Sub-GeV Dark Matter: Model Independent Bounds

Cristian Caniu
In collaboration with E. Bertuzzo and G. Grilli di Cortona

Universidade de São Paulo

caniu@if.usp.br

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Overview

Motivation and DM EFT framework

How much parameter space (Λ, m_χ) has been actually tested?

The framework:

Figure: D' Eramo and Procura, arXiv:1411.3342

Universal coupling to quarks

$$\mathcal{L} \supset \frac{g_*^2(\Lambda)}{\Lambda^2} \sum_{i=1}^{3} \left[\bar{u}^i \gamma^\mu u^i + \bar{d}^i \gamma^\mu d^i \right] \bar{\chi} \gamma_\mu \chi \tag{1}$$

We would therefore expect only experiments involving interactions between quarks and dark matter to contribute. However the running of the Wilson coefficient will introduce also couplings with leptons.

$$c_V^{(e)}(1\,\mathrm{GeV}) \simeq \frac{4\alpha}{3\pi} \ln \frac{\Lambda}{\mathrm{GeV}} g_*^2(\Lambda). \tag{2}$$

This leads to the possibility to get limits from LEP and from future DM-electron scattering experiments.

Universal coupling to quarks: $g_* = 4\pi$

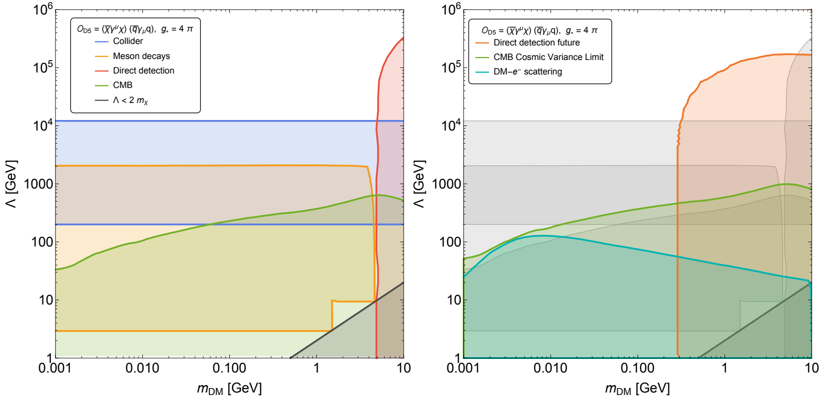

Figure: Universal coupling to quarks

Universal coupling to quarks: $g_* = 1$

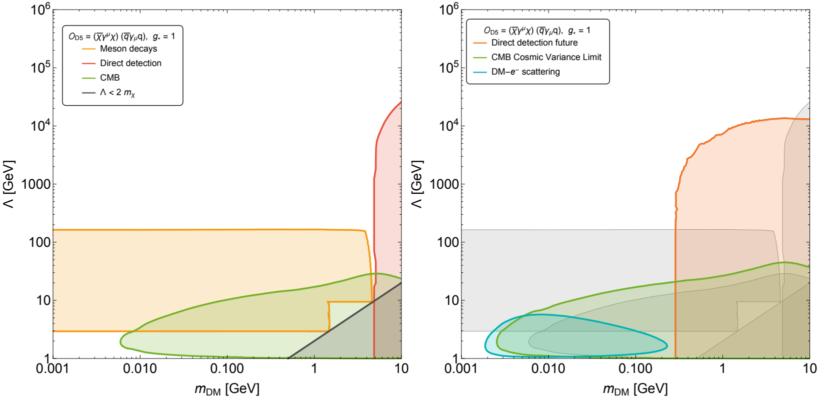

Figure: Universal coupling to quarks

Universal coupling to leptons

As a second scenario, we consider a SM gauge invariant effective field theory where the dark matter current couples universally only to leptons:

$$\mathcal{L} \supset \frac{g_*^2(\Lambda)}{\Lambda^2} \sum_{i=1}^{3} \left[\bar{\ell}^i \gamma^\mu \ell^i \right] \bar{\chi}\gamma_\mu \chi. \tag{3}$$

As before, the running induces also low energy Wilson coefficients with light quarks

$$\begin{aligned} c_V^{(u)}(1\,\mathrm{GeV}) &\simeq \ \frac{4\alpha}{3\pi} \ln \frac{\Lambda}{\mathrm{GeV}} g_*^2(\Lambda) \\ c_V^{(d)}(1\,\mathrm{GeV}) &\simeq -\frac{2\alpha}{3\pi} \ln \frac{\Lambda}{\mathrm{GeV}} g_*^2(\Lambda). \end{aligned} \tag{4}$$

The presence of this couplings makes possible constraints from direct detection experiments.

Universal coupling to leptons: $g_* = 4\pi$

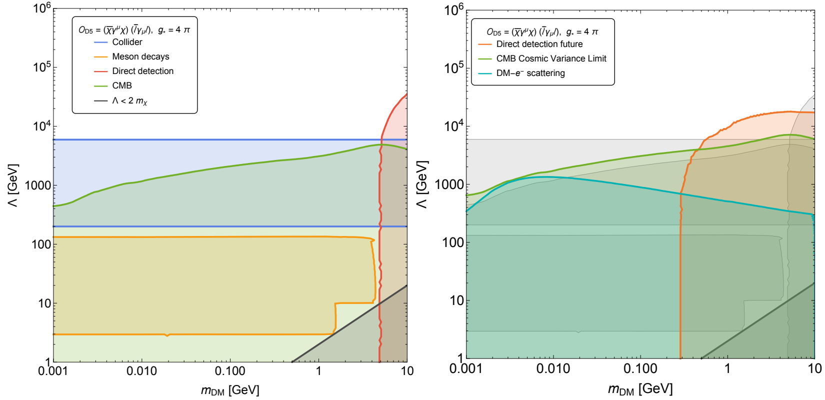

Figure: Universal coupling to quarks

Universal coupling to leptons: $g_* = 1$

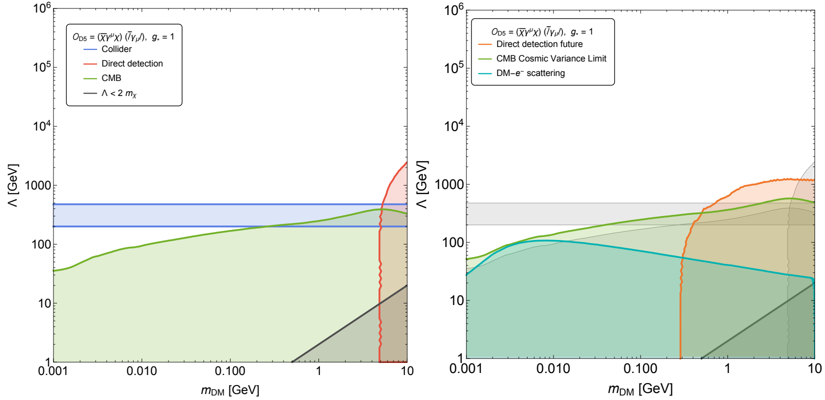

Figure: Universal coupling to leptons

Universal coupling to all fermions

The excluded regions correspond to the strongest constraints coming from the leptophobic and leptophilic case.

Relic density: Freeze-in production

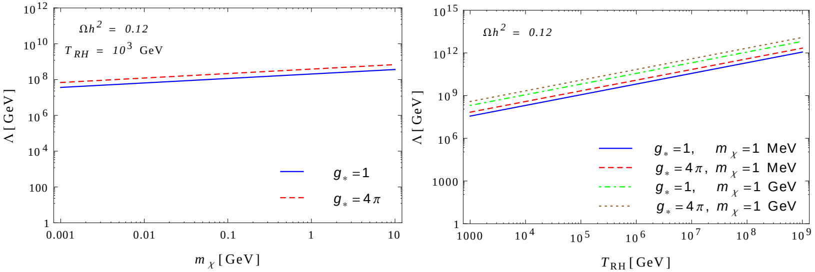

Figure: The expected value of Λ as a function of the DM mass m_χ or the reheating temperature T_{RH}.

Conclusions

- We apply the model independent EFT analysis to the case of sub-GeV DM.
- We take properly into account the running of the couplings and incorporate them to the calculations.
- For the cases considered, large regions of parameter space are already probed in a model independent way, even for relatively low cutoffs.
- In particular, in the context of EFT, no much room is left for observation at future experiments. We stress however that the situation may change for relatively light mediators, for which the EFT analysis does not apply.

Thanks