Long-term gamma-ray variability and multimessenger activity of the blazar GB6 J1542+6129

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Blazars as neutrino sources

- AGN: central regions of galaxies
    - supermassive black hole: gravitational energy → radiation
- jet: ionized matter by the axis of rotation
    - blazars
- high particle density → high-energy neutrino production

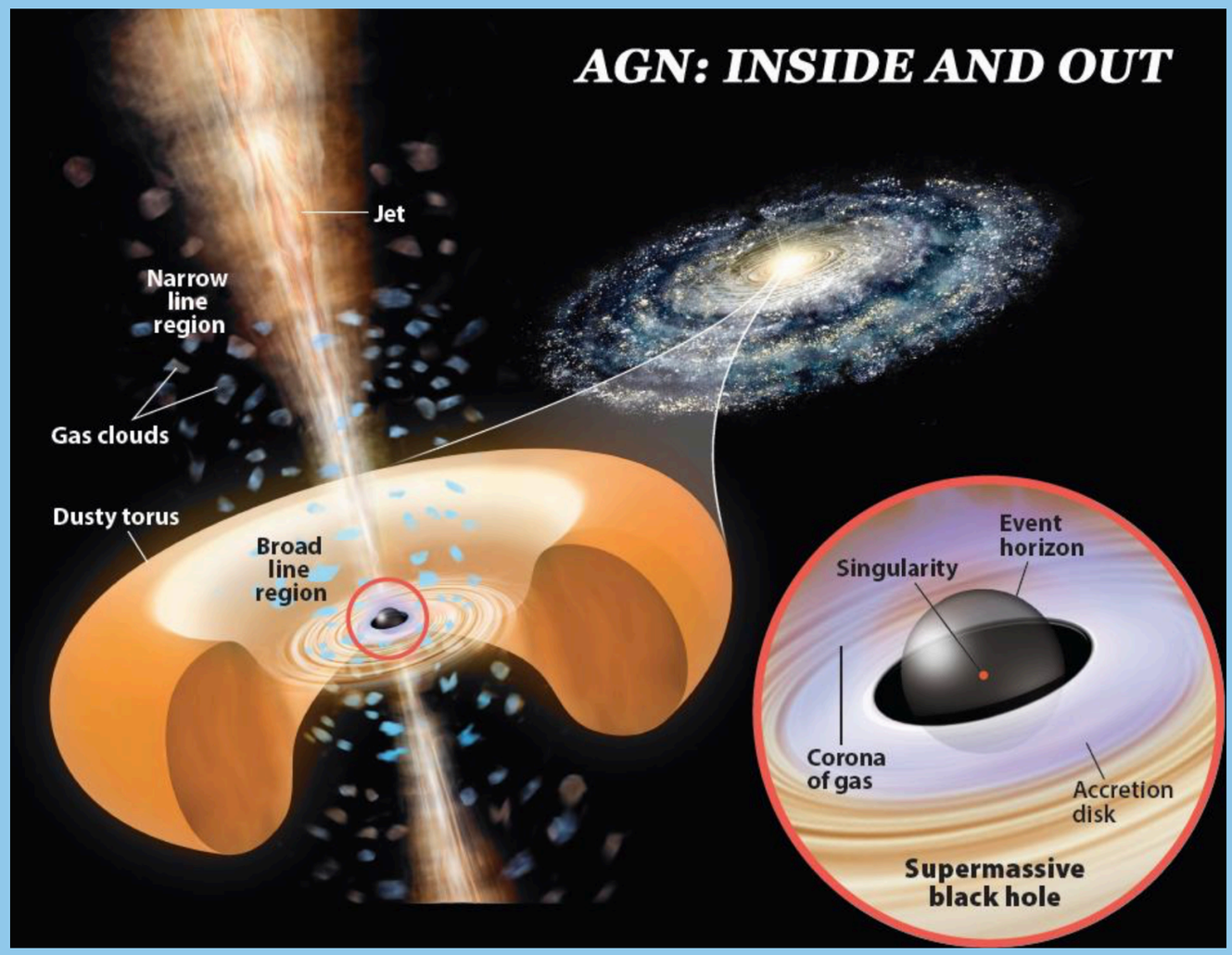


Fig. 1., Schematic illustration of an AGN structure.

The blazar GB6 J1542+6129

- IceCube Collaboration and M. G. Aartsen et al., Time-integrated Neutrino Source Searches with 10 years of IceCube Data, arXiv:1910.08488 (2019)
- 4th most significant candidate
- long term observation of high-energy processes
- multimessenger analysis

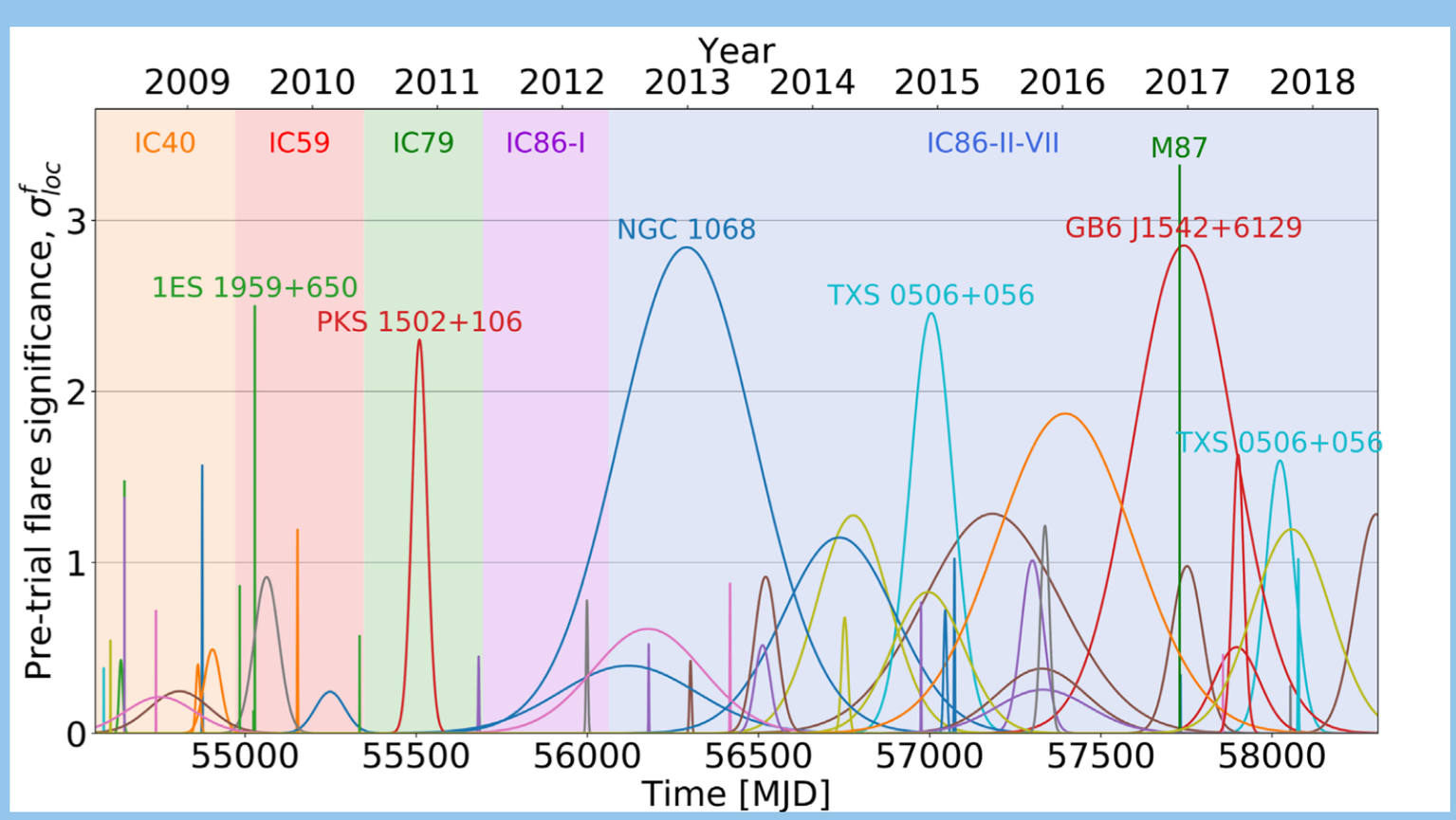


Fig. 2. Abbasi et. al., Search for Multi- are Neutrino Emissions in 10 yr of IceCube Data from a Catalog of Sources (2021)

The three channels

gamma-photons	radio emission	neutrinos
Fermi gamma-ray space telescope — LAT (Large Area Telescope)	MOJAVE programme — VLBI (Very Long Baseline Interferometry)	IceCube Neutrino Observatory
high energy photons, gamma-ray emission over a long period	combined telescopes, extremely high angular resolution, inner structure	interactions of high energy neutrinos, information of the possible sources
γ	RF	ν

Gamma-ray analysis

- photon events: detected by the LAT instrument
  - beginning of the mission - June 2025 → ~17 years of data
  - time, energy, angle
  - photon distribution
- models:
  - source catalog: up to 2018
  - galactic diffuse background: plane of the galaxy
  - isotropic background: all directions

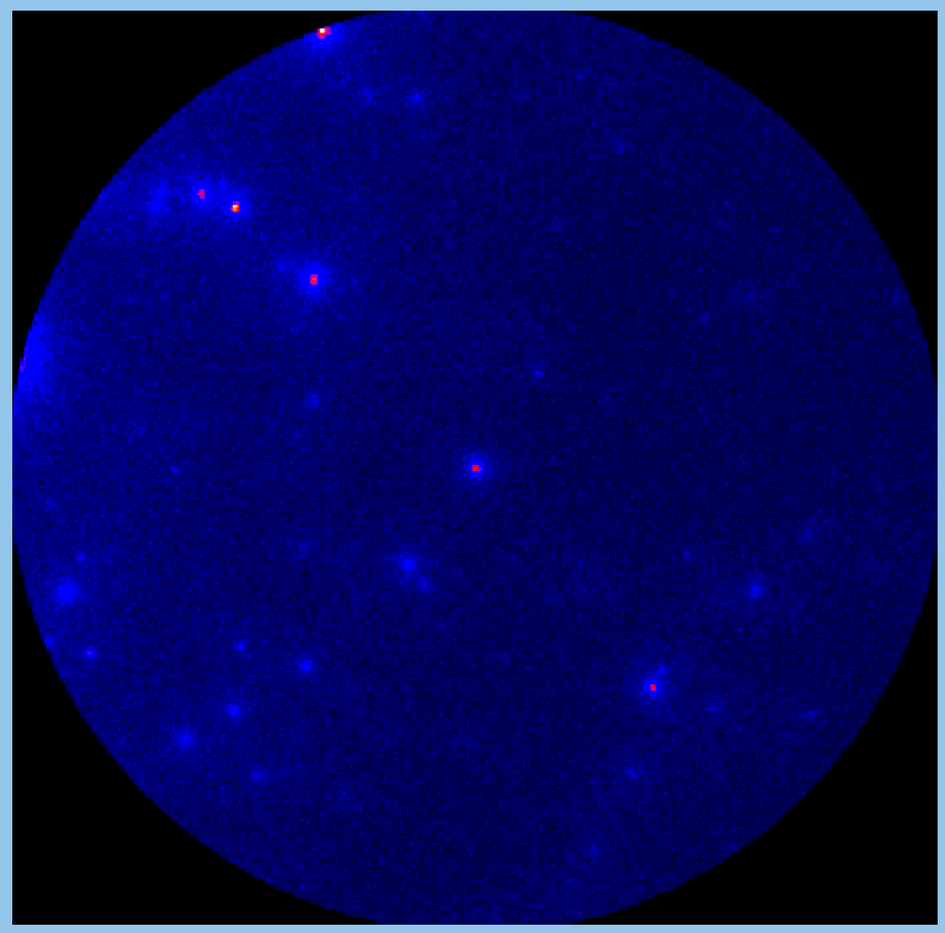


Fig. 3., ROI count map.

Maximum likelihood analysis

- the probability of the observed data given a specific model
- photon distribution from LAT data → test sources
- test statistics: $TS = -2ln(L_{max,0}/L_{max,1})$
    - maximum likelihood value without ($L_{max,0}$) and with ($L_{max,1}$) new source
    - $TS \leq 16 \sim 4\sigma$

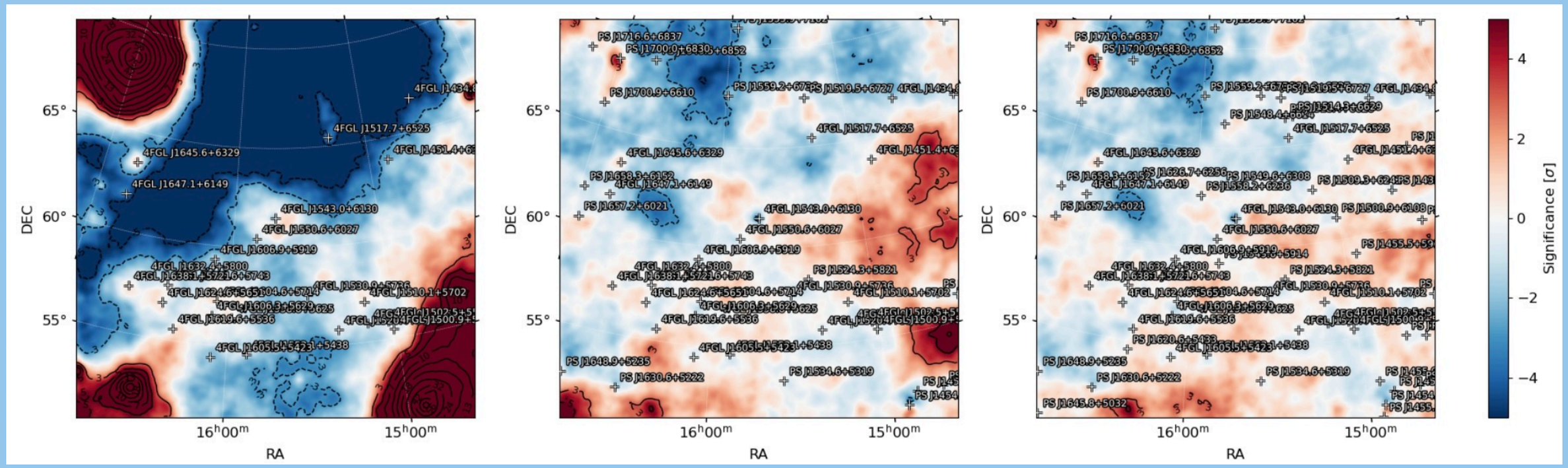


Fig. 4. Residual map throughout the different steps of maximum likelihood modelfitting.

Light curve

- adaptive binning:
    - adjusts to the current flux
    - uniform relative flux uncertainty → visible variation

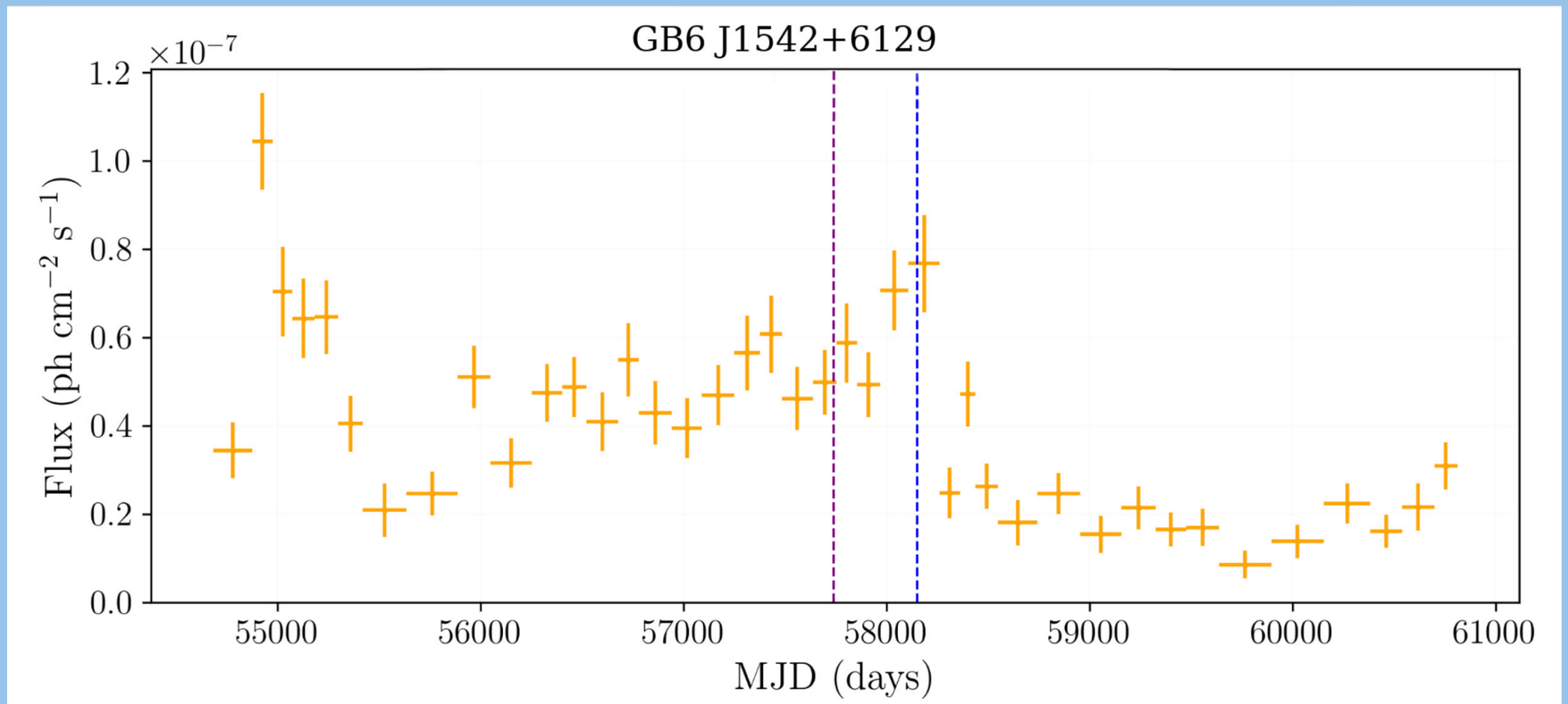


Fig. 5., Light curve of the blazar GB6 J1542+6129 with adaptive binning.

Multimessenger interpretation

Upstream neutrino production and delayed jet emission in the blazar GB6 J1542+6129

Emma Kun[1,2,3,4⋆], Imre Bartos[5], Breshna Hadi[6], Anna Göblyös[7], Julia Becker Tjus[4,8,9], Peter L. Biermann[10,11], Anna Franckowiak[6], Francis Halzen[12], Santiago del Palacio[8], and Claudio Ricci[13,14]

- increased activity in 2009 and 2018
- radio data follows the gamma data, maximum in 2018

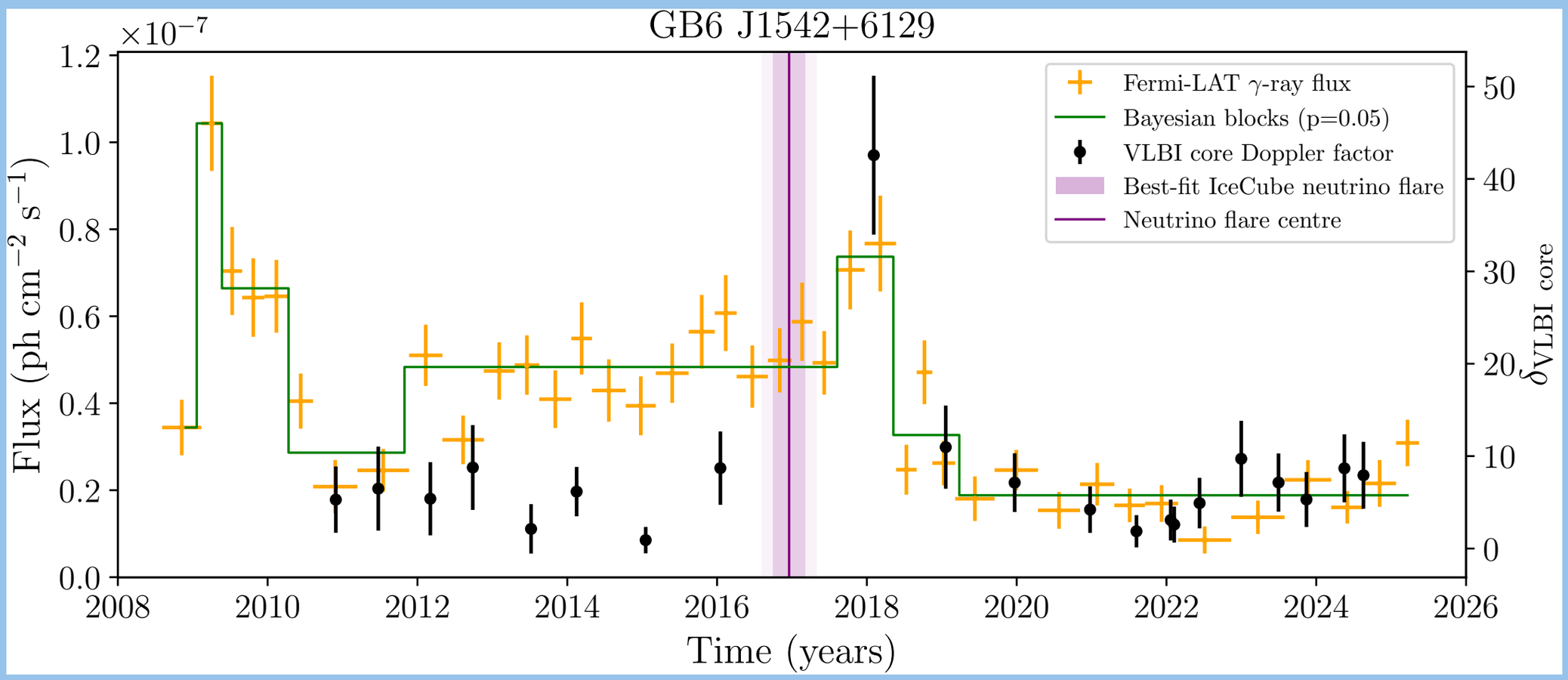


Fig. 6., E. Kun and I. Bartos et al., Upstream neutrino production and delayed jet emission in the blazar GB6 J1542+6129, (2026)

Multimessenger interpretation

- neutrino and electromagnetic emission: same physical process, but not from the same region
- disturbance or shock wave moving outward
- high particle density → hadronic interaction ($p\gamma$) → neutrinos
- plasma structure moving and reaching the VLBI core later

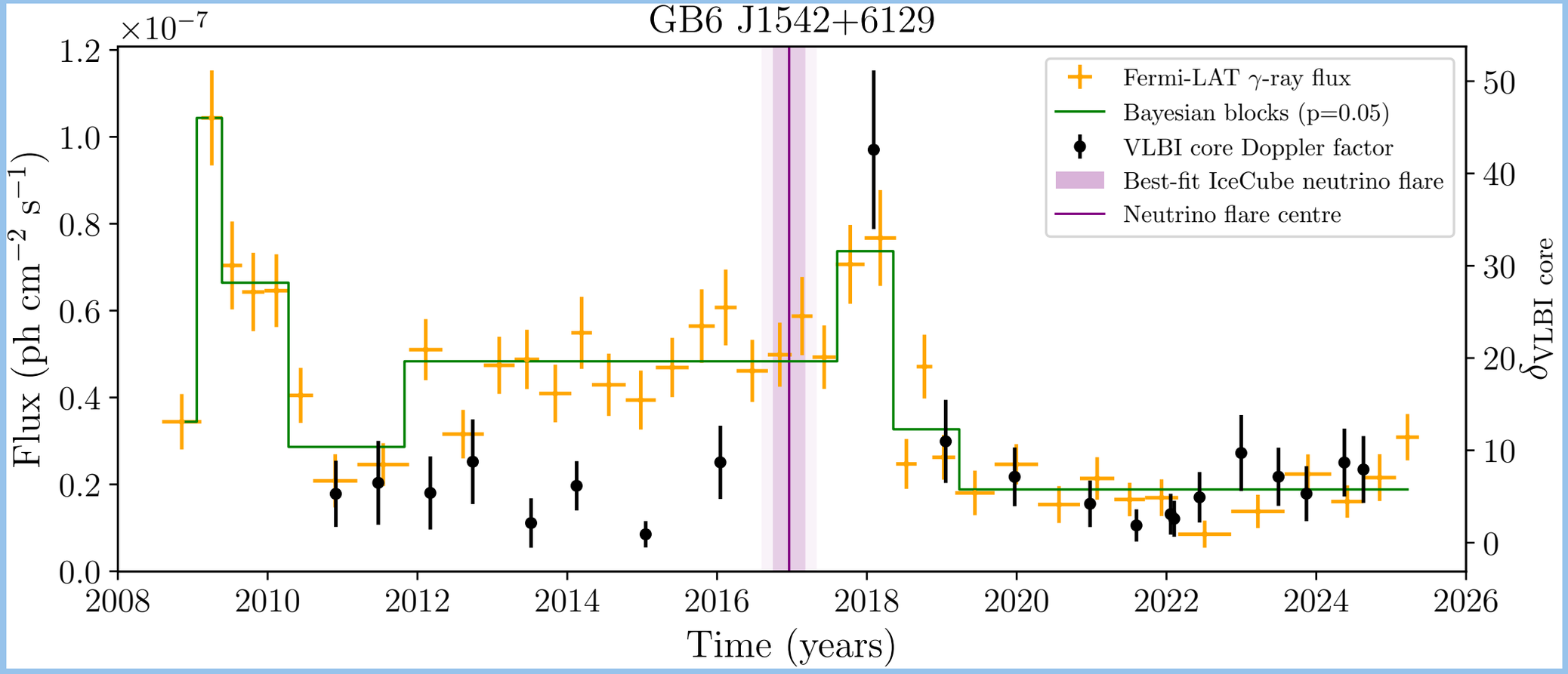


Fig. 6., E. Kun and I. Bartos et al., Upstream neutrino production and delayed jet emission in the blazar GB6 J1542+6129, (2026)

SED

- identical curves → consistent energy distribution
- increased number of particles during the flare
- no acceleration processes

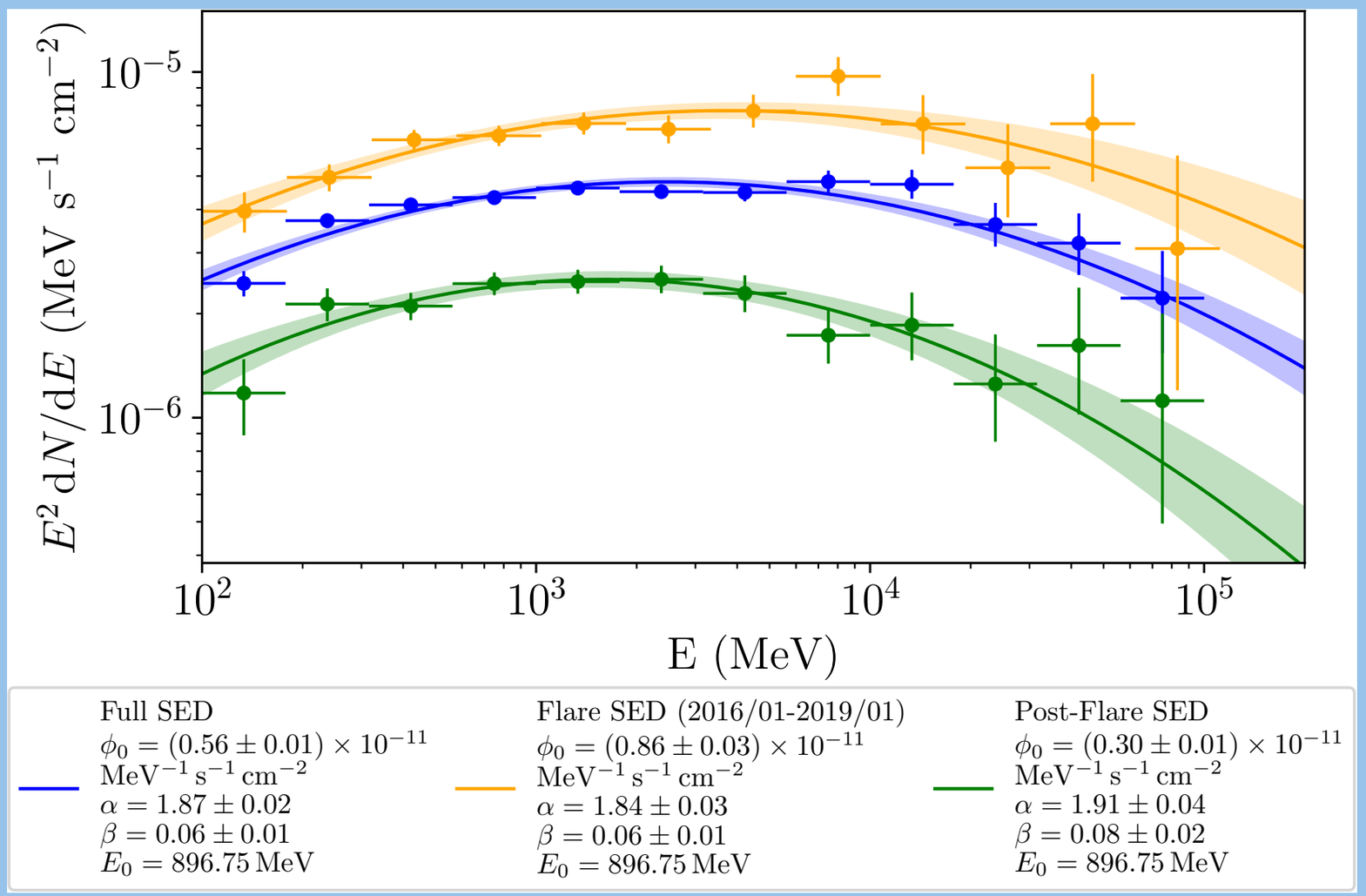


Fig. 7., Gamma-ray spectral energy distribution of the blazar GB6 J1542+6129 (E. Kun et. al., 2026)

Conclusion

- further investigation on the origin of the disturbance → reason of increased activity
- neutrinos:
    - weak ability to interact → great messengers
    - information that no other channel could provide

Thank you for your attention!

Sources

- IceCube Collaboration and M. G. Aartsen et al., Time-integrated Neutrino Source Searches with 10 years of IceCube Data, arXiv:1910.08488 (2019)
- E. Kun et. al., Possible correlation between unabsorbed hard x rays and neutrinos in radio-loud and radio-quiet active galactic nuclei (2024)
- https://fermi.gsfc.nasa.gov/ssc/data/access/lat/BackgroundModels.html
- https://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone_Likelihood/Likelihood_overview.html
- E. Kun and I. Bartos et al., Upstream neutrino production and delayed jet emission in the blazar GB6 J1542+6129, (2026)