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Two-zone models for blazar emission: implications for TXS 0506+056 and the neutrino event Icecube-170922A

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IceCube-170922A

IceCube Collaboration et al. 2018

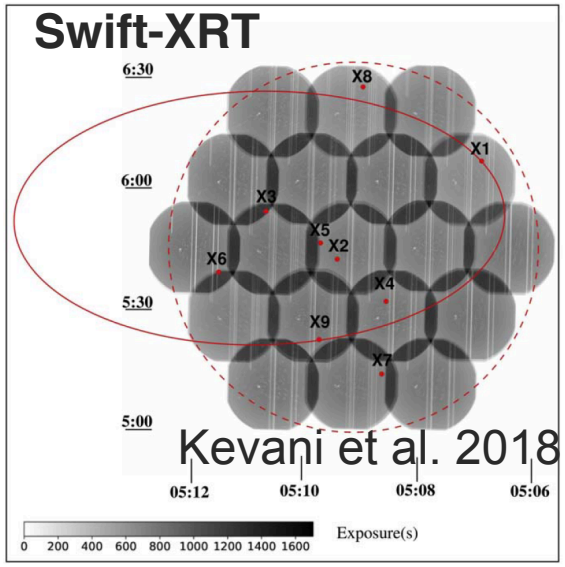


Figure 1. *Swift*-XRT follow-up of IceCube-170922A. X-ray exposure map resulting from the adopted 19-point tiling pattern centered on the initial IceCube neutrino localization is shown in grayscale, and the positions of all detected X-ray sources with red points. The red dashed circle shows the initial 90%-containment region. The red solid ellipse shows the updated 90%-containment region (Kopper & Blaufuss 2017). Grayscale levels indicate achieved exposure at each sky position, as shown by the color bar. White streaks are due to dead regions on the XRT detector caused by a micrometeroid impact (Abbey et al. 2006).

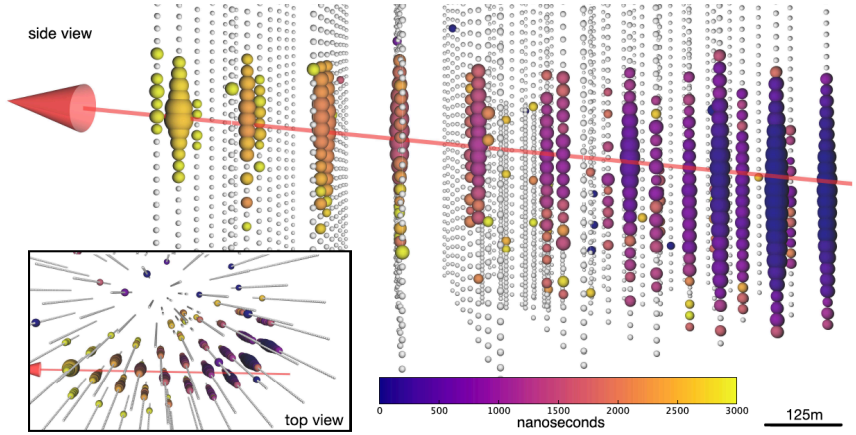
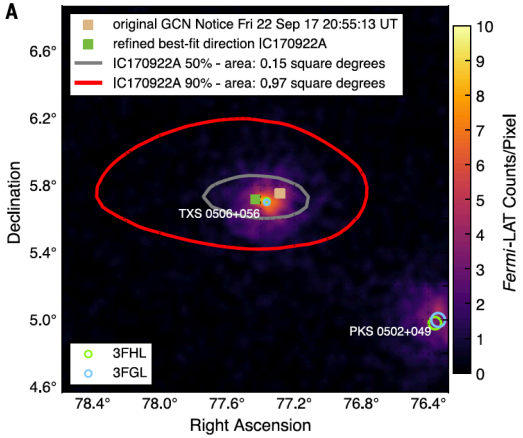
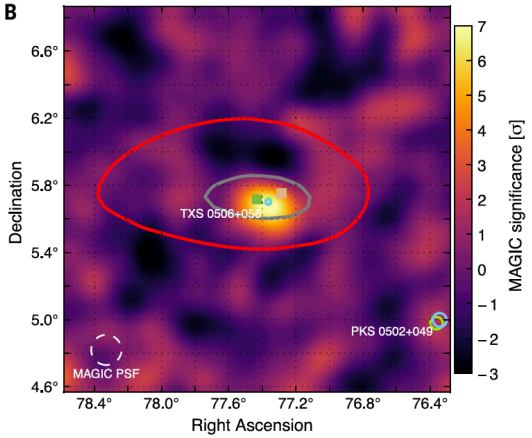


Fig. 1. Event display for neutrino event IceCube-170922A. The time at which a DOM observed a signal is reflected in the color of the hit, with dark blues for earliest hits and yellow for latest. Times shown are relative to the first DOM hit according to the track reconstruction, and earlier and later times are shown with the same colors as the first and last times, respectively. The total time the event took to cross the detector is ~3000 ns. The size of a colored sphere is proportional to the logarithm of the amount of light observed at the DOM, with larger spheres corresponding to larger signals. The total charge recorded is ~5800 photoelectrons. Inset is an overhead perspective view of the event. The best-fitting track direction is shown as an arrow, consistent with a zenith angle $5.7^{+0.50}_{-0.30}$ degrees below the horizon.

Fermi-LAT



MAGIC

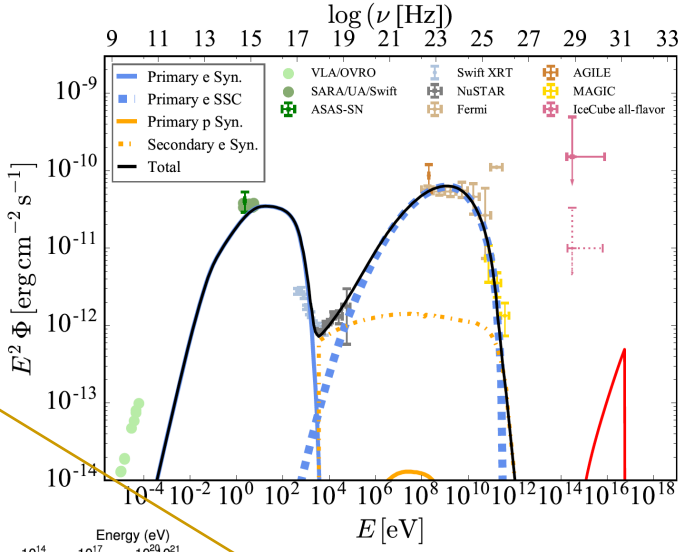


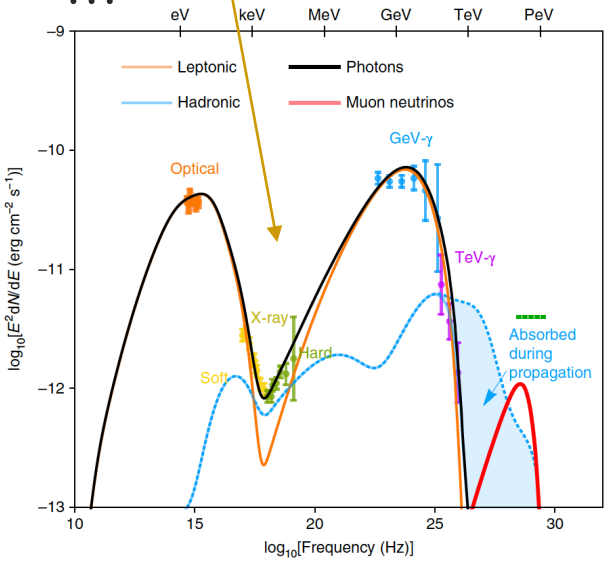
In temporal and spatial correlation with gamma-ray flare of a known blazar TXS 0506+056

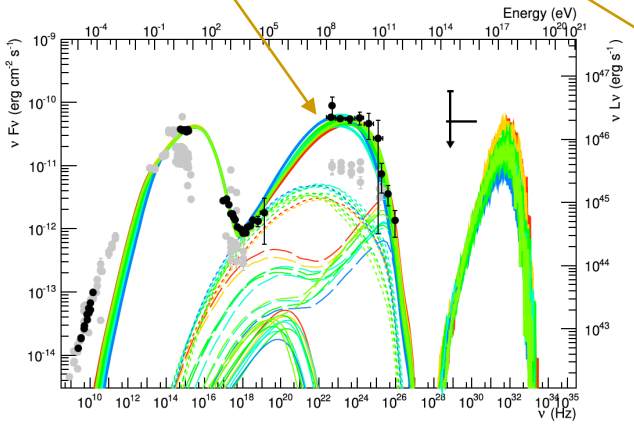
Previous modeling results

Photo-hadronic models

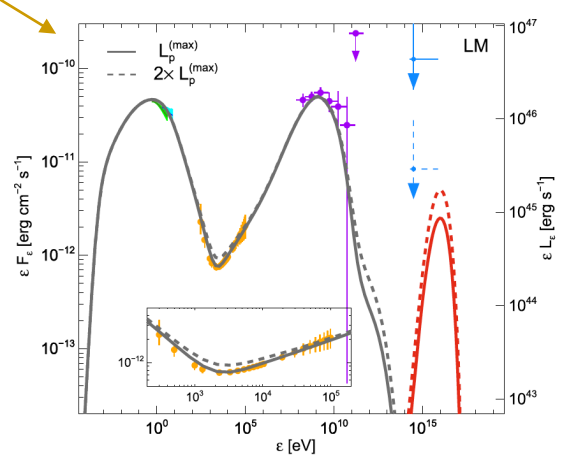
- Zhang, Fang & Li et al. 2019 (one-zone SSC)
- Keivani et al. 2018 (one-zone EC)
- Cerruti et al. 2019 (one-zone SSC)
- Gao et al. 2019 (one-zone SSC)
- …



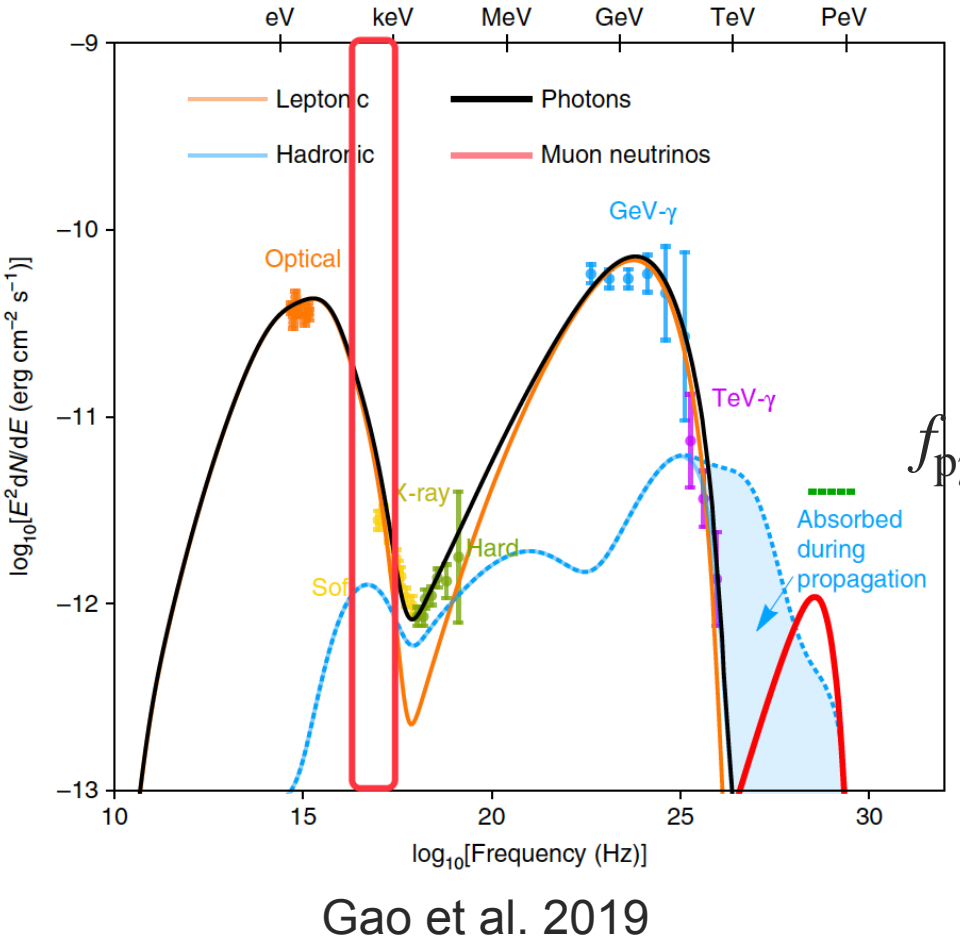




(b) Lepto-hadronic modeling of TXS 0506+056



One-zone SSC models



Gao et al. 2019

very low number density of synchrotron photons

↓

very low sub-TeV neutrino production efficiency

$$f_{p\gamma} \approx R_{blob} < \sigma_{p\gamma}\kappa > n_{soft} \sim 10^{-3}\tau_{\gamma\gamma}$$

↓

$$L_\nu \sim f_{p\gamma} L_p$$

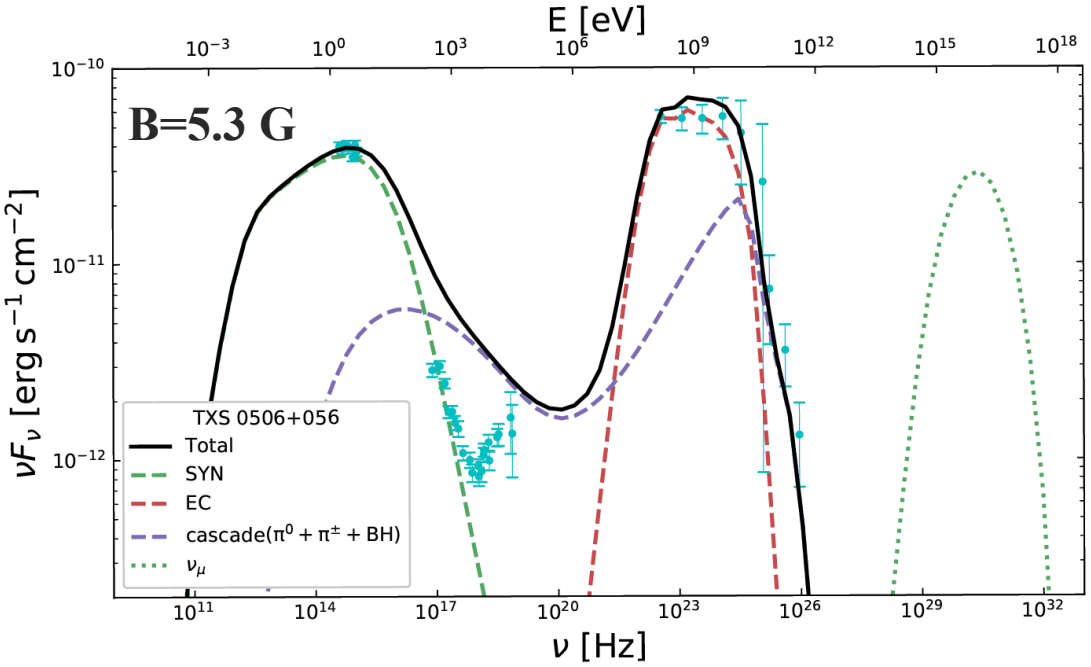
↓

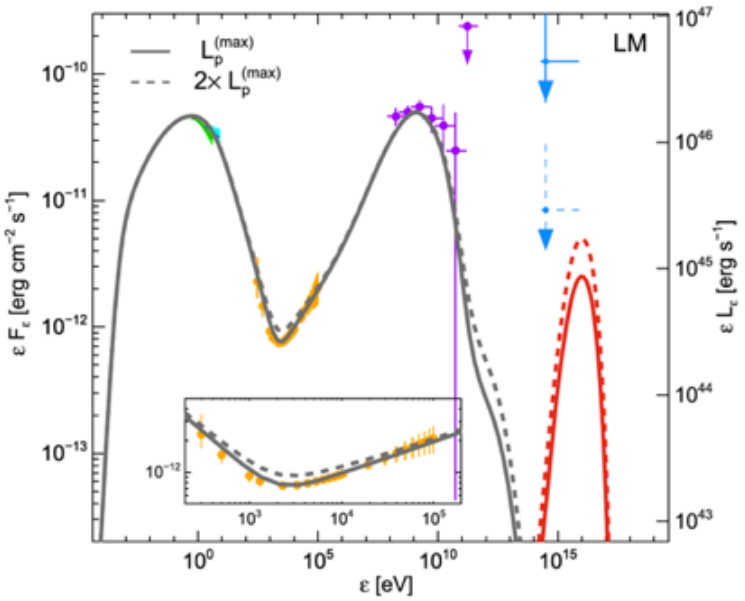
$$L_X \sim \tau_{\gamma\gamma} f_{p\gamma} L_p \sim f_{p\gamma}^2 L_p$$

yielding a EHE neutrino alert trigger rate of IceCube < 0.03 yr^-1 even with a super-Eddington jet power

One-zone EC models

External photons such as photons from the **BLR**, the **accretion disk** or **accretion flow**, or the **sheath** region of the jet can enhance the neutrino production efficiency.

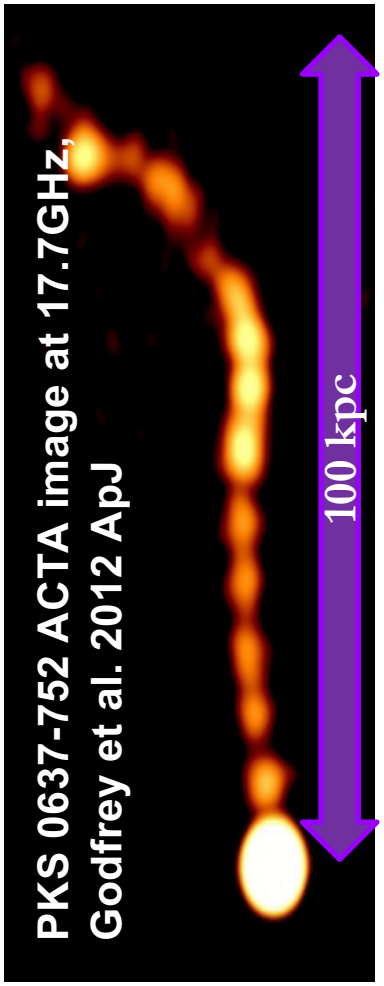


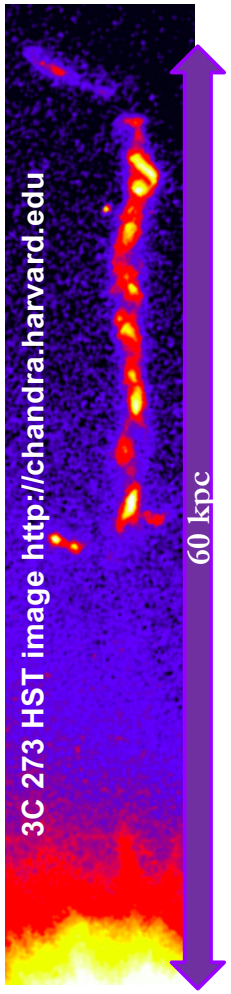


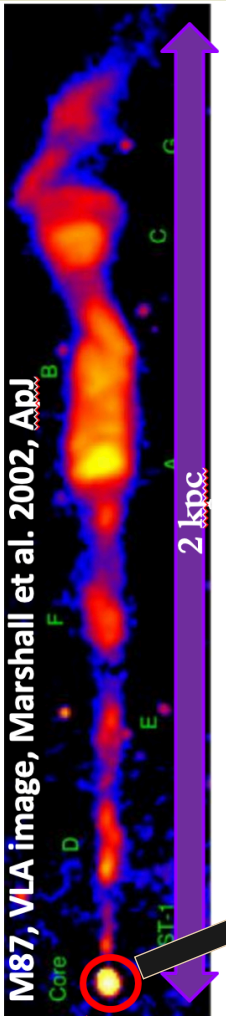
Keivani et al. 2018

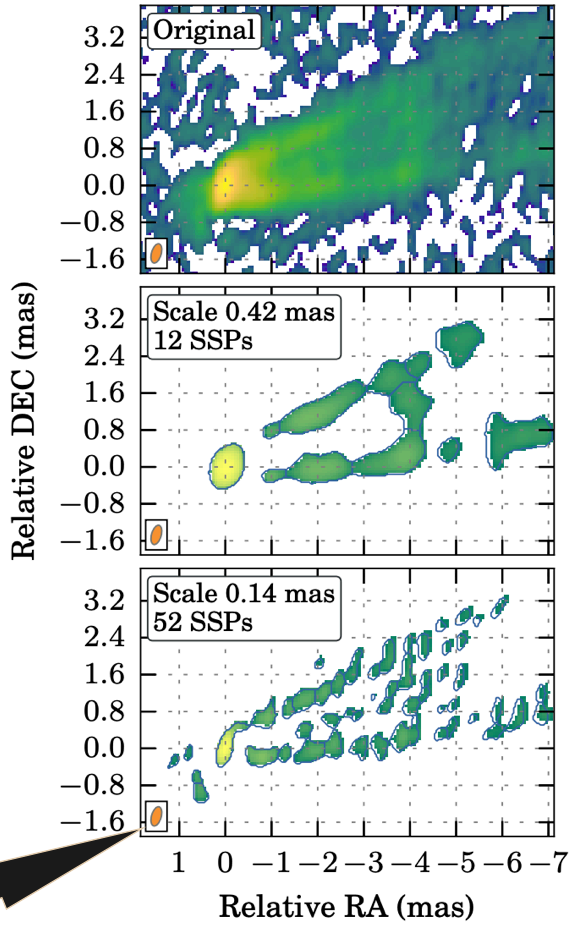
$\sim 0.01\ \mathrm{yr}^{-1}$

Multiple emission zones in jets of radio galaxies: from sub-Mpc scale to sub-pc scale





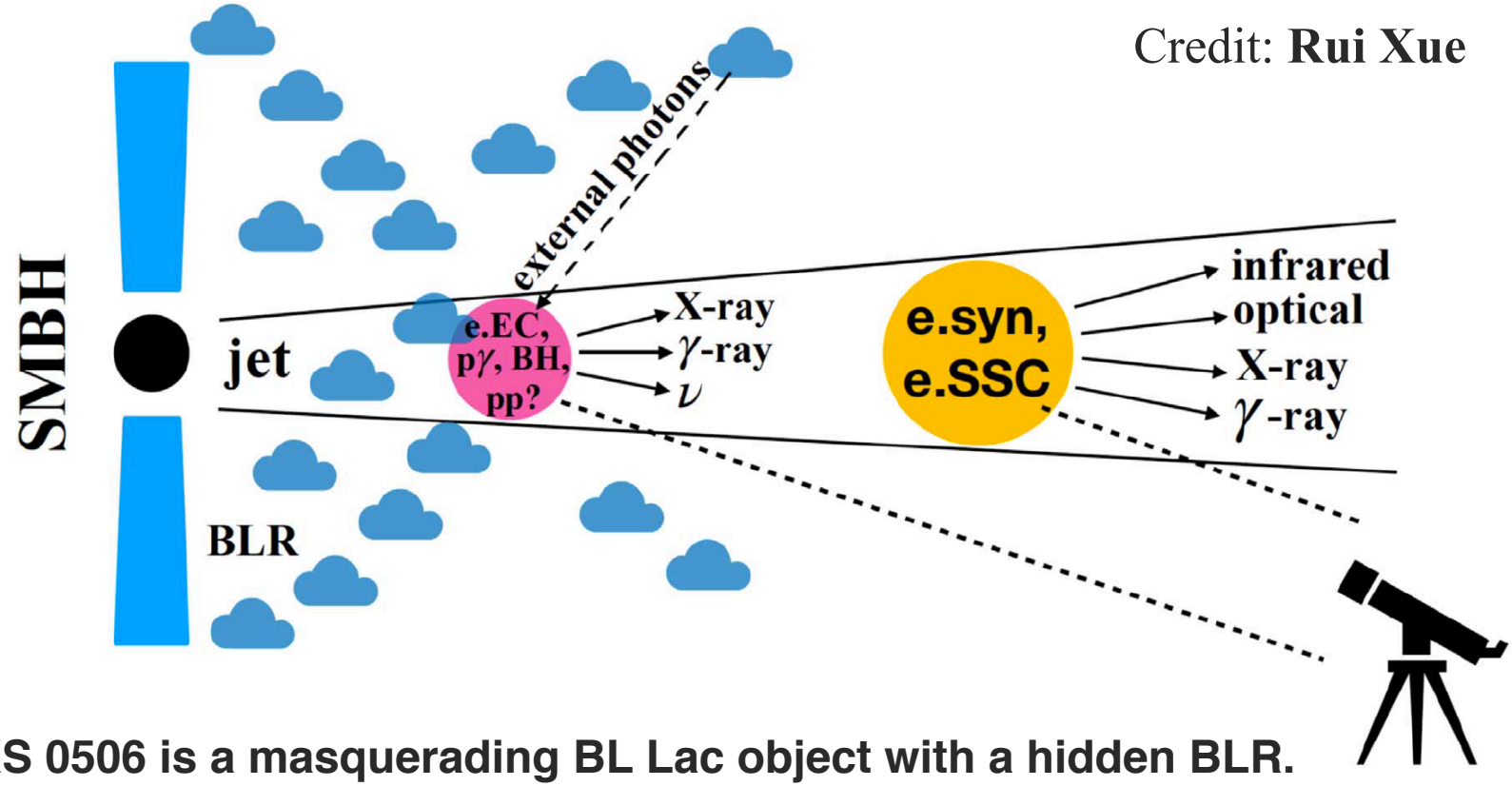




Mertens et al. (2016)

Multiple emission zones in blazar jets

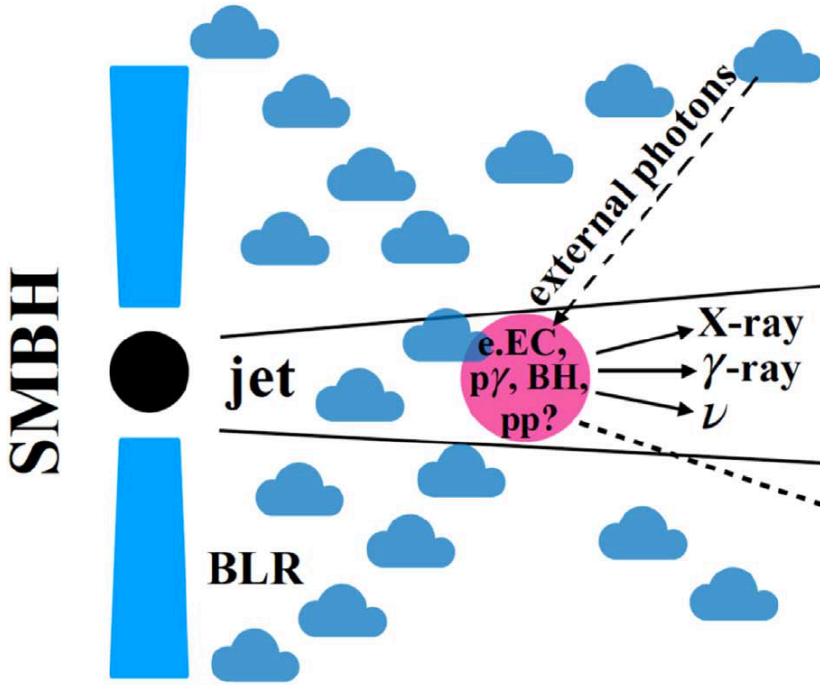
Credit: **Rui Xue**

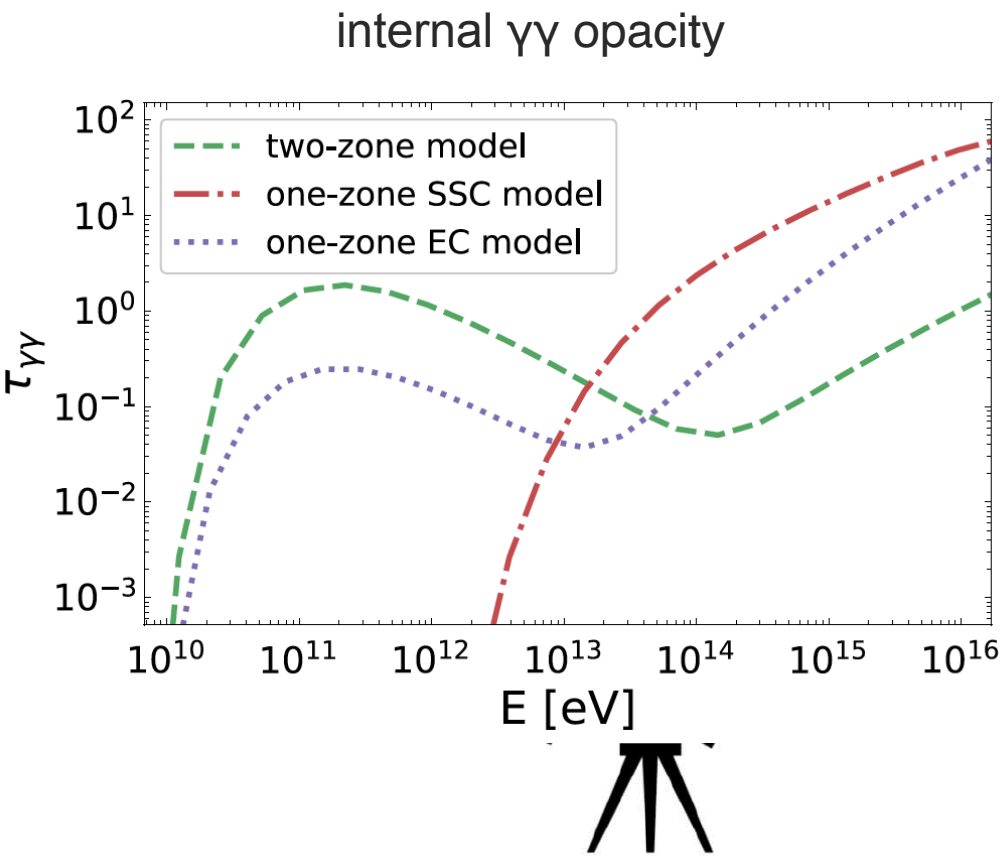


TXS 0506 is a masquerading BL Lac object with a hidden BLR.

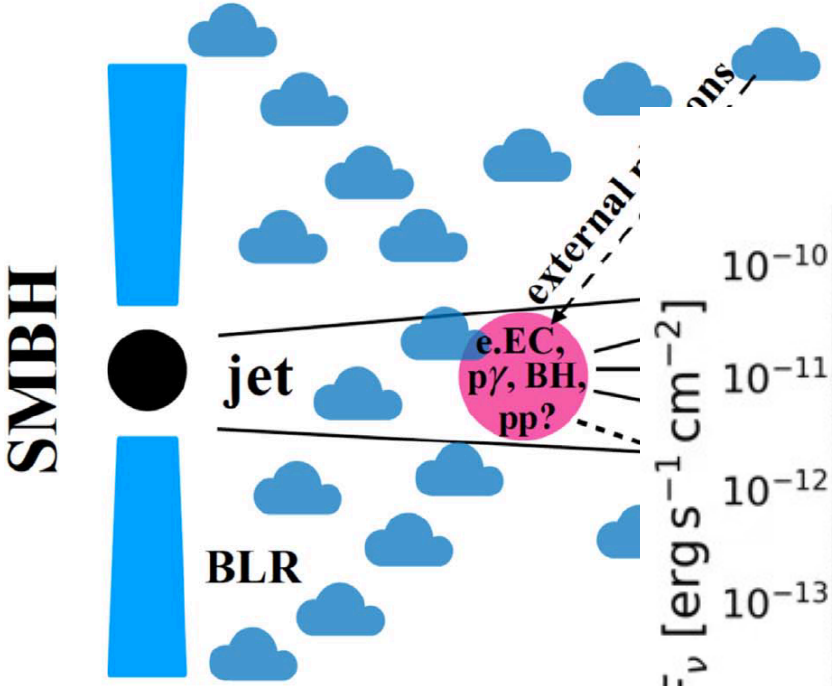
Padovani et al. 2019, MNRAS, 484, L104

Multiple emission zones in blazar jets

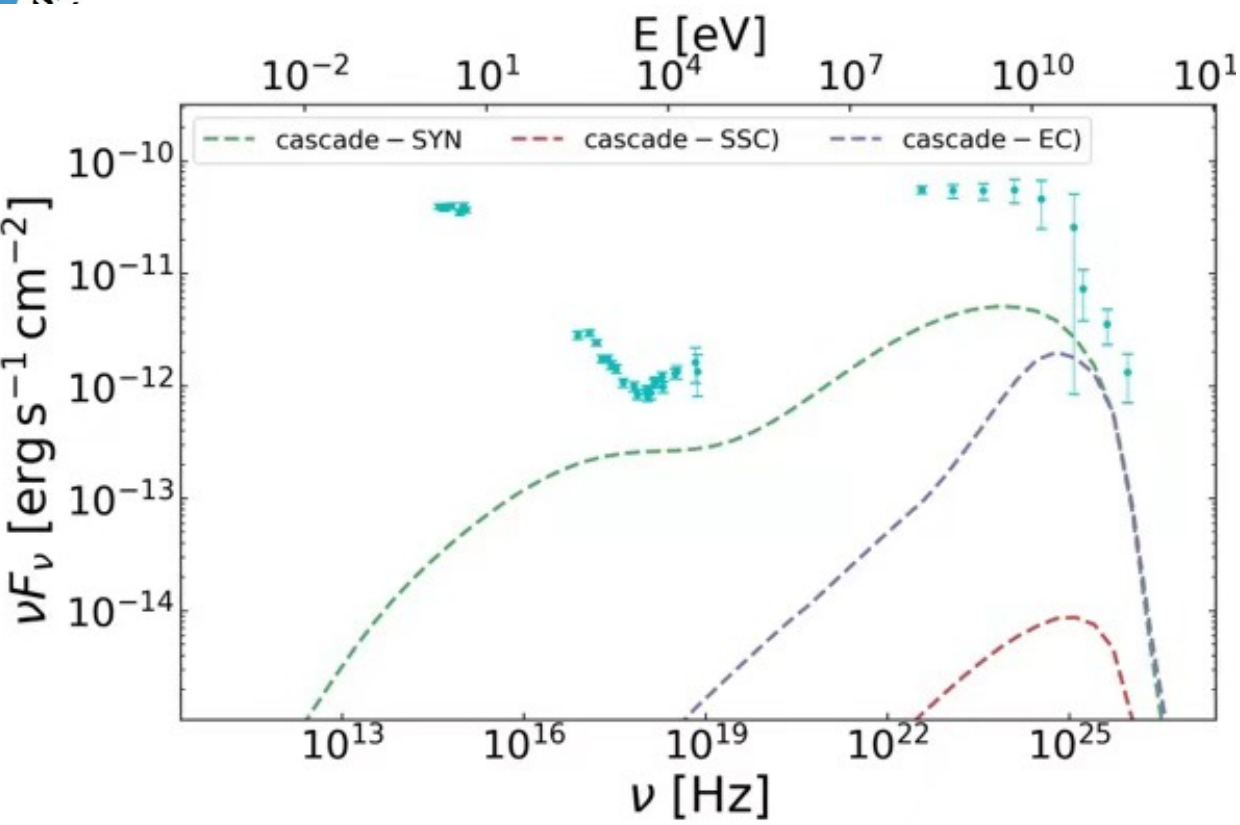




Multiple emission zones in blazar jets

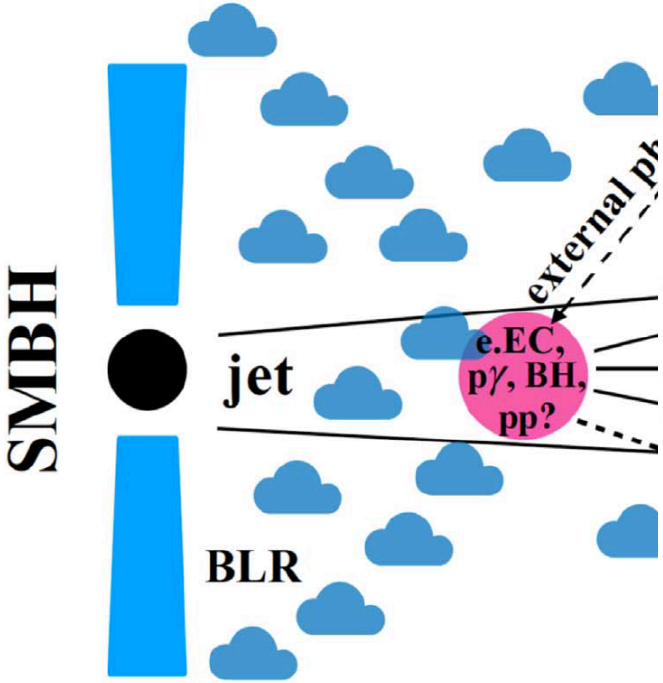


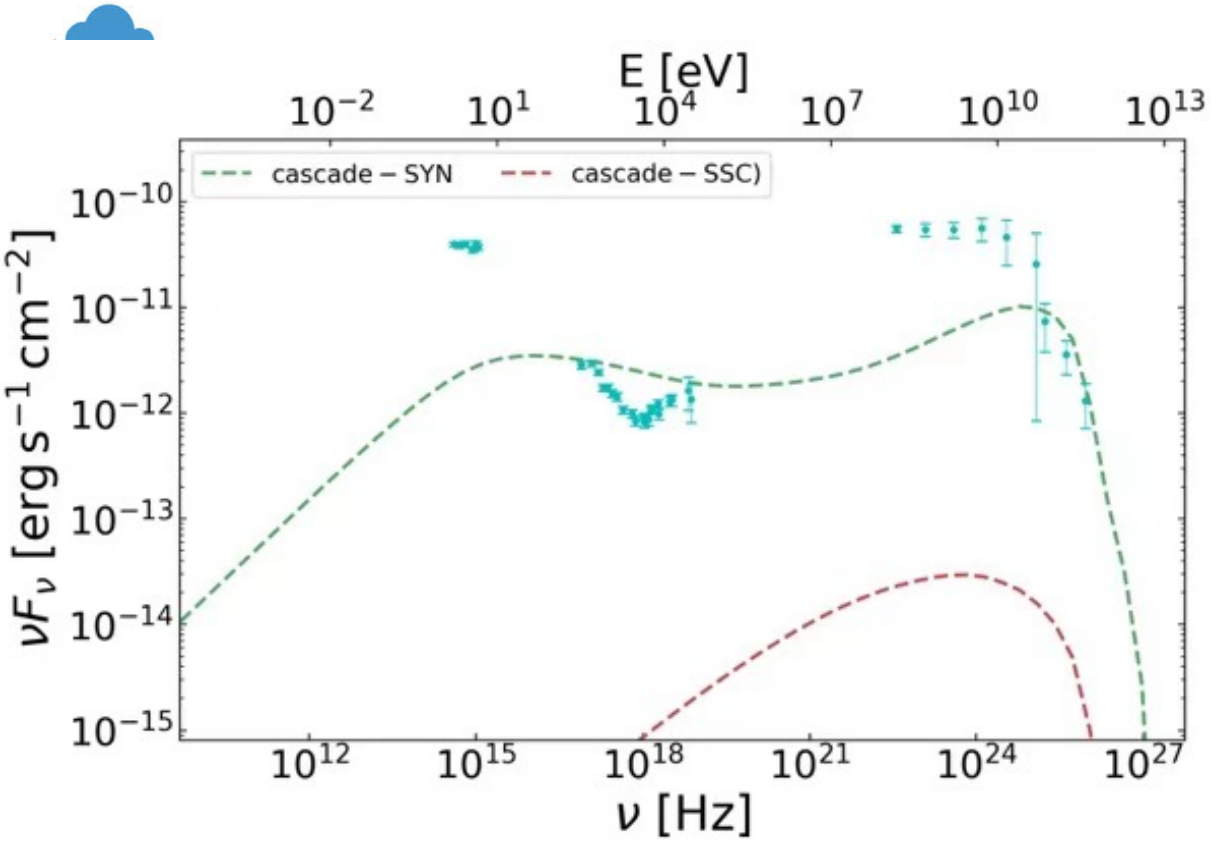
Turn on BLR emission



Multiple emission zones in blazar jets

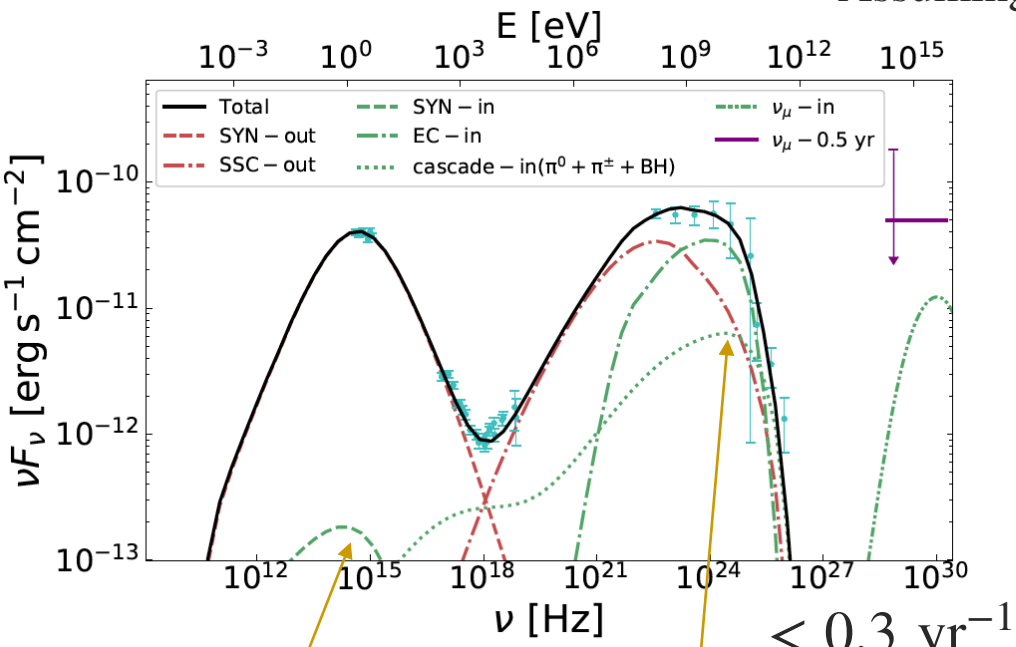
Turn off BLR emission



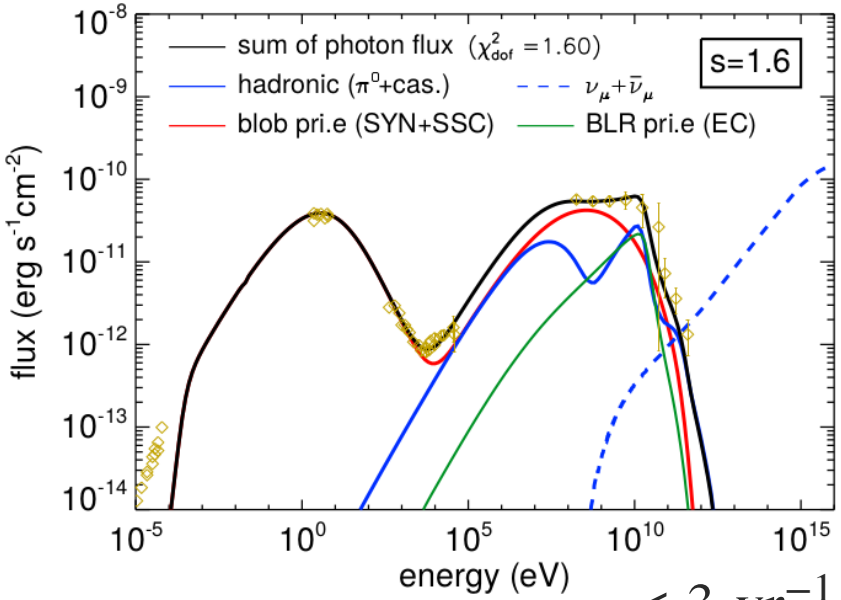


Two-zone models

Assuming $L_{p,k} = L_{Edd}$



$< 0.3\ \mathrm{yr}^{-1}$



$< 3\ \mathrm{yr}^{-1}$

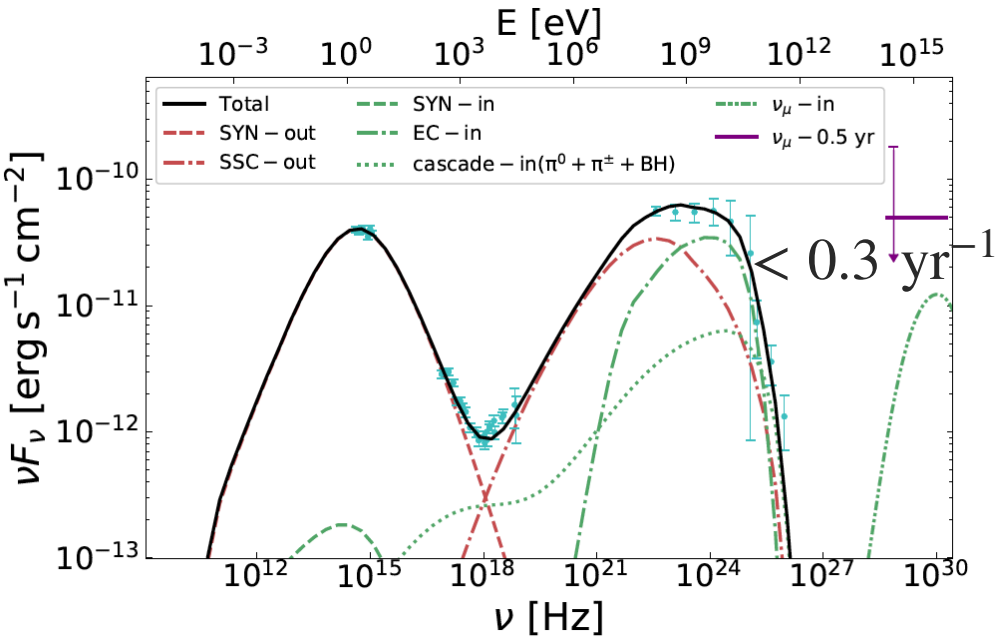
e.SYN in inner blob is suppressed by EC emission.

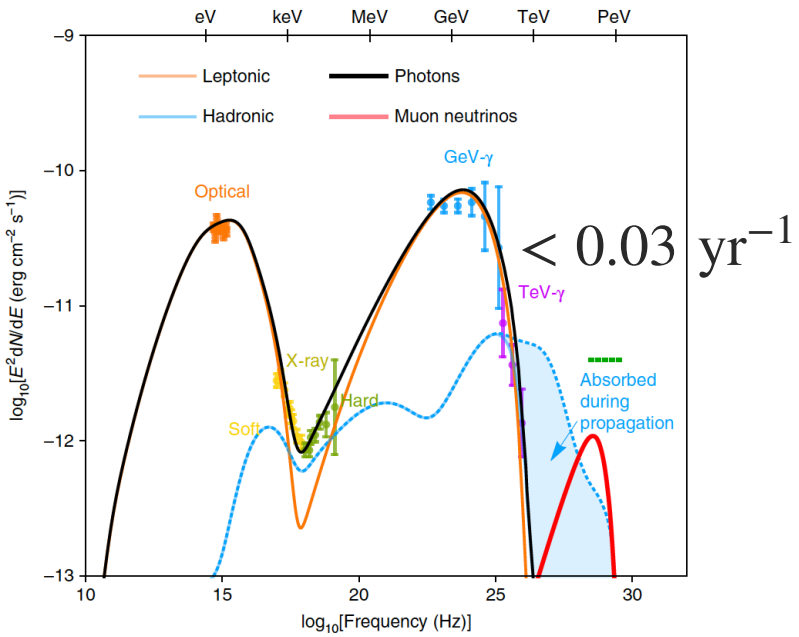
secondary electrons radiate mainly through the EC process

RX et al. 2019, ApJ

Liu, Wang, **RX** et al. 2019, PRD

Distinguishing between the Two-zone and one-zone pγ Model





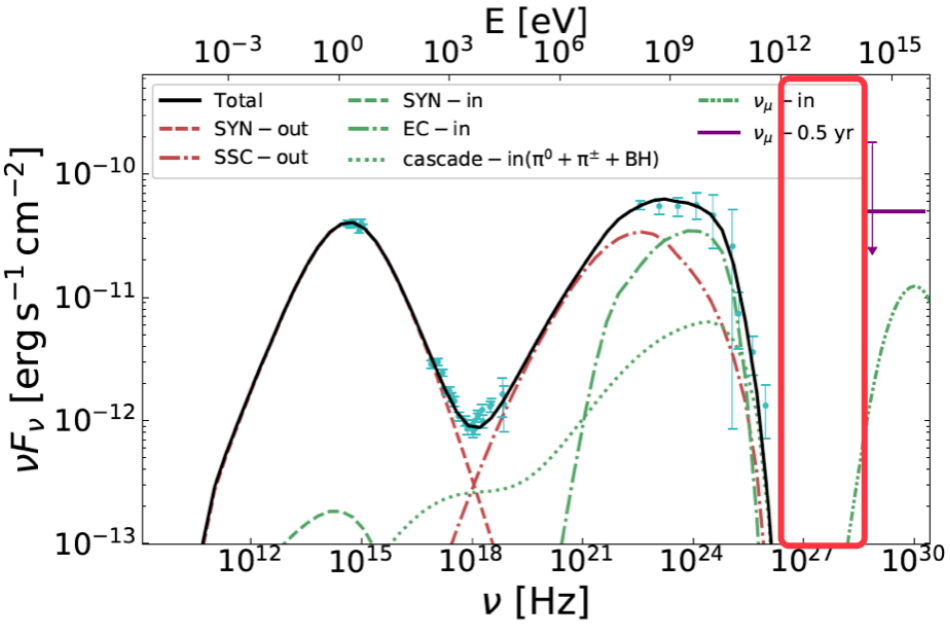
RX et al. 2019, ApJ

Gao et al. 2019

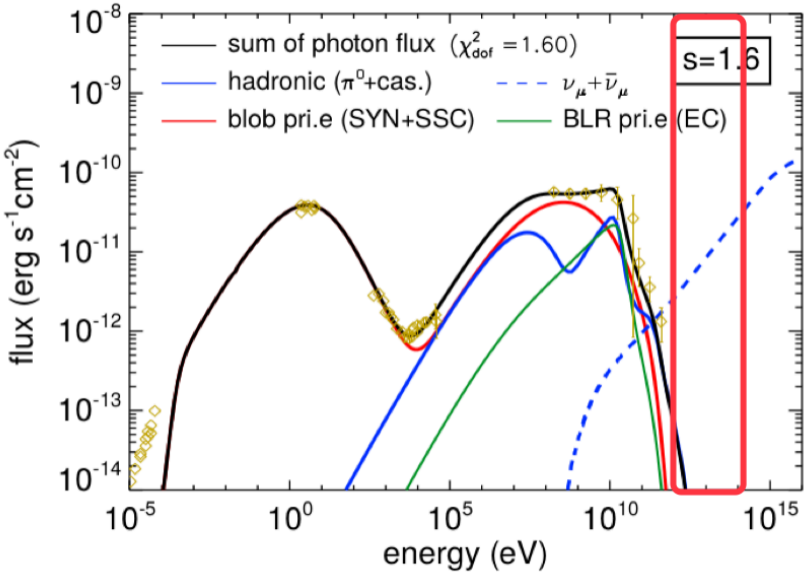
If multiple neutrinos from a similar blazar flare can be detected by next next-generation neutrino telescopes with larger effective areas, such as **IceCube-Gen2**, our two-zone model is more favored.

(one-zone model still predict < 1 neutrino per year)

Distinguishing between the Two-zone pγ and two-zone pp Model



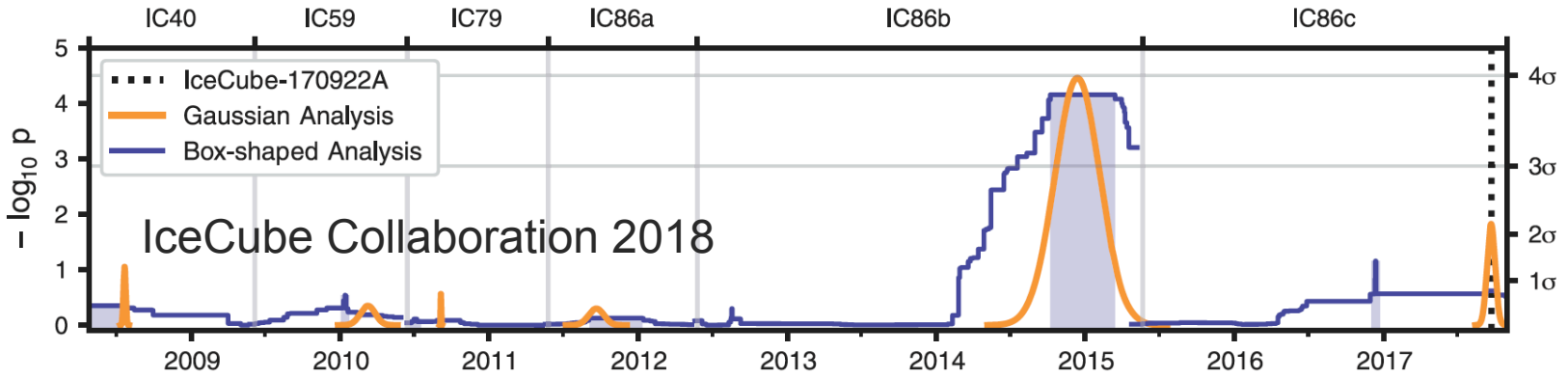
RX et al. 2019, ApJ

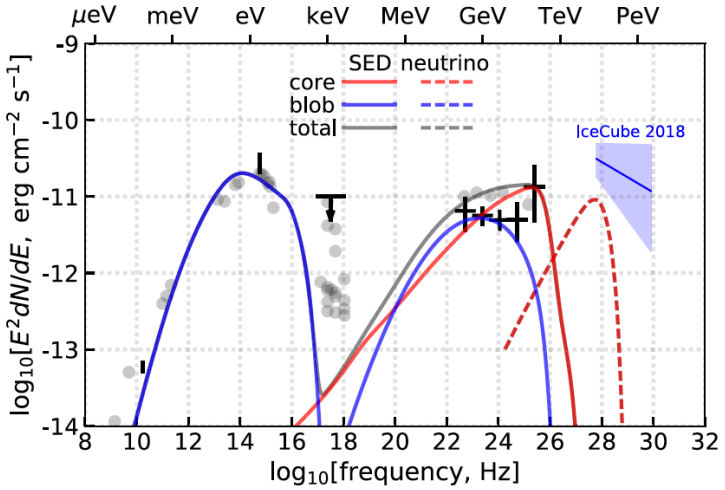


Liu, Wang, **RX** et al. 2019, PRD

If the neutrino spectrum can be measured or constrained in the TeV–PeV range in a blazar flare similar to that associated with IC-170922A in the future, we can distinguish between these two mechanisms.

Possible application to the 2014/2015 neutrino flare





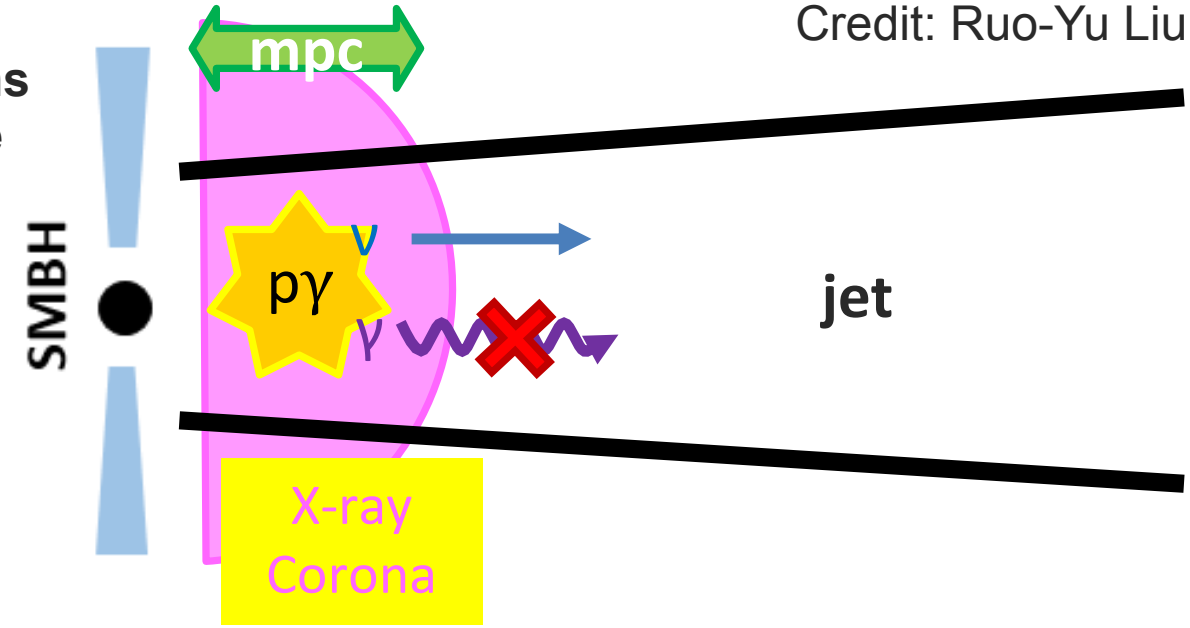
One-zone model cannot explain.

Rodrigues et al. 2019

Possible application to the 2014/2015 neutrino flare

if particles acceleration happens to occur at jet base

Credit: Ruo-Yu Liu



$$\tau_{\gamma\gamma} = \sigma_{\gamma\gamma} L_{\rm X}/4\pi r_{\rm co} c\epsilon_{\rm X,1keV} \simeq 16(L_{\rm X,1keV}/10^{43}{\rm erg\ s^{-1}})({\rm r_{co}}/10^{14}{\rm cm})^{-1}$$

$$f_\nu \simeq (3/8)\xi_\Delta \sigma_\Delta n_{\rm X} r_{\rm co} \sim 5\times (L_{\rm X,1keV}/10^{43}{\rm erg\ s^{-1}})(r_{\rm co}/10^{14}\,{\rm cm})^{-1}(E_\nu/15\,{\rm TeV})^{\alpha-1}$$

$$L_{\nu,\rm iso} \sim 6\times 10^{46}{\rm erg/s}$$

RX et al. 2019, ApJ

Summary

- There are multiple emission zones along a blazar jet.
- Emission zones inside (close to) BLR have different radiation feature from those outside (much beyond) BLR.
- Neutrino emission in the inner zone is efficient while accompanying cascade emission at X-ray is suppressed.
- Both IC-170922A and 14/15 neutrino flare can be explained in the two(multi)-zone model; potential application to other Blazars.

Thanks for your attention!