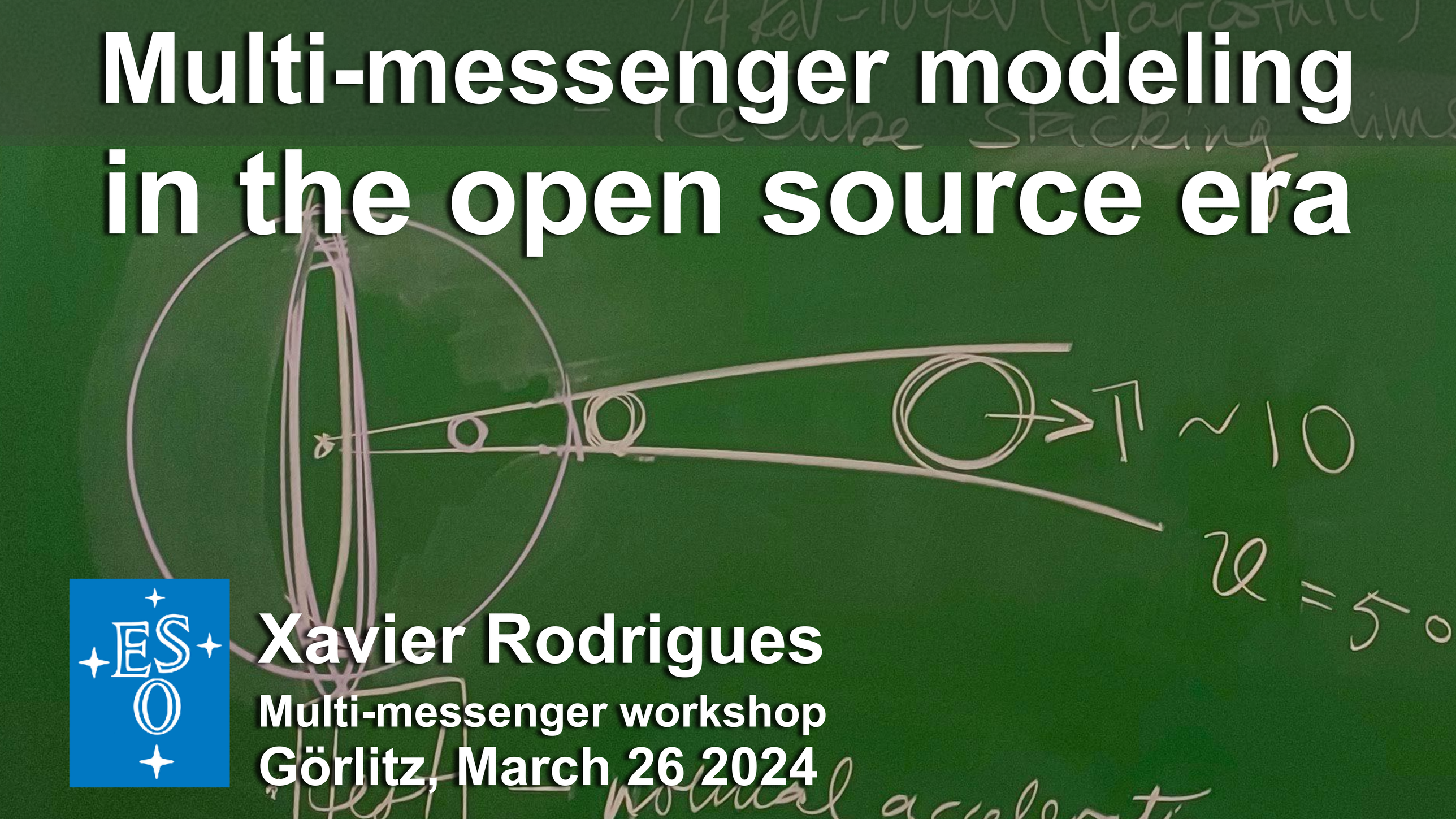
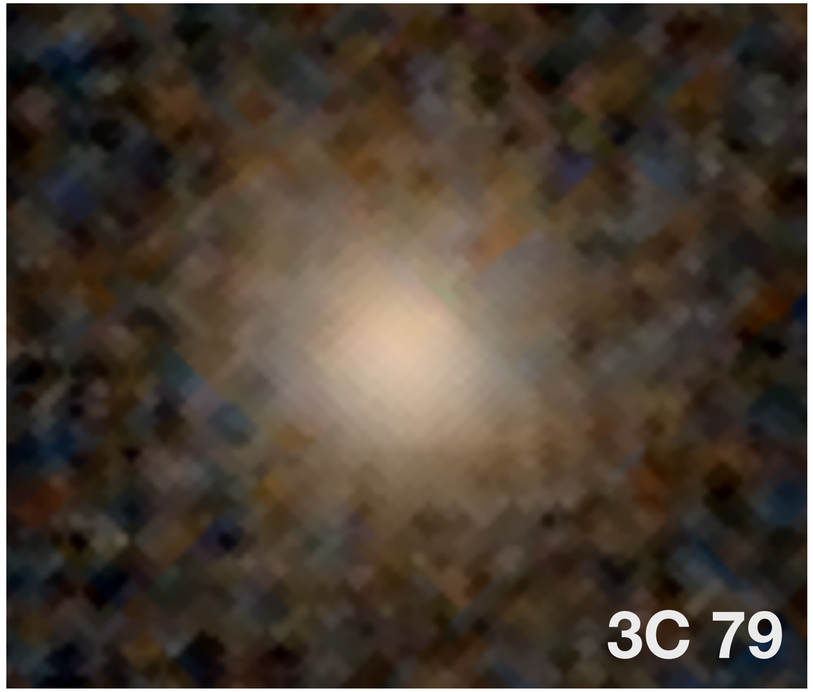
Multi-messenger modeling in the open source era



Xavier Rodrigues

Multi-messenger workshop

Görlitz, March 26 2024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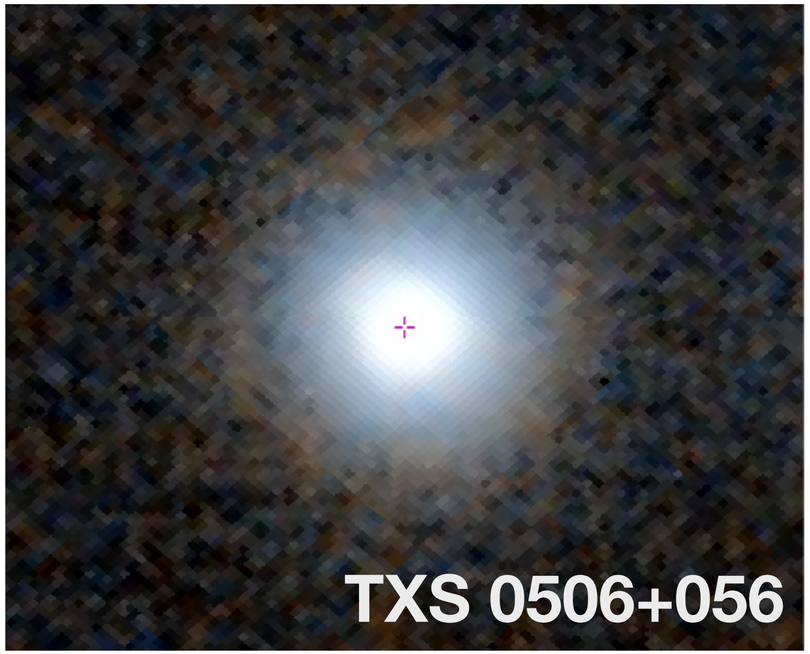
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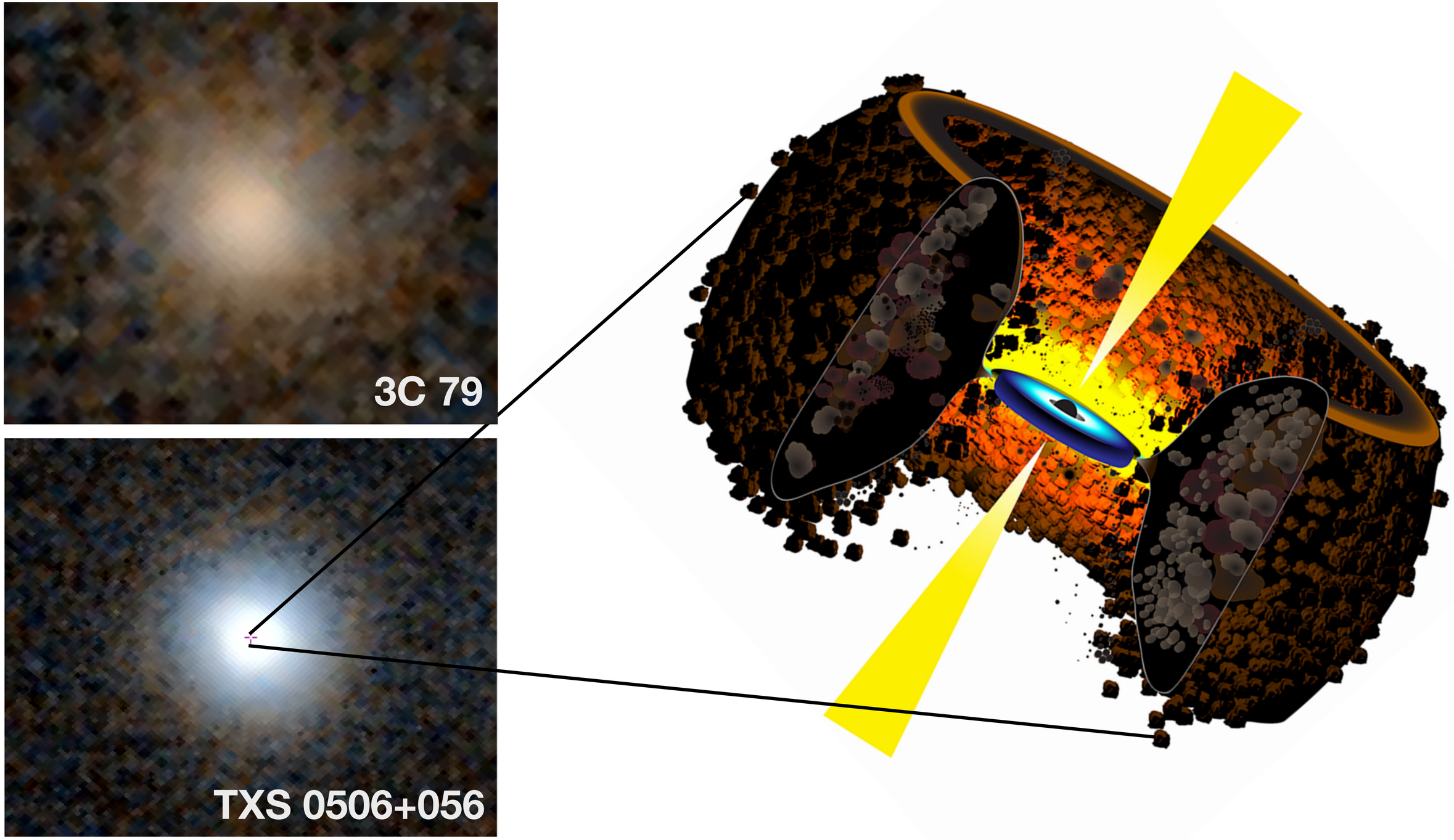
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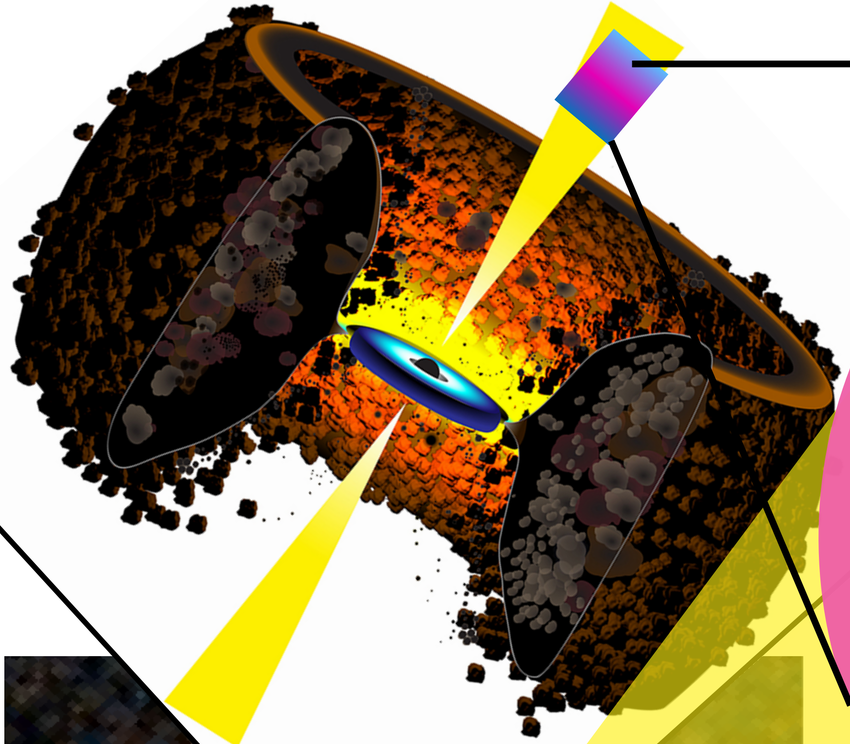

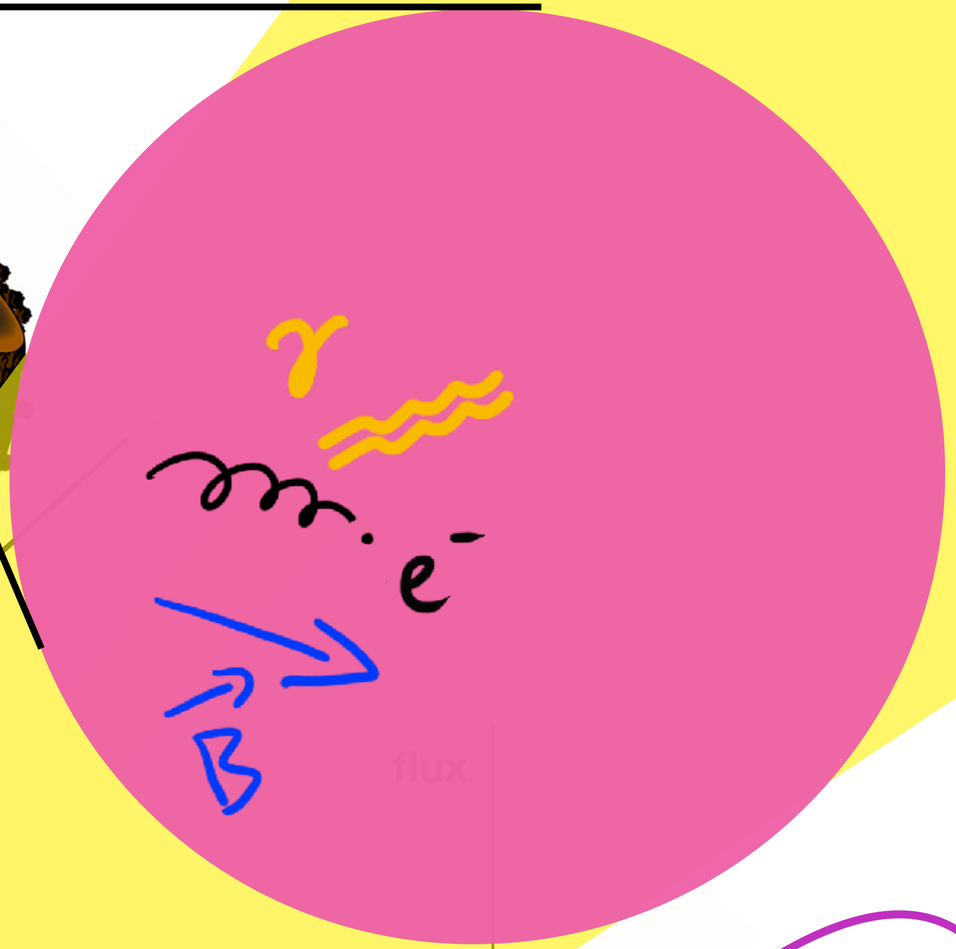
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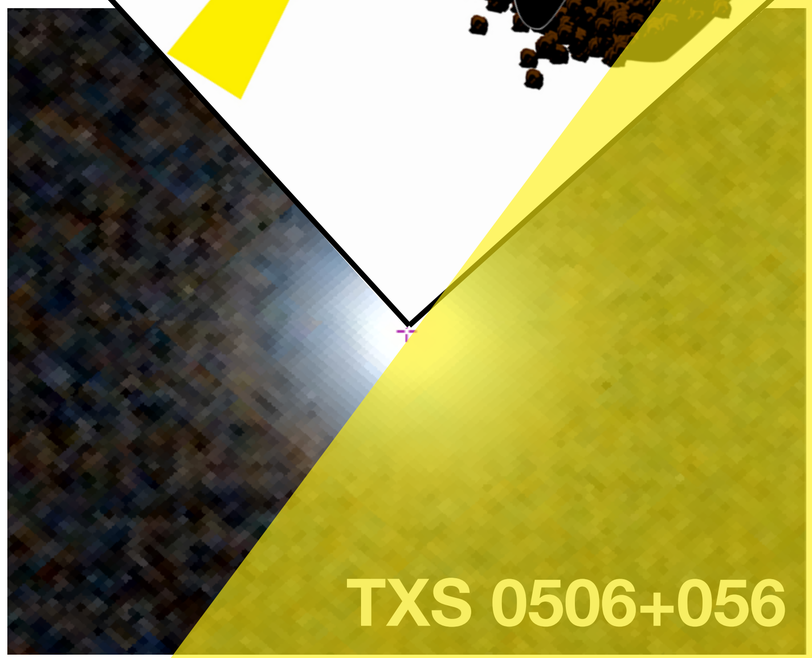
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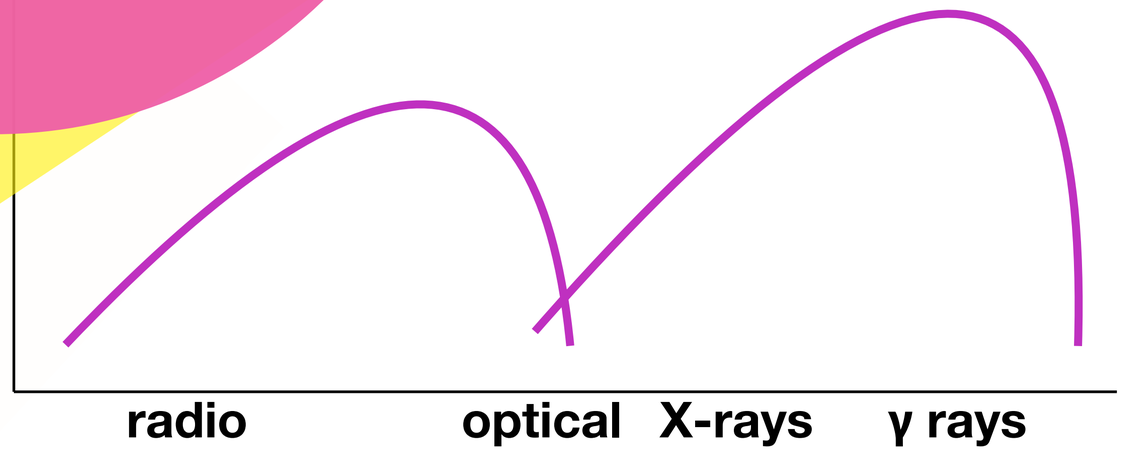
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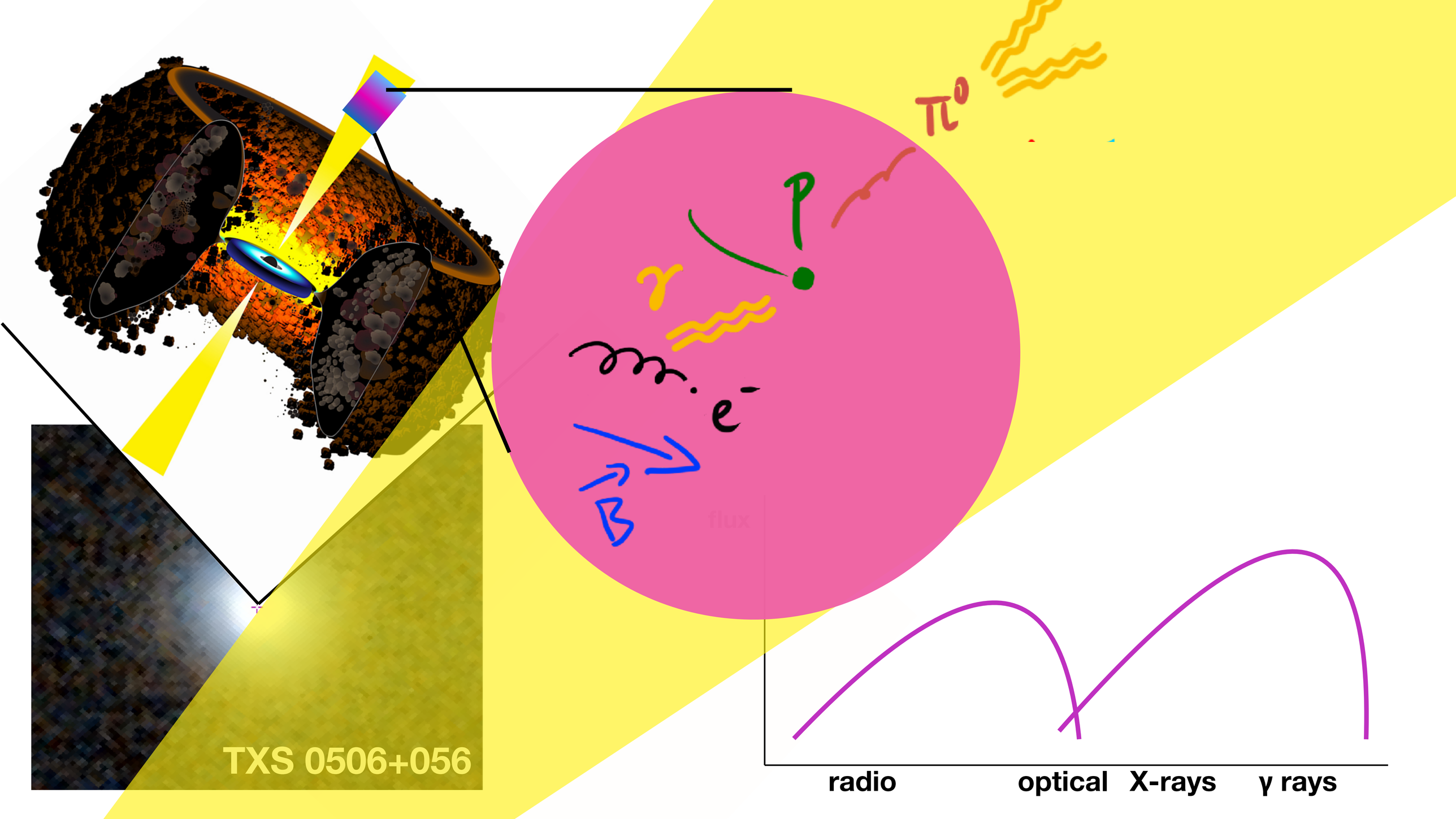
γ rays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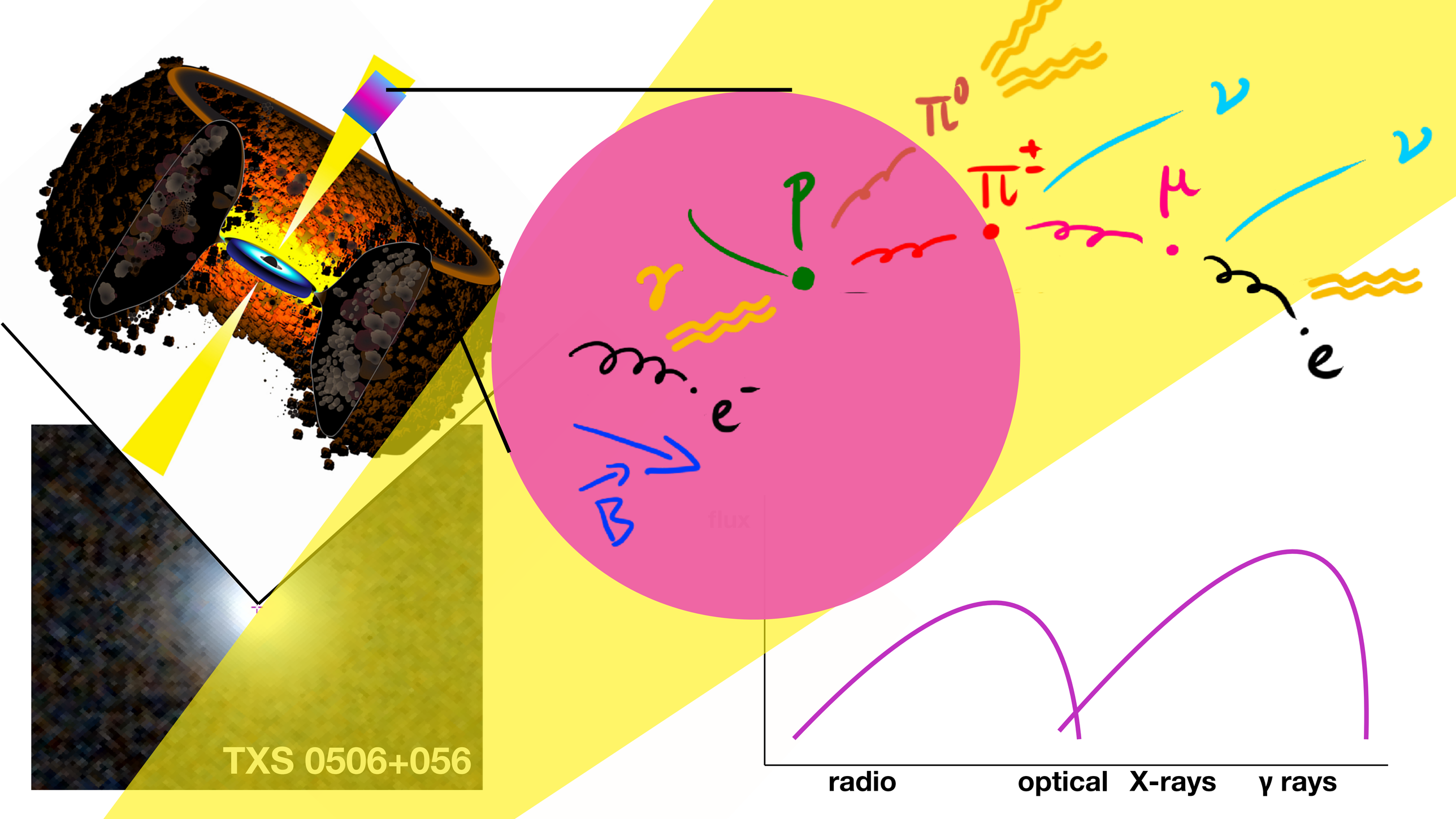
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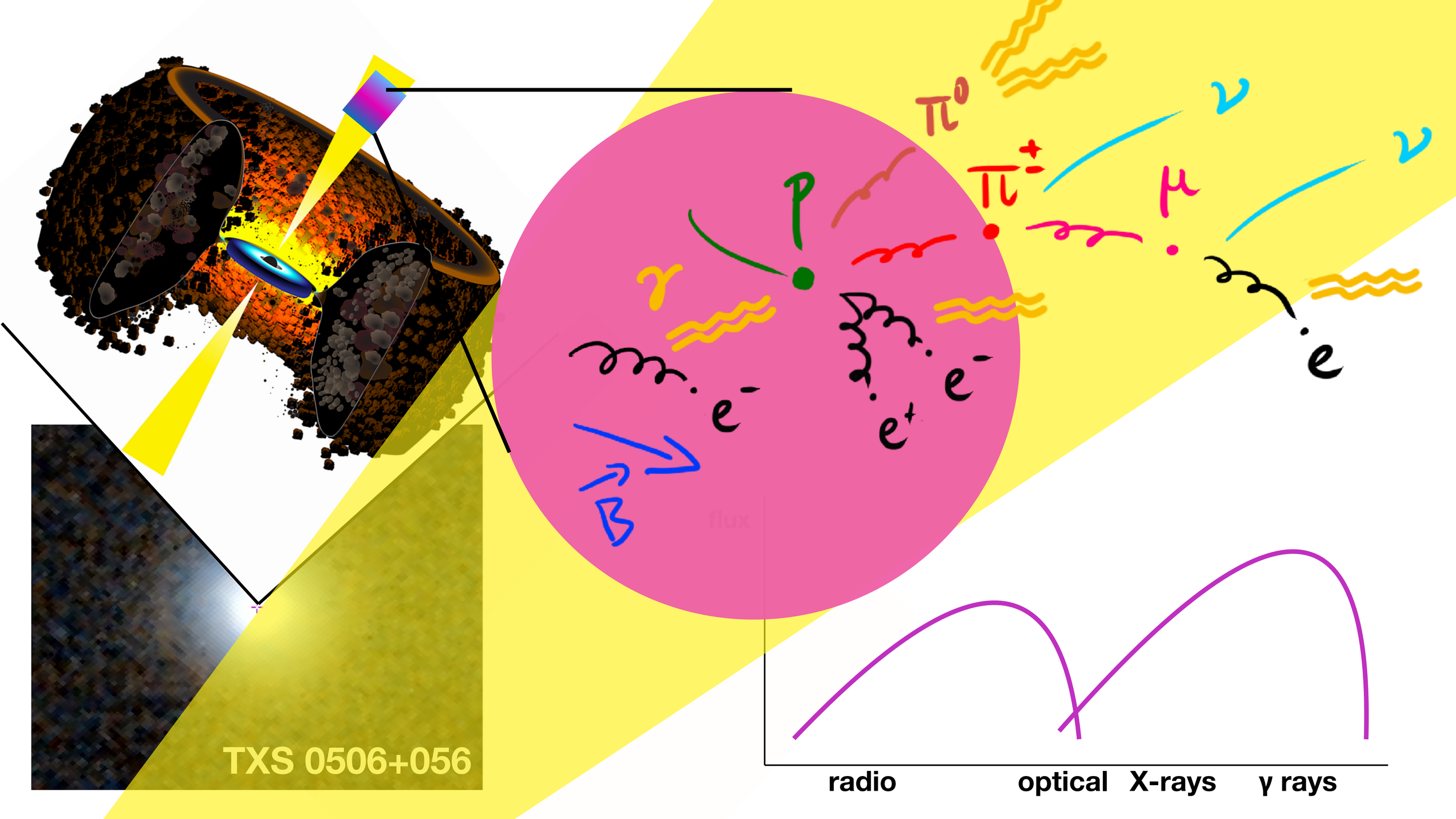
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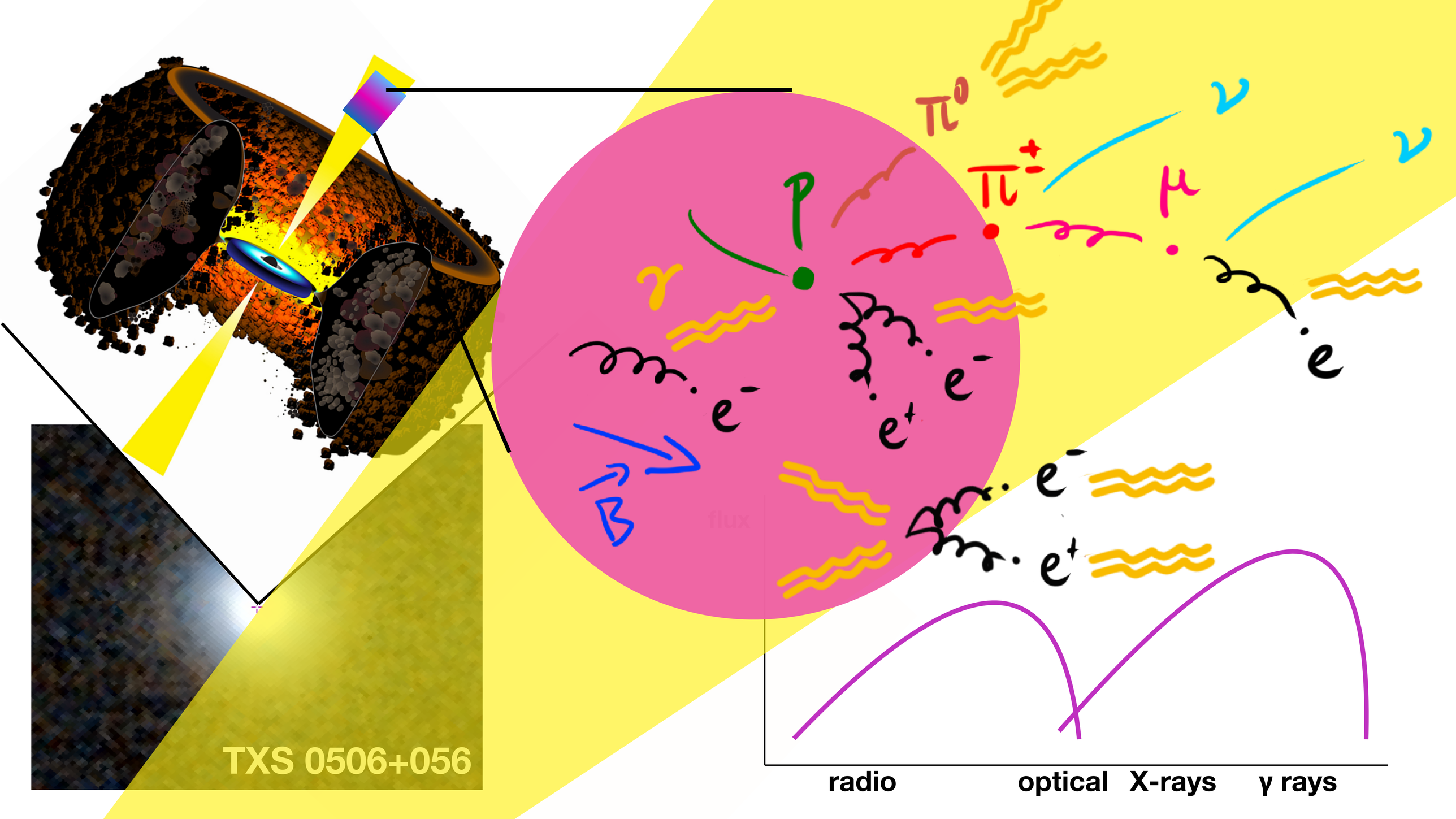
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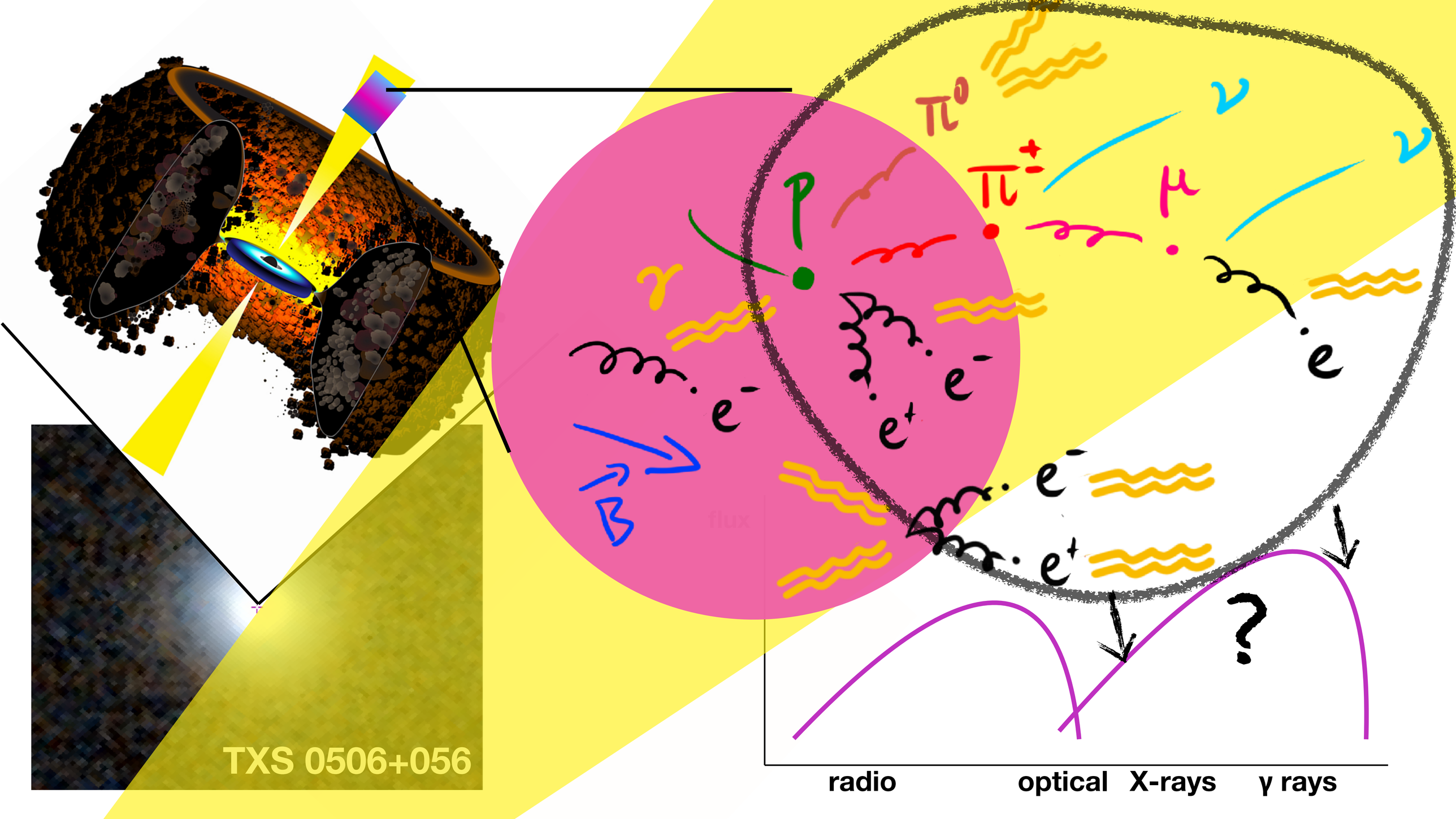
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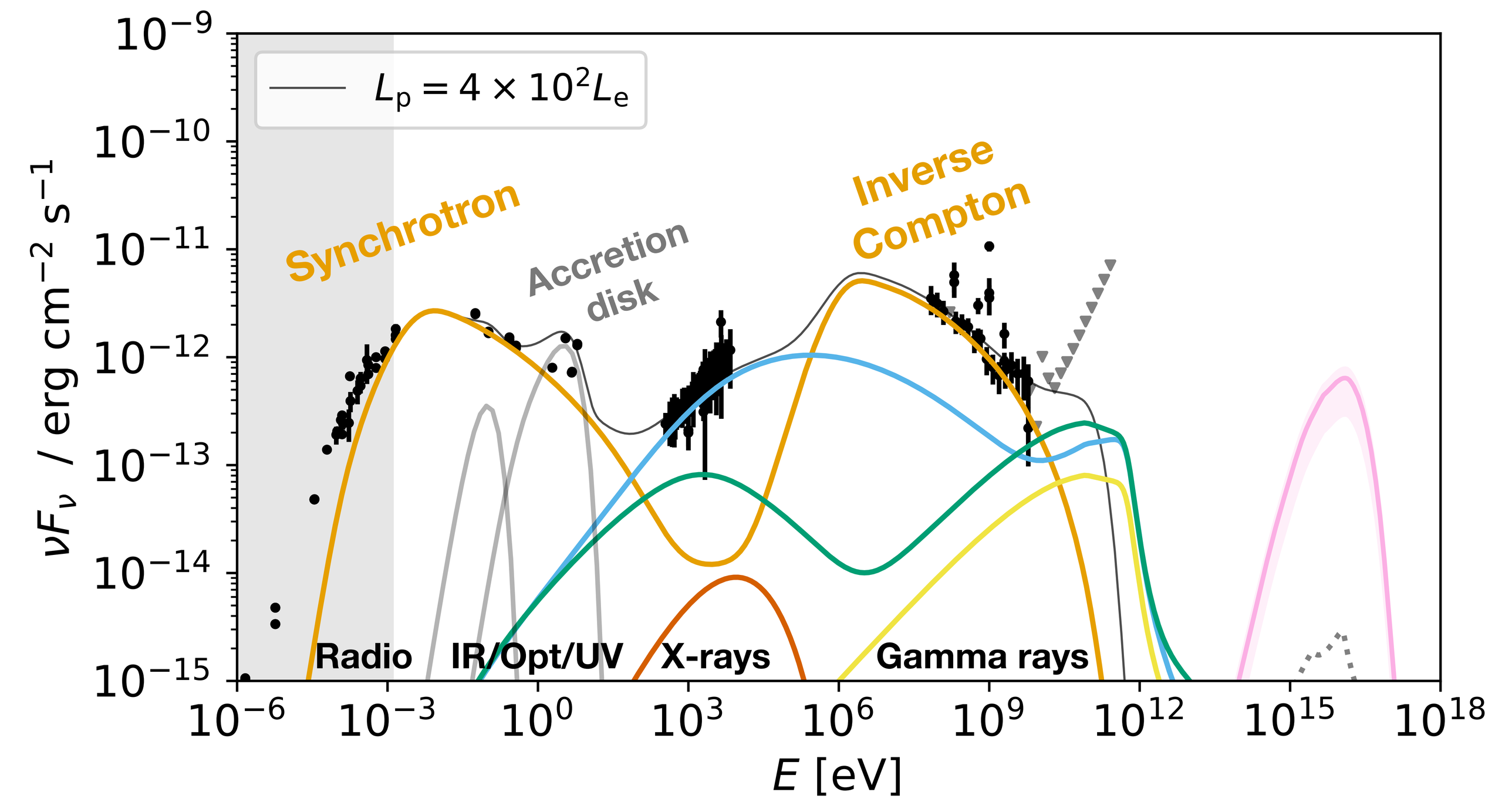
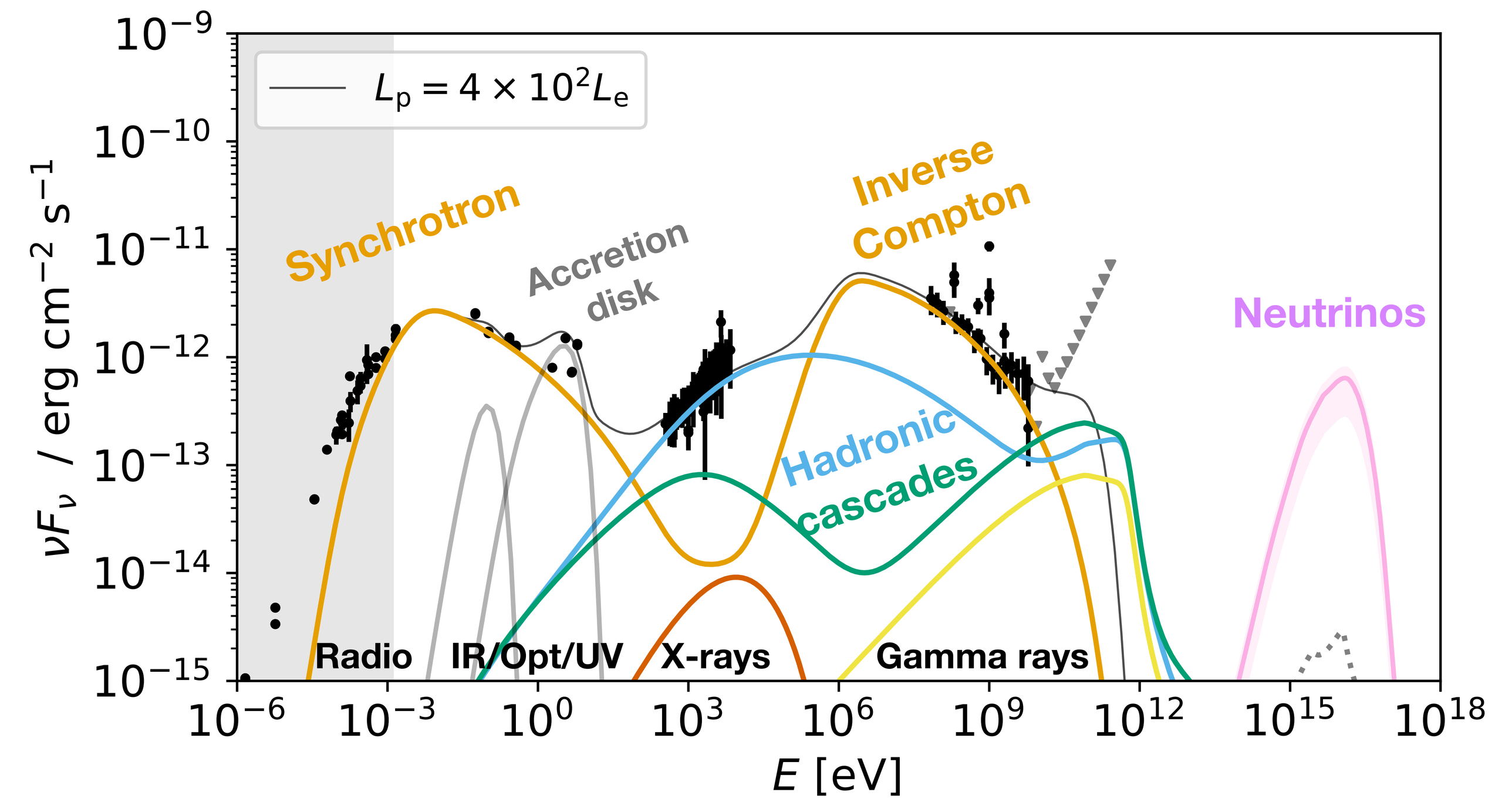
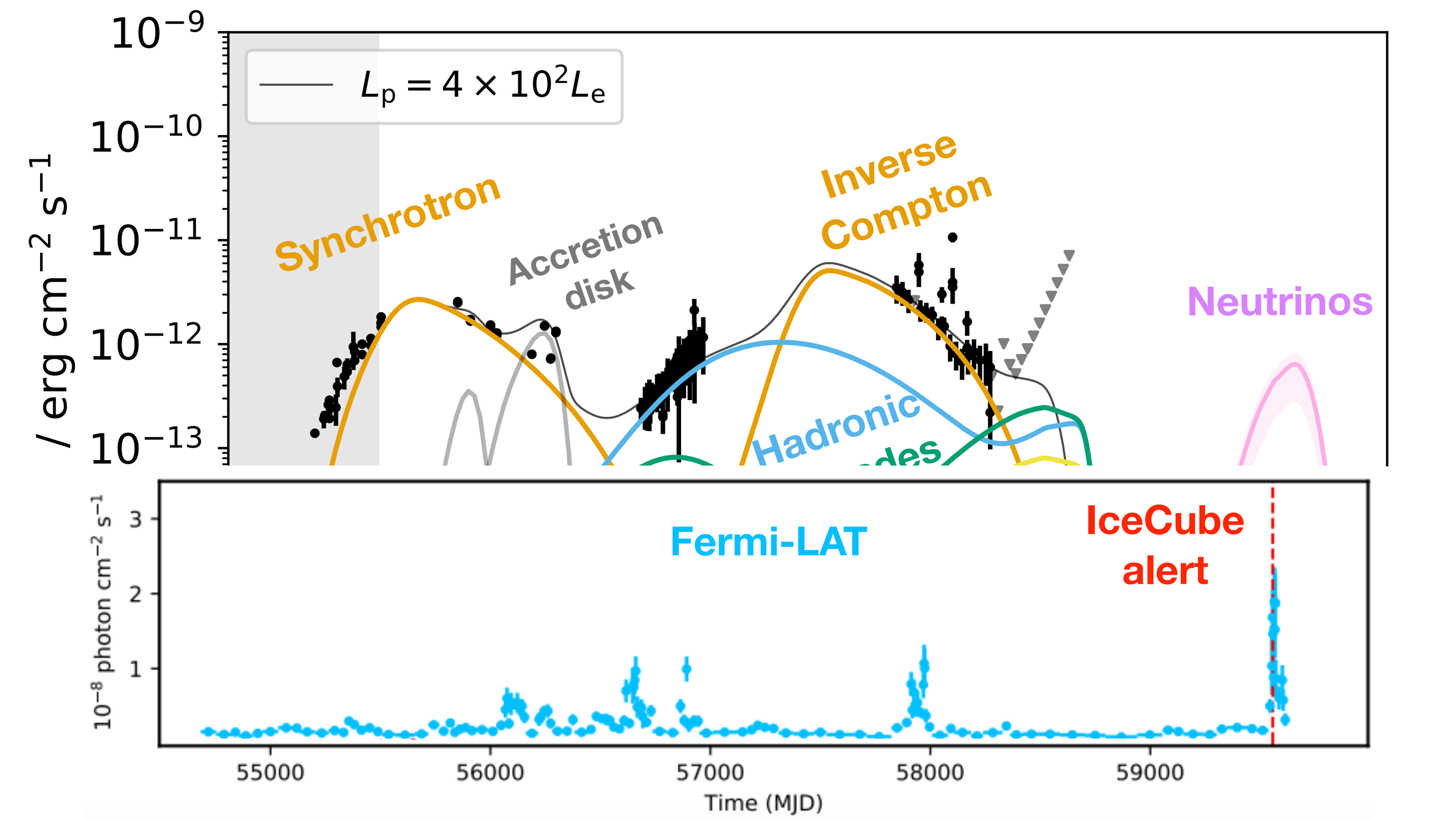


XR, Paliya, Garrappa, Omeliukh, Franckowiak & Winter, A&A 681 (2024)



XR, Paliya, Garrappa, Omeliukh, Franckowiak & Winter, A&A 681 (2024)


$L_p = 4 \times 10^2 L_e$
Synchrotron
Accretion disk
Inverse Compton
Hadronic
Neutrinos
/ erg cm^{-2} s^{-1}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
Fermi-LAT
IceCube alert
10^{-8} photon cm^{-2} s^{-1}
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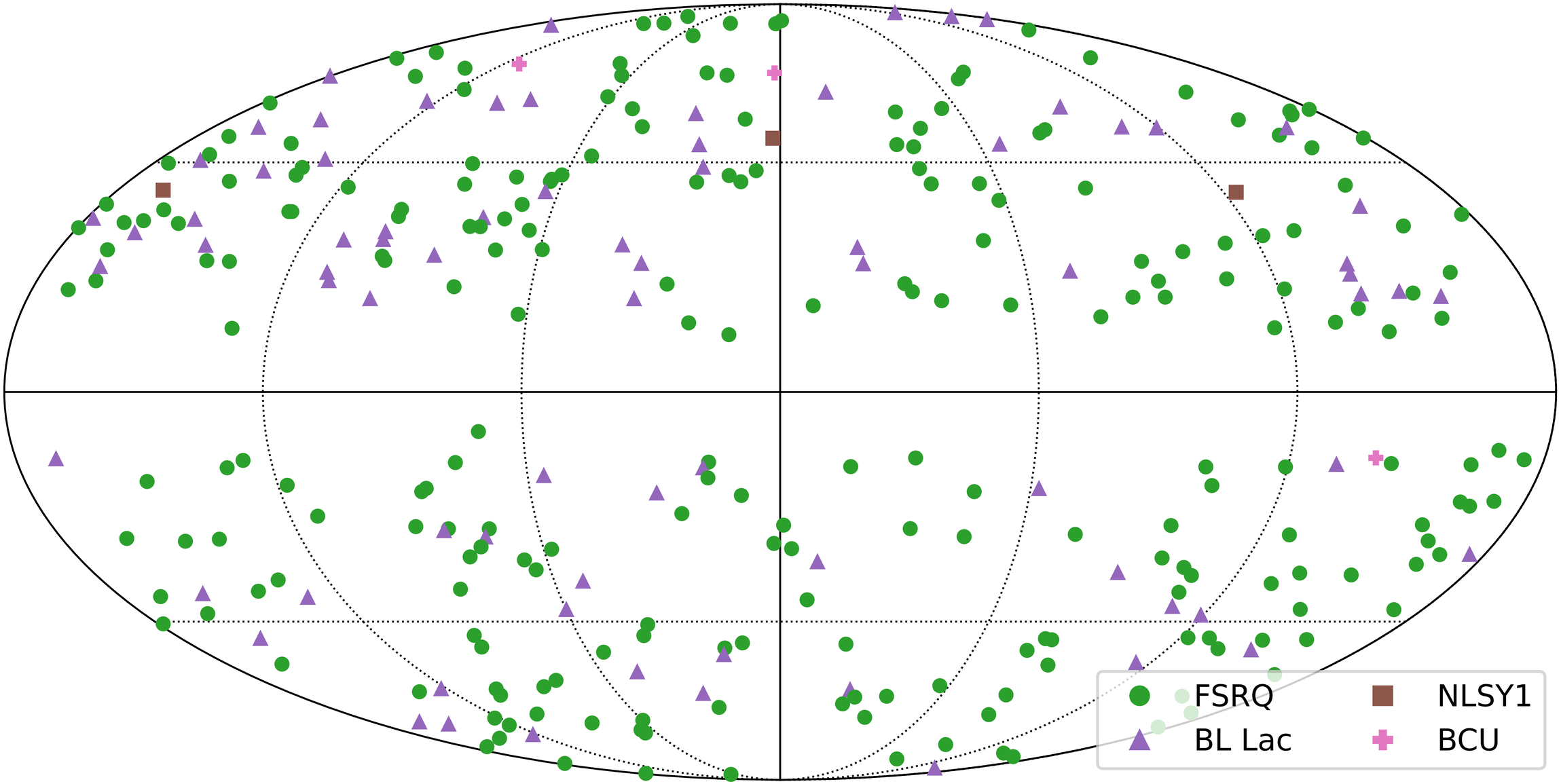
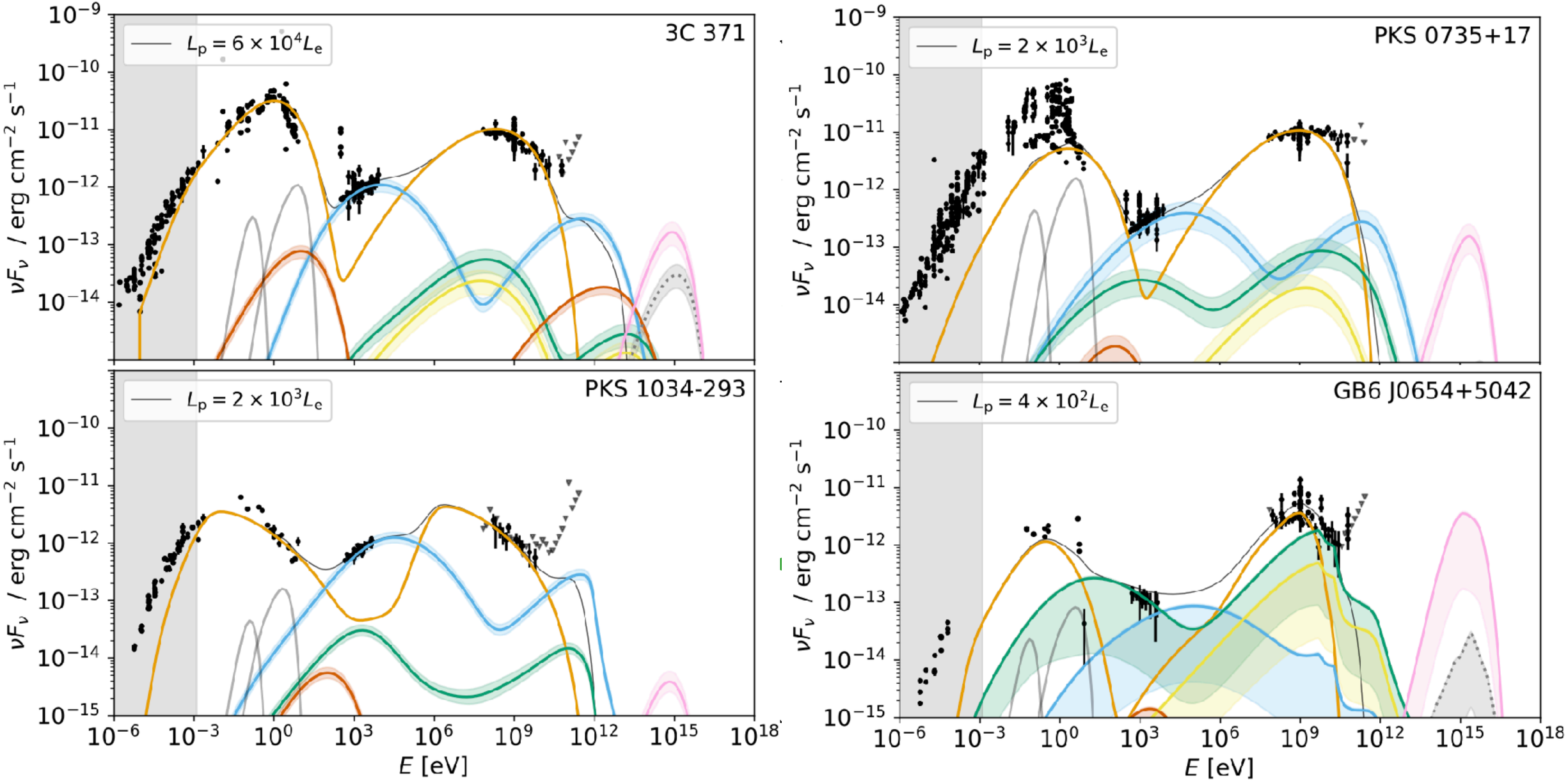
2
3
55000
56000
57000
58000
59000
Time (MJD)

Future goals I: From sources to samples



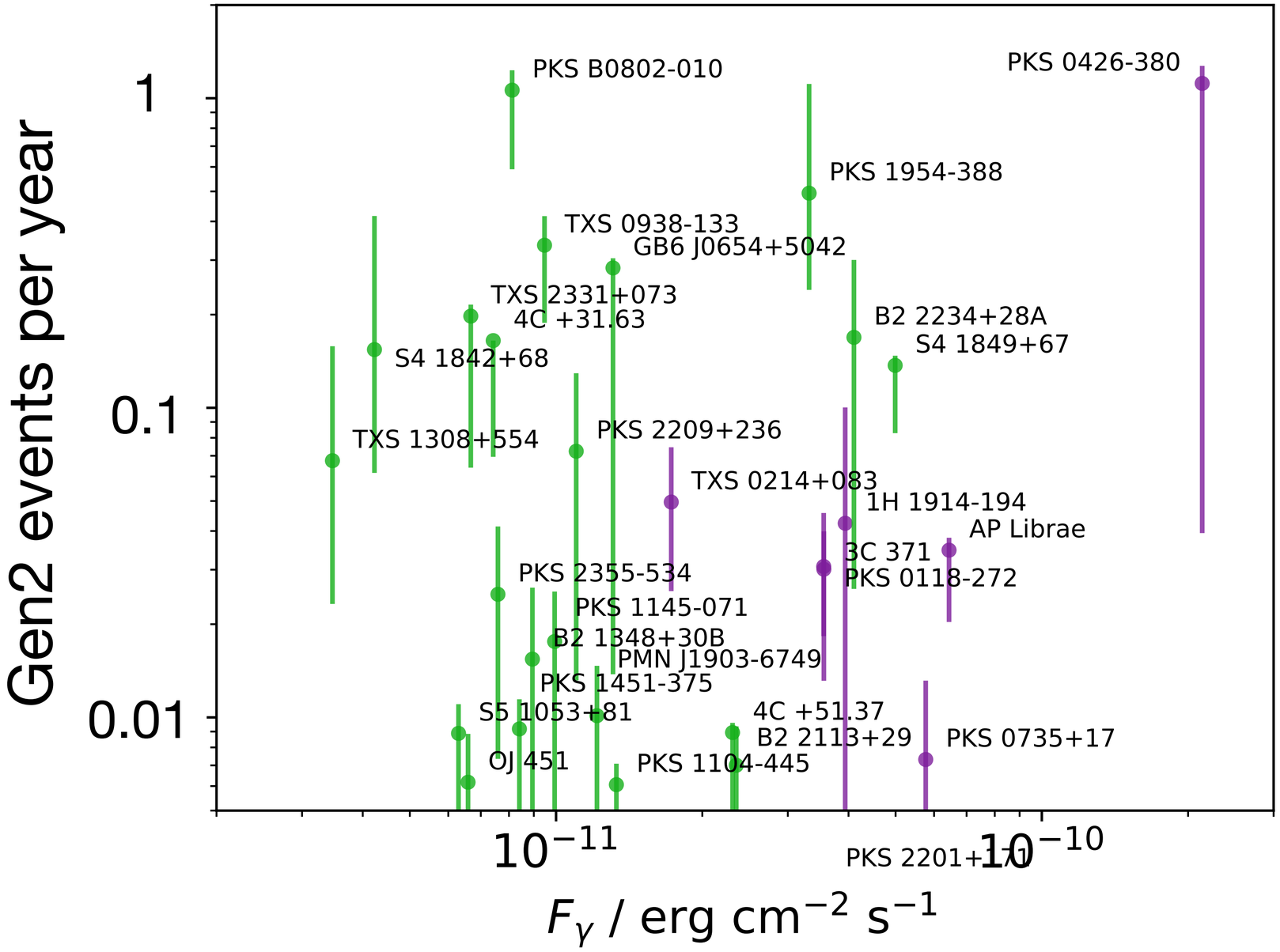
XR, Paliya, Garrappa, Omeliukh, Franckowiak & Winter, A&A 681 (2024)

Future goals I: From sources to samples



XR, Paliya, Garrappa, Omeliukh, Franckowiak & Winter, A&A 681 (2024)

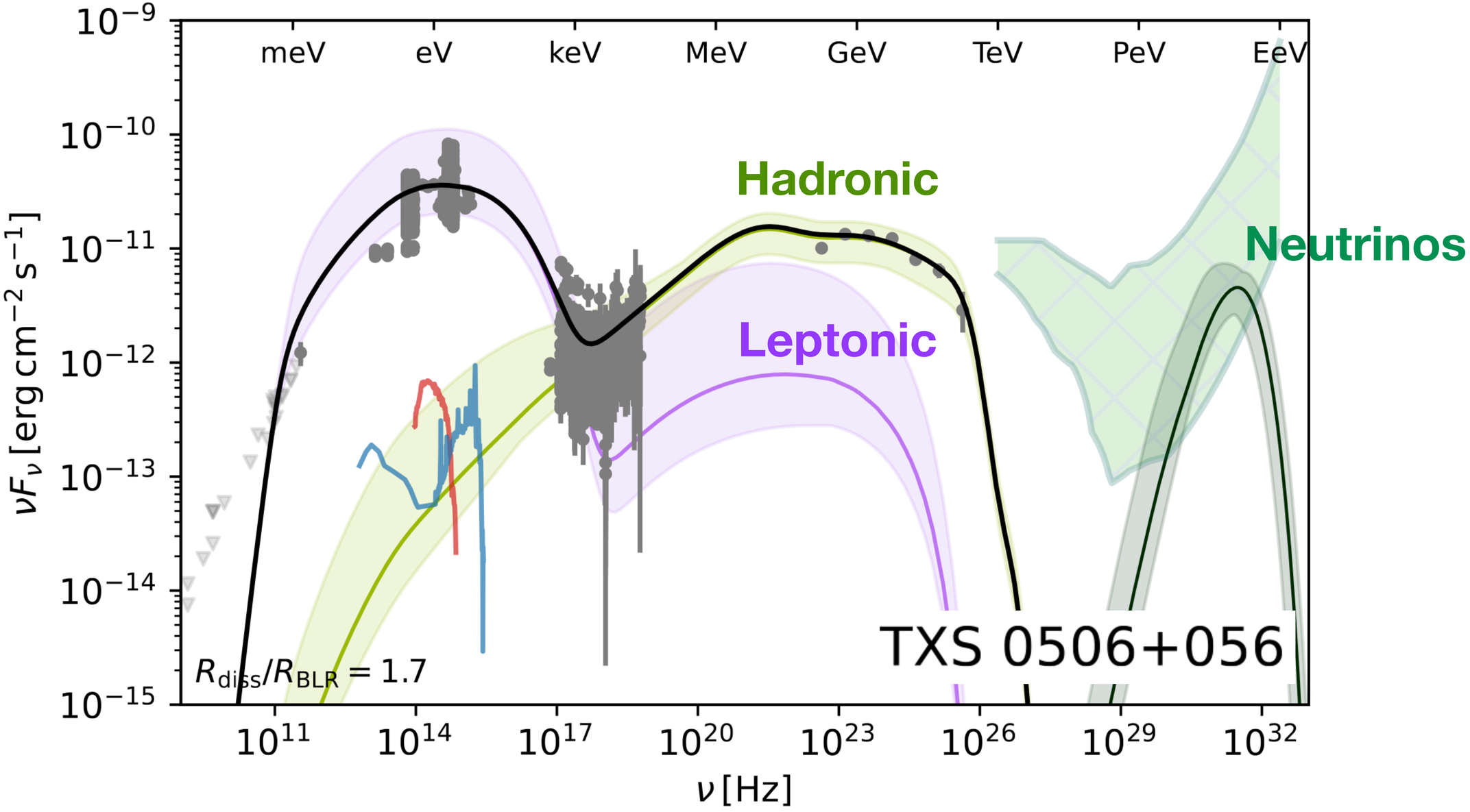
Future goals I: From sources to samples



IceCube-Gen2 will start probing ***steady-state emission*** from blazars

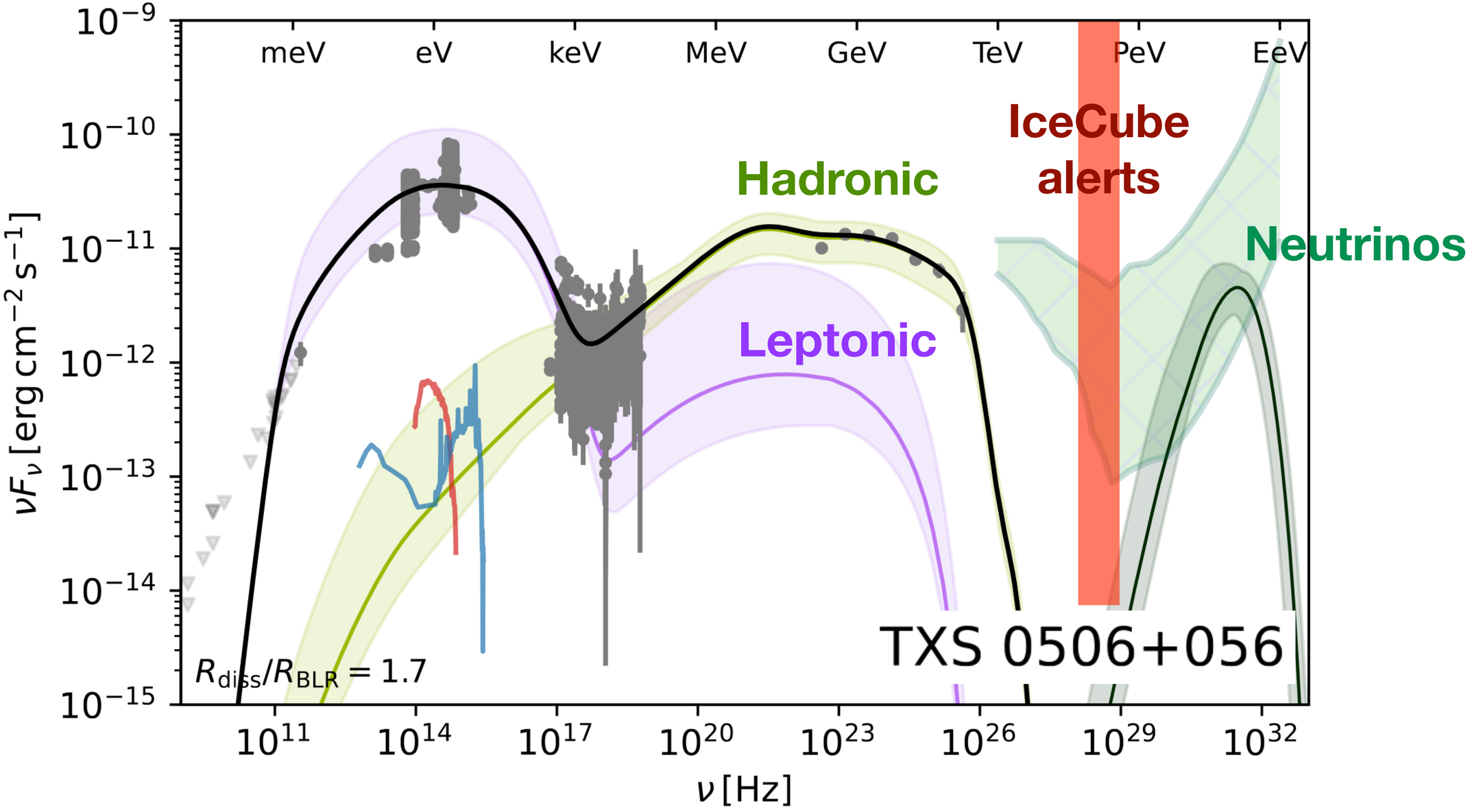
XR, Paliya, Garrappa, Omeliukh, Franckowiak & Winter, A&A 681 (2024)

Future goals II: Pushing the high-energy frontier



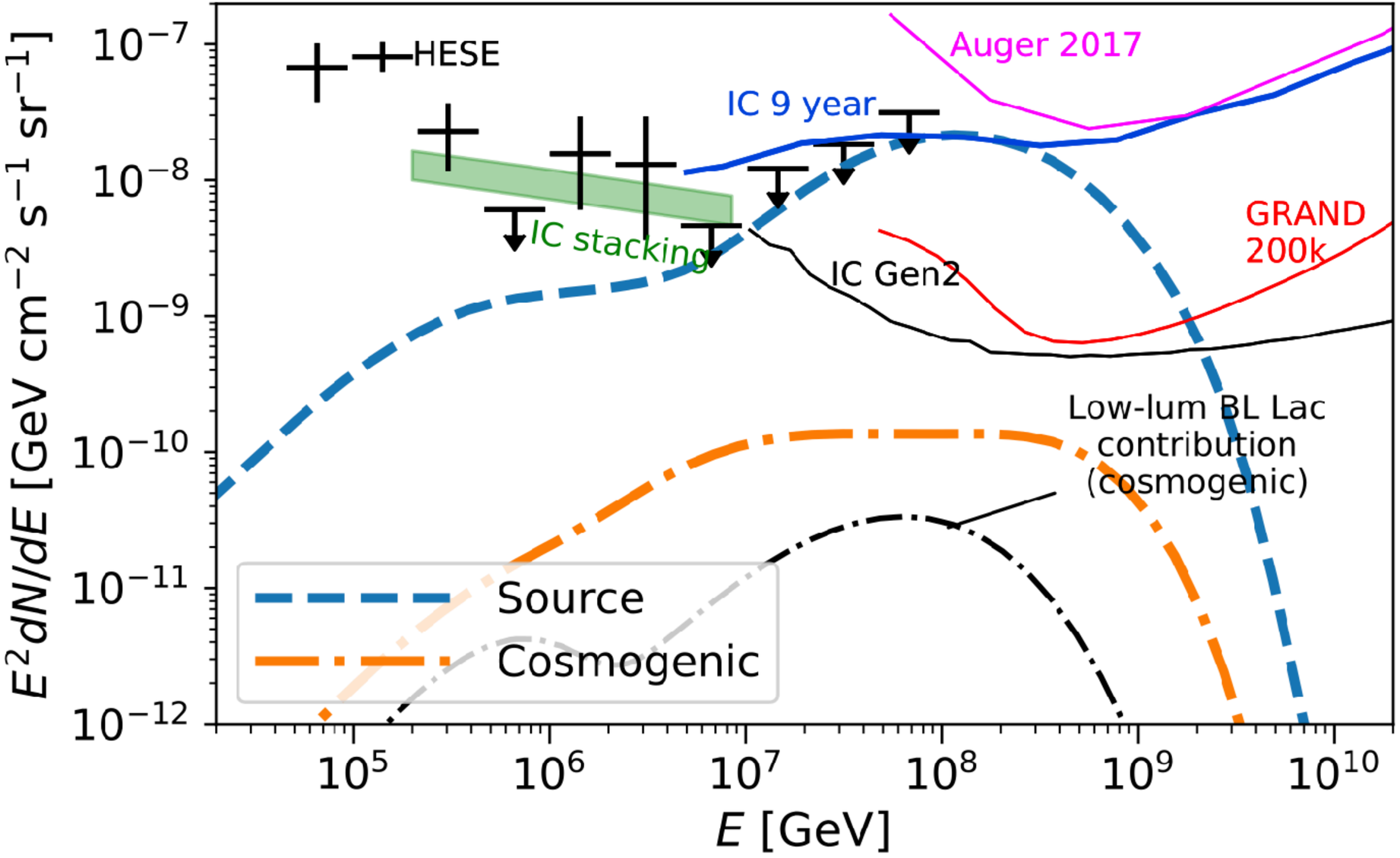
XR, Karl, Padovani, Giommi, Paiano, Falomo & Petropoulou, in prep

Future goals II: Pushing the high-energy frontier



XR, Karl, Padovani, Giommi, Paiano, Falomo & Petropoulou, in prep

Future goals II: Pushing the high-energy frontier



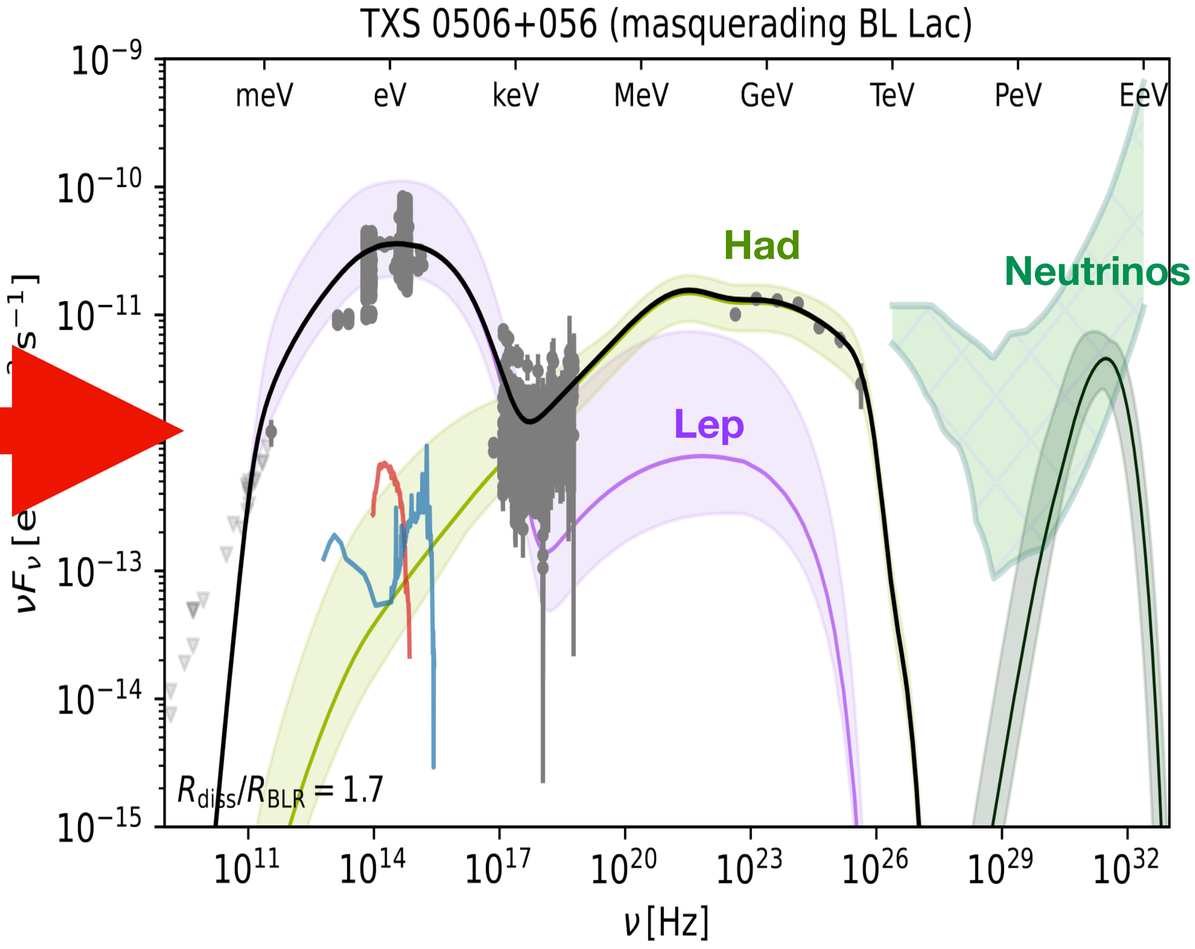
XR, Heinze, Palladino, van Vliet & Winter 2021, PRL 126

Future goals III: Leading a global modeling community

AM3

gitlab.desy.de/am3/am3

DESY



Preprint with the technical details:

Klinger, Rudolph, XR, et al. (arXiv:2312.13371)

Future goals III: Leading a global modeling community

Since last December, AM³ is open-source Python software

```python
import numpy as np
import am3
am3 = am3.AM3()
```

Preprint with the technical details:

Klinger, Rudolph, XR, et al. (arXiv:2312.13371)

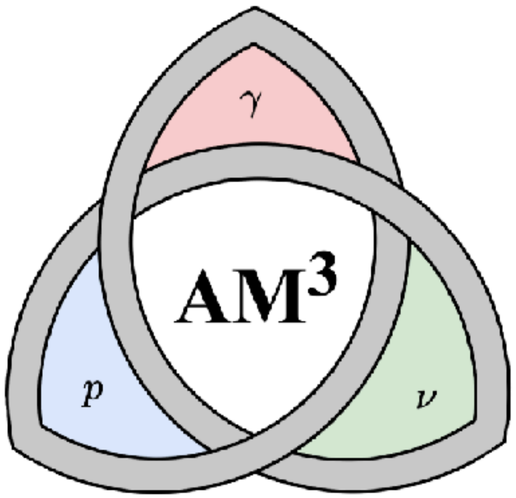
Future goals III: Leading a global modeling community

Gao

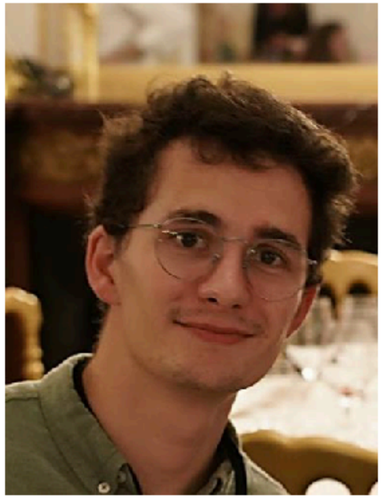
Klinger

Rudolph

Rodrigues



Yuan



Fichet De Clairfontaine

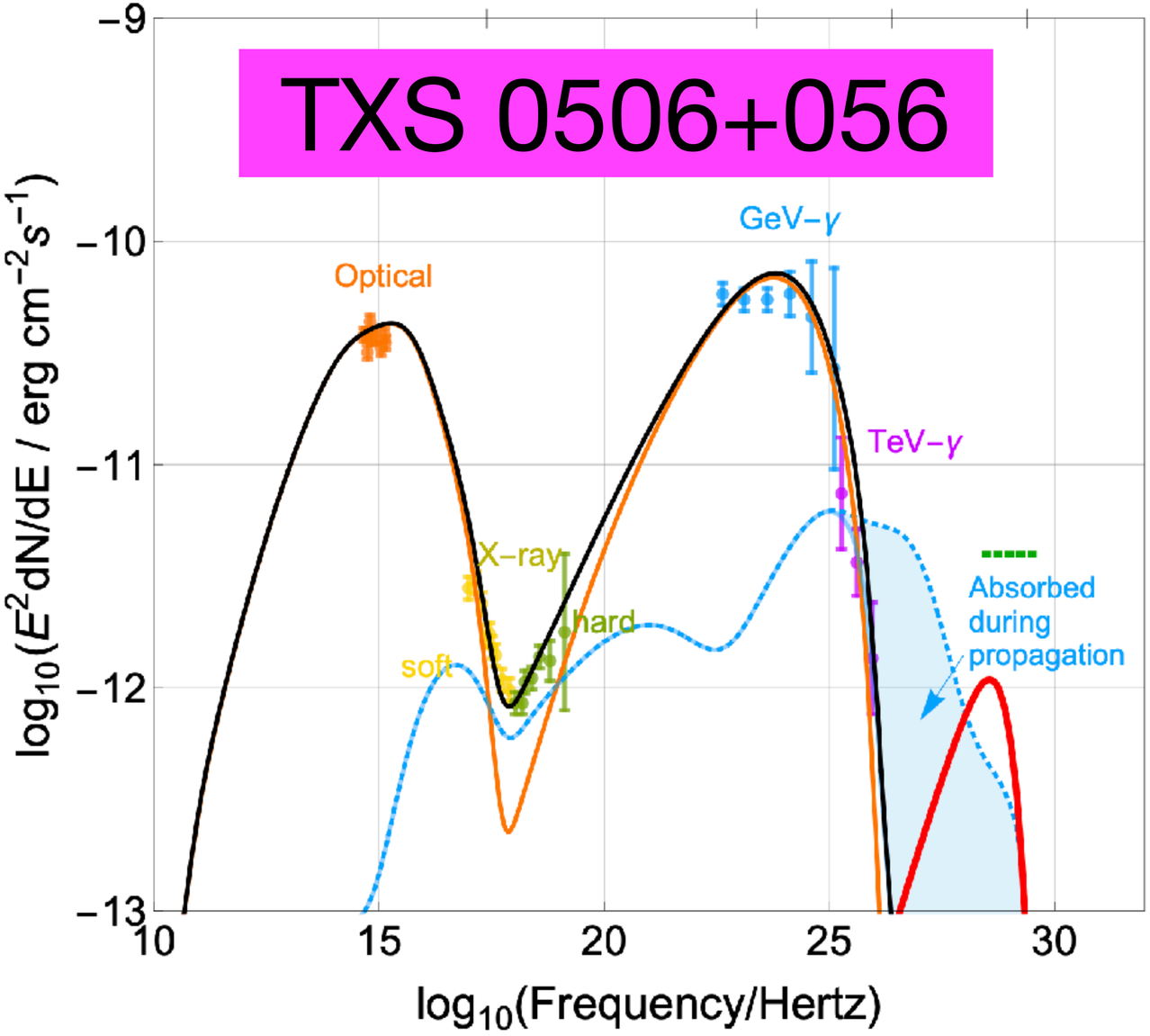
Fedynitch

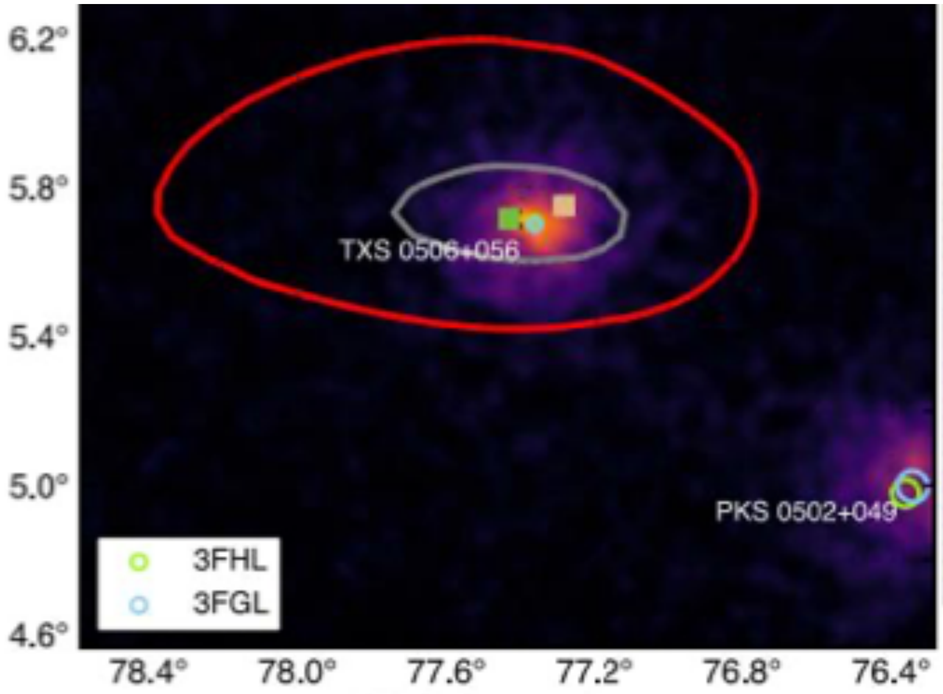
Winter

Pohl

What is a “hadronic signature”?

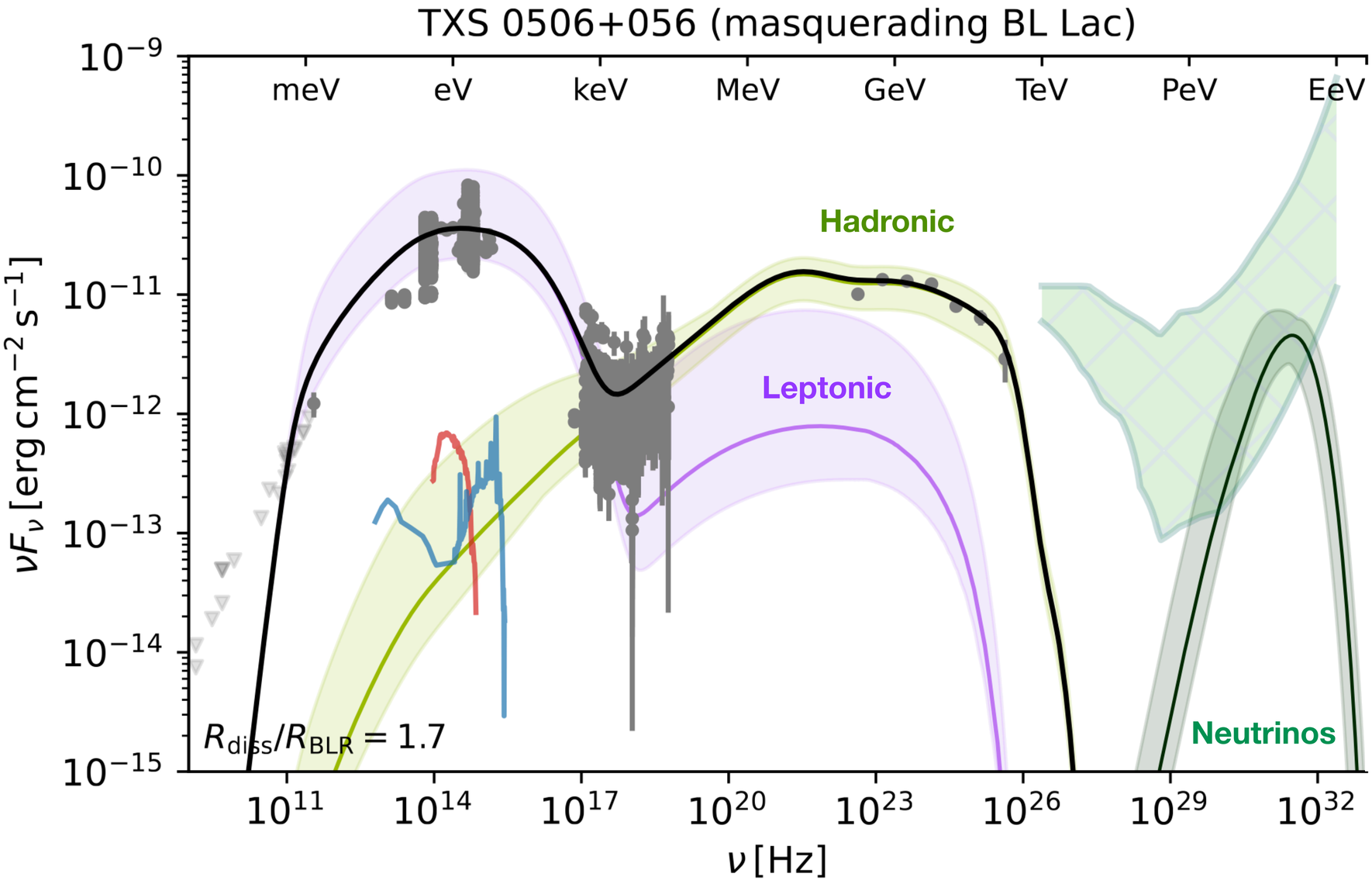
-> see Martin’s talk tomorrow

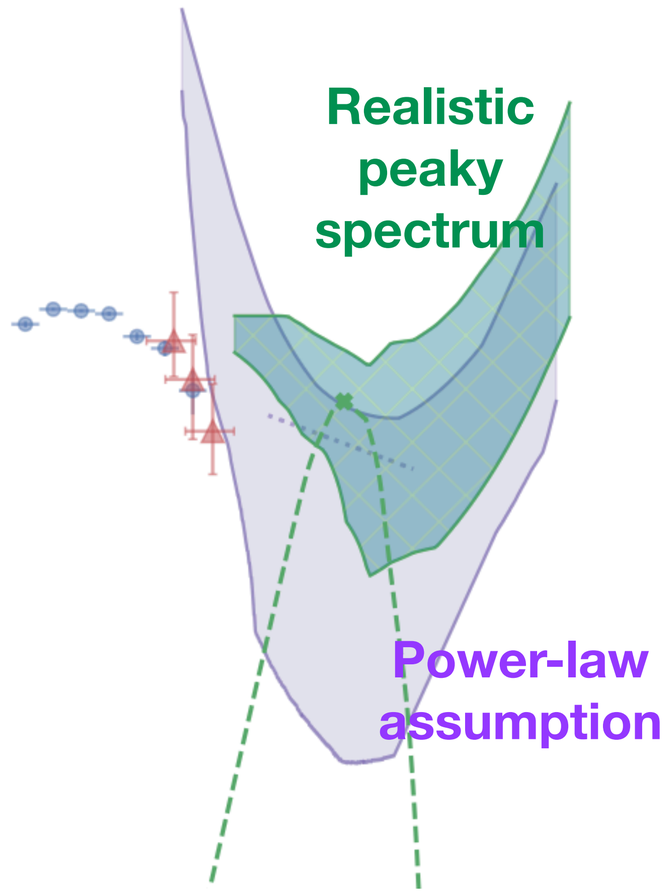




Gao+ Nat Astron. 3, 2019

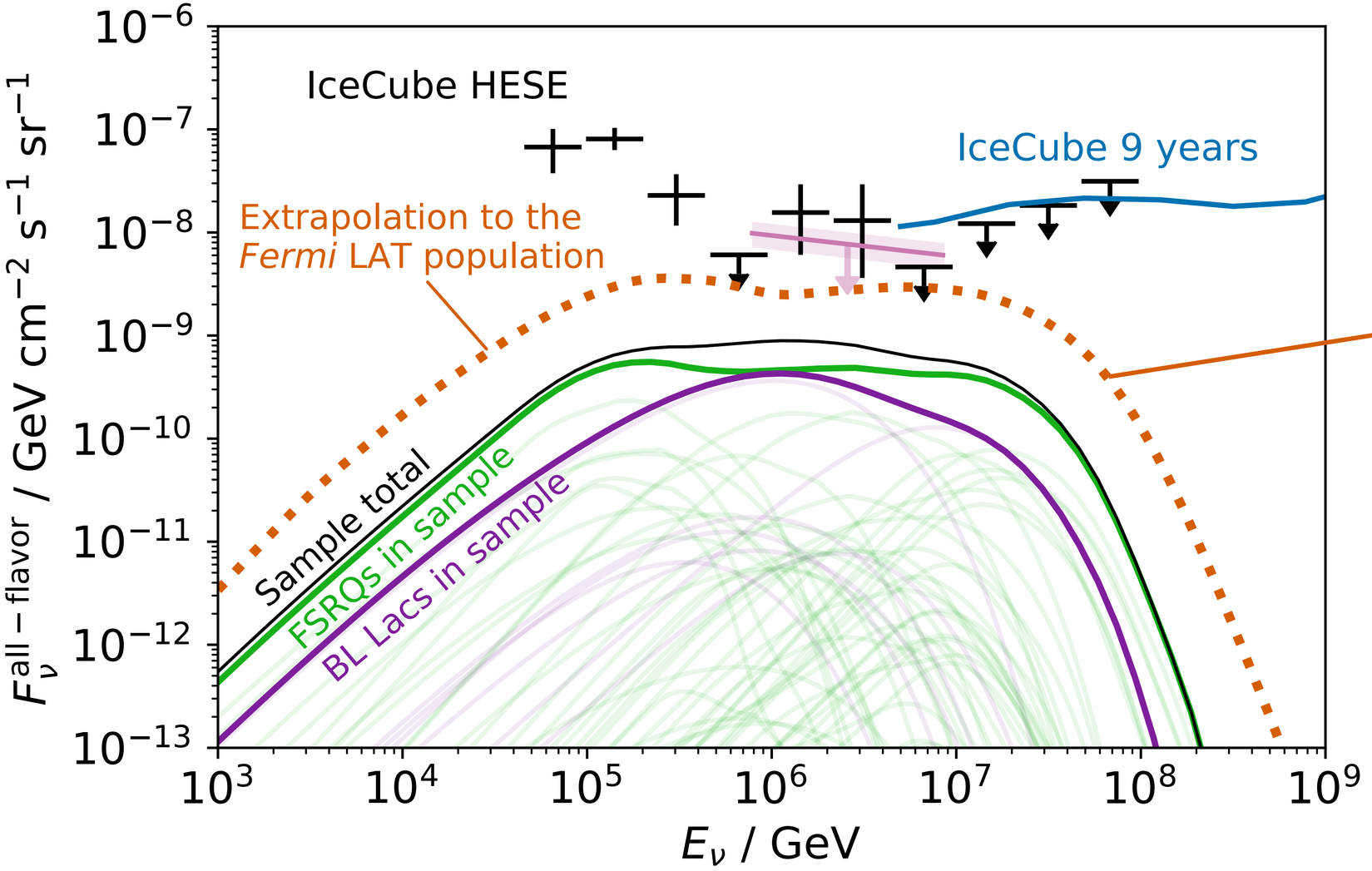
Future directions II: Pushing the high-energy frontier





XR, Karl, Padovani, Giommi, Paiano, Falomo & Petropoulou, in preparation

Future directions II: From sources to samples

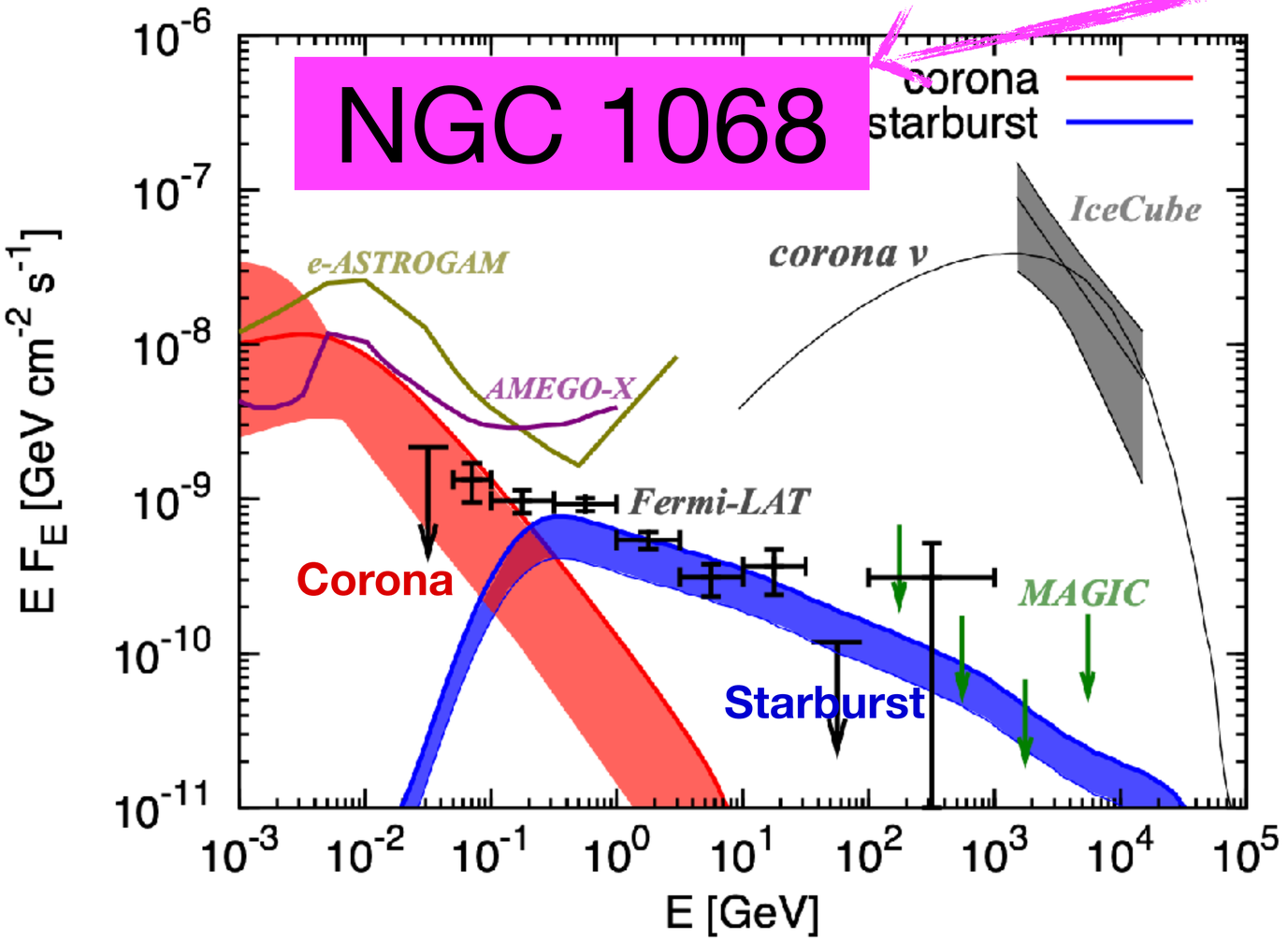


In this model, Fermi blazars contribute ~20% of the IceCube diffuse flux

XR, Paliya, Garrappa, Omeliukh, Franckowiak & Winter, A&A 681 (2024)

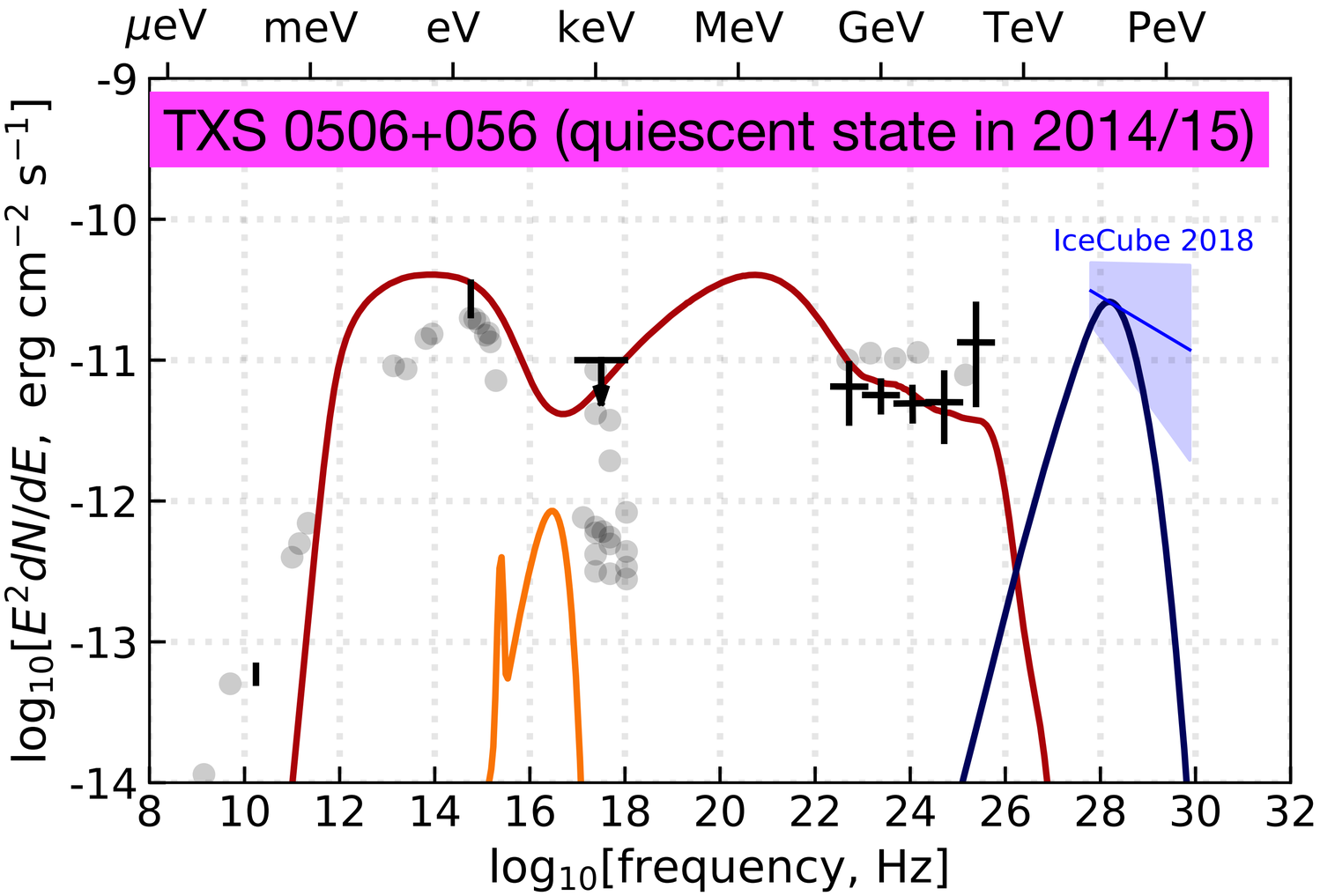
Do neutrinos come from opaque emission regions?

4.2 sigma detection
(IceCube 2022, Science 378)



Ajello, Murase & McDaniel, arXiv:2307.02333

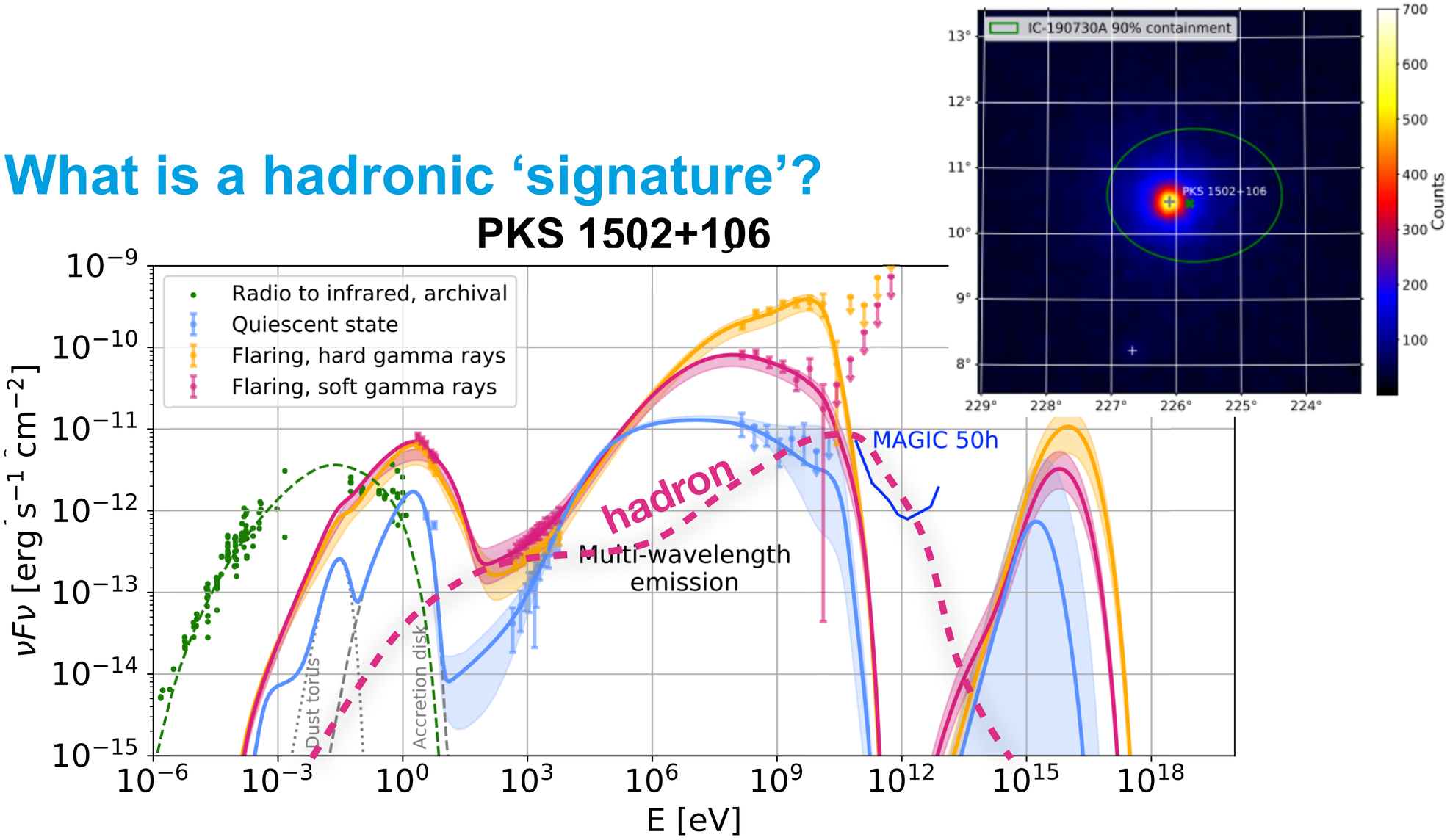
Do neutrinos come from opaque emission regions?



XR, Gao, Fedynitch, Palladino & Winter 2019, ApJ L874

See also Reimer, Boettcher & Buson 2019, ApJ 881

What is a hadronic ‘signature’?



Rodrigues, Garrappa, Gao, Paliya, Franckowiak and Winter, ApJ 912 (2021)