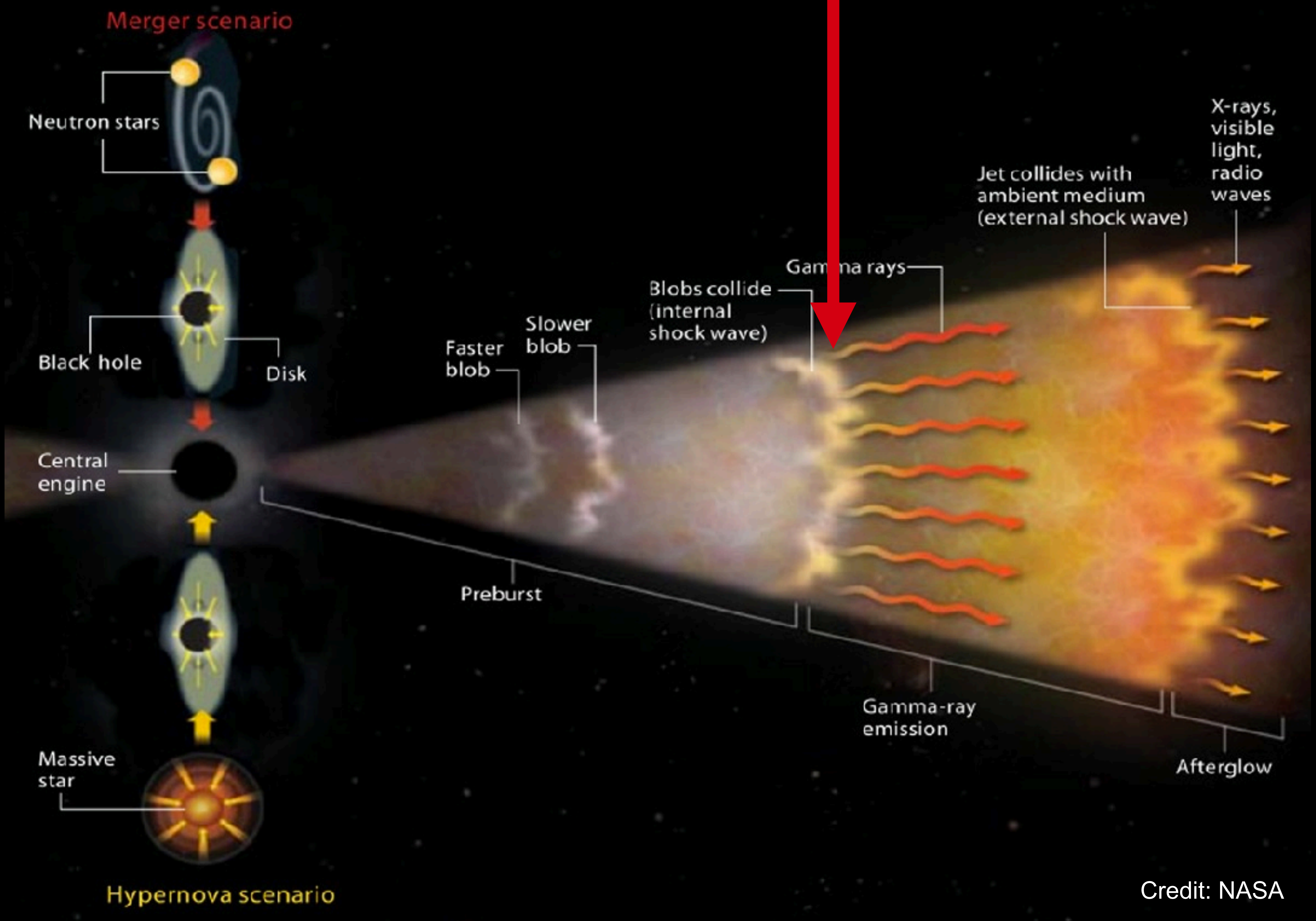
Highlights from the H.E.S.S. GRB ~~observation~~ detection programme

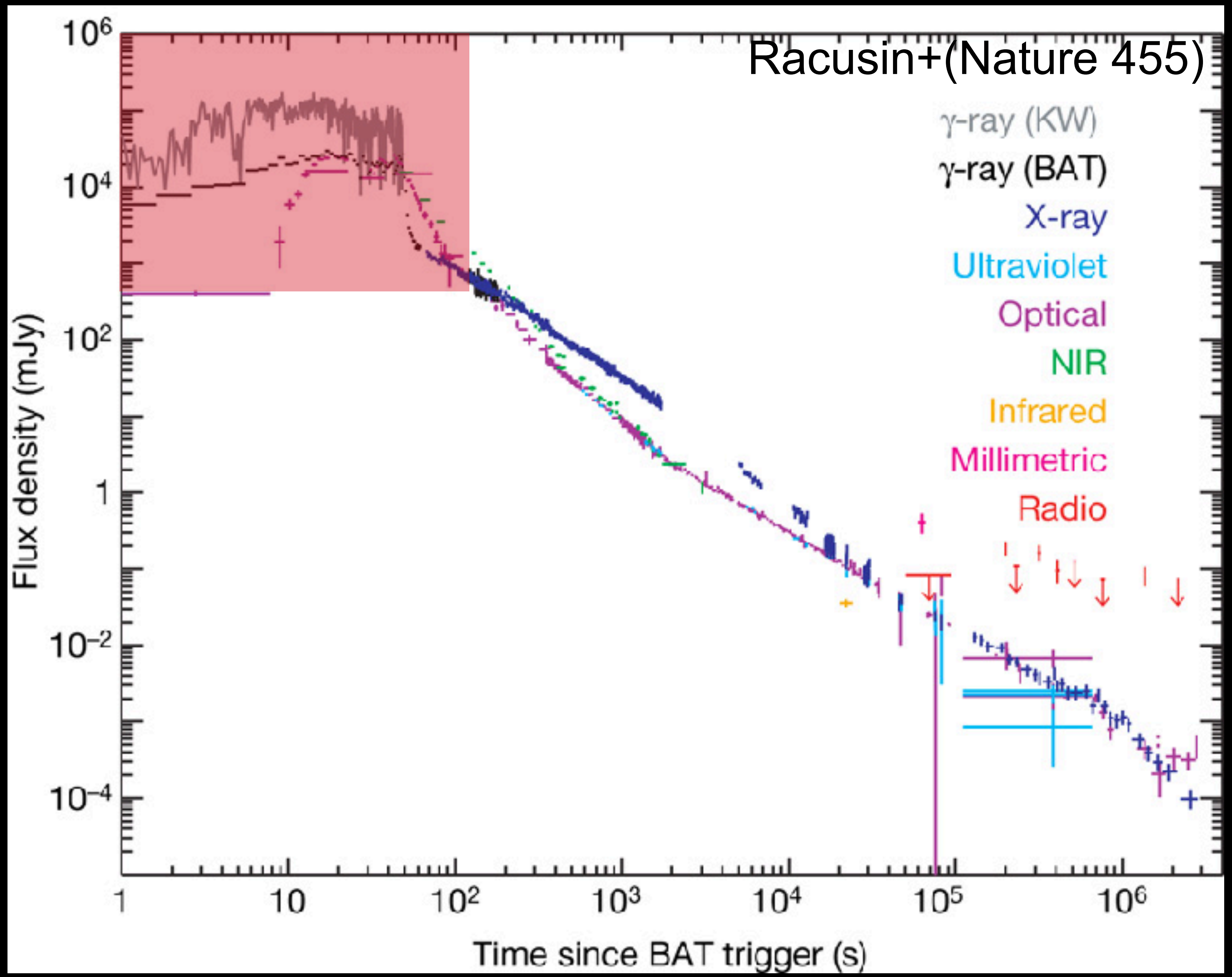
TeVPA 2019. Sydney, Australia

Edna L. Ruiz-Velasco (MPIK) for **the H.E.S.S. Collaboration**

Gamma-ray burst

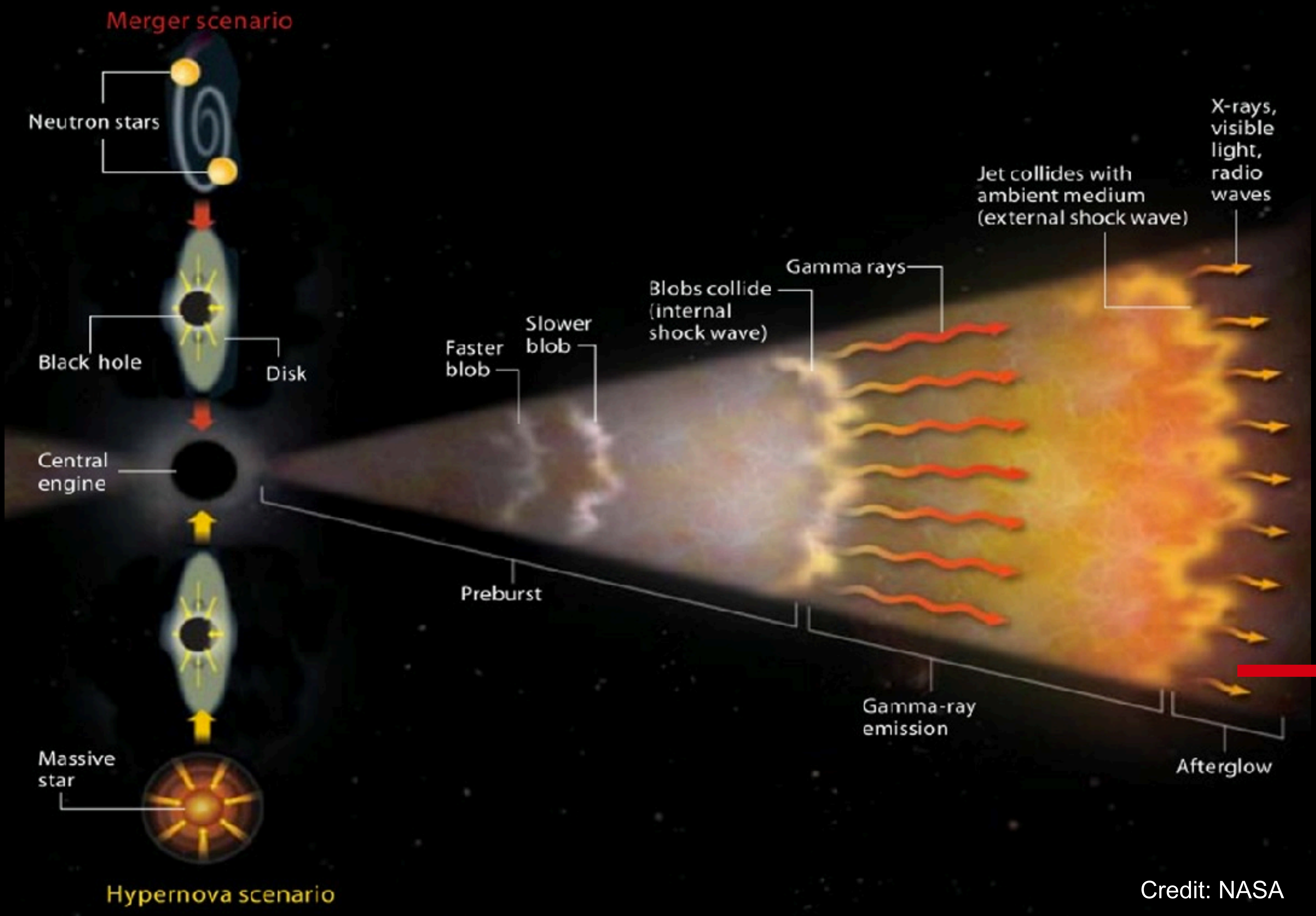
Prompt



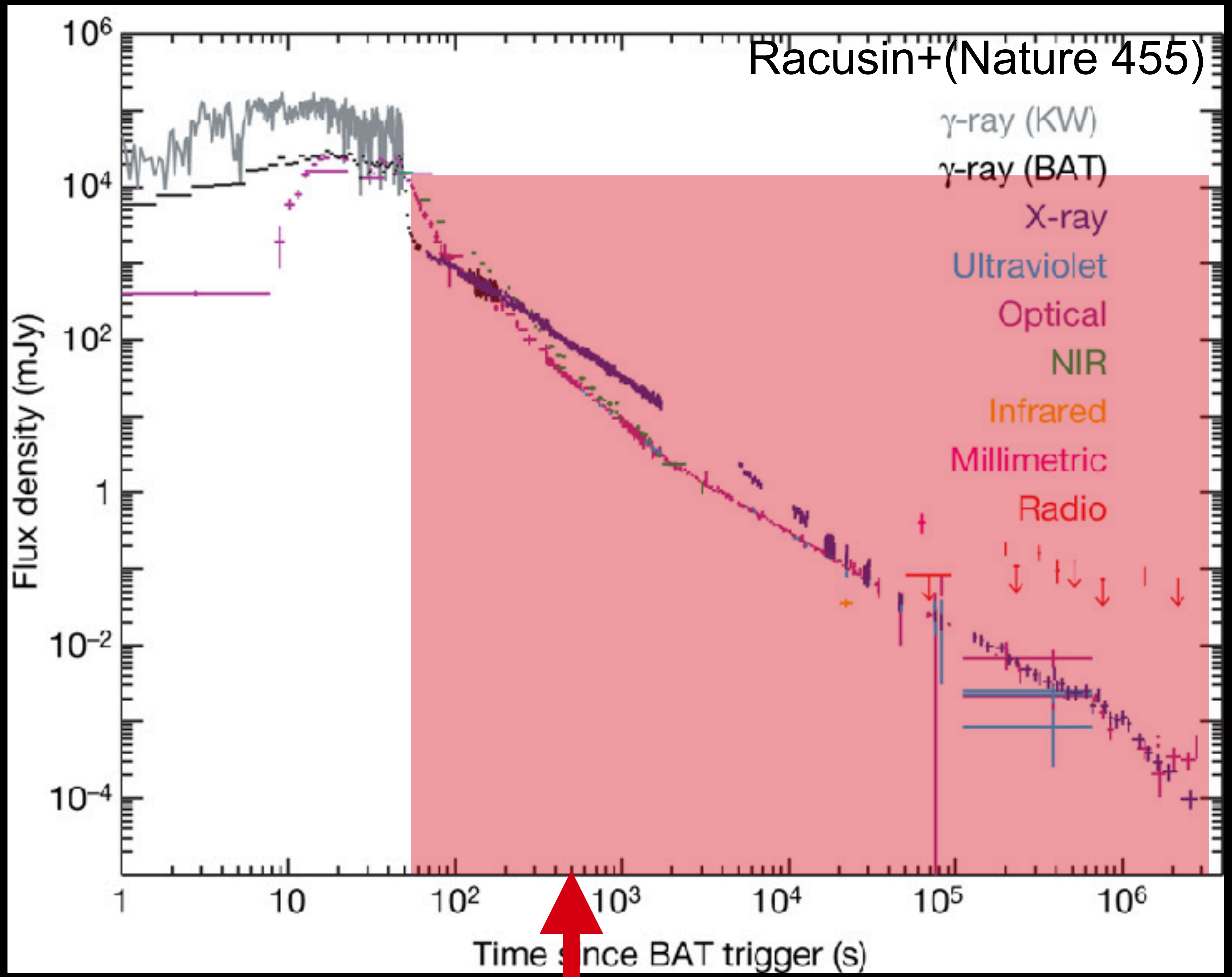


Credit: NASA

Gamma-ray burst



Credit: NASA



Afterglow

•GRBs at high and very-high energies:

- Fermi-GBM + Swift-BAT: ~300 GRBs/yr.
- ~6% detected by Fermi-LAT (E>100 MeV)
- <20% of LAT-GRBs reach E>10 GeV in observer's frame

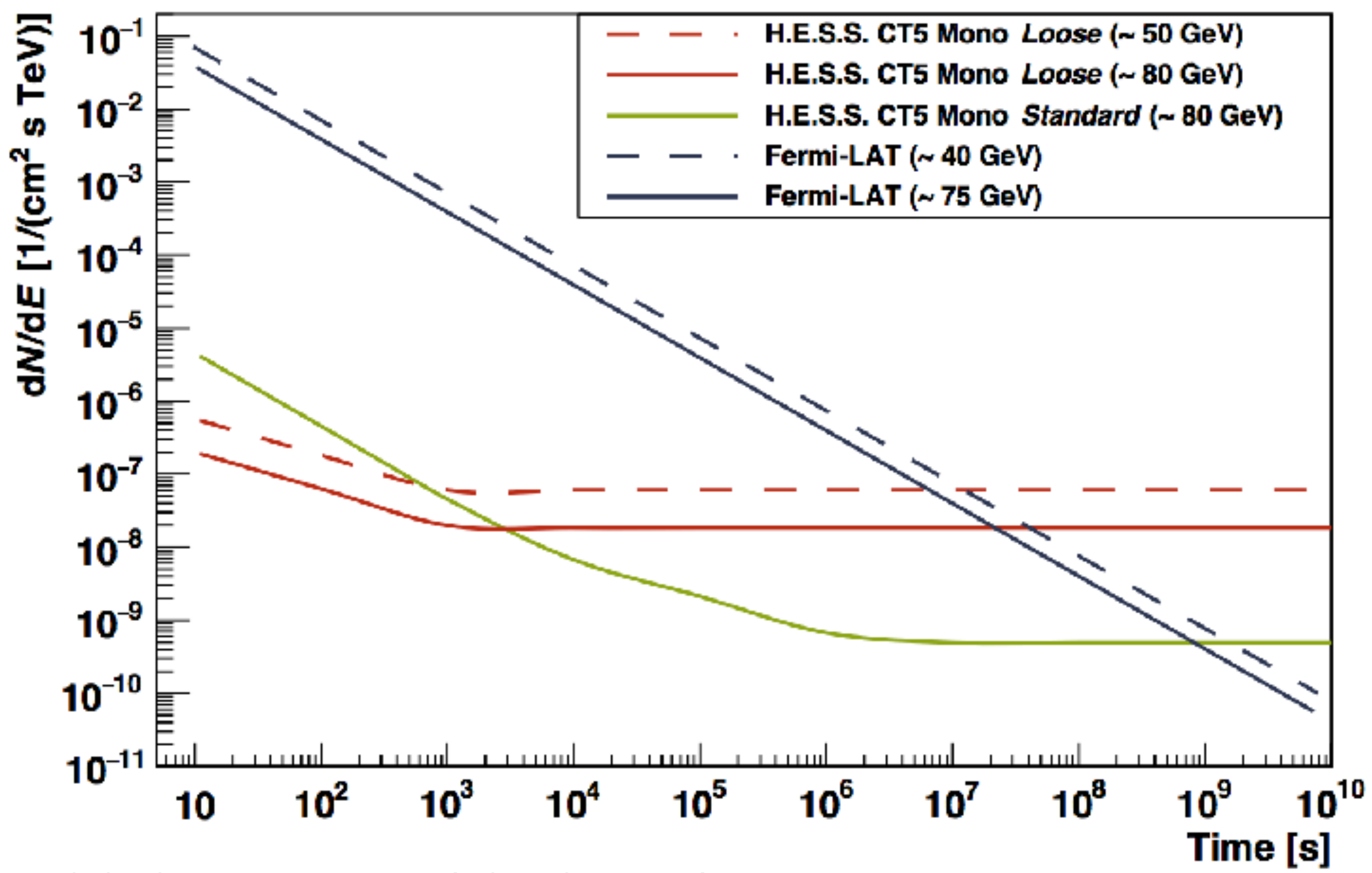
Before recent GRB detections:

- GRB130427A: Extended HE emission, 94 GeV max energy photon.

Now 3 in ~1.5 years!!! Will cover two here + next talk by Elena covers GRB190114C

H.E.S.S. telescopes

- Site: Namibia, Africa
- Five (Atmospheric) Cherenkov telescopes
- Small telescopes CT1-4. (GeV-TeV range) + CT5 (HESSII)



HESS Collaboration(ICRC2015)

CT5

- 28 m telescope
- $E_{thr.}$ ~50 GeV
- 60 s slewing speed

Swift-BAT/XRT
Fermi-LAT/GBM
GW, Neutrinos

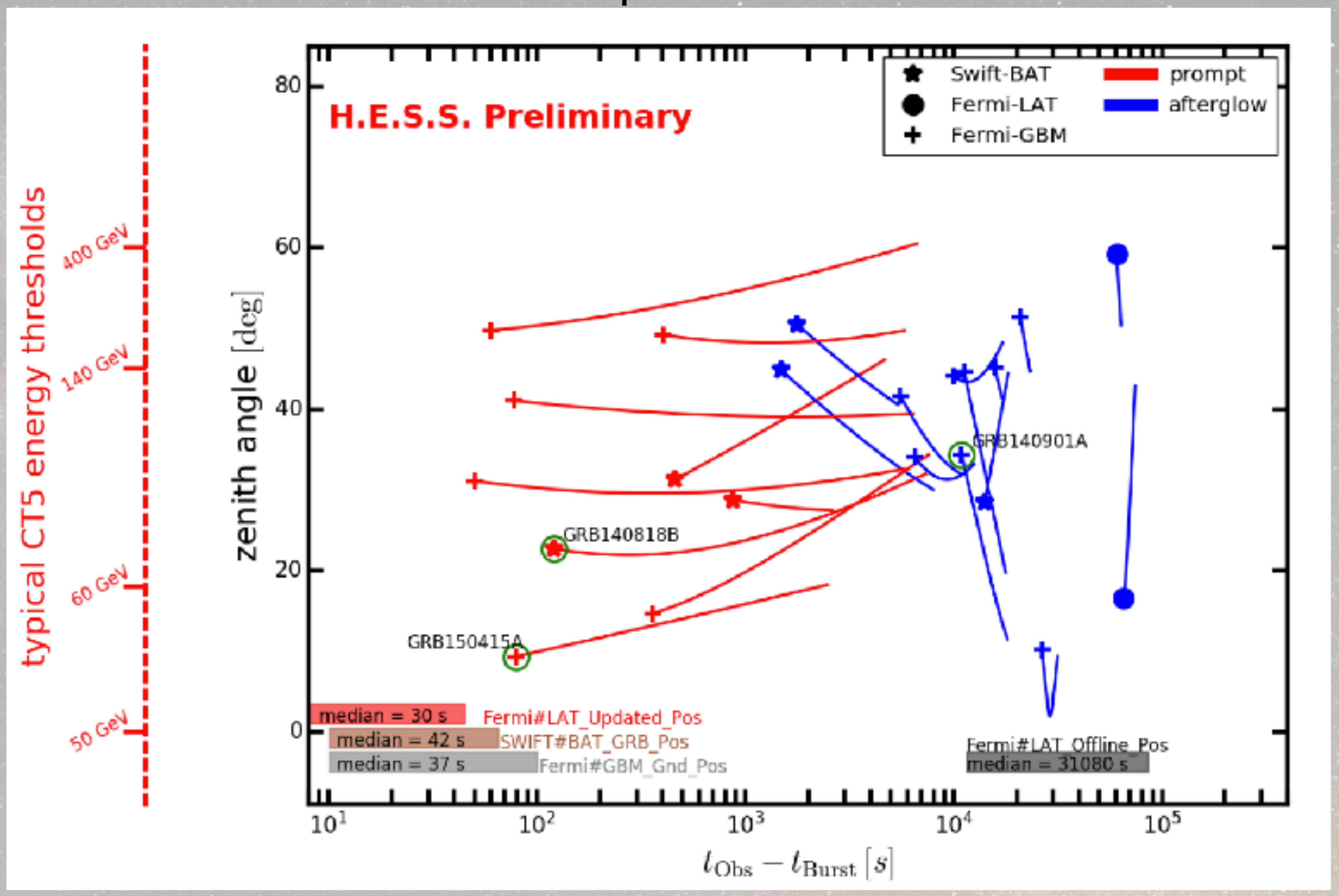
Talk by Fabian

VOEvent

H.E.S.S.
(t, z, ++Criteria)

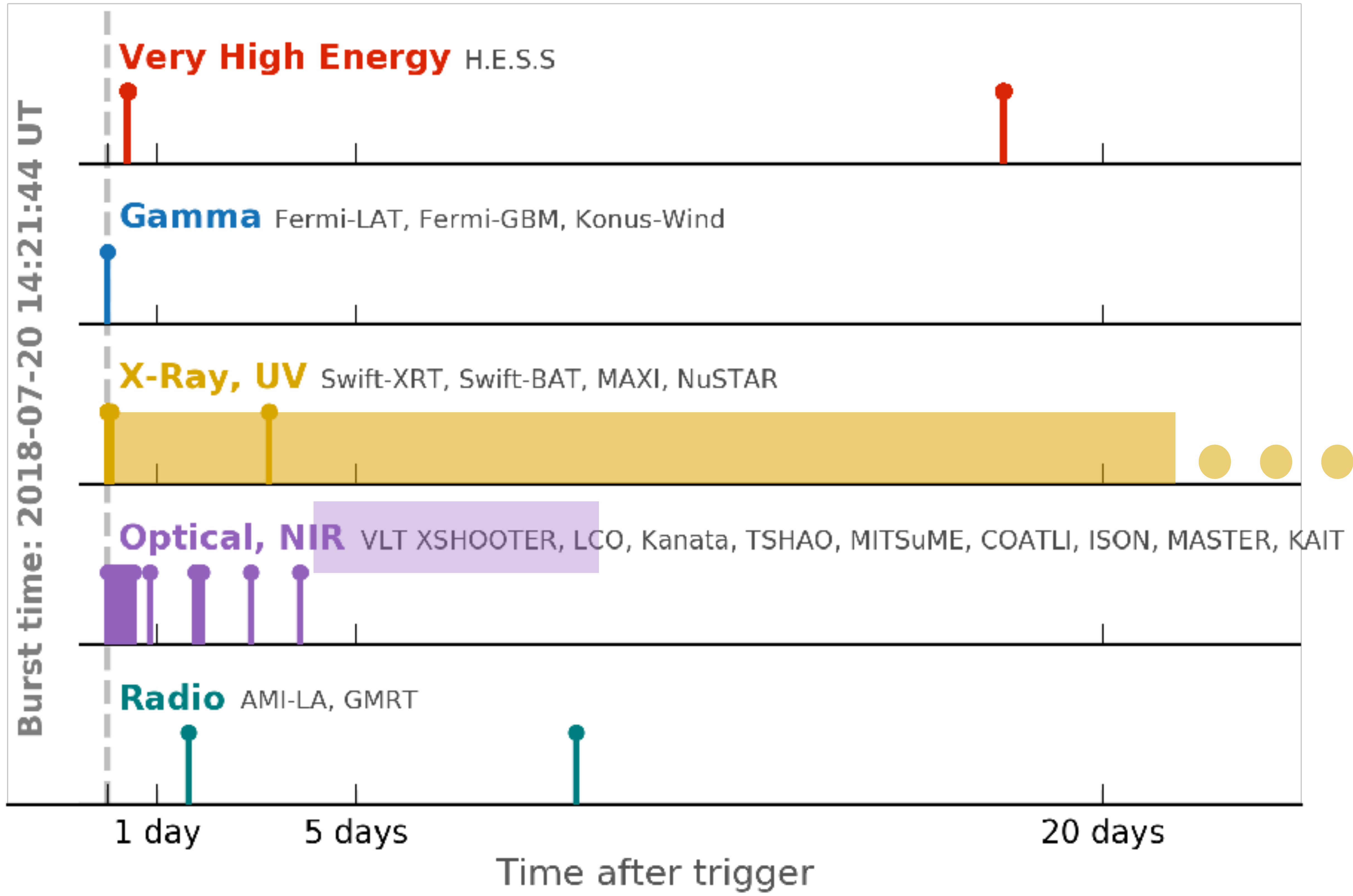
(~10 GRBs per year)

H.E.S.S. GRB follow-up observations from 2012 to 2017



C. Hoischen+ (ICRC 2017)

GRB 180720B

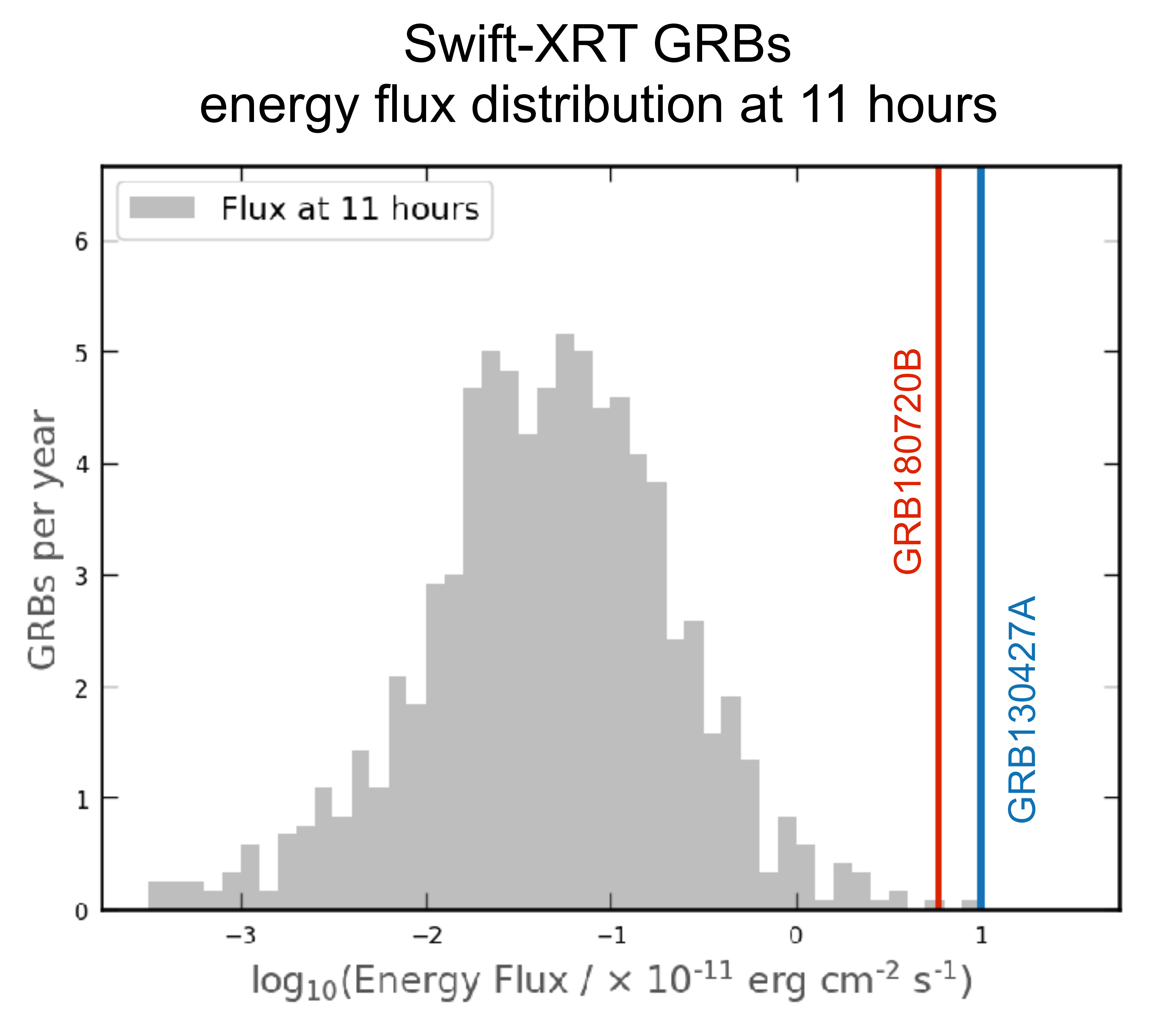


(1st CTA symposium)

z = 0.653

- Triggered Fermi-GBM and Swift-BAT (5 s later).
- Fermi-LAT detection from T_0 to T_0+700 s (max. energy photon 5 GeV).
- Extremely bright burst:
  - 2nd brightest afterglow measured by Swift-XRT.
  - 7th brightest prompt emission detected by Fermi-GBM.
- Very similar x-ray light curve to GRB130427A and GRB190114C.

GRB 180720B



Ruiz-Velasco+(1st CTA symposium)

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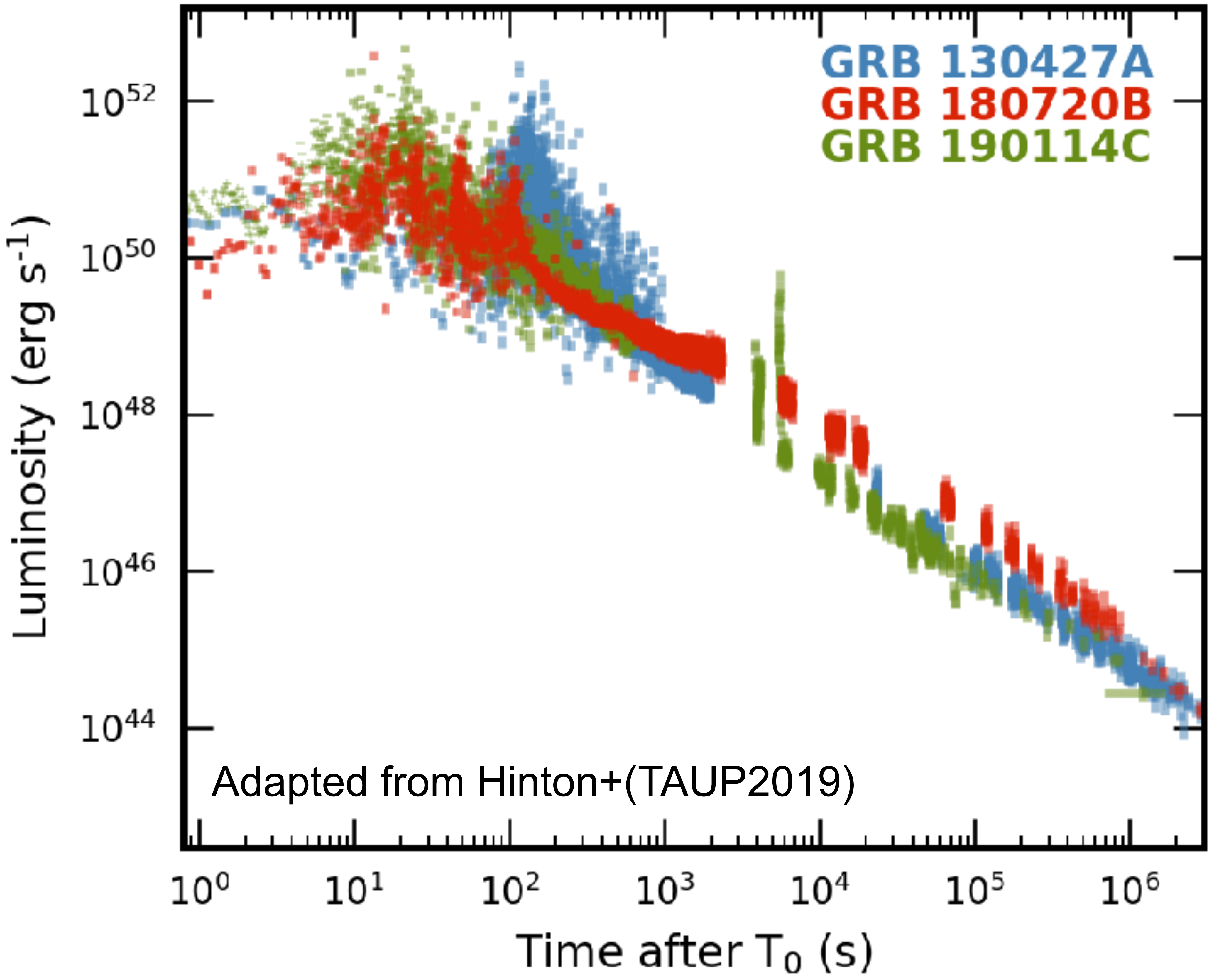
GRB 180720B



Adapted from Hinton+(TAUP2019)

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T90 ~ 48.9 seconds

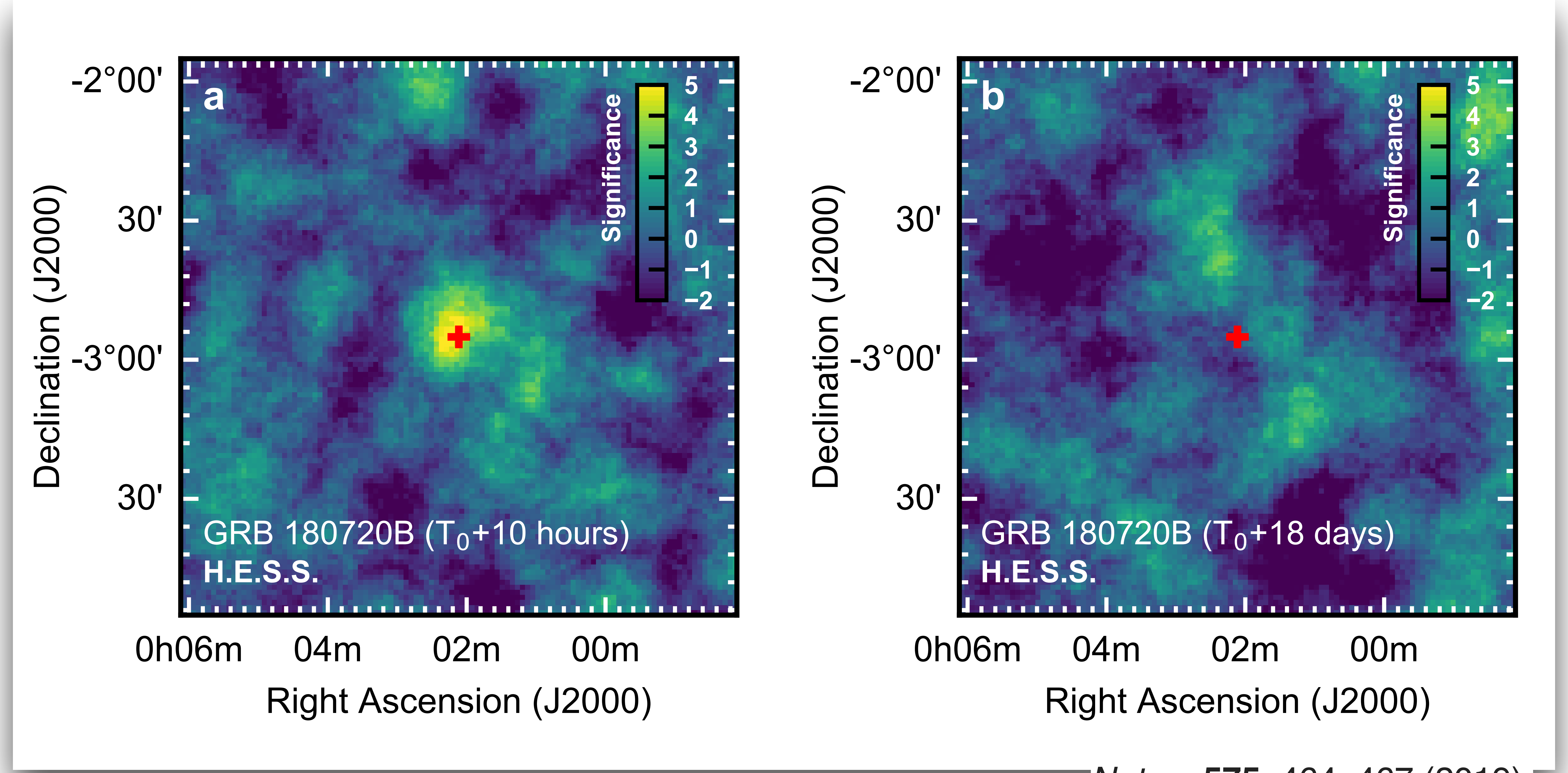
z = 0.653

GRB 180720B H.E.S.S. detection

- Observation started ~10 hours after the burst.
- Follow-up performed for ~2 consecutive hours (zenith 40º to 25º)

H.E.S.S. detection: ~5.3σ pre-trial, 5.0σ post-trial (5 similar searches).

- Moderate presence of clouds at the beginning not affecting the observations.
- Gone in re-observation 18 days after T0.
- Cross-check analysis (totally independent calibration and analysis chain)

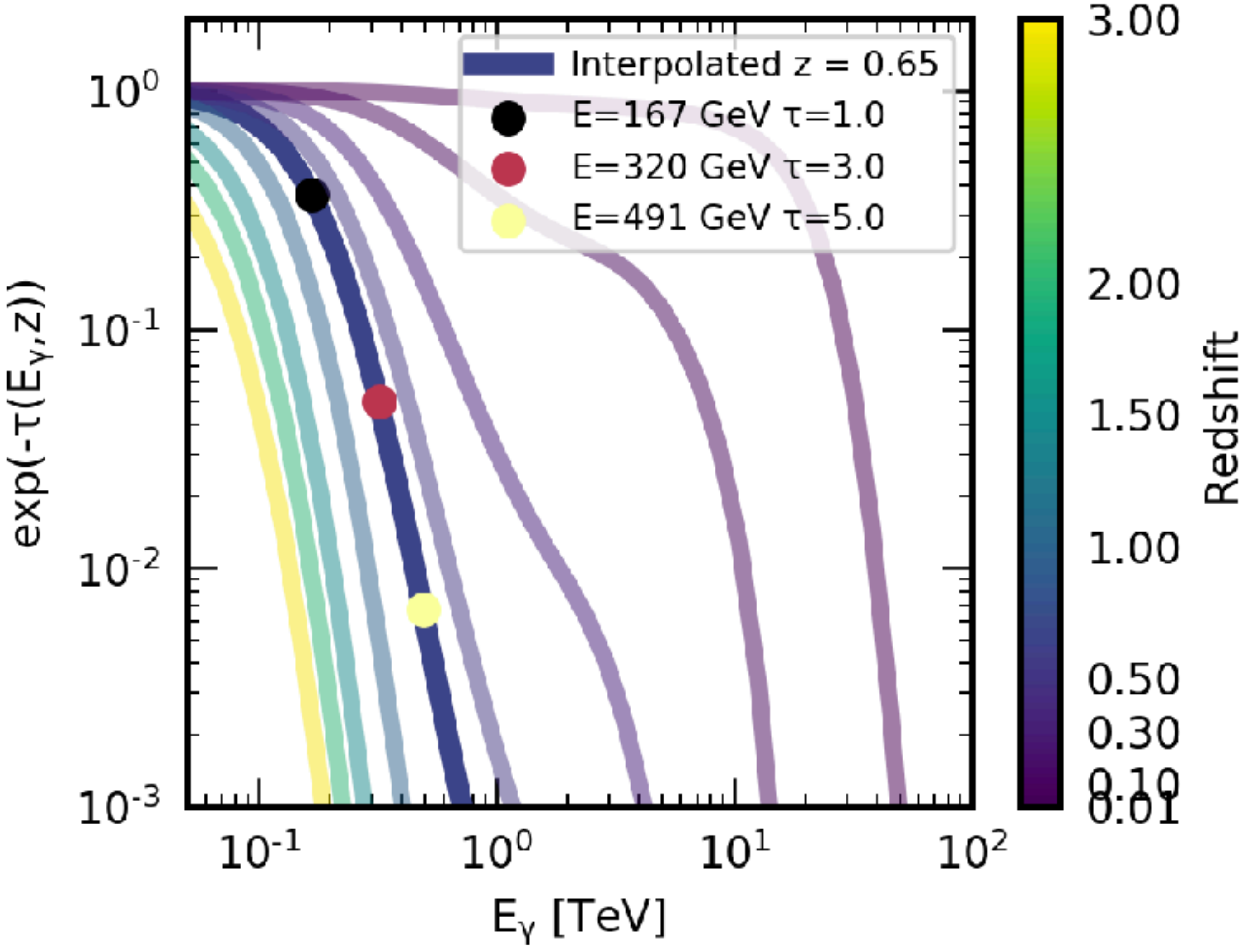


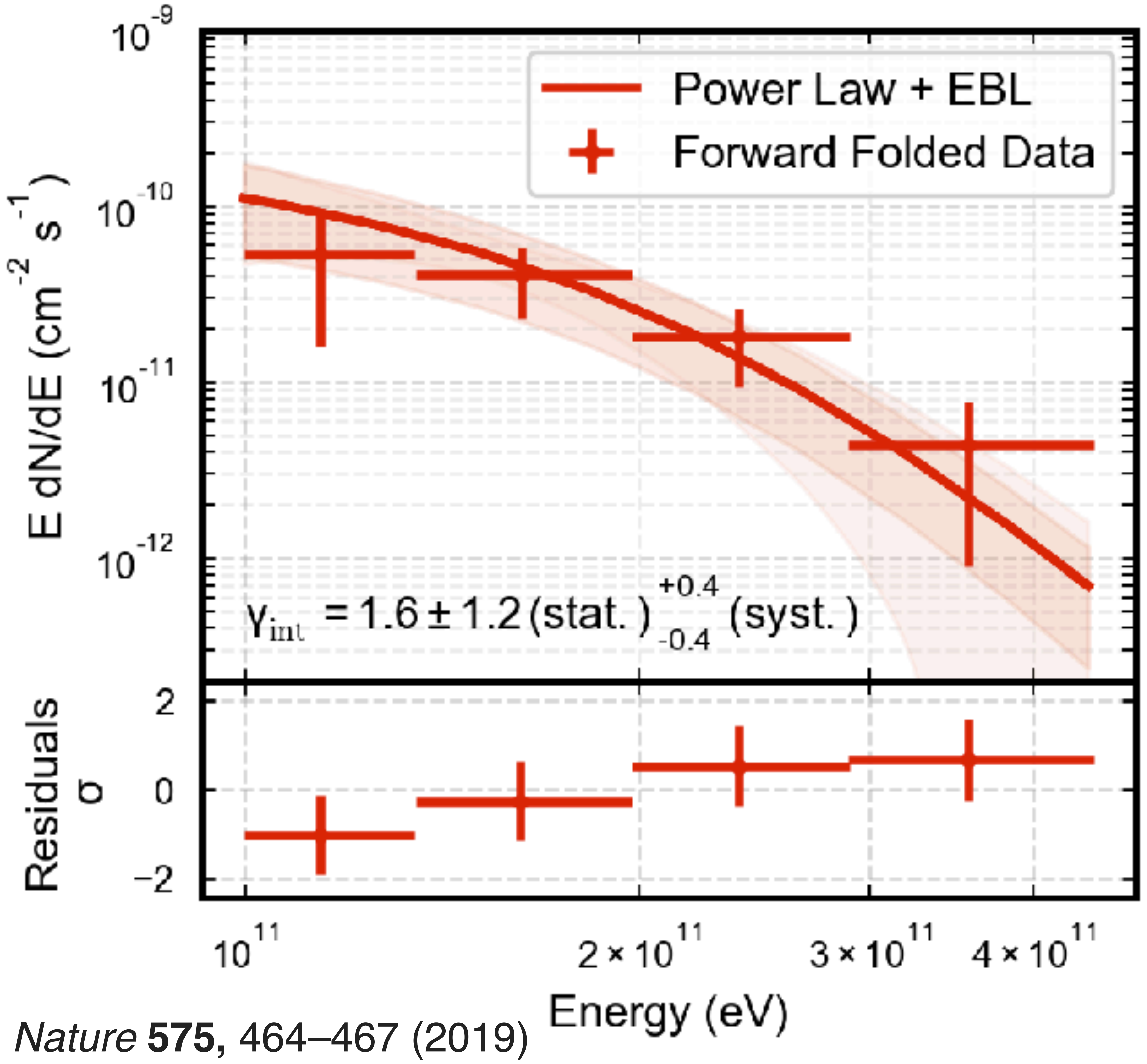
Nature **575,** 464–467 (2019)

GRB 180720B H.E.S.S. detection

Very hard intrinsic spectrum (EBL de-absorbed), redshift 0.65

$$\frac{dN}{dE} = \Phi_0 \left(\frac{E}{E_0}\right)^{-\gamma_{int}} \times exp(-\tau(E,z))$$

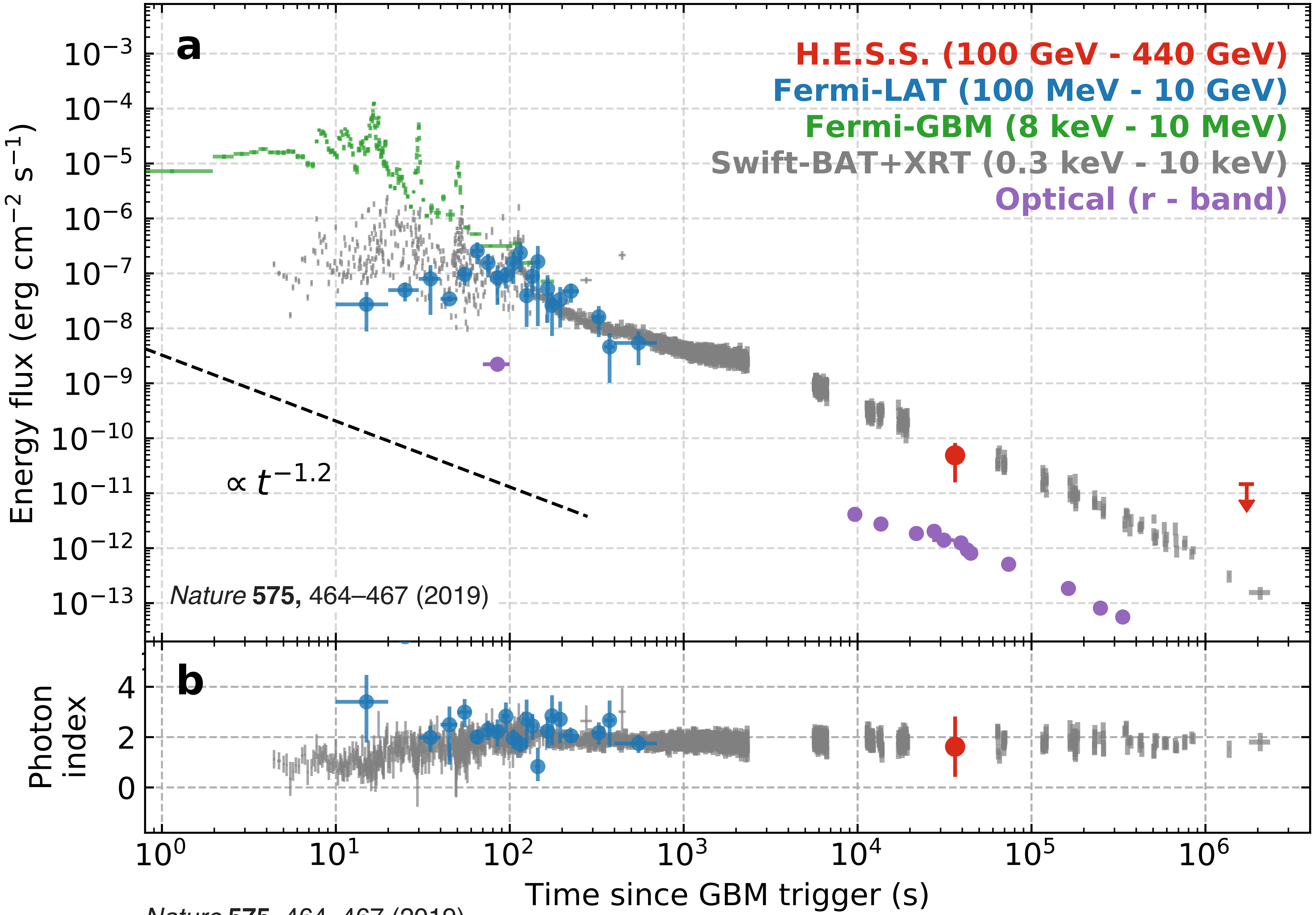




Nature **575,** 464–467 (2019)

GRB 180720B Multi-wavelength light curve

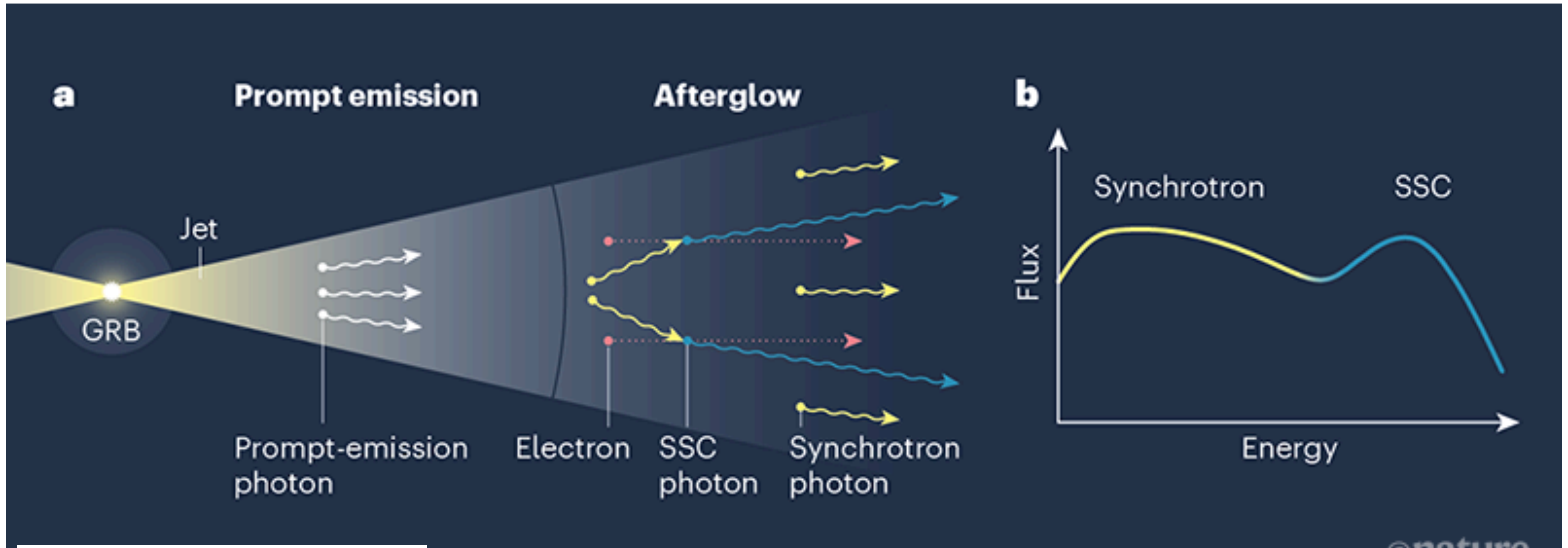
- Multi-peaked and very bright prompt emission.
- Fermi-LAT detection up to 700 s after trigger. Photon index -2.0.
- H.E.S.S. flux (100 to 440 GeV). Photon index consistent with -2.0.
- Gamma-ray energy flux at same level as X-Ray.
- Afterglow falling at same rate in all wave-lengths.



Nature **575,** 464–467 (2019)

Plausible emission mechanisms

- Higher efficiency favours leptonic mechanism.
- Lack of MWL coverage to rule out one or the other scenario (SYN, SSC).
- NO evidence of second bump in SED.

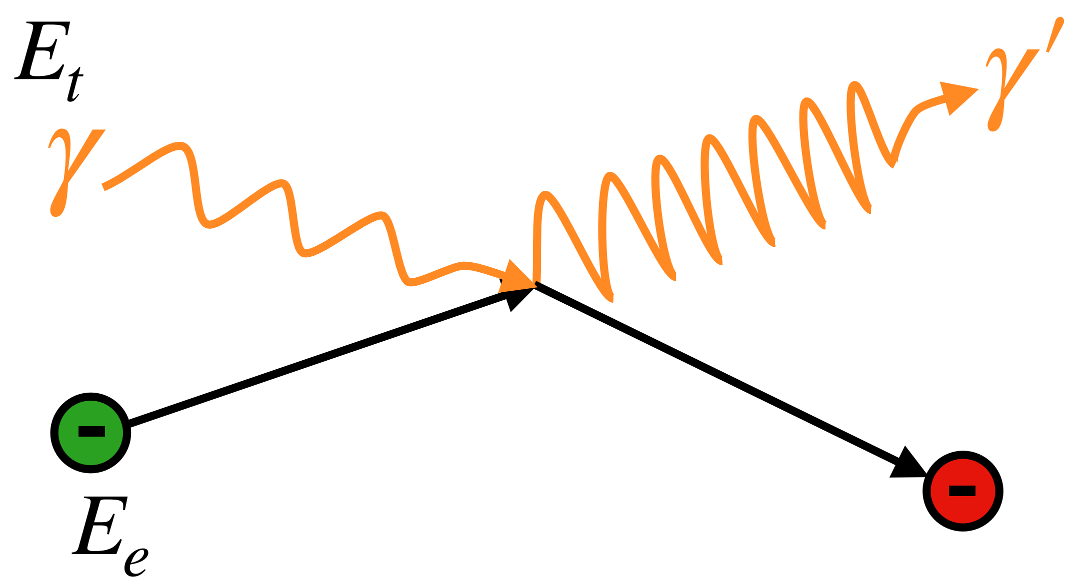


Nature **575**, 448-449 (2019)

$$E_{\rm sync}^{\rm max} = 100\Gamma\,{\rm MeV}$$

Γ>1000 at 10hrs!
while Γ~O(10) expected

Achieved with small scale magnetic turbulence OR E_e~O(PeV)

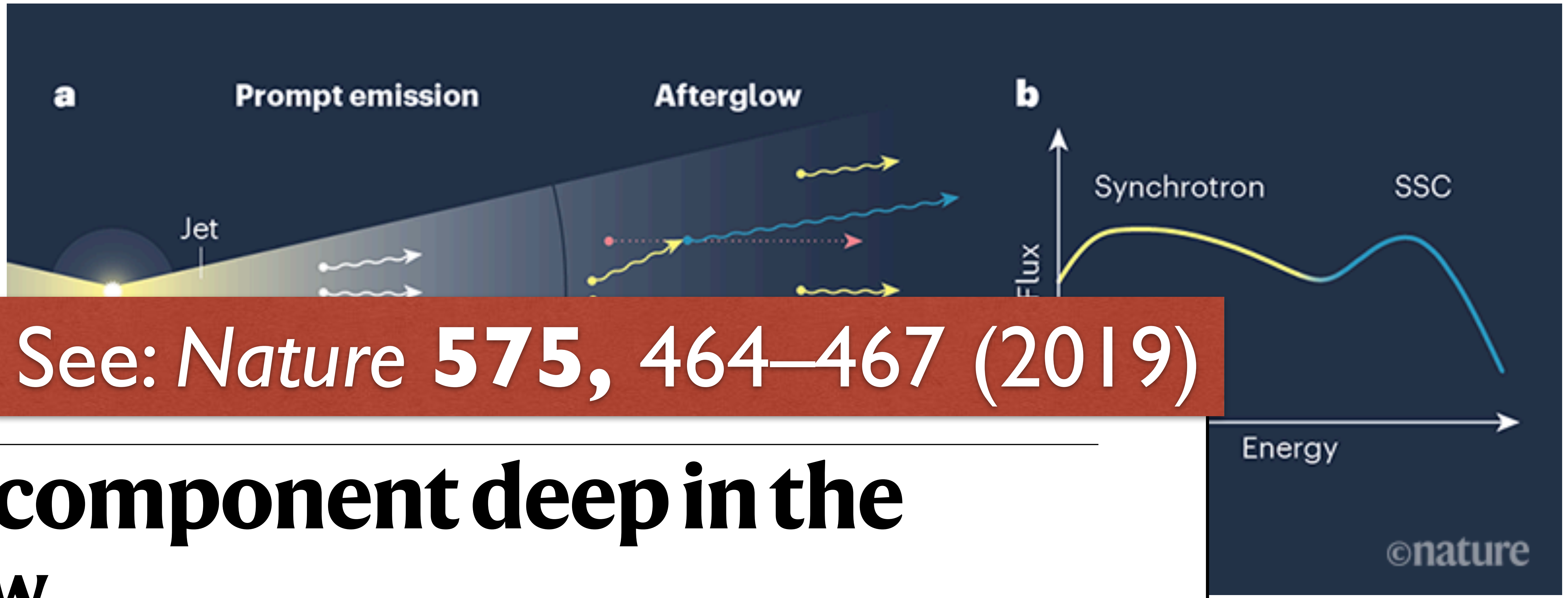


$$min\left[E_t\left(\frac{E_e}{m_e c^2}\right), \Gamma E_e\right]$$

i.e. Requires E_t~1keV for E_e~10GeV boosted with Γ~20

Plausible emission mechanisms

- Higher efficiency favours leptonic mechanism.
- Lack of MWL ... the other sce...
- NO evidence ...



See: *Nature* **575**, 464–467 (2019)

Article

A very-high-energy component deep in the γ-ray burst afterglow

https://doi.org/10.1038/s41586-019-1743-9
Received: 5 June 2019
Accepted: 30 September 2019
Published online: 20 November 2019

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Gamma-ray bursts (GRBs) are brief flashes of γ-rays and are considered to be the most energetic explosive phenomena in the Universe[1]. The emission from GRBs comprises a short (typically tens of seconds) and bright prompt emission, followed by a much longer afterglow phase. During the afterglow phase, the shocked outflow—produced by the interaction between the ejected matter and the circumburst medium—slows down, and a gradual decrease in brightness is observed[2]. GRBs typically emit most of

$E_{\rm sync}^{\rm max} =$

magnetic turbulence OR
$E_e \sim O(\rm PeV)$

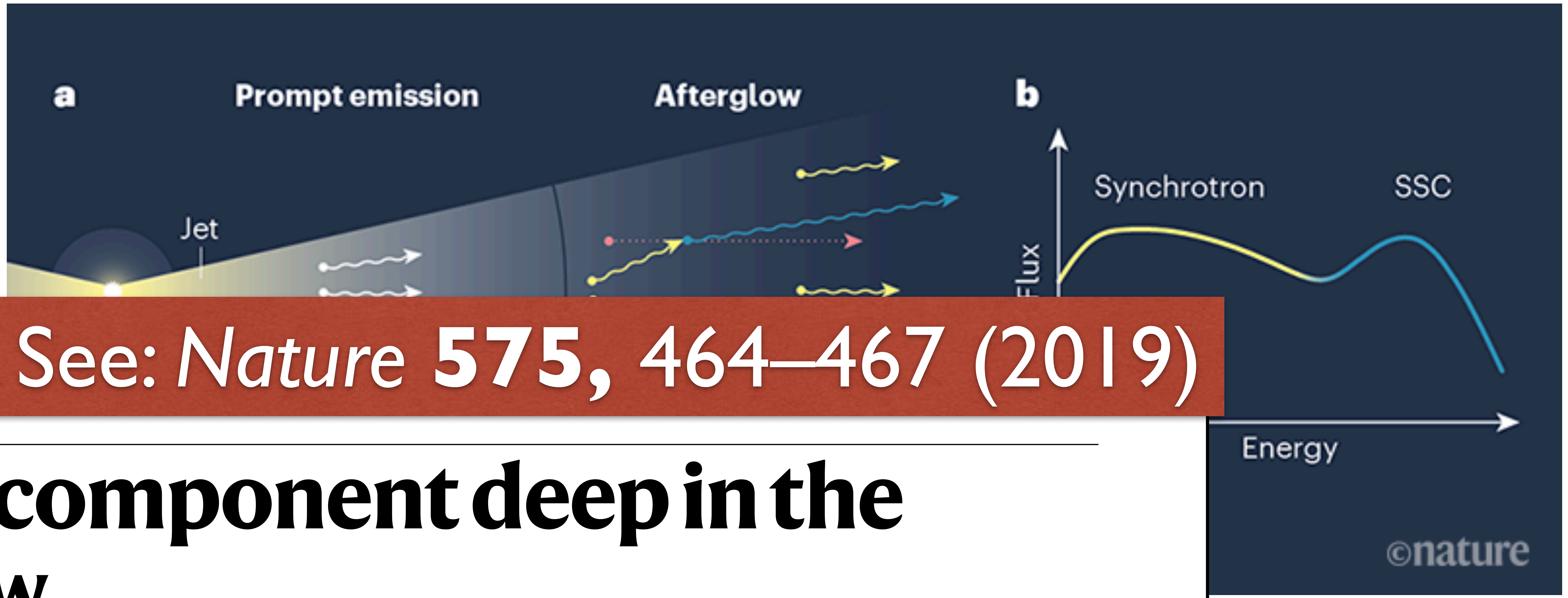
E_e ... $_e c^2$ $\Big)$ $, \Gamma E_e \Big]$

i.e. Requires $E_t \sim 1$keV for
$E_e \sim 10$GeV boosted with $\Gamma \sim 20$

H.E.S.S.

Plausible emission mechanisms

- Higher efficiency favours leptonic mechanism.
- Lack of MWL ... the other sce...
- NO evidence...



See: *Nature* **575**, 464–467 (2019)

Article

A very-high-energy component deep in the γ-ray burst afterglow

by the interaction between the ejected matter and the circumburst medium—slows down, and a gradual decrease in brightness is observed[2]. GRBs typically emit most of

GRB 180720B Strong input on follow-up criteria ——
——> GRB190829A detection

E^{max} ...

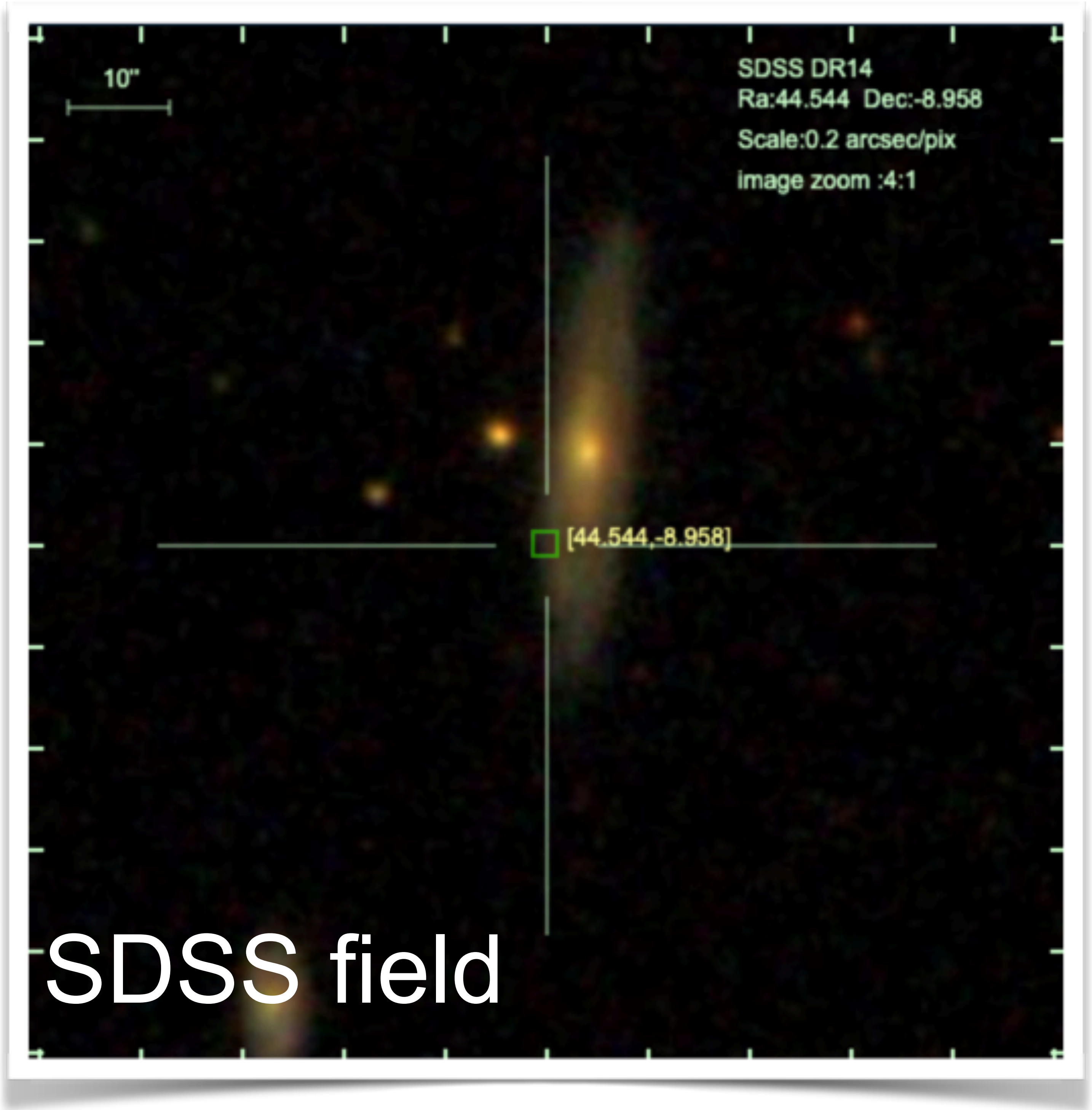
magnetic turbulence OR
E_e~O(PeV)

... ΓE_e ...

i.e. Requires E_t~1keV for
E_e~10GeV boosted with Γ~20

Detection of GRB 190829A

T90 ~ 60 seconds
z = 0.078



[Previous | Next | ADS]

GRB190829A: Detection of VHE gamma-ray emission with H.E.S.S.

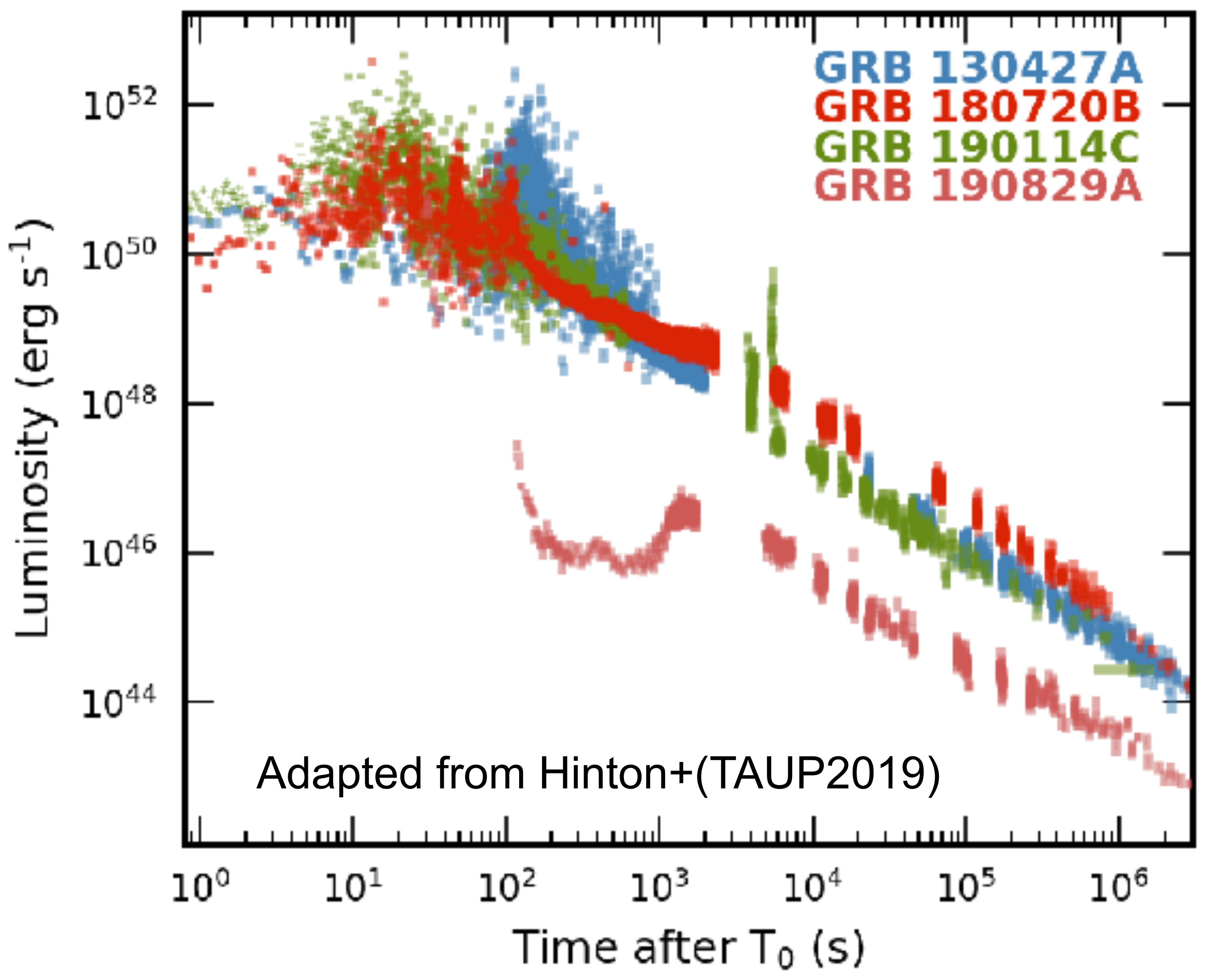
ATel #13052; ***M. de Naurois (H. E.S. S. Collaboration)***
on ***30 Aug 2019; 07:12 UT***
Credential Certification: Fabian SchÃ Â¼ssler (fabian.schussler@cea.fr)

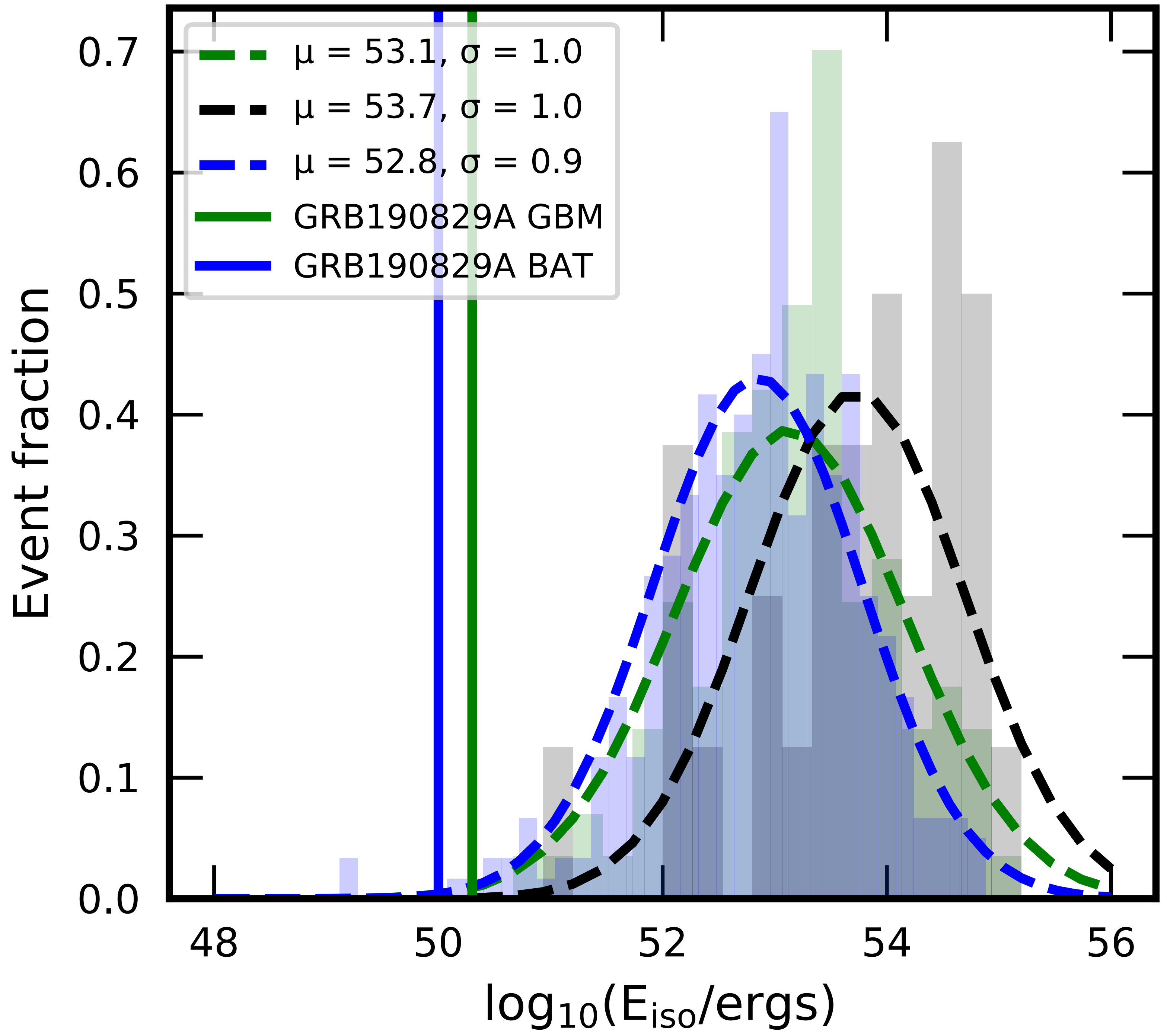
Subjects: Gamma Ray, >GeV, TeV, VHE, Gamma-Ray Burst

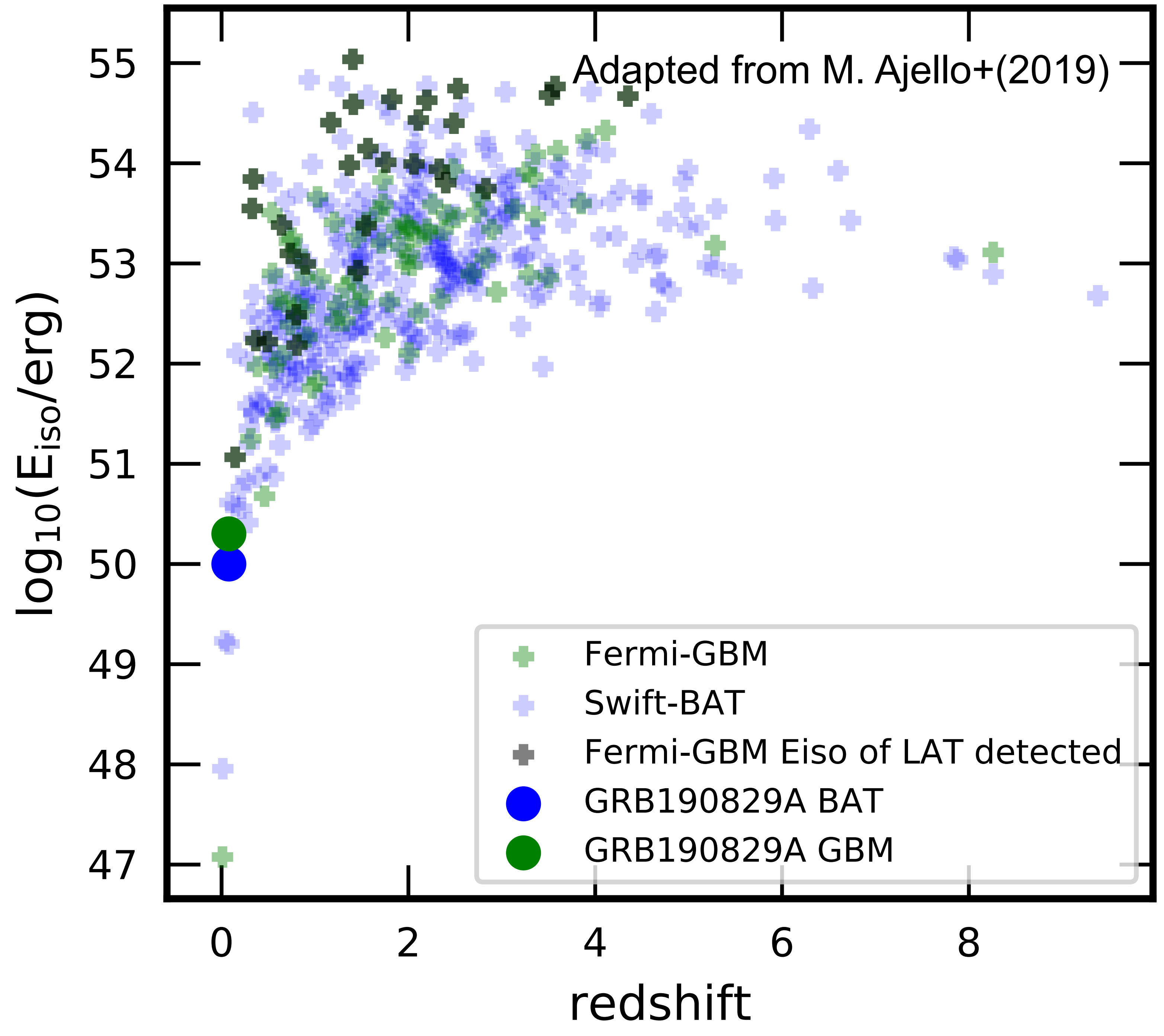
Tweet

The H.E.S.S. array of imaging atmospheric Cherenkov telescopes was used to carry out follow-up observations of the afterglow of GRB 190829A (Dichiara et al., GCN 25552). At a redshift of z = 0.0785 +/- 0.005 (A.F. Valeev et al., GCN 25565) this is one of the nearest GRBs detected to date. H.E.S.S. Observations started July 30 at 00:16 UTC (i.e. T0 + 4h20), lasted until 3h50 UTC and were taken under good conditions. A preliminary onsite analysis of the obtained data shows a >5sigma gamma-ray excess compatible with the direction of GRB190829A. Further analyses of the data are on-going and further H.E.S.S. observations are planned. We strongly encourage follow-up at all wavelengths. H.E.S.S. is an array of five imaging atmospheric Cherenkov telescopes for the detection of very-high-energy gamma-ray sources and is located in the Khomas Highlands in Namibia. It was constructed and is operated by researchers from Armenia, Australia, Austria, France, Germany, Ireland, Japan, the Netherlands, Poland, South Africa, Sweden, UK, and the host country, Namibia. For more details see https://www.mpi-hd.mpg.de/hfm/HESS/

GRB 190829A

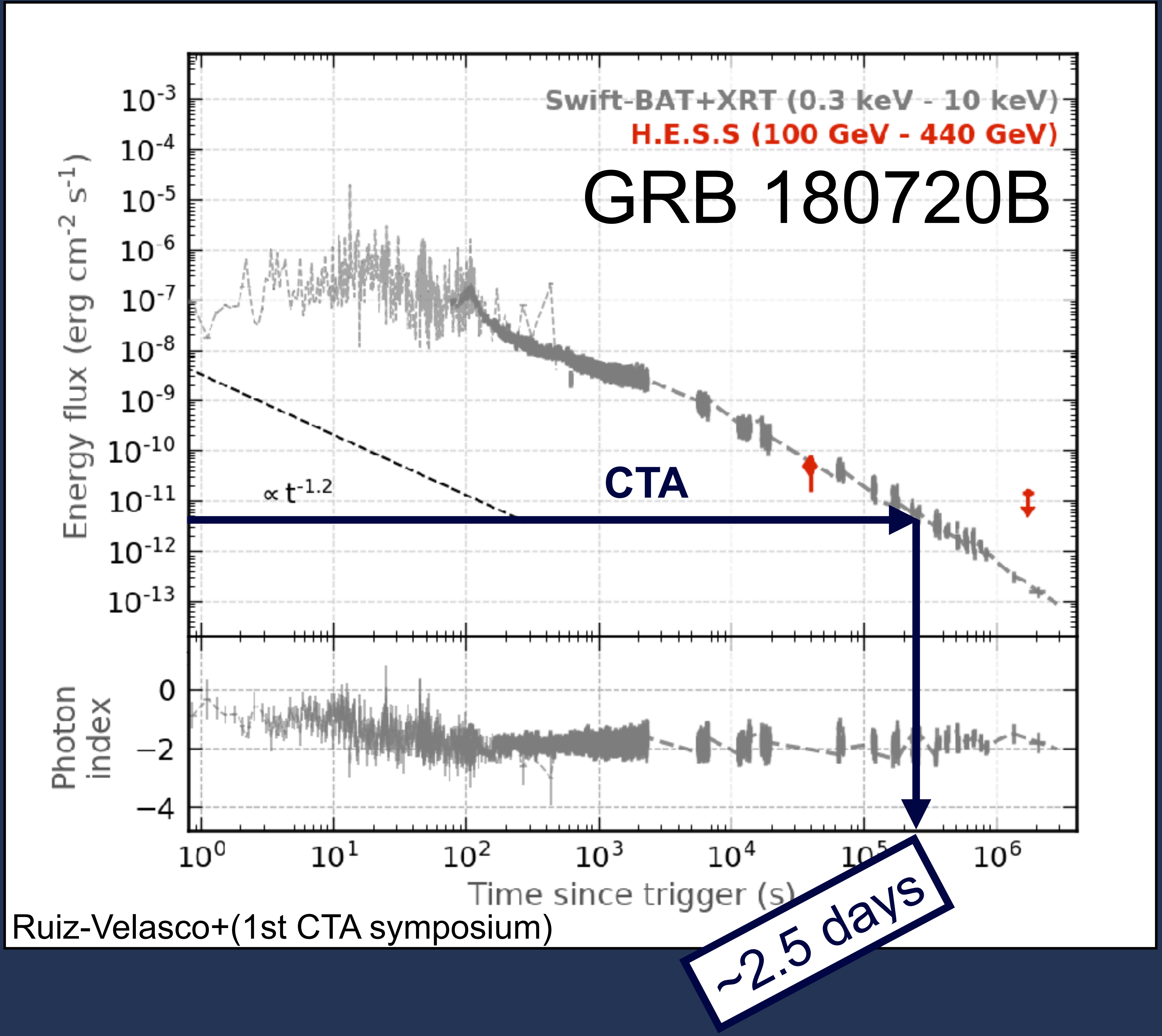

GRB 130427A
GRB 180720B
GRB 190114C
GRB 190829A
Luminosity (erg s-1)
Time after T0 (s)
Adapted from Hinton+(TAUP2019)


μ = 53.1, σ = 1.0
μ = 53.7, σ = 1.0
μ = 52.8, σ = 0.9
GRB190829A GBM
GRB190829A BAT
Event fraction
log10(Eiso/ergs)


Adapted from M. Ajello+(2019)
Fermi-GBM
Swift-BAT
Fermi-GBM Eiso of LAT detected
GRB190829A BAT
GRB190829A GBM
log10(Eiso/erg)
redshift

Prospects for future observatories

- Have ~10 times better sensitivity than H.E.S.S.
- Be able to detect flux over many decades in time with detailed spectra information.
- Boost the detection of GRBs at VHE.
  - ~ 3 GRBs per year at 11 hours after burst.
  - ~ 11 GRBs per year at 5 hours after burst



Ruiz-Velasco+(1st CTA symposium)

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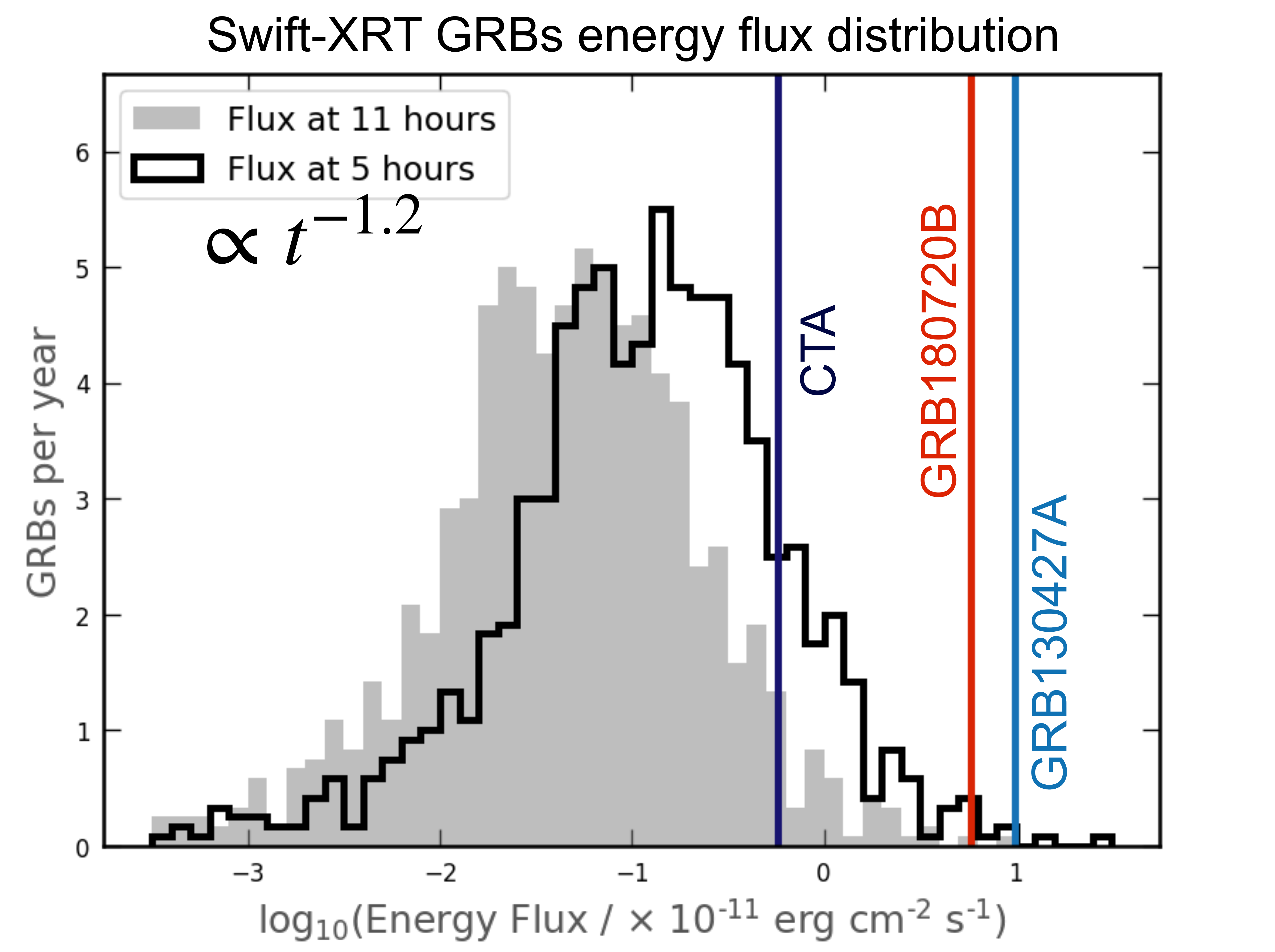


Ruiz-Velasco+(1st CTA symposium)

Conclusions

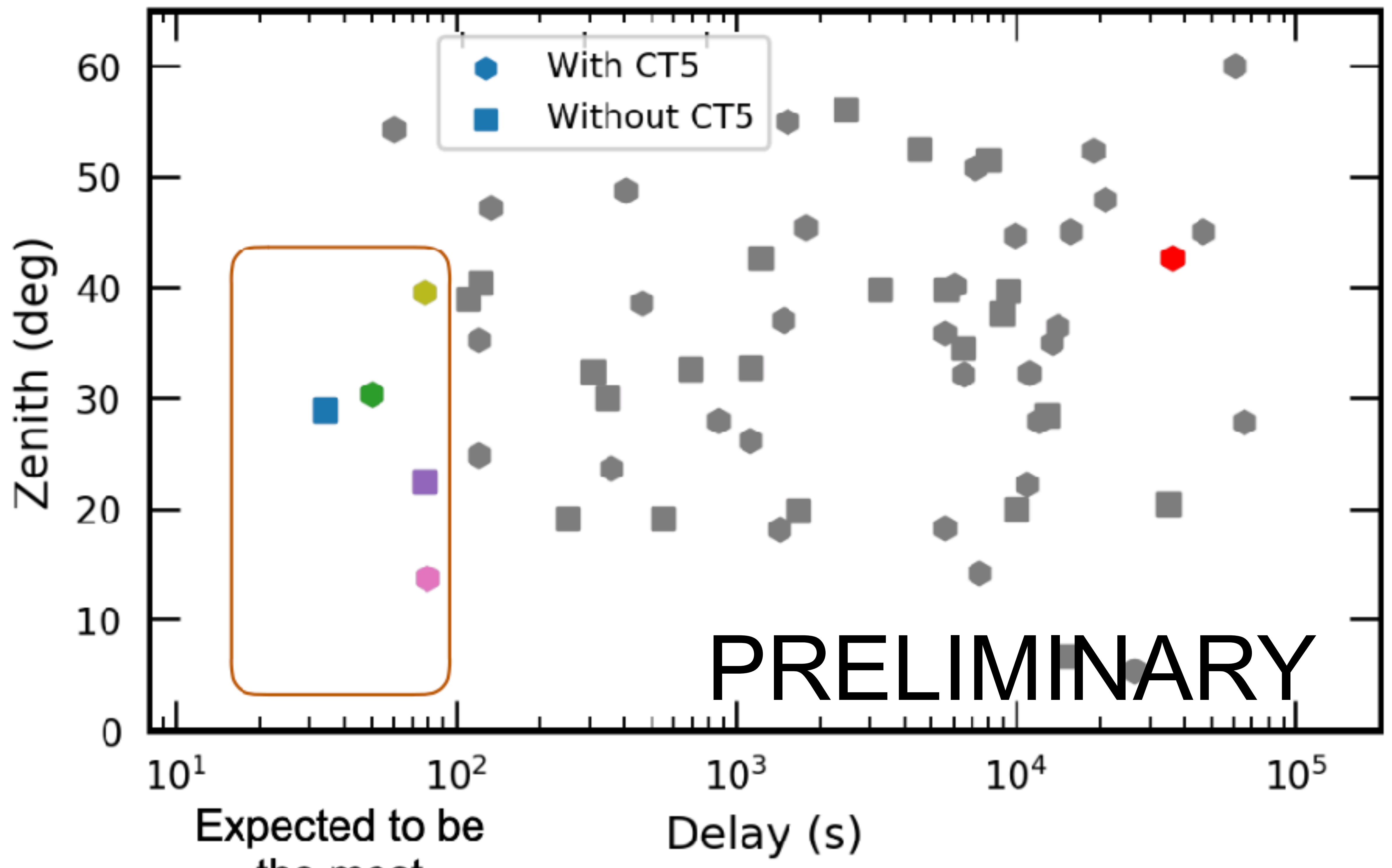
- GRB180720B
  - First detection of a GRB at VHE. The emission is detected at T_0+10 hours (100 - 440 GeV)
  - Photon index and temporal decay indicate possible emission scenarios: IC or extreme synchrotron.
  - Fast feedback on follow-up criteria

- GRB190829A
  - VHE detection! of this very nearby burst!
  - Upcoming publication

- Very exciting times with complementary observation of three GRBs at VHE (covering different times of the early-afterglow, late-afterglow), promising prospects for future and many open questions.

Backup

66 GRB follow-up observations since 2008

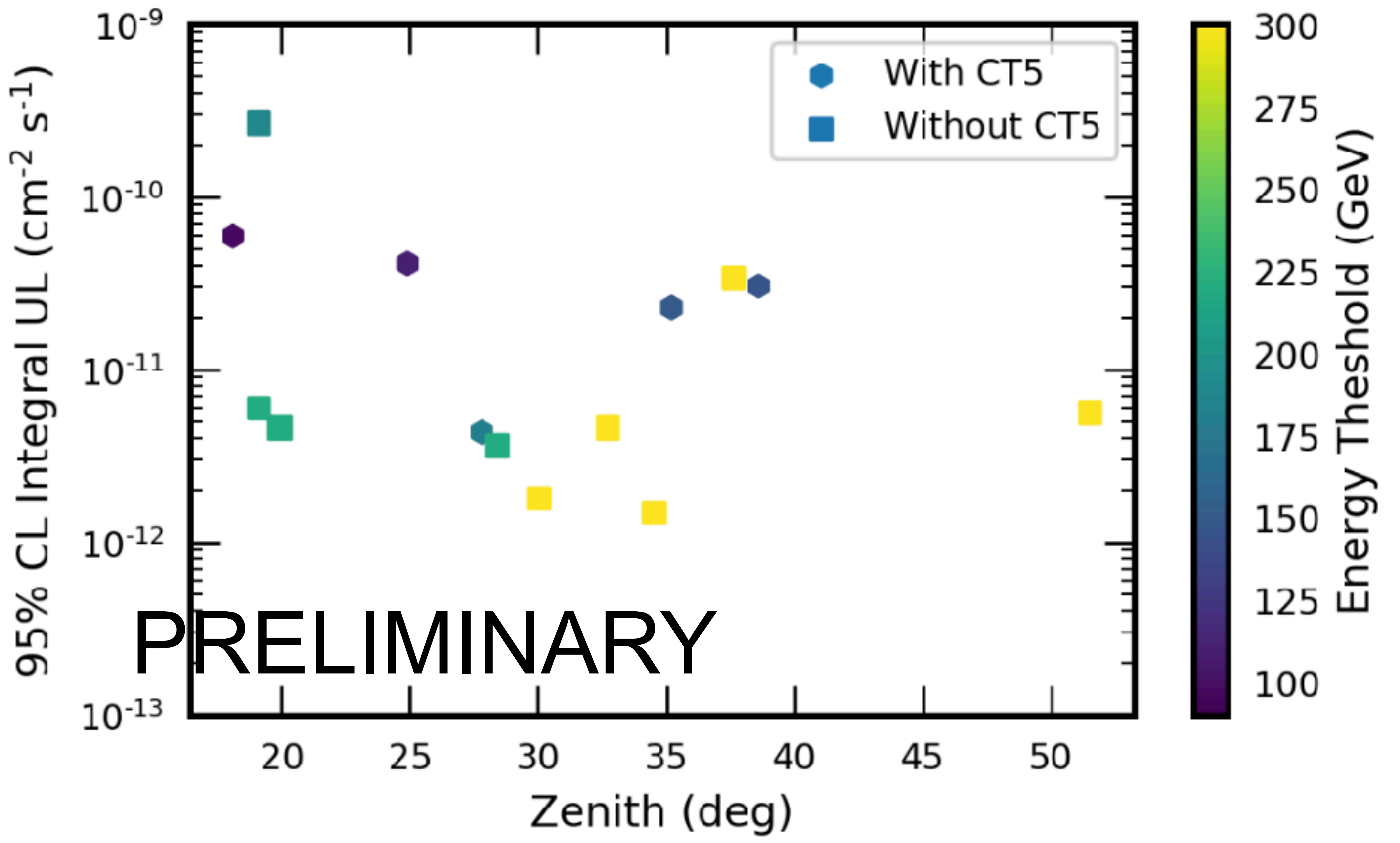


Expected to be the most promising due to short observation delay

increasing energy threshold

15 Swift-BAT GRBs have been analyzed:

- Integral ULs derived for 14 observations

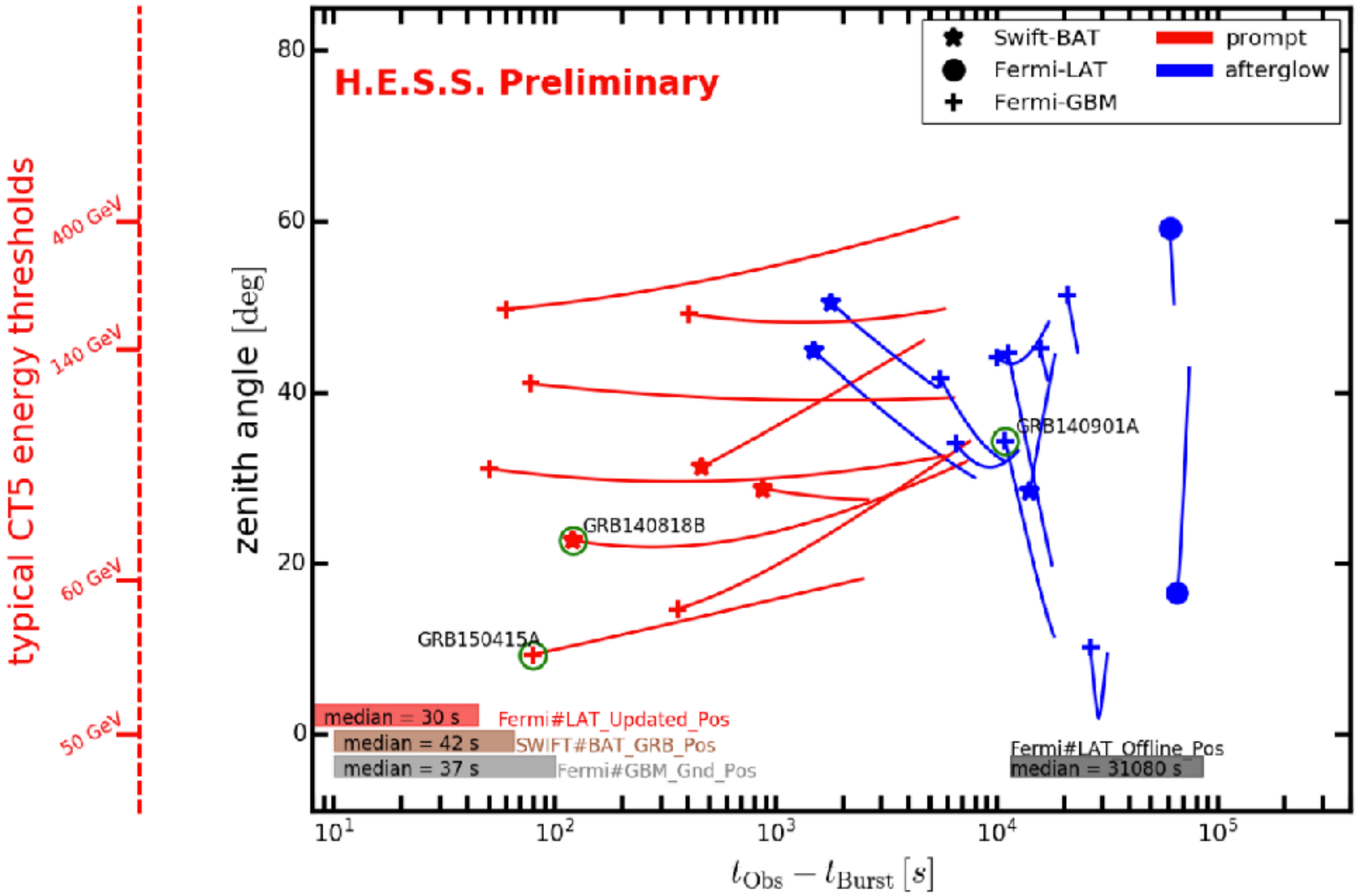


reported in the literature[62], corresponding to weaker magnetic fields by several orders of magnitude. Assuming that synchrotron emission beyond the 100 MeV energy limit in the co-moving frame can be achieved, the energy of the emitting electrons can be estimated as $E_e \approx 4[E/(100\,\mathrm{keV})]^{1/2}(\Gamma/20)^{-1/2}[B/(0.1\,\mathrm{G})]^{-1/2}\eta_{\mathrm{turb}}^{-1/2}$ TeV. The production of 100-GeV γ-rays through a synchrotron scenario therefore requires electrons of ultrahigh-energy, $E_e \approx 4$ PeV, unless a configuration with a very-small-scale turbulence is present. The energy of particles that provide the dominant contribution to the inverse Compton emission depends strongly on the spectrum of the target photons and the bulk Lorentz factor. An electron with energy E_e up-scatters a target

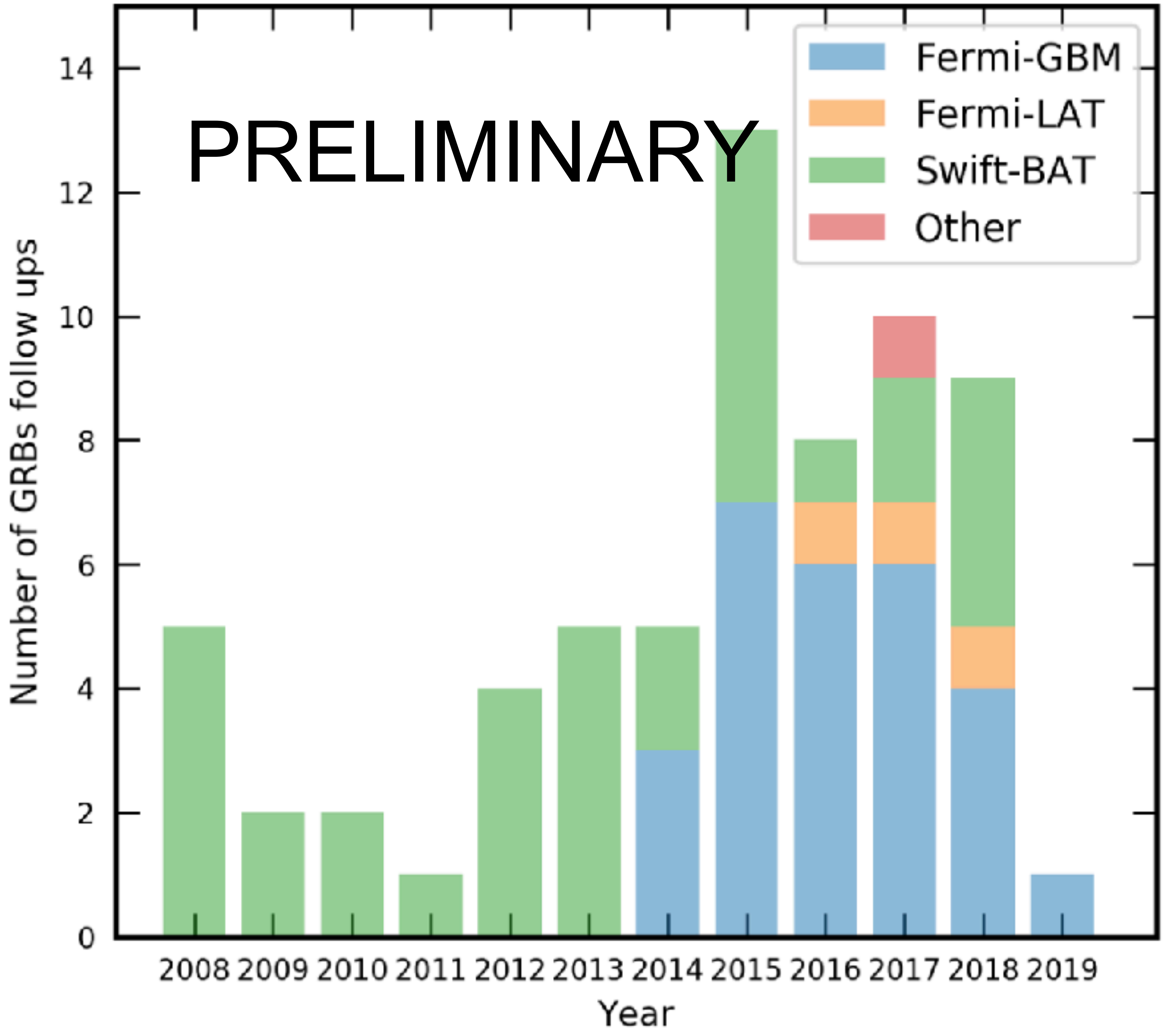
The H.E.S.S. GRB programme: Trigger criteria

- GRBs followed up automatically if in FoV at time of alert
- Monthly shift of GRB expert decides in a case by case for afterglows/extend observations.
- Redshift-delay dependant trigger:
  - 24h after trigger if z < 0.1
  - 12h after trigger if z < 0.3
  - 6h after trigger if z < 1.0
  - 4h after trigger if z unknown.

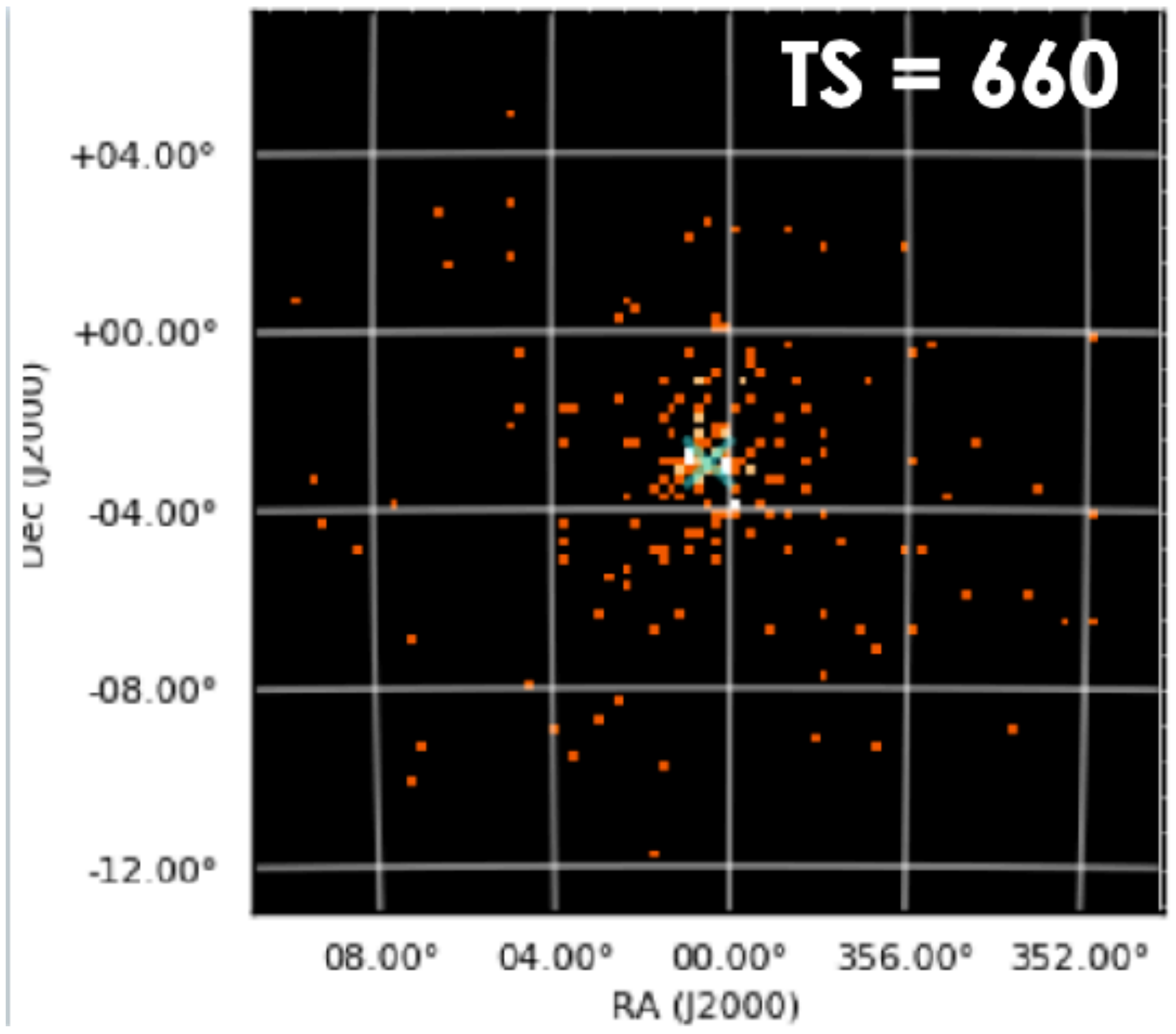
H.E.S.S. GRB follow-up observations from 2012 to 2017

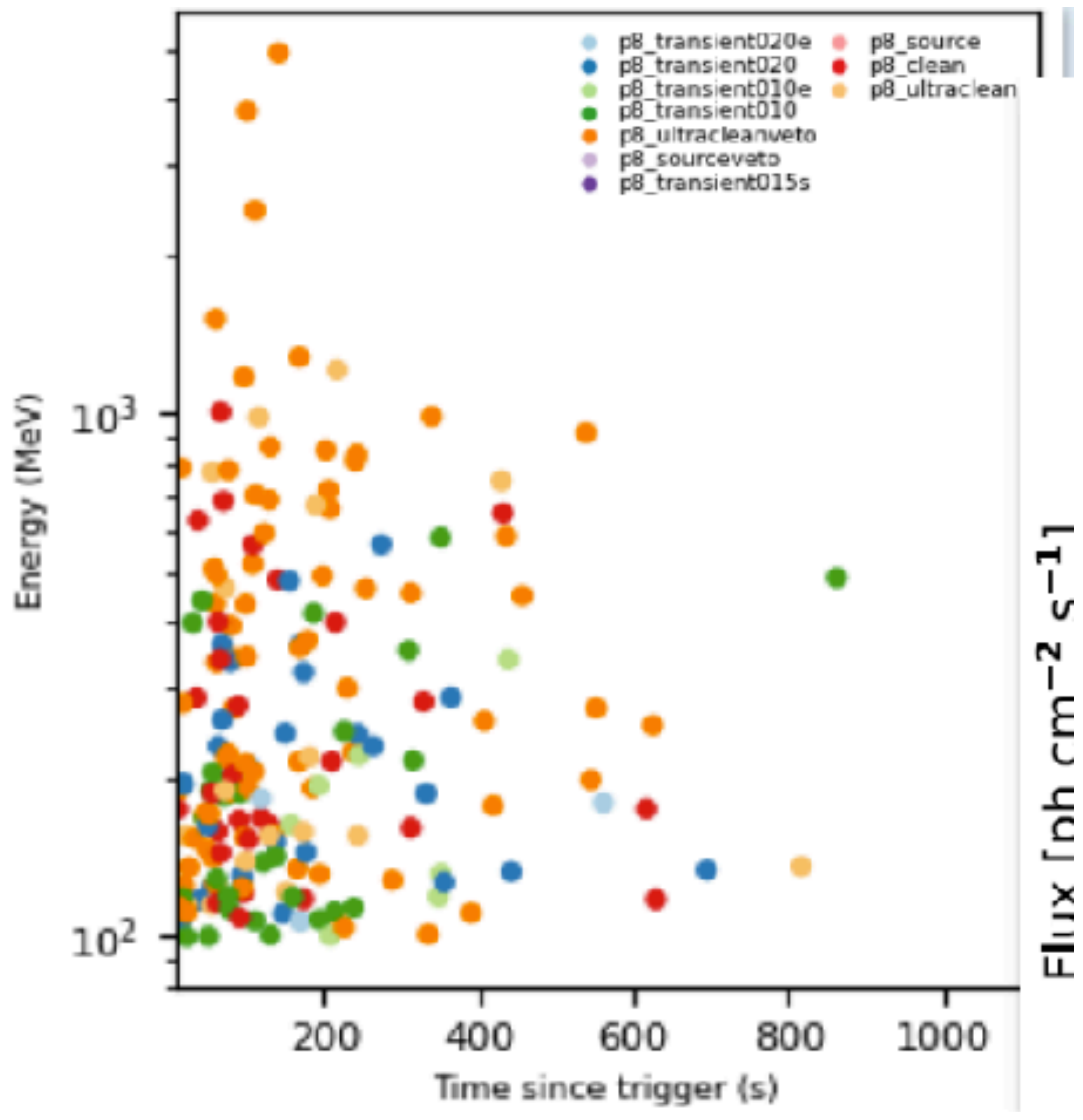


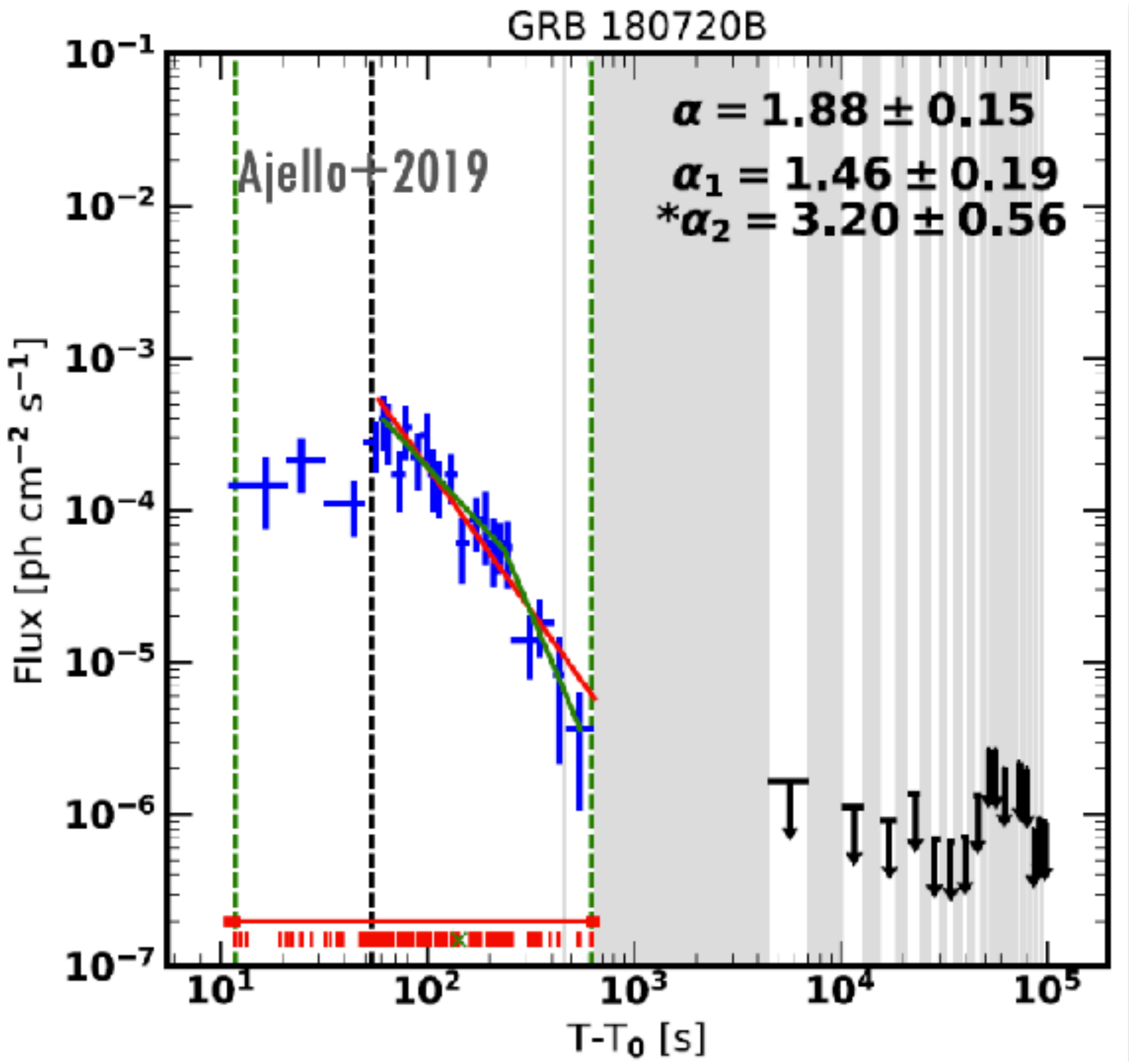
C. Hoischen+ (ICRC 2017)

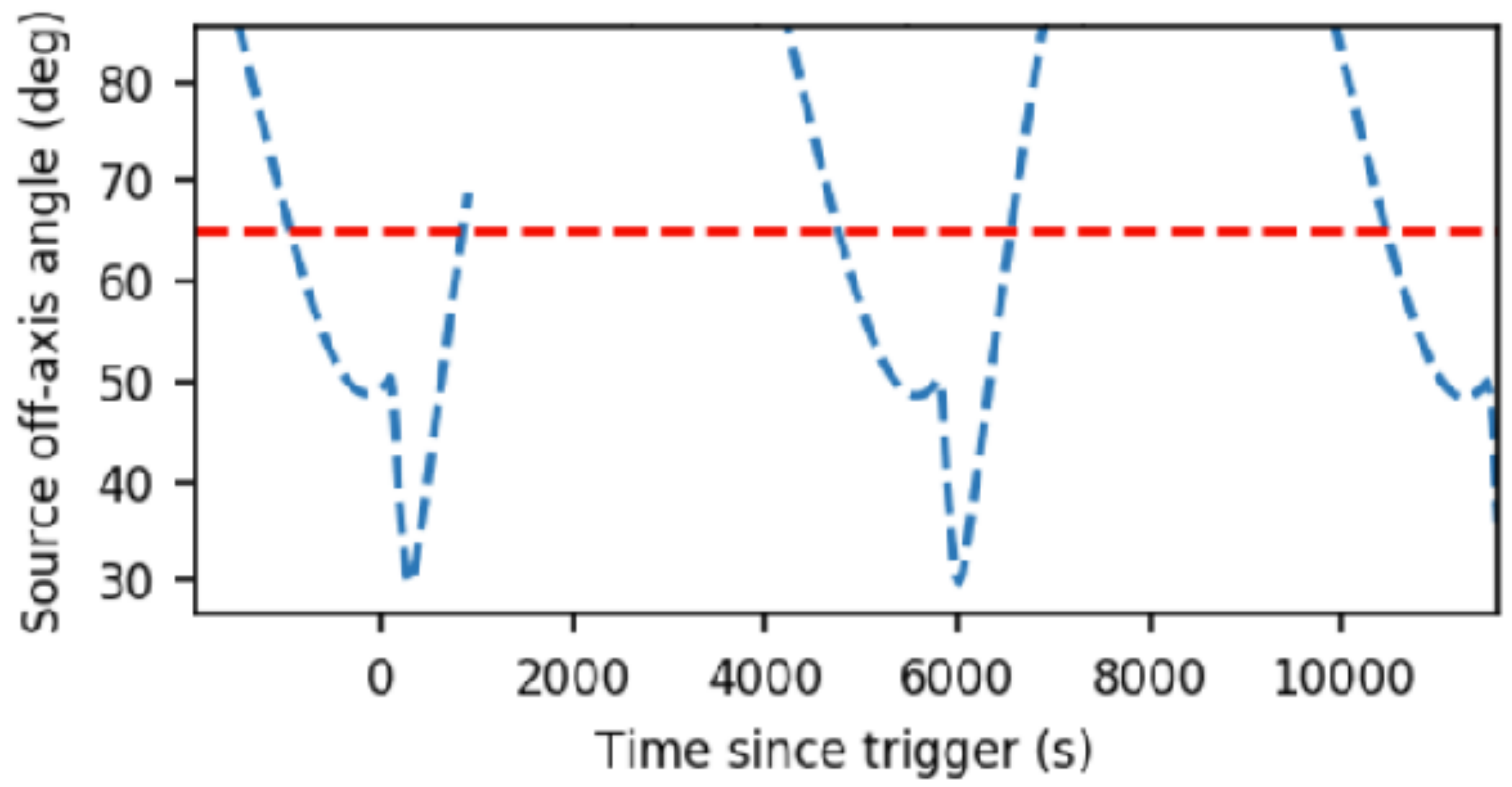

PRELIMINARY
Fermi-GBM
Fermi-LAT
Swift-BAT
Other
Number of GRBs follow ups
0
2
4
6
8
10
12
14
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year

Fermi-LAT analysis

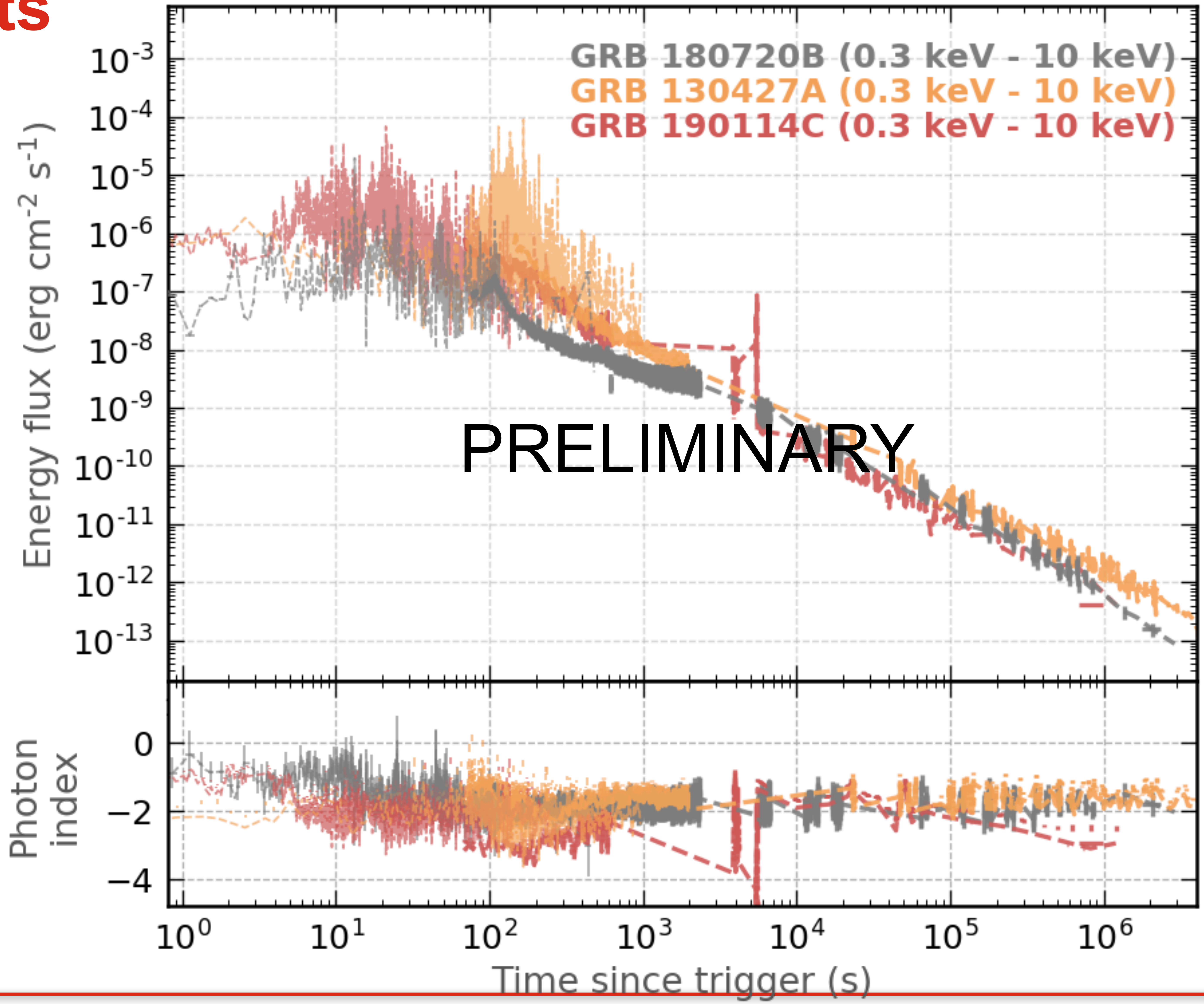




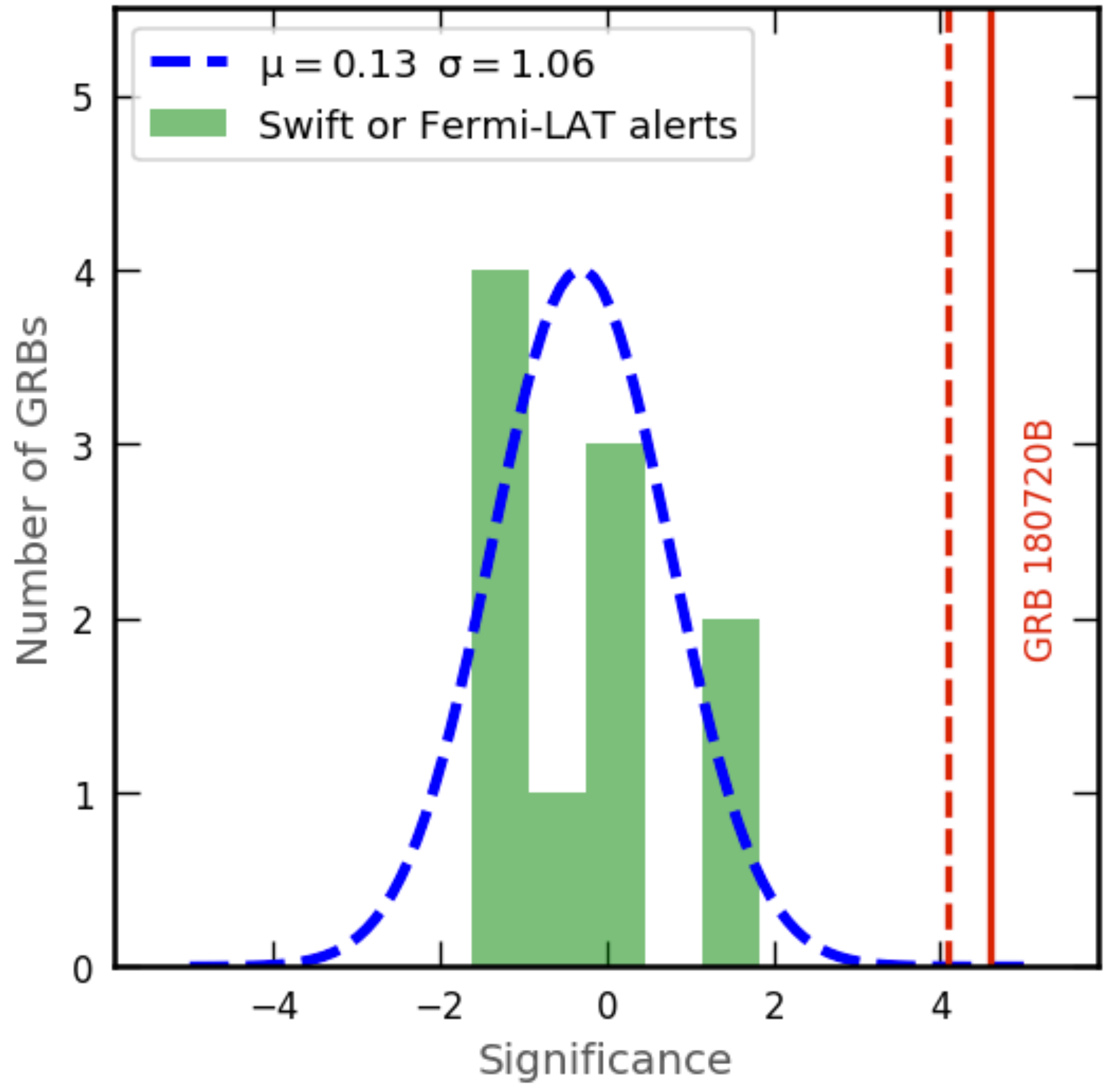




The three giants



Trials / FAR



10 well localised GRBs year < 2018

$$\sigma_{post}(4.6,10) = 4.1$$

$$\sigma_{post}\left(\sigma, N_t\right) = \sqrt{2}\, erfcinv\left[1 - \left(1 - erfc\left(\frac{\sigma}{\sqrt{2}}\right)\right)^{N_t}\right]$$