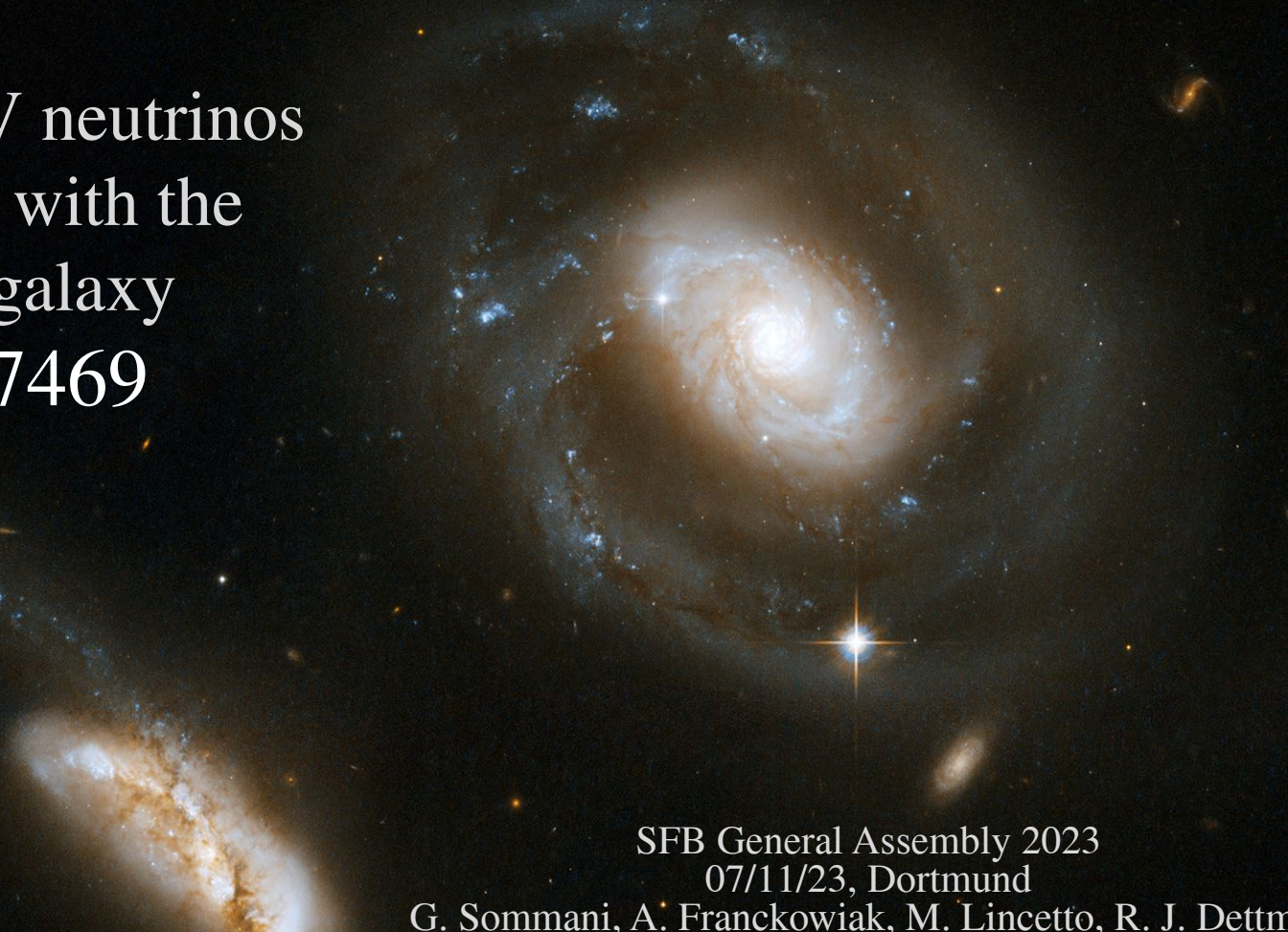


Two 100 TeV neutrinos  
coincident with the  
Seyfert galaxy  
NGC 7469



SFB General Assembly 2023  
07/11/23, Dortmund  
G. Sommani, A. Franckowiak, M. Lincetto, R. J. Dettmar

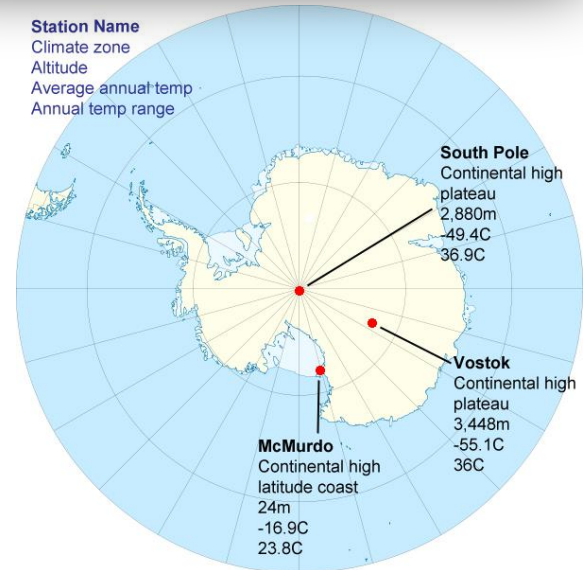
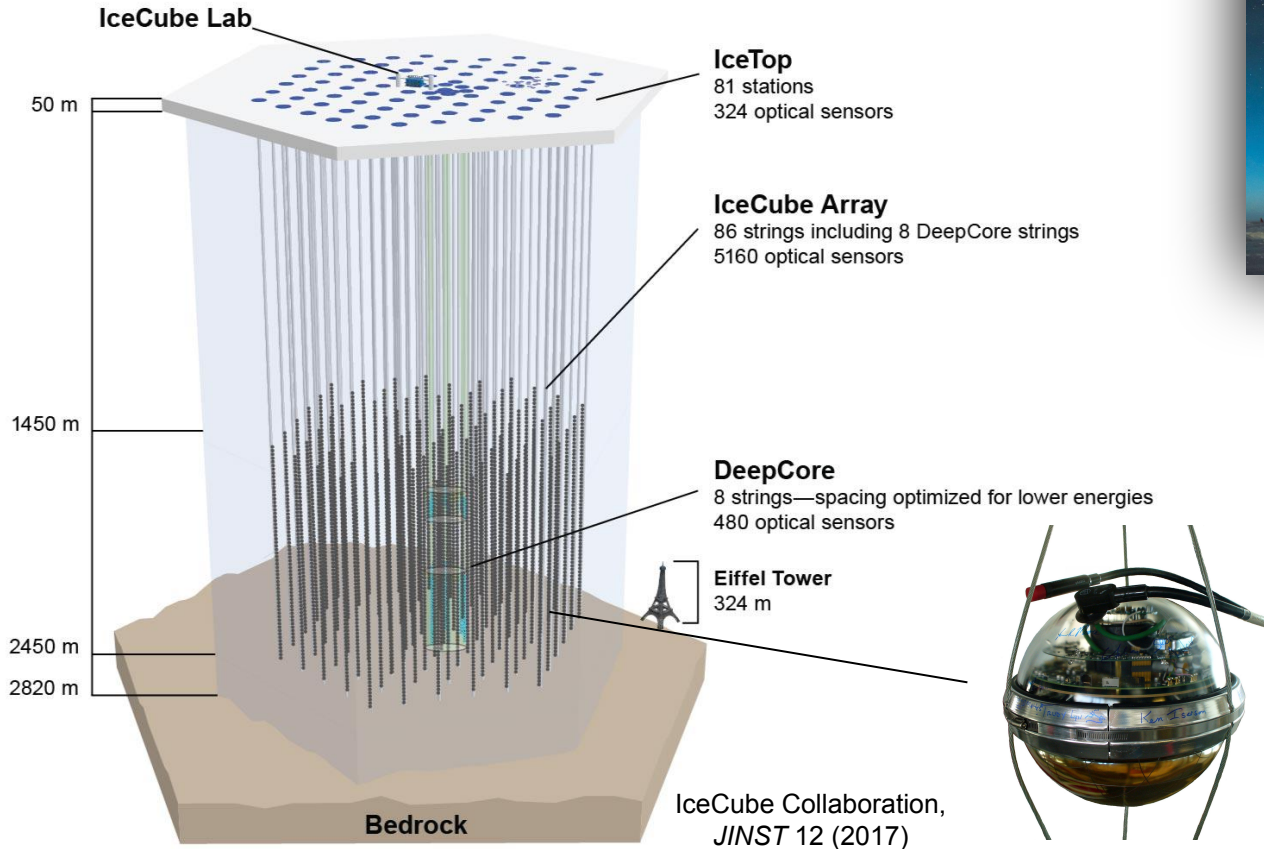
# Summary

- The IceCube Realtime Alerts;
- The two alerts IC220424A and IC230416A coincident with NGC 7469;
- Chance probability to have such a coincidence;
- NGC 7469 as source of high-energy neutrinos.

The image features a dark, star-filled background. In the upper right, there is a large, bright spiral galaxy with a glowing core and distinct arms. In the lower left, there is a smaller, elongated elliptical galaxy. The text "The IceCube Realtime Alerts" is centered in a white, serif font. Two bright stars with diffraction patterns are visible: one in the upper left and one in the lower right.

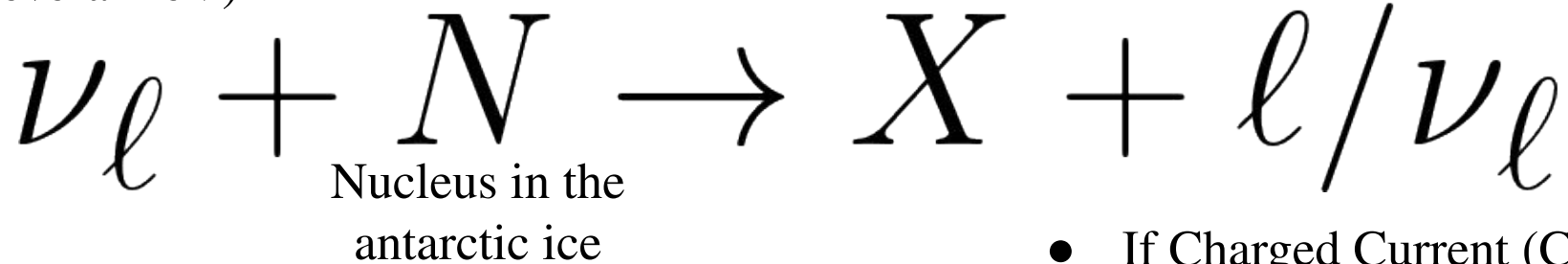
The IceCube Realtime Alerts

# The IceCube Neutrino Observatory



Incident neutrino  
(several TeV)

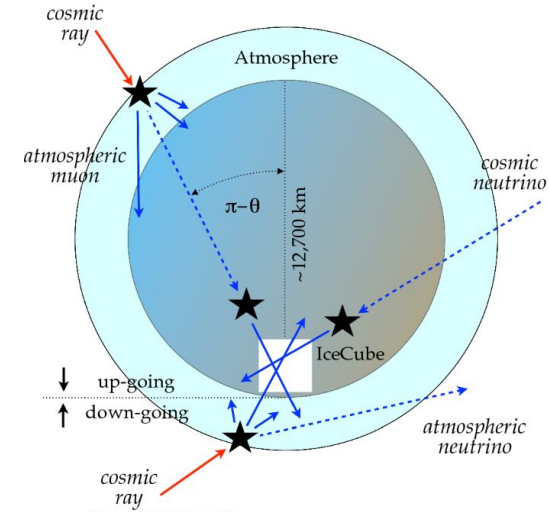
Hadronic cascade  
(destroyed nucleus)



- If Charged Current (CC), lepton  $\ell$ ;
- If Neutral Current (NC), neutrino  $\nu_{\ell}$ .

$$\ell = \begin{cases} e & \text{Produces electromagnetic cascades} \\ \mu & \text{Best angular reconstructions} \\ \tau & \end{cases}$$

# Realtime alerts to identify neutrino sources

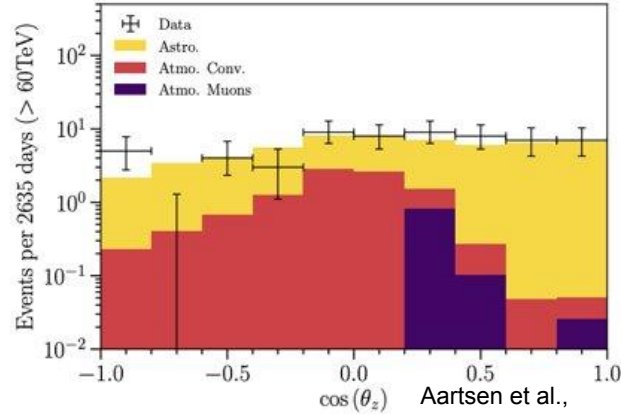
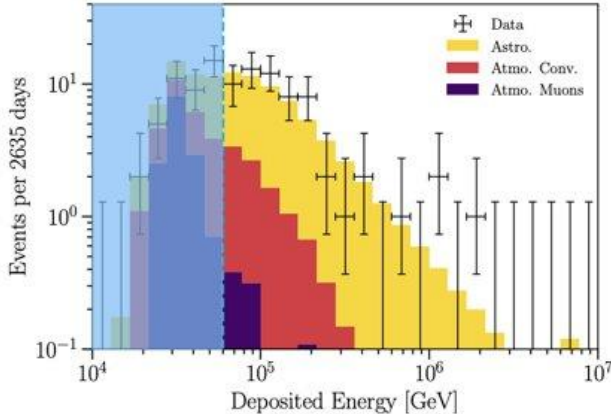


- Detection of a diffuse astrophysical neutrino flux in 2013.

Aartsen et al., *Science* 342 (2013), 1242856.



- Despite evidence of neutrino emission from some sources, origin of most of the astrophysical neutrino flux still unknown.

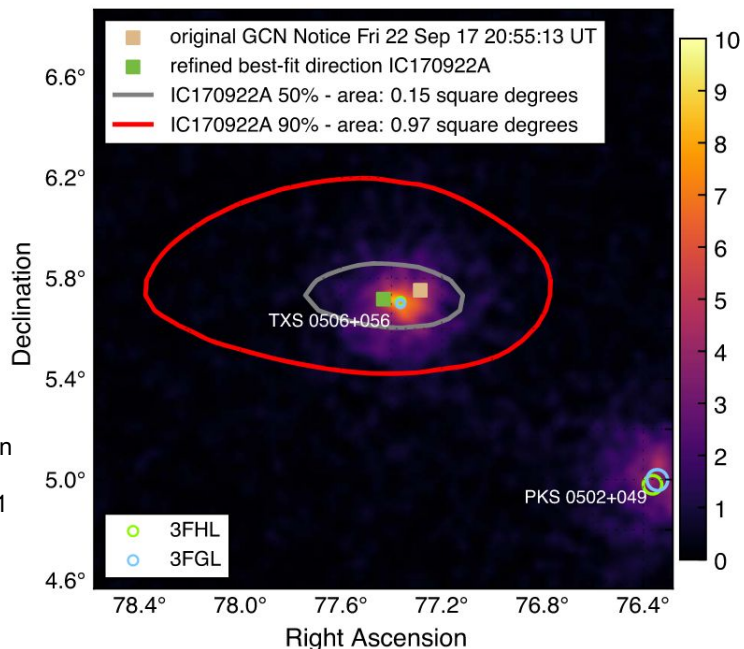


Aartsen et al.,  
*Science* 342 (2013), 1242856.

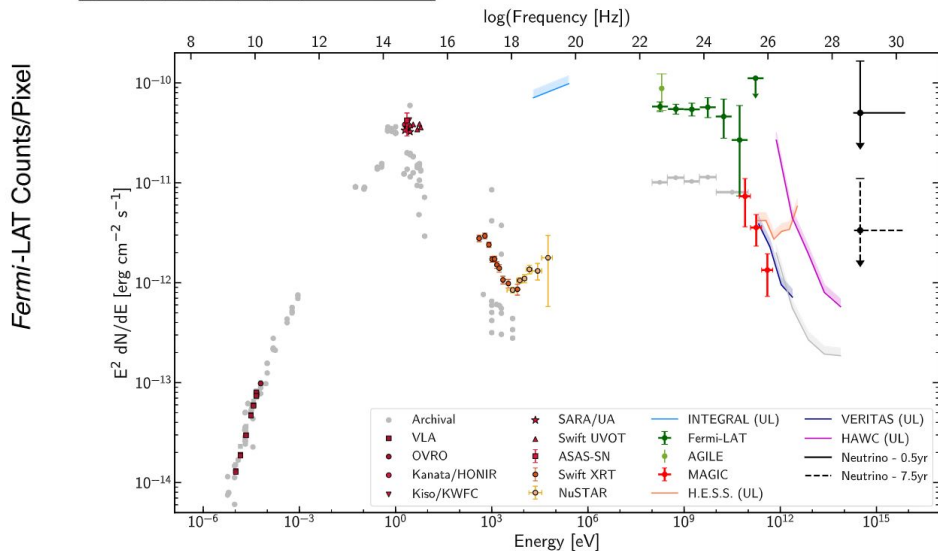
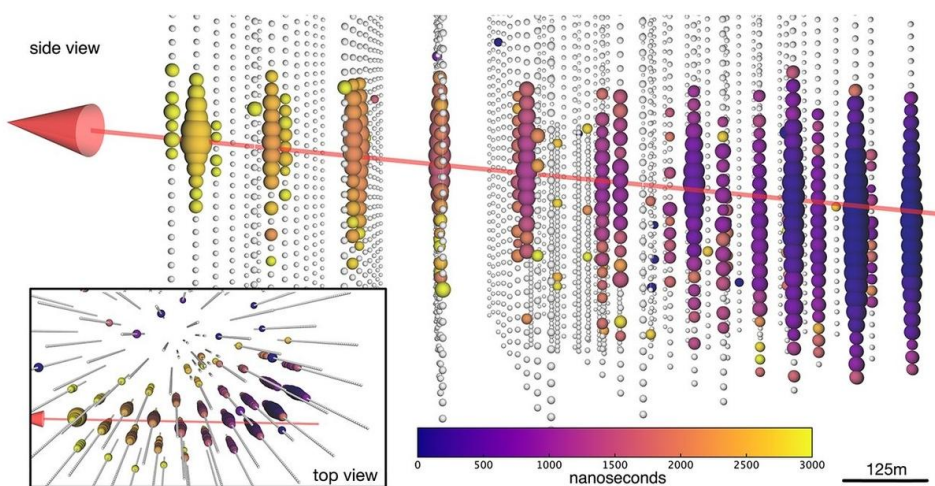
- **Realtime alerts to identify possible sources. Angular reconstruction extremely important.**

# Realtime alerts for Multi-messenger astrophysics: IC170922A 290 TeV neutrino

Coincident with the flaring blazar TXS 0506+056.



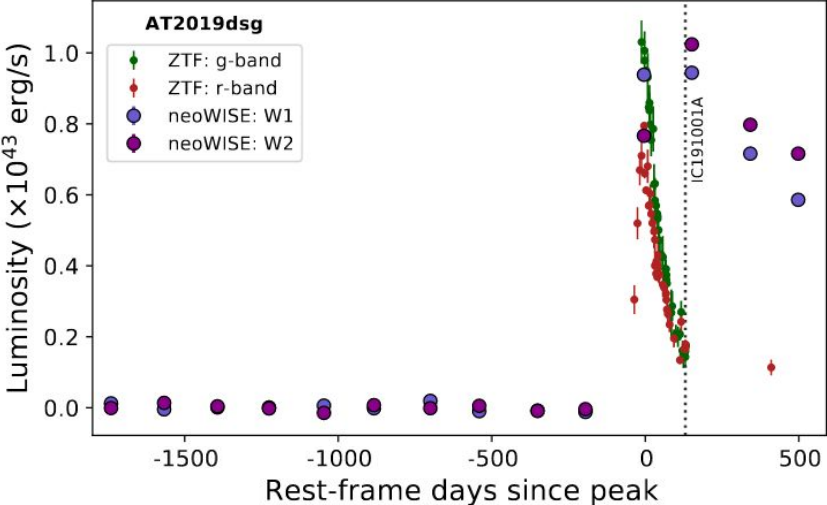
IceCube  
Collaboration  
et al.  
*Science* 361  
(2018),  
eaat1378.



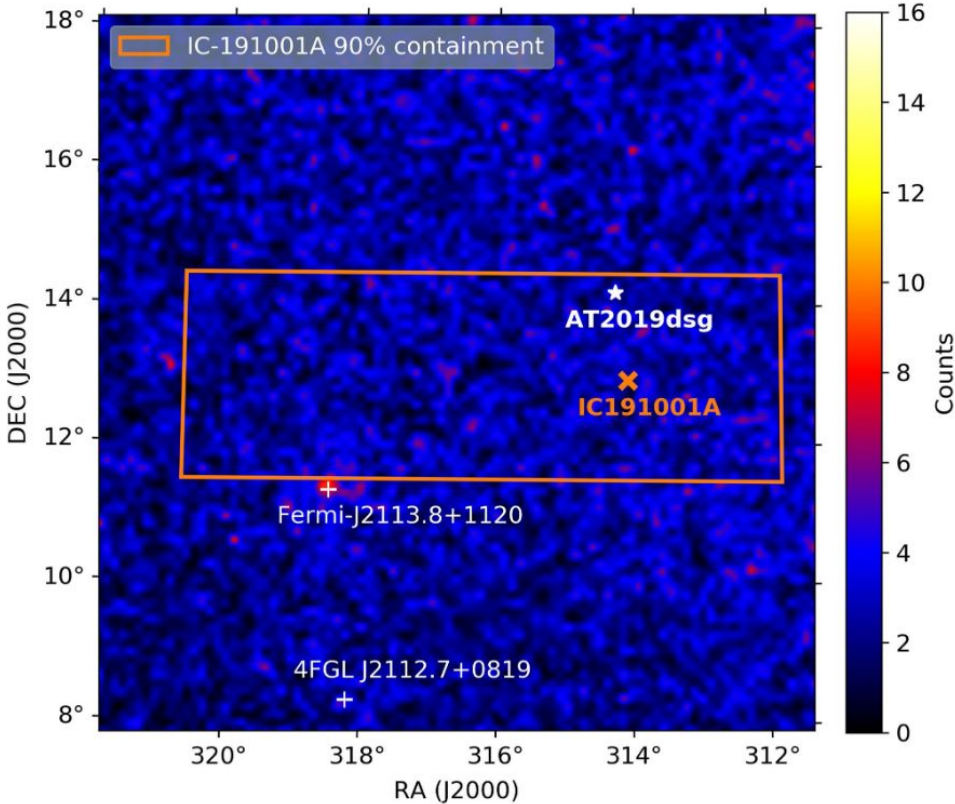
Two 100 TeV neutrinos coincident with the Seyfert galaxy NGC 7469, Dortmund, 07/11/23, Giacomo Sommani

# Multi-messenger astrophysics: Coincidence with a TDE

- Identification of a coincident TDE enabled by the realtime program.



van Velzen et al., *arXiv e-prints* (2021), arXiv:2111.09391.



Stein et al., *Nature Astronomy* 5, (2021), 510-518.



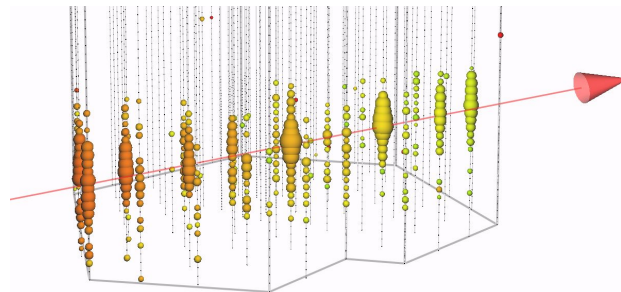


The two alerts IC220424A and  
IC230416A coincident with NGC 7469

# IC220424A, IC230416A and NGC 7469

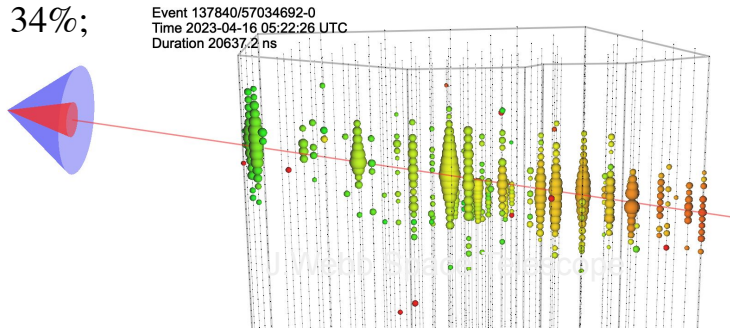
- **IC220424A:**

- Gold alert;
- Signalness 50%;
- 184 TeV.

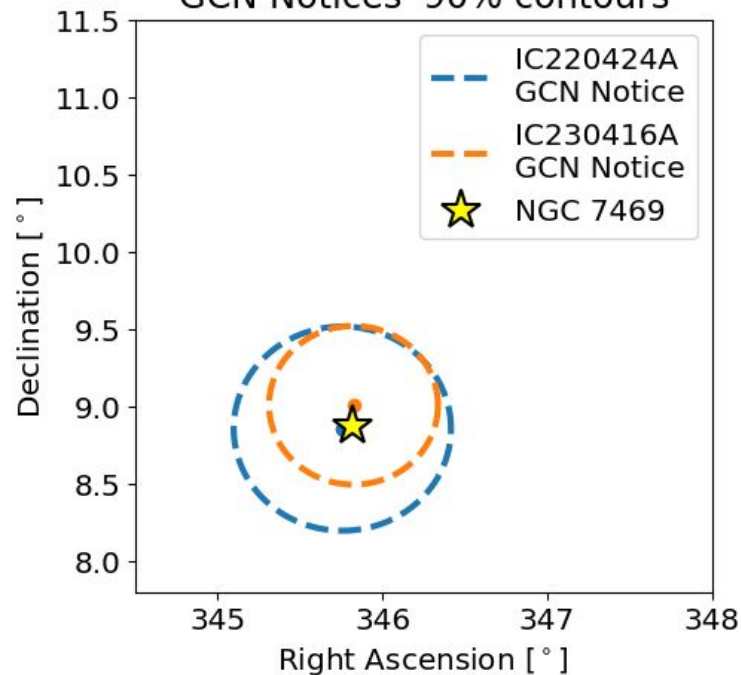


- **IC230416A:**

- Bronze alert;
- Signalness 34%;
- 127 TeV.



GCN Notices' 90% contours



# NGC 7469

Type I Seyfert galaxy (NGC 1068  
is type II)

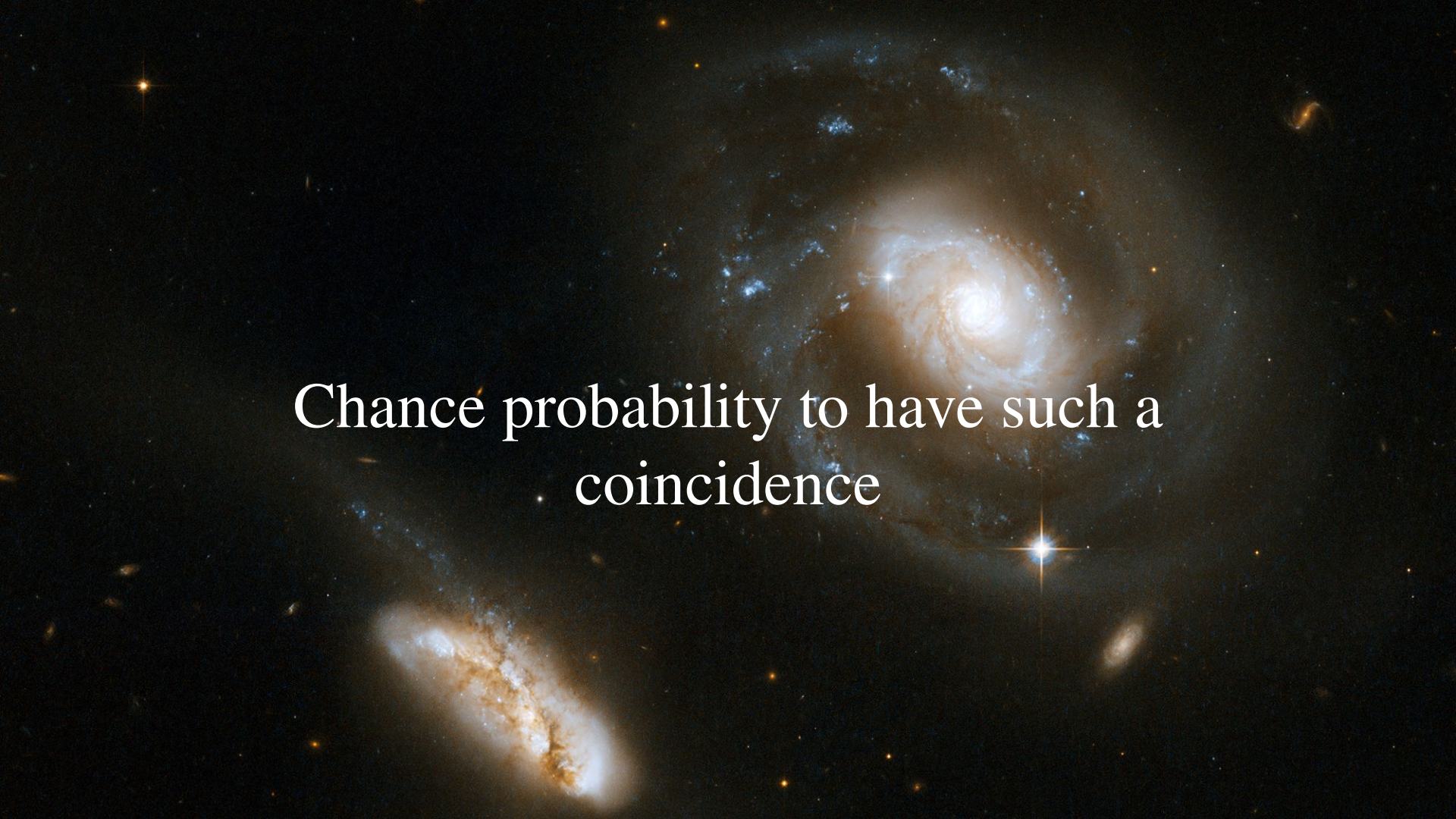
DL =  $49.7 \pm 4.9$  Mpc (Koshida, S., et al. 2017,  
ApJ, 842, L13) (NGC  
1068 is at 14 Mpc)

Starburst regions

One of the 6 Seyfert galaxies  
originally studied by Seyfert (with  
NGC 1068, [here](#) the paper)



J. Webb Space Telescope

A deep space photograph showing two galaxies in a close encounter. The upper galaxy is a bright, multi-colored (yellow, orange, and blue) spiral galaxy. The lower galaxy is a yellowish, elongated, and somewhat irregular galaxy. The background is dark with scattered stars and faint blue nebulae. The text "Chance probability to have such a coincidence" is overlaid in the center in a white serif font.

Chance probability to have such a  
coincidence

# Goodness-of-Fit test to estimate the chance probability

Test statistic built on two hypotheses one against the other:

- $H_0$ : The doublet is background.
- $H_1$ : The doublet is produced by a source.

Tested on the following catalogs:

- **All the AGN in the Milliquas catalog (50757 sources):**
  - With our TS, only the nearest ones really count.
- **Turin-SyCAT catalog (351 sources):**
  - Only Seyfert galaxies;
  - All sources relatively near.

# Results

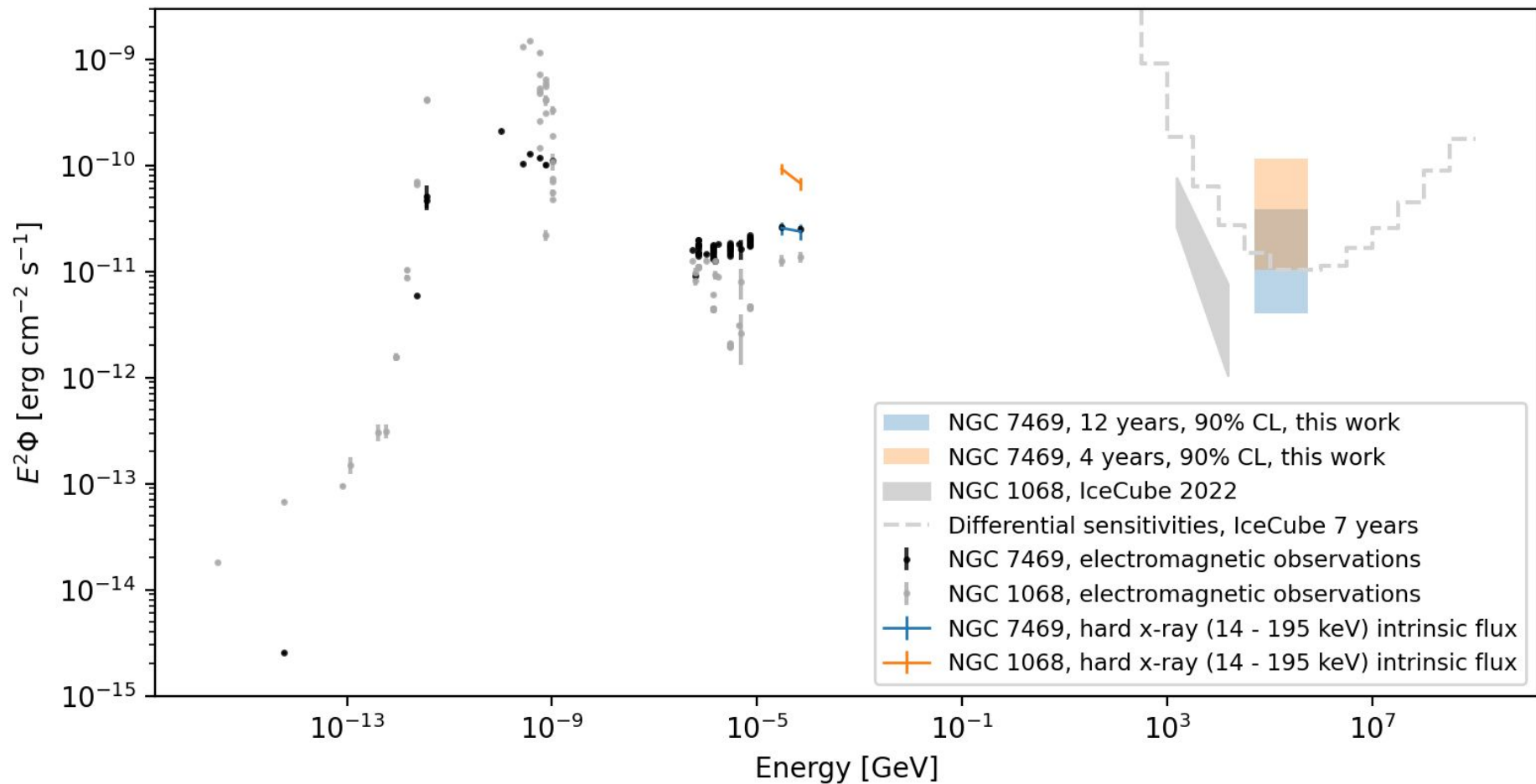
Reconstruction	Catalog	Best-doublet	Source	p-value	p-value (in $\sigma$ )
SplineMPE	Milliquas	IC220424A & IC230416A	NGC 7469	$2.4 \times 10^{-3}$	2.82
SplineMPE	Turin	IC220424A & IC230416A	NGC 7469	$2.8 \times 10^{-4}$	3.45

Best result: SplineMPE+Turin-SyCAT catalog with:

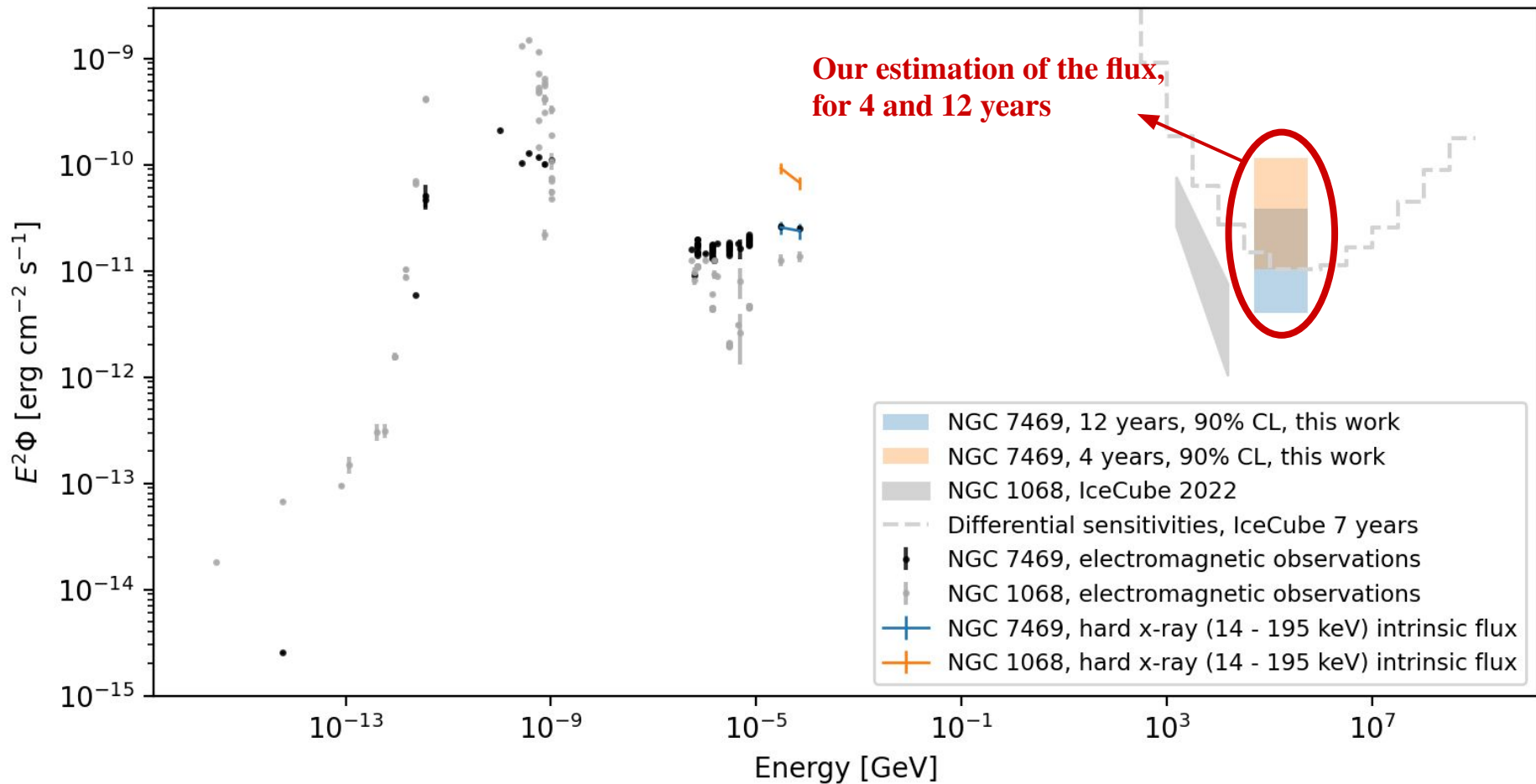
- 3.45  $\sigma$  (pre-trial)
- 3.26  $\sigma$  (post-trial)

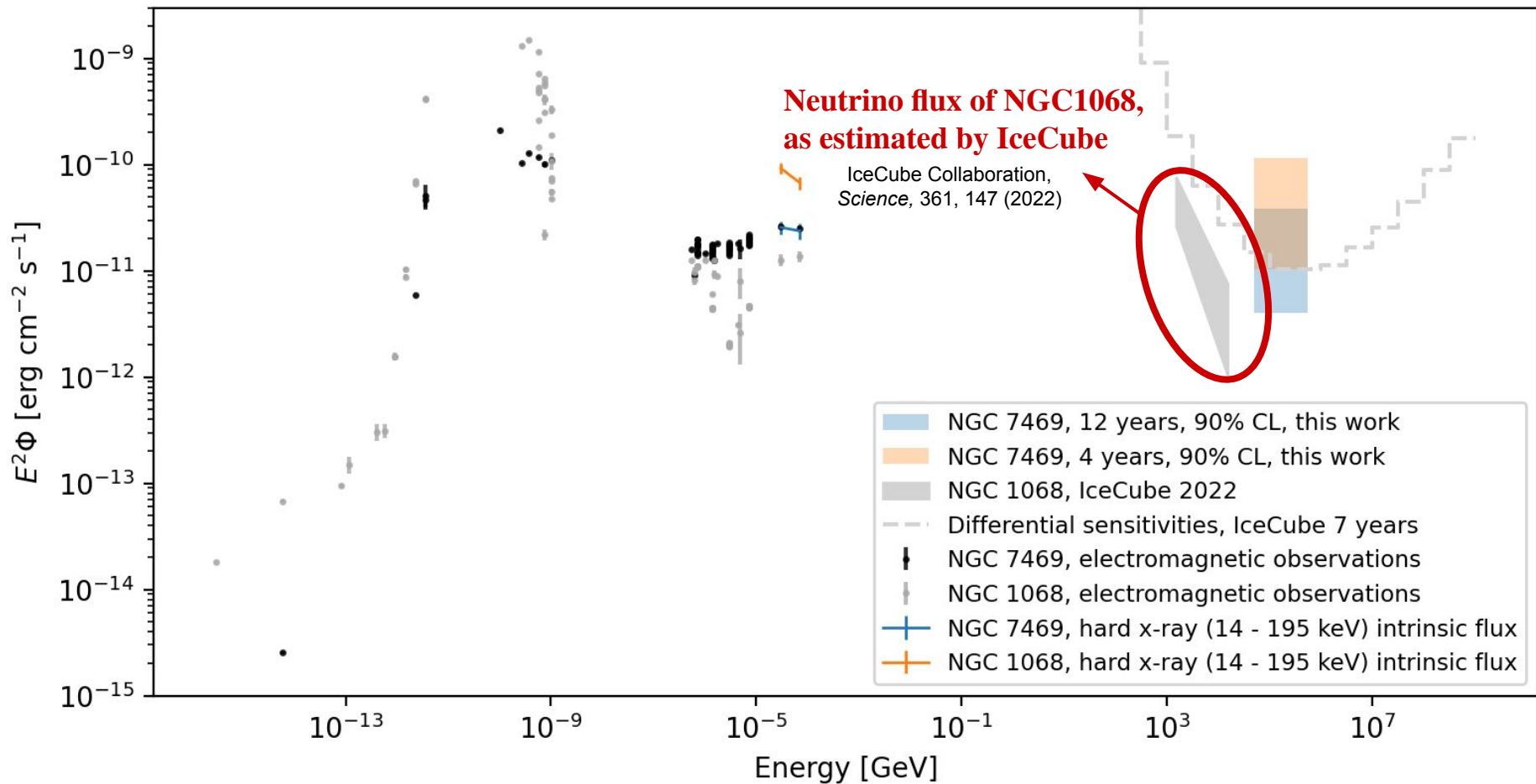


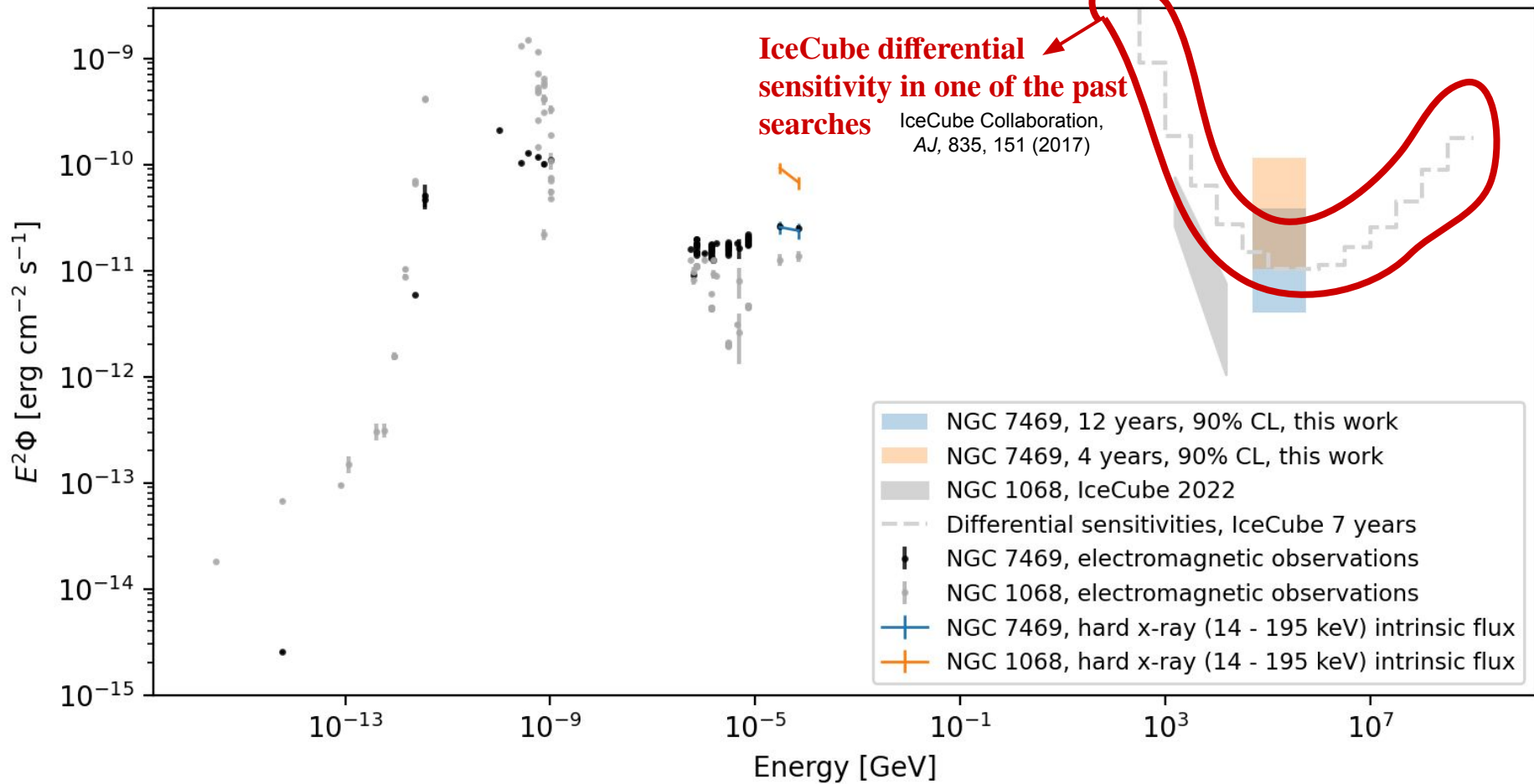
NGC 7469 as a source of high-energy  
neutrinos

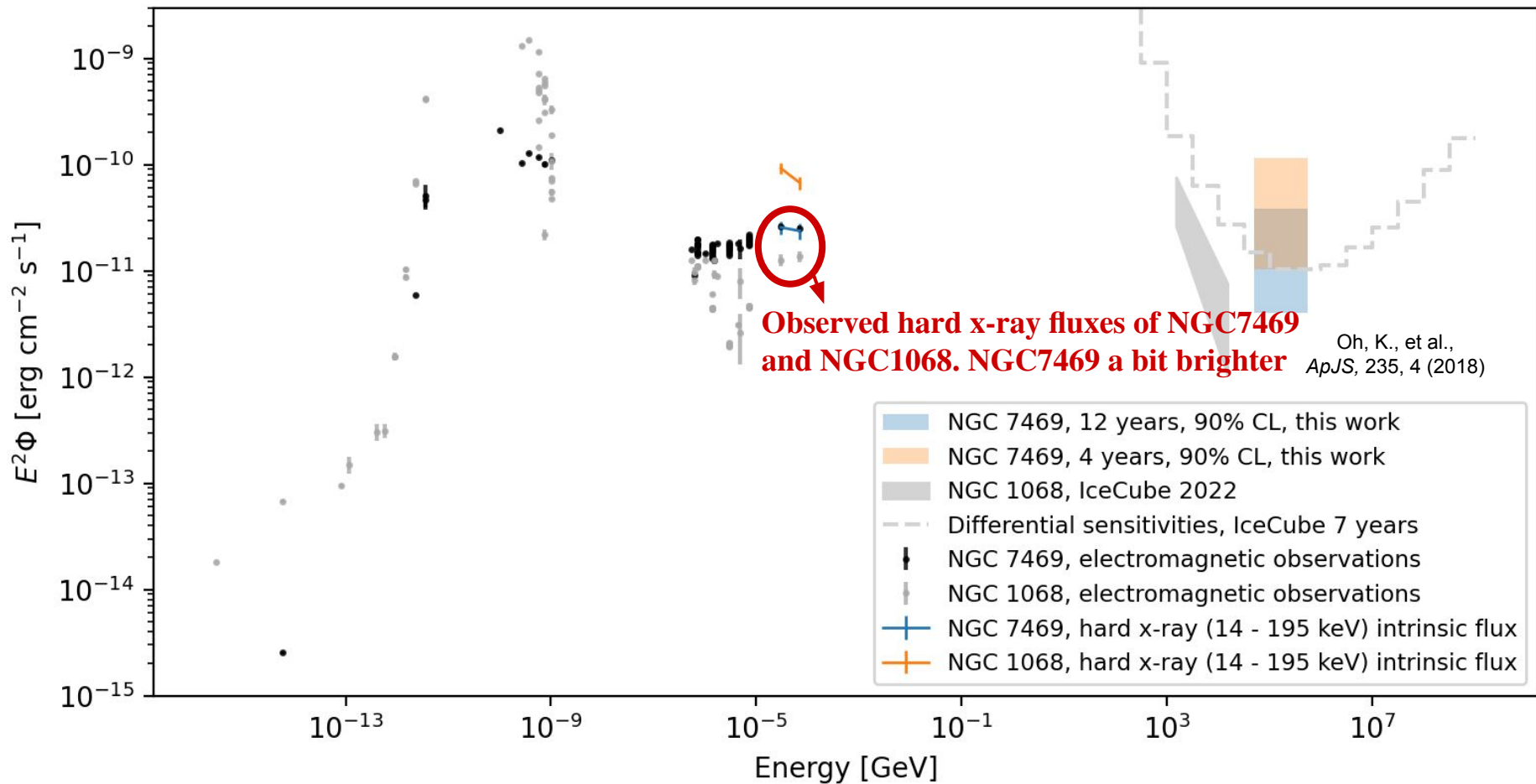


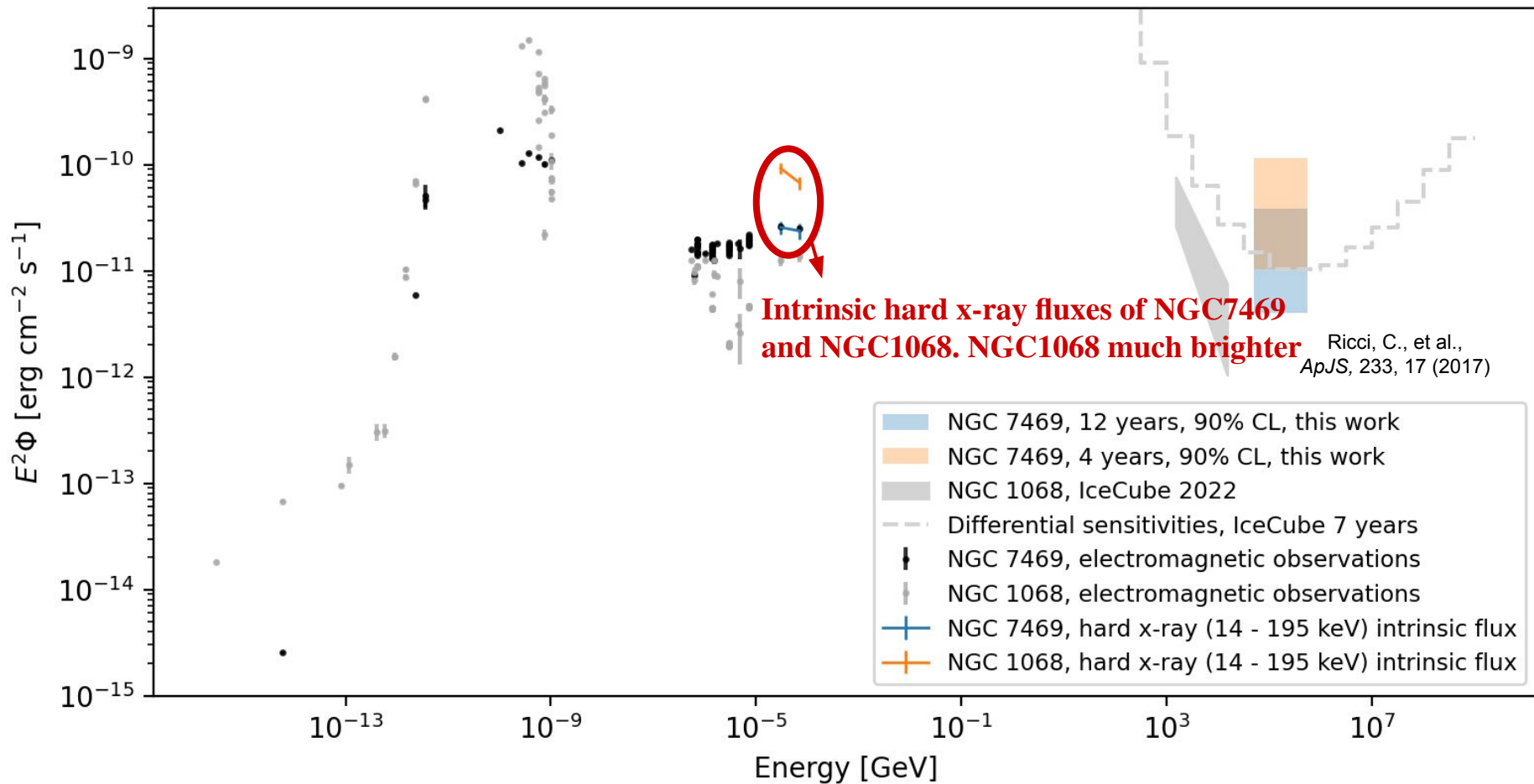








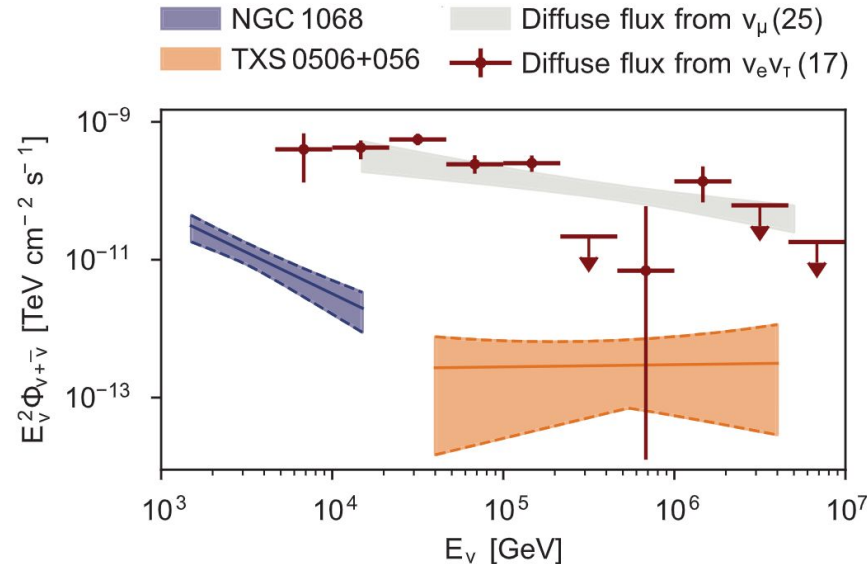




# If NGC 7469 is a high-energy neutrino source, why has it never been detected before?

Possible answer: because of a **hard spectral index**;

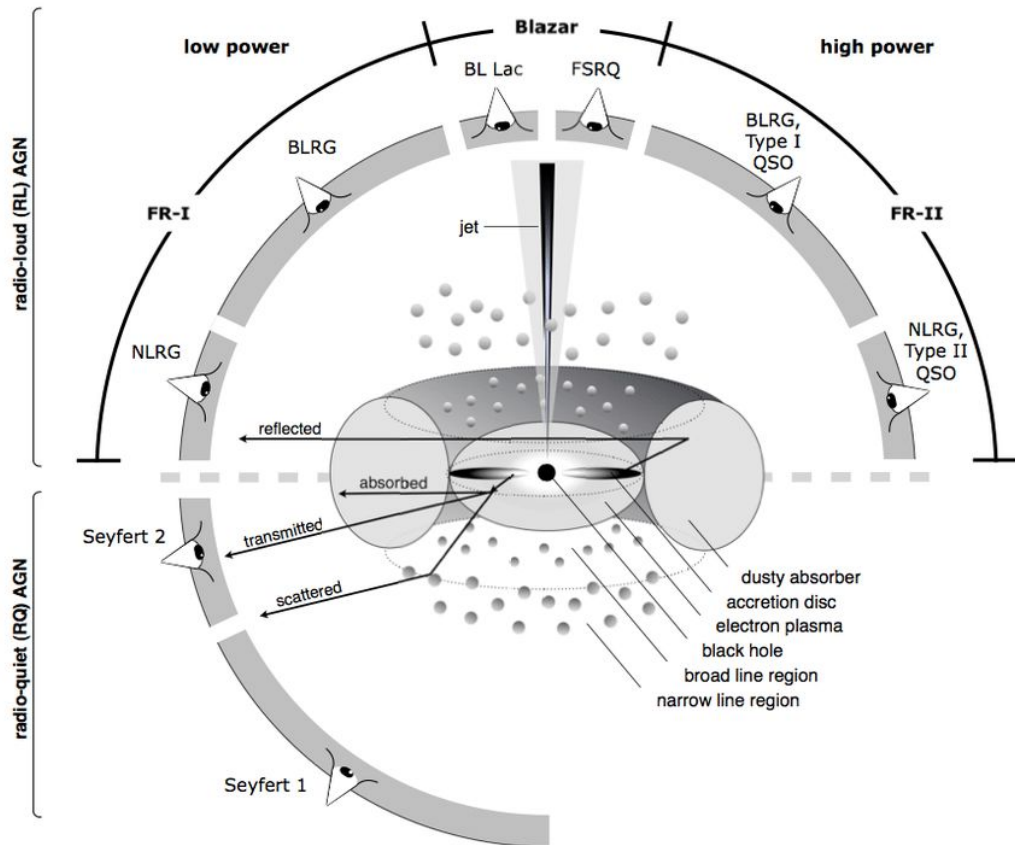
NGC 1068 has a soft spectral index ( $\sim 3.2$ ), but the astrophysical flux detected by IceCube is much harder ( $\sim 2.4$ ). **We need hard-spectral-index sources.**



IceCube  
Collaboration,  
*Science*, 361,  
147 (2022)

# By looking at the hard x-ray flux, this is:

- **Observationally**, higher for NGC 7469 than NGC 1068;
- **Intrinsically**, higher for NGC 1068 than NGC 7469;
- To remember: NGC 7469 is **~5 times further away** than NGC 1068:
- NGC 7469 is a Seyfert I (directed toward us) NGC 1068 a Seyfert II (inclined).



# Conclusions

- IceCube sends out realtime alerts to find new neutrino sources;
- Two neutrino alerts coincident with the Seyfert galaxy NGC 7469;
- Chance probability  $\sim 3.3$  sigma;
- If NGC 7469 is a neutrino source, it requires a hard spectral index;
- What would be the mechanism producing such a neutrino flux with a hard spectral index?





Thank you for listening!