Theoretical implications on the very high energy emission from GRB 190114C

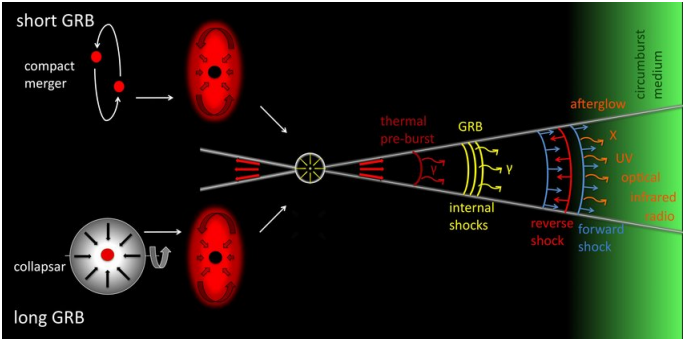
Davide Miceli
on behalf of the MAGIC Collaboration

University of Udine & INFN Trieste → **Laboratoire d'Annecy de Physique des Particules (LAPP)**

16th Marcel Grossmann meeting, 5th July 2021

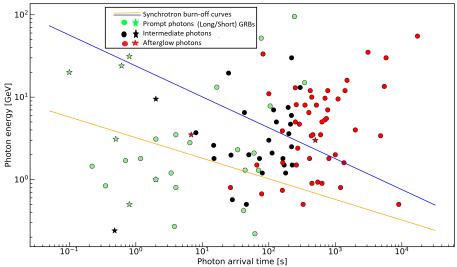
The picture before GRB 190114C

- The **Very High Energy (VHE)** emission component
  - Is it there? Up to TeV?
  - Is it common in all GRBs?
  - Radiation processes?
  - Relationship with lower energy component?

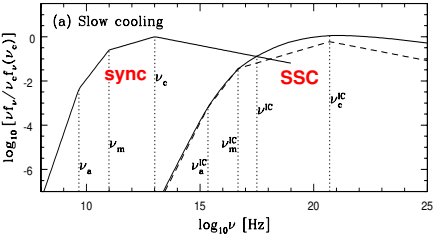


The picture before GRB 190114C

Why search for VHE emission?



Nava, 2018

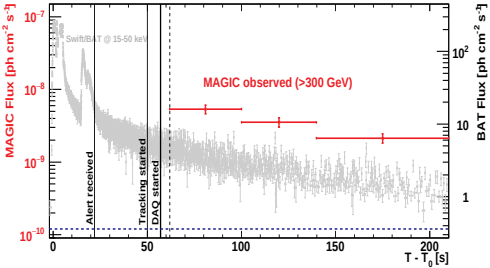


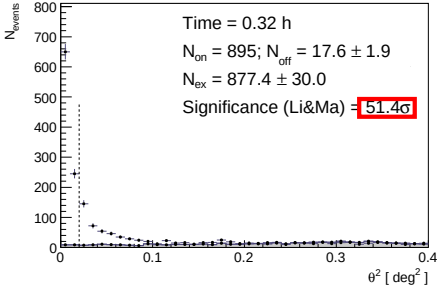
Sari & Esin, 2001

Theoretically expected but only observational hints

MAGIC detection of GRB 190114C

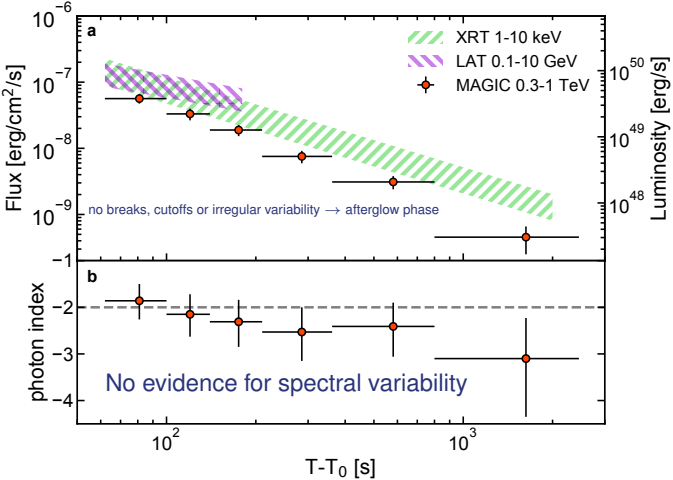
- Triggered by Swift-BAT on January 14, 2019 at 20:57:03 UT
- $T_{90} \sim 116$ - 362 s $\rightarrow$ **Long GRB**
- Redshift z = 0.4245
- Multiwavelength campaign from 1.3 GHz up to TeV





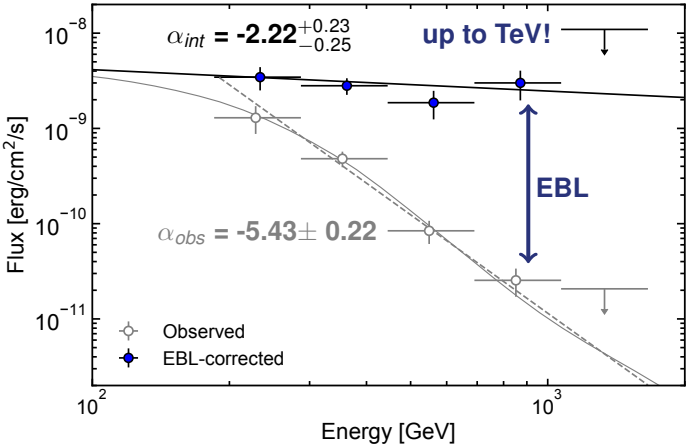
MAGIC Collaboration et al., 2019

X-ray, GeV and TeV light curves



MAGIC Collaboration et al., 2019. *Nature* 575, 455

MAGIC spectral energy distribution

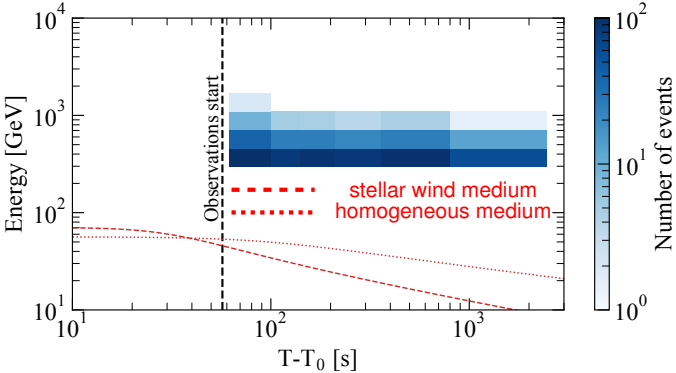


MAGIC Collaboration et al., 2019. *Nature* 575, 455

Synchrotron burnoff limit

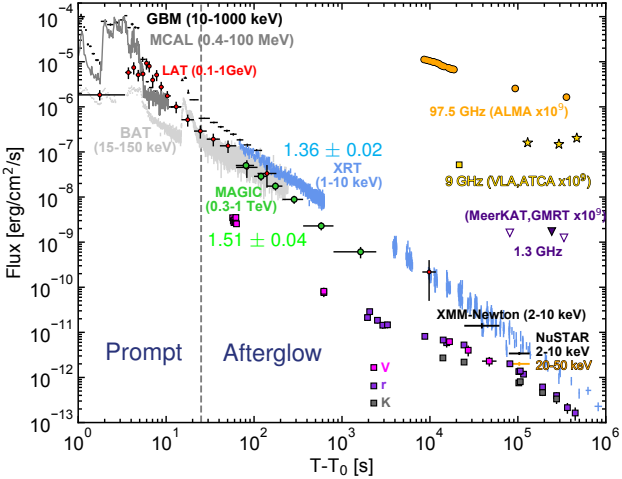
Maximum energy for synchrotron photons:

$$\varepsilon_{max}(t) \approx 100\ \mathrm{MeV}\,\frac{\Gamma(t)}{1+z}$$



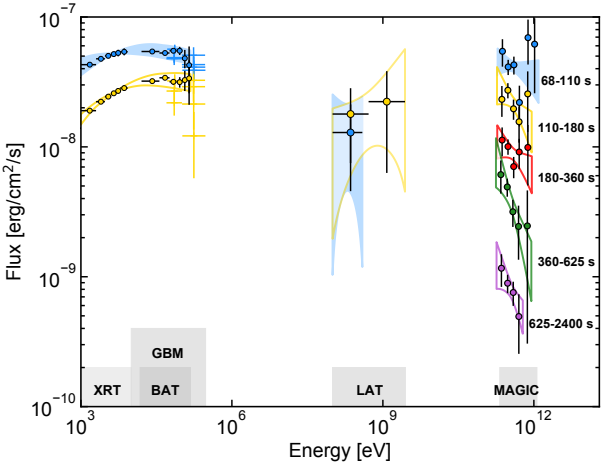
MAGIC Collaboration et al., 2019. *Nature* 575, 455

MWL light curve



MAGIC Collaboration et al., 2019. *Nature* 575, 459

MWL time-binned spectra



MAGIC Collaboration et al., 2019. *Nature* 575, 459

X-ray + GeV + TeV

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Spectral hardening for E > 0.2 TeV

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Can't be extention of Synchrotron component

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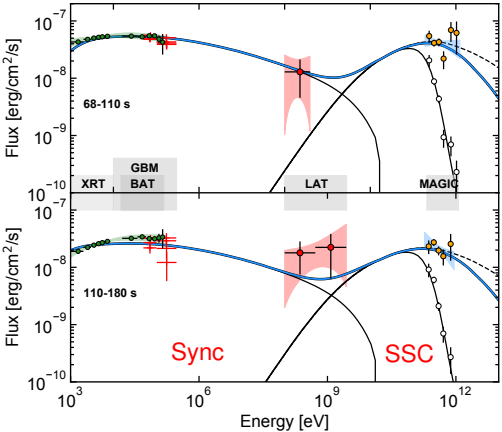
New emission component at VHE

MWL modeling

Sync + SSC external forward shock scenario



MAGIC Collaboration et al., 2019. *Nature* 575, 459

Observed

No γ-γ opacity

EBL-deabsorbed

MAGIC soft spectrum:

- Klein-Nishina
- γ-γ internal absorption

GRB afterglow parameters:

$E_k \gtrsim 3 \times 10^{53}$ erg

$\varepsilon_e \approx 0.05\text{-}0.15$

$\varepsilon_b \approx 0.05\text{-}1 \times 10^{-3}$

$n \approx 0.5\text{-}5$ cm^{-3}

$p \approx 2.4\text{-}2.6$

Results

190114C: a unique milestone for the study of GRB physics

- Clear detection of VHE emission **extend up to TeV**
- VHE component: **Synchrotron Self Compton** radiation mechanism
- First ever modeling of afterglow GRB multi-band data from radio to VHE $\rightarrow$ **Sync + SSC external fwd shock scenario**
- Sync and SSC component with comparable amount of power
- Afterglow modeling parameters $\rightarrow$ universality of VHE component in GRBs
- EBL impact on VHE component is consistent
- LIV limits with GRB 190114C (MAGIC Collaboration et al., 2020. *Phys. Rev. Lett.* 125)

GRB 190114C allows to explore many key questions for the first time...

Future

...but still a lot need to be addressed yet

- GRB populations at VHE is increasing:
  GRB 180720B, GRB 190114C, GRB 190829A, GRB 201216C,
  GRB 160821B (hint), GRB 201015A (hint)
- Sync + SSC one zone model? Structured jets? Off-axis view?
- Short GRBs $\rightleftarrows$ gravitational wave events

The work done on analysis and interpretation of GRB 190114C will be a reference point for future studies