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# Constraints on the high energy emission from the exceptional GRB 130427A

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# GRB 130427A

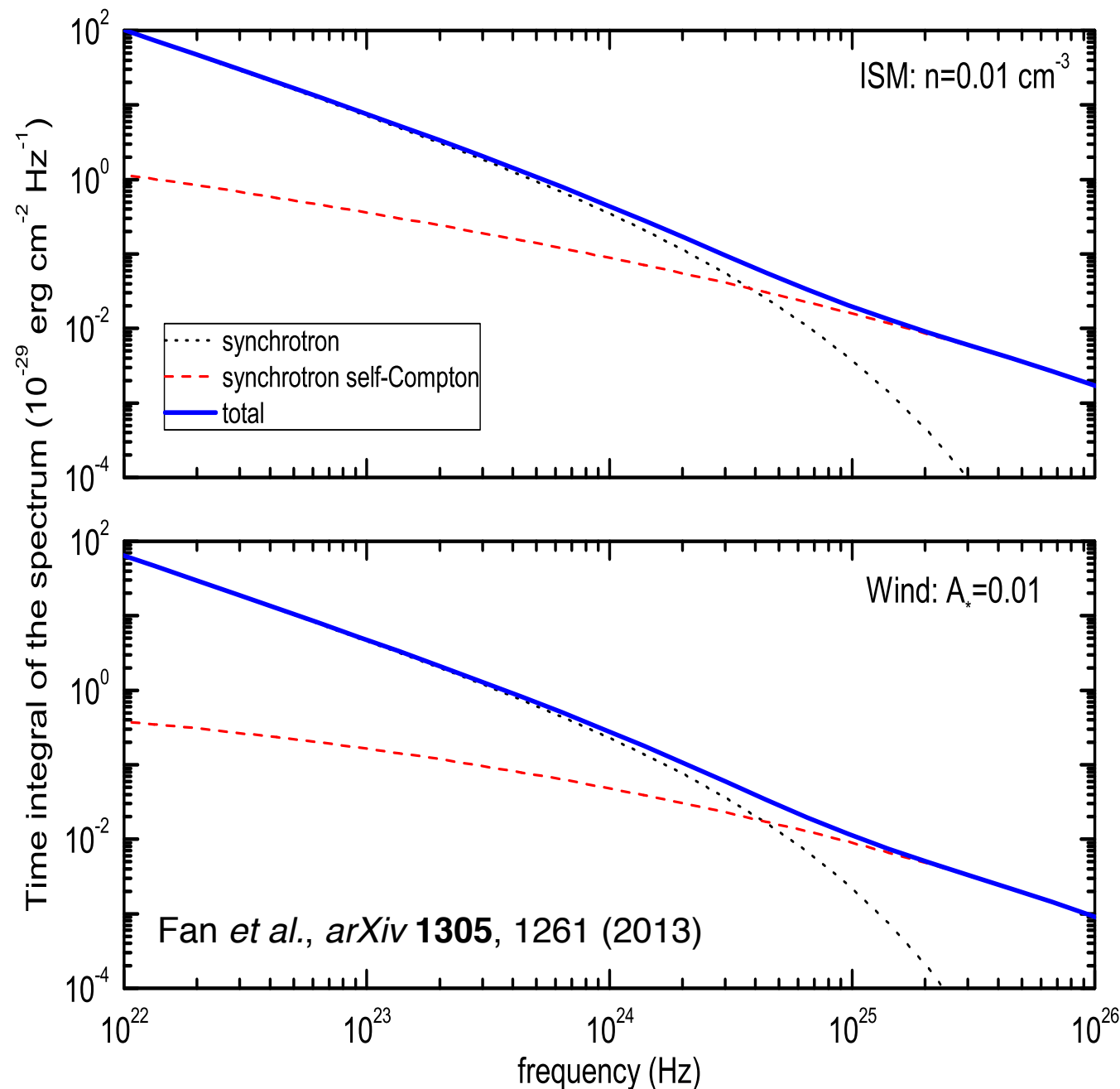
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## “Exceptional”

- ▶ **Coverage:** Emission independently detected at ~07:17 UTC by several orbiting telescopes and RAPTOR ground-based optical monitors
- ▶ **Nearby:** Associated with Type IC SN 2013cq in a galaxy at  $z = 0.34$
- ▶ **Observationally bright:** Highest prompt GRB fluence recorded by Konus-WIND, Fermi-GBM, and LAT
- ▶ **Long-lived high-energy:**
  - ▶ *Fermi*-LAT detected GeV emission for ~20 hours after trigger
  - ▶ Highest energy photon detected from a GRB: 72 GeV

Proximity is what makes this GRB special

# High-energy $\gamma$ rays from GRBs



- High-energy gamma rays are produced via synchrotron radiation and? inverse Compton (IC) scattering
- GeV - TeV observations can provide detailed information on the emission mechanisms, environment, and physical processes at work
- The proximity of GRB 130427A makes it an excellent target for a TeV observatory (EBL absorption is relatively low).



# VERITAS\*

\*New and improved

Very Energetic Radiation Imaging Telescope Array System





## Very Energetic Radiation Imaging Telescope Array System

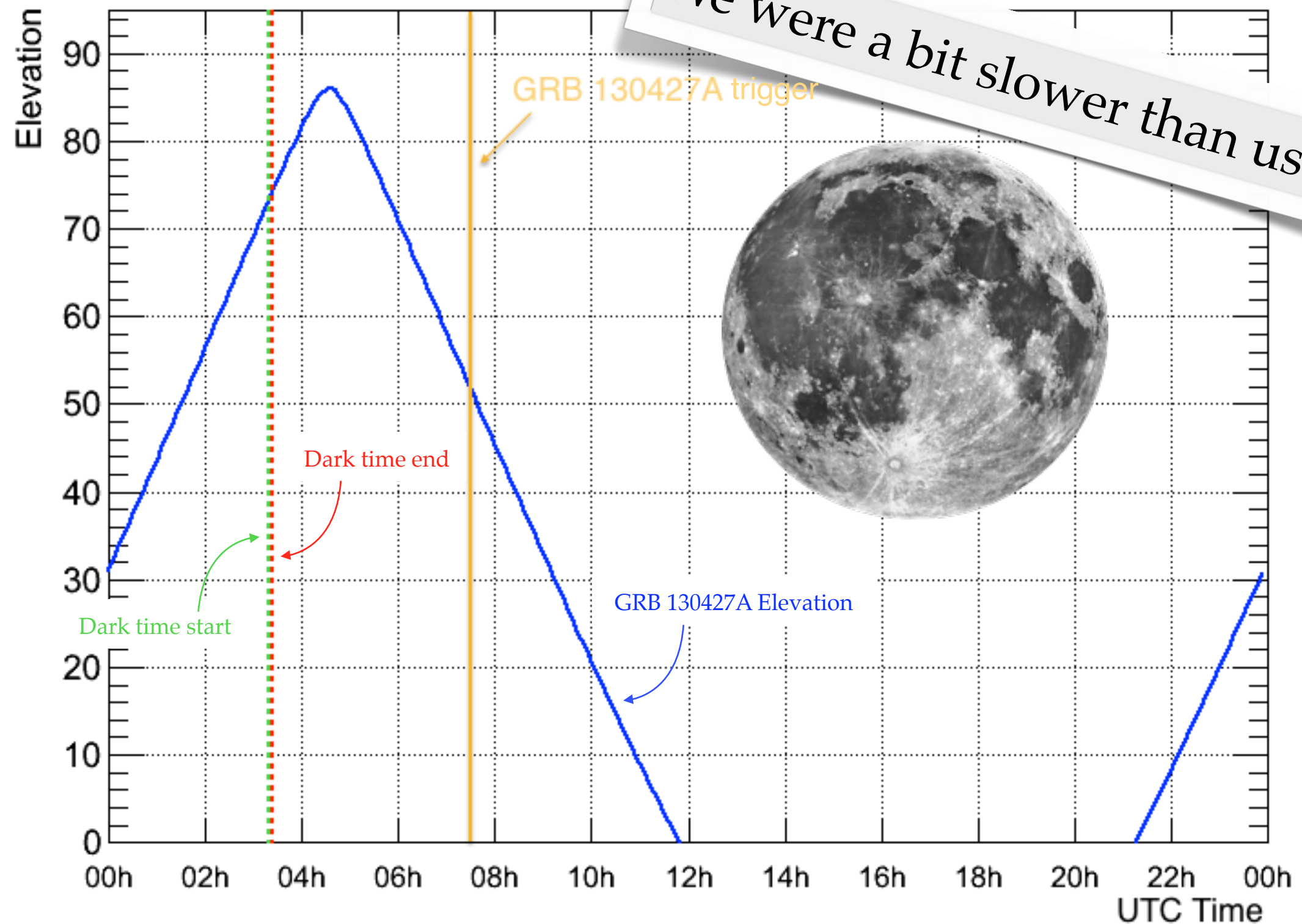
An IACT array located near Mt. Hopkins in southern Arizona, USA

- ▶ Energy Range\*: 100 GeV - >30 TeV
- ▶ Point-source sensitivity\*: 1% Crab in <30 h, 10% Crab in <30 min.
- ▶ Field of view:  $\varnothing$  3.5°
- ▶ ~1100 hours of observations / yr.
- ▶ Median unconstrained GRB observing delay (2012 / 2013): 159 s
- ▶ Peak effective area:  $\sim 10^5$  m<sup>2</sup>

Active VERITAS GRB program calls for collecting data on all observable GRBs less than 1 hour old<sup>†</sup> (triggered by GCN notices).

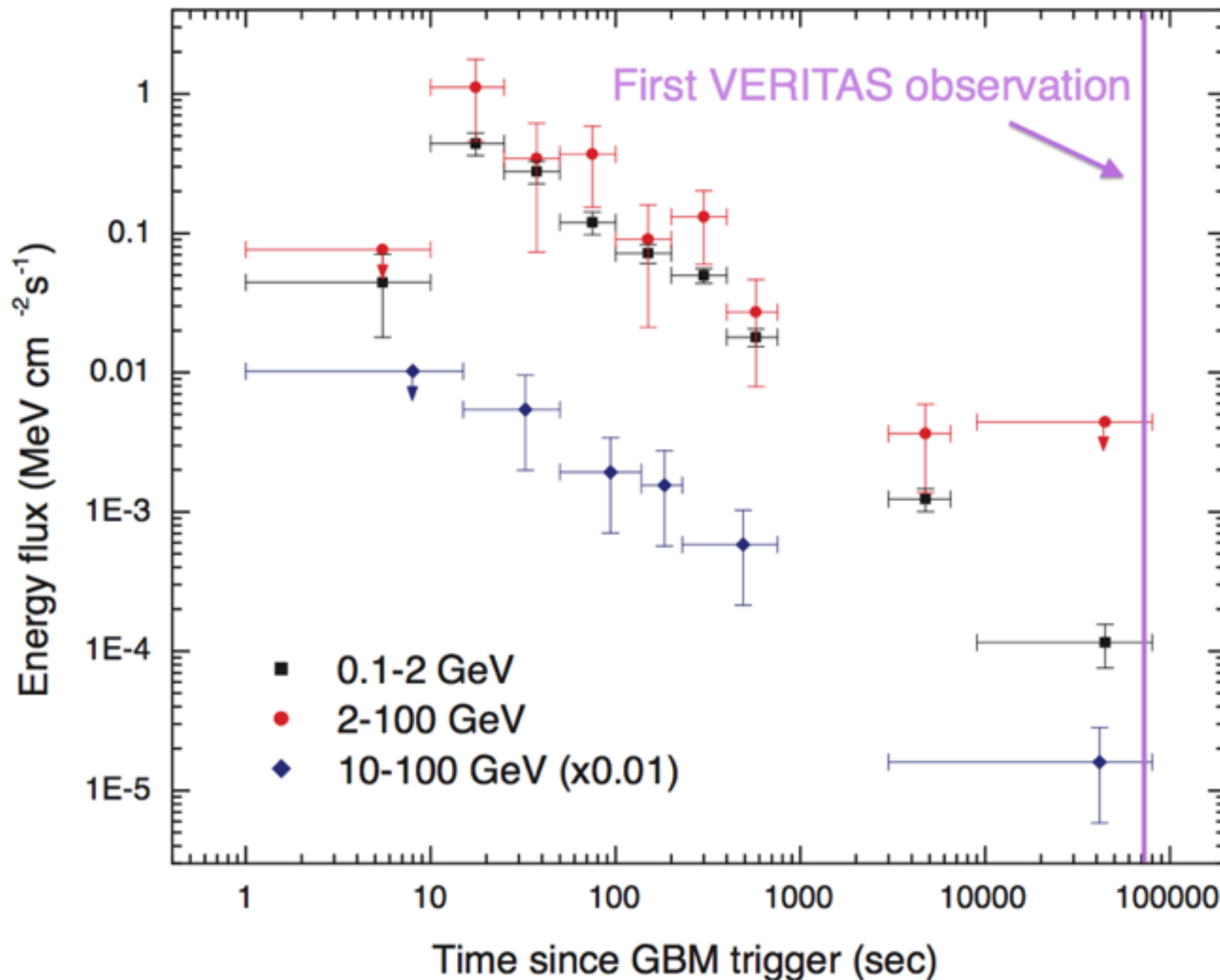
<sup>†</sup>Exceptions can be made

# VERITAS Observations of GRB 130427A



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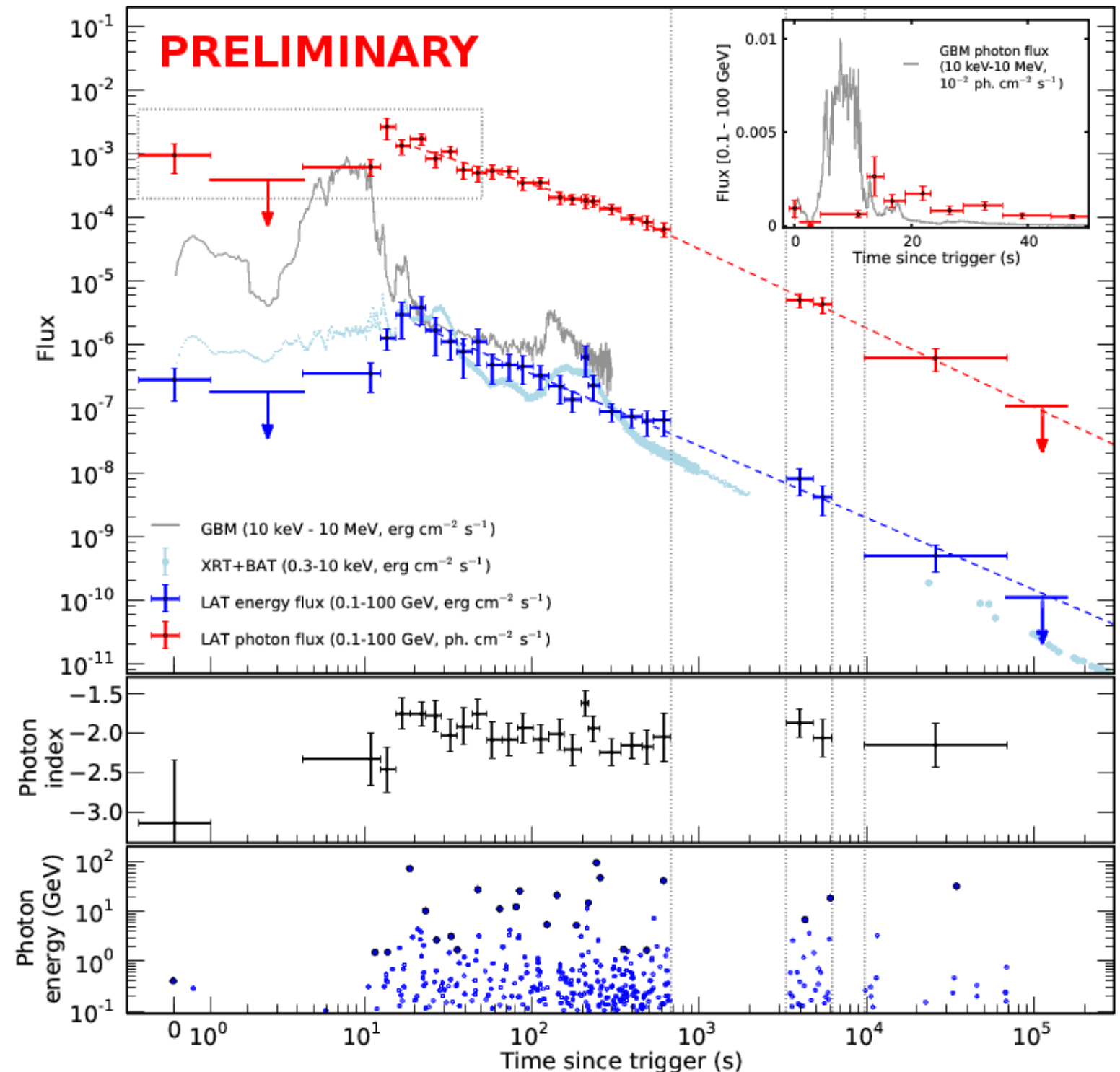
Tam et al., *arXiv astro-ph.HE*, 3217 (2013).



- ▶ Observations begin 19:45:28 ( $\sim 71$  ks) after *Fermi*-GBM trigger
- ▶ Data is taken for 3 consecutive nights
  - ▶ 28 April: 56:29
  - ▶ 29 April: 1:50:39
  - ▶ 30 April: 2:30:14
- ▶ Very high observation elevation ( $\sim 81^\circ$ )
- ▶ Marginal overlap in both time and energy with the *Fermi*-LAT

# Should VERITAS detect GRB 130427A?

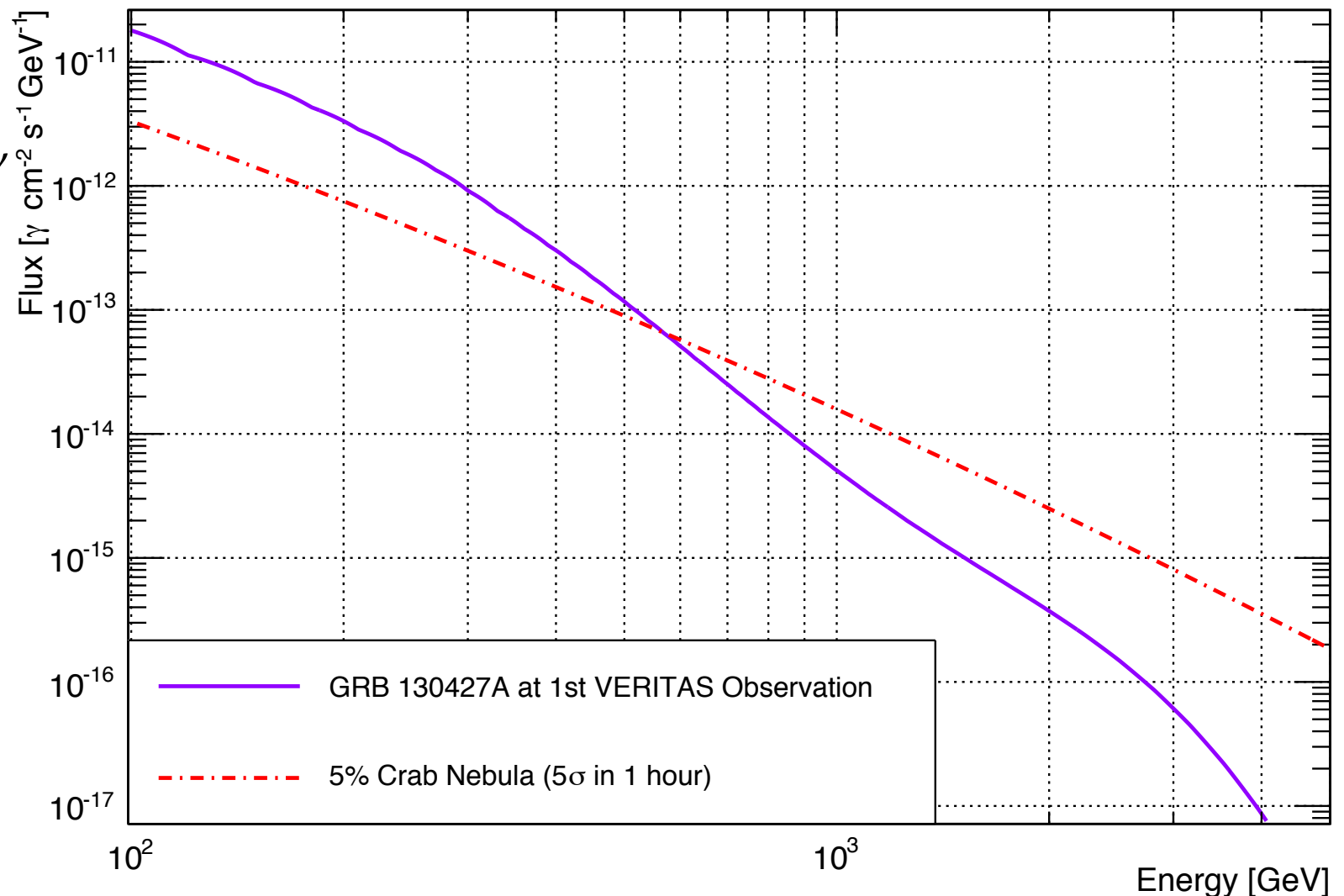
- ▶ *Fermi*-LAT provides detailed high E information up to ~20 hours post-trigger
- ▶ Spectrum flat in  $\log(E)$  - flux at late times dominated by 30 GeV  $\gamma$  at 30 ks
- ▶ Flux falling as  $t^{-1.35}$  at late times
- ▶ VERITAS observations at high elevation:  $E_{\text{th}} < 100$  GeV
- ▶ GRB close enough that EBL absorption is small (non-negligible)
- ▶ Seems promising!





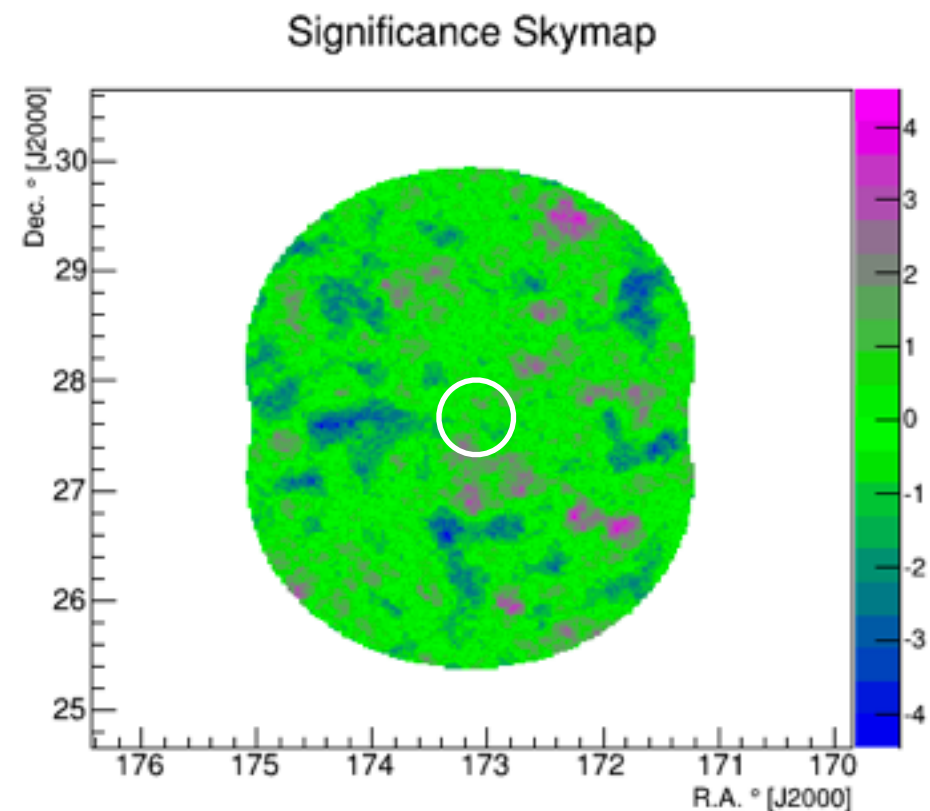
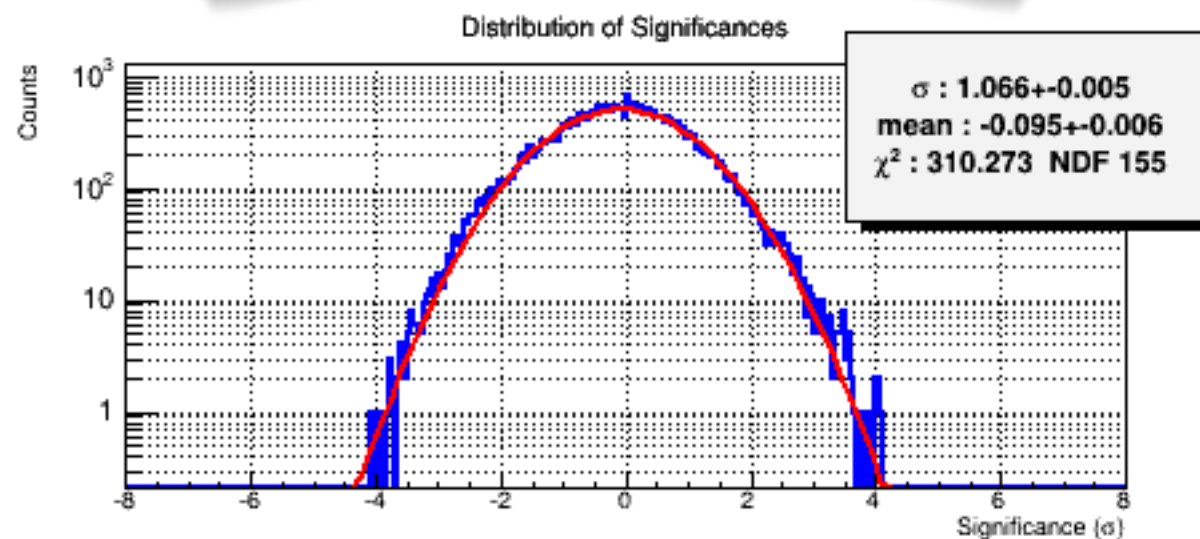
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# VERITAS Results on GRB 130427A

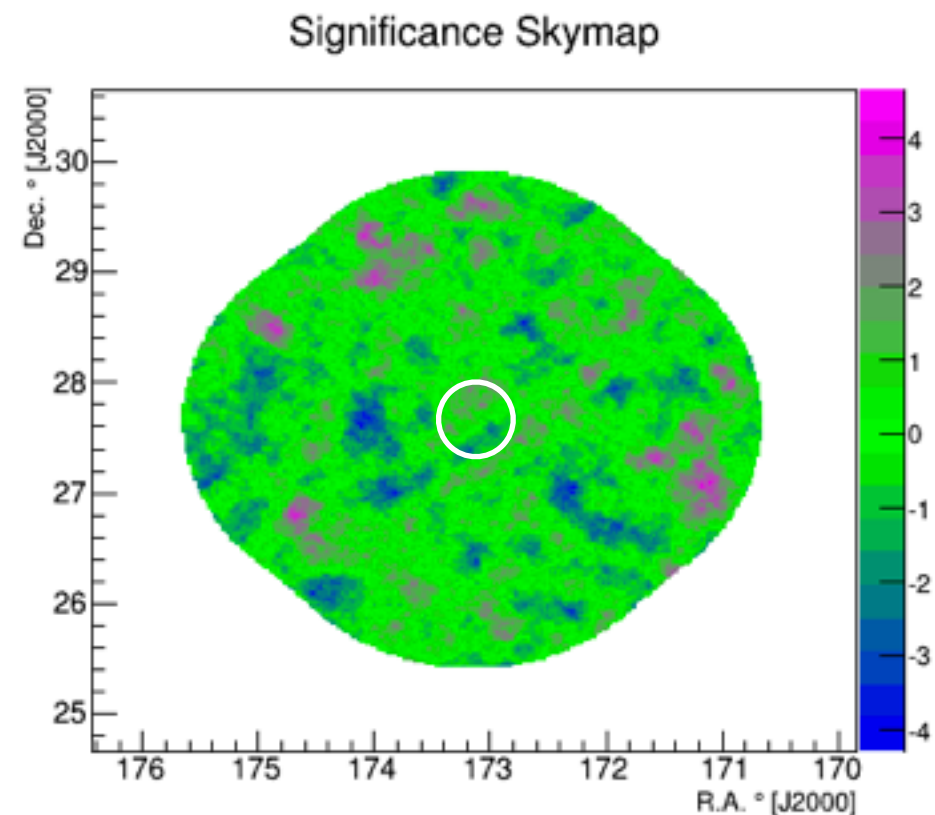
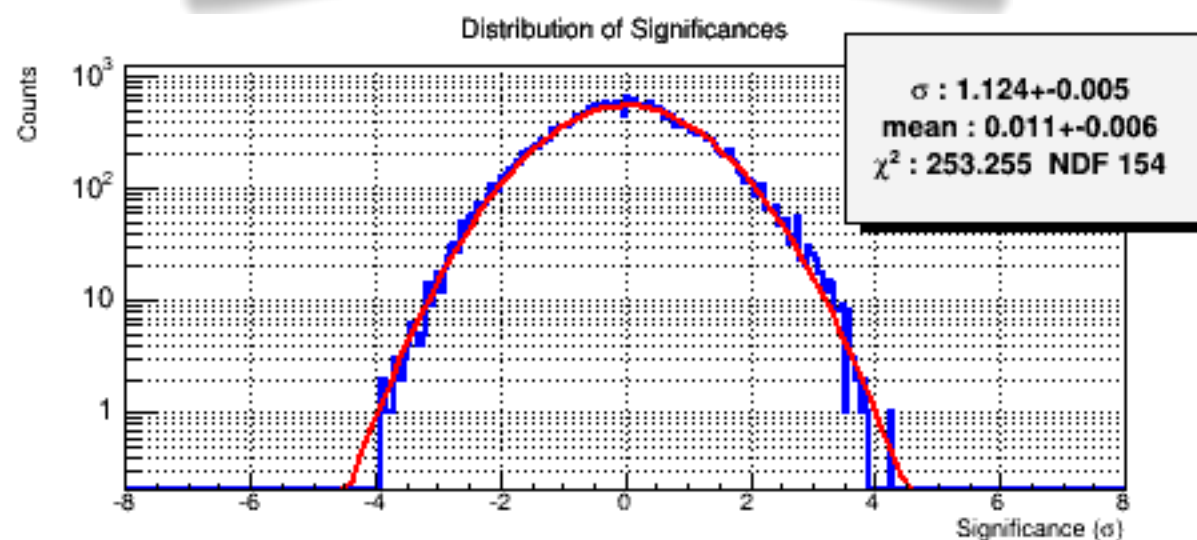
Day 1 - 28 April



Obs. Interval (from GBM trigger)	GRB Significance ( $\sigma$ )	99% C.L. U.L. on $\nu F_\nu$ @ 100 GeV ( $\text{erg cm}^{-2} \text{s}^{-1}$ )
71 - 75 ks	1.3	$9.4 \times 10^{-12}$
158 - 164 ks	1.1	$6.6 \times 10^{-12}$
244 - 254 ks	-0.5	$2.7 \times 10^{-12}$

# VERITAS Results on GRB 130427A

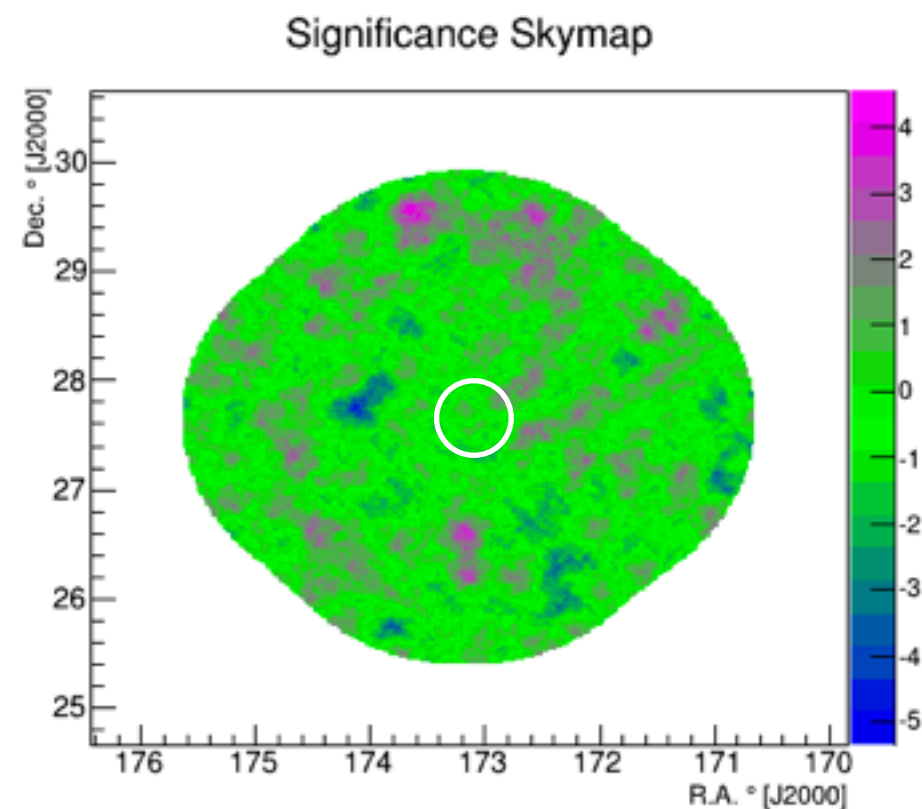
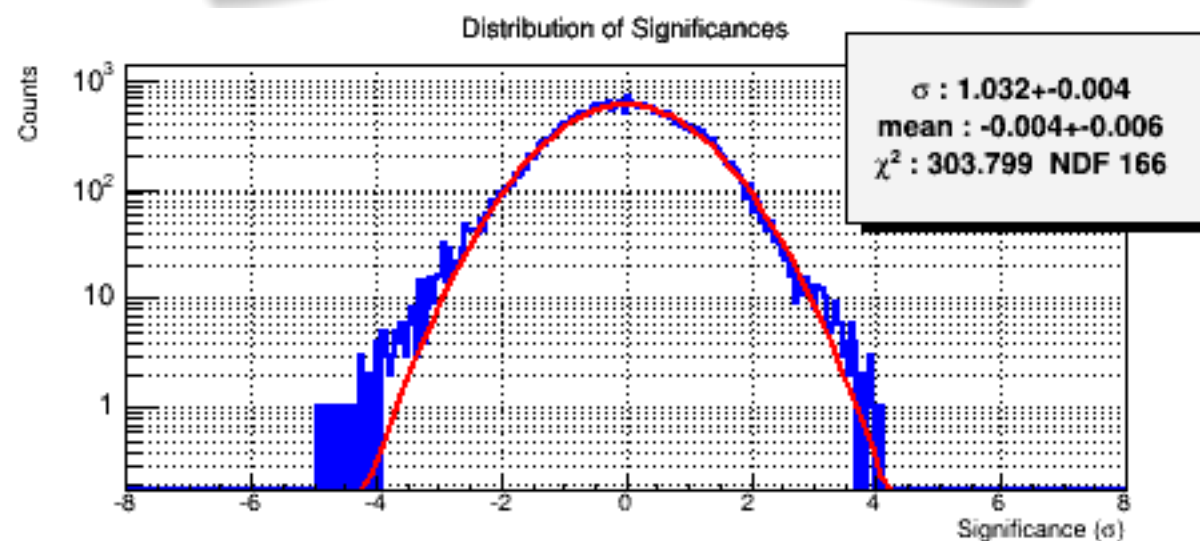
Day 2 - 29 April



Obs. Interval (from GBM trigger)	GRB Significance ( $\sigma$ )	99% C.L. U.L. on $\nu F_\nu$ @ 100 GeV ( $\text{erg cm}^{-2} \text{s}^{-1}$ )
71 - 75 ks	1.3	$9.4 \times 10^{-12}$
158 - 164 ks	1.1	$6.6 \times 10^{-12}$
244 - 254 ks	-0.5	$2.7 \times 10^{-12}$

# VERITAS Results on GRB 130427A

Day 3 - 30 April



Obs. Interval (from GBM trigger)	GRB Significance ( $\sigma$ )	99% C.L. U.L. on $\nu F_\nu$ @ 100 GeV ( $\text{erg cm}^{-2} \text{s}^{-1}$ )
71 - 75 ks	1.3	$9.4 \times 10^{-12}$
158 - 164 ks	1.1	$6.6 \times 10^{-12}$
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# Emission Models of GRB 130427A

- ▶ Late-time high-E emission of GRB 130427A cannot be explained by synchrotron processes

$$< 500(t^{-3/8}) \quad \text{orange arrow} \quad \text{red arrow } 0.34$$

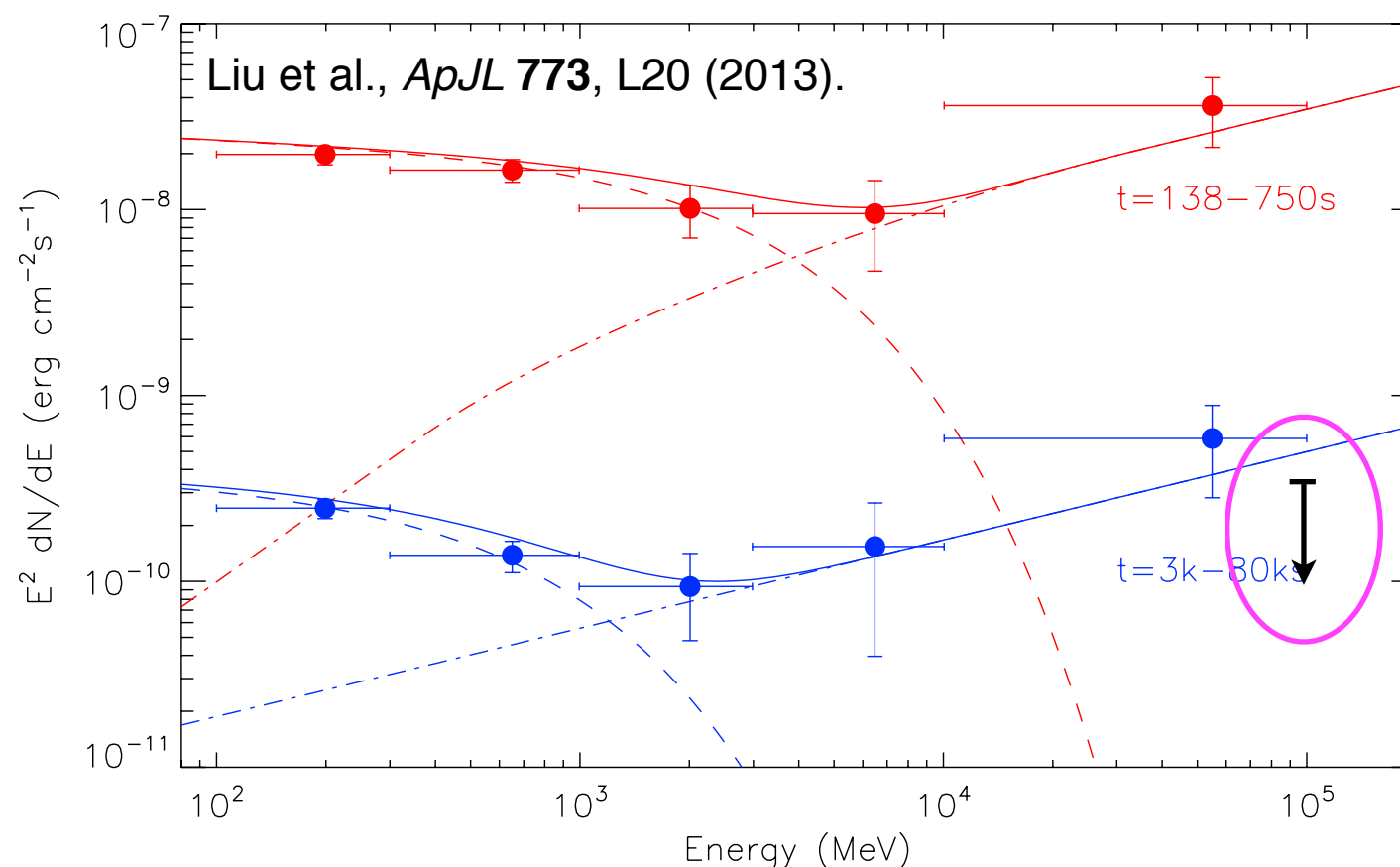
- ▶ Max synchrotron energy:

$$\epsilon_{\text{syn},M} \sim 100 \text{ MeV } \Gamma(1+z)^{-1} \\ \sim 37 \text{ GeV}$$

- ▶ GeV emission suggests inverse-Compton processes

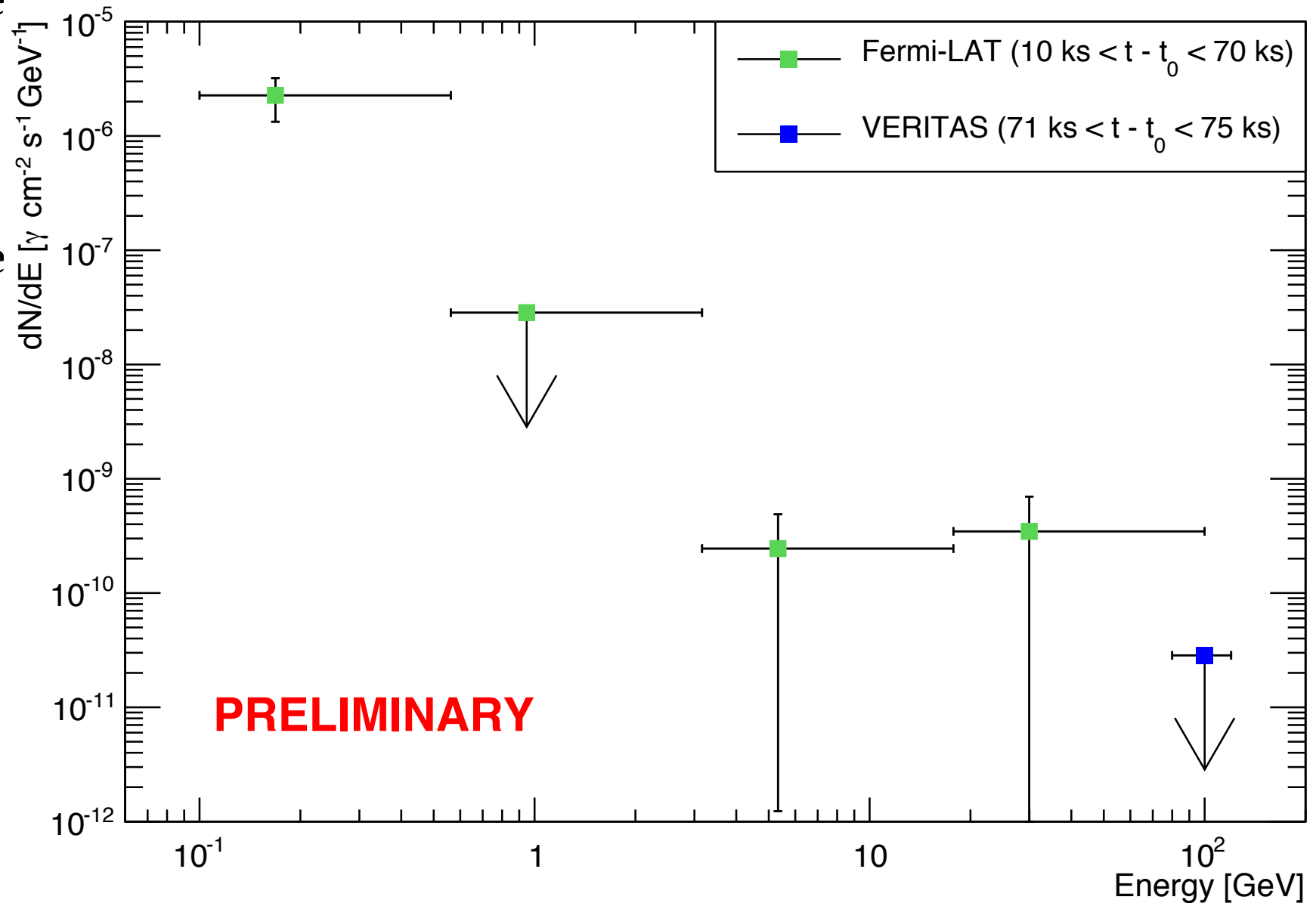
- ▶ Synchrotron self Compton emission would produce hard, high-E spectrum

- ▶ **VERITAS U.L.** disfavor SSC scenario above 100 GeV



# Emission Models of GRB 130427A

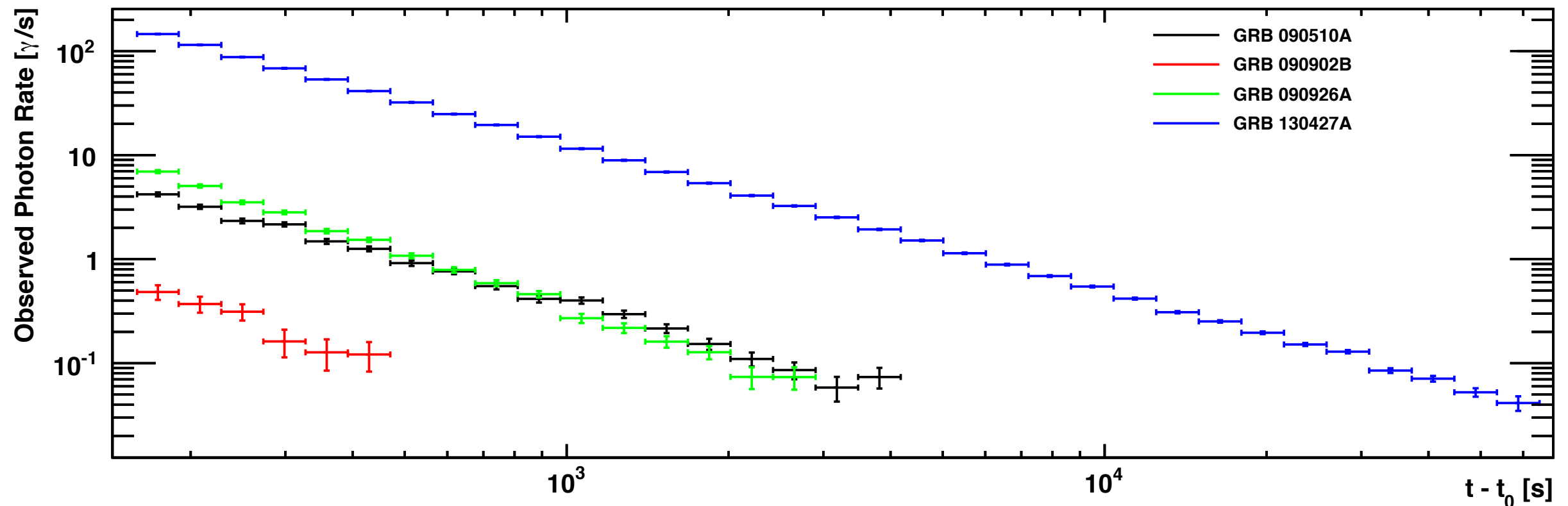
- ▶ *Fermi*-LAT light curve shows no significant deviation from smooth power-law - contrary to SSC
- ▶ Last significant LAT time bin shows a smooth  $E^{-2}$  spectrum
- ▶ VERITAS results indicate spectrum may soften above 100 GeV
- ▶ Statistics are extremely limited
- ▶ Other models of IC emission from GRB 130427A (e.g. EIC) may explain high-E emission



# What if...

...VERITAS had observed GRB 130427A at its median delay (159 s), what may we have seen?

Predicted VERITAS Lightcurve (all bins  $> 3\sigma$ )



Under suitable conditions, current-gen. IACTs can provide significant insights into GRB emission processes and environments