SUSY with a light Dirac bino:
B meson baryogenesis & sneutrino asymmetric DM

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Motivation

1. Can CP violation in neutral meson oscillations explain the matter-antimatter asymmetry of the Universe?
2. In SUSY with Dirac gauginos, the U(1) R-symmetry can be identified with baryon number.

Summary of model parameters

Parameter	Description	Baryogenesis & DM
m_Φ	Modulus mass	$11 - 100$ GeV
Γ_Φ	Modulus width	$3\times10^{-23} - 5\times10^{-21}\,\mathrm{GeV}^{-1}$
$m_{\tilde q}$	Squark Mass	$1 - 10\,\mathrm{TeV}$
$m_{\tilde B}$	Dirac Bino mass	$1.5 - 4.2\,\mathrm{GeV}$
m_N	RH neutrino mass	$0.3 - 2.7\,\mathrm{GeV}$
$m_{\tilde N}$	Sneutrino mass	$1.2 - 2.7\,\mathrm{GeV}$
λ_N	Yukawa for Bino-DM coupling	$\mathcal{O}(0.1)$
λ''_{123}	RPV coupling for $\tilde s_R u_R b_R$	$\mathcal{O}(1)$

Late-time B meson production

An out of equilibrium decaying scalar (inflaton, modulus, ...) generically produces a lot of b quarks.

If this happens late enough $T_{\mathrm{BBN}} < T < T_{\mathrm{QCD}}$, the b quarks hadronize and form B mesons.

U(1)R SUSY with Dirac gauginos

$$\mathbf{W} \subset y_u \mathbf{Q}\mathbf{H}_u\mathbf{U}^c - y_d\mathbf{Q}\mathbf{H}_d\mathbf{D}^c - y_e\mathbf{L}\mathbf{H}_d\mathbf{E}^c$$
$$+\lambda''_{ijk}/2\,\mathbf{U}^c_i\mathbf{D}^c_j\mathbf{D}^c_k + \mu_u\mathbf{H}_u\mathbf{R}_d + \mu_d\mathbf{R}_u\mathbf{H}_d$$

The R-symmetry forbids Majorana gaugino masses, but Dirac terms are allowed:

$$\sqrt{2}\int d^2\theta\, D\theta^\alpha\,\frac{1}{\Lambda}\mathbf{W}^{\tilde B}_\alpha\mathbf{S} + \mathrm{h.c.} \supset \sqrt{2}\frac{D}{\Lambda}\bar\psi\psi$$

A light Dirac bino $\psi = \begin{pmatrix}\tilde B\\ \lambda_s^\dagger\end{pmatrix}$ is possible.

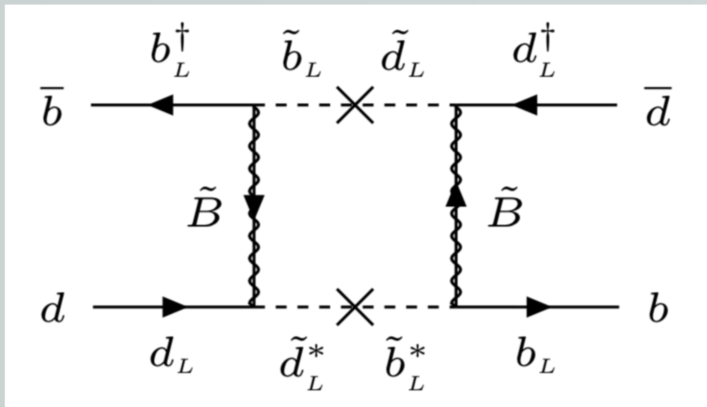
Superfield	$U(1)_R$ (B #)
$\mathbf{U}^c, \mathbf{D}^c$	2/3
$\mathbf{Q}$	4/3
$\mathbf{H}_u, \mathbf{H}_d$	0
$\mathbf{R}_u, \mathbf{R}_d$	2
$\mathbf{S}, \mathbf{T}, \mathbf{O}$	0
$\mathbf{L}$	1
$\mathbf{E}^c, \mathbf{N}^c_R$	1

Semileptonic asymmetries

Measure the amount of CPV in B meson oscillations.

The SM values are too small to generate the baryon asymmetry.

The bino can give extra contributions:



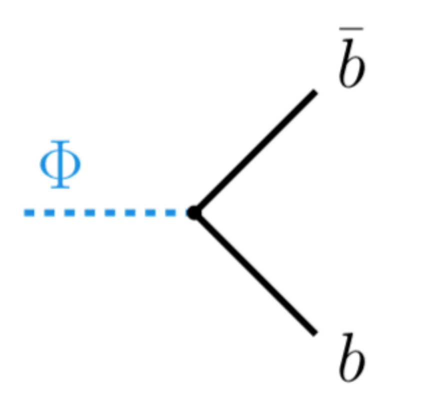
Experimental values (95% cl) are:

$$A^s_{\ell\ell} \in \left[-1.11\cdot10^{-3},\, 8.8\cdot10^{-4}\right],\quad A^d_{\ell\ell} \in \left[-5.9\cdot10^{-3},\, -4\cdot10^{-4}\right].$$

There is much room for new physics!

Sakharov condition I

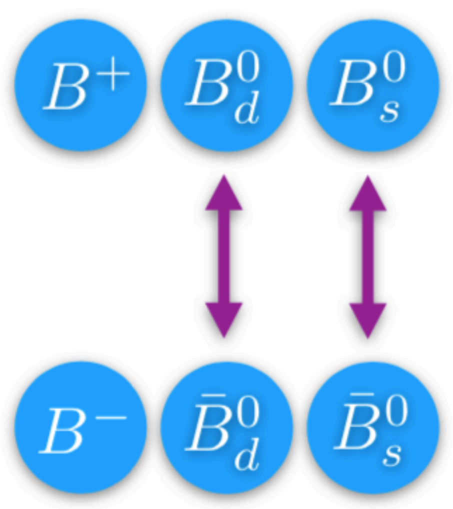
Out of equilibrium late time decay



$T_{\mathrm{RH}} \sim 20\,\mathrm{MeV}$

Sakharov condition II

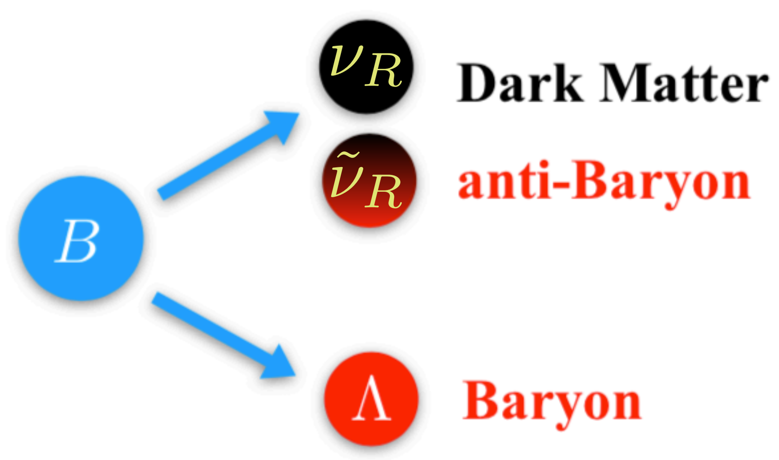
CP violating oscillations



$A^d_{\ell\ell}\quad A^s_{\ell\ell}$

Sakharov condition III

B-mesons decay into Dark Matter and hadrons



$\mathrm{BR}(B\to\phi\xi + \mathrm{Baryon} + \ldots)$

Baryogenesis

$Y_B = 8.7\times10^{-11}$

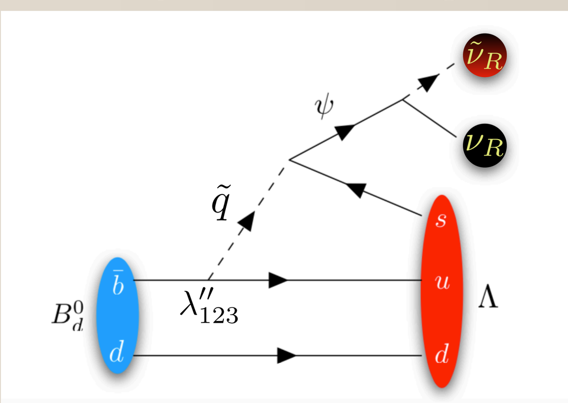
&

Dark Matter

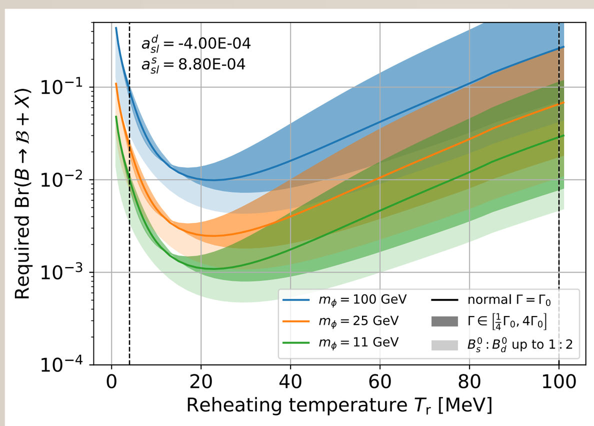
$\Omega_{\mathrm{DM}}h^2 = 0.12$

Invisible B meson decays

The bino mediates the apparently B-violating decay:



Predict a sizeable BR of B meson into baryons + DM:



RH sneutrino asymmetric DM

The superpotential of a right handed neutrino multiplet is

$$\mathbf{W} \supset \frac{\lambda_N}{4}\mathbf{S}\mathbf{N}^c_R\mathbf{N}^c_R + \mathbf{H}_u\mathbf{L}^I y_N^{IJ}\mathbf{N}^{c,J}_R + \frac{1}{2}\mathbf{N}^c_R M_M \mathbf{N}^c_R + \mathrm{h.c.}$$

The right handed sneutrinos carry baryon number B = -1.

The Dirac bino can decay $\begin{pmatrix}\tilde B\\ \lambda_s^\dagger\end{pmatrix} = \psi \longrightarrow \nu_R + \tilde\nu_R$

as long as $M_M \lesssim m_\psi \sim \text{few GeV}.$

$\Rightarrow$ Asymmetric sneutrino DM is generated during baryogenesis!

A symmetric component is usually overproduced, but efficiently annihilates into neutrinos via bino exchange if $\lambda_N \sim 0.1$.

Signals and testability

Particle physics

- Semileptonic asymmetries
- Flavor violation
- Exotic B decays
  $\mathrm{Br}\,(B\to\mathcal{B}+X) \gtrsim \text{few}\cdot10^{-4}$
- Long lived particles
  - Bino / RH neutrino
  - Faser, Mathusla, SHiP, ...
- Supergravity & RPV

Astrophysics

- Neutrino masses
  $y_N\sin\beta \sim 10^{-8}$
- DM decay
  $\tilde\nu_R \longrightarrow \nu_R + \bar u + \bar d + \bar d$
- Neutron stars
  - Production
    $m_{\tilde\nu_R} \gtrsim 1.2\,\mathrm{GeV}$
  - Capture

Conclusions

1. U(1)R SUSY with Dirac gauginos can accommodate baryogenesis and sterile sneturino asymmetric DM production via B meson oscillations.
2. The model can be tested: flavor & astrophysical observables.

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