

Astrophysical interpretation of KM3-230213A

<https://multimessenger.desy.de/>

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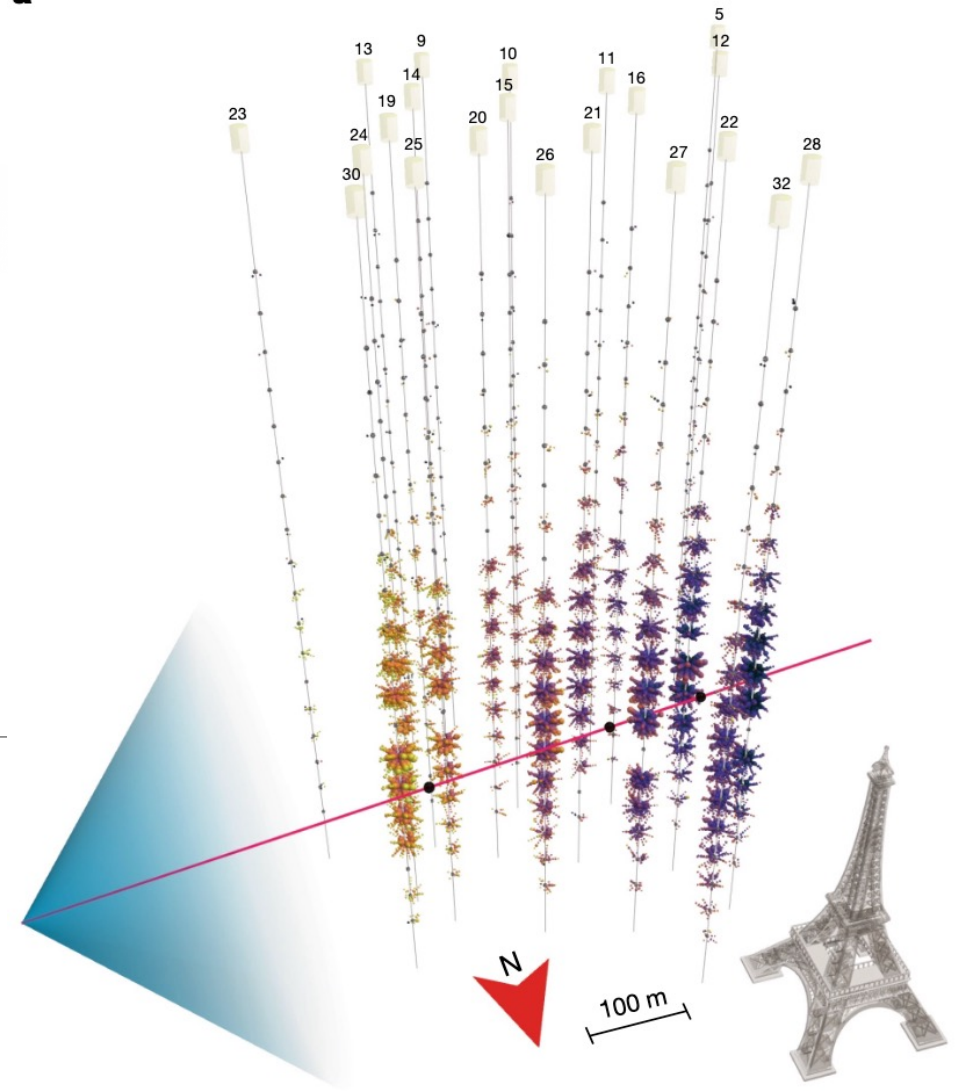
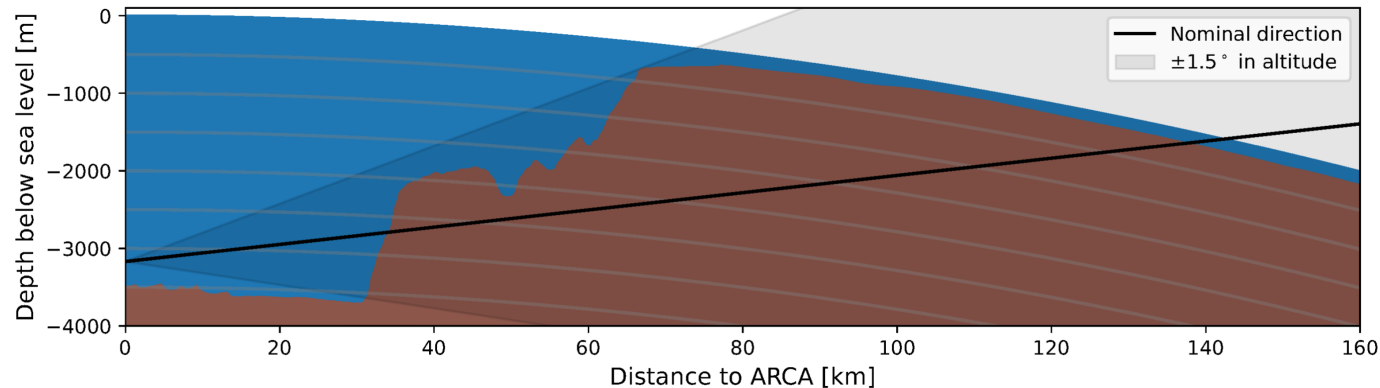
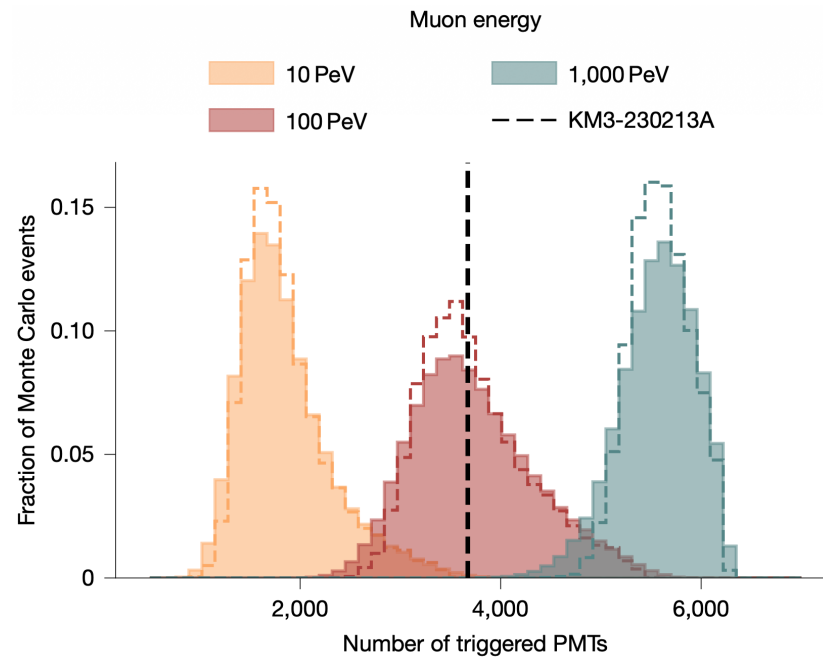
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The observation of KM3-230213A

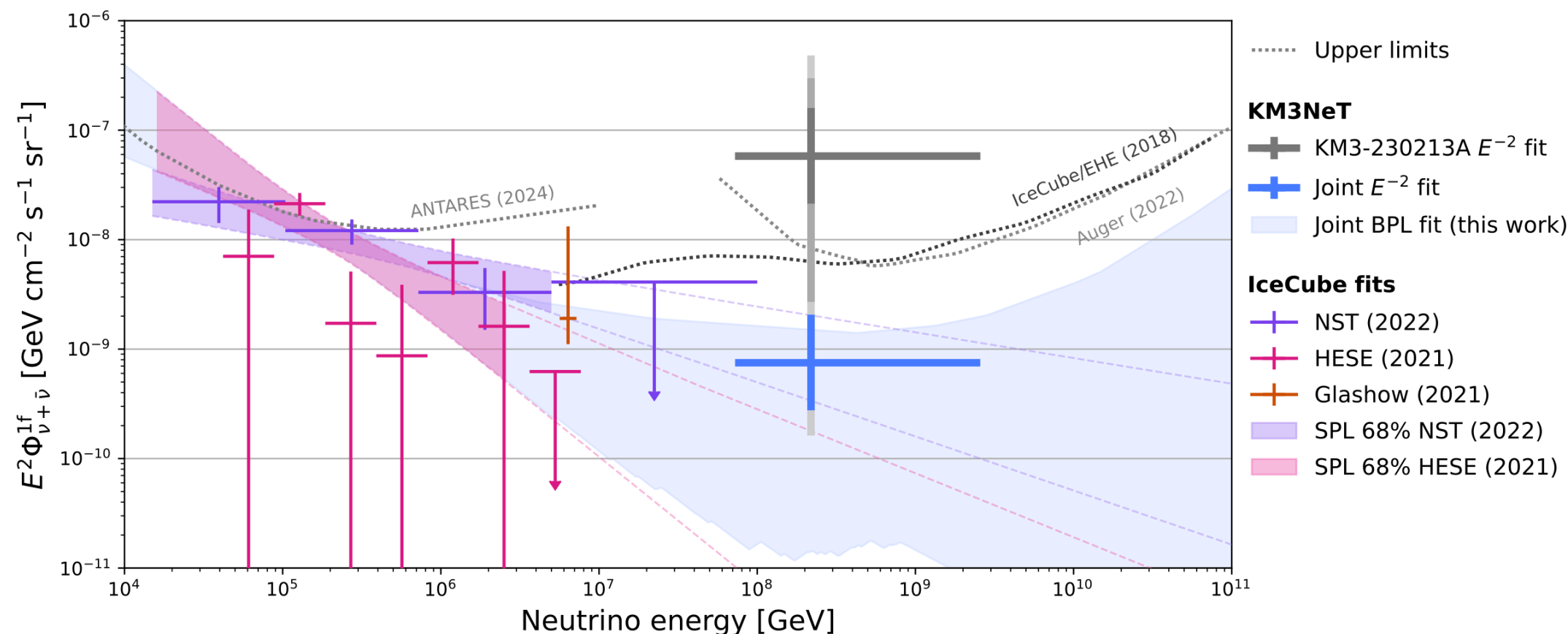
- Energy 220 PeV;
72 PeV – 2.6 EeV
90% CL interval
- Highest neutrino energy observed
ever, ever, ever
- Expected
background rate low



Nature 638 (2025) 8050, 376

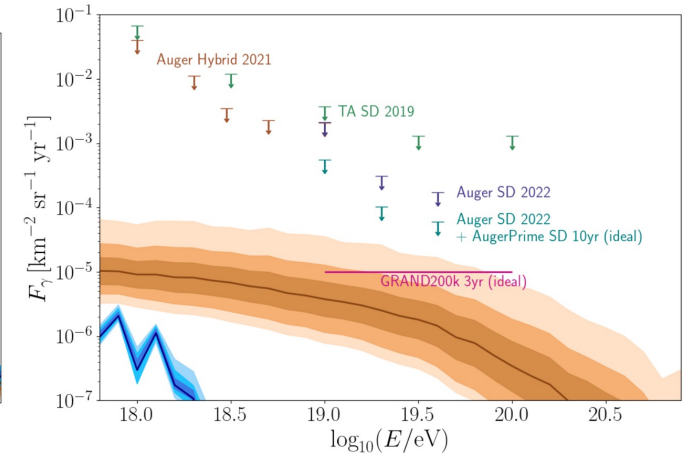
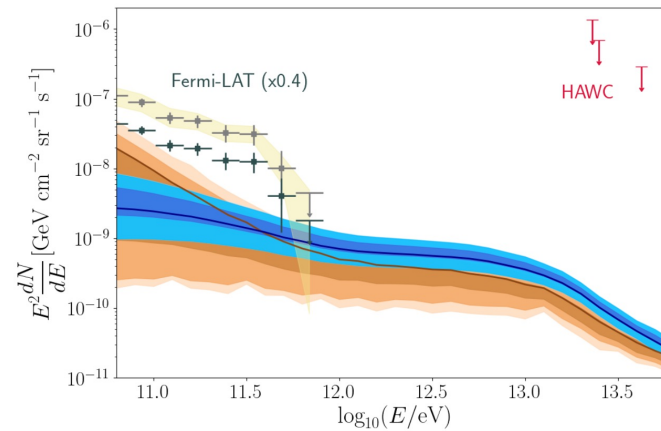
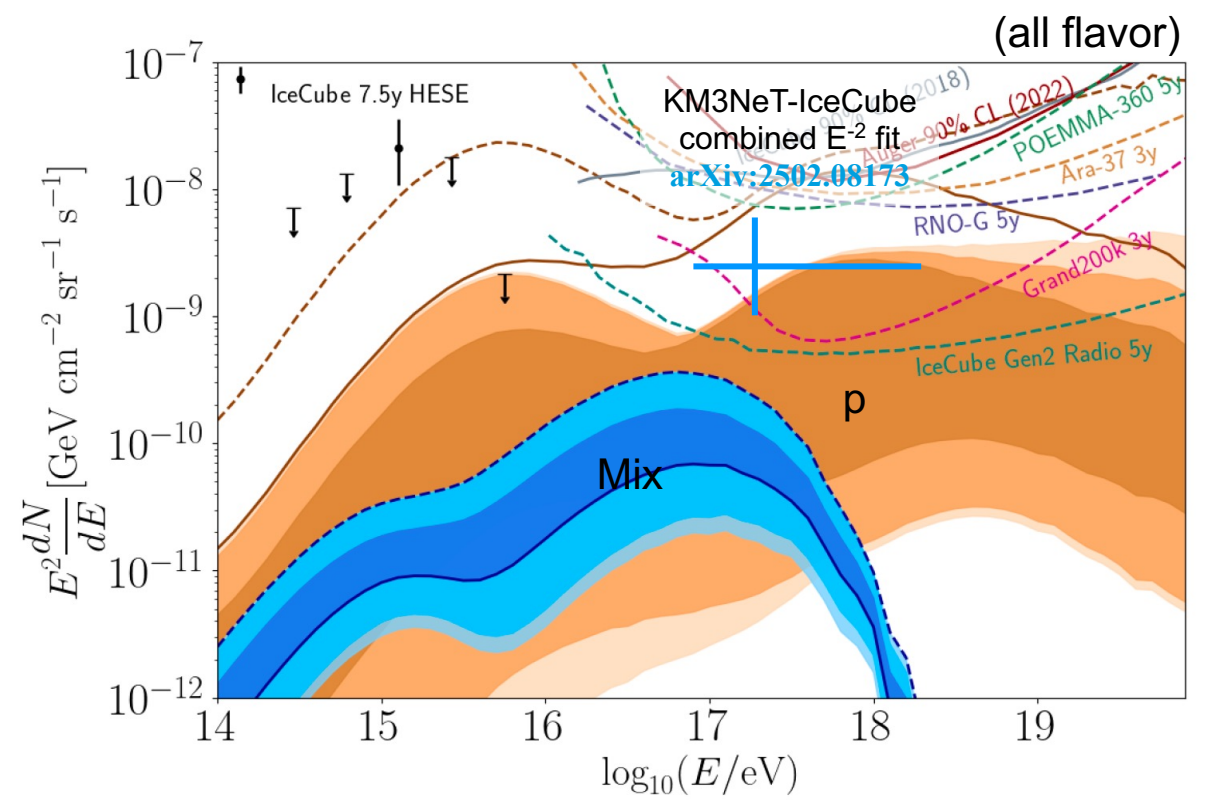
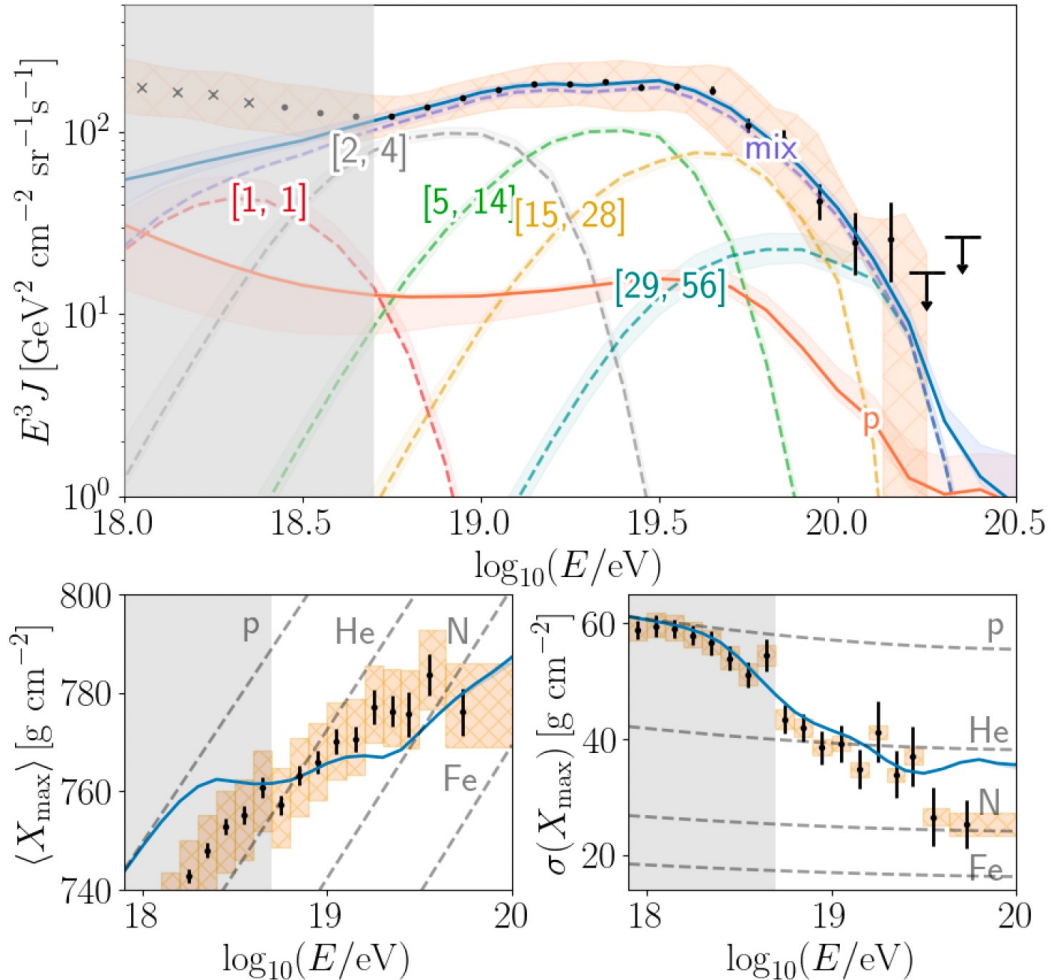
KM3-230213A in the global context

- Tension with IceCube data $\sim 2.5\text{-}3\sigma$
- Maybe favors “year-long transient” (compared to steady source, such as cosmogenic neutrinos)
[Neronov, Oikonomou, Semikoz, 2025; Li et al 2025; ...](#)
→ Tidal Disruption Event? AGN accretion flare? ...



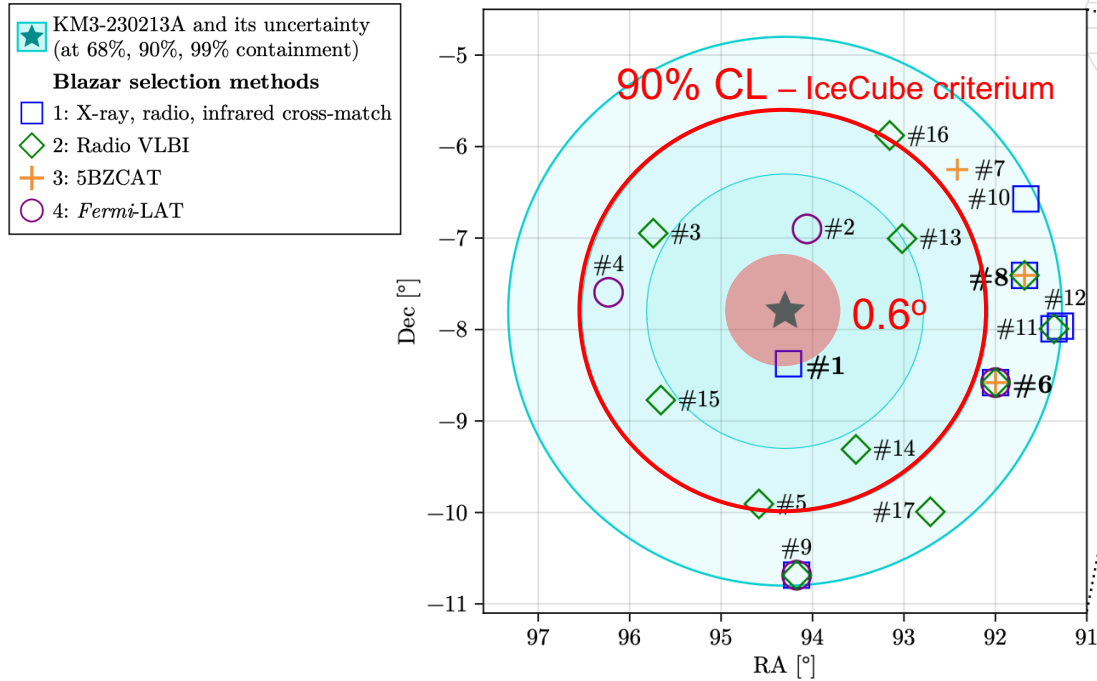
Cosmogenic origin?

Here: Two-component model with sub-leading “proton dip” population, which dominates the cosmogenic neutrino flux

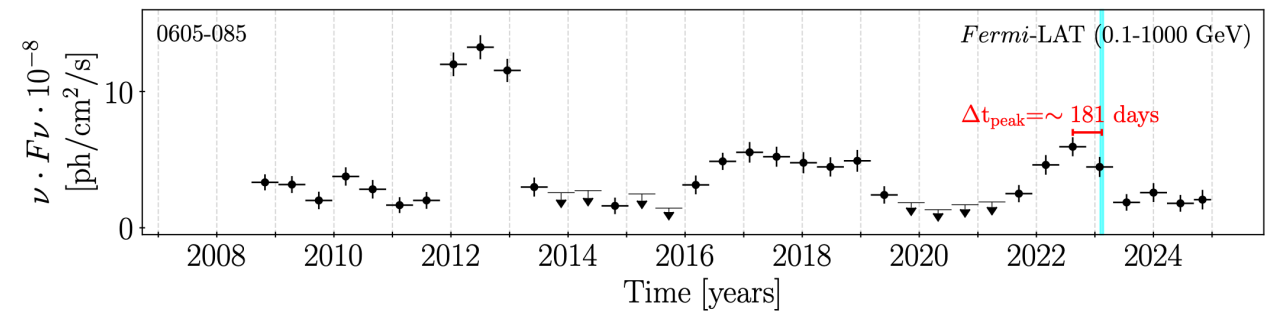


Ehlert, van Vliet, Oikonomou, Winter, JCAP 02 (2024) 022;
KM3NeT collab paper: ApJL 984 (2025) 2; see also: Muzio et al. 2019+2023; Das et al. 2021; ...

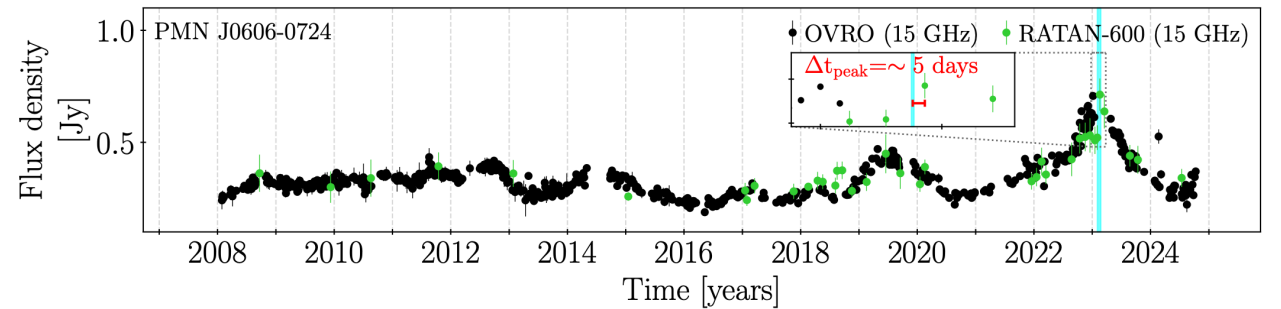
AGN blazar candidates



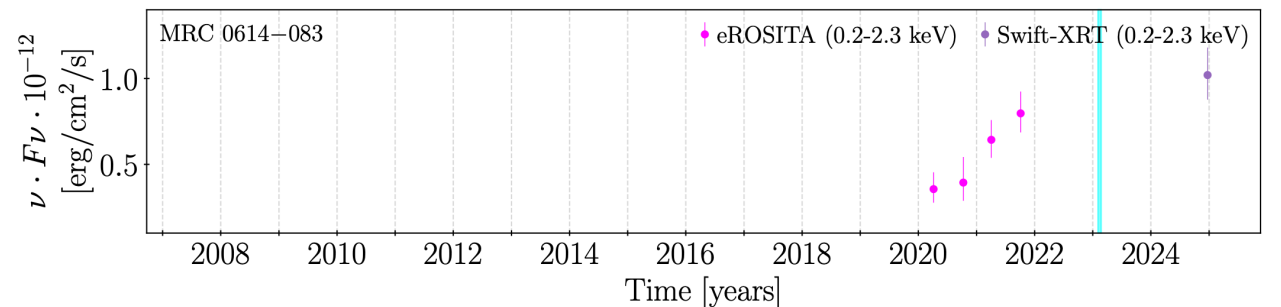
- 17 blazars within 99%CL region, #1 (MRC 0614-083) is closest source
- #1, #6, #8 exhibit interesting multi-wavelength activity
- **MRC 0614-083 is the only source in the 90% CL region which exhibits noteworthy multi-wavelength activity**



(a) The *Fermi*-LAT light curve and a VLBI image of 0605-085 (#6): the brightest radio source in the neutrino localization region that experiences a gamma-ray flaring activity around the neutrino arrival (Section 5.1.1). Δt_{peak} highlights the time difference of ~ 181 days between the flare peak and the neutrino arrival time.



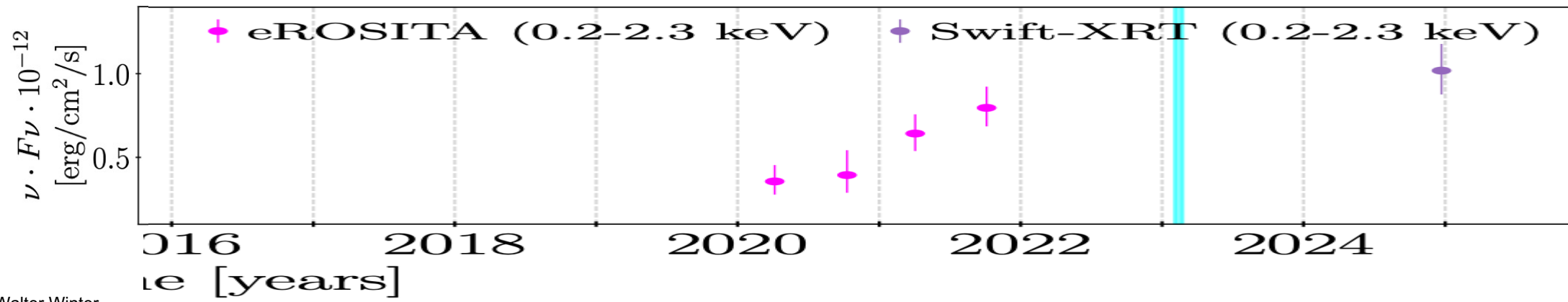
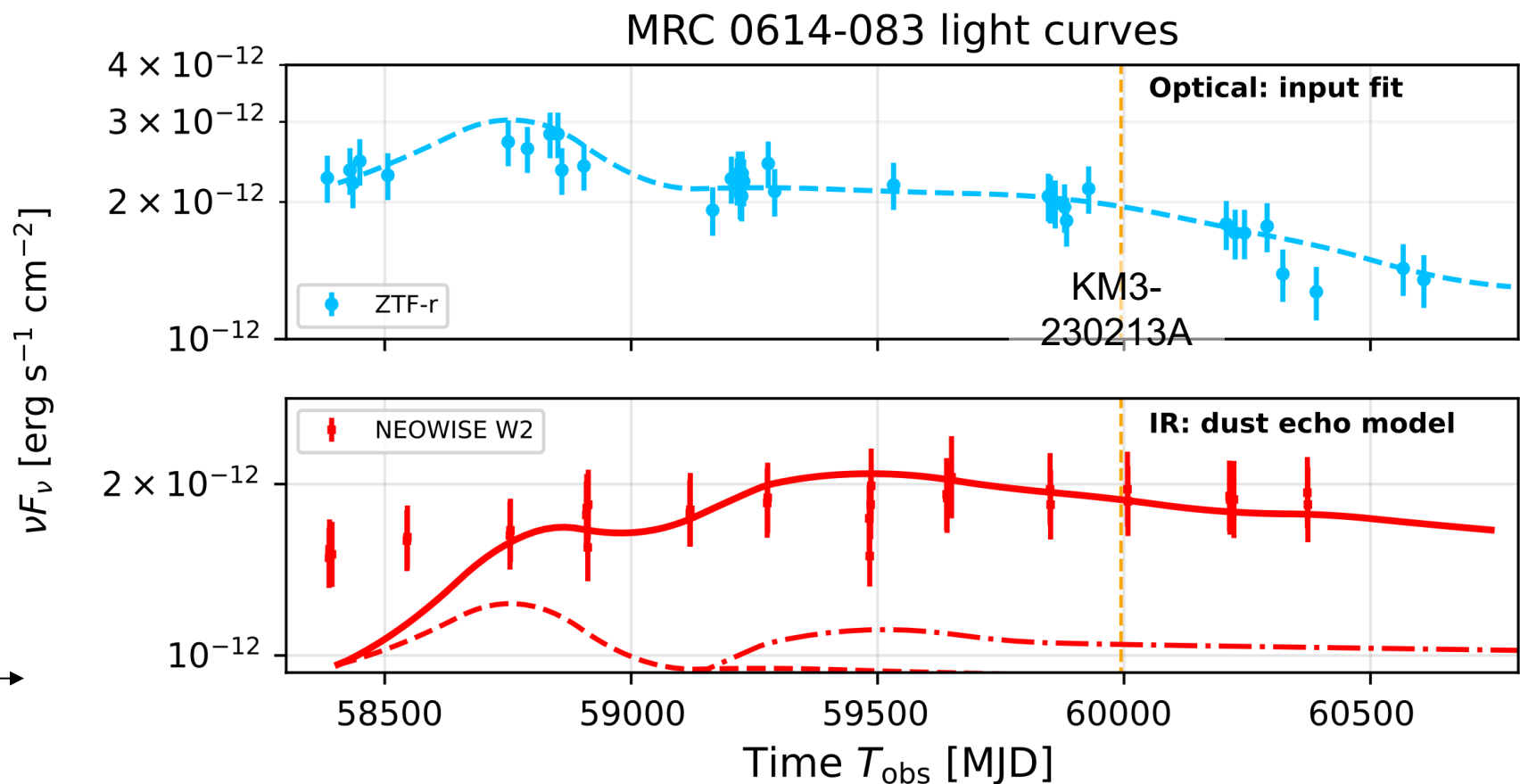
(b) The radio light curve for PMN J0606-0724 (#8) that experiences a major flare in close coincidence to the neutrino arrival (Section 5.1.2). Δt_{peak} highlights the time difference of ~ 5 days between the flare peak and the neutrino arrival time.



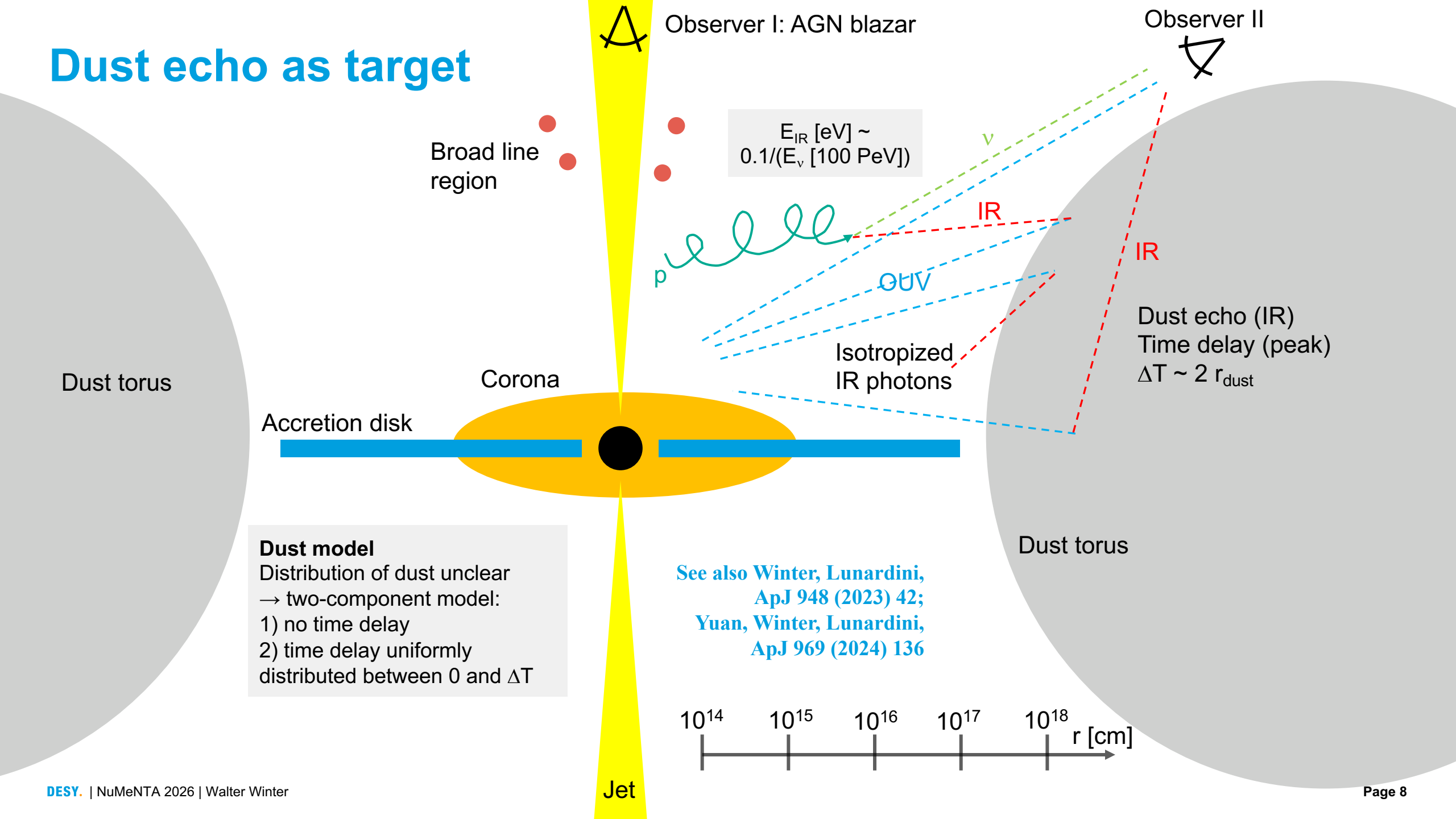
(c) The X-ray light curve for MRC 0614-083 (#1) that indicates a flaring activity around the neutrino arrival (Section 5.1.3).

MRC 0614-083: Data situation

- No redshift measurement
- Detected by radio surveys, but no detailed studies on Γ , jet opening angle
- Detected in optical, IR
- IR lightcurve exhibits time delay: **dust echo from an accretion flare?**
- Gamma rays: only UL
- X-ray flare? (archival ROSAT data much lower)

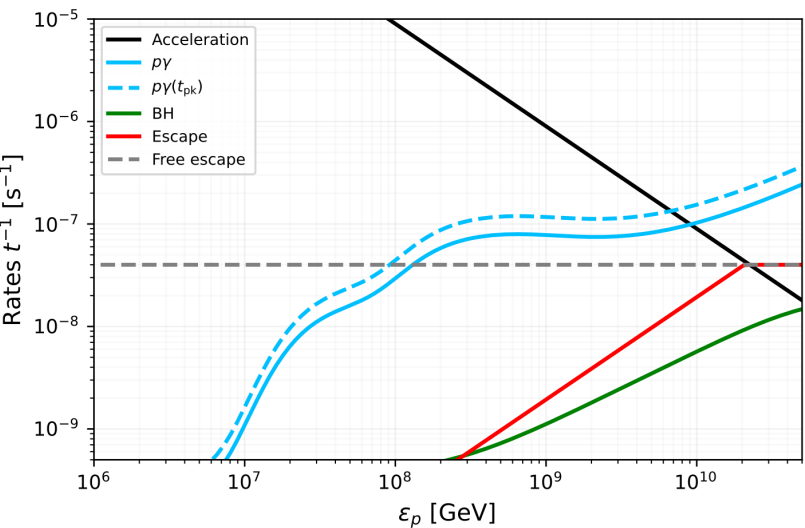


Dust echo as target



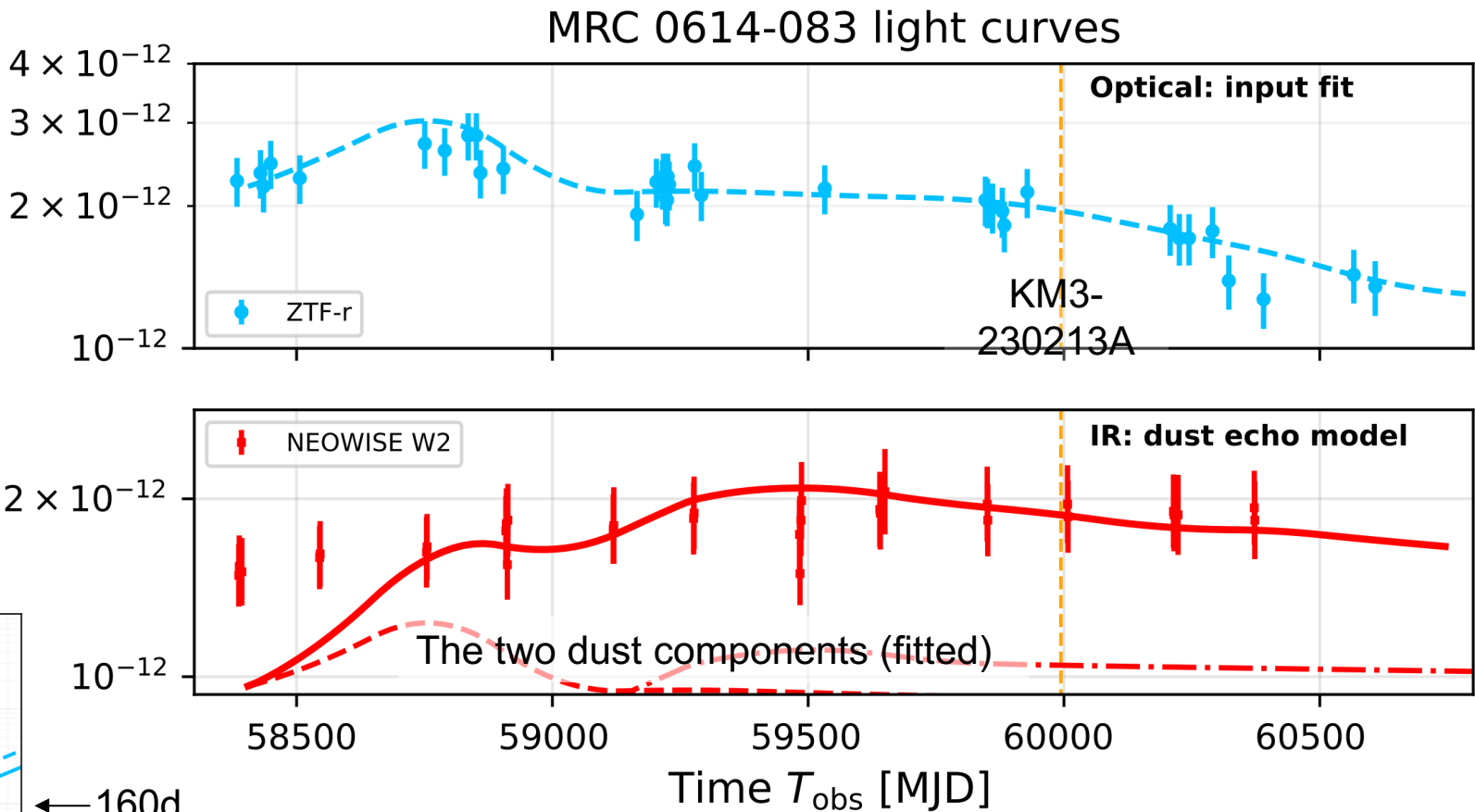
Model ingredients

- Assume that optical lightcurve follows accretion rate $\dot{M}_{\text{edd}}$ $\rightarrow$
- $L_p \sim \epsilon_p \dot{m}_{\text{pk}} \dot{M}_{\text{edd}} c^2$,
 $\epsilon_p \sim 0.2$, $\dot{m}_{\text{pk}} \sim 1$ (fitted)
(for $M_{\text{SMBH}} \sim 10^9 M_{\text{sol}}$)



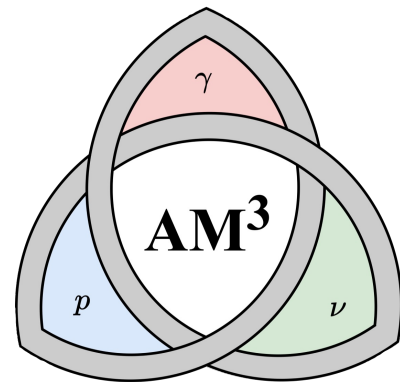
- $B \sim 0.1 \text{ G}$
($E_{p,\text{max}} \sim 10^9 \text{ to } 10^{10} \text{ GeV}$)

$\nu F_\nu \text{ [erg s}^{-1} \text{ cm}^{-2}\text{]}$



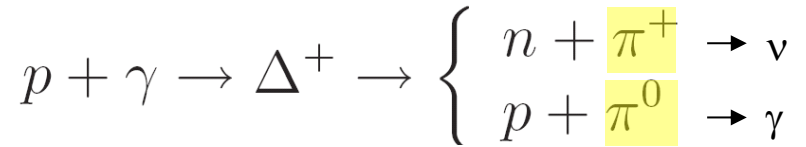
$\leftarrow 160\text{d}$

Yuan, Pfeiffer, Winter, Sanchez Zaballa, Buson,
Testagrossa, Azzollini, ApJL 998 (2026) 1;
AM3 software: Klinger et al, Astrophys. J .Suppl. 275 (2024) 1

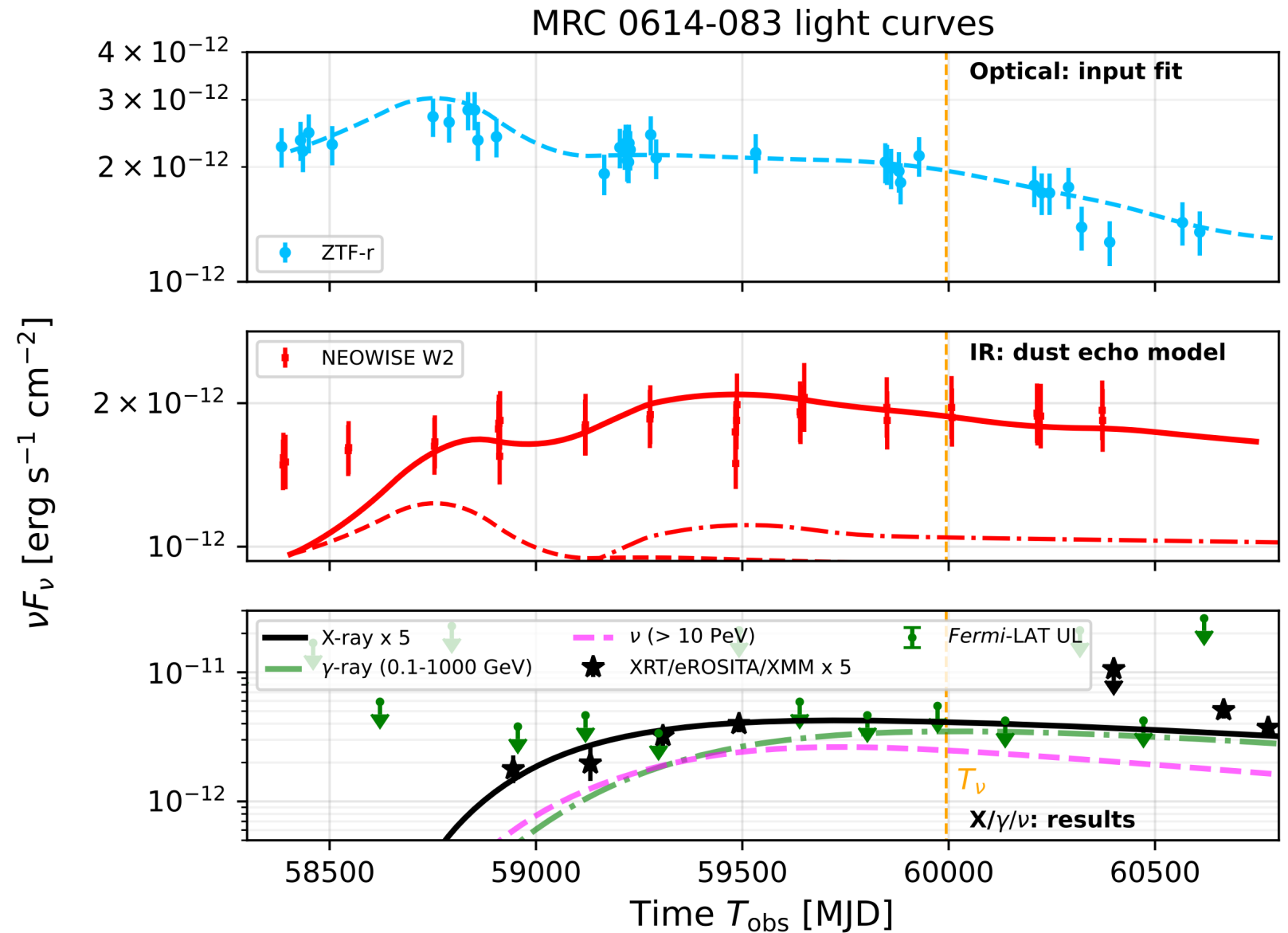


Result: Light curves

- Neutrino and accompanying EM cascade correlated

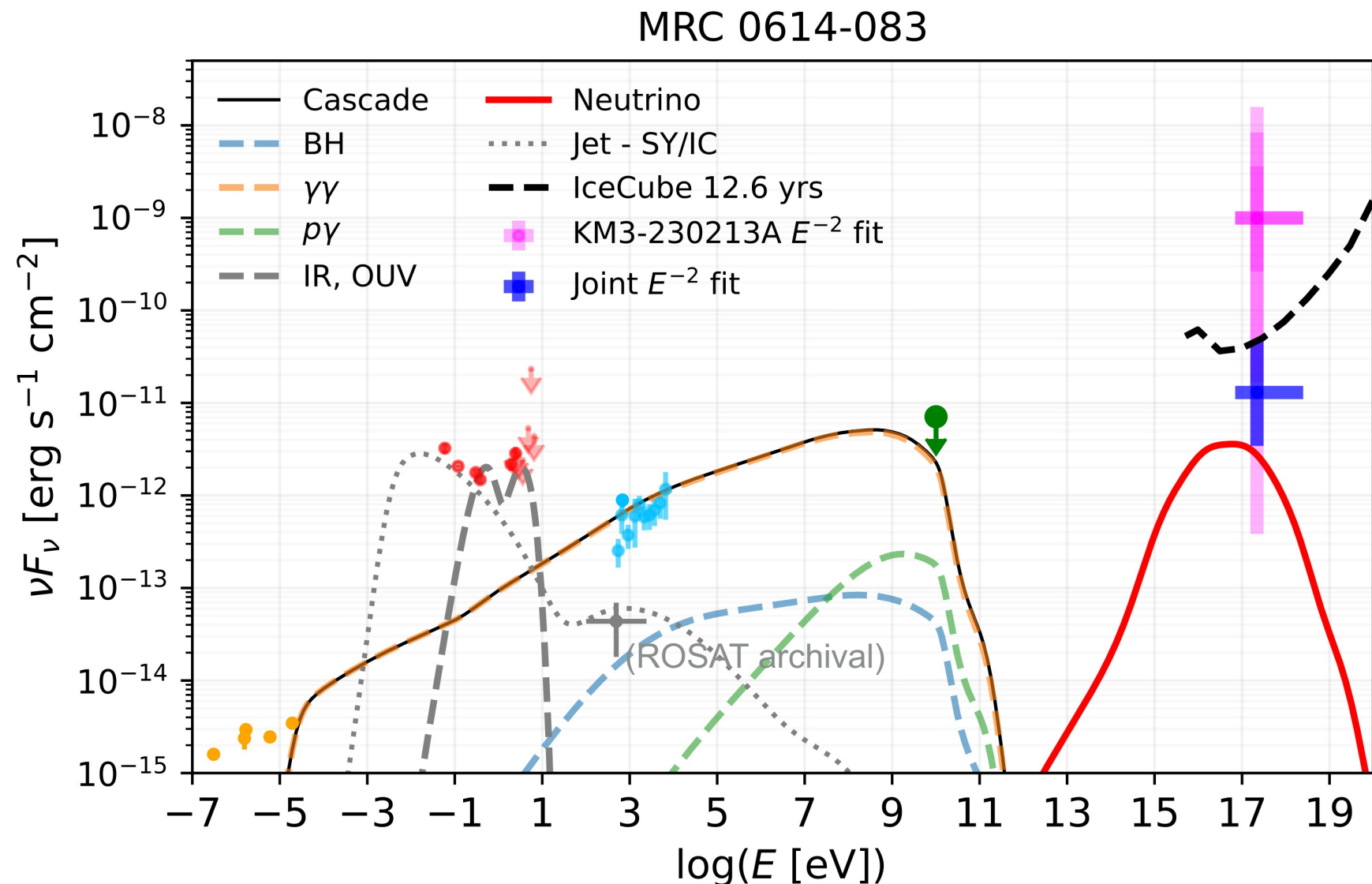


- Time delay related to t_{py} and ΔT
- X-ray data describe observed X-ray flare (output!)
- Gamma-ray upper limits satisfied



Results: Spectral energy distribution

- X-ray SED can we well described by model
- However: additional thermal radiative contributions needed to describe IR-optical data
- Far-infrared and archival ROSAT data may be related to the jet
- Radio data from less compact region, as usual



Yuan, Pfeiffer, Winter, Sanchez Zaballa, Buson,
Testagrossa, Azzollini, ApJL 998 (2026) 1

Summary and discussion

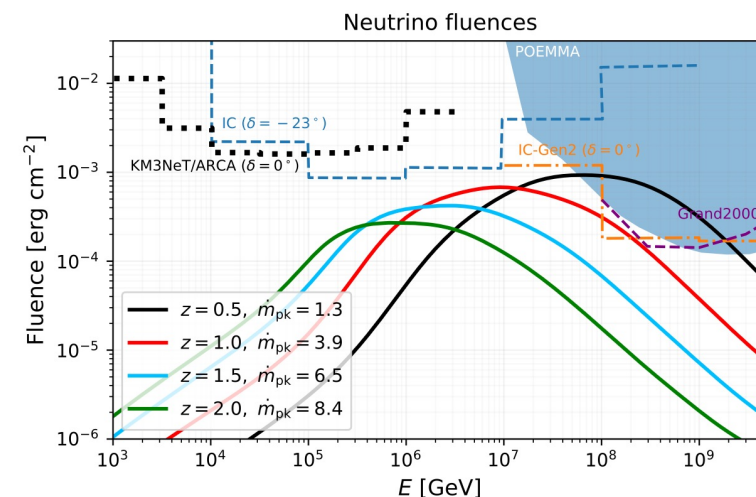
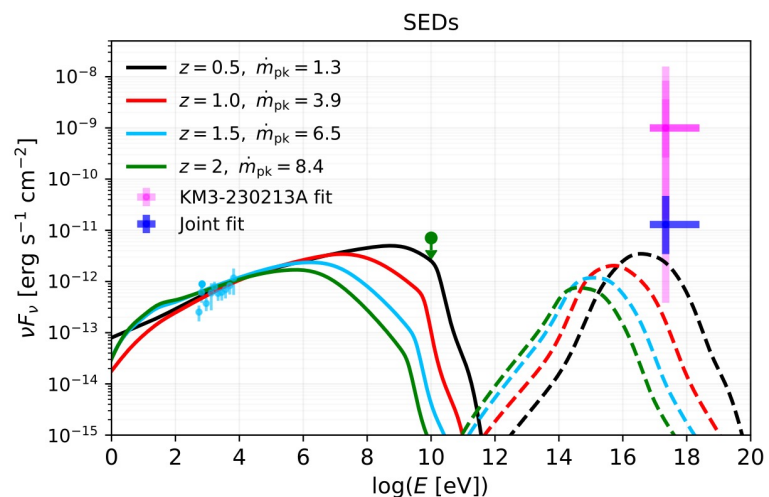
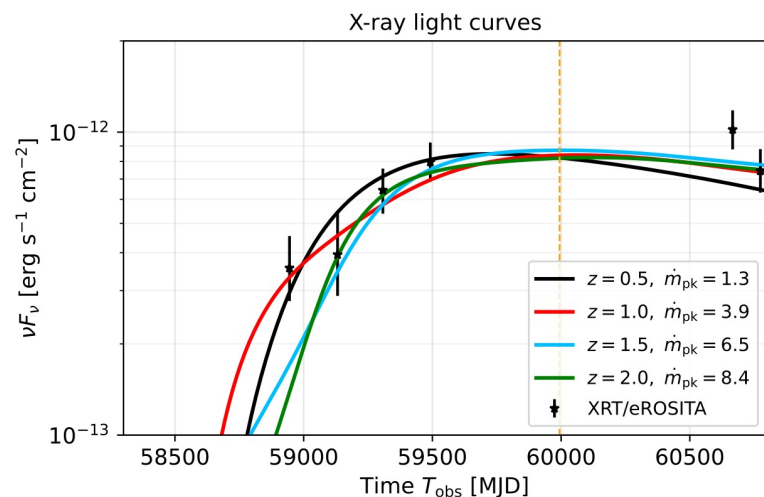
- KM3-230213A is the highest-energetic neutrino event ever, probably of astrophysical origin
- Possible association with UHECRs. Cosmogenic origin from sub-leading proton population?
- Some tension with IceCube/Auger limits at highest energies. Can be reduced for a transient.
- MRC 0614-083 is the only source in the 90% CL region which exhibits noteworthy multi-wavelength activity, identified as AGN blazar
- Accretion flare model proposed based on optical emission and infrared dust echo:
 - X-ray and neutrino flares may be simultaneously described by a (mildly) super-Eddington accretion flare (transient)
 - Time evolution and SED can be well described
 - Works for different redshifts $z < 2$. Nevertheless, redshift measurement highly needed!

Caveats

- Additional spectral components (thermal, jet) needed to describe the full SED
- Isotropic emission model not directly associated with detection as AGN blazar if acceleration in wind (alternative: e.g. the blazar jet hosts the proton accelerator, protons interact with external IR radiation field?)
- Several alternative sources (AGN blazars) exist, due to the relative large directional uncertainty

BACKUP

Results: Redshift dependence



Yuan, Pfeiffer, Winter, Sanchez Zaballa, Buson,
Testagrossa, Azzollini, ApJL 998 (2026) 1