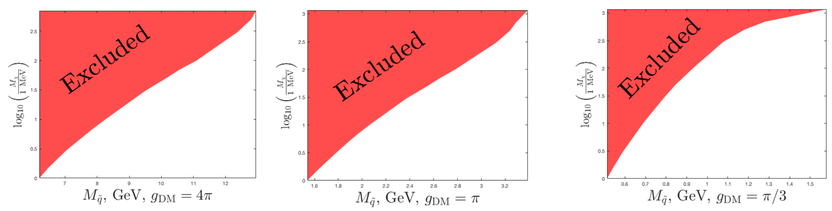
The bend in the graph corresponds to the decoupling moment. Solving this equation taking into account the conditions on the decoupling temperature, we can put constraints on the σ



From the obtained constraints on the interaction cross section σ, we can put constraints on the parameters of particular models that describe the interaction of the SIMPs with ordinary matter.

We considered Anthony DiFranzo and Keiko I. Nagao"s [3] model in which Dark Matter interacts with ordinary matter through a scalar mediator. And put constraints on relation of DM and mediator masses. Interacting cross section of DM with SM particles and constraints for various interaction constants are as follows:

$$\sigma_{SI}^{qL} = \frac{9}{64\pi}\frac{M_N^2 M_\chi^2}{(M_N + M_\chi)^2}\frac{g_{DM}^4}{(M_{\tilde{q}}^2 - M_\chi^2)^2}$$



Also we put constraints on other analogius models.

References:

1) Bertschinger E Phys. Rev. D 74 063509 (2006)
2) Loeb A, Zaldarriaga M Phys. Rev. D71 103520
3) A. DiFranzo, et al. JHEP 1311 (2013) 014