Observable signatures of the dark sector from supernovae

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DARK PHOTONS (hep-ph: 1901.08596)

Summary

- ***Even below cooling bound, supernovae produce many dark photons***
- Decay products are observable

Introduction

- Model: Dark photon kinetically mixed with SM photon

$$\mathcal{L} \supset \frac{1}{2} m' A'_\mu A'^\mu - \frac{1}{4} F'_{\mu\nu} F'^{\mu\nu} - \frac{\epsilon}{2} F'_{\mu\nu} F^{\mu\nu} \qquad A' \otimes \gamma$$

- SN progenitors
  - *Type II:* $r_{\rm esc} \sim 10^9$ km, ~2 per century per galaxy
  - *Type Ib/c:* $r_{\rm esc} \sim 2 \times 10^7$ km, ~0.2 per century per galaxy
- Dark photons decay to e^+e^- or $e^+e^-\gamma$ (~1% of decays)

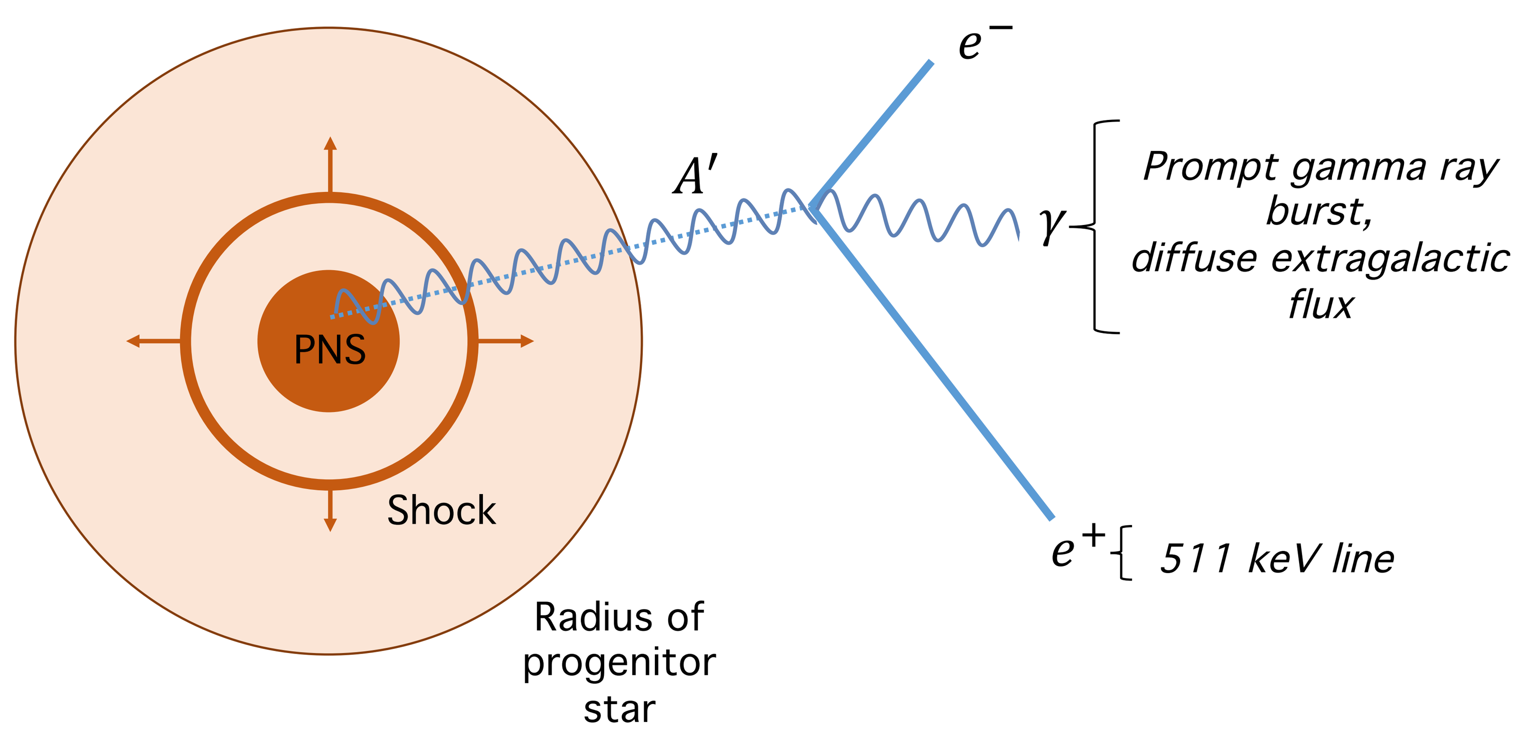

Figure 1: General setup for all signatures. The dark photon is produced in the protoneutron star (PNS) and escapes beyond the radius of the SN progenitor before decaying and contributing to observable signatures.

Signature 1: The 511 keV Line

- Positron annihilation constrained by INTEGRAL measurements of 511 keV line

Signature 2: SN1987a gamma rays

- GRS observations of SN1987a constrain gamma-ray flux
- Next galactic SN provides discovery potential!

Signature 3: Diffuse gamma-ray flux

- Fireball constrained by SMM and HEAO-1 measurements of diffuse extragalactic gamma-ray flux

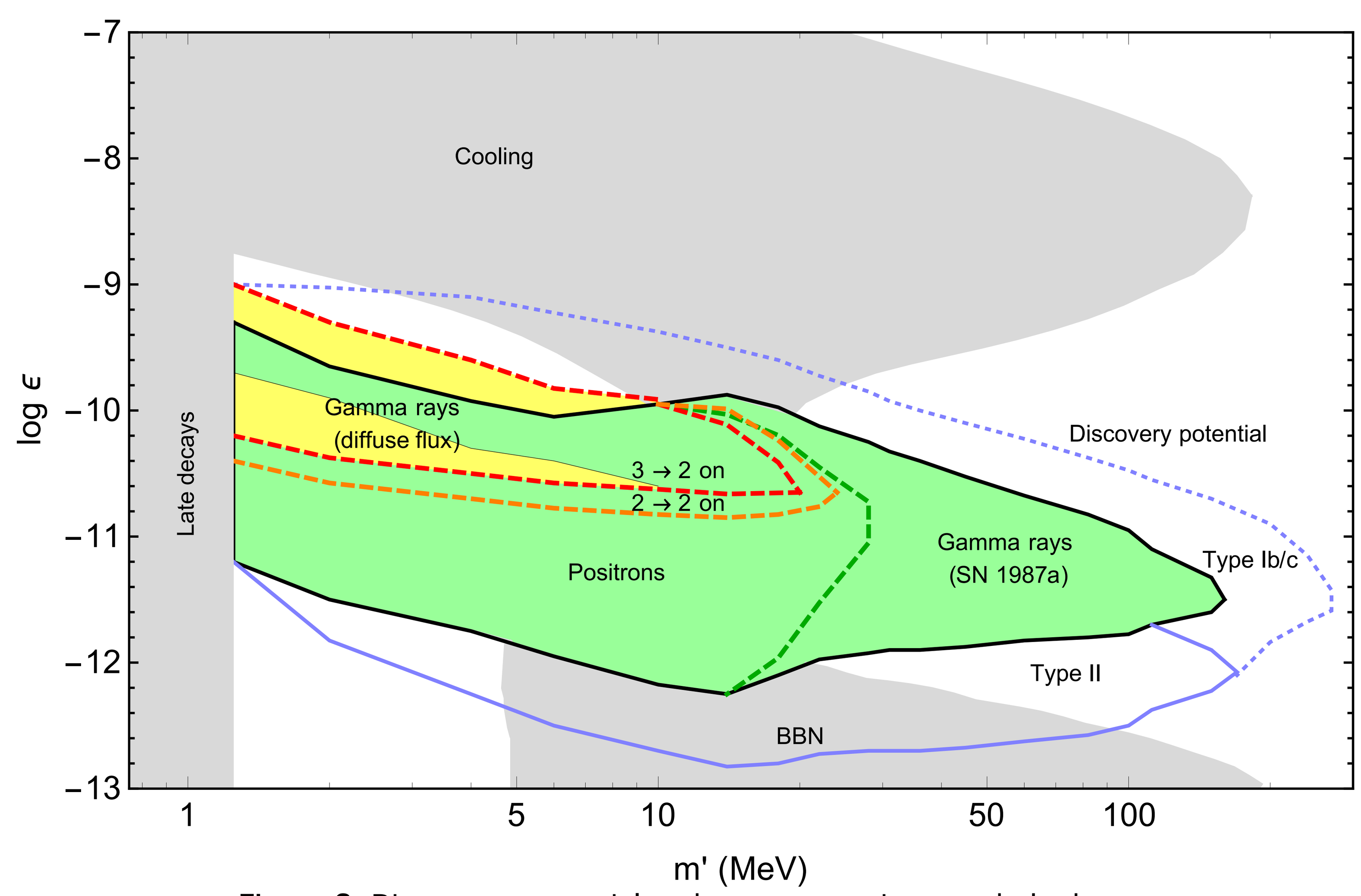

Figure 2: Discovery potential and new constraints on dark photons.

Results

- New constraints (green)
- Uncertain (fireball) (yellow)
- Existing bounds (grey)
- Discovery potential (next galactic SN) (solid and dashed lines)

DARK FERMIONS (hep-ph: 1905.09284)

Summary

- ***Existing WIMP detectors are sensitive to dark fermions produced by supernovae***
- Above cooling bound, dark fermions diffusively trapped
- Escaping dark fermions produce galactic diffuse flux

Introduction

Model: $U(1)$ dark sector with single stable fermion (χ) kinetically mixed to SM through heavy dark photon (A') with coupling ϵ

Production/annihilation	$\chi\,\bar{\chi} \longleftrightarrow e^+\,e^-$
Energy transfer	$\chi\,e \longrightarrow \chi\,e$
Diffusive scattering	$\chi\,p \longrightarrow \chi\,p$

Characteristic spheres:

- Interactions freeze out at different radii, setting spectrum

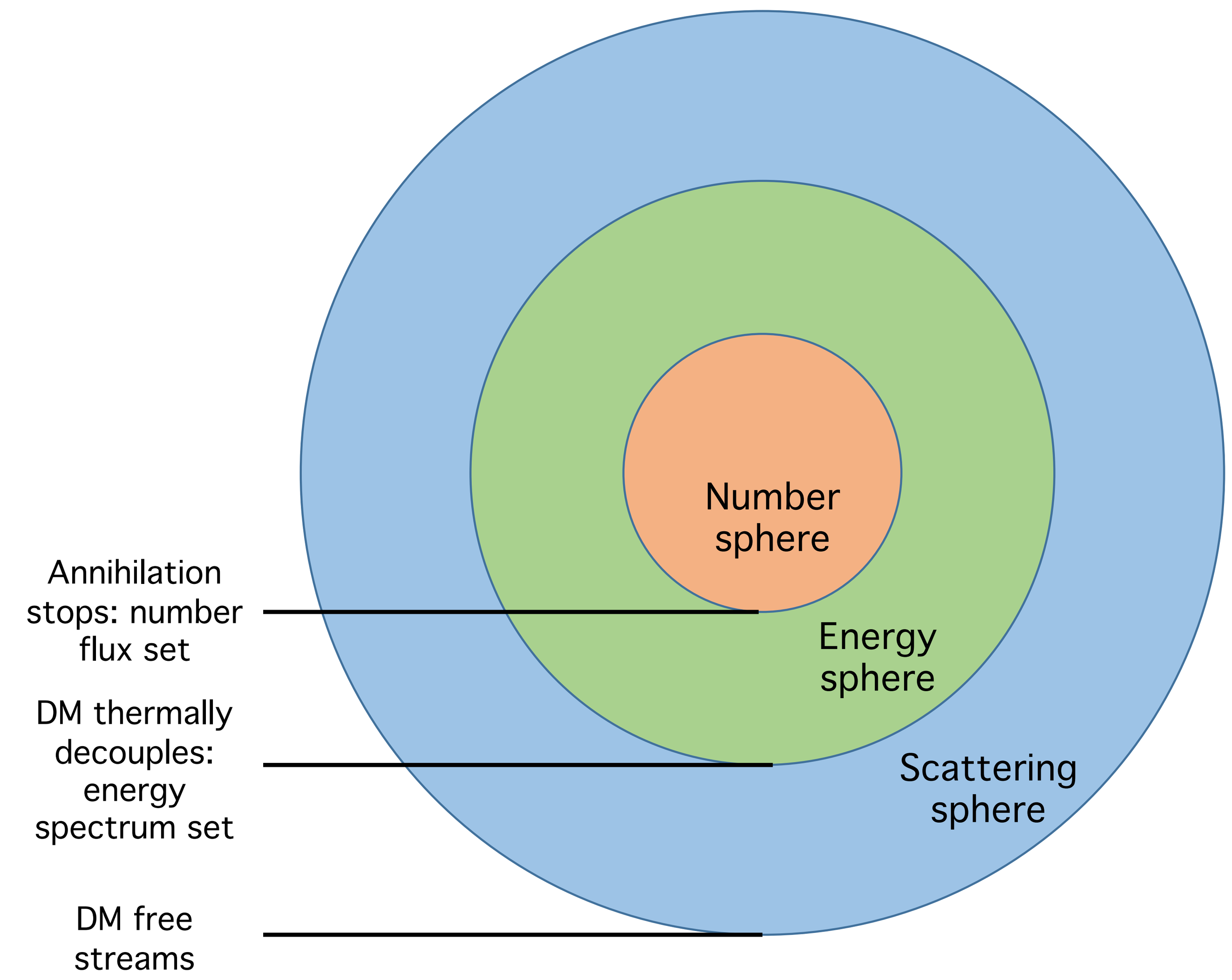

Figure 3: Characteristic radii of protoneutron star. Different interactions freeze out at different radii, fixing the number flux, energy spectrum, and free-streaming radius.

Detection

- Dark matter is emitted with spread in velocity (unlike neutrinos)
- Overlapping emissions from galactic SN form diffuse flux
- **Liquid xenon WIMP detectors are sensitive to flux of MeV-scale particles traveling near c (instead of virial velocity)**

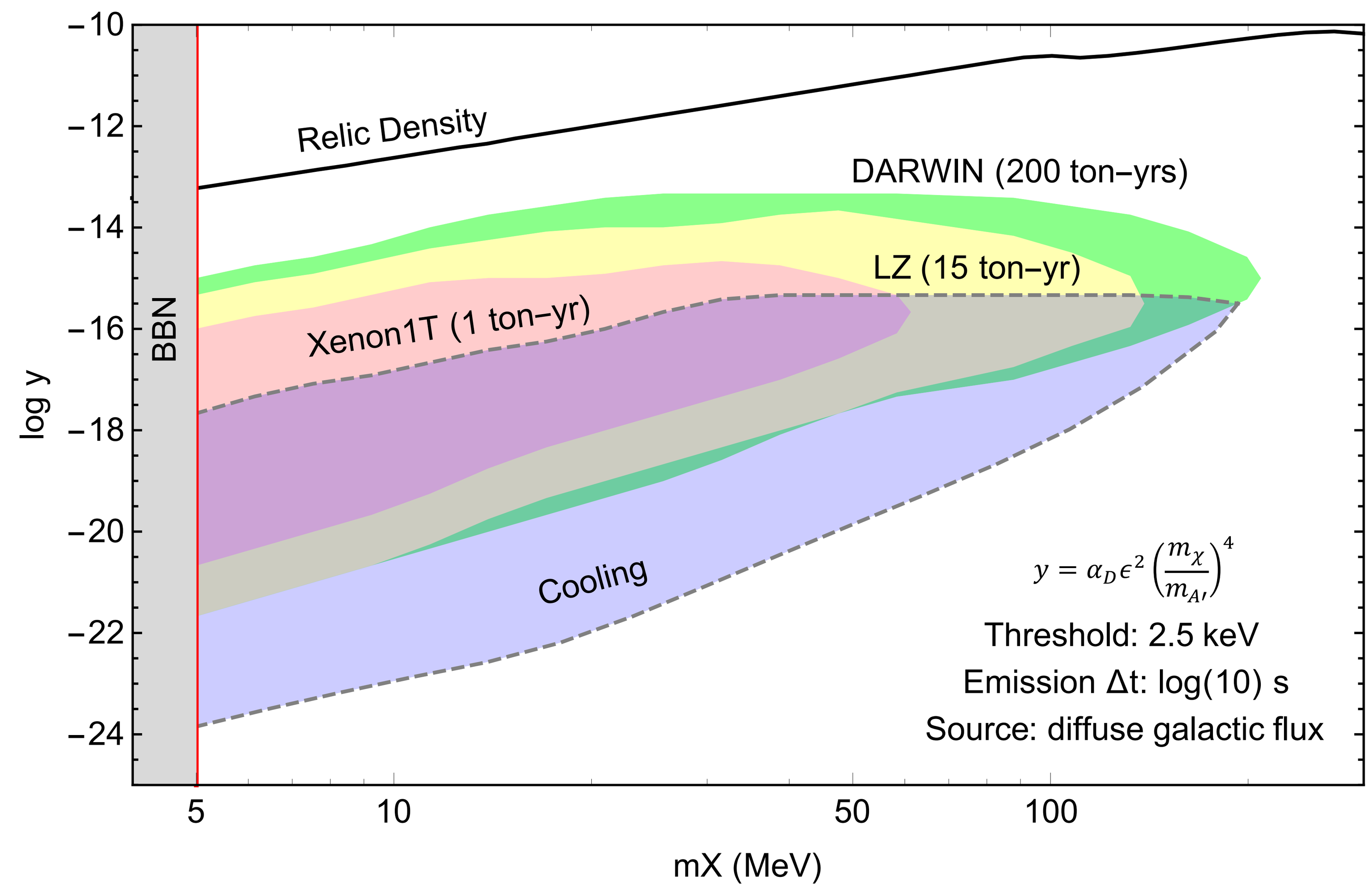

Figure 4: Experimental sensitivity to diffuse dark fermion flux and new cooling bound.

Results

- DARWIN (“ultimate” LXe detector)
- LUX-Zeplin (LXe detector currently under construction)
- Xenon1T (existing LXe detector taking data!)
- New cooling bound in **trapped regime**