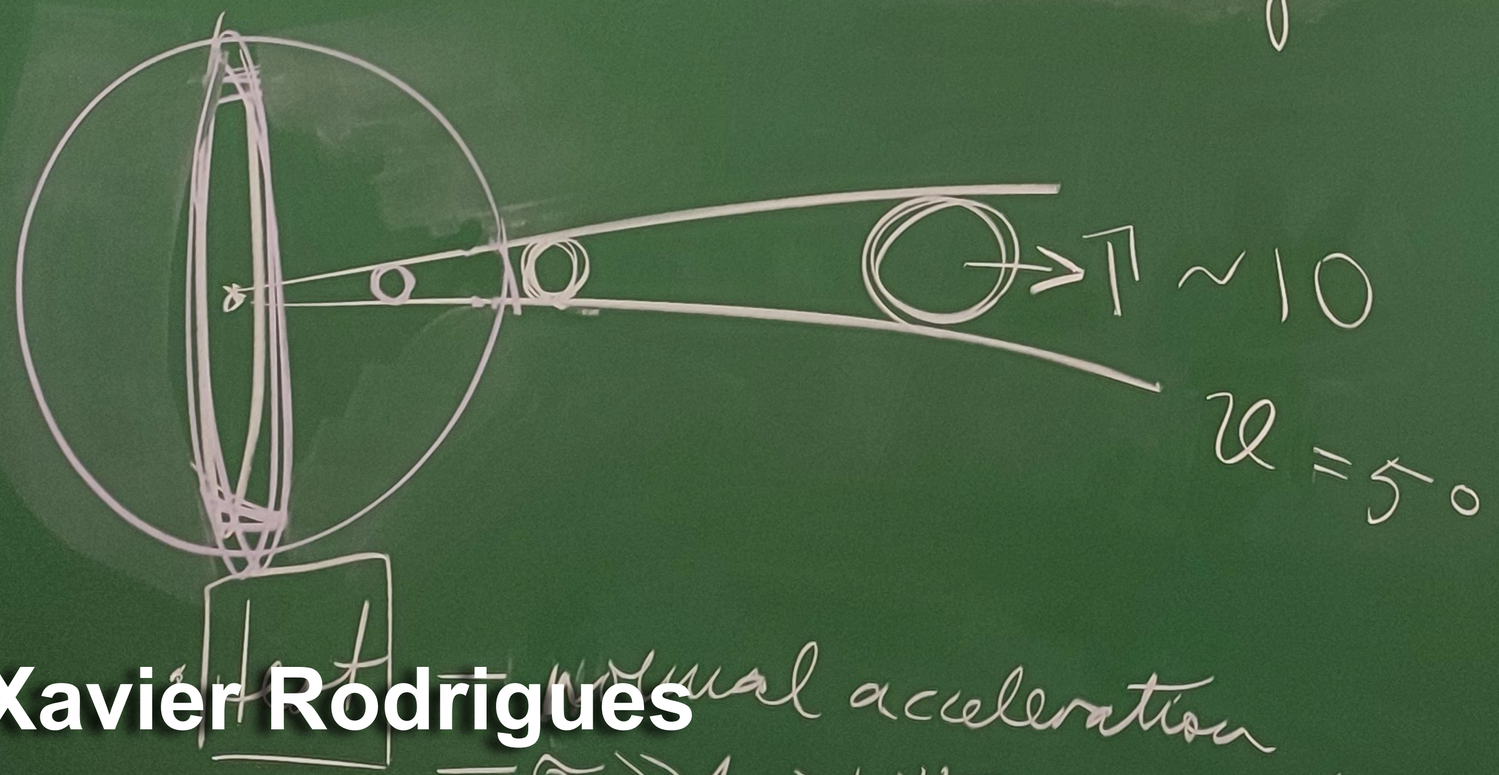
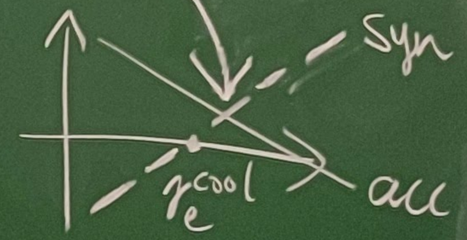
CRs and neutrinos from AGN

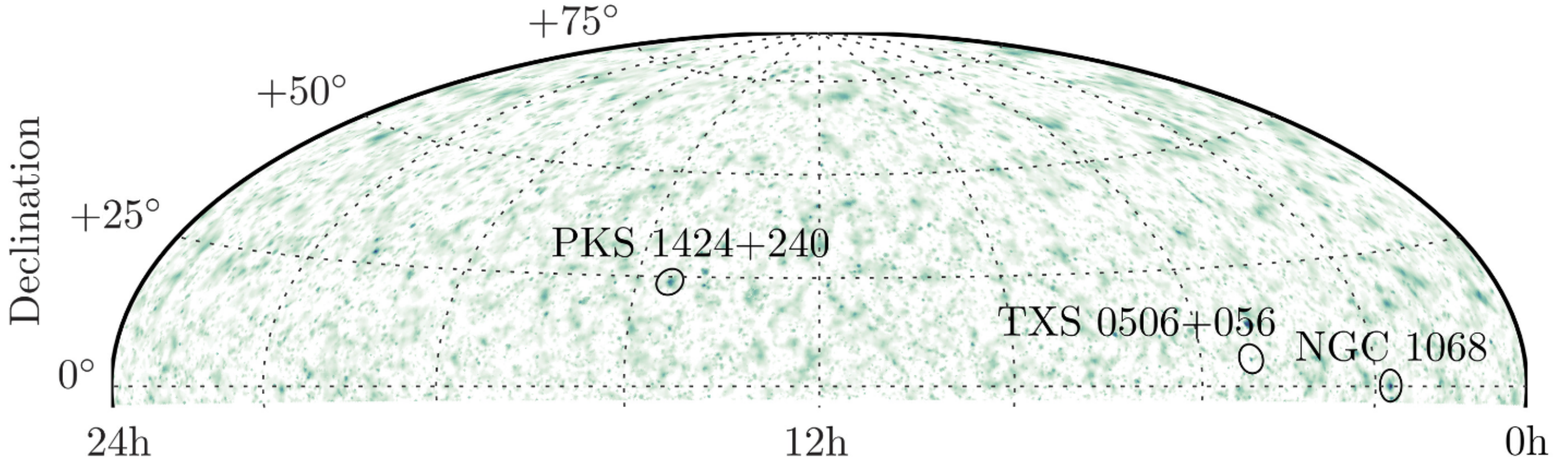




Xavier Rodrigues

Rencontres du Vietnam
Quy Nhon, January 10 2023

The origin of the IceCube neutrinos



IceCube collaboration, Science 378 (2022)

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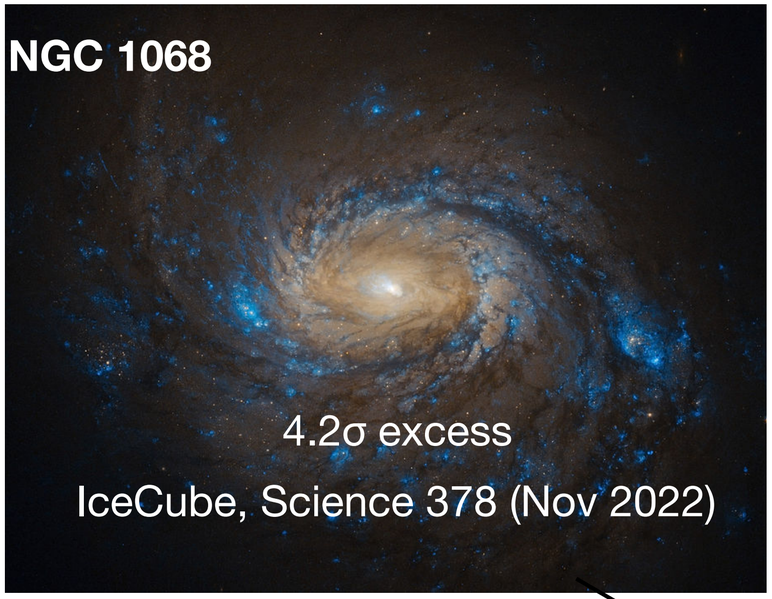

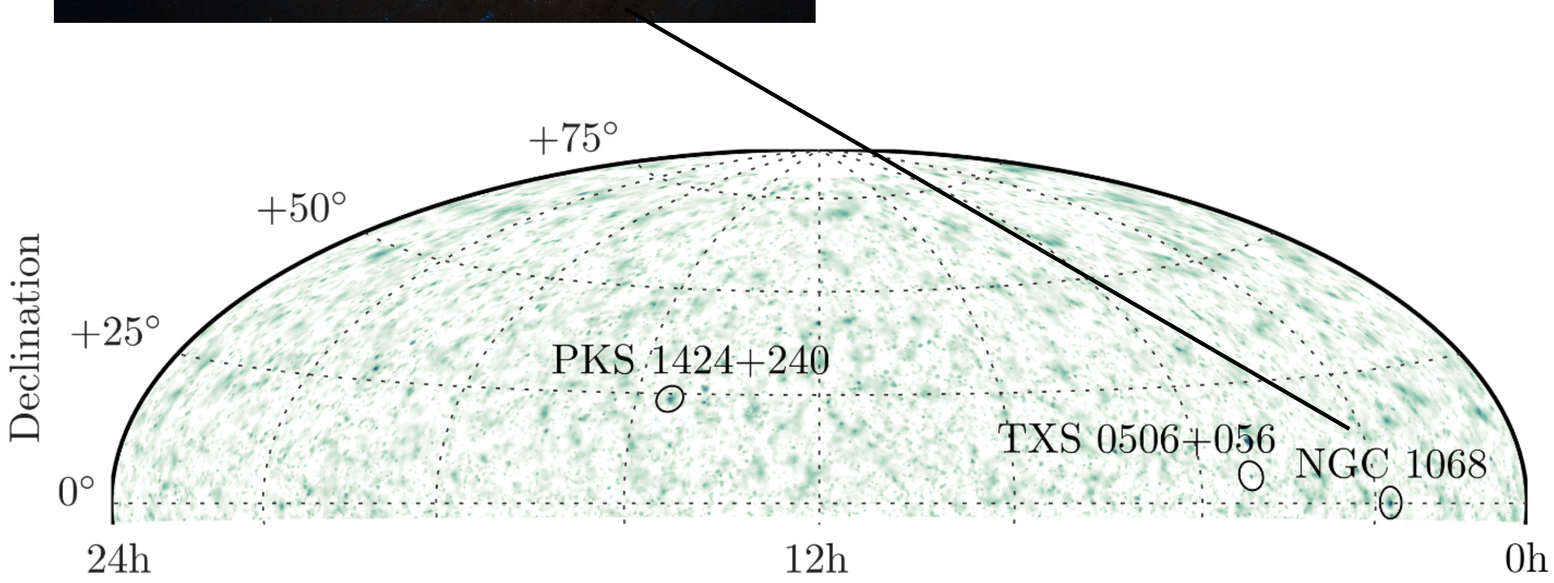

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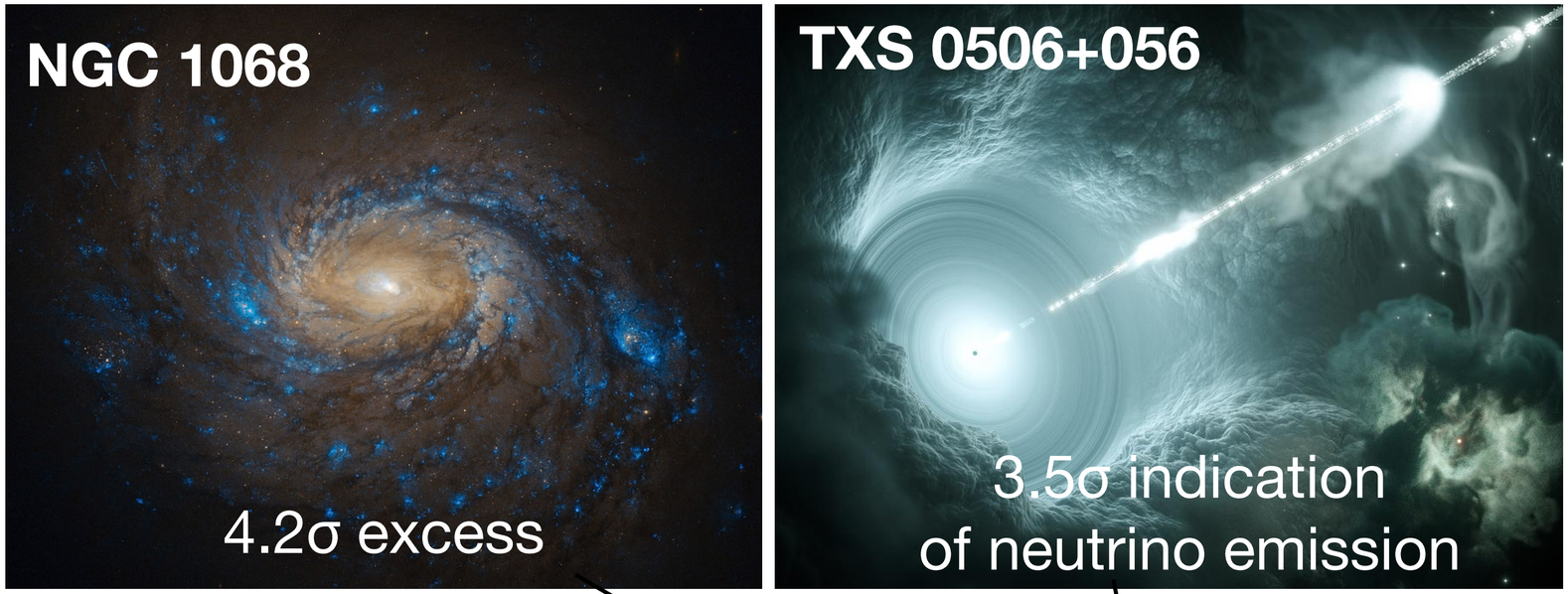

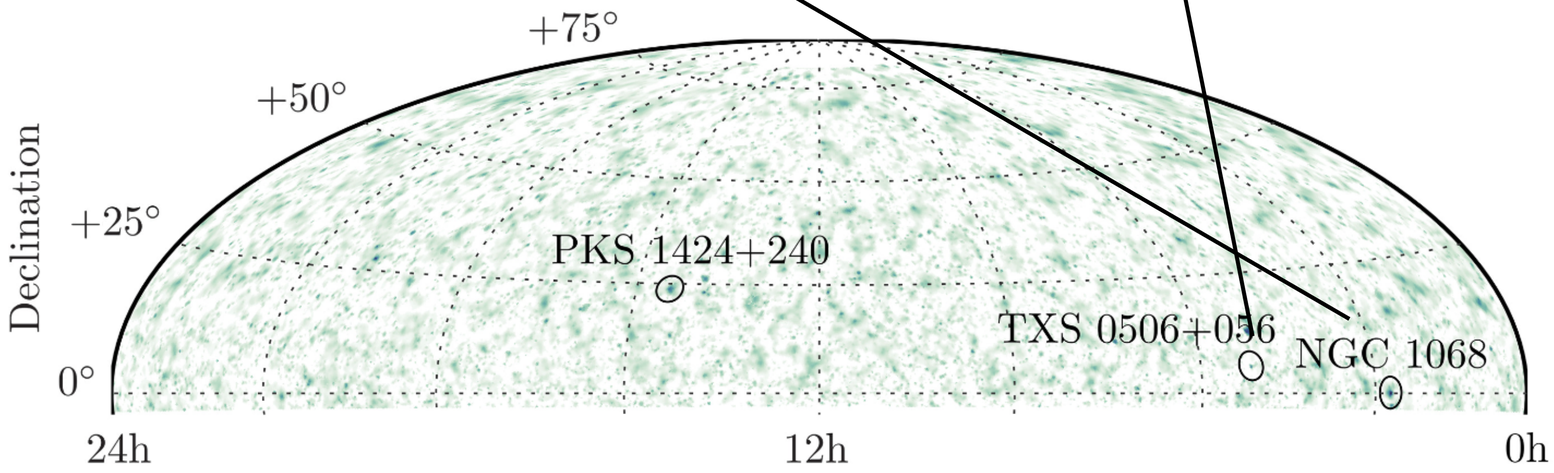

IceCube collaboration, Science 378 (2022)

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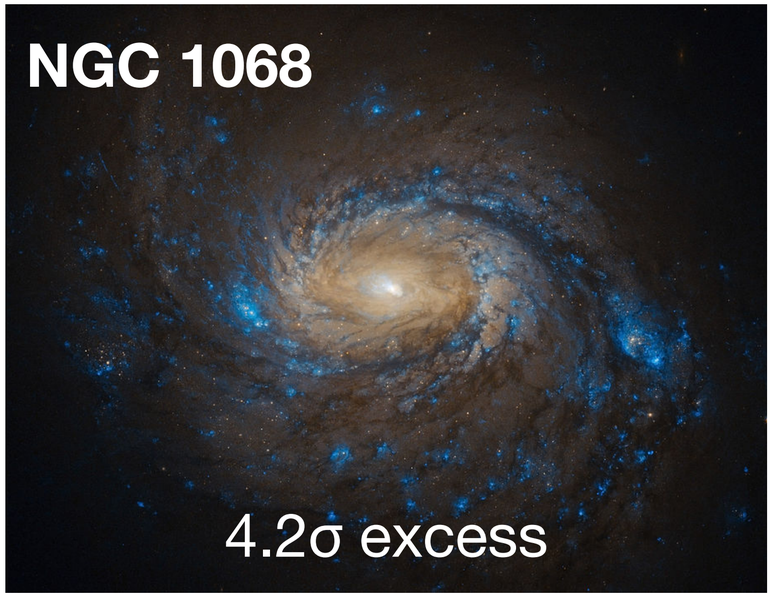

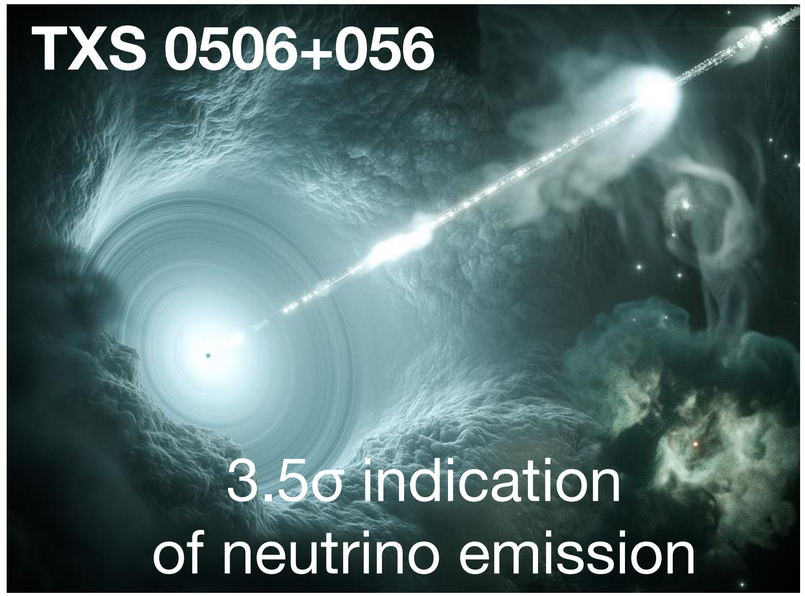

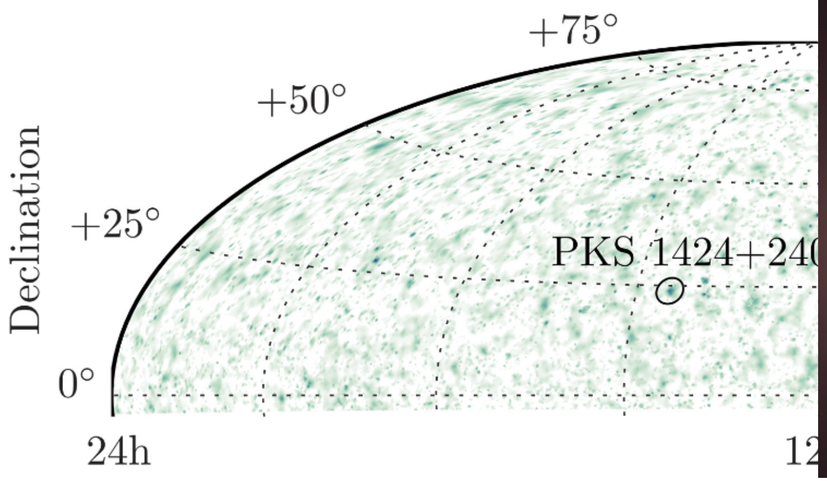

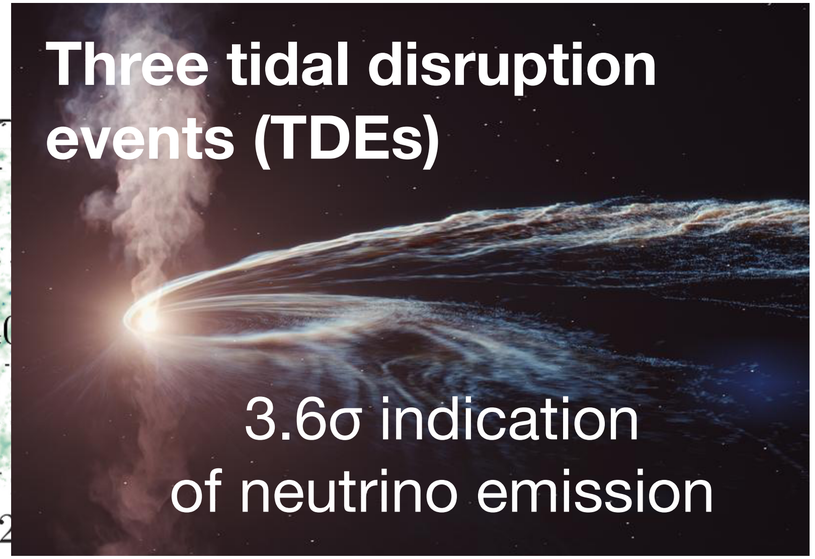

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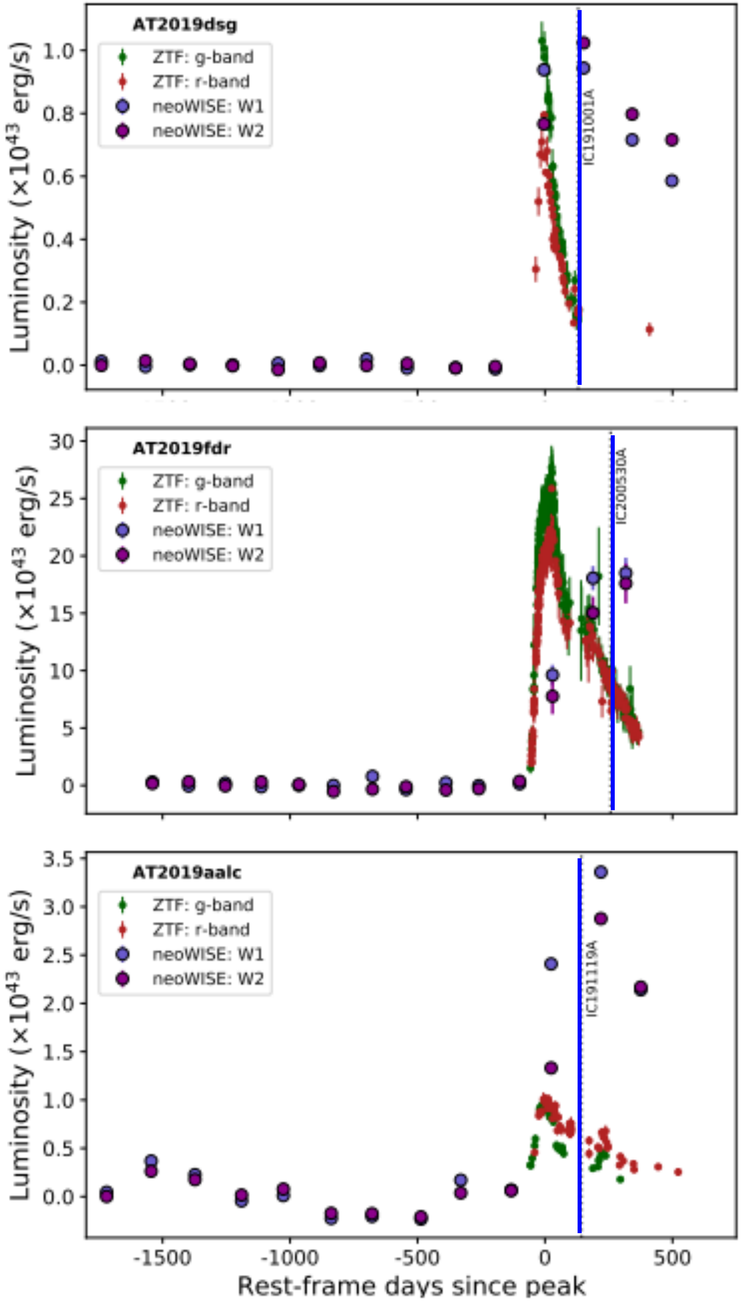
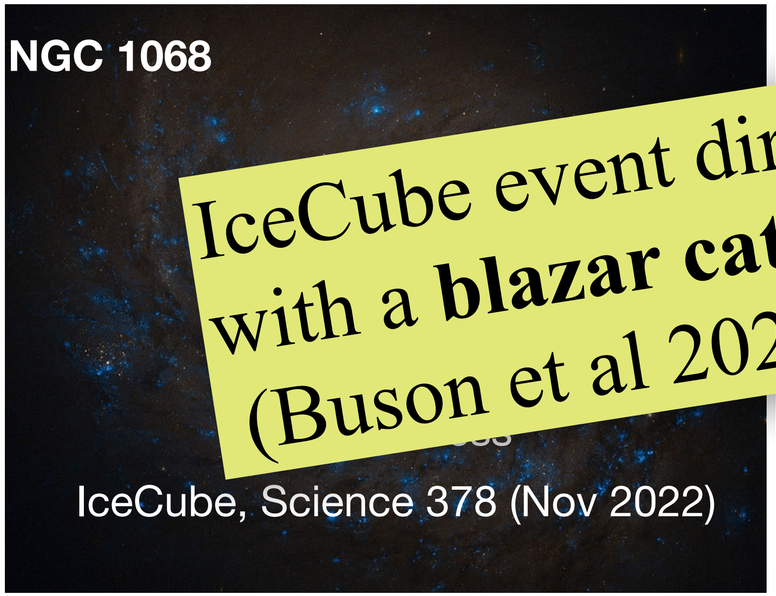
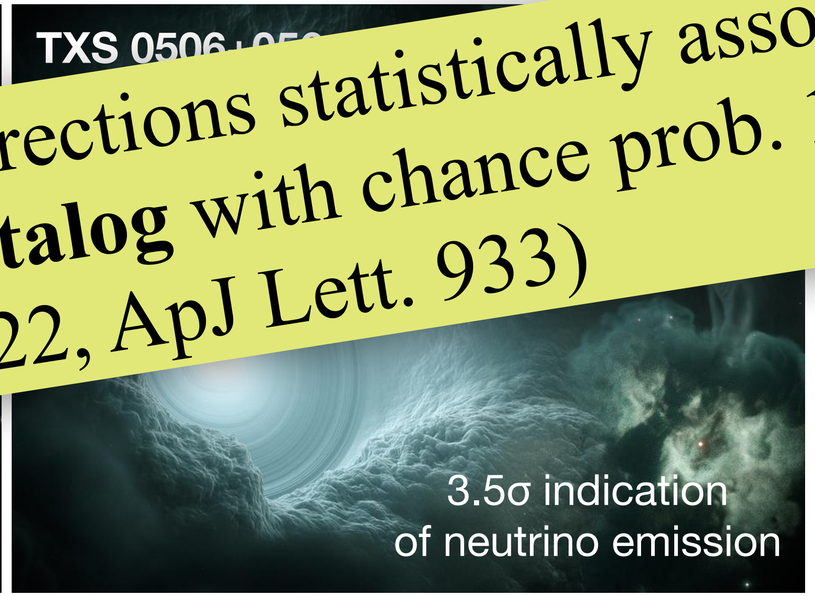


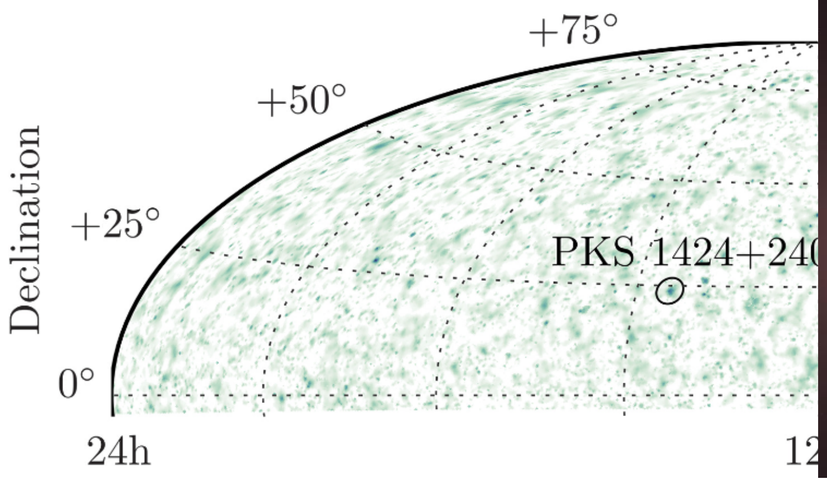
van Velzen et al 2011

The origin of the IceCube neutrinos

IceCube event directions statistically associated with a **blazar catalog** with chance prob. **1.6e-5** (!) (Buson et al 2022, ApJ Lett. 933)







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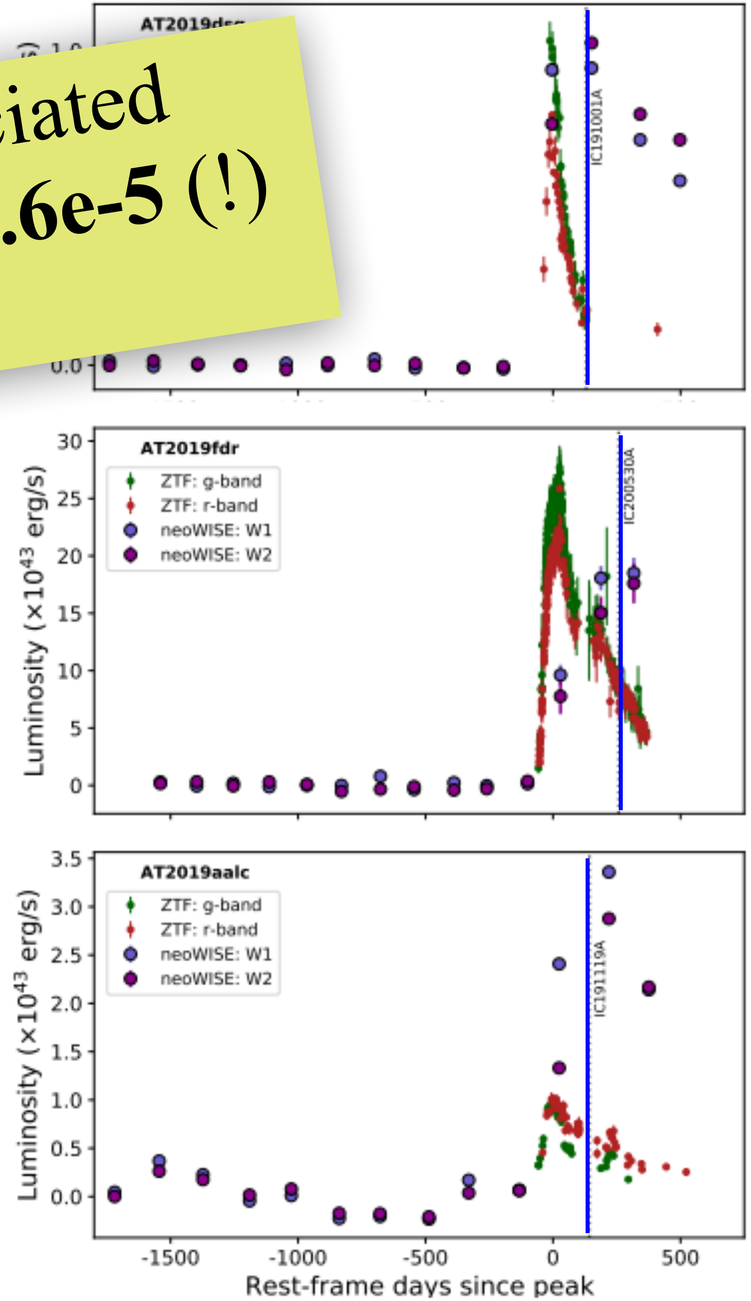

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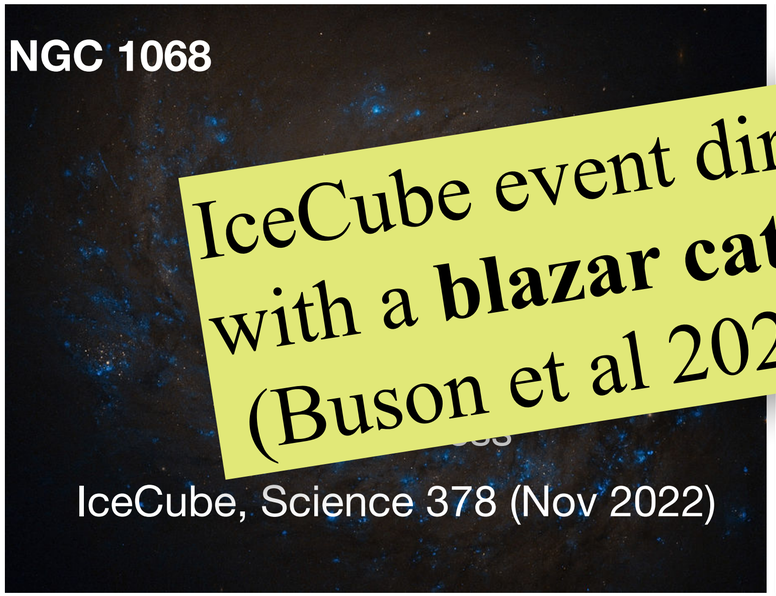
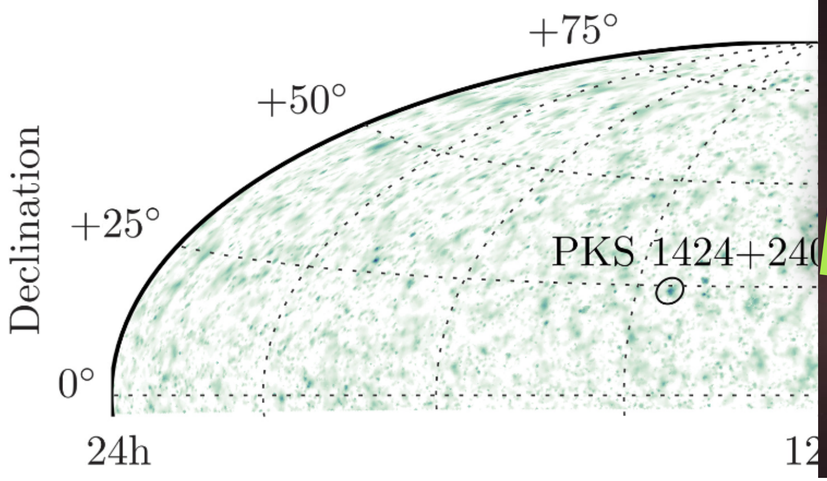


IceCube, Science 378 (Nov 2022)

3.5σ indication

IceCube event directions statistically associated with a **blazar catalog** with chance prob. **1.6e-5** (!) (Buson et al 2022, ApJ Lett. 933)

Significant correlation between IceCube events and **radio-loud AGN** (Plavin et al 2020, ApJ 894; Plavin et al 2021, ApJ 908; Hovatta et al 2021, A&A 650)



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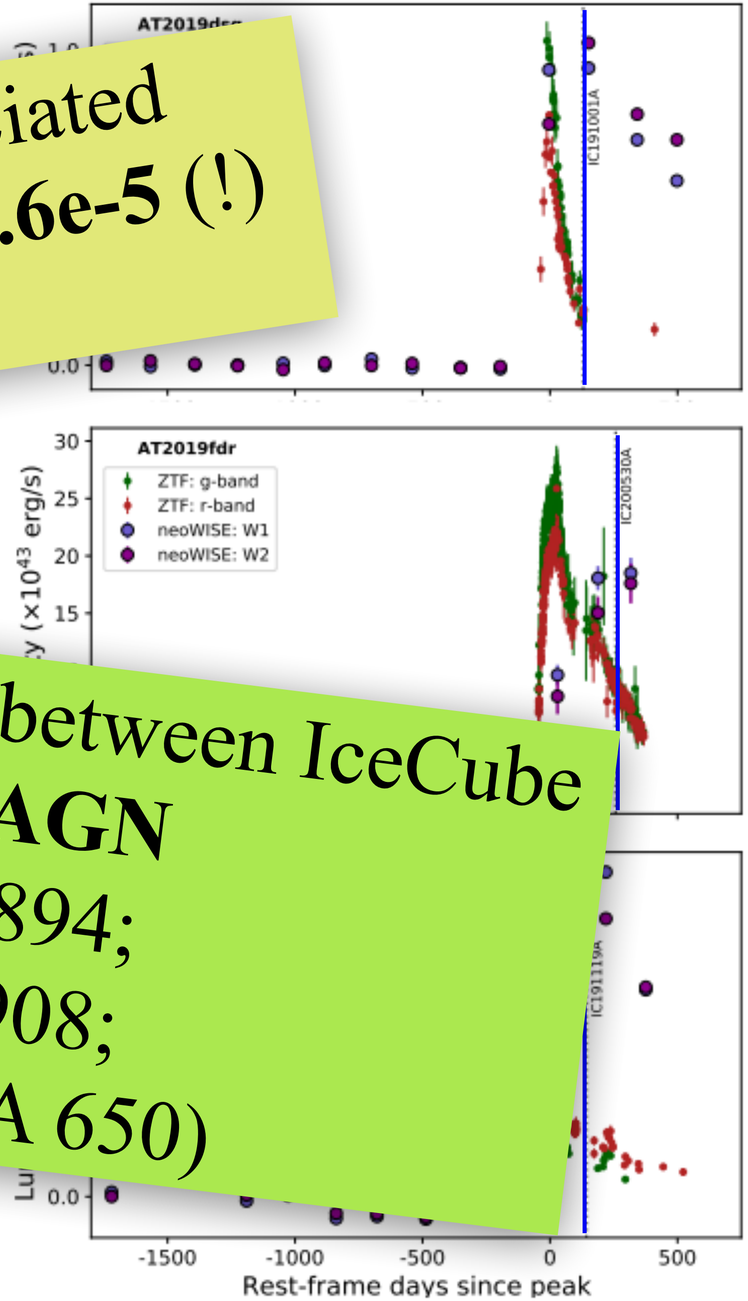
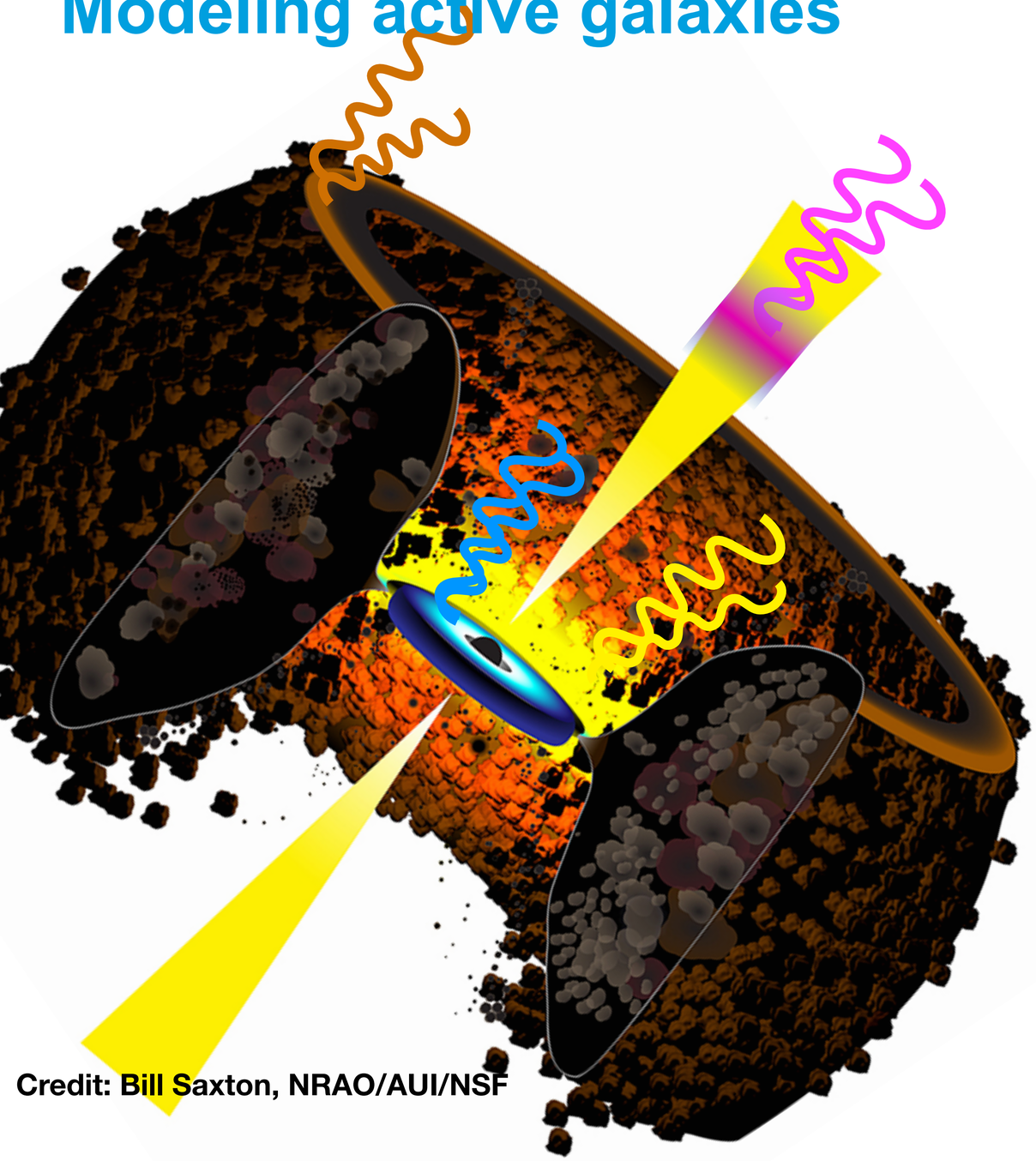
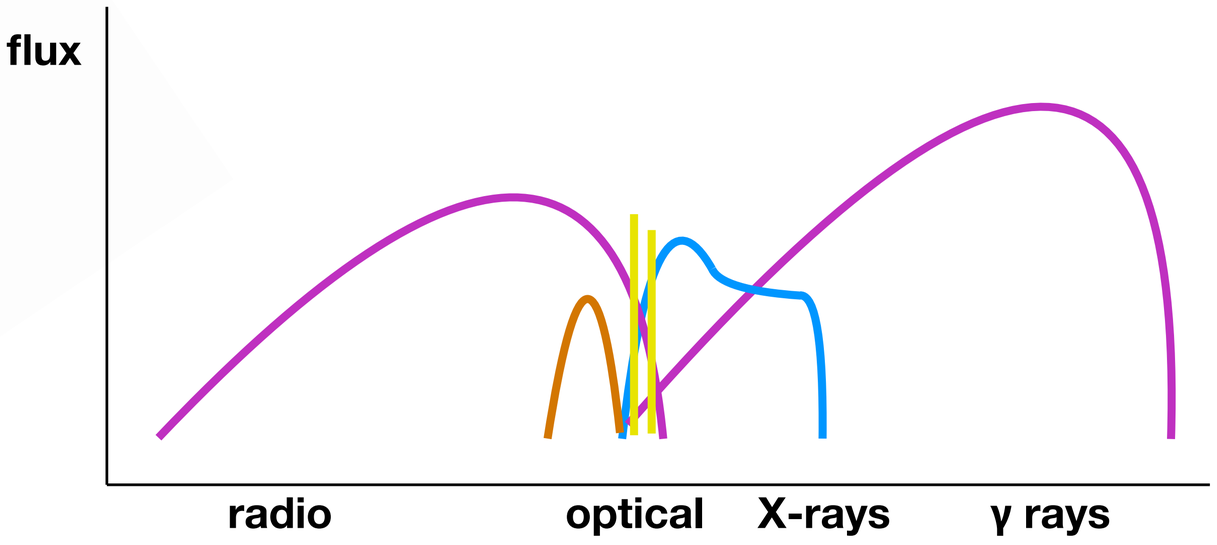


van Velzen et al 2011

Modeling active galaxies



Credit: Bill Saxton, NRAO/AUI/NSF



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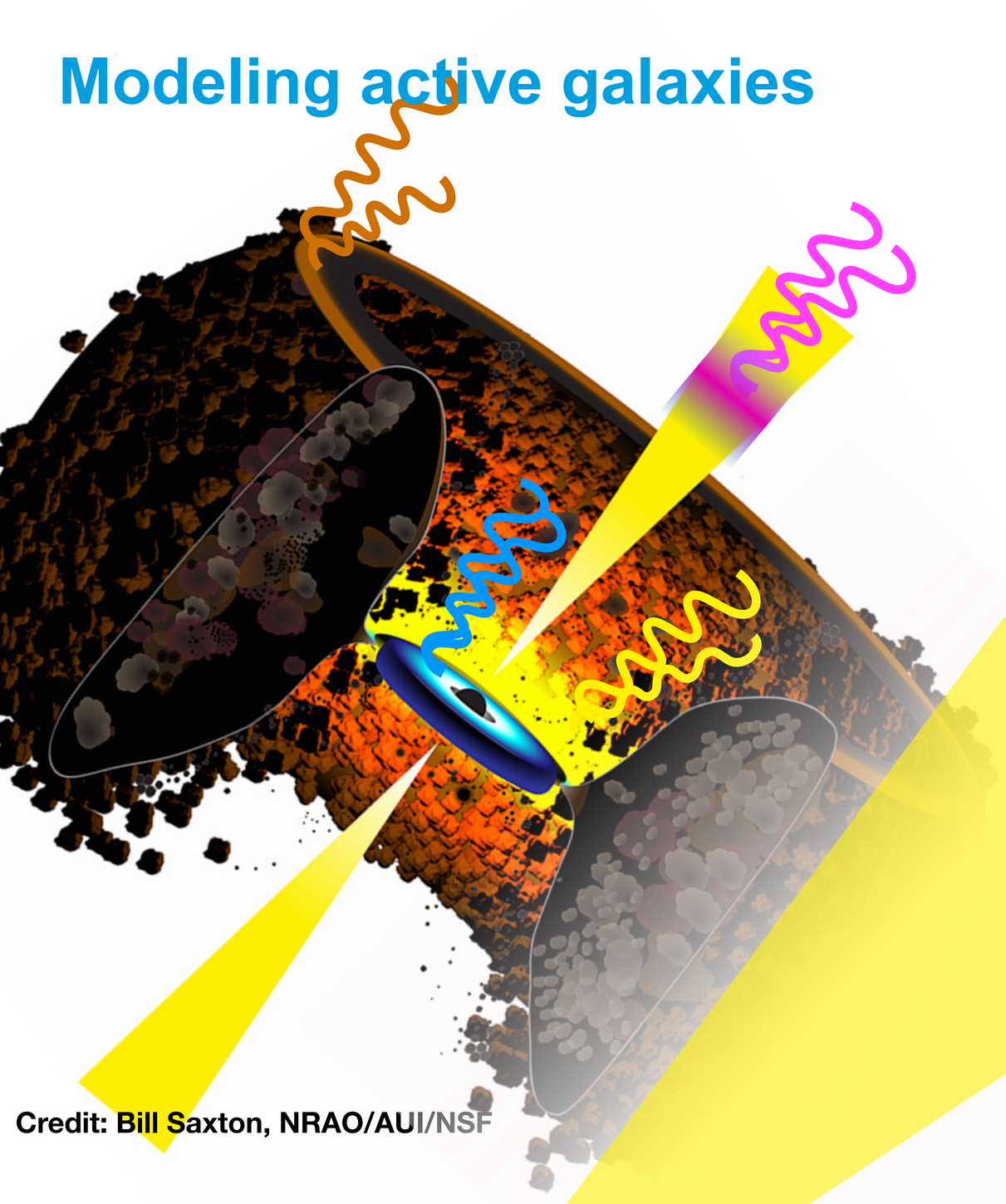

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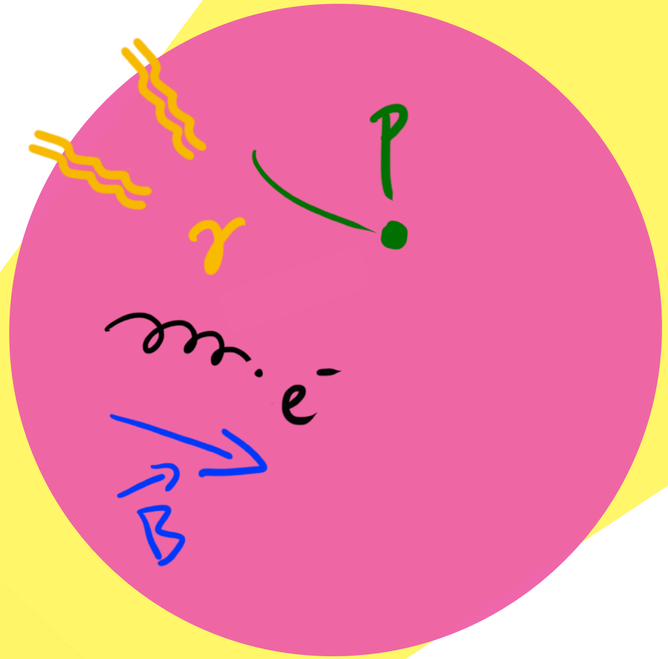

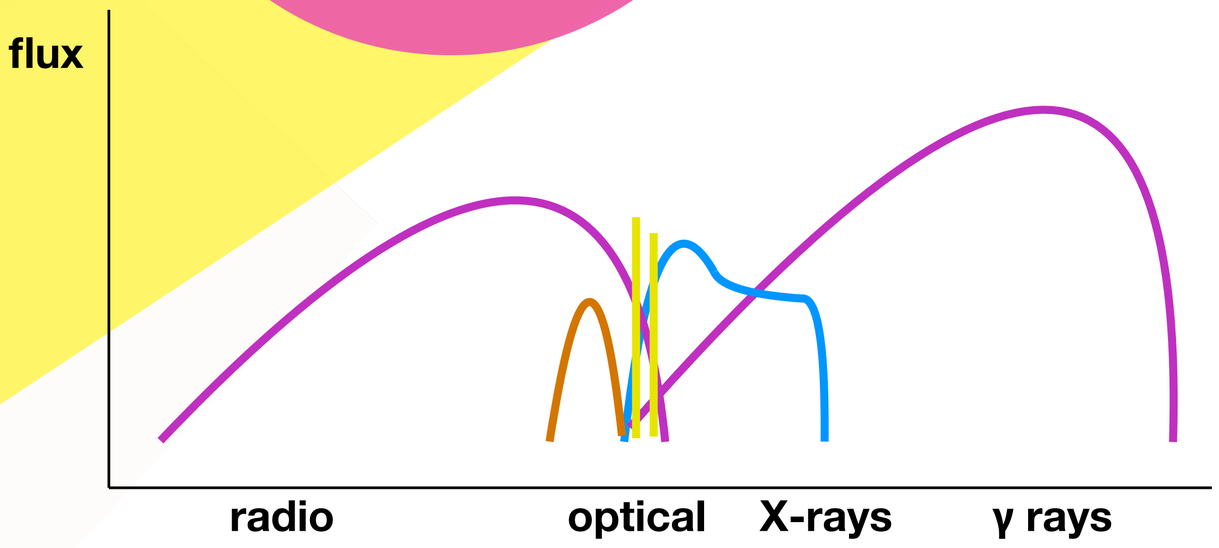

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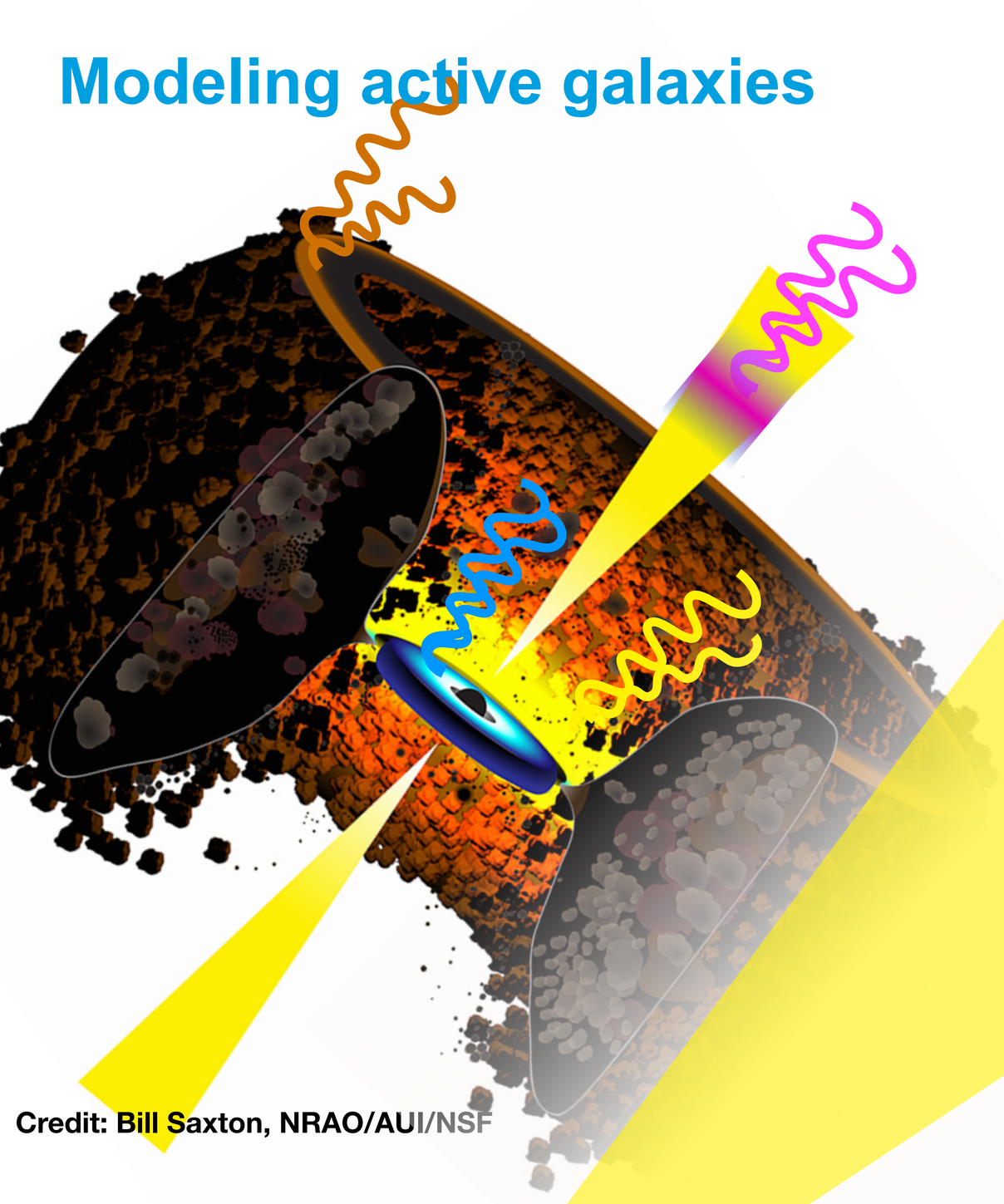

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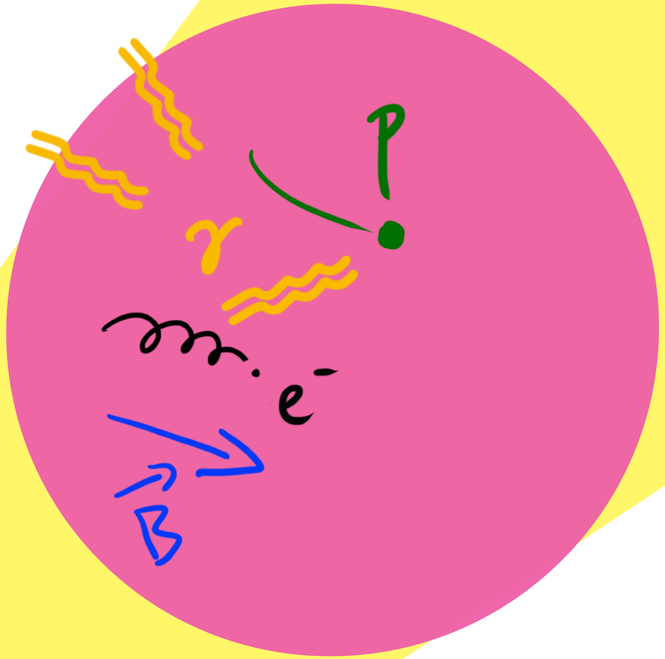

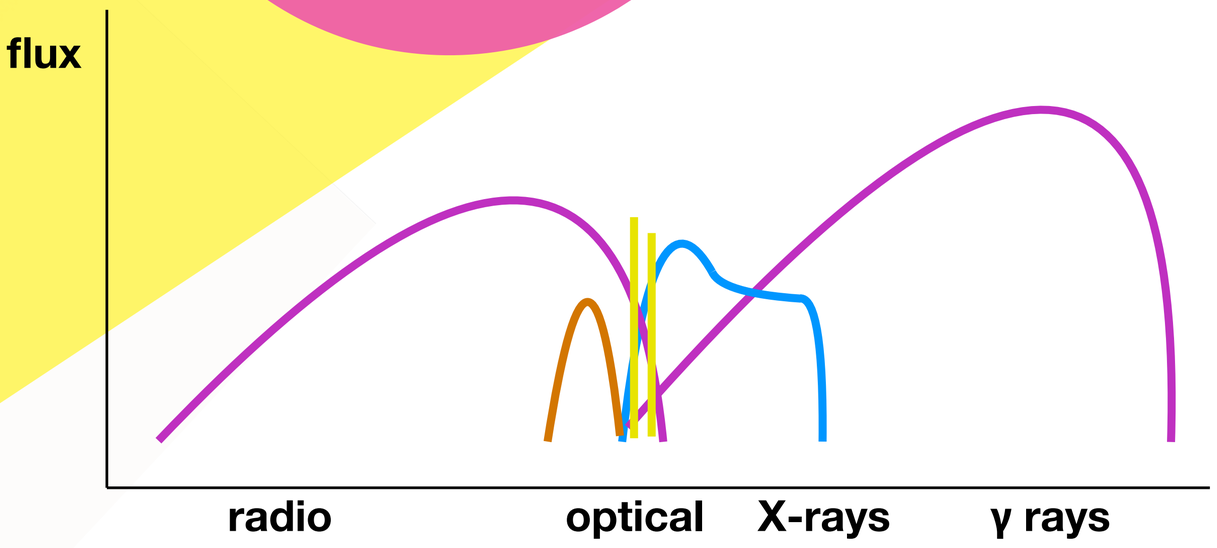

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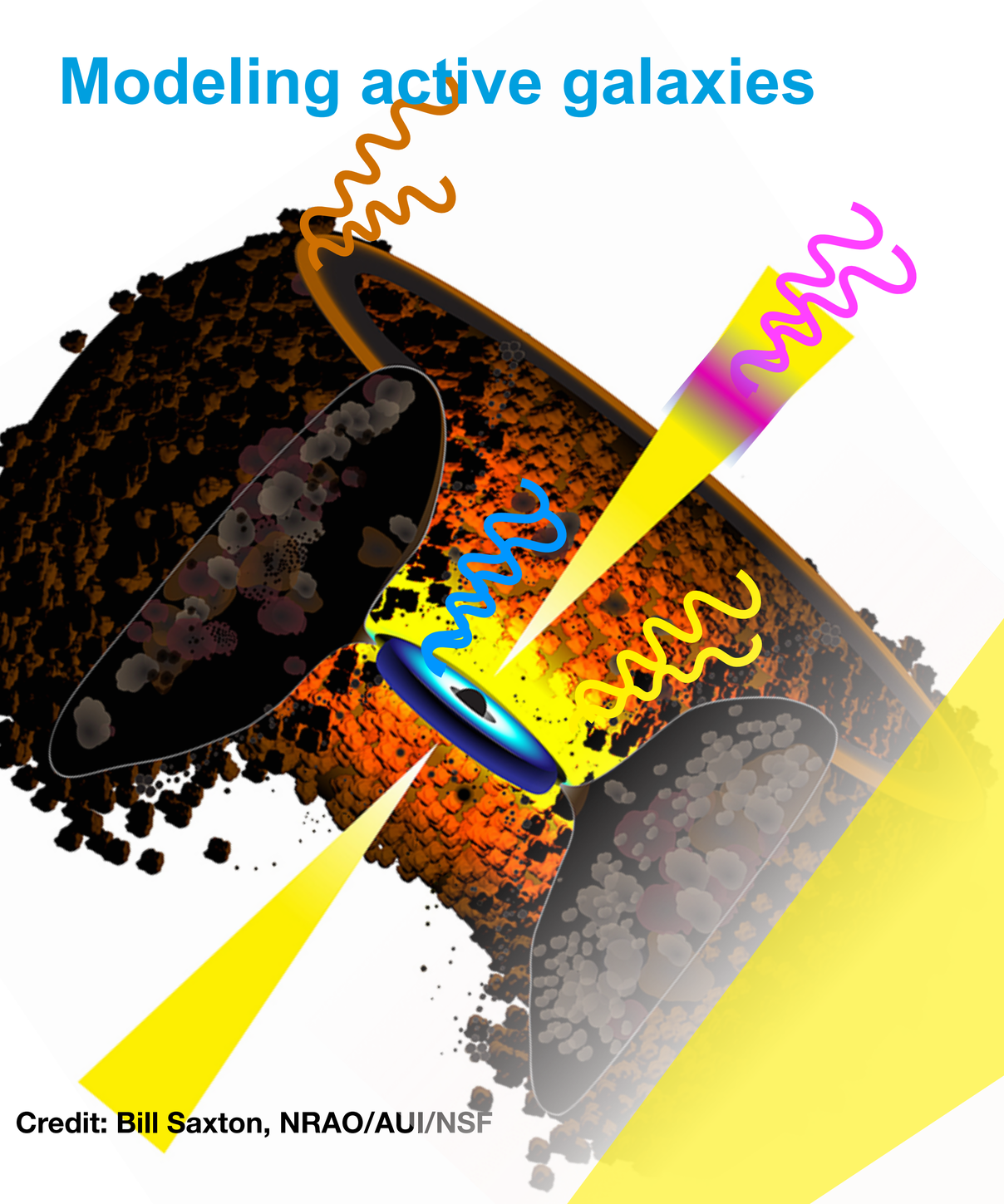

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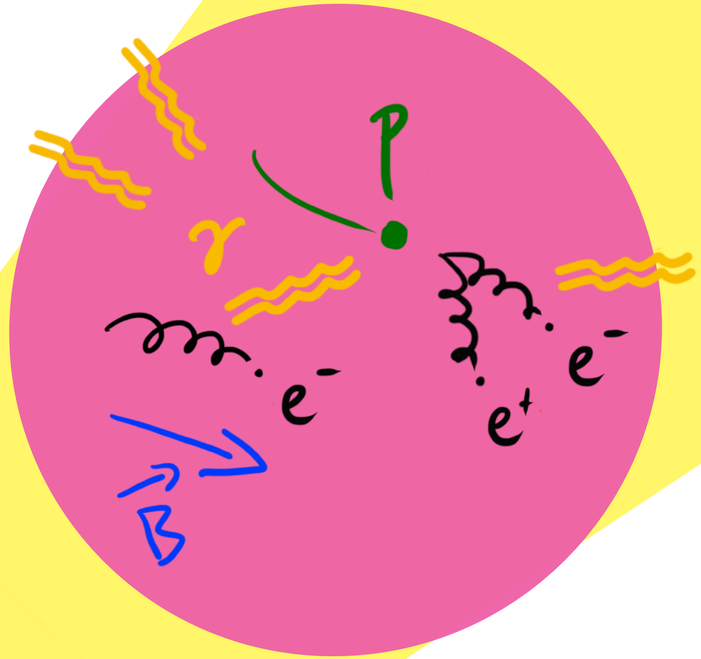

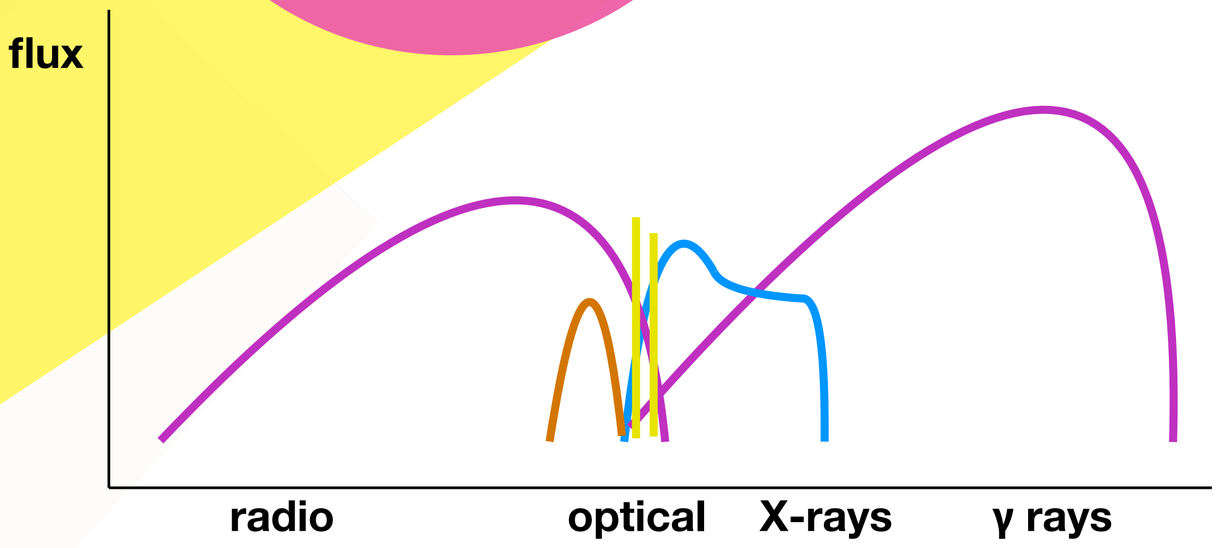

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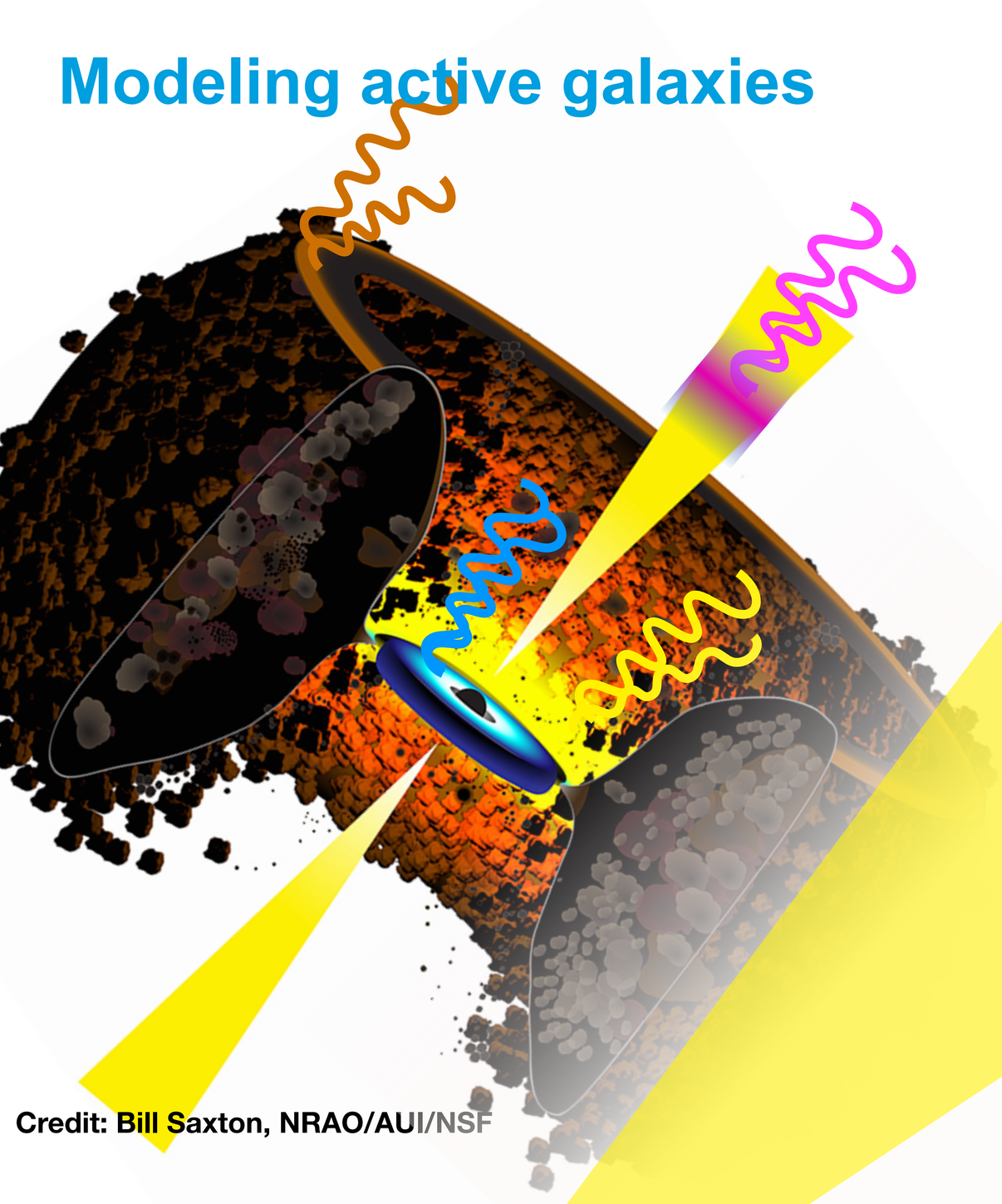

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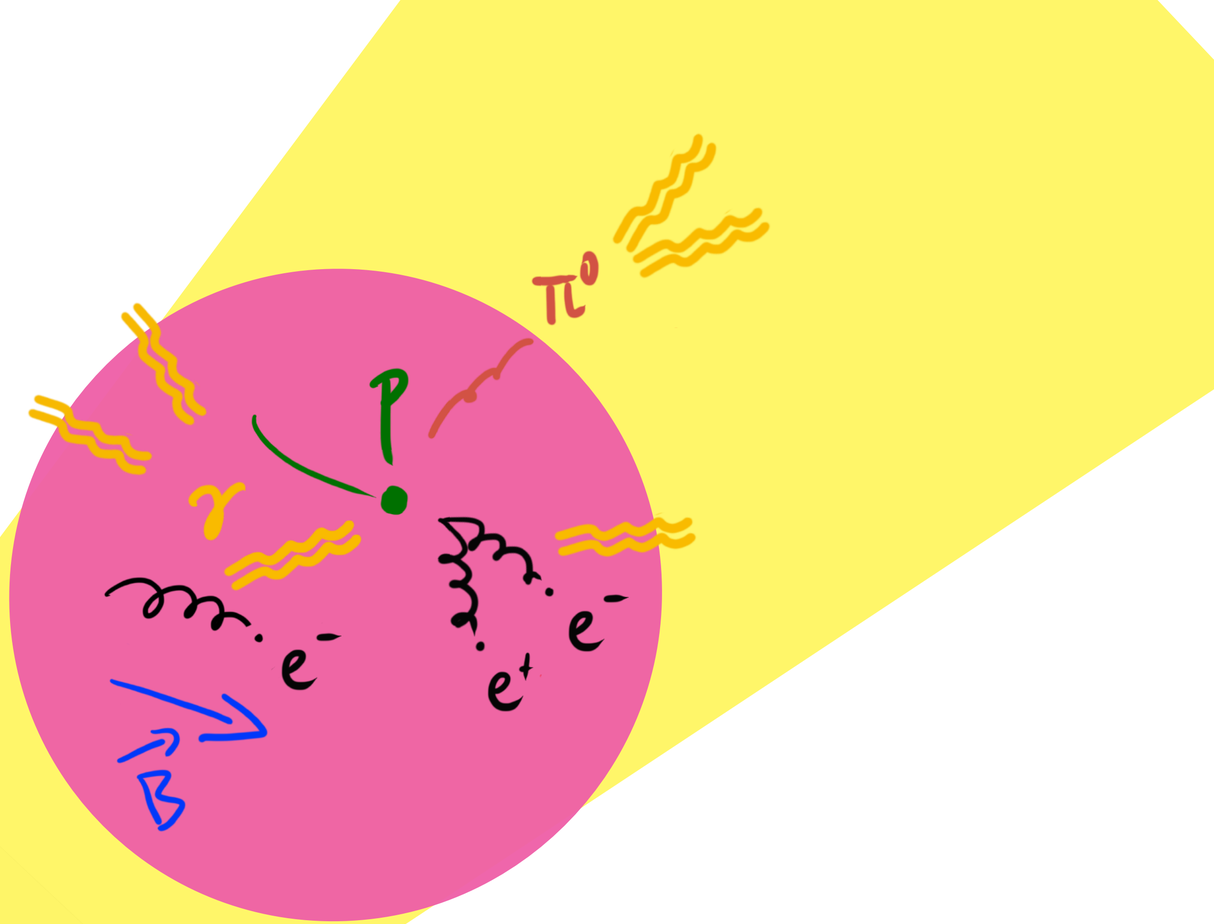

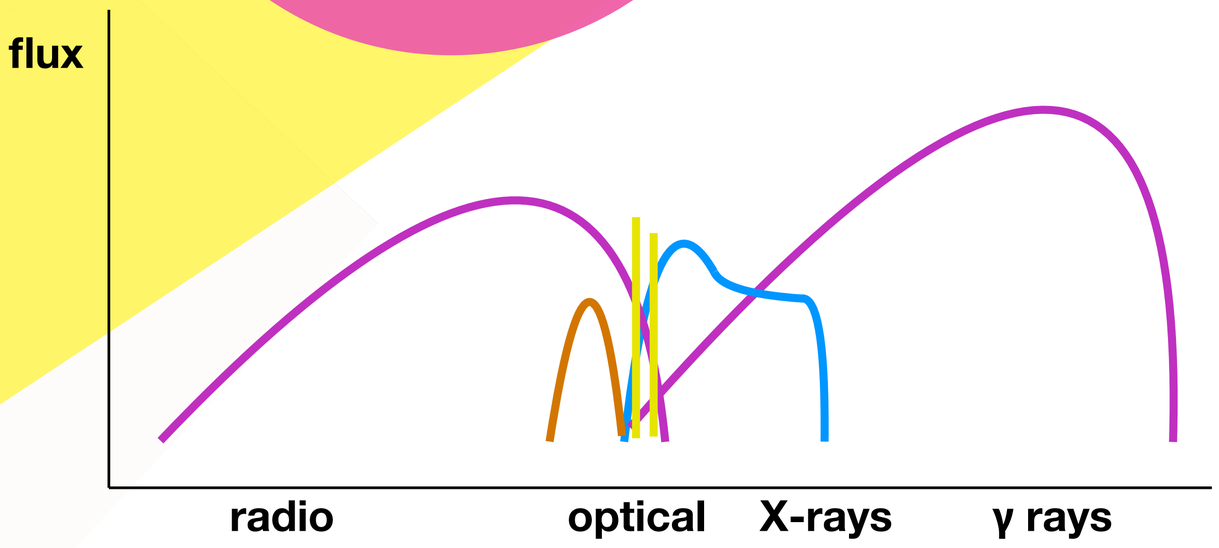

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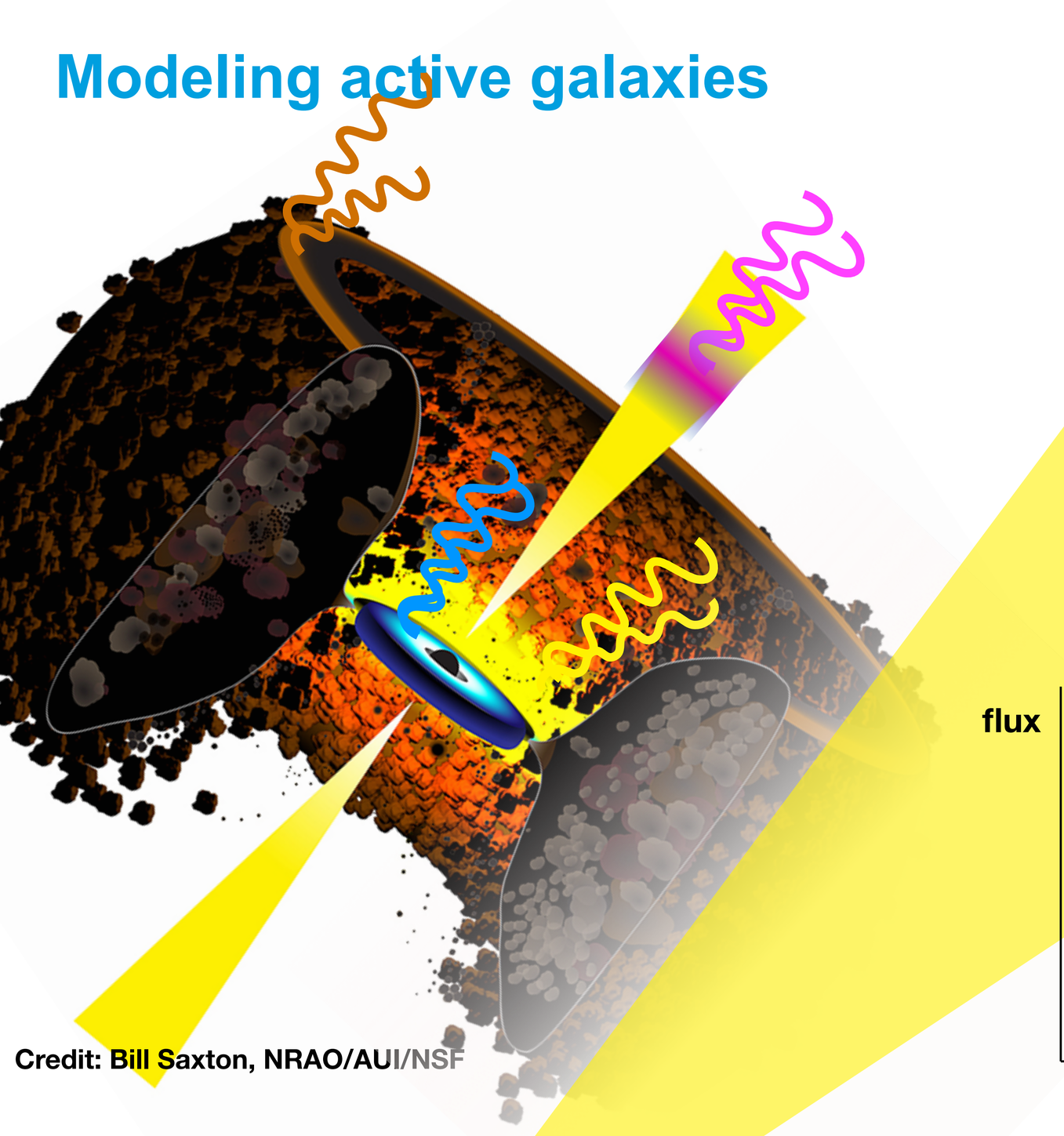

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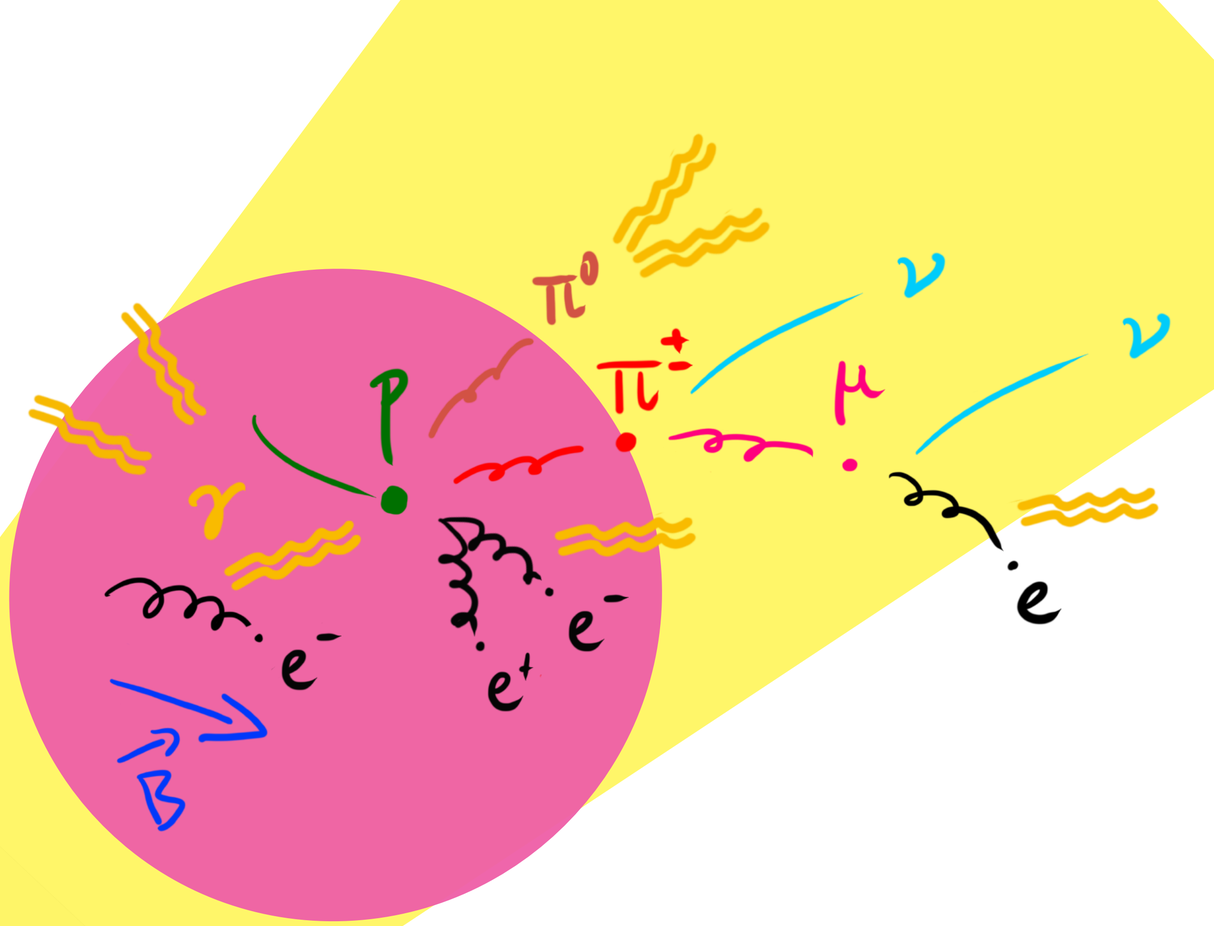

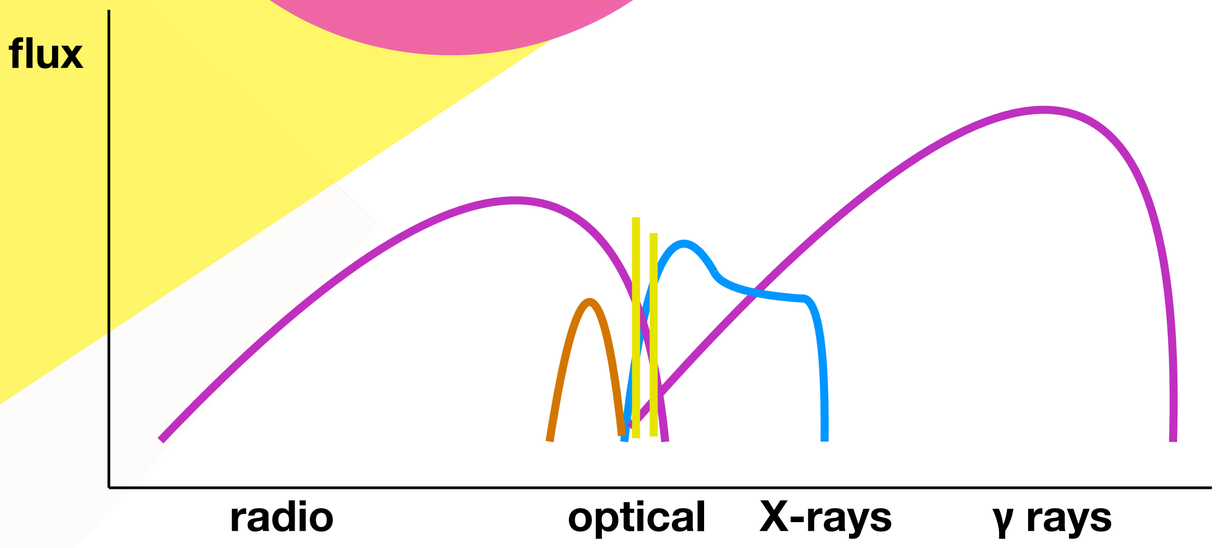

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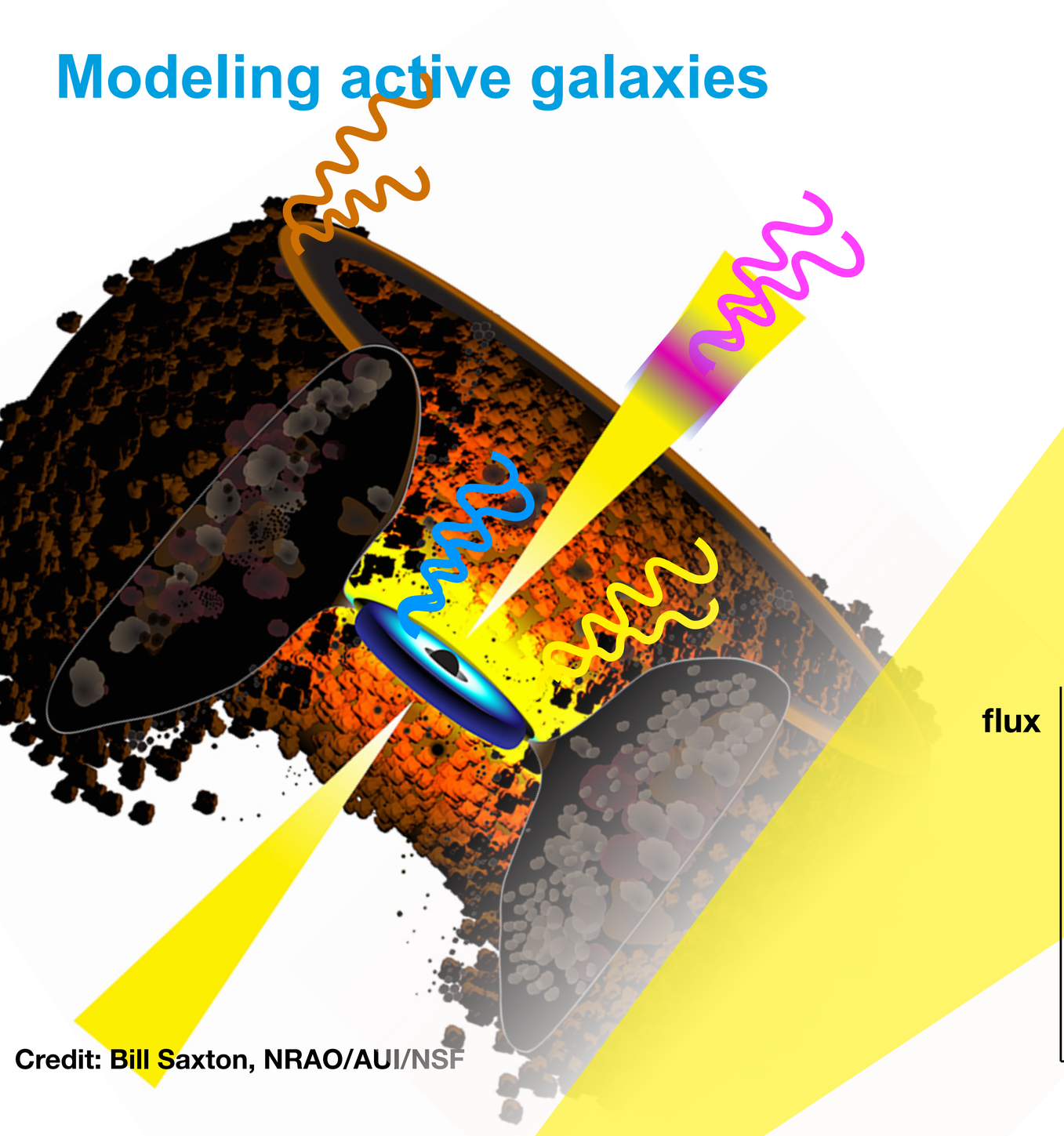

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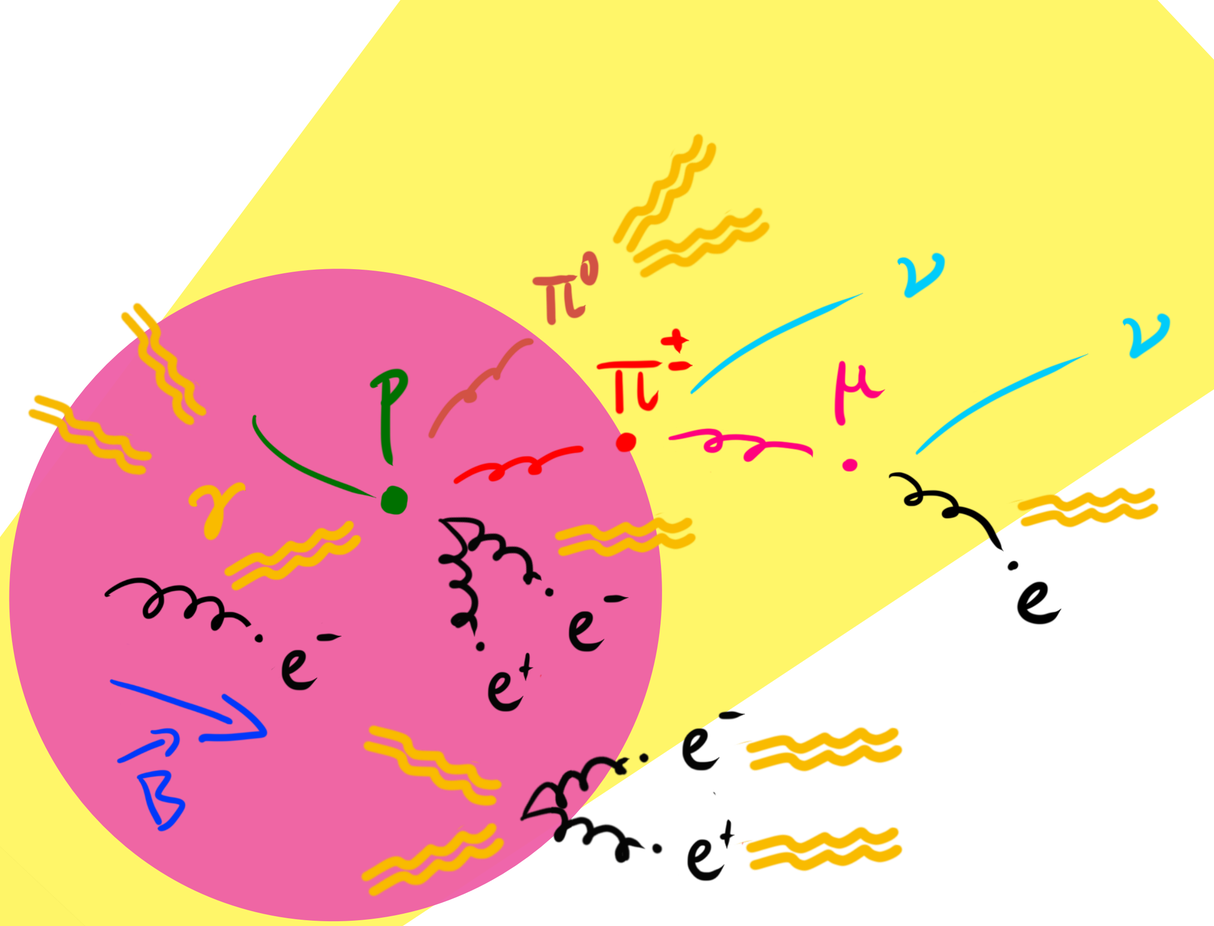

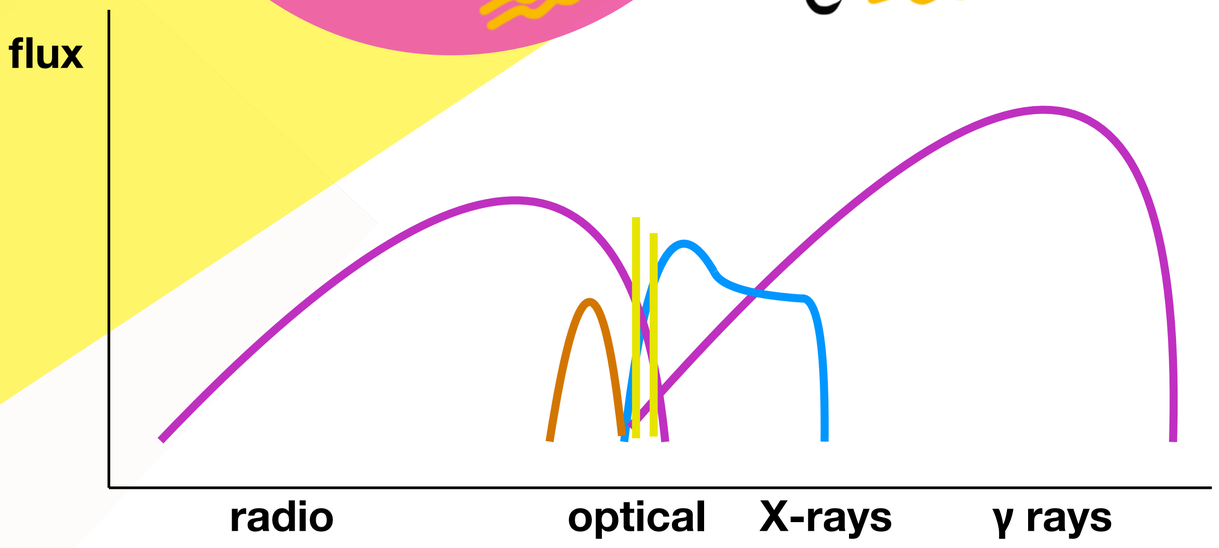

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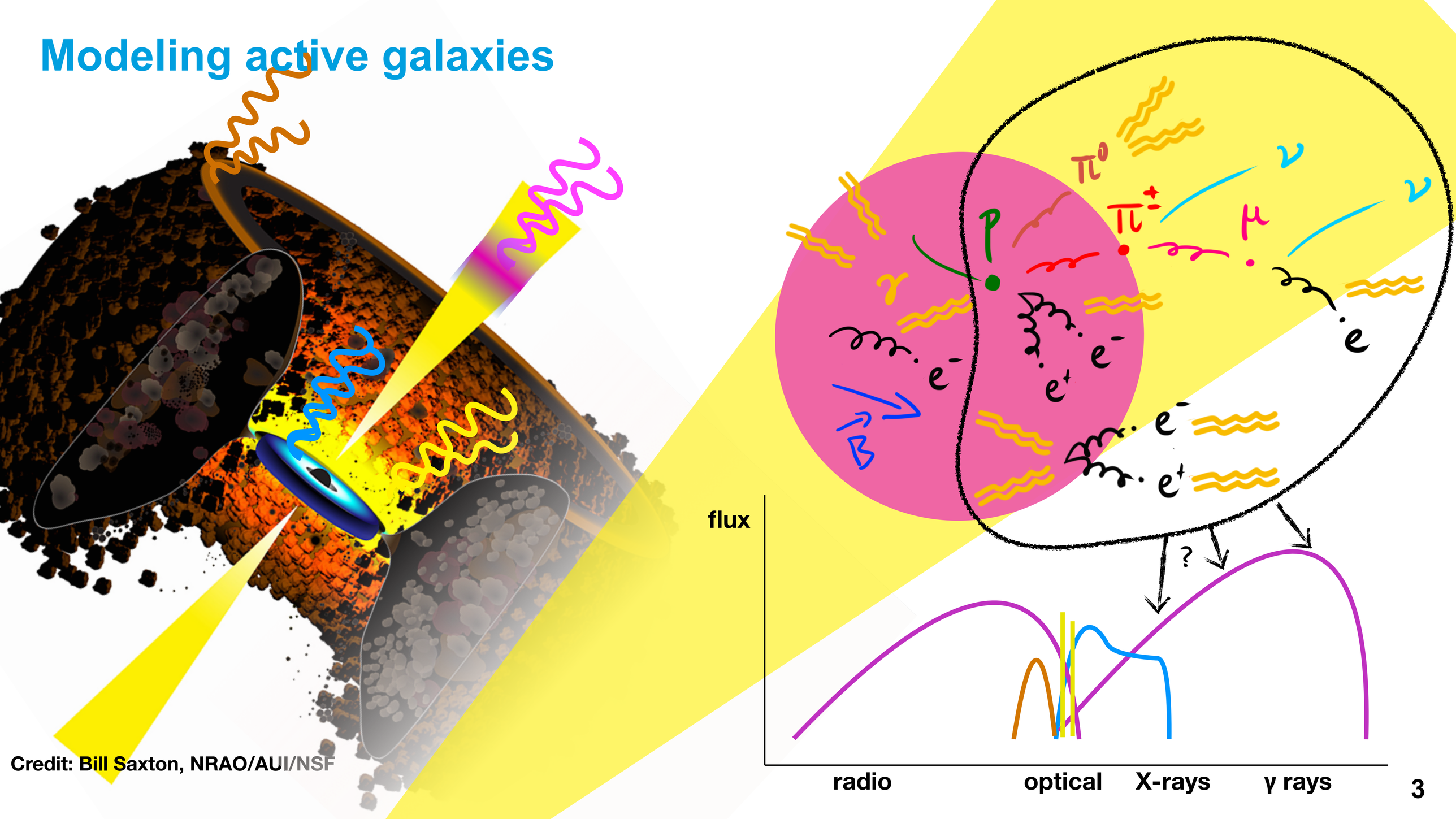

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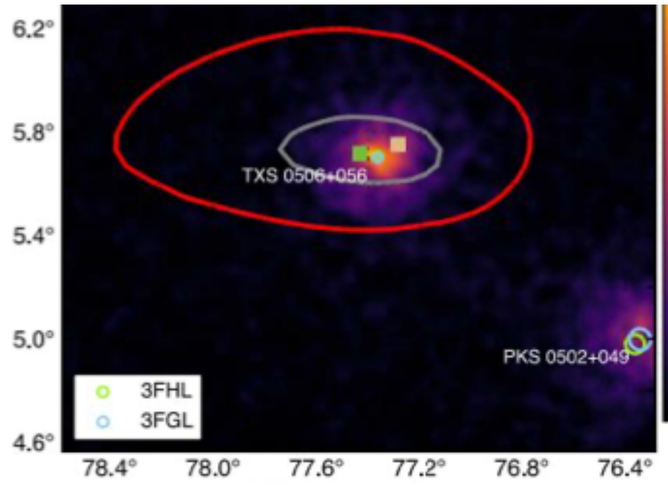
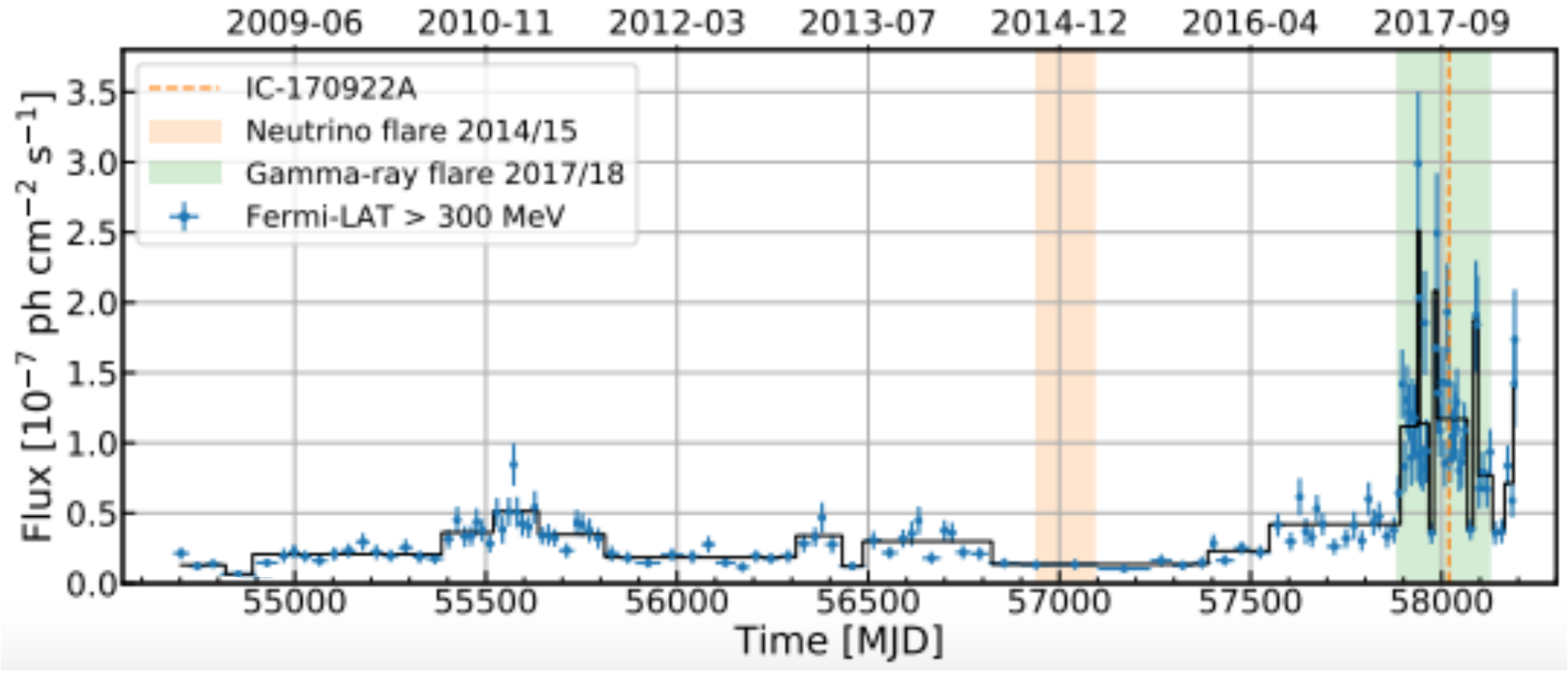
Will we find IceCube blazars in GeV γ-rays?



TXS 0506+056 (September 2017)



Garrappa+ 2019, ApJ 880

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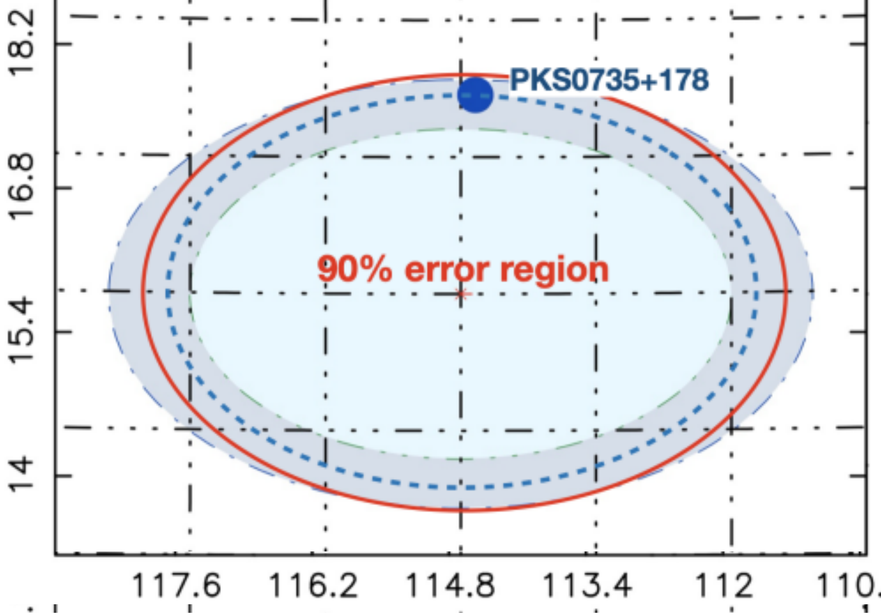
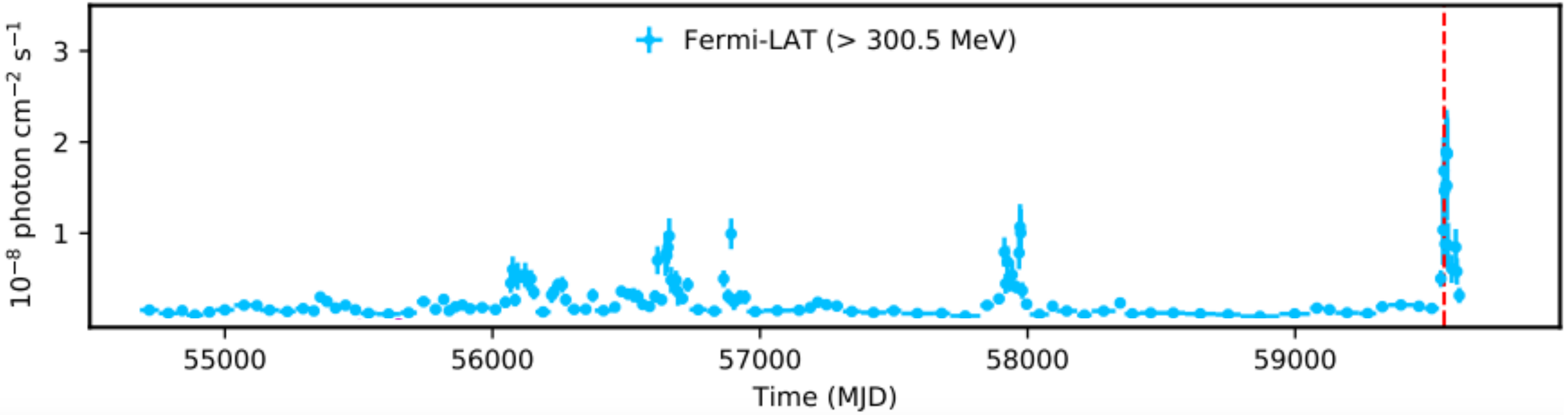


PKS 0735+178 (December 2021)



Sahakyan+ 2022 (2204.05060)

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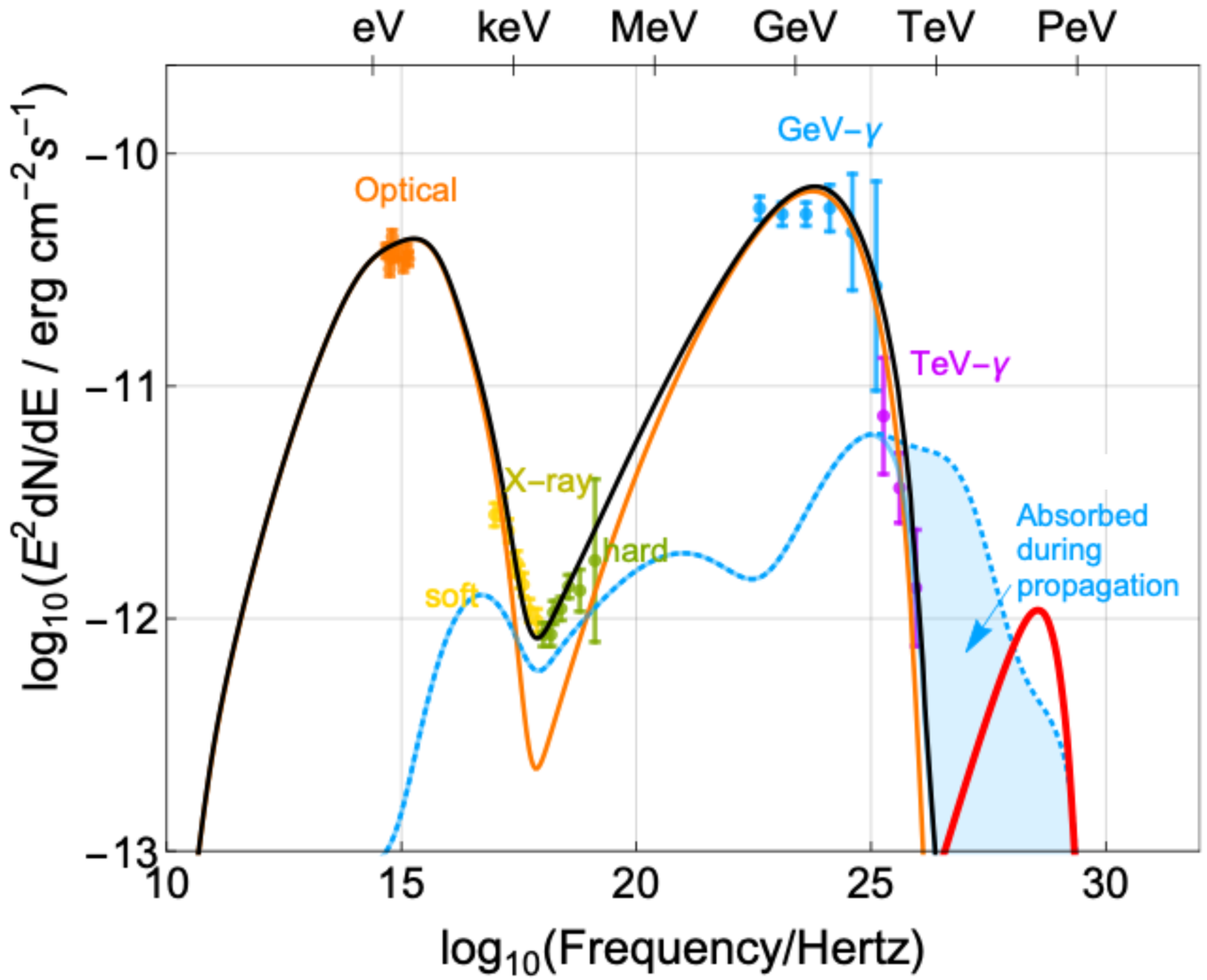

Gao, Fedynitch, Winter, Pohl, Nat.Astron. 3 (2019)

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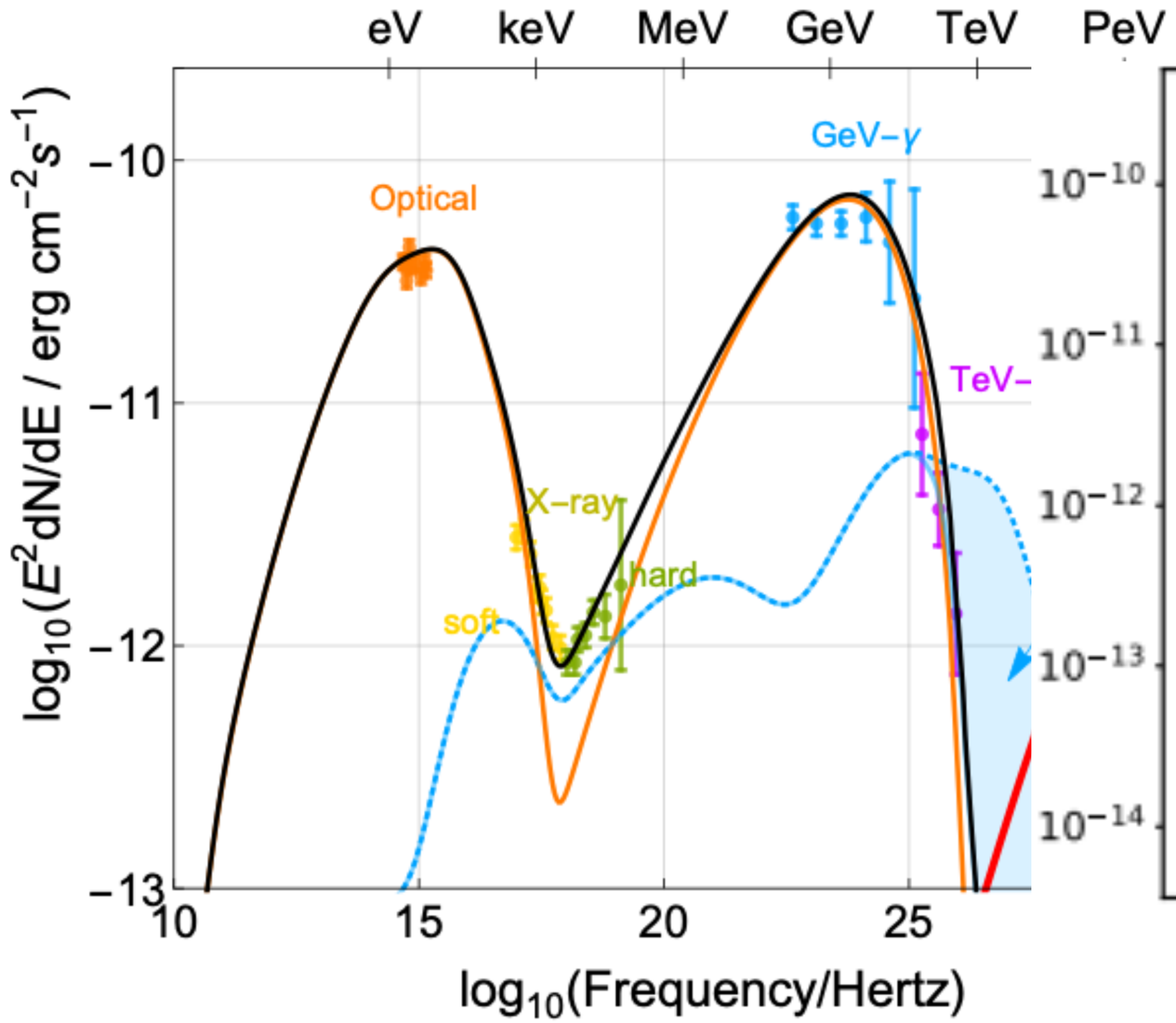

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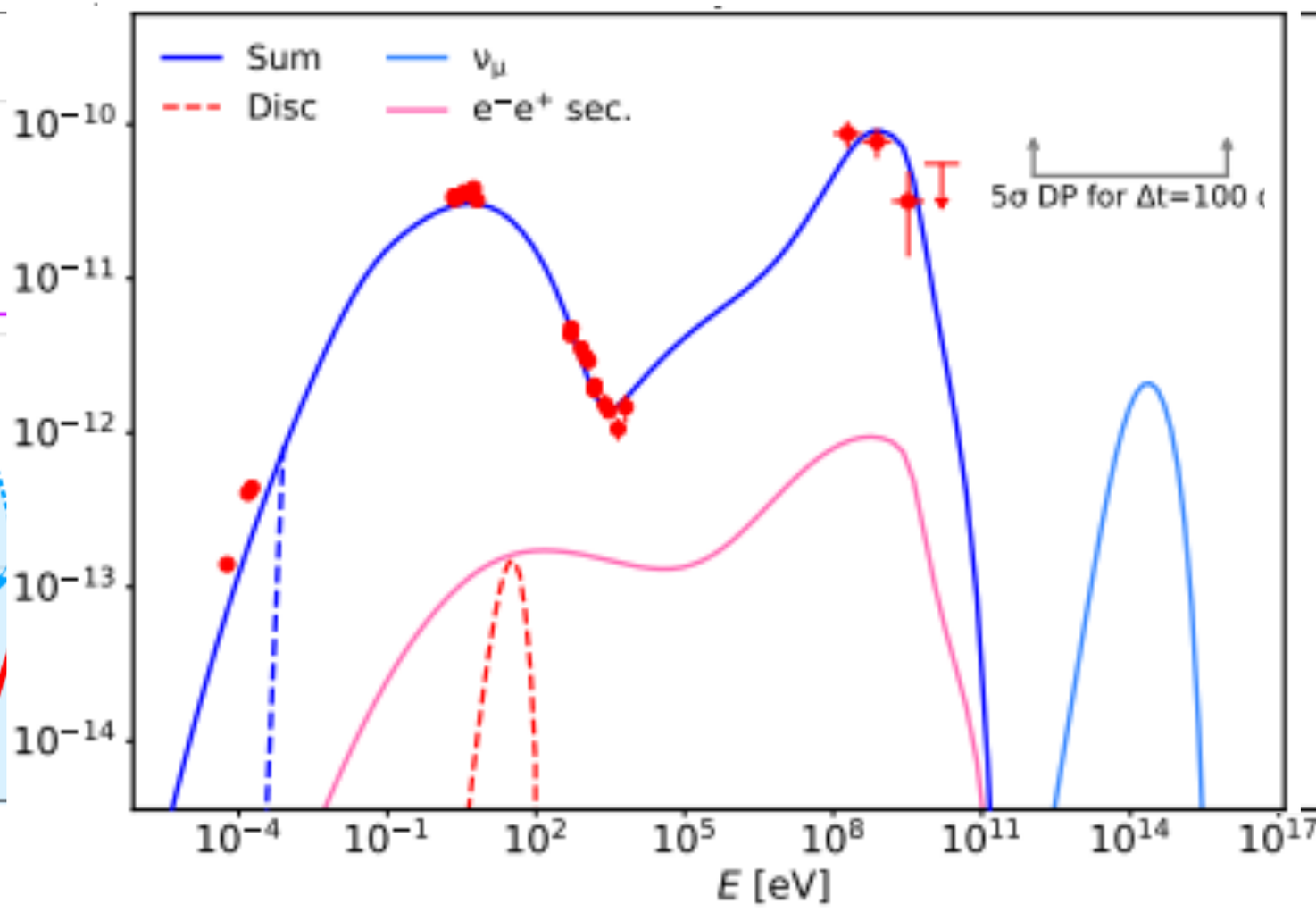
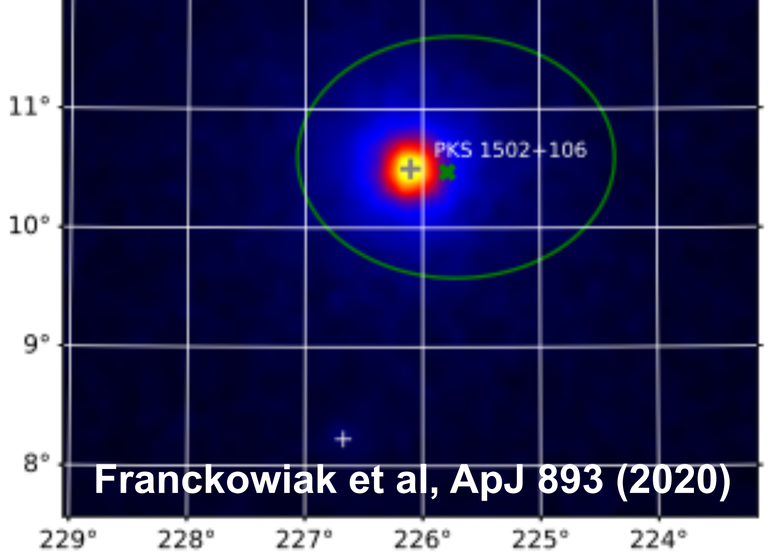


Gao, Fedynitch, Winter, Pohl, Nat.Astron. 3 (2019)

Sahakyan+ 2022 (2204.05060)

What is a hadronic ‘signature’?

PKS 1502+106 (August 2019)



Franckowiak et al, ApJ 893 (2020)

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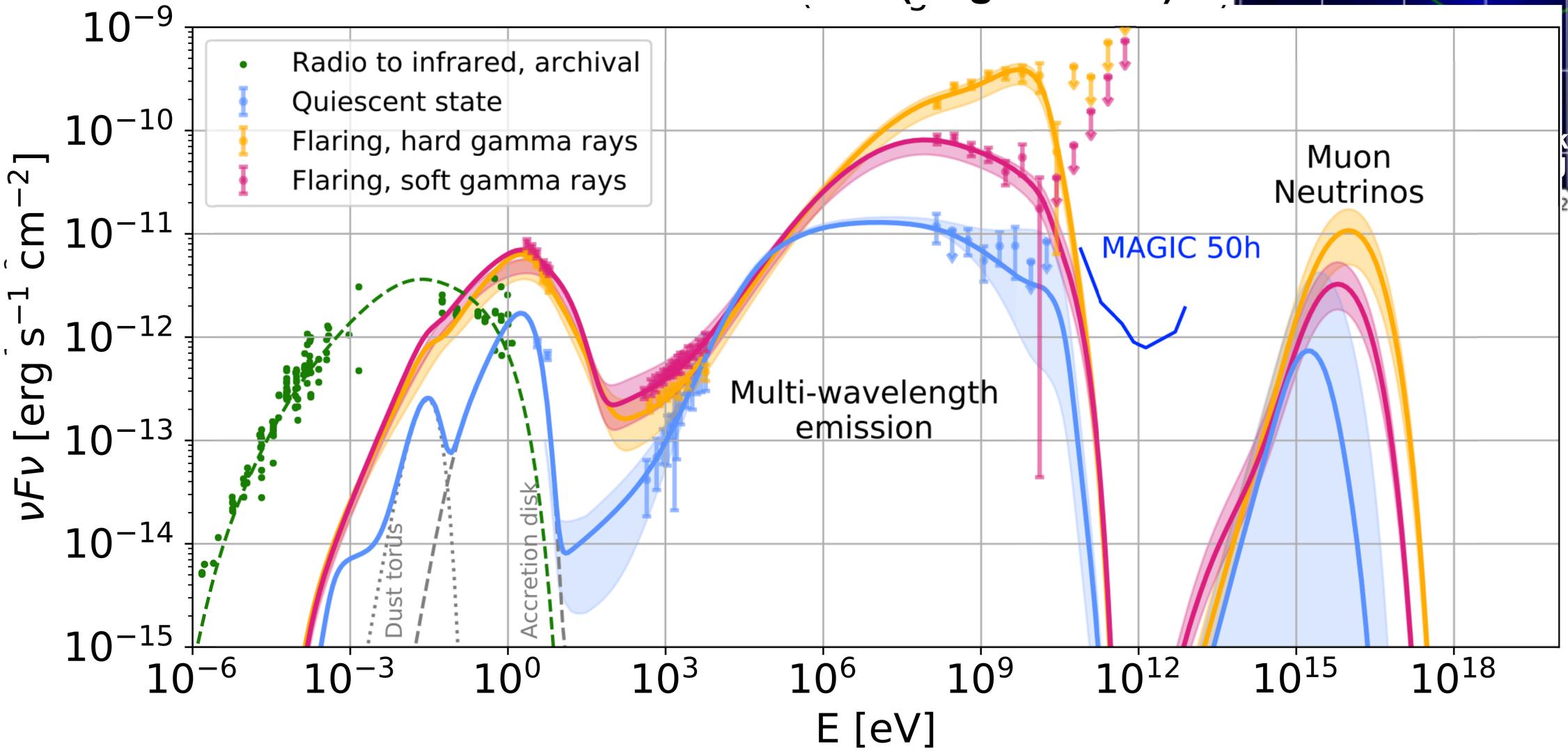

kowiak et al
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Rodrigues, Garrappa, Gao, Paliya, Franckowiak and Winter, ApJ 912 (2021)

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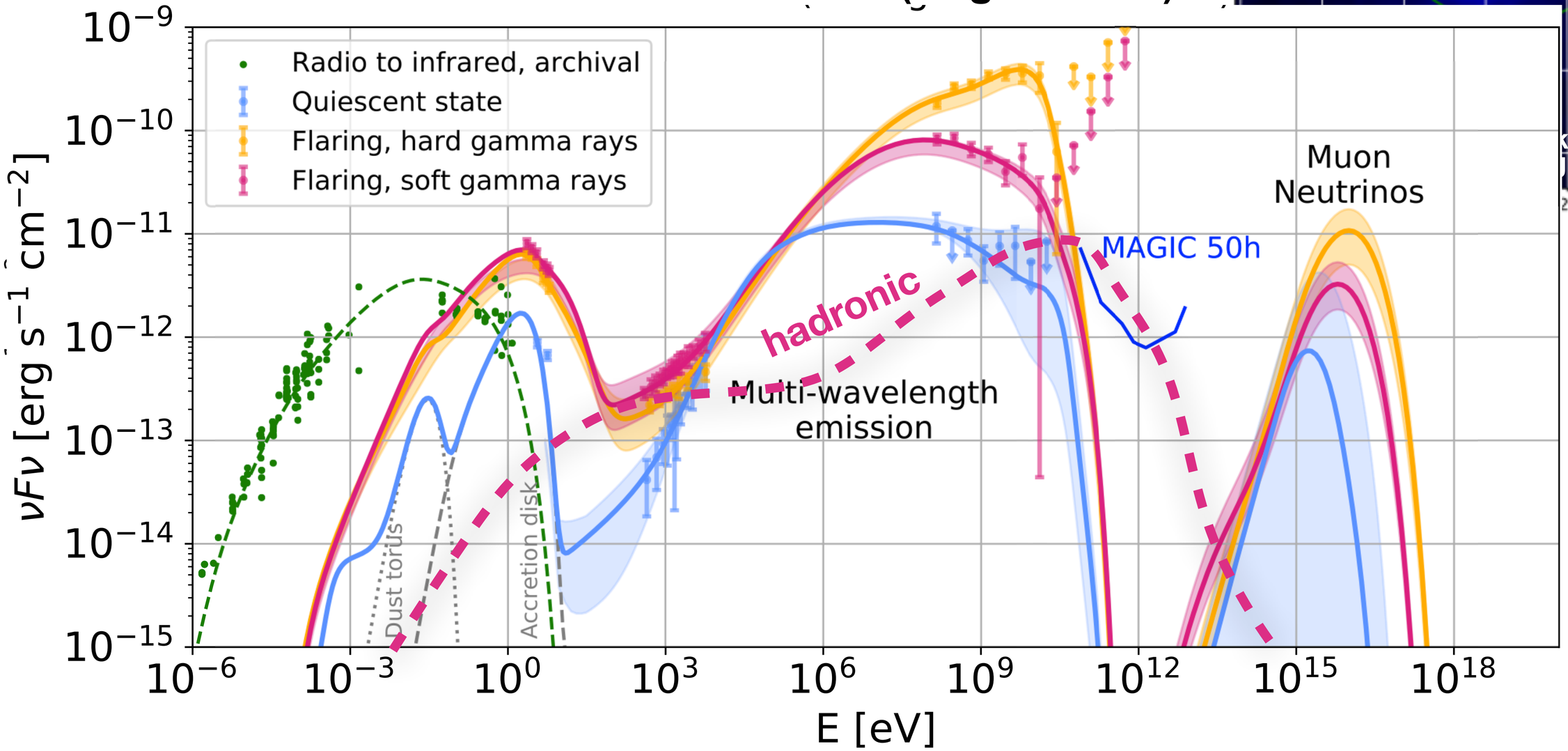

kowiak et al
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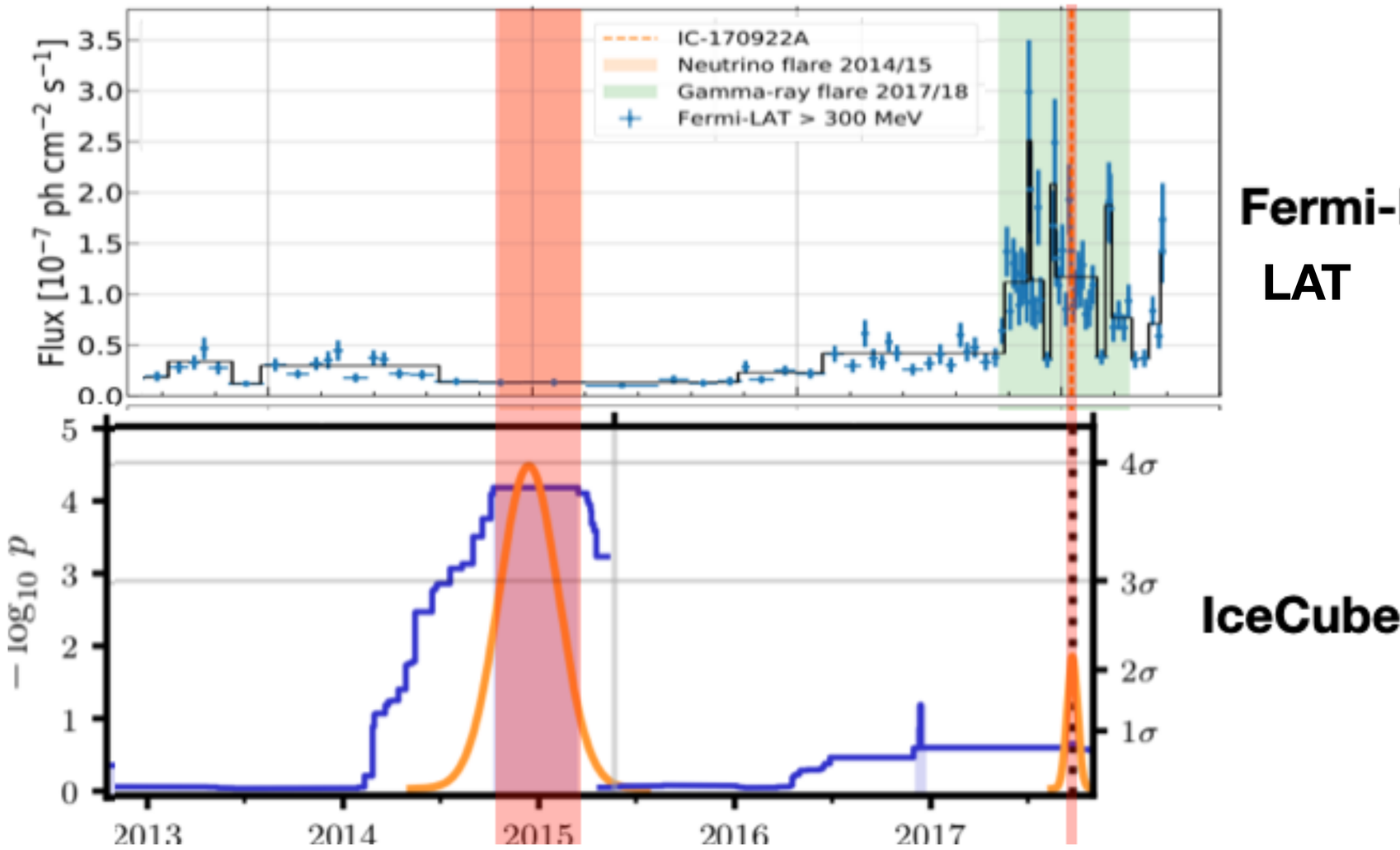
Will we find IceCube blazars in MeV gamma rays?



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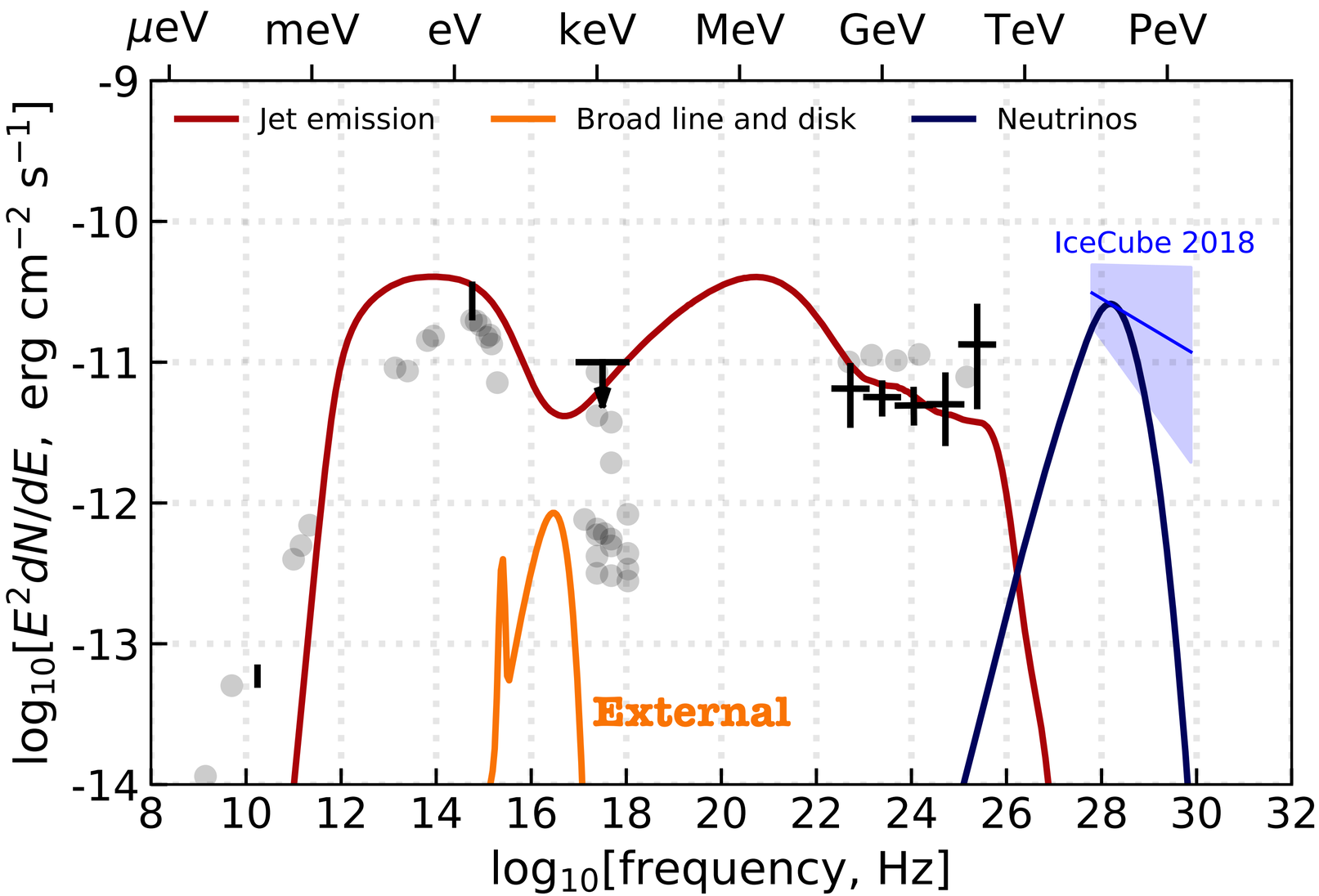

Rodrigues, Gao, Fedynitch, Palladino, Winter, ApJ L874 (2019)

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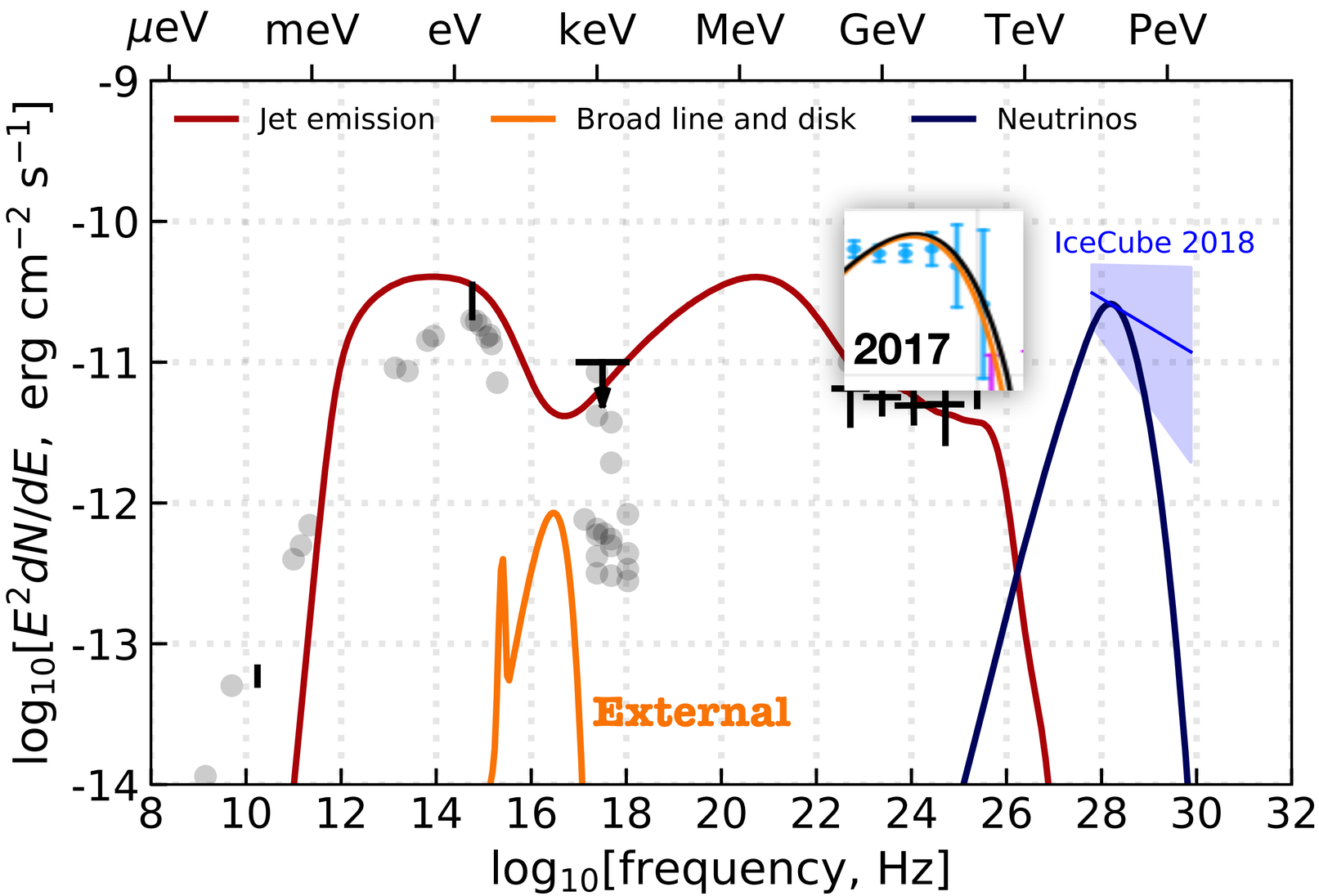

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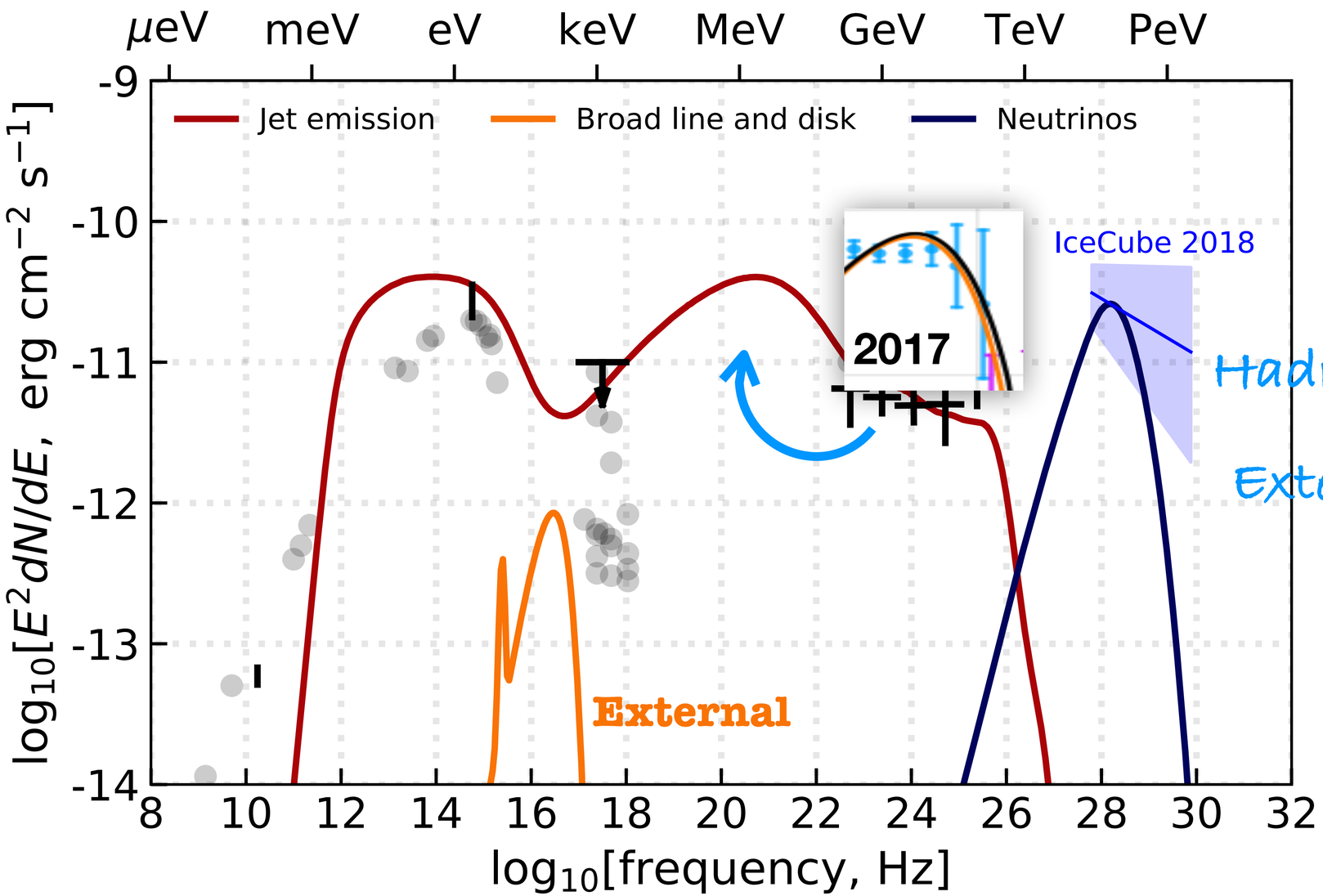

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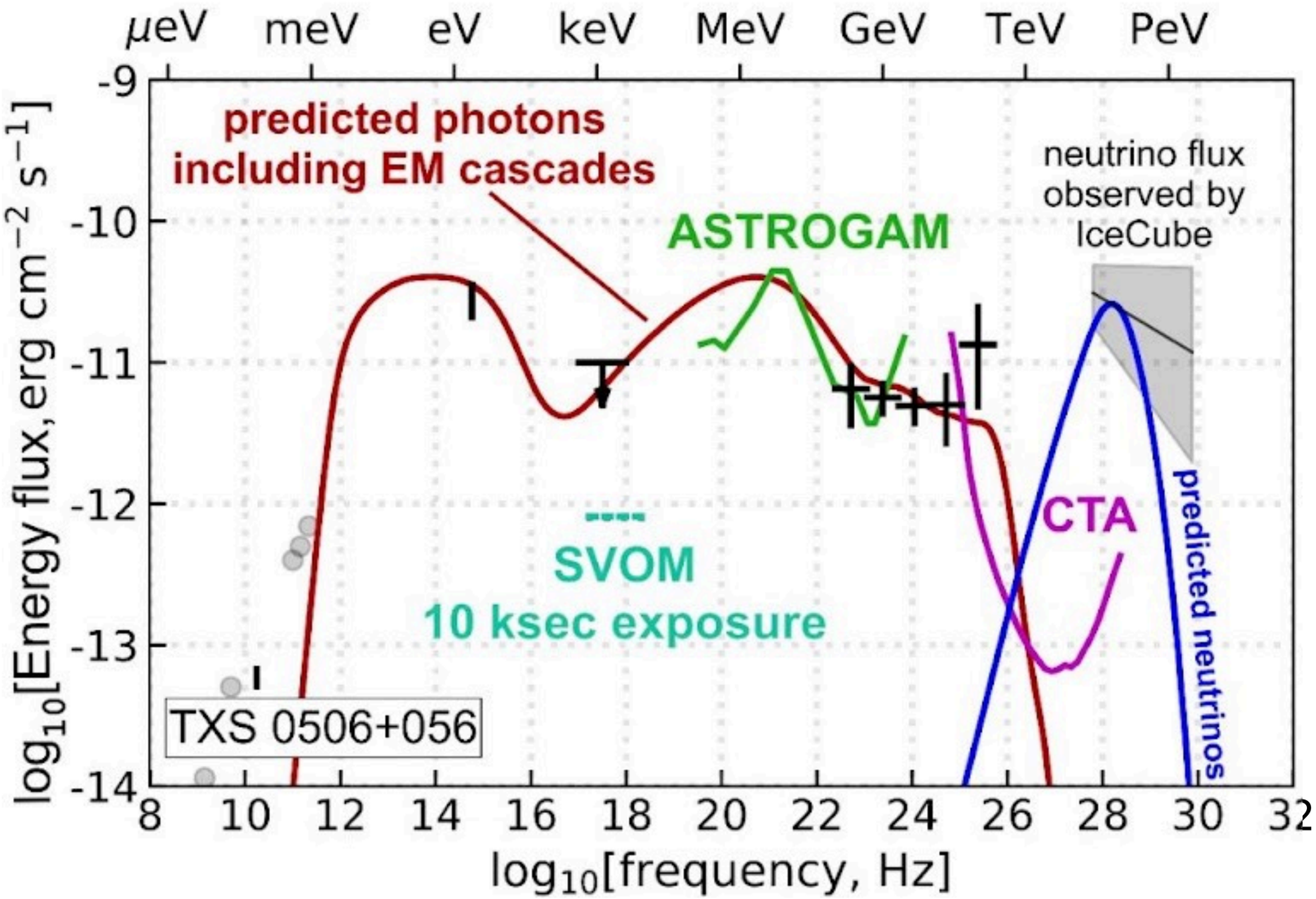
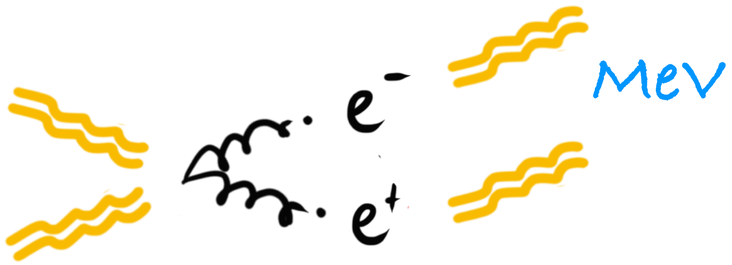
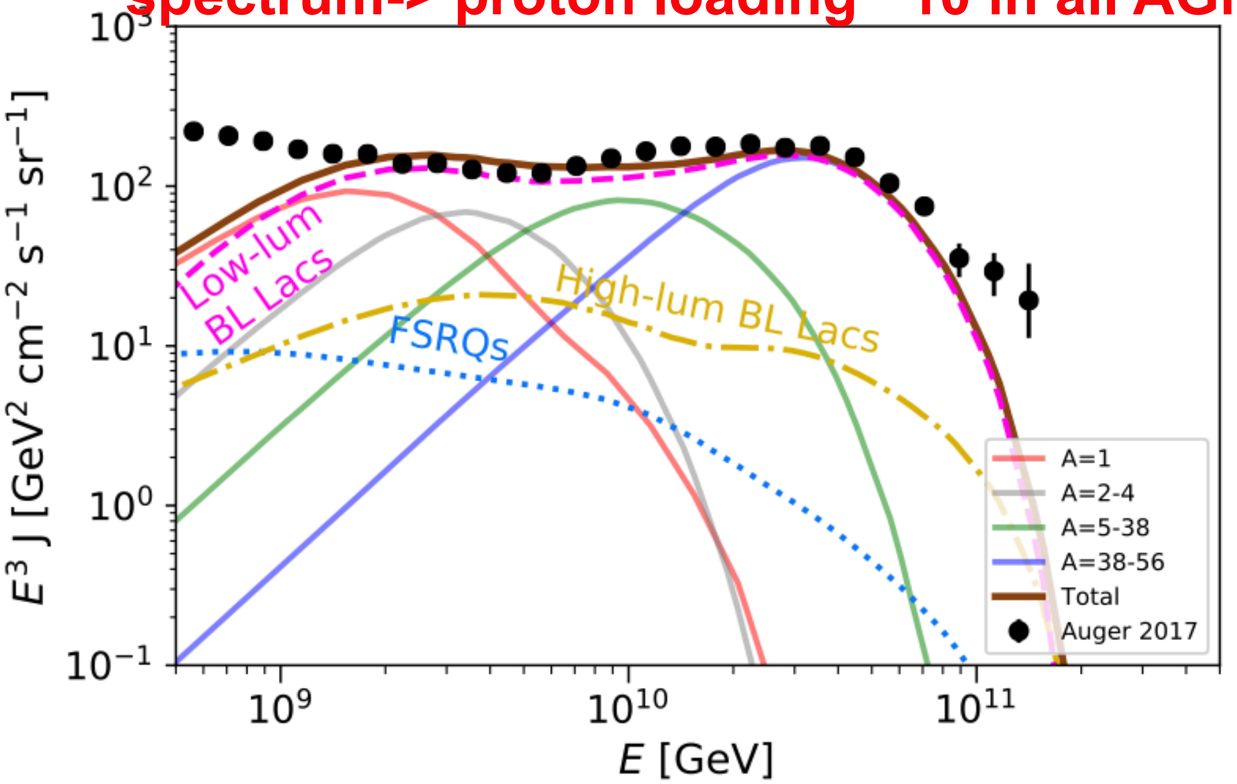




Rodrigues, Gao, Fedynitch, Palladino, Winter, ApJ L874 (2019)

What about the ultra-high energies?

Assuming AGN are accelerators of UHECRs…
(Best-case scenario, AGN exhaust the Auger spectrum-> proton loading ~10 in all AGN)



Rodrigues, Heinze, Palladino, van Vliet and Winter, PRL 126 (2021)

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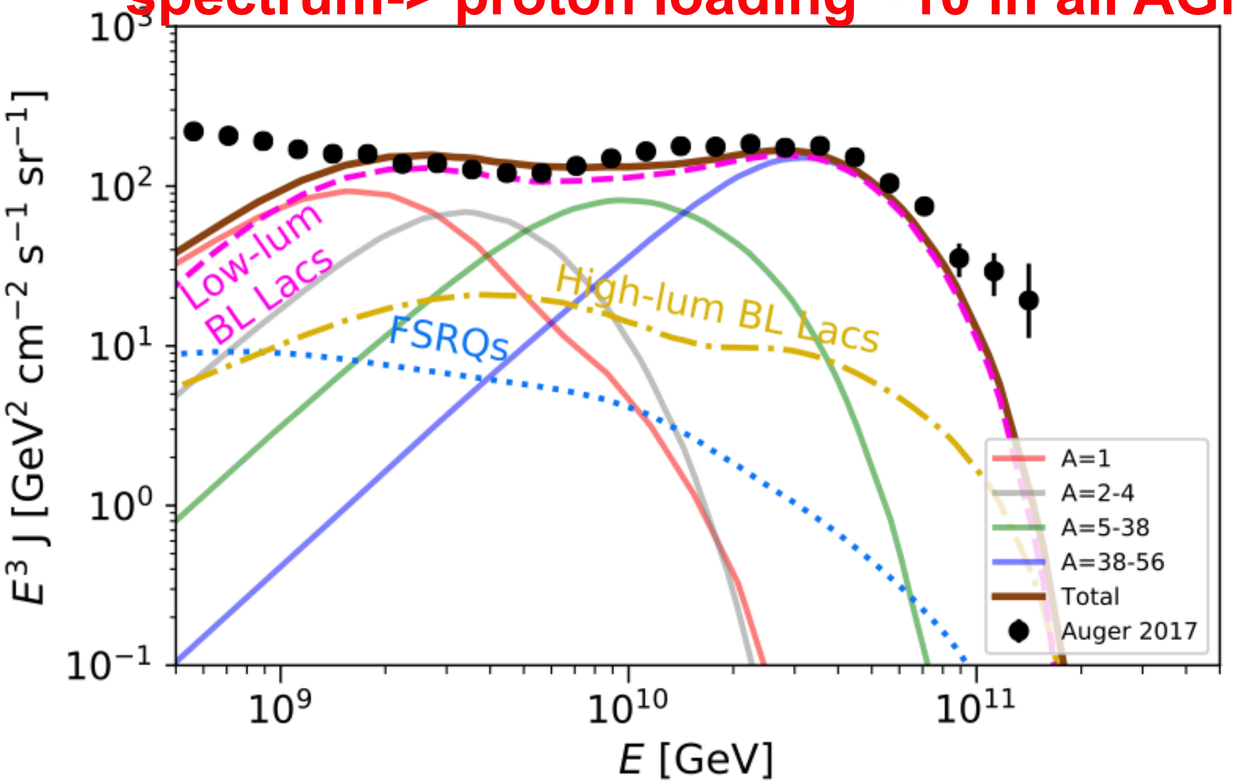
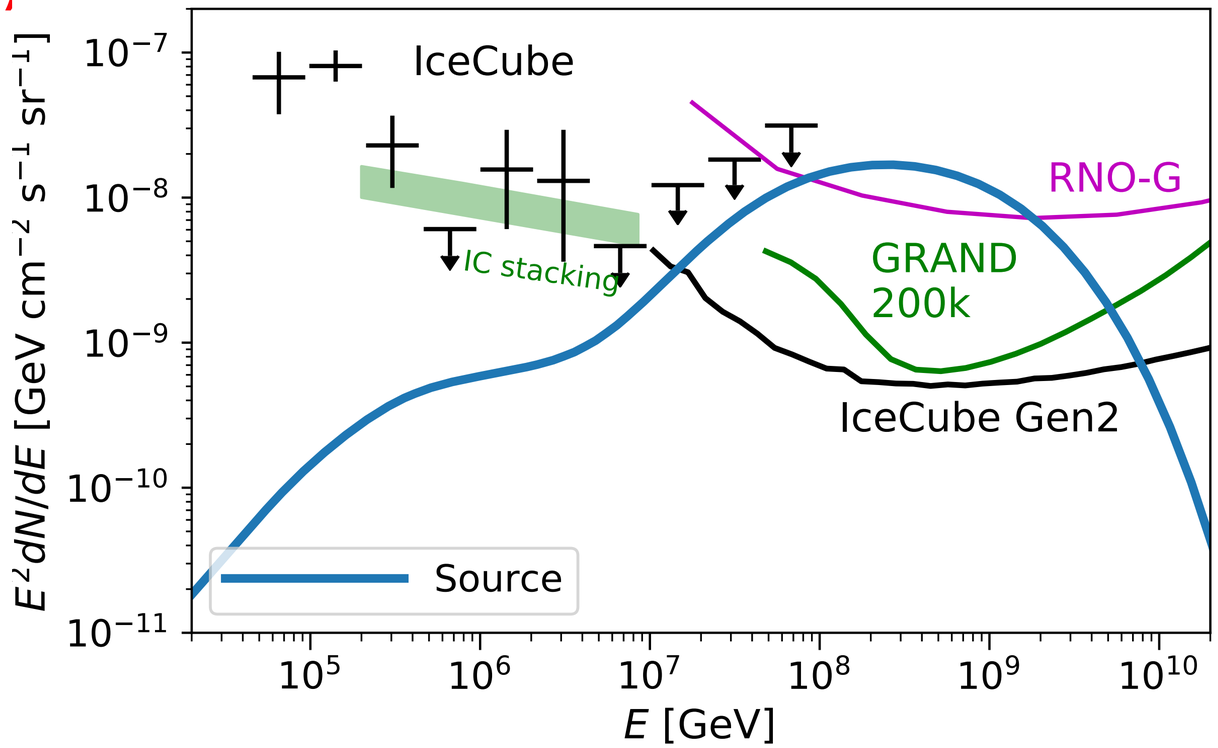


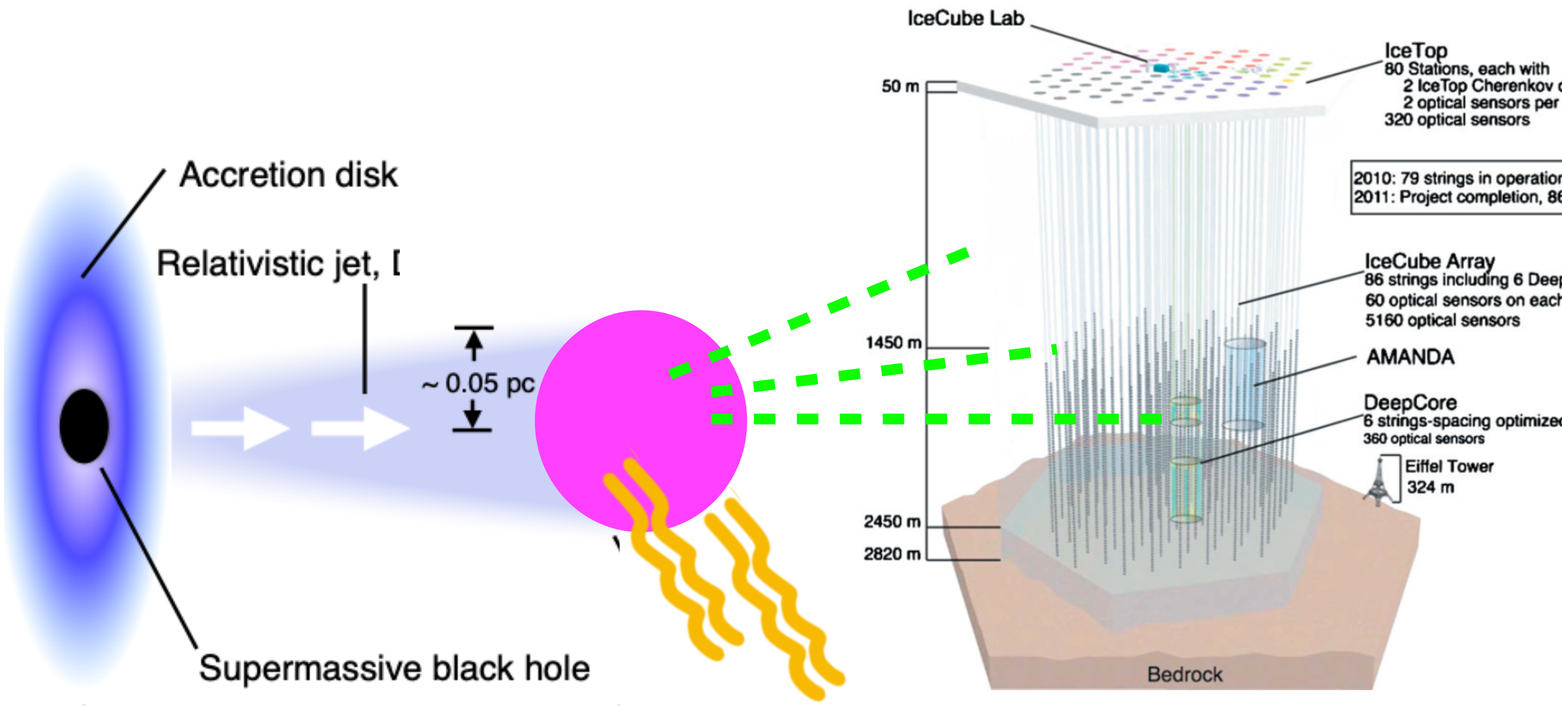
…we may currently be missing the bulk of their multi-messenger emission.



Rodrigues, Heinze, Palladino, van Vliet and Winter, PRL 126 (2021)

Summary

Synergies between **theory** and **multi-messenger experiments** already lead to a wealth of new information



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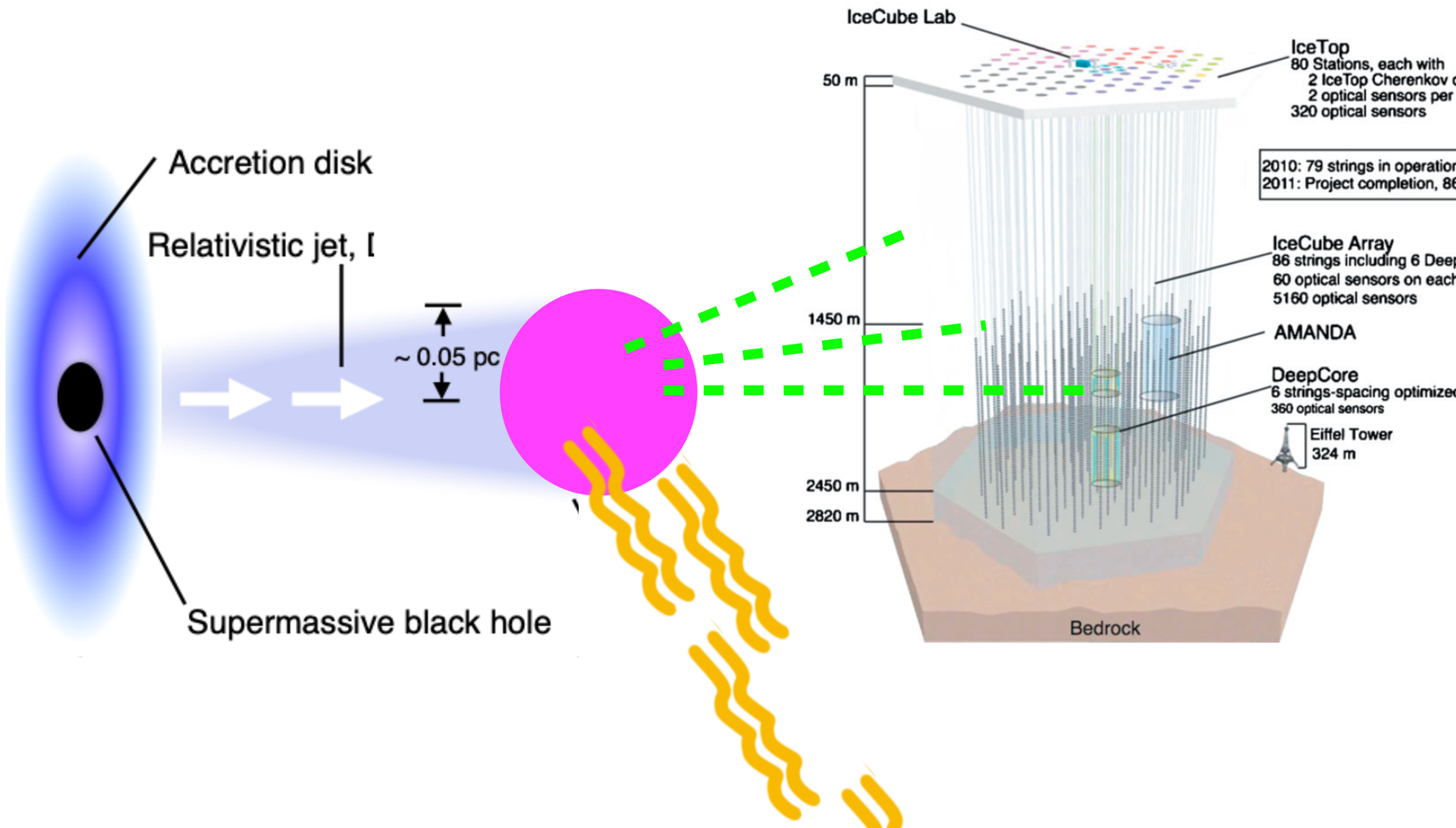

Future experiments will be crucial to **complete our multiwavelength picture!**