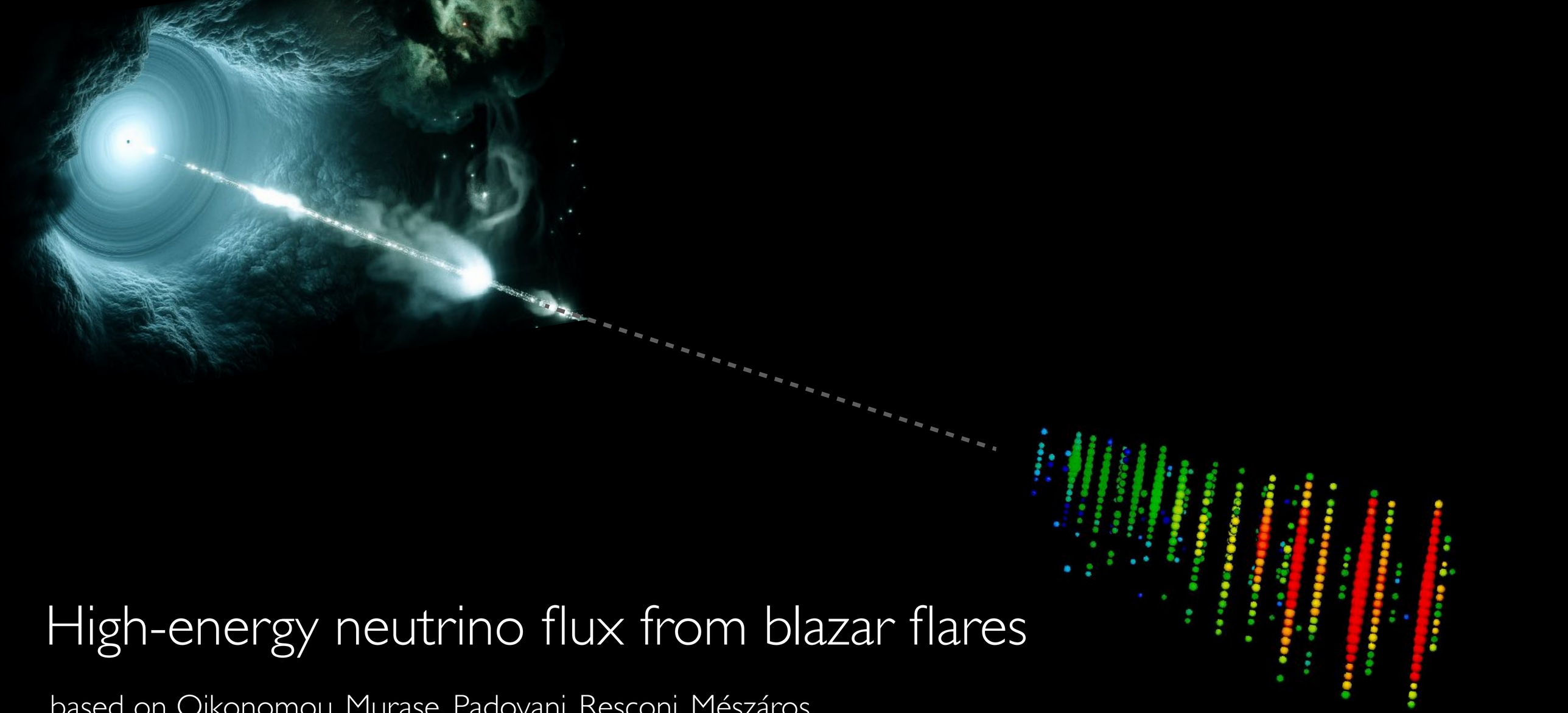

High-energy neutrino flux from blazar flares

based on Oikonomou, Murase, Padovani, Resconi, Mészáros,
accepted for publication in MNRAS, arXiv:1906.05302

Foteini Oikonomou

July 25th-ICRC 2019

Which blazar flares produce the most neutrinos?

- Flares are ideal times for neutrino production and detection

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- Luminous, not too distant, long flares

Which blazar flares produce the most neutrinos?

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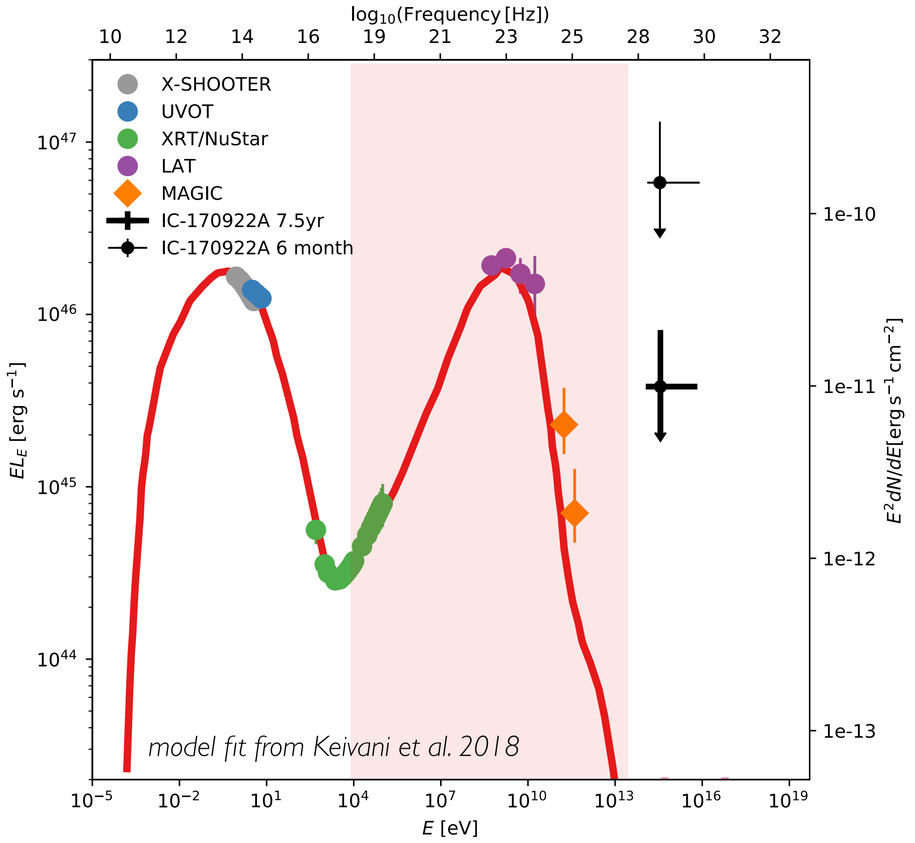
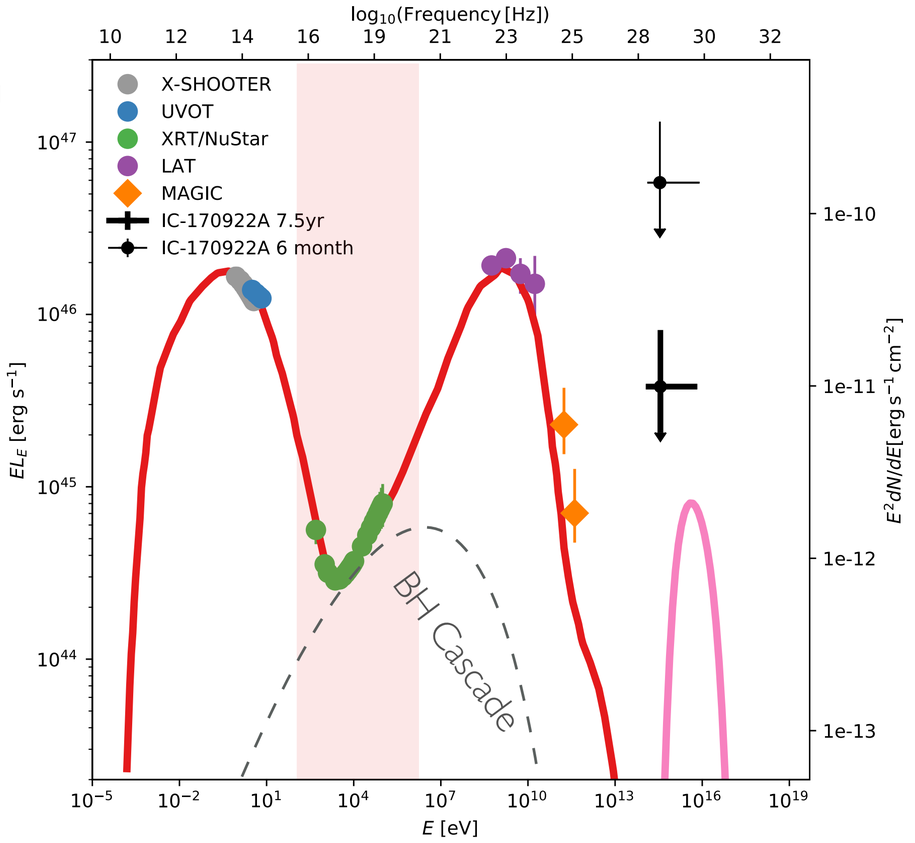


*TXS 0506+056 is not a BL Lac

Padovani, FO, Petropoulou, Giommi, Resconi, MNRAS, 484 L104, 2019

Which blazar flares produce the most neutrinos?

- Flares are ideal times for neutrino production and detection
- Luminous, not too distant, long flares
- High Compton dominance
- High X-ray cascade flux



$$E_\nu L_{E_\nu} \lesssim 10^{45}\ \mathrm{erg\ s^{-1}}\ \frac{L_{\mathrm{X,lim}}}{3\times 10^{44}\ \mathrm{erg\ s^{-1}}}\ \frac{0.1}{f_x}$$

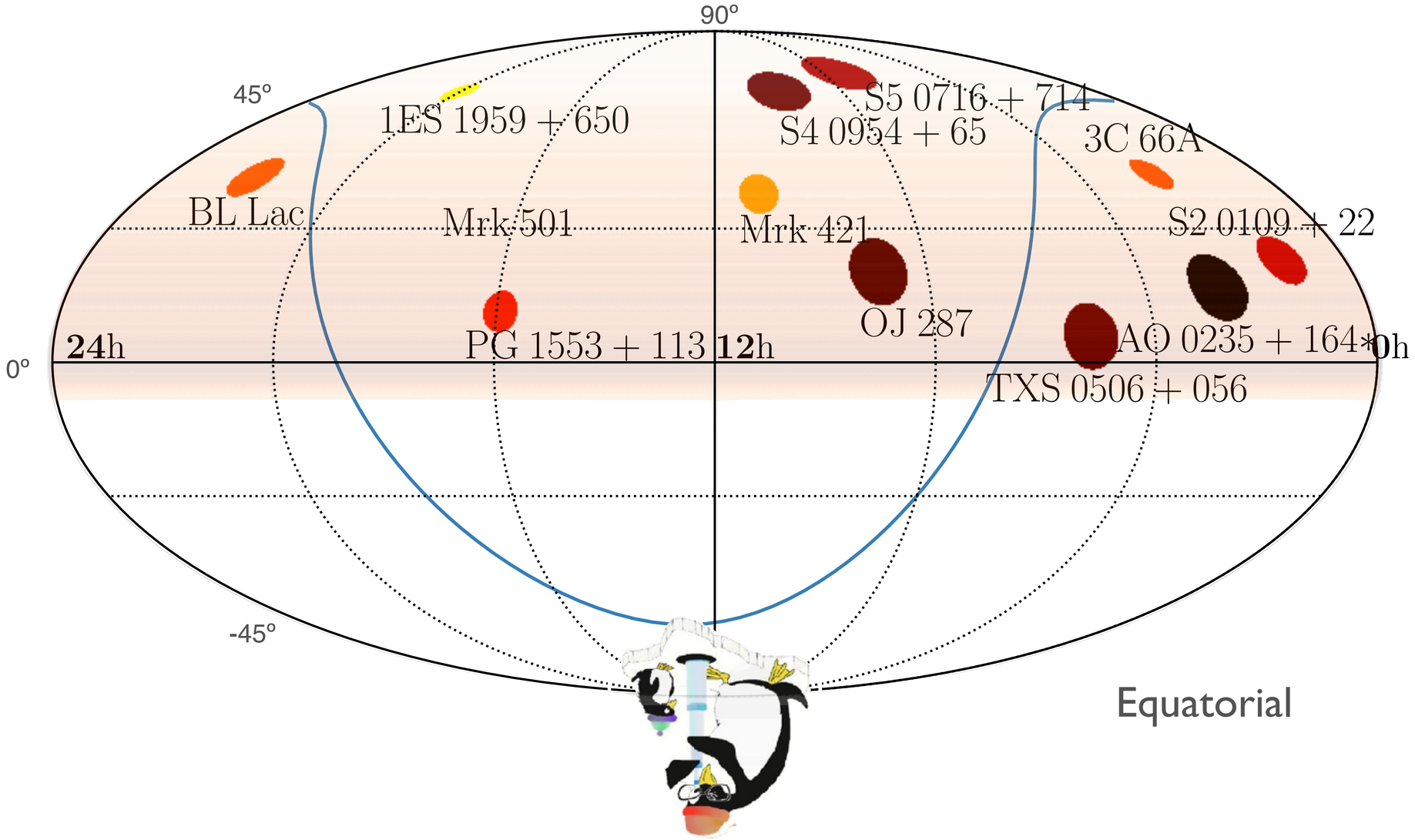
Murase, FO, Petropoulou ApJ 865 (2018) 124

[see also

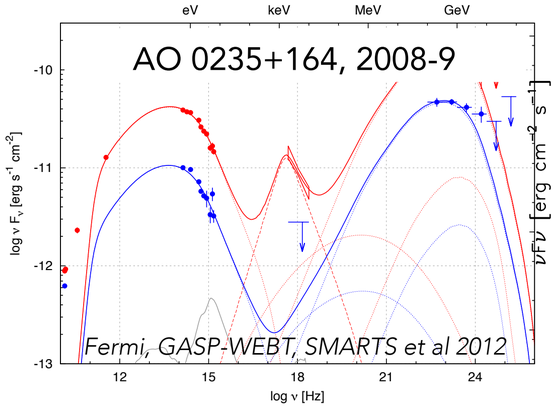
Petropoulou et al, 2015, MNRAS, 447, 36, Cerruti et al, 2019, MNRAS, 483, L12, Gao et al, 2019, Nat Astron, 3, 88, MAGIC Coll, 2018, ApJ 863, L10, Reimer et al, arXiv:1812.05654, Rodrigues, 2019, ApJ, 874, L29]

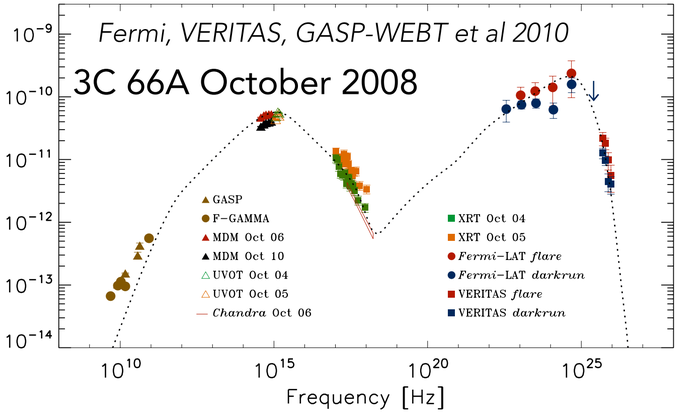
Flare sample

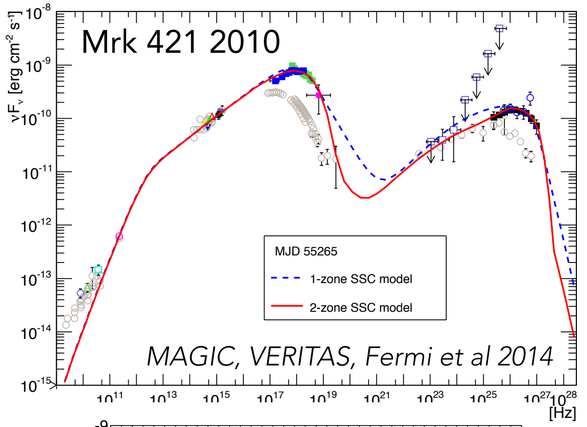
FO, Murase, Padovani, Resconi, Mészáros, MNRAS accepted, arXiv:1906.05302



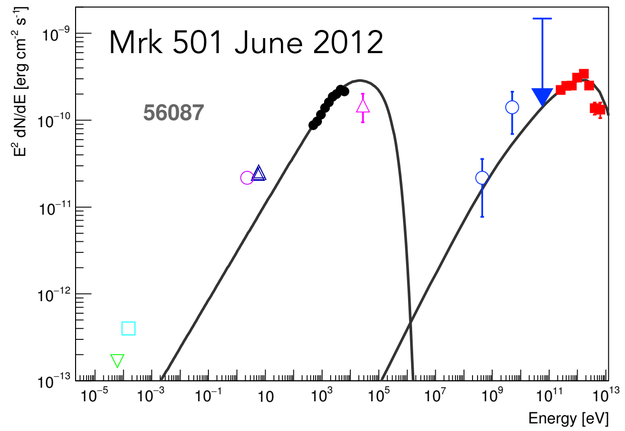
Flare sample

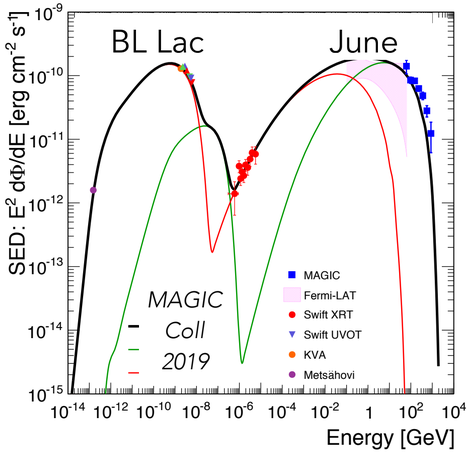


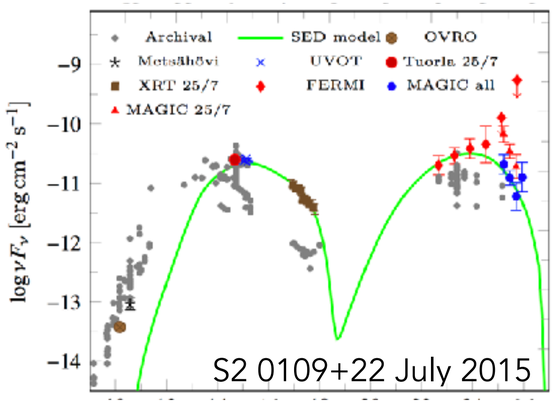




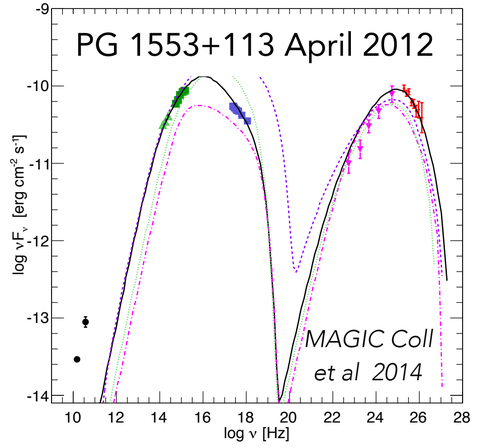
MAGIC ,FACT, VERITAS 2018

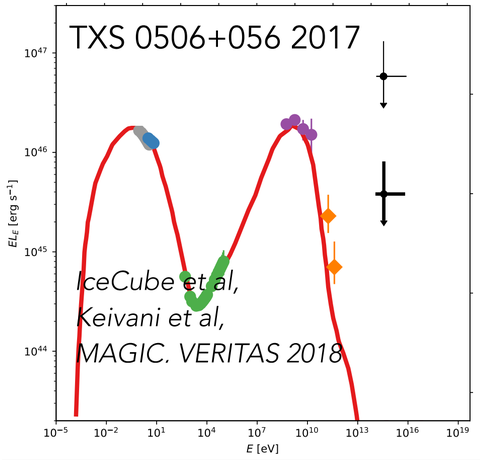


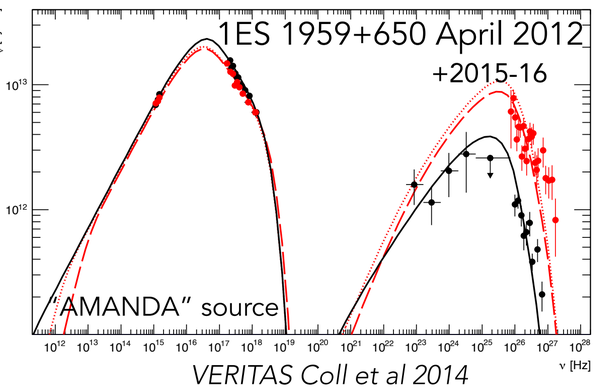




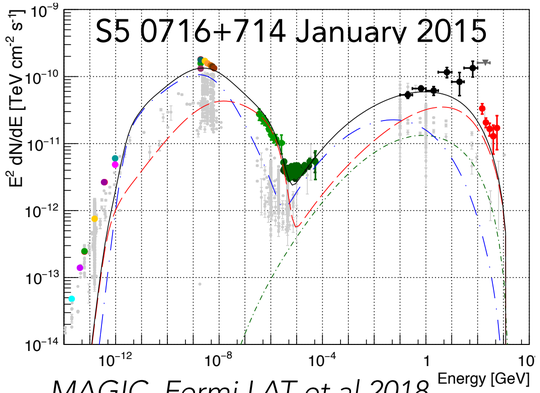
MAGIC , Fermi, et al 2018



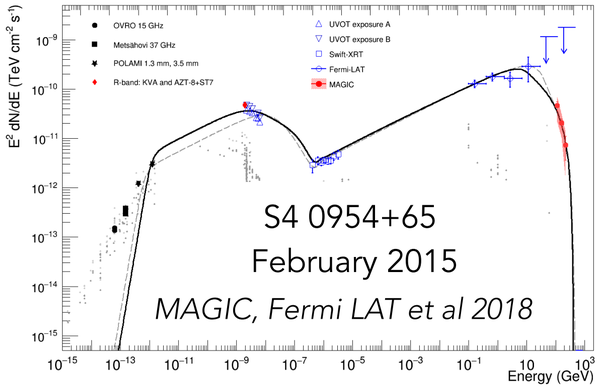


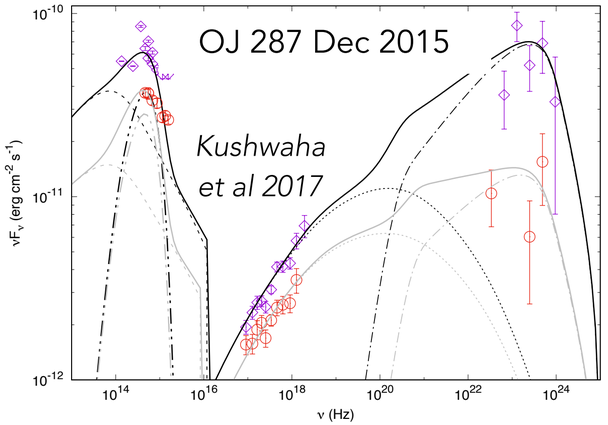


VERITAS Coll et al 2014

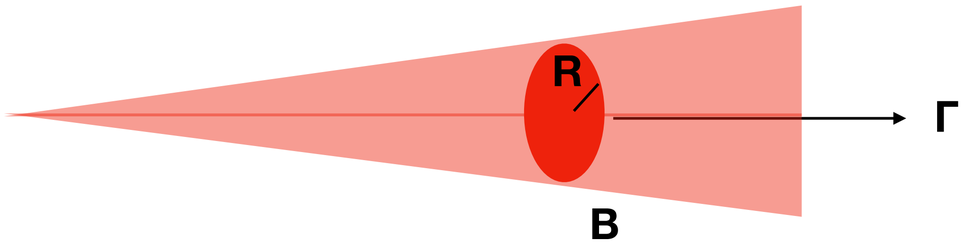


MAGIC, Fermi LAT et al 2018

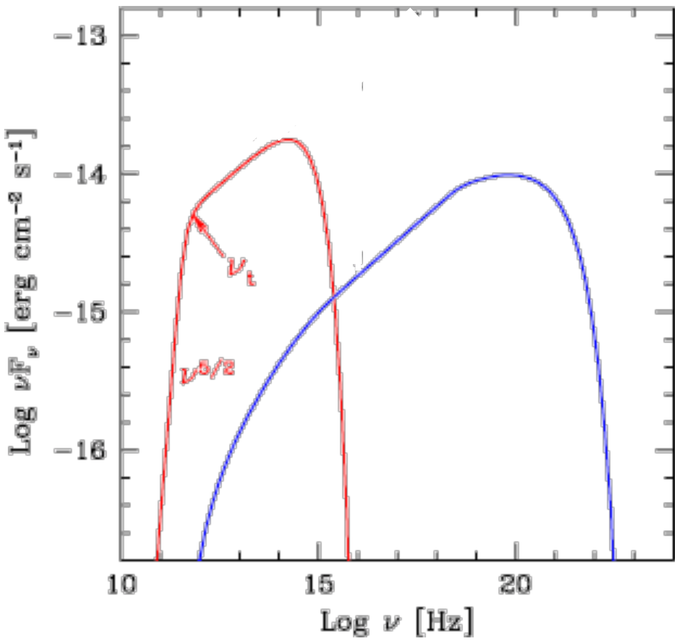




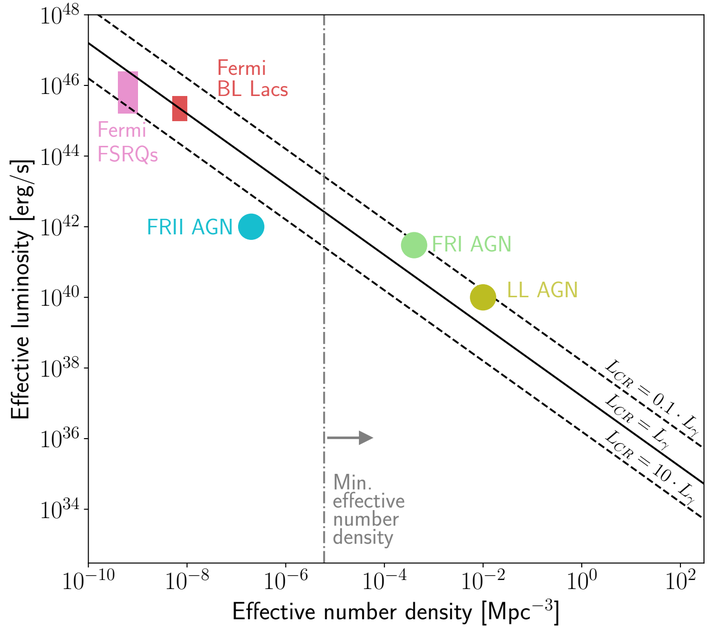
Scenario A



Ghisellini, Lecture Notes in Physics 2013



FO for MIAPP Review, 2019, FrASS, 6, 23



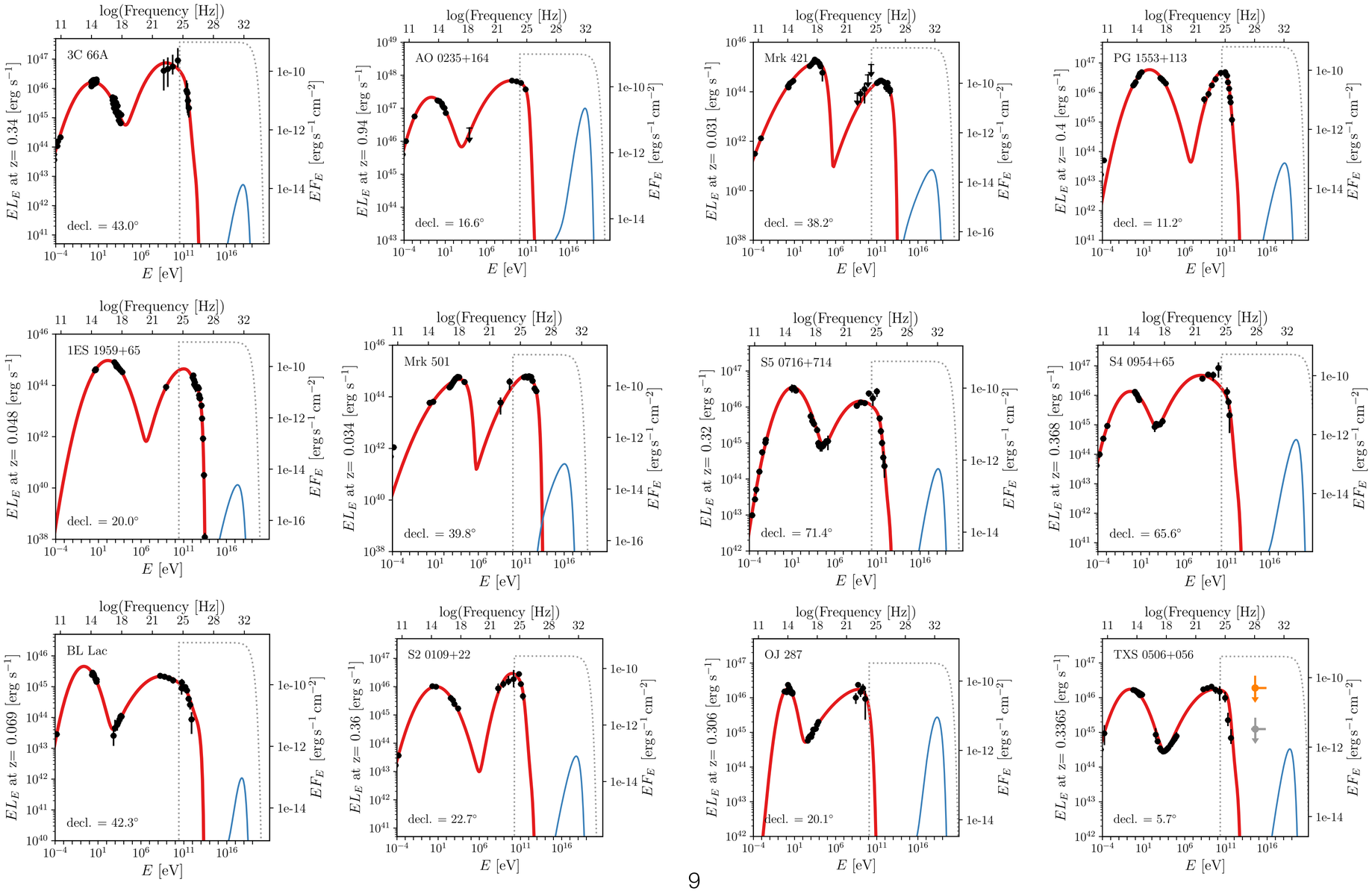
Simple synchrotron self-Compton scenario
High maximum energy

$$E_{\mathrm{CR,max}} \sim \left(\frac{\eta}{1}\right)\left(\frac{B}{0.1\ \mathrm{G}}\right)\left(\frac{R'}{10^{16}\ \mathrm{cm}}\right)\left(\frac{\Gamma}{25}\right) \sim 10^{19}\ \mathrm{eV}$$

Baryon loading = 10
(BL Lacs produce the observed UHECRs)

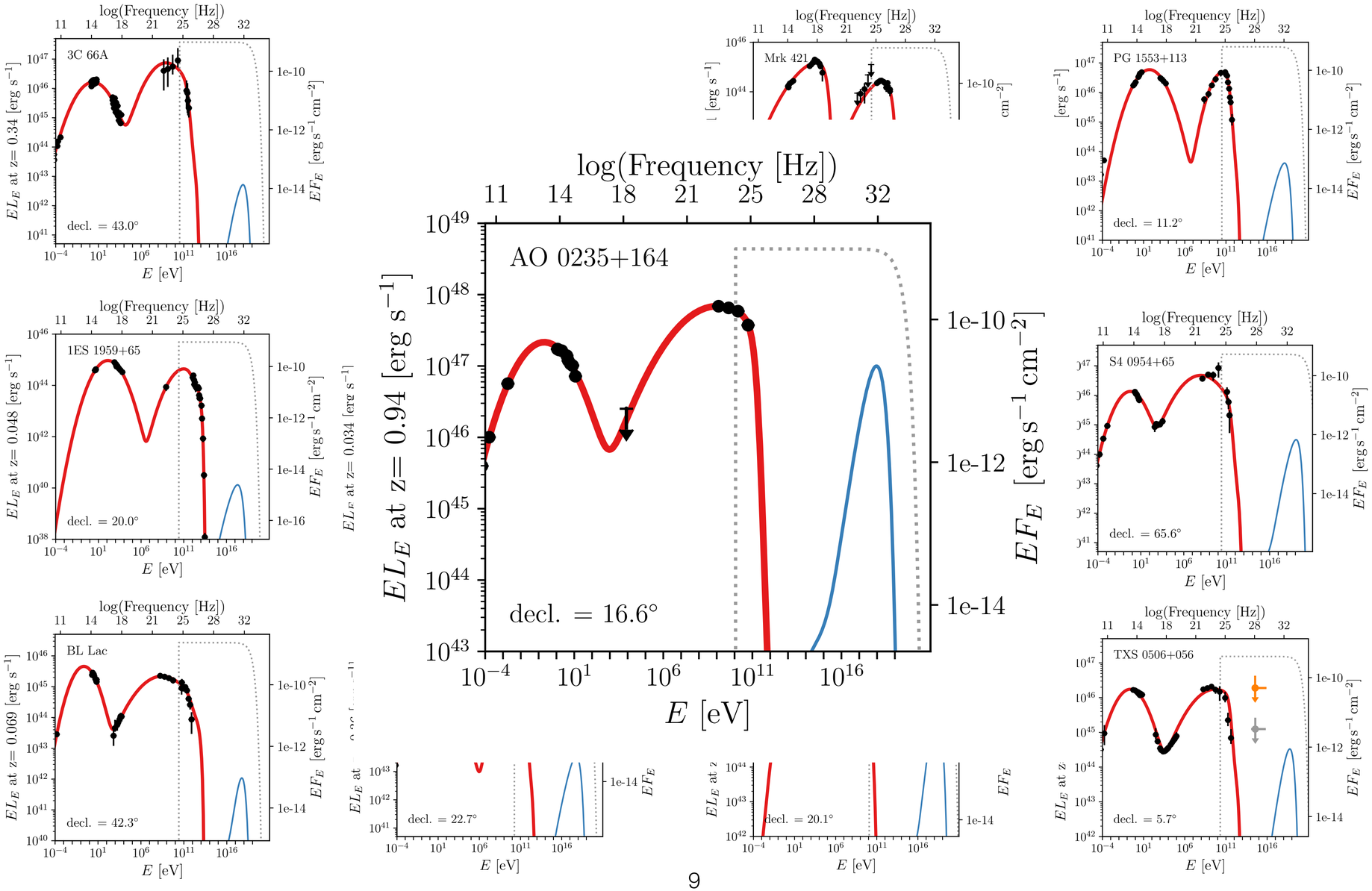
Scenario A

FO, Murase, Padovani, Resconi, Mészáros, MNRAS accepted, arXiv:1906.05302



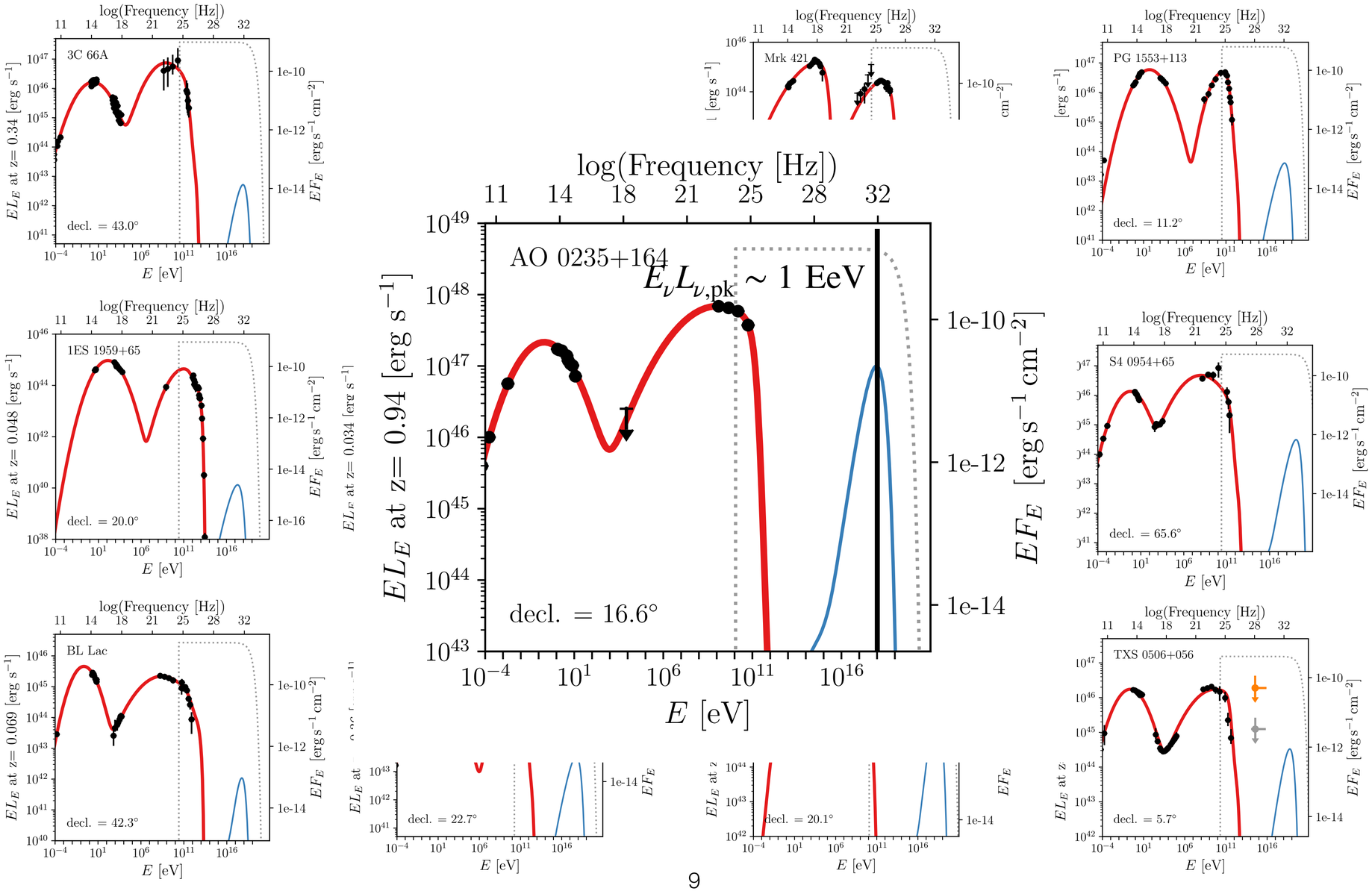
Scenario A

FO, Murase, Padovani, Resconi, Mészáros, MNRAS accepted, arXiv:1906.05302

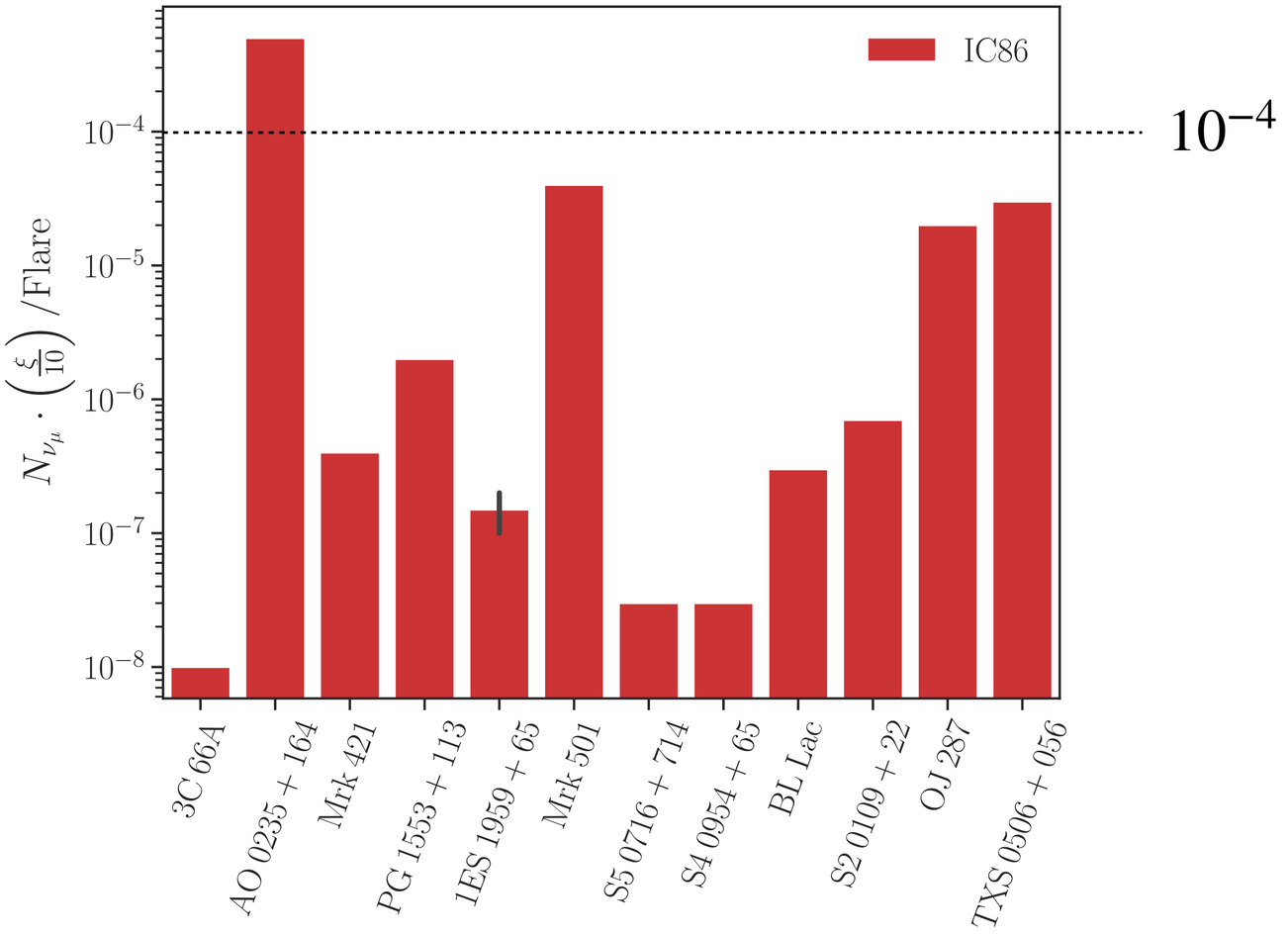


Scenario A

FO, Murase, Padovani, Resconi, Mészáros, MNRAS accepted, arXiv:1906.05302

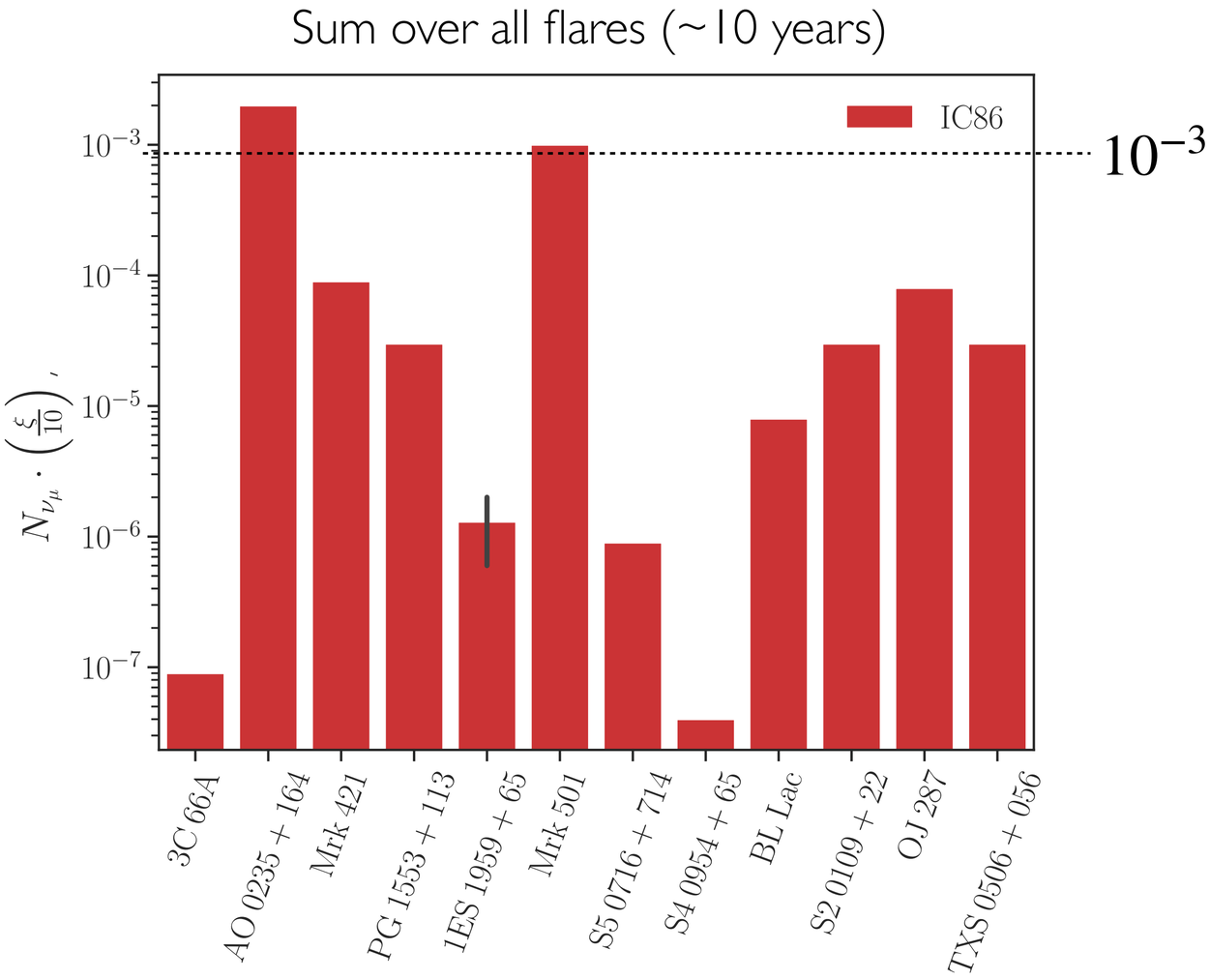


Scenario A



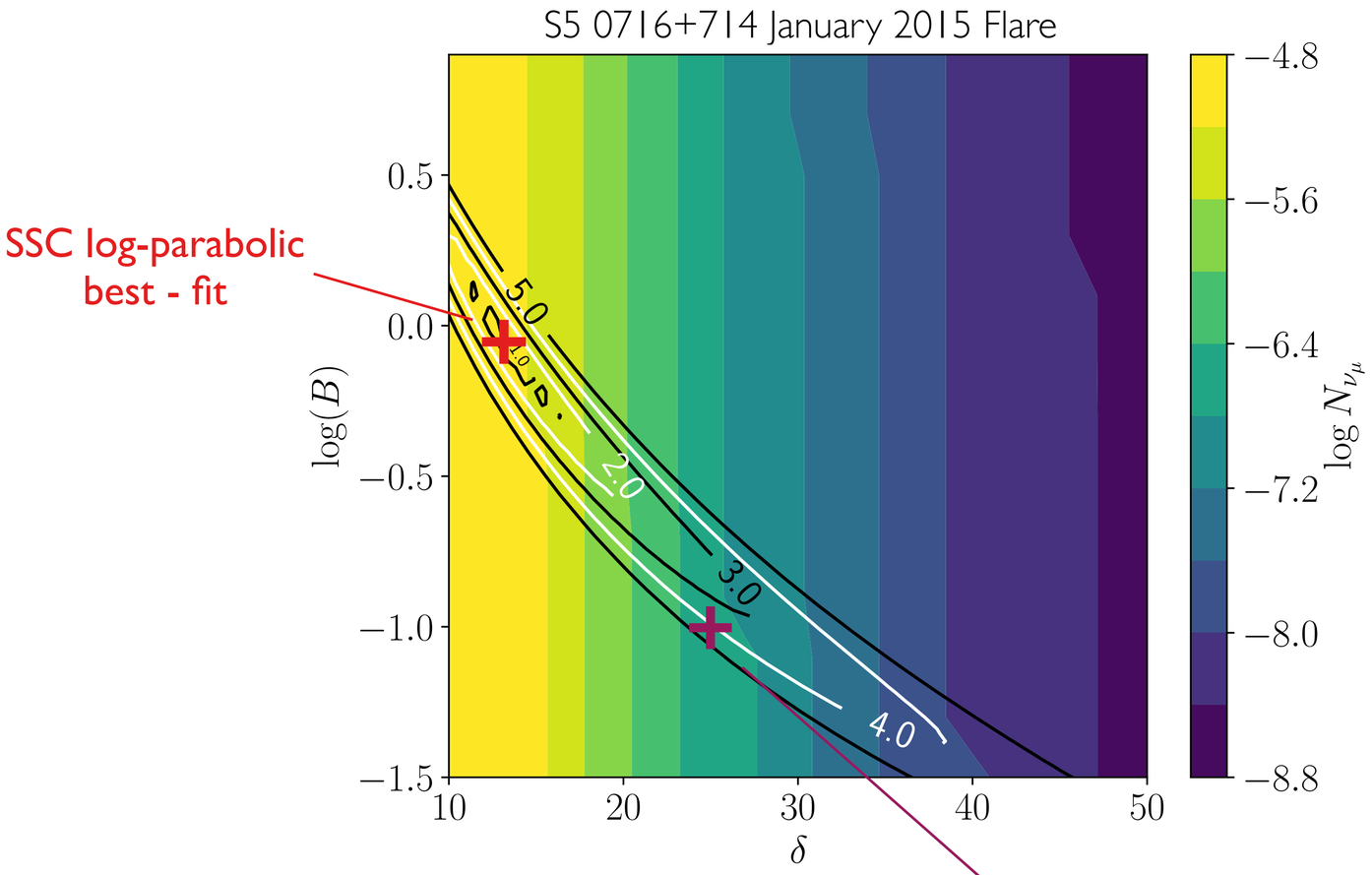
*Number of throughoing ν_μ / $\bar{\nu}_\mu$ expected in IC40/59/79/86 with A_{eff} of *IceCube Coll 2019, Eur. Phys. J., C79, 234*

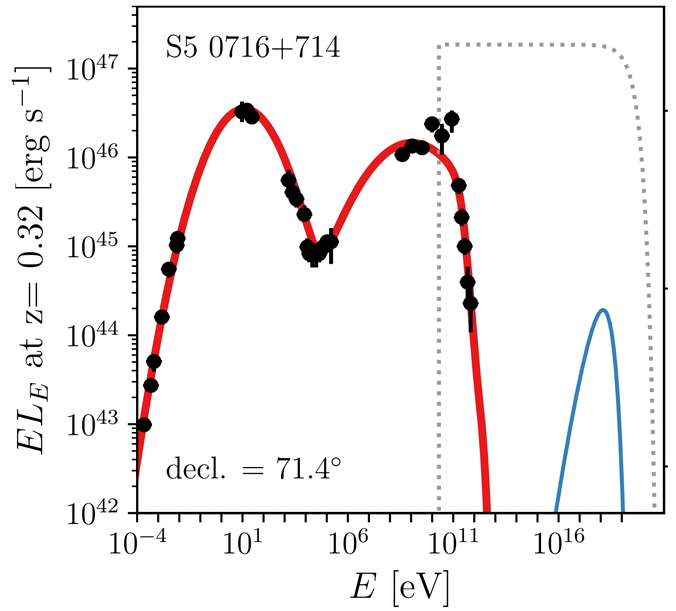
Scenario A



*Number of throughoing ν_μ / $\bar{\nu}_\mu$ expected in IC40/59/79/86 with A_{eff} of *IceCube Coll 2019, Eur. Phys. J., C79, 234*

The effect of systematic uncertainties on $N_{\nu\mu}$





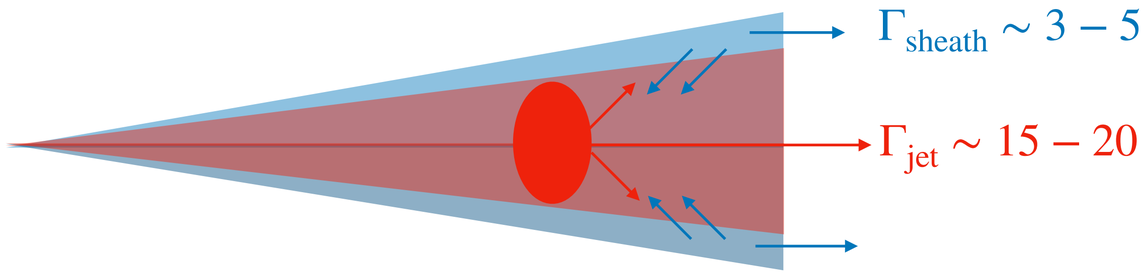
$\delta = 1/[\Gamma(1-\beta\cos\theta)] \sim \Gamma$ (for small θ)

Superluminal motion, $L_{\rm obs} = \delta^4 L_{\rm jet\ frame}$

Scenario B

Ghisellini, Tavecchio, Chiaberge 2005

Tavecchio & Ghisellini 2014

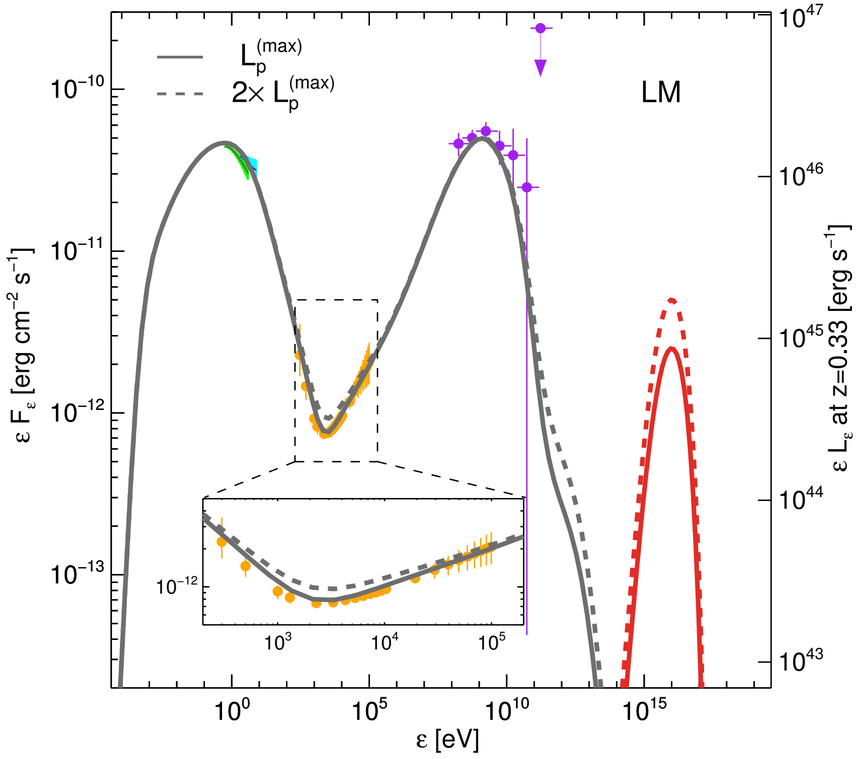


Inefficient proton acceleration

$$E_{\rm CR,max} \sim \left(\frac{\eta}{10^{-4}}\right)\left(\frac{B}{0.35\ {\rm G}}\right)\left(\frac{R'}{10^{16}\ {\rm cm}}\right)\left(\frac{\Gamma}{25}\right) \sim 5\times 10^{15}\ {\rm eV}$$

Keivani et al, 2018, ApJ, 864, 84

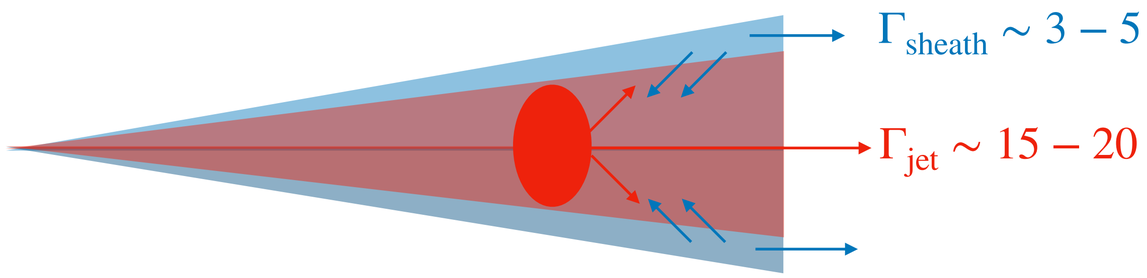
(see also MAGIC Coll. Astrophys.J. 863 (2018) L10)



Baryon loading = 1500
(Based on LMPL2B model of
Keivani et al, 2018, ApJ, 864, 84)

Scenario B

Ghisellini, Tavecchio, Chiaberge 2005
Tavecchio & Ghisellini 2014



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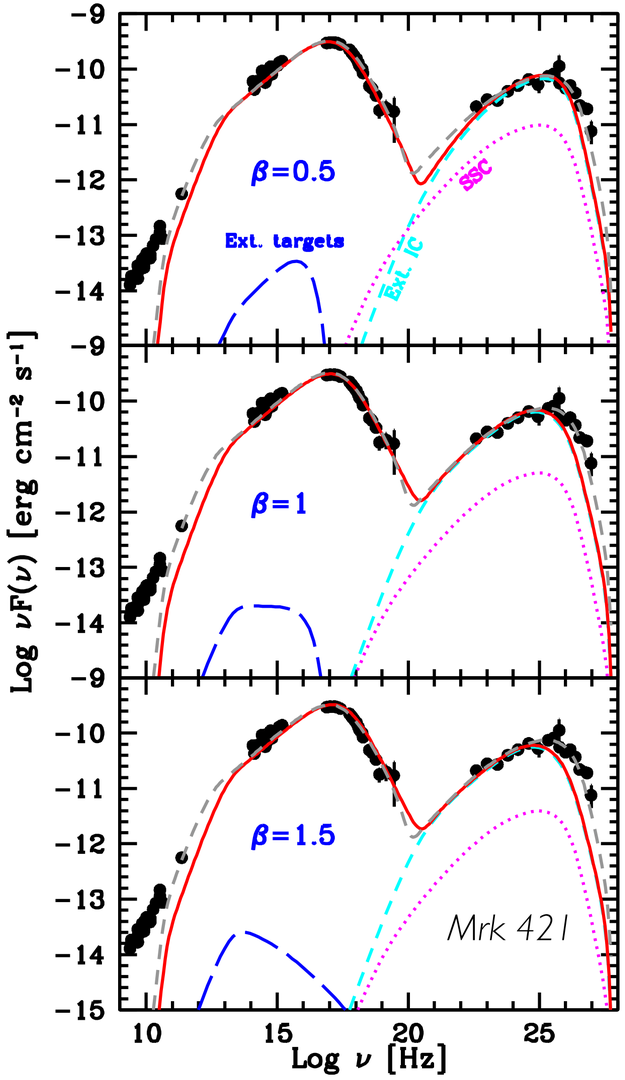
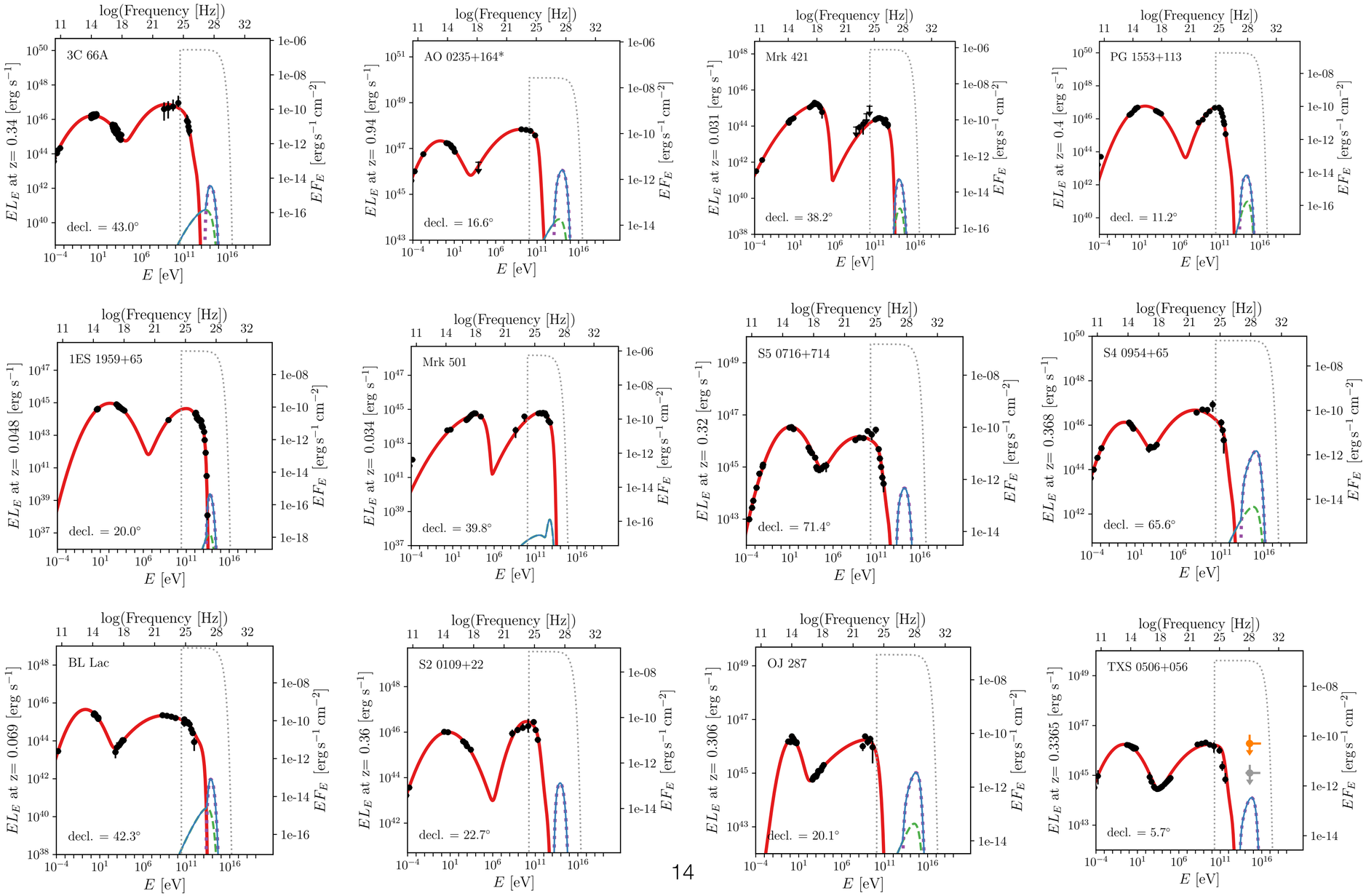
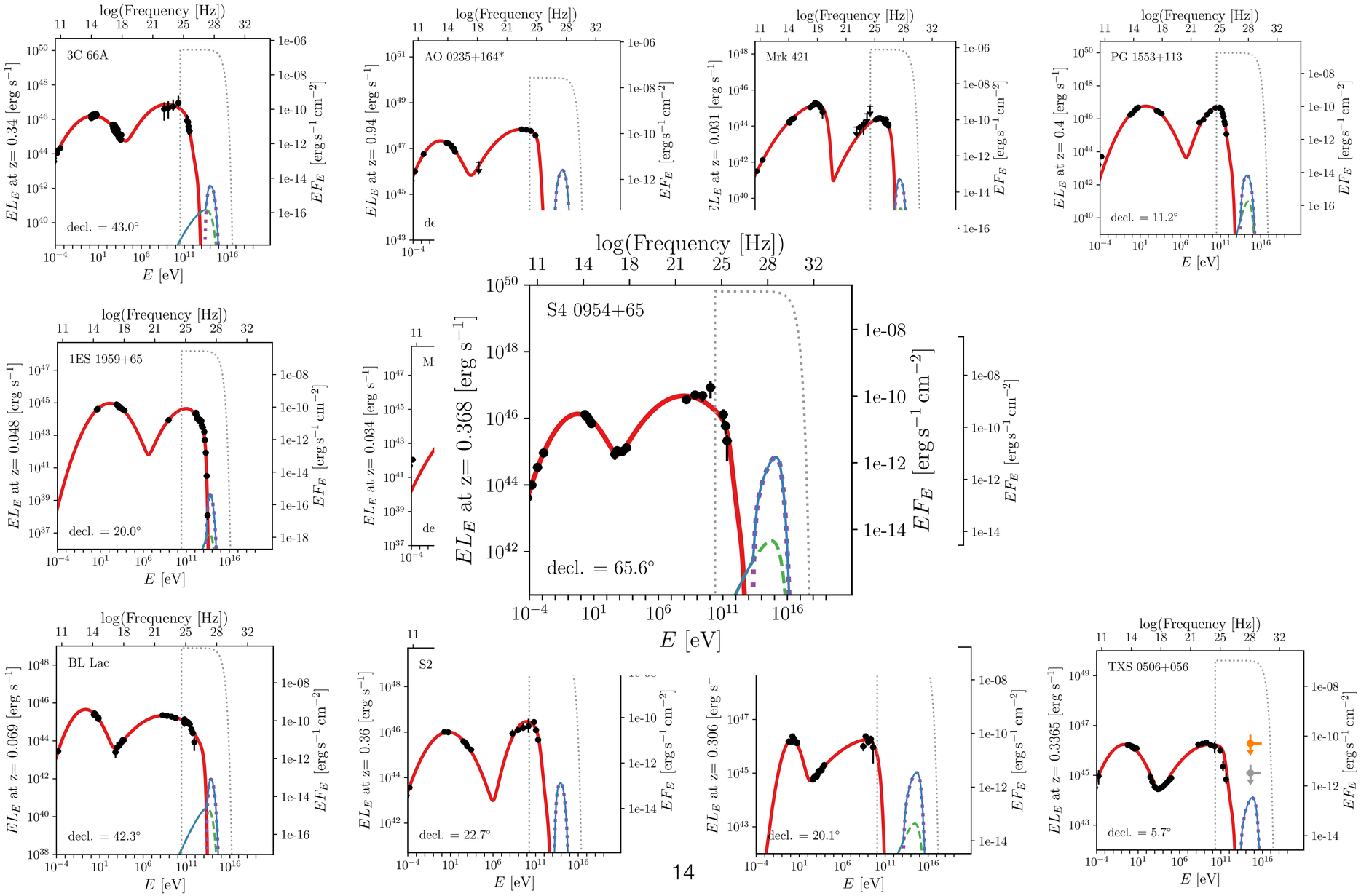
Tavecchio, FO, Righi, MNRAS accepted, 2019
arXiv:1906.02521



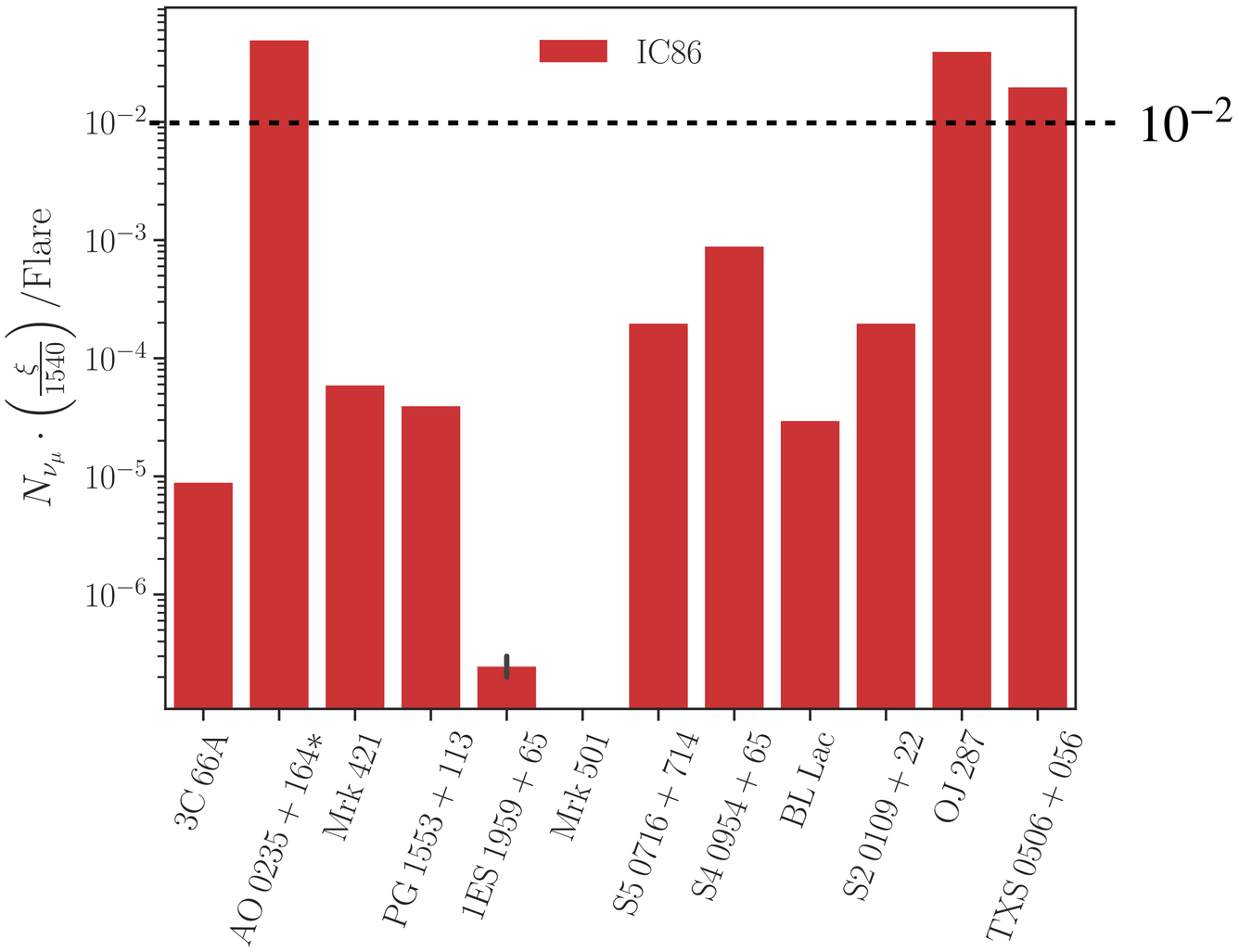
Scenario B


3C 66A
decl. = 43.0°
AO 0235+164*
decl. = 16.6°
Mrk 421
decl. = 38.2°
PG 1553+113
decl. = 11.2°
1ES 1959+65
decl. = 20.0°
Mrk 501
decl. = 39.8°
S5 0716+714
decl. = 71.4°
S4 0954+65
decl. = 65.6°
BL Lac
decl. = 42.3°
S2 0109+22
decl. = 22.7°
OJ 287
decl. = 20.1°
TXS 0506+056
decl. = 5.7°
log(Frequency [Hz])
E [eV]
EL_E at z= 0.34 [erg s^-1]
EL_E at z= 0.94 [erg s^-1]
EL_E at z= 0.031 [erg s^-1]
EL_E at z= 0.4 [erg s^-1]
EL_E at z= 0.048 [erg s^-1]
EL_E at z= 0.034 [erg s^-1]
EL_E at z= 0.32 [erg s^-1]
EL_E at z= 0.368 [erg s^-1]
EL_E at z= 0.069 [erg s^-1]
EL_E at z= 0.36 [erg s^-1]
EL_E at z= 0.306 [erg s^-1]
EL_E at z= 0.3365 [erg s^-1]
EF_E [erg s^-1 cm^-2]

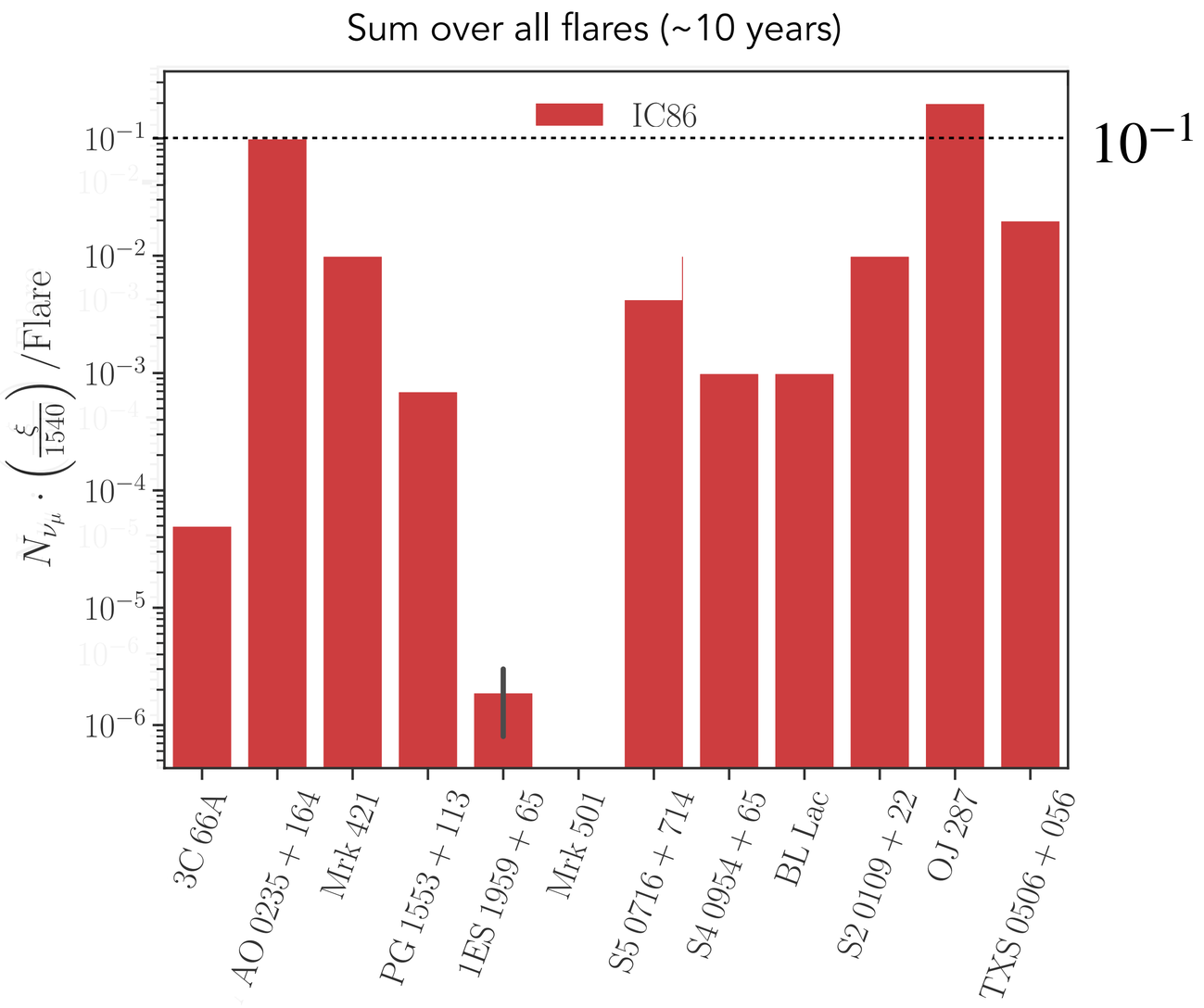
Scenario B


log(Frequency [Hz])
3C 66A
decl. = 43.0°
AO 0235+164*
Mrk 421
PG 1553+113
decl. = 11.2°
1ES 1959+65
decl. = 20.0°
S4 0954+65
decl. = 65.6°
BL Lac
decl. = 42.3°
S2
decl. = 22.7°
decl. = 20.1°
TXS 0506+056
decl. = 5.7°
E [eV]

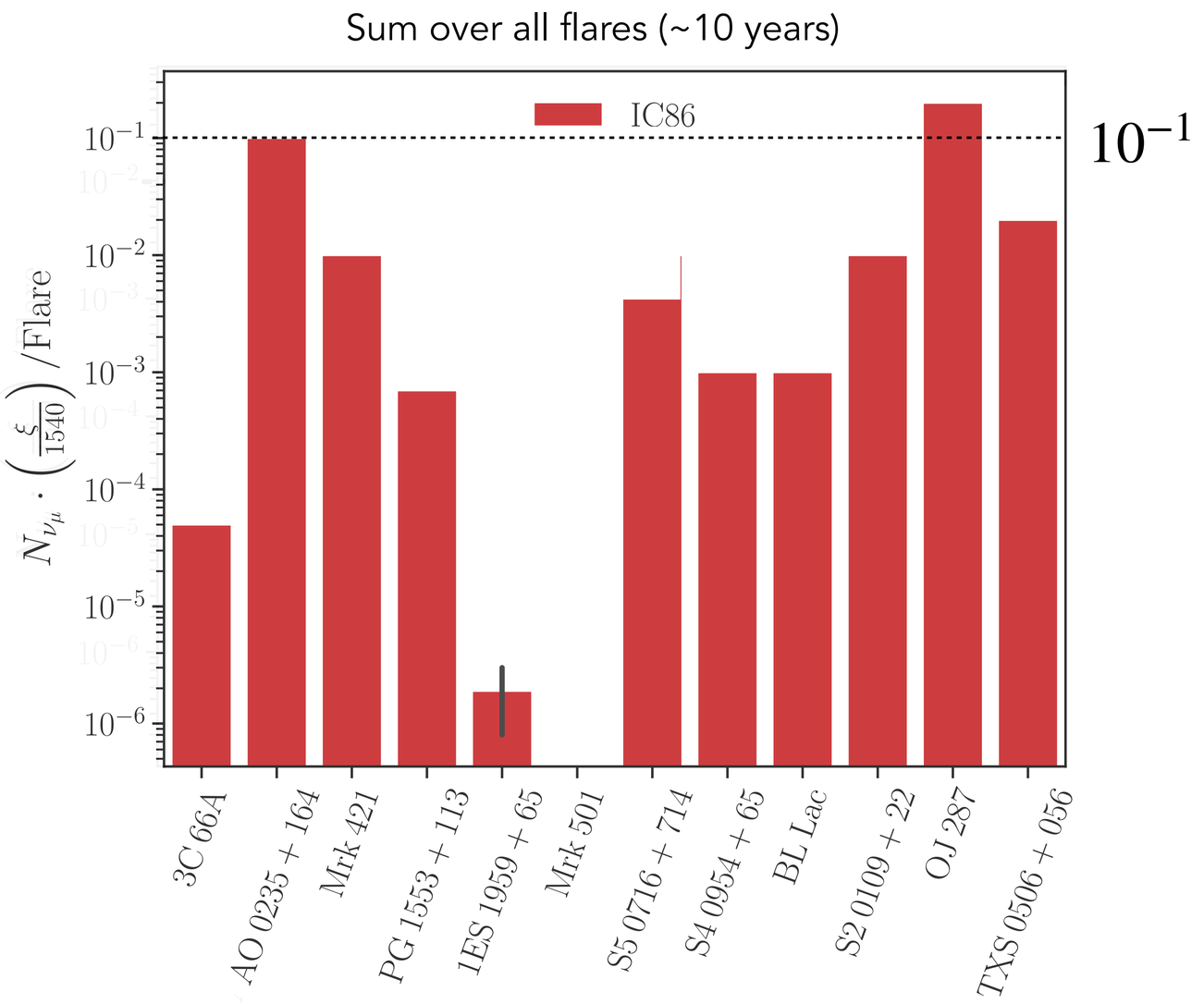
Scenario B

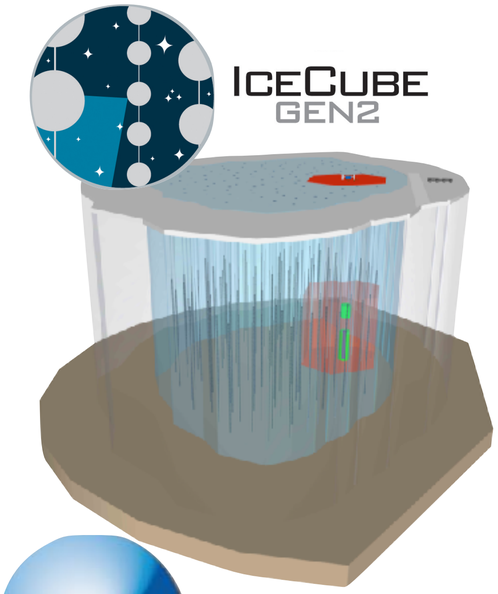

IC86
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
$N_{\nu_\mu} \cdot \left(\frac{\xi}{1540}\right)$ /Flare
10^{-2}
3C 66A
AO 0235 + 164*
Mrk 421
PG 1553 + 113
1ES 1959 + 65
Mrk 501
S5 0716 + 714
S4 0954 + 65
BL Lac
S2 0109 + 22
OJ 287
TXS 0506 + 056

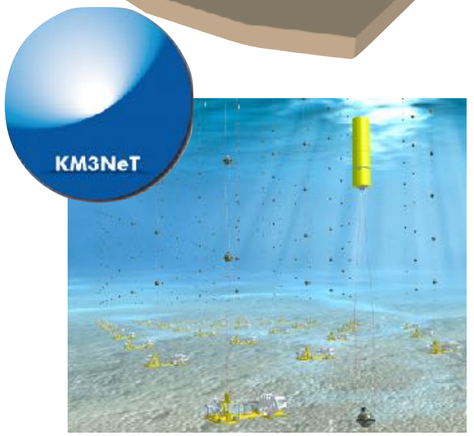
Scenario B


Sum over all flares (~10 years)
IC86
10^{-1}
$N_{\nu_\mu} \cdot \left(\frac{\xi}{1540}\right)$ /Flare
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
3C 66A
AO 0235 + 164
Mrk 421
PG 1553 + 113
1ES 1959 + 65
Mrk 501
S5 0716 + 714
S4 0954 + 65
BL Lac
S2 0109 + 22
OJ 287
TXS 0506 + 056

Scenario B


Sum over all flares (~10 years)
IC86
10^{-1}
$N_{\nu_\mu} \cdot \left(\frac{\xi}{1540}\right)$ /Flare
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
3C 66A
AO 0235 + 164
Mrk 421
PG 1553 + 113
1ES 1959 + 65
Mrk 501
S5 0716 + 714
S4 0954 + 65
BL Lac
S2 0109 + 22
OJ 287
TXS 0506 + 056

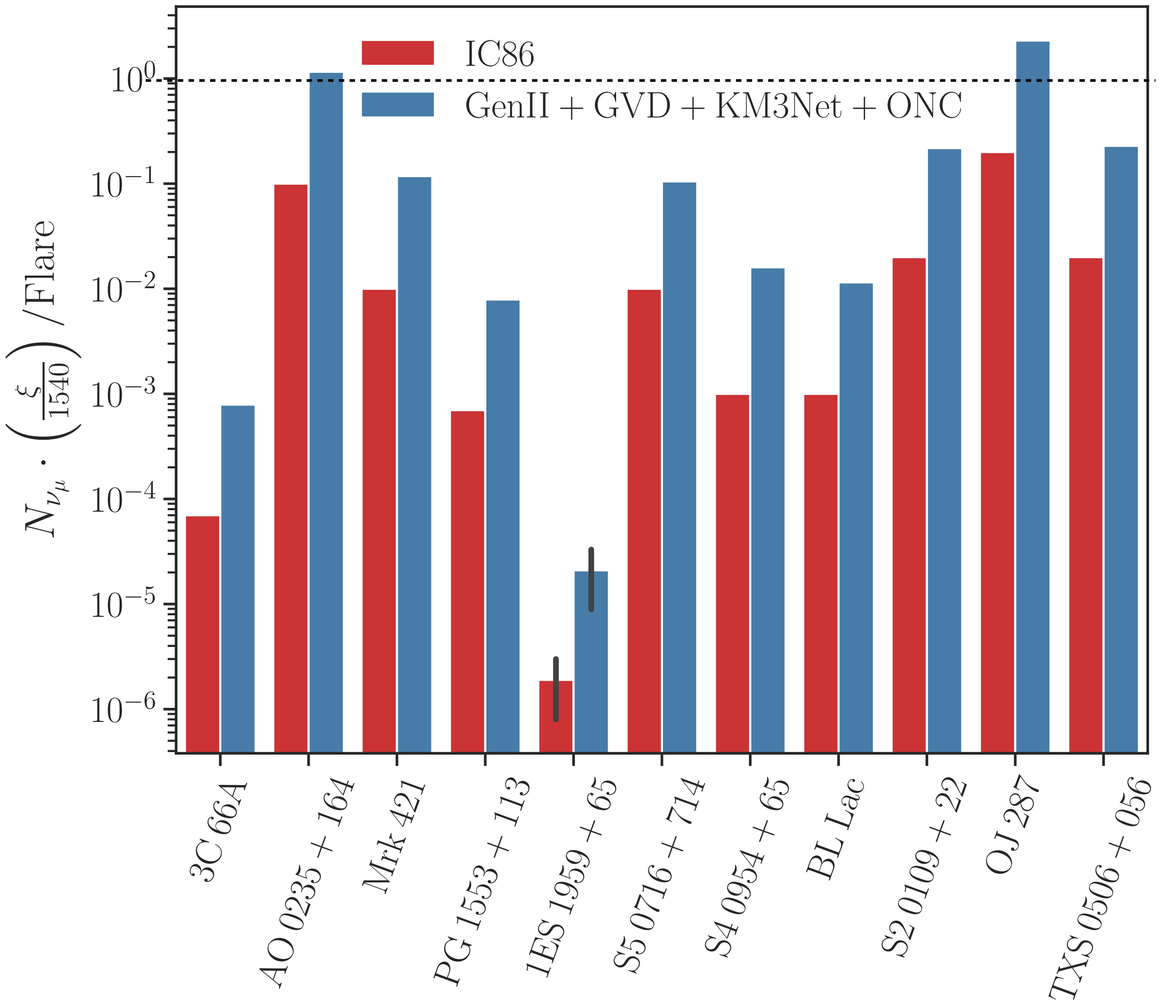

ICECUBE
GEN2


KM3NeT

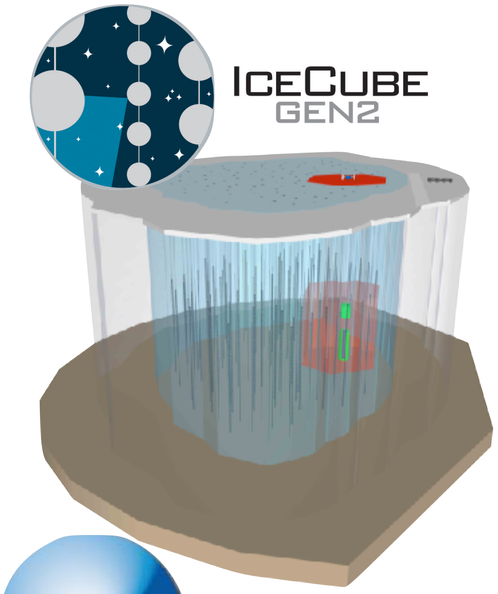
THE LAKE BAIKAL
NEUTRINO TELESCOPE

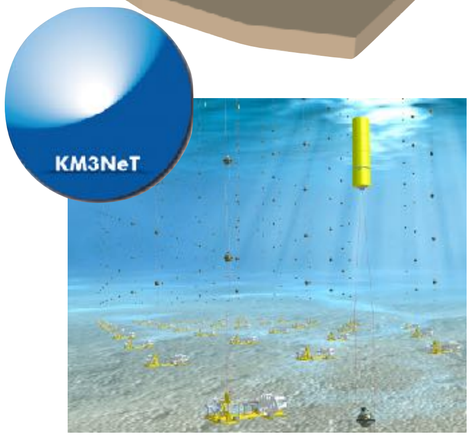
OCEAN
NETWORKS
CANADA

Scenario B


IC86
GenII + GVD + KM3Net + ONC
$N_{\nu_\mu} \cdot \left(\frac{\xi}{1540}\right)$ /Flare
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
3C 66A
AO 0235 + 164
Mrk 421
PG 1553 + 113
1ES 1959 + 65
S5 0716 + 714
S4 0954 + 65
BL Lac
S2 0109 + 22
OJ 287
TXS 0506 + 056

1


ICECUBE
GEN2

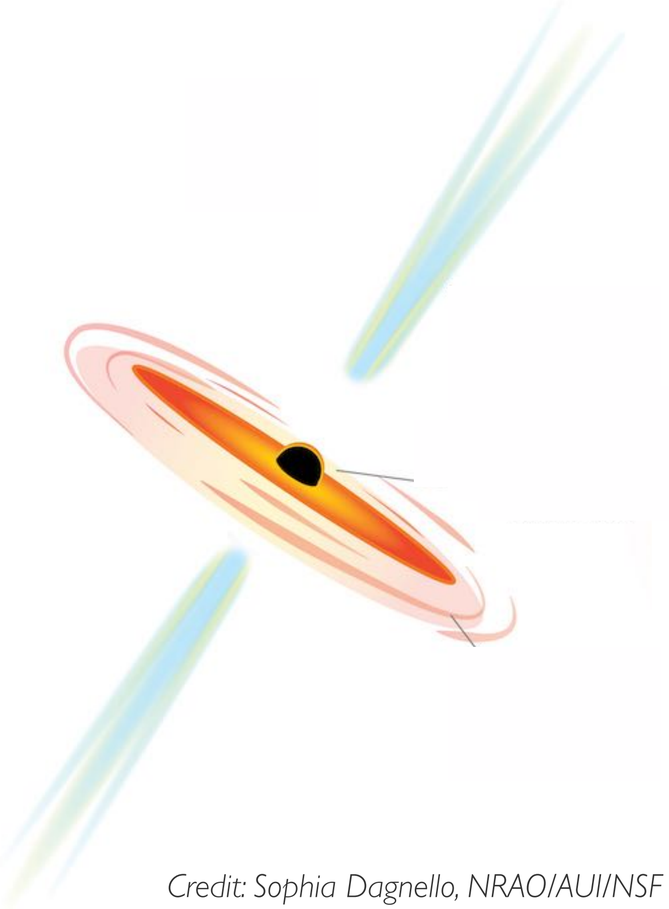

KM3NeT

THE LAKE BAIKAL
NEUTRINO TELESCOPE

OCEAN
NETWORKS
CANADA

Summary

- Individual or stacked flares challenging to detect with IceCube in simple lepto-hadronic scenarios
- TXS 0506+056 like flares identifiable with next generation detectors or constraining upper limit to proton content
- Strong dependence of neutrino expectation on physical parameters (baryon loading, doppler factor, magnetic field strength, external photon field energy density)
- To identify the brightest neutrino flares precise astronomical measurements needed

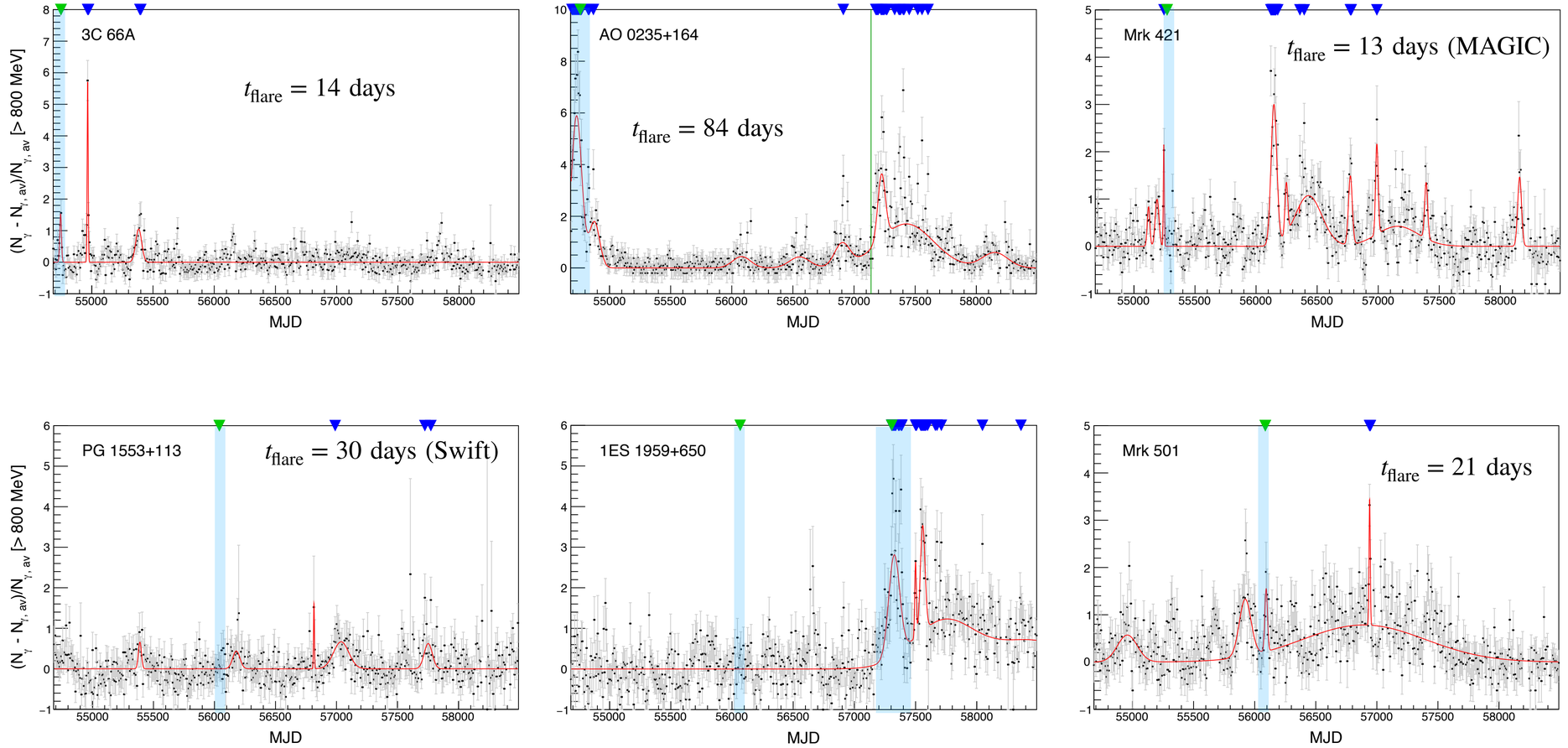


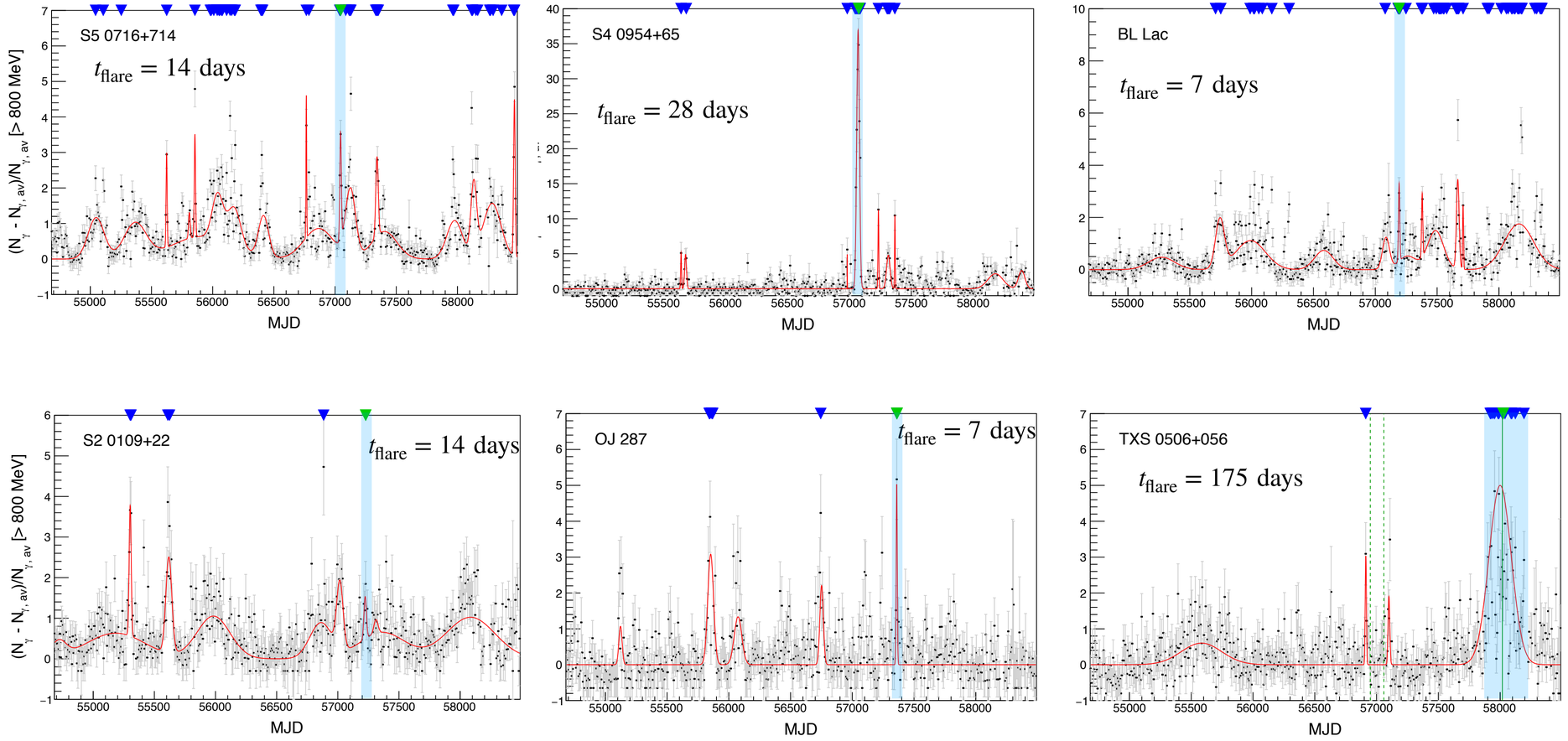
Credit: Sophia Dagnello, NRAO/AUI/NSF

Back-up

FAVA Lightcurves

light curves made using FAVA data, Abdollahi et al 2016, [from FO, Murase, Padovani, Resconi, Mészáros, arXiv:1906.05302]



FAVA Lightcurves

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