Féeton Dark Matter and probing high-energy physics with low-energy neutrino astronomy

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Publications:

1. Lin et al. 2022, PRD, arXiv: 2205.08171
2. Lin and Yanagida 2022, PRDL, arXiv: 2202.04496
3. Cheng et al. 2023, arXiv: 2310.05420

What is féeton?

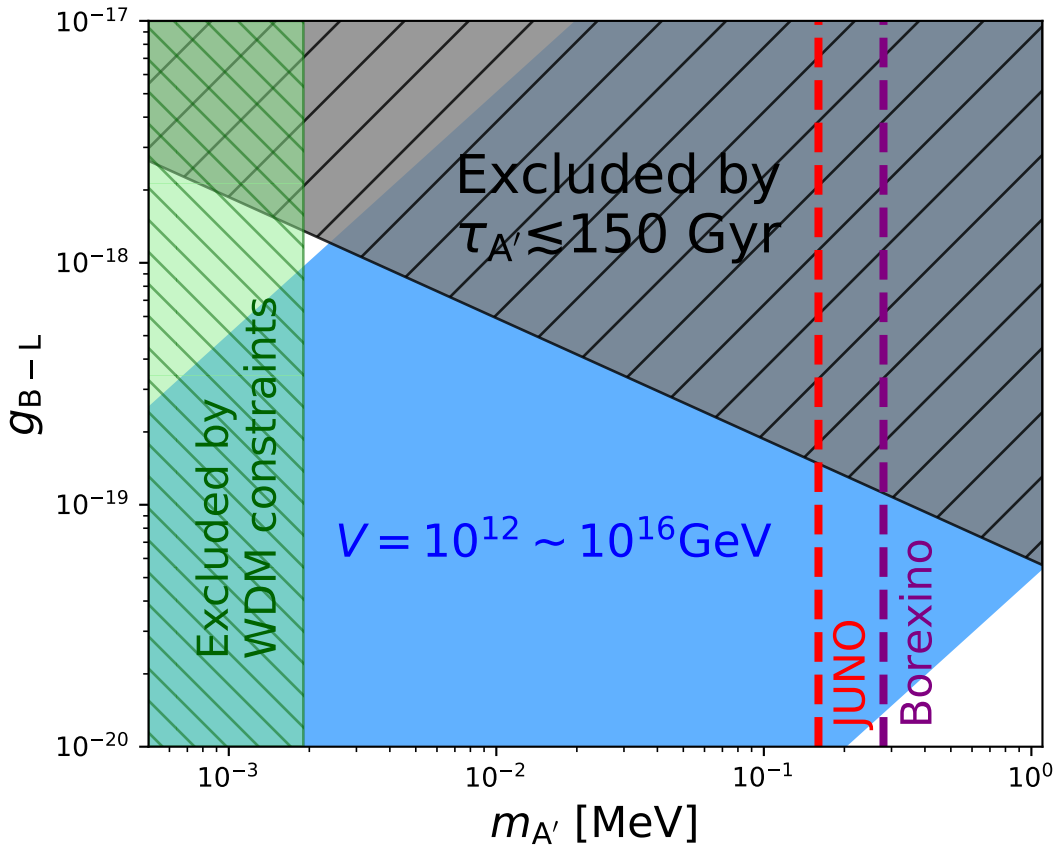
Féeton DM: B L gauge boson with a tiny coupling 10 ^{19} and a sub-MeV mass.

	Electromagnetism:	B-L gauge (hypothesis):
Charge	Positive – Negative	Baryon number – Lepton number
Force mediator	Electromagnetic field	B-L gauge boson
Range	Long, massless boson	Short, massive gauge field
Why needed?	Observed	Motivated by neutrino mass, cosmic baryon asymmetry via leptogenesis
		A new DM candidate

The model is characterized by the gauge coupling $g_{\mathrm{B\text{-}L}}$ and mass m_{f}.

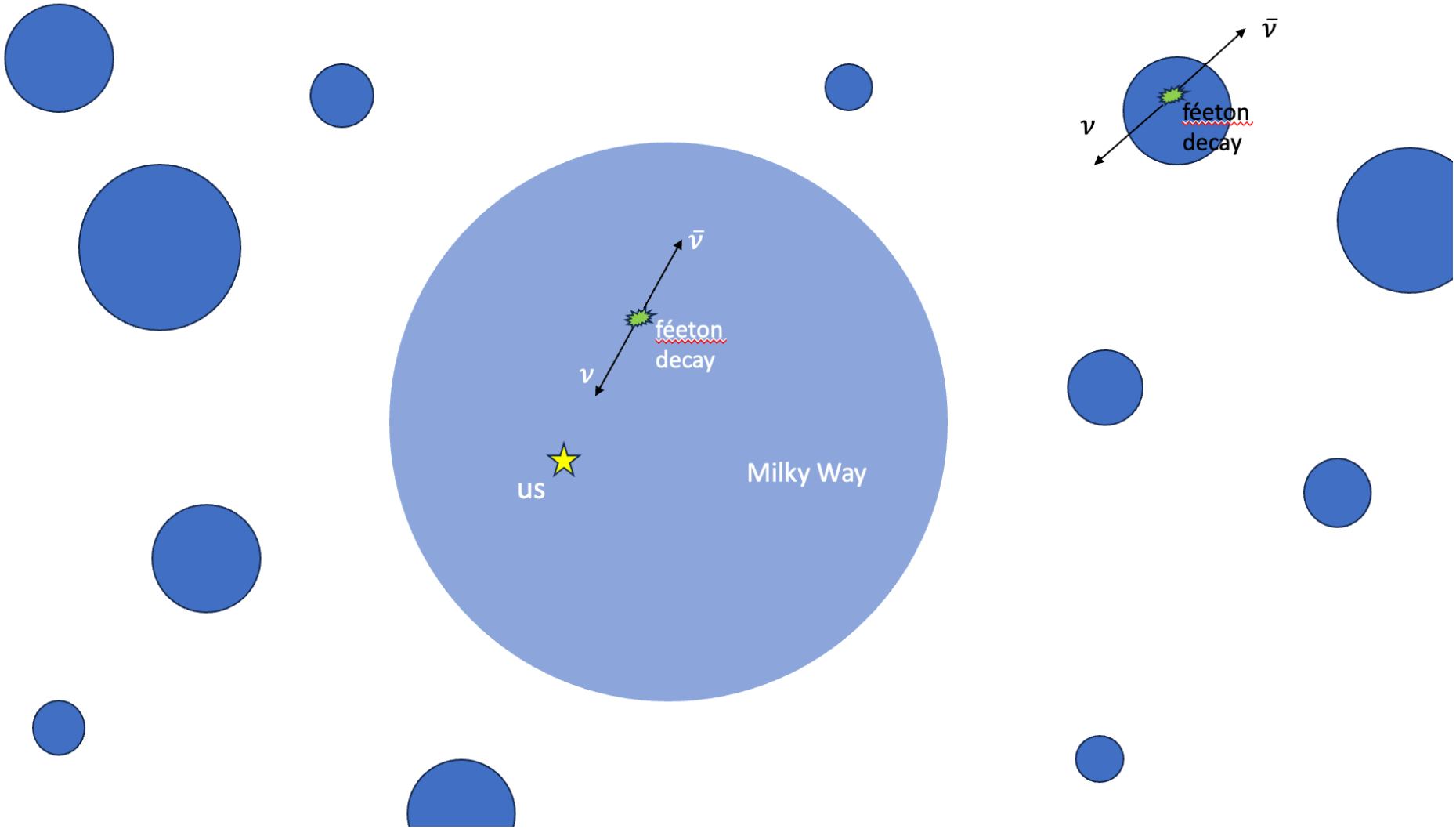
The féeton miracle

1. Needs to be sub-MeV, otherwise strong constraints;
2. Lifetime needs to be sufficiently long (gray);
3. Mass above keV (green, but can be modified);
4. The Seesaw mechanism consistency (blue).

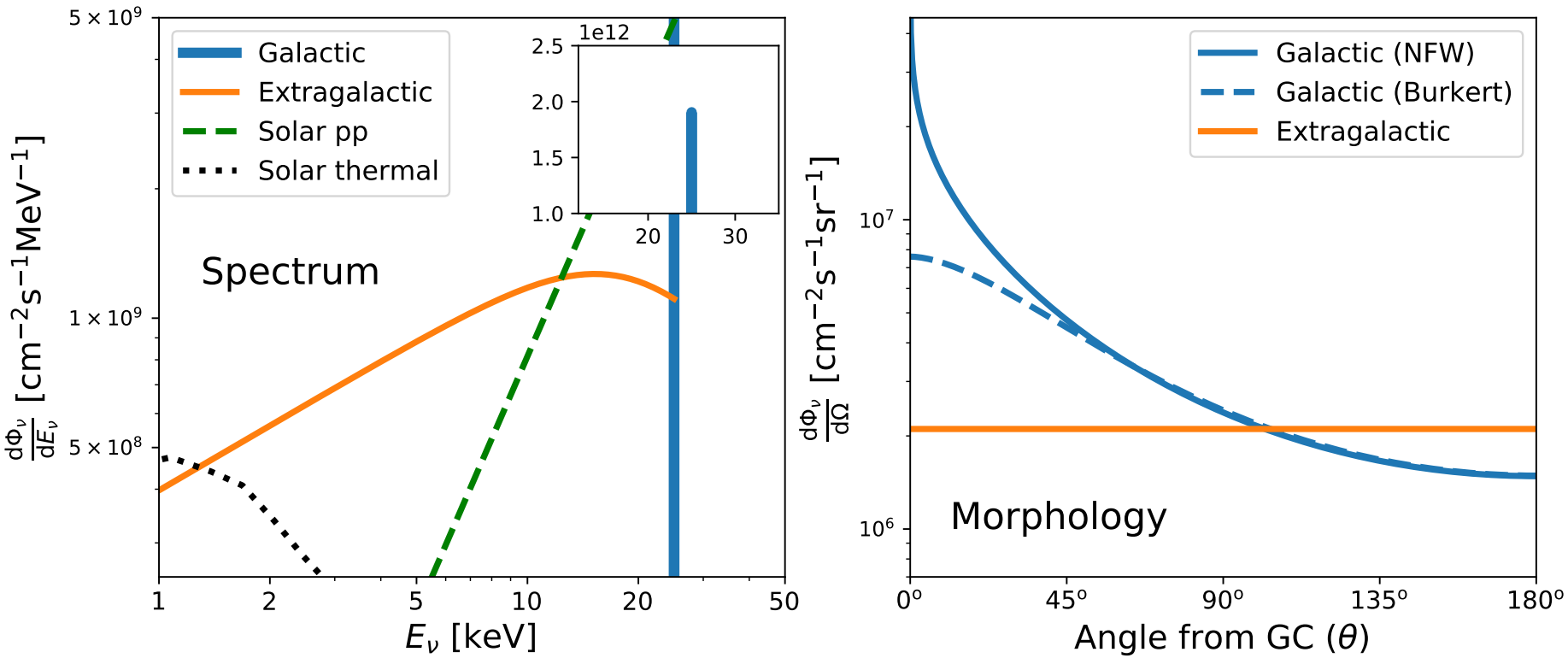


Miracle: if féeton is the dominant DM, the consistency with the Seesaw mechanism automatically makes it to be sub-MeV!

Féeton decays into neutrinos



Neutrino fluxes from Féeton decays



Left: Spectrum, taking maximal $g_{B\ \ L}$, comparable to solar components at corresponding energy;

Right: Morphology, rather smooth but concentrated towards the Galactic center.

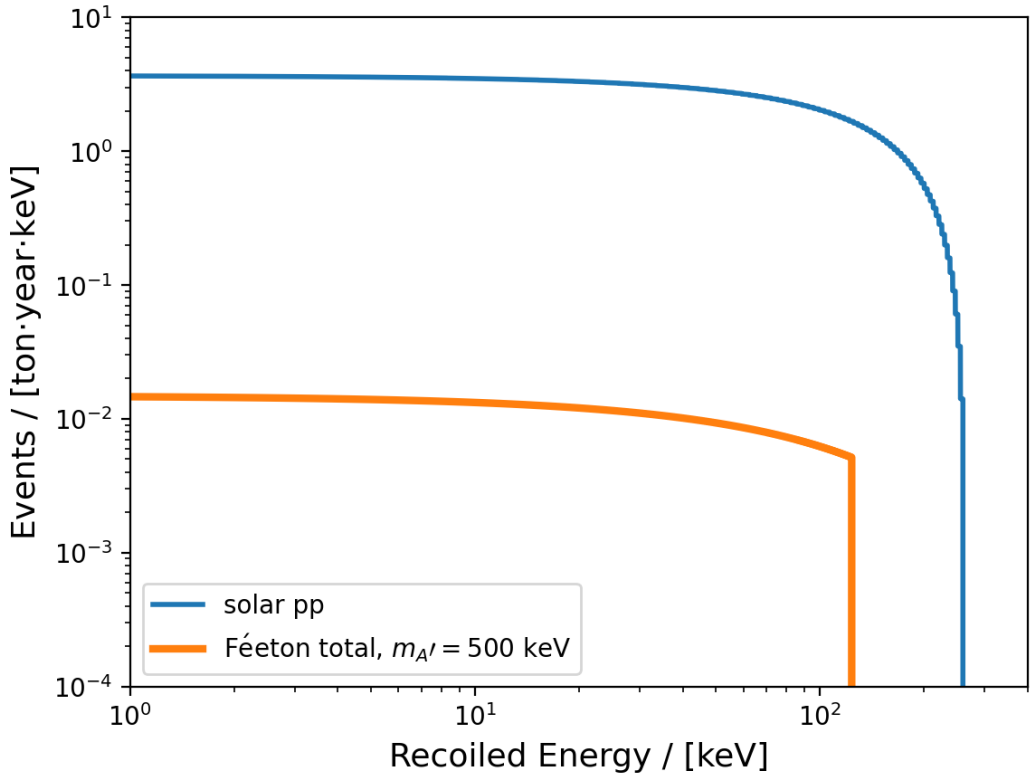
What can we learn if we detect the féeton neutrinos

$$\frac{\mathrm{d}\Phi_{\nu}^{\mathrm{Gal}}}{\mathrm{d}\Omega} = 7.9 \quad 10^{5}\tilde{D}_{\mathrm{N}}(\cos\theta)\left(\frac{g_{B-L}}{10^{\ 19}}\right)^{2}[\mathrm{cm}^{\ -2}\,\mathrm{s}^{\ -1}\,\mathrm{sr}^{\ -1}]$$

- The energy of the neutrino) féeton mass;
- Total flux) B L gauge coupling constant $g_{B\ L}$;
- Then from $V_{B\ L} = m_{\mathrm{f}}/2g_{B\ L}$) B L symmetry breaking scale. This provides a unique way to probe the high-energy B L physics.

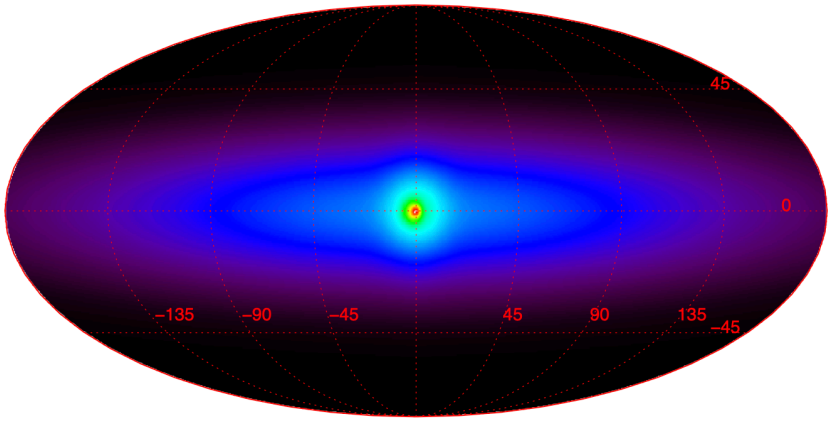
Solar neutrino-type experiments

- Solar pp neutrinos dominate;
- Direction determination will be helpful;
- JUNO and future Broxino can survey & 100 keV.



What if $m_f > 2m_e$? – féeton in addition decays into electron-positron pairs

Galactic 511-keV line (positron annihilation) excess



From INTEGRAL (Siegert et al. 2016)

Total	2.74	0.25	$10^{-3}\,\mathrm{cm}^{-1}\mathrm{s}^{-1}$
Bulge	0.96	0.07	$10^{-3}\,\mathrm{cm}^{-1}\mathrm{s}^{-1}$
Disk	1.66	0.35	$10^{-3}\,\mathrm{cm}^{-1}\mathrm{s}^{-1}$
f_{Ps}	1		
K_{ini}	. 3 MeV		

Adopted from (Siegert et al. 2016).

- First discovered in 1970's, $>$ 50 years;

  (Johnson, Harnden, and Haymes 1972; Haymes et al. 1975; Leventhal, MacCallum, and Stang 1978)

- Mainly positronium (intermediate form);

  (Harris et al. 1998; Siegert et al. 2016; Jean et al. 2006)

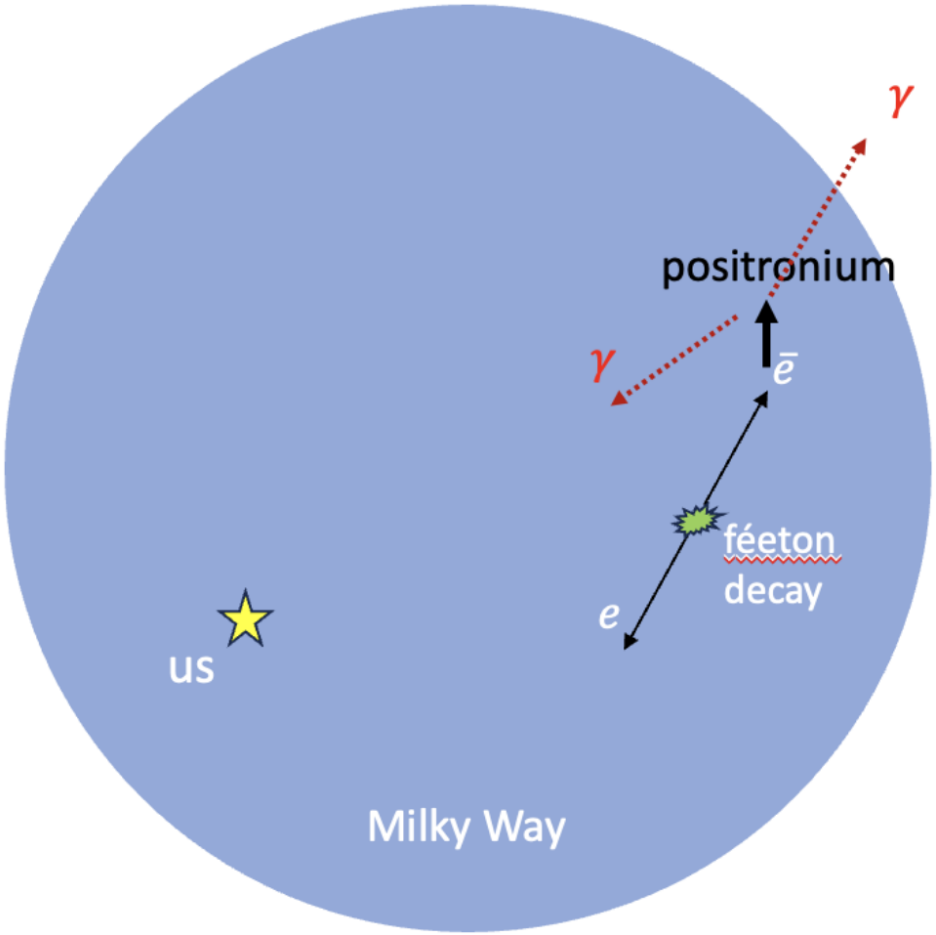
- Sharp towards the Galactic center;

  (Ascasibar et al. 2006)

- Positron initial energy . 3 MeV.

  (Beacom and Yuksel 2006; Sizun, Casse, and Schanne 2006)

Féeton decays and Galactic γ-ray excess

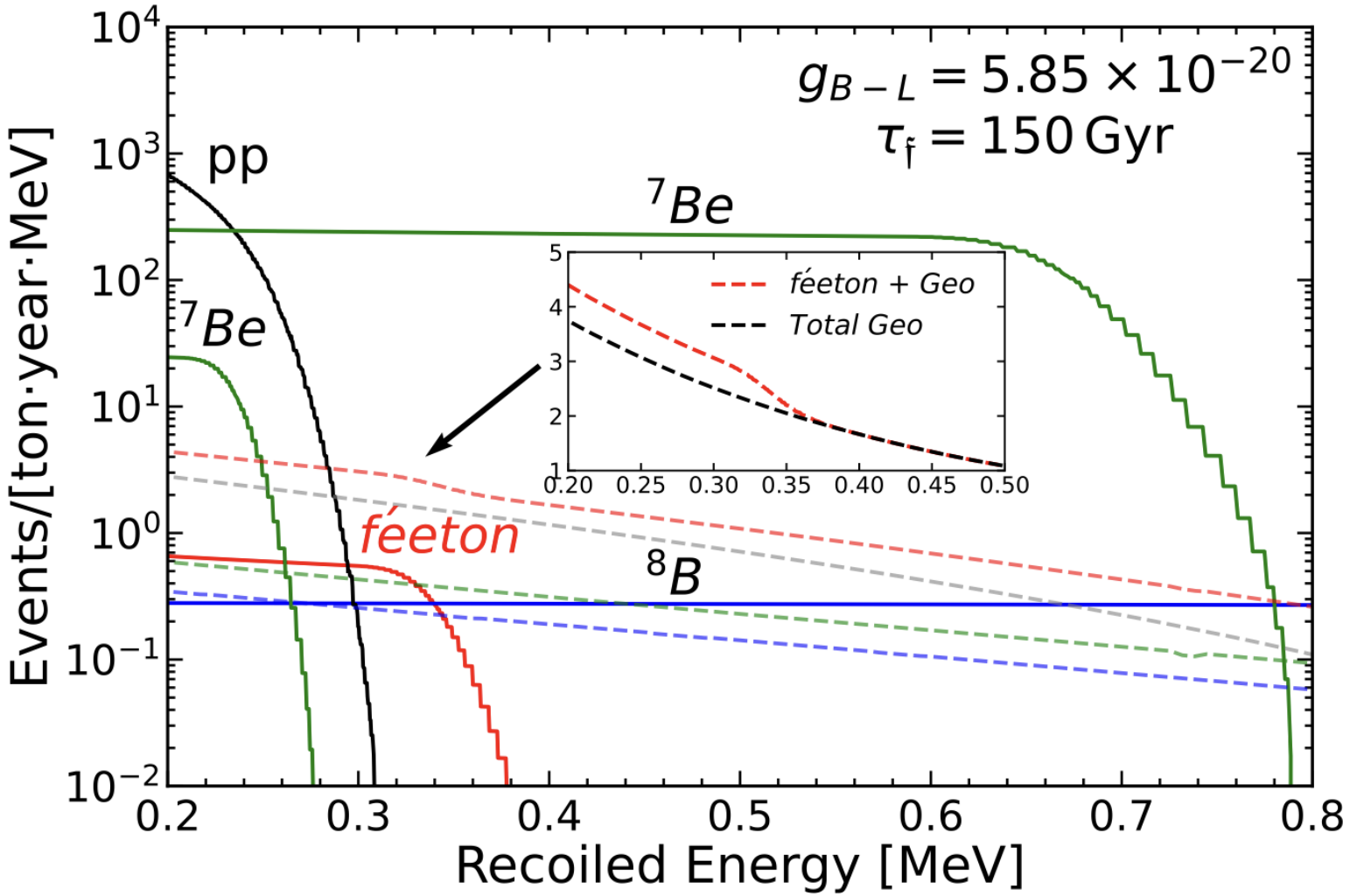


Two possible processes:

- $m_{\mathfrak{f}} > 2m_e + 13.6\,\mathrm{keV}$:
  1. Form positronium via charge exchanges hydrogen atoms;
  2. féeton cannot be dominant DM;
  Lin and Yanagida 2022, PRDL

- $2m_e < m_{\mathfrak{f}} < 2m_e + 13.6\,\mathrm{keV}$:
  1. Form positronium with free electrons in ionized environment;
  2. féeton can be dominant DM;
  Cheng et al. 2023, arXiv: 2310.05420

511 keV poistron annihilation anomaly



Summary

- B L gauge boson with a tiny coupling $g_{B\ L}$ 10^{-19} and a sub-MeV mass;
- Consistent in cosmology, seesaw mechanism, and leptogenesis;
- A low-energy neutrino signal potentially detectable in the near future;
- Fée, a French word for fairy — a small being that carrys an important message from heaven.

Féeton production during inflation

- Inflationary vector boson production (Graham, Mardon, and Rajendran 2016)

$$\Omega_X = \Omega_{\rm cdm} \sqrt{\frac{m_{\rm f}}{6 \quad 10^{\ 9}\,{\rm keV}}} \left(\frac{H_{\rm inf}}{10^{14}\,{\rm GeV}} \right)^2$$

  Then, $H_{\rm inf} \quad 1.6 \quad 10^{11}\,{\rm GeV}$ for $m_{\rm f} \quad 1\,{\rm MeV}$ and $\Omega_{\rm f} = \Omega_X = \Omega_{\rm cdm}$.

- Recall $H_{\rm inf} \ ' \ r^{1/2} \quad 2.6 \quad 10^{12}\,GeV \ ) \ r \quad 4 \quad 10^{\ 7}$;
  Falsified if PGWs should be detected in near future.

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