
GAMMA-RAY BURSTS AT THE HIGHEST ENERGIES



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13 SEPT 2022

GRB-V

TeV detections: a summary

Miceli D. & Nava L., 2022, *Galaxies*, 10, 66

	T_{90} s	$E_{\gamma,iso}$ erg	z	T_{delay} s	E_{range} TeV	IACT (sign.)
160821B	0.48	1.2×10^{49}	0.162	24	0.5-5	MAGIC (3.1σ)
180720B	48.9	6.0×10^{53}	0.654	3.64×10^4	0.1-0.44	H.E.S.S. (5.3σ)
190114C	362	2.5×10^{53}	0.424	57	0.3-1	MAGIC ($> 50\sigma$)
190829A	58.2	2.0×10^{50}	0.079	1.55×10^4	0.18-3.3	H.E.S.S. (21.7σ)
201015A	9.78	1.1×10^{50}	0.42	33	0.14	MAGIC (3.5σ)
201216C	48	4.7×10^{53}	1.1	56	0.1	MAGIC (6.0σ)

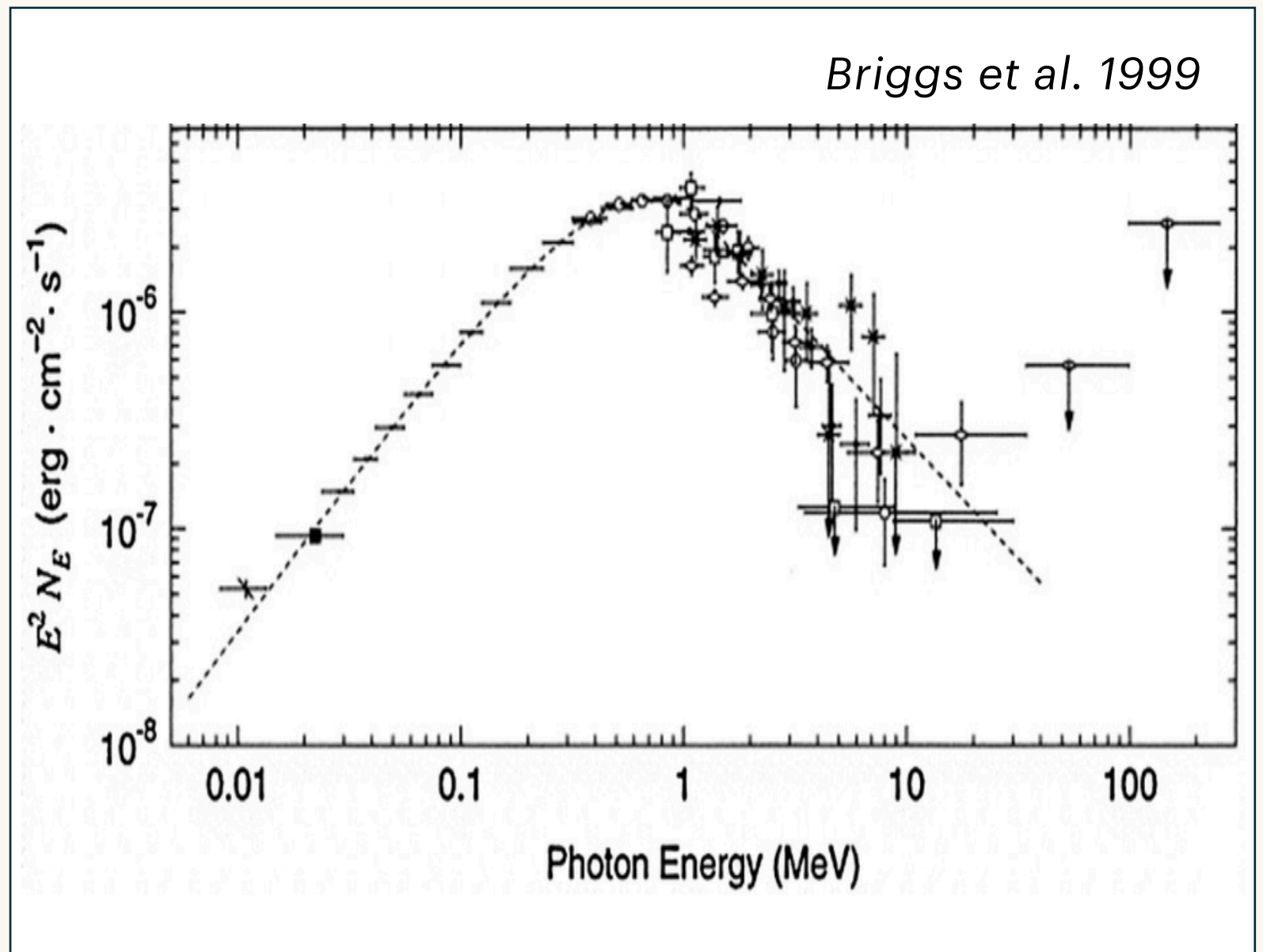
significance $< 5\sigma$

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GRB EMISSION AT ENERGIES $E < \text{GeV}$

Prompt emission

- keV - MeV
- Non-thermal
- Origin still uncertain
- One single spectral component

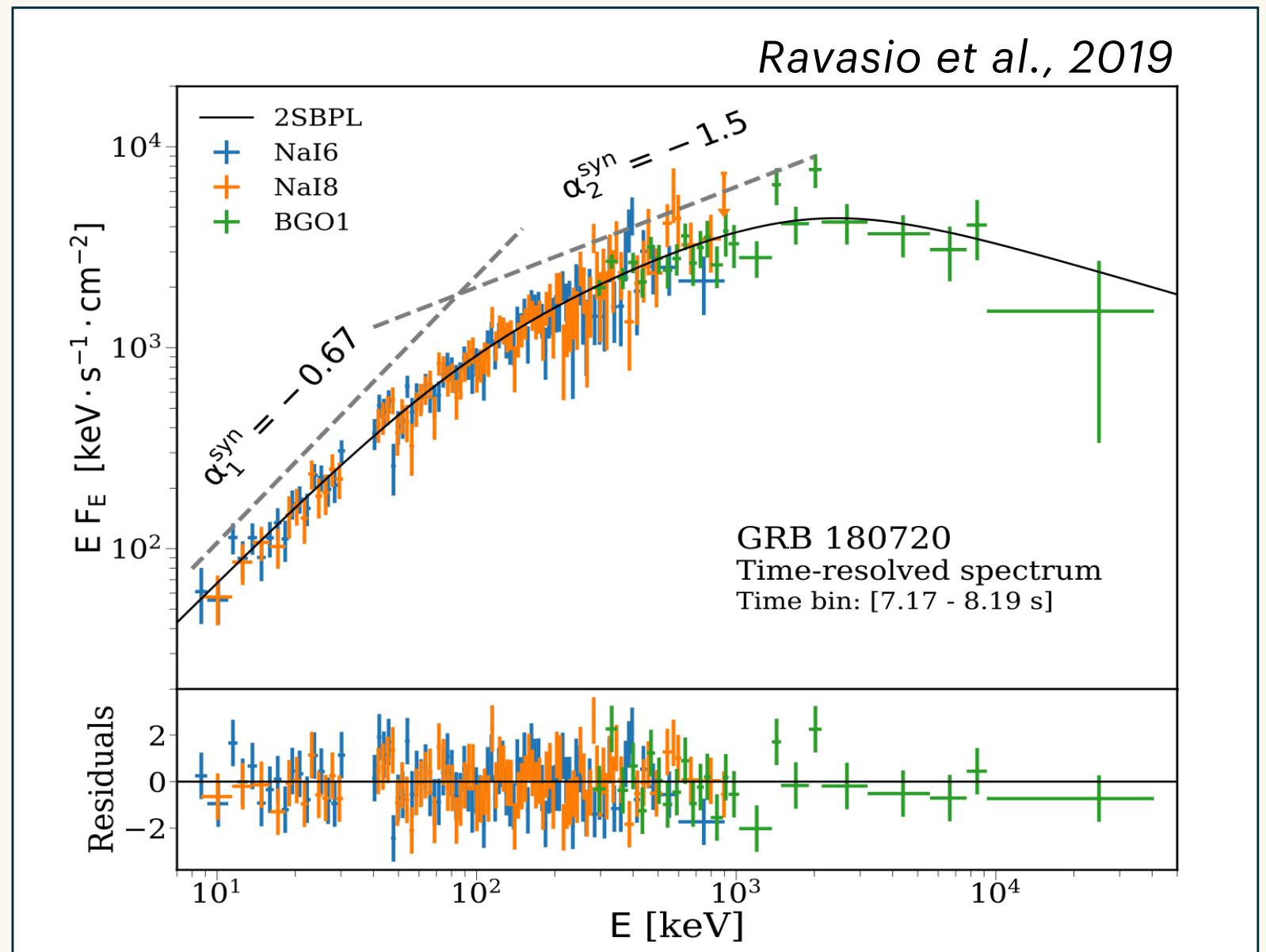


GRB EMISSION AT ENERGIES $E < \text{GeV}$

See talk by G. Oganesyan
and M.E. Ravasio

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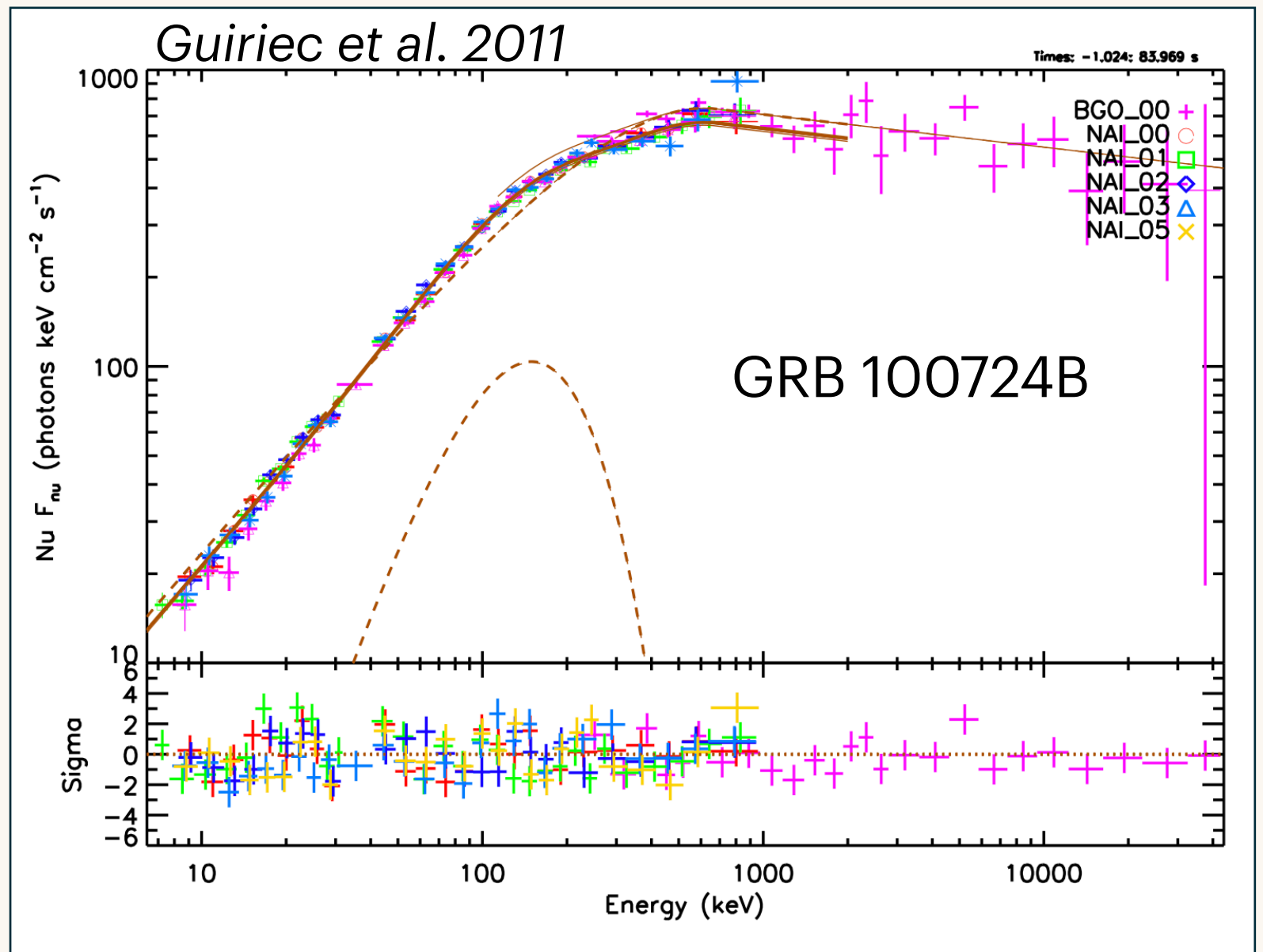
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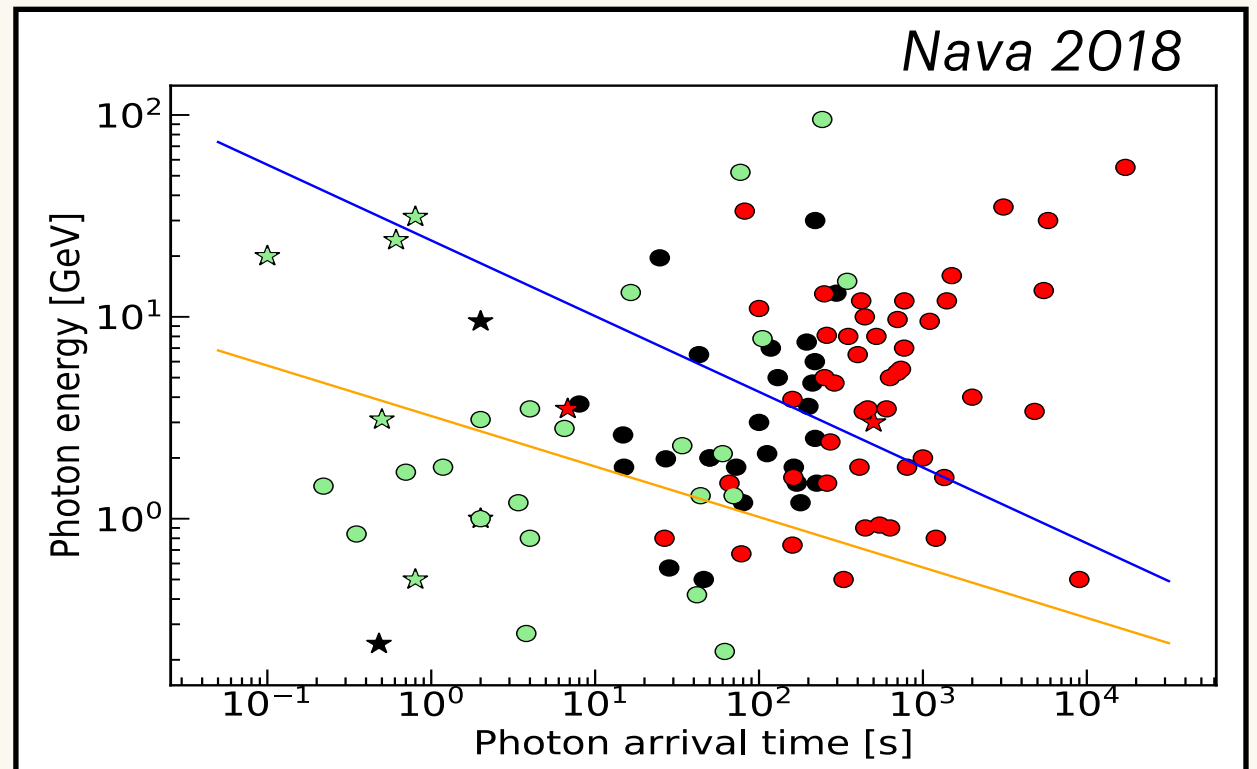
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EVIDENCE FOR HIGH-ENERGY ADDITIONAL SPECTRAL COMPONENTS FROM GeV OBSERVATIONS

Prompt emission

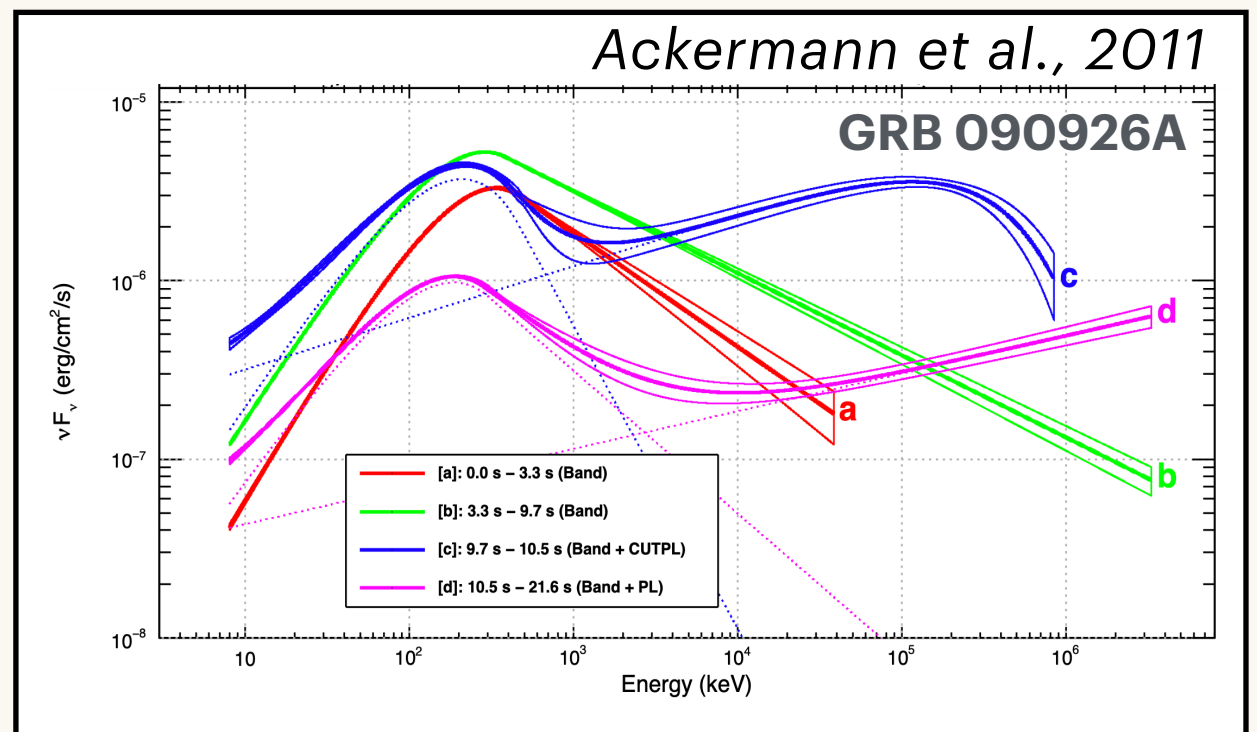
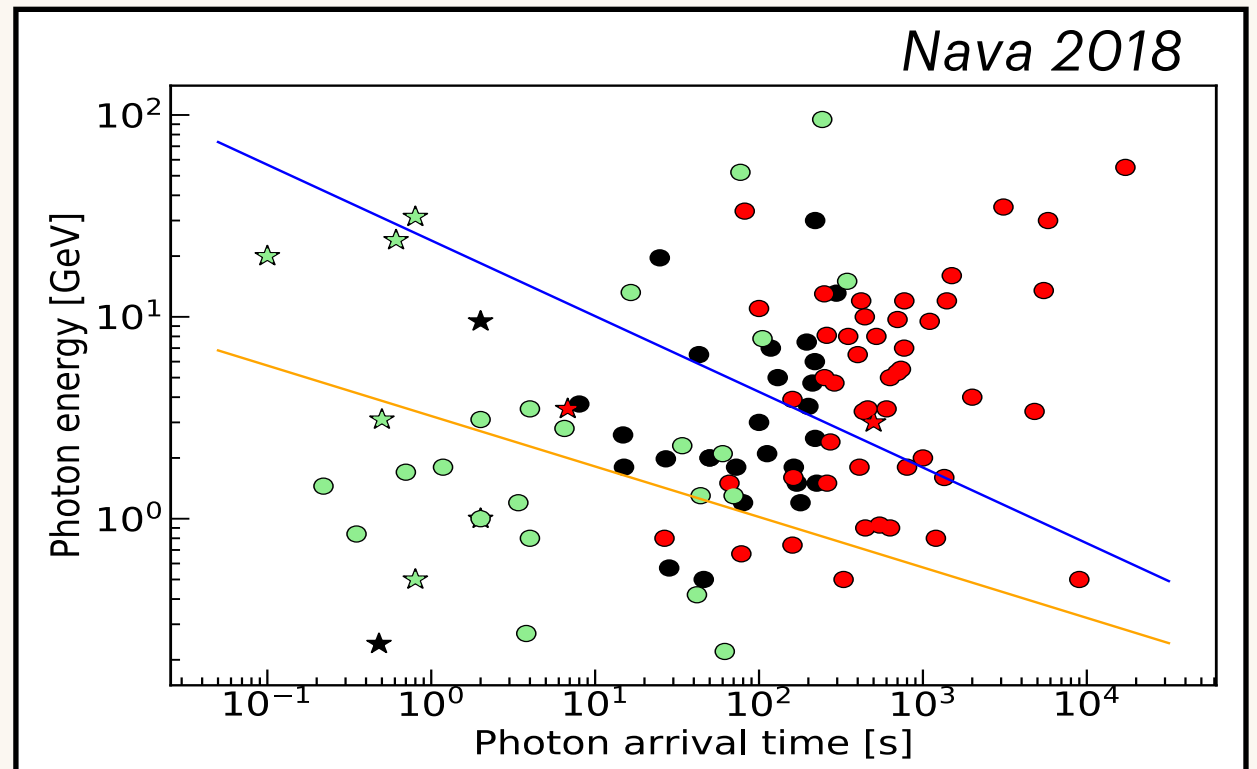
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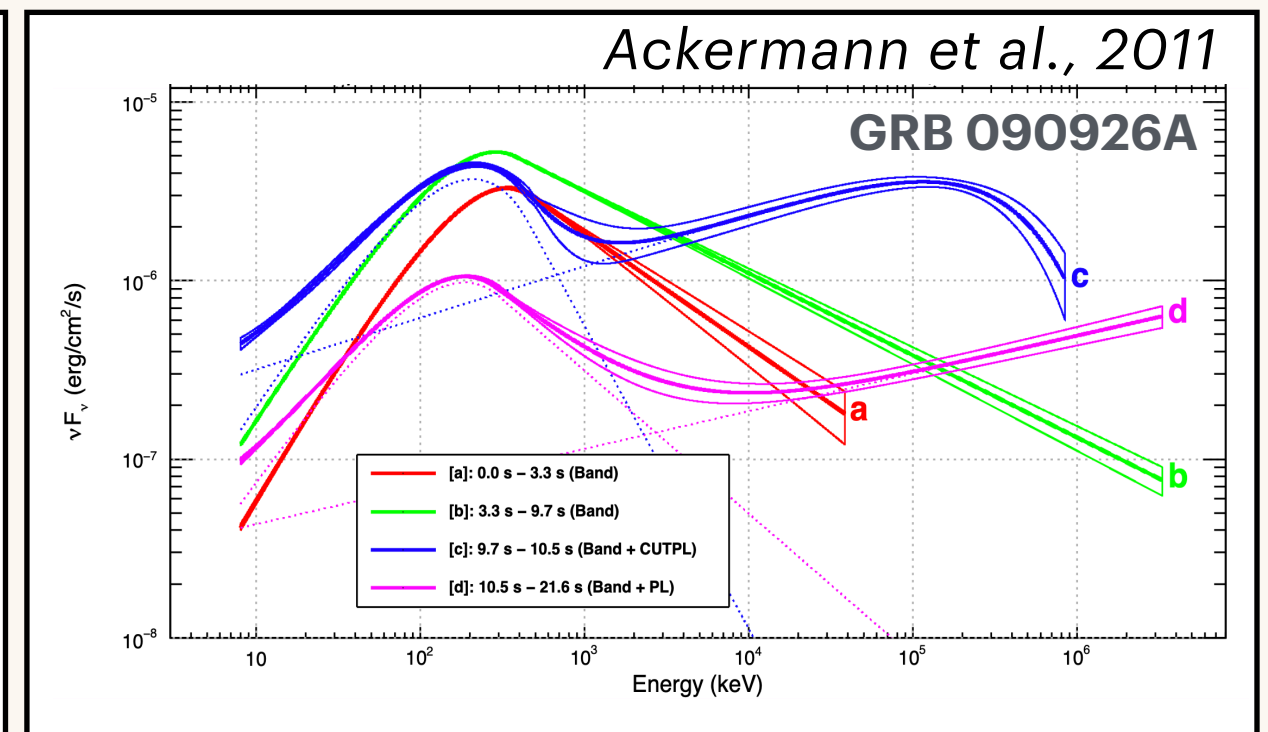
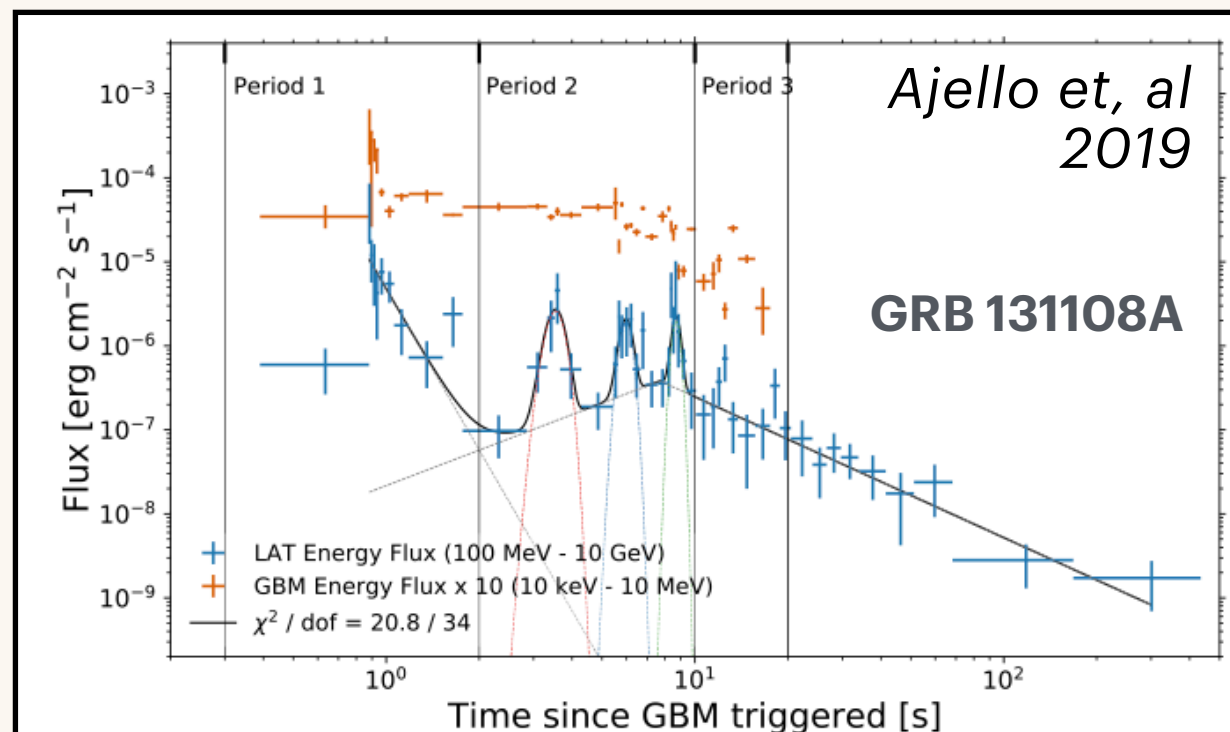
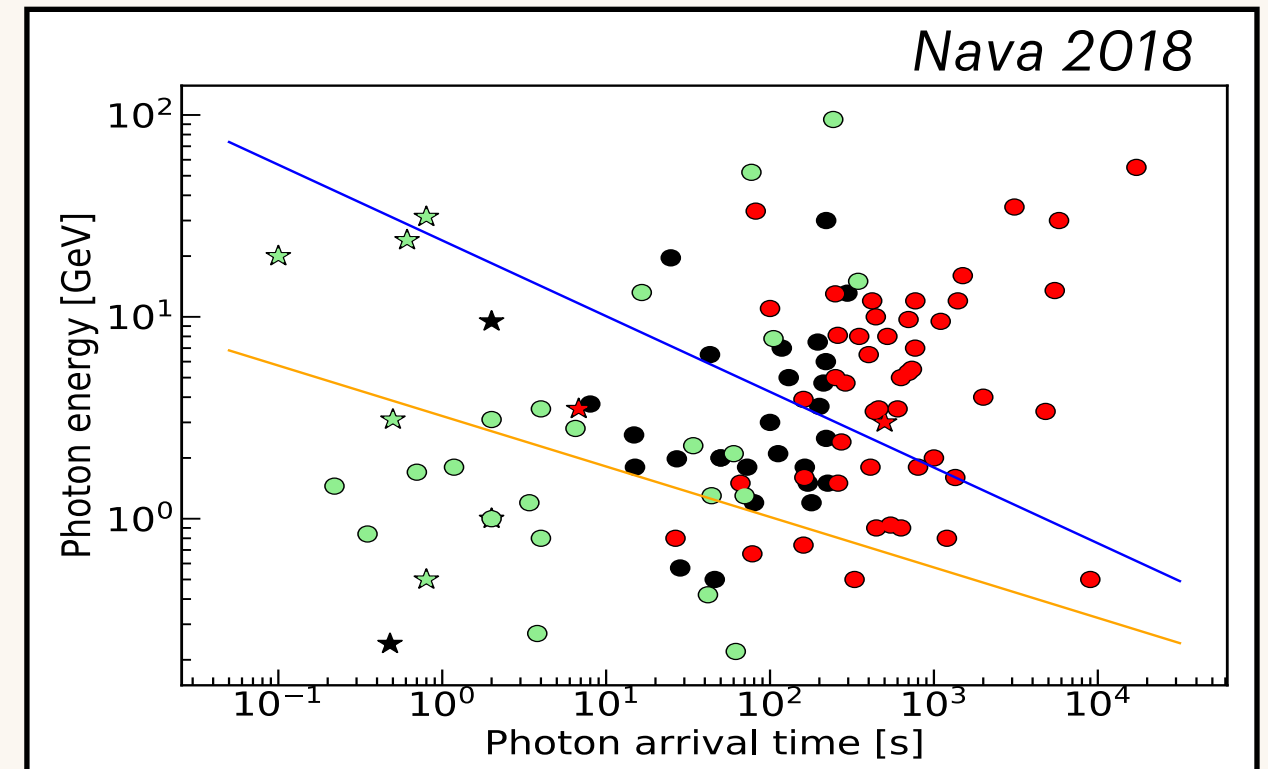
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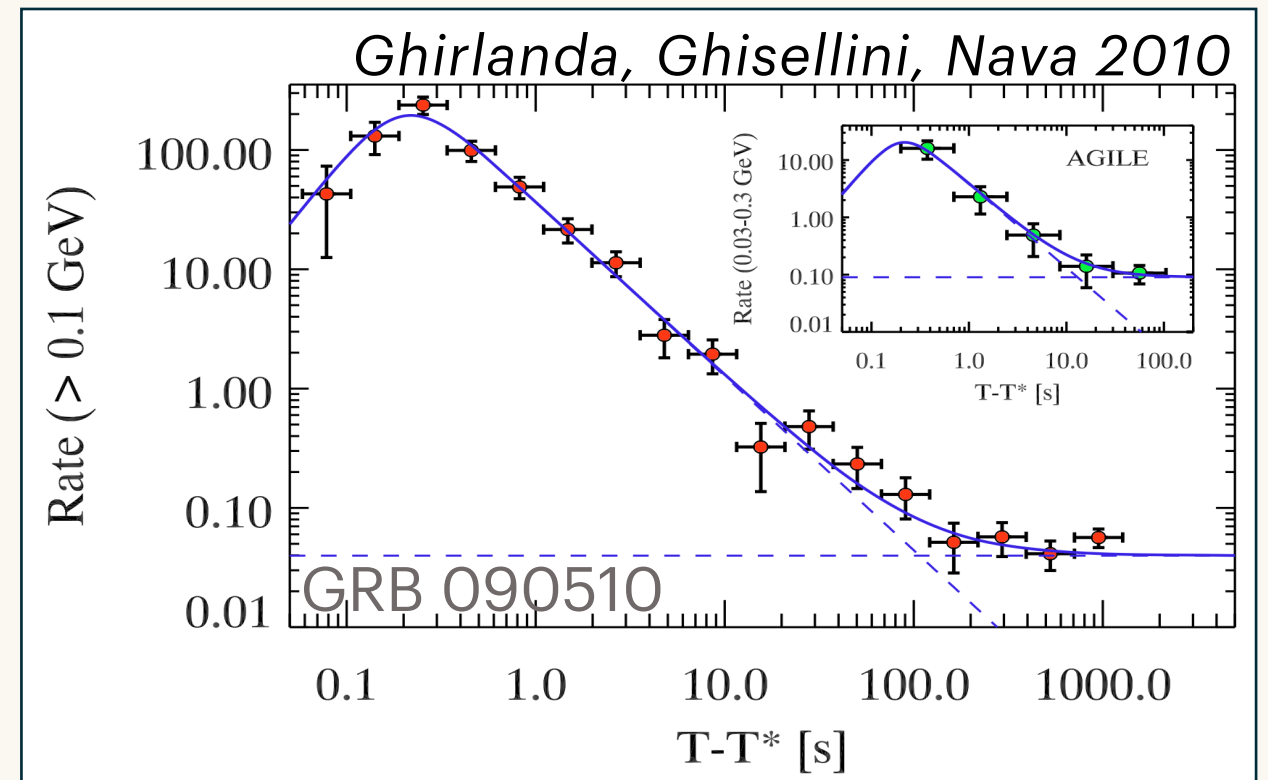
Prompt emission

- photons > 1 GeV have been detected during the prompt (green symbols)
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- evidence for GeV / multi-GeV variability??



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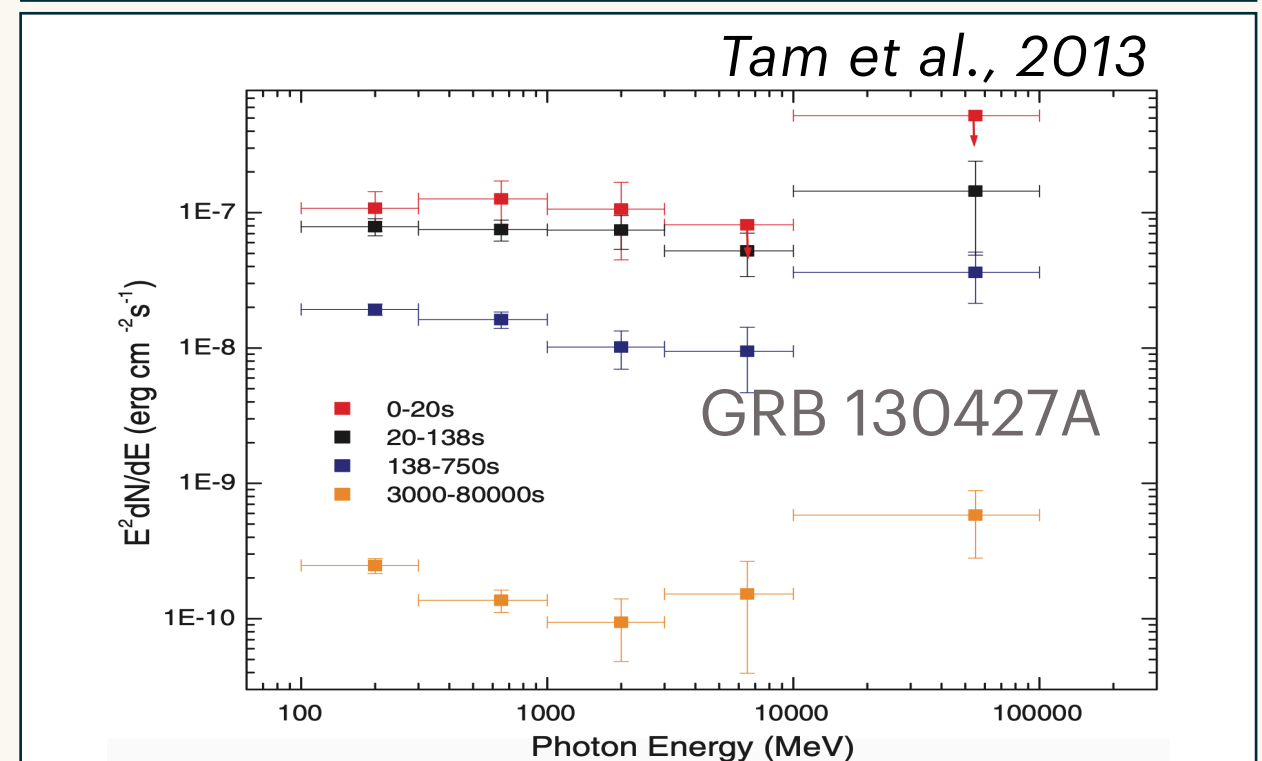
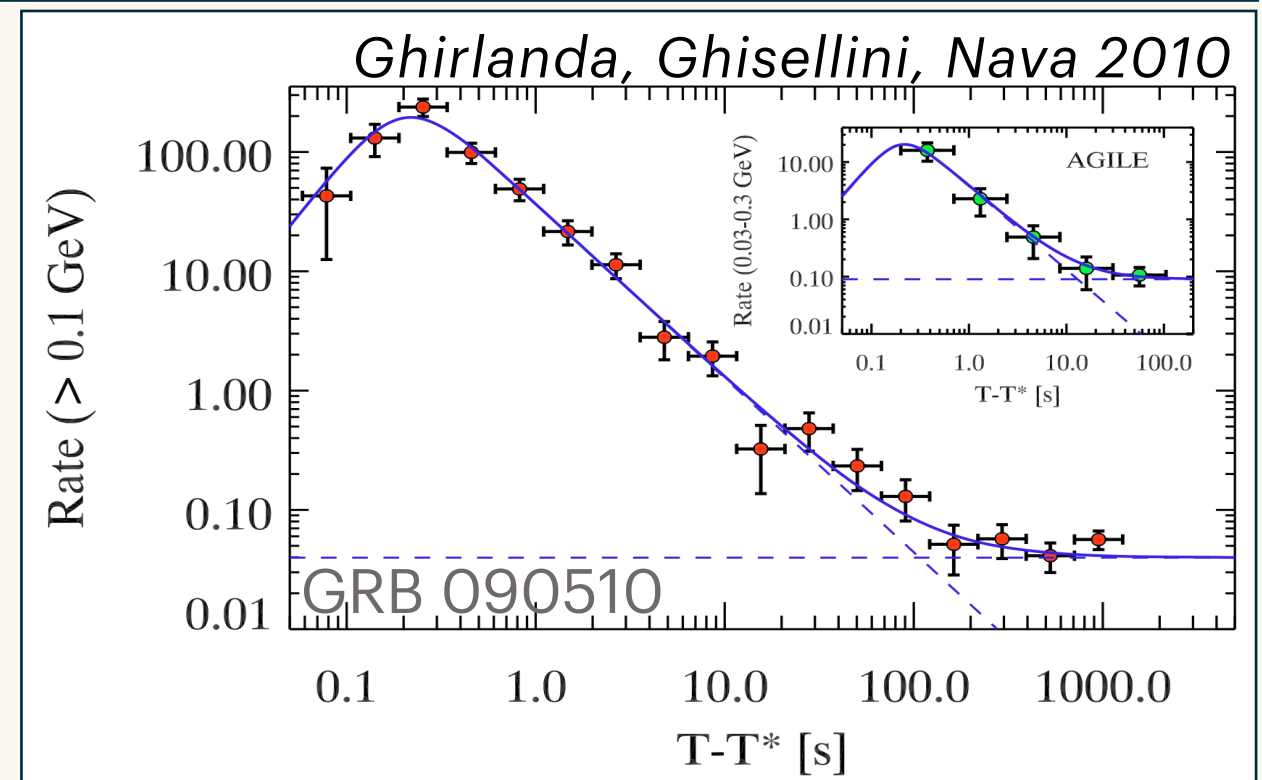
Afterglow emission



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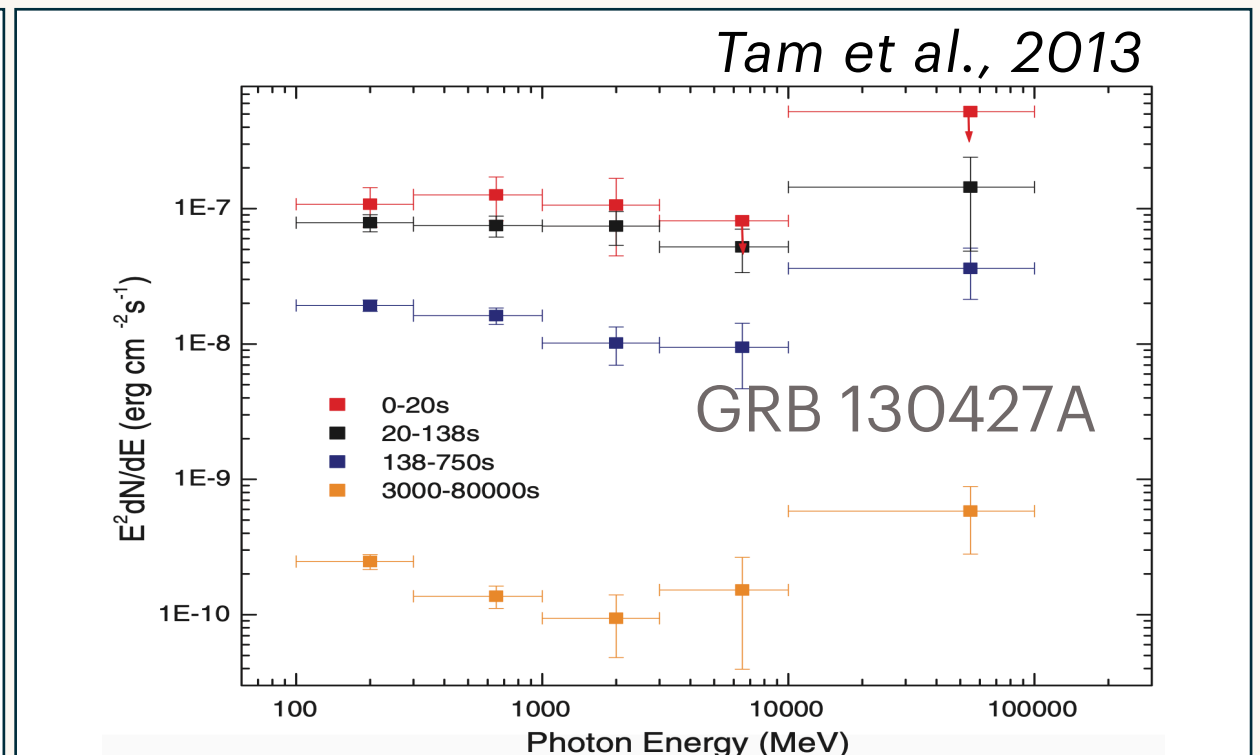
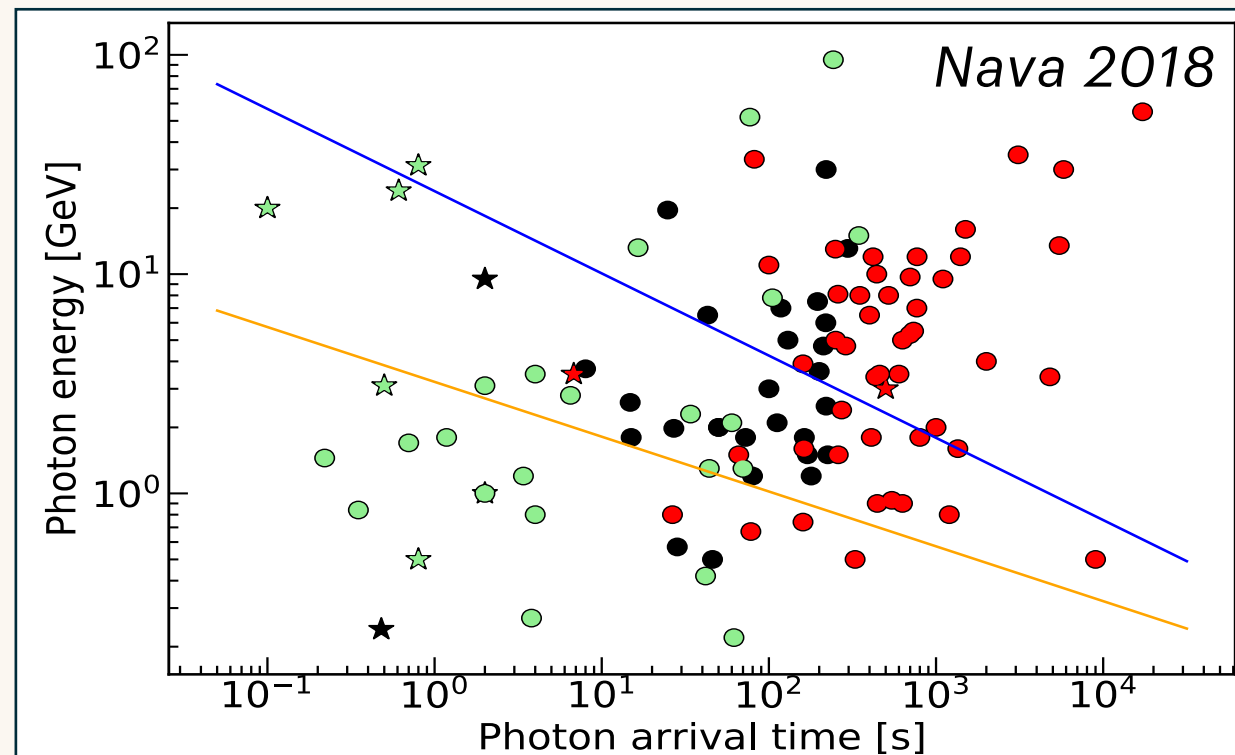
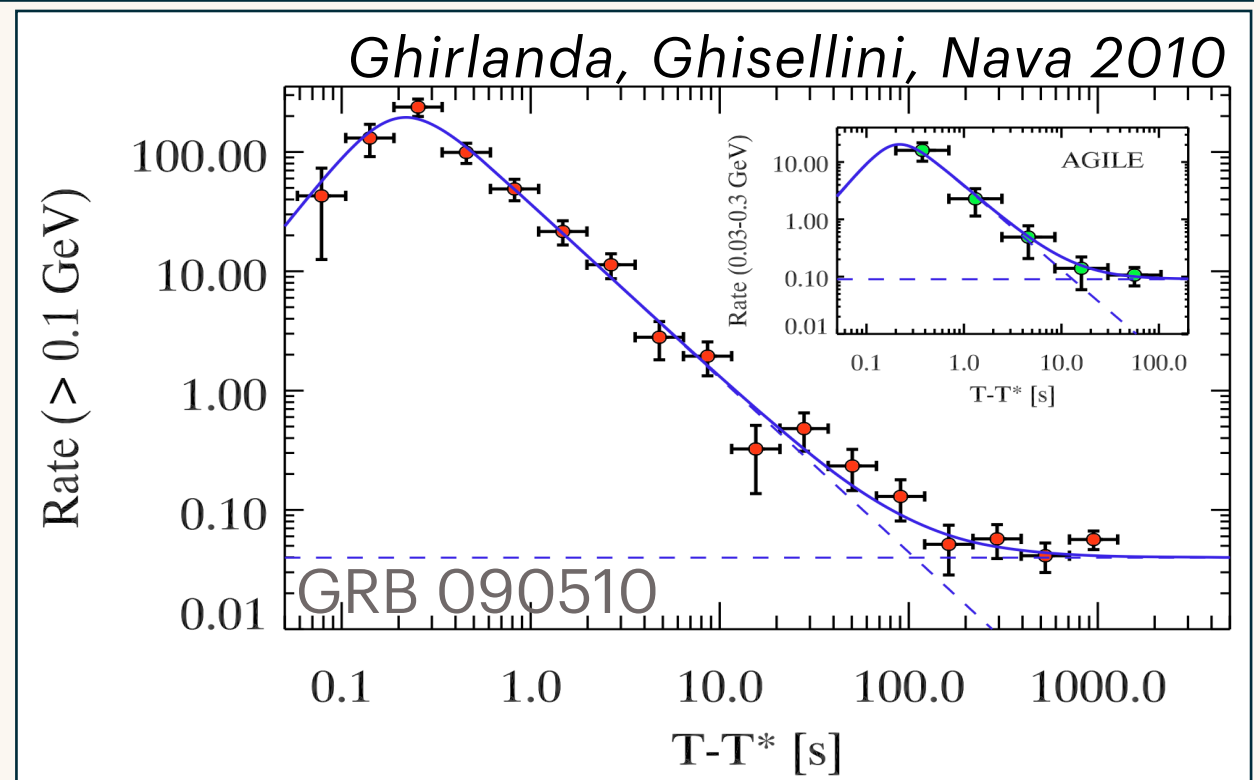
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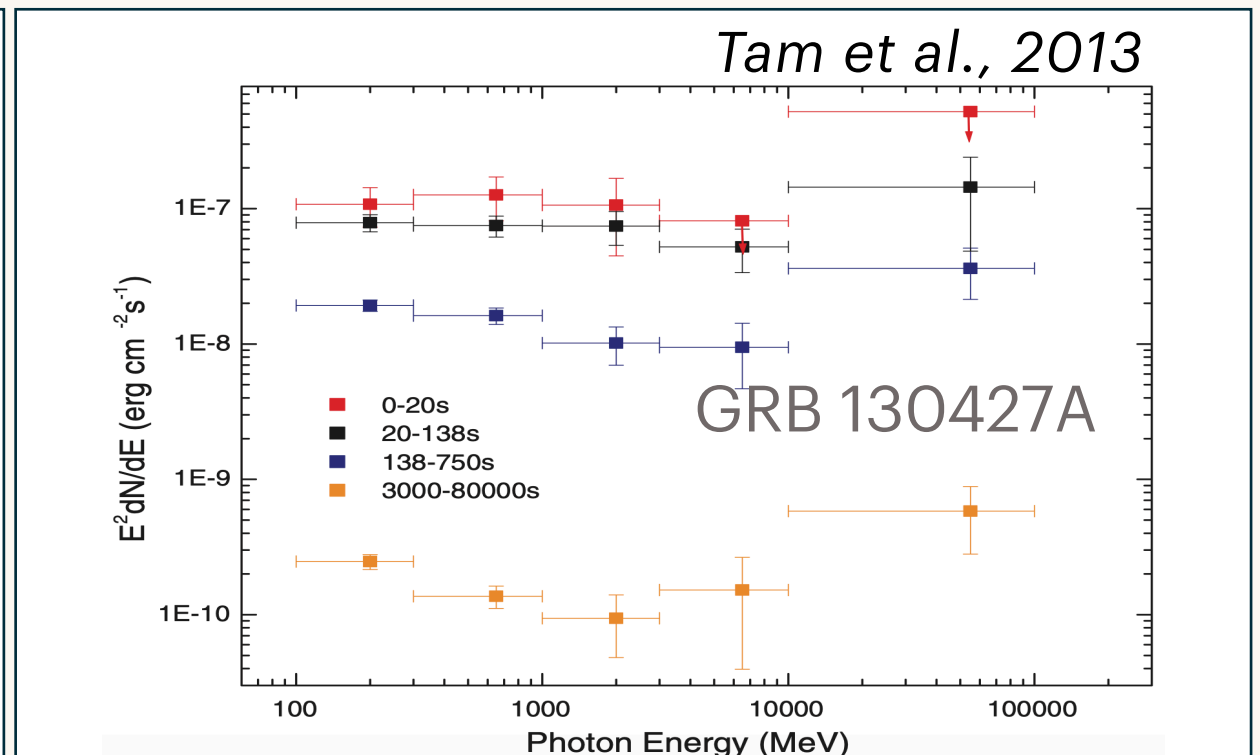
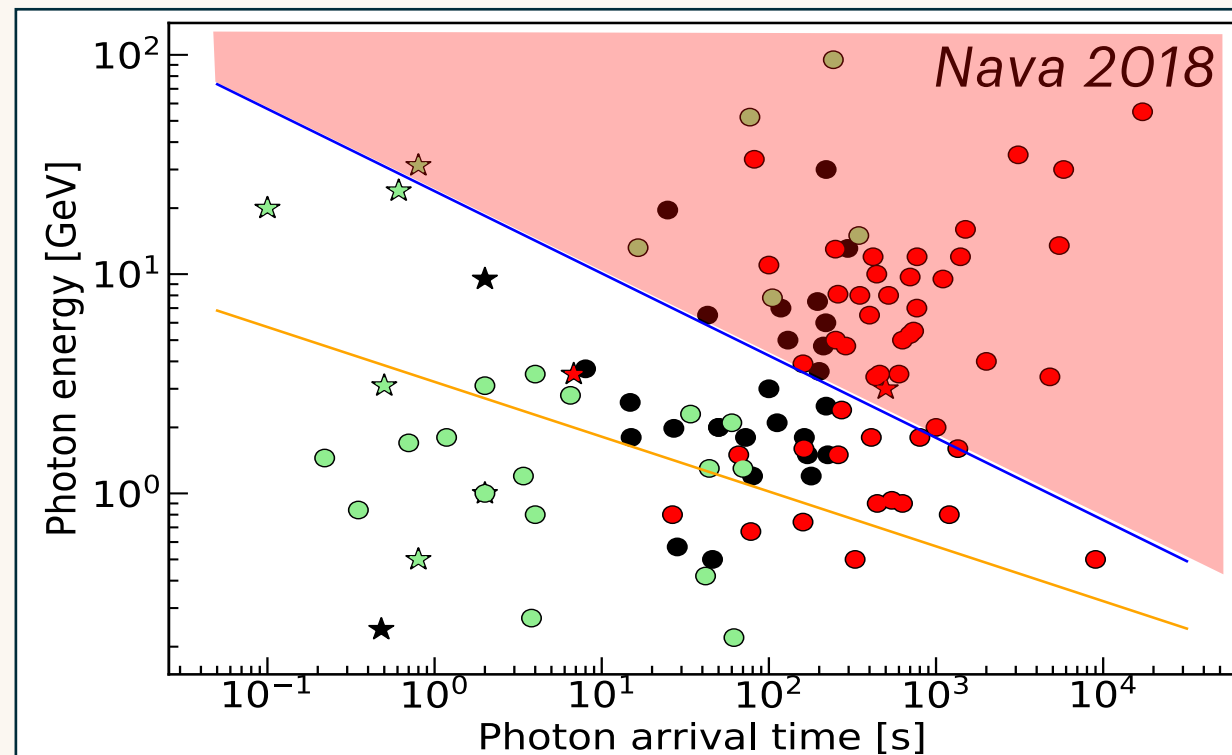
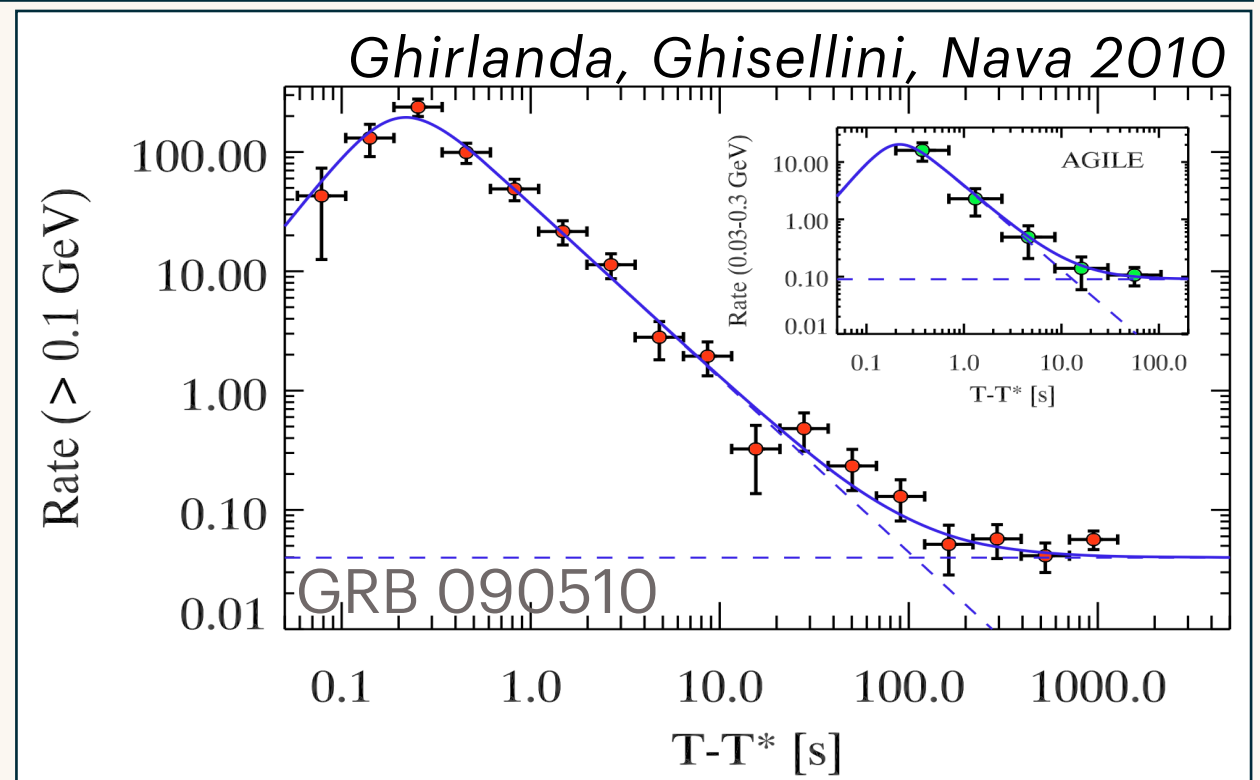
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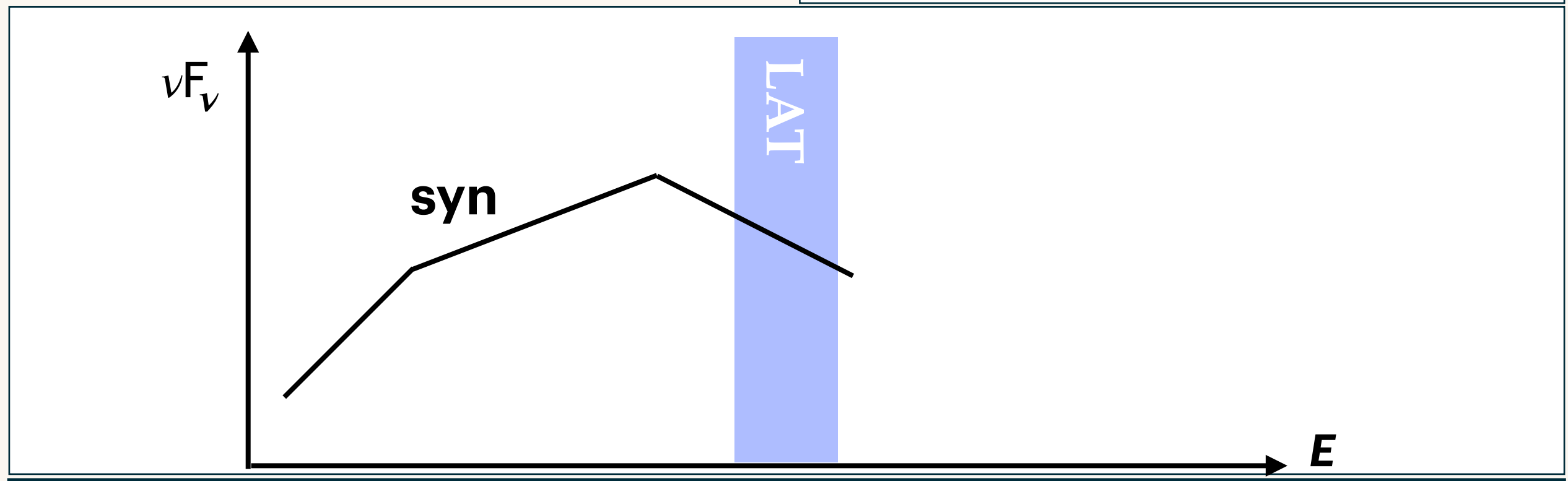
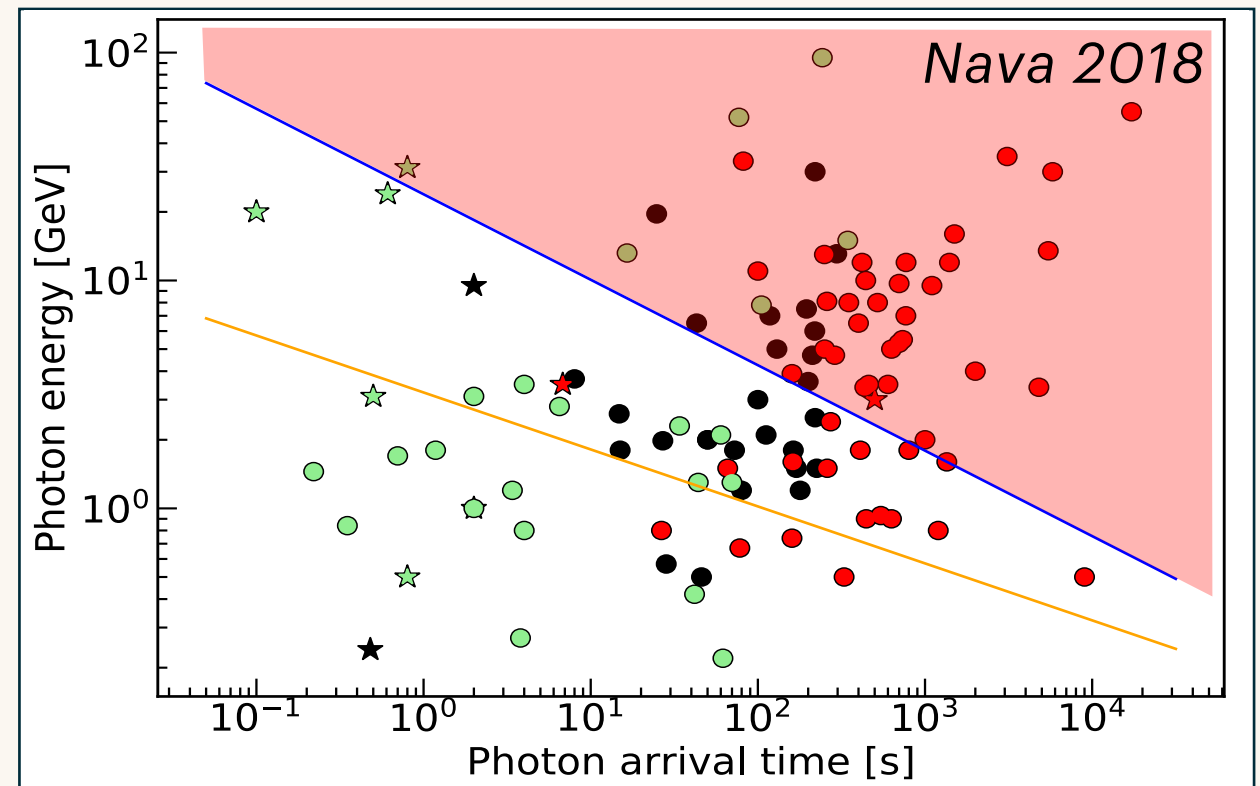
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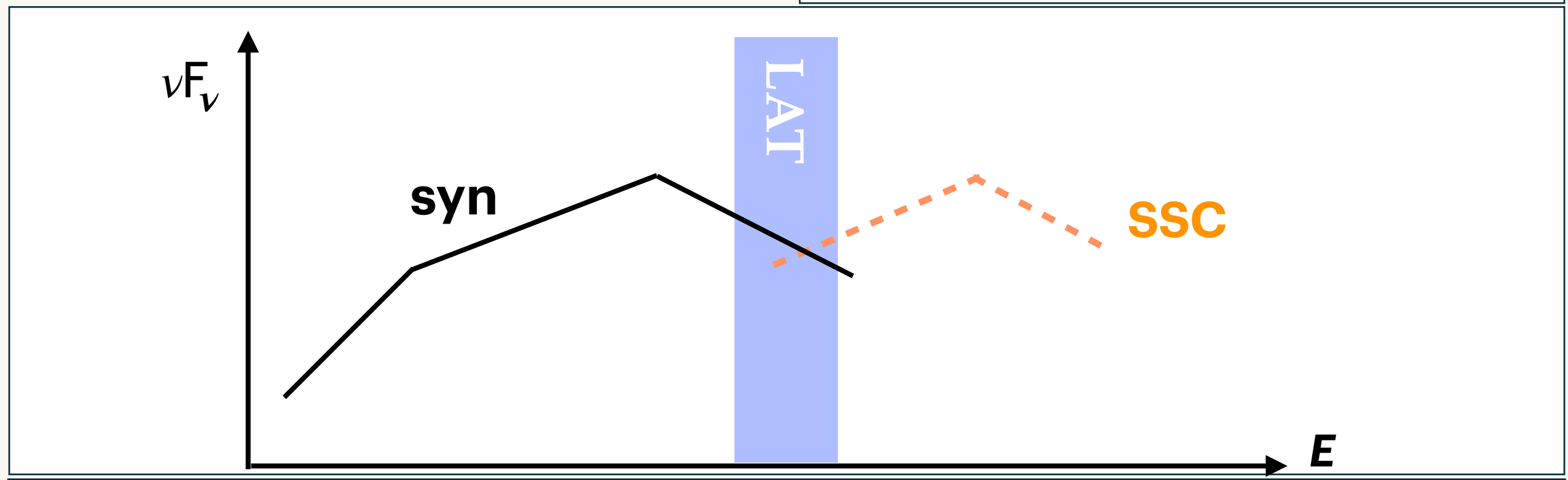
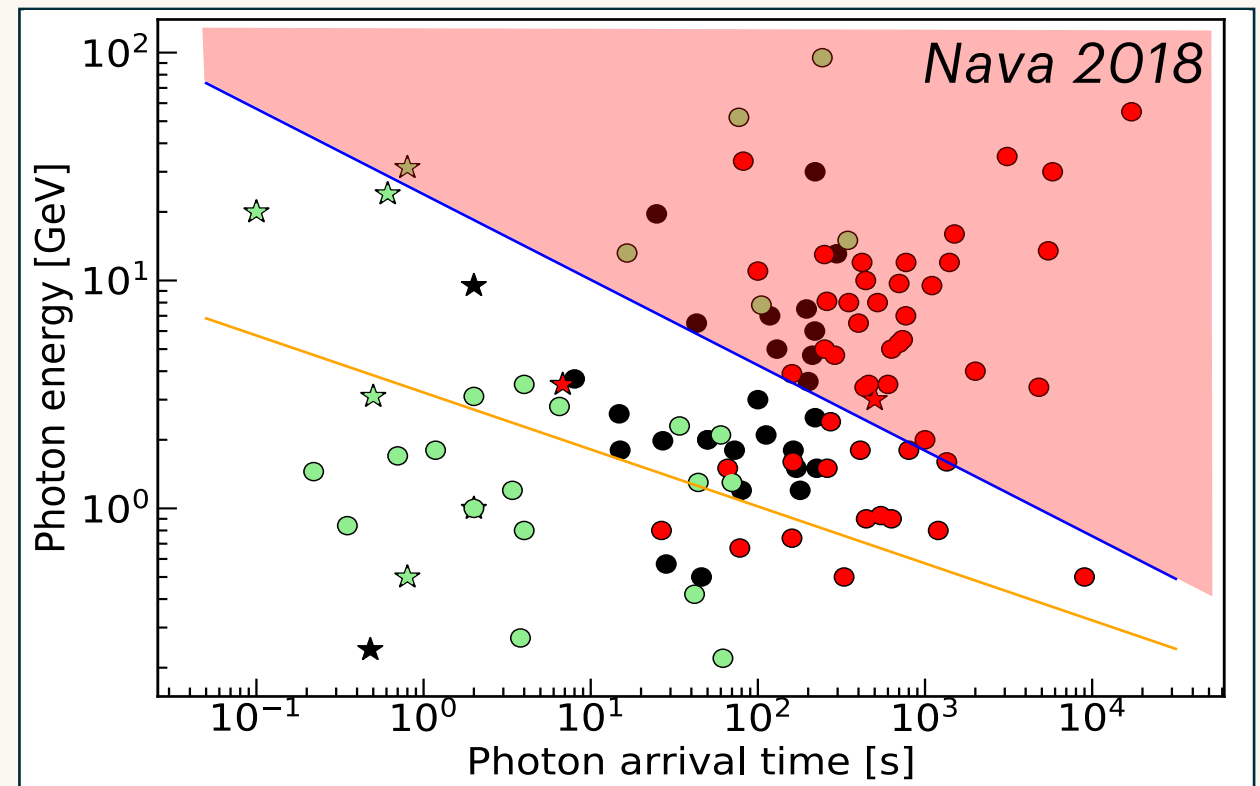
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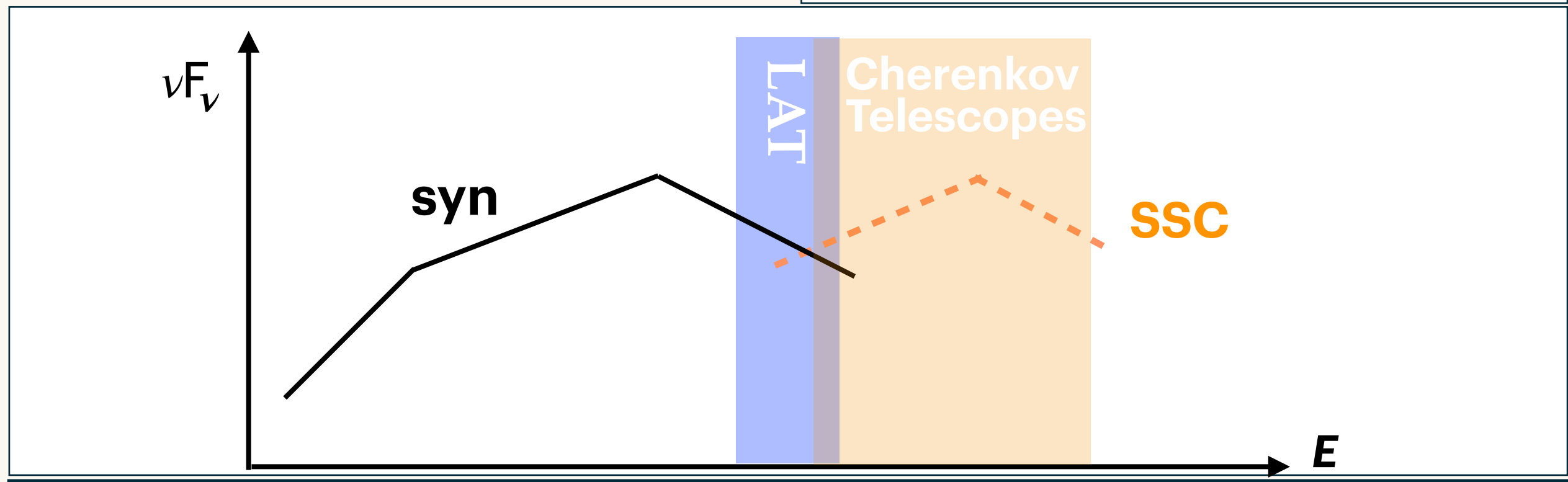
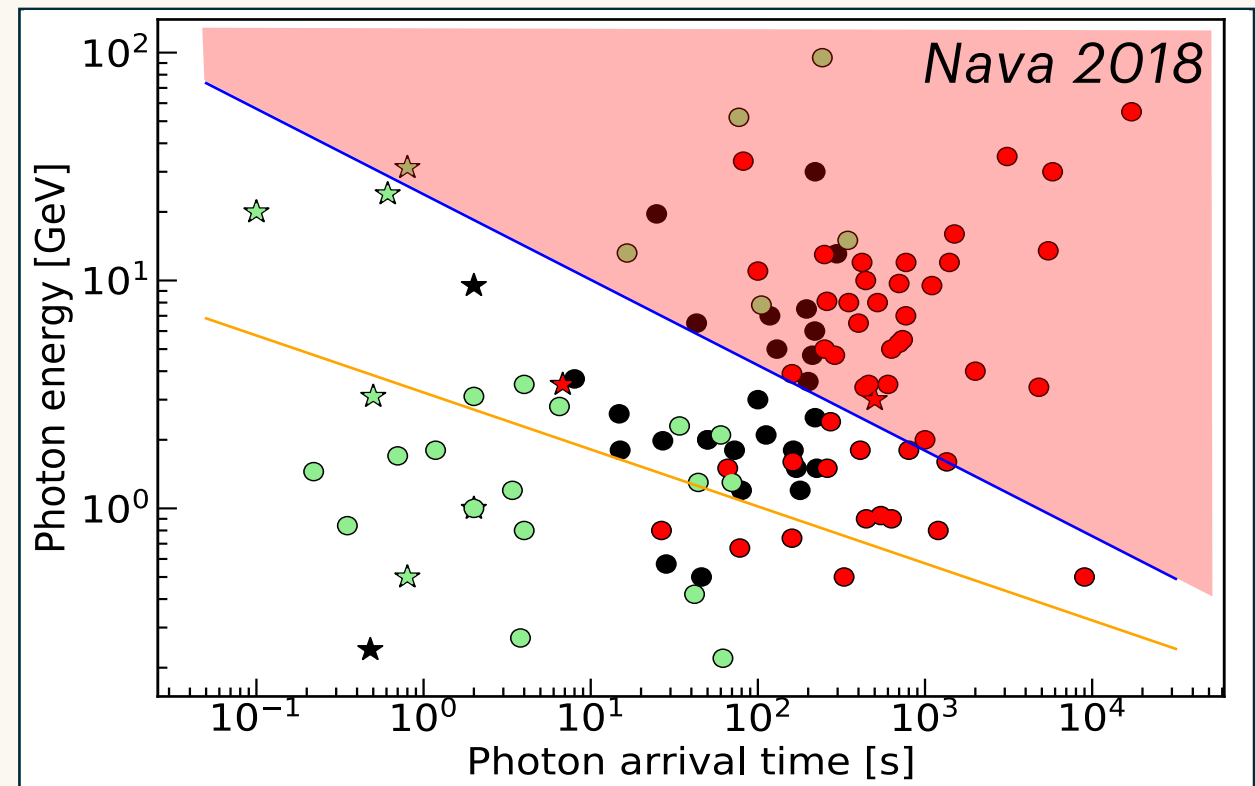
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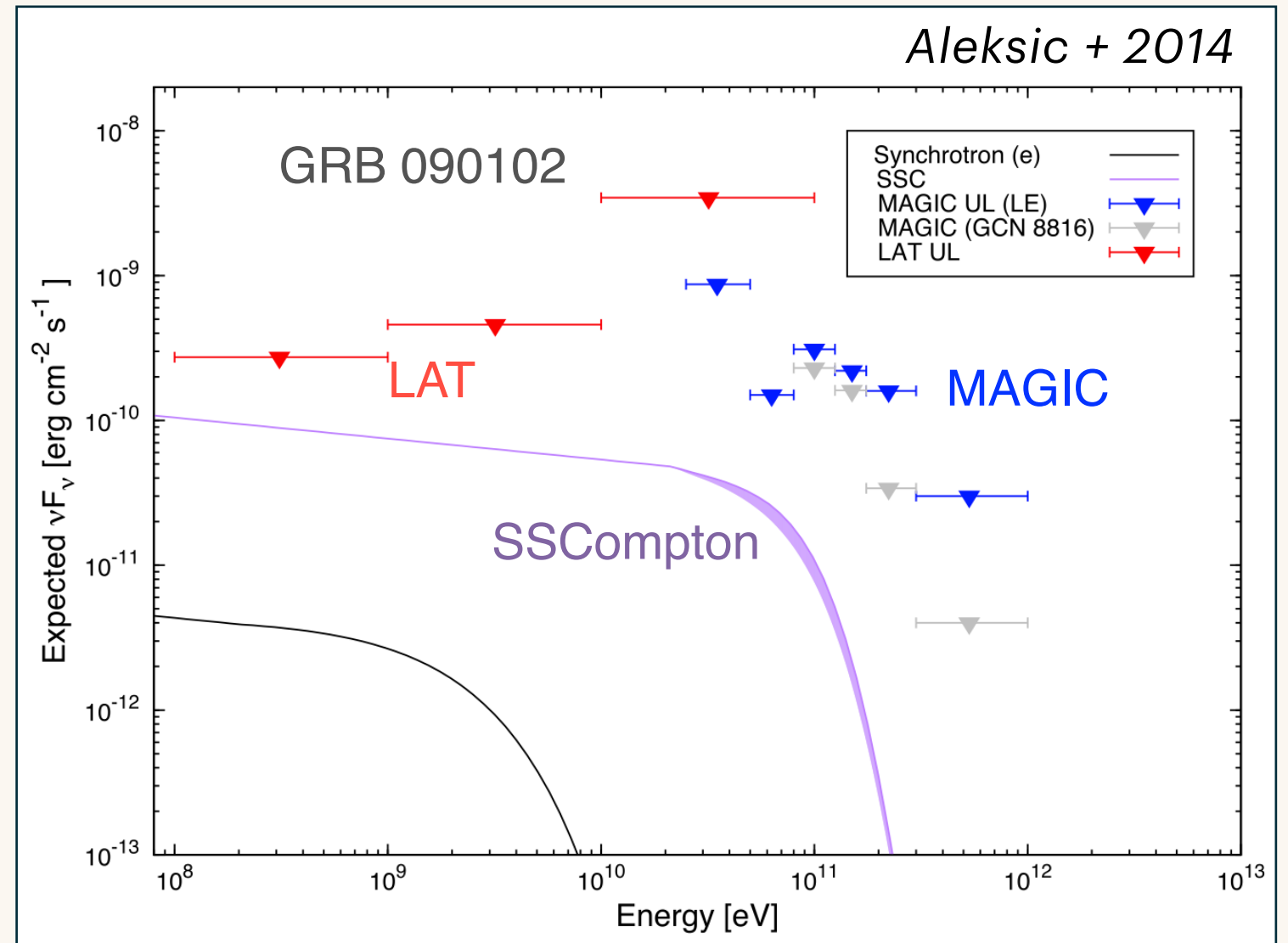


OBSERVATIONS AT TEV ENERGIES: CHERENKOV TELESCOPES

TeV OBSERVATIONS: CHERENKOV TELESCOPES

MAGIC / HESS / VERITAS

- Number of observed GRBs:
 - ▶ hundreds
- Low energy threshold:
 - ▶ 50 / 50 / 100 GeV
- Time delay:
 - ▶ < 100 s / 100-1000 s

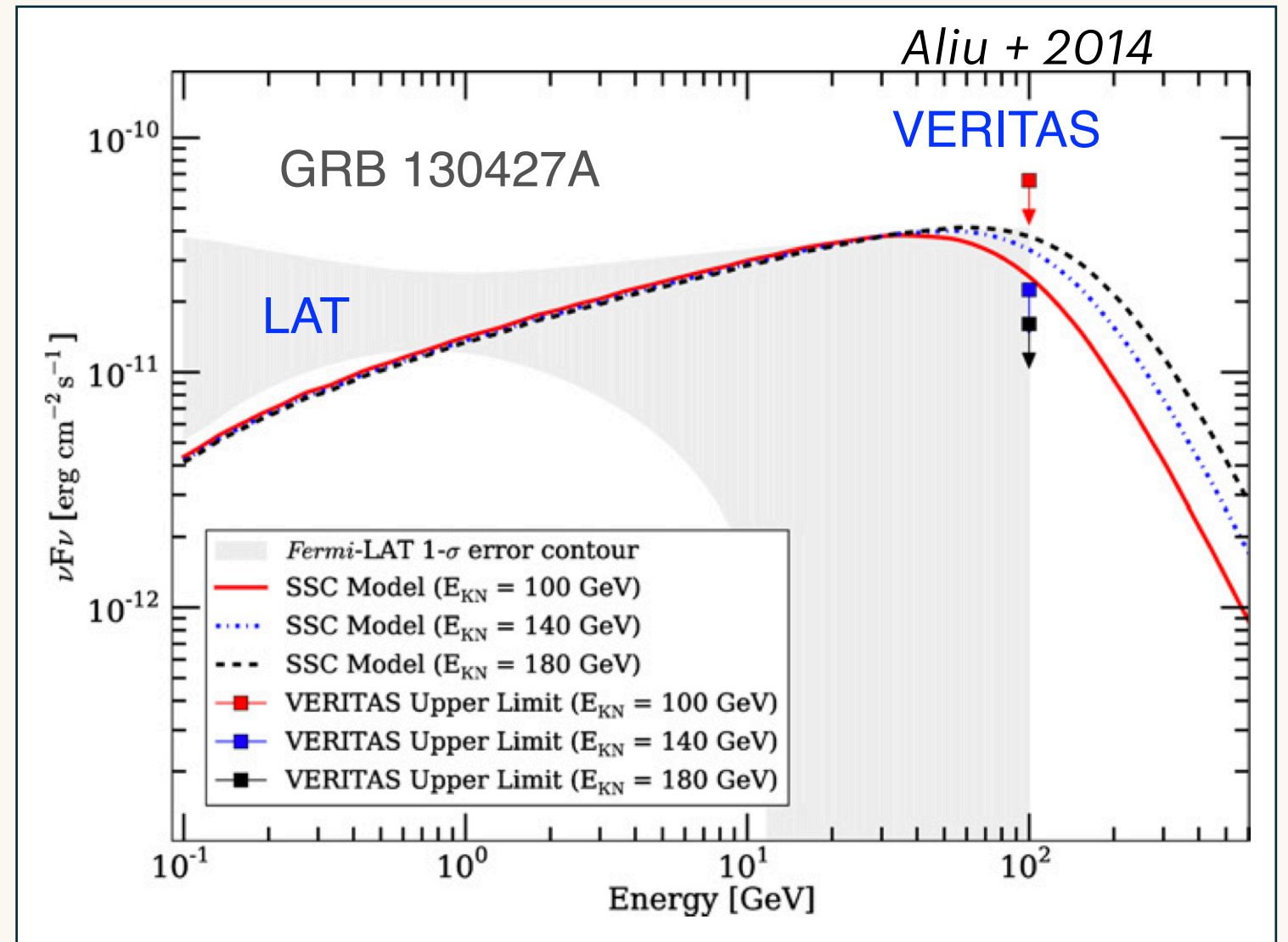


— until 2019: no detections, only upper limits —

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MAGIC DETECTION OF GRB 190114C

- Long GRB
- $z = 0.42$
- $E_{prompt} = 2.5 \times 10^{53} \text{erg}$

MAGIC detection

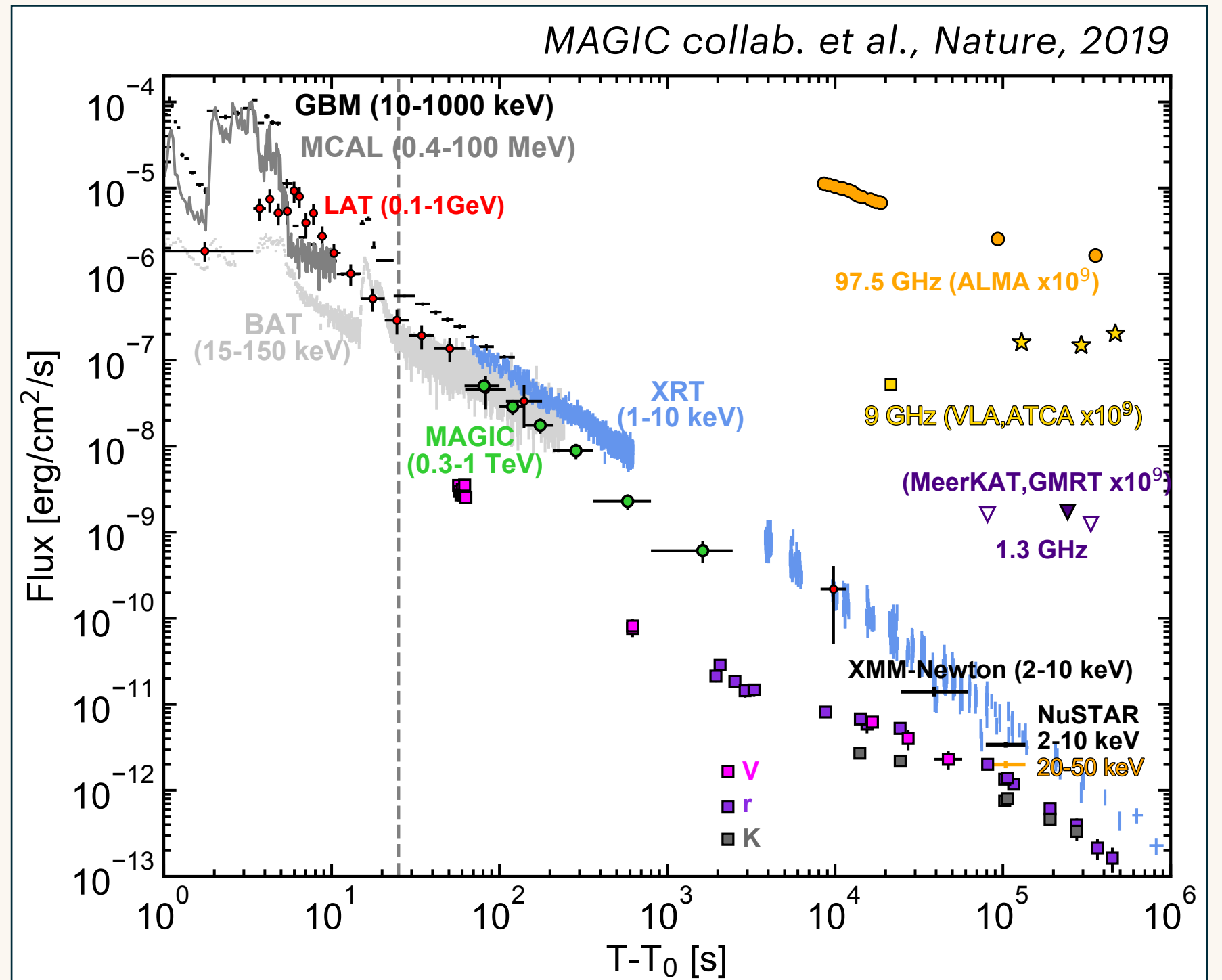
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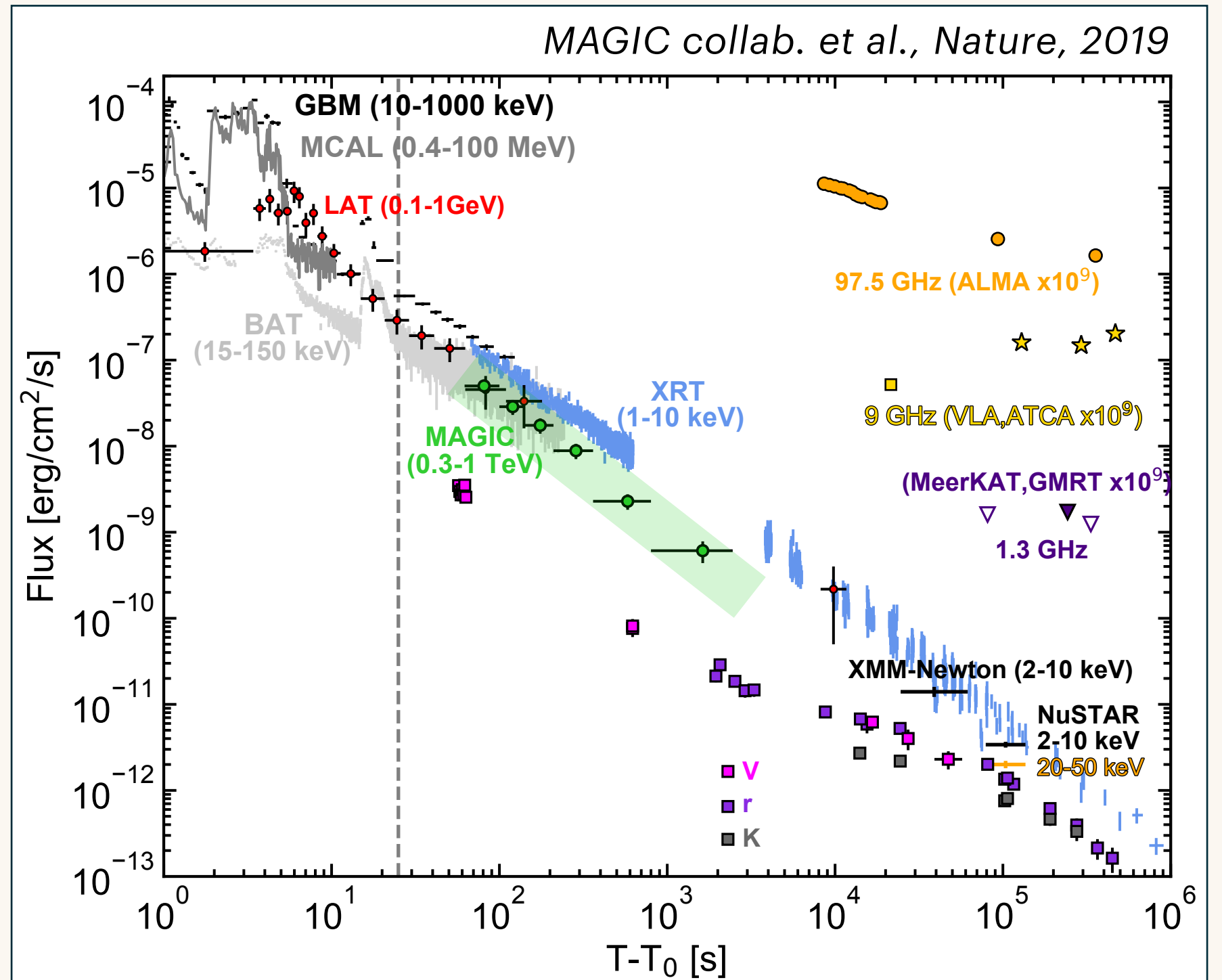


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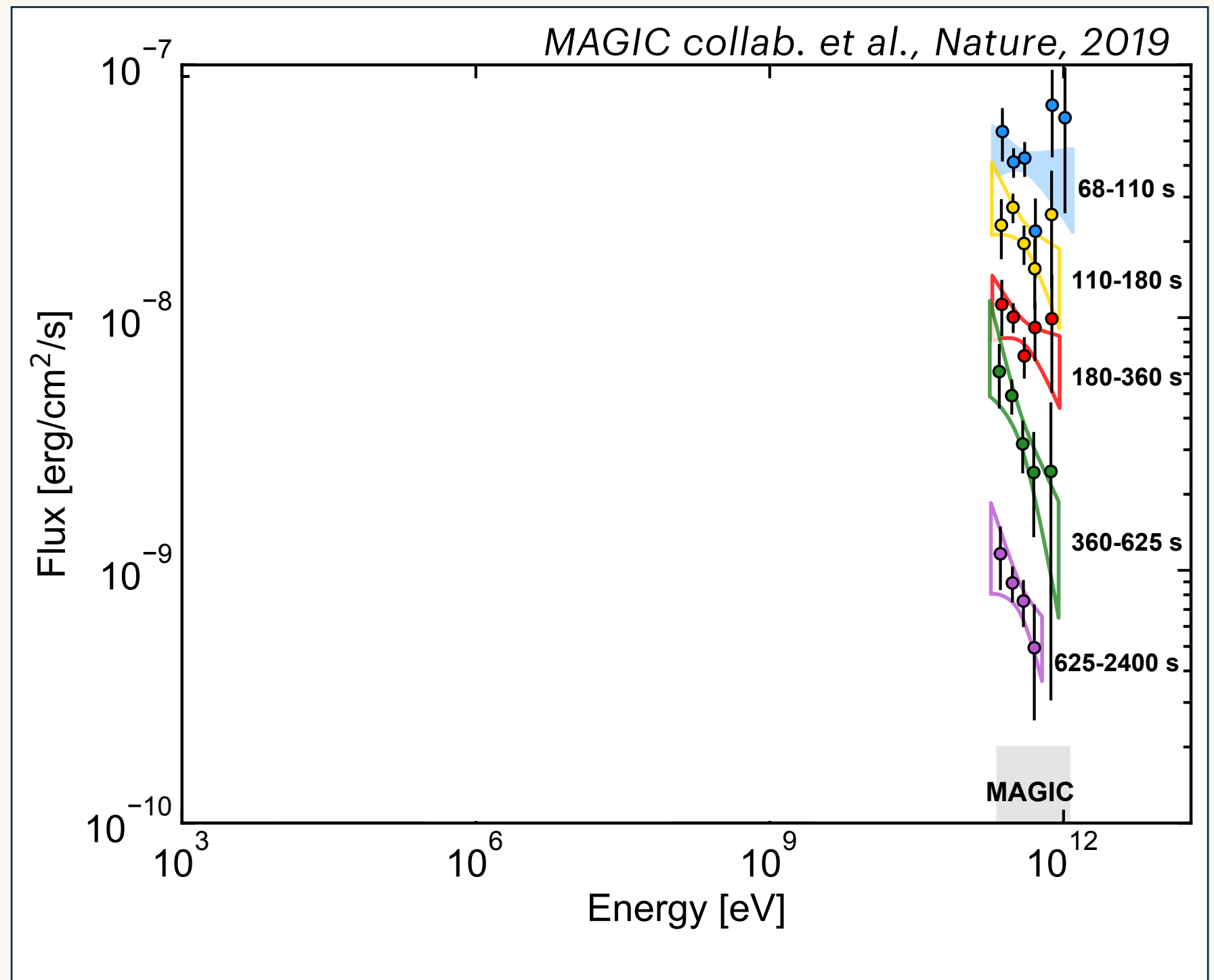


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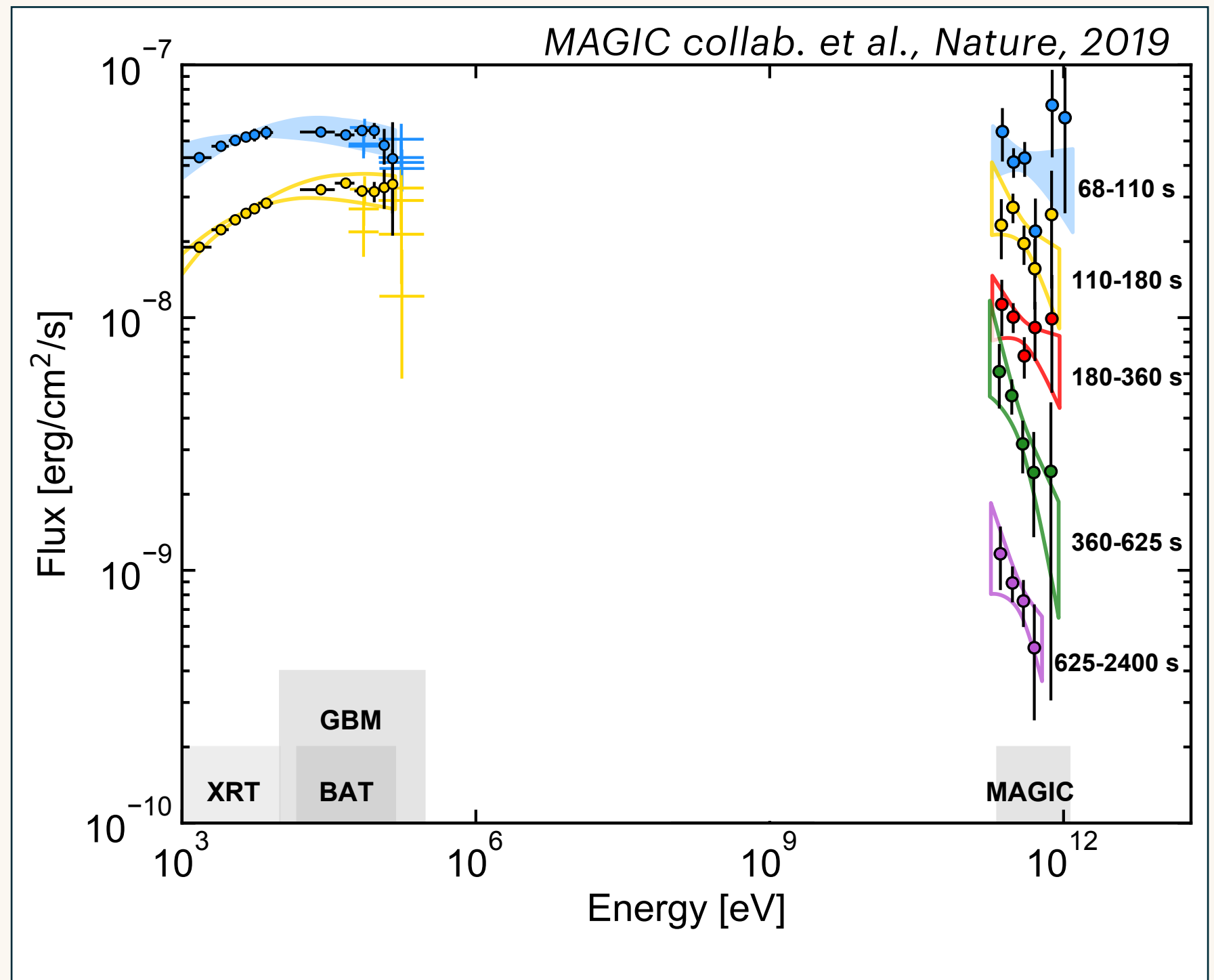


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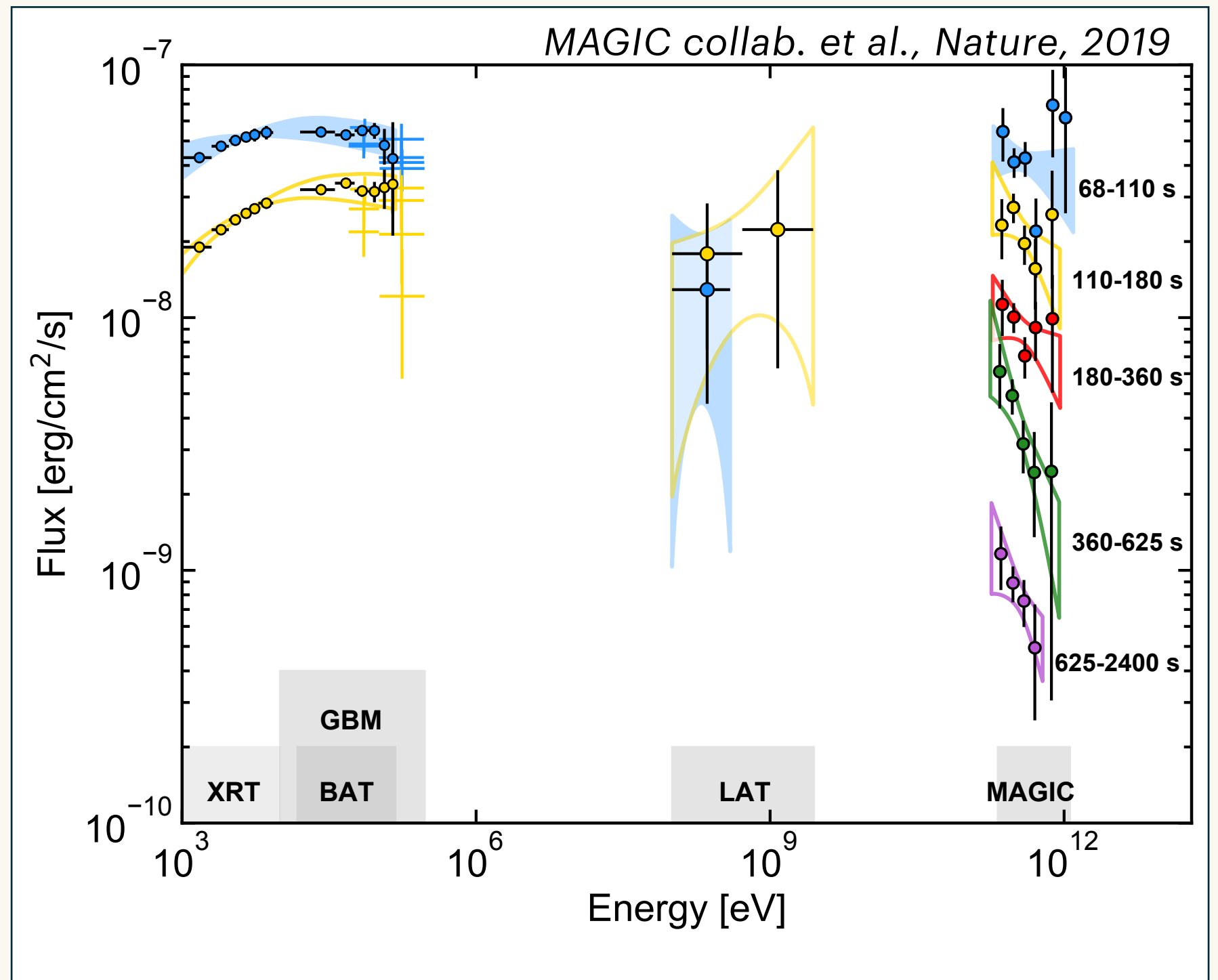


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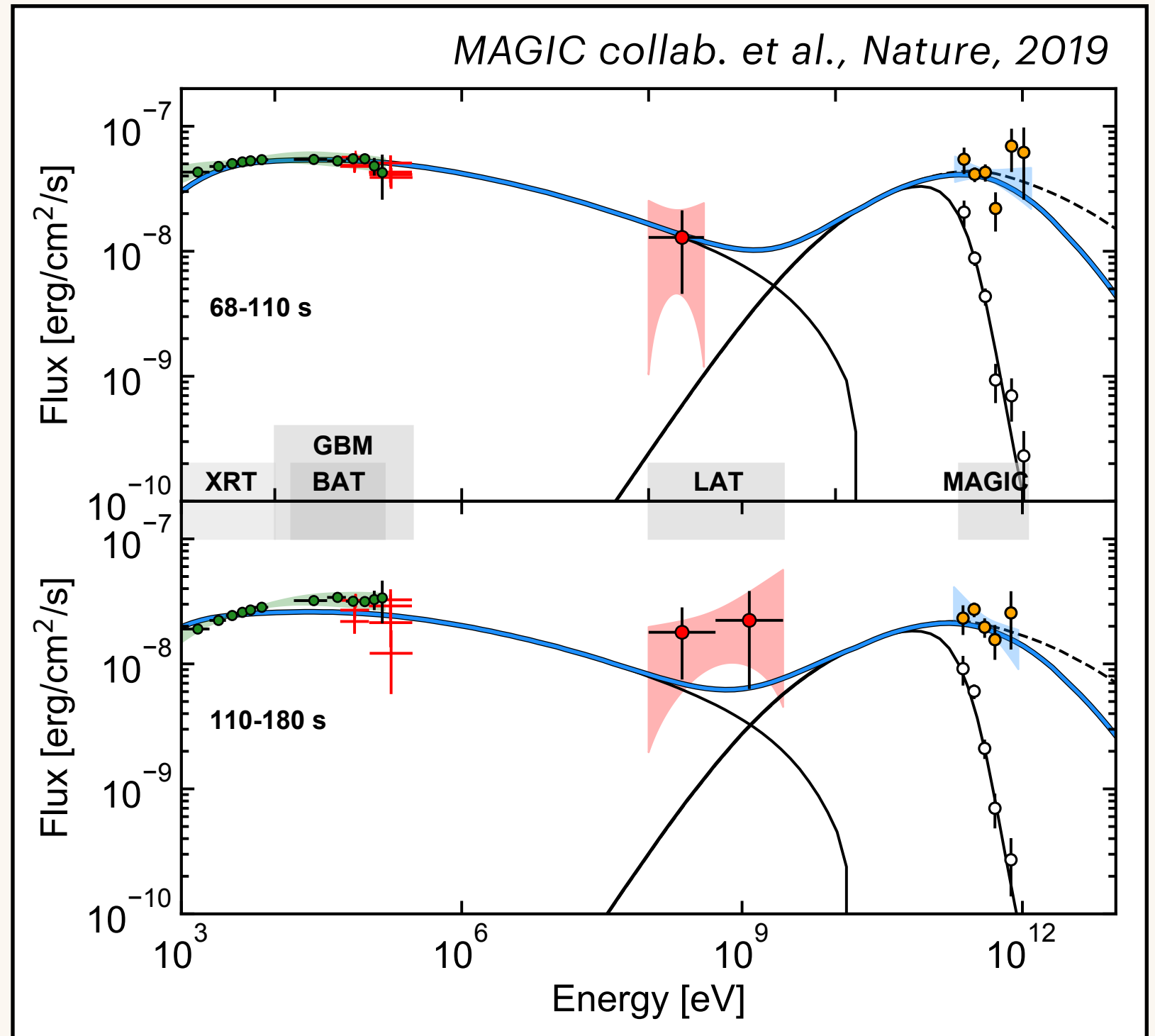


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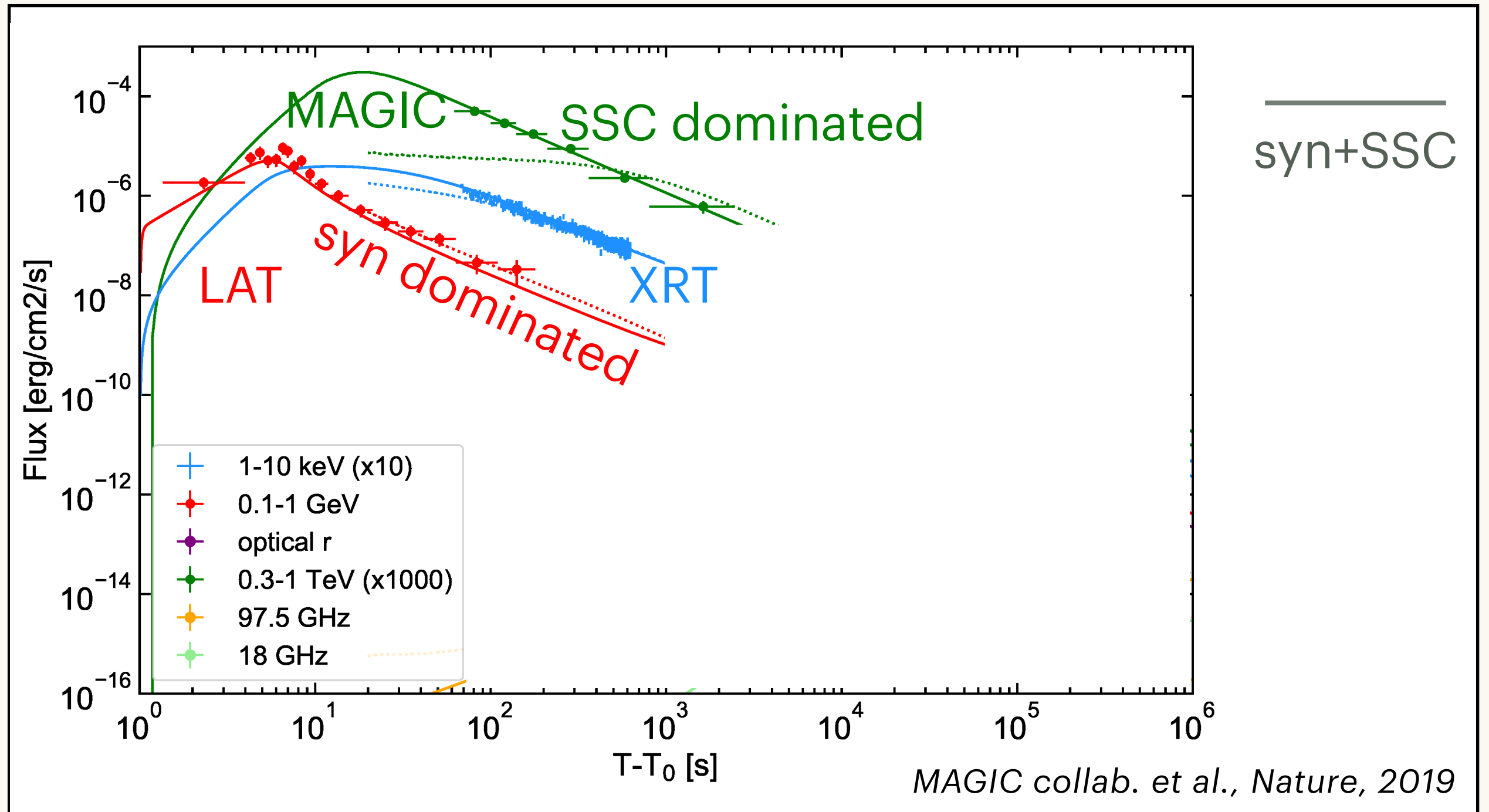
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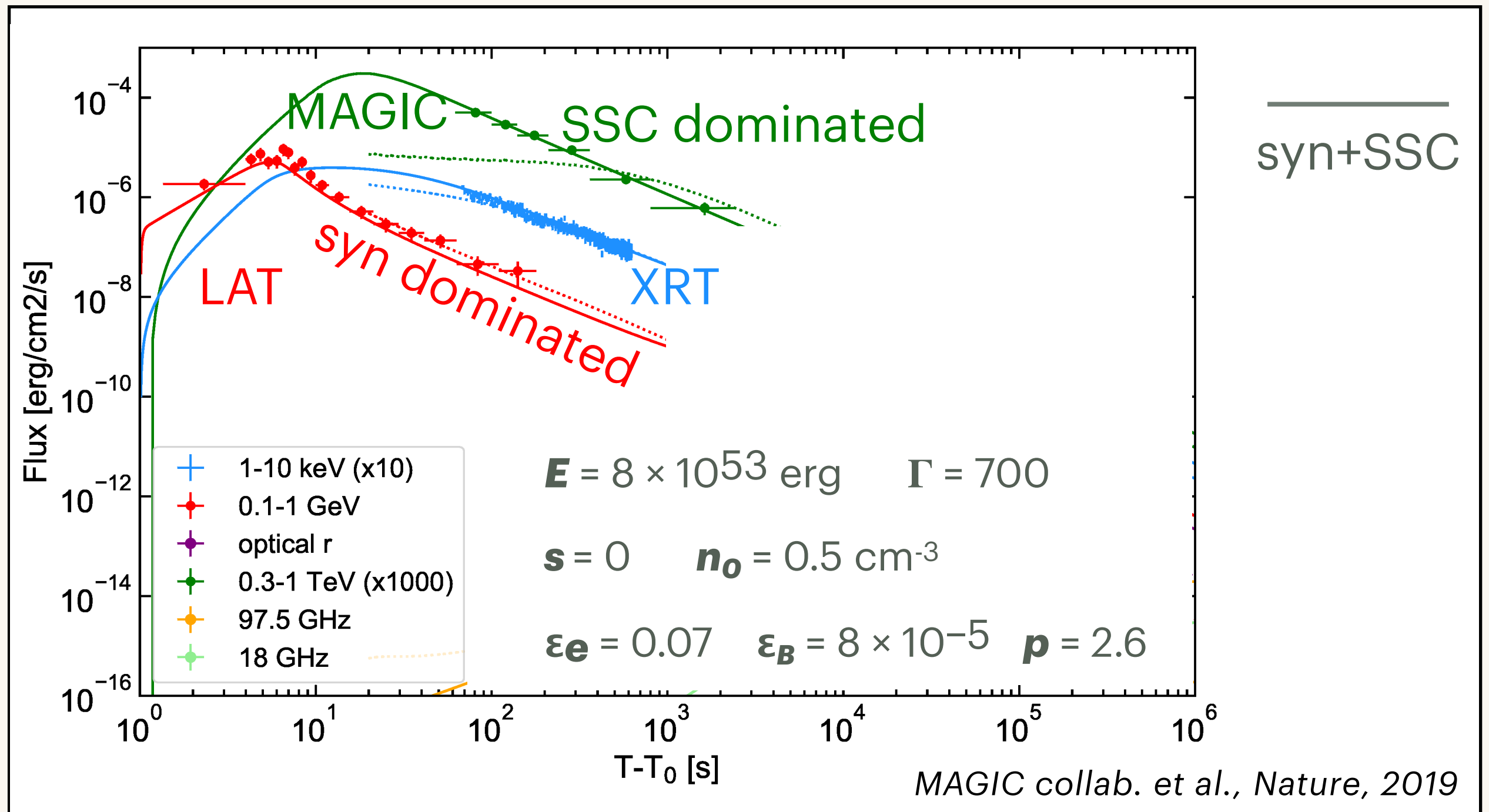
MAGIC DETECTION OF GRB 190114C

Light curve and SED modeling



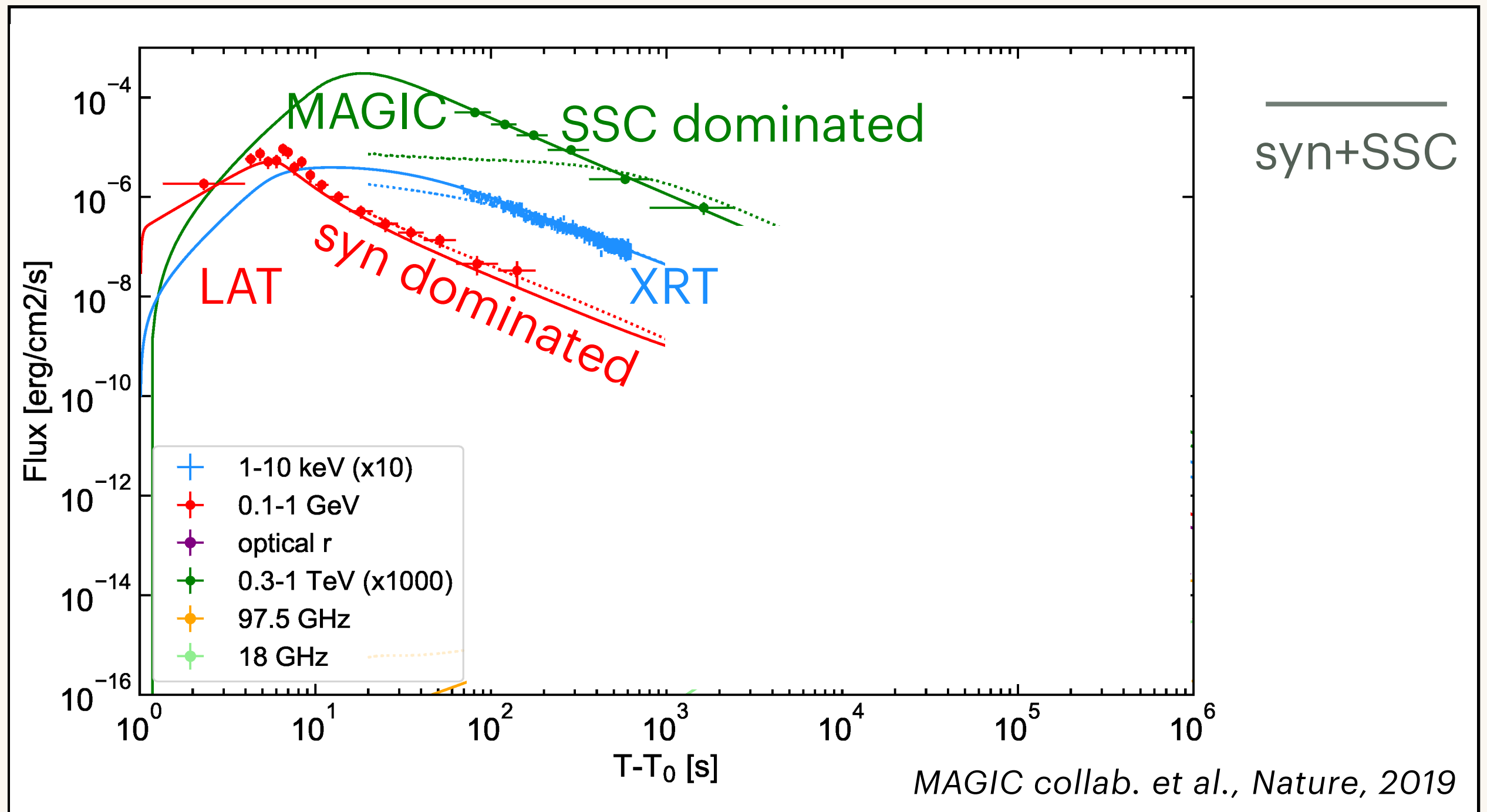
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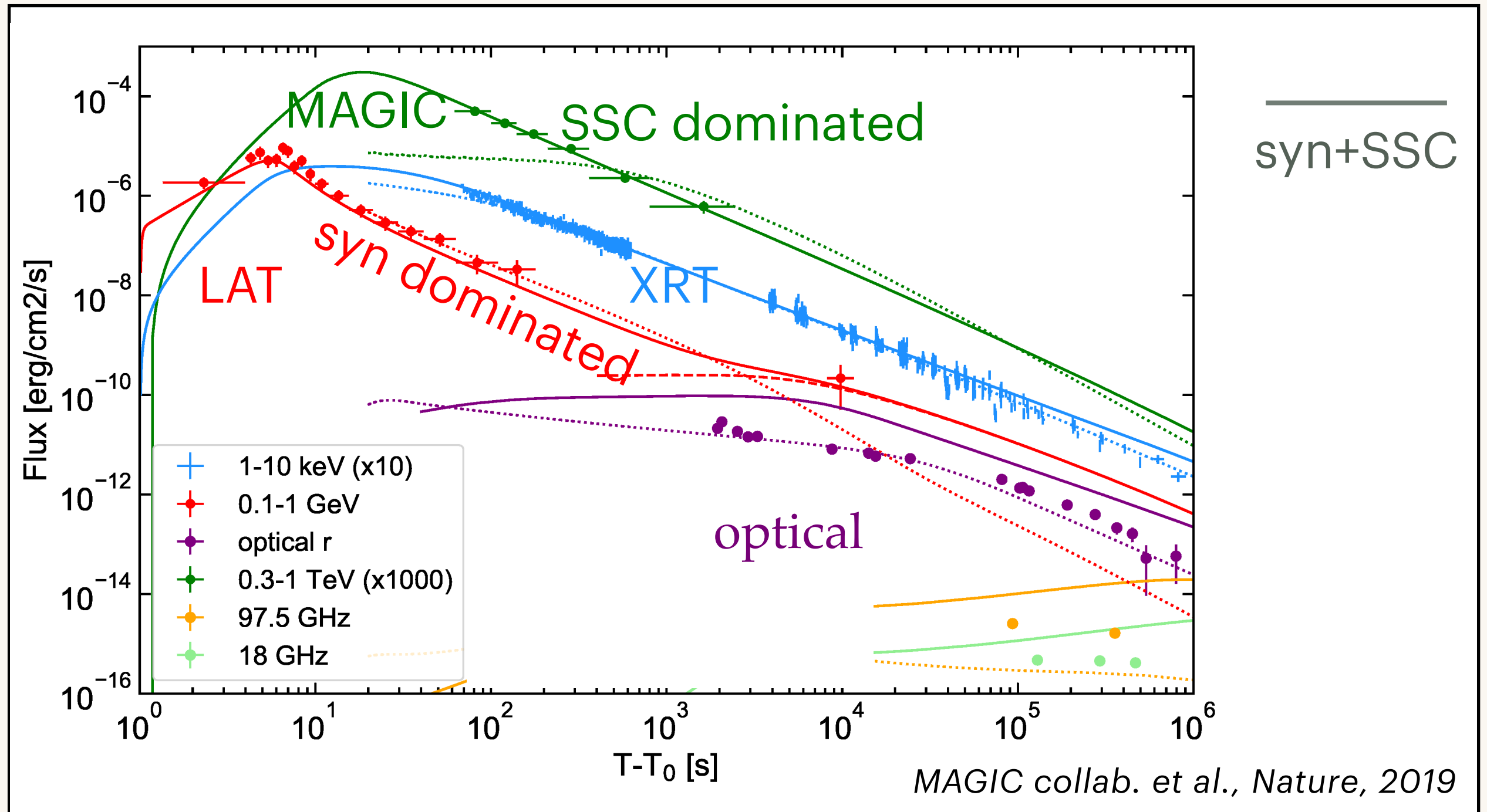
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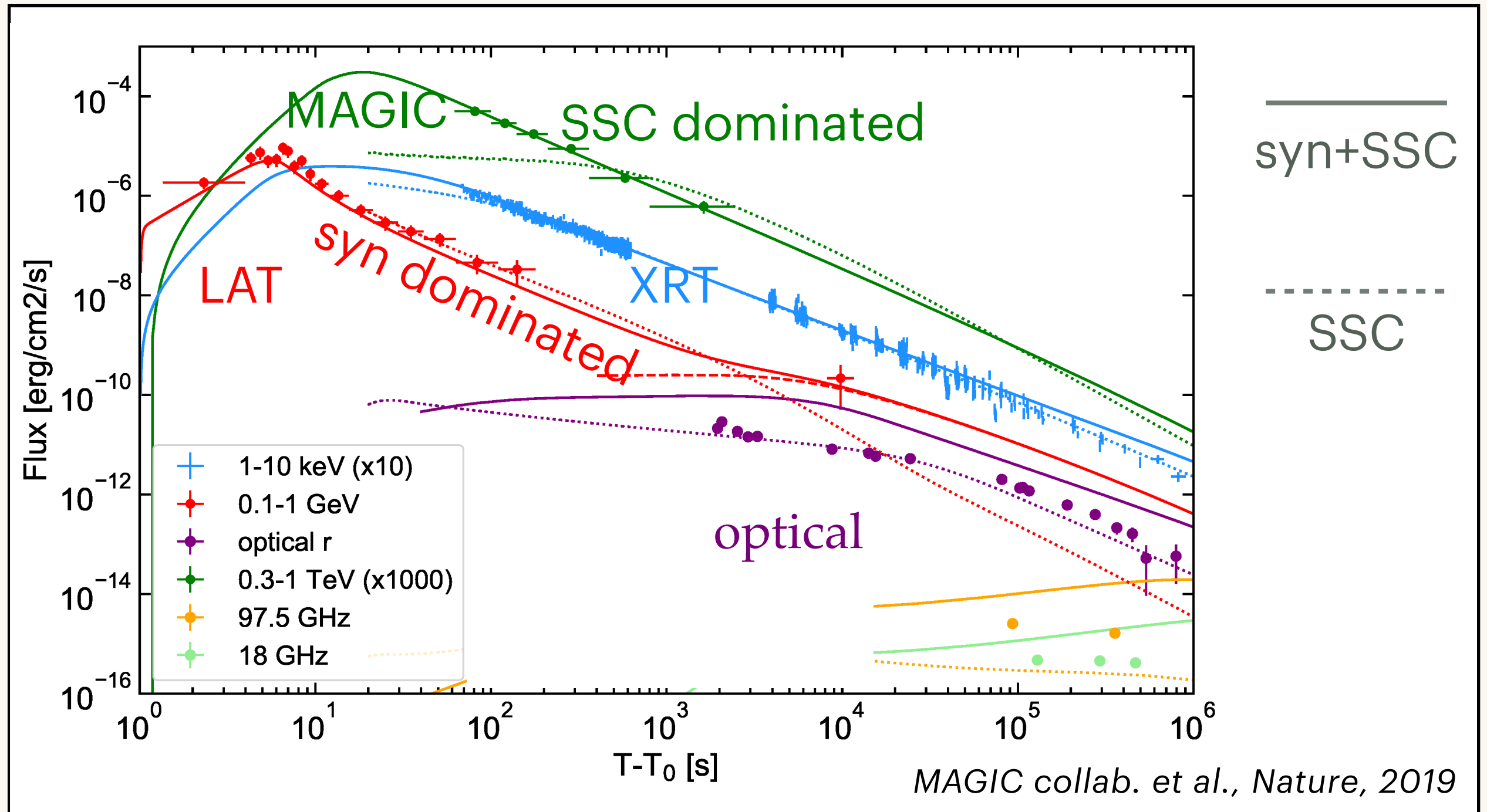
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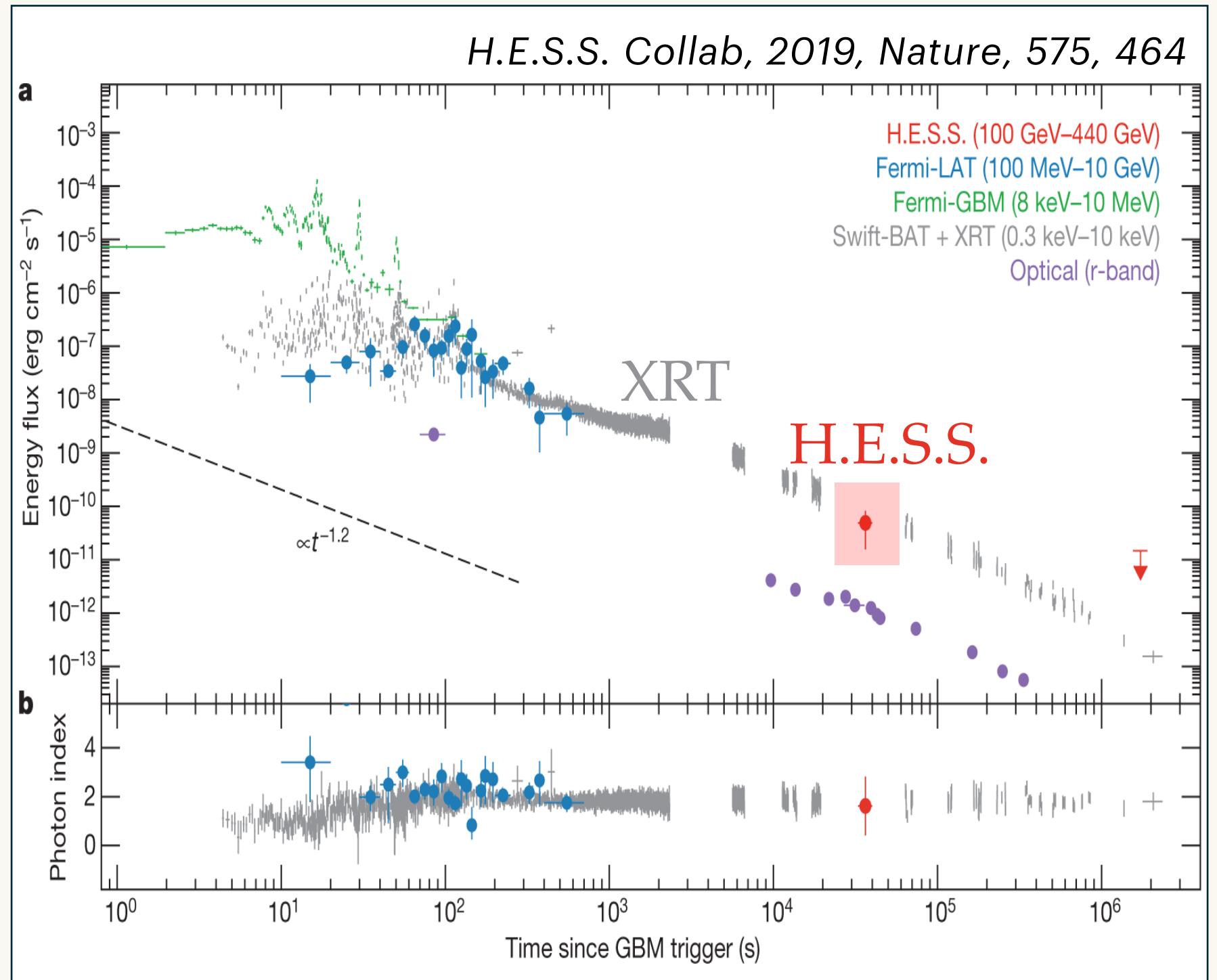


H.E.S.S. DETECTION OF GRB 180720B

- Long GRB
- $z = 0.65$
- $E_{prompt} = 6 \times 10^{53} \text{erg}$

H.E.S.S. detection

- ▶ ~10 hours after the GRB
- ▶ in the energy range 0.1-0.44 TeV



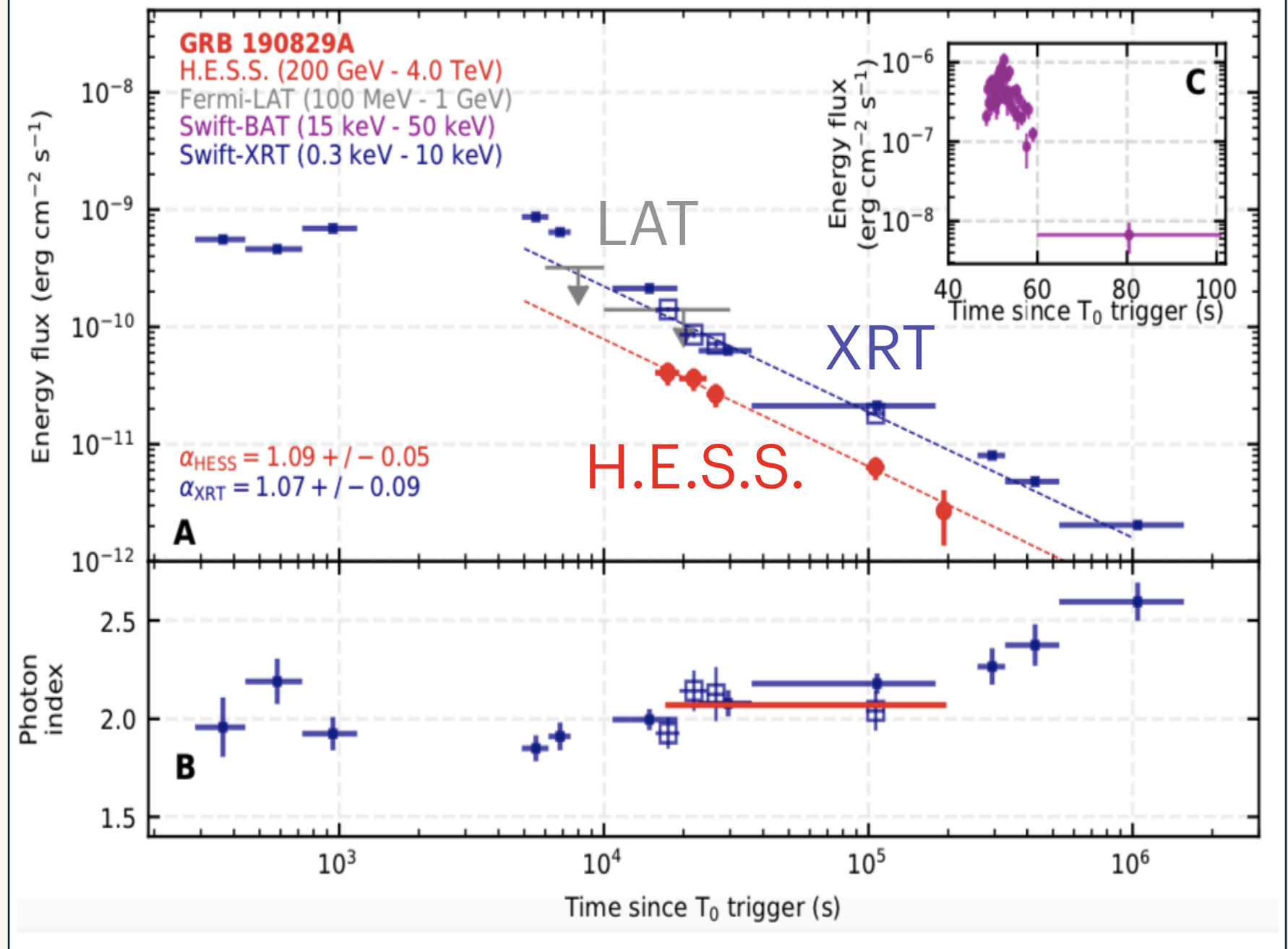
H.E.S.S. DETECTION OF GRB 190829A

- Long GRB
- $z = 0.078$
- $E_{prompt} = 2 \times 10^{50} \text{erg}$

H.E.S.S. detection

- ▶ 3 nights, from 4.3 to 55.9 hrs
- ▶ in the energy range 0.18-3.3 TeV

H.E.S.S. Collab, 2021, Science, 372, 6546

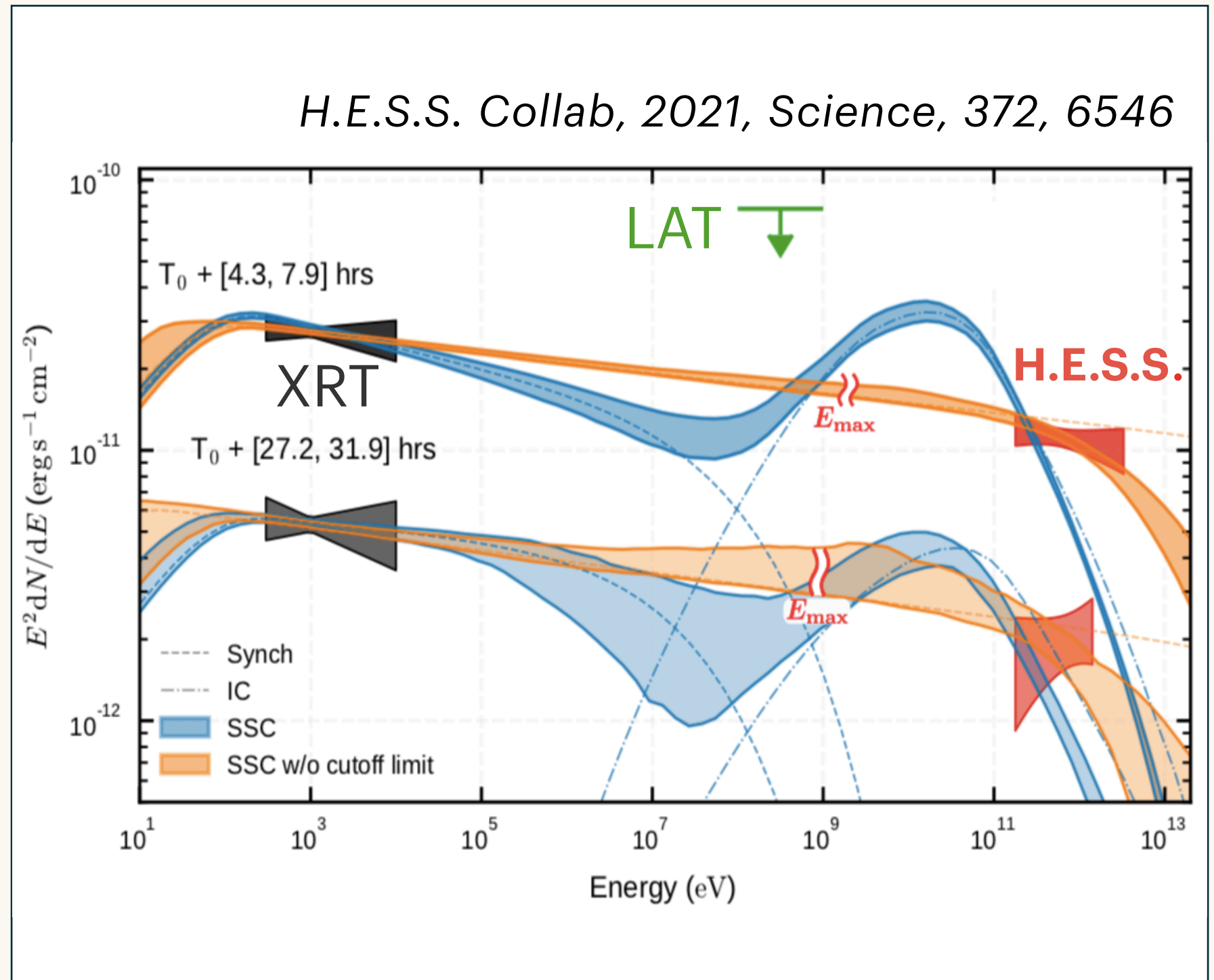


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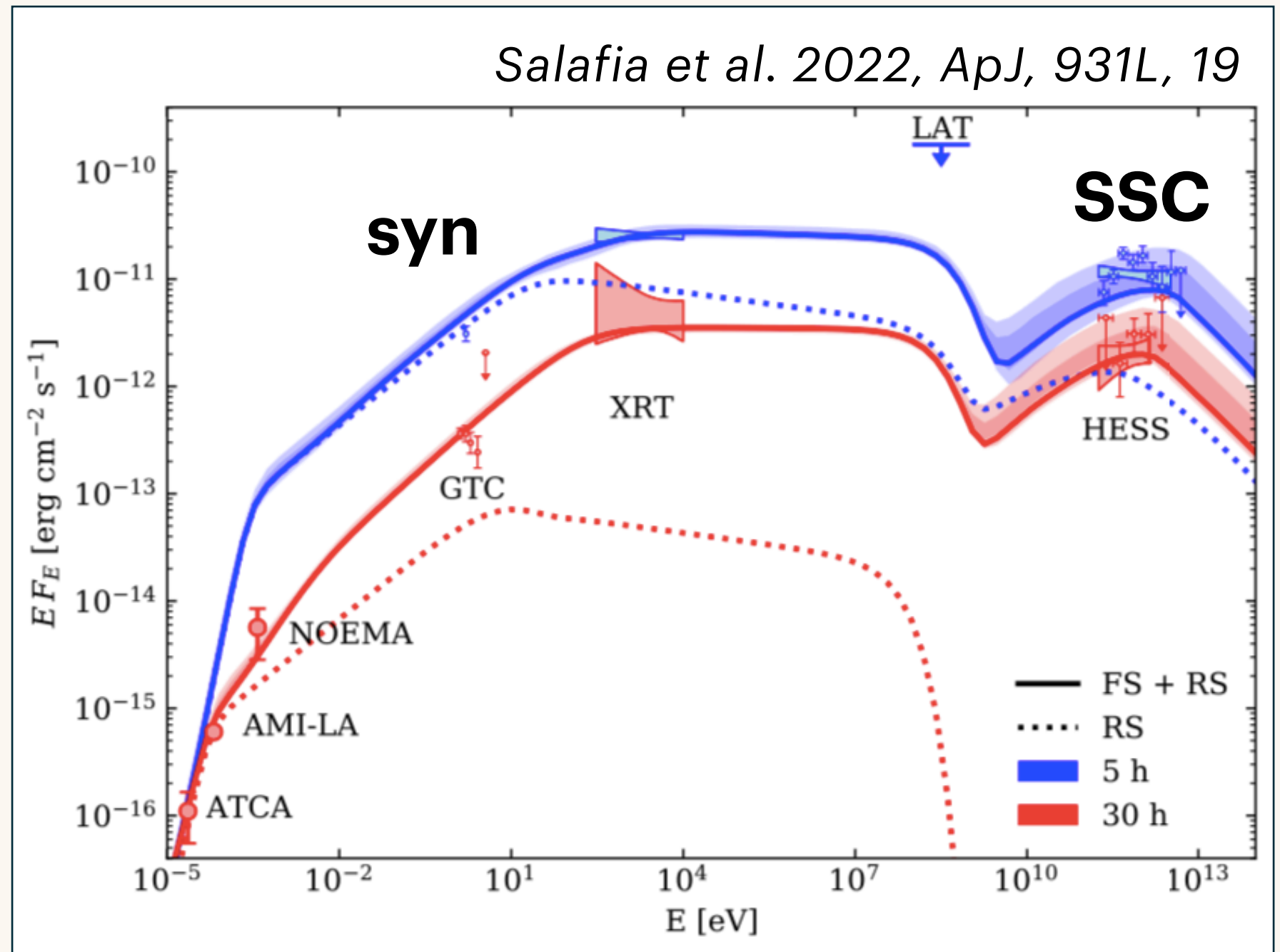


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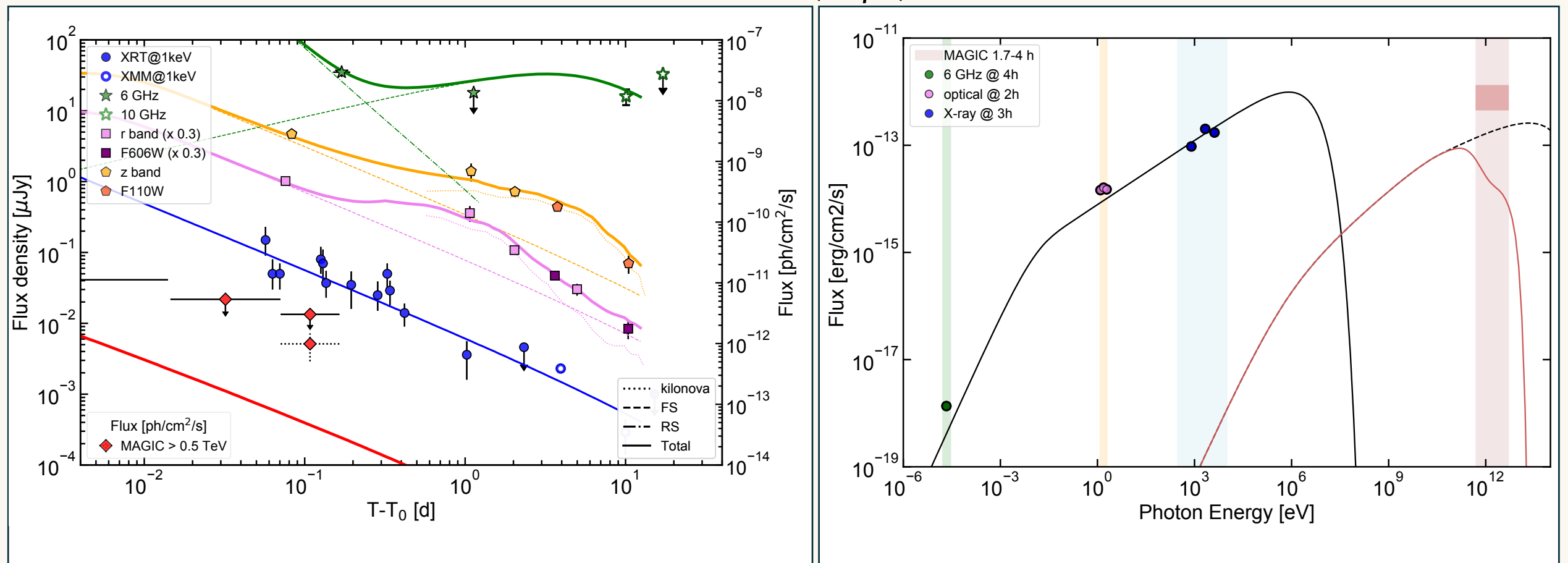
GRB 201216C (MAGIC)

- Long GRB
- $z = 1.1$
- $E_{prompt} = 5 \times 10^{53}$ erg
- 57 seconds after the prompt
- Significance of detection ~ 6 sigma

SHORT GRB 160821B

- ▶ $z = 0.16$
- ▶ Kilonova emission
- ▶ MAGIC: excess ~ 3 sigma

MAGIC Collab., ApJ, 2021

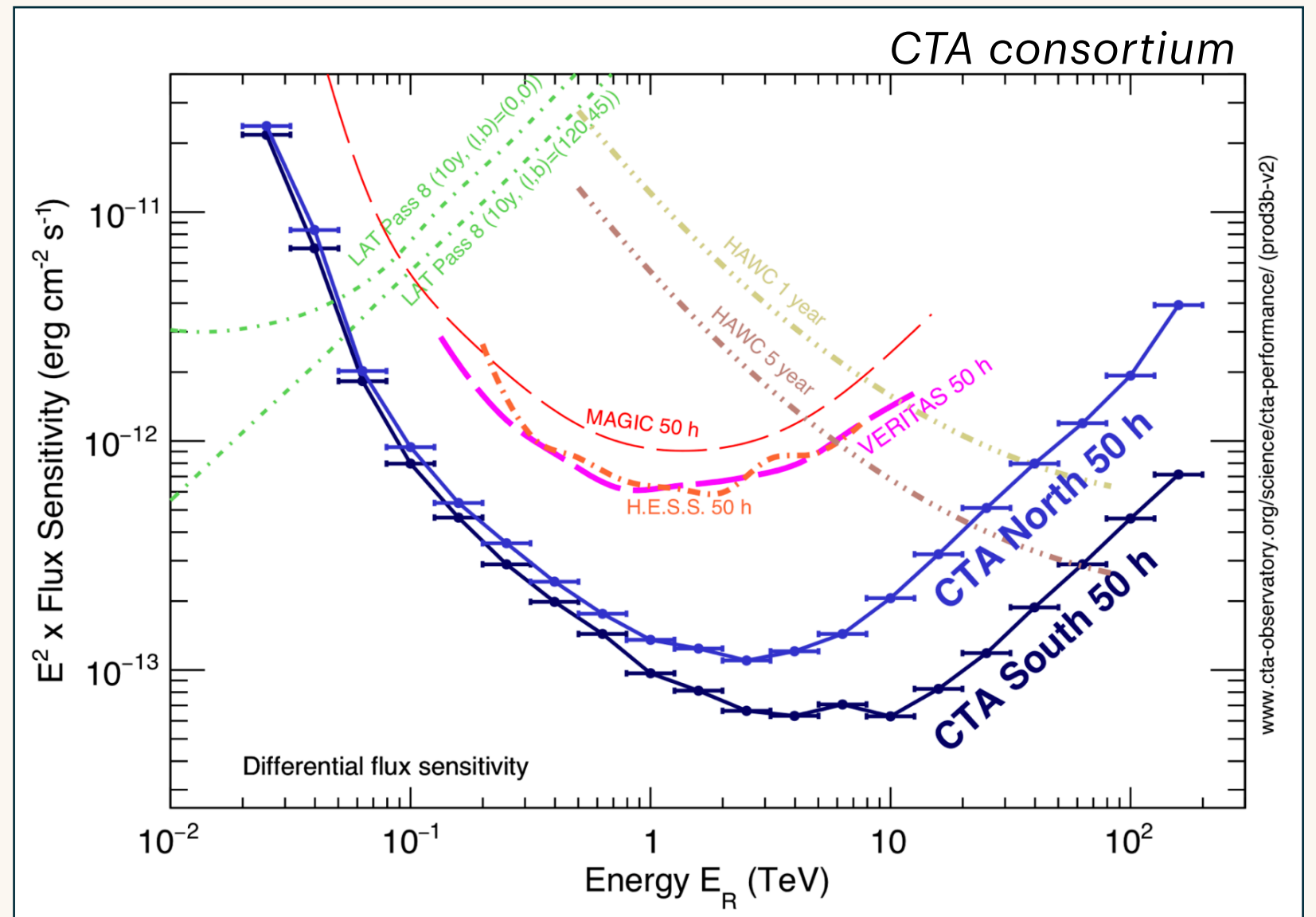


CTA - CHERENKOV TELESCOPE ARRAY

LST: 20 GeV - 3 TeV

MST: 80 GeV - 50 TeV

SST: 1 TeV - 300 TeV



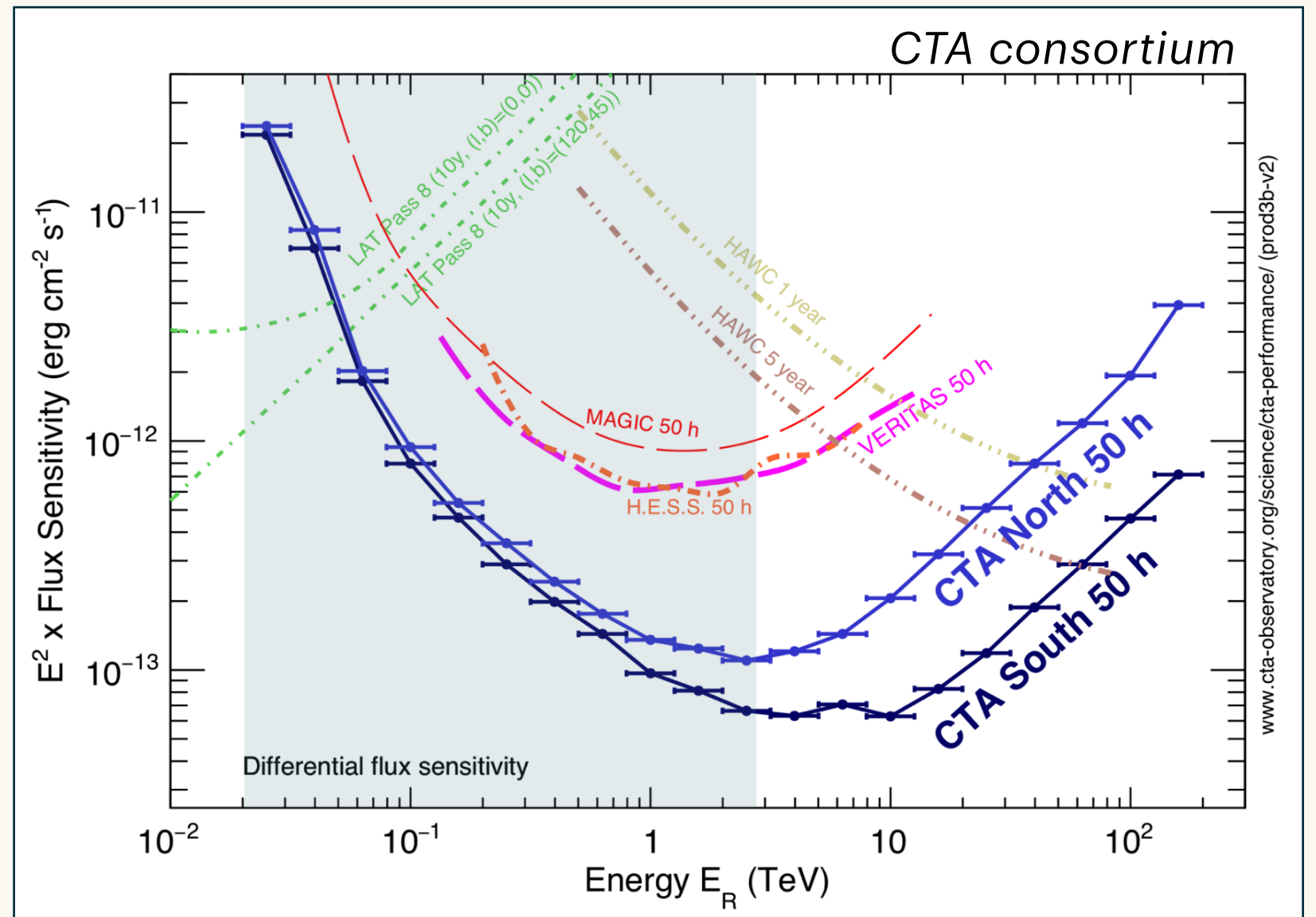
Consortium paper on prospects for CTA observations of GRB
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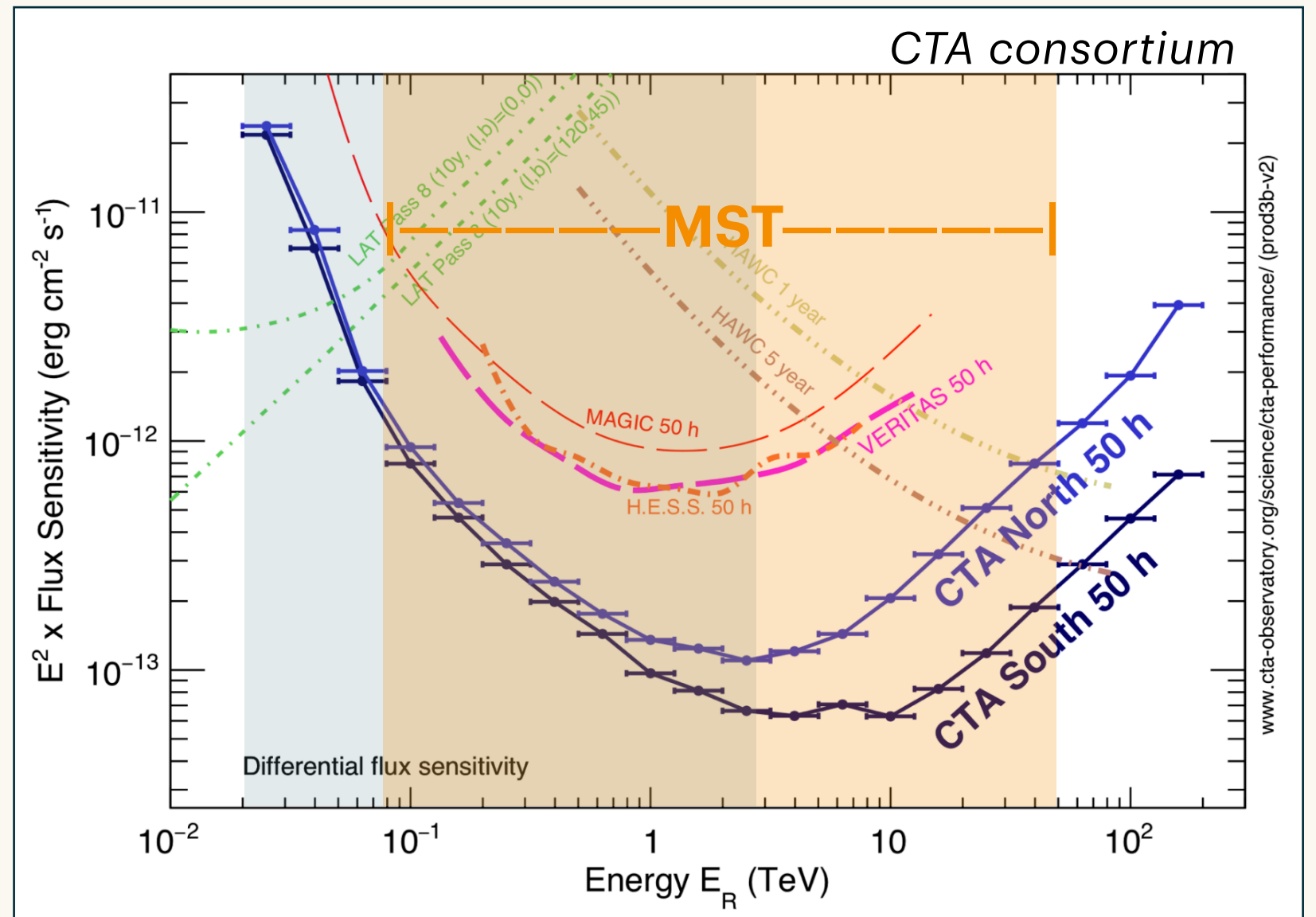
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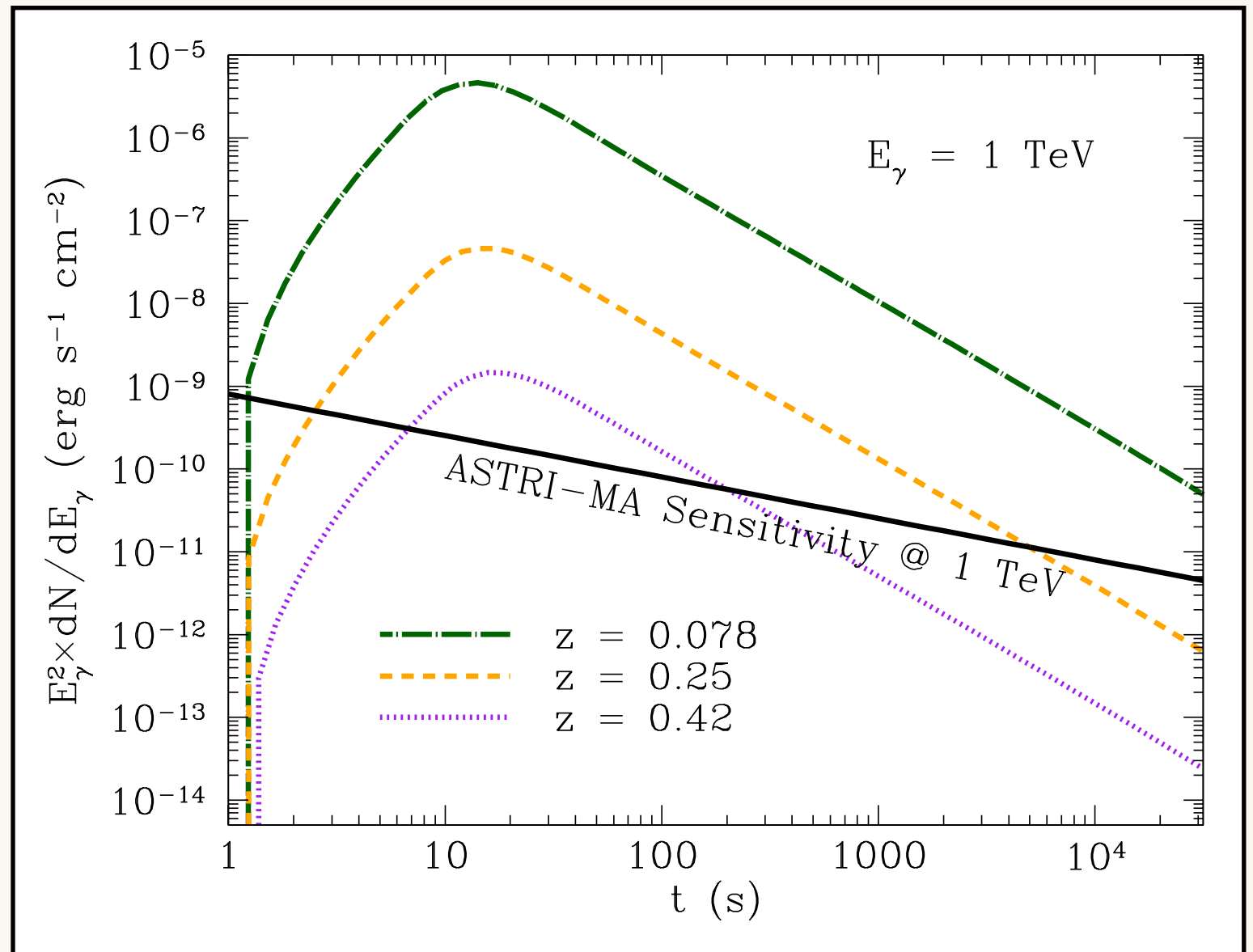


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ASTRI MINI-ARRAY

SIMULATIONS

- 190114C as a template
- moved at 3 different z
 - $z = 0.42$ (original z)
 - $z = 0.25$
 - $z = 0.078$ (same as HESS GRB 190829A)

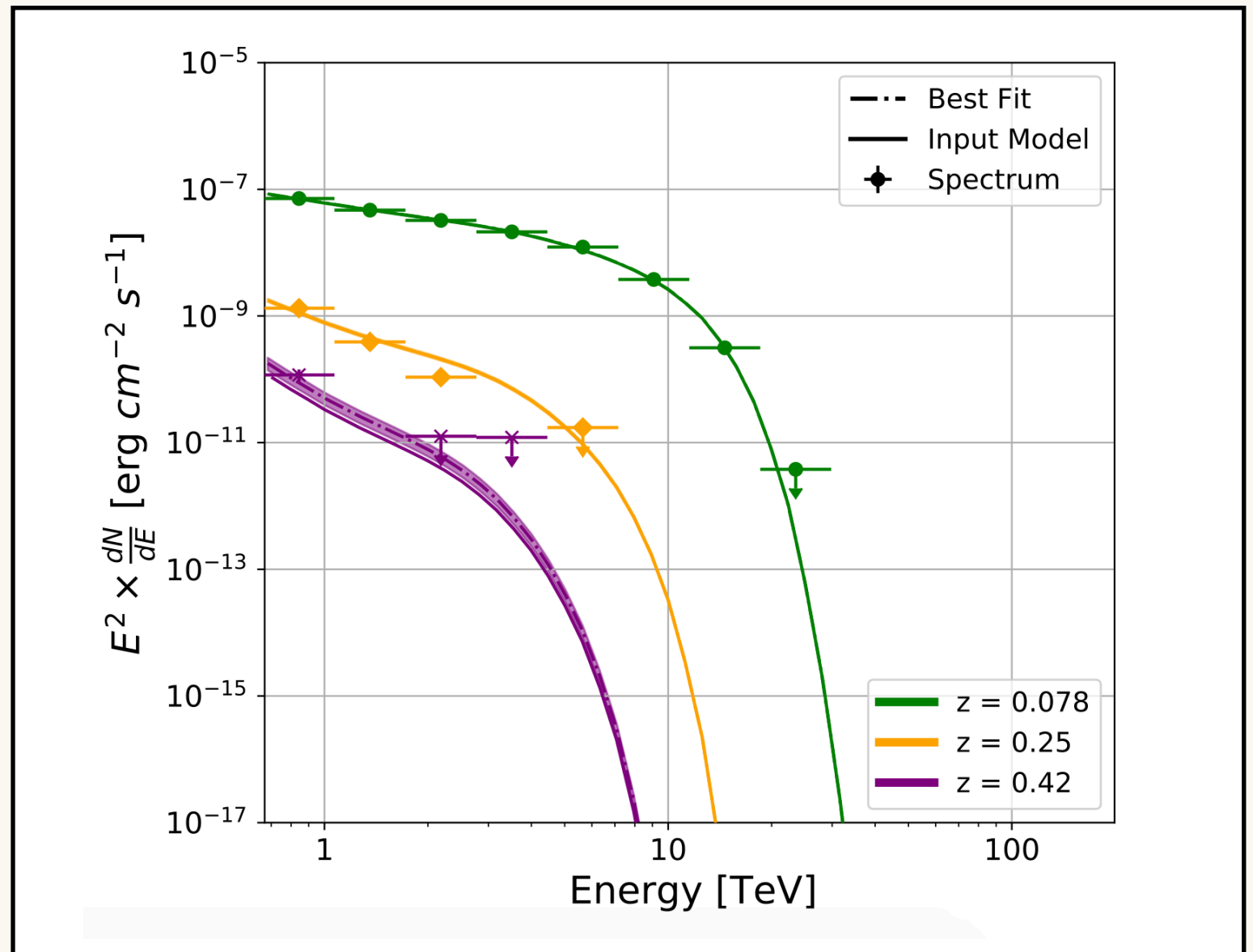


Paper on core science with ASTRI-MA in preparation

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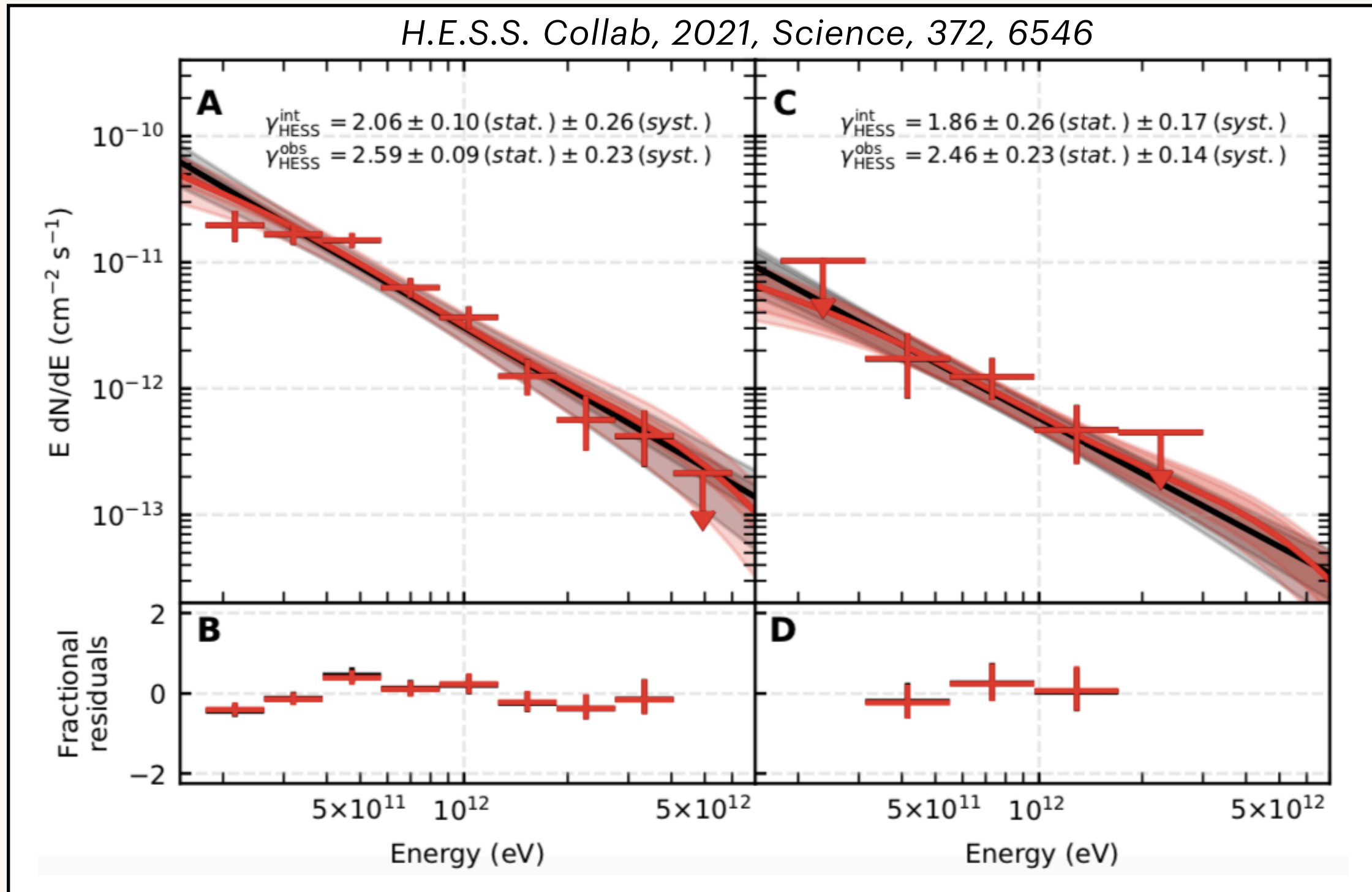
Paper on core science with ASTRI-MA in preparation

OPEN QUESTIONS & FUTURE CHALLENGES

- ▶ Does SSC interpretation hold for all detected GRBs?
- ▶ Which conditions are required to produce VHE component? How common are these conditions?
- ▶ Nature of TeV emission always the same or competing processes can dominate the TeV range?
- ▶ VHE observations during the prompt: unique tool to understand the origin of prompt radiation
- ▶ VHE emission in short GRBs: understand differences short/long (environment, jet,...)

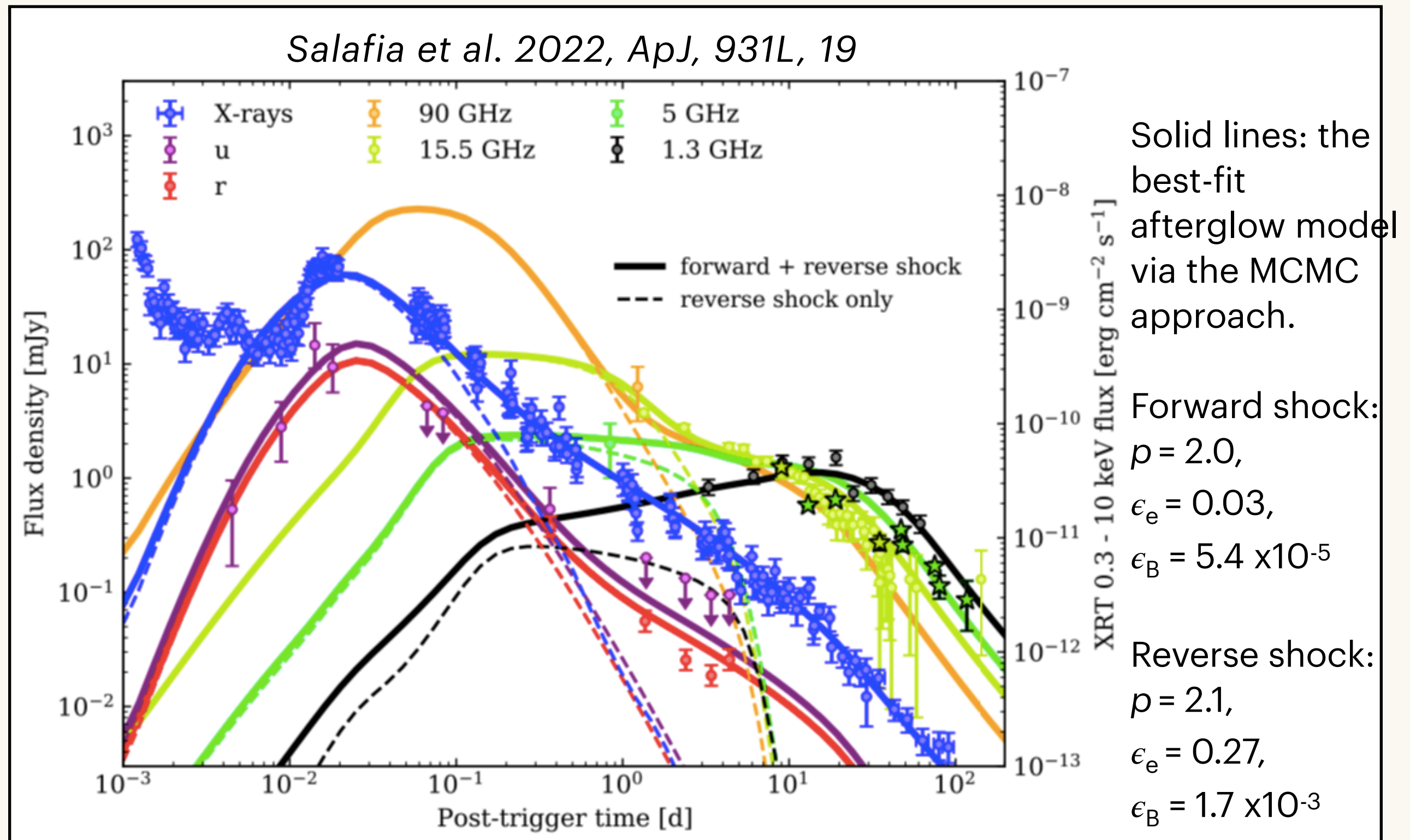
Backup slides

GRB 190829A: TEV SPECTRA



GRB 190829A: MODELING MW LIGHTCURVES

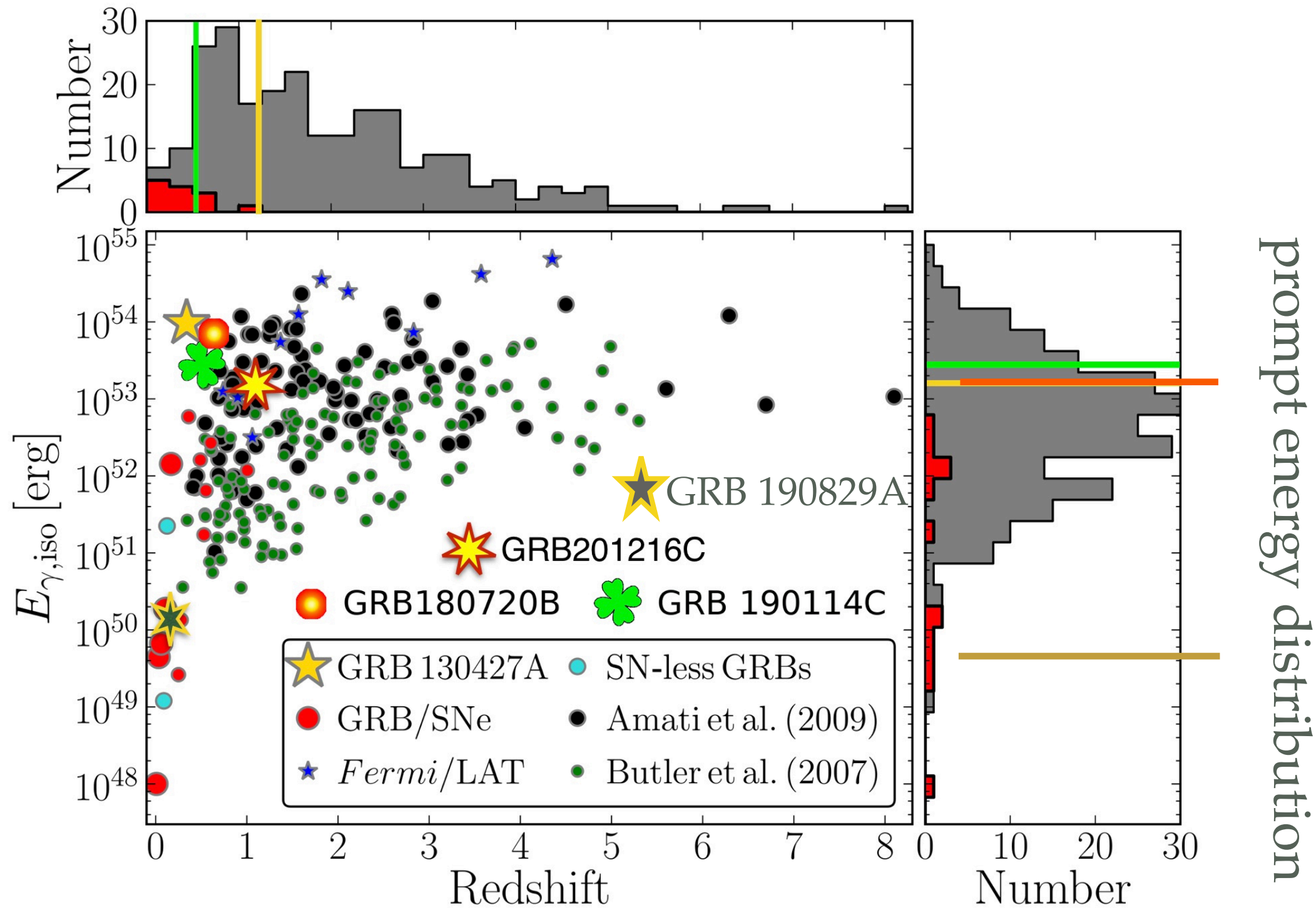
Salafia et al. 2022, ApJ, 931L, 19



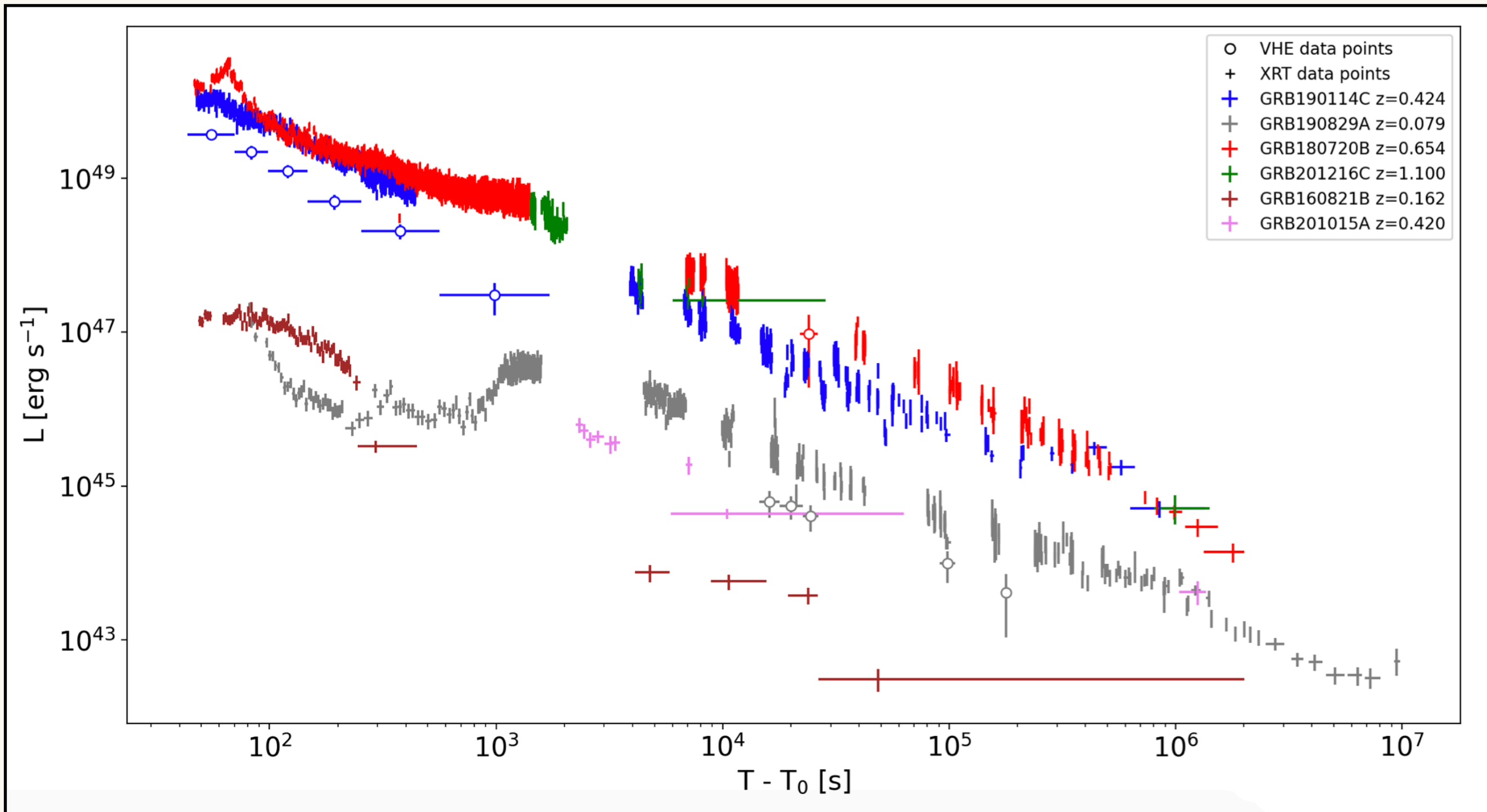
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Parameter ^a	narrow prior	wide prior	bounds	prior type ^b
$E_0/10^{53}$ erg	$2.17^{+2.35}_{-1.14}$	$2.17^{+63.1}_{-0.56}$	$10^{48} - 10^{56}$	l.u.
n/cm^{-3}	$0.175^{+0.35}_{-0.11}$	$0.175^{+5.77}_{-0.007}$	$10^{-6} - 10^2$	l.u.
Γ_0	$57.8^{+7.3}_{-7.0}$	$57.8^{+3.7}_{-8.2}$	> 10	l. u.
θ_j/deg	$15.1^{+1.9}_{-1.95}$	$15.1^{+2.2}_{-1.06}$	$0.6 - 60$	u.
$\epsilon_{e,FS}$	$0.029^{+0.036}_{-0.016}$	$0.029^{+0.017}_{-0.028}$	$10^{-6} - 0.6$	l. u.
$\epsilon_{B,FS}/10^{-4}$	$0.54^{+0.45}_{-0.39}$	< 0.63 (90%)	$10^{-6} - 0.3$	l. u.
p_{FS}	$2.01^{+0.002}_{-0.005}$	$2.01^{+0.006}_{-0.005}$	$2.001 - 2.9$	u.
$\chi_{e,FS}/10^{-2}$	$2.3^{+2.2}_{-1.3}$	$2.3^{+0.35}_{-2.15}$	$10^{-2}(10^{-10}) - 10^0$	l.u.
$\epsilon_{e,RS}$	$0.27^{+0.33}_{-0.08}$	$0.27^{+0.33}_{-0.26}$	$10^{-6} - 0.6$	l. u.
$\epsilon_{B,RS}/10^{-3}$	$1.7^{+3.6}_{-1.2}$	$1.7^{+0.1}_{-1.6}$	$10^{-6} - 0.3$	l. u.
p_{RS}	$2.15^{+0.014}_{-0.11}$	$2.15^{+0.015}_{-0.095}$	$2.001 - 2.9$	u.
$\rho_{sys}/10^{-2}$	$1.4^{+0.5}_{-0.2}$	$1.4^{+0.5}_{-0.2}$	$10^{-10} - 10^0$	l.u.
$E_{jet}/10^{51}$ erg	$7.5^{+9.3}_{-3.7}$	$7.5^{+170}_{-0.35}$	—	—
$\eta_\gamma/10^{-3}$	$1.3^{+1.5}_{-0.7}$	$1.3^{+0.5}_{-0.7}$	—	—



X-RAY AND TEV LUMINOSITY LIGHTCURVES



AMATI CORRELATION

