

15th International Workshop on the Identification of Dark Matter 2024, L'Aquila, Italy



Hunting for Dark Matter And Dark Photon Trident

Thong (Thomas) T. Q. Nguyen



Based on

- Tim Linden, **TTQN**, Tim Tait, *X-Ray Constraints on Dark Photon Tridents*, submitted to **PRL** (arXiv:2406.19445)
- Tim Linden, **TTQN**, Tim Tait, *Indirect Searches for Dark Photon-Photon Tridents in Celestial Objects*, submitted to **PRD** (arXiv:2402.01839)



Axion

Physicist

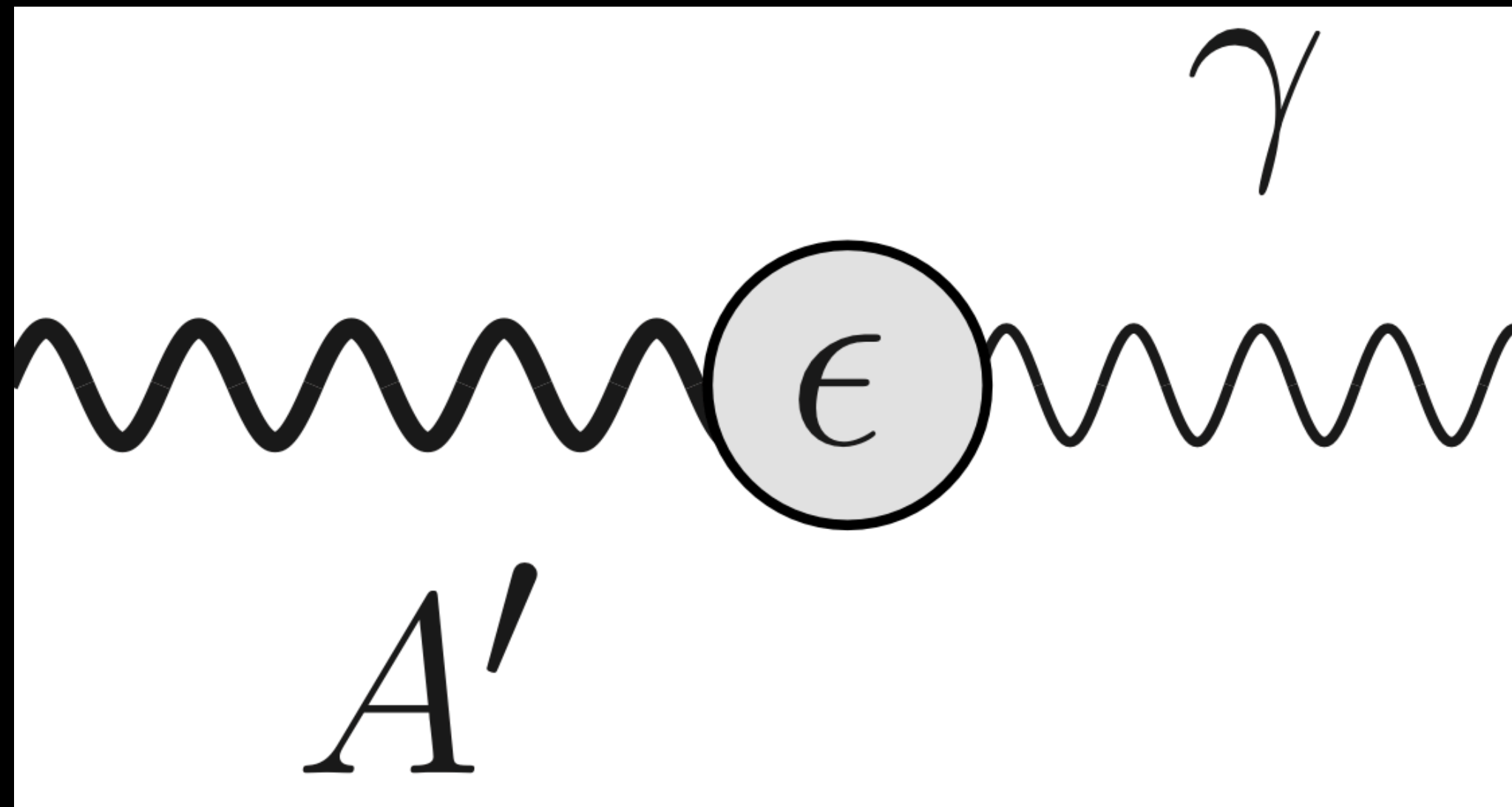
Dark Photon

Dark Photon

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

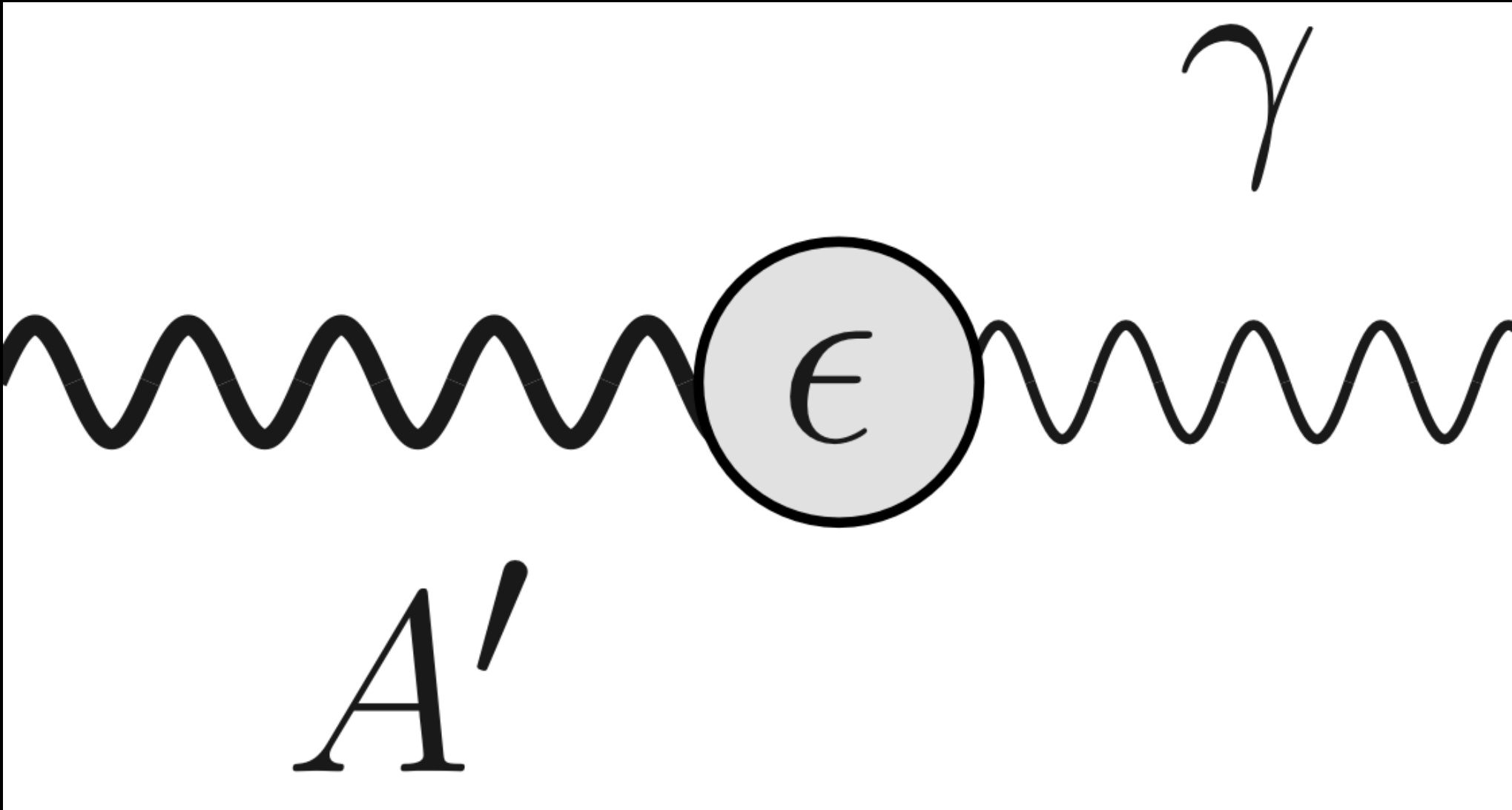
Dark Photon

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



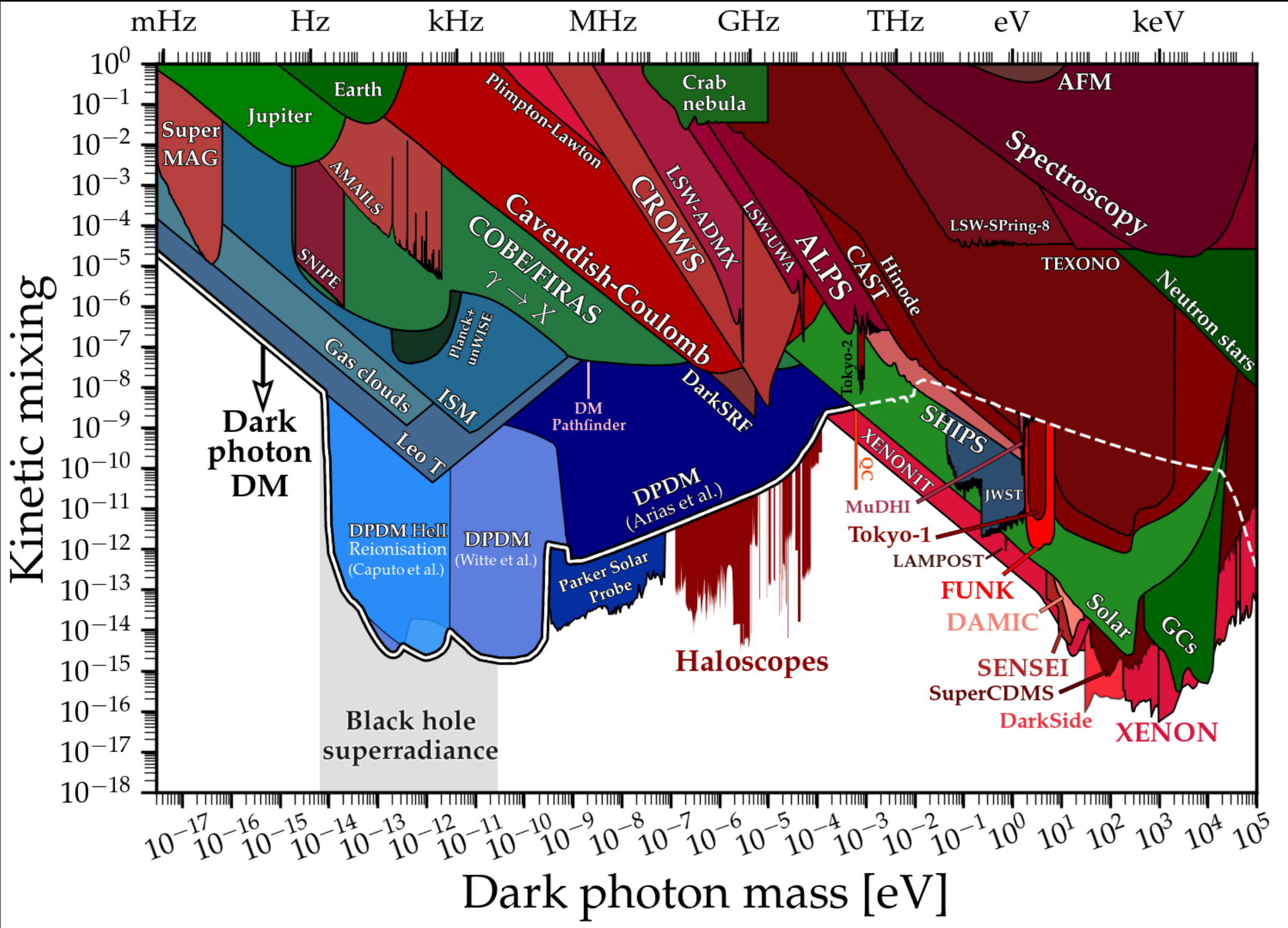
Dark Photon

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



Caputo, O'Hare, Millar, Vitagliano

(2105.04565)



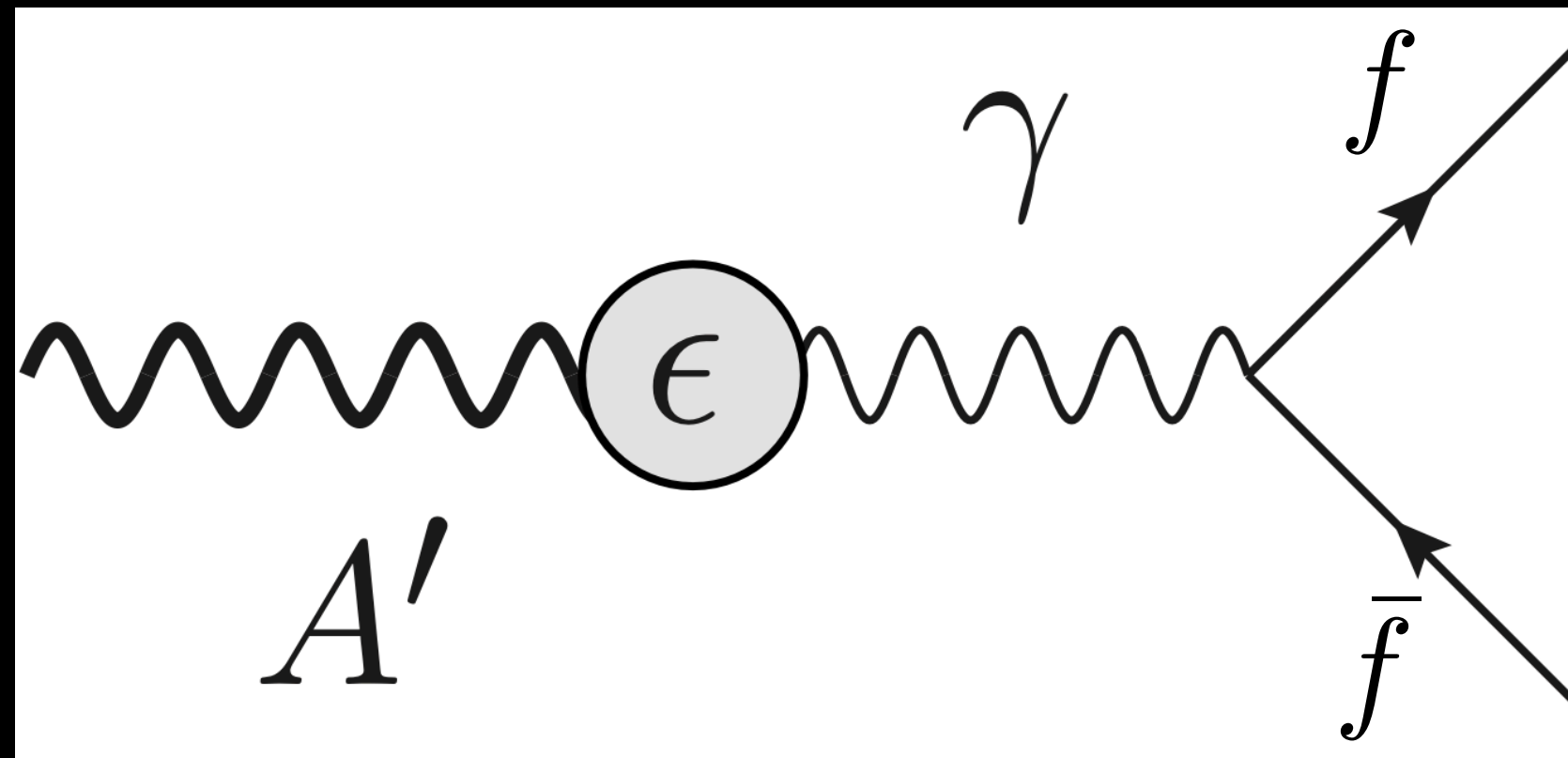
The Dark Photon Trident

Dark Photon decay

The Dark Photon Trident

Dark Photon decay

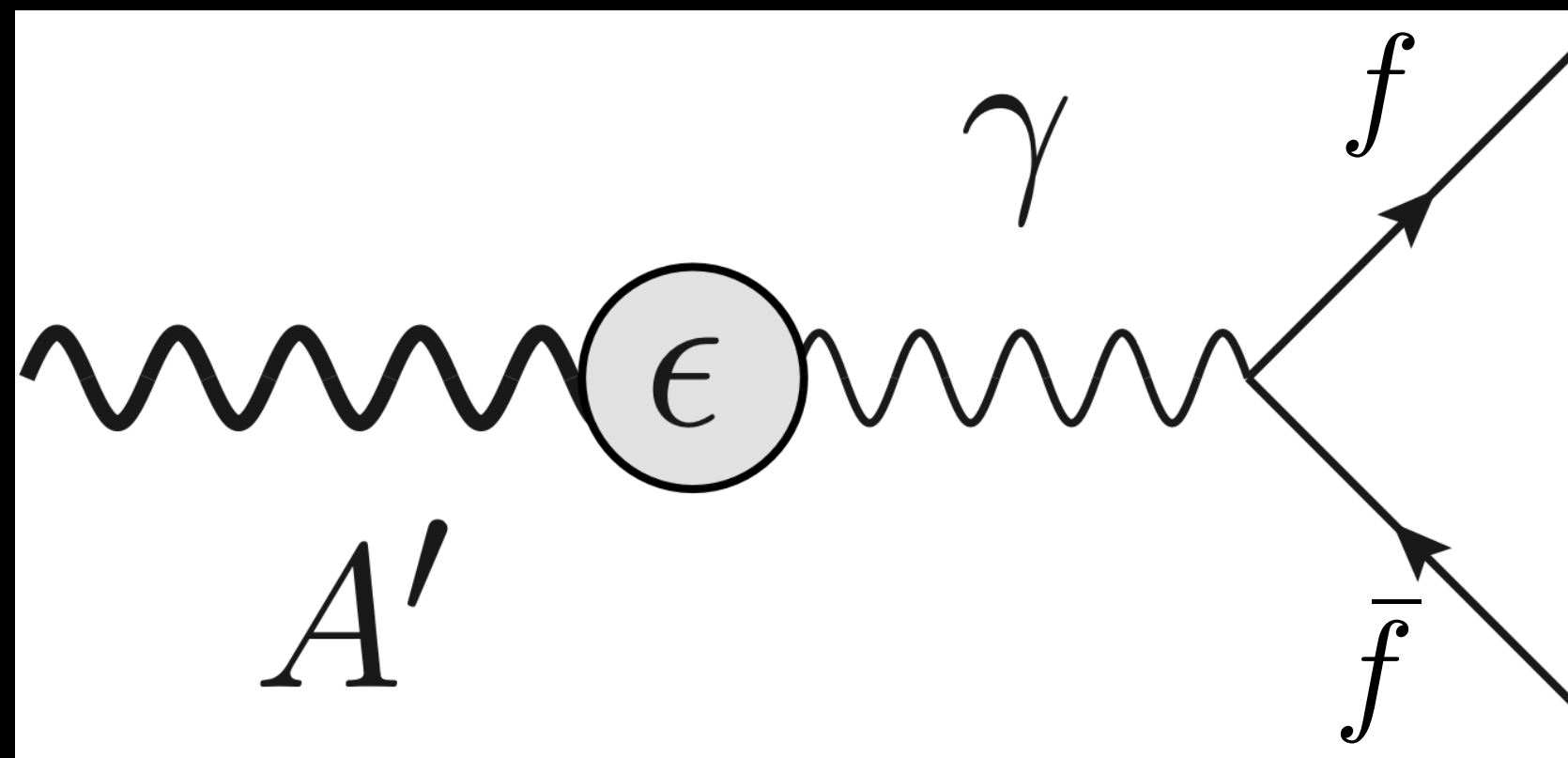
$$m_{A'} > 2m_f$$



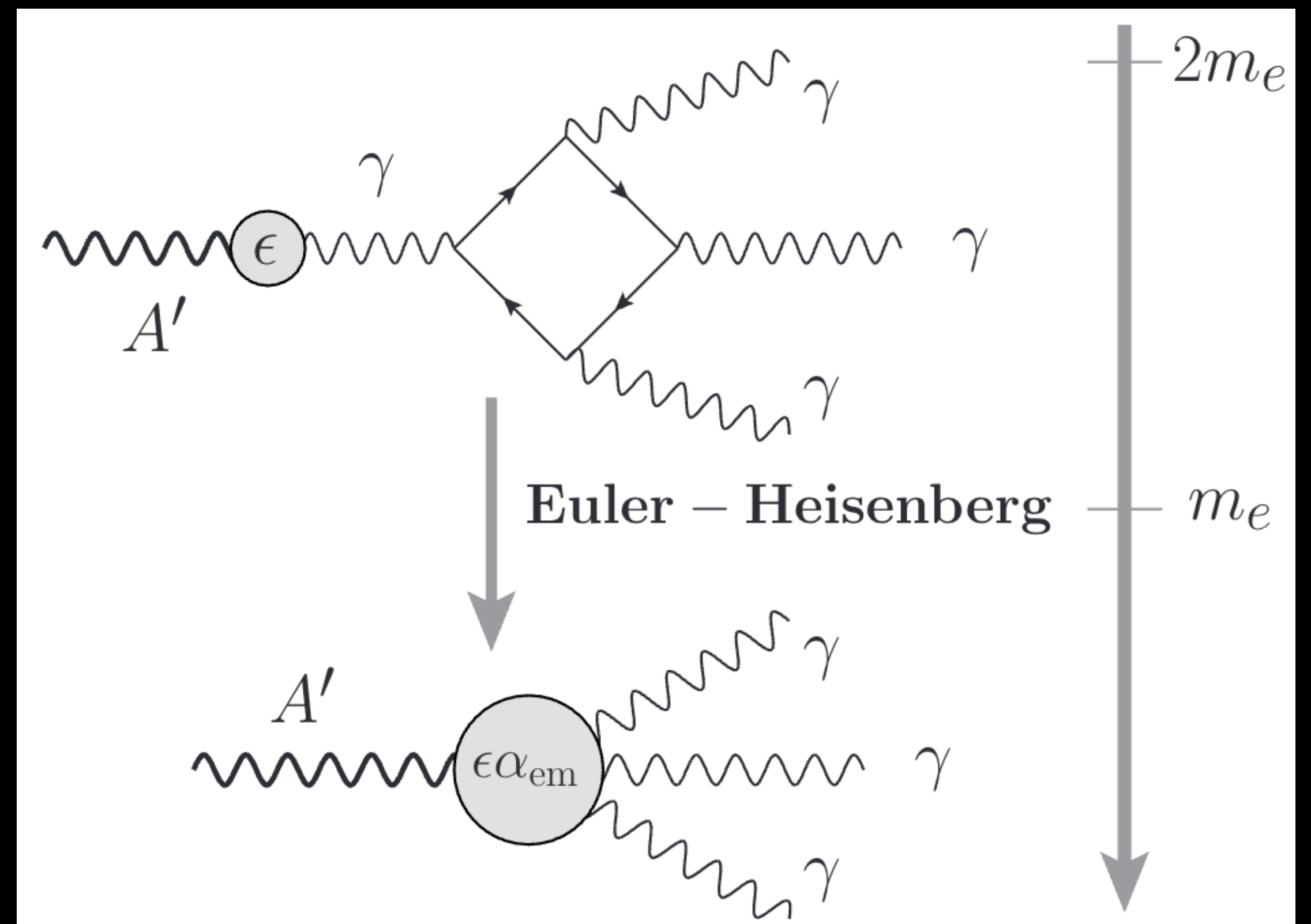
The Dark Photon Trident

Dark Photon decay

$$m_{A'} > 2m_f$$



$$m_{A'} \leq 2m_e$$



- Pospelov (0811.1030)
- Postma, Redondo (0811.0326)

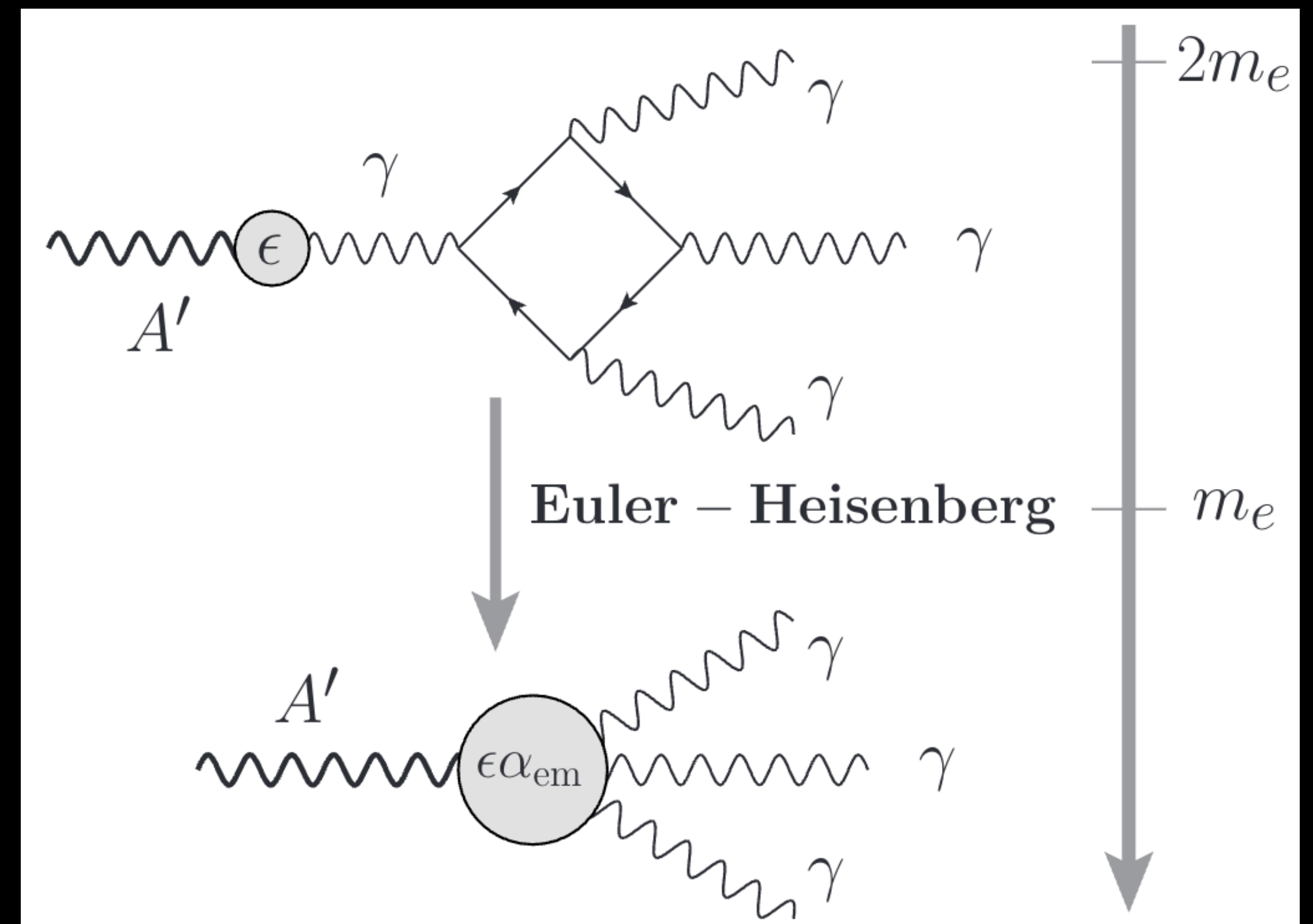
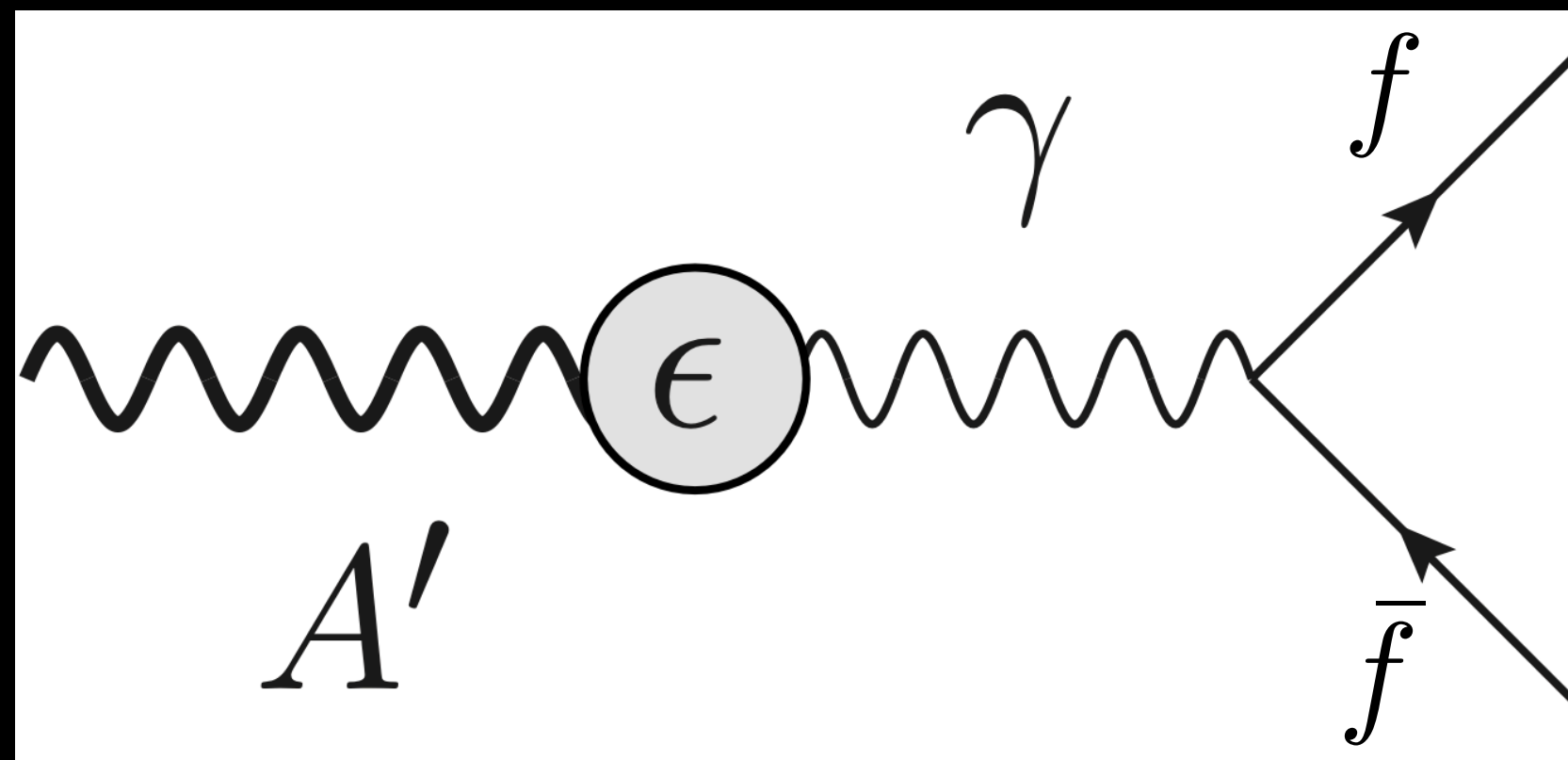
The Dark Photon Trident



Dark Photon decay

$$m_{A'} > 2m_f$$

$$m_{A'} \leq 2m_e$$



- Pospelov (0811.1030)
- Postma, Redondo (0811.0326)

Dark photon scenarios (models)

Dark Photon mediator

Dark Photon Dark Matter

Dark photon scenarios (models)

Dark Photon mediator

- Dark matter is fermionic particle
- Dark photon is the portal particle
- Dark matter can annihilate to SM particles through dark photon (new interaction)

Dark Photon Dark Matter

Dark photon scenarios (models)

Dark Photon mediator

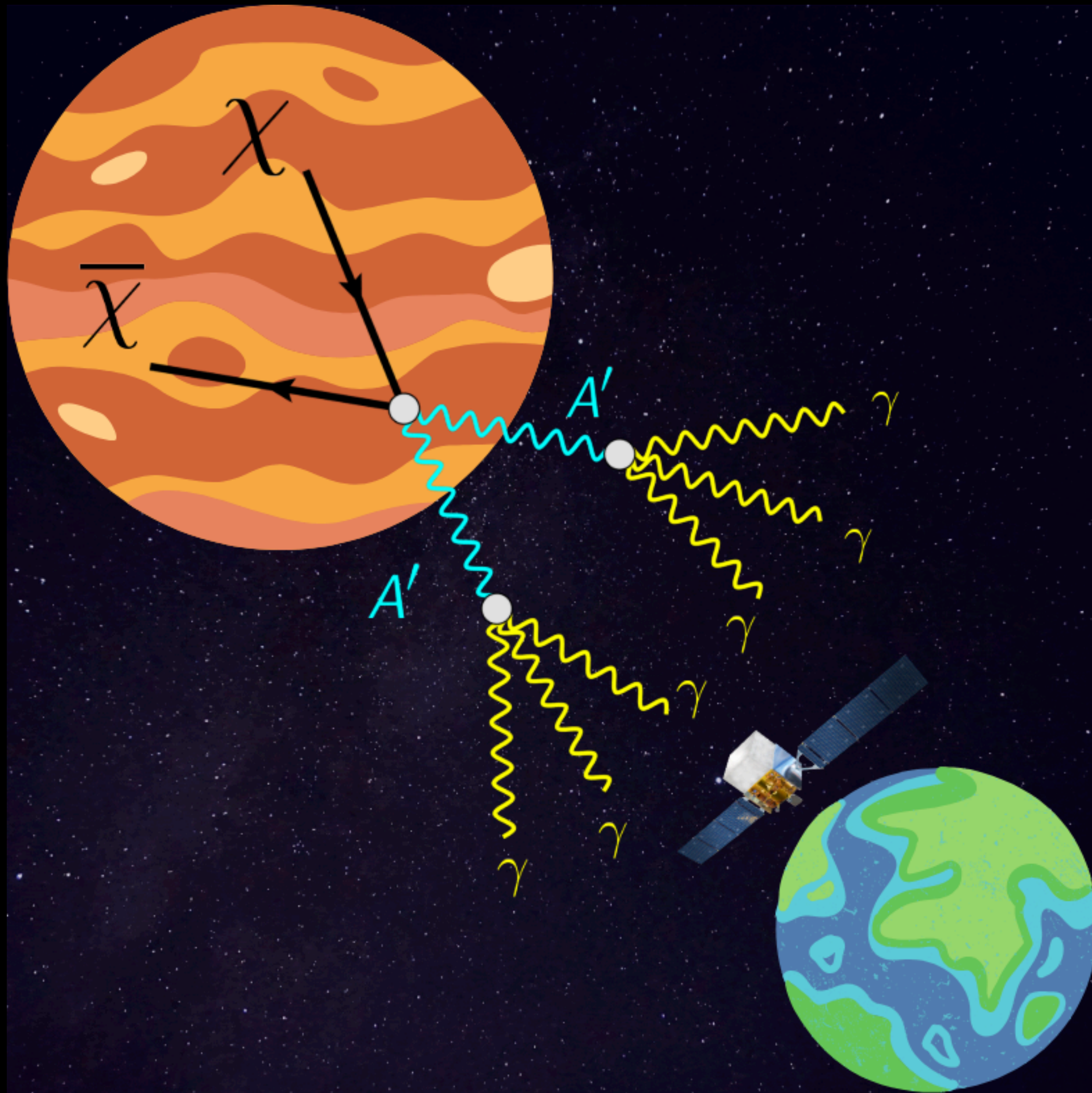
- Dark matter is fermionic particle
- Dark photon is the portal particle
- Dark matter can annihilate to SM particles through dark photon (new interaction)

Dark Photon Dark Matter

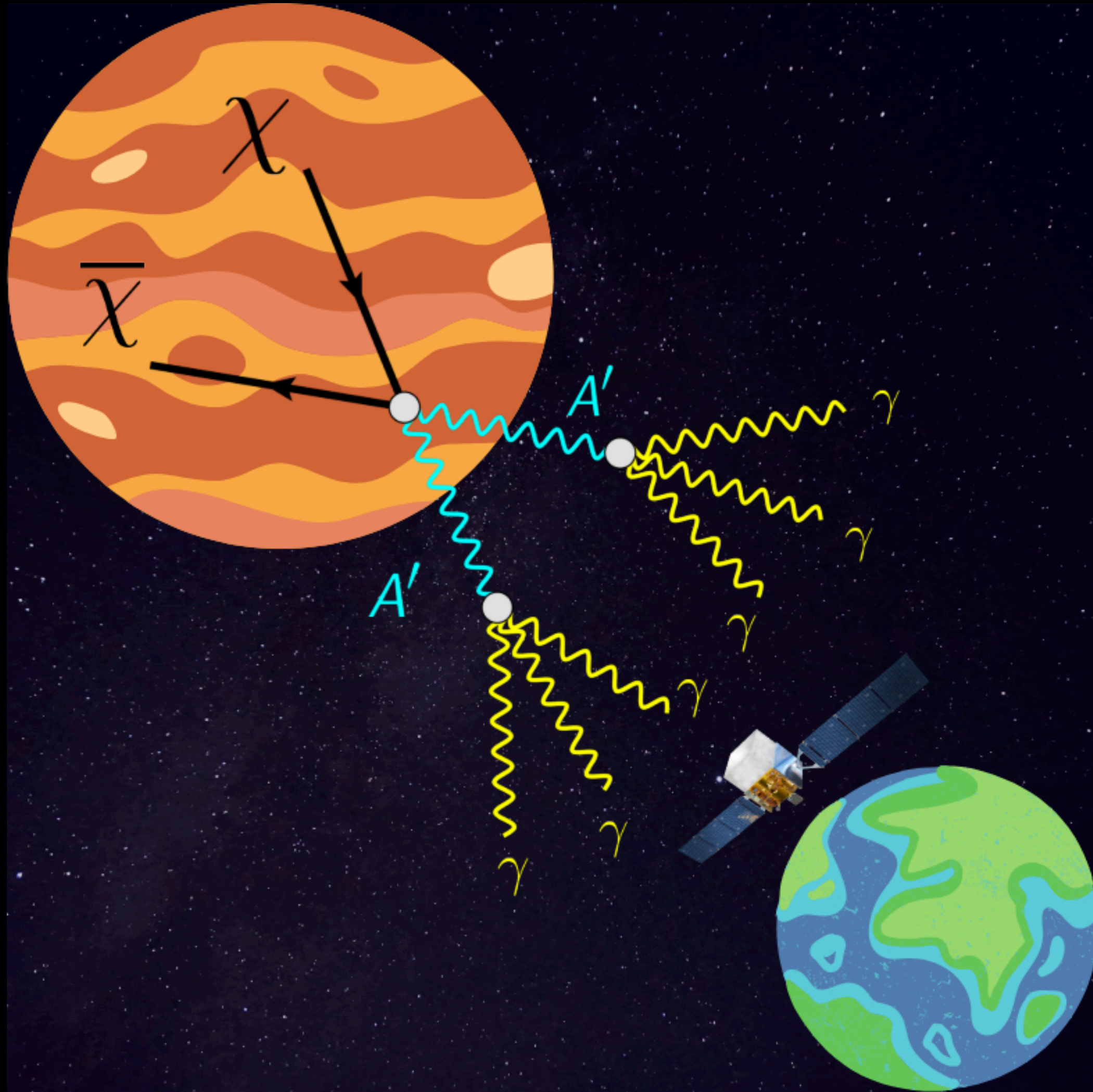
- Dark photon is dark matter
- Mixing with SM photon
- Decay to SM particles

Dark Photon Mediator

Dark photon from Celestial Objects

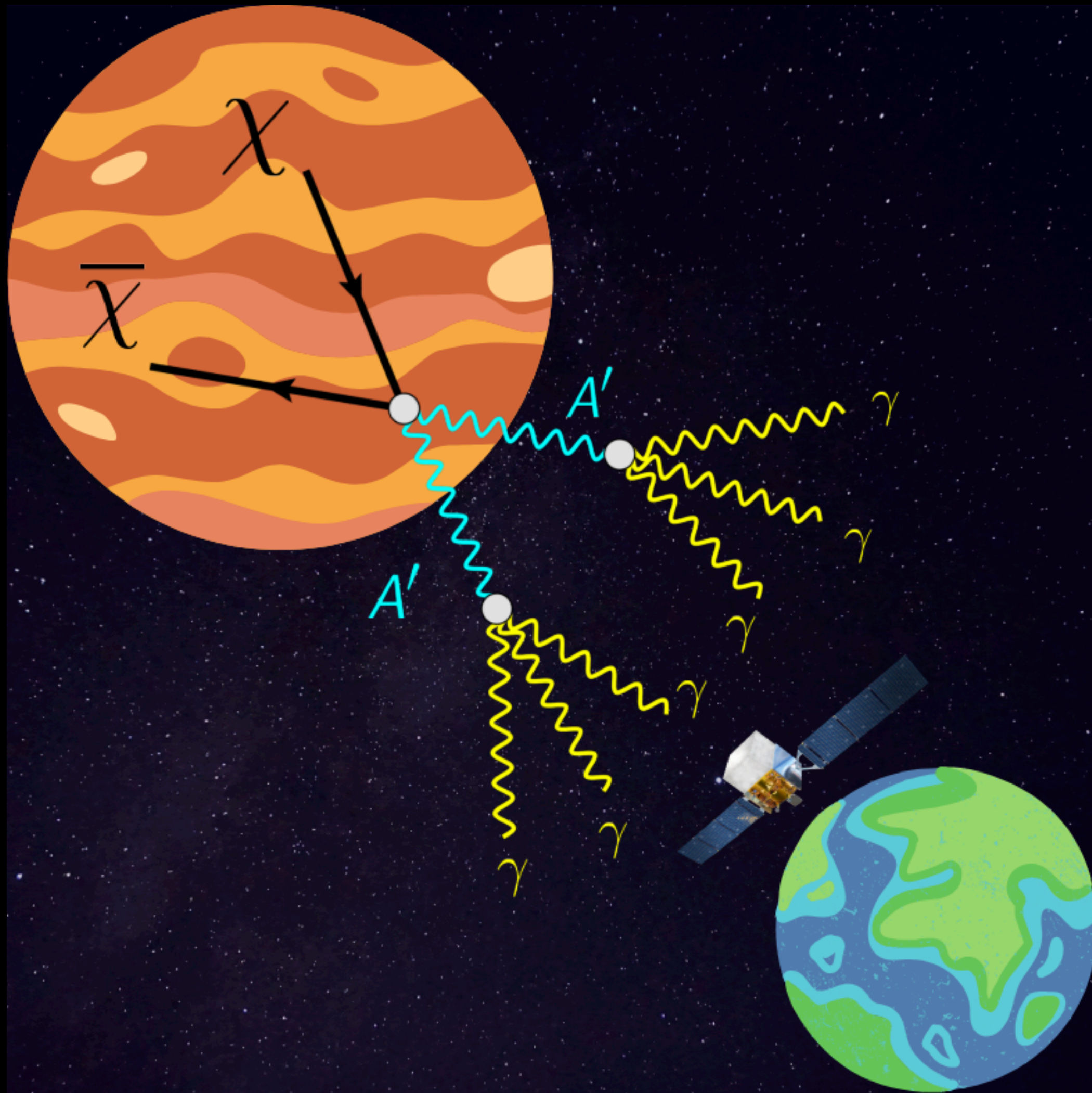


Dark photon from Celestial Objects



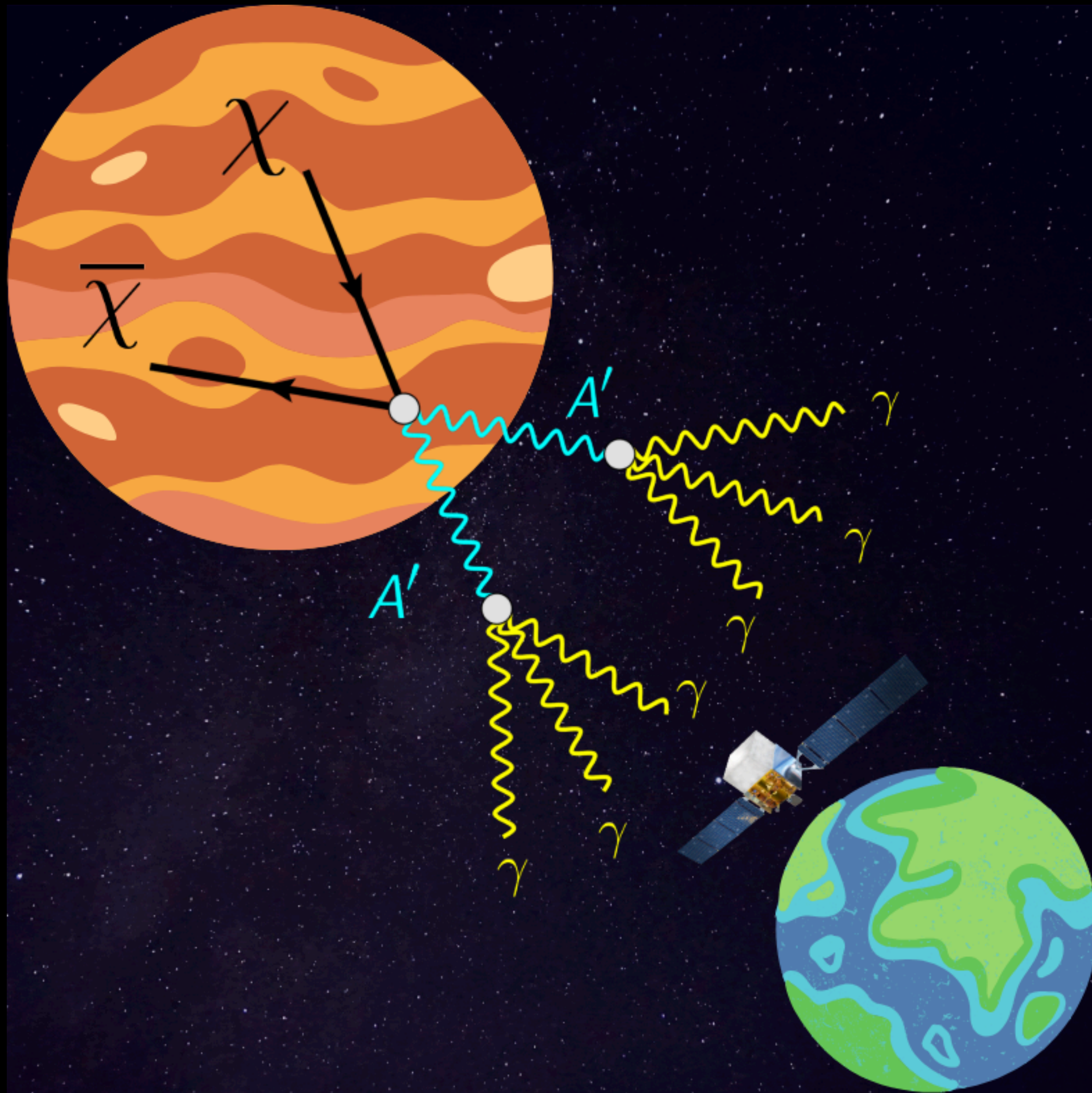
- Dark Matter scatters with nucleons inside celestial objects.

Dark photon from Celestial Objects



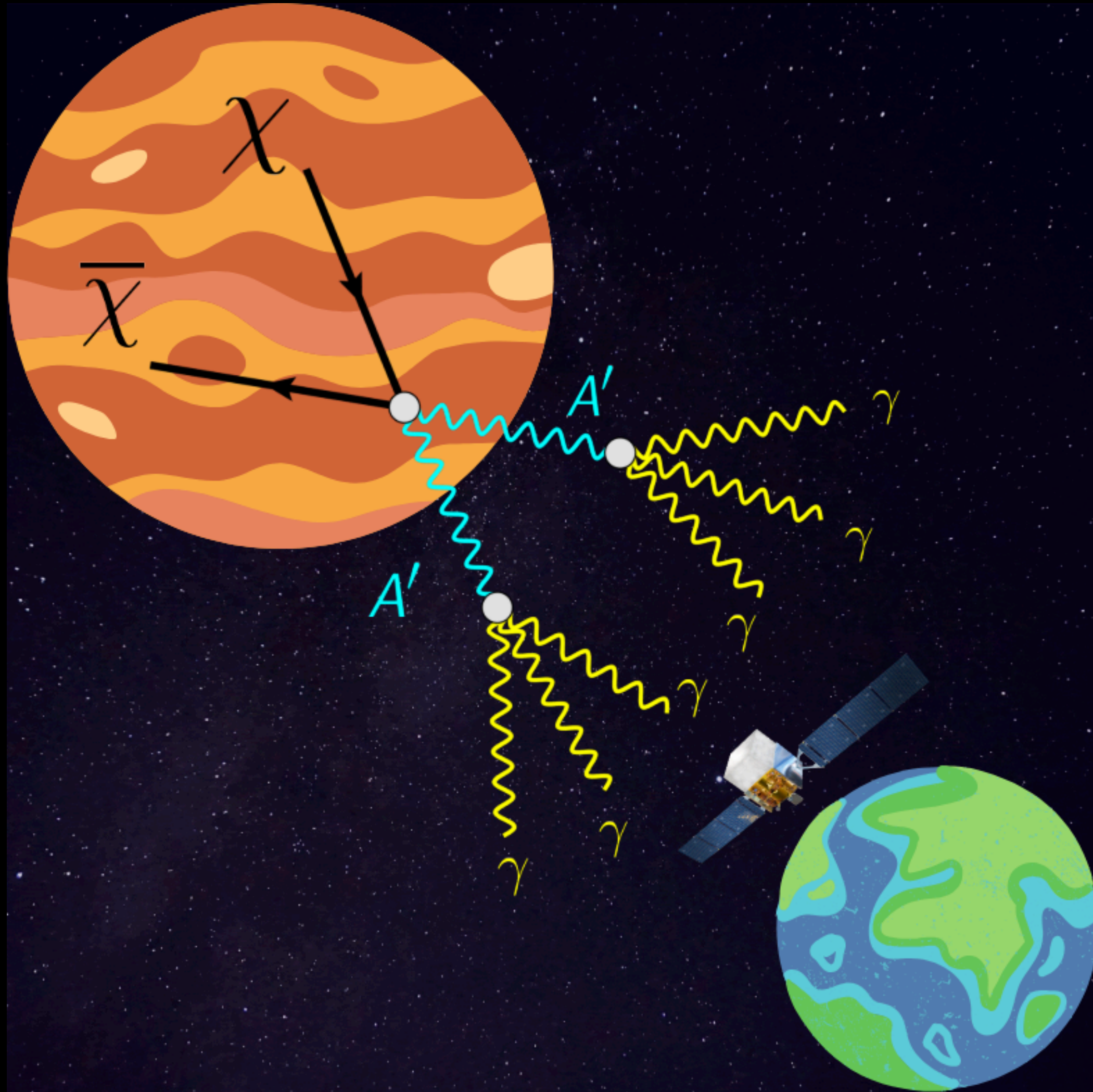
- Dark Matter scatters with nucleons inside celestial objects
- Dark Matter is captured by the celestial object.

Dark photon from Celestial Objects



- Dark Matter scatters with nucleons inside celestial objects
- Dark Matter is captured by the celestial object.
- Captured Dark Matters annihilate to long-lived mediators (dark photons).

Dark photon from Celestial Objects



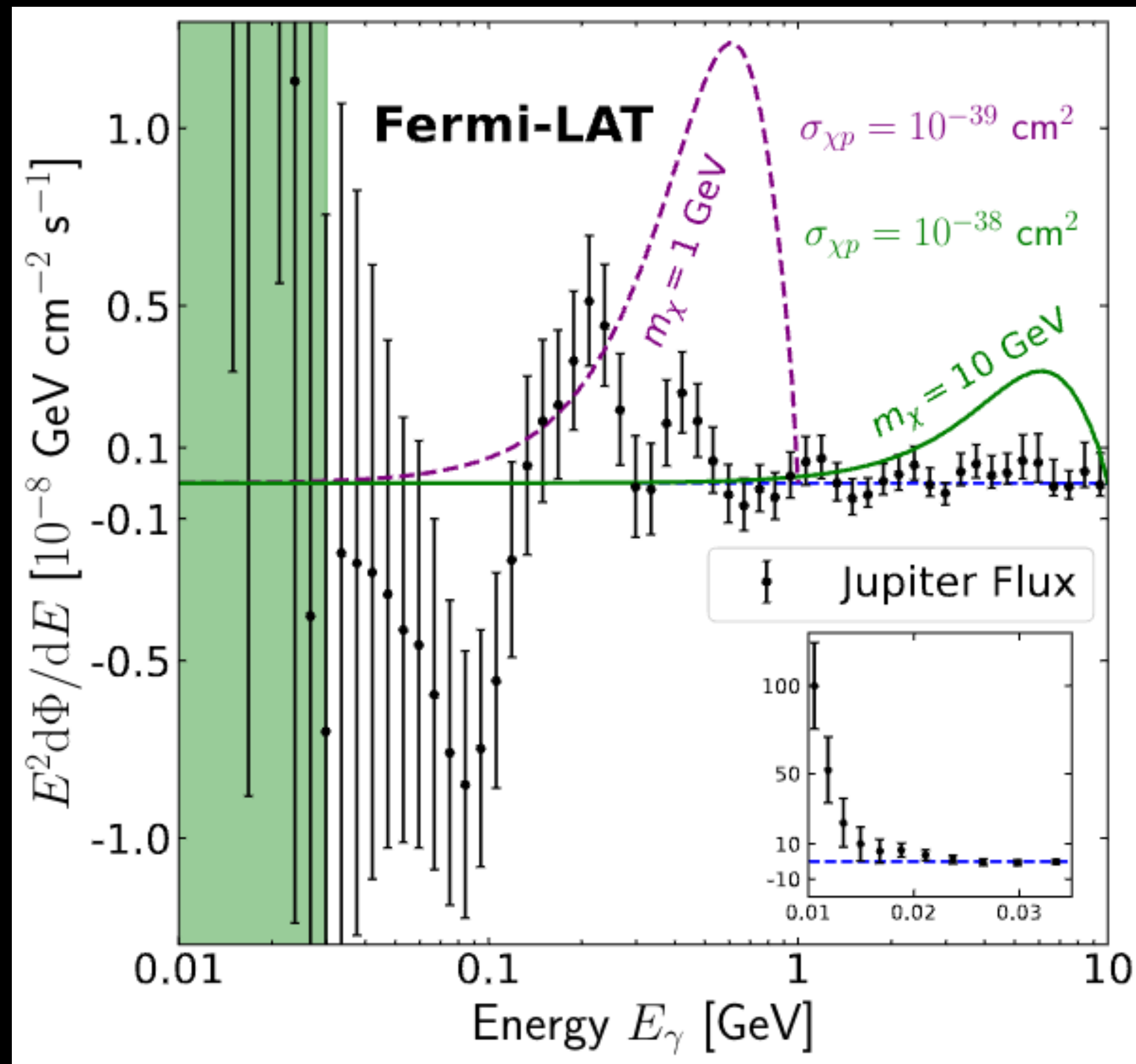
- Dark Matter scatters with nucleons inside celestial objects
- Dark Matter is captured by the celestial object.
- Captured Dark Matters annihilate to long-lived mediators (dark photons).
- Dark photons escape and decays into three photons.

Can we see these signals?

Celestial Objects in the Solar system

Celestial Objects in the Solar system

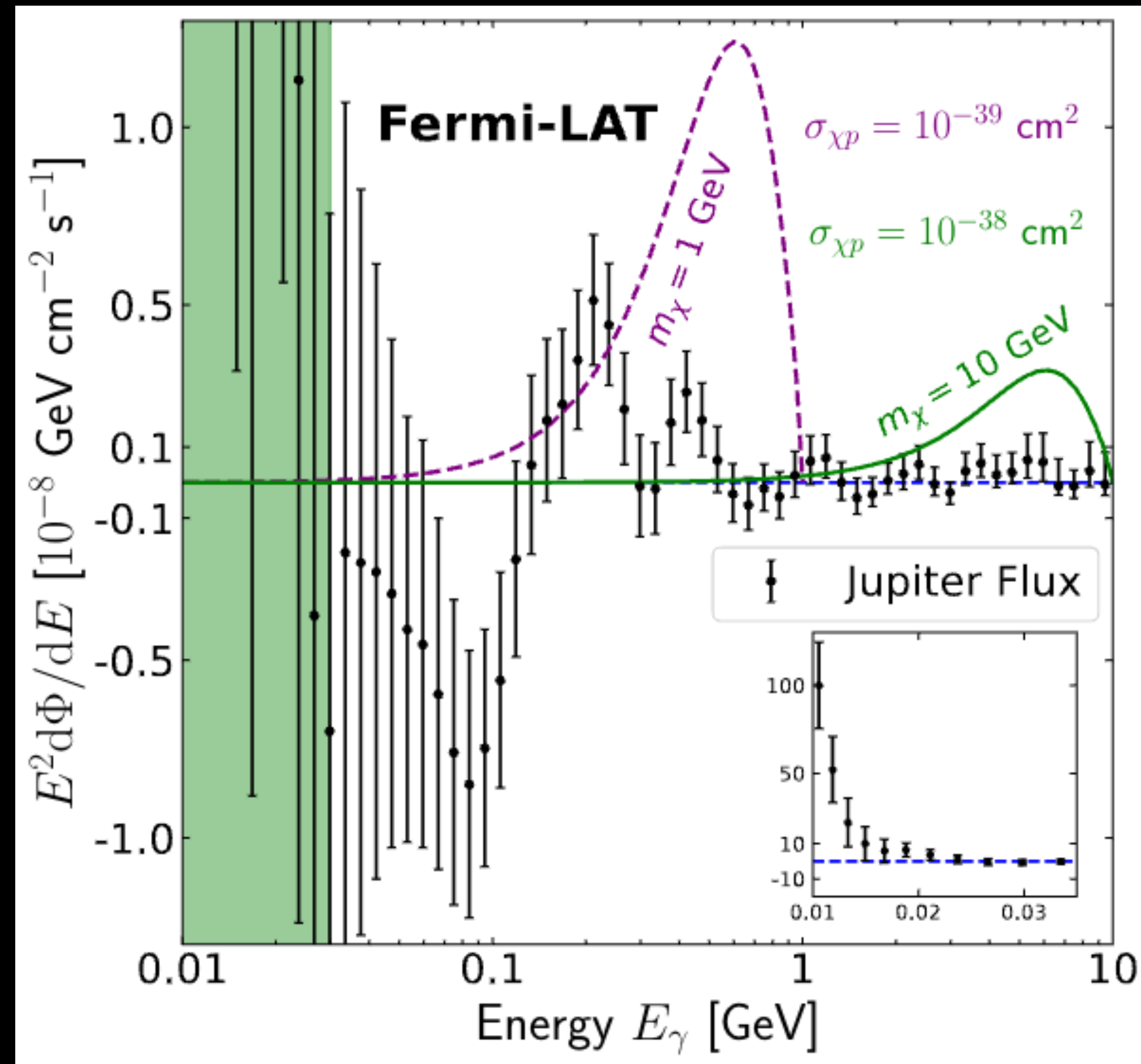
Jupiter



T. Linden, R. Leane (2104.02068)

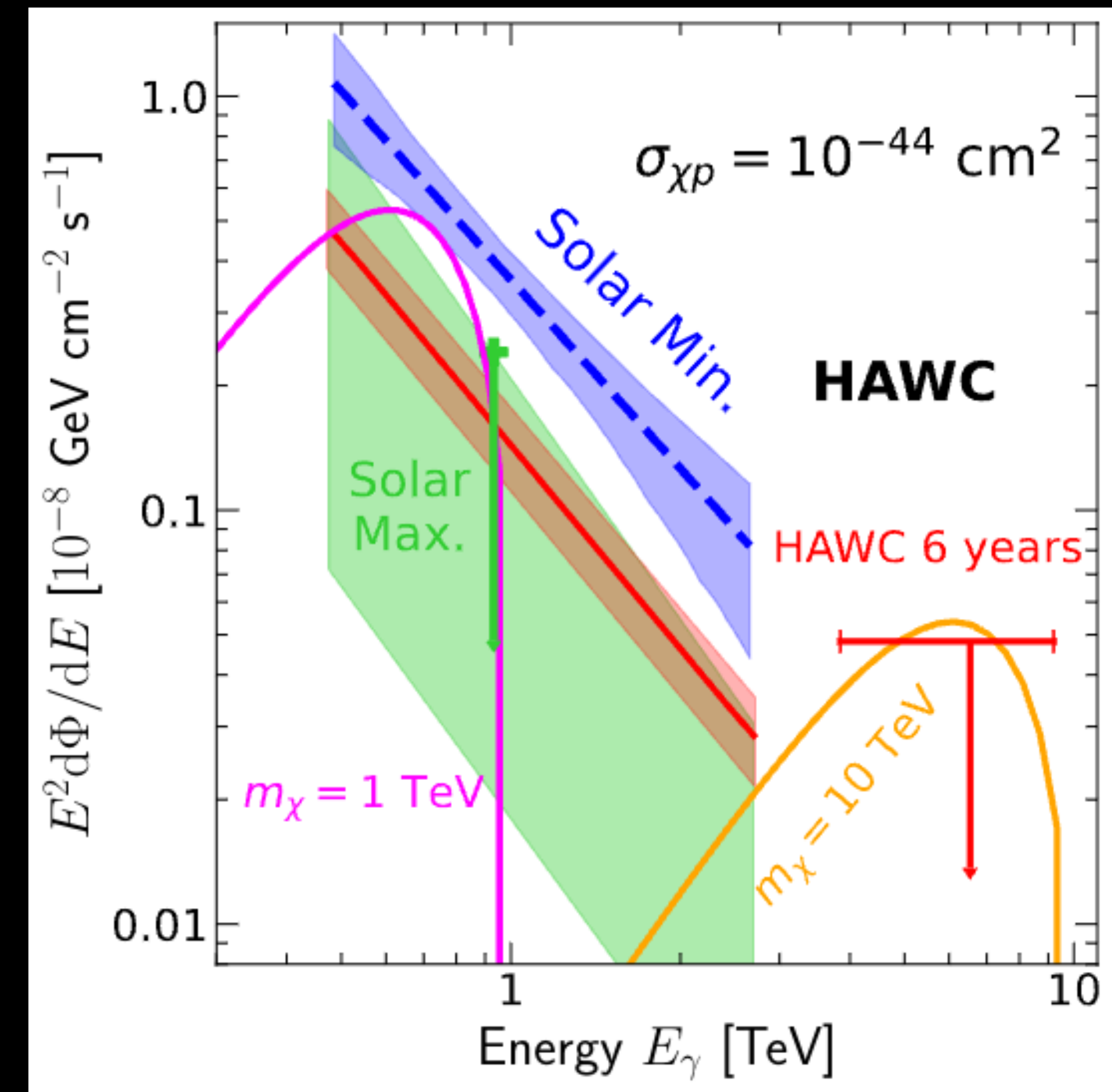
Celestial Objects in the Solar system

Jupiter



T. Linden, R. Leane (2104.02068)

The Sun



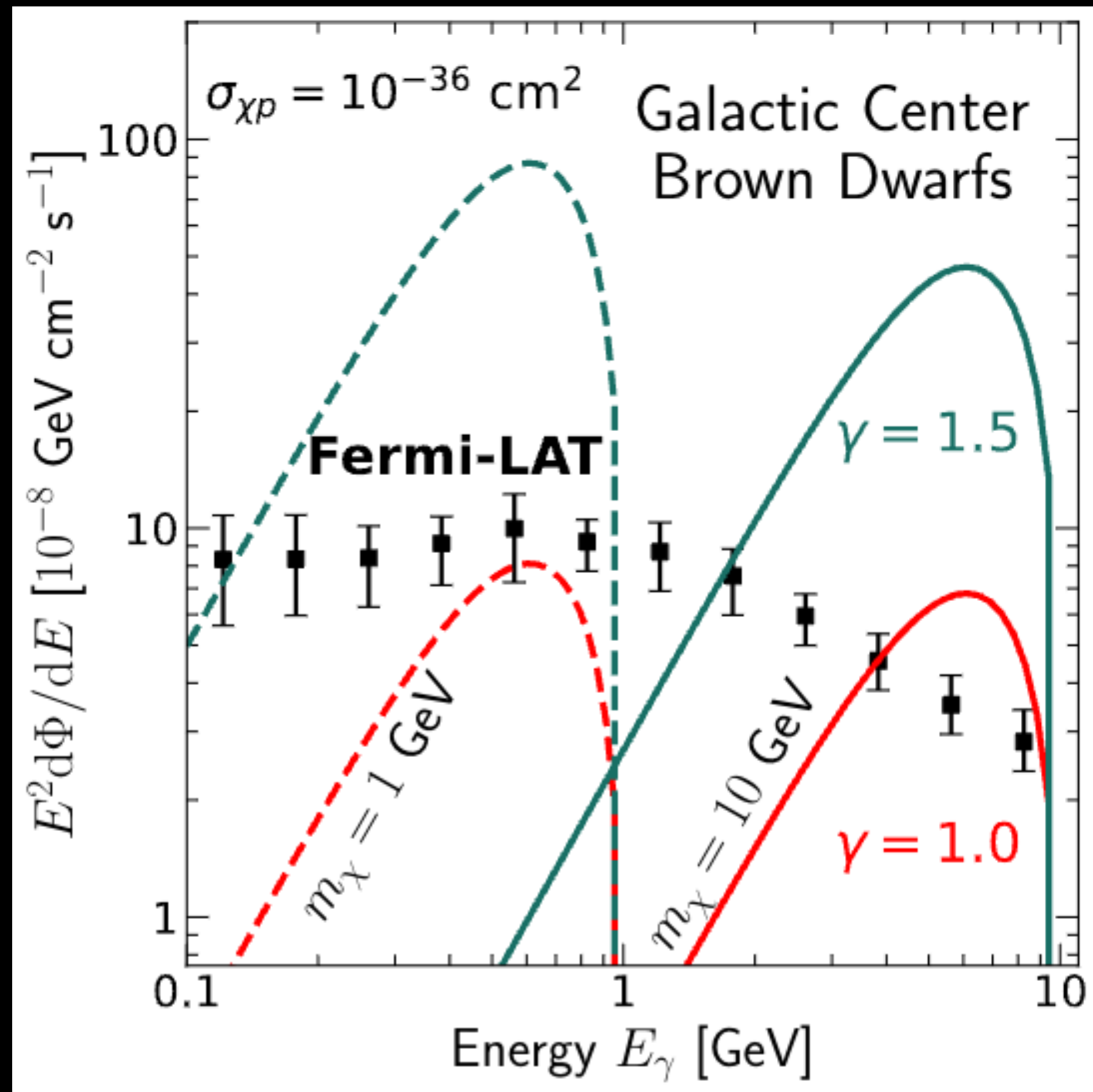
HAWC Collaboration (2212.00815)

Galactic Center Region

R. Leane, T. Linden, P. Mukhopadhyay, N. Toro (2101.12213)

Galactic Center Region

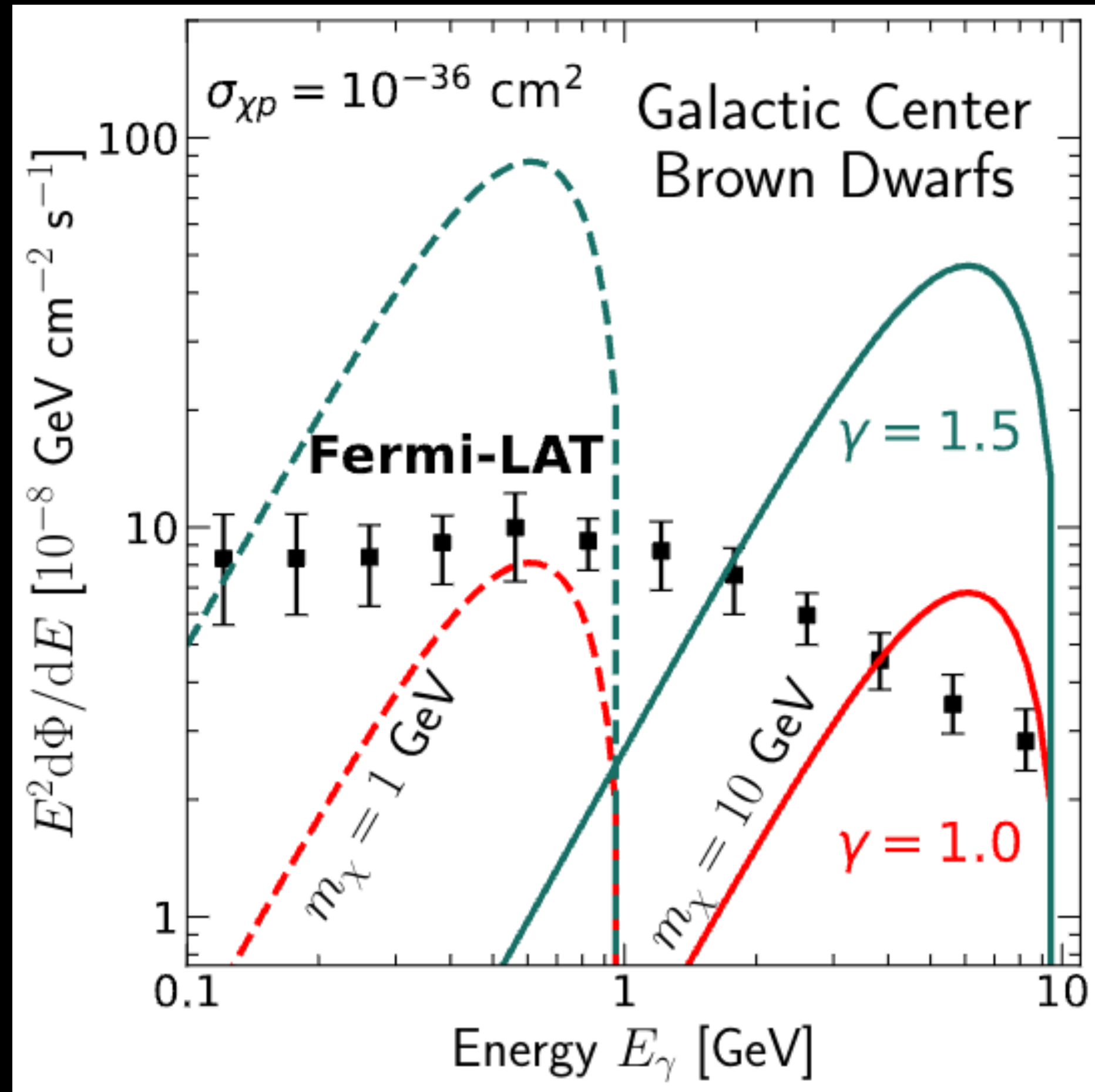
Brown Dwarfs



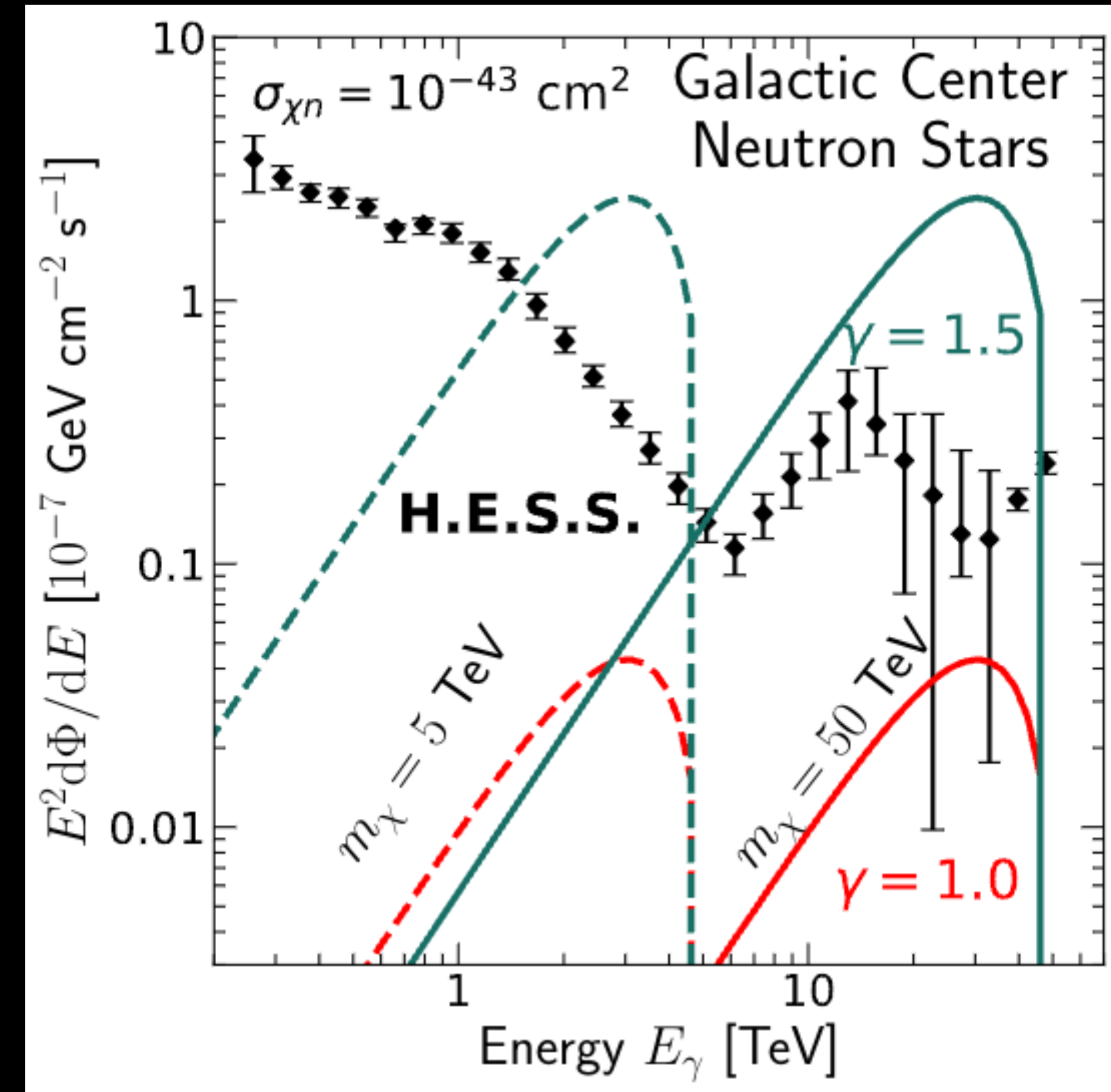
R. Leane, T. Linden, P. Mukhopadhyay, N. Toro (2101.12213)

Galactic Center Region

Brown Dwarfs



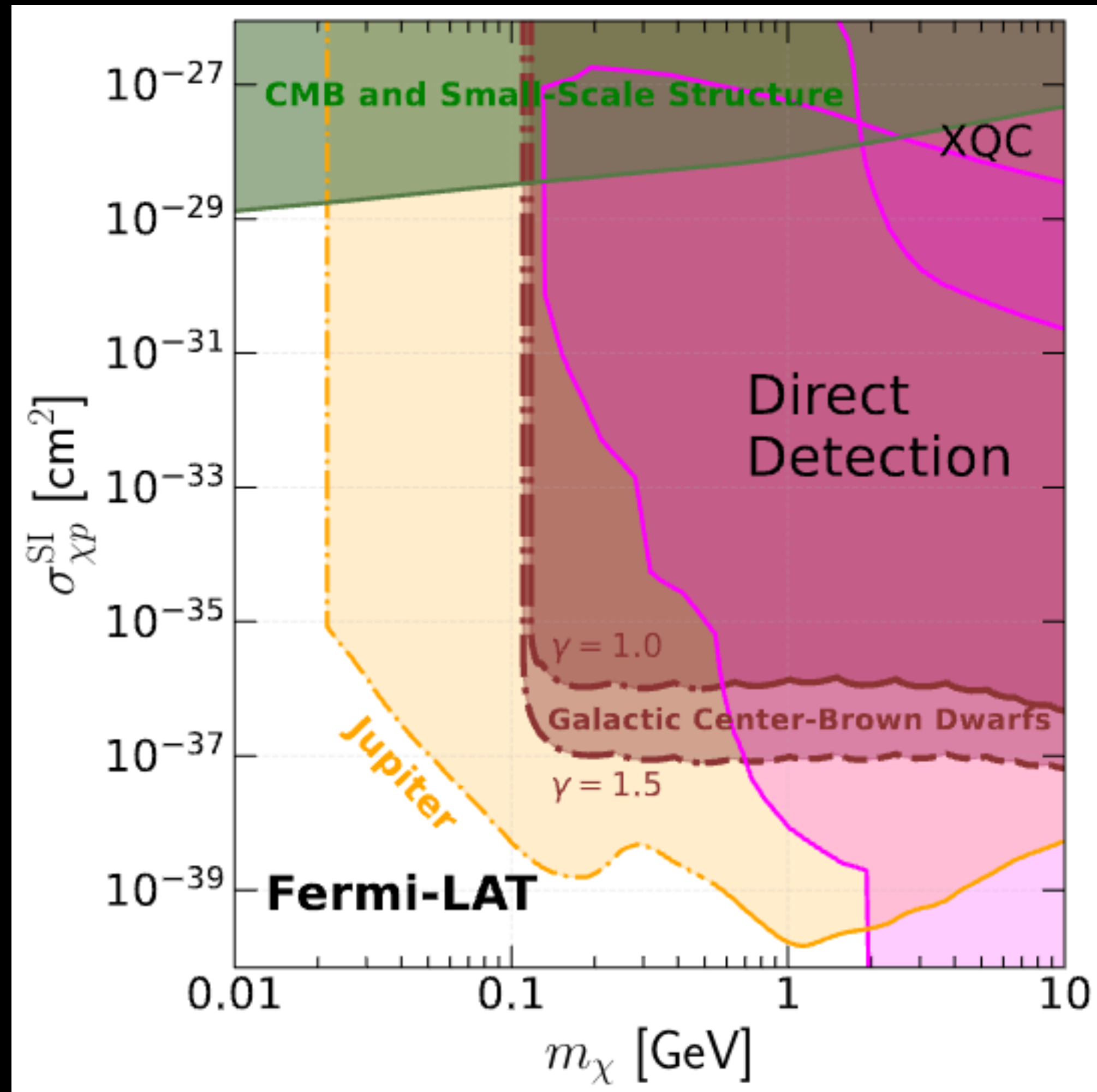
Neutron Stars



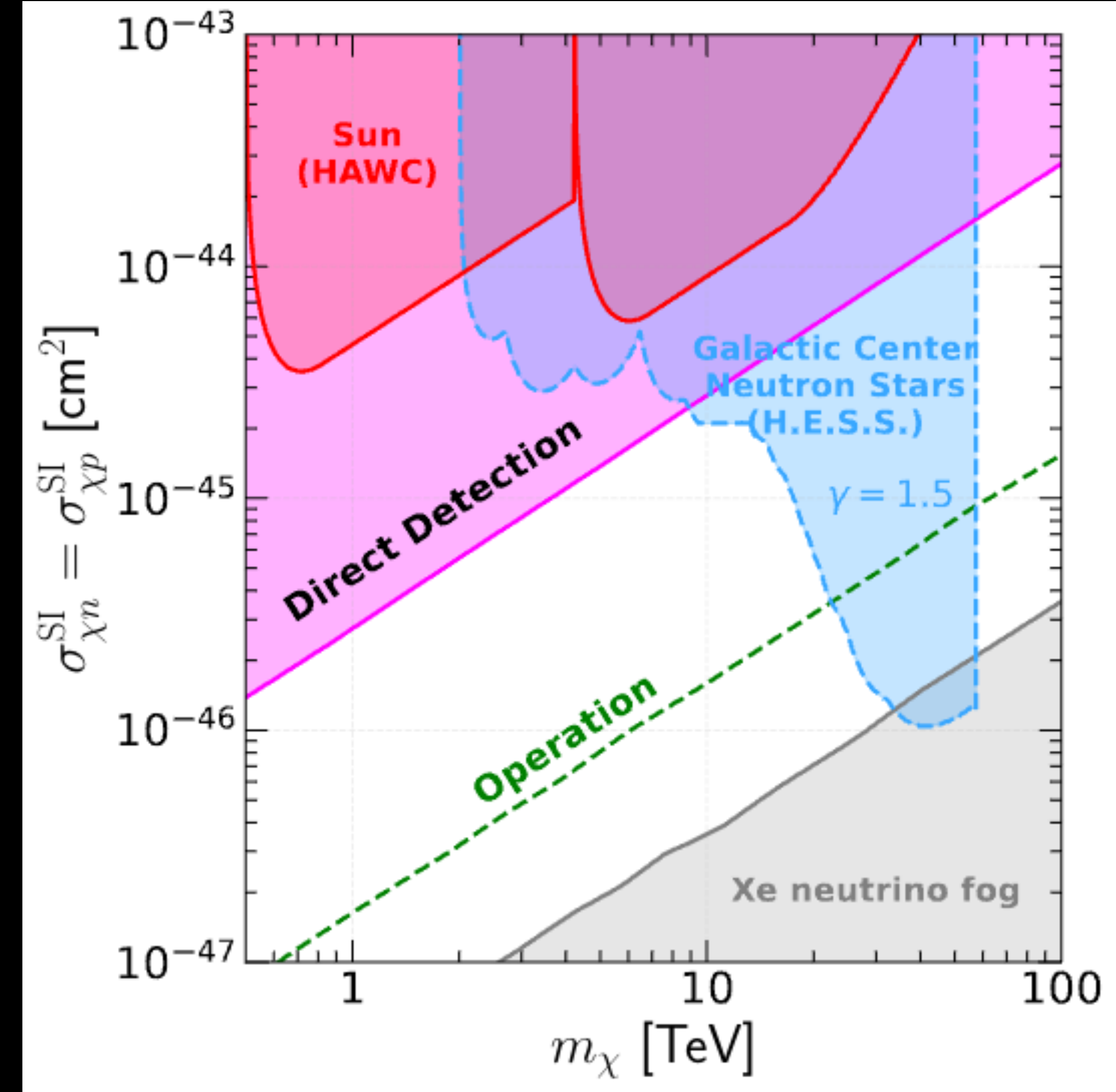
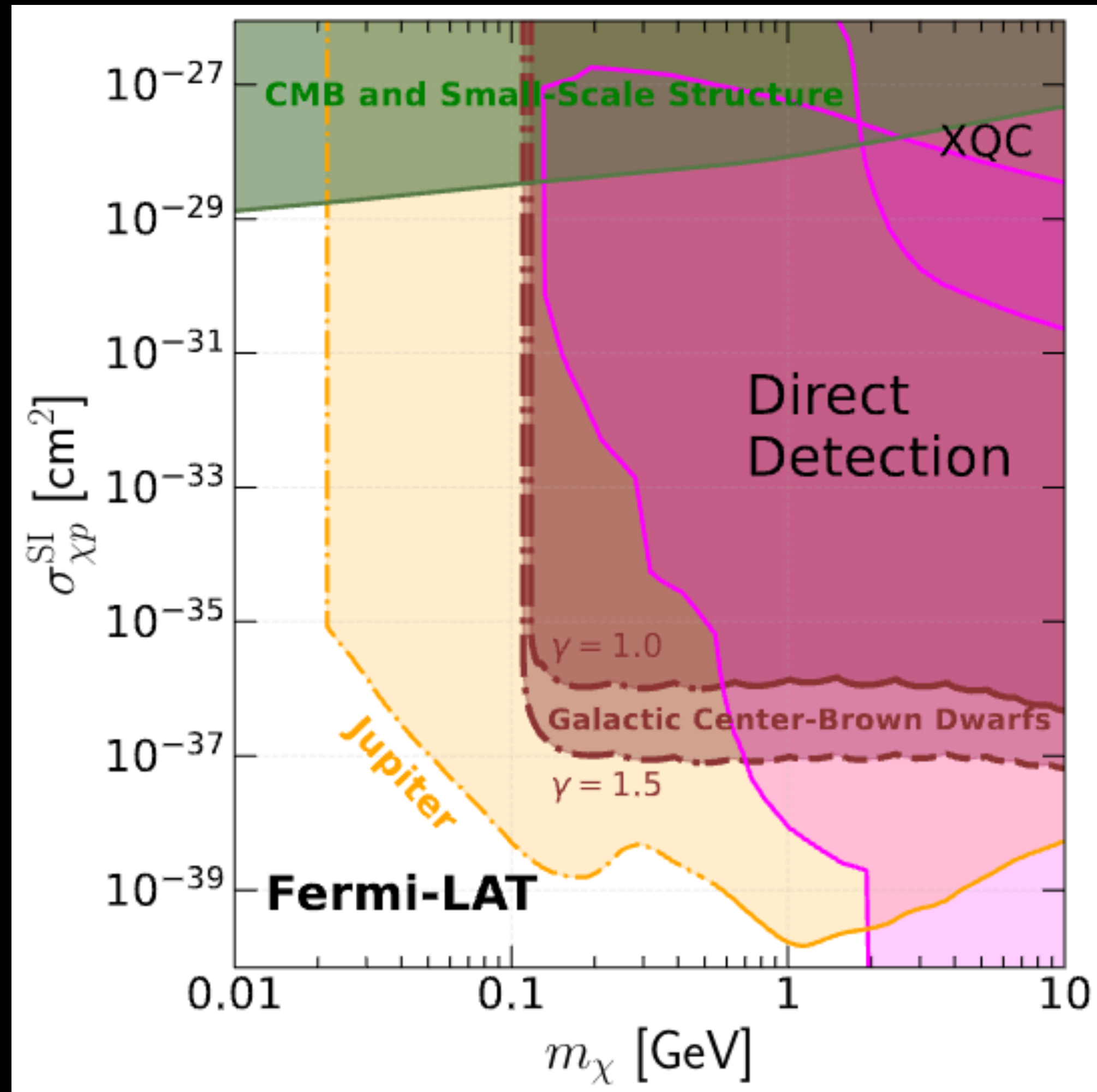
R. Leane, T. Linden, P. Mukhopadhyay, N. Toro (2101.12213)

Bounds on DM-nucleon cross section

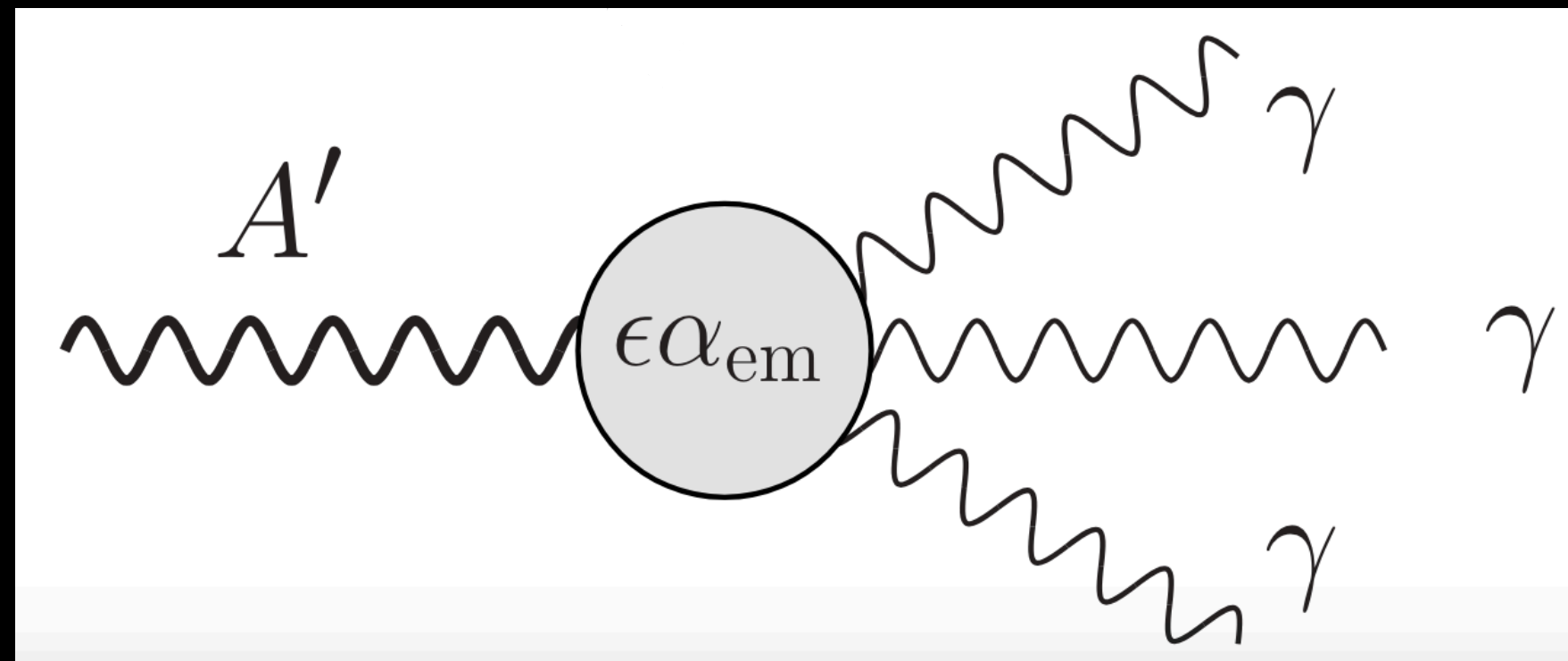
Bounds on DM-nucleon cross section



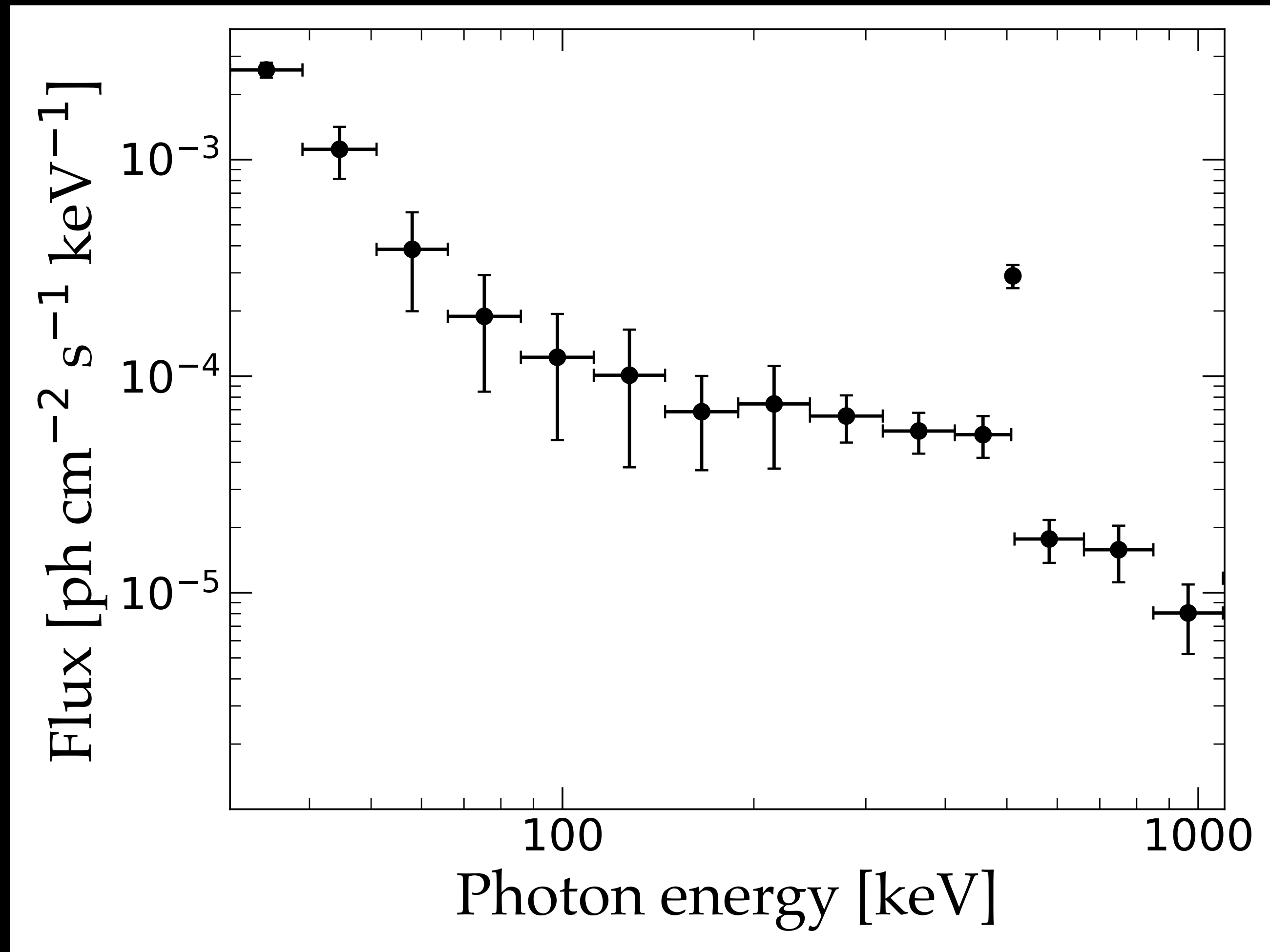
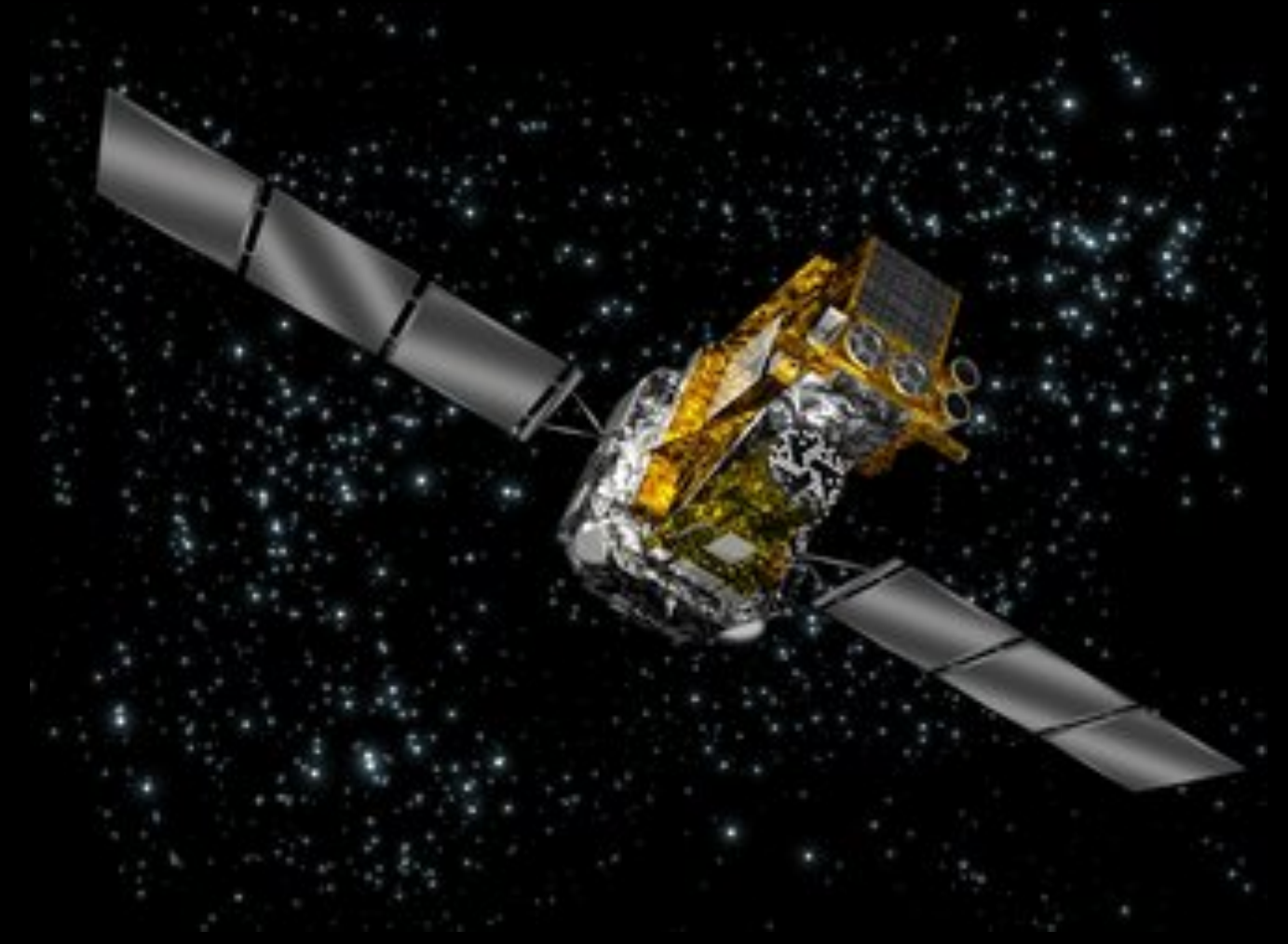
Bounds on DM-nucleon cross section



Dark Photon Dark Matter



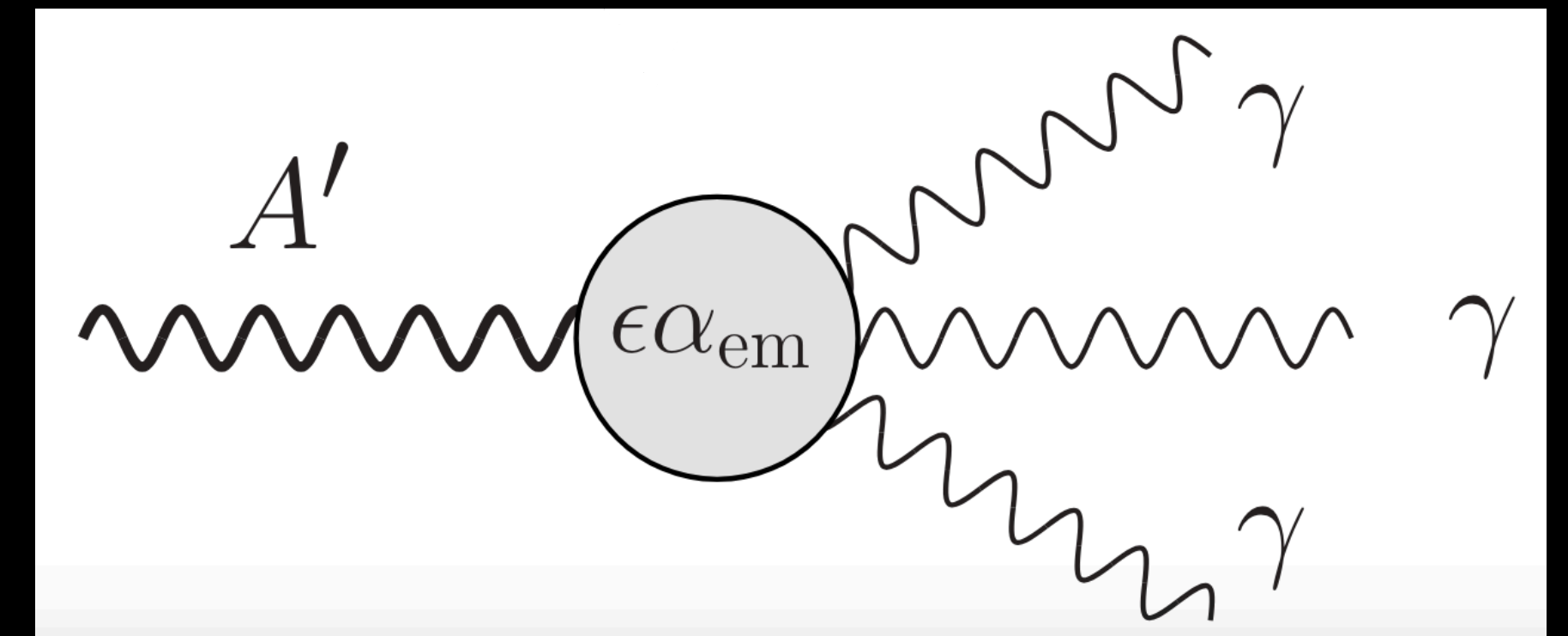
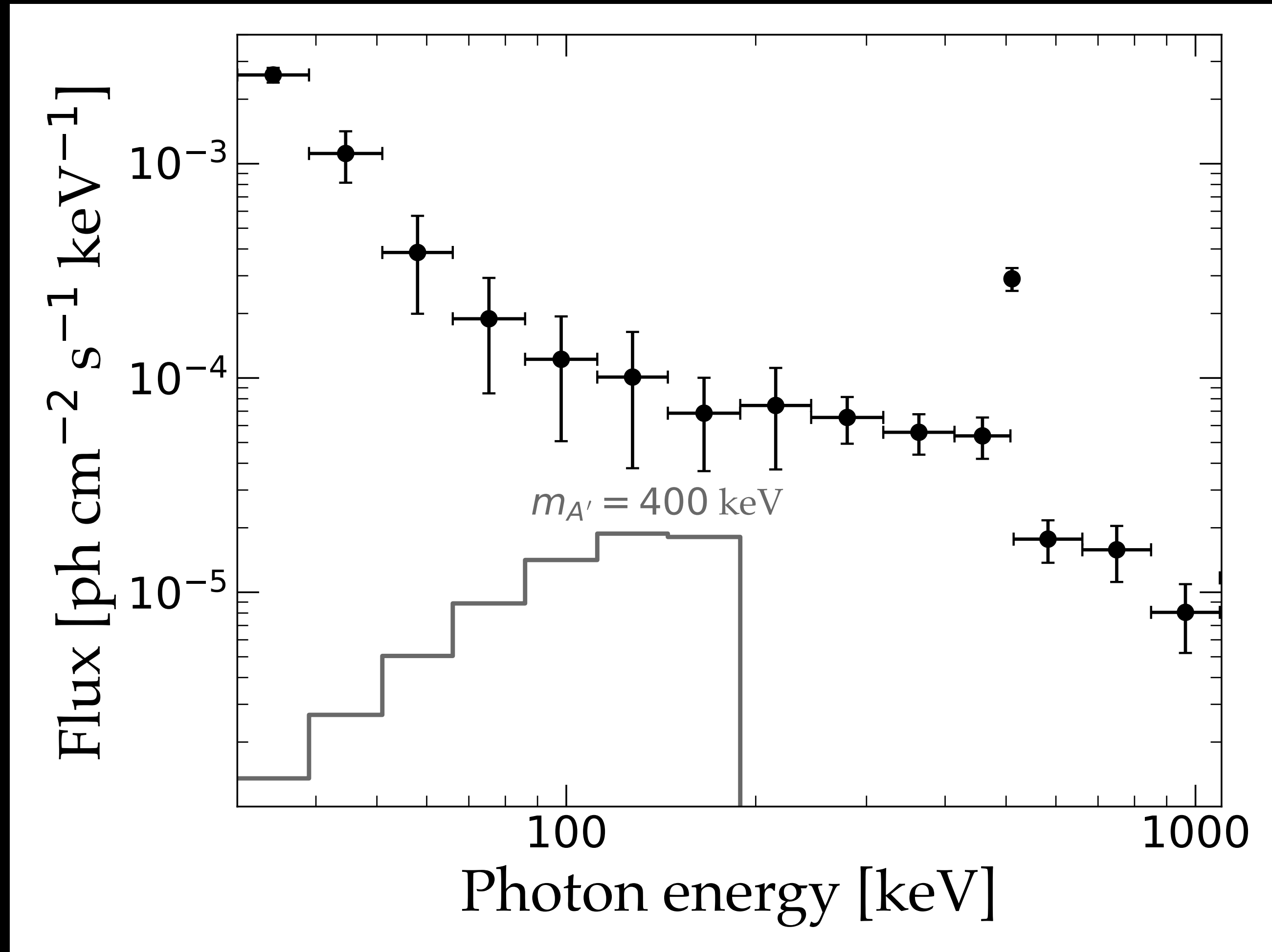
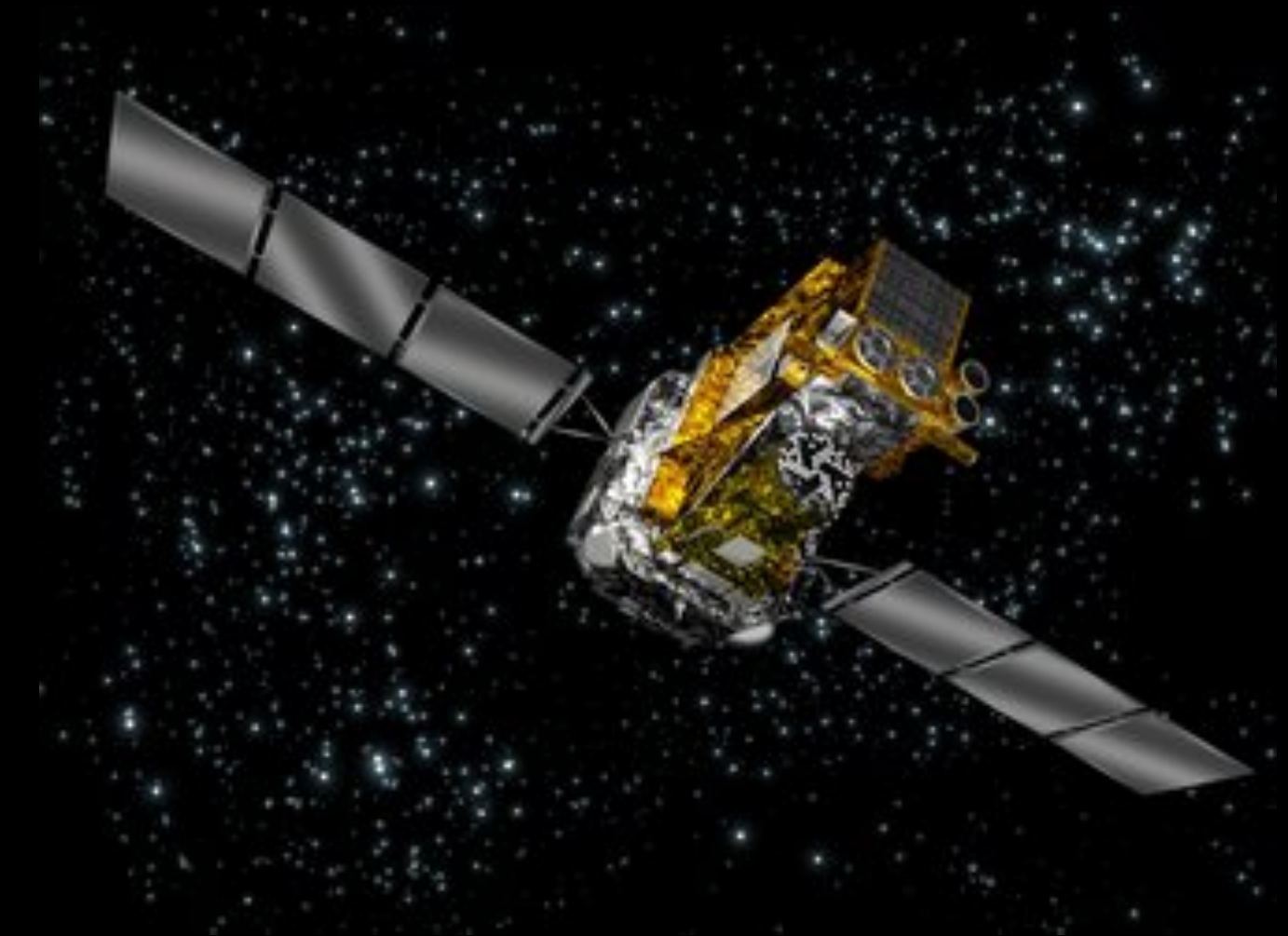
INTEGRAL/SPI 16 years-data



Tool: 3ML (1507.08343)

Template: Thomas Siegert, Francesca Calore, and collaborators (2209.06299, 2202.07483)

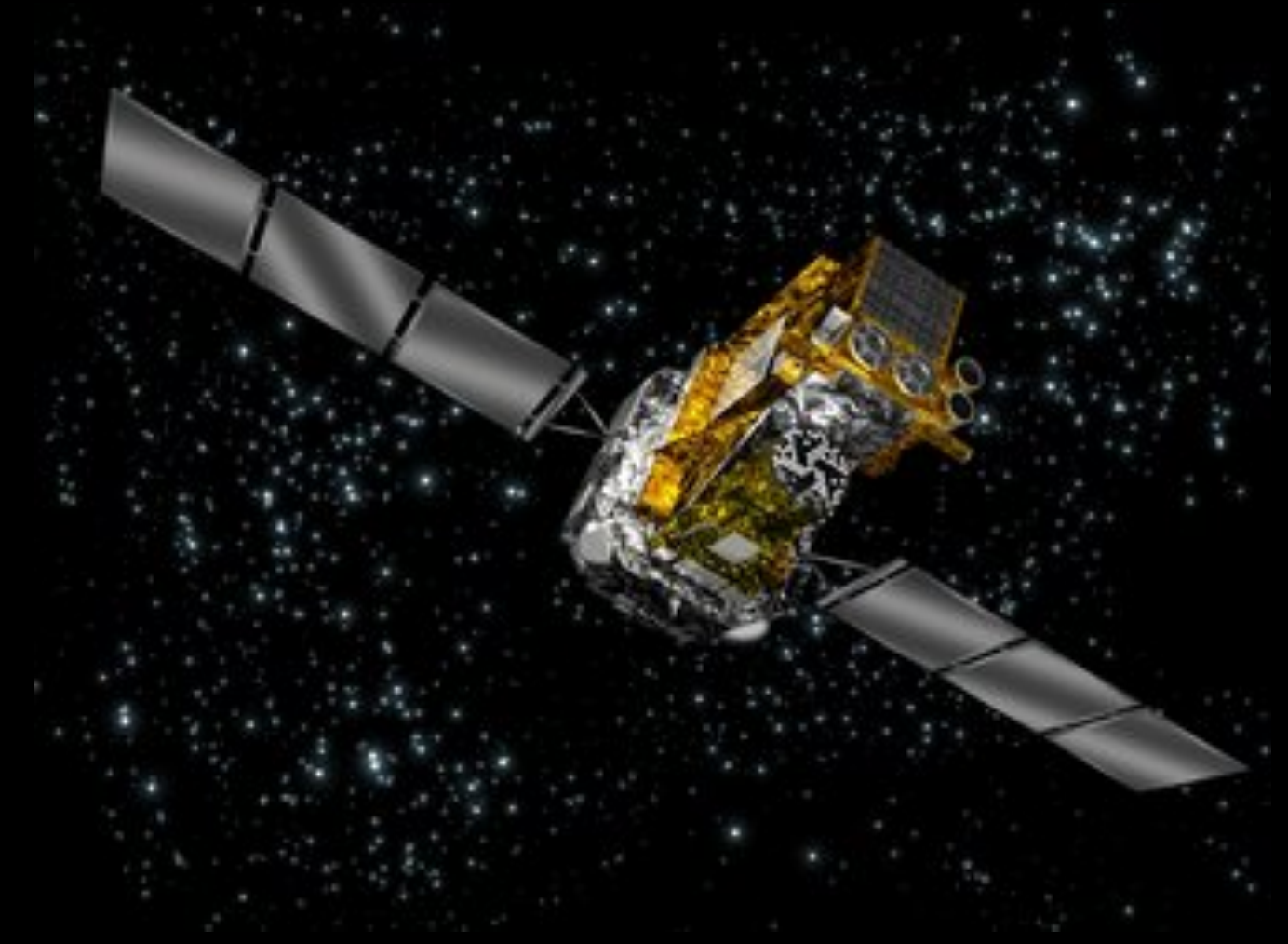
INTEGRAL/SPI 16 years-data



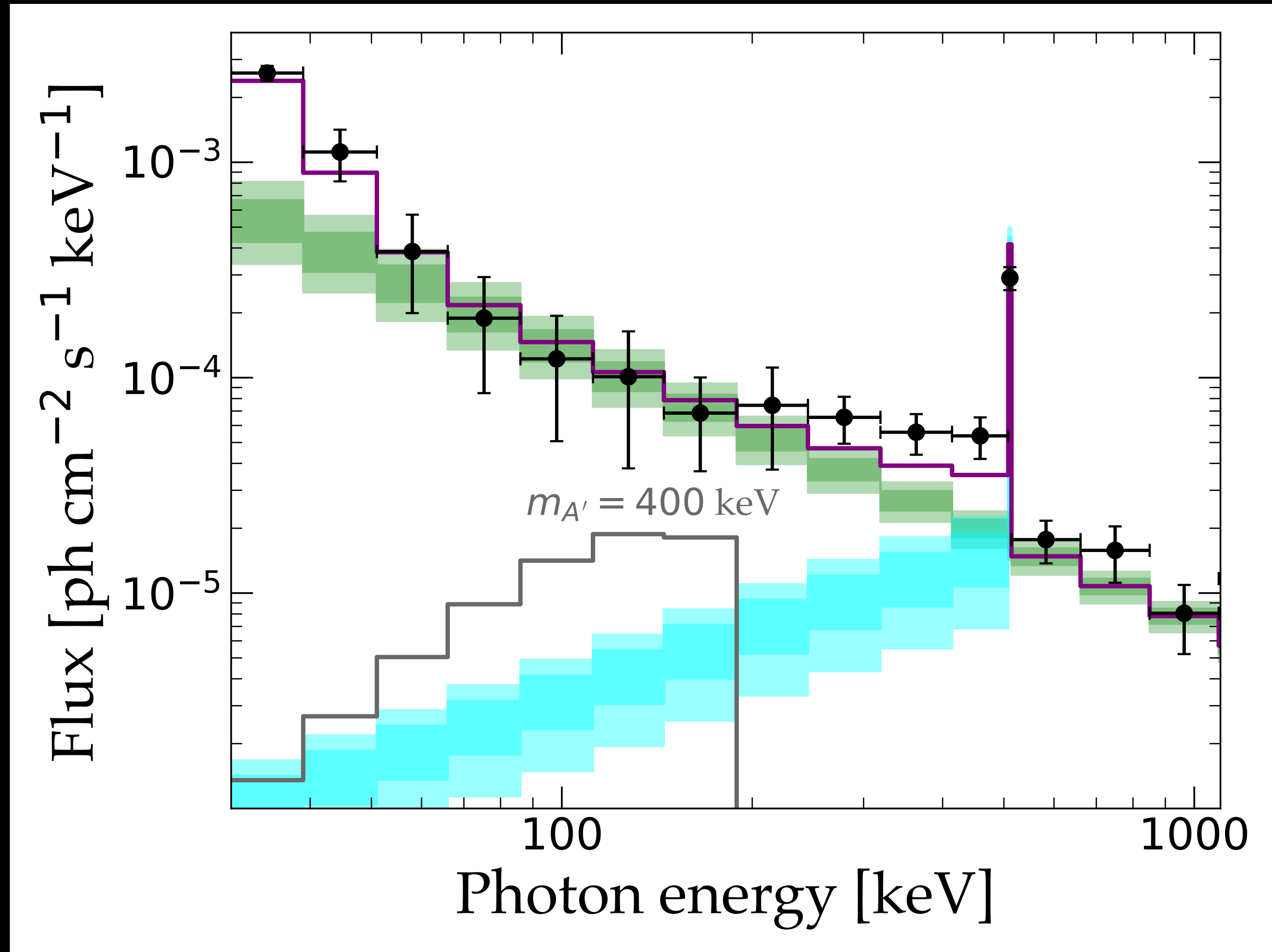
Tool: 3ML (1507.08343)

Template: Thomas Siebert, Francesca Calore, and collaborators (2209.06299, 2202.07483)

INTEGRAL/SPI 16 years-data



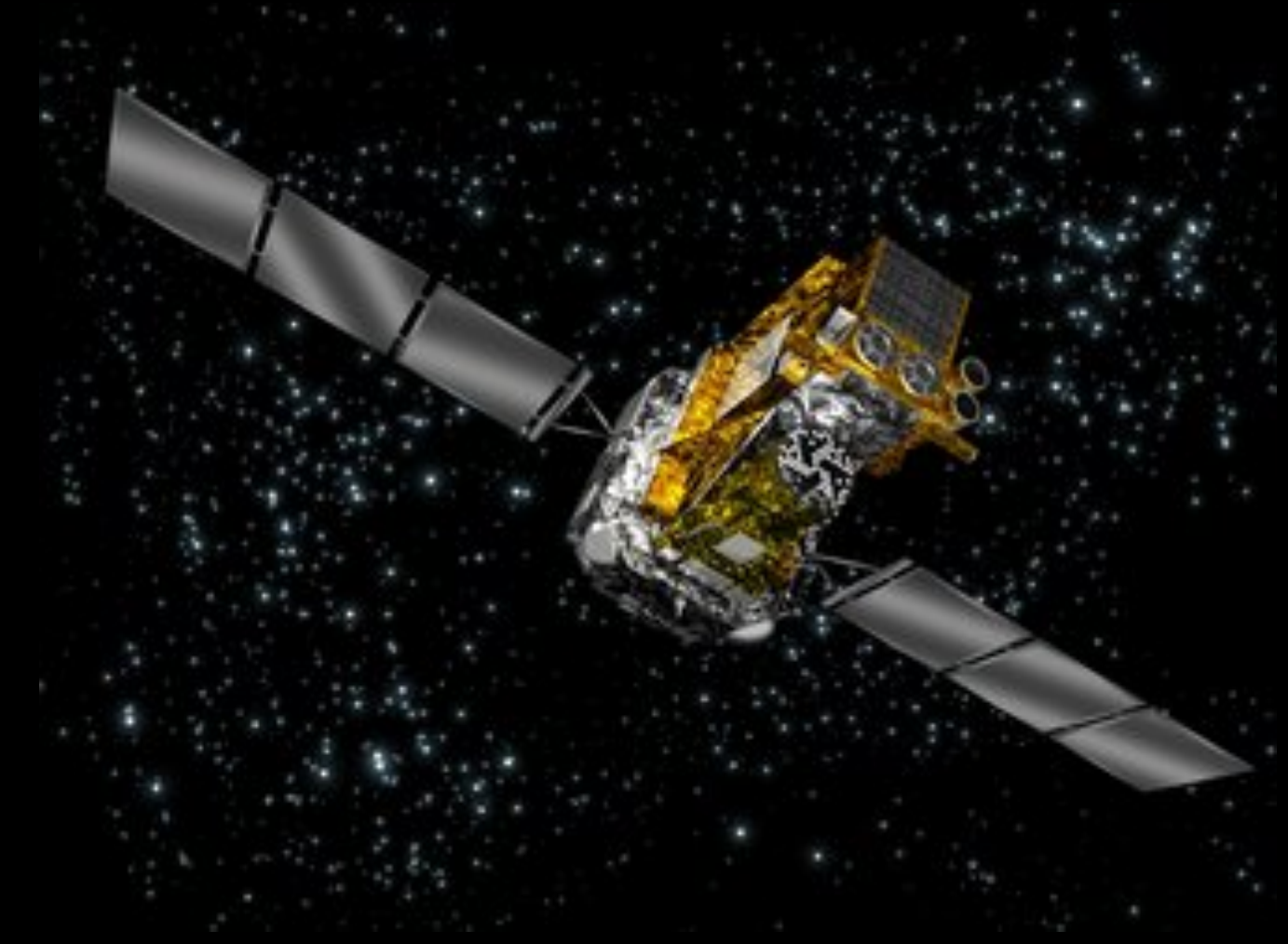
- **Unresolved sources**



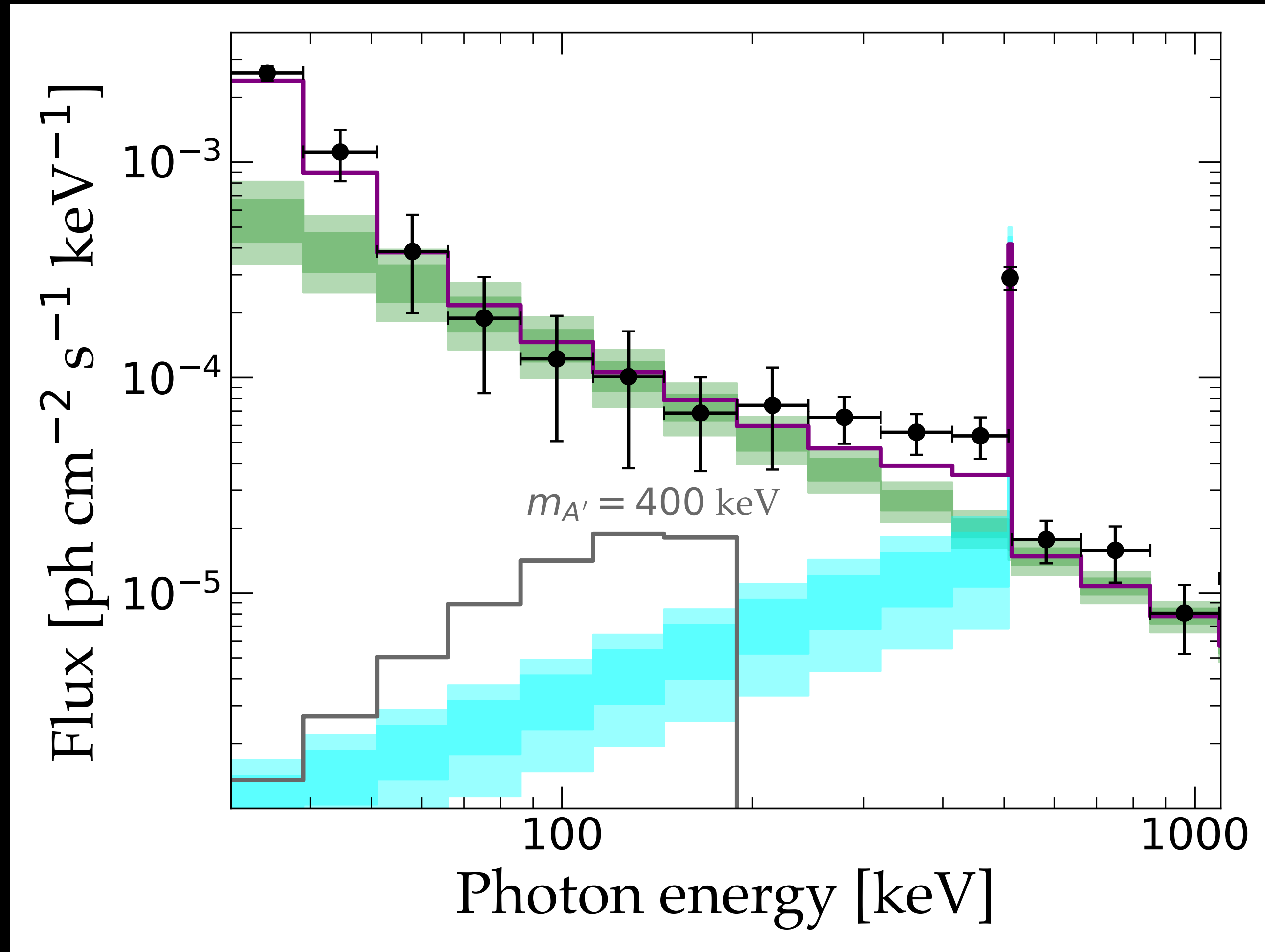
Tool: 3ML (1507.08343)

Template: Thomas Siegert, Francesca Calore, and collaborators (2209.06299, 2202.07483)

INTEGRAL/SPI 16 years-data



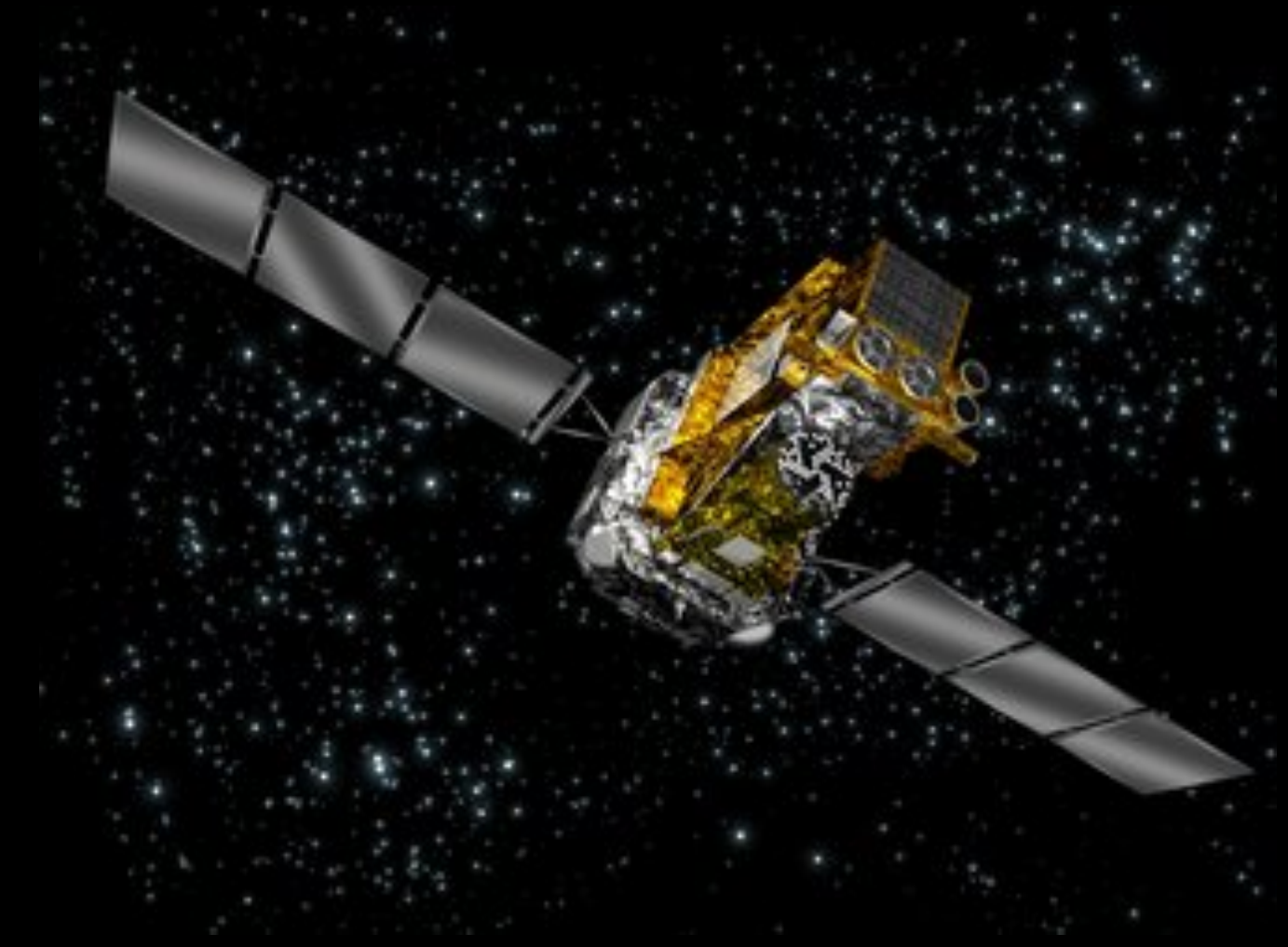
- **Unresolved sources**
- **Inverse Compton Scattering**



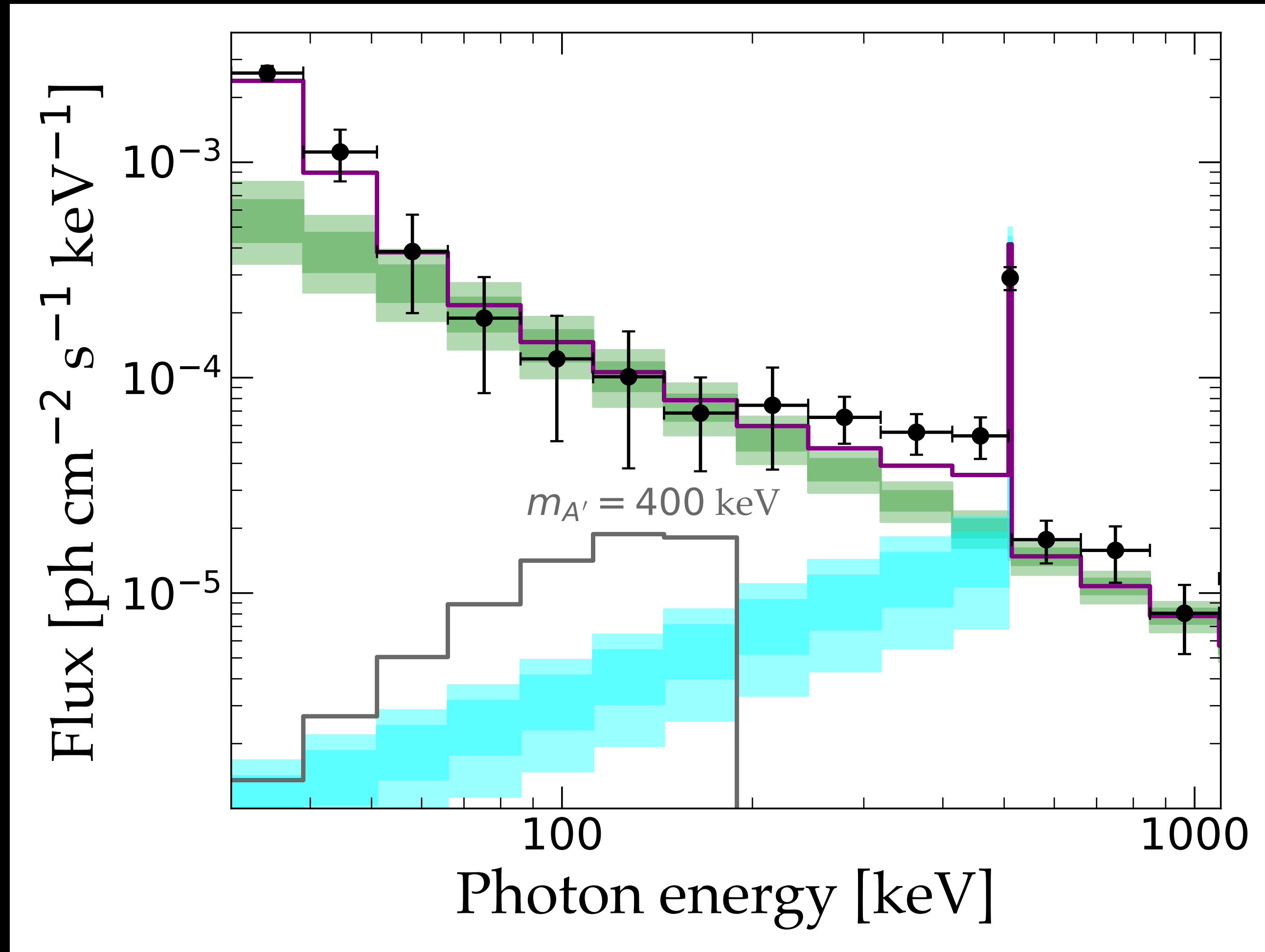
Tool: 3ML (1507.08343)

Template: Thomas Siegert, Francesca Calore, and collaborators (2209.06299, 2202.07483)

INTEGRAL/SPI 16 years-data



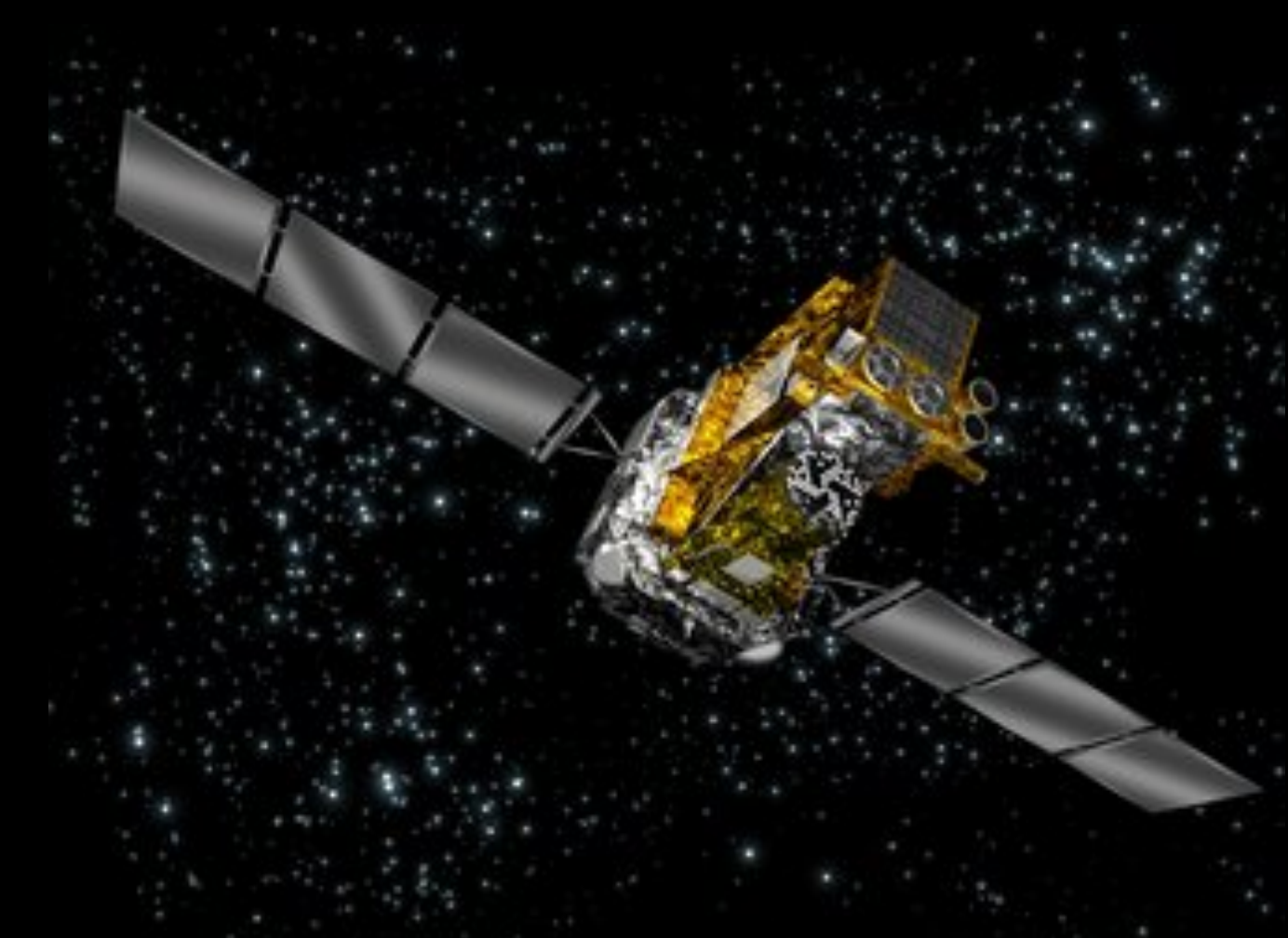
- **Unresolved sources**
- **Inverse Compton Scattering**
- **Positronium decay**



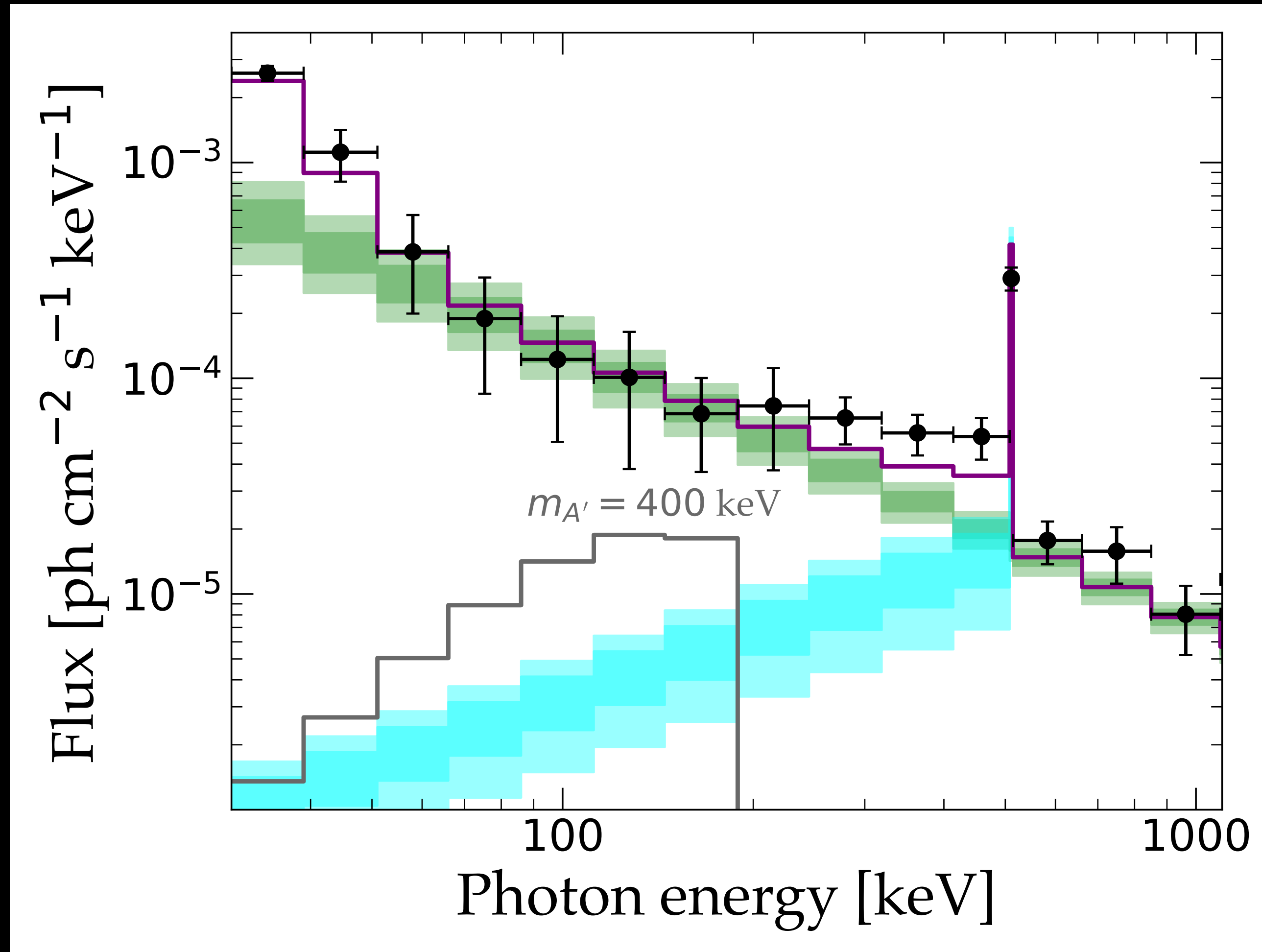
Tool: 3ML (1507.08343)

Template: Thomas Siegert, Francesca Calore, and collaborators (2209.06299, 2202.07483)

INTEGRAL/SPI 16 years-data



- **Unresolved sources**
- **Inverse Compton Scattering**
- **Positronium decay**
- **^7Be nuclear line**



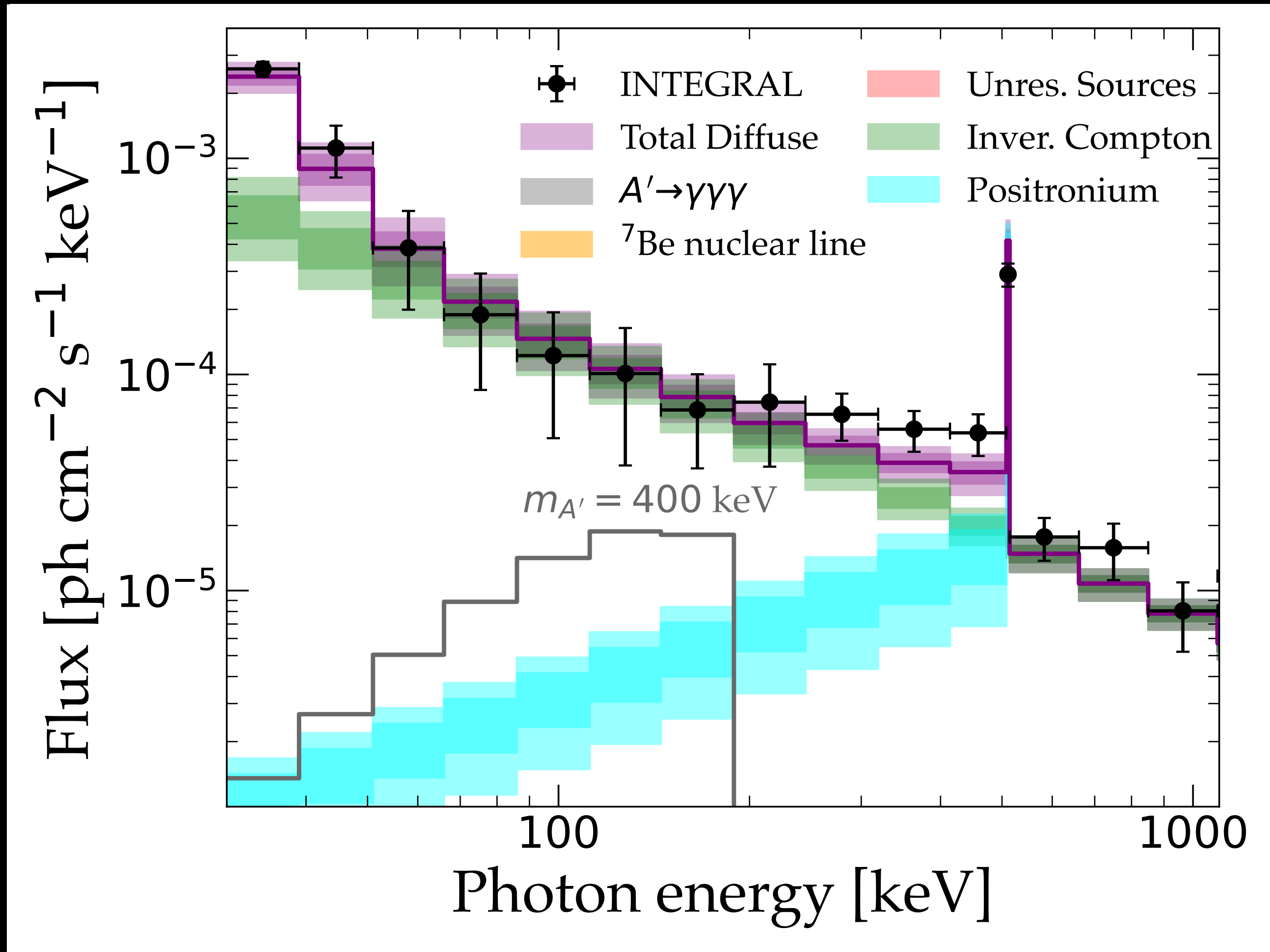
Tool: 3ML (1507.08343)

Template: Thomas Siegert, Francesca Calore, and collaborators (2209.06299, 2202.07483)

INTEGRAL/SPI 16 years-data



Nominated by INTEGRAL
and European Space Astronomy
Center (ESAC)
for Picture of the Month!

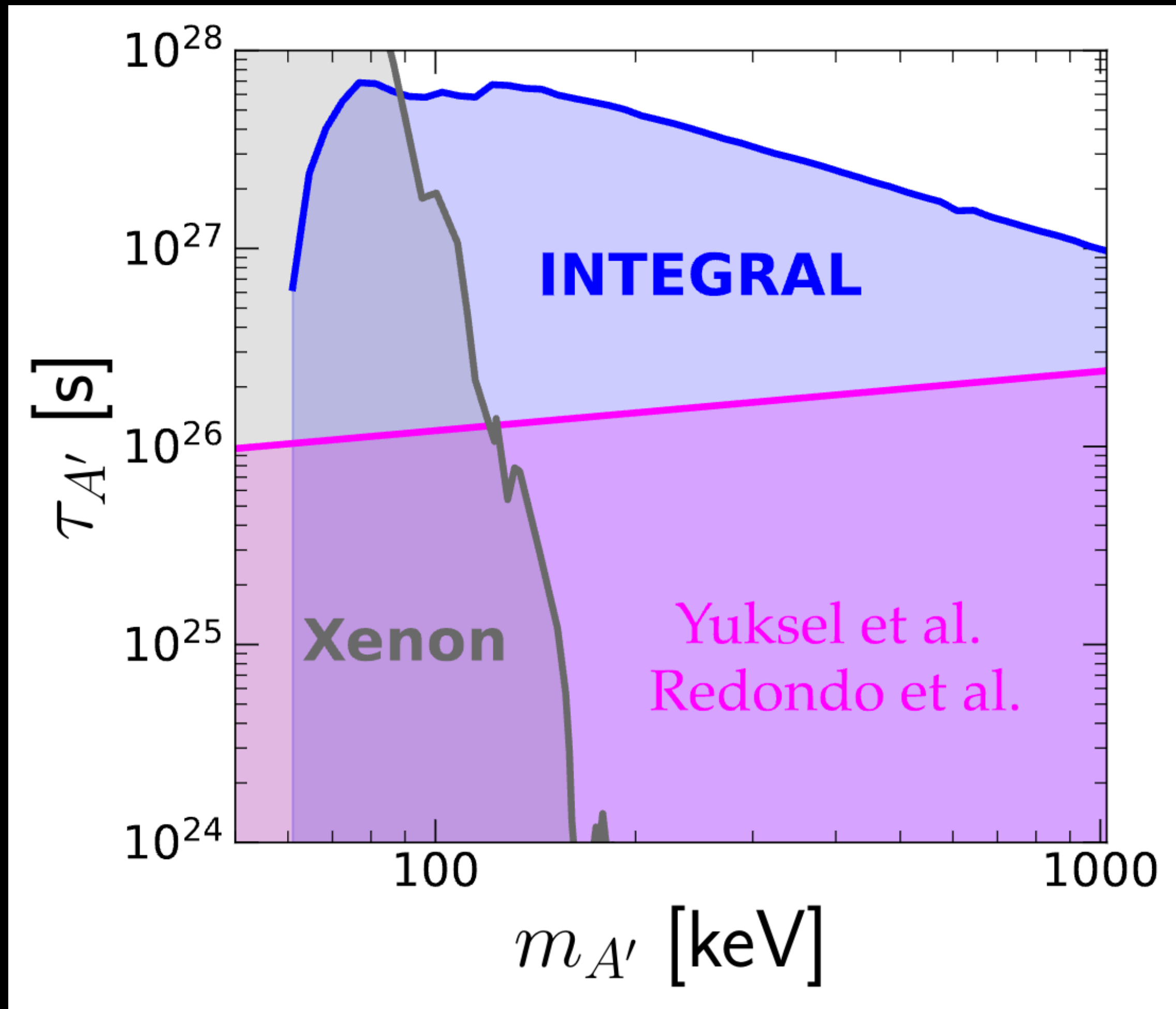


Tool: 3ML (1507.08343)

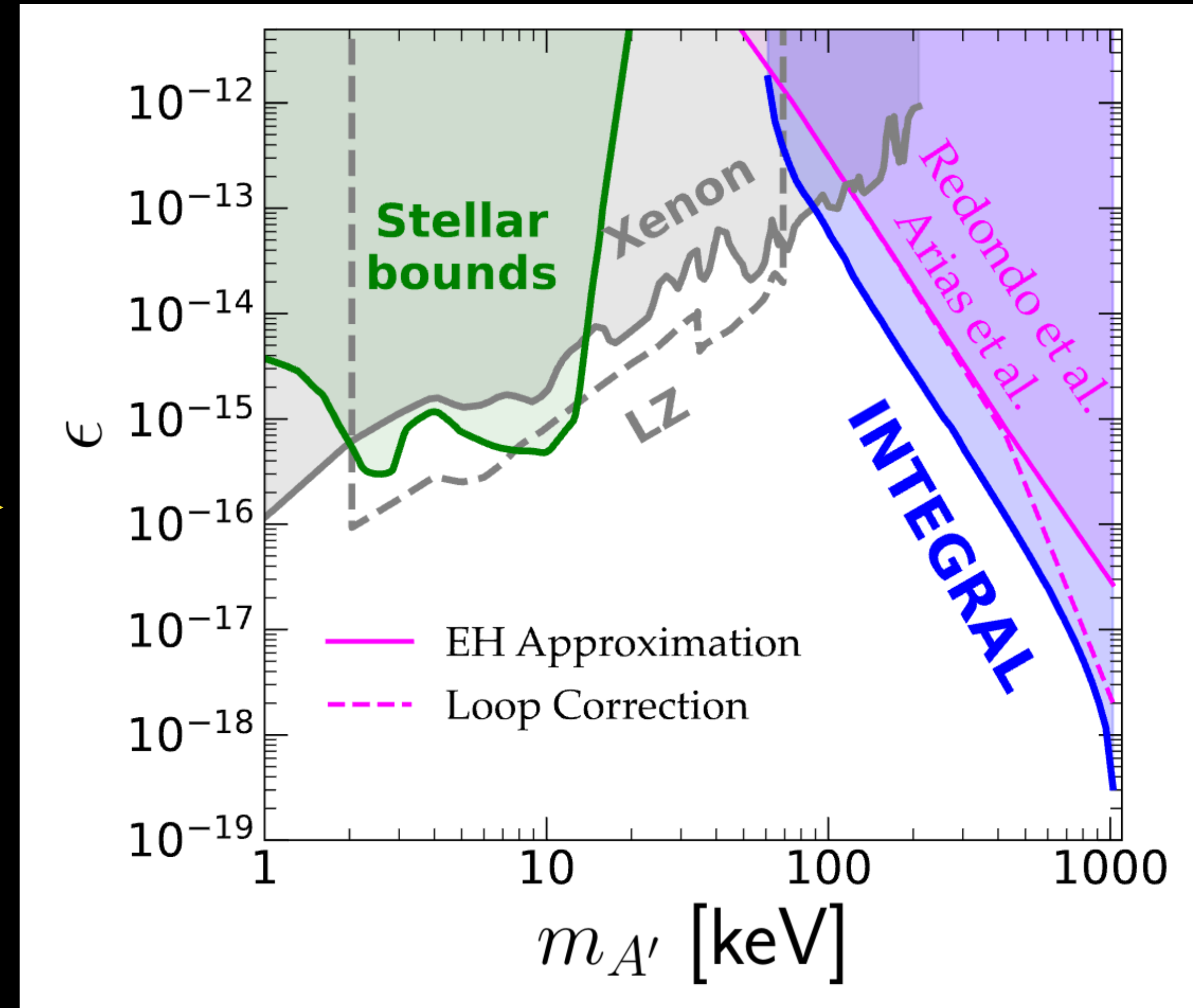
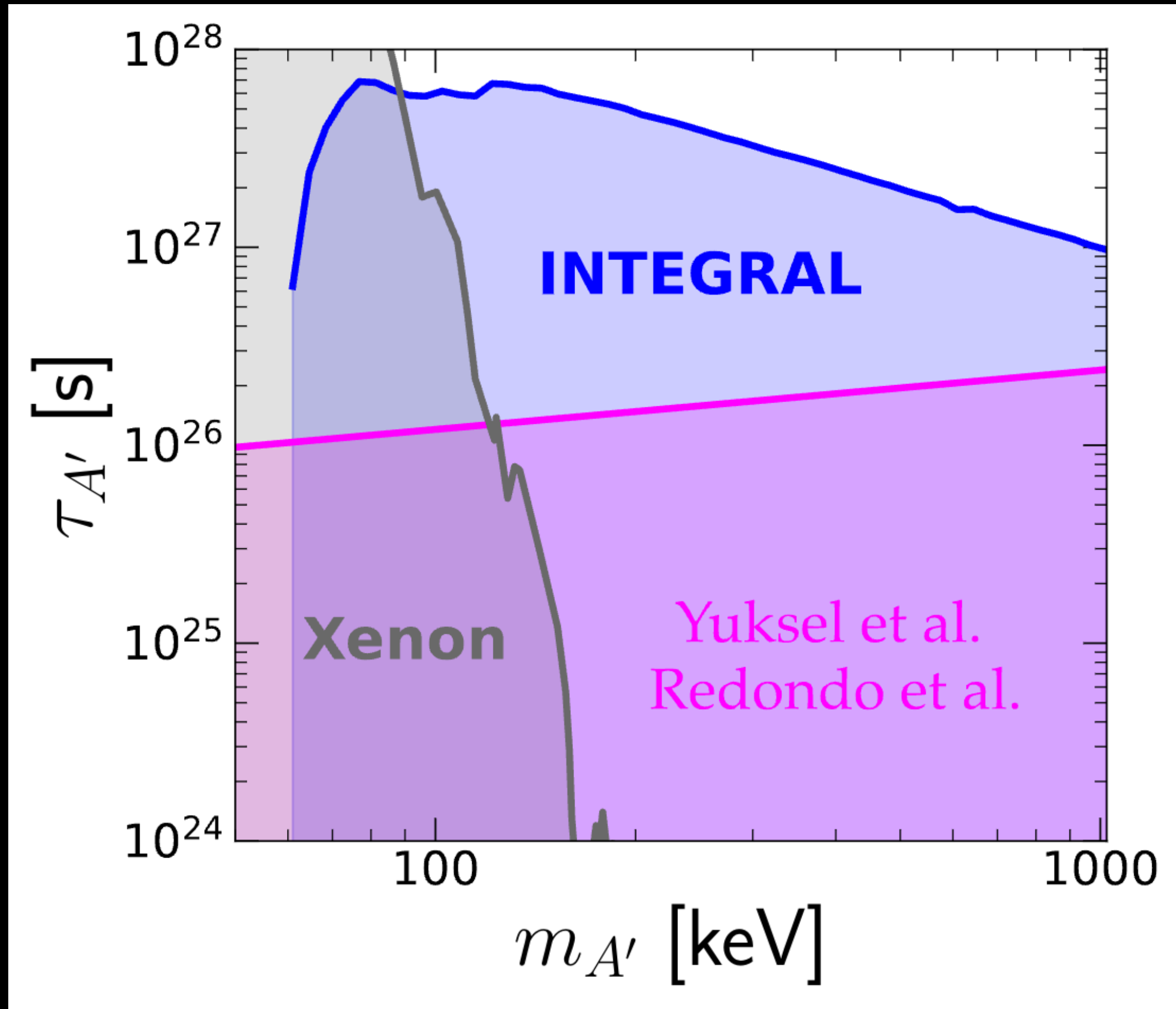
Template: Thomas Siegert, Francesca Calore, and collaborators (2209.06299, 2202.07483)

New Constraints on the Dark Photon

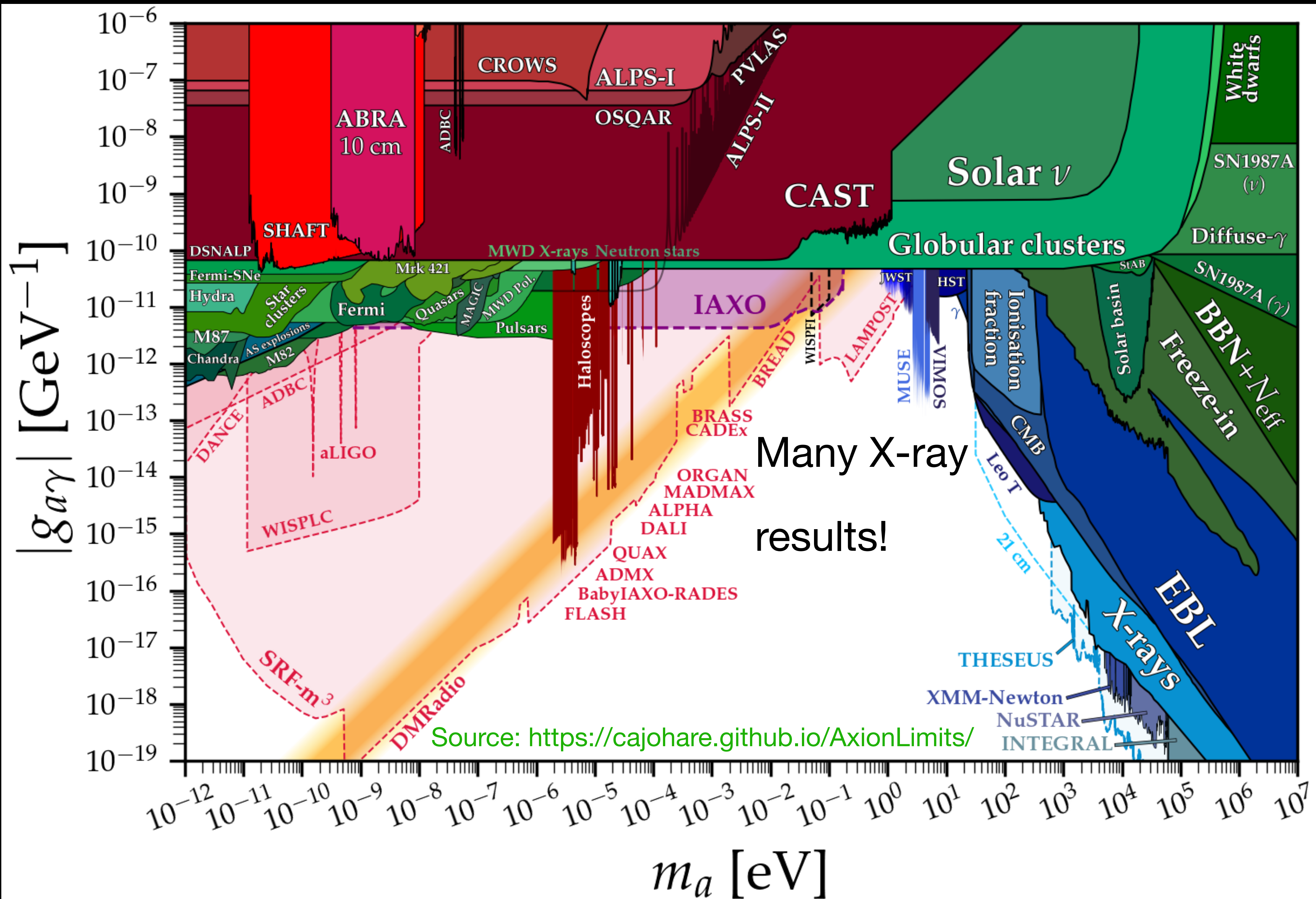
New Constraints on the Dark Photon



New Constraints on the Dark Photon



Any future for DPDM?



Take home message

- **Dark Photon is cool!**
- **Indirect detection is cool!**
- **On-going and future observations can probe more parameter space of this dark photon model, and other BSM scenarios as well!**

Thank you for listening!

Chiao is searching
for Dog-matter
too!

