Dark Matter via t-Channel Production: Leptophilic Models

Andrea Thamm

LHC DM WG t-channel White Paper - Status Report
9 June 2023

Outline

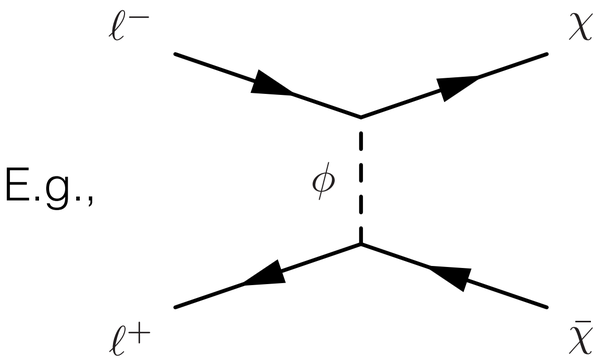
- Classification
- Benchmark models
- Phenomenology

Leptophilic Models: Classification

Leptophilic t-channel models:

DM **only** couples to SM leptons via a t-channel diagram

E.g.,



RH Model Parameters:

- m_χ
- $\Delta = (m_\phi - m_\chi)/m_\chi$
- y_R^i

- DM can couple to RH and/or LH e, μ and/or τ
- DM is gauge singlet $\Longrightarrow$ charged mediator
- Fermionic DM $\Longrightarrow$ bosonic mediator and vice versa
- DM could be a real or complex scalar, a Majorana or Dirac fermion or a real or complex vector
- The mediator must be complex/Dirac

$$\mathcal{L} \supset y_R^{ij}\phi^j\overline{\chi}\ell_R^i + y_L^{ik}\varphi^k\overline{\chi}L_L^i + h.c.$$

Field	$(su(3)_C, su(2)_L, u(1)_Y)$	Spin
ℓ_R	$(1, 1, -1)$	$1/2$
L_L	$(1, 2, -1/2)$	$1/2$
χ	$(1, 1, 0)$	$0, 1/2, 1$
ϕ	$(1, 1, 1)$	$1/2, \{0, 1\}, 1/2$
φ	$(1, 2, 1/2)$	$1/2, \{0, 1\}, 1/2$

Leptophilic Models: Benchmark models

1. Muon-philic model

- Two new fields:
  Majorana DM χ and complex scalar ϕ

$$\mathcal{L} \supset \frac{1}{2}\overline{\chi} i\partial\!\!\!/ \chi - \frac{1}{2} m_\chi \overline{\chi}\chi + D_\mu \phi^\dagger D^\mu \phi - m_\phi^2 |\phi|^2 + y_\chi \phi \overline{\chi} \mu_R + h.c. + \lambda_\phi |\phi|^4 + \lambda_{H\phi} |H|^2 |\phi|^2$$

2. Flavour universal model

- Four new fields:
  Majorana DM χ and 3 complex scalars ϕ_i

$$\mathcal{L} \supset \frac{1}{2}\overline{\chi} i\partial\!\!\!/ \chi - \frac{1}{2} m_\chi \overline{\chi}\chi + D_\mu \phi_i^\dagger D^\mu \phi_i - m_\phi^2 |\phi_i|^2 + y_\chi^{ij} \phi_i \overline{\chi} \ell_R^j + h.c. + V(H, \phi_i)$$

- We take $y_\chi^{11} = y_\chi^{22} = y_\chi^{33} \equiv y_\chi$ and all others 0
- Avoids constraints from $\mu \to e\gamma$

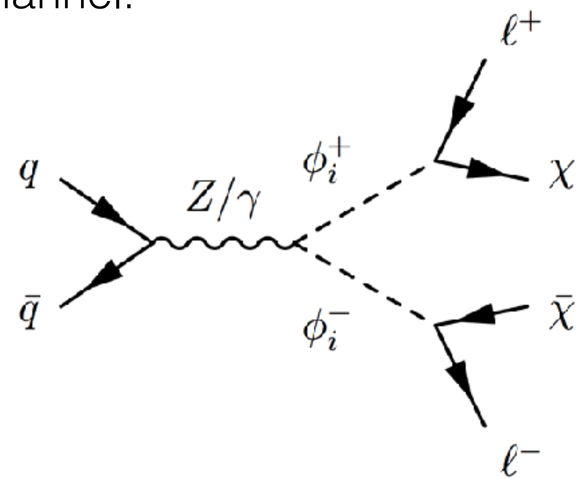
Leptophilic Models: Phenomenology

Phenomenology depends on

Mass Regime

- Decoupled: $0.3 \lesssim \Delta$
- Coannihilation: $0.02 \lesssim \Delta \lesssim 0.3$
- Quasi-degenerate: $\Delta \lesssim 0.02$

Main LHC channel:



Two (SF) OS leptons + MET

Mass Regimes:

- Decoupled: $\Longrightarrow$ hard leptons
- Coannihilation: $\Longrightarrow$ soft leptons (ISR boost?)
- Quasi-degenerate and small couplings: $\Longrightarrow$ long-lived mediator

Leptophilic Models: Phenomenology

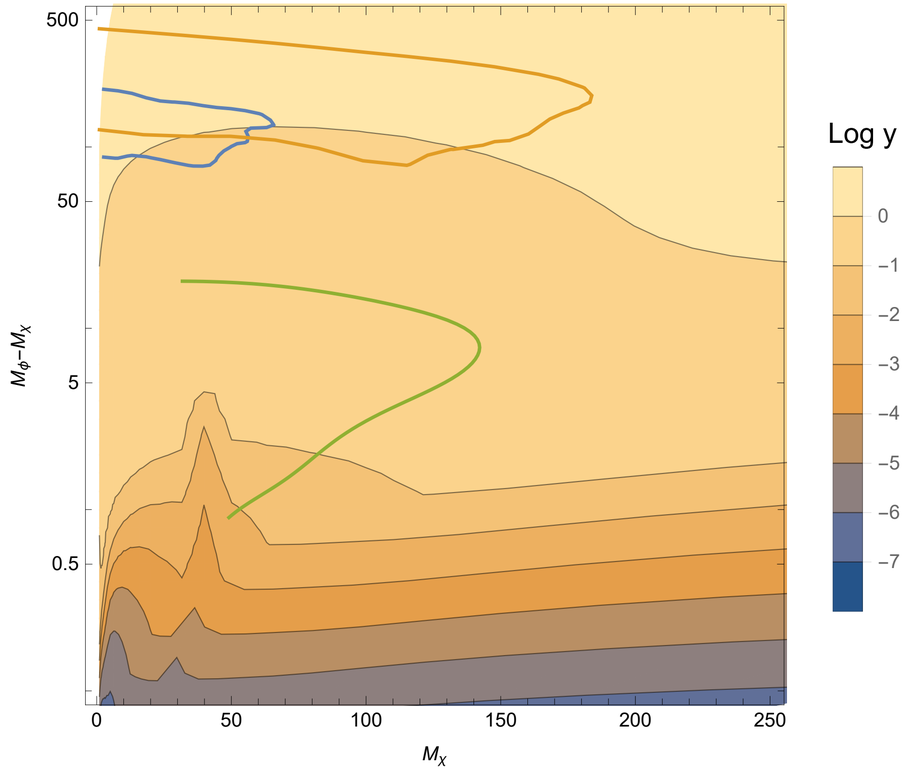
Phenomenology depends on

Mass Regime

- Decoupled: $0.3 \lesssim \Delta$
- Coannihilation: $0.02 \lesssim \Delta \lesssim 0.3$
- Quasi-degenerate: $\Delta \lesssim 0.02$

Decoupled and coannihilation region:

- Compressed spectra searches
  1911.12606, 1908.08215, 1403.5294



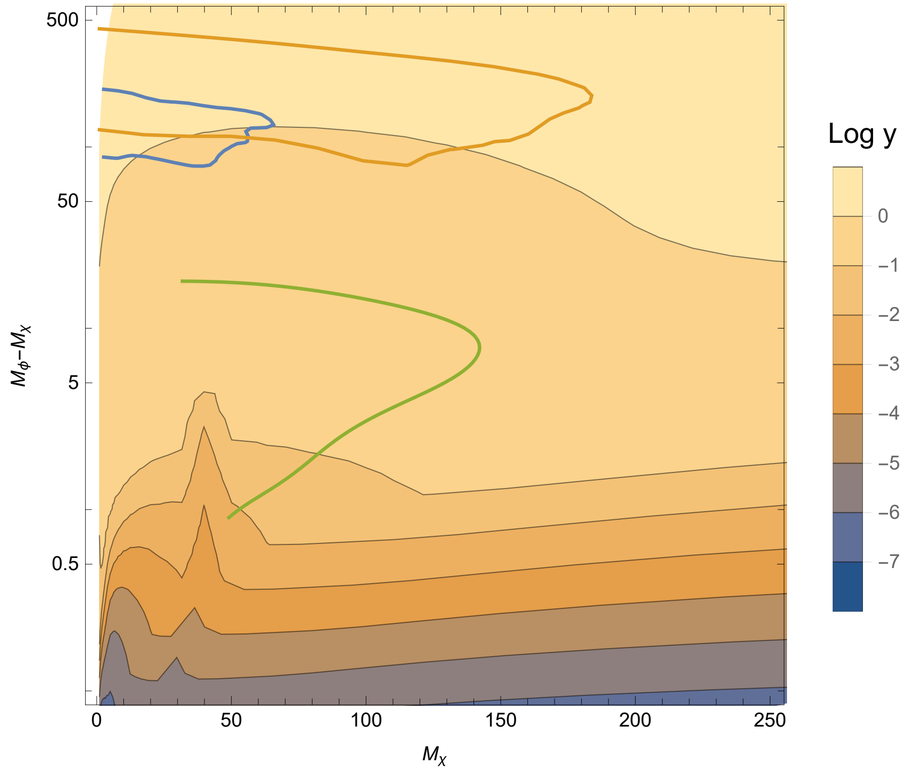
Leptophilic Models: Phenomenology

Phenomenology depends on

DM Production Mechanism (3 → 2 parameters)

- Freeze-out
- Freeze-in
- Other
- Undefined (3 parameters)

Relic surface:



Leptophilic Models: Scope of Contribution

- Classification [complete]
- Benchmark models [complete]
- Phenomenology [in progress]
- Projections and other experiments [in progress]

Thank you!