Combining dark matter searches and charm bounds

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Outline

Background

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  - But this simplicity hides all the interesting effects
- If there is a complex flavour structure, then typically Minimal Flavour Violation is invoked
- If your model obeys MFV $\Rightarrow$ can't get large new contributions to flavour measurements

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- Bad if you want to do some flavour physics

Beyond MFV

- If we want new physics effects, we have to go beyond MFV
- A relatively simple extension is Dark Minimal Flavour Violation (DMFV)

Dark Minimal Flavour Violation[1]

- Add dark matter that transforms under a new flavour symmetry $SU(3)_\chi$
- In the simplest case – three DM particles
- $SU(3)_\chi$ is broken by coupling matrix λ

[1] Agrawal, Blanke, Gemmler – arXiv:1405.6709

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- Charm bounds have not been looked at before

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- D mixing?
- Situation is quite unclear . . .

Charm vs Heavy Quark Expansion

- HQE is an expansion in $\frac{1}{m_Q}$ where Q is a heavy quark
- Works very well for b quarks ($m_\mathrm{b} \approx 4.6$ GeV)
  E.g. for B^0_s

$$\Delta\Gamma_\mathrm{theory} = 0.088 \pm 0.020\ \mathrm{ps}^{-1}$$
$$\Delta\Gamma_\mathrm{exp} = 0.083 \pm 0.006\ \mathrm{ps}^{-1}$$

- But for charm, $m_\mathrm{c} \approx 1.3$ GeV

Charm HQE predictions

- HQE is used to predict $\Delta\Gamma_D$ (and then ΔM_D)
- 3-4 orders of magnitude difference!

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- Maybe GIM suppression lifts at higher orders?

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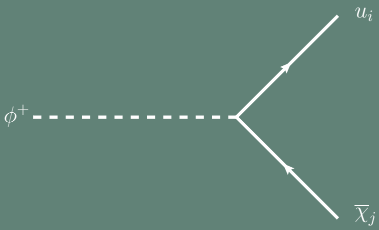
Charm bounds

- What charm processes can bound new physics?
- D mixing?
- Not a straightforward bound to apply

Charming dark matter model

- Our model has 4 new particles:
  - 3 DM particles χ_i – singlets under the SM gauge group
  - A mediator ϕ, with electric and colour charge
- The interaction part of the Lagrangian is:

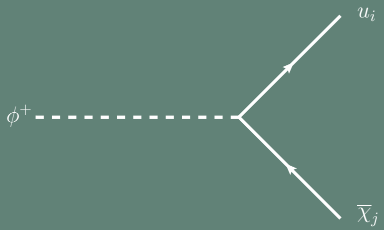
$$\mathcal{L}_{\text{int}}^{\text{NP}} = -\lambda_{ij}\overline{\text{u}}_i(1-\gamma^5)\chi_j\phi^+ - \lambda_{ij}^*\overline{\chi}_j(1+\gamma^5)\text{u}_i\phi^- + \frac{g_{\phi\phi}}{4}(\phi^+\phi^-)^2 + g_{H\phi}\phi^+\phi^-\text{H}^\dagger\text{H}$$



Model parameters

- For looking at D mixing constraints, the relevant Lagrangian terms are

$$\mathcal{L} = -\lambda_{ij}\overline{\mathrm{u}}_i(1-\gamma^5)\chi_j\phi^+ - \lambda_{ij}^*\overline{\chi}_j(1+\gamma^5)\mathrm{u}_i\phi^-$$



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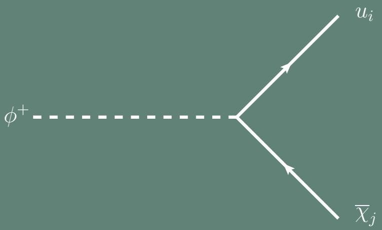
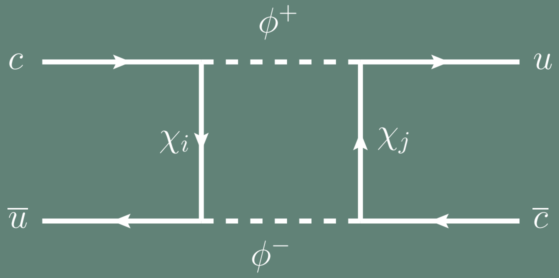
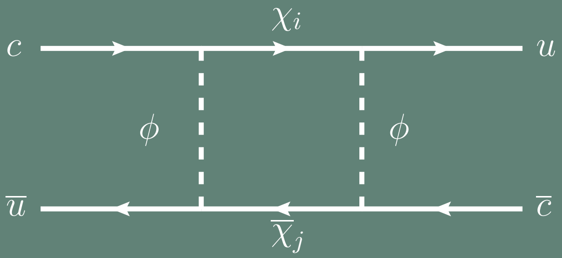
- Parameter space is 11 dimensional
  - m_ϕ, m_{χ_0}
  - λ can be parameterised by:
    - 3 mixing angles
    - 3 CP violating phases
    - 3 non-negative elements



New Box Diagrams

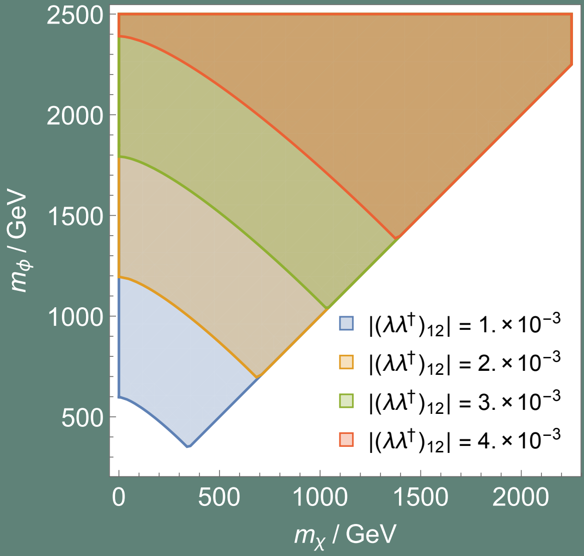




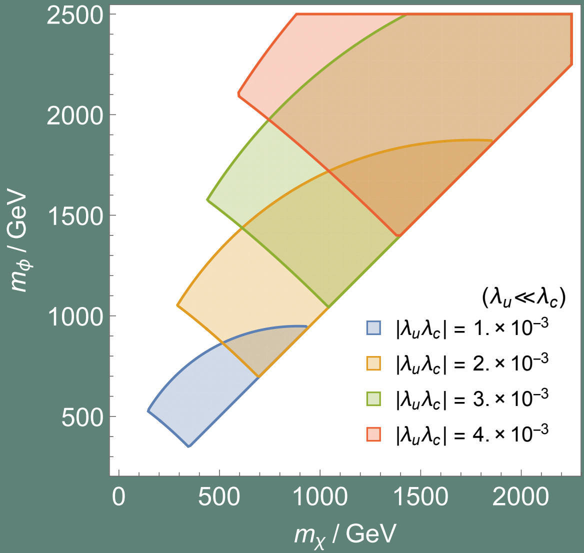
Constraints

- The constraints we impose upon our model are:
  - $\Delta M^{\text{NP}} \leqslant \Delta M^{\text{exp}}$, i.e. we are allowing for the uncertainty in the SM prediction
  - In simplified model, also have dark matter relic density constraint

Allowed Regions



Allowed regions – simplified model



Rare decays

- We also estimated the contributions our model gives to the rare decays $D^0 \to \mu\mu$ and $D^0 \to \gamma\gamma$
- The NP enhancement is $\ll$ the SM prediction

Summary

- We have shown that a model obeying Dark Minimal Flavour Violation can contribute to D^0 mixing over a reasonable amount of parameter space
- Currently working on: constraints from relic density, direct and indirect detection, collider searches

Backup

Benefits of DMVF

- At lowest order, all the DM particles have equal mass
- As long as one DM flavour is the lightest new particle, even non-renormalisable terms leading to decay are forbidden[1]

[1] Batell, Pradler, Spannowsky (arXiv:1105.1781)
Agrawal, Blanke, Gemmler (arXiv:1405.6709)