Gauged B-L interacting sterile neutrino dark matter revisited

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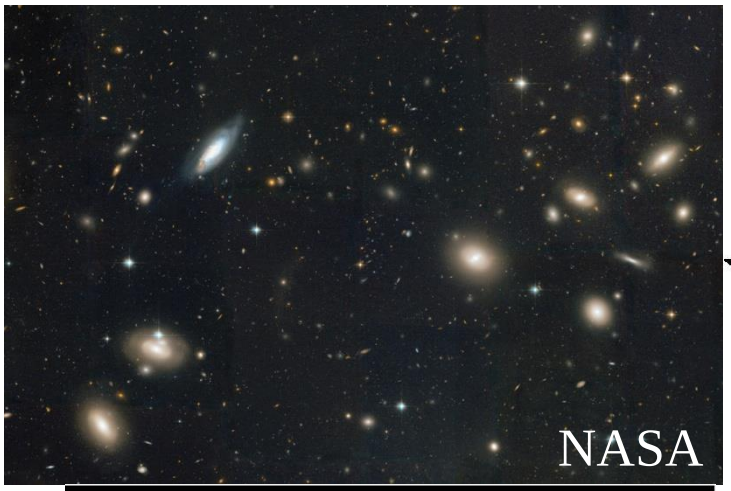
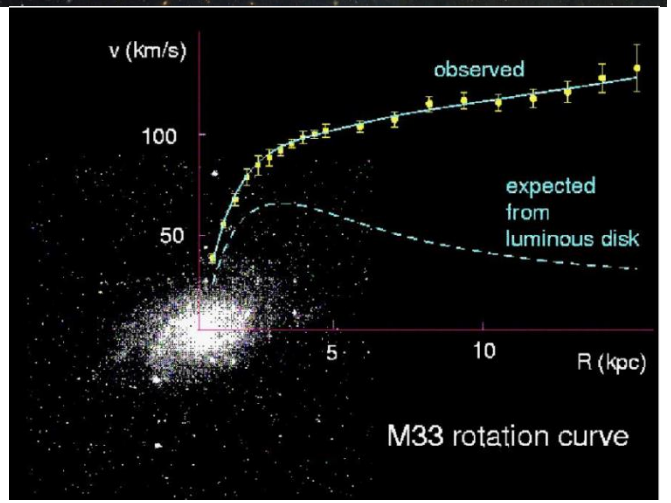
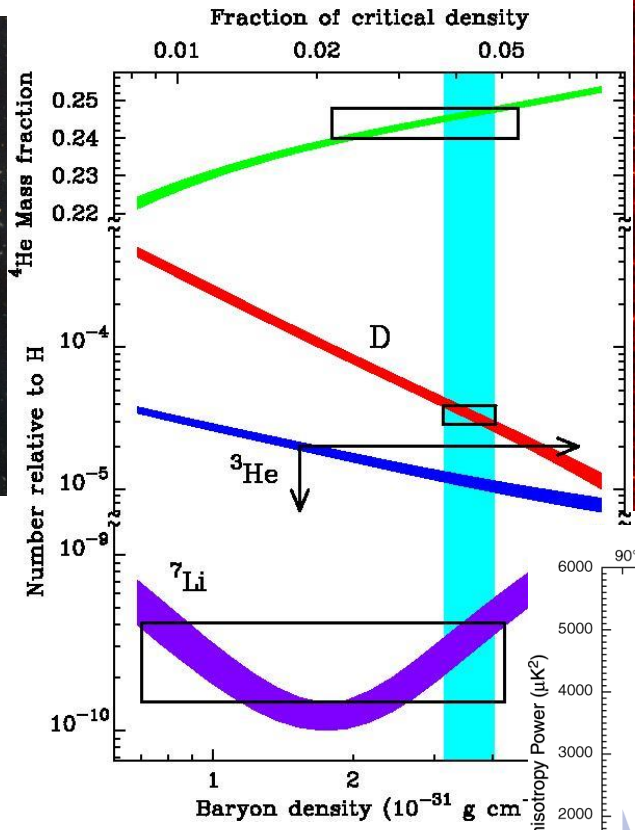
§ Introduction

Dark matter

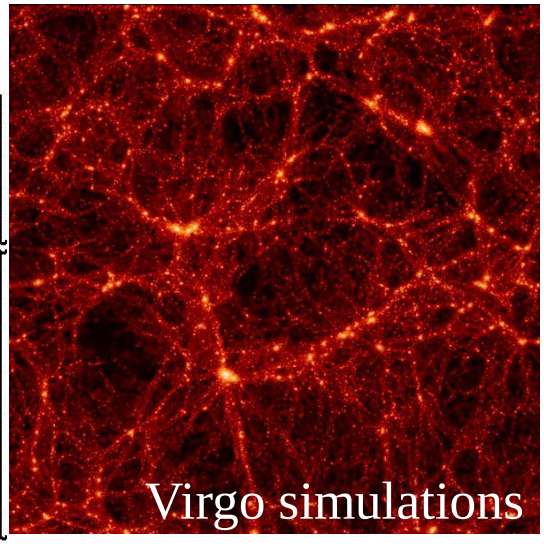
Convincing evidences

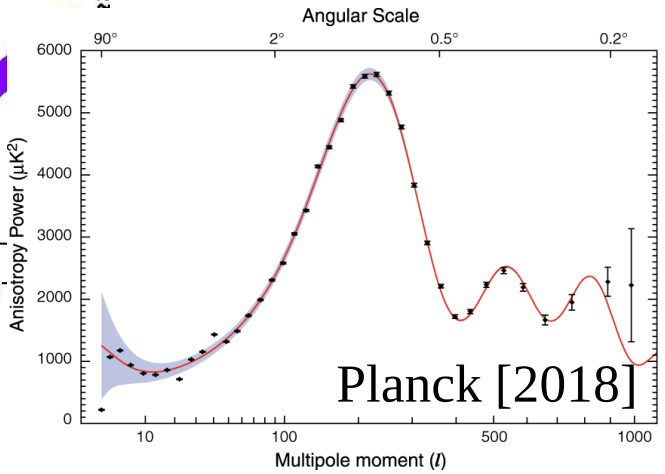






Burles et al [1999]





Dark matter candidates

Hypothetical candidates

Sterile neutrino

- $\nu_s \cong \theta\, \nu_L + \nu_R^C$

Almost RH

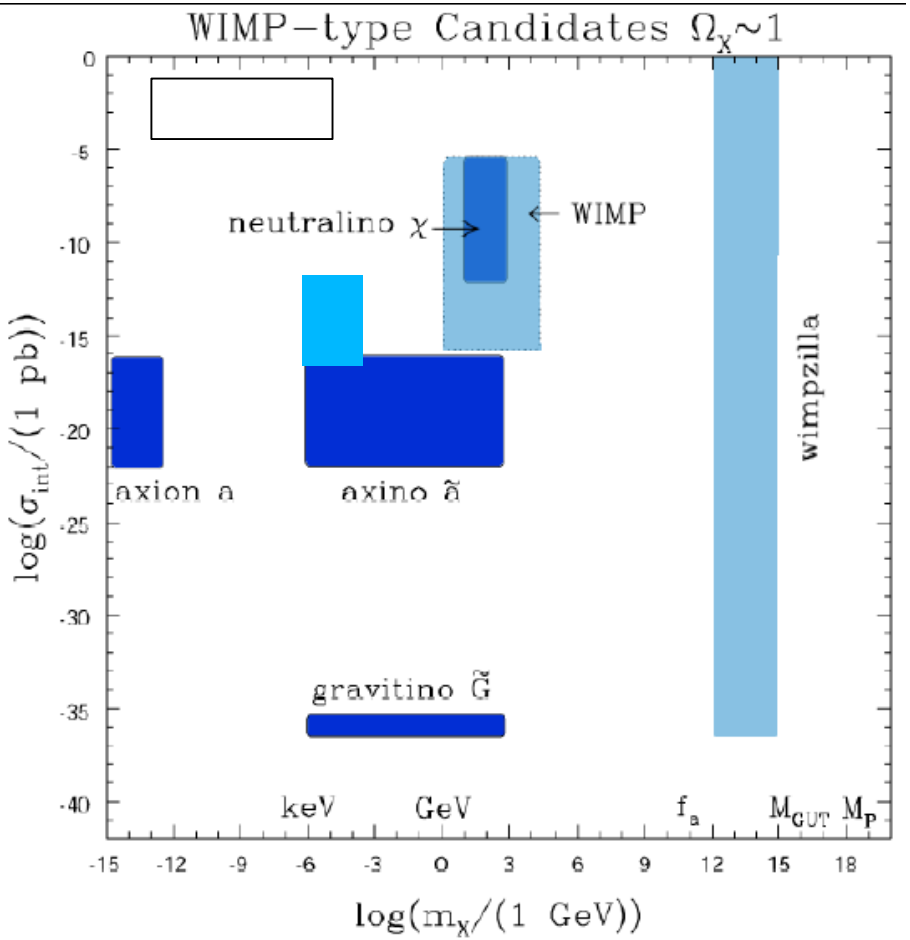
- $\theta = {}^{m_D}/_{M_M} \ll 1$

Tiny active-sterile mixing

Axion

WIMP

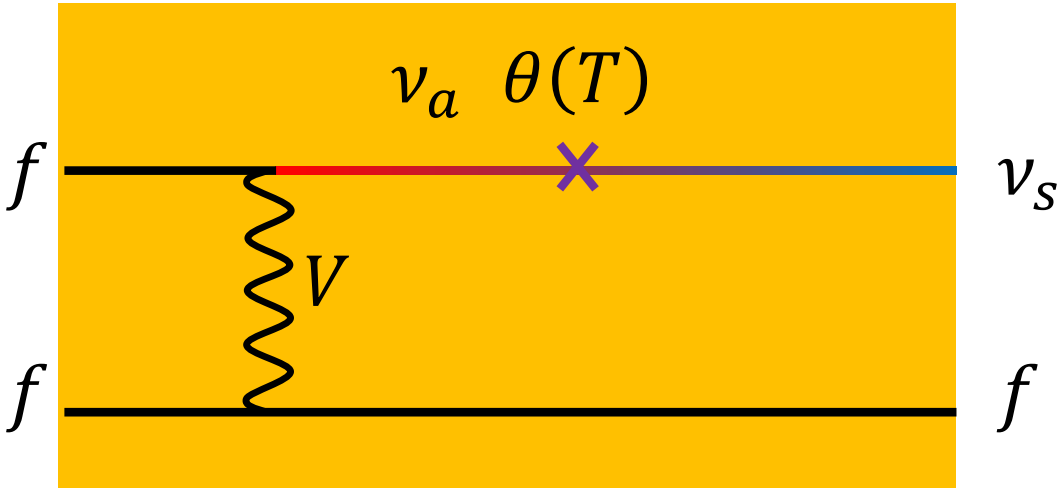
etc



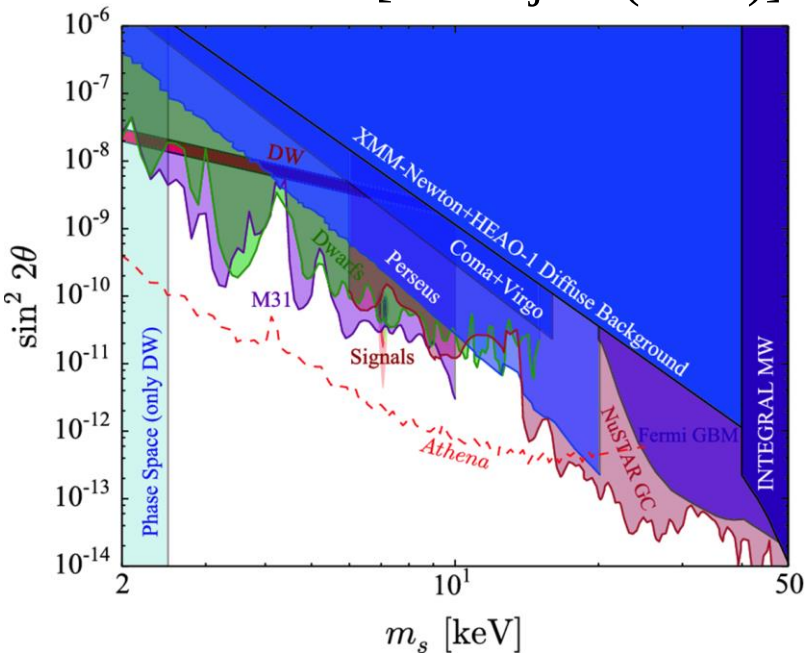
modified L. Roszkowski's diagram

Sterile neutrino is decaying DM

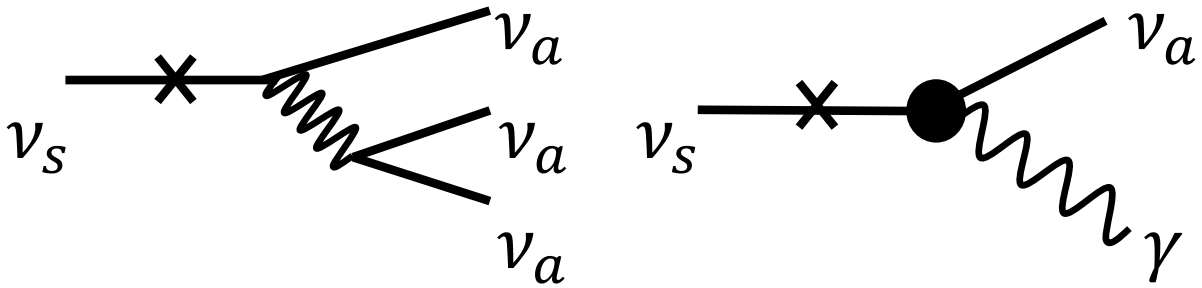
- Production: Dodelson-Widrow mechanism [Dodelson and Widrow (1994)]



[Abazajian (2019)]



- Decay [Pal and Wolfenstein (1982)]



Sterile neutrino is decaying DM

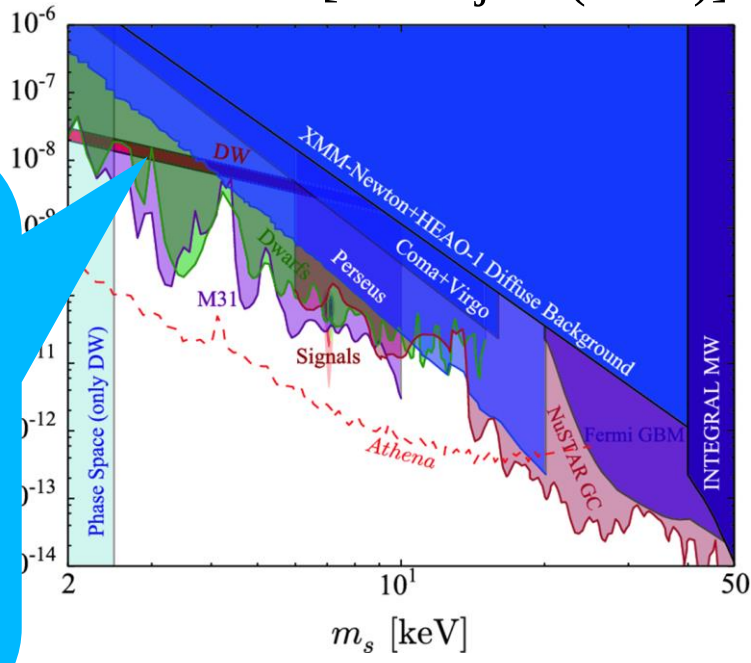
- Production: Dodelson-Widrow mechanism [Dodelson and Widrow (1994)]

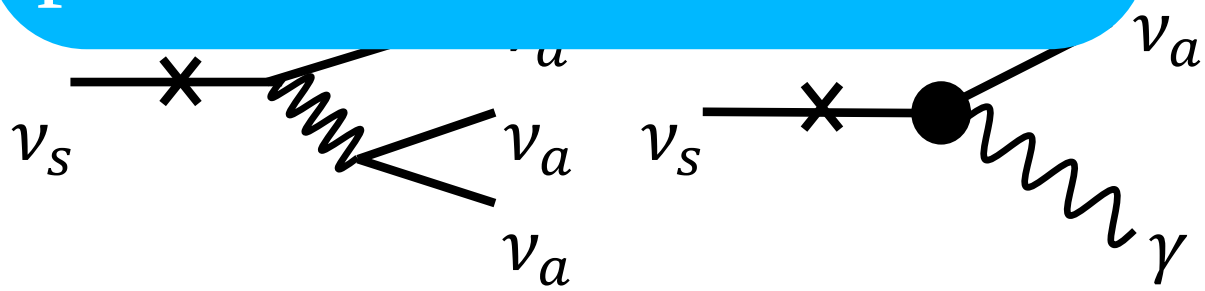
$\nu_a \;\; \theta(T)$

Not compatible

We need an alternative production mechanism

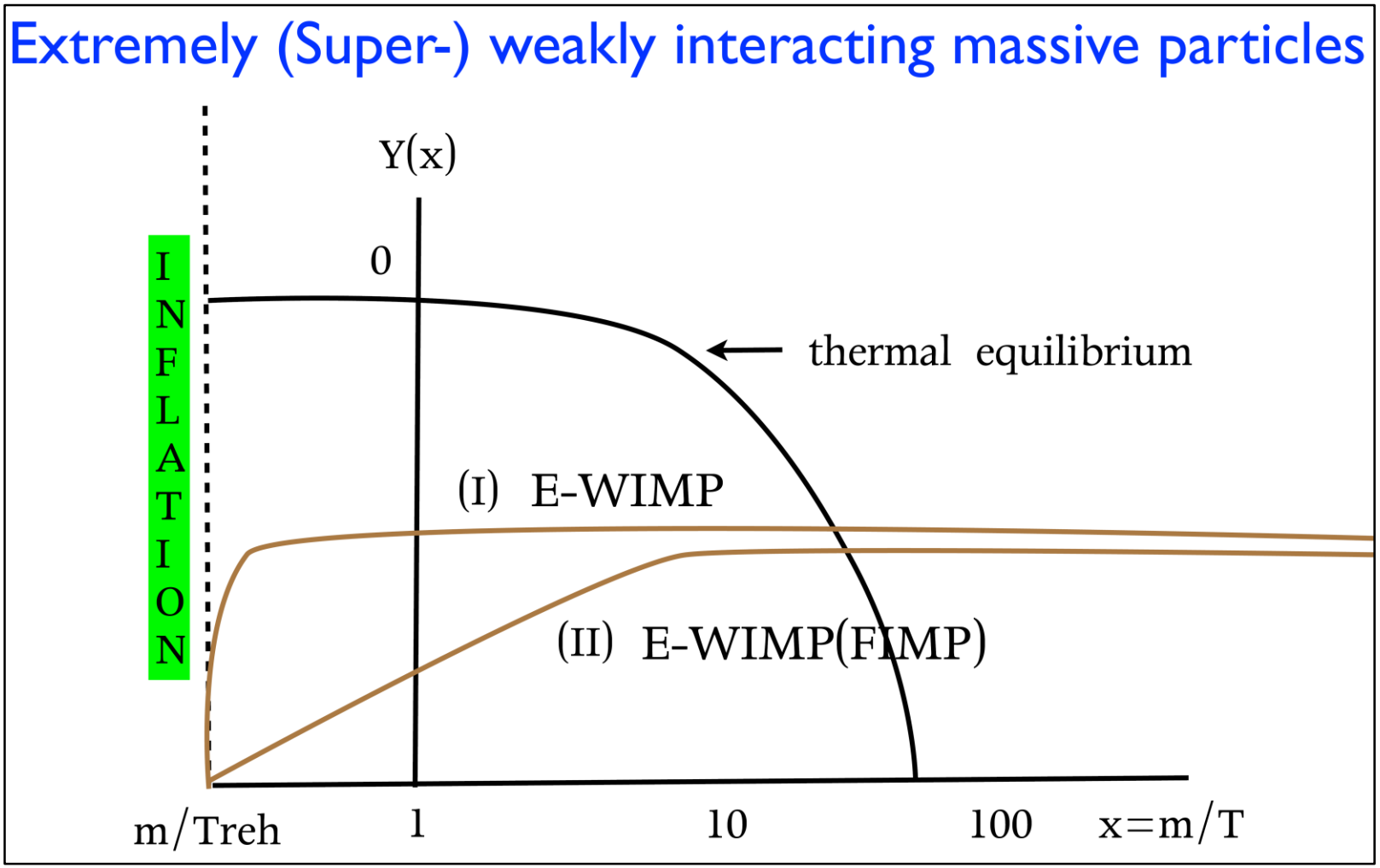
[Abazajian (2019)]





§ Freeze in Production

- A kind of non-thermal production



By courtesy of K.Y. Choi

§ Model

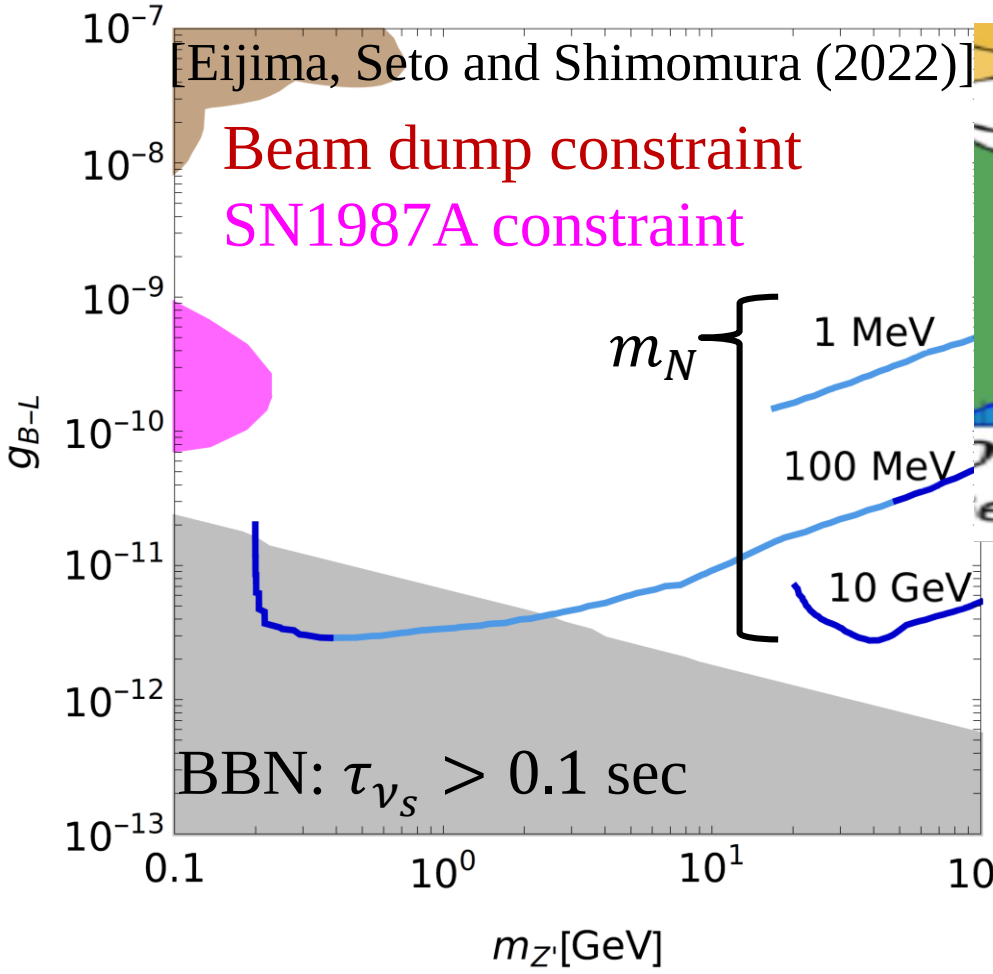
- Sterile neutrino DM in feeble gauged U(1) extended model
- Gauged U(1) extension
  - $U(1)_{B-L}$: +1 for baryon, -1 for lepton [Davidson (1979), Mohapatra and Marshak (1980), …]
  - Particle content

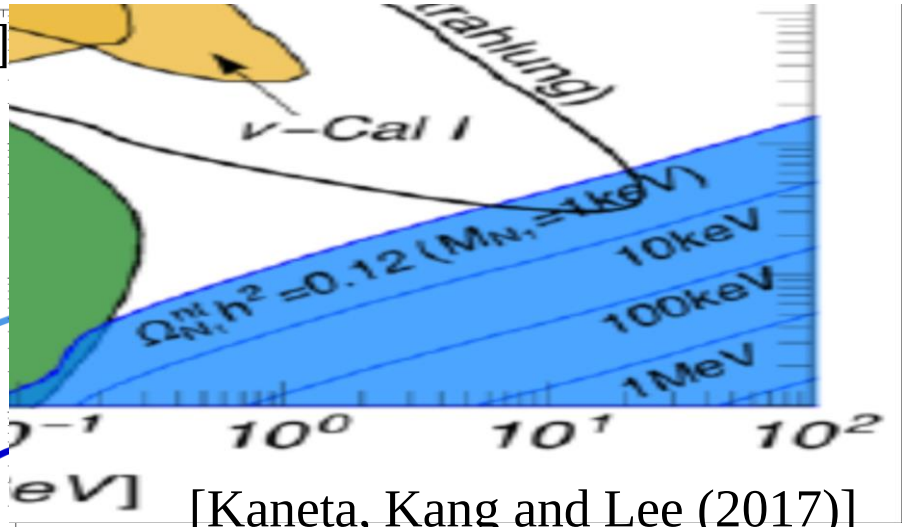
	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$U(1)_{B-L}$
Q^i	**3**	**2**	$\frac{1}{6}$	$\frac{1}{3}$
u_R^i	**3**	**1**	$\frac{2}{3}$	$\frac{1}{3}$
d_R^i	**3**	**1**	$-\frac{1}{3}$	$\frac{1}{3}$
L^i	**1**	**2**	$-\frac{1}{2}$	-1
e_R^i	**1**	**1**	-1	-1
ν_R^i	**1**	**1**	0	-1
Φ_H	**1**	**2**	$\frac{1}{2}$	0
Φ_{B-L}	**1**	**1**	0	2

  - Masses
    - $m_{Z'}^2 = 4g_{B-L}^2 v_{B-L}^2$
    - $m_{\nu_R^i} = \frac{y_{\nu_R^i}}{\sqrt{2}} v_{B-L}$
  - Singlet-like ϕ
  - SM-like h
    - The $h - \phi$ mixing α

§ § Heavy Z' : $2m_N < m_{Z'}$

- Production by decay: $Z' \to 2N$ (hereafter $N = \nu_s$)
- The free streaming length $\lambda_{\rm fs}$ bound





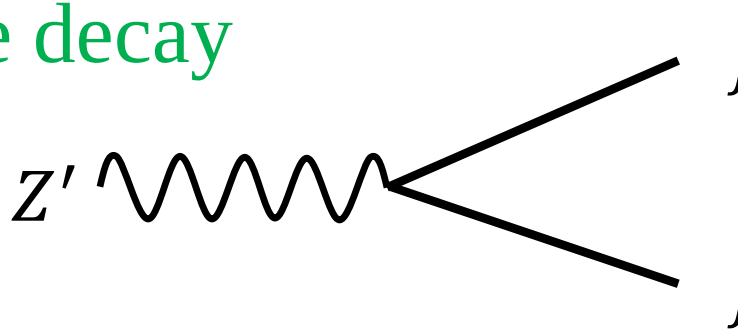
[Kaneta, Kang and Lee (2017)]

$0.01\text{Mpc} < \lambda_{\rm fs} < 0.1\ \text{Mpc}$

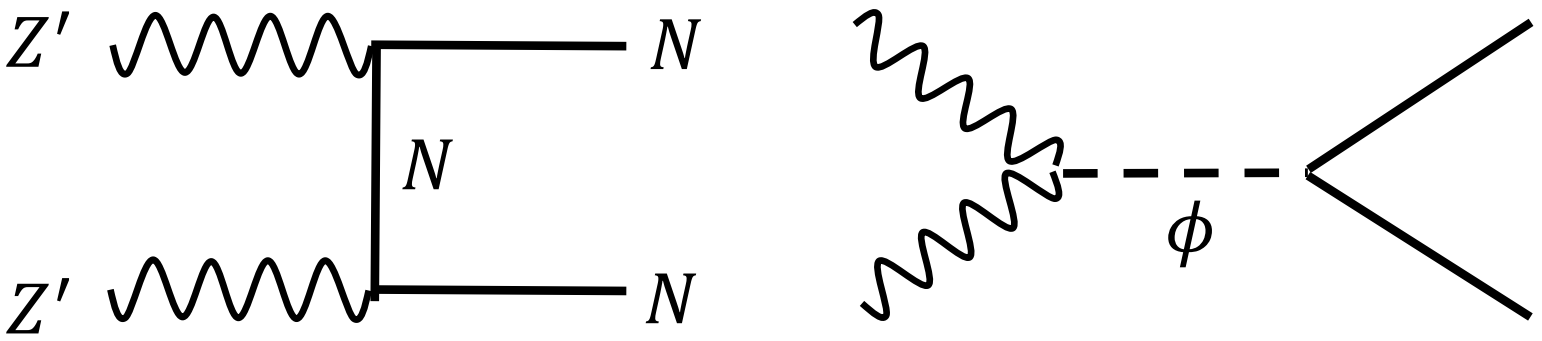
$\lambda_{\rm fs} < 0.01\ \text{Mpc}$

§§ Light Z' : $1\text{MeV} < m_{Z'} < 2m_N$

- Z' can be thermalized by the decay and the inverse decay



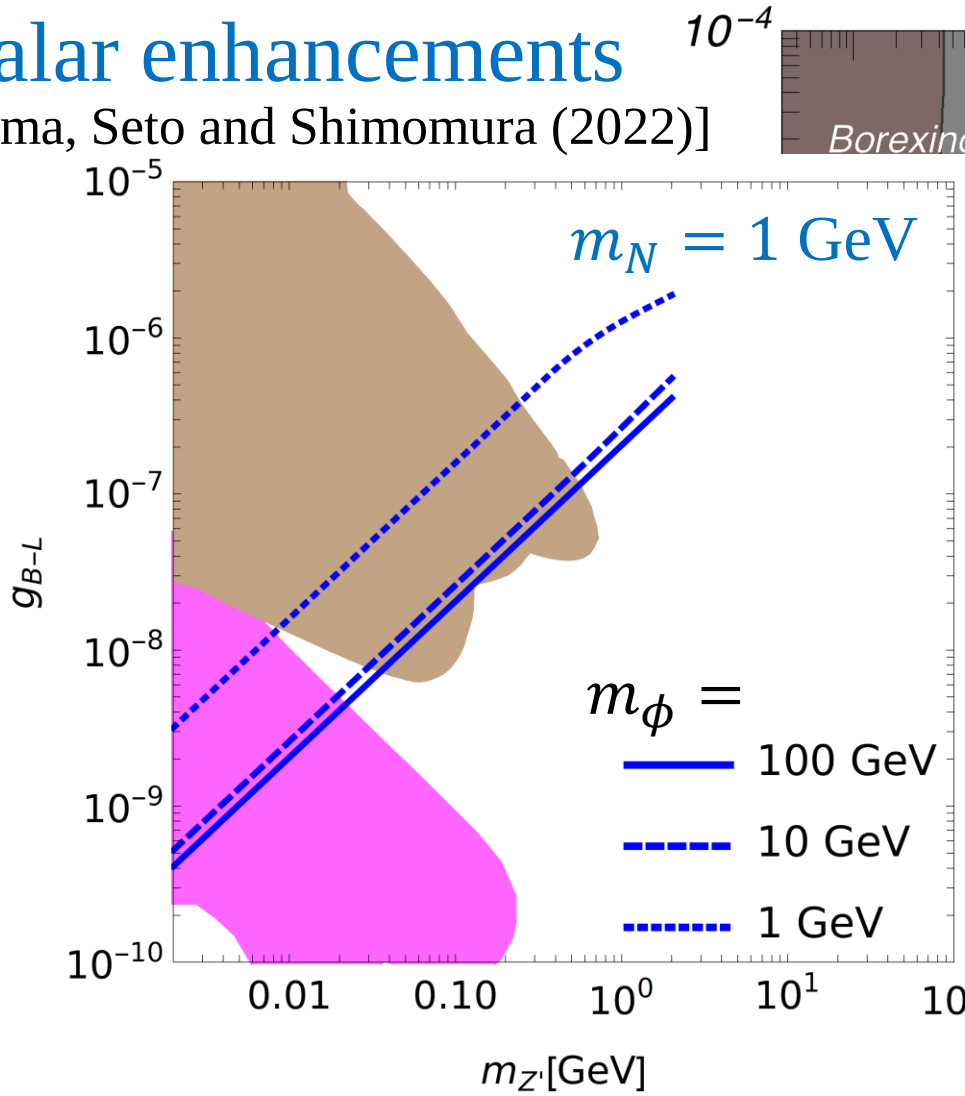
- The dominant production mode from Z'

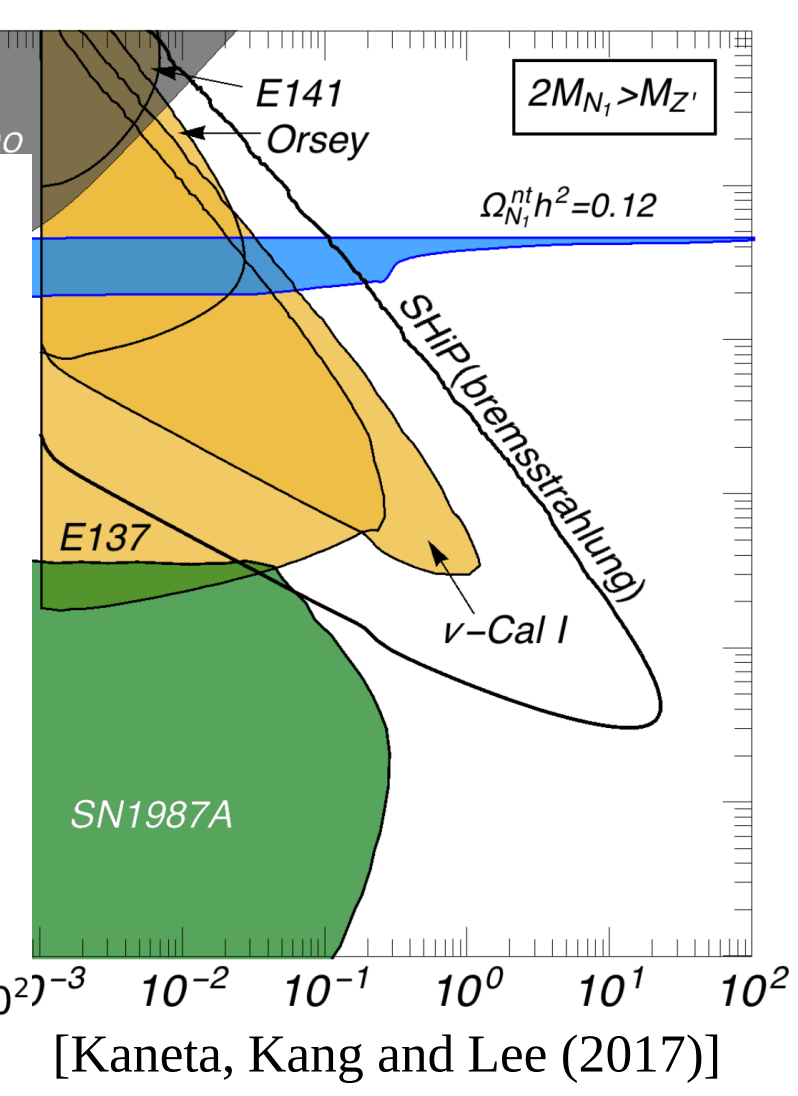


§§ Light Z' : $1\mathrm{MeV} < m_{Z'} < 2m_N$

longitudinal mode and scalar enhancements

[Eijima, Seto and Shimomura (2022)]



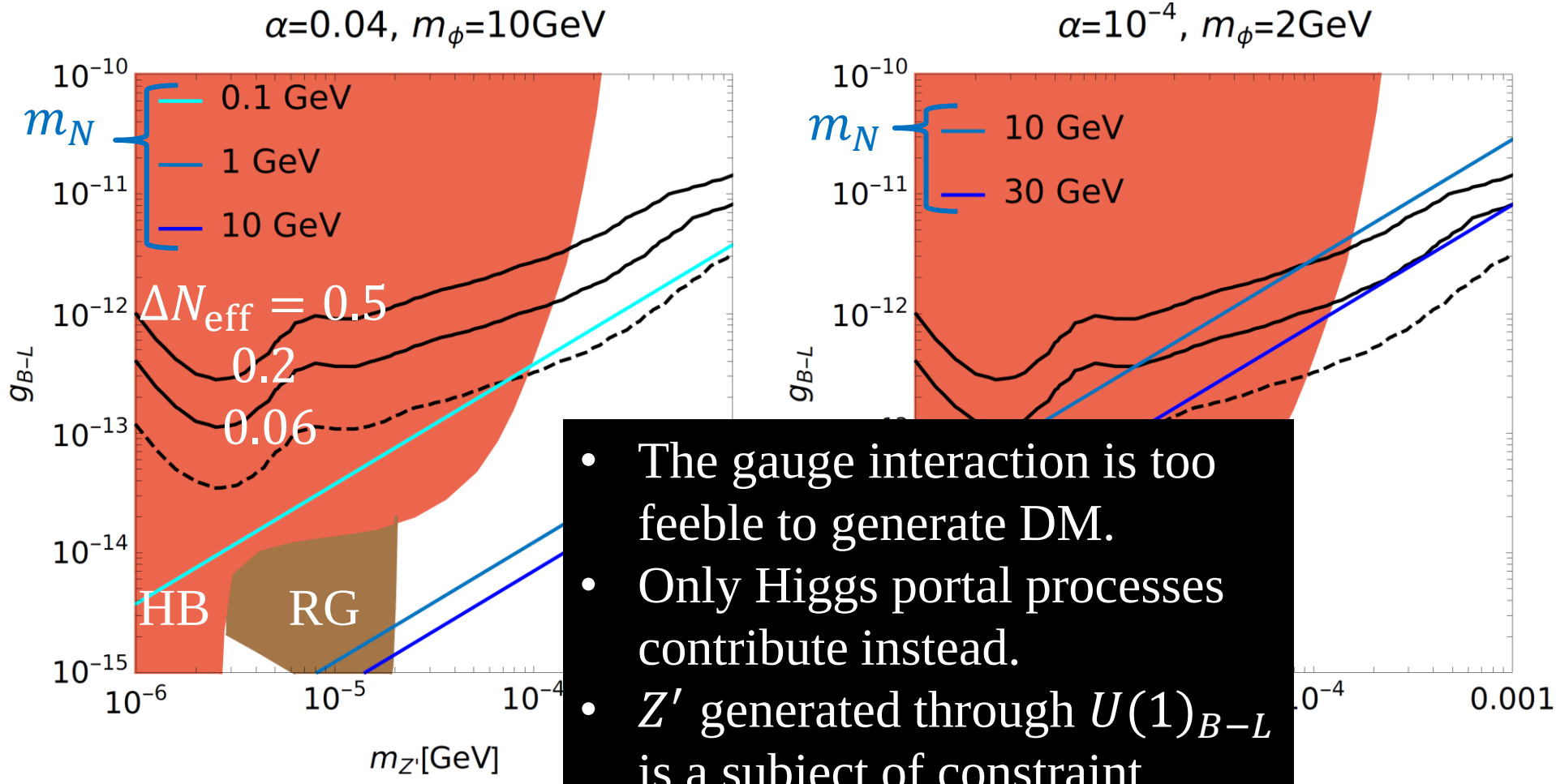


[Kaneta, Kang and Lee (2017)]

§§ Very light Z':

$m_{Z'} < 1\text{MeV} < 2m_N$

- Z' and the decay products become dark radiation



- The gauge interaction is too feeble to generate DM.
- Only Higgs portal processes contribute instead.
- Z' generated through $U(1)_{B-L}$ is a subject of constraint

§ Summary

- We reinvestigated sterile neutrino DM in gauged B-L model
- Production
  - Heavy Z': free streaming constraints
  - Light Z': longitudinal mode and scalar enhancements
  - Very light Z': only Higgs portal viable
- Mass
  - $\gtrsim$ 1 MeV
  - $\nu_s \to \nu_a l\bar{l}$, hadronic modes
    - ✓ c.f. X-ray from radiative decay for keV ν_s