Hadronic And Leptonic Processes in Extragalactic Sources:

a multi-messenger, multi-source approach to unveil the origin of γ-ray radiation and neutrinos

— Lara Nava —
INAF

Annual report 2019

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January 14th 2019: discovery of TeV radiation from GRBs

MAGIC ATel

First time detection of a GRB at sub-TeV energies; MAGIC detects the GRB 190114C

ATel #12390; ***Razmik Mirzoyan on behalf of the MAGIC Collaboration***
on 15 Jan 2019; 01:03 UT
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, Gamma-Ray Burst

Referred to by ATel #: 12395, 12475

Tweet

The MAGIC telescopes performed a rapid follow-up observation of GRB 190114C (Gropp et al., GCN 23688; Tyurina et al., GCN 23690, de Ugarte Postigo et al., GCN 23692, Lipunov et al. GCN 23693, Selsing et al. GCN 23695). This observation was triggered by the Swift-BAT alert; we started observing at about 50s after Swift T0: 20:57:03.19. The MAGIC real-time analysis shows a significance >20 sigma in the first 20 min of observations (starting at T0+50s) for energies >300GeV. The relatively high detection threshold is due to the large zenith angle of observations (>60 degrees) and the presence of partial Moon. Given the brightness of the event, MAGIC will continue the observation of GRB 190114C until it is observable tonight and also in the next days. We strongly encourage follow-up observations by other instruments. The MAGIC contact persons for these observations are R. Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de) and K. Noda (nodak@icrr.u-tokyo.ac.jp). MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatory Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.

GeV-TeV observations of GRBs:
the state-of-the-art (before Jan 14, 2019)

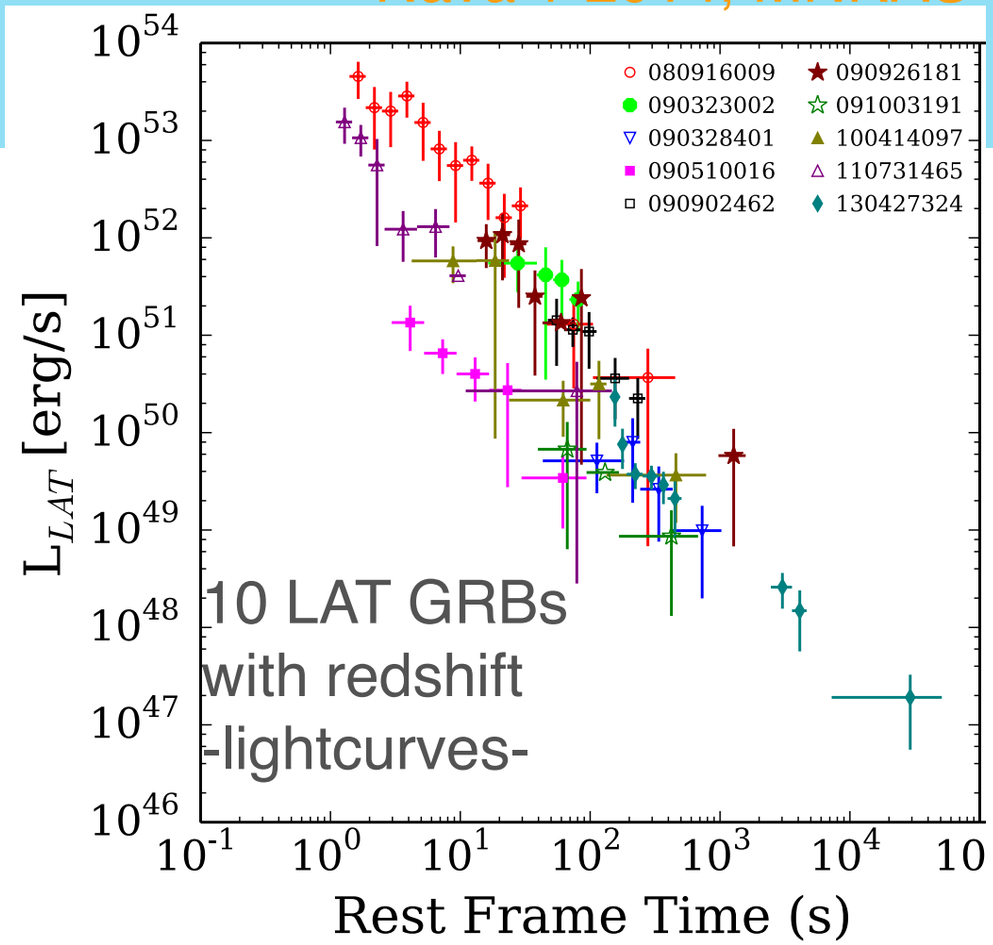
Space Missions:

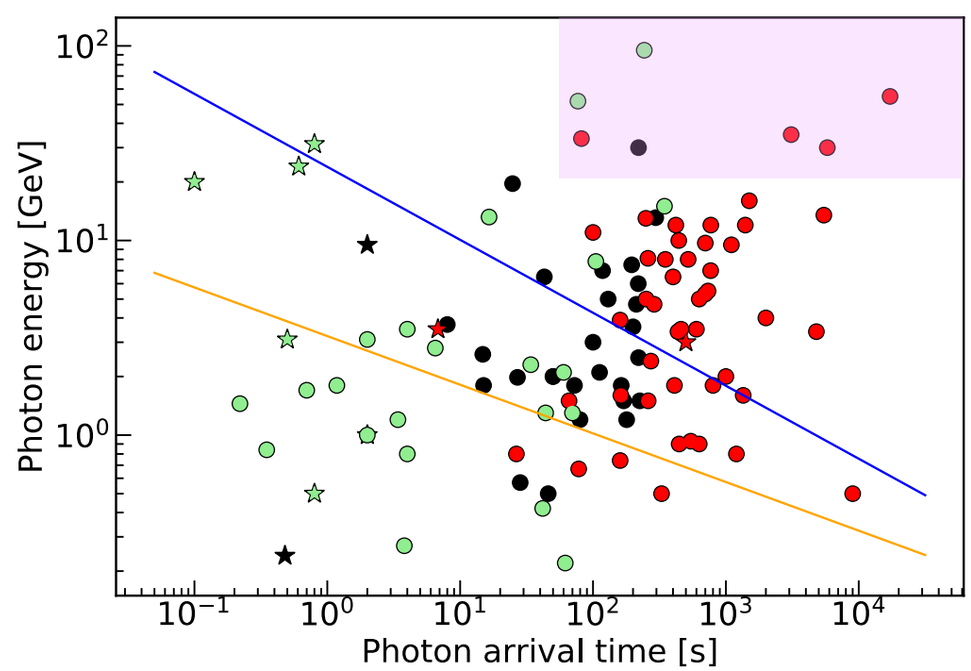
- CGRO-EGRET (20 MeV - 30 GeV)
  - 6 GRBs
  - 18 GeV photon 75 minutes after prompt

- AGILE-GRID (30 MeV - 50 GeV)
  - 9 GRBs (one short)
  - confirm long-lasting emission, PL decay

- Fermi-LAT (20 MeV - 300 GeV)
  - 180 GRBs (160 Long + 20 Short)
    - 12% of GBM bursts within FoV
    - 40 with redshift (0.145 - 4.35)
    - 18 between 20 GeV - 95 GeV
  - up to 10^4 seconds after prompt

Nava + 2014, MNRAS





Nava 2018, review HE emission from GRBs, 2018, IJMPD, 2742003, arXiv:1804.01524

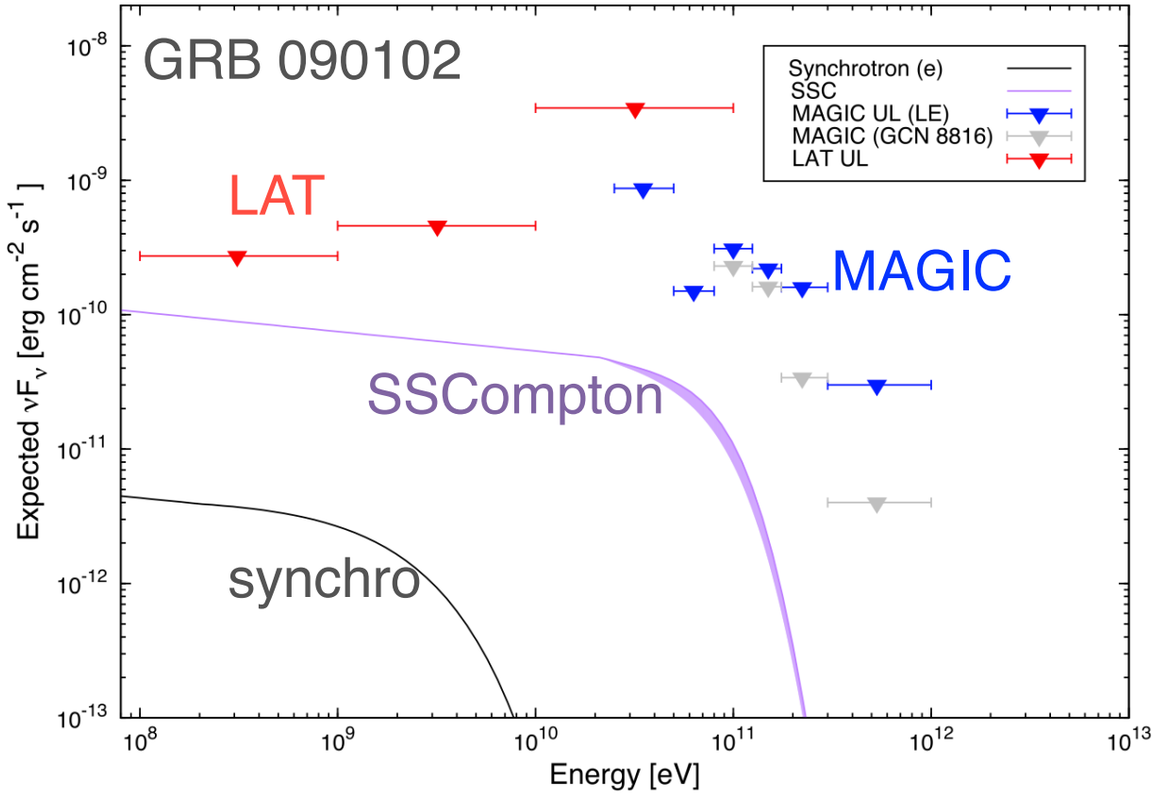
GeV-TeV observations of GRBs:
the state-of-the-art (before Jan 14, 2019)

Ground Observations (IACT - EAS)

- MAGIC / HESS / VERITAS
  - number of observed GRBs:
    - hundred / several tens
  - low energy threshold:
    - 50 / 50 / 100 GeV
  - time delay:
    - < 100 s / 100-1000 s

- HAWC
  - > 50 GeV, no time delay, 100 GRBs observed so far

Aleksic + 2014



— No detections, only upper limits —

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Fermi/GBM-LAT,
Swift/BAT-XRT-UVOT,
AGILE, INTEGRAL

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nIR-optical-UV (GROND, REM, LT, NOT, OASDG, NTT)
radio, submm (ATCA, VLA, ALMA, MeerKAT, GMRT, JCMT)
X-ray (NuSTAR, XMM)

Scheme of my Astrofit2 project

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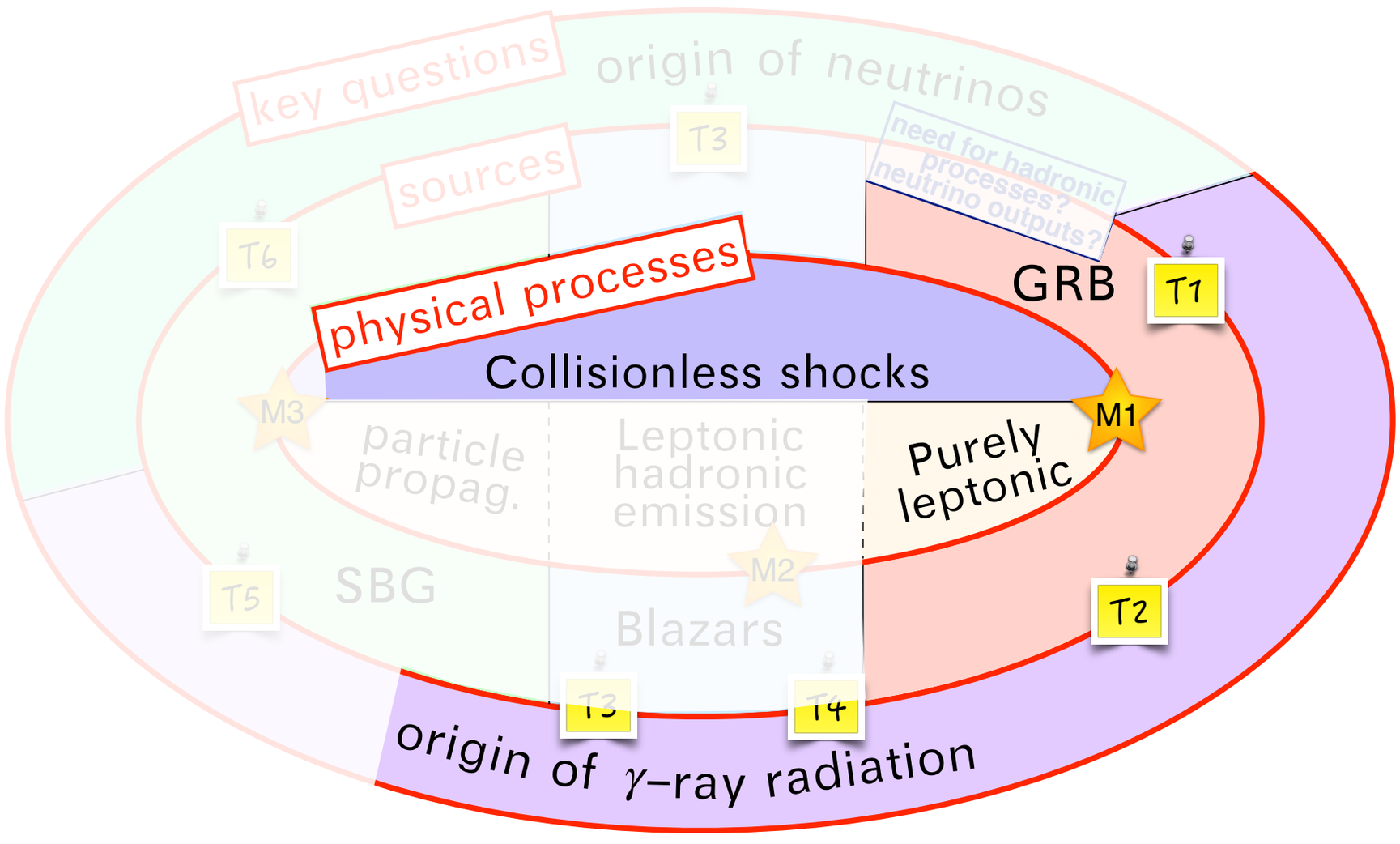


M1 Completion of leptonic code

T1 Modeling of LAT observations

T2 Modeling at GeV-TeV and CTA detectability

GRB 190114C - publications

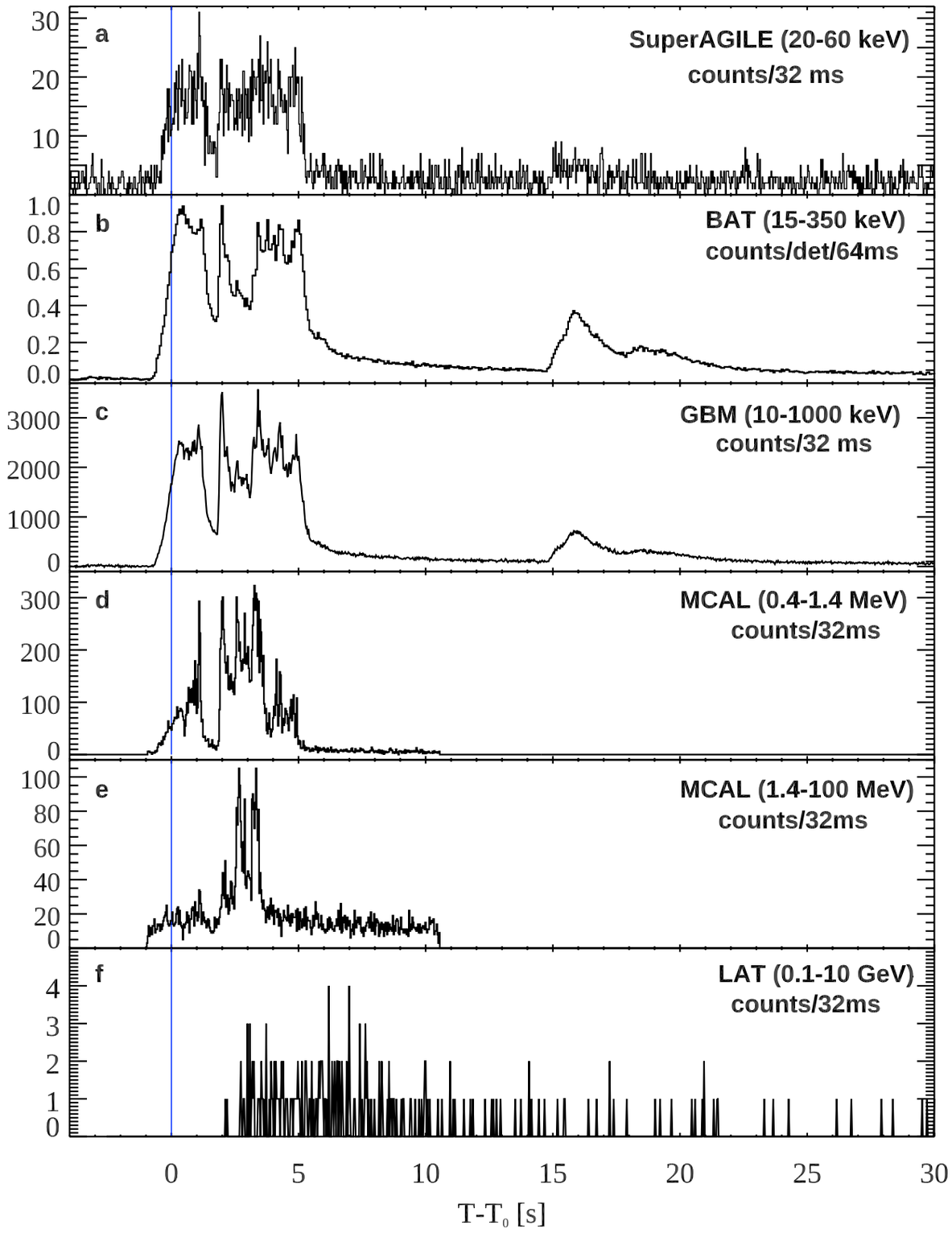
Two papers accepted by Nature - to be published in mid-November 2019

➡ MAGIC collaboration & LN

➡ MAGIC collaboration, LN, Fermi, Swift, AGILE + MWL community

GRB 190114C - prompt emission

Prompt emission light curves in different energy ranges



Long GRB (prompt duration >2), collapse of the core of a massive star

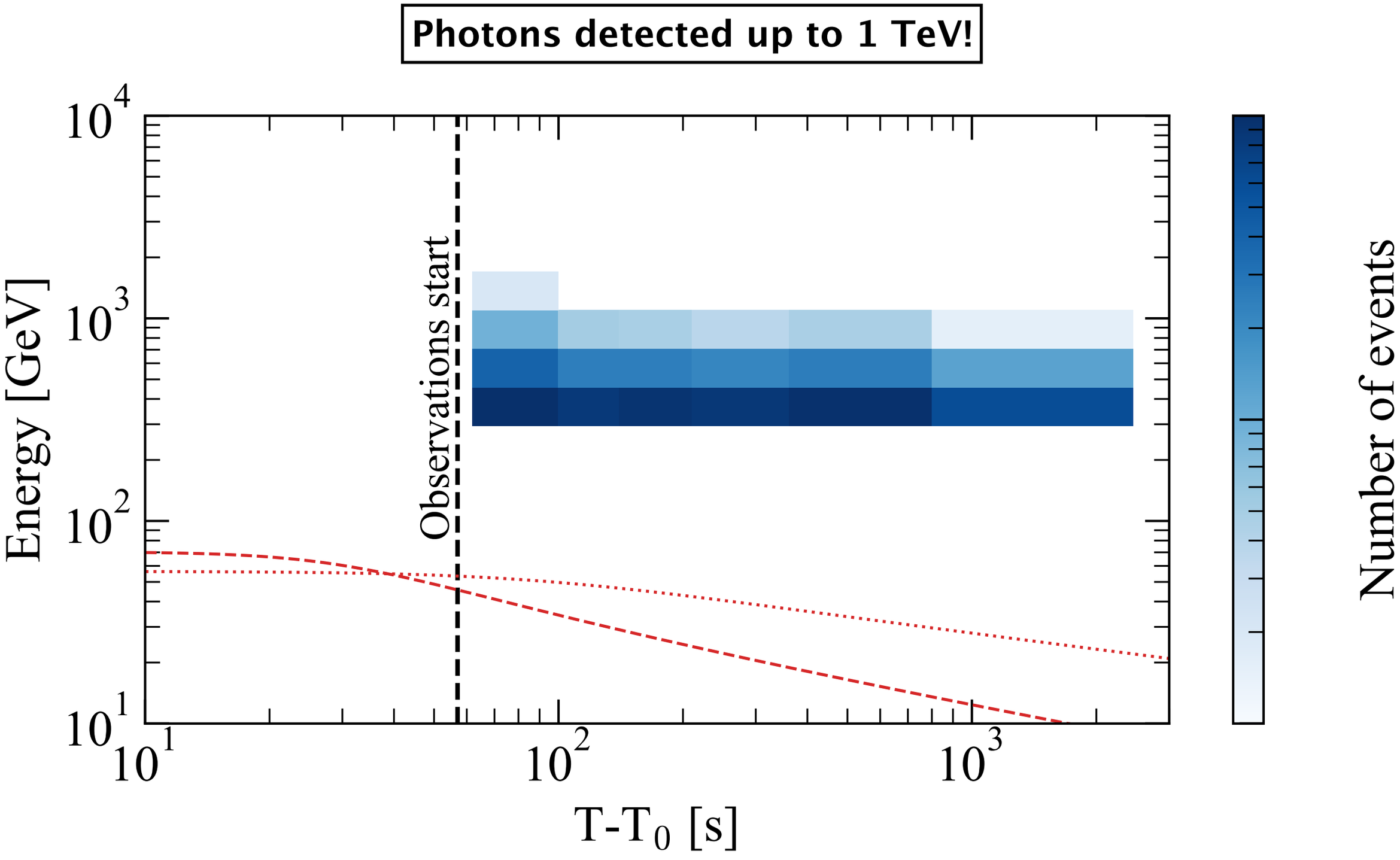
Redshift z = 0.424

Energy released during the prompt (1keV–10MeV)
E = 3×10^{53} erg

MAGIC collab. et al, Nature in press

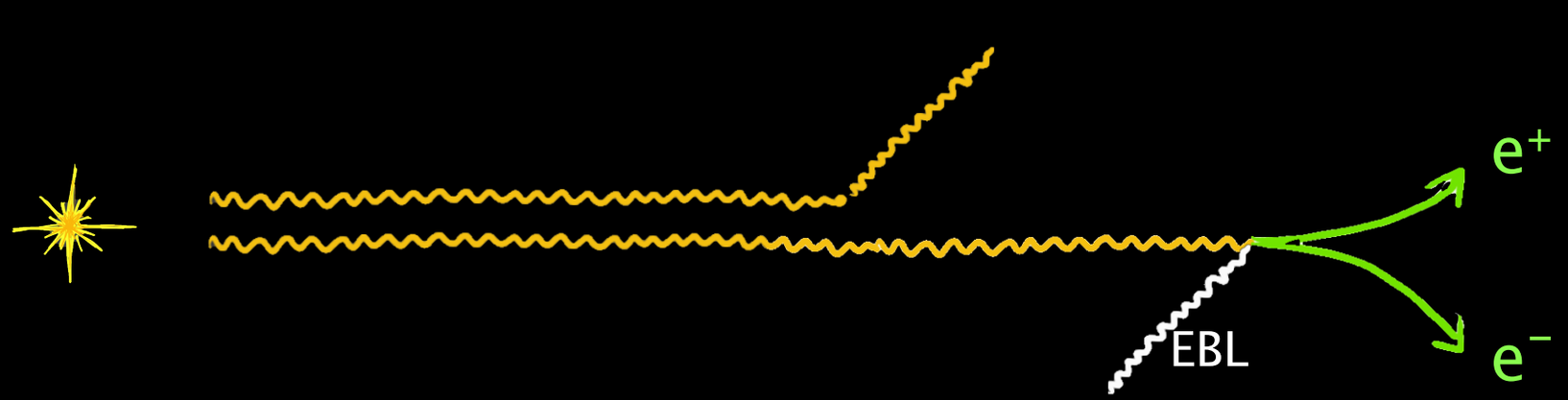
Discovery paper, MAGIC collaboration

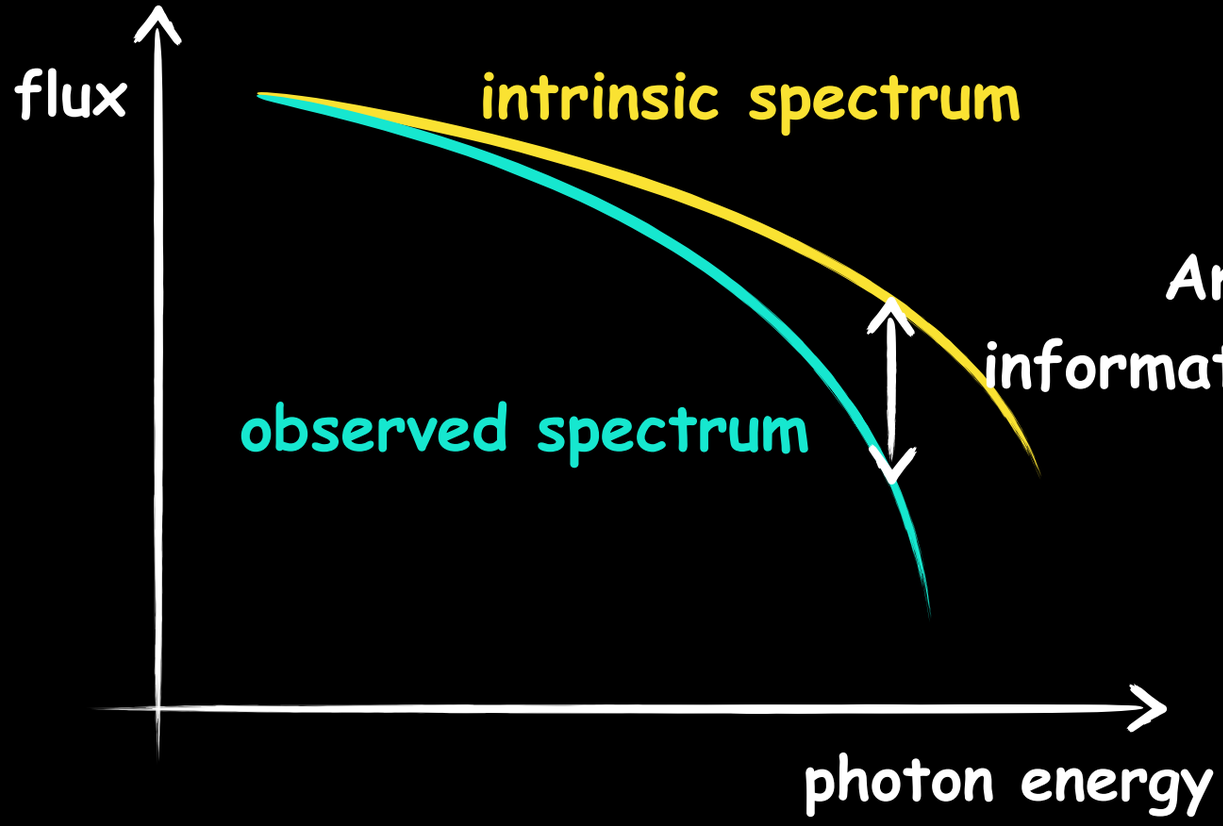
Nature, accepted (to be published in mid-November)



Photons

the Universe is not completely transparent to photons



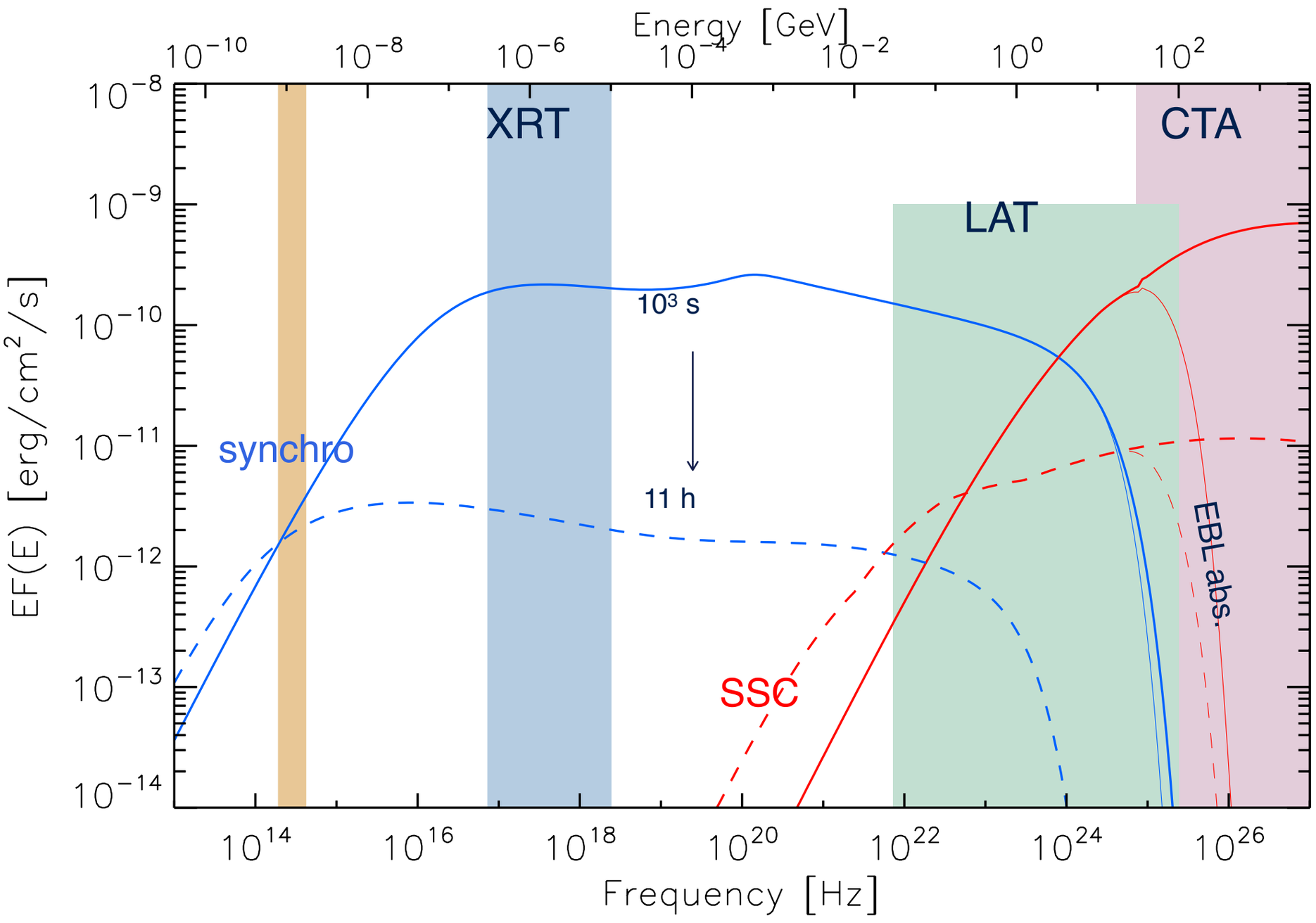


Amount of attenuation holds the information about absorbers/magnetic field/ background radiation fields…

…but we need to know the intrinsic spectrum first

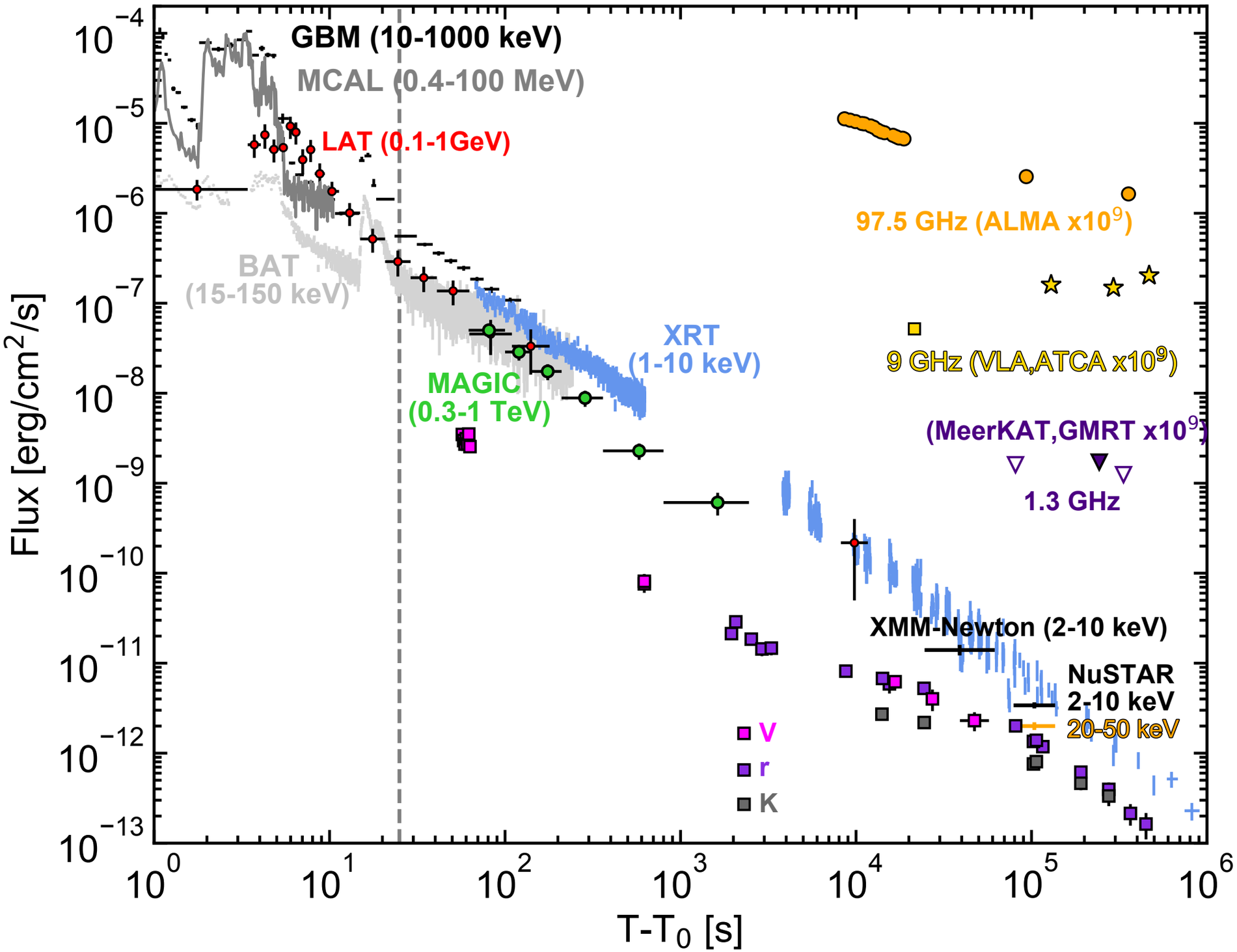
Example of broadband SED

synchrotron (blue) and SSC (red) spectra



190114C - Afterglow emission

First TeV lightcurve of a GRB!



Discovery paper, MAGIC collaboration

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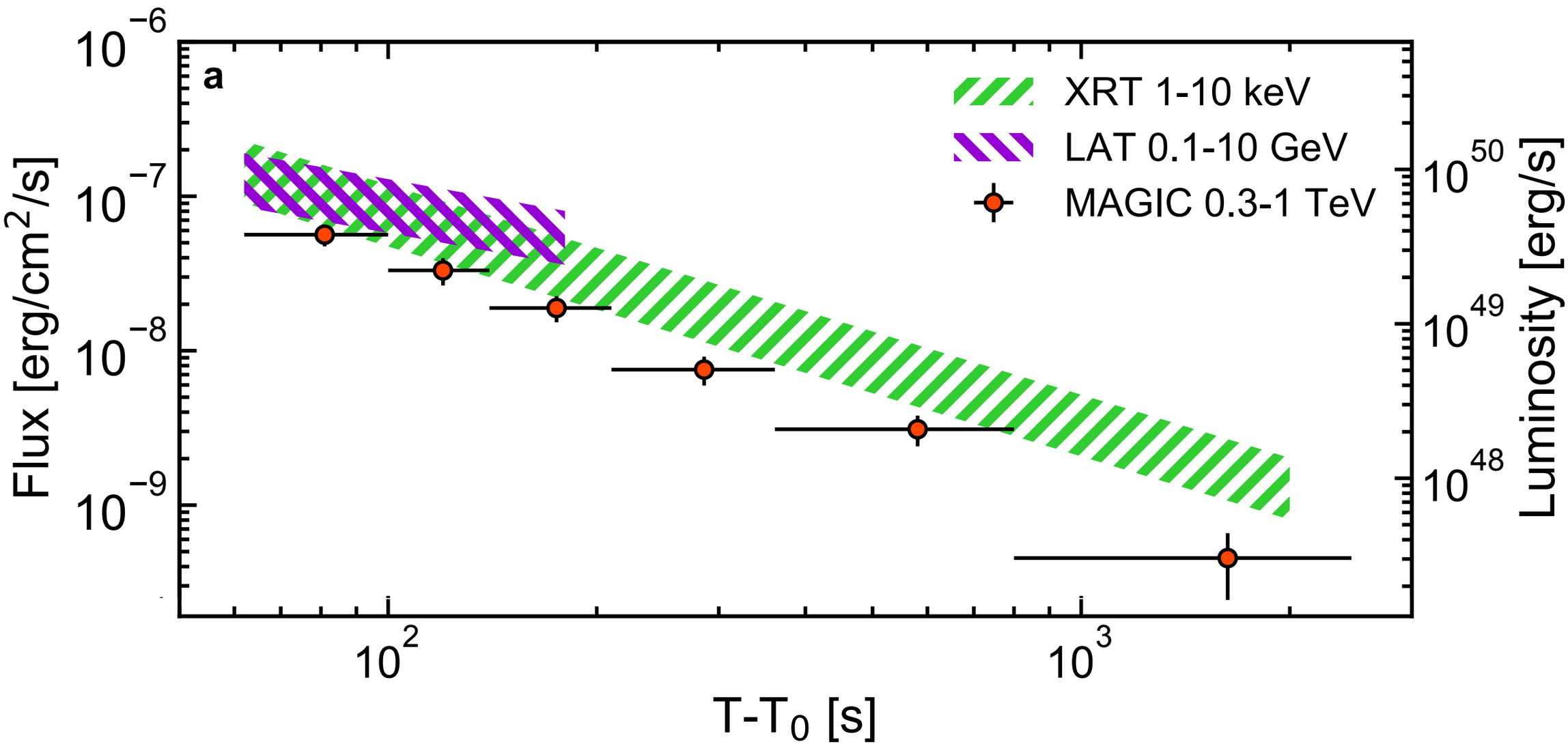
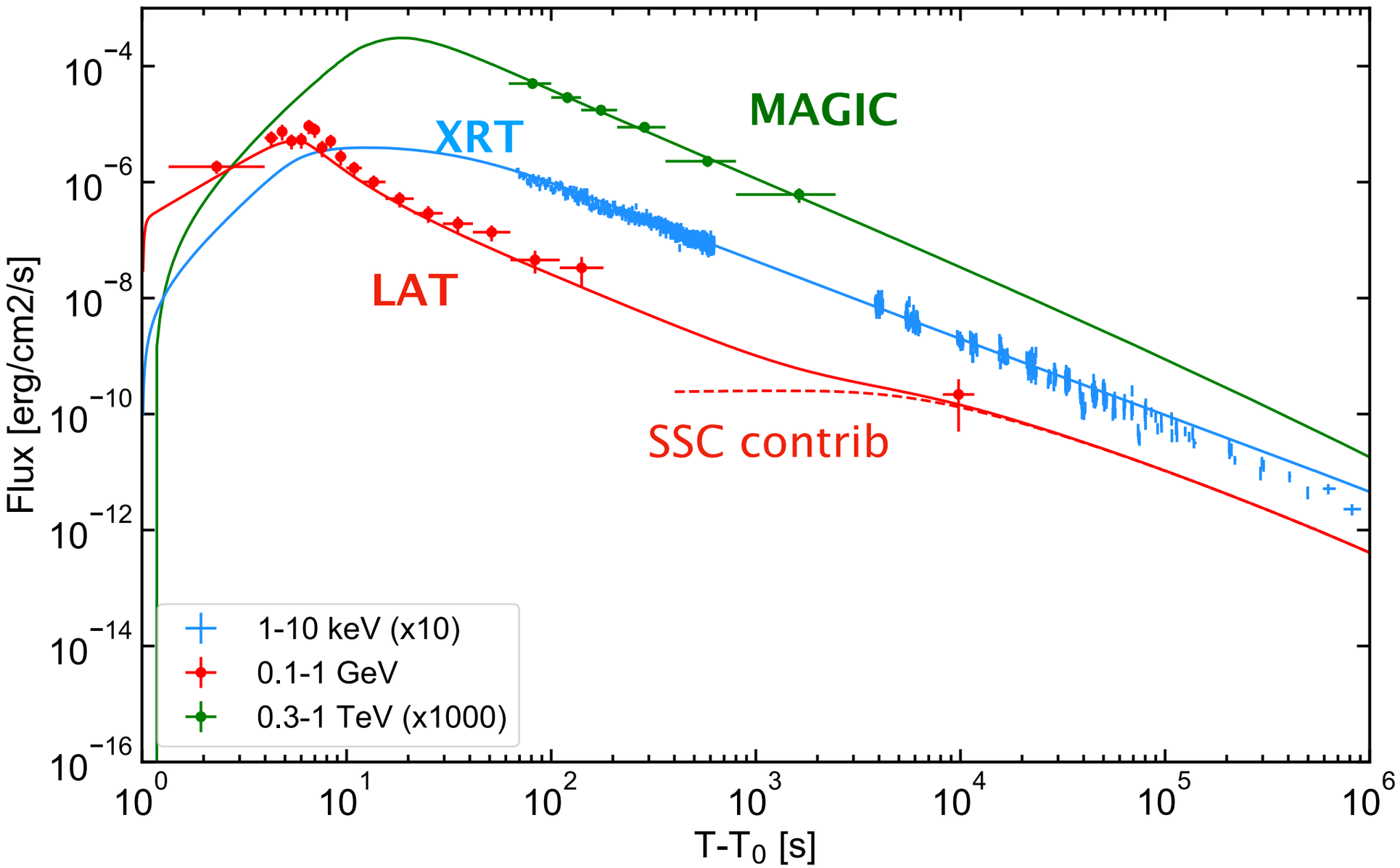


MWL paper, MAGIC collaboration +

Nature, accepted (to be published in mid-November)

First modeling of TeV emission from a GRB!



Observations / Modeling of TeV afterglow emission

- ➡ Broadband SED: double bump! Separated spectral component: DISCOVERY of SSC radiation

- ➡ Energy in SSC is similar to energy in synchrotron

- ➡ Constraints on parameters of the shock

- ➡ Observational strategies need to be revised!

TeV emission from GRBs: future prospects

GRB name	Redshift	E(prompt) (erg)	$T-T_0$	sign. (sigma)	Telescope
160821B SHORT	0.16	10^{50}	1.5-4 h	3.1	MAGIC
180720B LONG	0.653	$6x10^{53}$	10h	5	H.E.S.S
190114C LONG	0.424	$3x10^{53}$	60 - 2400 s	50	MAGIC
190829A LONG	0.078	$2x10^{50}$	4-8 h	>5	H.E.S.S

Relevance of GeV-TeV GRB studies

- In GRB physics
  - reveal the presence of an inverse Compton component
  - understand the nature of the radiative processes
  - place constraints on the magnetic field strength

- In other fields of astrophysics/ fundamental physics
  - EBL: GRBs are complementary to AGNs
  - LIV: Lorentz Invariance Violation tests
  - Physics of relativistic shocks

End of the fellowship: February 2020

- TeV emission from GRBs
  - modeling of other MAGIC observations
  - revisit LAT detections in light of discovery of SSC component

- TeV halos in PWN
  - collaboration with CR group at Osservatorio Astrofisico di Arcetri (6 week visit in June-July 2019)
  - study of self-confinement of CR as possible source of TeV halos
  - 3-week visit planned in November
  - application to Geminga TeV halo