Asymmetric dark matter via Leptogenesis

Enrique Fernández Martínez

Rencontres de Moriond 2011

Work in collaboration with M. Blennow,
B. Dasgupta and N. Rius JHEP 1103:014,2011

Asymmetric DM: Motivation

Baryonic Matter

Baryon mass: $m_B = 938\ \mathrm{MeV}$

Baryonic matter density:

$$\eta_B = \frac{n_B - n_{\bar{B}}}{n_\gamma} = \frac{n_B}{n_\gamma} = (6.19 \pm 0.15) \cdot 10^{-10}$$

Baryonic energy density:

$$\Omega_B = 0.0455$$

WMAP + BBN

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Dark Matter

DM mass: $m_{DM} = ?$

DM density:

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WIMP Dark Matter

DM mass:

$m_{WIMP} = 100\text{-}1000 \text{ GeV}$

DM density: from thermal freezeout of weak int

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Lets make DM more similar to baryonic matter:

Asymmetric Dark Matter

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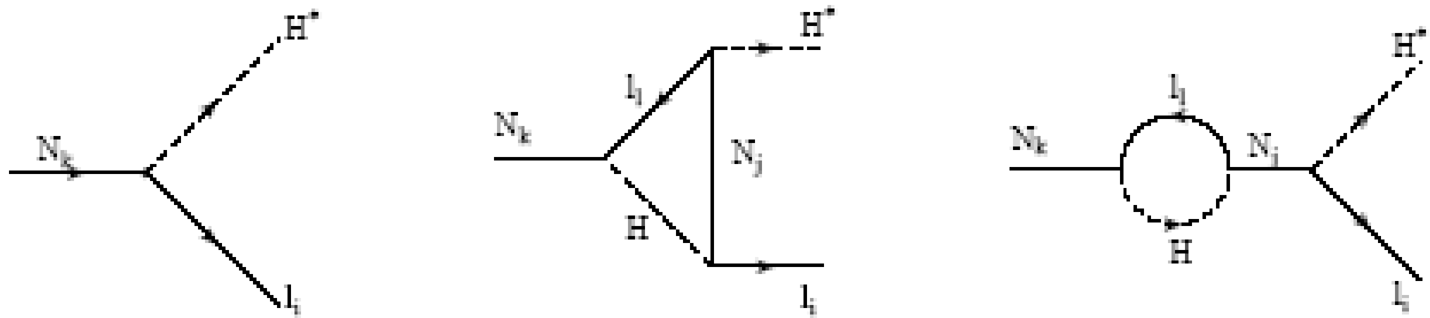
If the DM and baryon asymmetries have the same origin, will be similar, as suggested by the Ω_B-Ω_{DM} coincidence

typically $m_{DM} \sim 5\ \mathrm{GeV}$

Nussinov 1985; Barr, Chivukula and Farhi 1990; Kaplan 1992; Kuzmin 1997; Kusenko 1999; Kitano and Low 2004 and 2005; Hooper, March-Russell and West 2004; Farrar and Zaharijas 2004 and 2005; Agashe and Servant 2004; Cosme, Lopez Honorez and Tytgat 2005; Suematsu 2005; Banks, Echols and Jones 2006; Page 2007; Nardi, Sannino and Strumia 2009…

Asymmetric DM via Leptogenesis

Decay of Majorana right-handed neutrino N_R produces L asymmetry



CP and L violation in decay

M. Fukugita and T. Yanagida 1986

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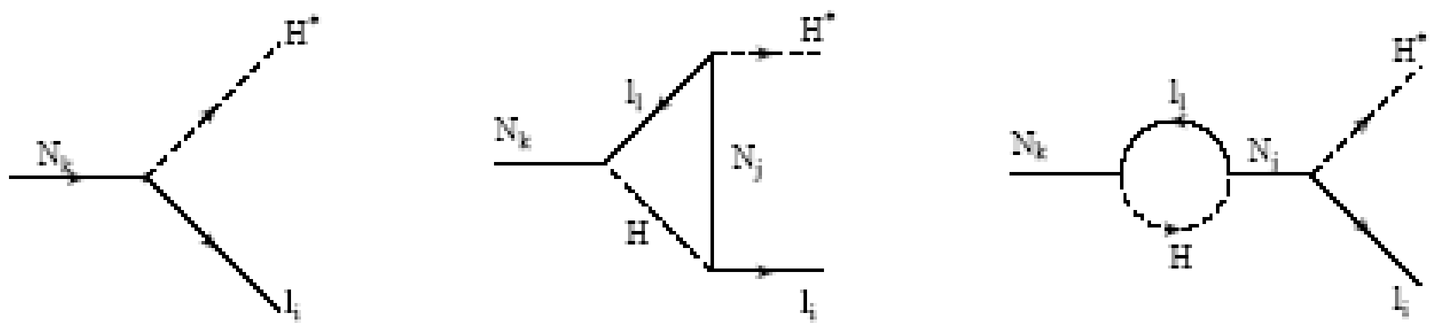

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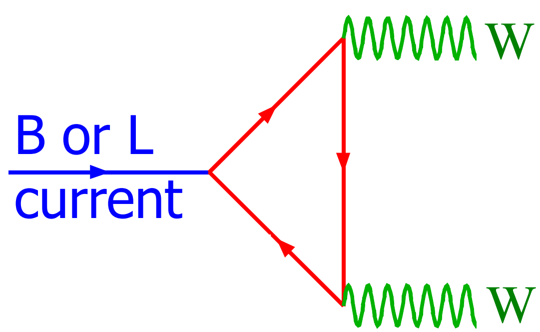
SM sphaleron processes partially convert L into B conserving B-L



B and L are anomalous and violated in the SM via sphaleron transitions to different EW vacua but B-L remains conserved

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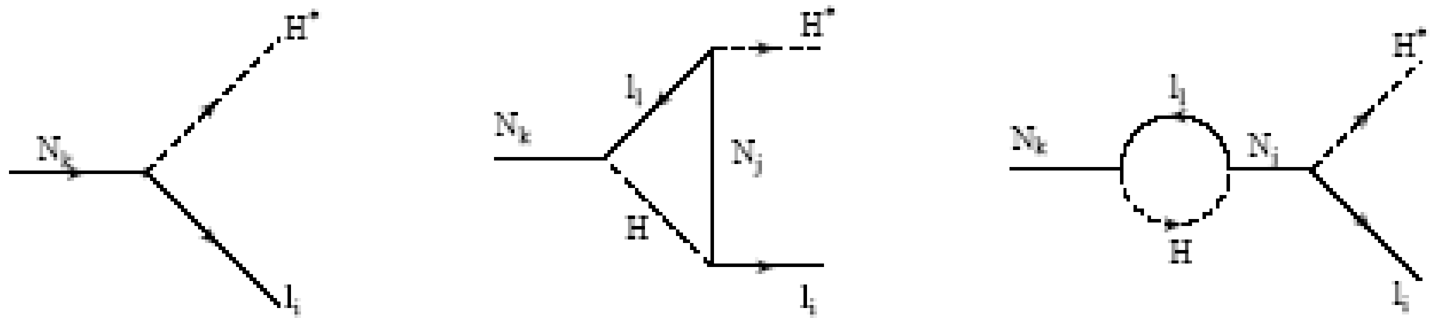

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Cant couple $5\ \mathrm{GeV}$ DM to SM sphalerons we need new sphalerons

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$SU(2)_H$ is a horizontal chiral symmetry that provides new sphalerons

$SU(2)_H$ doublets:

$$\begin{pmatrix} \mu \\ e \end{pmatrix}_R \quad \begin{pmatrix} s \\ d \end{pmatrix}_R \quad \begin{pmatrix} c \\ u \end{pmatrix}_R \quad \begin{pmatrix} x_2 \\ x_1 \end{pmatrix}_R$$

N_R and x_L are singlets to prevent anomalies

Asymmetric DM via Leptogenesis

N_R is a gauge singlet → Seesaw model and L generation in its decay

$SU(2)_L$ sphalerons violate B, L and X in the direction: $\Delta B = \Delta L$, $\Delta X = 0$
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Symmetric DM component from thermal freeze out form
"dark mesons" below the $SU(3)_{DC}$ phase transition which decay into
SM particles via the $SU(2)_H$ interaction

Constraints and phenomenology

"Dark mesons" should decay before BBN → lower bound

$$G_F^H > 10^{-(10-12)}\,\mathrm{GeV}^{-2}$$

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Lower bound on $SU(2)_H$ for sphalerons to be in thermal equilibrium

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$SU(2)_H$ interaction induces FCNC upper bound from $K^0 \to \mu\, e$

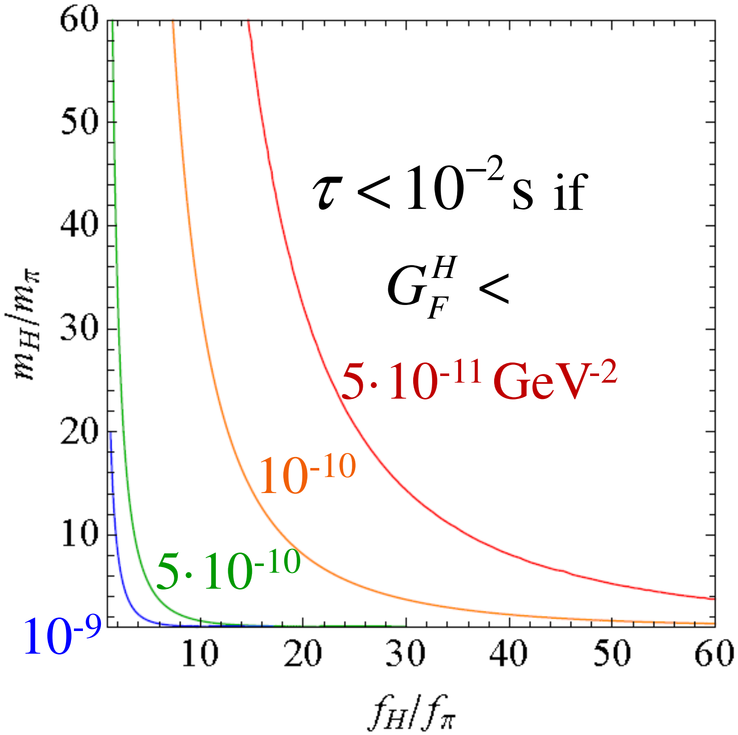
$$G_F^H < 3.6 \cdot 10^{-12}\,\mathrm{GeV}^{-2}$$

Tension with decay before BBN, need to break the symmetry in stages or to couple mainly to 2nd and 3rd generations

Breaking the symmetry in stages

If $SU(2)_H$ symmetry broken by vev of scalar triplet along σ_3 a flavour-conserving Z′ remains massless (like Georgi-Glashow model)

Milder constraints on the mass of the Z′ → can mediate "dark mesons" decay before BBN



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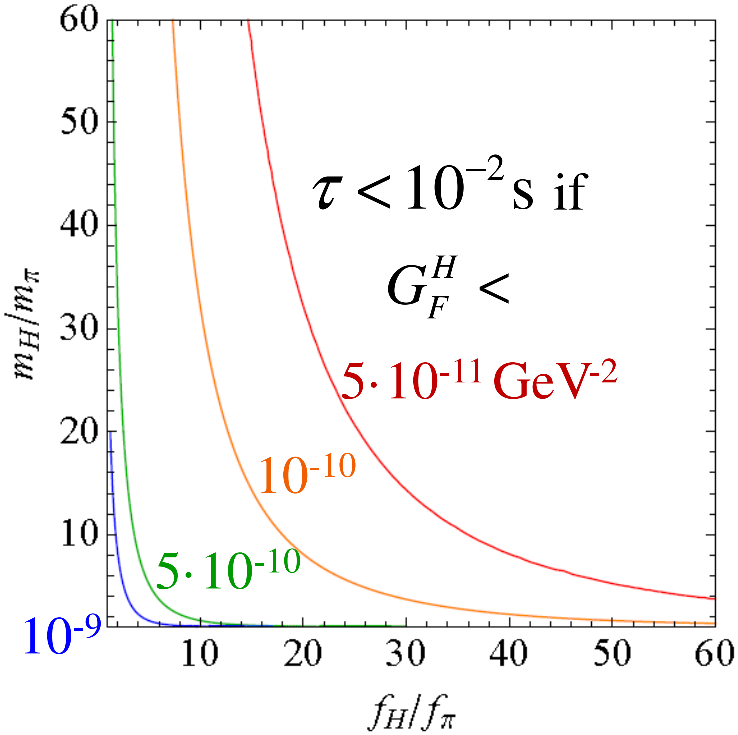
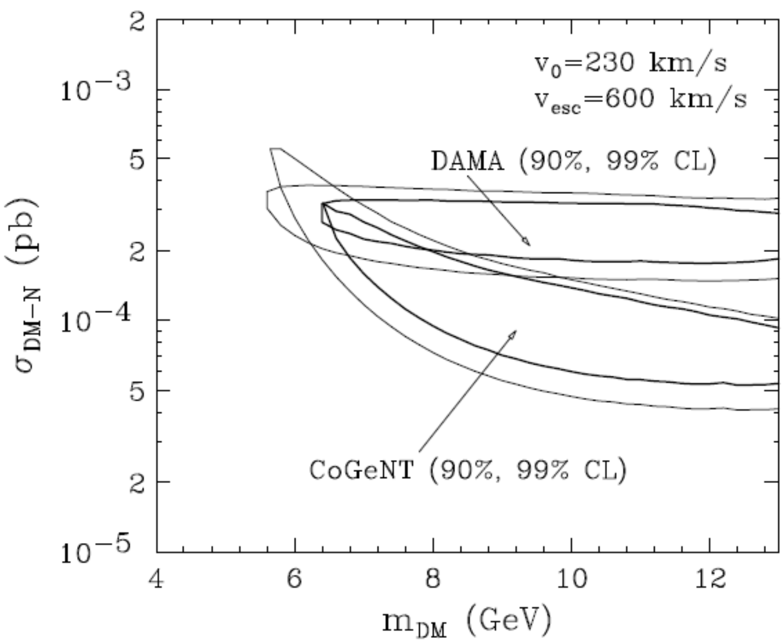


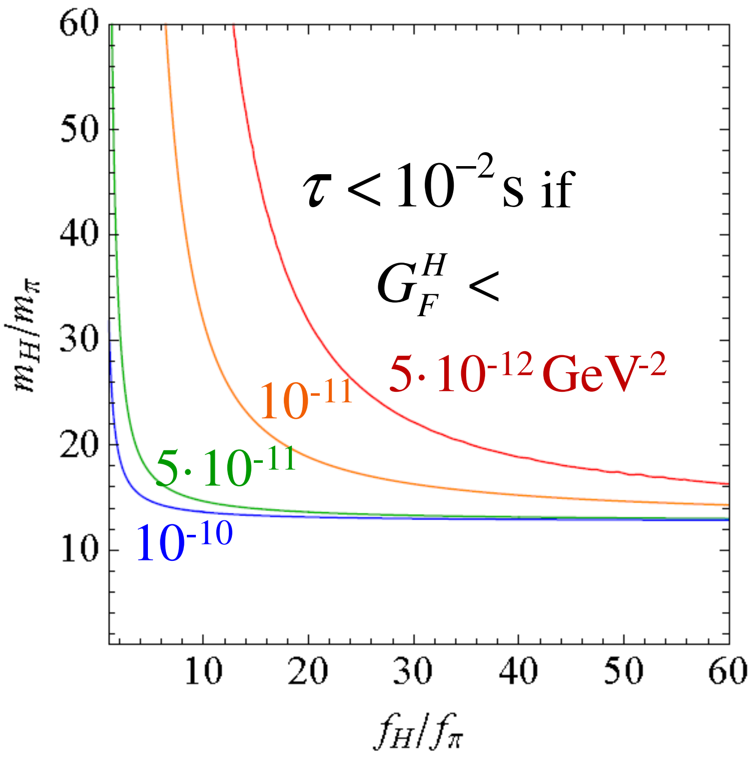


D. Hooper et al
arXiv:1007.1005

Requires $G_F^H \approx 10^{-7}$GeV^{-2}
tension with LEP bounds

Coupling to 2nd and 3rd generations

If $SU(2)_H$ interaction involves mainly 2nd and 3rd generations constraints are weaker



Can provide new source of mixing and CP violation in the B_s system

Conclusions and Outlook

- Extending the SM with N_R and DM fermions + $SU(2)_H \times SU(3)_{DC}$ induces asymmetric DM via leptogenesis

  - DM is stable without additional parities

  - DM mass and abundance similar to baryons

- A flavour-conserving Z′ remnant of $SU(2)_H$ can have low mass and lead to signals at colliders or direct detection experiments

- If $SU(2)_H$ couples mainly to the 2^{nd} and 3^{rd} generations it can provide new sources of mixing and CP violation in B system

- Can the $SU(2)_H$ symmetry breaking help with the flavour puzzle?