Gamma-ray burst observations at very-high-energies with H.E.S.S.

M. Seglar-Arroyo on behalf of Q. Piel for the H.E.S.S. Collaboration
GRB observations at high energies

- Fermi-GBM + Swift-BAT: ~300 GRBs/yr
- ~6% are detected by Fermi-LAT (E>100MeV)
- <20% of all LAT-GRBs reach E>10GeV in the observer frame
  - max. energy: 94 GeV (GRB 130427)
  - Temporal delay between low energy and high energy emission

See also E. Bissaldi talk GAD1b
The H.E.S.S. GRB follow-up program

- main design principles of the H.E.S.S. 28m telescope (CT5)
  - large photon collection area: 614 m$^2$ mirror (largest IACT worldwide)
  - high sensitivity at low E
  - rapid response time

H.E.S.S. Preliminary

Hoischen et al. ICRC 2017

Hofverberg et al., ICRC 2013

reverse tracking

GRB observations with H.E.S.S. - ICRC 2019, Madison/Wisconsin
Automatic reaction to alerts of H.E.S.S.

- Fully automatic procedures (alert reception - filtering - slewing - data taking)
- Optimized repointing and data taking procedures for 28m telescope, CT5
- Alert reception using VO standards (VoEvents)
- Around 10 GRB follow-ups / year
  - typically exposure: 2h / follow-up
Data analysis procedures

- Rigorous data quality verification and blinding procedures
  - data quality assessment at various levels
    - atmospheric effects (e.g. trigger rates, cloud monitors, etc.)
    - calibration stability (e.g. detection of faulty pixels in the camera(s), pixel pedestal values, the distribution of events within the field of view, etc.)
  - two independent data calibration and analysis chains
    - need approved data quality within both chains before unblinding of gamma-ray data
    - a priori selection of main analysis + independent cross-check
  - detailed verifications and comparisons of analysis results
GRB data analysis summary

- Since 2008: 66 GRB follow ups
  - H.E.S.S.-II: inauguration of CT5 in December 2012 => 56 observations
  - 20 observations removed (technical issues, bad weather conditions, insufficient statistics, etc.)
  - 21 observations still under analysis
  - 25 analysed GRB observations
    - 15 bursts with localisation uncertainties <0.1deg (e.g. Swift-BAT) => integral flux upper limits at the source position
      - 5 bursts with CT5 data
    - 10 bursts with larger localisation uncertainties (e.g. Fermi-GBM) => map of integral upper limits

Summary: 5 analysed GRBs with good localization and low threshold with CT5
GRB observations and results

66 GRB follow-up observations since 2008

15 Swift-BAT GRBs have been analyzed:
- Integral ULs derived for 14 observations

Expected to be the most promising due to short observation delay

increasing energy threshold

95% CL Integral UL (cm$^2$ s$^{-1}$)

Zenith (deg)

Energy Threshold (GeV)
GRB180720B

- Timeline of events
  - Fermi-GBM at $T_0 = 14:21:39.65$ UT
  - Redshift $z = 0.653$ (ESO-VLT/X-shooter)
  - Fermi-LAT: emission detected until $T_0 + 700s$
    - $E_{\text{max}} = 5$ GeV, $T_0 + 142s$
  - $T_{90} = 48.9 \pm 0.4$ s
  - $E_{\text{iso}} = (6.0 \pm 0.1) \times 10^{53}$ erg (50–300 keV)
  - 6th brightest GRB in Fermi-GBM
  - Swift-XRT: second highest energy flux at $T_0 + 11h$
    (after GRB130427A)
GRB180720B

- Timeline of events
  - Fermi-GBM at $T_0 = 14:21:39.65$ UT
  - Redshift $z = 0.653$ (ESO-VLT/X-shooter)
  - Fermi-LAT: emission detected until $T_0 + 700s$
    - $E_{\text{max}} = 5$ GeV, $T_0 + 142s$
  - $T_{90} = 48.9 \pm 0.4$ s
  - $E_{\text{iso}} = (6.0 \pm 0.1) \times 10^{53}$ erg (50–300 keV)
  - 6th brightest GRB in Fermi-GBM
  - Swift-XRT: second highest energy flux at $T_0 + 11h$
    (after GRB130427A)
  - H.E.S.S. observations starting $T_0 + 10.1h$
    - Total exposure: 2h
GRB180720B: H.E.S.S. results

- Low energy threshold: analysis of CT5 data in monoscopic mode
  - average zenith angle ~30.1 deg => energy threshold ~100 GeV
- H.E.S.S. data: ~5.3σ pre-trial (5.0σ post-trial accounting for the 5 similar searches)
- detailed studies of systematic uncertainties have been performed
  - cross-check analysis, background estimation methods, trigger rate stability, etc.

2 h exposure
10.1 h after the burst
GRB180720B: H.E.S.S. results

- Low energy threshold: analysis of CT5 data in monoscopic mode
  - average zenith angle ~30.1° => energy threshold ~100GeV
- H.E.S.S. data: ~5.3σ pre-trial (5.0σ post-trial accounting for the 5 similar searches)
- detailed studies of systematic uncertainties have been performed
  - cross-check analysis, background estimation methods, trigger rate stability, etc.

2 h exposure 10.1h after the burst

6.5 h exposure Verification dataset 18-25 days after the burst
GRB180720B: X-ray observations

![Graph showing energy flux and photon index over time since GBM trigger]

- Swift-BAT+XRT (0.3 keV - 10 keV)
- Fermi-GBM (8 keV - 10 MeV)
GRB180720B: High-energy gamma rays

![Graph showing energy flux and photon index over time for Swift-BAT+XRT, Fermi-GBM, and Fermi-LAT.](image)
GRB180720B: Very-high-energy gamma rays
GRB180720B: Summary

Further details in submitted publication.

Swift-BAT+XRT (0.3 keV - 10 keV)
Fermi-GBM (8 keV - 10 MeV)
Fermi-LAT (100 MeV - 10 GeV)
H.E.S.S. (100 GeV - 440 GeV)
Optical (r-band)

\[ E \sim t^{-1.2} \]
Summary

- Extensive transient program during H.E.S.S. phase-II
- GRB follow-up observations have the highest priority: fully automatic response of the whole observatory
- Compilation of VHE upper limits of 14 observations on Swift-BAT triggered GRBs

- First GRB detection with H.E.S.S.: GRB180720B
  - detected afterglow emission (T0 + 10.1h) between 100GeV - 440GeV

- Outlook
  - MAGIC detection of GRB190114C in the early afterglow phase (see Highlight talk by R. Mirzoyan)
  - promising future for GRB physics with VHE observatories
    - current IACTs
    - Cherenkov Telescope Array
    - HAWC, LHAASO, etc.
Back-up
Results
Results

**Very High Energy** H.E.S.S

**Gamma** Fermi-LAT, Fermi-GBM, Konus-Wind

**X-Ray, UV** Swift-XRT, Swift-BAT, MAXI, NuSTAR

**Optical, NIR** VLT XSHOOTER, LCO, Kanata, TSHAO, MITSuME, COATLI, ISON, MASTER, KAIT

**Radio** AMI-LA, GMRT

Burst time: 2018-07-20 14:21:44 UT

Time after trigger:
- 1 day
- 5 days
- 20 days
Results