



Using VLBI observations for modeling emission properties of neutrino candidate blazars

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based on Tamar-Kovalev (in-prep)

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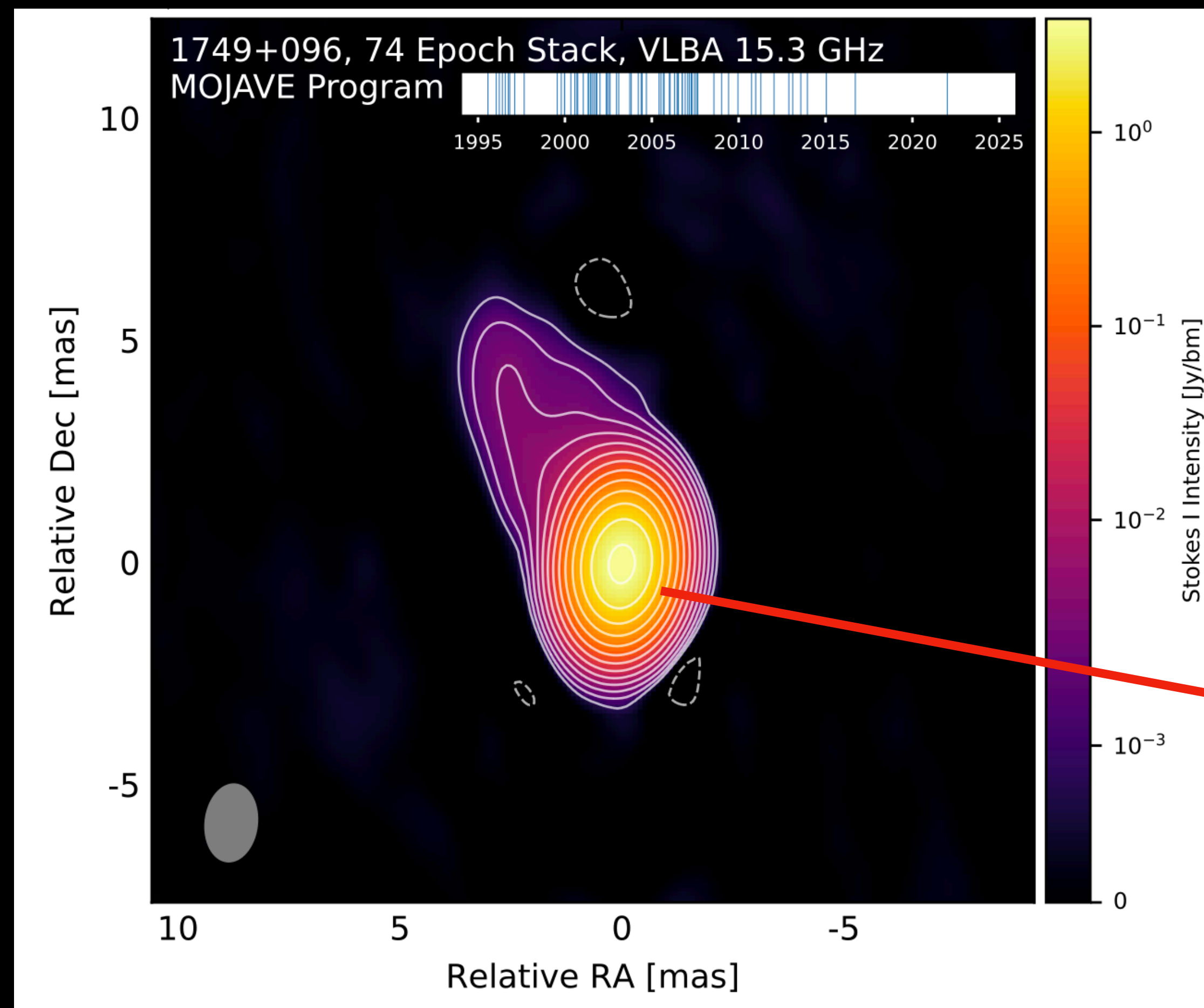
Motivations

- The era of multi-messenger astrophysics: IceCube, KM3NeT hunting for sources of astrophysical neutrinos.
- Radio observations through Very Long Baseline Interferometry (VLBI) playing a crucial in identifying sources of interest.
- Focus on blazars: Active Galactic Nuclei with black holes powering relativistic jets pointed directly at us.
- Key question: How to use VLBI observations to localize and model properties of emission region for neutrino production.

The source: 1749+096

- In the *Plavin et. al. 2025* ([2503.08667](#)) list which identified radio-loud blazars spatially around the IceCube alerts and has a Doppler factor of $\sim 100!$.
- It is a BL Lac object (no contribution from “external” photon fields) → multi-wavelength modeling is more “direct”.
- Extremely well studied source at radio frequencies (upto 230 GHz by the recent Event Horizon Telescope results [*Roder et. al., 2025*; [2501.05518](#)]).
- Also highly variable (intra-day!) and well studied across the electromagnetic spectrum (*Abe et. al. 2025*, [2410.22557](#)).

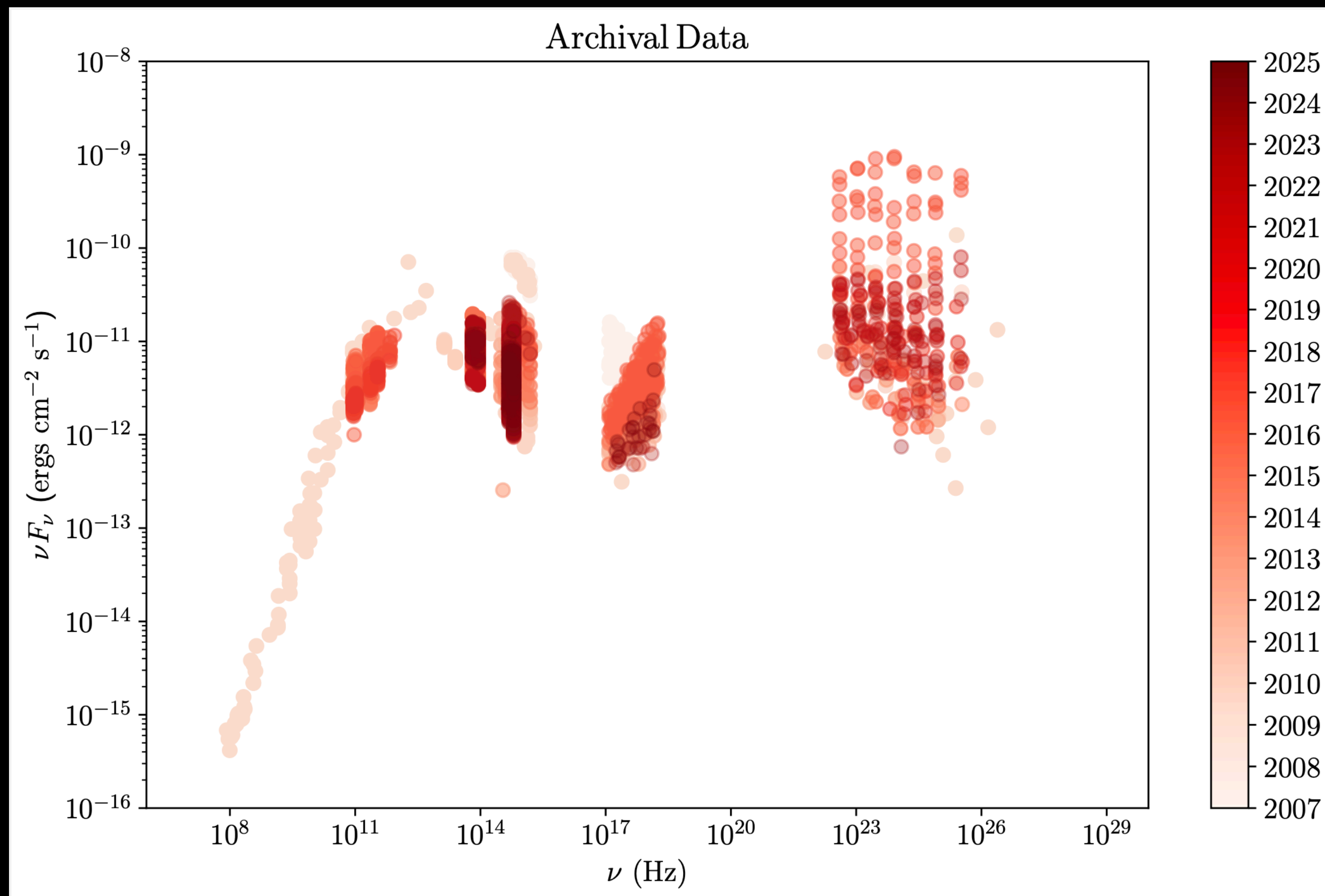
1749+096: VLBI Images



Stacking ~ 2 decades of 15 GHz observations by the Monitoring of Jets in Active galactic nuclei with VLBA (MOJAVE) program (*image from MOJAVE website*).



1749+096: Archival Spectral Energy Distribution (SED)



From Markarian
Multiwavelength Data
Center's website ([https://
www.mmdc.am/](https://www.mmdc.am/))



Multi-Messenger Modeling



Prevailing Sentiments

- Simple prescription: emission is **dominated** by a single zone in the jet → “one-zone” model.
- Works reasonably well for fitting multi-wavelength data across several orders in frequencies.
- Often provides good fits to high-energy (X-ray and beyond) data but fail to **simultaneously** fit the low-energy (radio-optical) data.
- Several open-source codes exist to track its evolution → this work uses AM³ (Klinger et. al., 2025; [2312.13371](#)).

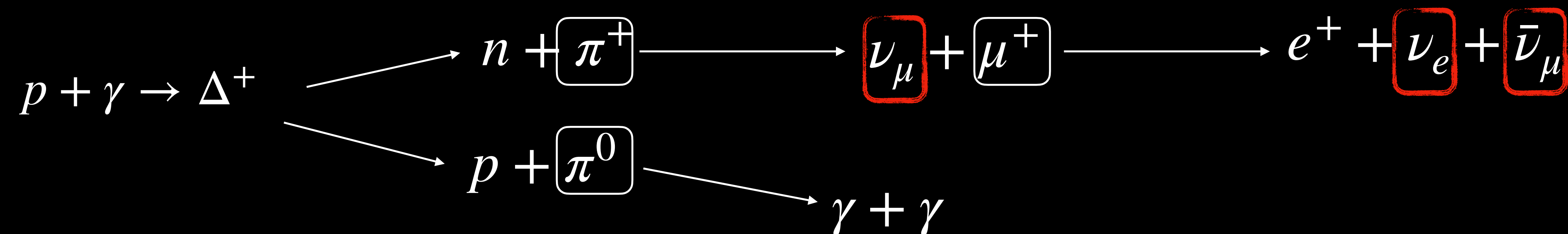


Leptohadronic processes

- Electrons and protons are injected into the region with a power-law profile.
- Processes taken into account:
 - Synchrotron Radiation (relativistic particles accelerating and radiating in a magnetic field),
 - Synchrotron Self Compton (synchrotron photons scattering off particles that produced them),
 - Photon-Photon Pair Production ($\gamma + \gamma \rightarrow e^- + e^+$),
 - Bethe-Heitler pair production ($p + \gamma \rightarrow e^- + e^+$).

Neutrino Production

- Neutrino production modeled via photopion production:



- But, can also have purely leptonic neutrino production! (*Hooper-Plant, 2023; 2305.06375*).



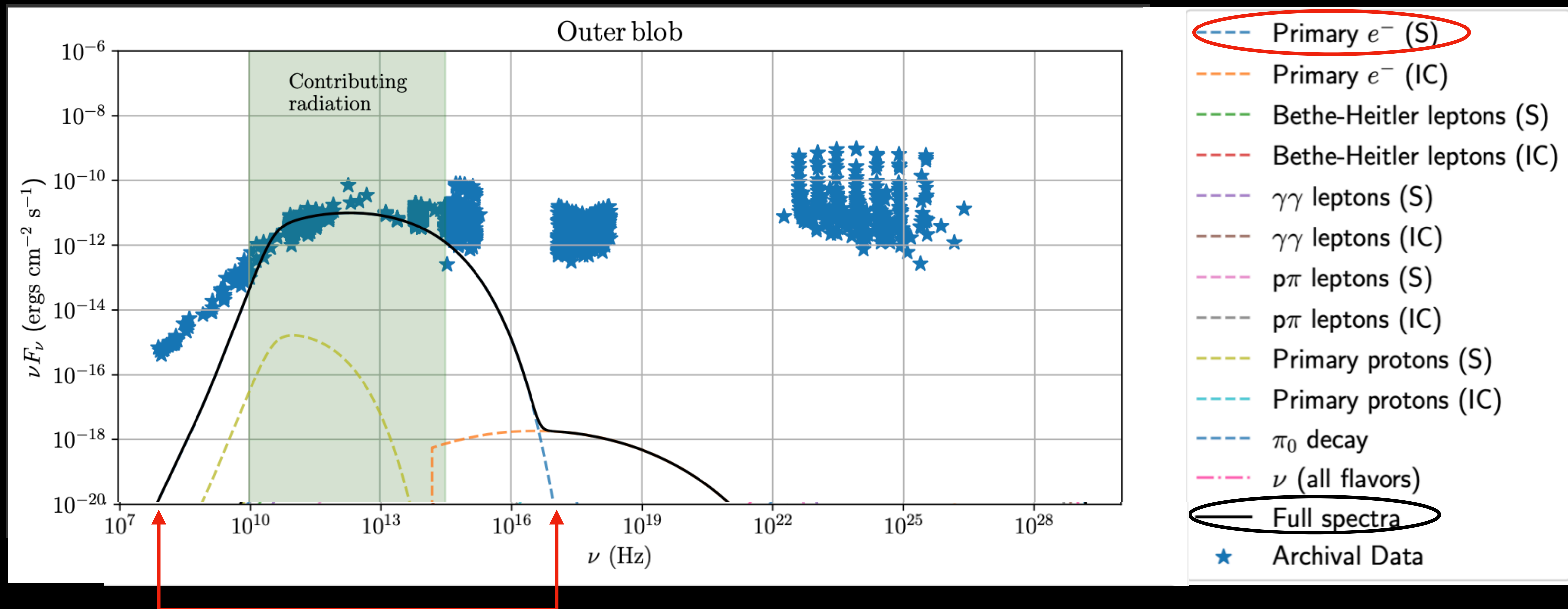
Modeling the emission region: the “*one-plus*” zone framework



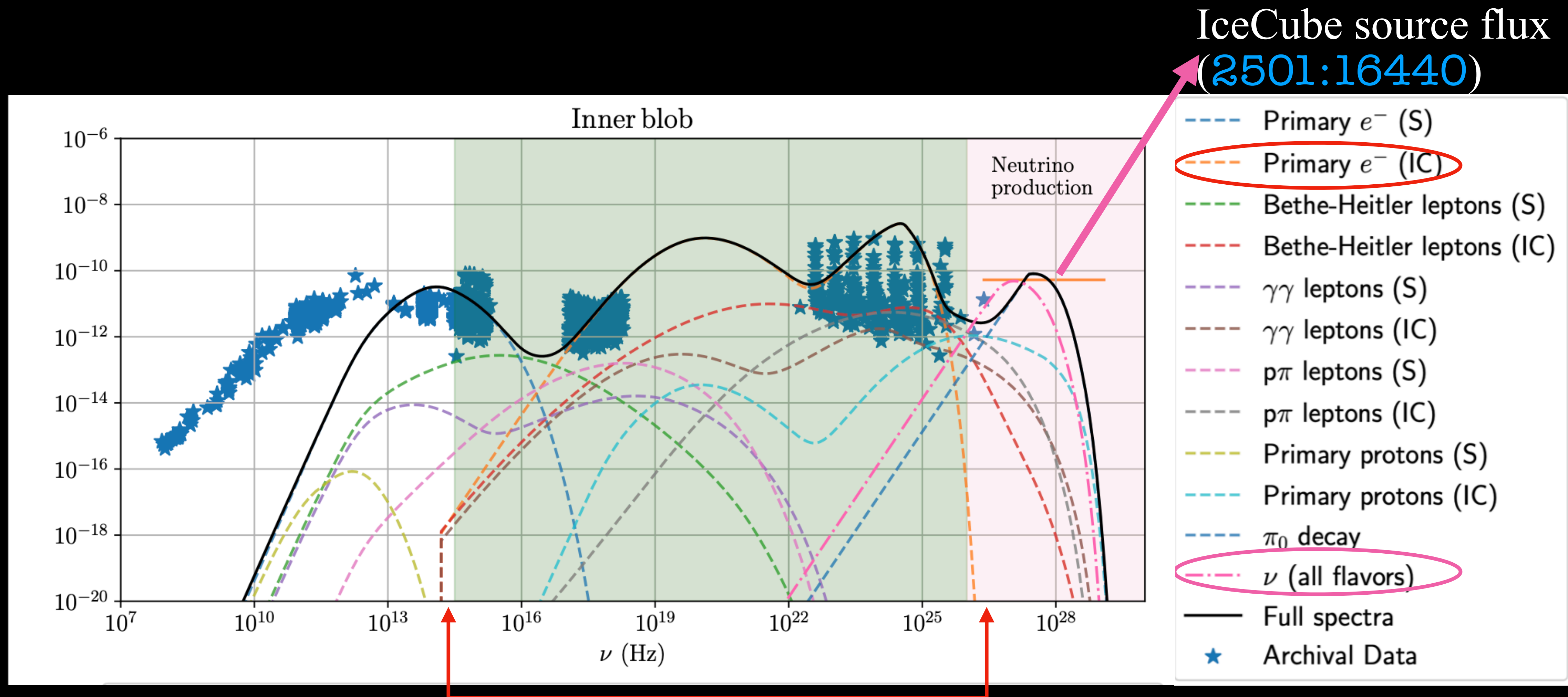
Key Ideas

- The emission region is located at parsec scale and is associated with location of the **radio core**.
- Fixed from VLBI: Doppler factor, magnetic field strength and power-law index of electrons → assume protons have same index (co-accelerated).
- Structure: A large blob (~size of radio core) is giving us radio → optical emission and a smaller blob “embedded” in it **at the same spatial location**, is giving the high-energy+**neutrino** emission.
- Working: outer blob pre-accelerates particles feeding into inner blob where **shear acceleration** (*Rieger-Duffy, 2004*; [0410269](#)) drives particle propagation.

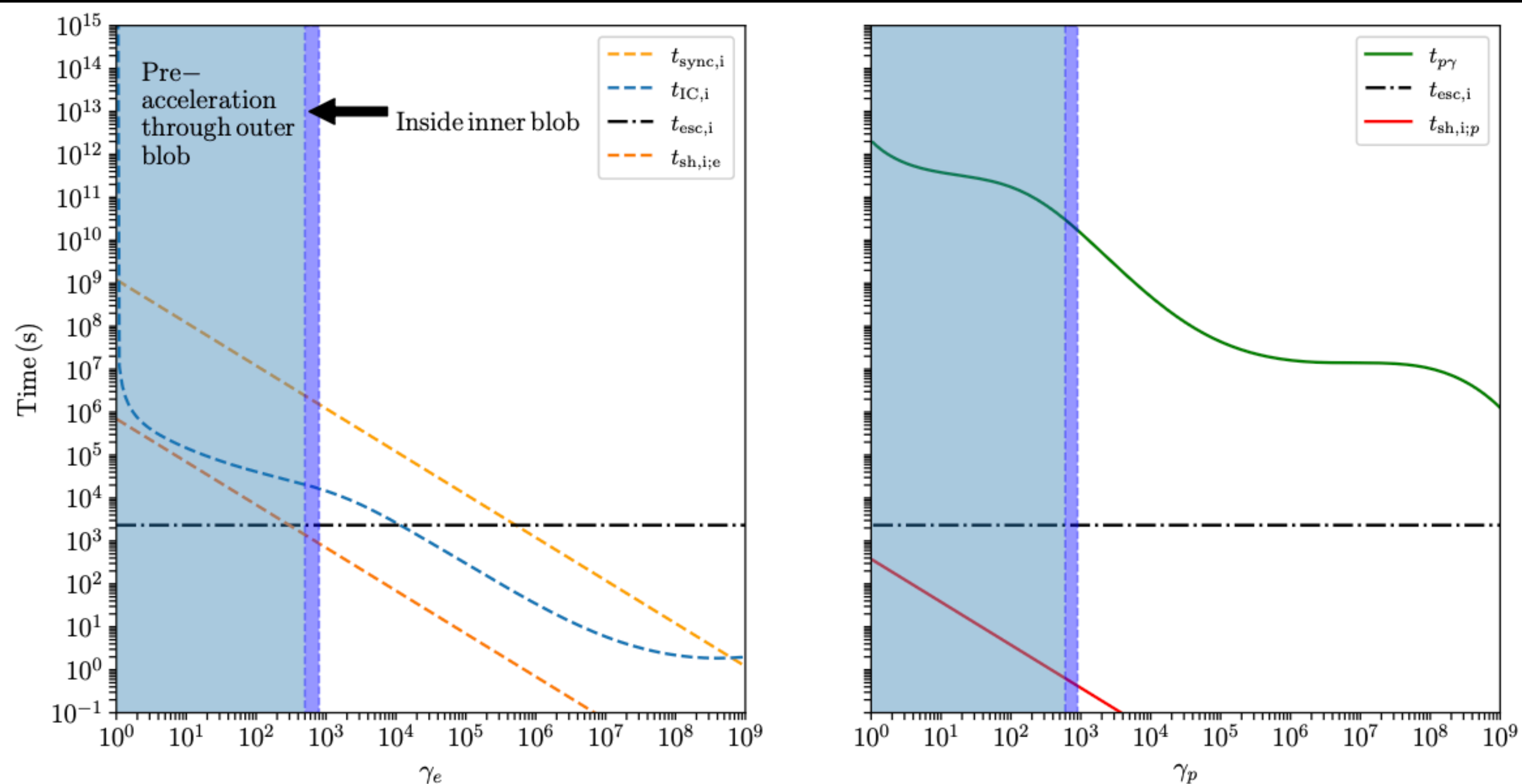
SED of *Low-Energy Emission*



SED of *High-Energy & Neutrino Emission*



Shear Acceleration and Emission Timescales





The Espresso Shot of Takeaways

- Radio-loud, strongly Doppler beamed blazars are very strong source candidates for astrophysical neutrinos being detected by IceCube (and beyond!).
- Using physical arguments and without numerical fitting, low-, high-energy and neutrino emission can be localized to parsec scales in blazar jets.
- Avenues being explore:
 - mapping synchrotron radiation observables from radio to neutrino production computations,
 - the role of shear acceleration in neutrino production in blazars,
 - extending the study to include polarimetry.



Thank You.

Feel free to get in touch with any questions!

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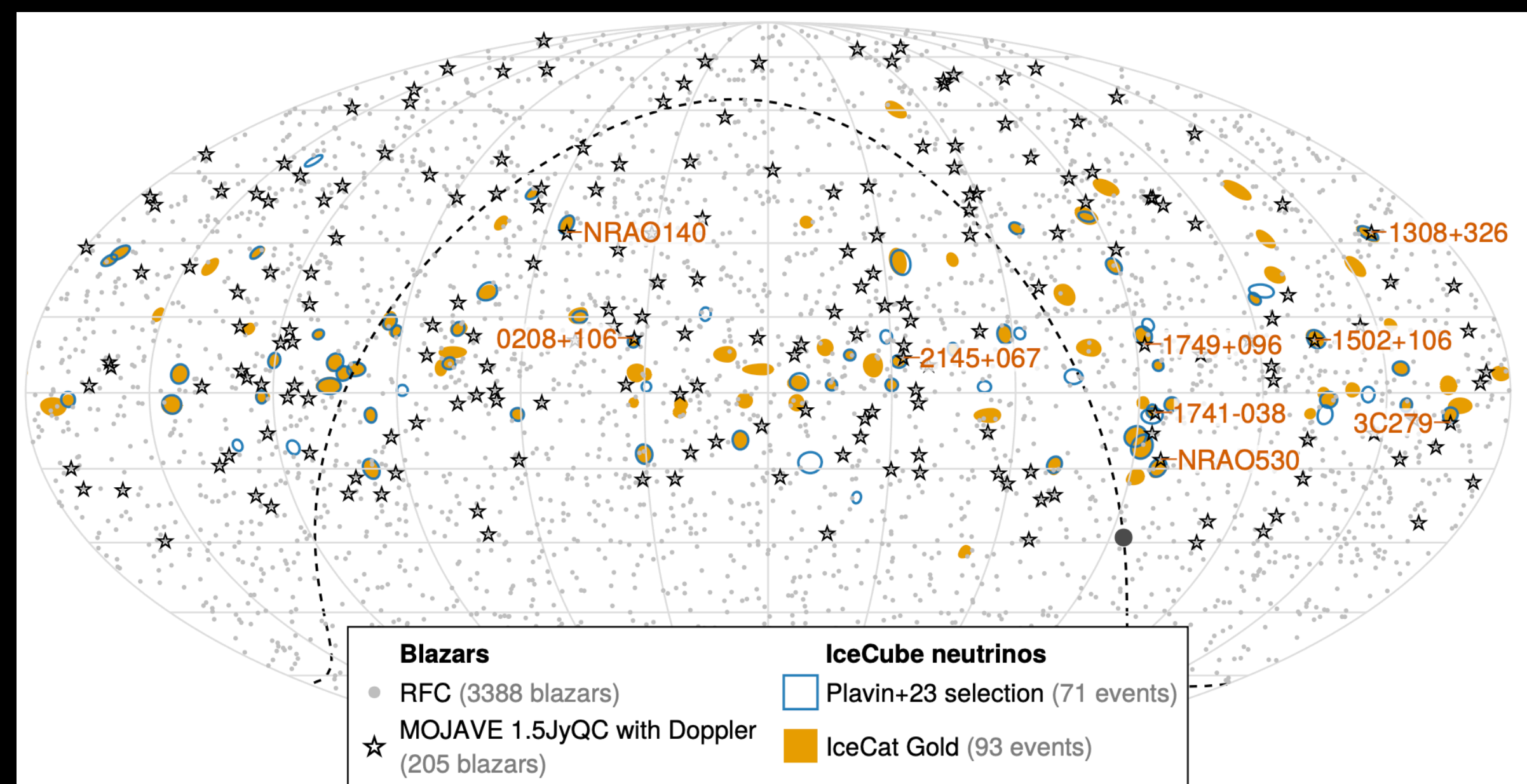
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Additional Slides

Devinette: What makes a blazar a “neutrino candidate”?

- The associations as of yet are statistical (due to limited sensitivity of IceCube).
- Source identification limited by the region of sky mapped by IceCube:



Plavin et. al. 2025 (2503.08667)
(P25)

- Subtle issue: Is there something *intrinsic* in certain kinds of blazars that can make them produce neutrinos?