GRB observations at very high energies with the MAGIC telescopes

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- for the MAGIC collaboration -

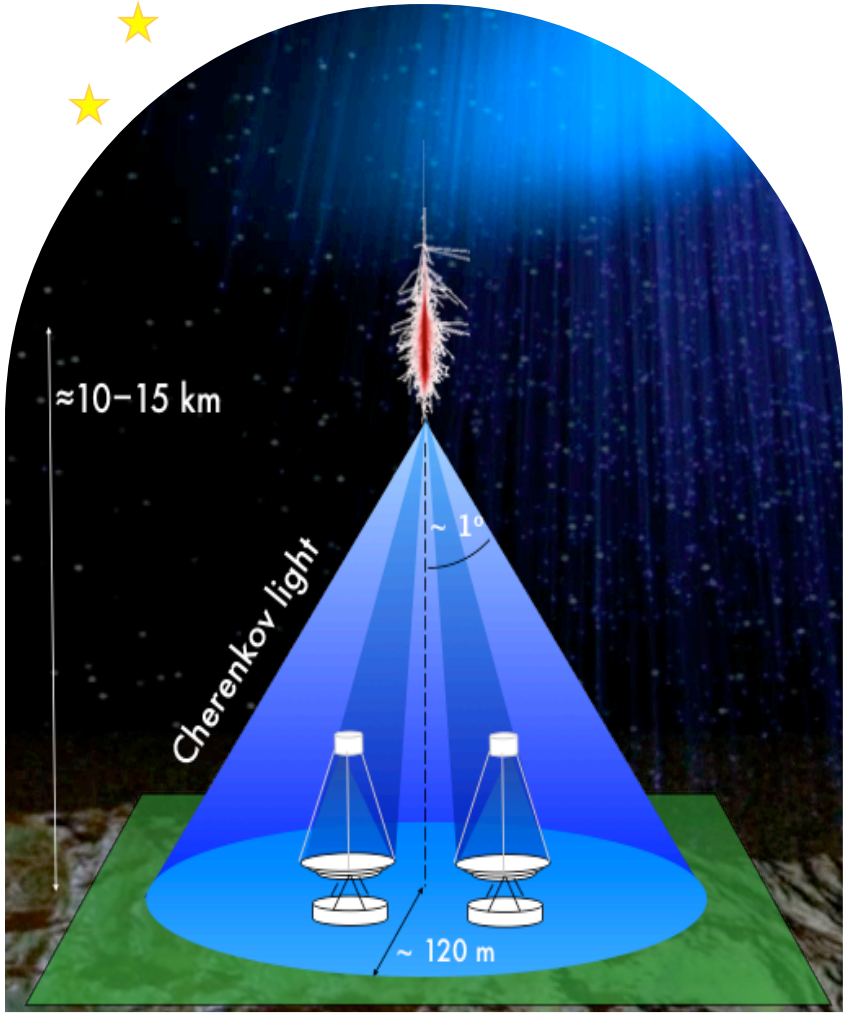
Major Atmospheric Gamma-ray Imaging Cherenkov Telescope

- La Palma, Canary Island, 2200 m a.s.l.
- MAGIC-I since 2004, stereo since 2009
- 2 × 236 m² mirror area
- E_{thr} = 50 GeV @ Zenith (stereo)
  reaching 25 GeV with sum-trigger
  → E overlap with satellites
- Sensitivity: 0.8% Crab (>200 GeV in 50h)
- Further special's in MAGIC:
  - Carbon fibre tube structure
  - Parabolic reflector
    → shower movies not images
  - Tessellated mirror surface made of diamond-turned Al-mirrors and glass mirrors (cold slumping technique)
  - Active Mirror Control (AMC)
  - Signal transferred over optical fibres
  - 2 GHz digitalization (DRS4)

→ light-weight construction
repositioning ΔAz = 180° in 20s

Observation of GRBs at VHE

IACT technique



- Exponential decrease of cosmic ray flux towards higher energies
- Satellites have limited detector area (~1 m^2)
- IACTs use earth's atmosphere as detector (~10^3 m^2)
- Detection of Cherenkov light flashes initiated in particle cascades
- IACTs have small FoV (3.5° in MAGIC)
- Attenuation of VHE photons by the EBL
- Comparison of the data with MC simulations

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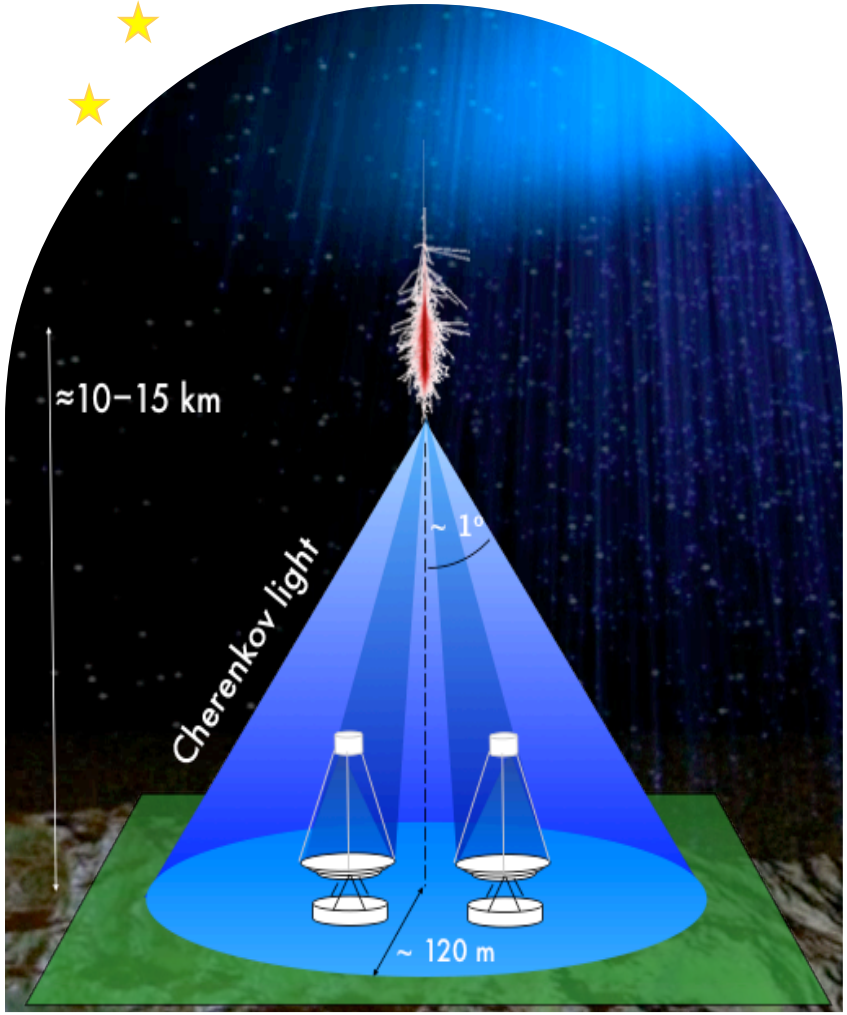
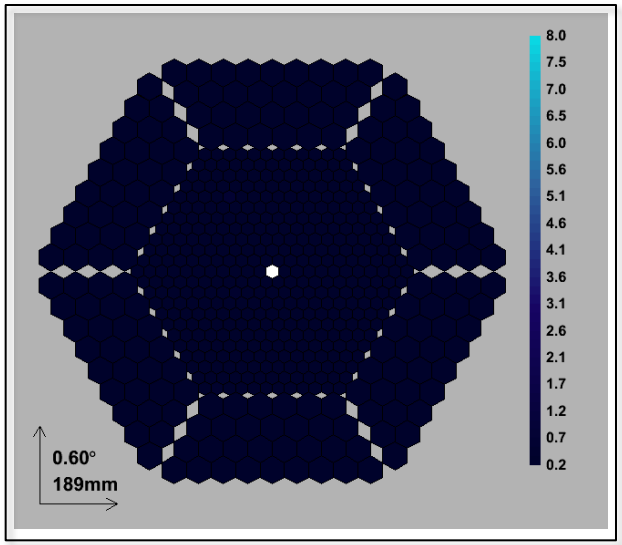
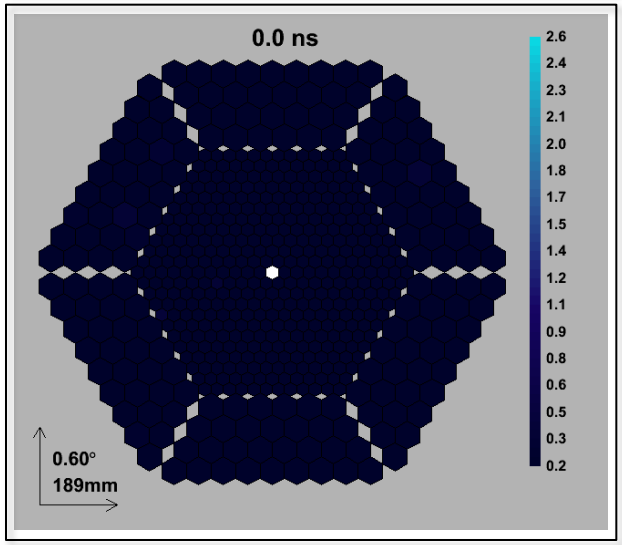




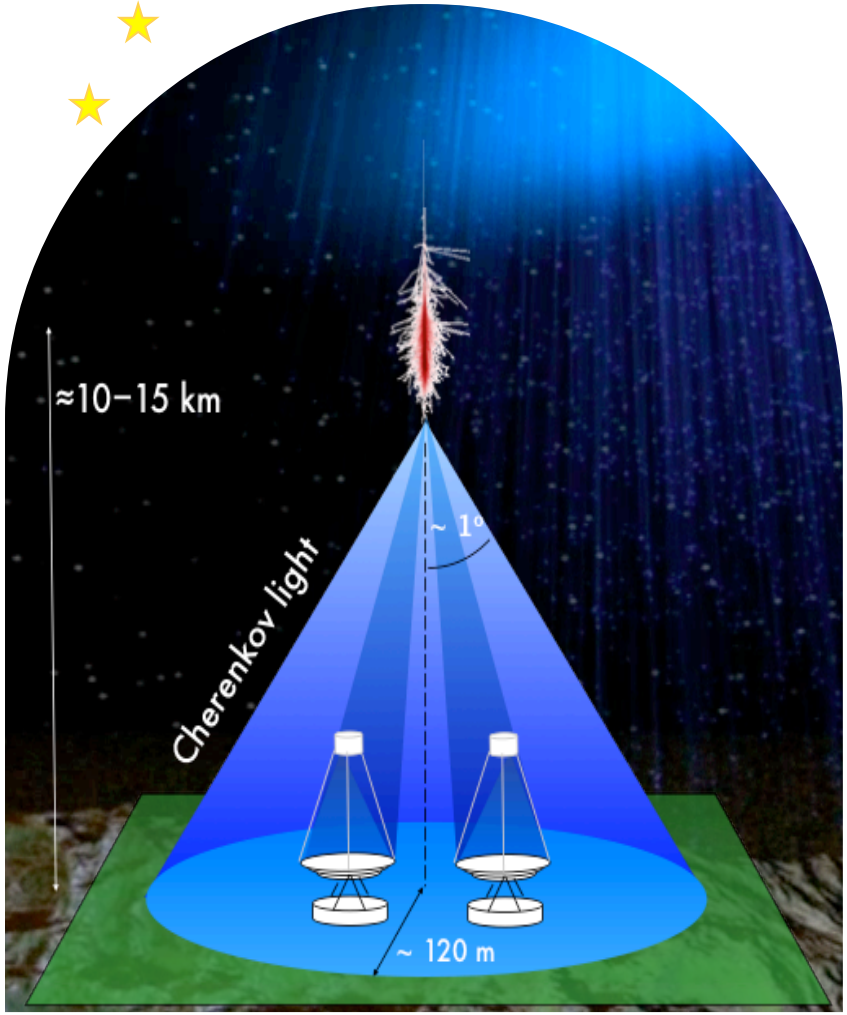
gamma-shower

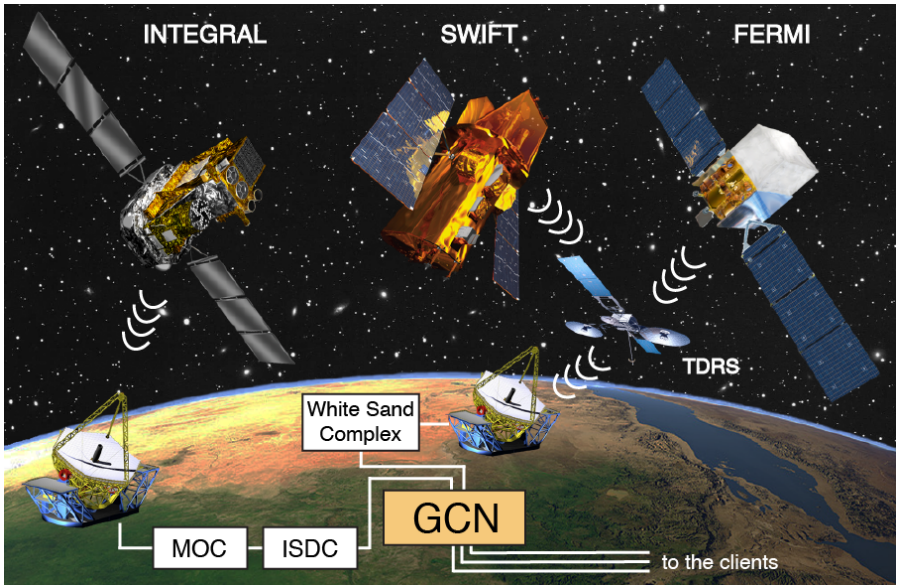


muon-shower

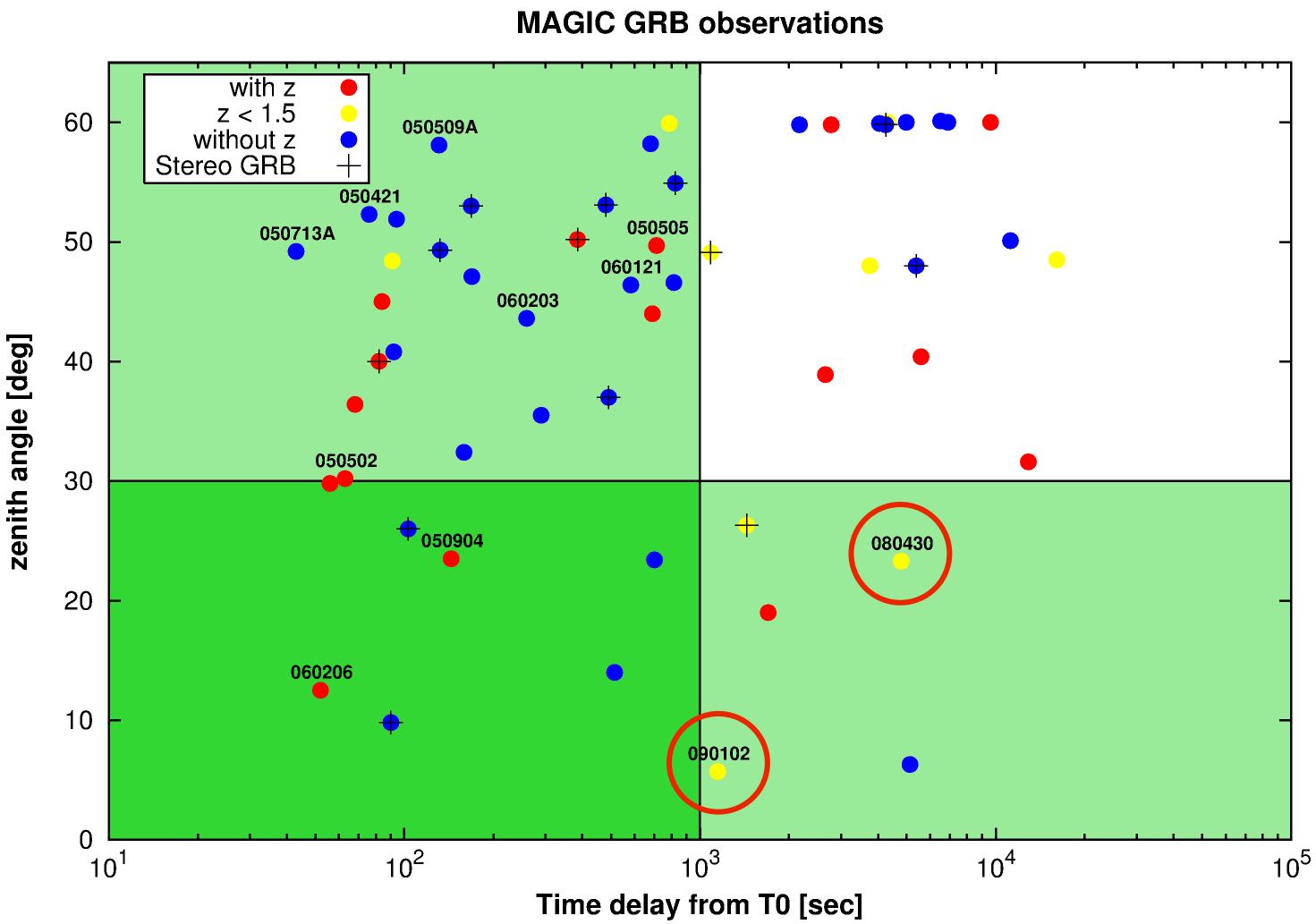
Observation of GRBs at VHE

IACT technique + GCN





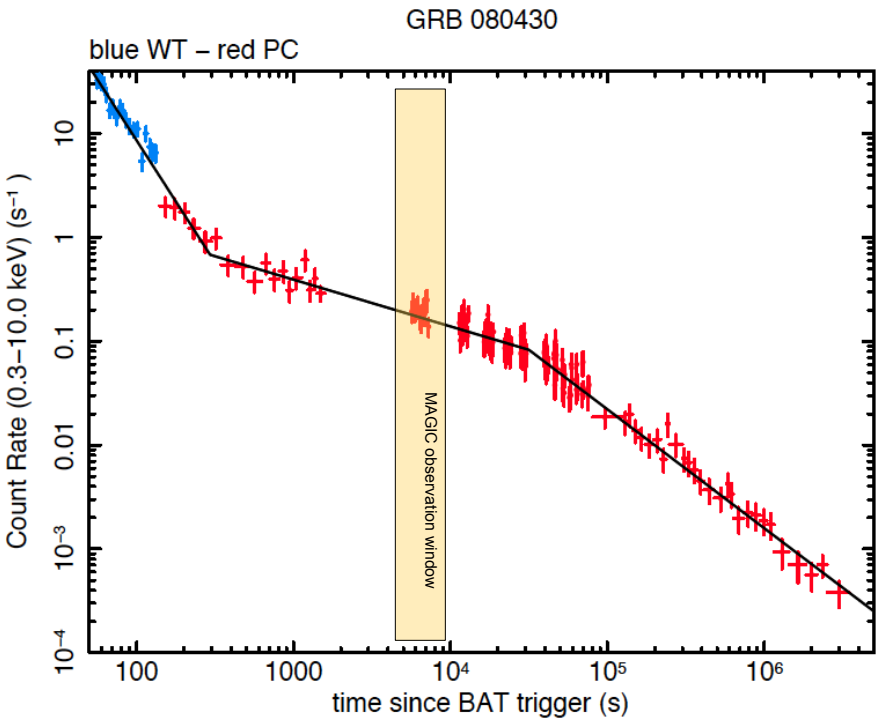
- Full automatic response to GCN alerts
- SWIFT + INTEGRAL + FERMI alerts
- Observation criteria (zenith angle, Moon distance, delay to T_0) → ~10% duty cycle
- On average 1 follow-up observation/month



- 55 GRB follow-up observations since 2004
- To date, only UL's with MAGIC

Important constraints:
- Short delay to T_0
- Low redshift (z<1.5)

GRB080430 afterglow



GCN-report 139.1

Facts:

- SWIFT BAT trigger, T_{90} = 16 s
- Redshift z = 0.758
- Only MAGIC-I mono, no sum-trigger
- Start MAGIC observation at T_0 + 4763 s (trigger during daytime in La Palma)
- Observation time: 9616 s
- Low zenith angle: 23° < Zd < 35°
- E_{th} = 90 GeV

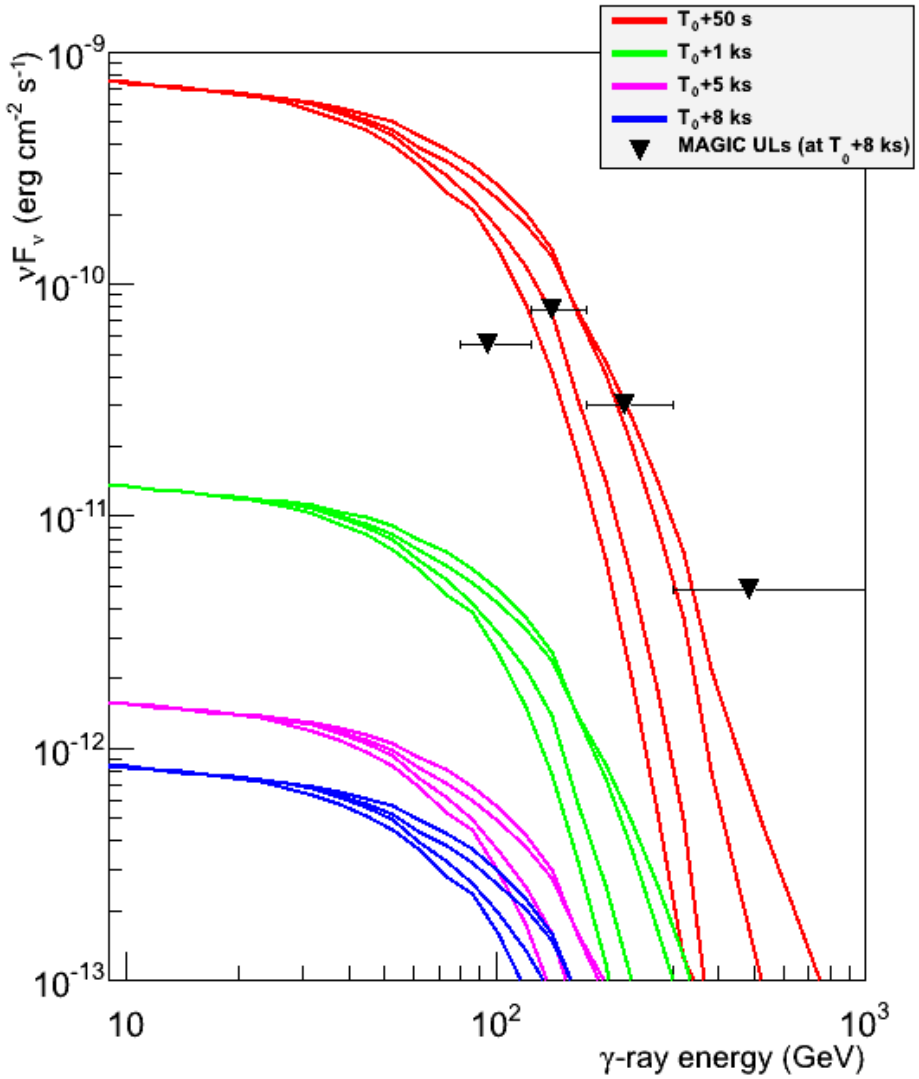
Afterglow modeling:

- Band function:
  - E_{peak} = 39 ± 12 keV, estimated from BAT data (best fit of Amati relation)
  - $E_{iso} = 3 \pm 0.9 \times 10^{51}$ erg
- Only SSC considered:

$F_{90GeV,\ 8ks} = 2.6 \times 10^{-13}$ erg cm^{-2} s^{-1}
$F_{MAGIC\ UL} = 5.5 \times 10^{-11}$ erg cm^{-2} s^{-1}

- Different EBL absorption models

GRB080430 afterglow



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Prompt emission/afterglow modeling:

- Band function:
  - E_{peak} = 39 ± 12 keV, estimated from BAT data (best fit of Amati relation)
  - E_{iso} = 3 ± 0.9 × 10^{51} erg
- Only SSC considered:

$F_{90GeV,\ 8ks}$ = 2.6 x 10^{-13} erg cm^{-2} s^{-1}
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- Different EBL absorption models

J. Aleksic et al., A&A, 517, 2010

GRB090102

- SWIFT BAT trigger, T_{90} = 27 ± 2 s
- Very good reconstruction of the prompt emission parameters: SWIFT, Konus Wind and INTEGRAL simultaneous observation
- Band function parameters:

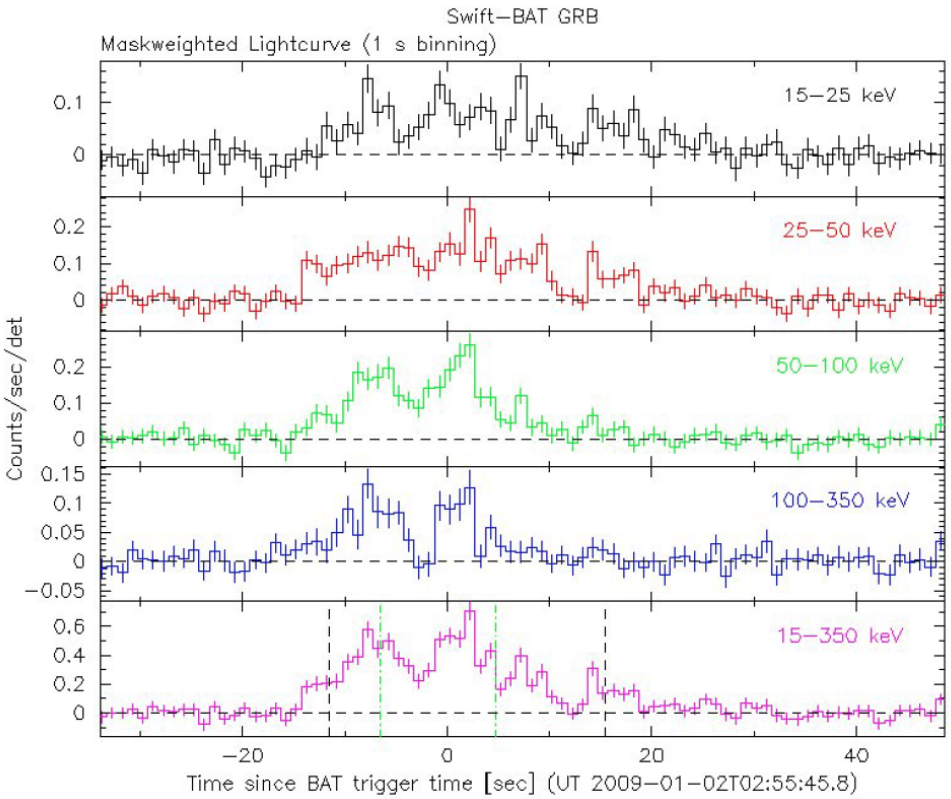
$$E_{peak} = 451^{+73}_{-58} keV$$

$$\phi_{20keV-2MeV} = 3.09^{+0.29}_{-0.25} \times 10^{5} \frac{erg}{cm^2}$$

- Redshift (NOT) z = 1.547
- Optical afterglow detected by various telescopes
- No signal with LAT

MAGIC observation:

- Start MAGIC observation at T_0 + 1161 s (delay due to technical problems)
- Zenith range 5º → 52º
- Total observation time: 13149 s, only first 5919 s used in this analysis (Zd < 25º)
- MAGIC-I + with sum-trigger



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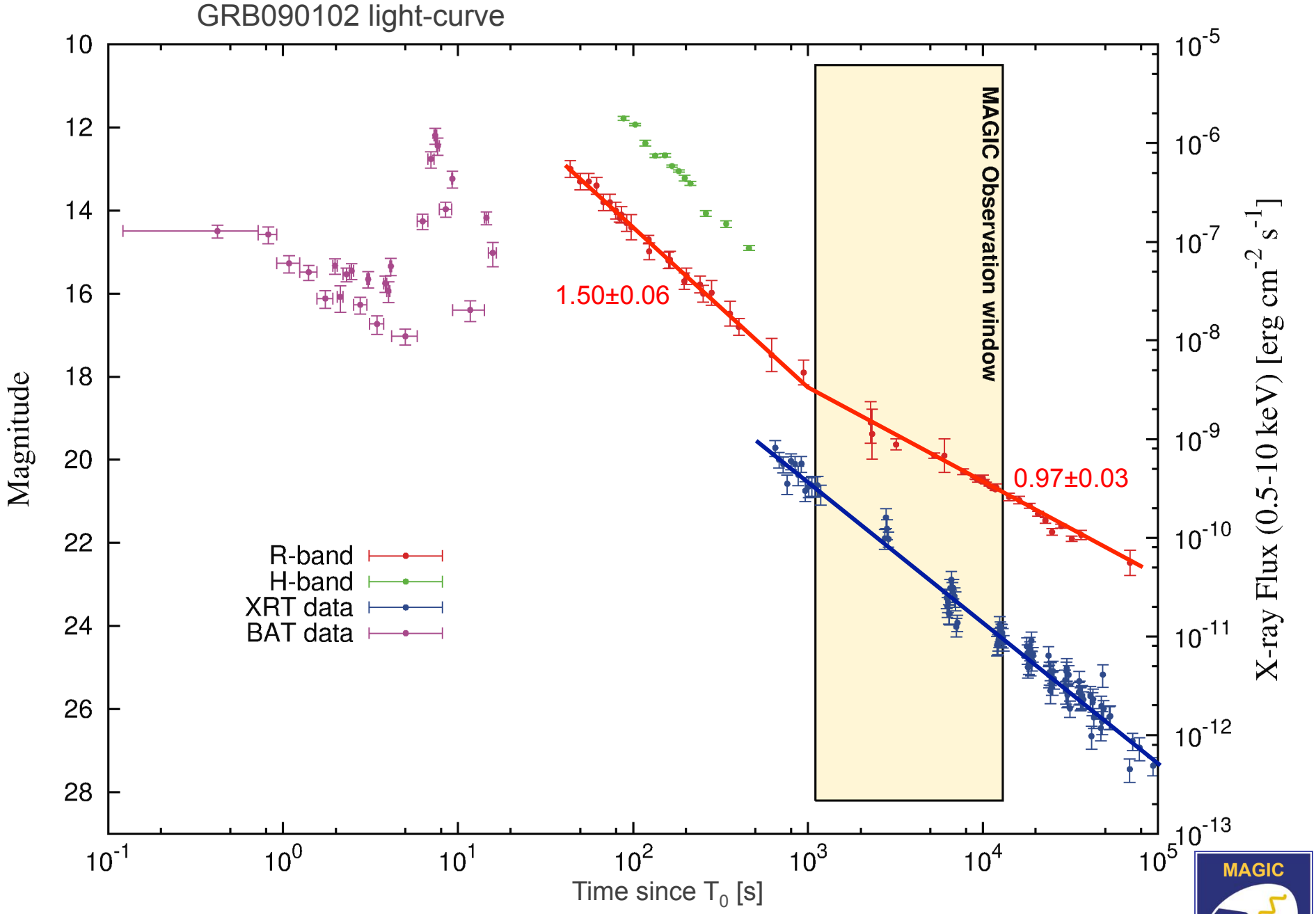
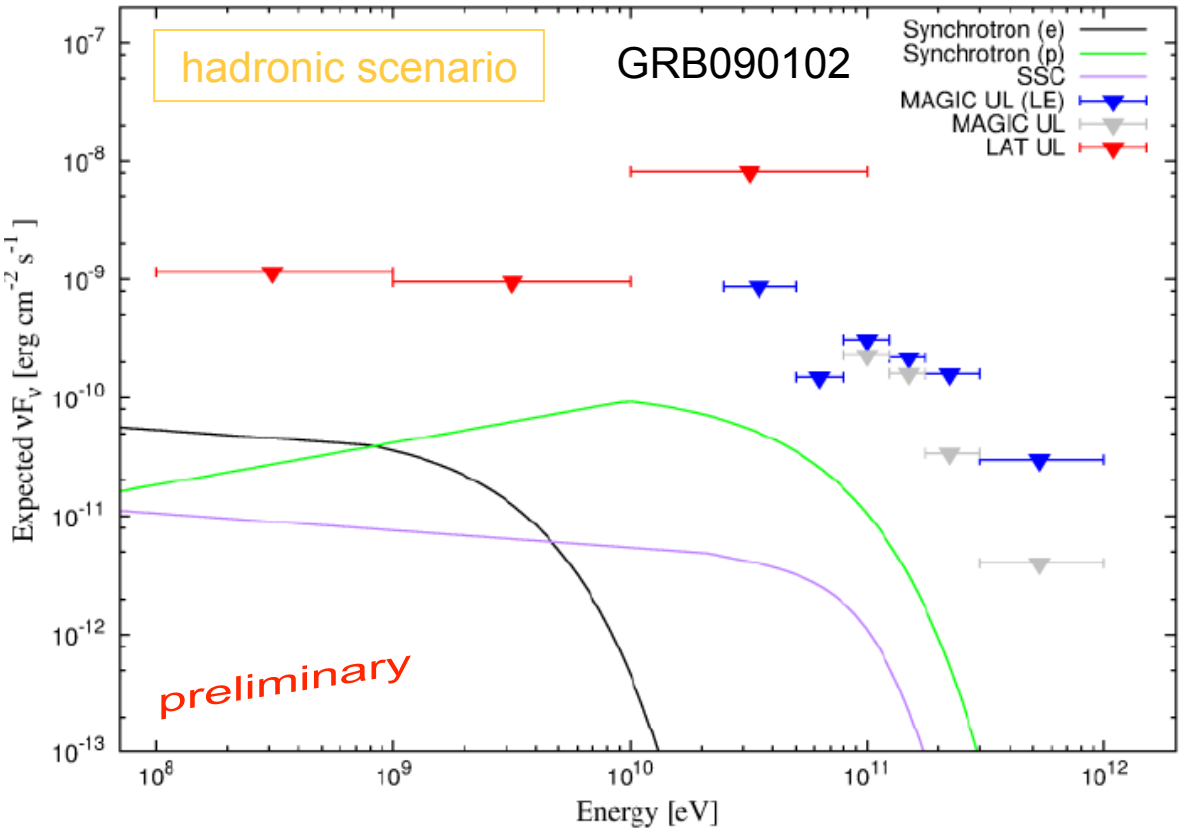
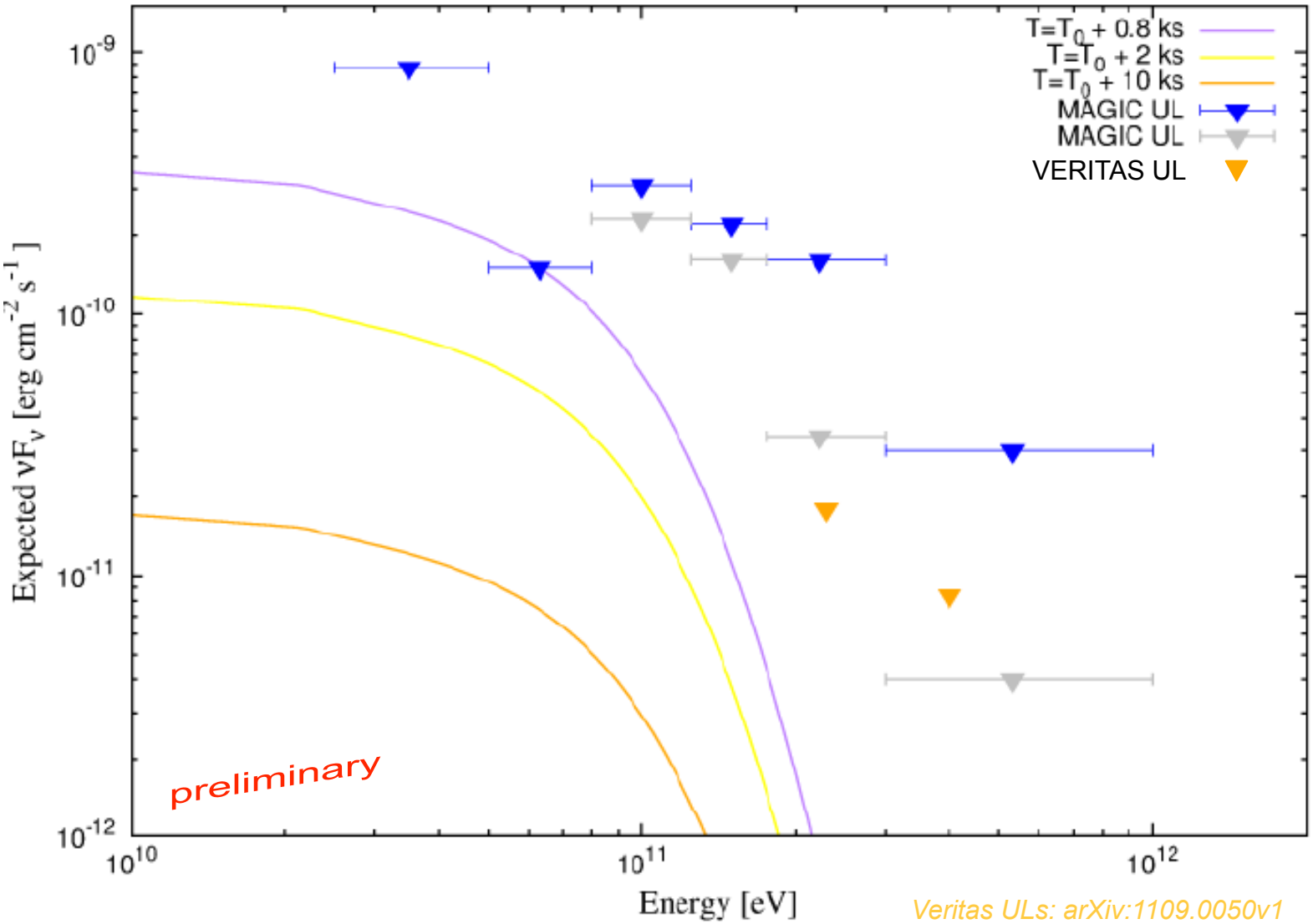

GRB090102 light-curve
Magnitude
X-ray Flux (0.5-10 keV) [erg cm^{-2} s^{-1}]
Time since T_0 [s]
MAGIC Observation window
1.50±0.06
0.97±0.03
R-band
H-band
XRT data
BAT data

Standard fireball model scenario

- First simultaneous GRB observation by MAGIC & LAT
- VHE photons produced by SSC
- Hadronic component can exceed the electron component at MAGIC energies



GRB090102 expected SSC emission



Veritas ULs: arXiv:1109.0050v1

Conclusions

- 55 GRB follow-up observations by MAGIC since 2004
- Most MAGIC observations without MWL coverage
- Several GBM follow-up's with large coordinate error
- To date, only UL's on VHE gamma ray emission by MAGIC
- Without redshift information interpretation of MAGIC results difficult
- Modeling of the VHE afterglow component for GRB080430 and GRB090102:
  → Big advantage of simultaneous LAT and MAGIC data
  → Due to low E_{th} already MAGIC-I was capable to detect the VHE emission
  → Until now MAGIC was unlucky (delays, initial failures)
  → Low redshift and short delay to T_0 are essential

Outlook

- Observing in stereo mode since 2009 (2 × higher sensitivity)
- 2011 readout upgrade (DRS4), this year upgrade of MAGIC-I camera
- Recent changes/improvements of the GRB observation performance
- GRB follow-up observations are a top priority for MAGIC

Wish MAGIC more luck for the future!