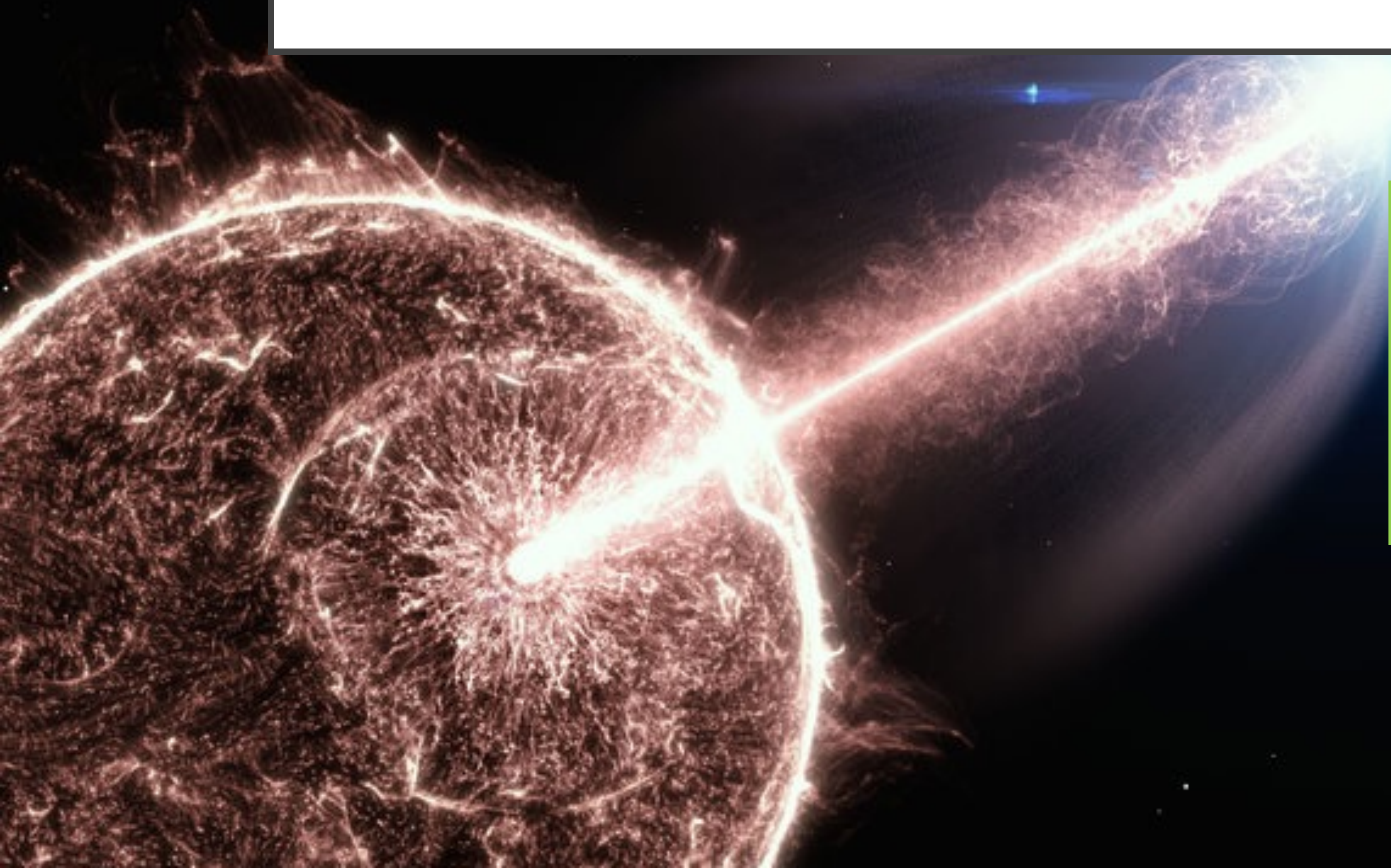
THE RATE OF DETECTABLE VHE GRBs WITH CURRENT IACTs



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THE VHE GRB SPECTRUM - FROM 2002 TO 2018

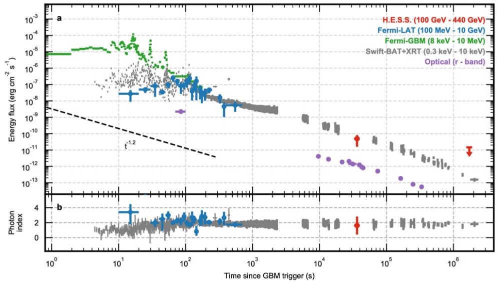
- H.E.S.S. I: 2002 - 2012
- H.E.S.S. II: 2012 - Present
- MAGIC I: 2009 - 2012
- MAGIC II: 2012 - Present
- VERITAS I: 2007 - 2012
- VERITAS II : 2012 - Present

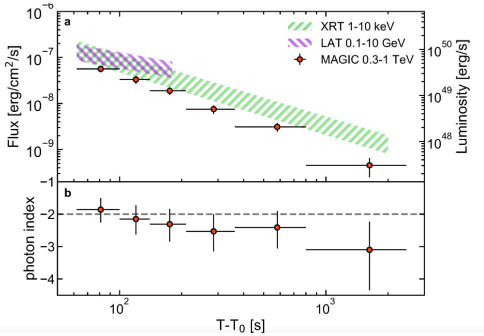
Hundreds of observations

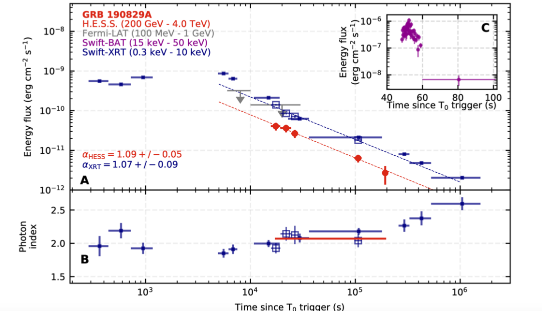
Detections > 100 GeV:

- GRB130427A: 90 GeV photon Fermi-LAT
- Nothing else during 16 years

THE VHE GRB SPECTRUM - FROM 2018 TO 2019







From 2018 to 2019

GRB 180720B

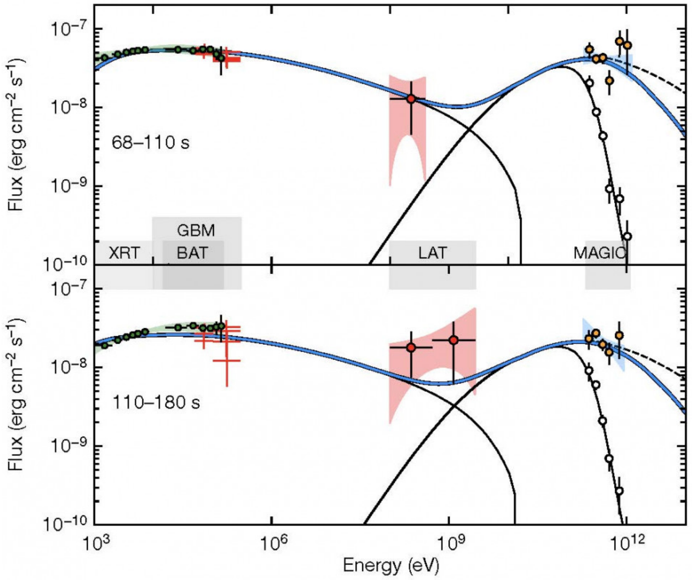
100 GeV – 440 GeV

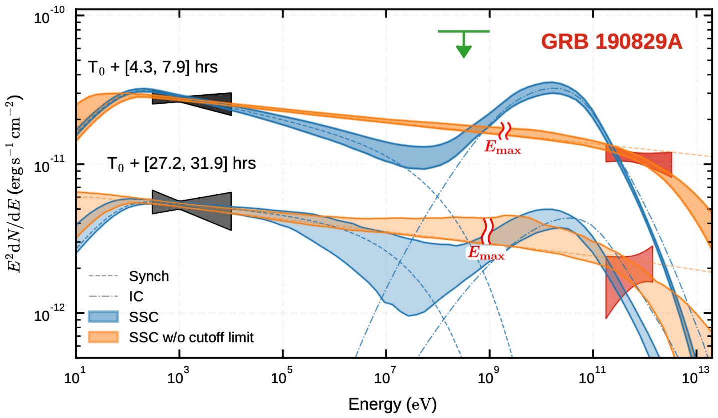
GRB 190114C

300 Gev – 1 TeV

GRB 190829A

200 GeV – 4 TeV





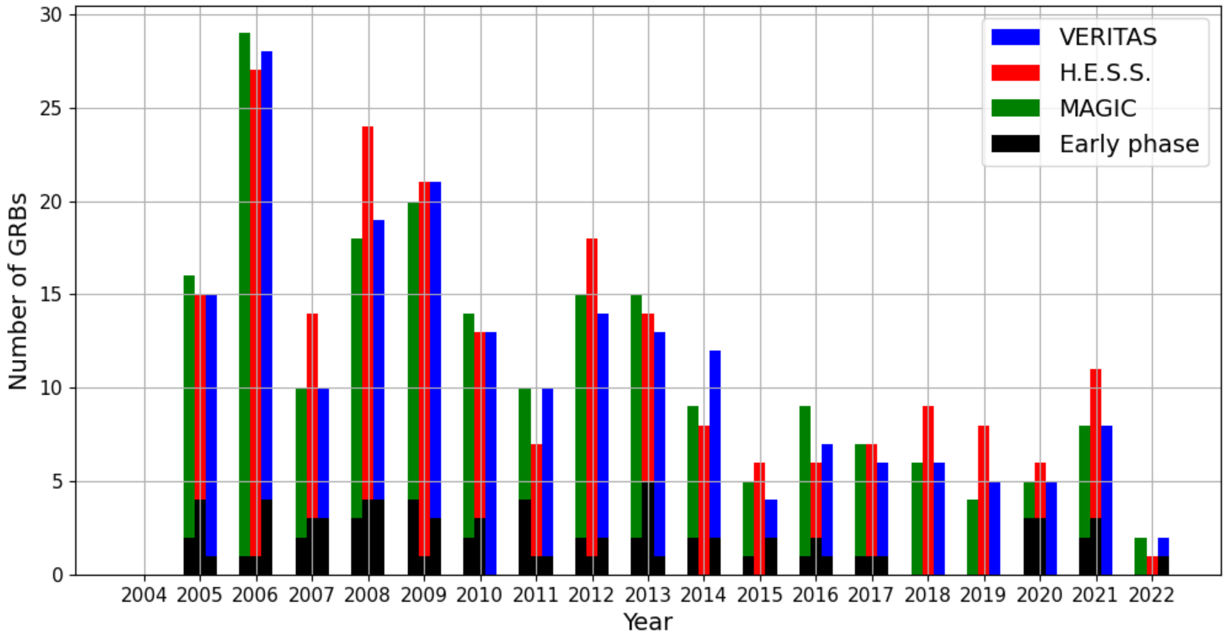
WHERE DID ALL THE VHE GRBS GO BETWEEN 2002 AND 2018?

A RETROSPECTIVE STUDY OF SWIFT GAMMA-RAY BURSTS VISIBILITY FOR IACTS: 2004 – MID 2022

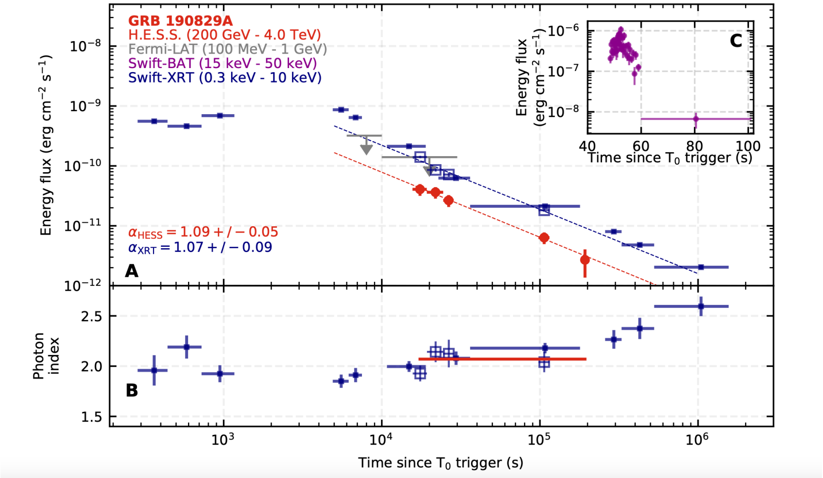
WHAT WAS OBSERVABLE?

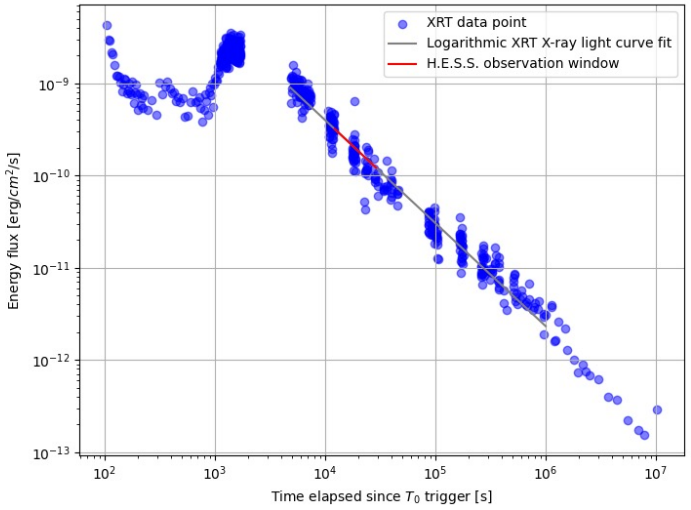
Maximum allowed zenith angle	60 deg
Field of view	2 deg
Maximum allowed observation delay	24 hours
Maximum Sun altitude	-16 deg
Maximum Moon Phase	40%
Maximum Moon altitude	65 deg
Minimum Moon-source separation	45 deg
Maximum Moon-source separation	145 deg
Minimum observation duration	6 minutes

Redshift measurement
> 2 X-ray points with Swift-XRT



We want to **INDEPENDENTLY** predict the VHE gamma-ray emission of all these GRBs and check if this VHE gamma-ray emission is detectable by IACTs using real-time observation conditions.





Phenomenological approach

Spectral shape: Power law with $\gamma = 2$

Emission level:

$\phi(u)_{\gamma\ (0.2\text{-}4\ \mathrm{TeV})} \times F \equiv \phi(u)_{X\ (0.2\text{-}10\ \mathrm{KeV})}$

with F between 1-3

Temporal decay: Power law decay with $\alpha_\gamma = \alpha_X$

➢Get the VHE gamma-ray intrinsic emission $\phi(u)_\gamma$

METHODOLOGY: TELESCOPE RESPONSE

EBL absorption: $\phi(e)_\gamma = \phi(u)_\gamma\, e^{-\tau\,(E,z)}$

- ➢Get the gamma-ray emission reaching Earth $\phi(e)_\gamma$
- ➢Effective area | Energy bounds | Background rates ←→ zenith angle

IACT	E_1 (TeV)	E_2 (TeV)	Reference for eff. area	α	Bkg. rate (Hz)	Zenith (deg)
H.E.S.S. I	0.2	4	H.E.S.S. collaboration et al. (2006)	0.14	0.0865	45
H.E.S.S. II	0.1	4	Holler et al. (2015)	0.08278	0.1287	45
H.E.S.S. MONO	0.1	4	Holler et al. (2015)	0.102	0.0837	45
VERITAS I	0.2	4	https://veritas.sao.arizona.edu	0.14	0.07951	20
VERITAS II	0.2	4	https://veritas.sao.arizona.edu	0.14	0.1101	20
MAGIC I	0.1	4	Aleksić et al. (2012)	0.2	1.125	< 30
MAGIC II	0.1	4	Aleksić et al. (2016)	0.2	0.64	< 30

$$\phi_\gamma^{(u)} \times F = \int_{E_1^{(u)}}^{E_2^{(u)}} E \frac{dN}{dE} dE \equiv \phi_X^{(u)}$$

↓

$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_0}\right)^{-\gamma}$$

↓

$$R_0 = \int_{E_1}^{E_2} \frac{dN}{dE}(t) e^{-\tau_{EBL}} A(E) dE$$

↓

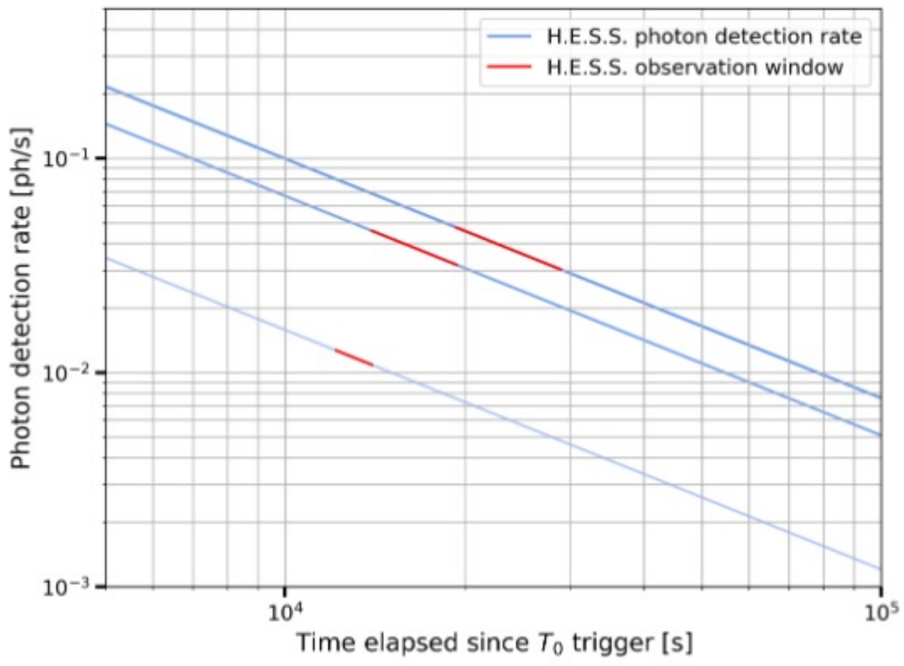
$$R(t) = R_0 \, t^{\alpha_X}$$

↓

$$S = \int_{t_1}^{t_2} R(t) dt \qquad B = \int_{t_1}^{t_2} R^B dt$$

↓

$$N_{ON} = S + \alpha B \qquad N_{OFF} = B$$



Across 3 different zenith angles (3 effective areas)

$$\sigma = \sqrt{-2 \ln \lambda} = \sqrt{2}\left\{N_{on} \ln\left[\frac{1+\alpha}{\alpha}\left(\frac{N_{on}}{N_{on}+N_{off}}\right)\right] + N_{off} \ln\left[(1+\alpha)\left(\frac{N_{off}}{N_{on}+N_{off}}\right)\right]\right\}^{1/2}$$

VALIDATION

GRB 190829A

Using the time window as reported in the H.E.S.S. paper we get:

20.9 σ vs. 21.7σ (reported)

Doubling the background rate lowers the significance to 16.5σ

Doubling the background rate for the $\gamma = 2.5$ case reduces the significance to 14.2σ

GRB 180720B

2.5 σ vs. 5.3 σ (reported)

Standard vs. Loose cuts

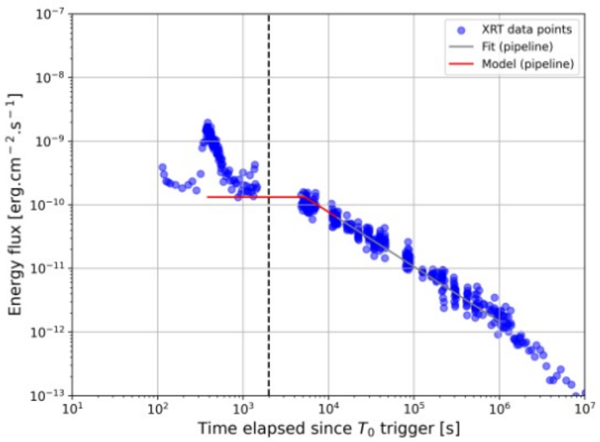
FIRST SELECTION

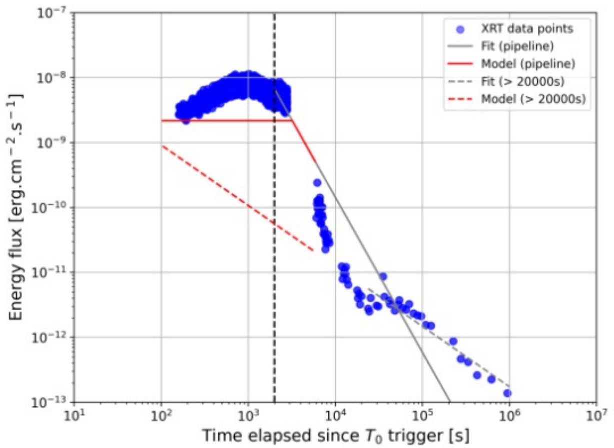
For H.E.S.S.:
GRB 060904B, 080605,
100621A, 100814A, 130925A, 131030A,
161219B, 180720B, 190829A and 210721A

For MAGIC:
GRB 060904B, 080605, 090112, 090417B,
101225A, 130430A,131030A, 190829A and
210619B

For VERITAS:
GRB 060218, 090618, 120729A and
190829A

- Take a deeper look into the X-ray curve
- 1st case: > 2000 seconds
- 2nd case: entire observation window





RESULTS

Low redshift GRBs are favored

Early observation times are favored.

Improve IACT effective areas at low energies

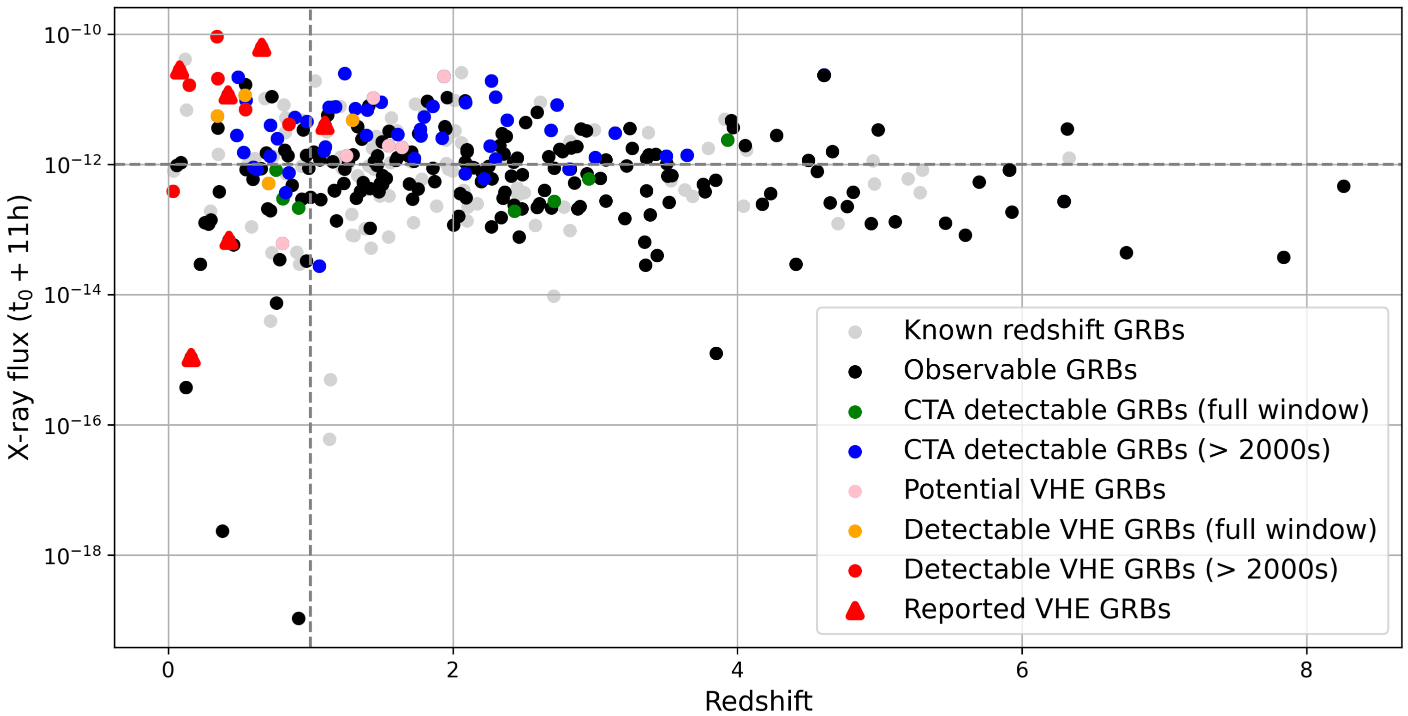
Some GRBs are flagged as interesting for more than one IACT

GRB Name	z	Time (UTC)	Obs. delay (s)	Obs. duration (s)	σ > 2000s (full) H.E.S.S. II	σ > 2000s (full) H.E.S.S. I
GRB060904B	0.7029	2006-09-04T02:31:03	26.0	5045.0	<1 (1.8)	**<1 (<1)**
GRB100621A	0.542	2010-06-21T03:03:32	40.0	4733.0	2.4 (19.6)	**<1 (5.7)**
GRB130925A	0.348	2013-09-25T04:11:24	60115.0	5303.0	**2.4 (2.4)**	1.0 (1.0)
GRB131030A	1.293	2013-10-30T20:56:18	27.0	8313.0	**<1 (2.0)**	<1 (<1)
GRB161219B	0.1475	2016-12-19T18:48:39	388.0	11899.0	**11.5 12.1**	7.7 (8.0)
GRB180720B	0.654	2018-07-20T14:21:44	35209.0	15302.0	**2.5 (2.5)**	<1 (<1)
GRB190829A	0.0785	2019-08-29T19:56:44	12179.0	16817.0	**31.5 (31.5)**	24.6 (24.6)

GRB Name	z	Time (UTC)	Obs. delay (s)	Obs. duration (s)	σ > 2000s (full) MAGIC II	σ > 2000s (full) MAGIC I
GRB090417B	0.345	2009-04-17T15:20:03	11456.0	20150.0	2.0 (2.0)	**1.2 (1.2)**
GRB101225A	0.847	2010-12-25T18:37:45	1124.0	5622.0	4.9 (5.4)	**3.9 (4.9)**
GRB130427A	0.3399	2013-04-27T07:47:57	39056.0	2424.0	**2.0 (2.0)**	1.0 (1.0)
GRB190829A	0.0785	2019-08-29T19:56:44	14906.0	11363.0	**9.7 (9.7)**	6.5 (6.5)

GRB Name	z	Time (UTC)	Obs. delay (s)	Obs. duration (s)	σ > 2000s (full) VERITAS II	σ > 2000s (full) VERITAS I
GRB060218	0.03342	2006-02-18T03:34:30	104.0	5766.0	63.7 (69)	**51.2 (56)**
GRB090618	0.54	2009-06-18T08:28:29	31.0	8553.0	1.5 (1.6)	**<1 (<1)**
GRB190829A	0.0785	2019-08-29T19:56:44	46116.0	10605.0	**6.0 (6.0)**	4.9 (4.9)

XZ DIAGRAM



Interesting VHE GRBs: < 1 per year (0.6 - 0.8 per year) for all IACTs
<1 every 2 years for a single site
These numbers increase by ½ - **1 order of magnitude** with CTA (2 vs. 3 sites)
The dedicated GRB CTA task force is working on the accurate numbers
→No surprise the rate is so low, especially with hard observation criteria.

DISCUSSION AND CONCLUSION

We highly encourage the three IACT collaborations to look for any data that might have been collected on the reported GRB

Loosening criteria and quicker observations

After all 3 of the 5 VHE reported GRBs where observed either with large observation delay or under moonlight observations (outside hard criteria)

Tests different hypothesis. GRB 221009A was not detected after 51 hours despite high X-ray emission

→ need to reconsider **F** for some cases?

X-ray ←→ VHE relations constraints through stacked analysis