Search for High Energy emission from GRBs with MAGIC

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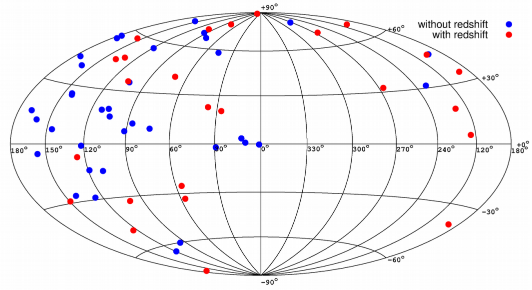
Outline

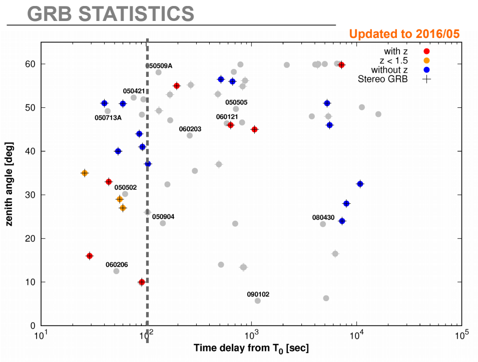
MAGIC: a good IACT for catching GRBs

- Two telescopes of 17 m of diameter located in La Palma, Canary Islands
- FoV of each telescope: 3.5°
- Energy threshold: $\sim$ 50 GeV at zenith, trigger level
- Sensitivity: less than 0.7% Crab above 220 GeV in 50 h
- Fast repositioning time for catching up GRBs: 7°/s
- **GRBs are top priority for MAGIC!**

MAGIC GRB follow-up

- Alert system linked with GRB Coordinate network
- New automatic procedure since 2013
- Fast repositioning if observational constraints are met
- Up to 4h of observation after the prompt emission





- Since 2005, 83 (good) GRBs observed, 37 of them with known redshift
- After new automatic procedure, 19 (good) GRBs observed, 10 of them with redshift information

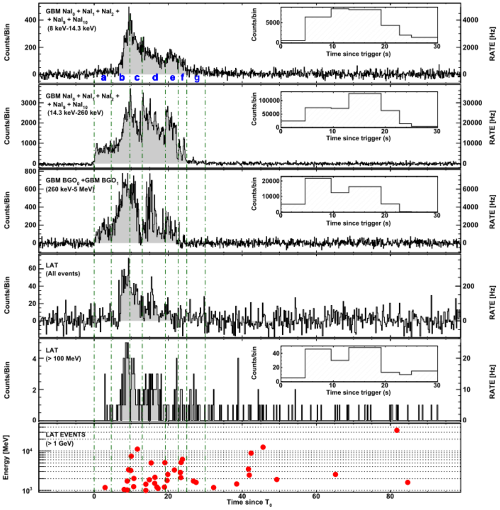
GRBs: what we do not fully understand?

- Prompt and early afterglow
- Emission processes
- Mechanism of jet formation and dissipation
- Jet composition
- Progenitors
- Are GRBs sources of UHECRs and GWs?
- Can we probe EBL with GRBs?
- High Energy (HE) and Very High Energy (VHE) emission $\longrightarrow$ this talk
- ...

HE emission from GRBs

Most of the information about HE emission by GRBs comes from *Fermi* satellite (LAT+GBM)

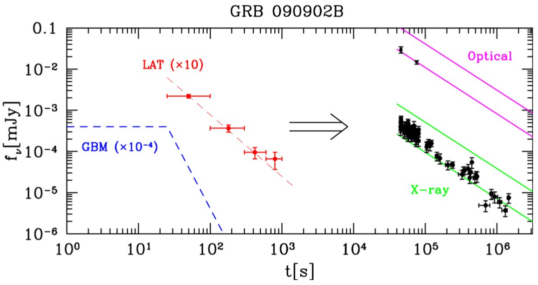
- GBM rate: $\sim 250\,\mathrm{yr}^{-1}$; $\sim 4-5\%$ detected also by LAT at $E > 100\,\mathrm{MeV}$
- $\sim$ half of LAT detected GRBs has $> 1\,\mathrm{GeV}$ photons (rate: $\sim 5\,\mathrm{yr}^{-1}$)
- Highest energy photon from GRB130427: 94 GeV
- HE emission extended in time
- HE emission is delayed
- GeV emission decays as t^{-1} (at least for late times)



GRB090902B: Abdo 2009

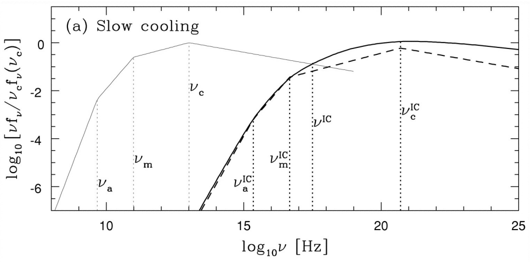
HE/VHE emission models

Synchrotron in external forward-shock



Kumar & Duran, 2010

Self-synchrotron Compton in external shock

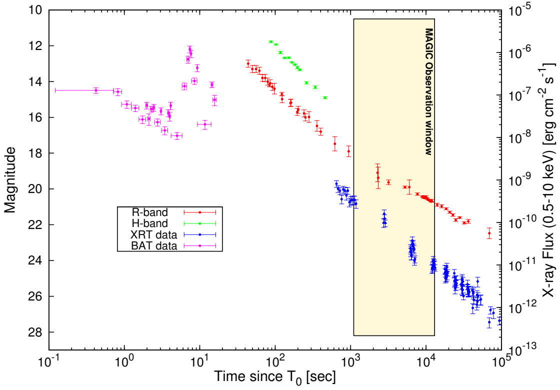


Sari & Esin, 2001

- SSC and synchrotron models for the afterglow can have leptonic (see also Zhang & Meszaros 2001) or hadronic origin (see Böttcher & Dermer 1998; Pe'er & Waxman 2005)
- Other models propose upscattering of prompt γ-rays by electrons (see Meszaros & Rees 1994; Belobodorov 2005; Fan et al. 2005), upscattering of CMB photons (see Plaga 1995) or Compton up-scattered photospheric emission ((see Toma et al. 2011))

MAGIC observation example: GRB090102

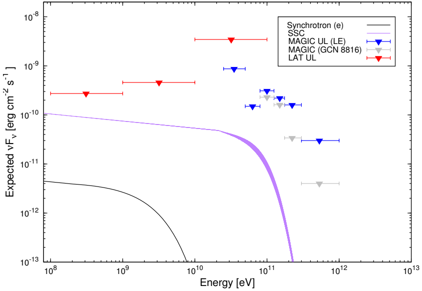
- Detected by *Swift* BAT, then by *Fermi* GBM, *Konus Wind* and *Integral* → good reconstruction of the prompt spectral parameters
- Long burst: $T_{90} = (27 \pm 2)\,\mathrm{s}$
- Redshift: $z = 1.547$
- Optical flux: broken power law $\alpha_1 = 1.50 \pm 0.06$ $\alpha_2 = 0.97 \pm 0.03$
- MAGIC observations from $T_0 + 1161\mathrm{s}$ in mono mode
- Zenith range: 5°-52°
- $T_{\mathrm{obs}} = 13\,149\,\mathrm{s}$ (only the first 5919 s used)
- Sum trigger used: $E_{\mathrm{thr}} \sim 30\,\mathrm{GeV}$
- Contemporaneous observation with Fermi-LAT



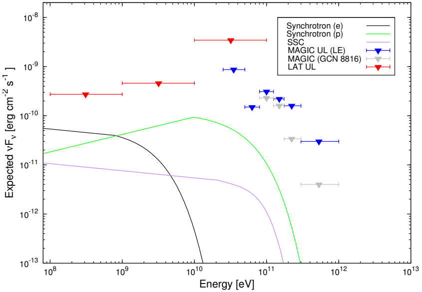
Aleksic et al. (2014)

GRB090102: UL on HE/VHE emission

- Prompt emission from internal shocks and afterglow from external shocks
- SSC (leptonic version) mechanism with relevant parameters ν_m and ν_c
- Model strongly dependent on GRB environment: outburst medium density n, energy equipartition parameters ϵ_e and ϵ_b, Compton parameter Y_e



Aleksic et al. (2014)

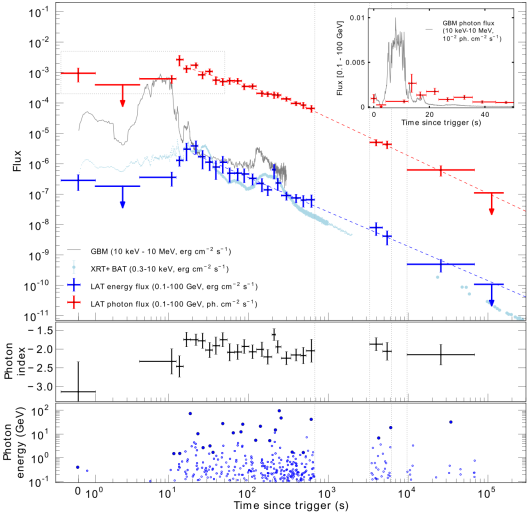


Aleksic et al. (2014)

- $E_{52} = 4.5$, $\epsilon_e = 0.001$, $\epsilon_b = 0.01$, $n = 100\,\mathrm{cm}^{-3}$ (leptonic)
- Leptonic vs hadronic component

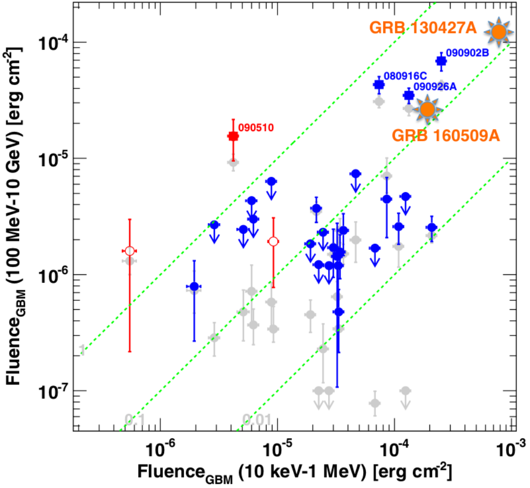
Late time observations

- Many LAT detected GRBs show late time (delayed) emission in the (early) afterglow phase
- MAGIC is changing its GRB observation strategy to include this kind of observations, observing events after ∼1 day



GRB130427A: Ackermann et al. 2014

Late time observations: GRB160310A and GRB160509A



GRB160310A

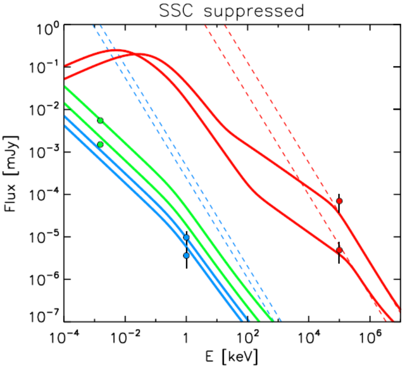
- T_0: 2016/03/10 – 00:22:42 UT
- T_{start}: 2016/03/10 – 20:30:16 UT
- Duration: 1h on on 2016/03/10-11-13
- Delay: $\sim$ 20 hours
- Zenith range: 35°-37°

GRB160509A (3rd on-board trigger fo LAT)

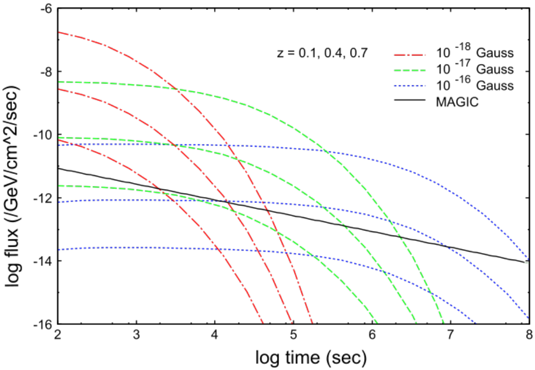
- T_0: 2016/05/09 – 08:59:04 UT
- T_{start}: 2016/05/11 – 21:21:07 UT
- Duration: 3h (2016/05/11), 4.5h (2016/05/12)
- Delay: $\sim$ 2.5 days
- Zenith range: 60°-72°

Upper limits: what for? Some examples

- Distinction between different HE/VHE models
- Direct upper limits on SSC emission if it dominates over synchrotron component (see Beniamini et al. 2015)
- Lower limits on IGMF from upper limits on the pair echo emission (see Takahashi et al 2008)

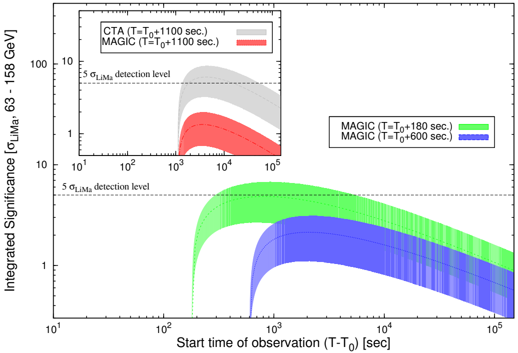


Beniamini et al. 2015



Takahashi et al 2008

Prospects for GRB observation and HE emission



Aleksic et al. (2014)

For MAGIC:

- Cross-check and UL of past years GRBs (2013-now) ⇒ my past/current work
- Low-energy optimized analysis
- Use of the sum trigger in stereo mode for GRBs
- More luck! (less distant GRBs, good weather)
- A paper in preparation with the good observed GRBs since 2013

For the future:

- CTA (Cherenkov Telescope Array) will have a sensitivity higher than current IACTs
- GRB detection possible even for a late time observation

Summary

MAGIC is a good IACT for catching GRBs (low energy threshold, fast repositioning) and observing their HE/VHE emission

HE/VHE emission from GRBs is very useful for several reasons:

- put constraints (also UL are useful!) on emission mechanisms
- discriminate between leptonic and hadronic scenarios
- discriminate between different EBL models

Multi-wavelength observations help in constraining the parameters of the emission models

THANK YOU FOR YOUR ATTENTION!
QUESTIONS?