

Baryogenesis & dark matter from B mesons: a supersymmetric story

Gonzalo Alonso-Álvarez

Work with: Gilly Elor, Ann Nelson, Huagyu Xiao, [arXiv:1907.10612](https://arxiv.org/abs/1907.10612)

BLV 2019 Workshop
IFT Madrid, 24 October 2019

elusi^oes



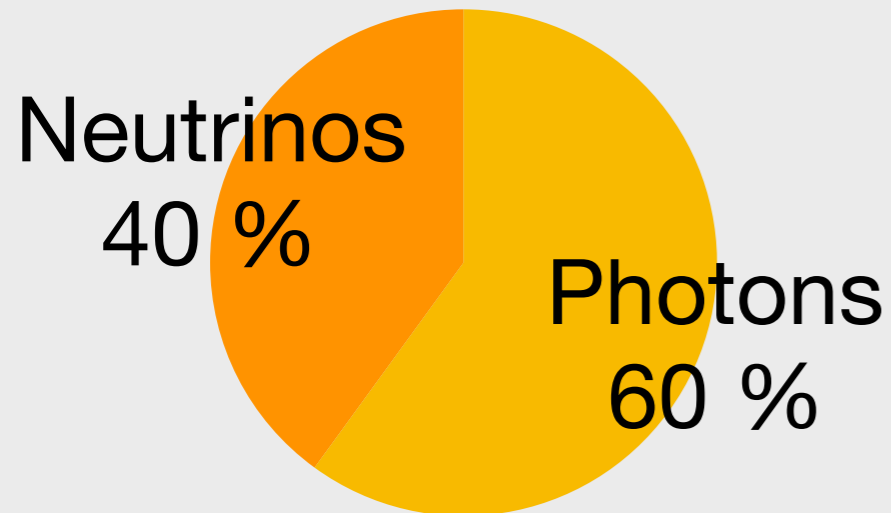
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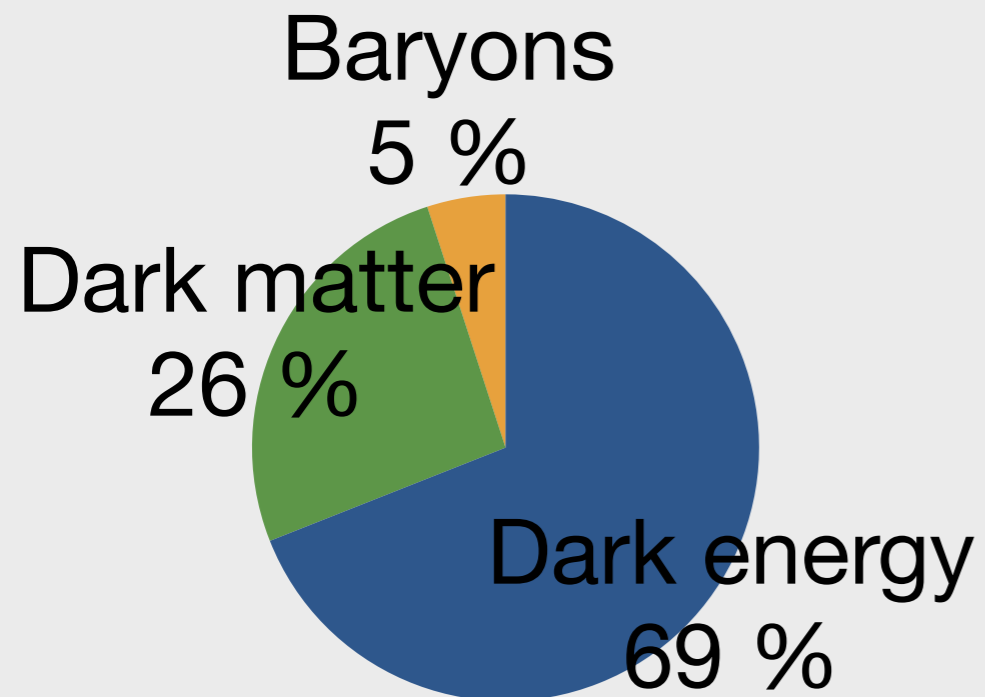
"la Caixa" Foundation

Motivation

We expect:

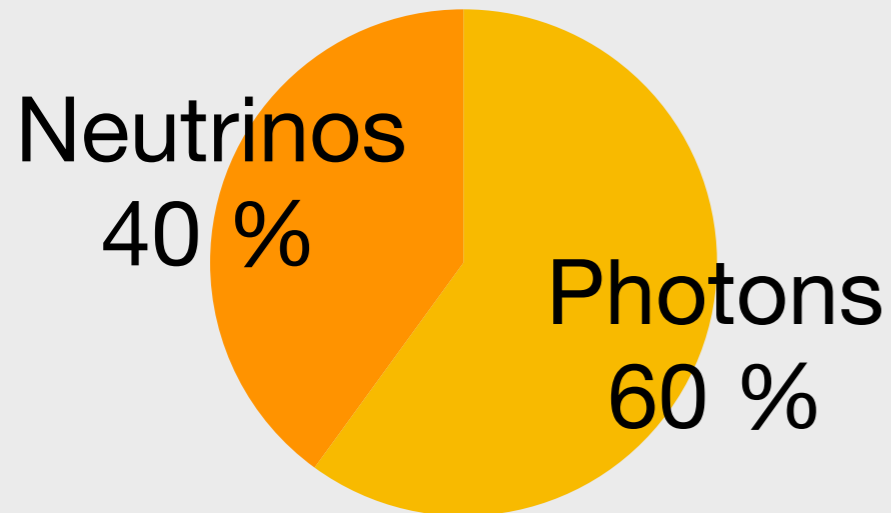


We see:

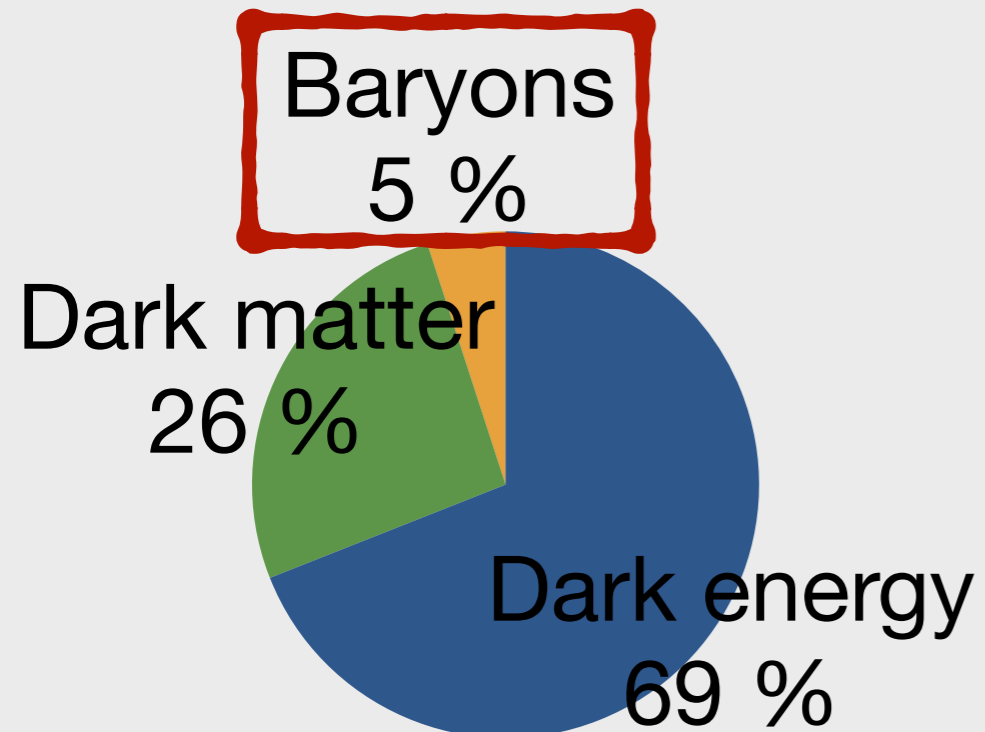


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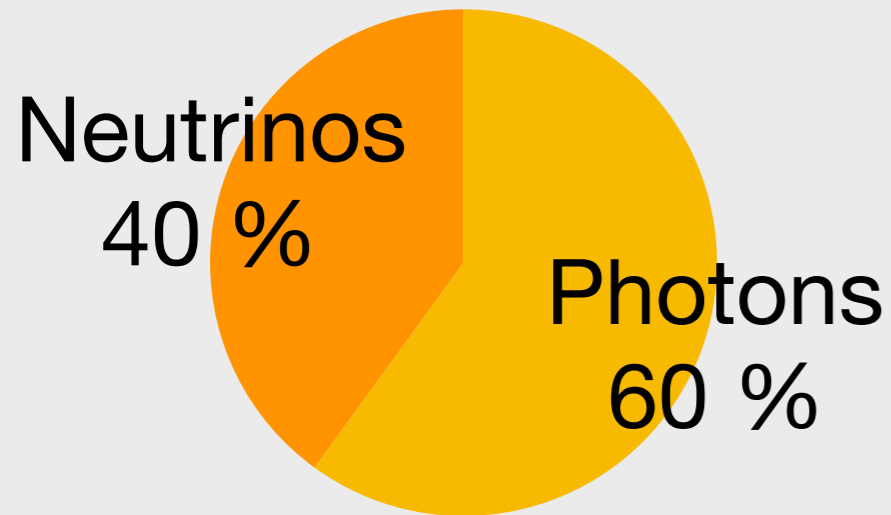


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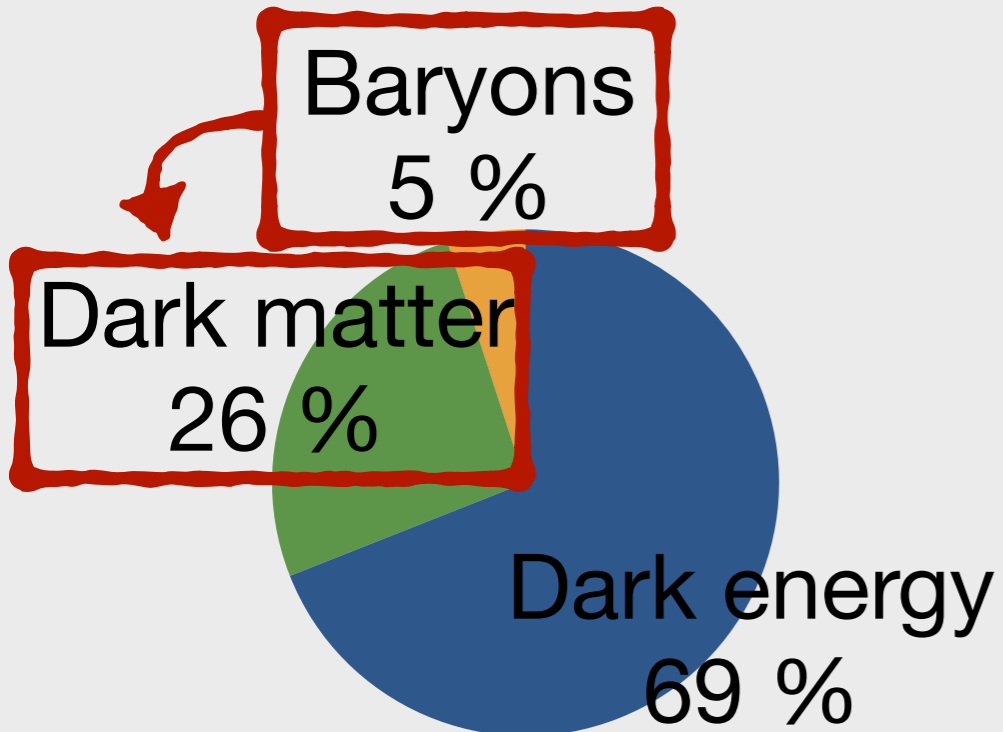


Motivation

We expect:



We see:



Motivation

Peter Paul Rubens, Jan Brueghel the Elder



- Baryon asymmetry of the visible Universe.

Motivation

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Motivation

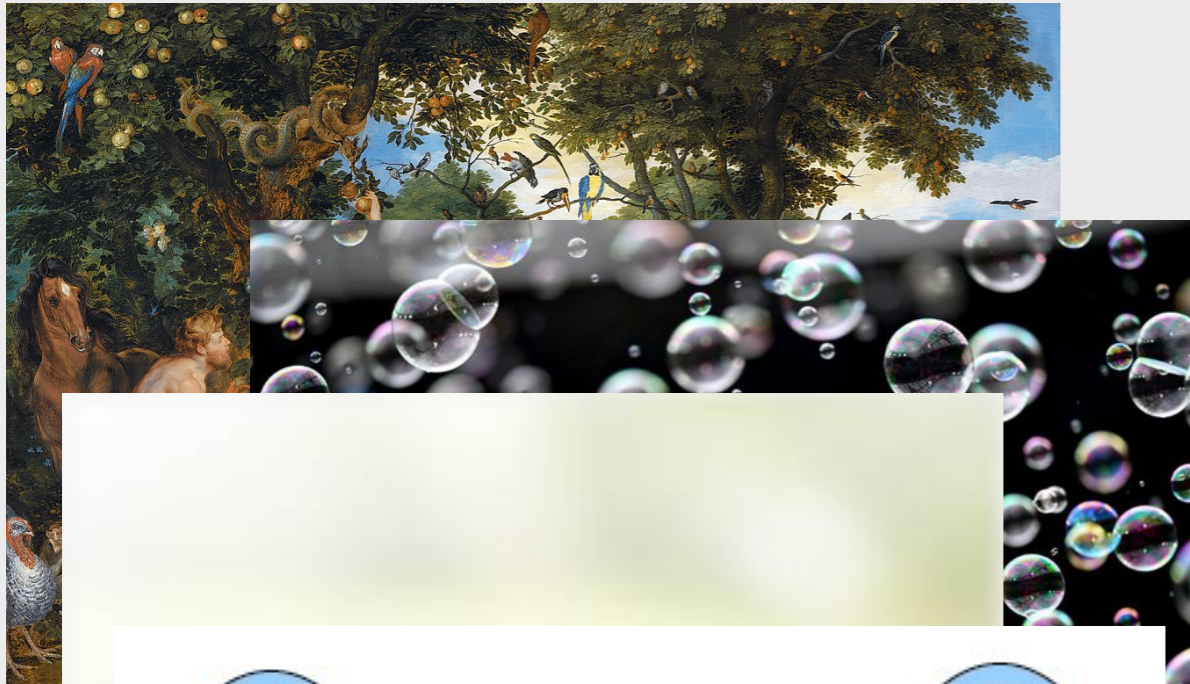
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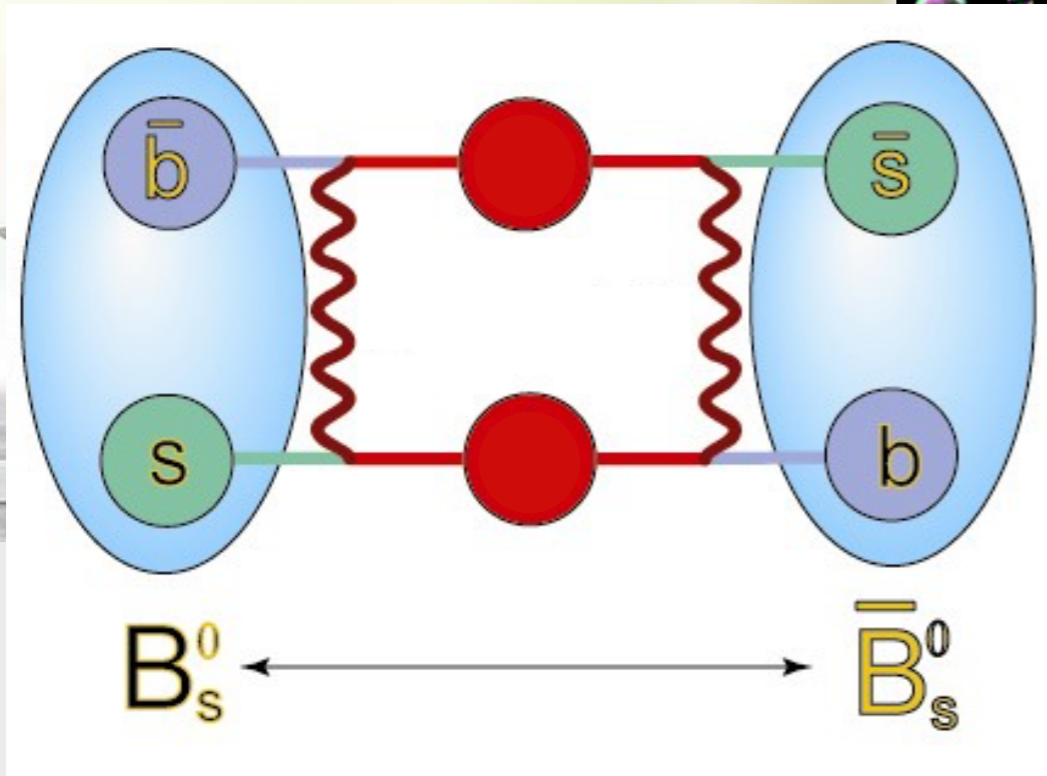
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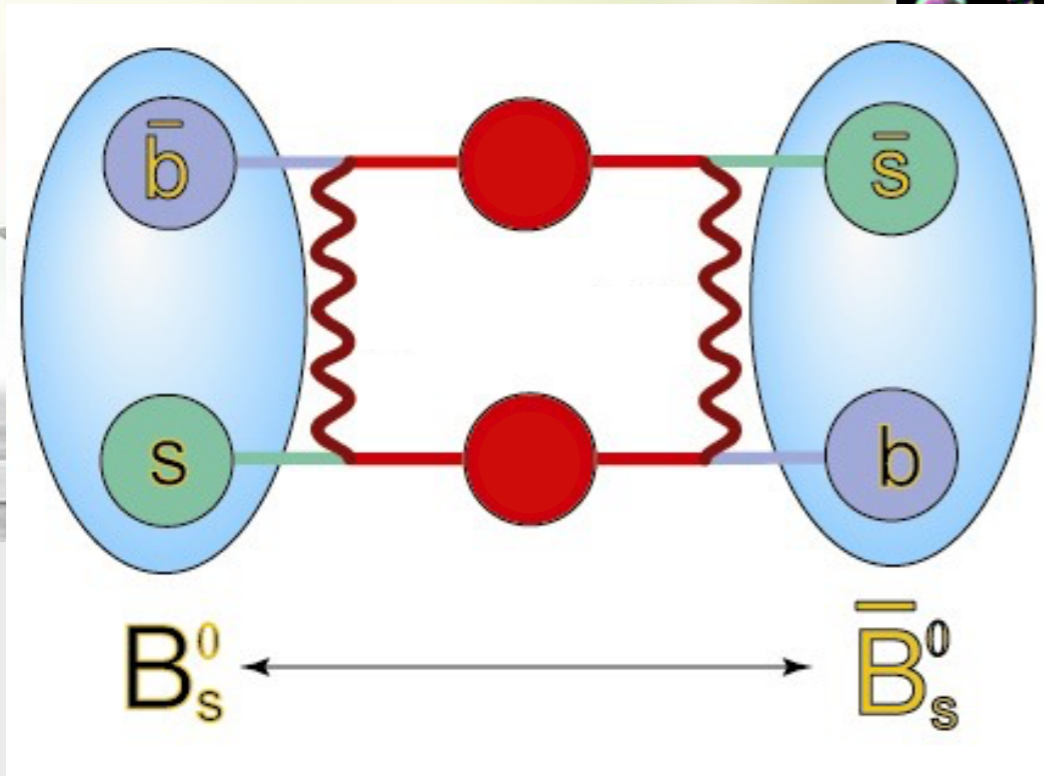
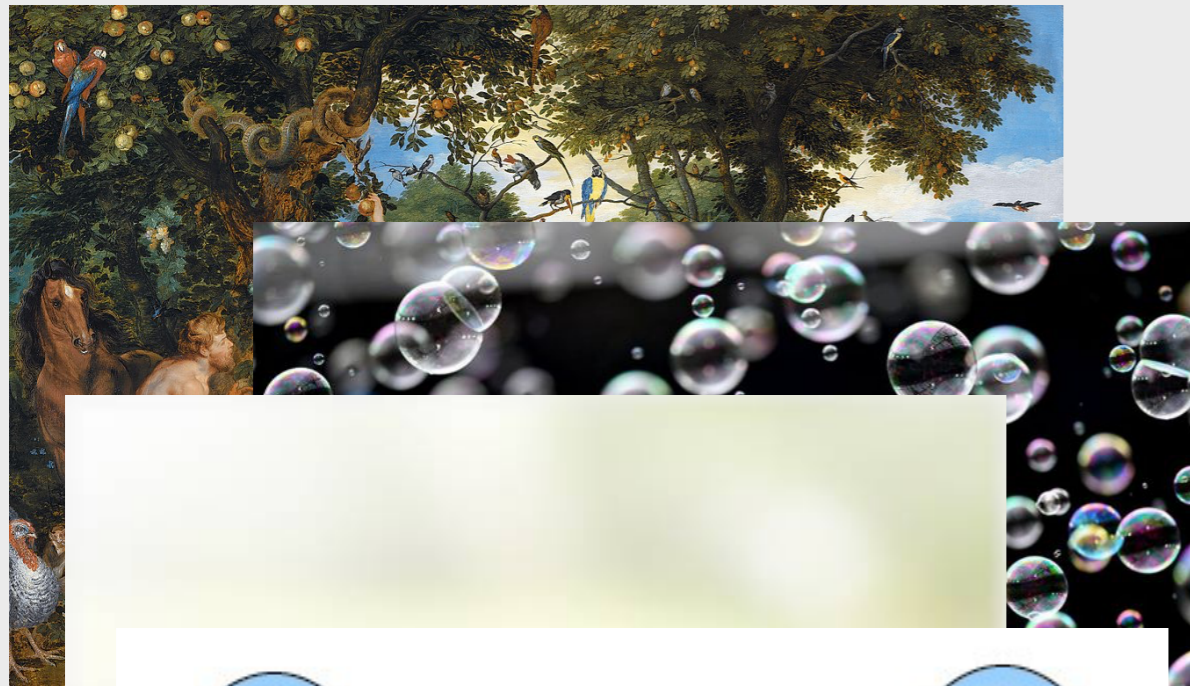


- Baryon asymmetry of the visible Universe.
- Baryogenesis from B meson oscillations:
Elor, Escudero & Nelson [1810.00880]



Motivation

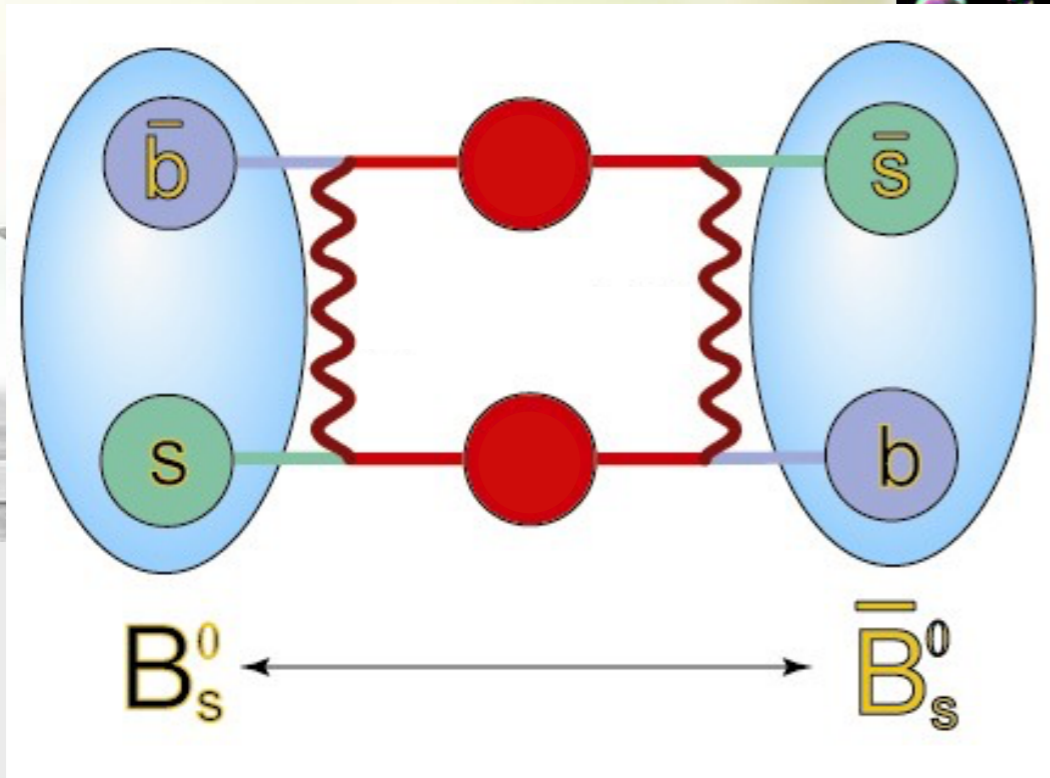
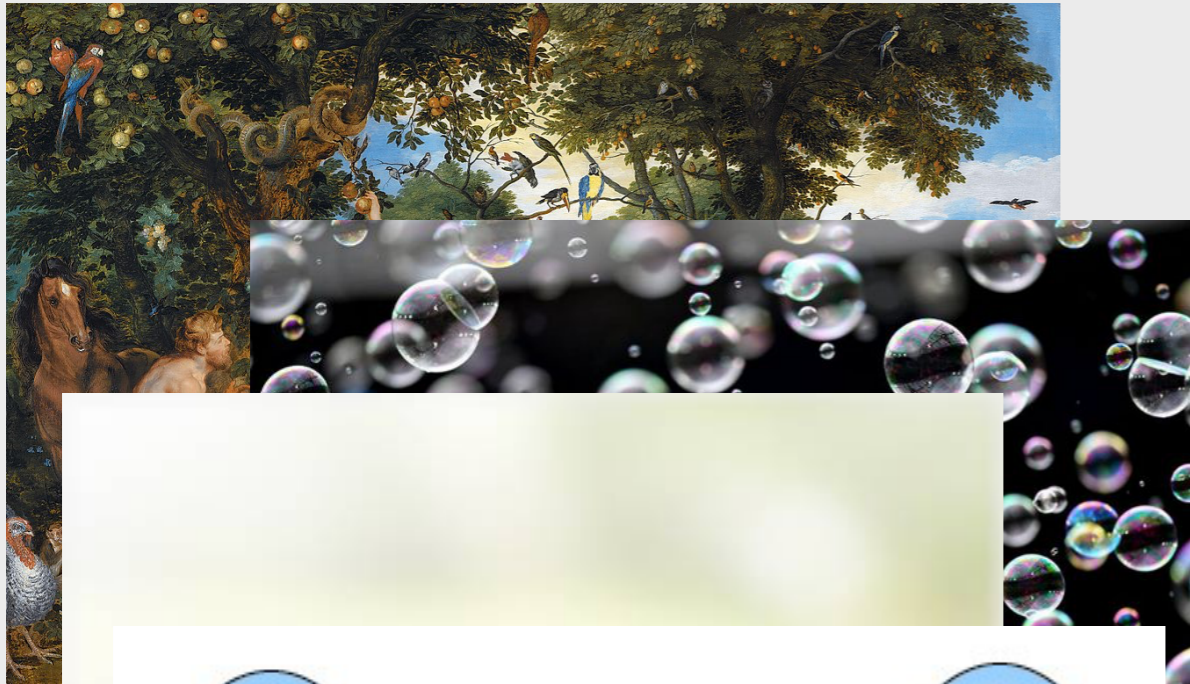
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- Baryon asymmetry of the visible Universe.
- Baryogenesis from B meson oscillations:
Elor, Escudero & Nelson [1810.00880]
- Self-contained model (SUSY)
 - Full flavor structure
 - DM = RH sneutrinoAlonso-Álvarez, Elor, Nelson & Xiao [1907.10612]

Motivation

Peter Paul Rubens, Jan Brueghel the Elder



- Baryon asymmetry of the visible Universe.
- Baryogenesis from B meson oscillations:
Elor, Escudero & Nelson [1810.00880]
- Self-contained model (SUSY)
 - Full flavor structure
 - DM = RH sneutrinoAlonso-Álvarez, Elor, Nelson & Xiao [1907.10612]
- **Very testable scenario.**

Main ideas

1. **Baryogenesis** and **dark matter** are linked.
2. The baryon asymmetry is related to **B-meson observables**.
3. **SUSY** theory contains all the ingredients.
4. **Fully testable** model: flavor, collider & astrophysical observables.

If you want to know more...

1. Go to Miguel Escudero's talk this afternoon

2. Talk to me!

Baryogenesis and Dark Matter from B Mesons

In this talk, based on arXiv:1810.00880, I will present a new mechanism of Baryogenesis and dark matter production in which both the dark matter relic abundance and the baryon asymmetry arise from neutral B meson oscillations and subsequent decays.

🕒 15:40 - 16:00
📍 Grey Room 2 (IFT)

Presenter: Miguel Escudero

Matter from B Mesons	neutrino searches at reactors	Inflat dark
Arnab Dasgupta	Light sterile neutrino searches at accelerators	DAM
Djuna Croon	Collider Searches for Heavy Neutrinos: Lessons ...	Blue

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

Gonzalo Alonso-Álvarez, Gilly Elor, Ann Nelson & Huangyu Xiao, arXiv:1907.10612

Can CP violation in neutral meson oscillations explain the matter-antimatter asymmetry of the Universe?

Baryogenesis from neutral B meson oscillations

Producing B mesons and baryon asymmetry cosmologically. Adapted from arxiv:1810.00880.

Baryogenesis
 $Y_B = 8.7 \times 10^{-11}$
&
Dark Matter
 $\Omega_{DM} h^2 = 0.12$

New particles

Particle	Mass	Description	SUSY
Φ	11-100 GeV	Late-decaying scalar	Modulus, inflaton...
\tilde{q}	1 - 4 TeV	Color-triplet scalar	Squark
$\tilde{\psi}$	1.2 - 4.2 GeV	Mediator	Dirac bino
$\tilde{\nu}_R$	0.3 - 2.7 GeV	Dark sector fermion	RH neutrino
$\tilde{\nu}_R$	1.2 - 2.7 GeV	DM scalar baryon	RH sneutrino

Constraints and testability

Particle physics

- Semileptonic asymmetries
- Flavor violation
- Exotic B decays
- Long lived particles
- Bino / RH neutrino
- Faser, MATHUSLA, SHIP, ...
- Supergravity & RPV

Astrophysics

- Neutrino masses
- $y_N \sin \beta \sim 10^{-8}$
- DM decay
- $\tilde{\nu}_R \rightarrow \nu + \bar{u} + \bar{d} + \bar{d}$
- Neutron stars
- Production
- $m_{\tilde{\nu}_R} \gtrsim 1.2 \text{ GeV}$
- Capture

Semileptonic asymmetries

Measure the amount of CPV in B meson oscillations
SM values are small to generate the baryon asymmetry

SM: $A_{FB}^{SM} = (2.22 \pm 0.27) \times 10^{-5}$
 $A_{FB}^{SM} = (-4.7 \pm 0.6) \times 10^{-4}$

Exp: $A_{FB}^{exp} = (-0.6 \pm 2.8) \times 10^{-3}$
 $A_{FB}^{exp} = (-2.1 \pm 1.7) \times 10^{-3}$

There is much room for new physics!

Test: invisible B meson decays

The bino mediates the apparently B-violating decay:
 $\text{Br}(B \rightarrow \text{DM} + \text{Baryon} + X) \gtrsim \text{few} \times 10^{-4}$

Good prospects, **B factories & LHCb:** $\text{Br}(B) \lesssim 10^{-5}$

But this inclusive mode has not been targeted
Search: B meson decay to a baryon + ME

RH sneutrino asymmetric DM

The Dirac bino decays $\psi \rightarrow \tilde{\nu}_R + \nu_R$

Asymmetric sneutrino DM generated at baryogenesis

Symmetric component is usually overproduced, but efficiently annihilates into neutrinos

Test: long-lived particles

Production channels of the bino \rightarrow RHN at the LHC:

$\tilde{\nu}_R$: Stable (DM)
 ν_R : Long lived

- If $m_{\nu_R} \lesssim m_{\tilde{\nu}_R}$, usual charged/neutral current decays
- If $m_{\nu_R} > m_{\tilde{\nu}_R}$, new LLD decay: $\nu_R \rightarrow \tilde{\nu}_R \bar{u} \bar{d} \bar{s}$

Search: Prompt b jet + MET / LLD of RH neutrino

U(1)_R SUSY with Dirac gauginos can accommodate baryogenesis & sterile sneutrino asymmetric DM production

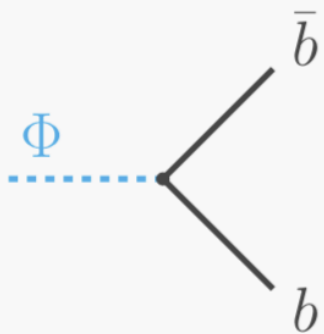
Gonzalo Alonso-Álvarez

BLV 2019, Madrid

Baryogenesis mechanism

Sakharov I

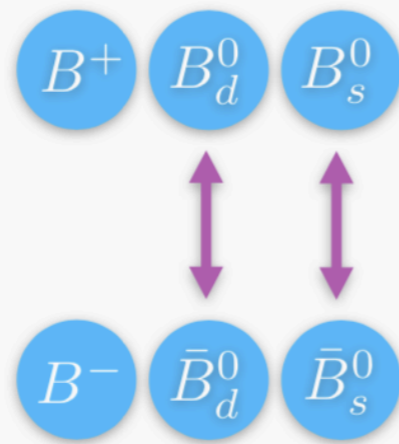
Out of equilibrium
late time decay



$$T_{RH} \sim 20 \text{ MeV}$$

Sakharov II

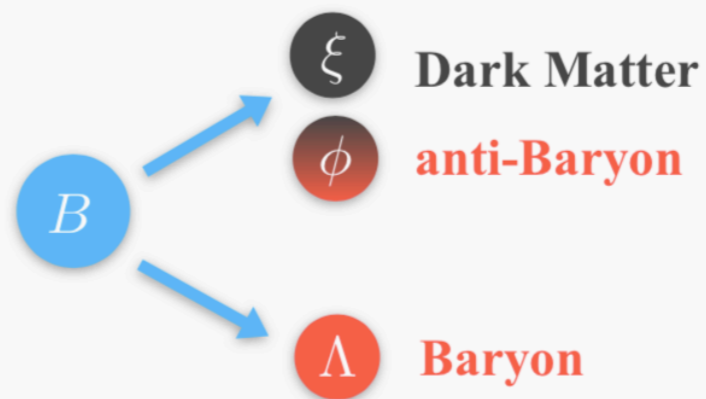
CP violating oscillations



$$A_{\ell\ell}^d \quad A_{\ell\ell}^s$$

Sakharov III

B-mesons decay into
Dark Matter and hadrons



$$\text{BR}(B \rightarrow \phi\xi + \text{Baryon} + \dots)$$

Baryogenesis

$$Y_B = 8.7 \times 10^{-11}$$

&

Dark Matter

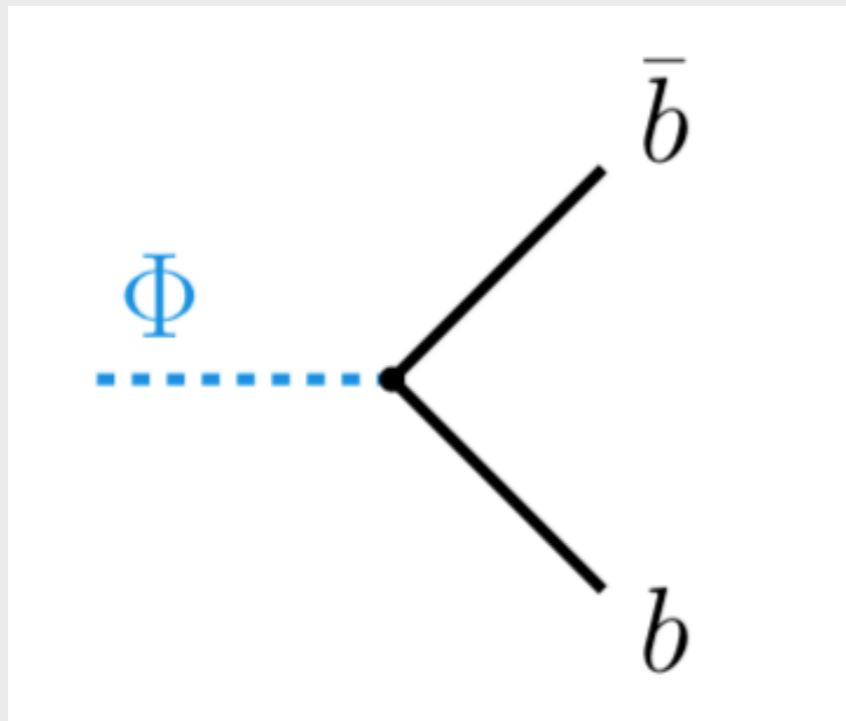
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New particles & SUSY model

Particle	Mass	Description	SUSY

New particles & SUSY model

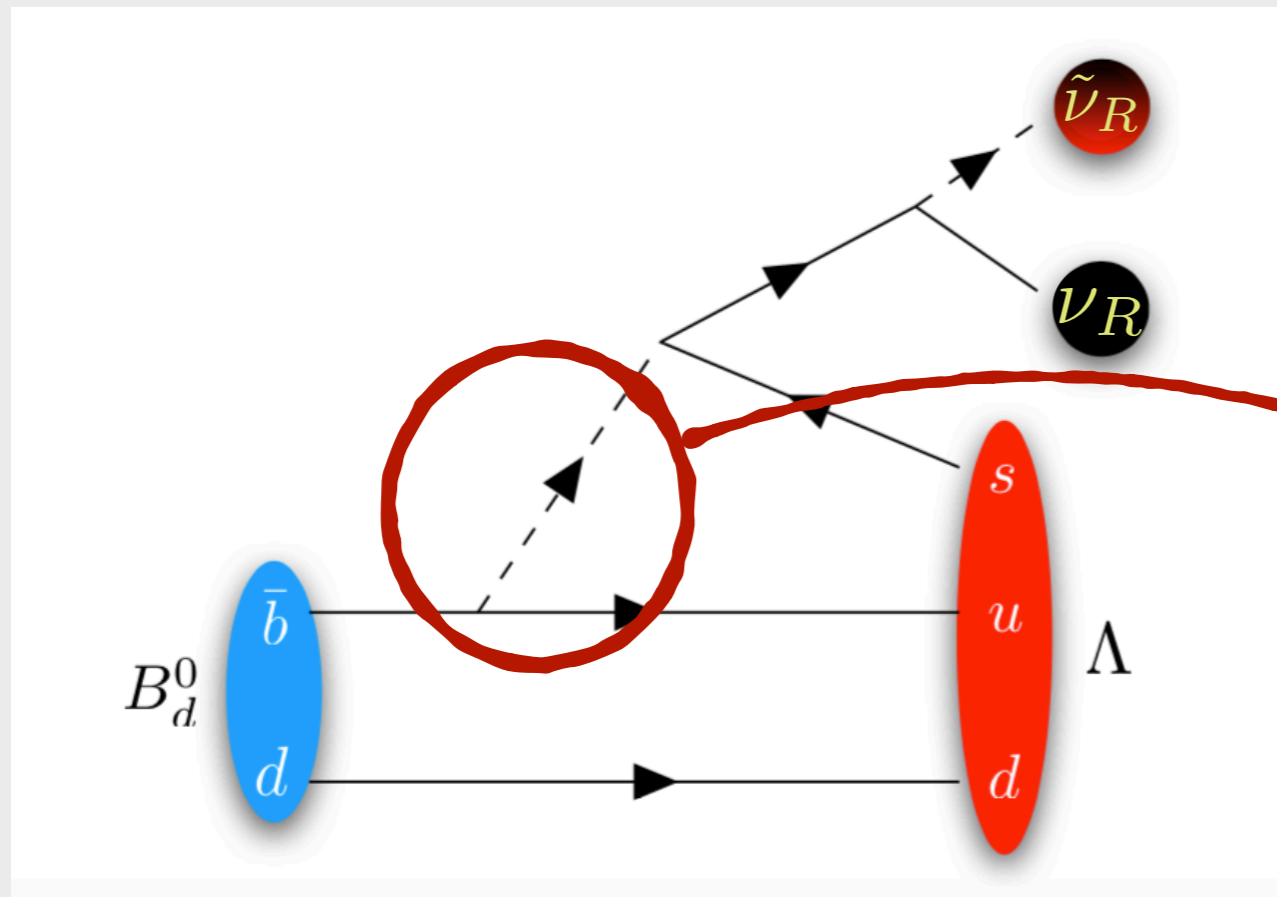
Particle	Mass	Description	SUSY
$\bar{\Phi}$	11-100 GeV	Late-time decaying scalar	Modulus, inflaton, ...



A scalar with mass
 $m_{\Phi} \in 11 - 100 \text{ GeV}$
generically decays into b quarks.

New particles & SUSY model

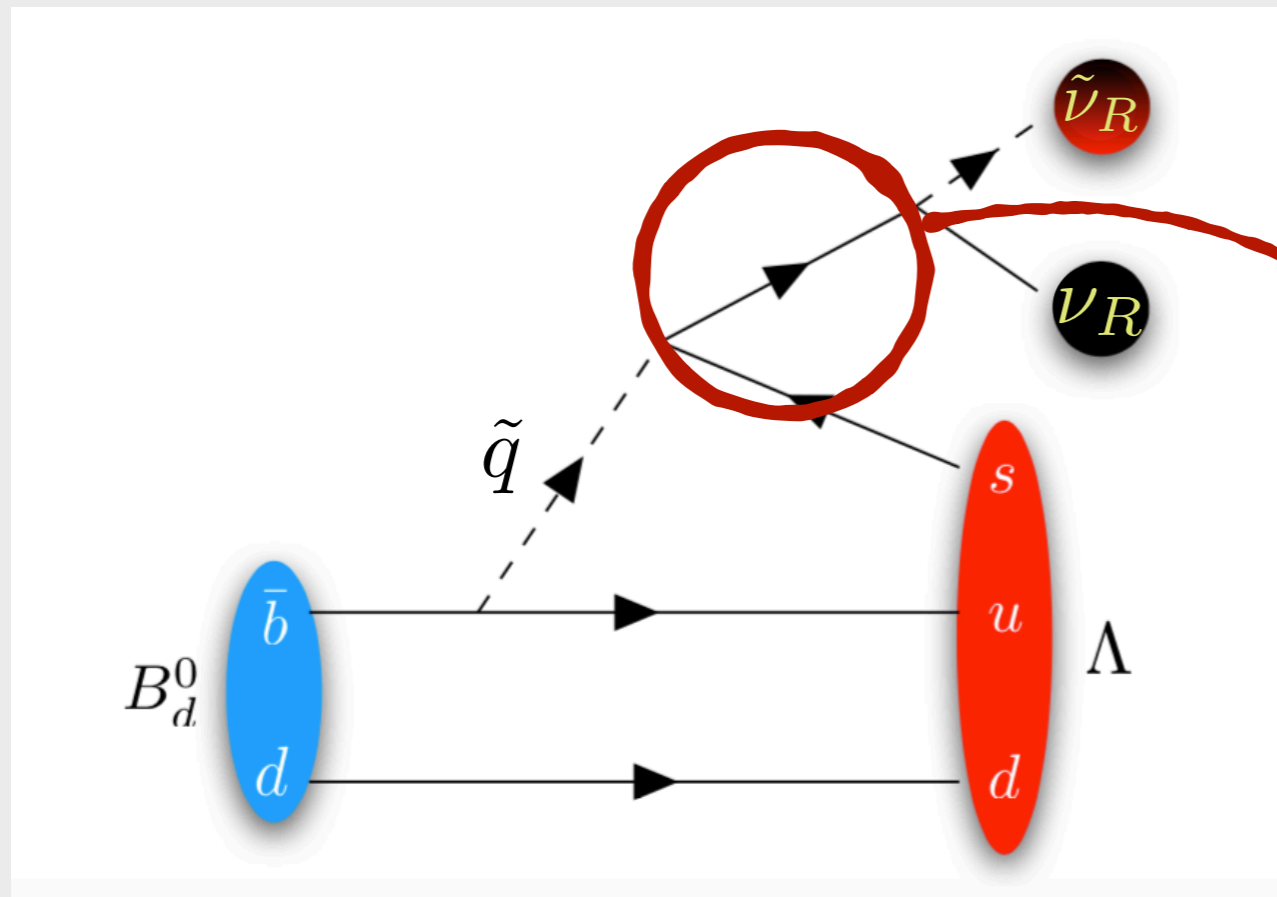
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Color-triplet scalar coupling to quarks

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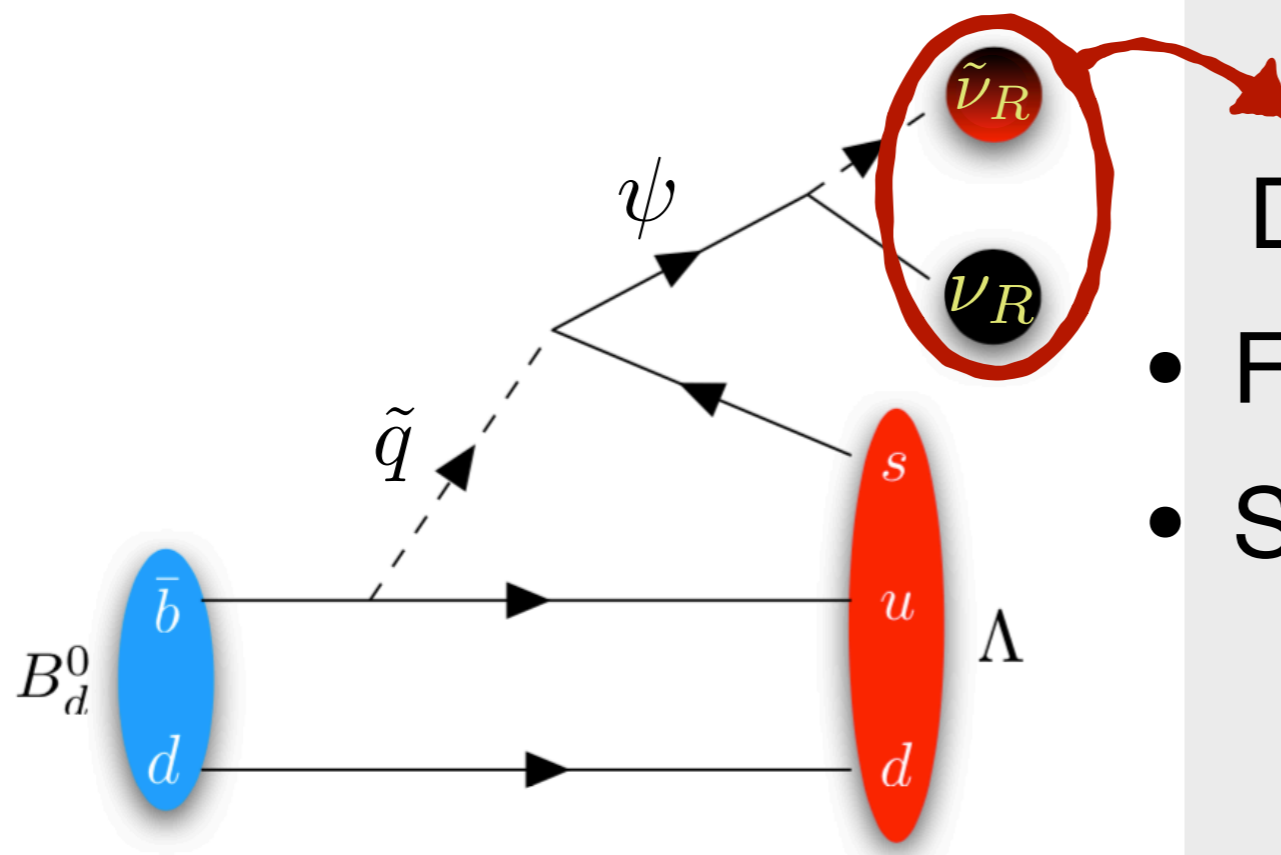
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Dirac fermion connecting the visible and dark sectors

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- Dark sector singlet states:
- Fermion: RH neutrino
 - Scalar baryon: RH sneutrino

Good DM candidate!

A very testable scenario

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- Flavor violation
- Exotic B decays

$$\text{Br}(B \rightarrow \mathcal{B} + X) \gtrsim \text{few} \cdot 10^{-4}$$

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$$\tilde{\nu}_R \longrightarrow \nu_R + \bar{u} + \bar{d} + \bar{d}$$

- Neutron stars

- Production

$$m_{\tilde{\nu}_R} \gtrsim 1.2 \text{ GeV}$$

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- Neutrino masses

$$y_N \sin \beta \sim 10^{-8}$$

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This project has received funding/support from the European Union's Horizon 2020 research and innovation programme

$U(1)_R$ SUSY

The $U(1)_R$ symmetry is identified with **baryon number**

Superfield	$U(1)_R$ (B #)
U^c, D^c	$2/3$
Q	$4/3$
H_u, H_d	0
R_u, R_d	2
S, T, O	0
L	1
E^c, N_R^c	1

Majorana gaugino masses are forbidden.

\Rightarrow Dirac gauginos, can be light.

$$m_{\tilde{B}} \sim \text{GeV}$$