Phenomenological consequences of an interacting multicomponent dark sector

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- JTA, Marco Fabbrichesi, and Piero Ullio, *Phenomenological consequences of an interacting multicomponent dark sector*, Phys. Rev. D 102, 083009 (2020).

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Setting up the framework

$$\mathscr{L} \supset -\frac{1}{4}X_{\mu\nu}X^{\mu\nu} + \bar{Q}\left(i\not{\partial} - m_Q - q_Q g_D \not{X}\right) Q \longrightarrow$$

Dark QED/U(1) (no kinetic mixing)

$$\begin{aligned}\mathscr{L} \supset & -g_L\left(\phi_L^\dagger \bar{\chi}_R l_L + S_L^{U\dagger}\bar{Q}_R^U q_L + S_L^{D\dagger}\bar{Q}_R^D q_L\right) \\ & - g_R\left(\phi_R^\dagger \bar{\chi}_L e_R + S_R^{U\dagger}\bar{Q}_L^U u_R + S_R^{D\dagger}\bar{Q}_L^D d_R\right) + h.c.\end{aligned} \longrightarrow$$

Dark sector-SM portal

$$\mathscr{L} \supset -\lambda_s S_0\left(H^\dagger \phi_R^\dagger \phi_L + H^\dagger S_R^{D\dagger} S_L^D + \tilde{H}^\dagger S_R^{U\dagger} S_L^U\right) + h.c. \longrightarrow$$

LR mixing

<u>Couplings</u>

Portal: α_L, α_R

Gauge: α_D

<u>Masses</u>

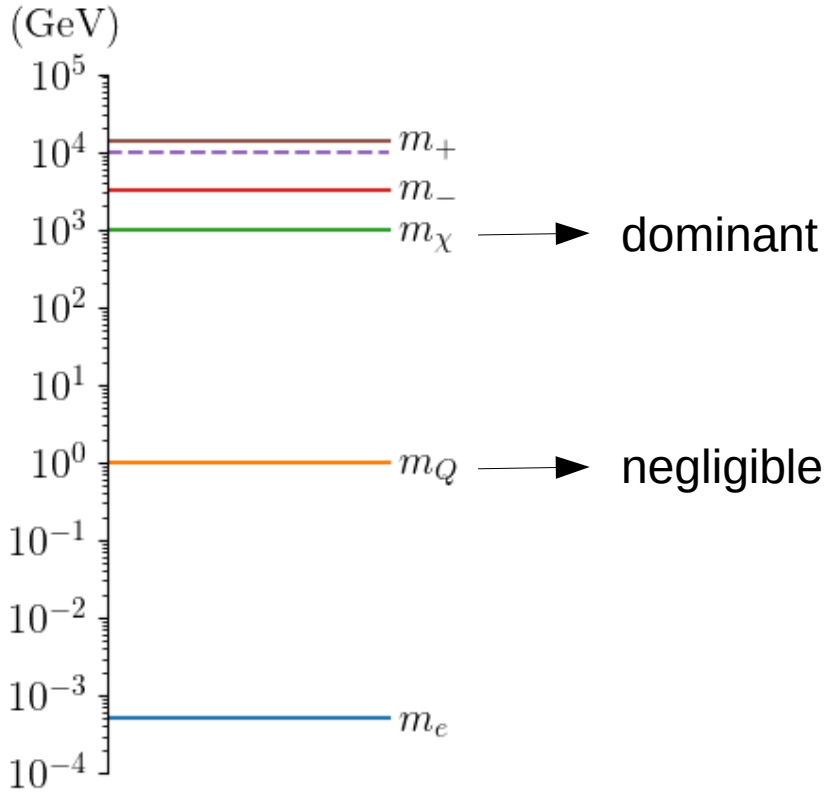
Lepton-like: m_χ

Quark-like: m_{Qu}, m_{Qd}

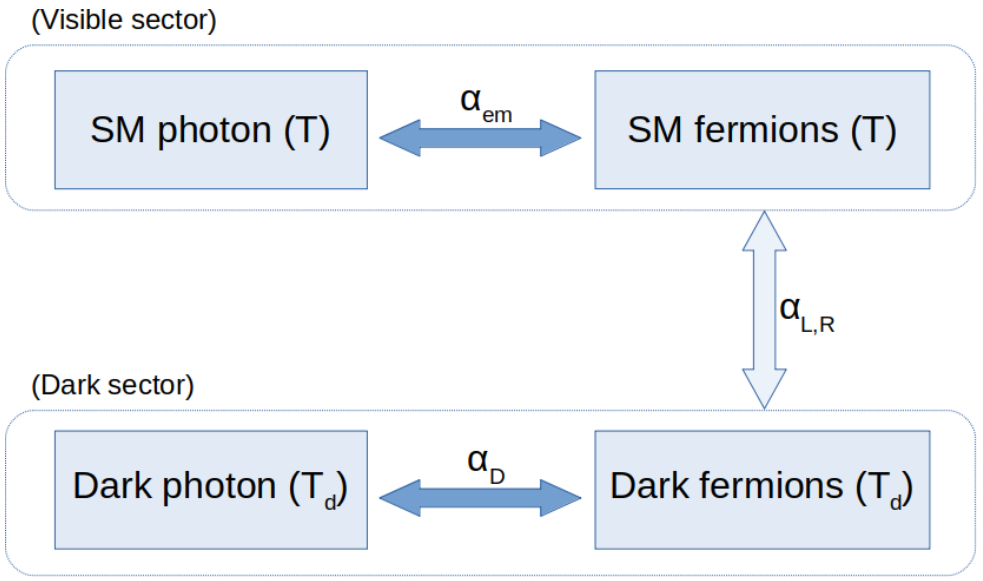
Messengers: $m_\pm$

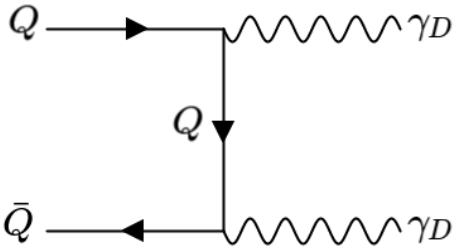
Complementary constraints

- Dipole moment of SM leptons
- Collider limits on squark masses
  - $m_S \geq 940$ GeV, $m_\phi \geq 1.5$ TeV
  - No limits on dark fermion masses
- Stellar cooling rates
  - Emission of γ_D
  - Stars in globular clusters (e^- Bremsstrahlung)
  - Neutron stars (nucleon Bremsstrahlung)
- Self-interaction limits

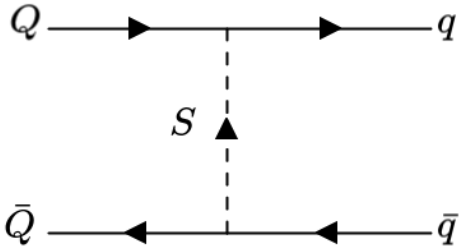


What about cosmological constraints?





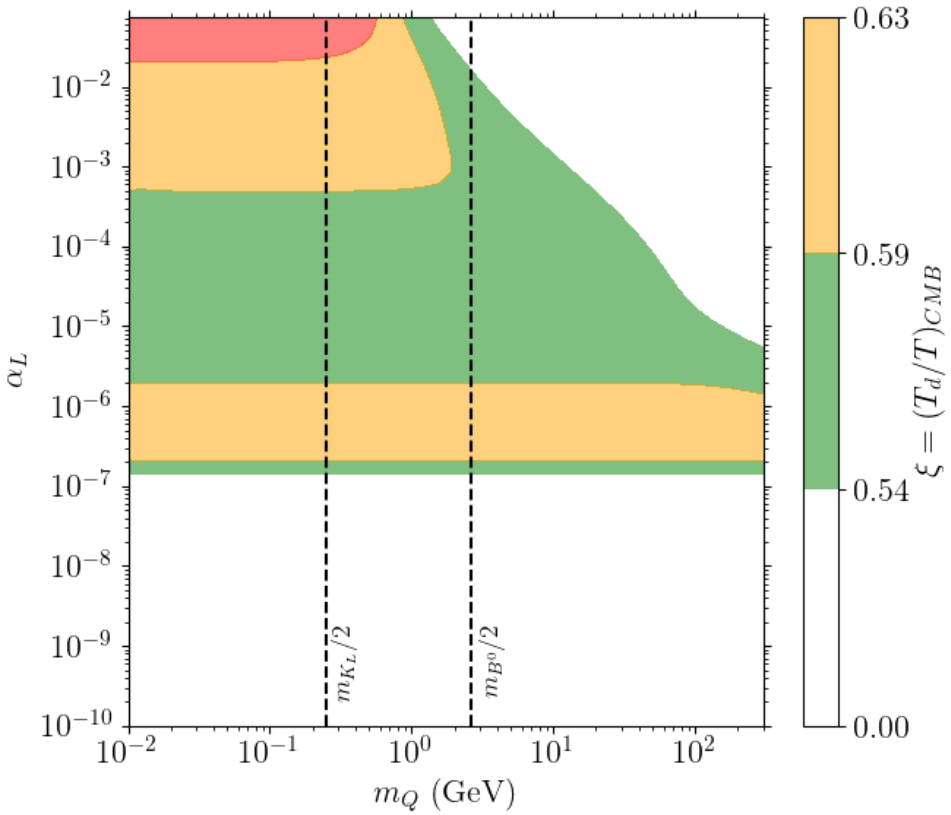
$$\langle \sigma v \rangle \sim \frac{\alpha_D^2}{m_Q^2}$$



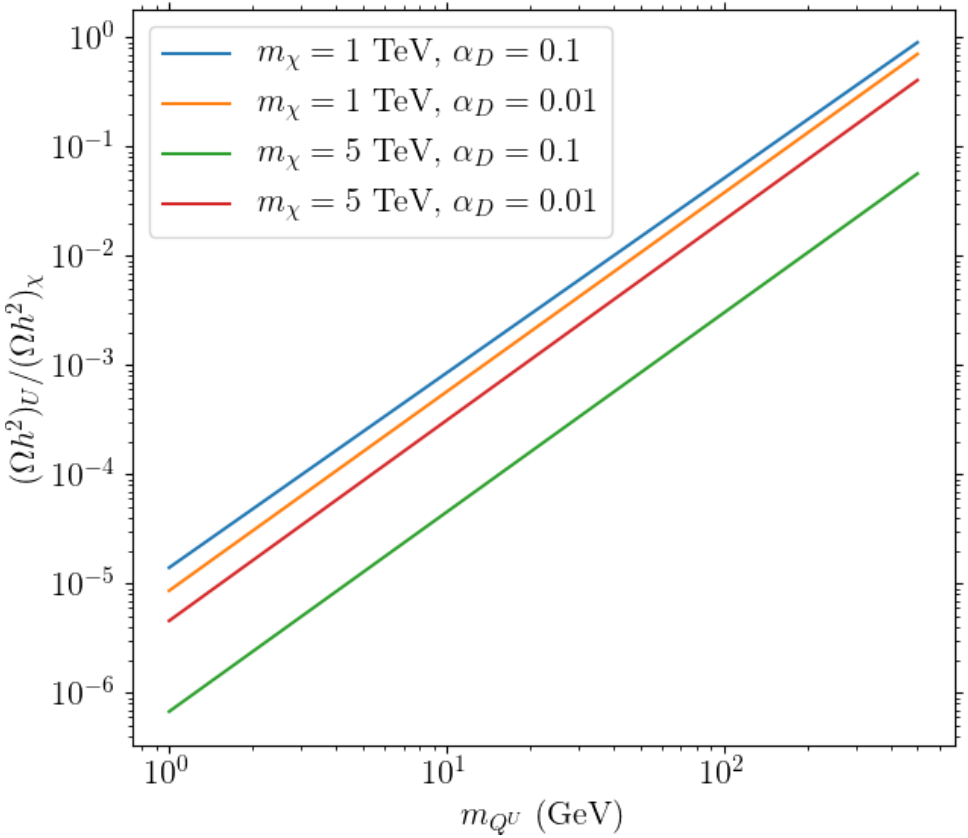
$$\langle \sigma v \rangle \sim \frac{\alpha_L^2 m_Q^2}{m_S^4}$$

$$m_S > m_Q$$

Sample constraints



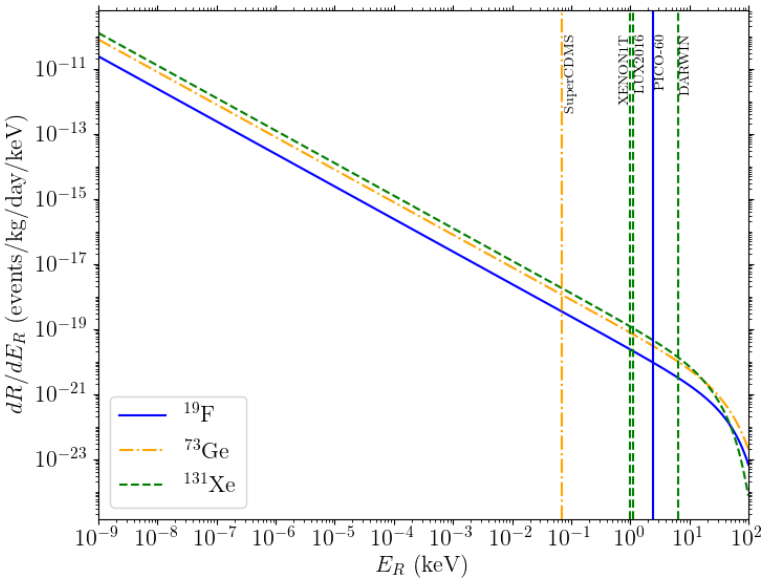
This suggests a lower bound on m_Q



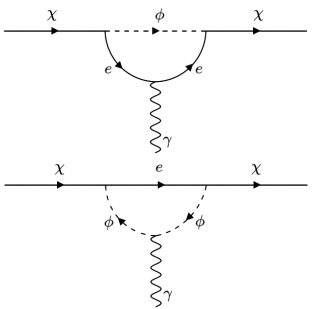
This suggests an upper bound on m_Q

Direct detection: γ- vs γ_D-mediated

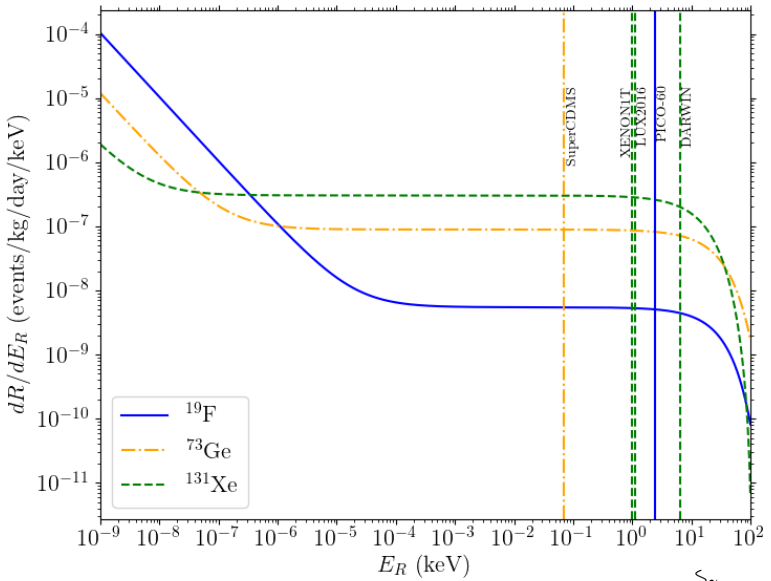
γ-mediated



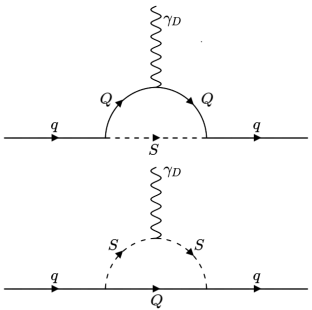
$$\frac{dR}{dE_R} \sim \frac{Z^2}{E_R}$$



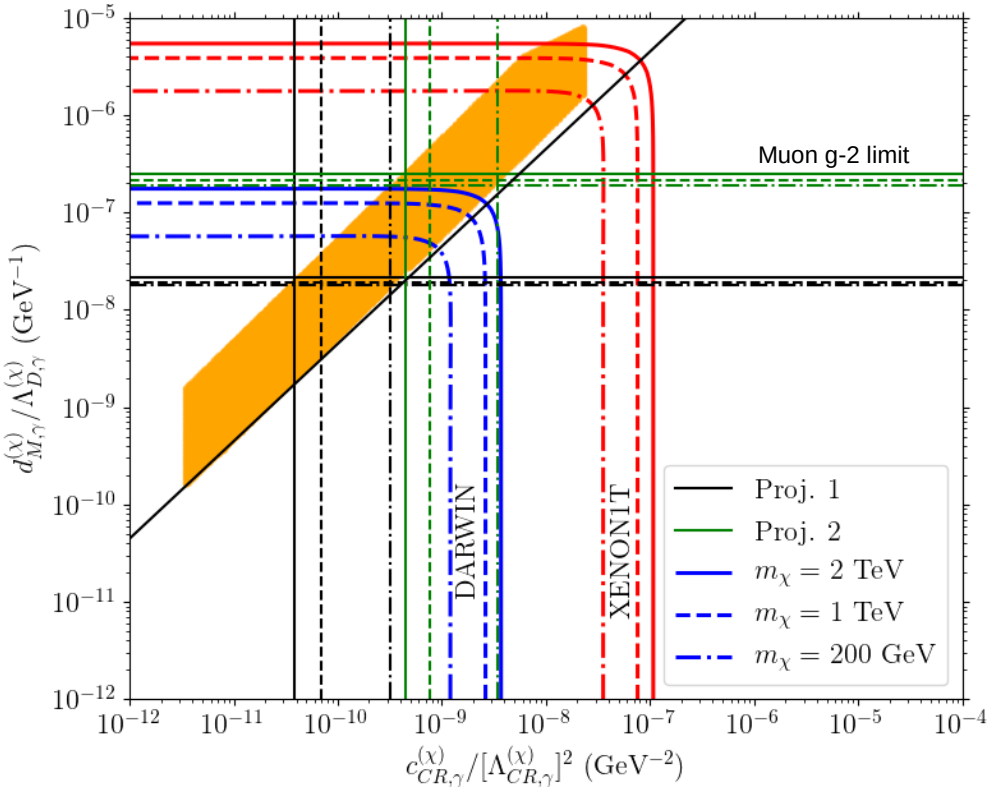
γ_D-mediated

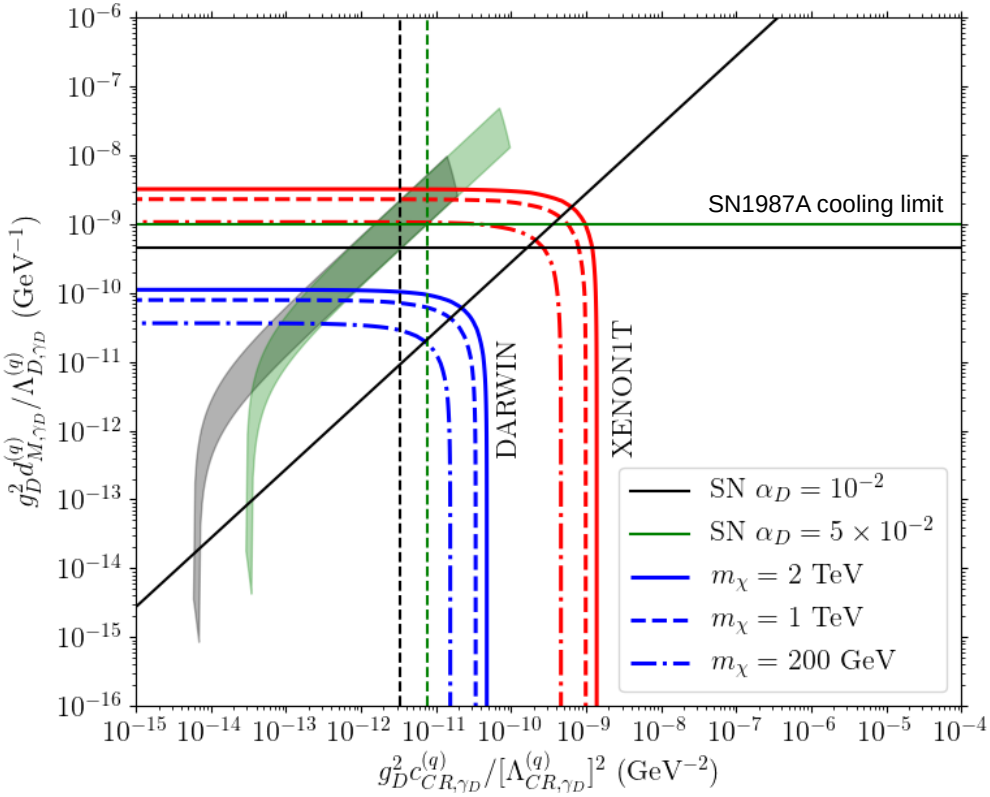


$$\frac{dR}{dE_R} \sim (\#)\frac{\langle \vec{S}_N^2 \rangle}{E_R} + (\#)\frac{m_T}{m_N^2 v^2}\langle \left(\vec{L}\cdot\vec{S}_N\right)^2 \rangle + (\#)\frac{A^2 m_T}{m_N^2 v^2}$$



Direct detection: γ- vs γ_D-mediated





Summary

- Cosmology
  - Relic density: $m_\chi \geq 500$ GeV for $\alpha_D = 10^{-2}$
  - N_{eff} limit: 2 light dark species, $m_Q \leq 2$ GeV excluded for $\alpha_L \approx 10^{-1}$
  - $M_Q \leq 100$ GeV for Ω_Q to be 1% of Ω_χ

- Direct detection
  - DM-nuclei scattering: mediated by γ and γ_D
  - Dipole: Long-range but incoherent vs CR: Contact but coherent
  - Treat dipole and CR as independent, get DD limits
  - Dipole and CR strongly correlated in DS model: dipole generally dominates

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