Fifteen years of GRB observations with the H.E.S.S. Telescopes

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based on A&A, 707 (2026) A382

enigmass+

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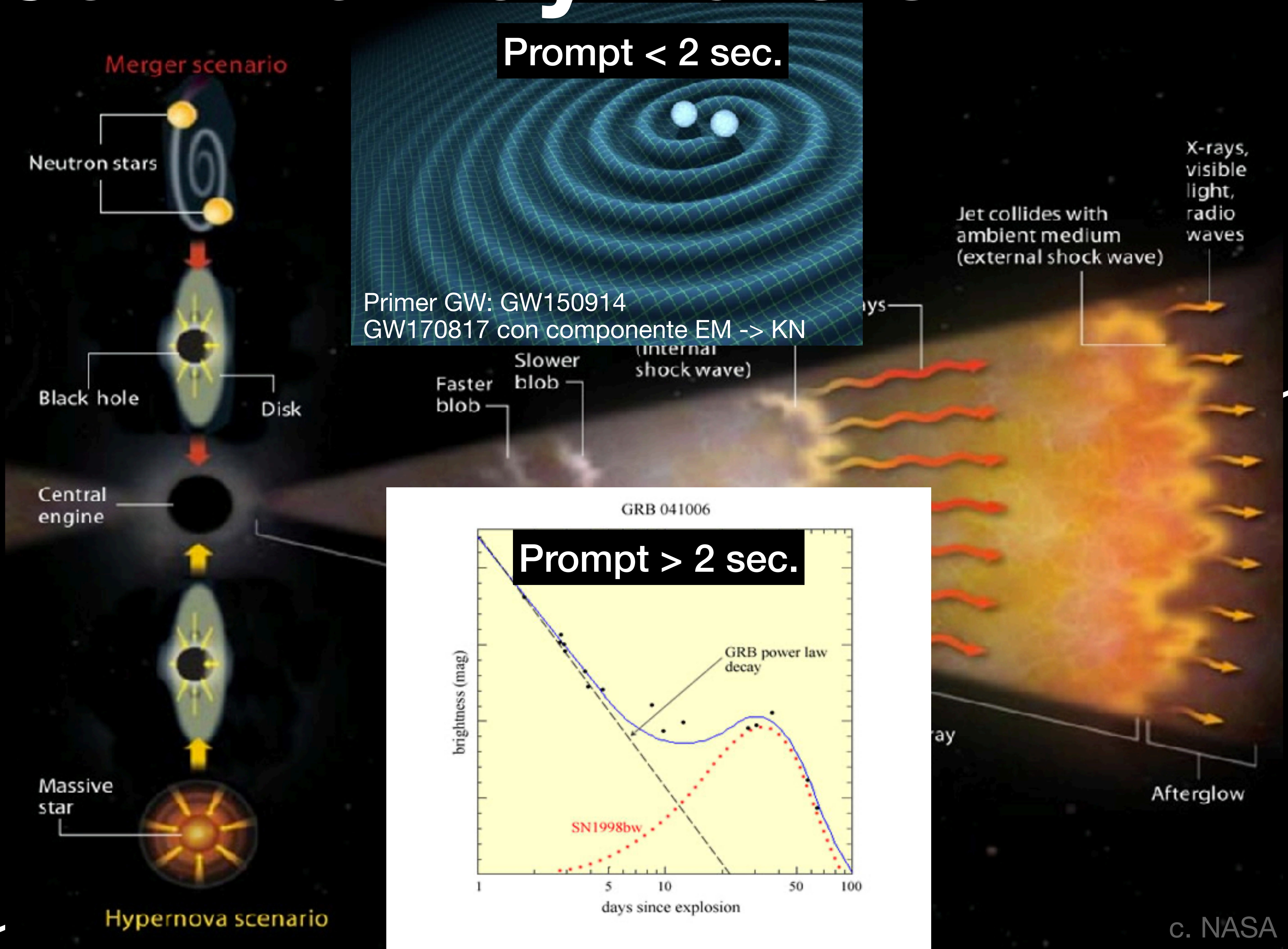
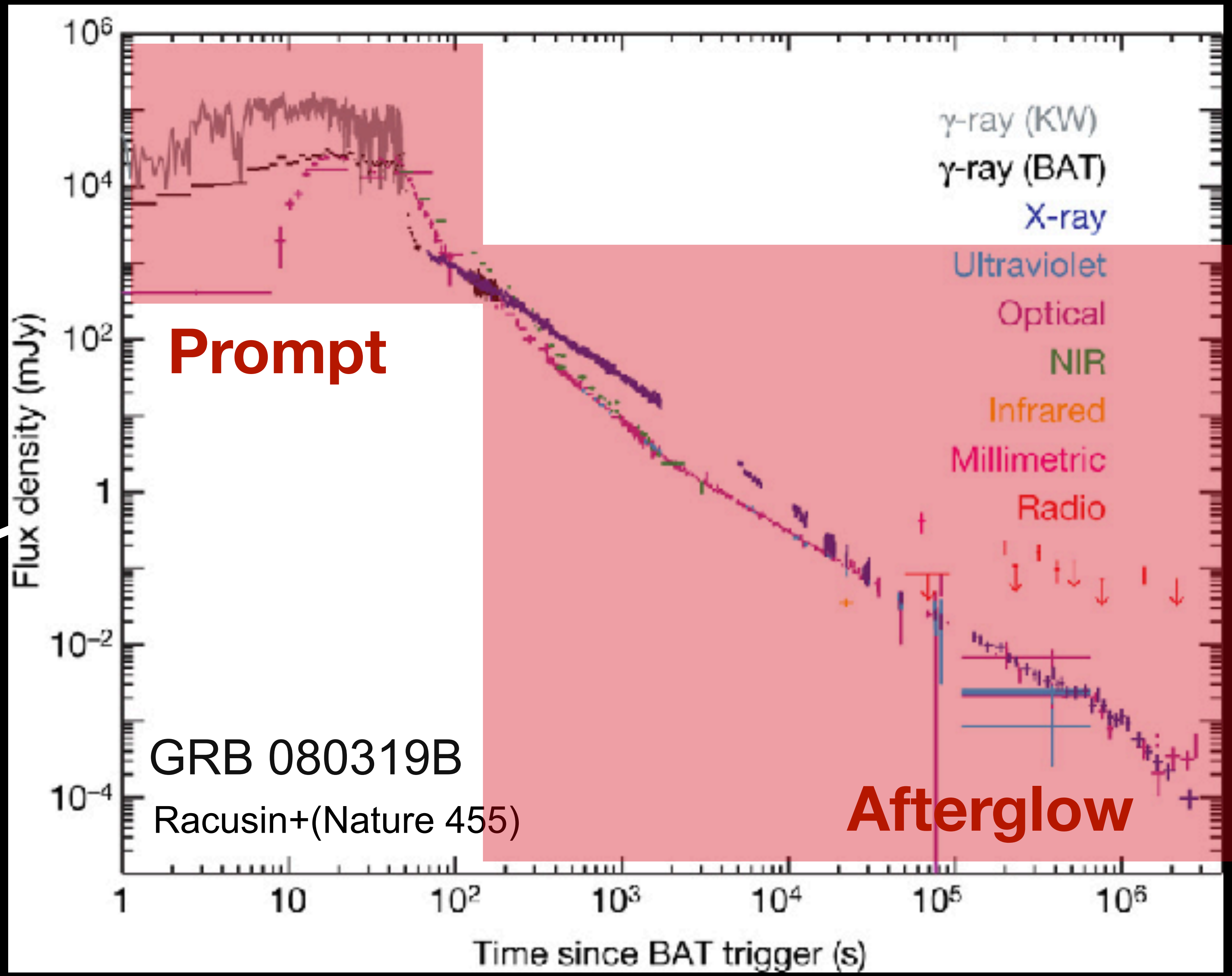
Gamma Ray Bursts





- Release ~10^{48}-10^{54} erg in few seconds. Can outshine any other object.
- Occurrence ~1 per day (x-ray satellites)

Why GRBs at Very High Energy?

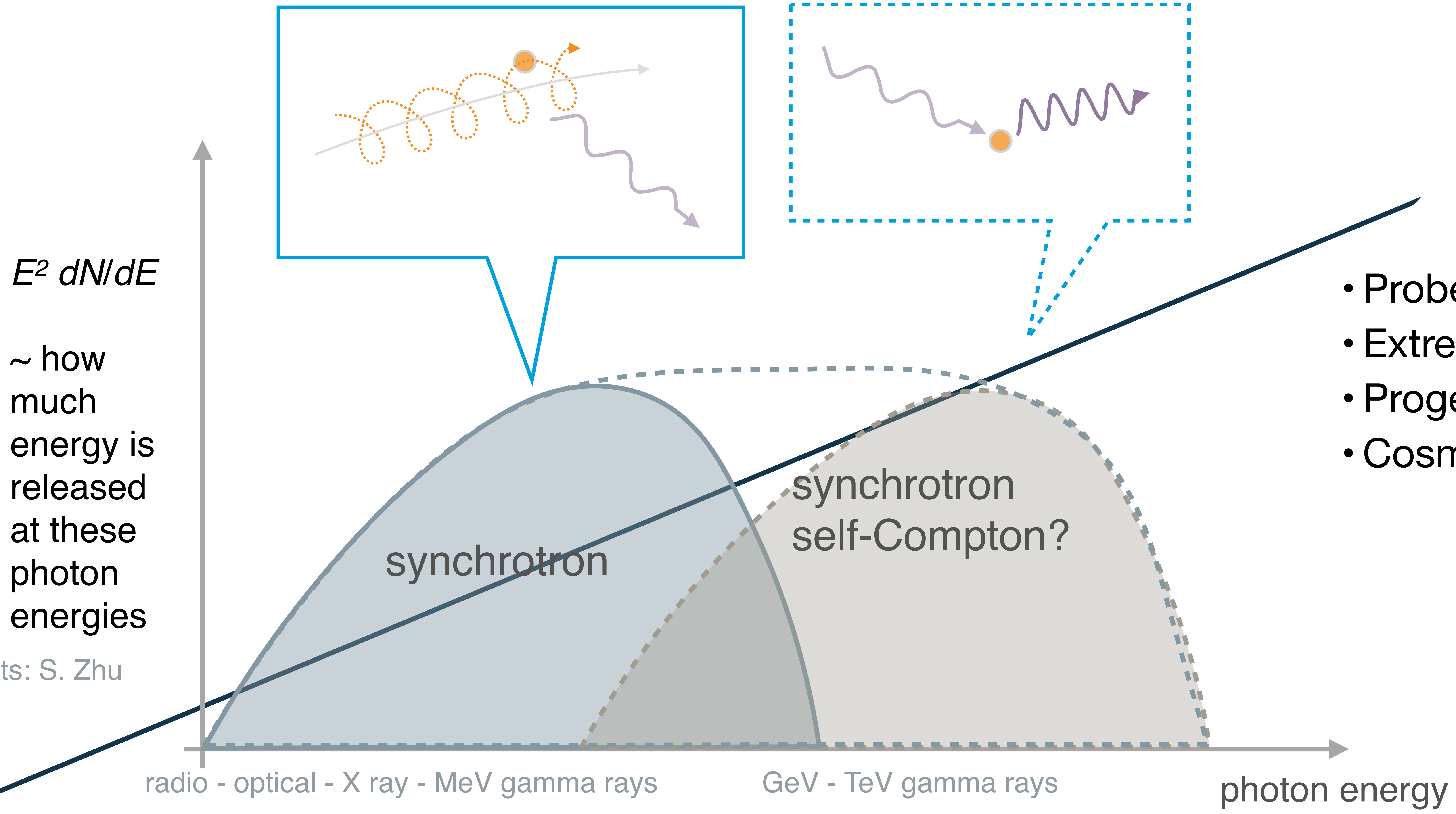
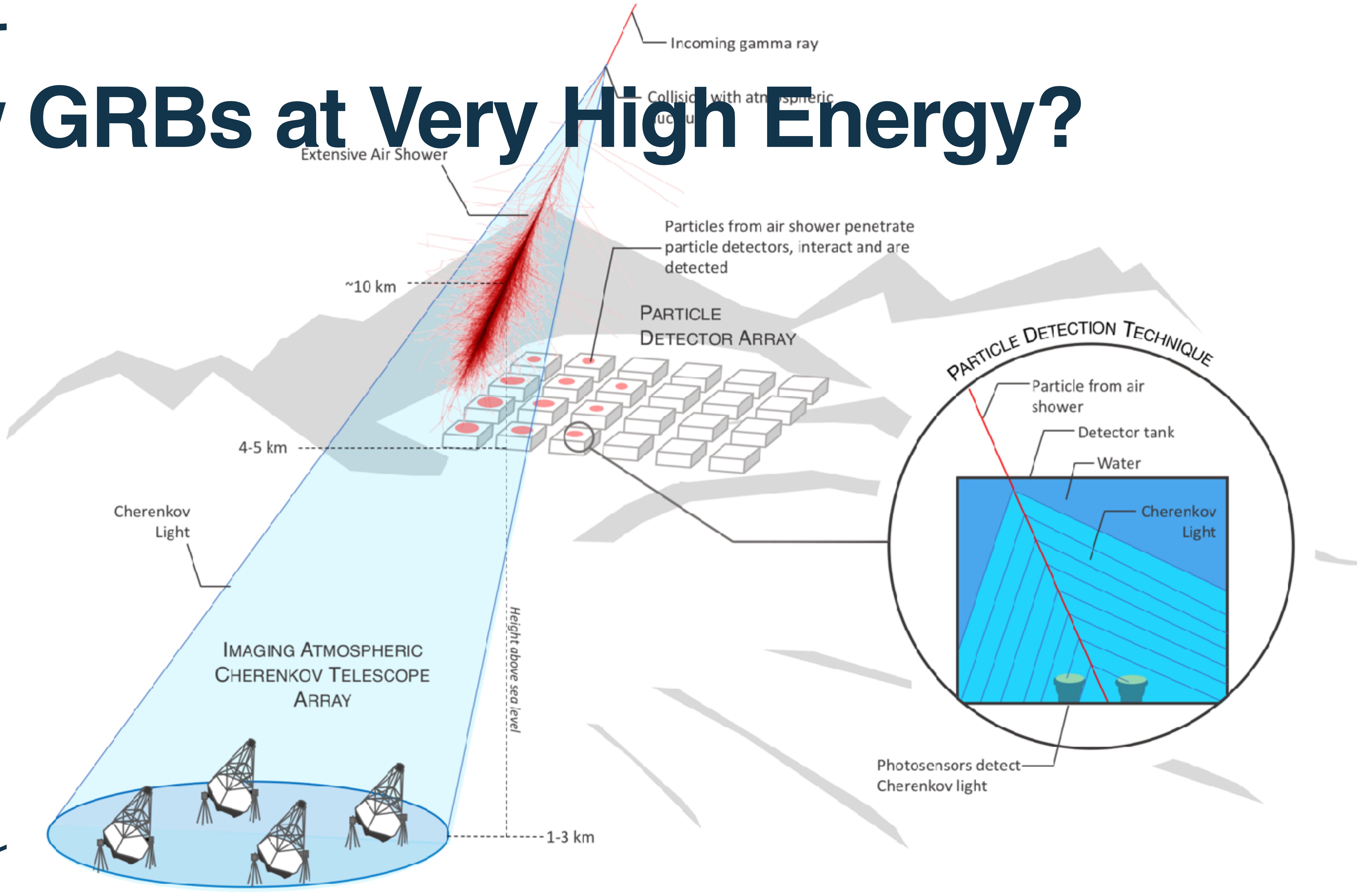


Diagram credits: S. Zhu

- Probes of BSM (Axions, LIV)
- Extreme Astrophysical Environments
- Progenitors
- Cosmological Probes

How GRBs at Very High Energy?



Shower image, 100 GeV γ-ray adapted from: F. Schmidt, J. Knapp, "CORSIKA Shower Images", 2005, https://www-zeuthen.desy.de/~jknapp/fs/showerimages.html

Cherenkov Telescopes: High Energy Stereoscopic System (H.E.S.S.)

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H.E.S.S.

- 3˚Field of View
- Max. 60 sec to be on target.

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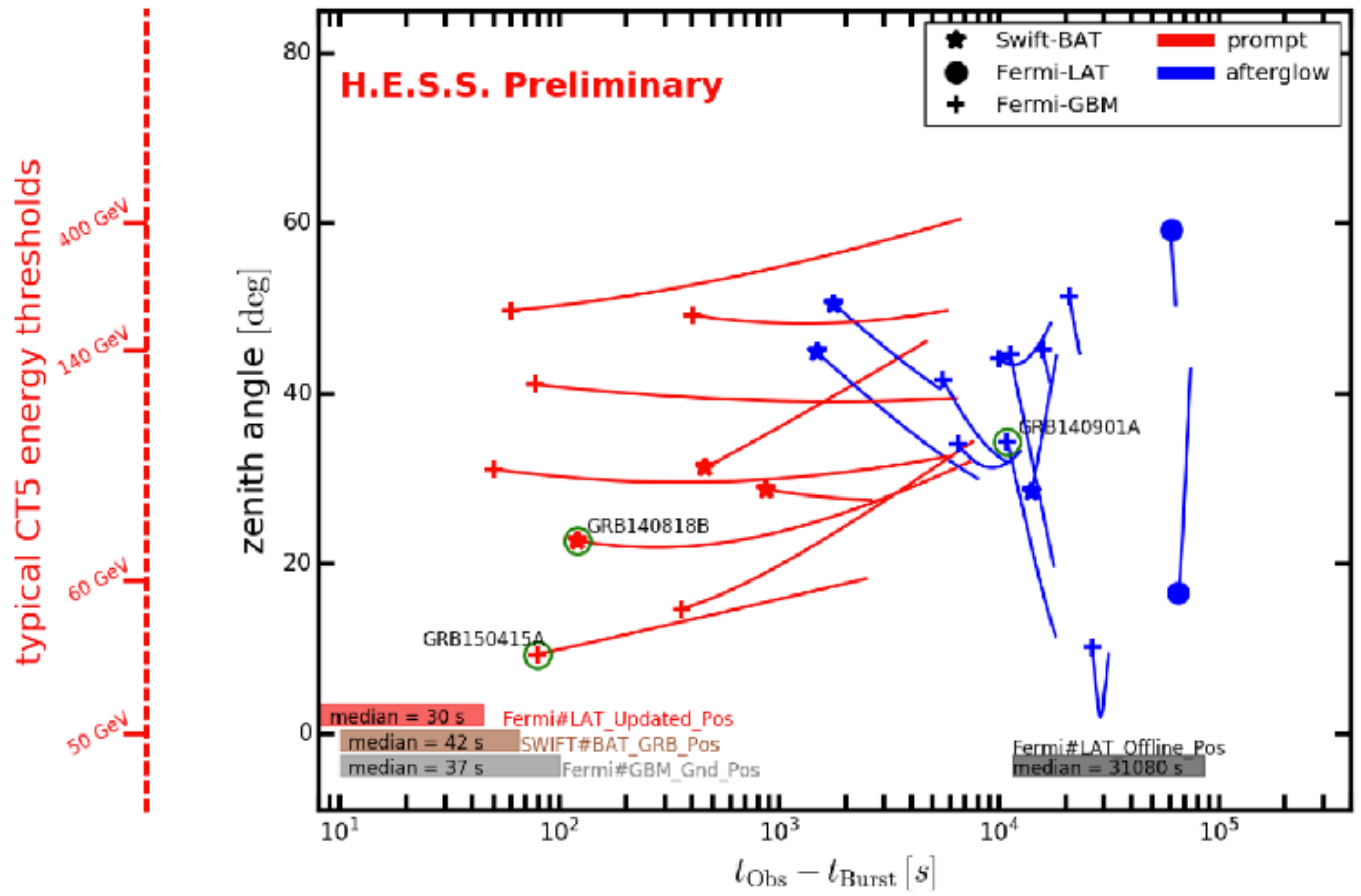
Swift-BAT/XRT
Fermi-LAT/GBM
GW, Neutrinos

GCN Notice

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

(~10 GRBs per year)



C. Hoischen+ (ICRC 2017)

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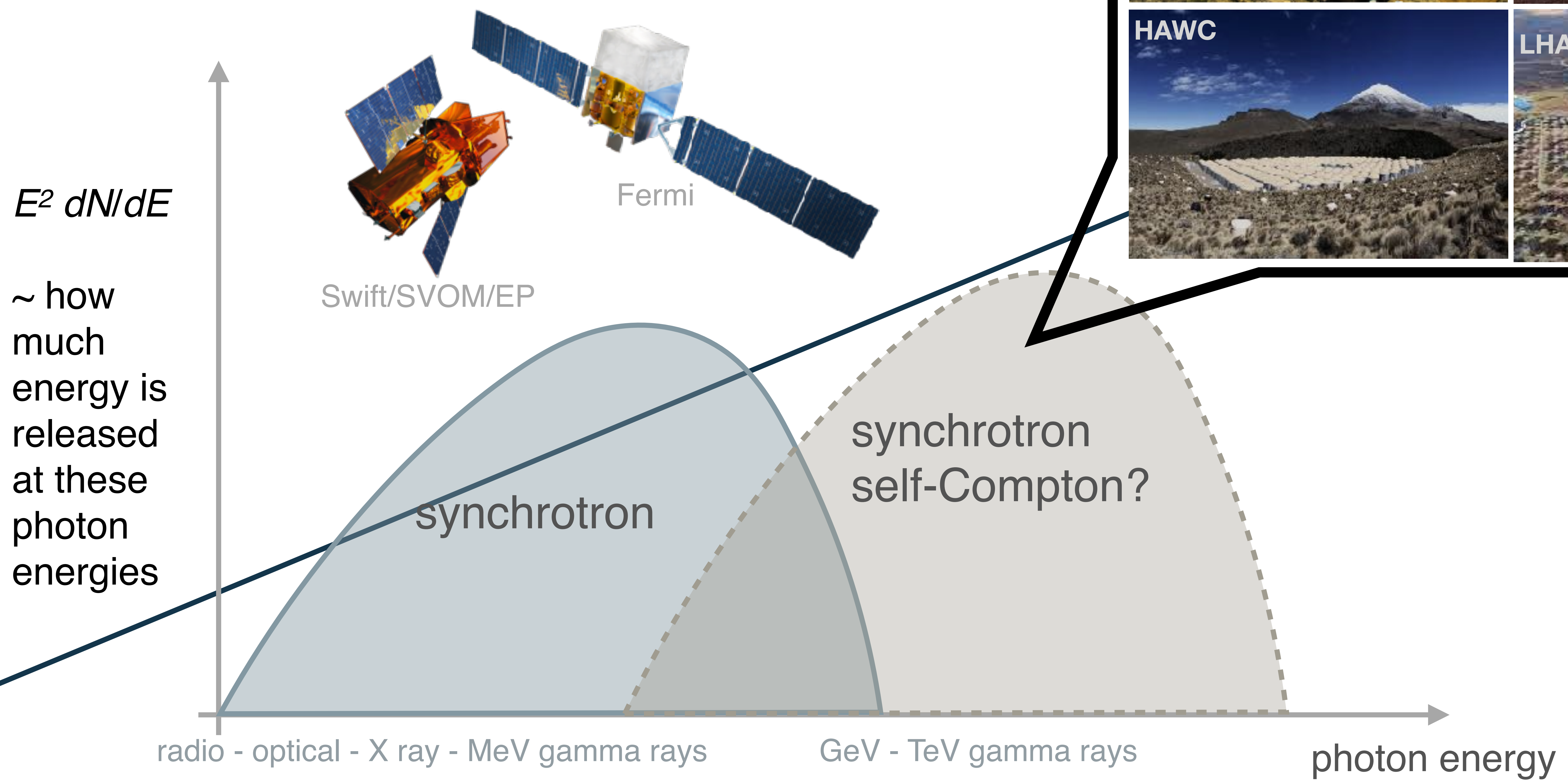
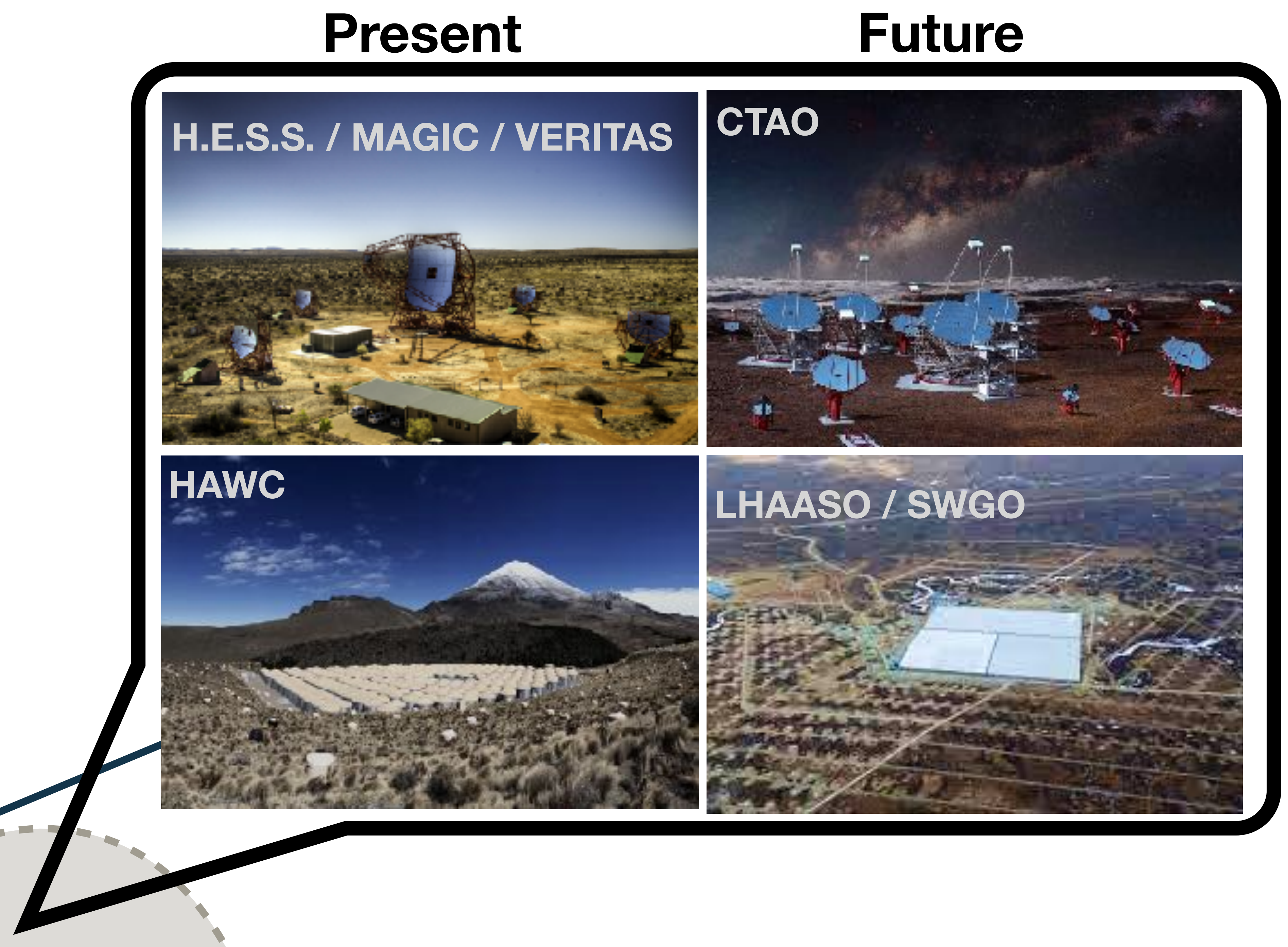
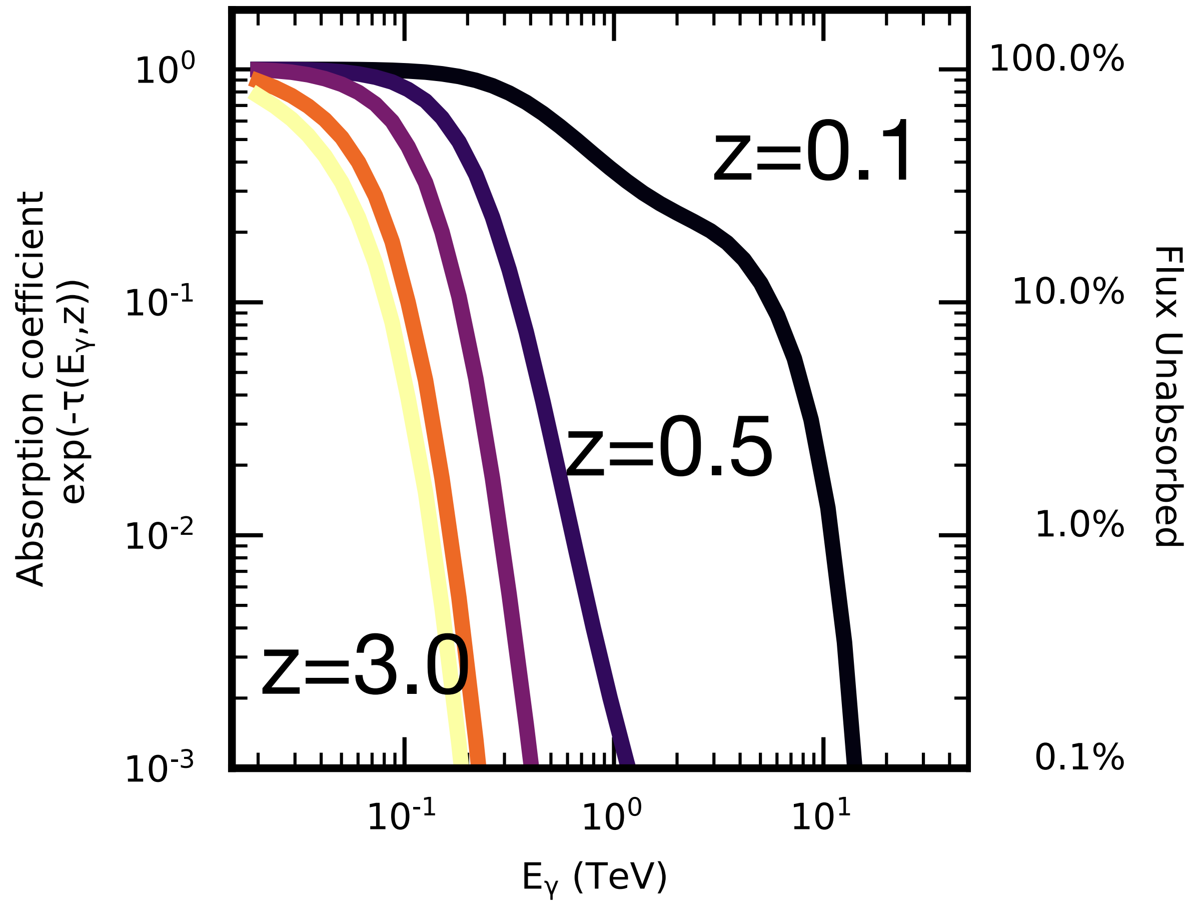
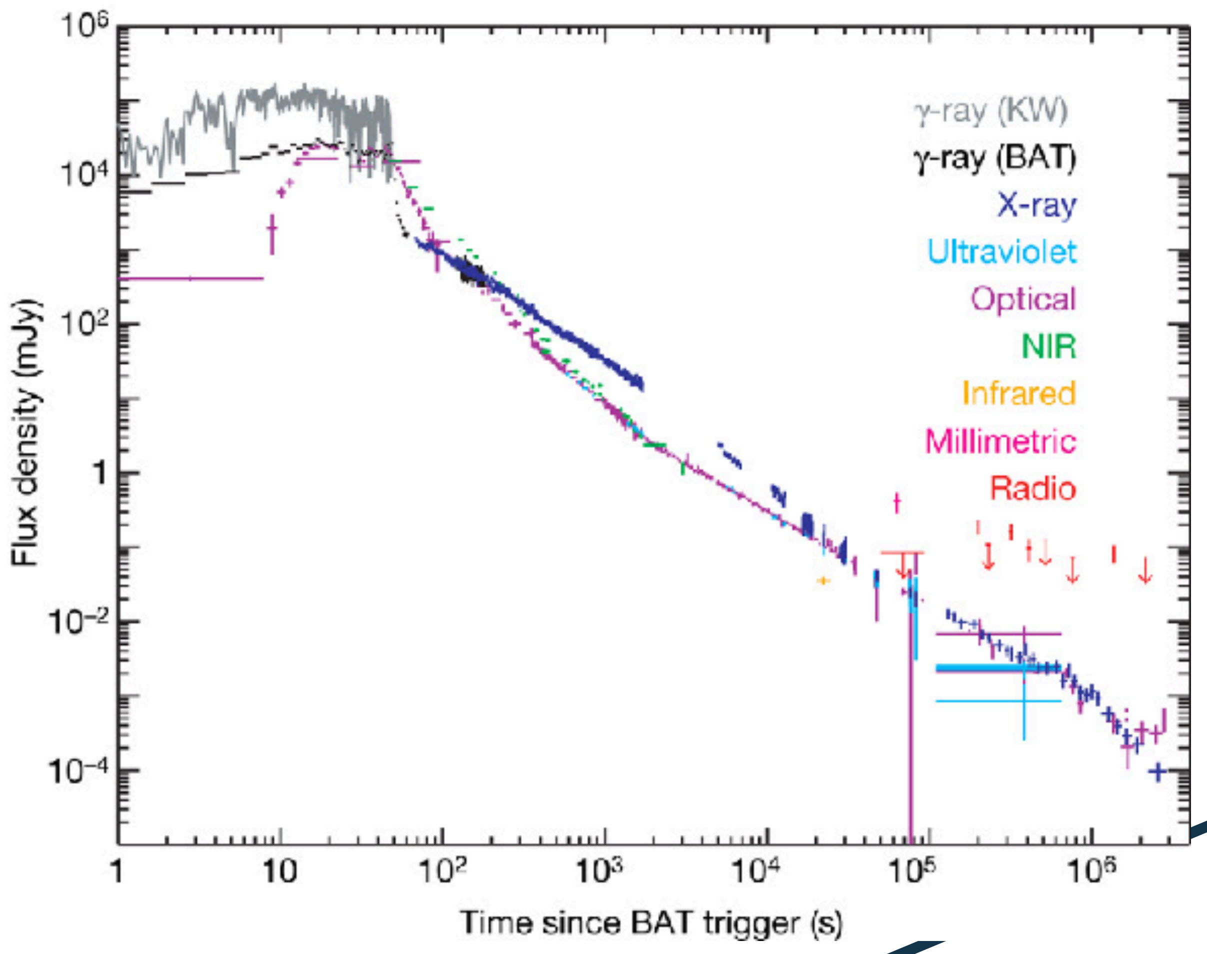


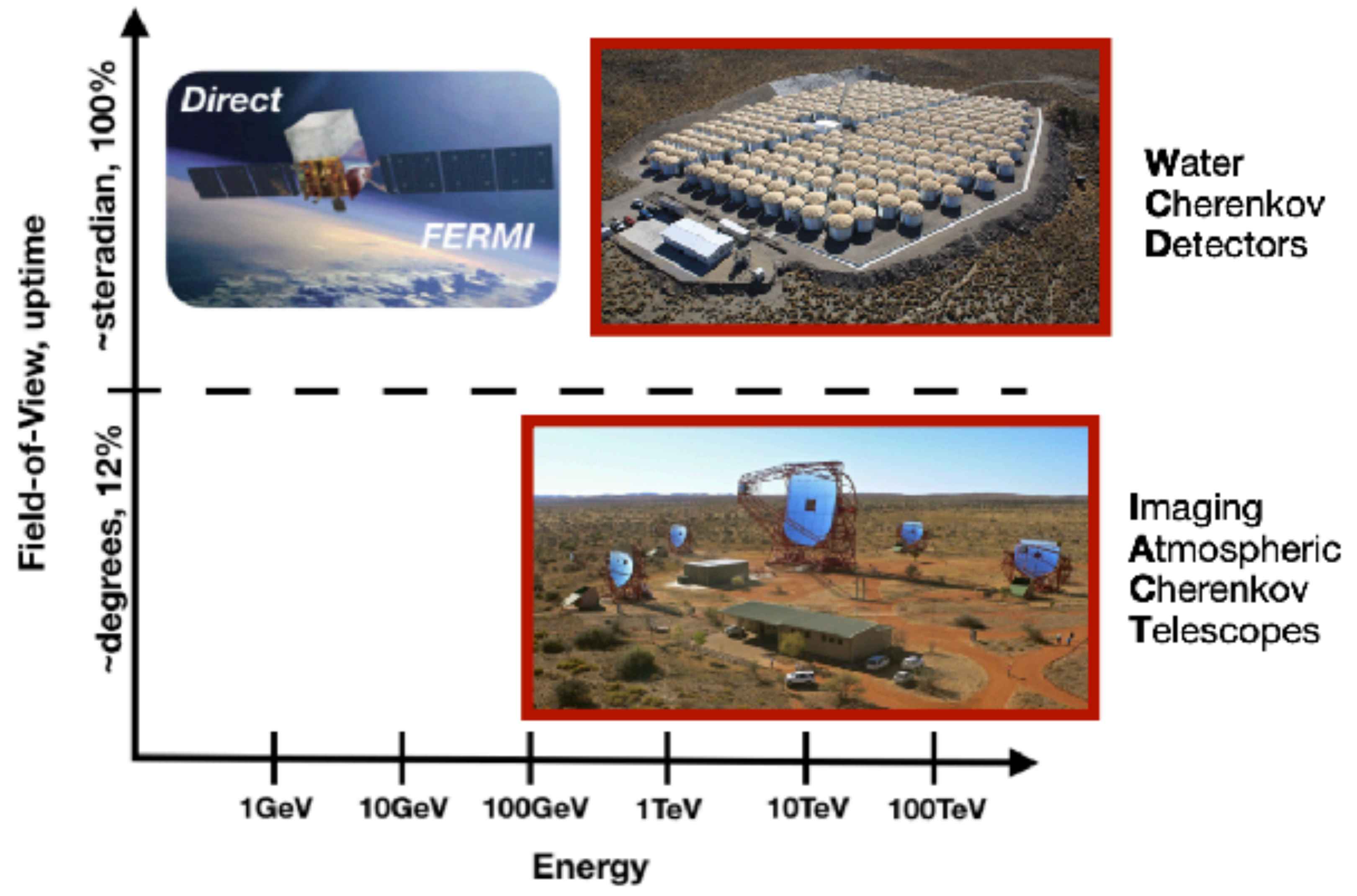


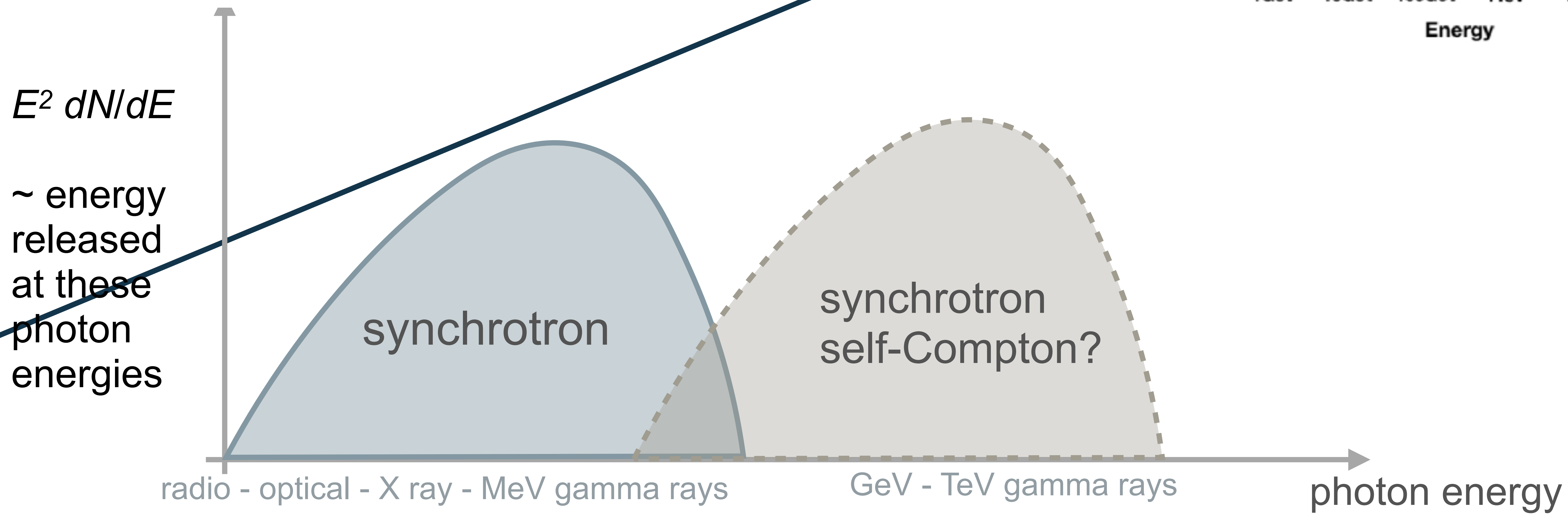
For the brightest GRBs, tens of instruments take part on observations, from radio up to TeV/neutrinos

The BIG challenge when detecting GRBs at VHEs

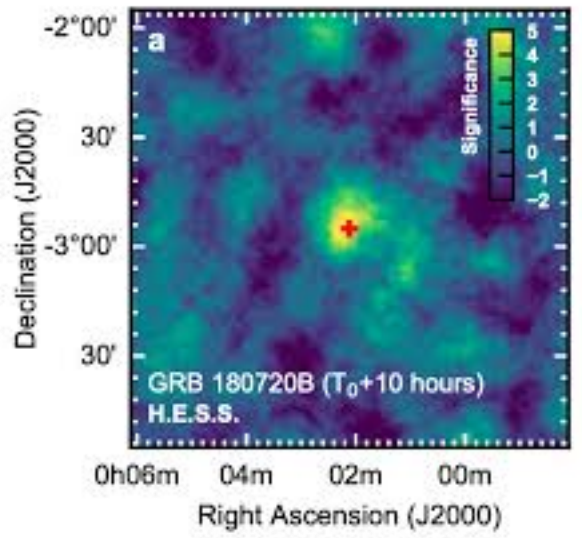




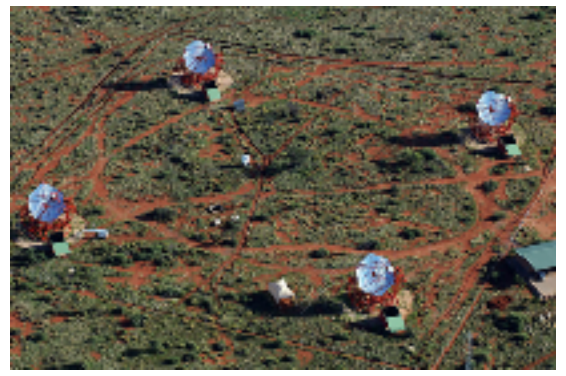




Timeline of HESS GRB programme

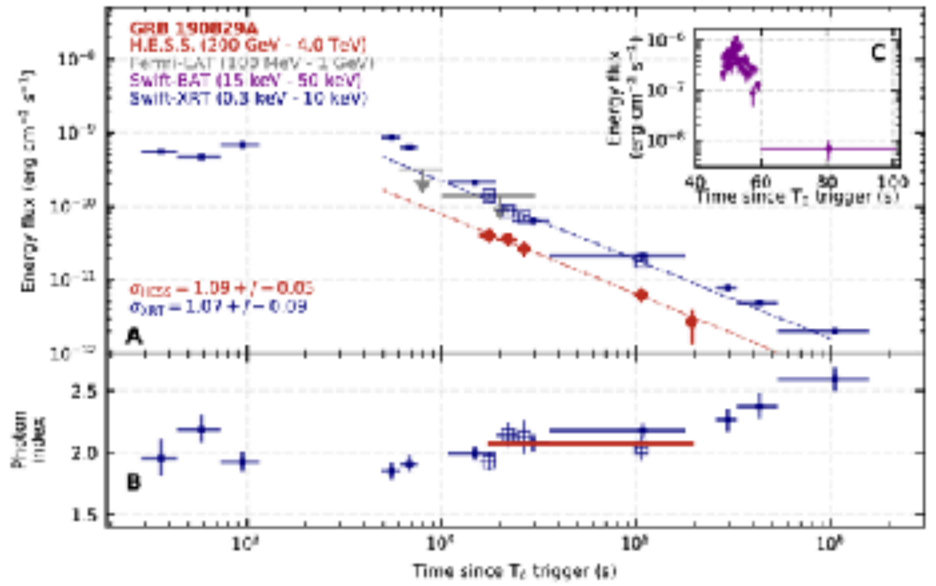


In **this catalog** we expand the analysis to all GRBs from **2004 until 2019**



- 2004 — Inauguration CT1-4
- 2005 — GCN connection
- 2011 — CT5 Added
- 2012 — Automatic reaction Implemented
- 2018 — **First detection of a GRB at VHEs**
- 2019 — Detection of GRB190829A
- 2019 — CT5 camera Upgrade

First Catalog 2003-2007



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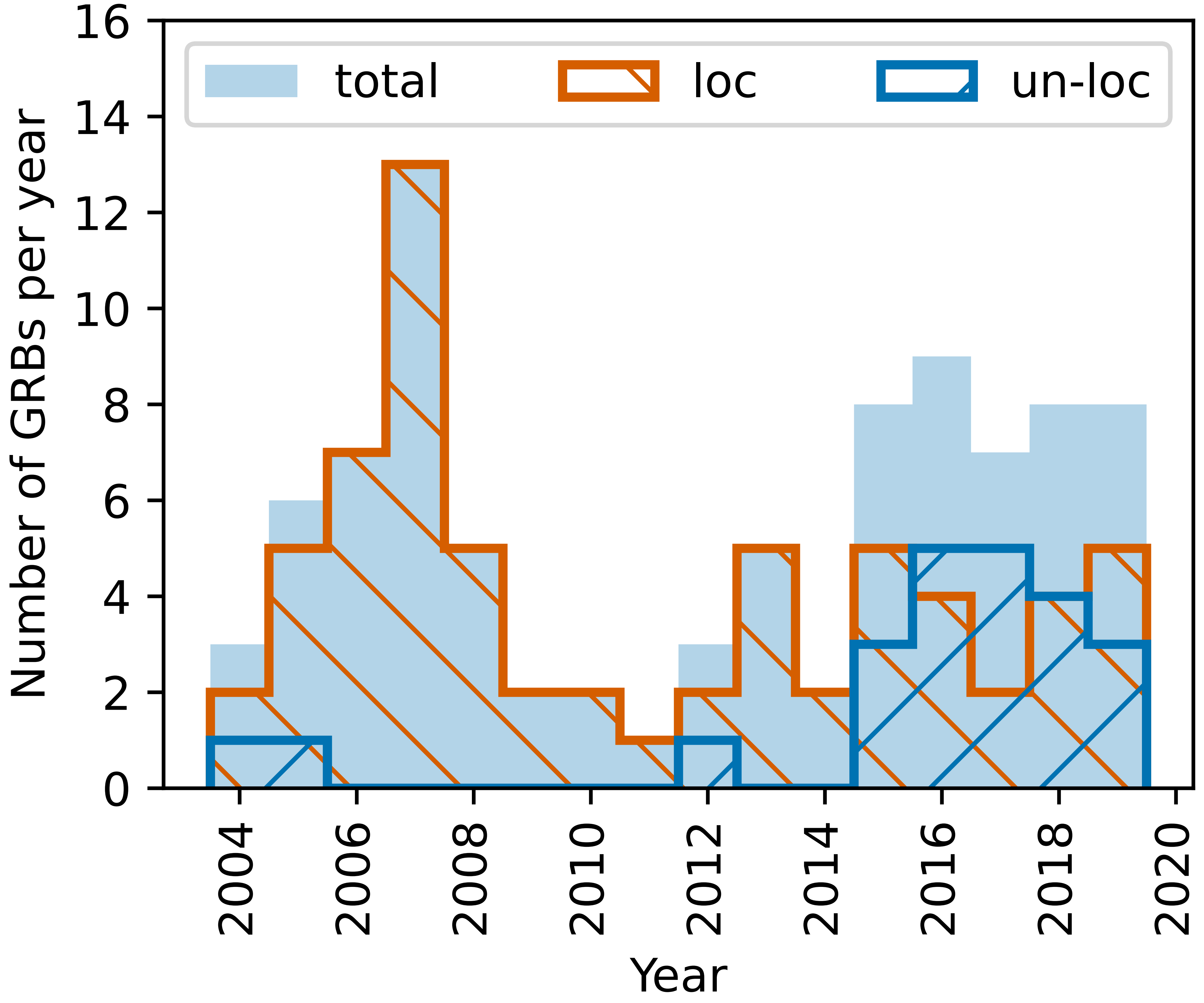
Observations of GRBs with HESS

Selection of data set



GRBs from bookeeping, adding more from cross-matched method:

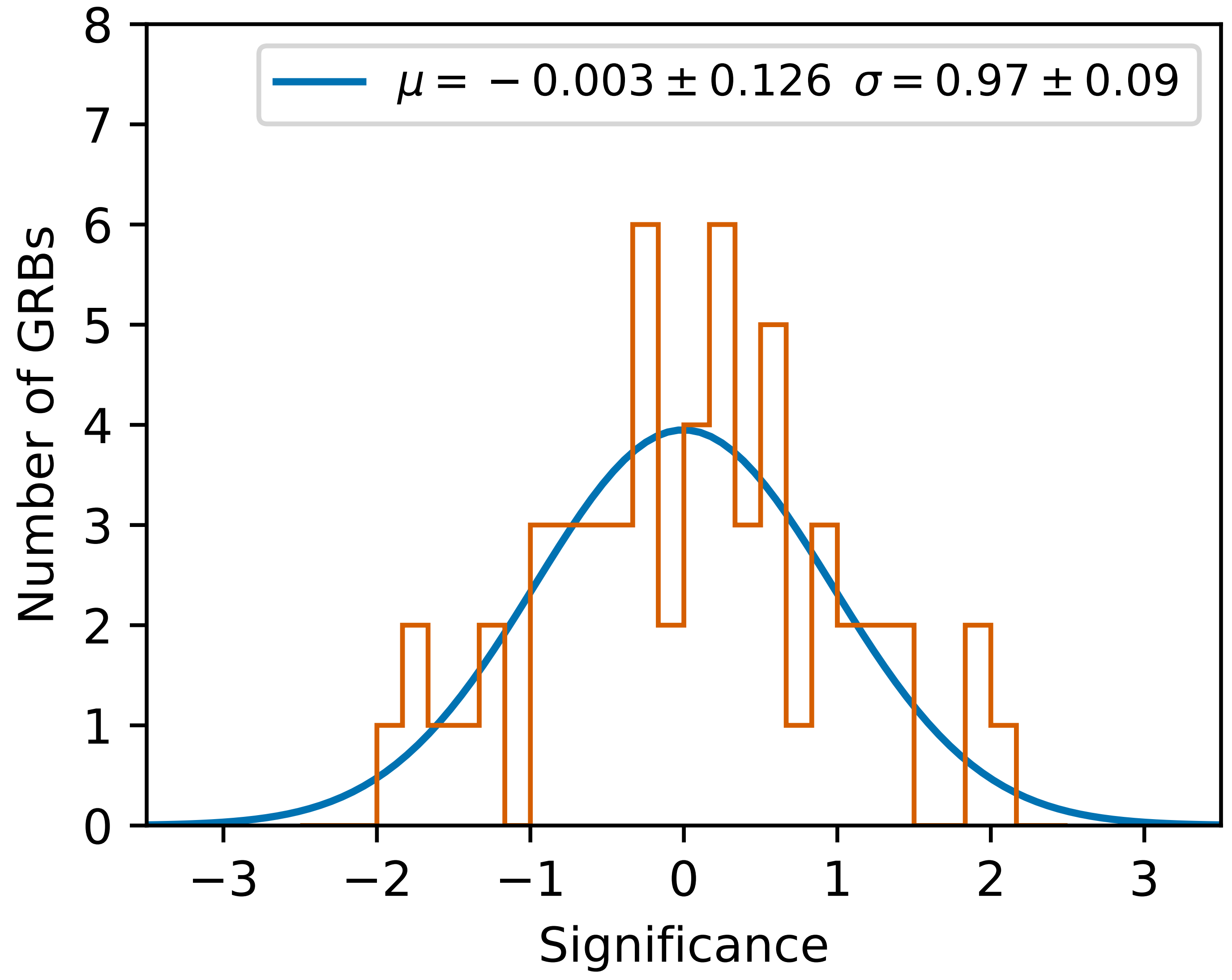
- **Loc**: Sky separation 2º, Delay 48 hours
- **Un-loc**: Cover 10% prob. region, Delay: 24 hours

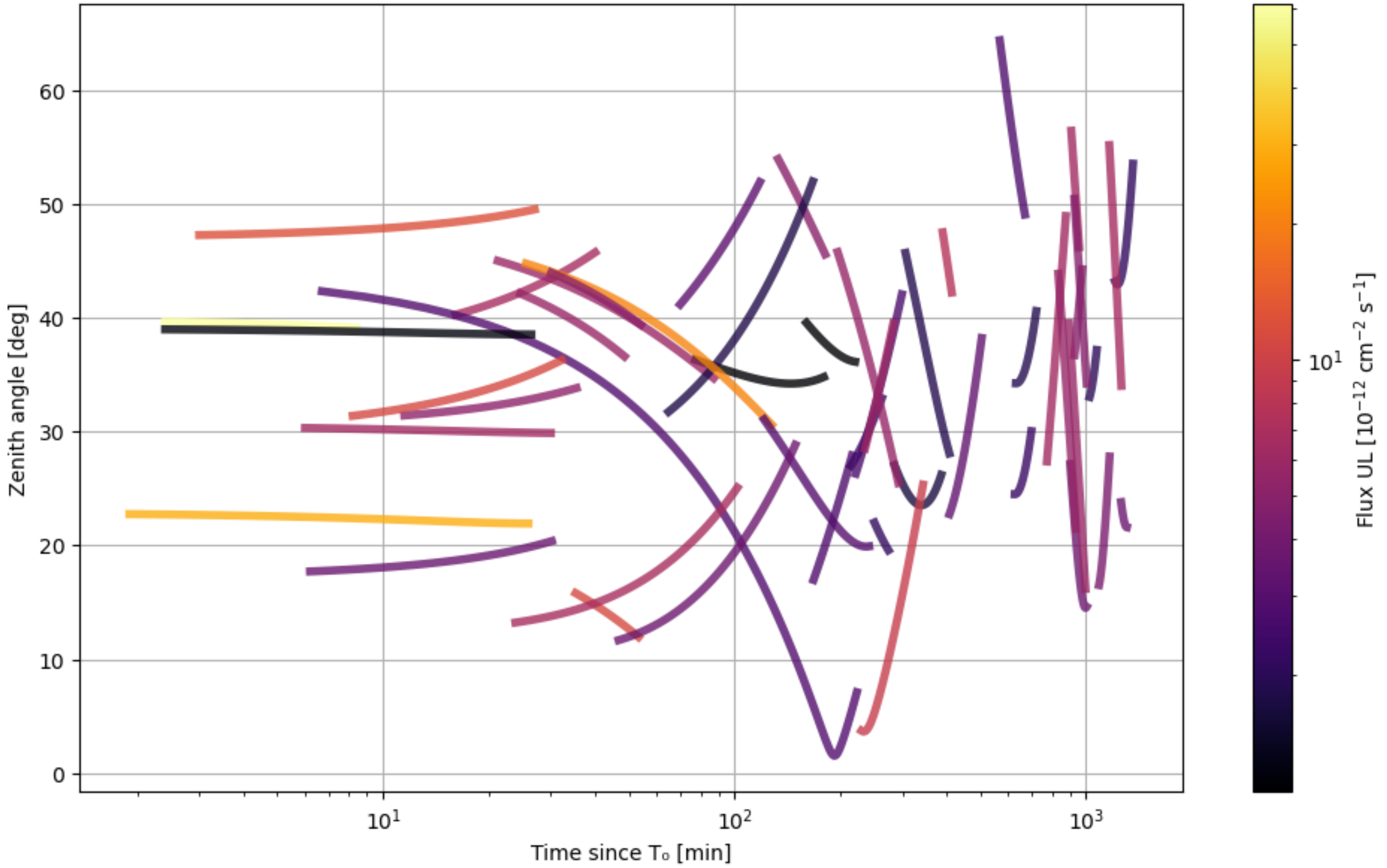
Stage	*loc* GRBs	*un-loc* GRBs	Total
Follow-up observations	-	-	107
Selected for analysis	66	23	89
Retained after quality selection	48	15	63
Flux ULs determined	48	1	49

Results

Emission search and distributions

- Median of pointing delay: 196.4 minutes
- Lowest delay: GRB 140818B of 1.9 minutes
- Most Constraining ULs: GRB 091018 and GRB 141004A at ~1.1×10^{-12} cm^{-2} s^{-1}

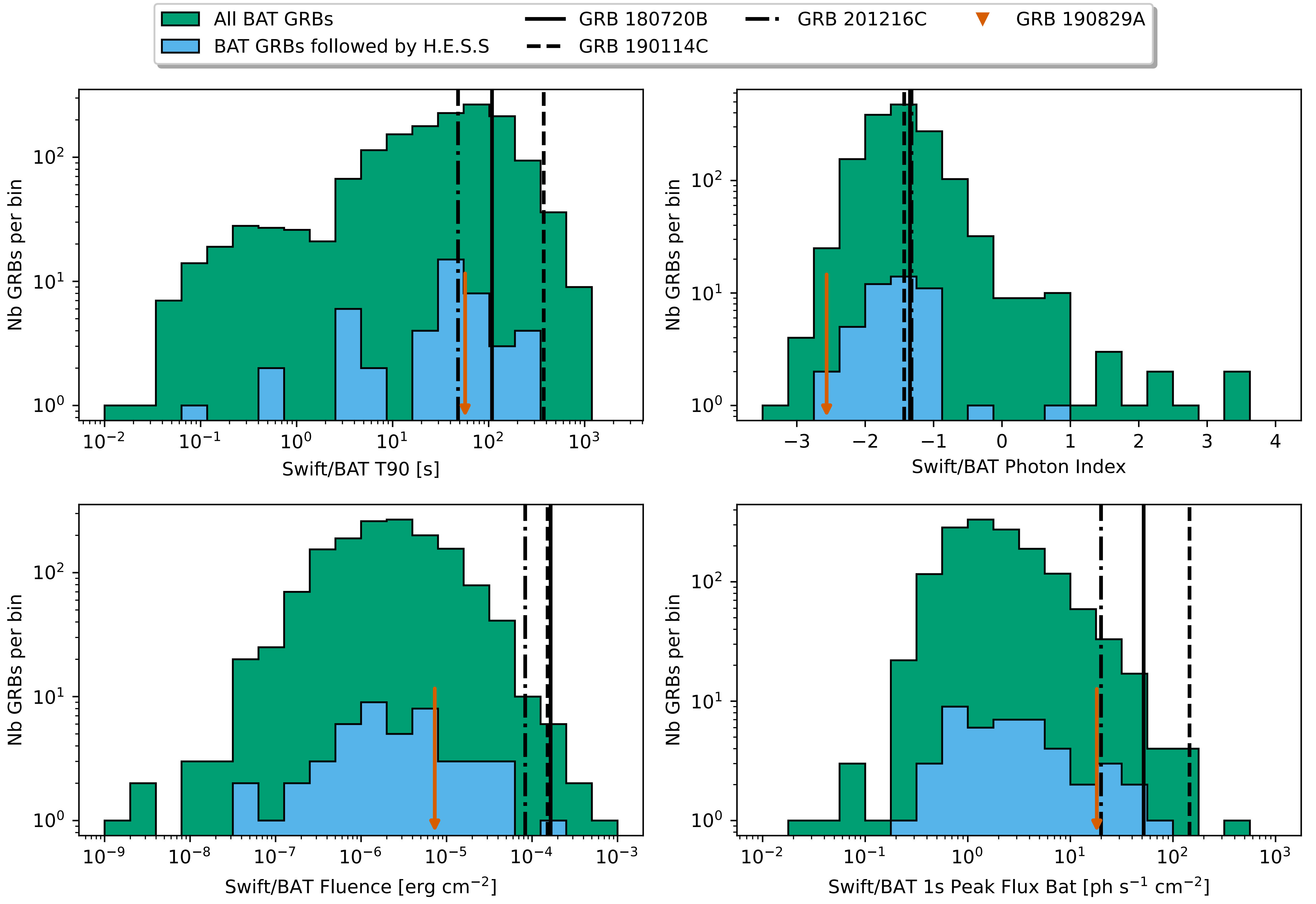




Population studies

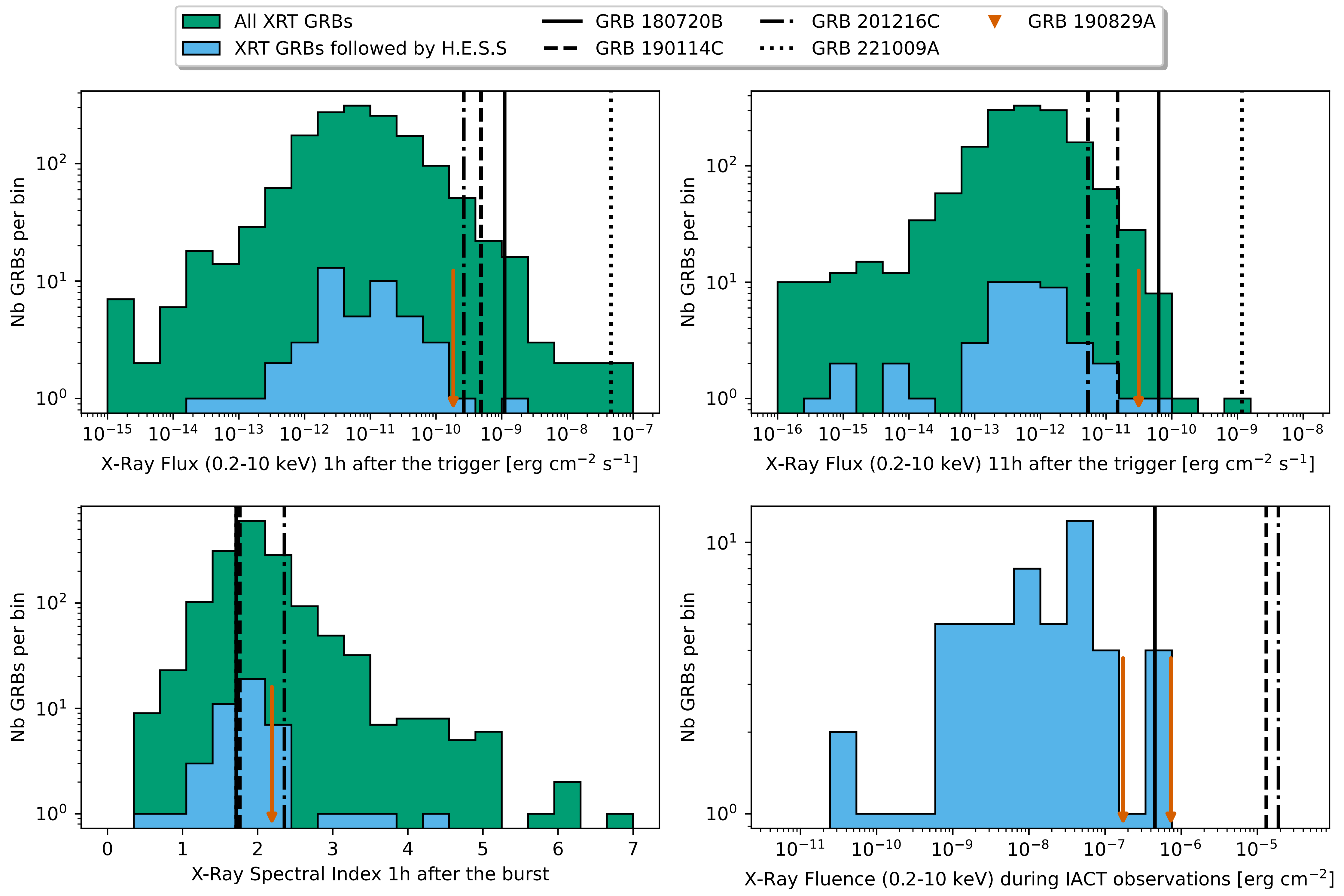
To pinpoint the conditions that favour VHE detections

Parameter	Observed vs All *p-value* (σ)	Detected at VHE vs All *p-value* (σ)	Detected at VHE (excl. GRB 190829A) *p-value* (σ)
T_{90}	0.16 (1.4σ)	0.13 (1.5σ)	0.25 (1.2σ)
Fluence	0.44 (0.8σ)	4.3×10^{-3} (2.9σ)	2.5×10^{-6} (4.7σ)
1s Peak Flux	0.10 (1.6σ)	6.2×10^{-6} (4.5σ)	1.0×10^{-4} (3.9σ)
Spectral Index	0.24 (1.2σ)	0.58 (0.6σ)	0.24 (1.2σ)



Population studies

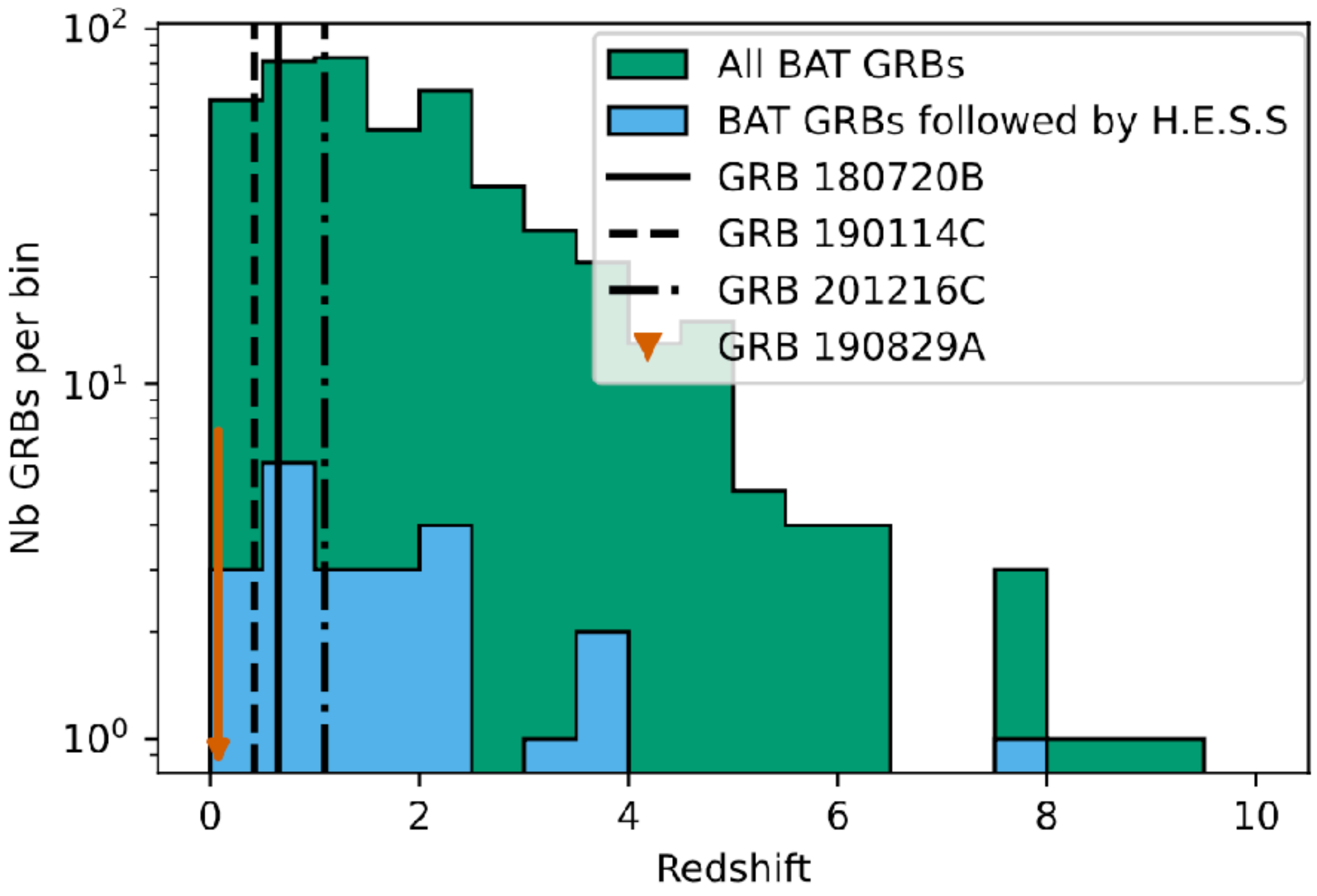
Parameter	Observed *p-value (σ)*	Detected at VHE *p-value (σ)*	Detected at VHE (excl. 190829A) *p-value (σ)*
Fluence during obs.	N/A	6.5×10^{-5} (4.0σ)	4.6×10^{-5} (4.1σ)
Flux @ 200 s	0.91 (0.1σ)	1.9×10^{-3} (3.1σ)	1.0×10^{-5} (4.4σ)
Flux @ 1 h	0.89 (0.1σ)	1.3×10^{-6} (4.0σ)	6.6×10^{-6} (4.5σ)
Flux @ 11 h	0.92 (0.1σ)	9.7×10^{-6} (4.8σ)	1.1×10^{-4} (3.8σ)
Flux @ 24 h	0.91 (0.1σ)	3.7×10^{-5} (4.1σ)	3.2×10^{-4} (3.6σ)
Spec. Index @ 200 s	0.97 (0.04σ)	0.60 (0.5σ)	0.26 (1.1σ)
Spec. Index @ 1 h	0.48 (0.7σ)	0.68 (0.4σ)	0.31 (1.0σ)
Spec. Index @ 11 h	0.73 (0.3σ)	0.77 (0.3σ)	0.82 (0.2σ)
Spec. Index @ 24 h	0.74 (0.3σ)	0.75 (0.3σ)	0.35 (0.9σ)



Population studies

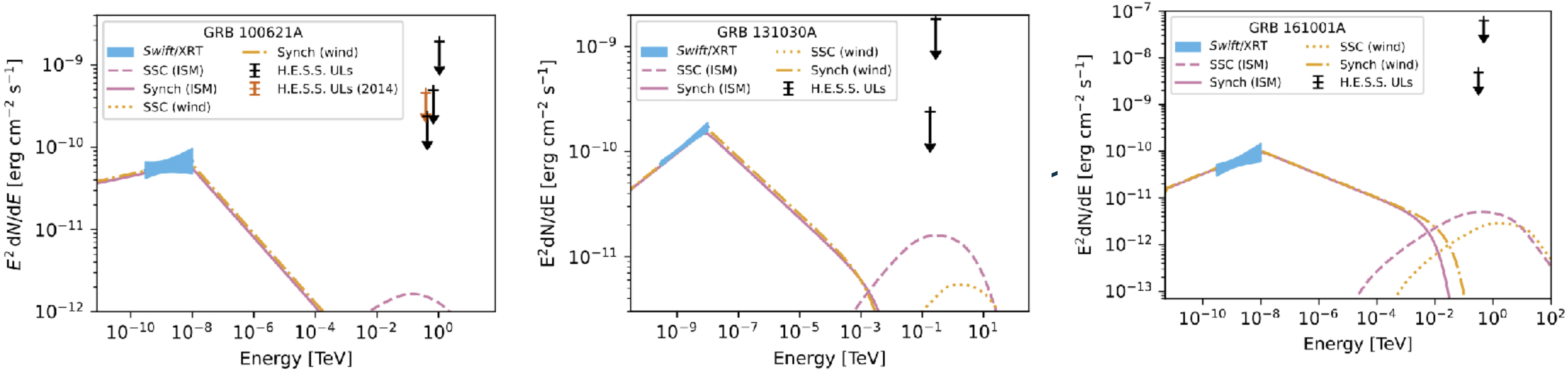
Redshift distribution

- Only 21 out of 63 GRBs analysed in this work have a redshift. 23 GRBs in this sample (GRB180720B+GRB190829A)
- **2 sigma deviation in both comparisons.**
- Expected bias due to selection criteria in observations favouring redshift information.



Theoretical Modelling of Specific GRBs

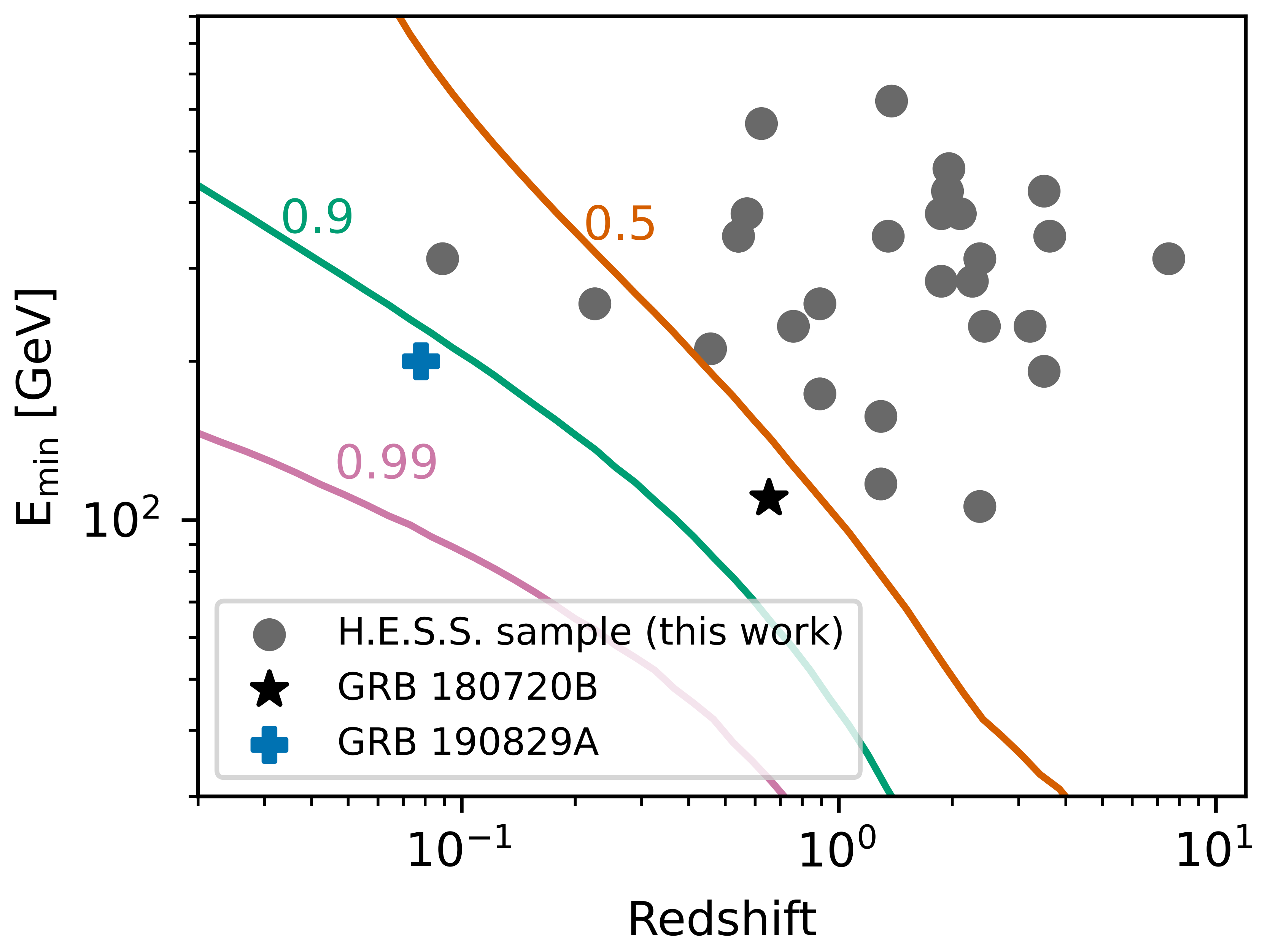
Closest, brightest, nearest of our set

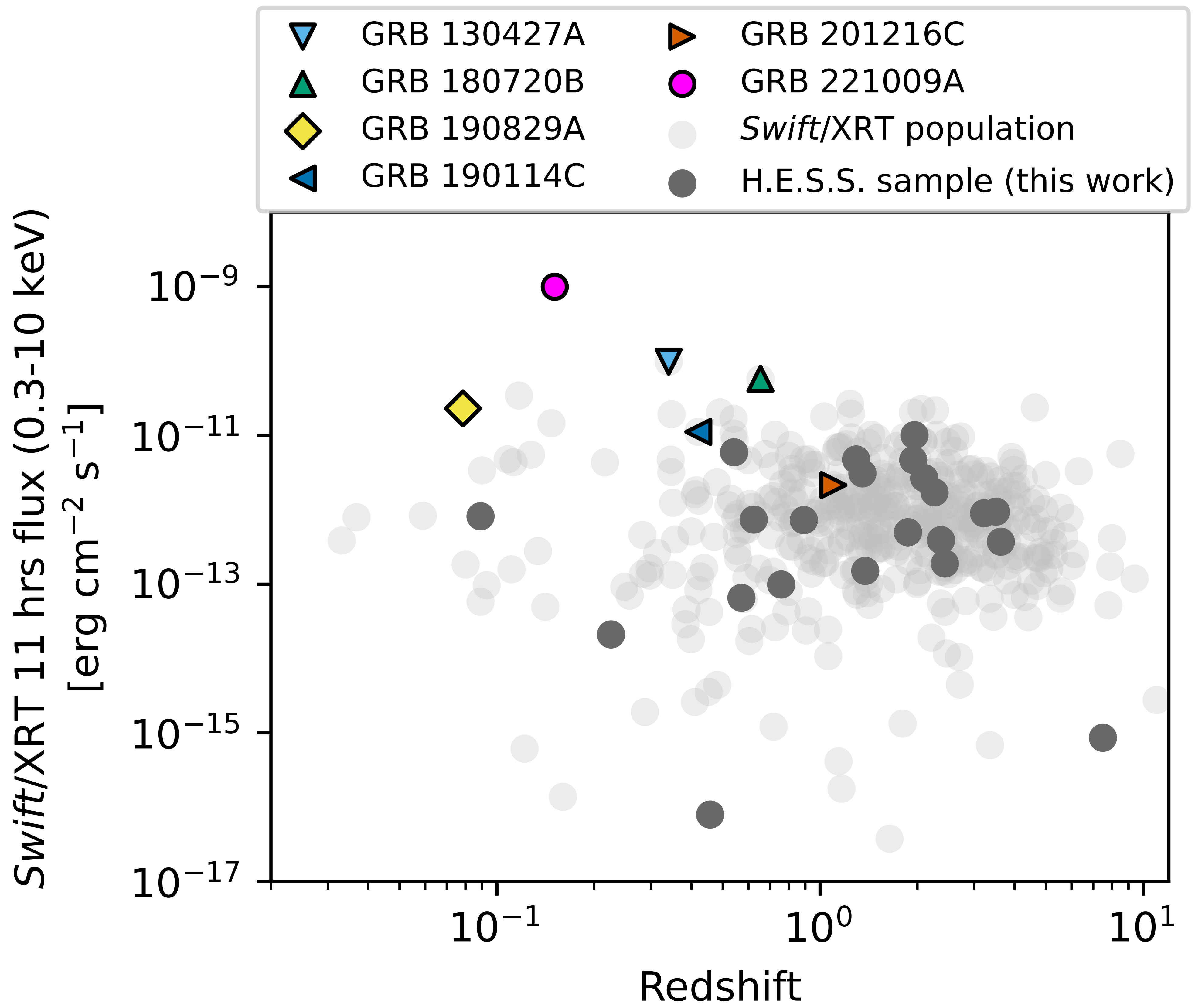


- All parameters within “standard” values.
- SSC consistent with the X-ray flux and non-detections
- Sensitivity/statistics to challenge these models is still low!

Parameter	GRB100621A	GRB 131030A	GRB161001A
Observation delay t (s)*	1500	1070	375
Injected electron-spectrum index p	2.84	2.54	2.5
Explosion shock energy E_{sh} (erg)	3×10^{54}	3×10^{54}	2×10^{53}
ISM case			
Magnetic partition fraction ϵ_B	3×10^{-4}	1.5×10^{-3}	5×10^{-3}
Electron partition fraction ϵ_e	0.025	0.04	0.045
Number density of ambient medium n_0 (cm^{-3})	0.01	1×10^{-3}	1×10^{-3}
Wind case			
Magnetic partition fraction ϵ_B	0.01	0.02	0.035
Electron partition fraction ϵ_e	0.016	0.045	0.05
A (cm^{-1})	3×10^{33}	1×10^{33}	3×10^{32}

A global view (to the future)





- EBL absorption greatly impacts the ability to observe distant sources.
- At 90% transparency, An E_{thr} of 100 Gev allows detections up to z~0.3, 50 GeV opens the range to z~0.8

- VHE detected GRBs are bright in X-rays.
- CTAO should be able to detect equivalent VHE emission to levels 10^{-13} erg cm^{-2} s^{-1} with redshift z=1.

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Conclusions

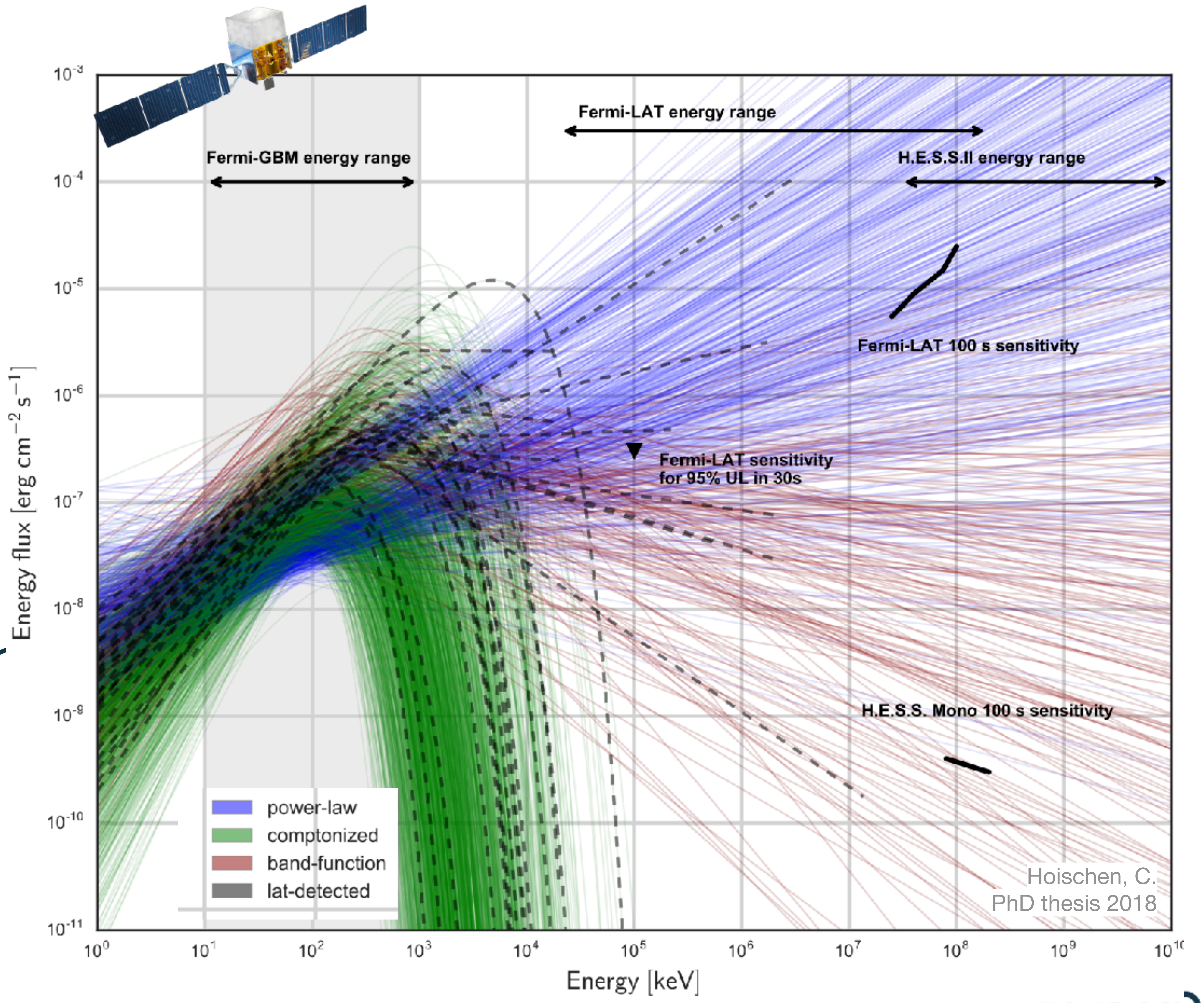
15 years of GRB observations with H.E.S.S.

1. No new detections were found -> See https://grbhess.github.io/ for real-time updates.
2. Population studies prove that:
   - VHE-detected GRBs are bright in X-rays
   - No significant bias in the HESS observed sample, apart from redshift.
3. The **lack of redshifts** increases difficulty to draw more conclusions. SSC cannot be challenged with the current statistics.
4. Future facilities (CTAO) require strong improvements in MWL information and sensitivities to address current open questions.

Backup

GRB x-ray spectrum

status before 2018…
Results from the Fermi-LAT/GBM satellite



Fermi-GBM (10 keV- 1000 keV)
Fermi-LAT (20 MeV- 300 GeV)
HESS,HAWC (100 GeV-10 TeV)

Occurrences:

- X-rays: 1 GRBs per day
- HE: 12 GRBs per year
- VHE: 0 GRBs in ~10 years

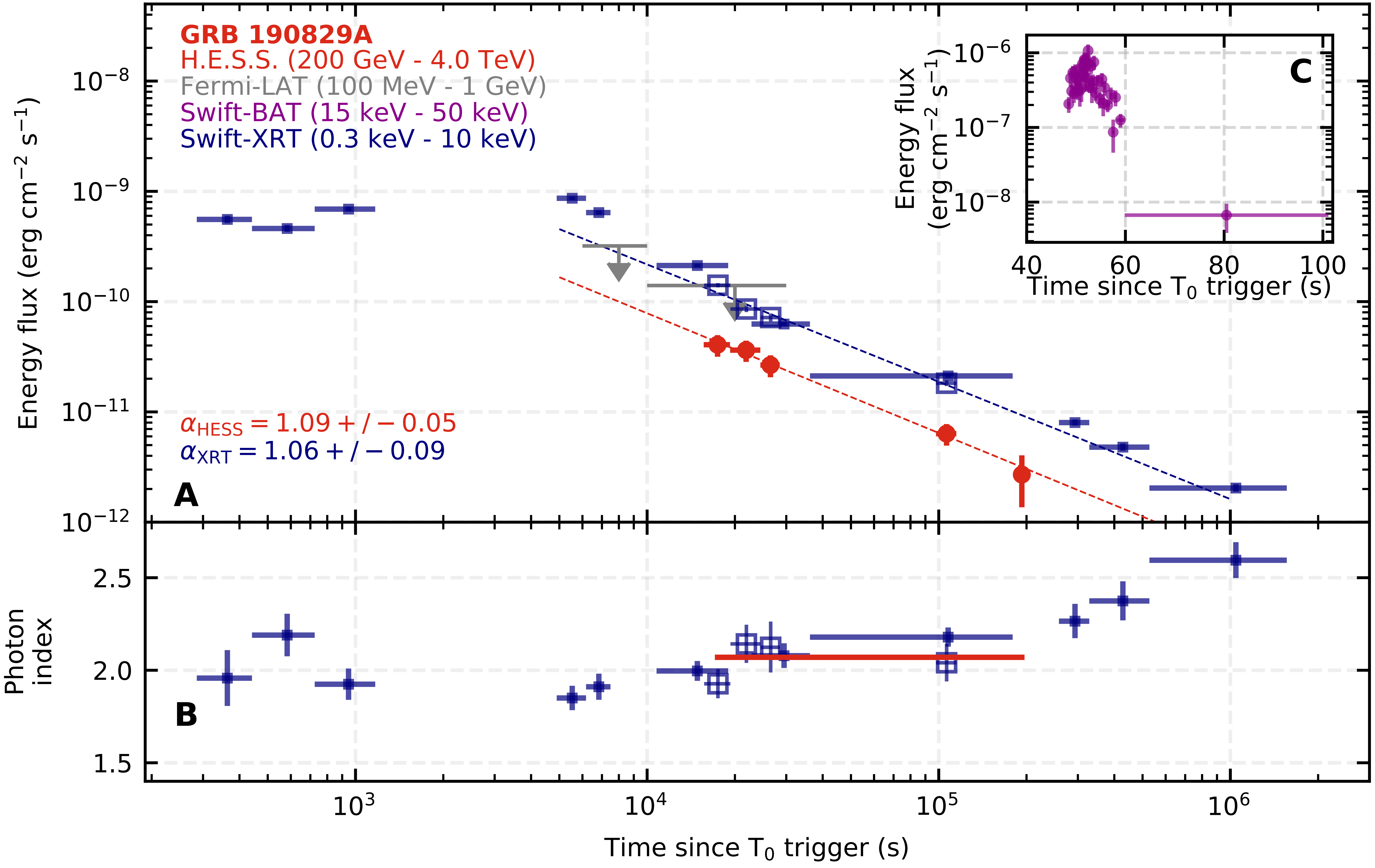
GRB 190829A

First measurement of the **afterglow decay** at VHE up to 4 TeV.

Strong similarities in the flux decay between x-rays and VHE, also in spectral-shape evolution.

Emission process connecting 8 orders of magnitude in energy?

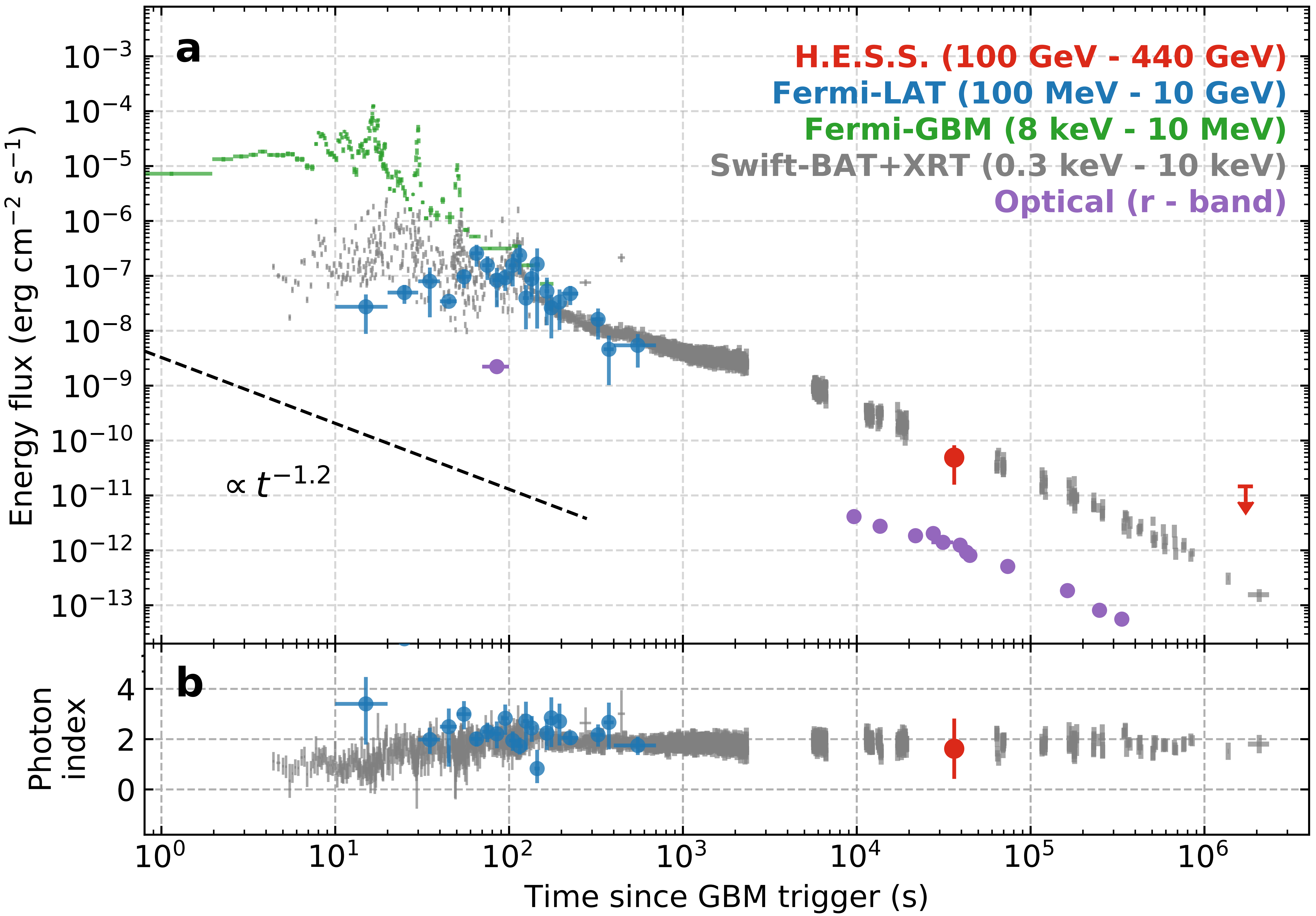
HESS Collab.
Science 2021
372, 6546 p.1081-1085



GRB 180720B

HESS Collaboration *Nature* **575,** 464–467 (2019)

- Surprising HESS detection **deep in the afterglow**
- **Similar temporal evolution** between Fermi-LAT and Swift-XRT.
- **Same level of flux** between HESS and Swift-XRT.
- Lack of data to rule out synchrotron or SSC as emission mechanism



Slide Title

Motivations/Goal

Despite limited number of GRBs detected at VHE, their properties may deviate from the broader GRB population. Deviations help:

- Pinpoint the conditions that favour VHE emission.
- Inform follow-up strategies and observation planning.
- Explore connections to emission models and progenitor environments.
- Quantify selection effects and potential intrinsic differences in GRBs seen by VHE instruments.

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Slide Title

Fitted SSC parameters

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GRBs Observed by H.E.S.S.

Loc GRBs
("Localised")

- Have precise coordinates (arcmin)
- Triggered by Swift/BAT, Fermi/LAT, INTEGRAL
- Follow-up possible with standard pointing

-Targeted Pointings
- -Early follow-ups
- - Deep exposure

un-loc GRBs
("unlocalised")

- No precise sky coords
- Only rough direction from Fermi-GBM
- Localisation radius often several deg^2
-

*Scan/tiling observations (strategy based on Fermi-GBM skymaps)
Sky location may change