GRB observations with H.E.S.S.

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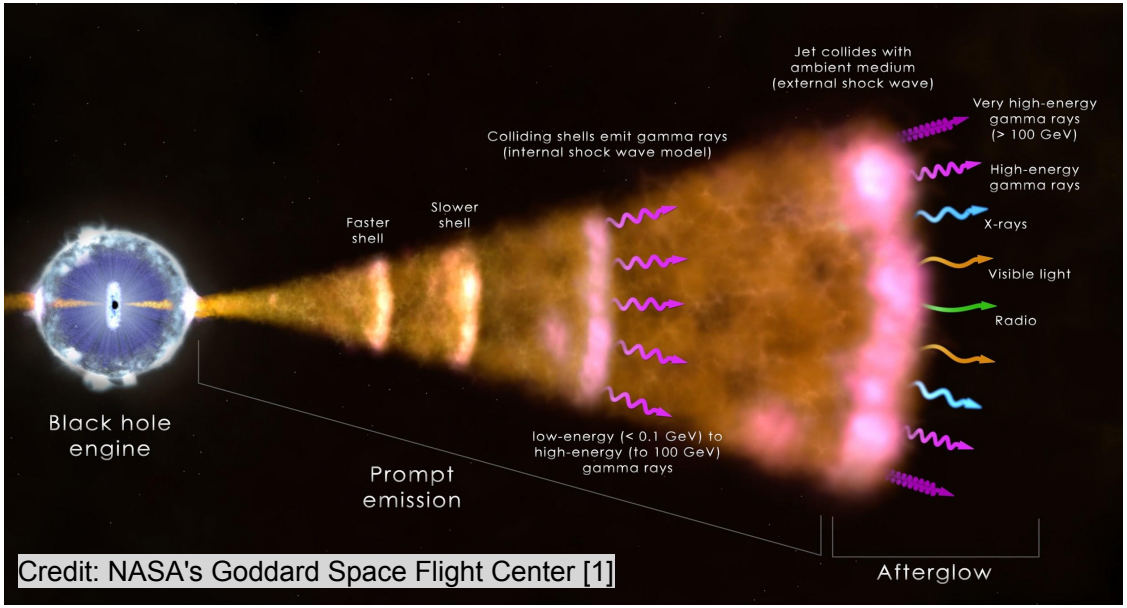
Gamma-ray Bursts (GRBs)

- **Origin:** Massive object merger or Supernova explosion ➡ accelerating a jet of particles
- **Prompt emission phase:** Collision between the shells in jets emits low energy gamma-rays ➡ perceived as Gamma-ray Burst, lasts for seconds to minutes
- **Afterglow emission phase:** Propagating jet interacts with the surrounding medium ➡ EM radiation in all wavelengths lasting months to years
- Approximately 4000 GRBs have been observed during the prompt phase by space-based instruments during the past two decades ➡ Afterglow emission is also observed from radio to gamma-ray energies



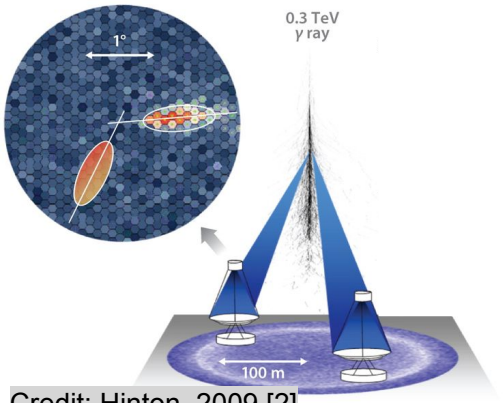
Credit: NASA's Goddard Space Flight Center [1]

Question: In the afterglow phase, are GRBs emitting very high energy gamma-rays (VHE; > 100 GeV) ?

Note: Due to extragalactic background light (EBL) absorption, VHE gamma-rays are observed as having a softer spectrum

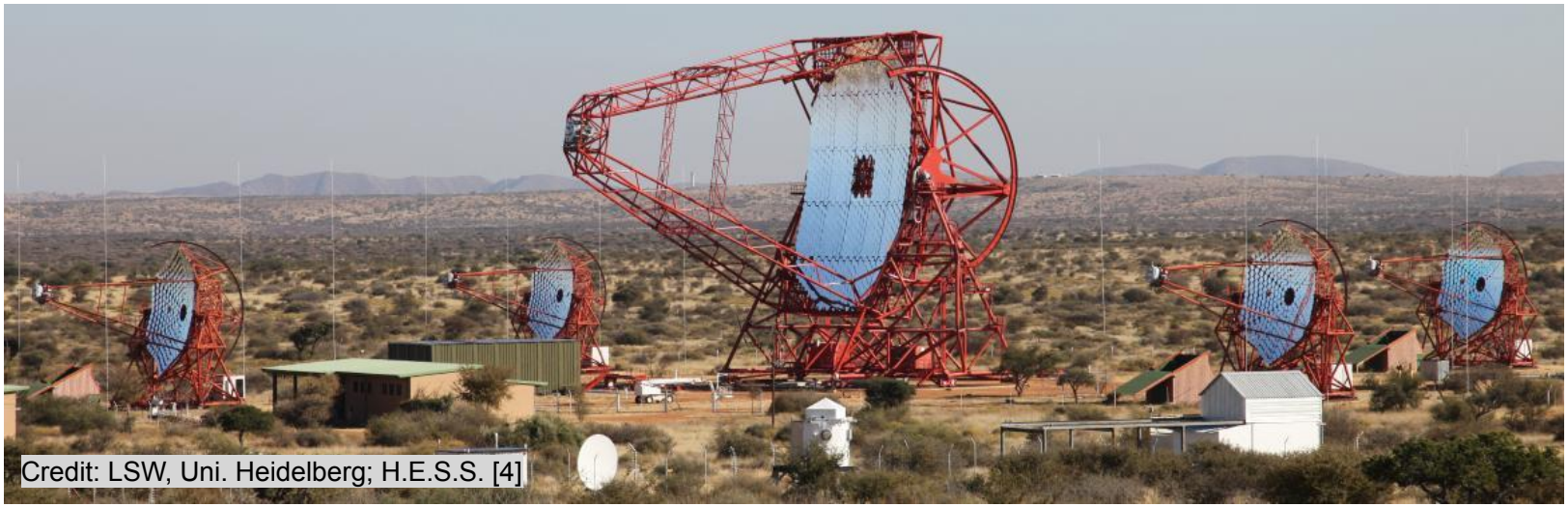
High Energy Stereoscopic System (H.E.S.S.)

- **Location:** ~100 km south-west of Windhoek, Namibia (1.8 km a.s.l)
- **Technique:** Imaging Atmospheric Cherenkov Technique
- **Telescopes:** Four 12-m telescopes (2004) and one 28-m telescope (2012)
- **Key features:** > 50 GeV; slew 100°/minute



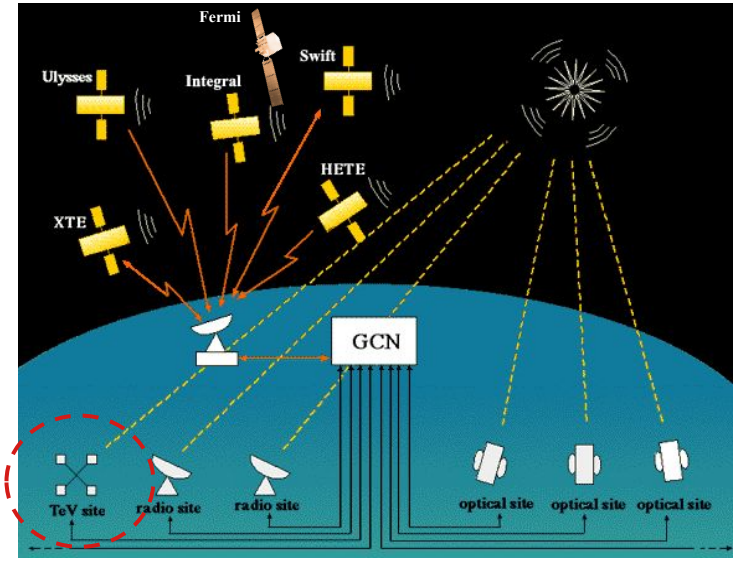
Credit: Hinton, 2009 [2]

H.E.S.S. has detected VHE gamma-rays from more than 130 sources [3]

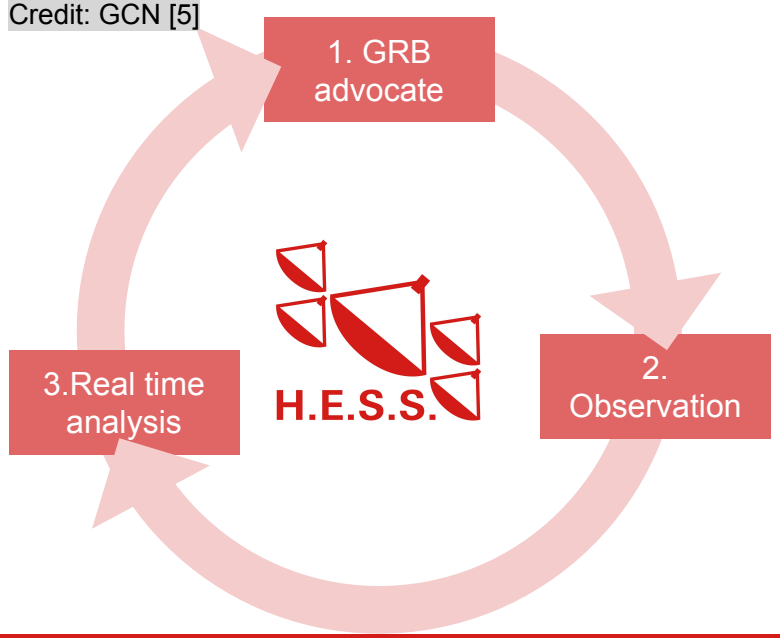

Credit: LSW, Uni. Heidelberg; H.E.S.S. [4]

H.E.S.S. GRB program

- An active program within H.E.S.S. collaboration since 2003 ➡ ~100 hours / year dedicated for GRB observations
- The Gamma-ray Coordinates Network ➡ prompt or afterglow alert
- Most of the GRB observations are automated ➡ to reduce follow-up delay
- The GRB advocate decides on the continuation of observation ➡ based on real time analysis and available multi-wavelength information
- Two significant GRB detections ➡ GRB 180720B & GRB 190829A



Credit: GCN [5]



GRB 180720B

Redshift: **z = 0.653**

20 Jul, 2018
14:21 UT (T_0)

T_0+ 10 min

(H.E.S.S. visibility constraints)

T_0+ 10.1 hr

Fermi-GBM
Swift-BAT

Swift XRT: 2nd bright ever observed (0.3 - 10 keV)

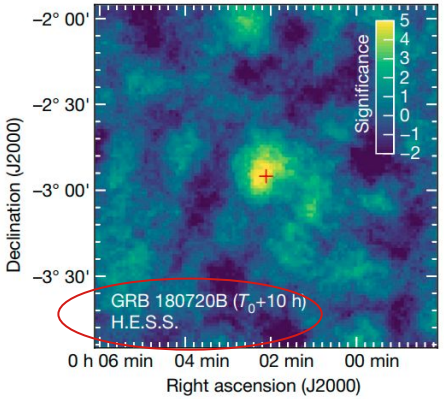
Fermi-LAT

Confirmed the detection of GeV photons

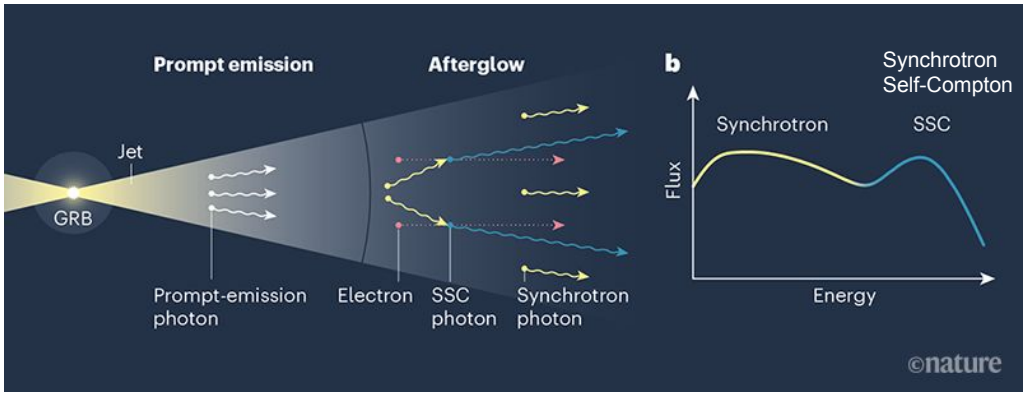
Multi-wavelength observations

H.E.S.S.

Observed afterglow for two hours
Zenith < 45°
100 - 440 GeV ➡ 5.3 σ detection



Credit: *Nature* 575, 464–467 (2019) [6]



Credit: *Nature* 575, 448-449 (2019) [7]

This observation establishes the existence of VHE gamma-rays in the afterglow, but whether it is SSC or some other mechanism remains to be seen.

GRB 190829A

Redshift: **z = 0.079**

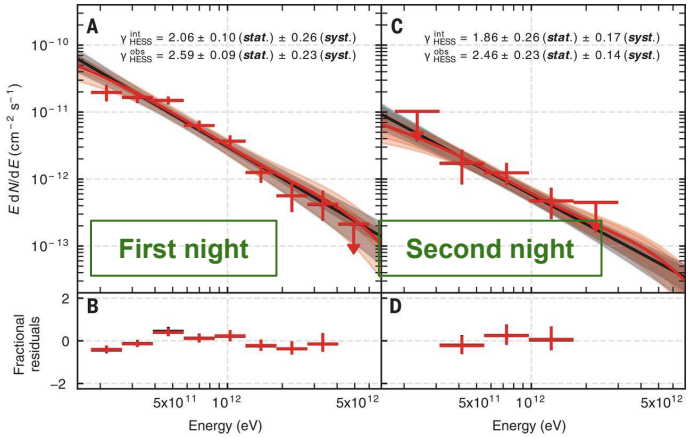
[A cosmic experience GRB 190829A]

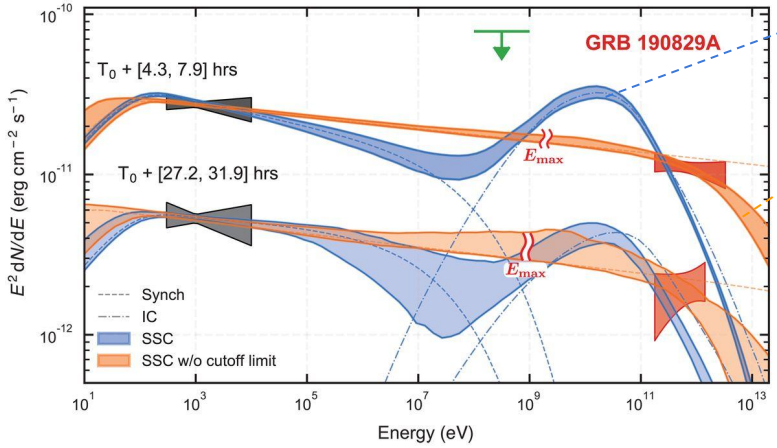
29 Aug, 2019
19:55 UT (T_0)

T_0+ 4.3 hr **T_0+ 27.2 hr**

Fermi-GBM Swift-BAT	Multi-wavelength observations	H.E.S.S., first night	H.E.S.S., second night	H.E.S.S., third night
		Observed afterglow 0.18 - 3.3 TeV 21.7 σ detection	Observed afterglow 0.18 - 1.4 TeV 5.5 σ detection	No detection

Credit: *Science* 372, 6546, 1081-1085 (2021) [8]





Synchrotron self-Compton: inconsistent with the H.E.S.S. observations

Synchrotron dominant: removes maximum photon energy (E_{max}) emitted by synchrotron process

- better fit (> 5σ) to multiwavelength data
- large difference in magnetic field strength or an unknown physical process

This result supports synchrotron dominant afterglow emission model but difficult to explain

Summary

- In the afterglow phase, GRBs are emitting very high energy gamma-rays ➡ Is it true for all the GRBs?
- The H.E.S.S. GRB observation strategy is successful in observing GeV - TeV afterglow emission from two GRBs so far ➡ motivates to improve the strategy to search for more GRBs
- The GRB afterglow emission model: Synchrotron self-Compton or Synchrotron dominant ➡ More GRBs should be observed to understand the emission model

References

1. GMS: A New Era in Gamma-ray Science
2. Teraelectronvolt Astronomy
3. TeVCat 2.0
4. HESS WG: Multiwavelength Studies
5. GCN
6. A very-high-energy component deep in the γ-ray burst afterglow
7. Extreme emission seen from γ-ray bursts
8. Revealing x-ray and gamma ray temporal and spectral similarities in the GRB 190829A afterglow

Thank you!