

The hunt for extraterrestrial high-energy neutrino sources

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Institute of Astrophysics

Foundation for Research and Technology- Hellas

Multi-Messenger Astrophysics in the Dynamic Universe
Kyoto 2026



Funded by
the European Union

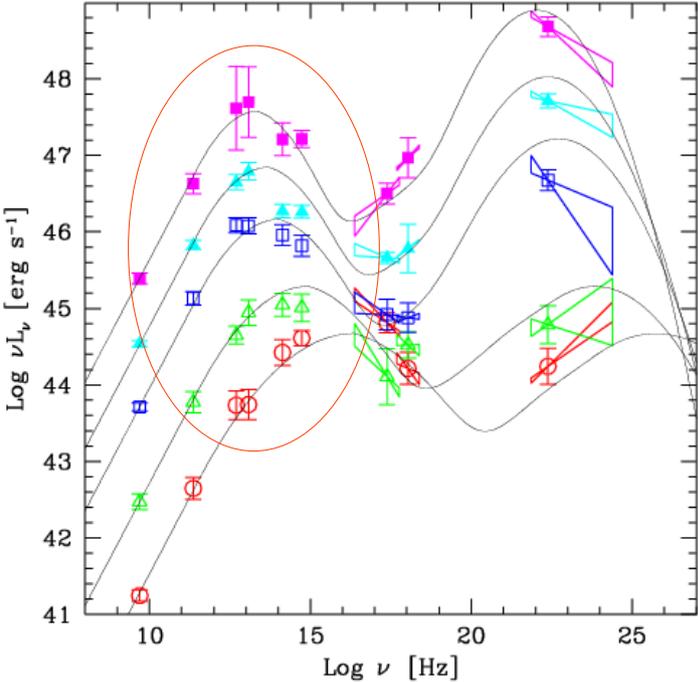
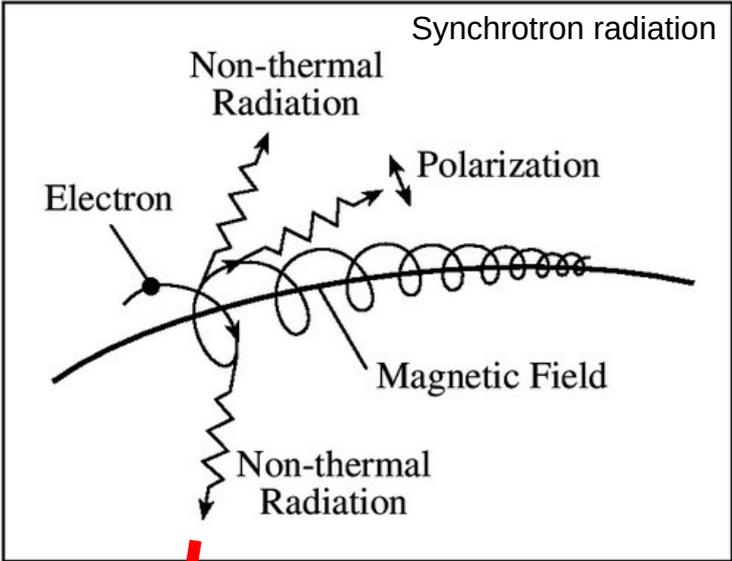


European Research Council
Established by the European Commission

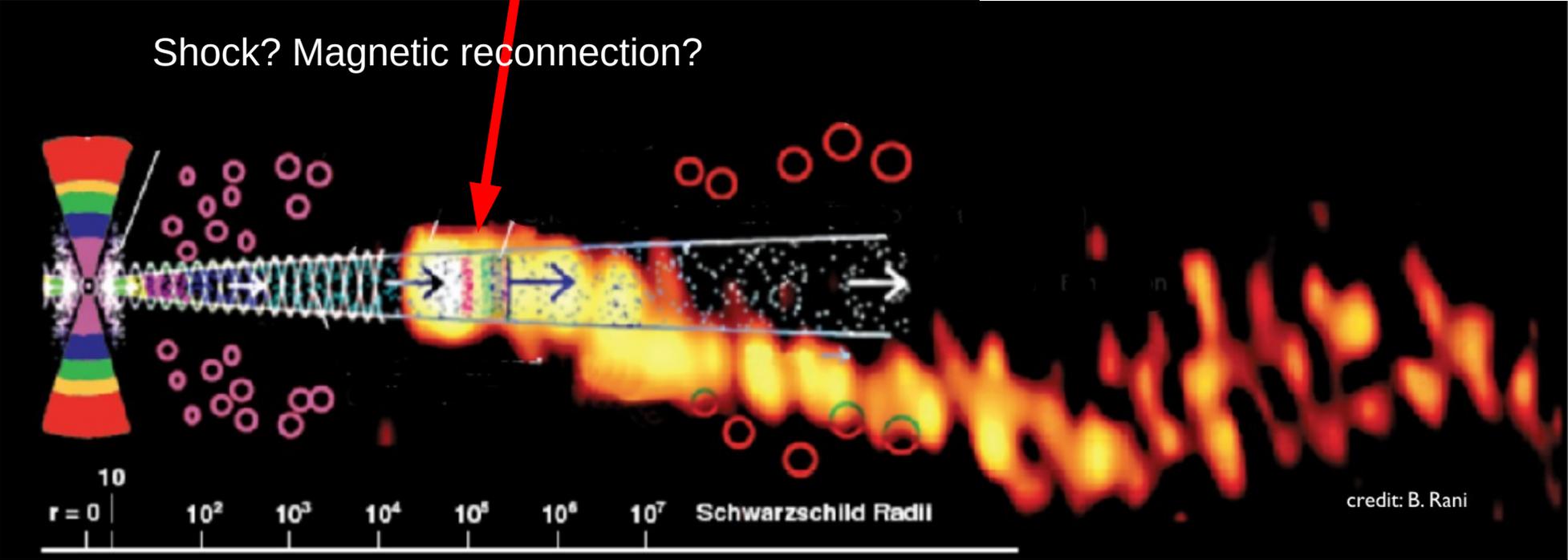


INSTITUTE OF ASTROPHYSICS
FOUNDATION FOR RESEARCH AND TECHNOLOGY HELLAS

How do blazars make light?

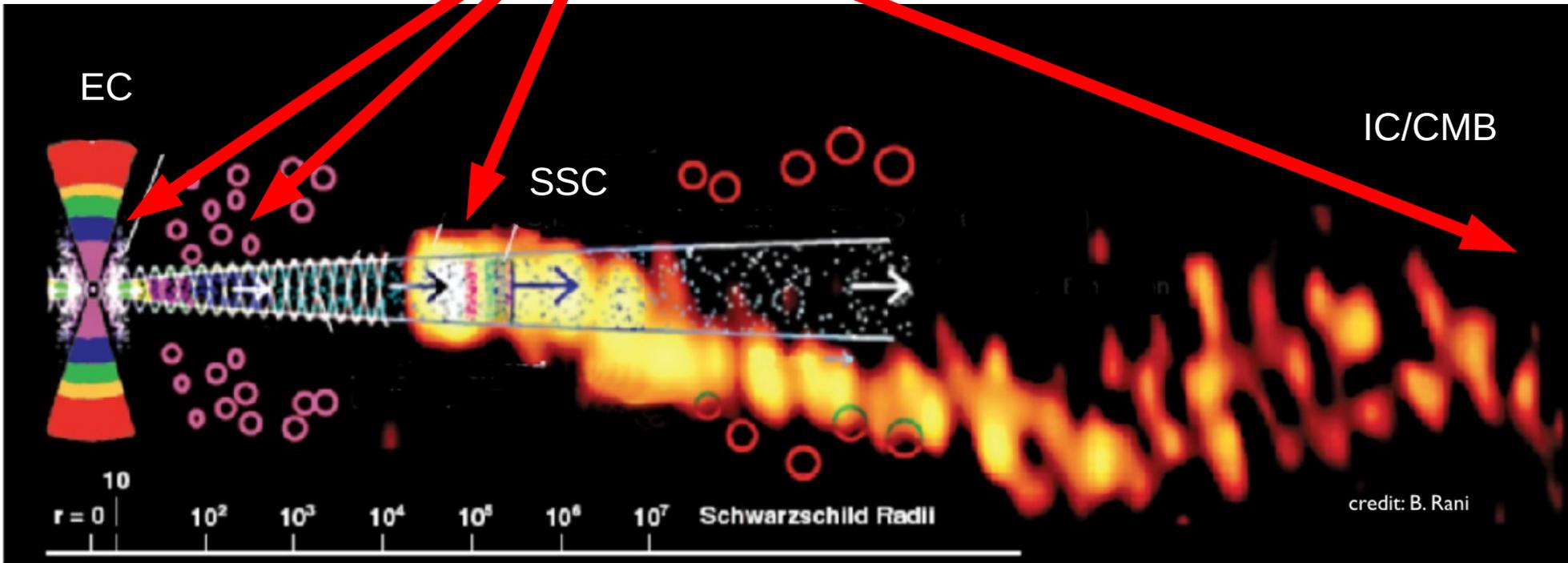
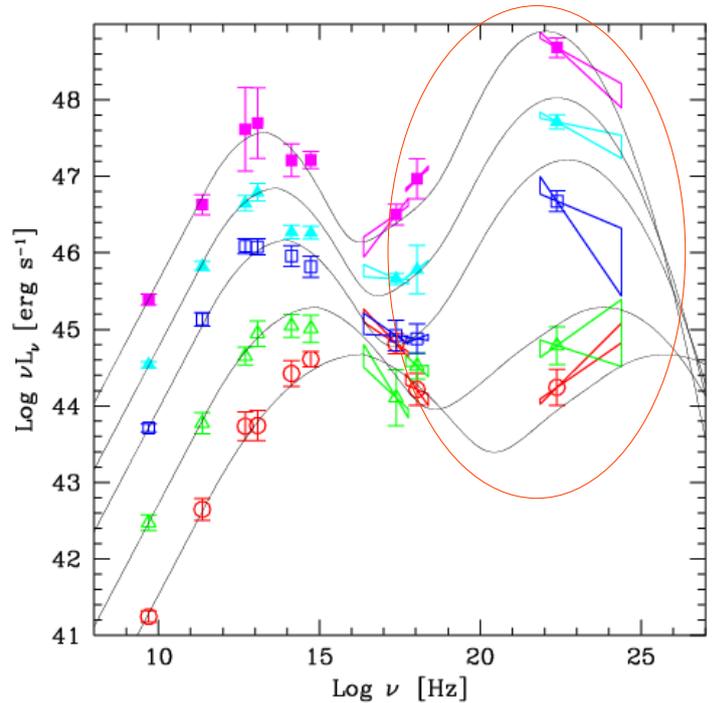
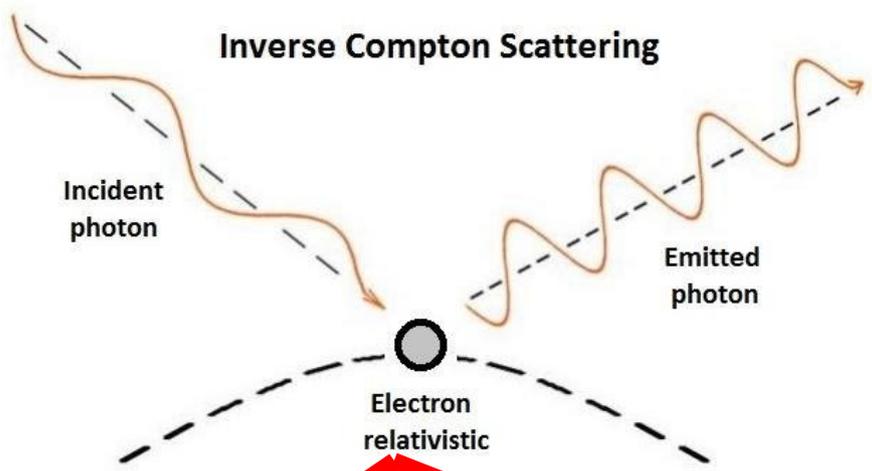


Shock? Magnetic reconnection?



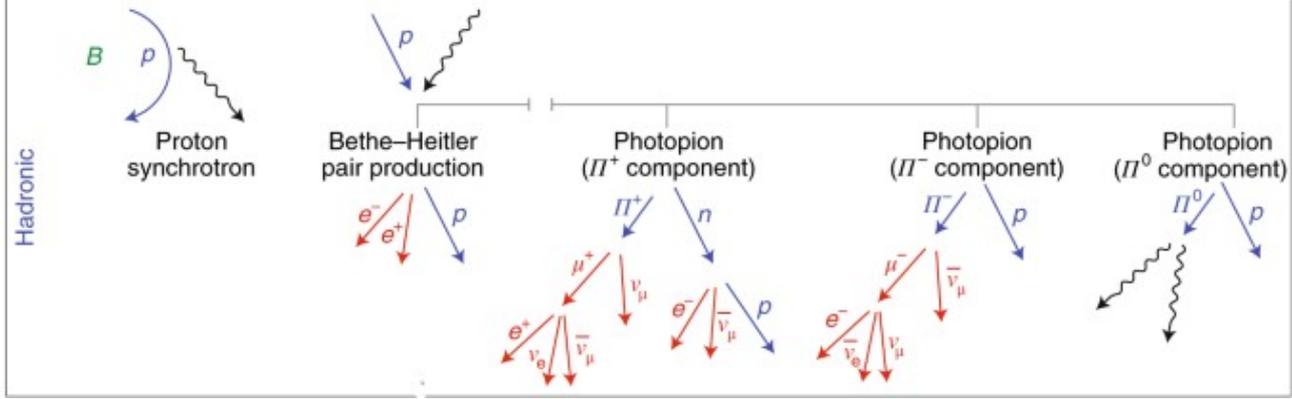
credit: B. Rani

How do blazars make light?

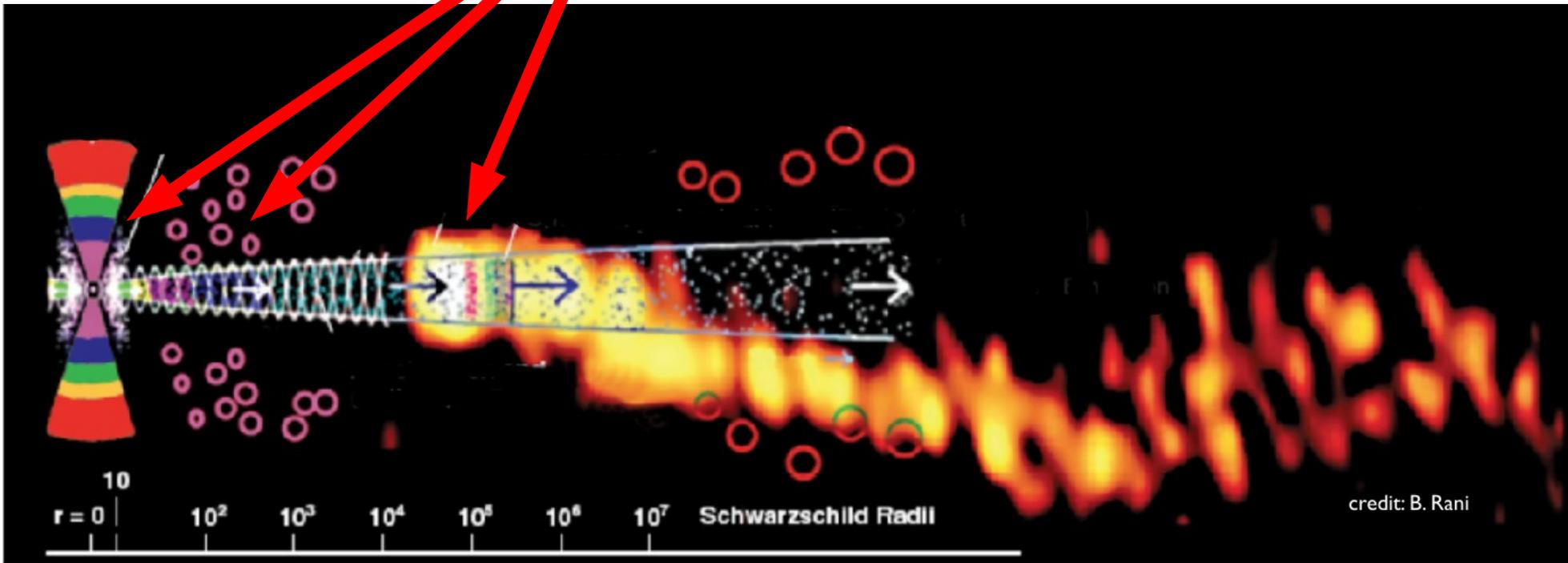
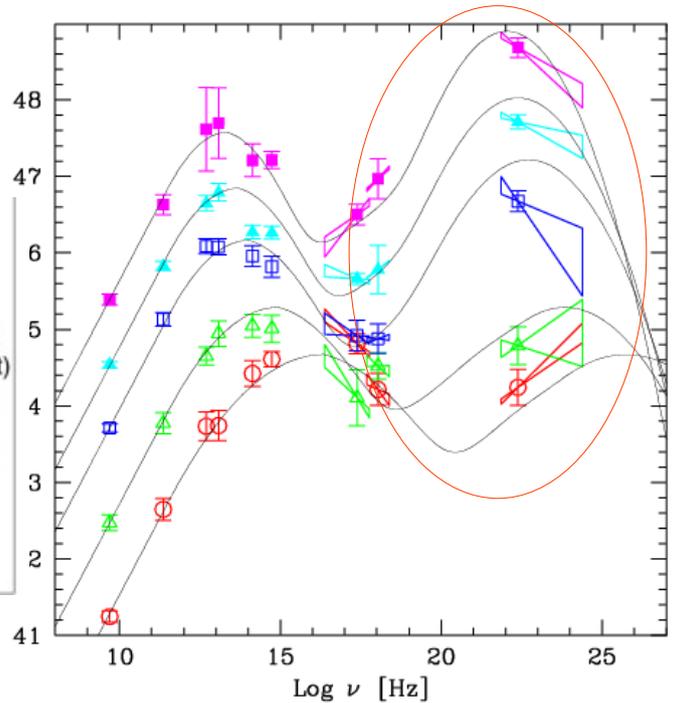


credit: B. Rani

How do blazars make light?

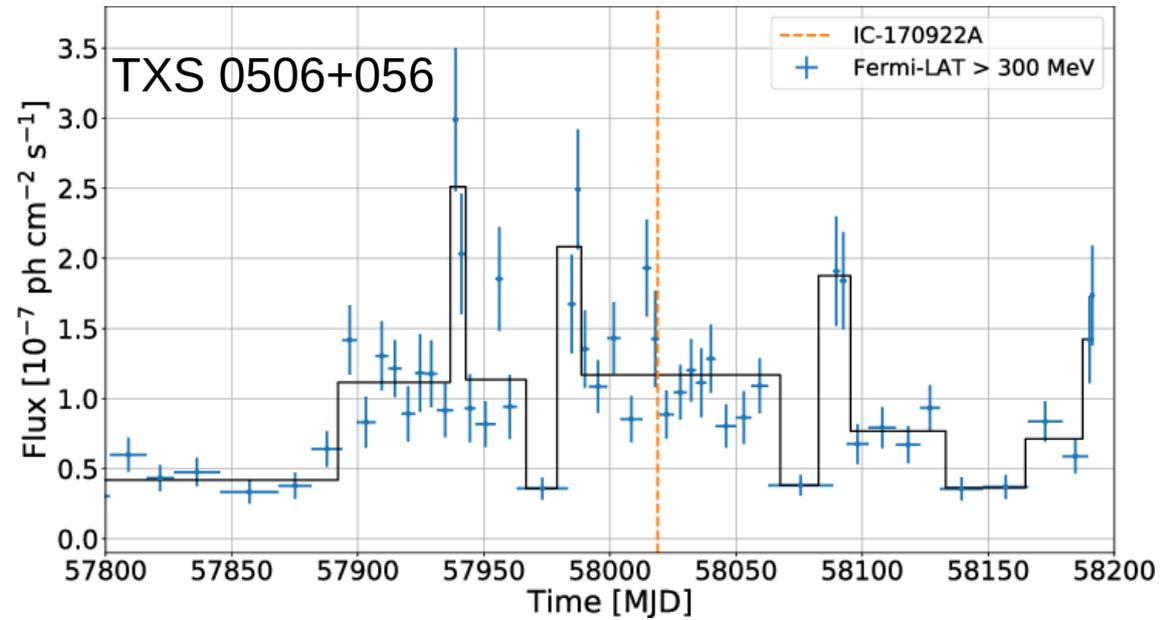
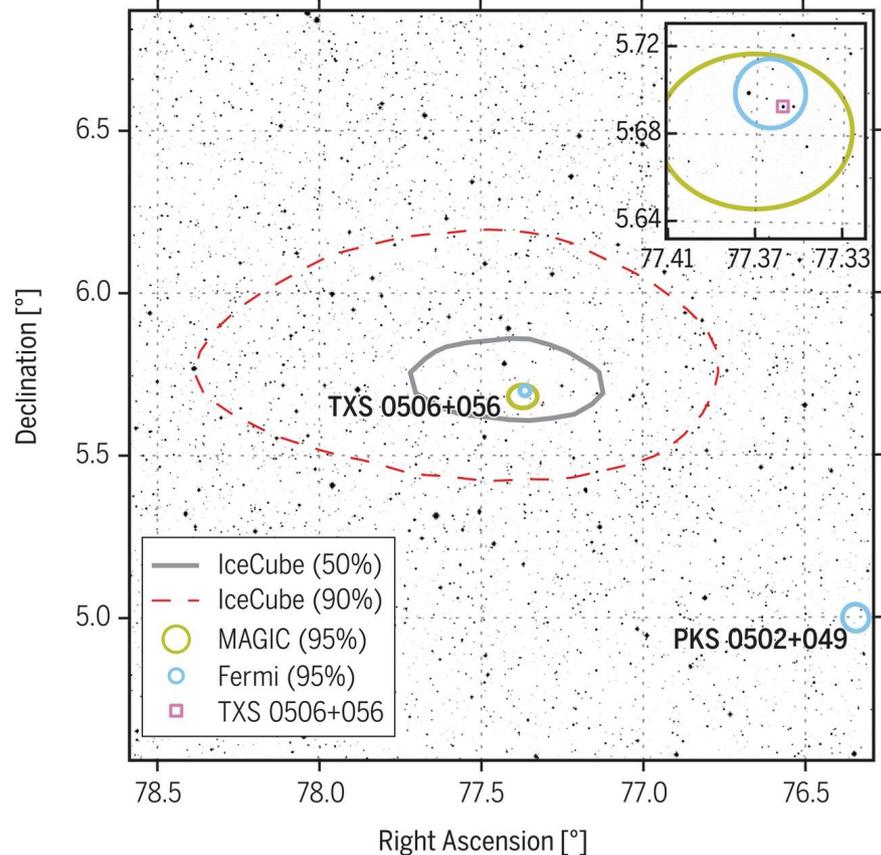


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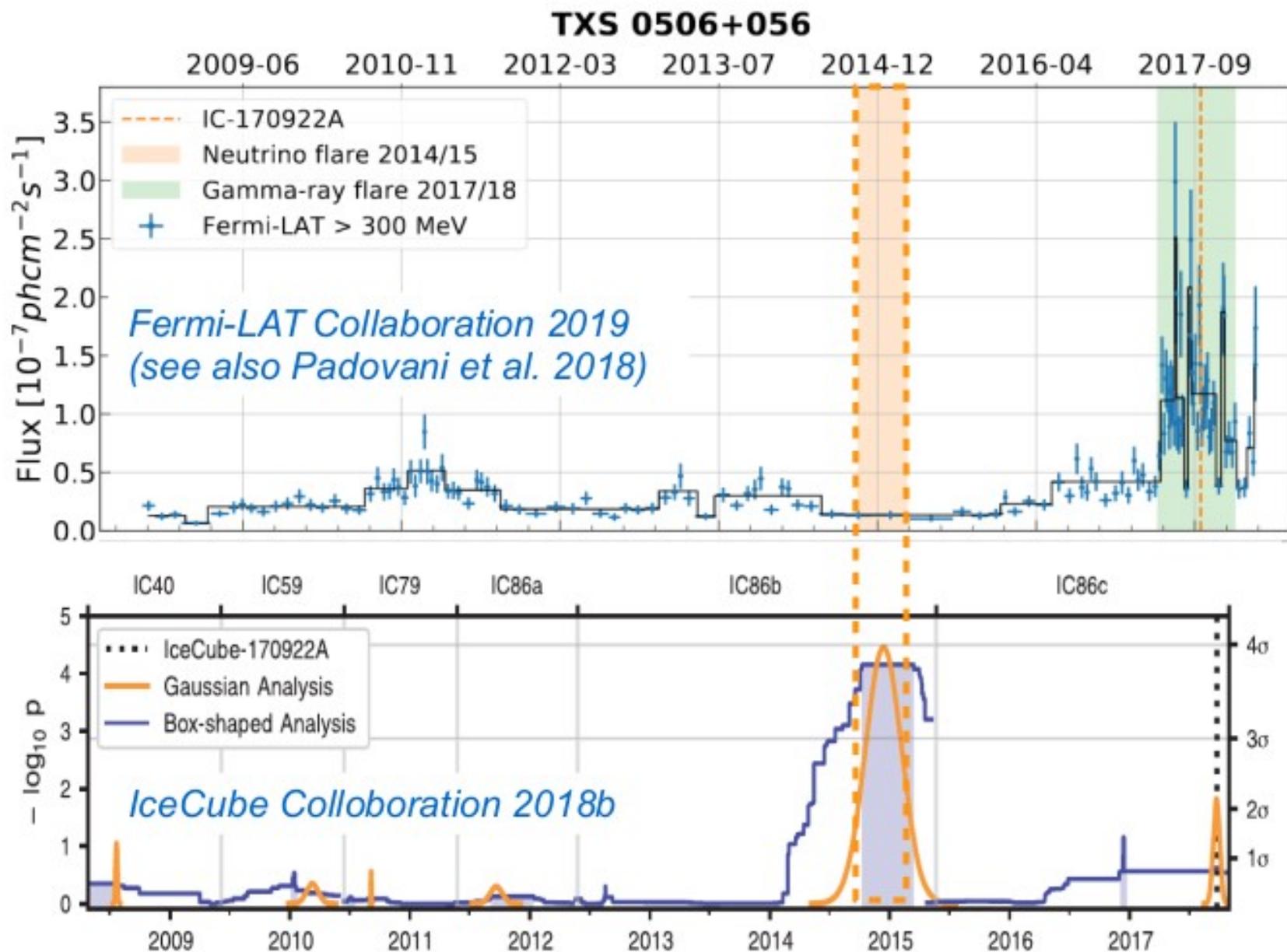


First extragalactic neutrino emitter?

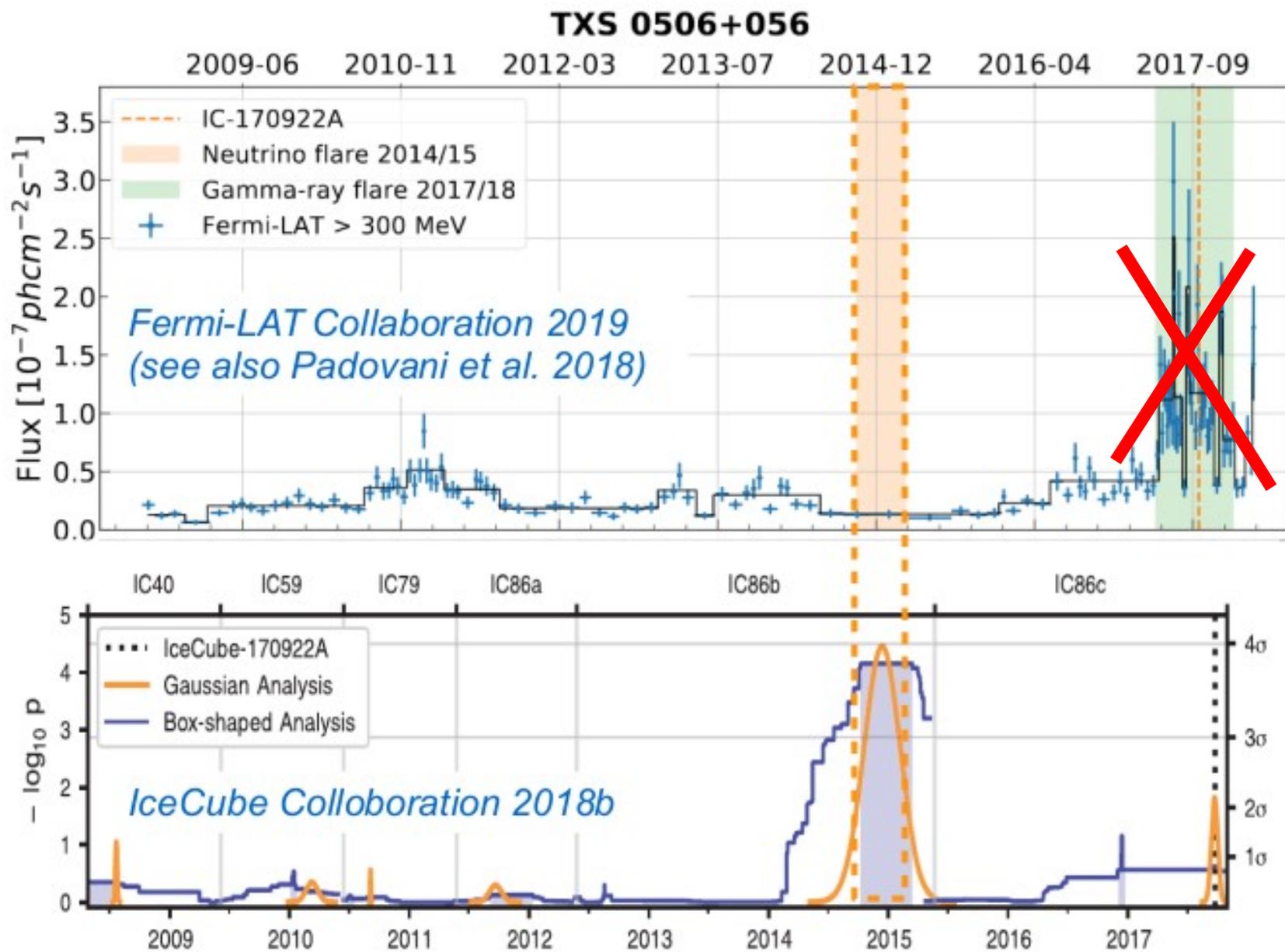
IceCube collaboration (2018)



First extragalactic neutrino emitter?

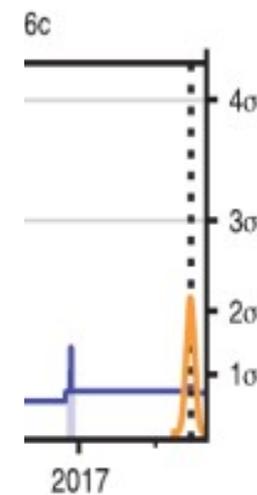
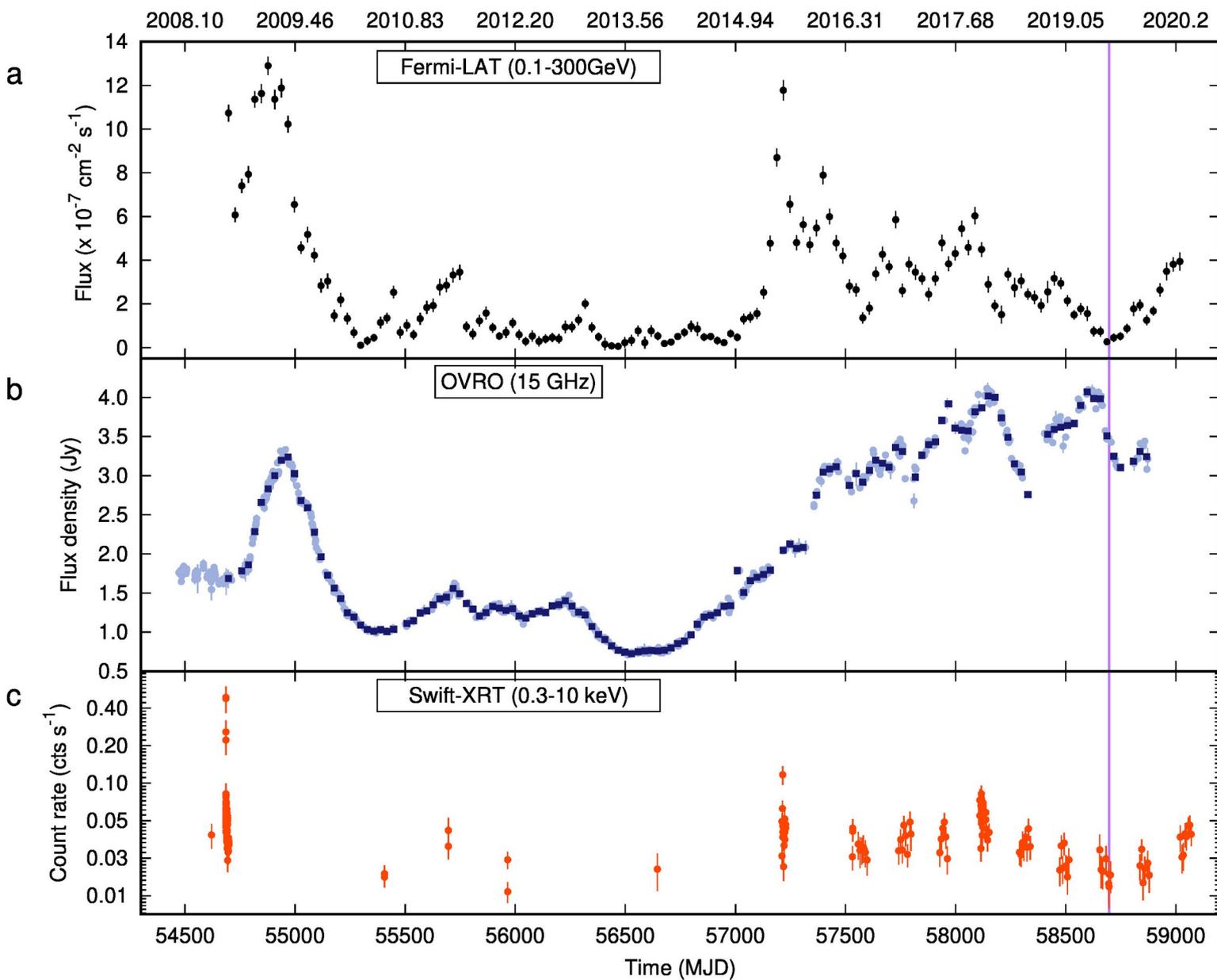


First extragalactic neutrino emitter?

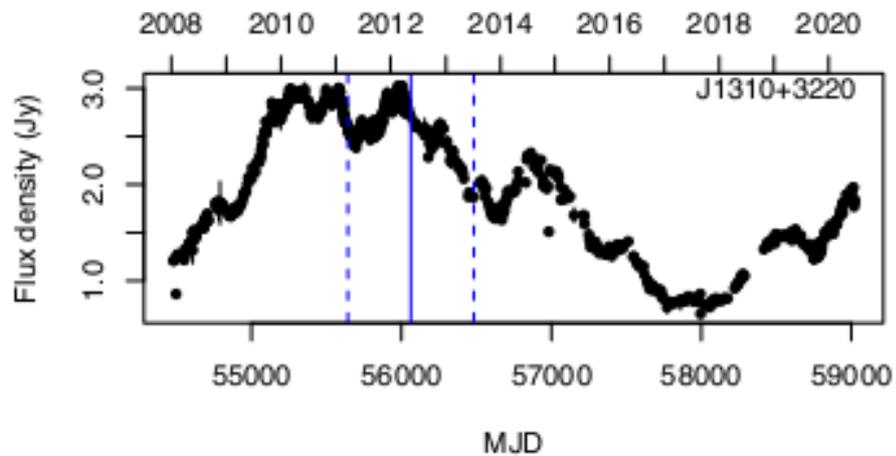
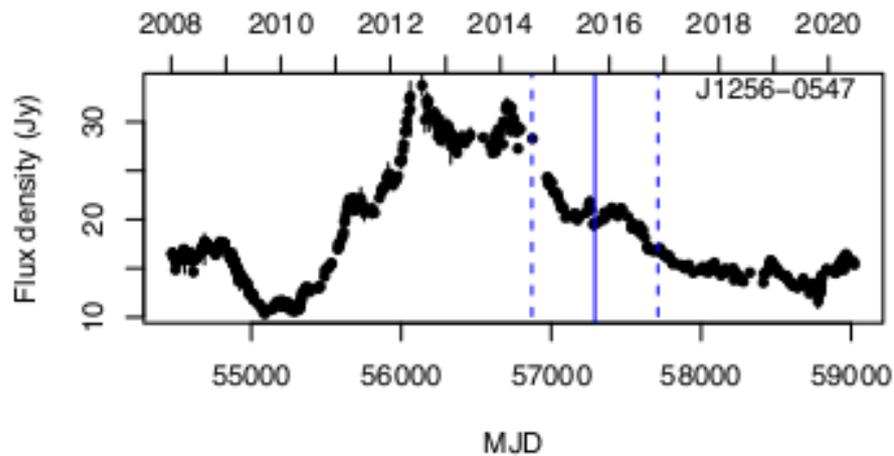
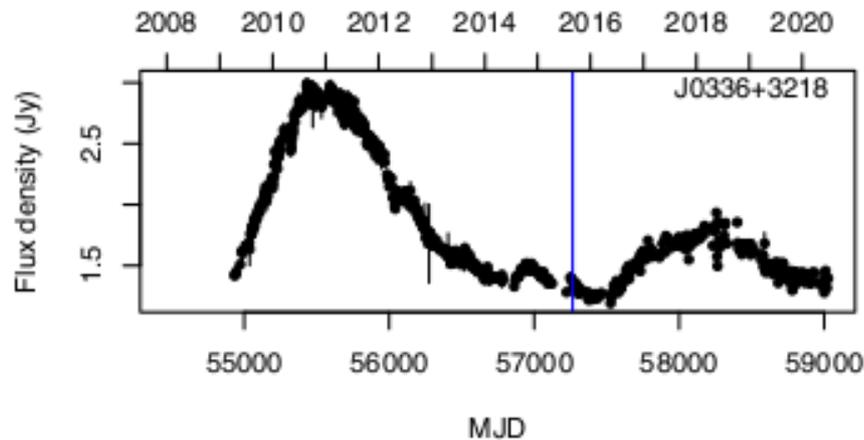
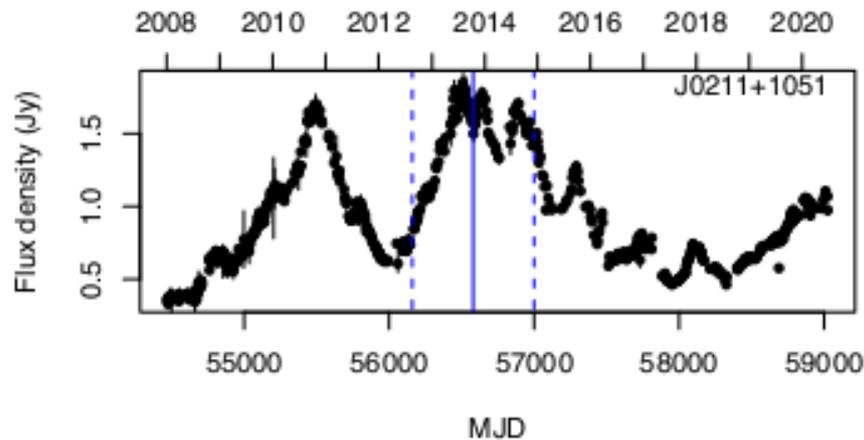


First extragalactic neutrino emitter?

PKS1502+106, Kun et al., (2021)



Radio emission to the rescue?



OVRO ~1800 jetted AGN

~100 neutrinos

~ 2σ association between blazars and neutrinos

9/20 sources are γ -ray dark!

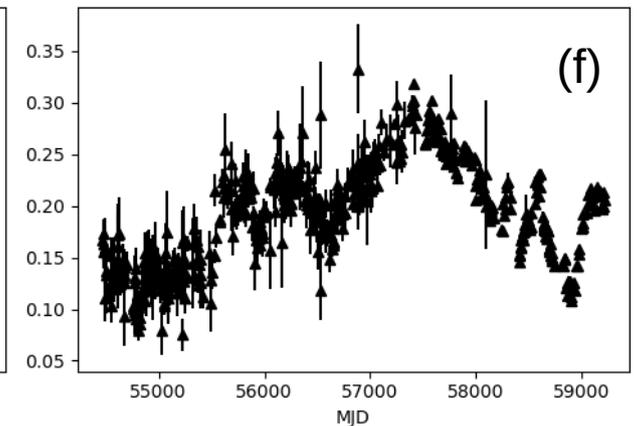
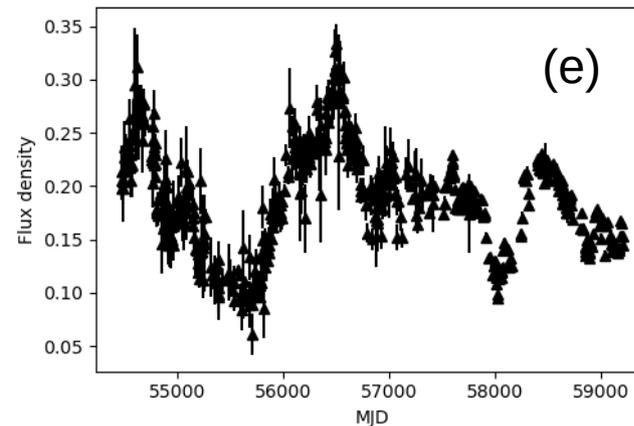
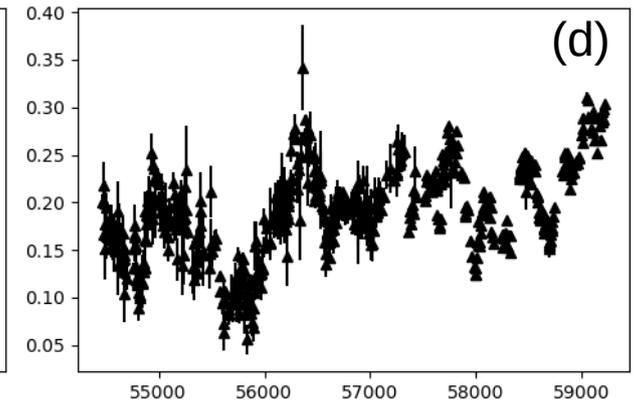
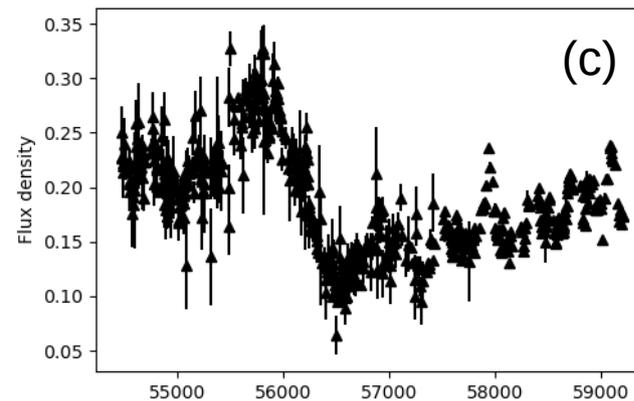
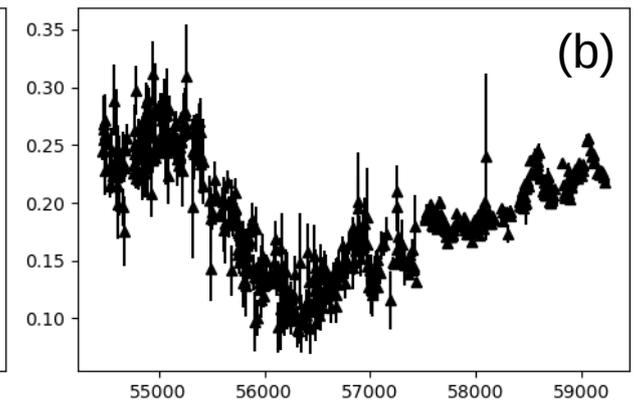
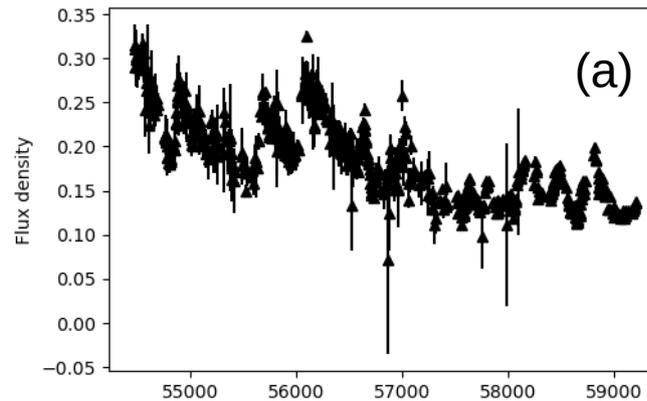
What would it take for a clear correlation?

If all neutrinos are coming from blazars we should see a significant correlation...

~5000 sources

~10 day cadence for 5 years

If neutrino luminosity correlates with radio flux we will achieve a $>4\sigma$ association



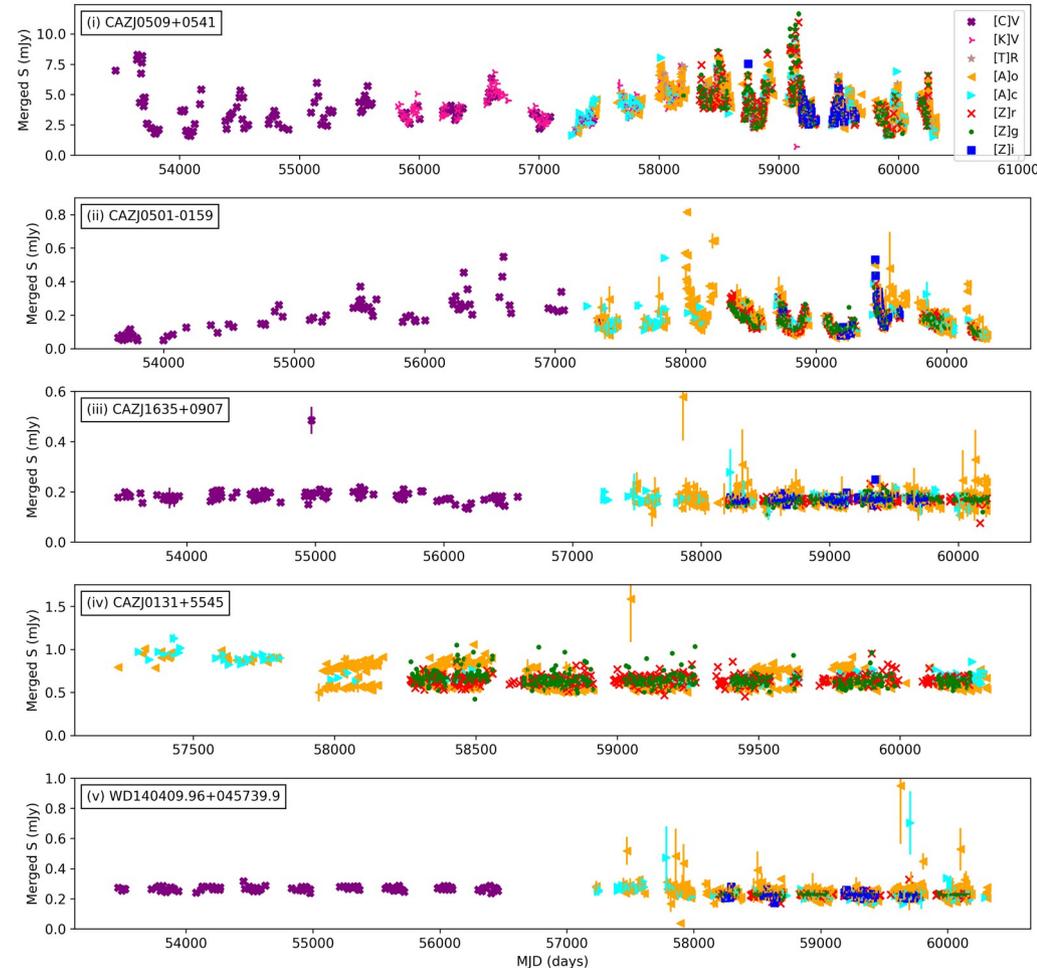
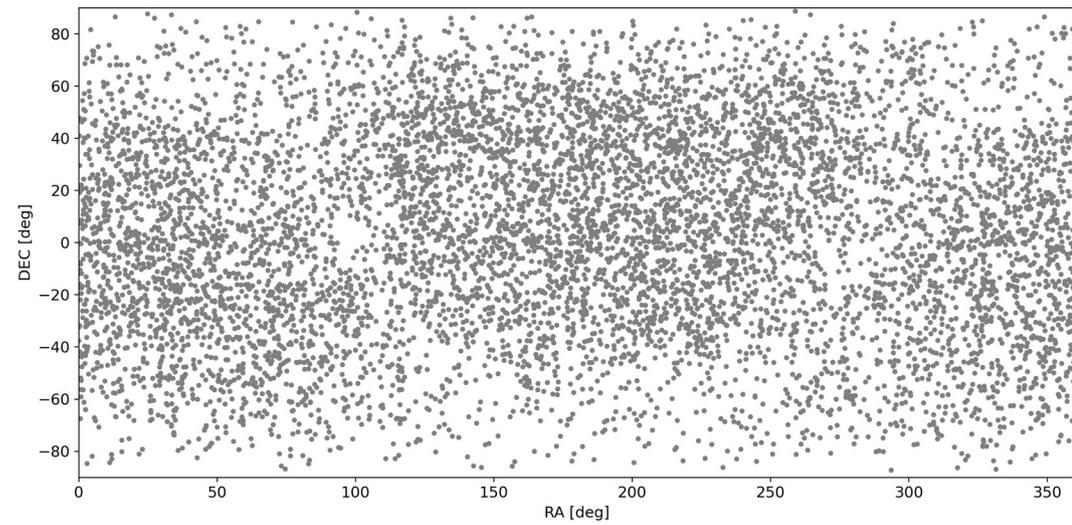
CAZ: a new catalog of blazars

7918 blazars and blazar-candidates

(~5000 with optical light curves)

(~5000 with X-ray observations)

Catalog includes a bunch for different properties: redshift, γ -ray flux, Doppler factors, SED/Spectral classification etc.



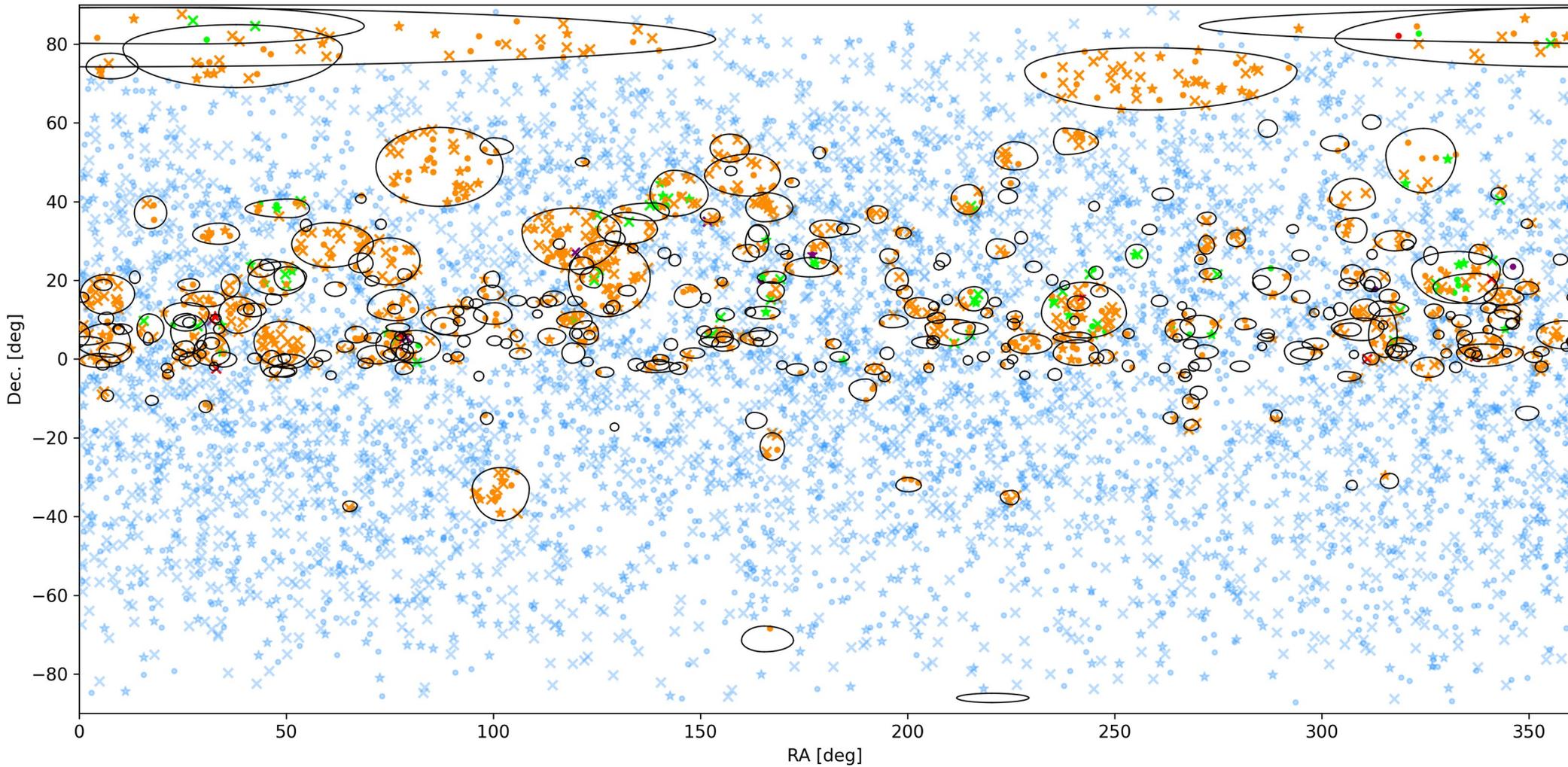
Pouya Kouch
Grad. Student at
U. Turku/FINCA



Alessandro Paggi
Postdoc at IA

CAZ: a new catalog of blazars

Kouch et al.[+IL] (2025b)



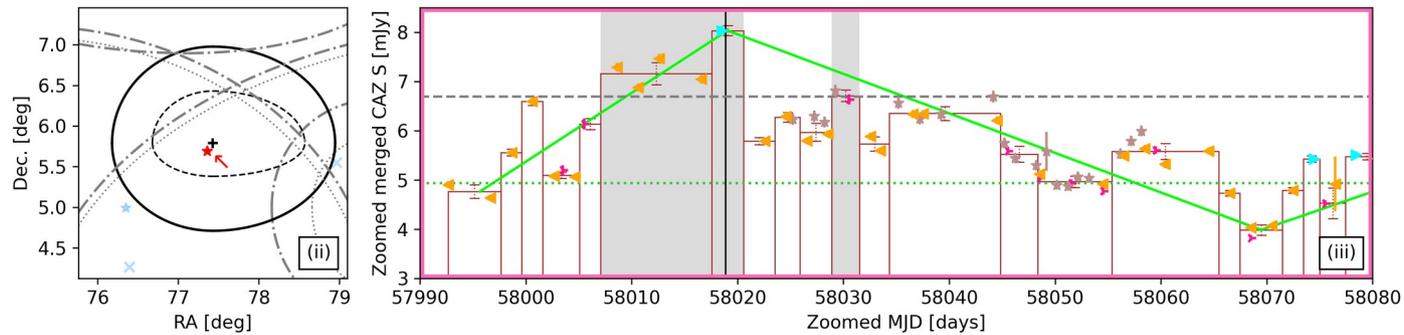
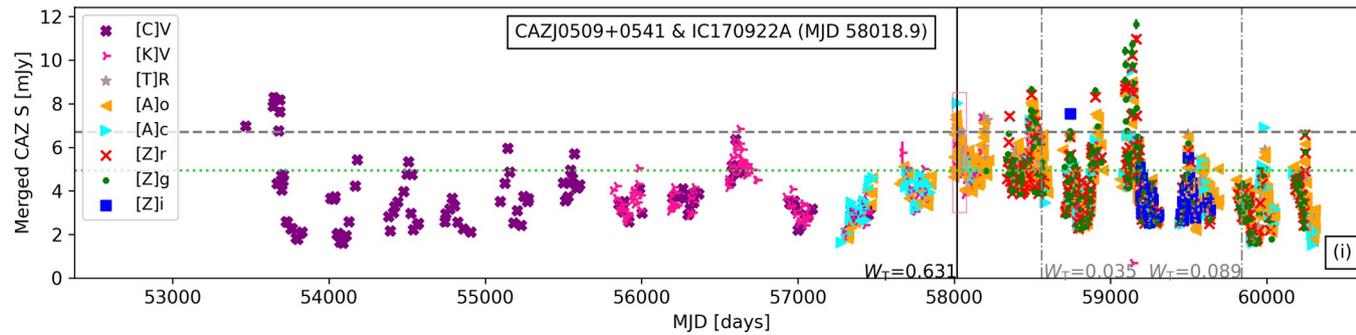
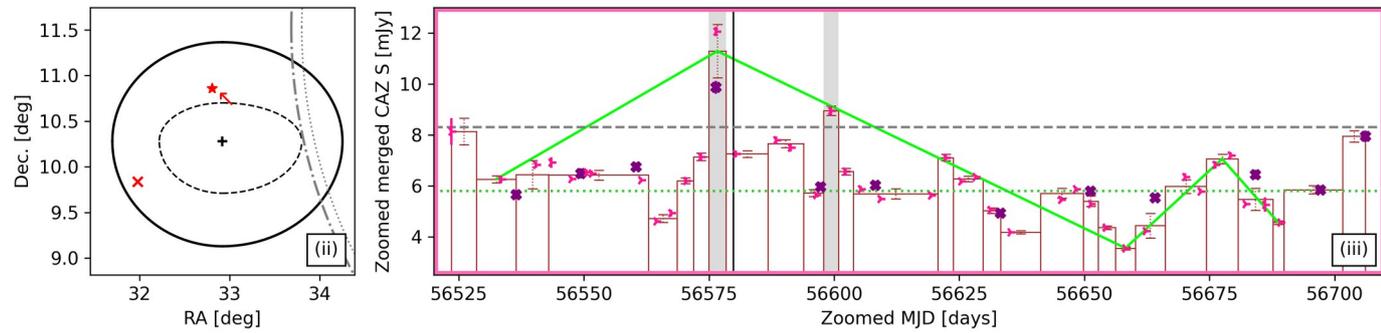
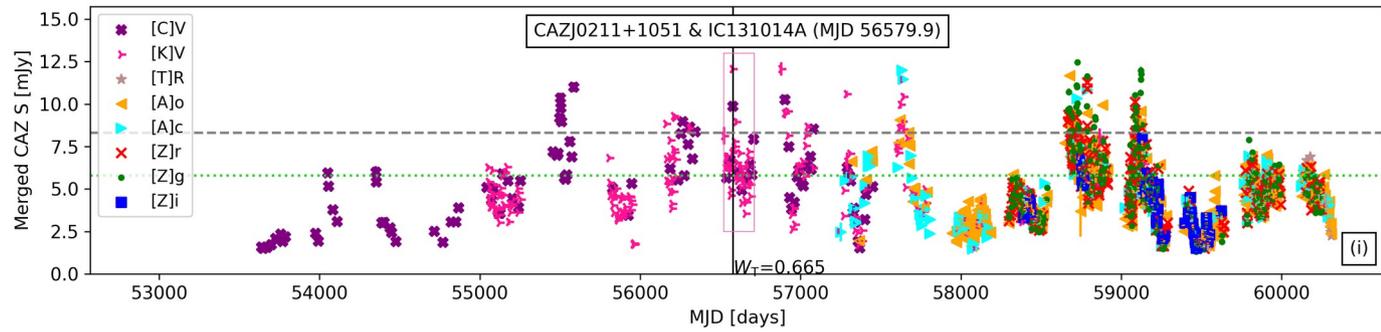
356 HE neutrinos
3225 radio-selected blazars
3814 γ -ray selected blazars

**$\sim 2\sigma$ correlation mostly
driven by two sources**

“Neutrino blazars” are
more beamed and
brighter in X-rays

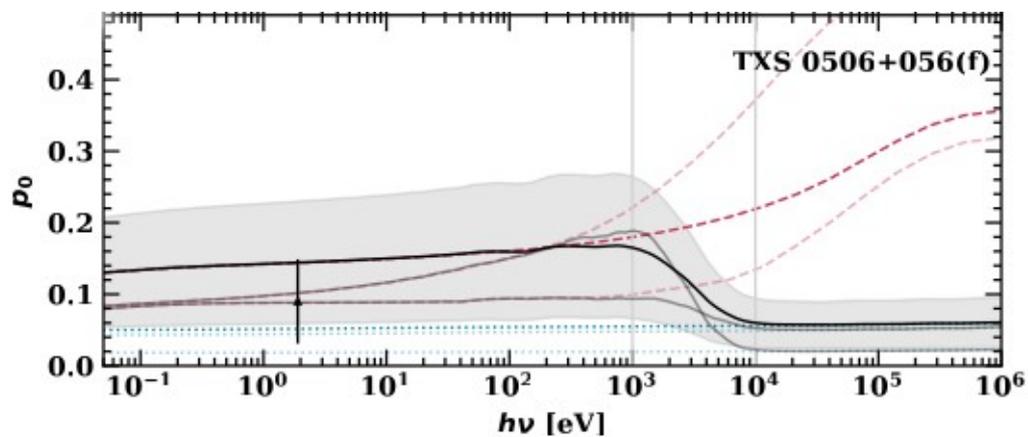
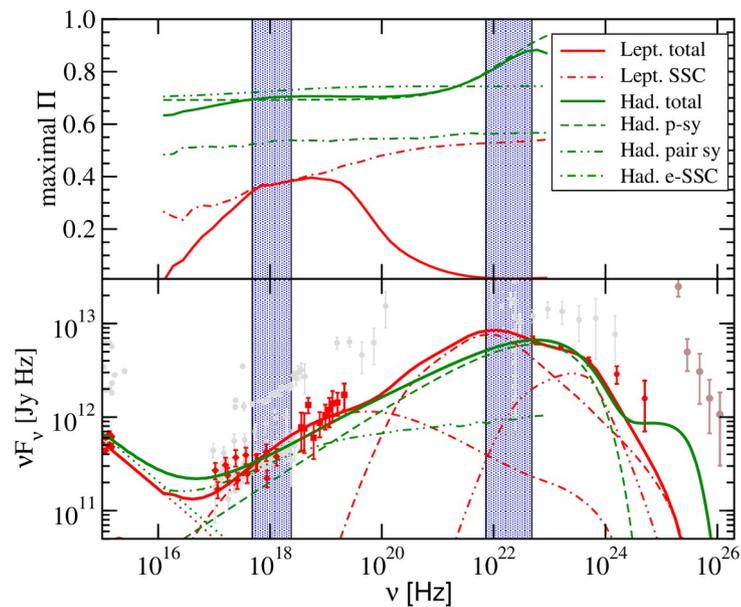
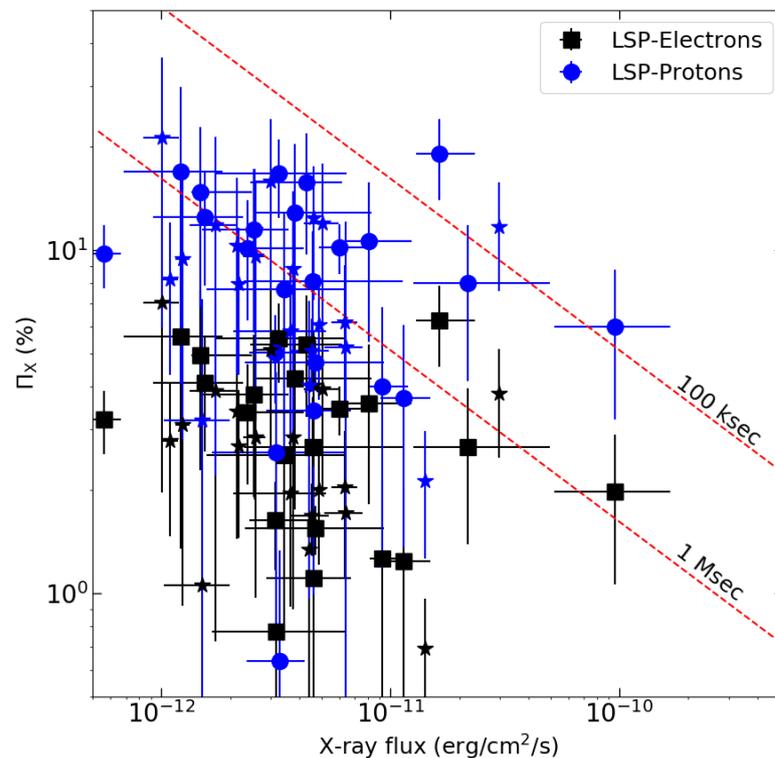
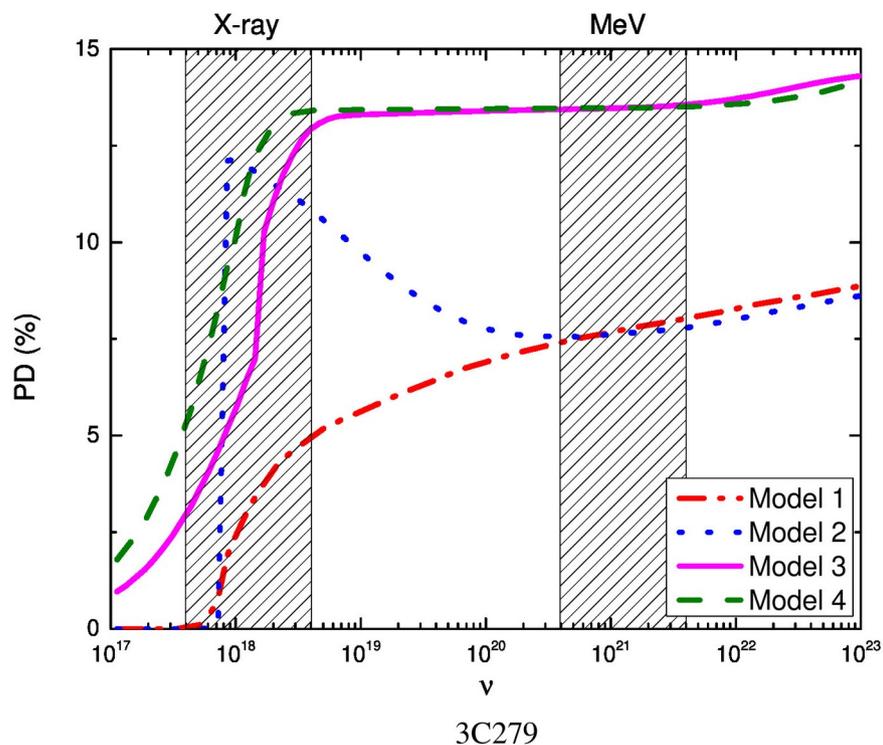
CAZ: a new catalog of blazars

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High-energy polarization predictions.

Lioudakis et al., (2019)
Peirson, Lioudakis et al., (2022)

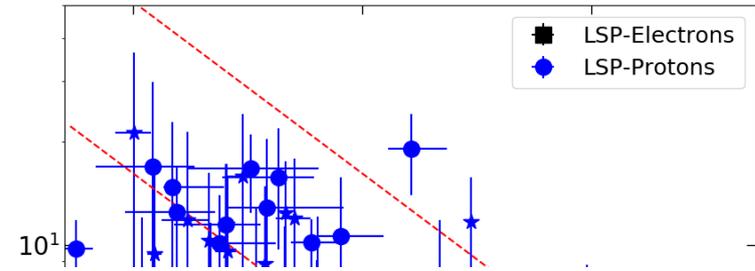
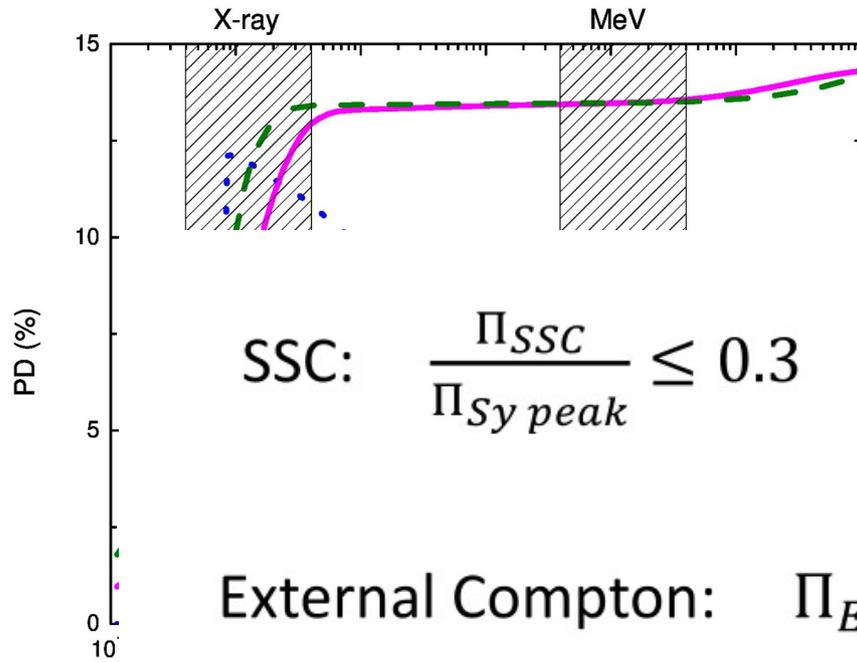


Zhang & Boettcher (2013)
Zhang et al., (2019)

High-energy polarization predictions.

Lioudakis et al., (2019)

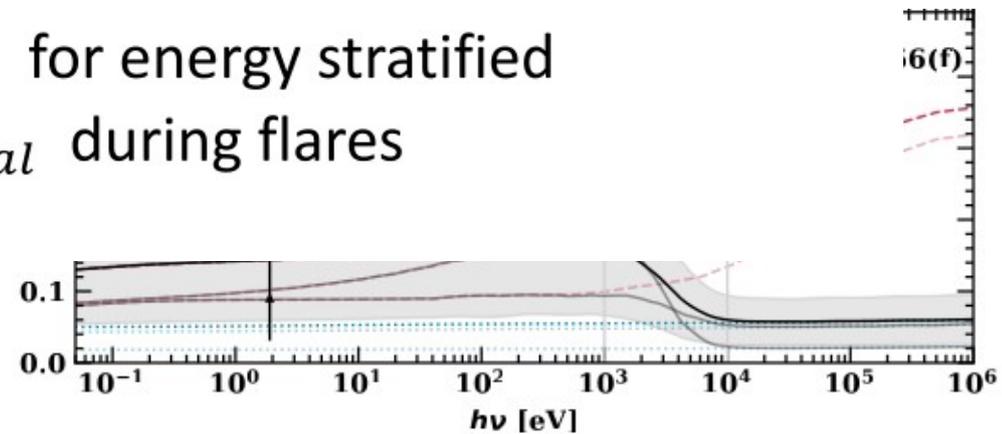
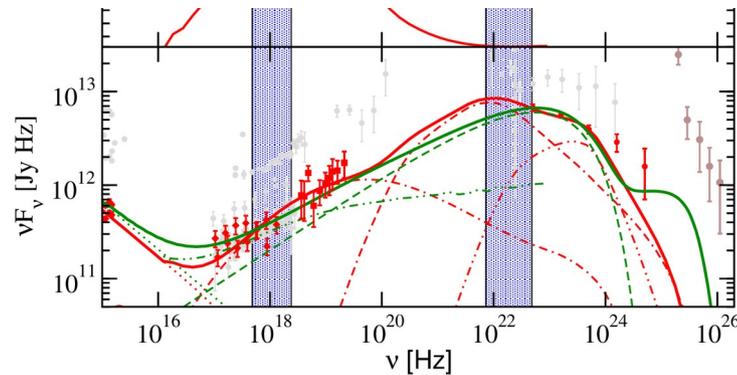
Peirson, Lioudakis et al., (2022)



Zhang, Boettcher, Lioudakis (2024)

Hadronic: $\Pi_{X, had} \approx \Pi_{radio}$ for energy stratified

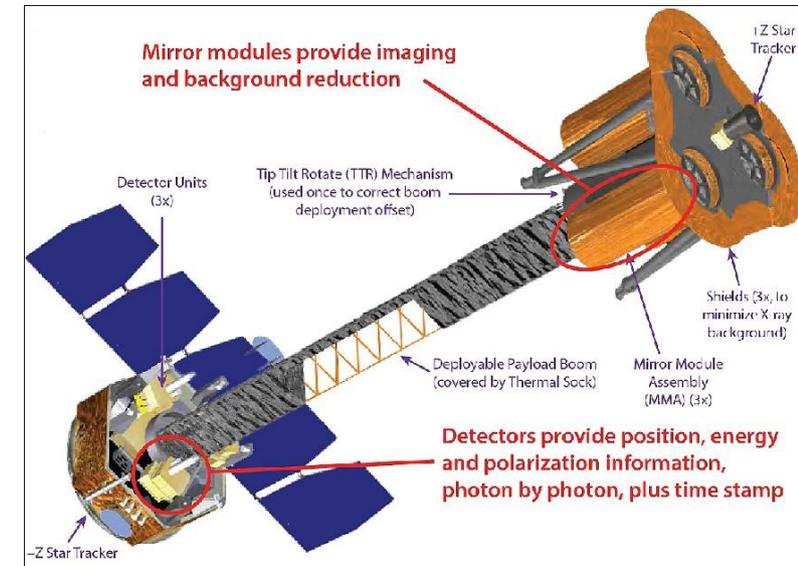
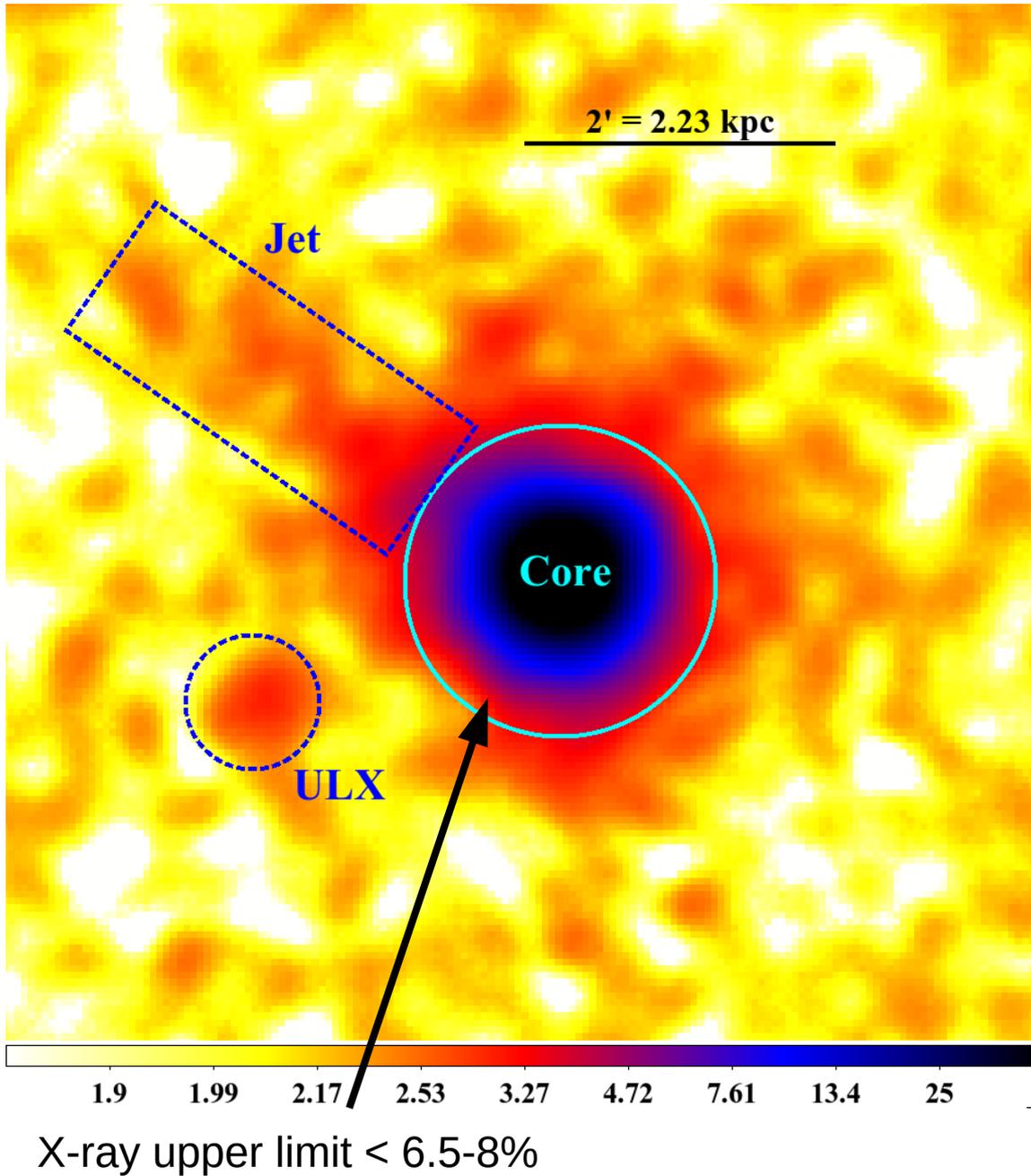
$\Pi_{X, had} \approx \Pi_{optical}$ during flares



Zhang & Boettcher (2013)

Zhang et al., (2019)

A new era with IXPE



Small NASA mission
Operating in the 2-8 keV
band

70+ published papers!
More on the way...
+ GO program Cycle 3 on-going!

Cen A
Ehlert et al.[+IL], (2022)

IXPE observations so far:

3C 454.3 (x2)

3C 273

3C 279

S5 0716+714

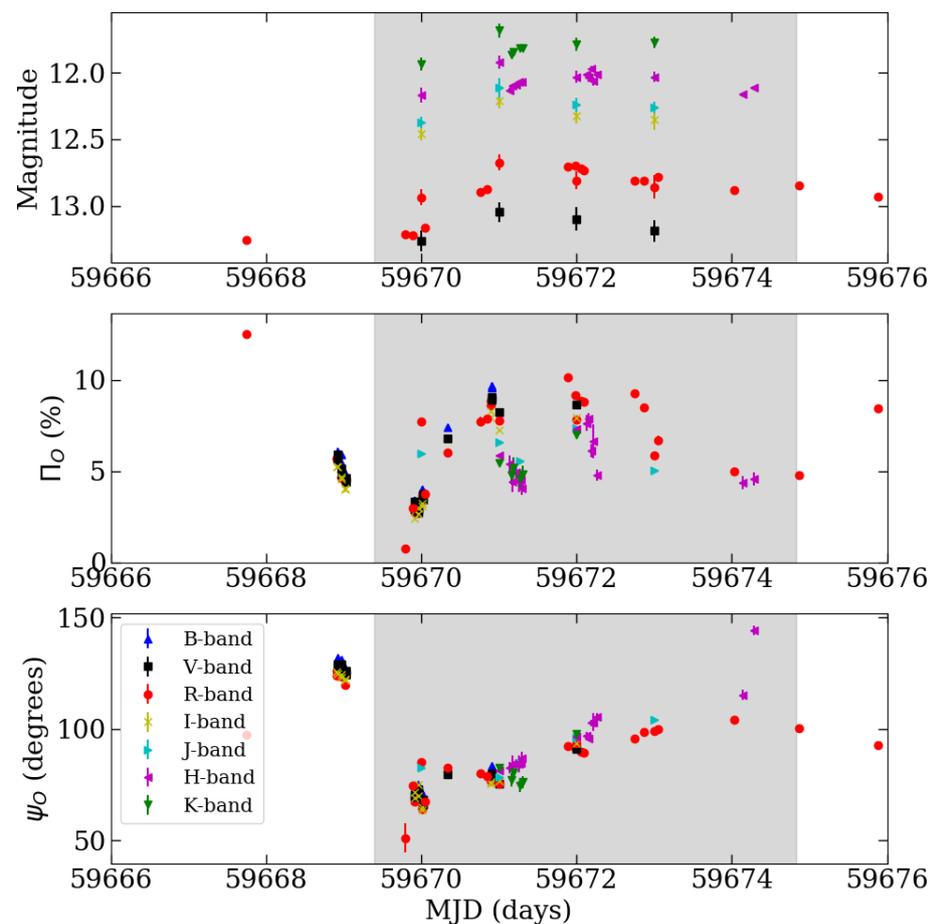
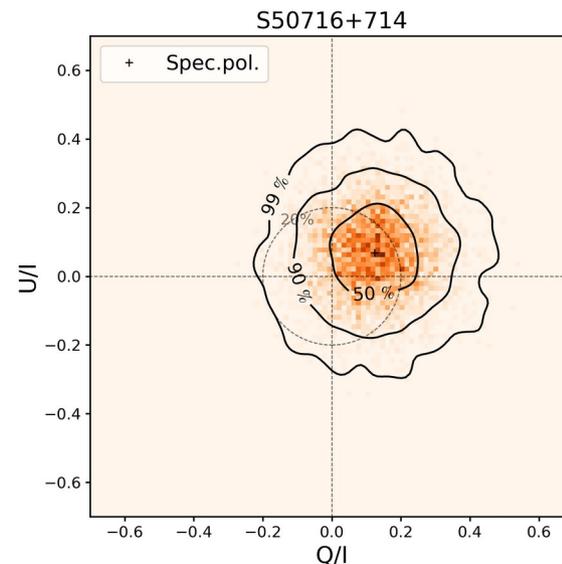
BL Lac (x4)

S4 0954+65

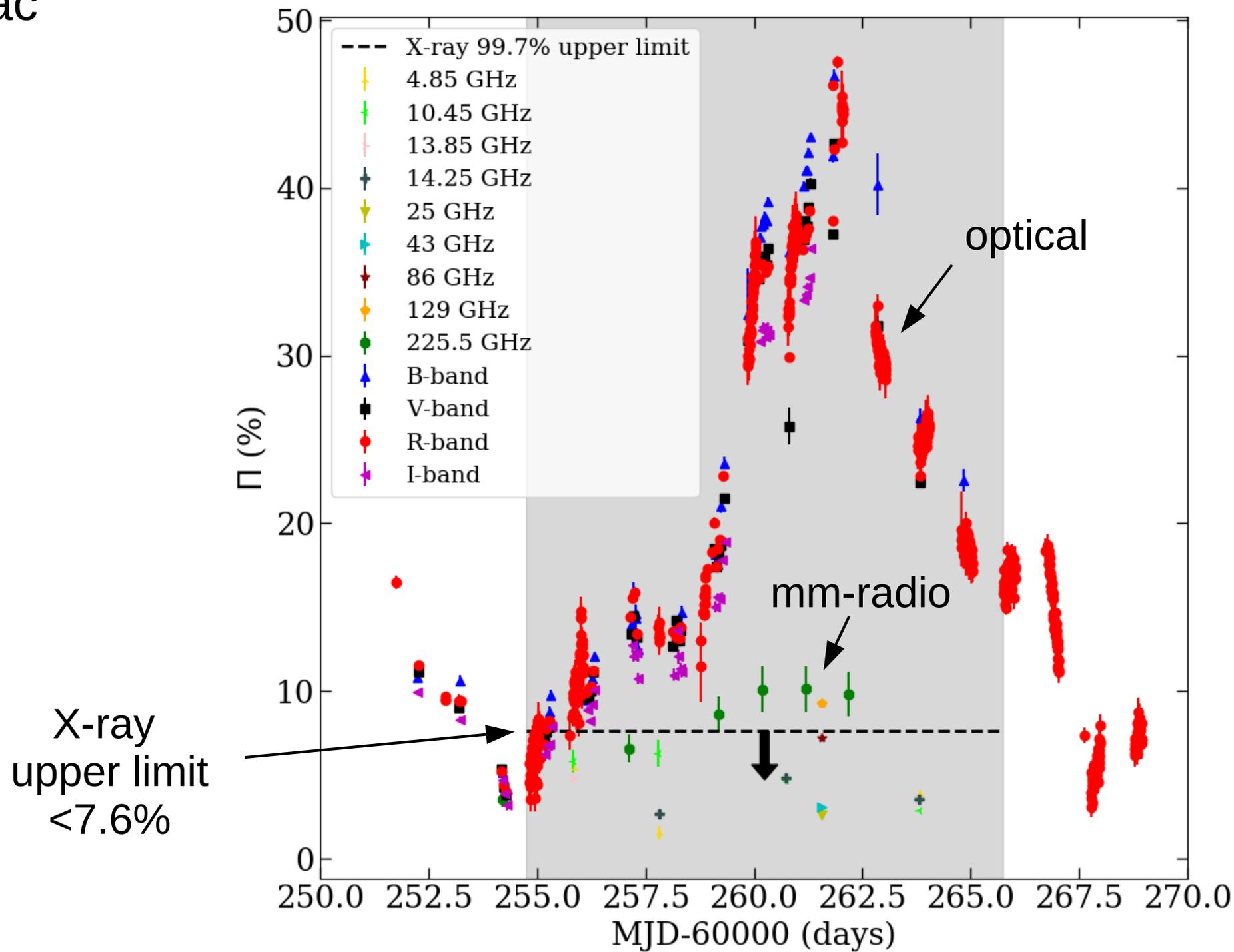
The X-ray polarization remains
undetected at typically <15%

Middel, Liodakis et al., (2023)

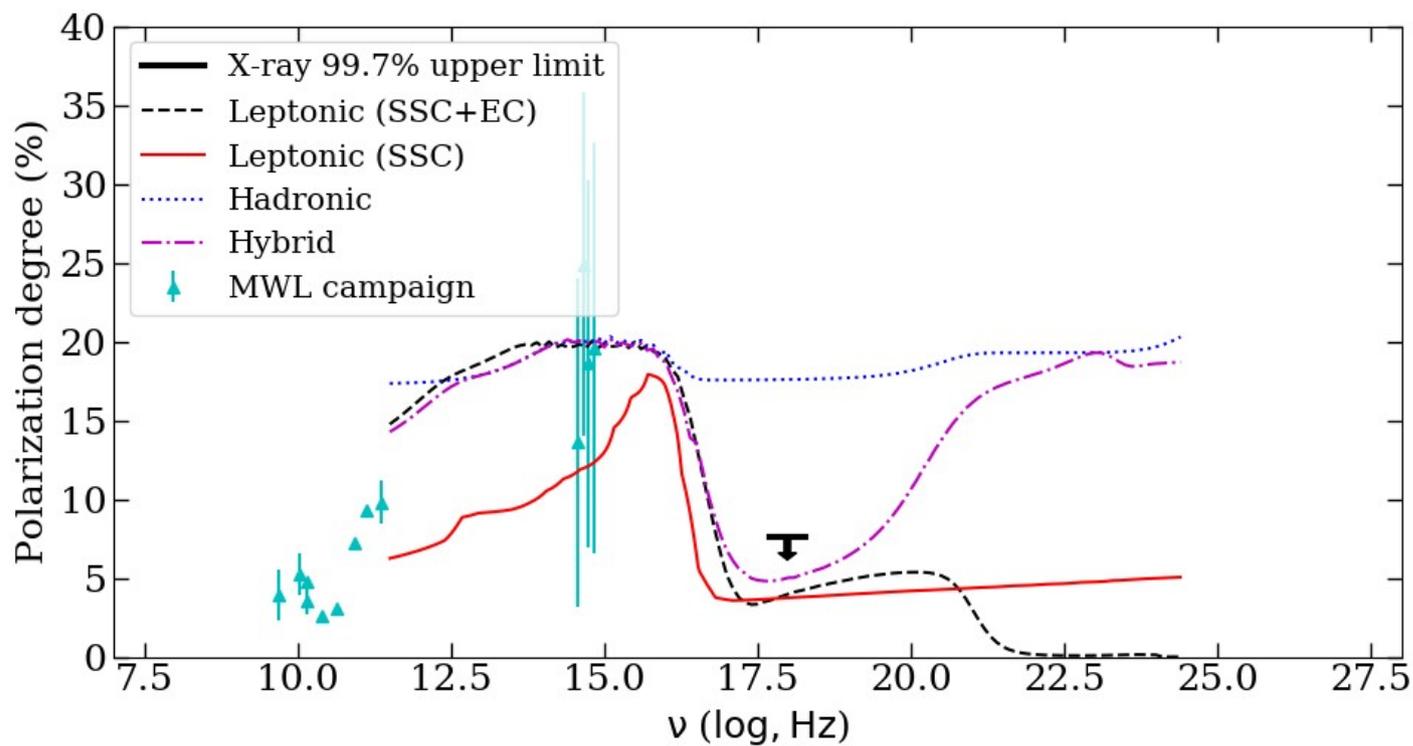
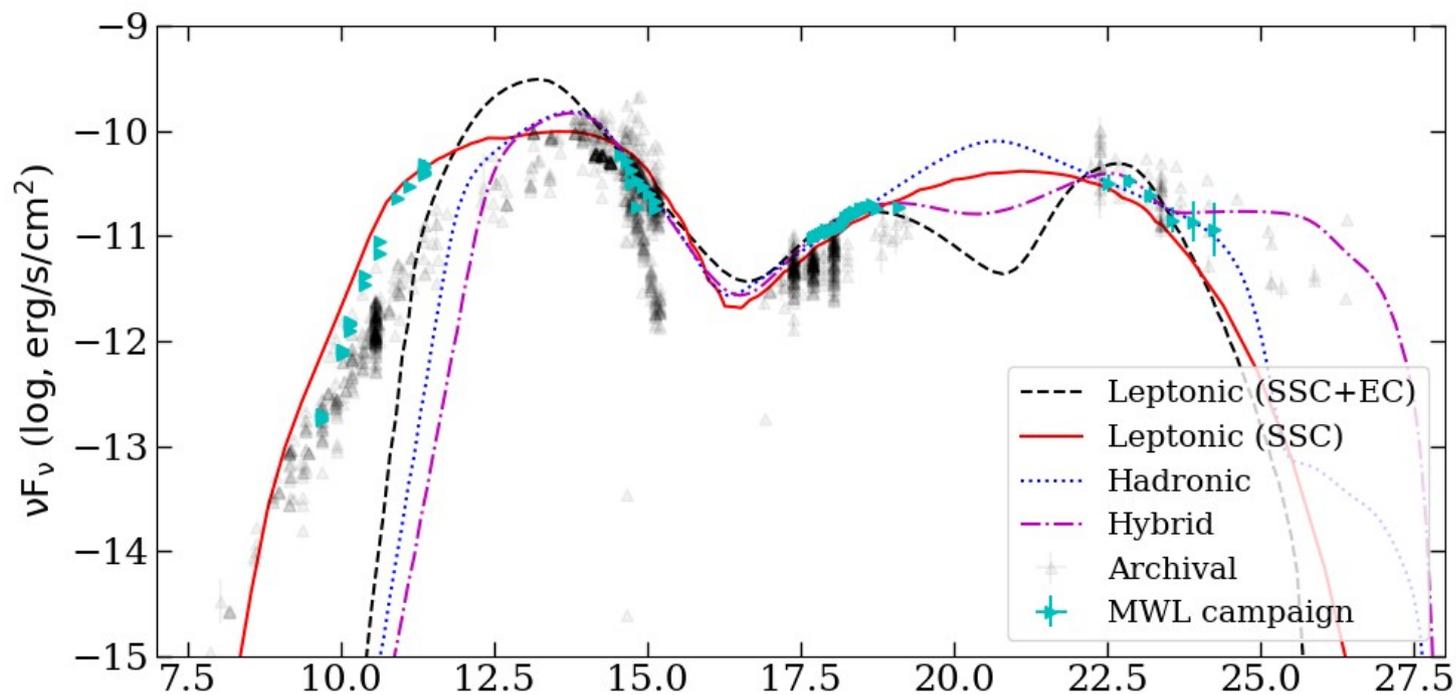
Marshall, Liodakis et al., (2024)



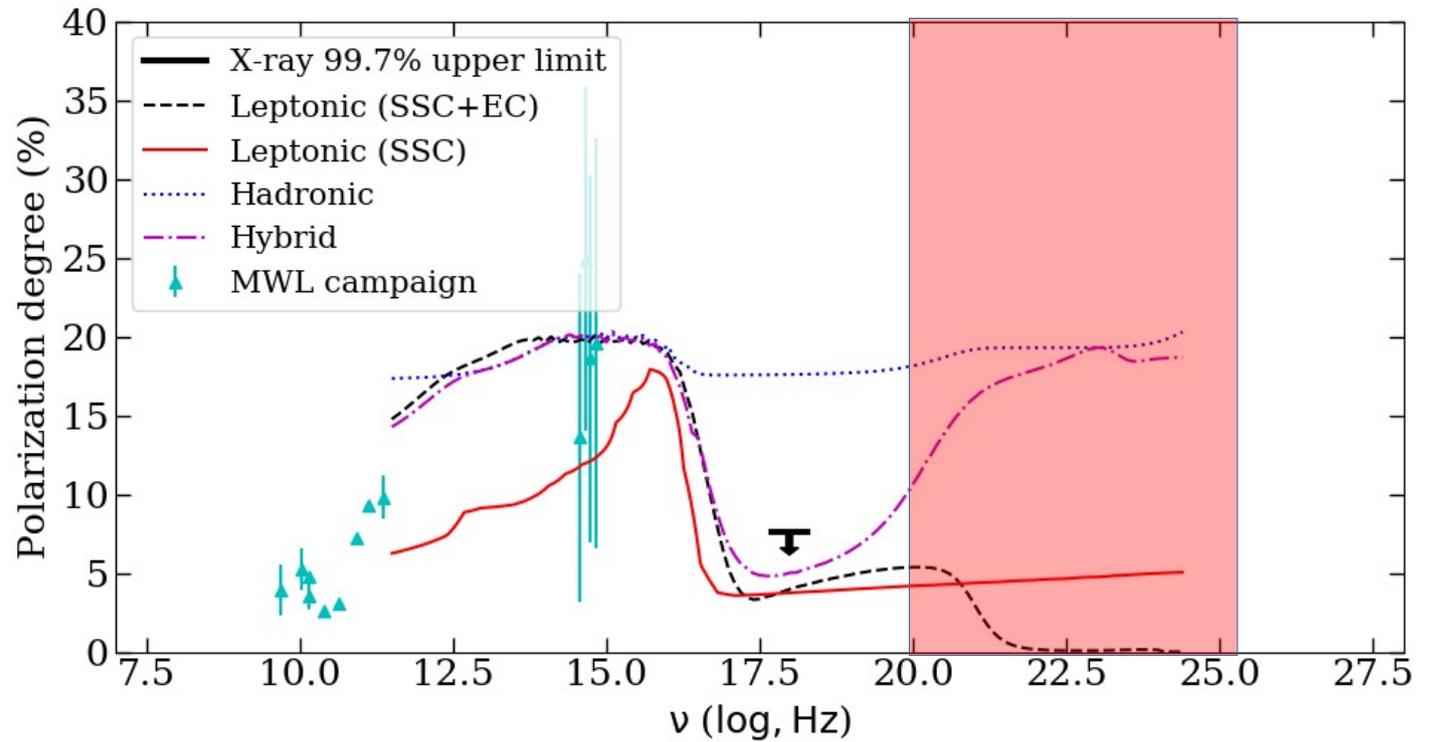
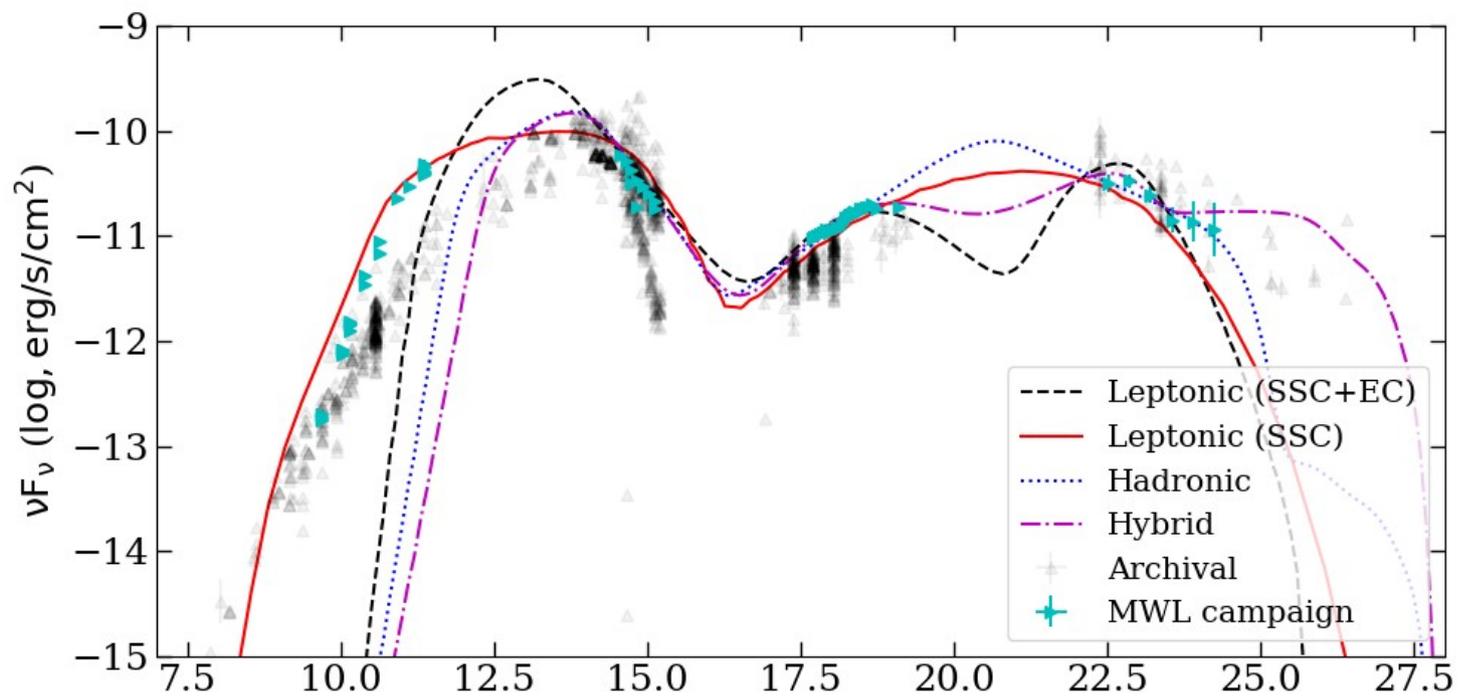
BL Lac



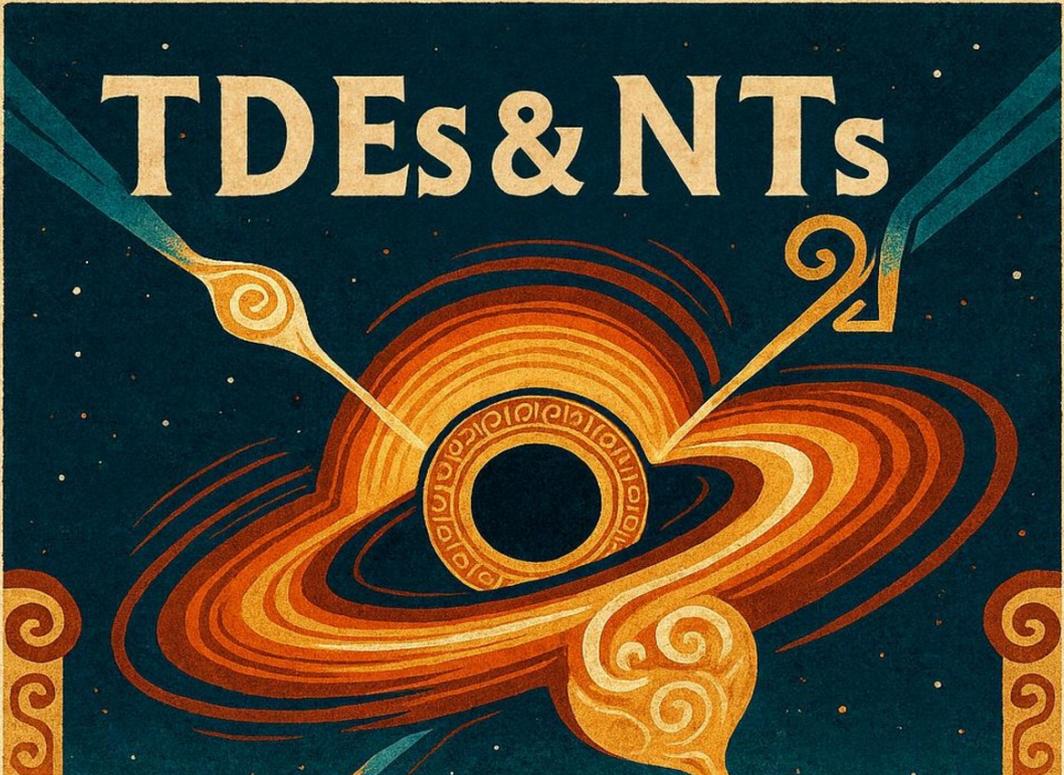
BL Lac



BL Lac



TDEs & NTs



Invited speakers

Luca Broggi
Joheen Chakraborty
Anna Franckowiak
Adelle Goodwin
Itai Linial
Andrew Mummery
Elena Rossi
Benny Trakhtenbrot
Sjoert van Velzen
Yuhan Yao

SOC

Kate Alexander
Iair Arcavi
Panos Charalampopoulos
Decker French
Ioannis Liodakis
Brenna Mockler
Nick Stone

LOC

Alberto Floris
Dimitris Langis
Ioannis Liodakis

Heraklion 24-28 2026

<https://sites.google.com/view/tdesandntsinscrete2026/>

CRETE 2026

Summary

The search for extragalactic neutrinos emitters continues...

Blazars still the most promising candidate sources, but with a lot of open questions...

X-rays in blazars come from electrons and Compton scattering!

If blazars make neutrinos, those are made through hybrid processes or most likely subdominant proton population...