Insights from modelling the brightest *Fermi*-LAT blazar flare

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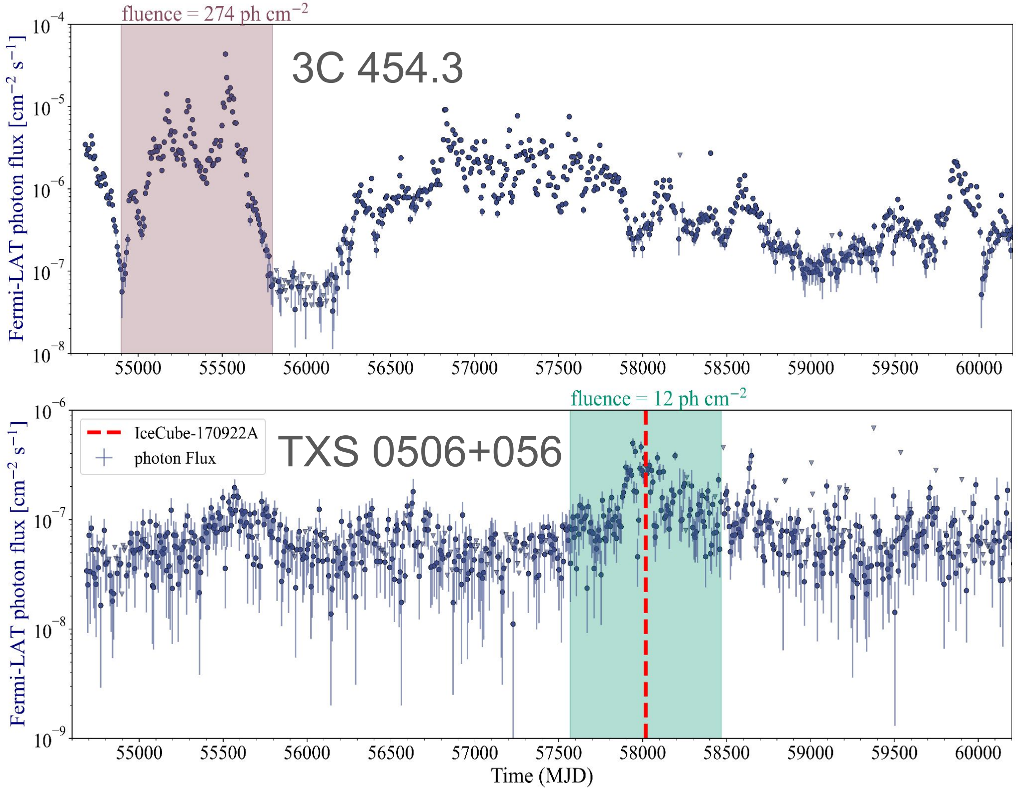
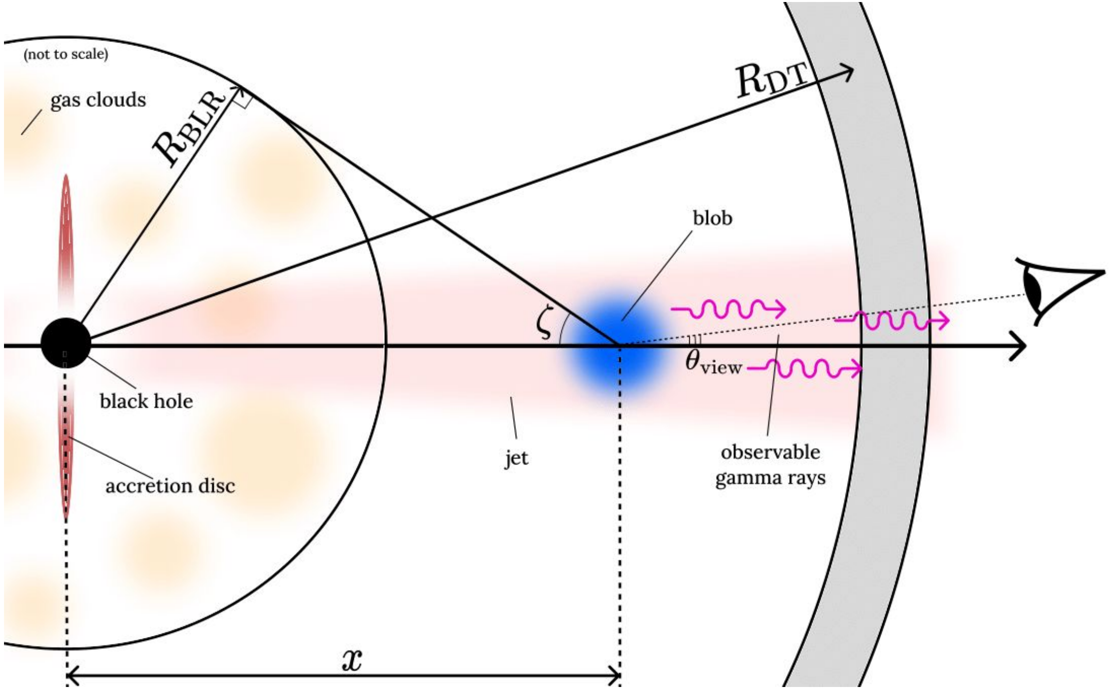
Motivation

- ➢ γ-ray fluence in the 2009-2010 3C 454.3 outburst was ~20 times higher than the fluence around IceCube-170922A!
- ➢ ~20 times more neutrinos?



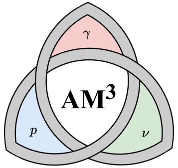
Motivation

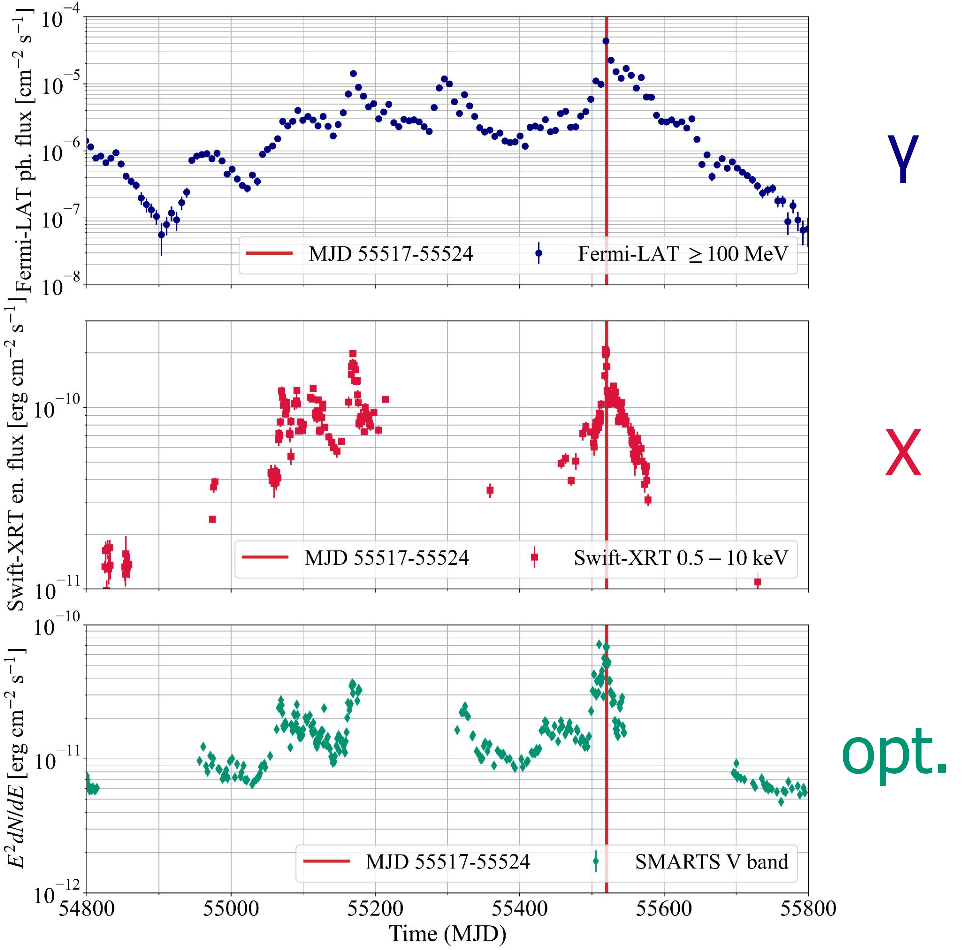
- ➢ 3C 454.3 – brightest *Fermi*-LAT FSRQ
- ➢ FSRQs host strong photon fields from accretion disks and broad-line regions
- ➢ During flares – enhanced luminosity and/or Doppler factor
- ➢ Background limited by the flare time window



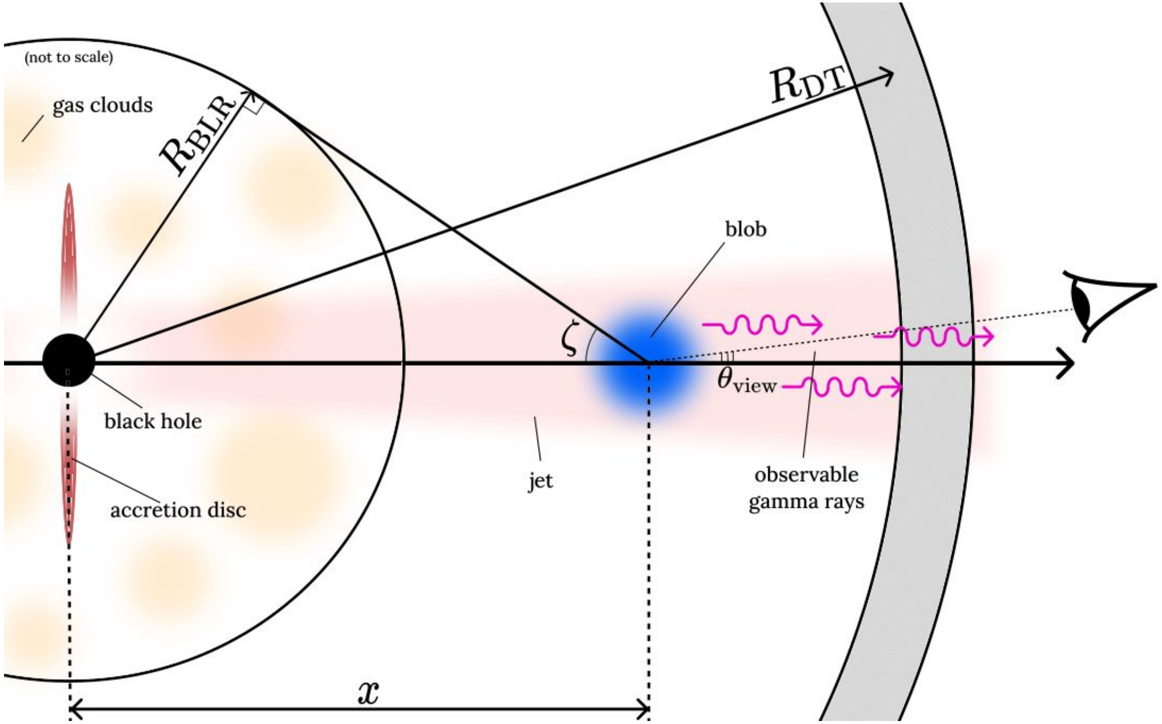
Data analysis

- Quasi-simultaneous analysis of γ-ray, X-ray, UV/optical/IR data around peak of Nov. 2010 flare of 3C 454.3
- Time-dependent modelling of the observed SEDs with AM^3



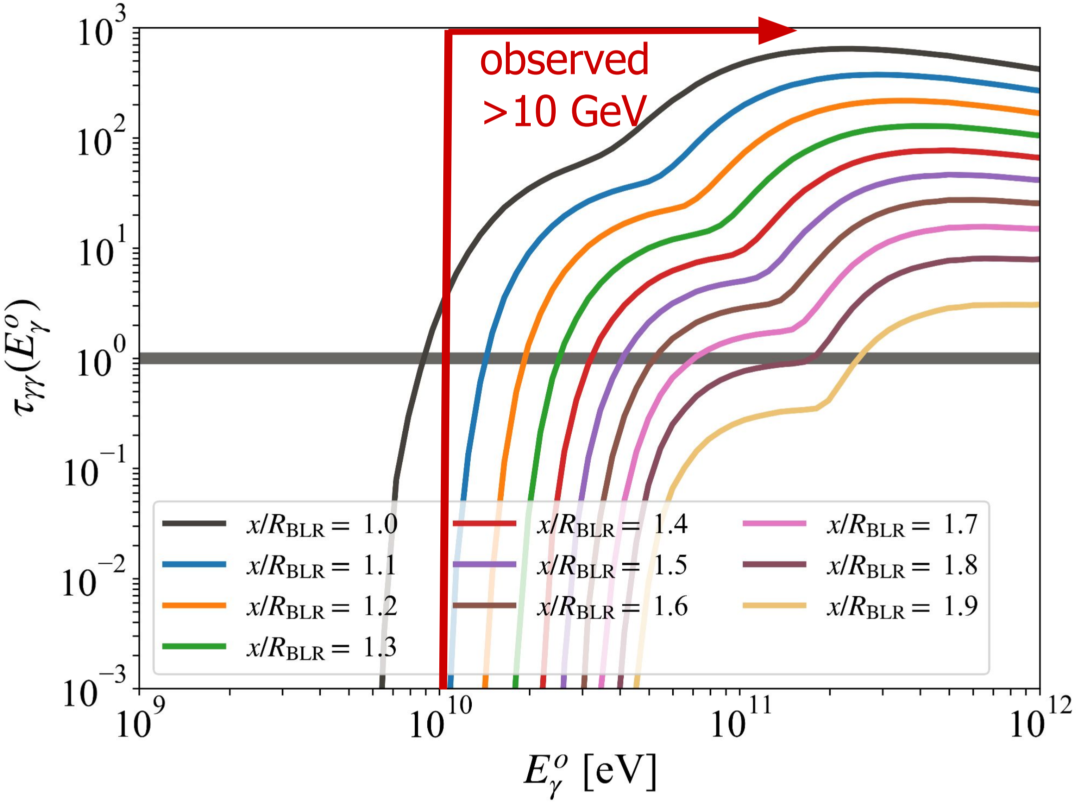


Is the blob inside the broad-line region?

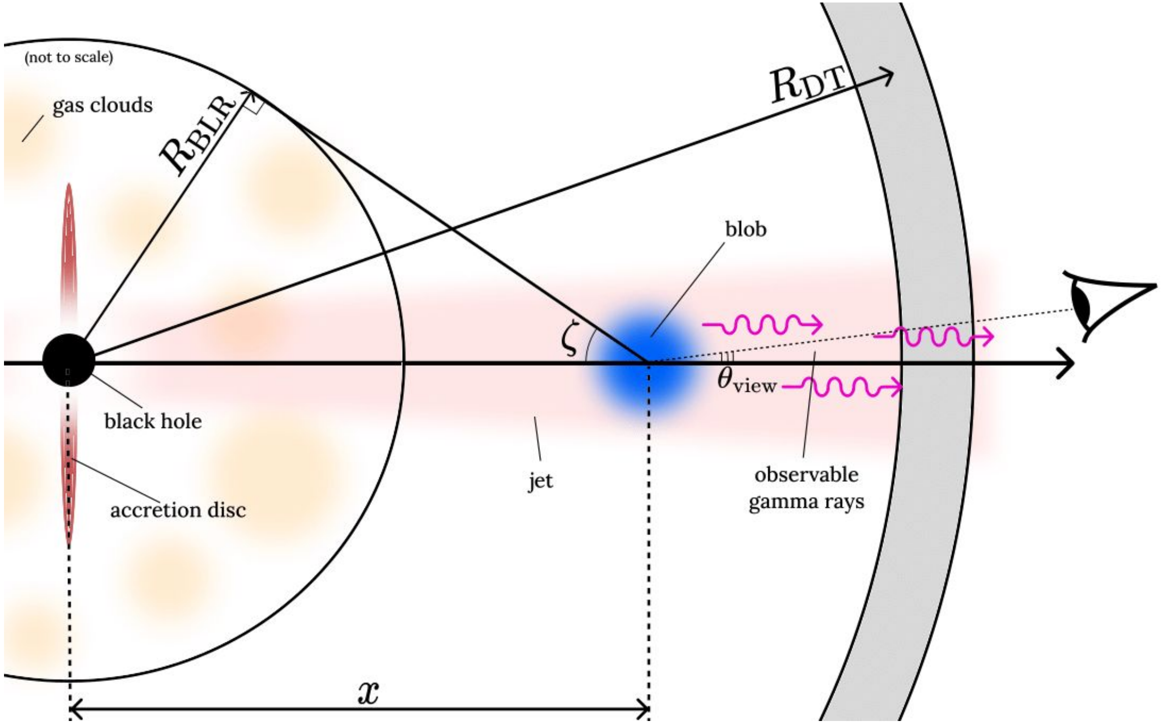


Location of the emitting region

- For all days of the flare, *Fermi*-LAT observes >10 GeV photons
- The blob is outside the broad-line region

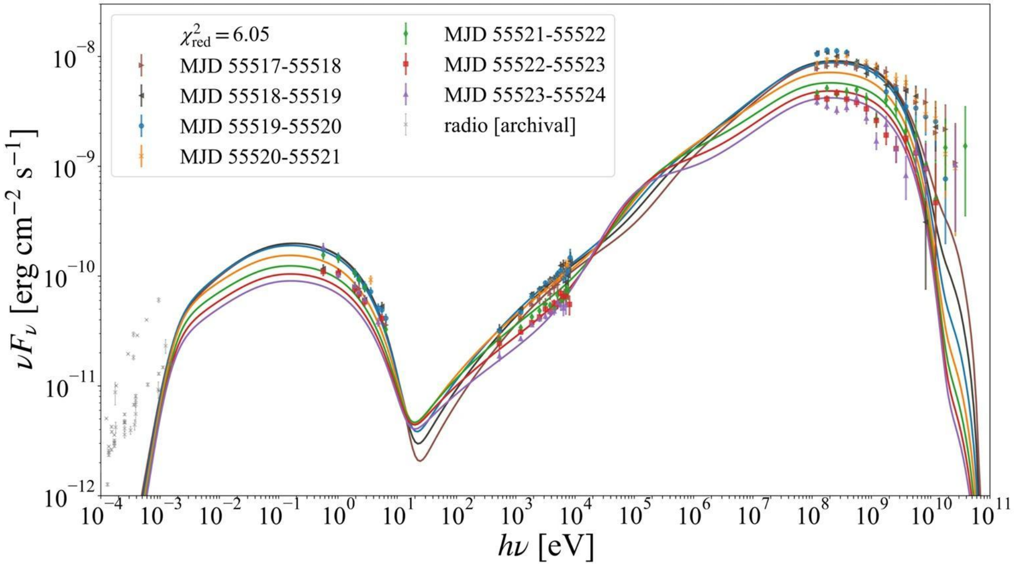


Is the emitting region a “moving” or “standing” blob?



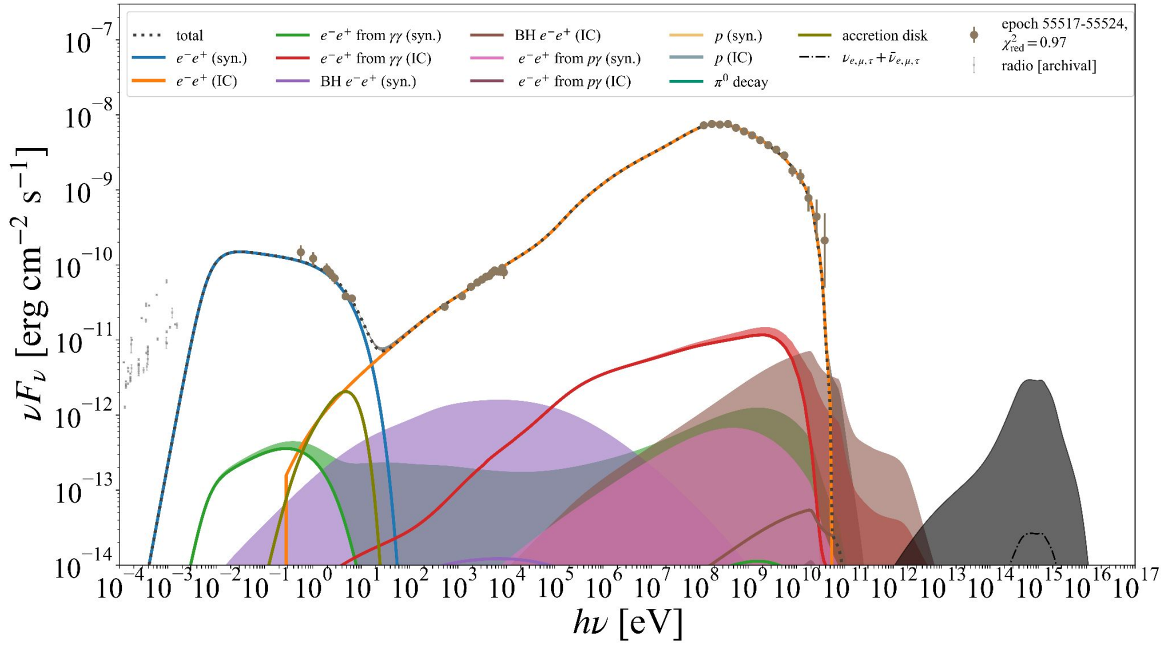
No “moving” blob

- “Moving-blob” model poorly describes the data
- Within a week, the blob is already $>10R_{BLR}$ away $\Rightarrow$ not enough target photons for the external Compton!
- The blob size is too big to explain ~h-scale variability!



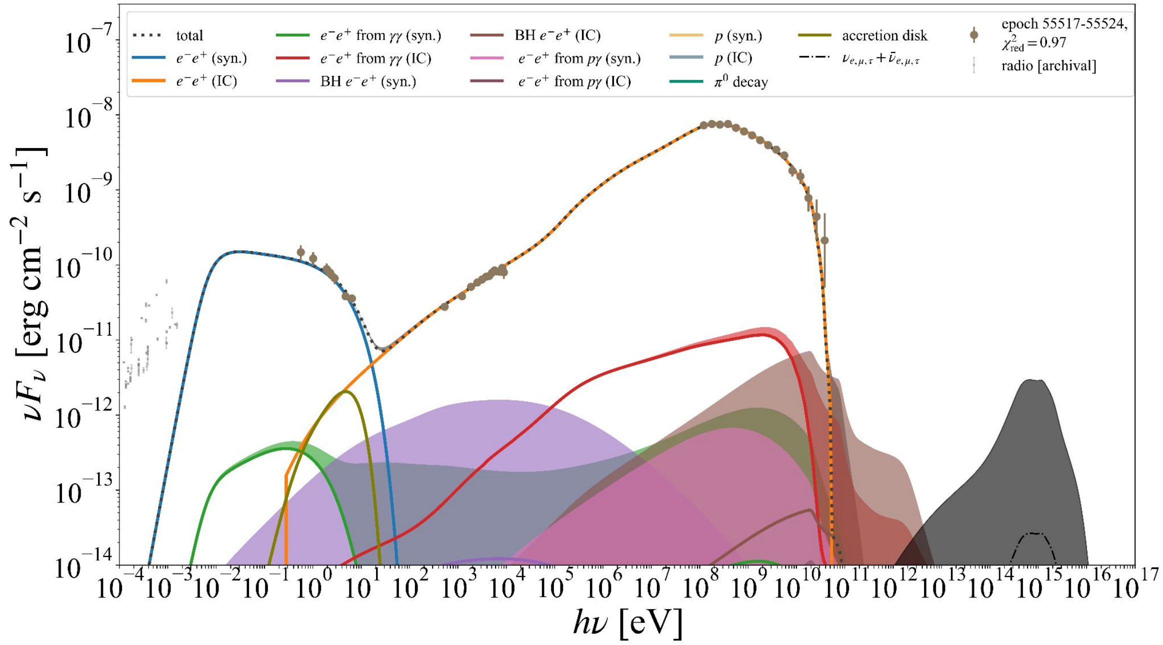
“Standing” blob

- “Standing-blob” pure leptonic model describes the data well
- Proton contribution is constrained by the X-ray data: proton to electron energy density ratio < 130



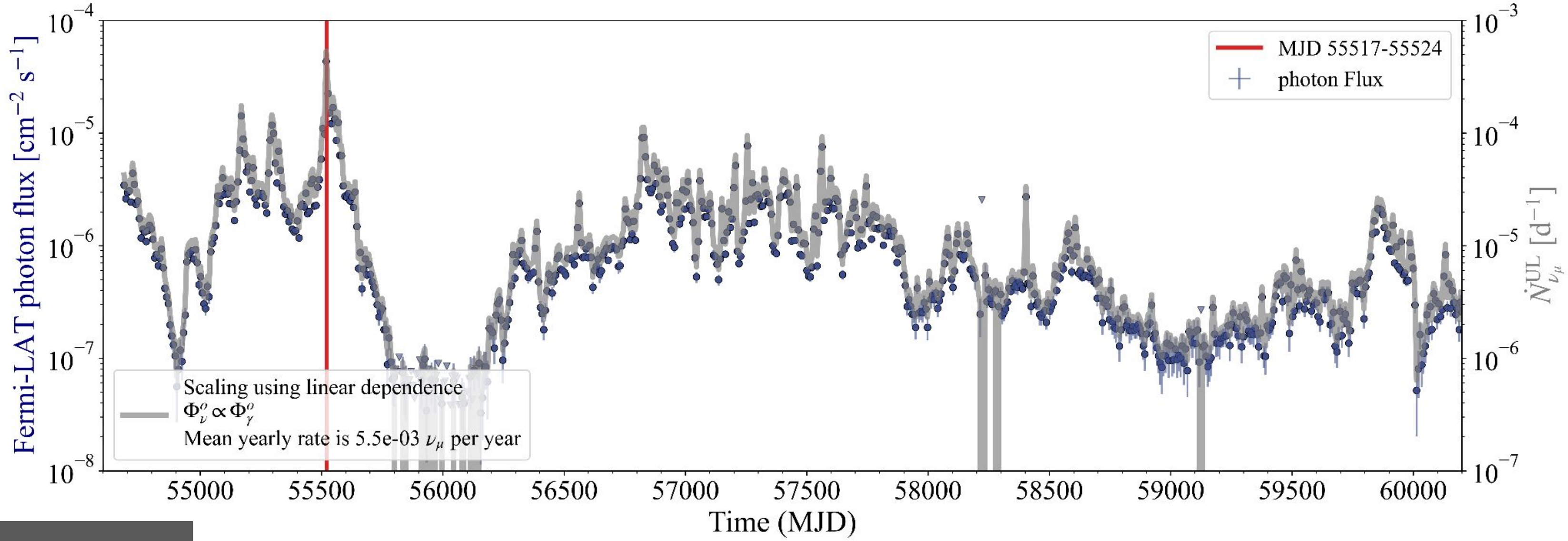
Neutrino production is limited ($E_\nu \geq 100$ TeV)

- Data indicate small maximum electron injection energy ~ 1 GeV
- Slow acceleration $\xi_{acc} \sim 10^7$, assuming the same acceleration efficiency for protons as for electrons, $E_p^{cut} \sim 10^{14}$ eV
- Slow photopion losses and deboosted BLR photon field



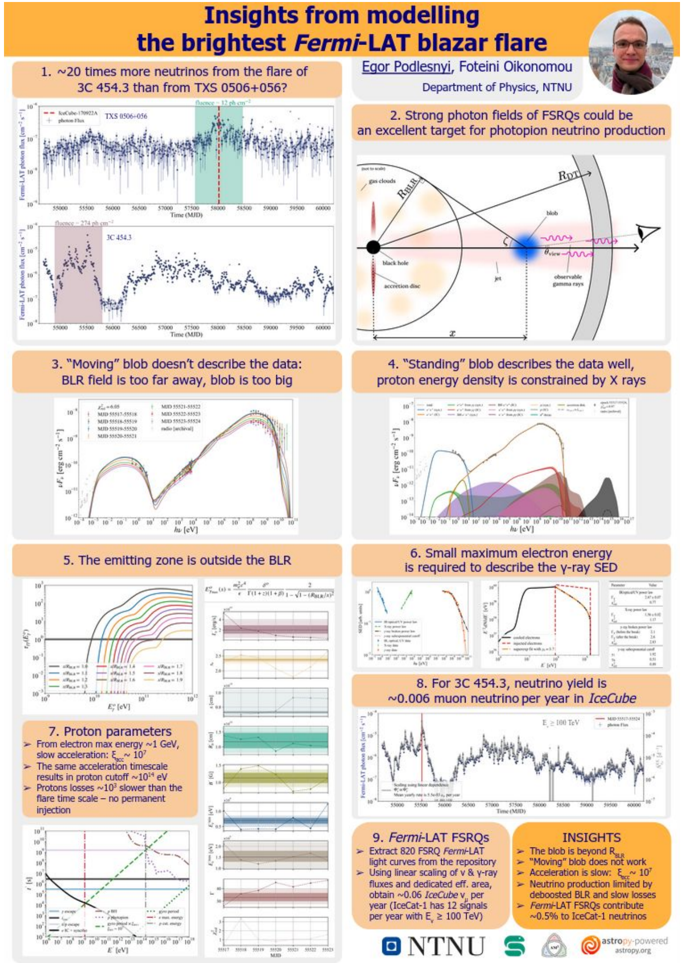
Neutrino production yield ($E_\nu \geq 100$ TeV)

- ~6×10^{-3} ν_μ per year in *IceCube* from 3C 454.3
- ~6×10^{-2} ν_μ per year in *IceCube* for all *Fermi*-LAT FSRQs
- ~0.5% contribution of *Fermi*-LAT FSRQs to the IceCat-1 neutrinos



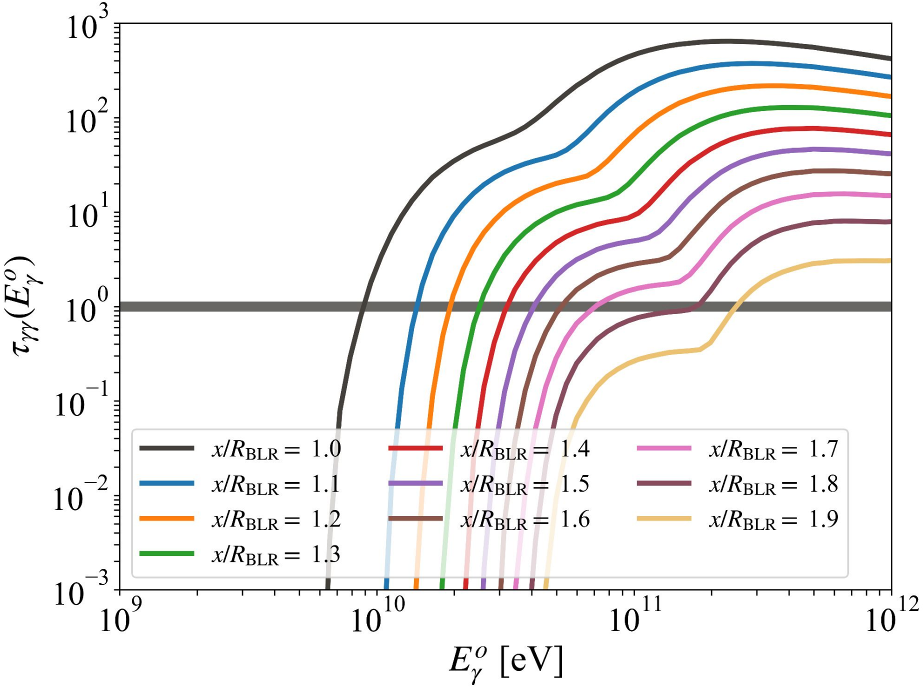
Summary

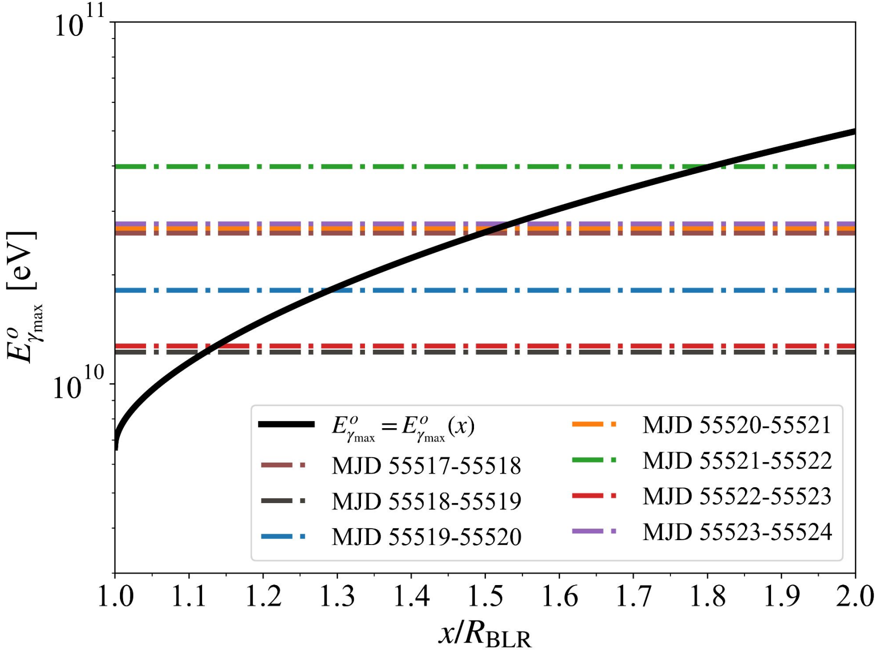
- ➢ The brightest *Fermi*-LAT blazar flare of 3C 454.3 modelled with time-dependent program AM^3 in a single-zone approach
- ➢ ~ 6×10^{-3} ν_μ per year in IceCube from 3C 454.3
- ➢ Extrapolation to all *Fermi*-LAT FSRQs results in ~ 0.5% contribution to the IceCat-1 neutrinos at energies ≥ 100 TeV



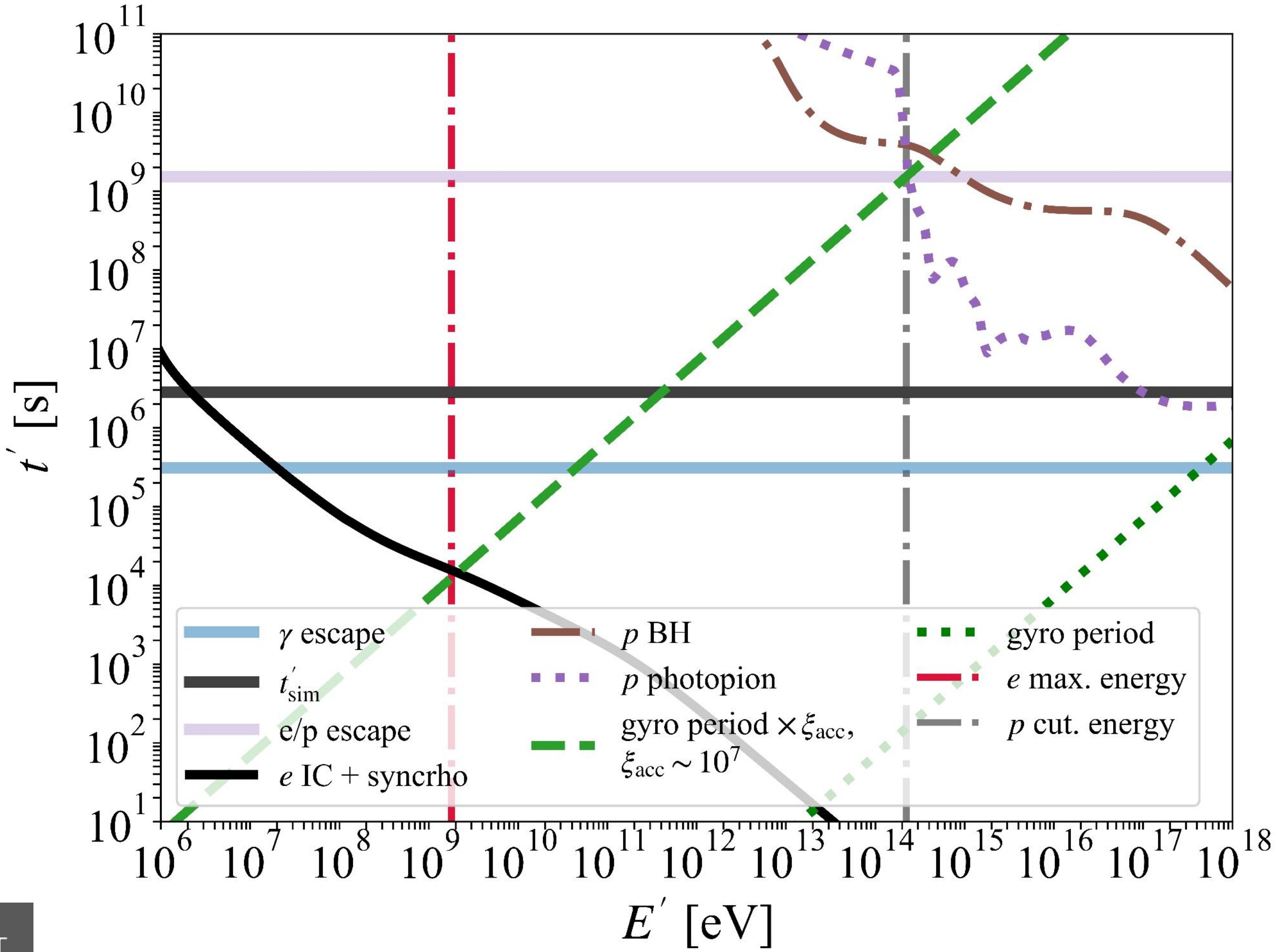
NTNU

Backup slides

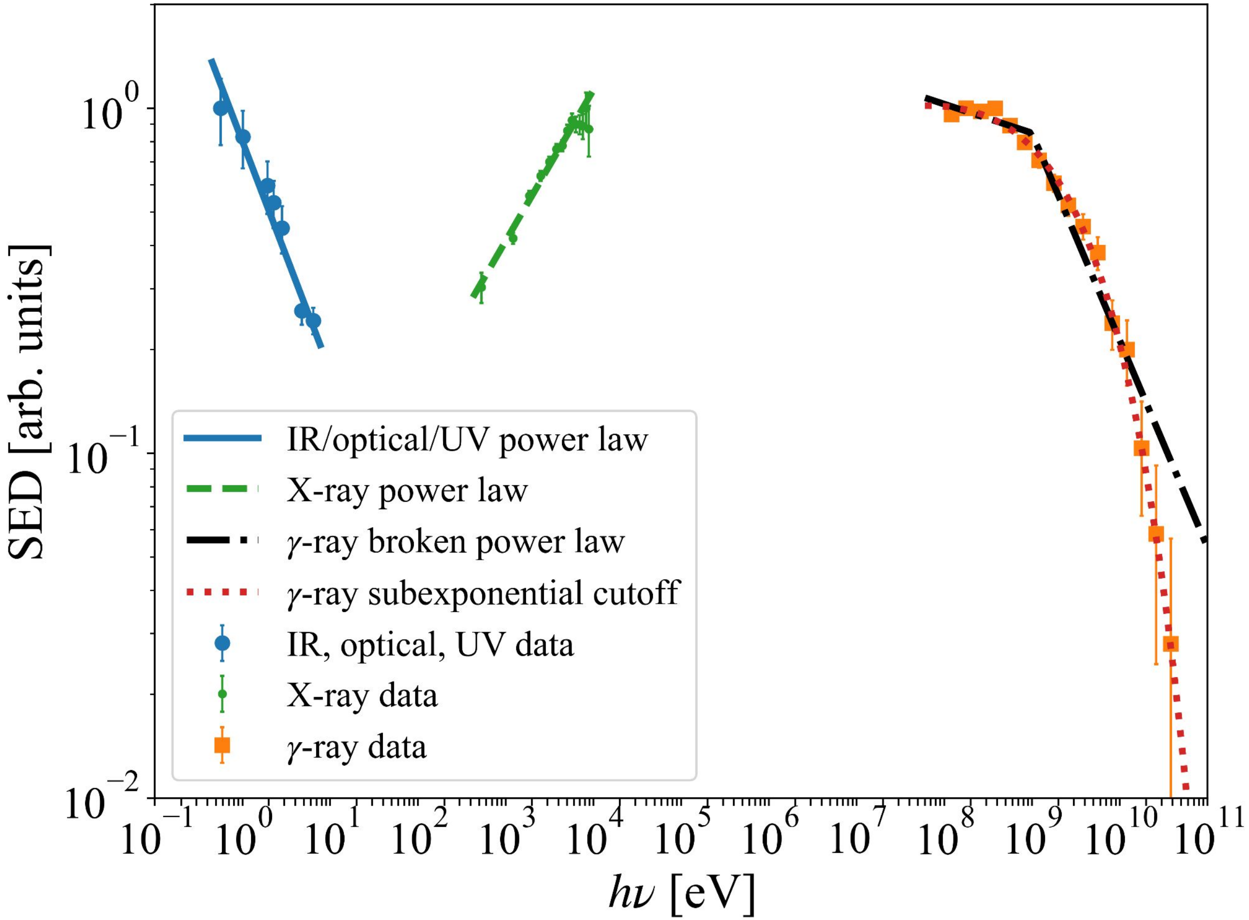




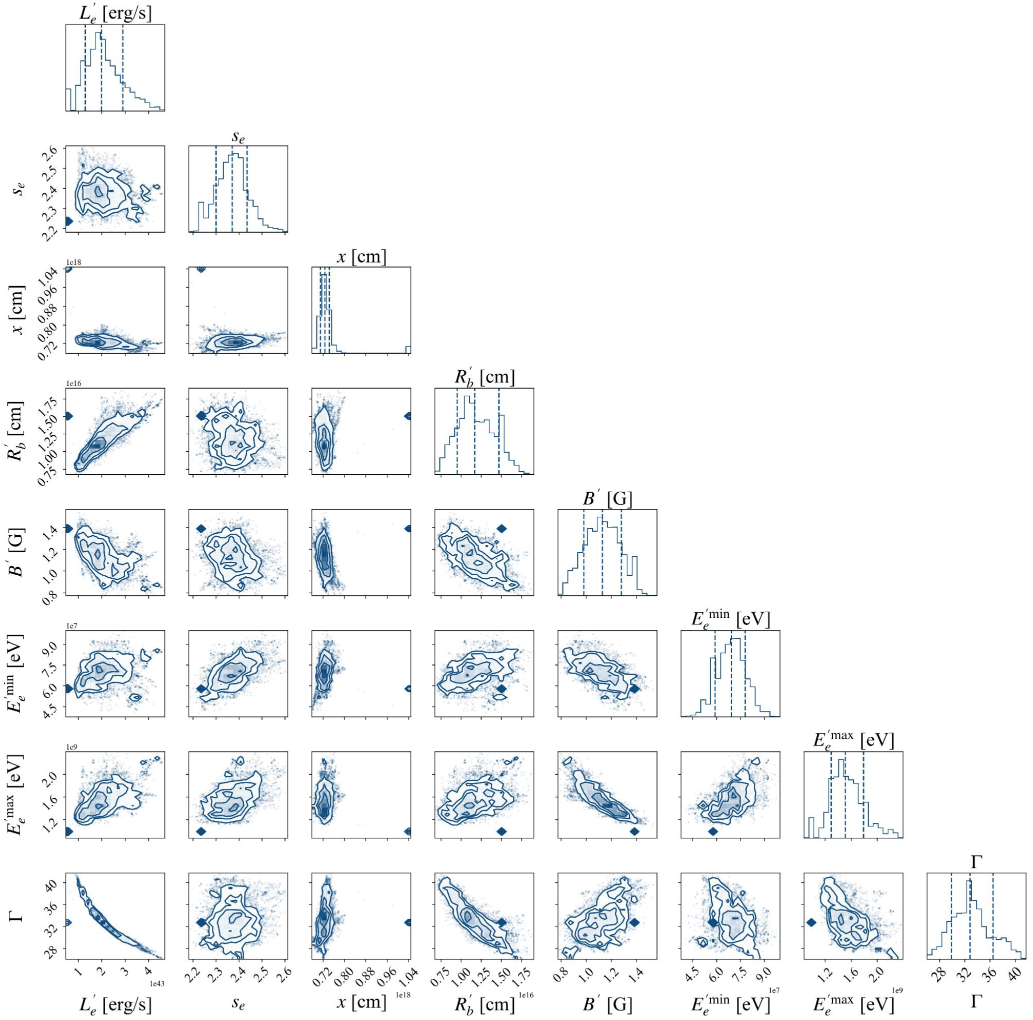
$$E^o_{\gamma_{max}}(x) = \frac{m_e^2 c^4}{\epsilon} \frac{\delta^o}{\Gamma(1+z)(1+\beta)} \frac{2}{1-\sqrt{1-(R_{BLR}/x)^2}}$$

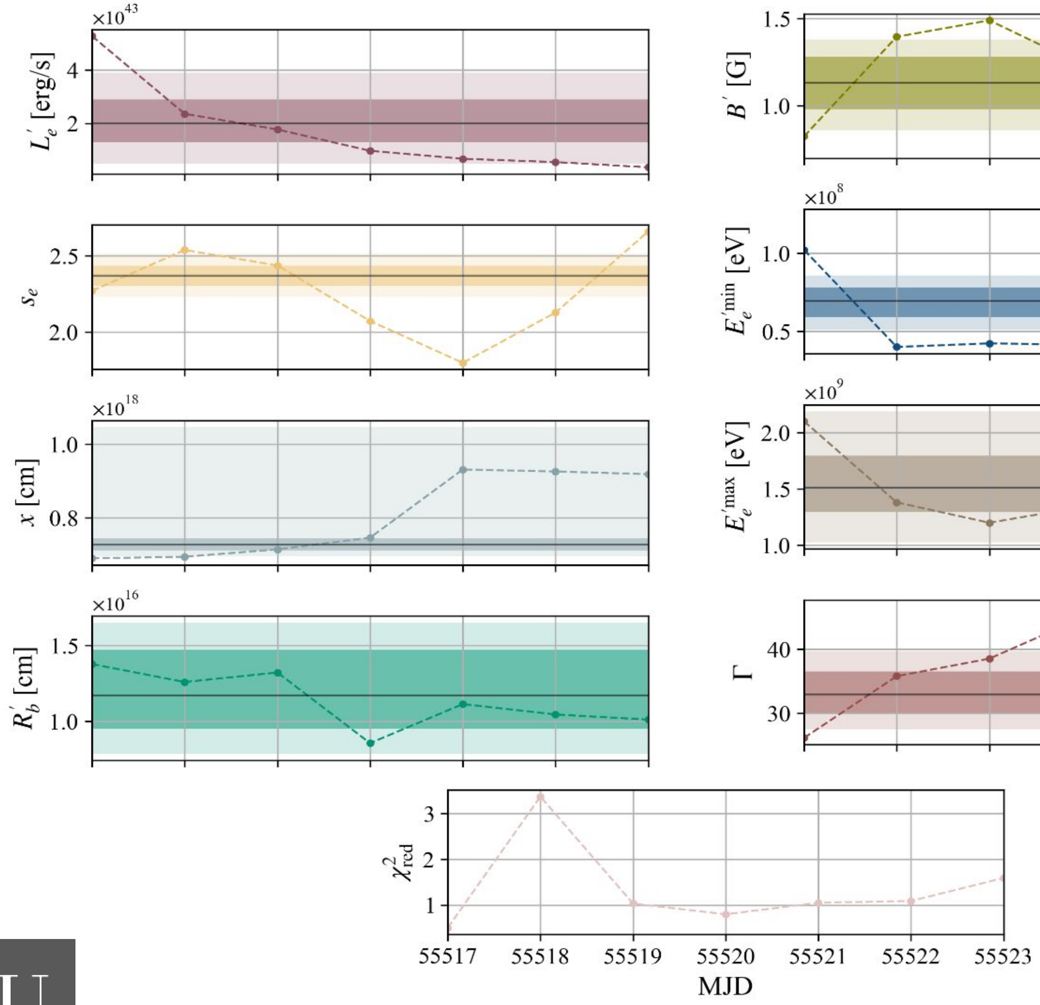


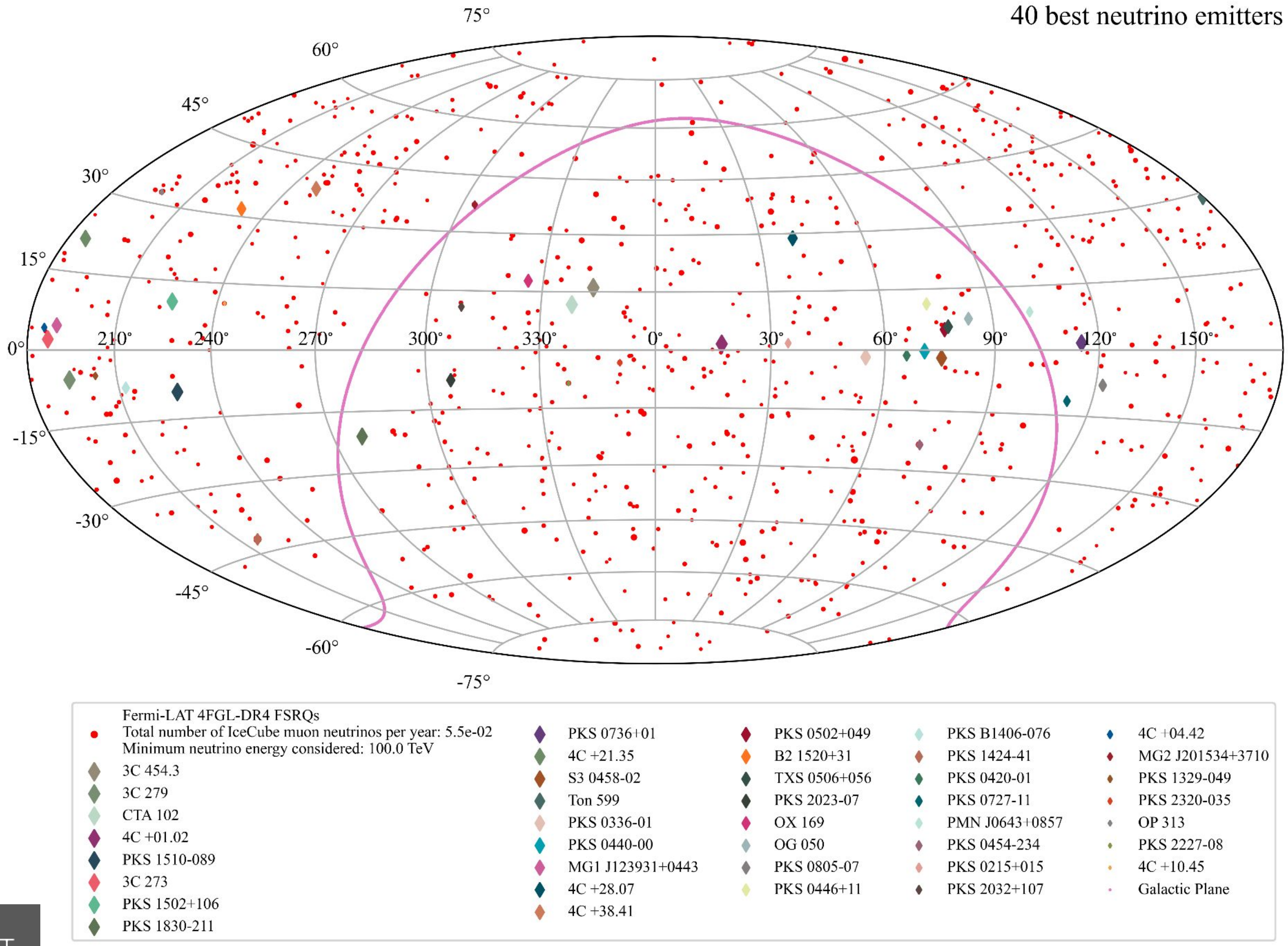
t' [s]
E' [eV]
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{6} 10^{7} 10^{8} 10^{9} 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18}
γ escape
$t'_{\rm sim}$
e/p escape
e IC + syncrho
p BH
p photopion
gyro period $\times\,\xi_{\rm acc}$, $\xi_{\rm acc}\sim 10^7$
gyro period
e max. energy
p cut. energy



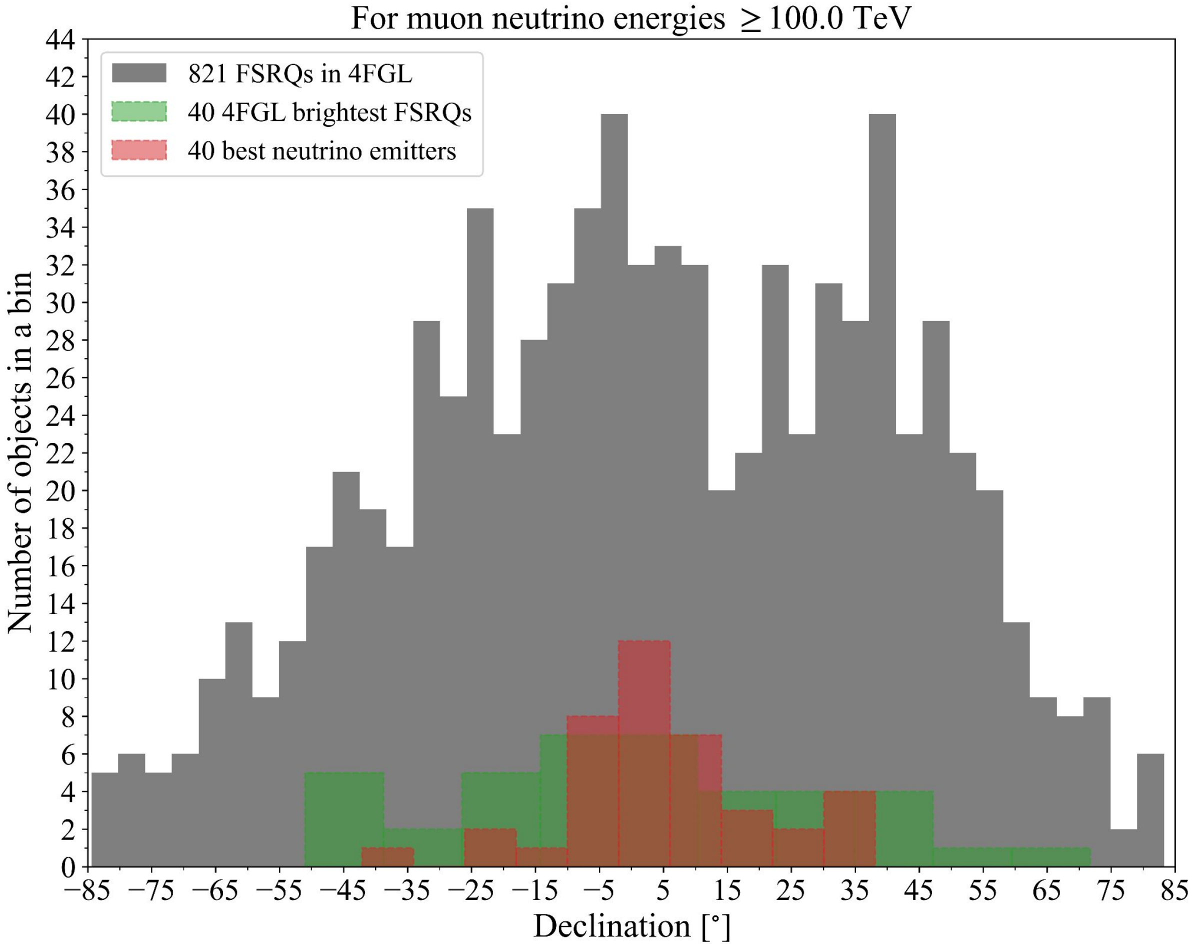
Parameter	Value
IR/optical/UV power law	
Γ_γ	2.67 ± 0.07
χ^2_{red}	0.77
X-ray power law	
Γ_γ	1.56 ± 0.02
χ^2_{red}	1.17
γ-ray broken power law	
Γ_γ (before the break)	2.1
Γ_γ (after the break)	2.6
χ^2_{red}	2.83
γ-ray subexponential cutoff	
γ_1	1.92
γ_b	0.51
χ^2_{red}	0.89


L_e' [erg/s]
s_e
x [cm]
R_b' [cm]
B' [G]
$E_e'^{min}$ [eV]
$E_e'^{max}$ [eV]
Γ
1e43
1e18
1e16
1e7
1e9


×10^43
L_e' [erg/s]
4
2
B' [G]
1.5
1.0
s_e
2.5
2.0
×10^8
$E_e'^{\rm min}$ [eV]
1.0
0.5
×10^18
x [cm]
1.0
0.8
×10^9
$E_e'^{\rm max}$ [eV]
2.0
1.5
1.0
×10^16
R_b' [cm]
1.5
1.0
Γ
40
30
$\chi^2_{\rm red}$
3
2
1
55517
55518
55519
55520
55521
55522
55523
MJD



TXS 0506+056 added manually



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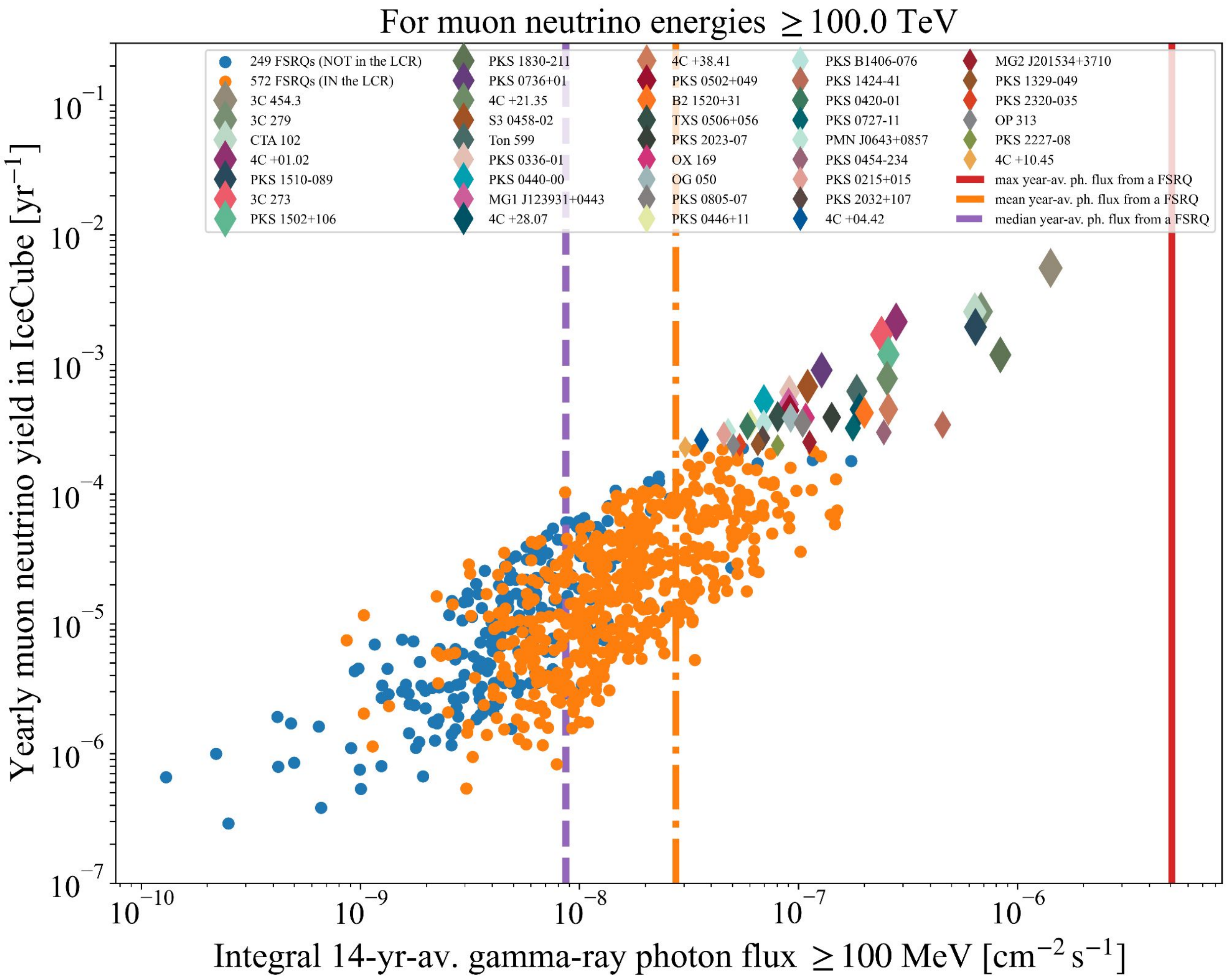

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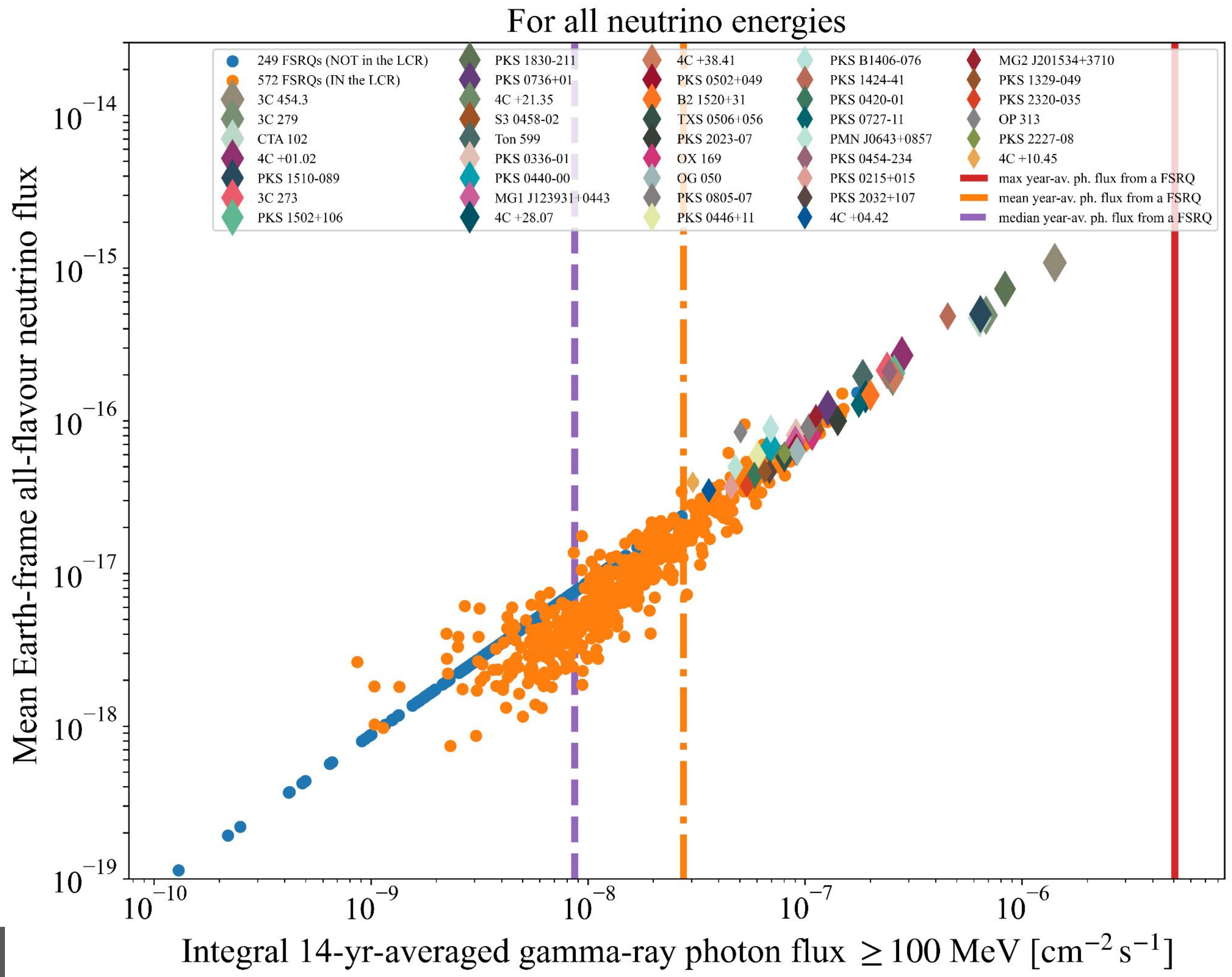

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