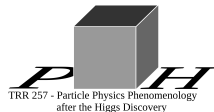


# Flavoured dark matter beyond Minimal Flavour Violation

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Dark Matter models with  $t$ -channel mediators @ LHC  
LHC DM WG public meeting  
April 26, 2019 – CERN

# Flavoured dark matter

## Unknown DM properties

- coupling to SM particles?
- single particle or entire sector?
- analogy to ordinary SM matter

➤ **flavoured?**

## Assumption:

dark matter carries flavour  
and comes in multiple copies



➤ **New coupling to quarks:**

$$\lambda^{ij} \bar{q}_i \chi_j \phi$$

- |           |                          |
|-----------|--------------------------|
| $q_i$     | SM quarks                |
| $\chi_j$  | DM particle, flavoured   |
| $\phi$    | coloured scalar mediator |
| $\lambda$ | coupling matrix          |

## Flavoured DM beyond MFV

AGRAWAL, MB, GEMMLER (2014)

MB, KAST (2017)

MB, DAS, KAST (2017)

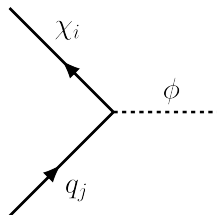
JUBB, KIRK, LENZ (2017)

CHEN, HUANG, TAKHISTOV (2015)

# Flavoured dark matter beyond MFV

- in general, DM quark coupling matrix  $\lambda_{ij}$  is a **new source of flavour and CP violation**
- flavour symmetry extended to

$$G_{\text{flavour}} = U(3)_q \times U(3)_u \times U(3)_d \times U(3)_\chi$$



## Dark Minimal Flavour Violation hypothesis

- The DM quark coupling matrix  $\lambda_{ij}$  constitutes **the only** new source of flavour and CP violation.
- minimal step beyond MFV limit, but vastly changed phenomenology
  - DM and mediator couple to all quark generations
- DM stability still ensured by flavour symmetry

AGRAWAL, MB, GEMMLER (2014)

# Simplified DMFV models

different simplified models possible, depending on coupling structure

## 1 down-quark DMFV

AGRAWAL, MB, GEMMLER (2014)

DM interacts with right-handed down quarks

$$\lambda_{ij} \bar{d}_{Ri} \chi_j \phi$$

## 2 up-quark DMFV

MB, KAST (2017); JUBB, KIRK, LENZ (2017)

DM interacts with right-handed up quarks

$$\lambda_{ij} \bar{u}_{Ri} \chi_j \phi$$

## 3 left-handed DMFV

MB, DAS, KAST (2017)

DM interacts with left-handed quark doublets

$$\lambda_{ij} \bar{Q}_{Li} \chi_j \Phi$$

**model parameters:** masses  $m_\chi, m_\phi$ ; coupling matrix  $\lambda$  (9 param.)

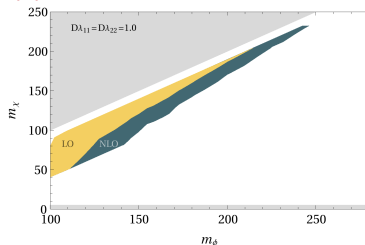
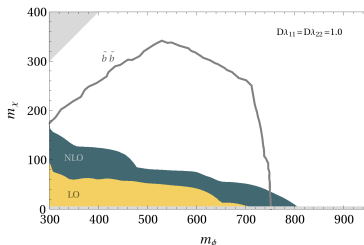
# Down-quark DMFV pheno in a nutshell

AGRAWAL, MB, GEMMLER (2014)

- $K$  and  $B_{d,s}$  oscillation constraints imply very non-generic structure for coupling matrix  $\lambda \Rightarrow$  small effects in rare meson decays
- bottom-flavoured DM phenomenologically preferred

AGRAWAL, BATELL, HOOPER, LIN (2014)

- mediator mass constrained from LHC ( $b$ ) squark and monojet searches



- direct detection constraints require cancellation between various contributions  $\Rightarrow$  xenophobic DM

FENG, KUMAR, SANFORD (2013)

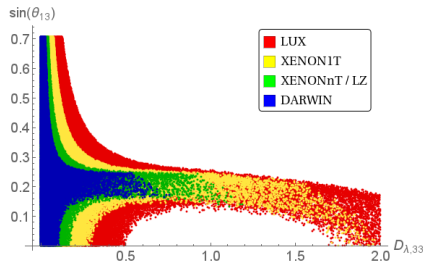
# Up-quark DMFV pheno in a nutshell

MB, KAST (2017)

- no contribution to  $K$  and  $B$  decays, but constraints from  $D^0$  mixing
- mediator mass constrained from LHC stop and squark searches
- new signature  $tc + \cancel{E}_T$ , c. f. flavour-violating SUSY

MB, GUIDICE, PARADISI, PEREZ, ZUPAN (2013); CHAKRABORTY ET AL. (2018)

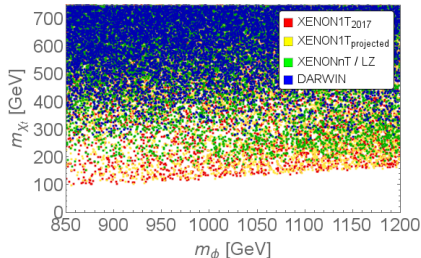
- with top-flavoured DM,  $Z$ -penguin contribution becomes relevant for direct detection ➤ different cancellation pattern
- for future experiments, cancellation not sufficiently effective for all xenon isotopes
  - upper bound on coupling
  - lower bound on DM mass



# Left-handed DMFV pheno in a nutshell

MB, DAS, KAST (2017)

- DM coupling to both up- and down-quarks via **doublet mediator**
  - non-trivial **combination of up- and down-quark models' pheno**
- $K - \bar{K}$  and  $D - \bar{D}$  meson mixing constraints require residual approximate  $U(2)$  **flavour symmetry**
- **stronger LHC bounds** partially counteracted by **weaker direct detection limits**
  - **allowed mass range comparable to up-quark model**



# Wrap-up

## Flavoured dark matter beyond MFV

- **variety of possible models**, including yet unstudied ones (different spins, more complicated dark sectors etc.)
- **rich phenomenology** with implications for
  - direct and indirect DM detection experiments
  - LHC searches with MET
  - flavour observables in  $B$ ,  $K$ ,  $D$  decays ( $\rightarrow$  discussion session)

