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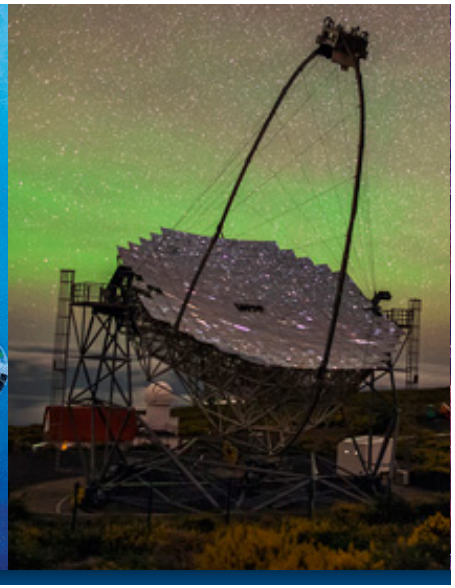


TXS 0506+056: models for the 2017 flare

Matteo Cerruti

"la Caixa" Junior Leader Fellow
Institute of Cosmos Sciences

Universitat de Barcelona

PAHEN 2019

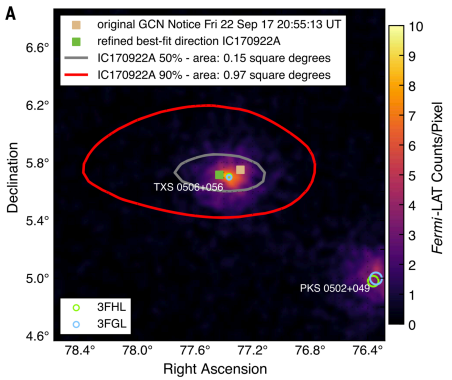
September 26, 2019
Berlin, Germany

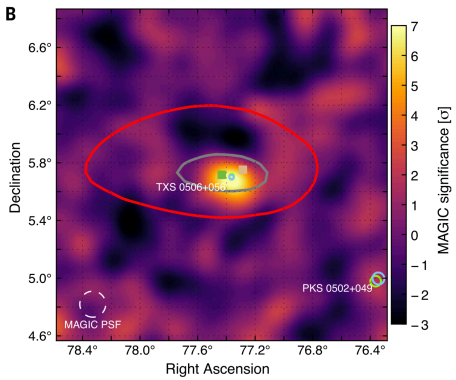
UNIVERSITAT DE BARCELONA

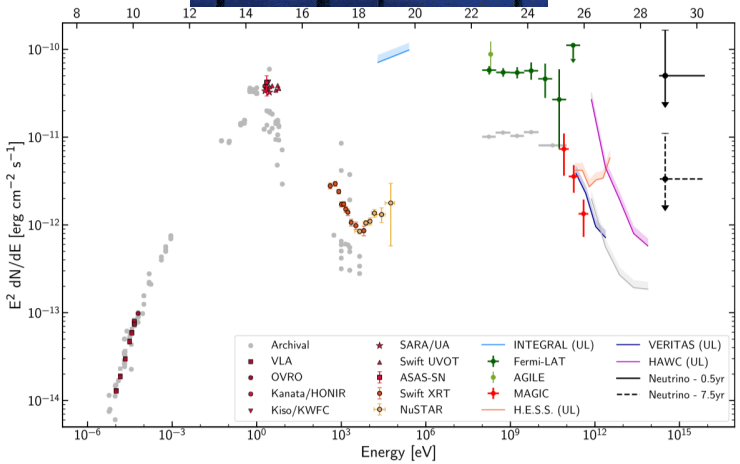
"la Caixa" Foundation

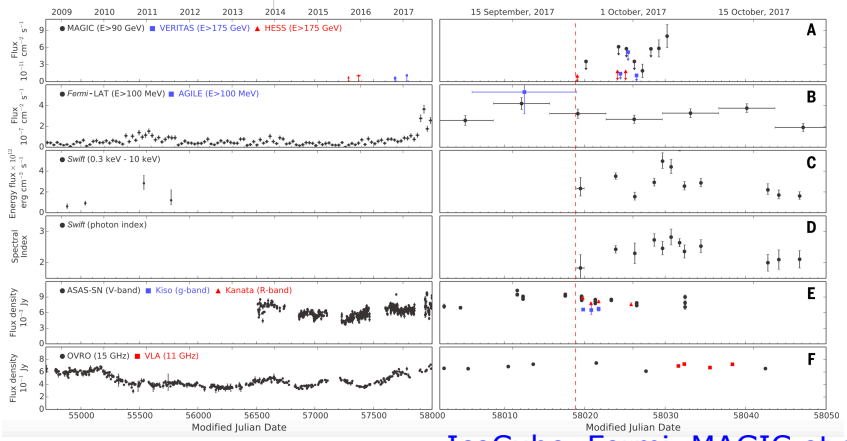
IceCube-170922A / TXS 0506+056

Most significant association (3σ)
of a high-energy (290 TeV) neutrino with an astrophysical source









IceCube, Fermi, MAGIC et al. 2018

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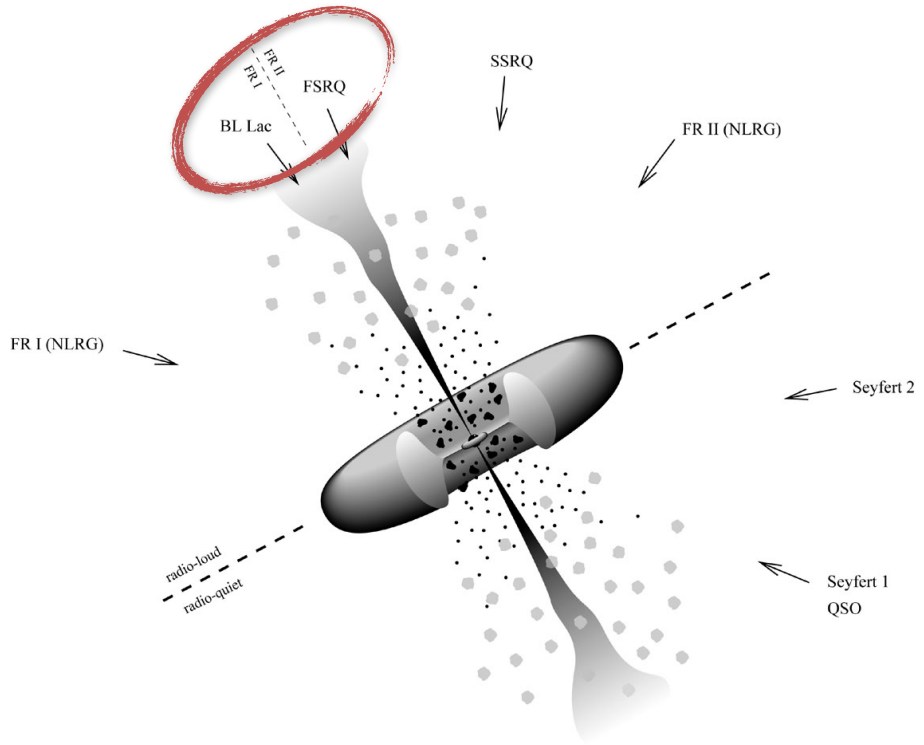
Blazars



Blazars: radio-loud Active Galactic Nucleus whose relativistic jet points towards the observer

→ emission from the jet outshines all other AGN components (disk, BLR, X-ray corona, …)

→ non-thermal emission from radio-to-gamma-rays, and extreme variability

Flat-spectrum-radio-quasars : optical spectrum with broad emission lines

BL Lacertae objects : optical spectrum is featureless (lines $\mathrm{EW} < 5\text{Å}$)

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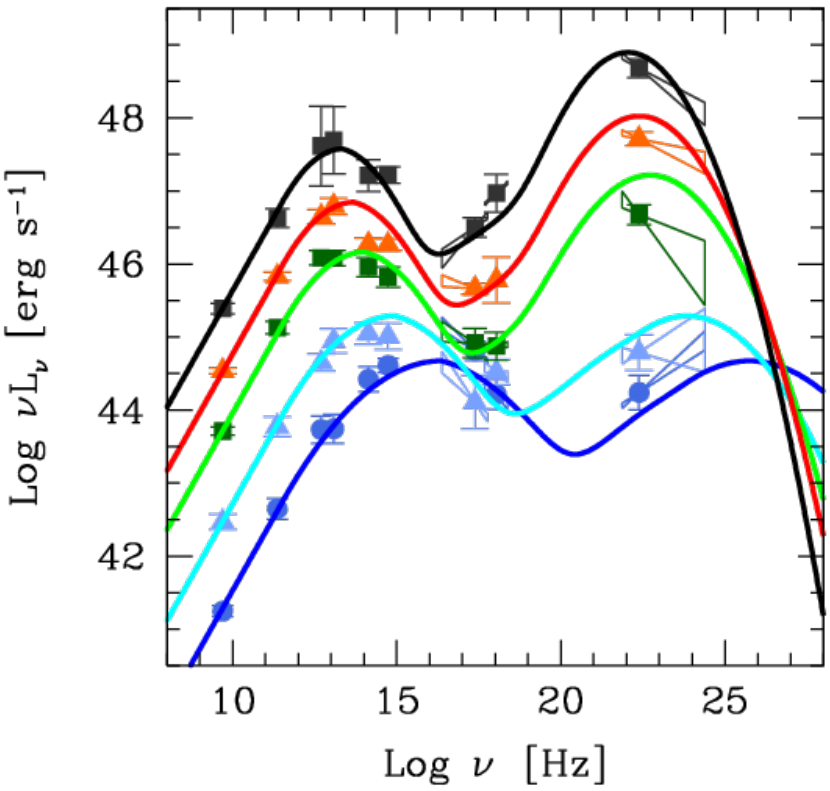

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Low-energy SED component is synchrotron emission by leptons

High-energy component?

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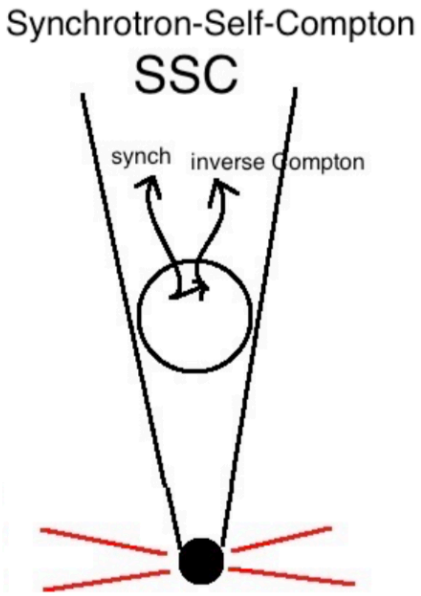
Leptonic models: inverse Compton scattering

Same leptons producing synchrotron
+ their own synchrotron radiation (SSC)



Blazar emission models

Low-energy SED component is synchrotron emission by leptons

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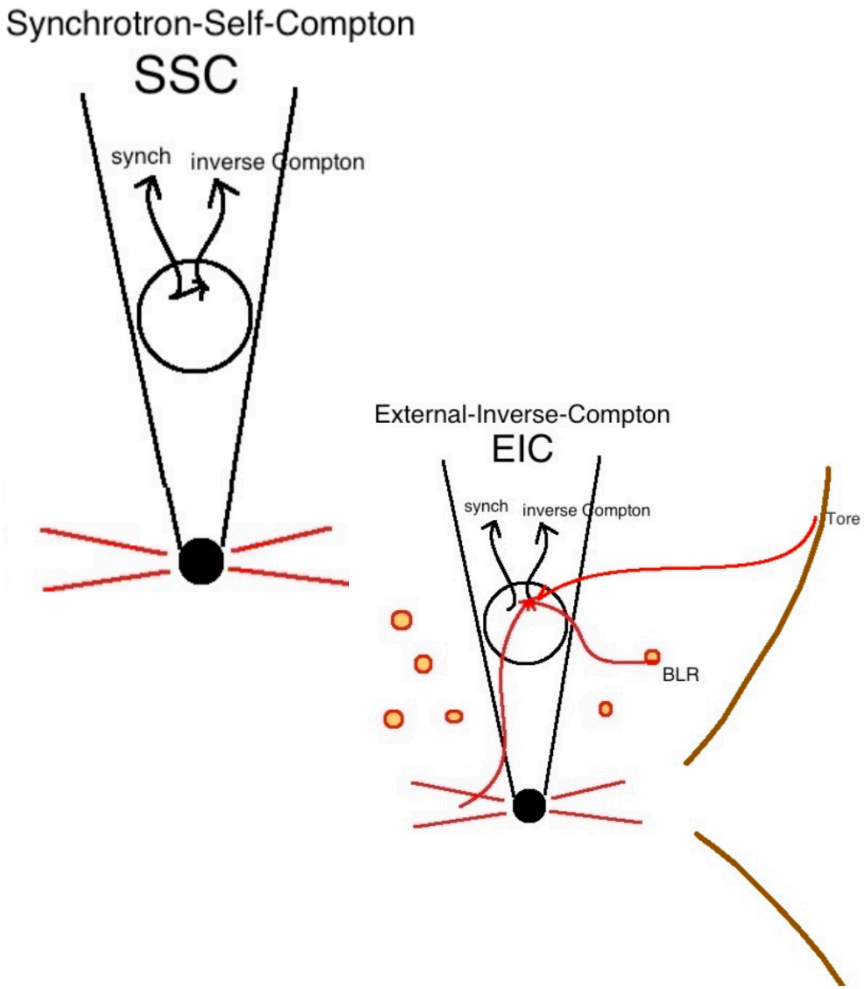

Blazar emission models

Low-energy SED component is synchrotron emission by leptons

High-energy component?

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+ their own synchrotron radiation (SSC)
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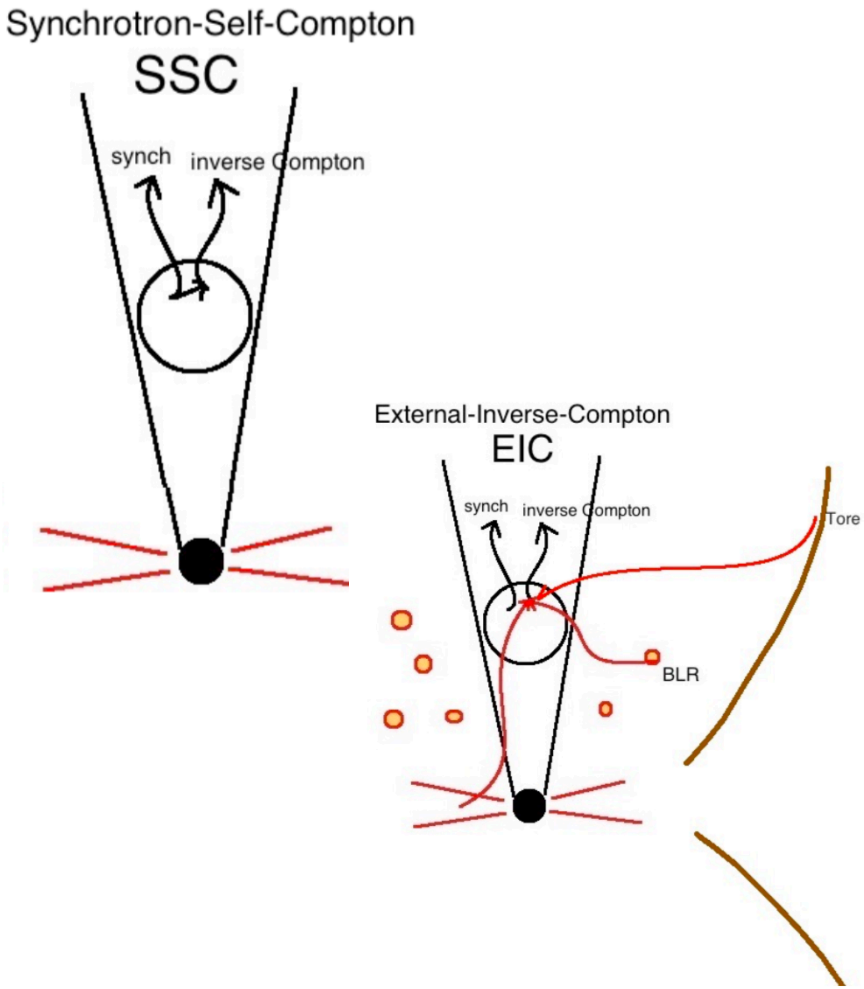
General consensus on the fact that
HBLs → SSC
LBLs / FSRQs → EIC



Blazar hadronic emission models

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- Natural link with neutrinos and cosmic rays:
AGNs are candidates for (UHE)CR acceleration

Blazar hadronic emission models

Why hadronic models if leptonic ones work?

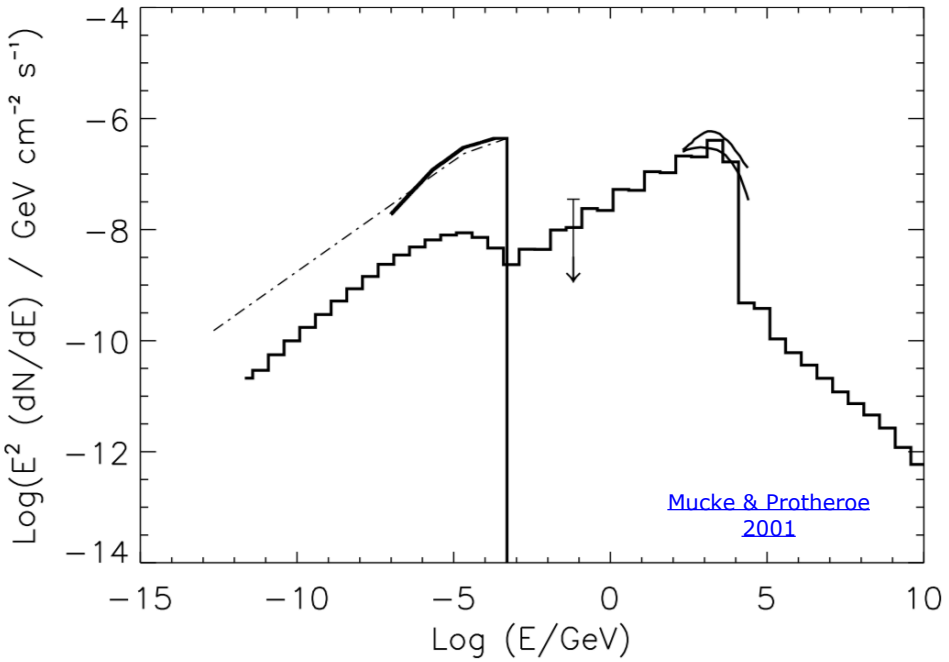
- Natural link with neutrinos and cosmic rays:
AGNs are candidates for (UHE)CR acceleration

- Leptonic models don’t always work well:
Orphan flares!

Blazar hadronic emission models

Simplest hadronic model

The high-energy component is proton synchrotron radiation (Mannheim 1993, Aharonian 2000, Mucke & Protheroe 2001)



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Blazar hadronic emission models

Proton-photon interactions complicate the modeling

Photo-meson

$$p + \gamma = n^0\pi^0 + n^+\pi^+ + n^-\pi^- + \ldots$$

$$\pi^0 \rightarrow 2\,\gamma$$

$$\pi^{\pm} \rightarrow \mu^{\pm} + \nu_\mu \rightarrow e^{\pm} + \nu_\mu + \bar{\nu}_\mu + \nu_e$$

Bethe-Heitler pair production

$$p + \gamma = p' + e^+ + e^-$$

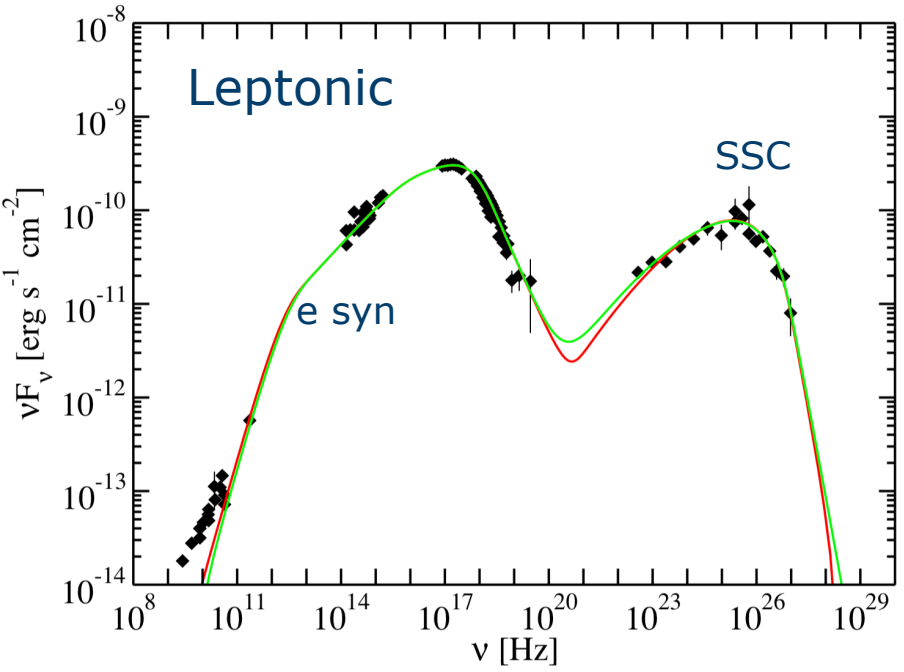
Injection of secondary leptons in the emitting region, triggering synchrotron supported pair-cascades

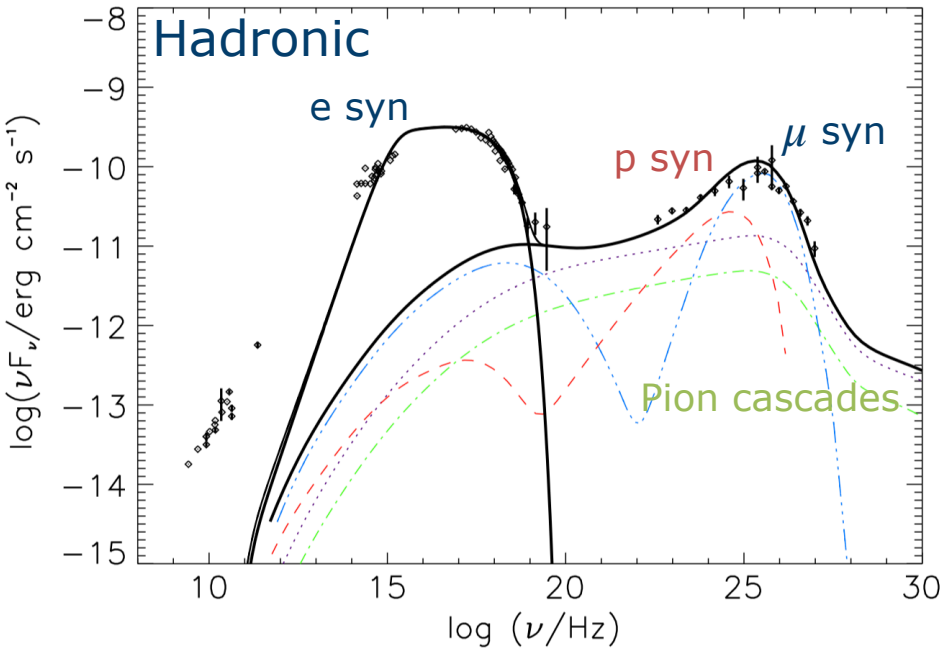
Synchrotron emission by muons can be important

Blazar emission models without ν

Leptonic and hadronic models can both work!

Example for Mrk 421 in 2011





[Abdo et al. 2011]

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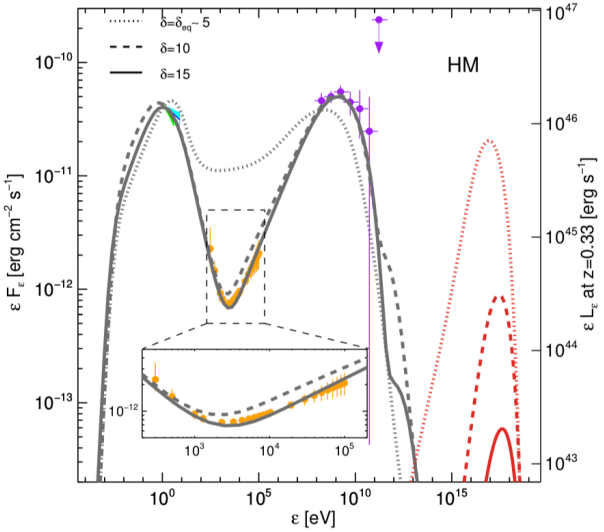
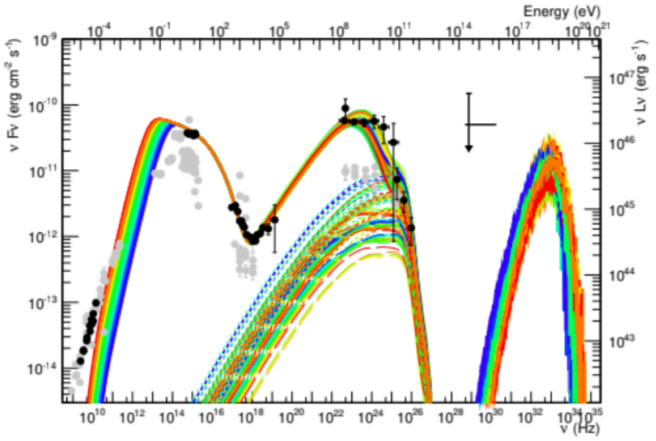
TXS0506+056: the 2017 flare

Proton synchrotron solutions



Keivani et al. 2018

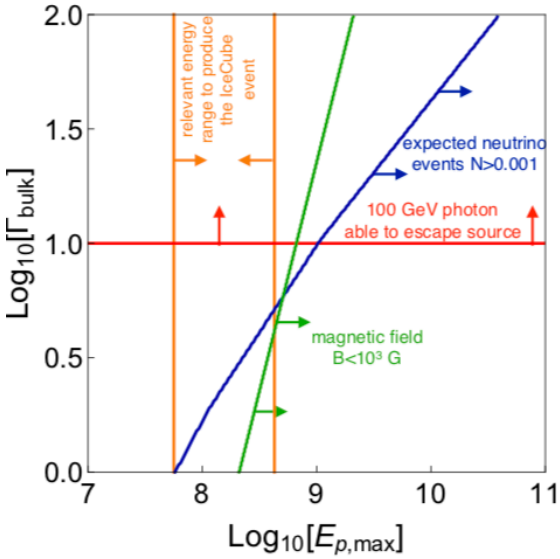
$\nu \simeq 10^{-5}\ yr^{-1}$



(a) Proton synchrotron modeling of TXS 0506+056

Cerruti et al. 2019

$\nu = 10^{-5} - 10^{-3}\ yr^{-1}$



Gao et al. 2018

Proton synchrotron solutions exist,
but the expected neutrino rate is very low

See Strotjohann et al. 2019

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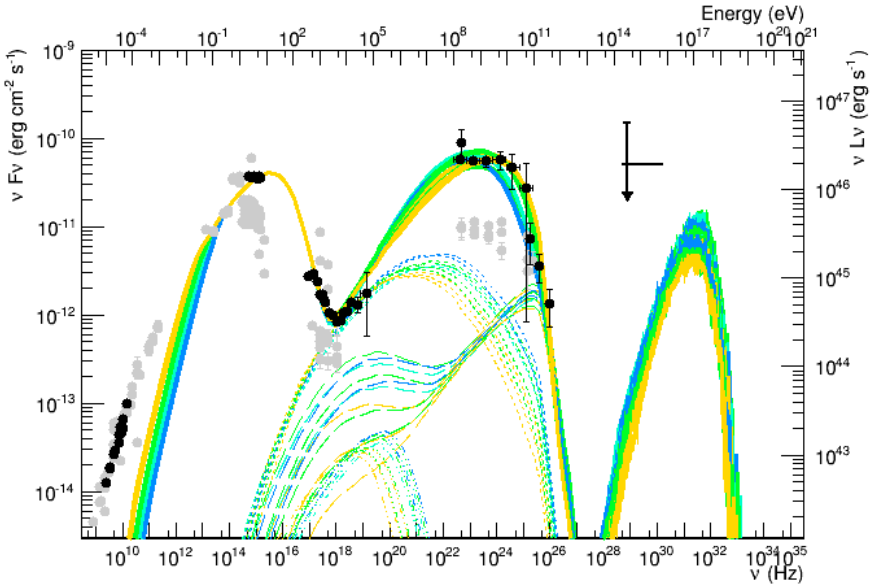
TXS0506+056: the 2017 flare

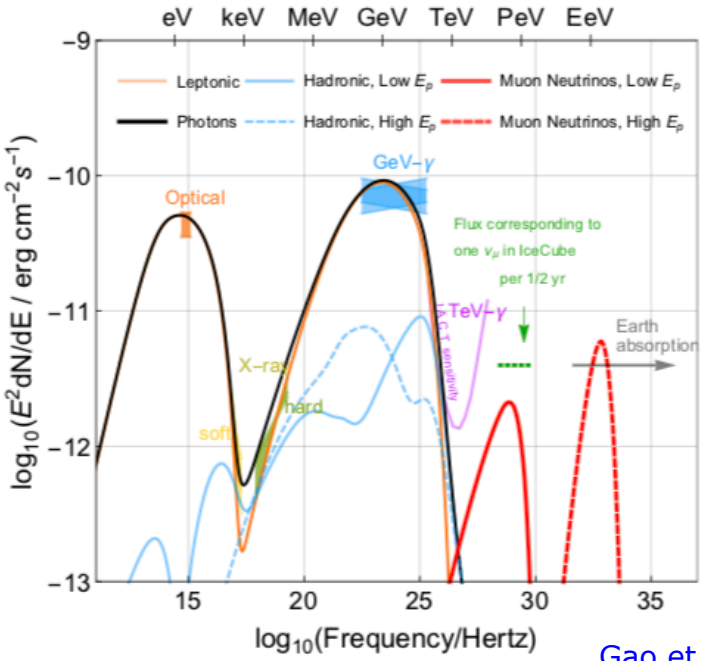
Lepto-hadronic solutions



Cerruti et al. 2019

$L_{jet} = (9 - 60) \times 10^{47} erg/s$

$\nu = 0.01 - 0.06\ yr^{-1}$



Gao et al. 2018

$L_{jet} \simeq \times 10^{50} erg/s$

$\nu = 0.3\ yr^{-1}$

They can work: neutrino rates of the order of 0.1 / yr

But rather high energetic requirement : $L_{jet} \gg L_{Edd} \simeq \times 10^{46-47}\ erg/s$

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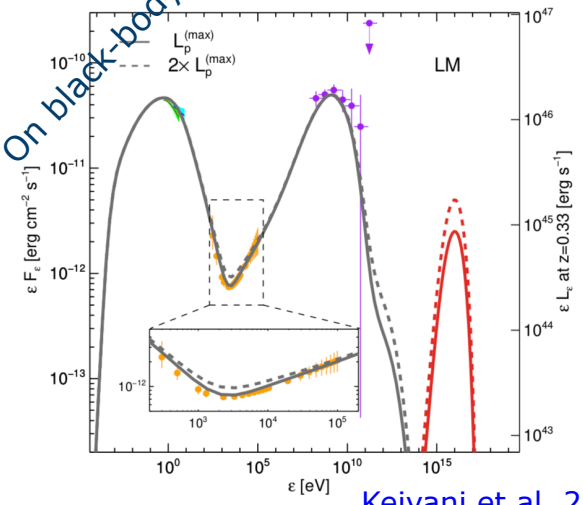
TXS0506+056: the 2017 flare

Proton-photon interaction on external photon fields

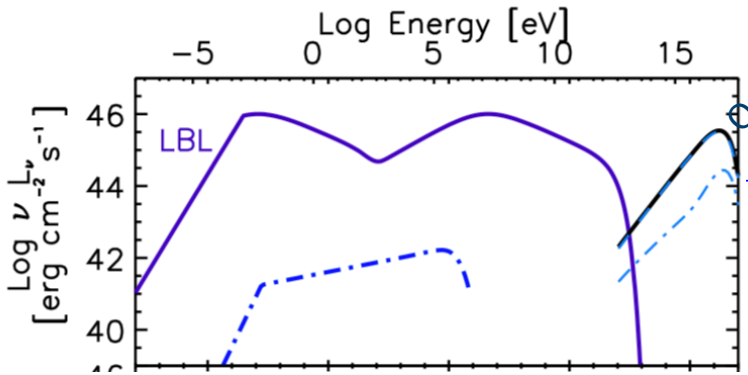
On black-body



Keivani et al. 2018

$$L_{jet} = (4-150)\times 10^{45} erg/s$$
$$\nu_{max} = 0.02\ yr^{-1}$$

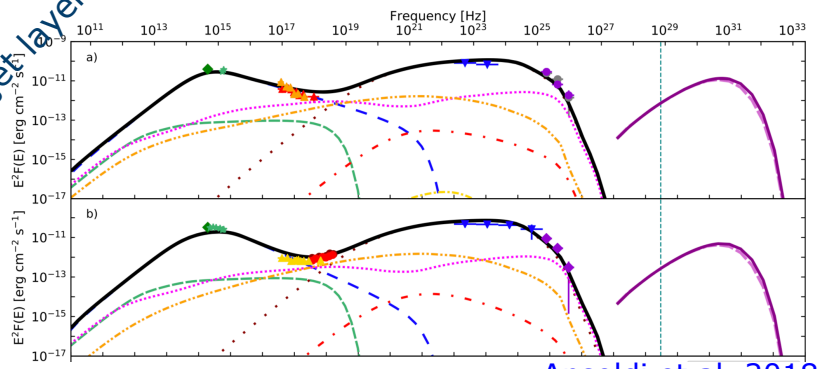
On RIAF



Righi et al. 2019

$$L_{jet} = 6.3\times 10^{45} erg/s$$
$$\nu = 0.14\ yr^{-1}$$

On jet layer



Ansoldi et al. 2018

$$L_{jet} = (3-8)\times 10^{45} erg/s$$
$$\nu = 0.12-0.34\ yr^{-1}$$

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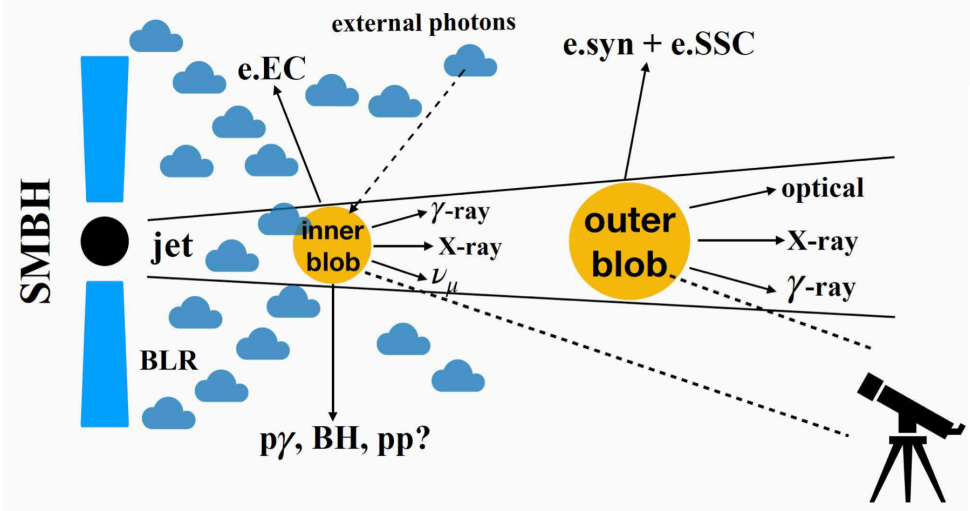
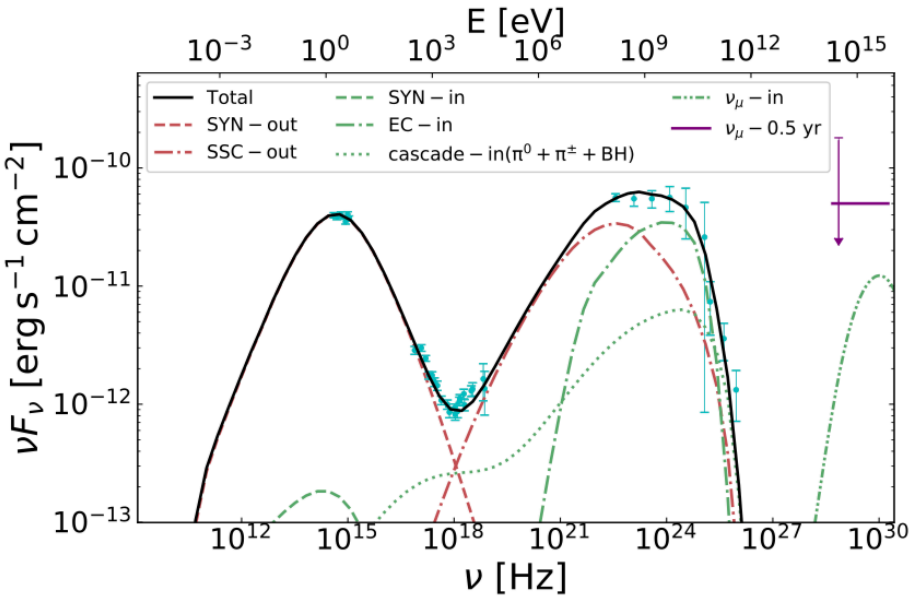
TXS0506+056: the 2017 flare

Two-zone model



Xue et al. 2019



$$L_{jet} = 1 \times 10^{47} erg/s$$
$$\nu_{max} = 0.3\ yr^{-1}$$

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TXS0506+056: the 2017 flare

See Strotjohann et al. 2019

TXS0506+056: the 2017 flare

What did we learn on blazars?

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- The favored scenario is a leptonic electromagnetic emission, with subdominant hadronic component

See Strotjohann et al. 2019

TXS0506+056: the 2017 flare

What did we learn on blazars?

- Pure hadronic solutions are excluded!

- The favored scenario is a leptonic electromagnetic emission, with subdominant hadronic component

- Simple one-zone models result in a high proton luminosity

- External fields as photon target can help on this aspect

- Two zone models can increase neutrino emission

See Strotjohann et al. 2019

Cosmic Rays from TXS0506+056

Can AGNs accelerate (UHE)CRs?

- From Cerruti et al. 2019, $E_{p,max} = (2-7) \times 10^{18} eV$

- From Ansoldi et al. 2018, $E_{p,max} = 2 \times 10^{15} - 2 \times 10^{19} eV$

- From Keivani et al. 2018, "assuming the IceCube-170922A association holds, TXS 0506+056 is not a significant UHECR accelerator"

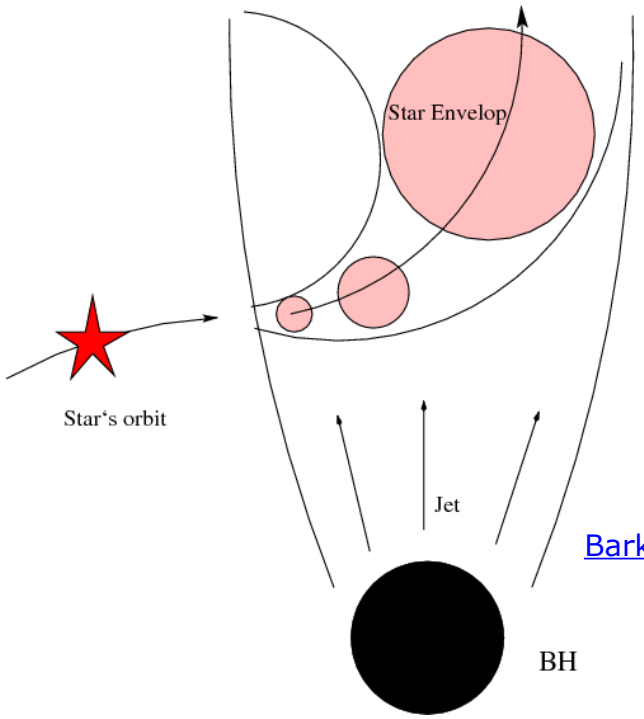
- From Gao et al. 2018, "The scenario [of UHECR in the source] is not acceptable"

TXS0506+056 not really an UHECR accelerator!

TXS0506+056: the 2017 flare

Alternative hadronic scenario

Jet - cloud interaction : $p + p = n^0\pi^0 + n^+\pi^+ + n^-\pi^-$



Barkov et al. 2012

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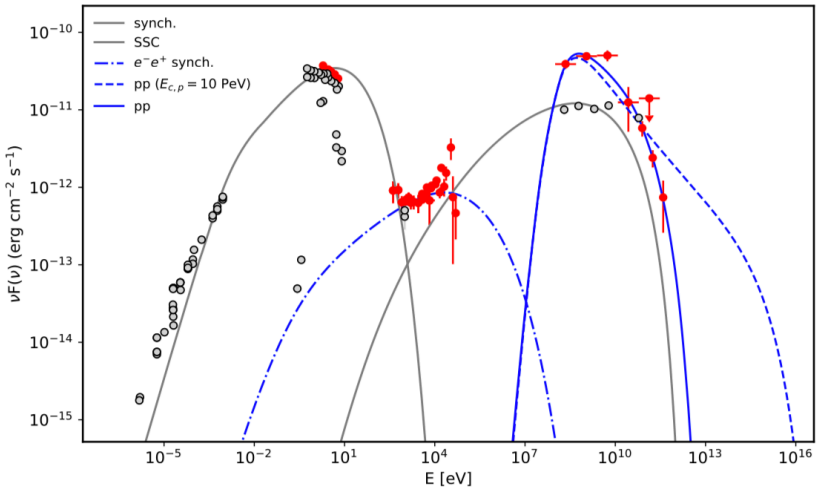
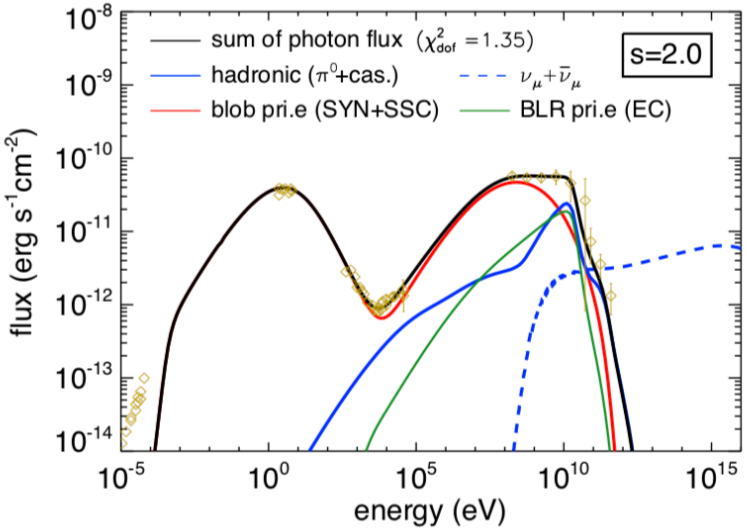


Sahakyan 2018

$L_{jet} = 1 \times 10^{48} erg/s$

$\nu = 0.13 - 0.46\ yr^{-1}$



$L_{jet} = (0.8 - 5) \times 10^{46} erg/s$

$\nu = 0.26\ yr^{-1}$

Liu et al. 2019

see as well Wang et al. 2018

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Neutrinos from blazars

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- Long-term brightening in gamma-rays (not that common)
- At moderate redshift, it is a luminous gamma-ray AGN

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- Are we learning something on AGN populations?
- Do we have hadronic/neutrino blazars and leptonic blazars?
- Does this dichotomy overlap with other blazar classifications?

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- Hard-X-rays / VHE gamma-rays proved to be extremely important to constrain the models

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