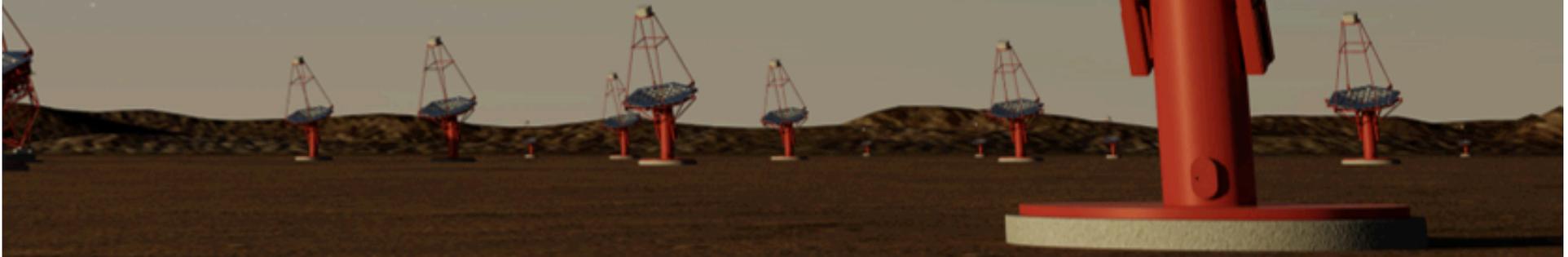


Prospects for Gamma-Ray Burst detection by the Cherenkov Telescope Array



E. Bissaldi, T. Di Girolamo,
F. Di Pierro, T. Gasparetto,
F. Longo, D. Missoni, M. Palatiello,
P. Vallania, C. Vigorito, and others



Goals

- Understand the possibility of detecting GRB with the full CTA array using **ctools**
- Detection of GRB with LST
- Better estimate of the GRB rate for CTA

GRB with CTA

- **This work focuses on Fermi-like GRBs with measured redshift**
- **Main goal:**
 - **Setting up a library of GRBs as observed by LAT simulated at different epochs for CTA**
- **Procedure:**
 - **Extrapolation of the LAT flux to CTA energies**
 - **Flux estimation at different post triggers epochs, taking into account the flux temporal evolution**
- **Preliminary results**
 - **Proceedings of RICAP16 & Scineghe16 conferences (Bissaldi +16, Bissaldi+17)**

Previous work

Prospects for Gamma-Ray Bursts detection by the Cherenkov Telescope Array

Elisabetta Bissaldi, Tristano Di Girolamo, Francesco Longo, Piero Vallania, Carlo Vigorito (for the CTA Consortium)

(Submitted on 4 Sep 2015)

The first Gamma-Ray Burst (GRB) catalog presented by the Fermi–Large Area Telescope (LAT) collaboration includes 28 GRBs, detected above 100 MeV over the first three years since the launch of the Fermi mission. However, more than 100 GRBs are expected to be found over a period of six years of data collection thanks to a new detection algorithm and to the development of a new LAT event reconstruction, the so-called "Pass 8." Our aim is to provide revised prospects for GRB alerts in the CTA era in light of these new LAT discoveries. We focus initially on the possibility of GRB detection with the Large Size Telescopes (LSTs). Moreover, we investigate the contribution of the Middle Size Telescopes (MSTs), which are crucial for the search of larger areas on short post trigger timescales. The study of different spectral components in the prompt and afterglow phase, and the limits on the Extragalactic background light are highlighted. Different strategies to repoint part of – or the entire array – are studied in detail.

arXiv:1509.01438

Work for the FermiSymposium

- Poster at the Fermi Symposium
- Short GRB 090510



Prospects for Gamma-Ray Bursts detection by the Cherenkov Telescope Array

E. Bissaldi⁽¹⁾, T. Di Girolamo^(2,3), F. Di Pierro^(4,5), F. Longo^(6,7), P. Vallania^(4,5), C. Vignorito^(7,8), for the CTA Consortium⁽⁹⁾

(1) INFN Bari, Italy (2) Università degli Studi di Napoli, Italy (3) INFN Napoli, Italy (4) INFAP-OATo, Italy (5) INFN Torino, Italy (6) Università degli Studi di Trieste, Italy (7) INFN Trieste, Italy (8) Università degli Studi di Torino, Italy (9) See www.cta-observatory.org for full author & affiliation list

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ABSTRACT The first Gamma-Ray Burst (GRB) catalog presented by the Fermi-Large Area Telescope (LAT) collaboration includes 26 GRBs, detected above 100 MeV over the first three years since the launch of the Fermi mission. However, more than 100 GRBs are expected to be found over a period of six years of data collection thanks to a new detection algorithm and to the development of the new LAT event reconstruction "Pass 8". Our aim is to provide revised prospects for GRB alerts in the Cherenkov Telescope Array (CTA) era in light of these new LAT discoveries. We initially focus on the possibility of high-energy GRB detection with the full CTA array by simulating the observation of two extremely bright test cases, GRB 130427A and GRB 090510. Furthermore we investigate how these GRBs would be seen by part of the array (e.g. only by the Large Size Telescopes, or by a subsample of the Mid-sized Telescopes) pointing initially towards different directions.

Supported by:



1. CTA configurations

In its current design, CTA consists of two arrays for a total amount of more than 100 telescopes, one in the Southern (Paranal, Chile) and one in the Northern (La Palma, Spain) hemisphere, including:

- Large Size Telescopes (LSTs)
 - 20 GeV – 100 GeV, N = 3 or 4, D = 23 m
 - Compact placement
- Medium Size Telescopes (MSTs)
 - 100 GeV – 10 TeV, N = ~25, D = 12 m
 - A = ~3 km²
- Small Size Telescopes (SSTs – only South)
 - 10 TeV – 100 TeV, N = ~70, D = 4 m
 - A = 6 – 7 km²

2. High-energy GRB observations

Our sample:

- Second Fermi-Gamma Ray Burst Monitor (GBM) GRB catalog [1]
 - ~1000 GRBs, 4 yrs, 8 keV – 40 MeV
- First Fermi-LAT GRB catalog [2]
 - ~35 GRBs, 3 yrs, 30 MeV – 300 GeV
- Second Fermi-LAT GRB Catalog [3]
 - ~100 GRBs, 6 yrs, 30 MeV – 300 GeV

Aims:

- Focus on Fermi-like GRBs with redshift (both prompt and late-time emission)
- Creation of a library of GRBs observed at different post-trigger epochs
- Extrapolation of the LAT flux to the highest energies, taking into account the flux temporal evolution.
- Test cases: two very bright GRBs with redshift (a long and a short one)

3. Effect of the EBL

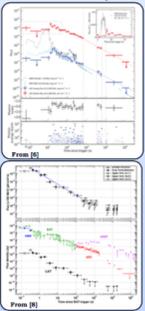
Cosmologically distant GRBs may be useful to add stronger constraints on EBL models and to give new hints on the existence of Axion-Like Particles.

Future steps:

- Inclusion of the EBL model [4]
- Extension of the spectrum up to 1 TeV.

4. Simulation of GRB observations with ctools

We base our GRB predictions on the use of ctools v0.9.0 [5]



Test case 1:
Extremely fluent long GRB 130427A (z = 0.34)

- Spectral and temporal parameters [from 6]:
 - $\gamma = -2.2$
 - $\tau = -1.35$

ctools input:

- E = 50 – 100 GeV (No EBL yet)
- On axis obs ($\theta = 20^\circ$)
- IRFs: North_0.5h + North_5h [7]

Test case 2:
Bright short GRB 090510 (z = 0.9)

- Spectral and temporal parameters [from 8,9]:
 - $\gamma = -1.6$ (t < 200 s), -2.5 (t > 200s)
 - $\tau = -1.38$

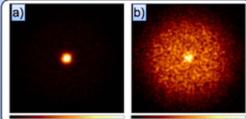
ctools input:

- E = 50 – 100 GeV (No EBL yet)
- On axis obs ($\theta = 20^\circ$)
- IRFs: North_0.5h + North_5h [7]

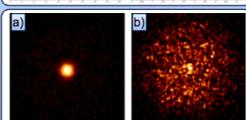
Results:
We obtain count maps at different epochs. Further analysis in progress!

GRB 130427A

a) 10 min observations
@ $T_{\text{obs}} = 1000$ s

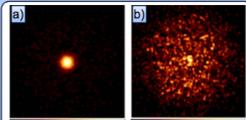


b) 1 hour observations
@ $T_{\text{obs}} = 10$ ks



GRB 090510

a) 100 s observations
@ $T_{\text{obs}} = 100$ s



b) 500 s observations
@ $T_{\text{obs}} = 1000$ s



ACKNOWLEDGEMENTS

We gratefully acknowledge support from the agencies and organizations under Funding Agencies at www.cta-observatory.org

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- [1] A. von Kienlin et al., *ApJSS* 211, 13 (2014)
- [2] M. Ackermann et al., *ApJSS* 209, 11 (2013)
- [3] G. Vianello et al., *eConf C141020*.
- [4] A. Franceschini, et al., *AAJ* 487, 837 (2008)
- [5] <http://cta.lbg.omp.eu/ctools/index.html>
- [6] M. Ackermann, et al., *Science* 343, 42 (2014)
- [7] <https://portal.cta-observatory.org/Pages/CTA-Performance.aspx>
- [8] De Paepe et al., *ApJL* 709, 146 (2012)
- [9] M. Ackermann, et al., *ApJ* 716, 1178 (2010)

F.Longo et al.

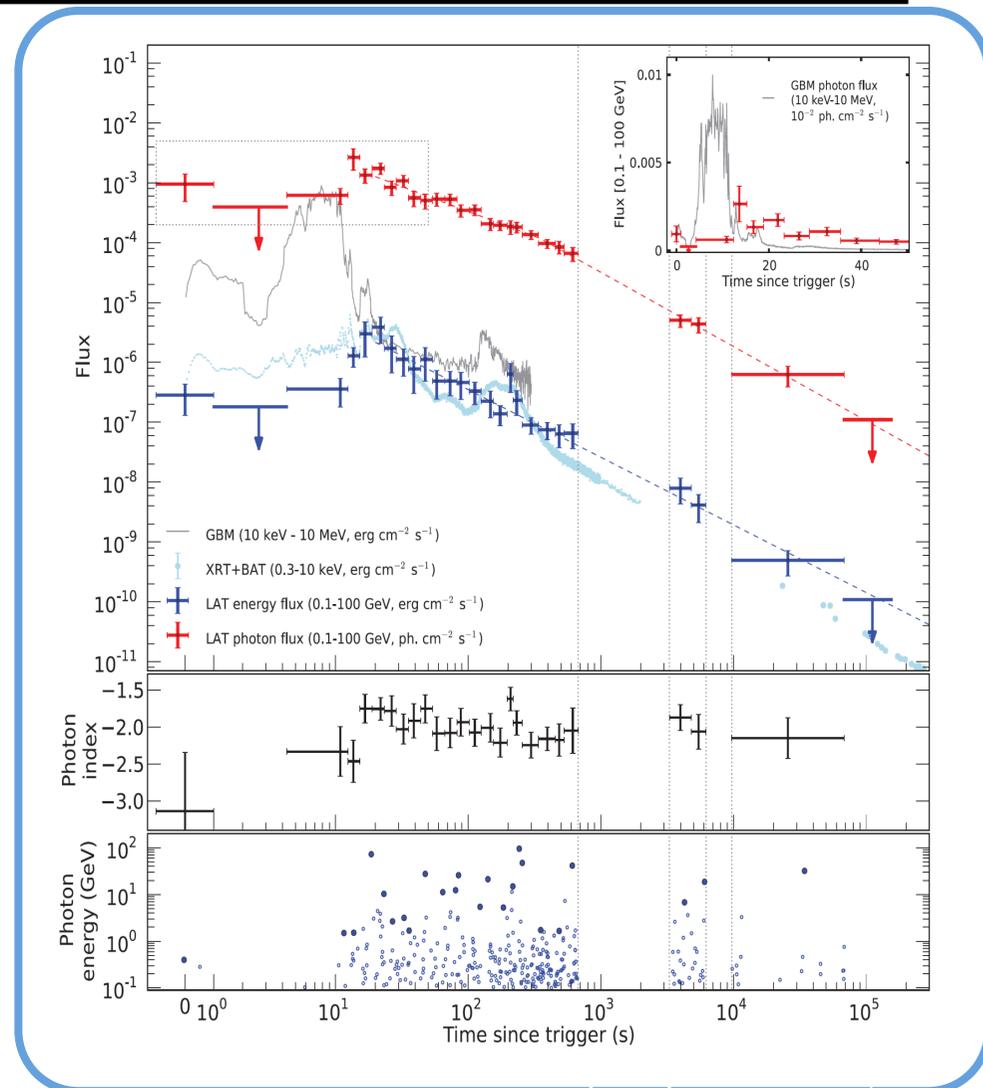
GRB studies with CTA



Test cases

1. GRB 130427A

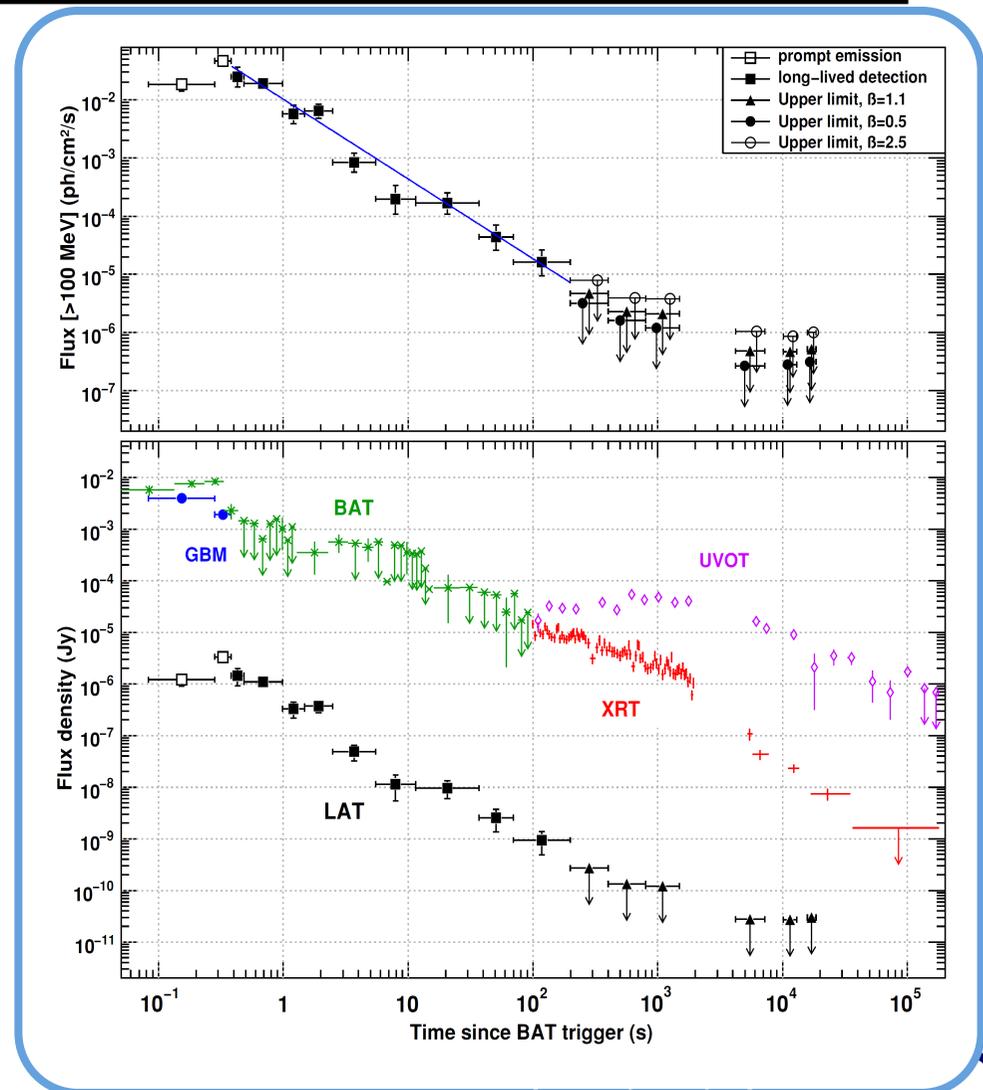
- Long GRB
- Max photon energy:
95 GeV (current record!)
- Redshift $z = 0.34$
- Spectral index
 $\gamma = -2.2$ (almost constant
from 400 s up to 70 ks after
the trigger)
- Temporal index
 $\tau = -1.35$
(valid for $t > 380$ s)



Test cases

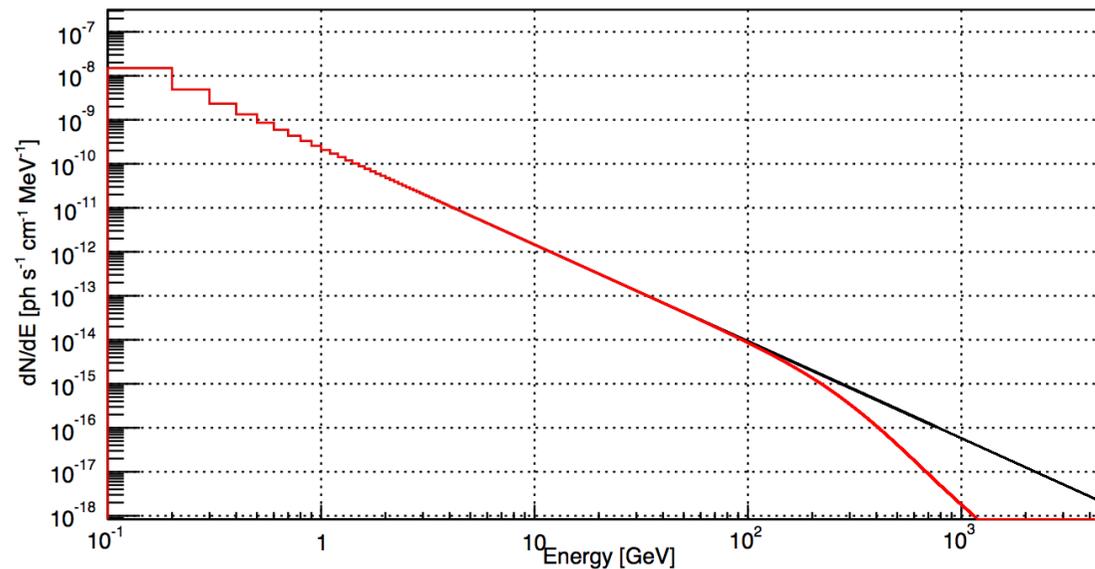
2. GRB 090510

- Short GRB
- Max photon energy:
31 GeV
- Redshift $z = 0.9$
- Spectral index
 $\gamma_1 = -1.6$ (for $t < 200$ s)
 $\gamma_2 = -2.5$ (for $t > 200$ s)
- Temporal index
 $\tau = -1.35$



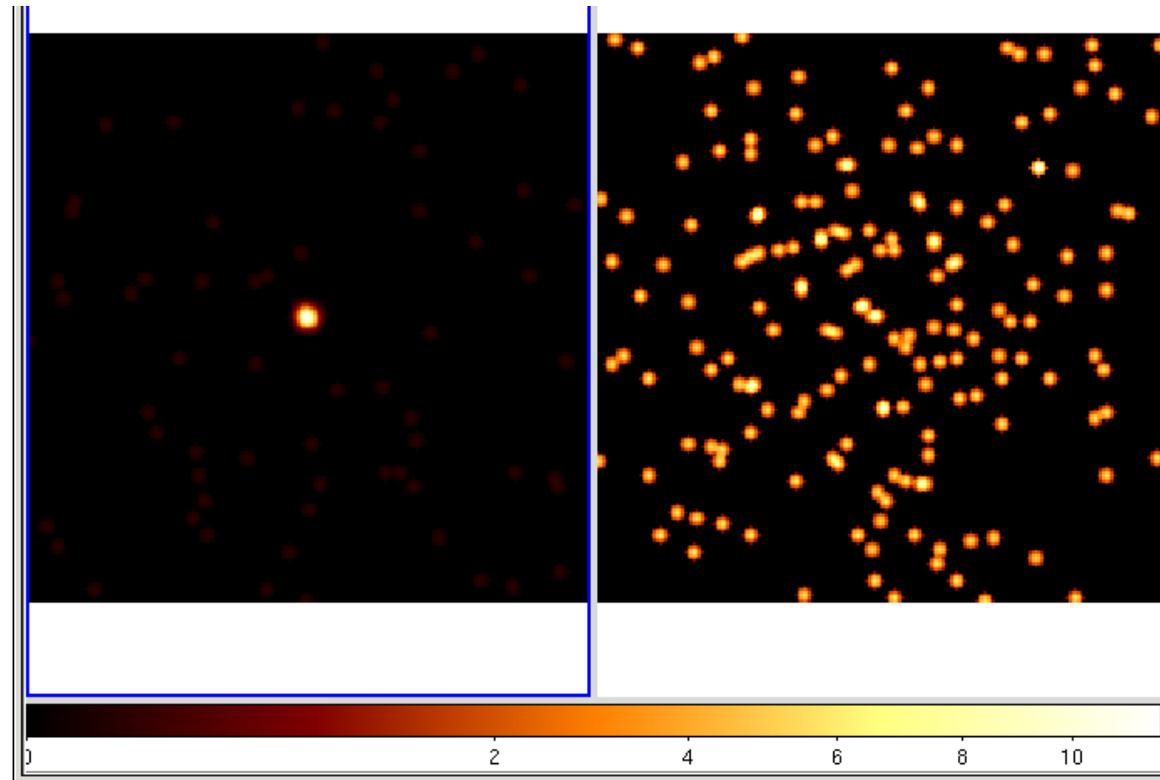
Past work

- Code to include the effect of EBL absorption (C.Vigorito)
- Table of EBL model provided by T.Di Girolamo



GRB 130427A at 10000s with EBL effect included ($z = 0.34$)

Test on EBL absorption



- On the left the simulation with no EBL
On the right the simulation with EBL
- Energy bin (1 TeV – 1.60 TeV)

Plans for GRB simulations

- **GRB library – Fluxes and spectral shapes from LAT**
- **GRB temporal shapes – (short, long)**
- **EBL attenuation – set of GRB at different z**
- **ctlike analysis**

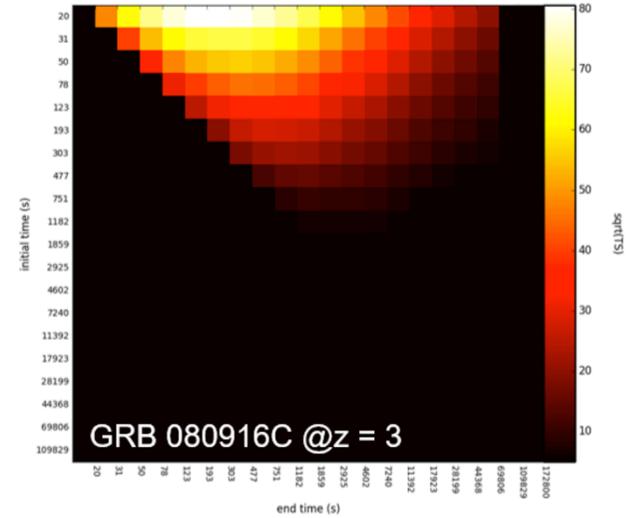
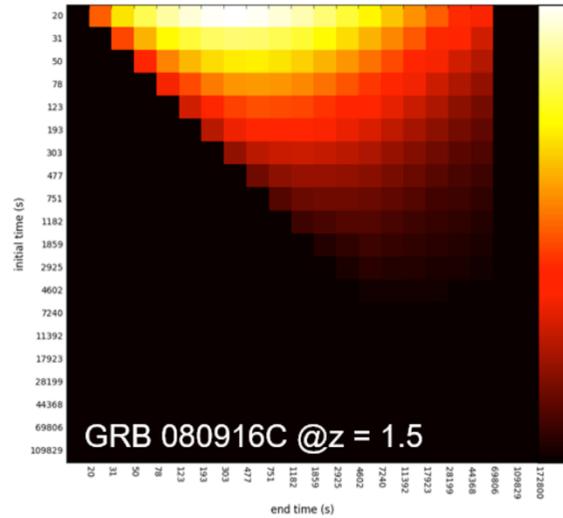
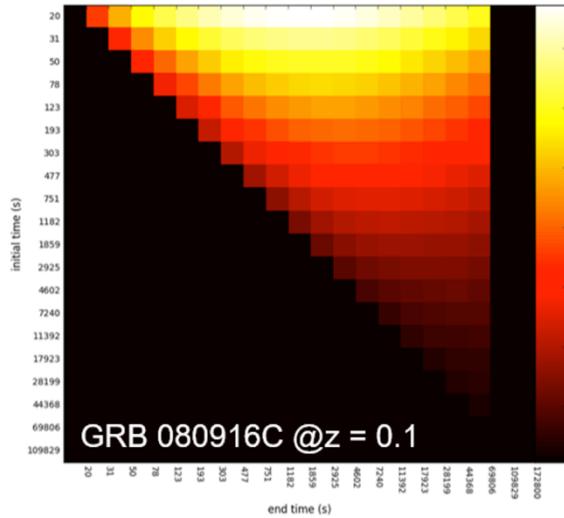
Time window optimization

GRB 080916C

$z = 0.1$

$z = 1.5$

$z = 3$



Simplified procedure for this study

- Fermi-LAT measured HE flux and spectral index (“afterglow” phase)
- Place at Southern sky ...
- Consider the flux at 20 GeV – 10 TeV (+EBL) in CTA energy range
- Calculate the TS and the flux obtained by CTA as function of the observation time (Tstart and Tstop)
- Concentration on “afterglow” detection ...
- Simplified procedure – unique temporal index $\alpha = -1.7$
- TS calculation at fixed times ($t_0 + 1h$)
- Use of new IRFs !

Sample of GRBs

GRB	Redshift
080916C	4.350
090510	0.903
090902B	1.822
090926	2.1062
091003	0.89
110731A	2.83
130427A	0.340
130518A	2.49
131108A	2.4
131231A	0.642
141028A	2.33
160509A	1.17
170214A	2.53

Preliminary results for afterglow detection

GRB	Redshift	20s	60s	180s	1800 s	3600 s
080916C	4.350	320	159	71	4	0
090510	0.903	1281	905	471	75	34
090902B	1.822	1823	1601	957	175	88
090926	2.1062	1060	847	438	66	29
091003	0.89	291	213	97	10	3
110731A	2.83	190	96	38	1	0
130427A	0.340	3221	2848	1782	407	225
130518A	2.49	2	1	0	0	0
131108A	2.4	81	68	29	0	0
131231A	0.642	793	540	276	41	17
141028A	2.33	21	18	8	0	0
160509A	1.17	429	245	113	10	4
170214A	2.53	154	148	127	14	5

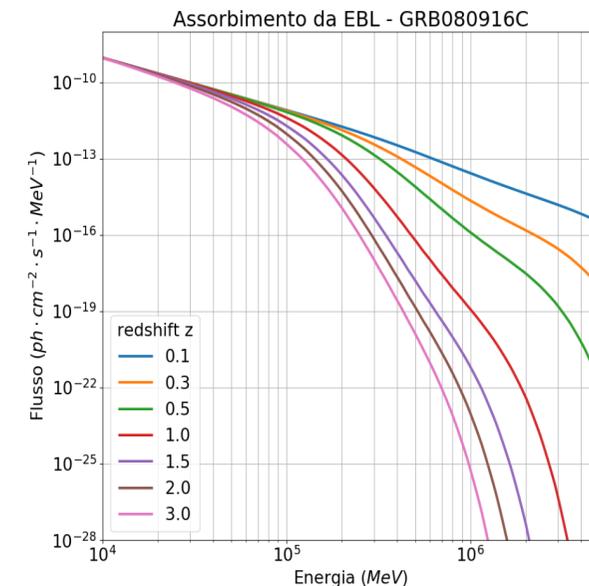
Procedure

- **Fermi-LAT measured HE spectral index and time decay power law index (“afterglow” phase)**
- **Consider the flux at 20 GeV – 5 TeV (+EBL) in CTA energy range**
- **Calculate the TS obtained by CTA**
- **Simulate similar source at different redshift (to simulate the effect of EBL absorption – using Franceschini et al. 2008)**

GRB with z sample

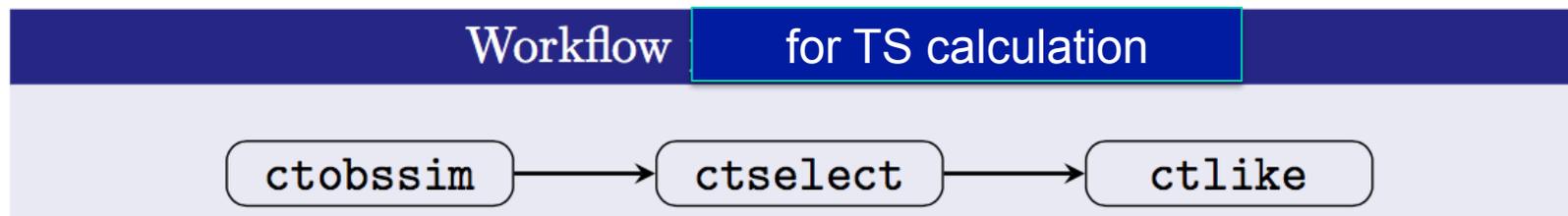
Name	F_p (ph/cm ² /s $\times 10^{-5}$)	En.index [β]	Time index [α]	t_p (s)
GRB080916C	500 \pm 100	2.05 \pm 0.07	1,37 \pm 0.07	6,6 \pm 0,9
GRB090323	6 \pm 3	2.3 \pm 0.2	1,0 \pm 0.3	40 \pm 30
GRB090328	9 \pm 4	2.0 \pm 0.2	1,0 \pm 0.3	40 \pm 30
GRB090510	3900 \pm 600	2,05 \pm 0.07	1,8 \pm 0.2	0,9 \pm 0,1
GRB090902B	600 \pm 100	1,95 \pm 0.05	1,56 \pm 0.06	9 \pm 1
GRB090926A	700 \pm 100	2,12 \pm 0.07	1,9 \pm 0.2	11 \pm 2
GRB091003	8 \pm 3	2,1 \pm 0.2	1,0 \pm 0.2	22 \pm 9
GRB100414	70 \pm 30	2.0 \pm 0.2	1,7 \pm 0.3	20 \pm 10
GRB110731A	220 \pm 60	2,4 \pm 0.2	1,8 \pm 0.2	4,8 \pm 0,7
GRB130427A	150 \pm 30	2.2 \pm 0.2	1.35 \pm 0.08	20 \pm 5

→ Example study
of EBL absorption
for GRB 080916C placed
at 7 different redshifts
(z = 0.1 – 3)

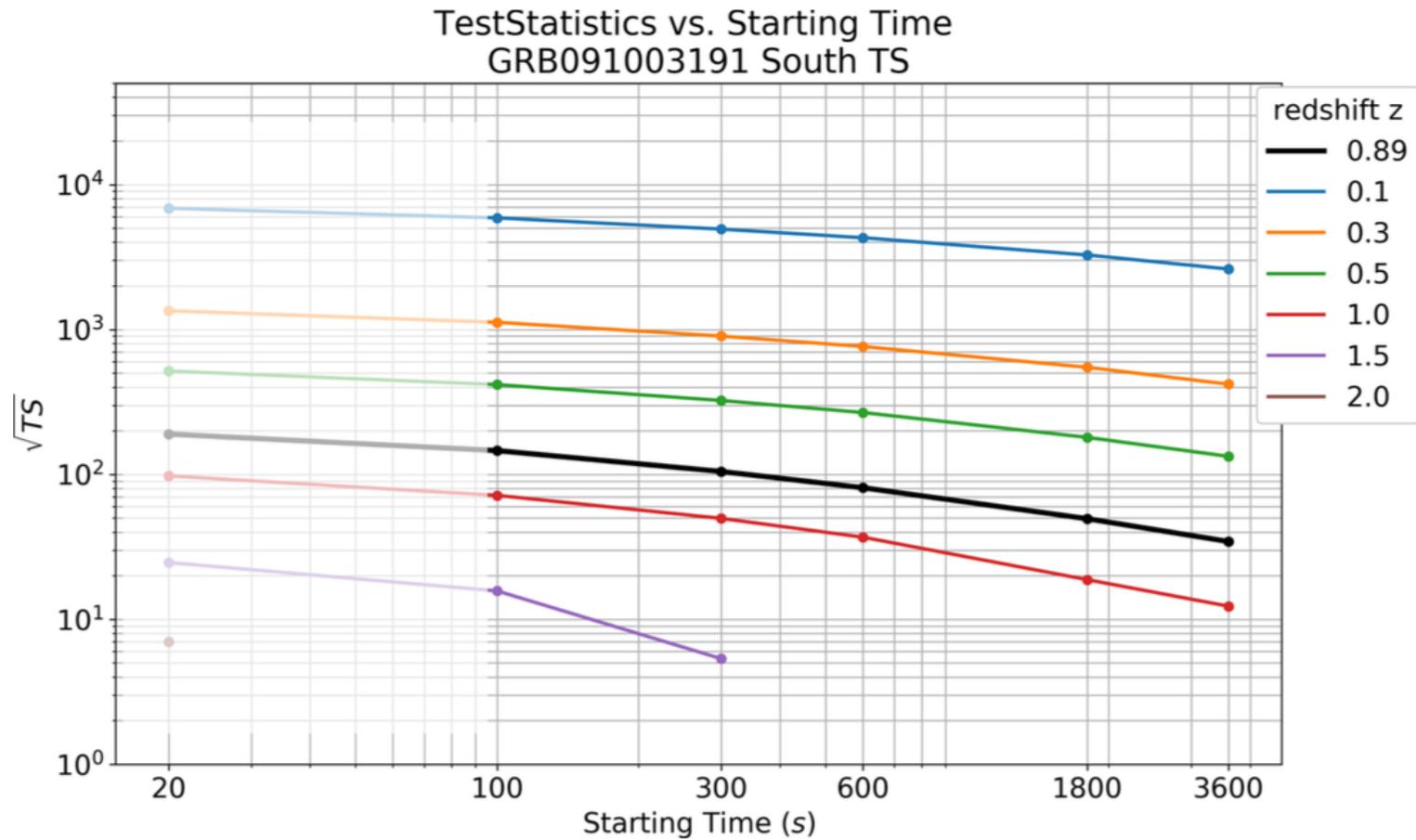


TS calculation

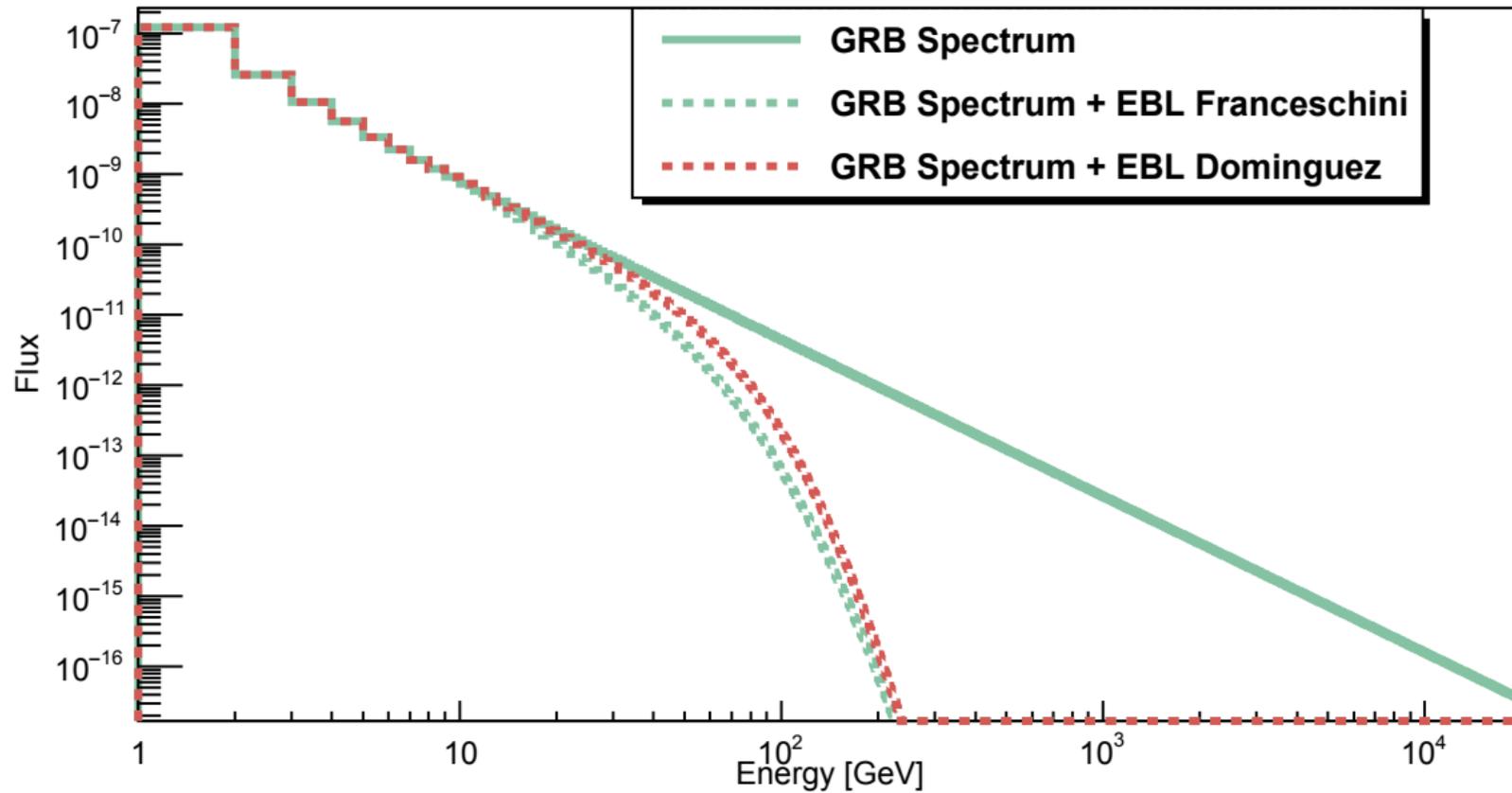
GRBs	IRFs	Redshift z	T start
GRB080916C ($z=4.35$)	Nord	0.1	20
GRB090510 ($z=0.90$)	Nord LST	0.3	100
GRB090902B ($z=1.82$)	Nord Threshold	0.5	300
GRB090926A ($z=2.11$)	Sud	1.0	600
GRB110931A ($z=2.83$)	Sud Threshold	2.0	1800
GRB130427A ($z=0.34$)	Sud Threshold MST	3.0	3600
GRB091003 ($z=0.98$)			



TS calculation



Check of EBL models



GRB Data Challenge proposal

- **Population of GRBs**
 - Simple GRID of GRBs
 - Flux, Spectral shapes, Duration (from LAT?)
 - CTA survey observation simulation scheme
 - “Some” Physical motivated scenario ...
 - Inclusion of Real Time Analysis SW
 - Opportunity to test the Detection and Analysis SW?
- **Proposal**
 - Organization of a small group of “sky-master” to prepare the GRB Data Challenge
 - Timeframe: Ready by April 2018?

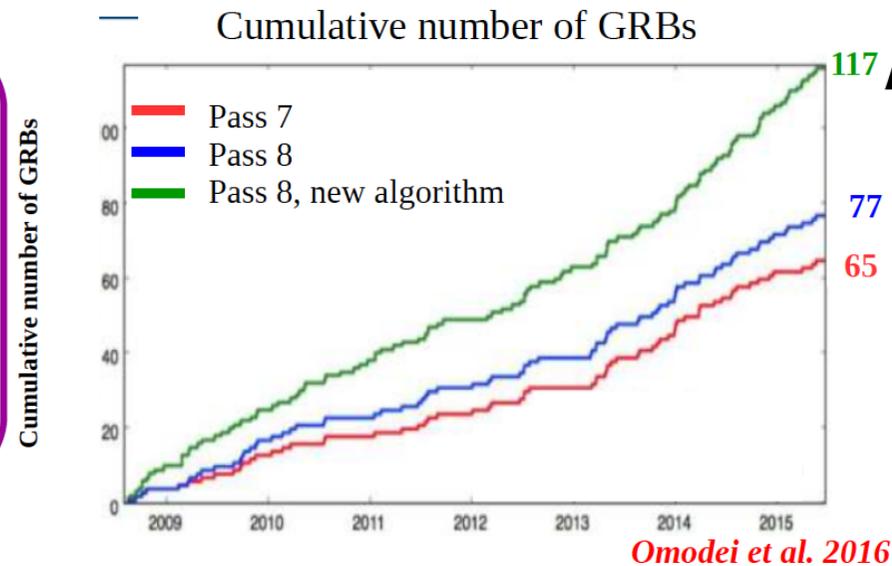
The 2nd LAT GRB catalog

Towards the 2nd Fermi/LAT GRB catalog



- New event reconstruction and classification algorithms “**Pass 8**”
- Development of a new detection algorithm for GRBs:
LTF (LAT Transient Factory, *Vianello et al. 2015*)

Increase by >50% of the rate of LAT-detected bursts

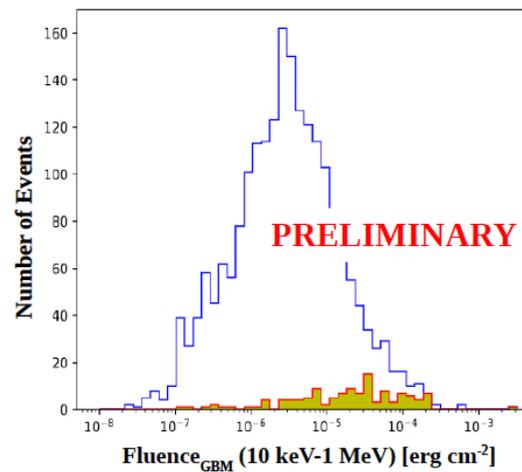
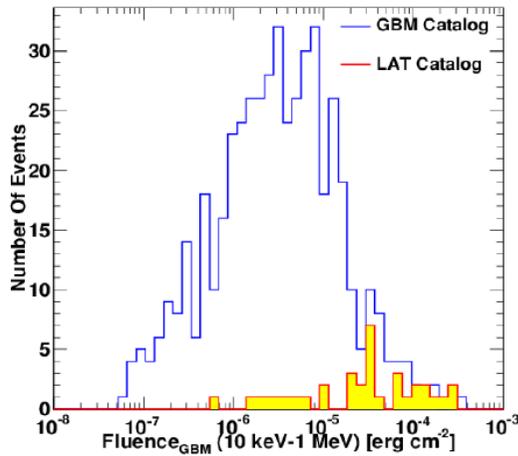


The 2nd LAT GRB catalog

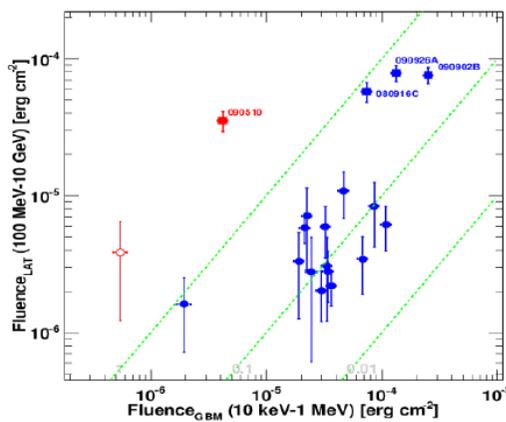
Towards the 2nd Fermi/LAT GRB catalog



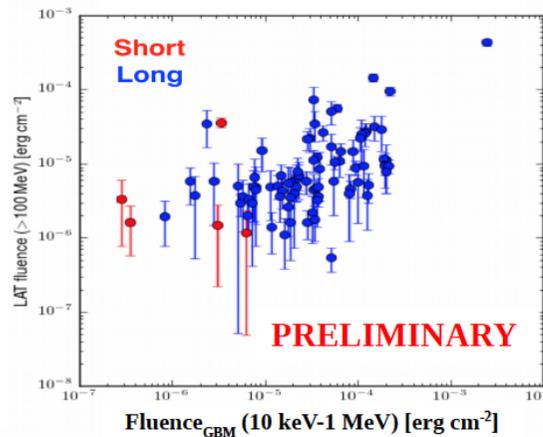
1st LAT GRB catalog → 2nd LAT GRB catalog



- Broader fluence range
- Similar fluence distribution



Ackermann et al. 2013



Vianello et al. 2017

- No difference between short and long GRB fluences



Prospects

- **Update the GRB library**
 - **Need to include the most updated LAT results**
- **Need to build a realistic redshift distribution for LAT GRB**
 - **Correct use of EBL absorption models**